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Comparative Analysis of Conventional and Wavelet Based OFDM in Long Term Evolution Using Different Modulation Techniques

Dr. Revathi.S[1], Raghavee N S[2]

[1]Asso.Prof, School of Electronics Engineering, Vellore Institute of Technology, Vellore, Tamilnadu, India

[2]Software Engineer, L&T Technology Services Limited, Bangalore, India

Abstract: *The generation LTE (long term evolution) uses two main techniques which are, OFDM (Orthogonal Frequency Division Multiplexing) and MIMO (Multiple Input and Multiple Output). In FDM (Frequency Division Multiplexing) has a very low level of spectral efficiency when compared with OFDM (Orthogonal Frequency Division Multiplexing) which has a very high spectral efficiency. In OFDM, there is a loss in Orthogonality in subcarriers leads to ISI (Inter Symbol Interference) as well as ICI (Inter Carrier Interference). So, this can be reduced by using cyclic prefix which uses a bandwidth by 20percent which is available. The use of wavelet OFDM can reduce the BER (Bit Error Rate) and it have a very good orthogonality as well. The spectrum efficiency in wavelet OFDM is improved, because there is no use of cyclic prefix in the wavelet OFDM. The DFT (Discrete Fourier Transform) has been replaced by the wavelet based OFDM in LTE. The comparison of BER (Bit Error Rate) performance has been done between the conventional OFDM and wavelet based OFDM.*

Keywords: *Orthogonal Frequency Division Multiplexing (OFDM), Frequency Division Multiplexing (FDM) and Additive White Gaussian Noise (AWGN).*

1. INTRODUCTION

4G networks has been developed to meet the users expectations for increasing data speed up to 20Mbps [1]. In doing this, it is very important that the standards of the service for any transmission, either be data or voice, should not be depreciated. The new algorithm should be able to maintain voice calls priority giving a small time window. Simultaneously, it should be able to accommodate the change in bandwidth based on the application and also maintain the transmission rate. Maintaining Quality of service means that it should maintain that the telephone carrier to prioritize the traffic based on users requirement. LTE delivers more data capacity and faster connectivity by using wider channels and more antennas (Multi input - Multi output).

Basic concept of OFDM is the orthogonality principle. Orthogonality principle can be explained that any two vectors must be linearly independent from each other. Here the subcarriers must be orthogonal to each other. This means that even if waveforms overlap, the orthogonality ensures zero interference. An overlap of sub carriers is seen in frequency domain of subcarriers, hence we dont have ICI in the band efficiency.

OFDM is a digital modulation technique which uses multiple carriers[2], that use an abundant tightly spaced orthogonal sub-carriers. Initial data is sent in form of a single stream which is then converted to parallel form. The parallel data or small chunks of data is then coded and then modulated on to a sub-carrier. These sub-carriers are modulated using any modulation schemes, usually quadrature amplitude modulation. These sub carriers are modulated at a low symbol rate maintaining same data rates similar to convention single carrier modulation scheme for same bandwidth. This is the reason why we observe lower bit rates on subcarrier com- pared to single carrier. This modulated data is transmitted on multi-fading channels such as Rayleigh fading channel. In this project, we use Additive White Gaussian Noise (AWGN) channel. Conventionally, OFDM uses fast Fourier transform for generation and detection [3].

2. CONVENTIONAL OFDM

OFDM implementation is almost similar in both analog modulation and digital modulation. Algorithm from analog domain can be extended to digital domain by using Fourier transforms. Fourier transforms play a major role in signal processing techniques. It helps in changing the perspective from time domain to frequency domain. Fourier transform helps in mapping digitally modulated data on to orthogonal sub carriers. Basic principle of OFDM uses IFFT to convert frequency domain to time domain signal. Input to IFFT is digitally modulated data.

