MULTICHANNEL VIDEO TRANSMISSION THROUGH LASER DIODE BASED FIBER OPTIC SYSTEMS

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ABSTRACT

This paper details some of the practical design considerations in employing injection laser diodes and avalanch photodiodes in the transmission of video signals through fiber optic cable. Specific attention is given to the noise properties associated with these devices (including laser noise, modal noise and noise due to coupling effects) and how it relates to system performance. The effect of laser diode non-linearities on noise and bandwidth is also discussed.

A three channel FDM-FM prototype system is presented and its measured performance is related to the optical devices employed.

INTRODUCTION

Throughout the summer and fall of last year we explored requirements necessary to implement a wideband analogue transmission link employing laser diodes. The primary emphasis was on a multichannel video system. Of the possible modulation techniques, FM was chosen and developed because of the possible noise bandwidth tradeoff. To this end, a prototype transmitter and receiver were designed and tested together with a Catel VFMS-2000 FM modulation system.

GENERAL CONSIDERATIONS

In the implementation of a wideband (>200 MHz) analogue system, 50µm core graded index fiber was selected as the best choice fiber. Fibers of this type will soon become readily available with bandwidths beyond 500 MHz-Km and attenuations less than 3db/Km and 1db/Km at wavelengths of 850 and 1300nm respectively. In the future even broader bandwidths will become available. Long wavelength sources and detectors presently are not as readily available as short wavelength devices. Furthermore, they do not perform as well. Primarily for this reason, only short wavelength devices are considered in this paper.

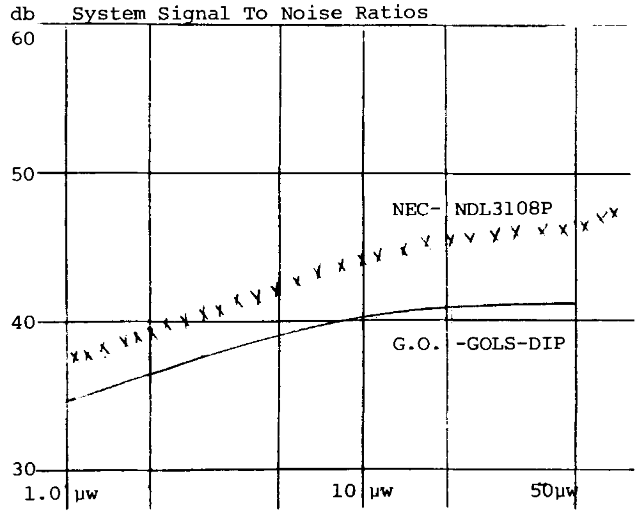
Of the three optical elements in the transmission system, the laser and laser fiber interaction present the most difficulty. LED sources are limited by material dispersion; therefore, they cannot be used in this application.

Both singlemode and multimode lasers were investigated. In the singlemode devices, the resultant modal noise caused noise floor variations as great as 15db. We felt this was unacceptable. Microwave modulation was attempted and the noise floor exhibited comparable stability to the multimode devices tested. Under this condition, the minimum noise initially observed was significantly below the level observed with u-wave modulation. Therefore, the program tended toward securing a multimode laser system.

LASER NOISE

It is now necessary to briefly describe the several noise processes.[1] The most fundamental is intensity fluctuations caused by the spontaneous and stimulated emission processes. These fluctuations are increased by reflection back into the laser cavity from the laser-fiber and fiber-fiber interfaces. While it is desirable to achieve tight coupling, this interference may decrease the carrier to noise (C/N) ratio sufficiently to limit the system S/N ratio even at moderate received power levels. Figure 1 shows the signal to noise ratio of our system with two different laser sources. For both lasers employed, the S/N flattens at high power levels. Theoretically, it should increase with the square root of the power (which it does for LED sources).

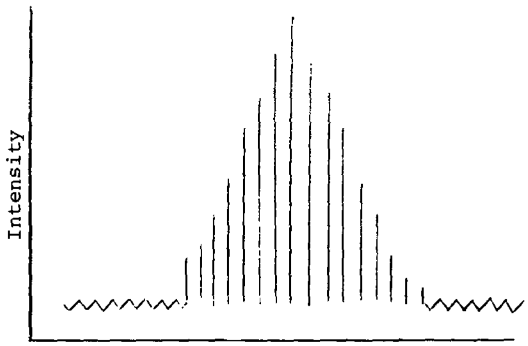
Figure 1.
System Signal To Noise Ratios



Receive Power µW

Figure 2 shows the spectral output of a typical multimode laser. It has been found by Ito[1,4] and others that individual modes can vary as much as 50db above the ensemble average. If all modes are passed evenly to the detector, little noise will appear. However, the fiber and connector form a mode selective network. As a consequence, the detected output voice floor will shift because of the uneven delay and attenuation characteristics in the fiber. This noise, therefore, is initiated by either fiber refractive index changes (e.g., an aerially suspended cable in wind) or thermal instabilities in the laser.

