SUBSCRIBER LOOP ELECTRONIC SYSTEMS

1. GENERAL

1.1 This section is intended as an aid to REA borrowers, consulting engineers and other interested parties in the design of telephone systems. This section provides a brief overview to illustrate the use of electronics in subscriber loop plant. It is intended to help the telco manager or engineer compare techniques and plan for the future with today's technology. For a more detailed discussion on these various systems, refer to other references such as those noted in Paragraph 2.4.

1.2 Electronics in the form of carrier multiplex was introduced into telephone trunk plant in 1918 and into subscriber loop plant in 1941. Electronic systems have been in widespread use in trunk plant for more than 30 years. Volume use of electronics in subscriber plant began about 1970 in the form of loop extenders, voice frequency repeaters and station carrier (analog subscriber carrier). Electronic component failures and some cable moisture problems slowed this growth during the mid 1970's.

1.3 After a long maturing process, electronic systems are in widespread use today in subscriber loop plant. Water resistant paired telephone cables are likely to continue serving the majority of rural subscribers for some time; and those cables are rapidly becoming the transmission path for subscriber loop electronic systems. Alternatives to paired telephone cables are becoming more commonplace in trunk systems. Microwave radio is now used more frequently to provide part of the subscriber loop facility (cluster applications). Coaxial cables and optical fibers are now used as trunk facilities for conventional telephony service. As the technology and economics improve, these facilities are expected to also be used as subscriber facilities for the transmission of broadband and integrated systems.

1.4 The invention of the transistor in 1947 led to the expanded use of modern electronic systems in subscriber loop plant. However, the integrated circuit (IC) has made large scale cost effective use of electronic systems even more practical. Using IC's, a small pocket calculator can do the work of older computers requiring several rooms of electronic equipment. Microprocessor development continues to accelerate the development of subscriber loop systems in the form of digital central offices and remote switching terminals.

1.5 Pulse code modulation (PCM) principles were developed in 1937 by ITT in France. It was 1962 before the first commercial PCM trunk carrier was placed into service by the Bell System. Independent telephony manufacturers extended the use of PCM carrier into subscriber loop plant before 1970. PCM transmission techniques have now been extended into switching systems. Early Bell efforts were concentrated on digital toll switches, while the Independent manufacturers have concentrated on integrated Class 5 digital switches, remote switches and digital subscriber carrier. Advances in telephony often depend on ideas and technology breakthroughs from very diverse groups. In the end, the scientist and manufacturer must satisfy the basic economic and practical needs of telephone managers and craftspersons for widespread success of electronics in subscriber loop plant

2. OVERVIEW

2.1 There is a wide range of subscriber loop electronic systems used in rural telephony today. These systems have gained favor in loop plant as alternatives to providing coarse gauge cables, or a cable pair for each telephone subscriber. Growth in new technology is very dynamic. Newer systems utilizing the latest technology (sometimes experimental models constructed in the laboratory) lack the years of experience gained by older systems. Older systems have proven experience, but may lack the innovative features of new systems. The user must weigh new technology against experience in choosing electronic systems that may be in service for an extended period of time. Experience in closely related technologies might be a good substitute for direct experience so that the latest technology can be utilized without undue concern. REA encourages the use of new technology under field trial agreements.

2.2 This section will provide only a brief overview of subscriber loop electronic systems. It is separated into five categories. The first four address conventional telephony; the last addresses systems beyond conventional telephony.

2.2.1 <u>Fine Gauge VF</u>: This part discusses the use of electronic voice frequency transmission and signaling systems as applied to fine gauge cables.

2.2.2 <u>Pair Gain</u>: Pair gain systems include subscriber carrier, concentrators, or combination carrier-concentrator systems. A pair gain system contains both central office and subscriber channels and lines. Pair gain systems are <u>independent</u> from the central office switching equipment.

2.2.3 <u>Distributed Switching</u>: Distributed switching describes the integrated systems of central office switching and subscriber loop pair gain. In concept, portions of the central office are distributed into the loop plant in the form of remote switches, etc. Most of this development is digital; but integrated analog techniques (voice frequency interface) are being developed also. Digital subscriber carrier and concentrators might be defined as distributed switching if a direct digital interface to the host digital COE is provided.

2.2.4 Alternatives: This part describes alternatives to paired telephone cables as a transmission facility for narrowband services. The discussion includes radio (including satellites) coaxial cables and optical fibers.

2.2.5 Broadband: This part describes broadband systems and the combination of broadband and narrowband (conventional telephony) systems.

2.3 The conventional telephony systems and services discussed are plain old telephone service (POTS). Special services such as foreign exchange, data and telemetry are not discussed. These services generally require limited bandwidth and can be applied over standard telephone voice circuits. In fact, many data and telemetry systems require only a fraction of a voice channel.

2.4 References: This is an overview section, and only covers subscriber loop electronic systems in a limited manner. The following TE&CM references are noted for a more in-depth review of guidelines on system design, equipment and application.

TE&CM Sections

200 Series on system design information; especially 230, 231 and 232 on serving area value engineering (SAVE).

300 Series on central office equipment, subscriber line concentrators and loop extenders.

400 Series on voice frequency subscriber loop design, voice frequency repeaters and transmission information; Section 470 covers switched special services and private branch exchange services.

