UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration

BULLETIN 1751H-703

SUBJECT: <u>BETRS Radio Systems</u>

TO: Telephone Borrowers
REA Telephone Staff

EFFECTIVE DATE: Date of Approval

EXPIRATION DATE: Three years from effective date

OFFICE OF PRIMARY INTEREST: Transmission Branch, Telecommunications Staff Division

PREVIOUS INSTRUCTIONS: This bulletin replaces the following Telecommunications Engineering and Construction Manual Sections:

TE&CM 948, Basic Exchange Telecommunications Radio Service
TE&CM 949, BETRS Radio Application Guidelines

FILING INSTRUCTIONS: Discard the following Telecommunications Engineering and Construction Manual Sections:

TE&CM 948, Basic Exchange Telecommunications Radio Service
TE&CM 949, BETRS Radio Application Guidelines

Replace with this bulletin.

PURPOSE: To provide information on Basic Exchange Telecommunications Radio Service, or BETRS. This bulletin includes a tutorial that provides a basic description of the BETRS concept and equipment. It also provides BETRS application guidelines and recommendations. All information in this bulletin is advisory.

[signature] C. [signature]
Administrator

9/18/91
Date

TABLE OF CONTENTS

INDEX:

Basic Exchange Telecommunications Radio Service
BETRS
BETRS Radio Systems
BETRS Radio Application

ABBREVIATIONS & DEFINITIONS

The principal abbreviations and terms are defined in a generic manner as they are commonly used in this bulletin and in telecommunications. These abbreviations and definitions are intended to provide descriptive illustrations to better understand BETRS concepts, equipment, and applications. The list contains a limited number of abbreviations and terms, and the definitions are not intended to be complete and precise. Additional digital transmission terms are covered in Bulletin 1751H-403.

AC: Alternating Current.

ADPCM: Adaptive Differential Pulse Code Modulation, a digital coding technique.

Base Radio Station: All equipment located at the BETRS central office radio terminal site. (FCC term: Central Office Station.)

BETRS: Basic Exchange Telecommunications Radio Service, a radio service authorized by the FCC in the 150, 450 and 800 MHz bands.

Cellular: Refers to Cellular Radio Service (or equipment), a mobile radio service authorized by the FCC in the 800 MHz band.

Codec: Coder and Decoder; used for analog to digital encoding and detection.

COE: Central Office Equipment.

Concentrator: A switching device that provides access between a larger number of ports or lines and a smaller number of paths or trunks.

Controller: A unit that interprets and acts on coded instructions.

DAMA: Demand Assignment Multiple Access; access from many sources or locations upon request (demand). Also see TDMA.

DC: Direct Current.

DS1: Digital Signal at the First level, 1.544 megabits per second.

DSX1: A DS1 interface or crossconnect point.

FAA: Federal Aviation Administration, a U.S. Government Agency.

FCC: Federal Communications Commission, a U.S. Government Agency.

FDM: Frequency Division Multiplex; multiplex by discrete frequency assignment of channels.

FDMA: Frequency Division Multiple Access; access from many sources or locations on a frequency division basis. Also see DAMA and FDM.

ABBREVIATIONS & DEFINITIONS - Continued

GHz: Gigahertz, one billion cycles per second.

kHz: Kilohertz, one thousand cycles per second.

LPC: Linear Predictive Coding, a digital coding technique.

MSA: Metropolitan Statistical Area.

MHz: Megahertz, one million cycles per second.

Processor: See Controller.

Repeater Radio Station: All equipment located at the BETRS radio repeater site. (FCC term: Relay Station.)

RSA: Rural Service Area; geographic areas designated by the FCC for cellular radio service in nonmetropolitan areas.

Subscriber Radio Station: All equipment located at the BETRS subscriber radio terminal site. (FCC term: Rural Subscriber Station.)

T1: A digital transmission system operating at DS1.

TDM: Time Division Multiplex; multiplex by discrete time assignment of channels.

TDMA: Time Division Multiple Access; access from many sources or locations on a time division basis. Also see DAMA and TDM.

Yagi: A type of directional antenna.

1. OVERVIEW

1.1 General

1.1.1 This bulletin provides borrowers of the Rural Electrification Administration (REA) and other interested parties with technical information on Basic Exchange Telecommunications Radio Service (BETRS). BETRS is a public telecommunications Rural Radio Service used as an alternative to traditional telecommunications outside plant, carrier and radio facilities. The information and recommendations in this bulletin are advisory.

1.1.2 BETRS was established by the Federal Communications Commission (FCC) in December 1987. FCC Rules concerning BETRS and other radio equipment and services are contained in the Code of Federal Regulations, Title 47. BETRS History is summarized in Appendix 1. This bulletin addresses BETRS in the 150 and 450 MHz bands that have co-primary status (primary and equal) with the Public Land Mobile Service and the 800 MHz band that has co-primary status with the Private Land Mobile Service (also called Specialized Mobile Radio Service or SMRS). BETRS in the 800 MHz Cellular Radio band is not covered in this bulletin. A discussion of Cellular Radio Systems is planned for Bulletin 1751H-705.

1.1.3 As a background for BETRS, this bulletin begins with a brief overview of subscriber radio equipment available for rural telecommunications service. Section 2 provides a description of the BETRS concept, existing analog equipment, and evolving digital equipment. Section 3 provides BETRS application guidelines with discussion on preliminary planning, radio system design, FCC Radio Station Authorization, specification considerations, system proposals, and system implementation. Generic descriptive terms are used to describe radio systems and equipment throughout this bulletin except that paragraph 3.5 uses FCC terms in discussing the FCC Radio Station Authorization.

1.1.4 While this bulletin is intended to aid REA borrowers in the design, procurement and implementation of BETRS for rural telecommunications service, it is not intended as a complete reference on BETRS radio system design. Specialized knowledge and reference material are required to design radio systems. This bulletin merely highlights selected aspects of radio system design which are key to adequate telecommunications service, approvals and conformance to requirements of the REA, FCC, and other local, state, and national organizations. Some material in this bulletin is abbreviated to reduce volume.

1.1.5 As reference material is subject to change, the latest issues of source reference documents should be obtained, reviewed, and addressed. The discussion and explanation of outside references contained in this bulletin serve as a guide, but may be outdated because of changes in source references. For instance, the latest FCC Rules should be addressed in FCC license applications. Electrical codes are periodically revised and code requirements may vary with localities.

1.1.6 In the past, BETRS type subscriber radio service was sometimes provided as a part of Improved Mobile Telephone Service at 150 and 450 MHz. Presently, BETRS is usually provided as a service that is separate from mobile service in these bands. The ultimate goal is BETRS equipment that is universal in application and interface, designed for economical point-to-multipoint demand assess (trunked) applications, packaged for easy installation, and available with model variations for special applications and features.

1.1.7 A trunked radio system where channels are available by demand assignment multiple access (DAMA) permits a limited number of radio frequencies and channels to serve a larger number of separately located telecommunications subscribers. This bulletin emphasizes equipment designed for point-to-multipoint application utilizing frequency division multiple access (FDMA), time division multiple access (TDMA), and combinations of FDMA and TDMA.

1.2. Subscriber Radio Equipment

1.2.1 The following is a summary of subscriber radio equipment used or available for rural telecommunications service.

1. Point-to-Multipoint (150, 450 and 800 MHz BETRS)
2. Point-to-Multipoint (2 GHz by FCC Waiver)
3. Point-to-Multipoint (800 MHz Cellular)
4. Point-to-Point (2 GHz and Other)
5. Point-to-Point (150 and 450 MHz BETRS)

1.2.2 Point-to-multipoint BETRS trunked radio equipment at 150, 450 and 800 MHz can be used to serve individual telephone subscribers from a common location on a demand access basis (Figure 1). A radio system with channels available by demand access is referenced by the FCC as a "trunked" radio system. Point-to-multipoint subscriber radio equipment has been available on the world market for several years. The BETRS action by the FCC prompted interest in the U.S. market. Some manufacturers developed new digital radio equipment and others used existing analog radio equipment to address this market. BETRS equipment is covered by Part 22 of the FCC rules.

1.2.3 Point-to-multipoint trunked radio equipment at 2 GHz is also used to serve individual subscribers from a common location on a demand access basis. One type of this equipment has been used in various parts of the world for over 10 years, and has successfully completed two REA field trials. FCC licenses were obtained by waiver because this equipment is not licensed in the common carrier band. The waiver process is often difficult and lengthy, and waivers to use this equipment have been denied since the BETRS authorization.

1.2.4 Point-to-multipoint trunked radio service in the 800 MHz Cellular Radio band is also available. Fixed subscriber service in the Cellular Service band was not addressed in the original FCC BETRS action. Cellular Rural Service Areas (RSAs) have been licensed by the FCC, and BETRS fixed service was permitted on a Secondary basis in a January 1989 FCC Order and further relaxed in a February 1990 FCC Order. BETRS is Secondary to cellular mobile service in this band. However, the cellular licensee has a reasonable degree of freedom in providing BETRS fixed service so long as the mobile service needs are adequately met. BETRS in the Cellular Radio Service band is mentioned for completeness, but will not be addressed in this bulletin. Cellular radio equipment is covered in Part 22 of the FCC rules.

1.2.5 Point-to-point microwave radio equipment is used to serve remote subscriber clusters (Figure 2). The most popular arrangement is 2 GHz digital radio equipment with 96 or 192 voice channels. From the remote radio equipment, subscribers are served with conventional telephone cables, or from digital subscriber carrier equipment extended over T1 span lines from the remote radio terminal. This digital radio equipment is covered by Part 21 of the FCC rules.

1.2.6 Point-to-point BETRS analog and digital radio equipment at 150 and 450 MHz is used to serve remote subscriber clusters. This is illustrated in Figure 3 and is similar to the point-to-point microwave radio illustrated in Figure 2, except that two or more radio channels are used to serve a nearby subscriber cluster.

1.2.6.1 Point-to-point analog radio equipment at 150 and 450 MHz is also used to serve individual subscribers on a dedicated channel basis (Figure 4). This equipment has been available in the past as "rural radio" or "line extender radio." It was licensed under FCC Part 22 Public Mobile Service as secondary service. The BETRS action by the FCC upgraded this application to co-primary status under FCC Part 22. Rural radio equipment is useful in select or small startup applications.

1.2.7 The radio service tools described above are presently available to REA borrowers. REA recommends the use of equipment that is most suitable and economical for the specific application. The balance of this bulletin will emphasize BETRS trunked radio equipment with demand access channels for point-to-multipoint service in the 150, 450 and 800 MHz bands.

2. BETRS EQUIPMENT AND SYSTEMS

2.1 Introduction

2.1.1 Basic Exchange Telecommunications Radio Service or BETRS was established by the FCC in December 1987. BETRS is a public telecommunications rural radio service used as an alternative to traditional telecommunications outside plant facilities. Co-primary status is provided for BETRS in the following bands.

Frequency	Channels	BETRS	Co-Primary Service & FCC Rules
150 MHz	18	Part 22	Public Land Mobile - Part 22
450 MHz	26	Part 22	Public Land Mobile - Part 22
800 MHz	50	Part 22	Private Land Mobile - Part 90

2.1.2 Some restrictions apply. For example, the FCC requires 800 MHz BETRS to be at least 100 miles from the border of the 54 largest Metropolitan Statistical Areas (MSAs). BETRS eligibility is limited to local exchange carriers and others with state authorization (where applicable). Cellular radio was not addressed in the original BETRS authorization, but was addressed in later FCC Reports and Orders concerning cellular systems. Cellular operators and resellers so authorized by their state regulatory entities may offer fixed BETRS in RSAs and rural parts of MSAs.

2.1.3 BETRS equipment is basically radio equipment that is substituted for traditional telecommunications facilities, including copper cable, carrier, lightwave and microwave radio systems. The BETRS equipment provides standard services and operates with standard telecommunications equipment and interfaces. This includes central office equipment, telephone sets, and other customer premises equipment meeting FCC Part 68; and standard voice and digital interfaces such as DS1. BETRS is intended as a direct replacement for hard wire circuits where cost effective.

2.1.4 BETRS can be used for area coverage, or can be used to supplement service by conventional facilities. In general, a mixture of conventional facilities and BETRS may be more economical than an all-BETRS design.

2.1.5 The REA continues to seek technologies for cost effective telecommunications service in rural areas. The use of radio to provide telephone service to subscribers in rural areas met with limited success prior to BETRS. With the FCC licensing of frequencies on a co-primary basis, the use of BETRS radio equipment is expected to increase. BETRS radio equipment can be used in conjunction with traditional telecommunications equipment and facilities to provide more cost effective service to subscribers.

