ATP 6-02.53

TECHNIQUES FOR TACTICAL RADIO OPERATIONS

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TECHNIQUES FOR TACTICAL RADIO OPERATIONS

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Preface

Army techniques publication (ATP) 6-02.53, *Techniques for Tactical Radio Operations*, serves as the primary doctrine publication for tactical radios and tactical radio networks employed at all echelons, across all phases of operations, supporting every warfighting function, to enable mission command in unified land operations. This publication describes the methods used to perform missions, functions, or tasks (techniques) for the employment of tactical radios, and incorporate information as it relates to the configuration and employment of radio networks. ATP 6-02.53 incorporates doctrine relative to the wide array of new communications and networking capabilities, addresses the employment of today's tactical network as a composite of enterprise and tactical systems, and capabilities that are interdependent and interoperable. The doctrine contained within supports the Army's portion of Department of Defense information networks goal to provide one integrated network that is interoperable across all mission environments during all phases of operations.

The principal audience for ATP 6-02.53 is commanders, staffs, supervisors, planners, radio operators, and Signal Soldiers providing a common reference for tactical radios. It provides basic guidance and gives the system planner the necessary steps for network planning, interoperability considerations, and equipment capabilities.

Commanders, staffs, and subordinates ensure that their decisions and actions comply with applicable United States, international, and in some cases host-nation laws and regulations. Commanders at all levels ensure that their Soldiers operate in accordance with the law of war and the rules of engagement. (See FM 27-10.)

ATP 6-02.53 uses joint terms where applicable. Selected joint and Army terms and definitions appear in both glossary and the text. Terms for which ATP 6-02.53 is the proponent publication (the authority) are italicized in the text and are marked with an asterisk (*) in the glossary. Terms and definitions for which ATP 6-02.53 is the proponent publication are boldfaced in the text. For other definitions shown in the text, the term is italicized and the number of the proponent publication follows the definition.

ATP 6-02.53 applies to the Active Army, Army National Guard, and United States Army Reserve, unless otherwise stated.

The proponent for this publication is the United States Army Cyber Center of Excellence. The preparing agency is the Doctrine Branch, United States Army Cyber Center of Excellence. Send comments and recommendations on a DA Form 2028 (Recommended Changes to Publications and Blank Forms) to Commander, United States Army Cyber Center of Excellence and Fort Gordon, ATTN: ATZH-DT (ATP 6-02.53), 506 Chamberlain Avenue, Fort Gordon, GA 30905-5735; or via e-mail to usarmy.gordon.cyber-coe.list.mbal-gord-fg-doctrine@mail.mil .

Unless this publication states otherwise, masculine nouns and pronouns do not refer exclusively to men.

Introduction

ATP 6-02.53 replaces Field Manual (FM) 6-02.53, *Tactical Radio Operations* and expands on the foundation of tactical radios operations found in FM 6-02, *Signal Support to Operations*.

ATP 6-02.53 incorporates numerous changes. The most significant change is the introduction and use of the term integrated tactical networking environment (ITNE) as the successor network environment to what was termed the Lower Tactical Internet, the combat net radio, and the lowest tactical level. The Integrated Tactical Networking Environment is a combination and evolution of all three concepts through the integration of the software based networking radio technologies, and mission command mounted and mobile applications management.

Communications and mobility are key enablers of mission command in support of the execution of successful unified land operations. Communications must support the Army's aim to seize, retain, and exploit the initiative to gain and maintain a position of relative advantage over the enemy in sustained land operations. In order to gain and maintain a position of relative advantage over the enemy, Army forces must be able to move repeatedly and communicate. Tactical situations change rapidly during sustained land operations, requiring tactical radios that are versatile and readily adaptable to rapidly changing tactical situations. Communications in support of unified land operations require the employment of communications capabilities at squad level and higher echelons. Communications at the squad level enables communication and situational awareness at the lowest level possible.

ATP 6-02.53 remains generally consistent with FM 6-02.53 on key topics while adopting updated terminology and concepts as necessary. This ATP presents techniques for Signal Soldiers to execute the Signal Corps' core competency associated with network transport.

ATP 6-02.53 contains twelve chapters and nine appendices—

Chapter 1 provides an overview of tactical radios, tactical radio networks, capabilities, and network management.

Chapter 2 addresses the employment of tactical radios at all echelons throughout the Army.

Chapter 3 addresses the tactical radio platforms and associated waveforms that Army forces employ at all echelons across all phases of operations.

Chapter 4 discusses the waveform and waveform application functional component of the tactical networking environment.

Chapter 5 describes the commercial-off-the-shelf very high frequency radios used to support tactical radio operations.

Chapter 6 addresses the ultrahigh frequency radios and systems that play a major role in network centric warfare.

Chapter 7 addresses the Army single channel tactical satellite capabilities associated with the legacy and enduring radio platform and planning considerations.

Chapter 8 addresses the airborne radios employed to provide communications for ground-to-air operations as well as air-to-air and air-to-sea missions.

Chapter 9 addresses various other tactical radio systems employed to enable communication and situational awareness during the conduct of operations.

Chapter 10 addresses antenna techniques, concepts, terms, types, effects, and provides examples of antenna field repairs.

Chapter 11 addresses key management techniques relative to protecting voice, data, and video information over tactical radio networks.

Chapter 12 addresses electronic warfare and the electronic protection techniques used to prevent enemy jamming and intrusion into friendly communications systems.

Appendix A provides a description of frequency modulation networks.

Appendix B identifies radio sets basic components, characteristics, properties of radio waves, wave modulation, and site considerations for single channel radios.

Appendix C addresses the importance of high frequency, very high frequency, ultrahigh frequency antenna selection.

Appendix D addresses radio operations in unusual environments.

Appendix E addresses the Julian date, synchronization time, and Zulu time. It also provides a time zone conversion chart.

Appendix F provides procedures for preventing a network compromise and addresses recovery options available to the commander and his staff.

Appendix G addresses data communications elements such as binary data, baud rate, modems, and forward error correction.

Appendix H addresses single channel ground airborne radio system implications and cosite interference mitigation.

Appendix I addresses the proper way to pronounce letters and numbers when sending messages over a radio as well as the proper procedures for opening and closing a radio net.

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Chapter 1
Overview

This chapter provides an overview of tactical radios, tactical radio networks, capabilities, and network management.

TACTICAL RADIOS

1-1. A radio is a device that enables Soldiers push-to-talk capabilities utilizing various frequencies and waveforms. Tactical radios are a necessity for Soldiers during the conduct of all operations. Squad leaders and higher employ tactical radios enabling Commanders to see and share a common view of the operational environment. Tactical radios provide Soldiers the capability to transmit and receive voice, data, and video communication over large distances. Tactical radios consist of the systems that form the primary means for Soldiers to communicate during operations including homeland defense and civil military operations. The versatile and adaptable design of today's tactical radios enables the radios to integrate into all environments.

TACTICAL RADIOS ACROSS ALL PHASES OF OPERATIONS

1-2. Soldiers at all echelons of the Army employ tactical radios across all phases of operations in support of all warfighting functions. Soldiers employ a wide array of high frequency (HF) radios, very high frequency (VHF) radios, ultrahigh frequency (UHF) radios, multiband radios, multimode radios, and secure wireless broadband solutions microwave radios in support of operations. The radios consist of legacy waveform radios, mobile ad-hoc networking waveform radios, soldier radio waveform radios, high performance waveform radios, integrated waveform radios, advanced networking wideband waveform radios, and network enterprise services. The radios support the Army's enterprise initiative to be an integrated and interoperable network, from the highest to the lowest echelon. Chapter 3 will discuss in detail the tactical radios and associated waveforms employed by Army forces.

TERRESTRIAL AND CELESTIAL COMMUNICATIONS PRODUCTS

1-3. Terrestrial and celestial communications products consist of software-defined tactical radio systems that enable tactical communications at the lowest tactical level and support current and future tactical communication for all services. Terrestrial and celestial communications products that enable tactical communication include Airborne Maritime Fixed Station, Mid-Tier Networking Vehicular Radio, and Handheld Man-Pack Small Form Fit Radio. The software based networking radios have the capability to deliver networks to the mounted and dismounted force and lays the foundation for achieving network connectivity across the radio frequency spectrum.

TACTICAL RADIO NETWORKS

1-4. Tactical radio networks play a vital role in facilitating mission command and providing situational awareness during operations. The primary role of tactical radio networks is voice transmission to enable communication and situational awareness at all echelons, across all phases of operations. It assumes a secondary role for data transmission where other data capabilities do not exist. Tactical radio networks are located at every echelon in the deployed tactical force from Corps to Soldier. Each echelon employs radio based networks to provide voice and data communication during all phases of operations in the most austere environments, and to provide and gain situational awareness in support of accomplishing the mission. Tactical radio networks provide the principal means for facilitating communication between Army forces. Tactical radio networks support Army forces requirements for a horizontally and vertically integrated digital information network that facilitates communication and situational understanding, and enhances the military decisionmaking process by providing reliable and secure communications connectivity for all Soldiers that require tactical radio network connectivity. The network also enables connectivity to civil and national authorities.

1-5. As technology changes, tactical radio networks capabilities change and incorporate into the network. The advances in technology and the wide array of new communications and networking capabilities associated with the currently fielded capability sets enhance communications capabilities. The capability enhancements enable Web services at command posts (CP), enable mission command on the move capabilities in leaders' vehicles, and extend the data network to mounted and dismounted platoon leaders and to team leaders operating on handheld android devices. The enhancements improve the overall accuracy of position location information and reduce latency of information to the Soldier.

TACTICAL INTERNET

1-6. The tactical internet is the physical communications network that provides the data backbone to support exchange of digital information in the form of communication and situational awareness messages. The tactical internet forms two distinct information exchange layers, the upper tactical internet, and the ITNE. The upper tactical internet is composed of multi-channel satellite systems and other Warfighter Information Network-Tactical (WIN-T) systems. The ITNE comprises the networking environment that enables the employment of communications support systems for units found at brigade and below. The ITNE is composed of—

- Combat net radios (CNR).
- Single-channel ground and airborne radio system (SINCGARS).
- Vehicular and dismounted mission command systems.
- Joint Battle Command Platform.
- Nett Warrior.
- Adhoc self-forming networks.
- Enhanced position location reporting system (EPLRS).
- Blue force tracking (BFT) I and II
- Wideband networking waveform (WNW).
- Soldier radio waveform (SRW).

Upper Tactical Internet

1-7. The upper tactical internet extends the strategic networks (SECRET Internet Protocol Router Network, Non-secure Internet Protocol Router Network, and Joint Worldwide Intelligence Communications System) to the expeditionary force from the regional hub nodes to the command post at corps, division, brigade, and battalions with WIN-T tactical communication nodes. WIN-T extends to the mobile commander with point of presence and Soldier network extension satellite communications (SATCOM) terminals from division, brigade, maneuver battalion and company expeditionary signal brigade extends upper tactical services to corps and division multifunctional brigades with small tactical deployable WIN-T systems.

Integrated Tactical Networking Environment

1-8. The ITNE formerly the lower tactical internet consists of two tiers that support data and voice communication and provide situational awareness information (friendly and enemy locations). Governed by the types of services requested, the tiers operate simultaneously and transparent to the user. The ITNE is primarily composed of voice and data radios connected to each other.

1-9. The ITNE is comprised of CNR at the lowest tactical level, software-defined radios based technologies, and mounted and mobile applications. The ITNE operates as a two-tiered network (lower tier and mid tier). The ITNE enables commanders and Soldiers to exchange secure and protected terrestrial based and celestial based voice and data communication at all echelons during all operations. Celestial-based communications consists of narrowband SATCOM capabilities. Terrestrial-based communications consist of Department of Defense information network operations (also known as DODIN operations) within Army lower tier (company) and mid tier (battalion) tactical radio networks. Each tier is mutually supportive and required in order to provide a robust radio based terrestrial layer for organic passage of voice and data for commanders at the lowest tactical level.

- **Lower Tier.** The lower tier is composed of organic tactical radio network resources to support company and below formations down to the Soldier. Single channel radios operating at the unclassified and secret level along with two channel radios at platoon and company to ensure multi-network integration and connectivity primarily characterizes the lower tier. Mobile applications that enable visualization, human machine interface with ancillary devices such as global positioning system (GPS) receivers for basic Soldier and unit situational awareness, fires targeting data, voice, and sensor capability provides the provisioning of information. The primary lower tier waveforms are the SRW and the SINCGARS.
- **Mid Tier.** The mid tier portion is composed of organic network resources from tactical radio components designed to support battalion and company level operations. The mid tier provides the battalion and company commander with the means to process voice and larger amounts of data across their tactical formation over a terrestrial based network. The mid tier is the interoperability point for higher echelons, Joint integration, aviation integration, and multinational interoperability. A primary mid tier waveform is the WNW.

1-10. The ITNE is composed of five primary functional components (Radio Platforms, Waveforms and Waveform Applications, Network Operations Management System, Ancillary Devices, and Mission Command Mounted and Mobile Applications Management). When combined, these components form a complete system of systems network capability enabling the commander to exchange secure and protected terrestrial and celestial voice and data across their entire formation. The ITNE requires that all functional components operate simultaneously. The failure of a single functional component to initialize and operate jeopardizes the overall ITNE capability. ITNE component failure can range from minor data exchange loss and or delay, to catastrophic failure of the network to initialize. Full description of the ITNE five primary functional components is as follows—

- **Radio Platforms.** Radio platforms are composed of a mix of all legacy radios and newly developed software defined radios. Over time, the Army tactical radio platform inventory changes based on the introduction of new tactical radios into the Army inventory and based on the transition of old tactical radios out of the Army inventory. The radio platform component is a combination of the hardware design inherent to the radio to include antenna, batteries, information operation device, vehicular, man-pack or base mounts, and the software design inherent in the radio operating system. The radio operating system software allows the interaction between the radio hardware components and the Network Operations Management System and Waveform Applications component software. In the legacy radios, the hardware and software design fully merge within the radio and include the waveform. The hardware and software link together less rigidly in software defined radios. This provides software defined radios greater interoperability with waveform applications and network management tools while also minimizing interoperability issues associated with the enhanced radio platform operating system. Radio platforms provide a comprehensive and overarching system of system capability for the maneuver commander. Radios are not stand alone capabilities but rather a complete set of nested and interoperable networks that provide a maneuver commander with a mobile ad hoc networking environment based on agile and resilient internet protocol (IP) based messaging. When planning the network architecture and design for radio platforms, the utilization of a single network management system for placement and function of all radio platforms is more suitable than a separate network management system per radio platform type performing placement and function in a singular and isolated approach.
- **Waveforms and Waveform Applications.** The waveform application component is composed of all current software defined waveform applications that provide a means to pass voice and data across the transport layer of the network in the lower and mid tier portions of the tactical radio network. Waveform applications are peer-to-peer programs that facilitate the exchange of application data across the spectrum of radio networks. The optimization of each waveform application meets the mission needs of the portion on which it operates (lower and mid tier). These are important considerations for tactical radio network planners as they develop their network architecture to meet their commander’s communication requirements. Plan, configure, and load waveform applications onto the radio platforms through the Network Operations Management

System. For near term capability sets, software defined radios are loaded with the waveform application through this means in order for that radio platform to be initialized and operational within that waveform environment. In the future, over the network distribution of radio files simplify and expedite the process of loading and reloading radios in support of mission, enemy, terrain and weather, troops and support available-time available and civil considerations requiring new task organization and subsequent battalion or brigade signal staff officer (S-6) unit task reorganization procedures.

- **Network Operations Management System.** The Network Operations Management System is the integrated capability that allows network managers to plan, configure, manage, and monitor all other components of the terrestrial and celestial based tier of tactical radio network. This includes radio platforms, mission command mobile/mounted applications, ancillary devices, and waveform applications. The Network Operations Management System is the capability through which the battalion S-6 develops and builds a network plan and initializes and operates the radio network for their respective command level. The functional integration of Department of Defense information network operations capabilities across the radio platform operating system, the waveform application software, and the Network Operations Management System results in the achievement of network operations. The battalion S-6 conducts a number of tasks manually to ensure the proper planning and configuration of the network, and to ensure proper management of the component devices of the network.
- **Ancillary Devices.** Ancillary Devices encompass all the networked and non-networked items that connect directly to the radio platform or provide assistance in the routing and transmission of data between radios or security environments within the lower and mid tier. These devices can range from talk selector switches that connect to the radio platform and provide ease of use across talk groups to tier III routers, cross domain solutions, and gateways for Joint and multinational interoperability or enterprise services such as positioning, navigation and timing provided by the GPS. Networked Ancillary Devices provide critical interconnectivity capability between radio networks and ensure voice and data are processed and routed according to the quality of service and prioritization established by the commander. Management of these devices takes place on an individual basis through commercial off the shelf configuration tools.
- **Mission Command Mobile and Mounted Applications Management.** The battalion S-6 and their staff are responsible for ensuring the proper planning, configuration, and initialization of mission command applications that operate on mounted platforms and mobile (dismounted Soldiers) platforms in support of the commander's mission. This responsibility requires the proper alignment of mounted and mobile applications with more fixed and traditional applications residing on the battle command common services stack of servers and other key information repository sources. The battalion S-6 ensures the proper alignment and interoperability between the mission command applications and the transport network of their battalion.
  - **Mounted Applications**. Mounted Applications consist of the following categories—

    Native Applications. Native applications built onto the Mounted Computing Environment software development kit share common components, user interfaces, and communication methods such as the GPS and Joint Battle Command-Platform. Web Services. Web services are applications accessed via a web browser and run as local web services with limited shared data such as Web Mail and command post of the future thin client. Virtual Machines. Virtual Machines run as stand-alone virtual machines on mounted platforms with minimal to no sharing such as command post of the future thick client or Distributed Common Ground System.
  - **Mobile Applications.** Mobile Applications consist of two categories, those that run natively on the mobile platform and those accessed as Web Services. The Web Service configured on a remote server that the mobile device subscribes to with an IP address provided by the controlling authority. The battalion S-6 configures native mobile applications with a planning tool. With this tool, the battalion S-6 can create, assemble, manage, and transfer mission data. Mission data includes digital map files, the unit task organization, photo image files, and other files in support of the mission. Prior to putting the mobile device into operation, the battalion S-6 ensures the conversion of map into a format accepted by the mobile platform. Using the

planning tool, the battalion S-6 ensures all files imported to the mobile platform are free of viruses or other destructive files.

NETWORK MANAGEMENT

1-11. The ITNE is a mixture of current radios (SINCGARS, HF, VHF/UHF, Narrowband SATCOM, and EPLRS) and new software defined radios that add to the network management complexity by adding additional planning requirements to support adhoc, self-forming, self-healing voice and data waveforms (WNW and SRW). The mixture of radios and complexity of network management require that the ITNE have multiple planning tools and capabilities to plan and manage the ITNE.

1-12. The network management tools for the ITNE do not operate as a stovepipe environment. A universal approach for network planning and management enables the accomplishment of network management at the tactical level. The effectiveness of the ITNE portion of network centric warfare depends largely on network planners' ability to plan complex mobile networks, share the network planning data across a joint operational environment, view network performance data, and provide situational awareness data across the different tiers of the ITNE. The ITNE network management tools enable Soldiers to operate in a net-centric environment without overburdening the network planners and mangers with complexity.

PLANNING TOOLS

1-13. The following planning tools are used for planning current radio systems within the ITNE—

- **Joint Automated Communications Electronics Operating Instruction System and Automated Communications Engineering Software**. Provides pre-deployment and post mission planning enabling the S-6 staff to conduct legacy radio network planning; and insure interoperability of radio frequency (RF) networks, cryptographic key tag, and transmission security key generation, signal operating instructions production, and advanced networking wideband waveform radio network planning. The Automated Communications Engineering Software provides the capability to support Black Key packaging and distribution and provides fills for the simple key loader (SKL) AN/PYQ-10 (C) with secure network information through direct cable connection or over-the-air rekey. Pre and post mission planning also consists of electronic protection (EP) data and radio network engineering for secure communication. The Joint Automated Communications Electronics Operating Instruction System and Automated Communications Engineering Software supports the following radios—
  - Harris Radios: Falcon III (AN/PRC-117G) and Falcon III (AN/PRC-152A) advanced networking wideband waveform radios.
  - All Legacy (SINCGARS, AN/PSC-5, AN/PRC-150) radio sets in the Army inventory.
- **EPLRS Network Manager.** The EPLRS Network Manager performs automated network management and control of the EPLRS network. Units that use EPLRS employ the EPLRS Network Manager as the network management system. The EPLRS Network Manager assigns configuration parameters to radio set sets to allow them to perform their missions. The EPLRS Network Manager manages the generation of cryptographic keys from a KOK-23 to load into the radio set. The EPLRS Network Manager can accommodate any size EPLRS radio set network. There are no restrictions on the number of radios stored and managed by a single EPLRS Network Manager. Practical limitations to the size of the network, limits the maximum needlines assigned to any single radio set to 64 needlines.

JOINT-TACTICAL NETWORKING ENVIRONMENT NETWORK OPERATIONS TOOLKIT

1-14. The Joint-Tactical Networking Environment Network Operations Toolkit (J-TNT) is the Network Operations Management System for the ITNE. The J-TNT is the critical subcomponent of the ITNE, which enables the S-6 staff to plan, manage, and analyze the radio networks for each respective command level. The J-TNT provides a means to load and configure software-defined radios. The J-TNT employs several lower tactical network tools, mostly radio management tools, onto one laptop, which enables users to configure legacy SINCGARS radios and monitor all radios on the battlefield from one compiled set of tools. The application user utilizes a graphical user interface to perform the following tasks—

- Create plans.
- Import third-party data.
- Generate radio configuration files.
- Generate reports.

1-15. The following three core software applications make up the J-TNT—

- **Joint Automated Communications Electronics Operating Instruction System and Automated Communications Engineering Software**. Provides pre-deployment configuration and post mission planning enabling the S-6 staff to conduct legacy radio network planning; and insure interoperability of radio frequency (RF) networks, cryptographic network planning, signal operating instructions production, and advanced networking wideband waveform radio network planning. Pre and post mission planning also consists of electronic protection (EP) data and radio network engineering for secure communication. The Joint Automated Communications Electronics Operating Instruction System and Automated Communications Engineering Software assists with communications security (COMSEC) keying, information key tags and signal operating instructions development and supports the following radios—
  - Harris Radios: Falcon III (AN/PRC-117G) and Falcon III (AN/PRC-152A) advanced networking wideband waveform radios.
  - All legacy: SINCGARS, AN/PSC-5 (Spitfire and Shadowfire), and AN/PRC-150 radios.
- **Joint Enterprise Network Manager**. Software defined radios require a network management system that can plan all the radio configuration presets in supporting multiple waveforms both current (SINCGARS, HF, SATCOM) and new mid tier and lower tier waveforms (WNW and SRW). The Joint Enterprise Network Manager software provides network management services to Army approved software defined radios. The Joint Enterprise Network Manager enables the S-6 staff to plan specific operationally relevant waveform application parameter settings and the ability to generate all the required radio configuration files from a network plan. Provides pre-deployment network management services planning for the waveform parameters of SRW radios. Process radio configuration files to create the exact file structure for the radio type to be loaded into a radio, SKL, compact disc or digital videodisc, or universal serial bus drive. The Joint Enterprise Network Manager also provides post deployment support in monitoring and controlling the deployed networks and radios. The Joint Enterprise Network Manager supports the following radios—
  - Handheld man-pack small form fit radios: AN/PRC-155 (Manpack), AN/PRC-154 (Rifleman) and AN/PRC-154A (C-Rifleman).
  - ITT Corporation common core radios: Sidehat and the Soldiers' rifleman radio.
  - Harris radios: Falcon III (AN/PRC-117G) and the Falcon III (AN/PRC-152A).
  - Mid Tier Networking Vehicular Radio (AN/VRC-118).
  - Airborne Maritime Fixed Station Radios.
- **Tactical Internet Management System**. The Tactical Internet Management System is part of the Joint Battle Command-Platform friendly and enemy force tracking and messaging system. The Tactical Internet Management System displays blue situational awareness icons generated by radio-based systems that report their geospatial position via position location information multicast messages. Tactical Internet Management System enables the S-6 to maintain live, near real-time situational awareness of lower and mid tier levels by alerting operators and leaders to situational awareness degradation. Implementation of radio based situation awareness monitoring by the S-6 provides the S-6 enhanced situational awareness. The use of position location information reports received from radios and hand-held devices enables the radio based situation awareness system to validate position location information reporting and infer radio up or down status across multiple networks.

Chapter 2

Tactical Radio Employment Across Echelons

When employed, tactical radios support all warfighting functions at all echelons across all phases of operations. This chapter addresses the employment of tactical radios at echelons throughout the Army.

THEATER ARMY

2-1. A Signal Command (Theater) (SC[T]) is the highest level and primary, deployable organization responsible for tactical radios and tactical radio network support at all echelons across all phases of operations. A SC(T) provides signal support to the Army Service component command (ASCC) including major combat operations. The SC(T) exercises control of multiple theater signal brigades and joint and coalition information signal support elements. A signal brigade rather than a full SC(T) typically provides support to ASCC missions that do not involve major combat operations.

2-2. A SC(T) utilizes Signal brigades and battalions to extend tactical radio and tactical radio network services to the deployed theater Army organizations and other deployed subordinate organizations allocated to the theater Army area of operations. Allocation of SC(T) signal assets providing signal support to the ASCC and major combat operations occurs based on mission requirements.

THEATER TACTICAL SIGNAL BRIGADE

2-3. A theater tactical signal brigade is assigned to a SC(T) or Theater Army as required. A theater tactical signal brigade supervises the installation, operation, and maintenance of in-theater communications systems and the network support in the theater of operations. A theater tactical signal brigade also provides real-time and near real-time in-theater source information to combatant commanders and Joint task force commanders for the control, management, and dissemination of high volumes of data to deployed and dispersed forces in the theater of operation. A theater tactical signal brigade enables communication and situational awareness to echelons above corps tactical signal battalions, theater strategic organizations, and separate companies requiring theater communications network support through wide dissemination of data and relevant information. The assistant chief of staff, signal (G-6), and the S-6 coordinate with supporting units theater tactical signal brigades for inclusions in their network.

Expeditionary Signal Battalion

2-4. Expeditionary signal battalions assigned to a theater tactical signal brigade oversee the engineering, installation, operation, and maintenance of nodal and extension communications in support of Army units, combatant commanders, ASCCs, or joint task force and joint land force component commands. An employed expeditionary signal battalion operates continually in austere environments to provide voice and data networking services to commanders. Expeditionary signal battalions provide pooled signal assets to augment organic division and corps network support capabilities and replace network support battle losses at all echelons. The G-6 and the S-6 coordinate with the supporting units' expeditionary signal battalions for inclusions in their network.

2-5. Expeditionary signal battalions enable staff planning and network management of all tactical communications assets within the battalion and communications electronic maintenance sustainment to perform network restoration. Although the expeditionary signal battalion is primarily a theater level asset, the expeditionary signal battalion also employ to support a corps, division, brigade combat team (BCT), Service component, or coalition headquarters. Expeditionary signal battalions or signal companies within a BCT provide tactical radio support to the theater Army depending on the mission and type of support required. The primary tactical radio communications capabilities employed within theater Army are—

- Single-channel (SC) tactical satellite (TACSAT).
- HF radio.
- UHF radio.
- EPLRS and EPLRS network control capabilities.
- SINCGARS.
- Tropospheric Scatter Radio Terminals.

THE ARMY AS A CORPS AND DIVISION

2-6. The Army as a corps and division enables the tailoring of tactical radio support to meet combatant commanders' needs. The tailoring of tactical radio support at the corps and division provides operational forces a mix of tactical radio and tactical radio network capabilities that enable commanders to exercise mission command in support of unified land operations. The advantage of organization as a corps and division is greater strategic, operational, and tactical flexibility. The numbered ASCC, corps and division serve as—

- On order, assume the role of the joint task force headquarters.
- Theater operational, strategic, and tactical mission command.
- A land force and joint support element.
- Mission command enabler for a BCT or sustainment brigade, as the primary tactical and support elements in a theater.

2-7. Organized and equipped primarily as an ASCC for a geographic combatant commander (GCC), or combatant command, the ASCC, corps and division serves as the senior Army headquarters for an area of operations. The numbered Army is a regionally focused, globally networked, headquarters that consolidates most functions into a single operational echelon. The numbered Army is responsible for—

- On order, assume the role of the coalition forces land component commander or the joint task force headquarters.
- Providing administrative control of all Army serviced personnel and installations in the GCCs area of operations.
- Integrating Army forces into the execution of an area of operations security cooperation plans.
- Providing Army support to joint forces, interagency elements, and multinational forces as directed by the GCC.
- Providing support to Army, joint, and multinational forces deployed to diverse joint operations areas.

CORPS

2-8. The corps G-6 and the corps signal company provide communications and information support at corps level. The corps signal company executes the communications plan to support the corps commander's intent through the employment of WIN-T and CNR systems. The WIN-T and CNR systems employed at corps level are primarily the joint network node, high capacity line of sight terminal, SINCGARS, SC TACSAT, and high frequency (HF) radios. These systems are mostly user-owned and operated systems with the higher command responsible for network control.

DIVISION

2-9. The division G-6 and the division signal company provide communications and information support at division level. The division signal company executes the communications plan to support the division commander's intent through the employment of WIN-T and CNR systems. The WIN-T and CNR systems employed at division level are primarily the joint network node, high capacity line of sight terminal, SINCGARS, SC TACSAT, and HF radios.

Geographic Combatant Commander and Army Service Component Commander Communications Team

2-10. The GCC and ASCC communications team provides communications support in the form of secure frequency modulation (FM) radio, UHF TACSAT to GCCs and ASCCs. The GCC and ASCC communications team consists of the following personnel—

- **Network Management Technician.** The network management technician—
  - Supervises and manages the tactical networking environment and administers the local area network and radio systems at the GCC and ASCC commander's location.
  - Plans, administers, manages, maintains, operates, integrates, secures, and troubleshoots commercial off-the-shelf (COTS) communications and automated information systems, and radio systems.
  - Leads the team and personnel, and manages the training of personnel on the installation, administration, management, maintenance, operation, integration, securing, and troubleshooting of COTS, intranets, radio systems, and video teleconferencing systems.
  - Performs system integration and administration, and implements
  - Cybersecurity programs to protect and defend information, computers, and networks from disruption, denial of service, degradation, or destruction.
  - Develops policy recommendations and advises commanders and staffs on planning, installing, administering, managing, maintaining, operating, integrating, and securing COTS communications, radio systems, and video teleconferencing systems on Army, Joint, Combined, and Multinational networks.
- **Information Systems Chief.** The Information Systems Chief is the principal information systems noncommissioned officer (NCO) for the GCC and ASCC communications team. When required the Information Systems Chief assumes the duties of the Network Management Tech as listed above. The Information Systems Chief —
  - Supervises, plans, coordinates, and directs the employment, operation, management, and unit level maintenance of multi-functional and multi-user information processing systems in mobile and fixed facilities.
  - Provides technical and tactical advice to command and staff concerning all aspects of information processing system operations, maintenance, and logistical support.
  - Supervises the installation, operation, strapping, restrapping, preventive maintenance checks, services, and software upgrades on COMSEC devices.
  - Conducts briefings on the status, relationship, and interface of information processing systems within assigned area of interest.
  - Supervises or prepares technical studies, evaluations, reports, correspondence, and records pertaining to multi-functional and multi-user information processing systems.
  - Plans, organizes, and conducts technical inspections.
  - Supervises development of the Information Systems Plan, Information Management Plan, and the Information Management Master Plan.
  - Reviews, consolidates, and forwards final written input for the Continuity of Operations Plan.
  - Develops and enforces policy and procedure for facility operations security and physical security in accordance with regulations and policies.
  - Prepares or supervises the preparation of technical studies, evaluations, reports, correspondence, software programs, program editing, debugging and associated functions.
  - Maintains records pertaining to information system operations.
- **Senior GCC and ASCC Information Technology NCO.** The Senior GCC and ASCC Information Technology NCO plans, supervises, coordinates, and provides technical assistance for the installation, operation, systems analyst functions, unit level maintenance, and management of GCC and ASCC Communications Team communications and information processing systems in support of the GCC and ASCC Commander. The Senior GCC and ASCC Information Technology NCO—

  - Installs, operates, and maintains communications and automated information systems in support of the GCC and ASCC Commander.
  - Supervises and implements classified document control policies, procedures, standards, and inspections.
  - Develops, directs, and supervises training programs to ensure Soldier proficiency and career development.
  - Organizes work schedules and ensure compliance with directives and policies on operations security, signal security, COMSEC and physical security.
  - Prepares or supervises the preparation of technical studies, evaluations, reports, correspondence, and records pertaining to information system operations.
  - Briefs staff and operations personnel on matters pertaining to GCC and ASCC communications and information systems.
- **GCC and ASCC Information Technology NCO.** The GCC and ASCC Information Technology NCO installs, operates, and maintains standard army and COTS communications and automated information systems equipment in support of the GCC and ASCC commander. The GCC and ASCC Information Technology NCO—
  - Compiles output reports in support of information systems operations.
  - Performs system studies using established techniques to develop new or revised system applications and programs.
  - Analyzes telecommunications information management needs, and request logistical support and coordinate systems integration.
  - Ensures that spare parts, supplies, and operating essentials are requisitioned and maintained.
  - Performs maintenance management and administrative duties related to facility operations, maintenance, security, and personnel.
  - Requisitions, receives, stores, issues, destroys, and accounts for COMSEC equipment and keying material on hand receipt from the property book officer or COMSEC account manager, including over the air key.
- **Senior GCC and ASCC Communications NCO**. The Senior GCC and ASCC communications NCO is responsible for supervising communications Soldiers of a GCC communications team. The Senior GCC and ASCC communications NCO—
  - Supervises plans and executes the installation, operation, and maintenance of signal support systems, to include local area networks, wide-area networks and routers; satellite radio communications and electronic support systems; and network integration using radio, wire, and COTS automated information systems.
  - Installs, operates, and maintains standard army and COTS communications and automated information systems in support of the GCC and ASCC commander.
  - Develops and implements unit level signal maintenance programs.
  - Directs unit signal training and provides technical advice and assistance to the GCC and ASCC Communications Team Chief.
  - Coordinates external signal support mission requirements.
  - Prepares and implements Signal operations orders and reports.

  Plans and requests signal logistics support for unit level operations and maintenance.
- **GCC and ASCC Communications NCO.** The GCC and ASCC communications NCO is responsible for supervising, installing, operating, and maintaining standard army and COTS communications and automated information systems in support of the GCC and ASCC Commander. The GCC and ASCC communications NCO—
  - Provides technical assistance and unit level training for automation, communication, and user owned and operated automated telecommunications computer systems, to include local area networks and routers; signal communications and electronic equipment; and satellite radio communications equipment.
  - Prepares maintenance and supply requests for unit level signal support.

- **Transmission Systems Operator NCO.** The Transmission Systems Operator NCO plans, installs, operates, and maintains communications and automated information systems in support of the GCC and ASCC Commander. The Transmission Systems Operator NCO provides the GCC and ASCC communications team chief assistance and advice on communications systems planning, Satellite Access Requests, propagation, spectrum management, and maintenance management for standard army and COTS communications and automated information systems used in support of the GCC and ASCC Commander.

2-11. Network Enterprise Technology Command/9th Signal Command (Army) supports the communications teams of combatant commanders with secure FM radio, UHF tactical satellite, record telecommunications message support, and COMSEC equipment maintenance.

BRIGADE

2-12. Internal brigade CNR assets provide communication and information support at maneuver brigade level. The SINCGARS, SC TACSAT, and HF radio are the primary means of communications within a maneuver brigade. Signal company assets internal to the brigade facilitate communications and situational awareness at the brigade CP. Sustainment units operating in the division area behind the brigade sustainment area use CNRs as a secondary means of communication, with WIN-T as the primary means of communication.

BRIGADE COMBAT TEAM

2-13. The brigade signal company provides communication and information support at the BCT level. The brigade signal company is unique in structure and capabilities. The brigade signal company consists of a headquarters and network support platoon, and two network extension platoons. The brigade signal company provides the following capabilities—

- Line of sight (secure voice and data).
- TACSAT.
- EPLRS and EPLRS network manager.
- Retransmission (RETRANS).
- AN/PRC-154
- AN/PRC-155
- AN/VRC-118

BATTALION AND BELOW

2-14. Critical information flow begins at the lowest echelons. Tactical radio communications at battalion and below plays a vital role in ensuring rapid two-way flow of information from the commander down to the Soldier level and the Soldier up to the commander. The handheld radios and man pack radios are the primary tactical radio capabilities employed at battalion and below that allow Soldiers instant sharing of information across the squad up through company and battalion echelons, as well as up the chain to higher headquarters when necessary. Communications at battalion and below consist of the following capabilities—

- Line of sight.
- TACSAT.
- EPLRS.
- BFT I or II.
- CNR (SINCGARS and HF radios).

2-15. The battalion S-6 is responsible for integrating and managing network resources at battalion and below. The battalion S-6 performs two primary functions regarding network resources for their commander. The first function is to perform subscriber functions associated with higher-level networks within the upper tactical internet and commercial networks, and blue force tracking I or blue force tracking II over which the battalion has no network control. The subscriber functions allow extension of strategic and operational services to the battalion based on the guidance of higher-level commanders. The battalion S-6 ensures compliance and configuration according to these instructions for all systems operated by higher echelons but physically resident within the battalion area of operations. The second primary functions performed by the battalion S-6 are the administrator functions associated with network resources owned by the battalion. The battalion S-6 will need to be able to plan, manage, and monitor the components that comprise the ITNE.

SPECIAL OPERATIONS FORCES

2-16. Special operations forces conduct worldwide special operations, across the range of military operations, in support of combatant commanders, American ambassadors and other agencies. Special operations forces include Special Forces units, Ranger units, special operations aviation units, civil affairs units, Psychological Operations units, and certain other units.

2-17. Special operations forces units require radio communications equipment that improves their operational capability without degrading their mobility. The tactical radios employed by special operations forces provide the critical communication link between special operations forces commanders and special operations forces teams involved in contingency operations and training exercises. The tactical radios employed by special operations forces also provide interoperability with all Services, various agencies of the United States (U.S.) Government, air traffic control, commercial agencies, and allied foreign forces. Employment of tactical radios enable special operations forces to rapidly and seamlessly establish and maintain fixed and mobile communications between infiltrated and operational elements and higher echelon headquarters, allowing special operations forces to operate with any force combination in multiple environments. The following paragraphs address tactical radio and communications requirements for each Army special operations forces unit. See FM 3-05.160 for further information on special operations forces tactical radio operations.

STANDARDIZED INTEGRATED COMMAND POST SYSTEM

2-18. Whether engaged in war, executing a peacekeeping mission, or providing humanitarian relief, effective situational awareness is essential to enable commanders to exercise mission command effectively. The standardized integrated command post system provides commanders with integrated CP capability including all supporting equipment and tools to enhance the mission command decisionmaking process across all phases of the operation. The standardized integrated command post system provides fully integrated, digitized, and interoperable tactical operations centers for use by joint, interagency, and multinational forces and civilian crisis management teams. It includes legacy CPs, Command Post Platforms, shelters, common shelters, and fixed CP facilities.

2-19. The standardized integrated command post system consists of the integration of approved and fielded mission command systems and other command, control, communications, computers, intelligence, surveillance and reconnaissance systems technology into platforms supporting the operational needs of armored, infantry, and Stryker BCT forces. The standardized integrated command post system consists of various systems, specifically the command post platform, which includes the command post local area network and command post communications system, the command center system, and the trailer mounted support system.

2-20. The command post platform hosts connectivity and multiple mission command tools to enable the commander to visualize the battle space and make the right decision based on real-time data. When employed the command post platform and related hardware enable ground commanders to form command posts at echelons ranging from brigade to corps. The command post platform contains the necessary hardware to connect to the upper and lower tactical internet and includes secure wireless capability for rapid, efficient processing and transfer of mission critical battlefield information.

2-21. The command post platform network architecture consists of but not limited to the following radios—

- SINCGARS.
- AN/VRC-103.
- AN/VRC-104.
- AN/PRC-117.
- AN/GRC-240.

- EPLRS.
- BFT I or II.
- AN/PSC-5.
- AN/PRC-154A.
- AN/PRC-155.
- AN/VRC-118.

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Chapter 3

Tactical Radio Platforms

This chapter addresses the tactical radio platforms and associated waveforms, which Army forces employ as communications enablers at all echelons across all phases of operations.

SECTION I – LEGACY AND ENDURING RADIO PLATFORM

3-1. The legacy and enduring radio platform design focuses on the complete integration of the radio-operating environment and the waveform capability. Most legacy and enduring radio platforms are non-digital in nature and operate on an analog infrastructure. Legacy and enduring radio platforms offer consistency of design, reliability, availability, and maintainability at the expense of improved performance over time and rigidity in the network design of each radio platform type. The primary value of the legacy and enduring radio platform is reliability to meet mission needs and the familiarity and level of training Soldiers already possess on most of these systems. Legacy and enduring radio platforms will continue to endure within formations to support the critical node connectivity required for assured, rapid, and reliable data dissemination.

SINGLE CHANNEL GROUND AND AIRBORNE RADIO SYSTEM CHARACTERISTICS AND CAPABILITES

3-2. Employed at all echelons across all phases of operations the SINCGARS family of radio sets design enables maximum commonality among various ground and airborne configurations. SINCGARS radio configurations consist of manpack and vehicle configurations. The individual components of SINCGARS radios are interchangeable from one configuration to the next. The SINCGARS design reduces the burden on the logistics system to provide repair parts.

3-3. The SINCGARS operates in either the single channel or frequency-hopping mode. The SINCGARS is compatible with all current Army and multinational VHF radios in the single channel non-secure mode. The SINCGARS is compatible with other U.S. Air Force, U.S. Marine Corps, and U.S. Navy SINCGARS in the frequency-hopping mode. The SINCGARS stores eight single channel frequencies, including the cue and manual frequencies and six separate hopsets.

3-4. The SINCGARS operates on any of 2,320 channels between 30–88 megahertz (MHz), with a channel separation of 25 kilohertz (kHz), and operates in nuclear or hostile environments.

3-5. The SINCGARS accepts either digital or analog input and imposes the signal onto a single channel or frequency-hopping output signal. During frequency hopping, the input changes frequency about 100 times per second over portions of the tactical VHF range. This hinders threat intercept and jamming units from locating or disrupting friendly communication.

3-6. The SINCGARS provides data rates of 600, 1,200, 2,400, 4,800, and 16,000 bits per second; enhanced data mode of 1200N, 2400N, 4800N, and 9600N; and packet and recommended standard-232 data. The system improvement program and advanced system improvement program radios provide enhanced data mode, which provide forward error correction, speed, range, and data transmission accuracy.

3-7. The SINCGARS has the ability to control output power. The receiver transmitter (RT) has three power settings that vary transmission range from 200 meters (656.1 feet) to 10 kilometers (6.2 miles). Adding a power amplifier increases the line of sight range to 40 kilometers (25 miles). The variable output power level allows users to lessen the electromagnetic signature given off by the radio set.

3-8. Using lower power is particularly important at major CPs, which operates in multiple networks. The ultimate goal is to reduce the electronic signature at the CPs. The net control station (NCS) should ensure all members of the network operate on the minimum power necessary to maintain reliable communications. ***Net control station*** **is a communications station designated to control traffic and enforce circuit discipline within a given net.**

3-9. The SINCGARS also has a built in test function that notify the radio operator when the RT is malfunctioning. It also identifies the faulty circuits for repair or maintenance.

3-10. The SINCGARS provides outside network access through a hailing method. The cue frequency provides the hailing ability to the SINCGARS. When hailing a network, an individual outside the network contacts the alternate NCS on the cue frequency. The NCS retains control of the network. Having the alternate NCS go to the cue assists in managing the network without disruption. In the active frequency-hopping mode, the SINCGARS gives audible and visual signals to the radio operator that an external subscriber wants to communicate with the frequency-hopping network. The SINCGARS alternate NCS radio operator switches to the cue frequency to communicate with the outside radio system.

3-11. The network uses the manual channel for initial network activation. The manual channel provides a common frequency for all members of the network to verify the equipment is operational. During initial network activation, all radio operators in the network tune to the manual channel using the same frequency. After establishing communications on the manual channel, the NCS transfers the hopset variables to the out stations and then switches the network to the frequency-hopping mode. Operating a SINCGARS frequency hopping NCS requires that operators—

- Perform starting procedures. (Set radio to GPS time using the precision lightweight global positioning or the defense advanced global positioning system receiver)
- Perform NCS permission checks.
- Perform NCS cold start net opening.
- Use correct call signs.
- Conduct frequency hopping communications.
- Perform NCS CUE late net entry.
- Use correct call signs.
- Conduct frequency hopping communications.
- Perform stopping procedures.

3-12. Refer to Appendix B for more information on single channel radio communications techniques, Appendix E for Julian date, synchronization time, and time conversion.

Single Channel Ground and Airborne Radio System Radio Sets

3-13. Using common components in the SINCGARS is the key to tailoring radio sets for specific missions with the RT being the basic building block for all radio configurations. The number of RTs, amplifiers, the installation kit, and the backpack component determine the model. Table 3-1, on page 3-3, compares the components of several versions of SINCGARS. For more information on the SINCGARS, refer to Technical Bulletin (TB) 11-5821-333-10-2.

Table 3-1. Comparison of SINCGARS versions and components

	Short Range (consist of 1 radio)	***Long Range (consist of 1 radio)***	***Power Amplifier***	***Dismount Manpack***	***Vehicular Amplifier Adapter (AM-7239C/E)***
AN/VRC-87	X				X
AN/VRC-88	X			X	X
AN/VRC-89	X	X	X		X
AN/VRC-90		X	X		X
AN/VRC-91	X	X	X	X	X
AN/VRC-92		X (2)	X (2)		X
AN/PRC-119	X			X	

3-14. There are several ground unit versions of the SINCGARS (RT-1523/A/B/C/D/E) and three airborne versions (RT-1476/1477/1478). Most airborne versions require external COMSEC devices. The RT-1478D has integrated COMSEC and an integrated data rate adapter. Airborne and ground versions are interoperable in frequency-hopping and single channel operations. The airborne versions differ in installation packages and requirements for data capable terminals. (Refer to Chapter 8 for Airborne SINCGARS versions.)

Ground Version Receiver Transmitter

3-15. Either the RT-1523/A/B/C/D or the RT-1523E comprises the core component of all ground-based radio sets. The RT-1523 series has internal COMSEC circuits (source of the integrated COMSEC designation). The ground versions are equipped with a whisper mode for noise restriction during patrolling or while in defensive positions. The radio operator whispers into the handset while being heard at the receiver in a normal voice.

Advanced System Improvement Program

3-16. The SINCGARS advanced system improvement program increases the performance of the SINCGARS system improvement program (RT-1523 C/D models). It also increases its operational capability in support of the tactical networking environment, specifically improved data capability, manpower and personnel integration requirement compliance, and flexibility in terms of interfaces with other systems.

3-17. Table 3-2, on page 3-4, outlines a comparison of the SINCGARS integrated COMSEC, SINCGARS system improvement program, and the SINCGARS advanced system improvement program radios. All advanced system improvement program radios can be remotely operated by another advanced system improvement program radio up to 4 kilometers (2.4 miles) away, via a two-wire twisted pair (typically wire direct-1 or wire field-16). To remote a radio, use an external two-wire adapter as the interface between the radio and the wires. Performance of the remote control feature occurs between the dismounted RT and the vehicular amplifier adapter, or between two dismounted RTs. Another host controller can control the advanced system improvement program radio via the external control interface when the advanced system improvement program radio system integrates as part of a larger system.

Table 3-2. SINCGARS enhancements comparison

Integrated communications security capabilities (RT-1523A/B) Point-to-point communications	***System improvement program capabilities (RT-1523C/D) Point-to-point communications***	***Advanced system improvement program capabilities (RT 1523E/F) Point-to-point communications***
1. Frequency-hopping per MIL-STD-188-242. 2. Mode 1, 2, 3 fill. 3. Electronic remote fill.	1. Frequency-hopping per MIL-STD-188-242. 2. Mode 1, 2, 3 fill. 3. Electronic remote refill.	1. Same as system improvement program.
Plain text and cipher text mode	***Circuit switching and packet network communications***	***Circuit switching and packet network communications***
1. Railman communications security. 2. Seville advanced remote keying.	1. Carrier sense multiple access protocol. 2. Railman communications security. 3. Seville advanced remote keying.	1. Same as system improvement program.
Point-to-point data communications	***Point-to-point data communications***	***Point-to-point data communications***
1. 600 to 4,800 bits per second standard data mode. 2. Tactical fire direction system, analog data. 3. Transparent 16 kilobits per second data.	1. 600 to 4,800 bits per second standard data mode. 2. Tactical fire direction system, analog data. 3. Transparent 16 kilobits per second data. 4. 1,200 to 9,600 bits per second enhanced data mode data. 5. Recommended standard-232 enhanced data mode data. 6. Packet data. 7. External control interface.	1. Same as system improvement program.
Other features	***Other features***	***Other features***
1. Noisy channel avoidance. 2. Enhanced message completion.	1. Noisy channel avoidance. 2. Enhanced message completion. 3. External global positioning system interface. 4. Embedded global positioning system hooks. 5. Remote control unit.	1. Same as system improvement program plus— • Enhanced system improvement program waveform. • Faster channel access to reduce network fragmentation. • Enhanced noisy channel avoidance algorithm to improve frequency-hopping synchronization probability. • Improved time of day tracking and adjustments. • Extra end of message hops to improve sync detection and reduce fade bridging. • Embedded battery.

Table 3-2. SINCGARS enhancements comparison (continued)

Vehicular Adapter Amplifier (AM-7239B):	*Vehicular Adapter Amplifier (AM-7239C):*	*Vehicular Adapter Amplifier (AM-7239E):*
1. Dual transmit power supply.	1. Dual transmit power supply. 2. Host interface. 3. Backbone interface. 4. MIL-STD-188-220D.	1. Same as system improvement program plus— • More powerful 860 microprocessor. • Ethernet interface. • Enhanced protocols. • Increased memory and buffer size.
LEGEND: MIL-STD	military standard	

Enhanced System Improvement Program Capabilities

3-19. The SINCGARS advanced system improvement program radio incorporates an enhanced system improvement program waveform. The waveform includes optimizations to the algorithms of the noisy channel avoidance scheme, the time of day tracking scheme, and the end of message scheme. Enhancements include—

- **Enhanced system improvement program waveform**-implements a faster channel access protocol, which reduces network fragmentation by shortening the collision intervals between voice and data transmissions. The result is the reduction of voice and data contention problems associated with shared voice and data networks.
- **Noisy channel avoidance algorithm**-always reverts to a known good frequency instead of constantly searching for clear frequencies, thus increasing the frequency-hopping synchronization probability in high noise and jamming conditions.
- **Time of day enhancement**-uses a reference built in test that assures time constraints are the same during each transmission.
- **End of message enhancement**-reduces fade bridging, whereby the transmission would linger even though adding extra end of message hops to increase the detection and probability of synchronization completes the message.

SINCGARS Internet Controller Card

3-20. The internet controller card, which is part of the SINCGARS vehicular amplifier adapter, supports data flow and permits an effective flow of information. The internet controller card is in the right hand side of the vehicular amplifier adapter, and only needed when the SINCGARS system is operating in the packet mode of operation.

3-21. The packet mode allows for the sharing of voice and data over the same operational network. A store and forward feature in the internet controller card delays data while voice traffic is ongoing, and puts data on the network when releasing the push-to-talk for voice. When the internet controller card is loaded with initialization data, it contains routing tables that identify the addresses of all members with which it is affiliated. The internet controller card loaded with initialization data also contains other routed radio networks. The host computers generate messages, along with the IP addresses of the individual(s) whom intended to receive the message.

3-22. When a message reaches an internet controller card, the internet controller card looks up its routing table to determine whether that message is for a member of its network or whether it requires submission to the next adjoining network. The packet mode automatically continues this routing process until it reaches its destination. The packet mode distinguishes if the message is for someone within its network, and if the message stops there, RETRANS of the message does not occur. This differs in a RETRANS site in that, network extension takes place for everything received at the RETRANS station.

3-23. The vehicular amplifier adapter mounted internet controller card is the predominant communications router for the tactical maneuver platforms participating in a SINCGARS enabled tactical networking environment. The internet controller card routes data between the SINCGARS and the EPLRS. The internet controller card uses commercial IP services to deliver unicast and multicast data packets.

3-24. The internet controller card has an improved microprocessor with increased memory buffer size and an Ethernet interface. Access to the Ethernet interface is through the same pin connector used for the EPLRS interface. Two of the nineteen pins used as twisted pairs provide for the 10Base-T Ethernet connection. This feature allows connection of multiple internet controller cards for the sharing or dissemination of information in a local area network configuration.

SINGLE CHANNEL GROUND AND AIRBORNE RADIO SYSTEM ANCILLARY EQUIPMENT

3-25. Remote control devices, data fill and variable storage transfer devices, and the vehicular intercommunications system are the main categories of ancillary equipment associated with SINCGARS addressed in the following paragraphs.

3-26. Remote control devices consist of intravehicular and external remotes. The intravehicular remote control unit is the remote for intravehicular radio control. The securable remote control unit is used to remote radios off the main site location. Utilize the system improvement program or advanced system improvement program radio as a remote control unit by selecting the remote control unit option under the remote control unit key of the system improvement program or advanced system improvement program RT keypad.

Intravehicular Remote Control Unit

3-27. Utilize the intravehicular remote control unit with either an integrated COMSEC or a non-integrated COMSEC radio. The intravehicular remote control unit controls up to two mounting adapters with up to three separate radio sets from a single station. The intravehicular remote control unit connects in parallel so that two different radio operators, such as the vehicle commander and the vehicle driver, can control the radios from their respective positions in the vehicle. Set the radio function switch to the remote operating position for the external control monitor to function correctly.

Securable Remote Control Unit

3-28. The securable remote control unit can securely remote a single radio up to 4 kilometers (2.4 miles). The securable remote control Unit and the RT are connected using field wire on the binding posts of the amplifier adapter or battery box. The securable remote control unit appears and operates almost identically to the RT. The securable remote control unit can secure the wire line between the radio and the terminal set. The securable remote control unit controls all radio functions including power output, channel selection, and radio keying.

3-29. The remote also provides an intercom function from the radio to the terminal unit and vice versa. COMSEC and data adapter devices attach directly to the securable remote control unit for secure communications over the transmission line and optimal interface with digital data terminals. The securable remote control unit replaced the AN/GRA-39. Four main configurations of the securable remote control unit include—

- Manpack radio in vehicular mounting adapter.
- Vehicular mounting adapter radio in manpack.
- Manpack radio in manpack.
- Vehicular mounting adapter radio in vehicular mounting adapter.

SINGLE CHANNEL GROUND AND AIRBORNE RADIO SYSTEM PLANNING

3-30. The initial operation plan and the unit's standard operating procedure determine the type of network(s) needed. The network planner answers the following questions—

- What type of information is passed: data, voice, or both?

- Does the unit require communications with users normally not in its network?
- Is the network a common-user or a designated membership network?
- Is RETRANS needed to extend the network's range?

3-31. The G-6 and the S-6, assistant chief of staff, operations and operations officer work together to answer all these questions. The answered questions begin the initial planning and coordination of the network. Many of the items are part of the unit's standard operating procedure. (Refer to Appendix A for information on FM networks.)

DATA NETS

3-32. The SINCGARS interfaces with several types of data terminal equipment. SINCGARS also provides automatic control of the radio transmission when a data device is connected. It disables the voice circuit during data transmissions, preventing voice input from disrupting the data stream; disconnecting the data device during emergencies overrides the disable feature. A single cable from the data terminal equipment to the radio or mounting adapter connects most data terminal equipment.

SECURE DEVICES

3-33. The SINCGARS uses an internal COMSEC module. The encryption format is compatible with VHF and UHF wideband tactical secure voice system cryptographic equipment devices, provided they are loaded with the same traffic encryption key (TEK). SINCGARS uses the KY-57 and KY-58 (VINSON) for non-integrated COMSEC airborne radio systems.

3-34. The VINSON secure device has six preset positions: five for the TEK and one for a key encryption key (KEK). The TEK positions allow operation in five different secure networks. The KEK position allows changing or updating the TEK through over-the-air rekeying. The integrated COMSEC secure module retains one TEK per preset hopset, net identifier, and one KEK.

3-35. The variables are loaded and updated the same in both devices. The SKL does the initial loading. Update variables by performing a second manual fill or by performing over-the-air rekeying. In accordance with COMSEC regulations, only transmit the TEK over the air. Physically load the KEK into either the VINSON or integrated COMSEC radio. Control each encryption variable through COMSEC channels and account for the variables in accordance with Army Regulation (AR) 380-40. (Refer to Appendix F for information on COMSEC compromise recovery procedures.)

3-36. Data input to the radio interleaves into the radio's digital data in a noncontiguous manner to increase performance. The VINSON or integrated COMSEC circuits encrypt the data before transmission. Digital data encrypted can occur before inputting the information into the radio Transmitting and receiving terminals require common COMSEC key variables coordinated between the two units passing information.

SINGLE CHANNEL GROUND AND AIRBORNE RADIO SYSTEM RETRANSMISSION STATION

3-37. Due to the limited number of SATCOM channels available in an area of responsibility, there is a crucial need for single channel push to talk capability at the theater, corps, and division. Most of the SATCOM channels available in an area of responsibility are controlled and assigned at the corps level and higher, and FM communications at corps, division, and brigade provide single channel communications on the move. FM RETRANS is the most available means of addressing the crucial need for single channel push to talk capability at the theater, corps, and division. FM RETRANS extends single channel communications around obstacles and across increased distances to its subordinate units.

3-38. The commander (with the recommendation of the signal officer) decides the critical networks requiring RETRANS support. RETRANS assets are primarily used to provide support for the following networks—

- Command.
- Administrative and logistic.
- Operations and intelligence.

- Fires.

Note. Refer to Appendix A for more information on FM networks.

3-39. The RETRANS station operates on the command network to which it is subordinate, unless specifically tasked to operate on another network. The primary radio monitors the command and operations and intelligence network; the secondary radio provides the RETRANS link. Prior planning provides the RETRANS station with the appropriate variables for the command network and RETRANS network. The unit standard operating procedure should direct the assignment of the RETRANS variables in accordance with possible alternatives.

3-40. SINCGARS can operate as either a secure or a non-secure RETRANS station. These radios automatically pass secure signals even if the RETRANS radios are operating non-secure. The RETRANS radio operator cannot monitor the communications unless the secure devices are filled and in the cipher mode.

RETRANSMISSION PLANNING

3-41. RETRANS planning requires linkage to the military decisionmaking process to ensure success. During RETRANS planning the S-6—

- Ensures integration of the communications operations course of action into the maneuver course of action.
- Plots primary and secondary RETRANS locations on the course of action sketch. Location selection requires mission, enemy, terrain and weather, troops and support available, time available, civil considerations analysis.
- Determines whether site collocation with another unit is required and considers security, logistics, and evacuation.
- Plans for contingency sites and establishes criteria, known to all concerned, that initiate relocation and evacuation procedures.
- Develops reporting procedures to the establishing headquarters.
- Builds a RETRANS team equipment list, and considers including the following communications equipment—
  - Defense advance global positioning system receiver.
  - SKL.
  - 2 x OE-254 or COM 201B antennas for each planned RETRANS net as well as all required cables.
  - Any extra AN/PRC-119 radios (used as a backup RT).
  - PRM-34 Test Kit.
  - Additional batteries.
- Establishes a pre-combat checklist and rehearses prior to deployment.

RETRANSMISSION MODES

3-42. The SINCGARS (ground) has built-in RETRANS capability that requires the addition of a retransmit cable (CX-13298) for operations. SINCGARS can perform the RETRANS function three ways. The network can be—

- Set up for single channel to single channel.
- Made of mixed modes (frequency hopping to single channel or vice versa).
- Used in its full capability of frequency hopping to frequency hopping.

3-43. These options enable RETRANS flexibility during operations. They also increase the prior coordination required before deployment. This ensures all users have access to the RETRANS function.

Single-Channel to Single-Channel Operations

3-44. Single-channel to single-channel operations requires a 10 MHz separation between the frequencies (as shown in Figure 3-1 depicts RETRANS operations). Physically moving antennas farther apart or lowering power output lessens the frequency separation.

Note. Obtain all RFs used from unit signal operating instruction, which are coordinated with the unit electromagnetic spectrum manager. Units do not establish their own RETRANS frequencies without electromagnetic spectrum manager coordination.

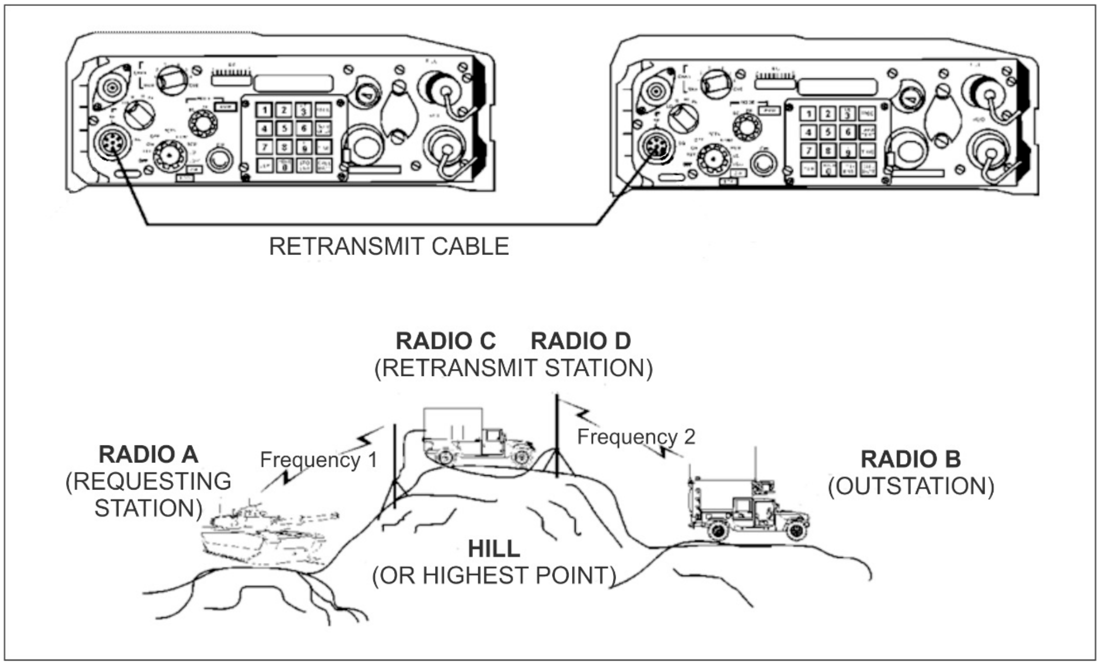

Figure 3-1. Retransmission operations

3-45. Table 3-3 shows the minimum antenna separation distance. The network NCS monitors the RETRANS station to ensure the command hopset provides continuous communications for the unit.

Table 3-3. Minimum antenna separation distance

Minimum Frequency Separation Required	*High Power Separation*	*Power Amplifier Power Separation*
10 MHz	5 feet (1.5 meters)	5 feet (1.5 meters)
7 MHz	10 feet (3 meters)	60 feet (18.2 meters)
4 MHz	50 feet (15.2 meters)	150 feet (45.7 meters)
2 MHz	200 feet (60.9 meters)	400 feet (121.9 meters)
1 MHz	350 feet (106.6 meters)	800 feet (243.8 meters)

Frequency Hopping to Single-Channel Operations

3-46. Frequency hopping to single-channel operations is a simple mode to set up and operate with no requirement for frequency or physical separation. The single-channel frequency should not be part of the hopset resource used on the frequency hopping side of the RETRANS. This method allows a single-channel radio user access to the frequency hopping net in an emergency. Avoid continual access to the frequency hopping net using this method in order to prevent lessening the electronic counter-countermeasures capability of the SINCGARS.

Note. The RETRANS station typically functions as the NCS during frequency hopping RETRANS operations.

Frequency Hopping to Frequency Hopping Retransmission Operations

3-47. Frequency hopping to frequency hopping RETRANS operations allows for the RETRANS of frequency hopping networks and is the simplest mode with no requirement for frequency or physical separation. Frequency hopping RETRANS operations are traditional F1:F2 or F1:F1, depending upon the model of SINCGARS and mission. The SINCGARS advanced system improvement program provides the capability for F1:F1 operations.

3-48. F1:F2 operations require at least one of the network identifiers to be different (for example, network identifier F410 to network identifier F411). Any one, or a combination of network identifiers, may change. The preferred method is for the network identifiers, for each side of the RETRANS, to be located within the same hopset. The RETRANS station radio operator functions like the network NCS for the outstation link. In this function, the radio operator answers all cues, electronic remote refill, and authenticate net entry. The RETRANS radio operator ensures the outstation RT is placed in the frequency hopping master mode; this ensures timing on this link is established and maintained.

3-49. F1:F1 operations allow both network identifiers to be the same. This is important when operating in the tactical networking environment. RETRANS is not an option in the packet mode for system improvement program and earlier SINCGARS, due to the critical timing associated with the packet mode. In a traditional F1:F1 RETRANS, a member of the outstation could potentially have captured the network due to the relatively long delays encountered at the RETRANS site; rendering the RETRANS packet lost.

3-50. The advanced system improvement program system overcomes this problem by assigning each radio at the RETRANS site as a dedicated receiver or transmitter. The advanced system improvement program shifts the incoming transmission by two hops in time and utilizes the same hopset on each leg of the RETRANS (commonly called F1:F1). Send packets out the moment received without going through the process of interleaving and deinterleaving. Shift in two hops is insignificant enough to affect the performance of the outstation and would make the RETRANS site appear to be a part of one large network. (Refer to Appendix D for information on radio operations in unusual environments.)

NAVIGATION

3-51. Frequency-hopping radios such as the SINCGARS depend on accurate time as part of the frequency-hopping scheme. SINCGARS obtain timing from a GPS receiver in precise positioning service mode. COMSEC enabled GPS services such as precise positioning service, mitigates the effect of position, navigation and timing jamming. Military regulations mandate the use of GPS receivers in precise positioning service mode in support of operations. Unencrypted GPS, standard positioning service or course acquisition mode, authorization is for unofficial personal situational awareness or logistics material tracking. Navigation employed to support tactical radio operations provide positioning data, time, and velocity.

DEFENSE ADVANCE GLOBAL POSITIONING SYSTEM RECEIVER

3-52. The defense advanced global positioning system receiver collects and processes the GPS satellite link one and link two signals to provide position, velocity, and timing information, as well as position reporting and navigation capabilities. The defense advanced global positioning system receiver is primarily a handheld unit with a built-in integral antenna, but can be installed in a host platform (ground facilities, air, sea, and land vehicles) using an external power source and an external antenna. When used as a handheld unit the defense advanced global positioning system receiver also operates with an external link one or link two, antenna external power source.

3-53. The defense advanced global positioning system receiver has a precise positioning service. HAVEQUICK, and SINCGARS page configure a defense advanced global positioning system receiver communications port for a time synchronizing output from the defense advanced global positioning system receiver (using external connectors J1 or J2) to another piece of equipment, such as a SINCGARS.

Figure 3-2 depicts a defense advanced global positioning system receiver. Refer to TB 11-5820-1172-10 and Technical Manual (TM) 11-5820-1172-13&P for more information on the defense advanced global positioning system receiver.

Figure 3-2. Defense advanced global positioning system receiver

ENHANCED POSITION LOCATION REPORTING SYSTEM

3-54. The EPLRS is a digital UHF radio that represents the Army's mid tier terrestrial mobile ad hoc networking backbone data network for the digitized environment and ground forces. The EPLRS provides terrestrial transport for operational environment situational awareness to the mobile user and their higher headquarters. This information greatly enhances situational awareness for tactical units by providing commanders with the location of friendly units, a dynamic representation of the Forward Line of Troops and abbreviated situation reports for conditions and identification of adjacent equipped units.

3-55. The EPLRS is a digital network, which comprises a network of individual radios that provide secure, electronic warfare resistant data communications to Army Mission Command Systems and the Force XXI Battle Command, Brigade and Below for situational awareness. The EPLRS provides interoperability with the U.S. Marine Corps Position Location Reporting System and interoperability with the Air National Guard and Air Force Situational Awareness Data Link.

3-56. The EPLRS provides Soldiers with an integrated network that supports warfighting systems across all phases of operations at all echelons in support of unified land operations. The EPLRS provides on the move, high-speed, automated data exchange, to deliver speed of service in support of Soldiers time sensitive critical information requirements. Use of the EPLRS enables Soldiers to leverage the extensive on-the-move networking capabilities of the EPLRS to display a common operational picture containing relevant operational information to enhance situational awareness. The EPLRS enables commanders to make informed command decisions during operations and the EPLRS enables Army interoperability with other Services during joint operations.

