FIBER OPTIC RETURN TRANSMITTERS FOR CATV

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Abstract

This paper discusses the use of fiber optic transmitters utilizing Fabret-Perot (FP) lasers for return links in CATV distribution networks. The dynamic range achievable with a link driven by this type of transmitter is dependant on many factors which limit the achievable performance. Knowledge of their effects is important for optimizing the return link. Performance of prototypes operating over a 22 kilometer (7.5 dB) fiber link are reviewed and some of the design details for achieving the performance are explained.

I. INTRODUCTION

Fiber optic return links are becoming increasingly important in CATV applications and the use of the inexpensive FP laser as a directly modulated optical source is attractive since the return band channel loading is low. A return cable path often has only a 5 to 50 MHz passband which can accommodate up to 7 NTSC channels. Usually, only a few channels are required and a low cost FP transmitter without an isolator can be used effectively to transmit the video carriers through a link with excellent carrier-to-noise (C/N) and distortion performance.

FP lasers with external optical isolator have been demonstrated for 42 channel forward band CATV transmission over a short (5dB) link [1]; however, for a return fiber link the use of an isolator is an expensive addition and optimization of other system parameters precludes its use.

Return channels sent back to the headend are required to be of high quality as they are to be transmitted back out through the forward cable system. CNRs in the high fifties are generally required for this type of application.

A prototype link capable of delivering 2 channels through a 7.5 dB link with Carrier-to-Noise ratios (CNR) of greater than 59 dB with no distortion products greater than -75 dBc has been demonstrated. This same link can deliver 4 channels with 55 dB CNR and -65 dBc worst case CSO and -70 dBc CTB. When the channel loading is increased to 7, 52 dB CNR with -62 dBc CSO and -67 dBc CTB is obtained and this performance is only slightly degraded as the transmitter is temperature cycled up to +60 celsius.

In order to achieve this performance, a laser with excellent linearity and fiber coupling must be selected. Also important is that the link it is driving must have minimal reflection back into the laser. Correspondingly, the receiving photodetector in the return receiver, as in the forward optical receivers, must have a high optical return loss even though the channel loading is low. In the return link the FP laser, with its characteristic multiple longitudinal mode optical spectrum, is extremely sensitive to reflection.

II. PROTOTYPE LINK PERFORMANCE

Figure 1 shows a block diagram of a prototype return transmitter using an FP laser with no isolator.

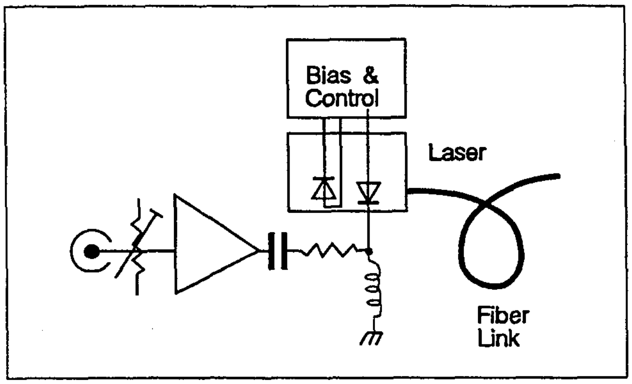

Figure 1.
Transmitter Block Diagram

The transmitter consists of a Motorola Return Band hybrid CATV amplifier driving a Philips CQF-57D FP laser. Resistive matching is used between the amplifier and the laser, though transformer matching has distinct advantages for return band transmitters. The use of transformer matching will be discussed later in this paper.

Optical power leveling is achieved by means of a differential amplifier which adjusts the bias to the laser to maintain the voltage across a resistor loading the monitor detector at a temperature compensated reference level. Figure 2 shows the 7 channel spectrum viewed at the receiver separated from the return transmitter by 7.5 dB loss of fiber.

