DMS-1* DIGITAL MULTIPLEX SYSTEM
DS1 DIGITAL LINE ENGINEERING

1. GENERAL

1.01 This section provides information required to engineer the DS1 digital line spans (Fig. 1) which connect the DMS-1 Control Concentrator Terminal (CCT) to the Remote Concentrator Terminal (RCT). Complete guidelines are given for the engineering of LD-1 lines terminating in DMS-1 or LD-1 span racks. Because the way a digital line is used with DMS-1 differs somewhat from normal trunking use, this section should only be used to engineer the lines for DMS-1 applications.

1.02 *Reason for Reissue:* to add new and revised information.

2. CABLES FOR LD-1/T-1 SPANS

2.01 The cables which may and may not be used by the LD-1 transmission system for DMS-1 applications can be summarized as follows:

Acceptable:

- Most exchange grade cables with standard sheaths. (Cables should be pressurized in areas where water may be a problem.)

Unacceptable:

- nonstaggered twist cables (uncommon)

- loaded pairs.

2.02 Up to five LD-1/T-1 systems may be accommodated in a cable unit which is also carrying analog carriers below 150 kHz. Any number of LD-1/T-1 systems may be carried in different cable units.

2.03 The LD-1/T-1 systems can be engineered in cables also containing analog carrier systems above 150 kHz, but this is not recommended.

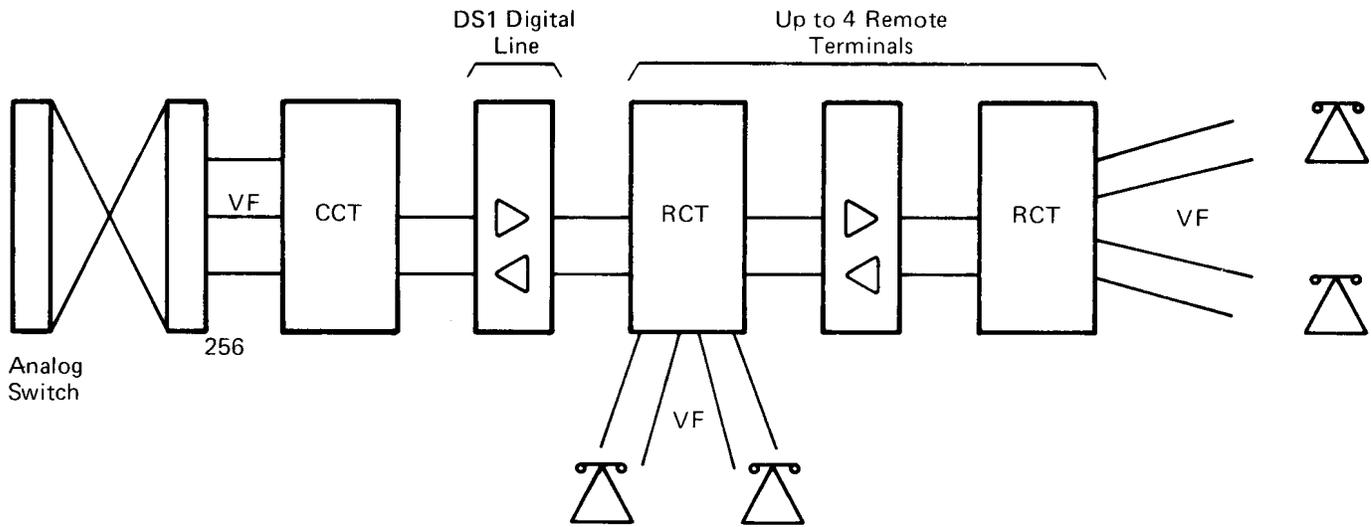* DMS-1 is a trademark of Northern Telecom Limited
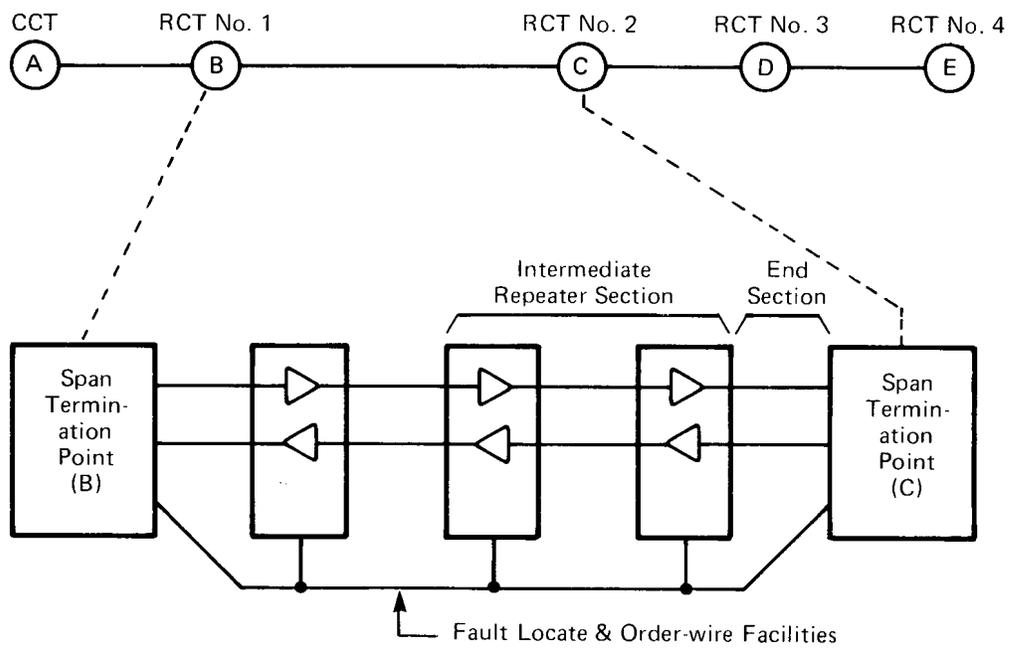
Fig. 1 — DMS-1 System
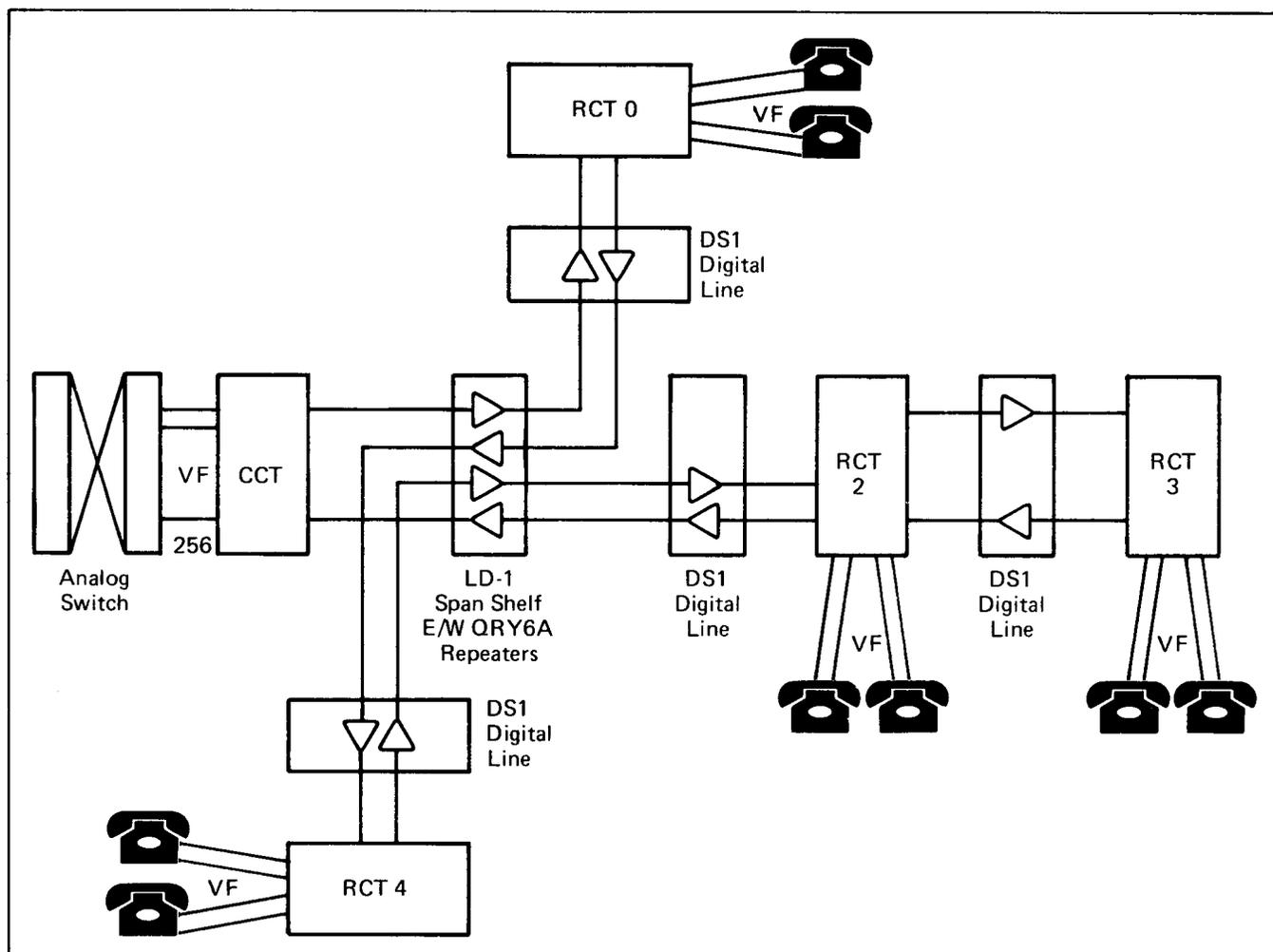

