RFOptic
Optical RF Solutions

White Paper

Why an optical solution using RF over Fiber is the preferred solution for 5G applications

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August 2020

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Glossary

5G	Fifth generation (5G) technology standard for cellular networks, which cellular phone companies began deploying worldwide in 2019
6G	Sixth generation (6G) technology is currently in the research phase and will replace 5G in the future. 6G is expected to enable speeds of 1TB or 8,000 gigabits per second with lower latency for instant device-to-device communication.
mm-Wave	Millimeter Wave - An electromagnetic (radio) wave typically within the 30–300 GHz frequency range
PIM	Passive Intermodulation
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. The main applications are the emerging 5G where bandwidths above 6GHz are required.

Where bandwidths are low, digital distribution 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, **sampling ADC converters** may become impractical for a number of reasons including: limitations of the **sample rate, power consumption, and dynamic range**.

RF distribution can fill the requirement for such distribution networks with high bandwidths. When signal bandwidths are in the range of 6Ghz (which is used for 5G networks) applications. 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 MIMO antenna arrays, long-distance signal transport, and even 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 other cases, frequency conversion adds too many side effects as to preclude the approach altogether. To illustrate: many scientific observatories, 5G and 6G tower infrastructure cannot use straight-forward frequency conversion solutions.

II. The Challenge

A practical solution is needed for low power delivery of ultra-wide bandwidth signals to a massive number of distant ports over manageable and low-cost media without sacrificing signal quality. 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 of signals to antennas which in turn create lots of electromagnetic radiation on purpose). Ideally, the transmission media is indifferent to the signal bandwidth, since installations could then be upgraded easily as bandwidth demands increase. 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 differently.

III. The solution

RFoF solutions are the answer 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.

These 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** will be 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. 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 5G base stations that require frequencies up to 6GHz as well as mm-Wave frequencies are discussed.

IV. Wideband RF vs Optical Distribution Networks for 5G applications

A. Current Approach

In the 2G, 3G, and 4G mobile networks generations, when vendors of base stations were testing their equipment, they created a mock deployment environment test range using hundreds of mobile devices connected with RF networks, RF switches, power dividers, attenuators and amplifiers to a base station array. This setup is then used to check for interoperation, interference, crosstalk, handover issues and more. Although there are many known issues (some quite esoteric e.g., PIM or passive intermodulation) along with strict shielding requirements, tuning and high maintenance costs of such setups, this approach was considered to be adequate.

Such RF-based distribution systems can become exceedingly more complex, consuming lots of power, and even becoming unmanageable due to factors causing performance degradation stemming from the effects of leakage and crosstalk, reflected signals and insertion losses. These test setups require constant vigilance to maintain the operating conditions aided by monitoring subsystems that detect signal leaks from bad or loose connectors and such. Such effects are well-known to RF system designers who deploy various additional circuit or system blocks for mitigation. However, that increases the power consumption of the system and its complexity even more. Relying on such complex hardware infrastructure makes test configuration changes very time consuming and tedious.

The mechanical and maintenance aspects of such RF signal distribution systems complicate the bulk of hundreds of coaxial lines which should be as thin as possible to make assembly and routing practical, but also as thick as possible to reduce PIM and insertion losses. To overcome this paradox, thousands of RF connectors are required to provide a maintainable segmentation of these RF cabling interconnects, each a potential weak point in the shield that results in unwanted crosstalk. While not completely impossible, the implementation of such RF signal distribution systems has to overcome major obstacles.

A more common instance where RF interconnect technology is deployed is in tower-mounted antenna arrays. Also is this case, there are the same issues such as cabling weight, insertion losses, VSWR, and reflections complicated by the need to weather the elements of the environment. In other cases, such as in tunnels, limitations can include the size of available conduits and corrosive environments.

