# Analytical Review on the OFDM- LTE System

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***Abstract:***

***Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input and Multiple Output (MIMO) are two main techniques employed in 4th Generation Long Term Evolution (LTE). In OFDM multiple carriers are used and it provides higher level of spectral efficiency as compared to Frequency Division Multiplexing (FDM). In OFDM because of loss of orthogonality between the subcarriers there is inter-carrier interference (ICI) and inter symbol interference (ISI) and to overcome this problem use of cyclic prefixing (CP) is required, which uses 20% of available bandwidth. Wavelet based OFDM provides good orthogonality and with its use Bit Error Rate (BER) is improved. Wavelet based system does not require cyclic prefix, so spectrum efficiency is increased. It is proposed to use wavelet based OFDM at the place of Discrete Fourier Transform (DFT) based OFDM in LTE. We have compared the BER performance of wavelets and DFT based OFDM.***

**Key Words:**

OFDM, LTE, Wireless Communication, BER.

## Introduction:

The revolution of wireless communications certainly was one of the most extraordinary Changes underlying our contemporary world although we may not realize it, everyday our lives are profoundly affected by the use of radio waves. Radio and television transmissions, radio- controlled devices, mobile telephones, satellite communications, and radar and systems of radio navigation are all examples of wireless communications happening around us. However, less than a hundred years ago, none of these existed, while the telegraph and telephone were most common for communication, which required direct wire connection between two places. There mark able advancement in communication of today is the result of an Italian scientist, Gugliemo Marconi, as he began experiments using radio waves for communication in 1895. These invisible transmittable waves traveled in air, and since the receiving and transmitting equipment was not connected by wires, the method of communication used was then recognized as wireless communication. Marconi's first success was in 1897, as his Demonstrated radio's ability to provide continuous contact with ships sailing the English Channel.

By 1920, radio circled the globe and the first radio transmitter was developed and broadcasted programs for the public. Later, the idea of the radio was adopted by Television, radar and communication systems, due to the advancement in electronics Equipment and enabled radio waves to be sent over greater distances.

**The Cellular Concept:**

The world's first cellular network was introduced in the early1980s, using analog radio Transmission technologies such as AMPS (Advanced Mobile Phone System).To explain the cellular concept, a diagrammatic representation is presented in Figure 1.1.

In Figure above, each colored cell is viewed as the (approximate) coverage area of a particular land site. Each cell uses a distinct set of frequencies (channels) and is shown by the difference in color between cells. However, cells that are far enough apart to avoid co-channel interference can reuse the same channel set. In the cellular concept, a mobile user is allowed mobility as a call is "handed off" from one cell to another as the user leaves one cell and enters another.

**Figure 1.1 Cellular Concepts**

The AMPS cellular system was very popular. However, with the gigantic increase in Subscribers in order of million each year, the AMPS cellular systems began to over loading capacity and became incapable of delivering sufficient air time to reach user .To overcome the problem, more effective multiple access techniques were invented.

**Bit Error Rate:**

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors.

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 unit less 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.

**Example:** As an example, assume this transmitted bit sequence:

0 1 1 0 0 0 1 0 1 1,

And the following received bit sequence:

0 0 1 0 1 0 1 0 0 1,

The number of bit errors (the underlined bits) is in this case 3. The BER is 3 incorrect bits divided by 10 transferred bits, resulting in a BER of 0.3 or 30%.

**Channel:**

In telecommunications and computer networking, a communication channel, or channel, refers either to a physical transmission medium such as a wire, or to a logical connection over a multiplexed medium such as a radio channel. A channel is used to convey an information signal, for example a digital bit stream, from one or several senders (or transmitters) to one or several receivers. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bits per second.

**Chanel models:**

A channel can be modeled physically by trying to calculate the physical processes which modify the transmitted signal. For example in wireless communications the channel can be modelled by calculating the reflection off every object in the environment. A sequence of random numbers might also be added in to simulate external interference and/or electronic noise in the receiver.

Statistically a communication channel is usually modelled as a triple consisting of an input alphabet, an output alphabet, and for each pair *(i, o)* of input and output elements a transition probability *p(i, o)*. Semantically, the transition probability is the probability that the symbol *o* is received given that *i* was transmitted over the channel.

Statistical and physical modeling can be combined. For example in wireless communications the channel is often modeled by a random attenuation (known as fading) of the transmitted signal, followed by additive noise. The attenuation term is a simplification of the underlying physical processes and captures the change in signal power over the course of the transmission. The noise in the model captures external interference and/or electronic noise in the receiver. If the attenuation term is complex it also describes the relative time a signal takes to get through the channel. The statistics of the random attenuation are decided by previous measurements or physical simulations.

