Field trial

Fiber optics study

Optical systems division

Program definition study
of
fiber optics rural distribution trial

northern telecom

Field trial Fiber optics study

Queen

DOC-CTCA

PROGRAM DEFINITION STUDY

OF

FIBER OPTICS RURAL DISTRIBUTION TRIAL

CONDUCTED

BY

NORTHERN TELECOM

UNDER CONTRACT NUMBER

OSS 77-00096

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1. GENERAL

1.1 INTRODUCTION

The Department of Communications (DOC), in conjunction with the Canadian Telecommunications Carriers Association (CTCA), is currently examining the applicability and feasibility of using fiber optics technology to provide improved telecommunication services in the rural environment. To stimulate the design and development of practical systems, and to obtain more precise assessement of the various operational, technical and economical aspects of fiber optics distribution networks, a field trial has been proposed by DOC-CTCA in a typical rural setting for 1980 implementation. As a first step towards the launching of the trial proper, a program definition study was requested to provide an estimate of the total cost and duration, as well as a detailed management and implementation plan. This study has been conducted by Northern Telecom under a Federal Government Contract with the Department of Supply and Services. The objectives of the study, as established in the work statement issued by DOC in their request for proposal, are summarized below:

(1) To determine the form that a useful rural field trial of fiber optics technology should take.

(2) To estimate the total cost of the program.

(3) To recommend trial duration and schedules.

(4) To suggest management and implementation plans.

(5) To document the value of the trial.

(6) To develop a general business plan for the introduction of fiber optics distribution networks.

The contract was awarded to Northern Telecom on December 1, 1977 with a completion date scheduled for May 31, 1978. The study was conducted by a specially selected Bell-Northern Research (BNR, a subsidary of Northern Telecom) project team. Other Northern Telecom and BNR expertise was utilized on an as required basis. This arrangement ensured that all the tasks involved were completed within the contract duration.

1.2 STUDY METHOD

A summary of the work plan is given in Table 1.1.1. The study is divided into four parts with all the tasks in each part constituting a major milestone towards the completion of the study. Each part also represents a logical division for internal review. It should be noted that while the main thrust of the study was on the definition of the Field Trial, a considerable amount of effort was also devoted to the design and analysis of cost-effective and implementable fiber optics systems for the mid 1980's.

The study began by building up an information base ranging from general rural demographic statistics to specific data on subscriber locations at the Field Trial site. After analyzing these data, system concepts and network architectures that are candidates for 1985 introduction were evaluated in depth in order to arrive at the system configuration most suitable for the Field Trial. With an aim for 1980 implementation, design and engineering on both Outside Plant and equipment were carried out. Finally cost estimates and trial schedules were established, management and introductory plans proposed, and all the results documented in this report.

PART	DEFINITION	WORK ITEMS	
1	INFORMATION BASE	1.1	Analyze Field Trial Site
		1.2	Define service requirements
		1.3	Establish performance objectives
		1.4	Characterize Canadian rural environment
		1.5	Review state-of-the-art of technology
		1.6	Survey other existing and proposed field trials
2	NETWORK ANALYSIS	2.1	Determine transmission capability
		2.2	Study different network topologies
		2.3	Develop selection criteria
		2.4	Perform distribution network modelling
		2.5	Evaluate system design options
3	TRIAL STUDY SPECIFICATION	3.1	Establish Trial System configuration
		3.2	Determine equipment location
		3.3	Estimate power and space requirements
		3.4	Develop Outside Plant route layout
		3.5	Develop cable and outside plant hardware specifications
		3.6	Develop equipment specifications
4	OUTPUT GENERATION	4.1	Produce Field Trial management plans
		4.2	Produce implementation schedules
		4.3	Produce equipment summary
		4.4	Produce total cost estimate and breakdown
		4.5	Project Canadian rural market
		4.6	Determine introduction strategies

TABLE 1.1.1

BREAKDOWN OF WORK ITEMS

1.3 SCOPE AND STRUCTURE OF REPORT

The report is structured such that each output requirement stated in the study objectives listed under Section 1.1 forms an individual section. The substantial amount of data and intermediate output produced in the course of the study have been condensed and are presented in tables and figures.

Briefly, Section 2 discusses the process used in determining the system configuration applicable in the 1985 time frame for rural areas. Section 3 contains a system and equipment description and assesses the technical value of the Field Trial System. In Section 4, recommendations are presented on program management, implementation schedules, operation and maintenance plans. The total cost of the Field Trial is estimated in Section 5. Section 6 addresses the longer term aspects such as cost effectiveness, market size and introduction strategies. Some of the more important intermediate results are included in the Appendices.

1.4 BACKGROUND INFORMATION

A few items are worth mentioning here to put the study in the proper perspective:

(1) In a previous DOC contract awarded to BNR, an extensive systems engineering study was conducted to identify and develop system concepts and methodologies for using fiber optics to deliver broadband services [1]. The output and expertize resulting from that study were of considerable value to the present study.

(2) The site of the Field Trial (Elie, Manitoba) was pre-determined by DOC-CTCA before the start of the study. Thus detailed engineering was undertaken based on data on the Elie Exchange supplied by the Manitoba Telephone System (MTS). While the proposed system configuration is sufficiently flexible to accommodate other trial sites, a change in location would require the Outside Plant engineering to be repeated.

(3) An understanding was reached between Northern Telecom and DOC-CTCA that the cost figures presented in this report do not constitute a budgetary quotation for the development, manufacture and installation of the Field Trial System.

(4) It was also agreed that Phase 1 of the Field Trial would serve 10 rural subscribers located to the north of the town of Elie. For Phase 2, 140 additional subscribers in the same exchange area would be selected with the assistance of MTS. Cost estimates were based on the assumption that both phases of the Field Trial constitute a single program.

(5) It was agreed by DOC-CTCA that business plans would be studied from the operating company point of view.

2

2. DETERMINATION OF FIELD TRIAL FORM

2.1 RURAL DEMOGRAPHIC AND TELEPHONE EXCHANGE CHARACTERISTICS

To achieve maximum benefits from performing the Field Trial, it is important that the proposed system should approximate as closely as possible the preferred configuration for 1985 introduction. Thus the first step taken in determining the Field Trial form was to establish the best topology of fiber based distribution networks for the delivery of integrated voice, video and data services. In this respect, demographic and geographic data on the rural population of Canada were assembled and analyzed [2] [3]. Moreover, details of existing telephony services including exchange boundaries and distribution patterns were used [3] [4] to reach a good understanding of the capabilities and limitations of the current local distribution networks. These statistics, which were processed at the beginning of the study period, are summarized in Tables 2.1.1 to 2.1.4. Emphasis was placed on the Prairie Provinces where the problems of providing good telecommunication services are more acute because of their lower subscriber densities. Table 2.1.4 compares Elie with 46 other rural exchanges in MTS.

The following findings were reached from the information received:

(1) In 1971, 28.6% of the total Canadian population resided in rural areas (defined by Statistics Canada to mean a population density of less than 390/km^2). By 1974 the percentage was reduced to approximately 23% as a result of urbanization.

(2) In 1971, rural household densities ranged from a low of 0.39/km^2 in Saskatchewan to a high of 3.1/km^2 in Nova Scotia. The national average was approximately 1.0 with the Prairie Provinces at 0.5. The average area served by a rural exchange was 844 km^2 in the Prairies, which was 20% above the national average. Manitoba was characterized by smaller exchanges (509 km^2) as compared with Saskatchewan (949 km^2) and Alberta (983 km^2).

(3) More than 90% of the rural households have TV and telephone service. The number of multi-party lines has been decreasing since most telephone operating companies launched their rural improvement programs to provide better POTS (Plain Ordinary Telephone Service) in the late 1970's. For example, the number of multi-party lines in Manitoba will be reduced from 47,000 in 1976 to 22,500 by 1981 resulting in an average of only 2.8 subscribers per line.

(4) Most of the rural telephone exchanges (particularly in the Prairie Provinces) are characterized by a single analog switcher located in the main community (town) which contains the base rate subscribers, one or more remote communities (referred to in this report as villages) and the rural subscribers scattered throughout the exchange area. These remote communities form island base rate pockets which can receive the same service as the exchange base rate areas. The average number of communities per exchange in the Prairie Provinces was 1.74 in 1971.

(5) Except for the areas close to the U.S. border, less than five broadcast channels can be received. Also very few of the rural households were within CATV licensed areas in 1976.

PROVINCE (1)	RURAL POPULATION	PERCENT OF TOTAL POPULATION	NUMBER OF RURAL HOUSEHOLDS	HOUSEHOLD DENSITY PER km^2
NEWFOUNDLAND	276244	52.9	57434	1.4
NOVA SCOTIA	372916	47.3	97630	3.1
NEW BRUNSWICK	335430	52.9	79291	2.3
PRINCE EDWARD ISLAND	74020	66.3	18837	3.4
QUEBEC	1465640	24.3	331895	1.9
ONTARIO	1838060	23.9	491485	1.6
MANITOBA	299910	30.3	78997	0.74
SASKATCHEWAN	468380	50.6	118995	0.39
ALBERTA	387830	23.8	111758	0.47
BRITISH COLUMBIA	639355	29.3	179590	0.90
TOTAL OF 10 PROVINCES	6157785	28.6	1565912	1.0

TABLE 2.1.1

RURAL POPULATION DISTRIBUTION BY PROVINCE IN 1971

NOTES:

(1) The numbers given only covers the Rural Study Area as defined by the Rural Communication Program Department of DOC and does not include the remote areas in each province.

PROVINCE	PERCENT OF HOUSEHOLD WITH TV IN 1971	PERCENT OF HOUSEHOLD WITH TELEPHONE (1) IN 1976	NUMBER OF EXCHANGE WITH 5000 POPULATION OR LESS IN 1976	NUMBER OF RESIDENTAL SUBSCRIBERS (4 OR MORE PARTY LINE) IN 1971	AVERAGE AREA OF EXCHANGE IN km^2 IN 1976
NEWFOUNDLAND		45.1	149	4250	264
NOVA SCOTIA		109.8	115	36037	274
NEW BRUNSWICK		84.5	70	28027	495
PRINCE EDWARD ISLAND		68.7	25	9286	224
QUEBEC	96.7	107.9	438	98670	395
ONTARIO	95.4	95.9	509	129808	624
MANITOBA	86.5		204	47000	618
SASKATCHEWAN	89.7		315	67000	965
ALBERTA	88.0		235	70000	1135
BRITISH COLUMBIA	86.0	94.0	233	67284	860
TOTAL		94.0	2241	557371	669

TABLE 2.1.2

RURAL TELECOMMUNICATION SERVICE STATISTICS BY PROVINCE

NOTES:

(1) The percentage exceeds 100 in some provinces because of households with more than one residence (cottages and chalets).

STATISTICS (1)	MANITOBA	SASKATCHEWAN	ALBERTA	TOTAL PRAIRIE
TOTAL POPULATION	243580	419115	347680	1010375
NUMBER OF COMMUNITIES	305	585	400	1290
NUMBER OF TELEPHONE EXCHANGES	194	320	226	740
NUMBER OF LINES	67454	110469	134862	312785
LAND AREA IN km^2	98811	303808	222076	624695
POPULATION DENSITY PER km^2	2.47	1.38	1.57	1.62
HOUSEHOLD DENSITY PER km^2	0.74	0.40	0.45	0.50
AVERAGE EXCHANGE AREA IN km^2	509	949	983	844
COMMUNITIES PER EXCHANGE	1.56	1.83	1.77	1.74
SUBSCRIBERS PER EXCHANGE	509	502	754	584

TABLE 2.1.3

RURAL EXCHANGE STATISTICS ON THE PRAIRIE PROVINCES IN 1971

NOTES:

(1) The numbers given only covers the Rural Study Area as defined by the Rural Communication Program Department of DOC and does not include the remote areas in each province.

EXCHANGE NAME	SPECIAL FEATURE	AREA SIZE IN km2	NO. OF SUBSCRIBERS		DENSITY PER km2		LONGEST DISTRIBUTION LENGTH IN km
			RURAL	TOTAL	RURAL	TOTAL	
ELIE	TRIAL SITE	378	219	452	0.58	1.24	24.4
STEPHENFIELD	MOST DENSE	755	233	246	1.04	1.09	17.6
WOODRIDGE	LEAST DENSE	666	82	144	0.13	0.21	28.8
VITA	LARGEST	1265	463	593	0.37	0.52	40.0
WANDERS	SMALLEST	38	33	70	0.86	1.82	8.0
AVERAGE			233	576	0.45	1.02	

TABLE 2.1.4

RURAL EXCHANGE STATISTICS ON 46 WIRE CENTRES IN MTS IN 1977

2.2 CHARACTERISTICS OF TRIAL SITE

Elie was selected by DOC-CTCA as the site to conduct the Field Trial. The exchange is in the southern part of Manitoba, covering an area approximately 26 km by 14 km for a total area of 378 km^2. The town (also named Elie), where the Community Dial Office (CDO) is located, is 48 km west of Winnipeg, on both the Trans-Canada Highway and Canadian National Railway (see Figure 2.2.1). Figures 2.2.2 and 2.2.3 shows the CDO and the downtown district in Elie. More detailed information on the exchange can be obtained in Appendix A.

In 1976, the exchange was upgraded to provide single-party service beyond the base rate area (town of Elie) to the island base rate area (village of St. Eustache 10 km north of Elie). Multi-party service in the rural areas was improved in the same year to 4-party lines or better. The exchange population was approximately 1000 in 1977 with 372 in Elie, 344 in St. Eustache, and the rest in the rural region, which is serviced by grid roads (1.6 km apart) running both N/S and E/W throughout the exchange. Most of the support service industries which include grain elevators, farm equipment dealers, garages, restaurants, banks, a high school, a senior citizens home and an office of the legion, are located in the town itself. In addition, Elie, because of its proximity to Winnipeg, has become increasingly popular as a residential community for commuters working in Winnipeg. Because of this, Elie is one of the few rural exchanges in Manitoba that will experience a very high growth rate in the next decade. A summary of the major characteristics of the exchange is given in Table 2.2.1

The geographic environment of this part of Manitoba, commonly referred to as the Red River Valley, consists mainly of deep, boulder free clay-silt soil. The area is extremely flat; the change in elevation across the entire exchange area is less than 2.4 metres. The road borders are predominantly flat, free of fences and tree shrubs, and thus offer excellent terrain for Outside Plant installation by plowing. The only major river is the Assiniboine River in the northern part of the exchange. Most existing Outside Plant is either buried or aerial, with a majority of the new constructions being buried.

The CDO is located in a single-storey building approximately 8 m by 10 m, which houses a Northern Telecom SA-1 switching machine installed in the early 1970's. The building is quite congested with very little room for additional equipment, but a building extension is planned for the summer of 1978 which will double the amount of usable space. There is no cable vault and existing copper cables are terminated within an enclosure (1.3 m by 1.3 m by 2.3 m) on the same floor. A Northern Telecom CDF (Combined Distributing Frame) is utilized for all line and trunk terminations.

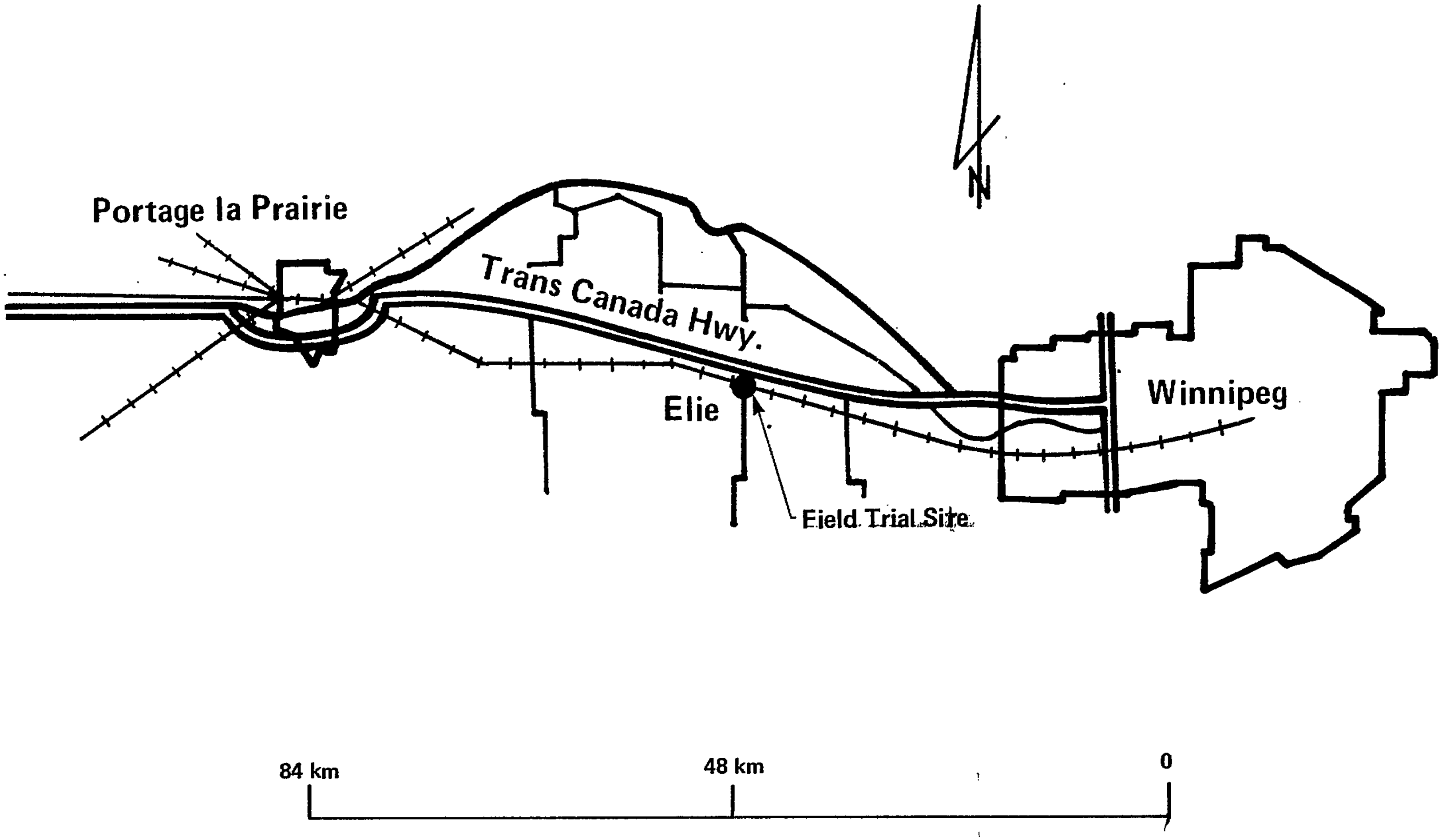

Figure 2.2.1 Location of Field Trial Site

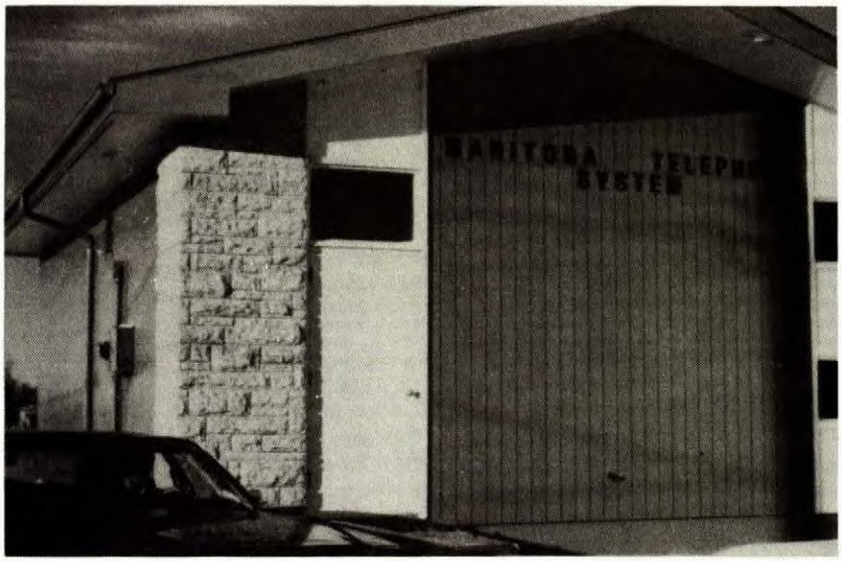

Figure 2.2.2 Community Dial Office in Elie

Figure 2.2.3 View of Downtown Elie

	TOWN OF ELIE	VILLAGE OF ST. EUSTACHE	RURAL AREA	TOTAL EXCHANGE
SIZE IN km^2	.62	.72	376.9	378.2
SUBSCRIBER DENSITY PER km^2	281	121	.58	1.20
NO. OF SUBSCRIBERS	146	87	219	452
SUBSCRIBERS PER LINE	1	1	2.8	1.5
STATIONS PER SUBSCRIBER	1.5	1.5	1.2	1.35
LONGEST DISTRIBUTION LENGTH FROM CDO IN km	1.1	10.6	24.4	-
PERCENT HOUSEHOLD WITH TELEPHONE	88	75	97	89
PROJECTED PERCENT HOUSEHOLD WITH TELEPHONE IN 1982	94	83	97	93
PROJECTED NUMBER OF SUBSCRIBERS IN 1982.	368	105	250	723

TABLE 2.2.1

EXCHANGE CHARACTERISTICS OF FIELD TRIAL SITE IN 1977

2.3 SERVICE AND PERFORMANCE REQUIREMENTS

An important factor in the determination of the network topology most suitable for an integrated fiber system lies in the service and performance requirements on future local broadband networks. Inclusion of the capability to provide all potential voice, video and data services would impose unrealistically severe economic penalties during initial installations. This is particularly true for the rural areas, where the quality and level of existing telecommunication services lag behind those in the urban/suburban areas.

In order to come up with a reasonable criterion, an approach illustrated in Figure 2.3.1 was adopted for evaluating these requirements. A service package on type and level was first derived based on the telecommunication needs of the rural environment. From these findings, the format and quality of the services were analyzed taking into consideration the simplicity and compactness of hardware at the subscriber premises, source management and administration, and, most important of all, the capability and transmission characteristics of the fiber link. As a bottom line performance objective, the integrated fiber network is required to equal or exceed the current telephony and CATV networks in terms of availability, maintainability, and grade-of-service.

To arrive at the type and level of service for the Field Trial, the services fundamental to the implementation of rural fiber optics distribution system were selected in consultation with MTS. Table 2.3.1 outlines the service and performance requirements for both Phases 1 and 2 of the Field Trial. Since the configuration of the proposed Field Trial System would dictate, to a large extent, the capability and flexibility of the many services that can be tested and evaluated, the numbers quoted should be viewed as the minimum requirements.

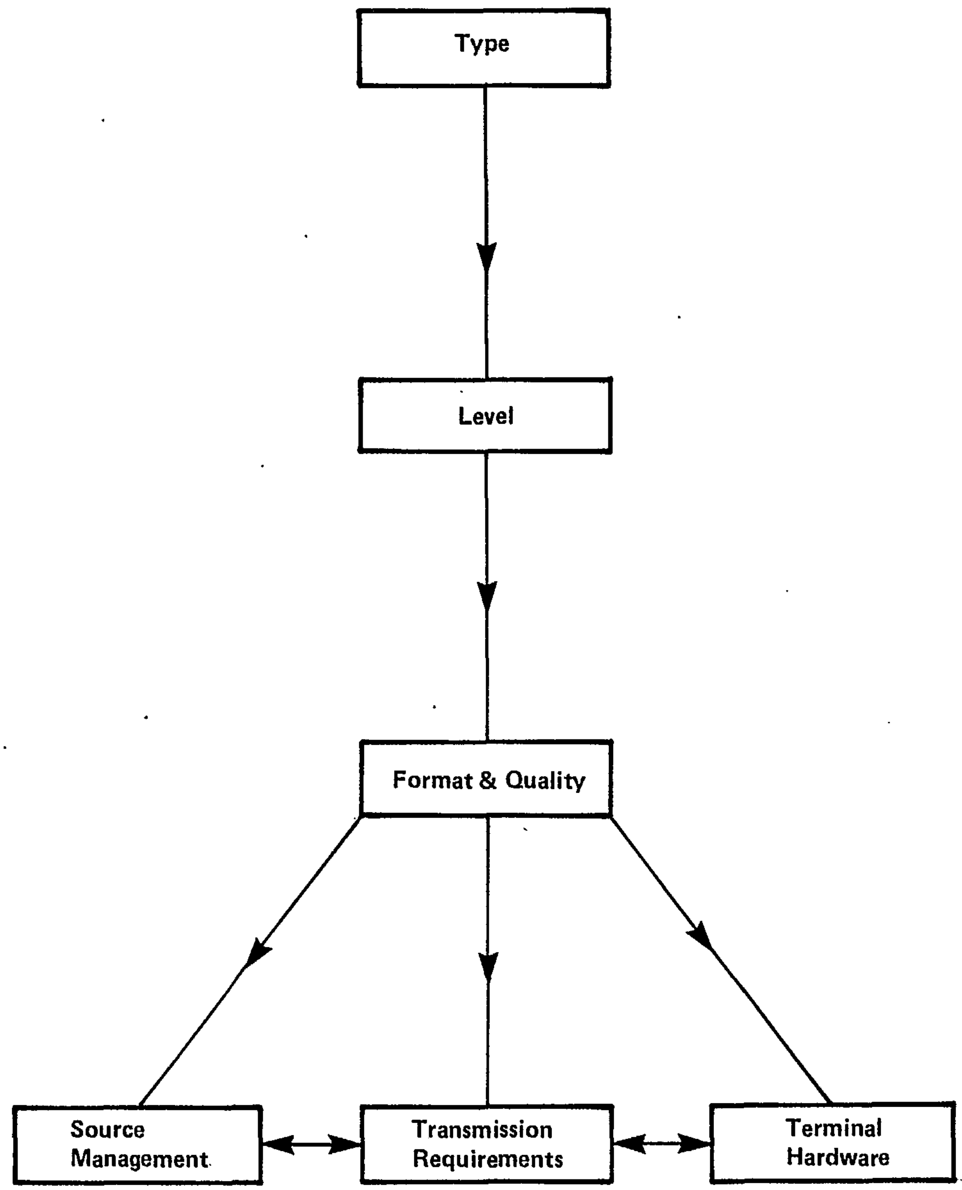

Figure 2.3.1 Approach to the Determination of Service and Performance Requirements

	MINIMUM SERVICE LEVEL			PERFORMANCE
TYPE	PHASE 1	PHASE 2	OPTIONAL	REQUIREMENTS
TELEPHONY	SINGLE PARTY POTS		SPECIAL SERVICES	NOISE 20 dBrnc LOSS 0 to 8 dB
FM STATIONS	-	3	FULL BAND	DOC BP 23
CATV	5	9 or 12	PAY TV VIDEO LIBRARY	DOC BP 23
DATA	-	9.6/kb/s	56 kb/s	BIT ERROR RATE 10^{-5}

TABLE 2.3.1

FIELD TRIAL SERVICE AND PERFORMANCE REQUIREMENTS

2.4 NETWORK CONFIGURATION OPTIONS AND SELECTION

The purpose of this section is to identify the network configurations suitable for the implementation of integrated fiber optics distribution systems in the 1985 time frame. Selection criteria were developed and the relative merits of the various configurations compared. Based on these findings, plus information already obtained in Sections 2.2 and 2.3, the system configuration proposed for the Field Trial was selected.

Based on information on the serving areas of rural telephone exchanges (Section 2.1), analysis indicated that none of the system configuration considered is capable of serving all of the subscribers from one central distribution point. Consequently a network topology consisting of remote distribution points (or centres) with trunking from the central office or program centre is considered in all cases. With that assumption the following network configurations were considered for the distribution portion of the network from these central or remote points out to the subscribers:

(a) STAR

This network configuration, which is characteristic of most telephone systems, utilizes a dedicated connection between each subscriber and the distribution centre. It is important to note that the configuration is defined here in terms of the type of connection and not the physical medium. One variation of the star, for example, attempts to reduce the fiber volume by using Wavelength-Division Multiplexing to combine the dedicated signals for each subscriber on a common fiber and route them to the proper subscriber at the other end. Such a system physically resembles a tree structure but actually provides a star connection. Two distinct implementations of the star network were considered. In the non-switched star each subscriber is supplied with all of the available video signals simultaneously. In the switched star only a selected number of TV channels (typically one to three) are transmitted to a particular subscriber, with the access to a large number of available channels being provided by a video switch. In both cases the telephone signals are provided on a conventional switched basis. Because of the large number of independent circuits required for the star systems, no repeaters beyond the distribution point are considered.

(b) TREE

In the tree configuration which is generally used in present coaxial CATV networks, a common signal containing all of the available channels is fed from the distribution centre and tapped by many subscribers. In an integrated distribution system, some method of sharing the common channel must be devised for provision of bidirectional services such as telephony and data. As tree structures must simultaneously carry a large number of video channels and must divide the optical power among a number of subscribers, the maximum distribution length without repeaters is very short (See Appendix B). Because of this and the fact that field repeater costs would be shared among many subscribers, field repeaters have been assumed for the tree configuration.

(c) RING

The ring structure, which has been considered for telephony, uses a closed unidirectional loop to serve a number of subscribers. The subscriber taps off the desired channel and inserts his output signal in the same loop. To avoid complete loss of service in case of line failure, a system with two rings whose signals are circulating in opposite directions is preferred. In case of a line failure, the nearest repeaters loop back their signals, thus maintaining service to all subscribers.

In an integrated ring distribution system, since each subscriber receives the same video signals, all the channels must be transmitted simultaneously. To achieve any reasonable serving range, the signal might have to be repeated at each subscriber's location. For a dual ring this would require two complete optical repeaters per subscriber.

The factors considered in the selection of the most suitable network topology for integrated distribution in a rural environment were: reach, suitability for telephony, flexibility and growth, minimum field electronics and capital cost. Each factor was considered for the three network topologies identified earlier in this section.

(1) REACH

The network configuration dictates the number of video channels to be transmitted and therefore, for a given technological scenario, the maximum achievable distribution distances. This is a critical factor in the low density rural areas since it determines the number of subscribers who share the cost of a remote distribution centre. The comparisons which follow are based on the provision of 12 CATV channels.

The switched star yields the longest distribution lengths, up to 10 km with 1985 components and more than 5 km with 1980 components. These lengths could be doubled by the use of modulation methods such as FM or PCM that permit the trade-off of bandwidth for reach. However, all these modulation schemes require an extra stage of modulation at the subscriber premises. Since it is shown in Section 6.1 that the overall network cost is minimized for a reach of 6-10 km, these modulation techniques are not recommended.

In the non-switched star all of the available signals must be simultaneously transmitted to each subscriber. For a 1985 system the maximum length is 3.7 km; for 1980 the reach is only 1.6 km and therefore is not considered practical in the rural environment. In the case of a tree, the distance between repeaters is shorter than the reach of the non-switched star because of noise accumulation in multiple repeaters and the need to share the optical power among several subscribers. For the low density rural situation one repeater per subscriber may be required. Greater repeater spacing may be achieved by using a parallel sub-feeder to avoid tapping the main feeder, but this would substantially increase the cost. Even though the repeater spacing is short, the total reach with tandem repeaters is comparable with that of the switched star. The ring would have nominally the same reach as the tree, as the return path to the distribution point from the farthest subscriber would carry only non-video signals.

(2) SUITABILITY FOR TELEPHONY

Telephone service demands very high availability and security. Star networks are compatible with these requirements because a dedicated channel is provided to each subscriber. For example, a broken fiber isolates only one subscriber and no subscriber receives signals intended for another. In a tree network numerous subscribers can be isolated by a single-fiber failure. Moreover, since the telephone (and data) signals for all subscribers are transmitted through each subscriber's home, unauthorized access would be relatively simple. In the ring configuration, use of a dual ring overcomes the availability problem but increases the cost. Security is even more of a problem with the ring since both directions of transmission are available in each subscriber's unit.

(3) FLEXIBILITY AND GROWTH

When analyzing the various configurations, it is important to consider the capability to provide for growth and customer movement as well as expansion of services during the operating life of the system. Examples for the latter are Pay TV and visual library services.

In a star configuration provision for growth and movement requires spare fibers in the fiber cables, which is standard practice in the telephone industry. Since the spare optical fibers represent a small fraction of the total installed cost of the cable, the impact on the overall cost is small. Tree and ring configurations on the other hand require spare capacity for telephone transmission plus additional margin for video to allow for more tapping or additional repeaters. This shortens the system reach and may cause performance degradation to existing subscribers when new subscribers are added. On the other hand, a star network can maintain constant performance as a dedicated fiber is utilized between each subscriber and the distribution centre.

Increasing the number of channels in a switched star is simply a matter of growing the video switch. In the non-switched star, tree, or ring configuration, increasing the number of available video signals reduces the maximum distribution distances or repeater spacings and could require reconfiguration of the network. The balance shifts further in favour of the star configuration as the total number of channels is increased.

(4) MINIMUM FIELD ELECTRONICS

The rural environment is characterized by long distances, extreme environment and a thinly manned maintenance force. From a system maintainability viewpoint it is important to minimize the amount of field electronics, particularly equipment such as line repeaters, which are not located in the remote distribution point. The increased costs associated with widely distributed electronics would substantially increase the system life cycle cost. The switched star, by virtue of its longer reach, has fewer remote distribution centres than the non-switched star. Both are superior to the tree and the ring in that no line repeaters are required.

(5) CAPITAL COST

Using component count methods the switched star might appear to have a higher capital cost than the tree configuration by virtue of the costs of video switching and the increased volume of optical fiber. However, as discussed in Appendix C, the projected cost of video switching is quite low. Since the sheath and placement costs are expected to dominate the total cable cost as the volume of fiber production increases, the larger fiber cables associated with the star configuration are not a significant drawback. Preliminary analysis indicates comparable costs between a switch star and a tree for rural areas.

The relative merits of the various configurations are summarized in Table 2.4.1 based on the factors identified above. The symbols of +, 0 and - used are intended to provide a comparative evaluation of the configurations involved. Thus a '+' sign indicatives clear advantage over the other configurations while a '-' sign should be viewed as distinct disadvantage. The switched star configuration appears to be most favorable and is therefore the proposed configuration for the Field Trial.

For an integrated rural distribution system it is very desirable that field repeaters be avoided by locating any required trunk repeaters in the remote distribution centres. This requires a maximum repeater spacing of the order of twice the maximum distribution lengths. From the information presented in Appendix B, such repeater spacing results in the transmission of one video channel per fiber using wideband Frequency Modulation or Digital PCM. Digital transmission has the advantage of better performance which is relatively independent of the length of the trunking system, as well as slightly longer repeater spacing. Its disadvantage is that the terminal costs are substantially higher at present. It is likely that digital trunking will eventually be more attractive when costs are reduced because of technological advances or when the broadcast facilities (cameras, video tape recorders and transmission equipment) become digital.

