Systems Engineers Use Optical Fiber Waveguides (OFW®) As Essential Architectural Tools Within C4ISR Network Infrastructure

Microwave Photonic Systems Inc. – Joshua L. Korson & Richard J. Stewart

THE INCREASING DEMAND for less costly and higher performing commercial-off-the-shelf (COTS) solutions within military Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) applications has elevated Optical Fiber Waveguides (OFW®) to new levels of acceptance and sophistication. The widespread deployment of OFW® throughout the defense C4ISR systems infrastructure has been fueled by **global demands for expanded coverage**, increased bandwidth and data rates, and flexible deployment architectures. The proliferation of OFW® technology can also be attributed due in large part to the **declining risks** associated with the emergence of a new technology. Whereby, the Systems Engineers, without risk to jeopardizing mission success, can leverage the size, weight and power (SWaP) improvements within the COTS marketplace to modernize C4ISR architectures across the battlespace.

RF PHOTONIC SYSTEM OPERATIONAL BENEFITS

Optical Fiber Waveguides (OFW®) have been continually evolving within critical defense C4ISR systems for nearly three decades. This evolution has lead to increased optical sub-component reliability, improved performance, and the implementation of novel system architectures. Furthermore, as a result of the commercialization of these components, **cost-effective pricing thresholds** have accelerated global adoption of OFW® technology. The fundamental characteristic of OFW® technology is the ability to support ultra-low loss transport of broadband RF signal transmissions **up to 40 GHz**, over **distances in excess of 100 km.**

Fiber optic cable, as a **non-metallic signal conductor** that is inherently immune to the effects of RFI, EMI, Electro Magnetic Pulse, and Lightning Strikes, is a key architectural design element for distributed network topologies throughout C4ISR systems. These attributes enable OFW® based systems to **securely route and distribute RF signal traffic** to remote locations that would otherwise be beyond the reach of conventional based coaxial systems.

This increased separation distance provides an architectural advantage: **reliable communications regardless of building construction, geographic terrain, horizon visibility or other infrastructure obstacles.** One such example is **secure and classified network operation centers** which must maintain information classification protocols and minimize boundary layer penetrations that could compromise the integrity of a hardened shelter. Additionally, OFW® systems can be used in conjunction with **optical switch technology** for creating diversity path networks and point-to-multipoint distribution architectures.

OFW® technology is utilized in a breadth of applications within C4ISR systems. Other examples include:

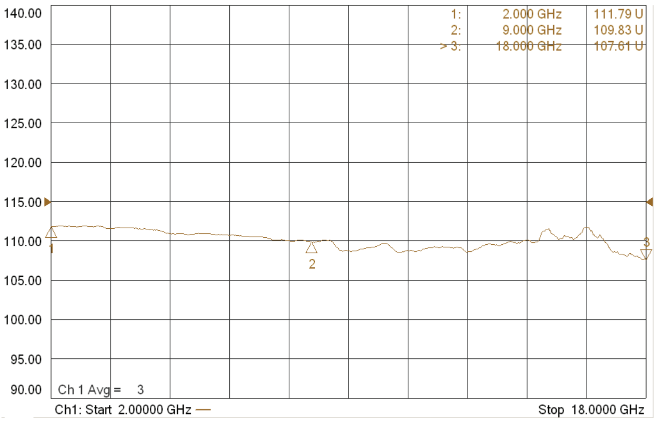
- Tactical **Fiber Optic Antenna Links** for UHF / VHF radios
- **In-Building Wireless** Distributed Antenna Systems (PCS, LTE, LMR)
- GPS **Timing and Synchronization** Networks
- **Radar Delay Lines**

Outdoor GPS Fiber Optic Antenna Link

SYSTEM NOISE TEMPERATURE & SPURIOUS FREE DYNAMIC RANGE

Modern SATCOM system downlinks are required to receive extremely low-level downlink signals, while operating in high-intensity RF environments. These two requirements greatly influence the system input Noise Temperature (T_{sys}) and Spurious Free Dynamic Range (SFDR) specifications. Therefore, when integrating analog linear OFW® into these systems, the Systems Engineer should pay special attention to the design **tradeoff between T_{sys} and SFDR.**

In OFW® subsystems, the optical transmitter is usually the limiting device with respect to T_{sys} and SFDR. The optical transmitter's potential "negative" impact on system SFDR can be alleviated by minimizing the gain of any preceding LNA/LNB stage. However, minimizing the system input T_{sys} usually requires maximizing the gain of the LNA/LNB,



SFDR wideband performance > 110 db • Hz $^{(2/3)}$

since the transmitter is also a major thermal noise source. The Systems Engineer must balance these tradeoffs in order to **successfully field an integrated SATCOM OFW® subsystem**. The following discussion defines SFDR and demonstrates that the tradeoffs between input T_{sys} and SFDR can be optimized to meet the system specifications demanded by military SATCOM systems.

