INTEGRATED FIBER OPTIC TRANSMISSION OF FM HDTV AND 622Mb/S DATA

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1. ABSTRACT

We report the integrated transmission of a 622 Mb/s (SONET STS-12 rate) data signal with three frequency-modulated (FM) component HDTV signals over 2 km of single-mode fiber. At -10 dBm received optical power a BER $<10^{-9}$ was measured on the data channel while simultaneously, the unweighted signal/noise ratio (SNR) was over 38 dB for the HDTV signals.

2. INTRODUCTION AND SUMMARY

NTSC video distribution using fiber optic subcarrier multiplexed (SCM) systems, in which analog modulation techniques and frequency-division multiplexing (FDM) at RF or microwave frequencies are employed, is a subject of great interest [1],[2],[3],[4]. With regards to SCM video distribution, two major concerns exist for the telephone companies - the transport of future wide-bandwidth HDTV signals [5], and the compatibility of SCM systems with baseband digital facilities [6],[7]

We suggest a solution to the above concerns in the manner of [6],[7], taking into consideration an emerging, switched 622 Mb/s (SONET STS-12 rate) broadband integrated services digital network (B-ISDN) which, in addition to providing voice and data services, will presumably carry multiple extended-quality NTSC channels [8]. It is intended to provide HDTV transport over this network. We propose here a possible interim solution whereby SCM HDTV signals and a baseband B-ISDN channel are simultaneously transmitted using a single optical transceiver pair. In this paper, we experimentally demonstrate the integrated transmission of a 622 Mb/s data signal, in baseband form, together with three FM component HDTV signals at carrier frequencies 1.3, 1.55 and 1.8 GHz over 2 km of single-mode (SM) fiber. At -10 dBm received optical power, a BER $<10^{-9}$ was measured on the data channel while simultaneously the measured unweighted signal/noise ratio (SNR) was over 38 dB for each component HDTV signal. The measured SNR value is within 4 dB of the inherent SNR capability of our HDTV source. No FM preemphasis/deemphasis filtering was employed in the experiment The measured system frequency response for each of the FM channels was greater than 20 MHz, the source signal bandwidth. In addition, the differential delay between the received component signals was less than 20 ns, and imposed no spatial color misregistration in the resulting picture.

3. EXPERIMENTAL SETUP AND RESULTS

The experimental setup is shown by Fig. 1. The optical transmitter is a 1.56 μm DFB laser diode and the receiver consists of a p-i-n photodiode with built-in 50 Ω matching resistor, followed by a low-noise, wideband, 50 Ω preamplifier. The bench-top FM modulator and demodulator are constructed using standard, commercial microwave components. The FM modulator is a 1-2 GHz voltage-controlled oscillator (VCO) and the FM demodulator is a phase-shift discriminator using a power divider, delay line, double-balanced mixer and low-pass filter. R, G and B component HDTV signals, on separate FM carriers between 1.3 and 1.8 GHz, are combined with a pseudo-random 622 Mb/s baseband digital signal to intensity modulate the laser diode. No optical isolator was employed in the laser transmitter. The optical signal propagates through 2 km of SM fiber followed by an optical attenuator After the optical receiver, the electrical signal is split four ways, each undergoing appropriate signal processing to recover the video and data signals. The FM demodulated component HDTV signals are connected to an HDTV monitor while BER measurements are performed on the data channel.

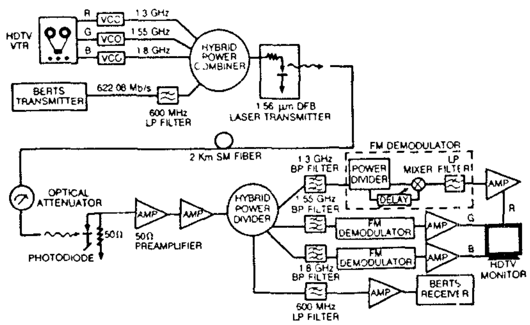

Fig. 1. Block diagram of experimental set-up.

For each HDTV channel, the optical modulation index, m, defined by $m = \frac{P_{\max} - P_0}{P_0}$, is 0.13, where P_0 and $P_{\max}$ are, respectively, the average and peak received optical power, with no other signals being simultaneously transmitted. The FM deviation ratio $D = \Delta f / W$ is about 2.1 where Δf is the peak carrier frequency deviation and $W \approx 20$ MHz is the bandwidth of the modulating HDTV signal The RF bandwidth per component is approximately $B_T = 2(D+2)W$. In our experiment, the system noise is dominated by the thermal noise of the 50 Ω receiver preamplifier, and the carrier/noise ratio (CNR) is given by

$$CNR = \frac{(mI_d)^2 50}{8FkTB_T}, \tag{1}$$

where I_d is the DC photocurrent and F is the amplifier noise figure. FM provides an improvement in SNR after demodulation over CNR given by [9]

$$\frac{SNR}{CNR} = \frac{3}{2} D^2 \frac{B_T}{W} = 3D^2 (D+2), \tag{2}$$

indicating a factor of improvement proportional to D^3. SNR in this paper refers to unweighted quantities.