Channel models may be continuous channel models in that there is no limit to how precisely their values may be defined.

Communication channels are also studied in a discrete-alphabet setting. This corresponds to abstracting a real world communication system in which the analog->digital and digital->analog blocks are out of the control of the designer. The mathematical model consists of a transition probability that specifies an output distribution for each possible sequence of channel inputs. In information theory, it is common to start with memory less channels in which the output probability distribution only depends on the current channel input.

**Additive white Gaussian noise (AWGN):**

Additive white Gaussian noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion. However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behavior of a system before these other phenomena are considered.

Wideband Gaussian noise comes from many natural sources, such as the thermal vibrations of atoms in conductors (referred to as thermal noise or Johnson-Nyquist noise), shot noise, black body radiation from the earth and other warm objects, and from celestial sources such as the Sun.

The AWGN channel is a good model for many satellite and deep space communication links. It is not a good model for most terrestrial links because of multipath, terrain blocking, interference, etc. However, for terrestrial path modeling, AWGN is commonly used to simulate background noise of the channel under study, in addition to multipath, terrain blocking, interference, ground clutter and self interference that modern radio systems encounter in terrestrial operation.

**Review of Literature:**

In 2010 Ian F. Akyildiz, David M. Gutierrez-Estevez, and Elias Chavarria Reyes worked on " The evolution to 4G cellular systems: LTE-Advanced". This work provides an in-depth view on the technologies being considered for Long Term Evolution-Advanced (LTE-Advanced). First, the evolution from third generation (3G) to fourth generation (4G) is described in terms of performance requirements and main characteristics. The new network architecture developed by the Third Generation Partnership Project (3GPP), which supports the integration of current and future radio access technologies, is highlighted. Then, the main technologies for LTE-Advanced are explained, together with possible improvements, their associated challenges, and some approaches that have been considered to tackle those challenges.

In 2010 Abbas Hasan Kattoush, Waleed A. Mahmoud, and S. Nihad worked on "The performance of multiwavelets based OFDM system under different channel conditions". In wireless communication reception, the reliability of orthogonal frequency division multiplexing (OFDM) is limited because of the time-varying nature of the channel. This causes inter-carrier interference (ICI) and increases inaccuracies in channel tracking. This can effectively be avoided at the cost of power loss and bandwidth expansion by inserting a cyclic prefix guard interval before each block of parallel data symbols. However, this guard interval decreases the spectral efficiency of the OFDM system as the corresponding amount. Recently, it was found that based on Haar-orthonormal wavelets, discrete wavelet based OFDM (DWT-OFDM) is capable of reducing the inter symbol interference (ISI) and ICI, which are caused by the loss in orthogonality between the carriers. DWT-OFDM can also support much higher spectrum efficiency than discrete Fourier-based OFDM (DFTOFDM).

In 2013 Mahesh Kumar Gupta, and S. Tiwari researched on "Performance evaluation of conventional and wavelet based OFDM system". In this work we have compared the bit error rate (BER) performance and power spectral density of Discrete Fourier Transform (DFT) based OFDM system with wavelet based OFDM system. We also compared the performance of Least Square (LS) and Linear Minimum Mean Square Error (LMMSE) channel estimation technique for wavelet based OFDM system as well as DFT based OFDM system.

In 2006 M. K. Lakshmanan and H. Nikookar worked on "A Review of Wavelets for Digital Wireless Communication". Wavelets have been favorably applied in almost all aspects of digital wireless communication systems including data compression, source and channel coding, signal denoising, channel modeling and design of transceivers. The main property of wavelets in these applications is in their flexibility and ability to characterize signals accurately. In this paper recent trends and developments in the use of wavelets in wireless communications are reviewed. Major applications of wavelets in wireless channel modeling are interference mitigation, denoising etc.

OFDM modulation, multiple access, Ultra Wideband communications, cognitive radio and wireless networks are surveyed. The confluence of information and communication technologies and the possibility of ubiquitous connectivity have posed a challenge to developing technologies and architectures capable of handling large volumes of data under severe resource constraints such as power and bandwidth. Wavelets are uniquely qualified to address this challenge. The flexibility and adaptation provided by wavelets have made wavelet technology a strong candidate for future wireless communication.