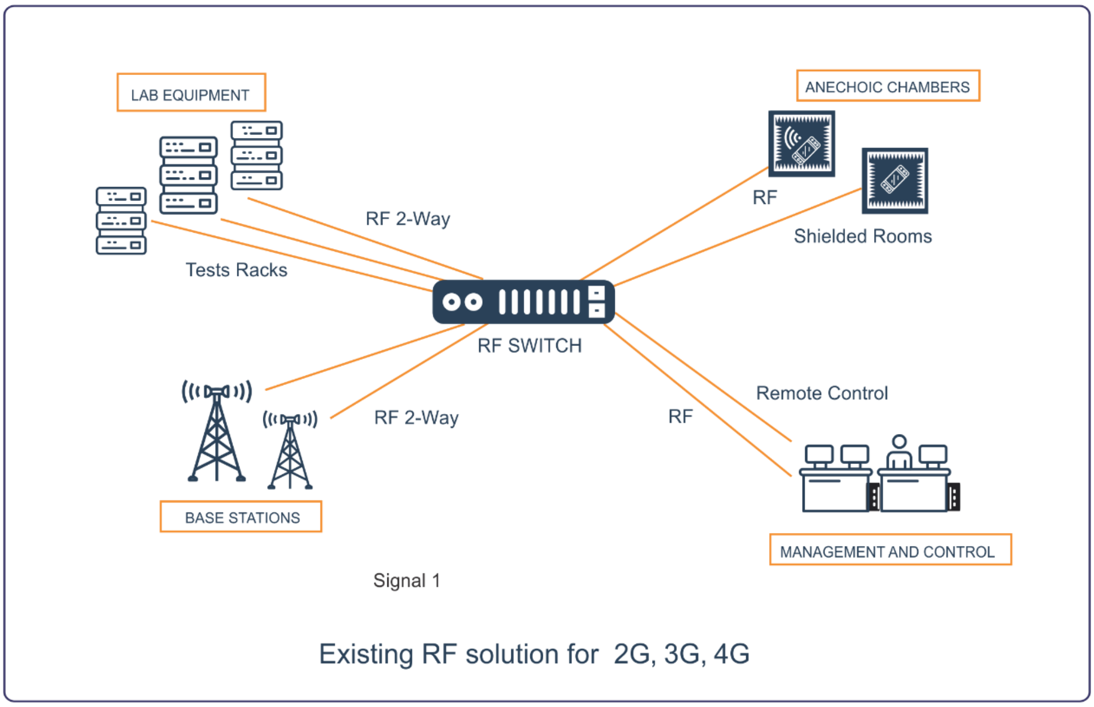

Figure 1 - Current RF Approach

B. The RFOptic Approach

An alternative and highly effective approach consists of a solution comprised of RFOptic's RFoF links and a managed optical switch. The solutions are comprised of:

a. 6GHz RFoF links with built in LNA including an internal digital attenuator, an optical power meter, and other features that makes it especially suitable for 5G applications.
b. 20GHz and 40GHz RFoF links with pre and post amplifier and gain control
c. An optical managed switch
d. SNMP/HTML remote management system

An Example of such signal distribution system is shown below in Figure 2.

The RFoF sub-system includes several unidirectional and Bidirectional RFoF links. Owing to the optical transmission media it is possible to service distant and shielded locations with EMI immunity for all interconnects.

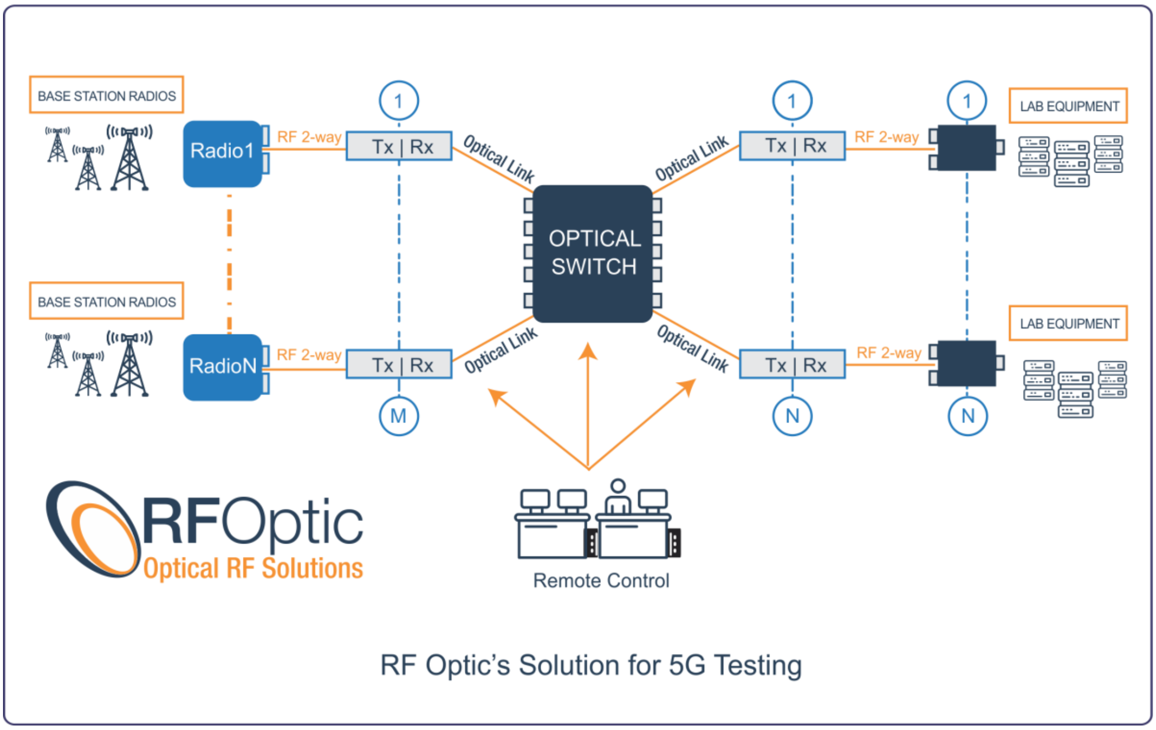

Figure 2 - RF Optical Approach

C. 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

Figure 3 - Comparison between RF Distribution Matrix and RFoF Distribution Matrix

V. Summary

The RF high frequency market is highly dynamic, evolving rapidly. Especially with 5G deployment accelerating and 6G testing intensifying, customers are looking for end-to-end systems combining best-of-breed technologies.

As discussed above, the deployment of optic is highly efficient for distribution networks that need to handle instantaneous bandwidths exceeding a few GHz and up to 40GHz.

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.

VI. 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.
For more information, please visit **www.rfoptic.com**