ELIE - AN INTEGRATED BROADBAND COMMUNICATION SYSTEM USING FIBER OPTICS

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ABSTRACT

An integrated fiber optics distribution system has been installed in the rural communities of Elie and St. Eustache, Manitoba. The system provides single-party telephone, cable TV, FM stereo and Telidon videotex services to 150 households in the community. The paper gives a technical description of the trial system and summarizes the results obtained to date.

INTRODUCTION

Fiber optics offers broad bandwidth, low attenuation and many other unique and advantageous features. These features, in conjunction with its low-cost potential, make it attractive for application in virtually all areas of telecommunications; from long-haul transmission, to inter-office trunking, to local distribution. While the application of fiber optics in the local distribution network is generally agreed to represent a greater economic challenge, it also offers the greatest potential benefit and impact.

Recognizing this potential benefit and impact, and with a view to determine the technical and operational feasibility of fiber optics for local distribution and for rural service improvement, the Canadian Department of Communications and the Canadian Telecommunications Carriers Association, in co-operation with the Manitoba Telephone System have sponsored the field trial of a broadband integrated fiber optic distribution system in the rural community of Elie, Manitoba. The system, designed, developed and installed by Bell-Northern Research and Northern Telecom, was cut into operation in October 1981.

This paper starts with a discussion of the rationale for the trial. A description of the design and architecture of the trial system then follows. The installation, operation and maintenance aspects of the system are then discussed.

THE RURAL COMMUNICATIONS CHALLENGE

Rural communities were selected as the location for the trial because it is in rural areas where the improvement of communication services is a major concern, both to the Government and to the common carriers, and because fiber optics appeared to offer a potential solution.

Approximately 6 million people or 27% of the Canadian population live in an area exceeding 1 million square kilometers which is classified as rural by the Canadian Department of Communications. This definition of rural areas comprises small settlements and villages having a population of 2500 or less, as well as sparsely populated areas with a population density of at least one person per square mile. This rural area represents essentially the agricultural areas of Canada.

There are almost 700,000 rural subscribers on multi-party telephone lines and the number of customers on a single line can range up to 10, with an average of about 4.

The principle of equal access to communications services for all is a recognized premise of carriers and governments. It can be argued that a rural household has a greater need for improved communications because of the greater distances and isolation from the necessities and amenities of life. Substitution of improved communications for travel to conserve time and energy is becoming increasingly important. The social, economic and environmental problems associated with urban migration are also important considerations favouring the improvement of rural communications.

The major obstacle to improving rural service is, of course, cost, which increases rapidly as subscriber density decreases. An example is the MTS's Rural Service Improvement Program, completed in 1981. This program involved service improvement to 60,000 multiparty customers whereby 44,000 may have a maximum of 4 customers per line (average 2.8), and 16,000 customers receive individual line service based on a density criteria of at least 9 customers per kilometer. This program was implemented over a 6 year period at an average cost of $1,000 per customer, using paired copper combined with the latest analogue and digital subscriber carrier technology.

One potential solution to the cost problems is integrated distribution plant. Integrated plant, the electronic highway, with broadband capability offering overall cost savings and increased revenue potentials from cable TV and other new services, has been recognized for many years. The advent of fiber optics, coupled with other cost reduction developments such as large scale integrated circuits and microprocessors, indicate that the mid-1980's could see introduction of integrated fiber optics distribution plant.

Of course, the changeover to integrated plant will not occur overnight. The large existing capital investment in copper pairs, and the large amount of new capital required to install new integrated plant will force a progressive program over a number of years.

DESIGN CONSIDERATIONS AND SERVICES PROVIDED

The Elie, Manitoba, fiber optics experiment is actually two experiments rolled into one. It is a test of fibre optics in a rural setting, and it is a test of new communication services, again in the rural setting. This trial was initially proposed for a number of reasons:

1. No cost effective system exists today to provide a full range of telecommunications services to the low rural subscriber density in the agricultural plain of Manitoba. The density averages about 3 subscribers per square mile. This is representative of the Canadian prairie provinces.

