

BASIC EXCHANGE TELECOMMUNICATIONS RADIO SERVICE

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1. GENERAL

1.1 This is a tutorial section that provides REA borrowers, consulting engineers, manufacturers, contractors, 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 section are advisory. BETRS application guidelines and recommendations are contained in a companion Section 949, BETRS Radio Application Guidelines.

1.2 BETRS was established by the Federal Communications Commission (FCC) in December 1987. This section addresses BETRS in the 150 and 450 MHz bands that has 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 section. Some of the terms used in this section are summarized in Appendix 1. BETRS History is summarized in Appendix 2.

1.3 As a background for BETRS, this section begins with a brief overview of subscriber radio equipment available for rural telecommunications service. This is followed by a description of the BETRS concept, characteristics of existing and evolving BETRS equipment, and recommendations for the future. 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 access applications, packaged for easy installation, and available with model variations for special applications and features.

1.4 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 section 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.

1.5 Generic descriptive terms are used to describe radio systems and equipment throughout this section except for a brief mention in Appendix 1. Generic descriptive terms are also used in Section 949 except that paragraph 5 uses FCC terms in discussing the FCC Radio Station Authorization.

2. SUBSCRIBER RADIO EQUIPMENT

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 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)

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." Several manufacturers have expressed interest in this point-to-multipoint BETRS market. Some are developing new digital radio equipment and others are using existing analog radio equipment to address this market. Subscriber radio equipment has been available on the world market for several years. The BETRS action by the FCC has prompted manufacturers to modify existing equipment for the US market. BETRS equipment is covered by Part 22 of the FCC rules.

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.

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 section. Cellular radio equipment is covered in Part 22 of the FCC rules.

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. Subscribers are served from the remote radio equipment 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.

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. BETRS equipment is covered by Part 22 of the FCC rules.

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. It is useful in select or small startup applications.

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 section will emphasize BETRS trunked radio equipment with demand access channels for point-to-multipoint service in the 150, 450 and 800 MHz bands.

3. BETRS RADIO SYSTEMS

3.1 Introduction: 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. BETRS is covered in Part 22 of the FCC Rules (Code of Federal Regulations, Title 47, Part 22). Co-primary status is provided for BETRS in the following bands.

<u>Frequency</u>	<u>Channels</u>	<u>BETRS</u>	<u>Co-Primary Service & FCC Rules</u>
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

3.1.1 Some restrictions apply. For example, BETRS at 800 MHz must 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.

3.1.2 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.

3.1.3 BETRS can be used for area coverage, or can be used to supplement service by conventional facilities. A mixture of conventional facilities and BETRS should generally be more economical than an all-BETRS design. It is likely that service by BETRS and conventional facilities will overlap; and the overlap will increase once a BETRS system is in place.

3.1.4 The Rural Electrification Administration (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.

3.1.5 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.

3.1.6 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.

3.1.7 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.

3.2 Point-to-Multipoint Systems: A basic point-to-multipoint BETRS radio system consists of a base radio station usually located at or near the central office (CO) switch, 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.

3.3 Base Radio Station: 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 fed into 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).

3.3.1 Power for the base radio station should be from a battery source to provide for at least 8 hours operation in the event of a commercial power failure. The 50 volt dc battery supply for the central office equipment is the preferred power source for a co-located base radio station.

3.4 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.

3.5 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 must 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.

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

3.5.2 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 electric bill for each subscriber location may be costly. Another option is to arrange for access to the radio subscriber's electric power. In this case, special attention must be given to national, state and local electrical codes concerning power wiring and grounding. For low power subscriber units, the use of UL Listed Class 2 transformers and low

voltage wiring may simplify installation. Radio station power consumption may require negotiation with the subscriber for power costs.

3.6 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 3.4. 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 most applications.

3.6.1 In this discussion of BETRS radio systems, the term "repeater" refers to 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 term "booster" is used to describe 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 is licensed as a "relay station" and a booster is considered under the basic authorization. See TE&CM Section 949 for additional discussion on FCC authorization.

3.6.2 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. 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.

3.6.3 The use of repeaters in a BETRS system application requires additional radio frequencies. Back-to-back radio channels are generally used as a repeater, but hetrodyne (frequency conversion) techniques may be used. Frequencies may be limited for this purpose. The use of repeaters may require increased radio spectrum efficiency such as subdividing the 25 kHz radio channel into multiple voice circuits.