SELECTION CRITERIA	SWITCHED STAR	NON-SWITCHED STAR	TREE	RING
REACH	+	-	0	0
SUITABILITY FOR TELEPHONY	+	+	-	0
FLEXIBILITY & GROWTH	+	-	-	-
FIELD ELECTRONICS	+	0	-	-
CAPITAL COST	+	0	+	-

TABLE 2.4.1

COMPARISON OF NETWORK CONFIGURATIONS

3

3. FIELD TRIAL SYSTEM SPECIFICATION

3.1 FIELD TRIAL SYSTEM CONFIGURATION

This section describes the system configuration for the proposed Integrated Fiber Optic Rural Distribution Trial to be implemented in Elie, Manitoba. The Field Trial will be conducted in two phases. The first phase, which will begin in the summer of 1980, will provide integrated voice and video as well as the capability of data services to 10 rural subscribers North of the town of Elie. Initially single party telephone service and 5 downstream CATV channels will be provided although the proposed system is capable of accommodating up to 30 channels on a switched basis at a small incremental cost. In Phase 2, 140 subscribers from the same exchange will be added. Seventy five will be served from Elie and 75 from a remote distribution centre (RDC) located near St. Eustache. Service would also be increased to 12 CATV channels plus 3 FM stereo signals. In both phases equal services can be provided to all subscribers.

The service integrated fiber optics distribution system will be overlaid onto the existing copper based system. Such an approach will minimize disturbance to the existing telephone service as well as providing full service protection against failure of the fiber link without requiring complex protection switching schemes. It also simplifies restoral to the original mode of service upon termination of the Field Trial Program.

Consideration was given to the possibility of combining the fiber and copper plants into a single network for the Field Trial, using the existing copper pairs mainly as switched-in backup for the subscriber fiber links during testing or in the infrequent events of failures. However, to include subscribers currently receiving multi-party service in the Field Trial in which they will be given single-party, several technical as well as operational problems have to be resolved. The technical difficulties arise because multi-party plant cannot be used to backup single-party plant without substantial upgrading of the multi-party plant itself. The operational problems are even more serious and include problems with directory-number assignments, ringing codes and billing. In view of these difficulties and the resulting inconveniences caused to the subscriber, the use of integrated copper back up is not recommended for the Field Trial.

The transmission plan for the Field Trial System will utilize digital trunking for telephony, between the CDO and the RDC, using separate fibers for each direction. No intermediate repeater is required. For video, both digital (PCM and DPCM) and analog (FM) trunking schemes can reach the RDC (8 km from the CDO) without field repeater. Since either approach would not affect the quality of signal to the subscribers, the specific format to be adopted would be left as an option to DOC-CTCA. Bi-directional transmission to the subscriber is accomplished using a baseband digital scheme for voice, data and signaling and an analog downstream video channel operating at either channel 2 or 3 of the VHF band. The overall Field Trial configuration for both phases is depicted in Figure 3.1.1. A number of features should be noted:

(1) Extensions of the switch, power, and distribution frame are required in the Community Dial Office (CDO).

(2) It is recommended that all equipment at the Field Trial Centre which is not useful after completion of the Field Trial should be located in a trailer. However, there is adequate space in the CDO to house the equipment should MTS decide against the trailer. (A trailer has been considered in the following sections.)

(3) The Display Centre located in one end of the trailer is an aesthetically designed, comfortably furnished room for demonstration of the Field Trial System to visitors. It contains a colour television set, an FM stereo receiver and two telephone sets, one serviced by the Field Trial System, the other connected to conventional copper plant.

(4) Power for equipment in the trailer is supplied from the power plant located in the CDO.

(5) CATV signals are obtained from the Inter City Broadband Network (ICBN) and from an antenna system located at the Field Trial Centre.

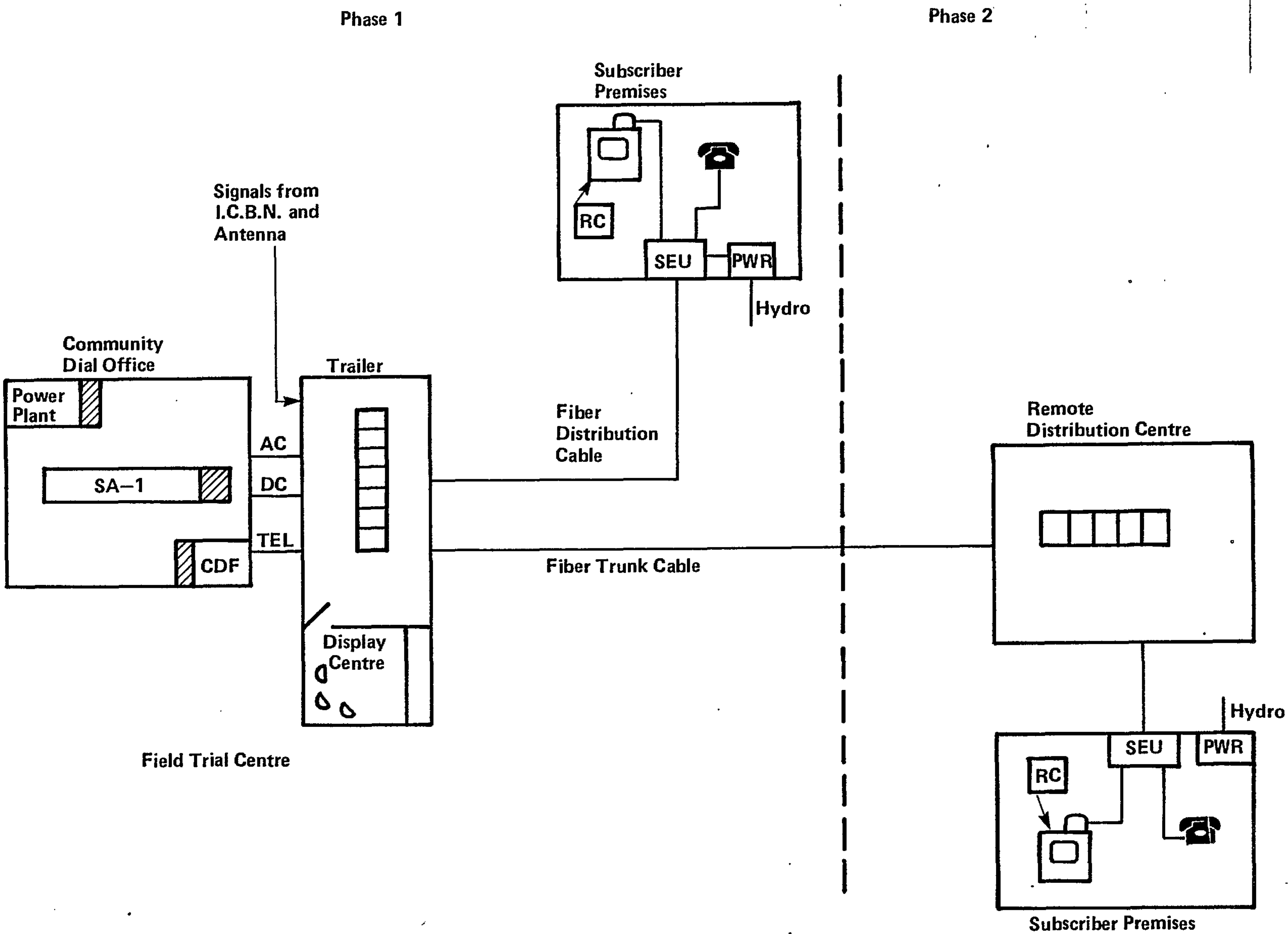

Figure 3.1.1 Field Trial Overall System Layout

(6) A single fiber connects each subscriber to the distribution centres; telephony is accomplished using bidirectional transmission.

(7) In Phase 2 a Remote Distribution Centre (RDC) is added which provides remote video and telephone switching. The RDC can be either in a trailer or a hut, depending on the preference of MTS. (A trailer has also been assumed in the following.)

(8) Power to the RDC is supplied from local hydro with battery backup.

(9) Trunks are required to connect the RDC to the Field Trial Centre.

Figure 3.1.2 is a more detailed functional diagram, to which the following notes apply:

(a) In the Field Trial Centre, the CATV signals are frequency converted to form a multi-channel FDM signal by the Program Centre equipment.

(b) In the Integrated Line Interface Unit (ILIU) the CATV signal is switched so that only one channel is transmitted at low VHF by intensity modulation to each subscriber.

(c) Switching is accomplished in the frequency domain with a frequency convertor which is remotely controllable by the subscriber. Up to 30 channels may be provided with only the addition of the extra head-end equipment and additional trunking equipment for subscribers served from the RDC.

(d) Asynchronous digital transmission using a Time-Division Multiplexed packet provides telephone transmission, TV control signalling and data communication to the subscriber's home.

(e) The problem of reflections of the transmitted signal from splices and connectors interfering with the received signal is avoided by operating in a half duplex burst

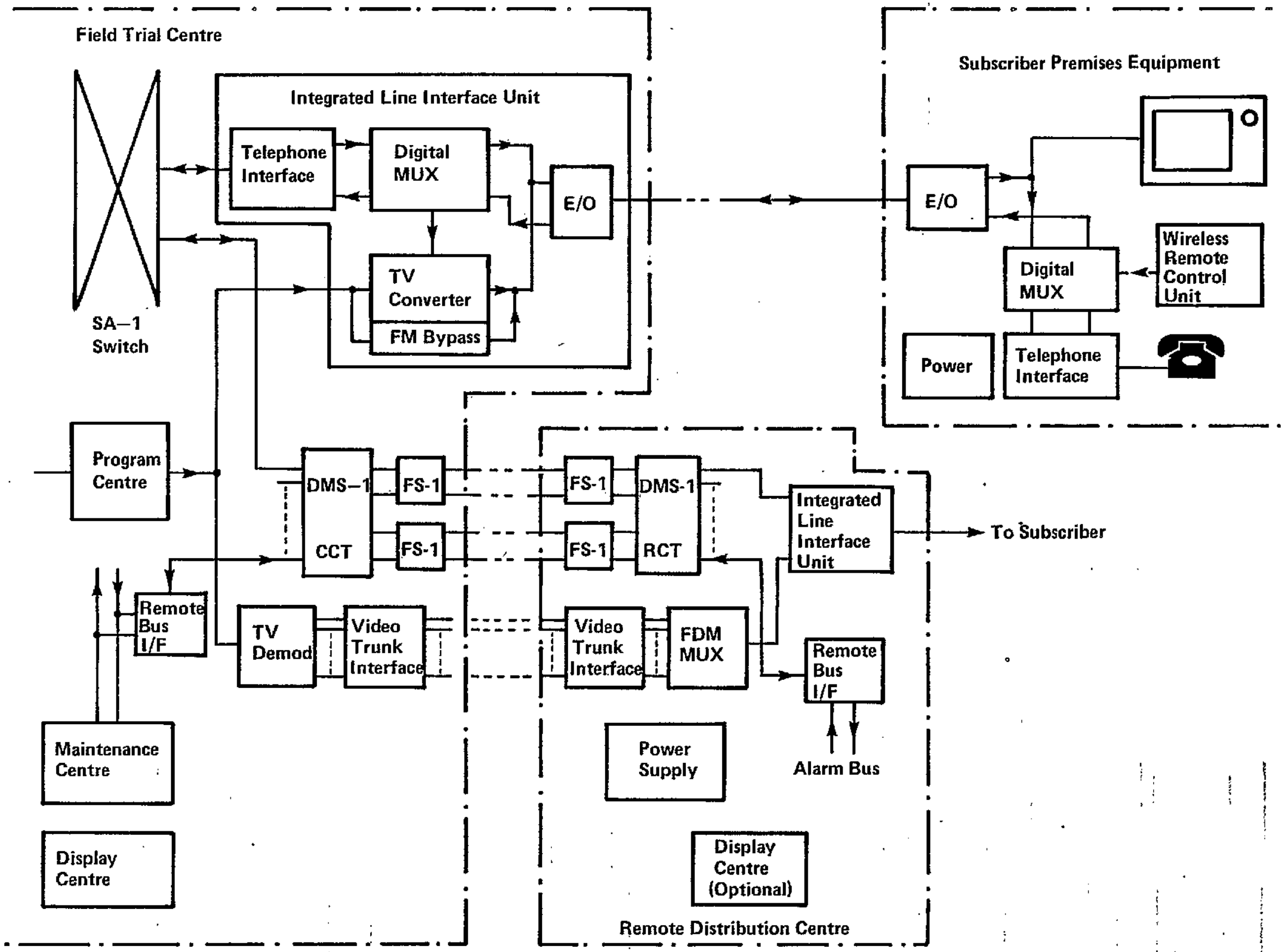

Figure 3.1.2 Functional Block Diagram of Field Trial System

(ping-pong) mode with the fiber being time-shared between upstream and downstream transmission.

(f) The Maintenance Centre monitors and displays the status of the line units for light source failure or loss of continuity to the subscriber circuit. Transmission of status information to a teletype in Winnipeg will be provided to allow for remote monitoring.

(g) The Subscriber Entrance Unit (SEU) is locally powered from the hydro with backup to provide service continuity up to 8 hours (higher if desired) in case of a hydro failure. Both the Subscriber Entrance Unit and the Power Supply Unit would be mounted inconspicuously near the hydro entrance (refer to Figure 3.1.3 for a detailed block diagram of the subscriber premises equipment).

(h) The telephone station will be a modern push button set which can be used at any one of 4 outlets located at the choice of the subscriber.

(i) TV channel selection is by means of a cordless hand-held, Remote Control Unit.

(j) In Phase 2, the telephone switch is extended to the RDC by means of the Northern Telecom DMS-1 digital subscriber carrier system (see Appendix E for detailed description) transmitted over the DS-1 digital Fiber Optic Transmission System (referred to as FS-1 in figure 3.1.2). Two independent digital trunks are provided for reliability. Television signals can be transmitted on the trunk by FM modulation using the Northern Telecom RM-3 FM modulator (refer to Appendix F) or by digital PCM.

(k) The Remote Bus Interface provides extension of the maintenance bus to the RDC. In addition to collecting status information this bus extension controls a remote alarm display.

(l) The Remote Display Centre, which is similar to the one at the Field Trial Centre, provides for demonstration capability to visitors.

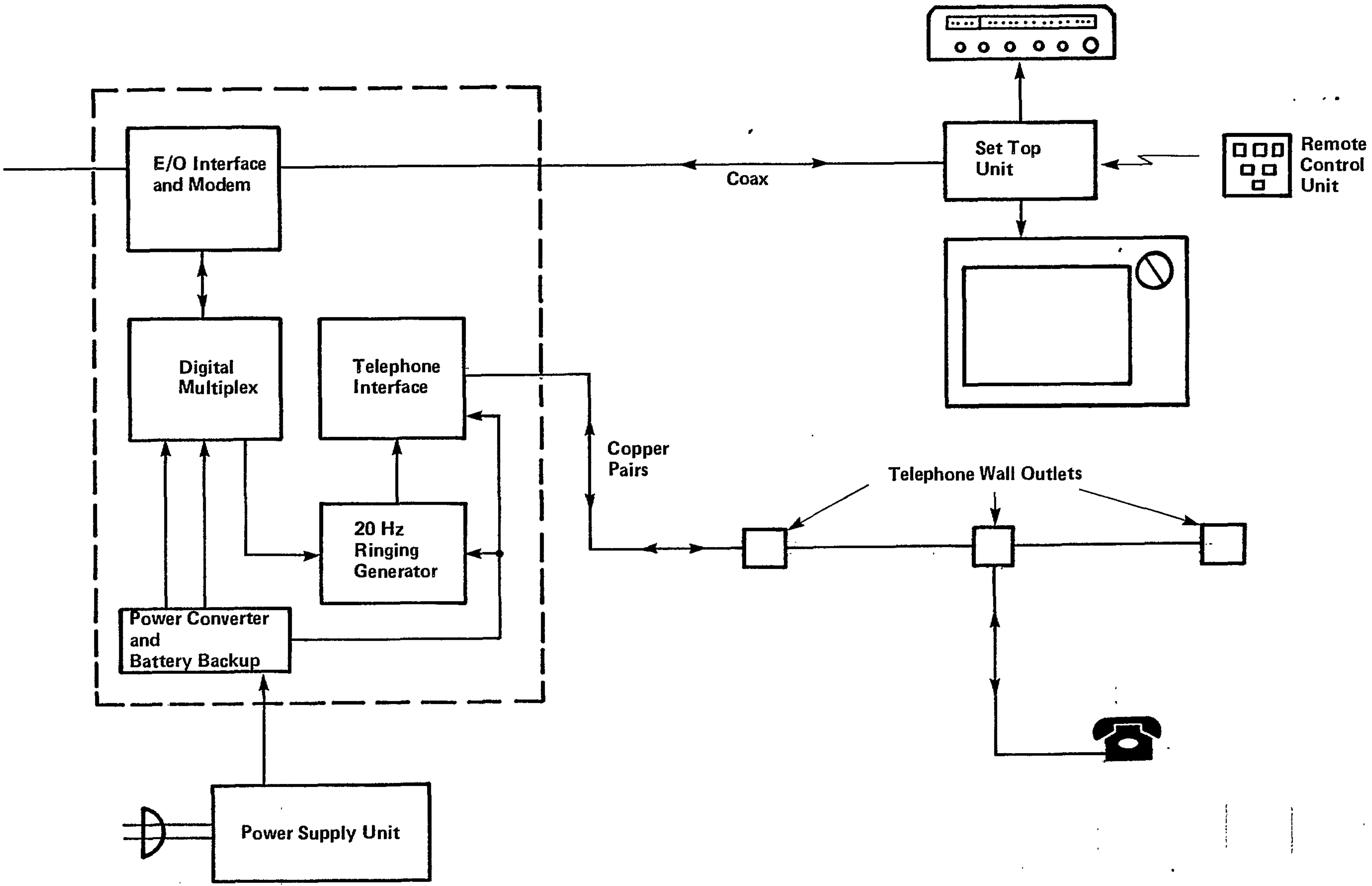

Figure 3.1.3 Subscriber Premises Equipment

3.2 EQUIPMENT DESCRIPTION AND LAYOUT

Figure 3.2.1 and 3.2.2 shows the equipment layout at the Field Trial Trailer and the Remote Distribution Centre. A brief description of each subsystem element is as follows:

(a) PROGRAM CENTRE

The Program Centre is made up of signal processors for translating the incoming TV and FM broadcast signals to channels suitable for transmission over the Field Trial System. Included also is a patch panel to allow flexible rearrangement of the channels. Standard high quality commercial CATV head-end equipment is used.

In Phase 1, equipment is provided for processing 5 TV channels. This is expanded in Phase 2 to handle 12 TV channels.

(b) SUBSCRIBER LINE INTERFACE

The Integrated Line Interface Unit (ILIU) is composed of a telephone interface, digital multiplex, video switch and electro-optical interface.

The telephony interface performs 2 wire to 4 wire conversion and A/D conversion using standard 8 bit companded ($\mu = 255$) PCM. It detects and encodes ringing signals from the SA-1 switch and provides conventional dial pulse/hook switch signaling to the SA-1 switch.

The digital multiplex combines two PCM words together with signaling, continuity, parity and other bits to form a 48 bit packet. This packet is transmitted in a asynchronous half duplex (ping-pong) mode via the digital muldem (multiplex/demultiplex) in the electro-optical interface.

The electro-optical interface converts the digital packet to a

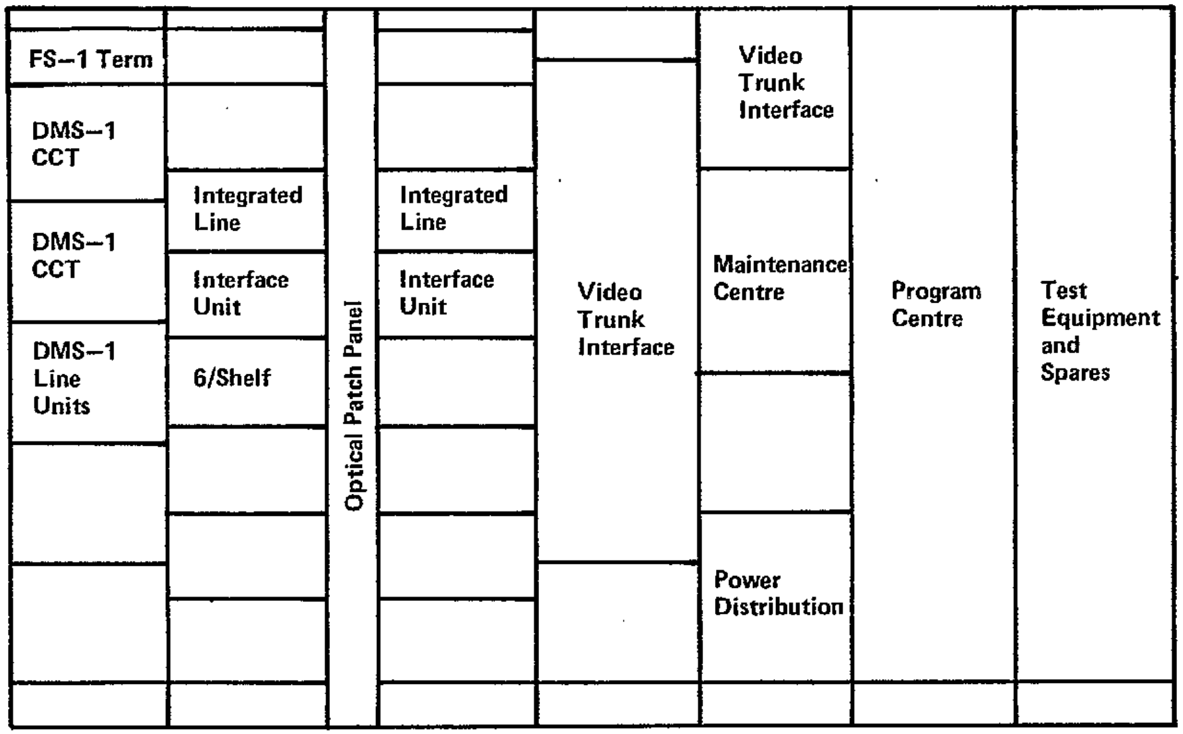

Figure 3.2.1 Field Trial Centre Trailer Frame Line–up

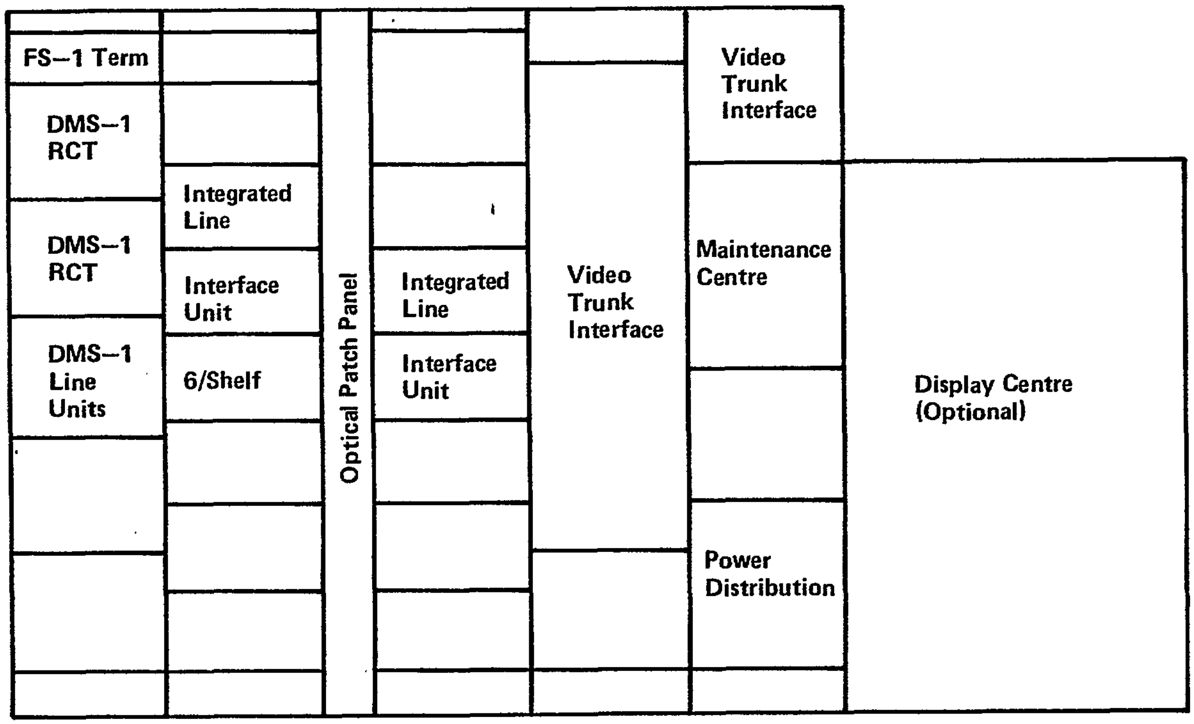

Figure 3.2.2 Remote Distribution Centre Frame Line–up

form suitable for transmission over the optical fiber link, combines this with the low VHF TV channel from the video switch to intensity modulate a diode injection laser. The signal is coupled to the fiber through a coupler which permits bidirectional transmission on a single fiber. The bidirectional coupler is designed to have lowest loss in the downstream direction.

The digital upstream signal containing digital telephone voice and TV control signaling is detected with an avalanche photodiode, pre-amplified, brought to a fixed level with AGC and applied to the digital demodulator. The output of the demodulator is applied to the digital muldem which separates the digital signal into its components and distributes them to the appropriate units.

The video switch is an electronically controllable TV converter which selects and converts one of the FDM multiplexed TV channels available at its input to a low VHF channel. The FM bypass enables the FM stereo broadcast signals in the 88-108 MHz band to bypass the video switch. Command signals for the video switch are relayed from the subscriber as part of the composite digital packet.

(c) MAINTENANCE CENTRE

The Maintenance Centre monitors and displays the continuity of the link to each subscriber and the power output of the laser in the ILIU. Provision is made for sending maintenance status messages to the MTS remote maintenance centre in Winnipeg. The system is implemented with a microprocessor to which all of the line units are connected by means of a common bus.

(d) SUBSCRIBER PREMISES EQUIPMENT

The Subscriber premises equipment consists of a Subscriber

Entrance Unit (SEU), a Power Supply Unit (PSU), a Set Top Unit (STU), a Remote Control Unit (RCU) and telephone sets (refer to Figure 3.1.3). The PSU is inconspicuously located near the hydro entrance. It plugs into a specially provided outlet and converts the 120 Volts AC to low voltage DC to power the SEU.

The SEU uses a rechargeable battery in standby/float mode to provide telephone service for 8 hours in the event of a hydro failure. The telephone interface provides power and ringing signals to the telephone sets, performs 2 wire-4 wire conversion and A/D conversion of the voice signals, accepts and decodes the hook switch/dial pulse signaling from the telephone set. The ringing signal is at a different frequency from the existing 20 Hz ringing to give a distinctive sound for positive identification of which telephone is ringing. The digital muldem multiplexes the PCM voice signals together with the telephone and TV channel selection signaling, data bits, alarm, continuity and parity bits and forms them into a 48 bit packet for transmission to its corresponding distribution centre.

The electro-optical interface and modem consist of a directional coupler, an avalanche photodiode and pre-amplifier for reception of the composite downstream signal and a high radiance LED for transmission of the upstream digital information.

Distribution of the TV and FM signals within the house is accomplished with coaxial cable. The Set Top Unit consists of a splitter to provide separate outputs for the TV and FM receiver, transformers to convert to 300 ohms balanced and an ultrasonic microphone to receive the signal from the ultrasonic TV Remote Control Unit provided for TV channel selection. Telephone distribution in the home is by paired cables terminating in up to 4 jacks located at the subscribers convenience. The telephone set is a Northern Telecom digipulse type which provides "touch phone" service in a dial pulse office.

In all, 7 frames of equipment (not counting the SA-1 extension) are required at the CDO and five at the RDC. The total power requirement of the Field Trial Centre Trailer is estimated to be 770 W from the battery and 1300 W from the hydro excluding the air conditioning units which will consume 10kW and does not contribute to the heat dissipation load. The total power requirements of the RDC is estimated to be 750 W from battery and 1000 W from hydro. Again the air conditioning will consume 10 kW. Because of technological advances and improved packaging, a product developed for 1985 application would require substantially less space and power.

3.3 CABLE & OUTSIDE PLANT HARDWARE

The Field Trial will consist of both buried and aerial plant to realistically simulate the typical rural distribution system. In Phase 1, only buried cable is required. Both buried and aerial plants will be trialed in Phase 2, to be implemented one year later.

In order to meet the stringent time requirement standard commercial or fully developed hardware will be used wherever appropriate. This will minimize development delays. In all instances the design life will exceed the minimum required.

All cables and hardware discussed in this section will be designed to meet the following environmental specifications.

MODE	DESIGN TEMPERATURE RANGE (°C)	
	BURIED	AERIAL
Operation	-5 to +25	-40 to +55
Installation	-20 to +50	-20 to +50
Storage and Transportation	-50 to +55	-50 to +55

The major Outside Plant components in the Field Trial are:

(a) Cable
(b) Remote Distribution Centre
(c) Splicing, Connectors and Associated Tools
(d) Sealed Pedestal, Terminal and Splice Closures
(e) Outside Plant Test Sets

Each component will be discussed separately below:

(a) CABLE

The Field Trial allows the operating company the opportunity to evaluate the field handling and placement properties of both buried and aerial fiber cables in a real Outside Plant environment. The system configuration requires a 24 fiber trunk, distribution cables of various fiber counts up to 48, along with a 2 fiber drop cable (refer to Appendix A for the detail route layout). The maximum attenuation of the cabled fiber will be 4 dB/km measured at 850 nanometers over the full operating temperature range.

Both the aerial and buried cables will be designed for unpressurized application, using a filled core construction. A composite sheath design will provide a moisture free and stress free environment for the fibers. This cable construction eliminates the expensive installation and maintenance costs involved in operating a cable pressure system. Filled core cables have been used successfully and are preferred by the operating company for conventional rural copper distribution systems.

For the Field Trial conventional cable placement equipment, techniques and methods will be used as all fiber cables will be designed to meet mechanical requirements similar to those of conventional telephony cables. Some of the major parameters are tensile strength, bending, crush resistance, vibration, twist, and impact strength. The cable construction will permit easy access and indentification of all individual fibers. This will allow splicing to be performed quickly and assist in maintenance and testing. For the Field Trial the cables will be manufactured in continuous lengths up to 2 km long. This will reduce the overall system optical loss because fewer splices will be required. It will also mean that cable placement costs can be kept down. Permanent distance markers will be placed at 1 meter intervals on the outer surface of the cable. In addition the Field Trial cables will be clearly identified to distinguish them from existing MTS cables.

(b) REMOTE DISTRIBUTION CENTRE

A controlled environment remote distribution centre is required in Phase 2 of the trial to house 5 frames of electronic equipment plus the optional display centre. This equipment can be placed either in a standard Northern Telecom DMS-1 type hut or a trailer.

(c) SPLICING CONNECTORS AND ASSOCIATED TOOLS

All splices and connectors will be field installed for the Field Trial using specialized fiber-optic tooling supplied by Northern Telecom. A training course will enable this work to be performed by the operating company. The fusion splicing technique to be used will give an average optical loss of less than 0.3 dB/splice. The maximum standard deviation is expected to be 0.1 dB. In order to perform this operation two specialized tools are required. The first a fiber preparation kit will prepare the fiber ends (i.e. stripping, breaking and cleaning) followed by the installation fixture which will perform the fusion joining and final packaging of the splice. The procedure used will ensure that a single fiber will not be bent to a diameter of less than 10 mm during splicing. A minimum 300 mm of slack fiber will be provided and stored at the splice for eventual re-entry and splicing.

A three component connector consisting of a central bulkhead and two common plug assemblies with a built-in locking feature will be used. The locking feature will ensure proper contact and alignment of the connector. Specialized tooling required to connect the individual fibers to the plug part of the connector will be supplied by Northern Telecom. Three connectors will be used per subscriber loop with an average optical loss of less than 1.0 dB per connector. Each connector will provide strain relief which will ensure that the operating bending diameter of the fiber is maintained. In addition, the fiber coating will be terminated in the connector to provide continuous end to end protection for the fiber.

(d) SEALED PEDESTAL, TERMINAL & SPLICE CLOSURES

The Field Trial requires aerial terminals, buried pedestals, and splice closures. Cable terminals or pedestals will be used at the junction of the subscribers drop cable and the feeder cable as well as to enclose all splices at the end of cable reels and at cross road junction points. Splice closures will be used for emergency repairs only.

In both applications, a sealed enclosure is required to provide mechanical and environmental protection to the individually exposed fibers and completed splices and to prevent moisture ingress. For the cable terminal/pedestal this enclosure must be re-enterable to provide access to the cable fibers for testing and rearrangement purposes. Some basic specifications for the terminal/pedestal and closure are given below:

(1) The buried cable pedestal will consist of a sealed re-enterable closure contained within a standard buried pedestal.

(2) The sealed, re-enterable closure will accommodate the range of cable sizes and designs to be used in this Field Trial. The closure will provide adequate inside space to allow a minimum 50 mm fiber bending diameter and the storage of at least 300 mm of each spliced fiber.

(3) The aerial terminal, buried and aerial splice closure design will be a modification of the closure described in item (2).

(4) Negligible optical loss will occur in any fiber due to the closing method used.

(5) Both the terminal/pedestal and closure will be designed to meet standard Outside Plant mechanical and environmental specifications.

(e) OUTSIDE PLANT TEST SETS

Attenuation test sets will be supplied to measure the attenuation in the fibers and the loss in the splices and connectors during the Field Trial installation. The proposed unit with a dynamic range of -45 dB will provide adequate testing capability. A fault locate test equipment using the time domain reflectometry (TDR) principle will also be provided for the Field Trial. This will allow fiber fault locating to be carried out by operating company personnel after proper training from Northern Telecom.

3.4 MERITS OF THE PROPOSED FIELD TRIAL SYSTEM

The most important merit of the proposed Field Trial System is that it will resemble very closely the network configuration that is projected as most suitable for actual implementation in the mid 1980's. This will allow for field trial verification of a number of features which will be of significant value in paving the way for a practical system in 1985. These features as well as their expected values, are summarized as follows:

(a) INTEGRATED DISTRIBUTIONS OF VOICE, VIDEO AND DATA

By using a single network for the transmission of voice, video and data services, considerable savings can be achieved in capital as well as annual charges due to the sharing of administrative and maintenance overhead, and elimination of redundant hardware/software and installation as compared to the use of separate plant.

