AN INTERCITY COAXIAL CABLE ELECTRONIC HIGHWAY

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MANITOBA TELEPHONE SYSTEM

ABSTRACT

Early in 1978 the Manitoba Telephone System announced its intention to proceed with the construction of a bi-directional coaxial cable intercity transmission network for the initial purpose of delivering television and FM broadcast signals to newly licensed CATV operators in more than twenty communities throughout southern Manitoba. This facility would provide a multi-purpose, user-shared "electronic highway" for the transmission of television, radio, data and new broadband telecommunications services.

The first 28 mile trunk was activated in February 1978 with the major 145 mile system from Winnipeg to Brandon placed in service on September 29. Performance test results using both frequency domain and baseband measurement techniques are presented along with operational experiences.

INTRODUCTION

In September of 1978 the Manitoba Telephone System (M.T.S.), placed in service a 171 mile broadband, bi-directional, coaxial cable transmission system linking Winnipeg, the province's capital and largest city, with Brandon, Manitoba' second largest city and three other major rural communities. This broadband "Electronic Highway" was designed for the transmission of CATV signals and various other broadcasting and telecommunications services to smaller rural cities and towns in southern Manitoba. The major initial users of the system, which is called the Intercity Broadband Network (ICBN), are newly-licensed CATV operators in the rural communities who are presently receiving U.S. network television and Winnipeg stereo FM signals via the ICBN for local distribution on coaxial cable within their communities.

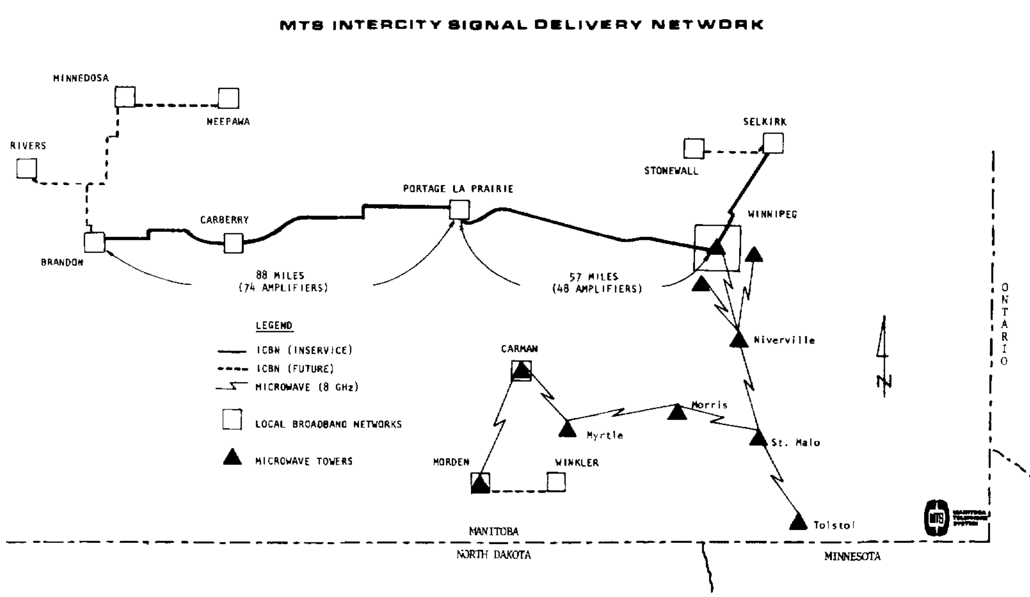


FIGURE 1

The capital cost of the ICBN highway is competitive with that of microwave radio for delivery of U.S. network CATV signals alone, with significant additional bandwidth being available for bi-directional transmission of telephony and other communications services.

A number of non-CATV services have already been transported on the highway with additional broadcasting and telecommunications services projected in the near future.

