HYBRID ANALOG-DIGITAL FIBER OPTIC NETWORK FOR AIRCRAFT COMMUNICATION AND CONTROL

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Introduction

Fiber optic networks are currently deployed throughout an aircraft to allow communication between the various systems on-board. Fibers offer the advantage of reduced weight, higher bandwidth and immunity to electromagnetic interference over traditional coaxial cabling. Typically, one network carries digital data from one on-board system to another, while another takes analog data for electronic warfare applications received from an external source and sends it to a central on-board system [1]. In order to reduce the complexity and maintenance of multiple fiber networks, it would be advantageous to use a single fiber network over which both types of signals could travel. Previous work has looked at combining both analog and digital signals over the same fiber [2, 3]. However these demonstrations required the analog signal to operate at a frequency beyond that of the digital data. In this paper we demonstrate a system to transmit both analog and digital signals within the same frequency bands over the same fiber network with minimal degradation of either signal due to interference from the other.

Experimental Setup and Results

The experimental setup appears in Fig. 1. The configuration for the receiver is similar to the one demonstrated in Ref. 4; however, that setup was used only for digital data and did not evaluate the use of analog signals. The output of a 1550 nm semiconductor laser (DFB) passes through a phase modulator and then a Mach-Zehnder intensity modulator (MZM). The light enters a 50/50 splitter, whose outputs are connected to two receivers. The first receiver is a single photodetector that is used for intensity-modulated data. The second receiver contains an asymmetric Mach-Zehnder (AMZ) demodulator, whose outputs are connected to a balanced photodetector. This receiver is used for phase-modulated data. Ideally, a single photodetector will not be sensitive to a phase-modulated signal, and the balanced photodetector should cancel any intensity-modulated signal. In our measurements, we have seen only a ~20dB cancellation of the intensity-modulated data at the balanced photodetector, which is due to mismatches in the losses of the two arms of the balanced photodetector. Thus, we decided to intensity-modulate the analog signal as the digital data would be more resilient to the leakage from the intensity-modulated analog signal. A 2.5 GHz PRBS pattern generator (PPG) is used for the digital data and a 1 GHz RF source was used to represent the analog signal. A 30 GHz bandwidth sampling oscilloscope monitors the recovered eye of the digital data while an electrical spectrum analyzer (ESA) monitors the RF signal. The PPG is connected to the phase modulator in order to generate a differential phase shift keyed (DPSK) signal, while the RF source is connected to the MZM to generate an intensity-modulated analog signal.

![Figure 1. Experimental setup for analog-digital system.](image)

In order to evaluate the digital data, the Q-factor is measured from the eye diagrams and the bit error rate (BER) is then calculated. The BER starts to degrade as the analog signal’s RF power increases. This can be seen in the set of eye diagrams that appear in Figs. 2(a)-(d). The “1’s” level noise becomes more pronounced as the...
RF power increases. The typical error-free threshold for BER is $1 \times 10^{-10}$ and the DPSK reaches that level around an RF power of 9 dBm (see Fig 2(d)). However, the fundamental gain (see Fig. 3) shows that the analog signal is in compression at 9 dBm. Since the analog signal will not be run in compression, the DPSK signal will remain error-free. In order to evaluate the analog signal, the RF gain is measured and compared to theory. For a photocurrent of 8 mA and $V_π$ of 5.9 V, the gain of -19.5 dB matches well with the theory (-19.3 dB). Figure 3 also shows the measured third harmonic and an OIP3 of 9.78 dBm. Again, this agrees well with the theory (9.84 dBm). From this data, we conclude that the DPSK signal does not adversely affect the intensity-modulated analog signal.

![Figure 2. Measured Eye diagrams for DPSK signal with RF signals of input power (a) No power (b) -13 dBm (c) -5dBm and (d) 9dBm.](image)

![Figure 3. Measured RF output power of fundamental and third harmonic as a function of input power.](image)

**Conclusion**

We have demonstrated a hybrid digital-analog scheme that allows for the transport of DPSK digital signals and intensity-modulated analog signals within the same frequency band without serious degradation of either signal. The method can be implemented in aircraft systems to allow a single fiber backbone to transport both types of signals. Future work can address the use of this scheme in a WDM environment to increase the number of systems that can be connected over a single fiber network.

**References**