2.1.6 The BETRS frequency allocation provides for a total of 94 radio channel pairs (94 base transmit channels and 94 subscriber transmit channels) in three radio frequency bands. Many of the 44 radio channels at 150 and 450 MHz may be in use for public mobile service; and the restrictions for the 50 radio channels in the private mobile service may limit their application. Radio spectrum efficiency will be necessary for maximum rural area coverage.

2.1.7 The spacing between radio channels is 25 kHz at 450 and 800 MHz, and 30 kHz at 150 kHz. This provides a maximum radio channel bandwidth of 25 kHz (or 30 kHz) with a usable bandwidth of less than 25 kHz. Radio channels are sometimes subdivided by using time division multiplex (TDM) or frequency division multiplex (FDM) to achieve two or more voice channels for each 25 kHz radio channel.

2.1.8 BETRS radio equipment and systems are evolving. Systems illustrated in the following paragraphs are representative of present equipment. However, all parts of the illustrated systems may not be available from one manufacturer at this time.

2.2 <u>BETRS Equipment Description</u>

2.2.1 <u>Point-to-Multipoint Systems</u>: A basic point-to-multipoint BETRS radio system consists of a base radio station and a number of subscriber radio stations located at or near individual subscribers (Figure 1). An example of a BETRS service area using point-to-multipoint radio equipment is illustrated in Figure 5. The base station may be co-located with the central office (CO) switch, or remotely located and connected via trunk facilities such as digital carrier.

2.2.2 <u>Base Radio Station</u>: A typical base radio station is illustrated in Figure 6. It consists of several radio transmitters and receivers (often called transceivers), a combiner, antenna, concentrator, codecs (coders and decoders), controller and power supply. The combined signals of radio transmitters and receivers are connected to an omnidirectional antenna. The number of radio channels required is determined by the number of subscribers and expected system use (traffic). For this illustration, three radio channels are shown for service to a larger number of subscribers. The subscriber lines are concentrated into three trunks or radio channels. The assignment of subscribers and radio channels is handled by a processor or controller through a concentrator. This action is similar to that of establishing a call through a central office switch. For incoming and outgoing calls, all radio subscribers have access to all idle trunks on a demand basis (trunked radio system).

2.2.2.1 Power for the base radio station should be from a battery source with sufficient capacity to provide for at least 8 hours standby operation in the event of a commercial power failure. The battery supply (nominal 50 volts dc) for the central office equipment is the preferred power source for a co-located base radio station.

2.2.3 __Modular Base Station__: The base station should be designed in modules to provide for growth. Another important reason for modular construction is to provide for separation of the base radio transceivers from office equipment interfacing the CO switch. This allows the radio transceivers to be located at the optimum antenna and subscriber service location without regard to the CO switch location (Figure 7). The concentrator might be at either the office or radio location. With the concentrator at the office, the links between the office and radio are trunks; with the concentrator at the radio, the links are lines. Trunk links are more efficient (fewer circuits required) and will be used for this discussion. The link between the BETRS office equipment and the base radio station may be voice frequency, carrier or radio circuits; but they are likely to be digital carrier (DS1) over T1 type span lines or digital radio. The trend will be toward standard digital interfaces (DSX1) for all BETRS radio systems.

2.2.4 __Subscriber Radio Station__: The subscriber radio station is illustrated in Figure 8. It consists of a radio transceiver, a directional antenna (with transmit-receive combiner or duplexer), a controller, codec and power supply. The subscriber radio transceiver should be capable of transmitting and receiving on any available channel on demand which requires a radio frequency synthesizer. The subscriber controller receives instructions from the base controller for channel assignment. The subscriber interface should be a standard modular jack for use with customer premises equipment.

2.2.4.1 Power for the subscriber radio station should be from a battery source with sufficient capacity to provide for at least 8 hours standby operation in the event of a commercial power failure. Small rechargable batteries in the range of 12 to 24 volts are generally used. Solar power with backup batteries are sometimes used for subscriber station power.

2.2.4.2 Access and use of commercial power at the subscriber location require special attention. The telco may place the BETRS equipment away from the subscriber's building and contract directly with the local electric utility for electricity. The cost of electricity at subscriber location should be considered in system economics. Another option is to arrange for access to the radio subscriber's electric power. This requires that special attention be given to national, state and local electrical codes concerning power wiring and grounding. For low power subscriber units, the use of Listed Class 2 transformers and low voltage wiring may simplify installation (Listed by United Laboratories or other similar type Listing agency acceptable to the authority having jurisdiction). Radio station power consumption may require negotiation with the subscriber for power costs.

2.2.5 Repeater Radio Station: A BETRS repeater radio station can be used to extend service from the CO building to a single base transceiver location in lieu of the office to base radio station link described in paragraph 2.2.3. Repeater radio stations can also be used to create multiple base transceiver locations to extend service over a wider area (Figure 9). The use of BETRS repeaters can increase the service area coverage, but may not be cost effective in many applications.

2.2.5.1 Two types of BETRS radio repeaters are discussed. The first involves the retransmission of radio signals into a distant service area using a new set of radio frequencies different from the basic service area radio frequencies. The second involves the reuse of the same radio frequencies as the base radio station to provide fill-in service into shadow areas within the basic service area. For purposes of FCC radio station authorization, a radio repeater requiring additional radio frequencies is separately licensed as a "relay station;" and a radio repeater that reuses the base radio station frequencies is considered under the basic authorization. See paragraph 3.5 for additional discussion on FCC authorization.

2.2.5.2 Figure 10 illustrates the allocation of radio frequencies for a three channel BETRS system in basic service. Figure 11 illustrates a similar BETRS system using repeaters that require additional frequencies. Three radio frequency pairs are required for the basic system and three additional frequency pairs are required for the repeatered system. The three frequency pairs (Tx1/Rec1, Tx2/Rec2, and Tx3/Rec3) that link the base radio station and repeater radio station can also be used to serve subscribers in the base station service area. In an actual arrangement like this, it is likely that more frequency pairs will be needed for the base radio station than the repeater radio station. This is because the base serves all of the repeater subscribers (through the repeater) in addition to the base subscribers.

2.2.5.3 Back-to-back radio channels or heterodyne (frequency conversion) techniques may be used to construct repeaters. Radio frequencies may be limited. The use of repeaters may require increased radio spectrum efficiency such as subdividing the 25 kHz radio channel into multiple voice circuits.

2.2.5.4 Another service possibility is to reuse the base and subscriber radio frequencies by amplifying the radio signals at a distant location. This type of radio repeater has been called a "booster" or "beam bender." This technique was previously used in microwave radio with linear amplifiers and highly directive antennas. Work is currently under way to use this technique in BETRS and cellular radio systems. This type of repeater may prove to be a cost effective method for fill-in service to shadow areas within the basic service area that cannot be reached by the base radio station. Because frequencies are reused and amplified, control of the repeater service area and co-channel interference is essential to the satisfactory application.

2.2.6 **Point-to-Point Systems**: Point-to-point radio refers to a radio system application between two locations; the radio system connects two points such as a central office switch and a subscriber or cluster of subscribers. In this bulletin, a BETRS point-to-point radio "system" refers to a system where multiple radio channels are shared on a demand access basis (trunk to line concentration) like point-to-multipoint BETRS systems. A point-to-point application where each radio channel is dedicated to an individual subscriber is called "rural radio equipment" (see paragraph 2.2.7). Because BETRS radio frequencies are limited, channel sharing spectrum efficiency is encouraged.

2.2.6.1 A point-to-point BETRS radio system consists of several radio channels between the central office and a remote subscriber cluster location with an integrated concentrator. This allows a larger number of subscribers to be served over a smaller number of trunks (voice channels). Figure 3 illustrates the basic concept. Equipment for both the base and remote radio stations would be similar to Figure 6 except that directional antennas would be used. Point-to-point BETRS equipment may be a special arrangement of point-to-multipoint BETRS equipment, or may be a separate unique system. Radio equipment and integrated system design may permit radio frequencies to be shared by point-to-point and point-to-multipoint systems.

2.2.6.2 A subscriber cluster application might be engineered with digital radio equipment as described in paragraph 1.2.5 and Figure 2; or might be engineered using BETRS radio equipment at 150, 450 or 800 MHz. The equipment choice will depend on the specific application. Larger channel quantities and longer distribution lengths tend to justify digital microwave radio equipment. Applications for small channel quantities may justify the use of BETRS radio equipment, especially if the cluster service is part of an overall distributed BETRS application sharing radio frequencies.

2.2.7 **Rural Radio Equipment**: Rural radio equipment refers to point-to-point radio equipment where each radio channel is dedicated to an individual subscriber (Figure 4). The subscriber radio station is located at or near the subscriber. The base radio station may be located at the CO switch or at some point along the outside plant route. Rural radio is useful in select or small startup applications.

2.2.8 **Radio Propagation Patterns**: Careful selection of antennas and radio station locations can improve radio system coverage, reduce interference, and minimize costs. Figure 12 illustrates some radio propagation patterns. The reference antenna for radiation patterns and gain is called an isotropic antenna, which is a theoretical point source in free space that radiates equally in all directions. The isotropic radiator would produce a spherical pattern; it is a theoretical antenna for reference purposes.

2.2.8.1 An antenna consisting of a vertical pole on top of a tall tower will radiate equally along the horizontal axis and produce a circular pattern (Figure 12A). This would be equivalent to a half wave dipole in free space and provide a modest gain over the isotropic reference. This vertical pole is generally referenced as an omnidirectional antenna, radiating in all (horizontal) directions.

2.2.8.2 An omnidirectional antenna in the real world will produce an irregular pattern because of obstacles in the radiation path (Figure 12B). In a point-to-multipoint system, the central station or base station antenna is generally placed on a tall tower or other point of high elevation above the surrounding area to minimize the effects of obstacles in the intended radiation path. This allows the many subscriber station antennas to be placed on smaller towers, reducing system costs.

2.2.8.3 Directional antennas are used to focus the radiation pattern into one or more directional patterns (Figure 12C). This focused radiation or directivity provides effective gain in the intended direction and minimizes interference in other directions. Directional antennas are used at subscriber locations in BETRS systems. These are generally Yagi antennas that produce about 10 dB gain over the isotropic reference.

2.2.8.4 In summary, BETRS systems generally use both omnidirectional and directional antennas. The base radio station will generally use an omnidirectional antenna, but may employ some directivity depending on service area coverage requirements. The subscriber radio station is required by the FCC to use a directional antenna which to reduce interference. A repeater radio station will use a directional antenna toward the radio base station; and will use an omnidirectional or directional antenna toward subscribers depending on service coverage requirements (Figure 11). The base radio station and repeater radio station may use partially directive or highly directive antennas to customize the service area coverage. A directional antenna at the base radio station may eliminate the need for a repeater radio station.

2.3 Present Analog Equipment

2.3.1 Analog subscriber radio equipment in the 150 and 450 MHz band has been available on the world market for many years. This equipment ranges from simple dedicated channel rural radio equipment to more elaborate multichannel demand access systems. Because of the past "secondary" FCC licensing status, the primary market for this equipment has been the world market with limited application within the US. While the radio equipment can fill a service need, the installed equipment may not meet traditional telecommunications network transmission standards such as circuit noise, voice frequency response, voice level stability, etc. It is important that the purchaser and seller reach agreement on basic equipment and installed system performance criteria before equipment is purchased.

2.3.2 The radio frequency range of coverage is limited to approximately line-of-sight and depends on factors such as radio transmitter output power, receiver sensitivity and selectivity, antenna type, and terrain. The limiting distance may be in the order of 10 to 40 miles, depending on the equipment and application. Power requirements are cited at one watt to 70 watts; this is largely dependent on the radio transmitter output power. Data transmission capability is generally cited in the range of 1200 to 9600 baud. The subscriber radio station of some models may be located at some distance from the subscriber (up to 1500 ohms of cable plus a 400 ohm telephone set).

2.3.3 The dedicated channel rural radio equipment is generally a small unit designed for indoor mounting. The subscriber unit may be a desktop or wall mount unit. Typically, this equipment is powered directly from commercial ac power with battery backup. Simplicity and low startup costs are key characteristics of this type of equipment. The installed equipment may not meet some of the traditional telecommunications network transmission standards such as circuit noise and voice frequency bandwidth.

2.3.4 Multichannel trunked radio systems are often modular equipment units designed for varied applications. Many equipment types can be applied as dedicated channel rural radio applications, and in multichannel demand access point-to-point and point-to-multipoint applications. Repeaters are generally available; these are usually back-to-back radio units. Outdoor housings are generally available for repeaters and subscriber radio stations. Many systems provide two voice channels within the allocated 25 kHz bandwidth by splitting the radio spectrum into two 12.5 kHz radio channels. Privacy options are available in some models by frequency inversion or scramblers. Conversation privacy options are recommended for fixed station BETRS applications. Optional compandors may be available in some models to reduce circuit noise. Battery backup is recommended for all applications, and especially where commercial ac power failure will affect more than one subscriber.

