Optical circuit switching for distributing RF signals over fiber in mission-critical applications

White Paper

HUBER+SUHNER

Greater resilience. Better performance. More secure. Less cost.

Radio Frequency (RF) signals have been distributed over coaxial cables for decades, but for today's mission critical government/military/intelligence operations it can be limiting and expensive, and can pose security risks. To overcome these limitations, RF systems engineers are turning more and more to RF distribution over optical fiber (RFoF). In RFoF systems, electro-optical (E/O) converters are used to convert an RF signal to optical at the signal source, then the signal is transmittted along a length of single-mode optical fiber to the destination where optical-electrical (O/E) converters convert it back to RF.

Why distribute RF signals over fiber?

Greater bandwidth and distance

Optical fiber can carry significantly more bandwidth than coaxial cables with less signal impairments. This reduces the need for expensive amplifiers and other signal condition equipment while allowing the signals to span much greater distances.

Superior Distribution Efficiency

Wavelength Division Multiplexing (WDM) allows users to combine up to 80 or more channels onto a single fiber.

High security

Optical fibers are much more difficult to tap than coaxial cables and any disturbance is much easier to detect and locate.

Future proof

Transmission of RF signals over optical fibers is independent of the RF signal format, frequency, and bit rate so the optical fiber can be used to transmit virtually any commercial RF signal. As RF signal formats change over time and bit rates increase, the same optical fiber infrastructure can be used without any need to be upgraded. Operators can even distribute different signal types through the same fiber infrastructure for maximum flexibility.

Cable cost and size

Optical fiber cables are a fraction of the size and weight of coaxial cables and are much simpler and less costly to install and maintain. Optical fiber cables are also inherently more reliable than coaxial and much less susceptible to corrosion and other environmental effects.

Coax comparison with fiber

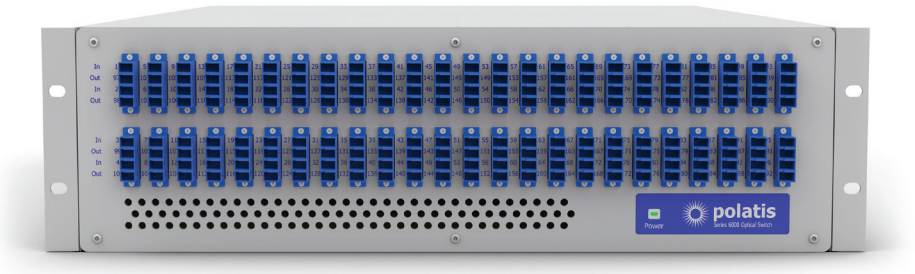
	 Coax cable	 Single mode fiber
Representative distance bandwidth products	100 MHz km	100,000+ MHz km
RF attenuation/km @ 1 GHz	>45 dB	0.4 dB
Cable diameter (typical)	12.7 mm (1/2")	6.35 mm (1/8")
Cable weight per km (typical)	204 kg (450 lbs)	6.8 kg (15 lbs)
Minimum bend radius (typical)	177 mm (7")	25 mm (1")
Data security	Low	Excellent
EMI immunity	OK	Excellent

Why switch in fiber instead of copper?

Switching in fiber using optical circuit switches allows users to take full advantage of the benefits of fiber optics end-to-end, including:

- High level of security from antenna to receiver.
- Redundant paths are easy to configure and inexpensive.
- Future proof: any frequency, any data rate, any modulation format – today and in the future – end-to-end.
- Optical circuit switches have an extremely compact form factor (1U for a 48x48 switch) and ultra-low power consumption.
- Cost of optical switches does not increase exponentially with size, unlike RF switches.

The analog nature of RF-over-Fiber requires a switching infrastructure that does not degrade the RF signal. This requires a high-performance, all-optical switch with ultra-stable operation as well as low back reflections and low insertion loss.



