Analysis of OFDM Scheme for RoF System and Characterization with GPON Architecture

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Abstract*— Radio over Fiber (RoF) system is a promising technique for microcell and picocell applications for deployment of future wireless data networks. However, the performance of RoF systems can be severely degraded due to non-linear effects in the channel. Also, Orthogonal Frequency Division Multiplexing (OFDM), as a standard for broadband wireless networks, is being proposed for deployment with RoF systems to facilitate the total performance of a system. The demand for high speed data rate and high capacity of bandwidth has increased due to recent advances in technology in the access networks bandwidth. The integration of wireless communication networks and fiber optic networks has provided a large number of advantages such as a high data rate, larger bandwidth and low consumption of power. The combination of Radio over Fiber (RoF) and Orthogonal Frequency Division Multiplexing (OFDM) techniques has resulted in a high-data-rate at lower cost in the last mile of wireless networks. The RoF-OFDM System link was modeled and simulated using a commercial optical system simulator named OptiSystem 12.0 by Optiwave.

Keywords: RoF, OFDM, Last Mile Wireless Network, data- rates.

INTRODUCTION

In optical communication nowadays, there is an urgent need to cater the service requirements of ultra-high speed and ultra-large capacity for wireless access network due its spectrum availability, and high-end digital signal processing radio frequency equipments. The current wireless signals suffer from relentless loss along the existing transmission channel as well as free space loss. The use of radio-over-fiber to provide radio access has a number of advantages including the ability to deploy small, low-cost remote antenna units and ease of upgrade for future potential exploration. For reducing the deployment and maintenance costs of wireless networks while providing low power consumption and large bandwidth, the ROF system seems to be a promising candidate that will make extensive use of many communication standards, such as wireless local area networks (also known as Wi-Fi), digital video and audio broadcasting standards, digital subscriber loop (DSL), and Worldwide Interoperability for Microwave Access (WiMAX).

Orthogonal frequency division multiplexing (OFDM) is becoming the chosen modulation technique for wireless communications because it can provide large data rates with sufficient robustness to radio channel impairments. OFDM is a transmission scheme uses multiple sub-carriers converts the high rate serial data streams into multiple parallel low rate data streams and hence prolongs the symbol duration, thus helping to eliminate Inter Symbol Interference (ISI) [3] [4]. A single mode or multimode optical fiber is used as a transport mode between the antenna and the base stations where a rack of electronics is located.

Radio over Fiber (RoF) system could be the answer to many demands of the wireless network. It is a suitable technology for wireless network and provides a low cost configuration, because the optical modulated signals are transmitted to the base station carrying to the fiber without significant loss and reach the mobile user via RF transmission.This paper includes an overview of OFDM system, RoF technique and combination of RoF-OFDM analysis of RoF-OFDM system. Radio over Fiber system is very attractive technique for wireless access network, because it can transmit microwave and millimeter wave through optical fiber for long and short distance. It is also possible to support WLAN and current 4th generation mobility network. Radio over Fiber system, it is the integration of RF and optical network and it increase channel capacity of mobility and application systems, as well as decreasing cost and power consumption. This system provide radio access has a number of applications to merge in the recent and next generation wireless systems includes Central Site (CS) and Remote Site (RS) connected to an optical fiber link, and signal is transmitted between CS and RS in the optical band through RoF network [1].

Passive Optical Networks (PON) technologies are available since the mid 90s, but in the last few years standards have matured and commercial standards are being implemented. First PON was ATM PON (APON) which evolved in Broadband PON (BPON). BPON is backward compatible with APON. Ethernet PON (EPON and newer GPON) is an alternate solution for PON networks. It is PON exclusively for Ethernet and IP traffic. Gigabit Passive Optical Network (GPON) is defined by ITU-T recommendation series G.984.1 through G.984.4. GPON has enhanced capability comparing with APON and BPON and is backward compatible. GPON is a point-to-multipoint access mechanism. Its main characteristic is the use of passive splitters in the fiber distribution network, enabling one single feeding fiber from the provider's central office to serve multiple homes and small businesses. GPON has a downstream capacity of 2.488 Gb/s and an upstream capacity of 1.244 Gbp/s that is shared among users. Encryption is used to keep each user's data secured and private from other users.

Although there are other technologies that could provide fiber to the home, passive optical networks (PONs) like GPON are generally considered the strongest candidate for widespread deployments.

