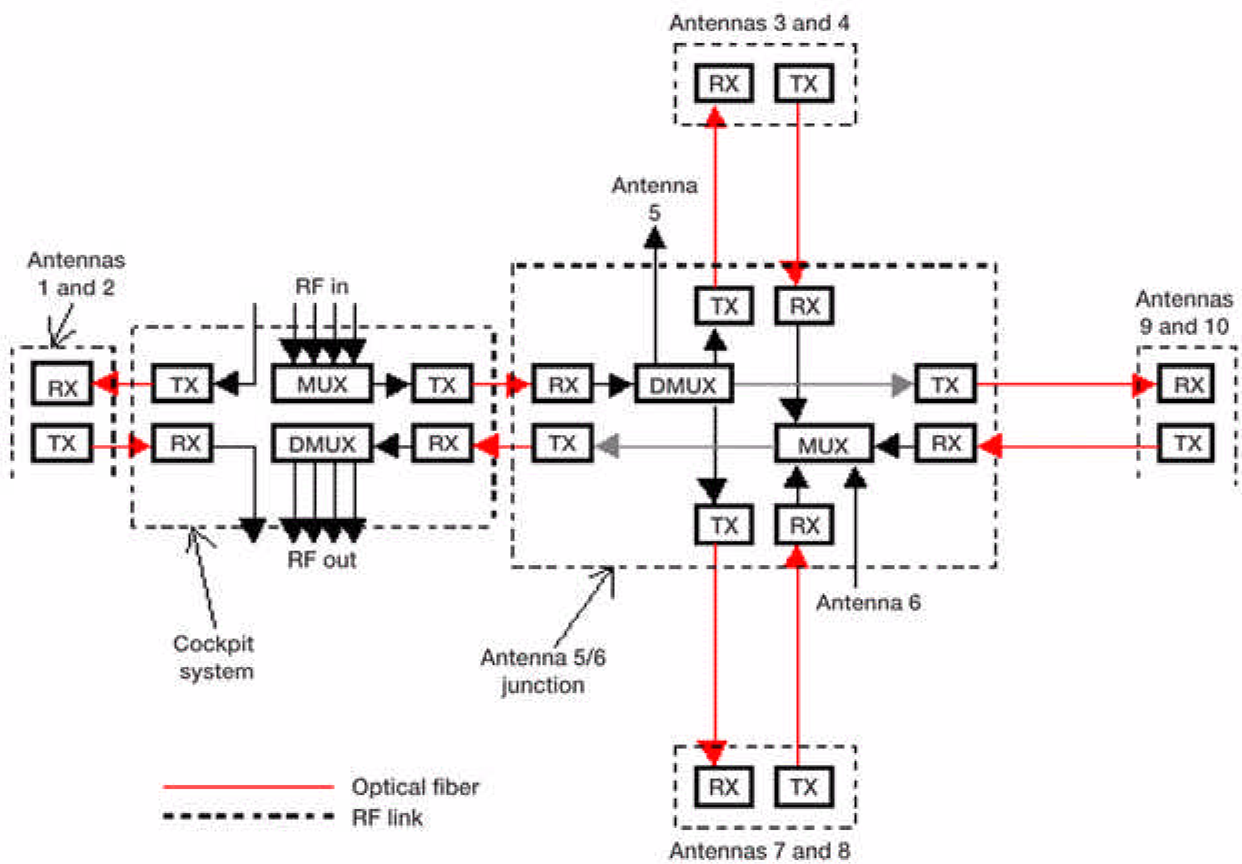
Fiber-Optic Network Architectures for Onboard Avionics Applications Investigated

This project is part of a study within the Advanced Air Transportation Technologies program undertaken at the NASA Glenn Research Center. The main focus of the program is the improvement of air transportation, with particular emphasis on air transportation safety. Current and future advances in digital data communications between an aircraft and the outside world will require high-bandwidth onboard communication networks. Radiofrequency (RF) systems, with their interconnection network based on coaxial cables and waveguides, increase the complexity of communication systems onboard modern civil and military aircraft with respect to weight, power consumption, and safety. In addition, safety and reliability concerns from electromagnetic interference between the RF components embedded in these communication systems exist.

