Investigation of OFDM with Reference to LTE

P.D.Ashok
Institute of Engineering and Technology
Devi Ahilya University Indore

***Abstract*—**In this work OFDM (Orthogonal Frequency Division Multiplexing) has been investigated from LTE (Long Term Evolution) perspective. Here I took 20 MHz system bandwidth, an FFT order of 2048 for efficient implementation. Spectrum has been analysed and received symbols along with BER (bit error rate) has been analysed in result section.

Keywords*—*LTE; OFDM; fading; bandwidth; radio frame

I. INTRODUCTION

LTE (Long Term Evolution) is the technology proposed by 3GPP, it has been termed as 4G and would be technology for future generation of wireless communications. The two major introduction in LTE [1], [2] are OFDM (Orthogonal Frequency Division Multiplexing) and MIMO (Multiple Input Multiple Output), they have led to enhancement in the data transmission rate. OFDM has not only increased the data rate but is spectrally efficient too. The modulation schemes preferred in LTE are QPSK/4QAM,16QAM and 64QAMs with different code rates.

In LTE in downlink transmission orthogonal frequency division multiple access (OFDMA) technique is used. In this technique a user is alloted a group of subcarriers. Here these subcarriers are orthogonal in nature. Besides the channels or subbands are overlapping in nature and hence number of channels supported are more. Thus there is increase in spectral efficiency and system throughput in gross scale.

In OFDM [3]–[10] alloted bandwidth is further divided into overlapping subcarriers. This is implemented using IFFT at the transmitter whereas at the receiver FFT is being employed. In this work I build the mathematical and conceptual background for LTE physical layer. It is followed by OFDM and its implementation. The transmitted signals have been plotted. Channel has been characterized and finally results have been obtained.

II PHYSICAL LAYER PARAMETERS FOR LTE

In LTE downlink a subcarrier spacing is of 15 KHz with a CP length of approximately 5µs. The basic unit of time in the LTE specifications is T_s = 1/30.72 s. LTE radio frame is of 10 ms (307200 samples i.e 307200 T_s), each frame is further divided into subframes of 1 ms each. Each subframe is made up of two slots each of 0.5 ms. An FFT order of 2048 may be taken for 20 MHz system bandwidth.

A. LTE Radio Frame

Fig. 1. One Radio Frame

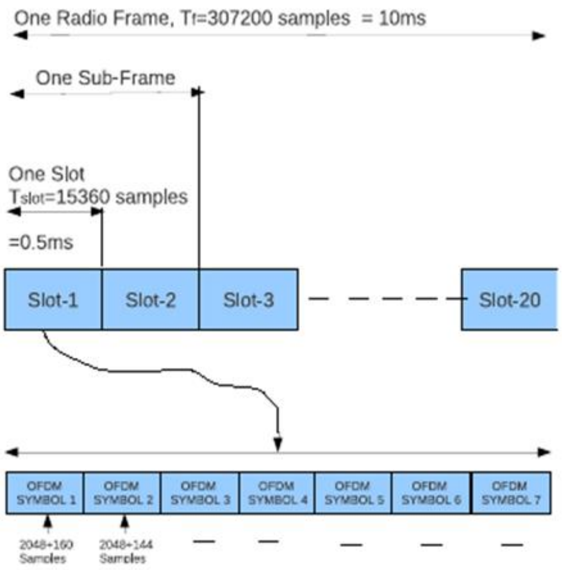

FIG. 1.ONE RADIO FRAME

III OFDM MODULATION AND DEMODULATION

The incoming data is serial to parallel converted and is then mapped onto N subcarriers using QAM/QPSK symbol mappers. If the symbol duration of each symbol was T_s , then after serial to parallel conversion the new symbol duration becomes T_{sym}=N T_s. This is the symbol duration of OFDM. Now I analyse the mathematical concept behind OFDM. If k=1,........,N be the number of subcarriers in one OFDM symbol and suppose m=1,....,M be the number of OFDM symbols to be sent, then OFDM may be expressed as

$$x_m(t) = \sum_{m=1}^{M}\sum_{k=1}^{N} X_m[k] e^{j2\pi f_k (t - mT_{sym})} \quad (1)$$