OVERVIEW OF OFDM

There is a long history behind FDM. Stimulated by telegraph companies hoping to multiply their profits, entrepreneurs and inventors of the 1870s sought ways to multiply the capacity of a telegraph transmission line by carrying several noninterfering information channels. Time-Division Multiplexing (TDM) or more dynamic Time Division Multiple Access (TDMA), with users taking turns in using time slots, was invented by Baudot [1] and others, and was particularly useful when the telegraph line was underutilized, with significant gaps between characters. Of course, burst speed would be limited by Inter Symbol Interference the dispersion of a pulse into its neighbors for which there was not yet a good channel equalizer. There were many initiatives with alternative multiplexing schemes. Edisons quadruplex telegraphy system [edison.rutgers.edu/quad.htm], for example, sent two messages simultaneously (in each direction), one varying amplitude and the other polarity. Interest turned fairly early to Frequency-Division Multiplexing. The evolution to the techniques known as multitone or OFDM began in the innovations of the 1870s. Alexander Graham Bell was initially funded by his future father-in-law Gardiner Hubbard to work on harmonic telegraphy, which was FDM transmission of multiple telegraph channels [2]. His competitor Elisha Gray simultaneously worked in this area and had an earlier patent [3]. Thomas Edison was also in hot pursuit of the multitone telegraph [4]. The access facilities for these techniques might be considered early implementations of Digital Subscriber Line (DSL). However, Bells first love was telephony, and he focused his energy on analog voice transmission rather than Discrete-Tone Multiplexed Telegraphy. FDM came into its largest general use in carrier systems for analog telephony. As described by Schwartz [5], FDM for analog voice signals may first have been demonstrated by George Squier, a major in the U.S. Army Signal Corps, in 1910, in an apparatus with one baseband and one passband channel. AT & T was skeptical, claiming too much dispersion and loss at the higher frequencies it assumed were required. But AT & T deployed its own five-channel system in 1918 that used not-so-high subcarrier frequencies and repeaters. FDM became the main multiplexing mechanism for telephone carrier systems. Bandwidth and dispersion were not serious problems with the relatively modest spacing of repeaters, and 8 kHz subchannel spacing was provided for 4 kHz voice signals. The N2 carrier system of the mid-1960s used double sideband amplitude modulation and transmitted up to 200 miles [6]. With the introduction of digital telephony, FDM carrier systems with individual subchannels for voice signals began, in the 1970s, to be replaced by TDM/FDM and pure TDM systems. Of course, the higher the aggregate speed of a TDM transmission line, the wider the bandwidth of this single channel and the greater the potential for Inter-Symbol Interference. High-Frequency (HF) radio systems had a particularly severe transmission problem, with selective fading across the transmission bandwidth causing considerable pulse dispersion and Inter-Symbol Interference. The answer to this problem with serial data transmission in Radio Frequency (RF) channels (and later in DSL with severely distorted channels) was to go back to fine-grained FDM, concentrating data in the less faded subchannels. Each subchannel would be affected by only a small part of the channel characteristic, which could be approximated by constant amplitude and phase. This narrow subchannel could easily be equalized, in a complex analytic model, by multiplication by the inverse complex number. The hope that the saving in equalization effort would compensate for the greater complexity of FDM became a reality with OFDM.

SYSTEM DESIGN

This RoF-OFDM simulation system supports bit data signal about 10 Gbit/s generated by Pseudo Random Bit Sequence Generator (PRBSG) connected to QAM sequence generator with 4 bits per symbol combine to M-ary pulse generator as shown in Figure:1.Splitting a high-rate data stream into a number of low-rate data streams and transmitting these over a number of narrowband subcarriers. The narrowband subcarrier data streams experience smaller distortions than high-speed ones and require no equalization.

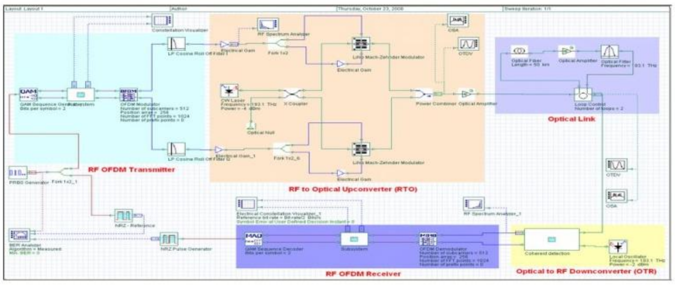

Figure 1: RoF-OFDM model

As it is shown in Figure: 1, data bits at the transmitter are first encoded then converted into a constellation map of a known modulation scheme such as a QAM. This data is interpreted as a frequency-domain data in an OFDM system and is subsequently converted to a time-domain signal by an IFFT operation of the OFDM block. The output of the IFFT is transmitted to the channel after the addition of cyclic prefix (CP). Then the OFDM time signals are transformed to the appropriate analog form by D/A converter and modulate the laser diode creating an optical signal pass through the optical link to be finally transmitted in wireless channel.

