A MULTICHANNEL, BI-DIRECTIONAL SINGLE WAVELENGTH, OPTICAL VIDEO LINK OVER A SINGLE FIBRE

Shane J. Shklov
Manitoba Telephone System

ABSTRACT

Over the past year the Manitoba Telephone System, working with both Catel in California and Cabletel in Toronto has developed a unique optical architecture. In comparison to conventional fibre architectures, this structure has reduced the cost and complexity while increasing the reliability and capacity without sacrificing technical performance.

This multinode, multichannel, bi-directional, single wavelength video conference structure is in use between hospitals in the province of Manitoba. Details of this configuration along with its performance are discussed.

INTRODUCTION

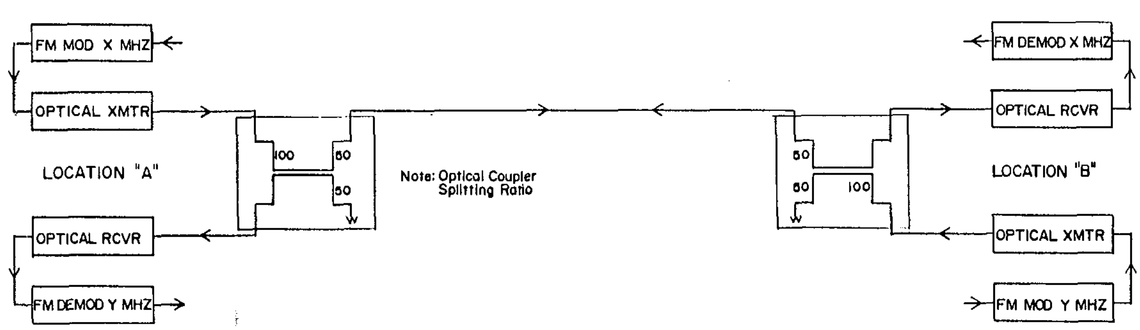
In order to comprehend this multinode, multichannel, bi-directional single wavelength, FM-FDM network architecture , the key building blocks are first examined. A bi-directional concept is combined with an optical structure having more than two nodes to achieve the end result. The theory is exemplified by the practical Hospital Conference Network with realistic system performance specifications.

BI-DIRECTIONAL OPTICAL LINK AT THE SAME WAVELENGTH

One key building block is illustrated in Figure 1. It is a bi-directional optical link at the same wavelength. The transmitter at location "A" is coupled into the fibre facility between "A" and "B" through a passive optical coupler. At "B" the circuit is completed with the receiver connected through another optical coupler. At the same time the transmitter at location "B" is coupled into the

FIGURE 1

BI-DIRECTIONAL OPTICAL LINK AT THE SAME WAVELENGTH



NOTE: ISOLATION BETWEEN INPUT PORTS OF OPTICAL COUPLERS MUST BE HIGH, TYPICALLY BETTER THAN 60dB
CARRIER FREQUENCY "Y" CAN BE THE SAME AS "X"

same fibre through the other port of the optical coupler. And this direction of the circuit is completed with the optical receiver at "A" coupled into the remaining port of the optical coupler at "A".

On the electrical side, the broadband RF signal input at "A" is regenerated at location "B". Simultaneously the broadband input at "B" is regenerated by the receiver at "A".

There are several reasons why the structure will operate in a non-interfering manner.

The photon density in the ten micron single mode fibre core is extremely low. Hence the probability of collisions between photons travelling in opposite directions is also low. Noise generated from such collisions is insignificant. An example of this would be the crossing of two flashlight beams which appear not to interfere with each other.

The other key to the operation of this circuit is the directivity of the optical couplers. Input port isolation is typically better than 60dB. This is important in isolating the receiver from the transmitter at the same location. Ideally the receiver at "A" should see only the optical signal transmitted from "B". Reflections or poor return loss in the optical network can mean that the transmitted signal at "A" will be received at "A" where it would interfere with overlapping RF spectrum. In other words, if the channel input at "A" is the same frequency as the channel input at "B", interference can occur if there is insufficient isolation between the two directions.

