Discussion Paper

INTEGRATED DISTRIBUTION OF BROADBAND AND NARROWBAND COMMUNICATIONS SERVICES IN RURAL AREAS WITH COAXIAL CABLE

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1. INTRODUCTION

Traditionally, telecommunications services have been provided through separate narrowband and broadband distribution facilities. This overlay of facilities, while uneconomical in many respects, has not posed any significant problem on the development of telecommunications services in urban areas, as these facilities can individually be supported through the large revenue base available in such areas.

In rural areas, however, the implementation of a stand-alone distribution facility, whether broadband or narrowband, becomes a very costly undertaking and, because of the relatively small revenue base, becomes economically unviable in many cases. As a result, while most city dwellers have access to ten or more distinct television channels through a broadband cable TV system, cable TV services are virtually non-existent in rural areas. As for the narrowband telephone service, the penetration is relatively higher, due in large part to the policy of cross-subsidization exercised by telephone companies. However, there still exists a large gap in the quality or level of service between rural and urban areas.

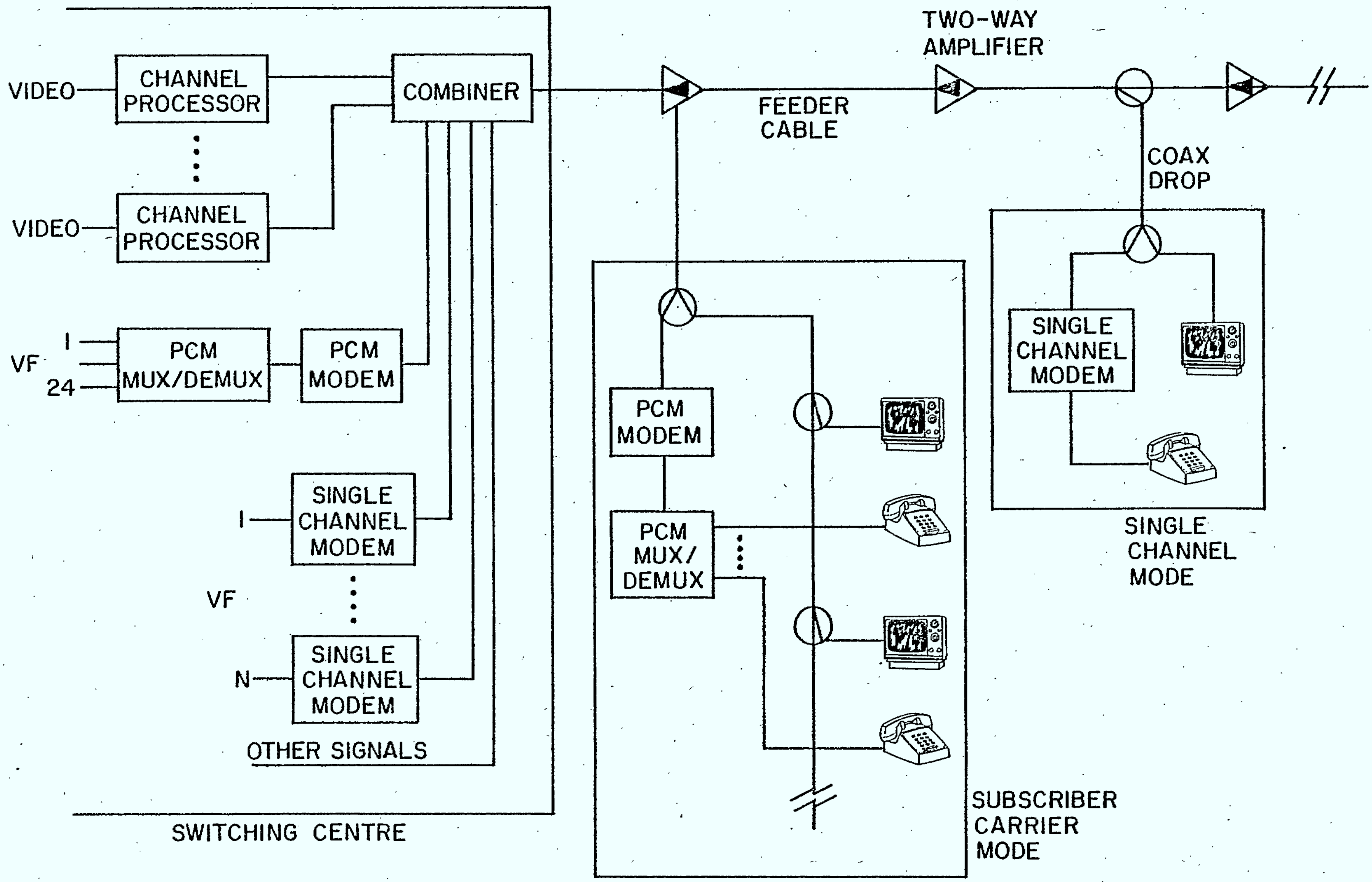
In this document, the technical, economic and operational feasibilities of using a single coaxial cable based broadband distribution network for the provision of broadband and narrowband communication services in rural areas are examined.

2. DESIGN OF INTEGRATED COAXIAL CABLE SYSTEMS

2.1 System Configuration

Basically, an integrated coaxial cable distribution system for telephony, video and other broadband and narrowband services can be implemented in the same way as a conventional two-way tree-structured CATV system. In addition to standard CATV hardware, however, equipment to modulate/demodulate and multiplex/demultiplex telephone and other signals for transmission over the system must be included. Figure 2.1 shows a general system configuration of a coaxial cable based integrated distribution system, with CATV headend co-located with the telephone switching center.