3-57. The EPLRS is employed as RETRANS platforms to provide RETRANS capability, in commander vehicles to create shared understanding between leaders in Army Airborne Command and Control System helicopters, and in CP and tactical CP platforms at the sustainment brigade and battalion level. Executive officers, first sergeants, platoon leaders, and platoon sergeants at the company and platoon level also employ the EPLRS as their tactical platform. The EPLRS provides an alternate data communications link (host-to-host) between information systems at the brigade and battalion level. The EPLRS provides the primary data communications link between brigade and battalion platforms and company and platoon tactical platforms.

3-58. A large net control station centrally managed the first generation EPLRS fielded to the Army, offering 56 kilobits per second of user throughput through a military implementation of the X25 interface standard. Today's 4th generation EPLRS no longer relies on centralized network management and provides 2 megabits per second of user throughput through an industry standard Transmission Control Protocol and IP interface. The EPLRS automatically routes and delivers messages, enabling accurate and timely computer-to-computer communications in the operational environment. Using time division multiple access, frequency hopping, and error correction coding technologies, the EPLRS provides the means for high-speed horizontal and vertical information distribution. The EPLRS radio sets are jam-resistant and secure data radios that transmit and receive tactical data that typically includes—

- Operation orders.
- Fire support plans.
- Logistics reports.
- Situational awareness data.
- Cryptographic keys for radio sets.
- Configuration files for radio sets.
- E-mail.

3-59. The basis for EPLRS radio connectivity is the EPLRS needline. Each needline defines the operational relationship between the source and destination EPLRS units, without specifying which additional EPLRS units are part of the connection. The type of transmitted data, the mode of operation, and the data rate effects the planning distance between individual EPLRS units and the number of “hops,” or relays, that can be included in an EPLRS link. Accurate planning and network configuration is critical to provide proper area coverage within the tactical environment. Refer to TB 11-5825-298-10-1, for more information on the EPLRS and refer to TM 11-5825-298-13&P for more information on the EPLRS network manager.

3-60. The EPLRS consists of an RT, an operator interface device (the user readout), an antenna, and a power source.

3-61. The radio set provides transmission network extension functions that are transparent to the user. The EPLRS radio set has the following characteristics and capabilities—

- Operates in the 420–450 MHz UHF frequency band.
- Provides secure, jam resistant digital communications and accurate position location capabilities.
- Uses time division multiple access, frequency hopping (512 times per second), and spread spectrum technology (eight frequencies between 420–450 MHz).
- Provides secure communications with a low probability of interception or detection using the embedded COMSEC module, transmission security (TRANSEC), and an adjustable power output.
- Built in test function activated at power turn on.
- Uses an omni-directional dipole antenna capable of covering the 420–450 MHz frequency ranges.
- Provides RETRANS functions that are transparent to the user. 3 to 10 kilometers (1.8 to 6.2 miles) distance between each radio and the maximum number of network extensions in the link form the basis for the maximum distance that the EPLRS can cover.
- Handles up to 30 needlines. The maximum number of needlines available is dependent on the bits per second required for each needline.

3-62. There are four different configurations of the EPLRS—

- AN/PSQ-6 manpack radio set.
- AN/VSQ-2 surface vehicle radio set.

- ASQ-177C airborne radio set.
- AN/GRC-229 grid reference radio set.

3-63. The RF network consists of EPLRS radio sets connected to host computers. This provides secure host-to-host data communications for the host computers.

3-64. The radio set uses a wide band direct sequence spread spectrum waveform, time division multiple access, frequency hopping, and embedded error correction encoding. These capabilities provide for secure, high-speed data communications between ground units and between ground units and aircraft. Most of the radio sets attributes are programmable and this programmability lets the planner set up the best possible anti-jam performance and data rate for unique environments and missions.

3-65. The EPLRS has automatic network extension capabilities to support beyond line of sight coverage. These capabilities are automatically and continually adapted to the changing conditions faced by a mobile communications system.

3-66. The radio set also supports position location and identification capabilities. Position location allows users to determine precisely where the user is. It is similar to, but independent of, the GPS. Using position location data from the radio sets, some hosts may have the capability to determine where other radio sets are and can perform navigation functions.

Enhanced Position Location Reporting System Needlines Functions

3-67. A logical channel number or permanent virtual circuits are other names used when referring to needlines. There can be many needlines running on a radio set at one time, supporting the hosts' data communications needs. Activate needlines manually via the user readout or host, or automatically by the host. The radio set automatically activates the needline upon receipt of any data received on the corresponding logical channel number. Turning the radio set off or any other loss of power, results in automatic reactivation of needlines upon restoration of power back to the radio set.

Types of Needlines

3-68. There are seven major types of needlines, each falling into the two major types of host-to-host services (broadcast and point-to-point)—

- **Point-to-point needlines** provide unequal data transfer capability for two endpoints' hosts. Endpoint can either have all the data transfer capability, or split the data transfer capability between them in various ratios. Data transfer occurs at user data rates from 1,200 bits per second each way, up to 56,000 bits per second one-way. An example of how a point-to-point needline works would be the same as one person talking to another person on a telephone.
- **Simplex (one-way) needlines** provide a single host the capability to send data to many hosts. For simplex needlines, transfer of data at user data rates from 160–3,840 bits per second. An example of how a simplex needline works would be the same effect as using a bullhorn to talk to many people at the same time who cannot talk back.
- **Carrier sense multiple access needlines** provide many hosts the capability to send data to each other. For carrier sense multiple access needlines, transfer of data at user data rates from 150–487,760 bits per second (for the whole needline). The radio set ensures no other radio sets utilize the carrier sense multiple access needline and then sends data from the host. When completed, another radio set ensures no other radio sets are using the needline and then transmit. This protocol allows many endpoints' hosts (multiple access) to use the same carrier sense multiple access needline to send data to one or more endpoints' hosts. An example of a carrier sense multiple access needline would be like a group of people on a contention voice network, each speaking when they have something to say and no one else is speaking.
- **Multisource group needlines** provide up to 16 hosts the capability to send data to many hosts. Multisource group needlines provide each source host guaranteed bandwidth without conflict, with user data rates from 37.5–485,760 bits per second. Data transferred from one source also goes to the other sources. If fewer sources are used, the sources can have more than 1/16th of the data transfer capability. Each 1/16th equates to a share. For example, a source endpoint can be assigned to have 4/16th of the total multisource group data transfer capability, with 12 other source

endpoints each having 1/16th of the total multisource group data transfer capability. If there are unused shares, a radio set whose host load is larger than its assignment on the multisource group needline utilize the available shares. The more shares a radio set has, the more data transfer capability it has. The radio set also supports eight and four share multisource group needlines that provide faster speed of service. An example of how a multisource group needline works would be the same effect as up to 16 people with bullhorns talking, in a round robin fashion, to many people who cannot talk back. A multisource group needline is similar to a carrier sense multiple access needline, but each sender has a dedicated, guaranteed amount of time to talk (similar to many concurrent simplex needlines).

- **Low data rate duplex (two-way) needlines** provide radio-acknowledged, higher reliability, balanced data transfer between two hosts with data rates from 20–1920 bits per second each way. They provide equal data rates in both directions. Either or both endpoints utilize this data transfer capability. The endpoint radio sets automatically ensure delivery of the data using radio set to radio set acknowledgement protocols. This needline type requires preplanning for the radio set to be able to use. An example of how a duplex needline works would be the same effect as talking to another person on a telephone.
- **Dynamically allocated permanent virtual circuit needlines** are a special type of duplex needline. They have capabilities similar to those of duplex needlines (rates are 60–1920 bits per second), but dynamically allocated permanent needlines are automatically set up and deleted on demand by the host, without any preplanning or NCS involvement. If the network resources are not available to support the data rate requested by the host, the needline rate reduces to the highest rate available that the radio set can support.
- **High data rate duplex needlines** have the same features as duplex needlines except that the data rates are higher, from 600–121,440 bits per second each way.

Enhanced Position Location Reporting System Communications Needlines Capabilities

3-69. An EPLRS radio set can support needlines as an endpoint, network extension, or as both. A radio set can be a network extension on some needlines, an endpoint on other needlines, and an endpoint and a network extension on other needlines, all at the same time. As an endpoint, a radio set can send and receive data to and from its host on a needline. A radio set that is only a network extension (not an endpoint) cannot send or receive data to and from its host, and might not even have a host. For simplex, duplex, and dynamically allocated permanent needlines, radio sets automatically sign up as a network extension if they have the resources available.

3-70. For point-to-point, carrier sense multiple access, multisource group, and high data rate duplex needlines, a network extension can only be endpoints on the needline, or they mst be manually set up. When existing radio sets cannot support the EPLRS network extension needs, then dedicated network extensions are required.

3-71. Many host-to-host communications services can run on a radio set at one time. There can be from one to thirty total needlines activated per radio set, depending upon the size of the needlines. If the maximum number is stored in the radio set, then another activated needline cause the deletion of the oldest stored needline. There can be a maximum of eight activated carrier sense multiple access, high data rate duplex, multisource group, and point-to-point needlines, total, per radio set.

3-72. A needline can use any of four waveform modes, 0–3. The higher the waveform mode number, the higher data rate capability the needline has, but the lower the needlines anti-jam capabilities. (For more information on the EPLRS and the EPLRS system components refer to TM 11-5825-283-10.)

ENHANCED POSITION LOCATION REPORTING SYSTEM NETWORK MANAGER

3-73. The EPLRS network manager equipment suite includes the following major components—

- **EPLRS network manager software package (compact disk)**. EPLRS network manager software program, which includes installation program for loading Enhanced Position Location Reporting System network manager and EPLRS network planner onto EPLRS network manager computer hard disk.

- **EPLRS network manager computer**. Consists of a central processing unit and associated cabling; host computer platform for EPLRS network manager software.
- **AN/VSQ-2D(V)1 surface vehicle radio set.** RT-1720DI/G, RT-1720EI/G, or RT-1720FI/G, with user readout—also serves as the EPLRS network manager radio set by connecting to the EPLRS network manager computer.
- **Surface vehicle unit installation kit for surface vehicle-radio set**. Consists of platform, cables, user readout mount, and AS-3449/VSQ-1 antenna.
- **KOK-23 key generator**. Generator key generation device for generating red and black cryptographic keys for network radio sets. (Not required for every EPLRS network manager.)

3-74. The EPLRS network manager is a collection of software applications that run on a rugged host computer. The EPLRS network manager performs automated network management and control of the EPLRS network. The EPLRS network manager assigns configuration parameters to radio set sets to allow them to perform their missions. The EPLRS network manager manages the generation of cryptographic keys from a KOK-23 to load into the radio set.

3-75. The EPLRS network manager application installed on a rugged laptop computer supports radio set configuration, planning, monitoring, managing, and maintaining an EPLRS network. Hosting EPLRS network manager on a laptop computer also enables the transport of EPLRS network manager into the field for direct connection to a radio set for configuration and troubleshooting. The EPLRS network manager computer physically connects to an EPLRS radio set called an EPLRS network manager radio set directly via either Ethernet 802.3 or recommended standard-232 point-to-point protocol.

3-76. The EPLRS network manager computer can also connect indirectly via a router using IP-over-Army Data Distribution System Interface Protocol. The EPLRS network manager vehicle is a high mobility multi-purpose wheeled vehicle that contains the EPLRS network manager and other communications equipment.

3-77. The EPLRS network manager plan and manage the EPLRS radio set network. The EPLRS network manager can accommodate any size EPLRS radio set network. There are no restrictions on the number of radios stored and managed by a single EPLRS network manager. A maximum of 64 needlines assigned to any single radio set, so there are practical limitations to the size of the network.

3-78. The EPLRS network manager's software application manages and controls the EPLRS network based on a deployment plan. EPLRS network manager loads the radio sets with the configuration data needed to perform their missions. The EPLRS network manager also generates the cryptographic keys for the radio sets. The EPLRS network manager runs on a rugged laptop computer that connects to an assigned radio set.

3-79. The EPLRS network manager operators set up, maintain, and manage the EPLRS network. There are two basic levels of EPLRS network manager controlled by software login: network and monitor. Network EPLRS network managers monitor the status of network radio sets, configure radio sets over the air, initiate network timing, and perform other managerial tasks. Monitor EPLRS network managers have a lower level of access and only monitor the status of the network radio sets. Monitor EPLRS network managers cannot perform the managerial task over-the-air reconfiguration of radio sets. Normally, one network EPLRS network manager is responsible for issuing the time master initiate command and distributing updated deployment plan files, if required. Other EPLRS network managers manage their own groups of assigned radio sets and coordinate with the time master EPLRS network manager as required.

3-80. The EPLRS network maintains continuity of operations. If a specific EPLRS network manager is disabled, control of the assets assigned results in automatic transfer of that EPLRS network manager to another EPLRS network manager. Once an EPLRS network manager initiates the network, the existing network continues to operate even if all EPLRS network managers are disabled. An EPLRS network manager is not required for the radio sets to maintain the network and provide communications services to the hosts.

MICRO-LIGHT MAN-PORTABLE RADIO

3-81. The Micro-Light Man-Portable Radio RT-1922 is an EPLRS radio that forms ad hoc networks to exchange data at up to 1 megabit per second. The RT-1922 transmits data using IP, allowing any personal computer-driven computer to accept and display information, images, and video. The radio moves video, data, and pictures in real time. A unit supported by forward observers can radio back to headquarters with information, pictures, and a map of the exact location of any threats. The Micro-Light Man-Portable Radio—

- Small IP based data radio used for a host of applications.
- Self-contained radio device with an option of industry standard host interfaces.
- Provides unsecured voice communications and remote capability at a range of 10 + Kilometers.

MICRO-LIGHT PERSONAL SOFTWARE DEFINED NETWORKED RADIO

3-82. The MicroLight-DH500 radio is fully integrated and lightweight personal software defined networked communications radio that provides Soldiers with simultaneous voice, video, data, and critical position location information. The radio utilizes the Micro-Light 2nd Generation technology in support of Army dismounted operations by hosting the EPLRS and SRW. The radio integrates the functionality of an external voice controller and a GPS receiver. The MicroLight-DH500 radio is compatible with advanced system improvement program–enhanced running EPLRS or SRW and EPLRS vehicular radios. The radio provides Software Communications Architecture compliant integrated Voice over Internet Protocol.

HIGH FREQUENCY RADIOS

3-83. HF radios provide tactical elements with stand-alone, terrain independent, robust communications, for line of sight and beyond line of sight, secure voice, and data communications. HF radios provide long distance, wide area, gap free, fixed or on the move, ground and ground to air communications. HF radios are terrestrial beyond line of sight systems that require a good understanding of HF capabilities and antenna design to support local beyond line of sight requirements. HF radios provide a combination of simplicity, economy, transportability, and versatility. HF radio operations require that radio operators continually adjust the system to compensate for the ionosphere, and an ever-changing terrestrial environment (electromagnetic interference from the other stations, atmospheric interference, and manmade noise). Successful HF communications performance depends on—

- Type of emission.
- Amount of transmitter power output.
- Characteristics of the transmitter antenna. (To select the best antenna the planner requires an understanding of wavelength, frequency, resonance, and polarization. Chapter 10 addresses antenna techniques in detail.)
- Amount of propagation path loss.
- Characteristics of the receiver antenna.
- Amount of noise received.
- Sensitivity and selectivity of the receiver.
- An approved list of usable frequencies within a selected frequency range.

3-84. HF radios have the following characteristics that make them ideal for tactical long distance, wide area communications—

- HF signals reflected off the ionosphere at high angles allow beyond line of sight communications at distances up to 400 miles (643.7 kilometers), without gaps in communications coverage.
- HF signals reflected off the ionosphere at low angles allow communication over distances of many thousands of miles.
- HF signals do not require the use of either SATCOM or RETRANS assets.
- HF systems engineered to operate independent of intervening terrain or manmade obstructions.

3-85. Training Soldiers on the operation and use of HF radios play a vital role in successful accomplishment of units' mission requirements. Communications planners at every level need to understand the concepts of propagation, path loss, antennas, antenna couplers, and digital signal processing. (Refer to Chapter 10 and Appendix D for more information on antennas and radio communications in unusual areas.)

3-86. The following paragraphs are examples of HF radios typically employed by Army forces.

RF-5800H RADIO

3-87. The RF-5800H is an advanced HF and VHF man-pack radio that supports HF single side band VHF-FM and provides reliable tactical communications through enhanced secure voice and data performance, networking, and extended battery life. The RF-5800 supports encrypted data, automatic link establishment (ALE), frequency hopping, vocoder, data link layer protocol (Automatic Repeat ReQuest), internal GPS, integrated telephony capability, and network management features.

HIGH FREQUENCY-SINGLE SIDE BAND

3-88. HF-Single Side Band is a terrestrial beyond line of sight tactical network capability employed as a redundant backup system to counter jamming in frequencies or distance. HF propagation requires an understanding of the radio's power capabilities, the frequency utilized on the radio, and the planning distance over which the utilized radio determines which type of antenna to utilize (whip, near vertical incident skywave, or doublet).

AN/VRC-100 RADIO

3-89. The Advanced High Frequency Ground Vehicular AN/VRC-100 radio is a multifunctional, full digital signal processing HF radio utilized for a variety of ground or mobile applications. The AN/VRC-100 radio is a fully integrated plug and play multi-mode voice or data communications system configured in a portable case. The radio allows substantial distance communications beyond line of sight by providing users the ability to maintain contact during short, mid, and long range operations. As an advanced data communications system, the AN/VRC-100 provides reliable digital connectivity.

3-90. The AN/VRC-100 radio uses the RT, power amplifier coupler, and control display unit line replaceable units of the AN/ARC-220 system without modification, within an aluminum-structured, bracketed case. The AN/VRC-100 has a portable, metal case, with a removable top, that provides easy access for removal of line replaceable units. All controls as well as the radio input and output are located on the front panel. The AN/VRC-100 provides beyond line of sight communications for CPs, air traffic control, and vehicular applications such as the high mobility multipurpose-wheeled vehicle. The AN/VRC-100 increases the situational awareness of aviation assets. The AN/VRC-100 has capabilities that are identical to the ARC-220 HF radio, which makes the AN/VRC-100 radio an ideal radio to support ARC-220 HF radio equipped airborne platforms. Key features of the AN/VRC-100 are—

- Full digital signal processing with embedded ALE, EP, and data modem.
- Spare card slot in the RT provides for future growth.
- Operates on 28 volts direct current volts direct current (and is compatible with 24 volts direct current vehicular power) or from 115 or 220 volts alternating current 50 and 60 Hertz power source.
- Personal computer or laptop connectivity.
- E-mail messaging using local recommended standard-232 interface.
- Capability to tune a variety of antennas.

3-91. Table 3-4 lists the three basic configurations of the AN/VRC-100. Refer to TM 11-5820-1141-12&P for more information on the AN/VRC-100(V) 1/2/3.

Table 3-4. AN/VRC-100 configurations

Configuration	*Description*
AN/VRC-100(V) 1	Consists of three line replaceable units housed in a metal casing with a power supply and speaker.
AN/VRC-100(V) 2	Consists of the AN/VRC-100(V) 1 mounted in a wheeled vehicle.
AN/VRC-100(V) 3	Consists of the AN/VRC-100(V) 1 with the AS-3791/G broadband antenna and is used at theater level.

Table 3-4 AN/VRC-100 configurations (continued)

AN/PRC-150 RADIO

3-92. The AN/PRC-150 radio provides tactical, homeland defense forces and emergency operations elements with stand-alone, terrain independent, robust communications, for line of sight and beyond line of sight, secure voice, and data communications. The AN/PRC-150 radio does not rely on RETRANS, or SATCOM. The radio provides long distance, wide area, gap free, fixed or on the move, ground and ground to air communications via plain text and secure analog voice with robust data and digital voice modes as well as advanced serial tone electronic counter-countermeasures modem IP networking. The AN/PRC-150 supports Red and Black key management and ALE link protection. HF signals travel longer distances over the ground than the VHF (SINCGARS) or UHF (EPLRS) signals. HF signals are least affected by factors such as terrain or vegetation. The AN/PRC-150 vehicular radio systems provide units with beyond line of sight communications without having to rely on satellite availability on a crowded tactical communications network. The systems' manpack and vehicular configurations ensure units have reliable communications while on the move, and allow for rapid transmission of data and imagery to display the display the Common Operational Picture.

3-93. When employed the AN/PRC-150 radio supports single channel radio operations, and frequency hopping radio operations. The AN/PRC-150 has the following characteristics and capabilities—

- Frequencies range from 1.6–29.9999 MHz using skywave modulation with selectable low, medium, and high output power. It also operates from 20.0000–59.9999 MHz FM with a maximum output of 10.0 watts.
- Configured in manpack, mobile and fixed station configurations.
- Embedded Type I multinational cryptographic algorithms allows secure voice and data communications between ground and aircraft.
- Able to interface with SINCGARS cryptographic ignition key embedded in the removable key pad.
- Advanced electronic counter-countermeasures serial-tone frequency hopping improves communications reliability in jamming environments.
- Supports frequency hopping in HF narrowband, wideband, and list.
- Programmable system presets for "one-button" operation.
- Internal tuning unit matches a wide variety of whip, dipole, and long-wire antenna automatically.
- Internal, high-speed military standard (MIL-STD) -188-110C serial-tone modem provides data operation up to 9,600 bits per second.
- Embedded MIL-STD-188-141C ALE, digital voice 600 simplifies HF operation by automatically selecting an accepted channel.
- Supports standardization agreement (STANAG) 4538 automatic radio control system link set-up and data link protocols in third generation ALE radio mode.
- Point-to-point protocol or Ethernet supports networking capabilities.
- Operating in STANAG 4538, supports wireless IP data transfer when operating in STANAG 4538.
- Supports frequency hopping in HF narrowband, wideband, and list.
- Does not support frequency hopping SINCGARS compatible loadsets.

3-94. The AN/PRC-150 transceiver has an extended frequency range of (1.6–60 MHz) in combination with 16 kilobits per second digital voice and data enables fixed frequency interoperability with other VHF FM CNRs. The AN/PRC-150 provides Type 1 voice and data encryption compatible with advanced narrowband digital voice terminal (ANDVT)/KY-99A, ANDVT/KY-100, VINSON/KY-57, and KG-84C cryptographic devices.

3-95. The AN/PRC-150 is also capable of data communications utilizing the Tactical Chat software provided with the radio. Point-to-point data transmission can be completely secure. Use of the radios third generation ALE enables synchronized scanning to take place quickly and smoothly.

AUTOMATIC LINK ESTABLISHMENT

3-96. HF radios with ALE capability permits radio stations to make contact with one another automatically. The success of ALE is dependent on effective frequency propagation and HF antenna construction and use. ALE occurs when a specialized radio modem, known as an ALE adaptive controller assigned the task of automatically controlling an HF receiver and transmitter, establishes the highest quality communications link with one or multiple HF radio stations. ALE controllers can be external devices or an embedded option in modern HF radio equipment.

3-97. ALE controllers function on the basic principles of link quality analysis and sounding. ALE tasks are accomplished using the following common elements—

- Each controller has a predetermined set of frequencies (properly propagated for conditions) programmed into memory channels.
- Channels continuously scanned (typically at a rate of two channels per second).
- Each controller has a predetermined set of network call signs programmed into memory that include its own station network call sign, network call signs, group call signs, and individual call signs.
- ALE controllers transmit link quality analysis, which sound the programmed frequencies for best link quality factors on a regular, automated, or operator-initiated basis.
- When in a listening mode, ALE units (receiver transmitter [RT]) log station call signs and associated frequencies, and assign a ranking score relevant to the quality of the link on a per channel basis.
- When a station desires to place a call, the ALE controller element attempts to link to the outstation using the data collected during ALE and sounding activities. If the sending ALE has not collected the outstation's data, the controller seeks the station, and attempt to link a logical circuit between two users on a network that enables the users to communicate using all programmed channels.

3-98. When the receiving station hears its address, it stops scanning and stays on that frequency. A handshake (a sequence of events governed by hardware or software, requiring mutual agreement of the state of the operational mode prior to information exchange) is required between the two stations. The two stations automatically conduct a handshake to confirm that a link was established. Upon a successful link, the ALE controllers cease the channel scanning process, and alert the radio operators that the system has established a connection and that stations should now exchange traffic.

3-99. Table 3-5 outlines communication between two stations during the handshake and link quality analysis.

Table 3-5. ALE system handshake

	Call Station	***Message***	***Receive Station***
Handshake Process	B3B	"T6Y this is B3B"	T6Y
	Receive Station	***Message***	***Call Station***
	B3B	"B3B this is T6Y"	T6Y
	Call Station	***Message***	***Receive Station***
	B3B	"T6Y this is B3B"	T6Y
		Systems Linked	

3-100. The channel numbers represent programmed frequencies, and the numbers in the matrix are the most recent channel-quality scores. Thus, if a radio operator wanted to make a call from "B3B" to "T6Y", the radio would attempt to call on Channel 18, which has the highest link quality analysis score.

3-101. When making multi-station calls, the radio (B3B) selects the channel with the best average score. Thus, for a multi-station call to all addresses in the matrix, select Channel 14. Table 3-6 on page 3-20 outlines the link quality analysis matrix for B3B.

Table 3-6. Notional link quality analysis matrix for a radio (B3B)

Address (call sign)	Channels				
	01	02	04	14	18
R3R	60	33	12	81	23
B6P	10	--	48	86	21
T6Y	--	--	29	52	63
E9T	21	00	00	45	--

3-102. Upon completion of a link session, the ALE controllers send a link termination command, and return to the scanning mode to await further traffic. Built-in safeguards ensure that ALE controllers return to the SCAN mode in case of a loss-of-contact condition.

3-103. Modern ALE controllers are capable of sending short orderwire digital messages known as automatic message displays to members of the network. Messages can be sent to “ANY” or “ALL” members of the NET or GROUP. ALE controllers can contact individual stations by their call sign, ALL stations, or ANY stations on the NET or GROUP. ALL calls and ANY calls make use of wildcard characters in substitution for individual call signs such as @?@ ALL and @@? ANY. NULL address calls used for systems maintenance, and sent as @@@. (Refer to ATP 6-02.72 for more information on HF ALE.)

Frequency Selection

3-104. For ALE to function properly, frequency selection is important. Consult with the spectrum manager early on in the process. When selecting frequencies to use in a network, take the following considerations—

- Time of operation.
- Communicated distance.
- Power level.
- Type of antenna used.
- Transmission in voice, data, or continuous wave mode.
- Location of transmitter and receiver.

3-105. HF propagation changes daily. Lower frequencies work better at night and higher frequencies work better during the day. Select frequencies based on the type of network and the distance between radios. When using these parameters, use a good propagation program to determine which frequencies propagate.

Third Generation ALE

3-106. The third generation HF ALE system uses a family of scalable burst waveform signaling formats for transmission of all control and data traffic signaling. Scalable burst waveforms define the various kinds of signaling required in the system, to meet their distinctive requirements as to payload, duration, time synchronization, and acquisition and demodulation performance in the presence of noise, fading, and multipath. All of the burst waveforms use the basic binary phase-shift key serial tone modulation at 2400 symbols per second as used in the MIL-STD 188-110C serial tone modem waveform. The low-level modulation and demodulation techniques are similar to those of the MIL-STD 188-110C modems.

3-107. In contrast to the MIL-STD-188-110C waveform, the waveforms used in the third generation HF ALE system design balance the potentially conflicting objectives of maximizing the time diversity achieved through interleaving, and minimizing on-air time and link turn-around delay. The latter objective plays an important role in improving the performance of ALE and automatic request for RETRANS systems, which by their nature require a high level of agility.

3-108. Third generation HF ALE systems establish one-to-one and one-to-many (broadcast and multicast) links. It uses a specialized carrier sense multiple access scheme to share calling channels, and monitors traffic channels prior to using them to avoid electromagnetic interference and collisions.

3-109. Calling and traffic channels may share frequencies, but the system is likely to achieve better performance when they are separate. Each calling channel is associated with one or more traffic channels that are sufficiently near in frequency to have similar propagation characteristics. The concept of associated control and traffic frequencies reduces to the case in which the control and traffic frequencies are identical.

3-110. Third generation HF ALE receivers continuously scan an assigned list of calling channels, listening for second generation or third generation calls. Second generation ALE is an asynchronous system in the sense that a calling station makes no assumption about when a destination station listens to any particular channel. The third generation HF ALE system includes a similar asynchronous mode; synchronous operation is likely to provide superior performance under conditions of moderate to high network load.

IMPROVED HIGH FREQUENCY RADIOS

3-111. Improved high frequency radios are manpack or vehicular mounted radios that operate in the 2 to 30 MHz range to provide medium-to long-range communications. Employed at all echelons, improved high frequency radios are single sideband radios that operate in upper or lower sideband. Improved high frequency radios accept voice and data rates input up to 2400 bits per second when used with appropriate data modems. Typically employed at brigade and below units, the low-power versions of the improved high frequency radios are user-owned and operated. When using the improved high frequency radio, secure all transmissions with an approved cryptographic device. The capabilities of improved high frequency radios enable the radios to be flexible, securable, mobile, and reliable.

3-112. The RT-1209 is the primary component of improved high frequency radio sets. Depending on the units' mission, the RT-1209 combined with other components creates manpack, vehicular or fixed station radios. The near-vertical incident sky wave antenna, AS-2259/GR is the issue item antenna for improved high frequency radios. The near-vertical incident sky wave antenna is interchangeable with the AN/GRA-50 and the whip antenna. The near-vertical incident sky wave antenna may be remotely located up to 61 meters (200 feet) from the radio set. Component changes to establish the different configurations are relatively small, which makes the sets lightweight and versatile. The improved high frequency radio configurations are—

- AN/PRC-104.
- AN/GRC-213.
- AN/GRC-193A.

AN/PRC-104

3-113. The AN/PRC-104 radio provides long-range CNR connectivity between operational elements at all echelons of the Army. The primary use of the AN/PRC-104 is back-up communications in the event the area common user system or organizational unique communications networks fail. The radio is capable of transmitting and receiving voice and data and externally secured with the KY-99A MINTERM COMSEC device. The AN/PRC-104 consists of the RT-1209, amplifier and coupler AM-6874, antennas, and handsets configured for manpack operations. The AN/PRC-104 is a low power radio that operates in the 2 to 29.999 MHz frequency range and passes secure information over medium to long distances and varying degrees of terrain features that would prevent the use of VHF and FM CNR. The AN/PRC-104 provides 280,000 tunable channels in 100-hertz (Hz) steps, and has automatic antenna tuning. (Refer to TM 11-5820-919-12 for more information on the AN/PRC-104)

AN/GRC-213

3-114. The AN/GRC-213 is a low power vehicular version of the AN/PRC-104 radio. The AN/GRC-213 consists of the AN/PRC-104 radio, vehicle mount, amplifier power supply AM-7152, and three antennas (whip, AN/GRA-50 doublet, and AS-2259 near-vertical incident sky wave antennas). The AN/GRC-213 provides the capability to bridge a local network of VHF-FM radio sets and a distant HF set at a command communications center. Do not exceed transmitting one minute within a 10-minute period when transmitting over the AN/GRC-213 or the AN/PRC-104.

AN/GRC-193A

3-115. The AN/GRC-193A is a medium and high power vehicular radio. The high power vehicular airborne adaptive configuration consists of a RT-1209 with required coupling device, amplifier, antenna (near-vertical incident sky wave and whip antennas); data input and output device; and external power sources. The radio has the capability of selectable power (100 watts, 400 watts); normal operation is 100 watts. The AN/GRC-193 utilizes the KY-99A for securing voice traffic, and uses the KG-84C for securing data traffic.

IMPROVING HIGH FREQUENCY RADIO OPERATIONS

3-116. In order to improve HF radio operations, whenever possible remove man packed radios from the radio operator's back and operate the radios from the ground. This decreases the capacitive coupling to ground effects of the radio operator's body that reduce signal strength. Drive the ground stake kit into the earth and connect it to the radio terminal when operating the radio from the ground. The kit provided with every radio provides a low-resistance return path for ground currents. Using the kit improves signal strength and communications efficiency.

3-117. All antennas in the same network should also have the same polarization. Mixing antenna polarization in a network results in significant loss of signal strength due to cross polarization. The S-6 ensures that all stations in a network have the same (horizontal or vertical) antenna polarization when possible.

3-118. Improve signal strength by constructing radial wires to the ground. Construct radials from insulated wire and connect one end to the radio ground terminal. Secure one-quarter wavelength long radials to the earth on their ends by means of nails or stakes. Distribution of the radials should be symmetrical. In operational terms for a brigade example, four wires (more if possible) of a practical length crossed in the center (X), and the center connected to the radio ground. Spread and secure the wires 90 degrees. (Chapter 10, Antenna Techniques, addresses how to construct a counterpoise similar to a radial.)

3-119. Using ground radials improves vertical antenna performance (gain) by allowing more current to flow in the antenna circuit and by lowering the antenna pattern's take off angle. This produces an increase in ground wave signal strength on low angles, where it is most useful for tactical communications. (Appendix D addresses radio operations in unusual environments.)

SINGLE CHANNEL TACTICAL SATELLITE RADIO

3-120. Single channel tactical satellite radios are small lightweight manpack multiband multimode radio (VHF and UHF) radios that provide communications for the corps and division and supports the Army Special Operations Forces communications requirements, in war, and in operations other than war. Single channel tactical satellite radios provide wideband and narrowband range extension for voice and data. The beyond line of sight range extension capability is utilized in the Army's SATCOM-On-The-Move OE-563 functionality in moving vehicular platforms (versus stationary).

Note. See Chapter 7 for detailed discussion on Single channel tactical satellite radio capabilities employed within Army formations.

BLUE FORCE TRACKING

3-121. Utilizing ground-based line-of-sight radios in an operational environment with obstructive terrain can cause significant network limitations and hinder commanders' ability to communicate and provide and maintain situational awareness. To overcome the network limitations, units may employ BFT.

3-122. BFT is a GPS enabled system that provides commanders and Soldiers with location information about friendly (and despite its name, also hostile) military forces. In NATO military symbology, blue typically denotes friendly forces. The system provides a common picture of the location of friendly forces and therefore is referred to as BFT.

3-123. Typical employment of BFT systems consist of a computer, used to display location information, a satellite terminal and satellite antenna, used to transmit location and other military data, a GPS receiver (to determine its own position), software to send and receive orders, and mapping software, usually in the form of a geographic information system that plots the BFT device on a map. The system displays the location of the host vehicle on the computer's terrain-map display, along with the locations of other platforms (friendly in blue, and enemy in red) in their respective locations. BFT can also be used to send and receive text and imagery messages, and BFT has a mechanism for reporting the locations of enemy forces and other battlefield conditions (for example, the location of mine fields, battlefield obstacles, bridges that are damaged).

3-124. Additional capability in some BFT devices is found in route planning tools. By inputting grid coordinates the BFT becomes both the map and compass for motorized units. With proximity warnings enabled the vehicle crew is made aware as they approach critical or turn points.

3-125. The BFT system continually transmits locations over the Force XXI Battle Command Brigade and Below network. BFT monitors the location and progress of friendly (and enemy) forces, and sends those specific coordinates to a central location, typically command posts. There the data are consolidated into a common operational picture, and sent to numerous destinations, such as the headquarters element, other in-theater forces, or back out to other military units for situational awareness. The system also allows users to input or update operational graphics (i.e. obstacles, engineer reconnaissance on the road, enemy forces). Once uploaded, it can either be sent to higher headquarters or "mailed" to other subscribers of that user's list, or other BFT users within the subscription system.

FORCE XXI BATTLE COMMAND BRIGADE AND BELOW JOINT CAPABILITIES RELEASE

3-126. The Force XXI Battle Command Brigade and Below Joint Capabilities Release is the next generation of battle situational awareness and mission command system featuring enhanced capabilities. The new version represents a major departure from the original architecture. The Force XXI Battle Command Brigade and Below Joint Capabilities Release tactical network has greater bandwidth allowing the movement of more information to more users within seconds rather than in minutes. The Joint Capabilities Release system upgrade includes BFT 2, a high-tech, high-speed force-tracking satellite-communications network. The BFT 2 is approximately ten times faster than the existing BFT system. Employment of the Joint Capabilities Release system with the BFT 2 transceiver and network upgrade enables friendly positions to be updated in seconds.

SECTION II – SOFTWARE DEFINED RADIO PLATFORM

3-127. The software defined radio platform is a combination of the hardware design inherent to the radio to include antenna, batteries, vehicular, man-pack or base mounts, and the software design inherent in the radio operating system. The radio operating system software allows the interaction between the radio hardware components and the network operations and waveform applications component software. In legacy radios, the hardware and software design merge within the radio and include the waveform. In software defined radios, the hardware, and software are less rigidly coupled. This provides a software defined radios greater interoperability with waveform applications and network management tools while also minimizing interoperability issues associated with enhancing the radio platform operating system. The radio operational environment software, such as the radio operating system is a foundational capability within the software defined radios of the ITNE and if not properly version controlled with other functional component software can easily disrupt or prevent the initialization and operation of the ITNE.

3-128. The software defined radio platform supports the design as an interoperable family of advanced software-reprogrammable, multi-band, multi-mode, net-centric, and reliable radio sets. The required capabilities of the software defined radio platform require the software defined radio platform sets to be interoperable with the current equipment used by military land, air, and maritime defense forces. The Joint Tactical Radio Ground Domain has three Programs of Record: the Handheld Manpack Small Form Fit, and the Mid-Tier Networking Vehicular Radio, and Airborne Maritime Fixed.

HANDHELD MANPACK SMALL FORM FIT

3-129. The Handheld Manpack Small Form Fit program provides single channel handheld and two-channel manpack radios to support Army operations. The Handheld Manpack Small Form Fit program consists of three radio types: the hand-held rifleman radio, the man-pack radio, and the small form fit radio (for unmanned aerial and ground systems).

RIFLEMAN RADIO

3-130. The rifleman radio (AN/PRC-154) is a single-channel radio that operates with the SRW. The rifleman radio uses Type 2 cryptography and is capable of handling controlled unclassified information. Individual riflemen within Infantry BCTs, Armored BCTs, and Stryker BCTs employ the rifleman radio. The rifleman radio provides intra-squad voice communications and automatic position location information beaconing. The rifleman radio also provides Soldiers vertical and horizontal network connectivity to achieve the information dominance deemed critical in successfully conducting dismounted operations independent of any vehicle or other communications infrastructure. The rifleman radio enables the individual Soldier to operate in a tactical voice network with other team members, team and squad leaders via a networking waveform such as the SRW. The rifleman radio enables—

- Employment of much bolder and more sophisticated strategies by squads to attack identified threats decisively.
- Increased speed of movement when conducting individual movement techniques as part of Fire Team and Squad.
- Improved networked communications while dispersed in complex terrain.
- Increased speed of maneuver, a reduced risk of potential fratricide, increased flexibility to transition missions on the move, more bold and sophisticated tactics, and the ability to attack identified threats decisively.
- Reduced exposure to the enemy, synchronized fire and maneuver in complex terrain, increased team movement distances, and a reduced limitation on movement locations.
- Soldiers to communicate with leaders when out of visual contact and shouting distance to conduct movement techniques as part of a squad.
- Leaders to display individual position location information of squad members (via an external display device or as part of a Ground Soldier Ensemble) when out of visual contact to coordinate fire and maneuver.
- Improved situational awareness for leaders to make informed and timely decisions.

Nett Warrior Radio

3-131. The Nett Warrior radio (AN/PRC-154A) is a Type 1 Secret and below single channel hand-held radio employed by dismounted leaders using the Nett Warrior application device for situational awareness. Employment of the Nett Warrior radio provide leaders secret access to platoon, company or other systems operating on the same network.

3-132. The Nett Warrior radio is capable of transmitting and receiving push-to-talk voice and data communications simultaneously using the SRW. The Nett Warrior radio provides team leaders and above voice communications and automatic position location information beaconing. Any squad member, regardless of security clearance, can use the radio. The non-cryptographic controlled item radio can either be keyed Secret to allow leaders to send and receive information or Sensitive-but-Unclassified to connect leaders to their non-cleared squad members, and the squad members to each other.

MANPACK RADIO

3-133. The manpack radio (AN/PRC-155) is a two-channel radio that provides better performance and range for use at the lowest echelon, and can be employed in a dismounted configuration on the back of a Soldier or the radio can be employed mounted in a vehicle. In addition to operating over SRW, the AN/PRC-155 radio operates over the Mobile User Objective System waveform as well as other versions of legacy waveforms that include SINCGARS, Enhanced Position Location Reporting System, ultra-high frequency satellite communications, and high frequency communications. The AN/PRC-155 radio is capable of Type 1 and Type 2 encryption and is capable of operating over a classified network.

SMALL FORM FIT-B RADIO

3-134. The Small Form Fit-B radio is a software defined, two-channel, Type-1 networking radio. When employed the Small Form Fit-B radio provides secure data networking beyond the platoon network and into the platform environment, allowing for secure transmission of voice, data and video.

3-135. The Small Form Fit-B supports the following waveforms—

- SRW.
- SINCGARS.
- EPLRS.

3-136. The small footprint of the Small Form Fit-B radio facilitates easy integration and the radio is tailored in accordance with platform mechanical configuration needs. The interface capability of the radio supports a wide array of devices to meet multiple mission requirements. External radio frequency control supports various third party power amplifiers. The Small Form Fit-B radio is compatible with multiple vehicular and body-worn displays. It connects to vehicle intercom systems via a platform adapter. The Small Form Fit-B radio is electromagnetic interference and electromagnetic compatibility compliant and compatible with legacy key fill devices. It also features separation of radio frequency channels. An optional internal selective availability anti-spoofing module GPS is available.

MID-TIER NETWORKING VEHICULAR RADIO

3-137. The Mid-Tier Networking Vehicular Radio (AN/PRC-118) provides the terrestrial backbone for the Army's tactical network enabling the extension of mission command through the integration of the upper and lower tiers. The Mid-Tier Networking Waveform Radio—

- Provides the capability to build a data extension to the lowest echelons, enabling the extension of services from the Forward Operating Base to the platform.
- Affords a dynamic, scalable, on-the-move network architecture that connects Soldiers to the mission command network; provides simultaneous exchange of voice and data faster than current systems.
- Provides rapid distribution of data and imagery with increased information assurance protection and automatic routing across complex terrain.

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Chapter 4

Waveform and Waveform Applications

The tactical networking environment composed of all current and future software defined waveform applications, provides the means to pass voice and data across the transport layer of the network in the lower and mid tier portions of the tactical networking environment. This chapter discusses the waveform and waveform application functional component of the tactical networking environment.

WAVEFORM

4-1. *Waveform* is an electromagnetic signal-in-space, typically defined by open systems interconnection layers 1 through 3, along with the controls and processes for a desired function or application. These processes do not include the message content. (DODI 4630.09)

4-2. A waveform is the representation of a signal that includes the frequency, modulation type, message format, and transmission system. In general usage, the term waveform refers to a known set of characteristics, for example, frequency bands, modulation techniques, message standards, and transmission systems. In tactical radio system usage, the term waveform describes the entire set of radio functions that occur from the user input to the RF output.

LOWER TIER WAVEFORMS

4-3. Lower tier waveforms of the tactical networking environment process voice and basic data elements. The data elements within the tactical networking environment are centered on friendly forces situational awareness, targeting (Ground and Airborne), and Medical. The spectrum and bandwidth availability is limited and only critical functions operate within this portion of the tactical networking environment. The following paragraphs discuss the key waveforms operating within the lower tier.

Soldier Radio Waveform

4-4. SRW is a wideband (1.2 MHz), multi-hop, adaptive power, self-forming, and self-healing mobile ad hoc network. SRW can support up to 40 nodes in a single tier network supporting simultaneously both data and five separate voice-calling groups. SRW supports both unclassified and secret networks. The planning ranges vary based on the radio platform's use of power and frequencies. The current handheld range of an SRW radio platform is 1-2 kilometers, man-pack range is 5 kilometers, vehicle mounted platform is 10 kilometers, and air to air and air to ground is approximately 30-70 kilometers.

4-5. The SRW provides local area connectivity and communications services for unmanned systems and small combat units to support interoperability between mounted BCT elements and individual dismounted Soldier organizational elements, missiles, intelligent munitions, sensors; and robotics. The SRW network connects via gateways to the mid tier backbone, which provides the range extension needed for communications across the entire area of operations.

4-6. Typical employment of the SRW is as follows—

- **Company SRW Network**. The company SRW network enables the commander to exercise mission command, and provides the commander situational awareness and common operational picture using Nett Warrior and position location information down to platoon leadership.
- **Platoon SRW Network**. The platoon SRW network enables the platoon leader to exercise authority and direction at the platoon level down to the squad level. The platoon SRW network provides the platoon leader situational awareness and common operational picture using Nett Warrior and position location information down to squad leadership. The platoon SRW networks

are gateways to the company SRW networks providing the company situation awareness of the platoon's activity as well as providing updated situation awareness to the platoon from the battalion and company.

Single Channel Ground Airborne Radio System

4-7. The SINCGARS provides the primary means of communication for units across all echelons via highly reliable, secure, easily maintained CNR voice and data handling capability. The SINCGARS provides network data services via mounted and dismounted configurations.

MID-TIER WAVEFORMS

4-8. Mid tier waveforms of the tactical networking environment process voice and larger volumes of data elements. The data elements include those of the lower tier as well as those data elements required by other staff elements within the battalion and headquarters elements. The mid tier possesses more overall bandwidth to accommodate additional data requirements. The tactical networking environment mid tier is limited as to what the mid tier can process as compared to BCT and higher headquarters Upper Tactical Internet high capacity options. The following paragraphs discuss the key waveforms operating within the mid tier.

Wideband Networking Waveform

4-9. WNW is a self-forming, self-healing, wireless network that allows the Joint Services to communicate securely with each other as well as provides access to the Department of Defense information networks. Employed as the battalion and below terrestrial data backbone the WNW connects battalion and below units together in a mobile ad hoc networking self-forming and self-healing IP data network. WNW provides a 2 megabits per second IP data network that supports up to 1600 nodes in the mid tier. WNW-planning range is 10 KM between nodes. The software-defined radios that support the WNW are the Mid Tier Networking Vehicular Radio and the Man-Pack Radio. WNW supports integration into the following WIN-T terminals—

- Tactical Communications Node.
- Point of Presence.
- Soldier Network Extension.

4-10. WNW provides a gateway point from the mid tier into the Army's portion of Department of Defense information networks. WNW does not provide native voice capability. WNW does support voice over Internet Protocol. WNW operates in two modes of operation Orthogonal Frequency Division Multiplexing or Anti-Jam. WNW supports dynamic IP routing protocols, which allows WNW networks to perform backbone routing and increased network scalability. Advanced Quality of Service metrics supports multi-level priority on voice, data, and video for assured service.

Single Channel Tactical Satellite

4-11. SC TACSAT provides interoperability between legacy TACSAT radios and software-defined radios. SC TACSAT provides users the capability to interoperate with legacy radio waveforms. The interoperability enables voice and limited data exchange for beyond-line-of-sight lowest tactical level users in the lower and mid tier.

Mobile User Objective System Waveform

4-12. The Mobile User Objective System (MUOS) is an UHF SATCOM system that provides celestial network connectivity and communications services for mounted and dismounted units to support beyond line-of-sight communications capability at Brigade and below. The MUOS waveform is used in lieu of line of sight waveforms to maintain communications when operating over great distances or in challenging terrain/environments. When fully integrated, MUOS will replace the legacy UHF Follow-On system before that system reaches its end of life to provide users with new capabilities and enhanced mobility, access, capacity, and quality of service. Currently MUOS is a U.S. only system. Legacy UHF SATCOM will continue to be used for coalition and allied partners beyond line of sight mission requirements.

4-13. MUOS is primarily intended for mobile users (aerial and maritime platforms, ground vehicles, and dismounted soldiers), MUOS is designed to extend users' voice and data communications networks beyond their lines-of-sight. The MUOS waveform operates as a global cellular service provider to support Soldiers with modern cell phone-like capabilities. It adapts a commercial third generation Wideband Code Division Multiple Access cellular phone architecture for use in the military UHF SATCOM frequency spectrum using four geosynchronous satellites in place of cell towers covering the globe. By operating in the UHF frequency band (300 -320MHz to transmit (User to Base) and 360-380MHz to receive (Base to User), a lower frequency band than that used by conventional terrestrial cellular networks, MUOS provides Soldiers with the tactical ability to communicate in "disadvantaged" environments, such as heavily forested regions where higher frequency signals would be unacceptably attenuated by the forest canopy. The radio uses the MUOS waveform to operate on one of four (5MHz) channels on one of 16 beams on one of four geosynchronous satellites.

4-14. MUOS waveform provides military point-to-point and netted communication users with precedence-based and pre-emptive access to voice and data up to 64Kbps that span the globe. Each MUOS terminal will have a 10 digit DSN assigned phone number when provisioned. Connections may be set up on demand by users in the field, within seconds, and then released just as easily, freeing resources for other users. In alignment with more traditional military communications methods, pre-planned networks can also be established either permanently or per specific schedule using the MUOS ground-based Network Management Center.

Integrated Waveform

4-15. SATCOM integrated waveform is an enhanced method of multiplexing radio networks on the same channel. Integrated waveform uses carrier phase modulation to allow more access on the same channel. Carrier phase modulation implemented in radios provides higher data throughput on the UHF dedicated satellite channels in line-of-sight-mode. Integrated waveform is an augmentation to time division multiple access services. Integrated waveform is a flexible waveform structure that allows communication access tailoring based upon operational need. Integrated waveform—

- Supports data rates up to 19.2 kilobits per second.
- Provides up to fourteen networks operating at 2400 bits per second each.
- Supports narrowband voice operations with mixed excitation linear prediction.

4-16. SC TACSAT capable radios that support integrated waveform technology are the AN/PRC-155, AN/PSC-5C/D, AN/PRC-117F/G, and AN/PRC-148.

Link 16 Waveform

4-17. Link 16 is a time division multiple access-based, secure, jam-resistant high-speed digital data link, which operates in the radio frequency band 960 to 1,215 MHz. The frequency range limits the exchange of information to users within line-of-sight of one another, although emerging technologies provide the means to pass Link 16 data over long-haul protocols such as Transmission Control Protocol, IP, and UHF SATCOM. Link 16 utilizes the transmission characteristics, protocols, conventions, and fixed-length or variable length message formats defined by MIL-STD 6016E. Although the radios and waveform can support throughputs upwards of 238 kilobits per second, information is typically passed at one of the three following data rates—

- 31.6 kilobits per second.
- 57.6 kilobits per second.
- 115.2 kilobits per second.

WAVEFORM APPLICATIONS

4-18. The Waveform Application component of the ITNE is composed of all current and future software defined waveform applications that provide a means to pass voice and or data across the transport layer of the network in both the lower and mid tier portions of the ITNE. Waveform Applications are peer-to-peer programs that facilitate the exchange of application data across the spectrum of radio networks. Each waveform application is optimized to meet the mission needs of the portion on which it operates (lower and mid tier). This means lower tier waveforms cannot meet mid tier requirements nor can mid tier waveforms scale easily to the lower tier. These are important considerations for ITNE planners as they develop their network architecture to meet their commander's mission command requirements. Waveform Applications are planned, configured, and loaded onto the radio platforms through the Network Operations Management System.

Chapter 5

Very High Frequency Radios

This chapter describes the commercial-off-the-shelf very high frequency radios used to support tactical radio operations.

MULTIBAND INTER/INTRA TEAM RADIO

5-1. Use the multiband inter/intra team radio (MBITR) (AN/PRC-148) for special operations forces and company size networks depending on command guidance and mission requirements. When used as a handheld radio the MBITR supports the secure communications requirements for a platoon, squad, or team. The MBITR enables small unit leaders' adequate control of subordinate elements activities. The MBITR can perform functions such as ground to air, ship to shore, non-demand assigned multiple access (DAMA) TACSAT, civil military, and multinational communications.

5-2. The MBITR radio set communicates with similar amplitude modulation (AM) and FM radios to perform two-way communications. The AN/PRC-148 frequency and waveform are interoperable with legacy and new systems. The radios concept ensures interoperability with virtually any common U.S. military or commercial waveform operating in the 30–512 MHz frequency range with either FM or AM radio RF output, and with a user selectable power output from 0.1–5 watts. The AN/VRC-111 is the vehicular version of the MBITR.

5-3. The MBITR consists of a portable, battery-operated transceiver capable of providing secure and non-secure communications. The MBITR operates in clear (analog) and secure (digital) voice and data. The basic radio is software upgradeable to add the following capabilities: SINCGARS, HAVEQUICK, ANDVT, and RETRANS.

5-4. The MBITR has the following operating characteristics—

- Stores up to 100 preset channels organized in 10 groups with 16 channels each.
- SINCGARS voice and system improvement program data interoperable.
- HAVEQUICK I/II interoperable.
- ANDVT interoperable.
- Transmits voice in a whisper mode.
- Transfers configuration information to other MBITRs by means of a cloning cable.

5-5. The radio is tunable over a frequency range of 30–512 MHz, in either 5 or 6.25 kHz tuning steps, using 25.0 kHz channel bandwidth, 12.5 kHz when set for narrowband operation, and 5 kHz bandwidth when set for ANDVT. The radio automatically selects the correct tuning size.

5-6. The RT consists of a single-channel modulated carrier. The modulating source is analog or digitized voice and data signals at 12 (Federal Standard-1023) and 16 kilobits per second (VINSON-compatible) in 25 kHz channel spacing. For emergencies the radio circuitry is capable of receiving clear messages while set for secure mode operation.

MULTIBAND INTER INTRA TEAM RADIO COMMUNICATIONS SECURITY

5-7. When operating in the secure mode, the radio disables the transmission of any tone squelch signals. Encryption key fill occurs through the audio and key fill connector. The urban MBITR has a standard U-283/U six-pin connector that is fully compatible with the SKL.

Multiband Inter Intra Team Radio and Single Channel Ground Airborne Radio System

5-8. SINCGARS operation is only available in those radios with the optional SINCGARS capability enabled. The following describes the TRANSEC capabilities of the MBITR with SINCGARS option—

- When operating in the SINCGARS mode, the available MBITR operating frequency range is 30–87.995 MHz.
- MBITR with SINCGARS functionality includes the operating modes of the basic MBITR radio and the following modes of operation—
  - Single-channel clear FM analog voice operation, FM encrypted digital voice, and over-the-air FM transfer of encrypted digital data. The single-channel data mode implements the SINCGARS standard data mode and enhanced data mode.
  - Frequency hopping plain text digital voice operation, frequency hopping FM encrypted digital voice in 16 kilobits per second continuously variable slope delta mode, and, using the SINCGARS and SINCGARS system improvement program waveforms, frequency hopping over-the-air FM transfer of encrypted digital data

Multiband Inter Intra Team Radio System Management

5-9. System management of the MBITR is the responsibility of the S-6 or communications section at all echelons. A Windows based personal computer radio programmer manages the quantity of radios. All radio functions accomplished through the individual radio control panel as required make it very difficult to set up the radios for a battalion or larger force manually using radio front panel controls.

5-10. The personal computer programmer has an interface that allows uploading and downloading information such as assigned frequency lists, waveform data, and radio power. Once a radio is loaded with system information, the capability exists to distribute this information (clone) to another MBITR. This cloning feature allows the S-6 system manager to distribute technical information down the tactical echelons to each individual radio.

Multiband Inter Intra Team Radio in Urban Operations

5-11. In small tactical units area coverage and distance extension has always been a problem. In urban operations, communication inside buildings or over urban terrain is a challenge. For these conditions, the MBITR system provides a "back-to-back" (two radios) RETRANS capability for COMSEC and plain text modes. Beside two radios, the only hardware required for RETRANS is a small cable kit and some electronic filters. When configured for RETRANS operations, a true digital repeater forms. Since the radios repeat the transmitted digits and since the radios do not have to have any COMSEC keys loaded in them, the radios do not degrade signal quality.

MULTIBAND HANDHELD RADIO

5-12. The multiband handheld radio (AN/PRC-152) is a single-channel multiband handheld radio that has software defined communications architecture. The AN/PRC-152 provides the optimal transition to and interoperability with software defined radio technology. The AN/PRC-152 supports SINCGARS, HAVEQUICK II, VHF, UHF, AM, and FM waveforms.

5-13. The AN/PRC-152 encryption device maximizes battery life in battery-powered radios. The AN/PRC-152 also supports all software defined radio, COMSEC, and TRANSEC requirements as well as the ability to support numerous device compatibility modes: KY-57/VINSON, ANDVT/KYV-5, KG-84C, DS-101, and DS-102.

5-14. The AN/PRC-152 includes an embedded GPS receiver to display local position and to provide automatic position reporting for situational awareness. The vehicular version of the AN/PRC-152 is the AN/VRC-110.

AN/PRC-152 VHF and UHF Line of Sight Fixed Frequency Plain Text

5-15. The AN/PRC-152 has the following fixed frequency plain text operation capabilities—

- **VHF low band.** 30.00000–89.99999 MHz.
- **VHF high band.** 90.00000–224.99999 MHz.
- **UHF band.** 225.00000–511.99999 MHz.

AN/PRC-152 VHF AND UHF LINE OF SIGHT FIXED FREQUENCY CIPHER TEXT

5-16. The AN/PRC-152 has following fixed frequency cipher text operation capabilities and limitations—

- **VINSON.** 16 kilobits per second data rate, 25 kHz wideband COMSEC (KY-57/58) mode for secure voice and data.
- **VINSON plain text override.** Alerts the radio operator of a receiving transmission from an AN/PRC-152 in plain text mode.
- **KG-84C compatible (data only).** Supports secure data transmission in FM mode 30.00000–511.99999 MHz, and AM mode from 90.00000–511.99999 MHz. Also used for UHF SATCOM operation.
- **TEK.** Electronically loaded 128-bit transmission encrypted key used to secure voice and data communications.
- **COMSEC fill.** TEKs, transmission security key, and KEKs filled from the SKL.

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Chapter 6

Ultra High Frequency Radios

This chapter addresses the ultra high frequency radios and systems that play a major role in network centric warfare.

ULTRA HIGH FREQUENCY RADIOS AND SYSTEMS

6-1. UHF radios and systems play an important role in the military today and have played a vital role in recent urban combat operations. Radios such as the Multifunctional Information Distribution System (MIDS), and the Joint Tactical Information Distribution System (JTIDS) are UHF capabilities in use throughout the Army for ground-to-air, ship-to-shore, and multinational communications.

MULTIFUNCTIONAL INFORMATION DISTRIBUTION SYSTEM

6-2. The MIDS is a high capacity digital information distribution system allowing the secure and jam-resistant exchange of real-time data between a wide variety of users, including all the components of a tactical air force, and when appropriate, land and naval forces. The MIDS is the follow-on to JTIDS terminals, providing improvements over the Class 2 family of terminals. Smaller and lighter than its predecessor, the MIDS installed in platforms that are limited in space and weight is fully compatible with Link 16 participants.

MULTIFUNCTIONAL INFORMATION DISTRIBUTION SYSTEM-LOW VOLUME TERMINAL

6-3. The Army's MIDS consists of the AN/USQ-140, Multifunctional Information Distribution System-Low Volume Terminal(2) (MIDS-LVT[2]) Link 16 Terminal, a terminal controller, and an antenna. The MIDS LVT(2) provides jam-resistant, near real-time, digital data and voice communication, position location reporting, navigation, and identification capabilities to host platforms. The MIDS-LVT(2) supports all operational modes of the Link 16 waveform and provides a distributed network with control service and North Atlantic Treaty Organization (NATO) interoperability.

6-4. The MIDS-LVT(2) features pseudo-random frequency hopping over fifty-one frequencies and is typically employed in support of air defense echelons and operations. The MIDS-LVT(2) also has an expanded data rate up to 2 megabits per second in support of ground, airborne and maritime operations. The MIDS-LVT(2) utilizes two antennas to transmit and receive data. The terminal also features encryption and navigation capabilities.

6-5. The MIDS-LVT(2) has the following characteristics and capabilities—

- Link 16 messaging tactical digital information link-joint and information distribution system message standard.
- Receive sensitivity classified meets specifications with 2–3 (decibel) dB margin.
- Transmit spectral performance greater than -60 dB in 1030/1090 MHz bands.
- Output transmit power 1, 25 or 200 watts.
- Host interfaces dual Army data distribution system interface (increased speed X.25) and multiple Ethernets.
- Keyfill interface (DS-101 protocol).
- Voice capability (optional) 2.4 kilobits per second linear predictive coding-10 and 16 kilobits per second continuous variable slope delta.

TACTICAL DIGITAL INFORMATION LINK-JOINT TERMINALS

6-6. The Tactical digital information link-joint is an approved data link used to exchange real-time information (NATO Link 16 is the near equivalent of tactical digital information link-joint). The tactical digital information link-joint is the protocol approved for joint (U.S. only) air and missile defense surveillance and battle management. The tactical digital information link-joint is a communications, navigation, and identification system that supports information exchange between tactical communications systems. The tactical digital information link-joint is a secure, frequency hopping, jam-resistant, high capacity link, and uses the JTIDS or MIDS communications data terminal for voice and data exchange.

6-7. JTIDS and MIDS operate on the principal of time division multiple access and time slots allocated among participant JTIDS units for the transmission of data. This eliminates the requirement for an NCS by providing a nodeless communications architecture.

6-8. Army tactical digital information link-joint terminals are the JTIDS Class 2M and the MIDS l LVT-2. Although other services' JTIDS and MIDS terminals exchange data and voice, Army JTIDS class 2M and MIDS LVT-2 terminals have no voice capability.

6-9. Tactical digital information link-joint networks participants include—

- Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System.
- F/A-18 Hornet and Super Hornet.
- Airborne Warning and Control System.
- E-2C Hawkeye Aircraft.
- Tactical Air Operations Module.
- Short-Range Air Defense.
- Aegis Ships.
- Medium Extended Air Defense System.
- Patriot.
- Air Operations Center.
- Theater High Altitude Air Defense.
- Air and Missile Defense Command.
- Joint Tactical Ground Station.

TACTICAL DIGITAL INFORMATION LINK-JOINT TERMINALS AND ENHANCED POSITIONING LOCATION REPORTING SYSTEM NETWORKS

6-10. EPLRS is the primary data distribution system for forward area air defense weapon systems. The typical short-range air defense battalion use EPLRS to establish a data network to interconnect the tactical air control party, air support operations center, command nodes, platoon and section headquarters, and individual weapons systems. Establishment of an EPLRS data network in a short-range air defense battalion, enable commanders to exercise airspace control to integrate and synchronize Army forces actions and operations with all airspace users. It passes the air picture and weapons control orders down, and then sends weapons systems status back up through the system. The extended air picture received from air and missile defense units, and E-3 Sentry-Airborne Warning and Control Systems fuse together with the air picture received from the AN/MPQ-64, Sentinel, filtered at the forward area air defense command node for specific geographical areas of interest, and broadcast to all subscribers.

JOINT TACTICAL INFORMATION DISTRIBUTION SYSTEM

6-11. JTIDS is a UHF terminal that operates in the 960–1215 MHz frequency band. It uses the Department of Defense (DOD) primary tactical data link to provide secure, jam-resistant, high-capacity interoperable voice, and data communications for tactical platforms and weapon systems. Using tactical digital information link-joint and the Interim JTIDS message specification, the Army JTIDS allows air defense artillery units to exchange mission essential data in near real-time, with other Army joint communications organizations performing joint area of responsibility air and missile defense.

6-12. Army JTIDS supports joint interoperability and attainment of dominant situational awareness, through integration of high throughput Link 16 messages, standard and waveform. Integrated in Army area of responsibility air and missile defense weapons systems, Army JTIDS complements land force and joint force objectives for airspace control, by rapidly and securely supporting the exchange of surveillance, identification, unit status, and engagement information in benign and electronic warfare (EW) conditions.

6-13. Host platforms for Army JTIDS and MIDS include—

- Forward Area Air Defense Command and Control System.
- Patriot Power Projection Platform.
- Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System.
- Theater High Altitude Air Defense.
- Medium Extended Air Defense System.
- Joint Tactical Ground Station.
- Air and Missile Defense Planning and Control System at air defense artillery brigades and Army air and missile defense commands.

6-14. The Army employs the JTIDS and MIDS at several operational levels as the medium to defense broadcast, and receive an enhanced joint air picture. An in-theater joint data network provides shared joint command and control data and targeting information. Sources of the joint data network include—

- E-3A Sentry-Airborne Warning and Control System.
- Control and reporting center.
- Intelligence platforms.
- E-2C Hawkeye aircraft.
- Aegis Ships.
- Fighter aircrafts.
- United States Marine Corps Tactical Air Operations Module.
- Air defense and airspace management cell.
- Air Defense Artillery Brigades.
- Short-Range Air Defense.
- Patriot.
- Theater High Altitude Air Defense.
- Joint Tactical Ground Station.

6-15. The Army JTIDS system is comprised of the Class 2M terminal, the JTIDS terminal controller, and the JTIDS antenna.

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Chapter 7
Single Channel Tactical Satellite Communications

This chapter addresses the Army single channel tactical satellite planning and the single channel tactical satellite capabilities employed associated with the legacy and enduring radio platform. This chapter also addresses single channel ground terminals and Army conventional forces.

SINGLE CHANNEL TACTICAL SATELLITE INTRODUCTION

7-1. The Army uses SC TACSAT and other satellite capabilities to provide long haul, worldwide communications coverage to support critical command communications to ground and mobile operating forces. The use of SC TACSAT and other satellite capabilities requires satellite control to ensure users access and use of SATCOM. See FM 3-14 for detailed discussion on Army signal unit capabilities and functions related to satellite control. SC TACSAT provides the ability to support a small number of burst transmissions per day for special operations forces, atomic demolition teams, and long-range surveillance units engaged in sensitive missions over extended distances and varied terrain. It also provides secure voice communications for communication and situational awareness for the special operations command, airborne, air assault, infantry divisions, and infantry brigades.

7-2. Army SC TACSAT radios provide the capability of transmitting data rates of up to 56 k on 25 kHz channels and 9.6 kilobits per second (with appropriate waveform) on 5 kHz channels. Due to the limited resources available on the UHF satellites and the increasing requirements for access by Army and all Service users, CJCSI 6251.01D identifies the interoperability requirements of DAMA and integrated waveform terminals when accessing non-processed narrowband SATCOM. DAMA allows more access to the satellites through the automated sharing of the channel but reduces the data rates provided to the users. Therefore, the normal access is limited to 2400 bits per second, providing voice using ANDVT and data. The improvement of the voice encoder in the radios using mixed excitation linear prediction vastly improves the voice quality and clarity.

7-3. The MIL-STDs governing the use of UHF improved and implemented a higher data throughput into the sharing of channels, which resulted in implementation of integrated waveform. Integrated waveform provides an improvement of up to four times the access seen in DAMA on a 25 kHz channel. In order to provide the voice clarity to support successful operations, radios require mixed excitation linear prediction voice encoder. Users that need to send large data files in a short period have the capability of changing data rates on the channels on demand. Integrated waveform provides the following capabilities—

- Network communications.
- Preplanned support to operations.
- Ad hoc communications.
- Point-to-point calls.

SATELLITE COMMUNICATIONS PLANNING CONSIDERATIONS

7-4. The key to efficient SATCOM apportionment planning support is for combatant commanders to maintain well-defined requirements within the SATCOM Database. In accordance with CJCSI 6250.01, the SATCOM Database is a centralized source of current and future SATCOM requirements in order to process and receive allocations of satellite resources.

7-5. Army units seeking to employ commercial SATCOM must follow all specified procedures to include satellite access requests, appropriate reports, and satellite database numbers for each commercial satellite network. Refer to Strategic Command Instruction 714-4 for more information on SATCOM planning considerations.

SINGLE CHANNEL TACTICAL SATELLITE PLANNING CONSIDERATIONS

7-6. Tactical communications networks change constantly. Control of the network is required or communications delay and a poor grade of service results. The best method of providing this control without hampering operation is through centralized planning. Execution of these plans should be decentralized. Apply this concept to the space systems portion and to the ground stations. The U.S. military satellite systems consist of terminals (ground segment), satellites (space segment), and tracking, telemetry, and control terminals (control segment), which all require consideration when planning networks.

7-7. The planning and system control process helps communications systems managers react appropriately to the mission of the force supported, the needs of the commander, and the current tactical situation. The type, size, and complexity of the system operated establish the method of control.

7-8. Communications control is a process in which the matching of resources with requirements takes place. This process occurs at all levels of the control and management structure. In each case, the availability of resources is considered.

7-9. SC TACSAT capabilities support worldwide tactical communications such as en route contingency communications, in-theater communications, and CNR range extension. SC TACSAT radios link CPs to all echelons, and include the long-range surveillance units and Army special operations forces units, which can operate hundreds of miles from main forces.

7-10. Army SC TACSAT operates in the UHF band, and is available in manpack and vehicle versions. The radios’ lightness, availability, and ease of use make them valuable for mobile and covert operations spanning unified land operations.

7-11. The communications planning range for SC TACSAT is limited to the specific satellite footprint assigned. The bridging of satellite footprints via an “M-Hop” network configuration may be possible through the appropriate coordination authority. The standardized channelization of each satellite provides flexibility and interoperability in normal operations. SC TACSAT does not directly interfere with other combat net communications systems due to the frequency bands in which it operates. Although SC TACSAT does not directly interfere with other ITNE systems, planning considerations require planners incorporate planning for deconfliction against electronic warfare effects.