If we sample at t=mT_{sym} + nTs with T_{sym} /N and f_k = k/T_{sym} , the above equation can be written in discrete time domain as

$$x_m(n) = \sum_{k=1}^{N} X_m[k] e^{j2\pi kn/N} \quad (2)$$

n=1,......,N

the above equation is basically IDFT of QAM/PSK data symbols X_m[k]N k=1 and this operation can be effectively performed using IFFT. The transmitted symbol X_m [k] can be recovered from received signal y_m (t) (considering no channel effect and noise)

$$Y_m[k] = X_m[k]$$

In the discrete time domain the above equations can be written as under the case k'=k

$$Y_m[k] = \frac{1}{T_{sym}} \int_{-\infty}^{\infty} y_m(t) e^{-j2\pi f_k (t - mT_{sym})} dt \quad (3)$$

$$Y_m[k] = \frac{1}{T_{sym}} \int_{-\infty}^{\infty} \sum_{k'=1}^{N} X_m[k'] e^{j2\pi f_{k'} (t - mT_{sym})} e^{-j2\pi f_k (t - mT_{sym})} dt$$

$$Y_m[k] = \sum_{k'=1}^{N} X_m[k'] \frac{1}{T_{sym}} \int_{0}^{\infty} e^{j2\pi (f_{k'} - f_k)(t - mT_{sym})} dt$$

$$Y_m[k] = X_m[k]$$

$$Y_m[k] = \sum_{n=1}^{N} y_m(n) e^{-j2\pi kn/N}$$

$$Y_m[k] = \sum_{n=1}^{N} \frac{1}{N} \sum_{k'=1}^{N} X_m[k'] e^{j2\pi k' n/N} e^{-j2\pi kn/N}$$

$$(4)$$

$$Y_m[k] = \frac{1}{N} \sum_{n=1}^{N} \sum_{k'=1}^{N} X_m[k'] e^{j2\pi (k'-k) n/N}$$

IV. SYSTEM MODEL

The system model used is as follows.

At the transmitter QAM symbol mapping is performed on the incoming data. It is followed by serial to parallel converter. Then IFFT is performed, cyclic prefix is added and sent through Rayleigh channel. The receiver is invert of the individual done at the transmitter. An equalizer is used to nullify the effect of medium.

V. BEHAVIOUR OF WIRELESS CHANNEL

When the signal passes through wireless medium if under-goes multiple reflections, diffractions and scattering. The signal reaches receiver from different paths and as these paths are of different distance arrival of the signal is at different times. Thus if a impulse is launched we receive copies of that impulse that too at different delays. This multipath effect causes much variation in the signal strength even though the distance distance of separation has slightly changed. As the window of observation is small this variation in the signal strength we call as small scale fading. If the observation is taken at large window separation the fading we term as large scale fading. Path loss and shadowing are the two components of large scale fading. Path loss is due to distance whereas shadowing is due to obstructions in the wireless medium

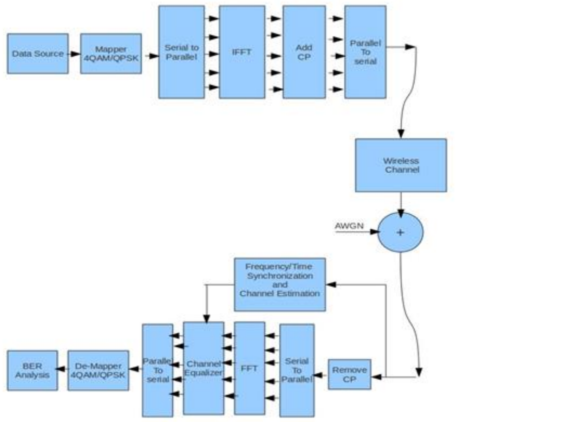

Fig 2. System Model: Block Diagram of Transmitter and Receiver used for simulating baseband OFDM

A. *Time Variance and Doppler Spectrum*

As the transmitter and receiver may not be stationary, generally receiver may be in motion. This relative motion between and receiver causes change in frequency. Thus the received signal frequency is shifted version of the transmitted frequency. This change in frequency is called as Doppler effect. There is range of frequency change which we call as Doppler spectrum.