2. It is considered desirable to test integrated distribution systems, capable of carrying not only telephone services, but also television, FM Stereo and Telidon videotex signals along with other as yet unidentified services. In effect, the electronic highway would be provided by MTS to be used by MTS and others.

3. The paired plant now providing the bulk of the rural facilities is limited to voice frequency use. While some rural carrier is placed on cable pairs, the circuits derived are for telephone or data services, but not for television.

4. The trial would encourage development of the technology of fiber optics, and gain experience in its application to rural areas.

The trial takes place in the exchange area of Elie and involves 150 subscribers. The subscribers include some residents in the town of Elie and the village of St. Eustache about eight kilometers north, and some farmers in the surrounding area. The system provides single party telephone, CATV and FM radio and a 56 kb/s data channel suitable for some inter-active computer services.

The 56 kb/s full duplex data channel is used to deliver Telidon videotex services, operating at the rate of 4.8 kb/s. Additional capacity is available in this data channel to provide other services if they should be required.

DESCRIPTION OF THE SYSTEM

The services are provided over a combination of laser and Light Emitting Diode (LED) driven loop circuits. Significant alternatives that are being examined include single fiber bidirectional transmission and simultaneous use of two independent video channels by individual subscribers.

A block diagram of the Elie-St. Eustache system is shown in Figure 1.

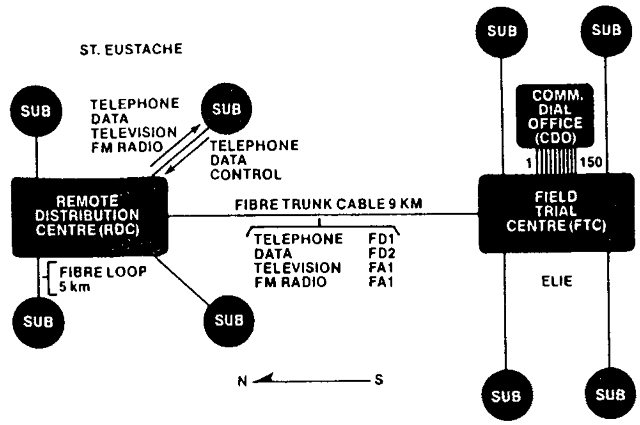

Figure 1 Elie and St. Eustache Switched Star Network Configuration.

The new fiber optics system is placed alongside existing copper facilities fed from the Elie Community Dial Office (CDO). The system architecture is based on a remote switched star configuration with two distribution centres connected by a dedicated fiber optic trunk cable. Telephone services over the trunk use the Northern Telecom Canada Ltd. (NTC) digital FD-1 system with a DS-1 rate of 1.544 Mb/s per fiber and the data services are provided over the NTC digital FD-2 system with a DS-2 rate of 6.312 Mb/s per fiber. The initial nine video channels are transmitted over the trunk fibers using the NTC analog FA-1 system. The FA-1 system is also used for the transmission of the seven FM channels over the trunk. Fiber distribution and fiber drop cables connect the distribution centres with the subscriber premises. Figure 2 shows the transmission frequency plan for integrated services over the fiber loop circuits.

