ANALOG MICROWAVE FIBER OPTIC COMMUNICATIONS LINKS

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ABSTRACT

Analog microwave fiber optic communication links have the potential to replace coaxial systems for transmission of RF signals at frequencies up to 15 GHz and beyond. Potential applications include antenna remoting, distribution networks, and communications. At TRW, prototype bandpass RF fiber optic links have been constructed with center frequencies up to 5 GHz. The performance of these links will be discussed.

INTRODUCTION

RF optical links using semiconductor lasers as transmitters have the potential to replace coaxial systems for the transmission of RF signals in the microwave and millimeter wave frequency ranges. Potential applications include (1) antenna remoting, (2) radar systems, and (3) secure RF communications. Coaxial transmission systems exhibit tremendous losses which render them impractical for operation over any appreciable distance. As an example, RG-400 coax has losses of 1115 dB/km and .141 semi-rigid coax has losses of 790 dB/km at 5.0 GHz[1]. These losses contrast sharply with silca based single-mode optical fiber losses at 1.3 μm of 0.47 dB/km[2], a reduction of three orders of magnitude. Even with the inclusion of loss due to electro-optical conversion and intercomponent optical coupling, the optical transmission system will provide lower losses for link lengths as short as 150 feet. As the frequency is increased above 5 GHz, the crossover point between coaxial-based systems and optical fiber-based systems will be reduced.

Fiber optic transmission systems have other characteristics that make them attractive for use as RF transmission media. They are lightweight, small, rugged, immune to EMI/EMP, secure and have extremely large bandwidths.

MODULATION TECHNIQUES

To modulate an optical signal at microwave frequencies, two approaches have been utilized. They are direct modulation of the current through the semiconductor laser diode or modulation of the optical beam by an external modulator. Using the the former approach, the frequency of modulation is limited by the photon lifetime, the electron lifetime and the ratio of the DC bias current to the laser threshold. In commercially available devices, this limit is between 3 and 8 GHz. It has recently been demonstrated by K.Y. Lau et al.[3], that direct modulation can be performed to 11 GHz with specially constructed laser diodes. For higher frequencies, external modulators have to be used. Modulation frequencies as high as 17 GHz have been demonstrated[4].

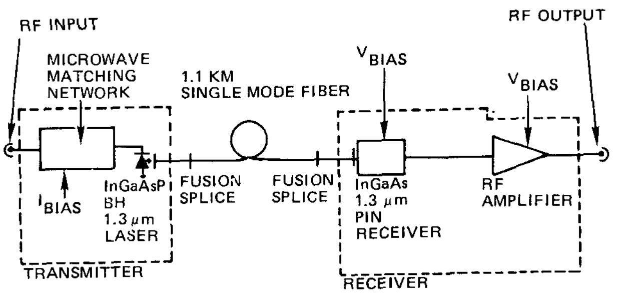

Figure 1. Generalized Block Diagram of a 1.3 μm Microwave Fiber Optic Link

TRW MICROWAVE FIBER OPTIC LINK EXPERIMENTS

TRW Electro Optics Research Center has constructed several prototype RF-Fiber Optic Links to demonstrate the transmission of RF signals. A generalized block diagram of these links is shown in Figure 1. This figure shows the principal components of the link including the transmitter, the receiver and the optical fiber. The transmitter consists of a passive microwave matching network and 1.3 μm InGaAsP BH semiconductor laser diode. In our experiments, the microwave matching network was implemented in microstrip on a board with an unloaded dielectric constant of 2.45. The circuitry consists of an RF path that matches the 50 ohm signal to the impedance of the laser diode and a DC current bias. The laser is pigtailed and connected to 1.1 kilometers of Corning single-mode optical fiber. Connections were formed by the use of fusion splices. The loss in the optical fiber at 1.3 μm is 1.08 dB/km. The fiber is terminated by a fusion splice to the receiver section. This section consists of a GaInAs 1.3 μm PIN detector and a low noise RF amplifier. The amplifier serves two purposes: (1) amplify the signal to the point where the throughput loss in the link is minimized and (2) in the case of narrow bandpass links, filter the output signal to suppress out-of-band signals (such as those generated by harmonics).

TABLE I. MEASURED PERFORMANCE OF THE 4.4 GHZ MICROWAVE FIBER OPTIC LINK

Optical Wavelength	1.3 μm
Frequency Center	4.4 GHz
Bandwidth	600 MHz
Length	1.1 km
Signal-to-noise ratio in 500 KHz band	60 dB
Frequency Response Flatness	±1 dB
Harmonic Suppression	52 dB
Two-Tone Intermodulation Product Suppression for -3 dBm inputs MHz Separation	36 dB
Non-Harmonic Spurious Response observed	None
Link Insertion Loss	-1 dB
Receiver Type	PIN with Amplifier

The narrow band links operated at center frequencies of 2.35 GHz, 4.4 GHz and 4.75 GHz with bandwidths of 500 MHz, 600 MHz and 700 MHz respectively. The wideband link had a 3 dB bandpass extending from 100 MHz to beyond 4 GHz. The 4.4 GHz link performance is typical for these prototype links. A summary of the measured performance of this link is shown in Table I.

Shown in Figure 2 is the measured RF insertion loss characteristic of this link. The small ripple in the response is due primarily to reflections from impedance mismatches. A 0 dBm signal on the input will result in a + 1 dBm signal at the receiver. Also shown in this figure is the suppression of the out-of-band frequencies by more than 25 dB. This suppression results from the fourth order microwave matching network in the transmitter.

CONCLUSION

Analog microwave fiber optic communication links have demonstrated the potential to be useful for transmission of RF signals over extended distances. As these links mature, new applications that exploit the unique capabilities of these links will emerge.

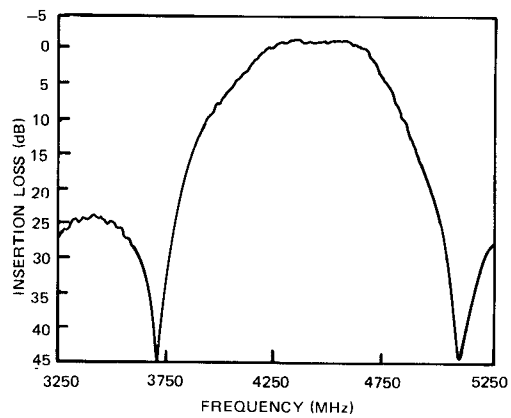

Figure 2. Measured RF Insertion Loss Characteristic of 1.3 μm 600 MHz/4.4 GHz, 1.1 km Fiber Optic Link

REFERENCES

(1) United Microwave Products Catalog, 1982.

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(4) C. M. Gee and G. D. Thurmond; "17-GHz Bandwidth Mach Modulator"; paper WA5, OFC'84 New Orleans, Louisiana, January 23-25, 1984.