TWO TRANSMITTERS AT THE SAME WAVELENGTH LOOKING INTO ONE OPTICAL RECEIVER

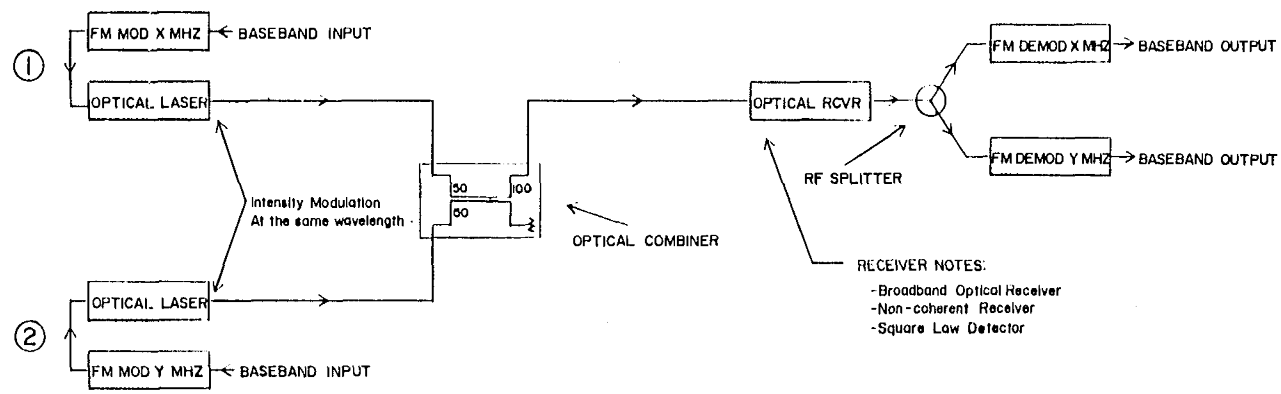
Figure 2 illustrates two optical transmitter signals of the same optical wavelength combined into one single mode fibre by means of a balanced optical combiner. The optical signals then travel through the fibre facility to the same optical receiver. The broadband RF inputs into laser "one" and laser "two" are regenerated by the optical receiver as a combined RF output. If the RF inputs overlap the RF output would also overlap but interference would only occur where the spectrum overlaps. the output of the optical receiver is then tuned by the appropriate frequency demodulator to retrieve the message signal.

On closer analysis, the vestigial sideband video signals are first frequency modulated onto different carriers. The transmitters accept the broadband inputs and directly modulate the current which drives the laser at 1310nm with a spectral line width of approximately 0.4nm. This means that the laser outputs are intensity modulated: there is no phase or frequency reference to the carrier at 1310nm.

The output of laser "one" is an intensity modulated waveform that represents the broadband RF spectrum at its input. Similarly laser "two" outputs an intensity modulated waveform that represents the spectrum at its input. The two optical signals combine through the optical coupler to produce an intensity modulated signal that represents the combined RF input spectrums. The information is contained in the optical power. The

FIGURE 2

TWO TRANSMITTERS AT THE SAME WAVELENGH
LOOKING INTO ONE OPTICAL RECEIVER



NOTE: RF input into laser number one can not overlap RF input into laser number two
ie) Carrier frequency "X" can not equal carrier frequency "Y"

combined optical signal is essentially a summation of optical powers. It is important that both of these optical signals are evenly balanced.

The receiver, by means of a square law detector regenerates the RF signals. The receiver is non-coherent; the phase and frequency of the incoming optical signal do not influence the receiver's output. In other words, the receiver does not lock (phaselock or frequency lock) onto any incoming signal. The FDM (frequency division multiplexing) provides the means by which the message signals are separated. To separate the signals at the receiver a simple frequency demodulator tuned to the appropriate frequency will reproduce the correct message signal. The frequency modulation provides the required signal to noise at the expense of more RF bandwidth as compared to direct amplitude modulation.

