Analysis of iterative receiver for OFDM based ROF systems

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Abstract: In this paper the impact of a Radio-over- Fiber (RoF) optical subsystem on the sensitivity to the phase noise of an Orthogonal Frequency Division Multiplexing (OFDM) system using Discrete Fourier Transform (DFT) and Discrete Wavelet Transform (DWT) are evaluated and compared by computer simulation. The study investigates the effect of phase jitter on the system Bit Error Rate (BER) of the DFT/DWT-based OFDM for different modulation schemes in the presence of optical sub-system's nonlinearities in AWGN channel. The conventional receiver for OFDM recovers the data by subtracting the negative subframe from the positive one. However, the signal analysis shows that the signals in the two subframes both contain the information of the transmitted data and can be used together to decode the data. An iterative receiver is then proposed to improve the transmission performance of OFDM by exploiting the signals in both subframes. Simulation results show that the proposed iterative receiver provides significant signal to noise ratio (SNR) gain over the conventional receiver.

Keywords: Optical wireless communication (OWC), orthogonal frequency division multiplexing (OFDM), iterative receiver. RoF, AWGN.

I. INTRODUCTION

Radio-over-Fiber (RoF) is a technology by which information bearing signals using RF carries are delivered by means of optical components and techniques. Better coverage and increased capacity, centralized upgrading and adaptation, higher reliability and lower maintenance costs, support for future broadband applications, and economic access to mobile broadband are among the most important advantages of RoF [1], [2]. However, RoF systems are vulnerable to nonlinearities in the optical subsystem that cause degradation of the system BER performance. Normally, these effects are expressed as AM-AM and AM-PM characteristics; the former is an amplitude transfer function while the latter is a phase transfer function. One area of interest in modern communications is OFDM which is becoming widely used in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and also its robustness to multi-path fading without requiring complex equalization techniques [3], [4], [5]. OFDM has been adopted in a number of wireless applications including Digital Audio Broadcast (DAB), Digital Video Broadcast (DVB), Wireless Local Area Network (WLAN) standards such as IEEE802.11g and Long Term Evolution (LTE) [6]. To mitigate Inter-Symbol Interference (ISI), a cyclic prefix (CP) is used which in turn leads to spectral inefficiency. In comparison to single carrier systems, more vulnerability to frequency offset and phase noise are OFDM disadvantages. In recent years, wavelet transform has been suggested to replace DFT in OFDM systems. While signals in DFT-OFDM systems overlap in the frequency domain only, DWT-OFDM signals overlap in the time domain as well, so there is no need for the CP as in the DFT-OFDM case [7,8]. Hence, some savings in bandwidth can be achieved. Hereafter DFT-OFDM and DWT-OFDM are referred as OFDM and OWDM (Orthogonal Wavelet Division Multiplexing), respectively.

In order to achieve high data rates and alleviate inter-symbol interference (ISI), orthogonal frequency division multiplexing (OFDM) has been employed in OWC [9–11]. Since intensity modulation and direct detection (IM/DD) is
commonly used in OWC systems, the transmitted signals must be real and nonnegative. Real time-domain signals can be obtained by imposing Hermitian symmetry on the OFDM subcarriers. Furthermore, to deal with the issue of bipolarity in OFDM signals, several OFDM schemes have been proposed for OWC. For example, direct current (DC) biased optical OFDM (DCOOFDM) [12], asymmetrically clipped optical OFDM (ACOOFDM) [13] and pulse-amplitude-modulated discrete multitone (PAM-DMT) [14]. There is a price paid with these three schemes. DCO-OFDM adds a DC bias to the OFDM symbols, which increases the power dissipation of the signal significantly. ACO-OFDM and PAM-DMT do not need DC bias because of the clipping operation, but each has only half the spectral efficiency of DCO-OFDM. This paper investigates the impact of an optical subsystem of an OFDM/OWDM based multicarrier (MC) RoF system on the BER performance in the presence of phase noise.

