A STUDY OF THE AVAILABLE PRODUCTS AND SYSTEMS FOR RURAL TELEPHONE - COMMUNICATIONS

PREPARED
FOR

DEPARTMENT
OF
COMMUNICATIONS
CANADA

APRIL 1976

(K)
K. LOGAN & ASSOCIATES
MONTREAL, QUEBEC

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SYNOPSIS

In rural telephone networks, the methods by which service is provided vary with the type of existing plant, the type of terrain and many other factors. Advances have been in the basic cable plant and the electronic systems to improve these services by a variety of applications.

The situation regarding the availability of products and systems for rural telephone service has been studied. The manufacturers and products have been identified as to the following product categories.

a) Cable systems.
b) Voice frequency electronic devices.
c) Station and Subscriber carrier systems.
d) Electronic Subscriber Switching systems.
e) Integrated Digital Multiplexer Switching systems.
f) Radio systems - direct subscriber circuits.
g) Integrated Radio transmission and electronic switching systems.

Each of these systems is discussed in five different sections.

a) Overall review of products and systems in North America.
b) Assessment of the supply situation in Canada.
c) Assessment of the supply situation in U.S.A.
d) Analysis of cost and performance of line transmission systems.
e) Analysis of costs and performance of radio transmission systems.

Future possibilities for the different systems are outlined and some projected developments in other areas of communications are discussed as to the potential application in rural telephone service.

TABLE OF CONTENTS

Page No:

SECTION VII

STUDY

OF

AVAILABLE PRODUCTS & SYSTEMS

FOR

RURAL TELEPHONE COMMUNICATION

EXECUTIVE SUMMARY

OBJECTIVES

1.0 To identify manufacturers and suppliers and systems required in subscriber distribution networks.

2.0 To establish a data base on products and systems available in North America.

3.0 To review the products and systems suitable for use in rural telephone networks.

4.0 To determine the market penetration of the available systems into the rural telephone network in Canada and U.S.A.

5.0 To determine the design and manufacturing content in Canada.

6.0 To analyse the cost and performance on a broad gauge basis - line transmission and radio.

7.0 To project future systems and products.

SURVEY

Seventy-seven suppliers of equipment and outside plant hardware, etc., for subscriber distribution systems were identified, of which 30 are subsidiaries of foreign companies, 13 in the Canadian owned category and the remainder either distributors for foreign suppliers or foreign companies that sell directly in Canada. 55 companies consisting of manufacturers, distributors, etc., were contacted, 43 in Canada and 12 in the U.S.A.

FINDINGS

1.0 Bulk of rural communications business in Canada consists of cables and wire, for which there are three major suppliers -

1. Northern Telecom Cable Division, Montreal, Quebec.

2. Phillips Cables, Brockville, Ontario.

3. Canada Wire & Cable, Winnipeg, Manitoba.

A secondary line of products consists of outside plant hardware. This business segment is more fragmented on a regional basis. The major suppliers are -

1. Northern Telecom.

2. Reliable.

3. G. T. E. Automatic Electric.

4. Cook Electric.

5. Superior Continental.

Third and smallest segment of suppliers are those associated with the electronic equipment that augments the cable -

1. Transcom

2. Lorain.

3. Northern Telecom.

4. G. T. E. Lenkurt.

5. Wescom.

6. I.T.T.

7. Tele-Radio.

8. Superior Continental.

Suppliers of radio equipment in use in rural systems are -

1. International Systcoms

2. Motorola.

3. Pye Canada.

4. Farinon Electric.

2.0 Available products and systems in Canada and the U.S.A. comprise voice frequency electronic devices, carrier systems - both analog and digital - subscriber switching systems (line concentrators) and integrated digital multiplex switching systems for line transmission and radio. In the U.S.A., telephone sets with built-in amplifiers are available for planned use on long route subscriber circuits.

3.0 Trend in U.S.A. is towards use of finer gauge cable, reducing cable size to minimize initial investment and fill future requirements by application of electronics. New outside plant designs and system planning improvements for rural telephone service are being implemented to reduce first costs of subscriber distribution by 30-50%. No evidence of similar trend in Canada.

4.0 Penetration of electronics into rural distribution is increasing rapidly in the U.S.A. - market forecasts indicate volume of $400 million for REA financed projects over the next eight years in carrier systems; based on present sales, in Canada the volume would be $16-20 million.

5.0 Major manufacturers opinion is that demand is insufficient for design and manufacture in Canada. Smaller companies question viability of design and manufacture for market that is dominated by imported products.

6.0 Acceptance of latest designs of digital multiplexer switching systems is far less than expected in Canada; probability is that products designed in Canada will be manufactured in U.S.A.

7.0 Development of radio systems in Canada for rural distribution is active; significant gains are being made in steering planning towards integration of radio systems on a permanent basis in subscriber plant.

8.0 Equipment and material costs for subscribers loops show a wide spread depending on type of outside plant structure (aerial or buried) cable. The order of magnitude savings by planning for minimum cable investment and providing additional circuits by electronics can be judged from the following -

				COST PER SUBSCRIBER	
Distance	System Type	Subscriber Distribution	Subscriber Service	New Plant	Additional circuits by electronics
50Kft	Physical etc.	Aerial	4-party	$1865	-
50Kft	Analog Station Carrier	Aerial	4-party	$1635	$225
50Kft	Physical	Buried Cable	4-party	$ 505	-

Cost for radio system would be in the range of $6,000 for a similar distance, but by the application of concentrators, this would decrease to $2,000 per subscriber.

FUTURE SYSTEMS

New carrier systems and integrated electronic concentrators with radio systems and line transmission are being developed. Since the circuit cost is heavily dependant on the connecting cable and support structure, concentration of traffic as close to subscriber's set as practical, appears an absolute economic necessity. Emphasis is on proving reliability of these new systems and reducing basic equipment costs by more widespread use of integrated circuitry.

Activity in this area is confined to U.S.A. in the line transmission system, however, development in radio systems by Canadian companies using these new techniques is ahead.

Developments in mobile radio concepts in the 900 MHz band in the U.S.A. could lead to wider applications of radio systems in rural areas.

CONCLUSION.

With the exceptions of some companies engaged in the development of radio systems, there appears to be very little knowledge in the Canadian manufacturing industry of the requirements for rural subscriber loops.

Most of the practical information published on this subject originates in the U.S.A. and activity towards the development of products and systems has been stimulated by the dedicated efforts of the Rural Electrification Administration (REA).

As indicated in the report, there are many variables in the methods by which rural subscribers telephone service is being improved.

The underpinning of the distribution network will continue to be cable systems for many years to come and the economic necessity will be to maximize utilisation of the expensive cable and outside plant hardware by concentrators, carrier systems and other electronic devices.

There is no one solution that can be put forward to solve the problems of rural subscriber service, for, in Canada, it is believed that approaches will vary throughout the different regions of the country.

Having now established a data base on the supply segment of the industry, the next step would appear to be to determine the basic requirements in these different regions for rural subscriber's loops and establish standards and procedures that will provide the base for decision making for optimum design as opposed to design by opinion.

SECTION I

1.0 INTRODUCTION

This report has been prepared for the Department of Communications in response to the request for a study of rural communications to determine the suitability of various system technologies and the availability of equipment to meet these technologies. This study is part of the Rural Communications Project under the direction of A. T. Schindler, Project Leader, Department of Communications.

To provide sparsely settled areas with good telephone service has always been of great concern in telephone company planning. Costs of the distribution circuits (subscriber loops) become a prime factor, because of the longer distances from the switching offices. To minimize costs per subscriber, multi-party lines have been used in most cases.

The subscriber loops are mainly twisted wire pairs of varying sizes. For the longer loops, heavy gauge wire is used to keep the electrical resistance low enough for good transmission and signalling. To serve these long loops by cable alone costs three to ten times more than the average urban loops. In addition, there is the inevitable compromise between costs and performance with the result that service to rural subscribers is invariably of lesser quality than it is to urban subscribers.

The original rural telephone distribution systems were open wire since this type of system had the advantages of low transmission attenuation, and was easy to install and maintain by lower grade personnel.[1] The disadvantages are the performance of such systems in ice and sleet and the outages caused by breaks due to these adverse weather conditions. Because of the high labour content involved, the costs today of providing open wire systems are very high with the net result that they are in a state of obsolescence and are being discontinued in favour of less costly cable systems. In some areas buried cables are used and in other areas aerial cable is used.

To improve circuit quality and reduce costs in rural area service, different types of electronic transmission systems, cable distribution methods, etc. have been designed, manufactured and installed over the last twenty years.

The earlier electronic systems had a chequered history and in many cases have been discontinued because of lack of reliability, the equipment complexity and high power consumption. The penetration of more recently developed electronic systems which will overcome these problems, appears to be at a very low level of acceptance in the Canadian network at the present time. The net result is that rural area service is still largely today provided by individual twisted wire pairs in cable, the open wire systems being gradually phased out.

[1] HOW TO BUILD RURAL TELEPHONE LINES. Northern Electric & Mfg. Co. Ltd. 1910.

Until 1965-66, the experience in the United States, mainly amongst the Rural Electrification Administration (REA) assisted telephone companies, was that the use of electronics in subscriber loop plant was confined to the provision of temporary facilities and to areas where it was not possible, or excessively costly, to develop a permanent cable distribution network. However, the rising costs due to inflation, and the need to conserve basic materials, has brought about a definite plan for the integration of loop electronics for permanent facilities in the United States.[2] The indications are that the market for electronic systems in subscriber distribution is increasing.

The new products and systems include integrated electronic circuits in the telephone set itself, electronics in V.F. (voice frequency) physical circuits, single and multi-channel analog carrier systems, multi-channel digital carrier systems and integrated time division switches with digital transmission.

A survey of 55 North American manufacturers has been carried out to determine the following:

1) Manufacturers' perception of rural telephone networks.
2) Current availability of products for rural telephony.

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[2] TELCO PLANNING FOR THE INTEGRATION OF LOOP ELECTRONICS FOR PERMANENT FACILITIES. M. N. EVANS, Southern New England Telephone, New Haven, Connecticut. National Telecommunications Conference, December 1-3, 1975. New Orleans. I.E.E. Catalogue Number 75 CH 1015-7 CSCB.

The main objective of this activity was to establish a data base on products for the Department of Communications study on rural communications.

A broad range of costs for the various system configurations has been established based on manufacturers' price lists and these have been documented in this study. For decision making planning purposes, a further refinement of the cost analysis would be necessary to take into consideration additional telephone company cost factors.

SECTION II

2.0 SCOPE OF STUDY

This study was limited to the manufacturing sector of the telecommunications industry with particular reference to subscriber telephone systems as they relate to rural area distribution. In general, the following objectives were established:

a) Identification of possible suppliers of electronic equipment, cable and miscellaneous hardware to the telecommunications carriers in both Canada and the U.S.A.

b) Assembly of a data base of information on systems for rural communications, e.g.

   1) loop extenders.
   2) dial long line circuits.
   3) ringing extenders for party line operation.
   4) Analog distributed (station) and lumped (subscriber) carrier systems.
   5) Digital distributed (station) and lumped (subscriber) carrier systems.
   6) low capacity v.h.f. and u.h.f. radio systems.
   7) small switching offices and electronic concentrators.
   8) types of wire and cable, buried and aerial.
   9) Microwave radio.

Provision of information on installation difficulties and costs of systems in different types of terrain where available.

c) The operating and maintenance features of the above list of systems with emphasis on automatic testing of systems.

d) The manufacturers' expected volume of production, anticipated market, past, present and future. The historical aspects of this market and the problems that manufacturers have found in producing and servicing this market.

e) Network configurations and costs for the above systems.

f) The existing and potential Canadian content in producing for this market.

SECTION III

3.0 METHODOLOGY

An initial meeting was held with A. T. Schindler, D.O.C., to review the work program and derive a list of the companies that should be contacted as possible sources of information.

Current literature relating to the particular types of products was obtained as well as the documentation outlining the various system parameters. This information was studied in conjuction with the material obtained by research into the conference publications and the technical literature available on this subject of subscriber plant and rural telephone networks.

From this data, a questionnaire was drawn up to establish a basis for further enquiry and discussion with the various suppliers. A total of 55 companies, (43 in Canada, 12 in the U.S.A.), engaged in the design, manufacture and supply of communications products were contacted and in general the response was very co-operative. The replies to a written questionnaire were not as responsive as the discussions that took place in follow-up meetings.

The companies contacted were as follows:

SUPPLIERS & MANUFACTURERS

CANADA

A.D.C. Telecommunications, Montreal, Quebec
A.E.I. Telecommunications, Winnepeg, Manitoba
Anaconda Canada Ltd., Toronto, Ontario
Aluminum Company of Canada, Montreal, Quebec
Andrews Antennas, Whitby, Ontario
Artican Communications, Vancouver, B.C.
Automatic Winding Corporation, Downsview, Ontario
Bayly Engineering, Ajax, Ontario
Brown Boveri (Canada) Ltd., Montreal, Quebec
Canada Wire & Cable, Winnipeg, Manitoba
Canadian General Electric, Toronto, Ontario
Canadian Quality Communications, Morden, Manitoba
Canadian Marconi Company, Montreal, Quebec
Collins Radio Company, Toronto, Ontario
Cook Electric Company of Canada, Winnipeg, Manitoba
Farinon Electric, Montreal, Quebec
G.T.E. (Lenkurt Electric), Vancouver, B.C.
G.T.E. (Automatic Electric) Brockville, Ontario
International Systcoms, Montreal, Quebec
I.T.T. Canada, Guelph, Ontario
L.M. Ericsson Ltd., Montreal, Quebec
Lorain Products of Canada, St. Thomas, Ontario
3M Canada Ltd., London, Ontario
Motorola Canada Ltd., Toronto, Ontario
Northern Telecom, Transmission Division, Montreal, Quebec
Northern Telecom, Apparatus Division, Belleville, Ontario
Northern Telecom, Cable Division, Montreal, Quebec
Osborne Electric, Toronto, Ontario
Phillips Cables, Brockville, Ontario
Pirelli Cables, St. Jean, Quebec
Pye Canada, Montreal, Quebec
Pylon Electronic Development Co., Lachine, Quebec
Raytheon Canada Ltd., Waterloo, Ontarop
R.C.A. Ltd., Ste. Anne de Bellevue, Quebec
SED Systems, Saskatoon, Saskachewan
Siemens Canada Ltd., Montreal, Quebec
Sinclair, Toronto, Ontario
Superior Continental Canada Ltd., Stratford, Ontario
Teleradio Co., Downsview, Ontario
Transcom Electronics Manufacturing, St. Jerome, Quebec
TRW Canada, Scarborough, Ontario
UNI Tel Ltd., Scarborough, Ontario
Wescom Canada Ltd., Brampton, Ontario

SUPPLIERS & MANUFACTURERS

U. S. A

Brand Rex Cables, Willimantic, Connecticut
Digital Telephone Systems, Novato, California
Farinon Electric, San Carlos, California
G.T.E. (Lenkurt Electric) San Carlos, California
General Cable Corporation, New York
Lear Siegler, Anaheim, California
Lynch Communications, Nevada
3M, Minnesota
Martin Marietta, Orlando, Florida
Telecommunications Industries, Copiague, New York
RFL Industries, Boonton, New Jersey

In addition, the United States Rural Electrification Administration (REA), was contacted in Washington, D.C.

From the discussions with the manufacturers, the necessary information was obtained for an overall assessment of the current supply situation to be prepared for inclusion in this report. The assessment is written in two sections, one dealing with Canada and the other with the U.S.A.

The material received from the manufacturers has been compiled to form a data base on the types of products that are available. The engineering and application information is also included.

In the U.S.A., the discussions with the manufacturers invariably related to the methods and procedures of the Rural Electrification Administration, and, although it cannot be considered as a supplier, it was thought that for the sake of completeness in the report, an in depth knowledge of this organization would add something to the considerations. Their response was excellent and it produced a greater understanding of the methods they are recommending for improving the rural telephone service.

For further background information, company profiles were prepared to acquaint the D.O.C. personnel with the necessary supporting data on each company's involvement in the telecommunications industry.

Under separate cover eleven volumes of information are supplied covering the following:

VOLUME I........Report on a study of the available products and systems for Rural Telephone Communications.

VOLUME II...	Index and listing of Suppliers of Subscriber Loop Plant to the Telecommunications Industry Canada and U.S.A.
VOLUME III..	Detailed engineering, applications and equipment information on Suppliers' Products. This is supplementary to the Suppliers' Catalogues that have been forwarded to the Department of Communications.
VOLUME IV...	
VOLUME V....	
VOLUME VI...	
VOLUME VII..	
VOLUME VIII.	Company Profiles.
VOLUME IX...	Company Profiles.
VOLUME X....	Compilation and Indexing of copies of referenced literature.
VOLUME XI...	

SECTION IV

OVERALL REVIEW OF PRODUCTS AND SYSTEMS

4.1 INTRODUCTION

In the overall design of the telephone network, as many as seven links may be connected in tandem on a direct distance dialling (DDD) call, and the emphasis on improvement has largely been directed towards the trunk and inter-switching office links. It is now felt that the development should be to improve the subscriber loop transmission, since the subscriber loops form the end links in the chain between the subscriber's telephone sets as shown in Fig. I.

The subscriber loops and distribution facilities make up the largest single investment in communications. Nationally, the breakdown of telephone company investment is as follows:

Outside Plant	- 31%
Switching Equipment	- 24%
Station Equipment	- 21%
Transmission Facilities	- 14%
Other investment (Land, Buildings, Vehicles) -	- 10%

On a regional basis, the outside plant investment varies from 25 - 35%, however, the percentage investment is much higher for purely rural areas, where subscribers may be located many miles from the central office and the population density is small.

—INTER – CITY SUBSCRIBER TO SUBSCRIBER CONNECTION—

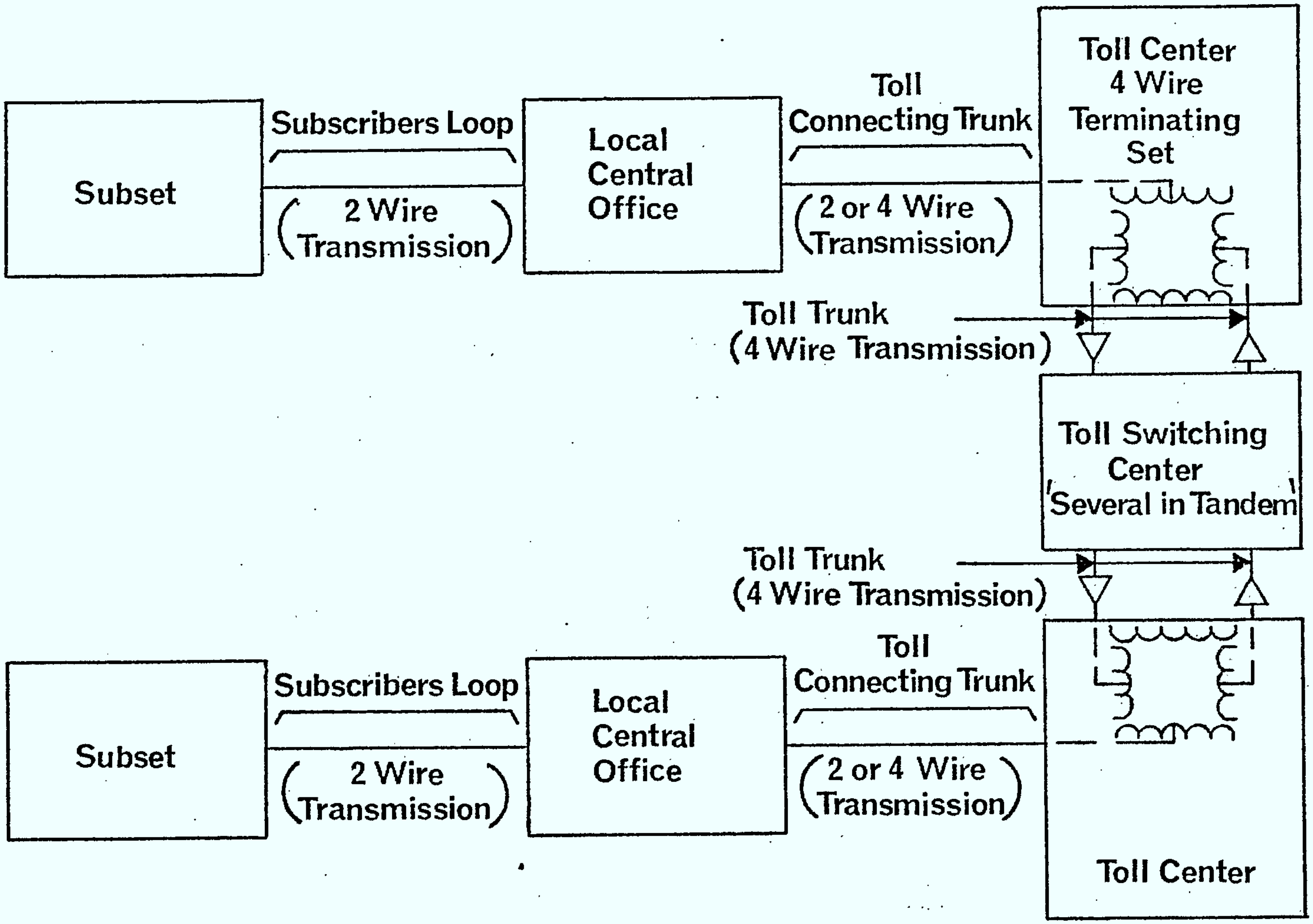

FIG.— 1

The distribution facilities usually consist of various gauges of cable which are arranged to provide the most economical routing and sizes commensurate with the locations of the subscriber's telephones, the transmission and signalling requirements as well as facilities for the predicted growth of the served area. Distribution facilities may be a few hundred feet in length, or may extend for many miles. The costs are highly sensitive to price increases of basic materials such as copper and plastic.

Outside plant distribution facilities are, therefore, the major element to be considered when striving to achieve the following objectives for rural telephone communications:

a) Reduced material costs.

b) Improved transmission quality.

c) Conservation of basic metal resources.

d) Reduced labour content.

e) Satisfaction of Customer's expectations of rising standards.

Most of these objectives are being met in the United States by the increasing use of electronics in subscriber systems, however, the application in Canada appears to be minimal. The following sections of this report review the types of systems that are available, and assesses the situation in each country.

4.2 TYPES OF SYSTEMS AVAILABLE

4.2.1 Voice frequency systems

In the older types of telephone exchanges, the signalling requirements restricted the resistance of the subscriber loop and telephone set to a maximum of 635 ohms. In the newer crossbar offices, this total resistance can be about 1500 ohms. Allowing 200 ohms for the set, the total cable pair resistance can be about 1300 ohms. Of this, 1200 ohms is allowed for the pair at normal temperature and without loading*, and 100 ohms for temperature effects and loading coil resistance.

With the improvements in telephone set efficiency that came about with the design of the 500 type set in 1953, it was possible to engineer subscriber loops right up to this 1200 ohm resistance limit and extend the loop length beyond 18,000 feet provided loading was used to reduce the attenuation and frequency distortion.

The net result of these improvements was to considerably reduce cable costs by using finer gauge wire and extend the subscriber loop lengths out to a maximum distance of 75,000 ft. The comparison of the early telephone set and later telephone set loop lengths is shown in Table I.

---

* The transmission loss of a pair of wires below a prescribed frequency can be reduced by inserting inductance periodically. This is called "loading".

TABLE I

Gauge	Max. loop length in feet Earlier 300 Set	Max. loop length in feet Later 500 Set
26	10,500	14,400
24	14,000	23,100
22	17,000	37,000
19	21,000	74,400

To help improve service in rural areas, where loops may extend as far as 60 miles from a central office, voice frequency and carrier frequency electronics have been used. The carrier frequency systems are discussed in the latter part of this section.

The voice frequency systems, wich are used to satisfy most of the rural growth demands, consist of equipment that extends the signalling and transmission range of the central office, enabling the telephone company to use smaller diameter wire pairs in cables. These voice frequency systems comprise equipment such as loop extenders, range extenders and just recently in the U.S.A. the telephone hand sets with built in amplifiers have been designed.

Loop entenders provide a battery boost and voice frequency repeaters provide gain either fixed or automatically variable for the a.c. speech currents. Range extenders with gain provide a combination of these two functions on a single unit. The amplifiers built into the telephone handset provide an additional 3 dB gain. The combination of these electronic equipments in a subscribers loop circuit permit a loop to extend out to 100,000 ft. using 22 gauge cable, resulting in a considerable saving in cable costs.

The earlier systems would have used 19 gauge cable for a major proportion of the circuit length. (19 gauge cable contains twice as much copper as 22 gauge cable). It is conservatively estimated that the savings in the Bell system in the U.S.A. will be three million dollars a year in copper.[3]

It is important to note that in these new designs of long range subscriber loops, the electronic equipment is located in the central office and the subscriber's telephone set, thus avoiding the high cost of housing, powering and maintaining field mounted repeaters as used in the earlier designs. Further detailed information on loop voice frequency electronics is given in Section VII of this report and in the data base material. (See Vols. II - VII)

4.2.2 Cable and wire

For many years, the distribution facilities in rural areas were provided by open wire lines, but this practice has now largely been discontinued in favour of cable systems. As in urban areas, the cables used were copper conductors, insulated with paper and sheathed in lead.

With the introduction of plastics in the 1950's it became possible to adopt extruded polyethylene in place of lead as the sheathing material and solid polyethylene instead of paper for the conductor insulation. The toughness of the polyethylene sheath suggested the direct burial of cable by trenching or mole-ploughing would be practical, and this practice has now been widely adopted in rural areas.

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[3] G.36 Handset. George T.Howley and Ryer A. Radosevich, Bell Lab Record August 1975.

The consequent savings in capital outlay as analysed in Section VII of this report result in a major reduction in the cost per subscriber from $1865 to $505.

Other possible lower cost designs of cable are in the use of cellular insulation in filled cable, thus permitting a thinner wall of insulation for similar transmission characteristics and aluminum in lieu of copper conductors.[4] Theoretical studies indicate up to 16% saving with "cell" insulation and 25 - 40% saving in the use of aluminum. "Filled" cable refers to petroleum jelly compound fill injected into the cable to seal all voids thus preventing the entry and flow of moisture within the cable. This has a significant effect on the maintenance costs of buried cable plant.

Cable types are discussed and cost comparisons given in Section VII of this report. Technical details and reference material are provided in Vols. II to XI of the data base.

4.2.3 Carrier Systems

Carrier systems have been designed to provide additional independent conversations to take place on one or two pairs that extend between the telephone customer and the central switching office. The earliest form of what might be called subscriber carrier, employed the technique of superimposing voice modulated signals on electric power lines.

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[4] Review of experience to date and future design considerations, Irving Kolodny - General Cable, March 1975.

This technique, called "power line carrier", brought telephone service to remote customers (provided they had electricity) without the necessity of stringing telephone wires. The disadvantages of this type of system are that it is expensive, (present day power line carrier systems can cost up to six to twelve thousand dollars per channel), it is not available when emergencies arise, i.e. power line failure, and it creates a maintenance problem, since it comes under two administrations.

Equipment developed in the early 1950's to provide carrier facilities in subscriber telephone plant, assign several customers to each line, thereby providing new customer service without adding cable pairs. This type of service was primarily to reach remote customers. These early systems provided service for 2 to 10 parties on one loop. The electronic circuitry made wide use of vacuum tubes, and therefore required periodic maintenance and adjustment. They were costly, bulky items that consumed a lot of power. A comparison of single channel carrier units designed for installation at a customer's premises in 1949 and 1976 would be as follows:

	1949	1976
Cost	$1200	$50
Power	350 watts	2.5 watts
Weight	50 lbs.	1 lb.

Carrier equipment was essentially considered to be a temporary expedient until physical lines could be installed. However, with the advent of solid state circuitry with improved reliability, reduced maintenance and low power consumption, the use of subscriber carrier systems has grown to the point where it can now be considered as a permanent item in customer distribution networks.