(b) NEW SERVICES

Because it provides a dedicated connection to each subscriber the switched star configuration can readily accommodate new services and enhancement of existing services. For example, an increase in the number of available video channels can be accomplished without any change to the distribution system. The dedicated connection also facilitates provision of sufficient data capacity for evolution of future data services such as electronic mail, remote meter reading, teleview etc.

(c) FLEXIBLE DESIGN

The current trend in the evolution of local networks is to utilize equipment of modular design that can grow gracefully from serving a limited number of subscribers at the beginning to substantially more subscribers without incurring large initial capital expenditures. The capability to provide remote distributed switching for all the services results in minimum start-up cost plus the ability to meet different growth demands.

(d) IMPROVED PERFORMANCE

For a given system reach the switched star fiber optics distribution system offers improved performance compared to other network topologies for fiber optic distribution. This is also true when compared to coaxial systems.

(e) DIGITAL TRANSMISSION

By transmitting the digital voice signals all the way to the subscriber premises, the proposed system allows integration and simplification in the transmission of the various non-video signals. This scheme is also compatible with the accelerating trend towards all-digital networks. It also paves the way for integrated voice and data switching which could greatly reduce the cost of providing multi-service data within local distribution networks.

Many technological issues which apply to the 1985 system are addressed in this Field Trial:

(1) Fiber Optic Tranmission

- Remoting of digital multiplex switching with fiber optics.
- Digital transmission of voice, data and TV control signaling plus VHF video transmission.
- Digital or FM trunking of video.
- Digital half-duplex (ping-pong) telephony.
- Continuous monitoring of subscriber premises equipment and optical link.
- Bi-directional transmission in a single fiber.

(2) Subscriber Premises Equipment and Service

- Integrated service for voice, video and data.
- Digital telephony to subscriber.
- Switched approach to provide CATV.
- Local powering at subscriber premises.
- Digital data to subscriber.

(3) Video Switching

- FDM switching.
- Remote control by subscriber signaling.

(4) Outside Plant

- Buried and aerial plants in a rural environment.
- Field handling and placement properties.

In conclusion, the proposed Field Trial System provides strong impetus for the delivery of broadband services to the rural environment in the mid 1980's. The system configuration is both flexible and cost-effective and allows the maximum benefit to be derived from the Field Trial Program. In fact, the proposed Field Trial System has the capability to trial new services at low incremental cost.

4

4 FIELD TRIAL PLAN

4.1 PROGRAM MANAGEMENT

A program of this size and complexity has to be closely managed and co-ordinated in order to ensure that all the tasks associated with the Field Trial Program are carried out successfully. This is particularly true when more than one organization is involved. Thus the first and most important step is for DOC-CTCA to assign a program manager working full time on the program as soon as the Field Trial is given the green light. The manager should be given the mandate of directing the entire program from start to finish. Any doubt or lack of confidence in that mandate would reduce the job to one of co-ordinating and reporting, which in turn would seriously jeopardize the success of the program.

The Program Manager should ideally possess previous experience in the handling of similar programs. Some of the more important assets should include a working knowledge of the manufacturing and operating aspects of the telecommunication industry, the ability to communicate effectively with all types and levels in both the public and private sector, plus a good understanding of fiber optics, telephony, CATV and their relation to the rural population.

The role of the Program Manager in the Field Trial is depicted in Figure 4.1.1. The main purpose of such an 'organization chart' is not to suggest that such a structure should be adopted, but rather to point out the various responsibilities of the Program Manager. Under close supervision from the Advisory Board, the Program Manager will work with the various organizations involved in the Field Trial Program. To keep the number of interfaces to a minimum, it is strongly recommended that one representative from each organization be held responsible for participating in the various planning functions called for in the program. Each representative would in turn co-ordinate all the activities required within that organization. In fact, the overall management plan can only be developed if the breakdown of the tasks and work structure are performed at the working level of each respective organization.

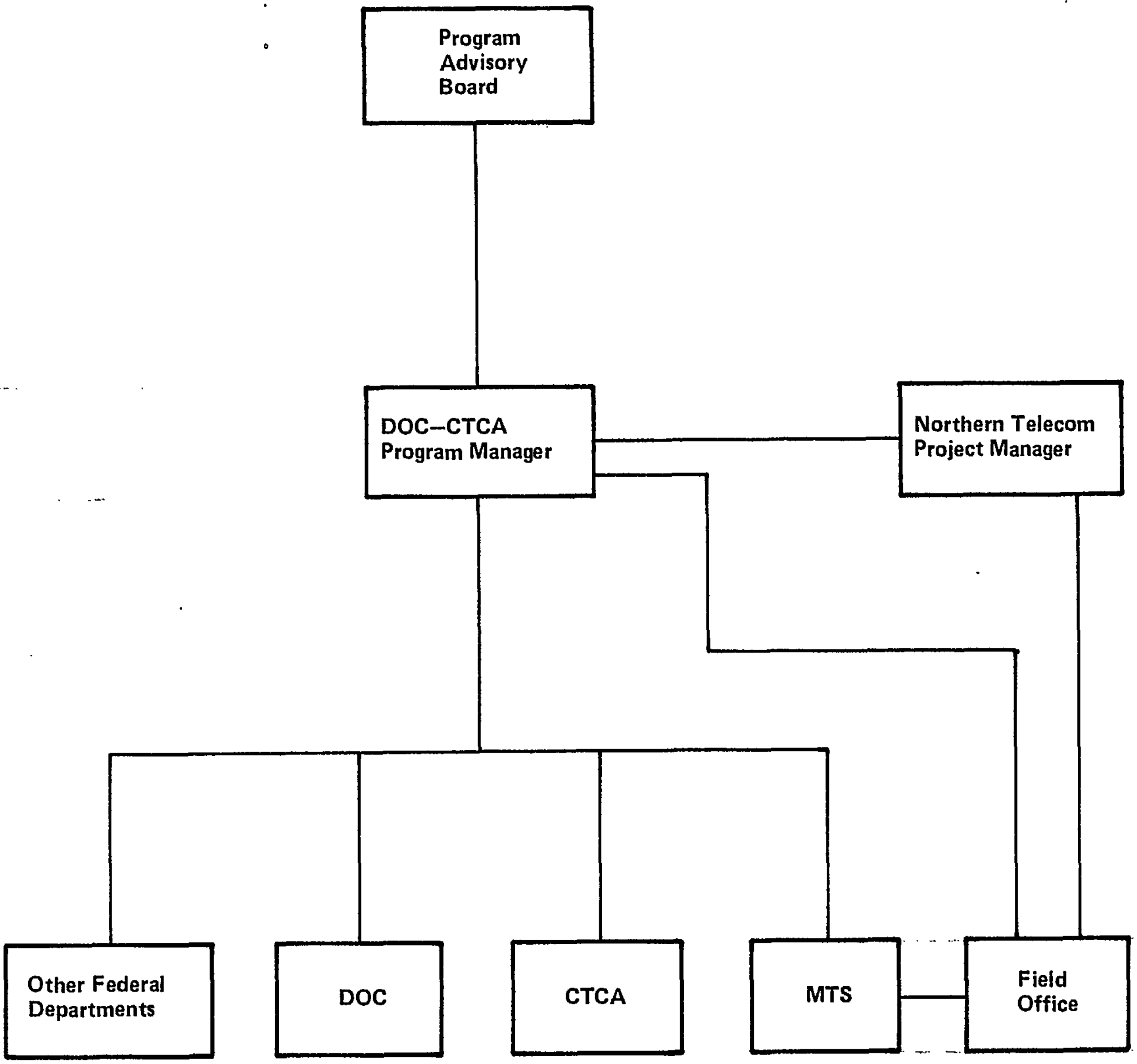

Figure 4.1.1 Field Trial Program Organization Chart

Thus Northern Telecom would establish a project office immediately after the award of the contract. Headed by an experienced Project Manager, the office would be responsible for undertaking the planning, design, development, cutover and termination of the Field Trial System. The Project Manager would also have the additional responsibility of interfacing with the Program Manager, to ensure that the scheduled activities satisfy requirements approved by the Program Advisory Board. Internally, the Project Manager has to interact with all the development, engineering and installation departments to ensure that all key dates are met. It is beyond the scope of the Program Definition Study to give a breakdown of all the tasks involved. However, a detail management plan would be submitted to the Advisory Board as soon as the planning phase of the project is completed.

4.2 IMPLEMENTATION SCHEDULE

Based on the objective to implement Phase 1 of the Field Trial in 1980, a preliminary implementation schedule is derived and is shown in Figure 4.2.1. A complementary milestone chart summarizing the completion dates for the major events is given in Table 4.2.1. In arriving at the set of dates quoted, the following points are taken into consideration:

(1) To meet the 'in-service' date of September 1980, the contract has to be signed not later than January 1979. This allows for a period of twelve months for design and development, four months for fabrication and testing, one month for shipping and four months for installation, system line-up and test (SLAT).

(2) The overall program planning should ideally be initiated as soon as the Program Definition Study report is received. Four months are allocated here for planning, budgeting, tendering and contract award, which corresponds to a the starting date of the Field Trial Program of September 1978.

(3) Phase 2 of the Field Trial System would be cutover in October 1981, with the shipping date scheduled for April and Outside Plant installation in early May. It is recommended that a duration of two years is sufficient to assess the various technical and operational aspects of the Field Trial System. Extending the Field Trial Program beyond 1982 would result in additional cost with little benefit in return.

Thus the total duration of the Field Trial Program is estimated to be 52 months from start to finish. System and service evaluation would be performed by DOC-CTCA and MTS to assess the system performance and service impact, with final documentation of the total expereince upon termination of the program. Leaving the Field Trial System in service

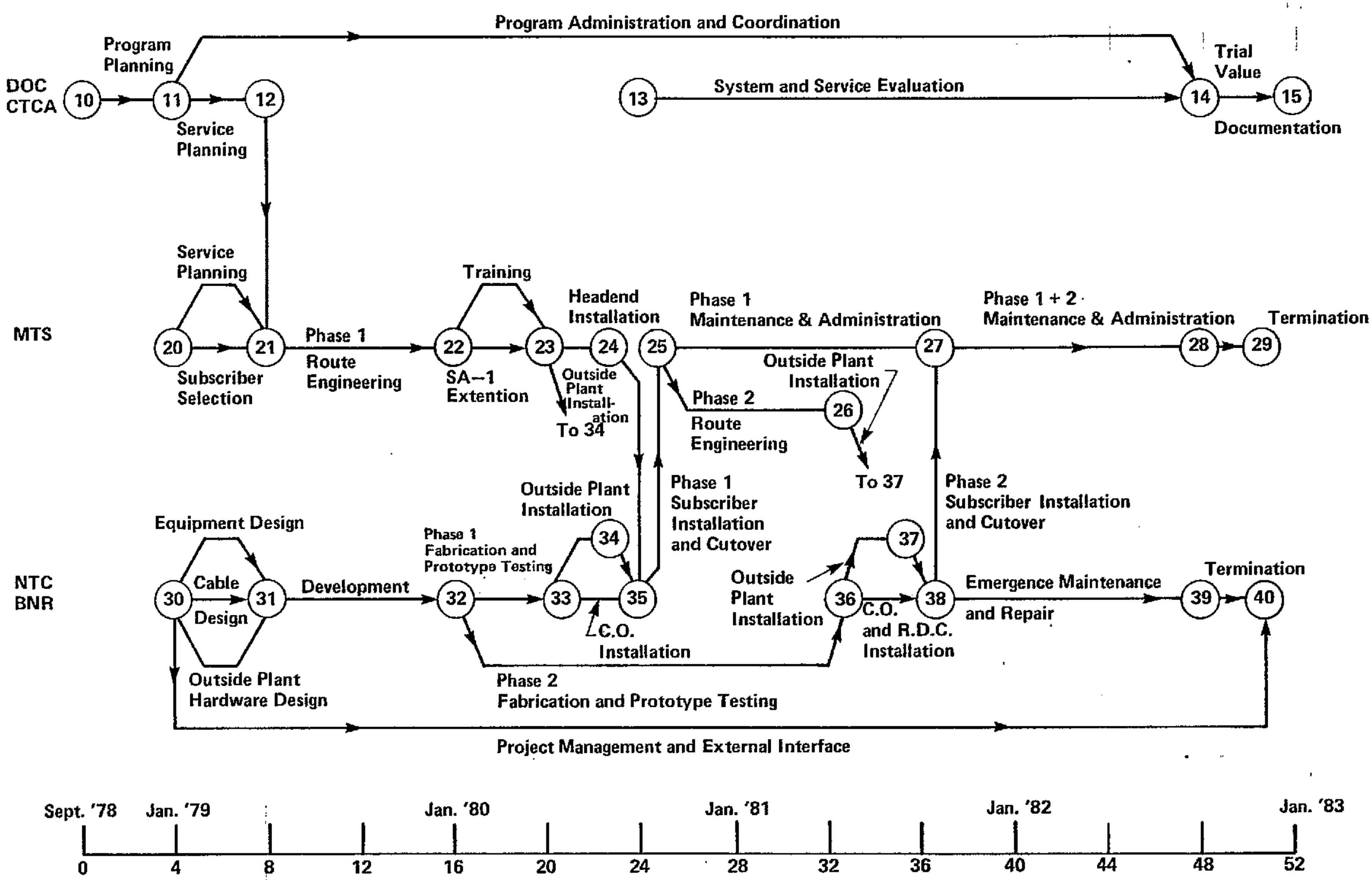

Figure 4.2.1 Field Trial System Implementation Schedule

MONTH FROM START	TASK ACCOMPLISHED	PRIME	COMPLETION DATE
0	PROGRAM MANAGER ASSIGNED	DOC/CTCA	SEPT. 78
4	FIELD TRIAL SYSTEM CONTRACT AWARDED	DOC/CTCA	JAN. 79
8	DETAIL SYSTEM DESIGN COMPLETED	NT	APRIL 79
12	SUBSCRIBER SELECTED	MTS	SEPT. 79
21	LABORATORY PROTOTYPE TESTED	NT	MAY 80
23	PHASE I OUTSIDE PLANT INSTALLED	NT/MTS	AUG. 80
24	PHASE I TRIAL SYSTEM CUTOVER	NT	SEPT. 80
36	PHASE II OUTSIDE PLANT INSTALLED	NT/MTS	SEPT. 81
37	PHASE II SERVICE CUTOVER	NT	OCT. 81
48	TRIAL SYSTEM EVALUATION COMPLETED	DOC/CTCA	SEPT. 82
50	TRIAL SYSTEM TERMINATED	NT/MTS	NOV. 82
52	VALUE OF TRIAL SYSTEM DOCUMENTED	DOC/CTCA	JAN. 83

TABLE 4.2.1

FIELD TRIAL SYSTEM MAJOR MILESTONE CHART after the completion of the program would result in administrative problems because the system is not standardized. It could also jeopardize the experimental nature of the Field Trial Program due to regulatory restrictions on cross ownership. However, some of the hardware (like cable for example) may be retained as a test bed for other experiments.

Although Northern Telecom would be responsible for the installation and cutover of the Field Trial System, it is expected that MTS would be involved in the placement of the Outside Plant portion of the Field Trial System, plus the engineering and installation of associated equipment. This includes the extension of the CDO, connection to the ICBN (Inter-City Broadband Network) and the construction of the VHF antenna system. Work to be performed at the subscriber's premises at all times would also be co-ordinated by MTS. Administration and maintenance of the Field Trial System will be performed by MTS to simulate real operating environment. Northern Telecom would provide emergency assistance plus equipment replacement and repair. Details on the division of responsibility will be written into the contract agreement. During the Program, the Field Trial System would be evaluated in terms of its practicability, performance and service implications. These evaluations will be undertaken by either DOC-CTCA or MTS, depending on the nature and objective of the tasks involved. At the end of the Field Trial Program, MTS will restore the service to the original mode, and remove the Field Trial equipment with the assistance of Northern Telecom. These tasks will be described in more detail in the following three sections.

4.3 INSTALLATION AND CUTOVER

Installation of the Field Trial will be carried out according to a schedule drawn up by the Project Manager and approved by the Program Manager on behalf of the Advisory Board. However, before the installation schedules are established, the prospective subscribers for both Phases 1 and 2 must be approached and informed of the nature and purpose of the Field Trial, their role in it, and the details of the services offered. If they agree to participate, then their service requirements will be obtained to permit determination of the eventual Outside Plant layout and the amount of standard equipment such as telephone sets to be ordered.

In general, where the installation work is carried out by the telephone company standard operating company procedures will be followed wherever possible. Any special procedures required because of the new technologies involved will be documented by Northern Telecom.

The first part of the installation work will involve extending the existing SA-1 switching system, the power plant and the CDF (Common Distribution Frame). These tasks should be completed by MTS before the arrival of the Field Trial equipment early in May, 1980. Site preparation for the Trailer, the setting up of the TV/FM antenna, connections to the ICBN, as well as any field-surveying required for the Outside Plant, should all be ready by this date.

Outside Plant installation will begin on about May 1, 1980, or as soon thereafter as the ground condition permits. The fiber cables will be tested end-to-end independently of the Field Trial Centre and the subscriber premises equipment.

The Trailer will arrive with all the frames required for Phase 1 installed and pre-tested in the factory. All plug-in units will be removed and separately packaged for transportation to the Field Trial site. These units will be re-installed and re-tested when the Trailer is located on-site, the hydro connected and the operational environmental conditions established. Connections to the TV/FM antenna, the ICBN, the SA-1 and the Outside Plant will then be made. The entire Field Trial Centre will then be thoroughly tested, including simulated subscriber tests using the

Display Centre connected in turn to each subscriber output of the Integrated Line Interface Unit, via an optical attenuator to simulate the subscriber optical line loss.

The Outside Plant cables will be connected to the Field Trial Centre after both have been independently tested. Following such connections, the subscriber installation can commence. The AC outlet will be installed first by a qualified electrician. The Subscriber Power Converter Unit, the Subscriber Entrance Unit, the in-house telephone and TV/FM cables, the Set Top Unit, the TV Remote Control Unit, and the telephone sets can then be installed and tested. After these units are connected, telephone service will be tested using standard telephone company procedures by dialing through the SA-1 to a test-number and checking the ability to talk through to the test-number as well as to be called from this number (ringing test). TV service will be tested using a portable TV-monitor and selecting a test-pattern sent from the Program Centre. Similarily, FM service will be tested with a portable receiver tuned to a test signal sent from the Program Centre. Other tests for evaluation of the Field Trial (see Section 4.5) will be performed at the same time. Standard telephony, FM and CATV test sets are expected to be provided by MTS. Special test sets for the measurement and monitoring of the Field Trial System will be provided by Northern Telecom.

When all subscribers are connected, Phase 1 is ready for cutover. Simultaneous cutover of all subscribers is recommended for Phase 1 to simulate the starting-up of a new service, and to provide an opportunity for publicity. To enable such a cutover, standard telephony cutover devices (MTS supplied) will be installed to temporarily deny service. Also, only one test signal for TV and FM will be transmitted from the Program Centre until the moment of cutover. After cutover, all the cutover devices will be removed and the additional TV and FM signals turned on at the same time.

For Phase 2, installation at the Field Trial Centre will involve adding frames and plug-ins for the new local subscribers and installation of the DMS-1 digital subscriber carrier system and video trunk equipment to the Remote Distribution Centre. At the RDC, the trailer or hut (if used) must be installed first and made operational before the arrival of the equipment frames. These frames will be installed and tested before the fiber trunk cable is connected. If a trailer is used, the frames will be pre-installed and pre-tested similar to the Field Trial Centre Trailer.

Outside Plant installation for Phase 2 will follow similar steps as for Phase 1, with the exception that the trunk cable will first be connected between the Field Trial Centre and the Remote Distribution Centre. Once these connections are made, the video trunks and the subscriber carrier system can be thoroughly tested before the Integrated Line Interface Units are connected and checked using the Remote Display Centre. Subscriber installation can commence after the distribution cables (feeder and drop) are connected to the ILIU using an optical cross-connect panel.

Unlike Phase 1 where all subscribers are simultaneously cut into service, the Phase 2 subscribers will be individually brought in as soon as each subscriber's installation is completed. This approach simulates the normal growth situation and avoids any possible congestions that might be caused in the SA-1 or in the DMS-1 when a large number of subscribers are simultaneously cut into service. Note that in Phase 1 the small number of subscribers is not expected to cause traffic congestions in the SA-1 with a simultaneous cutover. The cutover date for Phase 2 will therefore refer to that day when all the equipment in the Field Trial Centre, the fiber optics trunks and the Remote Distribution Centre become fully functional and ready for the connection of new subscribers.

4.4 ADMINISTRATION AND MAINTENANCE

The Field Trial will use standard maintenance practices as much as possible and be operated as closely as possible to normal service conditions. Since an overlay scheme is adopted, it will be necessary to advertise the new directory numbers before the cutover dates. In order to encourage the subscribers to use the Trial System rather than the existing telephone plant, it should be emphasized to the subscribers that the original sets will be maintained for backup purposes only.

During the Field Trial, the subscriber should pay no additional cost other than the regular telephone charges equivalent to his existing service. Thus, there should be no charges for the TV/FM service and for the basic set and as many extensions as are currently subscribed to on the existing telephone system. Extra extensions and long distance calls will be charged according to established MTS rates. In this way, the MTS will not gain or lose any revenue due to the Field Trial. To minimize the complications that might be caused to the MTS billing system, it is recommended that two bills be sent to each subscriber: one for the old directory number and the other for the new number. In the second bill, a credit will be allowed against the basic monthly equipment rental charges in the first bill.

In order to minimize inconvenience to the subscriber, the number of visits should be limited to one time for initial installation, one for equipment removal upon termination and no more than one or two at intermediate stages of the Field Trial for specific system evaluation tests. All other visits should be restricted to any necessary repair and subscriber movements. Similarly, subscriber surveys, by telephone or by mail, should be minimized.

A special, no-charge trouble-reporting number should be set up for the Field Trial subscribers to call in on problems encountered with the Field Trial System. This number should be answered at the MTS trouble-reporting bureau by a supervisor who will receive special training from Northern Telecom on how to obtain information about possible problem areas. Based on the data provided, the supervisor will determine whether the trouble lies in the conventional equipment or whether trouble is suspected with the specially designed hardware. In the first case, the trouble report will be routed to normal MTS departments for further action, with a copy forwarded to the MTS Field Trial coordinator for information. In the second case, the report will be sent to the MTS coordinator who will be responsible for clearing the reported trouble.

Northern Telecom will provide training to a maximum of six (four recommended) MTS craftsmen for maintenance of the Field Trial System. These will include at least one central office equipment foreman and one outside plant foreman. They will be provided by Northern Telecom with sufficient functional documentation and repair procedures to diagnose and repair most of the trouble on their own, using spare plug-in units where appropriate. Since no field repair of plug-in units will be made, detailed circuit descriptions will not be provided by Northern Telecom.

In the event that the MTS maintenance team cannot diagnose or repair a problem in the Field Trial System using the supplied documentation, an Emergency Assistance Group in Northern Telecom will be available for consultations and other forms of assistance, including field visits when necessary. This group will have a phone number and a teletypewriter number attended during regular business hours.

All replaced plug-in units with suspected trouble will be sent to Northern Telecom for diagnosis, repairs or exchange. The repaired or exchange units will be sent to MTS free of charge as soon as possible. Northern Telecom will ensure that a sufficient supply of spare units is always available in the field.

4.5 TERMINATION AND EVALUATION

On the date the Field Trial is scheduled to terminate, the connections to the SA-1 will be removed at the CDF so that no incoming or outgoing telephone calls involving these subscriber's directory numbers can be completed. Normal changed-number intercept service will be provided for incoming calls during the first three months after terminations. The date of the termination and the original directory numbers of the Field Trial subscribers will be advertised ahead of the effective termination date.

Also on the termination date, the TV and FM signal sources will be disconnected at the Program Centre except for the test signals similar to those provided during the initial installation. Thus all Field Trial subscribers will simultaneously return to the original service state before the Field Trial.

Visits to the subscribers will then be made within a reasonable short period of time to perform final evaluation tests and to remove all the equipment at the subscriber premises, except the house-wiring. The telephony house-wiring can be connected, at the discretion of MTS, to the existing copper pair system to provide the capability of using connectorized telephones. The TV/FM lead can be removed or left in according to the wish of the subscriber. For the final evaluation tests, temporary connections to the SA-1 might be made at the CDF. The conventional telephone might be used to coordinate such tests with a craftsman at the CDO.

Final evaluation tests will also be made at the Field Trial Centre and Remote Distribution Centre. At the completion of these tests, all Field Trial equipment will be removed with the exceptions of the buried Outside Plant and equipment purchased and installed by MTS.

The Telephone Company should be given the option of negotiating the purchase of any or all equipment before the commencement of the Field Trial Program. Items that may be used by the MTS for telephone services are the Remote Distribution Centre housing and the subscriber carrier system. The decision to purchase the latter should be made before Phase 2 installation begins so that the DMS-1 (Central Control Terminal) can be installed in the central office building rather than in the Trailer, and DS-1 rate digital carrier systems (such as the Northern Telecom LD-1) can also be laid between the Central Office and the Remote Distribution Centre at the same time as the fibre cables are placed.

Tests and evaluations of the Field Trial will be carried out as defined in the Program Management plan either jointly or separately by the participating organizations. The costs of the latter should be born by the individual organization. Northern Telecom will provide support to the Field Trial Program for special tests on the Field Trial System not related to normal design, installation and maintenance, as well as for technical analysis of the test results and other data generated during the Field Trial.

Reasonable access to the Field Trial System and various data, such as usage measurements and trouble reports, should be granted to all participating parties. Where such access could affect customer services or will require visits to the subscriber premises, authorization must first be obtained from the Program Manager who will also be responsible for coordinating such requests for access to Field Trial equipment or information, with concurrence from MTS and Northern Telecom.

At the completion of the Field Trial Program, all the data gathered during the Field Trial would be processed and analyzed by the Program Manager. This should include reliability and maintainability of the Field Trial System, subscriber reactions to new or improved service offerings as well as the operational aspects of a service integrated distribution network in a rural environment. A document would be issued shortly after summarizing the value of the Field Trial Program.

5

5. ESTIMATION OF TOTAL TRIAL COST

5.1 EQUIPMENT SUMMARY

The equipment summary, presented in Table 5.1.1 is based on the proposed Field Trial System design and Outside Plant layout. Any changes in design or layout, due for example to a different trial site or a different set of subscribers, will affect the quantities estimated. Moreover, the items identified only cover the key elements to be supplied by Northern Telecom and do not constitute a complete equipment list for the Field Trial System, which will include other equipment to be purchased directly by MTS. A more detailed breakdown of the equipment will be submitted to DOC-CTCA during the quotation stage of the Field Trial Program. It should be noted, however, that sufficient information was generated at the design, engineering and layout phases of this study to cover all the cost items related to the Engineering, Furnishing and Installation (EF&I) of the Field Trial System equipment.

ITEMS	PHASE 1	PHASE 1 AND PHASE 2
CABLE LENGTH IN km	7.3	50.8
FIBER LENGTH IN km	48.0	535.0
FIBER SPLICES	67	745
OPTICAL CONNECTORS (1)	33 (43)	490 (515)
SEALED CABLE TERMINALS/PEDESTALS	11	86
FIELD-TRIAL CENTRE TRAILER	1	1
REMOTE DISTRIBUTION CENTRE	0	1
SA-1 LINES (2)	12 (160)	154 (160)
LINES ON DIGITAL SUBSCRIBER CARRIER SYSTEM (1)	0	76 (84)
PROGRAM CENTRE	1	1
MAINTENANCE CENTRE	1	1
REMOTE MAINTENANCE INTERFACE	0	1
VIDEO TRUNKS	0	13
FS-1 OFFICE REPEATERS (1)	0	4 (5)
INTEGRATED LINE INTERFACE UNITS (1)	11 (14)	152 (160)
SUBSCRIBER PREMISES EQUIPMENT	11 (14)	152 (160)
DISPLAY CENTRES	1	2
TOTAL EQUIPMENT BAYS	5	12
REMOTE POWER SYSTEM	0	1
TOOL KITS	2	4
TEST SETS	3	4

TABLE 5.1.1

NORTHERN TELECOM FIELD TRIAL SYSTEM EQUIPMENT SUMMARY

Notes on Table 5.1.1

(1) Figures inside brackets are total quantities including spares.

(2) Planned SA-1 additions.

5.2 FIELD TRIAL EQUIPMENT COSTS

Cost estimates for Phase 1 and for Phase 1 plus Phase 2 are given in Tables 5.2.1 and 5.2.2 respectively. The figures shown for Phase 1 were calculated based on a prorating of total Phase 1 and 2 equipment quantities. This cost breakdown is provided to assist the Program Manager in the preparation of budget plans for capital expenditure during the Field Trial Program.

The cost estimates given included framework, power distribution as well as inside plant wiring at both the Field Trial Trailer and RDC, installation at the subscribers' premises, and $37,000 for cable placement to be subcontracted by Northern Telecom to MTS. It should also be noted that transportation cost was included in the EF&I estimates.

ITEMS	DESIGN AND DEVELOPMENT	EF & I	TOTAL
CABLE	30.9	63.3	94.2
OUTSIDE PLANT HARDWARE (1)	55.5	50.0	105.5
FIELD-TRIAL CENTRE TRAILER	5.0	15.0	20.0
PROGRAM CENTRE	6.0	24.0	30.0
MAINTENANCE CENTRE	70.0	20.0	90.0
INTEGRATED LINE INTERFACE UNITS	110.0	124.0	234.0
DISPLAY CENTRE	4.0	6.0	10.0
CO CABLING	2.0	16.0	18.0
TEST EQUIPMENT	5.0	52.8	57.8
SUBSCRIBER PREMISES EQUIPMENT	112.0	48.0	160.0
TOTAL EQUIPMENT	400.4	419.1	819.5

TABLE 5.2.1

NORTHERN TELECOM EQUIPMENT COST (THOUSANDS OF DOLLARS)

PHASE 1 ONLY

Notes:

(1) Includes sealed cable terminals and pedestals, tool kits, splices and connectors.

(2) All figures in 1978 dollars.

ITEMS	DESIGN AND DEVELOPMENT	EF & I	TOTAL
CABLE	139.2	380.0	519.2
OUTSIDE PLANT HARDWARE (1).	70.5	220.0	290.5
FIELD-TRIAL CENTRE TRAILER	5.0	15.0	20.0
REMOTE DISTRIBUTION CENTRE	5.0	15.0	20.0
DMS-1	0	60.0	60.0
CO CABLING	2.0	16.0	18.0
PROGRAM CENTRE	6.0	24.0	30.0
MAINTENANCE CENTRE	70.0	20.0	90.0
REMOTE MAINTENANCE INTERFACE	10.0	12.0	22.0
VIDEO TRUNK INTERFACE	12.0	264.0	276.0
FS-1 OFFICE REPEATERS	10.0	52.0	62.0
INTEGRATED LINE INTERFACE UNITS	110.0	832.0	942.0
DISPLAY CENTRES	4.0	12.0	16.0
REMOTE POWER AND CABLING	4.0	48.0	52.0
TEST EQUIPMENT	5.0	52.8	57.8
SUBSCRIBER PREMISES EQUIPMENT	112.0	490.0	602.0
TOTAL EQUIPMENT	564.7	2512.8	3077.5

TABLE 5.2.2

NORTHERN TELECOM EQUIPMENT COST (THOUSANDS OF DOLLARS)

PHASE 1 & PHASE 2

Notes:

(1) Includes sealed cable terminals and pedestals, tool kits, splices and connectors.

(2) All figures in 1978 dollars.

5.3 TOTAL NORTHERN TELECOM COST ESTIMATES

Besides equipment cost, additional costs are also required for documentation, training and project management. In order to arrive at the total Northern Telecom cost estimate, such cost items were approximated based on the implementation schedule outlined in Section 4.2. A breakdown of the total cost is given below in thousands of dollars.

Field Trial Equipment	3077.5
Development Management	200.0
Documentation	180.0
Training and Preparation	100.0
Field Assistance and Repair	120.0
System Planning	150.0
System Evaluation Support	60.0
Project Office	500.0
Total	4387.5

System design and development management was intentionally separated from the equipment cost to single out the requirement for detailed system planning and specification as well as the supervision of the development efforts. Documentation consists of information on the overall Field Trial System and equipment description to the operating company for adminstration and maintenance. Field assistance and system evaluation support include transportation and accommodation. The salary and travelling expenses of the Project Manager account for most of the cost identified under the project office.

5.4 ADDITIONAL COSTS TO BE INCURRED BY MTS

MTS is expected to provide the following:

(i) A coordinator to interface with DOC-CTCA and Northern Telecom on all aspects of the Field Trial Program.

(ii) Up to four part-time craftsmen to participate in the installation, operation and maintenance of the Field Trial. At least two of these should be foremen.

(iii) Engineering of cable routes.

(iv) Hydro stand-by at the Field Trial Trailer and RDC.

(v) Site preparation for Field Trial Centre and Remote Distribution Centre.

(vi) Extension of the CDO by 160 single party lines, estimated to be $40K EF & I.

(vii) TV/FM antenna system and its installation.

(viii) Connections from ICBN and TV/FM antenna to Field Trial Centre.

(ix) Salary, transportation and accommodation expenses of MTS personnel on training.

(x) Standard video signal generators and telephony test sets.

(xi) All subscriber liaison without exception, including subscriber selection, directory number assignments, advertisements, and billing.

(xii) Dedicated teletypewriter link for communication to Remote Maintenance Centre in Winnipeg from the Field Trial Maintenance Centre.

(xiii) Collection and tabulation of all trouble reports and other data related to the Field Trial.

(xiv) Removal of equipment after terminations.

5.5 COSTS TO BE INCURRED BY DOC-CTCA

The Field Trial is expected to incur costs to DOC-CTCA for the following:

(i) A full-time Program Manager for the entire elapsed time of the Field Trial Program plus support staffs.

(ii) Accounting and administration.

(iii) Office and meeting space.

(iv) System and service evaluation.

(v) Documentation of Field Trial value.

(vi) Disposal of removed Field Trial equipment after termination.

(vii) Publicity for the Field Trial.

6

6. INTRODUCTION PLANNING AND ANALYSIS

6.1 COST EFFECTIVENESS OF INTEGRATED FIBER NETWORK

This section of the report develops cost models for the proposed service integrated fiber optics distribution network for application in the rural environment in the 1985 time frame. All figures quoted are installed costs to the operating companies in 1978 dollars. Emphasis has been placed on providing a broad gauge cost on a per subscriber basis as a function of:

(a) rural subscriber density and cable route layout,

(b) segregation of subscribers into more densely populated communities (towns, villages) and the low density rural areas,

(c) repeater spacing for trunking from CO to RDC's,

(d) maximum distribution length based on transmission capability,

(e) relative cost of fiber cables (as a percentage of a nominal set of figures).