3.6.4 Another service possibility is to reuse and "boost" the base frequencies at a distant location. This is a form of "repeater" but is referenced here as a "booster" for clarification. This was previously accomplished in microwave radio through the use of linear amplifiers and highly directive antennas. Work is currently under way to use a similar technique in BETRS and cellular radio systems. Boosters 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. Control of the booster service area and control of co-channel interference within the basic service area is essential to success of boosters. Discussion of repeaters in this section is also intended to include boosters except for the technical differences concerning the FCC, frequencies, and service area coverage.

3.7 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 section, a BETRS point-to-point radio "system" refers to a system where multiple radio channels are shared on a demand access basis 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 3.8). Because BETRS radio frequencies are limited, channel sharing spectrum efficiency is encouraged.

3.7.1 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 and/or radio 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 system design may permit radio frequencies to be shared by point-to-point and point-to-multipoint integrated systems within a service area.

3.7.2 A subscriber cluster application might be engineered with digital radio equipment as described in paragraph 2.5 and Figure 2; or might be engineered using BETRS radio equipment at 150, 450 and 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.

3.8 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.

3.9 Radio Propagation Patterns: Careful selection of antennas and radio station locations can improve radio system coverage, reduce radio 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 point source that radiates equally in all directions. The isotropic radiator would produce a spherical pattern; it is a theoretical antenna for reference purposes.

3.9.1 An antenna consisting of a vertical pole on top of a very 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.

3.9.2 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.

3.9.3 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.

3.9.4 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 to improve gain and 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.

4. PRESENT ANALOG EQUIPMENT

4.1 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. For REA borrower applications, the radio equipment must be FCC type accepted for operation under FCC Part 22.

4.2 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. 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 4800 baud. The subscriber radio station of some models may be located at some distance from the subscriber (example: 1000 ohms of cable plus a 400 ohm telephone set).

4.3 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.

4.4 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 companders 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.

5. EVOLVING DIGITAL EQUIPMENT

5.1 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.

5.2 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 must be supplemented by subjective conversation comparison tests.

5.3 Spectrum efficient digital codes in combination with time division multiple access (TDMA) permit multiple voice channels within each 25 kHz radio channel available by frequency division multiple access (FDMA). When FDMA and TDMA are combined, each subscriber has 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.

5.3.1 The 25 kHz radio channel is modulated with a 64 kb/s signal. Using TDMA, the 64 kb/s signal is divided into four separate channels or 16 kb/s time slots. Each 16 kb/s channel is modulated with a spectrum efficient digital coding such as LPC. Each 16 kb/s time slot or voice channel can be

accessed by any subscriber within the system on a demand basis. One 16 kHz time slot in the system is a 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.

5.3.2 Figure 13 illustrates TDMA. The base radio station transmits a continuous signal on a radio channel that is divided into four time slots. Each subscriber can receive or access any available time slot on any assigned radio channel. The received 16 kb/s signal is decoded into a voice channel. Each subscriber can also transmit in any available time slot on any assigned channel. Each subscriber radio station transmits in synchronized bursts so that the radio signals from several subscriber transmitters effectively merge the time slots 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.

5.4 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. 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 1000 ohms of cable plus a 400 ohm telephone set).

6. SUMMARY AND RECOMMENDATIONS

6.1 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.

6.2 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.

6.3 BETRS Wish List: 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.

- 6.3.1 Reliability: Equipment reliability will improve with experience and quantity production. The goal is for a service reliability near that of conventional plant facilities.
- 6.3.2 Cost: Equipment and installed system costs must be reduced to compete with conventional plant facilities. Costs should improve with quantity production, experience and product evolution.
- 6.3.3 Power: Power consumption must 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 many potential BETRS subscribers have no commercial power or unreliable power, economical solar power is a desirable alternative at remote locations.
- 6.3.4 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.
- 6.3.5 Housing: Outside housings at subscriber locations are necessary for universal acceptance. The housings should be small, blend with the surrounding environment, dissipate the heat generated by the equipment and the sun, and provide environmental protection from the elements. Reduction of size and power consumption can lead to housing design improvements.
- 6.3.6 Installation: Equipment installation at remote subscriber locations should be simplified. Size, power consumption and housings are factors that affect installation simplicity and costs.
- 6.3.7 Repeaters: Low cost repeaters and boosters are needed to increase the service coverage area and for fill-in coverage.
- 6.3.8 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 future growth potential. Modular equipment can reduce obsolescence by providing for system upgrades in size and in new features and services.
- 6.3.9 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. One manufacturer uses time division multiplex to subdivide the 25 kHz radio channels into four subchannels, but this improved spectrum efficiency is not cost free. 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.