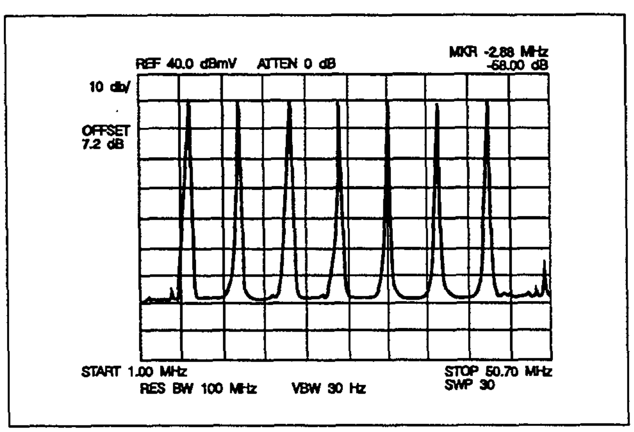

Figure 2.
Seven Channel Spectrum

The distortion products (second order distortion predominates) visible in this plot are both link and spectrum analyzer generated and calculation of their actual levels or use of a preselector filter reveals their true levels to be -62 dBc. Third order distortion must be characterized using a filter and worst case third order distortion (CTB) was measured to be less than -69 dBc. The return transmitter was fusion-spliced to the link for these measurements.

II. OPTICAL REFLECTION

With a fiber connector spliced into the link at the transmitter, there was a slope in the noise floor across the frequency band. This slope, when observed over a much larger frequency range, was found to be a periodic peaking in the noise floor of the link over its modulation bandwidth. This effect is caused by optical reflection from the connector and is similar to having a secondary resonant cavity external to the FP resonator. The frequency spacing of the noise peaks is equal to the reciprocal of the round trip travel time of light in the fiber from the laser to the connector interface. In order to improve the noise floor of the link so that it is more flat, one could use an optical isolator, a laser with a narrower optical linewidth, or use a lower reflection fiber link terminated in a better optically matched photodetector. The first two approaches add significant cost to the return fiber link; however, the third is potentially low cost with significant performance enhancement when properly implemented. Using this approach alone, increased channel loading can be accommodated.

III. CNR CALCULATION

The calculation of CNR for a directly modulated laser diode-driven link has been treated extensively in the literature and is covered in most standard text books on fiber optics so the details will not be reviewed in this paper. The FP laser link performance is effected significantly by optical reflection in the link so an analysis including only laser relative intensity noise (RIN) and receiver thermal and shot noise will predict CNR performance higher than what is observed if an optical reflection such as with a connector is present. For an FP link with no isolator, a more refined analysis is required. It is useful, however, to consider the achievable CNR without considering reflection, as if an ideal isolator were used at the output of the laser. The received CNR vs. link budget for an FP driven link with modulation index typical of 4 channel transmission is shown in Figure 3. It is assumed that; the transmit power of the laser is 2 mW (+3 dBm), the RIN of the FP laser is -135 dB/Hz, the receiving photodetector works into a 300 ohm load (achieved through a 4:1 impedance transformer from the 75 ohm receiving amplifier input) and has a dark current of less than 1 nA, and that the noise figure of the receiving amplifier is 4 dB.

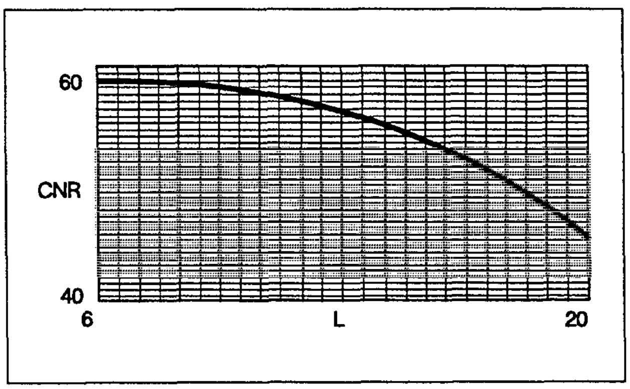

Figure 3.
CNR vs. Link Budget

This analysis is actually conservative for a return link. With low channel loading and narrow bandwidth, many of the design constraints of a receiver intended for forward band operation are lessened. Special purpose low noise receivers [2] with increased photodetector load impedance and low noise GaAs FET amplification can be applied and have excellent CSO performance, often a problem in return band links.

