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Microwave photonics technologies supporting high capacity and flexible wireless communications systems

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Abstract: Emerging 5G wireless systems require technologies for increased capacity, guarantee robustness, low latency and flexibility. We review a number of approaches to provide the above based on microwave photonics and hybrid optical fiber-wireless communication techniques.
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1. Introduction

The upcoming generation of wireless communication systems denominated 5G and is characterized by a set of stringent requirement on increased overall system capacity, high data rate including mobile, low latency, robustness and energy efficiency among other [1,2]. Complying with the above requirements imply the use a new technologies and techniques as well as a combination and coordination of such. Example of such combination of technologies are a) wireless and optical fiber communications in the form optical fiber front/backhauling b) cooperation among wireless transmission bands from microwave to millimeter wave and possibly up to sub-Terahertz c) radio frequency and free-space optics, d) and among wireless standards.

In this paper we would like consider the role techniques based on microwave photonics could play to support robustness and flexibility in 5G wireless communication systems. In particular, we are focusing on the use of vortex beam both in the wireless as in the optical domain.

2. Hybrid Optical fiber – free space optics supported by vortex beams

The low transmission loss of optical fiber allows for antenna remote placement supporting centralizing wireless carrier generation and signal processing in a central placing. Photonics is generally of advantage when generating and transmitting spectrally-broad and spectrally-efficient ultra-high capacity data signals. A well-studied approach is radio-over-fibre (RoF) where wireless signals are transmitted in analog from and to the Central office. On the other hand, free-space optics (FSO) has been proven to be a flexible tool to link short- to mid-range distances. A deficiency in FSO is the under-utilization of the available spectra. Orbital angular momentum (OAM) of light has been proposed to effectively increase the capacity of FSO links by multiplexing several channels using the modes of the light[3]. The OAM of light is the component of angular momentum of a light beam that is dependent on the field spatial distribution, and not on the polarization. It can be further split into an internal and an external OAM. The internal OAM is an origin-independent angular momentum of a light beam that can be associated with a helical or twisted wavefront. The external OAM is the origin-dependent angular momentum that can be obtained as cross product of the light beam position (center of the beam) and its total linear momentum. By manipulating the OAM modes, multiple light beams can co-exist within the same space without interfering to each other. This effectively increases the capacity of the channel.

Figure 1 shows a network scenario where FSO with OAM is used to support RoF signal distribution for mobile fronthaul systems. Regular single mode fiber (SMF) connections are used to distribute RoF signals to the cell stations; in case an isolated cell stations needs to be feed remotely through an FSO link, we employ OAM to effectively multiplex N-channels. At the isolated cell station, each individual OAM mode is recovered and the RoF signal fed to the antenna using multimode fiber (MMF), which is more convenient for low cost installations; MMF permits the use of the 850nm communication window, which is extensively used in data center environments and therefore has off-the-shelves components readily available.

The authorshave recently suggested the utilization of orbital angular momentum communications in cell cabinet linkage to overcome physical limitations on the deployment of mobile fronthaul wired infrastructures (lower section of Fig. 1) [4]. OAM using FSO offers the possibility to distribute the channels to cell site cabinets, and later transport the RoF signals to each of the antennas independently using OAM over MMF.

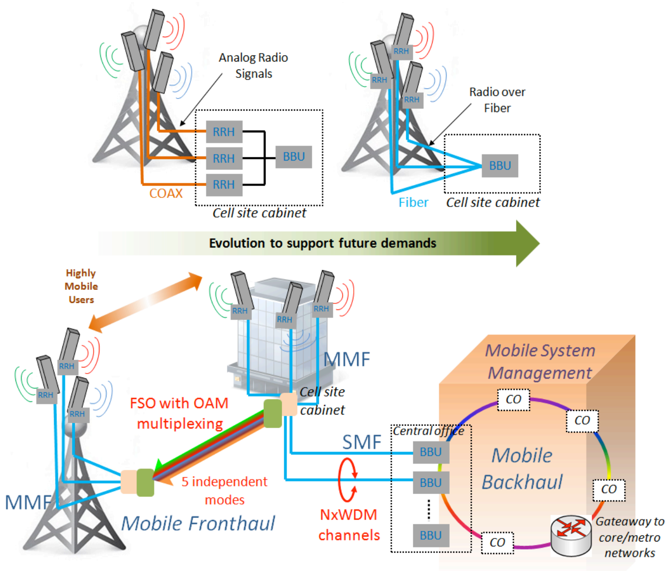

Figure 1: Schematic diagram for a combination of optical fiber and FSO backhaul links using vortex beams. Top: evolution path to 5G. Below: FSO and ROF with vortex beams to exploit MF infrastructure.

Experimental results show that the use of OAM in conventional 850 nm VCSEL based and OM3 MMF transmission allows to achieve distance over 100 m for RoF transport of LTE compatible modulation formats. Therefore the use of OAM has the potential to serve a robust transmission technique both in FSO and MMF fiber RoF systems but also as a way to offer signal multiplexing.

3. High Capacity hybrid optical fiber data links

The requirement for high bit-rate, above 10 Gbps, for 5G data links, implies the use of the use of high carrier frequencies such as mmw and beyond. The W-band (75-110 GHz) has in this context attracted a large interest lately. In particular, system capacity of 100 Gbps has been achieved by using photonic generation by optical mixing and coherent detection with digital signal processed assisted receivers [5]. Remaining challenges associated with beam forming and MIMO techniques are considered area where techniques inspired in microwave techniques can assist.

4. Dynamic optical switching for 5G

The goal for several players in 5G development is to increase by a factor of 1000 the system capacity per square km compared to 4G[1,2]. In this context a number of technological approaches are envisioned, including the dynamic use of resource by using a dynamic optical switching layer to the fiber front-haul[6]. This approach can serve a multifold of features for 5G-not only capacity on demand provisioning by lighting wavelength or optical fiber to antennas or cluster of antennas on demand, but also support for optical feeders for RF beamforming and cooperative co-existence of standards and overlay over passive optical fiber networks.

5. Summary

The requirements for overall system high capacity, high speed data links, robust transmission over diverse media such as FSO and even support for MMF RoF opens potential for use of photonics and photonic technologies. Such techqnues include robust vortex beam transmission, photonics generation of broadband signals and optical switching and beamforming.

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