Demand Assigned Multiple Access Networks

7-12. DAMA is a technique that matches user demands to available satellite time. Satellite channels grouped together as a bulk asset, and DAMA assigns users variable time slots that match the radio operator’s information transmission requirements. The radio operator does not notice a difference because the radio operator appears to have exclusive use of the channel. The increase in networks or radio users available by using DAMA depends on the type of users. DAMA is most effective where there are many users operating at low to moderate duty cycles. DAMA is effective with SC TACSAT systems.

7-13. DAMA efficiency also depends on the system’s formatting, which is how the access is controlled. Obtain the greatest user increase through unlimited access. This format sets up channel use on a first-come-first-serve basis. Other types of formats are prioritized cueing access and minimum percentage access. The prioritization technique is suitable for command type networks, while the minimum percentage is suitable for sustainment and logistic networks. Regardless of format, DAMA generally increases satellite capability by 5 to 14 times over normal dedicated channel operation. Nets on 5 kHz channel could be pre-empted based on priorities.

7-14. DAMA compliant SC TACSAT radios require a unique terminal base address. Upon initial issue of a TACSAT DAMA compliant radio, the receiving unit coordinates for a terminal base address in support of their radio system. Request a terminal base address through the Space and Naval Warfare Systems and provide the following information—

- Terminal type.
- Quantity of terminals.
- Unit or activity name.
- Point of contact information to include phone number and email address.

7-15. Manage terminal base addresses using the signal operating instructions production authority. Doing so will alleviate issues with two or more DAMA radios trying to access the same satellite resource with the same terminal base address.

7-16. The Space and Naval Warfare Systems no longer publish DOD wide DAMA call directories. The signal operating instructions production authority may call and receive existing terminal base address lists for their specific organizations

INTEGRATED WAVEFORM SINGLE CHANNEL TACTICAL SATELLITE PLANNING CONSIDERATIONS

7-17. Integrated waveform is an enhanced method of multiplexing radios on the same channel. It uses carrier phase modulation to allow for more access on the same channel. One channel is assigned as the master and contains the system forward orderwire. All other channels fall under the master channel and can be either 25-kHz or 5-kHz. Each channel has its own format that is changeable upon user demand. Time slots for ranging and other communications can be planned based on these same requirements. Updates are also obtained from pre-planned update forward order-wires transmitted on other channels. With data rates up to 19.2 kbps, the integrated waveform provides up to 14 networks operating at 2400 bps each. Integrated waveform supports narrowband voice operations with mixed excitation linear prediction. Unlike DAMA, each Net is guaranteed their timeslot.

SINGLE CHANNEL ULTRA HIGH FREQUENCY TERMINALS

7-18. SC TACSAT terminals provide reliable, highly portable communications, and satisfy the requirement to communicate over extended ranges without regard to terrain interference. The SC TACSAT systems operate in the UHF band between 225 MHz and 400 MHz, which provides an architecture that accommodates various users with various missions. The following paragraphs address single-channel UHF ground terminal radios employed at all echelons to provide the range extension required to conduct operations.

LIGHTWEIGHT SATELLITE TERMINALS

7-19. The lightweight satellite terminal-5B and lightweight satellite terminal-5C are SC TACSATs that operates in either a manpack, vehicular, shipboard, or airborne configuration. The terminals are capable of operation by remote control via dedicated hardware, or personal computer-based software through an X-mode connector. Radios modulate in AM and FM voice, cipher, data, and beacon. The terminals operate in the frequency range of 225–399.995 MHz with channel spacing of 5 kHz and 25 kHz.

7-20. The lightweight satellite terminal-5D has the added capability of DAMA, features embedded encryption devices for voice and data communications, as well as the channel capacity increases made possible through DAMA channel management. (Refer to ATP 6-02.90 for more information on tactics, techniques, and procedures for UHF TACSAT and DAMA operations.)

SINGLE-CHANNEL ANTI-JAM MAN-PORTABLE TERMINAL

7-21. The single-channel anti-jam man-portable (AN/PSC-11) terminal is a man packable system packaged for storage or transport in two transit cases. The single-channel anti-jam man-portable terminal consists of a RT, an interface unit that encrypts and decrypts the voice and data by using COMSEC keys, a handheld control device (30 key keypad), and a handset. (Additional associated equipment not provided with all terminals is available.)

7-22. The AN/PSC-11 terminal interfaces with the military strategic and tactical network extension system to provide secure, survivable voice and data communications via a low data rate payload. The AN/PSC-11 can operate over extremely high frequency packages on fleet satellite and UHF follow-on systems. The AN/PSC-11 terminal operates in either point-to-point or broadcast modes, and provides voice and data service at a maximum data rate of 2,400 bits per second. The terminal can interface in the data mode with CNRs and personal computers to provide range extension. The AN/PSC-11 terminal has the following characteristics and capabilities—

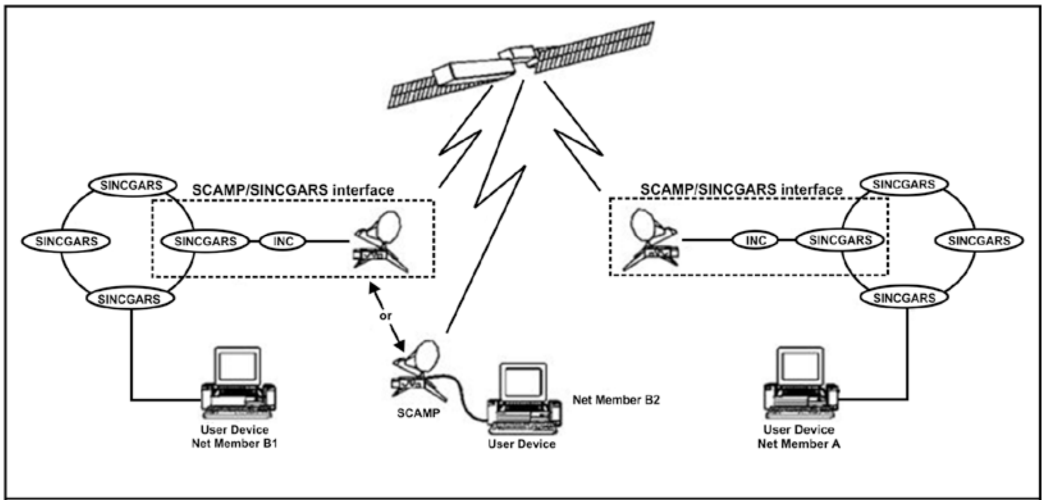
- **Throughput**. 24 kilobits per second (voice or data).

- **Modes of operation**. Point-to-point or broadcast.
- **Frequency**. Uplink, 43.5 to 45.5 gigahertz (GHz) Q Band with 2 GHz bandwidth.
- **Security**. Embedded cryptographic algorithm.

7-23. The AN/PSC-11 terminal can interface with a variety of Army user communications systems via the four baseband data ports. The satellite link is transparent to the user communications system. The baseband equipment and systems do not control the satellite access of the AN/PSC-11 terminal. In all cases, the operator first establishes the satellite path via the AN/PSC-11. Once the satellite path is operational, the operator can establish the baseband service. (Refer to TM 11-5820-1157-10 for more information on the single-channel anti-jam man portable terminal.)

Single-Channel Anti-Jam Man-Portable Terminal and Combat Net Radios

7-24. The AN/PSC-11 terminal supports the SINCGARS system improvement program and advanced system improvement program radios, providing range extension to the SINCGARS and CNR users. The SINCGARS RT operates in the data mode only with the AN/PSC-11. With SINCGARS, the AN/PSC-11 operates in a full duplex, point-to-point configuration that supports user baseband equipment, such as the secure telephone unit and all utilized data systems. The AN/PSC-11 can provide range extension to either a network or one SINCGARS. Connectivity via the red port or a black port (with an external cryptographic device such as the KG-84C/KIV-7) provides encryption. Figure 7-1 shows the two AN/PSC-11 CNR configurations.



LEGEND

INC	Internet Controller Card
SCAMP	Single-channel Anti-jam Man Portable
SINCGARS	Single Channel Ground and Airborne Radio System

Figure 7-1. Single-channel anti-jam man-portable terminal CNR configurations

SPITFIRE

7-25. The Spitfire (AN/PSC-5) is a small lightweight manpack multiband multimode radio (VHF and UHF) that provides communications for the corps, division, and Army special operations forces across the range of military operations. The Spitfire provides wideband and narrowband range extension for voice and data. The Spitfire utilizes beyond line of sight range extension capability in the Army's SATCOM-On-The-Move functionality in moving vehicular platforms (versus stationary). The Spitfire provides DAMA and narrowband secure voice, line of sight communications for voice and data, supports communications on the move, and extends SINCGARS communications when paired with SINCGARS as a RETRANS unit.

7-26. The Spitfire operates in the following plain text line of sight modes with the following characteristics and capabilities—

- **Frequency bands**.
  - 30.000–87.995 MHz.
  - 108.000–129.995 MHz.
  - 130.000–148.995 MHz.
  - 156.000–173.995 MHz.
  - 225.000–399.995 MHz.
- **Modulation**.
  - **AM**-60 to 90 percent at 1 kHz AM for plain text and cipher text line of sight voice modulation; 50 percent minimum for beacon mode.
  - **FM-**±5.6 kHz deviation at 1 kHz FM for plain text and cipher text line of sight voice modulation. The FM beacon modulation has a ±4 kHz nominal frequency deviation.
  - **FM**-frequency shift key (FSK) modulation rate of 16 kilobits per second plain text and cipher text voice and data. Used in line of sight and SATCOM modes.
- **Channel spacing**. 5 kHz.
- **Squelch**. Operator adjustable signal to noise ratio squelch. From 10dB signal, noise, and distortion at minimum squelched condition to at least 16 dB signal, noise, and distortion at maximum.
- **Half-duplex operation**.
- **Plain Text.** Transmitted voice or data not encrypted.
- **Cipher Text.** When a cipher-text voice message is received or transmitted (mode switch in cipher text), a single beep is heard in the handset at the beginning of the reception or transmission.
- **Noise figure Line of Sight**. 10 dB nominal.
- **Six presets**.
- **Frequency scanning**. Capable of scanning five presets in line of sight plain text voice and cipher text (VINSON) voice.

7-27. The Spitfire can scan up to five line of sight or dedicated SATCOM radio voice operation networks. Scanning combinations of cipher text (VINSON) and plain text networks allowed in voice mode only.

7-28. The Spitfire operates in the following SATCOM modes with these characteristics and capabilities—

- **Frequency band.** UHF band 225.000 MHz to 399.995 MHz.
- **Modulation.**
  - **AM**-60 to 90 percent at 1 kHz AM for plain text and cipher text line of sight voice modulation; 50 percent minimum for beacon mode.
  - **FM**-±5.6 kHz deviation at 1 kHz FM for plain text and cipher text line of sight voice modulation. The FM beacon modulation has a ±4 kHz nominal frequency deviation.
  - **FM**-FSK rate of 16 kilobits per second plain text and cipher text voice and data. Used in line of sight and SATCOM modes.
  - **Binary phase-shift keying**-modulation rate of 1200, 2400, and 9600 bits per second. Used in SATCOM mode.
- **Channel spacing**. 5 kHz and 25 kHz.
- **Squelch**. Operator adjustable signal to noise ratio squelch. From 10dB signal, noise, and distortion at minimum squelched condition to at least 16 dB signal, noise, and distortion at maximum.
- **Half-duplex operation**.
- **Plain Text**. Transmitted voice or data is not encrypted.
- **Cipher Text**. When a cipher text voice message is received or transmitted (mode switch in cipher text), a single beep is heard in the handset at the beginning of the reception or transmission.
- **Noise figure SATCOM**. Less than 4 dB (240–270 MHz).
- **Six presets**.

7-29. The Spitfire operates in the following DAMA modes with the following capabilities and limitations—

- **Frequency band**. UHF band 225.000–399.995 MHz.
- **Modulation**.
  - **Shaped offset quadrature phase-shift keying**-modulation rate of 600, 800, 1200, 2400, and 3000 bits per second used in 5 kHz DAMA mode.
  - **Binary phase-shift keying**-modulation rate of 19.2k and 9600 symbols per second used in 25 kHz DAMA mode.
  - **Differentially encoded quadrature phase-shift keying**-modulation rate of 32,000 symbols per second used in 25 kHz DAMA mode.
- **Channel spacing**. 5 kHz and 25 kHz, in accordance with MIL-STD 188-181C, 188-182B, and 188-183B.
- **Half-duplex operation**.
- **VINSON**. 16 kilobits per second data rate, 25 kHz COMSEC (KY-57 and KY-58) mode for secure voice and data.
- **KG-84C**. Compatible modes 3 and 4 (data only).
- **ANDVT**. 2400 bits per second mode for secure voice and data.
- **Six sets DAMA**. Including 20 "sub-presets" each for 5 kHz service setup, 5 kHz message setup, and 25 kHz service setup.

Spitfire Retransmission Capabilities

7-30. The Spitfire provides range extension for SINCGARS and Spitfire radios. A Spitfire-to-Spitfire RETRANS provides the required network extension when the network spans two satellite footprints. The actual terminals used for RETRANS are set up in the plain text mode, a W-5 cable is used between the two radios with SATCOM antennas connected, and the set up does not allow for an eavesdrop capability at the RETRANS site.

Note. Do not attach handsets or speakers to Spitfire terminals in the RETRANS configuration. If connected they produce a non-secure beep broadcast and National Security Agency (NSA) mandates secure, encrypted transmissions.

7-31. Although not recommended, the Spitfire terminals may be set up in the RETRANS mode with the line of sight antennas connected. The recommended configuration for this communications requirement is a SINCGARS RETRANS. The abbreviated RETRANS mode for SINCGARS requires installing one Spitfire with a SINCGARS at the RETRANS site. To accomplish the RETRANS, operate the Spitfire in plain text mode, or eavesdropping may take place at the SINCGARS terminal. The SINCGARS operates in 25 kHz increments, the same as the line of sight mode for the Spitfire. A request is required for SATCOM and DAMA, 5 kHz channels in order for the Spitfire to accomplish the communications link. The Spitfire set up at the distant end is in the cipher text mode. It then encrypts and decrypts transmissions using the COMSEC employed by the SINCGARS.

7-32. Use the Spitfire for beyond line of sight RETRANS of SINCGARS networks. Each net requires a SINCGARS and AN/PSC-5 terminal connected for RETRANS.

7-33. In the plain text mode, the RETRANS AN/PSC-5 cannot monitor the network or send messages; only the SINCGARS terminal can do this. Satellite channels require be in 25 kHz increments for SATCOM and DAMA. Once this configuration is complete, RETRANS occurs as if it were a SINCGARS-to-SINCGARS RETRANS site. The major difference is that the network at each end has beyond line of sight capability.

7-34. Other available RETRANS capabilities include DAMA-to-DAMA, DAMA-to-SATCOM, SATCOM-to-line of sight, and DAMA-to-line of sight configurations. These are used based on mission requirements, and are not normal RETRANS configurations. (For more information on the AN/PSC-5, refer to TM 11-5820-1130-12&P.)

SHADOWFIRE

7-35. The Shadowfire (AN/PSC-5C) is a field upgrade of the AN/PSC-5 Spitfire terminal. The upgrade provides all the capabilities of the AN/PSC-5 plus additional capabilities for HAVEQUICK I and II and SINCGARS anti-jam; the ability to receive and transmit over-the-air rekeying or over-the-air transfer; extended 30–420 MHz frequency range, MIL-STD-188-181C high data rate in line of sight and SATCOM; and MIL-STD 188-184 embedded advanced data controller.

7-36. Additional features include embedded tactical networking environment range extension and mixed excitation linear prediction voice coding, 142 preset channels, advanced key loading, DS-101 fill capability and embedded tactical IP and cryptographic algorithm. The Shadowfire operates in the VHF and UHF frequency spectrum and supports line of sight with frequency agile modes, satellite communications DAMA, and maritime operation. Voice and data operation is available in each of these modes. The Shadowfire also provides enhanced mixed excitation linear prediction, Vocoder and improved linear predictive coding, anti-jam communications, and over-the-air rekeying and over-the-air transfer capabilities.

MULTIBAND MULTI-MISSION RADIO

7-37. The multiband multi-mission radio (AN/PSC-5D) offers a higher frequency range than the Spitfire and Shadowfire. The AN/PSC-5D provides lightweight, secure, network-capable, multiband multi-mission, anti-jam, voice, imagery, and data communications capability in a single package. The AN/PSC-5D operates in the VHF and UHF frequency spectrum and supports line of sight with frequency agile modes, satellite communications, DAMA, and maritime operation. Voice and data operation is available in each of these modes. Table 7-1, on page 7-8, outlines a line of sight interoperability comparison of the AN/PSC-5 family of radios and the AN/PRC-117F. For more information on UHF SC TACSAT and DAMA, refer to ATP 6-02.90.

Table 7-1. AN/PSC-5/C/D, AN/PRC-117F and AN/ARC-231 line of sight interoperability

Radio Item	*AN/PSC-5 Spitfire*	*AN/PSC-5C Shadowfire*	*AN/PSC-5D and AN/ARC-231*	*AN/PRC-117F*
Frequency Range MHz	30–400 MHz	30–420 MHz	30–512 MHz	30–512 MHz
Voice 12 kilobits per second	FASCINATOR	FASCINATOR	FASCINATOR	FASCINATOR
Voice 16 kilobits per second	VINSON	VINSON	VINSON	VINSON
Data 16 kilobits per second	VINSON, 3 or 4 KG-84C	VINSON, 3 or 4 KG-84C	VINSON, 3 or 4 KG-84C	VINSON, 3 or 4 KG-84C
Data (over 16 kilobits per second	No	1–4 KG-84C (3 KG-84C)—up to 48 kilobits per second	1–4 KG-84C (3 KG-84C)—up to 48 kilobits per second	No
Continuous tone coded squelch system	No	Yes	Yes	No
SINCGARS Frequency Hopping	No	Yes	Yes	Yes
Guard frequency	No	Yes	Yes	No
Channel Spacing	5 and 25 kHz	5 and 25 kHz	5, 6.25, 8.33, 12.5, 25 kHz	10 Hz, 5, 8.33, 12.5 and 25 kHz

LEGEND
Hz hertz
kHz kilohertz
MHz megahertz
SINCGARS single-channel ground and airborne radio system

7-38. Tables 7-2 outlines a DAMA line of sight 5 kHz and 25 kHz interoperability comparison of the AN/PSC-5 family of radios and the AN/PRC-117F. For more information on UHF SC TACSAT and DAMA, refer to ATP 6-02.90.

Table 7-2. AN/PSC-5/C/D, AN/ARC-231 and AN/PRC-117F 5 kHz and 25 kHz DAMA interoperability

Terminal / *Mode*	*AN/PSC-5*	*AN/PSC-5C*	*AN/PSC-5D and AN/ARC-231*	*AN/PRC-117*
5 kHz voice 2400 bits per second	ANDVT	Mixed Excitation Linear Predictor (AUTO)	Mixed Excitation Linear Prediction (AUTO)	Mixed Excitation Linear Prediction (AUTO)
5 kHz Data 2400 bits per second	ANDVT, 3 or 4 KG-84C	ANDVT, 3 or 4 KG-84C	ANDVT, 3 or 4 KG-84C	ANDVT, 3 or 4 KG-84C
5 kHz Demand assigned single access data	ANDVT, 3 or 4 KG-84C up to 2400 bits per second	1–4 KG-84C (3 KG-84C)—up to 9600 bits per second	1–4 KG-84C (3 KG-84C)—up to 9600 bits per second	1–4 KG-84C (3 KG-84C)—up to 8000 bits per second *use 181B for interoperability (high performance waveform between 117F only)
25 kHz Voice 2400 bits per second	ANDVT	Mixed Excitation Linear Prediction (AUTO)	Mixed Excitation Linear Prediction (AUTO)	Mixed Excitation Linear Prediction (AUTO)
25 kHz Data 2400 bits per second	ANDVT, 3 or 4 KG-84C	ANDVT, 3 or 4 KG-84C	ANDVT, 3 or 4 KG-84C	ANDVT, 3 or 4 KG-84C
Data 4800 bits per second (limited access)	3 or 4 KG-84C	3 or 4 KG-84C	3 or 4 KG-84C	3 or 4 KG-84C
25 kHz Demand assigned single access data	Vinson, 3 KG-84C/4 KG—84 only up to 16 kilobits per second	1–4 KG-84C (3 KG-84C)—up to 48 kilobits per second	1–4 KG-84C (3 KG-84C)—up to 56 kilobits per second	1–4 KG-84C (3 KG-84C)—up to 56 kilobits per second *use 181B for interoperability
Data transfer	Yes	Yes	Yes	No
LEGEND **ANDVT Advance Narrowband Digital Voice Terminal** **AUTO automatic**				

7-39. Table 7-3 outlines a 25 kHz SATCOM interoperability comparison of the AN/PSC-5 family of radios and the AN/PRC-117F. For more information on UHF SC TACSAT and DAMA, refer to ATP 6-02.90.

Table 7-3. AN/PSC-5/C/D AN/ARC-231 and AN/PRC-117F 25 kHz SATCOM interoperability

Terminal / *Mode*	*AN/PSC-5*	*AN/PSC-5C*	*AN/PSC-5D and AN/ARC-231*	*AN/PRC-117*
Voice 16 kilobits per second	VINSON	VINSON	VINSON	VINSON
Data 16 kilobits per second	VINSON, 3 or 4 KG-84C	VINSON, 3 or 4 KG-84C	VINSON, 3 or 4 KG-84C	VINSON, 3 or 4 KG-84C
Data (over 16 kilobits per second)	NO	1–4 KG-84C (3 KG-84C)—up to 48 kilobits per second	1–4 KG-84C (3 KG-84C)—up to 56 kilobits per second	1–4 KG-84C (3 KG-84C)—up to 56 kilobits per second *Must use 181B for interoperability (high performance waveform between 117F only)

AN/PRC-117F

7-40. The AN/PRC-117F manpack radio is an advanced multiband multi-mission manpack radio that provides reliable tactical communications performance in a small, lightweight package that can maximize user mobility. The AN/PRC-117F is a multiprocessor based, fully digital, software controlled, voice and data transceiver. The AN/PRC-117F is capable of providing; line of sight, SATCOM, electronic counter-countermeasures, frequency hopping operations (SINCGARS and HAVEQUICK), and is compatible with all tactical VHF and UHF radios. (The AN/VRC-103 is the vehicular version of the AN/PRC-117F.)

7-41. The AN/PRC-117F requires regular updates to the firmware. Signal planners should pay special attention to ensuring that radios have the latest firmware as having multiple versions of the firmware within a unit can cause interoperability problems.

AN/PRC-117F Characteristics and Capabilities

7-42. The AN/PRC-117F as designed acts as the transmission means for communications input devices (digital data and analog). These include standard audio (voice) communications via a handset; line-level audio-data devices such as the handheld data terminals found in special operations forces, military intelligence, field artillery and other units; analog teletype modems; digital data terminal equipment as found in Army Mission Command Systems; personal computers; electronic mail systems, video systems, fax and more. The AN/PRC-117F can operate across the VHF and UHF military tactical frequency bands using either line of sight modes or satellite propagation media for beyond line of sight communications.

7-43. Due to the microprocessor design, digital signal processing and software control, the AN/PRC-117F is the equivalent of many current radios in one manpack or vehicle mounted box. This greatly reduces the space, weight, power, and support requirements for individual fighting platforms and command posts. This also greatly reduces cosite interference problems and, if used properly, can reduce the number of tactical radio networks required to support a digitally equipped fighting force. The AN/PRC-117F has the following characteristics and capabilities—

- **Frequency range of 30–512 MHz**. This frequency range covers not only the “standard” Army tactical (30–88 MHz) band but also covers the frequency bands and modulation modes commonly used by the United States Air Force, United States Navy, and Coast Guard for operations, air traffic control, tactical data links, and maritime uses. This makes the radio ideal for use as a “liaison radio” or “gateway” between service components using different waveforms for joint ground sea and air operations. The AN/PRC-117F frequency range and waveform modes are compatible with civil and public service frequency bands commonly used by non-DOD local, state, federal, and foreign agencies.

- **Modulation**. As delivered, the radio is programmed at the factory for compatibility with current "standard" modulation characteristics segmented in the traditional RF bands—
  - **VHF low band**. 30.00000–89.99999 MHz, FSK. This makes the radio interoperable with SINCGARS, AN/PRC-68, AN/PRC-126 and other tactical radios of foreign and domestic manufacture.
  - **VHF high band**. 90.00000–224.99999 MHz FM, AM, FSK, amplitude shift-keying. In this frequency band, utilize the radio for air-to-air, air-to-ground, and ground-to-ground voice and data communications using waveforms found in this band. The AN/PRC-117F is compatible with a variety of existing military aircraft and air-traffic-control radio communications, as well as military air-to-ground data-link communications, the commercial United States Marine Corps band, United States Navy and Coast Guard communications, civil police, fire, and emergency-management standard radios. The capability of the AN/PRC-117F enables users that employ the radio to accomplish Joint and civil-military liaison voice and data with one radio. This is particularly important to the Army National Guard because of their large role in defense support of civil authorities operations.
  - **UHF band**. 225.00000–511.99999 MHz. AM, FSK, amplitude shift keying. In this frequency band, Use the AN/PRC-117F to perform air-to-air, air-to-ground, ground-to-ground, fixed or mobile radio communications missions for voice and data modes. The AN/PRC-117F is also compatible with electronic counter-countermeasures capable equipment such as AN/ARC-164 and AN/ARC-182 that can be widely found in existing tri-service ground, airborne and special-mission systems.
  - **UHF SATCOM**. 243.00000–270.00000 MHz and 292.00000–318.00000 MHz. In this frequency range, AN/PRC-117F is fully compatible with SC TACSAT systems in dedicated channel or DAMA mode. The AN/PRC-117F also has full orderwire capability and can send and receive data at a rate of 64 kilobits per second in a 25 kHz channel or 12 kilobits per second in a 5 kHz channel. Embedded in the radio hardware and software are automatic requests for RETRANS of bad data packets and COMSEC. This key SATCOM capability gives the radio a feature no other standard CNR has: the ability to communicate beyond line of sight without RETRANS stations from the same radio package used for line of sight communications.

7-44. The AN/PRC-117F operates in the following line of sight fixed frequency cipher text operating capabilities and limitations—

- **VINSON**-16 kilobits per second data rate, 25 kHz COMSEC (KY-57 and KY-58) mode for secure voice and data.
- **KG-84C compatible-**(data only) supports voice only using a 12 kilobits per second data rate in FM and trellis code modulation from 30.00000–511.99999 MHz and AM mode from 90.00000–511.99999 MHz. Available in all modes of UHF SATCOM.
- **TEKs**-electronically loaded 128-bit transmission encryption keys used to secure voice and data communications.
- **COMSEC key fill-**TEKs, transmission security keys, and KEKs can be filled from the following devices—
  - AN/PYQ-10, SKL.
  - KIK-30 RASKL.
  - KIV-7M.

7-45. The AN/PRC-117F can operate in HAVEQUICK I and II mode, utilizing frequency hopping from 225–400 MHz, providing compatibility with current airborne frequency hopping. The AN/PRC-117F can also operate in SINCGARS frequency-hopping mode from 30.0000–87.975 MHz and supports SINCGARS system improvement program or enhanced system improvement program features by placing the AN/PRC-117F in either a net master or a net member mode.

7-46. The AN/PRC-117F can scan up to 10 line of sight fixed frequency or dedicated SATCOM radio voice operation networks. The AN/PRC-117F does not scan HAVEQUICK, SINCGARS, or UHF DAMA networks and does not use digital squelch. The plain text override feature of the VINSON and FASCINATOR cipher text mode allows scanning combinations of cipher text and plain text networks.

AN/PRC-117F DATA CAPABILITIES

7-47. The AN/PRC-117F has the capability for use as a digital data-transmission device. MIL-STD-188-114A lists the recommended serial data standard-232 and 422 as the serial data standards that are interoperable with synchronous and asynchronous data interfaces. This makes it very easy to interface data terminal equipment, computer workstations and networking components such as, CP routers, to the radio for data transmission applications. The AN/PRC-117F can send data transmission rates of 56 kilobits per second through SATCOM and 64 kilobits per second ground-to-ground (line of sight).

7-48. With these data rates, the AN/PRC-117F would make data transmission among brigade and battalion CPs and lower echelons fast enough to support lengthy database-to-database transfers. Transmission of databases, plans, orders, and reports that are difficult and time consuming to do over tactical radios would be much faster. This would not only improve operations but would also reduce system vulnerability to enemy intercept and detection. The data rates supports user desired collaborative tools such as video teleconferencing, imagery transmission, en route mission planning, and collaborative planning that are not practical using lower-data-rate equipment. (Refer to Appendix G for more information on data communications.)

AN/PRC-117G RADIO

7-49. The AN/PRC-117G radio is a single channel voice and data radio that is capable of operating in a frequency range of 30 MHz to 2 GHz. The AN/PRC-117G radio can be configured for manpack, vehicular-mounted, or base station operations. The AN/PRC-117G radio is capable of simultaneously transmitting Voice over Internet Protocol and digital data on a single channel. Digital data transmitted via the AN/PRC-117G radio includes file transfers, chat, streaming video, CNR, and position location information. The advanced networking wideband waveform enables units to use IP routing to transmit medium to high bandwidth data traffic over tactical VHF, UHF, and L-band radio networks. The AN/PRC-117G radio supports the following—

- Advanced networking wideband waveform.
- 181B-Dedicated Channel TACSAT.
- SINCGARS.
- HAVEQUICK II.
- VHF and UHF.
- AM and FM.
- DAMA.
- High performance waveform
- Integrated waveform.
- SRW.

7-50. The networking capabilities of the AN/PRC-117G radio can be enhanced using the RF-7800B Broadband Global Area Network Terminals. The RF-7800B terminals provide satellite-based wideband beyond-line-of-sight communications. When the RF-7800B is combined with the AN/PRC-117G, the systems provide automatic and secure range extension, connection to out-of-range networks, and entry into the Internet or remote private networks.

SINGLE CHANNEL TACTICAL SATELLITE FIRE SUPPORT NETWORKS

7-51. The need for a digital link between the Advanced Field Artillery Tactical Data System, Initial Fire Support Automation System, Forward Observer System, and non-fire support systems may require the use of SC TACSAT networks in the distribution plan to support digital traffic. The commander decides which network provides voice service, and which network carries data.

CORPS FIRE SUPPORT NETWORK

7-52. The purpose of the corps fire support network is for clearing fires, which refers to the coordination necessary when firing into an adjacent area of operations controlled by someone else. The coordination ensures the area is under enemy control and there are no friendly forces in the area. The primary users of the network include any of the following—

- Corps fires cell.
- Division fires cell.
- Field artillery brigades.
- Armored cavalry regiment fires cell.
- Attack regiment fires cell.

DIVISION FIRE SUPPORT NETWORK

7-53. The principle members of the division fire support network include the division fires cell, field artillery brigade, the brigade fires cell, fires battalion and the multiple launch rocket system battalion. The division fire support network provides fire support coordination and serves as an alternate for fire direction with elements throughout the division. The division CP is typically the NCS. This network normally operates as a voice network.

7-54. The separate brigade has unique long haul communications requirements, which line of sight operations cannot satisfy when dispersed over extended distances. These units deploy UHF SC TACSAT terminals with their headquarters to provide connectivity for communications and situational awareness with higher headquarters. The primary communications mode is secure voice.

FIELD ARTILLERY BRIGADE FIRE SUPPORT NETWORK

7-55. The field artillery brigade fire support network contain the operations elements from the field artillery brigade, field artillery brigade, fires battalion, and multiple launch rocket system battalions. The primary purpose of this network is to provide a long-range link to subordinate field artillery elements. This network is primarily a voice network, but can transmit digital traffic between Advanced Field Artillery Tactical Data System and other automated devices.

AIRBORNE AND AIR ASSAULT UNITS

7-56. The airborne and air assault units have a need for en route communications to maintain a connection with the sustaining base, other aircraft, and with the units that may already be in place. Airborne and air assault units accomplish this by using a secure en route communications package, which uses the Spitfire or a VHF and UHF DAMA-capable SC TACSAT. The DAMA-capable SC TACSAT provides communications in line of sight and SATCOM modes. The secure en route communications package supports the commander and his principal staff while en route to the area of operations. It supports ground operations independently of the aircraft at staging areas and during joint task force initial ground operations.

7-57. Well-equipped, rapidly deployable units such as the global response force (GRF) are a vital part of the Army's efforts to be an agile and capable expeditionary force. With help from the en route mission command capability (EMC2), the Army's new in-flight internet, and mission command capability. The EMC2 enable commanders of GRF units to plan missions in the air, while their Soldiers receive operational updates and watch full motion video of upcoming drop zones. The EMC2 provides Soldiers the ability to understand a situation and take appropriate action prior to arrival at their drop location, which enables the GRF to be more effective the moment the GRF arrives in the area of operations.

7-58. Installed on C-17 aircraft, the EMC2 provides Warfighter Information Network-Tactical access and mission command capability for GRF units while in flight, enabling the GRF to stay connected to joint, coalition, or strategic forces as they are traveling into a developing situation. The Army's EMC2 system integrated on additional C-17s expands U.S. special operations command capabilities, supporting the increased expeditionary nature of today's forces. The joint GRF consists of two components—

- **Air Force.** The Air Force supplies and sustains the C-17 and C-130 aircraft.

- **Army's XVIII Airborne Corps.** The Army's XVIII Airborne Corps primarily the 82nd Airborne Division, which has deployment-ready paratroopers and infantrymen, provide an immediate military capability on the ground in a short period to any operation worldwide.

7-59. The EMC2 provides internet service, mission command applications, full motion video, intelligence products, and collaborative planning tools along with a complete office suite of computers and voice phones onboard an aircraft. It enables en route mission command, so that as the situation develops in the destination area of operations, commanders are able to get updates, understand changes on the ground, and adjust their plan to accommodate for the changes. EMC2 provides a transformation in the situational awareness and effectiveness of the GRF in the first several hours of ground operations. Key components of EMC2 are—

- **Fixed install satellite antenna.** The fixed install satellite antenna provides the internet connection for the C-17. The fixed install satellite antenna provides increased bandwidth that enables employment of a new host of services on board the C-17, and increase the capability for GRF units to plan and maintain critical situational awareness in the air.
- **Key leader en route node.** The key leader en route node provides airborne units with broadband reach-back data capability, secure voice over Internet protocol communications between task force commanders and combatant commanders as well as communication between aircraft.

7-60. The EMC2 enable standard and high definition full motion video feeds from satellites, airplanes, and drone displays on board the aircraft on light-emitting diode screens, along with integrated marquees and an intercom system. The EMC2 enable Soldiers to see the airfield and drop zone at the landing destination, providing Soldiers enhanced situational awareness, and enable Soldiers better preparation for the mission. The EMC2 increases force mobility and versatility, enabling Soldiers easier access to the information they need to be successful anytime, anywhere.

Chapter 8

Airborne Radios

This chapter addresses the airborne radios employed to provide communications for ground-to-air operations as well as air-to-air and air-to-sea missions.

AIRBORNE RADIOS OVERVIEW

8-1. Airborne radios play a vital role in providing communications between ground elements and airborne elements. The capabilities of airborne radios enable users to conduct close air support, search and rescue, air-to-air, and air-to-ground communications. The following paragraphs address the airborne SINCGARS. (For more information on aviation brigades and communications refer to FM 3-04.111.)

AN/ARC-201 RADIO

8-2. The AN/ARC-201 SINCGARS radio is a tactical airborne radio subsystem that provides secure, anti-jam voice and data communications. Ground and airborne versions are interoperable even though they are physically different from each other. The major change in the airborne mode is the faceplate attached to the different configurations and the add-on modules that change each version's capabilities. Airborne versions RT-1476, RT-1477A/B/C, and RT-1478 require the KY-58 security equipment for cipher text operation.

RT-1476

8-3. The RT-1476, ARC-201 is the base radio in all three versions and they all operate in the single-channel and frequency hopping modes. The RT-1476, ARC-201 typically mounts in the cockpit of an aircraft. (Refer to TM 11-5821-357-12&P for more information on the AN/ARC-201.)

RT-1477

8-4. The RT-1477, ARC-201 provides a remote capability for installations where the employment of the radio away from the pilot's cockpit. It has a separate radio and a radio set control, C-11466, so the pilot can remotely control the radio from his position in the aircraft. All controls are on the remote control unit, located in the aircraft cockpit. The RT is located in a remote equipment compartment on the aircraft. Dedicated cables transmit control and status signals back and forth between the RT and remote control unit. The RT-1476 and RT-1477 have RETRANS capabilities.

RT-1478

8-5. The RT-1478, ARC-201 is a remote controlled RT. The aircraft system's control display unit controls the RT. The RT is located in the remote equipment compartment of the aircraft. The optional data rate adapter enables the radio to process 1,200 and 2,400 Hz frequency shift keying data through the radio set for data transmission and interfaces between the RT and the KY-58 COMSEC equipment. Operation of the data rate adapter is automatic; there is no operator interface.

SINCGARS Airborne System Improvement Program

8-6. The SINCGARS airborne system improvement program contains throughput and robust enhancements. It includes a RETRANS capability in the packet mode, improved error correction, more flexible remote control, and GPS compatibility. The airborne system improvement program combines three line replaceable units (RT-1478, data rate adapter, and external COMSEC/KY-58) into one unit, and reduces the overall weight of the radio system.

8-7. The SINCGARS airborne system improvement program RT-1478D, ARC-201D is a VHF FM radio set that provides users with the ability to transmit and receive voice and data communications in the 30–88 MHz band. The integration of COMSEC equipment and the data rate adapter combines three line replaceable units into one enclosed system. The radio can operate in secure or plain text mode. When operating in the frequency-hopping mode, the radio provides an EP capability. The RT-1478D, ARC-201D provides voice interoperability with legacy radios in the single-channel mode and is fully interoperable with the SINCGARS family of ground and airborne radios.

8-8. The RT-1478D, ARC-201D key features include—

- Automatic RETRANS.
- Built-in amplitude homing.
- Integrated data rate adapter functions to include—
  - Tactical fire direction system and SINCGARS data modes: 600, 1,200, 2,400, 4,800, and 16,000 bits per second.
  - Enhanced packet data modes: 1200N, 2400N, 4800N, 9600N; recommended standard-232 packet; and recommended standard-423 enhanced data mode is 16,000 bits per second only.
  - 1553B bus: provides radio control and data input and output.
- Built in test function.
- AM-7189 (aircraft radio communications compatible).
- Six frequency hopping presets (including TRANSEC keys).
- Six single-channel presets, plus manual and cue channels.

AN/ARC-210 RADIO

8-9. The AN/ARC-210 offered in several models, which when coupled with ancillary equipment, provides the aviation community with exceptional long-range capability. The RT-1556B provides line of sight VHF and UHF capability and HAVEQUICK I and II, and SINCGARS electronic counter-countermeasures waveforms. The RT-1794I, RT-1824I, RT-1851I, and RT-1851AI are network capable and include embedded cryptographic algorithm, 5 kHz and 25 kHz and DAMA SATCOM, and certified to MIL-STD-188-181C, MIL-STD-188-182B, and MIL-STD-188-183B.

8-10. The AN/ARC-210 provides air-to-air and air-to-ground, two-way voice communications via UHF and VHF. The embedded SATCOM functions that operate in the UHF radio band Data and voice communications.

8-11. The AN/ARC-210 provides the following key features—

- 30–400 MHz frequency range provides VHF and UHF in all radios; 121.5 and 243.0 MHz guard channels, and four-channel scan.
- 30–512 MHz frequency range providing VHF and UHF in the RT-1851AI; 121.5 and 243.0 MHz guard channels, four-channel scan.
- Synthesizer speed and rapid radio response time handles any developed electronic counter-countermeasures algorithm or link requirement.
- Data rates up to 80,000 bits per second SATCOM and 100,000 bits per second line of sight with bandwidth efficient advanced modulation technology.
- Compatible with Link 11, Link 4A and improved data modem.
- MIL-STD-1553B remote control and built in test to module level.
- Channel spacing of—
  - 25 kHz (30–512 MHz).
  - 8.33 kHz (118–137 MHz).
  - 12.5 kHz (400–512 MHz).
- Tuning capability: 5 kHz with remote control, 2.5 kHz via 1553 bus.
- Optional power amplifiers, mounts, and low noise amplifier and diplexer.

AN/ARC-220 RADIO

8-12. The AN/ARC-220 radio system is a microprocessor-based communications system intended for airborne applications. The ground version of the AN/ARC-220 is the AN/VRC-100. The AN/ARC-220 radio system uses advanced digital signal processor technology to provide two-way communication.

8-13. The AN/ARC-220 consists of three replaceable units; a RT (RT-1749/URC or RT-1749A/URC), power amplifier coupler (AM-7531/URC), and control display unit (C-12436/URC). The AN/ARC-220 has embedded ALE, serial tone data modem, and anti-jam (electronic counter-countermeasures) functions. The RT provides the electrical interface with other AN/ARC-220 Line replaceable units and associated aircraft systems such as interphone, GPS, and secure voice systems. The AN/ARC-220 also has the capability of programming up to twenty-five free text data messages via data fill created and edited in real time and the ability to receive data messages to be stored for later viewing.

8-14. The AN/ARC-220 radio system is capable of RETRANS if desired and built-in integration with external GPS units allow position data reports transmission with the push of a button. For more information on the AN/ARC-220 radio system, refer to TM 11-5821-357-12&P.

8-15. The AN/ARC-220 radio system provides the following capabilities—

- Frequency range from 2.000–29.9999 MHz in 100 Hz steps.
- Twenty user programmable simplex or half-duplex channels.
- Twenty programmable simplex or half-duplex channels.
- Twelve programmable electronic counter-countermeasures hop sets.
- Certified for ALE in accordance with MIL-STD-188-141C.
- An integrated data modem that enables communication in noisy environments where voice communications are often not possible.
- Built-in integration with external GPS units allows position data report submission with the push of a button.
- Embedded ALE, electronic counter-countermeasures, and data modem (Joint Interoperability Test Command certified).
- Rapidly and efficient capability to tune a variety of antennas.

AN/ARC-231 RADIO

8-16. The AN/ARC-231 is an airborne VHF/UHF line of sight and DAMA SATCOM radio system that has multiband multimission, secure anti-jam voice, data and imagery capabilities. The RT-1808 is the primary radio for the AN/ARC-231. One key feature of the RT-1808 is that it capitalizes on the AN/PSC-5 Spitfire's expandable architecture and permits users to upgrade as new requirements drive new capabilities. The AN/ARC-231 used in the Army Airborne Command and Control System provides communications capabilities to corps, division maneuver brigade, or attack helicopter commander's airborne tactical CP.

8-17. The AN/ARC-231 has the following characteristics and capabilities—

- HAVEQUICK I and II, and SINCGARS communications modes.
- DAMA and non-DAMA SATCOM communications modes.
- Frequency ranges of—
  - 30–87.975 MHz VHF FM SINCGARS.
  - 108–173.995 MHz VHF AM and VHF FM.
  - 225–399.995 MHz UHF AM HAVEQUICK II ground air band, UHF SATCOM band.
  - 403–511.995 MHz UHF FM public service band.
- Embedded COMSEC and TRANSEC keys with transmit and receive over-the-air rekeying.
- One hundred forty-eight preset channels.
- Independent red and black MIL-STD-1553B bus interfaces.
- Embedded MIL-STD-188-184A analog to digital converter and tactical IP.

- SINCGARS system improvement program and optional enhanced system improvement program and end of message.
- MIL-STD-188-181C high data rate in line of sight and SATCOM.
- 8.33 kHz air traffic control channelization coverage to 512 Hz.
- Minimal size and weight suitable for rotary and fixed wing applications.

AN/ARC-164 RADIO

8-18. The AN/ARC-164 is a UHF airborne radio used for air-to-air, air-to-ground, and ground-to-air communications. There are three major aircraft configurations of the AN/ARC-164 radio and one ground configuration of the AN/VRC-83(V). The AN/ARC-164 RT configurations include a panel mount (RT-1518C), remote control (C-11721), remote mount (RT-1504), and data bus compatible (RT-1614). These radios provide anti-jam, secure communications links for joint task force and Army aviation missions. The Army operational forces utilizing these radios are aviation units, air traffic services and Ranger units. The AN/ARC-164 also provides the Army the ability to communicate with United States Air Force, United States Navy, and NATO units in the UHF-AM mode, which is the communications band for tactical air operations.

8-19. The AN/ARC-164(V) 12 has the following capabilities and characteristics—

- Operations in single-channel or frequency hopping mode.
- Frequency range of 225–399.975 MHz.
- Capacity of 7,000 channels.
- Embedded electronic counter-countermeasures anti-jamming capabilities.
- Voice and data modulated signals with VINSON or VANDAL devices.

AN/ARC-186 RADIO

8-20. The AN/ARC-186 is a VHF AM and FM radio used in many types of fixed-wing aircraft. The AN/ARC-186 provides line of sight with limited range at terrain-flight altitudes but greater range at administrative altitudes normally associated with air traffic control communications. The AN/ARC-186 radio can back up the SINCGARS in the same 30–89.975 MHz frequency range. One disadvantage of the radio is that it has no frequency-hopping mode compatibility with the SINCGARS and it generally lacks KY-58 interface to provide secure FM communications.

8-21. Battalions typically operate a command network, operations and intelligence, and administrative and logistics network using the SINCGARS. Battalions also operate an internal air operations network using HAVEQUICK II. The AN/ARC-186 provides a secondary means of secure tactical communications to overcome SINCGARS and HAVEQUICK II line of sight constraints.

8-22. Although normally used for administrative purposes, the AN/ARC-186 radio may function as a platoon internal network. The battalion CP may also have access to WIN-T and SATCOM for communicating with higher headquarters. (Refer to TM 11-5821-318-12 for more information on the AN/ARC-186.

8-23. The AN/ARC-186 has the following capabilities—

- Secure communications when employed with the KY-58.
- Frequency ranges of—
  - AM transmit and receive: 116–151.975 MHz.
  - AM receive only: 108.000–115.975 MHz.
  - FM transmit and receive: 30.000–87.975 MHz.
- Channel spacing: 25 kHz.
- Twenty preset channels with electronic memory.

Chapter 9

Other Tactical Radio Systems

Army forces employ various other tactical radio systems to enable communication and situational awareness during the conduct of operations. The tactical radio system chosen for employment depends on the mission requirements. This chapter addresses various other tactical radio systems employed to enable communication and situational awareness during the conduct of operations.

AN/PRC-126 RADIO

9-1. The AN/PRC-126 radio is a short range, handheld tactical radio typically employed at the squad and platoon level to provide two-way, voice-communications. The AN/PRC-126 enables small unit leaders to control the activities of subordinate elements in carrying out the unit's mission.

9-2. The AN/PRC-126 is susceptible to enemy jamming and friendly cosite interference. Planners should identify alternate frequencies for use during jamming. Leaders ensure training takes place in order for Soldiers to recognize, overcome, and report jamming activities. Key features of the AN/PRC-126 include—

- Frequency range of 30–87.975 MHz.
- Frequency separation is 25 kHz.
- Nominal range for reliable communications over rolling, slightly wooded terrain is 500 meters (1,640.4 feet) with the short antenna, or 3,000 meters (9,842.5 feet) with the long antenna.
- Standard battery (lithium) operating time is 70 hours.
- Capable of operating with the SINCGARS in the fixed frequency mode.
- Capable of providing secure voice operation when used with the KYV-2A secure voice module.
- Digital communications for passing tactical fire direction information are possible when connected to the OG-174. (Refer to TM 11-5820-1025-10 for more information on the AN/PRC-126 and ATP 3-09.50 for additional information on tactical fire direction communications.)

9-3. In the infantry platoon, the rifle squad typically employs two AN/PRC-126 radios: one for the squad leader and the other for the team leader. Air assault and airborne infantry squads each typically employ one AN/PRC-126. If tasked to conduct a patrol, the dismounted section of a Bradley infantry fighting vehicle mechanized infantry platoon, should task organize its radio equipment in the preparation phase in order to establish communications for the teams.

ICOM HANDHELD RADIO

9-4. The Icom (Icom Incorporated) F43G handheld radio is a COTS short range, handheld radio capable of Type III encryption. The Icom F43 enables commanders to extend communications to create shared understanding with squad leaders and team leaders. The Icom F43 provides Soldier with a small, lightweight, rugged handheld radio with the capability of secure UHF 2-way communication. The Icom F43 has the following characteristics and capabilities—

- UHF operation in the 400–520 MHz frequency range.
- 4 miles (6.4 kilometers) plus transmission in the unencrypted mode.
- 256 memory channel capacity.
- 16 memory banks that allow for division and storage of a variety of flexible channel groupings.
- Built-in multi-format tone signaling and built-in voice scrambler.
- Data encryption standard card that is upgradable for secure communication.

LAND MOBILE RADIO

9-5. The land mobile radio is typically the primary system used for daily installation communications. The land mobile radio commonly employed and used for administrative installation activities in public safety organizations, is compliant with the Association of Public Safety Communications Officials Project 25 standards. Project 25 standards basis is on the public safety communities needs as they define them. The land mobile radio enhances communications interoperability with state and local agencies in a homeland defense or disaster situations, and provides non-secure logistics and administrative communications capabilities to First Responders.

9-6. Land mobile radio systems range from single-channel analog to digital trunked systems. The most basic land mobile radio systems are single-channel analog systems. Each radio is set to a particular frequency monitored by everyone utilizing the same channel. These systems have a dedicated channel for each group or agency using the system. In smaller agencies, if the system experiences heavy usage, users may not be able to place calls. The majority of these systems are VHF systems that offer very little flexibility in their operations. These systems fail to provide a common air interface and cannot accommodate users outside the system. These systems are inefficient users of spectrum, and many agencies have outgrown them. For United States and Possessions land mobile radio regulations, see Chapter 8 of the National Telecommunications and Information Administration *Redbook.*

9-7. Trunked systems utilize a relatively small number of paths, or channels, for a large number of users. This is similar to commercial telephones. Rather than having a dedicated wire line for every user, the phone company has a computer (switch) that manages many calls over a relatively small number of telephone lines. The basis of this assumption is that not every user requires a line at the same time.

9-8. A control console, repeaters, and radios generally make up trunked systems. Instead of using switches and phone lines, these systems use consoles and channels or frequencies to complete calls. The process is the dynamic allocation of a channel that is transparent to the user. When the user of a trunked system activates the push-to-talk, the system automatically searches for an unused channel on which to complete the call.

9-9. Digital trunked systems offer better performance and provide a more flexible platform. This system accommodates a greater number of users and offers an open-ended architecture. This allows for various modes of communications such as data, telephone-interconnect, and security functions. There is faster system access, more user privacy, and the ability to expand by providing a common air interface. For continental United States land mobile radio regulations refer to the National Telecommunications and Information Administration *Redbook*, Chapter 10. The user and unit are responsible for obtaining a frequency assignment in accordance with the National Telecommunications and Information Administration *Redbook*, AR 5-12 and AR 25-1. The absence of spectrum authorization and assignments prohibits the operation of radio frequency system.

9-10. The land mobile radio has the following characteristics and capabilities—

- Frequency range of 380–470 MHz.
- Power of 1–4 Watts.
- Battery life of 10 hours.
- Secure National Institute of Standards and Technology Type I and Type III encryption for point-to-point voice communications.
- Range of 5 kilometers (3.1 miles) max over smooth terrain.
- Programming of up to 512 channels.
- Easy radio reprogramming feature.
- Immerse to a depth of 1 meter (3.2 feet) for 30 minutes.
- Supports narrowband (12.5 kHz) and wideband (25 kHz) channel spacing.
- Intra-squad and team communications for non-critical command, administrative, and logistics functions.

COMBAT SURVIVOR EVADER LOCATOR

9-11. The Combat Survivor Evader Locator (CSEL) radio when utilized provides the capabilities required for locating and rescuing downed aircrew members via satellite. Flight crew personnel, special operations forces, and other personnel with a high potential of becoming isolated typically employ the CSEL radio. The CSEL radio is the primary search and rescue system used by special operations forces and aviation units. The CSEL radio replaces the AN/PRC-90 and AN/PRC-112 survival radios.

9-12. The CSEL radio system is composed of three segments: over-the-horizon segment, ground segment, and the user segment. The three segments use GPS, national and international satellites, and other national systems to provide geopositioning and radio communications for personnel recovery.

OVER-THE-HORIZON SEGMENT

9-13. The over-the-horizon segment operates over UHF SATCOM systems, and Search and Rescue Satellite Assisted Tracking. The UHF SATCOM mode supports two ways messaging and geoposition between an AN/GRC-242 radio set base station and the AN/PRQ-7 radio set.

GROUND SEGMENT

9-14. The ground segment is composed of CSEL radio workstations and the ground distribution network interconnecting with base stations. The ground segment provides highly reliable and timely global connection between all CSEL radio ground elements utilizing the Defense Information System Network.

USER SEGMENT

9-15. The user segment equipment consists of—

- AN/PRC-7 radio set.
- 431/PRQ-7 radio set adapter also referred to as the loader.
- Combat survivor evader locator planning computer and program software.

AN/PRQ-7 Radio Set

9-16. The AN/PRQ-7 provides data communications geo-positioning, voice beacons. The radio set adapter provides the physical interface the CSEL radio planning computer and two operational AN/PRQ-7s. One AN/PRQ-7 serves as the reference in the radio set adapter to acquire and store GPS almanac, ephemeris, and time for the transfer to the other (target) AN/PRQ-7. The CSEL radio planning computer host CSEL radio application software that allows loading of the AN/PRQ-7 through the radio set adapter. A window-operating environment enables loading a target AN/PRQ-7 with mission specific data and transfer GPS key loading. Loading current almanac and ephemeris data speed the satellite acquisition process in the GPS receiver. Transfer of current GPS data speeds the calculation of user position and transfer of current time allows faster acquisition of GPS.

9-17. The AN/PRQ-7 radio set has the following capabilities and characteristics—

- Water resistant.
- GPS receiver.
- Secure data UHF SATCOM transmit and receive capability.
- VHF and UHF voice and beacon.
- Low probability of exploitation of one way transmission.
- Search and rescue satellite transmission.

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Chapter 10

Antenna Techniques

This chapter addresses antenna techniques, concepts, terms, ground effects, antenna length, types of antennas, as well as examples of antenna field repairs.

ANTENNA TECHNIQUES OVERVIEW

10-1. All radios, whether transmitting or receiving, require an antenna. Network-centric operations require establishing tactical networking environments that provide reliable communications to enable communications in support of Unified Land Operations in austere environments. The antenna is the key component in establishing reliable communications in support of operations. Tactical radio networking environments established require employing antennas to establish tactical networking environments that are—

- Reliable.
- Robust.
- Capable of interconnection between networks of the same type.
- Capable of interconnection between networks that are dissimilar.

10-2. Conducting tactical communications during operations under complex terrain conditions can be hard even for an experienced radio operator. Factors that the G-6 and the S-6 and radio planners need to consider in order to provide successful tactical communications are—

- Antenna selection.
- Antenna location.
- Environment and terrain conditions.
- Mode of transmission.
- Frequency band.
- Antenna masking.
- Electronic warfare system deconfliction.

10-3. Antenna can be a significant hazard source. Assembly, emplacement, electro-magnetic discharge, and the physical hazard to others should be assessed and managed. See ATP 5-19 for detailed guidance on risk management.

HIGH FREQUENCY ANTENNA LOCATION CONSIDERATIONS

10-4. During operations, units will not always be able to locate their fixed and mobile radio assets at the most technically ideal positions for the best communications operations. HF communications planners should attempt to comply with as many of the following criteria as possible to gain the best technical advantages for the tactical situation—

- Use ground radials and ground stakes under vertical antenna to improve antenna efficiency and lower take off angles for better ground wave communications.
- Place vertical antennas on higher spots if possible, to enhance ground wave communications.
- Avoid placing vertical antennas behind metal fencing that shield ground wave signals.
- Avoid placing vertical antenna near vertical conducting structures such as masts, tight poles, trees, or metal buildings. Antennas need to be at distances of one wavelength or more to eliminate major pattern distortions and antenna impedance changes by induced current and reflections.
- Separate antenna as far as is practical to reduce electromagnetic interference effects between radio and antenna system.

10-5. Units that are operating in less than ideal positions may be required to communicate using simplex operation. Simplex operation, or one-way-reversible, consists of sending and receiving radio signals on one antenna. Single-channel radios normally use simplex operation. Utilize two antennas during duplex operation: one for transmitting and one for receiving. In either case, the transmitter generates a radio signal; a transmission line delivers the signal from the transmitter to the antenna.

10-6. The transmitting antenna sends the radio signal into space toward the receiving antenna, which intercepts the signal and sends it through a transmission line to the receiver. The receiver processes the radio signal in order for use to operate a data device, such as an AN/UXC-10 facsimile. Figure 10-1 provides an example of a typical transmitter and receiver connection.

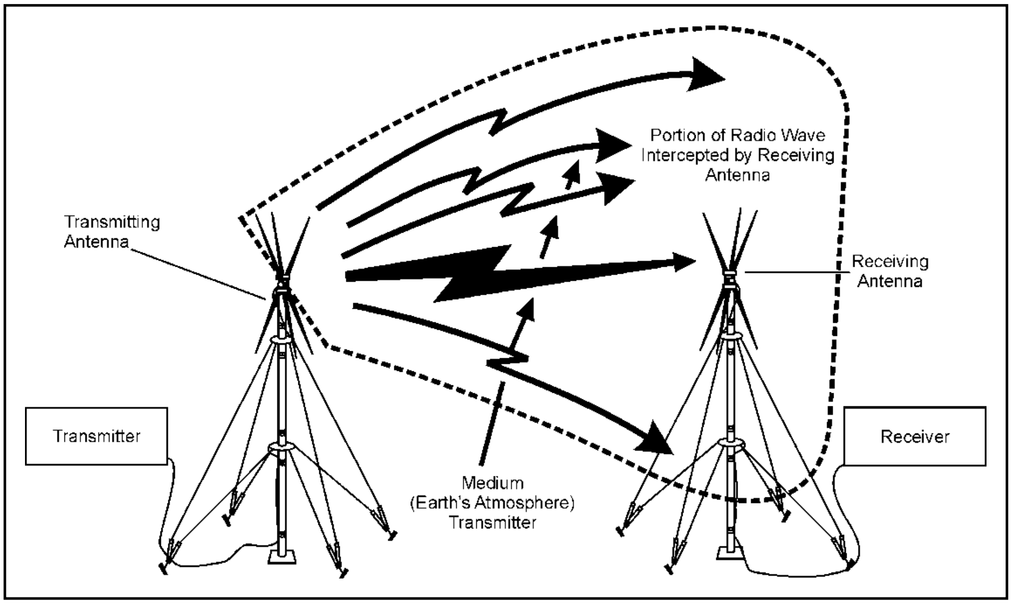


Figure 10-1. Typical transmitter and receiver connection

10-7. The function of an antenna depends on whether it is transmitting or receiving. A transmitting antenna transforms the output RF signal, in the form of an alternating electrical current produced by a radio transmitter (RF output power), into an electromagnetic field that radiates through space; the transmitting antenna converts energy from one form to another form. The receiving antenna reverses this process; it transforms the electromagnetic field into electrical energy delivered to a radio receiver.

ANTENNA CONCEPTS AND TERMS

10-8. An antenna transmits and receives electromagnetic waves, referred to as radio waves. Other concepts and terms are associated with selecting the right antenna. The following paragraphs address several basic terms and relationships to assist in understanding antenna fundamentals.

Forming a Radio Wave

10-9. When created around the conductor an alternating electric current flows through a conductor (wire), electric and magnetic fields. If the length of the conductor is short in comparison to a wavelength, the electric and magnetic fields generally die out within a distance of one or two wavelengths. Lengthening the conductor, the intensity of the field enlarges. Thus, an ever-increasing amount of energy escapes into space.

Radiation

10-10. A wire once connected to a transmitter and properly grounded, begins to oscillate electrically, causing the wave to convert nearly all of the transmitter power into an electromagnetic radio wave. The alternating flow of electrons impressed on the bottom end of the wire creates electromagnetic energy. The electrons travel upward on the wire to the top, where they have no place to go and bounce back toward the lower end. As the electrons reach the lower end in phase (for example, they are in step with the radio energy then being applied by the transmitter) the energy of their motion is strongly reinforced as they bounced back upward along the wire. This regenerative process sustains the oscillation. The wire is resonant at the frequency at which the source of energy is alternating.

10-11. The radio power supplied to a simple wire antenna appears nearly equally distributed throughout its length. The energy stored at any location along the wire is equal to the product of the voltage and the current at that point. High voltage at a given point requires a low current. High current requires low voltage. The electric current reaches its maximum near the bottom end of the wire.

Radiation Fields

10-12. RF power delivered to an antenna creates two fields: an induction field, which is associated with the stored energy, and a radiation field. At the antenna, the intensities of these fields are large, and are proportional to the amount of RF power delivered to the antenna. At a short distance from the transmitting antenna, and traveling toward the receiving antenna, only the radiation field remains; this radiation field is composed of electric and magnetic components.

10-13. The electric and magnetic fields (components) radiated from an antenna form the electromagnetic field. It is responsible for transmitting and receiving electromagnetic energy through free space. A radio wave is a moving electromagnetic field that has velocity in the direction of travel. Its components are of electric and magnetic intensity arranged at right angles to each other. Figure 10-2 provides an example of the components of electromagnetic waves.

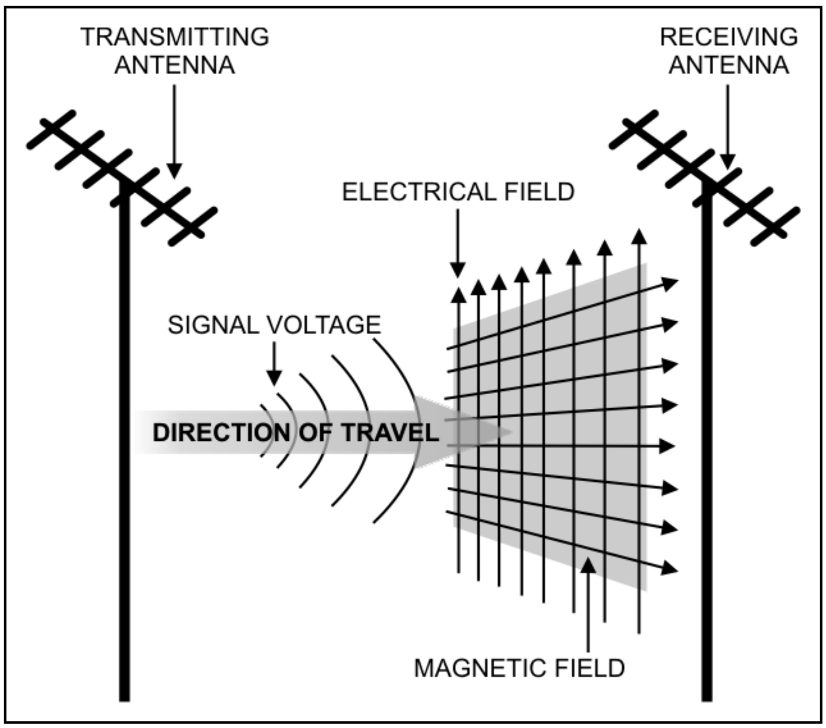


Figure 10-2. Components of electromagnetic waves

Radiation Patterns

10-14. The radiation pattern is a graphical depiction of the relative field strength transmitted from, or received by, the antenna. The full- or solid-radiation pattern appears as a three-dimensional figure that looks somewhat like a doughnut with a transmitting antenna in the center. The top figure shows a quarter-wave vertical antenna; the middle figure shows a half-wave horizontal antenna, located one-half wavelength above the ground; and the bottom figure shows a vertical half-rhombic antenna.

10-15. Figure 10-3 is an example of solid antenna radiation patterns.

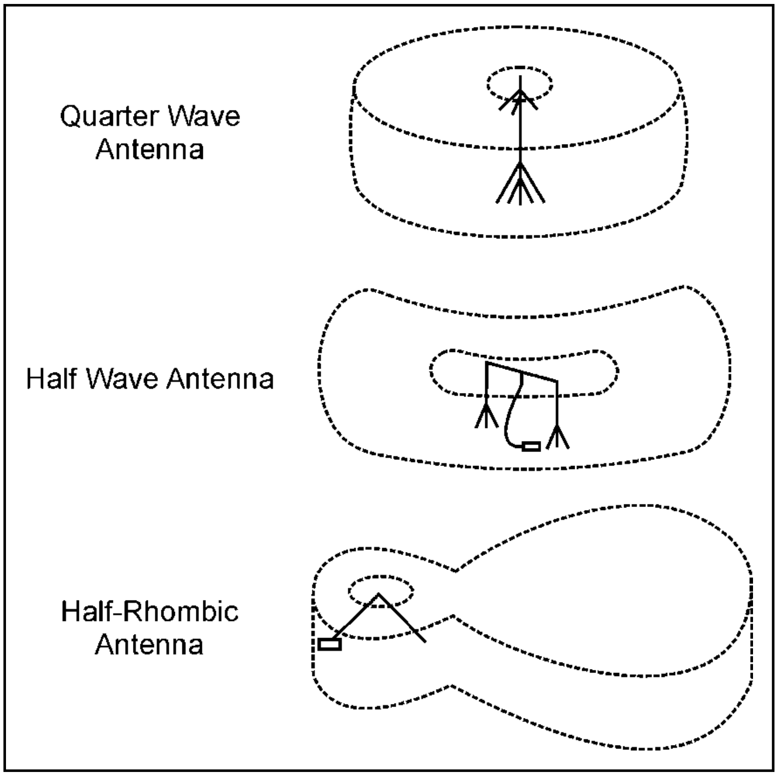


Figure 10-3. Solid radiation patterns

Polarization

10-16. The direction of the lines of force making up the electric field determines the polarization of a radiated wave. Polarization can be vertical, horizontal, or elliptical. A single-wire antenna when used to extract (receive) energy from a passing radio wave, maximum pickup results if the antenna is oriented to ensure that it lies in the same direction as the electric field component.

10-17. Horizontal or vertical polarization is satisfactory for VHF or UHF signals. The original polarization produced at the transmitting antenna maintains as the wave travels to the receiving antenna. Therefore, utilize a horizontal antenna for transmitting, and utilize a horizontal antenna for receiving.

Vertical Polarization

10-18. In a vertical polarized wave, the lines of electric force are at right angles to the surface of the earth. Figure 10-4, on page 10-5, illustrates a vertical polarized wave. Utilize a vertical antenna for efficient reception of vertically polarized waves.

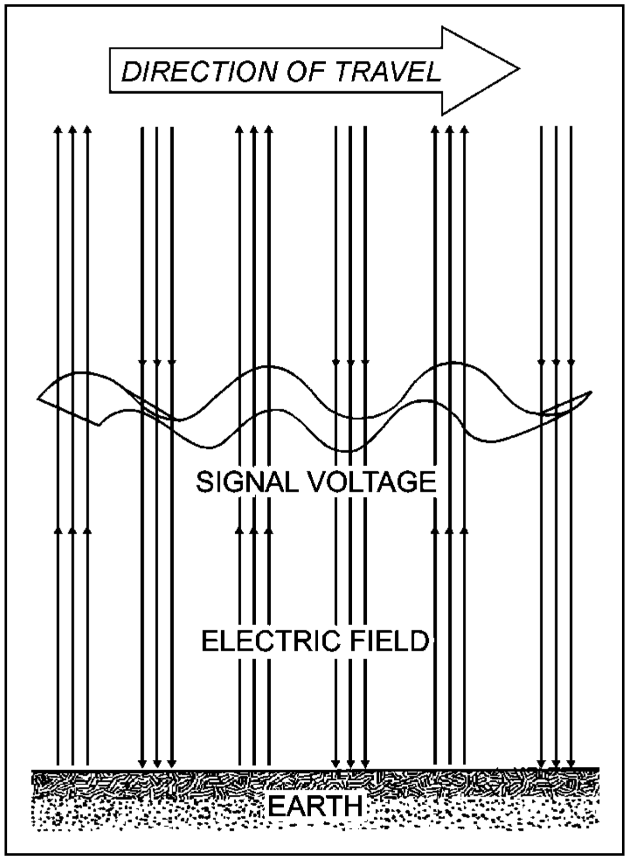


Figure 10-4. Vertically polarized wave

10-19. Vertical polarization is necessary at medium and low frequencies during the extensive use of ground-wave transmission. Vertical lines of force are perpendicular to the ground, and the radio wave can travel a considerable distance along the ground surface with a minimum amount of loss.

10-20. Vertical polarization provides a stronger received signal at frequencies up to approximately 50 MHz, when antenna heights are limited to 3.05 meters (10 feet) or less over land, as in a vehicular installation.

10-21. Reflections from aircraft flying over the transmission path have a lesser effect on vertically polarized radiation. This factor is important in areas where aircraft traffic is heavy.

