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Modulation and De-Modulation Process of Orthogonal Frequency Division Multiplexing

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Abstract: In this paper we address basic OFDM and related modulations and De-modulation, as well as techniques to improve the performance of OFDM for wireless communications, including energy efficient, time- and frequency-offset estimation and correction and multiple-input-multiple-output (MIMO) techniques. A general problem found in high speed communication is Inter-Symbol Interference (ISI). ISI occurs when a transmission interferes with itself and the receiver cannot decode the transmission correctly. Multiple-input-multiple-output and orthogonal frequency division multiplexing (MIMO-OFDM) systems provide high spectral efficiency for wireless communication system. The purpose of this paper is to process the modulation and De-modulation of Orthogonal Frequency Division Multiplexing.

Key words: Energy efficient · Inter symbol interference (ISI) · Multiple input-multiple-output (MIMO) orthogonal frequency-division multiplexing (OFDM) · Bit error rate(BER) · Signal to noise ratio(S/N ratio)

INTRODUCTION

In the last decade, orthogonal frequency division multiplexing (OFDM) has been successfully applied to a wide variety of digital communications for its high spectral efficiency. Recently, OFDM is adopted by long term evolution (LTE) in the third generation partnership project (3GPP) as the main air interface technique [1-3]. LTE supports a scalable bandwidth from 1.25 MHz to 20 MHz with subcarrier spacing of 15kHz. Based on the bandwidth, the fast Fourier transform (FFT) size is changed from 128 to 2048. LTE employs OFDM for downlink data transmission and discrete Fourier transform spread OFDM (DFT-s-OFDM) for uplink transmission. In wireless communications, multipath fading channel introduces inter-symbol interference (ISI) as well as inter-carrier interference (ICI) to OFDM signal which degrades the system performance seriously. Therefore, in practical OFDM systems, a cyclic prefix (CP), which is a copy of the last part of the symbol, is inserted in front of the symbol. When the CP is longer than the channel length, the ICI and ISI can be eliminated totally. The CP also converts linear convolution of signal and channel into circular convolution which makes it possible for one-tap equalization in the frequency domain at receiver [4-6].

Orthogonal Frequency Division Multiplexing (OFDM), a special form of Multi carrier Modulation (MCM) with densely spaced subcarriers and overlapping spectra was patented in the U.S. in 1970 [2]. OFDM abandoned the use of steep band pass filters that completely separated the spectrum of individual subcarriers, as it was common practice in older Frequency Division Multiplex (FDMA) systems (e.g. in analogue SSB telephone trunks), in Multi-tone telephone modems and still occurs in Frequency Division Multiple Access radio. Instead, OFDM time-domain waveforms are chosen such that mutual orthogonality is ensured even though subcarrier spectra may overlap. It appeared that such waveforms can be generated using a Fast Fourier Transform at the transmitter and receiver [3,4]. For a relatively long time, the practicality of the concept appeared limited. Implementation aspects such as the complexity of a real-time Fourier Transform appeared

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prohibitive, not to speak about the stability of oscillators in transmitter and receiver, the linearity required in RF power amplifiers and the power back-off associated with this. OFDM is a method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wide band digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL Internet access, wireless networks, power line networks and 4G mobile communications.

High-data-rate transmission over mobile or wireless channels is required by many applications. However, the symbol duration reduces with the increase of the data rate and dispersive fading of the wireless channels will cause more severe inter symbol interference (ISI) if single-carrier modulation, such as in time-division multiple access (TDMA) or Global System for Mobile Communications (GSM), is still used. From [5], to reduce the effect of ISI, the symbol duration must be much larger than the delay spread of wireless channels. In orthogonal frequency-division multiplexing (OFDM) [6-8], the entire channel is divided into many narrow-band sub channels, which are transmitted in parallel to maintain high-data-rate transmission and, at the same time, to increase the symbol duration to combat ISI.Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal.