Fig. 2 — Span Configuration

Fig. 3 — System Star Configuration

3. SPAN CONFIGURATION

3.01 DS1 systems are designed in spans which are self-contained for maintenance and powering. Spans can be designed in several configurations using bidirectional or unidirectional line repeaters. In the DMS-1 system, spans may be connected in tandem (Fig. 2) up to maximum lengths specified in Table A.

Note: The maximum CCT to RCT distance decreases with the increasing number of RCT because each RCT delays the bit stream passing through it by 125 μs. The distance also decreases with the increase in cable gauge because of the decrease in velocity of propagation.

3.02 The choice of the configuration is generally based on existing cable facilities, the number of RCT, diversity requirements, cost, and other systems to be provided on the route. The maximum permissible LD-1 span length is limited by powering constraints, equivalent to 4800 ohms. Therefore, Span Termination Points (STP) may be required at locations other than the RCT.

3.03 The STP should be chosen immediately after the repeater spacing has been determined. The choice of these points depends on the maximum allowable repeater spacing, the maximum operating ranges of the fault-locate and order-wire systems selected, and the location of existing and planned telephone plant and structures.

TABLE A
ROUND-TRIP DISTANCES VERSUS NUMBER OF RCT
FOR THREE VALUES OF SOFTWARE CYCLE TIME

NUMBER OF RCT	ROUND-TRIP DISTANCE (Miles) FOR INDICATED SOFTWARE CYCLE TIME		
	FOR 180 MS	FOR 240 MS	FOR 300 MS
1	97	284	472
2	81	269	456
3	65	253	440
4	50	238	425

Notes:

1. Distances listed are for 22-gauge cable:

   ● for 19-gauge cable multiply by factor 1.03
   ● for 24-gauge cable multiply by factor 0.94
   ● for 26-gauge cable multiply by factor 0.92.

2. On systems serving lines with coded ringing, the system length should be no more than 180 ms.

3.04 *Star Configuration.* The DMS-1 configuration is not limited to the in-line layout depicted in Fig. 1 and 2. Up to four RCT may be disposed radially from the CCT in any desired pattern. A typical example is shown in Fig. 3. In this case, a LD-1 span shelf is used in the office to accommodate the additional terminal repeaters required for the added arms of the "star". If this system is used:

(a) Use of 1-for-n protection switching is recommended.

(b) Additional terminal repeater requirements are provided by LD-1 QRY6A repeaters in a separate LD-1 span rack.

(c) The loopback feature does not function at the RCT at the end of an arm; but protection switching operates normally. In the example in Fig. 3, a cable cut, except between RCT3 and RCT4, fails the entire system. Restoral requires manual patching-out of the failed arm at the LD-1 span shelf.

3.05 Allowable system length in any configuation depends on the total round-trip length; i.e., CCT-RCT1-RCT2-RCT3-RCT4-CCT. See Table A.

Configurations Using Bidirectional Line Repeaters

3.06 Bidirectional line repeaters carry both directions of transmission for a single system. Therefore, if a line repeater fails, service on only one DS1 line is interrupted. To keep installation costs low, reduce splicing complexity, and make system changes easier in the future, only bidirectional repeaters should be used for DMS-1 applications.

(a) *Single Nonscreened Cable (Fig. 4).* Receive and transmit directions are carried in the same cable. This results in lowest installation costs. However, near-end crosstalk places a limit on the maximum section length and number of pairs that can be used.

(b) *Single Screened Cable (Fig. 5).* Receive and transmit directions are carried in the same cable, but separated by the screen. Initial cost is greater than single nonscreened cable but full pair utilization and maximum section lengths are possible. If the apparatus-case stub cable is not screened, its length must be kept as short as possible to reduce crosstalk problems.
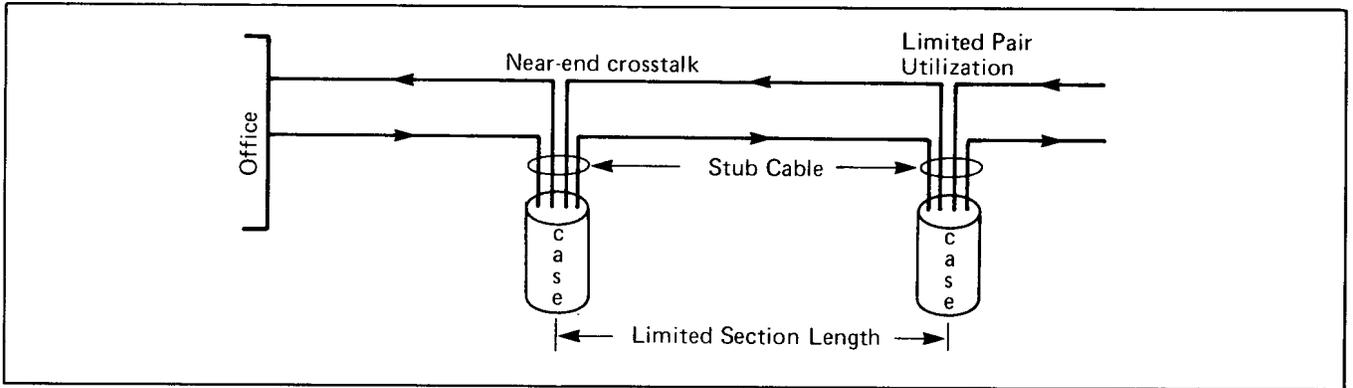
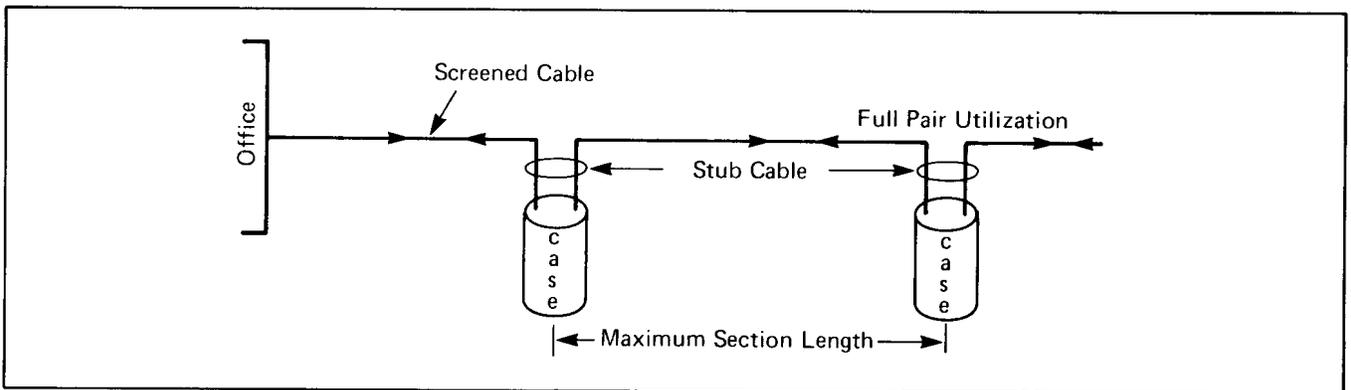Fig. 4 — Line Configuration with Unscreened Cable
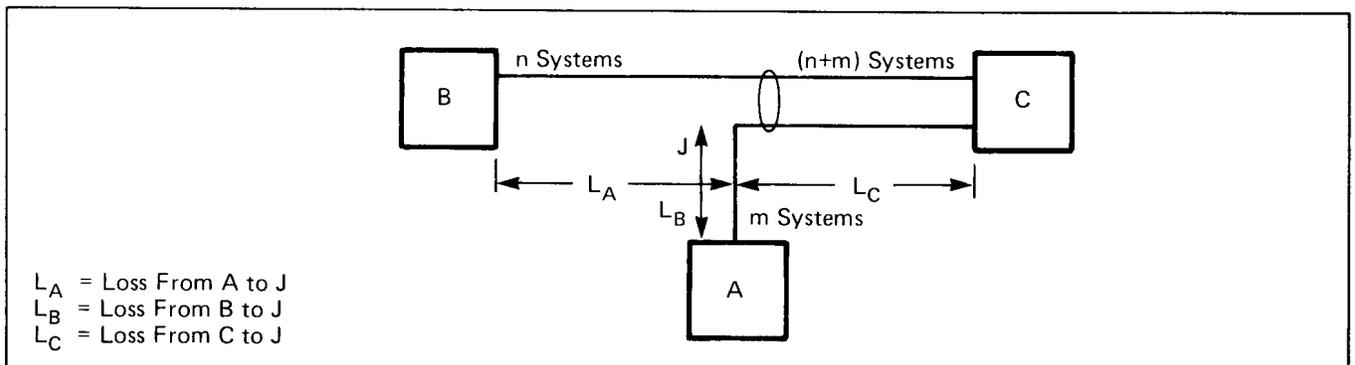