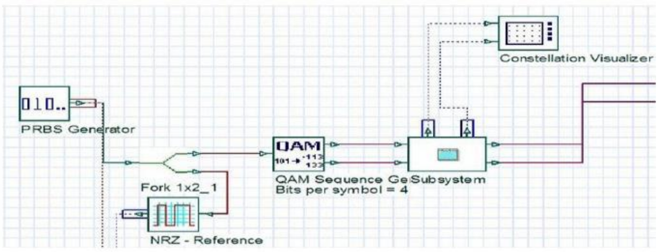

Figure 2: Transmitter part

Moreover, most of the required signal processing is performed in the RF domain and this has been modulated by the Quadrature Modulator [8] by setting the RF frequency to 10 GHz. The OFDMRoF transmitter system involves the conversion of one stream of serial data to longer duration parallel data streams, transmitter system were consist of OFDM modulation block system. The data in this design then modulated using 16 QAM/ 4 bit per symbol, then carried by different frequency of each sub carriers which are 64 sub carriers. An external modulator MZM is also placed between the laser and RF modulated signal due to high modulation efficiency.

The detection of the received optical signal is performed primarily by the photodetector. In most cases, the received optical signal is quite weak and thus electronic amplification circuitry is used, following the photodiode, to ensure that an optimized power Signal-To-Noise ratio (SNR) is achieved. The PIN photodiode and receiver total noise are calculated and superimposed over the ideal photodiode signal current. To evaluate the effect of noise added during the amplification process, a mathematical model explained in has been used. The reverse process is done at the receiver after the PIN photo detector. After the CP the received signal is converted to frequency domain by FFT operation [9]. Then the data were received back from the optical link in OFDM demodulation or OFDM receiver part

RESULTS AND DISCUSSION

Modulated Result.

The result for optical spectrum modulation is shown in the Figure: 3(a) and Figure: 3(b) below with more harmonics at the sideband of the spectrum. The data rate is set-to 10 Gb/s in this case. The result of both optical signals together with amplification before and after filtering based on the optical transmission link in optical domain shown in Figure: 3(a) and 3(b). Due to poor spectrum OFDM quality generated over from the baseband and transmission path, therefore enhancement spectrum option is needed through optical amplification. The performance is mainly hampered by the accumulated amplifier noise, the transmission channel of the system, internal performance system components and etc. the wavelength for CW laser is set to 193.1 THz, while the rest are to be set into default value from the optisystem. The optical fiber attenuation is 0.2 dB/km and the fiber length for the transmitting the signals is varied from 10 up to 50 km. Based on the Figure 3(a) and 3(b) above, we could see that the wavelength is 193.1 THz, but the power from both signal are different (about -38.868 dBm before the filtering and -21.013 dBm after the filtering). The optical modulation of RF carrier produces single sideband signals after filtering. To cause the RF OFDM signal to complex intermediate frequency proposed the architectures of a transmitter with an actual signal modulates the carrier with an optical MZM and one of the sidebands is suppressed with an optical filter. At the reception, the optical signal is detected by a photodiode and then demodulated. The RF frequency must be selected in order to remove the single-side band.

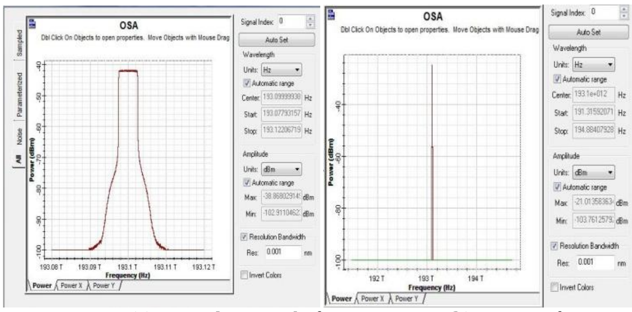

Figure: 3(a) Optical OFDM before filtering Figure: 3(b) OFDM after filtering

B. RF Spectrum After Regeneration

From the output of optical fiber link, the RF frequency keeps 10 GHz with different power approximate to -61.35 dBm as in the Figure: 4(a) while the input power at the laser source is -4dBm. From Figure: 4(b), after the inverse procedure of regenerating the RF frequency, the maximum power is about -5 dBm For system performance, baseband signals are analyzed with oscilloscope visualize. Subsequently, RF and optical signals are analyzed with RF spectrum and optical spectrum analyzer, respectively. Meanwhile, recover signal are also study with electrical constellation visualizer can be utilized as in the Figure: 5 to demonstrate the true periodicity of an assumed periodic signal referring from the source.

