Mitigation of Dispersion Effects for better Quality of Transmission in RoF system – A Review

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ABSTRACT
This paper presents a review of dispersion effects in optical fiber which occurs due to physical properties of transmission medium. The dispersion effect causes light pulse to broaden as it travel along the length of fiber. The dispersion effect will degrade the performance of Radio over Fiber systems. In literature, many of the dispersion suppression methods have been proposed. It has been observed that dispersion compensation can be achieved by using chirped fiber Bragg gratings, dispersion compensation fiber, interferometers and photonic crystal fiber.

Keywords- Dispersion compensating fiber; Chromatic Dispersion; Photonic Crystal fiber; Radio over Fiber

I. INTRODUCTION
Recently, the demand for high-speed and high-capacity multimedia services in wireless communication systems has been growing rapidly. According to the growing demand for mobile broadband services due to the diffusion of high capacity and always-on mobile devices, wireless networks are going to need a significant increase of their total bandwidth [1]. To meet the explosive demands of high capacity and broadband wireless access, the microcellular system; which consists of many small cells, has attracted attention as an effective method for attaining high-speed and high-capacity communication by improving frequency utilization efficiency. It leads to a large number of base stations (BS) to be deployed to cover a service area. However, the microcellular system has some problems, such as the large investment required in many base station (BS) facilities and the necessity for complicated channel control techniques among BSs for spectral delivery and the handoff procedure. The actual solutions to face this huge increase in data traffic aim at the implementation of system architecture where functions such as signal routing, handover and frequency allocation are carried out at a central control station (CS) rather than at the BS, such a centralized configuration allows sensitive equipment to be located in safer environment and enables the cost of expensive components to be shared among several BSs. Thus, the most promising solution to the wireless traffic problem will be the linking of a Central station with BSs in such a Radio Network is via an optical fiber, since fiber has low loss, is immune to electromagnetic interference and has broad bandwidth. In order to reduce the system cost, the transmission of radio signals over fiber, with simple optical to electrical conversion, followed by radiation at remote antennas, which are connected to a central station has been proposed. The reduction in cost can be brought in two ways. Firstly, the base stations required to perform only simple functions, it is smaller in size and low in cost. Secondly, the resources provided by the CS can be shared among many antenna BSs. This technique of modulating the radio frequency (RF) subcarrier onto an optical carrier for distribution over a fiber network is known as Radio over Fiber (RoF) technology. RoF technology takes advantage of the benefits of optical fiber with the mobility and ubiquity of wireless networks [2]. Radio over Fiber is a well established technique for the distribution of wireless communication systems [3]. RoF is basically an analog transmission system because it distributes the radio waveform, directly at the radio carrier frequency, from CS to BS. The analog signal that is transmitted over the optical fiber is RF signal The RoF network typically comprises a central control station, where all switching, routing, media access control and frequency management functions are performed, an optical fiber network, which interconnects a large number of functionally simple and compact antenna Base Stations for wireless signal distribution. The main function of BS is to convert optical signal to wireless and wireless to optical signal. The centralization of RF signal processing functions enables equipment sharing, dynamic allocation of resources, simplified system operation and maintenance. a general RoF architecture is shown in Fig.1. In this, RoF link consists of all the hardware
required to impose an RF signal on an optical carrier, the fiber optic link and the hardware required to recover the RF signal from the carrier. The optical carrier wavelength is usually selected to coincide with either the 1.3µm window, at which single mode fiber has minimum dispersion or the 1.55µm window, at which attenuation is minimum. At the optical transmitter, the RF signal can be imposed on the optical carrier by using direct or external modulation of the laser light. In the downlink transmission from the CS to the BS, the information from the internet or from the other CS is fed into a modulator in the CS. The RF signal modulates optical signal from laser diode. The modulated optical signal is transmitted to the BS via optical fiber. At the BS, the RF signal is recovered to detect the modulated optical signal by using a Photodiode. The recovered signal is transmitted to the Mobile Unit(MU) via antennas of the BS. In the uplink transmission from the Mobile Unit to the Control Station, the signal received at the BS are amplified and directly transmitted to the CS by modulating an optical signal from a laser diode. For utilizing the higher bandwidth of optical systems, multiplexed systems are preferred for transmitting huge information on to a single fiber[4]. Since RoF involves analog modulation, and detection of light, it is fundamentally an analog transmission system. Therefore, signal impairments such as noise and distortion, which are important in analog communication systems, are important in RoF systems as well. These impairments tend to limit the Noise Figure (NF) and Dynamic Range (DR) of the RoF links. DR is a very important parameter for mobile (cellular) communication systems because the power received at the BS from the MUs varies widely i.e. the RF power received from a MU which is close to the BS can be much higher than the RF power received from a MU which is several kilometres away, but within the same cell. The noise sources in analog optical fiber links include the laser’s Relative Intensity Noise (RIN), the laser’s phase noise, the photodiode’s shot noise, the amplifier’s thermal noise, and the fiber dispersion.