Figure 2



In summary every attempt should be made to align all connectors as accurately as possible, to insure good thermal stabilization of the laser, and to minimize reflections back into the laser cavity. This however will not totally eliminate modal noise. The resultant low C/N ratio makes wide deviation FM equipment necessary for multichannel applications.

COUPLING

One of our major objectives was efficient optical coupling. The small emitting area and large beam divergence in the direction perpendicular to the heterojunction produce 8 to 10db coupling loss for a cleaved fiber. The use of tapered fibers with hemispherical lenses formed on the end have been used by us with good results. Employing this technique, we have been able to achieve greater than 1mw output power consistently from a 5 - 8mw laser, coupling efficiencies of >30%.

A second objective was to minimize reflections back into the laser cavity. The smaller curvature of the lens after tapering, and the wider separation from the laser cavity, made possible by this technique, helps meet this objective.

DETECTORS AND SOURCES

Currently two kinds of detectors are employed in fiberoptic receivers. They are PIN diodes and avalanch photodiodes. Even for FM transmission good video will require sufficient received power to make leakage currents insignificant.

Of the two types of detectors, the APD has a significant advantage in wideband systems. The avalanch gain allows the detector shot noise to dominate the receiver noise at most received power levels. Furthermore, the APD can be used as a gain control element. The PIN diode may be employed in shorter distances and reduced channel capacity systems. Generally, they do not require the temperature compensation and large reverse bias supply of an APD.

In our prototype, the APD chosen was the RCA C30908E with integral light pipe. This device was chosen primarily because of its low excess noise.

Multimode lasers from LDL, NEC and G.O. were evaluated with the following results. The G.O. GOLS-DIP laser provided the most linear operation. Furthermore, the noise floor was the most stable, less than 1db. It was felt that this offset the increased average noise. Table 1 shows the measured signal to noise ratios for the NEC 3108P vs the G.O. GOLS/6687-DIP. The LDL SCW 10 produced the same noise characteristics as the NEC device. Linearity of the devices was measured using a two tone test method. The modulation index for the two tones was .3 each at 10 MHz and 17 MHz respectively. The NEC 3108 and LDL SCW-20 lasers measured at -33db 2nd harmonic distortion. General Optronics specifies their device at -40db 2nd and -50db 3rd.

Table 1
Output S/N NEC-3108P, GOLS 1/6687-DIP

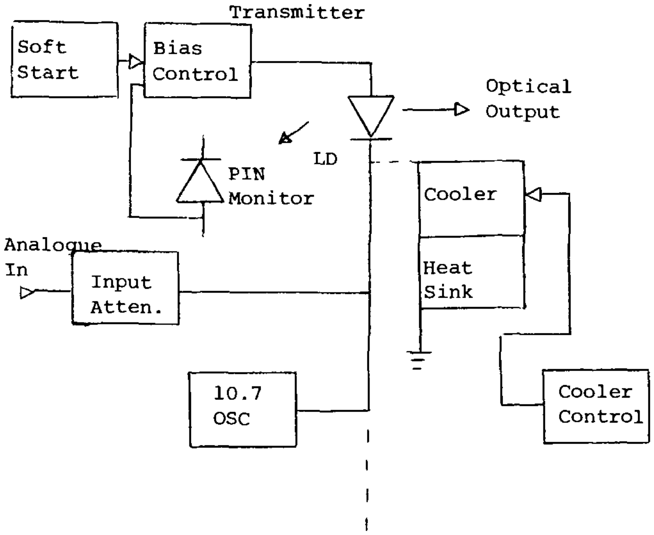
Laser Transmitter

	NEC		GOLS	
PIN	S/N_U	S/N_W	S/N_U	S/N_W
1	37.3	48.4	34.5	44.5
2	41	52.0	36.5	46.5
5	43.7	54.4	40.5	50.5
10	44.1	55.1	41.5	51.5
20	47.5	56.5	42	52.0
35	47.2	58.1	42	52.0
50	46.7	57.1	43	53.0

OPTICAL TRANSMITTER

Figure 3 shows a block diagram of the analogue transmitter. A 10.7 MHz oscillator is provided for AGC purposes. 10.7 MHz was chosen because relatively inexpensive ceramic filters could be purchased at that frequency. A PIN diode monitors the output power at the rear facet. The operating point is controlled within 1db.