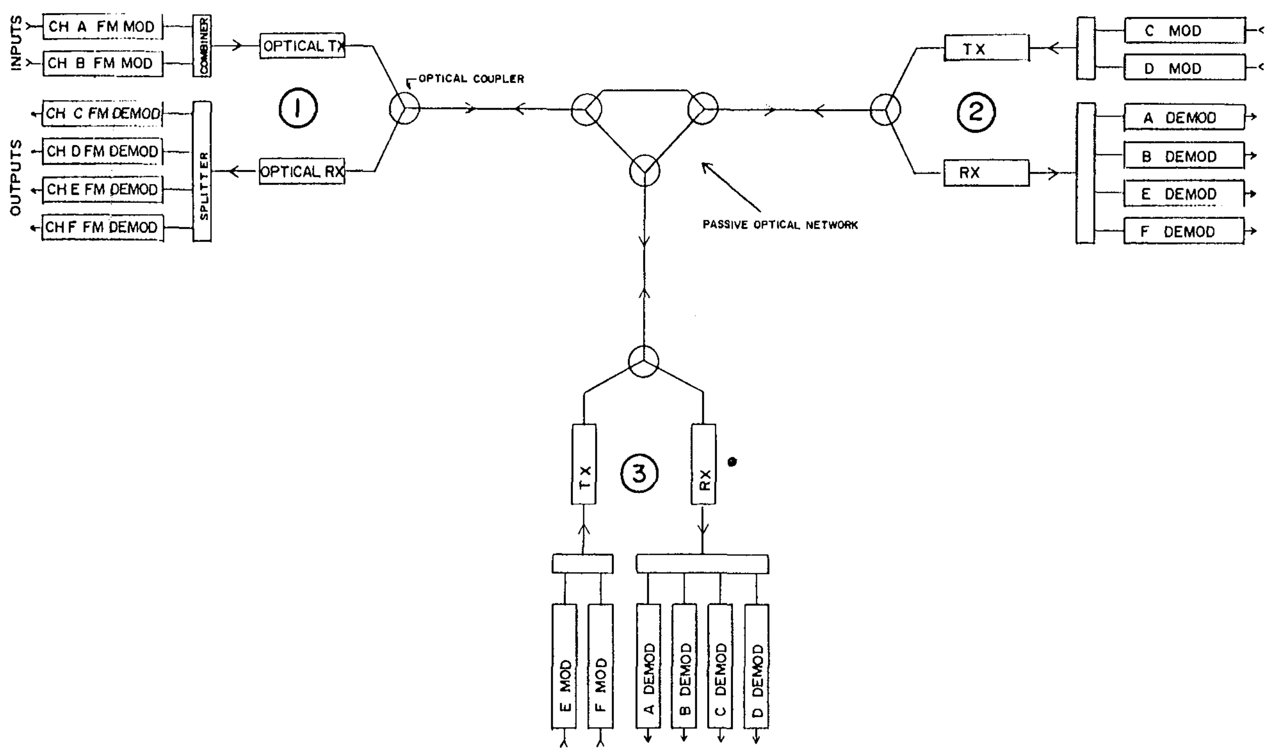
By combining the two principles of bi-directionality and multiple optical signals at the same wavelength traveling in the same direction on the same fibre the following network is derived.

MULTINODE, MULTICHANNEL, BI-DIRECTIONAL, SINGLE WAVELENGTH FM-FDM NETWORK ARCHITECTURE

Figure 3 illustrates a multinode, multichannel, bi-directional, single wavelength, frequency modulation, frequency division multiplexing network architecture. Three locations are shown. Each location has one optical transmitter and one optical receiver. All the transmitters are DFB lasers at the same wavelength. All transmitters are identical

FIGURE 3

MULTINODE, MULTICHANNEL, BI-DIRECTIONAL, SINGLE WAVELENGTH, FM-FDM NETWORK ARCHITECTURE



off-the-shelf standard wavelength DFB lasers. The receivers, one at each location are also all the same type. Optically the transmitter and receiver at each location are coupled into one single mode fibre. This means that only one optical fibre is required to provide the communication link to and from all the locations. Three fibres, one from each location come to a central passive combiner that is simply a combination of optical couplers designed to optically balance the network. The optical couplers are all fusion spliced to the fibre forming a transmission path entirely free of any active or mechanically connectorized devices other than the pigtails that connect directly to the optical transmitters and receivers.

Electrically, each location is transmitting two message signals; location 1 transmits channels A and B. Each location receives four signals; location 1 receives channels C and D from 2 and E and F from 3. The signals are transmitted as FM-FDM spectrum. This means that each message signal will be frequency modulated onto its own unique carrier. This is the key to differentiating the baseband signals at the receiver. The FDM is achieved through a simple passive RF combiner. On the receive side, the regenerated RF signal is split by a passive RF splitter and is fed into four frequency demodulators that are tuned to the required four channels.

This conferencing network clearly illustrates a Multinode, Multichannel, Bi-Directional, Single Wavelength, Single Fibre, FM-FDM communication facility. With this theory in hand the Manitoba Telephone System was ready for a real application of this form of fibre architecture.

