AN EXTERNALLY MODULATED FIBER-OPTIC LINK TEST BED FOR CHARACTERIZING LINK PERFORMANCE IN A SYSTEM

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ABSTRACT

The design and environmental testing of a modular analog fiber-optic link are reported. Over a 10-MHz bandwidth the link noise figure is 8 dB without electronic amplification. The link performance and the systems effects with active and passive implementations of module calibration and modulator bias stabilization are discussed.

Recently, the gain of externally modulated fiber-optic links has been improved by 60 dB, the noise figure by 50 dB, and the intermodulation-free dynamic range by 30 dB (1,2). These results were obtained in experiments designed to measure the improvement in a particular link parameter. Although this is a necessary development step, it is also important to measure link parameters under conditions that require the link to simultaneously satisfy the multiple constraints anticipated when it is used in a system. To meet this need, we have designed and built a test bed for characterizing fiber-optic links, which also enables us to examine the change in link parameters as a function of temperature. The measurements on the test bed have exposed the interactions between link parameters and support circuitry and have identified the essential support equipment.

We have assembled an externally modulated fiber-optic link test bed consisting of a link module and the support equipment. The module portion of the test bed, illustrated in Fig. 1(a), incorporates several functions. including calibration and active bias control. Since dc power is required at the module, we will refer to this as an active design. One attractive possibility of externally modulated fiber-optic links is that they can potentially avoid the need for dc module power. Figure 1(b) shows an example of such a passive module design.

A photograph of the module is shown in Fig. 2. It comprises an RF filter, a Mach-Zehnder modulator, a control board, and a photodetector assembly. This configuration, which divides the module into segments, facilitates changing of the individual parts. Module power of about 1 mA at 5 V is supplied by a photovoltaic cell (one of the photodetectors) that is illuminated by a 0.85-μm, 50-mW fiber-coupled diode laser. In addition to this laser, the support equipment consists of a 1.32-μm, 175-mW diode-laser-pumped solid state laser that supplies the CW-light to the external modulator, an automatic bias controller that maintains the optimum operating bias point of the modulator, and a link self-test circuit that provides a signal to the input of the link.

We have made a variety of measurements on the module as a function of temperature. One example of these data is shown in Fig. 3(a), which plots the intermodulation-free dynamic range in a 100-KHz noise bandwidth vs temperature. To our knowledge, this is the best result for this parameter reported to date.

We will concentrate on two areas, module calibration and modulator bias control, which are indicative of the integration issues these tests were intended to explore. Many applications will require the fiber-optic link to have a stable gain. One approach to achieve this is to send a calibration signal out to the module and switch the signal in as needed to measure the link gain. Since this approach requires dc power at the module, it is an active approach. Initial measurements of the calibration signal stability show gain variations are less than 1 dB over +40 to -60°C. A passive approach, which avoids the need for dc power at the module, is to stabilize the link gain by using the fact that in an externally modulated link operating at a fixed bias point, the link gain is proportional to the square of the average optical power in the link. Consequently, we can normalize the link gain using the square of the average photodetector current. As shown in Fig. 3(b), initial measurements with this approach indicate that it is capable of reducing 6-dB link gain changes to less than 1 dB. Further measurements show that the method can normalize at least 30 dB of gain variation to less than 1 dB.

One way to implement active bias stabilization is to add some form of dither signal to the modulator dc bias voltage. We will report on the design and performance of a circuit that adds a 500-Hz sine wave dither and adjusts the bias for minimum second-harmonic amplitude. Measurements show that this approach maintains the modulator bias point within 0.5 degrees of that desired. The problem we have found with the method is that the dither appears as sidebands around any CW signal applied to the modulator. Without careful choice of dither signal format and/or amplitude, these spurious dither sidebands can at best complicate, and at worst make impossible, subsequent signal processing. A passive approach to bias stabilization is to fabricate a modulator that is inherently stable, as has been recently reported (3). Since a dither signal is not required, its potentially deleterious effects are avoided. We have fabricated and tested such a passively stabilized modulator; its bias point moves less than 20 degrees when the modulator temperature changes by 100°C. Link model calculations indicate that this bias drift will result in less than 1-dB change in the gain, the noise figure and, for systems with less than an octave bandwidth, the dynamic range. Thus, while the passive approach is presently not as stable as the active approach, it should be sufficient for narrowband systems.