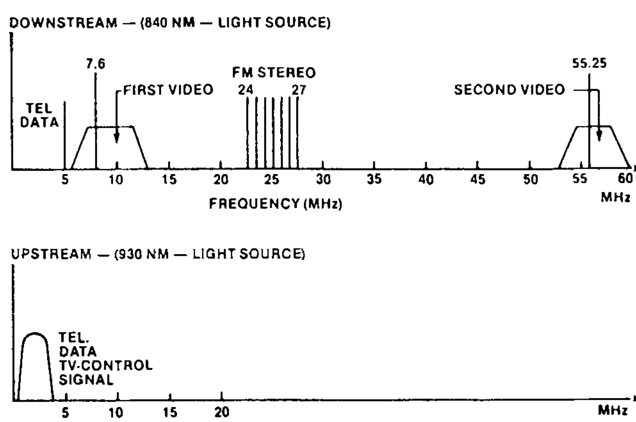

Figure 2 Loop Transmission Plan

For the basic service, the downstream light source at 840 nm is intensity modulated by a Frequency Division Multiplexed (FDM) signal containing one video signal, seven FM stereo signals and a Frequency-Shift-Keying (FSK) modulated carrier transmitting telephony, data and signalling in a Time Division Multiplexed (TDM) format. Video is transmitted in the standard NTSC-VSB-AM format on a visual carrier of 7.6MHz. Access of up to 12 video channels is provided by a video switch in the FTC and RDC. In the case of dual TV transmission, a second channel is added on a visual carrier frequency of 55.25 MHz. Pulse Code Modulated (PCM) voice and signalling are time division multiplexed with a 56 kb/s data signal, which is then bi-phase coded and FSK modulated on a 5 MHz carrier.

In the upstream direction, a light source at 930 nm is intensity modulated by a time division multiplexed data stream which consists of PCM-voice, signalling, 56 kb/s data and TV control signals for video switching and alarms. The composite signal is then bi-phase coded for baseband digital transmission to the distribution centres.

The fiber optic cable designed by NTC for transmission of signals between the distribution centres and over the loop circuits is filled with a dry powder compound and contains three to 36 fibers. Fiber parameters and cable installation details are shown in Figure 3. A cross-section of the NTC fiber optic cable is shown in Figure 4.

• FIBER PARAMETERS

TYPE	GRADED INDEX
PROCESS	I.V.P.
NA	0.17
ATTENUATION	<4 db/km (840 and 930 mm)
3 dB — OPT. BDW.	600 MHz
CORE — DIAM.	50 μm
CLADDING — DIAM.	120 μm
COATING — DIAM.	320 μm

• CABLE INSTALLATION DETAILS

TRUNK LENGTH	9 km
TOTAL LOOP LENGTH	75 km
CABLE PLACEMENT	70% BURIED 30% AERIAL

Figure 3 Fiber Parameters and Cable Installation Details.

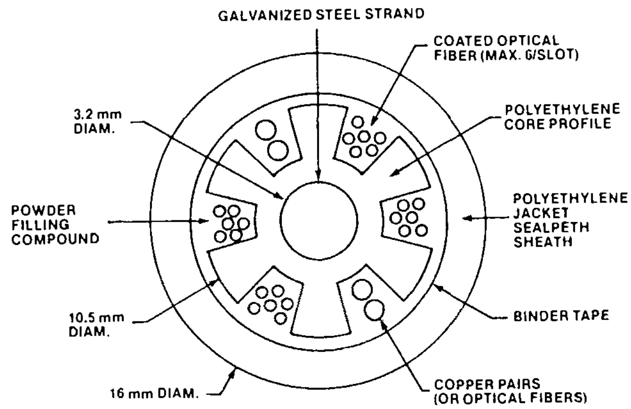

Figure 4 Cross-Section of NTC Optic Fiber Cable

The telephony service meets normal telephone loop requirements. The video and FM radio services meet normal distribution performance objectives. The 56 kb/s data performance is expected to be virtually error free.

FUNCTIONAL DESCRIPTION

The equipment located at the subscriber premises terminates the fiber loop and processes the received integrated signals for distribution to the various terminals. The units located at the subscriber premises are the Subscriber Entrance Unit (SEU), the Set Top Unit (STU) and the Remote Hand Held Controller (Rem.Ctl.) as shown in Figure 5.

