

TSB69

TIA/EIA TELECOMMUNICATIONS SYSTEMS BULLETIN

**A System and Standards Definition
for a Digital Land Mobile Radio System**

TSB69

NOVEMBER 1998

TELECOMMUNICATIONS INDUSTRY ASSOCIATION



Representing the telecommunications industry in
association with the Electronic Industries Alliance



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Foreword

(This foreword is not part of this bulletin)

This Enhanced Digital Access Communications System (EDACS®) and Standards Definition describes the functional elements of the EDACS System, as well as defining the basic system architecture. This document provides the basic expectations of Enhanced Digital Access Communications Systems, and outlines the organization of the family of documents. This bulletin also serves as a foundation for the coherent development of the remaining documents within the Enhanced Digital Access Communications System family of documents.

This document has been developed with inputs from the EDACS Task Group (TG-8.16), TIA Industry Members, and the International EDACS User's Group.

As a group, the family of Enhanced Digital Access Communications Systems documents describe the system, inclusive of the equipment requirements which allow both compatibility and interoperability between various systems and elements. The family of documents will be backward compatible and interoperable with existing installed Enhanced Digital Access Communications Systems as further defined within this bulletin.

This bulletin is not a TIA standard. It is being published because it is felt that there is a need for technical information on digital techniques for Land Mobile Radio Service.

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PATENT ADVISORY

Note: The user's attention is called to the possibility that compliance with this standard may require the use of one or more inventions covered by patent rights.

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Motorola Inc.

Patent Nos. US 4,698,805; US 4,716,407; US 5,239,678; US 4,882, 751; US 5,014, 345

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TIA shall not be responsible for identifying patents for which licenses may be required by this standard or for conducting inquiries into the legal validity or scope of those patents that are brought to its attention.

V

1. INTRODUCTION

1.1 Revision History

REVISION	DATE	COMMENTS
	July 4, 1995	Initial Release.
	July 31, 1995	Format Changes.
	October 9, 1995	Revisions for Task Group Comments
	December 8, 1995	Revisions for Task Group Comments
	July 10, 1997	Revisions for Task Group Comments
	August 7, 1997	Revisions for Task Group Comments
	January 19, 1998	Revisions for Ballot Comments
	April 2, 1998	Revisions for Ballot Comments
	August 5, 1998	Revisions for Default Ballot Comments

1.2 References

DOC. REFERENCE	DESCRIPTION
TSB69	Enhanced Digital Access Communications System Gateway Specification
TSB69-1	Enhanced Digital Access Communications System Console Interface Specification
TSB69-2	Enhanced Digital Access Communications System AME Vocoder and Encryption Definition
TSB69-3	Enhanced Digital Access Communications System Digital Signaling Specification
TSB69-4	Enhanced Digital Access Communications System Call Procedures
TSB69-5	Enhanced Digital Access Communications System Conformance Tests & Procedures
TSB69-6	Enhanced Digital Access Communications System IMBE Vocoder Description
TSB69-7	Land Mobile FM or PM Communications Equipment Measurement and Performance Standards. February 1993. EIA Eng. Publications Office
TSB69-8	Wireless Communications Systems. Performance in Noise- and Interference-limited Situations. Recommended Methods for Technology-independent Modeling, Simulation, and Verification
TSB69-9	Security Services Overview
TSB69-10	900 MHz Trunked Communications System Functional Requirements Development: APCO, Inc.

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Project 16-A. Donald D. Kavanagh

1.3 Scope

1.3.1 Scope of the System and Standards Definition

This Enhanced Digital Access Communications System and Standards Definition describes the functional elements of an FDMA, digital, trunked, Land Mobile Radio communication system, as well as defining the basic system architecture. This document provides the basic expectations of Enhanced Digital Access Communications Systems, and outlines the organization of the family of documents. This document also serves as a foundation for the coherent development of the remaining documents within the family of documents. Additional and more specific information can be referenced in each of the corresponding documents within this family.

1.3.2 Scope of the Family of Documents

As a group, the family of documents describe the Enhanced Digital Access Communications System, inclusive of the equipment requirements which allow both compatibility and interoperability between various systems and elements. These systems provide advanced digital land mobile radio services for private radio communications, and services for industrial, SMR, federal, public safety and utility organizations, on all levels, including local, state and national. The family of documents will be backward compatible and interoperable with existing installed Enhanced Digital Access Communications Systems (EDACS®) per the defined technical definition of section 4. This document describes trunked systems utilizing digital signaling, digital voice, and analog voice for conventional mutual aid operation.

This family of documents is applicable to Land Mobile equipment licensed under National Telecommunications And Information Administration (NTIA) and Federal Communications Commission (FCC) rules and regulations. They are suitable for 12.5 kHz or 25 kHz channels and designed for VHF, UHF, 800 and 900 MHz frequency bands. The family or specific documents within the family may be applicable in situations other than those noted above. Interested parties are encouraged to use the documents as appropriate but are cautioned to carefully compare the documents to the specific requirements of their application or equipment.

1.4 Definitions

Reference APPENDIX A: GLOSSARY for definitions of unfamiliar terms or acronyms.

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2. ORGANIZATION OF THE FAMILY OF DOCUMENTS

This section provides the structure, as well as a description of each of the Enhanced Digital Access Communications System documents within the family. The particular documents will each be assigned to a category, in which all related documents will also be categorized. Each category will deal with a general topic, and each document within that category will deal with a specific aspect of that topic.

2.1 Document Designation

The documents will be assigned a designation of the common form XXX69.Y-Z. The XXX may include either TSB (Telecommunications Systems Bulletin) or IS (Interim Standard) as appropriate for the particular document. This document will be referred to as TSB69, where first tier sub-documents will take the form XXX69.Y and second tier sub-documents become XXX69.Y-Z. The organization of this family of documents is represented below.

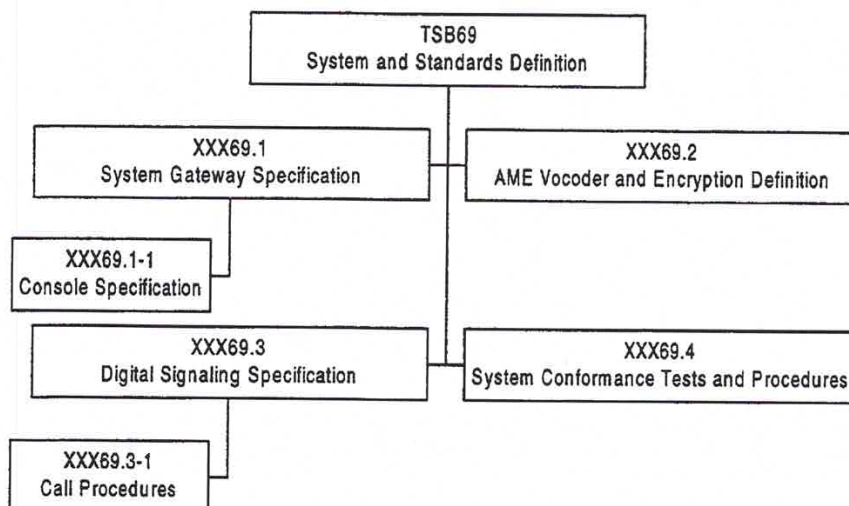


Figure 1. Document Organization

2.2 Document Descriptions

The following sections provide a brief description of the documents.

2.2.1 XXX69.1 - Enhanced Digital Access Communications System Gateway Specifications

This document describes the functional interfaces provided by the system including data, network management, console, telephone interconnect, and intersystem interface.

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2.2.2 XXX69.1-1 - Enhanced Digital Access Communications System Console Interface Specification

This document describes the interconnection between the Console and the System Controller. The document specifically identifies the formats and contents of all messages processed between the Console and the System Controller.

2.2.3 XXX69.2 - Enhanced Digital Access Communications System AME Vocoder and Encryption Definition

This document describes the voice and encryption transmission and reception requirements. The document specifically includes conversion of analog to digital voice (using the AME vocoder) details as well as encryption formats (including DES and VGE) and operations.

2.2.4 TSB69.3 - Enhanced Digital Access Communications System Digital Signaling Specification

This document defines the Digital Signaling for the configurations described in the system model. It also describes trunking, control and working channel formats and messages as well as error correction, channel access and modulation.

2.2.5 XXX69.3-1 - Enhanced Digital Access Communications System Call Procedures

This document describes unit addressing, voice and data transmit and receive operations, repeater operations, and call sequences and procedures.

2.2.6 XXX69.4 - Enhanced Digital Access Communications System Conformance Tests and Procedures

This document provides the conformance tests and procedures required to ensure interoperability between different manufacturers' equipment.

3. SYSTEM MODEL

The system model describes a trunked Enhanced Digital Access Communications System utilizing digital voice technology, as described later in this document. The system is made up of interconnected elements, acting together. These elements are represented by their physical and architectural attributes, and together describe the entire system, which provides several services for private land mobile radio communications.

Figure 2 displays the physical elements which are mapped into functional groups, such as mobiles or portables, base stations, system controller equipment, and mobile data terminals. Each of these functional groups performs specific functions that are necessary for the operation of the system, and some or all of these functional groups may be present in a specific system. Certain functions may be performed by one or more pieces of equipment within a functional group.

3.1 System Interfaces

Figure 2 represents the Enhanced Digital Access Communications System general system model. Figure 2 also identifies a total of 7 system interfaces that will be defined. These are designated Um, A, Ec, En, Et, Ed, and G.

3.1.1 Digital Air Interface

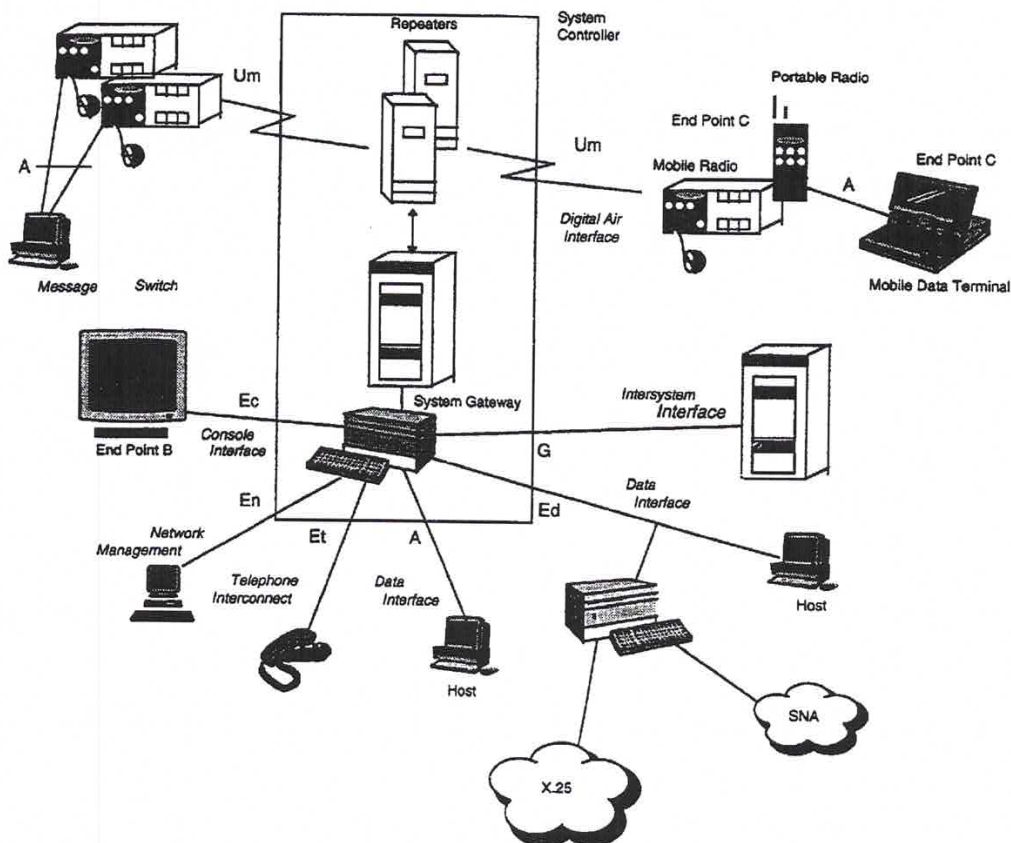
The digital air interface, Um, is required for every Enhanced Digital Access Communications System implementation. This interface defines all of the digital signaling that is required for communication between the base repeaters and the terminals (portable and mobile radios) and between terminals. One channel bit-rate and modulation technique are used for all voice and data communications. For single-channel operation, control, voice, and data features can be integrated into a common channel.