10-22. The use of vertical polarization results in a lesser production and pick up of electromagnetic interference from strong VHF and UHF transmissions (television and FM broadcasts). This factor is important when locating an antenna in an urban area that has television or FM broadcast stations.

Horizontal Polarization

10-23. In a horizontal polarized wave, the lines of electric force are parallel to the surface of the earth. Use a horizontal antenna for the reception of horizontally polarized waves. Figure 10-5, on page 10-6, is an example of a horizontal polarized wave.

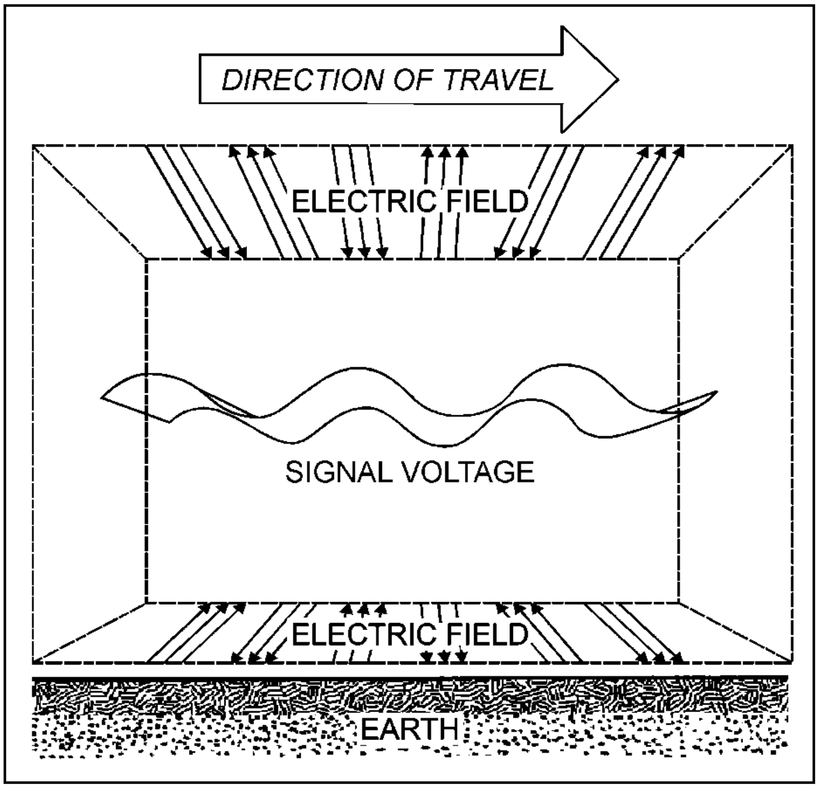


Figure 10-5. Horizontally polarized wave

10-24. At high frequencies, with sky wave transmission, it makes little difference whether horizontal or vertical polarization is used. The sky wave, after reflection by the ionosphere, arrives at the receiving antenna elliptically polarized. Therefore, mount the transmitting and receiving antennas either horizontally or vertically. Horizontal antennas are preferred, since they provide the capability to radiate effectively at high angles and have inherent directional properties.

10-25. A simple horizontal, half-wave antenna is bidirectional. This characteristic is useful when minimizing electromagnetic interference from certain directions and masking signals from the enemy. Horizontal antennas are less likely to pick up man made interference. When antennas are located near dense forests, horizontally polarized waves suffer lower losses, especially at frequencies above 100 MHz.

10-26. Small changes in antenna location do not cause large variations in the field intensity of horizontally polarized waves, when an antenna is located among trees or buildings.

Elliptical Polarization

10-27. In some cases, the field rotates as the waves travel through space. Under these conditions, horizontal and vertical components of the field exist and the wave has elliptical polarization.

10-28. Satellites and satellite terminals use a type of elliptical polarization, called circular polarization. Circular polarization describes a wave whose plane of polarization rotates through 360 degrees as it progresses forward; the rotation can be clockwise or counterclockwise. Circular polarization occurs when equal magnitudes of vertically and horizontally polarized waves combine with a phase difference of 90 degrees. Depending on their phase relationship, this causes rotation either in one direction or the other. Figure 10-6, on page 10-7, is an example of a circular polarized wave.

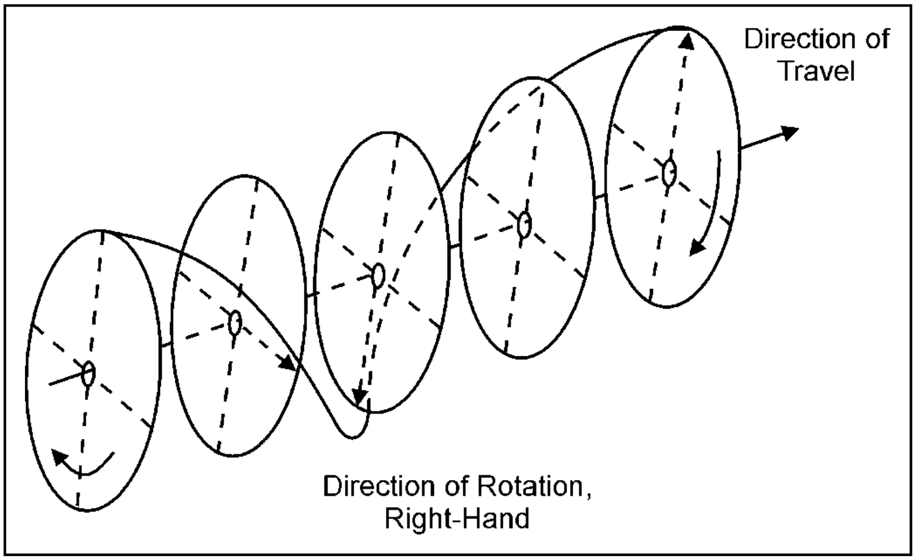


Figure 10-6. Circular polarized wave

Directionality

10-29. Vertical transmitting antennas radiate equally in horizontal directions; vertical receiving antennas accept radio signals equally from all horizontal directions. Thus, other stations operating on the same or nearby frequencies may interfere with the desired signal, making reception difficult or impossible. Use directional antennas to improve the reception of a desired signal.

10-30. Horizontal half-wave antennas accept radio signals from all directions. The strongest reception occurs from a direction perpendicular to the antenna, while the weakest reception occurs from the direction of the ends of the antenna. In order to eliminate or reduce interfering signals, change the antenna installation, to ensure that each end of the antenna points directly at the interfering station.

10-31. Communication over a radio circuit is satisfactory when the received signal is strong enough to override undesired signals and noise. Increasing the transmitting power between two radio stations increases communications effectiveness, as the receiver must be within range of the transmitter. In addition, changing the types of transmission, changing to a frequency that is not readily absorbed or using a directional antenna aids in communications effectiveness.

Resonance

10-32. Classify antennas as either resonant or nonresonant, depending on their design. In a resonant antenna, almost all of the radio signals fed to the antenna radiate. If the antenna receives a frequency other than the one for which it is resonant, much of the transmitted signal is lost and not radiated. A resonant antenna effectively radiates a radio signal for frequencies close to its design frequency. When using a resonant antenna for a radio circuit, build a separate antenna for each frequency for use on the radio circuit. A nonresonant antenna, on the other hand, effectively radiates a broad range of frequencies with less efficiency. The use of resonant and nonresonant antennas commonly occurs on tactical circuits. Achievement of resonance occurs in two ways: physically matching the length of the antenna to the wavelength and electronically matching the length of the antenna to the wavelength.

Reception

10-33. Electrons in the path of radio waves have an influence on other electrons in the path of radio waves. For example, as a HF wave enters the ionosphere, the HF wave reflects or refracts back to the Earth by the action of free electrons in this region of the atmosphere. When the radio wave encounters the wire or metallic conductors of the receiving antenna, the radio waves electric field cause the electrons in the antenna to oscillate back and forth in step with the wave as it passes. The movement of these electrons within the antenna is the small alternating electrical current, which the radio receiver detects.

10-34. When radio waves encounter electrons that are free to move under the influence of the wave's electric field, the free electrons oscillate in sympathy with the wave. This generates electric current, which then creates waves of its own called reflected or scattered waves. This process is electromagnetic scattering. All materials that are good electric conductors reflect or scatter RF energy. Since a receiving antenna is a good conductor, it too acts as a scatter. Only a portion of the energy that touches the antenna converts into received electrical power: the wire re-radiates a sizeable portion of the total power.

10-35. If an antenna is located within a congested urban environment or within a building, many objects may scatter or reradiate the energy in a manner that can be detrimental to reception. For example, the electric wiring inside a building can strongly reradiate RF energy. If a receiving antenna is in close proximity to wires, it is possible for the reflected energy to cancel the energy received directly from the desired signal path. When this condition exists, move the receiving antenna to another location within the room where the reflected and direct signals may reinforce rather than cancel each other.

Note. For more information on wave propagation, refer to Training Circular 9-64.

Reciprocity

10-36. Reciprocity refers to the various properties of an antenna that apply equally, regardless of whether utilizing the antenna for transmitting or receiving. For example, the more efficient a certain antenna is for transmitting, the more efficient it is for the antenna to receive the same frequency. The directive properties of a given antenna are the same whether used for transmission or reception.

10-37. There is a minimum amount of radiation along the axis of the antenna. If using the transmitting antenna as a receiving antenna, the antenna receives best in the same directions in which it produces maximum radiation (at right angles to the axis of the antenna). There is a minimum amount of signal received from transmitters located in the line with the antenna wire.

Impedance

10-38. Impedance is the relationship between voltage and current at any point in an alternating current circuit. The impedance of an antenna is equal to the ratio of the voltage to the current at the point on the antenna where the feed is connected (feed point). If the feed point is located at a point of maximum voltage point, the impedance is as much as 500 to 10,000 ohms.

10-39. The input impedance of an antenna depends on the conductivity or impedance of the ground. For, example, if the ground is a simple stake driven about a meter (3.2 feet) into earth of average conductivity, the impedance of the monopole may be double or even triple the quoted values. Because this additional resistance occurs at a point on the antenna circuit where the current is high, a large amount of transmitter power dissipates as heat into the ground rather than radiated as intended. Therefore, it is essential to provide as good a ground or artificial ground (counterpoise) connection as possible when using a vertical whip or monopole.

10-40. The amount of power an antenna radiates depends on the amount of current, which flows in it. Maximum power radiates when there is maximum current flowing. Maximum current flows when the impedance is minimized which is when the antenna is resonated so that its impedance is pure resistance. (When capacitive reactance equates to inductive reactance, they cancel each other, and impedance equals pure resistance.)

Bandwidth

10-41. Antenna bandwidth describes the range of frequencies over which the antenna can properly radiate or receive energy. The bandwidth of an antenna reflects the frequency range over which it performs within certain specified limits. These limits are with respect to impedance match, gain, and radiation pattern characteristics.

10-42. Necessary bandwidth for a given class of emission is the width of the frequency band, which is just sufficient to ensure the transmission of information at the rate and the quality required under specified conditions.

10-43. Bandwidth "computing" describes the maximum data transfer rate of a network or Internet connection. It measures how much data that can be transmitted over a specific connection in a given amount of time.

10-44. In the radio communications process, information changes from speech or writing to a low frequency signal utilized to modulate, or cause change, in a much higher frequency radio signal. When transmitted by an antenna, it is picked up and reconverted into the original speech or writing. There are natural laws, which govern and limit signal transmission. The more words per minute the higher the rate of modulation frequency, which results in the need for a wider or greater bandwidth. To transmit and receive the necessary information, the antenna bandwidth must be as wide as or wider than the signal bandwidth, otherwise it limits the signal frequencies, and cause voices and writing to be unintelligible. Too wide of a bandwidth is also bad, since it accepts extra voices and degrades the signal to noise ratio.

Shannon-Hartley Theorem

10-45. Planners take into consideration the Shannon-Hartley theorem when planning bandwidths. The Shannon-Hartley theorem tells the maximum rate at which information can be transmitted over a communications channel of a specified bandwidth in the presence of noise.

Antenna Gain

10-46. The antenna gain depends on its design. Transmitting antennas designed for high efficiency in radiating energy, and receiving antennas designed for high efficiency in picking up (gaining) energy. On many radio circuits, transmission is required between a transmitter and only one receiving station. Directed energy radiates in one direction because it is useful only in that direction. Directional receiving antennas increase the energy gain in the favored direction and reduce the reception of unwanted noise in signals from other directions. Transmitting and receiving antennas should have small energy losses and should be efficient as radiators and receptors.

10-47. For example, current omnidirectional antennas, when employed in forward combat areas, transmit and receive signals equally in all directions, and provide an equally strong signal to enemy EW units, and friendly units.

Take-Off Angle

10-48. The antenna's take-off angle is the angle above the horizon that an antenna radiates the largest amount of energy. VHF communications antennas design in manner so that the energy radiates parallel to the Earth (do not confuse take-off angle and polarization). The take-off angle of an HF communications antenna can determine whether a circuit is successful or not. HF sky wave antennas design support specific take-off angles, depending on the circuit distance. Utilize high take-off angles for short-range communications and utilize low take-off angles for long-range communications. Figure 10-7, on page 10-10, depicts an example of an antenna take-off angle.

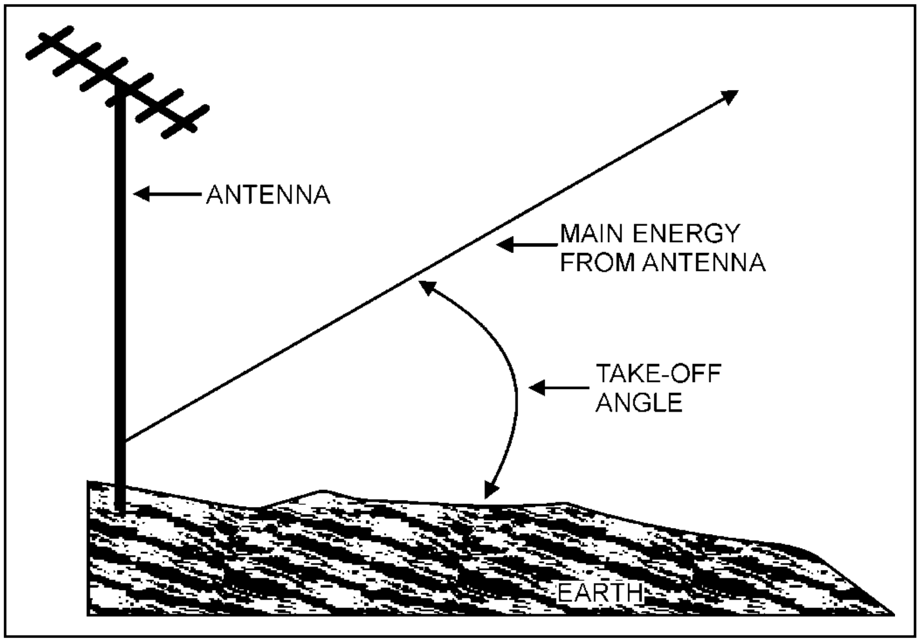


Figure 10-7. Antenna take-off angle

GROUND EFFECTS

10-49. Since most tactical antennas erected occur over the earth, and not out in free space (except for those on satellites), the ground alters the free space radiation patterns of antennas. The ground also has an effect on some of the electrical characteristics of antennas, specifically those mounted relatively close to the ground in terms of wavelength. For example, medium and HF antennas, elevated above the ground by only a fraction of a wavelength, have radiation patterns that are quite different from the free-space patterns.

GROUNDED ANTENNA THEORY

10-50. When grounded antennas are used, it is important that the ground have as high conductivity as possible. This reduces ground loss, and provides the best possible reflecting surface for the down-going radiated energy from the antenna.

10-51. The ground is a good conductor for medium and low frequencies, and acts as a large mirror for the radiated energy. This result in the ground reflecting a large amount of energy that radiates downward from an antenna mounted over it. Thus, a quarter-wave antenna erected vertically, with its lower end connected electrically to the ground, behaves like a half-wave antenna. Under these conditions, the vertical antenna (quarter wavelength) and the ground create the half wavelength. The ground portrays the quarter wavelength of radiated energy that reflects to complete the half wavelength. At higher frequencies, artificial grounds constructed of large metal surfaces are common to provide better wave propagation. Figure 10-8, on page 10-11, is an example of a quarter-wave connected to the ground.

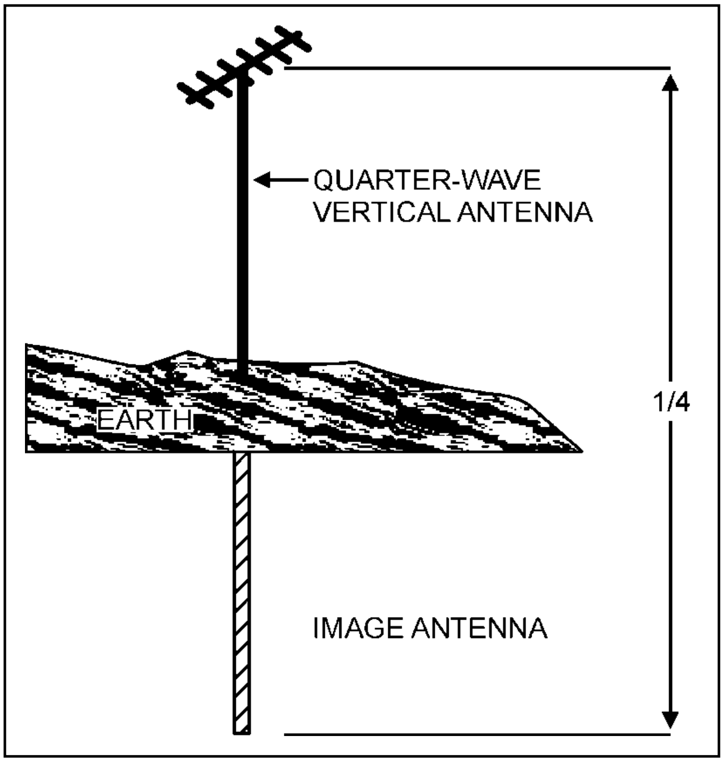


Figure 10-8. Quarter-wave antenna connected to ground

Types of Grounds

10-52. Establish the ground connection in such a way as to introduce the least possible amount of resistance to ground. At higher frequencies, artificial grounds constructed of large metal surfaces are common.

10-53. The ground connections take many forms, depending on the type of installation and the tolerated loss. In many simple field installations, one or more metal rods driven into the soil make the ground connection. Connect ground leads to existing grounded devices to accommodate for unsatisfactory arrangements. Ground connections typically consist of metal structures or underground pipes systems. In an emergency, create a ground connection by forcing one or more bayonets into the soil.

Soil Conditions

10-54. When erecting an antenna over soil with low conductivity, treat the soil to reduce resistance. Favorable, less favorable, or unfavorable are the categories used to describe soil ground conditions. The following paragraphs address a variety of grounding techniques used during these soil conditions.

Favorable Soil Conditions

10-55. Ground connections take many forms, depending on the type of installation and the tolerated loss. In many simple field installations, one or more metal rods driven into the soil make the ground connection. Connect ground leads to existing grounded devices to accommodate for unsatisfactory arrangements. Ground connections typically consist of metal structures or underground pipe systems. In an emergency, forcing one or more bayonets into the soil can make a ground connection.

Less Favorable Soil Conditions

10-56. When erecting an antenna over soil with low conductivity, treat the soil with substances that are highly conductive when in solution, to reduce its resistance.

10-57. For simple installations, fabricate a single ground rod in the field from the pipe or conduit. It is important to establish a low resistance connection between the ground wire and the ground rod. Clean the rod thoroughly by scraping and sand papering at the desired connection point, and install a clean ground clamp. Solder a ground wire to adjoin to the clamp cover. Cover with tape to prevent an increase in resistance because of oxidation.

Unfavorable Soil Conditions

10-58. When the high resistance of the soil, or because a large buried ground system is not practical, an actual ground connection cannot be used because of either a counterpoise or a ground screen may be used to replace the usual direct ground connection.

Counterpoise

10-59. When the high resistance of the soil or because a large buried ground system is not practical and prevents the use of an actual ground connection, use a counterpoise to replace the usual direct ground connection. The counterpoise consists of a device made of wire that is erected a short distance above the ground, and insulated from it. The size of the counterpoise should be equal to, or larger than, the size of the antenna. Figure 10-9 is an example of wire counterpoise.

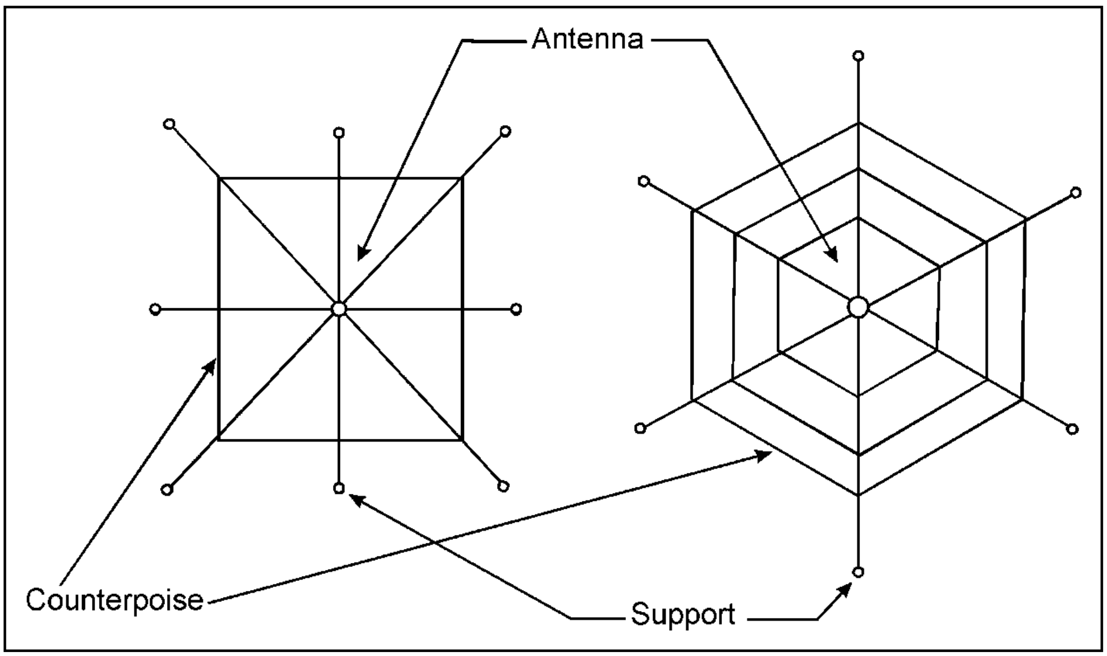


Figure 10-9. Wire counterpoise

10-60. When using a vertically mounted antenna, create the counterpoise into a simple geometric pattern; perfect symmetry is not required. The counterpoise appears to the antenna as an artificial ground that helps to produce the required radiation pattern.

10-61. In some VHF antenna installations on vehicles, utilize the metal roof of the vehicle (or shelter) as a counterpoise for the antenna. Small counterpoises of metal mesh are sometimes used with special VHF antennas require locating the antennas that must be located a considerable distance above the ground.

Ground Screen

10-62. A ground screen consists of a large area of metal mesh or screen laid on the surface of the ground under the antenna. There are two specific advantages in using ground screens. First, the ground screen reduces ground absorption losses that occur when an antenna is erected over ground with poor conductivity. Second, the height of the antenna can be set accurately. Thus, the radiation resistance of the antenna can be determined more accurately.

ANTENNA LENGTH

10-63. The antenna has a physical and electrical length; the two are never the same. The reduced velocities of the wave on the antenna, and a capacitive effect (known as end effect), make the antenna seem longer electrically than it is physically. The contributing factors are the ratio of the diameter of the antenna to its length, and the capacitive effect of terminal equipment (insulators, clamps) used to support the antenna.

10-64. To calculate the physical length of an antenna, use a correction of 0.95 for frequencies between 3.0–50.0 MHz. Table 10-1 provides antenna length calculations for a half-wave antenna.

Table 10-1. Antenna length calculations

<table>
<tr><td colspan="4">The formula below calculates the half-wave length, and uses a correction of 0.95 for frequencies between 3 and 50 MHz. The same formula calculates the height above ground for high frequency wire antennas.</td></tr>
<tr><td>Length (meters)</td><td colspan="2">=150 X 0.95/frequency in MHz</td><td>=142.5/frequency in MHz</td></tr>
<tr><td>Length (feet)</td><td colspan="2">=492 X 0.95/frequency in MHz</td><td>=468/frequency in MHz</td></tr>
<tr><td colspan="4">The length of a long wire antenna (one wavelength or longer) for harmonic operation is calculated by using the following formula:</td></tr>
<tr><td>Length (meters)</td><td colspan="3">=150 X (N-0.05)/frequency in MHz</td></tr>
<tr><td>Length (feet)</td><td colspan="3">=492 X (N-0.05)/frequency in MHz</td></tr>
<tr><td colspan="4">Where N equals the number of half-wave lengths in the total length of the antenna.
For example, if the number of half-wave lengths is 3 and the frequency in MHz is 7, then:
Length (meters)=150(N-0.05)/frequency in MHz</td></tr>
<tr><td>=150(3-0.05)/7</td><td colspan="2">=150 X 2.95/7</td><td>=63.2 meters</td></tr>
<tr><td colspan="4">LEGEND
MHz megahertz

Note. For HF antennas: a half wavelength in meters is 143/f where f is the frequency in MHz. If the frequency is 30 MHz, the wavelength is 5 meters. Often a half wavelength dipole is used and is center fed</td></tr>
</table>

ANTENNA ORIENTATION

10-65. The orientation of an antenna is extremely important. Determining the position of an antenna in relation to the points of the compass can make the difference between a marginal and good radio circuit.

10-66. If the azimuth of the radio path is not provided, determine azimuth should be determined by the best available means. The accuracy required in determining the azimuth of the path depends on the radiation pattern of the directional antenna.

10-67. If the antenna beam width is very wide (for example, a 90 degree angle between half-power points), an error of 10 degrees in azimuth is of little consequence. In transportable operation, the rhombic and V antennas may have such a narrow beam as to require great accuracy in azimuth determination. Erect the antenna with the correct azimuth unless a line of known azimuth is available at the site. A magnetic compass determines the best direction of the path. Figure 10-10, on page 10-14, is an example of a beam width measured on relative field strength and relative power patterns.

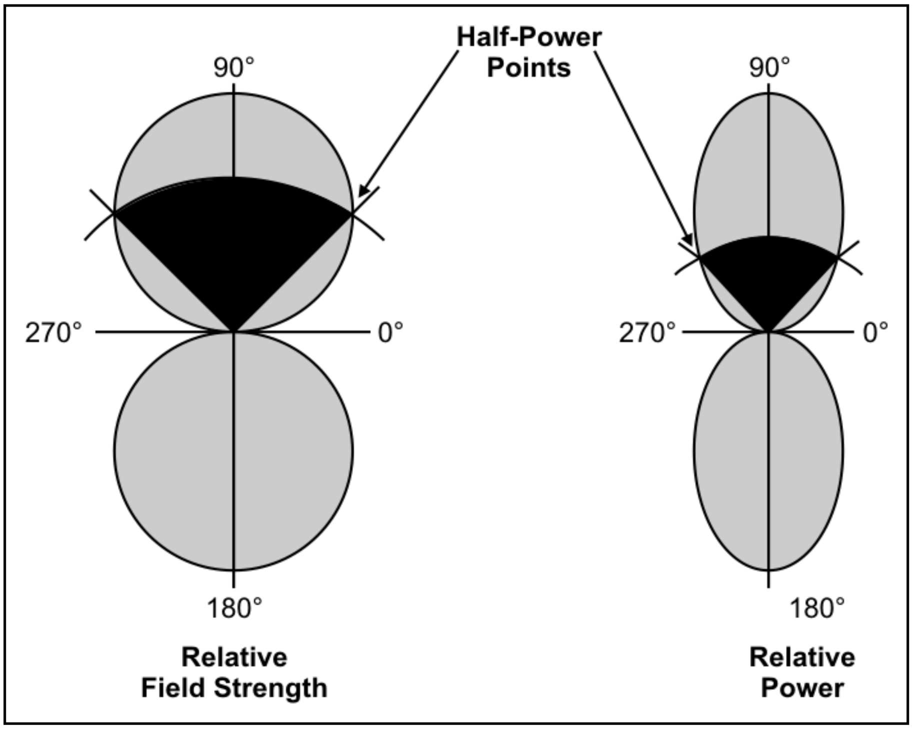


Figure 10-10. Beam width

10-68. This example shows the relationship between the three north points (magnetic, grid and true) as represented on topographic maps by a declination diagram. It is important to understand the difference between the three north points. It is also important to understand how to calculate the three north points. Magnetic azimuths are determined by using magnetic instruments such as lensatic or M2 compasses while a grid azimuth is plotted on a map between two points, the points are joined together by a straight line and a protractor is used to measure the angle between grid north and drawn line. Figure 10-11 is an example of a declination diagram.

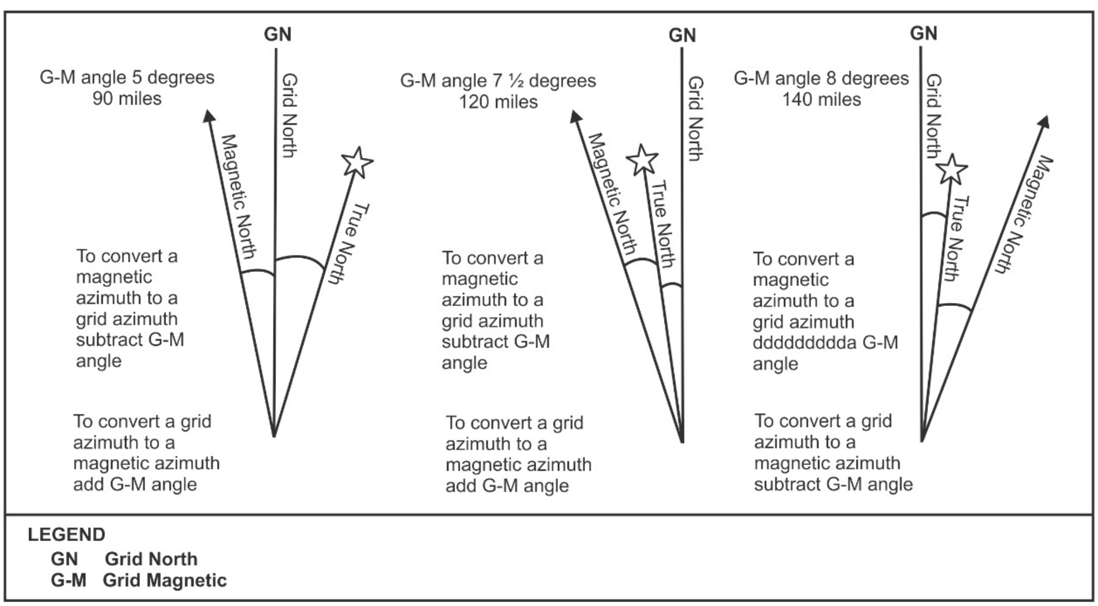


Figure 10-11. Example of a declination diagram

IMPROVEMENT OF MARGINAL COMMUNICATIONS

10-69. Under certain situations, it may not be possible to orient directional antennas to the correct azimuth of the desired radio path. As a result, marginal communications may suffer. To improve marginal communications—

- Check, tighten, and tape cable couplings and connections.
- Check antenna adjustment for the proper operating frequency (if possible).
- Change the heights of antennas.
- Move the antenna a short distance away, and in different locations, from its original location.
- Separate transmitters from receiving equipment, if possible.
- Separate transmitters from power fields.
- Ensure transmission lines are not crossing power lines.

10-70. An improvised antenna may change the performance of a radio set; use a distant station to test if an antenna is operating correctly. If the signal received from this station is strong, the antenna is operating satisfactorily. If the signal is weak, adjust the height and length of the antenna and the transmission line, to receive the strongest signal at a given setting on the volume control of the receiver. This is the best method of tuning an antenna when transmission is dangerous or forbidden.

10-71. Impedance matching a load to its source is an important consideration in transmission systems. If the load and source are mismatched, part of the power reflects back along the transmission line toward the source. This prevents maximum power transfer, and can be responsible for erroneous measurements of other parameters. It may also cause circuit damage in high-power applications.

10-72. The power reflected from the load interferes with the incident (forward) power, causing standing waves of voltages and current to exist along the line. Standing wave maximum-to-minimum ratio directly relates to the impedance mismatch of the load. Therefore, the standing wave ratio provides the means of determining impedance and mismatch.

10-73. After an adequate site selection and proper antenna orientation, the signal level at the receiver is proportional to the strength of the transmitted signal. Obtain a stronger signal by utilizing a high-gain antenna. Using a high quality transmission line (as short as possible and properly matched at both ends) reduces signal loss between the antenna and the equipment.

WARNING

Excessive signal strength may result in enemy intercept and electromagnetic interference, or in the operator interfering with adjacent frequencies.

TYPES OF ANTENNAS

10-74. Tactical antennas design requires that the antennas be rugged and that the antennas permit mobility with the least possible sacrifice of efficiency. Mounting antennas takes place on the sides of vehicles that have to move over rough terrain. Mounting of antennas also takes place on single masts, or suspended between sets of masts. All tactical antennas must be easy to install. Small antennas mount on the helmets of personnel who use the radio sets. Large antennas must be easy to dismantle, pack, and transport.

10-75. A Hertz antenna (also known as a doublet, dipole, an ungrounded, or a half-wave antenna) mounts in a vertical, horizontal, or slanting position and is generally used at higher frequencies (above 2 MHz). With Hertz antennas, the wavelength to which any wire electrically tunes depends directly upon its physical length. The basic Hertz antenna is center fed, and its total wire length is equal to approximately one half of the wavelength of the transmitted signal.

10-76. A Marconi antenna is a quarter-wave antenna with one end grounded (usually through the output of the transmitter or the coupling coil at the end of the feed line) which is required for the antenna to resonate. Positioned perpendicular to the earth, Marconi antenna utilization typically occurs at lower frequencies. When used on vehicles or aircraft, Marconi antennas operate at high frequencies. In these cases, the aircraft or vehicle chassis becomes the effective ground for the antenna.

10-77. The main advantage of the Marconi antenna over the Hertz antenna is that, for any given frequency, the Marconi antenna is physically much shorter. This is particularly important in all field and vehicular radio installations. Typical Marconi antennas include the inverted L, and the whip.

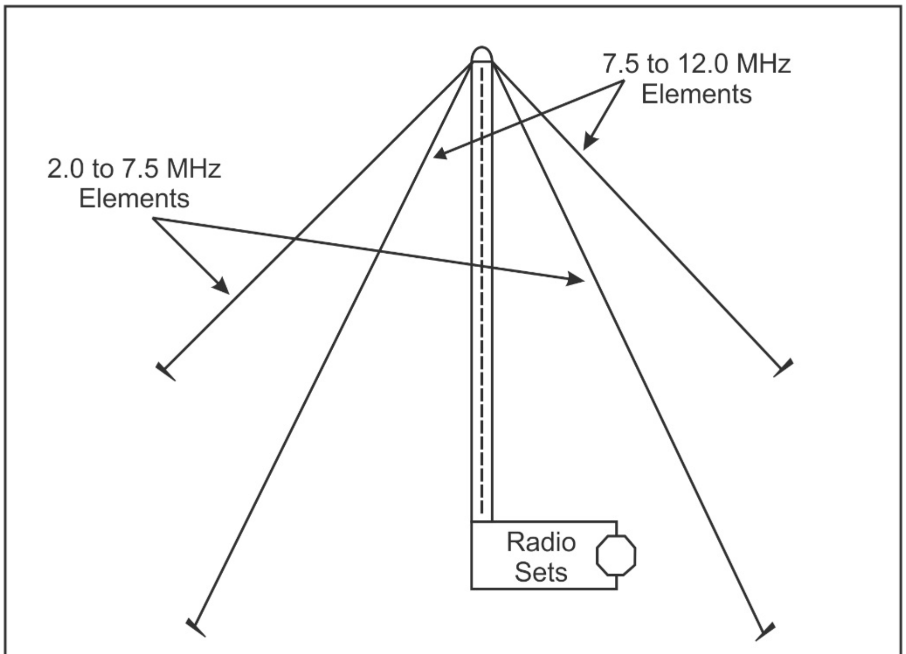
10-78. The best kinds of wire for antennas are copper and aluminum. In an emergency, use any available wire. The exact length of most antennas is critical. An expedient antenna should be the same length as the antenna it replaces.

HIGH FREQUENCY ANTENNAS

10-79. HF antennas vary in size, shape, and capability. The following paragraphs describe HF antennas and HF near-communications. Refer to Appendix C for information on antenna selection.

Near-Vertical Incident Sky Wave Antenna

10-80. The near-vertical incident sky wave antenna, AS-2259/GR, is a lightweight sloping dipole omnidirectional antenna. The AS-2259/GR antenna provides high-angle radiation (near vertical incidence) to permit short-range sky wave propagation to support HF communications (varying from 0 to 300 miles). The frequency range of the antenna is 2.0 to 12.0 MHz. The maximum RF power capacity is 1000 watts. The antenna operates with older AM and HF radio sets as well as with the older improved high frequency radio. Figure 10-12 is an example of the near-vertical incident sky wave antenna.



LEGEND
MHz megahertz

Figure 10-12. Near-vertical incident sky wave antenna, AS-2259/GR

Harris RF-1944, Inverted Vee HF Antenna

10-81. The Harris RF-1944 Inverted Vee HF antenna is a lightweight, broadband dipole COTS antenna that provides radiation patterns in support of HF sky wave communications. The antenna's primary use is for its ALE and frequency hopping capabilities. Other capabilities that the RF-1944 antenna include are—

- Horizontal polarization.
- Radiation patterns ideal for HF sky wave communications from 0–500 miles (0–804.7 kilometers).
- 1.6–30 MHz frequency range.
- Up to 20 watts power and 50 ohms input impedance.
- Gain:
  - -16 gain in decibels relative to isotropic (dBi) at 2 MHz.
  - -2 dBi at 30 MHz.
- Weight: 9 pounds.

10-82. The RF-1944 antenna does not include a mast. The primary components are a balanced to unbalanced transformer, two radiation elements with integral terminating loads, two ground stakes, a coaxial cable, a weighing throwing line, and a carrying bag. The RF-1944 antenna lightweight supports transporting the antenna.

Note. A balanced to unbalanced transformer is a device used to couple a balanced device or line to an unbalanced device or line.

V Antenna

10-83. The V antenna is a medium- to long-range, broadband sky wave antenna. The V antenna provides point-to-point communications to ranges exceeding 4,000 kilometers (2,500 miles). The V antenna consists of two wires arranged to form a V, with its ends at the apex (where the legs come together) attached to a transmission line (Figure 10-13, on page 10-18). Radiation lobes off each wire combine to increase gain in the direction of an imaginary line bisecting the apex angle; the pattern is bidirectional. Adding terminating resistors (300 ohms) to the far end of each leg make the pattern unidirectional (in the direction away from the apex angle).

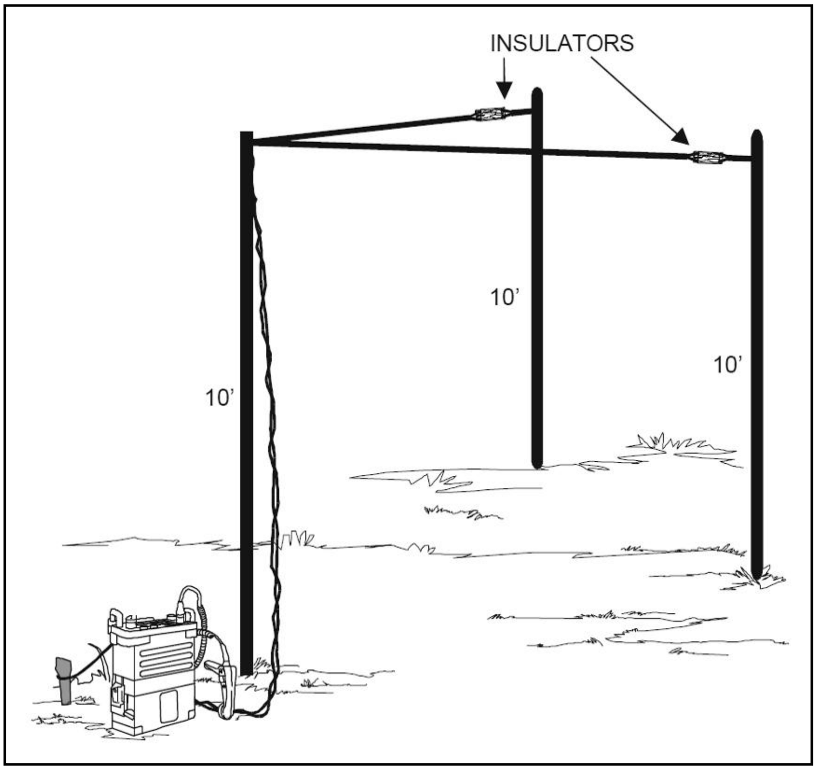


Figure 10-13. V antenna

10-84. The angle between the legs varies with the length of the legs to achieve maximum performance. Use Table10-2 to determine the angle and the length of the legs. When utilizing the antenna with more than one frequency or wavelength, use an apex angle that is midway between the extreme angles determined by the chart.

Table 10-2. Leg angle for V antennas

Antenna Length (Wavelength)	*Optimum Apex Angle (Degrees)*
1	90
2	70
3	58
4	50
6	40
8	35
10	33

Vertical Half Rhombic Antenna and the Long Wire Antenna

10-85. The vertical half-rhombic antenna and the long-wire antenna are two field expedient directional antennas. The long wire antenna directive pattern radiate in the horizontal and vertical planes and the vertical half-rhombic antenna radiate to the front and back of the sloping wires if resistors are not used. These antennas consist of a single wire, preferably two or more wavelengths long, supported on poles at a height of 3–7 meters (10–20 feet) above the ground. The antennas operate satisfactorily as low as 1 meter (approximately 3.2 feet) above the ground. The antennas primary use is for transmitting or receiving HF signals. Resistors on the far end of the wire connect to the ground through a non-inductive resistor of 500–600 ohms. To ensure that there no resistor burn out from the output power of the transmitter, use a resistor rated at least one-half the wattage output of the transmitter. Utilize a good ground, such as a number of ground rods or a counterpoise at both ends of the antenna.

10-86. Figure 10-14 is an example of a vertical half-rhombic antenna.

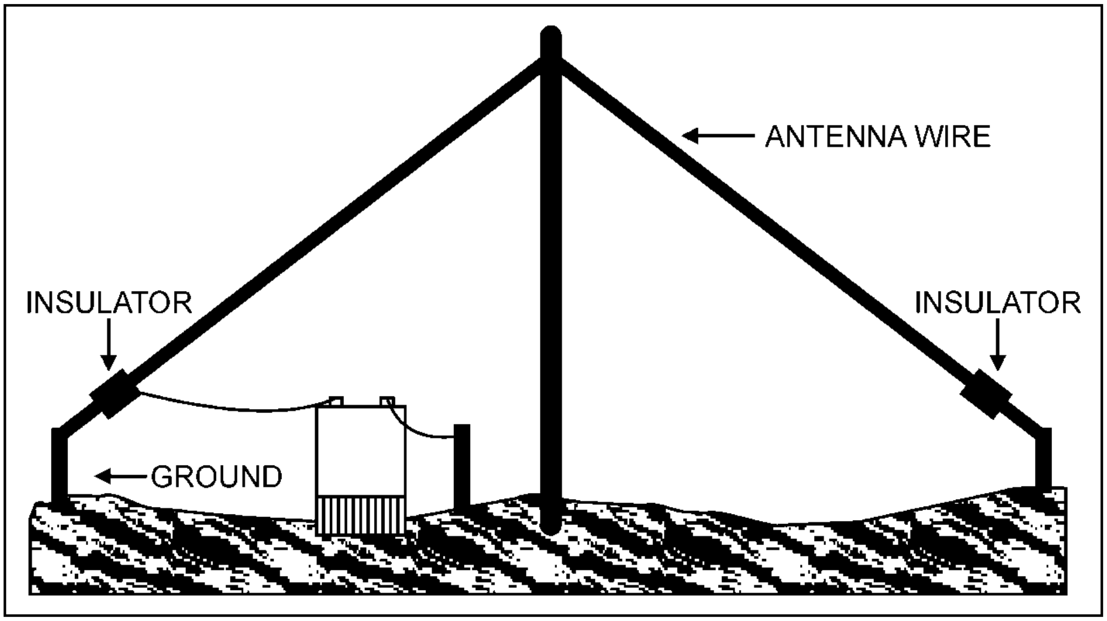


Figure 10-14. Vertical half rhombic antenna

10-87. Figure 10-15 is an example of the long wire antenna.

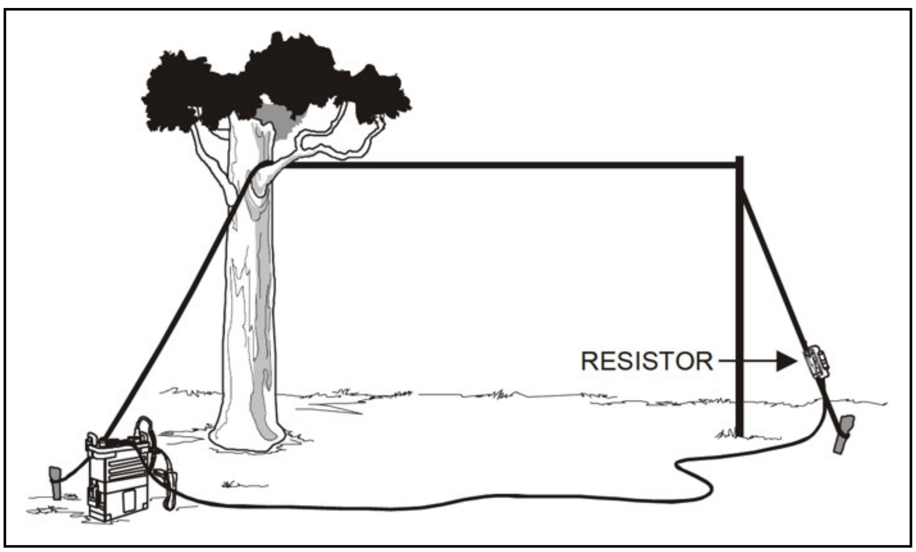


Figure 10-15. Long-wire antenna

Sloping V Antenna

10-88. The sloping V antenna is another field expedient directional antenna. To make construction easier, the legs may slope downward from the apex of the V (this is called a sloping V antenna).

10-89. To ensure that the antenna radiates in only one direction, add non-inductive terminating resistors from the end of each leg (not at the apex) to ground. The resistors should be approximately 500 ohms and have a power rating at least one half that of the output power of the transmitter used. Without the resistors, the antenna radiates bi-directionally, front and back. A balanced transmission line feeds the antenna. Figure 10-16 is an example of a sloping V antenna.

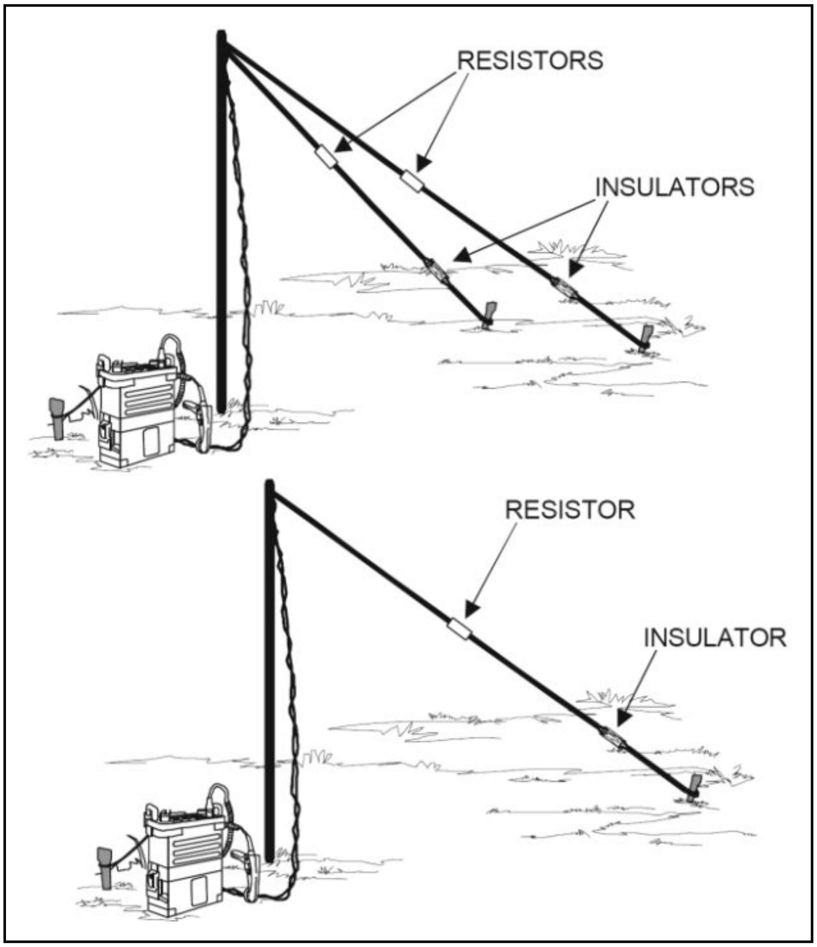


Figure 10-16. Sloping-V antenna

Inverted L Antenna

10-90. The inverted L is a combination antenna made up of vertical and horizontal wire sections. It provides radiation (when no resistors are used) from the vertical element for ground wave propagation, and high-angle radiation from the horizontal element for short-range sky wave propagation, 0–400 kilometers (0–250 miles). The classic inverted L has a quarter-wave vertical section and a half-wave horizontal section.

10-91. Table 10-3 on page 10-21, outlines the frequency and the length of the horizontal element. Using a vertical height of 11–12 meters (35–40 feet), this combination provide reasonable performance for short-range sky wave circuits.

Table 10-3. Frequency and inverted L horizontal element length

Operating Frequency	*Length of Horizontal Element*
5.0–7.0 MHz	24.3 meters (80 feet)
3.5–6.0 MHz	30.4 meters (100 feet)
2.5–4.0 MHz	45.7 meters (150 feet)
LEGEND **MHz** **megahertz**	

10-92. Figure 10-17, on page 10-21, is an example inverted L antenna.

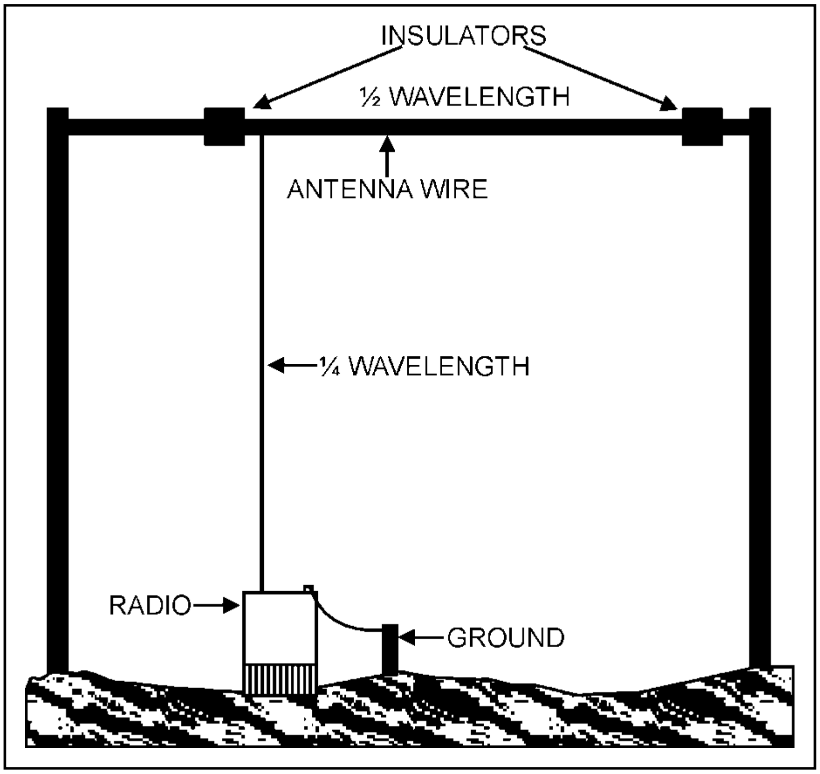


Figure 10-17. Inverted L antenna

Near-Vertical Incident Sky Wave Communications

10-93. The standard communications techniques used in the past do not support the widely deployed and fast moving formations of today's Army. Coupling this with the problems expected in deploying multi-channel line of sight systems with network extensions to keep up with present and future operation, HF radio and the near-vertical incident sky wave mode play an important role in establishing reliable communications. The HF radio is quickly deployable, securable, and capable of data transmission. HF communications typically deploy first, and are frequently the only, means of communicating with fast-moving or widely separated units. With this reliance on HF radio, communications planners, commanders, and operators require familiarization with near-vertical incident sky wave techniques and their applications and shortcomings in order to provide communications that are more reliable.

10-94. Near-vertical incident sky wave propagation is simply sky wave propagation that uses antennas with high angle radiation and low operation frequencies. Just as the proper selection of antenna can increase the reliability of a long-range circuit, the same holds true for short-range communications.

10-95. Near-vertical incident sky wave propagation uses high take-off angle (60–90 degrees) antennas to radiate the signal upward. The signal reflects back from the ionosphere and returns to Earth in a circular pattern around the transmitter. Because of near vertical radiation angle, there is no skip zone (skip zone is the area between the maximum ground wave distance and the shortest sky wave distances where no communications are possible). Communications are continuous out to several hundred kilometers from the transmitter. The nearly vertical angle of radiation also requires the utilization of lower frequencies.

10-96. Generally, near-vertical incident sky wave propagation uses frequencies up to 8 MHz. The steep up and down propagation of the signal gives the radio operator the ability to communicate over nearby ridgelines, mountains, and dense vegetation. A valley location may give the radio operator terrain shielding from hostile intercept or protect the circuit from ground wave and long wave electromagnetic interference. Antennas used for near-vertical incident sky wave propagation require high take-off angle radiation with very little ground wave radiation. Refer to Figure 10-18 for an example of near-vertical incident sky wave propagation.

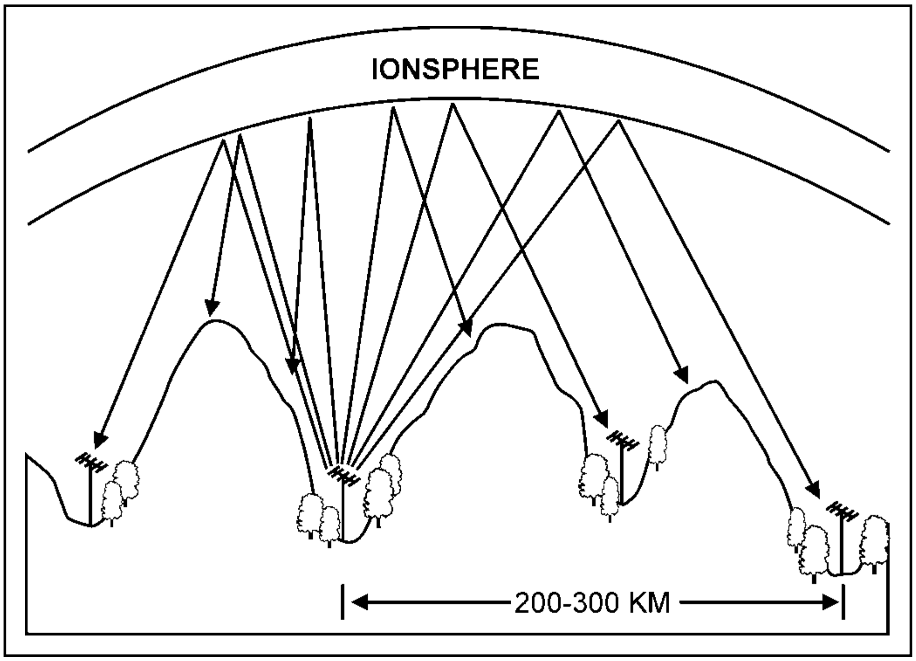


Figure 10-18. Near-vertical incident sky wave propagation

10-97. Using the HF antenna table matrix in Appendix C, the AS-2259/GR and the half wave dipole are the only antennas listed that meet the requirements of near-vertical incident sky wave propagation. While the inverted V and inverted L have high angle radiation, they can also have strong ground wave radiation that could interfere with the close-in near-vertical incident sky wave communications.

Disadvantages of Using the Near-Vertical Incident Sky Wave Concept

10-98. It is also important to understand that where near-vertical incident sky wave and ground wave signals are present, the ground wave can cause destructive electromagnetic interference. Proper antenna selection suppress ground wave radiation and minimize this effect while maximizing the amount of energy going into the near-vertical incident sky wave mode.

Advantages of Using the Near-Vertical Incident Sky Wave Concept

10-99. The following are advantages of using near-vertical incident sky wave in a tactical environment—

- There are skip-zone-free omnidirectional communications.
- Terrain does not affect loss of signal. This gives a more constant received signal level over the operational range instead of one that varies widely with distance.

- Operators are able to operate from protected, dug-in positions. Tactical commanders do not have to control the high ground for HF communications purposes.
- Orientation, such as, doublets and inverted antennas are not as critical.

10-100. The following are advantages of using near-vertical incident sky wave in an EW environment—

- **There is a lower probability of geolocation**. Near-vertical incident sky wave energy from above at very steep angles makes direction finding from nearby but beyond ground wave range locations more difficult.
- **Communications are harder to jam**. Ground wave jammers are subject to path loss. Utilize terrain features to attenuate a ground wave jammer without degrading the desired communication path. The terrain attenuates the jamming signal, while the sky wave near-vertical incident sky wave path loss remain constant. This forces the jammer to move very close to the target or put out more power. Either tactic makes jamming more difficult.
- **Operators can use low power successfully**. Successful utilization of the near-vertical incident sky wave is capable with very low power HF sets. This results in much lower probabilities of low probability of interception and detection.

VERY HIGH FREQUENCY AND ULTRA HIGH FREQUENCY ANTENNAS

10-101. Army forces employ a wide array of VHF and UHF antennas to extend communications over a longer range and to more users. The following paragraphs address VHF and UHF antennas and their characteristics and capabilities.

Whip Antenna

10-102. Whip antennas for VHF tactical radio sets are usually 4.5 meters (15 feet) long. A vehicular whip antenna in HF operations has a planning range of 400–4,000 kilometers (250–2,500 miles).

10-103. Lightweight portable FM radios use two whip antennas: a 0.9-meter (2.9 feet) long semi-rigid steel tape antenna, and a 3-meter (9.8 feet) long multi-section whip antenna. These antennas are shorter than a quarter wavelengths to ensure they are a practical length. (A quarter wavelength antenna for a 5.0 MHz radio would be over 14 meters or 45.9 feet long.) An antenna tuning unit, either built into the radio set or supplied with it, compensates for the missing length of the antenna. The tuning unit varies the electrical length of the antenna to accommodate a range of frequencies.

10-104. Utilize whip antennas with tactical radio sets because they radiate equally in all directions on the horizontal plane. Since stations in a radio net lie in random directions and change their positions frequently, the radiation pattern is ideal for tactical communications.

10-105. When a whip antenna mounts on a vehicle, the metal of the vehicle affects the operation of the antenna. Thus, the direction in which the vehicle is facing may also affect transmission and reception, particularly of distant or weak signals.

10-106. At lower frequencies where wavelengths are longer, it is impractical to use resonant-length tactical antennas with portable radio equipment, especially with vehicle-mounted radio sets. Tactical whip antennas are electrically short, vertical, base loaded types, fed with a nonresonant coaxial cable of about 52 ohms impedance. Figure 10-19 on page 10-24, is an example of a whip antenna.

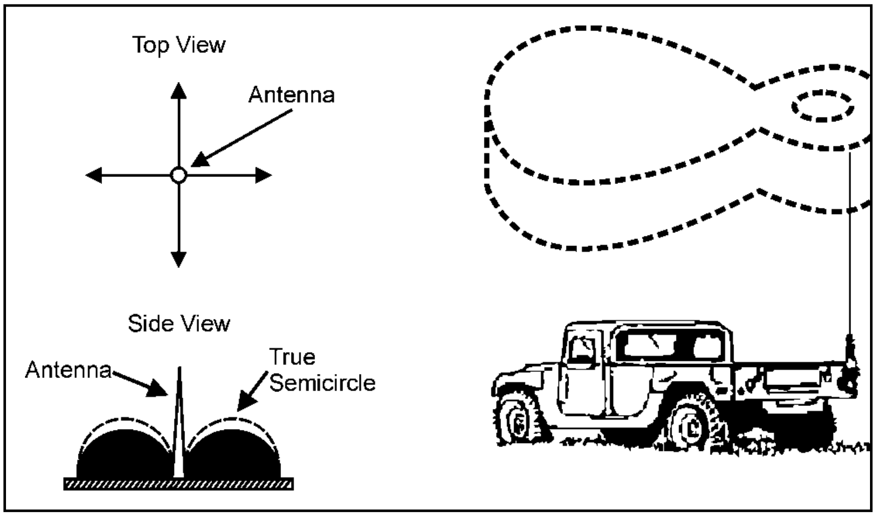


Figure 10-19. Whip antenna

10-107. To attain efficiency with a tactical whip, comparable to that of a half-wave antenna, the height of the vertical radiator should be a quarter wavelength. This is not always possible; therefore utilize the loaded whip instead. The loading increases the electrical length of the vertical radiator to a quarter wavelength. The ground, counterpoise, or any conducting surface that is large enough, supplies the missing quarter-wavelength of the antenna.

10-108. Figure 10-20 shows the best direction for whip antennas mounted on vehicles. A vehicle with a whip antenna mounted on the left rear side of the vehicle transmits its strongest signal in a line running from the antenna through the right front side of the vehicle. Similarly, an antenna mounted on the right rear side of the vehicle radiates its strongest signal in a direction toward the left front side. Obtain the best reception from signals traveling in the direction shown by the dashed arrows on the figure.

10-109. In some cases, the best direction for transmission can be determined by driving the vehicle in a small circle until the best position is located. Normally, the best direction for receiving from a distant station is also the best direction for transmitting to that station.

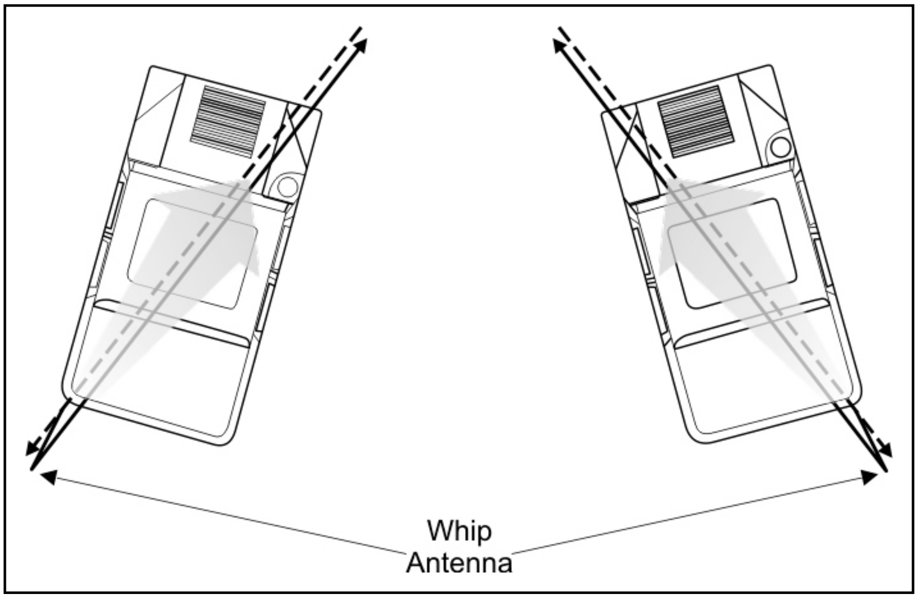


Figure 10-20. Whip antennas mounted on a vehicle

10-110. A whip antenna mounted on a vehicle may require leaving the antenna fully extended for instant use while the vehicle is in motion. The base-mounted insulator of the whip is fitted with a coil spring attached to a mounting bracket on the vehicle. The spring base allows horizontal tie down of the whip antenna when the vehicle is in motion, and when driving under low bridges or obstructions. Even in the vertical position, if the antenna hits an obstruction, the whip usually will not break because the spring base absorbs most of the shock.

10-111. Some of the energy leaving a whip antenna travels downward and the ground reflects the energy with practically no loss. To obtain greater distance in transmitting and receiving, it may be necessary to raise the whip antenna. When raised, the efficiency of a whip antenna decreases because it is further from the ground. Therefore, when using a whip antenna at the top of a mast, supply an elevated substitute for the ground (ground plane).

DANGER

When fully extended while in motion, avoid antenna contact with overhead power lines. Death or serious injury can result if a vehicular antenna strikes a high-voltage transmission line. When tied down, ensure the antenna tip protector is in place.

Broadband Omnidirectional Antenna

10-112. The OE-254 is a broadband omnidirectional antenna that contains a balanced to unbalanced transformer and supports frequency hopping. Table 10-4 shows the planning ranges for the OE-254 antenna. The OE-254 antenna—

- Operates in the 30–88 MHz range without any physical adjustments.
- Has input impedance of 50 ohms unbalanced with an average voltage standing wave ratio of 3:1 or less, at RF power levels up to 350 watts.
- Is capable of being assembled and erected by one individual.
- Meets the broadband and power handling requirements of the frequency hopping multiplexer (FHMUX). (For more information on the OE-254 antenna, refer to TM 11-5985-357-13.)

Table 10-4. OE-254 planning ranges

Terrain	*High Power*	*Low Power (Nominal Conditions)*
OE to OE		
Average Terrain	57.9 kilometers (36 miles)	19.3 kilometers (12 miles)
Difficult Terrain	48.3 kilometers (30 miles)	
OE to Vehicle Whip		
Average Terrain	48.3 kilometers (30 miles)	12.9 kilometers (8 miles)
Difficult Terrain	40.3 kilometers (25 miles)	

Quick Erect Antenna Mast

10-113. The quick erect antenna mast, AB 1386/U is used for elevating tactical communications antennas to a maximum height of 33 feet (10 meters) which results in more reliable communications over extended ranges. The quick erect antenna mast uses the same antenna elements and RF cable as the OE-254 antenna. The quick erect antenna mast mounts to the OE-254, WIN-T, and EPLRS antenna.

10-114. The mast can deploy and operate in a ground or vehicular (wheeled and tracked) mounted configuration. The antenna erects in less than 8 minutes with 2 Soldiers and in 15 minutes with one Soldier.

COM 201B Antenna

10-115. The COM 201B antenna is a commercial VHF and UHF vertically polarized, omnidirectional antenna that is versatile and has a unique design, which supports quick deployments the ability to deploy to support different applications. The COM 201B antenna has a tripod leg structure that allows the antenna to be mounted directly on the ground or on a standard communications mast and can be quickly assembled and disassembled for transport and storage which makes it ideal in situations where there is not enough time to erect the OE-254 antenna.

Note. The COM 201B is not an Army issued replacement for the OE-254 antenna.

10-116. The antennas ease of operations makes it ideal for use as a field expedient antenna or mounting to a vehicle when requiring more elevation. The eye fitting at the top of the antenna facilitates suspending it from buildings or trees when a mast is not available and when requiring more height.

10-117. The COM 201B antenna has the following characteristics and capabilities—

- Operates in the 30–88 MHz range.
- Vertically polarized.
- Input impedance of 50 ohms unbalanced with an average voltage standing wave ratio of 2.5:1, at RF power levels up to 200 watts.
- Maximum power is directed towards the horizon with a typical antenna gain of 0 dBi.
- Does not require active tuning.
- One individual can assemble and erect.
- Assembly can be stored in a space less than 36 inches long by 10 inches in diameter.

Very High Frequency Half-Rhombic Antenna

10-118. The OE-303, VHF half-rhombic antenna is a vertically polarized antenna that, when used with VHF FM tactical radios, extends the range of transmission considerably, and provides some degree of EP. The half-rhombic antenna, when properly employed, decreases VHF FM radio susceptibility to hostile EW operations, and enhances the communications ranges of the deployed radio sets. This effect occurs by directing the maximum signal strength in the direction of the desired friendly unit.

10-119. The VHF half-rhombic antenna is a high gain, lightweight, directional antenna. It operates over the frequency range of 30–88 MHz. The antenna and all the ancillary equipment (guys, stakes, tools, and mast sections) can be packaged in a carrying bag for manpack or vehicular transportation.

10-120. The planning range for the OE-303 is equivalent to the planning range of the OE-254. The OE-303 half rhombic antenna is used with the AB-1244 mast assembly, consisting of 12 tubular mast sections (five lower-mast sections, one mast transition adapter, five upper-mast sections, and antenna adapter), a mast base assembly, and assorted ancillary equipment. Stabilization of the erected mast assembly occurs by a two-level, four-way guying system. Figure 10-21 is an example of the OE-303 VHF half-rhombic antenna.