900 Series on subscriber carrier systems, digital transmission systems, and radio systems.

2000 Series on broadband systems.

3. FINE GAUGE VOICE FREQUENCY

3.1 In the mid 1960's telephone systems moved toward the use of finer gauge cables. Rural systems began using techniques to increase the loop signaling range and boost the voice signals. Several techniques were developed in the laboratories and a small variety found application in rural telephone systems. At this time, there is wide use of loop extenders (to boost the battery supply voltage and extend the pulsing range) and voice frequency repeaters (to amplify the voice). These have become economical and practical fine gauge systems. Loop extenders and voice repeaters are supplied as separate units or as integrated units.

3.2 As illustrated in Figure 1A, loop extenders and voice frequency repeaters are often placed between the central office switching equipment (outboard) and the main distribution frame (MDF) on a per line basis. With step type switching, loop extenders and repeaters have been integrated into the COE linefinder and connector circuits on a grouped basis, called "common mode" of operation. Only about 20 percent as many loop entenders and repeaters are required on this shared basis compared to a per line basis. To date, common mode has not been practical for common control COE, including digital equipment.

3.3 Loop extenders and repeaters can be used outboard of the COE with physical circuit concentrators. In a concentrator application, it is probable that loop extenders and repeaters can be applied on a trunk (concentrated) basis.

3.4 Loop extenders and repeaters are sometimes used at locations distant from the basic COE. As illustrated in Figures 1B and 1C, loop extenders and repeaters may be used outboard of digital remote switching terminals or subscriber carrier. Application to subscriber carrier has generally been limited to higher density grouped systems such as a PCM subscriber carrier where 50 volt battery is used as the basic battery feed voltage and is available to power the loop extenders and repeaters.

3.5 A loop extender is basically a voltage boosting circuit. It is generally a floating (isolated) 50 volt dc power supply placed in series with the normal battery supply providing 100 volts total for dial and talk battery.

3.6 Automatic gain control (AGC) repeaters are slightly more costly than fixed gain repeaters. AGC repeaters are preferred by some telcos, and are often considered more economical when administrative and operational costs are included.

3.7 Advantages: Low initial costs, low annual maintenance, and less skilled craftspersons required are the key advantages of loop extenders and repeaters over other types of electronics. Loop extenders and repeaters can be economically installed in small or large quantities. It is often advantageous to install good basic cable facilities in reasonable quantities initially, and to grow with pair gain electronics later. In planning for this conversion to pair gain later, cable gauge economics should consider both the initial voice frequency application and later possible carrier application.

3.8 Disadvantages: From a practical standpoint, fine gauge voice frequency design is distance limited. Some limiting factors are potential noise problems and high individual pair cost for each subscriber at long distances. Field mounted repeaters might be considered in small quantities; when large quantities are required, consider the economics, maintenance and transmission performance of alternate methods. An additional secondary consideration is that use of fine gauge small cables could result in higher maintenance costs in areas with high lightning exposure and high ground resistance.

4. PAIR GAIN

4.1 Pair gain systems utilize a conventional telephone cable pair to provide more than one subscriber circuit. Pair gain systems contain central office and subscriber channels and lines; and are independent (outboard) of the central office switching equipment. Central office interface considerations are usually minimal. Pair gain systems include subscriber carrier, concentrators, or combination carrier-concentrator systems.

4.1.1 The most widely used pair gain equipment in use today is station carrier. PCM subscriber carrier is fast gaining acceptance also. Concentrators and carrier-concentrator combinations are beginning to gain in use, and show promise of much increased use in the future. Station carrier is designed to eliminate the need for installation and maintenance adjustments for voice frequency loss, signaling, carrier levels and equalization. Except for a minor adjustment for voice frequency loss at installation, PCM subscriber carrier is also designed to eliminate installation and maintenance adjustments.

4.2 Station carrier is available in single channel and multichannel systems and arranged in distributed (individual channels) and grouped housings. The distributed multichannel station carrier is in predominant use by REA borrowers in rural areas. This type makes maximum use of existing cable facilities, including small distribution cables. Distributed one channel station carrier is also in frequent use by rural telcos, but in smaller quantities. Grouped applications of single and multichannel station carrier are becoming more popular. Where distribution facilities are available from a common field location (i.e., SAVE designs), grouped application is more economical to install and maintain. One channel systems provide one party ringing and multichannel systems provide one party and multiparty ringing. Station carrier repeaters and subscriber terminals are generally powered over the carrier system cable pairs. This limits the power available at the subscriber terminal, and generally imposes strict limits on the maximum number of ringers served by a channel. Figure 2 illustrates the application of station carrier.

4.2.1 <u>One Channel Station Carrier</u> is an add-on or second line type of subscriber carrier. It is applied to a physical circuit to derive two circuits over one cable pair. Distributed one channel carrier is seldom planned into a telephone system; it is used primarily for cable relief as the need occurs. The central office end may be installed in quantities of one or several shelves at a time; but subscriber channels are usually installed on an as-need basis. One channel systems provide one party service using straight line ringers (not frequency selective). Subscriber channels are arranged for grouped or distributed housing applications. Grouped housings provide for about 20 to 50 channels with subscriber cable drops limited to about 200 ohms from that location. Distributed (one channel per housing) types are designed for inside and outside applications. The facility drop limits are generally about 25 ohms for inside mounted types and about 200 ohms for outside mounted types.