Two different approaches can be employed for the distribution of telephone signals. First, a group of VF (voice frequency) circuits, say 24, are PCM encoded and multiplexed into a DS-1 digital stream (1.544 Mbps). This DS-1 stream is then appropriately modulated and combined with the TV signals for transmission through the coaxial cable system. At the other end, the digital stream is retrieved and demodulated, and the 24 VF circuits are then demultiplexed and decoded for distribution via VF drops to the subscribers' premises. This point-to-point distribution technique is essentially the same as that of digital



INTEGRATED COAXIAL CABLE DISTRIBUTION SYSTEM

FIGURE 2.1

subscriber carriers, with non-regenerative coaxial cable lines, instead of dedicated paired cables and regenerative repeaters, being used as the transmission medium. This approach is suitable in areas where there are clusters of subscribers or clustered growth. It is particularly advantageous in a digital switching environment.

The second approach to the distribution of telephony through the coaxial cable system uses single channel modems. A VF channel is modulated individually and combined with other signals on an FDM basis for transmission through the coaxial system. A similar modem is used at the subscriber's premises to interface with his telephone set, as depicted in Figure 2.1. With this method, both telephone and video signals are directly distributed, via coaxial cables, to subscribers homes. It is particularly suited for more sparsely populated or slow-growth areas.

It is noted that with the distribution technique commonly used for a CATV system, feeder cables are placed in parallel with the trunk cable. The signals are accessed from the feeder via directional couplers and subscriber drops. In low density rural areas, however, parallel installation of trunk and feeder cables may become very costly. In this case, direct access of the signals from the trunk cable, using directional couplers thus avoiding the need for the parallel feeder cable as shown in Figure 2.1, can be considered. In employing this alternative, however, one should take into consideration the fact that each directional coupler introduces approximately one dB of insertion loss to the trunk cable and hence reduces the repeater spacing and the total permissible system length. Also, this practice could create administrative, operational and technical problems in the long term, if the system were not carefully planned and engineered in the beginning.

2.2 Methods of Transmitting Telephony over Coaxial Cables

For transmission of telephone signals, whether single channel analog or multi-channel PCM, through analog repeatered coaxial cables, the signals must be modulated first and then frequency division multiplexed with the video and other signals. Given in the following are some of the modulation techniques which can be used, along with considerations on their cost-effectiveness and bandwidth utilization.

a) For single-channel analog signals

i) Amplitude Modulation (AM; DSB or DSB-SC): low modem cost; relatively efficient bandwidth utilization (8 to 12 KHz).

ii) Single Sideband AM (SSB-AM): Medium modem cost; most efficient bandwidth utilization (4-6 KHz).

iii) Frequency or Phase Modulation (FM or PM): Low modem cost; least efficient bandwidth utilization (25 KHz); good noise immunity.

For applications in rural areas, where bandwidth is available and where costs are of major concern, PM or FM is a preferred technique. With either of these techniques and assuming 25 KHz is required per VF channel, then a 6 MHz video channel in both directions can be used to provide telephone services to 240 subscribers.

b) <u>For multi-channel PCM signals</u>

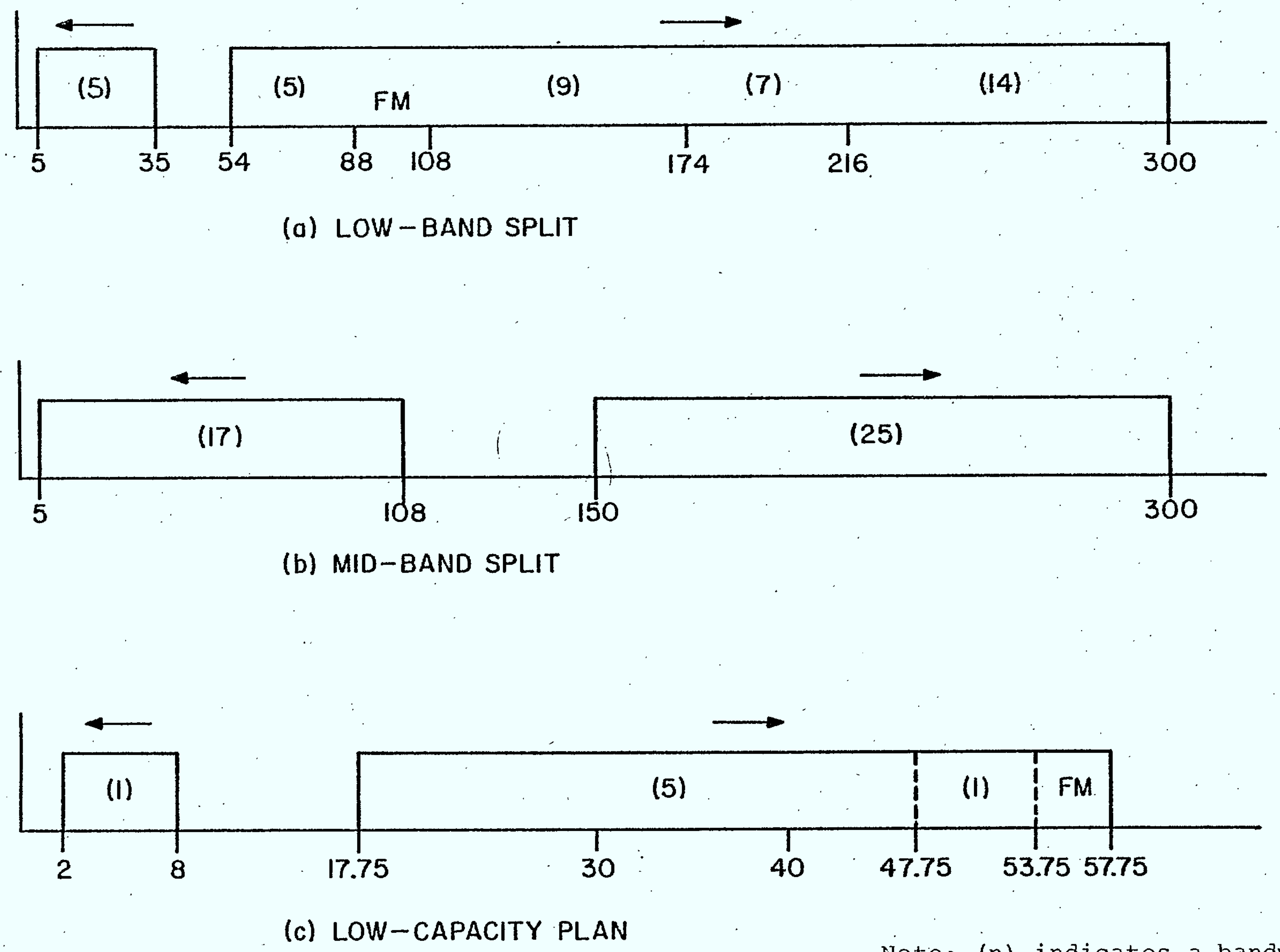
To transmit the digitally-encoded PCM signals through the RF band of the coaxial cable, modulation techniques commonly used in data modems like FSK, PSK, VSB, QAM, etc., can be used. For a 1.544 Mbps DS-1 digital stream, and by using 4-phase PSK or QAM, a bandwidth of approximately 1 MHz is required. Thus, 6 DS-1 signals, or equivalently 144 VF channels, can be accomodated within a 6 MHz video channel slot.