3.1.2 Mobile Data Terminal Interface

Standard terminals may support a port through which laptops, terminals or other terminal unit peripherals may be connected. This interface, A, allows communication between a terminal unit and a peripheral.

3.1.3 Console Interface

The interface between a system controller and a console unit is the console interface, Ec. This interface provides for control of certain system functions and features via the console unit.



3.1.6 Data Interface

The interface between a system controller and a computer network is called the Data Interface, Ed. This interface supports connection of the radio system to an established computer network via Internet Protocol (IP).

3.1.7 Intersystem Interface

Individual radio systems (sub-systems) can be interconnected into larger systems via the Intersystem Interface, G. This interface will also permit systems of different frequency bands and technologies to be interconnected together. This interface supports ISDN.

3.2 Functional Groups

A general description of the functional groups identified in Figure 2 is given below.

3.2.1 Mobile and Portable Radios

The mobile and portable radios are what are commonly referred to as the terminal units for the system. This group includes all mobile radios and portable radios. The functions include the transmission and reception of all Radio Frequency (RF) signals and the voice and/or data interface built into the radio. In the case of the Ericsson specific implementation for data, this includes the Radio Data Interface (RDI) function. The specifics of the data interface including the connector definition will be included in XXX69.1, System Gateway Specification.

3.2.2 Mobile Data Terminal

The mobile data terminal functional group includes all mobile, portable, and fixed remote data terminals. The functions include the data user interface of any data terminal attached to the radio.

3.2.3 System Controller

This system controller functional group refers to the equipment necessary for establishing, controlling and switching interconnection paths between system interfaces and the base station or fixed site repeatersⁱⁱ of the system infrastructure. The functions also include all frequency translation and signal processing associated with the transmit and receive signals, modulation and demodulation of the RF energy and base radio control. The extent of this equipment will vary by system as a function of the optional features included in a given system.

ⁱⁱ For example, in the Ericsson specific implementation, this functional group includes the GE Trunking Card or GETC, which performs the trunking control.

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3.3 System End Points

3.3.1 End Point B

This is the reference access point for services directed to or from the system console.

3.3.2 End Point C

This is the reference access point for services directed to or from a terminal unit (portable or mobile radio) or a mobile data terminal.

3.4 Communication Modes

The call types supported by an Enhanced Digital Access Communications System in each communication mode are defined below and described in section 4.5.2.1.

- Digital Voice. All call types, Group, Group Emergency, Individual and System All Call, are supported.
- Digital Data. Individual calls and group calls are supported.
- Encryption. Encrypting the already digitized voice provides very secure communications even against sophisticated eavesdroppers. The advantage provided by encryption is very high security with no loss of audio quality. Encryption is optional.
- Analog. Analog FM talk around per 16KOF3E standard signaling in accordance with TIA-603. Trunked voice services in analog mode are not included in this document.

3.4.1 Digital Data

Digital Data is transmitted at 9600 baud. Valid configurations include:

- Mobile Data Terminal (MDT) to fixed host
- Laptop PCs to fixed host.

TCP/IP, SNA, X.25 applications are supported and may require external gateway interfaces to data networks.

3.5 System Components

Trunking operation of an Enhanced Digital Access Communications System does not require a system controller. All of the trunking logic is maintained in the repeaters

which provide all the key trunking features as described in section 3.6. An addition of a system controller is required for additional features and/or additional services made available through gateways.

The components of a basic system are as follows:

- Base Stations
- Portable Terminal Units
- Mobile Terminal Units

The addition of a system controller allows the following optional external interfaces:

- Console
- Network Management
- Telephone Interconnect
- Network Data
- Intersystem Interface

For encrypted applications, add the following:

- Encryption option: DES or VGE
- Cryptographic Keyloader: DES or VGE

The Cryptographic Keyloader must be used to initially load crypto keys into the radio for secure operation.

3.6 Modes of Operation

The system can operate in one of three different modes:

- A trunking mode with a system controller,
- A basic trunked mode with no system controller, or
- Conventional non-trunked mode.

A complete system as defined by the system model will normally operate in the trunking mode with a system controller. The system controller allows access to the external network interfaces shown in the model. However, a system may exist with only repeaters and terminal units and no system controller (and therefore no network interfaces). A system with no system controller, or one that has lost operation of its system controller, still maintains a trunked mode of operation. In either trunking mode, the trunking function is actually performed by the control channel repeater. The system will recognize the failure of any of the repeaters and adjust accordingly. For example, if the control channel repeater is lost, another repeater will be designated as the new control channel. Trunking continues as long as there are at least three repeater stations operational. When only two repeaters remain, the repeaters switch modes and operate conventionally.

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In the basic trunked mode with no system controller, the system supports all mandatory features and services listed in Table 2 (Supplementary Services) and optional features and services not dependent on the system gateway.

3.7 Digital Voice Technology

The system incorporates digital voice technology utilizing an Adaptive Multiband Encoding (AME) vocoder technique. The addition of digital voice makes the system an all digital technology that maintains full backward compatibility with existing systems. Implementation of an IMBE™ vocoderⁱⁱⁱ for Enhanced Digital Access Communications Systems is an item of future study.

A vocoder transforms the analog voice input to a digital signal. Added to vocoded messages are channel signaling features to synchronize the signal at the receiving end, as well as error detection and correction.

The advantage is that the user receives the same voice recognition capability experienced with analog voice, yet in fringe radio coverage areas, the digital audio received can be improved through the use of digital error detection and correction.

3.7.1 Security

Encryption is also available as an option to provide an extra measure of security for those who require it.

The Data Encryption Standard (DES) algorithm is approved for 'sensitive but unclassified' United States Government communications. There are 7.2×10^{16} possible keys. Use is generally only permitted in the United States and Canada.

The VGE Encryption Algorithm provides a total of 1.8×10^{19} possible code combinations. Export from the United States requires a Department of Commerce license.

The digital voice capability provides an improvement in security over analog systems because audio transmissions cannot be overheard on standard radio scanners which rely on analog technology. Analog scanners can still receive the audio transmission signal, but the digital nature of the signaling shields against unauthorized listeners. Add encryption and the transmission becomes secure, providing protection against a significant number of eavesdroppers. A description of and a list of the threats that can be countered by using encryption is described in document TSB102.AAAB.

ⁱⁱⁱ IMBE™ is a trademark of Digital Voice Systems Inc.

3.7.1.1 Traffic Channel Security

Section 3.7.1.1 states the requirements for encryption of the user traffic in relation to the bearer and telecommunications services provided.

3.7.1.1.1 User Security Requirements

The system supports Type 3 and Type 4 encryption with compatible modes of operation.

- Type 3 Unclassified sensitive government communications (e.g., Public Safety)
- Type 4 Exportable

The family of documents defines a Type 3 and Type 4 encryption standard.

The system shall provide the user with an end-to-end encrypted service for digital voice using a non-encrypted control channel.

The system design shall be transparent to the actual type of encryption employed and shall provide for multiple types of encryption to be employed simultaneously on the same system.

All voice calls as identified in section 4.5.2.1 shall be provided with a user-selectable voice encryption option.

3.7.1.1.2 Encryption Performance Requirements

Digital encrypted systems are designed to offer the following performance levels:

- A voice quality approximately equal to clear-voice analog systems,
- A range performance approximately equal to clear-voice analog systems,
- A synchronization system commensurate with the above requirements and offering both initial and late entry capabilities.

3.7.1.1.2.1 Type 3 Algorithm Performance

The algorithm performance is defined in the FIPS 46 DES standard for Type 3 systems.

3.7.1.1.2.2 Format and Sync Performance

The format and sync was designed to meet the following objectives:

- Greater than 99% probability of correct acquisition at an average channel error rate of 3%.
- Protection of data from fades of up to 50 msec in length.
- Late entry capability for a receiver that enters the conversation after a voice transmission has begun.

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3.7.1.1.3 Key Requirements

The encryption system provides for a minimum of 8 crypto keys within each encrypted equipment.

3.7.1.1.4 Physical Security Requirements

All encrypted services are provided as end-to-end functions between communicating handheld or mobile radios or consoles.

As a consequence of the physical security requirements, no system function shall be designed to require encryption facilities within unattended RF subsystem components (i.e., infrastructure). Consequently, all functions related to infrastructure signaling are carried out in the unencrypted mode.

3.7.1.1.5 Key Management**3.7.1.1.5.1 Physical**

All encrypted radios require a common key-fill interface. All equipment using the same encryption device uses a common key-fill device.

It is not possible for key variables to be extracted from an encrypted radio for use in "cloning" an unfilled equipment.

3.7.1.2 Network Management

Network management encompasses the control functions associated with the provision of the network services, and is not directly concerned with the control of user radio equipment. The network management function is comprised of:

- Configuration management,
- Fault management,
- Performance management,
- Accounting management,
- Security management.

The security management function is responsible for controlling access to network elements and all of the associated management information.

Physical security requirements preclude the use of encryption devices within the network infrastructure, preventing the incorporation of an encrypted service for network management functions.

All of these aspects are defined, but are independent of the encryption service offered for end-to-end digital traffic. This shall allow the provision of a protected, but not fully encrypted, service for those systems where provision of encryption devices within the network infrastructure is precluded.

The minimum security requirements for network management are:

- Protection against unauthorized access via recording and replay of network management messages (spoofing),
- Authentication between source and destination equipment prior to any configuration or accounting management actions,
- Protection of mobile registration data against unauthorized eavesdropping.

3.7.2 Forward Error Detection

With the digital voice feature, standard radios no longer rely on signal strength alone to deliver the message. Error detection and correction provides some gain to overcome degradation from bit errors on weak signals during digital transmission.

3.7.3 Full Backward Compatibility

It is a requirement of this system that all radios are backward compatible with all existing analog radios and with the system infrastructure. This means that a radio user must be able to communicate on the system with others who have either similar digital radios, existing analog radios using mutual aid, or existing encrypted (optional) radios.

3.7.4 Digital Voice Implementation

The following figure depicts the digital coding process which includes the technique for converting analog speech signals to a digital data stream called vocoding. A detailed description of the AME vocoding process can be found in XXX69.2. Basically, the digital coding process consists of first converting the analog speech to digital or sampling the input speech signal at some standard rate. Each analog sample is assigned a 'code' of 8 bits to produce a digital data stream. The vocoding process consists of 'compressing' this high data rate to a lower, more manageable data rate in order to fit into a radio channel. This compression is accomplished by an advanced Digital Signal Processor (DSP).

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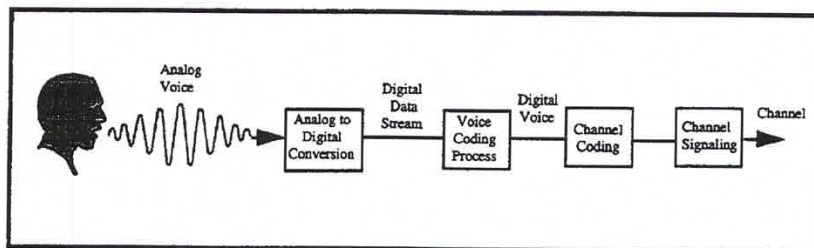


Figure 3. Digital Coding Process

After the vocoding process, error protection codes are added to the digitized audio stream. These sophisticated codes help correct data errors and protect the data stream in weak signal areas.

Weak Signal performance is particularly important in the radio environment where fading and noise are commonplace. The result is that digital voice provides enhanced weak signal performance.

The digitized audio stream along with its channel coding is split into data frames before transmission. Each of these frames is "encapsulated" with synchronization and embedded signaling information to form the 9600 bits per second data stream that is transmitted on the channel. This is the same 9.6 Kilobit data rate used everywhere on the system.

The signaling information in the data stream is used for a number of purposes. These include:

- Unit Identification (or Push-to-talk identifications - IDs);
- Cryptographic synchronization when using encryption;
- System update;
- Priority Scan information; and
- Talkgroup segmentation.