Fig.1: Downlink Architecture of a ROF System[19]

The remainder of the paper is organized as follows. Section II reviews various dispersion issues and related work. Section III discusses the results extracted from related issues. Finally, Section IV summarizes the main conclusion of the paper along with the future work.

II. BACKGROUND AND RELATED WORK

The broadening of light pulses, called dispersion, is a critical factor limiting the quality of signal transmission over optical links. Dispersion is a consequence of the physical properties of the transmission medium. A Dispersion mechanism includes Modal dispersion, Chromatic dispersion (CD) and Polarization mode dispersion (PMD). An input waveform distorts during propagation because its energy is distributed among several modes, each traveling at a different speed. Parts of the wave arrive at the output spreading out the waveform thus known as multimode (modal) dispersion. Multimode dispersion would not occur in single mode fiber as the waveguide allows only one mode to propagate. Single mode fibers, used in high-speed optical networks, are subject to Chromatic Dispersion (CD) that causes pulse broadening depending on wavelength, and to Polarization Mode Dispersion (PMD) that causes pulse broadening depending on polarization. Excessive spreading will cause bits to overflow their intended time slots and overlap adjacent bits. The receiver may then have difficulty discerning and properly interpreting adjacent bits, increasing the...
Bit Error Rate. Light within a medium travels at a slower speed than in vacuum. The speed at which light travels is determined by the medium’s refractive index. Ideally, the refractive index would not depend on the wavelength of the light. Since different wavelengths travel at different speeds within an optical fiber. Laser sources are spectrally thin, but not monochromatic. This means that the input pulse contains several wavelength components, traveling at different speeds, causing the pulse to spread. The detrimental effects of chromatic dispersion result in the slower wavelengths of one pulse intermixing with the faster wavelengths of an adjacent pulse, causing intersymbol interference. The Chromatic Dispersion of a fiber is representing the differential delay, or time spreading (in ps), for a source with a spectral width of 1 nm traveling on 1 km of the fiber. It depends on the fiber type, and it limits the bit rate or the transmission distance for a good quality of service. To reduce fiber dispersion, new types of fiber including dispersion shifted fibers and non-zero dispersion shifted fiber has been developed. The most commonly deployed fiber in networks called dispersion unshifted single mode fiber, has a small chromatic dispersion in the optical window around 1310 nm, but exhibits a higher CD in the 1550 nm region. This dispersion limits the possible transmission length without compensation on DWDM networks. A dispersion shifted fiber (DSF), designed to minimize chromatic dispersion in the 1550 nm window with zero dispersion between 1525 nm and 1575 nm. But this type of fiber has several drawbacks, such as higher polarization mode dispersion and a high Four Wave Mixing risk, rendering DWDM practically impossible. For these reasons, another single mode fiber the Non-Zero Dispersion Shifted Fiber (NZDSF) has been developed. NZDSF fibers have now replaced DSF fibers. Non-Zero Dispersion-Shifted Fibers were developed to eliminate non-linear effects experienced on DSF fibers.

