



Optical Switches for Dynamic Distribution of Radio Frequency Signals over Fiber Optic Cables

Application Summary

The distribution of RF signals over optical fiber has been in practice since the mid 1980's for cable TV, government and defense related applications. The advantages of distributing RF signals through optical fibers versus coaxial copper cable are well documented and include reduced EMI, less expensive and smaller cables, better RF link noise performance and longer potential cable runs. A representative RF distribution architecture is shown in figure 1. In this architecture the radios have access to all antennas and can be dynamically reconfigured by the optical switch.

The Polatis optical switch has found significant application in RF distribution systems, due to several distinguishing performance advantages of the Polatis switch. These performance differentiators include ultra-low-loss optical performance, dither-free alignment, low PDL, low crosstalk, high signal security and low optical return loss.

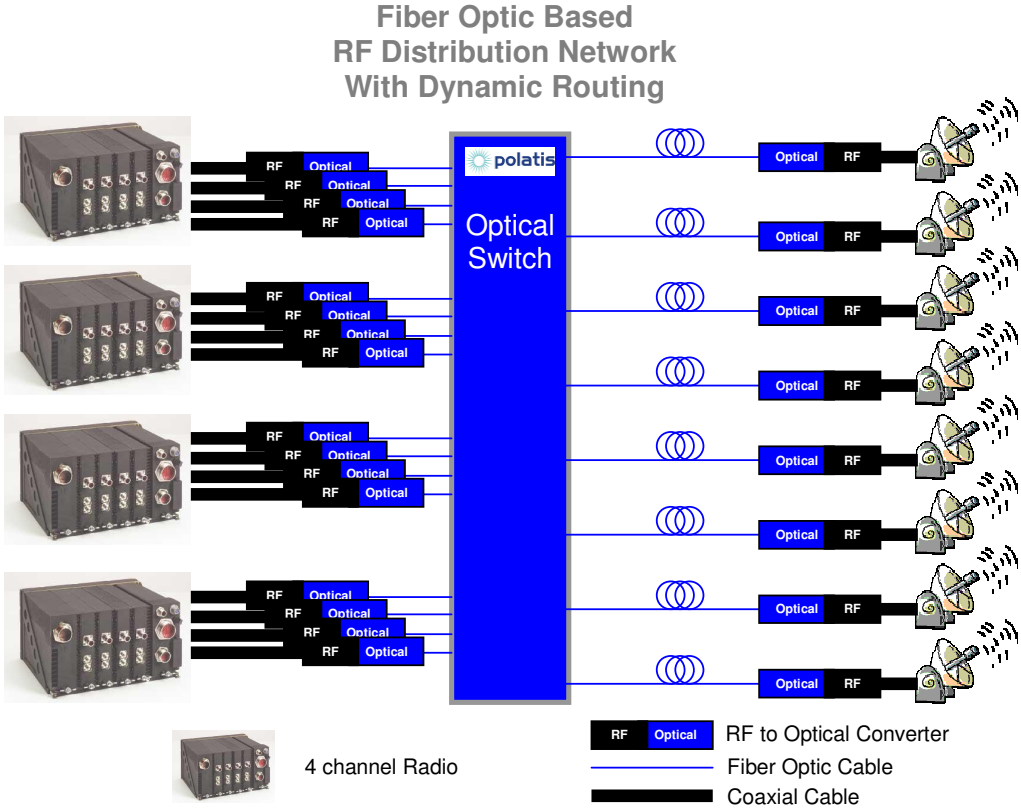


Figure 1 Representative RF Distribution Architecture

Polatis Optical Switch Differentiators

Ultra-Low-Loss Performance

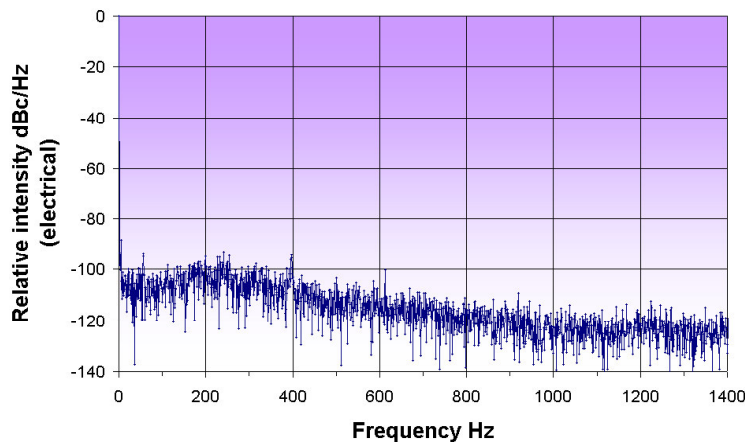
The 0.5 dB typical loss performance provided by the Polatis optical switch is a benefit for most applications and a unique enabler for others. Low optical loss is essential for high performance RF over fiber applications. Low loss optical paths are crucial for preserving a high level of RF link performance through the electrical to optical to electrical conversions. The ultra-low loss of the Polatis switch is unmatched by any other optical switch of the same size, making it the switch of choice when RF link performance is important. The difference between the 1 dB max insertion loss of the Polatis switch and 3-4 dB max of typical MEMs switches provides a significant system performance improvement for systems that utilize the Polatis switch for distribution.