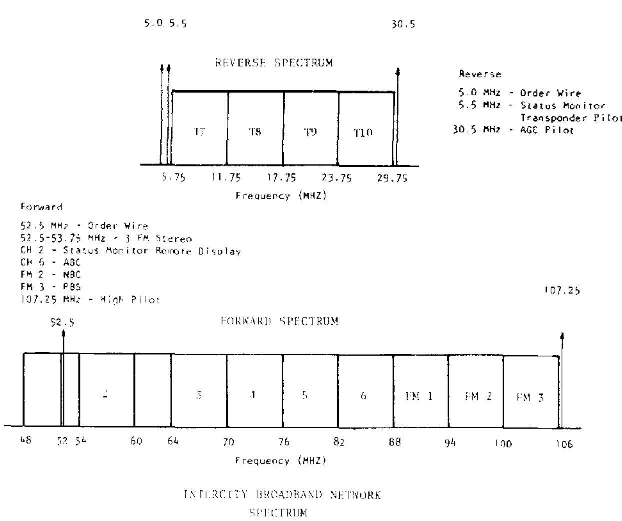
Extension of the present network to more than twenty additional communities in southern Manitoba is planned.

SYSTEM DESCRIPTION

At present the ICBN consists of two separate routes (Figure 1), a 26 mile, 23 amplifier system between Winnipeg and Selkirk, which has been operating for over one year, and a 145 mile western "highway" to Brandon which uses 122 cascaded amplifiers.

While standard CATV trunk systems normally are limited to approximately 30 miles by the buildup of noise and distortion from cascaded amplifiers, the ICBN employs a new "superlinear" amplifier to permit very good transmission over several hundred miles. The new amplifier, developed by Century III Electronics Inc., of Vancouver British Columbia, in response to M.T.S. specifications, utilizes the "feed-forward" technique for noise and distortion reduction.

The spectrum of the present system, shown in Figure 2, utilizes a "forward" transmission band of 50 to 108 MHz with "return" transmission occupying a band from 5 to 30 MHz. This spectrum plan permits forward transmission of up to 8 standard 6 MHz. television channels with return bandwidth equivalent to 4 such channels. Dual pilot carriers are employed in the forward transmission direction for automatic gain and slope control, with a single pilot Bode equalization system being used in the reverse direction.



INTERCITY BROADBAND NETWORK SPECTRUM

Figure 2

Amplifier stations are generally spaced at 6300 feet with the coaxial cable being direct buried at a nominal depth of 40 inches. The soil conditions and terrain in Manitoba allow ploughing of cables at very favourable costs. Intermediate splices are located in special splice pedestals above ground such that future upgrade of the system can be made to higher operating frequencies and greater bandwidth capacity. For example, transmission up to 220 or even 300 MHz would be permissable by coverting all existing amplifiers to 300 MHz units and adding additional 300 MHz stations at the intermediate splice pedestals. While system noise and distortion performance would be degraded somewhat by the additional amplifiers, the additional bandwidth available for transmission would be substantial (as many as 35 standard 6 MHz television channels in the forward direction) and use of frequency modulation transmission techniques could be implemented to more than overcome the loss in transmission performance.

The superlinear amplifiers were designed to provide certain transmission performance parameters specified by M.T.S. engineers for a hypothetical 225 mile system. This system length would allow M.T.S. to serve virtually all of the populated, southern area of the province. Table 1 details the transmission performance over 225 miles that could be met using the superlinear amplifiers actually supplied and specified by Century III Electronics.

TABLE I
CALCULATED 225 MILE RESULTANT ICBN PERFORMANCE USING CENTURY III SUPERLINEAR AMPLIFIERS

SIGNAL TO NOISE RATIO (SNR)	45 dB
CROSS MODULATION DISTORTION (8 CHANNELS-PER NCTA 002-0267)	-64 dB
SECOND ORDER DISTORTION	-65 dB
HUM MODULATION (PER DOC BP-23)	-47 dB

With this ICBN transmission performance, CATV signals delivered to a Local Broadband Network (LBN), with its own noise and distortion degradation, would, at the worst-case CATV subscriber terminals, exceed in quality, the requirements of the Department of Communications, Broadcast Procedure 23 standards.