2.3 Frequency Plans

Using state-of-the-art wideband amplifiers, a coaxial cable system can have a bandwidth capability of up to 300 MHz. With this bandwidth, the system can accomodate 35 down-stream and 5 up-stream video channels (low-band split) plus the full 20 MHz FM band, or 25 down-stream and 17 up-stream video channels (mid-band split). Any of the 6 MHz video channels can be used for the transmission of voice signals on the basis as discussed in the previous section.

Figure 2.2 shows the two frequency plans (a and b). Based on the previous discussions, the low-band split system (a) can accomodate, in addition to 30 down-stream video channels and standard 20 MHz FM band, up to 1200 voice channels with single channel FM modems, or 720 voice channels with multi-channel PCM carriers. Mixture of single channel and multi-channel carriers is, of course, permissible.

For the mid-band split system, the voice channel capacity is increased to 4080 with single channel modems, or 2448 with PCM carriers. At this maximum voice channel utilization, the downstream video capacity would be reduced to 8 channels.



Note: (n) indicates a bandwidth equivalent to n 6-MHz video channels

FREQUENCY PLANS
FIGURE 2.2

Since the attenuation of a coaxial cable increases linearly with the frequency, it may be rather uneconomical to design a system with bandwidth capability of 300 MHz if it cannot be fully utilized. Figure 2.2(c) shows a low capacity plan which may be suitable for certain rural areas.

With the low capacity plan, the system has an upper frequency of 58 MHz, instead of 300 MHz. Five television channels, a condensed FM band (4 MHz), and 500 voice channels may be provided. This number of possible voice channels is based on single channel per carrier with DSB-SC modulation at 12 KHz channel spacing. If SSB modulation is used, the system can carry up to 750 voice channels.

2.4 Design Considerations

The principle telephony and television transmission requirements are given in Tables 2.1 and 2.2. The video transmission requirements in table 2.1 are those specified in Broadcast Procedure BP-23 for CATV systems. The requirements for telephony listed in Table 2.2 are common transmission objectives used by telephone companies. Using state-of-the-art amplifiers, a coaxial cable system can be designed to meet these requirements without much difficulty. For single channel per carrier telephony, however, care must be taken in the design of the modem and the selection of the return amplifiers, so that the up-stream noise funneling

TABLE 2.1

PRIMARY VIDEO TRANSMISSION REQUIREMENTS

ITEM	REQUIREMENT
Signal-to-Random Noise Ratio	≥40 dB
Cross Modulation	≤-48 dB
Single Frequency Interference	-57 dB (see attached Weighting Curve)
Delay Distortion	±100 msec.
Amplitude Distortion	±1 dB
Hum	-34 dB
Maximum Differential Gain	2 dB
Maximum Differential Phase	±5 degrees

TABLE 2.2

PRIMARY TRANSMISSION REQUIREMENTS

FOR SINGLE-CHANNEL/CARRIER TELEPHONY

ITEM	REQUIREMENT
Frequency Response	300 to 3200 Hz + 1 to -3 dB 180 Hz and 3400 Hz - 10 dB or more
Steady State Noise	20 dBrnC
Harmonic Distortion	-30 dBmO or less with a 0 dBmO Test Tone Load
Crosstalk	-60 dBmC - Message Weighting with 0 dBmO FIZ Noise Disturber
VF Channel Input and Output Impedance	Echo and Singing Return Loss with respect to 900 ohms will not be less than 120 and 15 dB, respectively

effect associated with a tree-structured broadband system does not severely affect the system performance.

Based on available coaxial cables and state-of-the-art amplifiers, the maximum allowable spacing for a system that carries up to 35 TV channels and meets the transmission requirements specified in BP-23 is approximately Ø.5 - Ø.7 km. The exact figure depends upon the size of the cable, the quality of the amplifiers used, and the maximum route length.

