TRANSMISSION DESIGN AND COSTS CONSIDERATIONS OF FEEDER-DISTRIBUTION CABLE ENGINEERING (SAVE)

CONTENTS

1. GENERAL

1.1 This section provides REA borrowers, consulting engineers and other interested parties with transmission considerations on the application of electronic equipment to REA's Serving Area Value Engineering (SAVE) Guidelines for the design of rural telephone plant. This is a companion section to REA's TE&CM 230, General Principles of Feeder-Distribution Cable Engineering, and TE&CM 231, Design Techniques of Feeder-Distribution Cable Engineering. Emphasis is placed on the use of pair gain devices such as distributed and grouped station carrier, PCM carrier, remote switching terminals or switches, and electronic concentrators. Subscriber line radio and voice frequency repeaters (VFR) with automatic gain control (AGC) are also discussed. Many simplified application rules are used for the economic comparisons in this section. Where the results of applying these rules exceed the manufacturers' published application limits, those published limits must be followed when equipment is placed into service.

1.2 Multichannel station carrier provides up to 13 channels over a single nonloaded cable pair. It is available with either individual channel housings (distributed) or grouped channel housing. Station carrier should be considered as a means to provide feeder circuits without physical reinforcement of existing plant, especially on small size facilities. It should also be considered for use on new plant in area of very low subscriber density.

1.3 PCM subscriber carrier provides 24 subscriber circuits over a PCM span line which consists of two nonloaded cable pairs for transmission and two or more pairs for fault interrogation and order wire. Its application should be limited to new cable plant and existing cable plant which meets current REA cable specifications. This equipment can provide a large number of feeder circuits to a serving area interface (SAI).

1.4 Systems which employ switching at a location remote from the central office can also be used to provide pair gain (feeders) to an SAI. These systems might be classified broadly as concentrators, integrated carrier-concentrators, or digital remote switching terminals (RST). A concentrator may use physical wire trunks or carrier derived trunks (usually digital carrier in 24 channel increments). A carrier-concentrator or a digital RST generally consists of a concentrator using digital switching techniques with an integrated DS1 digital span line interface for trunks (in 24 channel increments). The line to trunk ratio is generally in the range of 4 to 6 lines for each trunk. These systems are constructed in modules as small as 32 lines with complete systems in the range of 96 lines to more than 500 lines. Such systems can be used effectively in lieu of other pair gain systems, or in locations as a substitute for an existing central office or a planned new central office.

1.5 Microwave-radio facilities are analogous to physical feeder facilities. Instead of applying carrier to physical plant it is transmitted over radio. Of particular interest to the system design is that carrier over radio could be used for feeder circuits to a remote SAI. PCM carrier and PCM carrier-concentrators are the type of equipment most likely to be employed in conjunction with microwave radio.

1.6 Lightwave cable facilities are also analogous to physical feeder facilities. The PCM carrier is applied to the electro-optical terminal and transmitted as digitized lightwave pulses.

2. VOICE FREQUENCY EQUIPMENT

2.1 Design of physical subscriber circuits should follow the procedure and guidelines outlined in Telephone Engineering and Construction Manual (TE&CM) Sections 415 and 424. The maximum design loop loss is limited to 8 dB at 1000 Hz. Application of the Serving Area Value Engineering Guidelines will not affect the transmission design of physical circuits except in the following instances.

2.1.1 The subscriber end section of a D-66 loaded line may range from 0 to 2.7 km (0 to 9 kilofeet). The subscriber end section of an H-88 loaded line may range from 0 to 1.8 km (0 to 6 kilofeet). These subscriber end section limits are 0.9 km (3 kilofeet) shorter than those noted in TE&CM Section 424. This is done to simplify design rules based on full load sections between the SAI and the first loading coil beyond the SAI. In hardship cases involving party line service, the additional 0.9 km (3 kf) may be used for subscriber end section limits provided that any SAI end section in excess of half section is deducted. The shorter end sections are used to facilitate the transition to carrier feeders at an SAI at a later date. They offset the added loss when the near-end sections facing the carrier terminal at an SAI are between one-half to a full load section long. Traditionally, a loaded voice frequency extension from a carrier channel would have the first load coil at a point one-half section from the carrier allowing a longer loop. The longer loop is sacrificed in the SAVE design concept to enable placement of the SAI's at the most desirable physical location. No sacrifice is made for the case of the near-end section being less than 0.4 load section long. In this case the near-end section is built out to a one-half load section. See Exhibit I.

2.1.2 An SAI can be located at any physical point at or between two load points. No special near-end section considerations are necessary except in situations where voice frequency gain may be required due to loop length beyond the SAI. Such conditions will usually be encountered when concentrators are used with carrier derived trunks and the voice extensions require voice frequency repeaters.

2.1.2.1 When the loaded cable near-end section of distribution pairs is between 0.4 and full load section, no special treatment is required 0.5 to 1.35 km for D66 (1.8 to 4.5 kf) and 0.7 to 1.8 km for H88 (2.4 to 6.0 kf). Line build-out network of the voice frequency repeater should be set for best return loss performance. If the end section is 0.8 to 1.0 full section, the return loss is slightly degraded but the performance is still acceptable.

2.1.2.2 Loaded cable near-end sections of distribution pairs shorter than 0.4 load section should be built out to one-half of a full load section by installing a capacitor of correct value at the location of the first loading coil beyond the SAI.

2.1.3 Where subscribers are at long distances from the central office, the design will generally provide for the use of carrier. The use of field mounted voice frequency repeaters is discouraged because long subscriber loops are subjected to noise induction from power lines. They should only be used where there would be an insufficient number of subscribers to warrant the economic introduction of subscriber carrier and noise is within limits.

2.1.4 Under this design strategy, it will be necessary to calculate the loss of a length of loaded line where the near-end section is not the ideal half-load section. The near-end section may be considered a half-load section when the physical length is shorter than the half section because the capacitor build-out provides the proper half-section performance. When the physical near-end section is longer than a half-load section, that length exceeding a half section in both the near and far-end section have losses equal to the same length of the nonloaded cable. This loss is added to the normal loaded loss of the remaining cable to arrive at the total loop loss. As an example, if a 24 gauge D-66 loop originating out from a PCM terminal begins with a full section, has three load coils and a far-end section of 4.5 kilofeet, the equivalent length of nonloaded cable is (4500 - 2250) + (4500 - 2250) = 4500 feet. This length of nonloaded cable has a loss of 2.0 dB. The loss of the remaining 13.5 kilofeet of loaded cable is 3.1 dB for a total loss of 5.1 dB.

