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The Fiber Optic Link and Delay System at OVRO

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Abstract

The design and performance details for a link, and a tracking delay system operating in the 0.5 to 4 GHz band are presented. This is a composite fiber optical and microwave system, with delay bits ranging from 512 to $\frac{1}{128}$ ns in binary steps.

System Overview : A block diagram of the system is shown in Fig. 1. The fiber optic (FO) transmitter is driven by the receiver electronics in 1 - 2 and 2.5 - 3.5 GHz multiplexed bands. The optical signal from the transmitter is propagated through temperature compensated FO cable to the delay system. The first three delay bits are fiber optical. The receiver output is boosted by a low noise 35-dB amplifier. Six subsequent delays are constructed with high-speed GaAs FET switches, and coaxial cable for the delay and reference segments respectively. The final eight delays are realized as microstrip circuits. Two "error-correction" bits are included that compensate for errors in the fiber and coax sections respectively. The system is amplitude equalized to within $\pm$ 2 dB.

The Fiber Optic Delay System : Each delay unit consists of two single-pole double-throw switches with delay and "reference" segments connected between the outputs. The delay segment includes the reference length, and the delay and reference paths are highly symmetrical to ensure that the output signal levels are identical. The refractive index of the fiber for the fiber delays is 1.466. The fiber segments are connected with dry rotary splices to opto-mechanical fiber switches. The splices are tuned to an insertion loss of less than 0.02 dB. The fiber switches have an insertion loss of 0.7 dB, resulting in a system loss of approximately 5 dB. The passband amplitude and phase profiles for the optical delay are shown in Figures 2 and 3 respectively.

The Microwave Delay System : The microwave (MW) delay system utilizes wide-bandwidth GaAs FET switches. These switches have an insertion loss of 2 dB, and a return loss of approximately 18 dB from DC to 5 GHz. The switches are mounted in a microstrip package, with wire-bond connections between the switch RF ports, and microstrip lines. The first six delays are made with coaxial cable. Inductance due to the skin effect results in a frequency-dependant attenuation and propagation constant for coaxial cable. This effect is especially important because long lengths of cable are used for the delays. A reference section of lossy 0.034 in cable is used to compensate for dispersion in the delay section, constructed with 0.085 and 0.250 in coax. The final eight delays in the microwave section are constructed as microstrip circuits. The delay circuits are fabricated on $\varepsilon_r = 10$ as-fired alumina. Via holes drilled at the sites of the chips are filled with conductive epoxy to hold the switch chip, and to make the ground connection. The losses through the delay and reference segments are matched by making fine adjustments to the control voltages driving the delay and reference segments.

Amplification is added at regular stages in the MW delay section. 3 dB attenuators are also included to attenuate reflected signals between delay units. The reference segments and the interconnecting segments are chosen to have random lengths to minimize coherent reflections that could cause delay errors. The passband of the microwave delay section is amplitude equalized with a simple RLC circuit. The passband amplitude and phase profiles of the microwave delay are shown in Figures 4 and 5 respectively. The overall bandwidth of the delay system is limited by the equalization stage, the switches, and the amplifiers used to boost the signal in the delay and equalization stages. The fiber delays and the coaxial delays are trimmed at the ± 500 and ± 25 ps level respectively. The microstrip delays are tuned to a ± 1 ps accuracy.

Two extra "error-correction" bits (4 and $\frac{1}{2}$ ns) are also included. The "error-correction" bits ensure that the delay can always be set to within half a smallest delay step of the required delay.

Conclusions : A composite fiber optical - microwave link - delay system has been developed to transmit signals in the frequency range of 0.5 to 4 GHz. The delays range from 512 to $\frac{1}{128}$ ns in binary steps, with two additional "error-correction" bits. The delay passband is equalized to within ± 2 dB.

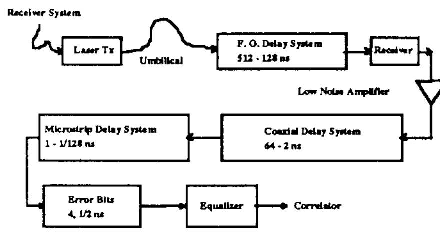

Fig. 1. FO link and delay system

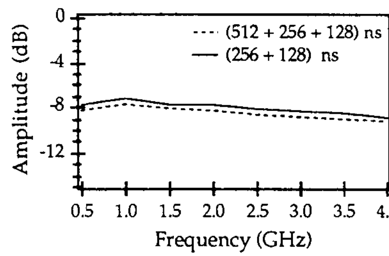

Fig. 2. Amplitude passband for FO delay

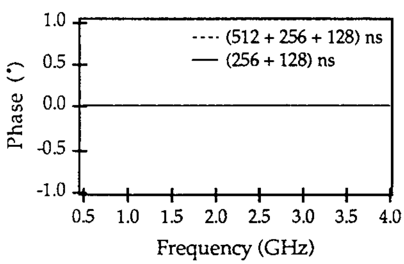

Fig. 3. Phase passband for FO delay

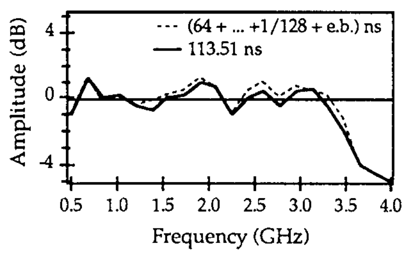

Fig. 4. Amplitude passband for MW delay

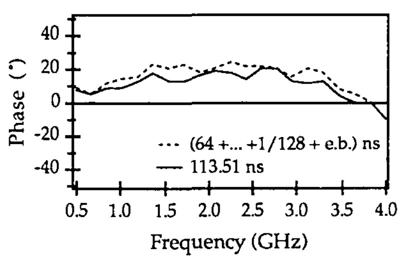

Fig. 5. Phase passband for MW delay

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