4.2.3.1 Subscriber and Station Carrier

The terms subscriber carrier and station carrier are often used synonymously because both systems perform the same function in much the same way. There is, however, by arbitrary definition, a technical difference between the two. In a subscriber carrier system, channels are usually terminated at one or two remote points, with the remote terminals being locally powered. Service to customers is then distributed from these remote points and each circuit can operate to a total resistance of 1600 ohms (6 miles, 24 gauge cable) between the subscriber's premises and the remote subscriber carrier terminal. This type is also called a "lumped carrier" system.

Station carrier systems permit up to 8 individual remote channels to be located randomly anywhere along the line, since they are all powered from the central office. The distance between the remote carrier terminal and the customer is usually limited to a few hundred feet because of the power feeding limitations. This type of system is also known as a "distributed" carrier system. Fig.2 shows a typical example of subscriber and station carrier applications.

Today there are many different systems of both types available in North America. In the station carrier, the design is

- Subscriber Carrier Systems Distribute Customer Lines From Locally Powered Remote Terminals. Station Carrier Terminals Are Powered From The Central Office And Are Randomly Distributed Along The Line.

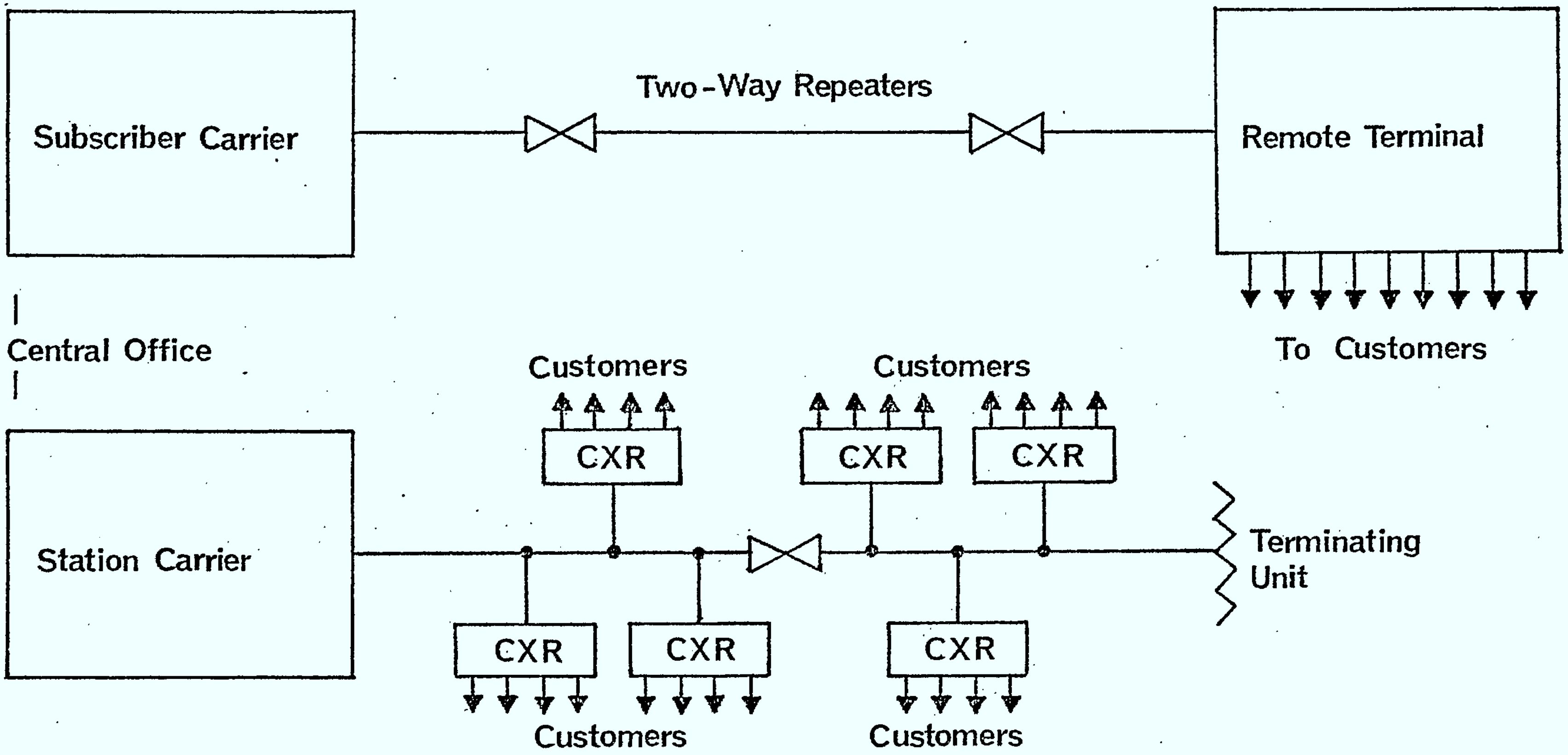


FIG.—2

based on analog transmission, while in the subscriber carrier system both analog and digital transmission is used.

During the last five years or so digital equipment prices have been reduced by almost 50% by the use of large-scale integration (LSI) of components, and this has led some proponents of these types of systems to make cost effectiveness claims that often cannot be realized in application due to the high cost of making the existing VF lines suitable for digital transmission. Experience over the last four or five years has shown that the total in-place costs of digital systems is still higher than analog systems.

Analog systems have shown a price reduction of only about 30% in the same period; however, most suppliers of carrier systems feel that the flexibility of analog station carrier, in its ability to drop off individual customers at reasonable cost, lends itself most readily to rural distribution. Station carrier systems have been installed and are providing service to customers up to 220 kf. (appros. 40 miles) from the central office.[5] One such system has been extended out to 60 miles from the central office.

[5] Carrier Applications to Long Loop Subscriber Design - D. H. Potter. Telephone & Engineer Management, March 1, 1973.

4.2.4 Electronic Subscriber Switching System (Line Concentrators)

In most cases the term "Electronic Switching Systems (ESS)" is used to denote the types of central offices that employ electronic sub-systems for the call processing in place of electro-mechanical devices. Some also employ solid state switches in place of the electro-mechanical switches. In this category would be placed the larger switching machines such as the Northern Telecom's SPI, the A.E. Company's EAX and the Bell (U.S.) E.S.S. 1, 2, 3, 4 offices.

Lately, however, the term has been applied to a smaller type of switch that is located remotely from the central office, to provide the concentration of traffic from the subscriber's sets to the local switching office. The earlier systems of this type were known as "line concentrators" that used electro-mechanical switches. Due to high maintenance costs and poor reliability, the line concentrators were not really accepted in subscriber distribution facilities. The modern concentrators now include solid state devices that have overcome some of the earlier problems and the application of these systems is increasing.

There are basically two types of subscriber switching system. One comprises switching and control that can be connected to the local switching office by voice frequency circuits or by analog or digital carrier transmission facilities (see Fig. 3). The other type is an integrated subscriber line concentrator and multiplexer that uses time division switching together with digital transmission, (see Fig. 4). Each system has its own advantages.

– TYPICAL SUBSCRIBER LINE CONCENTRATOR / MULTIPLEXER –
– SYSTEM –

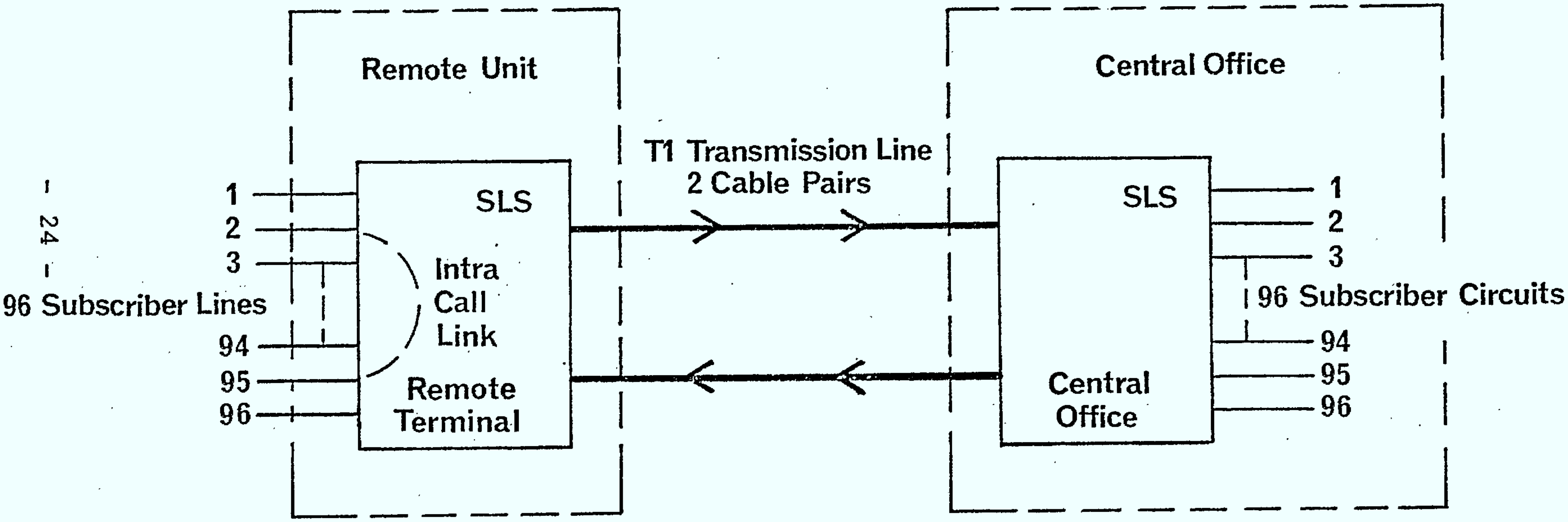
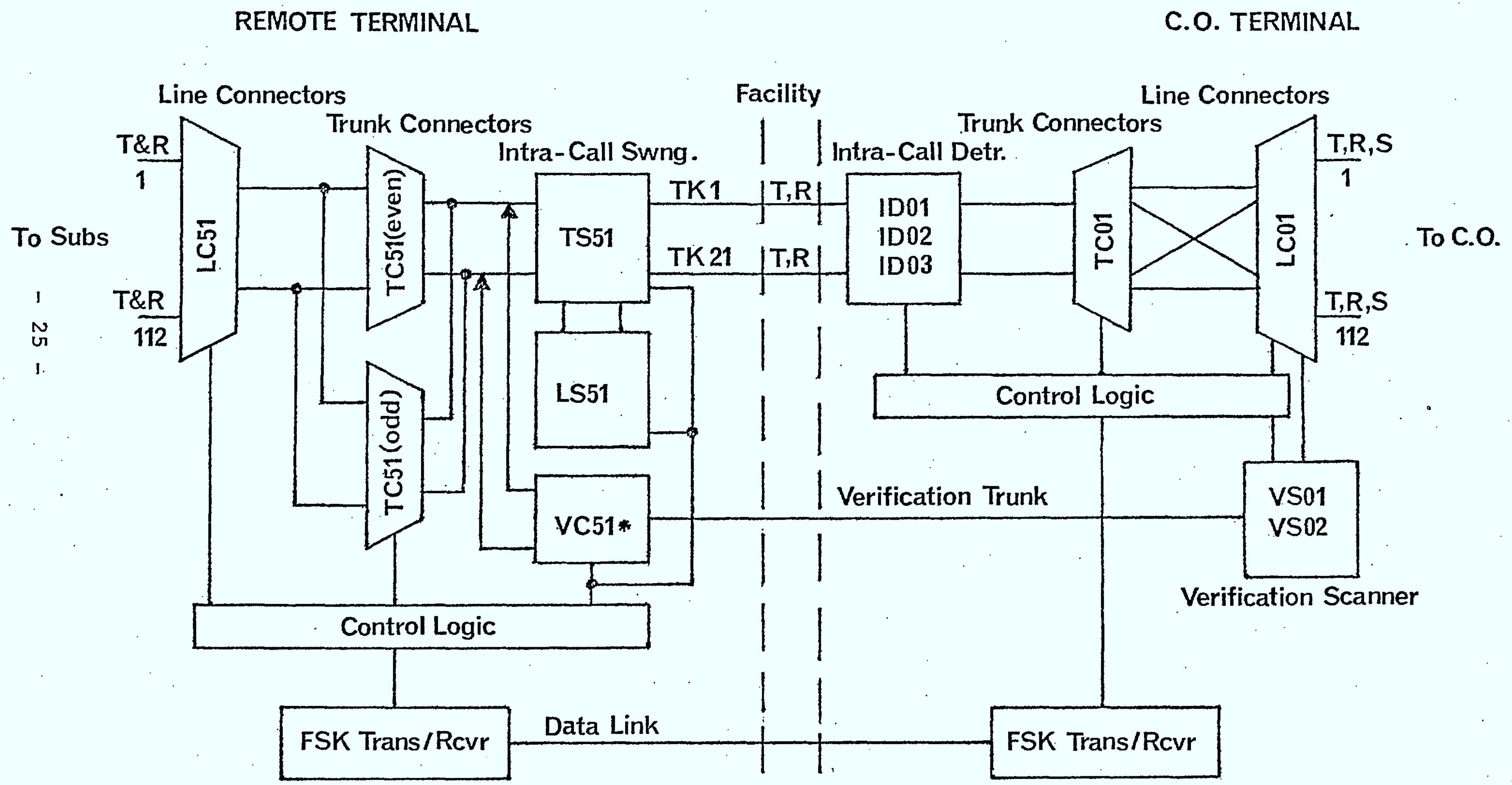


FIG.– 3

—ELECTRONIC SWITCHING SYSTEM— WITH INTRA-CALL FACILITIES



* Optional Verification Operator Access And Detector.

FIG.—4

The former system can readily be used with existing transmission facilities and therefore does not require the more expensive digital transmission line. The latter system would be used on routes designed for digital transmission and for integration into the digital switching offices of the future.[6,7]The basic costs for each type of system are about the same when using digital transmission, but are less when voice frequency trunks on subscriber carrier is used. Examples of costs of such systems are given in Section VII. These types of concentrators will in all probability be an economic necessity when considering service upgrade to remote rural areas that presently have limited cable distribution facilities. With the intra-call features added, the switch essentially has all the elements of a small community dial office. The big drawback is that in setting up a call, the initial control and processing has to be carried out by the equipment in the distant central office. This can present a problem when local emergency calls are required and there is no connection to the central office.

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[6] Digital techniques applied to the subscriber's area, D.A. Weir, H.Williams, E.S. Usher, Standard Telecommunications Laboratories, Harlow, Essex. I.E.E. Telecommunication Transmission - Sept., 1975

[7] A Loop Concentator Multiplexer System in a Digital Switching Environment. D. Gregory, ISLS, Ottawa, 1974.

4.2.5 Radio Systems

In radio, the systems presently available consist of single telephone circuits over v.h.f. equipment operating in the 138 - 174 MHz band. These have been used to provide "fringe area" or camp phones 20 or 30 miles from the central office. The basic equipment is essentially the same as that used on mobile radio with added applique units to provide the ringing, signalling and supervision. Total in-place cost is estimated to be approx. $6,000 for single party service. For 4 or 10 party service this would be $1600 and $750 respectively per subscriber. The disadvantages of this type of system are the limited number of radio frequencies available, the problems of ignition interference and the over-all noise performance requirement for subscriber loops not being met except under the most favorable conditions.

To overcome the problem of the limited number of r.f. channels available in the V.H.F. band, the concentrator or electronic switch technique has been adopted on some new systems and eight radio frequency channels can provide service to 100 or more subscribers. Also equipment has been developed in the U.H.F. band (1.5 GHz) using similar techniques, with improved noise performance and a cost objective of about $2000 per subscriber.

Further details of all the various subscriber distribution facilities discussed here are given in the later sections of this report and in the complete suppliers' manuals.

4.2.6 Future Systems

Forecasts tend to indicate a changing pattern of distribution. In a study by one telephone company the distribution six years ago was such that about 80% of the customer lines were within 15,000 ft. of the central office. In 1980, this is expected to be about 72% as a result of upgraded service and the continuing population shift away from the urban areas.[8] Notwithstanding these trends, the bulk of the new lines to be constructed will be within the 15,000 ft. zone. There is a continuing need, therefore, for development of improved means for serving subscribers relatively close to the office, as well as the development of new types of facilities for the longer, higher cost loops.

High capacity trunk distribution is being planned within urban areas by means of fibre optics, coaxial cable and microwave.[9,10] In addition, digital switches are planned to replace analog switches. The combination of these factors may well produce a new architecture in the distribution of telephone subscriber loops and this new technology may well be adopted in rural systems. However, considering the time period necessary to prove-in the reliability and practicality of these systems in the telephone network, the majority of suppliers

[8] A Survey of Customer Loops in the General System. C. H. Davis. A. E. Co. Journal, Oct. 1970.

[9] A Digital Radio Relay System for Urban Areas - Marc Liger, Phillipe G. Magne and Jean Pierre R. Poitvin. IEEE Transactions on Communications. Sept. 1974

[10] Advantages of Optical T-carrier Systems on Glass Fiber Cable - John Fulenwider and George Killinger. Annual Wire & Cable Symposium. 1975

do not anticipate large scale changes in the present methods in urban areas until the 1985 period.

In a recent paper,[11] M. E. Collier of Standard Telephone Laboratories expressed the opinion that subscriber telephone loops are unlikely ever to be economic with fibre-optics in competition with short metallic pairs. The eventual introduction of broadband subscriber service will present a different picture since it has been shown theoretically that fibre optics may be able to compete with coaxial cable that might otherwise be introduced for such services. These statements may also apply to rural area distribution.

The advanced system concepts being developed in mobile radio in the 900 MHz band could lead to new methods and approaches in rural telephone service. Systems with processor control and small, lightweight portable radiophones are now being designed. With the reduced costs that will come about by increasing demand, it is conceivable that radio will find wider applications and be considered as an integral part of the subscriber distribution network, especially in rural areas.

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[11] The application of fibre-optics to telecommunication transmission systems. M. E. Collier, I.E.E. Conference Publication on Telecommunication Transmission, Sept. 1975.

SECTION V

ASSESSMENT OF THE SUPPLIERS OF CANADA

5.1 INTRODUCTION

In this section of the report, the situation in Canada as regards the supply of products and systems for rural telephone systems is discussed. The list of suppliers provided in Volume II of the data base makes reference to 88 suppliers of the multiple pieces of hardware required. In this report, the major elements only are reviewed.

5.2 VOICE FREQUENCY SYSTEMS

In Canada the major suppliers of voice frequency equipment are Northern Telecom, Lenkurt Electric and Wescom. For these three companies, the total sales of this type of equipment amount to about $50 million per year; however, the largest proportion goes to providing special services circuits, PABX extensions and voice frequency inter-office trunks. The sales of products towards rural area telephone systems is not known since the telephone companies usually purchase on a bulk basis and engineer the equipment into their own plant. An outside estimate for rural systems would be about two million dollars per year.

The manufacturer's opinion is that the rural telephone system market at this time is not a visible high volume one and their development activity is directed towards the urban-suburban areas. As a consequence, these three manufacturers have some voice frequency products that can be used in rural telephone networks. However, the complete line of loop extenders, range extenders, etc., as discussed earlier are not in their portfolios.

Two companies in Canada, (Lorain and Transcom), both subsidiaries of U. S. companies, have through their parent companies devoted a major part of their development towards solving the problems of long voice frequency subscriber's loops. Their product sales are of the order of $1.5 - 2.0 million per year. Some small scale manufacturing of the older products is carried out in Canada, the newer products being imported directly from the U. S. A. There are no Canadian manufacturers supplying telephone sets with built-in amplifiers.

It thus appears that the Canadian content in the total design and manufacturing of voice frequency products for rural communications is very small.

The reasons for this deficiency may well be that the requirement has not been established due to lack of visibility of the problem and that the problems in setting up a design and manufacturing company in Canada in this product line are too great for such an enterprise to be a viable one. The first reason reflects the opinion of the large manufacturers, while the second one reflects a situation that was well expressed by the President of Tele-Radio in May, 1974.[12]

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[12] Manufacturing - is it viable? Ivor H. Nixon, President Tele-Radio - Canadian Electronics Engineer, May, 1974.

5.3 CABLE, WIRE AND ASSOCIATED HARDWARE

The cable industry in Canada consists of five suppliers:

1) Northern Telecom Ltd., Montreal, Quebec
2) Phillips Cables, Brockville, Ontario
3) Canada Wire & Cable, Winnipeg, Manitoba
4) Pirelli Cables, St. Jean, Quebec
5) Alcan Wire & Cable, Montreal, Quebec

Details of the sales volume, markets and the products supplied by each company are contained in the data base information Vols. IV - XI.

From the information received and the discussions with these suppliers, it appears that the full range of cable and associated hardware for rural communications is available from Canadian manufacturing sources. The types of cable include the latest state-of-the-art designs in petroleum jelly filled, cellular insulated, screened cable, etc., of large and small sizes.

The situation regarding cables using aluminum conductors in lieu of copper conductors is one of continuing study in the cable industry. It has been reported that because of the changes required in methods and practices in the use of aluminum cable, the actual in place costs would probably be higher, thus outweighing the basic material price advantage.

Some of the problems in this industry relate to the design and manufacture of cables to each individual telephone company's specification. In the past, the design specifications for cable in the Canadian telecommunications industry have numbered eight to ten; whereas in the U.S.A. with a very much larger volume, the cable suppliers have to respond to basically only three specifications. The Canadian situation has eased somewhat by the adoption of joint specifications by the Sasktel, A.G.T., M.T.S. and edmonton telephone companies.

From the published literature and discussions on cable systems and outside plant design in the U.S.A., the trend is definitely towards the use of finer gauge cable and the integration of permanent electronic facilities in rural subscriber systems. Claims are made of 30-50% reduction in capital investment by adopting a policy of minimum cable investment and rigorous planning and design of outside plant hardware for future application of electronic systems.[13,14].

To what extent this type of approach is being followed in Canada is not apparent, since there is very little published information on this very important aspect of telecommunications plant. The cable manufacturers at this time do not indicate any trend away from the heavy 19 and 22 gauge cable, nor is there any evidence of similar outside plant hardware design improvements. The relatively small projected increase by manufacturers in Canada for electronics in subscriber distribution would reinforce the opinion of minimal activity in the planning to satisfy the rural customer's expectations of rising standards.

[13] Outside Plant Design Criteria for Rural Telephone Systems. M.E. Conatser, REA. N.T.C. New Orleans, 1975.

[14] Rural Area Network Design. V.P. Chaudhary, Bell Labs. N.T.C. New Orleans 1975.

5.4 STATION CARRIER SYSTEMS

In the analog, multi-channel station carrier systems, there are three suppliers in Canada, two of whom are subsiduaries of U.S. companies. G.T.E. (Lenkurt Electric) and Superior Continental supply products of the parent company design, and Tele-Radio distribute Anaconda (U.S.) equipment.

1) G.T.E. Lenkurt Electric, Vancouver, B.C.
2) Tele-Radio Systems Ltd., Downsview, Ontario.
3) Superior Continental Canada Ltd., Stratford, Ontario.

The Canadian content is limited to the sale and assembly of system packages. The basic design and manufacture of the system and equipment is carried out in the U.S.A. Although this type of carrier seems to be preferred by administrations in the U.S.A. for rural subscriber distribution, and will probably fill about 90% of the requirements for carrier systems in subscriber plant in that country, there does not seem to be any activity towards design and manufacture in Canada, due to the small demand for systems of this type by the telephone companies.

To put this into perspective, it is forecasted that the total market for carrier systems required in REA borrowers plant* alone over the next eight years will amount to $350-400 million. Based on present sales in Canada, the sales volume for these products over the same period would be

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* It is estimated that the REA borrowers account for about 6% of the total subscribers lines in the U.S.A. Use of this figure would be misleading in establishing the total market in the U.S.A., a reasonable estimate maybe 2-3 times the amount shown.

about 20 million dollars. In terms of carrier derived channels on subscriber circuits, the estimated number of installed carrier channels in the REA program up to 1976 is 70,000, whereas the estimate for Canada would be no more than 4,000.

Considering that a manufacturer has to plan on recovery of development costs during a product life of 5 years, and the sales volume should be at least twenty times the development costs, the position of Canadian manufacturers is understandable at this time.

It appears that this cost effective solution has not been adequately considered by the Canadian carriers at the present time and future exposure could lead to more significant markets in Canada. Cost breakdowns for this type of system are given in Section VII of this report.

5.5 SUBSCRIBER CARRIER SYSTEMS

The station carrier discussed in the previous sub-section is also used as subscribers carrier where a small number of concentrated subscribers are to be serviced, and the existing transmission facilities are analog. With the more widespread use of digital transmission, subscriber PCM carrier systems of 24 channel capacity have been designed, and these are now available in Canada.

The suppliers are:-

1) G.T.E. (Lenkurt Electric) Canada, Vancouver, B.C.
2) Northern Telecom, Montreal, Quebec.
3) TRW Canada, Toronto, Ontario (VICOM)
4) Wescom Canada, Toronto, Ontario (G.E.)

Both G.T.E. (Lenkurt Electric) and Northern Telecom manufacture PCM equipment in Canada.

TRW in May 1975 took over VICOM from Superior Continental Co. and are now consolidating this product line into their own organization. This equipment is manufactured in Mountain View, California.

Late 1975, Wescom in the U.S.A. took over the manufacturing rights of General Electric (U.S.) pulse code modulation equipment and presumably will manufacture it in their Chicago plant.

The use of digital systems in subscriber networks is limited at this time, since the existing cable facilities in many instances are not suitable for straightforward application due to crosstalk problems; however, with the continuing cost reductions in hardware, the ready solution of the crosstalk problem by the use of special screened cable, and the trend towards all digital networks, many people are convinced that they are the way of the future.

In the U.S.A. some companies are planning office consolidation to reduce the number of small community dial offices in rural communities and provide improved services for these communities from large electronic switching machine equipped with the most up-to-date features.[15] They consider PCM subscriber carrier to be the best solution for new distribution networks in this kind of situation. Manufacturers in Canada have no knowledge of a similar approach being taken in this country.

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[15] Office Consolidation through the Use of PCM Subscriber Carrier. S.C. Vincent, National Telecommunications Conference, Dec. 1975.

Cost breakdowns for this type of equipment are given in Section VII of this report and manufacturers' product and application information is contained in the data base and manufacturers' catalogues supplied separately.

5.6 ELECTRONIC SUBSCRIBER SWITCHING SYSTEMS (LOOP CONCENTRATORS)

At present there are two or three installations of electronic subscriber switching systems in Canada. Two U.S. companies, Lynch and Anaconda, market them through a subsidiary company and a distributor company. One Canadian company, Pylon Electronics of Montreal, did complete a design that was on field trial in Saskatchewan, but additional features were required and the product has been mothballed pending further funding.

Two or three Anaconda systems are installed in Saskachewan and Quebec. Tele-Radio of Toronto, the distributor for Anaconda, do not forecast any sales in the immediate future.

The Lynch subsidiary, Transcom of St. Jerome, Quebec, see some possible sales for their B280 System to B.C. Telephone in late 1976.

5.7 DIGITAL MULTIPLEX SUBSCRIBER SWITCHING SYSTEMS

The integrated loop concentrators and digital multiplex systems are available in Canada from I.T.T. Guelph and Farinon Electric of Montreal.

The I.T.T. system was designed in the early 1970's and is manufactured in Guelph for sale in both Canada and the U.S.A. Fourteen to twenty systems have been manufactured and are either working or planned for operation in the Okanagan Tel, A.G.T., Northern Quebec, Bell Tel and N.B. Tel territories.

The Farinon equipment was designed originally in 1967 and is manufactured in the U.S.A. by the subsidiary company Digital Telephone System of Novato, California. There are two systems installed in B.C. and the SOTEL territory in Quebec.