2.2 The use of 24-gauge cable as the primary gauge is recommended for most applications as a means of reducing costs.

3. STATION CARRIER

3.1 Distributed Station Carrier

3.1.1 Field of Use: The use of distributed station carrier serves a unique purpose in this design concept. Its use often allows deferring reinforcement of small pair size cables and thus extends the life of existing plant. Low subscriber density and slow growth are factors that often make distributed station carrier the most economical method of reinforcement. It should also be used on long low density cable routes to eliminate the need for field mounted VFR's, reduce noise and the number of feeder cable pairs required. Presently, up to 13 one-party subscribers can be served on one cable pair using station carrier. However, most systems serve eight subscribers on one cable pair.

3.1.2 Multichannel distributed station carrier should be considered as an economical alternative to adding cable pairs. The carrier subscriber terminal is located near the subscriber it serves, eliminating the need for long distribution pairs. Distributed station carrier can be used with physical loops and PCM carrier in the same cable to arrive at the most economical and practical means of providing service and increasing the cable utilization.

3.2 Grouped Station Carrier

Grouped station carrier consists of the same electronic equipment as the distributed type except that the field mounted subscriber terminals are packaged in groups of complete systems. This results in substantial initial savings over the distributed type because of the elimination of the need for individual housings and power supplies. Grouped station carrier can be applied at SAI's to provide feeder pairs to a serving area. At the SAI, the carrier is cross-connected to distribution pairs. Grouped station carrier is well suited for the SAVE system design.

3.2.2 At this time, all station carrier manufacturers can now provide the grouped packaging. The voice frequency drop limits of the available equipment range from 450 ohms for distributed types to 1000 ohms for grouped types. This is the total resistance including the telephone set. These limits must be observed on the distribution pairs from the SAI. The variation in drop limits among the various manufacturers' equipment must be considered in selecting the proper equipment. Refer to Exhibit I.

3.3 Station Carrier Application

3.3.1 Repeatered Line: The station carrier repeatered line should be engineered as prescribed in TE&CM 911:

a. Establish the repeater points very near the computed 35 dB point (at 112 kHz). If the computed loss at an SAI or PCM repeater location is between 32 and 36 dB, that location should be chosen for the station carrier repeater.

b. If the loop resistance of the carrier line exceeds the system limitations (usually about 2600-3000 ohms), insert power at a convenient field location within the powering limitation. For economic reasons, choose a field location common to most or all systems requiring field power whenever possible.

c. Existing cables of 22 and 19-gauge should be considered for station carrier because of their low attenuation and resistance characteristics. These characteristics allow a greater distance between repeaters. A test of the electrical characteristics of existing 22 and 19-gauge cables must be made to insure that they meet station carrier requirements. This requires field measurements.

3.3.2 Subscriber Terminals: The subscriber terminals are designed so that one or more terminals may be placed individually or in groups within 35 dB of a repeater along the route (or the central office terminal). For distributed station carrier, the subscriber terminals can be placed inside the SAI or cable housings. This may require replacing small cable housings with larger housings. The subscriber terminal should be placed along the main cable route in the housing nearest the subscriber to be served. It may also be placed anywhere along the repeatered line within the limits stated for the voice drop. For grouped station carrier, the equipment should be housed in the cabinets furnished by the supplier for one or two groups. Larger type cabinets can also be procured from the supplier for large installations, 50-100 channels. This cabinet can be pad or pole mounted next to an SAI housing to which it is interconnected by means of a cable stub.

3.4 Options: The single-party ringing station carrier is generally the most economical. Many manufacturers also provide multiparty type ringing. Other options available can also provide for key systems, PABX's and pay station applications.

3.5 One Channel Carrier: The one channel add-on type of station carrier is a special use carrier. It is used within 5.5 km (18 kilofeet) of the office, the limit for nonloaded loops. The subscriber terminals may be mounted indoors to double the number of circuits in a small area. Another application of this carrier is to utilize groups to 10 or more units at an SAI to double the effective number of feeders. The distribution would be handled over normal distribution cables, not to exceed 250 ohms from the interface.

4. PCM SUBSCRIBER CARRIER

4.1 PCM subscriber carrier systems provide 24 subscriber circuits using digital techniques. While the transmissions of PCM carrier is done over two pairs of wire, more pairs are usually required for backup and diagnostic purposes. The subscriber terminal is placed at an SAI where cross-connection is made to distribution pairs. The feeder circuits back to the central office are via a T1 repeatered span line. The characteristics of this equipment are covered in TE&CM 950.

4.2 Screened filled 24-gauge cable designed for PCM carrier allows maximum usage for span line operation. If many systems of PCM prove economical, either initially or in the future, this type cable should be specified. Screened cable and its application to PCM carrier is covered in TE&CM 950.

4.3 PCM Carrier Application

4.3.1 Subscriber terminals are installed at SAI points.

4.3.2 The voice drop capabilities of PCM carrier are from 1200 to 1500 ohms. The 1000 Hz net loss through the PCM carrier equipment is about 2 dB. Therefore, the voice extension over distribution pairs is limited to 6 dB at 1000 Hz.

4.3.3 Loading is required for distribution pairs if the 1000 Hz loss is greater than 6 dB which equates to 4 km (13 kf) of 24 gauge cable. Since the subscriber terminal may be located at any point in relation to the load coil locations, the first load coil may be any distance away up to one full section instead of the usual half section. While there is a slight transmission degradation, this configuration will still provide satisfactory frequency response and impedance matching (return loss) provided that the end section requirements of paragraph 2.1.1 are met. Refer to Exhibit I.

4.3.4 The PCM span line is engineered as prescribed in TE&CM 950.

4.3.5 If SAI locations are established near proposed repeater points, repeaters may be placed at SAI's to reduce the number of housings required. While, in general, PCM repeaters should be spaced at 33.5 dB maximum intervals (23 dB for office end sections, these lengths may be shortened in cases where future intermediate systems are anticipated. This should be done in such a way as to minimize the number of repeater points in the ultimate system.

4.3.6 At the subscriber terminal 117 Vac commercial power is required with a battery standby.

4.3.7 A spare span line normally should be provided between the subscriber terminal and the central office.

4.3.8 It is recommended that PCM span lines be implemented on filled screened cable. A PCM carrier span line can be applied to buried air core cable only if the electrical properties are tested and will support PCM.

5. REMOTE SWITCHING TERMINALS AND CONCENTRATORS

5.1 Field of Use: Remote switching terminals and concentrators can be used to reduce feeder circuit requirements. This is done by providing switching equipment at the SAI. For each trunk (feeder), about four subscriber lines (distribution) can generally be served. Currently available concentrators provide 250 lines from 48 trunks, 96 or 128 lines from 24 trunks, or 24 lines from 6 trunks. Since installation of remote switching features reduces the call handling capabilities of the system, consideration must be given to the calling habits of the subscribers served by concentrators.

