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A Review on Spectrum Efficiency Improvement for Quasi-Constant Envelope OFDM

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Abstract - **Benefiting from low peak-to-average power ratio (PAPR), constant envelope OFDM (CE-OFDM) is a promising technique in coherent optical communication. However, the spectrum efficiency of CE-OFDM is only half of conventional coherent optical OFDM, which restricts its application. We proposed a novel quasi-constant envelope OFDM (Quasi-CE-OFDM) scheme with in-phase/quadrature (I/Q) modulator. Furthermore, a phase demodulation scheme based on Taylor series expansion is performed to reduce calculation complexity and avoid phase ambiguity. Simulation results show that the proposed scheme could double the spectrum efficiency effectively without losing the advantage of high nonlinearity tolerance.**

Keywords- **OFDM, Quasi-Constant Envelope, PAPR, Nonlinearity, I/Q modulator.**

I. INTRODUCTION

Effective underwater wireless communications are critical to many military and civil applications. In addition to submarine communication, underwater communication can also be used in many civil applications such as ocean exploration, undersea rescue, undersea disaster management, offshore oil production, pollution monitoring in environmental systems, collection of scientific data recorded at ocean bottom stations, speech transmission between divers, and mapping of the ocean floor for detection of objects as well as for the discovery of new resources [1]. However, underwater wireless communication systems are not easy to construct. There are real challenges associated with them, such as underwater channel modelling, signal attenuation in oceans, limited bandwidth especially for communication over long distances, high power consumption, low signal–to–noise ratio (SNR), inter-symbol interference (ISI) and multipath channel features with significant tap delays. Due to high absorption and attenuation of electromagnetic waves in underwater channels and rapid absorption and scattering of optical waves in such channels, acoustic channels are the most preferred channels to use in underwater wireless communications. Digital signal processing is indispensible for such underwater wireless communication problems.

For the optimal exploration and use of oceans and seas, researchers have been attracted to the development and deployment of video and image transmission in underwater acoustic communication [2]. High-speed underwater image transmission systems might be the next generation of undersea expeditions. Based on underwater sensor networks and digital image processing methodologies, researchers have worked to transmit images over underwater acoustic channels [3, 4]. However, current acoustic communication technologies cannot effectively support image transmission due to challenging nature of using underwater communication channels.

In particular, wireless digital communications is currently under intensive research, development and deployment to provide high data rate access plus mobility. One challenge in designing a wireless system is to overcome the effects of the wireless channel, which is characterized as having multiple transmission paths and as being time varying. Figure 1.1 illustrates a link with four reflecting paths between points A and B. These reflections are caused by physical objects in the environment. Due to the relative mobility between the points and the possibility that the reflecting objects are mobile, the channel changes with time.

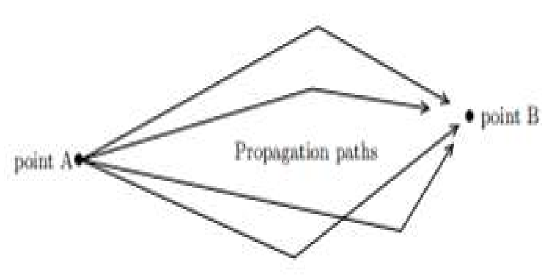
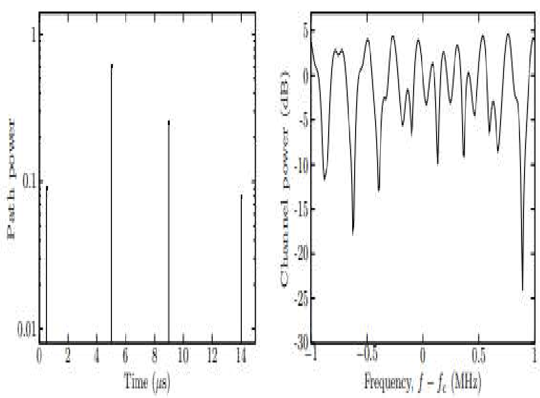


Fig.1. Representation of a wireless channel with multipath.

transmitted; the last path arrives with a 14 µs delay. The Fourier transform of the profile yields the frequency-domain representation shown in Figure 1.2(b). The channel is viewed over a 2 MHz range centered at the center frequency fc.

Notice that the channel power fluctuates by 30 dB (a factor of 1000) over the frequency range. The dispersion in the time domain leads to frequency-selectivity in the frequency domain.



(a) Time domain. (b) Frequency domain.

Fig.2. A wireless channel in time and frequency.

II. LITERATURE SURVEY

Yupeng Li et al. (2018) investigated the performance of the novel Quasi-CE-OFDM. The simulation results show a relative improvement of spectrum efficiency in comparison with existing CE-OFDM systems without losing the advantage of high nonlinearity tolerance. The proposed Quasi-CE-OFDM scheme maintains large tolerance to fiber nonlinearity and improves spectrum efficiency effectively.

Esequiel da V. Pereira et al. (2017) A low PAPR CO-OFDM system has been proposed and discussed to increase tolerance toward MZM and fiber nonlinearities. Based on CE signals (PAPR ¼ 3 dB) obtained after electrical PM, the denominated CO-CE-OFDM scheme outperforms conventional optical coherent-detection OFDM systems, in some specific circumstances. The simulation results showed that the proposed 100-Gb□s system with 16- and 64-QAM subcarrier modulation outperforms a conventional CO-OFDM system if an OMI ¼ 2.5 and an electrical PM index 2□h ¼ 3 are adopted. Despite the signal bandwidth enlargement, the achieved large NLT is attractive for fiber input power greater than 0 dBm, after propagation through 1200 km of dispersion-uncompensated standard SMF. A performance gain up to 26 dB was achieved for 10-dBm optical power, OMI ¼ 0.5, 2□h ¼ 3, OSNR ¼ 40 dB, and 64-QAM subcarrier mapping.