POLATIS 96x96 with LC connectors in 3RU

Advantages

POLATIS® – The ultimate optical circuit switch

For RF-over-Fiber applications

POLATIS ultra-reliable switching solutions have been meeting the needs of mission-critical RFoF applications in some of the most rugged environments for over 15 years. POLATIS optical circuit switches provide the superior specifications and features required for this application, including:

Lowest insertion loss
Less than 1 dB optical insertion loss minimizes signal impairment.

Ultra-low cross talk
Better than 100 dB RF isolation between channels at any frequency.

Unmatched performance
The only all-optical matrix switch with virtually no jitter and very low return loss.

Broad range of matrix sizes
Unparalleled choice of symmetric and asymmetric port configurations for any size deployment.

The patented DirectLight™ high-performance switching technology minimizes impairments to RFoF signals traversing the switch connections. POLATIS technology uses integrated position sensors to directly align optical collimators to make and hold dark-fiber connections which eliminates the need for signal dithering that can degrade RFoF signals.

This is a critical advantage over MEMs-based all-optical switching technologies that use mirror dithering as part of the alignment process to make and hold connections, which adds unwanted signal modulation. In RFoF systems this MEMS-based excess modulation is mixed directly with the RF signal, adding to the signal noise floor and degrading the RF signals as shown in Fig 2.