In order to more accurately predict the received CNR of an FP laser driven link, the effect of optical reflections must be modeled. Unfortunately, this is not particularly simple for an FP laser because the optical spectrum consists of a grouping of closely spaced longitudinal modes with wavelengths that are a half integer sub multiple of the FP laser cavity length and there is a combined effect from these modes (Figure 4). If there is dispersion in the fiber, the calculation of this effect is more than a simple extension the analysis of reflection in a DFB driven link.

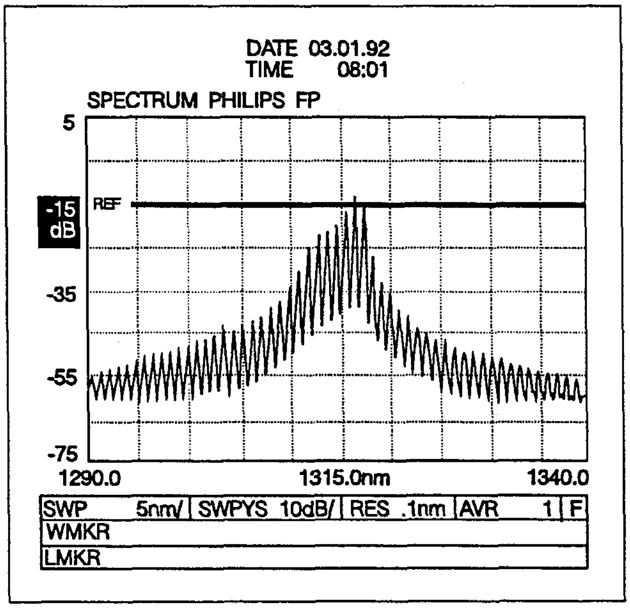

Figure 4.
FP LASER SPECTRUM

IV. TEMPERATURE EFFECTS

The optical spectrum of the FP laser is effected significantly by variations in temperature. Not only does the center wavelength of the peak in the mode distribution vary, but the mode distribution can vary significantly depending on whether most of the optical power is in a single, central mode, or shared by several adjacent modes. Often, an optimal operating temperature can be found at which point one mode is dominant and the effective linewidth for the particular laser is minimized. Under these conditions, the CNR and reflection immunity will be improved.

The use of a cooler is not always practical as they consume large ammounts of power (several watts is not unusual if a linear power supply is used). Not using a cooler can limit channel loading and CNR performance as well as the operating temperature range of the transmitter, so the choice of using a cooler or not is an important one.

V. RF DESIGN OF FIBER OPTIC RETURN BAND TRANSMITTERS

The RF circuits associated with the design of a return fiber optic transmitter include the input attenuator and the driver amplifier. Additionally, directional couplers for monitoring the laser drive or for combining auxiliary inputs are sometimes desired.

The primary requirement for the driver amplifier is that the output compression levels must be well above the input levels that distort the laser so that no significant amplifier distortion is produced and the dynamic range of the link is not limited by RF amplification. Almost any return band CATV hybrid amplifier is capable of driving the laser sufficiently, though improved efficiency through use of a discrete amplifier is favorable for the sparse channel loading required of a return system.

Transformer matching from the output of the amplifier down to the low impedance (5 ohms) of the laser diode is advantageous for narrow band applications because it reduces the required drive level to the laser. For an ideal transformer, the reduction in required drive level to attain a desired optical modulation depth is 6 dB, though for practical transformers with core loss, 4 or 5 dB can be realized. This lessens the output drive level required from the amplifier, thus relaxing the required output compression levels and gain. Less overall power consumption is required by the transmitter if this is properly implemented.

V. CONCLUSION

FP lasers can be used effectively without an isolator or cooler for return band CATV fiber links provided the channel loading is low and the link provides a low back reflection optical match to the laser.

Use of coolers and/or isolators can significantly enhance system performance of FP driven laser links; however, the cost and power requirements of the improved performance links are large.

REFERENCES

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