4. TECHNICAL DEFINITION

4.1 Scope

This section is a Technical Requirements Specification (TRS) for the Enhanced Digital Access Communications System . It provides a basis for system design and can be used as the criteria in judging alternate system designs. It gives an explanation of the services provided, including security and data services.

4.2 Call Sequence

When mobile and portable radios are turned on, they scan for the control channel repeater covering their area. The control channel continuously transmits a digital control signal, at 9600 bps NRZ, direct FM. Mobiles and portables receive and decode this outbound control channel signaling and synchronize to the control channel. Once synchronized to the control channel, mobiles and portables are synchronized to the system for inbound signaling. A detailed description of the control channel signaling procedures is provided in XXX69.3-1, Call Procedures.

Simplified exchanges between the radio unit and the system are described and shown in the diagrams in APPENDIX C - CALL SEQUENCES.

4.3 System Addressing

The system address scheme allows partitioning of radio units into groups so that users with like communication requirements can communicate with each other. In addition, the system address scheme allows each radio or console to be assigned its own ID so that radios or consoles can be identified and selectively called.

The address hierarchy, described in Appendix B, spans five categories, from broad to narrow. Appendix B also includes a detailed description of fleet mapping and its purpose.

4.4 Call Definition

When a call is placed on the system, it consists of two parts: the communication mode and the call type. The system supports three communication modes and four call types.

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CALL TYPE	MODE		
	Digital Voice	Digital Data	Analog (Mutual Aid)
Group	x	x	x
Group Emergency	x	-	x
Individual	x	x	-
System All Call	x	-	-

Table 1. Communication Modes and Call Types

To clearly define a call, one must specify both the communication mode and the call type. For example:

- Digital voice, group call, or
- Digital data, individual call.

4.5 Services / Features Provided

The following sections describe the available services and functions.

4.5.1 Bearer Services

Bearer Services are telecommunications services that carry user information between separate points within a network. These services are usually limited to the first, second, and third layers of the OSI model in functionality.

4.5.1.1 Confirmed Packet Delivery

Confirmed Packet Delivery is an optional service that offers a two-way delivery of confirmed packets between access points within a radio network. The service provides a variable information transfer rate. Channel sharing maximizes the usage of network resources for short burst information transfer. The network provides error correction and detection services and delivery confirmation is also provided. This service is accessible at reference point C and interface Ed.

4.5.2 Teleservices

Teleservices provide facilities for user information transport, and typically possess functionality which spans all levels of the OSI model. Teleservices may be based on a named bearer service, but may require the ability for unique bearer services.

4.5.2.1 Call Types

There are four mandatory call types, Group, Emergency Group, Individual and System All Call. These are defined below.

4.5.2.1.1 Group Call

The group call is the most common type of call on a trunked system. A group call can be a subfleet, fleet or agency call depending on the Group ID. Group calls may operate in one of three different modes: digital voice, digital data, or analog mutual aid. They are often referred to as "talkgroups."

This service is accessible at reference points B and C for voice calls and C and interface Ed for data calls.

4.5.2.1.2 Emergency Group Call

An emergency call is initiated by pressing the emergency button on the radio. Once initiated, the radio immediately transmits the emergency call request on the inbound control channel. The system receives the request and assigns the emergency call to a free channel. If all channels are busy, the request is placed at the 'top of the queue,' where it will be assigned the first available channel. Even on heavily loaded systems, emergency calls are handled quickly and efficiently.

During typical system operation, group calls are transmission trunked, while emergency group calls are message trunked. Transmission trunking means that a working channel is assigned for the duration of a caller's transmission. Upon the caller's un-key, the system immediately de-allocates the channel and makes it available for reassignment. This is equivalent to zero-second hang time. Transmission trunking for normal traffic increases system efficiency (reference section 4.5.5.1). Message trunking, on the other hand, means a channel is assigned for the duration of the conversation, or emergency (reference section 4.5.5.2).

Only the dispatcher or a radio with supervisory status can clear the group from emergency status.

This service is accessible at reference points B and C.

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4.5.2.1.3 Individual Call

Since each radio has a unique individual ID address, it is possible to individually call any single radio in the system. Individual call allows a one-on-one conversation that is not overheard by anyone else on the system. Individual calls may be initiated by a dispatcher or an appropriately equipped radio. Individual calls may operate in either the digital voice or digital data mode.

Individual call IDs may be preprogrammed into a radio, or can be entered directly from the keypad on the radio.

This service is accessible at reference points B and C for voice calls and C and interface Ed for data calls.

4.5.2.1.4 System All Call

System All Call allows a supervisor to communicate immediately to all radios within the system. The System All Call is a preprogrammed special call in a supervisory radio. The supervisor initiates a System All Call by activating the special call feature on the radio and positioning the group control to the "System All Call" position. When the system receives the call request, it immediately drops all calls in progress and assigns a single channel to everyone in the system.

This service is accessible at reference points B and C.

4.5.2.1.5 Packet Switched Data Network Access

A two-way data service between user endpoints which provides wireless access to communications and value-added services supported by land-based packet switched networks. This service is accessible at reference points C and interface Ed.

Protocols at the reference points may be identical, in which case the mobile access point would appear to the user as functionally identical to the switched network access point. Alternatively, different low-layer protocols may be used at the two access points. This service would typically utilize a bearer service for transit through the radio system, and would include additional gateway or interworking functions at both the subscriber and fixed terminations.

4.5.3 Supplementary Services

Supplementary services change or improve the abilities of bearer services and teleservices. A supplementary service may be associated with multiple bearer or teleservices, but may not be offered without association with at least a single bearer or teleservice. The following supplementary services may be offered with the system

MANDATORY FEATURES/SERVICES	OPTIONAL FEATURES/SERVICES	
Up to 16 System/Groups	Encryption	Telephone Interconnect
Automatic Call Sign	Dynamic Regrouping	Simulselect
Transmit Prompt Tone	Patch	Multiple Group Monitoring
Continuous Channel Updating	Console Pre-empt	8 Priority Levels
Late Entry	Conventional Operation	Recent User Priority
Random Retries	Alert Tone Disable	Dynamic Transmission Trunking
Convert to Callee	Status Messages	Message Trunking
Out of Range	Single Channel Autonomous Trunking	Call Validation
Caller ID Display	Power Up System/Group	Activity Logging
Group Scan	Basic Trunked Mode Display	Alarm Subsystem
Call Queuing	Radio Enable/Disable	Management Reporting
	I-Call Callback	Priority Scan
	Confirmed Call	Forced Site
	Wide-area Scanning	Unit Logout

Table 2. Supplementary Services**4.5.3.1 Automatic Call Sign**

The repeater can be programmed with a single Morse Code identification. The identification is transmitted at a set speed at a programmable time interval.

This service is accessible at reference points B and C.

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4.5.3.2 Transmit Prompt Tone

When the originating unit is assigned to the working channel and has completed the high-speed handshake, the radio operator hears a "transmit prompt tone." This tone provides positive feedback that the system has assigned a free working channel and communication may proceed. The details of the transmit prompt tone will be described in XXX69.3-1, Call Procedures.

This service is accessible at reference points B and C.

For surveillance applications, this tone can be optionally disabled for silent operation.

4.5.3.3 Continuous Channel Updating

The control channel continually transmits assignment information allowing a user to join calls in progress after the group has been assigned a working channel.

This service is accessible at reference points B and C.

4.5.3.4 Convert To Callee

When two or more radios within the same group key sequentially (not simultaneously) the system receives the first request and assigns the originating radio and the group to a channel. The radio which placed a request immediately after the first receives a "Convert to Callee" message. The "Convert to Callee" message prevents the second radio from transmitting and places it in the receive mode on the assigned working channel. Convert to Callee ensures that only one channel is assigned to the group and that only one person can transmit. This alleviates the possibility of having a common group communicating on separate channels. Users are, thereby, prevented from "stepping" on each other. (Reference Section 4.5.5.1; Transmitter Busy Lockout)

This service is accessible at reference points B and C.

4.5.3.5 Out Of Range

The radio is considered to be out of range of the system when the radio does not receive outbound control channel information. The radio provides a visual and audible indication to the user when they depress their PTT.

This service is accessible at reference point C.

4.5.3.6 Caller ID Display

Each transmission, or PTT, includes the caller's ID. This individual ID can be shown automatically on the radio's display when the caller is placing a Group, Group Emergency or Individual call. Radios which include alphanumeric displays can be

programmed to map the ID to a limited number of names or aliases, instead of the numeric ID.

This service is accessible at reference points B and C.

4.5.3.7 Group Scan

Properly equipped radios scan multiple groups within a set of groups. When the radio is monitoring the control channel, the radio responds to the channel assignment corresponding to any one of the groups in the group scan list.

This service is accessible at reference point C.

4.5.3.8 Call Queuing

When the system is fully loaded, a working channel may not be immediately available for the call requested. Call queuing comes into play in that case. The channel request is stored by the control channel repeater until a working channel becomes available. The control channel manages the calls using a simple First-In First-Out (FIFO) type of queue. In basic operation, all calls have equal priority except emergencies, which are always given "top of queue" priority.

When a call is queued, the operator and all members of the group are alerted by an audible tone that a call has been put in queue. 'Caller Queue Alert' notifies everyone in the group that a call was placed and is being processed by the system. When the system assigns the call to a working channel, a 'Transmit Prompt Tone' alerts the caller. This process prevents unnecessary manual retries and simplifies operation under fully loaded conditions. The details of the queue alert tone will be described in XXX69.3-1, Call Procedures.

If a radio makes a request to a group that is already in the queue, the new request is not queued. A unique audible tone is issued notifying the second radio that there is another request, to the same group, already queued.

This service is accessible at reference points B and C.

4.5.3.9 Status Messages

This feature optionally provides the radio with the capability to initiate a predefined status message or respond to status messages originated by the system controller. These status messages are available at a status monitor or dispatch console.

This service is accessible at reference points B and C.

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4.5.3.10 Conventional Operation

Available as an option, mobiles and portables can be specifically designed to continue to operate conventionally in the event of the loss of trunking service. This adds an additional layer of redundancy to the system. Radios shall automatically check for conventional operation when it cannot find the control channel. If conventional operation is detected, the radio shall automatically change to the conventional mode. The user shall be notified that the radio is in conventional operation. In addition, radios do need to be programmed with the appropriate frequency.

This service is accessible at reference point C.

4.5.3.11 Home

Radios can be programmed to automatically switch to a home system or group by pressing and holding the Home/Emergency key for the programmed time duration. If programmed to do so, the radio will also transmit an emergency message on the home system or group.

This service is accessible at reference point C.

4.5.3.12 Alert Tone Disable

This optional feature, allowing the disabling of audible alert tones, is useful in situations where minimal sound is required.

This service is accessible at reference points B and C.

4.5.3.13 Up to 16 Systems/Groups

This optional feature provides the ability to program up to 16 systems or groups into the radio. There are specifically 16 total combinations of systems and groups.

This service is accessible at reference point C.

4.5.3.14 SCAT (Single Channel Autonomous Trunking)

An available option, SCAT is a trunked system consisting of a single repeater which functions as either a control channel or a working channel, depending on the required trunked service. SCAT operates as a control channel in its idle state. When a channel request is made, it assigns the call to itself and converts to a working channel, maintaining address hierarchy and many trunking features.

4.5.3.15 Power up System/Group

As an optional feature, the radio can be programmed to access a certain system or group upon power up.

This service is accessible at reference point C.

4.5.3.16 Basic Trunked Mode Display

Radios can optionally be programmed to provide a display message in the event of the system entering the Basic Trunked Mode.

This service is accessible at reference point C.

4.5.3.17 Encryption

This optional service provides encryption of voice information within the radio system, but is not provided for information before it enters the system or after it leaves the system. This family of documents shall fully define both a Type 3 and a Type 4 encryption standard.

This service is accessible at reference points B and C.

4.5.3.18 8 Priority Levels

In a multi-agency system not all users are the same. Police may be in a life threatening situation. They need priority over non-emergency agencies. This ranking of importance is typically dependent on the level of responsibility, the nature of the activity and the urgency of the information transmitted.