APPENDIX 1

TERMS USED IN THIS SECTION

Some of the terms used in this section are summarized here for the purpose of description and illustration only. Information contained in this appendix are not "definitions," and are not proposed as standard telecommunications terms and definitions.

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

BETRS: Abbreviation for 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: Abbreviation for coder and decoder; used for analog to digital encoding and detection.

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

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

DAMA: Abbreviation for demand assignment multiple access; access from many sources or locations upon request (demand). Also see TDMA.

FDM: Abbreviation for frequency division multiplex; multiplex by discrete frequency assignment of channels.

FDMA: Abbreviation for frequency division multiple access; access from many sources or locations on a frequency division basis. Also see DAMA and FDM.

MSA: Abbreviation for Metropolitan Statistical Area.

Processor: See Controller.

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

RSA: Abbreviation for 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.)

TDM: Abbreviation for time division multiplex; multiplex by discrete time assignment of channels.

TDMA: Abbreviation for time division multiple access; access from many sources or locations on a time division basis. Also see DAMA and TDM.

APPENDIX 2

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 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 some "seed" money for 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 REA "seed" money. This dial mobile service was used extensively and was the forerunner to Improved Mobile Telephone Service (IMTS) 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

APPENDIX 2 - Continued

feasible if no 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 (NPRM) 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.

<u>Frequency</u>	<u>Channels</u>	<u>BETRS</u>	<u>Co-Primary Service & FCC Rules</u>
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, BETRS at 800 MHz must 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. The telco wishing to provide BETRS in this band must be the cellular licensee, or must negotiate with the cellular licensee for frequency spectrum.

APPENDIX 2 - 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.

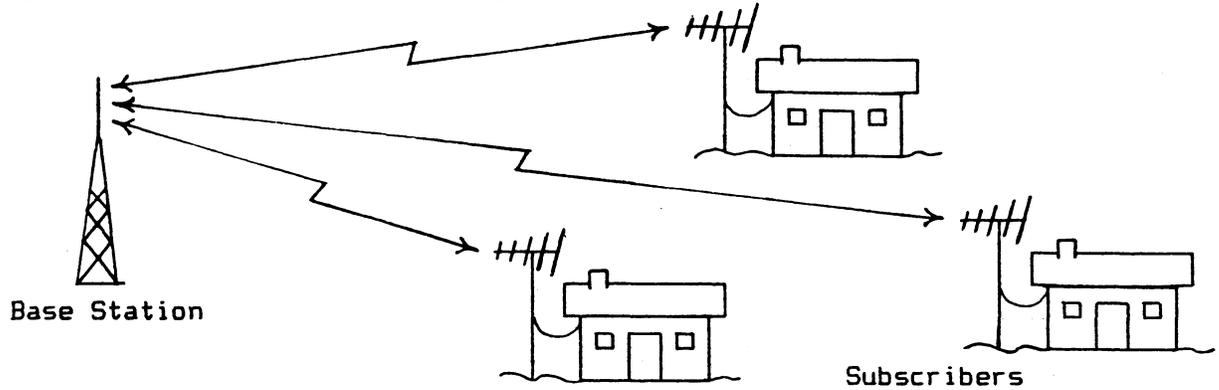
Petitions for Reconsideration of the original BETRS Report and Order were filed by Pacific Bell, Nevada Bell and the United States Telephone Association. The petitions requested several changes including additional spectrum and a liberal waiver policy for BETRS applicants to ease restrictions on the 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 must 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 multiplex or frequency multiplex to economically address specific markets.

