BER Evaluation of Orthogonal Frequency Division Multiplexing (OFDM) under various Modulation Techniques

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Abstract— Orthogonal frequency division multiplexing (OFDM) has recently received a lot of attention as an effective technique to remove all inter-symbol interference (ISI) caused by multipath fading.. OFDM is a promising future technology for wired/wireless communications. This paper gives a theoretical overview of OFDM, application and its advantages/disadvantages. The performance of the developed system is investigated in terms of Bit Error Rate.

Keywords— *OFDM, ISI, ICI, BER.*

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I. Introduction

Orthogonal frequency division multiplexing (OFDM) is used extensively in broadband wired and wireless communication systems. OFDM becomes increasingly important as data rates increase [1, 2, 3], where the complexity of equalization in serial schemes (QAM or NRZ) which use time domain equalization rises rapidly. While many details of OFDM systems are very complex, the basic concept of OFDM is quite simple [4, 5].

Data is transmitted in parallel on a number of different frequencies, and as a result the symbol period is much longer than for a serial system with the same total data rate. Because the symbol period is longer, ISI affects at most one symbol, and equalization is simplified. In most OFDM implementations any residual ISI is removed by using a form of guard interval called a cyclic prefix.

In OFDM each subcarrier frequencies are chosen so that the signals are linearly independent i.e. mathematically orthogonal over one OFDM symbol period. This is done by using an inverse fast Fourier transform (IFFT).
In OFDM the spectra of individual subcarriers overlap, but because of the orthogonality property, the subcarriers can be demodulated without interference and without the need for analog filtering to separate the received subcarriers. Demodulation and de-multiplexing is performed by a fast Fourier transform (FFT).

Fig. 1 shows spectra for OFDM.

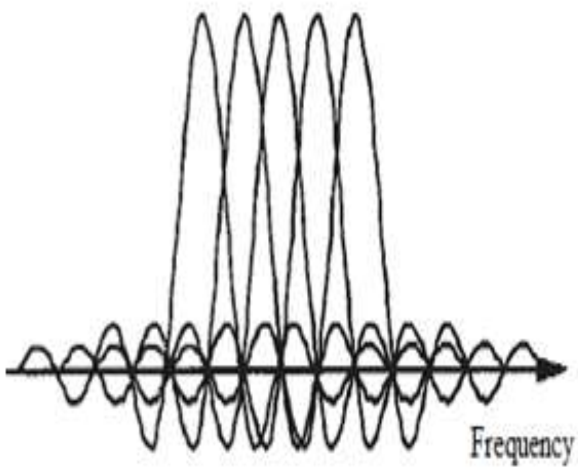

Figure 1: OFDM signal

The spectrum of an individual OFDM subcarrier has a form, so each OFDM subcarrier has significant side lobes over a frequency range which includes many other subcarriers.
This is the cause of one of the major disadvantages of OFDM: that it is quite sensitive to frequency offset and phase noise.

II. OFDM Generation

To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonality of the carriers. For this reason, OFDM is generated by firstly choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on

ISSN: 2321-8169
3377 – 3380

the modulation scheme (typically differential BPSK, QPSK, or QAM). The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform. The IFFT performs the transformation very efficiently, and provides a simple way to ensuring that the carrier signals produced are orthogonal. Fig. 2 shows the general model to generate OFDM signal.records.

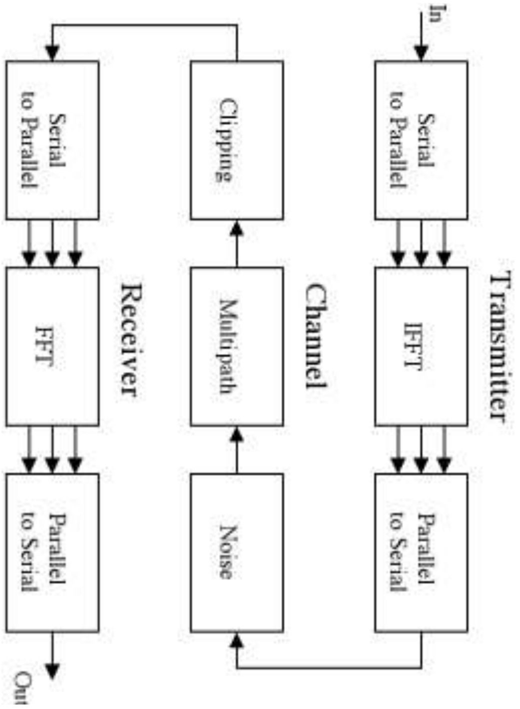

Figure 2: OFDM Model

The transmitter first converts the input data from a serial stream to parallel sets. Each set of data contains one symbol, Si, for each subcarrier. An inverse Fourier transform converts the frequency domain data set into samples of the corresponding time domain representation of this data. Specifically, the IFFT is useful for OFDM because it generates samples of a waveform with orthogonal frequency components. Then, the parallel to serial block creates the OFDM signal by sequentially outputting the time domain samples. The channel simulation will allow examination of the effects of noise, multipath, and clipping.