Northern Telecom have recently announced their DMS-1 System which will be available for delivery in 1977. This system was designed by Bell Northern Research, Ottawa and will be on field trial with the REA in the U.S.A. Further details and comparisons of all of the above systems are given in the data base information and the manufacturers' catalogues.

Prices vary from $480-580 per line depending on the maximum capacity.

As indicated in the analysis contained in Section VII of this report, the prime purpose of this type of system is to serve clusters of subscribers in suburban and rural areas. The manufacturers consider the former to be by far the larger market; however, the packaging and system layout does permit groups of say 8 to 56 subscribers to be dropped off at a series of remote stations and it is conceivable that this equipment will be more widely applied in rural areas. Manufacturers hesitate to forecast the rural area market.

The penetration of this type of system into the Canadian market has been slower than expected and with the greater sales opportunities and reduced production costs in the U.S.A., the manufacturing may be moved there.

5.8 RURAL RADIO SYSTEMS

Suppliers of radio equipment for rural telephone systems in Canada are:

1) International Systcoms, Montreal, Quebec.
2) Motorola Canada, Willowdale, Ontario.
3) Pye Electronics, Montreal, Quebec.
4) Farinon Electric, Montreal, Quebec.

The last three companies are subsidiaries of U.S. and U.K. organizations and further details are provided in the company profiles, Vols. VIII and IX of the data base.

The products and systems manufactured by International Systcoms, Motorola and Pye are basically for mobile radio use in the 150 and 450 MHz bands and have the necessary applique and signalling equipment to interface with the central office switch and the subscriber's telephone set. The radio equipment for this type of application costs about $3,500 but it can provide service for up to 10 subscribers on a party line service. With improved performance systems, the costs go up to about $5,000. It is estimated that the market for this type of rural radio system in Canada is about $2 million for the radio alone. Antennas and transmission line sales would have to be added to this.

Motorola in the U.S.A. have designed a system for rural subscriber radio in the VHF band which incorporates the line concentrator principles to provide service to about sixty subscribers over eight radio channels. It is possible that this type of system will find applications in Canada.

To overcome frequency congestion problems and improve the transmission quality of circuits over subscriber radio, Farinon Canada in their Montreal plant have designed and are now in the pre-production phase of a system that will give service to up to 256 customers over 16 radio channels in the 1.5 GHz band.

It is expected that the in-place cost per subscriber will be about $2,000-3,000 for these types of radio-concentrator systems and therefore competitive with physical circuits when the distance of 10-20 miles is taken into account.

5.9 SUMMARY

The overall impression received from the Canadian manufacturing industry was that there is, with a few exceptions, a complete lack of understanding regarding rural-telephony communications, and as a result imported electronic products dominate. The problem may be a two fold one. Firstly, the market may be so small that it would not be a viable proposition to enter into design and manufacture and, secondly, the requirements have not been defined by the telephone companies. For toll transmission, the Trans-Canada guidelines give a reasonable definition of the types of systems required; however, in the case of subscriber circuits, it would appear that this portion of the communication network is outside the area of concern of the Trans-Canada organization and each telephone company goes its own way, causing a further fragmentation of the small market, resulting in easy penetration by foreign suppliers' equipment.

In concluding this section on the Canadian situation and as food for thought in the further consideration of rural communications, it would seem appropriate to reproduce here the following extract from the Department of Communications working paper on the suppliers to the Canadian Telephone Industry.

> "One problem common to the smaller manufacturers is the question of standards and engineering specifications. Each of the twenty-two common carriers apparently writes individual engineering specifications, which may require expensive modifications to equipment by the suppliers before they are able to submit a quotation. Many manufacturers felt that some national organization should exercise an engineering standards co-ordination function which would ensure the same standards across Canada."

SECTION VI

ASSESSMENT OF THE SUPPLIERS IN THE U.S.A.

6.0 INTRODUCTION

In discussions in the U.S.A., the overall impression was that with the major gains made since 1966 in the use of complex state of the art systems in PABX's, the telephone company's reluctance to accept electronics in subscriber plant is disappearing and a major effort is now directed towards the design of systems that will result in cost reductions and improved performance of subscriber circuits. With the inflationary situation and the need to conserve basic resources, outside plant and subscriber distribution network designs are being closely examined and changed to circumvent the high labor and capital investment required using the old methods.

The planned improvements in the larger telephone companies are not confined to the urban and suburban areas, but extend out to the rural areas as well. For the smaller telephone companies, the REA is the major force in the planning to attain the same improvements for the rural subscribers.

6.1 MANUFACTURERS AND PRODUCTS

Since most of the products and systems discussed in this report are manufactured in the U.S.A., it is not intended to repeat them here, however it is of interest to list the activities of each of the manufacturers as they relate to rural communications.

6.1.1 Western Electric Co.

Bell Labs and Western Electric, have for many years been in the forefront of design of electronics for rural telephone distribution. Their products have covered dial long line units, negative impedance repeaters, hybrid voice frequency repeaters, to the present day range extenders, loop extenders and telephone sets with built-in gain devices. In cable systems and associated hardware, the planning for rural area distribution is most definitely towards the use of electronics as permanent facilities.

The early carrier systems were the "M" type power line carrier, and in the early 1950's the "P" type phase modulated open wire system was introduced. Neither of these two systems gained wide acceptance, largely due to high maintenance costs, even though the "P" carrier was one of the first transistorized transmission systems.

Their latest products include the SLM, 80 line subscriber loop multiplexer with 24 channel digital trunks to the central office combined with remote concentrator switching, and the SLC-40 that provides 40 lines on a digital transmission subscriber carrier.

In essence the philosophy appears to be to plan for physical facilities now and carrier systems later as a logical solution to quality service at a reasonable price to rural subscribers.

6.1.2 General Telephone System Companies

The suppliers to the General Telephone System in the U.S.A. include G.T.E. (Lenkurt Electric) and G.T.E. (Automatic Electric), the former company in transmission equipment and the latter in switching, telephone sets etc. Both companies have been very active in the supply of rural telephone systems in the U.S.A.

Lenkurt was originally founded by two ex-Bell Labs personnel, and their experience in the design of electronics for rural systems dates back to 1946. Over the years, they have produced many different types and designs of carrier systems that use double-sideband analog techniques, and FM, PM techniques. The acquisition of Panhandle in the early 1960's increased their penetration in this market. The latest subscriber equipment includes PCM carrier and they are presently completing a design that uses resonant transfer principles.[16] Although not specifically for rural systems, it is possible that a carrier equipment of lower power consumption and smaller number of active components for an in-place cost of $340 per channel will find some applications in rural areas.

The activities of G.T.E. (Automatic Electric) have been largely towards their new switching offices over the last few years. Some new designs on outside plant equipment have been produced, but developments on telephone sets with built-in electronics have been delayed pending further clarification of the requirements. This last item is covered

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[16] Multi Channel Subscriber Carrier for Suburbal Areas - J.F.Lester, GTE Lenkurt Electric, National Telecommunications Conference New Orleans, Dec. 1975.

in more detail in the minutes of the REA manufacturers' sub-committee meeting July 1975, contained in the REA section of Vol. VIII and IX of the data base.

6.1.3 Other Suppliers

The number of other suppliers to the rural telecommunications industry in the U.S.A. is an enormous one as evidenced by the list of suppliers contained in the REA List of Materials provided in Vol. II of the data base. This includes 24 suppliers of cable and 12 to 15 suppliers of electronic equipment. Most of the products and system types have been discussed earlier in the Section VI of this report. Some of the suppliers not mentioned previously are Stromberg Carlson, Seismograph Corporation and 3 M. These three companies manufacture and design subscriber carrier systems of the 24 channel PCM type, the 6-channel station carrier analog type and one of them has available a 1000 channel time division coaxial cable system, the objective of which is to "take the 'remote' out of rural". Further information on these systems is contained in Vols. III to VII of the data base.

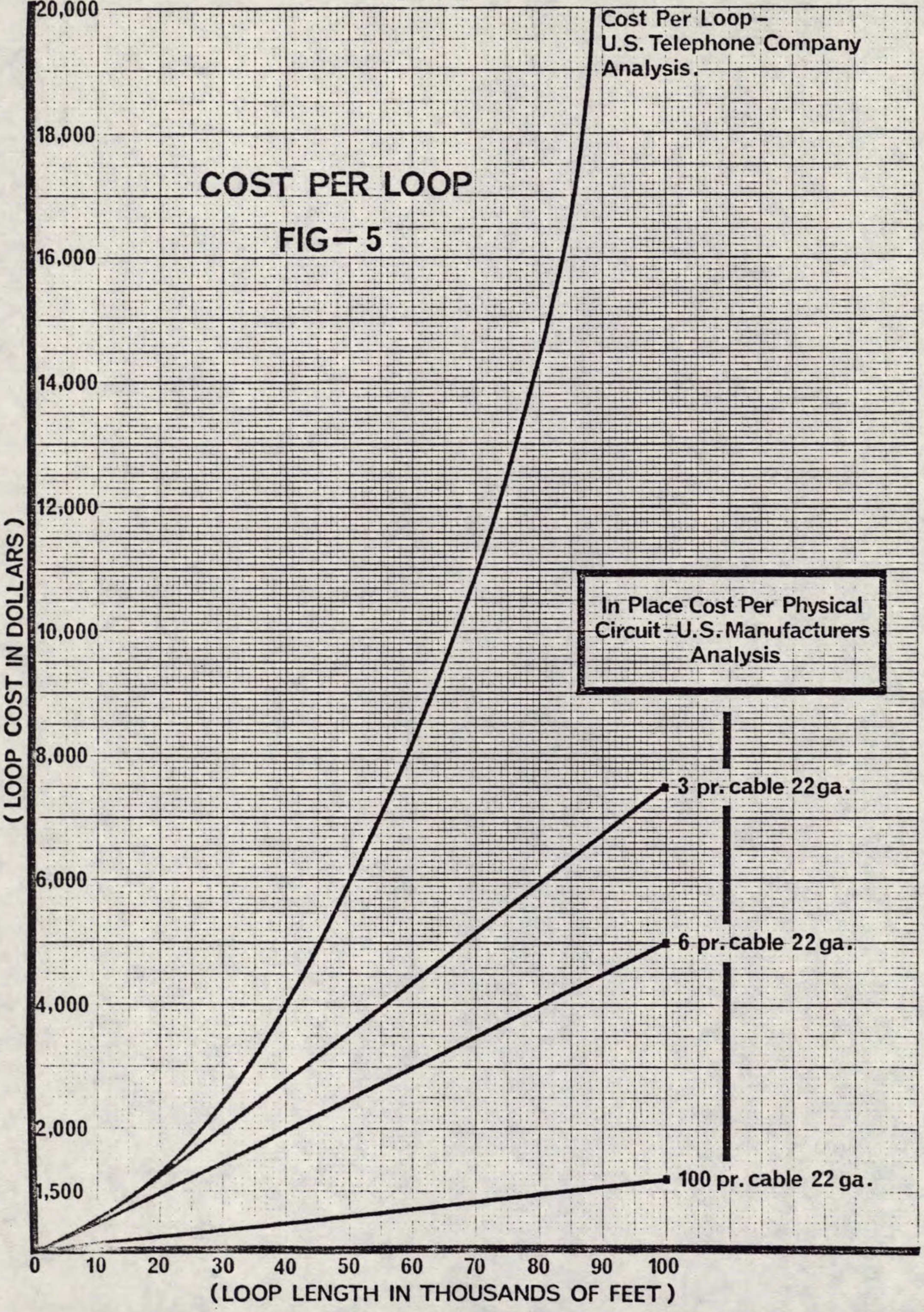
In the radio systems, Motorola have produced the rural subscriber radio system which will find application in the more remote areas, the major constraint being, of course, frequency congestion in the VHF band. Of interest as regards the use of mobile radio in an integrated telephone network are the activities of Motorola, Martin Marietta, Secode and General Electric. Some information on these systems has been provided, but further enquiry would be necessary to establish the potential impact on rural communities.

6.1.4 Summary

The overall impression of the U.S.A. rural telephone supply industry is that it is reacting in a dynamic fashion to the needs for more electronic systems in subscriber distribution networks. Most suppliers feel that the initiative of the REA organization has been of tremendous help in setting standards and specifications that offer them the opportunity to establish viable products. The emphasis over the past two years, probably as a result of the downturn in 1974 and the disastrous year of 1975, has been towards cost reduction and increased reliability in products. Nevertheless, some new systems have been produced.

Competition is very strong and prices are very competitive; the ratio of Canadian prices to American prices is of the order of 1.7 to 1. As discussed earlier, the market for carrier systems in the REA projects alone is estimated at $400 million over the next eight years, whereas in Canada it is between $16 - 20 million during the same period.

For the last ten years or so there has been a large amount of information published on the costs of subscriber loops in the U.S.A. by both the telephone companies and the suppliers. A comparison of some of these cost figures is shown in Fig. 5. The difference of cost figures leads one to the conclusion that even in the U.S.A. there is a great gap in the knowledge of the economics of subscriber circuits, between the suppliers and the carriers, but in spite of this, there is a strong, vigorous supply industry that is developing products and systems that find their way into the marketplace.


COST PER LOOP
FIG—5
Cost Per Loop – U.S. Telephone Company Analysis.
In Place Cost Per Physical Circuit – U.S. Manufacturers Analysis
3 pr. cable 22 ga.
6 pr. cable 22 ga.
100 pr. cable 22 ga.
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
1,500
0
10
20
30
40
50
60
70
80
90
100
(LOOP COST IN DOLLARS)
(LOOP LENGTH IN THOUSANDS OF FEET)

SECTION VII

ANALYSIS OF LINE TRANSMISSION SYSTEMS, COSTS AND PERFORMANCE

7.0 The following section gives a detailed analysis of system costs in Canada and a discussion of performance.

7.1 Introduction

The emphasis of this section is on comparative costs of various rural systems. This is very difficult to express in a meaningful way because of the large range of possibilities. To take a real system as an example would only yield typical answers if the real system were itself typical. However, this is impossible to ascertain as there is very little data available on the nature of existing Canadian rural systems. The method that has been chosen therefore is to postulate a set of models that seem most likely to fit the Canadian situation. These are hypothetical stand-alone systems whose basic parameters are based upon available United States data (mostly REA). Three categories are defined as the bases for the system models:

(i) A quantity of 25 subscribers distributed over a distance of 50 kilofeet from a central office.

(ii) A quantity of 100 subscribers concentrated at 50 kilofeet from a central office.

(iii) A quantity of 2 subscribers situated 100 kilofeet from a central office (or Remote Switching Terminal)

The three types of system have been kept separate for ease of comparative analysis although, in reality, any subscriber loop may comprise a mix of the different systems, possibly including large urban cables when close to the C.O.

Before discussing the systems and possible solutions in detail, the functions of the various product types commonly found in rural plant are described and also the types of system that these products are used in and their parameters in general.

A selection of possibilities is presented for realizing the three types of hypothetical system and the discussion of each possibility is accompanied by a sketch.

Following this, there is a cost analysis of each possibility using cost "building blocks" derived from suppliers' information. These are first costs of equipment and material only. The importance of "in-place" first costs and the proper evaluation of annual changes on a Present Worth basis is emphasized, for valid economic analysis. The operational costs and factors which go into the computation of annual charges depend on user, or Telephone Company, circumstances and are outside the scope of this study.

The section ends with a discussion of other factors than economic which can have a bearing on the eventual choice of system.

7.2 Subscriber Categories

7.2.1 Distributed Subscribers

Many rural subscribers are not included within towns or villages, but are spread out along rural roads, often in ones or twos, with large distances between neighbours.

Typically, these subscribers would be farmers and farm workers. A subscriber density of one per two kilofeet is thought to be common in Canada for such a situation. In the United States, such a density would qualify for a REA loan and it has been found that, on average, the subscriber density is still less than 5/kilofoot, even after 10 years. Distances from a Central Switching Office may vary from 5 - 20 miles (25 - 100 kilofeet), and the switching office may be a C.O. CDO or, in some cases, a remote subscriber terminal (see Section 7.6). Applications of various rural communication systems to distributed subscribers are illustrated in Section 7.5 and, in order to provide a common basis for comparison, a subscriber density of 1 per 2 kilofeet has been assumed, the furthest subscriber being 50 kft. from the C.O. The basic parameters of this model are given in Section 7.2, together with initial equipment and material costs.

7.2.2 Concentrated Subscribers

Rural communities such as villages and small towns represent a situation where rural subscribers are clustered together in a relatively small area. Apart from established communities with modest growth, high growth locations such as trailer courts and housing developments associated with developing resort areas or rural industries also fall into this category. Also, concentrated requirements may arise on a temporary basis such as would be the case with fairs and temporary housing at construction sites. Obviously such communities will vary considerably, not only in size, but also in their distance from a switching office.

To illustrate this subscriber category, 100 subscribers at a distance of 10 miles, (50 kilofeet) from a switching office has been taken as a model, all subscribers being within a radius of 5 kilofeet from the 50 kft. point, i.e., confined to an area of 2.8 square miles. Although the maximum subscriber drop length has been taken as 5 kft., the mean drop length has been taken as 1 kft. due to natural concentration towards the centre. This implies a mean subscriber density of 1.4 per acre. Applications of various rural communication systems to concentrated subscribers are illustrated in Section 7.6 and basic parameters of the model are given in Section 7.8, including the initial equipment and material costs. An important characteristic of concentrated rural subscribers is the community of interest which can affect the type of communication system used if the availability of trunk circuits is limited. Community of interest is relatively high in long term residential areas and increases with the distance from the switching office. By contrast, resort areas, having high transient populations, have very little, if any community of interest.

7.2.3 Extra Remote Rural Subscribers

A proportion of subscribers do not fall into either of the preceding categories solely by virtue of their relatively great distance from a switching office. These extra remote rural subscribers form a distinct category of their own. They may be remote farms or cottages, usually few in number.

REA has found that only 10% of subscriber loops exceed 45 kft. (8.5 miles) in length. Less than 1% however, exceed 80 kft (15 miles). For the purpose of illustrating the extra remote rural subscriber category here, subscriber distance from the switching office has been taken to be 100 kft. (19 miles) and the number of subscribers at that point to be two.

Applications of systems to extra remote rural subscribers are illustrated in Section 7.7 and basic model parameters given in Section 7.8, together with initial equipment and material costs.

7.3 Product Types

7.3.1 C.O. Equipment

The following is a list of Central Switching Office Equipment that may be used for rural communication systems:

Terminal Blocks
Protectors
Repeating Coils
Loop Extenders
VF Repeaters
Range Extenders with Gain
Station Carrier Terminals
Subscriber Carrier Terminals
Subscriber Switching Terminals

Terminal blocks and protectors are common items in Central Switching Offices providing a termination point for external wires and cables and protection against over-voltage and over-current. The terminal blocks also provide a convenient cross-connection point for assignment of subscriber lines to C.O. equipment.

Repeating coils provide longitudinal balance to help suppress noise and interference currents arriving at the C.O. as a result of interfering voltages being induced into the external wire or cable. In the case of open-wire systems, this is particularly prevalent and repeating coils have allowed phantom working whereby a pair of wires carries more than one telephone circuit.

Loop Extenders, VF Repeaters and Range Extemders with Gain are a class of long-loop electronic devices which permit signalling and speech currents to extend beyond the normal subscriber loop resistance limit of about 1700 ohms.

Loop extenders provide battery boost and VF Repeaters provide gain either fixed or automatically variable, for the a.c. speech currents.

Range Extenders with Gain provide a combination of these two functions on a single unit. Modern equipment provides these circuits on a plug-in unit basis.

Station Carrier C.O. Terminals provide up to 10 double side-band, amplitude modulated carrier channels to distributed subscribers, with no restriction on the location of subscriber terminals within the operating range of the system. Only a single pair of wires is required with separation of the GO and RETURN circuits into separate frequency bands. Single-party, multi-party, pay-station facilities and automatic number identification (ANI) are normally available, with the following ringing options:

- Single Party Service
- Superimposed Ringing
- Bridged Frequency Ringing
- Divided Coded Ringing
- Divided Frequency Ringing
- Ground Start

Practically any kind of line facility can be used and equipment is provided on a modular, plug-in basis for economy of growth.

Subscriber Carrier C.O. Terminals provide multiplexed carrier channels from the C.O. to a single remote point or, in some cases, to several remote points. The capacity of such terminals may be as few as 6, or as many as 48 channels and provide similar subscriber line facilities and ringing options to those provided by station carrier. Modular structure with Plug-in units is common.

Station carrier may be operated as subscriber carrier simply by providing all of the subscriber terminals together on a shelf at a single remote point. The C.O. terminal is identical to that used for station carrier. Equipments designed specifically for subscriber carrier may be either analog, or digital in their mode of operation and C.O. terminals comprise multiplexers, terminal repeaters, power feed for line repeaters, and sometimes protection switching equipment, order-wire and fault-location equipment as well.

Subscriber switching terminals provide a means of minimising the number of VF pairs or subscriber carrier channels required, by concentrating the subscriber lines onto a few trunks, according to demand. Traffic monitoring equipment is often included and also remote alarm facilities. Modern subscriber switching equipments are electronic, modular, with plug-in units and are often integrated into digital subscriber carrier terminals. Their use of course is associated with concentrated remote subscribers and includes upgrading of service on existing facilities, meeting demands for new service and also handling situations where there is uncertain growth or a temporary service demand.

7.3.2 Subscriber Premises Equipment

The following types of product may be found on rural subscriber premises:

- Telephone Sets
- Long-loop Telephone Sets with Gain (U.S.A. only)
- Ringing Range Extenders

Subscriber lines may also be terminated at rural pay-stations containing coin telephone sets.

Telephone sets can be dial pulse or touch-tone calling, operating on a single party or multi-party basis. Ringing isolators can be provided in individual station sets where grounded ringing is used, in order to preserve line balance.

Special telephone sets can provide a few decibels of gain in the transmitter and in the receiver thus providing long-loop facilities without external repeaters.

Where a subscriber's premises contains several telephones, and grounded ringing is used, a ringing range extender can be mounted at a central location to provide isolation for them all.

Coin telephone sets can be pre-pay, post-pay, semi post-pay, dial tone first, coin first, touch-tone, or dial.

7.3.3 Outside Plant & Equipment

A large variety of plant and equipment is used in the field. The following lists indicate the extent:

Pole Lines

- Poles
- Stubs
- Anchors
- Anchor Guys
- Cable Supports
- Cross-Arms
- Insulators
- Messenger Wire
- Aerial Cable
- Aerial Pair
- Drop Wire
- Aerial Splice Closures
- Aerial Cable Terminals
- Wire Terminals
- Aerial Wire

Buried cable & Wire Facilities

- Buried Cable
- Underground Wire
- Pedestal Cable Terminals
- Pedestal Splice Closures

General

- Loading Coils
- Loading Coil Cases
- Carrier Repeaters
- Carrier Repeater Housings
- Station Carrier Subscriber Terminals
- VF Repeaters

7.3.3.1 Pole Lines

Poles are available in a variety of sizes, ranging from 20 to 50 feet, treated or untreated. 10 ft. stubs are often used for insertion into the ground after years of service in order to prolong the life of the pole beyond its normal life cycle.

Anchors may be log or plate, the guys being stranded steel wire. Cross-arms with insulators are used for open wire, and cable supports for aerial cable.

7.3.3.2 Cables, Wires & Associated Hardware

General

Multi-pair telephone cables are available with 19, 22, 24 and 26 gauge copper pairs made up in sizes ranging from as few as six pairs up to many hundreds of pairs. For rural communications purposes, the cable sizes are generally small, rarely exceeding 50 pairs. REA are tending to provide new facilities using buried, 25 pair, 25 gauge cable for most applications.

Polyethylene-insulated (PIC) cable is most commonly used today and replaces paper-insulated cable for many telephone applications. PIC has the advantage that all pairs are usable, installation practices are simple as wires are fully colour-coded, pairs have a lower attenuation at carrier frequencies and the higher dielectic strength afforded by the polyethylene insulation gives added reliability where the cable is exposed to lightning, or possibly to contact with electrical power.

Aerial Cables and Wires

Aerial cables normally have an aluminum polyethylene covering (ALPETH). This comprises an aluminum shield over which is extended a black polyethylene jacket which has high resistance to sunlight and aging. Self-supporting cables are available in the smaller sizes. These are similar to ALPETH but a solid, or stranded, steel "messenger" wire is jacketed together with the cable so that the cross-section forms a figure 8 shape. Aerial cables may also be strung using separate messenger wire, but self-supporting cables are easier and quicker to install as there is then no need for a messenger wire.

Aerial pair is often used for rural distribution and as a replacement for open wire. The wires are 19 gauge copper with no shield inside the polyethylene jacket. A messenger wire is integrated either to form a figure 8 shape, or at the centre. Drop-wire is used to make the connection from the pole line to the subscriber's premises. It is also sometimes used to provide emergency facilities. The wires are 14 to 18 gauge copper coated steel, which is inherently self-supporting, covered with rubber insulation and with a neoprene jacket.

Open wire is normally 0.104" dia copper but is seldom installed today because of the high cost of copper and poor performance under adverse climatic conditions.

Buried Cables and Wires

Polyethylene - aluminum - polyethylene (PAP) covering is most widely used for buried cables. The covering is similar to ALPETH, but with an inner polyethylene jacket which serves as an additional moisture barrier should the outer jacket be punctured.

Further protective coverings are available. Gopher tape armour (GTA) comprises a single steel tape covered with jute and a preservative compound. This also helps to protect the cable when it is being ploughed in. Buried tape armour (BTA) comprises two layers of steel tape covered with jute, and affords greater mechanical protection.

Direct buried wires may be used for distribution and for service entrance to customer premises. These are commonly 1 or 2 pairs of 19 gauge or 2 pairs of 22 gauge copper. The covering can be steel wire or an aluminum shield over which is a tough black polyethylene jacket. These wires can be ploughed in. Some designs with aluminum tape also have a steel gopher protection tape for added protection.

Special types of Cable

- Low capacitance

  Cables are available with 0.066 microfarad per mile mutual capacitance instead of the regular 0.083 microfarad per mile. Low capacitance cables are sometimes used for carrier circuits.

- Waterproofing

  Cables are available, the cores of which are filled in the interstices with a compound which inhibits the ingress or passage of water.

  Various methods of cable construction are continuously being investigated. Cellular foam insulation in place of solid plastic is gaining favour and theoretical studies indicate a cost saving of 10 per cent over "standard" insulated cable. Further cost reductions are possible by the use of aluminum in place of copper. So far, aluminum conductors have not been widely used in North America due to splicing and terminating problems.

- Composite Cables

  Varying combinations of pairs in different wire gauges or different mutual capacitance values are available in any standard sheath.

- Screened PCM Cables

  Screened cables have a similar make-up to ALPETH but with an aluminum tape screen partitioning the cable into separate transmit and receive segments. This is to minimize near-end cross talk so that PCM repeaters may be placed with maximum spacing without having to resort to separate cables for the transmit and receive directions of transmission.

Terminals and Splicing Boxes

Terminals and splicing boxes are necessary for joining cables and wires on the route and also for providing access to the necessary pairs at the interfaces between the feeder cable and the distribution. Terminals and splices may be mounted in pole, pad, pedestal or wall boxes and may also be contained in aerial closures. Often space is available for a small number of loading coils. Modern units provide controlled access to cable pairs by providing a fixed number of terminals. This encourages the planning and organization of outside plant to reduce plant maintenance and administration problems that would arise if every cable pair were available at every interface. The principle is thus to assign enough pairs to the feeder/distribution interface in advance, to accommodate the expected demand growth in the serving area, over the lifetime of the facility. Also, the cable core is isolated from the installer's work area. Wire terminals are used for connecting drop wires to rural wire, cable or open wire.