2.4 Evolving Digital Equipment

2.4.1 The trend is toward the use of digital systems for transmission and switching in the telecommunications industry. New designs of digital radio equipment are being developed especially for the BETRS market. Bandwidth efficient digital coding techniques such as linear predictive coding (LPC) and adaptive differential pulse code modulation (ADPCM) are being employed for radio spectrum efficiency. Where digital coding other than North American standard 64 kb/s pulse code modulation (PCM) is employed within the radio system, interfaces at voice frequency and standard 64 kb/s are provided.

2.4.2 Digital BETRS radio systems are evolving. The characteristics cited are based on present equipment characteristics and tentative specifications for new equipment. This equipment is expected to meet telecommunications network transmission standards. Traditional transmission measurement techniques are analog in nature and may not be adequate to verify the transmission performance of some digital systems. Such test equipment was intended for use on analog circuits and digital waveform coding such as 64 kb/s PCM. New digital coding schemes are based on speech characteristics and some parameters cannot be verified with traditional measurement techniques. Until new measurement techniques are developed, the measurements can be supplemented by subjective conversation comparison tests.

2.4.3 Spectrum efficient digital codes in combination with time division multiple access (TDMA) or frequency division multiple access (FDMA) permit increased spectrum efficiency. FDMA and TDMA may be combined to allow subscriber access to any time slot in any radio channel, permitting maximum efficiency (traffic capability). Spectrum efficiency may be essential for larger systems, and where radio frequency availability is limited. One manufacturer uses TDM to provide four voice channels within one 25 kHz radio channel. This system applied in the 450 MHz band will be used to illustrate the TDM process and capability.

2.4.3.1 The 25 kHz radio channel is modulated with a 64 kb/s signal. Using TDMA, the 64 kb/s signal is divided into time slots for four separate 16 kb/s channels. Each 16 kb/s channel is modulated with a spectrum efficient digital coding such as LPC. Each 16 kb/s voice channel can be accessed by any subscriber within the system on a demand basis. One 16 kb/s channel is the system control channel. The control channel is the system manager for subscriber access and channel assignment. One radio channel provides three voice channels and one control channel. Four radio channels provide 15 voice channels and one control channel.

2.4.3.2 Figure 13 illustrates TDMA. The base radio station transmits a continuous signal on a radio channel that is divided into time slots for four channels. Each subscriber can access any available time slot on any assigned radio channel. Subscribers can receive and transmit in any available time slot on any assigned channel. The subscriber radio station transmits in synchronized bursts so that the radio signals from several subscriber transmitters effectively merge the transmitted bursts within time frames. Up to four subscribers can transmit in appropriate time slots of one 64 kb/s radio channel. Each subscriber has access to an idle channel or time slot on demand.

2.4.4 The radio frequency range of coverage is limited to approximately line-of-sight and depends on factors such as radio transmitter output power, receiver sensitivity and selectivity, timing, antenna type, and terrain. The limiting distance may be in the order of 10 to 40 miles, depending on the equipment and application. Digital systems provide a degree of conversation privacy that is superior to analog systems. Data transmission capability is generally cited in the range of 1200 to 4800 baud. Subscriber radio station power requirements range from about 20 watts idle to 70 watts in use. Solar power options are generally available for repeaters and subscriber radio stations. The subscriber radio station of some models may be located at some distance from the subscriber (up to 1500 ohms of cable plus a 400 ohm telephone set).

2.5 Transition Toward Future

2.5.1 The transition from secondary Rural Radio Service to co-primary Basic Exchange Telecommunications Radio Service has been relatively smooth. Manufacturers and operating telephone companies experienced the usual amount of problems with the introduction of new technology and equipment. Most problems were corrected and the BETRS equipment is serving subscribers that might not otherwise receive telephone service.

2.5.2 As the BETRS "get started" phase nears an end, manufacturers, telcos and REA need to assess how to move from selective BETRS applications toward truly universal BETRS applications. How can BETRS equipment become a more universal alternative to the traditional telecommunications outside plant facilities? To a large degree, BETRS is expected to follow a path of universal acceptance similar to that of subscriber carrier equipment. Subscriber carrier moved from a last resort facility to a preferred facility over a period of about 20 years. This transition did not occur by accident. It occurred through the work and actions of many people and organizations.

2.5.3 <u>BETRS Wish List</u>: The following are suggested as factors and improvements needed for widespread application and universal acceptance of

BETRS equipment as an alternative to traditional telecommunications outside plant facilities.

2.5.3.1 **Reliability**: Equipment reliability will improve with experience and quantity production. The goal is for a service reliability near that of conventional plant facilities.

2.5.3.2 **Cost**: Equipment and installed system costs should be reduced to compete with conventional plant facilities. Costs should improve with quantity production, experience and product evolution.

2.5.3.3 **Power**: Power consumption should be reduced, especially at the remote subscriber location. Reduced power consumption can improve initial installation costs and operating costs at remote locations. For customer furnished power, the use of Class 2 energy limiting transformers and low voltage wiring can reduce installation complexity and costs. Because some potential BETRS subscribers have no commercial power or unreliable power, economical solar power is a desirable alternative at remote locations.

2.5.3.4 **Size**: The equipment size should be reduced, especially at the remote subscriber location. Custom integrated circuits can be used to reduce the equipment size and power consumption.

2.5.3.5 **Housings**: Outside housings at subscriber locations are necessary for universal acceptance. The housing design should be small, blend with the surrounding environment, dissipate the heat generated by the equipment and the sun, provide environmental protection from the elements, and minimize infestation by insects. Reduction of size and power consumption can lead to housing design improvements.

2.5.3.6 **Installation**: Equipment installation at remote subscriber locations should be simplified. Size, power consumption and housings are factors that affect installation simplicity and costs.

2.5.3.7 **Repeaters**: Low cost repeaters are needed to increase the service coverage area and for fill-in coverage.

2.5.3.8 **Modularity**: Modular equipment components can increase equipment application flexibility and minimize startup costs for small systems. Modular equipment can be used to keep initial quantities and costs low without sacrificing growth potential. Modular equipment can reduce obsolescence by providing for system upgrades in size, features, and services.

2.5.3.9 **Frequencies**: Last, but no small matter, is radio frequency availability. With the potential for co-channel interference at 150 MHz and location restrictions at 800 MHz, the 26 channels at 450 MHz are the primary BETRS radio frequencies. The 450 MHz channels are heavily committed to mobile service in urban areas, and may not be available for BETRS in nearby rural areas. The 450 MHz channels provide an excellent opportunity to prove the technology and reach subscribers that would not otherwise have telephone service, but these frequencies are not adequate for widespread universal service. Manufacturers use spectrum efficient techniques, but this can increase equipment costs and limit the market. Dedicated blocks of frequencies are needed for BETRS to become a universal cost effective service.

Frequency blocks (with FCC authorization) would permit the design engineer to choose time division or frequency division multiplex to economically address specific markets.

3. BETRS APPLICATION

3.1 General

3.1.1 BETRS equipment and BETRS applications should provide standard telecommunications service that is equal to or better than wireline service. The BETRS system should provide service that is transparent to standard telecommunications interfaces and to the subscriber. This means that the BETRS radio equipment and systems are substitutes for conventional outside plant cables and carrier systems interfacing with central office equipment, telephone sets, and other customer premises equipment meeting FCC Part 68. BETRS equipment should provide some remote testing capability to minimize travel to customer locations scattered over a wide area.

3.1.2 BETRS may be used for first time service to an unserved area, or may be used to supplement or extend service within an existing service area. For temporary or permanent service, BETRS radio should be considered as an economic alternative to conventional telecommunications cable and carrier to:

a. Serve subscribers scattered over a wide area.
b. Provide new service or upgrade multiparty service.
c. Reinforce or replace existing plant.
d. Reduce or eliminate subscriber held-orders.
e. Serve uncertain growth areas.
f. Fill temporary and emergency service needs quickly.

3.1.3 BETRS radio equipment is the ultimate in "movable telecommunications plant." It can be used for temporary service, permanent service, or to delay construction of conventional plant until service needs are accurately identified. BETRS equipment can be removed and reused as needs dictate.

3.1.4 Telecommunications service should be provided by utilizing the most cost effective facilities and technology. Economic planning strategies should avoid an all or nothing approach. Economic studies should begin with broad prove-in or breakeven determinations, and then be refined to consider a mixture of facilities and factors such as isolated pockets of subscribers and terrain. Economic studies should be made on appropriate competitive facilities and equipment. When BETRS radio is potentially competitive with other service techniques, it is recommended that economic studies include mixtures of copper, fiber, and radio facilities, and possibly the use of more than one type of radio equipment. There is no magic formula for the prove-in of BETRS radio equipment.

3.2 Equipment and System Characteristics

3.2.1 Presently available BETRS radio systems range from dedicated channel analog point-to-point equipment and systems to trunked multichannel digital point-to-multipoint systems. In general, this discussion will emphasize universal application point-to-multipoint systems (analog or digital) with some discussion of point-to-point systems. Dedicated channel rural radio equipment is useful in select applications. It is not considered a system design tool for universal application and will be mentioned only briefly. The specific service requirements will determine the most appropriate BETRS system and/or equipment. The following components are used to describe BETRS radio equipment and system characteristics.

Base Radio Station is used to describe all equipment located at the BETRS central office radio terminal site. The FCC uses the term Central Office Station.

Repeater Radio Station is used to describe all equipment located at the BETRS radio repeater site. The FCC uses the term Relay Station.

Subscriber Radio Station is used to describe all equipment located at the BETRS subscriber radio terminal site. The FCC uses the term Rural Subscriber Station.

3.2.1.1 The FCC terms will be used in paragraph 3.5 and the generic descriptive terms will be used elsewhere.

3.2.2 **Point-to-Multipoint Systems**: A point-to-multipoint radio system used to serve scattered individual subscribers from a common location is illustrated in Figure 5. Subscribers are served on a "trunked" basis where radio channels are shared and idle channels are available on demand by any served subscriber. All subscribers have access to any available channel. The advantage of this equipment is versatility. It is nearly universal in application. Common equipment costs are shared by a number of subscribers, and economics may limit the minimum system size that is cost effective.

3.2.2.1 The base radio station equipment may be located in the central office building, or at a location some distance away. Part of the BETRS office terminal may be co-located with the central office equipment (COE), with the remainder of the office terminal (i.e., base radio) at a more appropriate radio service location. The two locations are usually connected by T1 span lines or digital microwave radio equipment. BETRS radio repeater stations can be used to extend service from the central office building to a single repeater radio station location or multiple repeater radio station locations to generally or selectively expand the service area.

3.2.3 **Point-to-Point Systems**: A point-to-point radio system used to serve subscriber clusters on a shared channel basis is illustrated in Figure 3. The major advantage of this equipment is the shared common costs associated with both the office and subscriber ends. This includes power supplies, subscriber housings, etc. Several radio channels are used as trunks for a larger number of subscriber lines. Concentration ratios are determined by traffic requirements and system characteristics such as local switching at the subscriber terminal.

3.2.3.1 Point-to-point cluster service may be provided by separate stand alone systems, or may be an option of point-to-multipoint systems. A common base radio station and shared use of radio frequencies may be practical with integrated point-to-point and point-to-multipoint systems. Otherwise, separate radio systems and channels will be required for each application, even with a common base station location.

3.2.4 <u>Rural Radio Equipment</u>: Point-to-point or "rural radio" equipment is used to serve individual subscribers on a dedicated channel basis. The major advantage of this equipment is the low startup cost to serve one or several scattered subscribers. It is similar in concept to the "add-on" one channel subscriber carrier. Rural radio equipment consists of frequency mated office and subscriber terminals. The radio frequency pair is preselected and fixed by the FCC. In general, the frequency cannot be reused within an exchange area which limits the growth capability. However, frequency reuse without interference may be possible depending on the specific radio station locations and directional antenna orientation. The office terminal may be located at the central office equipment (COE) building, at the end of a cable route, or other convenient location.

3.2.5 <u>Radio Repeaters</u>: Radio repeaters can be used with any of the above terminal equipment to extend the area of radio coverage as discussed in paragraph 2.2.5. This is accomplished by radio frequency reuse within the basic service area, and by the use of additional radio frequencies to serve areas beyond the basic service area. System economics, radio frequency availability, and potential co-channel interference will influence decisions concerning the use of repeaters.