When a coaxial cable based system is used for transmitting telephony alone, the amplifier spacing can be substantially greater than when it is used for carrying TV, because of the lower signal-to-noise ratio requirements and the smaller bandwidth requirements for telephone signals. With state-of-the-art cables and amplifiers, for instance, it is possible to install an amplifier every 2 km or more for digital telephony.

When both telephony and TV are to be carried by a coaxial cable system, the repeater spacing is dictated by the more stringent signal-to-noise ratio requirement for TV signals . Thus, if a system is designed for telephony first with TV service to be provided later, the initial cost of electronics can be minimized, but an incremental cost for implementing the subsequent TV service must be taken into account. Disruption of the telephone service while implementing the TV service cannot be permitted. Although modification of a system without service interruption appears possible, further investigation is needed. It is preferable to design the system for both telephony and video services initially. However, this may not always be possible or may incur higher start-up costs.

For a system which is designed for TV initially with telephony anticipated later, there will be less problems as far as the line modification is concerned. Disruption of the existing service can be avoided.

3. COST CONSIDERATIONS

3.1 Unit Costs

To determine the cost of a coaxial cable system for a particular route or area, the system design must first be detailed. The quantities of hardware and equipment required can then be derived and the total cost obtained by multiplying these quantities with the appropriate unit costs.

Table 3.1 gives sample broad gauge unit costs for a basic one-way CATV system and Table 3.2 presents sample unit costs for the additional equipment needed for an integrated cable system. These costs are based in part on some suppliers' latest price lists and in part on a recent broadband system study[2].

3.2 A Simplified Cost Model

To obtain the total system cost from detailed system design, although more accurate, is rather complex and tedious and is not always feasible or necessary. In cases where high precision is not required, the total cost (C_t) of a coaxial cable system for CATV or for integrated CATV and telephony can be closely estimated from the total route length (L_1) and the total number of subscribers to be served (N_s), as shown in the following expression:

TABLE 3.1

UNIT COSTS FOR CATV SYSTEMS

Feeder and Drop Cables	
.750"	$1670/km.
.500"	$ 860/km.
.412"	$ 620/km.
No. 6 drop cable	$ 210/km.
Amplifiers	
Manual Gain Control	$1064/unit
Automatic Gain/Slope Control	$1396/unit
Bridging Amplifier	$ 400/unit
Line Extender	$ 250/unit
Power Supplies (1 per 10 amplifiers)	$ 400/unit
Directional Couplers (Taps)	$ 25/unit
Installation	
Feeder Cable[1]	$ 1/meter
Drop Cable[1]	$ 0.5/meter
Amplifiers	$100/unit
Power Supplies	$250/unit
Tap	$ 5/unit

---

[1] Assuming buried construction with direct ploughing.

TABLE 3.2

UNIT COSTS OF ADDITIONAL EQUIPMENT FOR INTEGRATED CABLE SYSTEMS

Return Amplifiers and Filters	$250/unit
Battery Back-up	$800/unit
Fault Locate Units	$150/unit
Single Channel Telephone Modem	$325/sub.
24-Channel PCM Modem	$475/sub.
Installation	
Return Amplifiers[1]	-
Battery Back-up	$100/unit
Fault Locate Units	$ 20/unit
Single-Channel Modem	$ 10/unit
PCM Modem (1 per 24 channels)	$700
PCM Channel Units	$ 10/unit

[1] Installed at the same time as the main amplifier.

$$C_t = C_1 L_1 + C_s N_s$$

where C_1 is the installed cost per unit length associated with the cable line and C_s is the installed cost associated with the subscriber equipment, including drop cable, channel converter and telephone modem.

Similarly, if the linear subscriber density (D_s) is known, the cost per subscriber (C_{ts}) can be estimated as follows:

$$C_{ts} = C_1/D_s + C_s$$

where $D_s = N_s/L_1$

a) Line Cost (C_1)

Based on 0.750" foam dielectric cables equalized to 300 MHz (nominal attenuation 29 dB/km) and amplifiers of 21 dB gain, and assuming an average loss due to direct tapping of 1 dB/km, an amplifier spacing of 0.7 km. can be attained. The installed cost, in $/km., of a repeatered cable line can thus be estimated as follows:

	CATV	Integrated
Cable Material	1670	1670
Cable Installation	1000	1000
Basic Amplifiers Installed		
((3 x 1064 + 1396)/4 + 100)/0.7	1781	1781
Return Amplifiers		

250/0.7	-	357
Power Supplies (400 + 250)/0.7		
x 10	93	93
Battery Back-up (800 + 100)/0.7		
x 10	-	129
Fault Locate (150 + 20)/0.7 x 2	-	121
Total ($/km.)	4544	5151

It is assumed in the above cost estimates that automatic gain control is used at every fourth amplifier station and that each power supply unit provides power for ten amplifier stations. For integrated systems, battery back-up and fault locate units are required to improve the system reliability. Battery back-up equipment is installed at every power insertion location, whereas a fault locate unit is normally installed at every second amplifier station.

b) Per-Subscriber Cost (C_s)

The per-subscriber costs include the costs for the tap (directional coupler), drop cable, TV channel converter if required, and telephony modem. The cost of drop cable depends on the length of the drop and the type of the cable used. Assuming an average drop length of 150 meters in rural areas and assuming that the 0.412" foam dielectric cable is used, one can estimate the average per subscriber drop cost as follows:

	CATV	Integrated
Directional Coupler	30	30
Drop Cable		
(620 + 500) x 0.150	168	168
Telephony Modem (325 + 10)	–	335
Total	198	533

3.3 Cost Comparisons

Based on the simplified cost model and on the line costs and the per-subscriber costs derived in Section 3.2, we can readily calculate the total cost per subscriber for any given subscriber density for a CATV or integrated coaxial cable system. Table 3.3 gives this cost for subscriber densities of 20, 10, 5 and 1 subscriber/km. It is noted that the extra cost required for an integrated system compared to a one-way CATV system ranges from $365 to $942 per subscriber over these subscriber densities, which represents an increase of between 86% and 20%.