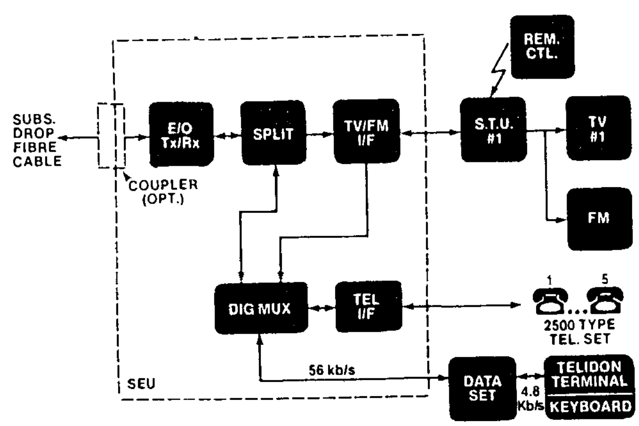

Figure 5 Subscriber Premises

Signals received by the SEU from the Line Interface Unit (LIU) and transmitted upstream to the LIU are shown in Figure 2. The STU is placed with the subscriber's television receiver. It receives infrared control signals from the Rem. Ctl. and displays the selected channel number. Connectorized access to the video and FM signals is also provided by the STU. The infrared control signals received by the STU are converted to a serial 200 b/s asynchronous start/stop format for transmission to the video switch in the LIU of the distribution centre.

Field Trial Centre (FTC)

Figure 6 shows the basic FTC system configuration. The DMS-1 Control Concentrator Terminal takes VF telephony inputs from the existing telephone switch and after digital encoding and multiplexing transmits them to two Remote Concentration Terminals (RCT), one in the FTC and one in the Remote Distribution Centre (RDC). These remote units are connected to the optical subscriber loops on a digital basis and provide the means for telephony concentration over the trunk facilities.

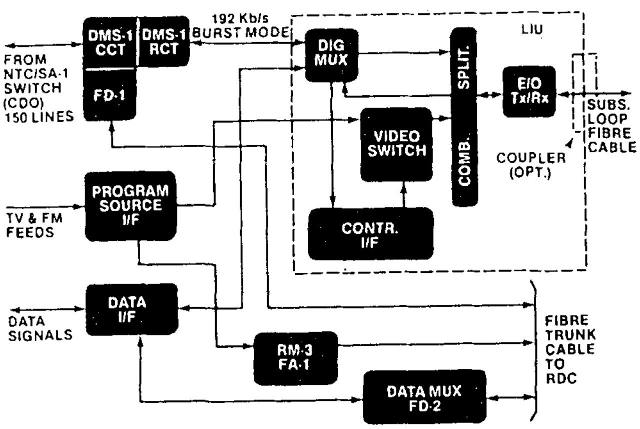

Figure 6 Field Trial Centre

In the program source interface, incoming television channels are demodulated and then transmitted to the RDC using an FM optical transmission system (RM3/FA-1). The channels to be distributed locally are remodulated into frequencies suitable for selection by the remotely controlled FDM video switch.

FM stereo program channels are similarly processed except in this case no switching takes place and all seven channels are transmitted to each subscriber.

The 56 kb/s data channel for each loop served directly by the FTC is time division multiplexed with the digitized voice and signalling. The composite bit stream is used to FSK modulate a 5 MHz carrier which is combined with the video and FM signals in the LIU. The optical transmitter in the LIU (either LED or laser) is intensity modulated by this composite signal for transmission to the subscribers. A composite signal that contains voice, data, signalling, TV control signals and system alarm information, is received from the subscriber's premises.

Remote Distribution Centre (RDC)

The RDC performs the same basic functions as the FTC, except incoming signals for distribution are derived from the FTC to RDC trunk system.