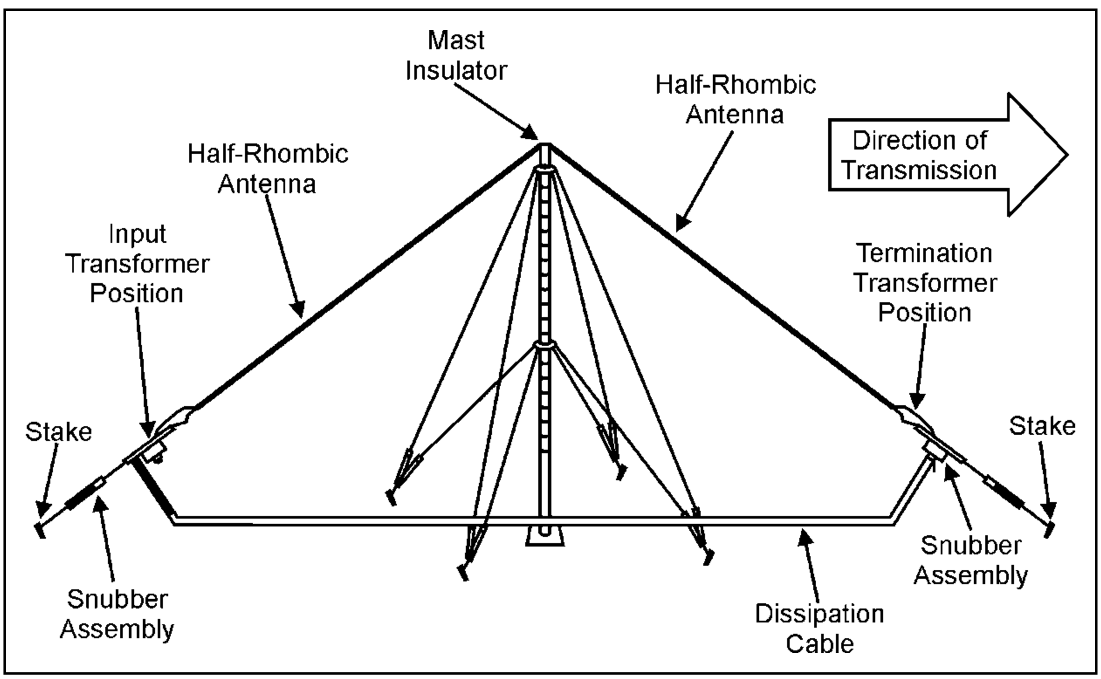


Figure 10-21. OE-303 half-rhombic VHF antenna

10-121. The OE-303 antenna handles RF power levels up to 200 watts. It matches nominal 50-ohm impedance with a voltage standing wave ratio of no more than 2:1, over the entire frequency range of the antenna. It meets the operation, storage, and transit requirements as specified in AR 70-38.

10-122. The OE-303 half rhombic antenna has the following characteristics and capabilities—

- Erected in a geographical area of 53.3 meters (175 feet) in diameter, or less, depending upon the frequency.
- Mounted on any structure approximately 15.2 meters (50 feet) in height.
- Azimuth directional change within 1 minute.
- Transported by manpack or tactical vehicle when fitted into a package.
- Operation with the four-port FHMUX.

10-123. The OE-303 half-rhombic antenna supports special applications and is task assigned as required. Its primary use is on command and intelligence networks to a higher headquarters. Units that habitually operate over extended distances from parent units, and special task units utilize the OE-303 half-rhombic antenna. For more information on the half-rhombic OE-303 antenna, refer to TM 11-5985-370-12.

High Frequency Antennas Usable at Very High Frequency and Ultra High Frequency

10-124. Simple vertical half-wave dipole (doublet) and quarter wave monopole antenna are very popular for omnidirectional transmission and reception over short-range distances. For longer distances, typically use rhombic antennas made of wire similar in design to HF versions to provide an advantage at frequencies as high as 1 GHz.

Dipole Antenna

10-125. The dipole (doublet) antenna also considered a center fed antenna is a half-wave antenna consisting of two-quarter wavelength sections on each side of the center. Figure 10-22 is an example of an improvised dipole (doublet) antenna used with FM radios.

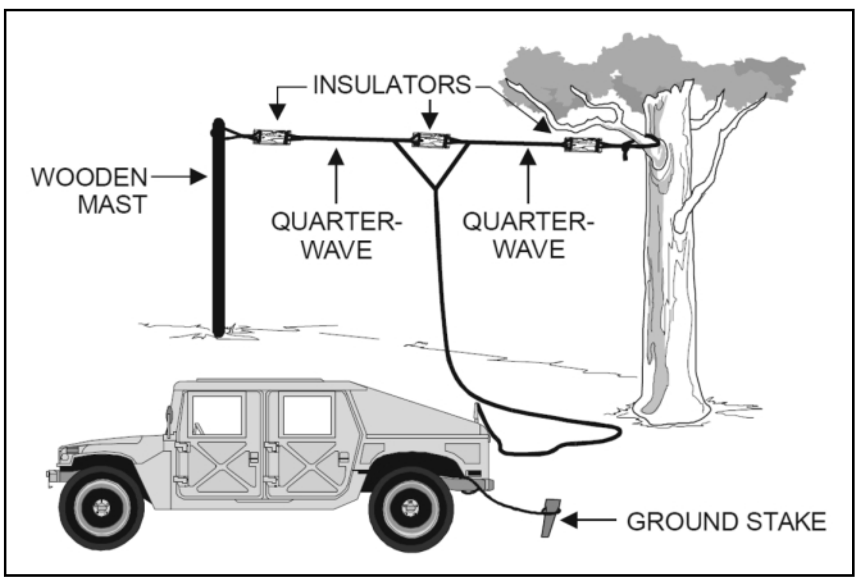


Figure 10-22. Half-wave dipole (doublet) antenna

10-126. A transmission line conducts electrical energy from one point to another, and transfers the output of a transmitter to an antenna. Although it is possible to connect an antenna directly to a transmitter, the antenna generally is located some distance away. In a vehicular installation, for example, the antenna is mounted outside, and the transmitter inside the vehicle.

10-127. Operators may utilize pieces of wood to support center-fed half-wave FM antennas. These antennas rotate to any position to obtain the best performance. If the antenna is erected vertically, the transmission line should be brought out horizontally from the antenna, for a distance equal to at least one-half of the antenna's length, before it is dropped down to the radio set. Figure 10-23 is an example of a horizontal (A) and vertical (B) center-fed half-wave antenna.

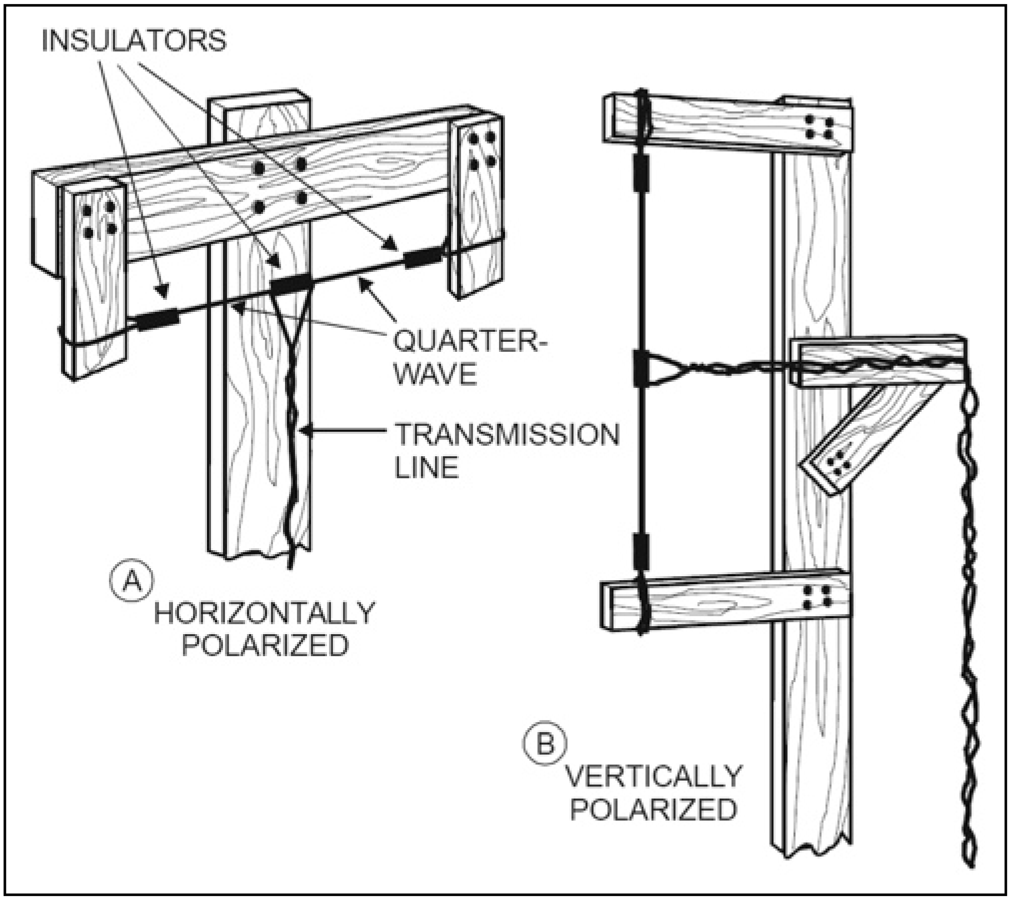


Figure 10-23. Center-fed half-wave antenna

10-128. Figure 10-24 is an example of an improvised vertical half-wave antenna. FM radios primarily utilize this technique. An improvised vertical half-wave antenna is effective in heavily wooded areas to increase the range of portable radios. The top guy wire can be connected to a limb, or passed over the limb and connected to the tree trunk or a stake.

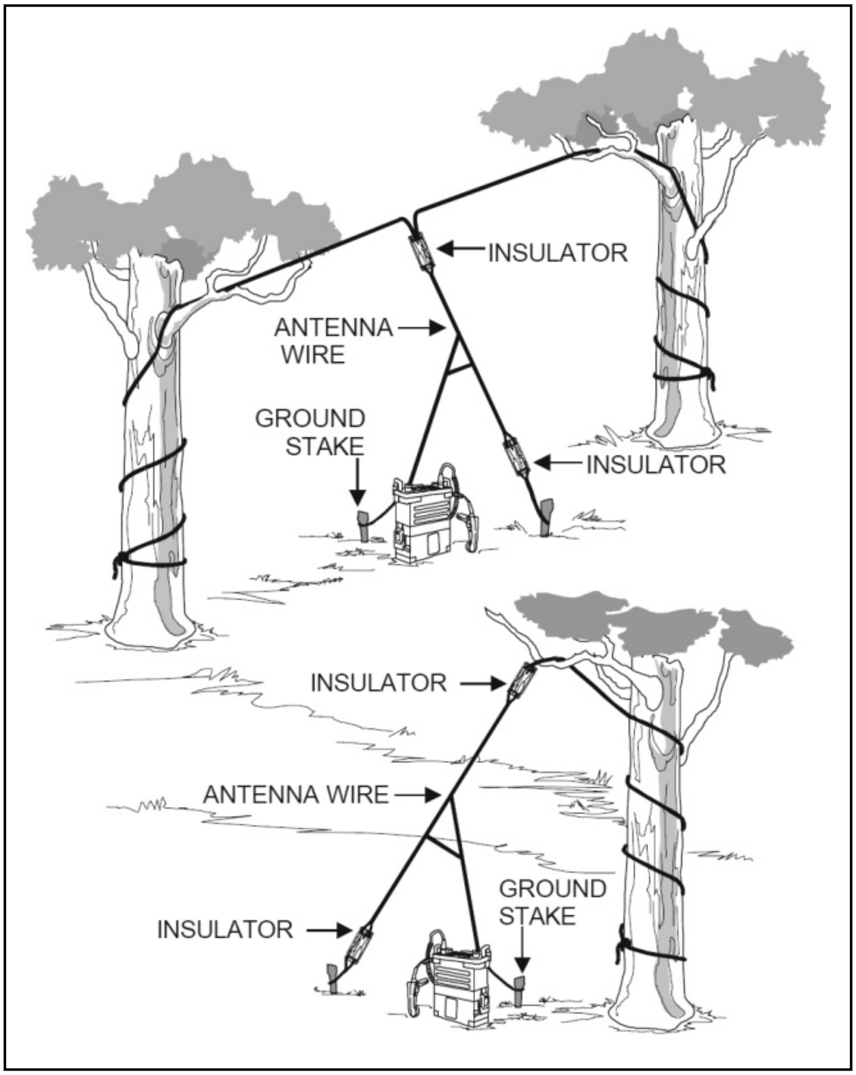


Figure 10-24. Improvised vertical half-wave antenna

Satellite Communications Antennas

10-129. The most important consideration in addressing line of sight equipment is the antenna elevation with respect to the path terrain. Choose sites that exploit natural elevations.

Antenna Siting Considerations

10-130. The most important consideration in siting over-the-horizon systems is the antenna horizon (screening angles) at the terminals. As the horizon angle increases, the transmission loss increases, resulting in a weaker signal.

10-131. The effect of the horizon on transmission loss is very significant. Except where the consideration of one or more other factors outweighs the effect of horizon angles, the site with the most negative angle should be first choice. If no sites with negative angles exist, the site with the smallest positive angle should be the first choice.

10-132. The horizon angle can be determined by using a transit at each site and sighting along the circuit path. The on-site survey determines the visual horizon angle. The radio horizon angle is slightly different from the visual horizon angle: the difference is generally insignificant.

10-133. Measure the horizon angle between the tangent at the exact location of the antenna and a direct line of sight to the horizon. The tangent line is a right angle (90 degrees) to a plumb line at the antenna site. If the line of sight to the horizon is below the tangent line, the horizon angel is negative.

10-134. Trees, building, hills, or the Earth can block a portion of the UHF signals, causing an obstruction loss. To avoid signal loss due to obstruction and shielding, clearance is required between the direct line of sight and the terrain. Utilize path profile plots to determine if there is adequate clearance in line of sight systems.

10-135. Weak or distorted signals may result from SATCOM sets operated near steel bridges, water towers, power lines, or power units. When employing a non-diversity mode, the presence of congested air-traffic conditions on the proximity of microwave equipment can result in significant signal fading.

10-136. For line of sight and TACSAT communications, the AN/PSC-5 family of radios is the most widely used radios. The AN/PSC-5 provides line of sight communications with the AS-3566 antenna and long range SATCOM with the AS-3567 and AS-3568 antennas. The AS-3566, AS-3567, and AS-3568 antennas characteristics are as follows—

- AS-3566, Low Gain Antenna.
  - Frequency range (line of sight): 30–400 MHz.
  - DAMA: 225–400 MHz.
  - Non DAMA: 225–400 MHz.
  - Polarization: directional.
  - Power capability: determined by terminating resistor.
  - Azimuth (bearing): directional.
- AS-3567, Medium Gain Antenna.
  - Frequency range: 225–399.995 MHz.
  - Beam width: 85 degrees.
  - Orientation: Directional.
  - Elevation (0–90 degrees).
  - Input impedance: 50 ohms.
  - Voltage standing wave ratio: 1.5:1
  - Gain: 6 dB (225–318 MHz). 5 dB (318–399.995 MHz).
- AS-3568, High Gain Antenna.
  - Frequency range: 240–400 MHz.
  - Beam width: 77 degrees.
  - Orientation: Directional.
  - Elevation: (0 to 90 degrees).
  - Azimuth: +180 degrees.
  - Input impedance: 50 ohms.
  - Voltage standing wave ratio: 1.5:1.
  - Gain: 8 dB (240–318 MHz) and 6 dB (318–400 MHz).
  - Power: up to 140 watts.

FIELD REPAIR

10-137. Antennas that are broken or damaged cause poor communications or even communications failure. If a spare antenna is available, replace the damaged antenna. When a spare is not available, the user may have to construct an emergency antenna. The following paragraphs provide recommendations on repairing antennas and antenna supports.

REPAIR OF A WHIP ANTENNA

10-138. If a whip antenna is broken in two sections, temporarily repair the antenna by rejoining the sections. Remove the paint and clean the sections to ensure a good electrical connection. Place the sections together, secure them with a pole or branch, and lash them with bare wire or tape above and below the break (refer to Figure 10-25 antenna A).

10-139. For badly damaged whip antennas, use a length of field wire (wire direct-1/TT) the same length as the original antenna. Remove the insulation from the lower end of the field wire antenna, twist the conductors together, insert them in the antenna base connector, and secure with a wooden block. Use either a pole or a tree to support the antenna wire (refer to Figure 10-25, antenna B).

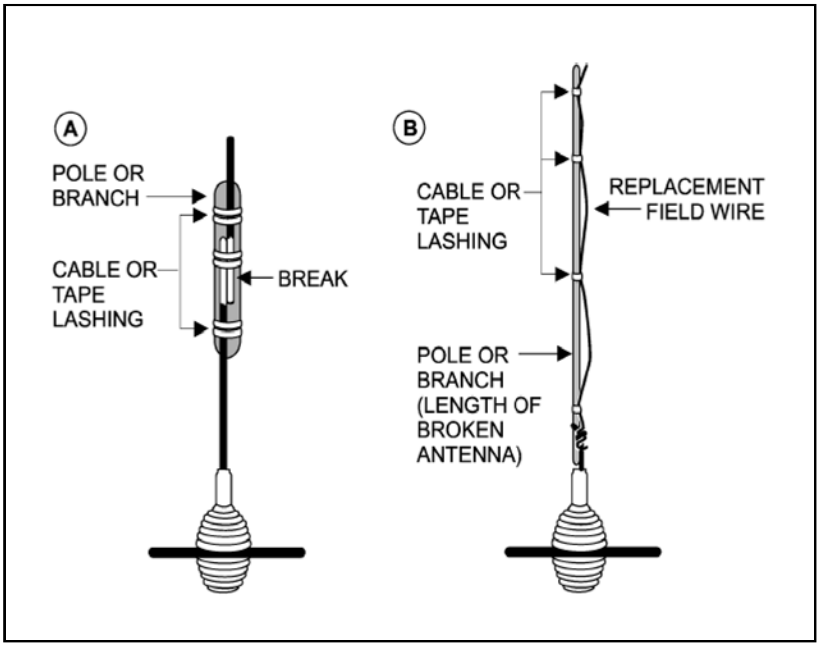


Figure 10-25. Field repair of broken whip antennas

WIRE ANTENNAS

10-140. Emergency repair of a wire antenna may involve the repair or replacement of the wire used as the antenna or transmission line. It may also involve the repair or replacement of the assembly used to support the antenna. When one or more antenna wires are broken, reconnecting the broken wires can repair the antenna. To do this, lower the antenna to the ground, clean the ends of the wires, and twist the wires together. When possible, solder the connection and reassemble.

10-141. Antenna supports may also require repair or replacement. Damaged antenna supports may require using a substitute item in place of a damaged support and, if properly insulated, may consist of any material of adequate strength. Radiating elements not properly insulated may short field antennas to ground, and be ineffective.

10-142. Operators may utilize many common items as field expedient insulators. Plastic or glass (to include plastic spoons, buttons, bottlenecks, and plastic bags) is the best insulator. Wood and rope also act as insulators although they are less effective than plastic and glass. The radiating element, the actual antenna wire, should only touch the antenna terminal, and physically separated from all other objects other than the supporting insulator.

10-143. Figure 10-26 is an example of field expedient antenna insulators.

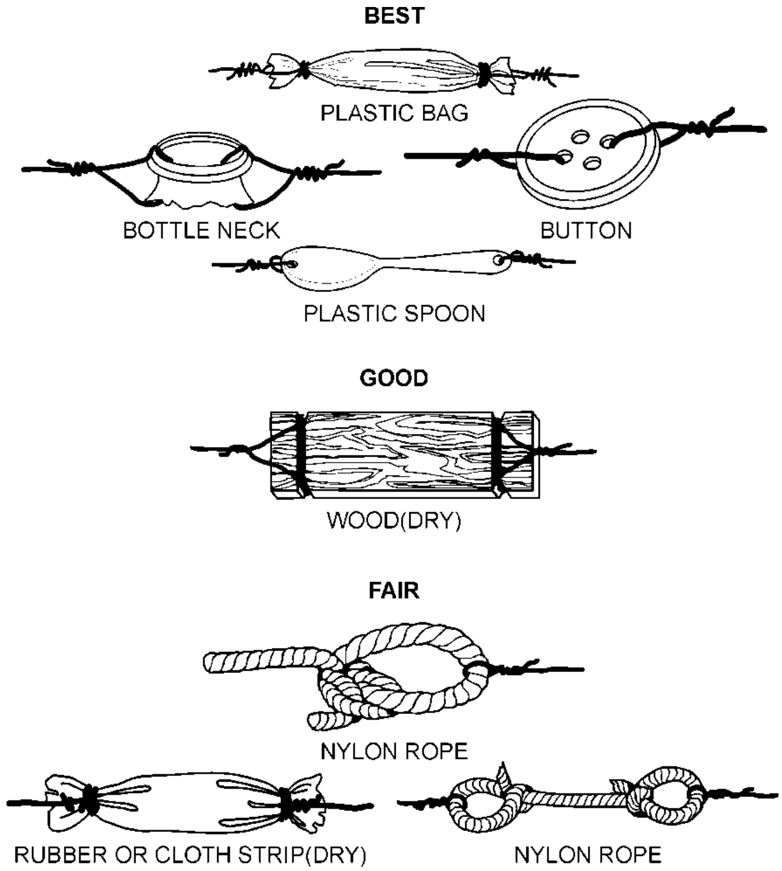


Figure 10-26. Examples of field expedient antenna insulators

ANTENNA GUYS

10-144. Antenna guys stabilize the supports for an antenna. They are usually made of wire, manila rope, or nylon rope. Repair broken guy rope by tying the two broken ends together. If the rope is too short after completing the tie, add another piece of rope or a piece of dry wood or cloth to lengthen it. Broken guy wire can be replaced with another piece of wire. To ensure that the guys made of wire do not affect the operation of the antenna, cut the wire into several short lengths and connect the pieces with insulators. Figure 10-27, on page 10-33, shows an example of repaired guy lines with wood.

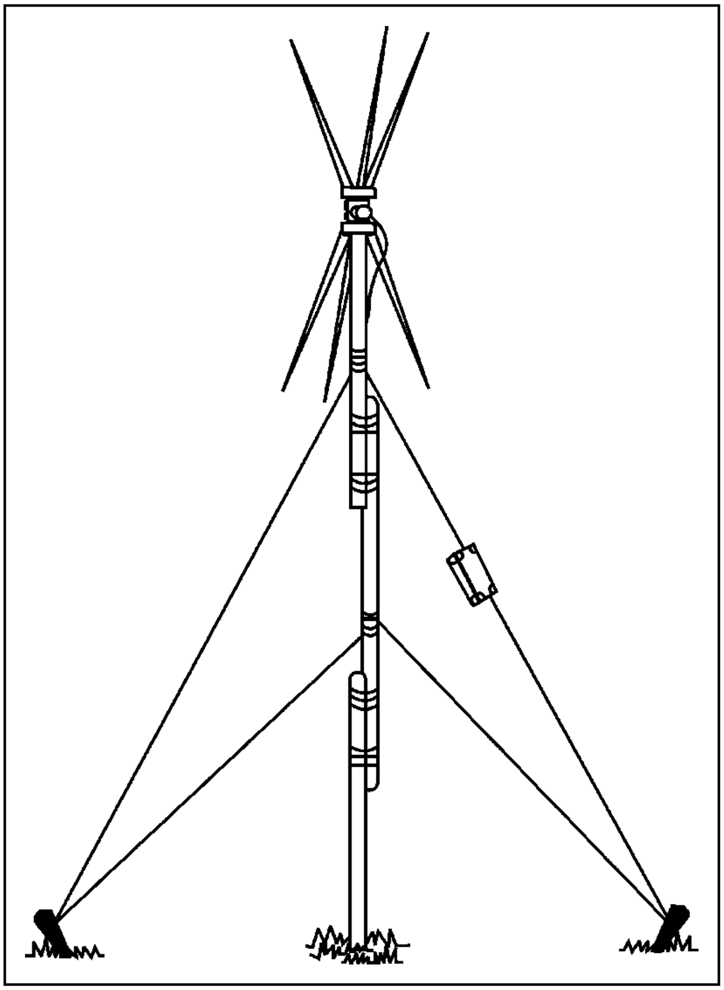


Figure 10-27. Repaired antenna guy lines and masts

Antenna Masts

10-145. Masts support some antennas and if broken, replace the mast with another mast of the same length. When long poles are not available as replacements, overlap and lash short poles together with rope or wire to provide a pole of the required length.

Chapter 11

Tactical Radio Key Management Techniques

This chapter addresses key management techniques relative to protecting voice, data, and video information over tactical radio networks.

ARMY KEY MANAGEMENT SYSTEM

11-1. The Army Key Management System (AKMS) automates the functions of COMSEC key management, control and distribution, EP generation and distribution, signal operating instruction management. The commander appoints COMSEC account managers to manage the AKMS. COMSEC account managers direct COMSEC policies and procedures to subordinate units and mitigate risk to COMSEC for the command. Frequency managers and COMSEC account managers manage the AKMS.

11-2. The AKMS provides commanders the necessary tools to work with the widely proliferating COMSEC systems associated with the WIN-T, JTIDS, EPLRS, SINCGARS, and other keying methods (electronic key generation, over-the-air rekeying, and electronic bulk encryption and transfer) being fielded by the Army.

11-3. The hardware and software of the AKMS provides communications planners the capability to design, develop, generate, distribute, and manage decentralized and automated communications-electronics operating instructions and signal operating instructions also known as the Joint Communications-Electronics Operating instructions. The AKMS produces the EP fill variables to support SINCGARS in data file and electronic formats; it also produces signal operating instructions outputs in either electronic or hard copy (paper) formats. The objective is to utilize the SKL to eliminate the need for exclusive use of a hard copy paper signal operating instructions.

11-4. The planning and distribution of AKMS products are essential to the success of military operations, and are a command responsibility. The controlling authority is the commander, who establishes a cryptographic network. Within divisions, brigades, and battalions, commanders may delegate authority and responsibilities depending upon command policy and operational situations.

11-5. Units at corps and division levels and separate brigades with authorized AKMS hardware and software have the capabilities to design, develop, generate, and distribute communications-electronics operating instructions and SINCGARS frequency hopping data, along with HF, UHF, and VHF frequency assignments at their respective levels and subordinate levels, as appropriate.

11-6. Brigades and separate battalion units use AKMS components to distribute generated communications-electronics operating instructions and SINCGARS frequency hopping data for use at their respective and subordinate levels.

> ***Note***. Refer to AR 380-40, AR 380-5, AR 25-2, and AR 380-53 for additional information on controlling authority and commanders' responsibilities regarding cryptographic networks.

KEY DISTRIBUTION

11-7. Key distribution is critical in achieving secure transmissions. Commanders must ensure establishment of these procedures in the unit's standard operating procedure. The COMSEC account manager is responsible for the brigade COMSEC account. The property book officer provides logistical support for the control and distribution of internal brigade and subordinate battalion COMSEC material using the Information Systems Security Program.

11-8. The representative authorized to order keys is the requesting unit's COMSEC account manager, with a valid COMSEC account (and requirement). TB 380-41 provides more information on the procedures for safeguarding, accounting, and the supply control of COMSEC material and COMSEC material distribution.

JOINT COMMUNICATIONS SECURITY KEY DISTRIBUTION

11-9. A joint contingency force, corps, and division key management plan provides guidance on the COMSEC key distribution; it does not change current unit procedures. The COMSEC account manager is responsible for key management plan coordination and the spectrum manager is responsible for the satellite access request. The COMSEC account manager and spectrum manager need to ensure prior coordination between the two in order to identify all requests for COMSEC from all units.

TRANSMISSION SECURITY (ORDERWIRE) KEY DISTRIBUTION

11-10. The DAMA key management plan provides guidance on obtaining orderwire keys using the Electronic Key Management System (EKMS) with the DAMA control system. It also provides instructions for the receipt of over-the-air rekeying by the users. The Spitfire provides an over-the-air rekeying capability for orderwire keys. Spitfire operators should have the current and next orderwire keys for each footprint in which they operate.

Note. Only the requesting unit's COMSEC account manager with a valid COMSEC account can order these keys. (Refer to TB 380-41.)

11-11. The DAMA semi-automatic controller (and possibly the NCS) places the orderwire keys in positions 0–7; the Spitfire uses positions 1–8. Users must perform careful coordination before the execution of any DAMA operations. Coordinate the location of the key within each footprint to ensure compatibility with the controller in all area of operations.

Automated Communications Engineering Software

11-12. Automated Communications Engineering Software (ACES) is a network planning software program that plans, creates, distributes, manages, and verifies cryptonets and key related information. ACES works in a ruggedized COTS platform for tactical operations as well as in desktop workstations in strategic locations. ACES allows users to perform fully automated cryptographic network, signal operating instructions, communications-electronics operating instructions, joint communications-electronics operating instructions and EP planning, management, validation and generation distribution at the time and location needed.

11-13. The network planning functionality of ACES incorporates cryptonet planning, key management, and key tag generation. The planning concept relates to the development of network structures supporting missions and plans. The data for a given plan includes individual networks, which are assigned individual network members. Network members are associated with a specific platform and equipment. Designated network members, define the platforms, specific equipment fill locations, and associate key tags/keys with the equipment locations.

11-14. Network members then download the equipment records, which include platform data, network data, and key tags associating the data with the required key. Similarly, the EP data and signal operating instructions generated by the ACES workstation operator enables the data download to the SKL.

Local COMSEC Management Software

11-15. Local COMSEC management software provides the interface between the local management device, key processor, and other AKMS elements. Local COMSEC management software provides the COMSEC account manager with many enhanced management capabilities. Tandem use of the local management device and key processor enables the COMSEC account manager to—

- Order and account for all forms of COMSEC material.
- Store key in encrypted form.
- Perform key generation and automatic key distribution.
- Perform COMSEC material accounting functions.
- Communicate directly with other AKMS elements. .

Master Net List

11-16. The master net list maintains all networks requiring signal operating instructions assignments. Maintaining the master net list is essential to creating signal operating instructions assignments. Networks created from the master net list or imported have editing potential, which allows tracking of individual frequency assignments with assigned equipment. The ACES version of the master net list has direct correlation to standard frequency action format line item numbers.

11-17. The master net list is the database link for all information listed under a plan, such as networks, frequencies, and equipment. The master net list provides the capability to create, edit, organize, and delete networks. Before creating the master net list, the ACES workstation operator identifies the number of networks required, types of equipment used, and specific information about the equipment, such as maximum transmit power, frequency bands, and emission designators. This information is available from the spectrum manager. This section provides the information in creating the master net list folder and entering and managing the information within the folder. (For detailed information on ACES and how to build a master net list, see TB 11-7010-293-10)

11-18. The master net list module of the ACES software also displays in Service specific views (U.S. Army, U.S. Navy, U.S. Air Force, and U.S. Marine Corps or Joint combined. The master net list also incorporates a number of standard frequency action format compatible fields to facilitate the transfer of data to and from other frequency management systems such as Spectrum XXI, as well as service unique systems. The database capabilities of the ACES workstation allow utilization of the data in the master net list to create the initial standard frequency action format frequency proposal and the signal operating instructions.

11-19. The software components on the ACES workstation include the ACES core module, general-purpose module, resource manager module, master net list module, signal operating instructions module, and CNR module.

Combat Net Radio Module

11-20. The CNR module provides the necessary functions and procedures to create and modify hopsets, loadsets, and to generate SINCGARS transmission security keys. It also provides the capability to plan CNR networks in all bands. CNR network planning integrates with the master net list module.

Resource Manager Module

11-21. The resource manager module contains imported frequency resources. The resource manager module allows use of the resources to create, edit, merge, delete, and print resources. The resource manager also provides the planner the capability to import and export resources in ACES, integrated system control, and standard frequency action format formats. The frequency resources are coordinated for a specific area of usage. Within United States and Possessions, frequency resources are only authorized for use within specific garrison installations and training areas. Authorization for the use of frequency resources outside of the United States and Possessions are directed under guidance within strategic agreements and will generally have established channels for coordination. See your organizational, ASCC or combatant command spectrum management office for additional information.

Signal Operating Instructions Module

11-22. The signal operating instructions module allows creation of editions and updates. Signal operating instructions identification occurs using a short title and edition and may contain up to ten time-periods. Signal operating instructions is a series of orders issued to control and coordination of the signal operations of a command or activity. It provides guidance needed to ensure the speed, simplicity, and security of communications. Net selection occurs from the master net list included in a generated signal operating instructions edition. Before signal operating instructions generation, save and validate the master net list.

11-23. Figure 11-1 is an example of the general sequence for planning a CNR network.

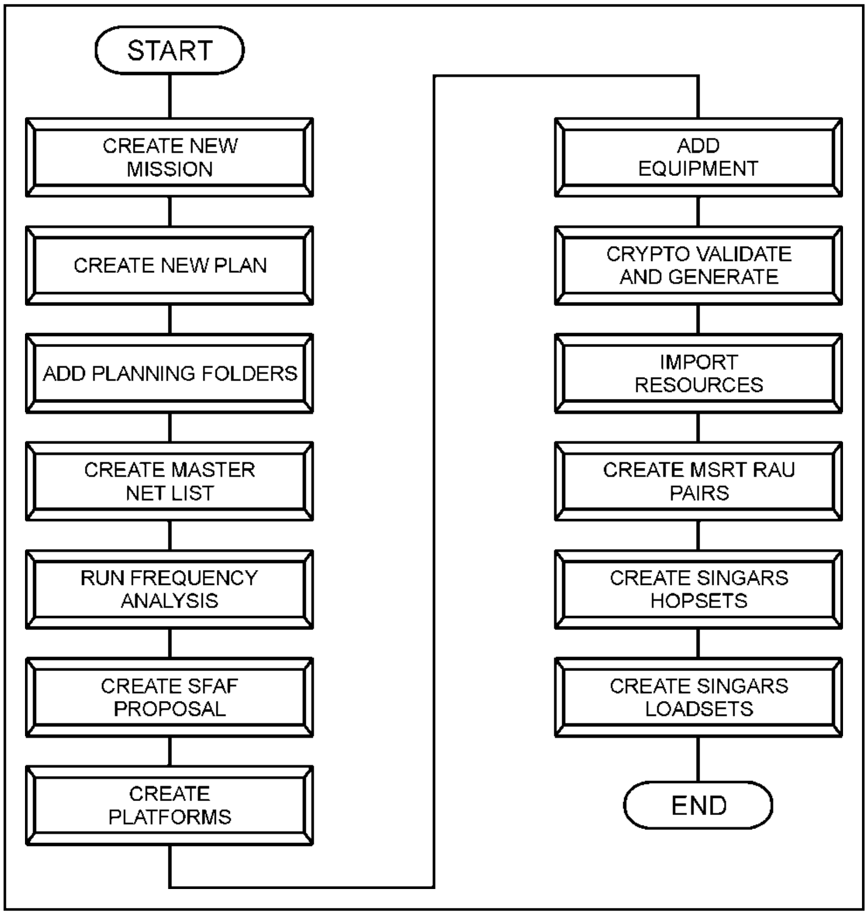


Figure 11-1. Example for planning a CNR network

COMMUNICATIONS-ELECTRONICS OPERATING INSTRUCTIONS AND SIGNAL OPERATING INSTRUCTIONS DEVELOPMENT

11-24. ACES assists in the production of the communications-electronics operating instruction and signal operating instructions generation. Data collection in support of first time signal operating instructions generation of a joint task force to Division size element may require 5-30 days or more. Building an initial Master Net List in support of a first time generation takes four to seven days. The hopset provides frequency resources, which are used in a loadset, The TSK key is the Transmission security key that determine the frequency hop pattern for the radio ACES is capable of generating a division size communications-electronics operating instructions and signal operating instructions in two to five hours.

11-25. Although ACES automates the generation process, the signal officer, communications chief, and frequency manager first designs the communications-electronics operating instructions and signal operating instructions on paper. Table 11-1, on page 11-5, lists the initial steps for designing and developing communications-electronics operating instructions and signal operating instructions data. The following paragraphs provide more detail on communications-electronics operating instructions and signal operating instructions development.

Table 11-1. Initializing ACES communications-electronics operating instructions and signal operating instructions data

Step	*Description*
1	Research and extract data from the modified table of organization and equipment, which authorizes the use of personnel and equipment.
2	Determine the doctrine to be followed.
3	Operation order, operation plan, or unit standard operating procedure.
4	Frequency list from the spectrum manager.
5	Determine how many networks and frequencies are required. Use the current communications-electronics operating instructions and signal operating instructions as a starting point.

LOADSETS

11-26. The G-6 and the S-6 section identify requirements for the construction of loadsets to support the radios that their organization employs. Once defined, the frequency manager constructs the loadsets using ACES, saves the loadsets to file, and distributes the loadsets to subordinate organizational units or elements for follow-on distribution to respective users. The identification of the networks that the radio user is required to enter and monitor is the basis for the construction of loadsets defined by the user

11-27. For example, the commander of an infantry battalion would normally be a member of several frequency hopping SINCGARS networks. One of the commander's SINCGARS could be preset to operate in the following nets —

- Brigade command network.
- Brigade operations network.
- Battalion command network.
- Battalion operations network.
- Brigade RETRANS network.

11-28. Radio operators typically load all six preset channels on the SINCGARS, with operational network identifiers and TEKs. If a requirement to perform an over-the-air rekeying arises, all stations involved with over-the-air rekeying load a KEK into preset Channel 6 on the SINCGARS, with an appropriate network identifier.

Loadset Updates

11-29. The responsible signal section personnel using ACES and revised loadset software, as appropriate, maintain loadset data. Update loadset data with new replacement key data, when appropriate, before the current key expires. The loadset data is then saved to file, and distributed to users via SKL, to ensure they are in place and available for loading into the SINCGARS at the appropriate key changeover time. The signal sections should have several sets of loadsets with associated keys, already constructed and distributed (or available for expeditious distribution) for immediate use.

Loadset Revisions and Creations

11-30. Existing loadsets may require revision when the required network content changes (unit reassignment or attachment). New loadsets may require construction to meet new requirements (for example, create a new task force organization).

JOINT AUTOMATED COMMUNICATIONS ELECTRONICS OPERATING INSTRUCTIONS SYSTEM

11-31. The Military Communications Electronics Board has designated ACES as the Joint Spectrum Management Planning software. For multi-service operations, it is known as the Joint Automated Communications Electronics Operating Instructions System. The Joint Automated Communications Electronics Operating Instructions System has the same basic function as ACES. The Joint Automated Communications Electronics Operating Instructions System core purpose is to allow an interface between the joint communications-electronics operating instructions generation tool with service unique communications planning software and spectrum management automated tools.

11-32. The joint communications-electronics operating instruction is the primary controlling document for single channel radio communications in joint operations and exercises. The joint communications-electronics operating instruction provides radio information for Joint forces, Service specific elements and units including—

- Daily changing and non-changing frequency assignments.
- SINCGARS cue, manual and net identification assignments.
- Call sign assignments.
- Call words assignments.
- Daily changing code words.

SIMPLE KEY LOADER

11-33. A limited understanding of the EKMS operating environment is helpful in understanding the operation of the SKL. The components of the EKMS include—

- **EKMS Tier 0.** The NSA central facility provides for production, management, and distribution of specialized electronic cryptographic key and associated materials.
- **EKMS Tier 1**. Facilities serve as focal points for the production, management, and distribution of service unique electronic cryptographic key and materials. Tier 1 facilities also provide an interface between the central facility and service EKMS Tier 2 elements, and facilitate interoperability for joint operations at the theater and strategic levels.
- **EKMS Tier 2**. Tier 2 or local COMSEC management software workstations perform generation, management, and distribution of electronic keying material. The local COMSEC management software workstation works in conjunction with the SKL to distribute electronic keying material to those networks with electronically keyed COMSEC equipment.
- **EKMS Tier 3**. Tier 3 or the SKL device integrates the functions of COMSEC key management, control, distribution, EP management, signal operating instructions management, benign fill, and other specialized capabilities into one comprehensive mobile system. The SKL interfaces with the ACES and local COMSEC management software workstations to receive its database information and then interface with end cryptographic units to upload the required keying material and information to those units.

11-34. The hardware platform that hosts the SKL software (including the Secure Library) is a vendor supplied ruggedized personal digital assistant device equipped with a KOV-21 Personal Computer Memory Card International Association card. The SKL is not equipped with a hard drive so all programs are stored in non-volatile flash memory.

11-35. The KOV-21 provides Type I encryption and decryption services and provides the secure interface between the host computer and interfacing devices. The SKL uses an embedded KOV-21 approach. NSA requires the use of a cryptographic ignition key to lock and unlock the KOV-21 information security card.

11-36. The cryptographic ignition key is a separate, removable, non-volatile memory device designed to protect internal SKL keys and data from physical compromise when the SKL is in an unattended, non-secured environment. Removal of the cryptographic ignition key from the SKL prevents the KOV-21 card from unlocking. This results in denied access to the data. The absence of the cryptographic ignition key prevents the use of SKL operations. (Refer to TM 11-5810-410-13&P for more information on the SKL.)

Chapter 12

Electronic Warfare and Protection Techniques

This chapter addresses electronic warfare and the electronic protection techniques used to prevent enemy jamming and intrusion into friendly communications systems. It also addresses electronic protection responsibilities, communications services planning, signal security, emission control, preventive and remedial electronic protection techniques and the joint spectrum interference resolution reporting procedures and requirements.

ELECTRONIC WARFARE

12-1. EW uses electromagnetic energy to determine, exploit, reduce, or prevent hostile use of the electromagnetic spectrum; it also involves actions taken to retain friendly use of the electromagnetic spectrum. Table 12-1 lists the three elements of EW.

Table 12-1. Electronic warfare elements

Element	***Responsibilities***
Electronic warfare support	Involves actions taken to search for, interrupt, locate, record, and analyze radio signals for using such signals in support of military operations.
	Provides electronic warfare information required to combat electronic countermeasures, to include threat detection, warning, avoidance, target location, and homing.
	Produces signals intelligence, communications intelligence, and electronic intelligence.
Electronic attack	Involves using electromagnetic or directed energy to attack personnel, facilities, or equipment with the intent of degrading.
	Includes actions taken to prevent or reduce the enemy's effective use of his frequencies; includes jamming and deception.
	Employs weapons that use either electromagnetic or directed energy as their primary destructive mechanism (lasers, radio frequency weapons, and particle beams).
Electronic protect	Ensures friendly effective use of frequencies, despite the enemy's use of electronic warfare.
	Provides defensive measures used to protect friendly systems from enemy EW activities, such as— ● Careful siting of radio equipment. ● Employment of directional antennas. ● Operations using lowest power required. ● Staying off the air unless necessary. ● Using a random schedule, if one is used. ● Using good radio techniques and continued operation. **Note**. Refer to Appendix H for more information on antenna placement and cosite interference.

ELECTRONIC WARFARE WHEN CONDUCTING ATTACKS ON ENEMY COMMAND AND CONTROL NODES

12-2. EW support, electronic attack (EA), and EP contribute to attack operations on enemy command and control capabilities. Electronic warfare support, in the form of combat information, can provide real-time information required for locating and identifying enemy command and control nodes, and for supporting early warning and offensive systems during attack missions on enemy command and control capabilities. EW support produces signals intelligence, and provides timely information about an enemy's communications capabilities and limitations. The additional information received updates previously known information about the enemy's command and control capabilities. This updated information can be used to plan enemy command and control attack operations, and provide damage assessment feedback on the effectiveness of the overall warfare plan for enemy command and control attack operations.

12-3. EA is present in most enemy command and control attack operations in a combat environment. It includes jamming and electromagnetic deception or destruction of enemy command and control nodes, with directed-energy weapons or anti-radiation missiles.

12-4. EP protects the electromagnetic spectrum for friendly forces. Coordinating the use of the electromagnetic spectrum through the joint restricted frequency list is a means of preventing fratricide among friendly electronic emissions. Equipment and procedures designed to prevent enemy disruption or exploitation of the electromagnetic spectrum are the best means friendly forces have to ensure their own uninterrupted use of the electromagnetic spectrum during enemy command and control attack operations. For more information on joint EW, refer to JP 3-13.1. For more information on joint electromagnetic spectrum management operations in the electromagnetic operational environment, refer to CJCSM 3320.01C. For information on policy and procedures for management and use of the electromagnetic spectrum refer to Department of Defense Instruction 4650.01.

ELECTRONIC WARFARE WHEN PROTECTING FRIENDLY COMMAND NODES

12-5. The three elements of EW can also contribute to friendly command nodes protect efforts. Utilize electronic warfare support, supported by signals intelligence data to monitor an impending enemy attack on friendly command nodes. Utilize electronic warfare support in the form of signal security monitoring to identify potential sources of information for an enemy to obtain knowledge about friendly information systems.

12-6. In order to defend a friendly force command nodes from enemy attack, exercise EP measures to safeguard friendly forces from exploitation by enemy electronic warfare support and signals intelligence operations. Frequency management using the joint restricted frequency list is an essential defense measure against attack operations on command nodes by the enemy.

ENEMY ATTACK ON FRIENDLY COMMAND NODES

12-7. Understanding the threat to the electromagnetic spectrum is the key to practicing sound EP techniques. Enemy attack on friendly command nodes encompasses the integration of EW and physical destruction of resources, to deny friendly forces the use of electronic control systems. Potential adversaries consider attack on friendly command nodes integral to all combat operations. They have invested in developing techniques and equipment to deny their enemies the effective use of the electromagnetic spectrum for communications.

12-8. Enemy attack on friendly command nodes disrupts or destroys at least 60 percent of the information, intelligence, and weapons systems communications (30 percent by jamming and 30 percent by destructive fires). To accomplish this goal, enemy forces expend considerable resources gathering combat information about their enemies. As locations are determined, and units are identified, enemy forces establish priorities to—

- Jam communications assets.
- Deceptively enter radio networks.
- Interfere with the normal flow of their enemy's communications.

COMMANDER'S ELECTRONIC PROTECTION RESPONSIBILITIES

12-9. EP is a command responsibility. The more emphasis the commander places on EP, the greater the benefits, in terms of casualty reduction and combat survivability, in a hostile environment. Commanders at all levels ensure the training of their ability to practice sound EP techniques.

12-10. Commanders constantly measure the effectiveness of the EP techniques; they also consider EP while planning tactical operations. Commanders' EP responsibilities are—

- Review all after action reports for jamming or deception, and assess the effectiveness of defensive EP.
- Ensure the G-6 the S-6 and the assistant chief of staff, intelligence and the battalion or brigade intelligence staff officer, report and properly analyze all encounters of electromagnetic interference, deception, or jamming.
- Analyze the impact of enemy efforts to disrupt or destroy friendly communications systems on friendly operation plans.
- Ensure the unit exercise COMSEC techniques daily. Units should—
  - Change network call signs and frequencies often (in accordance with the signal operating instructions).
  - Use approved encryption systems, codes, and authentication systems.
  - Control emissions.
  - Make EP equipment requirements known through quick reaction capabilities designed to expedite procedure for solving, research, development, procurement, testing, evaluation, installations modification, and logistics problems as they pertain to EW.
  - Ensure quick repair of radios with mechanical or electrical faults; this is one way to reduce radio-distinguishing characteristics.
  - Practice network discipline.

STAFF ELECTRONIC PROTECTION RESPONSIBILITIES

12-11. The organized staff assists the commander in accomplishing mission requirements. Specifically, the staff responds immediately to the commander and subordinate units. The staff should—

- Keep the commander informed.
- Reduce the time to control, integrate, and coordinate operations.
- Reduce the chance for error.

12-12. All staff officers provide information, furnish estimates, and provide recommendations to the commander; prepare plans and orders for military operations; and supervise subordinates to achieve mission accomplishment. Staff members should assist the commander in carrying out communications EP responsibilities. Specific responsibilities of the staff officers are—

- **Assistant chief of staff, intelligence and the battalion or brigade intelligence staff officer (S-2)**. Advises the commander of enemy capabilities that could be used to deny the unit effective use of the electromagnetic spectrum. They also keep the commander informed of the unit's signal security posture.
- **Assistant chief of staff, operations and the battalion or brigade operations staff officer**. Exercise staff responsibility for EP and includes electronic warfare support and EA scenarios in all CP and field training exercises, and evaluates EP techniques employed. They also include EP training in the unit training program.
- **G-6 and the S-6**.
  - Prepares and conducts the unit EP training program.
  - Ensures there are alternate means of communications for those systems most vulnerable to enemy jamming.
  - Ensures distribution of available COMSEC equipment to those systems most vulnerable to enemy information gathering activities and ensures measures are taken to protect critical friendly frequencies from intentional and unintentional electromagnetic interference.

  - Enforces proper use of radio, EP, and TRANSEC procedures on communications channels.
  - Performs frequency management duties, and issues signal operating instructions on a timely basis.
  - Prepares and maintains a restricted frequency list of taboo, protected, and guarded frequencies.
  - Prepares the EP and restricted frequency list appendices to the signal annex with appropriate cross-references to the other annexes (EW, operations security, and deception) and to the signal operating instructions for related information.
- **Electronic warfare officer**. As a member of the assistant chief of staff, operations staff, or the battalion or brigade operations staff, the electronic warfare officer plans, coordinates, and supports the execution of EW and other cyber electromagnetic activities. The electronic warfare officer integrates efforts across the warfighting functions to ensure that EW operations support the commander's objectives. The electronic warfare officer—
  - Leads the EW working group.
  - Plans, coordinates and assesses electronic attack, protect, and support requirements.
  - Supports the G-2 (S-2) during intelligence preparation of the battlefield.
  - Provides information collection requirements to the G-2 (S-2) to support the assessment of EW.
  - Supports the fire support coordinator to ensure the integration of EA with all other effects.
  - Provides EW support derived from tactical targeting information to the fire support coordinator.
  - Coordinates with the G-6 (S-6) to plan, assess, and implement friendly EP measures.
  - Prioritizes EW effects and targets with the fire support coordinator.
  - Plans and coordinates EW operations across functional and integrating cells.
  - Deconflicts EW operations with the spectrum manager within the Cyber Electromagnetic Activity element.
  - Maintains a current assessment of available EW resources.
  - Participates in other cells and working groups (as required) to ensure EW integration.
  - Serves as EW subject matter expert on existing EW rules of engagement.
  - Serves as the jamming control authority when designated.
  - Prepares, submits for approval, and supervises the issuing and implementation of fragmentary orders for EW operations.
  - Ensures EW operations are synchronized and deconflicted with intelligence collection activities.

COMMUNICATIONS PLANNING PROCESS

12-13. Assess threats to friendly communications during communications services planning process. Planning counters the enemy's attempts to take advantage of the vulnerabilities of friendly communications systems. At a minimum, consider the following four categories of EP planning: deployment, employment, replacement, and concealment.

COMMUNICATIONS PLANNING

12-14. When conducting communications planning, use spectrum management tools to assist in electromagnetic spectrum planning and to define and support requirements. Coordinate all frequency use before any emitter is activated in order to mitigate or eliminate electromagnetic interference or other negligible effects. Consider the following when conducting electromagnetic spectrum management planning—

- Transmitter and receiver locations.
- Antenna technical parameters and characteristics.
- Number of frequencies desired and separation requirements.

- Nature of the operation (fixed, mobile land, mobile aeronautical, and over water or maritime).
- Physical effects of the operational environment (ground and soil type, humidity, and topology).
- All electromagnetic spectrum-dependent equipment to be employed to include emitters, sensors, and unmanned aerial sensors.
- Start and end dates for use.

CONTROL OF COMPROMISING EMANATIONS

12-15. Radios have the potential to create a significant vulnerability in regards to control of compromising emanations (TEMPEST), if TEMPEST installation guidelines are not followed. Radios with embedded cryptographic devices should be installed and operated in accordance with any applicable operational security doctrine for that device or radio. The TEMPEST countermeasure review for a facility, platform or system may set additional TEMPEST countermeasure requirements for radios operating in those environments. Compliance with all TEMPEST countermeasure requirements is critical to ensuring the protection of classified information. For additional TEMPEST information, see AR 380-27, Control of Compromising Emanations. Contact the supporting certified TEMPEST technical authority for additional guidance on TEMPEST countermeasure compliance.

PRIMARY, ALTERNATE, CONTINGENCY, AND EMERGENCY PLAN

12-16. The primary, alternate, contingency, and emergency (PACE) plan is a communication plan that exists for a specific mission or task, not a specific unit, as the plan considers both intra- and inter-unit sharing of information. The PACE plan designates the order in which an element will move through available communications systems until contact can be established with the desired distant element.

12-17. The S6 develops a PACE plan for each phase of an operation to insure that the commander can maintain mission command of the formation. The plan reflects the training, equipment status, and true capabilities of the formation. Higher commands evaluate its communication requirements with subordinate echelons and work with the S6 to develop an effective plan. Upon receipt of an order from a higher command, the receiving unit evaluates the PACE plan for two key elements—

- Does the receiving unit have the assets to execute the plan to higher?
- How can the plan nest the higher command's plan when it develops its own plan to subordinate elements?

12-18. Accurate PACE plans are crucial to the commander's situational awareness. A subordinate unit that is untrained on a particular communication system or lacks all of the subcomponents to make the system mission capable, does not ensure continuity of mission command by including the communication system in the PACE plan. Commanders ability to exercise mission command during an operation can suffer due to communication systems that are in transit or otherwise unavailable. If a unit does not have four viable methods of communications, it is appropriate to issue a PACE plan that may only have two or three systems listed.

12-19. If the unit cannot execute the full PACE plan to its higher command, it must inform the issuing headquarters with an assessment of shortfalls, gaps, and possible mitigations as part of the mission analysis process during the military decision making process. During course of action development, the S6 nest his element's plan with higher command's plan whenever practical. This aids in maintaining continuity of effort.

12-20. If a higher command places any form of information requirement on one or more of its subordinate units, subordinate units address the requirement as follows—

- Generate an executable PACE plan.
- Include the PACE plan in the operations order or fragmentary order when published.
- Publish the data requirement in the base operations order or fragmentary order execution paragraph in the tasks section of the order including a reference to the specific annex for detailed format and PACE.

GEOMETRY

12-21. Analyze the terrain, and determine methods to make the geometry of the operations work in the favor of friendly forces. Adhering rigidly to standard CP deployment makes it easier for the enemy to use the direction finder and aim his jamming equipment at his enemies.

12-22. Deploying units and communications systems perpendicular to the forward line of own troops enhance the enemy's ability to intercept communication because U.S. forces aim transmissions in the enemy's direction. When possible, friendly forces are required to install terrestrial line of sight communications parallel to the forward line of own troops. This supports keeping the primary strength of U.S. transmissions in friendly terrain.

12-23. SC TACSAT systems reduce friendly CP vulnerability to enemy direction efforts. Tactical SATCOM systems are relieved of this constraint because of their inherent resistance to enemy direction finder efforts. When possible, utilize terrain features to mask friendly communication from enemy positions. This may require moving senior headquarters farther forward and using more jump or tactical CPs to ensure that commanders can continue to direct their units effectively.

12-24. Location of CPs requires carefully planning as CP locations generally determine antenna locations. The proper installation and positioning of antennas around CPs is critical. Disperse and position antennas and emitters at the maximum remote distance and terrain dependent from the CP to ensure that not all of a unit's transmissions are coming from one central location System Design

12-25. Establish alternate routes of communication when designing communications systems. This involves establishing sufficient communications paths to ensure that the loss of one or more routes does not seriously degrade the overall system. The commander establishes the priorities of critical communications links. Provide high priority links with the greatest number of alternate routes.

12-26. Alternate routes enable friendly units to continue to communicate despite the enemy's efforts to deny them the use of their communications systems. Alternate routes also transmit false messages and orders on the route that is experiencing electromagnetic interference, while they transmit actual messages and orders through another route or means. A positive benefit of continuing to operate in a degraded system is the problematic degraded system cause the enemy to waste assets used to impair friendly communication elsewhere.

12-27. Three routing concepts, or some permutation of them, can be used in communications—

- **Straight-line system**. Provides no alternate routes of communications.
- **Circular system**. Provides one alternate route of communications.
- **Grid system**. Provides as many alternate routes of communications as can be practically planned.

12-28. Avoid establishing a pattern of communication. Enemy intelligence analysts may be able to extract information from the pattern, and the text, of friendly transmissions. If easily identifiable patterns of friendly communication are established, the enemy can gain valuable information.

12-29. The number of friendly transmissions tends to increase or decrease according to the type of tactical operation being executed. Execute this deceptive communication traffic by using false peaks, or traffic leveling. Utilize false peaks to prevent the enemy from connecting an increase of communications with a tactical operation. Transmission increases on a random schedule create false peaks.

12-30. Tactically accomplish traffic leveling by designing messages to transmit when there is a decrease in transmission traffic. Traffic leveling keeps the transmission traffic constant. Coordinate messages transmitted for traffic leveling or false peaks to avoid operational security violations, electromagnetic interference, and confusion among friendly equipment operators.

12-31. ACES equipment, software, and subsequent signal operating instructions development resolve many problems concerning communications patterns; they allow users to change frequencies often, and at random. This is an important aspect of confusing enemy traffic analysts. Enemy traffic analysts are confused when frequencies, network call signs, locations, and operators are often changed. The enemy uses U.S. tactics, techniques, and procedures to help perform their mission. These procedures require flexibility to avoid establishing communications patterns.

REPLACEMENT

12-32. Replacement involves establishing alternate routes and means of doing what the commander requires. FM voice communications are the most critical communications used by the commander during enemy engagements and require reserving critical systems for critical operations. The enemy should not have access to information about friendly critical systems until the information is useless.

12-33. Utilize alternate means of communication before enemy engagements. This ensures the enemy cannot establish a database to destroy primary means of communication. If the primary means degrades, replace primary systems with alternate means of communication. Replacements require preplanning and careful coordination; if not, compromise of the alternate means of communication occurs and is no longer useful as the primary means of communication. Users of communications equipment require knowledge of how and when to use the primary and alternate means of communication. This planning and knowledge ensures the most efficient use of communications systems.

CONCEALMENT

12-34. Operation plans should include provisions to conceal communications personnel, equipment, and transmissions. It is difficult to conceal most communications systems; installing antennas as low as possible on the backside of terrain features, and behind man-made obstacles, helps conceal communications equipment while still permitting communication.

SIGNAL SECURITY

12-35. EP and signal security are closely related; they are defensive arts based on the same principle. If adversaries do not have access to the essential elements of friendly information of U.S. forces, they are much less effective. The goal of practicing sound EP techniques is to ensure the continued effective use of the electromagnetic spectrum. The goal of signal security is to ensure the enemy cannot exploit the friendly use of the electromagnetic spectrum for communication. Signal security techniques are designed to give commanders confidence in the security of their transmissions. Plan signal security and EP based on the enemy's ability to gather intelligence and degrade friendly communications systems.

12-36. Tactical commanders ensure effective employment of all communications equipment, despite the enemy's concerted efforts to degrade friendly communication to his tactical advantage. Modifying and developing equipment, to make friendly communication less susceptible to enemy exploitation, is an expensive process. Equipment that solves some EP problems is being developed and fielded. Ultimately, the commander, staff planners, and radio operators are responsible for security and continued operation of all communications equipment.

EMISSION CONTROL

12-37. The control of friendly electromagnetic emissions is essential to successful defense against the enemy's attempts to destroy or disrupt U.S. communications. Emission control is the selective and controlled use of electromagnetic, acoustic, or other emitters to optimize command and control capabilities while minimizing, for operations security. (JP 1-02) When operating radios, exercise emission control at all times. Only turn transmitters when needed to accomplish the mission. The enemy intelligence analyst looks for patterns he can turn into usable information. Inactive friendly transmitters do not provide the enemy with useable intelligence. Emission control can be total; for example, the commander may direct radio silence whenever desired. ***Radio silence*** **is the status on a radio network in which all stations are directed to continuously monitor without transmitting, except under established criteria.**

12-38. Keep transmissions to a minimum (20 seconds absolute maximum, 15 seconds maximum preferred) and should contain only mission-critical information. Good emission control makes the use of communications equipment appear random, and is therefore consistent with good EP practices. This technique alone will not eliminate the enemy's ability to find a friendly transmitter; but when combined with other EP techniques, it makes locating a transmitter more difficult.

PREVENTIVE ELECTRONIC PROTECTION TECHNIQUES

12-39. In planning communications, consider the enemy's capabilities to deny the effective use of communications equipment. EP should be planned and applied to force the enemy to commit more jamming, information gathering, and deception resources to a target than it is worth or than he has readily available. EP techniques also force the enemy to doubt the effectiveness of his jamming and deception efforts.

12-40. Radio operators use preventive EP techniques to safeguard friendly communications from enemy disruption and destruction. Preventive EP techniques include all measures taken to avoid enemy detection, and to deny enemy intelligence analysts useful information. These techniques include EP designed circuits (equipment features) and radio systems installation and operating procedures. Refer to AR 380-5 for the Department of the Army Information Security Program.

12-41. EP designed circuits comply with the MIL-STD for EP. The designed EP circuits focus on technology enhancements, to mitigate the effects of enemy radio electronic combat threats and reduce vulnerabilities to electronic countermeasures.

12-42. Radio operators have little control over the effectiveness of EP designed circuits; therefore, their primary focus is radio systems installation and operating procedures. (Appendix C addresses operations in cold weather, jungle, urban, desert, and nuclear environments.)

12-43. Incorrect operating procedures can jeopardize the unit's mission, and ultimately increase unit casualties. Communications equipment operators require instinctive use of preventive and remedial EP techniques. Maintenance personnel require knowledge that improper modifications to equipment may cause the equipment to develop peculiar characteristics readily identifiable by the enemy. Commanders and staff develop plans to ensure the continued use of friendly communications equipment and systems, while also evaluating joint spectrum interference resolution (JSIR) reports and after action reports to initiate appropriate remedial actions.

12-44. Effective jamming depends on knowing the frequencies and approximate locations of units to be jammed. Using the techniques addressed in the following paragraphs reduces the vulnerability of communication from enemy disruption or destruction. Do not disclose this information.

12-45. The most effective preventive EP technique is to minimize radio transmissions, and transmission times. Although normal day-to-day operations require radio communications, keep communication to the minimum needed to accomplish the mission. Table 12-2 on page 12-9 lists the techniques for minimizing transmissions and transmission times.

12-46. Minimizing transmissions safeguard radios for critical transmissions. This does not advocate total, continuing radio silence, it advocates minimum transmissions and transmission times.

Table 12-2. Techniques for minimizing transmissions and transmission times

Technique	***Description***
Ensure all transmissions are necessary.	Analysis of U.S. tactical communications indicates that most communication used in training exercises are explanatory and not directive. Radio communications must never be used as a substitute for complete planning. Tactical radio communications should be used to convey orders and critical information rapidly. Execution of the operation must be inherent in training, planning, ingenuity, teamwork, and established and practiced standing operating procedures. The high volume of radio communications that usually precedes a tactical operation makes the friendly force vulnerable to enemy interception, direction finding, jamming, and deception.
Note. When communications are secure, the volume of radio transmissions can betray an operation, and the enemy can still disrupt or destroy the ability of U.S. forces to communicate.	
Preplan messages before transmitting them.	The radio operator should know what he is going to say before beginning a transmission. When the situation and time permit, write out the message before beginning the transmission. This minimizes the number of pauses in the transmission and decreases transmission time. It also ensure the conciseness of the message. The Joint Interoperability of Tactical Command and Control System provide a standard vocabulary used for message planning. The Joint Interoperability of Tactical Command and Control System voice templates are some of the best tools a radio operator can use to minimize transmission time.
Transmit quickly and precisely.	This is critical when the quality of communications is poor. This minimizes the need to repeat a radio transmission. Unnecessary repetition increases transmission time and the enemy's opportunity to intercept U.S. transmissions and thus gain valuable information. When a transmission is necessary, the radio operator should speak in a clear, well-modulated voice, and use proper radiotelephone procedures.
Use equipment capable of data burst transmission.	This is one of the most significant advantages of tactical satellite communications systems. When messages are encoded on a digital entry device for transmission over satellite systems, the transmission time is greatly reduced.
Use an alternate means of communications.	Alternate means of communications, such as cable, wire, or organic Soldiers performing as messengers, can be used to convey necessary directives and information. Other means of communications must be used, when practical.
Use of brevity codes	A brevity code is a code which provides no security but which has as its sole purpose the shortening of messages rather than the concealment of their content. (Refer to ATP 1-02.1 for more information.)

Low Power

12-47. Power controls and antennas are closely related. The strength of the signal transmitted by an antenna depends on the strength of the signal delivered to it by the transmitter; the stronger the signal, the farther it travels. Plan and install a radio communications system, allowing all stations to communicate with each other. In carefully planned and installed communications systems, users can normally operate on low power, thereby decreasing the range, and making it more difficult for the enemy to detect and intercept transmissions. It also reserves high power for penetrating enemy jamming.

Radio Operator Procedures

12-48. The radio operator is essential to the success of preventive EP techniques. The radio operator ensures that radio transmissions are minimized and protected; thereby preventing the enemy from intercepting and disrupting or destroying communications based on information detected in the pattern or content of transmissions.

12-49. Certain voice characteristics or overused phrases readily identify many radio operators. The enemy can use these distinguishing characteristics to identify a unit, even though frequencies and network call signs change periodically. Strictly adhering to the proper use of procedure words, or unit standing operating procedures, helps keep operator-distinguishing characteristics to a minimum. Keep the use of accents and overused phrases to a minimum. The enemy must not be able to associate a particular radio operator with a particular unit.

12-50. The enemy can gather information based on the pattern, and the content, of radio communications. Therefore, do not develop patterns through hourly radio checks, daily reports at specific times, or any other periodic transmission. Make periodic reports by alternate means of communication. Take all reasonable measures to deny information to enemy intelligence analysts.

Authentication

12-51. Radio systems that do not use secure devices require authentication. The enemy has skilled experts, whose sole mission is to enter networks by imitating friendly radio stations. The use of proper authentication minimizes the threat to radio communications. The supplemental instructions to the signal operating instructions list the procedures for authentication. Report all instances in which the enemy attempts to enter networks deceptively to insert false information. Authentication is required if the user—

- Suspects the enemy is on his network.
- Is challenged by someone to authenticate. (Do not break radio silence to do this.)
- Transmits directions or orders that affect the tactical situation, such as change locations, shift fire, or change frequencies.
- Talks about enemy contact, gives an early warning report, or issues a follow-up report. (This rule applies even if he used a brevity list or operations code.)
- Tells a station to go to radio or listening silence, or asks it to break that silence. (Use transmission authentication for this.)
- Transmits to a station that is under radio silence. (Use transmission authentication for this.)
- Cancels a message by radio or visual means, and the other station cannot recognize him.
- Resumes transmitting after a long period, or if this is the first transmission.
- Is authorized to transmit a CLASSIFIED message in the clear. (Use transmission authentication for this.)
- Is forced, because of no response by a called station, to send a message in the blind. (Use transmission authentication for this.)

Encryption

12-52. Encrypt all essential elements of friendly information not for use by the enemy. A broad, general list of these items of information is contained in the supplemental instructions to the signal operating instructions. These items are applicable to most Army units engaged in training exercises or tactical operations. The list supports the Army self-monitoring program, and is not totally encompassing. Individual units should develop specific essential elements of friendly information list to be included in unit operation orders, operation plans, or field standing operating procedures. Encrypt these items of information manually or electronically before transmission. Accomplish manual encryption by using approved operations codes. Accomplish electronic encryption by using COMSEC devices such as the KIV-7, KG-95, KY-57/58, KY-99A, KY-100, and SKL. Utilization of manual and electronic encryption together is not required, as either method protect essential elements of friendly information from enemy exploitation.

Equipment and Communications Enhancements

12-53. Utilize equipment enhancements to reduce the vulnerability of friendly communication to hostile exploitations. Frequency hopping is particularly useful in lessening the effects of enemy communications jamming, and in denying friendly position location data to the enemy.

12-54. Adaptive antenna techniques achieve more survivable communications systems. These techniques typically link with spread spectrum waveforms to combine frequency hopping with pseudo-noise coding.

12-55. Spread spectrum techniques suppress electromagnetic interference by other users (hostile or friendly), to provide multiple access (user sharing), and to eliminate multi-path electromagnetic interference (self-jamming caused by a delayed signal). Deliberately spread across a very wide frequency band in the operating spectrum, the transmitted information becomes hard to detect from normal noise levels. EPLRS and JTIDS use spread spectrum techniques.

12-56. Adjustable power automatically limits the radiated power to a level sufficient for effective communications, thereby reducing the electronic signature of the subscriber.