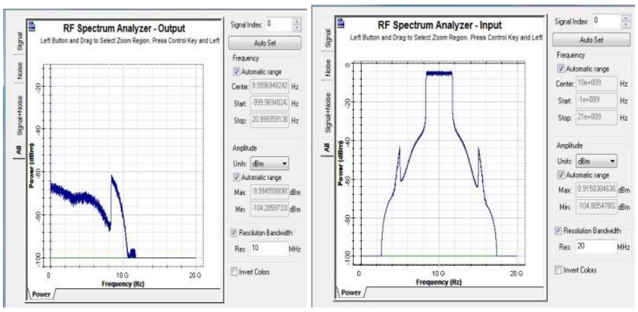

Figure: 4(a): RF frequency at the photo diode Figure: 4(b) : Radio frequency spectrum before wireless link

spectrum analyzer result is listed in table 1 as well as graphic in Figure: 5 below From the graphic set above, we can deduce while the number of loops is increased, the power after photo detector is not affected, but less the power at the laser diode output is less we have lower power at the reception. Therefore, there is more need of power at the Central Unit before launch the RF frequency through the optical fiber to reduce the use of electrical amplifiers at the Base Station side. Also from the Figure: 6(a), 6(b), 6(c), more the subcarriers , less the IQ factor of constellation at the reception that gives the following amplitude , 10.509a.u, 9.307a.u and 8.950a.u respectively from 256; 512 and 1024 subcarriers for a same laser power of -4 dBm. It is seen that noise with more subcarriers is mentioned in blue color in the Figure: 6(a), 6(b) and 6(c).

Power in dBm	No: of loops			
	2	3	4	4
-5	-36.45	-36.17	-33.03	-32.54
-1	-48.23	-46.85	-46.15	-42.33
-4	-54.01	-53.12	-51.85	-51.05
-10	-66.57	-66.29	-64.19	-63.24
-15	-76.26	-75.43	-74.01	-72.88
-20	-86.25	-86.15	-84.01	-82.89

Table 1: Power received after photo detector

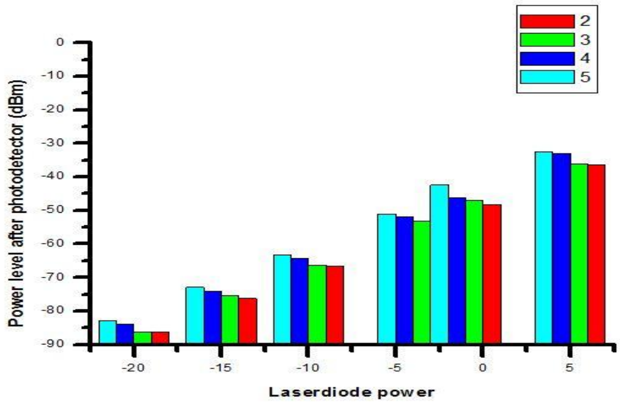

Figure 5: Graphical representation of the power after photo detector

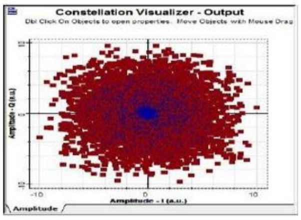

Figure: 6(a)

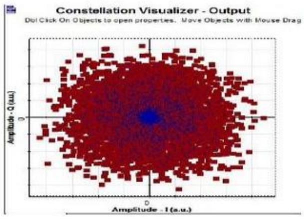

Figure: 6(b)

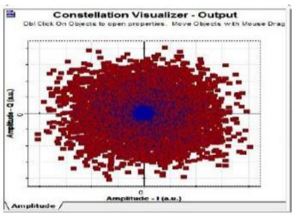

Figure: 6(c)

Figure: 6(a), 6(b), 6(c): Different value of IQ constellation at the reception. 256 subcarriers, 512 subcarriers, 1024 subcarriers

CONCLUSION

The use of OFDM in optical access networks and combining the OFDM modulation in RoF system a very high efficient communication system can be created which effectively utilizes the bandwidth. As Data rate increases, The outputs waveforms of RF spectrum analyzer & Optical spectrum analyzer began to broaden and hence quality decreases but comparing to existing communication standards OFDM-ROF system possess better efficiency. Similarly the constellation output also shows a decrease in Q-factor & constellation points increases. Hence by using OFDM in association with RoF a vigorous communication standard that efficiently uses the advantages of optical fiber can be created . Coherent system has high performance than direct detection system.

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