5.2 The remote switching terminals and concentrators available today vary widely in design.

a. The oldest type of concentrator design has both a central office and a subscriber terminal. Subscriber lines are concentrated into a number of trunk circuits. The trunks can be connected using either physical or carrier derived pairs. Concentrators using physical trunks are low in cost and are useful in serving subscriber clusters inside of the 'carrier breakeven point'. Since the terminals can be connected using carrier derived pairs, they can be applied to existing carrier installations to provide additional pair-gain. See Exhibit III.

b. A second general type of concentrator utilizes integrated PCM carrier trunks. The advantage of carrier derived trunks is that they become more economical as distances between terminals increase. In addition, transmission limits are easily met. See Exhibit IV.

c. Digital remote switching terminals (RST) are also a form of concentrator. These terminals are an integral part of a digital central office and are connected to the office directly by a PCM span line. The central office terminal hardware is reduced to span line terminals and interfaces to the digital switch. This eliminates not only the cost of the concentrator's central office line circuits, but also the host digital switch's line circuits. Since an RST is considered to be part of a central office, subscriber loop limits of up to 1900 ohms resistance and 8 dB of loss at 1000 Hz from the remote terminal are applicable.

5.3 Subscriber terminals of concentrator equipment can also be classified into three types, depending upon how the talking battery is provided to the subscriber. The three methods of providing talking battery are:

a. Directly from the central office battery supply.

b. From a subscriber carrier terminal.

c. From a local battery supply and talking bridge in the subscriber concentrator terminal.

5.4 Concentrator equipment is movable equipment.

5.5 <u>Concentrator Application</u>

5.5.1 <u>Subscriber and Remote Switching Terminals</u>: Subscriber concentrator terminals and remote switching terminals are generally located at the SAI. The trunk circuits (feeders) may be loaded cable pairs, individual carrier channels or DS1 groups (PCM span lines).

5.5.2 If the trunks are physical cable pairs and talking battery is provided from the central office, the maximum overall distance from the central office to the subscriber is determined by the limits of the central office and associated voice frequency repeater and loop extension equipment. For loaded physical trunks, the concentrator may be located at any point with respect to load coil locations unless intracalling is in use (see paragraph 5.5.4). If the combined distance to the subscriber load coil (including distance from load coil to SAI) is less than 2.7 km (9 kilofeet) for D-66 or 1.8 km (6 kilofeet) for H-88 loaded trunks, the distribution cables should be nonloaded. For longer distances loading should be continued on the distribution cables.

5.5.3 If the trunks are carrier derived and talking battery is provided from the carrier subscriber terminal, the maximum allowable distance from the concentrator terminal to the subscriber is determined by the resistance limit of the carrier subscriber terminal or the 8 dB at 1000 Hz limitation through the carrier and the voice drop. The transmission impairment incurred by placing the terminals at points other than the half load point is the same as for PCM subscriber carrier as discussed in paragraph 4.3.3.

5.5.4 Intracalling: Some concentrators include intracalling links to improve the concentrator's traffic capability. With intracall, a call between two subscribers served by the same concentrator does not tie up two trunks back to the central office. Instead a connection is made between the two subscribers within the concentrator itself. Talking battery is provided from a terminal battery supply and talking bridge at the subscriber concentrator terminal. The concentrator should be located halfway between load points if intracalls will be made between subscribers on loaded loops, otherwise, transmission will be degraded.

5.6 Special Applications: While, in general, the SAVE procedure allows location of interface points anywhere, there may be circumstances where the SAI should be located at the midpoint of a loading section.

5.6.1 If it is necessary to use voice frequency repeaters and loop extenders at a PCM carrier or concentrator terminal, the terminal should be located at the effective midpoint between the load coils. This can be done by locating the terminal at the physical midpoint between load coils or building out to a half load section with built-out capacitors. Otherwise, the voice frequency repeaters may be unstable in their operation.

5.6.2 If the PCM carrier or concentrator equipment is located in an area intended to become a new central office location, the proper location for the equipment is at midpoint to load coils. Likewise, if a small central office is replaced with PCM carrier or concentrator equipment, the equipment should be installed at (or near) the previous central office location. Refer to Exhibit II.

5.6.3 Where talking battery is provided from the subscriber terminal and the "intracall" feature is used, concentrators should be located halfway between load points as discussed above in paragraph 5.5.4.

6. RADIO

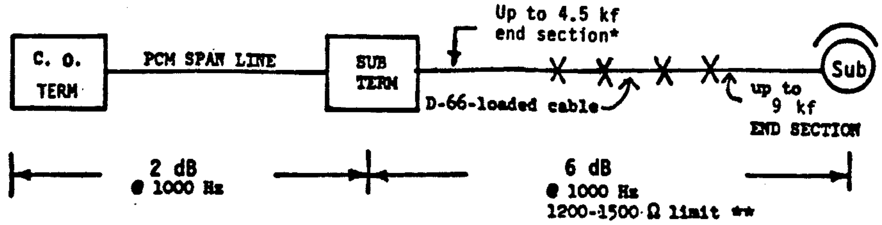
6.1 The basic telephone transmission facilities currently available for subscriber loops are paired wire and radio. Fiber optic cables are now being increasingly used for trunking applications but rarely for subscriber loop applications. In subscriber loop applications, wire is generally the only practical facility. In a few cases, however, radio is the better choice. As with wire, radio can provide a single voice circuit, but it can also provide many voice circuits with the application of multiplexing equipment. Service to a single subscriber or up to four multiparty subscribers maybe provided using a single channel version called a rural radio subscriber link. Service for 100 or more lines may be provided using wideband radio (microwave) with the application of multiplexed carrier. In both instances, ideally, the radio should be located at an SAI point along the major cable route. In reality, the radio terminal may be located off the main cable route (i.e., on a nearby hill) and a special SAI location at the radio terminal may be advantageous. Typically subscriber stations or other SAI's are connected to the radio SAI by cable pairs at distances of up to 1500 ohms (including telephone set). The carrier equipment applied to microwave is called multiplex equipment and may be of the digital or analog type.

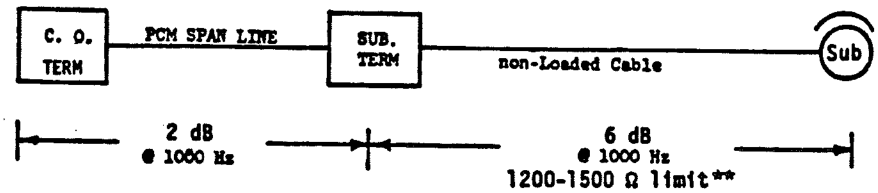
6.2 Radio should be used when the annual cost of the cable with span line repeaters is equal to or greater than the annual cost of radio. An example would be where the terrain or weather makes installation and maintenance costs of physical plant high. This could make radio feasible over relatively short distances.