By adding random data to the transmitted signal, simple noise can be simulated. Multipath simulation involves adding attenuated and delayed copies of the transmitted signal to the original. This simulates the problem in wireless communication when the signal propagates on many paths. For example, a receiver may see a signal via a direct path as well as a path that bounces off a building. Finally, clipping simulates the problem of amplifier saturation. This addresses a practical implementation problem in OFDM where the peak to average power ratio is high.

The receiver performs the inverse of the transmitter. First, the OFDM data are split from a serial stream into parallel sets. The Fast Fourier Transform (FFT) converts the time domain samples back into a frequency domain representation. The magnitudes of the frequency components correspond to the original data. Finally, the parallel to serial block converts this parallel data into a serial stream to recover the original input data.

III. HISTORY OF OFDM

From an historical point of view, the theoretical bases for the development of OFDM systems were laid out by R.W.Chang,1966 [2], where the orthogonality conditions for the perfect recovery of the transmitted signals were derived, while the possibility of efficiently realizing the multicarrier modulators through DFT processors was shown as early as 1970, in [3,4] . Nevertheless it was not until the late 1980s that, thanks to the advances in Digital Signal Processing technology that the implementation of OFDM systems began to appear as feasible [5, 6]. In the last few years, the filter less OFDM system with cyclic prefix is chosen, as the modulation format for several digital communication systems throughout the world.

In USA, it was adopted in the ADSL and HDSL standards for high bit rate data transmission over the twisted pair [7,8], whereas in Europe it is used by the standards for the digital terrestrial radio broadcasting of sounds (DAB) [9, 10] and television, first with the dTTb project [11,12,13] and later with the DVB-T standard [14].

In the OFDM system, Inverse Fast Fourier Transform/Fast Fourier Transform (IFFT /FFT) algorithms are used in the modulation and demodulation of the signal. The length of the IFFT/FFT vector determines the resistance of the system to errors caused by the multipath channel. The time span of this vector is chosen so that it is much larger than the maximum delay time of echoes in the received multipath signal. OFDM is generated by firstly choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme (typically differential BPSK, QPSK, or QAM). Then, the IFFT converts this spectrum into a time domain signal.

The FFT transforms a cyclic time domain signal into its equivalent frequency spectrum. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal.

IV. RESULT & DISCUSSION

We implement and verified the performance of OFDM system under various modulations. We have evaluated the performance for various BER vs. SNR plots for all the essential modulation. Figure 3 shows the performance of developed OFDM system under Additive White Gaussian Noise (AWGN) channel model. The Bit Error Rate (BER) plot obtained in the performance analysis showed that model works well on Signal to Noise Ratio (SNR) less than 25 dB.

The performance of the system under BPSK modulation is quite satisfactory as compared to other modulation techniques in AWGN channel which is smaller than that of other modulation techniques.

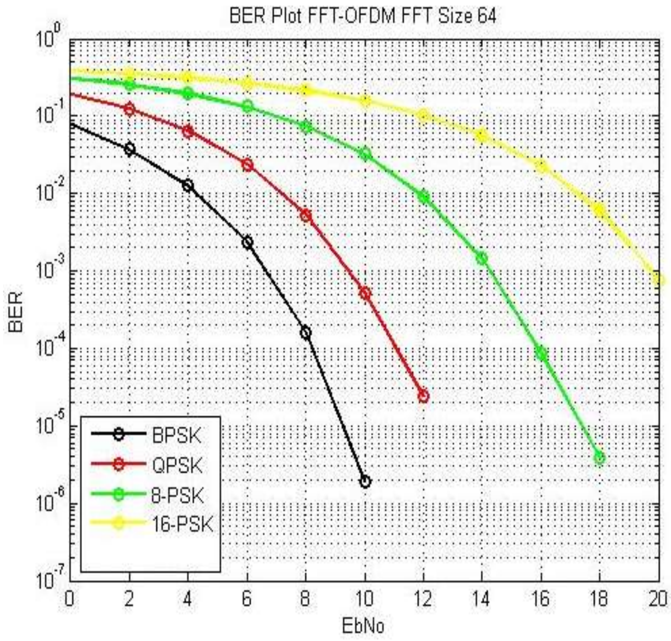

Fig. 3 BER of OFDM under various modulations

Similarly Figure 4 shows the performance of developed OFDM under Additive White Gaussian Noise (AWGN) channel model and for differential modulations.