Dither-Free Alignment

A subtle but very important performance advantage of the Polatis switch results from the technique used to maintain the internal switch alignment. In the Polatis switch the collimator pairs are pointed at each other to facilitate coupling of the optical energy from the input fiber to the output fiber. For efficient coupling, the collimators must be pointed very accurately at each other. The pointing direction of the collimators is precisely measured by capacitive position sensors located around the collimator. The pointing angles of the collimators, as measured by the position sensors, are maintained by fast acting digital control loops. The beneficial outcomes of this alignment technique are that the collimators are very accurately and statically pointed. To fully appreciate the importance of this alignment technique, one needs to understand how other optical matrix switches maintain alignment.

Most optical matrix switches use alignment techniques that involve dithering of some intermediate optical element, such as a lens or mirror, to provide feedback regarding the optimum position for best optical coupling from input to output. The problem this introduces is that the amplitude of the signal traversing the switch is modulated as the dithering element moves. In digital systems, the degradation of the optical signal due to amplitude modulation is not as critical but in analog RF systems the modulation is mixed directly onto the RF signal, adding to the signal noise floor and thus obscuring low level signals of interest.

The level of amplitude modulation induced by the control loop in a Polatis optical switch is typically less than 0.02% and, as illustrated by the frequency plot of Figure 2, this preserves very low levels of close-to-carrier noise on high dynamic range RF signals.



Low Polarization Dependence

The polarization state of light in a standard optical fiber fluctuates randomly with small changes in the thermal, vibration and stress environment along the length of the optical cable. If a component is introduced with high polarization-dependant loss, this real-time fluctuation in polarization state will be converted into amplitude modulation noise, degrading the achievable dynamic range of an RF/optical system in a similar way to that described above. Unlike competing technologies, polarization-dependant loss in the Polatis optical switch is less than 0.05 dB, ensuring transmission of RF signals with high fidelity.

Low Crosstalk

A key performance aspect of RF switch matrices is the achieved crosstalk value, the coupling of input signals to unintended output ports. In high dynamic range RF systems, strong signals can interfere with weak signals on adjacent switch channels if crosstalk values are not sufficient. The Polatis optical switch has maximum optical crosstalk values of -70 dB with typical values closer to -100 dB.

It is important to note that, because optical power incident on a photodetector is converted into electrical current, power ratios are squared (or doubled in dB) on optical to electrical conversion. Hence, an optical crosstalk value of -70 dB corresponds to an RF crosstalk level of -140dB. This level of crosstalk performance greatly surpasses that of conventional RF switches and can provide excellent performance for high dynamic range RF systems.

High Security

Another result of the internal alignment technique used in Polatis switches is the absolute preservation of the signal's integrity. There is not any chance for signals to be inadvertently leaked out of the switch in electrical format. MEMs switches, and other optical matrix switches, predominantly rely on the dither-based alignment technique previously described. The dither technique requires that an optical tap be placed on the output fiber to detect and measure the quality of coupling achieved. The optical tap bleeds off a small amount of the optical signal traversing the switch and converts it to electronic format for processing within the switch. Once the signal converts even a small amount of the optical signal into electronic format, EMI and TEMPEST concerns arise. Is the signal completely contained within the switch or does it leak out through emanations or conduction?

The Polatis switch utilizes capacitive position sensors to maintain the internal alignment of the switch and does not have any optical taps. The optical signal is never detected, never measured, never converted into electrical format. There is absolutely no opportunity for the signal to leak out of the switch through emanations or conduction.

Low Return Loss

Many high performance RF-to-optical converters are destabilized by back reflections of optical energy thus causing a raised noise floor and degraded RF link performance. The low return loss of the Polatis optical switch, 55 dB minimum, provides a level of performance that is not achieved by MEMs switches. Most MEMs switches have return loss specifications of 35 dB which is not sufficient to avoid degraded RF link performance from standard optical sources.

Conclusion

Traditionally, RF signals have been distributed by large coaxial cables and routed by RF switch matrices. The many advantages of RF distribution over optical fibers are now complemented by the ultra high performing Polatis optical switch for RF signal routing. The superior optical performance and dither-free alignment of the Polatis switch, as compared to today's MEMS switches, provides significant RF signal-to-noise improvements. The dither-free steering of the Polatis switch also provides a very high level of signal security by never converting any of the optical signal into electronic form where it could unintentionally emanate and provide a security problem in secure networks.

FOR MORE INFORMATION

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