6.3 Typical radio paths range from 16 to 64 km (10 to 40 miles in length with the average being about 40 km (25 miles). Frequency assignments, intervening terrain and precipitation are contributing factors that set the maximum length. (Precipitation is not a significant factor for operating frequencies below 11.0 GHz.) Line of sight transmission is required for microwave, but not for the single channel subscriber radio link. Antenna supporting structures (towers) will vary depending on path length and terrain elevations at the terminal sites and along the path. REA TE&CM 931, "Microwave Propagation and Path Surveys", covers design criteria.

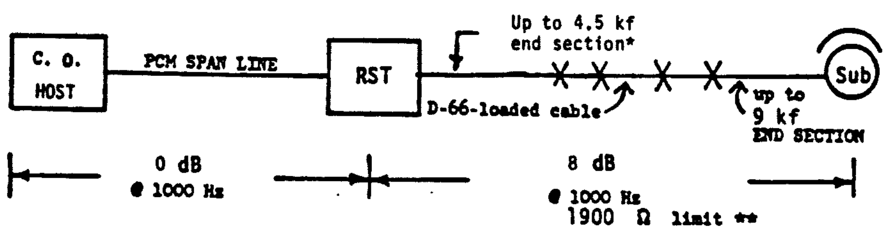
TRANSMISSION LIMITS

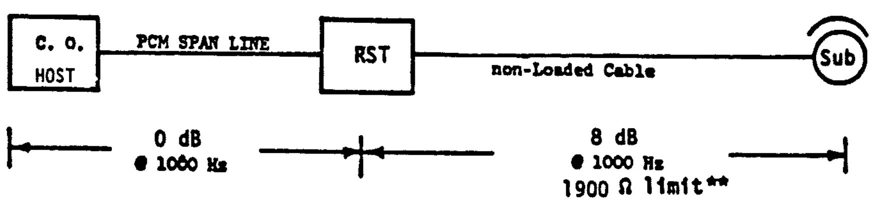
PCM SUBSCRIBER CARRIER/CONCENTRATOR





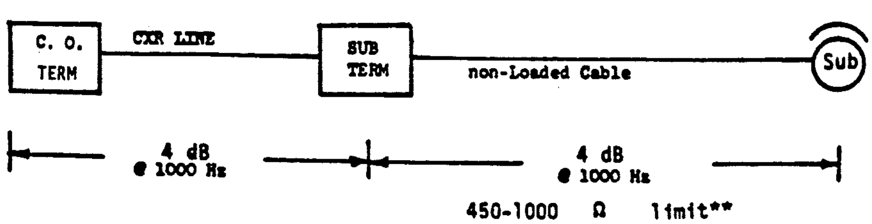
REMOTE SWITCHING TERMINAL





STATION CARRIER

GROUPED OR DISTRIBUTED TYPE

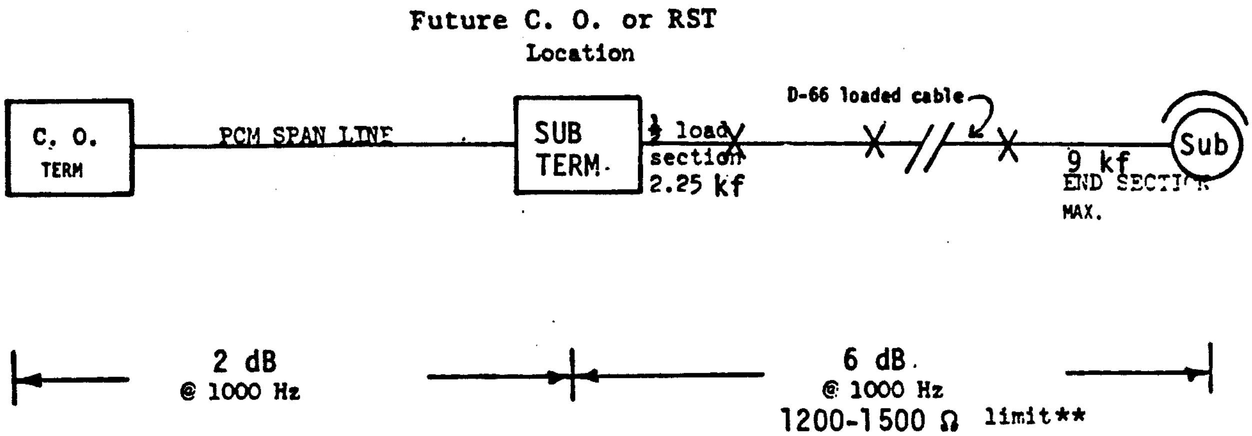


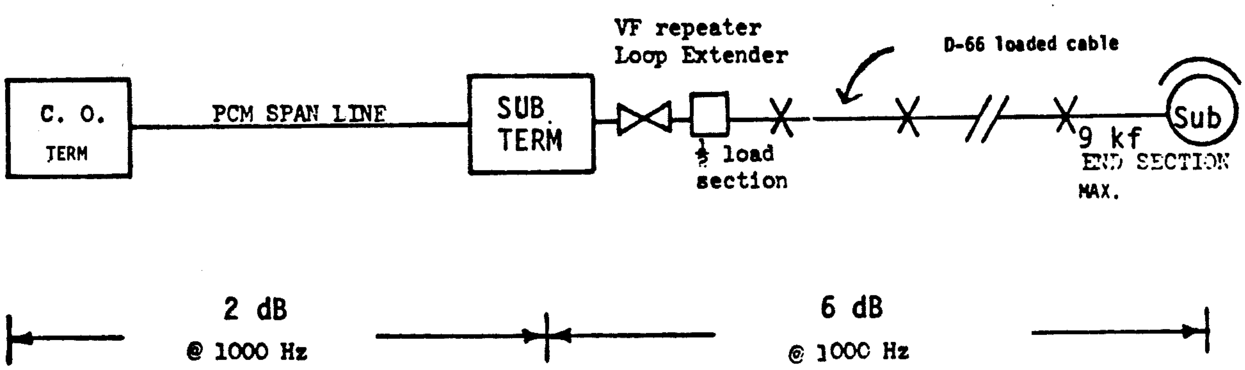
* IF LESS THAN 0.4 LOAD SECTION, BUILD OUT TO ½ LOAD SECTION.