ACKNOWLEDGMENT

This work was sponsored by the Department of the Air Force.

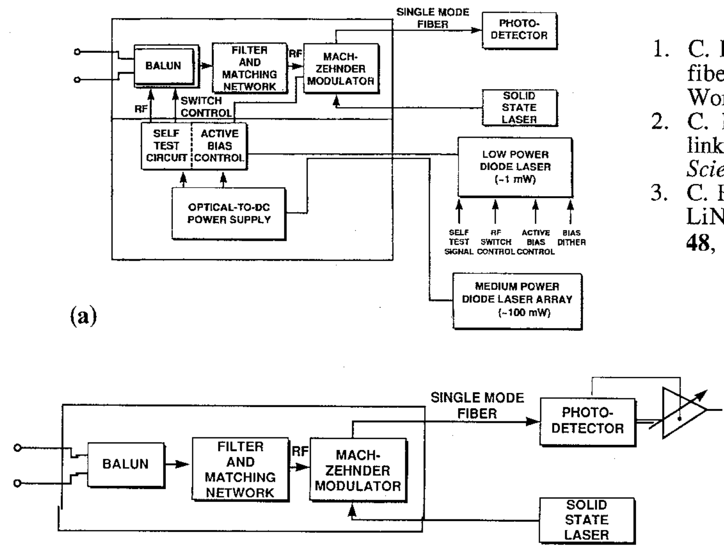

FIGURE 1 Fiber-optic test bed functional block diagram: (a) active implementation; (b) passive implementation.

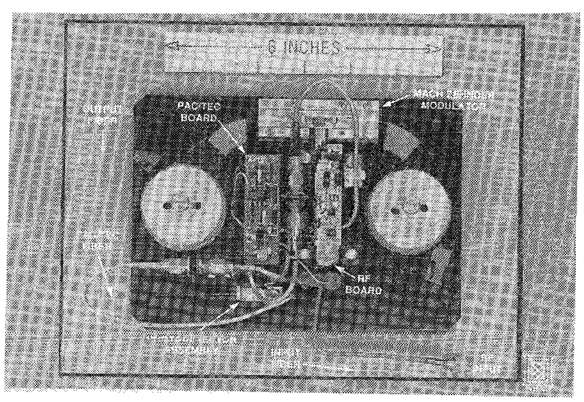

FIGURE 2 Module for fiber-optic test bed.

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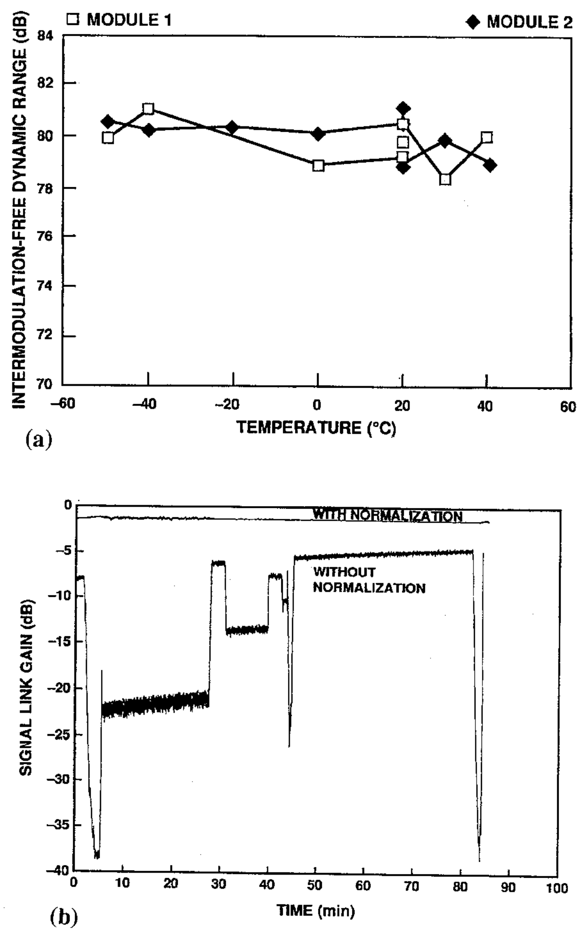

FIGURE 3 (a) Signal link dynamic range vs temperature; (b) signal link gain vs time.