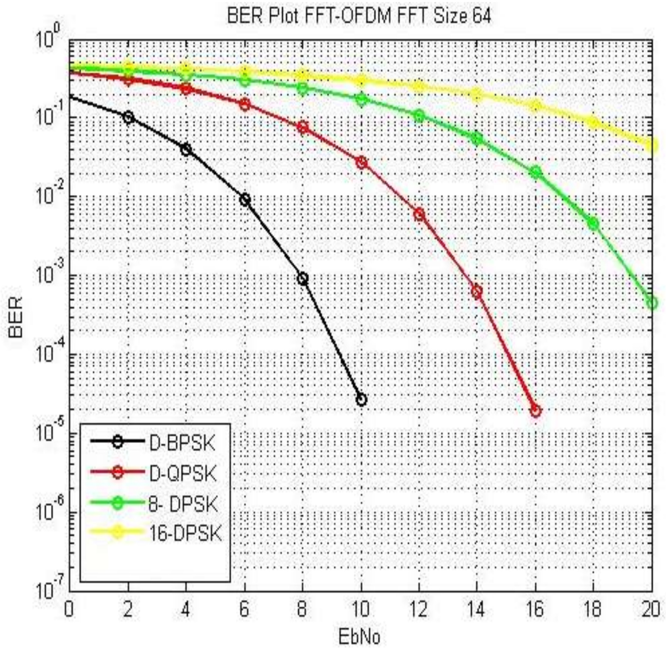

Fig. 4 BER of OFDM under Differential modulations

The performance of the system under BPSK modulation is quite satisfactory as compared to other modulation techniques in AWGN channel which is smaller than that of other modulation techniques. The BER performance of simple modulations is now compared with differential modulations. Figure 5 shows the performance of developed OFDM under simple as well as differential modulations under Additive White Gaussian Noise (AWGN) channel model.

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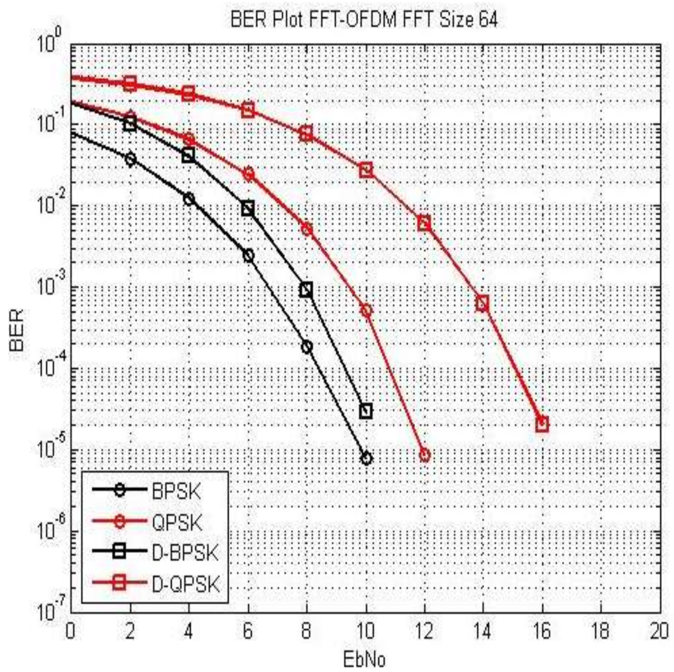

Fig. 5 Comparison of BER under Differential and non differential modulations

V. Conclusion

OFDM allows for a high spectral efficiency as the carrier power and modulation scheme can be individually controlled for each carrier. A performance analysis of an OFDM system for various modulations simple as well as differential has been carried out. The BER curves were used to compare the performance of different modulation techniques. Performance results highlight the impact of modulation scheme and show that BPSK modulation technique provides satisfactory performance among the four considered modulations. At the same time the simple modulation gives better results as compared with the differential one.

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