B. *Delay Spread and Frequency Selectivity*

$$h(\tau, t) = \sum_{n=1}^{N(t)} \alpha_n(t) e^{-j\phi_n(t)} \delta(\tau - \tau_n(t)) \quad (5)$$

Based on different delays the frequency selectivity of the channel is determined. The channel impulse can be expressed as where the number of paths at any time instant t is taken as N(t).

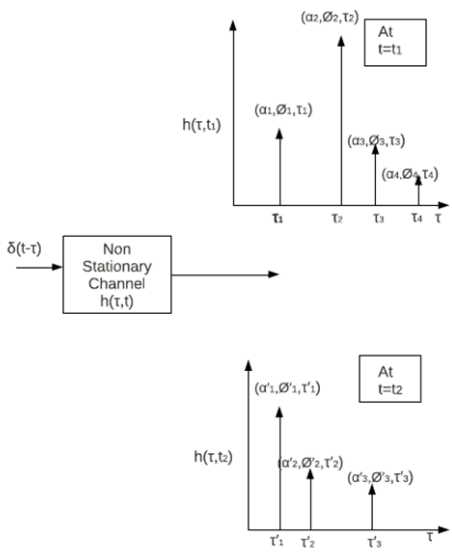

Fig. 3. Response of non-stationary channel to an impulse

The figure 3 depicts behavior of the channel to an impulse launched. It shows if an impulse is launched we receive copies of that impulse with different delay and with different amplitudes.

The time variant channel transfer function is defined as the Fourier transform along the delay domain.

$$H(f,t) = \int_{-\infty}^{\infty} h(\tau,t)e^{(-j2\pi f\tau)}d\tau \qquad (6)$$

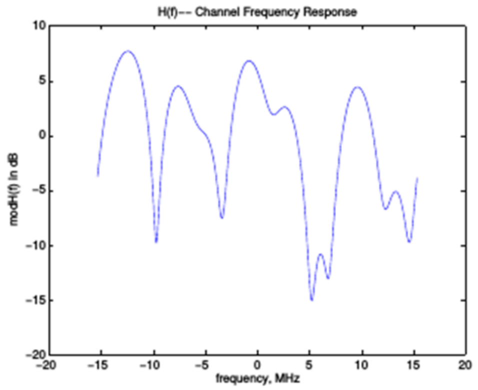

Fig. 4. Channel Frequency Response

The figure 4 depicts the channel behaviour to the different frequencies.

C. Effect of Wireless channel on OFDM

The effect of the medium to the OFDM symbols can be expressed as

$$y_m[n]=x_m[n]*h_m[n] + z_m[n]$$

$$Y_m[k]=X_m[k]H_m[k] + Z_m[k]$$

The OFDM symbol gets convolved with channel impulse response in time domain. In frequency domain this can be seen as simply the multiplication between transmitted OFDM symbol and channel transfer function when both are been taken in frequency domain.

VI. RESULTS AND THEIR ANALYSIS

A. Radio frames, slot taken for simulation

Number of radio frames=10

Number of slots in each radio frame= 20

Number of OFDM symbols taken in slot = 7

B. Transmitted Signal

B. Transmitted Signal

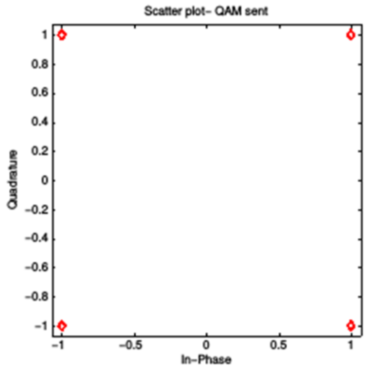

Fig. 5. QAM from symbol Mapper

The figure 5 shows the sent symbols been QAM.