12-57. The FHMUX and high power broadband vehicular whip antennas are available for use to enhance communications. The FHMUX is an antenna multiplexer used with SINCGARS in stationary and mobile operations. This multiplexer allow up to four SINCGARS to transmit and receive through one VHF-FM broadband antenna (OE-254 or high-power broadband vehicular whip antenna) while operating in the frequency hopping mode, non-hopping mode, or a combination of both. Using one antenna (instead of up to four) reduces visual and electronic profiles of CPs and reduce emplacement and displacement times.

REMEDIAL ELECTRONIC PROTECTION TECHNIQUES

12-58. Remedial EP techniques that help reduce the effectiveness of enemy efforts to jam U.S. radio networks are—

- Identify jamming signals.
- Determine if the electromagnetic interference is obvious or subtle jamming.
- Recognize jamming and electromagnetic interference by:
  - Determining whether the electromagnetic interference is internal or external to the radio.
  - Determining whether the electromagnetic interference is jamming or unintentional.
  - Reporting jamming and electromagnetic interference incidents.
- Overcome jamming and electromagnetic interference by adhering to the following techniques:
  - Continue to operate.
  - Improve the signal-to-jamming ratio.
  - Adjust the receiver.
  - Increase the transmitter power output.
  - Adjust or change the antenna.
  - Establish a RETRANS station.
  - Relocate the antenna.
  - Use an alternate route for communications.
  - Change the frequencies.
  - Acquire another satellite.
  - Timely installation/download of software upgrades.
  - Enhancements to tactical radio ancillary communications electronics equipment and COMSEC devices.

ELECTROMAGNETIC JAMMING

12-59. Electromagnetic jamming is deliberate radiation, reradiation, or reflection of electromagnetic energy for the purpose of preventing or reducing an enemy's effective use of the electromagnetic spectrum, and with the intent of degrading or neutralizing the enemy's combat capability (JP 3-13.1). Jamming is an effective way for the enemy to disrupt friendly communications. An enemy only needs a transmitter tuned to a U.S. frequency, with enough power to override friendly signals, to jam U.S. systems. Jammers operate against receivers, not transmitters. The two modes of jamming are spot and barrage jamming. Spot jamming is concentrated power directed toward one channel or frequency. Barrage jamming is power spread over several frequencies or channels at the same time. It is important to recognize jamming, but it can be difficult to detect.

Obvious Jamming

12-60. Obvious jamming is normally simple to detect. When experiencing jamming, it is more important to recognize and overcome the incident than to identify it formally. Table 12-3 lists some common jamming signals.

Table 12-3. Common jamming signals

Signal	*Description*
Random Noise	Synthetic radio noise. It is indiscriminate in amplitude and frequency. It is similar to normal background noise, and can be used to degrade all types of signals. Operators often mistake it for receiver or atmospheric noise, and fail to take appropriate electronic protection actions.
Stepped Tones	Tones transmitted in increasing and decreasing pitch. They resemble the sound of bagpipes. Stepped tones are normally used against single-channel amplitude modulation or frequency modulation voice circuits.
Spark	Easily produced and is one of the most effective jamming signals. Bursts are of short duration and high intensity; they are repeated at a rapid rate. This signal is effective in disrupting all types of radio communications.
Gulls	Generated by a quick rise and slow fall of a variable radio frequency, and are similar to the cry of a sea gull. It produces a nuisance effect and is very effective against voice radio communications.
Random Pulse	Pulses of varying amplitude, duration, and rate are generated and transmitted. They are used to disrupt teletypewriter, radar, and all types of data transmission systems.
Wobbler	A single frequency, modulated by a low and slowly varying tone. The result is a howling sound that causes a nuisance effect on voice radio communications.
Recorded Sounds	Any audible sound, especially of a variable nature, can be used to distract radio operators and disrupt communications. Music, screams, applause, whistles, machinery noise, and laughter are examples.
Preamble Jamming	A tone resembling the synchronization preamble of the speech security equipment is broadcast over the operating frequency of secure radio sets. Results in all radios being locked in the receive mode. It is especially effective when employed against radio networks using speech security devices.

Subtle Jamming

12-61. Subtle jamming is not obvious when there is no sound heard from the receivers. Although everything appears normal to the radio operator, the receiver cannot receive an incoming friendly signal. Often, users assume their radios are malfunctioning, instead of recognizing subtle jamming for what it is.

Recognizing Electromagnetic Jamming

12-62. Tactical radio operations require that radio operators be capable of recognizing electromagnetic jamming. This is not always an easy task, as electromagnetic interference can be internal and external. If the electromagnetic interference or suspected jamming remains, after grounding or disconnecting the antenna, the disturbance is most likely internal and caused by a malfunction of the radio. Contact maintenance personnel to repair it. Eliminate or substantially reduce the electromagnetic interference or suspected jamming by grounding the radio equipment or disconnecting the receiver antenna. The source of the disturbance is most likely external to the radio. Check external electromagnetic interference further for enemy jamming or unintentional electromagnetic interference.

12-63. Sources having nothing to do with enemy jamming may cause electromagnetic interference. Unintentional electromagnetic interference may be caused by—

- Other radios (friendly and enemy).
- Other electronic or electric and electromechanical equipment.
- Atmospheric conditions.
- Malfunction of the radio.
- A combination of any of the above.

12-64. Unintentional electromagnetic interference normally travels only a short distance; a search of the immediate area may reveal its source. Moving the receiving antenna short distances may cause noticeable variations in the strength of the interfering signal. Conversely, little or no variation normally indicates enemy jamming. Regardless of the source, take appropriate actions to reduce the effect of electromagnetic interference on friendly communications.

12-65. The enemy can use powerful unmodulated or noise modulated jamming signals. A lack of noise characterizes unmodulated jamming signals. Noise modulated jamming signals are characterized by obvious electromagnetic interference noise.

12-66. In all cases, report suspected enemy jamming and any unidentified or unintentional electromagnetic interference that disrupts the ability of U.S. forces to communicate. This applies even if the radio operator is able to overcome the effects of the jamming or electromagnetic interference. The JSIR report is the format used when reporting this information. As it applies to remedial EP techniques, utilize the information in the JSIR report provided to higher headquarters to destroy the enemy jamming efforts or take other action to the benefit of U.S. forces.

OVERCOMING JAMMING

12-67. The enemy constantly strives to perfect and use new and more confusing forms of jamming, which requires radio operators to be increasingly alert to the possibility of jamming. Training and experience are the most important tools operators have to determine when a particular signal is a jamming signal. Exposure to the effects of jamming in training, or actual situations, is invaluable. The ability to recognize jamming is important, as jamming is a problem that requires action. The following paragraphs address the actions to take for detected enemy jamming. If any of the actions taken alleviate the jamming problem, simply continue normal operations and submit a JSIR report to higher headquarters.

Continue to Operate

12-68. Enemy jamming usually involves a period of jamming followed by a brief listening period. Operator activity during this short period indicates to the enemy how effective his jamming has been. If the operation is continuing in a normal manner, as it was before the jamming began, the enemy assumes that his jamming has not been particularly effective. On the other hand, if he hears a discussion of the problem on the air or if the operation has terminated entirely, the enemy may assume that his jamming has been effective. Because the enemy jammer is monitoring operation this way, unless otherwise ordered, never terminate operations or in any way disclose to the enemy that the radio is adversely affected. This means normal operations should continue even when degraded by jamming.

Improve the Signal-to-Jamming Ratio

12-69. The signal-to-jamming ratio is the relative strength of the desired signal to the jamming signal at the receiver. Signal refers to the signal received. Jamming refers to the hostile or unidentified electromagnetic interference received. It is always best to have a signal-to-jamming ratio in which the desired signal is stronger than the jamming signal. In this situation, the jamming signal cannot significantly degrade the desired signal. To improve the signal-to-jamming ratio operators and signal leaders can consider the following—

- **Increase the transmitter power output**. To increase the power output at the time of jamming, set the transmitter to a setting less than full power when jamming begins. Using low power as a preventive EP technique depends on the enemy not being able to detect radio transmissions. Once the enemy begins jamming the radios, the threat of detection becomes obvious. Use the reserve power on the terrestrial line of sight radios to override the enemy's jamming signal.
- **Adjust or change the antenna**. When jamming occurs, the radio operator should ensure optimal adjustment of the antenna to receive the desired incoming signal. Specific methods that apply to a particular radio set are in the appropriate operator's manual. Depending on the antenna, some methods include—
  - Reorient the antenna.
  - Change the antenna polarization. (Required by all stations.)
  - Install an antenna with a longer range.
- **Establish a RETRANS station**. This can increase the range and power of a signal between two or more radio stations. Depending on the situation and available resources, this may be a viable method to improve the signal-to-jamming ratio.
- **Relocate the antenna**. Improve the signal-to-jamming ratio by relocating the antenna and associated radio set affected by the jamming or unidentified electromagnetic interference. This may mean moving it a few meters or several hundred meters. It is best to relocate the antenna and associated radio set, so there is a terrain feature between them and any suspected enemy jamming location.
- **Use an alternate route for communications**. In some instances, enemy jamming prevent friendly forces from communicating with another radio station. When degraded radio communications occurs between two radio stations that require communication between one another, utilize another radio station or route of communications as a network extension between the two radio stations.
- **Change frequencies**. If a communications network cannot overcome enemy jamming using the above measures, the commander (or designated representative) may direct to switch the network to an alternate or spare frequency. Preplanned and well-coordinated actions are required in order for practical, dummy stations to continue to operate on the frequency being jammed, to mask the change to an alternate frequency. During enemy jamming, it may be difficult to coordinate a change of frequency. All radio operators require knowledge of when, and under what circumstances, they are to switch to an alternate or spare frequency. If frequency change and transition does not occur smoothly, the enemy may discover what is happening, and try to degrade communications on the new frequency.

SINGLE CHANNEL GROUND AND AIRBORNE RADIO SYSTEM JAMMING AND ANTI-JAMMING

12-70. Jamming is the intentional transmission of signals that interrupts your ability to transmit and receive. If the radio signal is being jammed, the radio operator hears strong static, strange noise, random noise, no noise, or the network may be quiet with no signals heard. Jamming depends upon the type of signal utilized to jam transmit and receive capabilities and whether the radio network is operating in SC or frequency hopping mode.

12-71. The simplest method the enemy can utilize to disrupt your communication is to transmit noise or audio signals onto a single-channel operating frequency, or on multiple frequency hopping frequencies during frequency hopping operation. If the enemy can generate enough power onto a unit's hopset, it is possible to disrupt or stop communication capability.

12-72. SINCGARS as designed is jam resistant due to its frequency hopping capability. In the event that SINCGARS is jammed, it may be necessary for you to take corrective actions. The action taken depends on the type of jamming or electromagnetic interference that is disrupting network communications as well as the authorized frequency hopping hopset that is available to the network.

12-73. When radio electromagnetic interference occurs, the radio operator determines if jamming or equipment failure caused the electromagnetic interference. To do this, the radio operator—

- Disconnect antenna; if noise continues, the radio may be faulty.
- Set the "function" FCTN switch to "squelch off" SQ OFF and listen for modulated noise.
- Look for a small signal strength indication on the RT front panel.

12-74. The following are corrective actions to take if jamming is indicated—

- Reposition or reorient antenna to eliminate electromagnetic interference.
- Notify supervisor of suspected jamming signals.
- Continue to operate.
- Work through jamming.
- Report electromagnetic interference and jamming to the NCS.

12-75. For those RT-1523F advanced system improvement program-enhanced pure networks, the NCS conduct a network call in single-channel mode, and instruct all network members to switch to frequency hopping mode 2 and continue to operate normally.

12-76. For those non-RT-1523F advanced system improvement program-enhanced pure networks, the NCS conduct a network call in single-channel mode and instruct all non-RT-1523F advanced system improvement program-enhanced radios to switch to the backup single-channel secure frequency single-channel and cipher text. All RT-1523F advanced system improvement program-enhanced radios switch to frequency hopping mode 2. The NCS operates the network in a frequency hopping mixed network operation utilizing a SINCGARS mixed-mode RETRANS site and station to provide communications between the single-channel stations and the frequency hopping stations. Once neutralization of the jamming source occurs, the NCS instructs the network to switch back to frequency hopping mode 1.

Note. Operate SINCGARS in the single-channel and cipher text mode only when required.

ELECTRONIC WARFARE FOR SINGLE CHANNEL TACTICAL SATELLITE

12-77. SC TACSAT communications enhance commanders' ability to conduct operations. During operations, the enemy utilizes EW to direct parts of their resources against our satellite systems. How vulnerable we are to enemy EW and the success of our actions to deny the enemy success in EW efforts depends on our equipment and training of our signal personnel.

12-78. SC TACSAT communications is high on the enemy's target list. Shortly after placing tactical communications in operation, the enemy compiles data on the satellite. This data most likely includes—

- Data indicating the satellite's orbit and location.
- Information on frequency, bandwidth, and modulation used in the satellite.
- The amount, type, and frequency of traffic extended by the satellite.

12-79. With the satellite network extension located, direct the primary enemy threat toward locating ground stations through radio direction finding. Due to the directional antennas used with super high frequency and extremely high frequency SC TACSAT communications radios, there is a low probability of intercept and direction finding. A satellite based intercept station orbiting near our satellites can be successful. In this case, the enemy on his home ground, far from the area of operations, can do the analysis effort.

12-80. Because of the enemy's massive computer support SC TACSAT communications stations hide very little from the enemy. Even without ground station locations, the enemy can direct jamming towards the satellites. When this is occurs, SC TACSAT communications networks working through the satellite is operating in a "stressed" mode. Jamming signals directed toward the satellite can originate far from the operational area. Due to the directional antennas and frequencies used, jamming directed toward ground stations occurs locally. Besides jamming, the enemy may attempt deception from either the ground or his own satellites. The enemy may attempt to insert false or misleading information and may establish dummy networks operating through our satellites to cause confusion.

DEFENSIVE ELECTRONIC WARFARE

12-81. TACSAT communications operate within the environment just described. To do this, it is necessary to use available anti-jamming equipment and sound countermeasures. Communications discipline, security, and training underlie electronic counter-countermeasures. COMSEC techniques give the commander confidence in the security of his communications. Electronic counter-countermeasures equipment and techniques provide confidence in the continued operation of TACSAT communications in a hostile EW or stressed environment. Particularly in SC TACSAT communications, the two are closely related techniques serving an electronic counter-countermeasures role.

12-82. COMSEC techniques protect the transmitted information. Physical security safeguards COMSEC materiel and information from access or observation by unauthorized personnel using physical means. TRANSEC protects transmissions from hostile interception and exploitation. COMSEC and TRANSEC equipment protects most circuits. Some SC TACSAT orderwires may not be secure. Technical discussions between operators can contain information important to the enemy. The nature of any mission gives the enemy access to critical information about commanders, organizations, and locations of headquarters. Although revealed casually on the job, this information is sensitive and requires protection.

12-83. Electronic counter-countermeasures techniques protect against enemy attempts to detect, deceive, or destroy friendly communications. Changing frequency can defeat jamming. This requires the jammer to determine the new frequency, move to it, and change it again if required. This is the principle behind frequency hopping.

12-84. Since it takes about 0.25 seconds for the earth station satellite-earth station trip, frequency hopping four times per second denies the jammer access to the satellite to earth link. Frequency hopping at this rate relies on automated equipment. Frequency hopping at rates between 4 per second and 75 per second effectively avoids intercept and jamming when the enemy can receive only the downlink. With these low rates, bandwidth is still minimal while providing secure communications. Frequency hopping forces the jammer to spread his energy (broadband jamming). This reduces the jammer noise density on any one channel.

12-85. Spread spectrum modulation is another effective anti-jamming technique. With this technique, add the information transmitted to a pseudorandom noise code and utilize the information to modulate the SC TACSAT terminal transmitter. At the receiving end, an identical noise generator synchronized to the transmitter is used. It generates the same noise code as the one at the transmitter to cancel the noise signal from the incoming signal. Thus, only the transmitted information remains.

12-86. The spread spectrum signal can occupy the entire bandwidth of the satellite at the same time with several other spread spectrum signals. Each signal requires a different pseudorandom noise code. The noise code looks the same to the jammer regardless of the information carried over the satellite signal. This forces the jammer to spread his energy throughout the entire bandwidth of the random noise. This results in a reduced jamming noise density. The jammer has no knowledge of whether the jamming is effective.

ELECTROMAGNETIC COMPATIBILITY

12-87. An electromagnetic compatibility occurs when all equipment (radios, radars, generators) and vehicles (ignition systems) operate without electromagnetic interference from each other. With SC TACSAT communications terminals, a source of electromagnetic interference is solar weather (to include solar flares, solar winds, geomagnetic storms, and solar radiation storms). Control factors such as location and antenna orientation to eliminate this source of noise. For each piece of equipment, use proper grounding techniques and follow safety considerations. When required to collocate SC TACSAT communications terminals and other sets use a plan that prevents antennas from shooting directly into one another. Maintaining an adequate distance between antennas reduces mutual electromagnetic interference.

12-88. Desensitization is the most common electromagnetic interference problem. This reduces receiver sensitivity caused by signals from nearby transmitters. Include the electromagnetic compatibility in the plans for siting a SC TACSAT communications station. An electromagnetic pulse (EMP) is a threat to all sophisticated electronic systems.

COUNTER RADIO-CONTROLLED IMPROVISED EXPLOSIVE DEVICE ELECTRONIC WARFARE

12-89. Counter radio-controlled improvised explosive device electronic warfare (CREW) is a form of defensive electronic attack. CREW systems jam threat radio frequencies to preempt radio-controlled improvised explosive devices (RCIED) from receiving a firing signal. When properly used, a CREW system prevents the enemy's RF transmitter from communicating with the RCIED receiver, preventing the RCIED from detonating. CREW systems are programmed with threat-specific loadsets based on various sources of intelligence, including the technical exploitation of recovered RCIEDs

12-90. The U.S. military employ mounted, dismounted, and fixed CREW systems as electronic countermeasures to RCIED attacks. The Army serves as the executive agent and single service manager for ground based CREW systems. The Army manages CREW system acquisition to ensure interoperability and compatibility among fielded systems. CREW systems currently in service include—

- Mounted.
  - AN/VLQ-12 Duke V2/V3 (Army).
  - AN/VLQ-13 Counter Radio Controlled Improvised Device Vehicle Receiver/Jammer (V)1/(V)2 (Joint).
  - Symphony (Coalition).
  - EGON Active/Reactive Counter-IED System (special operations forces).
- Dismounted.
  - AN/PLQ-9 Thor III (Joint).
  - AN/PLT-5 Thor II (EOD).
  - AN/PLT-073 Guardian (Coalition).
  - Modi (special operations forces).
- Fixed Site.
  - AN/FLQ-13(V)1 Duke V2 EA.
- Other.
  - AN/GLM-11(V)1 Universal Test Set.

12-91. The electronic warfare officer is the commander's subject matter expert on CREW. The electronic warfare officer coordinates EW missions with the division G-6 and brigade S-6 to deconflict EA, manage and oversee the employment of CREW systems, conduct EW training, and monitor exploitation results for changes in the enemy's use of the spectrum to ensure the validity of loadsets.

PURPOSEFUL INTERFERENCE

12-92. The growing dependency on wireless services and the resulting escalation of cyberattacks has resulted in the need to enhance cybersecurity and protect against purposeful interference. Purposeful interference consists of deliberate actions taken to deny or disrupt a space system, service, or capability.

12-93. In cases of terrestrial interference within United States and its possessions, to include satellite downlink interference, the Combatant command/Services/Agencies owning or operating the affected system is responsible for investigating and resolving the interference. Downlink interference is defined as the part of the transmission link reaching from the satellite to the ground. Uplink interference is defined as the part of the transmission link from the earth station to the satellite.

ELECTROMAGNETIC INTERFERENCE

12-94. Electromagnetic interference is any electromagnetic disturbance, induced intentionally or unintentionally, that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics and electrical equipment (JP 3-13.1). Electromagnetic interference can be induced intentionally, in the form of EW, or unintentionally, as a result of spurious emissions and responses, and intermodulation products.

12-95. Timely and accurate identification, reporting, and resolution of electromagnetic interference are key functions of electromagnetic spectrum management. Resolution of electromagnetic interference is crucial in assuring vital information is exchanged quickly and accurately. Report all electromagnetic interference disturbances regardless of the severity, intensity, or duration. Conduct electromagnetic interference resolution tasks in order to resolve or mitigate electromagnetic interference incidents at the lowest possible level within the command structure. Refer to Strategic Instruction 714-5 for on information electromagnetic interference resolution procedures.

JOINT SPECTRUM INTERFERENCE RESOLUTION REPORTING

12-96. JSIR addresses electromagnetic interference incidents and EA affecting the DOD. The JSIR objective is to report and assist in resolving EA and persistent, recurring electromagnetic interference. Resolution is at the lowest possible level, using organic assets. Refer incidents that cannot be resolved locally up the chain of command with resolution attempted at each level.

12-97. CJCSI 3320.02F directs DOD components to resolve RF electromagnetic interference at the lowest possible level within the chain of command. To accomplish this, the Army established the Army interference resolution program.

ARMY INTERFERENCE RESOLUTION PROGRAM

12-98. The Army interference resolution program revolves around four functions: direction finding, signal monitoring, signal analysis, transportability and mobility. Table 12-4 describes these functions.

Table 12-4. Army interference resolution program functions

Function	*Description*
Direction Finding	Is often the key to locating the source of interference, and is an integral part of resolving and analyzing incidents and problems. The degree of accuracy depends upon the environment and frequency band.
Signal Monitoring	Signal Monitoring or spectrum surveillance incorporates a frequency spectrum analyzer or surveillance receiver, covering all spectrum bands of use. These systems perform real-time evaluation of spectrum usage and interference in a specific area.
Signal Analysis	Analysis of direction finding and monitoring data is required to determine the source of interference and misuse of the spectrum.
Transportability and Mobility	Degree, circumstances, and geographic location of the types of interference incidents and problems determine transportability and mobility requirements. Mobile and transportable direction finding and monitoring equipment is a requirement for tactical units and for incidents not necessarily confined to a specific geographical area. Consider man portable equipment for instances and conditions, as defined in unit standing operating procedures. Fixed equipment would be required for those areas that require real-time solutions in a defined geographical area.

INTERFERENCE RESOLUTION

12-99. Corps and division spectrum managers are the coordinating authorities for regional and local interference resolution. The impact of each interference incident is unique, and no standard procedure establishes or guarantees resolution in every case. A logical systematic approach reduces the time and cost required to resolve interference situations. Figure 12-1 on page 12-19 depicts a logical flow diagram (for instances when an Army unit is the victim of interference in a tactical operation).

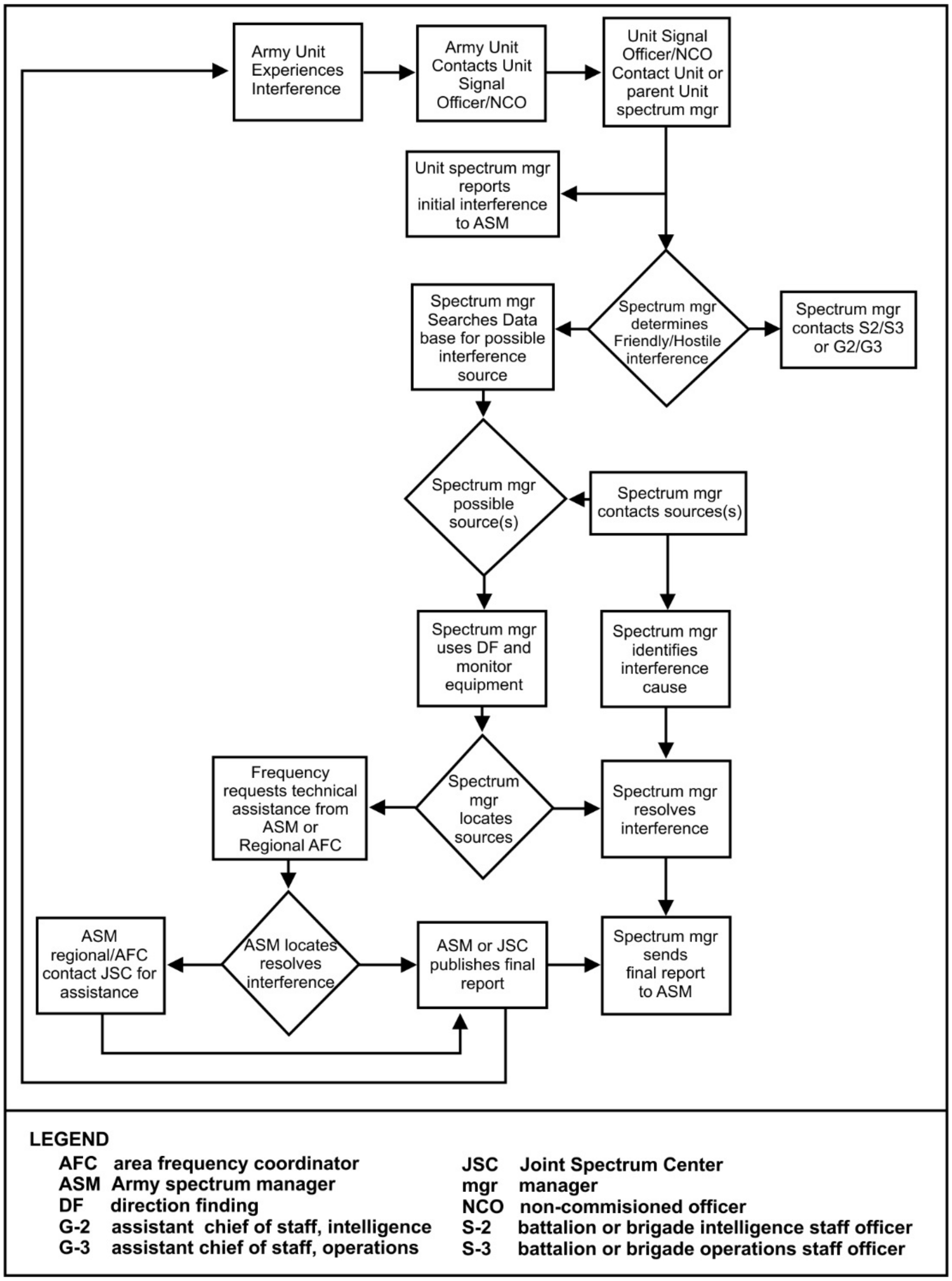


Figure 12-1. Local interference resolution (Army victim)

12-100. Figure 12-2, on page 12-20, shows a flow diagram for interference, when the Army unit is the source of the interference.

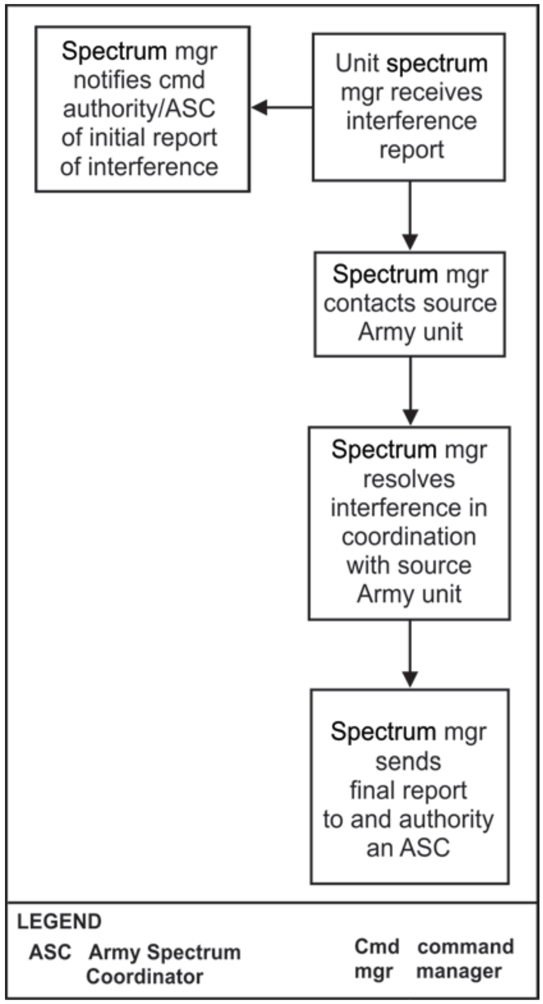


Figure 12-2. Interference resolution (Army source)

Reporting Procedure

12-101. Report all electromagnetic interference incidents through the proper channels. Submit all reports of suspected hostile electromagnetic interference via secure means. Do not hold reports up due to information not being readily available; use follow-up reports to provide additional information, as it becomes available.

12-102. The equipment operator experiencing the electromagnetic interference incident forwards the initial JSIR report through the chain of command to the unit operations center. Attempt to resolve the electromagnetic interference problem at the lowest possible level before submitting JSIR reports to higher headquarters.

12-103. Utilize the Joint Spectrum Management System or Spectrum XXI programs to submit the report electronically. The sender classifies the report by evaluating the security sensitivity of the electromagnetic interference on the affected system, and by considering the classification of the text comments.

12-104. Assign precedence to the JSIR report consistent with the urgency of the reported situation. Use ROUTINE or PRIORITY precedence, unless the organization originating the report believes the incident is hazardous to military operations. For this incident, use IMMEDIATE precedence.

12-105. Each Army unit submits reports through its chain of command, up to the major, or combatant command, or GCC level, and to the U.S. Army Communications-Electronic Services Office. Submit information copies of all incident reports to the Joint Spectrum Center for inclusion in the JSIR database. Refer to CJCSM 3320.02D for additional information on JSIR procedures.

12-106. Table 12-5 is a guide for JSIR security classification.

Table 12-5. JSIR security classification guide

Information Revealing	***Security Classification***
The specific identification of an unfriendly platform or location, by country or coordinates, as the source of interference or electronic attack.	SECRET (S)
Specific susceptibility or vulnerability of U.S. electronic equipment and systems.	SECRET (S)
Parametric data of classified U.S. electronic equipment.	In accordance with the classification guide of the affected equipment.
Suspected interference from unidentified sources while operating in or near hostile countries.	SECRET (S)
Interference to U.S. electromagnetic equipment and systems caused by electronic attack exercises in foreign nations.	CONFIDENTIAL
Suspected interference from friendly sources.	UNCLASSIFIED (U) or SECRET (S), if specific equipment vulnerability is revealed.
Information referring to joint spectrum interference resolution; stating that joint spectrum interference resolution analyses are a function of the Joint Spectrum Center.	UNCLASSIFIED (U)

Joint Spectrum Interference Resolution Report Content

12-107. Table 12-6 shows the minimum information requirements for the JSIR. The message subject line should indicate whether the report is initial, follow-up, or final.

Table 12-6. JSIR information requirements

Item Number	***Data Input***
1	Frequencies affected by the interference.
2	Locations of systems experiencing the interference.
3	The affected system name, nomenclature, manufacturer (with model number), or other system description. If available, include the equipment characteristics of the victim receiver, such as bandwidth, antenna type, and antenna size.
4	The operating mode of the affected system. If applicable, include the following: frequency agile, pulse Doppler, search, and upper and lower sidebands.
5	The characteristics of the interference (noise, pulsed, continuous, intermittent, frequency, or bandwidth.
6	The description of the interference effects on victim performance (reduced range, false targets, reduced intelligibility, or data errors).
7	Enter the dates and times the interference occurred. Indicate whether the duration of the interference is continuous or intermittent. Indicate whether the approximate repetition rate of the interference, and whether the amplitude of the interference is varying or constant. Indicate if the interference is occurring at a regular or irregular time of day, and if the occurrence of the interference coincides with any ongoing local activity.
8	The location of possible interference sources (coordinates or line of bearing, if known; otherwise, state as unknown).
9	A listing of other units affected by the interference (if known) and their location or distance, and bearing from the reporting site.
10	A clear and concise narrative summary of what is known about the interference, and any local actions that have been taken to resolve the problem. The operator is encouraged to provide any other information, based on observation or estimation that is pertinent in the technical or operational analysis of the incident. Identify whether the information being furnished is based on actual observation and measurement or is being estimated. Avoid the use of Army or program jargon and acronyms.
11	Reference message traffic that is related to the interference problem being reported. Include the message date-time group, originator, action addressees, and subject line.
12	Indicate whether the problem has been identified or resolved.
13	Indicate if joint spectrum interference resolution technical assistance is desired or anticipated.
14	Point of contact information, including name, unit, and contact phone numbers.

Appendix A
Frequency Modulation Radio Networks

Units from battalion to theater establish frequency modulation radio networks to enable communication during operations. Commanders may establish other networks in addition to frequency modulation radio networks to enhance mission accomplishment. The lack of sufficient single-channel tactical satellite frequency resources, single-channel radio systems density, and the need for radio retransmission capability all validate the need for frequency modulation networks. This appendix provides a description of frequency modulation networks.

FREQUENCY MODULATION

A-1. FM is the process of varying the frequency (rather than the amplitude) of the carrier signal in accordance with the variations of the modulating signals. The amplitude or power of the FM carrier does not vary during modulation. When the frequency of the carrier signal is non-modulated, refer to the signal as the center, or rest, frequency. When applying a modulating signal to the carrier, the carrier signal moves up and down in frequency away from the center, or rest, frequency.

A-2. The amplitude of the modulating signal determines how far away from the center frequency the carrier moves. This movement of the carrier, known as deviation, indicates how far the carrier moves. During reception of the FM signal, the amount of deviation determines the loudness or volume of the signal.

A-3. The FM signal leaving the transmitting antenna is constant in amplitude, but varies in frequency according to the audio signal. As the signal travels to the receiving antenna, it picks up natural and manmade electrical noises that cause amplitude variations in the signal. All of these undesirable amplitude variations amplify as the signal passes through successive stages of the receiver, until the signal reaches a part of the receiver called the limiter. The limiter is unique to FM receivers, as is the discriminator.

A-4. The limiter eliminates the amplitude variations in the signal, and then passes it on to the discriminator, which is sensitive to variations in the frequency of the RF wave. The discriminator circuit processes the resultant constant amplitude FM signal, which changes the frequency variations into corresponding voltage amplitude variations. These voltage variations reproduce the original modulating signal in a headset, loudspeaker, or teletypewriter. Radiotelephone transmitters operating in the VHF and higher frequency bands generally use FM.

COMMAND NETWORKS

A-5. Command networks are FM secure internal command networks. Established at various echelons in Army units, command networks provide organization and control of information passed via each network. Command networks support commanders' requirements to send and receive critical information during operations. Subscribers in a command network are members of that echelon and the next senior echelon command network. Command networks established at various echelons allow commanders greater flexibility, offering units the capability to be part of a smaller command network while still maintaining compatibility and accessibility with the larger overall command. The SINCGARS, which is an FM radio, is the primary radio used to establish secure command networks. When necessary units utilize RETRANS teams to overcome communication obstacles between higher and lower units. Command networks have the highest installation priority.

Table A-1, on page A-2, is an example of typical command networks established within a division and the network stations established within each command network. The command networks shown merely serve as a guide for establishing radio networks. The actual networks established depend on the existing situation, command guidance, and equipment available.

Table A-1. Example of division command networks

Network Stations	*Command Operations Network*	*Operations and Intelligence Network*	*Sustainment Operations Network*	*Administrative and Logistics Network*
Commander	X	X	X	X
Assistant commander	X			
Assistant chief of staff, operations	X	X	X	X
Assistant chief of staff, intelligence		X		X
Tactical command post assistant chief of staff, operations	X		X	X
Tactical command post assistant chief of staff, intelligence		X		
Tactical command post assistant chief of staff, signal	X	X	X	X
Subordinate brigade command post	X	X	X	X
Brigade support battalion	X		X	
Reconnaissance battalion	X	X	X	X
Aviation units	X	X	X	X
Engineer unit	X	X	X	X
Military intelligence unit	X	X		
Air defense artillery unit	X	X		X
Artillery units	X	X	X	X
Military police	X		X	
Sustainment operations center	X		X	X
Division Signal company	X	X	X	
Liaison officer	X			

A-6. Figure A-1, on page A-3, depicts the structure of a typical command network in a division.

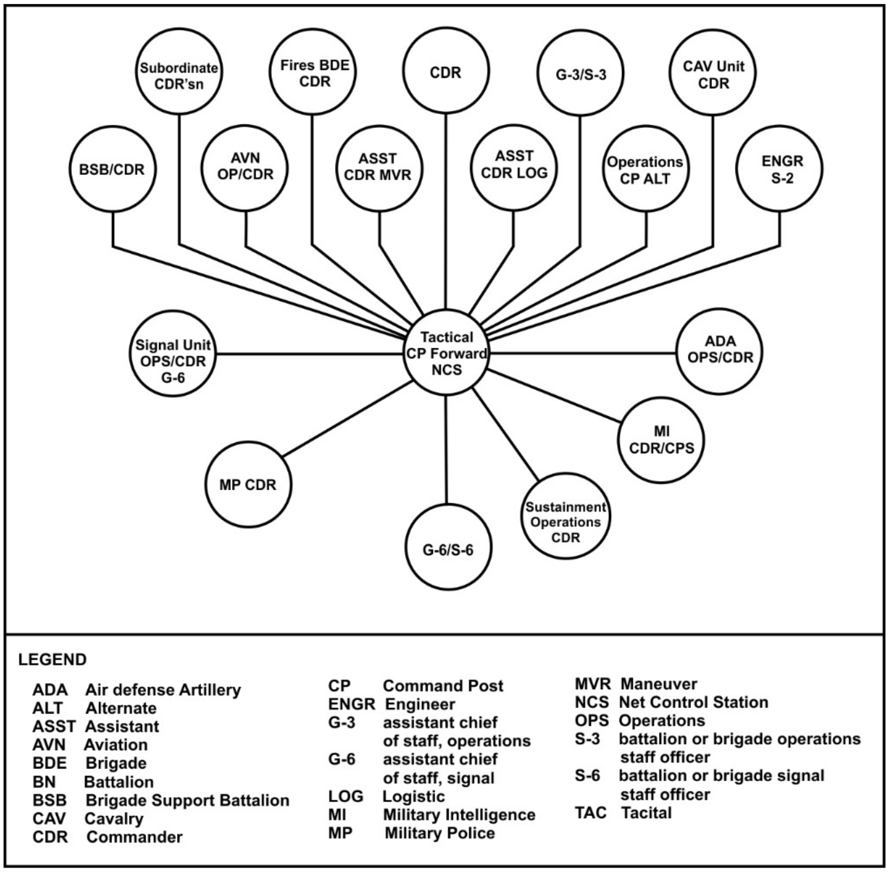


Figure A-1. Structure of a division command network

ADMINISTRATIVE AND LOGISTICS NETWORKS

A-7. Administrative and logistics networks controlled by the battalion or brigade personnel staff officer and the logistics staff officer transmit and receive administrative and logistics data. Figure A-2, on page A-4, is an example of a brigade administrative and logistics network.

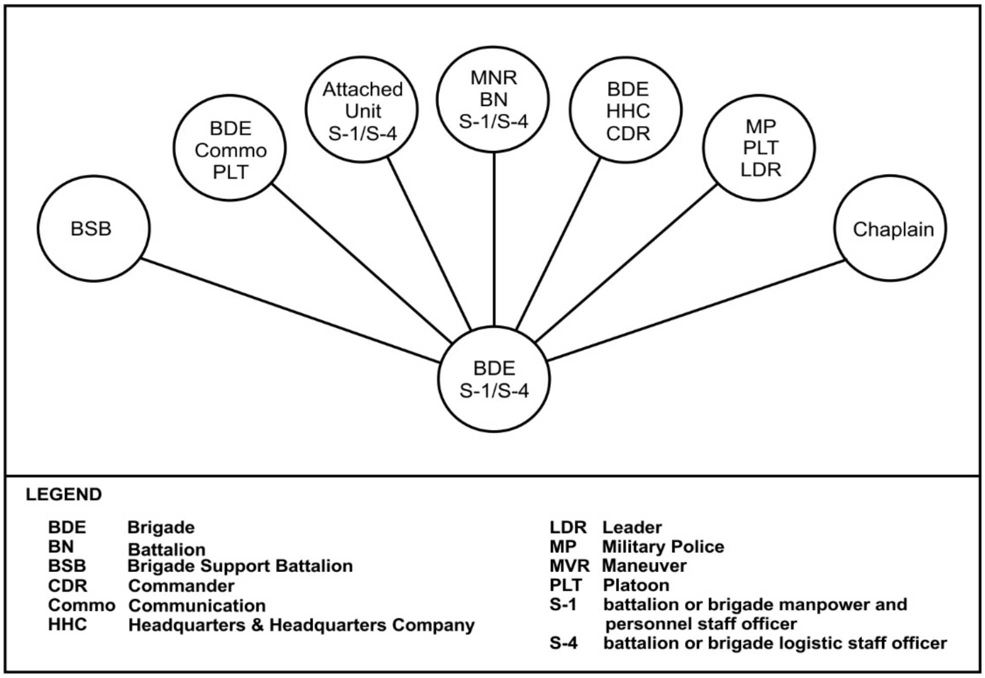
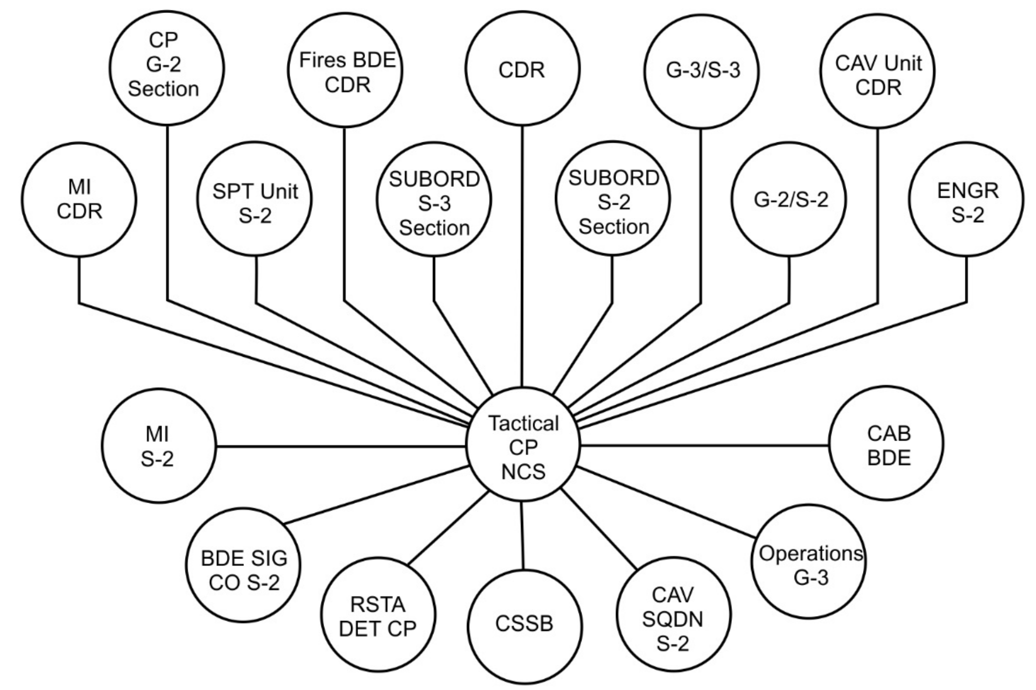


Figure A-2. Example of a brigade administrative logistics network

Operations and Intelligence Networks

A-8. Operations and intelligence networks controlled by the S-2 transmit and receive operations and intelligence reports, and functions as surveillance networks when required. Operations and intelligence networks provide details and discussion that lead to an analysis, which the appropriate commander receives once the analysis is completed. The unit executive officer ensures the analysis is completed and relayed in a timely manner by appropriate means. Subordinate elements may monitor the operations and intelligence networks to develop situational awareness of critical support requirements and problems. Figure A-3, on page A-5, is an example of a division operations and intelligence network. The information passed over these networks is continuous, and requires a separate network to prevent overloading the command network. The local situation determines whether other subscribers are added or deleted.



LEGEND

BDE	Brigade
CAB	combat aviation brigade
CAV	Cavalry
CDR	Commander
CO	Company
CP	Command Post
CSSB	Combat Support Sustainment Battalion
DET	Detachment
EMGR	Engineer
G-2	assistant chief of staff, intelligence
G-3	assistant chief of staff, operations
MI	Military Intelligence
NCS	Net Control Station
RSTA	reconnaissance, surveillance, and target acquisition
S-2	battalion or brigade intelligence staff officer
S-3	battalion or brigade operations staff officer
SIG	Signal
SPT	Support
SQDN	Squadron
SUBORD	Subordinate

Figure A-3. Example of a division operations and intelligence network

MEDICAL NETWORK

A-9. Medical units need dedicated, long-range, reliable communications systems that can be user-operated. Communications distances are substantial between major medical support bases and forward aid stations. ALE tuning (Harris 5000 series radios) and other simplified operating features make HF radios ideal for units with a limited number of signal personnel. Figure A-4, on page A-6, is an example of a corps medical operations network.

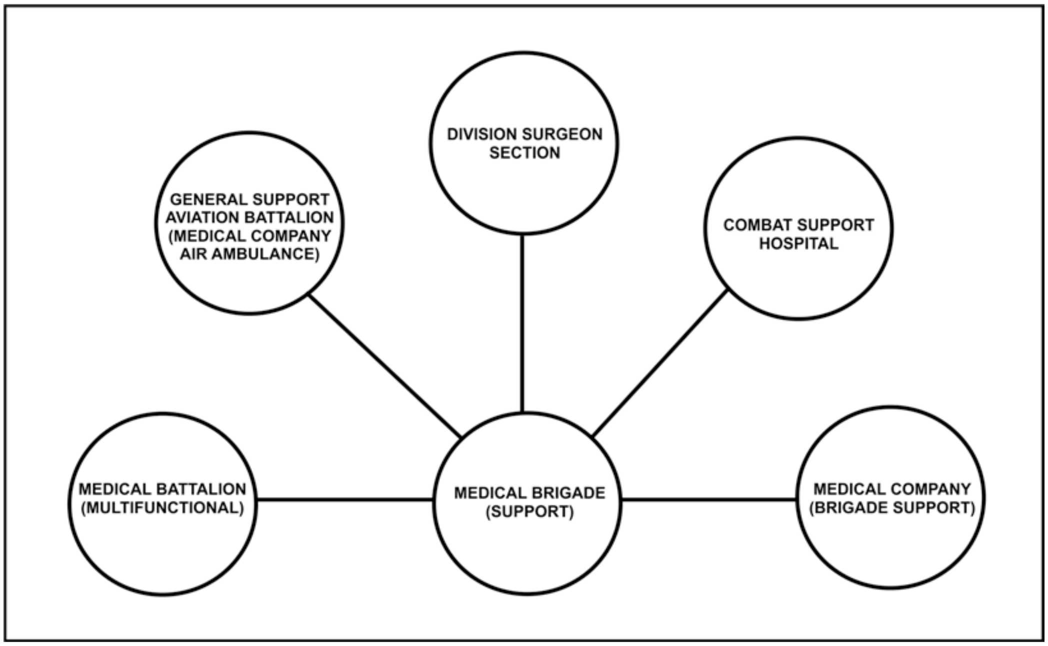
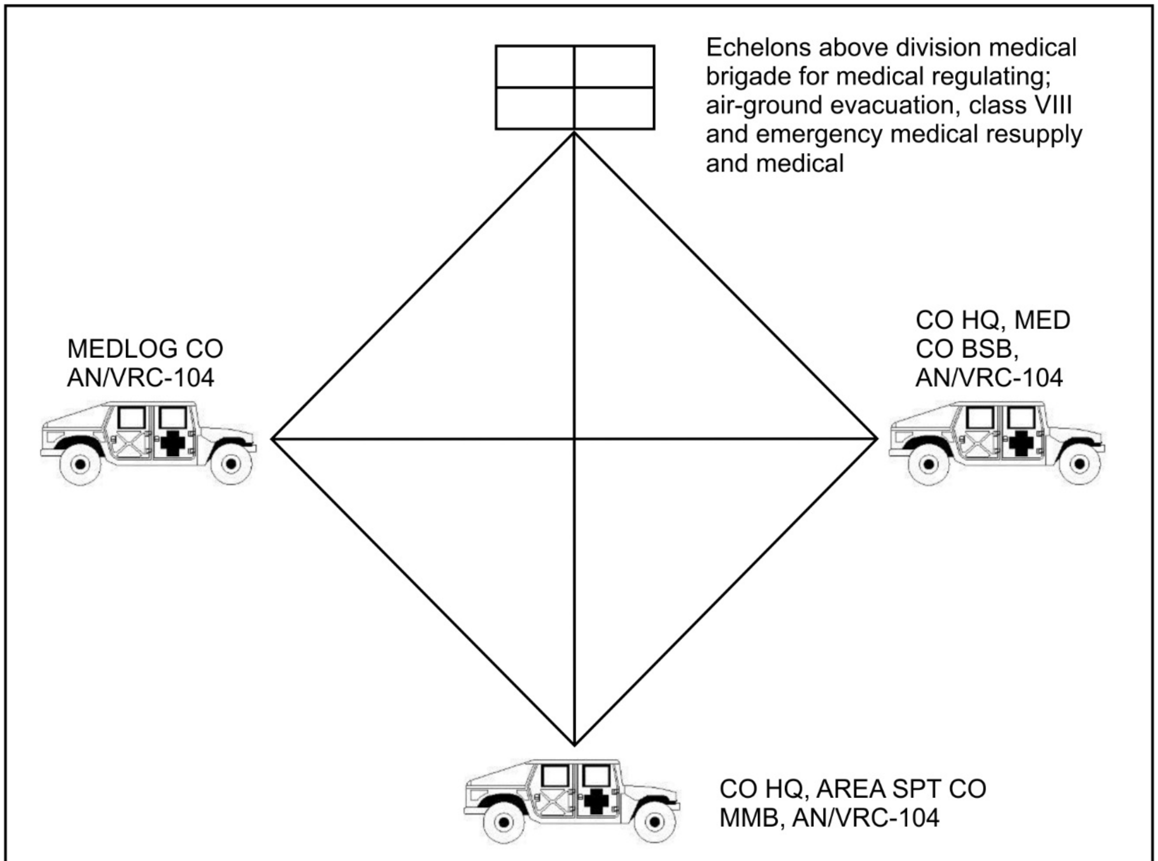


Figure A-4. Example of a corps medical operations network

A-10. Figure A-5, on page A-7, is an example of a division medical operations network.



LEGEND

BSB	Brigade Support Battalion	MEDLOG	Medical Logistics
CO	Company	MMB	Multifunctional Medical Battalion
HQ	Headquarters	SPT	Support
MED	Medical		

Figure A-5. Example of a medical operations network in a division

FIRE DIRECTION NETWORK

A-11. The fire direction network is the highest priority command network for fires units. The fire direction network provides fires units the capability to exchange technical and firing data via the network. RETRANS teams support fire direction networks as required.

SURVEILLANCE NETWORK

A-12. The surveillance network enables the transmission and receipt of reports related to enemy movement and massing. The battalion battlefield information control center establishes this network to coordinate and control the ground surveillance radar and unattended ground sensor teams. The information from this network is vital to commanders and given high priority for activation.

SUSTAINMENT AREA COMMAND NETWORK

A-13. Sustainment area operations ensure freedom of maneuver. They consist of actions taken by Army units and host nation units (singularly or in a combined effort) to secure the force, or to neutralize or defeat enemy operations in the sustainment area. The sustainment area command network consists of many units that are collocated in the division sustainment area.

A-14. Figure A-6 is an example of a division sustainment area command network. Members of the sustainment area command network also depend on themselves to form the base cluster defense.

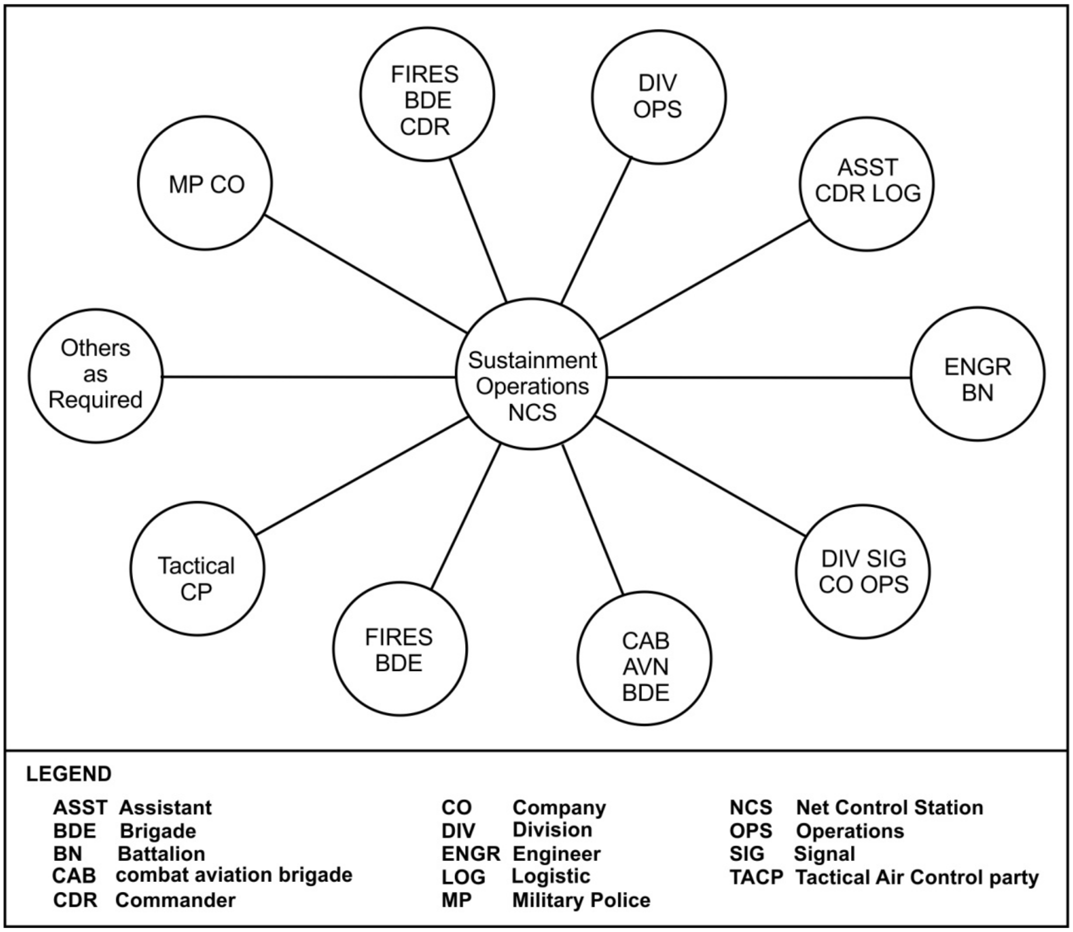


Figure A-6. Example of a division sustainment area command network

HIGH FREQUENCY NETWORKS

A-15. HF networks are similar to the VHF FM networks in function and establishment. Many HF networks are a backup or supplement to their VHF FM counterparts. HF networks are established when unit dispersal exceeds the planning range for VHF FM systems.

A-16. Figure A-7, on page A-9, is an example of a HF command network at division level. Note the similarity with the VHF FM command network. Commanders routinely establish a HF command network as a secondary means of controlling operations.

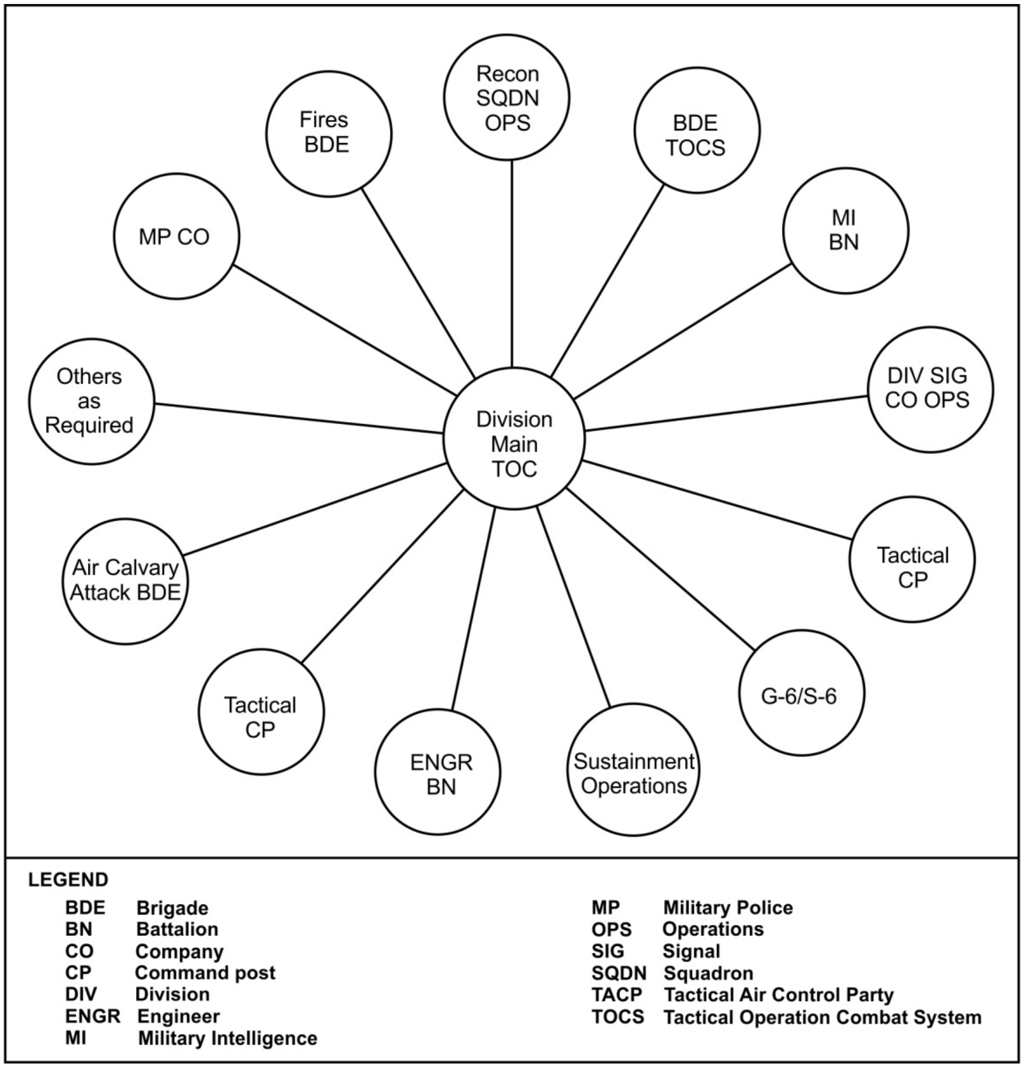


Figure A-7. Example of a division HF command network

Brigade Combat Team

A-17. The BCT employs traditional HF networks in support of command networks. The BCT typically establishes administrative and logistics, and operations and intelligence command networks in support of fires, and reconnaissance operations. A typical brigade today has enough HF radios to establish command networks down to the company and lower levels when the situation warrants it.

A-18. Logistics units employ HF radios to enable communication, provide situational awareness, and provide internal coordination due to the communications distances from the division support area to the brigade support area. HF network are a backup to FM networks, when the tactical spread of the division extends the lines of communication. The support units within the corps establish similar networks, or monitor the division networks to ensure push forward support.

HIGH FREQUENCY DATA NETWORK

A-19. Combat aviation brigades and air cavalry units use HF data networks to provide long-range, non-line of sight communications. Figure A-8, on page A-10, shows a typical cavalry unit HF data network. Cavalry squadrons and troops use the low power HF data network for their command networks when distance is not an issue. The same is true for divisional and regimental cavalry.

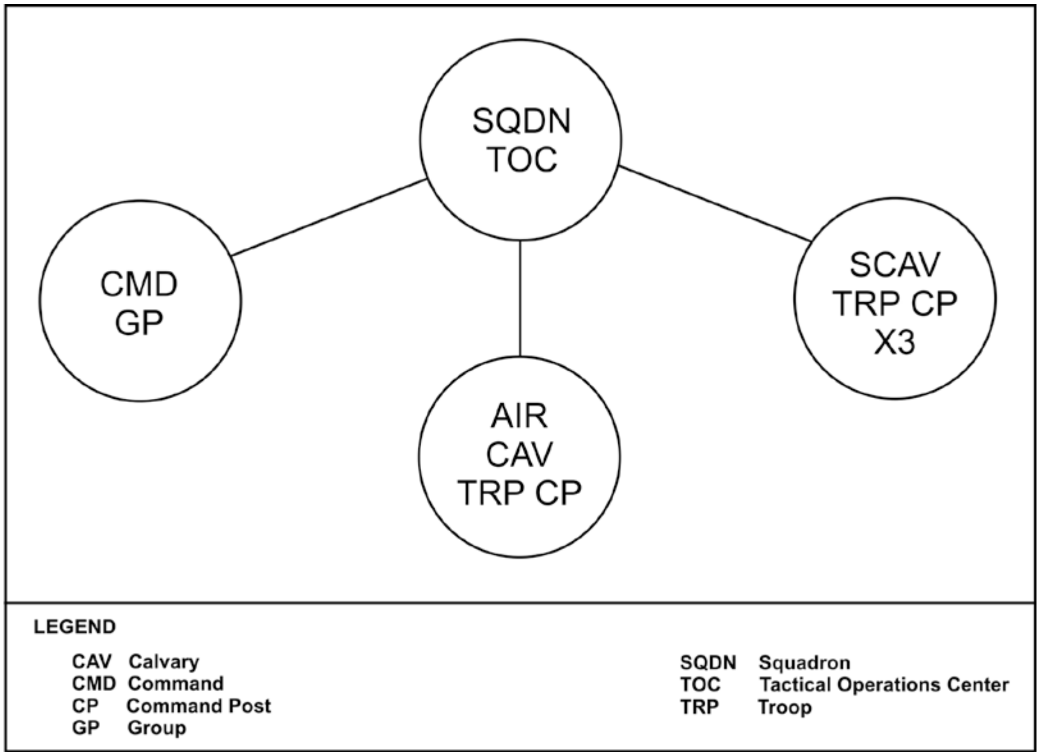


Figure A-8. Example of a cavalry unit HF data network

CAPABILITIES

A-20. Tactical radios that enable communication for Army forces during the conduct of unified land operations require that the capabilities of the tactical radios be versatile and adaptable to changing tactical situations. Key capabilities that tactical radios provide are—

- Lightweight.
- Portable.
- Mobile ad-hoc networking.
- Applications.
- Securable.
- Multiple waveform capable.
- Multiband and multi-mode capable.
- GPS capable.
- Software-based radios that provide squad level networking and integrate with legacy platforms.

A-21. The capabilities provided by tactical radios enhance interoperable networking between the software defined radio platform, legacy waveforms, and mobile ad-hoc networking waveforms. The capabilities of tactical radios leverage commercial technology and employ open-system architecture to ensure interoperability and portability of each waveform. The capabilities provide commanders the ability to exercise mission command and communicate with their forces via secure voice, video, and data mediums during operations.

Appendix B

Single Channel Radio Communications Techniques

Single channel radio communications equipment transmits and receives voice, data, or telegraphic voice code. This appendix addresses a radio set basic components, characteristics, and properties of radio waves, wave modulation, and site considerations for single-channel radios.

RADIO SET BASIC COMPONENTS

B-1. A radio set consists of a transmitter and receiver. Other items necessary for operation include a source of electrical power and an antenna for radiation and reception of radio waves.

B-2. The transmitter contains an oscillator that generates RF energy in the form of alternating current. A transmission line, or cable, feeds the RF to the antenna. The antenna converts the alternating current into electromagnetic energy radiated into space; a keying device used to control the transmission.

B-3. Normally, in single-channel radio operations, the receiver uses the same antenna as the transmitter to receive electromagnetic energy. The antenna converts the received electromagnetic energy into RF alternating current. Feed the RF to the receiver by a transmission line or cable. In the receiver, the RF converts to audio frequencies. The audio frequencies change into sound waves by a headset or loudspeaker.

B-4. Communication is possible when two radio sets operate on the same frequency, with the same type of modulation, and are within operating range.

RADIO TRANSMITTER

B-5. The simplest radio transmitter consists of a power supply and an oscillator. The power supply can be batteries, a generator, an alternating current power source with a rectifier and a filter, or a direct current rotating power source. The oscillator, which generates RF energy, requires a circuit to tune the transmitter to the desired operating frequency. The transmitter also requires a device for controlling the emission of the RF signal. The simplest device is a telegraph key, a type of switch for controlling the flow of electric current. As the key operates, the oscillator turns on and off for varying lengths of time. The varying pulses of RF energy produced correspond to dots and dashes. This is a continuous wave operation used when transmitting international Morse code.

B-6. Utilize a continuous wave radio transmitter to generate RF energy radiated into space. The transmitter may contain only a simple oscillator stage. Apply the output of the oscillator to a buffer stage to increase oscillator stability, and to a power amplifier that produces greater output. Utilize a telegraph key to control the energy waves produced by the transmitter. When the key is closed, the transmitter produces its maximum output. Opening the key produces no output.

B-7. By adding a modulator and a microphone, a radiotelephone transmitter can transmit messages by voice. When the modulating signal causes the amplitude of the radio wave to change, the radio is an AM set. When the modulating signal varies the frequency of the radio wave, the radio is an FM set.

B-8. The reliability of radio communications depends on the characteristics of the transmitted signal. The transmitter, and its associated antenna, forms the initial step in the transfer of energy to a distant receiver.

B-9. Use ground-wave transmission for field radio communications. The range of the ground wave becomes correspondingly shorter as the operating frequency of the transmitter increases through the applicable portions of the medium frequency (MF) band (300–3000 kHz) to the HF band (3.0–30 MHz). When the transmitter is operating at frequencies above 30 MHz, its range is generally limited to slightly more than line of sight. For circuits using sky wave propagation, the frequency selected depends on the geographic area, season, and time of day.

Note. Frequency selection is the responsibility of the spectrum manager not the radio operator.

B-10. For maximum transfer of energy, the radiating antenna must be the proper length for the operating frequency. The local terrain determines, in part, the radiation pattern, and therefore affects the directivity of the antenna and the possible range of the set in the desired direction. When possible, try several variations in the physical position of the antenna to determine the best operating position for radiating the greatest amount of energy in the desired direction.

B-11. The range of a transmitter is proportional to the power radiated by its antenna. An increase in the power output of the transmitter results in some increase in range. Under normal operating conditions, the transmitter should feed only enough power into the radiating antenna to establish reliable communications with the receiving station. Transmission of a signal more powerful than required is a breach of signal security, because enemy direction finding stations may easily identify the location of the transmitter. The signal can interfere with friendly stations operating on the same frequency.

RADIO RECEIVER

B-12. A radio receiver can receive modulated RF signals that carry speech, music, or other audio energy. It can also receive continuous wave signals that are bursts of RF energy conveying messages by means of coded (dot and dash) signals.

B-13. Detection is the process of recovering information from an RF signal. The circuit in which it occurs is a detector. The detector recovers the information from the carrier and makes it available for direct use, or for further amplification.

B-14. An RF signal rapidly diminishes in strength after it leaves the transmitting antenna. Many RF signals of various frequencies are crowded into the RF spectrum. An RF amplifier selects and amplifies the desired signal; it contains integrated circuits or microprocessors to amplify the signal to a usable level. The RF amplifier is included in the receiver to sharpen the selectivity, and to increase the sensitivity. The RF amplifier normally uses tunable circuits to select the desired signal.

B-15. The signal level of the output of a detector, with or without an RF amplifier, is generally very low. One or more audio frequency amplifiers in the receiver builds up the signal output to a useful level to operate headphones, a loudspeaker, or data devices.

B-16. When the transmitted signal reaches the receiver location, it arrives at a much lower power level than when it left the transmitter. The receiver must efficiently process this relatively weak signal to provide maximum reliability of communications.

B-17. Sensitivity describes how well a receiver responds to a weak signal at a given frequency. A receiver with high sensitivity is able to accept a very weak signal, and amplify and process it to provide a usable output. The principal factor that limits or lowers the sensitivity of a receiver is the noise generated by its own internal circuits. Selectivity describes how well a receiver is able to differentiate between a desired frequency and undesired frequencies.

B-18. In field radio communications, the type, location, and electrical characteristics of the receiving antenna are not as important as they are for the transmitting antenna. The receiving antenna requires sufficient length, proper coupling to the input of the receiver circuit, and (except in some cases for HF sky wave propagation) the same polarization as the transmitting antenna.

RADIO WAVES

B-19. Radio waves travel near the surface of the earth, and radiate skyward at various angles to the earth's surface. These electromagnetic waves travel through space at the speed of light, approximately 300,000 kilometers (186,000 miles) per second. Figure B-1 shows the wave radiation from a vertical antenna.