4.2.2 <u>Multichannel Station Carrier</u> systems provide for 6 to 13 channels over one cable pair. Multichannel types are arranged as grouped and distributed systems. Distributed station carrier has been widely used because it makes maximum utilization of existing cable plant. The subscriber terminals of a system are individually located near the subscriber served. This minimizes the need for distribution cable pairs to reduce or eliminate the need for feeder and distribution cable reinforcement. The current trend seems to be toward increased use of grouped systems. Grouped equipment costs are lower and maintenance is somewhat easier with all channels of a system at one location. One party and multiparty systems are available. Multiparty ringing systems generally serve up to four subscribers per channel using frequency selective ringers. Systems designed for one party ringing generally require the use of straight line ringers.

4.3 PCM Subscriber Carrier in general use are 24 channel systems over a T1 span line requiring two cable pairs for each system. PCM subscriber carrier is generally set at 2 dB loss, allowing 6 dB for the drop from the subscriber to the carrier subscriber terminal. For loaded cable, this equates to about 1300 ohms loop resistance. This can be extended by using loop extenders and voice frequency repeaters at the subscriber terminal, or by other methods of providing at least 20 mA dc and not more than 8 dB loss to the subscriber.

4.3.1 AC power is generally required at the subscriber terminal to achieve adequate service over the necessary design limits. Within limits, it is possible to distribute PCM channels along a route with one or few channels at each location, and to power the subscriber terminal over the carrier system pairs. For longer systems, economics and available power for conventional telephone sets are major obstacles. Reinsertion of power at strategic field locations can be a partial solution. Innovations in powering PCM subscriber carrier over the span line cable pairs are currently under consideration by carrier manufacturers.

4.3.2 Pole mounted or concrete pad mounted housings are available for one or two systems. Larger applications utilize larger housings, walk in huts or small buildings. The subscriber terminal housings may contain automatically controlled vents, small fans or heater strips to minimize the extreme range of the outside environment. There are economic trade-offs between environmental control of housings and equipment design to operate in a more harsh environment.

4.4 Subscriber Line Concentrators are used to reduce outside plant cable pair requirements. Concentrators are similar to grouped subscriber carrier in that feeder cable pair requirements are reduced, but distribution pair requirements from the subscriber terminal are not affected. Concentrators in current use range in size from 24 lines to 128 lines, or greater. The ratio of lines to trunks vary with equipment type, but is generally in the order of 4 to 1. Trunk access by subscriber lines may vary from as few as 4 trunks per line to full access of trunks. Concentrators may offer intra calling to further improve traffic handling. Two idle trunks may be required briefly to set up an intra call; also, one or two idle trunks may be required for operator verification. In considering intra call, review the cost and capability of each type of equipment to be considered. Depending on the concentrator equipment, trunks may be provided by physical cable pairs, PCM subscriber carrier or station carrier. Power to the concentrator subscriber terminal is sometimes provided over the physical cable trunks; but most systems utilize commercial AC power at the subscriber terminal. With some exceptions, subscriber loop limits are generally imposed by the central office for physical trunks, and by the carrier for carrier derived trunks.

4.5 Carrier-Concentrator Systems: The subscriber carrier and line concentrator are sometimes combined into an integrated system. Functionally, the combined systems are similar to separate carrier and concentrator systems. Integration can lead to reductions in cost, size and power requirements. Most integrated systems utilize PCM carrier; however, at least one integrated system uses analog station carrier.

4.6 Advantages: As a group, the major advantage of pair gain systems over fine gauge vf, distributed switching and alternative systems (as described in Paragraphs 6 and 7) is flexibility. The advantage over fine gauge vf is flexibility in growth with lower initial investment and less idle cable plant. The advantage over distributed switching is that pair gain systems are outboard of the COE and are flexible in that pair gain can be relocated from one COE type to another. Pair gain systems can generally be added in smaller cost increments than distributed switching or alternative systems. As a general rule, pair gain systems are less costly and less complex than distributed switching and alternative systems at this time. However, overall system costs are in a dynamic state; and each application should be compared separately.

4.6.1 Station Carrier Advantages: Distributed station carrier is attractive where small cables would require reinforcement with additional small cables. Low subscriber density along a cable route also seems to be a key factor. Where the density is less than about three subscribers per mile, and where little or no cable reinforcement would be necessary, distributed station carrier has a good probability of being the economical solution. As the density increases, it becomes more attractive to use a grouped type of system (carrier or concentrator). Scattered pockets of growth beyond about four miles become good candidates for grouped station carrier where little or no cable reinforcement is required. Station carrier does not generally require commercial ac power for the subscriber terminal. Grouped station carrier can have advantages over higher density PCM carrier or concentrator systems by terminating the channels at frequent intervals to relieve feeder cable pairs for subscriber distribution. Low frequency analog station carrier is more "forgiving" of minor plant problems than higher frequency pulse systems such as PCM subscriber carrier.

4.6.2 PCM Subscriber Carrier Advantages: PCM subscriber carrier becomes attractive in higher density applications. Key factors are existing feeder cables of moderate size (preferably filled core), large clusters of subscribers several miles from the central office, and longer distribution cables. PCM subscriber carrier offers a large variety of services and special features. The basic design of PCM carrier lends itself to automatic system monitoring and transfer, reducing subscriber down time. Channel bandwidth, system impulse noise performance and PCM encoding give PCM systems better data handling capability. PCM subscriber carrier can provide some of the emerging digital services without being integrated into the digital switching system.