The system optionally supports up to eight (8) priority levels. Seven (7) are assigned through the system manager. The highest priority is reserved for emergency calls. In a queued operation, the system continually sorts the queue by priority. Higher priority calls are placed in the queue ahead of lower priority calls. If two calls of equal priority are received, the system sorts them based on first-in first-out basis.

This service is accessible at reference points B and C.

4.5.3.19 Recent User Priority

Available as an option to help maintain continuity of a conversation in a heavily loaded system, the System Controller automatically increments a "recent user" call request priority by 0.5. Recent priority increment discriminates between equal priority requests based on how recent the caller/callee placed a call on the system, but does not pre-empt a request of a higher priority.

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This service is accessible at reference points B and C.

4.5.3.20 Dynamic Transmission / Message Trunking

The system optionally allows dynamic assignment of transmission and message trunking on a per group basis. This means that message and transmission trunking is user selectable on a per group basis. In addition, a single group can be switched between message and transmission trunking. In the event that time-critical information needs to be exchanged, the user selects a group which is message trunked to transmit the information. By maintaining the bulk of the calls in the transmission trunked mode, system efficiency is maximized and queuing and the time in queue are minimized.

4.5.3.21 Call Validation

Optionally, a personality profile is databased for each individual and group. This profile specifies information such as group ID, Logical ID, etc., for the individual or group. Additional details of this profile will be defined in XXX69.3-1, Call Procedures. When a radio transmits a channel request, the request is verified by the system controller against the personality profile on record.

This service is accessible at reference point C.

4.5.3.22 Activity Logging

As an option, the system controller will monitor the entire system and log all call requests, channel assignments and alarm information.

This service is accessible at reference points B and interface En.

4.5.3.23 Alarm Subsystem

The system optionally provides an alarm subsystem. .

This service is accessible at reference points B and C.

4.5.3.24 Management Reporting

The system shall provide extensive command and control as well as a means to evaluate the operational effectiveness of the radio system. The system optionally provides the following reports:

- Unit and Group Database Report
- Site Database Report
- Activity Summary Report

- Activity Detail Report
- Site Statistics
- Channel Statistics
- Alarms Report

This service is accessible at interface En.

4.5.3.25 Telephone Interconnect System

This optional service allows authorized radios to make and receive telephone calls without dispatcher assistance. Calls are placed from a radio to the telephone network and from the telephone network to an individual radio or group.

When an interconnect call request is received, the system controller verifies that the caller is permitted to place the call. If the caller is authorized, the system controller assigns a working channel.

This service is accessible at reference point C and interface Et.

4.5.3.26 Unit Disable

An individual unit can optionally be selectively enabled or disabled through the system controller. When a disable request is initiated, the system controller sends the disable message over the control channel using the logical ID. When the radio receives the disable message, it transmits an acknowledgment back to the system controller and then executes the disable command. While the radio is disabled, the radio can neither transmit nor receive dispatch communication. The disabled radio can only be reactivated through the enable command or re-programming. In the event that the radio is turned off when the system controller transmits the disable command, the system controller will continue to try to disable the radio until it is successful.

This service is accessible at reference point B.

4.5.3.27 Dynamic Regrouping

This optional feature allows radios to be programmed over the air with up to 8 new groups. Dynamic regrouping can be used for planned or unplanned events. For example, plans for a natural disaster in the form of a flood may be planned and the regrouping scheme outlined. An unexpected earthquake might require another regrouping scheme developed "on-scene" to respond appropriately.

During the dynamic regrouping process, the system manager commands the individual units to perform one of the following:

- Forced to regroup with no option to change group selection;

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- Forced to regroup with option to change group selection;
- Not forced to regroup with option to change new groups.

The individual radio units are called, one radio at a time, and are given their regrouping instructions. Although the radios receive their regrouping instructions, the radios do not automatically activate the instructions until an activation message is sent.

This service is accessible at reference point B.

4.5.3.28 Patch

As an option, Console Patch allows a dispatcher to dynamically integrate the communications of multiple trunked talkgroups and conventional channels. Historically, patch has involved the use of multiple channels to allow patched conventional radio users to intercommunicate. However, patched talkgroups are dynamically collected to a single repeater using a process known as "Dynamic Talkgroup Integration." In this case, only one frequency is required for the patch to be implemented.

This service is accessible at reference point B.

4.5.3.29 Simulselect

As an option, Simulselect allows a dispatcher to broadcast a message to multiple talkgroups simultaneously. This feature is often used for "All Points Bulletins" and general announcements to multiple groups.

This service is accessible at reference point B.

4.5.3.30 Console Pre-empt

This option gives dispatchers the ability to interrupt a transmitting radio in order to broadcast critical messages to a talkgroup. When a dispatcher pre-empts a radio transmission, all talkgroup members will hear the dispatcher instead of the transmitting radio. The transmitting unit will not hear the dispatcher's transmission until the unit releases the transmit button.

This service is accessible at reference point B.

4.5.3.31 Multiple Group Monitoring

This option gives dispatchers the ability to monitor multiple groups simultaneously.

This service is accessible at reference point B.

4.5.3.32 Priority Scan

This option enables a radio to monitor information transmitted on the working channel and respond to a priority group call. The priority group is dictated by the group currently selected by the radio user. If a call occurs on the priority group while the radio is involved in a call from one of the other groups from its scan list, the radio will immediately enter into the call on the priority group.

This service is accessible at reference point A.

4.5.3.33 Confirmed Call

This optional feature is performed by the system controller which verifies through the HLR/VLR database that the call recipient is available before a channel assignment is made.

4.5.3.34 Forced Site

This optional feature is performed by the system controller which verifies through the HLR/VLR database the sites involved in the call. The system controller then generates channel assignments to these sites independent of whether the recipient is logged on the system. If the radio is monitoring the control channel, it will be assigned to a channel.

4.5.3.35 Unit Logout

This optional feature is performed by the system controller which periodically polls the radio after a predefined level of inactivity on the system. If the radio does not respond to the Status Message, the unit is logged out.

4.5.4 Features

4.5.4.1 Late Entry

A radio "late enters" a call when the original channel assignment was missed. For example, the power may be turned off when the original channel assignment is made. Since the control channel continually transmits the channel assignments, the radio can still be updated as to which channel the call is using. The radio will automatically respond to the update and join the call in progress. The radio can late enter into individual or group calls.

This feature allows field units to late enter for any of the following reasons:

- Turned 'on' after the communication was underway;
- Roams into the system;
- Passes out of a coverage hole; or
- Completes another call.

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4.5.4.2 Random Retries

If control channel access is not complete for the following reasons, the radio will “retry” to complete the call.

- Two or more radios transmit simultaneously and the messages collide on the channel;
- A field unit's transmission is not received on the inbound control channel; or
- A field unit fails to see the channel assignment message on the outbound control channel.

In all cases, the radio initiates a retry algorithm a predetermined number of times. In the case of simultaneous transmissions, the algorithm minimizes additional collisions by making the radios wait a random number of inbound time “slots” before transmitting.

4.5.4.3 I-Call Callback

This optional feature allows the radio to remember the last incoming individual call (I-Call) and return a call to this number (ID), when the user pushes the PTT directly.

4.5.4.4 Wide-area Scanning

This optional feature provides an extended adjacent site table for the radio which stores additional control channel frequencies for roaming.

4.5.5 System Types**4.5.5.1 Transmission Trunking**

Transmission trunking means that the working channel is dropped immediately after the originating unit releases PTT. All radios assigned to the working channel are 'dropped' from the working channel and return immediately to the control channel.

A typical dispatch conversation is made up of 4 or 5 transmissions. With transmission trunking, each transmission places a channel request on the system. On the surface this may seem cumbersome and inefficient, however, transmission trunking is the most efficient mode of trunking, when the channel access time and channel drop times are fast. This translates to fewer queued calls and less time in queue, especially during the peak periods.

An additional advantage of transmission trunking is that each transmission can be assigned a different working channel. Scanners cannot readily monitor group calls when this happens.

Transmitter Busy Lockout

One of the unique benefits of transmission trunking is the ability to prevent "stepped on" calls. This is when an individual tries to capture the channel when someone else is talking. "Stepping-on" calls causes major disruptions and at times cause a total breakdown in communication.

With transmitter busy lockout, all receiving radios in a group are transmit disabled for the duration of the originator's transmission. Only one radio, the originator, is allowed to transmit.

In the event of an emergency, an operator can initiate an emergency group call even if the radio is monitoring a group call in progress. When an emergency button is pushed, the radio transmits the emergency group call on the control channel. The system assigns the user a free, working channel. To gather the balance of the group, the system drops the group call in progress. All radios monitoring the group call immediately move over to the new channel and late enter into the emergency call. The originator of the call in progress late enters into the emergency group call when the radio is unkeyed.

4.5.5.2 Message Trunking

Message trunking offers the same fast access time as transmission trunking. A hang time keeps the working channel on the air for a specific length of time when PTT is released. This allows any operator to capture a channel as long as they respond, i.e., transmit, within the hang time. The conversation is assumed to be over when there is no activity on the channel during the hang-period time. Once the hang time expires, the channel is available for reassignment.

Message trunking is very useful to the supervisor who requires a dedicated channel while transmitting critical instructions or for emergency calls. Message trunking assures a dedicated channel for the duration of a conversation as long as the group holds the channel up.

Message trunking is appropriate in the cases described above. It may, however, be less efficient in traffic channel utilization than transmission trunking in some cases. There is an interval of silence, the hang time, at the end of each transmission. This period represents lost airtime for other users. However, it may be more efficient in control channel utilization than transmission trunking in some cases.

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The system can be set for message trunking on all calls, dramatically affecting system capacity. This is especially noticeable during peak periods because there is more queuing and long waits for available channels.

4.5.5.3 Mixed Transmission/Message Trunking

One feature is the ability to selectively mix the efficiency of transmission trunking with the 'dedicated' channel of message trunking. The system can be programmed to dynamically switch between transmission trunked or message trunked mode based on a user or group basis. A message trunked hang time of 2 seconds is automatically assigned to all emergency calls.

Transmission trunking is typically the primary mode in which the existing system customers operate their systems. This takes advantage of the system efficiencies created by the fast channel access and drop times. Emergency calls are typically message trunked. Maintaining the bulk of the calls in the transmission trunked mode minimizes queuing and the time in queue during peak periods.

4.5.5.4 Voice/Data Trunking

Voice/data trunking, provides a fault tolerant voice and data system that adaptively balances voice and data loading. External data devices such as mobile data terminals, MS-DOS PCs or automatic vehicle location (AVL) devices and their associated host equipment are fully integrated with the trunked radio system.

Data calls are trunked similar to voice calls, bringing the same significant efficiency advantages of trunking to data. Data transmissions are done on a confirmed basis, and therefore may involve re-transmissions.

The following figure represents voice and data transmissions on a small trunked system. Each line represents an available traffic channel that may be assigned by the trunking controller. The blocks on the traffic channels represent group voice calls, data calls, individual calls and telephone interconnect calls.

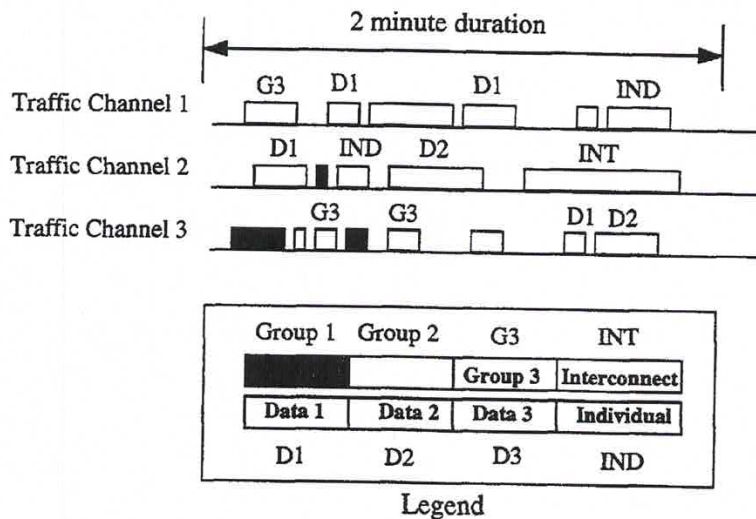


Figure 4. Integrated Voice and Data on a Trunked System

The voids between the voice group messages represent the delays between speakers or idle times when voice traffic does not fill the traffic channel to capacity. When the data is in the form of short, bursty messages, the data calls tend to fill in the "space" between the voice group calls. By filling the "space" with data calls, spectrum efficiency and system utilization can be optimized.