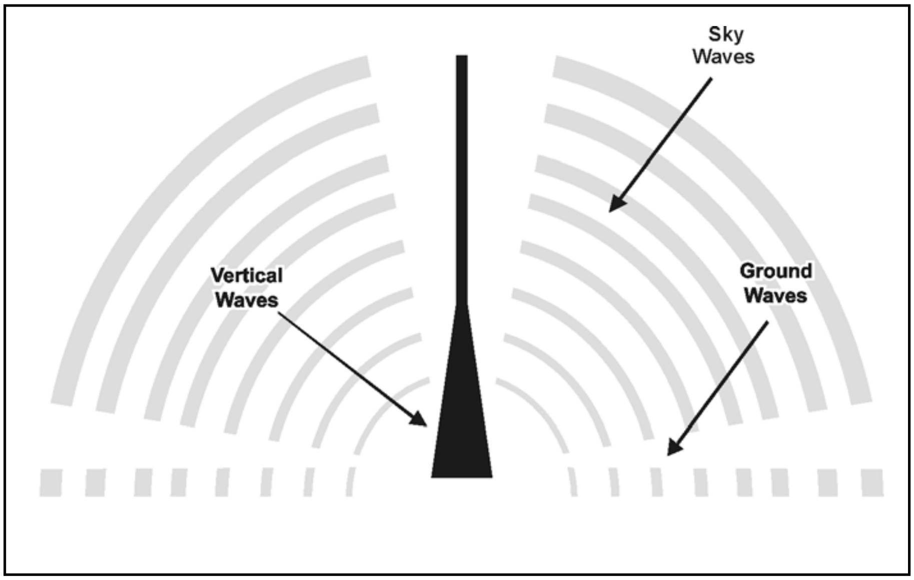


Figure B-1. Radiation of radio waves from a vertical antenna

WAVELENGTH

B-20. The wavelength is defined as the distance between the crest of one wave to the crest of the next wave; it is the length (always measured in meters) of one complete cycle of the waveform. Figure B-2 shows the wavelength of a radio wave.

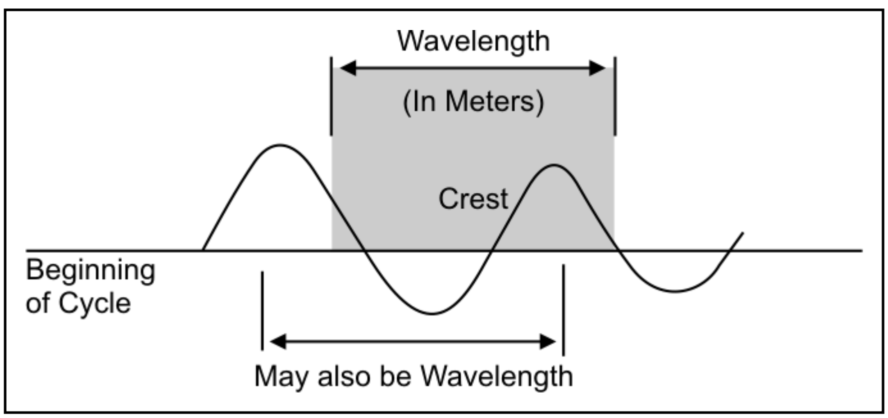


Figure B-2. Wavelength of a radio wave

FREQUENCY

B-21. The frequency of a radio wave is the same as the number of complete cycles that occur in one second. The longer the time of one cycle, the longer the wavelength and the lower the frequency. Measure and state frequency in Hz. State one cycle per second as 1 Hz. Because the frequency of a radio wave is very high, generally measure and state the frequency in kHz (one thousand hertz) or MHz (one million hertz) per second. As required, also express frequency in GHz (one billion hertz) per second.

Frequency Calculation

B-22. For practical purposes, the velocity of a radio wave is constant, regardless of the frequency or the amplitude of the transmitted wave. Therefore, to find the frequency when the free-space wavelength is known, divide the velocity by the wavelength, for example—

- **Frequency (Hz)** = 300,000,000 (meters per second)/wavelength in meters.
- **Wavelength (meters)** = 300,000,000 (meters per second)/frequency in Hz.

Frequency Bands

B-23. The RF spectrum divides radio frequencies into groups, or bands, of frequencies. Table B-1 lists the frequency band coverage. Most tactical radio sets operate within a 2–400 MHz range within the frequency spectrum.

Table B-1. Frequency band chart

Band	*Frequency*
Very low frequency	3–30 kHz
Low frequency	30–300 kHz
Medium frequency	0.3–3.0 MHz
High frequency	3.0–30 MHz
Very high frequency	30–300 MHz
Ultrahigh frequency	300–3,000 MHz
Super high frequency	3–30 GHz
Extremely High Frequency	30–300 GHz
LEGEND **GHz** **gigahertz** **MHz** **megahertz** **kHz** **kilohertz**	

B-24. Table B-2 lists certain characteristics of each frequency band. The ranges and power requirements shown are for normal operating conditions (proper site selection and antenna orientation, and correct operating procedures). The ranges change according to the condition of the propagation medium and the transmitter output power.

Table B-2. Frequency band characteristics

Band	*Range*				*Power Required (Kilowatt)*
	Ground Wave		*Sky Wave*		
	Miles	*Kilometers*	*Miles*	*Kilometers*	
Low frequency	0–1,000	0–1,609	500–8,000	805–12,872	Above 50
Medium frequency	0–100	0–161	100–1,500	161–2,415	.5–50
High frequency	0–50	0–83	100–8,000	161–12,872	.5–5
Very high frequency	0–30	0–48	50–150	80.5–241	.5 or Less
Ultrahigh frequency	0–50	0–83	unlimited (refer to paragraph B-30)		.5 or Less

B-25. The frequency of the radio wave affects its propagation characteristics. At low frequencies (.03–.3 MHz), the ground wave is very useful for communication over great distances. The ground wave signals are quite stable and show little seasonal variation.

B-26. In the MF band (.3–3.0 MHz); the range of the ground wave varies from about 24 kilometers (15 miles) at 3 MHz to about 640 kilometers (400 miles) at the lowest frequencies of this band. Sky wave reception is possible during the day or night at any of the lower frequencies in this band. At night, the sky wave is receivable at distances up to 12,870 kilometers (8,000 miles). Major uses of the MF band include medium distance communications, radio navigation, and AM broadcasting.

B-27. In the HF band (3.0–30 MHz), the range of the ground wave decreases as frequency increases, and the sky waves receive influence from ionospheric considerations. HF is widely used for long distance communications, short-wave broadcasting, and over-the-horizon radar; HF supplements tactical communications when line of sight communications is not possible or feasible.

B-28. In the VHF band (30–300 MHz), there is no usable ground wave and only slight refraction of sky waves by the ionosphere at the lower frequencies. The direct wave (line of sight) provides communication if the transmitting and receiving antennas are elevated high enough above the surface of the Earth.

B-29. In the UHF band (300–3,000 GHz), use the direct wave for all transmissions (15–100 miles). Communication is limited to a short distance beyond the horizon. Lack of static and fading in these bands makes line of sight reception satisfactory. Use directional to concentrate the beam of RF energy, thus increasing the signal intensity. UHF satellite transmissions can cover thousands of miles, depending on altitude, power, and antenna configuration.

PROPAGATION

B-30. Ground waves and sky waves are the two principal paths by which radio waves travel from a transmitter to a receiver. Figure B-3 is an example of the principal paths of radio waves. Ground waves travel directly from the transmitter to the receiver; sky waves travel up to the ionosphere and are refracted (bent downward) back to the earth. Ground waves create short distance, UHF, and upper VHF transmissions. Sky waves principally create long distance transmission. Single-channel radio sets utilize either ground wave or sky wave propagation for communication.

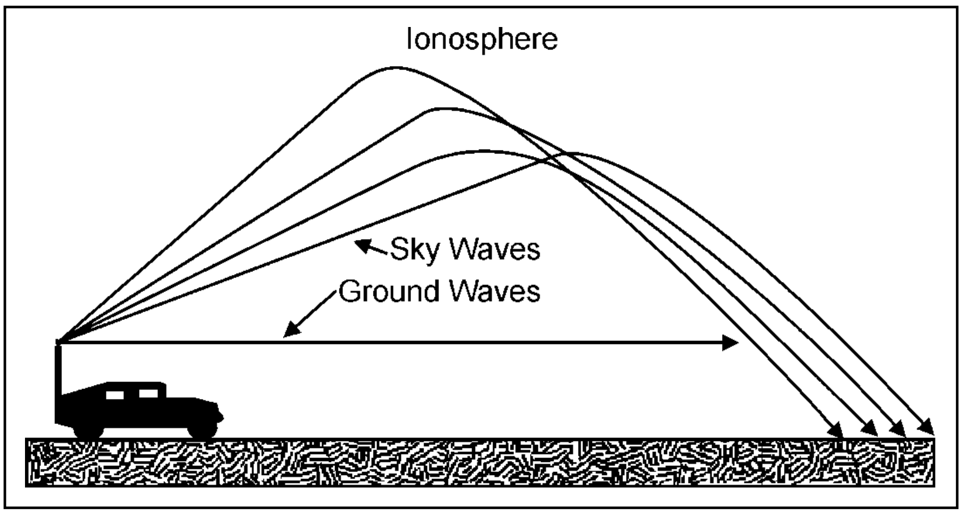


Figure B-3. Principal paths of radio waves

GROUND WAVE PROPAGATION

B-31. Radio communications that use ground wave propagation does not use or depend on waves that refract from the ionosphere (sky waves). The electrical characteristics of the earth and the amount of diffraction (bending) of the waves along the curvature of the earth affect ground wave propagation. The strength of the ground wave at the receiver depends on the power output and frequency of the transmitter, the shape, and conductivity of the earth along the transmission path, and the local weather conditions. Figure B-4, on page B-6, shows possible routes for ground waves.

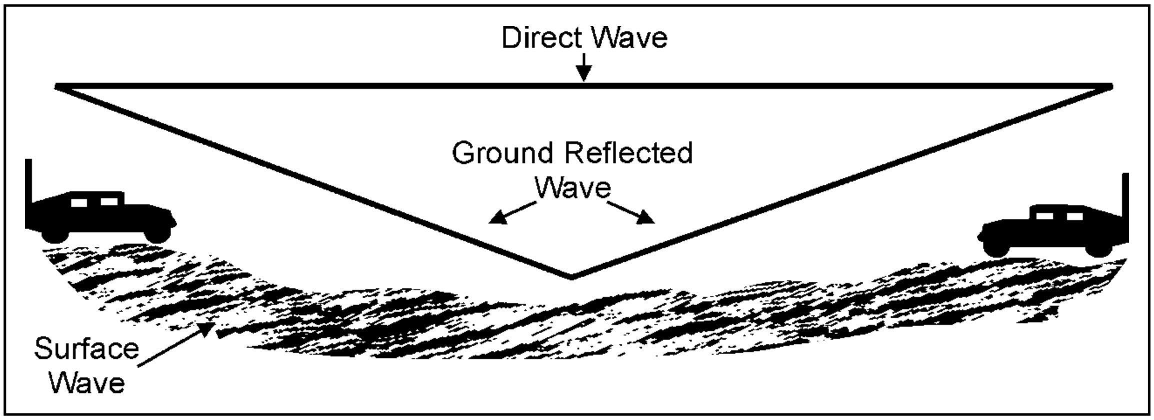


Figure B-4. Possible routes for ground waves

Direct Wave

B-32. The direct wave travels directly from the transmitting antenna to the receiving antenna. The direct part of the wave is limited to the line of sight distance between the transmitting and receiving antennas, and the small distance added by atmospheric refraction and diffraction of the wave around the curvature of the Earth. Increasing the height of the transmitting or receiving antenna, or both, can extend the antenna transmit and receive distance.

Ground-Reflected Wave

B-33. The ground wave reaches the receiving antenna after reflecting from the surface of the earth. Cancellation of the radio signal can occur when the ground reflected component and the direct wave component arrive at the receiving antenna at the same time, and are 180 degrees out of phase with each other.

Surface Wave

B-34. The surface wave follows the Earth's curvature. The earth's conductivity and dielectric constant affects the surface wave.

Frequency Characteristics of Ground Waves

B-35. Various frequencies determine which wave component prevail along any given signal path. For example, when the Earth's conductivity is high and the frequency of a radiated signal is low, the surface wave is the predominant component. For frequencies below 10 MHz, the surface wave is sometimes the predominant component. Above 10 MHz, losses sustained by the surface wave component are so great that the other components (direct and sky wave) become predominant.

B-36. At frequencies of 30–300 kHz, ground losses are very small, so the surface wave component follows the Earth's curvature. Use the Earth's curvature for long-distance communication, provided the radio operator has enough power from the transmitter. Use 300 kHz–3 MHz frequencies for long distance communication over seawater and for medium-distance communication over land.

B-37. At HF, 3–30 MHz, the ground's conductivity is extremely important, especially above 10 MHz where the dielectric constant or conductivity of the Earth's surface determines how much signal absorption occurs. In general, the signal is strongest at the lower frequencies when the surface over which it travels has a high dielectric constant and conductivity.

B-38. The dielectric constant or Earth's surface conductivity determines how much of the surface wave signal energy will be absorbed or lost. Although the Earth's surface conductivity as a whole is generally poor, Table B-3 shows a comparison of the conductivity of varying surface conditions.

Table B-3. Surface conductivity

Surface Type	*Relative Conductivity*
Large body of fresh water	Very good
Ocean or sea water	Good
Flat or hilly loamy soil	Fair
Rocky terrain	Poor
Desert	Poor
Jungle	Very poor

SKY WAVE PROPAGATION

B-39. Radio communications that use sky wave propagation depend on the ionosphere to provide the signal path between the transmitting and receiving antennas. The ionosphere has four distinct layers. These layers labeled D, E, F1, and F2, in the order of increasing heights and decreasing molecular densities. During the day, when the rays of the sun direct toward that portion of the atmosphere, all four layers may be present. During the night, the F1 and F2 layers seem to merge into a single F layer, while the D and E layers fade out. The actual number of layers, their height above the earth, and their relative intensity of ionization, varies constantly. Table B-4 provides a description of the ionosphere layers.

Table B-4. Ionosphere layers

Region	*Description*
D Region	Exists only during daylight hours and has little effect in bending the paths of high frequency radio waves. The main effect of the D region is to attenuate high frequency waves when the transmission path is in sunlit regions.
E Region	Used during the day for high frequency radio transmission over intermediate distances (less than 2,400 kilometers [1,500 miles]). At night, the intensity of the E region decreases and it becomes useless for radio transmission.
F Region	Exists at heights up to 380 kilometers (240 miles) above the earth and is ionized all the time. It has two well-defined layers (F1 and F2) during the day and one layer (F) during the night. At night, the F region remains at a height of about 260 kilometers (170 miles) and is useful for long-range radio communications (over 2,400 kilometers [1,500 miles]). The F2 layer is the most useful of all layers for long-range radio communications, although its degree of ionization varies appreciably from day to day.

B-40. Figure B-5, on page B-8, shows the average layer distribution of the ionosphere.

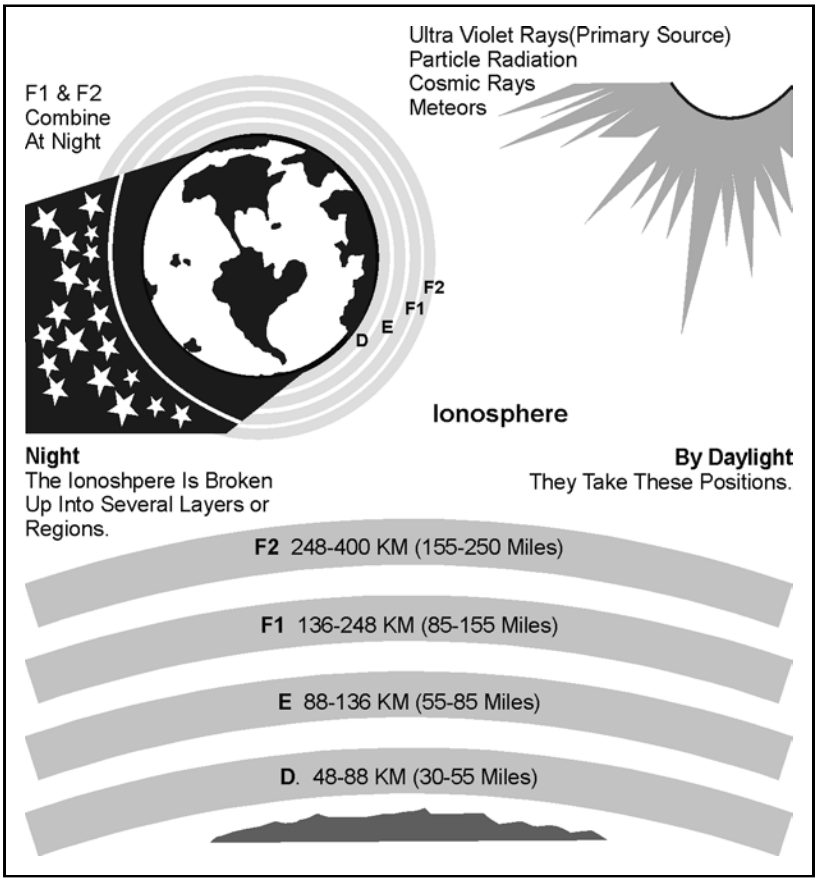


Figure B-5. Average layer distribution of the ionosphere

B-41. The movement of the earth around the sun, and changes in the sun's activity, contribute to ionospheric variations. These variations are regular, and therefore predictable; and irregular, which occur from abnormal behavior of the sun. Table B-5 lists the regular variations of the ionosphere.

Table B-5. Regular variations of the ionosphere

Variation	*Description*
Daily	Caused by the rotation of the earth.
Seasonal	Caused by the north and south progression of the sun.
27-day	Caused by the rotation of the sun on its axis.
11-year	Caused by the sunspot activity cycle going from maximum through minimum back to maximum levels of intensity.

B-42. In planning a communications system, anticipate the status of the four regular variations. Irregular variations must also be considered since they have a degrading effect (at times blanking out communications), which currently cannot be controlled or compensated for. Table B-6, on page B-9, lists some irregular variations of the ionosphere.

Table B-6. Irregular variations of the ionosphere

Variation	*Description*
Sporadic E	When excessively ionized, the E layer often blanks out the reflections back from the higher layers. It can also cause unexpected propagation of signals hundreds of miles beyond the normal range. This effect can occur at any time.
Sudden Ionospheric Disturbance	Coincides with a bright solar eruption, and causes abnormal ionization of the D layer. This effect causes total absorption of all frequencies above approximately 1 MHz. It can occur without warning during daylight hours, and can last from a few minutes to several hours. When it occurs, receivers seem to go dead.
Ionospheric Storms	During these storms, sky wave reception above approximately 1.5 MHz shows low intensity, and is subject to a type of rapid blasting and fading called flutter fading. May last from several hours to several days, and usually extend over the entire earth.
LEGEND **MHz megahertz**	

B-44. Sunspots generate bursts of radiation that cause high levels of ionization. More sunspots equates to greater ionization. During periods of low sunspot activity, frequencies above 20 MHz tend to be unusable because the E and F layers weak ionization reflects signal back to Earth. At the peak of the sunspot cycle, it is unusual to have worldwide propagation on frequencies above 30 MHz.

B-45. Primarily, the ionization density of each layer determines the range of long distance radio transmissions; the higher the frequency, the greater the ionization density required to reflect radio waves back to earth. The upper (E and F) regions reflect the higher frequencies, because they are the most highly ionized. The D region, which is the least ionized, does not reflect frequencies above approximately 500 kHz. At any given time and for each ionized region, there is an upper frequency limit known as critical frequency, which radio waves sent vertically upward reflect back to earth.

B-46. Radio waves directed vertically at frequencies higher than the critical frequency pass through the ionized layer out into space. All radio waves directed vertically into the ionosphere at frequencies lower than the critical frequency reflected back to earth.

B-47. Generally, radio waves used in communications directed toward the ionosphere at some oblique angle, called the angle of incidence. Radio waves at frequencies above the critical frequency reflect back to earth if transmitted at angles of incidence smaller than a certain angle, called the critical angle. At the critical angle, and at all angles larger than the critical angle, the radio waves pass through the ionosphere if the frequency is higher than the critical frequency.

TRANSMISSION PATHS

B-48. Sky wave propagation refers to those types of radio transmissions that depend on the ionosphere to provide signal paths between transmitters and receivers. Figure B-6, on page B-10, shows the sky wave transmission paths. Skip distance refers to the distance from the transmitting antenna to the location, where the sky waves first return to earth. The skip distance depends upon the angle of incidence, the operating frequency, and the height and density of the ionosphere.

B-49. The antenna height, in relation to the operating frequency, affects the angles at which transmitted radio waves strike and penetrate the ionosphere and then return to Earth. Control this angle of incidence to obtain the desired area of coverage. Lowering the antenna height increases the angle of transmission. This provides broad and even signal patterns in an area the size of a typical corps. Near-vertical incident sky wave utilizes near-vertical transmission paths. Raising the antenna height lowers the angle of incidence.

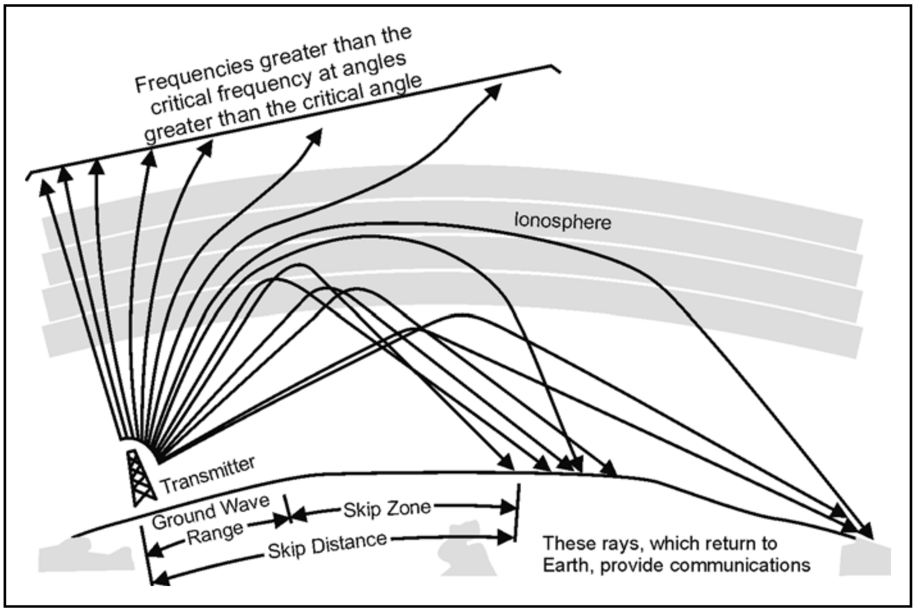


Figure B-6. Sky wave transmission paths

B-50. Lowering the angle of incidence can produce a skip zone in which does not allow the receipt of a usable signal. This bounds the area by the outer edge of usable ground wave propagation and the point nearest the antenna at which the sky wave returns to earth. In corps area communications situations, the skip zone is not a desirable condition. Low angles of incidence make long distance communications possible.

B-51. When a transmitted wave reflects back to the surface of the earth, the earth absorbs part of its energy. The remainder of its energy reflects back into the ionosphere and reflected back to earth again. This means of transmission (by alternately reflecting the radio wave between the ionosphere and the earth) referred to as hops, enable the receiving of radio waves at great distances from the point of origin. Figure B-7 is an example of sky wave transmission hop paths.

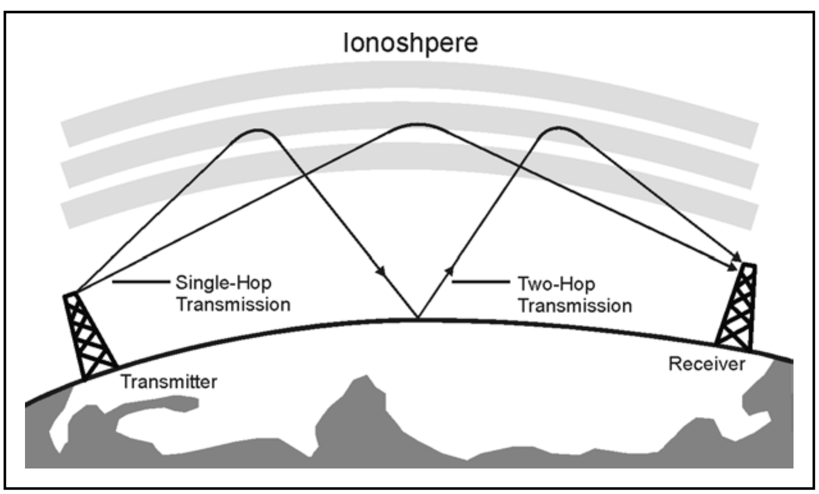


Figure B-7. Sky wave transmission hop paths

Fading

B-52. Fading is the periodic increase and decrease of received signal strength. Fading occurs from a radio signal received over a long distance path in the HF range. There is little common knowledge of what precautions to take to reduce or eliminate fading's troublesome effects. Fading associated with sky wave paths is the greatest detriment to reliable communications. Those responsible for communications circuits rely on raising the transmitter power or increasing antenna gain to overcome fading. Such actions often do not work and seldom improve reliability. Only when the signal level fades down below the background noise level for an appreciable fraction of time increased transmitter power or antenna gain yield an overall circuit improvement. Choosing the correct frequency and using transmitting and receiving equipment intelligently ensure a strong and reliable receiving signal, even when low power is used.

Maximum Usable Frequency and Lowest Usable Frequency

B-53. The maximum usable frequency is the maximum frequency at which a radio wave return to earth at a given distance, when using a given ionized layer and a transmitting antenna with a fixed angle of radiation. It is the monthly median of the daily highest frequency predicted for sky wave transmission over a particular path at a particular hour of the day. The maximum usable frequency is always higher than the critical frequency because the angle of incidence is less than 90 degrees.

B-54. If the distance between the transmitter and the receiver is increased, the maximum usable frequency also increase. Radio waves lose some of their energy through absorption by the D region, and a portion of the E region of the ionosphere, on certain transmission frequencies. The total absorption is less, and communications more satisfactory, when using higher frequencies up to the level of the maximum usable frequency.

B-55. The absorption rate is greatest for frequencies ranging from approximately 500 kHz–2 MHz during the day. During the night, the absorption rate decreases for all frequencies. As the frequency of transmission over any skywave path increases from low to high, a frequency occurs at which the received signal overrides the level of atmospheric and other radio noise interference. This is the lowest usable frequency, because frequencies lower than these are too weak for useful communications. The lowest usable frequency also depends on the power output of the transmitter, and the transmission distance. When the lowest usable frequency is greater than the maximum usable frequency, no sky wave transmission is possible. The spectrum manager uses SPECTRUM XXI to identify optimum frequency groupings.

Other Factors Affecting Propagation

B-56. In VHF and UHF ranges, extending from 30–300 MHz and beyond, the presence of object (buildings or towers for example) may produce strong reflections that arrive at the receiving antenna in such a way that they cancel the signal from the desired propagation path and render communications impossible.

B-57. Choose receiver locations that avoid the proximity of an airfield due to possible adverse electromagnetic interference from signals bouncing off the aircrafts. Avoid locating transmitters and receivers where an airfield is at or near midpoint of the propagation path of frequencies above 20 MHz.

B-58. Many other factors may affect the propagation of a radio wave. Hills, mountains, buildings, water towers, tall fences, and even other antenna can have a marked effect on the condition and reliability of a given propagation path. Conductivity of the local ground or body of water can greatly alter the strength of the transmitted or received signal. Energy radiation from the Sun's surface also greatly affects conditions within the ionosphere and alters the characteristics of long-distance propagation at 2–30 MHz.

Path Loss

B-59. Radio waves become weaker as they spread outwards from the transmitter. Path loss refers to the ratio of the received power. Line of sight paths at VHF and UHF require relatively little power since the total path loss at the radio horizon is only about 25 dB greater than the path loss over the same distance in free space (absence of ground). This additional loss results from some energy reflected from the ground, canceling part of the direct wave energy. This is unavoidable in almost every practical case. The total path loss for a line of sight path above average terrain varies with the following factors—

- Total path loss between transmitting and receiving antenna terminals.
- Frequency.
- Distance.

- Transmitting antenna gain.
- Receiving antenna gain.

Reflected Waves

B-60. Often, it is possible to communicate beyond the normal line of sight distance by exploiting the reflection from a tall building, nearby mountain, or water tower. If the transmitting and receiving antennas can see the top portion of a structure or hill readily, it may be possible to achieve practical communications by directing both antennas toward the point of maximum reflection. If the reflecting object is very large in terms of a wavelength, the path loss, including the reflection, can be very low.

B-61. If a structure or hill exists adjacent to a line of sight path, reflected energy may either add to or subtract from the energy arriving from the direct path. If the reflected energy arrives at the receiving antenna with the same amplitude (strength) as the direct signal but has the opposite phase, both signals cancel and communication is impossible. If the same condition exists but both signals arrive in phase, they add and double the signal strength. These two conditions represent destructive and constructive combinations of the reflected and direct waves.

B-62. Reflection from the ground at the common midpoint between the receiving and transmitting antennas may also arrive in a constructive or destructive manner. Generally, in the VHF and UHF range, the reflected wave is out of phase (destructive) with respect to the direct wave at vertical angles less than a few degrees above the horizon. Since the ground is not a perfect conductor, the amplitude of the reflected wave seldom approaches that of the direct wave. Thus, even though the two arrive out of phase, complete cancellation does not occur. Some improvement may result from using vertical polarization rather than horizontal polarization over line of sight paths because there tends to be less phase difference between direct and reflected waves. The difference is usually less than 10 dB, in favor of vertical polarization.

Diffraction

B-63. Unlike the ship passing beyond the visual horizon, a radio wave does not fade out completely when it reaches the radio horizon. A small amount of radio energy travels beyond the radio horizon by a process called diffraction. Diffraction also occurs when a light source held near an opaque object, casts a shadow on a surface behind it. Near the edge of the shadow, a narrow band displays which is neither completely light nor dark. The transition from total light to total darkness does not occur abruptly, but changes smoothly as the light diffracts.

B-64. A radio wave passing over either the curved surface of the Earth or a mountain ridge behaves in much the same fashion as a light wave. For example, people living in a valley below a high, sharp, mountain ridge can often receive a TV station located many miles below on the other side. Mountain ridges diffract and bend TV station waves downward in the direction of the town. The energy decays very rapidly as the angle of propagation departs from the straight line of sight path. Typically, a diffracted signal may undergo a reduction of 30 to 40 dB by a bend of only 5 feet (1.5 meters) by a mountain ridge. The actual amount of diffracted signal depends on the shape of the surface, the frequency, the diffraction angle, and many other factors. It is sufficient to say that there are times when the use of diffraction becomes practical as a means for communicating in the VHF and UHF over long distances.

Refraction

B-65. Refraction is the bending of a wave as it passes through air layers of different density (refractive index). In semitropical regions, a layer of air 5–100 meters (16.4–328 feet) (thick with distinctive characteristics may form close to the ground, usually the result of a temperature inversion. For example, on an unusually warm day after a rainy spell, the Sun may heat up the ground and create a layer of warm, moist air. After sunset, the air a few meters above the ground cool very rapidly while the moisture in the air close to the ground serves as a blanket for the remaining heat. After a few hours, a sizable difference in temperature may exist between the air near the ground and the air at a height of 10–20 meters (32.8–65.6 feet) resulting in a marked difference in air pressure. Thus, the air near the ground is considerably denser than the air higher up. This condition may exist over an area of several hundred square kilometers or over a long area of land near a seacoast. When such an air mass forms, it usually remains stable until dawn, when the ground begins to cool and the temperature inversion ends.

B-66. When a VHF or UHF radio wave launches within such air mass, it may bend or become trapped (forced to follow the inversion layer). This layer then acts as a duct between the transmitting antenna and a distant receiving site. The effects of such ducting occur frequently during the year in certain locations where TV or VHF FM stations received over paths of several hundred kilometers. The total path loss within such a duct is usually very low and may exceed the free space loss by only a few dBs.

B-67. It is also possible to communicate over long distances by means of tropospheric scatter. At altitudes of a few kilometers, the air mass has varying temperature, pressure, and moisture content. Small fluctuations in tropospheric characteristics at high altitude create blobs. Within a blob, the temperature, pressure, and humidity are different from the surrounding air. If the difference is large enough, it may modify the refractive index at VHF and UHF. A random distribution of these blobs exists at various altitudes at all times. If a high-power transmitter (greater than 1 kilowatt) and high gain antenna (10 dB or more) are used, sufficient energy may be scattered from these blobs down to the receiver to make reliable communication possible over several hundred kilometers. Communications circuits employing this mode of propagation must use very sensitive receivers and some form of diversity to reduce the effects of the rapid and deep fading. Scatter propagation is usually limited to path distances of less than about 500 kilometers (310.6 miles).

Noise

B-68. Noise consists of all undesired radio signals, manmade or natural. Noise masks and degrades useful information reception. The radio signal’s strength is of little importance if the signal power is greater than the received noise power. This is why signal to noise ratio is the most important quantity in a receiving system. Increasing receiver amplification cannot improve the signal to noise ratio since signal and noise amplifies and signal to noise ratio remains unchanged. Normally, receivers have more than enough amplification.

B-69. Natural noise has two principle sources: thunderstorms (atmospheric noise) and stars (galactic noise). Both sources generate sharp pulses of electromagnetic energy over all frequencies. The pulses propagate according to the same laws as manmade signals, and receiving systems must accept them along with the desired signal. Atmospheric noise is dominant from 0–5 MHz, and galactic noise is most important at higher frequencies. Low frequency transmitters must generate very strong signals to overcome noise. Strong signals and strong noise mean that the receiving antenna does not have to be large to collect a usable signal. A 1.5 meter (4.9 feet) tuned whip antenna adequately delivers all of the signals that can be received at frequencies below 1 MHz.

B-70. Manmade noise is a product of urban civilization that appears wherever electric power is used. It is generated anywhere that there is an electric arc (automobile, power lines, motors or fluorescent lights). Each source is small, but there are so many that together they can completely hide a weak signal that would be above the natural noise in rural areas. Manmade noise is troublesome when the receiving antenna is near the source, but being near the source produces exploitable noise wave characteristics. Waves near a source tend to be vertically polarized. A horizontally polarized receiving antenna generally receives less noise than a vertically polarized antenna.

B-71. Any conductors near the source, including the antenna, transmission line, and equipment cases, induce manmade noise currents. If the antenna and transmission line are balanced with respect to the ground, then the noise voltages will balance and cancel with respect to the receiver input terminals (zero voltage across terminals), and this noise will not be received. Near perfect balance is difficult to achieve, but any balance may help.

B-72. Other ways to avoid manmade noise are to locate the most troublesome sources and turn them off, or move the receiving system away from them. Moving at least one kilometer (.6 miles) away from a busy street or highway significantly reduces noise. Although broadband receiving antennas are convenient because they do not require tuning to each working frequency, sometimes a narrowband antenna can make the difference between communicating and not communicating. The HF band is now so crowded with users that electromagnetic interference and noise, not signal strength, are the main reasons for poor communications.

A narrowband antenna rejects strong interfering signals near the desired frequency and helps maintain good communication.

WAVE MODULATION

B-73. FM and AM transmitters produce RF carriers. The carrier is a wave of constant amplitude, frequency, and phase that modulates by changing its amplitude, frequency, or phase. Modulation is the process of superimposing information (voice or coded signals) on the carrier. Figure B-8 shows different wave shapes.

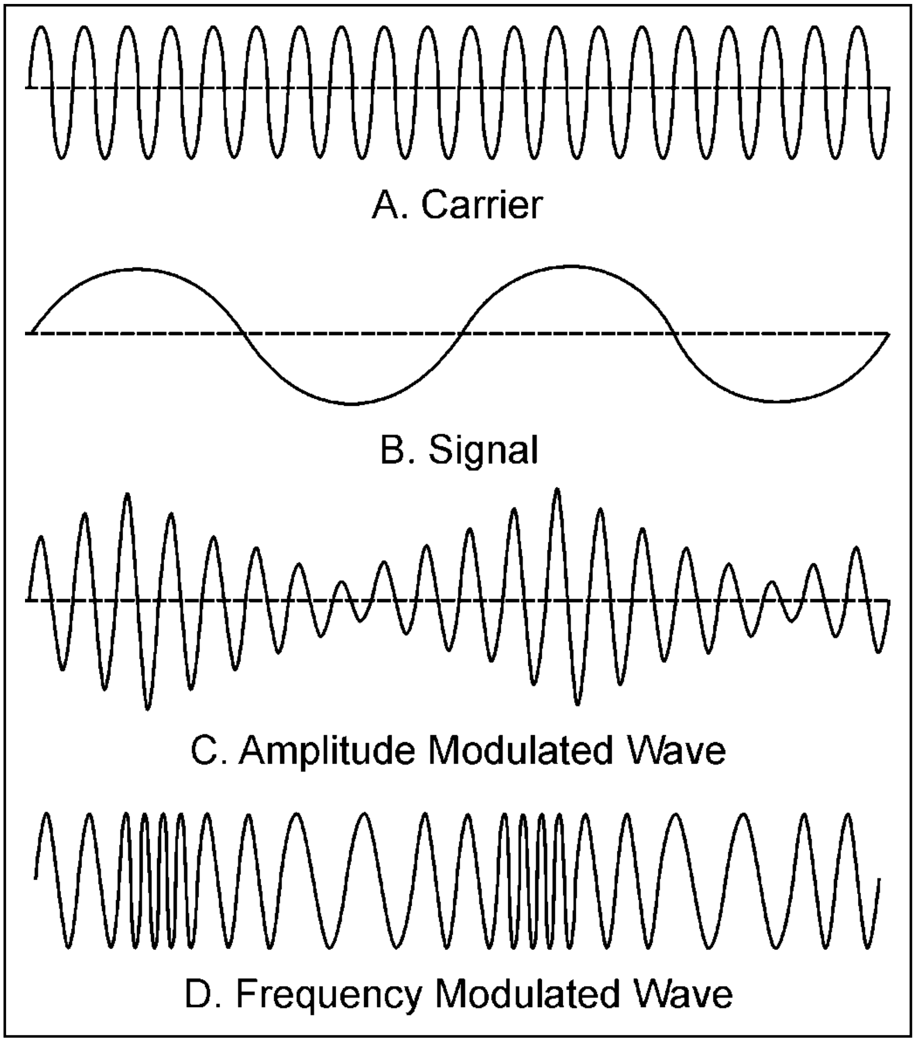


Figure B-8. Wave shapes

AMPLITUDE MODULATION

B-74. AM is the variation of the RF power output of a transmitter at an audio rate. The RF energy increases and decreases in power, according to the audio frequencies superimposed on the carrier signal.

B-75. When audio frequency signals superimpose on the RF carrier signal, additional RF signals generate. These additional frequencies are equal to the sum and the difference of the audio frequency and RF used. For example, assume a 500 kHz carrier modulates by a one kHz audio tone. Two new frequencies develop one at 501 kHz (the sum of 500 kHz and one kHz) and the other at 499 kHz (the difference between 500 kHz and 1 kHz). If using a complex audio signal instead of a single tone, the creation of two new frequencies occurs for each of the audio frequencies involved. New frequencies resulting from superimposing an audio frequency signal on a RF signal are sidebands.

B-76. When the RF carrier modulates by complex tones, such as speech, each separate frequency component of the modulating signal produces its own upper and lower sideband frequencies. The upper sideband contains the sum of the RF and audio frequency signals, and the lower sideband contains the difference between the RF and audio frequency signals. Figure B-9 shows an AM system.

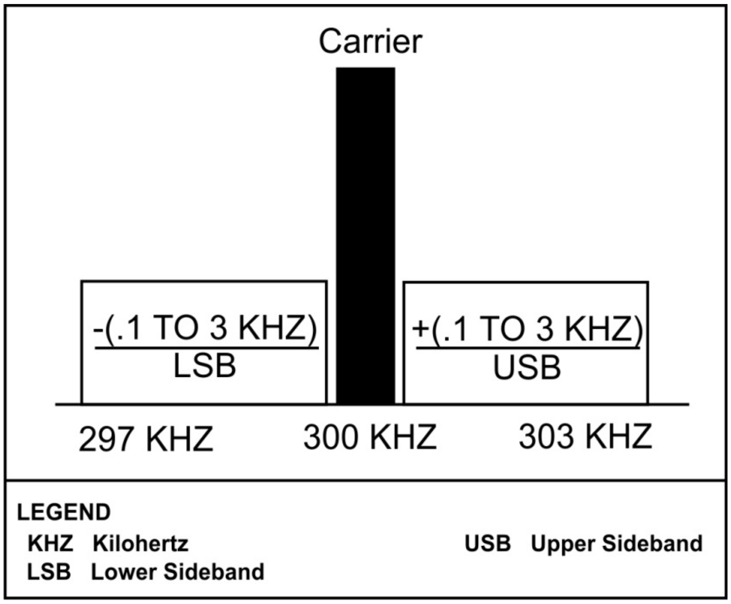


Figure B-9. AM system

B-77. The space occupied by a carrier and its associated sidebands in the RF spectrum is a channel. In AM, the width of the channel (bandwidth) is equal to twice the highest modulating frequency. For example, if a band of frequencies modulates a 5,000 kHz (5 MHz) carrier ranging from 200–5,000 cycles (.2–5 kHz); the upper sideband extends from 5000.2–5005 kHz. The lower sideband extends from 4,999.8–4,995 kHz. Thus, the bandwidth is the difference between 5,005 Hz–4,995 kHz, a total of 10 kHz.

B-78. Radiotelephone transmitters operating in the medium and HF bands generally use AM; the information of an AM signal exists solely in the sidebands.

SINGLE SIDE BAND

B-79. Each sideband contains all the information needed for communication. Although both sidebands generate within the modulation circuitry of the single side band radio set, the carrier and one sideband detach before any signal transmits. Figure B-10, on page B-16, shows a single side band system.

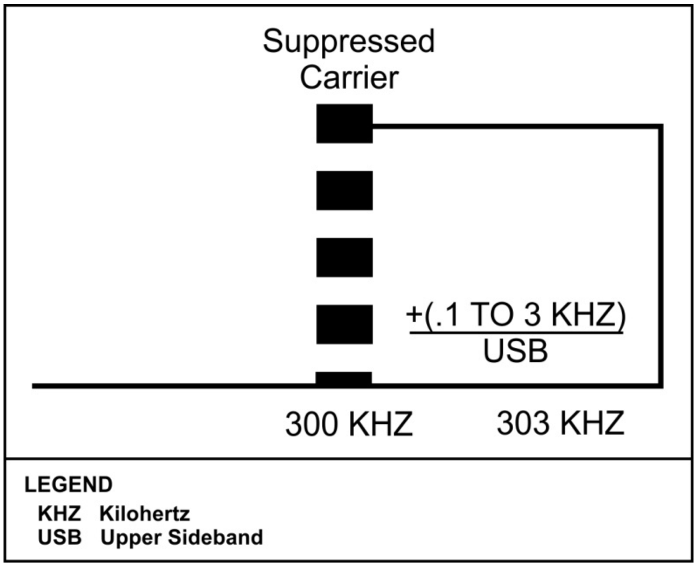


Figure B-10. Single side band system

B-80. The upper side band is higher in frequency than the carrier is and the lower side band is lower in frequency. Use either an upper or a lower side band for communication, provided appropriate adjustment to the transmitter and the receiver to the same sideband. Most Army single side band equipment operates in the upper side band mode.

B-81. The transmission of only one sideband leaves open that portion of the RF spectrum normally occupied by the other sideband of an AM signal. This allows more emitters to be used within a given frequency range.

B-82. Single side band transmission is used in applications where it is desired to—

- Obtain greater reliability.
- Limit size and weight of equipment.
- Increase effective output without increasing antenna voltage.
- Operate a large number of radio sets without heterodyne interference (whistles and squeals) from RF carriers.
- Operate over long ranges without loss of intelligibility due to selective fading.

Appendix C
Antenna Selection

Selecting an antenna that radiates at a high elevation angle is not enough to ensure optimum communications. This appendix addresses the importance of high frequency, very high frequency, ultra high frequency antenna selection.

HIGH FREQUENCY ANTENNA SELECTION

C-1. Radio waves in the 3–30 MHz frequency range are capable of being reflected and returned to Earth by the ionosphere with predictable regularity. To optimize the probability of a successful sky wave communications link, select the frequency, and take-off angle that is most appropriate for the time of day transmission is to take place.

C-2. Various large conducting objects, in particular the Earth's surface, modify an antenna's radiation pattern. Sometimes nearby scattering objects may modify the antenna's pattern favorable by concentrating more power toward the receiving antenna. Often, the pattern alteration results in less signals transmitted toward the receiver.

C-3. When selecting an antenna site, the operator should avoid as many scattering objects as possible. Although near-vertical incident sky wave is the chief mode of short-haul HF propagation, the ground wave and direction (line of sight) modes are also useful over short paths. How far a ground wave is useful depends on the electrical conductivity of the terrain or body of water over which it travels. The direct wave is useful only to the radio horizon, which extends slightly beyond the visual horizon.

ANTENNA SELECTION PROCEDURES

C-4. Selecting the right antenna for an HF radio circuit is very important. When selecting an HF antenna, first consider the type of propagation. Ground wave propagation requires low take-off angle and vertically polarized antennas. The whip antenna included with most radio sets provides good omnidirectional ground wave radiation.

C-5. Selecting an antenna for sky wave propagation is very complex. First, find the circuit (range) distance to ensure that the required take-off angle can be determined. A circuit distance of 966 kilometers (600 miles) requires a take-off angle of approximately 25 degrees during the day and 40 degrees at night. Select a high gain antenna (25–40 degrees). If propagation predictions are available, skip this step, since the predictions give the take-off angles required.

C-6. Next, determine the required coverage. A radio circuit with mobile (vehicle) stations or several stations at different directions from the transmitter requires an omnidirectional antenna. A point-to-point circuit uses either a bidirectional or directional antenna. Normally, the receiving station location dictates this choice. Refer to Table C-1, on page C-2, for take-off angles versus distance.

Table C-1. Take-off angle versus distance

Take off Angle (Degrees)	*Distance*			
	F2 Region Daytime		*F2 Region Nighttime*	
	kilometers	*miles*	*kilometers*	*miles*
0	3220	2000	4508	2800
5	2415	1500	3703	2300
10	1932	1200	2898	1800
15	1450	900	2254	1400
20	1127	700	1771	1100
25	966	600	1610	1000
30	725	450	1328	825
35	644	400	1127	700
40	564	350	966	600
45	443	275	805	500
50	403	250	685	425
60	258	160	443	275
70	153	95	290	180
80	80	50	145	90
90	0	0	0	0

C-7. Before selecting a specific antenna, examine the available construction materials. Horizontal dipoles require at least two supports to erect, with a third support in the middle for frequencies of 5 MHz or less. Do not construct the dipole when support items are unavailable, and select another antenna. Examine the proposed antenna site to determine if the antenna fit the mission requirements. If not, select a different antenna.

C-8. The site is another important consideration. Usually, the tactical situation determines the position of the communications antenna. The ideal setting would be a clear, flat area (no trees, fences, power lines, or mountains). Unfortunately, an ideal location is seldom available. Choose the clearest, flattest area possible. Situations often require constructing an antenna on an irregular site. This does not mean that the antenna will not work. It means that the site affects the antenna's pattern and function.

C-9. After selecting the antenna, determine how to feed the power from the radio to the antenna. The coaxial cable (RG-213) feed most tactical antennas. Coaxial cable is a reasonable compromise of efficiency, convenience, and durability. Issued antennas include the necessary connectors for coaxial cable or for direct connection to the radio.

C-10. Problems may arise in connecting field expedient antenna. The horizontal half-wave dipole uses a balanced transmission line (open-wire). Use coaxial cable but it may cause unwanted RF current.

C-11. A balanced to unbalanced transformer prevents unwanted RF current flow, which causes a radio to be hot or shock the radio operator. Install the balanced to unbalanced transformer at the dipole feed point (center) to prevent unwanted RF current flow on the coaxial cable. If a balanced to unbalanced transformer is unavailable, use the coaxial cable that feeds the antenna as a choke. Connect the cable's center wire to one leg of the dipole and the cable braid to the other leg. Form the coaxial cable into a 6-inch coil (consisting of ten turns), and tape it to the antenna under the insulator for support.

DETERMINING ANTENNA GAIN

C-12. Figure C-1, on page C-3, shows the vertical antenna pattern for the 32-foot vertical whip antenna. The numbers along the outer ring (90, 80, and 70 degrees) represent the angle above the Earth; 90 degrees would be straight up, and 0 degrees would be along the ground. Along the bottom of the pattern are numbers from -10 (at the center) to = 15 (at the edges). These numbers represent the dBi over an isotropic radiator.

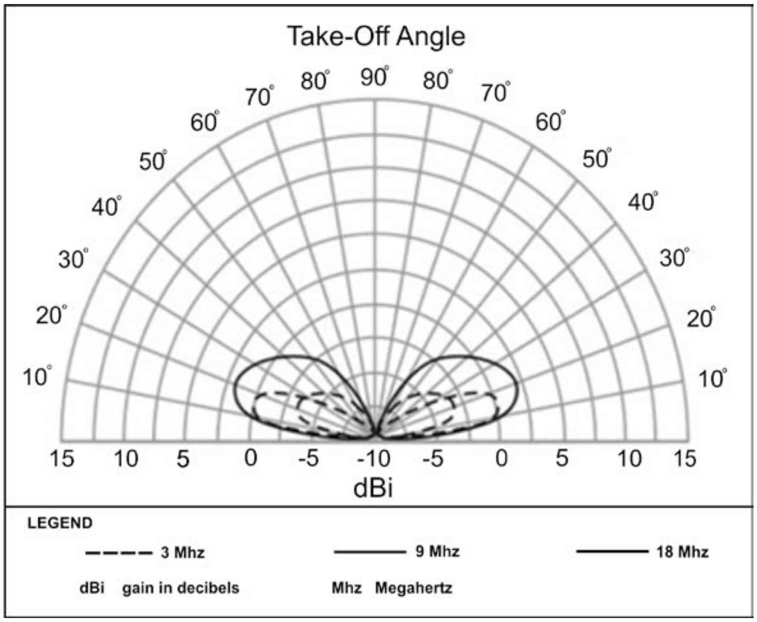


Figure C-1. 32-foot vertical whip, vertical antenna pattern

C-13. To find the antenna gain at a particular frequency and take-off angle, locate the desired take-off angle on the plot. Follow that line toward the center of the plot to the pattern of the desired frequency. Drop down and read the gain from the bottom scale. If the gain of 32-foot vertical whip at 9 MHz and 20-degree take-off angle desired, locate 20-degrees along the outer scale. Follow this line to the 9 MHz pattern line. Move down to the bottom scale. The gain is a little less than 2.5 dBi. The gain of the 32-foot vertical whip at 9 MHz and 20 degrees is 2 dBi.

C-14. Once the antenna's overall characteristics are determined, use the HF antenna selection matrix (Table C-2 on page C-4), to find the specific antenna for a circuit. If the proposed circuit requires a short-range, omnidirectional, wideband antenna, the selection matrix shows that the only antenna that meets all the criteria is the AS-2259/GR.

Table C-2. HF antenna selection matrix

	Use				*Directivity*			*Polarization*		*Band width*	
		Skywave									
	Ground Wave	Short 500 Miles	Medium 500 to 1200 Miles	Long 1200 Miles	Omnidirectional	Bidirectional	Directional	Horizontal	Vertical	Wide	Narrow
AS-2259/GR		X			X					X	
Vertical Whip	X				X				X	X	
Half-Wave Dipole		X	X			X		X			X
Long Wire	X		X	X		X	X		X	X	
Inverted L	X	X	X		X	X		X	X		X
Sloping V	X		X	X			X	X		X	
Vertical Half Rhombic	X		X	X			X		X	X	

UHF AND VHF ANTENNA SELECTION

C-15. The VHF portion of the radio spectrum extends from 30–300 MHz and the UHF range reaches from 300–3,000 MHz (3 GHz). Both frequency ranges are extremely useful for short-range (less than 50 kilometers or 31 miles) communications. This includes point-to-point, mobile, air-to-ground, and general-purpose communications. Wavelengths at these frequencies ranges are considerably shorter.

C-16. Because VHF and UHF antennas are small, it is possible to use multiple radiating elements to form arrays, which provide a considerable gain in a given direction or directions. An array is an arrangement of antenna elements, usually dipoles, used to control the direction in which most of the antenna power radiates.

C-17. Within the VHF and UHF portion of the spectrum, there are sub-frequencies bands for specific uses such VHF aircraft band, UHF aircraft band, and public communications.

POLARIZATION

C-18. In many countries, FM and television broadcasting in the VHF range use horizontal polarization. One reason is that it reduces ignition interference, which is mainly vertically polarized. Mobile communications often is vertical polarization or two reasons. First, the vehicle antenna installation has physical limitations, and second, there is no interruption in the reception or transmission as the vehicle changes heading to achieve Omni directionality.

C-19. Using directional antennas and horizontal polarization (when possible) reduces manmade noise interference in urban locations. Choose horizontal polarization only where an antenna height of many wavelengths is possible. Ground reflections tend to cancel horizontally polarized waves at low angles. Use only vertically polarized antennas when the antenna must be located at a height of less than 10 meters (32.8 feet) above the ground, or when desiring omnidirectional radiation or reception.

GAIN AND DIRECTIVITY

C-20. VHF and UHF (above 30 MHz) antenna gain are extremely important for several reasons. Assuming the same antenna gain and propagation path, the received signal strength drops as frequency is increased. At

VHF and UHF, more of the received signal is lost in the transmission line than is lost at HF. A 10–20 dB loss is uncommon in a 30 meter (98.4 feet) length of coaxial line at 450 MHz.

C-21. At frequencies below 30 MHz, system sensitivity is usually limited by receive noise rather than by noise external to the antenna. Generally, wider modulation or signal bandwidths employ in VHF and UHF transmissions than at HF. Since system noise power is directly proportional to bandwidth, additional antenna gain is necessary to preserve a usable signal to noise ratio.

C-22. VHF and UHF antenna directivity (gain) aids security by restricting the amount of power radiated in unwanted directions. Receiver sensitivity is generally poorer at VHF and UHF (with the exception of high quality state-of-the-art receivers). Obstructions (buildings, trees, hills) may seriously decrease the signal strength available to the receiving antenna because VHF and UHF signals travel a straight line of sight path.

C-23. Obtaining communications reliability over difficult VHF and UHF propagation paths requires considerable attention to the design of high-gain directive antenna arrays. Unlike HF communications, the shorter VHF and UHF wavelengths support walkie-talkie transceivers and simple mobile transmissions units. Communicating or receiving with such devices over distance beyond 1 or 2 kilometers (6 or 1.2 miles) requires maximum antenna gain at the base station or fixed end of the link.

C-24. The best VHF and UHF communications established with line of sight paths that are free from obstacles. The VHF and UHF wavelengths are short enough that it is possible to construct resonant antenna arrays.

C-25. An array provides directivity (the ability to concentrate radiated energy into a beam directed toward the intended receiver). Arrays of resonant elements, (half-wave dipoles, can be constructed of rigid metal rods or tubing or copper foil laid out or pasted on a flat non-conducting surface. Directing power helps to increase the range of the communications path and tends to decrease the likelihood of the interception of jamming from hostile radio stations. Highly directive antennas place an added burden on the radio operator to ensure that the antenna is properly oriented.

ANTENNA PLANNING PROGRAMS

C-26. Several line of sight radios require the planner or operator to do an analysis and prediction of the antennas line of sight paths to ensure the availability of communications from different planned locations. There are several programs designed to generate, store and disseminate communications information for antenna analysis and prediction. The Tactical Internet Management System, as well as terrain and mapping software also generate information for antenna analysis and prediction. The following paragraphs address several programs that are available for use.

SYSTEM PLANNING, ENGINEERING AND EVALUATION DEVICE

C-27. The Marine Corps Tactical Systems Support Activity hosts the system planning, engineering, and evaluation device program. The system planning, engineering, and evaluation device is a software package that provides communications planners with the tools necessary to engineer and plan radio communications analysis.

C-28. The system planning, engineering, and evaluation device is a complete stand alone, self-installing software package that provides the tools necessary to plan and analyze communications equipment. System planning, engineering, and evaluation device software contains HF analysis, radio coverage analysis, point-to-point, and satellite planning tools, which allows planning in response to rapidly changing communications architectures.

C-29. Communications planners load topographical information before each operation to generate report, maps, and matrices.

VOICE OF AMERICA COVERAGE ANALYSIS PROGRAM

C-30. Voice of America Coverage Analysis Program software released to the public is downloadable from the U.S. Department of Commerce (National Telecommunications Information Administration, Institute for Telecommunications Sciences; Boulder, Colorado) to use as a HF prediction and analysis tool. Voice of

America is a component of the International Bureau of Broadcasting, which is an entity within the Broadcasting Board of Governors.

C-31. Voice of America Coverage Analysis Program offers the following capabilities—

- Easy to use graphical user interface.
- Detailed point-to-point graphs and area coverage maps for parameters such as:
  - Signal to noise radio.
  - Required power gain.
  - Signal power.
  - Maximum usable frequency.
  - Take-off and arrival angle.
- Point-to-point performance versus distance for any given parameters at one or all user assigned frequencies.
- Calculates methods for antenna patterns.

C-32. Planners must input several parameters before the Voice of America Coverage Analysis Program is capable of providing propagation prediction such as the method and the antennas used.

IONOSPHERIC COMMUNICATIONS ENHANCED PROFILE ANALYSIS AND CIRCUIT PREDICTION PROGRAM

C-33. The ionospheric communications enhanced profile analysis and circuit prediction program is a full system performance model for HF radio communications in the frequency range of 2–30 MHz. capable of daily prediction methods with improved high latitude propagation models. The ionospheric communications enhanced profile and circuit prediction program provides ionospheric communications analysis and prediction with an ionospheric conductivity and electron density profile model added, which is a statistical model of the large-scale features of the northern hemisphere ionosphere.

Appendix D
Communications in Unusual Environments

Communications in unusual environments require special consideration. This appendix addresses radio operations in cold weather, jungle, urban, desert, mountain areas, and nuclear areas.

COLD WEATHER OPERATIONS

D-1. Single-channel radio equipment has certain capabilities and limitations that require careful consideration when operating in extremely cold areas. In spite of significant limitations, the radio is still the normal means of communication in such areas.

D-2. One of the most important capabilities of radio in cold weather operations is its versatility. Vehicular mounted radios move to almost any point where it is possible to install a command headquarters. Smaller, man packed radios move to any point accessible by aircraft or on foot.

D-3. Electromagnetic interference by ionospheric disturbances limits radio communications in extremely cold areas. These disturbances, known as ionospheric storms, have a definite degrading effect on sky wave propagation. Ionospheric storms and the Northern Lights (aurora borealis) activity can cause complete failure of radio communications. Static may block out some frequencies completely for extended periods during storm activity. Fading, caused by changes in the density and height of the ionosphere, can also occur, and may last from several minutes to several weeks. These occurrences are difficult to predict, but when they do occur, the use of alternate frequencies, and a greater reliance on FM or other means of communications, is required.

TECHNIQUES FOR BETTER COMMUNICATIONS

D-4. When possible, install radio sets for tactical operations in vehicles to reduce the problem of transportation and shelter for radio operators. This resolves some of the grounding and antenna installation problems due to the climate.

D-5. It is difficult to establish good electrical grounds in extremely cold areas because of permafrost and deep snow. The conductivity of frozen ground is often too low to provide good ground wave propagation. To improve ground wave operation, use a counterpoise to offset the degrading effects of poor electrical ground conductivity. Install a counterpoise to prevent snow from covering an antenna. If possible, install the antenna high enough above the ground to prevent snow from covering the antenna.

D-6. In general, antenna installation in arctic-like areas presents no serious difficulties. Installing some antennas may take longer because of adverse working conditions. Tips for installing antennas in extremely cold areas include—

- Handle the mast sections and antenna cables carefully since they become brittle in very low temperatures.
- Construct antennas overhead to prevent damage from heavy snow and frost.
- Use nylon rope guys, if available, in preference to cotton or hemp, because nylon ropes do not readily absorb moisture, and are less likely to freeze and break.
- Use extra guy wires, supports, and anchor stakes to strengthen antennas, and to withstand heavy ice and wind loading.

D-7. Some radios (generally older generation radios) adjusted to a particular frequency in a relatively warm place, may drift off frequency when exposed to extreme cold. Low battery voltage can also cause frequency drift. When possible, allow a radio to warm up several minutes before placing it into operation. Since extreme cold tends to lower output voltage of a dry battery, try warming the battery with body heat before operating the radio set; this minimizes frequency drift.

D-8. Northern regions sometimes experience flakes or pellets of highly electrically charged snow. When these particles strike the antenna, the resulting electrical discharge causes a high-pitched static roar that can blanket all frequencies. To overcome this static, cover antenna elements with polystyrene tape and shellac.

MAINTENANCE IMPROVEMENT

D-9. The maintenance of radio equipment in extreme cold presents many difficulties. Protect radio sets from blowing snow because snow freeze to dials and knobs, and blow into the wiring, which cause shorts and grounds. Carefully handle cords and cables as they may lose their flexibility in extreme cold. Winterize all radio equipment and power units. Check the appropriate TM for winterization procedures. The following paragraphs provide suggestions for radio maintenance in arctic areas.

Power Units

D-10. As the temperature goes down, it becomes increasingly difficult to operate and maintain generators. Protect generators as much as possible from the weather.

Batteries

D-11. The effect of cold weather conditions on wet or dry cell batteries depends on the type of battery, the load on the battery, and the degree of exposure to cold temperatures. Batteries perform best at moderate temperatures and generally have a shorter life at very cold temperatures.

Shock Damage

D-12. Damage may occur to vehicular radio sets by the jolting of the vehicle. Most synthetic rubber shock mounts become stiff and brittle in extreme cold, and fail to cushion equipment. Check the shock mounts frequently, and change them as required.

Winterization

D-13. Check the TMs for the radio set and power source to see if there are special precautions for operation in extremely cold climates. For example, normal lubricants may solidify and permit damage or malfunctions to the radio equipment. Replace normal lubricants with the recommended arctic lubricants. A light coat of silicon compound on antenna mast connections helps to keep them from freezing together and becoming hard to dismantle.

Microphones

D-14. Use standard microphone covers to prevent moisture from breath freezing on the perforated cover plate of the microphone. If standard covers are not available, improvise a suitable cover from rubber or cellophane membranes, or from rayon or nylon cloths.

Breathing and Sweating

D-15. A radio set generates heat when operated. The air inside a powered off radio set cools and contracts, drawing cold air into the set from the outside. This is breathing. When a radio breathes and the still-hot parts encounters subzero air, the glass, plastic, and ceramic parts of the set may cool too rapidly and break.

D-16. Sweating occurs when cold equipment suddenly encounters warm air and moisture condenses on the equipment parts. Before locating cold equipment into a heated area, wrap the equipment in a blanket or parka to ensure that it warms gradually to reduce sweating. Equipment must be thoroughly dry before taking it back into the cold air, or the moisture freeze.

Vehicular Mounted Radios

D-17. These radios present special problems during winter operations because of their continuous exposure to the elements. Observe proper starting procedures. The radio's power switch must be off prior to starting the vehicle, especially when vehicles are slave-started. If the radio is cold soaked from prolonged shutdown, frost may have collected inside the radio and could cause circuit arcing. Allow time for the vehicle's heater to warm the radio sufficiently to ensure that any frost collected within the radio has a chance to thaw.

D-18. The defrosting process may take up to an hour. After powering on the radio, allow the radio to warm up for approximately 15 minutes before transmitting or changing frequencies. This allows components to stabilize.

D-19. A vehicle operated at a low idle with radios, heater, and lights on may drain the batteries. Before increasing engine revolutions per minute charge the batteries. Turn off radios to avoid an excessive power surge.

OPERATIONS IN JUNGLE AREAS

D-20. Limitations on radio communications in jungle areas stem from the climate and the density of jungle growth. The hot and humid climate increases the maintenance problems of keeping equipment operable. Thick jungle growth acts as a vertically polarized absorbing screen for RF energy that, in effect, reduces transmission range. Therefore, increased emphasis on maintenance and antenna site selection is inherently important when operating in jungle areas.

D-21. Radio communications in jungle areas require careful planning. Dense jungle growth, heavy rains, and hilly terrain all significantly reduces the range of radio transmission. Trees and underbrush absorb VHF and UHF radio energy. In addition to the ordinary free space loss between transmitting and receiving antennas, a radio wave passing through a forest undergoes an additional loss. This extra loss increases rapidly as the transmission frequency increase. Near the ground (antenna heights of less than 3 meters [9.8 feet]) vertical polarization is preferred. If it is possible to elevate the receiving and transmitting antenna as much as 10–20 meters (32.8–65.6 feet), horizontal polarization is preferable to vertical polarization. Considerable reduction in total path loss results if either the transmitting or receiving antenna placement occurs above tree level through which communications occurs.

D-22. Single-channel radios deploy in many configurations, especially man packed, which make it a valuable communications asset. Carefully consider the capabilities and limitations of tactical radios when used by friendly forces in a jungle environment. The mobility and various configurations in which the tactical radio deploy are its primary advantages in jungle areas.

TECHNIQUES FOR BETTER COMMUNICATIONS

D-23. The site selection of the antenna is the main problem in establishing radio communications in jungle areas. Techniques to improve communications in the jungle include—

- Place antennas in clearings on the edge farthest from the distant station, and as high as possible.
- Keep antenna cables and connectors off the ground to lessen the effects of moisture, fungus, and insects. This also applies to all power and telephone cables.
- Use complete antenna systems, such as broadband and dipoles. They are more effective than fractional wavelength whip antennas.
- Clear vegetation from antenna sites. If an antenna touches any foliage, especially wet foliage, grounding of the signal occurs.
- Use horizontally polarized antennas in preference to vertically polarized antennas because vegetation, particularly when wet, act as a vertically polarized screen and absorb much of any vertically polarized signal.

MAINTENANCE IMPROVEMENT

D-24. Because of moisture and fungus, the maintenance of radio sets in tropical climates is more difficult than in temperate climates. The high relative humidity causes condensation to form on the equipment, and encourages the growth of fungus. Radio operators and maintenance personnel should check the appropriate TMs for any special maintenance requirements. Techniques for improving maintenance in jungle areas include—

- Keep the equipment as dry as possible and in lighted areas to retard fungal growth.
- Keep all air vents clear of obstructions to ensure that air can properly circulate for cooling and drying of the equipment.
- Use moisture and fungus proofing paint, tape, or silicone grease to protect equipment after repairs, or to protect damaged or scratched painted surfaces.

EXPEDIENT ANTENNAS

D-25. Dismounted patrols, and units of company size and below, can greatly improve their ability to communicate in the jungle by using expedient antennas. While moving, users are generally restricted to using the short or long whip antennas that come with their manpack radios. Utilizing an expedient antenna when stationary allow users to broadcast farther, and receive more clearly. An antenna that is not tuned or cut to the operating frequency is not as effective as the whip antennas supplied with the radio. Circuits inside the radio load the whips properly to tune the radios to give maximum output. Whips are not as effective as a tuned doublet or a broadband (such as the OE-254), when the doublet or broadband is tuned to the operating frequency.

D-26. When used properly, the expedient OE-254 type antenna increases the ability to communicate. In its entirety, the OE-254 type antenna is bulky and heavy, and is not generally acceptable for dismounted patrols or small unit operations. A Soldier can manage by, carrying only the masthead and antenna sections, mounting these on wooden poles, or hanging them up when not on the move.

OPERATIONS IN URBAN AREAS

D-27. Radio communications in urbanized terrain pose special problems. When the Army is engaged in urban combat operations the communications situation is considerably different from the situation faced by civil government or cell phone users. Military factors include—

- Restriction of operation to the frequency range of common military radios (2–512 MHz).
- Limits on the output power of military radio equipment.
- Limited number of available repeater assets if any.
- Limited access to good repeater locations due to enemy action.
- Need to communicate to both outside street locations and inside structures.
- Lack of standard compact antenna systems useful for urban combat.
- Severe restrictions on the movements of system users.
- Lack of manpower required to cover multiple signal sites can easily exceed available resources.
- Problems with obstacles blocking transmission paths.
- Problems with poor electrical conductivity due to pavement surfaces.
- Problem with commercial power lines interference.
- Distorted radio wave propagation in built-up areas and the limited availability of open lines of communication makes it difficult to move and install fixed station and multichannel systems.

D-28. FM and VHF radios have their effectiveness reduced in built-up areas. The operating frequencies and power output of these sets demand line of sight between antennas. Line of sight at street level is not always possible in built-up areas. AM HF sets are less affected by the line of sight problem because operating frequencies are lower, yet power output is greater. In experiences, HF radios were not organic to the small units that conducted clearing operations. RETRANS of VHF signals overcomes this limitation if available to utilize.

TECHNIQUES FOR BETTER COMMUNICATIONS

D-29. When available, RETRANS stations in aerial platforms could provide the most effective means; depending on the requirement, use organic RETRANS sets. Hide or blend radio antennas in with the surroundings to ensure they will not be landmarks for the enemy to locate. Water towers, commercial antennas, and steeples can conceal military antennas.

D-30. Lay wire while friendly forces are in static positions, but careful planning is necessary. Use existing telephone poles to raise wire lines above the streets. Use ditches, culverts, and tunnels to keep the wire below the streets. If not taken as precautions, tracked and wheeled vehicles constantly tear lines apart, and disrupt communications.