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As shown by Fig. 2, measurements indicate that the analog video signals had minimal effect on the received BER of the digital data. In contrast, the data signal significantly affected the quality of the video signal, as evidenced by approximately 6 dB improvement in CNR when the data signal was extinguished at the transmit side. This is attributable both to a factor of two decrease in effective optical modulation index of the video signals due to large amplitude data modulation, and "in-band" leakage interference from the data signal due to non-ideal band limiting of this signal prior to the power combiner.

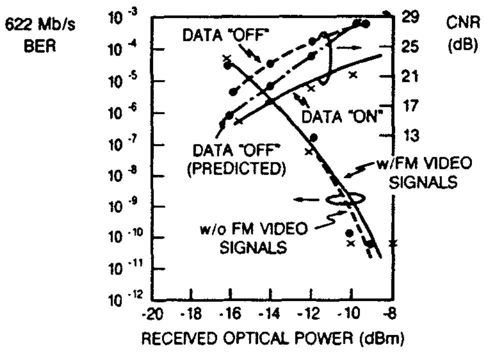

Fig. 2. Measured data BER and video CNR as functions of received optical power.

At -10 dBm received optical power, a summary of the video signal parameters is given by Fig. 3. With the data turned off, the average measured CNR is 27.4 dB, in excellent agreement with the expected CNR of 28 dB using (1) and given $I_d \approx 90\mu A$, F=3 dB and B_T=161 MHz. With the data on, the average measured SNR is 38.1 dB, again in close agreement with the expected SNR of 38.7 dB using the average measured CNR of 21.4 dB in (2). The term "average" refers to the mean of the R, G and B channel values. The inherent 42 dB SNR limitation of our HDTV source determined the FM improvement obtainable in this experiment. In case of a practical system where higher SNR is desired for the same CNR, simple preemphasis and deemphasis filtering would provide about 15 dB additional SNR improvement. Average measured frequency response of the FM channels is 26.7 MHz. Differential delay among the three received component signals is less than 20 ns. Overall, the quality of the received picture was excellent, reproducing the detail of the source program and displaying only a slight noise increase over the original picture.

The receiver sensitivity of -10 dBm for 10^{-9} BER on the data signal is attributable primarily to the thermal noise of the wideband 50 Ω receiver, and to over 4 dB extinction ratio power penalty incurred in order to accommodate the required video signal amplitudes. A well-designed receiver should give much better sensitivity. As it is, with 0 dBm optical power launched into the fiber at the transmitter, the experimental link would provide a 5 dB optical loss budget with 5 dB margin.

	PARAMETER	CHANNEL R	CHANNEL G	CHANNEL B
DATA OFF	EXPECTED CNR	28 dB		
	MEASURED CNR	28 2 dB	26.7 dB	27 3 dB
DATA ON	MEASURED CNR	21 dB	20.6 dB	22 5 dB
	UNWEIGHTED SNR[1]	37.7 dB	37.1 dB	39 6 dB
	UNWEIGHTED SNR[2]	38 3 dB	37 9 dB	39.8 dB
	CHANNEL BW	26 MHz	32 MHz	22 MHz
	DIFF DELAY	<20 ns		

1 - MEASURED
2 - CALCULATED FROM MEASURED CNR USING EQN (2) (SNR = CNR + 10 log$[3D^2(D+2)]$)

Fig. 3. Summary of received HDTV signal parameters at -10 dBm detected optical power.

4. CONCLUSION

We have demonstrated the simultaneous transport of a component HDTV signal using FM techniques with a baseband 622 Mb/s signal over 2 km of SM fiber using standard fiber optic and microwave components. At -10 dBm received optical power, a BER $<10^{-9}$ was obtained on the digital signal. Simultaneously, the received HDTV signal had SNR > 38 dB and provided full accommodation of the 20 MHz signal bandwidth. Furthermore, we have shown, in principle, an overlay architecture where compatibility is maintained between an SCM system for video distribution and a B-ISDN lightwave transmission facility. This hybrid transmission architecture has advantages of compatibility with existing systems, flexibility of service accommodation, and near-term implementability. It can serve as an interim strategy for integrated transport of telephony, data, and various video services, including HDTV, until the future establishment of an all-digital network.

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