Assume two RF signals of equal power and have fundamental frequencies f1 and f2, respectively. When the two signals are applied to the input of the OFW®, the output frequency spectrum of the link will contain both the fundamental frequencies and the resulting Third Order Intermodulation (TOI) distortion products. The TOI distortion products have frequencies at $2f_1 - f_2$ and $2f_2 - f_1$ and are generated by the nonlinear transfer function characteristics of the link.

The presence of TOI products can cause serious problems, because they fall within the system pass band, and as such tend to interfere with the receiver's ability to detect the desired signals. The SFDR is defined as the **maximum input signal-to-noise ratio** (SNR) that the link can accept without generating TOI products that are greater than the output noise floor of the link. The SFDR, normalized in a 1 Hz bandwidth (BW), can be calculated using the following equation:

$$\text{SFDR} = 2/3[174\text{dBm}_{/\text{Hz}} + \text{OIP3}_{\text{dBm}} - \text{G}_{\text{dB}} - \text{NF}_{\text{dB}} - 10\log\text{BW}]$$
$$\text{where } \text{NF}_{\text{dB}} = 10\log[\text{T}_{\text{N}}/290 + 1].$$

The Systems Engineer can use hybrid RF and optical models for the SATCOM downlink chain to perfrom the RF cascade analysis to determine the system input Tsys and SFDR as a function of the LNA/LNB performance. The results of this tradeoff analysis can be used iteratively to optimize RF characteristics of both the LNA/LNB and the OFW®. Similarly, this tradeoff analysis should be completed for the uplink chain and is likewise applicable to line of sight (LOS) systems.

Ka-band fiber optic interfacility link

PRODUCT SPOTLIGHT: KA-BAND SATCOM FIBER OPTIC INTERFACILITY LINK (IFL)

The OFW-7000 is a specialized transmission subsystem designed to support the optical signal conversion, transport and distribution of RF signals in the 17 to 26 GHz frequency range, with extended capabilities out to 32 GHz. When used as a transceiver pair, the **IFL provides a high dynamic range and low noise bidirectional transport capability** to remote Ka-Band SATCOM uplink (UL) and downlink (DL) signals between the satellite modem(s) and antenna(s). The characteristics of the fiber optic IFL have been designed to seamlessly replace a copper-based coaxial IFL and provide redundant capability to the high priority RF channels.

The OFW-7000 circuit topography schemes does not employ a non-volatile memory and has no ability to process, retain or analyze any classified data. Furthermore, the optical conversion process is **transparent to the RF carriers frequency** and data modulation format and rate. Therfore, when the OFW-7000 is configured within a classified installation, it functions only as a passive teleport for the transfer of Ka-Band payload data.

The **health and status of the optical link can be monitored** through the use of a serial interface protocol port and the systems user's computer network. The optical link monitored parameters include laser power, received optical power, temperature and power supply conditions. Options can be delivered to offer RS-232, RS-485 and Ethernet.

The OFW-7000 product line can be packaged as a standalone flange mount unit for integrators, outdoor enclosures, or high density 1RU rack chassis. When deployed in a 3 or 4RU chassis form factor, MPS offers complimentary **switch, amplifiers, and dispersion compensation** plug-in modules to provide complete subsystem capabilities.

SUBJECT MATTER EXPERTS

The C4ISR community is using readily available OFW® technologies designed by Microwave Photonic Systems (MPS) to augment traditional communication architectures. As a global provider of critical RF photonic transport systems, MPS has been at the vanguard of the engineering development and deployment of OFW® for more than 15 years. **MPS's dedicated research, design and manufacturing team** has leveraged its expertise to develop robust solutions that can serve as essential building blocks within any C4ISR system. ■

Microwave Photonic Systems Inc. MPS

Contact details:
Microwave Photonic Systems, Inc.
1155 Phoenixville Pike
West Chester, PA 19380

US Toll Free: 888-868-8967
Phone: 610-344-7676
Email: info@b2bphotonics.com
Web: www.b2bphotonics.com/expand