7.3.3.3 General Apparatus

Loading Coils and Cases

Loading coils are usually 88 or 66 milliHenry and are used to reduce the cable pair attenuation at voice frequencies on long loops. 88 mH coils are normally spaced at 6 kft intervals (known as H88 loading) and 66mH coils at 4.5 kft intervals (known as D66 loading).

Loading coils effectively convert the cable pair into a low-pass filter with a cut-off frequency that prevents the use of carrier systems. However, at voice frequencies, as the attenuation is considerably lowered, loops may be longer or use smaller gauge than would otherwise be necessary.

H88 loading is most commonly used. REA has, however, standardized on D66 to prevent high frequency roll-off on long loops which can impair performance.

Loading coil cases are available in many sizes, with coil capacities ranging from one to many hundreds of coils. A case for 25 coils would have a diameter of 2 inches and length a little over 16 inches.

VF Repeaters

Voice frequency repeaters for use in the subscriber loop plant are 2 wire repeaters, either negative impedance or hybrid transformer type. The purpose is to provide a few decibels of gain in the subscriber loop circuit to compensate for the high losses of long loops. Fixed (selected) gain repeaters are common but, recently, VF repeaters with automatic gain control (AGC) have become available. AGC repeaters adjust their gain automatically to compensate for different loop losses and for changes of loop loss due to temperature changes, thus maintaining a common net loop loss.

Station Carrier Subscriber Terminals

Subscriber terminals may be single, dual or multiple channel terminals. Automatic level control allows these to be located anywhere within 35dB of a repeater. Consequently, a channel, or channels, can be located at a point on the feeder route that is closest to the subscribers to be served. Nevertheless, depending on the ringing option required and the kind of drop cable used, the subscriber terminal may be located several miles from the subscribers.

Carrier Repeaters and Housings

Repeaters for analog carrier systems are normally spaced about 35dB apart at the carrier reference frequency and compensate for the cable loss. In the case of a station carrier or subscriber carrier system operating in the region of 112 kHz, 35dB represents about 30 kft (5.7 miles) of 19 gauge pair at + 20°C, (20 kft of 22 gauge, 15 kft of 24 gauge or 11 kft of 26 gauge). Housings for such repeaters are normally capable of accommodating several bi-directional repeaters which are power fed from the Central Office over the same pair of wires over which the carrier signals are transmitted. For very long systems, power can be fed from both ends of the system. Housings can be provided for mounting on poles, pedestals, walls or in manholes.

Digital subscriber carrier systems use T-1 type repeaters which regenerate the 1.544 Mbits/sec bipolar signal originating from the Central Office or Remote Terminal. The maximum pair loss between repeaters is 31 or 32dB at 13°C except for the C.O. incoming end section which is 23dB due to C.O. noise. For 22 gauge buried cables, (one T-screened cable or separate cables for transmit and receive directions), repeater spacing is normally 3 kft from the C.O. and then at 6 kft intervals. This corresponds to H88 load coil spacing. Performance is dependent on insertion loss and near-end crosstalk and buried, T-screened cable (or 2 cables) results in the most economical repeater spacing. Twice as many repeaters would be needed for a single, unscreened aerial cable with 26 gauge pairs than for a screened, buried, 22 gauge cable. Repeater housings are available in 6, 12 and 25 repeater capacities.

7.3.4 Remote or Subscriber Terminals

The following is a list of equipment that may be used at remote terminals:

Terminal Blocks

Protectors

Repeating Coils

Subscriber Carrier Terminals

Subscriber Switching Terminals

Outdoor Housings

Batteries

Battery Chargers

The functions of terminal blocks, protectors, repeating coils, subscriber carrier terminals and subscriber switching terminals were covered in Section 7.3.1 in the context of a central switching office. Remote subscriber switching terminals may incorporate a number of local or intra-call links, depending on the community of interest among the remote subscribers. Intra-call facilities normally utilize the trunk circuit to the C.O. only for setting up the local call. When the connection is made, the trunk circuit is freed for other calls, thus economizing in the number of trunk circuits that need to be provided. However, if trunk circuits are already available, it is more economical to use them than to provide the intra-call feature.

Remote terminals may be accommodated on C.O. type rack framework and housed in a building, or, alternatively, accommodated in special outdoor housings, or huts. Subscriber carrier terminals can usually be accommodated in small cabinets which may be mounted on poles, pedestals or H-frames. Subscriber switching terminals are much larger and often require several outdoor cabinets or huts, four or five feet in height, mounted on a raised platform. Power for remote terminals is usually supplied by power units driven from a local a.c. supply, sometimes with floating batteries capable of giving 8 hours of emergency service. The larger outdoor cabinets or huts can accommodate batteries and battery chargers. Doors on outdoor cabinets are gasket sealed against rain and snow and the equipment is capable of operating over a wide range of environmental conditions, usually -40°C to +60°C.

Connectorization of external wires and cables is a common feature of remote terminal equipment to facilitate fast, accurate installation. This, together with the modular, plug-in structure of the equipment units, reduces maintenance in the field to a simple replacement operation.

7.4 SYSTEM TYPES

7.4.1 Physical Systems

Physical systems provide a metallic facility for the transmission of telephony at voice frequencies, d.c. signalling and a.c. ringing. Metallic facilities for rural feeder routes may be open-wire pole lines or cable. Open-wire facilities are not installed today because modern cable systems can provide a better performance more economically. Multi-pair cable facilities in the rural plant may be aerial or buried, filled or unfilled cable with various protective coverings. Single pairs also find economical use where the population density is small. Distribution from the feeder to individual subscribers is also on physical facilities, aerial or buried, whether the feeder is a physical or a carrier facility. Rural feeder cable sizes for physical circuits without subscriber switching or concentration depend on initial and growth requirements. REA provide 1 pair per existing living unit and 0.75 pair per forecasted living unit. Thus if 70 living units had to be served initially and growth was 5% per year compounded, a 100-pair cable would provide service for 10 years.

Resistance Design

The most commonly used method for designing physical loops has been to keep the loop resistance from the C.O. to the subscriber within 1300 ohms. Thus the total maximum circuit resistance becomes 1800 ohms, (including 500 ohms for the C.O. equipment and the subscriber's telephone set) and will maintain 23 mA loop current when the C.O. 48 volts battery is 15% low.

All loops less than or equal to 15 kft. in length use 26 gauge pairs. All loops between 15 and 50 kft. in length use a combination of the two finest gauges out of 19, 22, 24,and 26 gauge that keeps the loop resistance within the

1300 ohms limit, the finest gauge always being closest to the C.O.

Circuits over 18 kft. in length are loaded H88.

Unigauge Design

Unigauge (uniform gauge), design is intended to maximise the use of 26 gauge pairs close to the C.O. in order to avoid duct congestion, reduce copper costs and to use less loading coils.

All loops less than or equal to 30 kft. in length use 26 gauge pairs. All loops between 30 and 52 kft. use a combination of 26 gauge and 22 gauge, with 26 gauge between the C.O. and 15 kft. Circuits over 15 kft. in length are loaded H88, the first loading coil being located 15 kft. from the C.O. Long loops share range extenders with gain. Where the C.O. switching machine is No. 5 Crossbar, range extenders with gain are concentrated within the switching machine on the basis of 1 range extender for every 5 subscriber loops. No. 2 ESS also provides 1:5 concentration but only repeaters are required as the switching machine provides range extension to 2500 ohms of loop resistance.

REA

Rural physical loop design is based on a transmission objective of 8 dB maximum loss at 1 kHz but transmission computations are eliminated in most cases as design emphasis is on the following factors:

i) 24 and 22 gauge cable (standard capacitance) is used as the backbone and the use of 19 ga and 26 ga is de-emphasised. Where 26 ga cable must be used, it is restricted to within 15 kft. of the C.O.

ii) All loops beyond 18 kft. in length have maximum loading(D66 to avoid loss of articulation on long loops due to high frequency roll-off).

Loop extension devices are used on all loops exceeding 1700 ohms outside plant resistance.

Extra Long Loops

Loops beyond 2800 ohms (e.g. 174 kft of 19 ga or 87 kft of 22 ga), present the problem that signalling range extension with gain located at the C.O. is not enough. Some gain must be located remotely. This has normally been provided by mounting VF repeaters in remote cabinets. However, these are relatively costly and difficult to maintain. Recently, Bell Labs designed a telephone handset incorporating 3 dB of gain in the transmit path and in the receive path, the telephone set being capable of operating on a current as low as 3 milliamps. This enables subscriber loops to extend out to 3600 ohms (224 kft of 19 ga or 112 kft of 22 ga) without requiring outside mounted equipment.

7.4.2 Station Carrier Systems

Station carrier systems are double side-band amplitude modulated systems with transmitted carrier. Systems are available for up to 10 channels. They can operate over virtually any wire facility and are designed to serve distributed subscribers via a single pair of wires, the two directions of transmission being separated into different frequency bands. It is not possible to operate the station carrier without loading coils in the circuit as they modify the circuit into a voice frequency low-pass filter. Also, a physical circuit is not possible due to the presence on the pair of a d.c. power feeding current to energize the station carrier repeaters and subscriber terminals. Maximum range of such systems is 140 dB at 112 kHz. This ranges from 120 kft. (23 miles) of 19 ga to 45 kft (8.5 miles) of 26 ga. Much greater distances are possible on open wire because of the heavy conductors used.

Single channel carrier can be used to add a circuit to an existing working physical pair although no loading is permitted. Its operating range is usually therefore in the order of 18 kft.

7.4.3 Subscriber Carrier Systems

Subscriber carrier systems terminate at one or several remote points with the remote terminals being locally powered. This kind of system therefore best serves locations where subscribers are concentrated or clustered. Service to customers is distributed from the remote point on physical facilities. Analog subscriber carrier systems are very similar to station carrier systems where all of the subscriber terminals are located at one remote point. In such cases they are provided on a shelf similar to the C.O. terminal instead of in separate housings, and the remote terminal may be located on a rack framework inside a building or in an outdoor, weatherproof cabinet.

Digital subscriber carrier systems can currently provide up to 24 channels (PCM) or 32 channels (Delta-modulation) via a T-1 type line, the distance being up to about 50 miles with power feeding from both ends. A separate pair of wires is used for each direction. Such systems can provide for automatic protection switching to a spare span-line and also provide order-wire and remote fault location facilities. The order wire and fault location facilities use separate loaded pairs and the digital repeater housings are able to accommodate the necessary loading coils. 6 pairs would be needed for a working span line, spare span line, order-wire and fault-location. With digital systems, near-end crosstalk between systems is a limiting parameter which, in the past, has led to separate cables being used for transmit and receive. However, single cable operation is possible with screened cable which partitions the cable core into separate transmit and receive portions. Digital systems are particularly intolerant of bridged taps, cable dampness, building-out networks, etc., which can lead to high cost when upgrading existing physical facilities.

7.4.4 Subscriber Switching Systems

Subscriber switching systems provide trunk concentration where the number of subscriber circuits at a remote point exceeds the number of pairs available in the feeder to the C.O. Optional local intra-call facilities are also available to relieve trunk usage on locally originated and terminated calls. Subscriber switching systems therefore find application where remote subscribers are concentrated. Modern systems use electronic switching and various capacities are available, ranging from 24 single-party subscribers sharing 6 trunks to 256 single-party subscribers sharing 48 trunks. Some systems use space division switching interfacing with physical circuits or subscriber carrier multiplex, and other systems integrate the switching and multiplexing functions into a time-division modulated switcher/concentrator interfacing with a T-1 type line facility at 1.544 Mbits/sec. Subscriber switching systems comprise remote and central office terminals, features such as remote intra-call, remote alarm display, span-line protection switching, traffic monitoring and remote testing of subscriber lines being commonly available. Typically a busy-hour calling rate per subscriber of up to about 5.5 ccs can be accommodated with a grade of service of 0.01 or better. If insufficient pairs or trunks are available, intra-call links can reduce the trunk circuit requirement where there is a strong community of interest. However, if pairs are already available it can be more economical to use them than to provide local intra-call facilities.

7.5 DISTRIBUTED SUBSCRIBERS

The following systems are a selection of possibilities for serving 25 subscribers distributed over a distance of 50 kft. To provide a common basis for comparison of different methods, it has been assumed 4 distribution points exist along the length of the feeder, coinciding with loading points on the H88 plan and all subscribers have shared (4-party selective ringing) service.

7.5.1 Physical

7.5.1.1 Open Wire (Fig. 6)

The feeder is an open wire route and one pair is required for each circuit feeding 4 subscribers. Distribution to the subscribers is aerial. No circuit conditioning is required.

7.5.1.2 Aerial Pair (Fig. 7)

Here the feeder as well as the distribution are aerial pair. Loading coils are provided on all circuits over 18 kft from the C.O.

7.5.1.3 Aerial Cable (Fig. 8)

11-pair aerial cable is used here and unigauge design has been assumed. 26 gauge, mixed 22 and 26 gauge and 22 gauge cables are provided with load coils from 15 kft for the circuits longer than 24 kft. Range extenders with gain are provided at the C.O. for circuits longer than 15 kft.

7.5.1.4 Buried Cable (Fig. 9)

Similar to the previous case except that the cable is a filled type and is directly buried into the ground. The distribution is a buried 19 gauge pair.

7.5.2 Station Carrier

7.5.2.1 Aerial Pair (Fig. 10)

This system has a feeder comprising a single 19 gauge pair, but 6 channels of station carrier are provided, 1 per 4 subscribers. A repeater is required at the 30 kft point and a termination after the last distribution point, to prevent reflection. The distribution is with aerial pair also, the distribution points being the station carrier subscriber terminals.

— DISTRIBUTED SUBSCRIBERS —

o/w - PHYSICAL

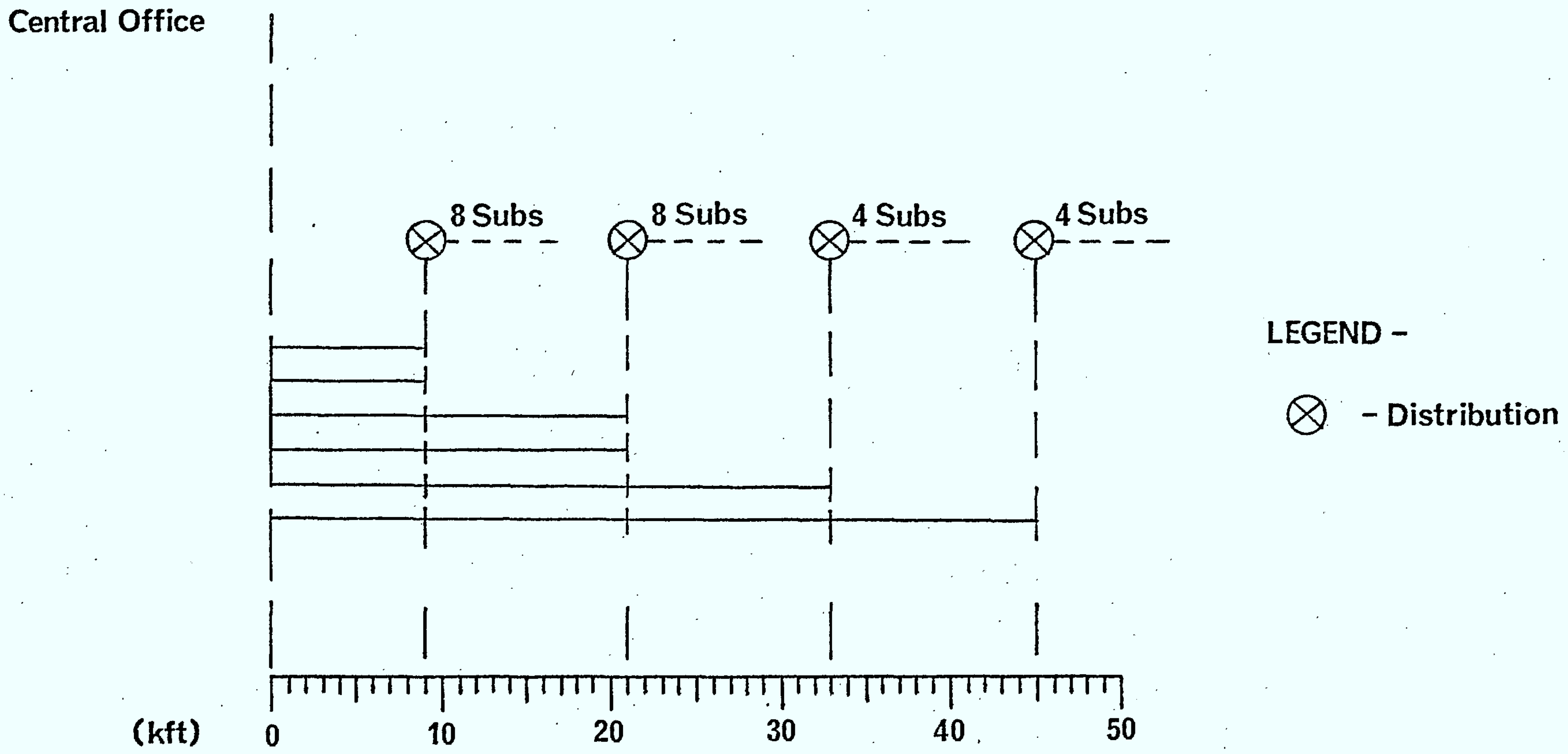


FIG.— 6

—DISTRIBUTED SUBSCRIBERS—

AERIAL PAIR - PHYSICAL

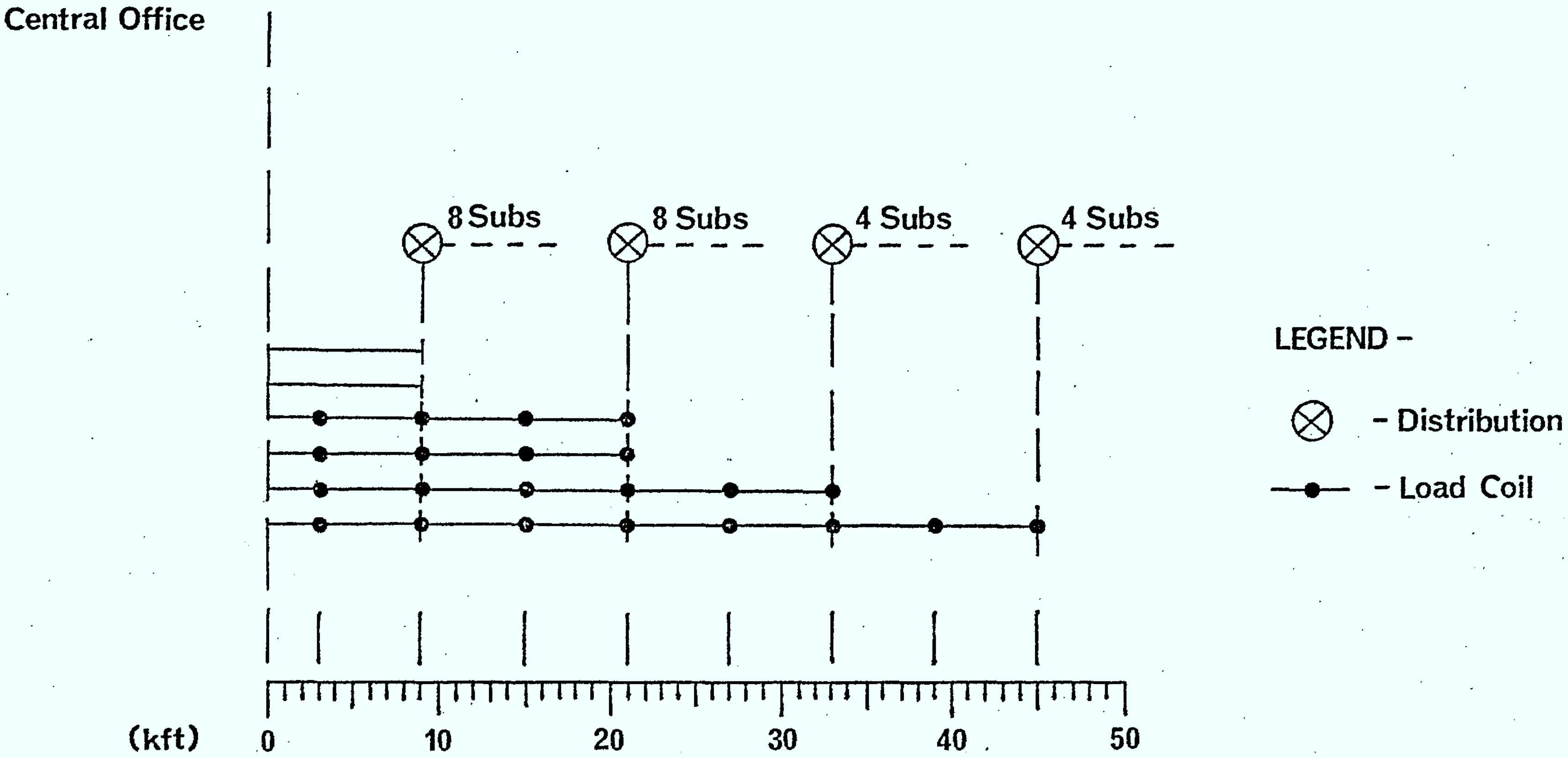


FIG.— 7

-DISTRIBUTED SUBSCRIBERS-

AERIAL CABLE-PHYSICAL

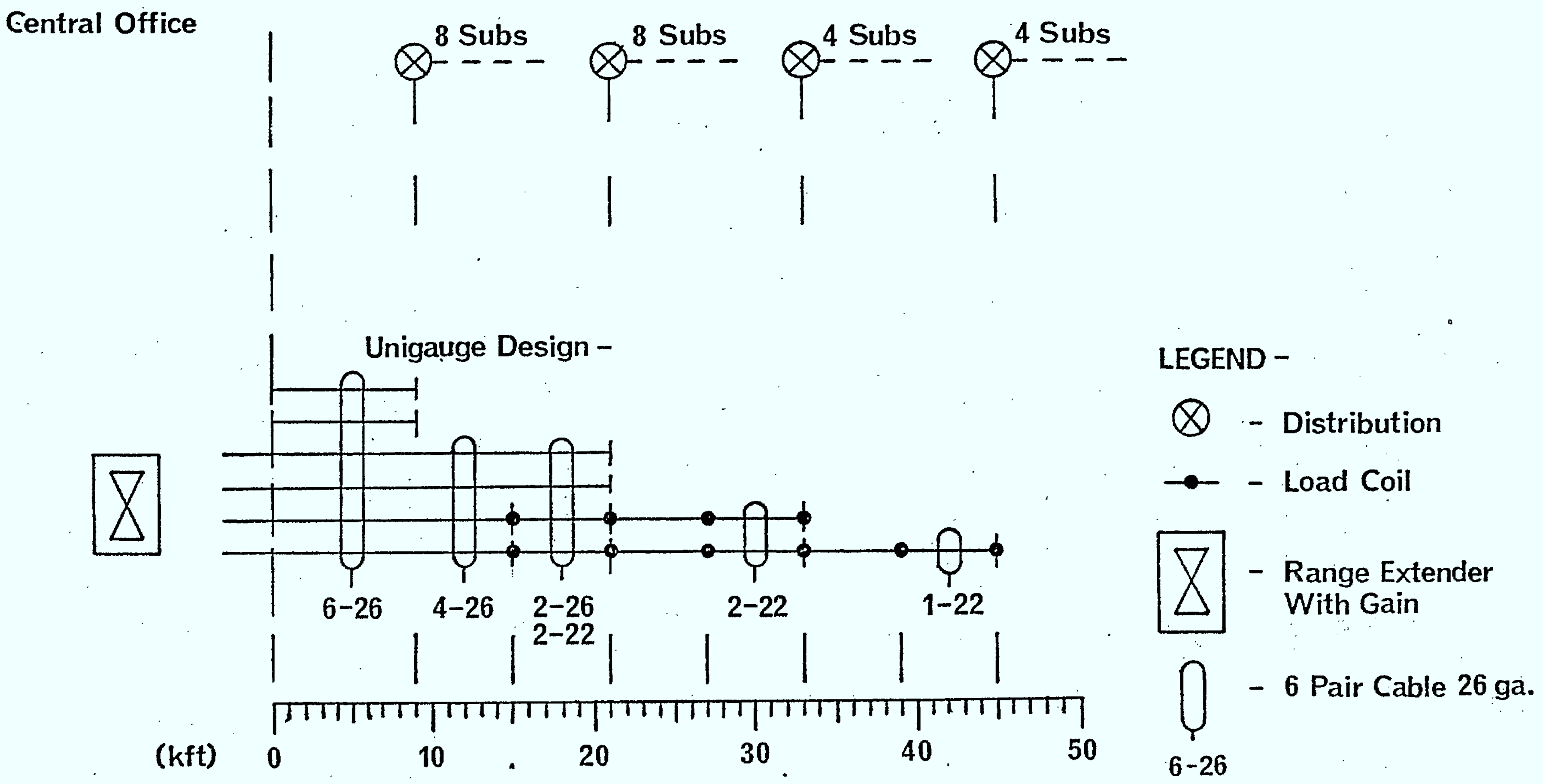
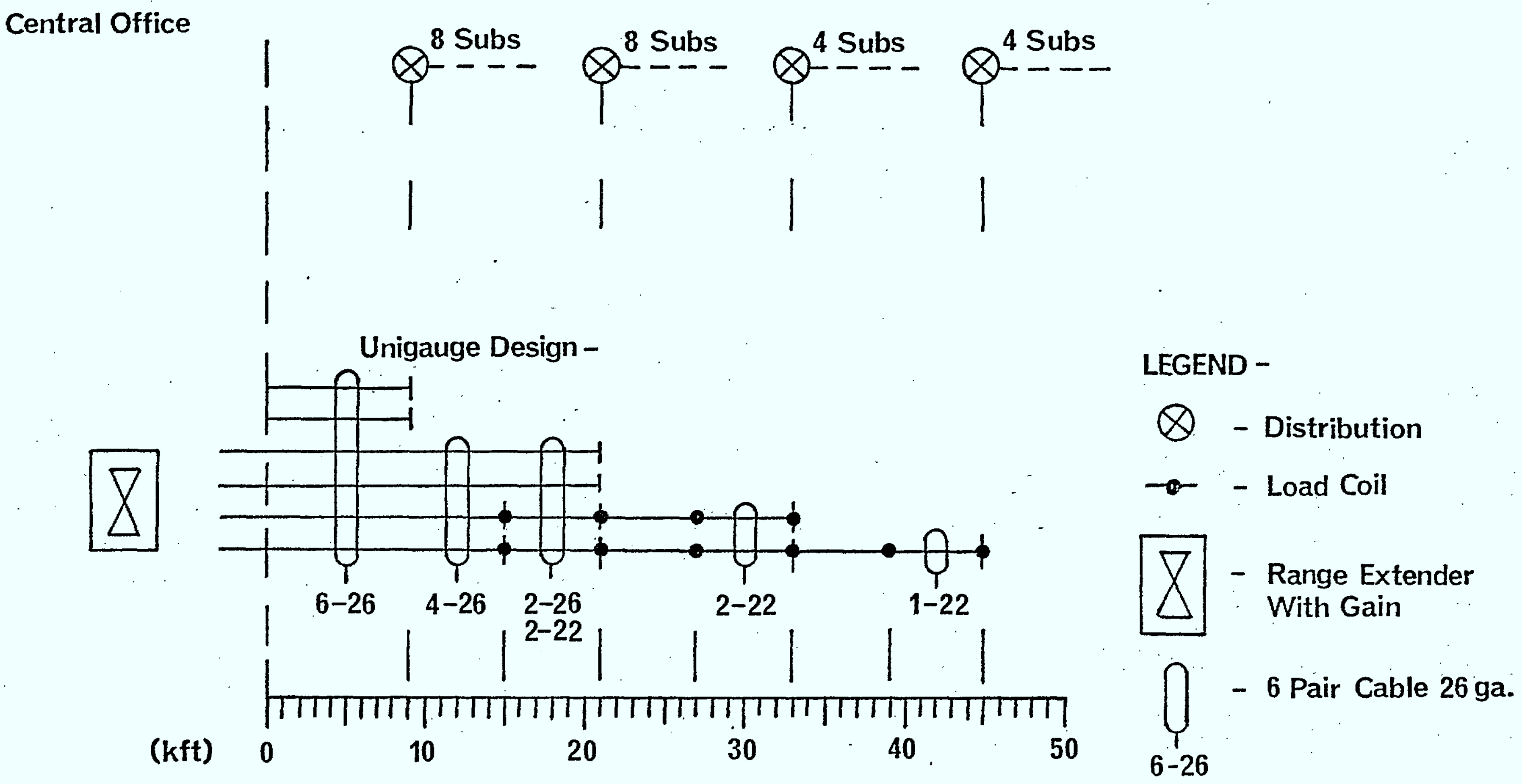


