White Paper

Why an optical solution using RF over Fiber is the preferred solution for multi-antenna array for EW applications

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Glossary

ADC	Analog-to-digital converter
ELINT	Electronic Intelligence
EW	Electronic Warfare
mm-Wave	Millimeter Wave - An electromagnetic (radio) wave typically within the 30–300 GHz frequency range
RADAR	Radio Detection and Ranging
RF	Radio Frequency
RFoF	RF over Fiber
VSWR	Voltage standing wave ratio

I. Introduction

Many RF applications require signal distribution / collection that interconnects over substantial distances using wide bandwidth. Examples of such systems include antenna arrays and signal distribution networks. Some main applications are antennas arrays for ELINT and direction-finding systems with and without interferometry, RADAR target simulators, and spatially power managed EW countermeasures.

Where bandwidths are low, digital distribution and collection is king, as the signal information content can be maintained over long distances without degradation other than from the original sampling quantization errors. However, when the bandwidth requirement is increased, which is the common case in multi-threat military equipment, **sampling ADC converters** may become impractical for a number of reasons including: limitations of the **sample rate, transmission media limitations, power consumption, and dynamic range**.

RF distribution can fill the requirement for such distribution networks with high bandwidths, when wide signal bandwidths are needed in multi-antenna applications in close proximity. Sophisticated and complex **up-and-down frequency conversion solutions** are possible with low loss coaxial lines serving to transport the signals. However, frequency conversion becomes less practical and even impossible for some applications which require massive antenna arrays, long-distance signal transport, and still wider bandwidths. RF solutions becomes very difficult to design and implement when there are many distribution points. In some cases, it is simply the sheer weight and girth of all those coax cables that becomes unmanageable in existing conduits. In other cases, frequency conversion adds too many side effects as to preclude the approach altogether. To illustrate: the techniques that are used to isolate real signals from intermodulation products limit the sampling time and reduce the probability of detection. Consequently, advanced ELINT and surveillance systems, multi-use target simulators as well as test ranges strive to avoid frequency conversion solutions.

II. The Challenge

A practical solution is needed for low power delivery and collection of ultra-wide bandwidth signals to and from massive number of distant ports over manageable and low-cost media without sacrificing signal quality and affording consistent time delay. Such a solution should support low-loss transmission media which is immune to radiated electromagnetic noise (after all, the transmission media is intended for delivery or collection of signals near or to antennas which in turn produce lots of electromagnetic radiation on purpose). Ideally, the transmission media is indifferent to the signal bandwidth allowing future bandwidth upgrades without retrofit of the media itself. Flexibility and scalability are desirable too, especially when it is certain that future upgrades will include even more signals, channels, antennas, and bandwidth to be distributed to additional or different ports.

III. THE SOLUTION

RF over Fiber solutions (RFoF) answer all the requirements by addressing all of the key criteria outlined above. Such RFoF links provide extreme bandwidths exceeding 40GHz for high end solutions, RF bandwidth agnostic low-loss transmission media in the form of lightweight optical fibers that can be bundled to deliver massive parallel transmission channels over long distances with immunity to electromagnetic noise. All the while the cross-section size of fiber solutions is tiny as compared with the coaxial infrastructure that they replace, this allows even more bandwidth and more signals to travel in the same existing conduits.

RFoF converters consume miniscule amount of power as compared to their high-speed ADCs or RF frequency conversion schemes. As a result, RFoF-based **optical analog distribution** is the logical choice for distribution networks that need to handle instantaneous bandwidths exceeding a few GHz. These signal distribution systems perform exceptionally well over substantial distances owing to the low losses of optical fibers. They can also maintain unmatched SFDR and dynamic range allowing signals with different levels to coexist with minimal interference. With optical WDM, the throughput and flexibility can be increased dramatically in such a way that such signal delivery systems stand out unchallenged and alone in their performance.

In this white paper, applications for multi-antennas array for EW, phased array, ELINT, and surveillance applications will be discussed.