Fig. 5 — Line Configuration with Screened Cable

L_A = Loss From A to J
L_B = Loss From B to J
L_C = Loss From C to J

Fig. 6 — DS1 Line Junction

4. REPEATER SECTION ENGINEERING

Maximum Loss

4.01 After allowance has been made for the distribution of cable attenuation and the effect of temperature, at 772 kHz the maximum losses allowable in a repeater section are:

(a) underground sections: 32.2 dB maximum at 55°F (13°C),

(b) aerial sections: 31.1 dB maximum at 55°F (13°C).

In pratice, these values must often be further reduced for crosstalk or office noise considerations.

Design Procedure

4.02 Use the following procedure to calculate the loss on the cable and the maximum length of each section.

(1) *Calculate Maximum Design Loss of Each Section (dB).* Use the number of systems eventually to be placed in the cable, including spare, to ensure that an orderly growth is possible.

(2) *Find Maximum Engineering Loss of the Cable (dB/kft).* Values in Table C represent the highest average cable loss likely to be encountered with a given cable.

(3) *Calculate the Maximum Length of Each Section (kft).* Divide maximum design loss by maximum engineering loss.

Design Considerations for End Sections

4.03 *Based on Noise.* For sections entering an office or a RCT, the primary limitation is due to equipment impulse noise. To ensure adequate error-rate performance, the Noise Path Loss (NPL) to the repeater input must be at least 52 dB greater than the signal path design loss, L_D:

$$NPL \geqslant 52 \text{ dB} + L_D, \text{ or}$$
$$L_D \leqslant NPL - 52 \text{ dB}.$$

A temperature factor must be included to ensure the requirement is met at all temperatures.

4.04 Use NPL values given in Table B when vf pairs are in the same binder group as DS1 pairs and both enter the office. When no vf pairs are in the same binder group as DS1 pairs, or the vf pairs do not enter the office, or the vf pairs are not cross-connected at the frame, the value of NPL may be increased by 10 dB.

4.05 *Based on Crosstalk.* Near-end crosstalk is the noise coupled from all high-level output signals to a low-level repeater input. The crosstalk loss of the cable and the number of interfering signals are considered when calculating a maximum design loss that ensures a satisfactory signal-to-noise ratio at a repeater input. The equation used to determine design loss also allows for cable manufacturing tolerances, and temperature effects. Far-end crosstalk is not significant in single cable operation.

4.06 *Office Cabling Restrictions.*

● Use common shielded cables (ABAY type) to connect outside cables at the main or protector frame to the repeater equipment.

● Use separate cables to carry transmit and receive signals.

● Use separate cables to carry signals from different spans. Otherwise, where incoming lines from different spans and with different levels are mixed in the same cable, evaluate the crosstalk between the pairs to establish maximum permissible cable length.

● Avoid using common entrance cables. Outside cables carrying LD-1 signals should be terminated on the frame. If a common entrance cable must be used, a crosstalk calculation must be performed for the entrance cable, with crosstalk parameters suitably modified for the shorter cable involved.

4.07 When an end section loss is less than 9 dB, the QAH19 attenuator must be wired between the DMS-1 repeaters and the digital line. (Two possible occasions where the end section is less than 9 dB are a RCT installation in an existing digital line or the use of the protection switching option requiring DMS-1 repeaters with non-LD-1 span rack and terminal repeaters.) The attenuator consists or three buildout networks mounted on a single printed circuit board which is mounted to the RCT power shelf or CCT common shelf 2 backplanes on standoffs. The attenuator attenuates the digital signal to a level that is compatible with the receive section of the DMS-1 repeaters.

4.08 *Separate Span Rack.* If the digital line is terminated on a separate span rack (LD-1 or other digital line with compatible DS1 interface specifications) the following distance limitations apply.

(1) The maximum distance between the CCT or RCT bay and the separate span rack is 750 feet (22 AWG). Switch options on the QPP419 digroup circuit pack must be used to adjust the signal level transmitted from the DMS-1 system to a level compatible with the terminal repeaters in the span rack.

(2) When the bypass option is installed in a RCT, the maximum distance between the DMS-1 bay and the separate span rack is 75 feet (22 AWG). This ensures that the signal level from the output of the terminal repeater receive section, when bypassed around the RCT, is high enough to meet the input requirements of the transmit section of the terminal repeater.

Design Considerations for Intermediate Sections

4.09 In intermediate repeater sections, the primary restriction on section length is near-end crosstalk from high-level repeater outputs to low-level repeater inputs. The design equation determines maximum section loss based on cable parameters, pair assignment, and number of systems. The equation includes a safety factor to allow for variations in cable manufacture and far-end crosstalk. When more than one cable type is used within a section, calculate the maximum design loss for each cable type longer than 20 feet. Then use the minimum figure corresponding to a cable type within 3 dB of the transmitting repeater. If any other design loss figure is more than 3 dB less than the previous figure, use the lower design loss.

Route Junction Considerations

4.10 A route junction is a point at which two or more DS1 systems working at different levels in different sheaths are merged in one sheath. Because the level difference between the systems can introduce substantial far-end crosstalk into the lower level system, the junction must be carefully engineered. Because of this, and because entry into a sheath with working systems poses a hazard to service, route junctions should be avoided if at all possible, especially in working cables.

4.11 A simple alternative to engineering a junction is to merge the two sheaths at an existing repeater location. This eliminates the problem of level difference, and makes splicing less hazardous.

4.12 If a junction must be engineered, the following paragraphs suggest two procedures. The first is preferred if the expense of adding the repeater is not excessive.

4.13 *Method 1.* The first method involves engineering a new repeater point at the proposed junction. This method solves the level difference problem, but entails breaking into a working cable. It may be adopted only subject to the following constraints.

(a) All DS1 lines merging into the same sheath must have repeaters installed in them.

(b) The repeater spacings between the new repeater location and all adjacent repeater locations must meet the design criteria of this section using the new total number of systems expected in the cross-section in question.

4.14 *Method 2.* The second method involves ensuring that the losses in all branches of the junctions satisfy certain conditions. In Fig. 6, a junction is shown in which DS1 systems from A and B merge towards C. For simplicity, no systems are shown from A to B.

4.15 In this configuration, a junction may be constructed at J, if

(1) $9 \leqslant L_A + L_C \leqslant L_{MAC}$, where L_{MAC} is maximum loss determined in this section assuming n systems in cable types from A through J, and (n + m) systems in cable types from C through J.

(2) $9 \leqslant L_B + L_C \leqslant L_{MBC}$ where L_{MBC} is similar to L_{MAC}.

(3) $L_A - L_B \leqslant L_D$ where $L_D = 3$ dB, if the DS1 systems from A and B merge into the same unit; or $L_D = 10$ dB if they merge in different units.

Note: The requirements in Steps (1), (2), and (3) above, can be met by making $L_A = L_B$.

4.16 If systems from A to B also exist, then a similar set of equations must be satisfied for the other two orientations (B and C merging toward A, and A and C merging toward B). Note that in this situation, q systems connected from B to A and C means 2q systems in section BJ.

DMS-1/LD-1 Line

4.17 The following symbols are used in design equations for the end sections and intermediate sections.

L_D = maximum section design loss;

NPL = noise path loss (see Table B for values);

T_C = temperature factor = 1.04 underground, = 1.08 aerial;

A = m − σ;

Where:

m = means near-end crosstalk coupling loss

σ = standard deviation of the crosstalk coupling loss (see Table B for values);

n = number of systems that will ultimately be carried in the cable, including spare lines;

L = engineering loss of cable (dB/kft);

l = maximum section length.