FIG.— 8



–DISTRIBUTED SUBSCRIBERS–

BURIED CABLE-PHYSICAL

FIG.– 9

—DISTRIBUTED SUBSCRIBERS—

AERIAL PAIR–STATION CARR. (ANALOG)

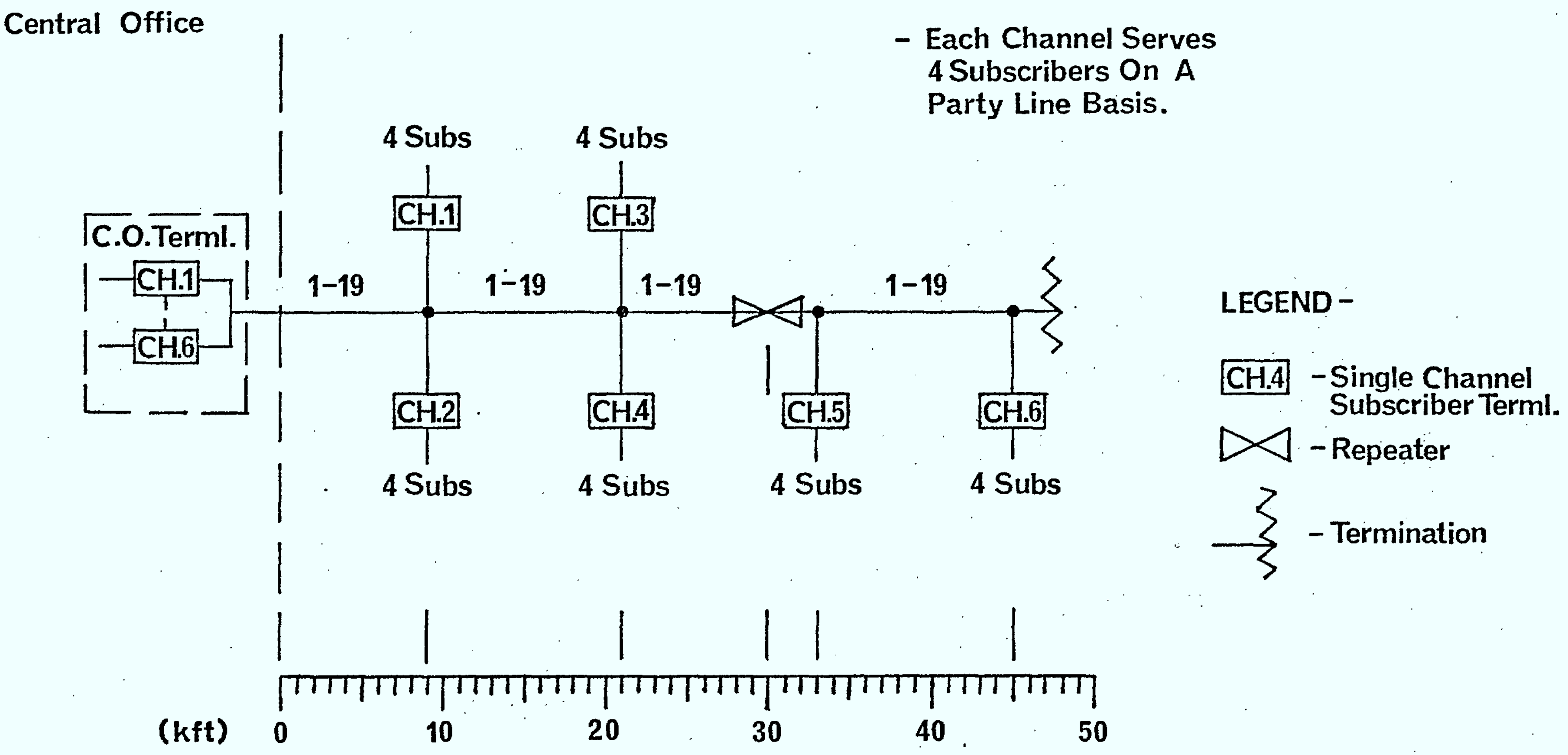


FIG.— 10

7.6 Concentrated Subscribers

Eight examples have been used to illustrate ways of providing service to 100 subscribers concentrated at a point 50 kft from the Central Office. The systems illustrated range from purely physical facilities with 4-party service to sophisticated systems using digital subscriber carrier and TDM switching, offering single-party service. The furthest subscriber is 55 kft from the C.O. Distribution from the remote terminal to the subscribers is via physical circuits with a mean subscriber distribution length of 1 kft. Remote terminals are assumed located in a separate building, unless otherwise stated. Remote terminal power is provided from a 48 volts battery with a charger operated from the local A.C. supply. In the event of local A.C. supply failure, the battery will provide emergency service for at least 8 hours.

7.6.1 Physical Circuits

7.6.1.1 Open Wire (Fig. 11)

The feeder is open wire, 25 pairs to serve the 100 subscribers on a 4-party basis. Distribution is with aerial pair. No circuit conditioning is required.

7.6.1.2 Aerial Cable (Fig. 12)

This sytem uses a 50 pair 24 gauge aerial cable of which 25 pairs are required to serve the 100 subscribers on a 4-party shared basis. All 25 pairs are loaded H88 and range extenders with gain are equipped at the central office in common mode (i.e. they are shared by the subscriber lines on a 5:1 basis). Distribution is aerial.

7.6.1.3 Buried Cable - Analog Sub. Switching (Fig. 13)

In this system the feeder is a buried 25-pair, 24 gauge cable loaded H88. Range extenders with gain are provided at the C.O. end. An analog subscriber switching concentrator system is provided to reduce the number of feeder pairs required and to provide local switching at the remote end. A calling rate of 3.0 ccs/subscriber has been assumed, with 50% community of interest. On this basis, 10 trunks are required to handle the traffic for the 100 subscribers on a single-party basis, providing a grade of service of P.01. Two extra trunks are provided for control and verification, making a total of 12 trunk pairs in use in the feeder. Traffic monitor and maintenance monitor facilities are provided. Distribution to subscribers is by buried pair.

7.6.2 Analog Carrier Systems

7.6.2.1 Aerial Cable - Analog Multiplex & Sub. Switching (Fig. 14)

A 6-pair, 22 gauge aerial cable is used with analog subscriber carrier and analog subscriber switching to provide single-party service to 100 subscribers via only 2 pairs of wires. The subscriber switching system is exactly as described in 7.6.1.3, but the 12 trunk lines in this case are provided by two 6-channel lumped multiplex systems. Two repeater positions are required and, as there are two systems, they are provided in dual repeater housings. Subscriber distribution in this system is via aerial pair.

7.6.2.2 Buried Cable - Analog Multiplex & Sub. Switching (Fig. 15)

This system is similar in principle to that described in 7.6.2.1, except that the feeder is a buried 25-pair, 24 gauge cable. In this instance, as before, only two pairs would be in use but the implication is that there is growth potential. REA are tending to plough in 25-pair 24 gauge cable for all new applications wherever possible. In this case, 3 repeater positions are required as the 24 gauge pairs have a greater attenuation than 22 gauge pairs. Subscriber distribution is assumed to be buried.

7.6.3 Digital Carrier Systems (PCM)

7.6.3.1 Buried Cable - PCM Multiplex & Analog Subs. Switching (Fig. 16)

This system has a buried 25-pair, 24 gauge, screened cable feeder cable and T-1 type PCM repeaters operating at a bit rate of 1.544 Mbits/sec. Although the system capacity is 24 voice channels, only 12 are required initially. Two T-1 span lines are provided, each requiring two cable pairs. One span line is spare and is on hot standby in case the working system fails. Span line terminals at the C.O. and Remote locations provide automatic span line protection switching and fault location, and also contain terminal repeaters. A maintenence order-wire circuit is also provided for the T-1 system. The order-wire and fault-location systems require separate VF pairs with H88 loading. The subscriber switching system is exactly as described in 7.6.1.3 with the 12 trunk lines provided by the PCM transmission system. Distribution is with buried pair.

7.6.3.2 Buried Cable - PCM Multiplex & Digital Subs. Switching (Fig.17)

The feeder for this system is also buried 25-pair, 24 gauge, T-screened cable with T-1 type repeaters. However, in this case, the system provides 48 trunks requiring two separate working T-1 span lines. A third span line is provided as a hot standby and protection switching is provided at the terminals. Order-wire and fault-location circuits are also provided.

The subscriber switching in this case is time division and is integrated, together with the PCM multiplexing, into central office (C.O.) and remote concentrator terminals. With 30% community of interest and 24 local intra-call links, the available trunks enable a maximum of 256 subscribers to be connected at one to four remote locations on a single-party basis with a calling rate per subscriber of 6.6 ccs and grade of service of P.005.

Only 100 subscribers at a single location are assumed here, which implies considerable growth potential. Subscriber distribution is assumed to be buried and the remote terminal to be mounted in outdoor cabinets.

7.6.4 Digital Carrier Systems (Delta-Modulation)

7.6.4.1 Buried Cable - Delta-Mod.Multiplex & Digital Subs. Switching (Fig. 18)

The feeder is buried screened cable as before. Two T-1 type span lines are provided, one of which is on hot-standby. The system uses delta-modulation on a per-line basis and time division switching to concentrate up to 128 subscribers onto 32 channels. The 32 delta modulated channels are transmitted at the same bit rate (1.54 Mbits/sec), as for 24 PCM channels. Up to 8 remote terminals are possible. A calling rate per subscriber of 5.4 ccs gives a grade of service of P.005 with the full 128 subscribers connected. With the intra-call feature, the calling rate can be as high as 7.5 ccs/subscriber for the same grade of service. Subscriber distribution is assumed to be buried.