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. The low symbol rate makes the use of a between symbols affordable, making it possible to eliminate intersymbol interference (ISI) and utilize echoes and time-spreading (on analogue TV these are visible as ghosting and blurring, respectively) to achieve a diversity gain, i.e. a signal-to-noise ratio improvement. This mechanism also facilitates the design of single frequency networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

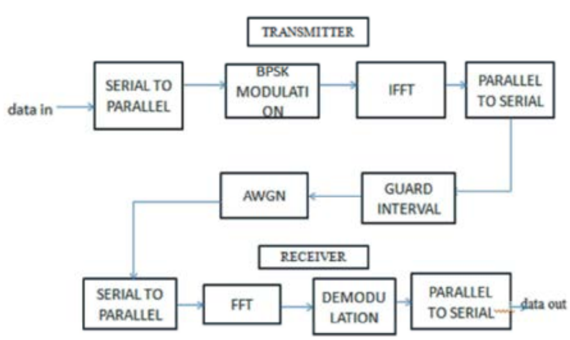
Related Works

Energy Efficient in OFDM: In wireless communications, multipath fading channel introduces inter-symbol interference (ISI) as well as inter-carrier interference (ICI) to OFDM signal which degrades the system performance seriously [1]. Therefore, in practical OFDM systems, a cyclic prefix (CP), which is a copy of the last part of the symbol, is inserted in front of the symbol. When the CP is longer than the channel length, the ICI and ISI can be eliminated totally. If the CP is too long, the energy loss will be considerable high. We propose an energy efficient transmission scheme for OFDM systems in Long Term Evolution (LTE) which is developed based on reduction of the CP energy. This can save up to about 10% of the total energy, while keeping almost the same bit-error-rate (BER) performance in some applications [9-11].

MIMO-OFDM Systems: Different applications require different levels of accuracy of channel state information (CSI) for system optimization. For example, for a single-input single-output (SISO) system, the channel amplitude information at the transmitter is enough for system optimization [2]. However, for a MIMO system, both amplitude and phase information can be exploited by the transmitter for system optimization. With complete CSI at the transmitter, a MIMO system can reach the closed-loop capacity by using the Eigen-matrix of the MIMO channel as a linear precoding matrix, together with optimal power allocation based on the water-filling scheme. To obtain the closed-loop capacity of a multiple input and multiple-output (MIMO) orthogonal frequency division multiplexing (OFDM) system, channel state information (CSI) is required at the transmitter. To reduce the data rate of CSI feedback, precoding matrix approach has been proposed for MIMO systems in flat fading channels. we develop a novel approach for MIMO-OFDM systems in frequency-selective fading channels. This approach exploits the correlation of frequency responses at different subchannels in MIMO-OFDM systems to reduce CSI feedback. It is not only flexible to multiple data stream transmission but also has better performance than the existing approaches

Frequency Selective Channels: The quality of wireless channel varies with time and frequency [3]. Therefore, link adaptation can be used to improve transmission performance.With link adaptation, modulation order, coding rate and transmit power can be selected according to channel state information (CSI).Energy efficiency is becoming increasingly important for small form factor mobile devices, as battery technology has not kept up with the growing requirements stemming from ubiquitous multimedia applications. our scheme maximizes energy efficiency by adapting both overall transmit power and its allocation, according to the channel states and the circuit power consumed. We demonstrate the existence of a unique globally optimal link adaptation solution and develop iterative algorithms to obtain it. We consider the special case of flat-fading channels to develop an upper bound on energy efficiency and to characterize its variation with bandwidth, channel gain and circuit power. OFDM systems demonstrate improved energy savings with energy optimal link adaptation as well as illustrate the fundamental tradeoff between energy-efficient and spectrum-efficient transmission.