TECHNICAL SPECIFICATIONS

Telephone Service

Meets or exceeds present grade of service of the standards of the existing telephone network. This fiber optic system is designed to meet the following objectives:

- Idle Channel Noise	20 dBrnco	max
- Echo Return Loss	18 dB min	(C Message Weighting)
- Singing Point Return Loss	15 dB min	(C Message Weighting)
- Frequency Response Loss Relative to 1 kHz Loss	60 Hz	-20 dB min
Measured with 0 dBm0 Input	300-3200 Hz	+1.0 to -3.0 dB
	600-2400 Hz	±1 dB

Television and FM Stereo Service

Television meets or exceeds the Broadcast Procedure BP-23 Grade 1 performance objective at the subscriber set.

Data Channels

- Maximum bit error rate 10^{-6} for 99.9 per cent of the time at 56 kb/s, exclusive of outage.
- Zero blocking

PHYSICAL ENVIRONMENT

The physical environment on the Canadian prairie is a challenge to cable and equipment designers and manufacturers. While all electronics for the Elie trial are located in buildings, the cable and hardware is designed to meet the following environmental conditions:

- storage and transportation	-50°C to +55°C
- installation	-20°C to +50°C
- operation	-40°C to +55°C

The geographic environment of this part of Manitoba, commonly referred to as the Red River Valley, consists mainly of deep, boulder free clay-silt soil. The area is extremely flat; the change in elevation across the entire exchange area is less than 2.4 metres. The road borders are predominantly flat, free of fences and tree shrubs, and thus offer excellent terrain for cable ploughing. The existing cable is either buried or aerial, and the new fiber cable is also buried or aerial to test both methods of installation. In fact, the buried cables were placed above typical frost line.

EXPERIENCE WITH TRIAL SYSTEM

The trial system became operational in October, 1981, and will operate until the end of March, 1983. Experience with the trial system is limited at the time of writing.

Installation

A major contract was awarded to Northern Telecom Canada in 1979 for the design, development, manufacture and installation of the system. Much of the work was carried out by an associated company Bell-Northern Research. To facilitate the installation and associated equipment testing, trailers were used as the Field Trial Centre and the Remote Distribution Centre. The equipment was installed in the trailers at BNR in Ottawa, then transported by road to Elie.

The equipment installed in each subscribers home was installed by MTS personnel, and the fiber optics cables were installed and spliced by MTS construction crews through a sub-contract with Northern Telecom Canada. Training and instructional practices were provided by NTC. No serious problems were encountered during the installation phase. One goal of the trial was that regular construction crews could install the cables and equipment using standard installation equipment and procedures. This goal was met. The major change was the splicing of the optical fibers which required special training and special equipment.

Operation

The telephone, television, FM and Telidon services are all working satisfactorily. Trouble reporting procedures for the subscribers have been established. Procedures between the services providers, Manitoba Telephone System, the cable television licensee, and the Telidon data base providers have also been established.

Surveys will be taken over the duration of the trial to determine the subscribers' likes and dislikes, reactions and preferences, and usage of the service provided. Of major interest to the trial sponsors will be the subscribers' reaction to Telidon data base upgrades, to include messaging, interactive computer programs, etc.

Maintenance

Maintenance of the trial system is being performed by MTS maintenance personnel. Special training courses and maintenance practices were provided by NTC for the new and unique equipment. The maintenance philosophy is the same as for most modern equipment - field replacement of defective units and factory repair of those units. A stock of spare units on site is essential to keep the "mean time to restore" at a minimum.

A sophisticated alarm system complete with diagnostic features has been provided with the trial system to allow rapid identification of failed units and provide general system status.

The general maintenance experience to date has been good. There has been the usual "start up" problems which are being solved. A complete maintenance record is being kept so that analysis (Mean time between failure, mean time to restore, component failure patterns, fiber troubles, etc.) can be done on an ongoing basis.

SUMMARY OF TRIAL RESULTS

It is still too early for a complete summary. It is the plan of the sponsors of the trial to develop a System Evaluation Report to address all facets of the trial system from design to final disposition at the end of the trial.

At this time, it can be said that the system design meets the stated performance specifications and the system is operating satisfactorily.

ACKNOWLEDGEMENTS

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