CONCENTRATED SUBSCRIBERS

OPEN WIRE PHYSICAL

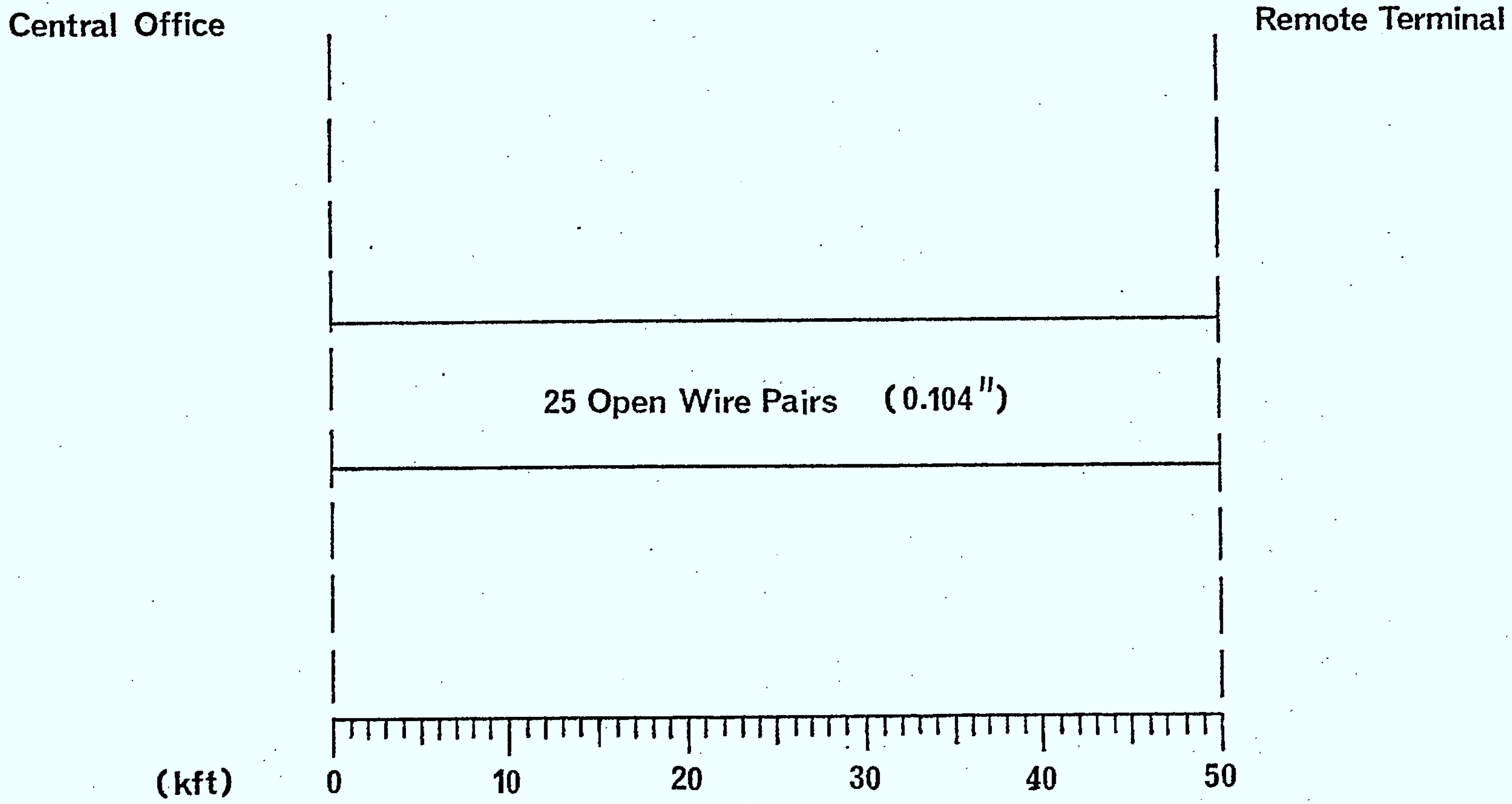


FIG.—11

— CONCENTRATED SUBSCRIBERS —

AERIAL CABLE - PHYSICAL

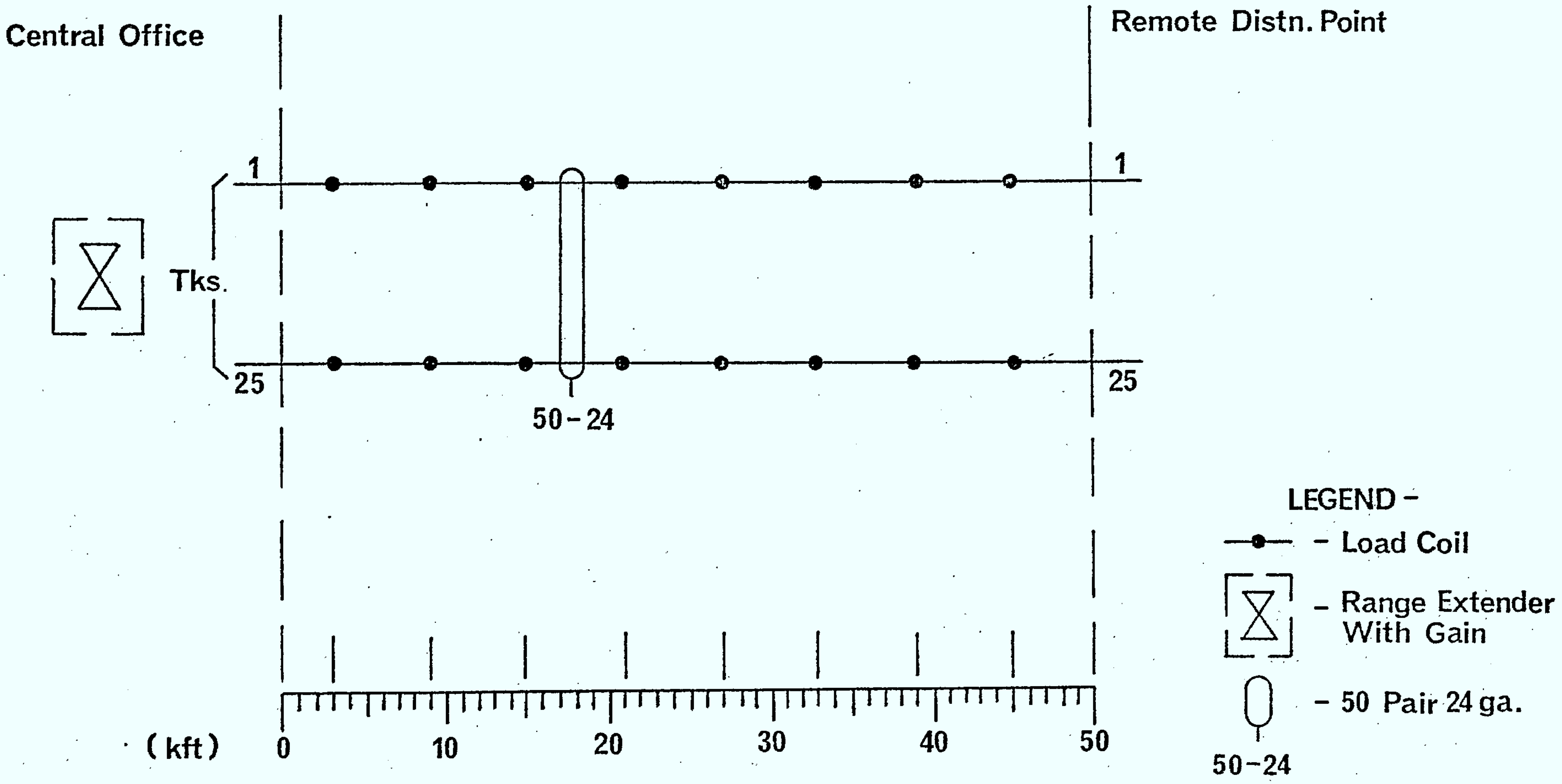


FIG.— 12

— CONCENTRATED SUBSCRIBERS —

BURIED CABLE-PHYSICAL
WITH SUBSCRIBER SWITCHING

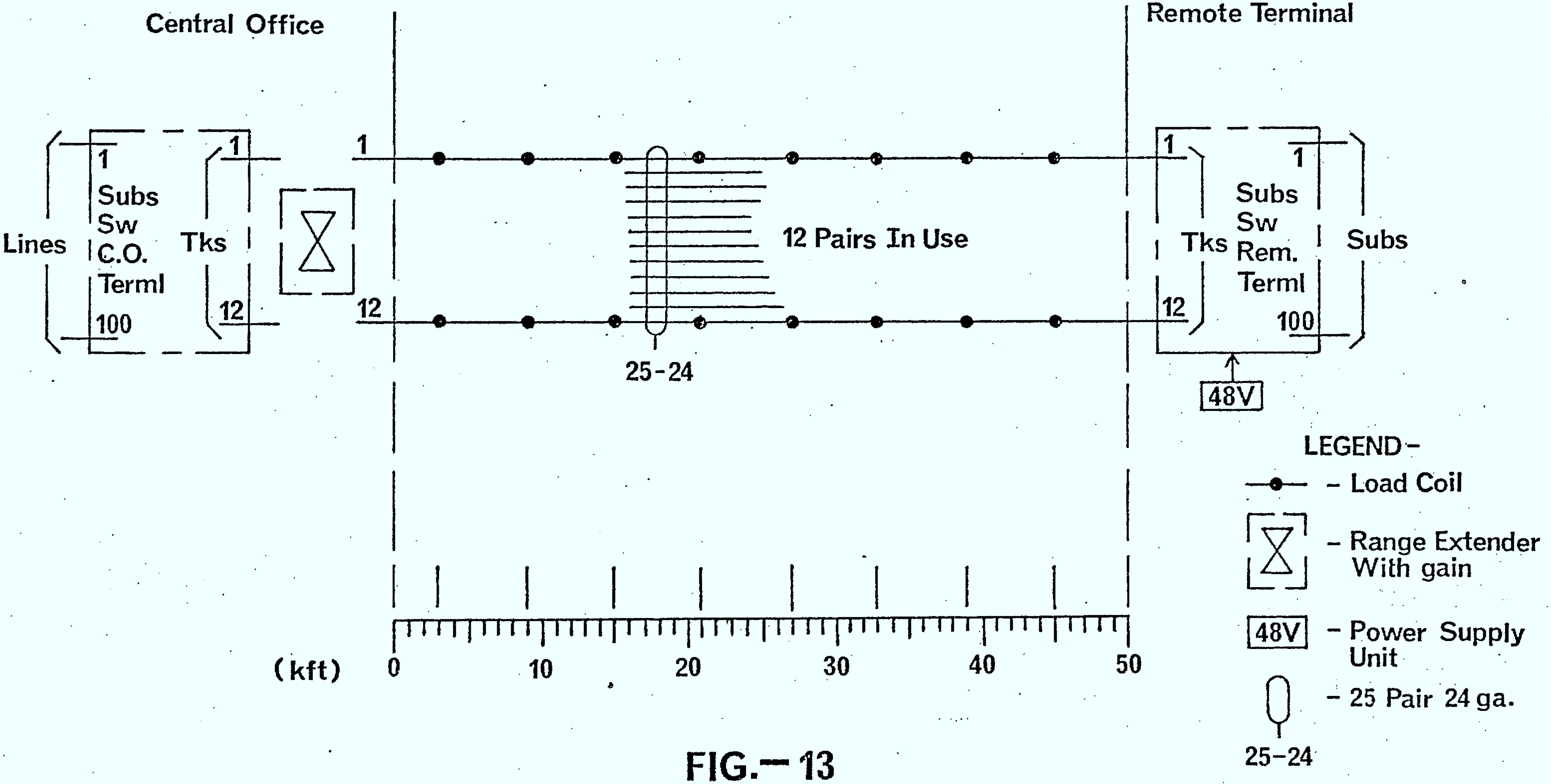


FIG.— 13

— CONCENTRATED SUBSCRIBERS —

AERIAL CABLE — LUMPED CARR. (ANALOG) WITH SUBSCRIBER SWITCHING

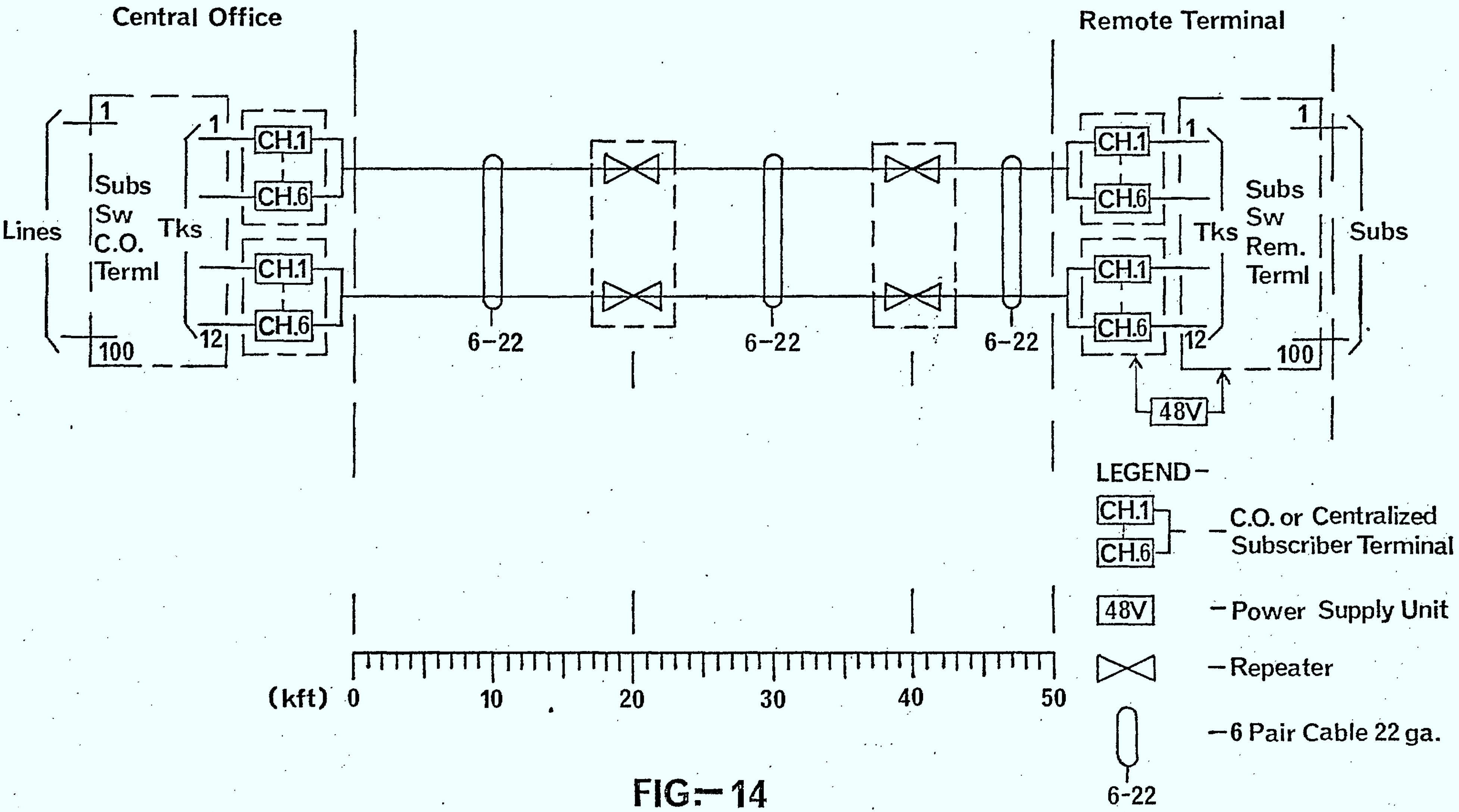


FIG:— 14

— CONCENTRATED SUBSCRIBERS —

BURIED CABLE — LUMPED CARR. (ANALOG)
WITH SUBSCRIBER SWITCHING

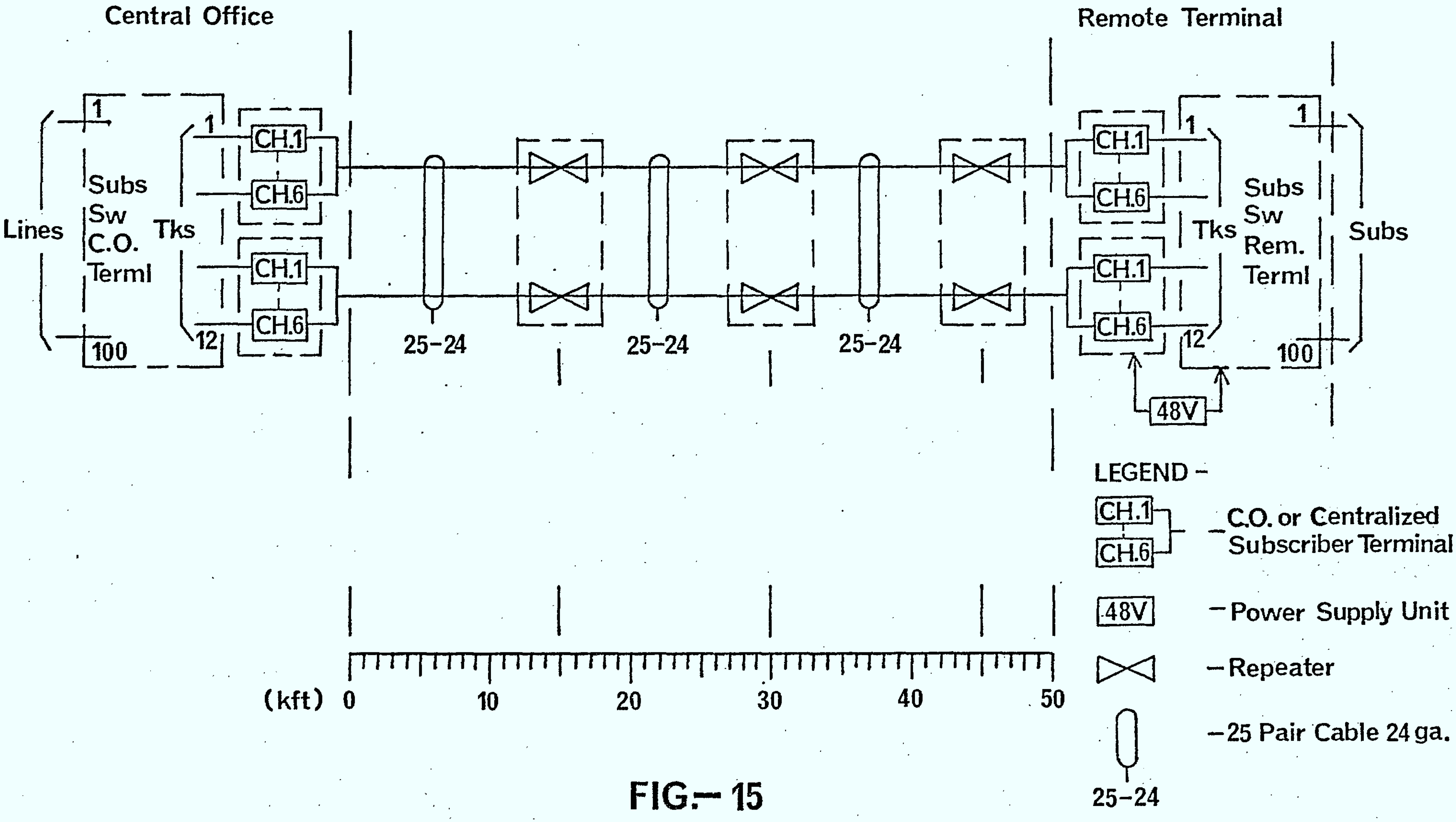


FIG.— 15

— CONCENTRATED SUBSCRIBERS —

BURIED CABLE — LUMPED CARR. (PCM)
WITH ANALOG SUBSCRIBER SWITCHING

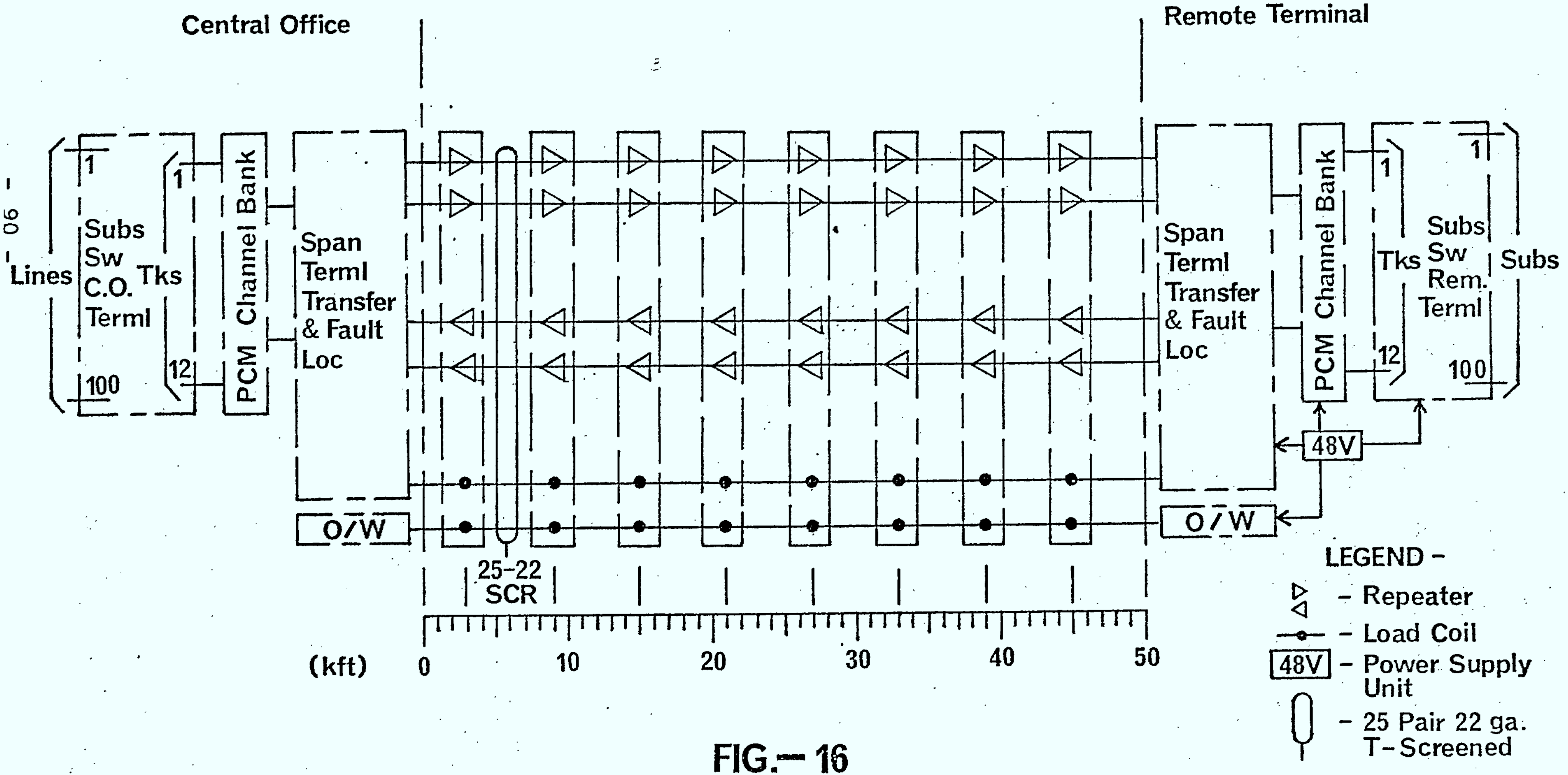


FIG.— 16

—CONCENTRATED SUBSCRIBERS—

BURIED CABLE — LUMPED CARR. (PCM)
WITH DIGITAL SUBSCRIBER SWITCHING

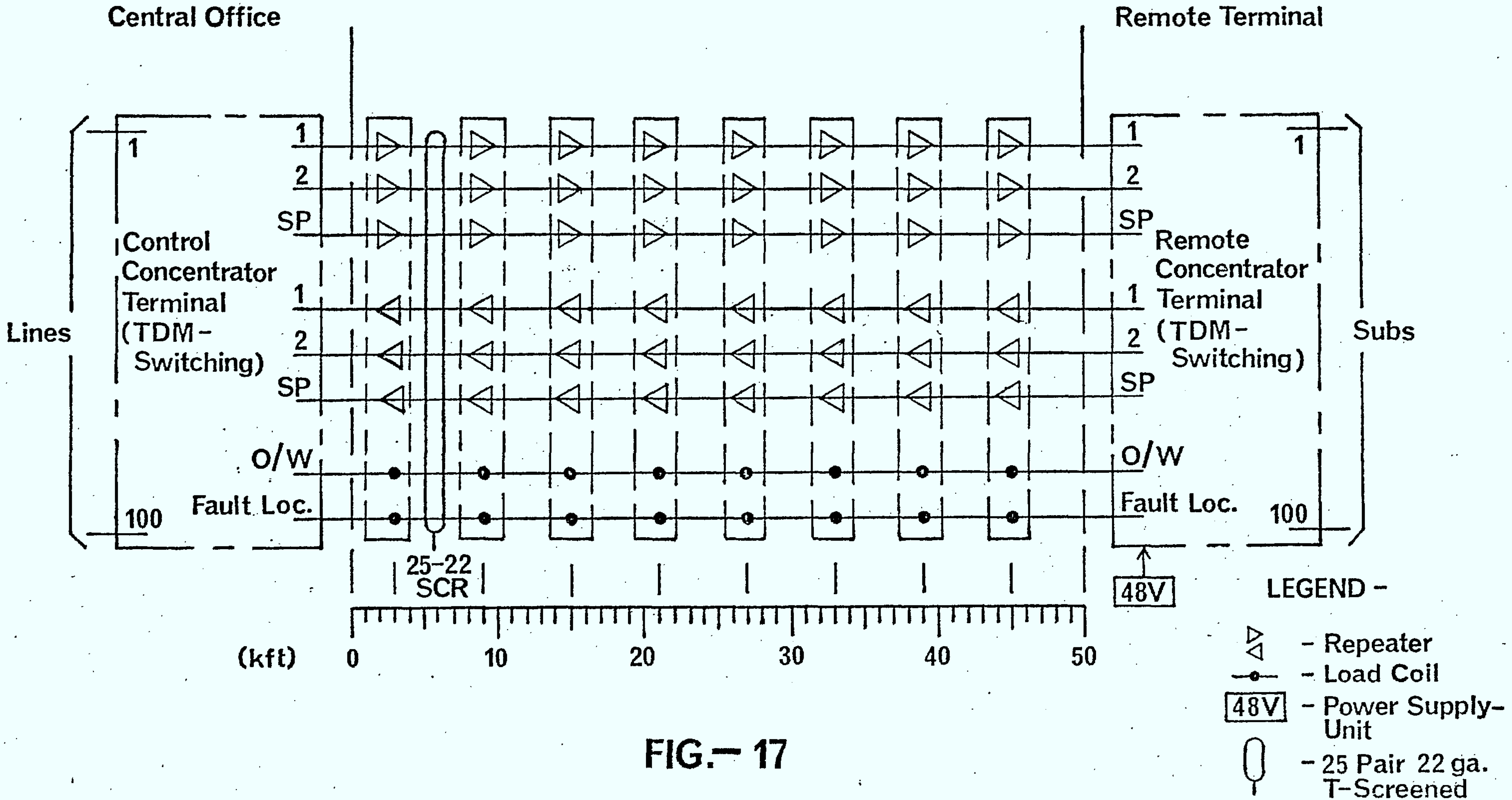


FIG.— 17

—CONCENTRATED SUBSCRIBERS—

BURIED CABLE — LUMPED CARR. DELTA - MODULATION WITH DIGITAL SUBSCRIBER SWITCHING

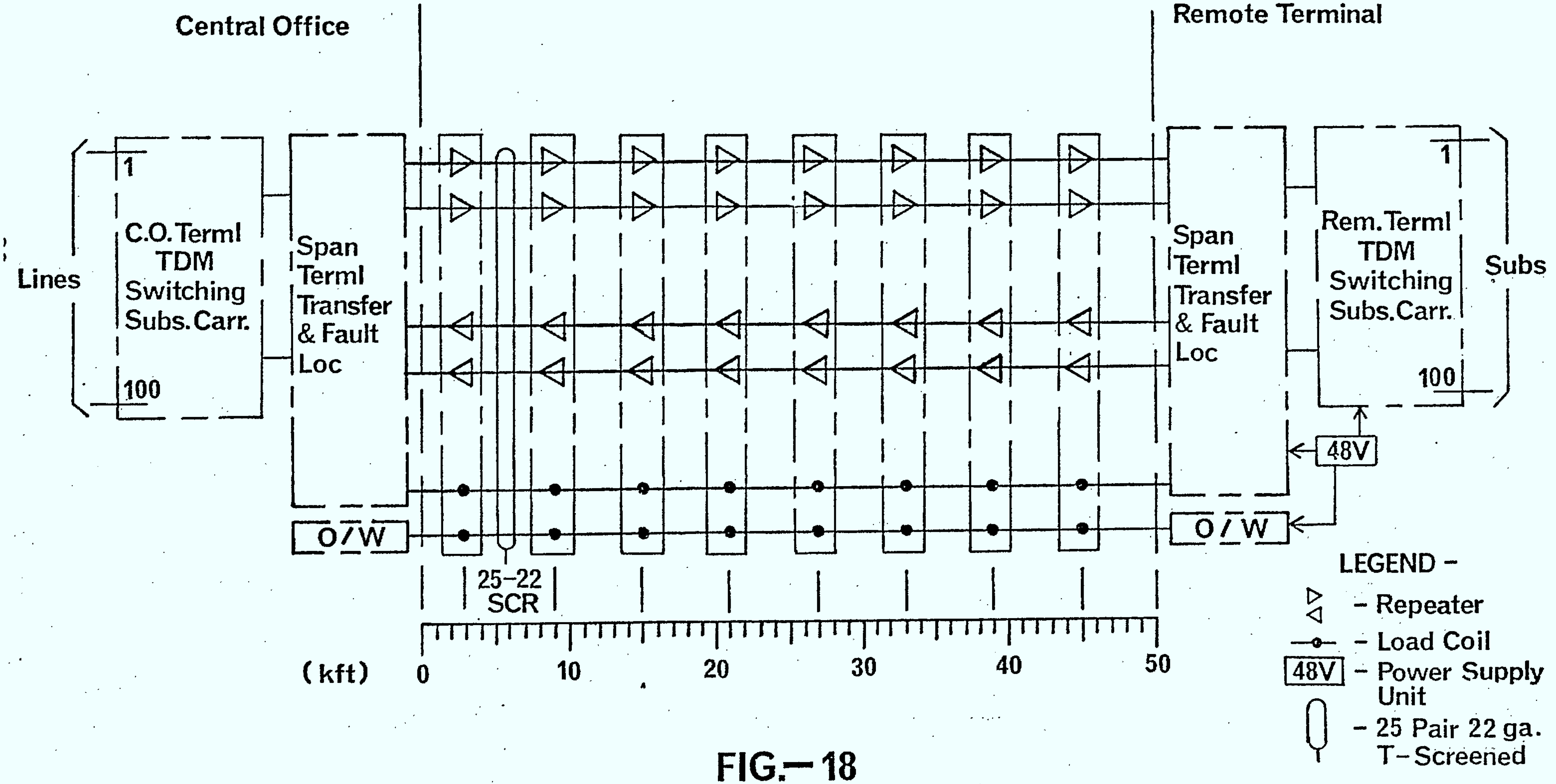


FIG.—18

7.7 Extra Remote Subscribers

Three examples have been chosen to illustrate the provision of service to two subscribers located 100 kft from a Central Office (or Remote Terminal).

7.7.1. Open-Wire Physical System (Fig.19)

This system provides one open-wire pair with 2-party shared service. No circuit conditioning is provided.

7.7.2 Aerial Pair - Physical System (Fig.20)

One 19 gauge aerial pair is provided, with D66 loading, for 2-party shared service.

7.7.3 Buried Cable - Physical System (Fig.21)

A 6-pair, 22 gauge buried cable is provided, one pair loaded D66. A range extender with gain is located at the C.O. and each of the two subscribers has an electronic telephone set with 3 dB of gain in the transmit and receive paths.

EXTRA REMOTE SUBSCRIBER

OPEN WIRE PHYSICAL

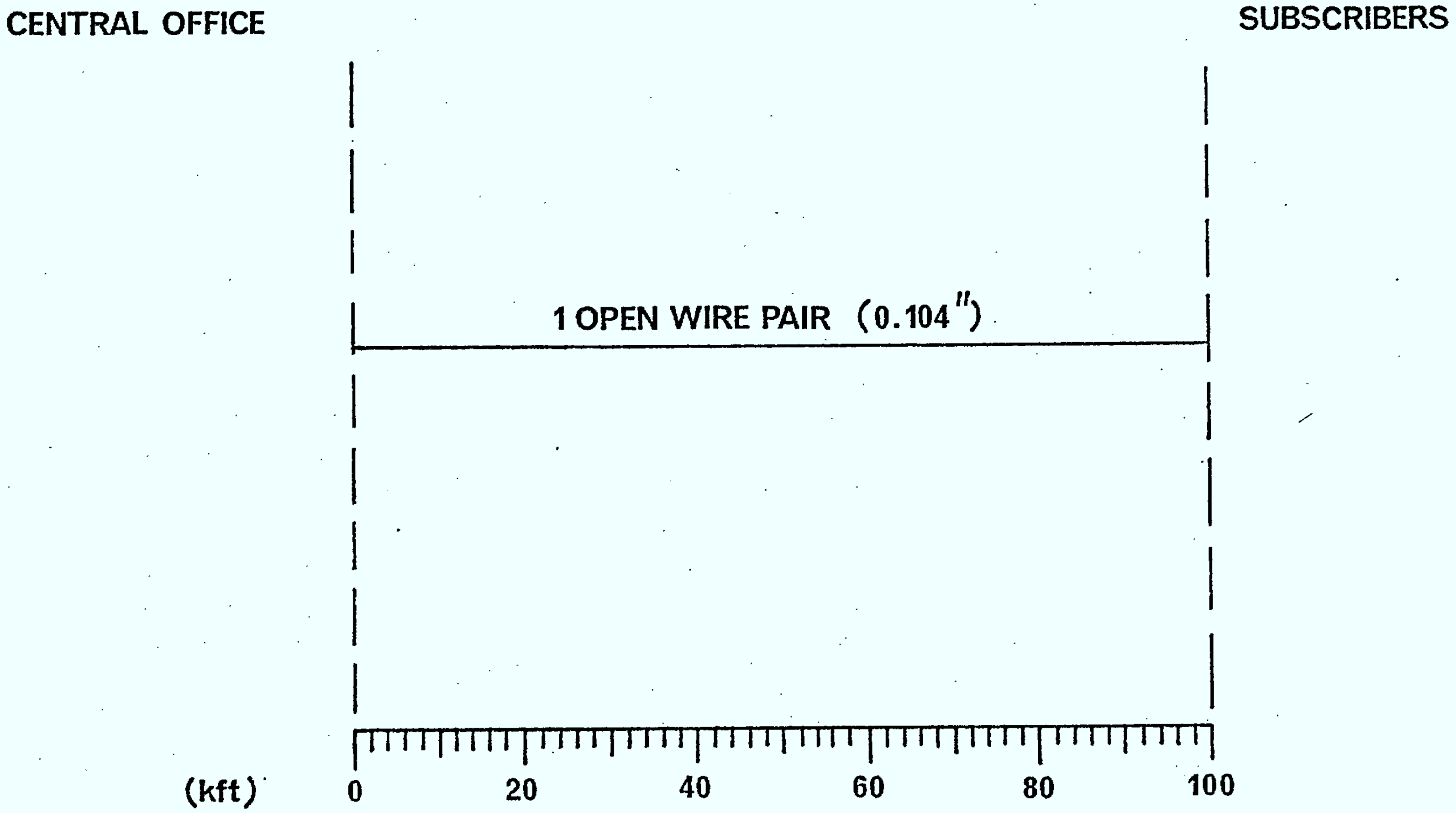


FIG.— 19

EXTRA REMOTE SUBSCRIBER

AERIAL PAIR PHYSICAL

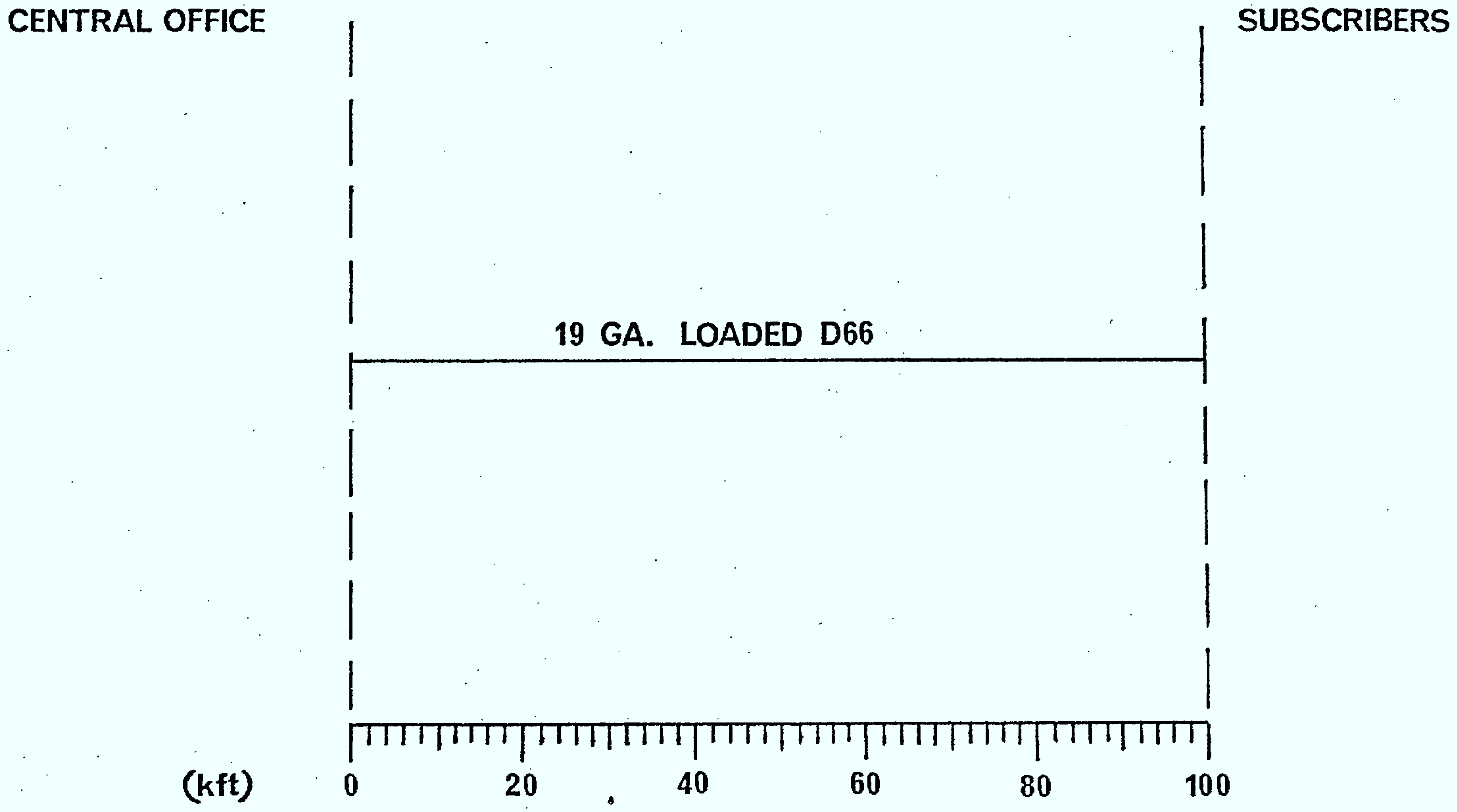


FIG.— 20

EXTRA REMOTE SUBSCRIBER

BURIED CABLE PHYSICAL

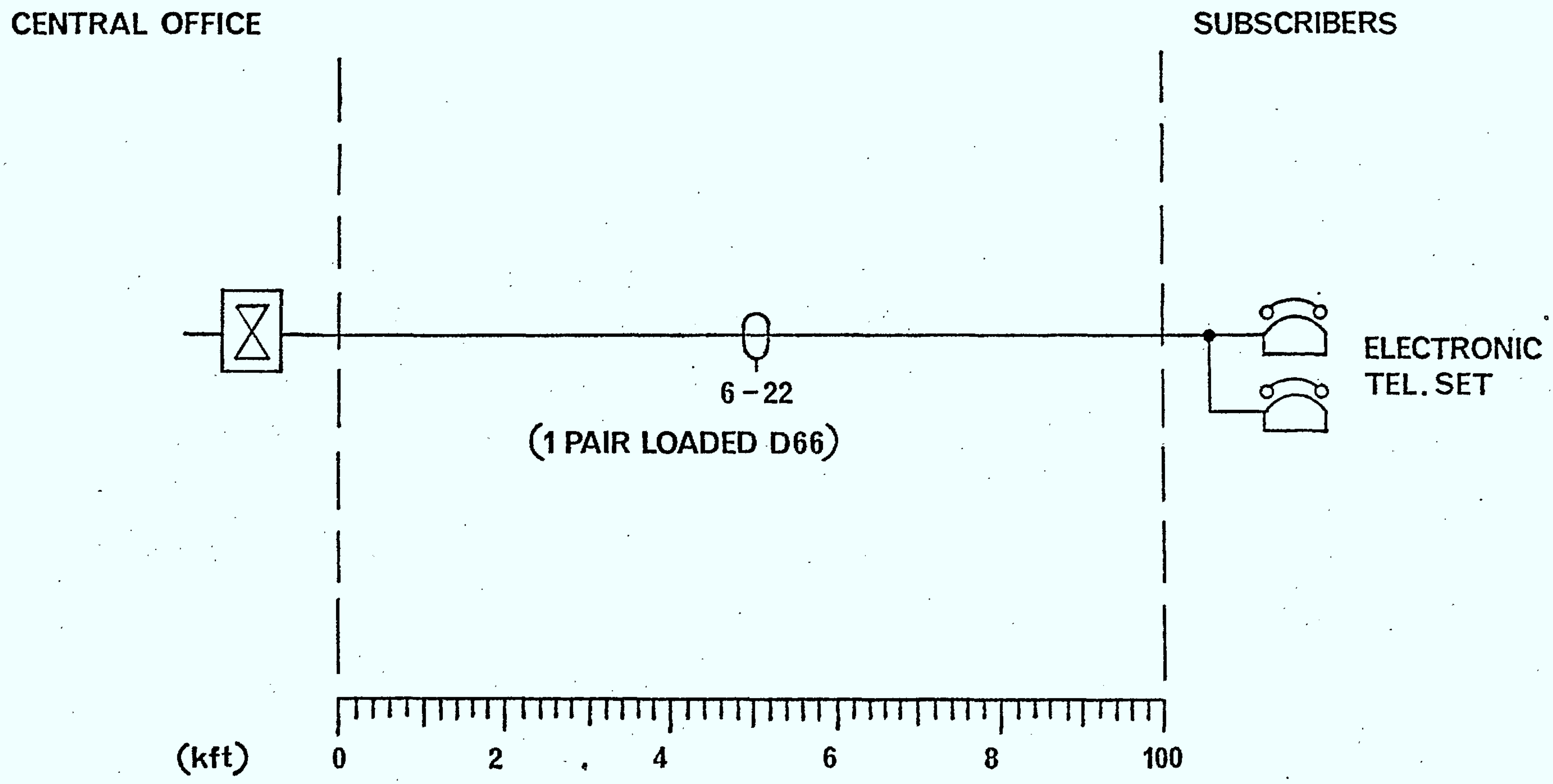


FIG.— 21

7.8 Cost Comparisons (Figs. 22 - 25)

7.8.1 General

The examples shown in figs. 6-21 are compared on a detailed cost basis in the table in fig. 22. The various elements or "building blocks" of the systems considered have been allocated unit costs and then extended, according to quantity, length, etc. into each of the system types. At the foot of the table, each system cost is summed and divided by the number of subscribers served by that system, to obtain the cost per subscriber. Note that this is only equal to the cost per circuit for those cases where single party service is provided. In other cases, the cost per subscriber must be multiplied by the number of subscribers sharing the circuit in order to arrive at the cost per circuit.

It is important to note that the costs stated are initial costs for equipment and material only. They have mostly been derived from the list price information provided by many suppliers and, as such, give an order of magnitude only. Nevertheless, they provide a useful insight into the relative first equipment cost magnitudes of various system types.

A further factor to be borne in mind is that the system examples chosen within each category are only equivalent in terms of the number of subscribers served and the distances involved. Figs. 23-25 which summarize the systems, indicate some of the features which are different between the various systems.

Other differences lie in tangible but time-related factors such as different ultimate system capacities, different life times, etc., and also in less tangible factors such as different reliablilities, performance, equipment options, etc. Proper comparative cost studies attempt to assign values to all such factors and take into account the time value of money. Some comments on comparative economic cost studies are given in section 7.10.