4.6.3 Subscriber Line Concentrator Advantages: Subscriber line concentrators are generally direct competitors for PCM subscriber carrier and distributed switching. Utilizing physical cable trunks, no special cable performance requirements are imposed on concentrators as compared to carrier. Also, some types of concentrators can provide power for the subscriber terminal over the physical trunk cable pairs. Concentrators applied with carrier trunks can be used in lieu of small central offices or remotes; and have the advantage of being outboard of the switching system. The same applies to integrated carrier-concentrator systems.

4.7 Disadvantages: As a group, the major disadvantage of pair gain systems is cost. Cable is generally more economical than pair gain systems. Pair gain systems add a degree of complexity; and require a slightly higher level craftsperson with some specialized training to maintain the systems. Pair gain requires added equipment which increases the overall failure rate. The subscriber trouble index for pair gain systems can be higher or lower than physical circuits depending on such things as system alarms and application.

5. DISTRIBUTED SWITCHING

5.1 Distributed switching is an emerging technology with great potential for providing a wide range of telecommunications services at reasonable costs. The functions of central office switching and subscriber loop pair gain can be integrated, contructed in hardware and software modules, and distributed at multiple service locations. The most notable example of distributed switching in service today are host and remote digital central office equipment. In concept, portions of the host central office are distributed into the loop plant in the form of remote switching terminals (RST). The RST can generally provide all of the services available at the host but the RST is usually dependent on the host for instructions.

5.1.1 Figure 3A is an illustration of a host Class 5 digital COE and several RST's. The host and RST's are directly connected on a digital basis, usually with T1 span lines. Local switching of subscribers is provided at each RST. However, each RST is usually a "slave" of the host COE. If the data link between the host and RST is cut, service cannot be provided at the RST. There is some work in progress to enhance the slave RST. This is discussed in a later paragraph.

5.1.2 A typical RST is usually arranged in building blocks of 250 to 350 lines each. Each group of 250 to 350 lines generally requires two T1 span lines. This results in a line to trunk ratio of somewhere between 250 to 48 and 350 to 48. Calls between an RST and host COE, or between separate RST's are encoded once and decoded once. All signals between these units remain in a digital format. The host COE does not require line equipment for subscribers served by the RST. There are large potential savings in this switching area. In comparison to a carrier - concentrator, the savings in transmission equipment is small; while channel banks can be eliminated, direct digital interfaces (T1 span line buffers) to the COE partially offset these savings.

5.1.3 Digital COE manufacturers are considering several alternatives for serving small groups of subscribers on a direct digital interface basis. One method is to distribute a 250 to 350 line group of a COE at multiple RST locations. The RST's would share two span lines and each would terminate a portion of the 250 to 350 lines. An example of a distributed RST is shown in

Figure 3B. Another method is to utilize subscriber terminals of PCM subscriber carrier and interface the COE on a direct digital basis (omit channel bank at CO). One manufacturer also plans to interface PCM subscriber carrier into the RST as well as the COE. Figure 3C describes this arrangement.

5.2 While most of the current work in distributed switching utilizes digital switching and transmission techniques, analog techniques are also being explored. There is no standardization of signaling and control functions for subscriber loop electronics systems. Without standardization, digital subscriber systems of one manufacturer cannot be integrated into host digital central offices of another manufacturer.

5.3 Enhancement of slave RST's with such features as "stand alone" (even for plain old telephone service) adds to the complexity and costs. Such enhanced remotes may approach the cost of a Class 5 central office. Some work is also in progress to design very small Class 5 central offices in lieu of slave RST's. The small Class 5 may be able to share the same office number code with other Class 5 offices.

5.4 Some design work is also in progress to provide remote switches for step and crossbar (analog) central offices. These systems could extend the service life of existing central offices, and to some degree can be an alternative to the use of digital distributed switching systems. There are at least two justifications for considering analog distributed switching. They are (a) to extend the life of undepreciated central office equipment; and (b) because there is no standardization of digital subscriber systems.

5.5 Advantages: Since distributed switching is an emerging technology, advantages and disadvantages are in reality potential advantages and disadvantages. The potential advantages are many. The major advantage is economics. Distributed switching has the potential for large telephone system savings. By using distributed switching, there can be savings in COE, transmission and outside plant. As these systems further emerge, and as the demand for telecommunications grows, techniques such as distributed switching offer addition savings potential (i.e., data or other services). Digital distributed switching offers transmission advantages also. The voice frequency can be encoded at or near the subscribers' locations and be almost immune to transmission degradation.

5.6 Disadvantages: The major disadvantage is also economics. Present digital distributed switching systems require a major new investment. As with any emerging technology, it is difficult to estimate the service life of hardware and especially software. Lack of standardization may reduce the service life of digital hardware and software, especially early systems.

6. ALTERNATIVES

6.1 This refers to transmission facilities which can be used as alternatives to paired telephone cables to provide narrowband subscriber service. Alternatives include radio, coaxial cables and optical fibers. Some of these alternatives are in wide use for trunk service, but have been in limited use for subscriber service. The reason is economics; these alternatives are generally economical only in large circuit quantities in point-to-point applications. However, new technology could improve the economic outlook for alternatives in subscriber loop plant.