Vinicius O.C.Dias et al. (2017) The influence of the electrical phase modulation index in the performance of constant-envelope orthogonal frequency division multiplexing (CE-OFDM) in coherent detection optical systems is treated analytically and its range of validity examined by simulations. A compromise between and subcarrier mapping is identified according to differences in sensitivity related to non-linear ties inserted by the optical modulator. It is shown that the proposed scheme outperforms conventional coherent detection OFDM systems, which is strongly dependent on both phase and optical modulation indexes.

Yupeng Li et al. (2017) Benefiting from the high spectral efficiency and low peak-to-average power ratio, constant envelope orthogonal frequency division multiplexing (OFDM) is a promising technique in coherent optical communication. Polarization-division multiplexing (PDM) has been employed as an effective way to double the transmission capacity in the commercial 100□□Gb/s PDM-QPSK system. We investigated constant envelope OFDM together with PDM. Simulation results show that the acceptable maximum launch power into the fiber improves 10 and 6 dB for 80- and 320-km transmission, respectively (compared with the conventional PDM OFDM system). The maximum reachable distance of the constant envelope OFDM system is able to reach 800 km, and even 1200 km is reachable if an ideal erbium doped fiber amplifier is employed.

ELIAS GIACOUMIDIS et al. (2016) A novel versatile digital signal processing (DSP) based equalizer using support vector machine regression (SVR) is proposed for 16-quadrature amplitude modulated (16- QAM) coherent optical orthogonal frequency-division multiplexing (CO-OFDM) and experimentally compared to traditional DSP-based deterministic fiber-induced nonlinearity equalizers (NLEs), namely the full-field digital back propagation (DBP) and the inverse Volterraseries transfer function based NLE (V-NLE). For 40-Gb/s 16-QAM CO-OFDM at 2000 km, SVR-NLE extends the optimum launched optical power (LOP) by 4 dB compared to V-NLE by means of reduction of fiber nonlinearity. In comparison to full-field DBP at a LOP of 6 dBm SVR-NLE outperforms by ~1 dB in Q-factor. In addition, SVR-NLE is the most computational efficient DSP-NLE.

Josep M. Fabrega et al. (2013) In constant envelope optical orthogonal frequency division multiplexing, the modulator voltage has a significant impact on receiver sensitivity. It is a tradeoff between phase range and distortions inherent to the digital signal processing. In this letter, the sensitivity improvement due to the modulator driving voltage is theoretically analyzed and further validated by simulations.

III. BENEFITS OF OFDM

The description of the OFDM modulation technique in the preceding sections motivates an understanding of some of its truly graceful properties. Below, a brief point-by-point summary is provided of the various benefits which have made OFDM a mainstay in the wireless communications industry for the past decade:

- With minimal equalization, OFDM enables faithful broadband communications even over the erratic frequency selectivity of wideband RF multipath channels.

- Subcarrier orthogonality of OFDM allows for the dense packing of subcarrier symbols into an allotted bandwidth to improve overall spectral efficiency with respect to traditional FDM modulation.
- Subcarrier orthogonality of OFDM enables a host of practical PHY and MAC layer technologies.
  - o Adaptive bit-loading, which allows OFDM systems to weight data through put toward subcarrier channels with better flat-channel characteristics
  - Power allocation, which allows OFDM systems to weight transmission power towards subcarrier channels with poorer flat-channel fading
  - Flexible designation of subcarrier duties: control subcarriers, guard subcarriers, synchronizing subcarriers, channel sensing subcarriers, etc.
- OFDM modulators and demodulators can be implemented very simply with the FFT algorithm, which is readily performable with great efficiency on modern DSP chips.

These reasons have made OFDM a seminal enabler of the multimedia explosion of the early 21st century. From the 802.11 Wi-Fi protocols, to the 4G cellular standards, OFDM has played an indispensable role in enabling wireless networks to support high-speed, multi-media rich services. OFDM, and its multi-carrier variants, will continue to figure prominently in the foreseeable future of wireless communications due to the grace with which it handles some of the more troubling problems of broadband wireless systems.
As is true of any technology, OFDM is not without critical faults and design challenges. The benefits of OFDM must be reconciled with its inherently high peak-to-average power ratio (PAPR) – a dilemma often termed the PAPR problem. The purpose of the following chapter of this thesis is to motivate an understanding of OFDM's PAPR problem as well as its critical implications for the power efficiency of OFDM and its multicarrier variants, and its broader implications concerning the sustainability of an increasingly OFDM and multicarrier enabled generation of multimedia wireless communications.

IV. CONCLUTION

Benefiting from low peak-to-average power ratio (PAPR), constant envelope OFDM (CE-OFDM) is a promising technique in coherent optical communication. However, the spectrum efficiency of CE-OFDM is only half of conventional Coherent optical OFDM, which restricts its application. We proposed a novel quasi-constant envelope OFDM(Quasi-CE-OFDM) scheme with in-phase/quadrature (I/Q)modulator. Furthermore, a phase demodulation scheme based on Taylor series expansion is performed to reduce calculation Complexity and avoid phase ambiguity. Simulation results show that the proposed scheme could double the spectrum efficiency effectively without losing the advantage of high nonlinearity tolerance. The performance of Quasi-CE-OFDM was compared with PM-CE-OFDM, RF-CE-OFDM and Con-CO-OFDM in the presence of nonlinearity. In order to make an unbiased and fair performance comparison, in all OFDM schemes, the number of subcarriers used for data transmission, the duration of an OFDM symbol, the overhead and the net data rate are equal. The duration of an OFDM symbol, the overhead and the net data rate are equal.

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