D-31. Messengers provide security and flexibility. Carefully select messenger routes to avoid pockets of enemy resistance. Vary routes and time schedules to avoid establishing a pattern. Pyrotechnics, smoke, and marker panels are also excellent means for communicating, but they require coordination and understanding by air and ground forces. The noise of combat in built-up areas makes it difficult to use sound signals effectively.

D-32. The possible seizure or retention of established communications facilities must be included in planning. Make every effort to prevent damage or destruction of these facilities. The local telephone system is already in place and tailored to the city or town. Army forces use local telephone systems to provide immediate access to wire communications with overhead and buried cable. This procedure helps overcome the problems encountered with radios, and provides a cable system less susceptible to combat damage.

D-33. Local media, such as newspapers, radio stations, and television stations, provide communications with the local populace after the level of combat declines. Intact police or taxi communications facilities are also possible radio systems, tailored to the city, with RETRANS facilities already in place.

D-34. Radio equipped vehicles should be parked inside of buildings for cover and concealment when possible; dismount radio equipment, and install it inside buildings (in basements, if available). Place generators against buildings or under sheds to increase noise absorption, provide concealment, and always remember to ensure adequate ventilation is available.

D-35. Another important consideration for urban combat is raw power. The more power used the more path loss and the deeper the signals penetrate into structures. Common tactical VHF man-pack radios like SINCGARS have a maximum output power of four watts. The AN/PRC-150 I HF radio has a maximum output power of 20 watts. That is 7 dB more signal power to overcome losses caused by the path, path obstructions, inefficient antennas and other signal consuming factors. The extra power improves the radio capabilities. The following are examples of power relationships—

- 4 watts = 36 decibels-miliwatt (dBm).
- 20 watts = 43 dBm.
- 50 watts = 47 dBm.
- 150 watts = 52 dBm.
- 400 watts = 56 dBm.

D-36. The dB is a logarithmic unit used to describe a ratio. The ratio may be power, voltage, intensity, or several other factors but in this case, it is power (watts). If the radio operator looks at the math, he sees that he can measure the difference of two power levels by taking a logarithm of $\log_{10}$ of their power ratio. If the ratio of power is, for example, two, meaning one radio transmitter is double the power of the other then the difference is 3dB. Put another way, for every 3dB gained by making a more efficient antenna system or cutting transmission line loss, is the equivalent to doubling the transmitter power.

D-37. The important point is that often, adjustments to antenna systems or operational frequencies to make an antenna more efficient can produce far more dBs of signal power than simply increasing the raw transmitter power. More power assists in overcoming path loss for the near-vertical incident sky wave and ground wave systems but many times it is not the best or only answer to the solution. If the radio is already operating at the maximum power that the transmitter can produce then these adjustments (to the antenna systems or frequencies) do become the only way to compensate for path loss and improve signal penetration in the urban combat environment.

Note. It is important to remember that in some situations the power required to operate a radio may not need to be at the maximum power, use only the power necessary to operate.

D-38. Communications between two radio stations requires that the transmitter power-transmitter antenna gain-receiver antenna gain-receiver performance overcome the path loss between stations. A low power outstation radio such as a man-pack radio with an inefficient antenna used by forward troops can be “compensated for” to a degree when communicating with a base station that is typically using a higher performance receiver and a more efficient antenna. When reserving the path, typically higher-power base-station transmitter and the more efficient antenna again compensates for lower performing combat unit radios in the net. Communications between low-power outstations is much more difficult and may even require RETRANS through a more efficient base station.

D-39. In urban operations, small HF radios, such as the AN/PRC-150 I are extremely portable, but are antenna and power challenged based on location. Obtain a high degree of portable near-vertical incident sky wave effect when needed by physically reorienting standard vertical man-pack or vehicle (whip) antennas to the horizontal plane. Direct (surface wave) signals are simpler to generate and use inside structures produced from the same antenna by just leaving the antenna vertical.

D-40. Because of their longer wavelengths, (lower frequency) HF (2–30 MHz) signals naturally penetrate urban structures deeper than signals on higher, shorter wavelength frequencies. How deep the penetration depends on exact frequency, signal power level, antenna efficiency and the makeup of the urban structures in the path.

D-41. In all radio communications and particularly urban combat radio communications, it is important to overcome path loss. The greater the radiated signal, the lower the frequency the more path loss reduction. This raises the probability of successful communications in urban areas and inside buildings.

D-42. As an example of HF signal penetration, it is not uncommon for a small ground penetrating radar transmitter operating in the HF frequency range to penetrate over 100 feet (30.4 meters) into common kinds of earth while the same power radar on a higher frequency penetrate much less. If the radio operator is using a common VHF military radio operating at 30 MHz (lowest frequency for single-channel ground-to-air radio systems) and replaces it with an HF radio AN/PRC-150 I operating at 5 MHz the path loss drops by 20 dB because of the way that longer wavelength (lower frequency) signals propagate. In this case lowering the frequency is the equivalent to increasing the power of the transmitter by a factor of almost seven.

OPERATIONS IN DESERT AREAS

D-43. Radios are usually the primary means of communications in the desert. Radios employed in desert climate and terrain provide the highly mobile means of communications required for widely dispersed forces. Desert terrain provides poor electrical ground and counterpoises are needed to improve operation. The following paragraphs address operations in desert or arid areas.

D-44. Dust and extreme heat are two of the biggest problems involved in desert operations. Temperatures may vary from 58º Celsius (136º Fahrenheit), in summer, to -46º Celsius (-50º Fahrenheit), in winter. The heat can take a toll on generators, wire, communications equipment, and personnel.

D-45. Dust and sand particles damage equipment. Some CNRs have ventilating ports and channels that may clog with dust. Check these ports regularly and keep clean to prevent overheating.

D-46. In a desert environment, ground equipment by burying ground plates in the sand and by pouring salt solutions on the ground plates. Clean equipment daily (for example, generators, and air filters) to prevent equipment damage.

TECHNIQUES FOR BETTER COMMUNICATIONS

D-47. Cut or adjust antennas to the length of the operating frequency. Emplace antennas in the required direction. Approximate azimuth produced by guesswork is not sufficient. A basic whip antenna relies on the capacitor effect, between itself and the ground, for efficient propagation. The electrical ground may be very poor, and degrade the antenna performance by as much as one-third if the surface soil lacks moisture (which is normally the case in the desert).

D-48. If a ground-mounted antenna is not fitted with a counterpoise (refer to Chapter 10 for more information on a counterpoise), dampen the ground around it using any fluid available. Vehicle mounted antennas are more efficient if the mass (main structure) of the vehicle is forward of the antennas, and is oriented toward the distant station.

D-49. Keep all radios cool and clean in accordance with preventive maintenance. Operate them in a shaded or ventilated area, and at low power whenever possible. Place a flat sheet of wood, cardboard or a vehicle's canvas top over the top of the radio to create manmade shade. Leaving a space between the wood, cardboard and the radio, help to cool the radio by causing air to circulate in the shaded area between the radio and the wood. Using caution, cover hot radios with a damp cloth (ensure it is not soaking wet) without blocking air ventilation outlets; moisture evaporation from the cloth also cools the radio.

DESERT TERRAIN

D-50. Desert terrain can cause excessive signal attenuation, making planning ranges shorter. Desert operations require dispersion, yet the environment is likely to degrade the transmission range of radios, particularly VHFs (FM) fitted with secure equipment. This degradation is most likely to occur during the hottest part of the day, from approximately 1200–1700 hours.

D-51. If, during the hottest time of day, CNR stations begin to lose contact, alternative communications plans must be ready, and may include—

- Using RETRANS capabilities, including airborne RETRANS capabilities (the aircraft must remain at least 4,000 meters behind the line of contact). Plan RETRANS in conjunction with the scheme of maneuver.
- Deploying any unemployed vehicle with a radio as RETRANS between stations.
- Using alternative radio links, such as VHF multichannel telephones at higher level or HF-single side band voice.

D-52. After dark, rapid temperature drop create heat inversion that can disrupt radio communications until the atmosphere stabilizes.

D-53. Do not use wire due to fluid military operations. Wire may be of some value in some static defensive situations. When possible, bury wire and cables deep in the soft sand to prevent heat damage to cable insulation, as well as to prevent vehicle, or foot traffic damage.

D-54. Prevent the exposure of floppy disks and computers to dust and sand. Covering computers and disks with plastic bags reduce damage. Extended periods of covering computers and radios may cause condensation inside these components and subsequent equipment damage or data loss. Compressed air cans facilitate the cleaning of keyboards and other components of computer systems.

D-55. Wind-blown sand and grit damage electrical wire insulation over time. Protect all cables that have the potential for damage with tape. Sand also find its way into parts of items such as spaghetti cord plugs, either preventing electrical contact or making it impossible to join the plugs together. Use a brush, such as an old toothbrush, to clean cords and plugs prior to connection.

D-56. Static electricity is prevalent in the desert. Many factors cause static electricity. One factor is wind-blown dust particles. Extremely low humidity contributes highly to static discharges between charged particles. Poor grounding conditions aggravate the problem. Be sure to tape all sharp edges (tips) of antennas to cut down on wind-caused static discharges and the accompanying noise. Ground equipment properly at all times if you are operating from a fixed position. Since static-caused noise diminishes with an increase in frequency, use the highest frequencies that are available and authorized.

OPERATIONS IN MOUNTAIN AREAS

D-57. Radio operations in mountainous areas have some of the same problems as in cold weather areas. Mobility is difficult in mountainous terrain, and it can be difficult to find a level area for a communications site.

D-58. Generators and communications equipment need level ground to operate properly. It may difficult to drive ground rods and guy wire stakes into rocky, mountainous terrain and an alternate grounding method may be necessary. This rocky soil provides poor grounds. Adding salt solutions improves electrical flow.

D-59. Operating in mountainous terrain may require additional RETRANS assets. Line of sight paths are more difficult to plan, but use of RETRANS capabilities improves communications. Positioning antennas is crucial in mountainous terrain, as moving an antenna, even a small distance, can drastically affect reception.

OPERATIONS IN A NUCLEAR AREA

D-60. A nuclear area adversely affects sensitive radio equipment and components. Take measures to protect signal equipment, and ensure equipment survivability and availability for future use. Nearly everyone is aware of the effects of nuclear blast, heat, and radiation. The ionization of the atmosphere by a nuclear explosion will have degrading effects on communications because of static and the disruption of the ionosphere.

D-61. EMP is the radiation generated because of a nuclear detonation. Gamma rays, high-energy photons, radiate outward from the point of the nuclear detonation, and strip electrons from the atoms in the air. This creates a wall of fast moving, negatively charged electrons, which undergo rapid deceleration, radiating an intense electromagnetic field. This electromagnetic energy affects unprotected communications equipment, causing disruption and destruction of delicate circuitry and components. The residual ionized cloud also causes disruption of transmissions.

D-62. EMP can disable electronic systems as far as 6,000 kilometers (3,720 miles) (for an above the atmosphere [exoatmospheric] or high altitude EMP) from the site of the detonation. EMP can also cause severe disruption and sometimes damage when other weapon effects are absent. The enemy may use a high yield nuclear weapon, burst above the atmosphere to knock out a SC TACSAT communications system’s operational status without doing any other significant damage. The range of EMP diminishes if the weapon detonates at a lower altitude within the atmosphere.

D-63. An idea of the strength of EMP gained when we compare it with fields from manufactured sources. A typical high level EMP could have an intensity (when taking into account the rise time, duration and amplitude of the pulse) which is one thousand times more intense than a radar beam. A radar beam has sufficient power to cause biological damage such as blindness or sterilization. The EMP spectrum is broad and extends from low frequencies into the UHF band. The most likely EMP effect would be stopping communications service temporarily. This can occur even without permanent damage. This delay could give an enemy enough of an advantage to change the outcome of the battle.

D-64. All TACSAT communications systems incorporate built-in features and techniques to counter the EMP effects. Shielding can further reduce the level of the EMP. Shielding is using equipment location and possible known directions of nuclear blasts to reduce EMP exposure. Shielding also depends on good grounding. Electronic systems depend on protection against EMP and signal equipment is very susceptible to EMP.

D-65. All equipment not required in primary systems should remain disconnected and stored within a sealed shelter, or other shielded enclosure, for protection from EMP. This reduces the likelihood of the simultaneous damage of all equipment by EMP, and provides a source of backup components to reinstall affected systems.

D-66. Shield and properly ground wire and cable and keep the cable length as short as possible. Connect shields on all cables to the grounding systems, where provided. Effective grounding is necessary to reduce the effects of EMP.

D-67. Disconnect antennas from radio sets when not in use, and reduce operational networks to a minimum. Most tactical radios with fully closed metal cases provide adequate EMP protection if all external connectors have been removed. Placing radios in vehicles, vans, and underground shelters provides effective protection.

GENERAL RADIO SITE CONSIDERATIONS

D-68. The reliability of radio communications depends largely on the selection of a good radio site. Since it is difficult to select a radio site that satisfies all the technical, tactical, and security requirements, select the best site of all those available. In all cases, sites should be selected with the principals of site defense in mind—observation, avenues of approach, cover, obstacles, and key terrain.

D-69. Site selection is a leader and operator responsibility. It is also good planning to select a primary site and an alternate site. If, for some reason, radio communications cannot be established and maintained at the primary location, move the radio equipment a short distance to the alternate site.

D-70. Locate a radio station in a position that assures communications with all other stations with which it is to operate, while maintaining a degree of physical and communication securities. To obtain efficiency of transmission and reception, the following factors should be considered—

- For operation at frequencies above 30 MHz, and whenever possible, select a location that allow line of sight communications. Try to avoid locations that provide the enemy with a jamming capability, visual sighting, or easy interception.
- Dry ground has high resistance, and limits the range of the radio set. If possible, locate the station near moist ground, which has much less resistance. Water, especially fresh water, greatly increases the distances covered.
- Trees with heavy foliage absorb radio waves, and leafy trees have more of an adverse effect than evergreens. Keep the antenna clear of all foliage and dense brush. Try to use available trees and shrubs for cover and concealment, and for screening from enemy jamming.

D-71. When located near man-made obstructions—

- Do not select an antenna position in a tunnel, or beneath an underpass or steel bridge. Transmission and reception under these conditions are almost impossible because of high absorption of RF energy.
- Avoid buildings located between radio stations, particularly steel and reinforced concrete structures; as they hinder transmission and reception. Try to use buildings to camouflage antennas from the enemy.
- Avoid all types of suspended wire lines, such as telephone, telegraph, and high-tension power lines, when selecting a site for a radio station. Wire lines absorb power from radiating antennas located in their vicinity. They also introduce humming and noise interference in receiving antennas.
- Avoid positions adjacent to heavily traveled roads and highways. In addition to the noise and confusion caused by tanks and trucks, ignition systems in these vehicles may cause electrical interference.
- Do not locate battery charging units and generators close to the radio station.
- Do not locate radio stations close to each other.
- Locate radio stations in relatively quiet areas. The copying of weak signals requires great concentration by the radio operator, and his attention should not be diverted by outside noises.

LOCAL COMMAND REQUIREMENTS

D-72. Radio stations should be located some distance from the unit headquarters or CP they serve. This distance separation ensures that enemy direction finding capability will not target the CP with long-range artillery fire, missiles, or aerial bombardment.

D-73. The locations selected should provide the best cover and concealment possible, consistent with good transmission and reception. Perfect cover and concealment may impair communications. The permissible amount of impairment depends upon the range required, the power of the transmitter, the sensitivity of the receiver, the efficiency of the antenna system, and the nature of the terrain. When a radio communicates over a distance that is well under the maximum range, some sacrifice of communications efficiency takes place to permit better concealment of the radio from enemy observation.

PRACTICAL CONSIDERATIONS

D-74. Manpack radio sets have sufficiently long cordage to permit operation from a concealed position (set and operator), while the antenna is mounted in the best position for communications. Remote control of some radio sets can occur remotely from distances of 30.4 meters (100 feet) or more. The remotely controlled set can be set up in a relatively exposed position, if necessary, while the radio operator remains concealed.

D-75. Mount all radio set antennas higher than ground level to permit normal communications. Small tactical sets usually have whip antennas. These antennas are difficult to see from a distance, especially when not silhouetted against the sky. They have a 360-degree radiation pattern and are extremely vulnerable to enemy listening.

D-76. Avoid open crests of hills and mountains. A position protected from enemy fire just behind the crest gives better concealment and sometimes provides better communications. Camouflage all permanent and semi-permanent positions for protection from aerial and ground observation. The antenna should not touch trees, brush, or the camouflage material.

D-77. Use one well-sited, broadband antenna and a FHMUX to serve several radios. This allows quicker set-up and disassemble times, and reduces camouflaging time and materials.

RADIO OPERATORS SKILLS

D-78. The skills and technical abilities of the radio operators at the transmitter and receiver play important roles in obtaining the maximum range possible. Correctly tune the transmitter, output coupling, and antenna feeder circuits to obtain maximum power output. Properly construct the radiating antenna and the receiving antenna with regard to electrical characteristics and conditions of the local terrain. The radio operator is the main defense against electromagnetic interference by the enemy. The skills of the radio operator can be the final determining factor in maintaining communications in the face of an enemy's efforts to disrupt it.

Appendix E

Julian Date, Synchronization Time, and Time Conversion

Accurate time is essential for single channel ground airborne radios to operate in the frequency-hopping mode. A time variance greater than plus or minus four seconds disrupt the single channel ground airborne radios frequency-hopping communications. This appendix addresses the Julian date, synchronization time, and Zulu time. It also provides a time zone conversion chart.

JULIAN DATE

E-1. The SINCGARS uses a special two-digit form of the Julian date as part of the synchronization time. The two-digit Julian date begins with 01 on 1 January and continues through 00, repeating as necessary to cover the entire year.

E-2. Table E-1 shows the two-digit Julian date calendar for a regular year. The two-digit Julian year terminates on 65 (or 66 for the leap year), every 1 January change the Julian date to 01. This can be accomplished by—

- The NCS sending an electronic remote refill.
- Operators reloading time directly from a defense advanced global positioning system receiver.
- Operators manually changing the date in the radio by using the RT keypad.

Table E-1. Julian date calendar regular year

Day	*JAN*	*FEB*	*MAR*	*APR*	*MAY*	*JUN*	*JUL*	*AUG*	*SEP*	*OCT*	*NOV*	*DEC*
1	01	32	60	91	21	52	82	13	44	74	05	35
2	02	33	61	92	22	53	83	14	45	75	06	36
3	03	34	62	93	23	54	84	15	46	76	07	36
4	04	35	63	94	24	55	85	16	47	77	08	38
5	05	36	64	95	25	56	86	17	48	78	09	39
6	06	37	65	96	26	57	87	18	49	79	10	40
7	07	38	66	97	27	58	88	19	50	80	11	41
8	08	39	67	98	28	59	89	20	51	81	12	42
9	09	40	68	99	29	60	90	21	52	82	13	43
10	10	41	69	00	30	61	91	22	53	83	14	44
11	11	42	70	01	31	62	92	23	54	84	15	45
12	12	43	71	02	32	63	93	24	55	85	16	46
13	13	44	72	03	33	64	94	25	56	86	17	47
14	14	45	73	04	34	65	95	26	57	87	18	48
15	15	46	74	05	35	66	96	27	58	88	19	49
16	16	47	75	06	36	67	97	28	59	89	20	50
17	17	48	76	07	37	68	98	29	60	90	21	51
18	18	49	77	08	38	69	99	30	61	91	22	52
19	19	50	78	09	39	70	00	31	62	92	23	53
20	20	51	79	10	40	71	01	32	63	93	24	54
21	21	52	80	11	41	72	02	33	64	94	25	55
22	22	53	81	12	42	73	03	34	65	95	26	56
23	23	54	82	13	43	74	04	35	66	96	27	57

Table E-1. Julian date calendar regular year (continued)

Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
24	24	55	83	14	44	75	05	36	67	97	28	58
25	25	56	84	15	45	76	06	37	68	98	29	59
26	26	57	85	16	46	77	07	38	69	99	30	60
27	27	58	86	17	47	78	08	39	70	00	31	61
28	28	59	87	18	48	79	09	40	71	01	32	62
29	29		88	19	49	80	10	41	72	02	33	63
30	30		89	20	50	81	11	42	73	03	34	64
31	31		90		51		12	43		04		65

E-3. Table E-2 shows the two-digit Julian date calendar for a leap year.

Table E-2. Julian date calendar (leap year)

Julian Date Calendar (Leap Year)												
Day	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	01	32	61	92	22	53	83	14	45	75	06	36
2	02	33	62	93	23	54	84	15	46	76	07	37
3	03	34	63	94	24	55	85	16	47	77	08	38
4	04	35	64	95	25	56	86	17	48	78	09	39
5	05	36	65	96	26	57	87	18	49	79	10	40
6	06	37	66	97	27	58	88	19	50	80	11	41
7	07	38	67	98	28	59	89	20	51	81	12	42
8	08	39	68	99	29	60	90	21	52	82	13	43
9	09	40	69	00	30	61	91	22	53	83	14	44
10	10	41	70	01	31	62	92	23	54	84	15	45
11	11	42	71	02	32	63	93	24	55	85	16	46
12	12	43	72	03	33	64	94	25	56	86	17	47
13	13	44	73	04	34	65	95	26	57	87	18	48
14	14	45	74	05	35	66	96	27	58	88	19	49
15	15	46	75	06	36	67	97	28	59	89	20	50
16	16	47	76	07	37	68	98	29	60	90	21	51
17	17	48	77	08	38	69	99	30	61	91	22	52
18	18	49	78	09	39	70	00	31	62	92	23	53
19	19	50	79	10	40	71	01	32	63	93	24	54
20	20	51	80	11	41	72	02	33	64	94	25	55
21	21	52	81	12	42	73	03	34	65	95	26	56
22	22	53	82	13	43	74	04	35	66	96	27	57
23	23	54	83	14	44	75	05	36	67	97	28	58
24	24	55	84	15	45	76	06	37	68	98	29	59
25	25	56	85	16	46	77	07	38	69	99	30	60
26	26	57	86	17	47	78	08	39	70	00	31	61
27	27	58	87	18	48	79	09	40	71	01	32	62
28	28	59	88	19	49	80	10	41	72	02	33	63
29	29	60	89	20	50	81	11	42	73	03	34	64
30	30		90	21	51	82	12	43	74	04	35	65
31	31		91		52		13	44		05		66

SYNCHRONIZATION TIME

E-4. To maintain proper synchronization time, the SINCGARS uses seven internal clocks: a base clock, plus one for each of the six frequency hopping channels. Manual and cue settings display the base clock time.

E-5. The defense advanced global positioning system receiver provide units a ready source of highly accurate GPS time. By opening, all networks on GPS time and updating NCS RT synchronization time to

GPS time daily, keeps all networks of a division, corps, or larger force within the plus or minus four-second window required for frequency hopping communications.

ZULU TIME

E-6. Zulu time remains in synchronization with the Naval Observatory Atomic Clock. Zulu time can be confirmed from the U.S. Naval Observatory master. Another alternative is to use the time from a defense advanced global positioning system receiver that is tracking at least one satellite. The NCS should update and verify net time daily or according to unit standing operating procedures.

E-7. There are 25 integer World Time Zones from 12 through 0 Coordinated Universal Time (formerly Greenwich Mean Time) to +12. Each is 15 degrees longitude, as measured East and West, from the Prime Meridian of the earth at Greenwich, England.

E-8. When Coordinated Universal Time is 12:00, the diametrically opposed time zone is 00:00, which the dashed line indicates, and indicates a date change. By convention, the area to the left of the dashed line is the following day, while the area to the right is the preceding day. Table E-3 outlines each time zone around the world, and its relationship to Zulu time.

Table E-3. Example of world time zone conversion (standard time)

Y	X	W	V	U	T	S	R	Q	P	O	N	Z	A	B	C	D	E	F	G	H	I	K	L	M
Civilian Time Zones																								
IDLW	NT	HST	ASDT	PST	MST	CST	EST	AST	NST	AT	WAT	UTC	CET	EET	BT	ZP4	ZP5	ZP6	WAST	CCT	JST	GST	SBT	IDLE
1200	1300	1400	1500	1600	1700	1800	1900**	2000	2100	2200	2300	2400	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200*

Standard Time=Universal Time + Value from Table

Z	0	E	+5	K	+10	P	-3	U	-8
A	+1	F	+6	L	+11	Q	-4	V	-9
B	+2	G	+7	M	+12	R	-5	W	-10
C	+3	H	+8	N	-1	S	-6	X	-11
D	+4	I	+9	O	-2	T	-7	Y	-12

* =Today ** =Yesterday

AT-Azores Time	AWST-Australian Western Standard Time	
IDLW-International Date Line West	WAT-West Africa Time	CCT-China Coast Time
NST-Newfoundland Standard Time	UTC-Coordinated Universal Time	GST-Guam Standard Time
HST-Hawaii Standard Time	CET-Central European Time	JST-Japan Standard Time
EET-Eastern European Time	IDLE-International Date Line East	ASDT-Alaska Standard Time
PST-Pacific Standard Time	BT-Baghdad	NT-Nome Time
MST-Mountain Standard Time	ZP-4	WAST-West Africa Time Zone
CST-Central Standard Time	ZP-5	AST-Atlantic Standard Time
EST-Eastern Standard time	ZP-6	SBT-Solomon Island Time

E-9. Figure E-1, on page E-4, shows a world time zone map.

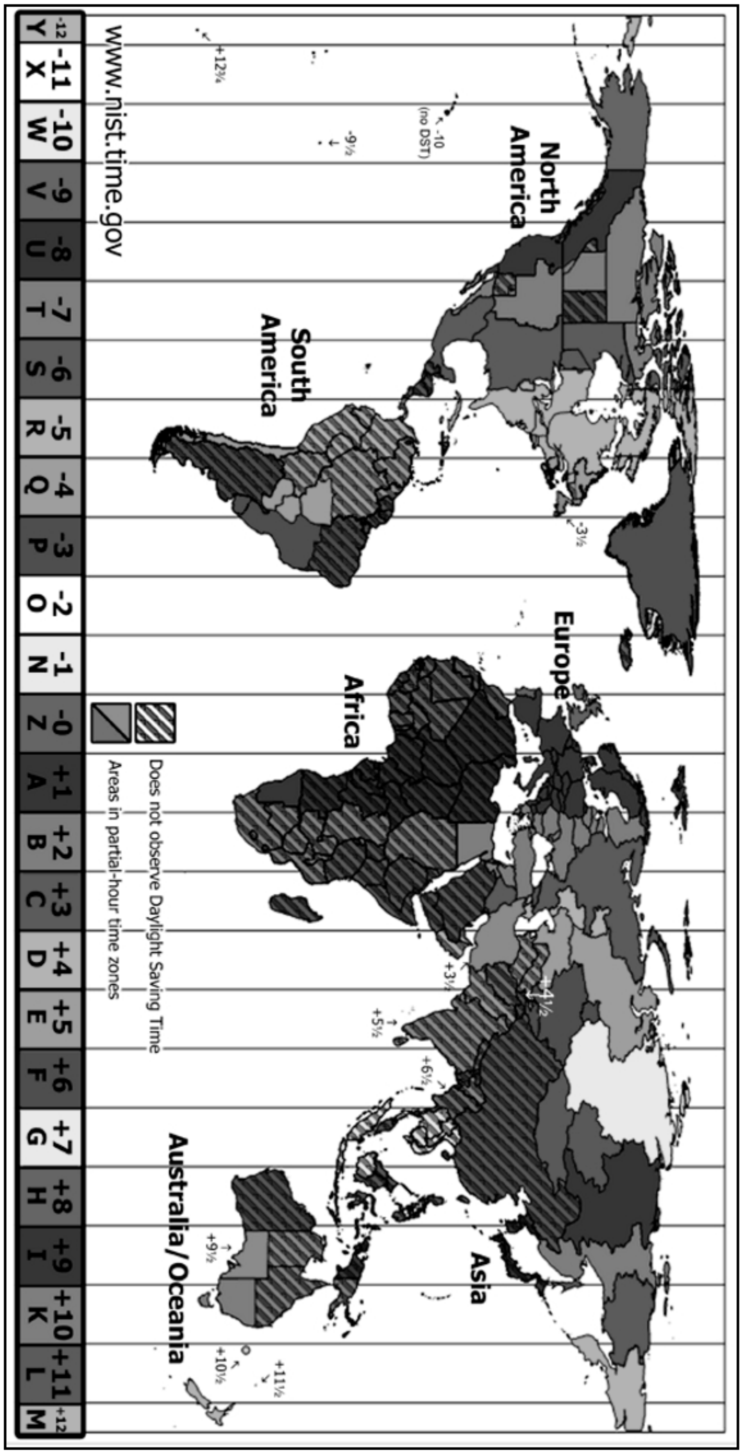


Figure E-1. World time zone map

Appendix F

Radio Compromise Recovery Procedures

Net compromise recovery procedures are essential to maintaining secure communications, and preventing an enemy from disrupting communications due to loss or capture of communications security equipment. This appendix provides procedures for preventing and recovering a network after a compromise, and addresses recovery options available to the commander and his staff.

SECURE COMMUNICATIONS IMPERATIVES

F-1. The following imperatives increase the unit's ability to operate without enemy intervention on its networks—

- SKLs below the battalion level only have the current TEK and KEK of the unit, and the minimum signal operating instructions data to perform the mission.
- Load SKL with network identifier 999 in each fill position, to prevent compromise of unit networks if captured. Do not assign network identifier 999 as an operational network. (SINCGARS has the capability to manipulate all three digits of the network identifier.)
- Store or transport SKLs and cryptographic ignition keys separately to decrease ease of captured equipment operation by the enemy.
- Assign unique KEKs down to the company level. (Situations may arise that require unique KEKs at lower levels.)
- Units assign specific network identifiers as COMSEC recovery networks. (Address predetermined network identifiers in each unit's tactical standard operating procedures operation orders.)

COMPROMISE DETERMINATION

F-2. The S-6, the battalion or brigade operations staff officer, and the S-2 work together in determining the possibility of a compromise and the potential damage the compromise may cause. This damage is determined by evaluating the equipment captured or lost, and what COMSEC key was loaded into the equipment. Upon determining there has been a compromise, COMSEC key replacement is required to secure the network.

F-3. Upon notification by the staff, the commander has three options. He can—

- Immediately implement the unit's compromise recovery procedures to secure the network.
- Extend the use of validated, intact COMSEC keys up to 24-hours. (Only if the commander is the controlling authority.) Commands request permission to change COMSEC keys through the correct command channels.
- As a last resort, continue to use the compromised COMSEC keys.

COMPROMISE RECOVERY

F-4. If the controlling authority decides to continue using the compromised key, the commander, under advisement from the G-6 and S-6, may initiate actions to protect network security.

F-5. If an operational radio and a filled SKL falls into an enemy's hands, the unit standard operating procedures should assume the enemy has English-speaking soldiers who can operate the radio, and SKL. Standard operating procedures should also assume the enemy is able to listen to U.S. secure frequency hopping network communications and can transmit on that same U.S. network, if desired.

F-6. Other assumptions and factors to consider if faced with a compromise recovery requirement include—

- Can the enemy move the captured radio and continue to operate that radio?
- What is the range of the captured radio?

- What is the expected duration of the battery or other power source?
- How long until the next periodic COMSEC key update?
- How serious is the enemy's access to your network?
- What is the potential impact of the captured loadset on other networks?
- What was the nature of, and how critical is, the unit operation at the time that the compromise recovery was considered?

F-7. Two sets of network compromise recovery procedures exist to provide units guidance on recovering from a network compromise. Table F-1, on page F-3, provides procedures for those units that have compromised TEKs and KEKs.

Table F-1. Compromised network recovery procedures: compromised TEKs and KEKs

Step	***Procedure***
1	The net control station is advised of loss of radio, automated net control device, or simple key loader.
2	The S-6 notifies next higher command and controlling authority, and requests permission to change to reserve traffic encryption key.
3	The G-6 or the S-6 and the commander determine if compromise recovery action is warranted. Depending on the operational situation, the G-6 or the S-6 and the commander may elect to temporarily continue to use the presumably compromised network until it is determined that the compromise and compromise procedures will not interfere with current operations.
4	If compromise recovery action is required, the net control station broadcasts unit code word, meaning “Standby for activation of compromise procedures.” (Enemy does not know the meaning of this code-word.)
5	In accordance with compromise procedures, each operator in the network will answer back with “WILCO, out,” verifying they understand and will comply. The operator will then switch to the units predetermined alternate network identifier, and wait for the net control station to perform a network call.
6	The net control station maintains a tracking chart to log all subscribers confirming the code word. If possible, the net control station should maintain additional single-channel ground and airborne radio systems on the old network identifier to ensure that all users move to the alternate network identifier. (Commonly referred to as straggler control.)
7	The net control station then changes to the predetermined alternate network identifier and performs a network call. The net control station operator logs in the users as they answer on the alternate network identifier.
8	Upon gaining controlling authority approval to change to the new traffic encryption key, the net control station will initiate a network call and inform all users of the manual communications security distribution plan. Each radio, automated net control device, and simple key loader will require a manual fill from another device with the new communications security. (This is a mandatory physical distribution due to the key encryption key compromise.)
9	Upon complete distribution of the new communications security, the net control station will initiate a network call, informing the unit of the time to change to the new communications security, and return to the original network identifier.
10	At the designated time, the net control station will return to the original network identifier and log all subscribers on a tracking chart as they return to the original network identifier on the new communications security. If possible, the net control station should maintain an additional radio on the alternate network identifier to ensure that all users transfer over to the original network identifier.
11	The losing unit and network has now effectively recovered from the actual or potential compromise situation.

F-8. Table F-2 provides procedures for those units that have compromised traffic encryption keys only. These procedures offer ways to help protect network security. This is not a substitute for distributing new COMSEC keys as soon as operationally possible.

Table F-2. Compromised network recovery procedures: compromised TEKs

Step	*Procedures*
1	The net control station of the network is advised of loss of radio, automated net control device, or simple key loader.
2	The S-6 notifies next higher command, and controlling authority, and requests permission to change to the reserve traffic encryption key.
3	The assistant chief of staff, signal or the S-6 and the commander determine if compromise recovery action is warranted. Depending on the operational situation, the G-6 or the S-6 and the commander may elect to temporarily continue to use the presumably compromised network until they determine the compromise and compromise procedures will not interfere with current operations.
4	If compromise recovery action is required, the net control station broadcasts unit code-word, meaning "Standby for activation of compromise procedures." (Enemy does not know the meaning of this code-word, and does not know the alternate network identifier.)
5	In accordance with compromise procedures, each operator in the network will answer back with "WILCO, out," verifying that he understands and will comply. The operator will then switch to the alternate network identifier, and wait for the net control station to perform a network call.
6	The net control station maintains a tracking chart to log all subscribers confirming the code-word. If possible, the net control station should maintain an additional radio on the old network identifier to ensure that all users transfer over to the alternate network identifier. (Commonly referred to as straggler control.)
7	The net control station then changes to the predetermined alternate network identifier and performs a network call. The net control station logs in users as they answer on the alternate network identifier.
8	Upon gaining approval from the controlling authority to change to the new traffic encryption key, the net control station will initiate a network call and over-the-air rekeying procedures, or initiate a manual rekeying of the unit's single-channel ground and airborne radio systems and fill devices. (Utilize over-the-air rekeying —automatic key procedures only at the effective time of the COMSEC key.)
9	Upon complete distribution of the new COMSEC key, the net control station will initiate a network call informing the unit of the time to change to the new COMSEC key and return to the original network identifier.
10	At the designated time, the net control station will return to the original network identifier and log all subscribers on a tracking chart as they return to the original network identifier on the new COMSEC key. If possible, the net control station should maintain an additional radio on the alternate network identifier to ensure that all users transfer to the original network identifier.
11	The losing unit and network has now effectively recovered from the actual or potential compromise situation.

F-9. Since the entire division and brigade is operating on the same TEK, the division G-6 and brigade S-6 may elect to have all networks change to a new TEK. Accomplish this change by the physical transfer from SKL to SKL, or by over-the-air rekeying, as most appropriate for the operational situation.

Appendix G
Data Communications

This appendix addresses data communications elements such as binary data, baud rate, modems, and forward error correction.

BINARY DATA

G-1. Bits are part of a numbering system (binary digits) having a base of two that uses only the symbols 0 and 1. Thus, a bit is any variable that assumes two distinct states. For example, a switch is open or closed; a voltage is positive or negative. In terms of communications, words become binary digits for transformation over a channel (specific frequency range), via a HF radio transmitter, to a HF receiver.

G-2. A simple way to communicate binary data is to switch a circuit on and off in patterns that are interpreted at the other end; the same as the telegraph. Later schemes used a bit to select one of two possible states of the properties that characterize a carrier, FM or AM. Currently, the carrier assumes more than two states, and is able to represent multiple bits.

BAUD RATE

G-3. Measure data transmission speed in bits per second. The word baud represents bits per second, although the terms are different. Baud measures the signaling speed and is a measurement of symbols per second. Symbols may represent a bit or more.

G-4. The bandwidth determines the maximum baud rate on a radio channel; the larger the bandwidth, the greater the baud rate. The rate at which information is transmitted (the bit rate) depends on how many bits are used per symbol.

ASYNCHRONOUS AND SYNCHRONOUS DATA

G-5. The transmission of data occurs in either the asynchronous or the synchronous mode. In asynchronous data transmission, each character has a start and stop bit. The start bit prepares the data receiver to accept the character. The stop bit brings the data receiver back to the wait state. Synchronous data transmission eliminates the start and stop bits. This type of system typically uses a preamble (a known sequence of bits at the start of the message) to synchronize the receiver's internal clock and to alert the data receiver that a message is coming.

G-6. Asynchronous systems eliminate the need for complex synchronization circuits, but at the cost of higher overhead than synchronous systems. With asynchronous systems the start and stop bits increase the length of the character from 8 bits (one byte) to 10 bits, a 25 percent increase.

HIGH FREQUENCY MODEMS

G-7. The average voice radio cannot transmit data directly. Convert data digital voltage levels to audio using a modulator device that applies the audio to the transmitter. At the receiver, a demodulator converts the audio back to digital voltage levels. HF modems fall into three basic categories—

- Modems with slow-speed audio FSK capable of operating at data rates of 75, 150, 300, and 600 bits per second.
- High-speed parallel tone.
- High-speed serial tone capable of operating at data rates between 75 and 2, 400 bits per second.

G-8. The simplest modems use FSK to encode binary data. The input to the modulator is a digital signal that takes one of two possible voltage levels. The output of the modulator is an audio signal that is one of two possible tones. HF FSK systems are limited to data rates less than 75 bits per second, due to the effects of multipath propagation. Higher rates are possible with multi-tone FSK, which uses a greater number of frequencies.

G-9. High-speed HF modem technology, using parallel and serial tone waveforms, allows data transmissions at up to 4,800 bits per second. The serial tone modem carries information on a single audio tone. This vastly improves data communications on HF channels, including greater toughness, less sensitivity to electromagnetic interference, and a higher data rate with more powerful forward error correction.

IMPROVED DATA MODEM

G-10. The improved data modem allows air and ground forces to exchange complex information in short bursts. It permits four different radios to simultaneously transmit and receive information, transmit data at 16,000 bits per second, and process messages up to 3,500 characters in length. The improved data modem allows air and ground forces to exchange information on the Tactical Internet via BFT satellite transponders. Interface to the aviation platform is through MIL-STD-1553B data bus, or Ethernet interface.

FORWARD ERROR CODING

G-11. Forward error correction adds redundant data to the data stream to allow the data receiver to detect and correct errors. It does not require a return channel for the acknowledgment. If a data receiver detects an error, it simply corrects it and accurately reproduces the original data without notifying the data sender that there was an error.

G-12. Forward error correction coding is most effective if errors occur randomly in a data stream. The HF medium typically introduces errors that occur in bursts. To take advantage of the forward error correction coding technique, interleaving randomizes the errors that occur in the channel. At the demodulator, de-interleaving reverses the process.

G-13. Soft-decision decoding further enhances the power of the error correction coding. In this process, a comparison for a group of detected symbols that retains its analog character occurs against a set of possible transmitted code words. The system remembers the voltage from the detector, and applies a weighing factor to each symbol in the code word before making a decision about the transmitted code word.

G-14. Data communications techniques also encrypt voice calls by a voice encoder, a derivative of voice coder-decoder. The voice encoder converts sound into a data stream for transmission over a HF channel. The voice encoder at the receiving end reconstructs the data into telephone quality sound.

G-15. In addition to error correction techniques, high-speed serial modems may include two signal-processing schemes that improve data transmission. An automatic-channel equalizer compensates for variations in the channel characteristics when receiving the data. An adaptive excision filter seeks output, and suppresses narrowband electromagnetic interference in the demodulator input, thereby reducing the effects of co-channel electromagnetic interference; electromagnetic interference on the same channel being used.

Appendix H

Cosite Interference

The complexity of telecommunications systems, the emplacement of several antennas on the same platform, multiple radios on the same or dissimilar frequency bands are all factors that cause cosite interference to communications and degrades system performance. This appendix addresses single channel ground airborne radio system implications and cosite interference mitigation.

SINCGARS IMPLICATIONS

H-1. Due to SINCGARS frequency hopping capabilities, frequency management alone does not reduce cosite interference. The addition of computer central processing units, displays, switches, routers, hubs, and cables in the confined CP amplifies the potential for cosite interference. Within a CP or a mobile platform (vehicle or aircraft), cosite interference depends on several factors, including—

- The number of transmitters within the restricted area.
- The duty cycle of each transmitter-the transmitting time of the radio, divided by the transmitting time plus the time before the next transmission. (Example: if a radio transmits for four seconds and waits six seconds before the next transmission, the duty cycle is 40 percent.)
- The hopset bandwidth (if hopping).
- An increase in the system data rate increases the electromagnetic flux of the system, thus increasing cosite interference potential.
- Antenna placement.
- Equipment shielding.
- Bonding.
- Grounding.

H-2. SINCGARS that habitually transmit to distances of 35–40 kilometers (21.7–24.8 miles), by themselves, can transmit at distances reduced to less than 5 kilometers (3.1 miles) when influenced by cosite interference. This degradation, if not properly addressed, adversely distress the flow of communications. This distress may lead to the physical shutdown of non-critical systems that pass information onto critical systems.

H-3. SINCGARS transmitting at maximum power with collocated radio terminals operating on the same frequency spectrum degrade communications performance due to high receiver noise-energy levels in the collocated radio equipment that are operating on the same frequency spectrum. Antennas require 20+ feet of separation to overcome the SINCGARS-generated increase in background noise. This separation allows an acceptable signal to noise ratio for other radios to establish a successful link.

H-4. If SINCGARS transmits at a power of four watts or less, collocated radios can establish a voice link with some reduction in data quality. SINCGARS low power (4 watts) output reduces the SINCGARS planning range by 90 percent, and subjects the SINCGARS to increased noise generated by the collocated, transmitting radios.

H-5. When configuring SINCGARS to hop outside the prescribed frequency range of a collocated radio (59–88 MHz outside the continental United States or 40–50 MHz continental United States, plus an additional 5 MHz cushion in both areas of operation), the other radio is relatively resistant to SINCGARS cosite interference. This causes a significant reduction of the available frequency spectrum, and a constraint on the capabilities of the SINCGARS. Full frequency range and full power hopping transmissions from SINCGARS reduces operational distances.

COSITE INTERFERENCE MITIGATION

H-6. Cosite interference is the effect of unwanted energy, due to emissions, radiation, or induction, on reception in a radio communications system. This could cause system performance degradation, misinterpretation, or loss of information. A number of options are available to mitigate cosite interference, but there are no comprehensive solutions. The user must decide if an option is applicable to his tactical situation, and take the appropriate action to resolve cosite interference.

H-7. Some equipment systems are not as critical as others are. The G-6 and S-6 recommend to the commander a system priority list that ensures the transmission of critical mission information. During interference, the G-6 and S-6 must be prepared to shut down less critical systems. The following paragraphs address ways to reduce cosite interference.

TRANSMISSION

H-8. When possible and operationally acceptable, transmit at the lowest power level. This allows collocated SINCGARS and other transmission systems to operate with minimal interference in data and voice communications at the receivers. This option may be unacceptable due to the significant transmission range reduction of the SINCGARS.

H-9. Remotely locating antennas and transmitting from the CP at low power to a full power RETRANS system mitigates cosite interference. Certain critical CP networks would then be able to maintain their high power advantage.

ANTENNA PLACEMENT

H-10. Antenna placement is critical when the antennas operate in the same or nearby frequency range(s); separate antennas as much as possible. The greater the separation between the transmitting and receiving antennas, the less interference encountered. As required issue CPs, a significant quantity of mast-mounted antennas (OE-254 or equivalent) to match the number of installed SINCGARS. Extra length low-loss coaxial transmission lines should be included with each requirement. This may cause an increase in the physical size of the CP location, and an increase in CP setup and disassembly times.

H-11. Tilting the tops of the transmitting and receiving antennas away from each other can enhance vertically polarized ground wave communications. Tilt angles between 15 and 30 degrees provide the best results. Achieve the best angle by trial and error.

DIRECTIONAL ANTENNAS

H-12. Use directional antennas whenever possible. This may require the prefabrication of VHF directional antennas, since these are not available in the current Army inventory. Change antenna polarization on systems where distance is not an issue. A horizontally polarized ground wave has less signal loss than a vertically polarized ground wave if antenna heights exceed treetop levels or other horizontal energy absorbers.

MAST ASSEMBLIES

H-13. If possible, stack antennas in the null space of another vertical antenna. The radiation pattern of a vertical antenna has a deep energy void directly overhead (90 degrees). Figure H-1, on page H-3, shows possible antenna stacks. Configure the mast assemblies to mount two OE-254 broadband antennas using vertical separation.

H-14. Both dual-antenna mast assemblies must provide at least 12 dB or greater antenna isolation (at 30 MHz) over that obtained using the same distance horizontal separation. Take advantage of the lateral wave propagation of vertical antennas. Energy transference is negligible on a receiving antenna in this null space. Early fabrication of mounting devices may be required to achieve antenna stacking.

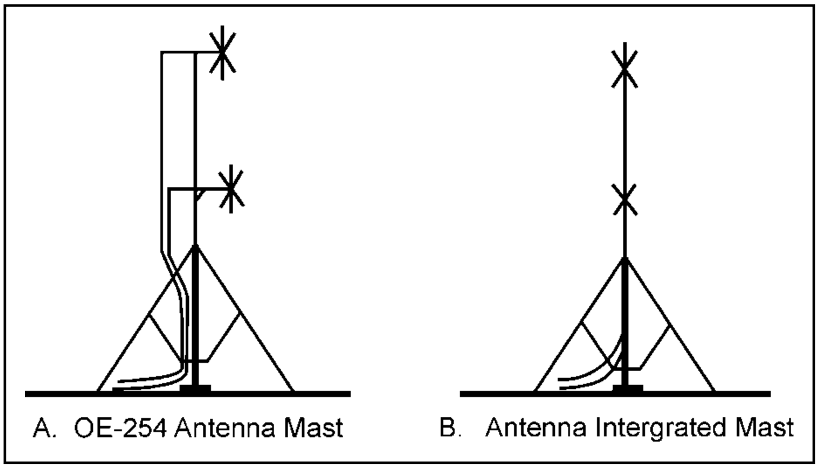


Figure H-1. Possible antenna stacks

GROUNDING

H-15. Properly ground electronic equipment within the CP. Proper grounding ensures that each item does not develop interference-producing electromagnetic fields, or simulate the properties of an unwanted, energy-radiating transmitting antenna within the CP.

H-16. Another option is to counterpoise the antenna. The wires used in the counterpoise should be either a half wavelength, or a full wavelength long for best results. Achieve a greater direction gain by placing the counterpoise wires in the direction of the receiving antenna. (Refer to Chapter 10 for more information on how to construct a counterpoise.)

SINGLE CHANNEL OPERATIONS

H-17. When operating against less sophisticated adversaries, using SINCGARS single-channel mode of operation also mitigates cosite interference. Even when operating at full power, properly chosen frequencies can reduce cosite interference, and provide increased range capability due to better bit error rate, inherent with single-channel operation.

INITIATIVES

H-18. Two cosite mitigation initiatives are the FHMUX, and the software defined family of radios. Communications integration and cosite mitigation science and technology objectives products enhance both initiatives.

Frequency Hopping Multiplexer

H-19. The FHMUX, TD-1456/VRC is a hardware solution to cosite interference. It is compatible with the SINCGARS in EP (frequency hopping) and single-channel (non-frequency hopping) modes of operation. Table H-1, on page H-4, shows the effects of multiple transmitters on transmission ranges (within a vehicle) with and without the FHMUX. The FHMUX is an antenna multi-coupler that—

- Reduces visual signature of the command vehicle, by reducing the antenna count, thus increasing the survivability of the vehicle.
- Reduces collocated network-to-network interference (cosite).
- Reduces setup time. The user erects one OE-254 antenna, and four networks are operational via the FHMUX. The FHMUX is compatible with high power whip antennas, such as the AS-3900A/VRC or AS-3916/VRC.

- Reduces the parasitic effect of the antennas. The transmit radiation of one antenna in close proximity (10 feet/3 meters) interact with another antenna producing undesirable distortions within the pattern of each antenna.
- Provides up to 300 meters (.3 kilometers) multi-coupler to antenna separation, to reduce exposure of the CP to hostile fire.
- Provides frequency conflict arbitration software that optimizes the transmission range.

Table H-1. Transmitters and transmission ranges with and without the FHMUX

Transmitters On	*Range to target receiver without FHMUX*	*Range to target receiver with FHMUX*
zero	35 kilometers or 21.7 miles	35 kilometers or 21.7 miles
one	14 kilometers or 8.6 miles	32 kilometers or 19.8 miles
two	9 kilometers or 5.5 miles	27 kilometers or 16.7 miles
three	3 kilometers or 1.8 miles	19 kilometers or 11.8 miles

Legend:
FHMUX frequency hopping multiplexer

Note. Range to target receiver from a vehicle, compared to the number of transmitters operating on the vehicle.

H-20. The FHMUX contains bandpass filters that tune synchronously with the radios. These filters remove most of the broadband transmit interference. Signals coming from the antenna also pass through these bandpass filters, and remove strong non-bandpass signals. This greatly improves the performance of the radio system when in a cosite environment.

H-21. In the EP mode, the FHMUX is most effective when the hopset contains at least 800 channels and it spreads over at least 20 MHz of the VHF band. When enemy intrusion is not an issue, and the single-channel mode is used, the FHMUX is most effective when frequencies separation takes place by a five percent delta for each radio. (Refer to TB 9-2320-387-35-4 for more information on the FHMUX.)

Software Defined Radio Platform

H-22. The software defined radio platform technology eliminates most, if not all, co-site interference problems that occur when multiple radios in the same or dissimilar frequency bands integrate within the same mobile communications CP platform. The software defined radio platform operates at full performance levels, and does not degrade mission effectiveness of host systems and platforms engaged in their tactical environments, including weapons firing and movements.

H-23. The VHF and UHF multiplexer utilize RF signal combining, and cosite mitigation technology to reduce the platform antenna visual signature and software defined radio platform self-jamming interference. The initial and objective multiplexer development efforts exploit emerging technology applications in the areas of wideband interference mitigation and compact delay lines.

H-24. Communications integration and cosite mitigation science and technology includes a multiband VHF and UHF power amplifier that eliminates dissimilar legacy radio amplifiers and their logistics, training, and maintenance infrastructures, and provides a programmable software defined radio waveform capability. The power amplifier utilizes laterally diffused metal oxide semiconductor and silicone carbide device technology to meet higher power and frequency requirements.

Appendix I
Radio Operating Procedures

This chapter addresses the proper way to pronounce letters and numbers when sending messages over a radio as well as the proper procedures for opening and closing a radio net.

PHONETIC ALPHABET

I-1. A phonetic alphabet is a list of words used to identify letters in a message transmitted by radio or telephone as seen in Table I-1. Spoken words from an approved list substitute for letters. Radio operators communicate over the radio, using the phonetic alphabet to pronounce individual letters of the alphabet.

Table I-1. Phonetic alphabet

LETTER	*WORD*	*PRONUNCIATION*
A	ALPHA	AL FAH
B	BRAVO	BRAH VOH
C	CHARLIE	CHAR LEE OR SHAR LEE
D	DELTA	DELL TAH
E	ECHO	ECH OH
F	FOXTROT	FOKS TROT
G	GOLF	GOLF
H	HOTEL	HOH TELL
I	INDIA	IN DEE AH
J	JULIETT	JEW LEE ETT
K	KILO	KEY LOH
L	LIMA	LEE MAH
M	MIKE	MIKE
N	NOVEMBER	NO VEM BER
O	OSCAR	OSS CAH
P	PAPA	PAH PAH
Q	QUEBEC	KEH BECK
R	ROMEO	ROW ME OH
S	SIERRA	SEE AIR RAH
T	TANGO	TANG GO
U	UNIFORM	YOU NEE FORM OR OO NEE FORM
V	VICTOR	VIC TAH
W	WISKEY	WISS KEY
X	XRAY	ECKS RAY
Y	YANKEE	YANG KEY
Z	ZULU	ZOO LOO

NUMERICAL PRONUNCIATION

I-2. To distinguish numerals from words similarly pronounced, the proword use "FIGURES" preceding such numbers. Table I-2 outlines how to pronounce numerals transmitted by radio.

Table I-2. Numerical pronunciation

NUMERAL	*SPOKEN AS*
0	ZE-RO
1	WUN
2	TOO
3	TREE
4	FOW-ER
5	FIFE
6	SIX
7	SEV-EN
8	AIT
9	NIN-ER

I-3. Transmit numbers digit by digit. Exact multiples of thousands may be spoken as such (refer to Table I-3). There are special cases, such as anti-air warfare reporting procedures, when the normal pronunciation of numerals as prescribed for example, 17 would then be "seventeen."

Table I-3. Numerals in combinations

NUMBERAL	*SPOKEN AS*
44	FOW-ER, FOW-ER
90	NIN-ER, ZE-RO
136	WUN, TREE, SIX
TIME 1200	WUN, TOO, ZE-RO, ZE-RO
1748	WUN, SEV-EN, FOW-ER, AIT
7000	SEV-EN, TOU-SAND
16000	WUN, SIX, TOU-SAND
812681	AIT, WUN, TOO, SIX, AIT, WUN

I-4. Write the figure "ZERO" as "0," write the figure "ONE" as "1" and the write letter "ZULU" as "Z". Spell out difficult words phonetically. Pronounce abbreviations and isolated letters without the proword "I SPELL".

Note. Phonetically transmit any abbreviated words used in the message, for example, 1st is sent as ONE SIERRA TANGO, or headquarters as HOTEL QUEBEC.

PROCEDURE WORDS

I-5. Table I-4, on page I-3, outlines proper procedure words (often called prowords) and their meanings used during radio transmissions. Prowords are words or phrases limited to radio operator procedures used to facilitate communication by conveying information in a condensed form.

Table I-4. Prowords listed alphabetically

PROWORD	***MEANING***
ACKNOWLEDGE	A directive from the originator requiring the addressee (s) to advise the originator that his communication has been received and understood. This term is normally included in the electronic transmission of orders to ensure the receiving station or person confirms the receipt of the orders.
ALL AFTER	The portion of the message to which I have referenced is all that which follows.
ALL BEFORE	The portion of the message to which I have reference is all that proceeds.
AUTHENTICATE	The station called is to reply to the challenge, which follows.
AUTHENTICATION IS	The transmission authentication of this message is.
BREAK	I hereby indicated the separation of the text from other portions of the message.
CLEAR	To eliminate transmission on a network in order to allow a higher-precedence transmission to occur.
CORRECT	You are correct, or what you have transmitted is correct.
CORRECTION	An error has been made in this transmission. Transmission continue with the last word correctly transmitted.
DISREGARD THIS TRANSMISSION-OUT	This transmission is in error. Disregard it. (The proword shall not be used to cancel any message that has been completely transmitted and for which receipt or acknowledgement has been received.)
DO NOT ANSWER	Stations called are not to answer this call, receipt for this message, or otherwise to transmit in connection with this transmission. When this proword is employed, the transmission shall be ended with the proword “OUT”.
EXEMPT	The addressees immediately following are exempted from the collective call.
FIGURES	Numerals or numbers follow. (Optional)
FLASH	Precedence FLASH. Reserved for initial enemy contact reports on special operational combat traffic originated by specifically designated high commanders of units directly affected. This traffic is SHORT reports of emergency situations of vital proportion. Handling is as fast as possible with an objective time of 10 minutes or less.
FROM	The originator of this message is indicated by the address designator immediately following.
GROUPS	This message contains numbers of groups indicated.
I AUTHENTICATE	The group that follows it is the reply to your challenge to authenticate.
IMMEDIATE	Precedence IMMEDIATE. Reserved for messages relating to situations which gravely affect the security of national and multinational forces of populace, and which require immediate delivery.
INFO	The addressees immediately following are addressed for information.
I READ BACK	The following is my response to your instructions to read back.
I SAY AGAIN	I am repeating transmission or portion indicated.
I SPELL	I shall spell the next word phonetically.
I VERIFY	That which follows has been verified at your request and is repeated. (To be used as a reply to verify information.)
MESSAGE	A message which requires recording is about to follow. (Transmitted immediately after the call.)
MORE TO FOLLOW	Transmitting station has additional traffic for the receiving station.
OUT	This is the end of my transmission to you and no answer is required or expected. (Since OVER and OUT have opposite meanings, they are never used together.)

Table I-4. Prowords listed alphabetically (continued)

PROWORD	*MEANING*
OVER	This is the end of my transmission to you and a response is necessary. Go ahead; transmit.
PRIORITY	Precedence PRIORITY. Reserved for important messages, which must have precedence over routine traffic. This is the highest precedence, which normally may be assigned to a message of administrative nature.
READ BACK	Repeat this entire transmission back to me exactly as received.
RELAY (TO)	Transmit this message to all addressee (or addresses immediately following this proword). The address component is mandatory when this proword is used.
ROGER	I have received your last transmission satisfactorily.
ROUTINE	Precedence ROUTINE. Reserved for all types of messages, which are not of sufficient urgency to justify a higher precedence, but must be delivered to the addressee without delay.
SAY AGAIN	Repeat all of your last transmission. (Followed by identification data means to repeat after the portion indicated.
SILENCE	“Cease Transmission Immediately.” Silence will be maintained until lifted. (Transmission imposing silence must be authenticated.)
SILENCE LIFTED	Silence is lifted. (When authentication system is in force the transmission silence is to be authenticated.)
SPEAK SLOWER	Your transmission is at too fast of a speed. Reduce speed of transmission.
THIS IS	This transmission is from the station whose designator immediately follows.
TIME	That which immediately follows is the time or date and time group of the message.
TO	The addressee(s) immediately following is (are) addressed for action.
UNKNOWN STATION	The identity of the station with whom I am attempting to establish communications is unknown.
VERIFY	Verify the entire message (or portion indicated) with the originator and send correct version. (To be issued only at the discretion of the addressee to which the questioned message was directed.)
WAIT	I must pause for a few seconds.
WILCO	I have received your signal, understand it and will comply. (To be used only by the addressee. Since the meaning of ROGER is included in that of WILCO, the two prowords are never used together)
WORD AFTER	The word of the message to which I have reference is that which follows…
WORD BEFORE	The word of the message to which I have reference is that which proceeds…
WORD TWICE	Communication is difficult. Transmit (ring) each phrase (or each code group) twice. This procedure word may be used as an order, request, or as information.
WRONG	Your last transmission was incorrect. The correct version is…

RADIO CALL PROCEDURES

I-6. A preliminary call transmission occurs when the sending station wishes to know if the receiving station is ready to receive a message. When communication reception is good and contact has been continuous, a preliminary call is optional. The following is an example of a preliminary call—

- A1D THIS IS B6T, OVER.
- B6T THIS IS A1D, OVER.
- A1D THIS IS B6T (sends message), OVER.
- B6T THIS IS A1D, ROGER OUT.

Note. For more information on radio call signs and procedures refer to Allied Communications Publication 121 and 125.

OPENING A RADIO NET

I-7. During radio net calls, the last letter of the call sign determines the answering order. The stations in a network respond alphabetically, for example, A3D answers before A2W and A2E answers before B1F. If two stations in a network have the same last letter, for instance, A1D and A2D, then the answering order is determined by numerical sequence, with the lower number A1D answering first.

I-8. The following is an example of a secure voice network opening by the NCS and several distant stations—

- NET THIS NCS, OVER.
- NCS THIS IS A1D, OVER.
- NCS THIS IS A2D, OVER.
- NCS THIS A2E, OVER.
- NET THIS IS NCS, OUT (IF THE NCS HAS NO TRAFFIC).

RADIO CHECKS

I-9. To minimize transmission time, use radio checks sparingly or by unit standing operating procedures. The following is an example of a radio check with the NCS—

- NET THIS IS NCS, RADIO CHECK OVER.
- NCS THIS IS A1D, ROGER OUT.
- NCS THIS IS A2D, WEAK READABLE OVER (A2D is receiving the NCS's signal weak).
- NCS THIS IS A2E, ROGER OUT.
- NET THIS IS NCS, ROGER OUT.

STATION ENTERING A NET ALREADY ESTABLISHED

I-10. The following is an example of how a radio station would enter a network after the network was opened and the station was unable to answer and now wants to report into the network (NCS)—

- NCS THIS B4G, REPORTING INTO THE NET OVER.
- B4G THIS NCS, AUTHENTICATE OVER.
- NCS THIS B4G, I AUTHENTICATE (B4G authenticates) OVER.
- B4G THIS IS NCS, I AUTHENTICATE (NCS authenticates) OVER.
- NCS THIS IS B4G, ROGER OUT.

Note. *Authentication* is a security measure designed to protect a communications system against acceptance of a fraudulent transmission or simulation by establishing the validity of a transmission, message, or originator (JP 3-50).

STATION REQUESTING TO LEAVE A NET

I-11. The following is an example of a radio station requesting permission to leave a network from the NCS of the network—

- NCS THIS A24, REQUEST PERMISSION TO CLOSE DOWN (OR LEAVE NET), OVER.
- A24 THIS IS NCS, ROGER OUT.

CLOSING A SECURE VOICE NET

I-12. The following is an example of a NCS closing a secure voice radio network. Authentication can be used for a non-secure network.

- NET THIS IS NCS, CLOSE DOWN, OVER.
- NCS THIS A1D, ROGER OUT.
- NCS THIS A2D, ROGER OUT.
- NCS THIS B2D, ROGER OUT.

Glossary

The glossary lists acronyms and terms with Army, multi-service, or joint definitions, and other selected terms. Where Army and joint definitions are different, (Army) follows the term. Terms for which ATP 6-02.53 is the proponent manual (the authority) are marked with an asterisk (*). The proponent manual for other terms is listed in parentheses after the definition.

SECTION I – ACRONYMS AND ABBREVIATIONS

ACES	Automated Communications Engineering Software
AKMS	Army Key Management System
ALE	automatic link establishment
AM	amplitude modulation
ANDVT	advanced narrowband digital voice terminal
ASCC	Army Service component command
BFT	blue force tracking
CNR	combat net radio
COMSEC	communications security
COTS	commercial off-the-shelf
CP	command post
CREW	counter radio-controlled improvised explosive device electronic warfare
CSEL	Combat Survivor Evader Locator
DAMA	demand assigned multiple access
DOD	Department of Defense
EA	electronic attack
EKMS	Electronic Key Management System
EMC2	en route mission command capability
EMP	electromagnetic pulse
EP	electronic protection
EPLRS	enhanced position location reporting system
EW	electronic warfare
FHMUX	frequency hopping multiplexer
FSK	frequency shift key
G-6	assistant chief of staff, signal
GCC	geographic combatant commander
GHz	gigahertz
GPS	global positioning system
GRF	global response force
HF	high frequency
ITNE	integrated tactical networking environment
IP	internet protocol
JSIR	joint spectrum interference resolution
JTIDS	Joint Tactical Information Distribution System

J-TNT	Joint-Tactical Networking Environment Network Operations Toolkit
KEK	key encryption key
MBITR	multiband inter/intra team radio
MF	medium frequency
MHz	megahertz
MIDS	Multifunctional Information Distribution System
MIDS- LVT(2)	Multifunctional Information Distribution System-Low Volume Terminal(2)
MIL-STD	military standard
MUOS	Mobile User Objective System
NATO	North Atlantic Treaty Organization
NCO	noncommissioned officer
NCS	net control station
NSA	National Security Agency
PACE	primary, alternate, contingency, and emergency
RCIED	radio-controlled improvised explosive device
RETRANS	retransmission
RF	radio frequency
RT	receiver transmitter
S-2	battalion or brigade intelligence staff officer
S-6	battalion or brigade signal staff officer
SATCOM	satellite communications
SC	single-channel
SC(T)	Signal Command (Theater)
SINCGARS	single-channel ground and airborne radio system
SKL	simple key loader
SRW	Soldier radio waveform
STANAG	standardization agreement
TACSAT	tactical satellite
TEK	traffic encryption key
TM	technical manual
TRANSEC	transmission security
UHF	ultrahigh frequency
U.S.	United States
VHF	very high frequency
WIN-T	Warfighter Information Network-Tactical
WNW	wideband networking waveform

SECTION II – TERMS

authentication

1. A security measure designed to protect a communications system against acceptance of a fraudulent transmission or simulation by establishing the validity of a transmission, message, or originator. 2. A

means of identifying individuals and verifying their eligibility to receive specific categories of information. 3. Evidence by proper signature or seal that a document is genuine and official. 4. In personnel recovery missions, the process whereby the identity of an isolated person is confirmed. See also **evader; evasion; recovery operations; security.** (JP 3-50)

call sign

Any combination of characters or pronounceable words, which identifies a communication facility, a command, an authority, an activity, or a unit; used primarily for establishing and maintaining communications. Also called **CS.** (JP 3-50)

communications network

An organization of stations capable of intercommunications, but not necessarily on the same channel. (JP 6-0)

communications security

The protection resulting from all measures designed to deny unauthorized persons information of value that might be derived from the possession and study of telecommunications, or to mislead unauthorized persons in their interpretation of the results of such possession and study. (JP 6-0)

electromagnetic interference

Any electromagnetic disturbance, induced intentionally or unintentionally, that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronics and electrical equipment. (JP 3-13.1)

electromagnetic pulse

The electromagnetic radiation from a strong electronic pulse, most commonly caused by a nuclear explosion, that may couple with electrical or electronic systems to produce damaging current and voltage surges. (JP 3-13.1)

electromagnetic spectrum

The range of frequencies of electromagnetic radiation from zero to infinity. It is divided into 26 alphabetically designated bands. (JP 3-13.1)

electronic protection

Division of electronic warfare involving actions taken to protect personnel, facilities, and equipment from any effects of friendly or enemy use of the electromagnetic spectrum that degrade, neutralize or destroy friendly combat capability. (JP 3-13.1)

electronic warfare

Military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy. (JP 3-13.1)

electronic warfare support

Division of electronic warfare involving actions tasked by, or under direct control of, an operational commander to search for, intercept, identify, and locate or localize sources of intentional and unintentional radiated electromagnetic energy for the purpose of immediate threat recognition, targeting, planning, and conduct of future operations. (JP 3-13.1)

emission control

The selective and controlled use of electromagnetic, acoustic, or other emitters to optimize command and control capabilities while minimizing, for operations security: a. detection by enemy sensors; b. mutual interference among friendly systems; and/or c. enemy interference with the ability to execute a military deception plan. (JP 3-13.1)

forward line of own troops

A line that indicates the most forward positions of friendly forces in any kind of military operation at a specific time. (JP 3-03)

line of sight

(Army/Marine Corps) The unobstructed path from a Soldier's/Marine's weapon, weapon site, electronic sending and receiving antennas, or piece of reconnaissance equipment from one point to another. (ATP 2-01.3)

message

A narrowly focused communication directed at a specific audience to support a specific theme. (JP 3-61)

***net control station**

A communications station designated to control traffic and enforce circuit discipline within a given net. Also called NCS.

procedure word

A word or phrase limited to radio telephone procedure used to facilitate communication by conveying information in a condensed standard form. Also called **proword**. (JP 3-09.3)

***radio silence**

The the status on a radio network in which all stations are directed to continuously monitor without transmitting, except under established criteria.

SECRET Internet Protocol Router Network

The worldwide SECRET-level packet switch network that uses high-speed internet protocol routers and high-capacity Defense Information Systems Network circuitry. Also called SIPRNET. (JP 6-0)

signal operating instructions

A series of orders issued for technical control and coordination of the signal communication activities of a command. (JP 6-0)

Universal Time

A measure of time that conforms, within a close approximation, to the mean diurnal rotation of the Earth and serves as the basis of civil timekeeping. Also called ZULU time. (Formerly called Greenwich Mean Time.) (JP 5-0)

waveform

An electromagnetic signal-in-space, typically defined by OSI layers 1 through 3, along with the controls and processes for a desired function or application. These processes do not include the message content. (DODI 4630.09)

Zulu Time

See Universal Time.

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None

REFERENCED FORMS

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By Order of the Secretary of the Army:

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