3.2.6 <u>Miscellaneous Considerations</u>: In the planning and design of BETRS radio systems, factors such as loop length from the subscriber radio station, power at remote terminal and repeater locations, remote housings, equipment accessibility, installation, and maintenance should be considered. Subscriber loop length may be short for service to individual subscribers, but BETRS systems should be capable of extended outside plant loops beyond the subscriber radio station for cluster service applications. Reliable commercial ac power should be the first choice for primary system power if it is available. Solar power may be considered as an alternative for low power consumption repeater and subscriber radio stations, but may be costly for high power consumption units. Physical access is always important, even the most reliable equipment.

3.2.6.1 Only single party (private line) BETRS radio equipment is considered. While it is possible for the BETRS equipment to provide multiparty service, it is not recommended because of increased equipment complexity and cost. Conversation privacy should always be a consideration for fixed station BETRS applications. Privacy options are recommended for analog systems. Digital systems provide a degree of conversation privacy that is superior to analog systems.

3.3 <u>Preliminary Planning</u>

3.3.1 Preliminary planning should begin with an up-to-date area coverage survey or similar subscriber survey. The planning and layout of a radio system is often done in incremental stages. A radio propagation study is essential. However, preliminary system and path planning should be completed before the final radio propagation study is made. The following is suggested. Identify known and potential telephone subscribers in an exchange area or an overall service area. Is it practical to reach all subscribers by radio from the central office building or another common location? Is a radio tower already in place at the central office or other location? Is there a hill or other point of high elevation within the service area for the radio base station? If the radio base station is placed at one of these locations, will some subscribers be blocked because of terrain or manmade structures? What are the alternatives (such as repeaters, multiple base stations, or cable extensions) for serving those remaining hard-to-reach subscribers?

3.3.2 Preliminary planning can be accomplished by using a common sense approach. If a mobile radio system is already in place, it can be used to estimate the service area coverage with a BETRS radio system. If good to marginal service is available to all subscriber locations with the mobile system, directional antennas on towers at subscriber locations should provide improved service - with the same transmitter power in the same radio frequency band. The new BETRS system may use different frequency bands and lower transmit power than the existing mobile system. These differences may alter the service coverage area.

3.3.3 From topographical maps and visual inspection, pick a base radio station location. Draw lines on the map from the base station to (a) the more distant subscribers, and (b) the subscribers with obstacles in the path. Either by sketch or by mental image, view some of the potentially difficult paths. Allow for growth of vegetation and potential building development. For example, would towers of 100 feet at the base station and 40 feet at the subscriber locations provide a path above the path obstacles? The object of this review is to identify probable base station locations and to be relatively sure of adequate radio propagation (preferably line of sight) to most potential subscribers at an early planning stage. Figure 14 illustrates a simplified profile view of the radio propagation path between a base radio station and a subscriber station.

3.3.4 Review the costs and construction ease or burden for providing rural telecommunications service by using conventional facilities. Would new construction be economical using telephone cable, optical fibers, or digital microwave radio equipment? Is it possible or practical to apply digital or analog subscriber carrier (including distributed carrier) to existing cables? Consider the economics of using mixtures of BETRS and conventional facilities.

3.3.5 Power availability, cost and reliability at subscriber and repeater radio stations are important considerations in the planning and implementation of a BETRS system. Will commercial power be available, reliable and reasonable in cost? Is solar power a practical alternative to commercial power? Power for BETRS equipment should be considered in system economic studies and reliability calculations.

3.3.6 Review available BETRS equipment and compare with service requirements. Can the available equipment provide for initial service and projected growth? Will the system provide for traditional telecommunications service and standards? BETRS may be the only practical way to serve scattered rural subscribers.

3.4 Radio System Design

3.4.1 **Overview**: During the system design and implementation stages, compliance with building, safety and electrical codes and approvals by REA, FCC, Federal Aviation Administration (FAA) and others are necessary. The suggestions and illustrations provided here are advisory. They serve only to illustrate the process of BETRS implementation. Early in the implementation process, approvals are required by REA for financing; by the FCC for radio station operation; possibly by FAA for tower construction; possibly by the Bureau of Land Management, U.S. Fish and Wildlife, and State Historic Preservation on environmental impact; and by other organizations in the enforcement of local, state and national codes. Part 17 of FCC Rules covers tower height, lighting, painting and FAA notification. In planning tower locations, be aware of nearby airports, landing strips, and flight paths.

3.4.1.1 REA approvals are required for:

a. Equipment: REA Acceptance.
b. Plans and Specifications: REA Form 397 or 398 with appropriate attached specifications.
c. Other stages of regulatory and financial approval.

3.4.1.2 In general, BETRS equipment needs to be REA Accepted (shown on the REA List of Materials or have REA Technical Acceptance). Exceptions are equipment placed on an REA field trial or waiver provided in special circumstances. The request for REA approval of Plans and Specifications and the request for FCC approval for Radio Station Authorization should occur at approximately the same time.

3.4.1.3 It is suggested that point-to-multipoint BETRS systems be designed for 99.9 percent availability. This permits a total down time of 8.8 hours a year to the average individual subscriber due to propagation conditions and equipment failures. Circumstances may dictate other design availability requirements.

3.4.2 <u>System Design Considerations</u>: A review of the quantity and location of subscribers to be served is the first order of business. Determine the most cost effective mix of BETRS and conventional telecommunications facilities. Determine if individual radio stations at each subscriber location is necessary, or if it is practical to share subscriber radio stations at common locations. Determine if cluster service to some or all subscribers is practical. Shared subscriber equipment is generally more economical than individual subscriber units. Determine if all subscribers can be served from one base radio station. If not, determine base radio station locations that minimize the number of base stations. Plan systems that eliminate or minimize the use of repeaters.

3.4.2.1 Determine the number of voice trunks and radio channels required to serve the subscribers (traffic calculation). Some BETRS radio systems require a radio channel for each voice trunk. Other systems subdivide the radio channel to provide up to 4 voice channels for each radio channel. Determine if the base radio station can be located at or near the COE. If not, determine the most appropriate method of providing circuits between the COE and the base radio station (i.e., T1 span line, repeater radio station, etc.).

3.4.2.2 Determine the most appropriate power sources for subscriber radio stations, repeater radio stations, and any base radio stations not co-located with the COE. In general, this will be commercial ac power contracted with the local power company or the subscriber being served. AC power connections require that attention must be given to local, state and national electrical codes for the safety of the general public and telco employees. Power for the base radio station located at the COE should be provided by the central office battery supply. Solar power may be appropriate for repeater radio stations and subscriber radio stations. Power consumption (idle and in use) and battery reserve calculations (8 hours recommended) for all sites are needed.

3.4.2.3 Electrical protection for equipment and safety of people require special attention where antennas are located. Generally, the higher the antenna above surrounding structures, the greater the exposure to lightning, and the greater the need for low resistance grounds and bonding connections. All exposed metallic surfaces (inside and outside cabinets) within the area require common bonding and grounding. Careful attention should be given to proper bonding and grounding at digital COE buildings to minimize damage to sensitive electronic equipment. The BETRS equipment manufacturer's recommendations concerning safety and protection should be followed. The manufacturer's recommendations should include surge protection for the ac power connection, antenna, and equipment interfaces.

3.4.3 **Radio Propagation Study**: After the sites for base radio stations are chosen (and radio repeaters if used), a radio propagation study is needed for each base station. Actually, two types of radio propagation studies are needed. A propagation study is required for the FCC using the Carey Method in FCC Report R-6406 (Technical Factors Affecting the Assignment of Facilities in the Domestic Land Mobile Radio Service, by Roger B. Carey, June 24, 1964). A survey using the Carey Method will show the general radio service area coverage and radio interference. However, the Carey Method is intended for Mobile Service with at least 90 percent coverage probability. An additional propagation study will be needed for reliable BETRS fixed service.

3.4.3.1 While BETRS is usually a point-to-multipoint application of equipment similar to mobile service, the subscriber stations are fixed. "Carey" or "Average" coverage does not ensure that each BETRS subscriber will receive reliable service. Therefore, the radio propagation study for reliable BETRS should include a point-to-point propagation study (similar to a point-to-point microwave path survey). A study of the path propagation between the base radio station and each subscriber radio station should be made. Requirements for base station antenna tower height, radio transmitter power (and effective radiated power), and individual subscriber station antenna tower height are determined from the study. Figure 14 is a simplified profile view of a radio propagation path. Factors such as earth curvature are not considered. For information on radio propagation and path surveys, refer to engineering textbooks and to REA TE&CM Section 932 (planned for conversion into Bulletin 1751H-701).

3.4.3.2 Horizontal or vertical antenna polarization can be used for BETRS point-to-multipoint systems. Horizontal polarization for BETRS will provide some interference isolation from vertically polarized mobile system antennas. However, omnidirectional radiation patterns are easily obtained from simple vertically polarized antennas. Generally, BETRS systems will use omnidirectional (or multidirectional) antennas for the base radio station and directional antennas for the subscriber radio stations. Antenna polarization may be either horizontal or vertical, but need to be the same for both the base and distant ends of a system. The antennas are included in the propagation study. FCC waivers are required for omnidirectional antennas and for vertical polarization in BETRS systems. Such waivers are routinely considered by the FCC, but waivers need to be requested in the application.

3.4.3.3 Questions about the radio propagation study and system responsibility are often raised. Will the Purchaser or Seller make the preliminary and/or final radio propagation study? In the case of marginal or unreliable service, is the Purchaser or Seller responsible for corrective action to achieve reliable service? The remedies and responsibilities may be different for minor system alterations to reach one or two subscribers than for major path and service problems found after equipment has been installed. These remedies and responsibilities should be clearly stated in the contract for BETRS. The contract should be one for a "Reliable System" or "Service," and not just a contract for hardware. System reliability and service should be defined quantitatively to the extent possible. System and service guarantees may prove costly in some cases.

3.5 FCC Radio Station Authorization

3.5.1 BETRS is covered in Part 22 of the FCC Rules under the general heading of Public Mobile Service. The FCC Rules require radio equipment Type Acceptance (equipment manufacturer) and a Radio Station Authorization (telco) to construct and operate a BETRS radio system. The applicant should be familiar with Part 22 of the FCC Rules and other referenced Rules and Reports. The following briefly highlights some aspects of the procedure and information required in the application.

3.5.2 When the application is ready to be filed, a call to the FCC Public Mobile Radio Branch may be helpful to clarify issues and avoid processing delays. The applicant may wish to seek specialized assistance and contract for filing the FCC application and search for available BETRS frequencies. Currently, FCC submissions and applications that require fees are filed with the Mellon Bank in Pittsburgh, Pennsylvania, using FCC Form 155. Submissions with fees that are filed elsewhere are returned to the sender.

3.5.3 The Authorization process begins with FCC Form 401, "Application for New or Modified Common Carrier Radio Station Authorization Under Part 22" filed with the FCC by the telco. At regular intervals, the FCC will issue public notice listings on applications (and other matters) to allow the public an opportunity to comment on FCC proposed actions. The Radio Station Authorization permits the BETRS system construction to begin. It specifies the construction start date and terms of the authorization. When construction has been completed in accordance with the radio station authorization, the licensee notifies the FCC on Form 489, "Notification of Status of Facilities." BETRS service can commence the day that Form 489 is placed in the mail to the FCC. See 22.45 of the FCC Rules for the License Period. Reply by the FCC is not required. (FCC filings can be delivered to the FCC and receive a stamped record copy.) If construction is not complete within the terms of the authorization, the authorization will automatically expire unless a time extension application (FCC Form 489) is filed and approved by the FCC.

3.5.4 FCC Application: The Application for FCC Radio Station Authorization consists of a completed FCC Form 401 with attachments. Follow the instructions and furnish information specifically as noted. Some information is to be provided on FCC Form 401 while other information may be provided as attachments. The waivers, supplementary showings and other items discussed are routinely considered by the FCC for BETRS authorization. However, waivers need to be requested and required information furnished with the application. Unless noted otherwise, the following discussion and comments apply to a point-to-multipoint BETRS system application.

3.5.4.1 The applicant should be familiar with FCC Rules contained in Part 22. A selected sample is discussed below.

22.15(b)(1): Search and list all co-channel stations within distances:

1-Way	35 MHz to 162 MHz	67 Miles
2-Way	152 MHz to 162 MHz	84 Miles
2-Way	450 MHz to 460 MHz	67 Miles
1 & 2-Way	Above height/power limits	125 Miles

22.15(b)(2): Interference studies may be made one of two ways:

1. By using Class of station and Geographic separation listed in 22.502 and 22.503.
2. Utilizing the Carey Method in FCC Report R-6406.

22.16(a)&(b): A showing is required for radio channels. A maximum of four radio channels is normally granted with each initial application, and each application for additions to existing systems. An application for more than four channels may be granted, but will require additional coordination within the FCC and may cause delay in the authorization.