THE HOSPITAL VIDEO NETWORK

The application here is a private conference network for use between hospitals in the Winnipeg and Brandon areas. The customer, The University of Manitoba (teaching hospital) requires conferencing between three locations. This network is illustrated in Figure 4. The three conference locations are: The University of Manitoba, The St. Boniface Hospital and the Brandon Mental Hospital; two in Winnipeg, one in Brandon, 200km west of Winnipeg. The link between Brandon Mental and the Winnipeg Fort Rouge TOC (television operating centre) uses an NEC video codec (digital video to and from Brandon). In Winnipeg, fibre exists between the TOC and the University of Manitoba, and the TOC and the St. Boniface Hospital.

In essence the Fort Rouge TOC becomes the third location, representing the Brandon node. The passive optical network that links all the locations is best located right at the TOC where all the fibres terminate. With the optical passive network at one of the nodes, the TOC, the optical signal levels are unbalanced. The optical combining/splitting network can be configured to balance the three optical links. In our particular case this was achieved by using a 30/70% power split (as illustrated) effectively only dropping off 30% of the light to the TOC and combining only 30% of the light from the TOC. Seventy percent of the power passes to and from the University of Manitoba and the St. Boniface Hospital.

The link contains a total of four video channels; two transmitted from the University of Manitoba, one transmitted from Ft. Rouge TOC (the Brandon signal) and one transmitted from the St. Boniface Hospital. RF channels in the 400-500 MHZ range originate at the University of Manitoba, in the 200-300 MHZ range from St. Boniface and in the 300-400 MHZ range from Ft. Rouge TOC.

The Catel Multichannel Fibre Optic System which incorporates the series 3000 Broadband FM Transmission System with the OT-1010 Optical Transmitter and the OR-1010 Optical Receiver is used throughout the electrical network. BT&D (British Telecom & Dupont) optical couplers are used in the optical network. The optics contain only fusion splices and bypass Telephone System optical patch panels.

The network was turned up and has operated since February of 1990. We are not aware of a comparable network in existance to date.

SYSTEM PERFORMANCE

Following is the network performance summary. Table one is an overview of measured video parameters at each location. The measurements were made with the Tektronics VM 700 automated test