OFDM message is generated in complex domain. Input data is separated into chunks as symbols. Each symbol is modulated on to sub carriers using different modulation techniques. In this project we used, PSK and QAM for digital modulation. There is a conversion of data symbols from parallel to series form. The frequency spacing between adjacent subcarriers is 2/N, and the number of subcarriers is N. This can be easily attained by replacing the (IFFT) Inverse Fast Fourier Transform operation with the (IDFT) Inverse Discrete Fourier Transform. Hence, the OFDM symbol is produced, for a system which has N samples for N subcarriers, with the ith sample looks as below,

$$x_i = \sum_{n=0}^{N-1} C_n e^{-i2n/N} \quad (1)$$

Now near the receiver side, in order to get the manipulate the symbols which are from time domain which changes its form to frequency domain, the OFDM signal undergo the exact opposite operation in the DFT (Discrete Fourier Transform). In the application, the baseband OFDM receiver performs the fast Fourier transform (FFT) of the receive message to recover the information that was originally sent. Figure 1 below shows the general block diagram of how OFDM is implemented using FFT

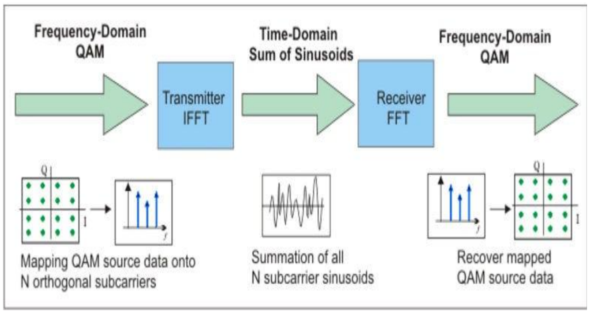

Fig 1: *OFDM with FFT*

The critical disadvantage is its high peak-to-average power ratio (PAPR). Reason for high PAPR is the modulation where many subcarriers are added to form the transmitting signal. The peak magnitude increases with linear proportionality with number of subcarriers that are added for modulation whereas the RMS value is low because of destructive interference. Signals with high PAPR requires complex hardware which usually has high power consumption and low efficiency. There is a lot of research on reduction of PAPR and many reduction techniques were proposed. Among the techniques, simple solution is to break the signal when the amplitude of signal reaches a threshold. This process is known as clipping and is a nonlinear process. It produces high out of band interference(OBI).

Additive White Gaussian Noise is one most commonly used channel model. As the name suggests, we can tell that noise type in this channel model is white noise. in this channel, noise is either a linear addition of wideband or white noise with specific spectral density and a constant amplitude with Gaussian distribution. Drawback of this model is that the channel does not simulate fading or interference or nonlinearity. The reason it is commonly used despite drawbacks is that its mathematical models can be simply realized and extract very useful information of the signal which tells us the behavior of the systems. Gaussian noise is created by only natural sources like thermal vibrations, radiations from many objects. AWGN channel is one of the best models to simulate background noises. It is even used for many satellite and space links. But this channels mode doesn't work well for terrestrial communication because of path fading and interference. Still, for a modeling terrestrial path, AWGN model is used to simulate background noise and other models are also used to simulate multipath fading[4], interference, self-interference that radio systems now a days encounter with.

Because of the multipath seen in the channel we see different versions of signals received over different timings. This can be seen because we have a number of different paths to reach the destination between the transmitter and receiver, Because of this phenomenon the time dispersion extends so that it follows a particular symbol in the receiving side. This overlap in the symbols can be called as ISI (Inter Symbol Interference) which acts as an important factor in the timing offset. Another form of interference seen here known as ICI (Inter Carrier Interference). The signal can successfully demodulated only if we maintain the orthogonality between the sub carriers, in OFDM. Demodulate of any specific subcarrier N is done only at its spectral peak, i.e. spectra at the Nth center frequency all the other carriers must contain consistent zero (from a frequency domain perspective). Frequency offsets causes a criterion of not being met. The performance of the OFDM system can be delay or obstruct because of this problem.