6.1.1 Subscriber loop alternative facilities include low and high density radio (including satellites), coaxial cables and optical fibers. Due to the limited use in subscriber telephone service, coaxial cables and optical fibers are considered emerging technology. Radio is sometimes used in subscriber telephone service, but economics often limits the use of radio to cover special circumstances.

6.2 Radio: Various types and applications of radio have been used in subscriber service when conventional telephone facilities were not practical. The radio may contain integrated carrier channels or concentrators, or may be the base facility for application of other transmission or switching systems. Subscriber radio links may serve only one, or very few subscribers in isolated areas. Microwave radio is sometimes used to serve larger clusters of subscribers as economics and other circumstances warrant. The use of digital transmission and switching systems may improve the economics of radio in subscriber service. In some areas such as Alaska, radio (terrestrial or satellite) may be the only practical method of serving isolated clusters of subscribers.

6.2.1 Perhaps the most promising economical use of radio for rural subscriber applications is for a medium density (96 or more channels) digital link between two locations. For the purpose of this discussion, a digital radio can be considered (a) a digital radio where DS1 signals (i.e., T1 span lines) are directly applied to the radio baseband; or (b) where DS1 signals are multiplexed and applied in a suitable form to an analog radio. As illustrated in Figure 4A, the subscriber channels can be terminated at one or more locations by extension over standard T1 span lines or other digital transmission links. Digital radio can be used to provide a transmission link in lieu of paired cables; can be used to provide additional capacity along an established subscriber route; or can be used as an alternate path between a digital host central office and an RST.

6.2.2 Figure 4B illustrates the use of a radio concentrator to serve more isolated subscribers. Up to eight radio channels can be used to serve as many as 30 or more subscribers by sharing the radio channels. Figure 4C illustrates the use of a mobile telephone system to primarily serve mobile (vehicle) subscribers. Paging service can be added to this system to generate additional revenue. If the circumstances warrant, an occasional fixed subscriber can be added to the mobile telephone system.

6.3 Coaxial Cable: Coaxial cable has been in very limited use in subscriber telephone (narrowband) service. Coaxial cable is an excellent transmission medium for both analog and digital systems. However, coaxial cable systems are generally economical for narrowband services only where high circuit capacity is required. Coaxial cables show more promise as a broadband subscriber service facility.

6.4 Optical Fibers: The emerging technology of optical fiber systems is growing at a rapid rate. Optical fibers provide an excellent transmission medium for digital systems. Where high telephone circuit capacity is required, optical fiber systems are currently cost competitive (i.e., high density trunk applications). The economics of fiber systems is expected to continue to improve for several years. Analog transmission over optical fibers is not economically practical at this time. Except for special applications and experimental systems, optical fibers are expected to be used primarily for digital transmission in high density trunk applications for the next several years.

6.5 Advantages: Alternative facilities are generally high quality and reliable systems. They can be used in applications where other techniques are not practical. Alternative facilities can be an interim step toward broadband services. Sometimes, there is no difference between alternative narrowband facilities and broadband facilities. The difference may only be application and services. However, some facilities may be economical for one service (narrowband or broadband), but not for the other.

6.6 Disadvantages: At this time, alternative facilities are generally not economical for conventional subscriber telephone service. This could change with technology breakthroughs.

7. BROADBAND

7.1 While most telephone services can be transmitted over narrowband facilities and systems, wideband or broadband facilities and systems are required for services such as cable television (CATV). Broadband in rural areas is basically emerging technology. CATV systems have been in service for years, but have made very limited penetration in rural areas. REA pioneered and continues to pursue the concept of providing total telecommunications to rural areas using a broadband facility. Broadband services are now gaining attention in rural areas. This should help to focus attention on the design of broadband systems especially for rural areas. Improved technology and system costs should follow.

7.2 Broadband services and systems are under continual review at this time. The potential is great, but the cost is high. Existing hardware must be used initially and adapted for rural area distribution. Cost may necessarily limit the service area at this time. System cost reductions and expanded service areas can be achieved with volume use and experience.

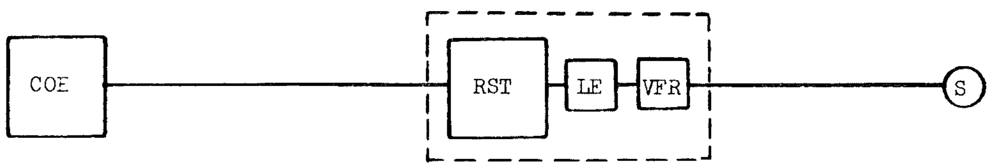
7.3 Broadband systems and applications should be considered for CATV alone, and CATV in combination with conventional telephone services, and a wide range of data, telemetry and other special services. One way and two way capabilities and economics should be reviewed. Planning is important. Economics may force a compromise on the initial system design; but it may be possible to engineer a basic initial system that can easily be expanded at moderate costs and minimum service interruptions. Refer to the 2000 Series of TE&CM for more information on broadband systems.

FIGURE 1
FINE GAUGE VF ELECTRONICS

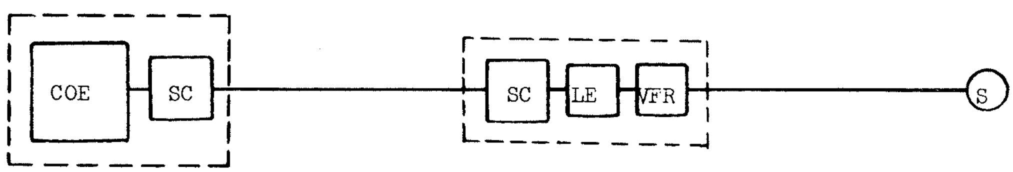
A. LE and VFR at COE Location

LE and VFR may be used outboard of COE on an individual line basis, with concentrators, or on a common mode basis within the COE.