22.108 & 22.110: Note antenna direction and polarization requirements. A fixed station is required to utilize a directional antenna with horizontal polarization. Waivers are required for omnidirectional base station antennas and for vertical polarization.

22.600: Note that subscriber stations are generally covered under the base station authorization.

22.609: Note the supplementary showing required with applications for rural radio (BETRS) facilities.

3.5.4.2 FCC Form 401: One Schedule A is required with each Application. One Schedule B is required for each Antenna Location (generally base station antenna locations). Schedule A is self explanatory. All exhibits that are attached to the application are listed on Schedule A (Item 22). The following examples of attached exhibits are based on the information requirements of Schedules A and B.

FCC Form 401 - Schedule A

Item 20: If the application requests one or more additional radio channels for existing service, a loading study (traffic study) is required.

Item 21: If the application requests more than one radio channel for new service, a statistical survey or other showing is required.

FCC Form 401 - Schedule B

Item 29: If waivers are requested, the exhibit has to specify the FCC Rule(s) that apply and show good cause for each waiver requested. For point-to-multipoint BETRS systems, waivers need to be requested for omnidirectional base station antennas and for vertical polarization of radiated signals (base and subscriber).

Item 37: The height and power engineering data require special attention. Some data is required on FCC Form 401 and exhibits may be required for other data. For example, 37(i) requires an exhibit if the antenna is not mounted on top of the antenna structure. Often an existing antenna structure will be used and the top of the structure is already used. An omnidirectional or other radiation pattern can be obtained, but an explanation is required. Effective radiated power and co-channel interference also require attention.

FCC Form 401 - Miscellaneous

Other attachments may also be required that are not specifically listed on FCC Form 401. For example, 22.601(a)(4) should be addressed to state that the applicant is authorized to provide BETRS (State certification or other authorization). Also, 22.609(a) requires a supplementary showing why it is impractical to provide the required communication service by means of wireline facilities. If relay stations are required, 22.601(b)(1) requires a showing why it is impractical to achieve the communications without relay stations (i.e., out of signal range of central office station). The application for relay stations can be filed with the BETRS application.

3.6 System Specifications

3.6.1 Plans and Specifications: At this time, REA does not publish specifications that are appropriate for BETRS equipment and application, and none are known to exist in the public domain. Appropriate specifications or benchmark references are needed for REA Acceptance (Listing) of BETRS systems, and appropriate equipment and application specifications are needed as attachments to REA contracts for REA-financed BETRS purchases. Appropriate portions of other specifications by REA, Bellcore, industry and manufacturers are usually referenced by REA, telcos, engineers and manufacturers. For example, Bellcore Generic Requirements for Basic Exchange Radio Systems (TA-TSY-000911) covers digital BETRS systems.

3.6.2 For REA financing, BETRS systems should be purchased on REA contract Form 397 (or REA Form 398) with appropriate specifications attached to the contract. These performance specifications are developed by the telephone company's engineer. REA Form 397e, Mobile and Fixed Radiotelephone Specifications is useful as a guide (and only as a guide) for BETRS performance specifications. Form 397e was intended as a mobile radio system specification with possible incidental use of fixed rural radio applications. It is outdated and incomplete as a BETRS system specification. REA Form 397c, Design Specifications for Subscriber Carrier Systems is also useful as a guide for BETRS performance specifications. Selected portions of REA specifications such as PE-64a (digital subscriber carrier) and REA Forms 397a through 397h might be helpful to the engineer in developing BETRS specification attachments. Portions of traditional telecommunications standards and manufacturers' specifications for BETRS radio equipment can also be used. Specific target values and limitations should be stated in the contract. It is important that all parties reach agreement on contract provisions before the contract is signed.

3.6.3 BETRS specifications should be realistic and provide for reliable, high quality telecommunications service. In some cases, compromises may be required. In time, traditional performance parameters are expected to apply to BETRS without exception. Traditional transmission measurement techniques may not be adequate to verify some performance parameters of digital BETRS systems. Traditional transmission measurement techniques are analog in nature and may not be effective in testing new digital speech coding systems. In addition to agreement on performance parameters, Purchaser and Seller agreement may be needed on test techniques to verify performance.

3.6.4 **BETRS Performance Specifications** should be separated into four parts as illustrated below.

Part 1: Basic BETRS System and Equipment Performance
Part 2: Installation and Acceptance Tests
Part 3: Detailed Purchaser's Requirements
Part 4: Seller's Proposal

3.6.4.1 For the basic BETRS system and equipment performance requirements, the format in REA Form 397e, Part I is suggested. Appendix 2 provides an example of BETRS equipment specifications (partial list only) that might be attached to REA Form 397. Appendix 2 contains portions of selected standards and specifications from several sources including REA and the telecommunications industry. If manufacturers' specifications are used, care should be taken to keep the specifications generic to the Purchaser's needs and not favor one manufacturer or equipment over another.

3.6.4.2 Installation and Acceptance Requirements should follow a format similar to REA Form 397e, Part II. The specific details of installation and acceptance test requirements need to be updated with special attention given to both the office and subscriber locations. Proper bonding and grounding of antenna, equipment, and power is required to meet electrical and safety codes for the safety of people and protection of equipment and property at subscriber locations. Proper bonding and grounding are also important at locations of other modern electronic equipment including digital central office equipment. Careful attention should be given to antenna grounding and connection to other grounds external to the central office building; to the building entrance of ac power, telephone cables, and coaxial cables from the antenna; and to bonding and ground connections within the building. A suggested REA reference is "Electrical Protection of Electronic Analog and Digital Central Office Equipment" currently published as REA TE&CM Section 810 and planned for conversion into Bulletin 1751F-810.

3.6.4.3 Detailed Purchaser's Requirements should follow a format similar to Form 397e, Part IIIA. These requirements should outline the specific system and equipment needs for BETRS service, and contain sufficient detail for a clear understanding of the Purchaser's requirements. Purchaser requirements and Seller responsibilities should be clearly stated in all parts of the Purchaser's specifications.

3.6.4.4 Equipment and service requirements should be covered in detail. General requirements and special requirements for business, data, paystations and other special applications should be stated. Outside plant loop resistance from subscriber radio stations should be stated. (For total drop resistance, add 400 ohms for customer premises equipment.) Major and minor alarm requirements for radio equipment and related requirements such as power systems and tower lighting should be stated.

3.6.4.5 The BETRS performance specifications should contain a Seller's Proposal Summary similar to Form 397e, Part IIIB. This should summarize the Seller responses to Purchaser requirements and serve as a quick reference check list that assures the Purchaser that the Seller is proposing a complete system to fulfill the Purchaser's system requirements. The Summary should contain a statement that the proposed system meets all Purchaser requirements, or note specific exceptions to Purchaser's requirements. The Summary should contain a checklist of detailed attachments by the Seller in response to the Purchase requirements.

3.6.4.6 The Purchaser's Requirements and the Seller's Proposal should each contain a Narrative. The Purchaser's Narrative should describe the initial and ultimate (growth) requirements for the equipment, system and service. The purpose of the Narrative is to outline the Purchaser's plans so that the initial equipment furnished under the contract can later be expanded to ultimate service needs with minimal impact. The Seller's Narrative should describe the proposed system(s), equipment, component parts, accessories, options and necessary test equipment. The Seller should also outline a plan for orderly growth from the initial quantities of equipment to the Purchaser's ultimate system requirements.

3.6.4.7 The proposal should describe the options available to the Purchaser if the FCC does not grant a radio station authorization, or grants authorization for less than the number of radio channels required for adequate telecommunications service (present and future traffic requirements). A termination clause or fallback provision in the contract may be advisable.

3.7 System Proposals

3.7.1 It is recommended that the Purchaser seek proposals from several manufacturers (or Sellers) of BETRS radio equipment. Each Seller proposal should be reviewed for responsiveness to the Purchaser's contract provisions including the radio system plans and specifications. The lowest cost proposal that is responsive to the contract provisions should be selected unless there are valid reasons to select another proposal. The following proposal items should be noted.

3.7.2 Did the proposal respond to all contract provisions? Are some responses vague or inconclusive? Did the Seller take exception to some contract provisions? Are the exceptions logical? Are the excepted contract provisions essential to the service requirements, or do they substantially alter the service requirements or contract provisions? Is this a responsive proposal?

3.7.3 Does the proposal include adequate spare parts? Are the warranty provisions reasonable? Is the Repair and Return policy satisfactorily addressed? Has on-site and factory training been addressed? Does system maintenance require special test equipment? Does the telco have adequate general and special purpose test equipment for radio system maintenance?

3.7.4 Does the proposal include adequate documentation? The proposal should include equipment installation, operation and maintenance manuals, and final copies of drawings that outline selected options, special features, or other provisions.

3.7.5 Are the Seller's installation and test responsibilities clearly stated? Are other responsibilities by the Purchaser and Seller clearly outlined in the contract? Has the proposal reinforced the responsibility provisions, or did the proposal raise questions in some areas? If the radio system fails to provide the necessary service, are the alternatives clearly stated? Does the Purchaser or Seller bear the cost if additional equipment or more costly alternative equipment is required for satisfactory operation? What limits are imposed on remedies and alternatives?

3.7.6 The Purchaser and Seller should reach agreement on all aspects of the contract before it is signed. Minor problems can become major problems when contract provisions are not clearly stated.

3.8 System Implementation

3.8.1 If the planning, system design, FCC application, and contract provisions are thorough and complete, system implementation should be relatively smooth. Installation should be coordinated with all parties involved. The installer should be provided reasonable access to buildings, facilities and equipment, and be provided reasonable assistance by qualified telco personnel.

3.8.2 Installation should be monitored by a qualified telco representative. Care should be taken to ensure that contract provisions are met and that the installation meets building, electrical, and safety code requirements. Special attention should be given to bonding and grounding at antenna locations, digital central office equipment locations, subscriber locations, and commercial power connections.

3.8.3 System installation should always include equipment and system acceptance tests. Acceptance tests serve to demonstrate equipment performance relative to contract provisions, and serve as a benchmark for later comparison and troubleshooting. Acceptance tests should include physical inspection, operational tests, and electrical tests such as radio frequency transmit power, receive signal strength, bit error rate, voice levels, noise and distortion. To the degree practical, radio fade margin tests should be made on radio stations with marginal receive levels.

3.8.4 A properly designed and installed BETRS system should provide telecommunications service that is equal to or better than wireline service. The subscriber should not be able to distinguish between service provided by BETRS radio equipment and traditional telecommunications facilities.

APPENDIX 1

BETRS HISTORY

It has been technically and economically possible for decades to use a radio circuit as a link between a subscriber's telephone set and a telephone switching office. In many areas of the world outside the United States, radio circuits are routinely used. Radio circuits are used in such widespread regions as parts of Africa, Australia, Canada, South America, and the Middle East. Radio links proved to be the technology of choice for conditions such as large land masses, little or poor telecommunications infrastructure, hostile environment, scattered clusters of subscribers, and scattered individual subscribers. These conditions are common in many parts of the world including the United States, especially in the West, Midwest and Alaska.

Radio would seem a natural medium for serving rural telephone subscribers. Radio has been used for rural telephone service, but on a somewhat limited basis. Rural subscribers generally have access to mobile dial radio service, and microwave radio equipment is often used as a trunk or subscriber link for central offices or large clusters of subscribers. However, the use of radio for telephone service to individual fixed subscribers (wireless telephone loop) has been infrequent.

Soon after the REA was authorized by Congress in 1949 to make loans for rural telephone service, REA engineers investigated unique methods to provide this service economically. Radio was one of the methods explored for this service in sparsely populated rural areas. During the 1950s REA provided small grants to fund the development of subscriber radio systems. General Electric and Motorola provided single channel radio links in the 150 MHz radio band at locations in Virginia and Alabama. Raytheon developed a 6 GHz radio system that provided two multiparty channels to serve a small cluster of subscribers. It was first used by an REA borrower in northern Wisconsin.

Dial mobile radio systems in the 150 MHz band were also developed with the aid of REA grants. This dial mobile service was used extensively and was the forerunner to Improved Mobile Telephone Service and Cellular mobile service. Service to fixed subscribers was permitted as secondary to mobile service in this band.

In general, each of these subscriber radio systems might be described as a technological success. However, none of the systems proved to be a long term solution for telephone service in sparsely populated rural areas. The basic impediments were economics and regulation.

Rural radio service to fixed subscribers has long been available on a secondary basis in the 150 and 450 MHz bands allocated for Public Land Mobile Service if no harmful interference is caused to mobile service. FCC permission for fixed service was always secondary to mobile service, and rural radio was viewed more as temporary plant rather than permanent plant.