Table C lists engineering loss for most commonly used cables. For cables not listed in Table C, and for reclaimed cables, refer to the appropriate reference to determine the engineering loss.

4.18 Use the following design equations for end sections (sections between STP or RCT and the first apparatus case):

(1) Calculate maximum design loss for office noise:

$$L_{D1} = (NPL - 52)/T_C$$

(2) Calculate maximum design loss for crosstalk:

$$L_{D2} = [(A - 10 \log n - 32)/T_C]$$
$$- (CO\ Repeater\ Loss)$$
$$- (CO\ Wiring\ Loss)$$

(3) Select L_D, as the smaller of L_{D1}, L_{D2}, and L_{D3}.

Where:

$$L_{D3} = L_M - (CO\ Repeater\ Loss)$$
$$- (CO\ Wiring\ Loss)$$

L_M = 31.1 dB for aerial cable, = 32.2 dB for underground.

(4) Calculate maximum section length.

$$l = L_D/L.$$

4.19 Use the following equations to design the intermediate sections (sections between apparatus cases):

(1) Calculate maximum section design loss L_D (dB):

$$L_D = (A - 10 \log n - 32)/T_C$$

Maximum L_D = underground sections, = 31.1 dB for aerial sections.

Note: The equation applies only to span configurations producing near-end crosstalk. For systems using two cables, set L_D to maximum shown.

(2) Calculate maximum section length l (kft):

$$l = L_D/L.$$

4.20 *Line Repeater Location.* Using the maximum section lengths derived, repeaters may be located to make optimum use of existing plant structures and allow easy accessibility for installation and maintenance.

4.21 *Using Protected or Unprotected Line Repeaters.* When the number of line repeater locations have been determined, use protected or unprotected line repeaters at these locations as follows:

(a) for all locations directly connected to exposed plant, use protected repeaters,

(b) otherwise unprotected repeaters.

TABLE B
NOISE PATH AND CROSSTALK COUPLING LOSS

	19 AWG		22 AWG		24 AWG		26 AWG	
NONSCREENED CABLE (Staggered Pair Twist)	A (dB)	NPL (dB)	A (dB)	NPL (dB)	A (dB)	NPL (dB)	A (dB)	NPL (dB)
PAP CABLE, UNIT CONSTRUCTION		74		75		76		77
Pairs in same 100-pair splicing group	70		71		72		73	
Pairs in adjacent splicing groups	80		81		82		83	
Pairs in nonadjacent splicing group	95		96		97		98	
Pairs in same 50-pair unit	64		65		66		67	
Pairs in adjacent 50-pair units	79		80		81		82	
Pairs in nonadjacent 50-pair units	93		94		95		96	
PAP CABLE, LAYER CONSTRUCTION		74		75		76		77
Pairs in same 100-pair splicing group	65		66		67		68	
Pairs in adjacent groups	74		75		76		77	
Pairs in nonadjacent groups	83		84		85		86	
PIC CABLE, UNIT CONSTRUCTION		74		75		76		77
Pairs in same 8- or 9-pair unit	56		57		58		59	
Pairs in same 12- or 13-pair unit	58		59		60		61	
Pairs in same 25-pair unit	62		63		64		65	
Pairs in adjacent 8-, 9-, 12-, or 13-pair units	67		68		69		70	
Pairs in nonadjacent 8-, 9-, 12-, 13-, or 25-pair units	83		84		85		86	
Pairs in adjacent 25-pair groups — (made up of 8 + 8 + 9 pair units)	68		69		70		71	
SCREENED CABLE NE-C-BJAB (22 gauge only) $A = 65 + 10 \log N$ N = number of pairs.				75				

The near-end crosstalk coupling loss is measured at 772 kHz.

$A = m - \sigma$ where m is the mean near-end crosstalk coupling loss and σ is the standard deviation of the loss.

NPL is the loss in the path by which noise arrives at the repeater inputs and is equivalent to the crosstalk separation requirement. An approximation to NPL is the mean of the near-end crosstalk coupling loss between pairs in the same binder group or unit.

5. SPAN LINE POWERING

5.01 The power for line repeaters is transmitted, in a simplex arrangement, over the transmission pairs. The powering current required is 100 mA. This current is generated by the QPP437 or QRY6A powering office repeater. The office repeater is supplied with a 48-V input voltage and generates up to ±130 V output, automatically regulated to 100 mA.

5.02 Typical powering limits are 40 miles with 19-gauge cable or 25 miles with 22-gauge cable. For short spans (approximately 12.5 miles or less on 22-gauge cable) powering may only be required at one end of the span.

5.03 *Determining the Powering Required.* Use the following procedure to determine the powering requirement for line repeaters.

(a) From Table D determine the total effective dc resistance ($RE_1 + RE_2$) of all line repeaters in the span.

(b) From the graph (Fig. 8), determine the dc resistance RE_S, of the simplex power loop.

(c) Add the values obtained in (a) and (b) to find the effective dc resistance of the span:

$$RE = RE_1 + RE_2 + RE_S.$$

For RE less than 2400 ohms. Span line may be powered from one end of the span and looped at the office at the far end; i.e., use a QPP437 or QRY6A powering office repeater at one end and a QPP436 or QRY7A nonpowering office repeater (with looping option) at the other end of the span.

For RE between 2400 and 4800 ohms. Span line must be powered from both ends of the span and looped at a line repeater such that the effective resistance to each end from the looping point is 2400 or less. The effective resistance of the line repeater with the looping option is included in the power loop of the office repeater transmitting to side 1 of the line repeater.

TABLE C
CABLE ENGINEERING LOSS

CABLE TYPE	LOSS (dB/kft)
ABAY	4.2
ABMY	5.2
750-type	5.6

GAUGE	CABLE TYPE	LOSS L (dB/kft)
19	TB, ANB, DNB, GND	3.00
19	BHB	3.18
19	BNB, CNB, ENB, FNB	3.80
19	ADB	3.80
22	BJAB, C-BJAB	4.00
22	NA, ANA	4.60
22	CSA, DSA, ESA	5.10
22	BHA	4.39
22	ADA	5.10
24	CSM, ESM	5.85
24	DSM, FSM	6.80
24	BKM	5.58
24	ADM	6.80
26	CST	6.79
26	BST	7.70
26	DST	8.17
26	BKT	7.48

TABLE D
EFFECTIVE RESISTANCE OF REPEATERS

NUMBER OF REPEATERS	QRY4-TYPE (RE_1)	QRY5-TYPE (RE_2)
1	82.4	94.2
2	164.8	188.4
3	247.2	282.6
4	329.6	376.8
5	412.0	471.0
6	494.4	565.2
7	576.8	659.4
8	659.2	753.6
9	741.6	847.8
10	824.0	942.0
11	906.4	1036.2
12	988.8	1130.4
13	1071.2	1224.6
14	1153.6	1318.8
15	1236.0	1413.0
16	1318.4	1507.2
17	1400.8	1601.4
18	1483.2	1695.6
19	1565.6	1789.8
20	1648.0	1884.0
21	1730.4	1978.2
22	1812.8	2072.4
23	1895.2	2166.6
24	1977.6	2260.8
25	2060.0	2355.0

6. ORDER WIRE

6.01 DMS-1 provides order-wire appearances at each terminal. The number of terminals which must be equipped with order-wire termination points depends on the length and configuration of the DMS-1 system. If a STP coincides with a RCT, and a subscriber line is required for outdialing, because the span is too long to be accessed completely from one end, then it may be necessary to extend the order-wire back to a CO on one (or two) vf pair(s), using long-loop design if required. If the DMS-1 system uses at least two digroups (including a protection LD-1/T-1 line), then it may be preferable to assign to the order-wire pair one line-appearance at each RCT which is also an order-wire termination point.

6.02 A QPP302 order-wire terminal interfaces at the CCT between the order-wire pair and the switched network to allow access to the switched network from any apparatus case or office. The QPP302 also supplies the talk battery for the order-wire. The order-wire facility uses a vf loaded pair.

Order-Wire Powering (Fig. 7)

6.03 For short spans (<15.5 miles of 22-gauge cable) a QPP302 may only be needed at one end of a span. The other end would then use a QPP304 bridging circuit. For longer spans, a QPP302 is needed at both ends with a pair of capacitors at the apparatus case at the looping point. The capacitors used are 4 μF NE-CM01Y4004J200. To determine whether the span needs one or two QPP302, use Fig. 8 to find the loop resistance of the order-wire pair. Then for,

(a) *loop resistance less than 2800 ohms*, use a QPP302 at one end and a QPP304 at the other end;

(b) *loop resistance between 2800 and 5600 ohms*, use a QPP302 at both ends with splitting capacitors in an apparatus case such that the dc loop resistance from each direction is less than 2800 ohms.