Voice/data trunking also simplifies both the system design and upgrade path by eliminating the need to allocate available frequencies to dedicated voice-only and data-only channels. The simplified system design eliminates guesswork, increases efficiency and allows seamless upgrades from voice-only to voice and data, and potentially, to data-only applications. Voice and data are fully integrated into one radio, eliminating the need for separate user or system resources for data. This is economical and simplifies installation.

4.6 Performance

The system meets, at the minimum, the performance requirements of APCO 16A. In cases where the APCO 16A requirement is exceeded, the requirements defined in this document take precedence. The Project 16A documents are available from the APCO Institute, Inc.

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4.6.1 System Characteristics

The system is expandable and upgradeable through a building block approach without requiring existing equipment change-outs.

- The system allows for single station sites, with no loss of text, voice, or control capability.
- The system allows for direct communication between mobiles at any time without degrading the normal system performance.
- Direct communication in range of the fixed equipment shall accomplish no more than temporarily capturing receivers from possible outbound messages.
- Direct communication is possible at any time, while out of range of the fixed equipment, without degrading performance or capacity of the system.
- The system is equally adaptive, at the minimum, to all public safety mobile radio frequency bands and spectrum blocks, without precluding its adaptation to other land mobile bands.
- The system provides little interference to existing adjacent channel analog systems in accordance with TIA-603, while working within its specified performance parameters.
- The system conforms to the performance specifications of all detailed standards identified in document XXX69.4, System Conformance Tests and Procedures.

4.6.2 Channel Utilization

The system shall optionally provide channel utilization with increased efficiency over current analog systems. This utilization shall be representative of a transition from 25 kHz channels to 12.5 kHz channels.

4.6.3 PSTN Interconnection

The system shall optionally provide interconnection to Public Switched Telephone Network system (PSTN).

4.6.4 Range

Range of the system is designed to be equal or superior to the range of current analog clear-voice systems, when equivalent bandwidth systems are compared, when in clear or encrypted voice mode while maintaining the voice quality identified in section 4.6.8 as a minimum.

Performance effects due to the transition from wideband (25 kHz) to narrowband (12.5 kHz) systems varies based on a number of system configuration, performance and implementation factors. Additional information on performance factors can be found in document TSB 88. Range is achieved with no increase in the Maximum Permissible Exposure defined in FCC Rulemaking document 93-62.

4.6.5 Resilience

The system shall be resistant to interference from co-channel, adjacent channel and intermodulation effects, at least to meet the standard of Continuous Tone Coded Squelch Systems (CTCSS).

The system control channel and working channel both implement forward error correction via message triplication and the inclusion of a BCH parity code with every message. This BCH code calculation can be modified to provide resistance to interference. The BCH coding process is modified by allowing an extra initialization byte through the BCH calculation process before the message bytes are processed. This allows both co-channel and adjacent channel interference from neighboring sites to be rejected. Further details of this procedure are provided in TSB69.3, Digital Signaling Specification.

Communications systems must be reliable and provide a basic level of service encompassing the majority of communications traffic, even in the event of facilities and equipment failure. In this context, resilience requires a design that provides essential communications in the presence of degrees of failure. Resilience is provided within a design by that designs' support of basic communication modes through simple, reliable paths. Features that are used rarely, for example, may be supported through high level switching, allowing failures in more complex areas of the system to result in reduction of features rather than the loss of a basic communication mode.

The system provides a high level of error reporting and alarming as an additional aid to resilience. The alarms and reports contain sufficient information, which aids the system operator in the condition's repair.

4.6.6 Encrypted Voice

Encrypted mode performance is equivalent to clear mode performance. .

4.6.7 Compatibility

The system can co-existent with analog systems. Careful adjacent channel frequency coordination may be desirable for narrowband (12.5 kHz) system implementations.

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4.6.8 Voice Quality

Voice quality for clear and encrypted communication is designed to be approximately equal to the voice quality for current analog clear-voice systems. Based on the strength of the received signal, the digital voice may appear to sound slightly better or slightly worse than analog voice.

4.6.9 Channel Access Time

The system has an average channel access time of 0.5 seconds at 5% BER.

The average channel access time, is defined as the elapsed time from PTT to the user's receipt of the 'transmit prompt tone.' Channel access time is dependent on system/network configuration. In good signal areas, the channel access time is a function of the signaling time between the radio and the system plus the call processing time. More complex systems and networks require longer call processing times. In poor signal areas, additional delays may occur due to the occasional retransmission of the channel request message because of bit errors.

4.6.10 Call Delays

Throughput delays will be less than indicated below:

- 250 msec for direct radio-radio communications
- 350 msec for direct radio-radio communications through a single repeater
- 500 msec for direct radio-radio communications within a system

4.6.11 Gross Bit Rate

Over the RF link, data transmissions are at a gross bit rate of 9600 bps with minimal re-transmissions.

4.6.12 Control Channel Loading

The trunking control channel accommodates an average load of 12.3 calls per second..

4.6.13 Registration Times

A radio entering a coverage area is required to be validated before operating on the system. This requires registration procedures as described in document XXX69.3-1, Call Procedures.

4.6.14 Number Ranges**4.6.14.1 Talk Groups and Radios**

In conventional and trunked mode, the system allows each radio to uniquely identify at least 2047 talk groups and at least 16,382 radio units.

4.6.15 Battery Performance**4.6.15.1 Battery Life**

Battery operated portable radio units provide a minimum of 8 hours operation given a 5,5,90 (5% transmit, 5% receive, 90% standby) duty cycle.

4.7 Mobile Data

Mobile data greatly improves the efficiency of communications and the utilization of the RF spectrum. It provides a number of different functions to meet different requirements, such as the following:

- Access to computer based information including automobile registrations or customer service data;
- Data acquisition, such as reading electric or gas meters or remote alarm signals; and
- Control applications, such as electric distribution automation.

Enhanced Digital Access Communications Systems utilizing mobile data are designed to take full advantage of digital signaling, fast call set-up and integrated voice and data operation. Typically these systems consist of both mobile and fixed RF equipment. The mobile equipment includes the following components:

Mobile Equipment:

- Mobile Data Terminal (MDT)
- Digital Mobile Radio

The fixed equipment for RF data include the following components:

- Message Switch or Gateway to Host Computer or Network

4.7.1 Open Systems Philosophy

All systems that support data are designed to be used as transparent data networks. The intent is to provide a fast access, fully integrated digital trunked radio platform that inherently supports the transfer of data between standard computer hardware. Towards this goal the system hardware interfaces, protocols and methods are

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compliant with the Open Systems Interconnect (OSI) model for communications systems. The diagram on the following page depicts the data network in terms of the OSI model.

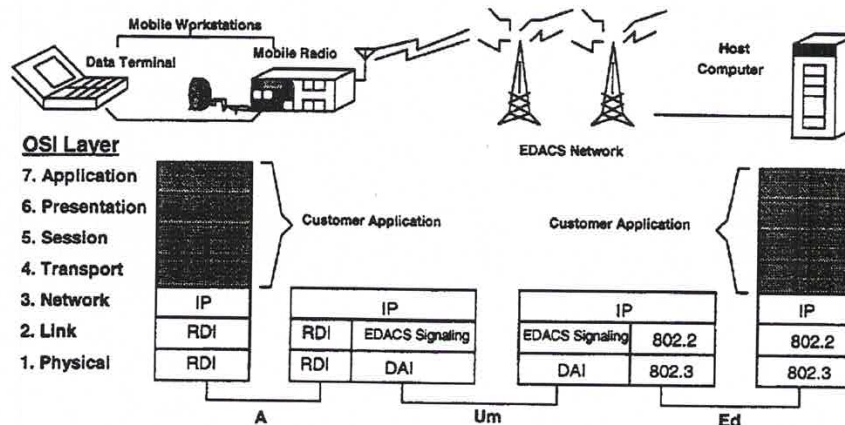


Figure 5. Data Network In Terms of the OSI Model

This open approach maximizes both the number and type of hardware and software sourcing options available to the customer. Mobile data terminal options range from traditional purpose built MDTs to standard MS-DOS pen based, notebook or laptop PCs. Existing host computers and networks are easily accessed through RDI protocol interface or the more ubiquitous Internet Protocol (IP) optional packet switching standard. Other protocols such as SNA and X.25 can be supported using external gateways. See XXX69.1, System Gateway Specification for additional information.

4.7.2 Mobile Data Configurations

Mobile data can encompass two types of configurations. The first is the basic form and is commonly referred to as mobile to mobile (RDI or gateway) data. This configuration (shown in Figure 2) is intended for basic single site applications with no system controller. In the mobile to mobile gateway case, a simple message switch acts as a gateway between a host computer and a base radio at the system site.

A more advanced configuration is referred to as mobile to fixed host (Landline) data. In this configuration, the system controller is used to form a transparent "bearer" network between a mobile terminal and a host application. This enables users of single or multi-site networks to fully integrate voice and data trunking across all sites. Data calls are transferred over the existing, high speed, Landline communications links established for voice communications.

4.8 Subscriber Roaming Capability

Roaming is the procedure a subscriber unit utilizes to allow it to change fixed end control capability. This occurs when a subscriber unit comes in contact with a system whose control channel offers quality which is more desired than the control channel currently selected.

4.8.1 Roaming Modes

Roaming can be viewed as having two modes. The first mode is "passive" and the other is "active." The following sections further define these concepts.

4.8.1.1 Passive Mode

In the idle state, the subscriber unit monitors and evaluates the current control channel assignment. The subscriber unit shall have a log of other control channels in the area with the associated RF channel quality from that control channel's RF subsystem controller. The quality of the control channel will be determined by a signal strength indication which the subscriber unit determines directly from the control channel. A record of several past signal strengths will be stored in the subscriber unit's data base. This will allow the subscriber unit to evaluate the longevity of the quality of the control channel.

As an example, control channel candidates may have a series of signal strengths that indicates that the subscriber unit is moving either toward or away from the control channel's site. Also, the record of the past signal strengths of a control channel candidate will provide a measure of stability of the signal which will minimize assignment of the subscriber unit to a control channel which is experiencing propagation anomalies.

4.8.1.2 Active Mode

When a subscriber unit determines that the currently assigned control channel does not meet its minimum requirements for quality, the device initiates an active mode of roaming. In this mode, the subscriber unit will attempt to be reassigned to an adjacent control channel of which it has knowledge. If the subscriber unit does not have a current "suggestion" for a next best control channel, the unit will perform a systematic search of all programmed channels. The unit will be programmed to periodically steer the search to a list of preset channel assignments and/or to the list of candidates which were being monitored.

4.8.2 Roaming Conditions

The following sections identify the conditions under which a subscriber unit will choose to roam.

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4.8.2.1 Initial Registration

This condition will exist when the unit is initially turned on or is not properly registered on a system.

4.8.2.2 Control Channel Signal Quality

As a subscriber unit moves out of the coverage of a control channel, the control channel signal strength will fall below the minimum set level.

4.8.2.3 Registration Denied

Registration may be when a subscriber unit is initially granted service while the unit's identification is being validated. If the system determines that the unit is not authorized service, the system denies subscriber unit registration by withholding confirmation.

4.8.2.4 Intra-system Roaming

During the 'idle' state, the mobile terminal continuously evaluates the need to select another base station to provide a communication path. When the subscriber terminal decides to change base station, a registration procedure may be required. This is initiated by the subscriber terminal resulting in an update of the location register in the system.

The received information from the mobile terminal is examined and checked against the information about the mobile terminal held by the system. If the system determines that the unit is not authorized service, the system denies subscriber unit registration; otherwise, registration is performed. . All but single-site trunked systems will require registration procedures. These will be further defined in document XXX69.3-1, Call Procedures.

4.8.3 Roaming Services

In order to provide an efficient service to the system operator, a number of standard services need to be supplied by the system. The following services will be defined in the document, but it is a system operator option as to whether they will be supported:

- Registration,
- Disable terminal.