In the late 1980s, two Texas REA borrowers were confronted with deteriorating outside plant serving some of their remote subscribers. Replacing the existing outside plant with buried filled cable was considered prohibitively expensive. Using radio links, while expensive, was considered feasible if no

APPENDIX 1 - Continued

future changes were necessary. For good cause, the FCC will waive their rules. The two borrowers requested that the FCC waive the rules and grant them licenses in a geographically underused radio band different from the secondary rural radio service band. They cited economic hardship and the remote likelihood of the requested frequencies being used for the intended service in that area. After due process, the FCC granted a license by waiver to operate in the 2 GHz band.

In May 1985, the REA Assistant Administrator (Telephone) called on members of the four national telephone associations to join in an ad hoc task force to prepare a petition to the FCC. The National Rural Telecomm Association, the National Telephone Cooperative Association, the Organization for the Protection and Advancement of Small Telephone Companies, and the United States Telephone Association agreed to participate with REA. The objective was to eliminate the secondary status and the need for individual waivers. The task force filed a petition with the FCC in May 1986. The petition requested three changes in the FCC rules for BETRS.

1. Co-Primary status on unused frequencies.
2. Access to 26 frequency pairs in the 450 MHz band.
3. Set aside 2 MHz of the cellular radio reserve.

The FCC issued a Notice of Proposed Rulemaking (NPRN) on BETRS in January 1987. The BETRS proposal received wide support including Regional Bell Operating Companies and radio equipment manufacturers. In December 1987, the FCC adopted the Report and Order establishing BETRS, and then published a Final Rule in February 1988. Co-primary status was provided for BETRS in the following bands.

Frequency	Channels	BETRS	Co-Primary Service & FCC Rules
150 MHz	18	Part 22	Public Land Mobile - Part 22
450 MHz	26	Part 22	Public Land Mobile - Part 22
800 MHz	50	Part 22	Private Land Mobile - Part 90

Some restrictions apply. For example, the FCC requires BETRS at 800 MHz to be at least 100 miles from the 54 largest Metropolitan Statistical Areas. The BETRS authorization provides for a total of 94 radio channels. Many of the 44 radio channels at 150 and 450 MHz may already be licensed for nearby public mobile service; and the restrictions for the 50 radio channels in the private mobile service may limit their application. While the requested 2 MHz cellular reserve spectrum was denied, the FCC indicated that if the allocated spectrum at a later time was insufficient, additional spectrum would be considered.

In October 1988, the FCC adopted a BETRS provision in the cellular service band. The FCC Order included, "In the Domestic Public Cellular Radio Telecommunications Service, this service provides public message communication service to fixed subscribers in Rural Service areas and rural parts of Metropolitan Statistical Areas." In the cellular band, the FCC license is awarded to cellular system operator. This requires the telco wishing to provide BETRS in this band to be the cellular licensee or negotiate with the cellular licensee for frequency spectrum.

APPENDIX 1 - Continued

EPILOG

The January 1987 BETRS authorization provided an opportunity to provide service in rural areas on a "permanent" basis. BETRS will be of limited value in certain regions because of limited radio channel availability and restrictions. Even in less populated areas, radio spectrum efficiency will be necessary for maximum rural area coverage. The October 1988 Cellular BETRS authorization provided additional potential for BETRS in rural areas. Cellular Rural Service Areas are being licensed at the time of this writing. However, rural cellular systems have not yet been constructed and placed into operation. It is too soon to judge the degree or timetable that cellular radio will fill this need in rural areas, especially in less populated areas.

Petitions for Reconsideration of the original BETRS Report and Order were filed by Pacific Bell, Nevada Bell and the United States Telephone Association. The petitions requested several changes including additional spectrum and a liberal waiver policy for BETRS applicants to ease restrictions on the present BETRS spectrum allocation. The liberal waiver policy would permit broader application of the existing BETRS allocation. Additional spectrum and especially discrete spectrum permitting dynamic bandwidth allocation schemes would encourage economical radio system design and universal systematic BETRS applications.

The Request for Reconsideration was denied by the FCC in May 1989. The FCC indicated that the need for reconsideration had not been established by the Petitioners.

Through BETRS, the FCC has provided a means to serve subscribers in rural areas on a "permanent" basis. This is an opportunity to get started with BETRS. The need for additional spectrum and waivers will have to be demonstrated. Additional frequency spectrum with dedicated blocks of frequencies will be needed for BETRS to become a universal cost effective service. Dedicated frequency blocks would permit the radio manufacturer's design engineer to choose time division or frequency division multiplex to economically address specific markets.

APPENDIX 2

EXAMPLE OF BETRS EQUIPMENT SPECIFICATIONS

This Appendix provides an example of BETRS equipment specifications (partial list only) that might be attached to REA Form 397. It is essentially a combination of selected standards and specifications from several sources including REA and the telecommunications industry. Care should be taken to keep the specifications generic to the Purchaser's needs and not favor one manufacturer or equipment over another.

1. GENERAL

1.1 Equipment interfaces to the telecommunications network, equipment, and facilities shall conform to traditional telecommunications analog voice frequency and signaling standards, or to D4/DS1 digital standards.

1.2 The equipment shall be designed for proper operation and interface with customer premises equipment registered under FCC Part 68. Customer premises equipment and material shall meet the Listing requirements of national and local codes.

1.3 The equipment shall be Type Accepted under FCC Part 22 and other applicable FCC requirements. Specific FCC Acceptance Designations shall be stated.

1.4 The radio equipment shall return to an on-hook condition (a) if the receive level falls below the minimum service threshold for more than five seconds; (b) within 5 seconds of subscriber or central office disconnection; or, (c) within one minute for calls not completed.

2. ENVIRONMENT

2.1 Equipment mounted inside buildings shall operate satisfactorily within an ambient temperature range of 0° to 50°C and at 80 percent relative humidity between 10° and 40°C. Equipment mounted outdoors shall operate satisfactorily within an ambient temperature range of -40° to 60°C and at 95 percent relative humidity between 10° and 40°C.

2.2 DC powered equipment shall operate satisfactorily over a range of 44 to 56 volts unless stated otherwise. AC powered equipment shall operate satisfactorily over a range of 108 to 132 volts unless stated otherwise. AC powered equipment shall be equipped with battery backup for a minimum of eight hours operation.

2.3 Power requirements shall be stated by the Seller at 50 volts dc or 120 volts ac input for minimum power conditions (low traffic or standby) and for maximum power conditions (high traffic, ringing, or in use).

2.4 Outdoor equipment housings shall be of rugged construction, corrosion resistant, and water tight or weather resistant to provide proper electrical and mechanical performance, protect the equipment from damage or faulty operation due to moisture, dust and other airborne particles, and minimize infestation by insects.

APPENDIX 2 - Continued

3. VOICE FREQUENCY

3.1 **Impedance:** 2-Wire: 900 Ohms.
4-Wire: 600 Ohms.
Minimum Return Loss:
From CO End: 18 dB ERL; 12 dB SRL.
From Subscriber End: 16 dB ERL; 10 dB SRL.

3.2 1004 Hertz Loss: Set at 2 dB; 1.0 dB Maximum Variation, Long Term.
Level Tracking: 0.5 dB Maximum Variation, From +3 to -37 dBm0 Input.
1.0 dB Maximum Variation, From -37 to -50 dBm0 Input.
Frequency Response Relative to 1004 Hertz:
+1 to -1 dB Maximum Variation, From 600 to 2400 Hertz
+1 to -3 dB Maximum Variation, From 300 to 3200 Hertz
-20 dB or Lower at 60 Hertz.

3.3 Circuit Noise: 20 dBrnC Maximum (Operational).
Signal to Noise: 33 dB Minimum, From +3 to -30 dBm0 Input.
(Quantizing 27 dB Minimum, From -30 to -40 dBm0 Input.
Distortion) 22 dB Minimum, From -40 to -45 dBm0 Input.
Circuit Balance: 60 dB Minimum (ANSI/IEEE 455-1985).
Channel Crosstalk Loss: 65 dB Minimum.

3.4 Voiceband Data: 2400 Baud Minimum (4800 Baud Objective).

4. RADIO FREQUENCY

4.1 General: RF Channels Required ____________________
Maximum Bit Error Rate ____________________
Maximum Path Loss in dB ____________________

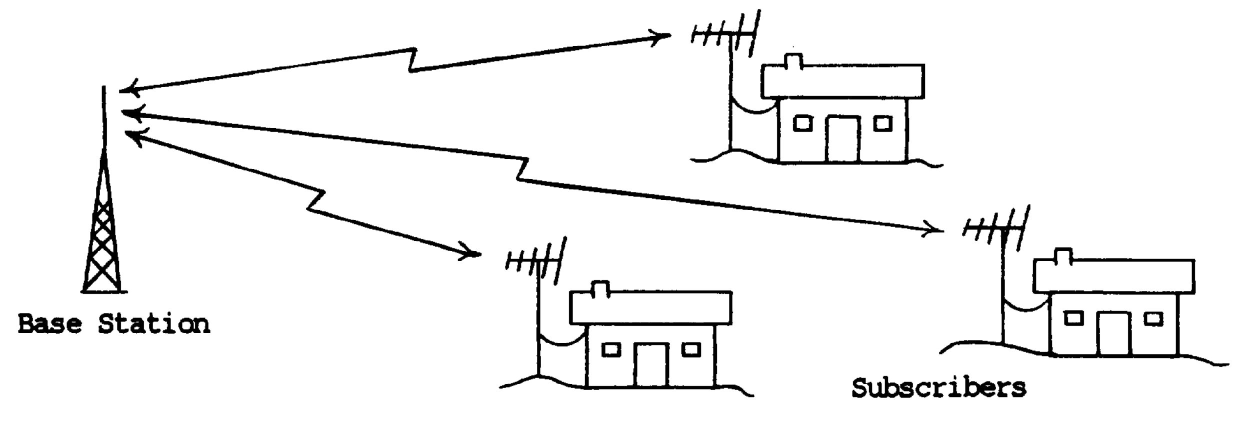
4.2 Base Station: Transmit Frequencies ____________________
Transmit Power Output (Per RF) ______________
Effective Radiated Power (Per RF) ____________
Minimum Receive Level ____________________
Receive Level Range (Min to Max) ____________
Adjacent Channel Receive Rejection __________
Co-Channel Receive Isolation ______________
Transmit to Receive Isolation ______________

4.3 Subscriber Stations: Transmit Frequencies ______________
Transmit Power Output (Per RF) ________
Effective Radiated Power (Per RF) ______
Minimum Receive Level ______________
Receive Level Range (Min to Max) ________
Adjacent Channel Receive Rejection ______
Co-Channel Receive Isolation ________
Transmit to Receive Isolation ________