Access to a Subscriber Line

6.04 If access to the switched network is required, a QPP302 is connected to a subscriber-line circuit.

6.05 The maximum length for a 2-wire vf extension is determined primarily by the signaling range of the switching machine. The QPP302 terminal has an internal resistance of 120 ohms. For example, if connecting to a step-by-step switching machine whose signaling range is limited to 1500 ohms, subtracting the internal resistance of the QPP302 terminal gives a maximum loop resistance of 1380 ohms for the extension pair, rather than the more usual 1300 ohms resulting from the assumption of a 200-ohm station set.

6.06 If the 2-wire vf extension cannot be used, a 4-wire system can extend the signaling range (Fig. 8). This can be engineered by using standard vf design techniques.

7. FAULT LOCATING

7.01 The fault-locate system uses a filter at each repeater location. A test set transmits a digital signal over the repeatered line, and the filter returns the audio component of the test signal over the fault-locate pair. The fault-locate pair is an ordinary vf loaded pair.

7.02 Two types of fault-locate systems may be used with DMS-1. The powered fault-locate system provides a maximum of maintenance features, testing all repeaters in a span from either end of the span. The unpowered system offers some economic advantages, in that performance may be adequate, if the span is short with a manned office at each end of the span. However, because this is unlikely in a DMS-1 system, it is recommended that a powered fault-locate system only be used. In a distributed system, a powered fault-locate system is mandatory.

7.03 For purposes of apparatus code and option selection, the repeater locations in a span are designated, starting with location 1 at one STP, location 2 at the first line repeater location, and proceeding sequentially through to the other STP. If two spans are included in one fault-locating system, the intermediate span termination point is assigned a location number. See Fig. 10.

Fault-Locate Design with DMS-1 Span Termination and LD-1 Line (Fig. 11)

7.04 Up to 24 repeater locations may be fault-located by using one fault-locate pair. Each of the 12 fault-locate tones (A through M, omitting I) can be assigned to two locations, with each location selected by either high- or low-voltage powering, according to the option set in the filter. Transmit and receive directions are selected by voltage polarity. For systems with more than 24 repeater locations, a second fault-locate pair is required.
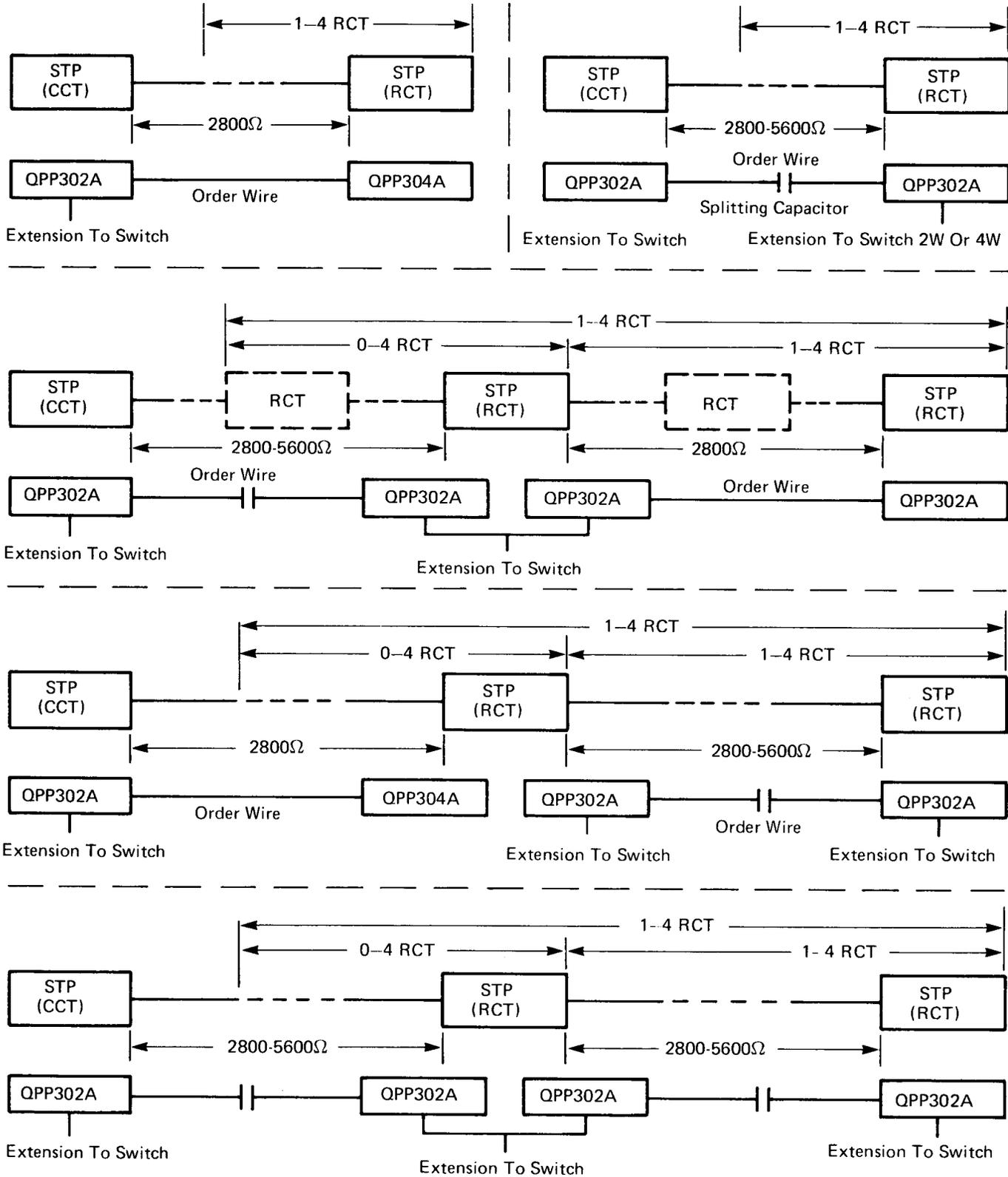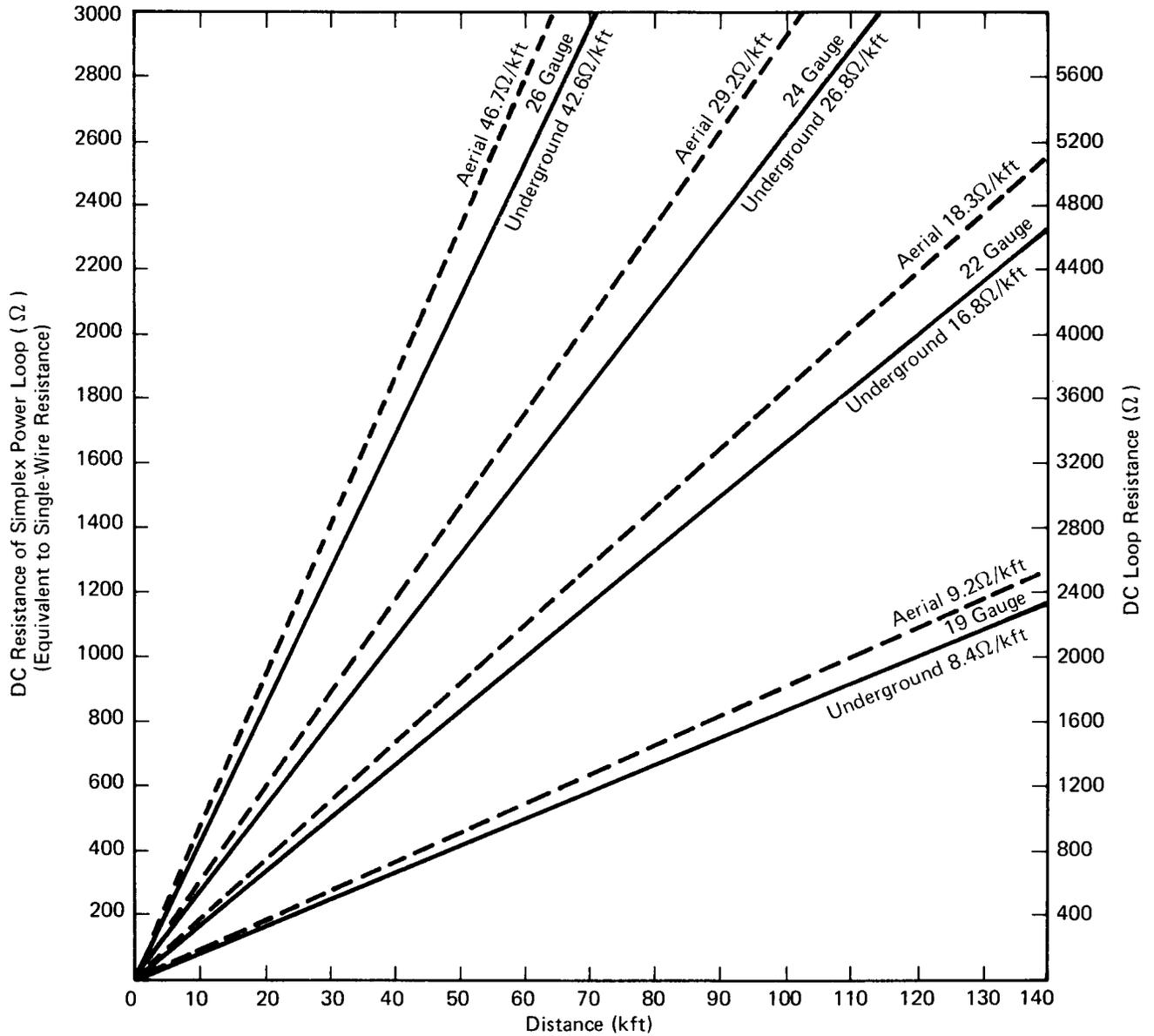
Fig. 7 — Order-Wire Configurations