The synchronization of OFDM demodulation should hap- pen in both frequency as well as the time domain. By adding a CP (Cyclic Prefix) to each of the OFDM symbol a guard time has been added, which will make it easy to follow the goal. The cyclic prefix is present in the end of the OFDM message samples which are relocated at the beginning of an OFDM symbol. Without changing its frequency spectrum there can be an increase in the length Tsym of the transmitted signal or a message.

The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of bits transferred during a particular interval of time.

3. WAVELET BASED OFDM

Wavelet Transform seems to have the potential to replace DFT. Using Wavelet transform we can have time-frequency localization. Wavelet transform is able to provide the time as well as the frequency information simultaneously, hence it gives us a time-frequency representation of the signal[5].

Wavelet transforms works almost same as Short-time Fourier transform (STFT) to find the unknown data in particular bandwidth. The problem with STFT is that the window size is fixed for all the data. The problem arises when we take a window size less than that the interested Bandwidth, we cannot completely find out the information from that signal. This is where Wavelet Transform comes in. Wavelet Transform provides us with a variable window size. The advantage of this is we can extract any large chunks of data. Because of this variable size, the resolution of time-frequency signals are improved.

Wavelet Transform can be briefly described as follows. On passing the time domain signal through a number of high pass and the low pass filters, which results in either a high frequency or a low frequency signal[6-7]. This entire process is repeated a number of times every single time a small part of a signal related to its respective frequency will be removed. This is how it works, on considering a frequency of a signal to be in the range between 1000 Hz. This 1000Hz signal is passed through high pass and low pass filters and divided into two parts. Outputs of this level is a signal with 0-500Hz frequency range and the other part with 500-1000 Hz. The same process is repeated for both signals and further divided. This process is called decomposition. This process is repeated till we reach desired levels. The maximum we could is number of input data as this levels are integers. Now we have a bundle of signals, which represents the same signal, but all are of different frequency bands and ranges. Here we have all the idea about which signal is respective to which frequency band, and if we plot them on a single graph, with time on one axis, frequency on second and amplitude on third, we can guess the frequency range corresponding to it's time and amplitude. But we cannot tell the exact frequency corresponding to time.

This is known as "uncertainty principle," which states that, we cannot exactly know the particular frequency at particular time instance, but we can only know what frequency band that exists during time intervals). The uncertainty principle, originally found and formulated by Heisenberg, states that, "The momentum and the position of a moving particle cannot be known simultaneously". This applies to our subject as follows. The frequency and time information of a signal at a certain point in the time - frequency plane cannot be known. But the spectrum at a given interval can be known. Best solution for this problem is to look at spectral component that is in our interests at given interval of time. This is a problem of resolution, and this is the reason why many researchers have shifted from using STFT to WT. STFT uses fixed resolution at all times, whereas WT uses variable window size making variable resolution possible[8-9].

Figure 2 and figure 3 illustrates the working principle of Wavelet Transform:

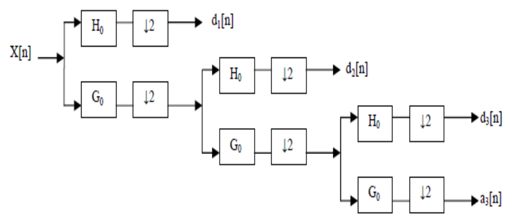

Fig 2: *Wavelet transform while decomposition*

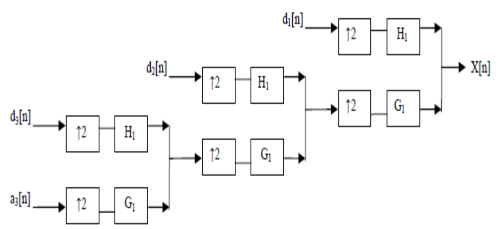

Fig 3: *Wavelet transform while reconstruction*

The top level shows the decomposition of the signal and the bottom one shows the reconstruction of the signal. Reconstruction is achieved by up sampling the input coefficients and then passed through High Pass filters and Low pass filters following the levels. From the above figure we can say understand that each signal is being divided into its lower frequency values or approximated coefficients and higher frequency values or also known as detailed coefficients. These can be easily written in equation as follows