4.8.3.1 Registration

When a subscriber unit roams, there will be two types of registration available, full registration and local registration.

4.8.3.1.1 Full Registration

This type of registration will require the most control channel resource and processing capacity. There are four conditions for this type of registration. An explanation of these conditions follows:

- Power-up registration
- Intersystem roaming
- Internetwork roaming
- Forced registration

For full registration, the subscriber unit must identify itself to the desired control channel. The subscriber unit will provide the radio identity (Logical ID) for the unit. Additional information may also be transmitted with the inbound data to provide any unique identification information related to the subscriber unit.

Once the visiting subscriber unit has identified itself, this identity will be checked in a data base defined as the Visitor Location Register (VLR) to determine if it is allowed access. If the unit is allowed access, the VLR is updated to reflect the presence of this unit at the specific site. If this VLR does not yet contain any information concerning this subscriber unit, then it must reference the proper Home Location Register (HLR) for the unit's identity. The VLR will receive the pertinent information concerning the unit's identity from the HLR and make an appropriate decision to allow or deny registration.

In an unsuccessful registration process, the requesting subscriber unit will not receive a suitable response to its registration request on the outbound control channel. In a successful registration process, the requesting subscriber unit will receive a system status update.

4.8.3.1.2 Local Registration

This type of registration will require a minimum of control channel resource and processing capacity. The following are two conditions for this type of registration:

- Intrasytem roaming
- Registration updates

As the unit roams in a system which it has previously performed a full registration, the unit will generally not need to be given new system specific parameters. The unit will usually only need to indicate that it prefers the currently assigned control channel.

As the unit moves among systems of a network, it may be able to perform the registration to a control channel in short form, as long as pertinent system parameters are not changed. When the communication system needs to verify the registration condition for the unit, the response to the communications system will normally be sufficient.

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Typically, the unit will indicate its identity as the current working identity within the system. Generally the unit will receive a confirmation of a successful registration to this control channel.

4.8.3.2 Disable Terminal

Procedures to disable and re-enable the participation of specific mobile and line-connected terminals from the system are defined in document XXX69.3-1, Call Procedures.

4.9 Network Management Services

All information at the network management interface shall be functionally defined.

There shall be a logical single point of entry, which may be connected to geographically separate input points, for management of system components and software levels. The system management shall allow vertical partitioning and delegation of control to the organization responsible for the operation of the partition.

Administrative services such as call statistics and traffic recording capability will not be standardized.

4.9.1 Network Management Interface

This interface is between the system controller and a Network Management Center, so that the center can provide control for components of the system. Communications will be based on the internet (SNMP) protocol, and the provider of the network management element shall support the protocol. The interface shall be defined in document XXX69.1, System Gateway Specification.

4.9.2 Call Statistics Services

The requirement for obtaining call statistics is likely to vary between different systems. The system administrator will determine which call statistics are to be available by the system. It may be possible for systems to exchange some call statistics for intersystem working purposes. As an option, systems shall be capable of exchanging such call statistics as the system administrator may elect.

4.9.3 Traffic Recording Services

As an option, traffic recording services shall have the capability to provide call traffic and associated call statistics in a suitable format to a recording device. The traffic recording will be possible for selected individual communications or for categories of target communications. Traffic recording will also be possible for all communications.

Where the traffic-recording service is offered, a method for selecting which traffic to record will be necessary. The traffic-recording service shall only be made available to authorized users.

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5. APPENDIX A: GLOSSARY

Adaptive Multiband	A digital vocoding method defined in document XXX69.2, Vocoder and Encryption Definition.
Agency	A specific group of fleets and their associated subfleets. For example, in a municipal trunked system, examples of agencies could be fire, police, public works and administration.
Bit Error Rate (BER)	The average rate of errors on a radio channel. Usually measured by a percentage number, e.g., 5% error rate, meaning 1 error in 20 bits on the average.
Call Queuing	When all channels on the system are busy, the call request is held in a First-In-First-Out queue. The caller and all members of his group are notified that a call request has been queued. Upon channel assignment, the caller is alerted and is allowed to proceed with push-to-talk (PTT).
Callee	The party to whom the call is placed, i.e., an individual or group of radios.
Caller	The originating party of the call request, i.e., an individual radio.
Channel Access Time	The time duration between activation of the caller's PTT and reception of a transmit prompt tone at the caller's radio.
Channel Coding	Method to protect digital data stream from the effects of channel errors that occur as a result of fading and interference, also called error correction and detection.
Channel Drop Time	The time duration between radio unkey and when it is actually available for another call..
Control Channel	The repeater channel on which system control information is continually transmitted and channel request/status information is received from the field radio units. Any one repeater channel may serve as the control channel. The field radios monitor the control channel when not active on a working channel.
Data	Normally refers to information as from a data terminal. May also be used to refer to any digital information.

Data Rate	The speed that data is sent over a channel. the system uses a 9600 bits per second data rate.
Data Terminal	A device containing a display and keyboard which supports the transmission of data. Interfaces to a radio through a Radio Data Interface (RDI).
Digitization	The technique of converting a continuous analog waveform to binary digital data..
Dynamic Regrouping	Over-The-Air-Programming of field radio units. Multiple talk groups can be added to a radio unit while the radio is active in the field. Optionally, field units can be forced to communicate on designated talk groups..
Enhanced Digital Access Communications System	A trunked Land Mobile Radio communication system designed for Public Service, Industrial, Utility and Commercial applications.
Emergency	An "Emergency" message is initiated by the caller and automatically transmitted by the radio on the control channel. The system automatically assigns the highest priority to the talk group. All members of the talk group are notified of the emergency condition.
Encapsulation	Formatting the digital data stream with information to enable synchronization and signaling functions.
Encryption	The process of randomizing a digital data stream to prevent unauthorized monitoring.
Encryption Algorithm	A mathematical manipulation of data bits designed to make the resulting data stream difficult to decipher without the proper crypto code (key). Algorithm examples are the data encryption standard (DES) developed for the US government and Ericsson's proprietary VGE. For US government use, DES encryption also requires a physical security to protect the communications devices. This is defined in Federal Standard 1027 (FS-1027), and the superseding document FIPS-140.
Fault Tolerant	A design and implementation philosophy that permits a system to continue operating in the event of failure of major

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	components.
FIPS	Federal Information Processing Standard
Fleet	The third layer in the organization hierarchy of addressing - a predefined collection of subfleets.
Fleet Call	A call to all subfleets of the fleet on which the call is made. For example, a "patrol" fleet call would call all north, south and central patrols if they were subfleets under the Patrol fleet.
Group (Talk Group)	A collection of people with a need to communicate with each other. When a caller places a call within a group, the system signals to collect all members onto the same working channel. A group call can be placed on the agency, fleet or subfleet level.
Group Call	A call by any member of a group that puts all members of the group on the same channel. All radios in the group can hear the call.
Group ID	The system uses a 2048 Group Address scheme. Each talkgroup is assigned a Group ID from 0 - 2047.
Group Scan	The radio monitors the control channel and responds to all group channel assignments associated with the "scan" list. The "priority" group is dictated by the group currently selected. If a call occurs on the "priority" group while monitoring one of the scan groups, the radio will immediately late enter into the "priority" group.
HLR	Home Location Register
Identification (ID)	A number associated with field radios (unit ID) that uniquely identifies the radio. This number, referred to as logical ID, is automatically sent anytime the radio transmits. ID may also refer to the group number, or group ID, which uniquely identifies the talkgroup in the system.
Individual Call or I-Call	A private call on the system from one field radio to another or field radio (or dispatcher and a field radio). This call is made possible since radios have a unique unit ID number. The system assigns a working channel to the caller and callee.
Key	As in crypto key. A specific code (usually a sequence of random binary digits) used with an encryption algorithm to

	"encrypt" the data bits according to a predefined pattern.
Keyloader	A handheld, battery operated device that provides a method to load, store and transfer keys to a radio.
Late Entry	If a radio is powered up while its talkgroup has a call in progress on a working channel, the radio will "Late Enter" into the call even though it missed the original channel assignment. This is achieved through the assignment updates the control channel continually transmits. A radio may "Late Enter" if the radio is turned on, passes through a coverage void or changes talk groups.
Logical ID	The system uses a 16,384 Individual (Logical) Address scheme. The system reserves ID "0" and ID "16,383." Each radio is assigned Logical IDs from 1 - 16,382.
Message	An alphanumeric communication preprogrammed into a radio. Messages are transmitted immediately via the control channel. Message is intended to allow users to send communications such as "SEND EMS" or "SEND HELP" to the dispatcher.
Message Trunking	Once assigned a working channel, the working channel remains assigned for the duration of the conversation. Keeping the working channel assigned is accomplished by putting a hang time on the repeater for several seconds.
Multisite	A network of multiple systems. Each system networked may have a different number of working channels. To prevent RF interference, adjacent systems do not use the same RF frequencies.
Network	An Intelligent Wide Area Network links systems. Users may roam from one system to another while the System Controllers automatically tracks location and status.
NRZ	Non-Return to Zero is a binary signaling format in which 1s and 0s are represented by equal positive and negative levels.
Out of Range	When the radio is out of range of the system and the operator PTTs, the radio alerts the operator with an audible "Out of Range" tone.
Patch	The process of connecting two (or more) groups together at a console. A patch allows two (or more) groups to

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	communicate as if they were one group and uses only one base station.
Power Monitor (PMU)	Collocated with the system controller. Monitors the transmitter power outputs and VSWR for the antenna system. Provides an alarm notification to the system controller.
Priority Level	When all the working channels are busy, the next call request received is queued. Preassigned priority levels for each Group and Individual are used to determine which call request is assigned first. Eight priority levels are offered, seven may be assigned and the eighth, "Emergency Priority," is reserved as the highest priority. Within a priority level, the call requests are assigned on a First-In-First-Out basis.
Priority Scan	Information transmitted on a talk group which enables a radio to monitor and respond to a priority group call.
Priority System Scan	A priority or "home" system is preprogrammed into the radio continually searches (scans) for its priority system and if found locks onto it. Priority System Scan improves network efficiency by keeping as many radios on the primary (priority) system as possible, thus preventing unnecessary multisited calls.
PSTN	Public Switched Telephone Network
Radio Data Interface (RDI)	A protocol and level converter which interfaces between a data terminal and the mobile radio.
Range	Used interchangeably with coverage to define the limits of a two-way radio system. Range is the greatest distance between two-way radios over which communications are possible. Coverage is the area surrounding a base station where communications with the mobiles or portables are possible.
Registration	A transmission from a field radio that occurs automatically and informs the system that the specific unit is active on a certain group and system. Registration occurs when a radio scans from one system to another system, when a group is changed and when the radio is turned on.
Roaming	<u>Automatic</u> - Upon loss of the control channel, the radio automatically begins a search for a new control channel

from a preprogrammed list of surrounding systems.

Manual - The radio operator manually switches his System selector to a new system.