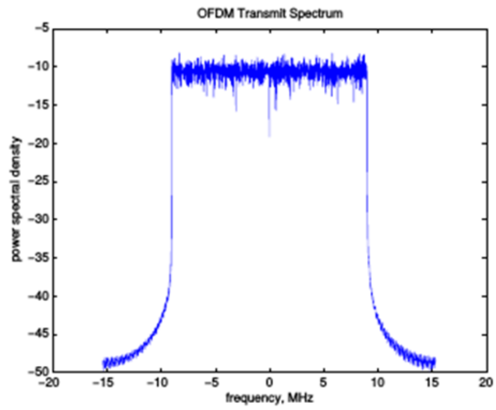

Fig. 6. Spectrum of LTE OFDM symbol

The figure 6 shows the transmitted LTE spectrum. We took a LTE bandwidth of 20 MHz for transmission.

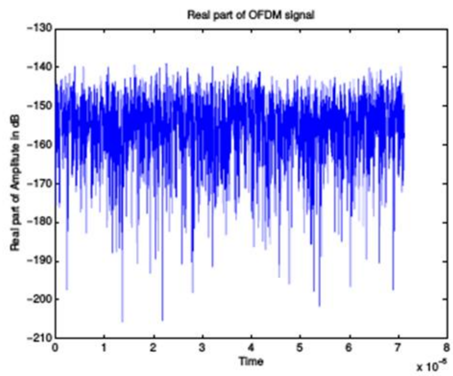

Fig. 7. Real part of OFDM symbol

The figure 7 shows the real part of the transmitted LTE-OFDM symbol.

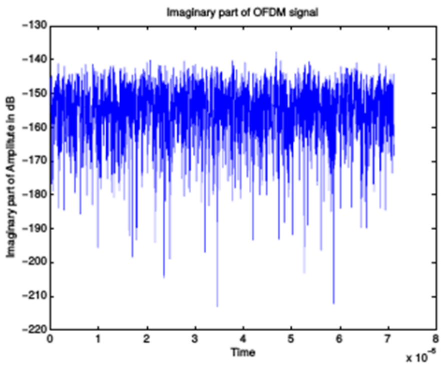

Fig. 8. Imaginary part of OFDM symbol

The figure 8 shows the imaginary part of the transmitted LTE-OFDM symbol.

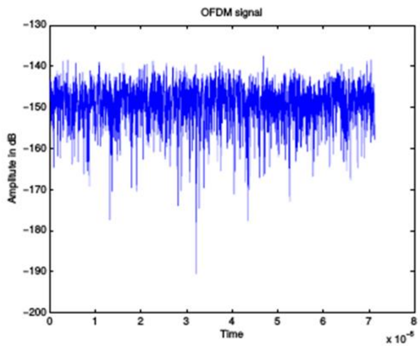

Fig. 9. Absolute Amplitude of OFDM symbol with its duration

Tu +TG

The figure 9 shows the absolute part of the transmitted LTE-OFDM symbol.

The figure 10 shows the received QAM symbols. Here I used SNR as 6 dB.

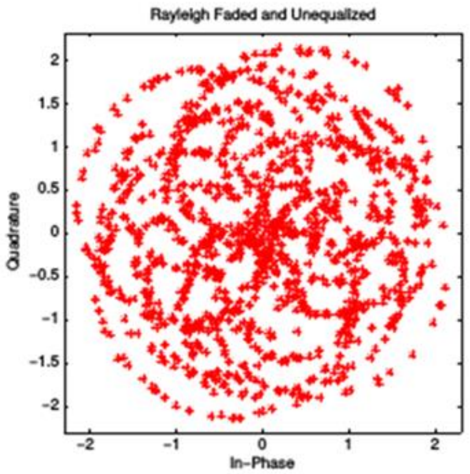

Fig. 10. Received symbol due to fading channel, SNR=6dB

It is seen that due the channel behaviour a symbol launched is received as multiple symbols with different amplitudes and with different phases. It is also seen that these symbols are scattered in nature. scattered in nature.

The figure 11 shows the received QAM symbols after equalization.