4.4 Repeater Station(s): ______________________________

FIGURE 1

POINT-TO-MULTIPOINT BETRS RADIO SERVICE



Demand Assignment Multiple Access Radio Channels

FIGURE 2

POINT-TO-POINT MICROWAVE RADIO SUBSCRIBER SERVICE

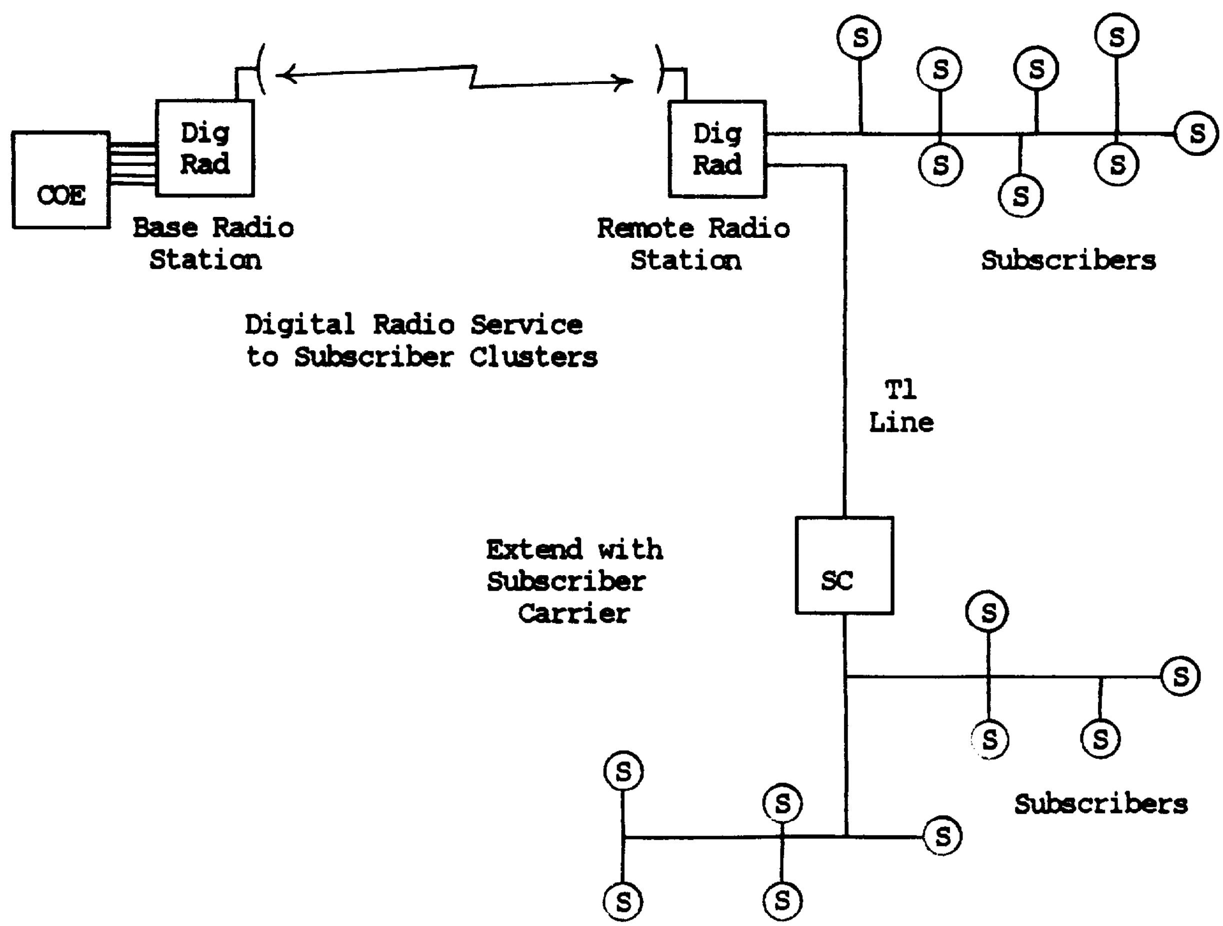
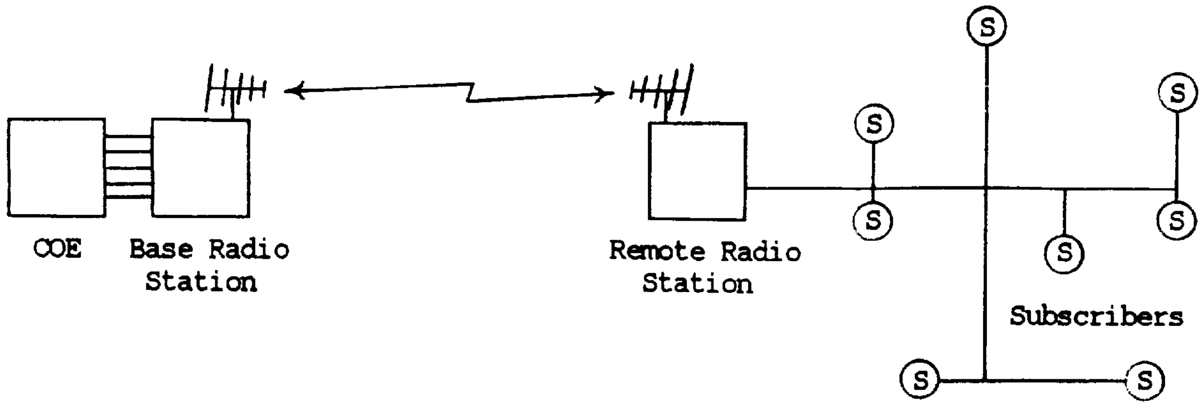


FIGURE 3

POINT-TO-POINT BETRS RADIO SERVICE



Notes: 1. One Base Radio Station and One Subscriber Radio Station.
2. Requires Several Trunks or Channels (Radio/Voice).
3. Conventional Multipair Telephone Cable to Subscribers.

FIGURE 4

POINT-TO-POINT RURAL RADIO SERVICE

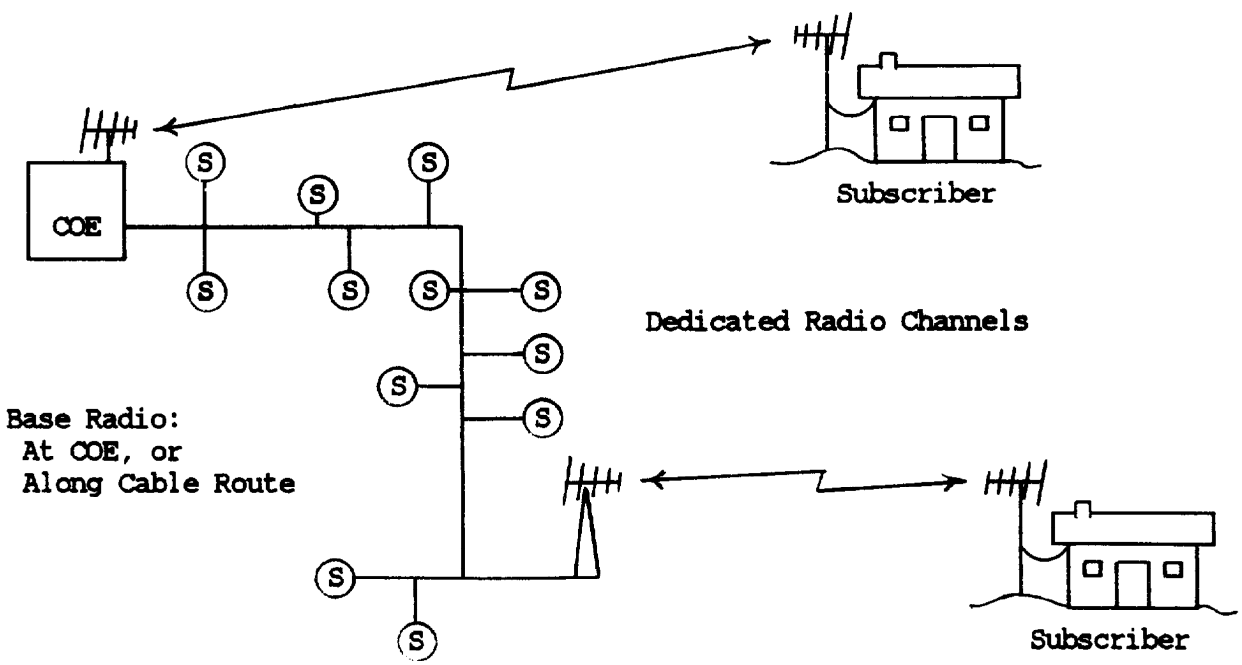
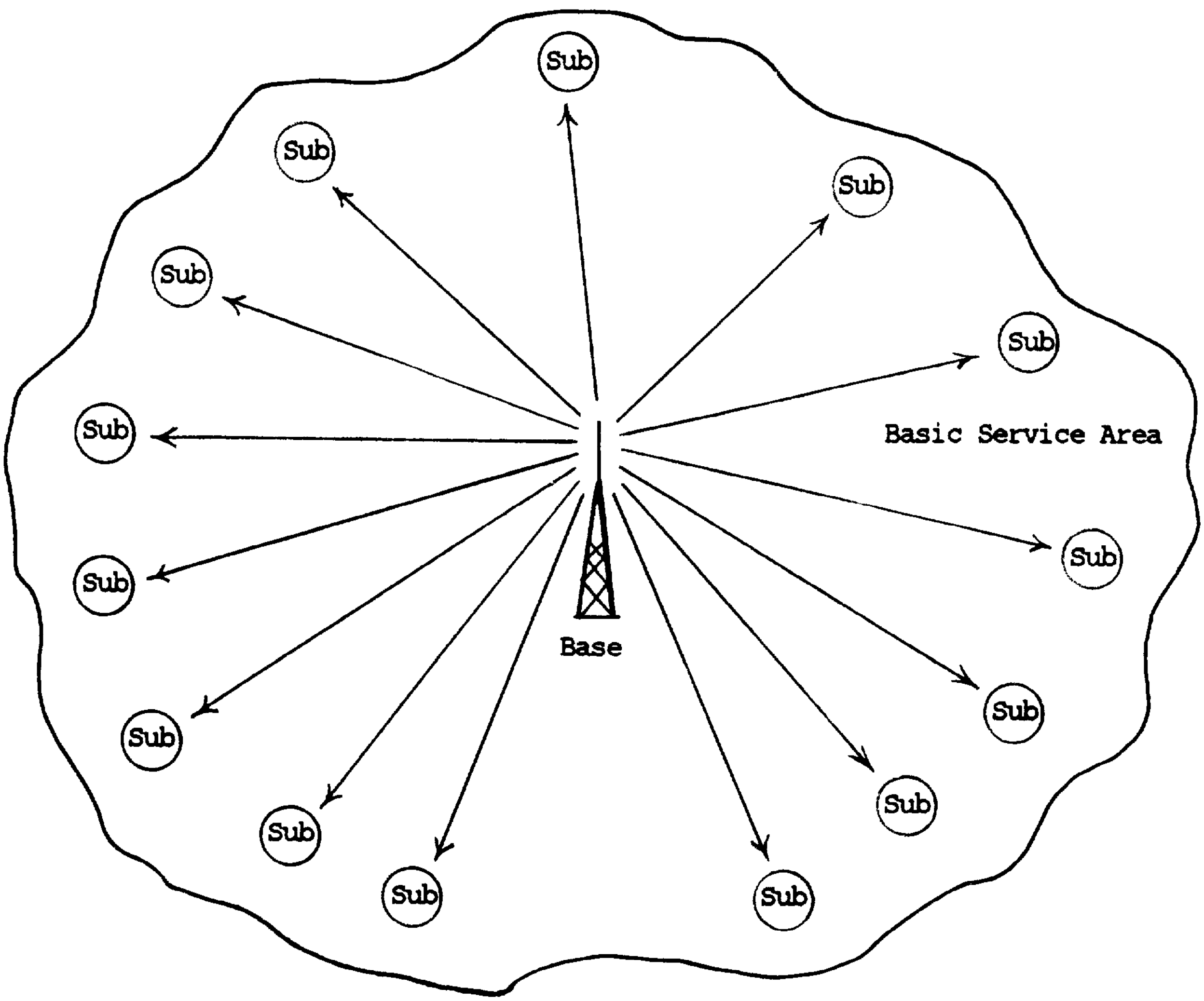


FIGURE 5

POINT-TO-MULTIPOINT BETRS RADIO SERVICE AREA



Notes: 1. One Base Radio Station.
2. Requires Several Trunks or Channels (Radio/Voice).
3. Subscriber Radio Station at Each Subscriber Location.