Using the same cost figures as derived above, we can compare the cost of an integrated system with the combined cost of separate plants, i.e. telephony over paired cables and CATV over coaxial cables. The cost of telephony over paired cables depends not only on the subscriber density, but also on the length of the route from the telephone

TABLE 3.3

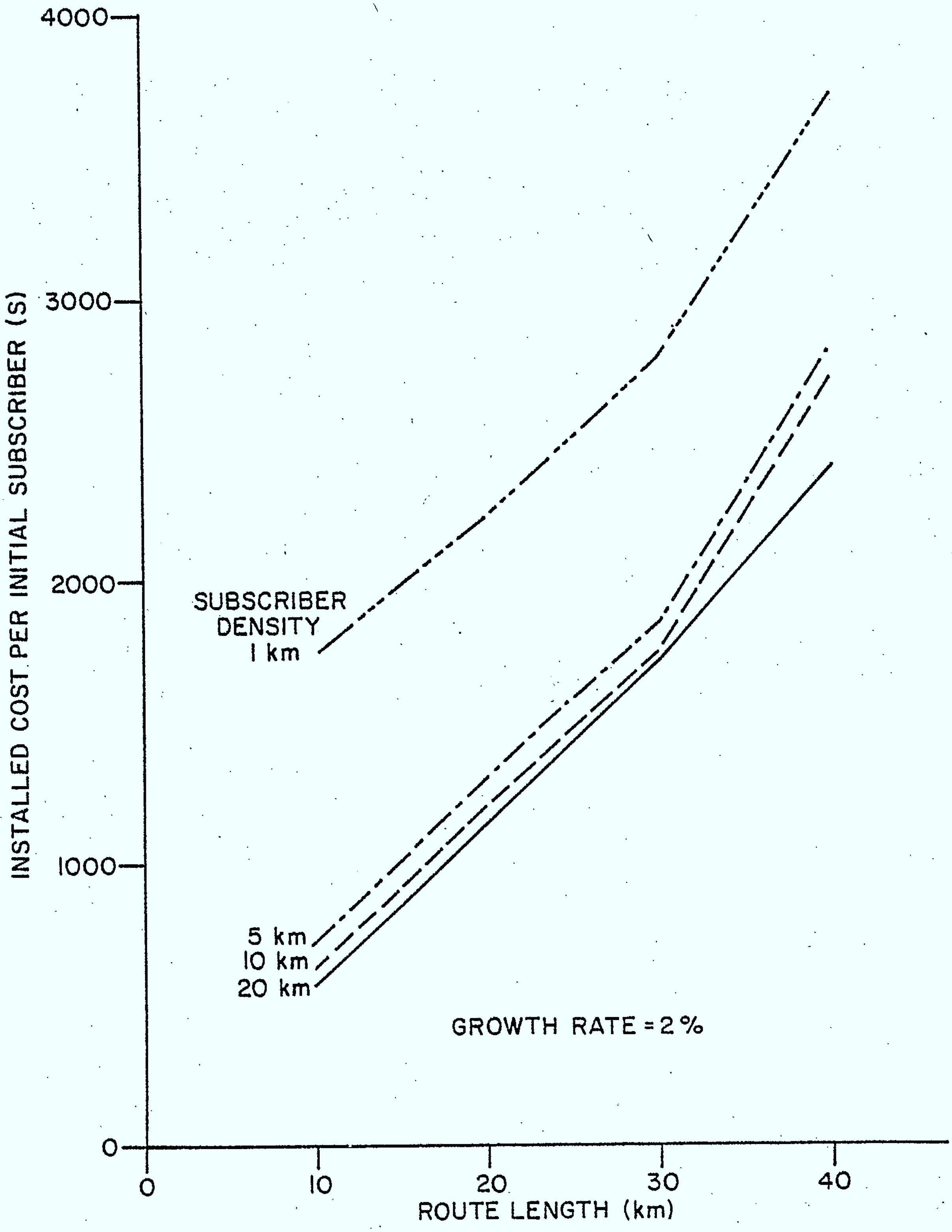
COSTS OF CATV AND INTEGRATED SYSTEMS FOR VARIOUS SUBSCRIBER DENSITIES

Sub. Density D_s (sub./km.)	Cost of CATV ($/sub.)	Cost of Int. Syst. ($/sub.)	Cost Increase of Int. Syst. over CATV	
			$/sub.	%
20	425	790	365	86%
10	652	1048	395	61%
5	1107	1563	456	41%
1	4742	5684	942	20%

switching centre. Based on a computer program developed at the Rural Communications Program, and on unit costs of the Manitoba Telephone System, the average installed costs per subscriber of providing single-party telephone service as a function of route length for subscriber densities of 1 to 20 per km are given in Figure 3.1. It is noted that in obtaining this figure, it is assumed that the growth rate is 2% compounded and the cables are installed to meet a 10-year growth requirement. Also cable sizes are those commonly available to the telcos, and the optimum design with minimum cost is used. Further details on the basic assumptions for the derivation of Figure 3.1 can be found in Reference (8).

Based on the above results, Table 3.4 - 3.7 compare the costs of integrated and separated systems for the route lengths of 10, 20, 30 and 40 km. From these tables, one can observe that the cost savings that can be expected from an integrated system are particularly significant for long routes. For the 40 km route, for example, the cost savings per subscriber range from \$2038 to \$2767, representing 32.7 to 72.0% of the combined costs of separated systems.