** OHM LIMITS SPECIFIED INCLUDE TELEPHONE SET.

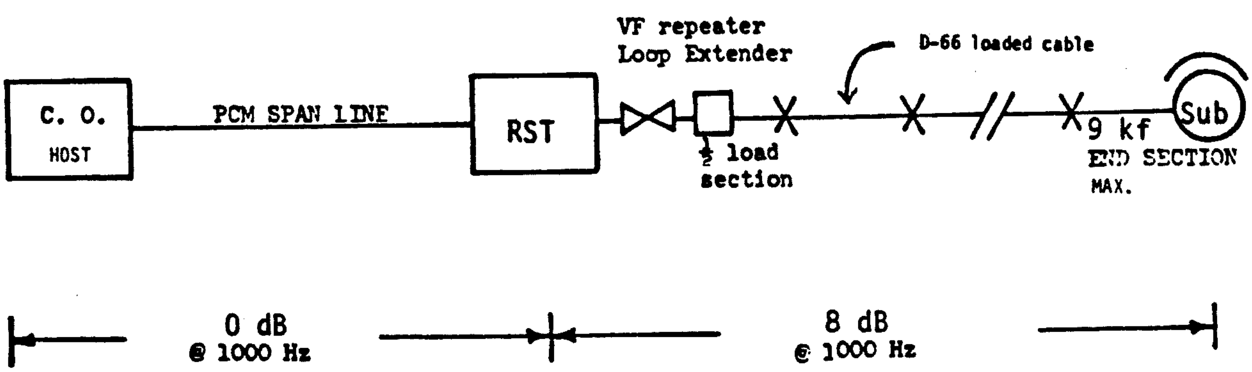
EXHIBIT I

TRANSMISSION LIMITS
SPECIAL APPLICATIONS
PCM SUBSCRIBER CARRIER/CONCENTRATOR





REMOTE SWITCHING TERMINAL



* WHERE A CENTRAL OFFICE OR REMOTE SWITCHING TERMINAL MAY BE ESTABLISHED OR IF VF REPEATERS ARE REQUIRED AT SUBSCRIBER TERMINAL, PLACE EQUIPMENT AT ½ LOAD POINT OR BUILD OUT TO ½ LOAD SECTION.

** OHM LIMITS SPECIFIED INCLUDE TELEPHONE SET.

EXHIBIT II

Subscriber Line Concentrator

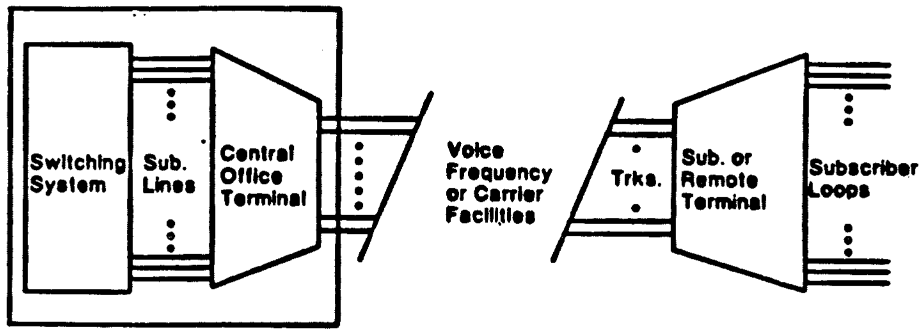


EXHIBIT III

Subscriber Line Concentrator With Integral Digital Carrier

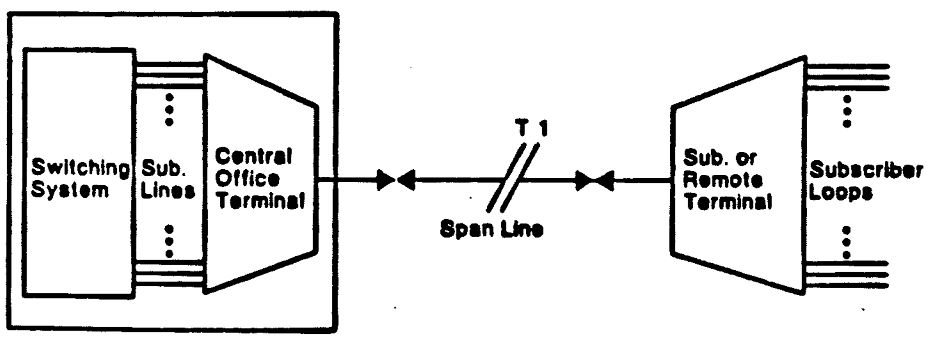


EXHIBIT IV

Digital Remote Switching Terminal

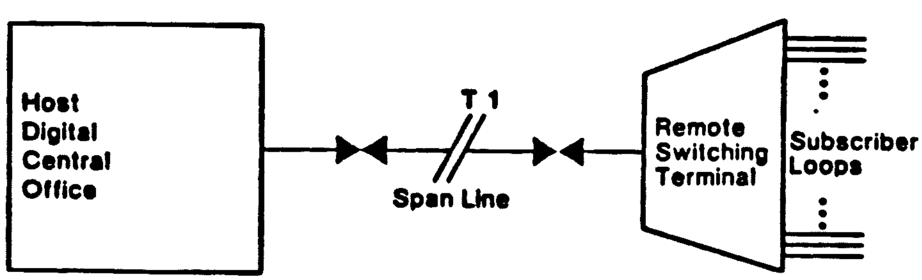


EXHIBIT V

APPENDIX

Examples Showing Development of Carrier Channel, Subscriber Concentrator Line and Remote Switching Terminal Line Costs

1. To compare electronic equipment versus physical cable costs and determine the economical alternative design, some form of cost averaging must be developed. This appendix serves as an example of how to separate these costs into a useful form that can be periodically updated. It must be emphasized that these costs serve only as an example of a portion of the equipment available today. Current costs should be determined and updated periodically.

   a. From this exercise the following conclusions can be made concerning the effect that subscriber density and the number of systems along a route has on per circuit cost:

      1) Distributed station carrier costs are rather uniform (for a given type). Since there is very little shared equipment, the per circuit costs are almost unaffected.

      2) Grouped station carrier costs are only moderately affected because there is some shared equipment such as subscriber housings.

      3) PCM subscriber carrier, subscriber line concentrators, and RST's costs are greatly affected since there is considerable shared equipment.

   b. All per channel and line costs are affected by system length. This is reflected in the per channel share of repeater costs.

1.1 In the development of these costs, the following assumptions are made. The carrier facilities are to be used on existing 24-gauge filled cable. Each system is fully equipped with channels. Spare parts are calculated at 5 percent of basic electronic equipment costs. The central office terminal installation costs include hardware, wiring, and labor. To establish ac power at a location, a charge of $225 is used. A more specific breakdown of the assignment of costs is shown in the following paragraphs.