COMPONENT DESCRIPTION

The cable utilized for all presently installed systems is General Cable's Fused Disc 750 type cable, flooded and jacketed, which has proven to be able to withstand direct ploughing without any major difficulties.

A Century III superlinear amplifier station is shown in Figure 3. A modular approach was followed in design with a standard CATV trunk amplifier housing accomodating the forward (50-108 MHz) and reverse (5-30 MHz) amplifier modules. It is also equipped with a dual power supply module with automatic changeover, diplexing filters, AGC and ASC module and a microprocessor-based status monitor transponder. The performance specifications for the feed-forward (50-108 MHz) amplifier are listed in Table 2. The most noticeable specification improvement over high quality conventional trunk amplifiers is the dramatic decrease of approximately 30 dB in cross modulation distortion.

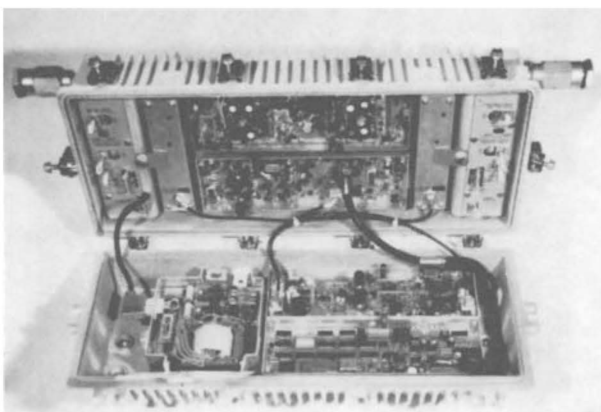


FIGURE 3

TABLE 2
FEEDFORWARD TRUNK AMPLIFIER
SPECIFICATIONS

FREQUENCY RANGE	45-110 MHz
FLATNESS	$\pm$0.15 dB
RETURN LOSS (ALL PARTS)	20 dB Min.
OPERATING LEVELS CH 2 110 MHz	 +43 dBmV +47 dBmV
GAIN (NOMINAL)	30 dB
CROSS MODULATION (8 CHANNELS-PER NCTA 002-0267)	-110 dB
TRIPLE BEAT	-120 dB
INTERMODULATION	-88 dB
HUM MODULATION (PER DOC BP-23)	-70 dB
NOISE FIGURE (0 dB EQLR)	7.5 dB

Reverse system performance is virtually identical to that of the superlinear forward package and by virtue of the light, four channel loading, the reverse amplifier does not have to employ the "feed-forward" technique.

The feed-forward module is, by its very nature, redundant. In fact it is very difficult to identify when one of the feed-forward gain blocks has failed since the increase in system noise and distortion is almost inperceptible. To facilitate identification of a failed chip an internal Amplifier Balance Check can be made on each station under the control of the status monitor terminal in Winnipeg. Under control of the amplifier microprocessor 4.8 KHz modulation is applied separately to the main and error amplifiers such that an ABC receiver will quickly indicate the measure of feed forward balance in that station under test.

An incident in October 1978 illustrates well the system "headroom" and tolerance for even major failures. A faulty amplifier connector introduced a 20 dB loss at the output of a system amplifier, yet system AGC and the substantial SNR margin in the system resulted in no visible signal degredation at the Brandon terminal. This tolerance can be used to advantage for restoration of service in that an entire amplifier section can be bypassed with flexible 412 cable with an overall SNR penalty of less than 3 dB.

Powering for the system is via the cable itself with power supplies located at a maximum of every 9 amplifier stations. The power supply, shown in Figure 4, is a special 105 volt quasi-square wave regulated unit built to meet M.T.S.