Time Reversed OFDM: Time-reversed orthogonal frequency division multiplexing (TR-OFDM) has recently received attention as a promising scheme for supporting single-input multiple-output communications over time-dispersive fading channels with high bandwidth efficiency [4]. In TR-OFDM, the use of passive time reversal processing offers a simple means of reducing channel time dispersion. Consequently, a cyclic prefix (CP) with a length shorter than the channel order can be used without inducing much inter-block interference (IBI). It tackles a technical challenge critical to the success of TR-OFDM, that is, how to minimize the CP length while satisfying certain performance requirements. Based on a data model derived for TR-OFDM, a quantitative relationship between the CP length and error performance is first established and a design procedure is then proposed. Our design reveals that the optimal CP length depends on the power delay profiles of underlying channels. Our design also leads to new insight in the time reversal operation and helps identify channel situations where TR-OFDM might not work effectively.



Block Diagram Description

OFDM Modulation and DE-Modulation: OFDM is a technique used in modern broadband wireless communications systems. To mitigate the effect of dispersive channel distortion in high data rate OFDM systems, cyclic prefix is introduced to eliminate inter-symbol interference (ISI). It copies the end section of an IFFT packet to the beginning of an OFDM symbol. Typically, the length of the cyclic prefix must be longer than the length of the dispersive channel to completely remove ISI.

OFDM modulation in a transmitter includes inverse fast Fourier transform (IFFT) operation and cyclic prefix insertion. In an OFDM receiver, the cyclic prefix is removed before the packet data is sent to FFT for demodulation.

FFT and Inverse FFT Operations: The most computationally intensive operation of OFDM modulation is IFFT and similarly, the core of OFDM demodulation is FFT. High FFT throughput is essential in broadband systems, especially when FFT is shared between multiple data paths. In modern scalable wireless systems such as WiMAX and 3GPP LTE, run-time reconfigurability is also an integral part of system requirements.

Operation: Binary Data input is given in the form of (0,1) in a modulation input b(t). It's for an given input signals to generate a data for an modulating input data. A Serial to Parallel conversion of an given input signal is to be modulated by a transmitted signal. Bits insertion in the form of parallel views as called inserting bits to an operation. Its output denoted as d(k). Pilot insertion is used to avoid the overlapping of two signals. The IFFT and FFT Transforms are used as an applying transform domain data and normalizing data. IFFT converts time domain signal in to frequency domain signal. FFT converts frequency domain signal in to time domain signal. Adding prefix cycles Xg(n) for the cyclic insertion operation, after the transformed data's are to be cyclic prefix data's are operated for an insertion. Parallel data is to be converted into serial data in the form of serialized data is to be given threw wave channel for demodulating processes. The conversion of an digital to analog signal for an demodulation processes proceeded for an given input data's are analyzed. The channel operation is for that as demodulation process. The modulated signal as to be given input in the form of serial data's. The form of serial data is to be converted into parallel form for an demodulation operation. For an demodulation process the cyclic prefixed data's are to be removed. The demodulation processes the inserted and modulated pilot values that are removed and demodulated. The FFT and IFFT transforms are modulated as to be again modulated for an demodulation. The error rate calculations are to be measured in that for an given bits modulated and demodulated functions. ISI for an inter symbol interference for an cyclic prefix inserted in guard interval to suppress the Inter Symbol Interference for an equalized frequency maintenance. The demodulated outputs are in the form as getting in the serialized data's to be measured.

RESULTS AND DISCUSSION

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a studied time interval. BER is a unitless performance measure, often expressed as a percentage.

The bit error probability p_e is the expectation value of the BER. The BER can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors.

The channel experienced by each subcarrier in an OFDM system is a flat fading channel with each subcarrier. So, assuming that the number of taps in the channel is lower than the cyclic prefix duration (which ensures that there is no inter symbol interference), the BER for OFDM.

The Carrier Frequency Offset (CFO) significantly degrades the achievable BER performance of OFDM systems. When there is no CFO, there are no bit errors, since we stated before that we have ignored the effects of background noise. When the normalized CFO is low, the BER increases exponentially with the normalized CFO.

analysis and those accruing from our simulations match well for various numbers of OFDM subcarriers.