A functional block diagram of the various network components that constitute the integrated fiber network is given in Figure 6.1.1. The unit cost data adopted for modelling is given in Table 6.1.1. The nominal cost of the fiber cable per meter is assumed to be:

$1 + $0.1 per allocated fiber for trunk and feeder

and $ .50 for service drop

Other items that require explanatory notes are:

(1) A digital switch capable of handling combined voice and data switching with an ultimate capacity of 6000 lines is assumed. The installed cost of $200K covers the common equipment.

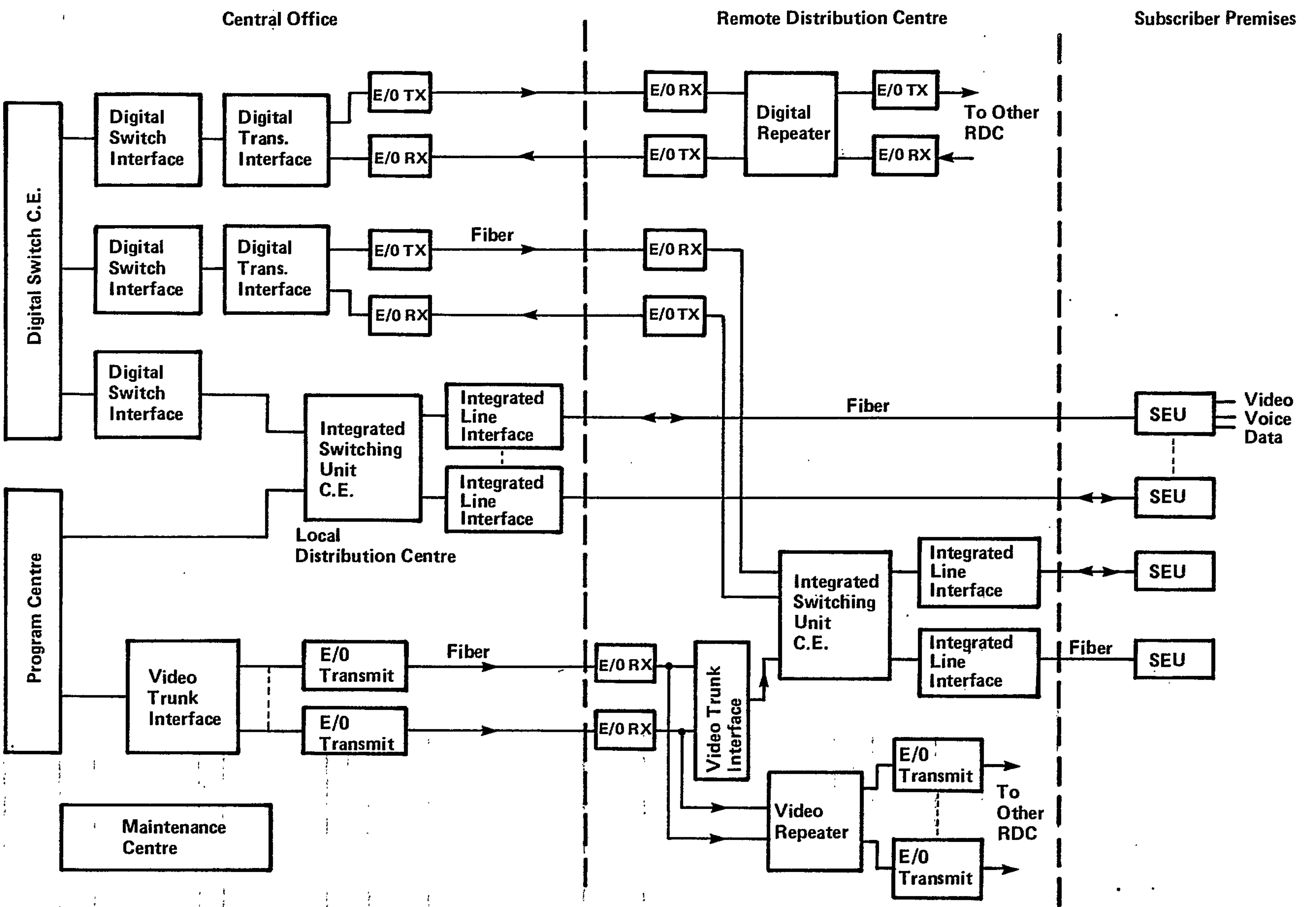

Figure 6.1.1 Functional Block Diagram of Integrated Fiber Network

NETWORK ELEMENT	DESCRIPTION OF UNIT	INSTALLED COST IN 1978 $
CENTRAL OFFICE	Digital Voice and Data Switch	200,000
	Video Program Centre	40,000
	Maintenance and Test Centre	10,000
REMOTE/LOCAL DISTRIBUTION CENTRE	ISU Common Equipment	7,500
	Housing And Powering	15,600
	Optical Cross-Connect Panel	750
	Digital Transmission Interface Per DS-1	175
	Digital Switch Interface Per DS-1	2,500
	Video Trunk Interface Per Trunk	800
	Integrated Line Interface Unit Per Subscriber	400
SUBSCRIBER PREMISES	Subscriber.Entrance Unit Per Subscriber	300
FIBER CABLE	Cable Sheath Per Meter	1.00
	Fiber Per Meter	0.10
	Drop Cable Per Meter	0.50
CABLE PLACEMENT	Cable Placement in Town/Village per Meter	2.0
	Cable Placement in Rural Area Per Meter	1.25
	Drop Cable Placement Per Meter	1.20

TABLE 6.1.1

INTEGRATED FIBER NETWORK UNIT COST DATA

(2) Both the voice and data channel are transmitted at 64 kb/s, which in essence provides two 64 kb/s path between the RDC and subscriber.

(3) Digital trunking for video is assumed. However, digital video transmission to the subscriber is not considered due to the high cost associated with terminal equipment.

(4) Video switching at the Integrated Switching Unit (ISU) will use space switching with a capacity of up to 30 channels per subscriber.

(5) The video program centre does not include programming or software costs.

A computer program was developed (see Appendix D for detail) that gives the total cost breakdown of the integrated fiber network based on the input variables listed above. A typical example is shown in Tables 6.1.2 and 6.1.3 under the following set of conditions:

(i) The same remote distribution centre (RDC) serves the remote village and the surrounding rural populations based on maximum distribution length of 8 km.

(ii) Repeater spacing is assumed to be 16 km for both voice and video trunking, implying that no field repeater sites are required.

(iii) No sharing of trunk and feeder cable is assumed though the computer program developed can exercise that option.

(iv) Fiber cable is assumed to be available in increments of 6 fibers. Tapered cable is assumed on trunk and feeder.

(v) Bi-direction transmission is assumed for distribution but not for trunking.

LOCATION	NO. OF CENTRE	AREA IN km^2	NO. OF SUBSCRIBER
TOWN	1	8	1600
VILLAGE	1	1	200
RURAL	8	1024	1024
TOTAL	8	1024	2824

TABLE 6.1.2

HYPOTHETICAL DATA OF A RURAL DISTRIBUTION NETWORK

	PERCENTAGE OF TOTAL COST				
LOCATION	CABLE & CABLE PLACEMENT	SUBSCRIBER TERMINAL EQUIPMENT	INTEGRATED SWITCHING UNIT	CENTRAL OFFICE	COST/PER SUBSCRIBER IN $
TOWN	50	47	1	2	1469
VILLAGE	41	55	1	3	1268
RURAL	66	24	6	4	4082
TOTAL	58	32	4	6	2492

TABLE 6.1.3

COST PER SUBSCRIBER OF INTEGRATED FIBER NETWORK

Because of the higher subscriber density in the town and village, the cost per subscriber is lower than the rural subscribers. This will result in an average cost of $2492/sub. for the overall distribution network. In all instances, cable and cable placement make up more than 40% of the total cost.

In order to provide a better understanding of cost effectiveness of integrated fiber network, curves of cost per rural subscriber were constructed first by varying the rural subscriber density and maximum distribution length and second by varying the cost of fiber and the rural subscriber density. The results are shown in Figures 6.1.2 and 6.1.3 respectively. In Figure 6.1.4, the variables chosen are fiber cable cost and maximum distribution length. Parameters that are kept constant are identical to those provided in Tables 6.1.1 and 6.1.2. Supporting notes for these figures are given below:

Notes on Figure 6.1.2

- Based on the unit cost data established, the average cost of the rural subscribers first decreases as the maximum distribution length increases until a certain length and then increases up again. The change in slope represents the point when the costs of cable and placement begin to dominate.

- As the subscriber density increases, the minimum cost distribution length decreases. This indicates that the contribution of the RDC to the total cost becomes less and less significant when its common equipment and housing is shared by more and more subscribers. However, the difference is small for the densities typical of the Canadian rural environment (refer to Table 2.1.1). It also implies that modelling based on maximum reach might not necessarily be optimal, depending on the subscriber density in question.

- Note that to give a better appreciation of the low density rural areas alone, the cost of town and village subscribers are not included.

Notes on Figure 6.1.3

- The average cost per rural subscriber is very sensitive to subscriber density in the region where the density varies from 0.5 to 2.0 per km^2 and then gradually tapers off as the density increases.

- The impact of lowering the fiber cable cost to 80%, 60%, 40% and 20% of the nominal cost results in a reduction in cost per subscriber of between $200 to $800 per decrement, depending on subscriber density. The cost is below $1400 for a density of 5.0 sub/km2 with fiber cables at 20% of the nominal cost assumed.

Notes on Figure 6.1.4

- Keeping the rural subscriber density constant at 1.0 sub/km2, which is the national average, the lowest cost per subscriber, including town and villages, occurs when the maximum distribution length is 8-10 km. This number represents the projected state-of-the-art of the fiber transmission link for broadband distribution in the 1985 time frame (Refer to Appendix B for detail).

- As the maximum allowable distribution length increases, the effect of varying the fiber cable cost becomes more significant, due to the higher contribution of cabling on a per subscriber basis.

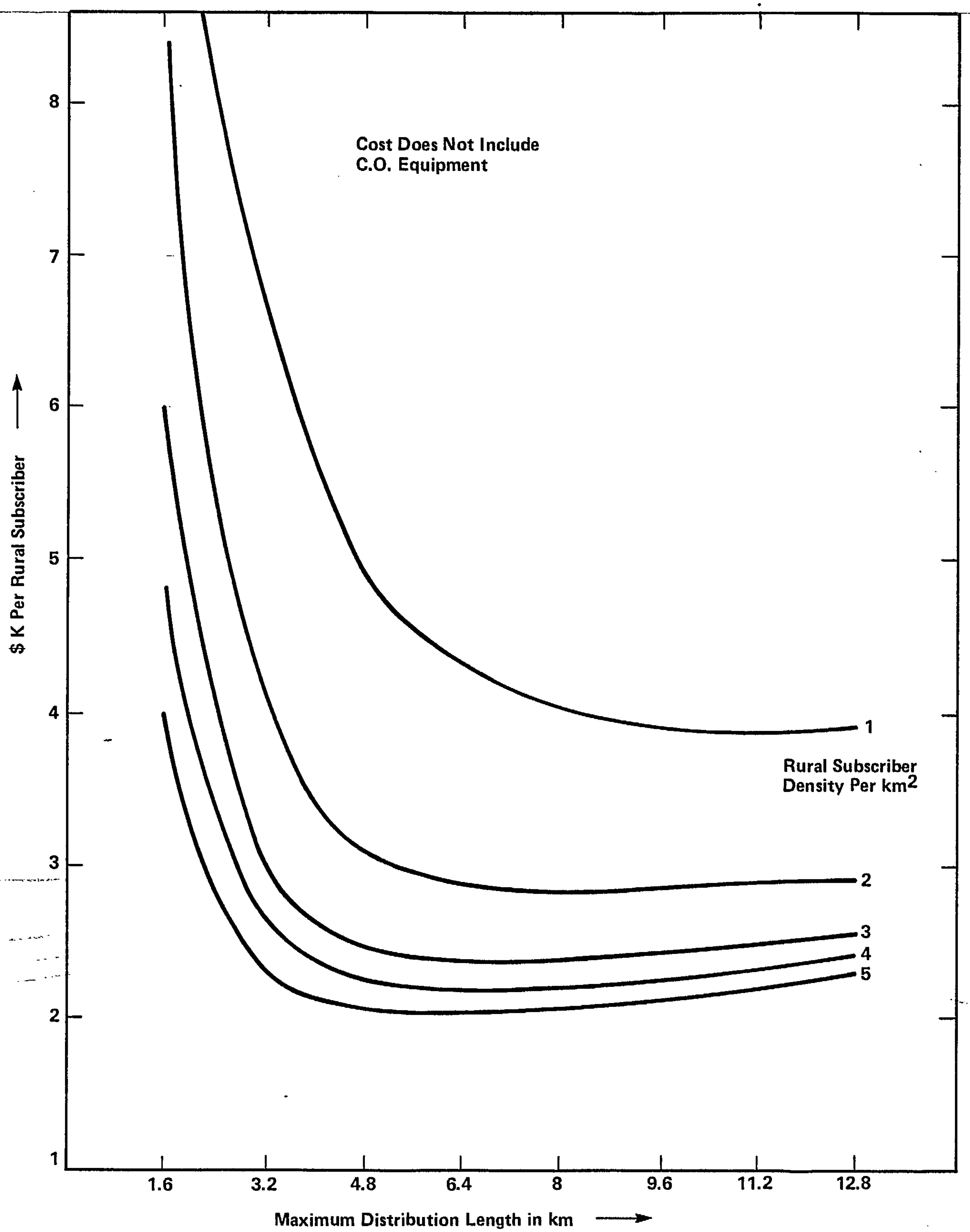

Figure 6.1.2 Average Cost Per Rural Subscriber vs. Maximum Distribution Length For Integrated Fiber Network

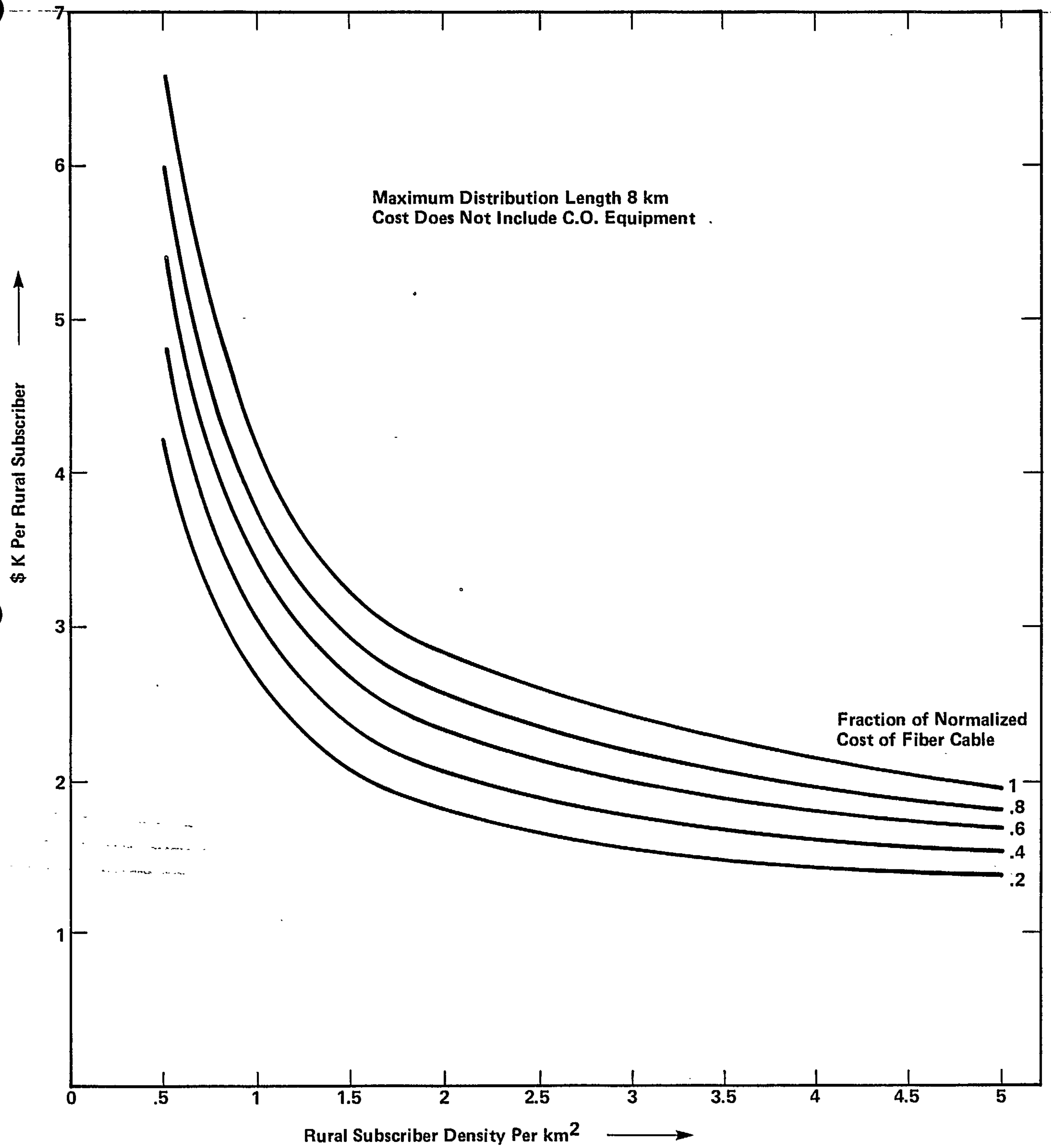

Figure 6.1.3 Average Cost Per Rural Subscriber vs. Rural Subscriber Density For Integrated Fiber Network

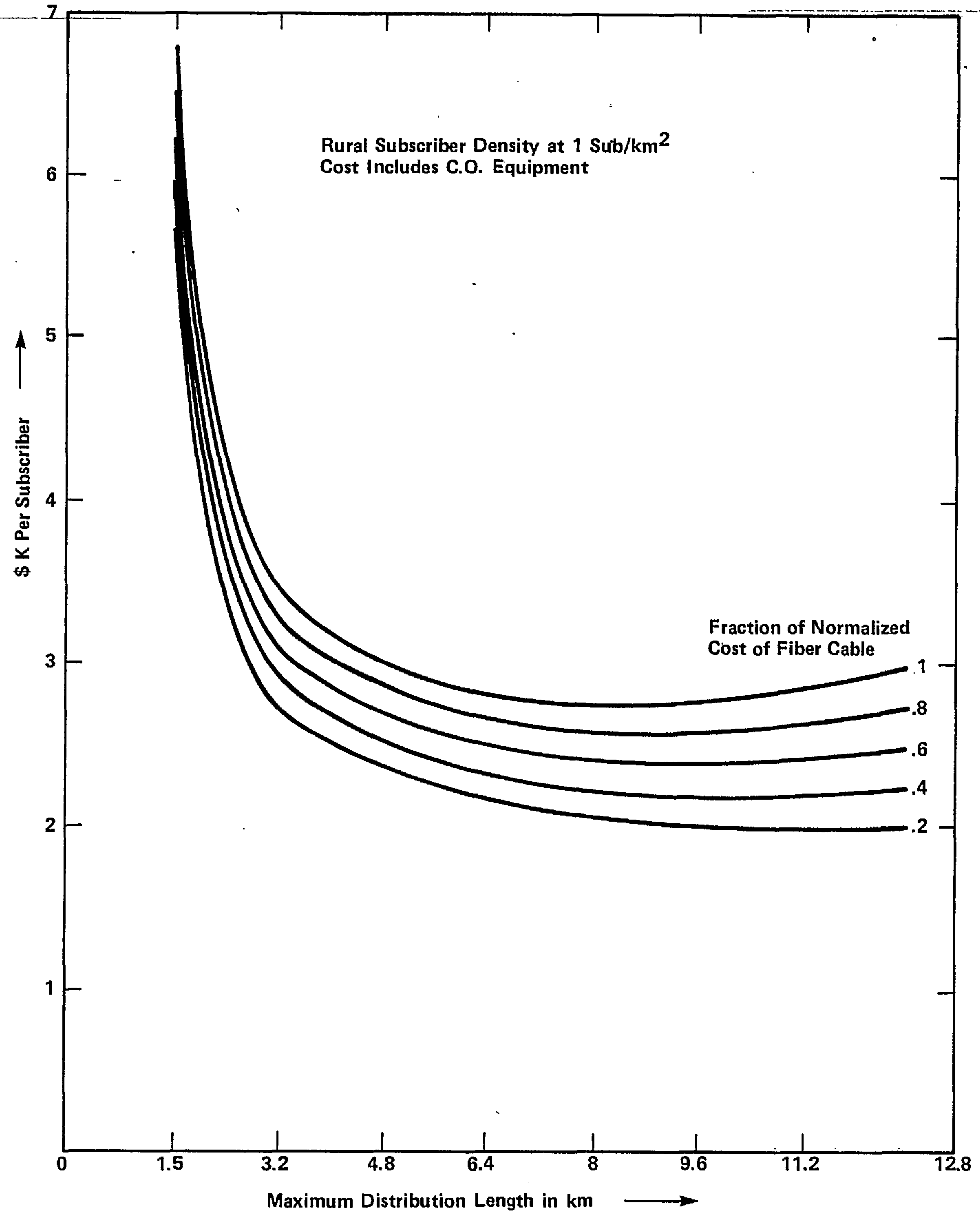

Figure 6.1.4 Average Cost Per Subscriber vs. Maximum Distribution Length For Integrated Fiber Network

6.2 APPLICABILITY TO THE PRAIRIE PROVINCES

One of the main objectives of the Program Definition Study is to assess the technical and economical feasibility of the configuration used in the Field Trial System. Section 6.1 attempted to supply some preliminary estimates on the cost of delivering broadband services in the rural environment by modelling a rural distribution network based on existing exchange boundaries, rural subscriber densities and distribution pattern. Any further cost modelling in this direction would not result in a more accurate estimate since so many assumptions have been necessary. What is required is to conduct specific application studies of typical rural exchange areas and routes. A study was conducted using the data collected on Elie to determine the relative cost of an integrated fiber network versus separate networks using conventional copper pairs for telephony and coax facilities for CATV. Such a comparison provides some insight into the applicability of fiber optics for rural distribution in the Prairie Provinces. It can also be used as a bench mark system for comparison with other cost studies [5] [6].

A total of 161 subscribers were selected instead of the total exchange population. The original intent was to use the figures for projecting the cost of the Field Trial System into 1985 for the same group of subscribers selected for the Field Trial. However, due to the change in transmission capability from 1980 to 1985 such a projection cannot properly be made. The result of the cost comparison is given in Table 6.2.1 using the following assumptions:

(1) For CATV, .50" coaxial cable was assumed on trunks with a repeater gain of 26 dB. .412" cable was assumed for feeders and RG-59 for drops.

(2) For telephony, the existing copper distribution plant consisting of 19 and 22 gauge pair cables were used.

(3) Cable placement cost estimates included all Outside Plant hardware plus road and river crossing.

(4) As in the previous cost models, the cost of remoting was absorbed by the rural subscribers, thus reflecting a lower than expected per subscriber cost for St. Eustache.

(5) Separate trunk and feeder fiber cable were assumed with joint placement.

It can be seen that on a per subscriber basis, assuming full penetration for both Telephony and CATV, the total prorated cost per subscriber of the integrated fiber system is 26% less than for separate copper plants, but is only marginally less than joint placement of these facilities. In extending the number of subscribers to cover the total exchange and also taking into consideration the growth projected up to 1982, it is found that the average cost per subscriber would be reduced to below $1600. The figure, however, does not cover the cost of the central office common equipment. It can easily be shown that if the existing analog switcher is replaced simultaneously by a digital switcher, the total cost saving will be substantially increased since the extra stage of A/D conversion can then be eliminated. Thus it appears that new fiber optics integrated networks can find application as complete replacement of the current rural distribution networks, including the existing CDO's, provided that such a gradual modernization program is properly planned to allow for new construction budgeting.

LOCATION	NUMBER OF SUBSCRIBERS	CONVENTIONAL COPPER PAIR AND COAX FACILITIES — SEPARATE SYSTEM: TELEPHONY	CATV	COMBINED	JOINT PLACEMENT	INTEGRATED FIBER SYSTEM
ELIE	39	248	252	500	368	1215
ST. EUSTACHE	45	1089	1036	2125	1682	1067
RURAL	77	2156	1877	4038	3317	3143
TOTAL	161	1396	1248	2644	2145	2096

TABLE 6.2.1

COST COMPARISON BETWEEN FIBER PLANT AND COPPER PLANTS ($PER SUBSCRIBER)

6.3 PROJECTION OF THE CANADIAN RURAL MARKET

The size of the Canadian rural market for integrated fiber networks is a function of the services that they can provide as well as the subscription fees charged. Since the proposed services for such networks include single-party POTS, FM and CATV as a basic minimum, a rough projection of the market potential can be established by estimating the number of rural households who do not currently have access to these services. It should be pointed out, however, that since a detailed market study was not called for, figures presented here only represent a first order approximation of the volume involved.

(a) RURAL CATV MARKET

Based on data obtained from Statistics Canada [7] [8], Table 6.3.1 was constructed summarizing the statistics of TV households. It can be observed that the number of rural households with TV in Canada (1,436,000) is smaller than the TV households in areas not licensed for CATV (1,888,000). This is generally true for all the provinces except British Columbia, where the penetration of CATV (number of actual and potential subscribers) is exceptionally high (90%) as compared to the national average of 67%. Thus it can be assumed that the number of potential rural subscribers in Canada can be as high as 1,436,000, which is equal to the total number of rural TV households in 1975 and is growing at a rate of approximately 5% a year.

It was also found that there were 54,000 subscribers served by the 129 smaller CATV systems (defined to be less than 1000 subscriber per system) in Canada in 1975. Since smaller systems are typical of the rural environment, this implies that the number of CATV subscribers in the rural areas was no more than 54,000 (less than 4% of rural TV household), and thus provides some validity to the original estimate of 1.4 million potential subscribers. However, a detailed market study is required to determine the exact segregation between rural and its urban/suburban counterpart.

(b) RURAL TELEPHONY MARKET

- Approximately 94% of rural households subscribe to telephone service. Of the remaining 6%, 2% cannot afford the cost and the other 4% are beyond reach. Thus the potential market is basically reduced to one of service enhancement and systems replacement, as the growth in rural population is not expected to be substantial in the next few years. Service enhancement can come in the form of upgrading all the multi-party subscribers (estimated to be about 600,000 in 1976) to single-party. System replacements can be implemented by the timely retirement of the aging distribution plants and step-by-step switching machines with fiber based networks. The questions of introduction timing, transitional strategies, compatibility with the evolving toll network etc., however, have to be tackled first.

Thus, there appears to be a strong potential market for providing improved and enhanced telecommunication services to the rural population in Canada. Fiber optics distribution systems, as described in the previous sections, is an excellent candidate to capture this market by utilizing the synergism among fiber, digital switching and digital transmission. This is particularly true if integrated services are offered to reduce the capital expenditure required on a per-service basis. Such networks, if provided with video switching capability, will offer all rural subscribers a broadband distribution system that can deliver a full range of services. To give an idea of the market size, if 1 million rural households were to be upgraded to integrated fiber networks in the ten years period between 1985-1995, at $1500 per subscriber, the market would be $150 millions a year for ten years.

PROVINCES	NUMBER OF TV HOUSEHOLDS	NUMBER OF RURAL TV HOUSEHOLDS	TV HOUSEHOLDS IN NON-LICENSED AREAS	TV HOUSEHOLDS WHICH ARE NEITHER POTENTIAL SUBSCRIBER NOR SUBSCRIBERS
ATLANTIC PROVINCES	526	237 (45)	377 (72)	384 (73)
QUEBEC	1,726	293 (17)	530 (31)	690 (40)
ONTARIO	2,470	420 (17)	473 (19)	543 (22)
MANITOBA	296	83 (28)	103 (35)	110 (37)
SASKATCHEWAN	264	111 (42)	248 (94)	249 (94)
ALBERTA	495	114 (23)	115 (23)	126 (29)
BRITISH COLUMBIA	711	178 (25)	43 (6)	68 (10)
TOTAL CANADA	6,488	1436 (22)	1,888 (29)	2,170 (33)

TABLE 6.3.1

TV HOUSEHOLD STATISTICS IN 1975

NOTES:

(1) All numbers given should be multiplied by 1000

(2) The numbers in bracket represent percentages of TV households

6.4 ANALYSIS OF INTRODUCTION STRATEGIES

The decision on the extent and timing of fiber optics utilization for both broadband and narrowband telecommunications services to the rural sector of Canada is not an easy one to make. Although Sections 6.1, 6.2 and 6.3 have provided some understanding of the cost effectiveness of integrated fiber networks and the potential market, questions on compatibility with existing telephony and CATV plants, generation of capital for network overbuild, selection of subscribers and service level remains to be answered. A computer program was developed which will be of value in answering these questions.

For the purpose of this analysis, the long term objective of the operating company has been assumed to be: to provide telephony and CATV services in the serving areas specified in the previous sections of this report. The serving area typically consists of a town, one or more villages and the rural region. The objective of the analysis was to identify firstly from the economic viewpoint of the operating company the starting points to provide these services, and secondly, the relative economics for providing limited services. Five strategies have been identified for analysis using a non-discounted payback period as the liquidity indicator. The payback period evaluator is defined as the number of years required for the accumulated net cash flow (non-discounted) to equal zero and to remain greater than zero for the remaining life of the serving scenario.

There are other well-known engineering economic indicators such as PWAC (Present Worth of Annual Charges) and NPV (Net Present Value) for assessment of planning strategies. To utilize these indicators in a meaningfull manner will require a detailed application study of each strategy in time, supported by a thorough understanding of the specific operating company with respect to its financial parameters, tax structures and engineering philosophy. In the absence of this information the non-discounted payback period indicator was evaluated to serve the purpose of indicating the relative worth of each strategy. The five possible service scenarios were:

(1) Introduce integrated services (i.e. CATV, single-party POTS) to all subscribers in the serving area.

(2) Introduce integrated services to town subscribers, with rural and village subscribers only getting single-party POTS.

(3) Introduce integrated services to town and village subscribers, with rural subscribers only getting single-party POTS.

(4) Introduce integrated services to rural subscribers with town and village subscribers only getting single-party POTS.

(5) Introduce integrated services to rural and village subscribers with town subscribers only getting single-party POTS.

The descriptions of the parameters included in the analysis are listed in Table 6.4.1 and the results of the analysis based on the estimated parameter values are presented in Tables 6.4.2 and 6.4.3. Based on the set of figures used, strategy 1 gives the lowest pay-back period before discount, implying that integrated services should be introduced to the total serving areas of town, village and rural subscribers in this case.

It is important to note that the numerical results only serve as relative indicators. In reality these values will vary according to the characteristics of the operating companies and the associated telephone networks.

DISTRIBUTION OF TOTAL SUBSCRIBERS IN SERVING AREA	TOWN IN %	VILLAGE IN %	RURAL IN %
Capital Expenditures Per Subscriber			
- Integrated	CATV, FM, POTS	CATV, FM, POTS	CATV, FM, POTS
- Non-Integrated	POTS Only	POTS Only	POTS Only
Maintenance & Operating Expense Per Subscriber			
- Integrated	CATV, FM, POTS	CATV, FM, POTS	CATV, FM, POTS
- Non-Integrated	POTS	POTS	POTS
Revenues Per Subscriber			
Integrated - Captive Revenue (1)	CATV, FM, POTS	CATV, FM, POTS	CATV, FM, POTS
- Potential Revenues	New Services	New Services	New Services
Non-Integrated - Captive (1)	POTS	POTS	POTS
- Potential	POTS Upgrade	POTS Upgrade	POTS Upgrade

TABLE 6.4.1

PARAMETERS INCLUDED IN PAYBACK PERIOD ANALYSIS

NOTES:

(1) Adjustments have to be made to reflect the fact that not all subscribers want single party service.

```
FILE: PARAMETR MAY09    A    TIME= 11:59:27 DATE: 05/09/78 BELL-NORTHERN RESEARCH

2800      L       TOTAL SUBSCRIBERS WITHIN STUDY AREA
.4        SDT      SUBSCRIBER DISTRIBUTION BY  TOWN
.1        SDV      "       "         "      "   VILLAGE
.5        SDR      "       "         "      "   RURAL
1200.     STCEI   INTEGRATED TOTAL CAPITAL COST PER LINE-TOWN
1500.     SVCEI    "          "       "       "     "    "-VILLAGE
2500.     SRCEI    "          "       "       "     "    "-RURAL
500.      STCE    NON-INTERGRATED CAPITAL COST/SUB -TOWN
1500.     SVCE     "                    "       "   -VILLAGE
2000.     SRCE     "                    "       "   -RURAL
10.       STOPI   INTEGRATED ANNUAL OPERATING EXPENSES/SUB -TOWN
15.       SVOPI    "          "       "                 "       -VILLAGE
20.       SROPI    "          "       "                 "       -RURAL
15.       STOP    NON-INTEGRATED ANNUAL OPERATING EXPENSE/SUB-TOWN
20.       SVOP         "          "        "              "     -VILLAGE
30.       SROP         "          "        "              "     -RURAL
200.      STRVCI  INTEGRATED ANNUAL CAPTIVE REVENUE/SUB- TOWN
200.      SVRVCI       "      "      "            "      - VILLAGE
300.      SRRVCI       "      "      "            "      -RURAL
100.      STRVI   INTEGRATED ANNUAL POTENTIAL   REVENUES/SUB -TOWN
50.       SVRVI        "      "      "                 "      -VILLAGE
50.       SRRVI        "      "      "                 "      -RURAL
80.       STRVC   NON-INTEGRATED CAPTIVE REVENUES/SUB -TOWN    (ANNUAL)
80.       SVRVC        "                "          "  -VILLAGE (  "   )
100.      SRRVC       "                 "          "  -RURAL   (  "   )
20.       STRV    NON-INTEGRATED POTENTIAL   REVENUES/SUB -TOWN    (ANNUAL)
10.       SVRV           "          "                 "   -VILLAGE (  "   )
10.       SRRV           "          "                 "   -RURAL   (  "   )
5         IS      NUMBER OF STRATEGIS
```

Table 6.4.2 Input to Introduction Strategy Analysis Program

	STRATEGY1	STRATEGY2	STRATEGY3	STRATEGY4	STRATEGY5
CAPITAL EXPENDITURE	5264000.	4564000.	4564000.	4480000.	4480000.
OPERATING EXPENSE	43400.	58800.	57400.	50400.	49000.
REVENUE CAPTIVE	700000.	386400.	420000.	532000.	565600.
REVENUE POTENTIAL	196000.	128800.	140000.	95200.	106400.
TOTAL REVENUES	896000.	515200.	560000.	627200.	672000.
PAYBACK PERIOD NON-DISC	6.2	10.0	9.1	7.8	7.2

Table 6.4.3 Output from Introduction Strategy Analysis Program

6.5 JUSTIFICATION AND TIMING OF FIELD TRIAL

The Department of Communications has stated explicitly that the main purposes of the Field Trial are to foster the participation of Canadian industry in this important new technology during its early stages of development and to encourage Canadian design and marketing of practical alternatives to the use of the radio frequency spectrum for the delivery of broadband communication services. To achieve both ends, it has to be clearly demonstrated that the Field Trial System reflects the state-of-the-art of the evolution of the fiber optics technology while simultaneously illustrating its practical and economical feasibility from an administrative and maintenance standpoint.