B. LE and VFR at RST Location



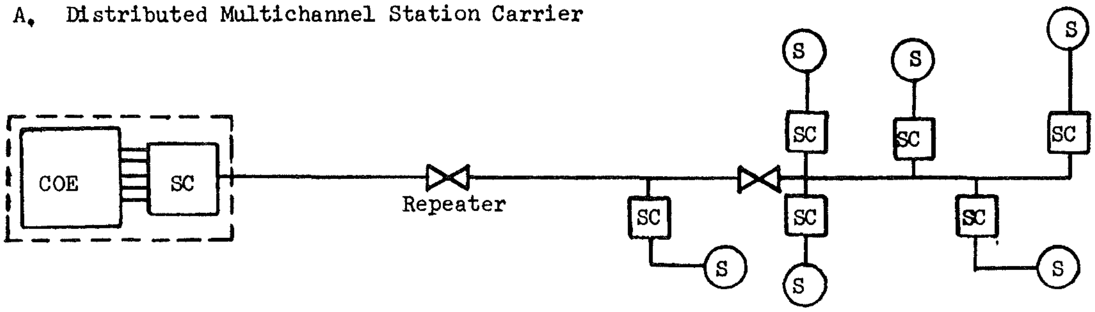
C. LE and VFR at SC Location



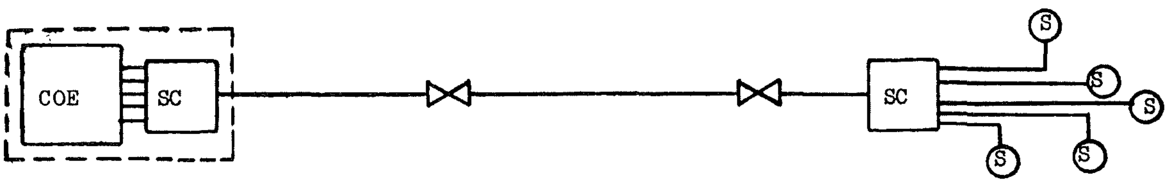
NOTES:
- LE = loop extender
- VFR = voice frequency repeater
- COE = central office equipment
- RST = remote switching unit
- SC = subscriber carrier
- S = subscriber

FIGURE 2
PAIR GAIN SYSTEMS

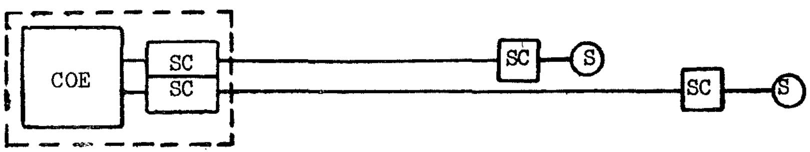
A. Distributed Multichannel Station Carrier



B. Grouped Multichannel Station Carrier



C. Distributed One Channel Station Carrier



D. Grouped One Channel Station Carrier

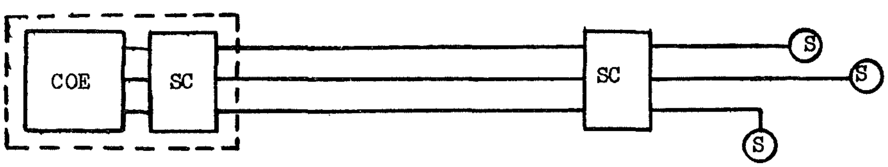


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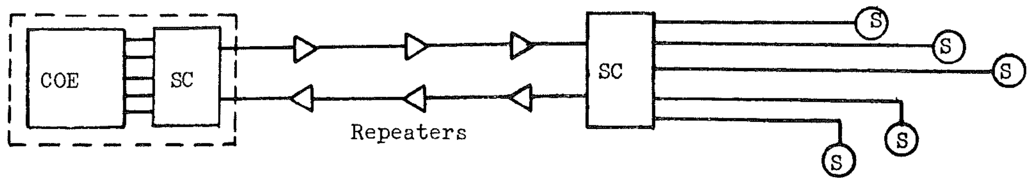
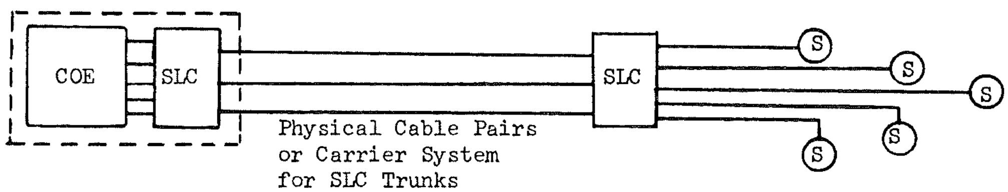
FIGURE 2
PAIR GAIN SYSTEMS - CONTINUED