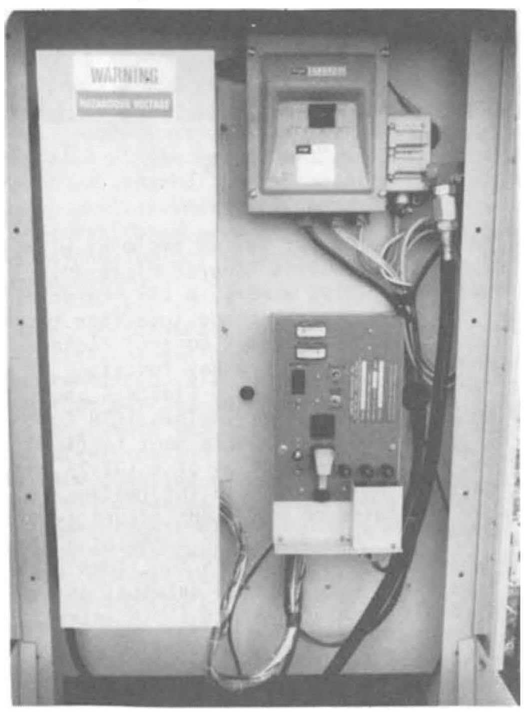


FIGURE 4

specifications by Sawyer Industries of California. Standby power, in the event of electrical utility outages, is provided by a battery bank and inverter, controlled by electronic logic. The supply achieves "no-break" standby powering thereby eliminating any "bumps" or switching transients.

Failure of primary power resulting in standby battery operation is sensed by the associated amplifier status monitor transponder and an alarm is conveyed to the control centre in Winnipeg.

Pedestals to house the amplifiers, mid-span splices and field power supplies were designed by M.T.S. and built by Inventronics Limited of Brandon, Manitoba. Figure 5 shows an amplifier pedestal (right foreground) with a larger power supply pedestal in the left rear. Climatic conditions in Manitoba, particularly frost heaving, necessitate extremely strong and stable pedestals and staking. With temperatures varying between -40°F and +95°F and winter frosts penetrating as deep as 7 feet, both electronic transmission and mechanical assemblies are severely tested.

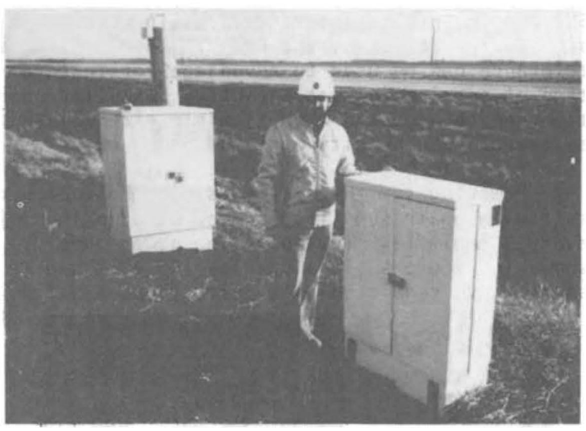


FIGURE 5

The status monitor system employed with the ICBN highway uses a Data General Micro Nova 3 with dual floppy disk memory, a CRT, hardcopy printer and a custom telephone interface to provide a comprehensive network control package which continuously monitors key functions at each amplifier and power station. Figure 6 shows the prototype terminal at the Winnipeg ICBN Control Centre. Interrogation data is sent to field locations via AFSK modulation of a 107.25 MHz pilot carrier, while response information is similarly modulated on a 5.5 MHz return system pilot carrier. Each amplifier contains a transponder which monitors analogue functions such as pilot levels and feed-forward balance, as well as failure condition alarm inputs (both internal and external to the amplifier), and power supply standby battery reserve measurement. Analogue inputs are digitized with all data continuously available to the control terminal. Automatic call out routines and various video and hardcopy information printouts are software features of the system. With the potential of several hundred amplifier stations being associated with the network, many located in remote locations, it is obvious that a sophisticated status monitor system is absolutely essential.