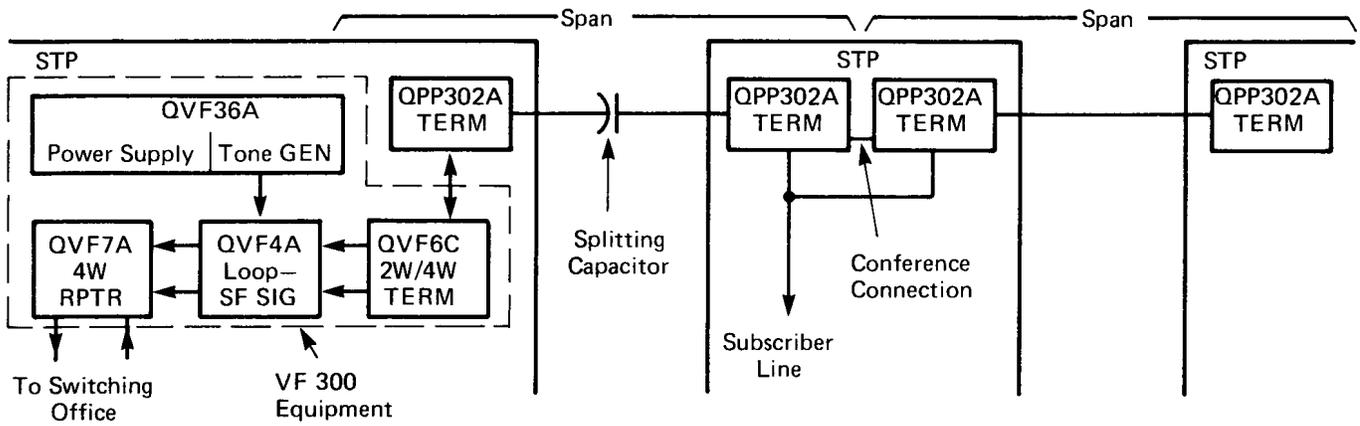Fig. 8 — DC Resistance of Simplex Power Loop
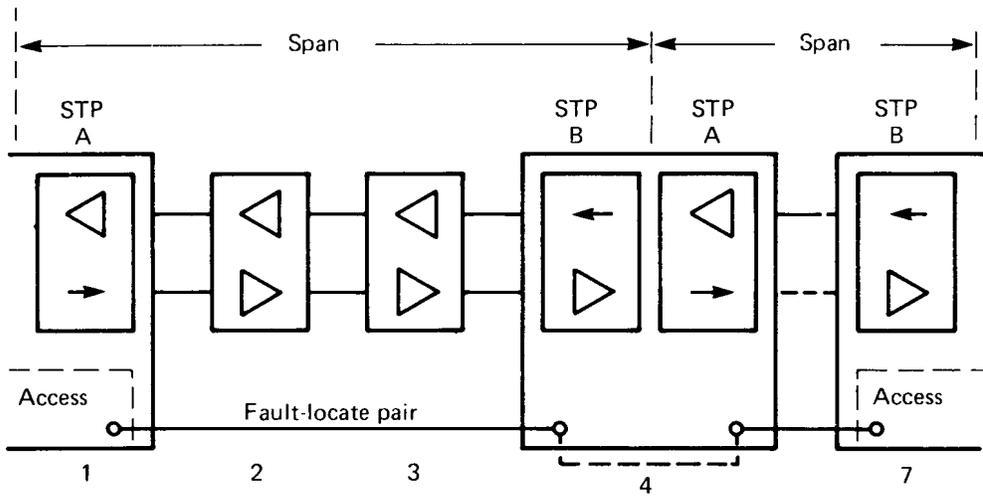
Fig. 9 — Typical 4-Wire Extension Using VF-300 Equipment
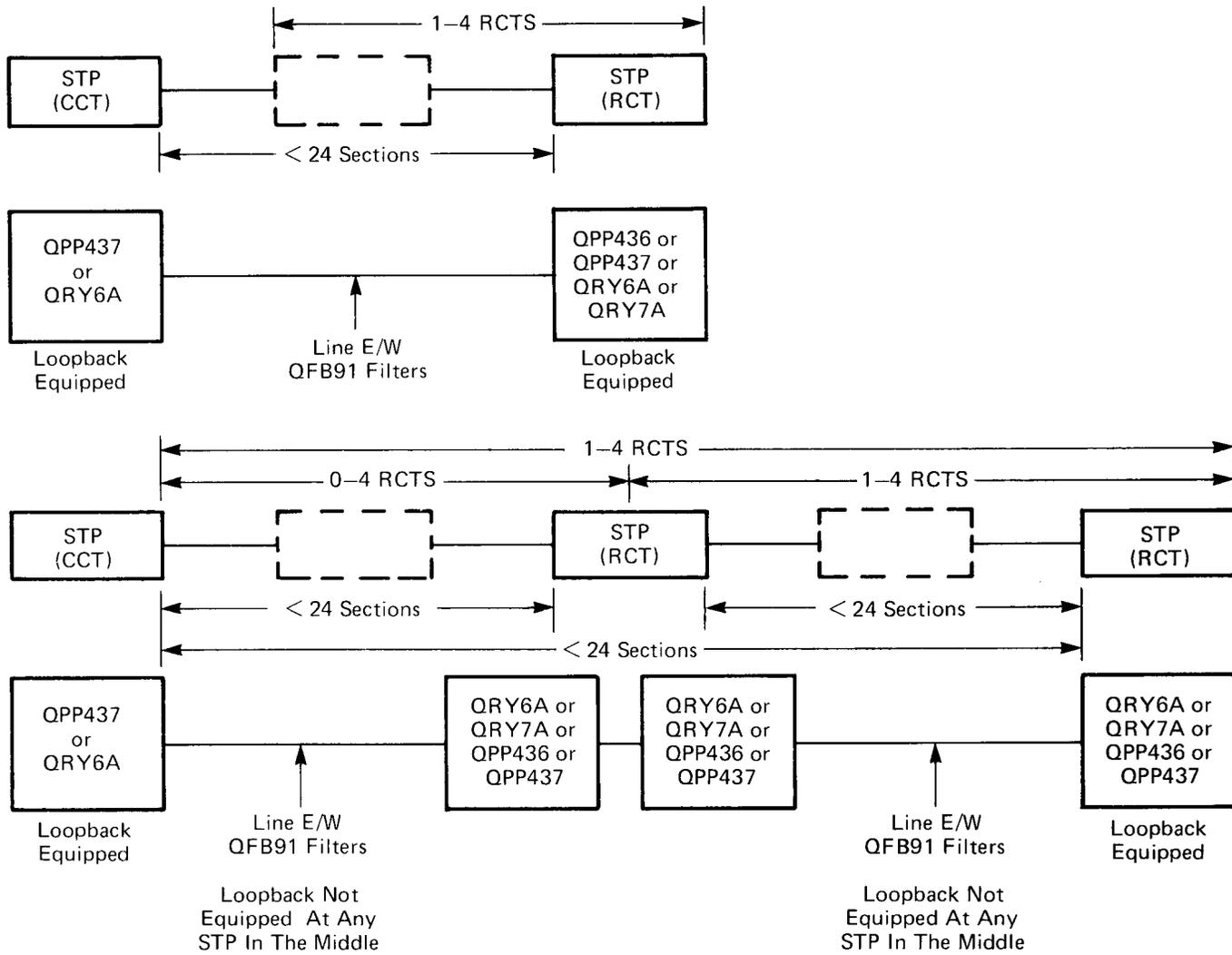
Fig. 10 — Repeater Location Numbering