1.2 Because of significant differences between carrier applications and physical applications, a comparison between physical and carrier plan is best done by comparing 80 to 90 percent filled physical circuits with 100 percent filled carrier channels for applications involving reinforcement to existing cable plant. For designs involving new cable plant and certain other situations discussed in TE&CM Section 231 comparisons should be made using the incremental cost per new cable pair and 100 percent filled carrier channels (or RST lines). It is pointed out that in Phase I, the number of circuits required is determined using fill factors corresponding to low, medium, or high growth expectations, whether physical or carrier derived feeders are involved. In Phase II, the correct number of carrier pairs are specified to provide carrier systems to meet the circuit requirements. During application engineering of carrier systems, fill the systems as close to 100 percent capacity as possible. Carrier pairs are available for adding more carrier systems if needed. The costs derived here are based on full carrier systems.

1.3 Cost Comparisons

1.3.1 Table A-1 shows the typical installed per channel cost of full subscriber carrier systems where there are one to four systems on a route. The most significant savings is because of the shared repeater housing. Also note that the per channel cost of remote power for station carrier is reduced significantly if the remote power unit can be shared with several systems.

1.3.2 If carrier is applied to existing facilities, telephone ringer changeout (estimated at $13 per channel) and loading coil removal (estimated at $3 to $8 per channel would be added to the per channel costs. One-party carrier channels usually require straight-line ringers.

1.3.3 Table A-2 shows the typical installed per line cost for concentrator and RST systems. Costs for 64 and 128-line concentrators are provided since these are typical configurations. Costs for 32-line systems are provided as a basis for analyzing the use of line concentrators and RST's on low density routes. Costs for 256-line RST's are provided since this is a typical size for RST's. In the case of the step-by-step RST, the equipment is typically limited to groups of 96 lines.

1.4 Description of Electronic Equipment Costs

1.4.1 Distributed Station Carrier

a. Channel costs include:
   Common = CO shelf, common equipment and termination unit
   Channels = CO channel cards and subscriber channels

b. Subscriber installation includes labor and some costs for pedestal housing changeout.

c. Repeater installation includes labor and either a shared housing cost or some pedestal changeout costs.

d. If the system length exceeds 3000 ohms, remote power, installation, and ac power costs are included.

1.4.2 Grouped Subscriber Carrier

a. Channel costs include:
   Common = CO shelf, CO common equipment, subscriber common equipment, and subscriber housing.

   Channels = CO and subscriber channel cards

b. Subscriber installation is primarily labor to install the housing.

c. Repeater installation cost includes labor and either a shared housing cost or some pedestal changeout costs.

d. If the system length exceeds 3000 ohms, remote power, installation and ac power costs are included.

1.4.3 PCM Subscriber Carrier

a. Channel costs include:
- Common = CO common equipment, subscriber common equipment, office and subscriber repeaters, subscriber batteries, ringing and power equipment, and subscriber housing.
- Lines = CO and subscriber line cards, and CO and subscriber line switching equipment (matrix) that is determined by the number of lines.
- Trunks = CO and subscriber trunk cards, and CO and subscriber switching equipment that is sized based upon the number of trunks.

b. Subscriber installation costs include labor for the housing and the cost to establish ac power.

1.4.4 Subscriber Line Concentrator

a. Line costs include:
- Common = CO common equipment, subscriber terminal common equipment, subscriber batteries, ringing and power equipment, and subscriber terminal housing.
- Lines = CO and subscriber line cards, and CO and subscriber line switching equipment (matrix) that is determined by the number of lines.
- Trunks = CO and subscriber trunk cards, and CO and subscriber switching equipment that is sized based upon the number of trunks.

b. Subscriber installation costs include labor for the housing and the cost to establish ac power.

1.4.5 Subscriber Line Concentrator with Integral PCM Carrier Trunks

a. Line costs include:
- Common = CO common equipment, subscriber terminal common equipment, office and subscriber repeaters, subscriber batteries, ringing and power equipment, and subscriber housing.
- Lines = CO and subscriber line cards.

b. Subscriber installation costs include labor for housing installation and cost to establish ac power.

c. Repeater installation is calculated at 10 percent of the housing cost.

1.4.6 <u>Digital Remote Switching Terminals</u>

a. Installed line costs include:
Common = CO common equipment, subscriber common equipment, office and subscriber repeaters, subscriber batteries, ringing and power equipment, and subscriber housing.
Line = RST line cards

Line Credit = Credit for CO lines replaced by RST lines

b. Repeater installation is calculated at 10 percent of the housing and repeater costs.

1.4.7 <u>SxS Remote Switching Terminal</u>

a. Net per line costs include:
Total Equipment = CO common equipment and interface to step-by-step office, subscriber common equipment, subscriber batteries, ringing and power equipment, line and intrasystem trunk circuits, and subscriber terminal housing.
CO Equipment Replaced = Credit for line circuits (lock-out), line-finders and connector-circuits, shelves and frames replaced by RST terminal equipment.

b. Subscriber installation costs include labor for the housing installation and the cost to establish ac power.

2. <u>Development of Equipment Costs</u>

2.1 Distributed Station Carrier (8 Channels)

Common		$ 160
Channels ($375 x 8)		3,000
System Cost	=	$3,160

Channel Equipment Cost = $3,160 - 8 = $395

There are no shared costs except in the changeout of pedestal housing for repeaters and subscriber terminals. These are included as a part of the installation costs.

Channel Cost		$395
Spare Parts (5%)		20
CO Installation		14
Subscriber Installation		21
Installed Per Channel Cost	=	$450

Repeater		$275
Spare Parts (5%)		14
Installation		28
Installed Repeater Cost	=	$317

Per Channel Share of Repeater = $317 - 8 = $40 per channel

Installed Per Channel Costs
(8 Ch. Dist. Station Carrier)

Repeaters	Costs	Per Channel Cost
0	$450 + 0	$450
1	$450 + 40	$490
2	$450 + 80	$530
3	$450 + 120	$570
4*	$450 + 160	$610
5*	$450 + 200	$650

2.2 Grouped Station Carrier (8 Channels)

	One System	Two Systems	Four Systems
Common	$ 570	$ 855	$1,440
Channels ($255 x 8)	2,040	4,080	8,160
Totals	$2,610	$4,935	$9,600
Per Channel Cost =	$326	$308	$300
Channel Cost	$326	$308	$300
Spare Parts (5%)	16	15	15
CO Installation	14	13	12
Subscriber Installation	18	17	16
Installed Per Channel Cost =	$374	$353	$343
Repeater	$275	$275	$275
Spare Parts	14	14	14
Installation	28	28	28
Installed Repeater Cost =	$317	$317	$317