FIGURE 1

POINT-TO-MULTIPOINT BETRS RADIO SERVICE



Demand Assignment Multiple Access Radio Channels

FIGURE 2

POINT-TO-POINT MICROWAVE RADIO SUBSCRIBER SERVICE

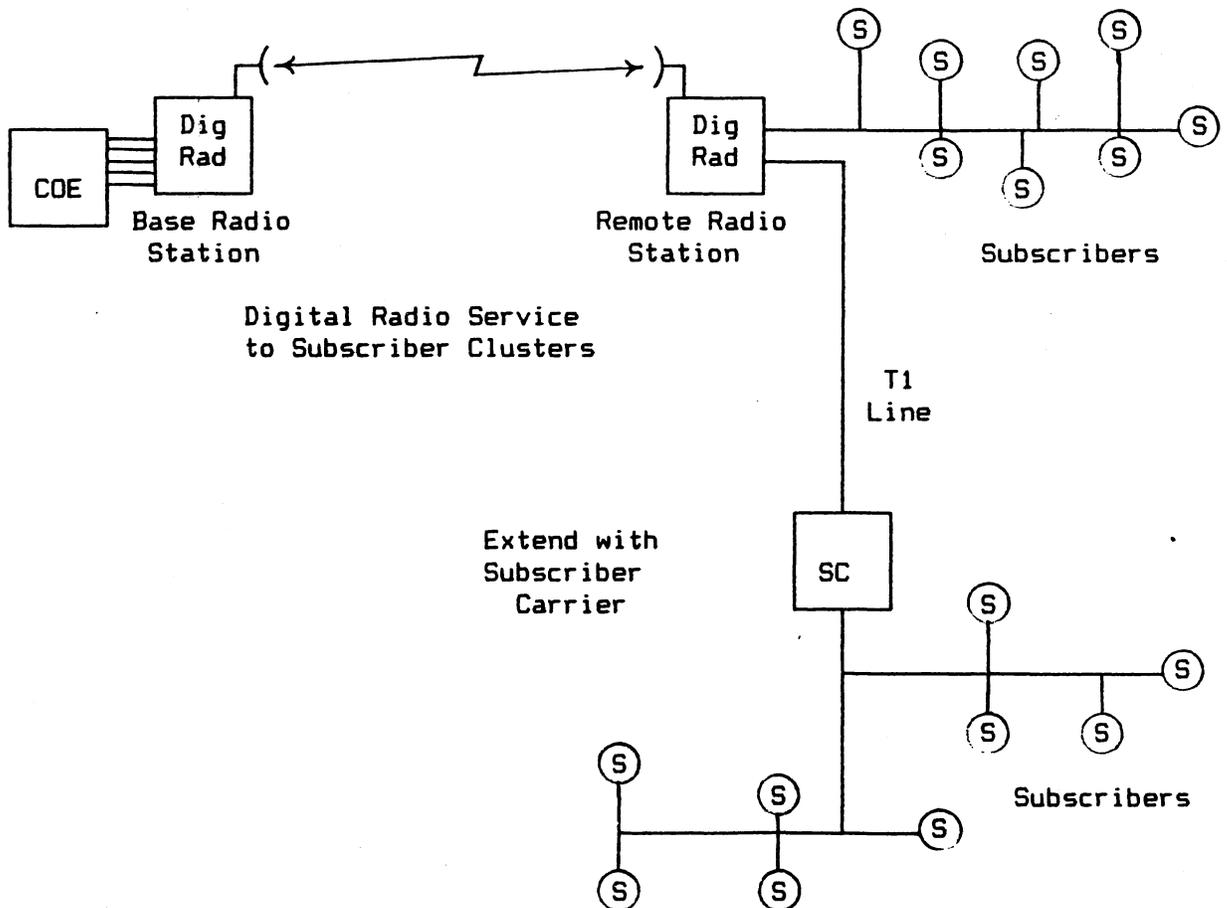


FIGURE 3

POINT-TO-POINT BETRS RADIO SYSTEM