The BER vs. SNR curves for OFDM system are obtained for different system parameters. The analysis of the obtained results shows that the developed model can efficiently simulate and demonstrate the effect of changing of OFDM system parameters.

Figure 1 represents the modulated process output for bit error probability curve for BPSK using OFDM. Table 1 represents the Eb/No Vs BER for modulated output. Figure 2 represents the De-modulated process output for bit error probability curve for BPSK using OFDM. Table 2 represents the Eb/No Vs BER for De-modulated output [12-20].

Table 1: Eb/No Vs BER for modulated output

Eb/No in db	BER
0	0.07955
2	0.03935
4	0.01282
6	0.002571
8	0.0001712

Table 2: Eb/No Vs BER for demodulated output

Eb/No in db	BER
0	0.07865
2	0.03751
4	0.0125
6	0.002388
8	0.0001709

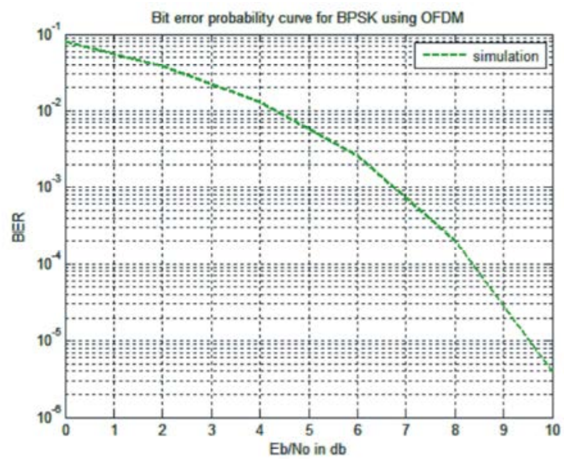


Fig. 1: Modulated output

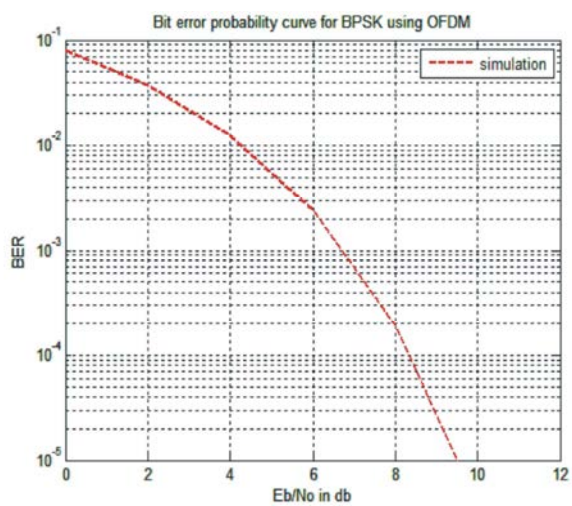


Fig. 2: Demodulated output

In modulation process inverse FFT process takes place and for De-modulation process FFT process takes place.

Here Eb/No Vs BER for demodulated output is reduced when compared with Eb/No Vs BER for Modulated output.

CONCLUSION

A general problem found in high speed communication is Inter-Symbol Interference (ISI). ISI occurs when a transmission interferes with itself and the receiver cannot decode the transmission correctly. Orthogonal Frequency Division Multiplexing (OFDM) is a bandwidth efficient signaling scheme for wide band digital communications Orthogonal frequency division multiplex (OFDM) modulation is being used more and more in telecommunication, wired and wireless. DVB and DAB already use this modulation technique and ADSL is based on it. The advantages of this modulation are the reason for its increasing usage. OFDM can be implemented easily, it is spectrally efficient and can provide high data rates with sufficient robustness to channel imperfections. In this paper, various OFDM techniques have been discussed and we enhanced the Bit Error Ratio (BER) for modulator and De-modulator process of OFDM. Currently many techniques have been performed based on OFDM.

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