**Multiple Accesses: Definition:** Satellites are always built with the intension that many users will share the bandwidth. The ability of the satellite to carry many signals at the same time is known as multiple accesses. It allows the communication capacity of the satellite to be shared among a large number of earth stations. The signals that earth stations transmit to a satellite may differ widely in their character but they can be sent through the same satellite using multiple accesses and multiplexing techniques.

Multiplexing is the process of combining multiple signals into a single signal so that it can be processed by a single amplifier or transmitted over a single radio channel. The corresponding technique the recovers the individual signal back is called as demultiplexing.

The distinction between multiplexing and multiple accesses is that multiplexing is done at one location whereas multiple accesses refers to the signals from a number of different geographic locations.

**Multiple Access Techniques:**

Multiplexing is done at the earth stations then after modulating the signals at the earth stations it is transmitted to the satellite. At the satellite the signals will share the satellite transponder by different multiple access techniques. There are basically three multiple access techniques. They are:

1. Frequency division multiple access (FDMA)
2. Time division multiple access (TDMA)
3. Code division multiple access (CDMA)

The reason of using such techniques is to allow all users of a cellular system to be able to Share the available bandwidth in a cellular system simultaneously.

**Proposed Methodology:**

In previous works use of Discrete Fourier Transform was proposed for the implementation of OFDM. Wavelet transform show the potential to replace the DFT in OFDM. Wavelet transform is a tool for analysis of the signal in time and frequency domain jointly. It is a multi-resolution analysis mechanism where input signal is decomposed into different frequency components for the analysis with particular resolution matching to scale. Using any particular type of wavelet filter the system can be designed according to the need and also the multi resolution signal can be generated by the use of wavelets. By the use of varying wavelet filter, one can design waveforms with selectable time/frequency partitioning for multi user application. Wavelets possess better orthogonality and have localization both in time and frequency domain. Because of good orthogonality wavelets are capable of reducing the power of the ISI and ICI, which results from loss of orthogonality.

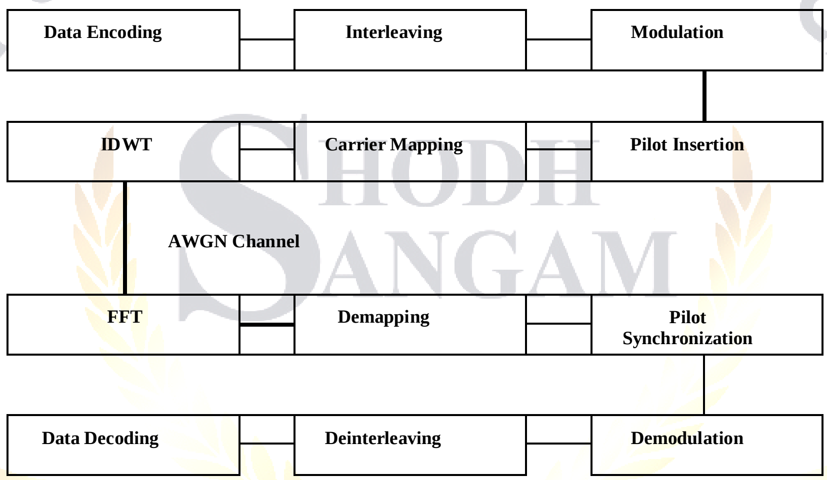


**Figure 2 Wavelet based proposed OFDM system design**

In this proposed model we are using IDWT and DWT at the place of IDFT and DFT. AWGN channel is used for transmission and cyclic prefixing is not used. Here first of all conventional encoding is done followed by interleaving then data is converted to decimal form and modulation is done next. After modulation the pilot insertion and sub carrier mapping is done then comes the IDWT of the data, which provides the orthogonality to the subcarriers. IDWT will convert time domain signal to the frequency domain. After passing through the channel on the signal DWT will be performed and then pilot synchronization where the inserted pilots at the transmitter are removed then the demodulation is done. Demodulated data is converted to binary form and the de-interleaved and decoded to obtain the original data transmitted.

## Conclusion:

In this work we studied the performance of wavelet based OFDM system and compared it with the performance of DFT based OFDM system. From the expected performance curve we have observed that the BER curves obtained from wavelet based OFDM can be better than that of DFT based OFDM. This work proposed three modulation techniques for implementation that can be QPSK, 16 QAM and 64 QAM, which will used in LTE. In wavelet based OFDM different types of filters can be used with the help of different wavelets available. This work used daubechies2 and haar wavelets, both provide their best performances at different intervals of SNR.

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