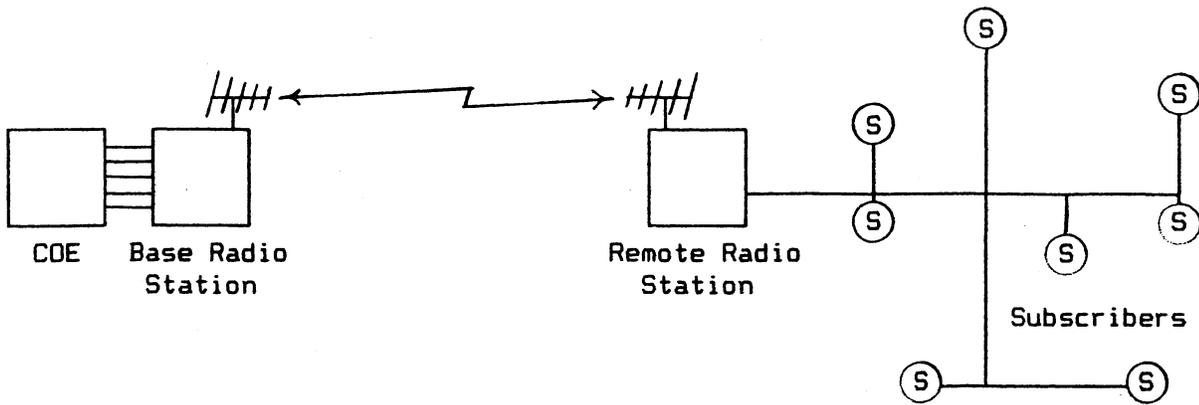


FIGURE 4

POINT-TO-POINT RURAL RADIO SERVICE

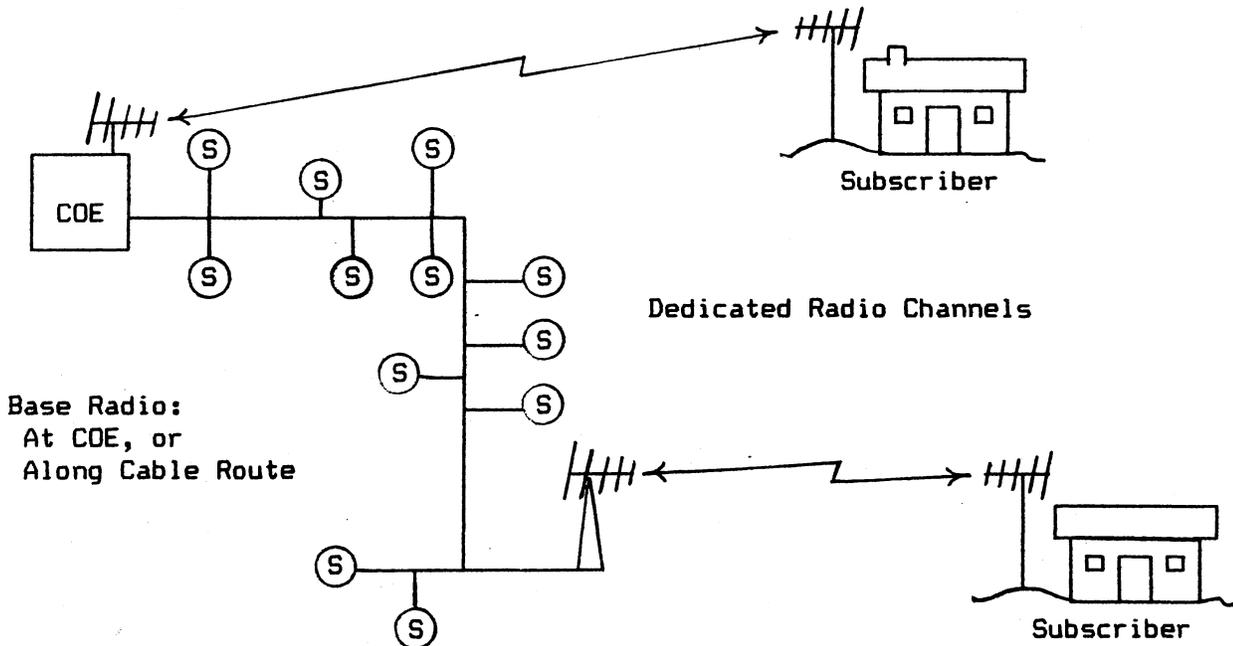


FIGURE 5

BETRS SERVICE AREA

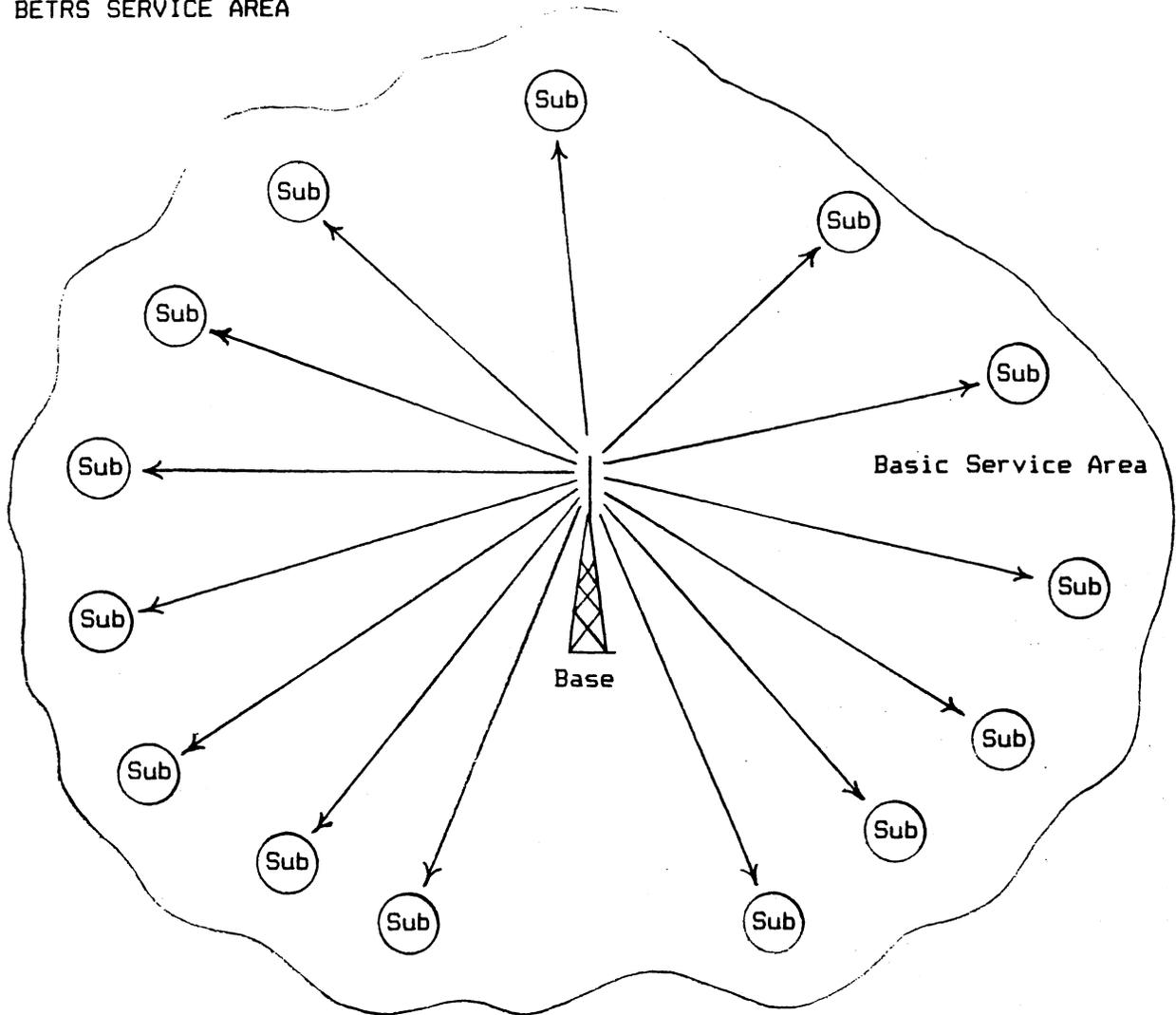


FIGURE 6
BASE RADIO STATION