ADVANTAGES OF USING OPTIC VERSUS COAX

Feature	RF Distribution Matrix	RFoF Distribution Matrix
Distance between RF ports	Limited with frequency	There is no practical limitation due to the low loss of fibers
RF Bandwidth	Limited due to the coax and distance	Practically unlimited RF bandwidth
Weight and Size	Bulky and heavy RF Cables	Compact and light fibers is frequency and bandwidth agnostic
Environment	Sensitive to corrosion and chemicals	Less sensitive to corrosion
Operating Expenses (OPEX)	Complex system, requires frequent maintenance	Simpler system, with minimal maintenance
Isolation	Limited by coaxial shields and connectors	Insensitive to RF EM radiation
System Cost	Increases with the frequency	Cost benefit increases as RF bandwidth increases

Table 1 - Comparison between RF Distribution Matrix and RFoF Distribution Matrix

IV. Wide Band Multi-Antenna Arrays For EW and Surveillance Applications

RF Current Approach

A main application of signal distribution systems is the multi-antenna Array or Phased Array. Such arrays have many uses, be it beam forming for RADAR or target simulation and test ranges to test those RADARS. Other applications can be for ELINT identification and collection as well as intelligent active jammers or simulators for testing those systems. The challenges that were mentioned before are taken to the extreme since modern systems operate over wide frequency bands exceeding the traditional 20GHz. Furthermore, many systems use conformal antenna arrays in which the antennas are spread over large sections of the platform such as wings, body or deck structures. In such cases the transmission media must be lightweight and maneuverable for easy routing and installation.

RFoF based optical analog distribution is the logical choice for signal distribution networks that need to handle instantaneous bandwidths exceeding 20GHz or 40GHz, since they perform exceptionally well over substantial distances. It can also maintain unmatched SFDR and dynamic range allowing signals with different levels to coexist with minimal interference. Since the RFoF based signal distribution system is inherently wide-band it is effectively a true time delay distribution setup (more on that in a future RF Optic publication).

RFOptic Approach

In order to solve the challenges outlined above, RFOptic offers a solution which is comprised of the following blocks:

1. RFoF High SFDR links which support 20GHz and 40GHz instantaneous bandwidths.
2. RF to Optical conversion modules with optional signal level control functionality.
3. Optical Matrix fast routing with **n***M ports enabling to switch between any of the **n** optical inputs and combinations thereof to the **M** optical antenna outputs with reliable multi-fiber interfaces.
4. Optical to RF conversion antenna modules, each with managed RF power amplifiers to produce the desired RF level at each antenna port.
5. Scalable modular design which allows upgrades of the number of antennas **M** and number of signals n with minimal changes to the system architecture.
6. Management and monitoring state of the art system based on popular standard protocols.
7. Optional Optical delay line and modulation capabilities for the **n** input signals.

The advantages of the RF optical solution versus only RF solutions are described in Table 2.