FIG.– 22 INITIAL COST–EQUIPMENT & MATERIAL

			25 DISTRIBUTED SUBSCRIBERS –										100 CONCENTRATED SUBSCRIBERS –																2 Extra Remote Subs –					
			FIG.6		FIG.7		FIG.8		FIG.9		FIG.10		FIG.11		FIG.12		FIG.13		FIG.14		FIG.15		FIG.16		FIG.17		FIG.18		FIG.19		FIG.20		FIG.21	
(CENTRAL OFFICE & REMOTE TERMINAL EQUIPMENT)●			Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn $k	Qty	Extn Sk
Range Extender With Gain	$175	cct.					4	0.7	4	0.7					5	0.9	12	2.1															1	0.2
Station Carr. Terminal (6 ch. single party br. ring)	$1710	ea.																	4	6.8	4	6.8												
" " " (6 ch. 4 party sel. ring)	$1950	ea.									1	1.95																						
P.C.M. Subs. Carr. Ch. Bk. (12 ch. single party br. ring) – Both Ends	$1200	cct.																					1	14.4										
" " " " " 24 " " " " " " "	$720	"																																
Dig. Span Line Terminal & Switching With Order Wire – Both Ends	$2735	ea.																					1	2.7			1	2.7						
Max. 112 Lines Analog Subs Switcher / Concentrator (100 Lines)-Both Ends	$445	line															1	44.5	1	44.5	1	44.5												
" 128 " Delta-Mod. Subs Mulpx With TDM Sw/Conc " " " "	$470	"																									1	47.0						
" 256 " P.C.M. Mulpx With TDM Sw/Conc (100 Lines) Plus Span Line Sw-Both Ends Incl. Cabinets	$580	"																							1	75								
(OUTSIDE PLANT MATERIAL & EQUIPMENT)●																																		
Pole Route Hardware For Open Wire or Aerial Cable & Distribution Wire	$445	kft.	70	31.1	70	31.1	70	31.1			70	31.1	80	35.6	80	35.6			80	35.6									100	44.5	100	44.5		
Open Wire (Single Wire)	$63	"	264	16.6									2500	157.5															200	12.6				
Aerial Cable (6 Pr. 22ga.) With Splicing & Terminating Hardware	$245	"																	50	12.3														
" " (11 " Mixed 26 & 22ga.) " " " "	$275	"					45	12.4																										
" " 50 " 24ga. " " " "	$565	"													50	28.2																		
" Pair 19 " " " " "	$60	"			140	8.4					45	2.7																						
Buried Cable (11 Pr. Mixed 26 & 22ga.) " " " "	$190	"							45	8.5																								
" " 25 " 24ga. " " " "	$305	"															50	15.2			50	15.2												
" " 25 " 24 " -Screened " " " "	$350	"																					50	17.5	50	17.5	50	17.5						
" " 6 " 22 " " " " "	$180	"																															100	18
Aerial Distrib'n Wire With Drop Wire " " " "	$60	"	25	1.5	25	1.5	25	1.5			25	1.5	30	1.8	30	1.8			100	6.0														
Buried " " " " " " " " "	$100	"							25	2.5							30	3.0			100	10.0	100	10.0	100	10.0	100	10.0						
Loading Coil Case For 25 Coils – 1 per 6 kft. H88 / 4.5 kft. D66	$130	ea.			4	0.52									8	10.4	8	10.4																
Loading Coils	$5	"			22	0.1	10	0.1	10	0.1					200	1.0	96	0.5													23	0.1	23	0.1
Single Sta. Carr. Repltr. With Single Housing (kft) 1 per 30-19ga / 20-22 / 15-24	$555	"																																
Dual " " " " Dual " " " " "	$1060	"																	2	2.1	3	3.2												
Single " " Subs Terminal	$540	"									2	1.1																						
Dual " " " "	$1000	"									2	2.0																						
T-1 Type PCM Repltr. Hsng. / 3 Repltrs & 2 Load Coils 1 per 6 kft. 22ga.	$1625	"																							8	13.0								
" " " " " 2 " " " " " "	$1205	"																					8	9.6			8	9.6						
Buried Screened Cable																																		
(MISCELLANEOUS ITEMS)●																																		
Electronic Telephone Set	$70	"																															2	0.11
Ringing Range Extender For Subs Premises (Long Loops Grd Ring)	$50	line					16	0.8	16	0.8																								
				49.2		41.62		46.6		12.6		40.9		194.9		68.54		66.34		107.3		79.7		99.0		115.5		86.6		57.1		50.6		10.44
				$1970 Sub		$1665 Sub		$1865 Sub		$505 Sub		$1635 Sub		$1950 Sub		$685 Sub		$663 Sub		$1075 Sub		$795 Sub		$990 Sub		$1155 Sub		$870 Sub		$28.6 k/Sub		$25.3 k/Sub		$ k 9.22

NOTES –

1. GOPHER PROTECTION ADDS $150/kft. TO BURIED CABLE.
2. FIGS. BASED ON 130 FT. POLE ROUTE SPANS. LONG SPANS (260 FT) ARE SOMETIMES POSSIBLE WHEN LIGHTLY LOADED, AND WOULD HALVE THE STATED COST.

25 DISTRIBUTED SUBSCRIBERS

Initial System Costs - Equipment & Material

Fig	System Type	Feeder Type	Average Fill	Subscr. Distrib.	Subscr. Service	Subscr. Density	Furthest Subscr.	Mean Subscr. Distrib. Length	Load Plan	COST PER SUBSCRIBER (dollars)		
										All New Plant	Add New Feeder Circuits to Ex. Plant	Add Pair-Electronics to Existing Pl.
6	Physical	Open Wire	--	Aerial	4-party	1 per 2Kft	50Kft	3Kft	--	1970	665	
7	Physical	Aerial Pair	--	Aerial	4-party	1 per 2Kft	50Kft	3Kft	H88	1655	350	--
8	Physical	Aerial Cable	30%	Aerial	4-party	1 per 2Kft	50Kft	3Kft	H88	1865	530	--
9	Physical	Buried Cable	30%	Buried	4-party	1 per 2Kft	50Kft	3Kft	H88	505	370	--
10	Analog Station Carrier	Aerial Pair	--	Aerial	4-party	1 per 2Kft	50Kft	3Kft	--	1635	330	225

FIG.— 23

100 CONCENTRATED SUBSCRIBERS

Initial System Costs - Equipment & Material

Fig	System Type	Feeder Type	Average Fill	Subscr. Distrib	Subscr. Switching & Concentration	Subscr. Service	Trans. Prot. Switching	Furthest Subscr	Mean Subscr. Distrib Length	Load Plan	COST PER SUBSCRIBER ($)		
											All New Plant	Add new Feeder Circuits to Ex.Pl.	Add Pair Gain Electronics to Ex.Plant
11	Physical	Open Wire	--	Aerial	--	4-party	--	55Kft	1Kft	--	1950	1575	--
12	Physical	Aerial Cable	50%	Aerial	--	4-party	--	55Kft	1Kft	H88	680	305	--
13	Physical	Buried Cable	50%	Buried	Space Div.	1-party	--	55Kft	1Kft	H88	660	630	445
14	Analog Subscr. Carrier	Aerial Cable	33%	Aerial	Space Div.	1-party	--	55Kft	1Kft	--	1075	655	535
15	Analog Subscr. Carrier	Buried Cable	10%	Buried	Space Div.	1-party	--	55Kft	1Kft	--	795	695	545
16	PCM Subscr.	Buried Cable	25%	Buried	Space Div.	1-party	1.1	55Kft	1Kft	--	990	890	710
17	PCM Subsc. Carrier	Buried Cable	33%	Buried	Time Div.	1-party	1.2	55Kft	1Kft	--	[illegible]	[illegible]	[illegible]
18	Delta Mod Subs	Buried Cable	25%	Buried	Time Div.	1-party	1.1	55Kft	1Kft	--	870	770	595

FIG. — 24

2 EXTRA REMOTE SUBSCRIBERS

Initial System Costs - Equipment & Material

Fig.	System Type	Feeder Type	Avge. Fill	Subscr. Service	Furthest Subscr.	Load Plan	COST PER SUBSCRIBER
19	Physical	Open Wire	-	2-party	100Kft	-	$28,600
20	Physical	Aerial Pair	-	2-party	100Kft	D66	$25,300
21	Physical	Buried Cable	33%	1-party	100Kft	D66	$ 9,220

FIG.—25

7.8.2 Installation

The cost figures stated do not include the cost of installing the equipment and material.

The following factors, applied to the equipment and material costs in fig. 22 will give an order of magnitude for in-place costs. These factors are typical, but do not necessarily represent any specific situation as the actual in-place cost of an item depends on variable factors such as terrain, location, climate, accessibility, etc., as well as variations in structure, features, etc. of the equipment being installed.

In-Place Cost Factors

Pole route hardware	2.0
Open Wire	1.4
Aerial Cable	1.4
Aerial pair & distribution	2.8
Buried cable	1.5
Buried distribution pair	2.1
Buried screened cable	1.5
Electronic Equipment outdoors	1.3
Electronic Equipment inside buildings	1.1

7.8.3 Cost Analysis

The initial costs of equipment and material derived in fig. 22, are shown in figs. 23, 24 & 25 in terms of cost per subscriber for three different situations. The first situation is where all the equipment and material is new and is being provided for the first time. The second condition is where feeder pole routes already exist (in the case of aerial systems) and so does all the distribution material and hardware whether aerial or buried, and all that is to be done is to provide a new feeder including the cable and any associated hardware and electronic equipment. This would correspond to providing a new feeder facility to an existing community to provide growth potential. The third situation is where the feeder cable and distribution facilities exist and "pair gain" electronics plant is to be added to the existing physical facilities to handle growth that would shortly outstrip the capacity of those physical facilities. The models chosen, their various solutions and the types of equipment and material used are by no means exhaustive, but are illustrative of rural systems. Figure 22 permits other combinations and choices, and the construction of other hypothetical systems using the same hardware types, and it could also be expanded to include other hardware types. Furthermore, real systems are rarely "pure" in the sense of conforming strictly to one or other of the subscriber categories shown. A typical rural subscriber loop is likely to comprise a mixture of facilities, perhaps being part of a large urban cable for part of its length and then branching off into a variety of facilities of different types, sizes and constructions before eventually reaching the subscriber.

7.9 Performance Comparisons

Transmission objectives have been defined for subscriber loops, however, it is questionable to what extent these objectives are being met, particularly in regard to rural loops. Some surveys have indicated that one in five of all subscriber's loops are out of limits, so it could be expected that rural loops show a higher percentage than this.

Application of electronics to rural subscriber loops would most probably improve this situation.

In rural loop design today, the transmission objective is for a loop not to exceed 8dB for the actual required loss. The echo return loss should be no less than 18dB and the steady state noise should not exceed 20 dBRNC.

Measurements on voice frequency circuits in subscriber plant have shown that with voice frequency repeaters plus cable loading, loops can be within 4.5 to 6.0 dB with 19 dBRNC noise. Temperature variations have presented many problems when electronics have been applied and these can be quite severe when aerial cable is involved. Voice frequency repeaters with automatic gain control have largely overcome this problem.

Carrier equipment in general can readily meet these objectives, however, the reliability does not appear to be good enough for large scale application in telephone distribution plant and further improvements are needed.

Improvements Needed in Subscriber Equipment

a) The reliability of present equipment has improved but it is still not good enough. As an objective, the mean time between failures for an electronically derived telephone circuit should be not less than five years.

b) Maintenance features in subscriber equipment are now being added little by little. Continued advances are necessary. It should be possible for a telephone craftsman to check out all field-mounted equipment from the central office location. This should include the repeaters, subscriber terminal, and voice drop to the subscriber's telephone.

Status alarm indicators which monitor the operational state of the subscriber equipment should be a part of subscriber carrier equipment.

c) The design of the packaging and assembly of subscriber equipment should consider the capability of the telephone craftsman who will maintain it. The modules should be rugged to withstand normal handling practices encountered in a telephone company.

d) Field support of equipment varies widely among present manufacturers. Manufacturers must clearly understand that adequate support means prompt repair and return of service at reasonable cost.

e) Manufacturer's design changes and component changes too often cause unexpected field problems. New changes, especially cost-cutting changes, should be thoroughly checked by benefit of a field trial before releasing new equipment to customers.

Manufacturers are reacting to these requests for improvements as indicated in the latest product designs, but at some point there appears to be a limit when reconciling these improvements with the need to reduce costs.

7.10 Comparative Economic Cost Studies

In order to prepare valid economic data on alternative methods of providing service to subscribers, it is necessary to assess the complete economic impact of all factors affecting the first costs of implementation (in-place costs), and the recurring annual operating costs. Only by considering and comparing all of this data can a logical selection be made.

As, through interest, the cost of money is intimately associated with time, different cost items occurring at different points in time can only be validly compared in economic studies by expressing them in terms of a common date. Thus time is an essential element of a comparative economic study, not only because alternative construction programs (and hence their in-place costs) may occur at different times, but also because the operating costs of the alternative methods may not be uniform over the study period and alternative plans may not commence and finish in precisely the same time frame.

In order to make a comparison taking all of these factors into account, a commonly used method is to express both the first costs and the recurring operating costs in terms of recurring annual costs, or annual charges, in order to put them on a common base, and then to express the total recurring annual charges over the study period as a sum of money that would be required to be invested today to provide for all of the recurring annual charges over the study period. This sum is the Present Worth of Annual Charges (PWAC).

Most of the study effort goes into properly expressing the Annual Charges, which are comprised of the following elements:

Capital or "First Costs" Part

- Cost of capital (return on capital)
- Depreciation (capital repayment)
- Income tax (on the return on equity)

These costs are expressed as an annuity

Operating Costs Part

- Maintenance
- Property tax

These are already recurring annual charges

Annual charges are usually expressed as a percentage of first costs andgreat care must be taken to arrive at the correct factors. Such factors as retirement of existing plant, net salvage value, re-use of plant elsewhere, use of building space, etc., must all be taken into account. Telephone companies tend to develop standard annual charge factors to aid them in their economic studies and, as their circumstances usually differ, their factors may differ also.

7.11 Other Factors Influencing System Choice

Although the proper assessment of the relative economic advantages of alternative systems is an essential input to the decision making process, other, less tangible factors should also bear on the choice of system. Many factors are difficult to express in dollars and underline the importance of good engineering judgement in the decision making process. Some of the factors which may come into this category are as follows:

- The need for new or extended services outside of the study period.
- Eventual integration with another, developing network which is at the leading edge of new technology.
- Differences in availability of service as determined by suppliers' different equipment increments and also by different methods of failure rate analysis.
- The value of features such as touch-tone calling, traffic measurement and automated maintenance facilities.
- Terrain, ground composition, climate, icing, high winds, gophers.
- Accessibility of subscribers
- Lightning incidence and the presence of interference from adjacent power lines.

SECTION VIII

ANALYSIS OF RADIO SYSTEMS, COSTS AND PERFORMANCE

8.1 INTRODUCTION

The use of radio in the rural environment provides some elegant solutions to the communications problem, while the same properties that make it useful result in difficulties and restrict its use in other areas. It is necessary to take advantage of its good properties, while attempting to minimize the shortcomings by good engineering.

The following description considers systems where the subscriber is served directly via a radio link. There is also some discussion of low-capacity, low-cost, multi-channel point-to-point radio systems that could be utilized for connecting circuits.

Within certain limitations, it is generally true to say that radio propagation tends not to be restricted by distance and the radio waves tend to spread out over a large area. These characteristics can be desirable in a public broadcast station, while in instances where it is necessary to establish a communications channel between two specific individuals, the arrangement is wasteful of the frequency spectrum if each individual must be assigned a separate frequency of operation.

However, in rural areas where large distances have to be spanned and the population densities are low, the radio approach seems to hold promise, particularly as the circuit cost is not directly related to distance.

8.2 THE RADIO FREQUENCY SPECTRUM

The radio frequency of operation is an important consideration in determining the propagation characteristics and so is the proper use of the particular band in order to derive most benefit from its utilization.

The lowest frequency bands available for rural communications occupy a number of allocations within the high frequency (HF) band of 3 MHz to 30 MHz. This band of operation is noted for its extremely long range of communications made possible by "skywave reflections", that is, reflections of radio waves by the ionosphere. Communications over thousands of miles are realized without the use of high RF power.

These propagation characteristics are, however, very unpredictable and subject to interference due to the freak nature of propagation and the long range obtainable. The long range is an advantage to "reach out" while at the same time restricting the reuse of frequencies because of the possibility of interference over large geographic areas.

The HF band is, therefore, used for long-range voice and telegraph communication, such as communication to ocean-going ships. However, some of the more essential services in this category are now being replaced by satellite communication.

The next available band of interest is the frequencies in the region of 150 MHz. Essentially, this band is primarily allocated for two-way mobile radio communications, with fixed communications usually permitted on a secondary basis.

The propagation in this band is fairly well predictable and transmissions beyond line of sight are possible. Most present-day subscriber rural radio systems operate in this band.

Frequencies around 450 MHz are also available for rural communications systems, but again, they are primarily intended for mobile radio service.

Higher in the frequency spectrum available for public communications, is the band 890 MHz to 960 MHz. This band is intended for low-capacity point-to-point systems, such as may be found in the rural areas. This band is generally used for point-to-point communications and requires line of sight between antennas. The higher frequency bands, i.e. microwave bands, are generally allocated for use as bearer circuits for high voice-channel density telephone service and TV circuits.

The exception to the use of microwave for high-density systems is an allocation 1429 MHz to 1525 MHz set aside by D.O.C. specifically for rural radio. This band appears to hold a lot of promise for rural use.

This report contains a description of a rather unique

1.5 GHz rural subscriber radio system. An interesting development in the U.S.A. is the recent opening up of the 900 MHz frequencies for mobile radio usage. In Canada, the corresponding frequencies are presently allocated for broadcasting and fixed milti-channel systems.

8.3 GENERAL RURAL RADIO - HISTORY AND BACKGROUND

The use of rural subscriber radio appears to have been restricted in growth for a number of reasons. Telephone company outside plant people appear to have regarded radio as too complex a device, unreliable, costly and difficult to maintain.

This has resulted in subscriber radio being used only as a last resort to provide communications. This type of service is often used to provide circuits to fishing camps and remote resorts (camp phone). One advantage of this approach is that the subscriber radio can be easily reused someplace else when the service is no longer required.

Subscribers have found in the past that radio has had some characteristics that have set it apart from the normal telephone system. Special operating techniques, such as push-to-talk and release-to-listen were necessary. Most likely the voice quality was very poor. At any rate, all of these factors appear to have contributed to the limited use of radio.

Other applications of radio in the rural environment have been for two-way mobile car radio and to a limited extent for paging.

Foreign manufacturers had made special adaptations of radios for rural use for special cases, but there seems to have been a lack of active marketing of this product. Other suppliers have had rural radio products in their home country that did not meet the local requirements or were not marketed here because of the small volume. In Canada it was not until about 1968 that International Systems developed a rural VHF radio that performed like an extension to the subscriber loop and operated like an ordinary telephone.

Along with the general trend towards using more electronics in the telephone plant, there is significant evidence that with the greatly improved reliability of radio, the use of improved automatic control, and the integration with line concentrators, a great deal more radio will be applied on the rural scene.

It is also quite apparent that there is a definite trend to utilize radio in serving the subscriber as a "transparent device", i.e., the end user is not aware that he is talking over radio.

It is only recently that Motorola has announced a sophisticated VHF rural radio system that includes line concentrator equipment and has the option of 8 VHF, RF channels shared equally by a number of subscribers. This equipment works as an extension to the subscriber loop. As far as it is known, all previous systems in Canada have been of the single RF channel variety.

To overcome the problems of RF bandwidth limitations in the VHF band, that result in poorer noise performance, the Farinon S/R equipment has been developed. This employs the latest technology in an integrated radio and switching system intended specifically for rural communications, and from the system point of view is engineered for permanent facilities in an integrated subscriber network.

8.4 OUTLINE OF AVAILABLE RURAL RADIO SYSTEMS

Summary of present radio systems used for rural service:

1. Simple HF radio with push-to-talk, release-to-listen and voice calling. This mode of operation is also used with VHF or UHF.
2. Single RF channel VHF or UHF rural radio providing regular telephone service.
3. Multi-channel rural radio providing regular telephone service to a number of subscribers, including a line concentrator to enable efficient sharing of the assigned radio channels.
4. Multi-channel point-to-point radio systems.
5. 1.5 GHz microwave rural radio providing regular telephone service, including a line concentrator to provide private line service to a number of customers.
6. Mobile radio telephone service.

7

8.5 DESCRIPTION OF AVAILABLE SYSTEMS

8.5.1 Simple HF Radio with Push-to-talk, Release-to-listen Operation

The HF (high frequency) band is considered to extend from 3 MHz to 30 MHz.

This equipment is normally used as an ordinary two-way radio with push-to-talk, release-to-listen and voice calling operation. It is not provided with the features associated with a regular telephone.

The use of HF Single Side Band (SSB) equipment has been phased out wherever possible because of unpredictable propagation characteristics. It is retained only for communications to the most remote, isolated communities of say 60 or more miles from a populated area. This simple type of radio operation has also been used for communications in the VHF band, over shorter distances.

The cost of a SSB HF radio terminal is $2,000 - $3,500 depending on the number of frequencies available and other technical features. The total cost of the radio link would be twice the above amount.

8.5.2 Single RF Channel VHF or UHF Rural Radio Providing Regular Telephone Service

This type of operation provides a service that is compatible with standard telephone service with the radio link acting as an extension to the subscriber's loop. This equipment operates in the 150 MHz frequency range and uses FM modulation. The 450 MHz band is also available for this service. The radio operates in a full duplex mode, with supervision, ringing and dial service and is in every way comparable to standard telephone service.

An RF frequency separation of 5 MHz is required between the transmit and receive frequencies for full duplex operation.

8.5.2.1 Hardwired Party-line Operation (Fig. 26)

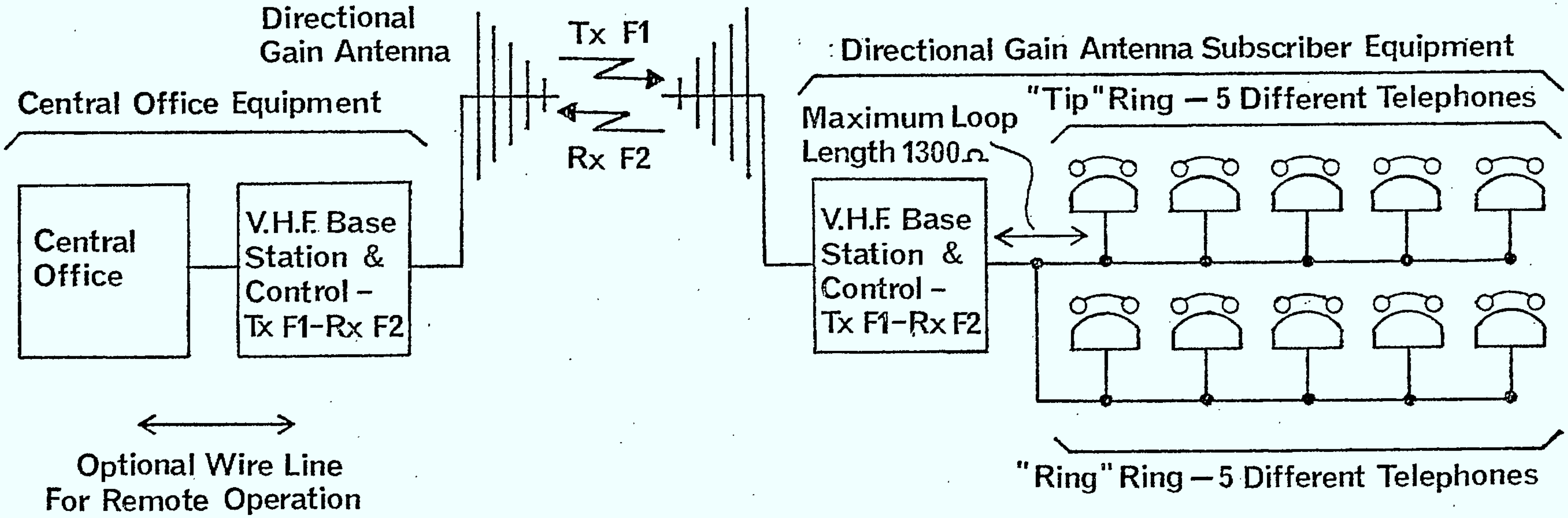
Two basic systems arrangements are possible. The first type of system uses a single subscriber radio terminal and may have connected to it up to 10 hardwired party-line telephones, as illustrated in Fig. 26. The central office terminal can be equipped to selectively ring any one of the ten parties by a combination of divided ringing and frequency selective ringers on the telephone set. Calls originating from the subscriber terminal are not usually identified as to the originating party; hence, toll calls must be intercepted by an operator. There is no provision for privacy between the subscribers connected to the common radio base-station. Anyone can pick up the telephone and listen in. This arrangement makes no provision for signalling between local subscribers; however, this feature could be incorporated as an extra.

8.5.2.2 RF Party-line Operation (Fig. 27)

The second type of system is to have several subscribers each with their own subscriber radio terminal sharing a common central office VHF base-station and a common pair of radio frequencies. This arrangement is shown in Fig. 27.

— SINGLE CHANNEL V.H.F. RURAL RADIO —

OPTION 'A' HARDWIRE PARTY LINE



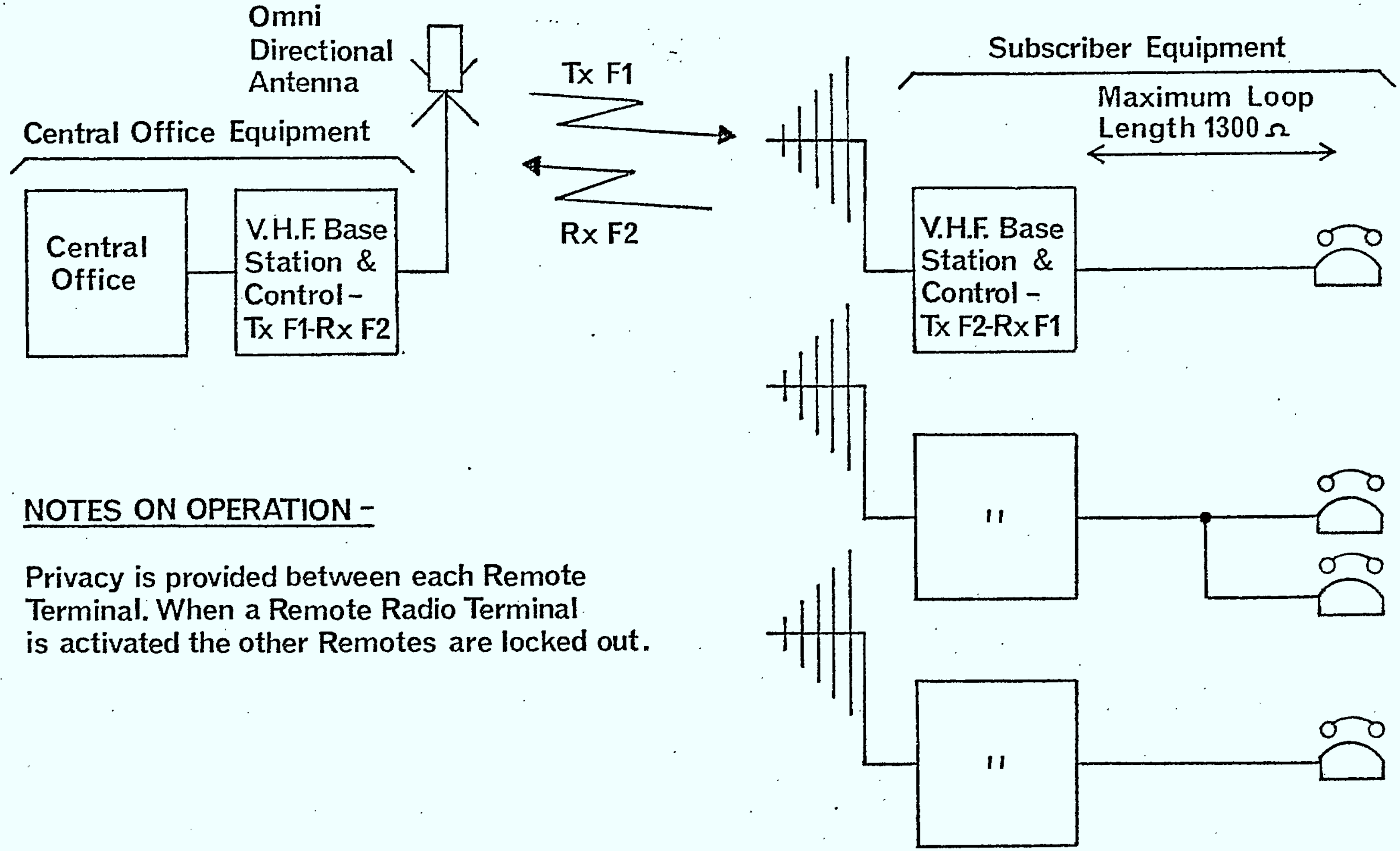
NOTES ON OPERATION —

1- Directional Gain Antennas can be used at both the Central Office and Subscriber location for Extended Range Communications.
2- Selective Ringers can be used at the Subscriber Terminal, to Selectively Signal up to 10 Subscribers.
3- Privacy is not provided.