FIGURE 4

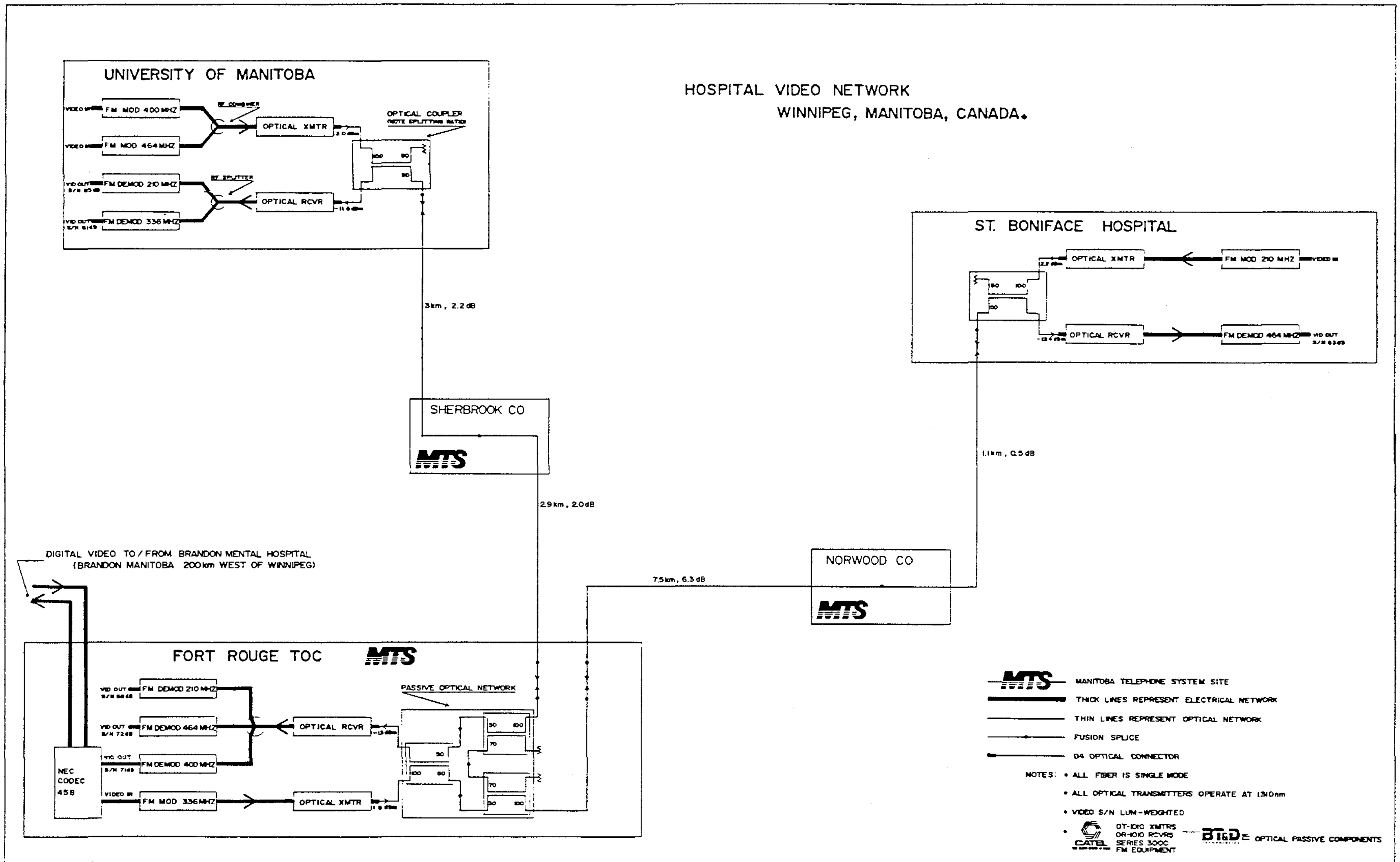

HOSPITAL VIDEO NETWORK
WINNIPEG, MANITOBA, CANADA.
UNIVERSITY OF MANITOBA
FM MOD 400 MHZ
FM MOD 464 MHZ
FM DEMOD 210 MHZ
FM DEMOD 336 MHZ
OPTICAL XMTR
OPTICAL RCVR
OPTICAL COUPLER
3km, 2.2 dB
ST. BONIFACE HOSPITAL
OPTICAL XMTR
FM MOD 210 MHZ
OPTICAL RCVR
FM DEMOD 464 MHZ
SHERBROOK CO
MTS
2.9 km, 2.0 dB
1.1 km, 0.5 dB
DIGITAL VIDEO TO / FROM BRANDON MENTAL HOSPITAL
(BRANDON MANITOBA 200km WEST OF WINNIPEG)
7.5 km, 6.3 dB
NORWOOD CO
MTS
FORT ROUGE TOC
MTS
FM DEMOD 210 MHZ
FM DEMOD 464 MHZ
FM DEMOD 400 MHZ
FM MOD 336 MHZ
OPTICAL RCVR
OPTICAL XMTR
PASSIVE OPTICAL NETWORK
NEC CODEC 458
MANITOBA TELEPHONE SYSTEM SITE
THICK LINES REPRESENT ELECTRICAL NETWORK
THIN LINES REPRESENT OPTICAL NETWORK
FUSION SPLICE
D4 OPTICAL CONNECTOR
NOTES: • ALL FIBER IS SINGLE MODE
• ALL OPTICAL TRANSMITTERS OPERATE AT 1310nm
• VIDEO S/N LUM-WEIGHTED
OPTICAL PASSIVE COMPONENTS

