Performance Analysis of OFDM Scheme for RoF System

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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, FDM, Last Mile Wireless Network, data-rates.

1. 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 to the 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].

2. 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.
considerable pulse dispersion and Inter-Symbol Interference. Fading across the transmission bandwidth causing particularly severe transmission problem, with selective Interference. High-Frequency (HF) radio systems had a single channel and the greater the potential for Inter-Symbol interference to go back to fine-grained Radio Frequency (RF) channels (and later in DSL with 3.24 GHz. The OFDM-RoF transmitter system involves the multiplication by the inverse complex number. The hope that TDM transmission line, the wider the bandwidth of this 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.

3. System Design

3.1 Basic RoF-OFDM Model

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.

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.

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 OFDM-RoF 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.
4. Results and Discussions

A. 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 Figure: 3(b) OFDM after filtering 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.

Table 1: Power received after photo detector

<table>
<thead>
<tr>
<th>Power in</th>
<th>No: of loops</th>
</tr>
</thead>
<tbody>
<tr>
<td>dBm</td>
<td>2</td>
</tr>
<tr>
<td>-5</td>
<td>-36.45</td>
</tr>
<tr>
<td>-1</td>
<td>-48.23</td>
</tr>
<tr>
<td>-4</td>
<td>-54.01</td>
</tr>
<tr>
<td>-10</td>
<td>-66.57</td>
</tr>
<tr>
<td>-15</td>
<td>-76.26</td>
</tr>
<tr>
<td>-20</td>
<td>-86.25</td>
</tr>
</tbody>
</table>

Figure 5: Graphical representation of the power after photo detector

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).

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

Figure 6(a)                             Figure 6(b)
5. 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.

References


Author Profile

Arun Raj M S received the B.Tech degree in Electronics and Communication Engineering from College of Engineering Perumon Kollam, Kerala under Cochin University of Science and Technology in 2012 and now undergoing final semester of P.G. specializing in Optoelectronics and Communication Systems in Thangal Kunju Musaliar Institute of Technology Karuvelil Kollam under Cochin University of Science and Technology.