The Canadian rural environment is characterized by long distances and extreme temperatures compared to those of most other countries with an active interest in the fiber optics technology. Thus, components and systems developed in other countries might not be optimum for Canada. To ensure the availability of fiber optics systems specifically tailored for Canada's needs, it is necessary to develop a strong Canadian manufacturing base in this technology. Since the proposed Field Trial System has been specifically designed for the Canadian rural environment, adopting the proposed Field Trial System would satisfy the interests of the public and private sectors in this new technology. Note that, as in all other new technology developments, the success of directly involved Canadian manufacturers will ripple through to other Canadian industries.

In Section 3.4, the technical merits of the Field Trial System have been discussed. A number of features are unique in comparison with other field trials that have been conducted and planned. These include:

(1) Bidirectional transmission of integrated voice, video and data.
(2) Digital telephony and data to the subscriber premises.
(3) Subscriber-initiated centrally-switched video distribution.
(4) Aerial and buried plant, and field handling in a rural environment.

The Field Trial System was designed and configured to overcome the technical limitations imposed by the state-of-the-art of the fiber optics technology such as light source linearity while at the same time taking full advantage of the many beneficial characteristics of this non-metallic medium. To permit a more complete and precise assessment of the technical and operational aspects of fiber based distribution systems, these features have to be field trialed to check if the expectations are born out in reality.

The integrated fiber optics distribution system recommended for the Field Trial was also found to be cost-effective against conventional copper base plants, even when joint placement was assumed. Due to limitations in the quality of service that can be provided by the coax based CATV networks in the rural environment, a better broadband medium like fiber optics can definitely find application. This is particularly true if other services can be offered at only a small incremental cost. However, before full scale implementation can begin, market penetration, subscriber's preferences on new services etc. have to be evaluated. The Field Trial can provide very useful information on these items.

An evaluation of the projected fiber optics technology has revealed that it will be ready for introduction into the Canadian rural environment in 1985. A switched star configuration has been identified as the most suitable for such an environment. By demonstrating to the operating companies that the Field Trial System configuration can be implemented in the intermediate future, that it is fully compatible with the current evolutionary trend to digital local distribution networks and that the inherent modularity of the systems can allow for graceful growth and service expansion; all of these will help establish the confidence that is necessary for wide spread use of this new technology.

High technology telecommunication products normally require 4 to 5 years from conceptual design to market introduction. To aim for mid 1985 implementation, all the basic ground work in terms of system analysis, exploratory research and development, technology and field trials etc. has to be done within the next two or three years. Thus it is imperative that if Canada is to play a leading role in the application of fiber optics into the rural environment, the decision on the Field Trial Program should not be delayed.

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A

APPENDIX A

DETAILED ROUTE LAYOUT OF FIELD TRIAL SITE

The rural telephone exchange of Elie, Manitoba has been selected as the Field Trial site. The complete exchange totalling 452 subscribers in 1977 is illustrated in Figure A.1.

A typical rural distribution field trial should consist of both buried and aerial cables serving subscribers in all sectors of the exchange, namely rural, town and villages. This has been accomplished by selecting subscribers located in the town of Elie, the village of St. Eustache and the surrounding rural area. The specific type of Outside Plant construction to be trialed is listed in Table A.1.

An appraisal of the existing telephone plant, construction methods and route engineering details were obtained from MTS during the two field visits. The Elie Field Trial will consist of two phases totalling 150 subscribers. In Phase 1, 10 subscribers will be provided service. These subscribers as depicted in Figure A.2 will be located immediately north of the Trans Canada Highway along MTS's rural cable routes 100, 144, and 145. Table A.2 gives a name list of these subscribers, which include nine rural subscribers and one business enterprise (Madeleine's Restaurant). Phase 1 will be a completely buried trial. Figure A.2 also illustrates the cable sizes, route layout and location of the required sealed cable pedestals and splices.

The first section of the route will consist of a buried section in the town of Elie with the cable being placed in the shoulder of the road. In the rural section north of the Trans Canada the cable will be buried on private property easement. Road allowance will be used where easement cannot be procured. The cable will be placed under the Trans Canada Highway and any road crossings of Highway 248 (R.R.100) using the standard MTS pipe pushing technique. The total cable requirements for Phase 1 of the Field Trial are summarized in Table A.3.

To facilitate the construction of Phase 1 of the Field Trial separate cables will be provided for the two phases. The only exception will be that cables for both Phases 1 and 2 will be installed simultaneously under the Trans Canada Highway thereby saving a second major road crossing cost.

The main feeder cable for Phase 1 will be a twelve fiber cable which provides two spare fibers for testing or emergency requirements. A two fiber buried drop will be used with only one fiber being spliced to each subscriber. At each end, a fiber-optic connector will link the Outside Plant with the respective electro-optical interface equipment.

All field splicing, using the fusion splicing technique, will be performed at sealed buried cable pedestals (11 total). Initial acceptance testing will be conducted on the fibers before splicing. A final end to end measurement will verify the quality of the Outside Plant loop.

Phase 2 will demonstrate a rural fiber distribution system on a larger scale. 140 additional subscribers will be provided service in three areas of the exchange, namely the town of Elie, the village of St. Eustache, and the rural farming regions.

Section 3 of this report has detailed the system configuration required to provide service to these areas. It requires the use of two distribution centres, one located at the CDO and a Remote Distribution Centre located 8.4 km north of Elie at the junction of Highway 248 and 241 (See Figure A.3). A dedicated 24 fiber trunk cable will connect the CDO to the RDC. Figures A.3, A.4, and A.5 detail the route layout, subscriber locations, type of construction (buried or aerial), cable sizes and cable terminal/pedestal locations. The total length of fiber cable required for this phase of the trial is presented in Table A.4. These cables will be buried on private property easement, on the east and north of all rural roads following standard MTS practice.

Cable lengths up to 2 km will be used to minimize the number of fiber splices. Where there is a feeder and trunk cable along the same route it is expected that the two cables will be placed jointly. A two fiber drop cable will again be used in Phase 2. The range of fiber-optic drop and feeder distribution lengths in both phases of the trial are illustrated in Table A.5. Note that the fiber distribution parameters are similar for both distribution centres. 10 km of buried drop cable and 4 km of aerial drop cable will be trialed in Phases 1 and 2 along with 36.8 km of main cable. In addition, the Field Trial will involve a total of eighty six sealed cable terminals and pedestals (47 buried pedestals and 39 aerial terminals) and approximately 800 field fiber splices.

Table A.6 summarizes the subscriber locations for both Phase 1 and 2 and illustrates that the Field Trial covers all sections of a rural distribution system. In addition, both front and back access to the subscriber homes will be tested within the town of Elie.

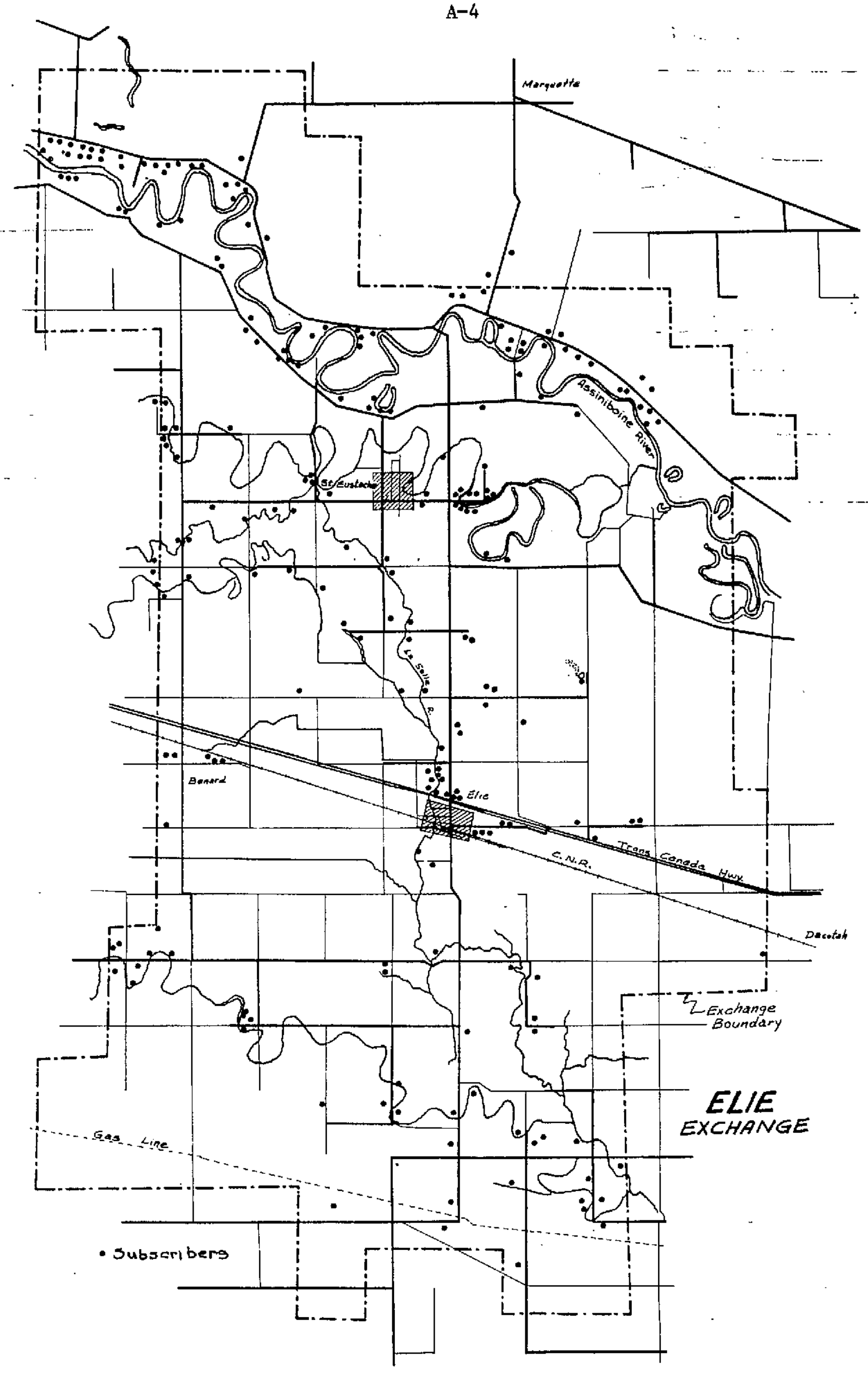

Figure A.1 Rural Exchange of Elie, Manitoba

LOCATION	BURIED	AERIAL *
Town of Elie	YES	YES
Village of St. Eustache	NO	YES
Rural	YES	NO

TABLE A.1

TYPE OF OUTSIDE PLANT CONSTRUCTION

* Aerial Construction will only be used where there is existing aerial plant thereby saving the cost of constructing new pole lines.

NAME	RURAL ROUTE LOCATION	DISTRIBUTION DISTANCE - km		
		FEEDER	DROP	TOTAL
Madeleine's Rest.	100	.65	.06	.71
R. Girard	100	.93	.53	1.46
W. Carmichael	100	.93	.62	1.55
P. Dufresne	100	1.32	.55	1.87
L. Bouchard	100	2.20	.31	2.51
R. Bernardin	100	2.60	.03	2.63
L. Bernardin	100	2.60	.31	2.91
P. Bouchard	101	2.27	.07	2.34
R. Williams	144	1.32	.17	1.49
G. Bernardin	145	2.06	.44	2.50
	AVE	1.69	.31	2.00

TABLE A.2

PHASE 1 SUBSCRIBER DETAILS

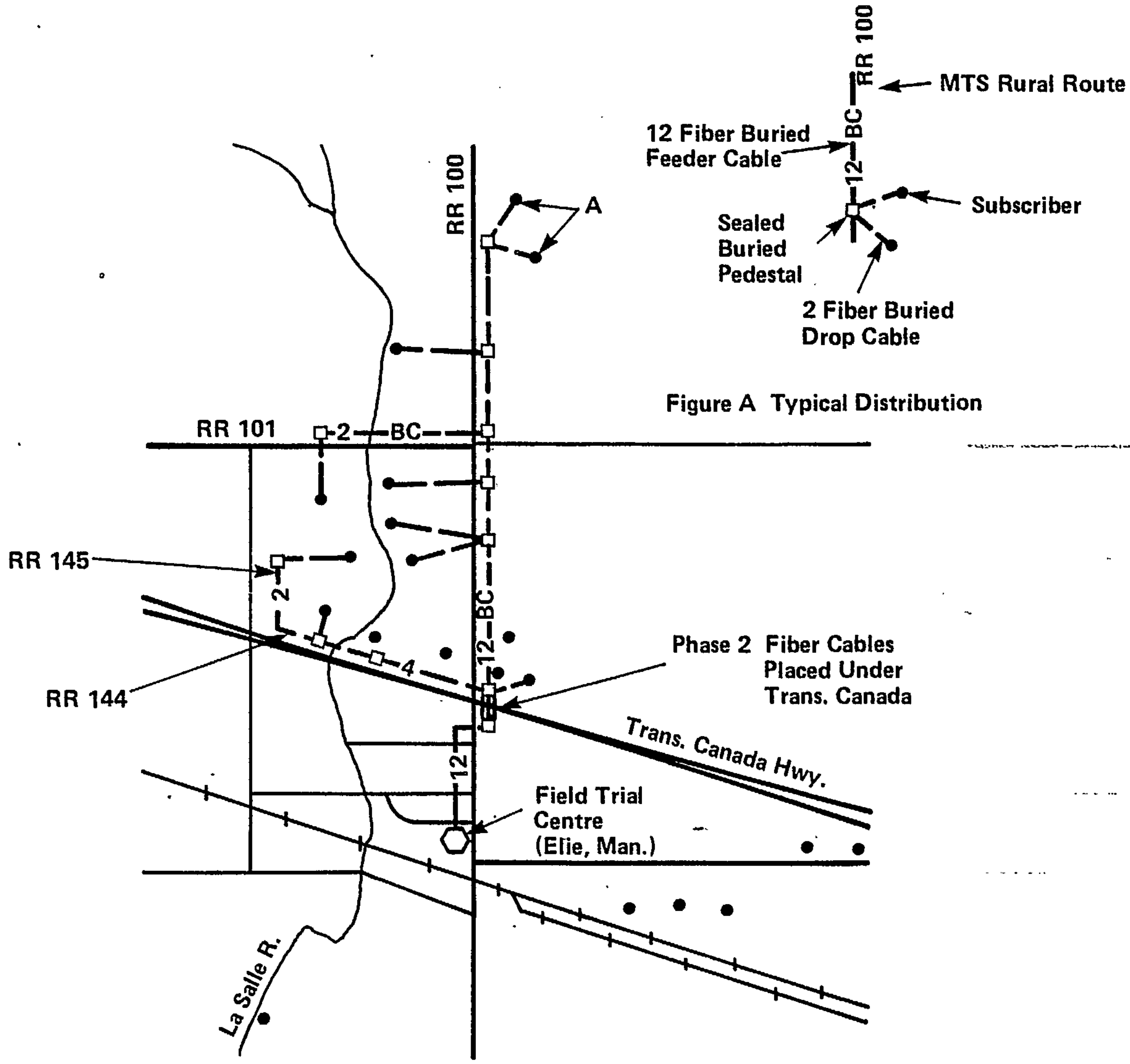

Figure A.2 Phase 1 Outside Plant Route Details

NO. OF FIBERS /CABLE	LENGTH (km)
12	3.2
4	.7
2	3.4

TABLE A.3

PHASE 1 CABLE REQUIREMENTS

<u>Summary</u> Total Cable Length 7.3 km
Total Fiber Length 48.0 km

NO. OF FIBERS/CABLE	CABLE LENGTH (km) TYPE OF CONSTRUCTION	
	BURIED	AERIAL
48	.8	1.2
24	9.8	.9
12	2.4	.7
6	7.0	-
4	6.8	-
2	9.9	4.0
CABLE LENGTH	36.7	6.8
FIBER LENGTH	391.4	95.6

TABLE A.4

PHASE 2 CABLE REQUIREMENTS

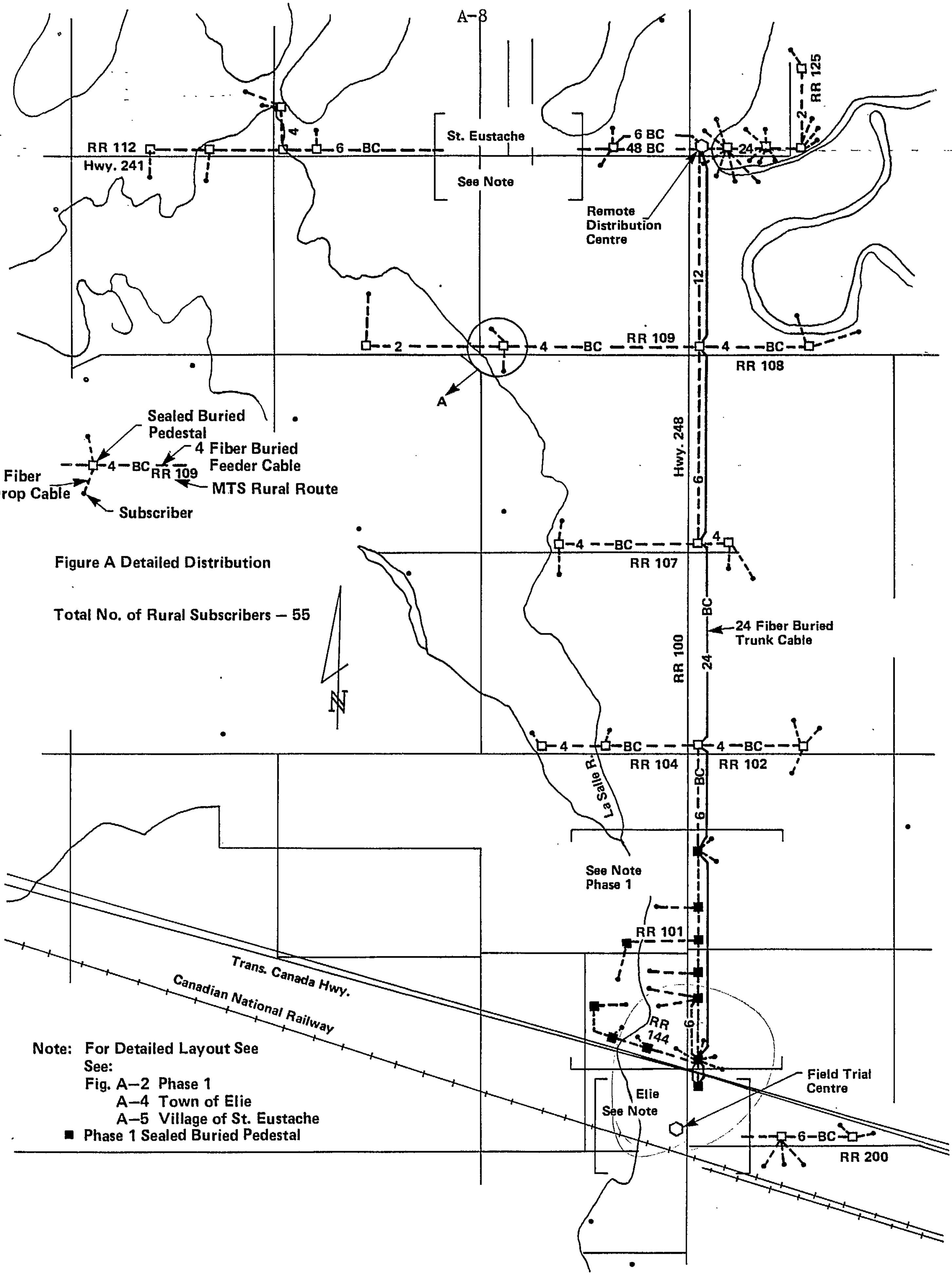

Figure A.3 Phase 2 Outside Plant Route Details-Rural

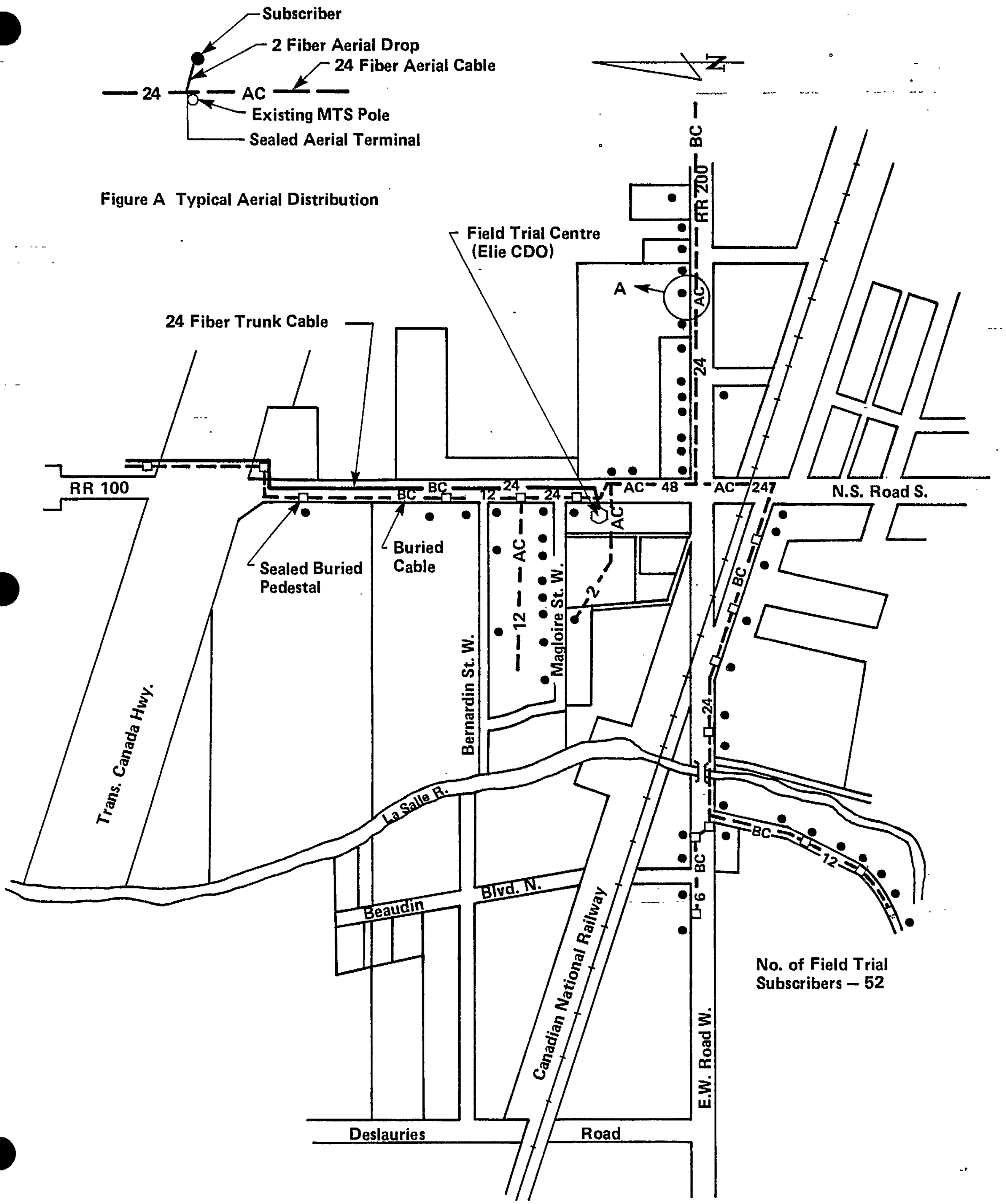

Figure A.4 Phase 2 Outside Plant Route Details – Town of Elie

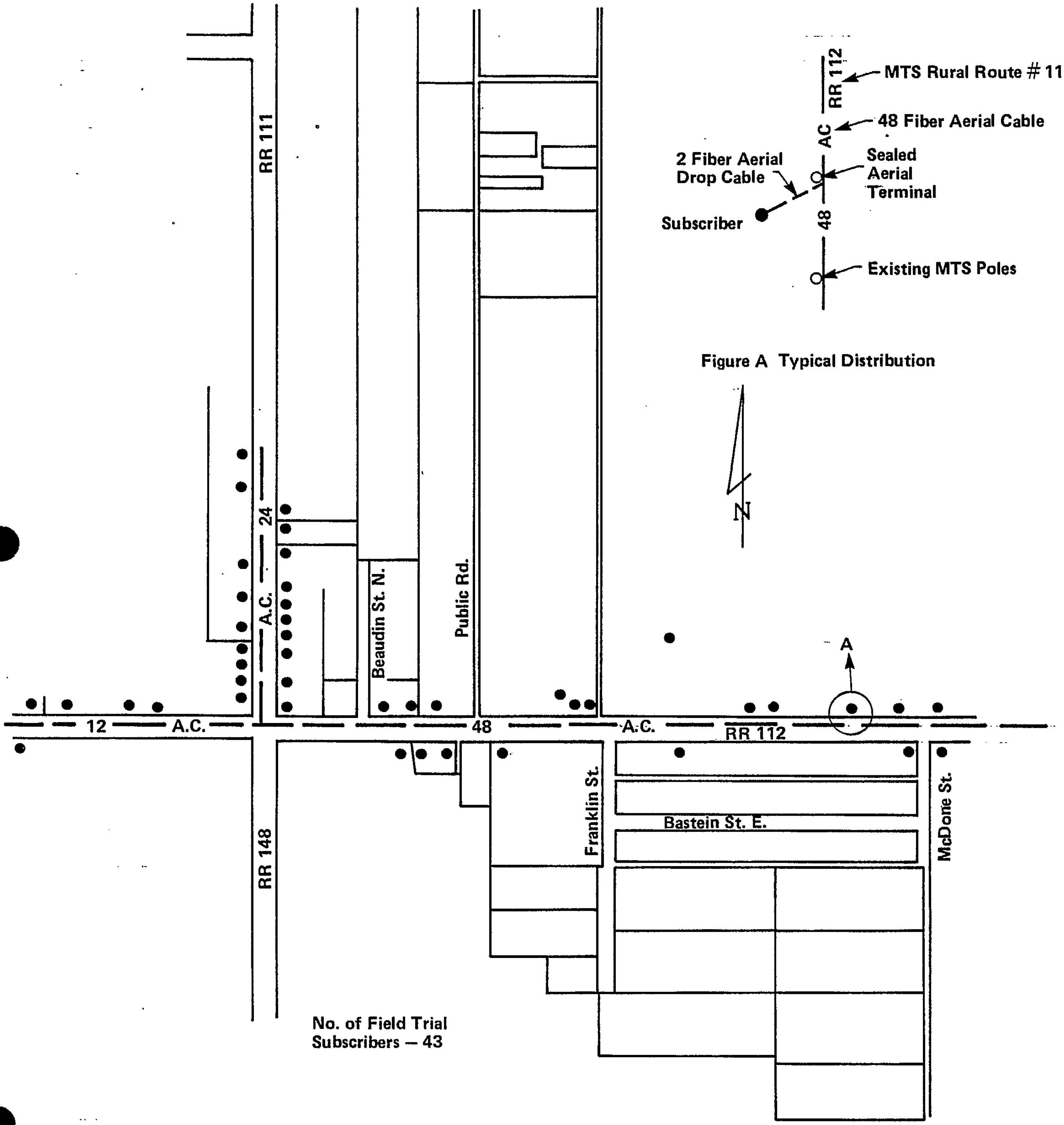

Figure A.5 Phase 2 Outside Plant Route Details — Village of St. Eustache

DISTRIBUTION POINT	SUBS. LOCATION	NO. OF SUBS.	DISTRIBUTION LENGTH (km)					
			FEEDER		DROP		TOTAL	
			AVE	RANGE	AVE	RANGE	AVE	RANGE
FIELD TRIAL CENTRE	RURAL	23	1.96	.65-4.31	.22	.03-.55	2.18	.71-4.74
	TOWN OF ELIE	52	.41	.03-1.00	.04	-	.45	.06-1.03
REMOTE DISTRIBUTION CENTRE	RURAL	32	1.94	.24-4.45	.15	.03-.61	2.09	.36-5.00
	VILLAGE OF ST. EUSTACHE	43	1.59	.82-2.02	.05	-	1.64	.87-2.07

TABLE A.5

FIELD TRIAL DISTRIBUTION LENGTHS

DISTRIBUTION CENTRE		NO. OF FIELD TRIAL SUBSCRIBERS			
		RURAL	TOWN OF ELIE	VILLAGE OF ST. EUSTACHE	TOTAL
FIELD TRIAL CENTRE (CDO)		23	52	-	75
REMOTE DISTRIBUTION CENTRE		32	-	43	75
SUMMARY		55	52	43	150
TYPE OF SERVICE	BURIED	55	25	-	80
	AERIAL	-	27	43	70

TABLE A.6

FIELD TRIAL SUBSCRIBER BREAKDOWN

B

APPENDIX B

TRANSMISSION CAPABILITY OF FIBER OPTICS TECHNOLOGY

This appendix summarizes predictions of the characteristics of fiber optics components and the transmission capabilities of a number of candidate systems for the 1980 and 1985 time frames. Maximum transmission distances were computed using the analysis methods described in [9] with some minor improvements.

Table B.1 shows the predicted characteristics of commercially available cabled optical fiber at 850 nm. Note that the loss includes an allowance for losses induced in the cabling process and by extreme temperatures. Because the information obtained on the sources and detectors strongly suggests the availability of longer wavelength (1300 nm) components by 1985, the cable characteristics for 1985 are given for both 850 and 1300 nm. Items not shown are assumed to be the same as the previous column.

Table B.2 shows the projected characteristics of short and long wavelength LED's for 1980 and for 1985. Table B.3 presents the projections for injection lasers. Tables B.4 and B.5 present the projections on PIN and avalanche photodiodes respectively.

Maximum transmission capability were then computed based on the characteristics of the fiber optics components listed in Tables B.1 to B.5. Where a range is quoted the more conservative figure is used. The overall video signal to noise requirement was taken to be 40 dB NCTA. The requirement for that portion of the network from the Remote Distribution Centre outward was set to be 43 dB assuming 46 dB each for the head-end and trunk. A 3 dB unallocated optical loss margin was also assumed. Table B.6 summarizes the results of these calculations for the distribution portion of the network where laser light sources are used. PIN detectors are assumed except in the case of FM modulation where APD detectors are selected. For the tree configuration only the case where 4 subscribers at the end of one unrepeatered link is shown. Addition of more repeaters will make the length per repeater even shorter.

Figures B.1 and B.2 show the performance of various modulation methods for trunking. VSB-AM is vestigial sideband amplitude modulation which is the same as NTSC. Digital PCM offers the best trunking performance but requires analog to digital conversion in the terminals. FM offers nearly equivalent performance for a considerable reduction in terminal costs.

CHARACTERISTICS	1980	1985	
Wavelength of operation	850 nm	850 nm	1300 nm
Cabled loss, -40 to +60°C (dB/km)	3-4	2-3	1-2.5
Loss increase, -55 to +60°C (dB/km)	0.5	0.3	0.3
Chromatic dispersion (ps/km-nm)	90	90	negligible
Modal dispersion ns/km	0.3 - 0.7	0.2 - 0.5	
Core diameter (μm)	50-75		
Numerical aperture	0.22		
Continuous fiber cable length (km)	2 - 4		
Splice loss (dB)	0.3	0.2	
Connector loss (dB)	1.0	0.5	

TABLE B.1

PROJECTED CHARACTERISTICS OF OPTICAL FIBER CABLE

LED

MATERIAL	POWER INTO FIBER @ 200 ma (μW)	BANDWIDTH (MHz)	WAVE LENGTH λ (nm)	Δλ (nm)	THD @ 100 ma (dB)	ESTIMATED PRICE
1980						
GaAlAs	170	85 to 120	850	45	-45dB	$30-40
	500	23 to 30				
GaInAs	15		1060	65		$150-300
1985						
GaAlAs	PERFORMANCE SAME AS 1980					$5-10
GaInAs	100-150	35 to 50	1100-1300	600-1000	-45dB	$40-60

TABLE B.2

PROJECTED CHARACTERISTICS OF INFRARED LIGHT EMITTING DIODES

Notes:

(1) Power coupled into step index fiber (core diameter =85 μm, NA = 0.16)

(2) Bandwidth at which the electrical output of a photodetector is reduced 3dB from its value at DC.

(3) Efficiency at 25°C. For constant DC input, optical output decreases .1 to .2% / °C.

(4) Lifetime - 10^6 hrs at 25°C ambient.

TYPE	THRESHOLD	P_o	WAVE LENGTH λ	$\Delta\lambda$	LINEARITY	MEDIAN LIFETIME	ESTIMATED PRICE
1980							
GaAlAs	70-100mA	5-10mW	850nm	2nm	better than -50dB at 2-3 mW into fiber	10^5 hrs.	$250-500
1985							
GaAlAs	50-100mA	5-10mW	850nm	1nm	-50dB	10^6 hrs.	$ 25-50
GaInAsP	100-150	5-10mW	1100-1300nm	2nm	-50dB	10^5 hrs.	$100-200

TABLE B.3

PROJECTED CHARACTERISTICS OF INJECTION LASERS

It is expected that longer wavelength lasers will be commercially available by 1985, although none is available as of Februrary 1978.