Scan	The process of monitoring a selected list of groups in a field radio. If a call occurs on any of the scan list groups, the radio will switch to that group. The group manually selected is the priority group (also the transmitting group) and the radio will return to the priority group if a call occurs for that group even if the radio has been monitoring one of the other scan groups.
Simulcast	<u>Simultaneous broadcast</u> by two or more transmitters located at different sites operating on the same RF frequency. Simulcasting requires precision RF frequencies, audio responses and synchronized data. A Simulcast trunked system consists of two or more transmitting systems. Each system has the same number of channels and uses a common set of RF frequencies. Simulcast "operates" as a single trunked system irrespective of the number of systems simulcasted.
Simulselect	The process of a console operator communicating with two or more groups simultaneously using only a single radio channel.
Single Channel Autonomous Trunking (SCAT)	SCAT is a trunked system consisting of a single repeater and a RF channel. Operationally, SCAT functions as a control channel or a working channel depending on the trunked service required. In its idle state, SCAT operates as a control channel. When a channel request is made, SCAT assigns the call to itself and converts to working channel operation. The address hierarchy is maintained as are many trunking features.
Status	A short digital message transmitted or received on the control channel. Typically it is initiated by the radio operator to identify the current condition of the field unit, i.e., In route, At scene.
Subfleet	The fourth and final layer in the Group Address hierarchy. Group communication is specific to the subfleet.
Synchronization	Digital technique of allowing a digital receiver to achieve time alignment with the incoming digital data stream from a

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	transmitting radio.
System	Normally refers to the collection of equipment at a specific location such as the "North System."
System Controller	A computer running application software that controls the moment to moment trunking process plus such features as telephone interconnect, dynamic regrouping and queuing management.
System Scan	The process that occurs in a field unit when the unit moves out of the coverage area of one site. System scan searches for another control channel from a preprogrammed list of site frequencies. See priority system scan.
System Update	Information sent periodically to radios concerning ongoing systems activity.
System-Address	The first layer in the Group Address hierarchy. Group communication includes all Agencies, Fleets and Subfleets.
Telephone Interconnect	Collocated with the system controller, it interfaces the public Switched Telephone Network to the trunked system, allowing radio operators to place or receive telephone calls. Telephone callers have the option of calling an individual or a group.
Terminal Unit	A terminal unit is a radio or data device that operates at end point C per the system model.
Tracking	In a Wide Area Network, all radio log-ins are recorded in a database. Through the database, the System Controller determines the systems to be conferenced for the wide area calls. It is the tracking mechanism which allows the network to limit the wide area calls to those systems in which a member of the group has logged in.
Transmission Trunking	Once assigned as a working channel, the working channel remains assigned for the duration of the caller's transmission. Upon the caller's unkey, the system immediately deallocates the channel and makes it available for reassignment. This is equivalent to a zero-second hang time. Because of the fast access and drop times of the system, transmission trunking is significantly more efficient than message trunking providing the system operator increased call throughput or fewer calls queued or both.

Trunking	The process of dynamically allocating a limited number of radio channels to groups of people in need of communication.
Unit Disable	Unit Disable allows the system manager to disable a lost or stolen radio. Once disabled, the radio cannot transmit or receive. The radio may be reactivated on command from the system manager.
Unit Identification	Digital code transmitted by radios containing the ID number or address of the radio.
VLR	Visitor Location Register
Vocoding	Digital technique to convert an analog voice signal to a digital data stream via the use of advanced signal processing algorithms.
VGE	VGE Encryption operates at the same data rate as the system signaling, 9.6 kbps, thus providing inherent radio-to-radio digital voice encryption capability on the system.
Wide Area System Scan	When the radio unit loses the control channel of the current system, the radio automatically begins searching for a new control channel. The intelligent search algorithm uses a map of adjacent systems to ensure minimum transition time.
Working Channel	All repeater channels except the single control channel operate as working channels. Radios intercommunicate, either encryption, mutual aid, analog voice, digital voice or digital data, through a working channel.

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6. APPENDIX B - SYSTEM ADDRESS SCHEME

- System -** This is the entire radio trunking system and includes all mobiles, portables, control stations and consoles.
- Agency -** A specific group of fleets and their associated subfleets. For example, in a municipal trunked system, examples of agencies could be fire, police, public works and administration.
- Fleet -** A specific group of subfleets which incorporate the individual units. In the police agency, examples of fleets could be patrol, detective, traffic and criminal investigation.
- Subfleet -** A specific group of individual units. In the Criminal investigation fleet, examples of subfleets could be Vice, Major Crime and Youth.
- Individual Unit -** Each unit in the system, up to 16382 units total, is assigned a Logical ID or LID. The Logical ID for the unit remains the same regardless of the Agency, Fleet and Subfleet to which it is assigned.

Examples of system address schemes by different organizations follow.

6.1 Public Service

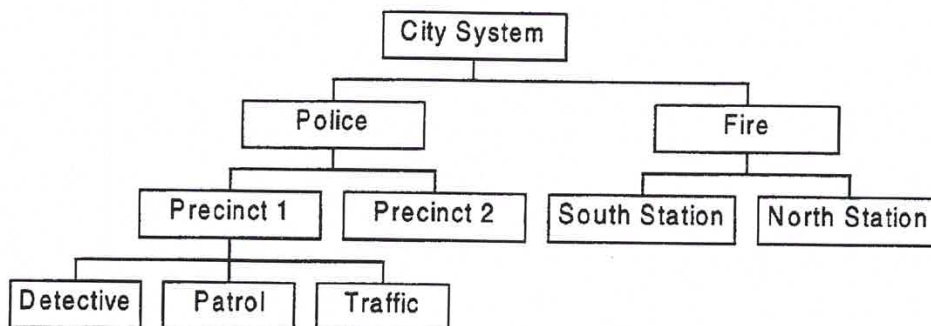


Figure 6. Public Service

In many community-wide communication systems, the community is divided into agencies, such as police and fire departments. These agencies are typically broken down further into fleets, such as precinct 1 and precinct 2. Precincts can be further broken down into subfleets such as detectives, traffic and patrols.

Up to 16,382 individual radios can operate under any subfleet.

6.2 Electric Utility

An electric utility uses the same system address scheme, but geographic boundaries as well as operational boundaries are reflected in their system partitioning.

- Agency level is the Region.
- Fleet level are the Districts within the Regions.
- Subfleet are the Operating Groups within the District or Regions.

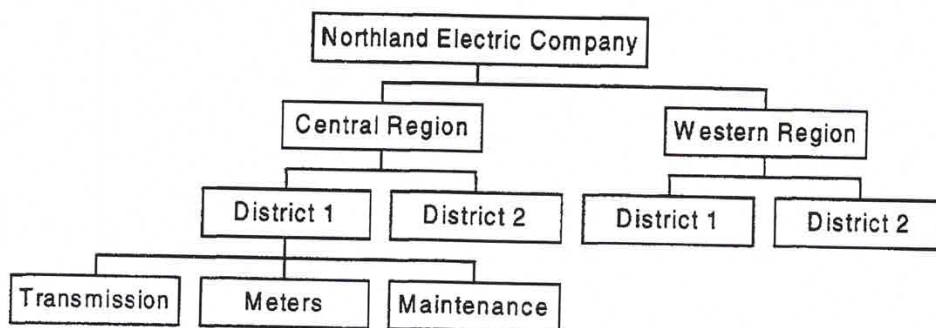


Figure 7. Electric Utility

Shown in Figure 7 are typical examples of the names that might be associated with groups in such an electric utility.

Up to 16,382 individual radios can operate under any subfleet.

6.3 Fleet Mapping

The purpose of fleet mapping is to logically associate subfleets to a fleet call and fleets to an agency call. For example, when a fleet call is made, the radio must understand whether or not to respond to the call. The system address structure has been established to implement a simple, reliable method of logically associating subfleets together.

The system address structure supports the following group calls:

- Agency;
- Fleet; and
- Subfleet

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Establishing a fleet map structure dictates the maximum number of agency and fleet calls which can be assigned. Within the fleet map structure, the more agencies that are set up, the more agency calls that can be assigned. The same is true for fleet calls. To enhance each agency's flexibility, different fleet and subfleet structures can be used for each agency to suit their specific requirements.

A group call is addressed using a Group ID (GID). The GID is composed of 11 bits to define a total of 2048 groups. The fleet map is structured by partitioning the 11 bits. Restrictions on the structure of the 11 bits are as follows:

- Maximum of 5 bits to be used for agencies;
- Minimum of 1 bit to be used for fleets; and
- Minimum of 2 bits to be used for subfleets.

The fleet map structure logically associates subfleets to a fleet call and fleets to an agency call using a simple and reliable design approach.

Alternative methods such as dynamically associating subfleets together were proven to be less reliable. To dynamically associate subfleets, a central database would have to be created, typically in the system controller. In the event of system controller failure, the database could not be accessed and the Agency/Fleet call feature would be lost. For the system, the loss of Agency/Fleet calls during a possible emergency was deemed unacceptable. For this reason, the fleet map structure was embedded into the signaling.

7. APPENDIX C - CALL SEQUENCES

7.1 Request

- 1) All mobiles and portables are monitoring the control channel.
- 2) The call originating unit presses the PTT button and sends the inbound request onto the control channel.
- 3) The inbound message includes:
 Who am I (from) Individual ID,
 What call type and communication mode:
 Group, Individual, Telephone, Data, Digital,
 Who am I Calling (to): Individual, Group
- 4) The control channel receives the message.

A representation of this process is shown in the following figure.

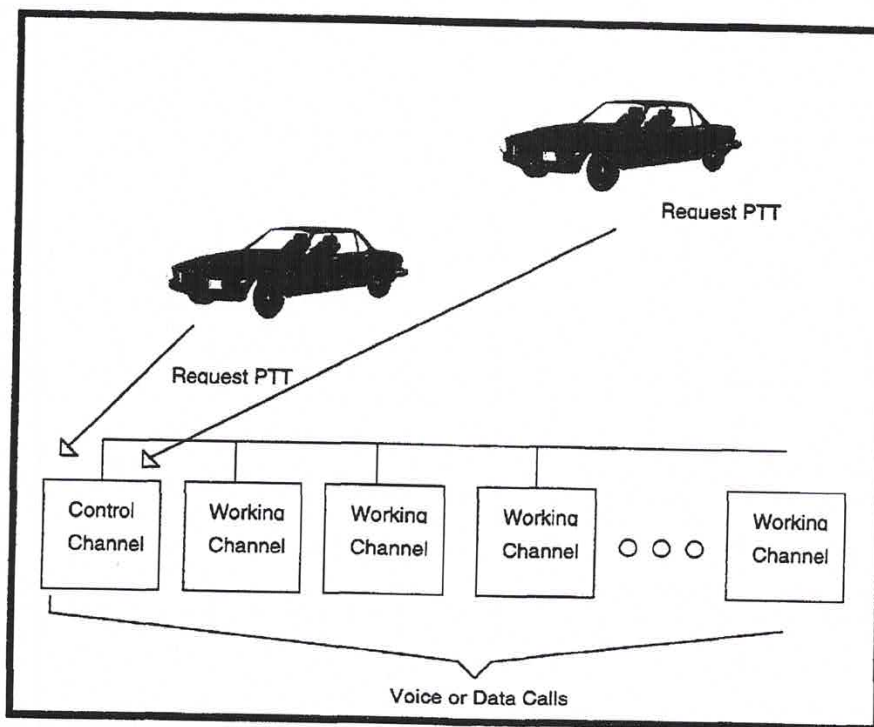


Figure 8. Request PTT

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This request to talk process is shown below.

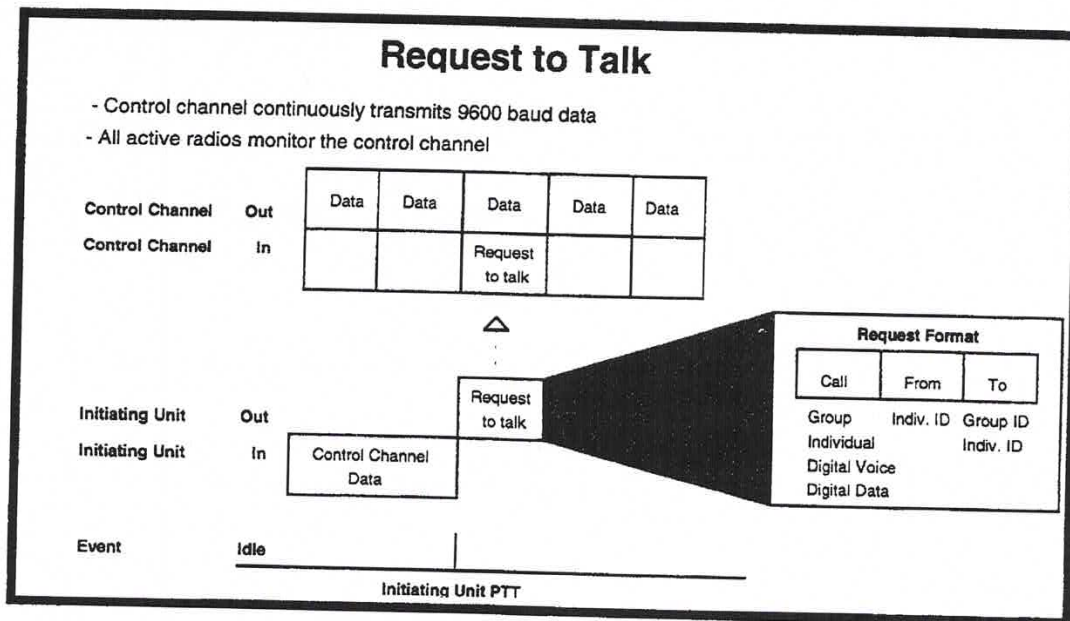


Figure 9. Request To Talk

The channel assignment follows the request very rapidly, as shown in the following figure.

