Performance Evaluation of OFDM system with and without RS coding

Vikas	extsuperscript{1}, Satnam Singh	extsuperscript{2}

	extsuperscript{1}M. Tech Scholar, Department of ECE, SSCET, Badhani, Pathankot, Punjab, India
	extsuperscript{2}AP, Department of ECE, SSCET, Badhani, Pathankot, Punjab, India

Abstract—Orthogonal frequency division multiplexing (OFDM) is a multi-carrier transmission technique that has been recently recognized as an excellent method for high speed bi-directional wired/wireless data communication. High capacity and variable bit rate information transmission with high bandwidth efficiency are just some of the requirements that the modern transceivers have to meet in order for a variety of new high quality services to be delivered to the customers. In this paper an overview of a OFDM (Orthogonal Frequency Division Multiplex) is given and performance is evaluated in terms of BER. We evaluate the performance of OFDM with and without RS coding under various modulation formats.

Keywords—OFDM, BER, RS, WLAN.

I. INTRODUCTION

The OFDM is deriving from FDM. It seems to be the optimal form of a multicarrier modulation scheme. It employs modern digital modulation technique FFT (fast Fourier transform), which inherently avoids bank of oscillators, demodulators and filters. This supports smart antennas, directional and advance antenna techniques. The OFDM is a good conflict against interferences and multi path fading. The number of sub channels inversely related to data rate for each individual subcarrier, in return increases the time laps of symbol. This solves the problem of delayed version of signals in multipath environment. Each sub channel is orthogonal to each other and faces flat fading. Orthogonality depends on carrier spacing. Carrier space is to choose that it must be reciprocal of symbol period.

Orthogonal Frequency Division Multiplexing (OFDM) has been gaining year after year a well-deserved reputation, demonstrating its high data rate and robustness to wireless environments capabilities. In the multipath environment, broadband communications will suffer from frequency selective fading. OFDM is an attractive modulation scheme used in broadband wireless systems that encounter large delay spreads. OFDM avoids temporal equalization altogether, using a cyclic prefix technique with a small penalty in channel capacity. Where Line-of-Sight (LoS) cannot be achieved, there is likely to be significant multipath dispersion, which could limit the maximum data rate. Technologies like OFDM are probably best placed to overcome these, allowing nearly arbitrary data rates on dispersive channels [1].

OFDM is a technique for transmitting data in parallel by using a large number of modulated sub-carriers. These sub-carriers (or sub-channels) divide the available bandwidth and are sufficiently separated in frequency (frequency spacing) so that they are orthogonal. The word orthogonal indicates that there is a precise mathematical relationship between the frequencies of the carriers in the system. In a normal frequency-division multiplex system, many carriers are spaced apart in such a way that the signals can be received using conventional filters and demodulators. In such receivers, guard bands are introduced between the different carriers and in the frequency domain, which results in a lowering of spectrum efficiency.

Fig.1: Spectra of (a) an OFDM sub-channel and (b) and OFDM signal.

II. HISTORICAL BACKGROUND

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 [15].

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.

III. 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 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.

The Fast Fourier Transform (FFT) transforms a cyclic time domain signal into its equivalent frequency spectrum. This is done by finding the equivalent waveform, generated by a sum of orthogonal sinusoidal components. The amplitude and phase of the sinusoidal components represent the frequency spectrum of the time domain signal.

The IFFT performs the reverse process, transforming a spectrum (amplitude and phase of each component) into a time domain signal. An IFFT converts a number of complex data points, of length which is a power of 2, into the time domain signal of the same number of points. Each data point in frequency spectrum used for an FFT or IFFT is called a bin [15].

The orthogonal carriers required for the OFDM signal can be easily generated by setting the amplitude and phase of each bin, then performing the IFFT. Since each bin of an IFFT corresponds to the amplitude and phase of a set of orthogonal sinusoids, the reverse process guarantees that the carriers generated are orthogonal.

A block diagram showing a simplified configuration for an OFDM transmitter and receiver is given in Figure 2.2.

![OFDM System Diagram](image-url)
IV. REED-SOLOMON CODES

Reed-Solomon codes are block-based error correcting codes with a wide range of applications in digital communications and storage. Reed-Solomon codes are used to correct errors in many systems including:

- Storage devices (including tape, Compact Disk, DVD, barcodes, etc)
- Wireless or mobile communications (including cellular telephones, microwave links, etc)
- Satellite communications
- Digital television / DVB
- High-speed modems such as ADSL, xDSL, etc.

Fig. 2 A typical Reed-Solomon encoder systems

The Reed-Solomon encoder takes a block of digital data and adds extra "redundant" bits. Errors occur during transmission or storage for a number of reasons (for example noise or interference, scratches on a CD, etc). The Reed-Solomon decoder processes each block and attempts to correct errors and recover the original data. The number and type of errors that can be corrected depends on the characteristics of the Reed-Solomon code.

(A) Properties of Reed-Solomon Codes

Reed Solomon codes are a subset of BCH codes and are linear block codes. A Reed-Solomon code is specified as RS (n,k) with s-bit symbols. This means that the encoder takes k data symbols of s bits each and adds parity symbols to make an n symbol codeword. There are n-k parity symbols of s bits each. A Reed-Solomon decoder can correct up to t symbols that contain errors in a codeword, where 2t = n-k.

The following diagram shows a typical Reed-Solomon codeword (this is known as a Systematic code because the data is left unchanged and the parity symbols are appended):

![Diagram of Reed-Solomon encoder system]

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Reed-Solomon Encoder</th>
<th>Communication Channel or Storage Device</th>
<th>Reed-Solomon Decoder</th>
<th>Data Sink</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise/ Error</td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

![Diagram of Reed-Solomon encoder system]

![Diagram of Reed-Solomon encoder system]

Fig. 3 Basic idea of RS Coding

Given a symbol size s, the maximum codeword length (n) for a Reed-Solomon code is

For example, the maximum length of a code with 8-bit symbols (s=8) is 255 bytes.

Reed-Solomon codes may be shortened by (conceptually) making a number of data symbols zero at the encoder, not transmitting them, and then re-inserting them at the decoder. The amount of processing "power" required to encode and decode Reed-Solomon codes is related to the number of parity symbols per codeword. A large value of t means that a large number of errors can be corrected but requires more computational power than a small value of t. Reed-Solomon algebraic decoding procedures can correct errors and erasures. An erasure occurs when the position of an erred symbol is known. A decoder can correct up to t errors or up to 2t erasures. Erasure information can often be supplied by the demodulator in a digital communication system, i.e. the demodulator "flags" received symbols that are likely to contain errors.

V. RESULTS

We have evaluated the performance for various BER vs. SNR plots for all the essential modulation and with and without RS coding. Figure 3 shows the performance of OFDM without RS coding 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.

Similarly Figure 4 shows the performance of OFDM with RS coding under Additive White Gaussian Noise (AWGN) channel model. 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 RS coded OFDM is better as compared to simple OFDM system.
VI. CONCLUSIONS

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 with and without RS code 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 the implementation of an Reed-Solomon code under BPSK modulation technique under AWGN channel provides satisfactory performance among the four considered modulations. The BER performance of RS coded OFDM is better as compared to simple OFDM system.

REFERENCES