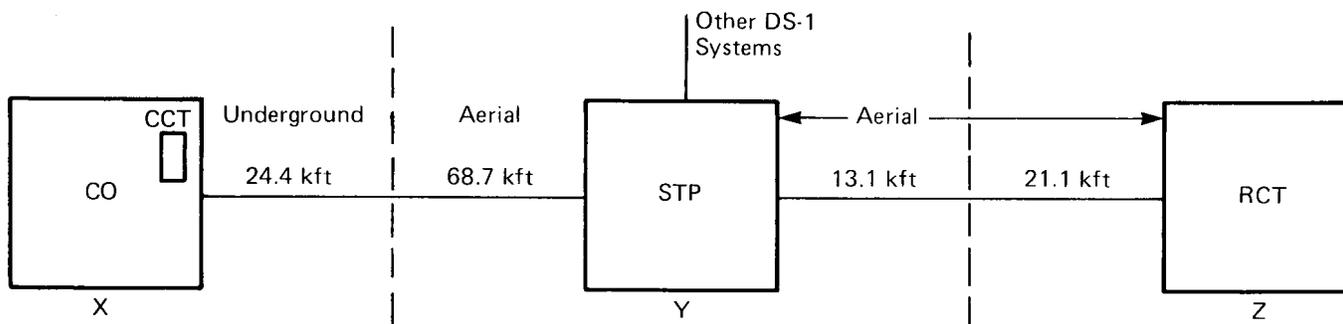Fig. 11 — Digital Line Configurations During Fault Location

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                                    | Other DS-1
                                    | Systems
        CCT   Underground |  Aerial  |          |——— Aerial ———|
    CO                    |          | STP      13.1 kft   | 21.1 kft    RCT
        24.4 kft |  68.7 kft |        |          |          |

    X                     |          | Y        |          |          Z
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Fig. 12 — Typical Span Configuration

7.05 *Filter Codes.* QPP300 filters are used in offices; QFB91(-) filters are used in apparatus cases. Codes of filters are assigned alphabetically with a QPP300 at location 1, QFB91B at location 2, through to M at location 12. Codes A through M are then repeated for locations 13 through 24. At the intermediate STP (location 4 in Fig. 10) two QPP300 filters with the same code are required.

7.06 *Access to Fault-Locate Pairs.* Access to fault-locate pairs at each office, except the intermediate office in the distributed RCT mode, can be obtained by using a QPP301 fault-locate access unit at each end. One QPP301 access unit contains two circuits to access the fault-locate pairs in two spans. The use of a QPP301 at an intermediate RCT is not recommended, as it is not possible to locate faults through that RCT from an end terminal. If the QPP301 is used at the end RCT in the distributed RCT system, the continuity of the fault-locate pair through the intermediate RCT must be maintained (Fig. 10).

> *Note:* A QPP301 has an amplifier which can be switched in to amplify the returned fault-locate tones to accommodate a wider range of fault-locating test sets.

When the repeaters for two spans are mounted in separate span racks and share a QPP301 access unit, cabling between the two span racks is required.

8. PROTECTION FEATURES

8.01 Protection switching for the LD-1 lines terminating LD-1 or DMS-1 terminal repeaters can be supplied by providing a QPP429 protection switch for the CCT and a QPP428 protection switch for each RCT. In this case, a LD-1 line must be engineered to provide a protection line in addition to the one or two working lines. No further engineering is required, except as noted in 4.08.

9. EQUIPMENT HOUSING

9.01 To minimize space requirements, it is recommended that LD-1 lines be terminated directly on the DMS-1 bay using DMS-1 terminal repeaters and the DMS-1 fault-locate and order-wire shelf. If the lines are terminated in a standard LD-1 span termination shelf, a separate bay is required. All STP that are not RCT require this method of termination.

10. SYSTEM DESIGN EXAMPLE

10.01 The following is a typical design procedure for the DMS-1 system.

DMS-1 Configuration	one RCT with two LD-1 digroups
Span Configuration (Fig. 12)	127.3 kft, single nonscreened cable; 24.4 kft DSA22 underground cable; 68.7 kft DSA22 aerial cable; STP; 13.1 kft BHA22 aerial cable; 21.1 kft BKM24 aerial cable.
Binder Group Assignment	adacent bundle for DSA; adjacent 13-pair unit for BHA; same 13-pair unit for BKM.

Number of LD-1 systems to be installed from CCT to STP;

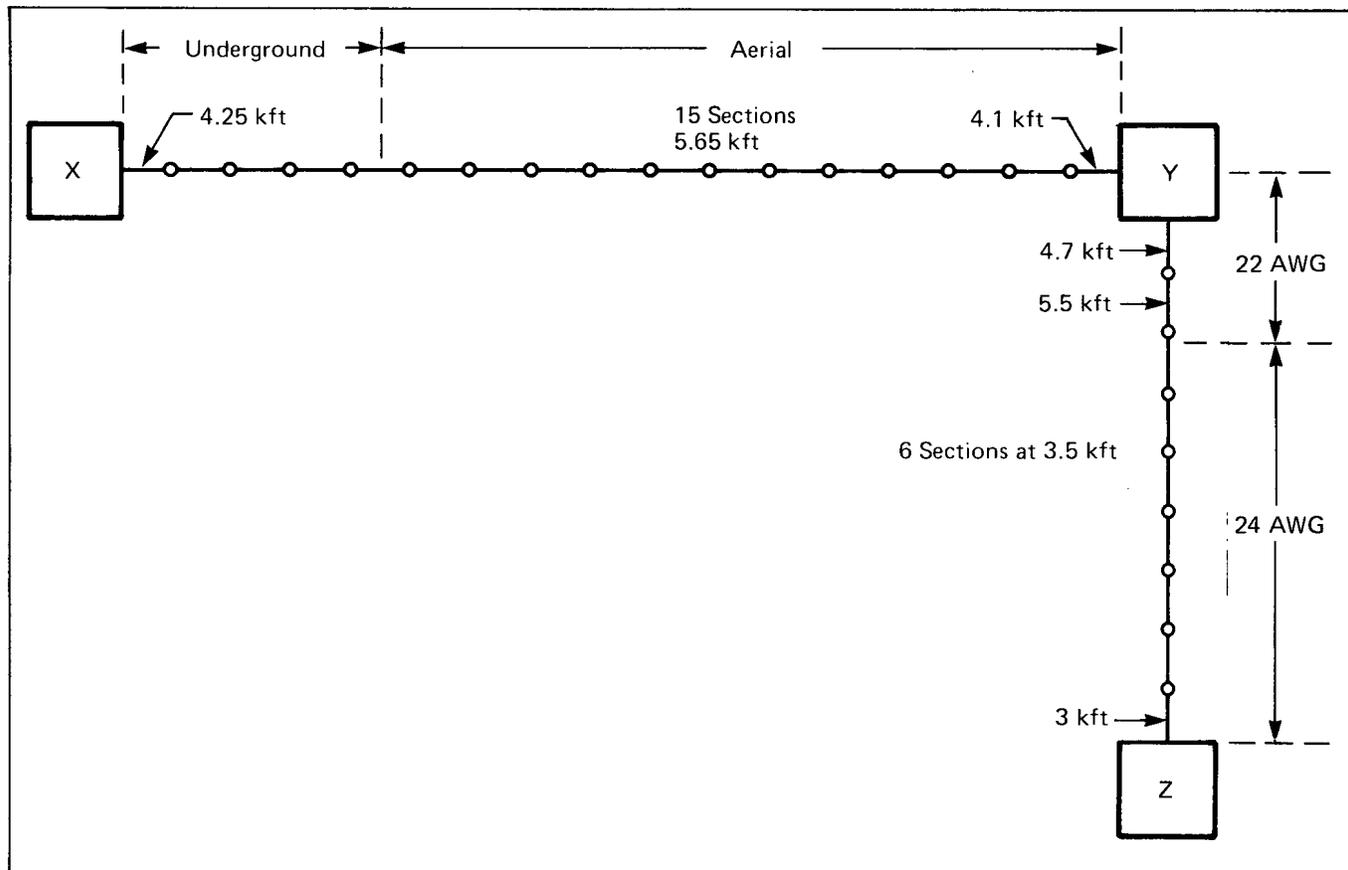|		
present	=	30
future	=	30
total	=	60.

Fig. 13 — Basic Line Design

Number of systems between STP and RCT:

present = 2
future   = 2
total   = 4.