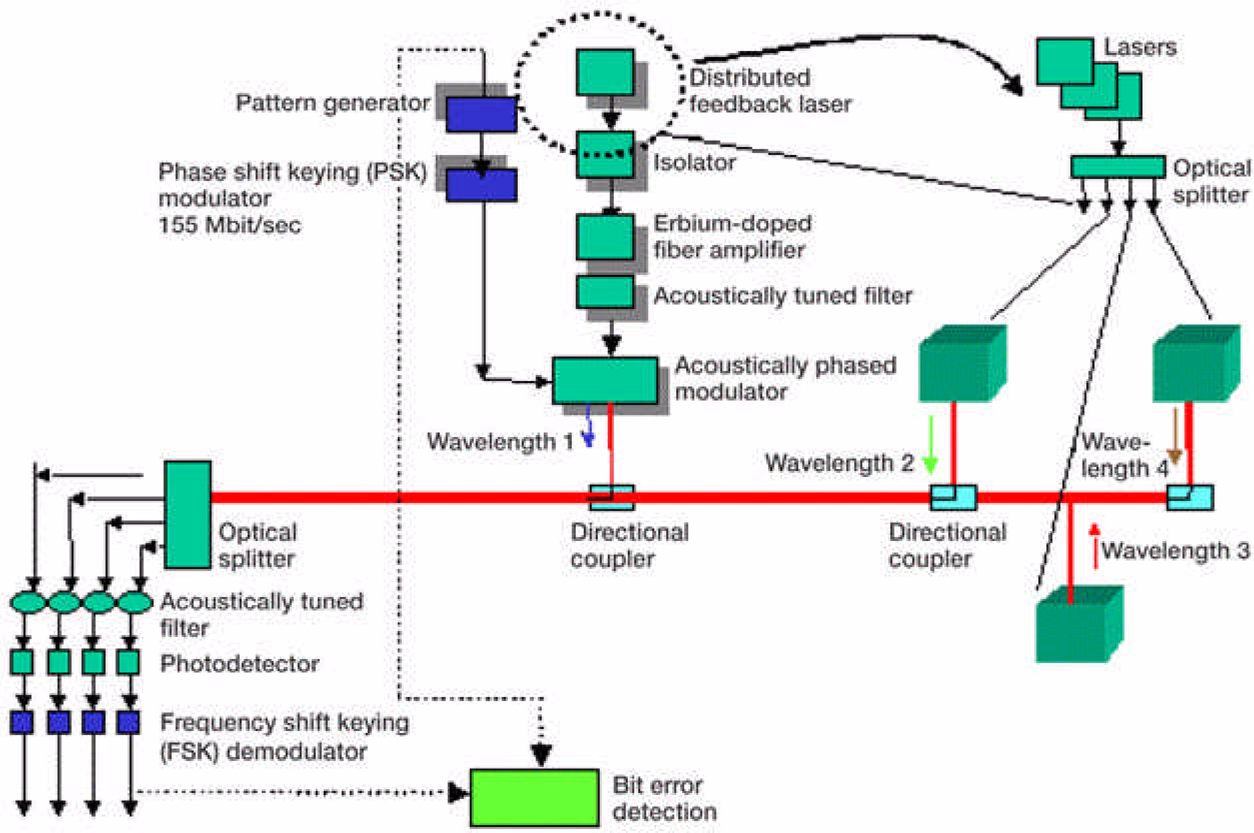
A simple, reliable, and lightweight network that is free from the effects of electromagnetic interference and capable of supporting the broadband communications needs of future onboard digital avionics systems cannot be easily implemented using existing coaxial cable-based systems. Fiber-optical communication systems can meet all these challenges of modern avionics applications in an efficient, cost-effective manner.



Hybrid RF-optical approach. MUX, RF power combiner (multiplexer); DMUX, RF demultiplexer; TX, optical transmitter; RX, optical receiver.