Per Channel Share of Repeater = $317 - 8 = $40 per channel

Installed Per Channel Costs
(8 Ch. Grouped Station Carrier)

	1 System		2 Systems		4 Systems	
Rptrs	Costs	Per Ch. Cost	Costs	Per Ch. Cost	Costs	Per Ch. Cost
0	$374 + 0	$374	$353 + 0	$353	$343 + 0	$343
1	$374 + 40	$414	$353 + 40	$393	$343 + 40	$383
2	$374 + 80	$454	$353 + 80	$433	$353 + 80	$423
3	$374 + 120	$494	$353 + 120	$473	$343 + 120	$463
4*	$374 + 160	$534	$353 + 160	$513	$343 + 160	$503
5*	$374 + 200	$574	$353 + 200	$553	$343 + 200	$543

* See paragraph 2.2.1

2.2.1 Station Carrier Remote Power Costs

If the system length exceeds 3000 ohms, remote power is required along the cable route. The installed cost for the first system is $1,925, including $1,550 for equipment, $225 to establish ac power and $150 for installation. The cost for each additional system is $225, including installation.

Systems	Installed Costs	Channels	Per Channel Cost
1	$1,925	8	$241
2	$2,150	16	$134
3	$2,375	24	$99
4	$2,600	32	$81

2.3 PCM Subscriber Carrier (24 Channels)

	Terminal Size, 24 Ch/System		
	1 System	2 Systems	4 Systems
Common	$ 6,160	$ 9,820	$19,640
Channels ($160 x 24)	3,840	7,680	15,360
Total	$10,000	$17,500	$35,000
Per Channel Cost =	$417	$365	$365
Channel Cost	$417	$365	$365
Spare Parts (5%)	21	18	18
CO Installation	15	15	15
Subscriber Installation	26	22	19
Installed Per Channel Cost	$479	$420	$417

	Single System (24 Ch.) Configuration		
Terminals per route:	1 Terminal	2 Terminals	4 Terminals
Carrier Installed per Chan. Cost	$479	$479	$479
Spare Span Line Terminals	$ 880	$1,760	$ 3,520
Automatic Protection Switches (APS) Optional	[2,000]	[5,000]	[14,000]
Totals	880	$1,760	$ 3,520
Per Channel Cost	$37	$37	$37
Total Installed per Channel Cost	$516	$516	$516

	2 System (24 Ch.) Config.		4 System (96 Ch.)
Terminals per route:	1 Terminal	2 Terminals	1 Terminal
Carrier Installed per Chan. Cost	$420	$420	$417
Spare Span Line Terminals	$ 880	$1,760	$ 880
APS (Optional)	[3,000]	[8,000]	[5,000]
Totals	$880	$1,760	$880
Per Channel Cost	$18	$18	$9
Total Installed per Channel Cost =	$438	$438	$426

Span Line Equipment

Systems per route:	1 System	2 Systems	4 Systems
Repeaters (1 per system + 1 spare @ $90 ea.)	$180	$270	$450
Housing	400	400	400
Spare Parts (5% of rptrs & housing)	29	34	43
Installation	58	67	85
Totals	$667	$771	$978
Per Channel Share of Repeaters =	$28	$16	$10
Cable facilities required inside LP#13 and first terminal location	6	8	12

Cost of spare span line terminals included to insure reliable service to subscribers on PCM systems.

Cost of automatic protection switches should be included if the telephone organization normally specified their use to increase reliability.

Span line costs include cost of spare span line repeaters.

Installed Per Channel Costs (24 Ch. PCM)

	1 Terminal		2 Terminals		4 Terminals	
Repeaters	Costs	Per Chan. Cost	Costs	Per Chan. Cost	Costs	Per Chan. Cost
0	$516 + 0	$516	$516 + 0	$419	$516 + 0	$516
4	$516 + 112	$628	$516 + 56	$580	$516 + 40	$556
8	$516 + 224	$740	$516 + 112	$644	$516 + 80	$596
12	$516 + 336	$852	$516 + 168	$708	$516 + 120	$636
16	$516 + 448	$964	$516 + 224	$772	$516 + 160	$676

2.4 Subscriber Line Concentrator on Physical Pairs

Lines	32	64	128
Trunks	8	16	24
Equipment Costs			
Common	$16,500	$16,500	$18,000
Lines	3,400	6,800	13,600
Trunks	1,200	2,400	3,600
	$21,100	$25,700	$35,200
Per Line Cost	$659	$402	$275
Spare Parts (5%)	33	20	14
CO Installation	15	15	15
Subscriber Installation	26	21	19
Installed per Channel Cost	$733	$458	$323
Facilities Required (VF or Carrier Derived Pairs)	8	16	24
Net Pair Gain	24	48	104
Pair Gain Ratio	4	4	5.3
Load Coil Cost per Subscriber	$1.25	$1.25	$0.94
LE/VFR/Sub.	$37.50	$37.50	$28.13

2.5 Subscriber Line Concentrator with Integral PCM Carrier

Line Size	32	64	128
Common	$10,700	$10,700	$12,600
Channels ($290/Line)	9,280	18,560	37,120
	$19,980	$29,260	$49,720
Per Channel Cost	$624	$457	$388
Channel Cost	$624	$457	$388
Spare Parts (5%)	31	23	19
CO Installation	15	15	15
Subscriber Installation	26	21	19
Installed per Channel Cost	$696	$516	$441

Terminal Line Size	32	64	128
Repeater	$180	$180	$180
Housing	400	400	400
Spare Parts (5%)	29	29	29
Installation	58	58	58
	$667	$667	$677
Repeater Cost per Line	$20.80	$10.40	$5.20
Cable Facilities Required:			
Span Line Pairs	2	2	2
Spare or 2nd Span Line Pair	2	2	2
Order Wire	1	1	1
Interrogation Pair (one per 11 field repeaters)	1	1	1
	6	6	6
Net Pair Gain (Line Size - requirements)			
Terminal inside LP #13	28	58	122
Terminal inside LP #26	27	57	121
Pair Gain Ratio Inside LP #13	8	10.6	21

Cost of spare span line repeaters is included in the span line costs insure reliable service..