$$Y_{high}[k] = \sum nx[n]g[2k-n] \quad (2)$$

$$Y_{low}[k] = \sum nx[n]h[2k-n] \quad (3)$$

Where original signal is x[n], its impulse response of half band high pass filter be g[n] and an impulse response of half- band low pass filter be h[n]. $Y_{high}[k]$ and $Y_{low}[k]$ are obtained after filtering and decimation by a factor of 2. Using Discrete Wavelet Transform (DWT)[7] the new method is proposed so that the need of Cyclic Prefix is eliminated and the interference, Inter Carrier Interference (ICI) and Inter Symbol Interference (ISI) are almost eliminated. This new method reduces complexity from O[Nlog2N] to O[N]. This new method also guarantees reduction of bandwidth by 20percent. Performance of this new method can be compared by finding the values of BER and plotting them with different SNR.

4. PROPOSED METHOD

In the proposed method, instead of DFT, DWT is used for implementing OFDM. Using DWT there is an increase in the efficiency of the channel and usage of bandwidth is reduced. In simulation of OFDM for this project, AWGN channel is used. Any other channel models that simulates fading can also be used. Replacing DFT also eliminates the use of cyclic prefix or guard band in between spectrum. In this process, firstly, input data is encoded . This encoded data is followed by interleaving which scrambles the order of data. Then data is then modulated and plot insertion is done. This data is then transmitted using IDWT. This provides orthogonality to subcarriers. DWT converts time domain signal to a frequency domain where unknown signal information can extracted using wavelets. This signal is transmitted via AWGN channel. On the receiver side, the process is done in exact reverse order from the transmitter side. Once demodulation is done, the data is converted to binary and decoded to obtain original data. The proposed method is shown in block diagram below

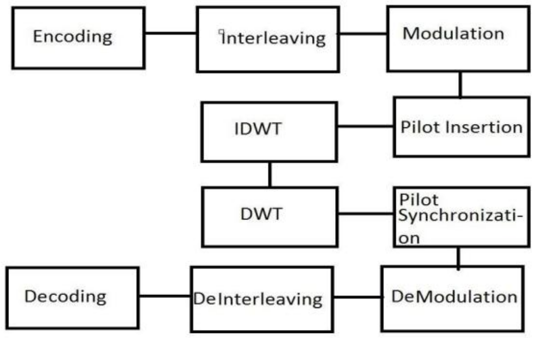

Fig 4: *Block Diagram of OFDM*

MATLAB is used to compare the performance characteristics of DFT based OFDM and DWT based OFDM. In this project we have used QPSK, 16 QAM and 64-QAM for simulation purposes. These modulation techniques are suitable and can be used for LTE communication. But if data rate is too high, QPSK is not suitable because it doesn't carry high speeds. If SNR is high, then we can use higher modulation schemes like 64-QAM. Whereas, lower modulation scheme as QPSK doesn't require high SNR. For simulation purposes, we varied SNR for different values for AWGN channel. We used 100000 bits of data. For obtaining BER, we averaged the output for particular value of SNR and this is repeated for different values of SNR.

5. RESULTS

Figure 5 shows the variation of BER with respect to SNR for DFT, DWT with Haar and db4 wavelets. QPSK modulation is used for drawing the above plot. QPSK doesnt work with high SNRs which is justified from plot. From the above plot we can see that BER keeps decreasing. It is also observed that DWT has less BER when compared with DFT which proves the proposed method.