FIGURE 6

To facilitate communications and control from field locations, a portable multi-channel ICBN RF order wire was designed and built by M.T.S. engineers. This attache case-sized unit has 6 channel scanning with full duplex capability for voice communications, and a touch-tone pad for signalling and remote control. Touchtones can be used to control functions on the network through the status monitor computer or to dial telephone numbers through an interface with the public switched-network.

U.S. Network CATV signals available in Winnipeg at video baseband are modulated into the ICBN using Scientific Atlanta 6350 modulators manufactured for ICBN channel assignments. At M.T.S. Toll Offices in each of the rural communities special Scientific Atlanta 6150 processors convert the CATV signals to the VHF channel assignments licensed to the local CATV operator. These signals are then distributed to the CATV subscribers on the M.T.S. Local Broadband Network (LBN). Provision is made with the processors for the use of chroma delay equalizers. Chroma delay distortion is not a problem with the higher forward channels presently in use but equalization will be necessary on channels closer to 50 MHz.

TRANSMISSION PERFORMANCE

The availability of a new Tektronix 1450 demodulator allowed transmission testing of SNR crossmodulation, intermodulation and hum modulation to be done at baseband, using standard telephone industry video test procedures. These key parameters were also tested using the RF techniques common to the CATV industry, through use of Hewlett Packard 8553 and Tektronix 7L13 spectrum analyzers, Dix Hills R-12/5X-16 system and accessories.

Comparison of RF with baseband measurements of *major parameters proved to be very gratifying. There was very close agreement (within 1 dB) between the results independently measured using* each technique.

Figure 7 shows the acceptance testing underway at the Brandon ICBN terminus.

FIGURE 7

Table 3 details the overall test results respectively.

TABLE 3
WINNIPEG-BRANDON ICBN
OVERALL TEST RESULTS
145 MILES - 122 AMPLIFIERS

SIGNAL TO NOISE RATIO (WORST CASE)	53 dB
CROSSMODULATION (8 CHS-PER NCTA 002-0267)	<-66 dB
HUM MODULATION (PER DOC BP-23)	-51 dB
INTERMODULATION	<-80 dB
FREQUENCY RESPONSE	±0.3 dB
LINE TIME DISTORTION	2% Max.*
PULSE TO BAR RATIO	*3% Max.* *
2T PULSE SHAPE (K FACTOR)	2% Max.*
LUMINANCE NON-LINEARITY	2% Max.*
SYNC COMPRESSION	2.5% Max.*
CHROMINANCE GAIN NON-LINEARITY	4% Max.*
DIFFERENTIAL GAIN	2% Max.*
DIFFERENTIAL PHASE	1% Max.*

It should be noted that careful baseband testing of the modulators in Winnipeg clearly established that the baseband test values (asterisk) were established by the origination modulator-Tektronix demodulator combination and that there was no measurable degradation of these parameters by the ICBN transmission system.

INTEGRATED SERVICES

While there are many interesting aspects to the new technology associated with ICBN, the most exciting side of the network is its role as a multi-purpose, shared user, broadband electronic highway. In six months of operation it has already demonstrated several unique service applications beyond the delivery of CATV service to rural communities.

During the Canada Winter Games, a two week athletic event of national interest, held this year in Brandon, coaxial cable facilities including the ICBN carried daily live video and audio originations which fed the national French and English television and radio networks of the Canadian Broadcasting Corporation (CBC), an organization respected throughout the world for its stringent technical standards. Every second of programming was carried to some extent by coaxial cable with ICBN being used in the reverse direction to transport four 15 KHz audio circuits to Winnipeg which distributed daily programming across Canada. Catel FM modems were used on the ICBN and the Brandon LBN for audio and some video transmission. Scientific Atlanta modulators/demodulators handled the rest of the video transmission.

The private CTV network affiliate in Winnipeg operates a network of seven rebroadcasting stations in western and northern Manitoba. ICBN facilities have been used to carry special programming from Winnipeg to western Manitoba for this broadcaster.