YEAR	WAVE LENGTH	QUANTUM EFF.	DARK CURRENT (nA)	RISETIME (ns)	CAPACITANCE (pF)	AREA (mm^2)	ESTIMATED PRICE (WITH CONNECTOR)
1980	850	80-90	1	1	0.6	.01	\$50- 75
1985	850	80-90	1	1	0.6	.01	\$2 - 5
	1300	80	5 - 100	<.5	1-2		\$5 - 10

TABLE B.4

PROJECTED CHARACTERISTICS OF PIN PHOTODIODES

MATERIAL	WAVE LENGTH (nm)	QUANTUM EFF. n%	AREA (mm^2)	DARK CURRENT BULK (nA)	DARK CURRENT SURFACE (nA)	EXCESS NOISE FACTOR K	MAX. USE-ABLE GAIN	RISE-TIME (ns)	CAP. (pF)	V_b	$\frac{\Delta V_b}{\Delta T}$	ESTIMATED PRICE (WITH CONNECTOR)
1980												
Si	850	77	.2	.01	20	.02	150	.5	1.6	225	.6	\$30
1985												
Si	850											\$20
(III-V)	1300	80 -90		1-100	20	.1-.5		.2	2-3			\$100-200
Ge	1300	6 0		100		.5		.5	3			\$30-\$50

TABLE B.5

PROJECTED CHARACTERISTICS OF AVALANCHE PHOTODIODES

NETWORK CONFIGURATION	MODE	NUMBER OF CHANNELS/FIBER	NUMBER OF SUBSCRIBERS/FIBER	MODULATION	MAX DISTRIBUTION LENGTHS IN km	
					1980	1985
STAR	SWITCHED	1	1	NTSC	5.6	10.4
				FM	11.5	16.0
	NON-SWITCHED	5	1	NTSC	3.1	-
		12	1		-	3.7
TREE	NON-SWITCHED	5	4	NTSC	1.2	-
		12	4	NTSC	-	0.76

TABLE B.6

MAXIMUM DISTRIBUTION DISTANCES WITHOUT REPEATERS

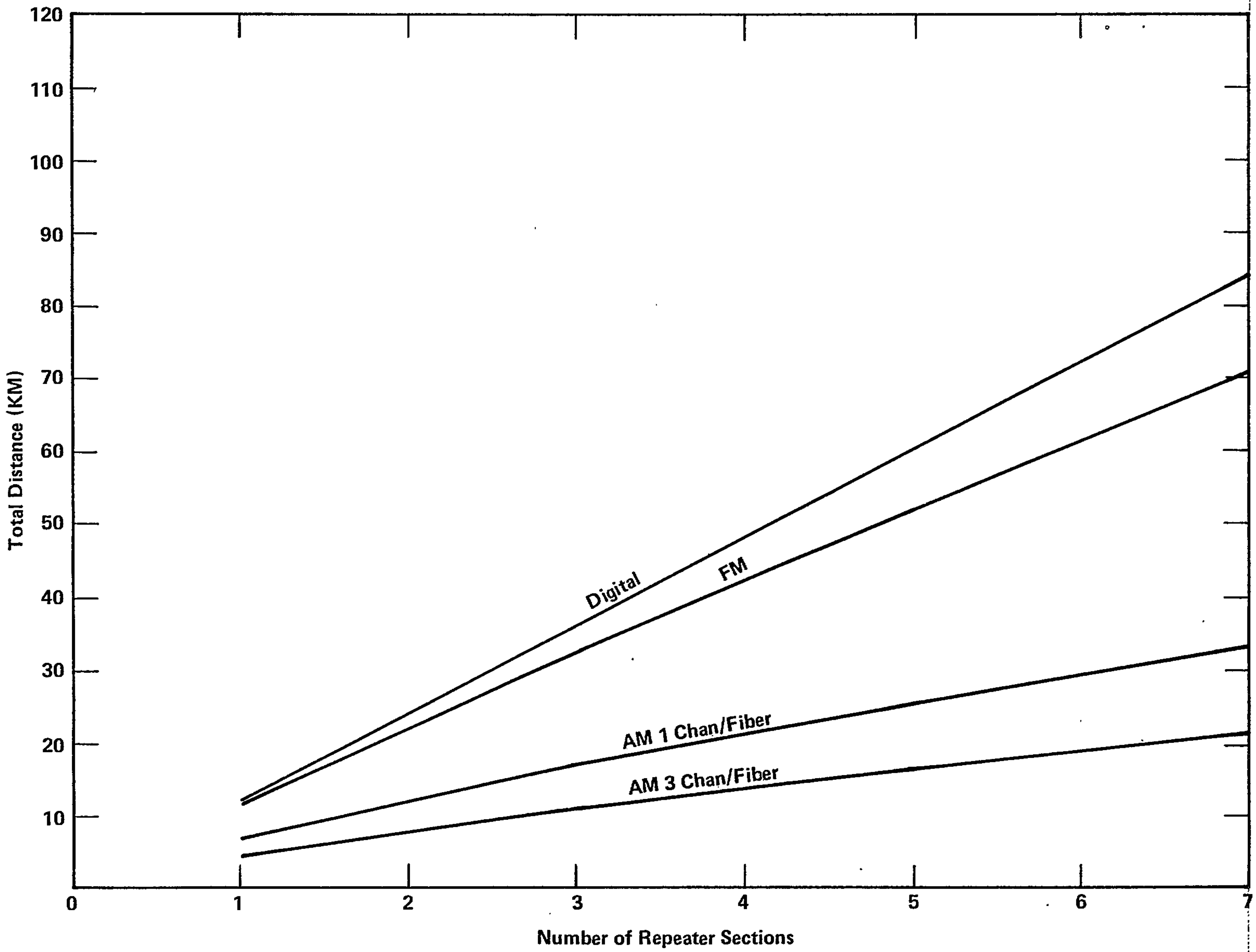

Figure B.1 Trunking Capabilities (1980)

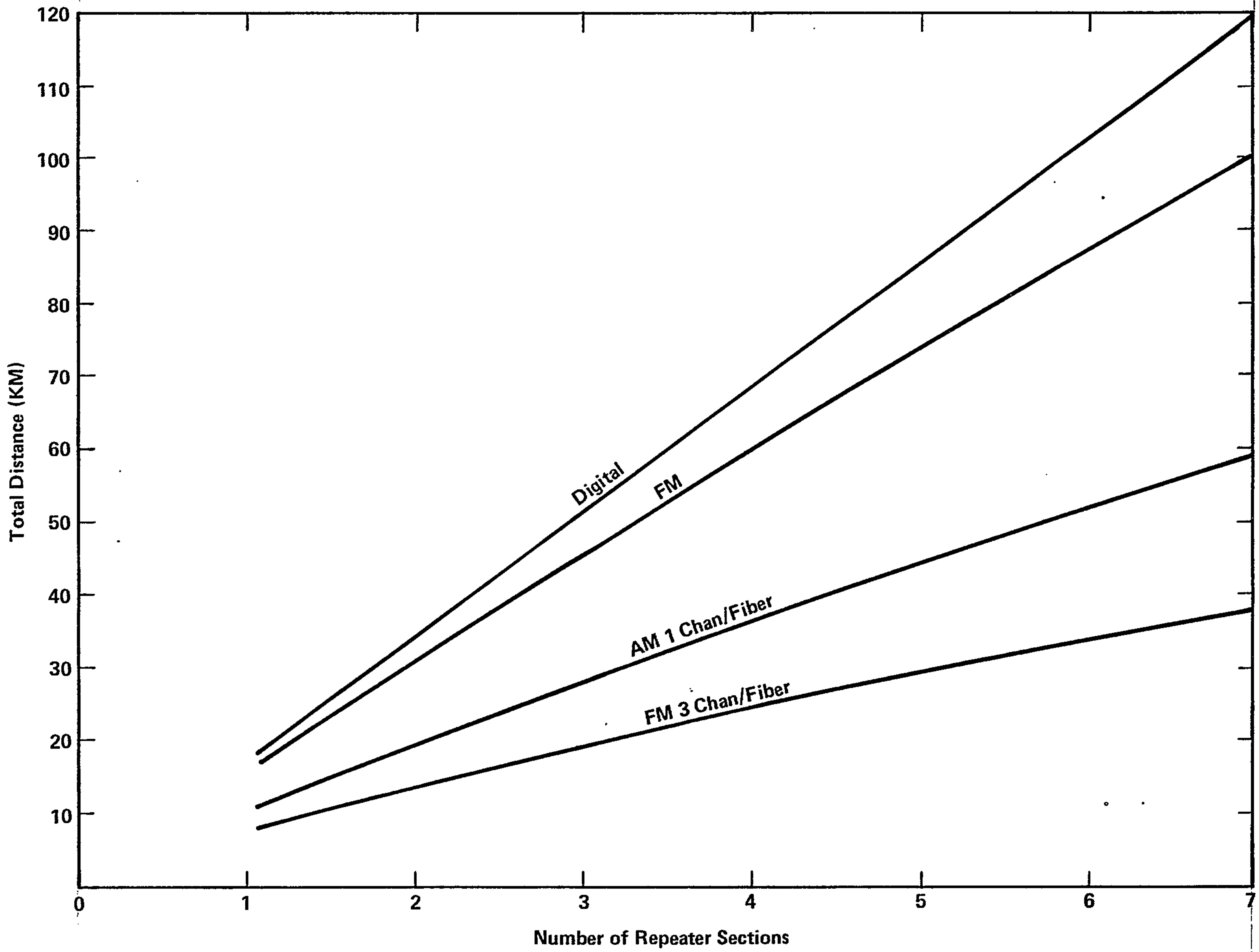

Figure B.2 Trunking Capabilities (1985)

C

APPENDIX C

STATE-OF-THE-ART OF VIDEO SWITCHING

C.1 CURRENT USE OF VIDEO SWITCHING

There are two situations where video switching is commonly used today:

(i) Studio and network TV distribution - In this application, very high quality analogue baseband space switches are used. Because of the low volume and high quality, prices are high.

(ii) Home terminal TV channel selection - In this situation, a VHF or UHF tuner or cable TV converter is used to select the desired channel or station, in a form of Frequency-Division Multiplex (FDM) switching. Since high volume is involved, special technologies have been developed. Cost of production is therefore already at a low level.

A less common situation where video switching is used is the switched star for cable TV distribution, such as the schemes by Rediffusion [10] [11]. Unlike the conventional CATV scheme using a coaxial tree distribution the switched star involves network switching at a hub location, one dedicated link per household carrying the selected TV channel, and an upstream control signaling channel. The advantages of this scheme are that relatively low bandwidth demands are put on the subscriber connections and that there is no theoretical upper limit to the number of TV channels or other one-way TV services that can be provided.

C.2 VIDEO SWITCHING FOR CATV SERVICE USING OPTICAL FIBERS IN A RURAL ENVIRONMENT

The basic subscriber CATV services might be established as 12 TV channels and some FM stations. In order to be compatible with off-air broadcasting, the standard VHF TV and FM sets will be used without modifications.

Considering TV services only, there are many possible video switching schemes depending on the subscriber transmission system used. From the viewpoint of low switching cost, the best transmission method would be multi-channel VHF, which is the same as used in coaxial systems today. As only 12 TV channels are considered, no TV-converter is required, i.e., no additional switching cost over and above the TV-tuner. However, this would result in high transmission costs in a rural environment, due to the short distance over which 12 TV channels can be transmitted without repeaters in 1985. Therefore, it is worthwhile to consider network switching to increase the non-repeatered distribution length. Moreover, network switching would definitely be required if services such as videophone and library-TV were to be provided.

In a switched star using fiber optics, the selected TV channel can be delivered to the home in 3 ways: baseband, low RF (e.g. T7) and VHF. Since a VHF TV set is considered, baseband transmission would result in an expensive VHF modulator per home, in addition to potential 60 Hz interference problems, and would thus be unworthy of further consideration unless TV sets with baseband video inputs were to become universally and economically available in the future. Choice of low RF or VHF will depend on the finer tradeoffs of transmission, video switching and in-home converter costs.

C.3 VIDEO SWITCHING TECHNOLOGIES

(a) SPACE SWITCHING

In a space switch, each of the input and output channels have dedicated switch terminals and a connection is made in physical space using a crosspoint dedicated to that particular input-output pair.

The most critical transmission consideration in a video space switch is crosstalk. There are two ways in which crosstalk is introduced: lack of crosspoint isolation and inter-circuit coupling. The first results in the leakage of the input signal to the output across an "open" crosspoint. The second causes the appearance in one path of an unwanted signal from a parallel path.

For low RF transmission on the output fiber, e.g. at the T7 band (5.75 - 11.75 MHz), analysis showed that, based on the DOC BP23 [12] [13] requirements, crosspoint isolation is the dominant factor in the choice of a video space-switching technology demanding approximately -74 dB isolation at 10 MHz for a single crosspoint. A comparison of space-switching technologies is given in Table C.1. Except for the reed switch, none of the other types of crosspoints approach the required isolation of -74 dB. Therefore, techniques for improving crosspoint isolation are needed. An improvement of 13 dB (-75 dB isolation) has been achieved in experimental reed switches [14] and about -60 dB crosstalk obtained from experimental PNPN matrices [15] [16]. Similar improvements are not expected in production because of the difficulty in maintaining very good matching. Therefore, multi-element crosspoints using the T-structure is more attractive. T-switching requires low cost switch elements, thus eliminating crossbar and reed switches. Using DMOS (Double-diffused MOS) in a T-switch, the composite crosspoint isolation can be improved to be better than -74 dB. Given the suitability of DMOS for high-density monolithic integration, it is therefore a good choice for video space switching at low RF. With the expected continuing advancements in integrated technology, the cost of DMOS switching is expected to be low in 1985.

For VHF transmission to the subscriber, while it is technically feasible to develop a VHF crosspoint, the costs of such crosspoints as well as of packaging and shielding will be high. A more cost effective design would be to switch at T7 followed by a simple up-converter. The cost of such a converter would be lower than the functionally similar one required in the home when low RF transmission is used, due to the possibility of sharing common components at a hub-switch, such as the local oscillator.

(b) FREQUENCY-DIVISION MULTIPLEX (FDM) SWITCHING.

FDM switching is typically used in TV tuners and converters and involves the mixing of a controlled local oscillator frequency with an FDM signal containing all the input TV channels. The desired channel is then selected with a fixed bandpass filter.

For VHF transmission to the subscriber, an FDM switch can be used at the hub-location (almost identical to the TV converter). The main difference is that improved output filtering is required to remove the image and spurious frequencies which can interfere with other signals on the fiber. SAW (Surface Acoustic Wave) filters being developed for TV applications can be used for the output filters.

For T7 transmission, the cost of FDM switching will increase due to the need to pre-filter the desired channel before down-conversion to T7 and the fact that SAW technology is not suitable for T7 output filtering.

(c) OTHER SWITCHING TECHNOLOGIES

Time-Division Multiplex (TDM) switching have been used in telephony. It is, however, not considered suitable for video applications because of the extremely high transition frequencies involved and the resulting circuit and packaging difficulties.

Optical switching techniques are interesting for the future, particularly from the viewpoint of integrated optical switching and transmission, with no intermediate electronic components. However, it does not appear that the necessary components and packaging technology will be developed by 1985 to permit an optical switching system to be designed competitive in cost to the space and FDM techniques.

C.4 CONCLUSIONS

A survey of the state-of-the-art in video switching has revealed that the technology will be available by 1985 for a low-cost hub-switch in a switched star fiber optics distribution system. DMOS space switching is shown to be suitable whether the selected channel is transmitted at low RF (T7 band) or at VHF to the subscriber, while FDM is competitive in the VHF case only.

The study assumed a standard TV set with VHF/UHF inputs only. If TV sets were to be available in future with baseband inputs, the economics of fiber optics CATV distribution would turn even more towards a switched star with video space switching at the hub.

CROSSPOINT TECHNOLOGY	ISOLATION BASIC SINGLE ELEMENT 75 Ω@ 10 MHz	ON RES. Ω	SWITCH SPEED	POWER DISSIPATION (INCLUDING DRIVE CCT)	COST OF DRIVE CIRCUITRY	MONOLITHIC INTEGRATION COMPLEXITY	INTEG. DENSITY	COMPARATIVE PRICE $
CROSSBAR	-50 dB (Ref. 6)	1	25 msec	500mW	Very High	-	-	15
REED	-62 dB (Ref. 5)	1	2 msec	100mW	High	-	-	20
PNPN DIODE OR SCR	-32 dB	8	1 μsec	20mW	Medium	High (dielectric or air isolation)	low	3
JFET	-58 dB	10	1 μsec	5mW	low	Medium (Bi-FET Technology)	medium	1.5
NMOS	-48 dB	10	1 μsec	1mW	low	low	high	1
DMOS	-52 dB	30	1 μsec	1mW	low	medium	high	1

TABLE C.1

COMPARISON OF VIDEO SPACE SWITCHING TECHNOLOGIES

D

APPENDIX D

COST MODELLING OF INTEGRATED FIBER NETWORK

D.1 INTRODUCTION

The computer model described in this appendix was developed to facilitate the evaluation of the cost effectiveness of service integrated fiber optics distribution networks in a rural environment. In order to simulate as closely as possible the actual rural population distribution patterns (as identified in Section 2.1 of the main report), the local network distribution model is made up of a town (defined in here as the community housing the existing Community Dial Office), a number of villages (defined as communities remote to the town served by the same exchange) and the low density rural population. Such a model matches quite well the areas served by the existing rural exchange boundaries all across Canada, and is believed to be an acceptable tool for assessing the cost structure and breakdown of the.various subsystems of integrated fiber network. The computer program package is composed of the following four programs:

(1) Sizing
(2) Cable and Equipment Provisioning
(3) Cost Evaluation
(4) Report Generation

The sizing program translates the distribution characteristics of the rural sector into distribution cells for the three network elements (town, village and rural). The provisioning program determines the quantities of cable and equipment required based on a set of pre-established provisioning rules. The cost program computes the cost of each subsystem for each network element based on a set of unit cost data. Finally the report generation program organizes the input and output and produce the desired reports.

D.2 ASSUMPTIONS

Preliminary studies have indicated that the most economical serving arrangement in the rural areas would be to divide the exchange into several serving areas with each area consisting of a Remote Distribution Centre, a local distribution network providing one fiber per household and a concentrated trunk link to the CDO. Each serving area is characterized by a diamond shape with the diagonal of the diamond running parallel to the grid roads. Figure D.1 shows an integrated fiber network with its diamond shaped serving cells simulating an exchange n km by m km. Further analysis has indicated that a square serving area concept would result in 10 to 15% higher cost due to a smaller number of subscribers per cell for the same maximum distribution length. The evaluation is based on engineering, furnishing and installation (EF&I) first costs in 1978 dollars. Since the total cost of an integrated fiber network is so heavily dependent on initial costs, it was felt that any additional information resulting from a more detailed time study would not justify at this time the additional effort required. However, such an enhancement to the model could be added at a later date.

D.3 INPUT/OUTPUT PARAMETERS

(a) Sizing

- Town - Size and density
- Village - Number, size and density
- Rural - size and density

(b) Provisioning

- Maximum distribution length
- Number of video and FM channels
- Repeater spacing
- Drop length in town, village and rural regions
- Line concentration ratio for digital voice trunking
- Cable size in multiples of fiber
- Joint or separate cable sheath for trunk and distribution

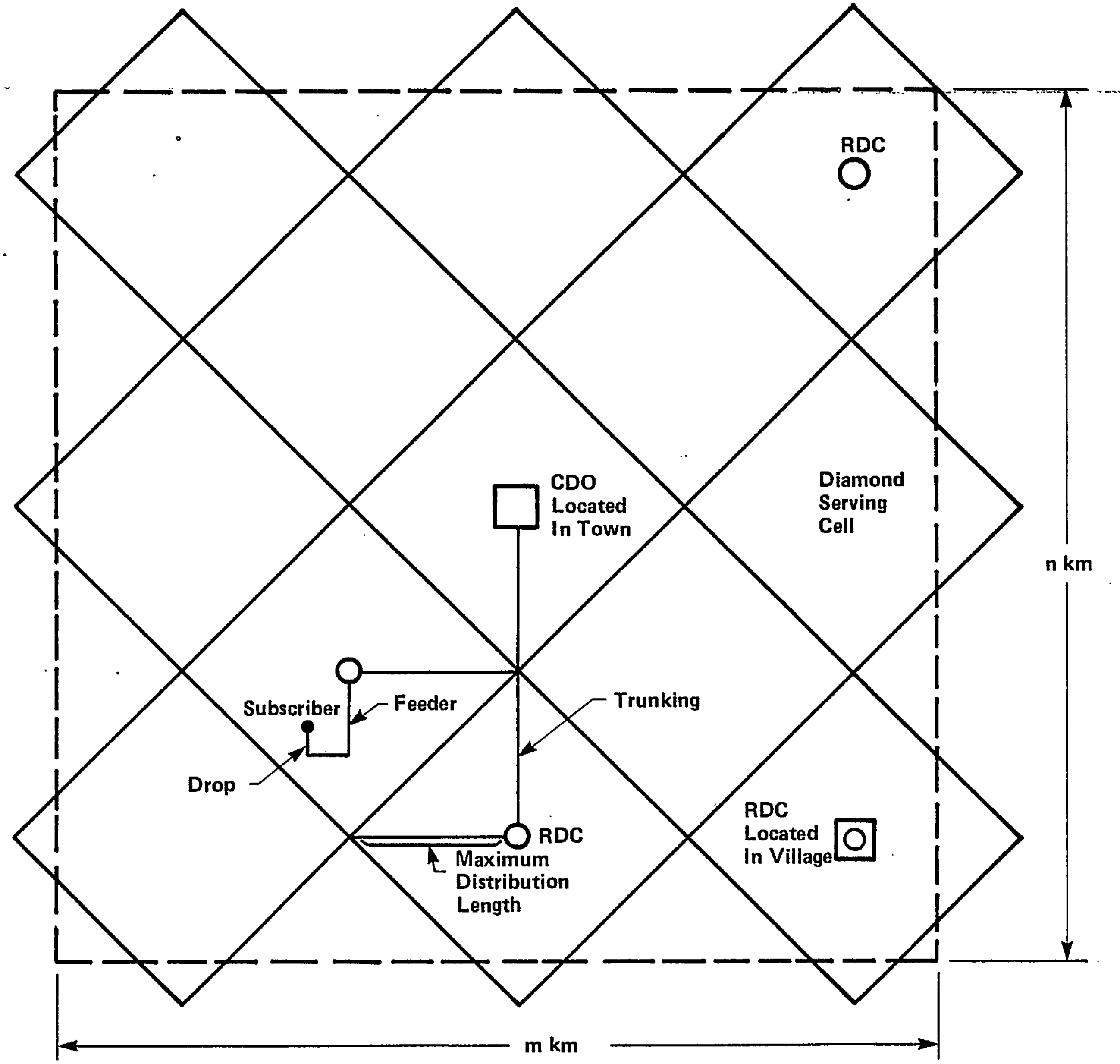

Figure D.1 Rural Distribution Network Model

(c) Unit Cost Data

- Furnished cost per unit for equipment, power, housing, cable etc.
- Loading factors for engineering and installation.
- Cable placement costs for town, village and rural.

(d) Output

- A sample of the program printout is given in Figure D.2.

D.4 SUMMARY AND DISCUSSIONS

With a limited number of input parameters, the computer model described in this appendix can be used to provide a good cost estimate for an integrated fiber network. It can also be used to determine the optimum distribution cell size as well as the optimum wire centre size. Sufficient flexibility has been built into the program design so that the following enhancements can be added:

(1) Generalization of the model to cover copper based facilitites as well as individual service for telephony and CATV.

(2) Inclusion of growth factors to allow for a more extended time study.

(3) A more sophisticated serving area configuration where the CDO would be treated as the remote unit of a large combined local/toll digital switching machine.

FILE: TYOUTPUT DATA A TIME= 10:59:15 DATE: 05/05/78 BELL-NORTHERN RESEARCH

	SUBSCRIBER	CABLE	IRSU	CO	LINES	AREA	NO. CELLS
	RURAL						
COST ($K)	12976.43	16355.05	303.83	488.37	13107.00	2621.44	8.00
PERCENT	0.43	0.54	0.01	0.02	30123.68	TOTAL COST ($K)	
COST/LINE	990.04	1247.81	23.18	37.26	2298.29	TOTAL COST/LINE	
	VILLAGE						
COST ($K)	143.38	100.82	1.34	6.80	199.00	2.00	1.00
PERCENT	0.57	0.40	0.01	0.03	252.34	TOTAL COST ($K)	
COST/LINE	720.50	506.63	6.73	34.17	1268.04	TOTAL COST/LINE	
	TOWN						
COST ($K)	1107.81	1200.02	0.50	40.50	1599.00	8.00	1.00
PERCENT	0.47	0.51	0.00	0.02	2348.83	TOTAL COST ($K)	
COST/LINE	692.81	750.48	0.31	25.33	1468.94	TOTAL COST/LINE	
	COMMON EQUIPMENT						
COST ($K)	0.0	0.0	0.0	250.00			
	TOTAL						
COST ($K)	14227.62	17655.89	305.67	785.67	14905.00	2621.44	10.00
PERCENT	0.43	0.54	0.01	0.02	32974.84	TOTAL COST ($K)	
COST/LINE	954.55	1184.56	20.51	52.71	2212.33	TOTAL COST/LINE	

Figure D.2 A Sample of the Program Printout

E

DMS-1

Digital Multiplex System

northern telecom

APPENDIX E
Northern Telecom DMS-1 Digital Multiplex System

A Northern Telecom product for the

DIGITAL WORLD

Contents

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Diagrams

DMS-1

Northern's DMS-1 Digital Multiplex System is designed to meet a wide variety of applications so that telephone companies can provide service to small communities with maximum profitability. It can be used as a Digital Subscriber Carrier System or as a Remote Digital Switch for CDO replacement. It uses one or two T-1 Type (hereinafter referred to as LD-1/T-1 lines) for transmission between a Control Concentrator Terminal in the central office and one to four Remote Concentrator Terminals.

The system contains certain basic features, and also offers a variety of options which can be provided either on the first installation or plugged in at any later date.

These options are indicated both in the equipment description and in the ordering information.

DMS-1 uses D3 type frame format providing toll grade PCM to give connected subscribers full access to all of the 48 channels provided by the two LD-1/T-1 lines. 24 local links can also be provided by the system for calls between subscribers connected to the same remote terminal, so that LD-1/T-1 channels are only used for setting up such calls. A system with 256 subscriber lines, one remote terminal and two LD-1/T-1 lines, with local links handling 30% of the traffic, and a 0.5% blocking probability provides a traffic handling capacity of 6.6 ccs/line.

Applications

The DMS-1 system will have applications in:

1. Deferring or replacing community dial offices in suburban and rural pocket communities, or for recentering service on large switching centers.
2. Deferring cable replacements by providing up to 64 to 1 pair gain on existing cable.
3. Relieving high growth locations such as trailer courts, new housing developments and shopping centers.
4. Temporary service to fairs, exhibitions, convention centers, etc.
5. Reduction of feeder cable size and gauge to high rise and apartment buildings.
6. Service to several crossroads communities by distributed remote terminals homing on one C.O. terminal.

Maintenance

DMS-1 has extensive protection switching so that in the event of a LD-1/T-1 line failure, all traffic is automatically transferred to a spare line if available or reassigned to spare channels on another operating line. If a remote terminal fails it is automatically bypassed by the LD-1/T-1 lines, and should these lines fail between remote terminals, they are automatically looped back to the C.O. terminal at the last operating remote terminal.

Fault conditions are detected and displayed in the Central Office, and not only can they be sectionalized to a subscriber line or to the system, but also extensive tests of individual subscriber lines can be performed from the C.O. terminal.

Note:
LD-1 is Northern's T-1 line system incorporating state of the art techniques and features.

2.0 Equipment Description

Digital Multiplex System which can be used as a Digital Subscriber Carrier System or as a Remote Digital Switch for CDO replacement. Provides service to as many as 256 subscriber lines over one or two LD-1/T-1 lines. (Fig. 1)

2.1 The Control Concentrator Terminal

Shelf Dimensions
The control concentrator terminal (CCT) which is located in the central office consists of plug-in printed circuit packs assembled into shelves 14" high by 12" deep mounted on standard 19" frames. (Fig. 2) The shelves have been designed for connectorized shelf to shelf and subscriber line connections.

PCB Backplane Wiring
Troubles due to incorrect or damaged connector wiring are eliminated as all interconnections between the plug-ins are made by a printed circuit board covering the back of each shelf.

Standard C.O. Battery
Room for 256 lines in two 7' bays
The CCT operates from a standard -48 volt office battery supply.
Consists of a minimum of 3 shelves (Figs. 4, 5, and 6) mounted in one bay, to a maximum of 10 shelves mounted in two 7' (Fig. 2) bays depending upon the features selected and the number of subscriber lines serviced.

The CCT consists of the following equipment:

- ■ line circuits (interface with switching machine)
- ■ system controller and logic
- ■ power converters
- ■ protection switching (option)
- ■ alarm and optional traffic units (system house keeping)
- ■ repeaters LD-1/T-1 Terminal

The CCT extends the subscriber lines serviced by all the remote concentrator terminals (RCT) in the system to the central office switching equipment.
In each line circuit the two wire connection is split into transmit and receive paths in a hybrid. The signal from the transmit port of the hybrid is sampled at an 8kHz rate and encoded into an 8 bit PCM word with $\mu = 255$ companding. Each PCM word is inserted into its assigned channel in either of the two 24 channel digroups. Each of the two digroup binary signals is converted into bipolar for connection to the repeatered lines.

On the receive side, the bipolar signal returned by the RCT is converted to unipolar, frames are synchronized, line circuits are enabled during the correct channel time interval, the PCM words are decoded and the analog signal reconstructed. This signal is then connected to the receive port of the hybrid where the 4-wire path is converted to a 2-wire connection to the analog switching equipment.

Since the system is concentrating up to 256 lines onto 48 trunks, the CCT on receipt of a request for service must also search and assign available channels, store channel assignments, balance usage of the two LD-1/T-1 lines, recognize and set up local link calls and recognize "All Channels busy" conditions. The PCM bit stream contains both information bits and signalling bits, the latter being assembled into A and B words for communications with the RCT, storing hook and ring conditions and flagging new conditions, and storing and generating operating codes for such features as protection switching, testing and pay phone operation.

Sophisticated on the inside
Electronic functions have been implemented with the aid of recent innovations in electronic components including the use of custom designed large scale integrated LSI circuits, micro processors (μP) solid state memories (PROM, RAM), active filters and thick film hybrid codecs (A/D – D/A conversion).

Simple on the Outside
Optimum legibility of designations and protection of components is provided by face plates on plug-in units. There are no installation or maintenance adjustments. Faulty cards are replaced by spares.

2.2 The Remote Concentrator Terminal

Bay Mounted or Cabinet Mounted
The remote concentrator terminal (RCT) like the CCT, consists of plug-in printed circuit cards assembled into connectorized shelves (Figs. 7 and 8). The shelves can be bay mounted (Fig. 3) for housing in environmentally controlled huts or cabinets mounted for outside deployment.

One to Four Remote Terminals Homing on the same Control Terminal
The DMS-1 system may be configured with a single remote terminal located up to 25 miles (repeatered line power limit on 22 gauge cables) from the control terminal and serving up to 256 subscriber lines. Alternately up to 4 remote terminals may be distributed along a 50 mile loop of LD-1/T-1 lines—each one serving any mix of subscriber lines up to a cumulative sum of 256. The LD-1/T-1 signals from the CCT pass through each RCT in sequence with each RCT picking off and reinserting signals from its off-hook lines into channels assigned to it by the CCT. In the RCT the bipolar signals are converted to binary and correctly timed and framed. The information (I) bits in each channel slot are routed to the correct line circuit from channel assignment information which has been previously received from the CCT and stored by the RCT during call set up. In the line circuit packs the (I) bits are decoded and the original analog signal is reconstructed and connected to the subsriber line. In the same way, the analog input from the subscriber is encoded in the line circuit into an 8 bit binary word, the word is inserted into the assigned channel slot in the bit stream and the bit stream is converted to bipolar for transmission back to the CCT over one of the LD-1/T-1 lines.

As with the CCT, the RCT provides many additional house-keeping features such as storing and verifying the B words, decoding each operation code and steering the appropriate bits to the correct memory or register, storing the line number assigned to each digroup channel, storing multi-party and pay phone control bits, etc.

Hydro Power with Battery Back-Up for Cabinet Mounting
The RCT operates from standard 115V, 60Hz hydro power source. Should ac power fail, batteries automatically take over and have enough capacity to provide power for six hours at -40°C.

The RCT consists of the following equipment:

■	line circuits to subscribers
■	ring generators
■	power converters
■	protection switching (option)
■	subscribers line test (option)
■	alarm unit
■	LD-1/T-1 repeaters
■	rectifier (option)

2.3 Subscribers Services

There are multiple types of line circuit packs which provide subscriber services for

Single Party	■ single party bridged ringing.
Two Party	■ two party divided ringing with A.N.I. (option)
Multi Party	■ multiparty with divided coded ringing (up to 5 ringers per tip and 5 per ring). (option)
Coin	■ coin telephone for loop start applications capable of accepting prepay, postpay or semi post pay operation. (option)
Frequency Selective Ringing	■ frequency selective ringing. (option)
Dial Pulse and Touch Tone®	■ dial pulse and touch tone® signalling (option)
Dedicated Channels High Priority Channels	■ dedicated or high priority access to channels for selected lines (single party only). (option)

Local Links (option)
Special features have been developed to conserve usage of the LD-1/T-1 channels. The system will set up local calls between subscribers serviced by the same remote terminal without using the LD-1/T-1 channels once the call has been set up. The system can handle a total of 24 local calls simultaneously.

Reorder Tone for all Channels Busy (option)
Reorder tone will be returned to the switching equipment on a ringing line when all channels are busy.

Data
The system will handle analog data modems up to 2400 baud.

2.4 Traffic Monitoring Features (option)

Traffic measurement capabilities are:

- number of occasions "All Channels Busy"

■ peg count all calls	■ high hourly CCS
■ total time all channels busy	■ total local link CCS
■ total CCS	■ terminating calls blocked

2.5 Protection Switching Features

All systems are provided with the following features;

LD-1/T-1 Line failure	■ LD-1/T-1 line failure (single or distributed RCT's), when operating with two LD-1/T-1 lines. When one LD-1/T-1 line fails, traffic previously on that line can be reassigned to the remaining working line up to the 24 channel capacity.

As an option the following additional features can be provided (both automatic and manual):

Spare Standby Line	■ Traffic can be transferred to a spare line from either one of the working digital lines.
Remote Terminal Bypassed	■ Remote terminal failure (distributed RCT's). The RCT can be bypassed on either or both LD-1/T-1 lines to maintain service to following remote terminals.
Remote Terminal Loopback	■ Both LD-1/T-1 lines fail (distributed RCT's). The LD-1/T-1 lines can be looped back to the CCT at the last operating RCT.