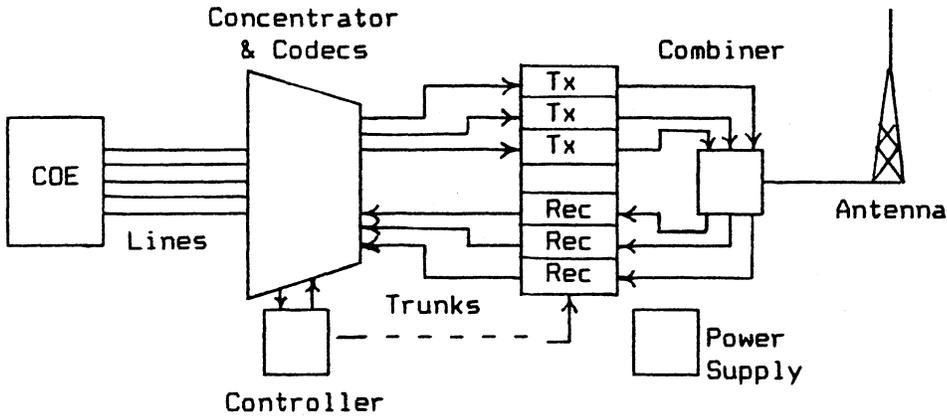


FIGURE 7
MODULAR BASE STATION

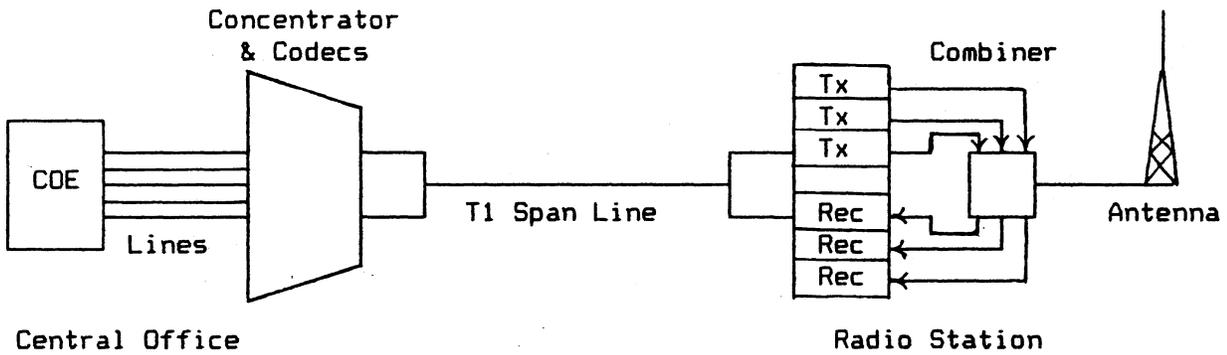


FIGURE 8
SUBSCRIBER RADIO STATION

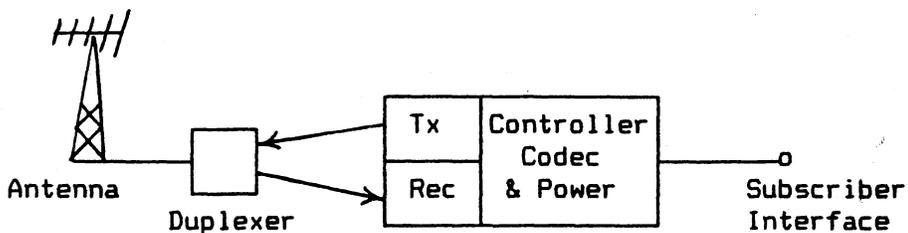


FIGURE 9

REPEATER SERVICE AREA

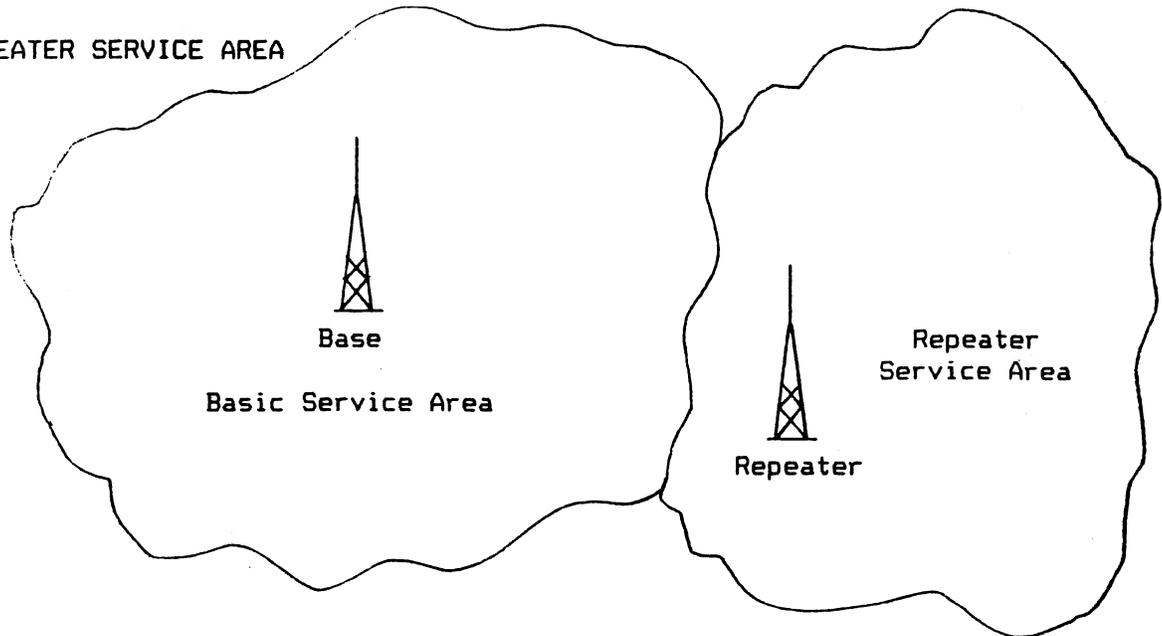