E. PCM Subscriber Carrier



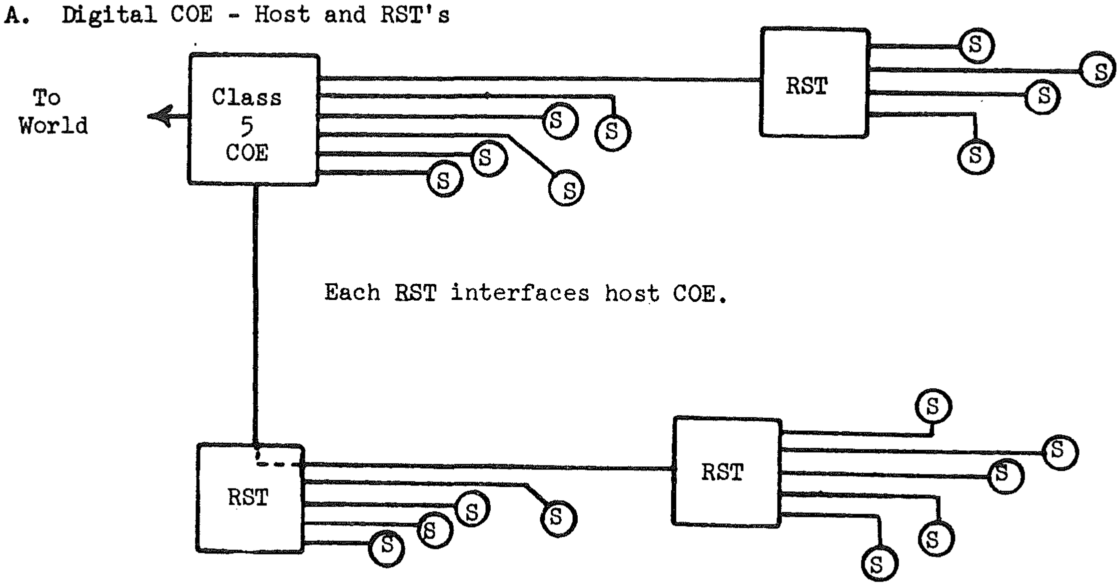
F. Subscriber Line Concentrators



NOTES: COE = central office equipment
SC = subscriber carrier
S = subscriber

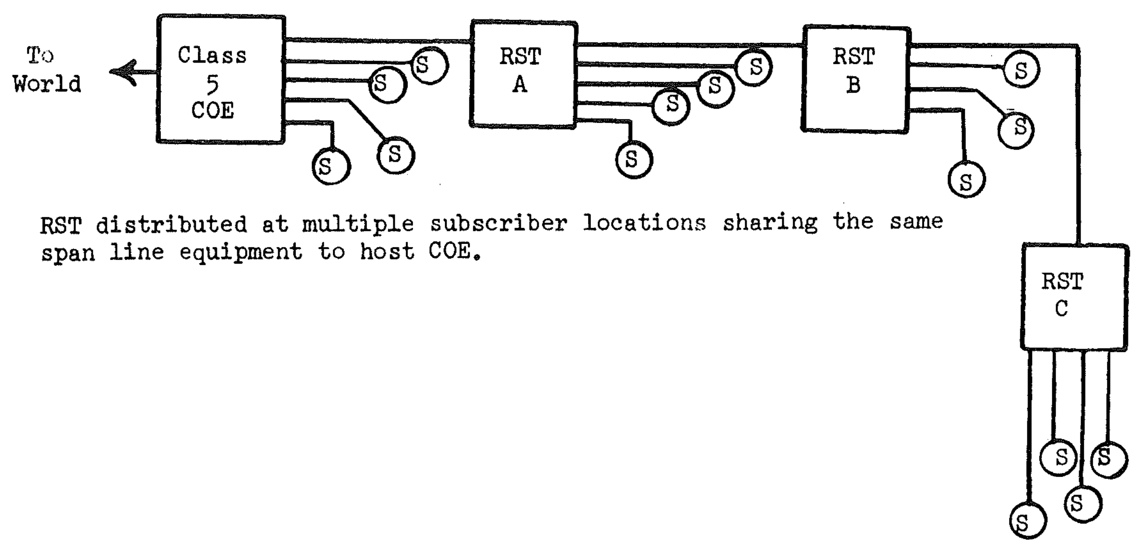
FIGURE 3
DISTRIBUTED SWITCHING

A. Digital COE - Host and RST's



Each RST interfaces host COE.

B. Digital COE - Host and Distributed RST



RST distributed at multiple subscriber locations sharing the same span line equipment to host COE.

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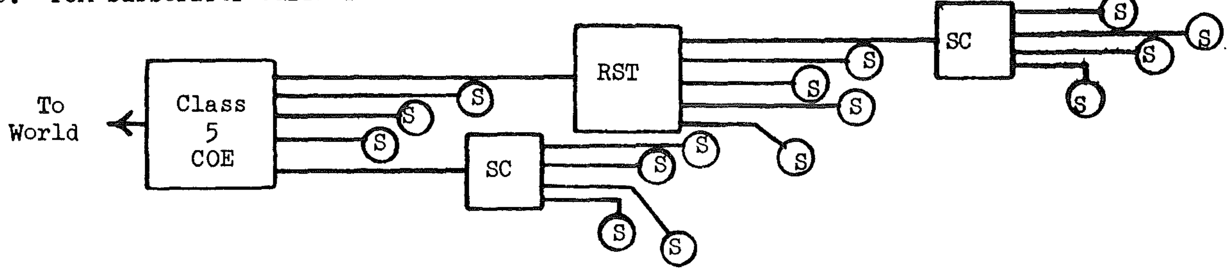
FIGURE 3
DISTRIBUTED SWITCHING - CONTINUED