For a more typical rural route of 20 km in length, the cost benefit ranges from \$770 or 49.4% saving at the density of 20 subscribers/km to \$1274 or 18.3% saving at 1 subscriber/km. It is interesting to note that in this case, the integrated system is even more economical than the



INSTALLED COST PER SUBSCRIBER FOR SINGLE-PARTY TELEPHONY WITH PAIRED CABLE

FIGURE 3.1

TABLE 3.4

COST COMPARISON OF SEPARATE AND INTEGRATED SYSTEMS

FOR A 10 KM ROUTE

Sub. Density (Sub./km.)	Separate Plants			Integrated Coax. System	Savings	
	Telephony	CATV	Combined		$/sub.	%
20	560	425	985	790	195	19.8
10	616	652	1268	1048	220	17.4
5	729	1107	1836	1563	273	14.9
1	1731	4742	6473	5684	789	12.2

TABLE 3.5

COST COMPARISON OF SEPARATE AND INTEGRATED SYSTEMS

FOR A 20 KM ROUTE

Sub. Density (Sub./km.)	Separate Plants			Integrated Coax. System	Savings	
	Telephony	CATV	Combined		$/sub.	%
20	1135	425	1560	790	770	49.4
10	1194	652	1846	1048	798	43.2
5	1310	1107	2417	1563	854	35.3
1	2216	4742	6958	5684	1274	18.3

TABLE 3.6

COST COMPARISON OF SEPARATE AND INTEGRATED SYSTEMS

FOR A 30 KM ROUTE

Sub. Density (Sub./km.)	Separate Plants			Integrated Coax. System	Savings	
	Telephony	CATV	Combined		$/sub.	%
20	1721	425	2146	790	1356	63.2
10	1723	652	2375	1048	1327	55.9
5	1840	1107	2947	1563	1384	47.0
1	2783	4742	7525	5684	1841	24.5

TABLE 3.7

COST COMPARISON OF SEPARATE AND INTEGRATED SYSTEMS

FOR A 40 KM ROUTE

Sub. Density (Sub./km.)	Separate Plants			Integrated Coax. System	Savings	
	Telephony	CATV	Combined		$/sub.	%
20	2403	425	2828	790	2038	72.0
10	2703	652	3355	1048	2307	68.8
5	2816	1107	3923	1563	2360	60.2
1	3709	4742	8451	5684	2767	32.7

paired system for telephony alone for subscriber densities of 10 or more per km. This phenomenon extends to 5 subscribers per km for the 30 and 40 km routes.

From the percentage standpoint, Table 3.4 - 3.7 indicate that the cost savings are most significant for subscriber densities above 5 per km. With the total per subscriber cost of approximately $1500 or less, the integrated system approach also appears to be most attractive and most likely to become economically viable for densities above 5 subscribers per km.

3.4 Previous Economic Studies of Integrated Coaxial Cable Systems

Several studies on integration of telephone and CATV services with coaxial cable systems have been carried out recently. These include a study by Rural Electrification Administration (REA) in 1977 for the U.S. Inter-Agency Committee on Rural Communications[3], a study made by Canstar in 1978 as part of its program definition study of a fiber optic integrated system for the planned field trial in Elie,[2] and one conducted by BNR in 1975 as part of its rural distribution study for the three Prairie Provinces[4].

The REA study is based on a typical rural area consisting of a primary or hub community with four outlying smaller, satellite communities. The primary office has 10 routes in various directions ranging from 1.41 miles to 31.88 miles in length serving a total of 1803 subscribers. Each of the four satellite offices is identical, having four routes ranging from 14.70 miles to 40.89 miles in length and serving a total of 520 subscribers. The total route length is 559 miles (900 km.) serving a total of 3883 subscribers. The study shows that an integrated coaxial cable network can result in capital savings of 23.6% of the cost of providing parallel paired and coaxial cables constructed separately. The study also shows that significant cost savings can be derived from central office consolidation and reduction of operation and maintenance efforts. In total, the sample integrated system is expected to save 26% on initial capital investment, which is equivalent to an annual saving of $339 for each of the 3883 subscribers.

The Canstar study is based on one route of the Elie exchange area in Manitoba. The route requires 37.25 km. of feeder cable and serves 244 subscribers. Two integrated systems are considered; one is based on the 3M Company's CS II system and the other operates on a loop/tree topology similar to one which Canstar proposed for its fiber optic integrated system. The results show that the integration of telephone and CATV services on the same coaxial cable leads to a cost reduction of $334 to $799 per subscriber, or 15.4% to 36.8% respectively, compared to the separated plants.

The BNR study was based on three rural routes, one from each of the three prairie provincial telcos. The subscriber densities for these three routes vary substantially. On the basic present worth of capital expenditures, the study shows that the savings that can be expected from integration range from 4.8% to 12.4%. These are smaller than those of the other two studies. It should be noted, however, that the BNR study was conducted in 1975 when no telephony modems were commercially available and relatively high cost estimates for such modems were used.

Table 3.8 summarizes the results of the three studies. These results, as well as those shown in Table 3.4, strongly re-affirm that considerable cost savings can be expected by integrating broadband and narrowband communication services with coaxial cable systems in rural areas.

TABLE 3.8

COST SUMMARY OF PREVIOUS STUDIES OF INTEGRATED COAXIAL CABLE SYSTEMS

Study by	Estimated Sub. Density (sub./km.)	Separate Plants			Integrated Coax. System	Savings	
		Telephony	CATV	Combined		$/sub.	%
CANSTAR[1] (1978)	6.6	1304	865	2169	1835	334	15.4
					1370	799	36.8
REA (1977)	4.3	436	1272	1708	1304	404	23.6
BNR[2] (1975)	17.7	610	1042	1652	1447	205	12.4
	0.6	672	3207	3879	3689	190	4.8
	3.7	485	558	1043	947	96	9.1

1 Two different types of integrated coaxial cable systems are considered in this study. as reflected by the two cost figures.