2.6 Test and Maintenance

Any Subscriber Line Tested Directly From Control Terminal (option)

Many test and maintenance features are available with the system. For example, any line circuit can be looped back on itself at the VF interface of the RCT and tested for round trip loss. The line number to be tested is selected at the CCT. The subscriber line can also be tested for loop capacitance unbalance, leakage, foreign dc or ac EMF, noise. The results of the tests are displayed as "passed/marginal/failed" indication at the CCT. Threshold levels for each test are selectable on the RCT line test circuit pack.

Manually Exercise Protection Switching Features

Various maintenance features are available which allow one to manually exercise the protection switching options (see 2.5 Protection Switching Features).

- generate a manual request for a protection switch through push buttons on the protection switching circuit pack. One push button is provided for simulating the failure of repeatered line A and one for line B.
- generate a manual request for traffic reassignment.
- generate a bypass request.
- generate a loopback request.

2.7 Alarms

Major and Minor Alarms
The control terminal displays both CCT and RCT alarms. The alarms are classified as major—indicating a condition causing a service failure—or minor—indicating an equipment failure or out of limits condition not causing a service failure.

The CCT alarms are:

- loss of frame and no protection switch (major)
- fuse failure (major)
- loss of frame (major)
- LD-1/T-1 line failure (minor) *
- protection switch (minor)
- system controller failure (major) (minor if backup controller equipped)

The RCT alarms are:

- write RCT memory confirmation failure (minor)
- loss of frame (minor)
- LD-1/T-1 line failure (minor) *
- by pass operated (major).
- loop back operated (major)
- ac failure (minor).
- voltage out of limits (minor)
- over temperature (minor)
- door open (minor)
- emergency power source on (minor)

***Note:**
LD-1/T-1 line failure is a major alarm when operating with one LD-1/T-1 line.

2.8 Digital Line Power

Digital Line Power Options
The lines can be powered directly from the CCT and RCT bays. The maximum power feed source to the loop back point on 22 gauge cable is 12.5 miles, so the maximum distance from the CCT to the RCT with power feed from each is 25 miles. The repeatered line is powered from a ± 130 volt power converter mounted on the terminal repeater circuit pack. The terminal repeater span shelf may be mounted on the CCT bay or on a separate bay.

There are several line power options at the remote terminals depending on whether the system is distributed or single RCT. The power loop back connection is normal for a single RCT with a repeatered line less than 12.5 miles. The through power connection is used in intermediate RCTs in distributed systems. The second section of a repeatered line greater than 12.5 miles is powered from an RCT. At a branch point, the branch repeatered line is either powered from the remote or power fed through.

3.0 Bay Arrangements

Modularity for Easy Growth
Since DMS-1 is equipped with connectorized shelves the system can be expanded as required in the field.

These arrangements can be achieved either by mounting shelves on frames in the field (four bolts are all that is required for mounting on 19" frames with 1¾" or 1" mounting spaces), or by ordering factory-assembled bays arranged to suit your needs. One of the main advantages of system modularity is that equipment can be initially installed to service as few as 32 subscriber lines, and later extra line shelves can be added (32 lines per shelf) as required, allowing easy system growth up to 256 lines.

256 Lines in Two 7' Bays
Both the CCT and RCT equipments are offered pre-mounted in 7' bays. For a typical CCT bay arrangement see fig. 2. Up to 96 lines fit in the first bay and a fully loaded system (256 lines) is packaged into two 7' foot bays. The equipment can also be mounted in 9' and 11'6" bays.

Cabinets for Outside Plant (option)
In applications which require distributed remote terminals the RCT equipment is available in cabinets for outside plant deployment on poles.

- back up batteries to maintain service during ac power failure.
- full length doors secured by internal throw bolts and gasket sealed against rain and snow.
- through-the-bottom cable access to prevent water entry.
- space for repeater span shelf, order wire and repeater fault locating equipment.
- Protector block and cross-connect facilities.

4.0 Office Line-ups and Wiring

Fast Installation

To facilitate fast, accurate installation of shelves, all voice frequency and digital connections to DMS-1 are made with connectorized cables. The cables are carried down the sides of the frame and plug into connectors at the back of the shelf structure. As simple techniques and tools are available for field-mounting connectors on cables, connectorized cables may be made up during installation. This eliminates the problems associated with specifying and ordering cables of predetermined lengths.

5.0 Power Requirements

Depending on the number of subscriber lines served, the mix of line units (single party, universal, coin, . . .) and the features selected, (re-order tone, traffic, . . .) the approximate power drain of DMS-1 will vary from a minimum of 100 watts to a maximum of 500 watts in the RCT and from 180 to 380 watts in the CCT. Assuming 256 lines with 48 lines off-hook, a normal mix of line units, an average loop resistance of 500 ohms, local link, reorder tone and traffic option cards, the total average power drain in the CCT is 380 watts and in the RCT is 450 watts. For the design of power feed and fusing arrangements, a maximum current drain of 10 amps per CCT and 5.3 amps @ 117Vac per RCT should be used.

6.0 Specifications

General	
Subscriber lines	4 minimum to 256 maximum in growth steps of 4 lines per circuit pack, 32 lines per line shelf.
No. of channels	1 or 2 x 24 CCT or RCT.
No. of LD-1/T-1 channels	LD-1/T-1 digital repeatered line, radio or equivalent.
Number of remote terminals	4 maximum.
Types of Subscriber Services	
Single party line card (4 line circuits)	Bridged ringing, dial pulse and Touch Tone® signalling. Optional dedicated or priority access to channels for selected lines.
Universal line card (4 line circuits)	Single party bridged ringing. Two party divided ringing with ANI. Multiparty with divided coded ringing (up to 5 ringers per tip and 5 per ring). Dial pulse and Touch Tone® signalling.
[redacted]	[redacted]
Frequency selective ringing line card (4 line circuits)	Frequency selective ringing. Dial pulse and Touch Tone® signalling.
Coin line card (2 line circuits)	Bridged ringing, loop start, prepay, post pay or semi post pay stations. Dial pulse and Touch Tone® signalling.
Local links	Local calls between subscribers connected to the same RCT without use of trunk lines, after call has been set up, up to a total of 24 calls (shared between all RCTs).
V.F. Characteristics	
Channel net loss	2dB ± .5 dB typical
Overload level	+ 3 dbm.
Frequency response loss	− 1 to + 3 db 0.3 to 3.2 kHz. Relative to 1020 Hz output.
Longitudinal balance	
− 200 Hz	66 dB min.
− 1 kHz	60 dB min.
− 3 kHz	58 dB min.
Impedance	900 ohm nominal.
Echo return loss	18 dB minimum.
Singing return loss	18 dB minimum.
Idle channel noise	20 dBrnc maximum.
Crosstalk	65 dB down.
Subscriber loop	1300 ohms excluding subscriber set. (44V battery) 1900 ohms excluding subscriber set (52V battery)

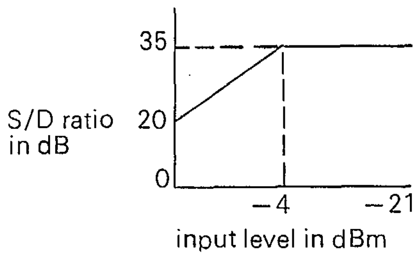
Distortion Products

a)	Overload level @ Input level	input/output signal ratio deviation at fundamental frequency.
	+ 3 dBm	0.1 dB max.
	+ 5 dBm	1.2 dB max.
	+ 10 dBm	5.5 dB max.
b)	Harmonic @ 0dBm input	−40dBm output level max 2.04 and 3.06 kHzI 8(

c) Foldover—0 dBm0 input level at

	Max. Output Level 0 − 4 KHz	4 − 8 kHz
3.5 kHz	—	30 dBm
4.5 kHz	30 dBm	40 dBm
6.0 kHz	25 dBm	50 dBm
8.0 kHz	33 dBm	63 dBm

d) Intermodulation two tone test signal to distortion ratio



A = 740Hz B = 1255Hz	Output level at freq. A±B, 2A±B, A±2B (see diagram)
A = 0.3 to 3.2 kHz @ − 9dBm B = 60 Hz @ −23dBm	−49dBm max.

e) Quantization signal to distortion ratio

@ 0 to −30dBm	33 dB min.
@ −30 to −40dBm	27 dB min.
@ −40 to −45dBm	27 dB min.

f) Spurious signals

	Output level
50Hz to 4kHz	−40dBm max.
8 kHz	−50dBm max.

Level Tracking

Deviation

@ + 3 to − 37 dBm0 input	± 1dB
@ − 37 to − 47 dBm0 input	± 1.5 dB
@ − 47 to − 57 dBm0 input	± 3.0 dB

Idle Channel Noise

Input terminated	20 dBrnC max.	
Input terminated	30 dBrnC max.	3 kHz flat
Zero level code into decoder	15 dBrnC max.	

Envelope Delay Distortion

1.0 to 2.4 kHz	100 μs max.

Signalling

	RCT	CCT	
a) Dial pulsing rate	10 ± 2.5 pps	10 ± 2.5 pps	
b) % break	51 to 69.5 received	50 to 70 transmitted from CCT with 60% break Rcvd at RCT	
c) Ringing voltage	86±15Vrms Connected at RCT	76 to 110Vrms Received from CCT	superimposed on −48Vdc
d) Ringing frequency	20 ± 2 Hz	20 ± 2 Hz	

Subscriber Line

Current from RCT	23mA min. 90mA max.	
from switching equipment	45mA max.	
Voltage	−50±6V −130V @ 100 mA max. +130V @ 100 mA max.	single and multiparty. pay phone only for coin return. pay phone only for coin collect.
Resistance	1900 ohms max. (52V battery) 1300 ohms min. (44V battery)	

LD-1/T-1 Interfaces

(i) Digroup-output

a) Bit rate	1.544 mbit/sec ± 150 bit/sec.
b) Line code	Bipolar.
c) Line impedance	100 ohms nominal at 772 kHz.
d) Pulse characteristics:	
Base to peak height	6V ± .6V
Unbalance in height of Negative and positive pulses	± .3V
Half amplitude width	324 ± 30 nsec.
Unbalance in width of Positive and negative pulse	± 15 nsec. 3
Maximum rise or Fall time	80 nsec.
Overshoot at trailing edge of pulse	20 to 40% of pulse height with decay to 10% or less of base line to peak value within 400sec.
Minimum density	Normally 1 in 8, no more than 14 consecutive zeros.

(ii) Input to Digroup	
a) Line rate	1.544 mbit/sec ± 150 bit/sec.
b) Line code	Bipolar.
c) Amplitude	±1.5 to 3 volts
d) Input impedance	100 ohms nominal at 772 kHz.
e) Jitter	Max. 200 ns
(iii) Input to Repeater	
a) Input level	0.07 to 1.5V
b) Pulse characteristics	Equivalent to those of (i)d) attenuated by a 6dB pad and from 6 to 36dB of 22 gauge PIC cable.

With LD-1 Line

(i) Line Length		on 22 gauge cable
a) Power limit max.	12.5 miles	per power point
b) Fault locate	24 rptrs	includes terminal repeaters
c) Order wire		
—talk	25 miles	
—dial into switch equipment	12.5 miles	
(ii) Line Power		
—current	100 ± 10 mA	
—voltage	± 130V max.	to ground

Power	
CCT	180-380 watts. 10A max. @ − 44 to − 56V dc.
RCT	100-500 watts. 5.3A max. @ 117 V ac nominal (95 - 130) 60 ± 5 Hz. Standby battery—gelled electrolyte 6 hrs. min. at − 40°C

Environmental	
CCT and RCT hut mounted	0 to + 50°C
RCT cabinet	− 40°C to + 60°C
Repeatered line	− 40°C to + 60°C
Humidity	95% at 35°C

7. Ordering Information

Use of the Tables

The tables should be used to determine which J-Lists and apparatus codes to order for different line sizes in bays of 7', 9' and 11'6" height, equipped with various options.

Tables 1-5 indicate the basic J-lists and the apparatus codes for the Buffer circuit pack (QPP 412A) & Line Power Converter (QPP 439A) and Option Circuit Packs. If, for example 192 lines are required all the J-lists and apparatus codes in the column headed 192 and in all the columns headed by lower numbers must be ordered. If, at a later date it is desired to expand to 224 lines only the J-lists and apparatus codes in the column headed 224 are required.

There are separate tables for the CCT and for the RCT.

Details of the Common Circuit Packs are in tables 3 and 4 (also summarized in tables 1-6).

Table 5 lists the Optional Circuit Packs.

Table 6 shows the line Circuit Packs and table 8 gives details of the shelves.

Table 1. Ordering Information: **for CCTS**

Equip. or App. Codes		Description	Number of Lines (See Note 1) 32	64	96	128	160	192	224	256	Notes
J7208A-1	List 1	Unequal flange 19" duct type 7' frame (ED1408-G7) with 1¾" mounting spaces e/w 2 common shelves (ED7208-30-31), power distribution panel, ground system, rear guard rail extension, covers and common wiring.	■								7' Basic
J7208A-1	List 2	Unequal flange 19" duct type, 7' frame (ED1408-G7) with 1¾" mounting spaces e/w power distribution panel, ground system, rear guard rail extension, covers and common wiring.				■					7' Ext.
J7208A-1	List 3	Unequal flange 19" duct type 9' frame (ED1408-G9) with 1¾" mounting centers e/w 2 common shelves (ED7208-30 and 31), power distribution panel, ground system, rear guard rail extension, covers and common wiring.	■								9' Basic
J7208A-1	List 4	Unequal flange 19" duct type 9' frame (ED1408-G9) with 1¾" mounting spaces e/w power distribution panel, ground system, rear guard rail extension, covers and common wiring.					■				9' Ext.
J7208A-1	List 5	Unequal flange 19" duct type 11'6" frame (ED1408-G11) with 1¾" mounting spaces e/w 2 common shelves (ED7208-30 and 31), power distribution panel, ground system, rear guard rail extension, covers and common wiring.	■								11'6" Basic
J7208A-1	List 6	Unequal flange 19" duct type 11'6" frame (ED1408-G11) with 1¾" mounting spaces e/w power distribution panel, ground system, rear guard rail extension, covers and common wiring.							■		11'6" Ext.
J7208A-1	List 7	One line shelf (ED7208-32) and wiring for power and connection to the common shelves. Maximum 3 per list 1 — 5 per list 2 — 4 per list 3 4 per list 4 — 6 per list 5 — 2 per list 6	■	■	■	■	■	■	■	■	
J7208A-1	List 8	Equipment to add jackfield (ED7208-34) to one line shelf. Maximum 1 per list 7.	■	■	■	■	■	■	■	■	Note 2 on page 25
J7208A-1	List 9	Wiring and equipment required in addition to the above lists for LD-1 lines, order wire and fault location shelf.	■								

Table 2. Ordering Information: **for RCTS**

Equip. or App. Codes		Description	Number of Lines (See Note 1)								Notes
			32	64	96	128	160	192	224	256	
J7209A-1	List 1	Unequal flange 19" duct type 7" frame (ED1408-G7) with 1¾" mounting spaces e/w one common shelf (ED7209-30) one power shelf (ED7209-31), power distribution panel, ground system, rear guard rail extension, covers and common wiring.	■								7' Basic
J7209A-1	List 2	Unequal flange 19" duct type 7' frame (ED1408-G7) with 1¾" mounting spaces e/w power distribution panel, ground system, rear guard rail extension, covers and common wiring.				■					7' Ext.
J7209A-1	List 3	Unequal flange 19" duct type 9' frame (ED1409-G9) with 1¾" mounting spaces, e/w one common shelf (ED7209-30) and one power shelf (ED7209-31), power distribution panel, ground system, rear guard rail extension, covers and common wiring.	■								9' Basic
J7209A-1	List 4	Unequal flange 19" duct type 9' frame (ED1408-G9) with 1¾" mounting spaces e/w power distribution panel, ground system, rear guard rail extension, covers and common wiring.					■				9' Ext.
J7209A-1	List 5	Unequal flange 19" duct type 11'6" frame (ED1408-G11) with 1¾" mounting spaces e/w one common shelf (ED7209-30), one power shelf (ED7209-31), power distribution panel, ground system, rear guard rail extension, covers and common wiring.	■								11'6" Basic
J7209A-1	List 6	Unequal flange 19" duct type 11'6" frame (ED1408-G11) with 1¾" mounting spaces e/w power distribution panel, ground system, rear guard rail extension, covers and common wiring.							■		11'6" Ext.
J7209A-1	List 7	One line shelf (ED7209-32) and wiring for power and connection to the common power shelf. Maximum 3 per list 1 — 5 per list 2 — 4 per list 3 4 per list 4 — 6 per list 5 — 2 per list 3	■	■	■	■	■	■	■	■	
J7209A-1	List 8	Equipment to add jackfield (ED7208-34) to one line shelf. Maximum 1 per list 7.	■	■	■	■	■	■	■	■	Note 2 on page 25
J7209A-1	List 9	Wiring and equipment required in addition to the above lists for LD-1 lines, order wire and fault location shelf.	■								

Table 3. Ordering Information: **Common Circuit Packs J7208F-1CCT**

Equip. or App. Codes		Description	Qty	Code	Number of Lines (See Note 1)								Notes
					32	64	96	128	160	192	224	256	
J7208F-1	List 1	Single Digroup	1	QPP413A Driver	■								
		Common Circuit Packs	1	QPP418A Address Control									
		128 lines max.		—Office	■								
			1	QPP419A Digroup									
			1	QPP421A Alarm—Office	■								
			1	QPP425A Test									
			1	QPP431A System Controller	■								
			1	QPP432A B Word	■								
			2	QPP438A Power Converter									
J7208F-1	List 2	Additional circuit	1	QPP413A Driver				■					Note 3 on page 25
		packs for dual digroup	1	QPP418A Address Control CCT				■					
		operation up to 128											
		lines.	1	QPP419A Digroup				■					
J7208F-1	List 3	Circuit packs required	2	QPP413A Driver					■				
		in addition to list 1,							■				
		or list 1, plus list 2 for							■				
		operation above 128 lines											
J7208F-1	List 4	Additions to list 1 to	1	QPP301C Fault Locate Access	■								
		provide LD-1 line	2	QPP300 Fault Locate Filter	■								
		order wire and fault		(specify frequency)									
		location circuit packs.	1	QPP302A Order Wire	■								
				Termination	■								
			1	QPP303A Telephone Set	■								

Table 4. Ordering Information: **Common Circuit Packs J7209F-1 -RCT**

Equip. or App. Codes		Description	Qty	Code	Number of Lines (See Note 1) 32	64	96	128	160	192	224	256	Notes
J7209F-1	List 1	Single Digroup Common Circuit Packs —128 lines max.	1	QPP413A Driver	■								
			1	QPP417A Address Control —Remote	■								
			1	QPP419A Digroup									
			2	QPP438A Power Converter	■								
			1	QPP420A Alarm—Remote	■								
			1	QPP426A Ring Generator	■								
J7209F-1	List 2	Additional circuit packs for dual digroup operation of up to 128 lines.	1	QPP413A Driver				■					
			1	QPP417A Address Control —Remote				■					Note 3 on page 25
			1	QPP419A Digroup				■					
J7209F-1	List 3	Circuit packs required in addition to list 1 or list 1 plus list 2 for operation above 128 lines.	2	QPP413A Driver					■				
J7209F-1	List 4	Additions to list 1 to provide LD-1 line order wire and fault location circuit packs (Note 1).	2	QPP300 Fault Locate Filter (specify frequency)	■								
			1	QPP301C Fault Locate Access	■								
			1	QPP302A Order Wire Termination	■								
			1	QPP303A Telephone Set	■								

Note 1:
Repeaters not included. Order 1 of QPP436A if the LD-1 line is not to be powered from the RCT, 1 of QPP437A if the line is to be powered from the RCT per repeatered line equipped.

Table 5. Ordering Information: **Buffer, Line Power Converter and Option Circuit Packs**

Equip. or App. Codes	Description	Number of Lines (See Note 1)								Notes
		32	64	96	128	160	192	224	256	
QPP412A	Buffer Circuit Pack	■	■	■	■	■	■	■	■	
QPP414A (Opt.)	Local Switch Circuit Pack	■								4
QPP415A (Opt.)	Local Lock Circuit Pack	■								4
QPP416A (Opt.)	Local Link Detector Circuit Pack	■								4
QPP424A (Opt.)	Line Test Circuit Pack	■								11
QPP426A (Opt.)	Ring Generator Circuit Pack	■								12
QPP427A (Opt.)	Reorder Tone Circuit Pack	■								5
QPP428A (Opt.)	Protection Switch Circuit Pack	■								10
QPP429A (Opt.)	Protection Switch Circuit Pack	■								10
QPP430A (Opt.)	Power Rectifier	■								13
QPP431A (Opt.)	Stand-By System Controller Circuit Pack	■								7
QPP432A (Opt.)	Stand-By B-Word Generator Circuit Pack	■								8
QPP434A (Opt.)	Traffic Measurement Circuit Pack	■								6
QPP436A (Opt.)	Repeater Non-Powering	1-6								14,15
QPP437A (Opt.)	Line Powering Repeater	1-3								9
QPP439A	Line Power Converter	■	■	■	■	■	■	■	■	

See Notes 1-15 on page 26

Table 6. Ordering Information: Subscriber Services

Type	RCT	CCT Without Reorder Tone	CCT With Reorder Tone
Single Party	QPP405A	QPP406A	QPP406B
Universal	QPP407A	QPP408A	QPP408B
Coin Telephone (Note 2.)	QPP409A	QPP410A	QPP410B
Priority Dedicated		QPP411A	
Selective Signal	QPP440A	QPP441A	QPP441B
Buffer (Note 1)	QPP412A	QPP412A	QPP412A
Line Power Converter (Note 1)	QPP439A	QPP439A	QPP439A

Notes
1. One Buffer and one line power converter are required per line shelf, i.e. per 8 line circuit packs.
2. Coin cards have 2 lines per card all other cards have 4 lines per card.

Table 7. CCT and RCT Shelves

CCT Shelves

ED 7208-30	Common Shelf #1
ED 7208-31	Common Shelf #2
ED 7208-32	Line Shelf
ED 7208-33	LD-1 Span Shelf
ED 7208-10	Typical Bay Cabling

RCT Shelves

ED 7209-30	Common Shelf
ED 7209-31	Power Shelf
ED 7209-32	Line Shelf
ED 7209-33	LD-1 Span Shelf
ED 7209-10	Typical Bay Cabling

Note:
These ED numbers form part of the build-up of the CCT and RCT J lists in tables 1 and 2. Further details will be available later.

Notes:

1. These line sizes are based on 4 lines per line card. 8 line cards per line shelf, 8 line shelves per system.

This holds true for all line cards except coin cards. Coin cards have 2 lines per card and this fact must be remembered when using this chart.

2. The jackfield is a connectorized module and can be added to the line shelf at any time provided the proper precautions are taken.

3. It is recommended that second digroup operation be initiated when the system reaches 128 line capacity. However, each system should be evaluated separately to determine the desirability of single or dual digroup operation.

4. The QPP415A local lock and QPP416A local link circuit packs in the CCT, along with the QPP414A "local switch" in the RCT combine to allow local calls between subscribers serviced by the same remote terminal without using the trunk lines once the call has been set up.

The system can handle a total of 24 local calls simultaneously.

5. The QPP427A re-order tone circuit pack provides facilities to return an audible signal, interrupted at a rate of 120 interruptions per minute, to indicate to the originating operator that all paths to the called line are busy (sometimes called fast busy) and requires "B" version of line circuit packs.

6. The QPP434A "Traffic Measurement" circuit pack provides facilities to perform the following traffic measurements:

Peg count—all channels
Number of occasions all channels busy
Total CCS
High hourly CCS
Total local link CCS
Total time all channels busy.

7. This option provides a hot standby system controller which is automatically switched into service in the event of a malfunction in the main "system controller".

8. This option provides a hot standby "B-word generator" which is automatically switched into service in the event of a malfunction in the main "B-word generator".

9. This option provides the office repeater used to power the span line. In the event that a span rack is already present in the office, the normal office repeater would be used and this option would not be required.

Qty Required
Single digroup operation —(1) QPP437A
Dual digroup operation —(2) QPP437A
In addition to above for
one protection span line —(1) QPP437A

10. The QPP429A "Prot Sw" circuit pack in the CCT along with the QPP428A "Prot Sw" circuit pack in the R.C.T. combine to provide facilities to automatically insert the protection span line in the event of a failure in one or both of the working span lines. Bypass and loop-back features are also controlled by these units.

11. The QPP424A "Line Test" circuit pack provides facilities for testing the subscriber lines for loop capacitance, leakage, foreign E.M.F.'s and noise directly from the control terminal. System test facilities are standard features provided by QPP425A.

12. This option provides a hot standby "ring generator" which is automatically switched into service in the event of a malfunction in the main "ring generator".

13. The QPP430A "Power Rectifier" is required when the RCT is to be operated from 115V A.C.

14. The choice of powering (QPP437A) or non-powering (QPP436A) repeaters will depend on the system design of the span line.

15. The quantity of repeaters required varies with the number of span lines equipped and whether the RCT is part of a distributed system.

Non-Distributed System
Single Digroup Operation—(1) QPP436A or 437A
Dual Digroup Operation —(2) QPP436A or 437A
In addition to above for
one protection span line —(1) QPP436A or 437A

Distributed System
Double the amount of repeaters for each intermediate RCT. (max 6).