The objective of this project is to present a number of optical network architectures for onboard RF signal distribution. Because of the emergence of a number of digital avionics devices requiring high-bandwidth connectivity, fiber-optic RF networks onboard modern aircraft will play a vital role in ensuring a low-noise, highly reliable RF communication system. Two approaches are being used for network architectures for aircraft onboard fiber-optic distribution systems: a hybrid RF-optical network and an all-optical wavelength division multiplexing (WDM) network (ref. 1). For almost all cases, either a hybrid RF-optical approach or an all-optical approach can be taken, depending on the design specification requirements.

The hybrid RF-optical approach shown in the preceding figure has the advantage of low signal loss due to repeated regeneration of the RF signal, and requires fewer fibers. The use of so many optical transmitters and receivers increases the weight and the cost of the hybrid system, however, and also increases electromagnetic interference. On the other hand, the all-optical WDM approach depicted in the following figure overcomes these difficulties by ensuring a continuous light-path from a fiber-optic transmitter to one or more fiber-optic receivers while sustaining a strong optical signal. Furthermore, an all-optical approach has the potential for replacing multiple-fiber cables by carrying a number of RF signals on different wavelengths on a single fiber simultaneously, thereby reducing the weight. In addition, all-optical solutions use a number of passive components like power combiners, power splitters, and wavelength demultiplexers, all of which require no power supply. Hence, an all-optical solution requires less power than the hybrid RF-optical solution.



All optical solution using wavelength division multiplexing for implementation of multiple-source multiple-receiver network architecture.

Long description of figure 2 The diagram shows the path from the pattern generator to the phase shift keying modulator (155 Mbit/sec) to the acoustically phased modulator to wavelength 1 to a directional coupler. It also shows the path from the distributed feedback laser to the optical splitter to the isolator to the erbium-doped fiber amplifier to the acoustically tuned filter to the acoustically phased modulator to a directional coupler. It also shows the path from the laser to the optical splitter to wavelength 2 to a directional coupler and to wavelength 4 and wavelength 3 to a directional coupler. Finally it shows the path from the directional couplers to the optical splitter to the acoustically tuned filter to the photodetector to the frequency shift keying demodulator to bit error detection.

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Because of budget constraints, we only established the experimental platform for the all-optical WDM architecture described in this figure. From this setup, the transmission of FM (frequency-modulated) and AM (amplitude-modulated) analog modulated signals[1] as well as frequency shift keying (FSK) digital modulation over fiber-optic links were investigated, and the overall systems performance was characterized by taking measurements of power loss, delay, signal-to-noise ratio, carrier-to-noise ratio, total harmonic distortion, and bit error rate. These experimental results have been described in detail in other publications (ref. 2). Among these measurements, signal-to-noise ratio and carrier-to-noise ratio are the most essential factors when evaluating the merits of a communication system.

The signal-to-noise ratios for AM and FM at 1310 and 1550 nm are approximately 55 and 40 dB, respectively. These measurements suggest good analog signal transmission over WDM fiber-optic links since they exceed the 30 dB standard for good AM and FM radio reception. In addition, the carrier-to-noise ratios for 1310 and 1550 nm are approximately 65 and 52 dB, respectively, which exceeds the standard quality level of 40 dB. With these results, the fiber-optic systems ensure good communication signal transmission between the antennas and the cockpit of an aircraft.

References

1. Alam, M.F., et al.: Fiber-Optic Network Architectures for On-Board Digital Avionics Signal Distribution. Int. J. Commun. Syst., vol. 15, nos. 2-3, 2002, pp. 175-190.

2. Slaveski, Filip, et al.: Transmission of RF Signals Over Optical Fiber for Avionics Applications. Presented at the 21st Digital Avionics System Conference, Technical section D, 3D2, IEEE, Oct. 2002.

Find out more about the research of Glenn's Applied RF Technology Branch http://ctd.grc.nasa.gov/5640/5640.html.

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[1]Frequency-modulated and amplitude-modulated signals.