FIG.— 26

– SINGLE CHANNEL V.H.F. RURAL RADIO –

OPTION 'B' R.F. PARTY LINE



NOTES ON OPERATION –

1. Privacy is provided between each Remote Terminal. When a Remote Radio Terminal is activated the other Remotes are locked out.

FIG.– 27

In this type of operation only one subscriber at a time can activate his transmitter. The first subscriber that activates his transmitter locks out the other remote transmitters.

This type of operation provides privacy of conversation. Automatic subscriber identification may or may not be provided on the calls originated by the subscriber depending on the manufacturer. The subscribers can be provided with a feature whereby they can call each other directly over the radio channel. To accomplish this, the frequency of the transmitter must be changed to make the subscriber transmit on the same frequency as the central office unit. The local calls are carried out on a simplex basis with push to talk and release to listen.

Both of the above systems normally use in-band dual tone signalling for all supervision, ringing and dialling.

The radio terminals can be located remotely from both the C.O. and the subscriber set, for a maximum subscriber loop resistance of 1300 ohms. The subscriber equipment is designed to be mounted in outdoor enclosures.

APPROXIMATE EQUIPMENT COST

Subscriber radio terminal	$1,800
Subscriber antenna system	$ 300
Central office base station	$2,000-3,000
*Central office antenna system	$ 700

* This assumes that either an existing tower is available at the C.O. or a simple pole is adequate for a support structure.

8.5.3 Multi RF Channel Rural Radio Complete with Line Concentrator

Presently only Motorola offers a VHF rural radio system that can be equipped with up to eight RF channels and includes a line concentrator that enables these channels to be shared at random on a first-come, first-served basis between all of the subscribers. Any reasonable number of subscribers can be allocated a number of RF channels based on the traffic pattern and the acceptable level of service. Fig. 28 shows the block schematic of this arrangement.

Each of the remote subscribers is equipped with a subscriber radio terminal to provide private-line or party-line service if necessary.

As was the case with the single-channel rural radio, the subscriber terminal can be located outdoors and remote from the user. The Motorola system has, however, a rather short subscriber loop limit of 300 ohms.

The equipment includes a number of features to facilitate maintenance. The most important of these is the ability to test the subscriber loop remotely from the C.O. This test can be completed without the involvement of the subscriber. Protection of the subscriber's telephone line against lightning and other voltage transients caused by power lines is included with the standard equipment.

Extended range can be achieved by including an optional RF repeater, and a single RF channel option is also available.

NOTES ON OPERATION

1. Each "on hook" subscriber radio terminal continually scans all idle RF channel monitoring for possible calls.

2. Each subscriber has been assigned a 4 digit call number. This same number is used to automatically identify each calling originator.

3. Each subscriber radio provides full duplex operation complete with busy tones, supervision over any of a number of RF channels available.

4. Once connection has been established the system becomes "transparent". The radio and associated equipment becomes an extension of the cable.

—MULTI-RF CHANNEL V.H.F RURAL RADIO WITH FULLY AUTOMATIC OPERATION—

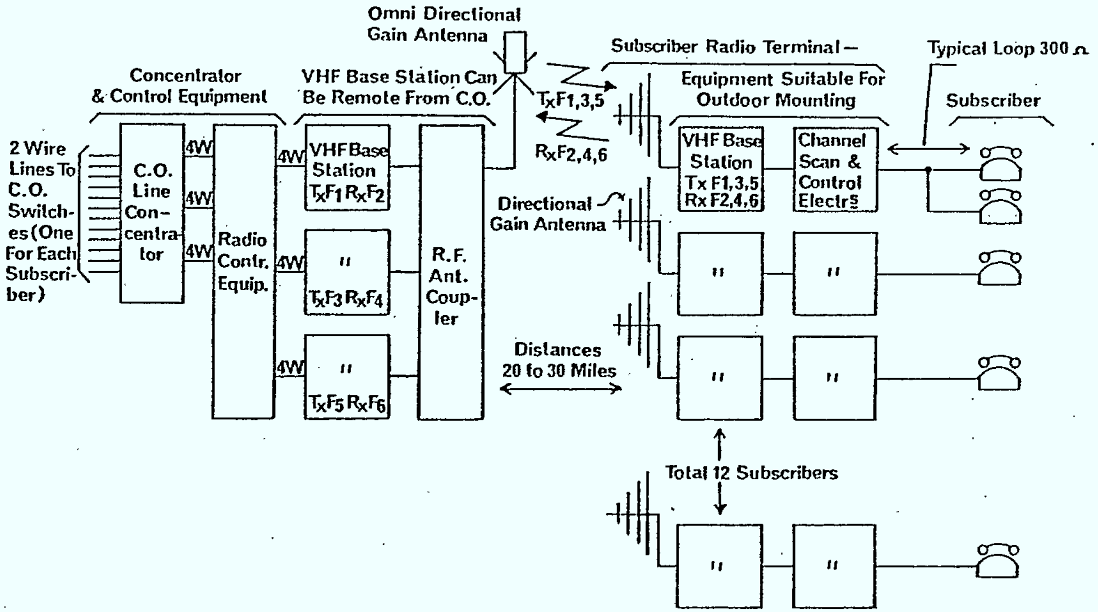


FIG.— 28

Further details of the system operation are given in Vol. II - VII of the data base.

Approximate costs for equipment of this type would be as follows:

C.O. base station equipment - first RF channel	$3,350	
Each additional C.O. base station	$1,650	(per rf channel)
Each subscriber line at the C.O.	$ 500	
Subscriber radio terminal	$1,800	

8.5.3.1 Performance of VHF and UHF Rural Subscriber Radio

What makes the 150 MHz VHF and 450 MHz UHF frequency bands attractive for subscriber rural radio application is that line of sight is not required for reliable communications, the propagation performance can be predicted to a reasonable degree, and these frequencies are not subject to long-distance freak propagation that limits the re-use of frequencies of the HF band.

The distance that can be obtained between the central office and the subscriber radio, while maintaining propagation reliability and noise performance, depends on a great number of variables, but distances of 20 to 30 miles are normal.

Much longer distances can be obtained by sacrificing performance or by taking advantage of a mountain or a high tower. In a system where a strong radio signal exists, the idle noise performance of this type of service is typically 38 dBRNC. This noise performance can then be relaxed to whatever is considered acceptable. The objective of the telephone company is 20 dBRNC for the subscriber's loop.

Despite the fact that the radio does not meet the subscriber loop objective, the circuit will still be judged to be quiet. Also in an actual telephone circuit there would be considerable noise contribution from other sources in the overall connection.

8.5.3.2 Options Available on VHF and UHF Rural Subscriber Radio

The system range can be doubled by including an RF repeater at the middle of the system, and additional service features such as pay phone can be incorporated, while paging and mobile radio systems can be included in this type of operation for very little extra cost.

8.5.4 Multi-Channel Point-to-point Systems

During the early 1960 period, there was widespread use of multi-channel point-to-point systems to provide service to rural communities. Equipment of 4 to 24 voice channel capacity was designed and manufactured in Canada by Lenkurt Electric of Vancouver for operation in the 150, 450, and 900 MHz bands. Equipment designed in the U.S.A. was also manufactured by Farinon Electric in Montreal and Northern Electric (Telecom) acquired a license to manufacture a U.S. designed 450 MHz equipment.

Following this radio development, lower cost, low-capacity single sideband multiplex was designed in Canada by Lenkurt Electric and Northern Electric, and Farinon manufactured new U.S. designed equivalents.

Because of frequency congestion and the secondary position of fixed radio systems in these bands, the demand for these types of systems in Canada has decreased somewhat and some manufacturers did not progress into the all solid state versions in these frequency bands. At present the 2 GHz band is mostly used for these types of systems.

As mentioned earlier, the 150 MHz band is particularly suited to low voice capacity communications when line of sight conditions do not exist. The availability of high RF output power and directional gain antennas, with reasonable equipment cost, often make this type of system the only practical choice for some rural systems that have very light voice loading.

The facts that the antenna system is less costly than that of a microwave system, and that the supporting tower does not require the same rigidity as would be necessary for a microwave system, nor is line of sight required, all contribute to the lower overall systems cost.

Motorola has this class of equipment available in a solid state version in Canada with a maximum capacity of 8-voice channels. When used with a concentrator this radio system can effectively serve approximately 64 subscribers.

Pye Telecom has a similar type of point-to-point radio equipment that can act as a bearer for 2 voice-channels.

The performance of this system can be designed to be within the telephone company subscribers' loop noise objective of 20 dbRNC under favorable conditions.

Approximate Equipment Costs

Radio terminal	$5000
Each multiplex channel (both ends)	$1600-2500

Several manufacturers have multi-channel point-to-point equipment in this frequency 450 MHz band. This band retains some of the desirable characteristics of the 150 MHz part of the spectrum, but due to the lower RF output power available and the higher propagation losses, operation beyond line of sight becomes increasingly difficult. This is particularly the case in multi-channel applications where a good RF signal level is essential.

Radio equipment capable of channel loadings of up to 60 voice channels are available in this band.

A limited number of frequencies have been allocated for point-to-point service in this band. However, generally speaking, the 415 MHz to 470 MHz band has been allocated to terrestial mobile radio service on a priority basis with fixed point-to-point systems being licenced on a secondary basis only.

Approximate Equipment Costs

450 MHz radio terminal	$5,000

Point-to-point equipment in the 960 MHz band is readily available from a number of suppliers with up to 120 voice channel loading capability.

Approximate Equipment Costs

960 MHz radio terminal	$5,000

In Canada, the 1429 MHz to 1525 MHz frequency spectrum has been allocated for low capacity point-to-point and subscriber rural radio, however, there does not seem to be very much point-to-point radio equipment available for this band at this time. It is widely used overseas and Pye Telecom, a subsidiary of the Philips group, have the L313 equipment that provides a bearer circuit for up to 60 voice channels.

Microwave systems operating in the 2GHz, 4GHz, 6 GHz and 11 GHz bands are intended for higher-density systems and would normally not find application in the rural environment.

8.6 SUBSCRIBER RADIO (S/R) MICROWAVE RADIO SYSTEM (Fig.29)

Systems that require multi-voice channel capacity are eventually being crowded out of the 150, 450 MHz bands as the demand for mobile radio systems increases. In the U.S.A. the 900 MHz band is also being used for mobile services. With the allocation of radio channels in the 1.5 GHz band for subscriber rural radio, Farinon Electric of Montreal has developed and is now in the manufacturing phase of a system that offers a novel application of state-of-the-art technology to provide a composite system of radio and switching equipment designed to integrate with hard-wired telephone systems in the rural environment.

This system is not intended to compete with existing stand alone VHF rural radio (sometimes referred to as fringe area radio by the telephone companies), but is intended

SUBSCRIBER RADIO MESSAGE FORMAT AND MODULATION

1. Each voice circuit (maximum 15 at any one time), is allowed a time slot in each word transmitted.
2. The 16th time slot carries synchronization and "housekeeping" information.
3. The time slot allowed for one voice channel is modulated by the relative position of a short pulse. The position of the pulse in relation to reference is analogous to the voice amplitude.
4. The voice and housekeeping channel is then FM modulated in a bipolar data stream.

DESCRIPTION OF BASIC OPERATION

1. Central office terminal and outlying station operation is synchronized at all times.
2. Central office transmitter is on continually transmitting sync and voice modulation to all of the 200 lines over the 15 trunks allocated for voice modulation.
3. The outlying stations reply one at a time by activating their transmitters to return voice modulated messages from the subscriber assigned lines. Each outlying station transmitter is on for only a few microseconds to transmit the necessary information.
4. Each subscriber is addressed directly rather than having an association with the outlying station.
5. The operations are fully automatic in all respects to regular telephone service. The user is not aware he is talking over radio.
6. All ringing options presented to the subscriber radio equipment at the C.O. are duplicated at the outlying station serving the subscriber.

SIMPLIFIED SYSTEM

When only 16 subscriber lines are served, the line concentrator equipment is not required and the system operation is greatly simplified.

— FARINON MICROWAVE SUBSCRIBER RADIO S/R—

BLOCK SCHEMATIC

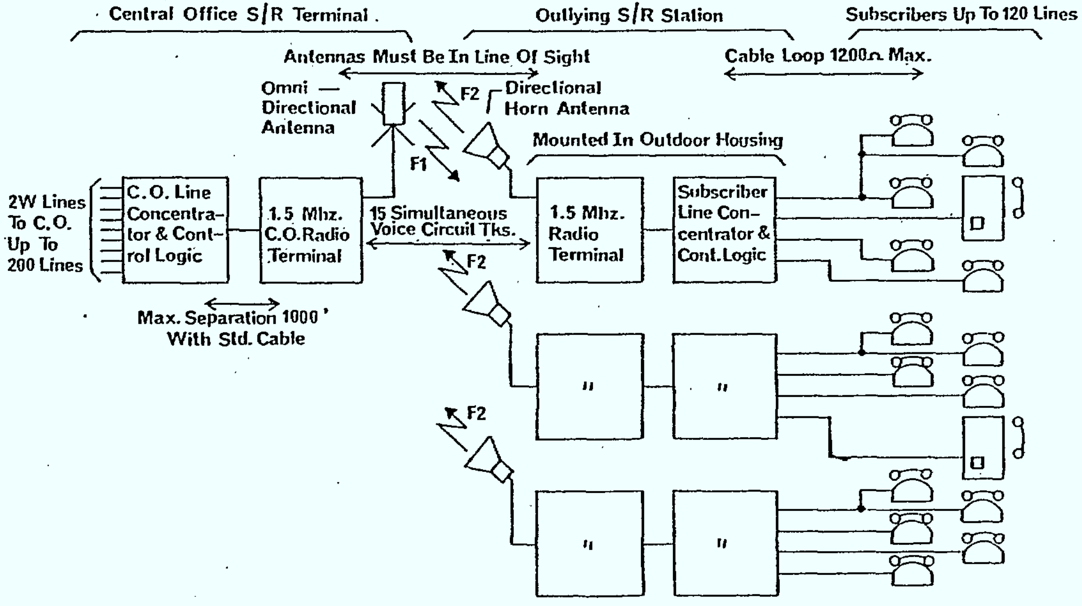


FIG.— 29

to serve subscribers where line of sight transmission can be established between the Central Office and the subscriber radio terminal, and reduces costs for subscriber loops of 10 to 20 miles from the Central Office.

Some of the shortcomings often attributed to radio systems have been circumvented by designing a system that needs a minimum of field adjustment and provides reliable service. The design objective has been to provide a Mean Time Before Failure (MRBF) of 30,000 hours for any line. The equipment is a.c. operated, but the design is such that the outlying station can be powered from an ordinary 12 v car battery under emergency conditions.

Three S/R radio systems were originally on field trial, presently only one remains. Additional systems will be placed in service in the near future, but the equipment will not be available from normal production until 1977. Future plans call for the development of an RF repeater for extended range communications. The system arrangement is illustrated in Fig. 29.

A budgetary estimate for a subscriber radio terminal and say eight remote or outlying terminals serving 50 lines would be about $75,000 and with the other necessary items such as antennas, towers, transmission lines, the cost per subscriber line would be in the range of $2,000 to $3,000. For loops of 10 to 20 miles or so, this could be a very economical solution to the problems of rural distribution.

The objective is to achieve a similar performance or better than that obtained on short urban loops so that the radio facility appears to be "transparent" to the subscriber.

8.7 MOBILE RADIO SYSTEMS

In rural areas people are out of reach of the telephone for long periods of time and mobile services could find wider applications. Various systems using paging, portable telephones and rugged mountain top radio repeaters are available and are described in the literature provided in the data base. Plug-in mobile radios are available that can be plugged into a car adapter and when removed, they become hand carried units operating from re-chargeable batteries with reduced RF output power.

There are other developments, not related directly at this time towards rural applications, but rather pointing in the direction of future developments, that certainly deserve some attention. The most significant of these is the opening of the frequency band of 806 to 960 MHz in the U.S. for mobile radio use. 115 MHz of band-width is available for two-way mobile radio use. As a direct result of this, a number of large communications companies plan a highly complex mobile radio communications system, referred to as the cellular system, for large metropolitan areas. This system is based on a network of limited coverage cells working with low-power mobile radio telephones. Extensive geographic re-use of frequencies is built into the systems design. This provides for a better utilization of frequencies rather than relying on the past approach of using the highest possible antenna site and the highest possible RF power for providing a usable signal over as wide an area as possible. The system is designed for a systematic and orderly growth. Inherent in the design is extensive use of computers to identify the parties, signal, set up connections and switch the mobile from one base station to another as the signal from one becomes weak and that of another becomes stronger.

Presently, advanced paging and mobile radio communications are available from a number of U.S. manufacturers such as Martin Marietta Corporation, Motorola, and others.

Motorola has developed an experimental hand-held radio telephone referred to as DYNA T.A.C. The name refers to Dynamic Adaptive Total Area Coverage. The fixed base station equipment working in conjunction with the portable equipment involves one high-powered central transmitter and a number of strategically-located receiver sites. A number of receiver sites is necessary because of the low RF power output of the telephone. All of the fixed receivers connect to a central point where "voting" takes place to determine which is the best signal to be allowed to pass through.

This experimental telephone incorporates a number of novel features and demonstrates the high complexity that can be put into a small package when using large-scale integration.

8.8 COST FACTORS IN RADIO COMMUNICATIONS SYSTEMS

In this section typical cost elements of radio system are listed. Based on the equipments costs indicated earlier and the addition of the tower, antenna costs, etc., the cost per subscriber are computed for each of the system configurations.

8.8.1 TYPICAL RADIO SYSTEM COST ELEMENTS

8.8.1.1 COST OF SUBSCRIBER TYPE OF VHF RADIO SYSTEM

Typical Central Office Costs

The following assumes that a building exists -

Cost of light 100 ft. guyed tower installed	$5,300.00
Equipment rack & miscellaneous material	$ 200.00
Simplest antenna system	$ 350.00
High gain omni directional antenna system	$ 850.00
Simple single channel radio terminal	$2,400.00
3RF channel radio including line concentrator for 25 subscribers	$18,430.00
Multi-coupling equipment for 3RF channels	$ 800.00

Typical Subscriber Terminal Costs.

This assumes that the radio terminal is located near the subscriber's location.

Subscriber Radio Terminal	$1,800.00
Simple gain antenna system, pipe mounted to the side of an existing structure.	$ 170.00

Miscellaneous installation materials	30.00

8.8.1.2 OTHER MAJOR COST ITEMS ASSOCIATED WITH RURAL RADIO SYSTEMS

Tower and Support Structures

The following towers are intended for light loads such as those that are typically used for VHF subscriber radio. The prices should be used as a guide only, since the cost of each tower involves a great number of variables, each affecting the end cost.

The following towers could also be used for 150 MHz, or 450 MHz point-to-point radio system. They would be inadequate for 900 MHz point-to-point radio with the exception of the guyed towers.

100 ft. guyed tower installed	$5,300.00
150 ft. guyed tower installed	$8,000.00
200 ft. guyed tower installed	$12,800.00
100 ft. self-supporting tower installed	$15,500.00
150 ft. self-supporting tower installed	$30,000.00
200 ft. self-supporting tower installed	$52,000.00
60 ft. wooden pole installed	$1,500 - $2,000

Low cost TV antenna masts may be used at the subscriber end for support structure.

8.8.1.3 COST OF POINT-TO-POINT RADIO SYSTEMS

The following provides some order of magnitude costs of the major items in point-to-point communications systems. Actual costs will vary greatly depending on the specifications of the items in question, source of supply and the discounts negotiated. The following figures should be used as a guide only.

Buildings

8 ft. x 10 ft. prefabricated building	$2,500.00
8 ft. x 8 ft. fiberglas building	$5,000-$6,000

Voice Multiplex

Each SSBSC voice multiplex channel	$2,500.00

Access Road

Short access road	$3,000.00

Commercial Power

Typical short commercial a.c. power connection	$1,500.00

Standby Power

The cost of standby power can vary greatly depending on the type of system. Standby power could mean an expensive diesel generator or it could, in some instances, mean a simple standby battery. A good approach is to select equipment that works directly from d.c. Then a charger is provided to convert commercial power to d.c. and feed the output to storage batteries. The communications equipment is permanently connected to the batteries. The cost of such a system will depend on the number of hours of standby working required and features of the design.

Average cost of charger and battery plant	$1,000 - $3,500

Antenna System

Typical medium gain antenna system of 150 ft. tower

150 MHz System	$ 650.00
450 MHz System	950.00
960 MHz System	1,350.00

8.8.1.4 SERVICES

The direct cost of services will vary greatly. The cost of installation will vary even more, depending on the remoteness of the location, travel cost, and other factors.

Some typical figures that may be used are suggested below for budget costing of radio systems.

Installation at central office	8-12% of equipment costs.
Installation at remote locations	12-18% of equipment costs.
Engineering	5% of equipment costs.

8.8.2 COST OF TYPICAL RADIO SYSTEMS

The following provides per subscriber costs of some typical radio systems based on the cost considerations of the previous paragraphs.

The cost figures include installation, engineering and make an allowance for shipping charges.

While in all of the systems it is possible to locate the C.O. radio terminal remote for extended range, this has not been included. It is further assumed that the subscriber terminal will be mounted outdoors within a relatively short distance from the subscriber.

8.8.2.1 SINGLE RF CHANNEL VHF RURAL RADIO SYSTEM

This type of system provides normal telephone service over a radio link to a subscriber 20-30 miles from the C.O. The subscriber radio can provide private line service to a single subscriber or it can serve up to 10 subscribers on a party-line basis with selective ringing.

Because of the point-to-point nature of this system, high gain directional antennas can be provided at both the C.O. and subscribers end. The cost of the antenna structure has a significant effect on the system cost.

	Simple Pipe Mounted Antenna at the C.O.	100 ft. Guyed Tower at the C.O.
Private line service to one customer	$6,180	$11,480
4-party service cost per subscriber	$1,665	$ 2,990
10-party service cost per subscriber	$ 740	$ 1,270

NOTE: It is also possible to provide party-line service over a common RF channel to a number of radio-equipped subscribers. This type of service provides privacy. Each additional subscriber radio terminal would cost about $2,000.

8.8.2.2 4 RF CHANNEL VHF RURAL RADIO SYSTEM

This system provides 4 trunk lines to be shared equally by 25 subscribers. The system includes VHF radio, line concentrator and associated equipment. Under normal conditions about 5% of attempted calls would be blocked during the busy hour.

It has been assumed that a 100 ft. guyed tower would be required at the C.O.

Cost per subscriber with private line. (Each subscriber will be equipped with a VHF radio terminal)	$4,070
Cost per subscriber with 4-party line service per each subscriber VHF radio. (100 subscribers with reduced grade of service.)	$1,380

8.8.2.3 1.5 GHz SUBSCRIBER RADIO SYSTEM SERVING 50 SUBSCRIBERS

This system costing assumes 50 subscribers served by 9 outlying stations all sharing 15 trunks. A 100 ft. tower has been assumed at the C.O. The outlying stations would use wooden poles for antenna support with the equipment (outlying station) attached to the pole. Wiring to each subscriber is included.

Cost of each private subscriber line	$2,140
Cost of 4-party line service	
cost per subscriber	$ 625

8.8.3 OTHER COST FACTORS

As discussed in Section VII, the basic equipment and material costs, have other costs added to them when determining the total price to the end user.

The factors that have to be considered are as follows:

Preliminary planning & feasibility studies.
Engineering & preparation of specifications.
Evaluation of tenders & negotiations
Surveys
Purchasing
Right of way easements
Land acquisition
Legal fees & licences
Insurance
Storage
Access roads
Buildings
Primary power
Standby power
Equipment rentals
Transportation
Contract Management
Modifications & changes to original design.
Carrying charges
Site preparation (clearing, etc.)
Shipping charges & packing
Cost of equipment
Installation
Installation materials
Testing & optimization
Test equipment costs
Manuals
Documentation and records

The ultimate price that a telecommunications end user must pay also includes the cost of operation. This is sometimes referred to as the recurring cost. The recurring cost is concerned with costs after the equipment is placed in service and must include all items associated with maintaining the equipment in good working order. It is important to remember to include an allowance for the overhead.

Good engineering must always consider economics and this should not be limited to the first non-recurring cost, but must include assumptions as to the useful life of the equipment and the cost of maintenance. Most communications companies use the above factors along with the "cost of money" to arrive at what is referred to as equivalent annual cost. The equivalent annual cost then serves as an equitable way of evaluating what will be the most economical system to implement.

In actual systems, depending on the competitive situation, list prices are discounted depending on the quantity involved. When electronics are sold as part of an overall integrated system, they are not, as a rule, discounted. Some equipment sold as "hardware," such as antennas and transmission line, when sold to a manufacturer for resale as part of an overall communications systems, are typically discounted by about 20-25%.

It is apparent that it is an absolute necessity to add further refinements to this basic equipment analysis before the end costs of placing telephone service in rural communities can be arrived at and the most economical solutions determined. Radio systems, since the cost of them is not distance dependant, will continue to find application in subscriber distribution networks. However, it is required that they be designed into the permanent facilities as an essential part of them and not be considered as stand alone items.

8.9 CONCLUSION

VHF rural radio equipment for direct radio links between the C.O. and the most isolated and remote subscriber's premises is readily available. From the standpoint of the initial in-place cost this approach is attractive considering the distance that can be spanned without difficulty.

Of the systems considered for rural telephone service, the Farinon Canadian developed 1.5GHz S/R radio is the most applicable product design, combining radio and concentrator in a single integrated package, that is engineered to complement the hardwired rural subscriber distribution plant. The Farinon S/R radio will be on the market in the near future and it will be most interesting to monitor the general acceptance and performance of this product.

Another significant Canadian radio equipment development is that of a point-to-point low capacity MCS 6900 digital radio by Canadian Marconi. This system combined with line concentrators could provide an all digital facility similar to the Digital Multiplexer Subscriber system described in the line transmission section. However, it does not seem that this product would find application in the rural market at this time.

Judging by new product developments and availability of higher frequencies, it is reasonable to conclude that more rural service could be provided by means of radio systems in the future.

A STUDY OF THE AVAILABLE
PRODUCTS AND SYSTEMS FOR
RURAL TELEPHONE COMMUNICATIONS.