

# APPLICATIONS OF ANALOG FIBER OPTIC TECHNOLOGY FOR RF, MICROWAVE AND MILLIMETER WAVE SYSTEMS



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## Introduction

Analog fiber optic links are finding their way into many high frequency systems. Fiber optic transmission technology has much appeal due to the wide bandwidth and low loss of the optical fiber allowing long transmission distance. Analog fiber optics is well established in the CATV and SATCOM (satellite communications) industries. With recent improvements in photonic device performance, new optical integrated circuit technology, and Dense Wavelength Division Multiplexing (DWDM), numerous opportunities for analog fiber optic links are appearing at up to 40 GHz. Artisan Laboratories Corporation is uniquely positioned to provide our customers with microwave, millimeter wave and fiber optic systems due to our expertise in these technologies. This paper presents an overview of current and future applications for analog fiber optics in RF, microwave and millimeter wave systems.

## Test Equipment

**Sidelighter eliminates the dead-zone.** Fiber optic technology, traditionally used for long haul communications, is finding new applications in short haul communication systems in military airborne and shipboard platforms. New commercial services such as fiber-to-the-premise for broadband to the business and home, broadband wireless Internet, and digital video services are being installed across the USA. The service providers and installers of these new systems require new methods of testing fiber optic link performance in distances from a few meters to less than 1 Km. Optical time domain reflectometers (OTDRs) traditionally are used for long haul communication systems but are limited in their use in military systems and new commercial services due to dead zones. Artisan Laboratories Corporation has developed the Sidelighter (Patent Pending.); a new test and measurement system eliminates the dead-zone associated with OTDRs thus making it attractive for both military and new commercial applications. The Sidelighter has a resolution of a few centimeters and is field portable.



## Antenna Ranges and Electro-Magnetic Interference Testing Environments

Testing of avionic and ground based systems in high Electro Magnetic Interference (EMI) environments requires isolation between the platform under test and the data collection center. Additionally, these systems can require a low noise floor down to very low RF frequencies. Similar requirements are needed to perform antenna measurements. Fiber optics offers the high isolation needed to perform testing

*The Sidelighter can be used to locate failures in fiber optic networks such as in building and in military platforms. The Sidelighter eliminates the dead-zone commonly found in OTDRs*



due to the immunity from EMI of the optical signal through the fiber. Artisan offers a Low Noise Optical Transmitter System specifically designed for testing in high EMI environments. This system is designed with a low noise figure down to 1 MHz.



*Artisan has designed demonstrated advanced microwave target simulators using fiber optic technology*

### **Radar and Communication System Testing**

Radar and communication system tests require outdoor ranges to determine system performance. Using an outdoor range is expensive and time consuming so alternate solutions are sought. Radar tests use fixed targets miles away from the radar for calibration. Microwave time delays can be used to simulate targets that allow for testing in a laboratory setting [1]. Artisan is a premier designer of very long microwave time delay systems. Artisan has developed a bidirectional (*Patent pending*) microwave communication channel simulator for two way radio transmission at RF and microwave frequencies that allow testing in a laboratory environment.

### **Communications**

Fiber optic transmission of digital data for long haul and metro access is widely used in the telecommunications industry. As new services are being developed and offered, such as PCS, Broadband Wireless Internet, Digital Video, and Passive Optical Networks, new opportunities for analog fiber optic distribution are emerging. The demonstration of a DWDM analog fiber optic system used to distribute PCS and Broadband Wireless Internet showed that distributing RF over fiber up to 3 GHz has the advantage of simplifying the system architecture and reducing base station complexity.

In this demonstration, a DWDM broadband photonic transport system was able to meet the requirements for both IS-95 Personal Communications Services operating at 1.9 GHz and Broadband Wireless Internet operating over the band of 2.5 to 2.7 GHz. Each DWDM channel operates from 1 to 3 GHz and transports services up to 80 Km [2]. Artisan Laboratories Corporation currently offers optical transmission equipment suitable for these applications.



*Artisan has demonstrated the delivery of personal communications and broadband services such as wireless internet and digital video over a hybrid RF and fiber optic system.*



## Spacecraft

New developments for the next generation of communication satellites and space based radar systems include the application of active phased array antennas. In communication systems, active phased array antennas offer on-board reconfigurability and multi-beam operation. These features greatly reduce business risk by allowing the beam shape to change depending on customer demands. Fiber optic distribution has been proposed for the transmission of microwave signals from the satellite bus to the phased array antenna. The advantages of using this technology are higher phase stability with temperature due to the fiber mechanical properties; lighter weight and flexibility of the fiber; and smaller size of the optical interconnect and optical power dividers. The use of fiber also allows for a high level of integration with antenna elements thus reducing size and weight. Artisan Laboratories Corporation is currently developing multi-level microwave photonic modules [3] that utilize such integration.



*Fiber optics can be used to distribute signals on board spacecraft. Artisan Laboratories Corporation is developing Ultralight Fiber Optic Link technology to improve signal transmission efficiency.*

While these new developments show promise, fiber optic distribution has the disadvantage of high power consumption compared with passive networks such as coaxial transmission lines. The increased demand on power consumption can make the use of fiber in spacecraft prohibitive. To make fiber optic signal distribution competitive with other transmission technologies, Artisan Laboratories Corporation is currently developing a new type of fiber optic technology call Ultralight Fiber Optic Link that can significantly reduce the prime power consumption of the distribution system [4].

## Satellite Communications

SATCOM applications make use of fiber optic links to receive signals from the antenna at a remote location such as a shelter. These links are commonly available and operate at an IF of 70 MHz. This architecture requires a low noise amplifier (LNA), frequency translation circuitry (down-converters), local oscillators, filters and a laser transmitter all located at the antenna site. Another architecture allows for the transmission of the RF or microwave frequency from the satellite antenna directly over fiber to an integrated photoreceiver and down-converter system located at a shelter. This architecture reduces the equipment required at the antenna site to the LNA and laser transmitter. Artisan Laboratories Corporation is offering a high performance Low Noise Optical Transmitter System and Integrated Photoreceiver Down-Converter System that directs the signal directly from the antenna to a microwave modem. The Low Noise Optical



Transmitter System is connected directly to satellite antenna systems eliminating the need for a separate low noise amplifier. The Integrated Photoreceiver Down-Converter System is an all-in-one system that detects RF and microwave signals over fiber, amplifies the signals, and down-converts them to an intermediate frequency (IF) to interface with commercially available microwave data modems. This system can detect RF over fiber at modulation frequencies up to 6 GHz and can convert the modulation to an IF of 70 MHz or 140 MHz.



*Fiber optic systems are used to distribute signals from satellite antennas. Artisan has an array of fiber optic transmission products for this application.*

In applications in which signals from multiple SATCOM antennas must be combined and distributed, DWDM analog fiber optic transmission can be employed. DWDM transmitter and receiver capability include signal transmission over 100 Km and bandwidth that exceeds multiple octaves with a CNR of 32 dB in the band of 950 to 2150 MHz [5].

## Conclusions

New applications continue to emerge in which analog fiber optic link transmission can be employed. Fiber optic link technology has many benefits that include long transmission distances, high isolation in EMI environments, and high frequency operation. These benefits can be utilized in space-based systems, new communication services, and antenna remoting. For the successful development and deployment of fiber optic systems, experience in RF, microwave and fiber optic technology is paramount. Artisan Laboratories Corporation is rich in this type of experience and is uniquely positioned to design, develop, and deploy state-of-the-art analog fiber optic systems for a variety of applications.

## References

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