FIGURE 6

BASE RADIO STATION

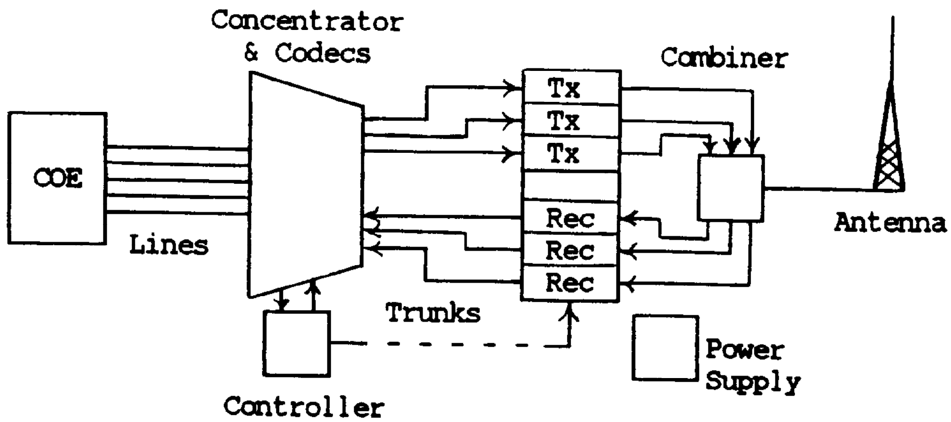


FIGURE 7

MODULAR BASE STATION

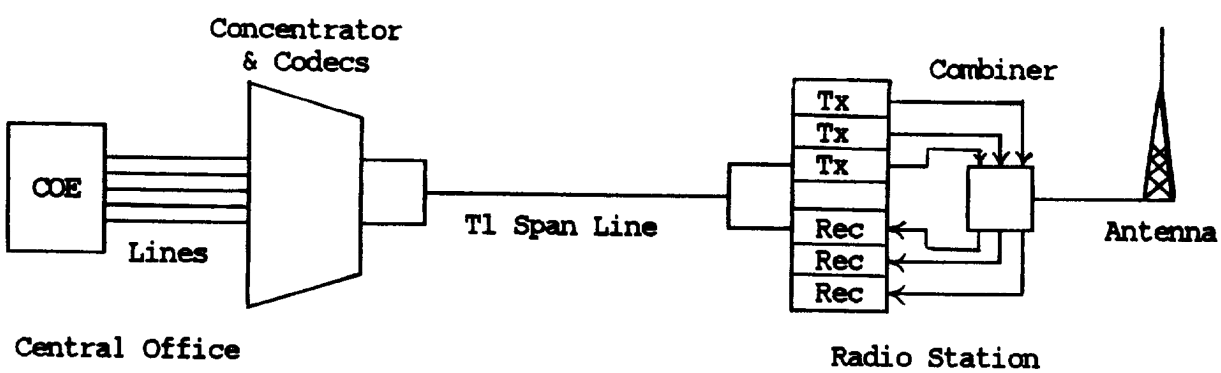


FIGURE 8

SUBSCRIBER RADIO STATION

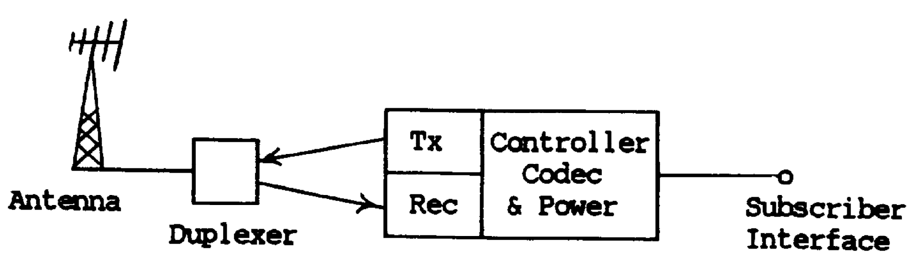


FIGURE 9

BETRS RADIO REPEATER SERVICE AREA

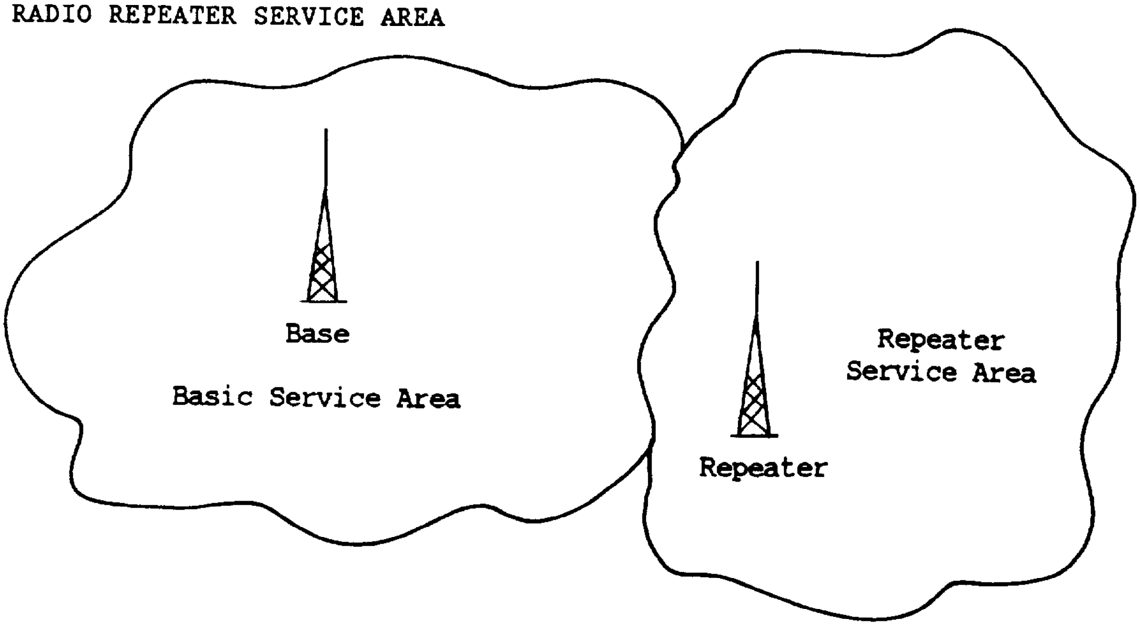


FIGURE 10

RADIO FREQUENCIES - BASIC SYSTEM

FIGURE 11

RADIO FREQUENCIES - SYSTEM WITH REPEATER

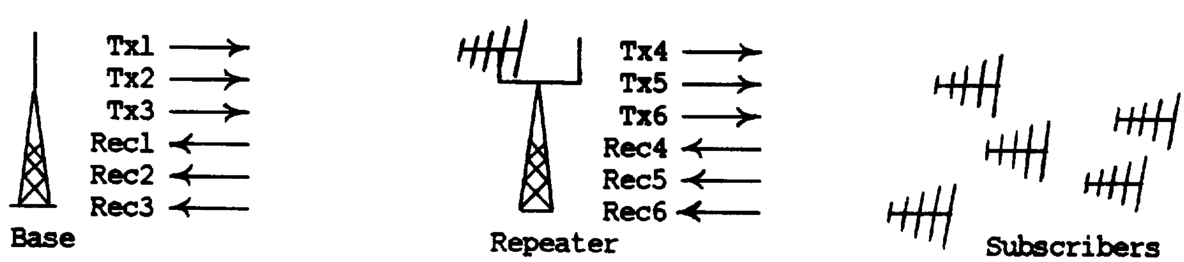
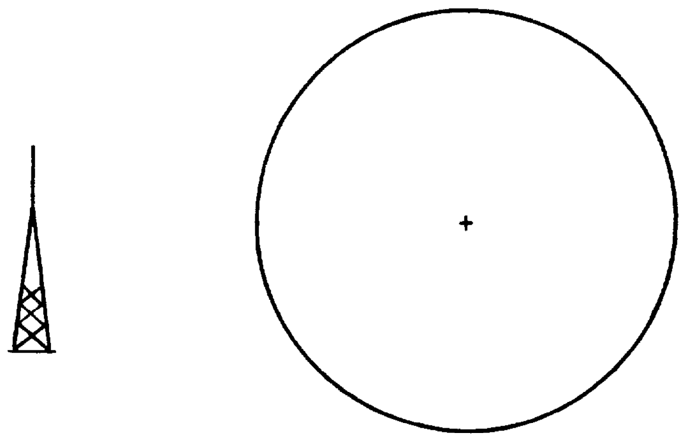
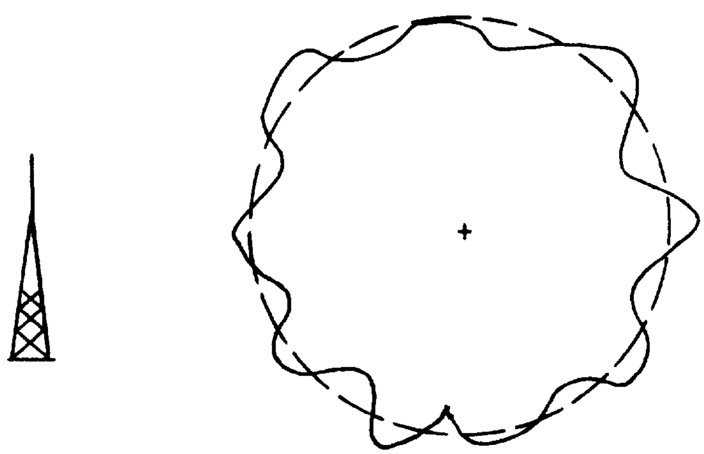


FIGURE 12 - RADIO PROPAGATION PATTERNS

12A: Omnidirectional Antenna in Free Space



12B: Omnidirectional Antenna in Real World



12C: Directional Antenna - Yagi Typical

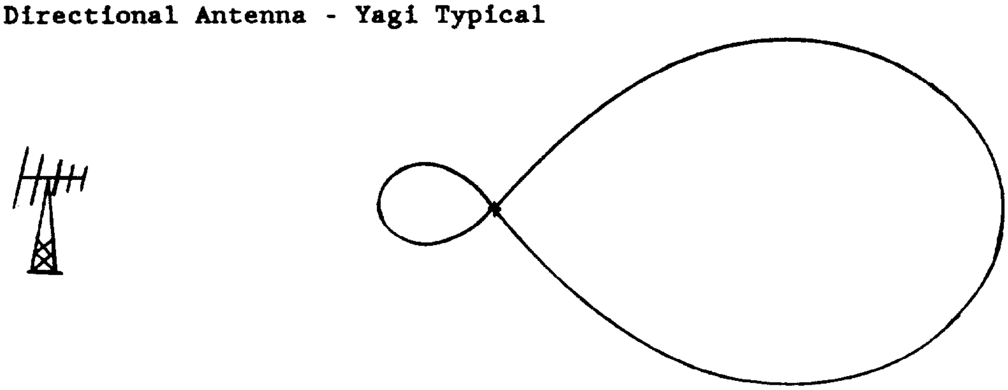
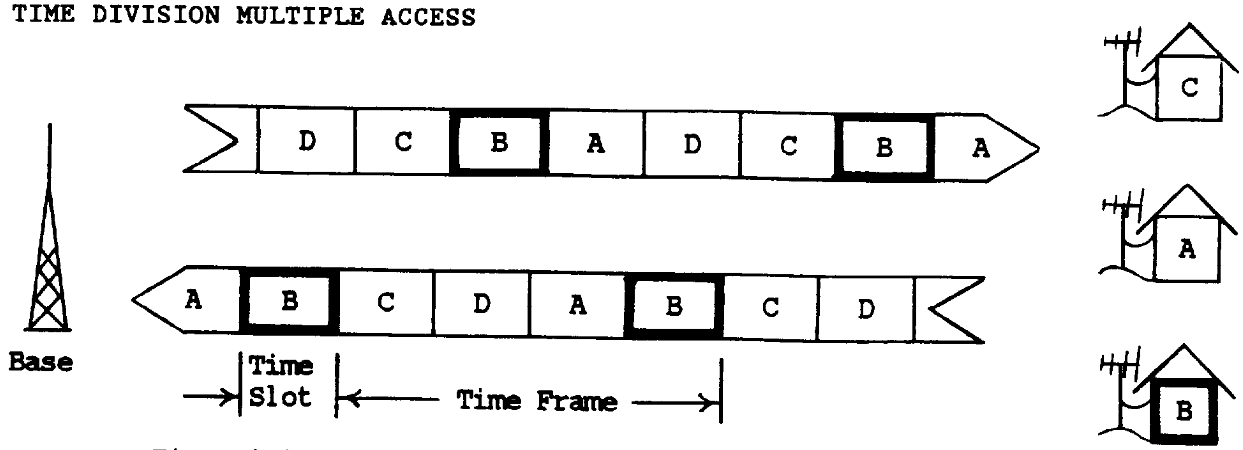


FIGURE 13

TIME DIVISION MULTIPLE ACCESS



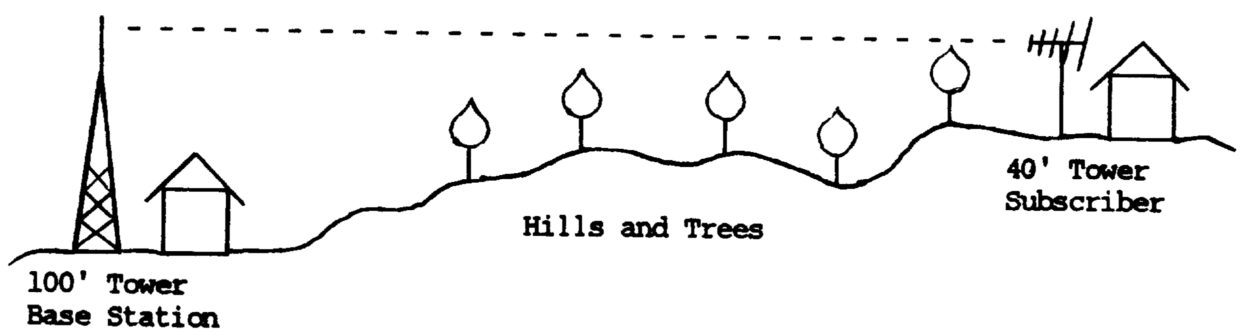
<u>Time Division Multiple Access</u>

The base transmits a continuous signal, divided into time slots and time frames.

Subscribers transmit in bursts, to merge signals into time slots within time frames.

FIGURE 14

SIMPLIFIED PROFILE VIEW OF RADIO PATH



<u>Note</u>: Simplified Profile View of the Radio Propagation Path from the Base Radio Station to Subscriber.