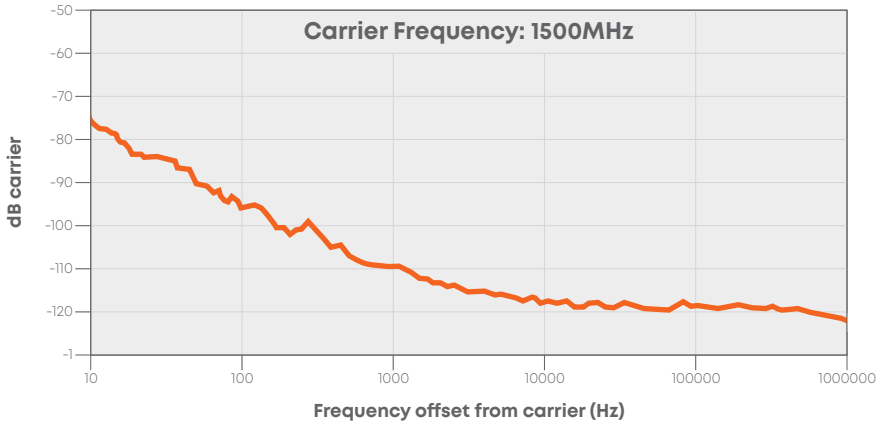


Fig 1: RF link performance with a POLATIS switch in the path

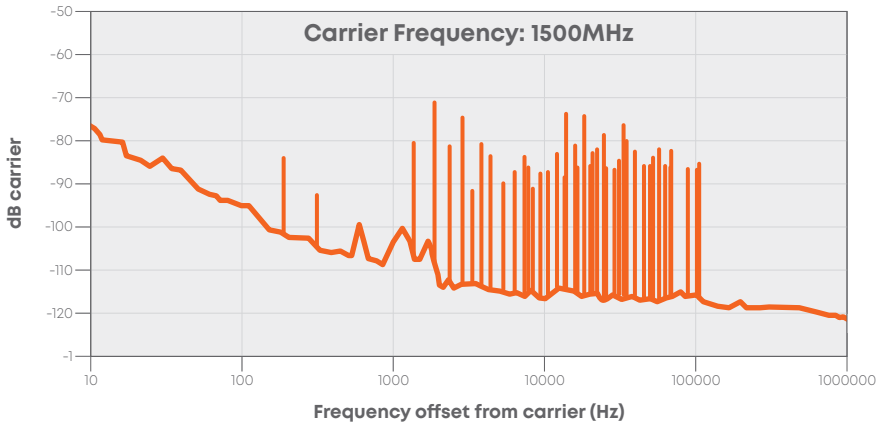


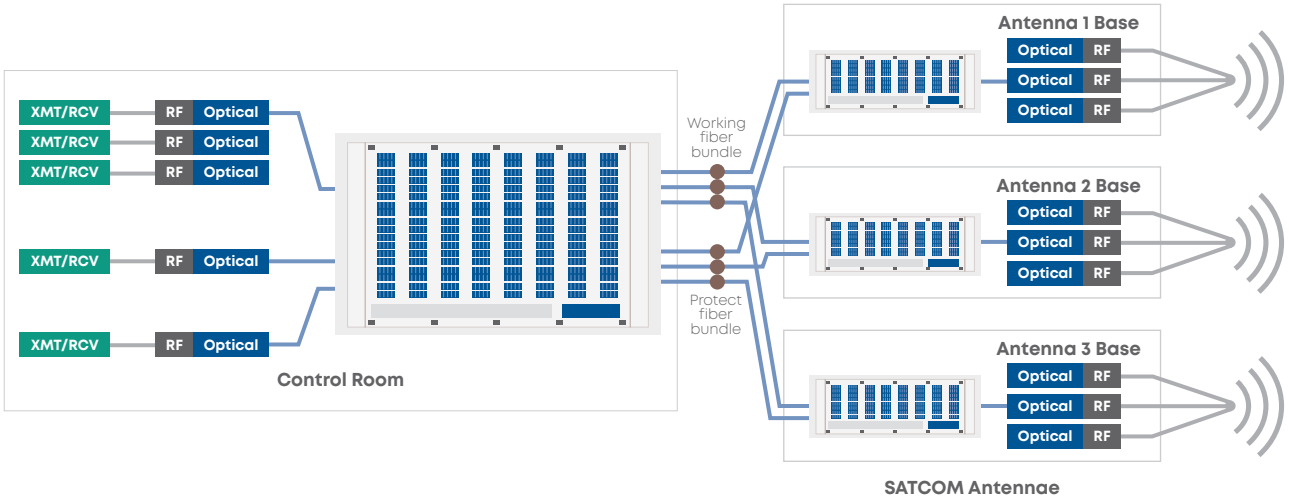
Fig 2: RF link performance with a MEMS switch in the path

Use case

Satellite ground stations

Distribution of RF signals over a fiber network with optical circuit switching enables organisations to deploy highly secure solutions with capabilities that are not possible with traditional coaxial-based systems. In a typical satellite ground station deployment there are significant benefits of an all fiber-based approach that provide organisations with key advantages:

- Optical fiber can carry significantly more bandwidth than coax cables with much lower signal impairment. This reduces the need for expensive amplifiers and other signal conditioning equipment while allowing the signals to span much greater distances – control rooms can be safely located further away from antennae.
- Provisioning can be done remotely, automatically and instantly – from anywhere in the world.
- Satellite dishes can be shared by different organisations.
- Data can be easily and automatically rerouted around failures.



Use case

RF test facilities

Distribution of RF test signals using non-metallic fiber optic cables brings many advantages to RF test labs such as communications test labs or electronic warfare test facilities. The use of fiber cables within anechoic RF test chambers does not negatively impact the chamber performance in the way that coaxial cables can, since fiber cables are non-conducting. RF signals can be distributed over fiber over large distances without degradation.

RF test signals can be generated in labs located outside the chamber, converted to fiber and transmitted to appropriate locations throughout the chamber.

Likewise, antennae inside the chamber can have their signals converted to optical format and distributed to labs outside the chamber for analysis. The ingress and egress of fiber cables to and from the chamber do not bring the typical issues of EMI and lightning protection associated with penetrating chambers with coaxial cable.

An optical circuit switch can be used to dynamically distribute the RFoF signals, thus creating a remotely reconfigurable test environment at the click of a mouse, or under test automation software control.

