

# INCOHERENT OPTICAL FREQUENCY DOMAIN INTERFEROMETRY FOR AVIONICS

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## Introduction

We present a new approach to fault location in avionics fiber optic networks. A frequency domain reflectometry technique is introduced where the light from a transmitting laser is frequency modulated at a RF frequency and the reflected signal is heterodyne beaten with a portion of the transmitted signal on an optical detector. The detected beat frequency is proportional to the time-of-flight of the transmitted signal reflected from a fault down the fiber. Since the transmitting laser is operated CW and does not require high peak optical power, a significant advantage is obtained, compared to a time-domain reflectometry technique. This advantage becomes very significant in applications requiring built-in test, as for avionics applications, where one must use the existing transmitter circuit with a given power supply. Very low reflections are detected and an optical dynamic range of 73 dB is obtained, which can be further increased.

## Incoherent Frequency Domain Reflectometry

Reflectometry in the optical time domain has been extensively studied for locating reflections and measuring backscattering in optical fibers. Here, we present a frequency domain technique that has interesting advantages for the detection of discrete reflections over the common time domain technique. Our approach uses a linearly chirped frequency, constant amplitude, RF signal to optically modulate the output power of a laser. This technique is called Incoherent Optical Frequency Domain Reflectometry (IOFDR) and is different from the coherent optical frequency domain reflectometry technique where the optical frequency of a narrow linewidth optical signal itself is chirped.

In our case, the microwave signal directly modulates the current of a DFB laser. In this approach, the optical phase of the laser is not very important. Reflected signals from flaws or faults in the fiber, or from slightly optically mismatched optical components, produce a return signal delayed by propagation in the fiber. This, in turn, produces a delay in the sweep phase of the modulation. The return signal is heterodyned down with the reference drive signal using a microwave mixer to produce a correlation signal in the frequency domain, which is then observed with a spectrum analyzer. Since the noise power of an optical receiver is proportional to its bandwidth, and since the receiver bandwidth is directly proportional to the resolvable distance in the frequency domain, we expect to obtain very good signal-to-noise ratios and high dynamic range for the location of discrete reflections. By comparison, the time domain technique requires a receiver bandwidth which is inversely proportional to the resolvable distance. This signal is then integrated over time. If the observation time in both techniques is the same and if the peak optical power is the same, it is found that the frequency domain technique has a significant advantage over the time domain approach because the frequency domain measures the signal continuously, where the time domain approach typically has to wait for the return pulse before sending another pulse. There is effectively a dead-time which can be compensated by using high peak power. The latter is not an option for a time domain built-in test since this system must use the existing transmitter and its power supply.

## Results

Our experiment was performed at 1.55  $\mu\text{m}$ , using a SMF-28 fiber. A schematic of our

experimental set-up is shown in Fig. 1. The high linearity of the IOFDR technique was demonstrated over distances up to 25 km. For these measurements, the microwave frequency was linearly chirped from less than 1 MHz to 1 GHz in a time of about 100 ms. The spectrum of the beat signal from a reflection from an unterminated fiber is shown in Fig. 2. An optical dynamic range in excess of 73 dB is realized in our experiment.

Simultaneous fault location was demonstrated and reflections from two FC/PC connectors were measured. A distance resolution of 10 cm was obtained. A chip integration of the table-top functionality of the present system is presently being considered and appears realizable. This demonstrates the high potential of the IOFDR technique in built-in test for avionic fiber networks.

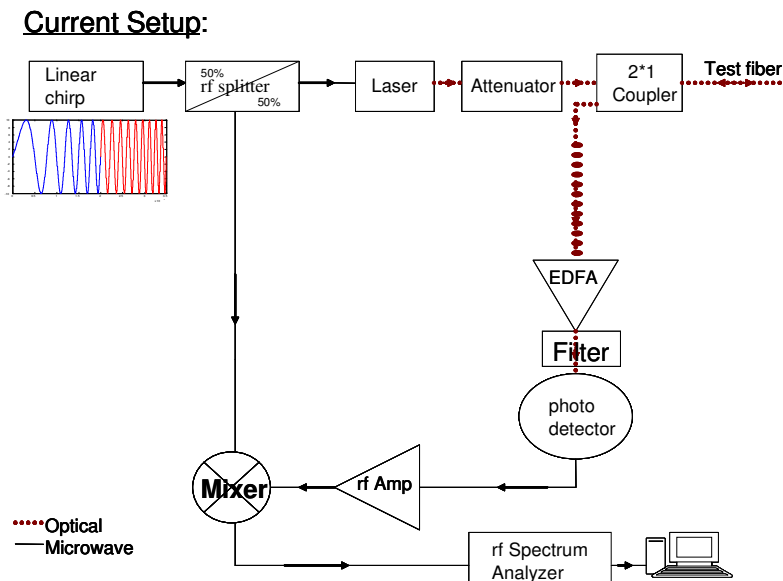


Fig. 1 Experimental set-up

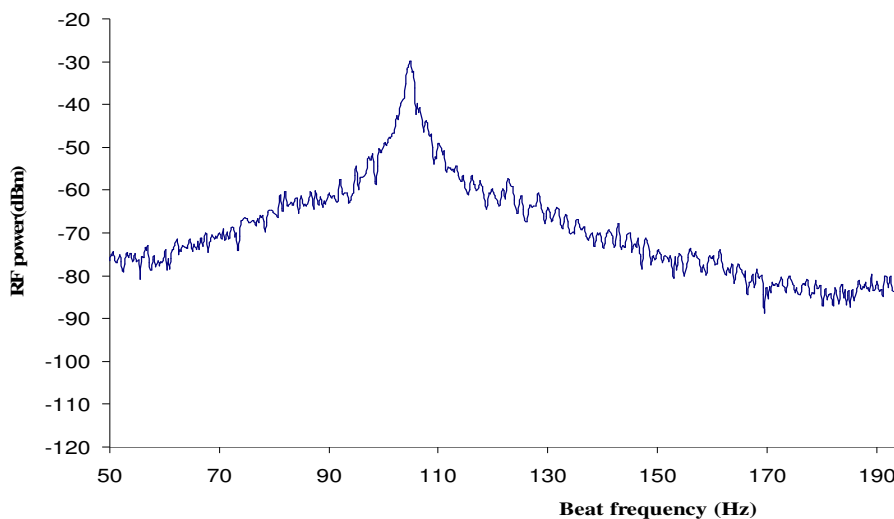


Fig. 2 Reflection from an unterminated fiber end.