2 These cost figures are present worth of capital expenditures (PWAX). The three cases represent the results of studies on three different routes.

4. OTHER CONSIDERATIONS

4.1 Growth Flexibility

Because of its high capacity, the integrated coaxial cable system can much more readily and gracefully meet the telephone growth requirement compared to paired cables. Virtually no major outside plant modifications and a small incremental per-subscriber cost are required to add new subscribers onto the system. The 1200 voice channel capacity for the low-band split system and 2880 for the mid-band split system should be capable of meeting the present and future requirements in most rural areas. For a route with 500 initial subscribers and with 2% compound growth rate, for example, the above capacities would not be filled for 81 and 88 years, respectively.

4.2 New Services

Although the previous discussions are based primarily on the integration of telephone and CATV services, it should be noted that a wide range of new information, social and entertainment services can also be provided readily through an integrated coaxial cable system. These include, for example, computer data based videotex services, fire and security alarm, meter reading and load shedding, local programming, telemedicine, educational TV and Pay-TV. Many field trials are currently being undertaken, and many more are planned, to determine the technical feasibility and marketability of these services. Particularly worthy of mentioning are QUBE system in Columbus, Ohio, Prestel (Viewdata) in U.K. and ANTIOPE in France. In Canada, a number of medium and large-scale, new-services-related field trials will be conducted in the near future by cable TV operators and common carriers. Although it is difficult to assess the social acceptability of the new services at this point in time, preliminary indications are that some new services will very likely become popular and widely demanded in the future.

Since an integrated coaxial cable system is basically bi-directional and can accomodate video, telephone and digital signals, practically all new services can be implemented over the system without major modifications; any addition or modification required will likely be at the central office or the subscriber's premises.

Economically, implementation of new services on an integrated coaxial cable system should prove to be more attractive as compared to their implementation on either of the segregated telephony and one-way cable TV plants. To implement new services on a one-way cable TV system, the cost of upgrading the system for two-way capability must be borne by the new services provided, whereas with an integrated system, no extra cost is required in this regard. Alternatively, revenues available from the new services can be used to defray the initial capital costs and operating expenses, thus making the system more economically viable.

4.3 Operation and Administration

Operation and maintenance is another area where an integrated system can have significant cost advantages. Indeed, the costs for the operation and maintenance, including the expenses for supplies and services and the salaries for managerial, technical and support personnel, of a single integrated system can be substantially lower than those for two separate companies. Based on the REA study of the typical rural area, a company operating the integrated system can expect an annual savings in salary expense of 19%. Further savings in services and supplies, for such items as single mailing of a consolidated bill and reduced requirement for office space and vehicles, in the range of 20-25% is expected, with the proposed company saving at 23.8% per year.

4.4 System Reliability

One of the major areas of uncertainty about providing telephony over an analog repeatered coaxial cable line concerns system reliability. Because of the non-critical entertainment nature of the CATV service, there has not been any significant attempt to meet the telephony standards of system reliability.

The reliability of a coaxial cable system is determined primarily by the reliability of its repeater amplifiers, which are remotely located in the field. The mean-time-between-failures (MTBF) for, say, the Jerrold Starline 20 main gain modules is 32 years. For the automatic gain modules, it is 16 years. With AGC repeaters used at every third station, the MTBF for a coaxial cable line of 40 amplifiers (20 km.) is approximately 7 months, which is substantially shorter than the MTBF of a rural subscriber carrier line of comparable length (greater than 5 years).

The use of back-up batteries and fault locating equipment as indicated earlier would substantially increase the system reliability. Further, some new amplifiers such as the Jerrold Starline 300 series have incorporated features that increase the reliability, such as redundant gain modules, power packs and a fault locating mechanism. New amplifiers of feed-forward design have also inherent redundant features. Using these amplifiers, the system reliability would be significantly increased, possibly to a level approaching that of a telephone plant, although the cost would also be higher. Improvement of system reliability at a reasonable cost is therefore an area that warrants some further study.

4.5 Hardware Availability

Because of the rapid growth of the CATV industry in the past decade or so, the technologies related to broadband coaxial cable systems have almost reached a state of maturity. Consequently, all the components that are required to implement a coaxial cable distribution system for CATV can be obtained readily off the shelf. Hardware needed for an integrated system as described here, however, has only recently become available - from a manufacturer in the U.S.

4.6 Privacy

With the multi-channel subscriber carrier mode, where the telephone service is provided from the remote terminal through individual VF pairs, telephone privacy is not a problem. With single channel modems, a subscriber may, in priciple, tune his receiver modem unit to monitor other telephone channels. However, by incorporating a privacy filter in the receiver unit, so that only the allocated channel signal is available to the subscriber, the telephone privacy may be raised to an adequate level. The modem unit design should, of course, be such that its interior cannot be readily accessible to the subscriber. Remotely locating the modem unit from the subscriber's premises, if necessary, should also be considered.

4.7 Integration with Coaxial Cable or Optical Fibre?

Because of its broad bandwidth, low attenuation and many other unique features, optical fibre is also very attractive for providing a combination of telephone, CATV and future services. Several recent studies have shown that if and when projected low costs of fibre cables (e.g. at \$.Ø3/fibre-metre) do materialize, fibre optics will become attractive for application to local distribution in rural as well as in urban areas . Because of the very low fiber price requirement, however, it is generally considered that penetration of fiber optics into the local distribution network in a major scale is unlikely to occur before the mid-198Ø's.

