Wireless future drives microwave photonics

Microwave photonics is the vibrant and somewhat niche field that marries the high-frequency and analog nature of radio signals with the low-power requirements and better processing capabilities of optics. Many companies operating in this field expect the market to grow as manufacturing capabilities continue to improve and costs come down.

"There's quite a number of applications that have emerged in the past few years, both commercial and military," says Arthur Paolella, CEO of Artisan Laboratories in the US, which builds optical transmission systems for sending radiofrequency (RF) and microwave signals of up to 40 GHz over optical fibres.

The defence sector, for instance, is a big customer for Artisan. "Military systems are very wideband. Companies are trying to pump a lot of data through these systems," Paolella points out. Trying to push such high-frequency signals directly through coaxial cable would require significant power and suffer from considerable losses. "One of the key attractions of 'radio over fibre' systems is that the losses are of the order of 0.1 dB km^{-1}, whereas in coaxial cable the losses are nearly 1 dB for every 30 cm," he explains.

Many types of military hardware rely on sending and receiving high-frequency RF signals. For example, antennas are found on the tips of aircraft wings, unmanned aerial vehicles, aircraft carriers and orbiting satellites. In environments such as these, there is neither enough space nor enough electrical power for the equipment to convert the analog RF signal to the digital signal formats used by traditional optical telecommunications systems. Encoding the analog signal onto a light beam makes it possible to put bulky, complex equipment in a more convenient location at the end of a link, where signal processing can be performed.

This advantage is not only useful for distributing signals around environments as big as aircraft carriers, but it is also appealing for customers who want to place antennas in remote locations, such as the satellite farms that transmit signals to communications satellites. Edward Ackerman, vice president of research and development at Photonics Systems in Billerica, Massachusetts, USA, says that radio astronomy is one market for his company's microwave photonic links. Indeed, links manufactured by Photonics Systems are now used in the SETI Institute's Allen Telescope Array.


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Optical fibre has another important advantage over electrical wiring: it weighs only 2 kg km^{-1}. Coaxial cable, in contrast, weighs around 560 kg km^{-1}. This property makes optical fibre attractive for use in aircraft, satellites and cell-phone towers, says Paolella. Instead of using a thick and heavy bundle of coaxial cables, telecommunications companies can use a far thinner, lighter collection of optical fibres to carry the analog signal to the ground.

"The first phase of microwave photonics is building a system to send signals along the fibre, and the second is performing analog processing of the signal," says Lute Maleki, president and CEO of OEwaves in Pasadena, California, USA. Many companies have the ability to build filters, oscillators and down-converters. "You can do things using optical techniques that you cannot do directly in the electronic domain," Maleki says. For instance, the high spectral purities achievable by modern oscillators allow users to squeeze more channels into a single band than ever before, thus increasing the amount of data that can be sent without raising costs. "Everybody's interested in transmitting multigigabits of information wirelessly," he says.

Paolella believes the market for microwave photonic equipment is likely to grow with consumer demand for wireless gigabit services. The IEEE standard WiMAX (the Worldwide Interoperability for Microwave Access) was recently upgraded to handle data rates of 1 Gbit s^{-1}, and Paolella believes many small, WiMAX-based stations — known as picocells — will soon start to spring up. "With the proliferation of tablets devices such as iPads, you're going to need a lot more wireless infrastructure," he says. He also believes the demand for microwave photonics will be driven by the growth of fibre links directly to the home.

According to Paolella, the market has benefited significantly from the tenfold drop in component costs seen over the past decade. This price reduction has come about as components have become more highly integrated, although there is still room for improvement. Meanwhile, the technology has also improved. The semiconductor lasers that provide the optical carrier signal for the fibre have increased in power and now exhibit narrower linewidths, thus allowing for higher signal fidelities. Improvements have been made in photodetector efficiency and the sensitivity of the modulators used to encode the RF signal onto the optical carrier. In addition, says Ackerman, the industry has developed better ways to model the whole chain of components, which has led to better system design.

Despite such progress, development has been hampered by the recent decision of the US Defense Advanced Projects Research Administration (DARPA) to pull back on funding. "Unfortunately, for reasons that are not very clear, DARPA has severely curtailed the number of programmes that go into microwave photonics, really at a bad time," Maleki explains.

One area of the market still has much room for improvement — cost. "Price sensitivity is the parameter that is keeping microwave photonics from becoming more embedded in commercial systems," Maleki says. Ackerman agrees: "It has to be about getting things cheaper." One effort that might help to bring costs down is the development of silicon photonics. Building photonic components using silicon and the CMOS fabrication technology used to make computer chips should help make the technology cheaper and easier to integrate with future electronics.

The roll out of high-speed wireless networks is likely to drive the adoption of microwave photonic technology. ❐