Stereo FM transmission on the ICBN highway is particularly cost effective. Those familiar with telephony will recognize that stereo transmission on message facilities requires two full "groups" of channels with precise phase differential and amplitude equalization. Such facilities are very costly compared to ICBN which can transport the stereophonic signals either in encoded format or as separate left and right channels with excellent gain-frequency response, distortion and noise characteristics. At present four Winnipeg stereo FM stations are on the ICBN with strong possibilities existing that more will be added. The CBC, apparently pleased with performance during the Winter Games, has recorded its interest in further investigating ICBN for the transmission of network signals to Brandon on a full time basis.

While telephony transmission on coaxial cable has been successfully trialed by various organizations, and is providing message service near Rimouski, Quebec to customers of the Quebec Telephone System, most approaches to telephony on coax have married the digital PCM format with existing CATV AM or FM modems in a satisfactory, but bandwidth inefficient manner. Theoretical calculations, reinforced by careful testing and monitoring, have indicated that ICBN is capable of high capacity (up to 1200 message channels in 6 MHz bandwidth) telephony transmission using standard AM suppressed carried techniques. An AM SSBSC modem specification has been issued to a number of CATV and telecommunications manufacturers soliciting techno-economic response regarding manufacture of such a unit. M.T.S. is carefully evaluating competitive costs of providing additional required message circuits in all areas of Manitoba using conventional techniques, coaxial cable and fibre optics, with a recognition of future broadband service requirements.

It is anticipated that the imminent usage of Canadian satellites to deliver additional programming services to CATV subscribers will prove to be a stimulus to ICBN usage. Ground receive station costs in Canada are, for a variety of reasons, significantly higher than in the United States and the most cost effective way of distributing satellite signals to small rural communities may be via ICBN from satellite receivers established in the larger centres. At present, delivery of the live proceedings of the Canadian House of Commons to rural CATV operators is being considered using ICBN from a ground receive station in Winnipeg.

Similarly there is great interest concerning possible delivery of live proceedings of the Provincial Legislature to rural communities using ICBN.

With the coaxial cable facilities in Winnipeg being used by M.T.S. to distribute full time bi-directional medical information between two major hospitals in Winnipeg, and the existance of a large 2.5 GHz information retrieval ETV system with a major software library, in suburban Winnipeg, there are major opportunities for extension of medical and educational television services to provincial communities on, or near the electronic highway.

Presumably other new futuristic services such as Videotex, alarm and meter reading, teleshopping, facsimile, electronic mail and electronic newspapers could be distributed on the multi-purpose, multi-user electronic highway.

CONCLUSION

While fibre optics technology (FOTS) has generally been advanced by the common carriers as the means of providing the shared-user, multiservice communications "electronic highway", the Manitoba Telephone System has established a medium haul facility in southern Manitoba using coaxial cable which is already assuming "electronic highway" stature with the promise of more to come in the near future. While the existing coaxial system is likely to serve user needs for many years, it can be expanded substantially in capacity with minimal additional cost. The physical electrical and logistical tests provided by this operating facility are almost identical to those which will be critically important to future fibre optics systems, particularly in the severe Manitoba climate.

The development of a superlinear broadband "feedforward" amplifier which was paramount to the success of this project will have important consequences for all segments of the CATV industry in that development by its manufacturer is well advanced on a 300 MHz unit which will provide dramatic improvements in system transmission performance, and the economics of local distribution. This progress is particularly important at this time when cabling of the larger American cities, with required lengthly trunk amplifier systems, appears to be on the horizon.

The development of a sophisticated status monitoring system with expansive software capabilities, a new 105 volt "no-break" standby power supply, a new series of rugged pedestals, and a multi-channel, portable, full-duplex telephone for use on bi-directional coaxial cable systems are important and interesting side-benefits associated with the ICBN.

Most important, interesting and cost effective new integrated applications have already and will continue to be established for coaxial cable technology using the M.T.S. ICBN.

REFERENCES

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