They were developed especially for DWDM applications in the 1550 nm window. They have a cut-off wavelength around 1310 nm, limiting their operation around this wavelength. PMD can highly degrade the quality of transmission. It is a difficult parameter to measure, however, because it varies with time and depends on environmental conditions. PMD occurs from the difference in the propagation constants of a fiber due to geometrical imperfections in the fiber. The term PMD denotes both the physical phenomenon and the associated temporal delay. PMD also causes a system penalty because of the associated pulse spreading in a high-speed digital transmission system. The physical origin of PMD is essentially linear birefringence due to core eccentricity. These appear during the manufacturing process or result from external stresses on the fiber, such as bends and twists, and can be considered constant over a length called the coupling length. The typical value of the coupling length is several hundred meters and depends on fiber manufacturing parameters. This means that for distances that are practical for transmission applications, the actual length of the fiber is much greater than the coupling length. The PMD phenomenon is characterized by Differential Group Delay (DGD).

DGD is the difference in propagation time between minimum and maximum propagation time for each wavelength. Fiber Bragg Grating is a promising scheme for dispersion compensation in optical fiber communication. Fiber Bragg Grating has a very narrow operating window. So for broadening the window of Fiber Bragg grating an efficient method has been developed in which the value of coupling constant varies from one to six with interval one[5]. Chromatic Dispersion (CD) and Polarization Mode Dispersion (PMD) by a linear filter [6], which can operate adaptively to overcome time-varying impairments. One of the most efficient ways to mitigate the impact of dispersion is to implement dispersion mapping [7] by placing dispersion compensating fibers (DCFs) with large negative dispersion and at carefully chosen location in the transmission line. Chromatic dispersion can be controlled by using PCFs and PCF finds realistic applications in optical fiber communications [8] and dispersion compensation [9]. The authors in [10], has proposed the Erbium-doped PCFs which have good dispersion compensating characteristics, but their fabrication can be difficult. Z. Tan et al. [11] proposed the methods of dispersion compensation by using sampled chirped fiber Bragg gratings (SCFBGs) that also serves as a XPM suppression. In [12], dual-concentric-core fibers have been proposed for broadband dispersion compensation of SMFs but the problem due to Ge doping still remains. F. Begum et al.[13] has proposed a dispersion compensating photonic crystal fiber(DC-PCF) for wide-band high-speed transmission systems. In DC-PCF a larger negative dispersion coefficient, better dispersion slope compensation and confinement losses less than10^4 dB/m in the entire S+C+L telecommunication band by using a modest number of design parameters has been observed[13].
III. Results and Discussion

In [5] the dispersion is determined by sending a Gaussian pulse as an input and thrived to compensate dispersion up to 38.8 for 150 Km length of fiber. The corresponding dispersion in designed PCF[9] at 1.55 m is of about 474.4 ps/nm/km which is due to a small core has a small effective mode area (1.6 m) and large coupling loss with the standard fiber. So that it can compensate the dispersion of over 28 times of length of conventional single mode fiber. The dispersion compensation demonstrated by Z. Tan et al. [11] has many advantages due to the fact that CFBGs has low cost, low insertion loss, small package size, and reduced nonlinear effects compared to other fiber-based solutions [11]. However, the use of SCFBGs becomes a disadvantage if an improper delay between the channels is implemented and this will degrade the system performance [11]. The major features of DCF design scheme in [12] were provision for dispersion slope compensation over the relevant operating wavelength ranges, attainment of an Aeff as close as possible to that of the signal fiber to reduce the probability of occurrence of potentially harmful nonlinear effects, low sensitivity to bend loss, and low Rayleigh scatter loss coefficient. It was found that by adjusting structural parameters of the fiber, broadband DC-PCFs with large negative dispersion over 180 nm range, better dispersion slope, low confinement loss, and low bending loss has been obtained. The proposed module can be used in 40 Gb/s dense wavelength division multiplexing (DWDM) systems in optical fiber communication networks [13].

IV. Conclusion

In this paper, a review of the dispersion effects occurring in optical fibers has been presented. These dispersion effects impose stringent limitations on the design of RoF systems. It has been concluded that the dispersion induced pulse broadening limits the link distance and induces high BER. However, by increasing the transmitter input power, the effect of dispersion could be reduced and therefore it would be possible to achieve longer propagation distance with significant lower BER. The main challenge in RoF system will be controlling these dispersion effects and, in particular, their interplay. It has also found that the dispersion compensating fibers present the following advantages low polarization mode dispersion, good matched dispersion for transmission fibers, low nonlinearity and good stability for environmental variation.

REFERENCES