Figure 3
Transmitter



THE OPTICAL RECEIVER

Figure 4 shows the preamplifier detector circuits. The APD can be used as a linear gain control element. To this end two separate bias control networks are provided. The first bias control allows the gain to vary from 100 to 20 as power is increased. The second circuit fixes the gain at 20 for all increased power levels. The preamplifier is of the transimpedance type with a transimpedance of about 1K.

Figure 4
Preamplifier

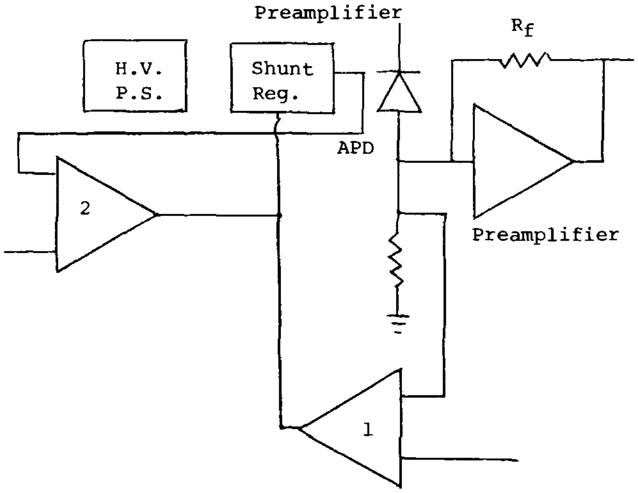
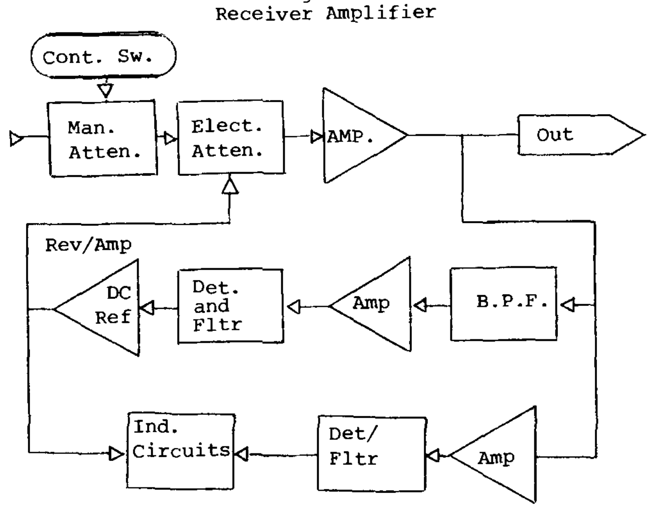


Figure 5 shows the rest of the amplifier. This circuitry employs a FET attenuation network and a manual gain switch. The output is sampled and fed through a 10.7 MHz band pass filter which detects the pilot tone used to control the AGC elements. A high frequency modulation detector is also provided. The receiver bandwidth is about 200 MHz. Harmonic distortion for this receiver is typically at -50db second, and -55db third. The dynamic range of the receiver is about 20db optical.

Figure 5
Receiver Amplifier



SUMMARY OF TEST RESULTS

The initial objective was to produce a wideband system capable of supporting at least 3 FM video channels with better than 50db S/N ratio. If the maximum modulation depth (m) is restricted to, say, .2 per channel and the system is shot noise limited at the detector, approx. 3μw received power would be required for 50db S/N ratio (CCIR weighted).

The output signal to noise ratio of our system employing the Catel FM modulators is shown in Table 1. Note that the 50db S/N ratio was achieved only for the NEC laser. Its noise floor was subject however to 3 to 4db variations, making the exact S/N difficult to establish. The G.O. laser was stable and produced noise 6db greater than anticipated.

Interference susceptibility against a gray screen was found to be imperceptible at -40db in most cases, -50db in all cases. It is felt that if the number of channels were small, 3 or 4, a channel plan could be found which would allow minimum interference possibilities and allow increased modulation depths, say a 70 MHz, 90 MHz, 130 MHz plan. The FM enhancement is about 4db with standard Catel modulators. The CCIR weighting network improves the S/N additionally 10 to 11db. This corresponds well to the 16db measured total improvement. It is extremely advantageous to increase the modulation index (β) of the FM modulators even further.

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CONCLUSIONS

1. Increased source noise make wide deviation FM equipment necessary.

2. Laser noise produced results which indicated system noise limited by source C/N ratio.

3. Multimode lasers are preferred as they limit modal noise.

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