FIGURE 10

RADIO FREQUENCIES - BASIC SYSTEM



FIGURE 11

RADIO FREQUENCIES - SYSTEM WITH REPEATER

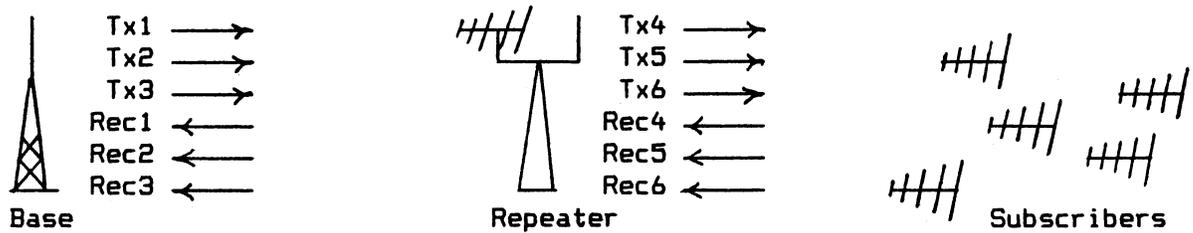
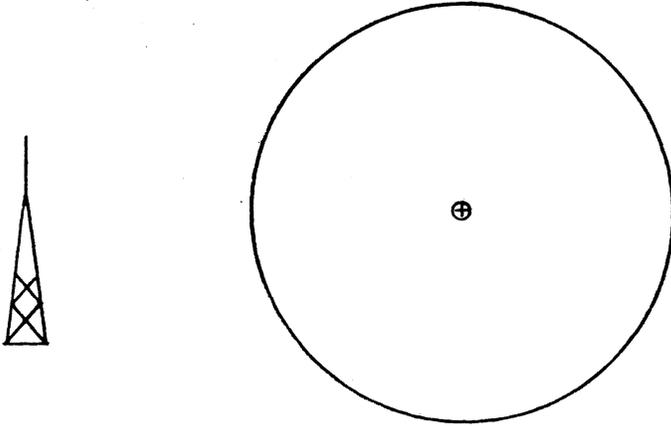
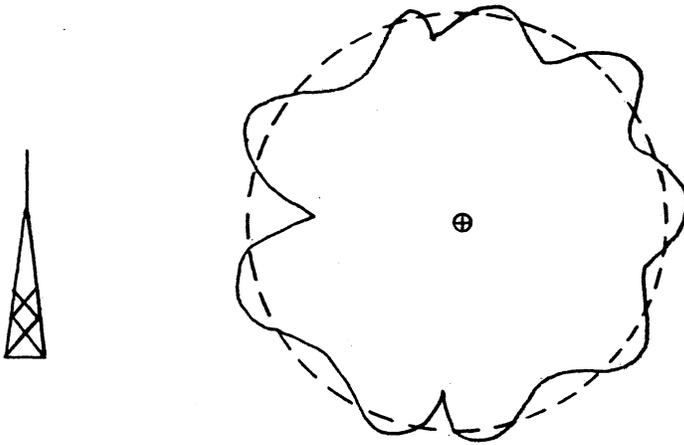


FIGURE 12 - RADIO PROPAGATION PATTERNS