TABLE 1

Video Parameter	University of Manitoba 210 MHz	University of Manitoba 336 MHz	TOC, Fort Rouge 400 MHz	TOC, Fort Rouge 464 MHz	TOC, Fort Rouge 210 MHz	St. Boniface Hospital 400 MHz	St. Boniface Hospital 464 MHz	St. Boniface Hospital 336 MHz
Bar Amplitude (IRE)	100.6	101.4	99.4	101.5	98.9	100.2	99.9	100.0
Sync Amplitude (% Bar)	40.2	40.0	40.1	40.0	40.1	40.4	40.5	40.1
Line Time Distortion (%)	0.5	0.3	0.5	0.1	0.9	0.5	0.9	0.4
Pulse / Bar Ratio (%)	95.8	96.1	92.6	95.2	97.1	92.1	89.1	90.0
2T Pulse K-Factor (% K-f)	0.6	0.6	0.5	0.6	0.4	0.7	0.9	0.4
S/N Unweighted (dB)	55.3	50.9	63.5	64.4	57.0	56.2	56.3	55.1
S/N Lum-Weighted (dB)	64.5	61.2	71.2	71.5	67.5	66.3	66.3	67.1
S/N Periodic (dB)	50.0	44.7	58.3	58.9	50.9	51.1	51.3	55.4
Chroma-Luma Delay (ns)	30.5	10.5	15.1	6.3	19.6	21.5	27.1	18.8
Chroma-Luma Gain (%)	97.9	98.8	98.4	95.1	99.8	101.9	97.5	98.6
Differential Gain (%)	0.99	3.36	4.60	2.46	1.67	0.50	0.77	0.80
Differential Phase (Deg)	0.77	1.11	1.53	3.04	1.03	1.41	0.89	1.32
Lum-Non-Linearity (%)	1.58	0.20	1.22	0.67	1.48	2.46	3.80	2.91
80 IRE Chroma (IRE)	77.8	80.3	77.4	78.0	77.0	78.2	77.7	78.0
Chr NL Phase (Deg)	3.0	1.6	2.8	1.4	3.0	0.9	0.5	1.2
Chr-Lum Intmd (IRE)	-1.8	-0.4	-1.1	-0.4	-1.6	-2.4	-3.7	-2.5
Field Time Dist (% Bar)	0.64	1.01	0.85	0.79	0.64	1.02	1.11	0.95

set. Measurements were made with simultaneous modulation at each location on each video channel.

Table two shows optical transmit levels. Table three shows all combinations of optical receive levels.

Table four shows received RF levels at each location.

CONCLUSIONS

The network described in this paper uses commercially available off-the-shelf components.

The structure is ideal for video conferencing and educational networks over moderate distances. The Hospital Video Network with three locations proves to be economical, reliable, and simple without sacrificing performance. The maintenance of this network is also very straightforward. Spare parts are compatible at all locations. Only 1310nm transmitters are used, FM modulators and

TABLE 2

Optical Transmit Power (dBm)		
University of Manitoba Laser "A"	St. Boniface Hospital Laser "B"	Ft. Rouge TOC Laser "C"
2.0	2.2	1.6

TABLE 3

Optical Receive Power (dBm)			Laser Status	
University of Manitoba	St. Boniface Hospital	Ft. Rouge TOC	ON	OFF
0.0	0.0	0.0		A,B,C
-36.2	-12.2	-12.5	A	B,C
-11.2	-44.5	-10.2	B	A,C
-13.5	-10.9	-40.2	C	A,B
-12.0	-12.2	-12.3	A,B	C
-13.5	-8.2	-12.5	A,C	B
-13.4	-10.9	-10.2	B,C	A
-11.6	-13.4	-13.0	A,B,C	

Note: Optical Receiver Sensitivity, -25dBm

TABLE 4

LOCATION	RF RECEIVE LEVELS (dBmv) 210 MHZ	336 MHZ	400MHZ	464MHZ
University of Manitoba	28	30	-56	-54
St. Boniface Hospital	-50	30	32	32
Ft. Rouge TOC	30	-52	30	30

demodulators are all frequency agile and there are no active devices or optical connections outside of the three locations. The spare parts for this network are as follows:

One 1310nm transmitter
One 1310nm receiver
One FM modulator (agile)
One FM demodulator (agile)
One power supply

The optical passive devices used in the network are BT&D couplers which are minor cost items.

Other structures could be used to link three locations for video conferencing. One such structure would be individual fibres to and from each location with separate transmitters and receivers. With the Hospital Video Network this would have meant twice the number of transmitters and receivers or in other words over a 1/3 increase in the total network cost.

Another structure would involve using wavelength division multiplexing (WDM). WDM devices which are optical prisms that separate the wavelengths are fairly expensive. Also transmitters and receivers would be at different wavelengths requiring twice the number of spare parts. This type of network would be more expensive, more complex and harder to maintain.

Figure 5 shows direct comparisons of equipment and complexity based on different fibre architectures. Clearly as locations are added savings can be substantial. The performance of this multinode, multichannel, bi-directional, single wavelength, FM-FDM network with more than three nodes and more than four channels is a question that requires further investigation.

FIGURE 5

VIDEO CONFERENCE FIBER ARCHITECTURES