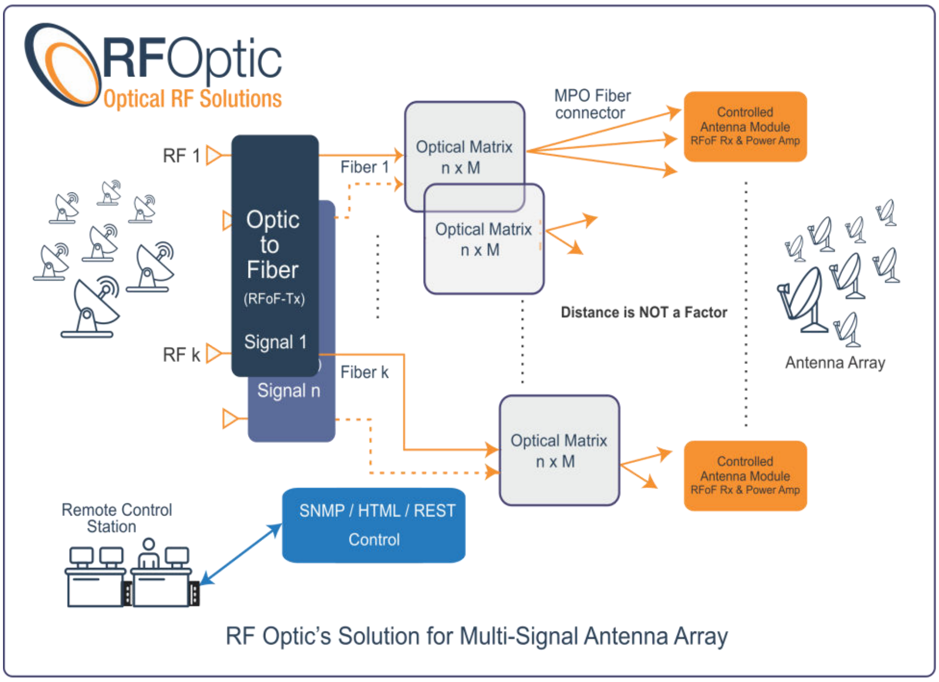

Figure 3 - RF Optical Solution

V. 40GHz Case Study

A recent requirement involved a transmit system with 40GHz of signal bandwidth operating at the high end of the Ka band. The system required - 1:500 signal routing and distribution systems with two input signals considering a future expansion to 4 or 8 different input signals.

The operational protocol required sub micro-second routing of any of the input signals to any combination of the 500 outputs delivering Watt level signals to the antennas. The antenna array covered a few square meters. The distribution system had to be designed in a modular way in order to maximize the number of identical component modules to allow efficient production.

A key requirement of coherency between the signals from all antennas made frequency conversion-based solution unattractive. The direct RF implementation of this signal distribution system at mm-Wave frequencies was compared to an RFoF-based solution. Some of the trade-offs are listed in the following table which focuses on the key differences.

Property	RF System	RFoF system
Input module	Multi-stage High gain PA's and power dividers	RFoF Transmitter Optical Amplifier and power dividers
1:500 Switch routing network	Modular 1:N Ka RF switches	Optical 1:N ultrafast switches
500 port antenna interfaces	Ka coaxial cables, blind multi-connector interfaces	N in 1 multiple optical fiber connectors and fiber bundles
500 Antenna output modules	High gain (>50dB) power amplifiers	RFoF Receiver module and low gain (~30dB) power amplifier

Figure 4 - Comparison between RF and RFoF systems

While each of the components of the RF implementation directly effects the gain flatness and phase coherency, for the RFoF system only the RFoF transmitter and the antenna output modules with its lower gain (fewer stages) impact the flatness and phase coherency. All other elements of the RFoF system are completely transparent to the RF bandwidth. Since fiber losses were negligible, the 500-port antenna cabling was far easier to deploy and is also easy to maintain.

VI. Summary

The range of Homeland Security and Defense applications of RF High SFDR wideband links is highly dynamic, and is evolving rapidly. Especially those applications which benefit directly from phase coherence and true time delay which are natural features of these RFoF links. Requirements involving deployment of these links in harsh environments and tight spaces are frequent and push the envelope of the technology. Recently, requirements for several multi-antenna arrays for EW and surveillance applications have been entertained and customers are looking for end-to-end systems that combine the best of RF and Optical technologies. Such RF and Optical optimization in End-to-End signal distribution and collection solutions has been the hallmark of RF Optic from its inception.

Only optical analog distribution performs exceptionally well over substantial distances while maintaining unmatched SFDR and dynamic range allowing signals with disparate levels with minimal interference.

VII. About RFOptic

RFOptic is a leading provider of RF over Fiber (RFoF) and Optical Delay Line (ODL) solutions. For the last 20 years, its team of industry veterans has been developing, designing, and integrating superior quality technology for a wide range of RFoF and ODL solutions. The solutions are deployed in various industries, including broadcasting, aviation, automotive, and defense. RFOptic offers its customers and OEMs various off-the-shelf products, as well as custom-made solutions optimized for a wide range of RFoF products at affordable prices and with a quick turnaround. RFOptic makes it its mission to help its customers to turn innovation into real business by providing them with the highest quality, cutting edge RFoF solutions as well as customized solutions based on individual requests and objectives.
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