12A: Omnidirectional Antenna in Free Space
(Isotropic Radiator)



12B: Omnidirectional Antenna in Real World



12C: Directional Antenna - Yagi Typical

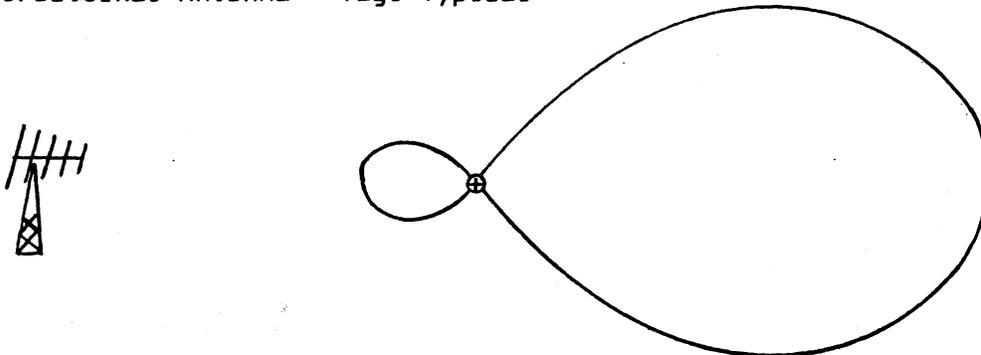


FIGURE 13

TIME DIVISION MULTIPLE ACCESS