7.2 Assignment

- 5) The control channel repeater determines the working channel to which the call is assigned.
- 6) An outbound message from the control channel to the originating unit, plus all users in the group call, directs them to the assigned working channel.
- 7) Radio units automatically switch to the working channel frequency.

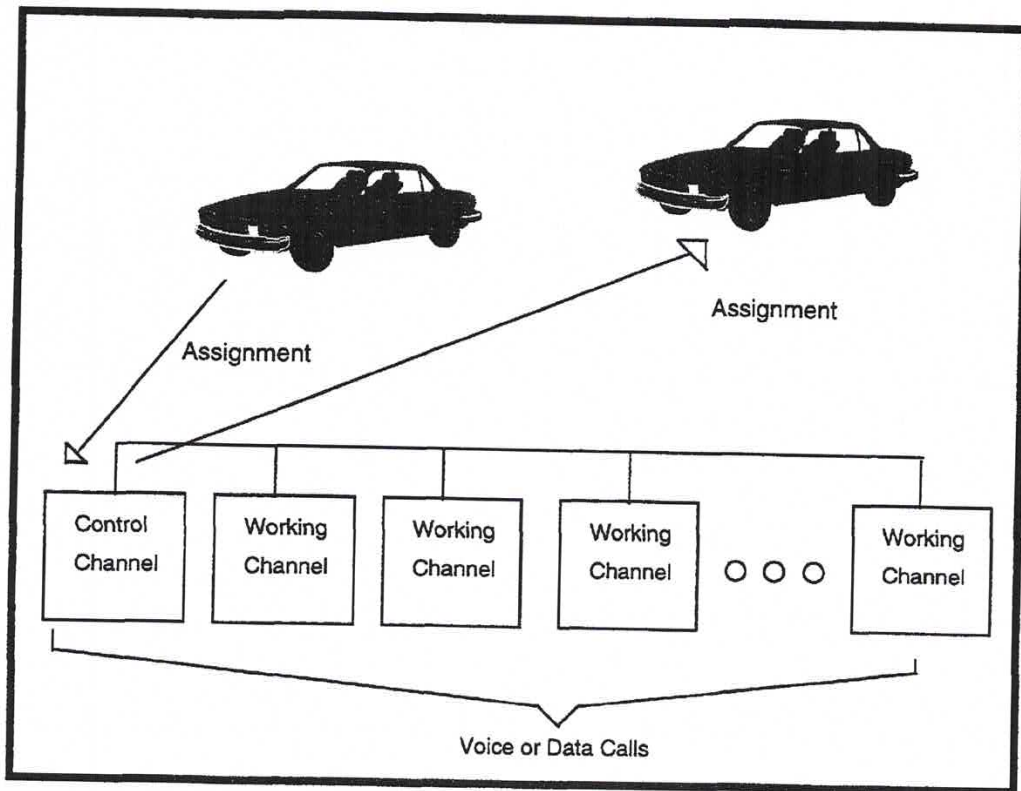


Figure 10. Assignment

7.3 Transmit and Receive

- 8) A high speed handshake on the working channel with the call-originating unit occurs.
- 9) After confirmation, the call originator hears the "OK-to-transmit-prompt tone," alerting the originator to begin talking. The transmit prompt tone provides a positive confirmation of channel assignment.
- 10) Signaling on the assigned working channel tells the receiving units to unmute their speakers, allowing audio to be heard.

The transmit and receive process is shown as follows.

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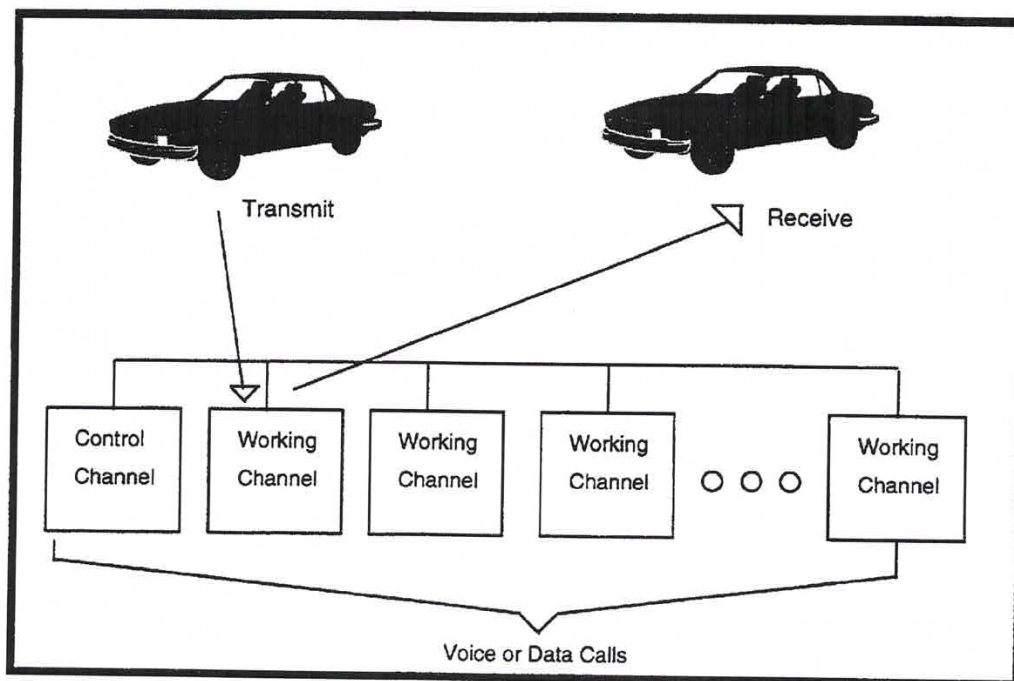


Figure 11. Transmit and Receive

The channel assignment process is shown in the following diagram. The channel assignment takes place very rapidly. In less than one-half of a second, the operator is alerted that communications may proceed. Because of the high-speed digital signaling, virtually no delay is apparent to the user in obtaining a channel assignment. All that is apparent is that a clear channel is available for communications.

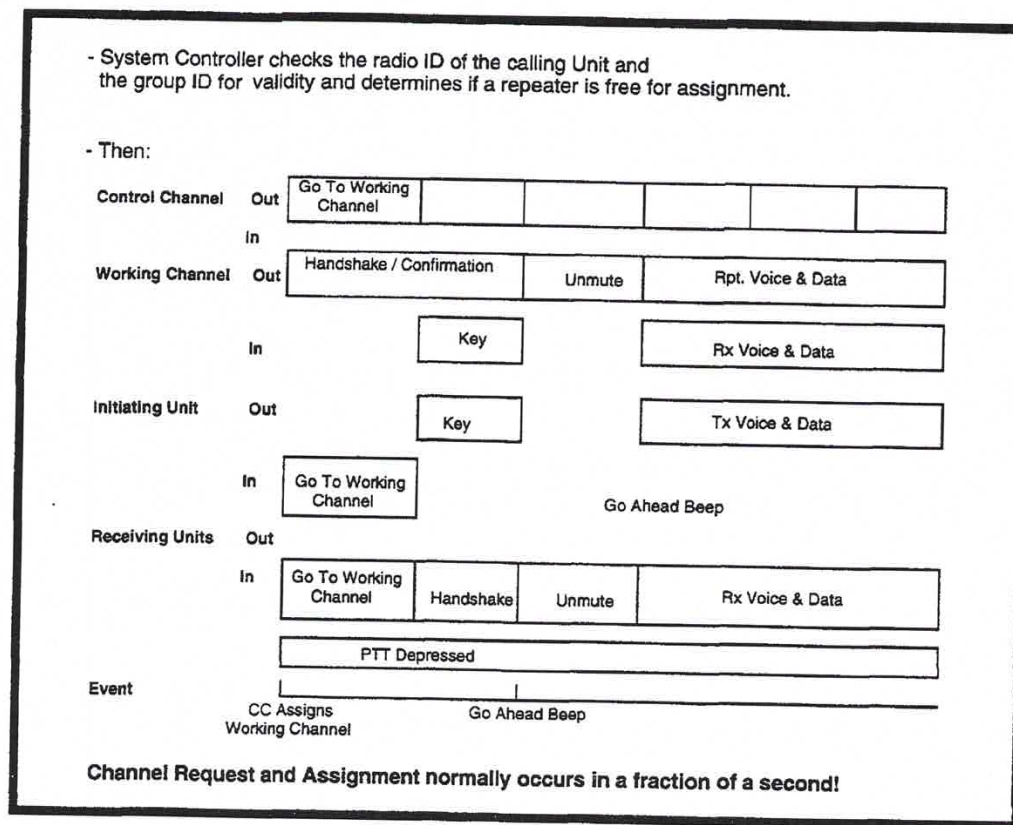


Figure 12. Call Process - Channel Assignment

If the call is "message trunked," a fixed amount of time (hang-time) will elapse between the receipt of the un-key message and issuing of the channel-drop message. This type of message trunking lets other radios in the group acquire the channel without repeating the channel acquisition process.

7.4 Call Termination

- 11) When the originator finishes talking, the PTT is released, sending an un-key message to the working channel and all receiving units.
- 12) All units return to the control channel.

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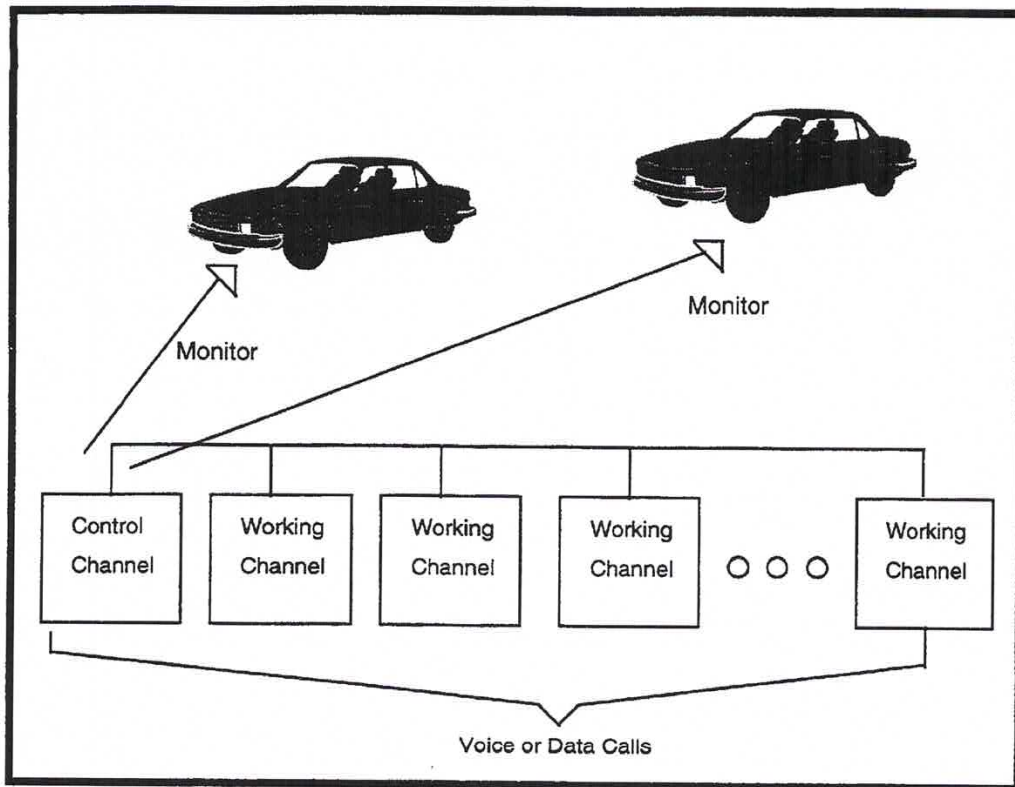


Figure 13. Call Termination