Figure 1. DMS-1 System

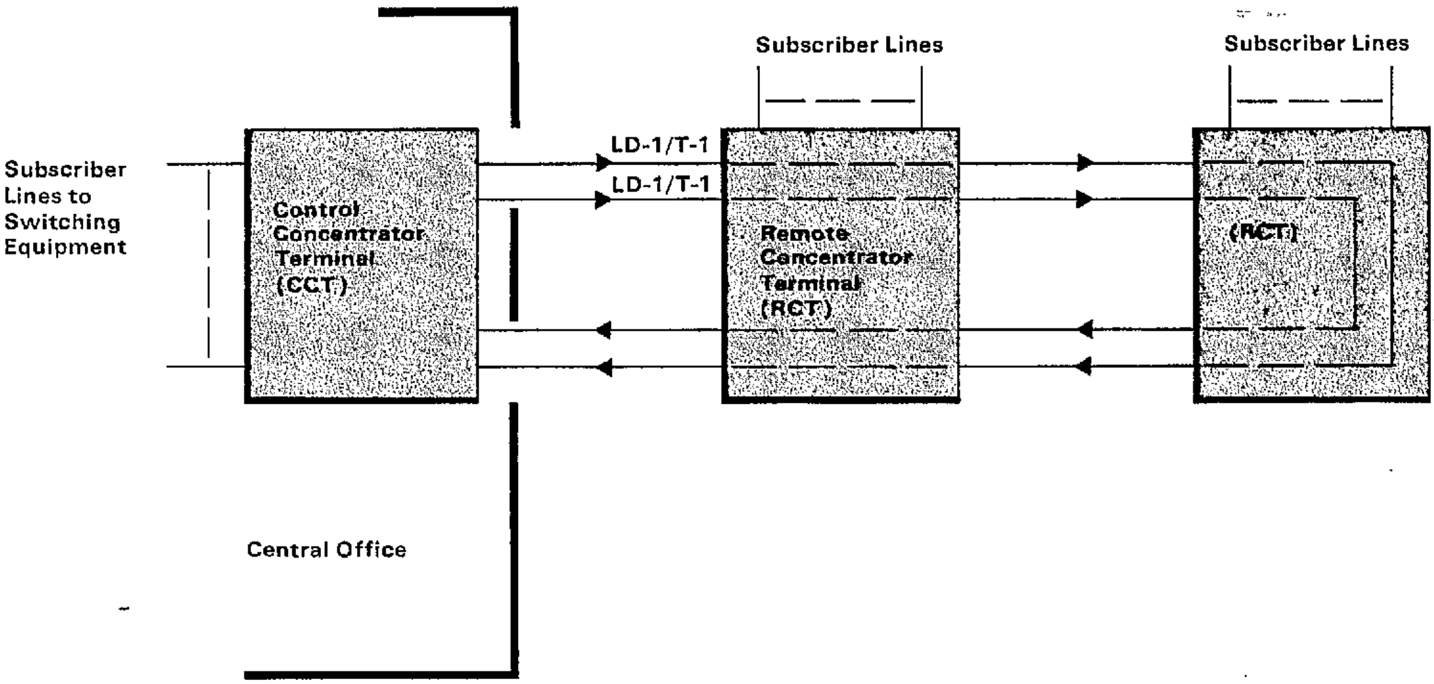


Figure 2. CCT Arrangement using 7′0″ Bays

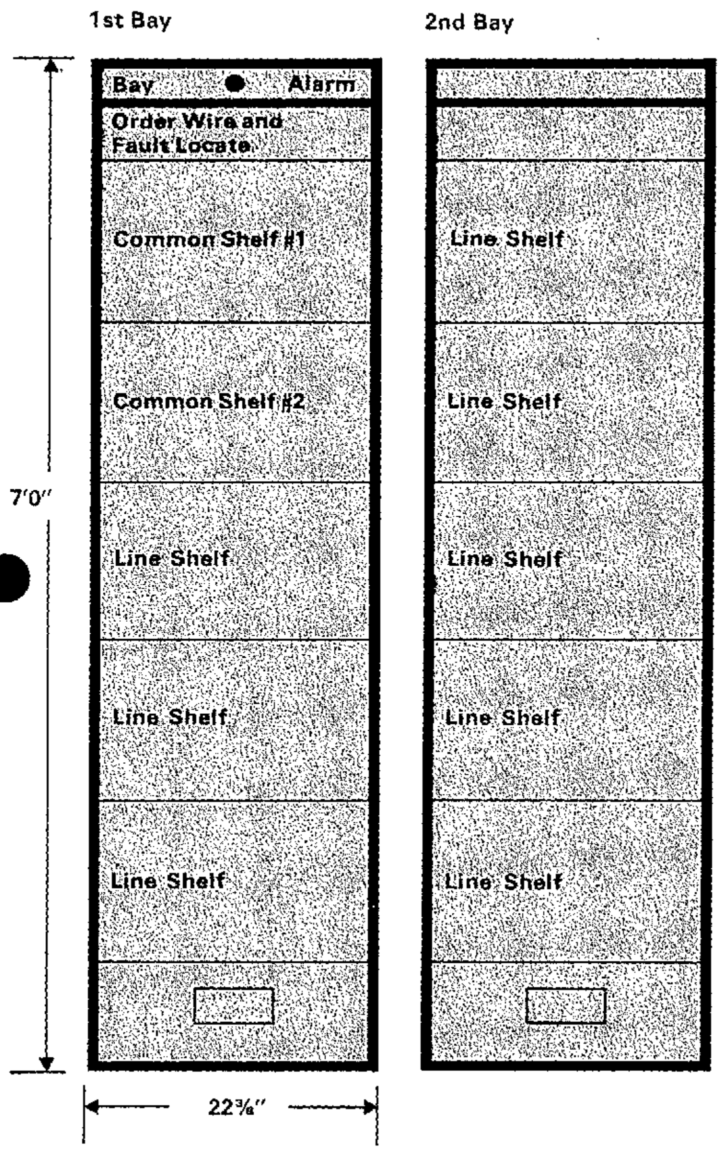


Figure 3. RCT Arrangement using 7′0″ Bays

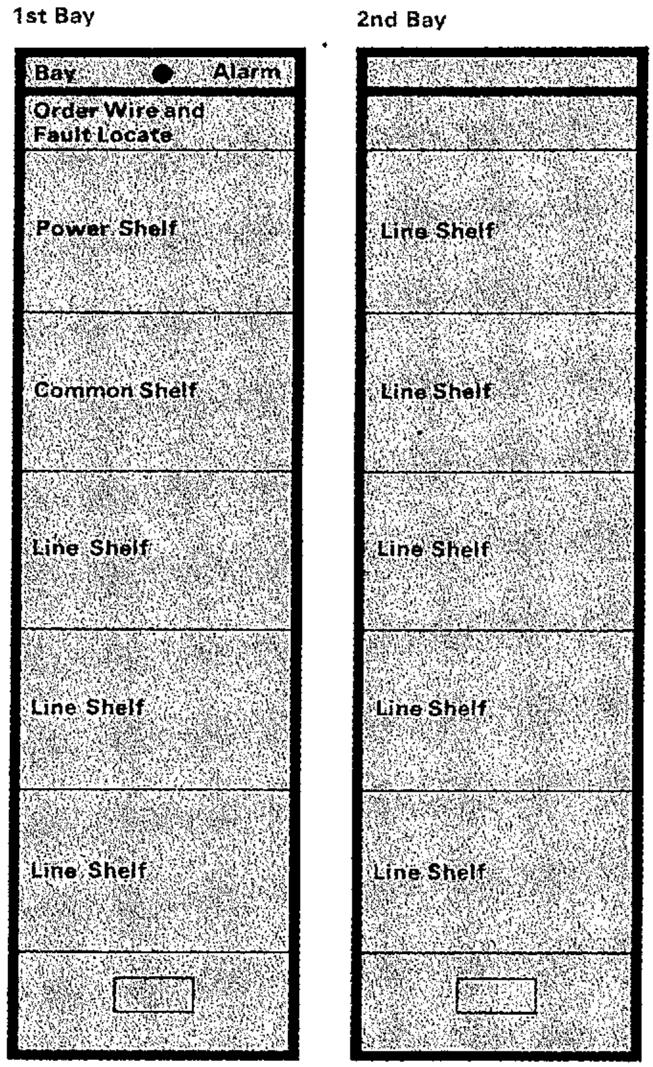


Figure 4. CCT Common Shelf #1

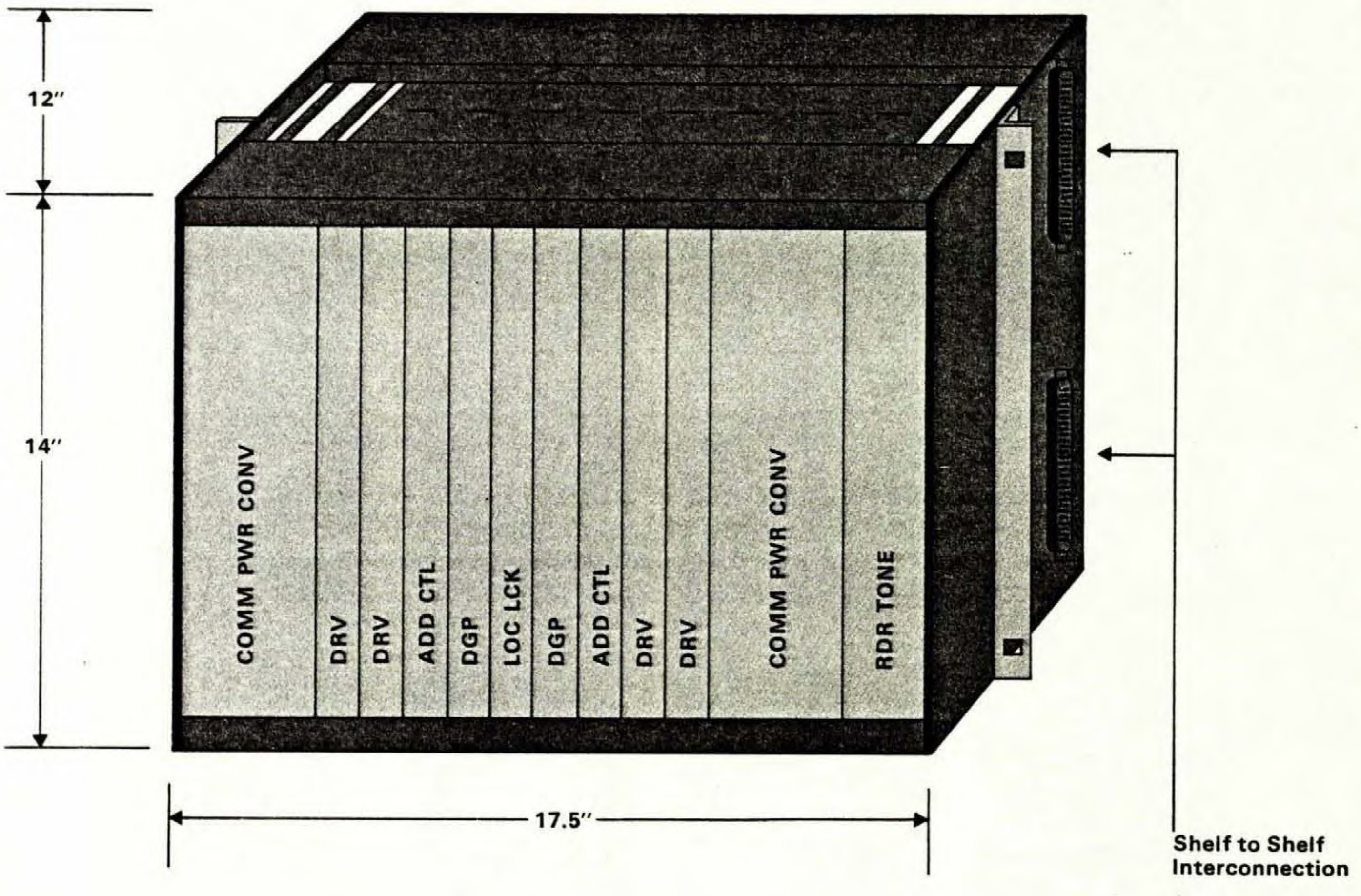


Figure 5. CCT Common Shelf # 2

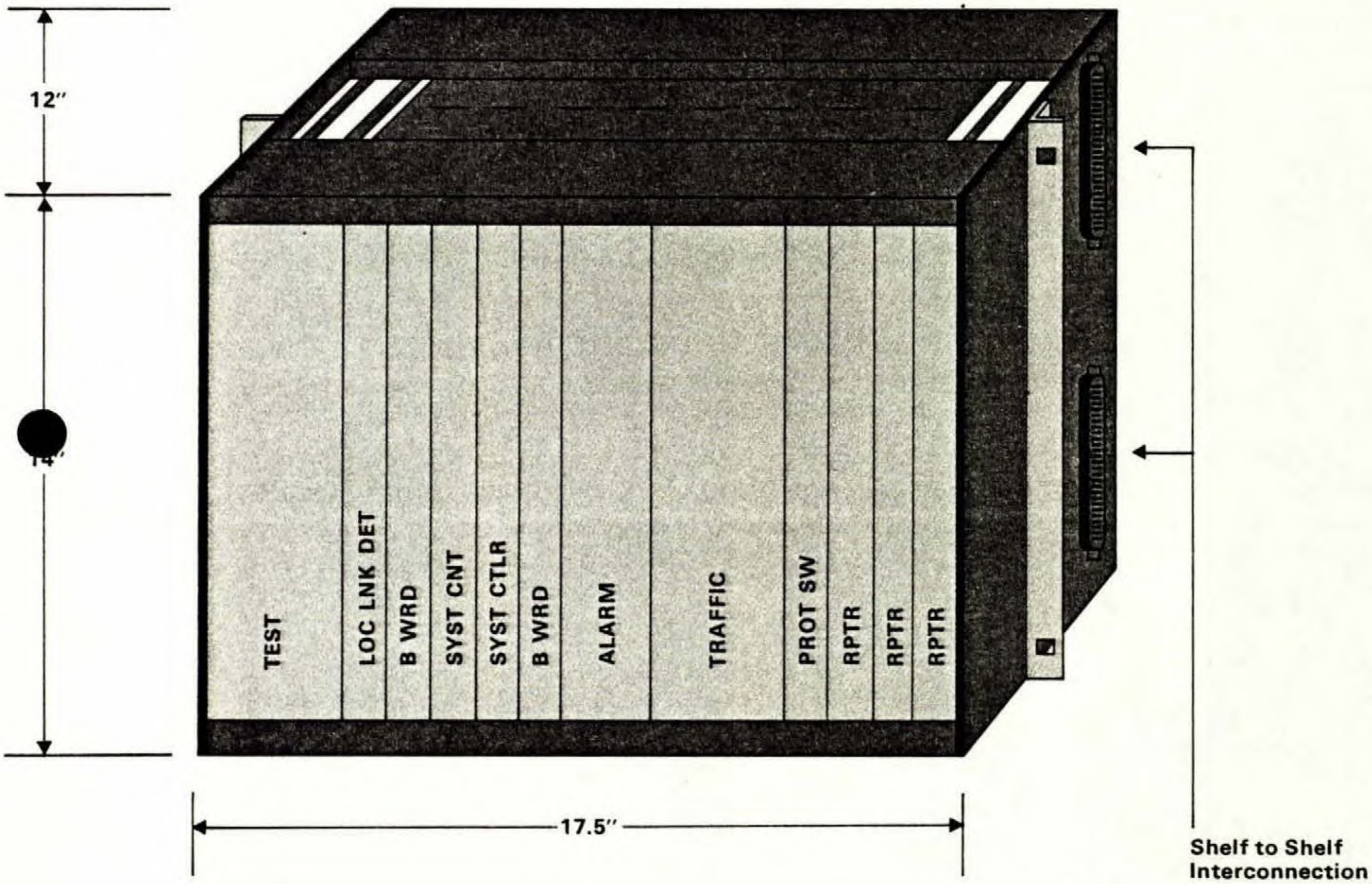


Figure 6. Line Shelf

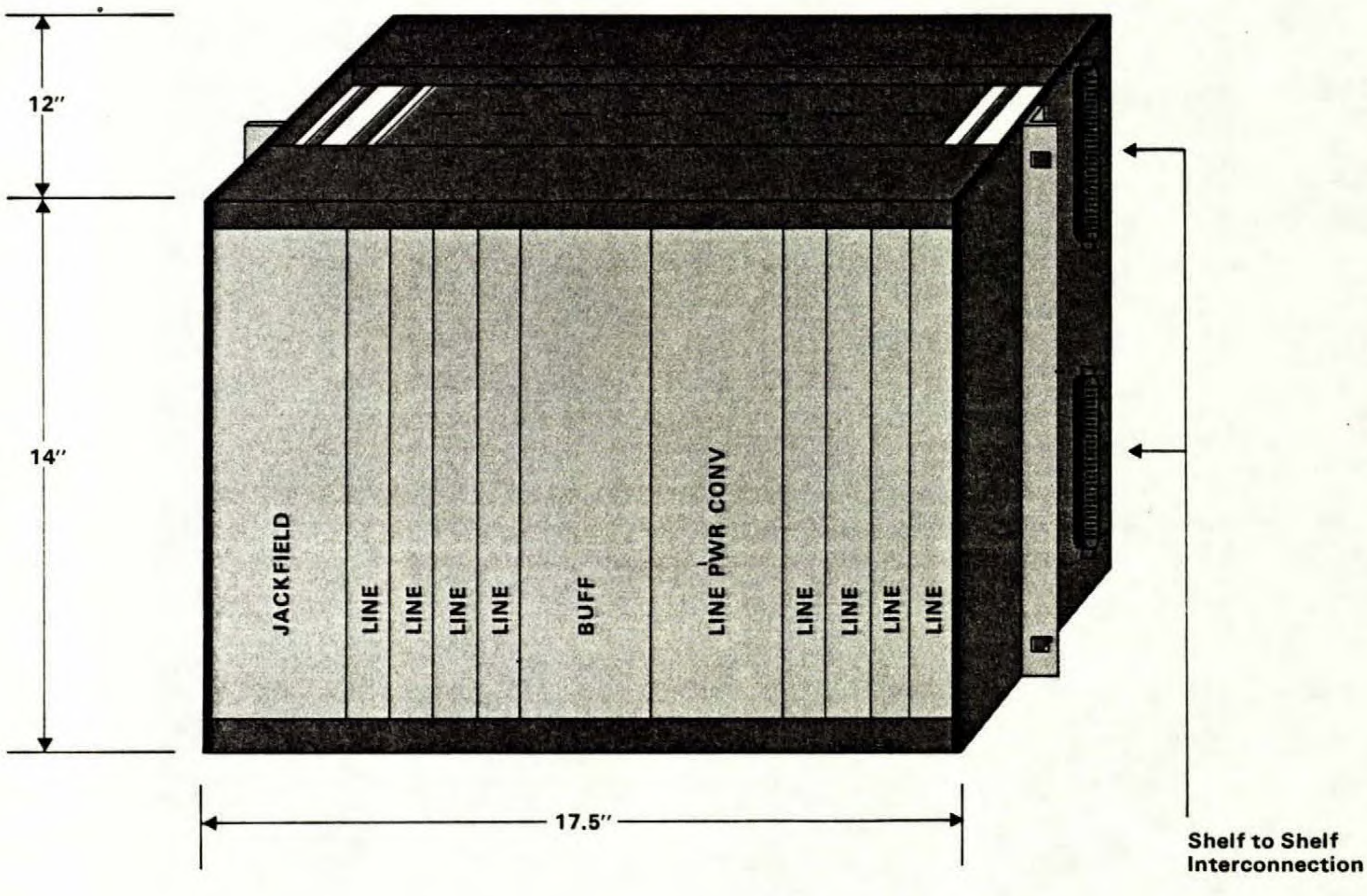


Figure 7. RCT Common Shelf

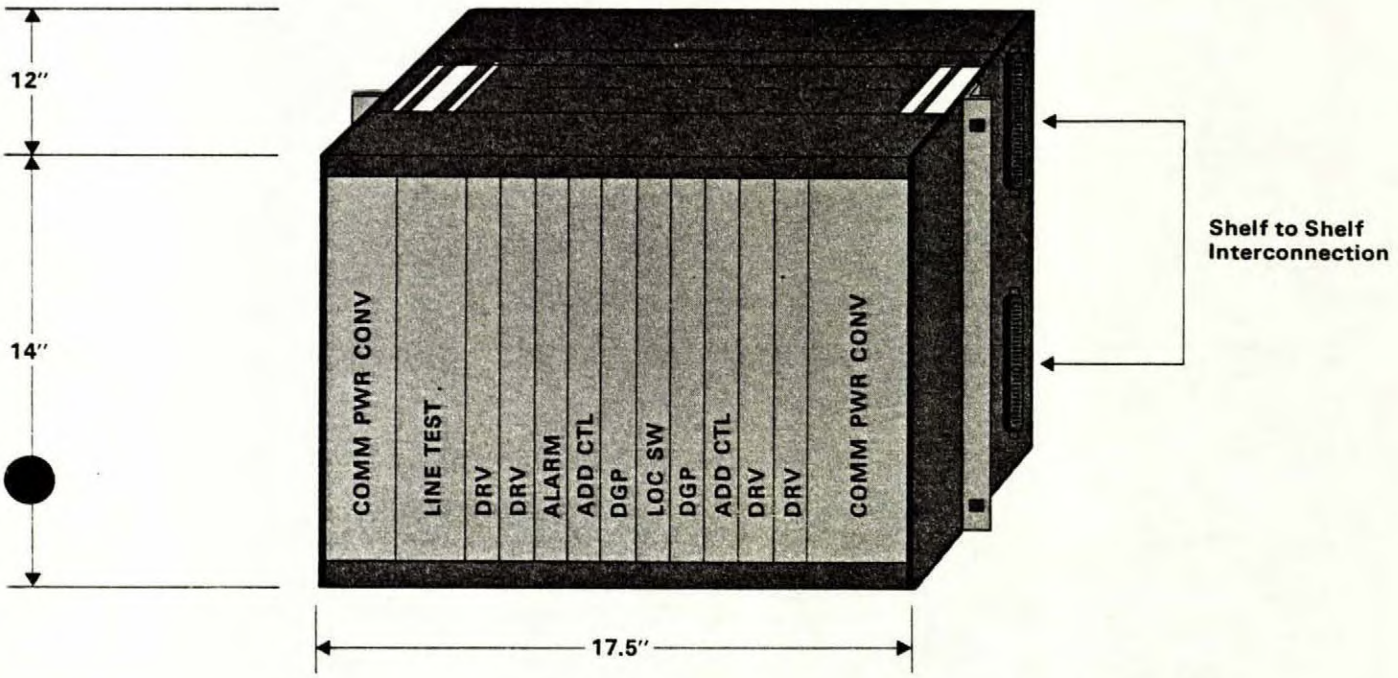
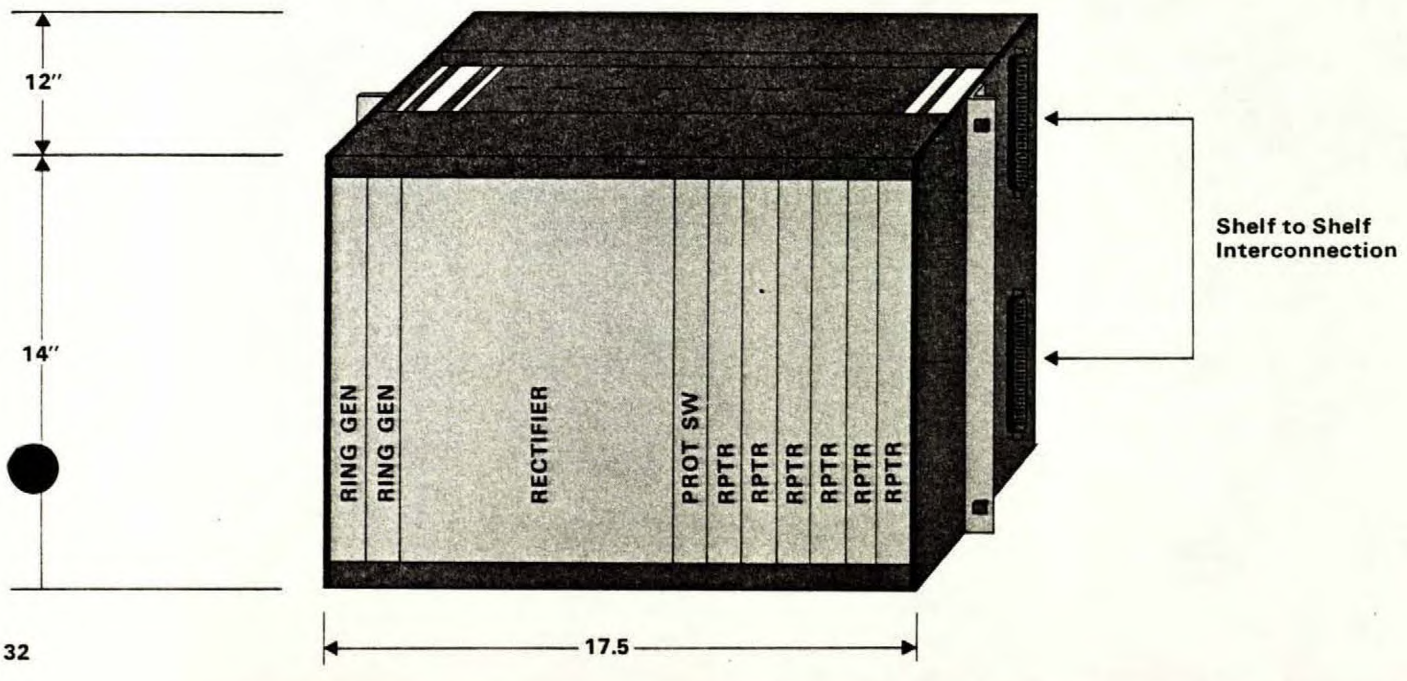


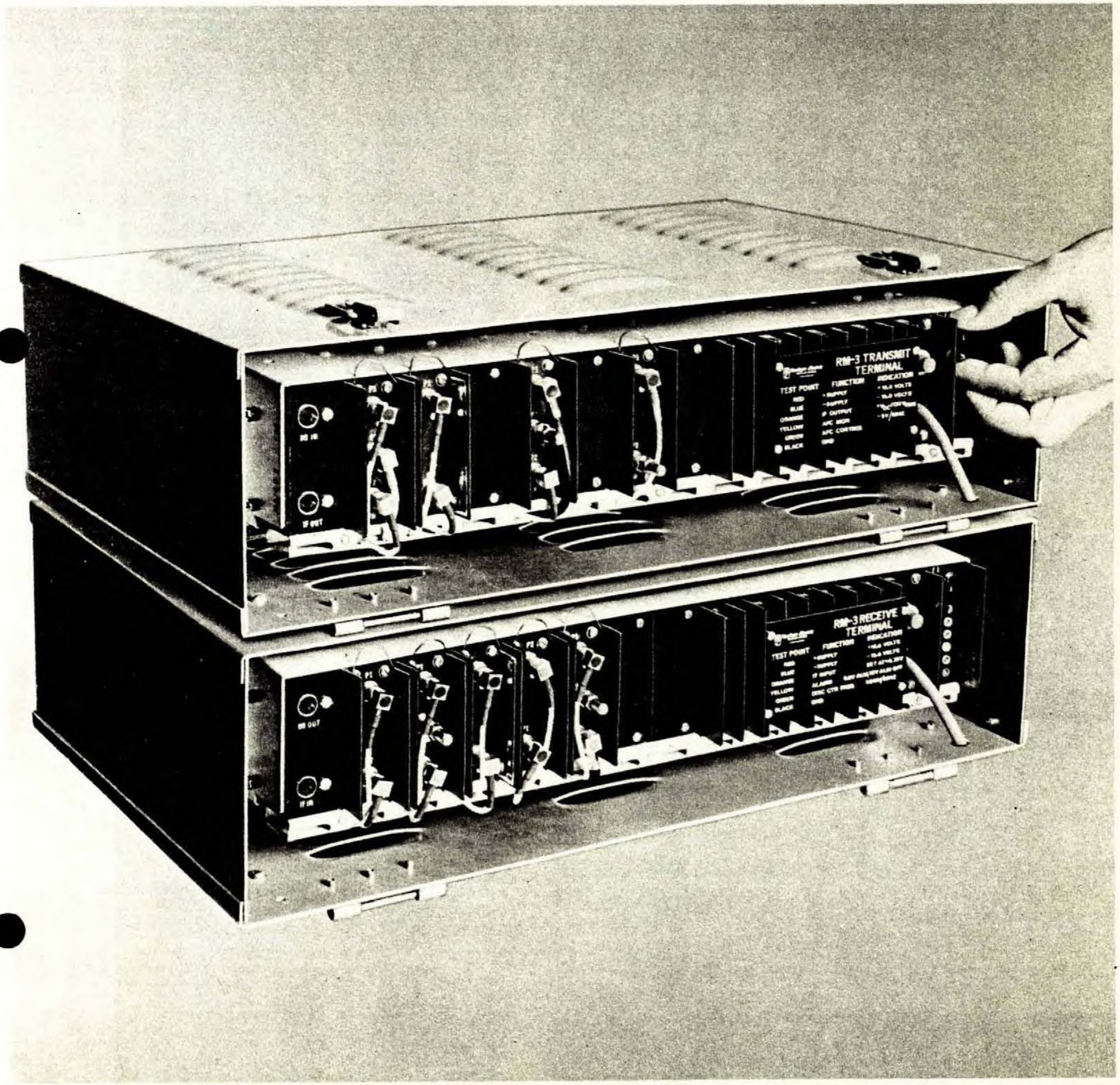
Figure 8. RCT Power Shelf



F

APPENDIX F

Northern Telecom RM-3 FM Terminal



RM-3

FM terminal

Table of Contents **Page**

1 Application

2 Performance

Application

The RM-3 FM Terminal is a 70 MHz IF frequency modulated modem. It is used for modulation and demodulation of the baseband on large capacity IF heterodyne microwave radio relay links. It is available in shelves for mounting in a relay rack or in a portable carrying case. The portable version may be used for system testing and maintenance.

Performance

The RM-3 transmits up to 1800 frequency division multiplexed voice frequency telephone channels with as little as 10 pWpO of noise contribution. Its wideband deviation capability will transmit more than 1800 channels.

Alternatively, the RM-3 may be used to transmit video signals with up to four sound subcarriers with excellent transmission characteristics.

The use of thick film technology—conservative design—close tolerances used in manufacturing and testing—all contribute to a highly reliable product. The transmit or the receive terminal has an MTBF of 150,000 hours.

3 Packaging flexibility

Packaging Flexibility

The RM-3 is modular in concept. The resulting flexibility offers a variety of choices to suit individual requirements. The units are compactly packaged in plug-in modules and are available in equipment shelves for relay rack mounting or in portable carrying cases. An equipment shelf for either a transmitter or receiver is 19 inches wide, 3½ inches high and 15 inches deep and mounts in a 19 inch relay rack. The shelf uses a back-plane printed circuit board, permitting all plug-in modules except the alarm unit and the power supply to be mounted in any position. The alarm unit occupies the extreme right position and the power supply takes up the five positions next to it.

4 Equipment description

Equipment Description

The basic modules are described below. A typical message FM terminal arrangement is shown in the block diagram, figure #1.

4.1 Alarm Unit

The alarm unit provides an interface for dc input wiring. It provides alarm extension, test points for AFC monitor, AFC control, discriminator zero, IF levels and ± 15V for inservice checks and includes the power fuse. It combines the various alarm inputs to release a normally energized relay. Relay contacts operate a lamp for a local indication and provide

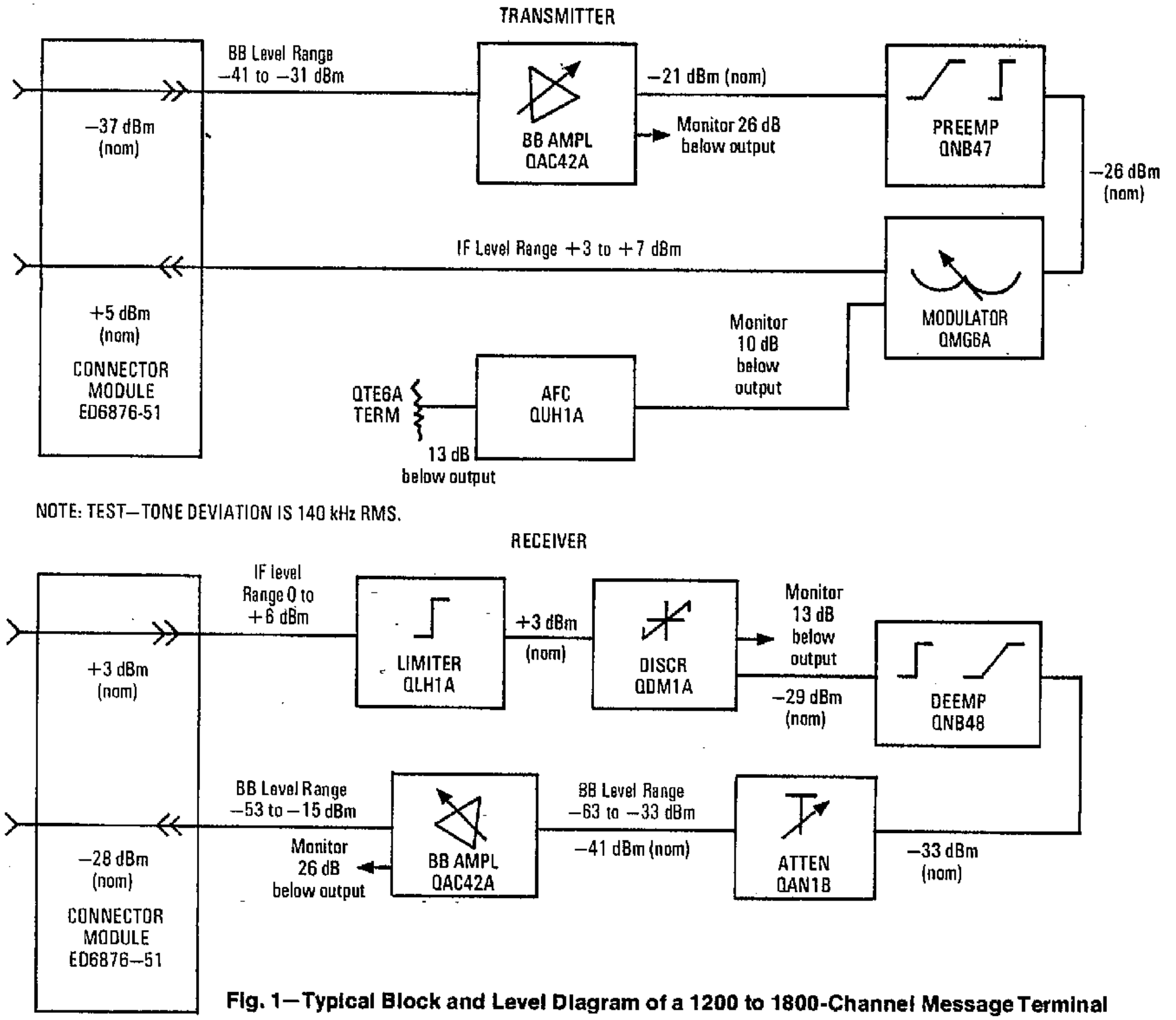


Fig. 1—Typical Block and Level Diagram of a 1200 to 1800-Channel Message Terminal

dry form C alarm connections. This unit also provides the interface to insert the sub-baseband service channels into the modulator.

4.2 Power Supply

The power supply unit accepts the primary input, —48V or —24V dc via the alarm unit, or 115V ac, and delivers +15 and —15V to feed various units in the shelf. The ac power supply has an illuminated push-button on/off switch, and is equipped with a power cord and plug.

4.3 Modulator Unit

The modulator unit accepts the baseband input and delivers 70 MHz frequency modulated IF. The baseband input is applied to two voltage-controlled UHF oscillators operating in such a way that the resulting 70 MHz IF deviation obtained through the difference of the two frequencies adds in phase to achieve wideband and ultralinear deviation capability. IF level and slope, and center-frequency adjustment controls are provided on the side of the unit.

Modulator sensitivity:—26 dBm into 75 ohm/140 kHz rms
IF Output: +5 dBm, adjustable thru +3 to +7 dBm
Service Channel Insert:—11 dBm into 600 ohm unbal/140 kHz rms

4.4 Automatic Frequency Control

The AFC unit automatically corrects the 70 MHz IF modulator frequency, if it drifts from its correct frequency.

An AFC "stress" alarm, is generated when the frequency correction required exceeds a certain pre-set voltage to warn maintenance personnel to take corrective action. The modulation frequency still will be 70 MHz ±20 kHz.

4.5 Pre-and de-emphasis Networks

A selection of pre-and de-emphasis units of CCIR or TD-2/TD-3 types, is available to suit various loadings.

4.6 Limiter Unit

The limiter unit accepts the 70 MHz frequency modulated IF input and delivers the signal to the discriminator after limiting. The unit has an IF level adjustment control to set the input level from 0 to +6 dBm.

4.7 Discriminator

The discriminator unit accepts the 70 MHz frequency modulated IF from a limiter and delivers the baseband signal with very low distortion. "Linearity" and "discriminator zero" controls are provided on the side of the unit.

Discriminator sensitivity 140 kHz rms/-29 dBm into 75 ohms.

4.8 Baseband Amplifiers

Baseband amplifiers are available with various options as shown in table 1, to suite particular needs. The terminals are basically 75 ohms unbalanced. Substitution of the unbalanced amplifiers by the balanced ones will convert them into 124 ohm balanced baseband operation. All units have "Gain" and "HF Adj" adjustment controls. Gain range controls are continuously adjustable. The "HF Adj" provides high frequency compensation ±.25 dB at 10 MHz. The transmit terminal "HF Adj" control is normally factory adjusted. The maximum test tone output should be limited to —15 dBm to avoid distortion.

TABLE #1

CODE	GAIN RANGE (dB)	IMPEDANCE IN	IMPEDANCE OUT	USED FOR
QAC42A	10 to 20	75	75	Message or video
QAC42B	16 to 26	75	75	Message or video
QAC43A	10 to 14	124	75	Message or video
QAC43B	15 to 19	124	75	Message or video
QAC44A	5 to 9	75	124	Message or video
QAC44B	9 to 13	75	124	Message or video
QAC45A	Unity	75	75	Video inverter

4.9 Attenuator-Splitter units

The attenuator-splitter unit provides a strapable attenuator, 2, 4, 8 or 16 dB followed by a 6 dB loss resistive splitter. The input and output impedance is 75 ohms.

QAN1A is the attenuator-splitter
QAN1B is the attenuator only

4.10 Connector Unit

The connector unit adapts the Conhex type connectors to permit the coaxial input/output interface to be NE-477B, TNC or BNC-type jacks.

4.11 Dummy Modules, Power Extension Module

Power extension modules are available to extend the units for adjustment purposes, and dummy modules can be supplied to fill up unused positions.

5 Equipment requirements

Equipment Requirements

The following list includes the equipment required for a standard RM-3 terminal and includes recommended maintenance spares and test equipment.

5.1 Typical Terminal

A typical RM-3 FM Terminal consists of:—

Transmit Terminal J6876B-2 L5, 9

Nominal levels
Baseband in: —37dBm
IF out: +5 dBm

This comprises one shelf equipped with:

1 Connector Unit
1 QAC42A baseband amplifier
1 1260 channel pre-emphasis network
1 modulator unit
1 automatic frequency control unit
3 dummy modules
1 —48V power supply
1 —48V alarm unit
Interconnecting cables

Receive Terminal J6876C-2 L5, 9

Nominal levels
IF in: +3 dBm
Baseband out: —28 dBm

This comprises one shelf equipped with:

1 Connector Unit
1 limiter
1 discriminator
1 QAN1B attenuator
1 QAC42A baseband amplifier
1 1260 channel de-emphasis network
2 dummy modules
1 —48V power supply
1 —48V alarm unit
Interconnecting cables

5.2 Test Equipment

A power extension module with two test cords is available from Northern to extend modules for tests and adjustments.

Other test equipment recommended:—
AVO meter, 2%, 20,000 ohms per volt
NE-70 B power meter
Frequency counter, 70 MHz
Pegelmesser and sender
HP link analyzer
Marconi white noise test set

6 Installation and maintenance

Installation and Maintenance

Each shelf is supplied in a separate container completely assembled and wired, with the plug-ins in place. The installation procedure consists of simply removing the shelves from the containers and mounting them on standard 19 inch relay racks, connecting the primary power, and making the baseband, IF and other local connections. Installation adjustments include: checking ±15V dc, frequency drift, (AFC pull in) modulator sensitivity by Bessell drop-out, Tx/Rx loop gain, alarm and monitor functions, and then finally conducting system tests over the radio channel.

If Tx and Rx shelves are available at one location, additional tests may be performed on a back-to-back basis. These tests are baseband response, spurious tones and white noise.

6.1 Recommended Maintenance Routines

Routine 1: is normally carried out in conjunction with the radio system at 3 or 4 month intervals and consists of the following tests:

±15V dc voltage check
Tx frequency and If output level
Modulator sensitivity by Bessel drop out
Tx/Rx loop gain

Routine 2: is carried out at one year intervals, and consists of the following tests, in addition to those of routine 1:

checking alarm and monitor functions
baseband response, spurious tones and white noise, if Tx and Rx shelves are available at one location.

6.2 Maintenance Spares

The use of thick film technology and high quality discrete components, minimizes maintenance requirements. The recommended spares listed below (only the active modules) are based on the philosophy that Northern's repair and replacement service will be used:

Baseband amplifier
Modulator
AFC Unit
Limiter
Discriminator
Power supply
Alarm Unit

7 Technical summary

RM-3

FM terminal

Performance Specifications

Level interface
(includes CCIR pre-and de-emphasis)

Baseband in	−38 dBm ± 3 dB/140 kHz, rms deviation, 75 ohms
IF out	70 MHz, +5 dBm ±2dB
IF in	70 MHz, +3 dBm ±3dB
Baseband out	−22dBm or −28dBm ± 3dB, 75 ohms
Video in and out	1V pk-to-pk/8 MHz pk-to-pk deviation, 75 ohms.
Balanced baseband operation (different levels can be accommodated to suit customer's requirements)	124 ohms optional
IF return loss	30 dB over 70 ± 10 MHz
Baseband return loss	30 dB over 10 Hz to 10 MHz
IF frequency stability	± 20 kHz

Back-to-back Telephony (1800 channel)

Loaded noise	10 pWpO top slots
Baseband response 10 Hz to 8 MHz	.2 dB w/o pre-& de-emphasis
10 Hz to 8 MHz	.25 dB with pre-& de-emphasis

Video

Baseband response 10 Hz to 8 MHz	.2 dB w/o pre-& de-emphasis .25 dB with pre-& de-emphasis
Diff. Gain	.2% 10 to 90% APL
Diff. Phase	.3° 10 to 90% APL
Multiburst	± 1 IEEE units
Axis Shift	<1 IEEE units
Square wave tilt & bulge at field or line rate	<.5%
Overshoot	<1%
Signal to noise ratio	>75 dB pk-to-pk picture/rms noise, 10 kHz to 4.2 MHz >75 dB, pk-to-pk picture/rms noise, below 4 kHz

Power Requirements

	−48V dc (+8/-6V)
	−24V dc (+4/−3V) (optional)
Input voltage	115V ac (optional)
Power consumption	15W (max) per transmit or receive terminal

Environmental Conditions

Normal Operating Temperatures	0° to 50°C (32° to 122° F)
Extreme Operating Temperatures	−30° to 60°C (−22° to 140° F)
Relative humidity	20% to 95% with a maximum absolute humidity of 25 mm Hg water vapour pressure

Physical Characteristics
(per transmit/receive shelf)

Height	(90 mm)	3½ in.
Width	(483 mm)	19 in.
Depth	(254 mm)	10 in.
Weight	(9 kg)	20 lb.

Field trial Fiber optics study