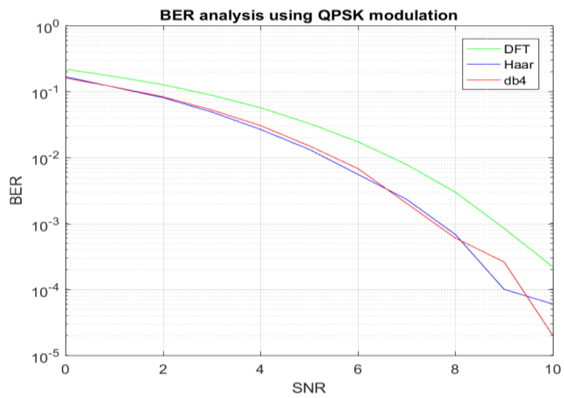

Fig 5: *BER vs SNR using QPSK modulation*

Figure 6 shows the variation of BER with respect to SNR for DFT, DWT with Haar and db4 wavelets using 16-QAM modulation technique. It is seen that BER keeps decreasing and becomes less when DWT is used. It is also observed that DWT is used is less than BER when DFT is used which proves the proposed method.

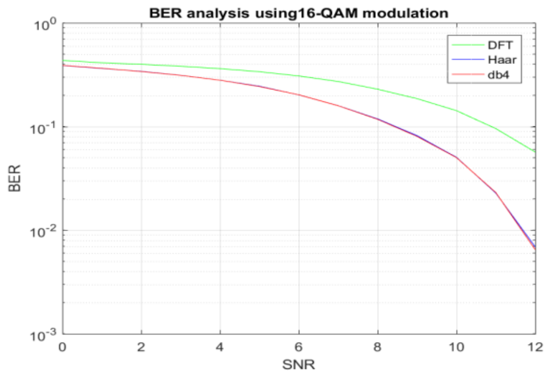

Fig 6: *BER vs SNR using 16-QAM modulation*

Figure 7 shows the variation of BER with respect to SNR for DFT, DWT with Haar and db4 wavelets using 64- QAM modulation technique. It is seen from the graph, here also the BER keeps decreasing. It is also observed that DWT is used is less than BER when DFT is used which proves the proposed method.

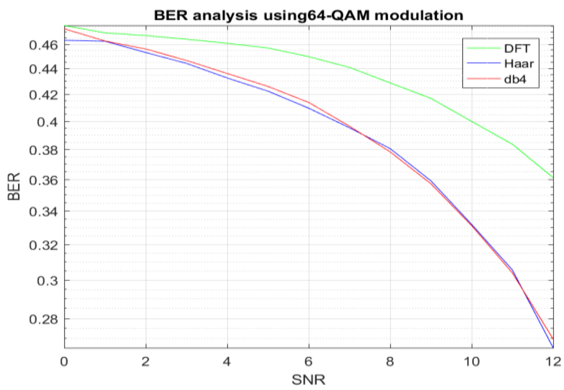

Fig 7: *BER vs SNR using 64-QAM modulation*

6. CONCLUSION

In this project the performance of wavelet based OFDM system has been compared with the performance of DFT based OFDM system. From the performance curve results obtained it can observed that those BER curves acquired from wavelet based OFDM have a better performance than that of DFT based OFDM. The three different modulation techniques used for the implementation are QPSK, 16 QAM and 64 QAM and these are the modulation techniques which have been used in LTE. Since we have different wavelets available we can use different types of filters. Here we have used daubechies4 and haar wavelets and both provide their best performances at different intervals of SNR.

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AUTHORS' BIOGRAPHIES

Dr. S.Revathi, working as Asso.Prof in VIT university, has a teaching experience of nearly 20 years at VIT, Published more than 20 Research papers in National and International Journals, Area of interest includes Optical Communication and Networks, OFDM, OTDM, RF and Microwave Engineering.

Raghavee N S, Graduated B,Tech degree from VIT University, Presently working as Software Engineer for L&T Technology Service limited.