Aircraft on test in anechoic test chamber*

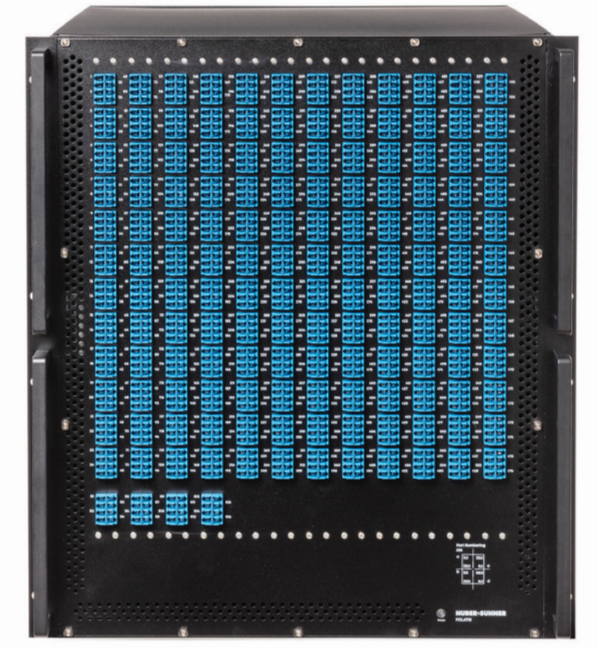
*The appearance of U.S. Department of Defense (DoD) visual information does not imply or constitute DoD endorsement.

The POLATIS® optical circuit switch advantage

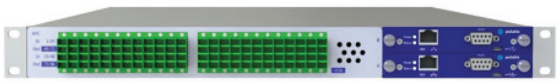
Ideally suited to signal switching in RFoF applications

In applications where RF signals need to be distributed and switched, converting to RfoF and using POLATIS® optical circuit switches offers significant advantages over conventional RF switches, including:

- POLATIS switches are protocol and data rate agnostic so future-proofed against changes in format, bit rate and signal types.
- They offer industry leading ultra-low insertion loss to protect link margins, superior optical performance and stability, and near-zero signal latency.
- Highly stable connections and low back reflection preserve RFoF signal integrity.
- The patented DirectLight™ beam-steering technology minimizes impairments to RFoF signals traversing the switch connections. POLATIS switches use integrated position sensors to directly align optical collimators to make and hold dark-fiber connections, which eliminates the need for signal dithering that can degrade RFoF signals.
- Dark fiber switching capability also extends to supporting low power or intermittent signals.
- They achieve greater than 100dB of RF isolation between channels at any RF frequency.
- The optics are fully bi-directional.
- Optional Optical Power Monitors offer real time signal monitoring to alert for degradation or loss of signal.
- Optional Variable Optical Attenuation allows the signal coming out of the switch to be attenuated so that the power levels going into test devices or sensitive receivers are controlled.
- Fully software-defined with a seamless interface via command line interfaces such as TL1, SCPI and SNMP, SDN controllers over RESTCONF and NETCONF and the POLATIS web GUI.
- Easily integrated with leading lab automation software solutions.
- Eco-friendly, low power consumption.
- The broadest range of matrix sizes from 16x16 to 576x576 ports and available in symmetric NxN, asymmetric MxN and custom configurable port configurations.
- Small form factor requires little rack space (48x48 in 1 RU).



POLATIS 576x576 with LC connectors



POLATIS 48x48 in 1 RU

HUBER+SUHNER

The POLATIS team at HUBER+SUHNER has over 20 years of expertise in optical circuit switching. With this extensive knowledge we actively drive the development of RFoF applications with optical circuit switching across multiple industries.

HUBER+SUHNER offers a broad range of products that offer the best-in-class RF and fiber optic components and systems needed for end-to-end RF over Fiber solutions. HUBER+SUHNER provides RF cables, connectors and RF-to-optical transceivers, multiplexers if running different channels on a single fiber, and a host of fiber and RF cabling and cable management products. HUBER+SUHNER can offer complete turnkey solutions for RF signal distribution.

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