The technologies for coaxial cable systems have, on the other hand, fully matured today and, as shown in the previous sections, integrated coaxial cable systems are more economical than conventional separated systems now. Even over the long term, when fibre optic technology becomes mature, an integrated coaxial system may still be cost-competitive when compared with an integrated optical fibre system. Implementation of integrated coaxial cable systems, particularly in the rural areas where provision of broadband services and/or upgrading of existing narrowband services are desired, warrants serious consideration.

In the future, if and when an integrated local distribution system based on optical fibre proves to be more economically attractive, it will be possible to interface readily the integrated coaxial cable systems then in existence with the new integrated optical fibre systems. This is particularly true if the optical fibre system topology is similar to that proposed by Canstar .

4.8 Introduction Strategy

It is recognized that there has already been in existence a paired-cable plant for telephone service, mostly multi-party, in many rural areas. Clearly, this prior investment would off-set some economic advantages of integration. However, there still exist many rural areas where an integrated system can be implemented to yield significant cost benefits. Rural areas which are candidates for immediate introduction of an integrated coaxial cable system include .

a) areas where telephone and CATV services are not available yet, including new developments, trailer parks, etc;

b) areas where upgrading of multi-party telephony to single party is needed and provision of CATV service is desired, and

c) areas where outdated existing telephone plants need replacement or major reinforcement and CATV service is desired.

It is believed that by adopting an introduction plan based on a set of criteria as described above, integrated distribution systems could be gradually and smoothly introduced into the rural areas of Canada.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

We have shown in this study that the integration of telephone and CATV services in rural areas using coaxial cables can result in significant cost savings over conventional separate systems of paired cables for telephony and coaxial cables for CATV. Based on the results derived from the simplified cost model as well as on those of the previous application studies, it is reasonable to expect a cost saving in the 25 to 50% range for an average rural area.

Since the initial-cost comparisons do not take into account what are existing in the plant, the economic advantage of integration in areas where there is already in existence a paired-cable telephone system will not be as much as indicated above. However, in areas where the existing plant is due for replacement, where upgrading of multi-party to single-party telephone service is required, and where the addition of broadband services is desired, an integrated coaxial cable system will still offer significant economic advantages and its implementation warrants serious consideration. With an integrated system, substantial cost savings can also be expected in the areas of operation and administration.

An integrated coaxial cable system also offers the capacity and growth flexibility to meet the present and future broadband and narrowband service requirements in most rural areas. Further, it is amenable to the addition of new information, entertainment and social services, as little or no modification to the outside plant is required.

System reliability is an area of major concern for an integrated coaxial cable system. With the use of back-up batteries at the power supply points and automatic fault locating equipment, the system reliability can be substantially improved. The use of repeater stations with redundant amplifier modules or feedforward amplifiers would further increase the system reliability, but the cost would be higher.

An integrated local distribution system can also be implemented with optical fibre. However, integrated fibre optic systems are not anticipated to be cost-effective for introduction in the loop plant until mid-1980's. Coaxial cable technologies for integrated distribution, on the other hand, are relatively mature and available today. Further, it is expected that integrated coaxial cable systems are capable of interfacing easily with the integrated optical fibre systems if and when they are introduced in the future.

In summary, integrated distribution with a single coaxial cable cable system is a very attractive solution to the current problems of rural communications. Through such an integrated system, both the upgrading of multi-party to single-party telephony and the provision of much-desired CATV and other broadband services in the rural areas of Canada can be accomplished at the same time.

5.2 Recommendations

Based on the above findings, it is recommended that:

1) the use of integrated coaxial cable systems be seriously considered and recommended as a solution to the improvement of broadband and narrowband telecommunications services in rural Canada. As a next step, the areas where this solution could be most attractively applied relative to other technological solutions, such as direct broadcasting satellite and radio, should be identified, and an overall technological approach to the improvement of telecommunications services derived. It is conceivable that the integrated solution is most attractive in such rural areas where the subscriber density is greater than, say, 5 subscribers per km.

2) the barriers hindering the development of integrated systems in rural areas, including regulatory, institutional and financial, be identified and removed. Current regulations requiring the CATV operators to own active components, for example, may have served well in urban areas, but have also prevented the use of integrated systems as a solution to the provision of communication services in rural areas. It is noted that in the U.S., where a similar rule called "cross-ownership ban" exists, a general waiver for this rule in rural areas with subscriber density less than 30 per mile (approx. 20 per km.) has been proposed and actively pursued.

3) the development of hardware for the multiplexing of telephony onto coaxial cable by the Canadian manufacturing industry be actively encouraged and, if necessary, financially assisted. Should the rule preventing the integration of communication services in rural areas be removed, it is anticipated that there will be a substantial demand for the equipment and hardware required for integrated coaxial cable systems. Although there is no shortage of manufacturers

and suppliers for the equipment and hardware for basic CATV-type coaxial cable systems in Canada, telephone multiplexing equipment required for an integrated coaxial system, such as single and multi-channel telephony modems, is relatively new and still require development efforts. In the U.S., a manufacturer has recently developed, with the blessing of REA, an integrated coaxial cable system suitable for application in rural areas. Field Trials of this sytem are being conducted in several rural locations. Encouragement and assistance of Canadian industry for the development of similar hardware is important and timely if the Canadian market in this area is not to be dominated by foreign manufacturers.

4) the rural areas in Canada most suitable for early introduction of an integrated system be identified and detailed application studies for selected areas be carried out. This task should preferably be conducted jointly with the common carriers and/or cable TV operating companies. With a positive outcome, it should naturally be followed by the preparation and implementation of a field trial and introduction plan.

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