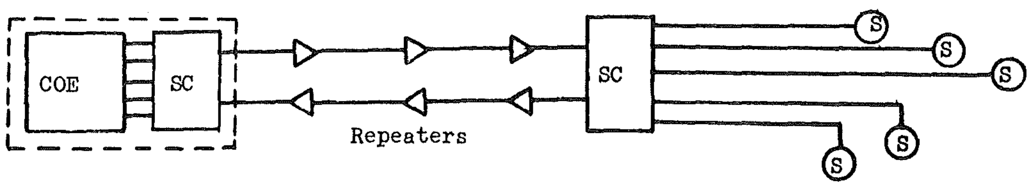
C. PCM Subscriber Carrier - Interface to COE and RST



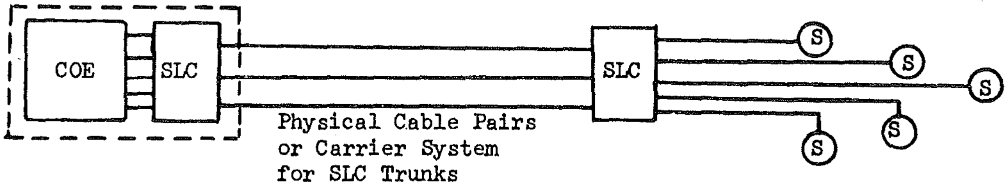
NOTES: COE = Class 5 digital central office equipment
RST = remote switching terminal
SC = subscriber carrier
S = subscriber

FIGURE 2
PAIR GAIN SYSTEMS - CONTINUED

E. PCM Subscriber Carrier



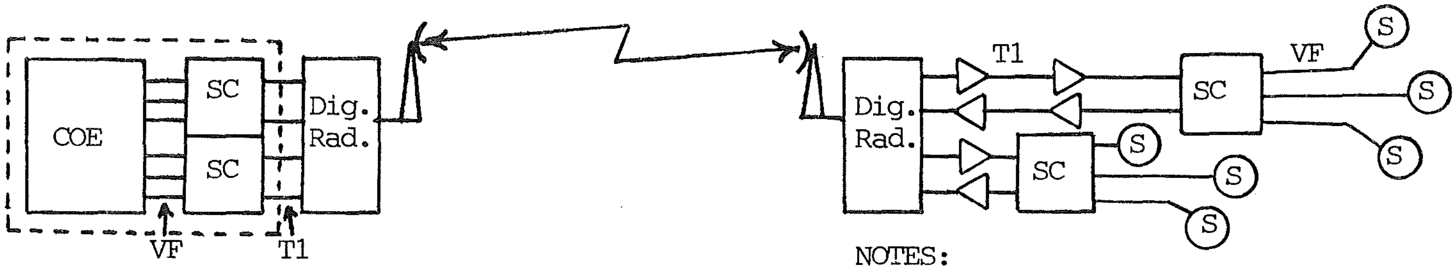
F. Subscriber Line Concentrators



NOTES: COE = central office equipment
SC = subscriber carrier
S = subscriber

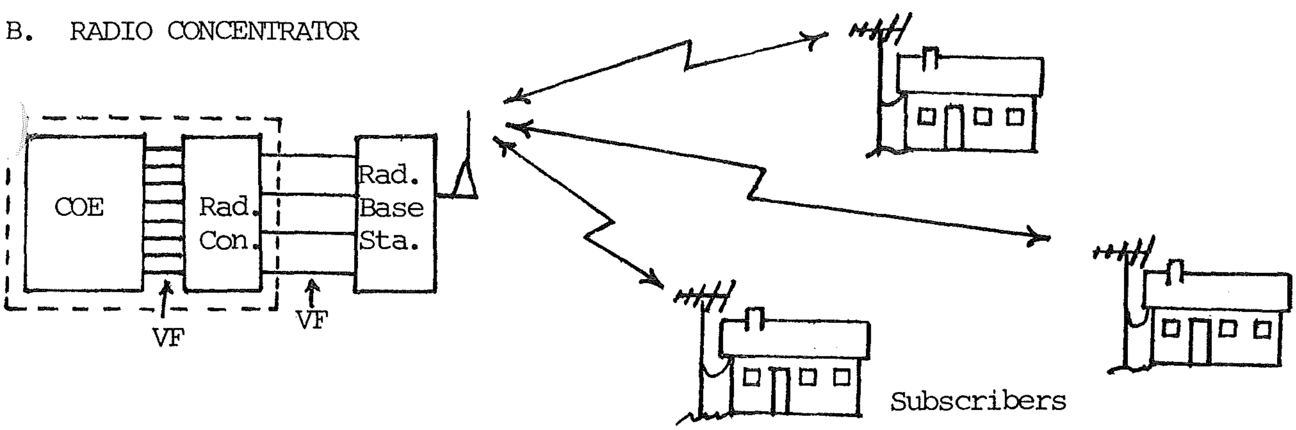
IGURE 4
ALTERNATIVES

A. DIGITAL RADIO AND PCM SUBSCRIBER CARRIER



NOTES:
COE = central office equipment
SC = subscriber carrier
S = subscriber

B. RADIO CONCENTRATOR



C. MOBILE TELEPHONE SYSTEM