II. SYSTEM DESIGN MODEL
A. SYSTEM MODEL
The block diagram of a Flip-OFDM transmitter with N subcarriers is illustrated in Fig. 1 [9]. To ensure that the time-domain signal is real in IM/DD systems, the input data vector \( X = [X(0);X(1); \ldots ;X(N-1)]^T \) should satisfy the Hermitian symmetry property, i.e.,

\[
X(k) = X^*(N-k), \quad k = 1, 2, \ldots , N/2 - 1.
\]

Note that \( X(0) \) and \( X(N/2) \) are usually set to zero since the DC part of OFDM signal is left unused in practical applications. Hence, the time-domain signal vector \( x = [x(0); x(1); \ldots ; x(N-1)] \) after inverse fast Fourier transform (IFFT) operation can be represented as

\[
x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) \exp(j2\pi kn/N)
\]

\[
= \frac{2}{\sqrt{N}} \sum_{k=1}^{N/2-1} \text{Re} [X(k) \exp(j2\pi kn/N)]
\]

\( n = 0, 1, \ldots , N - 1. \)

![Fig. 1. Block diagram of a OFDM transmitter.](image)

The positive component \( x^+ \) is transmitted in the first subframe (positive subframe), while the flipped negative component \( x^- \) is transmitted in the second subframe (negative subframe).

B. Radio-over-Fiber (RoF)
Radio-over-Fiber (RoF) is a technology by which information bearing signals using RF carriers are delivered by means of optical components and techniques. Better coverage and increased capacity, centralized upgrading and adaptation, higher reliability and lower maintenance costs, support for future broadband applications, and economic access to mobile broadband are among the most important advantages of RoF [1], [2]. However, RoF systems are vulnerable to nonlinearities in the optical subsystem that cause degradation of the system BER performance. Normally, these effects are expressed as AM-AM and AM-PM characteristics; the former is an amplitude transfer function while the latter is a phase transfer function.

![Fig. 2 Block Diagram of MC RoF.](image)

In order to evaluate the system performance, computer simulations were carried out based on the system model presented in Fig. 2. The data source transmits 1,000,000 bits. For the sake of simplicity and focusing on the phase distortion itself, operations such as coding and interleaving are not considered. Then, the data are mapped using a QPSK/16PSK/16QAM modulator. To produce OFDM symbols, first the resultant signal is converted from serial to parallel. Then, either an Inverse
Discrete Fourier Transform (IDFT) or an Inverse Discrete Wavelet Transform (IDWT) is taken. The resultant signal in the OFDM case is converted to serial, and in order to mitigate ISI, a CP with a length of 25% of the whole OFDM symbol period is added. Then the resultant signal is filtered by the receive RRC filter followed by the CP removal from the OFDM signal, and thereafter it is converted to parallel symbols. Subsequently, a DFT / DWT is taken followed by a conversion to serial data. For a fair comparison of the effect of carrier phase noise, no channel estimation is performed. After being demodulated, the received data are compared with those transmitted.

III. SIMULATION RESULTS

In this section, the bit error rate (BER) performance of the proposed iterative receiver is evaluated by simulations. The number of subcarriers is 64, the length of cyclic prefix (CP) is 16, and 16-QAM is used for constellation mapping. Both LOS and NLOS channels are tested with the parameters of configuration. For comparison, the BER curves corresponding to the noise filtering receiver and the case in which the sign matrices are perfectly known (“lower bound”) are also plotted.

To investigate the effect of RoF nonlinearity, additional simulations were performed. Figure shows BER versus for different wavelets along with that of OFDM for the MC RoF-QPSK at OBO=1 dB. The behaviors of the BER plots follow approximately the same trend as in the linear scenario. One can observe that while wavelet sym2, from Group I, achieves poor performance, OFDM and the other wavelets have comparable BER performance for low values.

![Fig. 3. BER comparison of different receivers for Flip-OFDM. (a) LOS channels. (b) NLOS channels.](image-url)
Fig. 4. BER performance of the iterative receiver
Fig. 5 BER vs. standard deviation of phase noise for different iteration numbers.
uncoded MC RoF-QPSK at OBO=1 dB in AWGN.

IV. CONCLUSION

In this paper, an iterative receiver is proposed for Flip-OFDM in IM/DD based OWC systems. In order to improve the receiver performance, the iterative receiver obtains the additional diversity gain by exploiting the signals in both the positive subframe and negative subframe. The simulation results show that the iterative receiver with only two iterations provides a significant SNR gain over the conventional receiver. The performance of different wavelets are slightly different, especially at low values. Finally, MQAM signals are more robust to phase noise than MPSK signals in a RoF system. Performance assessment of the aforementioned modulation schemes in the presence of colored phase noise, both in AWGN and time varying RF channels.

REFERENCES