2.6 Digital Remote Switching Terminal (RST)

Terminal Line Size	32	64	128	256
Common Equipment	$22,000	$22,000	$25,000	$28,000
Lines ($150 each)	4,800	9,600	19,200	38,400
Totals	$26,800	$31,600	$44,200	$66,400
	$838	$494	$345	$259
Credit for CO Lines	($150)	($150)	($150)	($150)
Per Line Cost	$688	$344	$195	$109
Span Line Costs:				
Repeater	$180	$180	$180	$180
Housing	400	400	400	400
Spare Parts (5%)	29	29	29	29
Installation	58	58	58	58
Totals	$667	$667	$667	$667
Per Line Share of Repeater =	$20.80	$10.40	$5.20	$2.60
Cable Facilities Required: Inside LP #13	6	6	6	6

2.7 SxS Remote Switching Terminal

Terminal Line Size	32 Lines	64 Lines	96 Lines
Total Equipment Cost	$28,700	$30,000	$33,600
Per Line Cost	$897	$469	$350
Spare Parts (5%)	45	23	18
CO Installation	15	15	15
Subscriber Installation	26	21	19
Gross Cost per Line Installed	$983	$528	$402
CO Equipment Replaced	($9,000)	($15,400)	($21,400)
Per Line Credit	($281)	($241)	($223)
Net Cost per Line Installed	$702	$287	$179
Facilities Required: (VF or Carrier Derived Pairs)			
Overhead	5	5	5
Originating Traffic	6	9	11
Terminating Traffic	5	7	9
	16	21	25
Net Pair Gain	16	43	71
Pair Gain Ratio	2	3	3.8

NOTE: Overhead pairs include two pairs for data links and one each for busy verification, intercept and maintenance.

COMPARISON OF TYPICAL INSTALLED SUBSCRIBER CARRIER COSTS

Sub. Term.	Ohms	Rep.	Distributed 8 Ch.			Grouped 8 Ch.			Rep.	PCM 24 Ch. Terminals			PCM 48 Ch. Terminals		PCM 96 Ch.
			1 Sys.	2 Sys.	4 Sys.	1 Sys.	2 Sys.	4 Sys.		1 Ter.	2 Ter.	4 Ter	1 Ter.	2 Ter.	1 Ter.
(D-66) LP 1	117	0	450	450	450	374	353	343	0	516	516	516	438	438	426
2	350	0	450	450	450	374	353	343	1	544	532	526	454	448	436
3	584	0	450	450	450	374	353	343	2	572	548	536	470	458	446
4	817	0	450	450	450	374	353	343	3	600	564	546	486	468	456
5	1051	1	490	490	490	414	393	383	4	628	580	556	502	478	466
6	1285	1	490	490	490	414	393	383	5	656	596	566	518	488	476
7	1518	1	490	490	490	414	393	383	6	684	612	576	534	498	486
8	1752	2	530	530	530	454	433	423	7	712	628	586	550	508	496
9	1985	2	530	530	530	454	433	423	8	740	644	595	566	518	506
10	2219	2	530	530	530	454	433	423	9	768	660	606	582	528	516
11	2452	2	530	530	530	454	433	423	10	796	676	616	598	538	526
12	2686	3	570	570	570	494	473	463	11	824	692	626	614	548	536
13	2919	3	570	570	570	494	473	463	12	852	708	636	630	558	546
14	3153	3	811*	704*	651*	735*	607*	544*	13	880	724	646	646	568	556
15	3386	4	851*	744*	691*	775*	647*	584*	14	908	740	656	662	578	566
16	3620	4	851*	744*	691*	775*	647*	584*	15	936	756	666	678	588	576
17	3854	4	851*	744*	691*	775*	647*	584*	16	964	772	676	694	598	586
18	4087	4	851*	744*	691*	775*	647*	584*	17	992	788	686	710	608	596

Notes:
1. PCM repeaters - 23 dB from office and spaced at 23 dB thereafter on existing nonscreened cable.
2. Station carrier repeaters at loading points 4, 7.5, 11, 14.5, and 18.
3. Per channel station carrier cost based on full systems on existing 24 gauge filled buried cable.

* Exceeds 3000 ohms 24 gauge cable; cost of field power included.

TABLE A-1

COMPARISON OF TYPICAL INSTALLED CONCENTRATORS AND REMOTE SWITCHING TERMINALS COSTS

		Subscriber Line Concentrators							Remote Switching Terminals							
Sub. Term.	Non Loaded Ohms	VF or Carrier Trunks			Span Line Rep.	With Integral Span Line			Digital				Non Loaded Ohms	Step-by-Step		
Line Size		32	64	128		32	64	128	32	64	128	256		32	64	96
(D-66)																
LP 1	117	733	458	323	0	696	516	441	688	344	195	109	117	702	287	179
2	350	733	458	323	1	717	526	446	709	354	200	112	350	702	287	179
3	584	737	462	326	2	738	537	451	730	365	205	114	584	710	292	183
4	817	738	463	327	3	758	547	457	750	375	211	117	817	712	294	184
5	1051	739	464	328	4	779	558	462	771	386	216	119	1051	899	416	281
6	1285	741	466	329	5	800	568	467	792	396	221	122	1285	899	416	281
7	1518	742	467	330	6	821	578	472	813	406	226	125	1518	899	416	281
8	1752	781	506	359	7	842	589	477	834	417	231	127	1752	919	429	292
9	1985	782	507	360	8	862	599	483	854	427	237	130	1985	919	429	292
10	2219	783	508	361	9	883	610	488	875	438	242	132	2219	919	429	292
11	2452	784	509	361	10	904	620	493	896	448	247	135	2452	919	429	292
12	2686	786	511	362	11	925	630	498	917	458	252	138	2686	939	442	302
13	2919	787	512	363	12	946	641	503	938	469	257	140	2919	939	442	302
14	3153	788	513	364	13	966	651	509	958	479	263	143	3153	1006	486	337
15	3386	789	514	365	14	987	662	514	979	490	268	145	3386	1026	499	347
16	3620	791	516	366	15	1008	672	519	1000	500	273	148	3620	1026	499	347
17	3854	792	517	367	16	1029	682	524	1021	510	278	151	3854	1026	499	347
18	4087	793	518	368	17	1050	693	529	1042	521	283	153	4087	1026	499	347
Pair Required VF or Carrier Metallic		8	16	24		6-7	6-7	6-7	6-7	6-7	6-7	6-7		16	21	25

Notes:
1. PCM repeaters - 23 dB from office and spaced at 23 dB intervals thereafter on existing nonscreened cable.
2. VF cable betweeen step-by-step office and RST is typical limited to 1000 ohms. Thereafter installed line costs for LP 5 and beyond include carrier costs based upon line cost of 2 system grouped station carrier.
3. Per line costs based upon applying equipment to existing 24 gauge filled buried cable D-66 loaded.

TABLE A-2

*U.S. Government Printing Office : 1987 - 180-917/60501