Office Losses: 350 ft ABAY in main CO and DS1 hut (1.5 dB);
120 ft ABAY in RCT (0.5 dB);
3.0 dB repeater pad.

Cable Data

DSA NPL = 75 dB
  A = 81 dB
  L = 5.1 dB/kft

BHA NPL = 75
  A = 68
  L = 4.39 dB/kft

BKM NPL = 76
  A = 60
  L = 5.58 dB/kft.

Choosing the Section Length (Fig. 13)

10.02   The various section length maximums are derived from Table E. This information shows that a minimum of 16 line repeaters are required between the main CO (X) and STP (Y) for intermediate span lengths of 5650 ft with office sections of 4250 ft at X and 4100 ft at Y.

Similarly, since a minimum of 9 line repeaters are required between the STP (Y) and the RCT (Z), select an intermediate spacing of 3.5 kft on the 24 AWG cable (including the junction with 22 AWG), 5.5 kft on the 22 AWG cable, 4.7 kft at Y, and 3 kft at Z.

Line Repeater Selection

'A' type repeaters are required for single cable operation; QRY5A for the aerial sections plus the first underground repeater; QRY4A for the remaining sections.

Line Powering

10.03 *Determine Span Termination Points.* Since there are 26 sections between X and Z, an intermediate powering point is required. The STP (Y) is the logical location.

10.04 *Determining the Powering Required.* The effective dc resistance of span X-Y is:

24.4 kft, 22 AWG underground	= 409.9 ohms
68.7 kft, 22 AWG aerial	= 1257.2 ohms
13 QRY5A line repeaters	= 1224.6 ohms
3 QRY4A line repeaters	= 247.2 ohms
Total Effective Resistance X-Y	= 3138.9 ohms

The effective dc resistance of span Y-Z is:

13.1 kft, 22 AWG aerial	= 239.7 ohms
21.1 kft, 24 AWG aerial	= 616.1 ohms
8 QRY5A line repeaters	= 659.2 ohms
Total Effective Resistance Y-Z	= 1515.0 ohms

Power Looping Point

10.05 Note that X-Y requires a power looping point, Y-Z does not. Initially set the power looping point at the eighth repeater from office X. Since splicing is to be arranged so that office X transmits to side 1 of the line repeaters, the resistance of the power loop repeater is included in the power loop from office X.

Effective power loop resistance from office X is:

24.4 kft, 22 gauge underground	= 409.9 ohms
19.4 kft, 22 gauge, aerial	= 355.0 ohms
5 QRY5A line repeaters	= 471.0 ohms
3 QRY4A line repeaters	= 247.2 ohms
Total Effective Loop Resistance (X)	= 1483.1 ohms

Effective power-loop resistance from office Y is:

49.3 kft, 22 gauge, aerial	= 902.2 ohms
8 QRY5A line repeaters	= 753.6 ohms
Total Effective Loop Resistance (Y)	= 1655.8 ohms

Since the effective resistances of both power loops are within the allowable range (less than 2400 ohms), the choice of the power looping point is confirmed.

Order-Wire (Fig. 7 and 12)

The dc loop resistance of span X-Y is:

24.4 kft, 22 gauge, underground	= 819.8 ohms
68.7 kft, 22 gauge, aerial	= 2514.4 ohms
Total Loop Resistance	= 3334.2 ohms

For this value of loop resistance (2800 to 5600 ohms), a QPP302 span order-wire terminal is required at both ends of the span.

Also the loop resistance of span Y-Z is:

13.1 kft, 22 gauge, aerial	= 479.4 ohms
21.1 kft, 29 gauge, aerial	= 1232.2 ohms
Total loop resistance	= 1711.6 ohms

Therefore, a QPP302 span order-wire terminal is required at only one end of the span. At the other end a QPP304 may be used.

Splitting Capacitors

Initially set the splitting capacitors at the power looping point in span X-Y.

Loop resistance from office X is:

24.4 kft, 22 gauge, underground	= 819.8 ohms
19.4 kft, 22 gauge, aerial	= 710.0 ohms
Total Loop Resistance	= 1529.8 ohms

Loop resistance from office Y is:

49.3 kft, 22 gauge, aerial	= 1804.4 ohms

Since both loop resistances are less than the maximum of 2800 ohms, the choice of capacitor location is confirmed.

Extension to Direct Distance Dialing (DDD)

10.06 If Y provides a connection to the DDD network, it is possible to connect the order-wire system directly to the switch at Y. Otherwise, it is necessary to provide a 2- or 4-wire extension to some switch near to Y. Note that no special arrangements are required at Z, because the order wire at Z is powered from Y and connected to the DDD network at Y.

Fault Locate

10.07 In span X-Y, repeater locations are designated 1 through 18 starting at office X. A powered fault-locate system is needed not only because office Y is unattended but also to improve the signal-to-noise ratio.

10.08 A QPP300 is assigned to office X, a QFB91B at location 2, a QFB91C at location 3, through to a QPP300 at Y. Filters A through M at locations 1 through 12 are assigned high-voltage options, and locations 13 through 18 are assigned low-voltage options. The standard PN option on line filters allows testing of the line from X to Y (side 1) with positive-polarity powering and from Y to X (side 2) with negative-polarity powering.

10.09 Similarly in span Y-Z, repeater locations are designated 1 through 11 starting at Y. To facilitate fault location from Y or Z, a powered system is used here also to provide remote looping and improve signal-to-noise ratio.

10.10 As in span X-Y, a QPP300 is assigned at Y, a QFB91B at location 2, etc. All filters are assigned the low-voltage options.

11. USE OF DMS-1 WITH NON-LD-1 LINES

11.01 Although DMS-1 is optimized for operation with LD-1 lines, it may also be used with non-LD-1 lines, either terminating in a LD-1 or DMS-1 span termination shelf, or terminating in a non-LD-1 or non-DMS-1 span terminating shelf.

11.02 If terminated in a non-LD-1 or non-DMS-1 span terminating shelf, the DS1 line must be engineered, terminated, and maintained according to the manufacturer's instructions. The digital output from the line is then coupled to the DMS-1 digroup inputs, but note the restrictions in 4.07 and 4.08.

11.03 Where non-LD-1 line repeaters are used in the digital line an LD-1 or DMS-1 span termination shelf, the line repeaters must be compatible with LD-1 operation (e.g., 100 mA power feed). Ideally LD-1 apparatus cases with LD-1 filters should be used to allow maximum feasible fault-locate distance. If LD-1 apparatus cases and filters are not used, the fault-locate system may still work, but the range is reduced.

TABLE E
SYSTEM DESIGN EXAMPLE

End Section Design	A + X	A + Y (toward X)	A + Y (toward Z)
CO Losses (Cabling)	= 1.5 + 3.0 = 4.5 dB	= 15 + 3.0 = 4.5 dB	= 1.5 + 3.0 = 4.5 dB
Design loss for noise	L_D = (NPL − 52)/T_c + CO Losses = (75 − 52)/1.04 + 4.5 = 26.6 dB	= (75 − 52)/1.08 + 4.5 = 25.8 dB	= (75 − 52)/1.08 + 4.5 = 25.8 dB
Design Loss for crosstalk	L_D = (A − 10 $\log_{10}$ n − 32)/T_c = (81 − 10 $\log_{10}$ 60 − 32)/1.04 = 30.0 dB	= (81 − 10 $\log_{10}$ 60 − 32)/1.08 = 28.9 dB	= (68 − 10 $\log_{10}$ 4 − 32)/1.08 = 27.7 dB
Maximum design loss	L_D = 26.6 dB since noise is the most severe criterion	= 25.8 dB since noise is the most severe criterion	= 25.8 dB since noise is the most severe criterion
Allowable losses for main cable	= 26.6 − 4.5 = 22.1 dB	= 25.8 − 4.5 = 21.3 dB	= 25.8 − 4.5 = 21.3 dB
Maximum section length	l = 22.1/5.1 = 4.333 kft	= 21.3/5.1 = 4.176 kft	= 21.3/4.39 = 4.852 kft
Intermediate Section Design	Sections from office X for 23.5 kft	Sections from office Y for 67.7 kft	Sections from Y toward Z for 12.1 kft
Design loss for crosstalk	L_D = (A − 10 $\log_{10}$ n − 32)/T_c = (81 − 10 $\log_{10}$ 60 − 32)/1.04 = 30.0 dB	= (81 − 10 $\log_{10}$ 60 − 32)/1.08 = 28.9 dB	= (68 − 10 $\log_{10}$ 4 − 32)/1.08 = 27.7 dB
Maximum section length	l = 30.0/5.1 = 5.882 kft	= 28.9/5.1 = 5.667 kft	= 27.7/4.39 = 6.310 kft