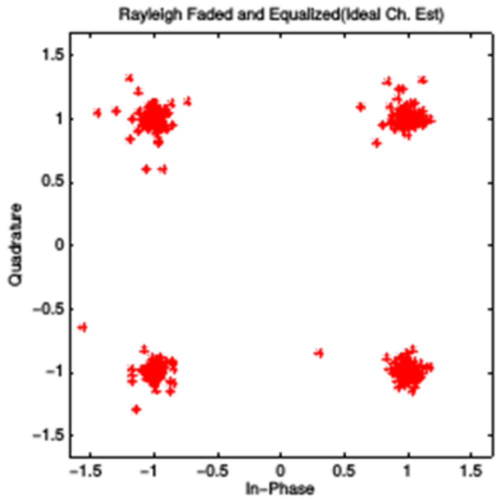

Fig. 11. Received symbols after equalization, Ch.Est ideal),SNR=6dB

From the figure it is seen that the symbols which were scattered, after passing through equalizer gets centered to the ideal transmitted locations

The figure 12 shows the bit error rate (BER) observed when the received equalized QAM symbols are demapped/demodulated into bits.

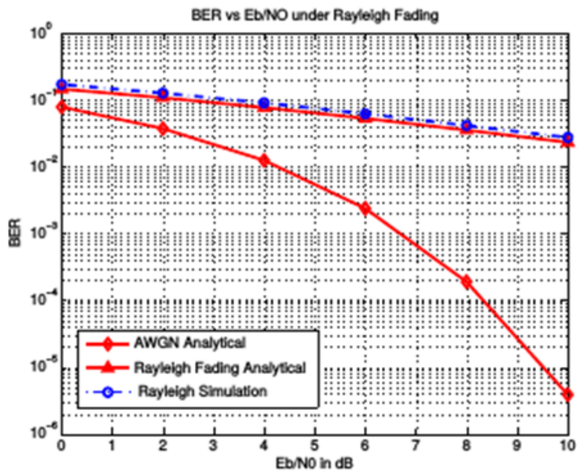

Fig. 12.
BER vs.Eb/N0 for 4QAM,SNR=6dB

In the figure BER of the received symbols/signal is seen as Rayleigh fading BER. It is seen that the BER of the received symbols/signal is always higher than that through the AWGN channel. Further it is also observed that our simulation BER matches that with the analytical results.

VII. C ONCLUSION

In this work OFDM has been analysed from LTE perspective. It is seen that our simulation result matches with the analytical results.

REFERENCES

[1] H. A. M. Ramli, K. Sandrasegaran, R. Basukala, and L. Wu, "Modeling and simulation of packet scheduling in the downlink long term evolution system," in 2009 15th Asia-Pacific Conference on Communications, Oct 2009, pp. 68–71.

[2] A. Daeinabi, K. Sandrasegaran, and X. Zhu, "Survey of intercell interference mitigation techniques in lte downlink networks," in Telecommunication Networks and Applications Conference (ATNAC), 2012 Australasian, 2012, pp. 1–6.

[3] K. Liu, F. Yin, W. Wang, and Y. Liu, "An efficient greedy loading algorithm for adaptive modulation in ofdm systems," in Personal, Indoor and Mobile Radio Communications, 2005. PIMRC 2005. IEEE 16th International Symposium on, vol. 2,

[4] Z. Song, K. Zhang, and Y. L. Guan, "Statistical adaptive modulation for qam-ofdm systems," in Global Telecommunications Conference, 2002. GLOBECOM '02. IEEE, vol. 1, Nov., pp. 706–710 vol.1.

[5] J. Jang and K.-B. Lee, "Transmit power adaptation for multiuser ofdm systems," Selected Areas in Communications, IEEE Journal on, vol. 21, no. 2, pp. 171–178, Feb 2003.

[6] W. Wang, T. Ottosson, M. Sternad, A. Ahlen, and A. Svensson, "Impact of multiuser diversity and channel variability on adaptive ofdm," in Vehicular Technology Conference, 2003. VTC 2003-Fall. 2003 IEEE 58th, vol. 1, Oct., pp. 547–551 Vol.1.

[7] M. Speth, S. Fechtel, G. Fock, and H. Meyr, "Optimum receiver design for wireless broad-band systems using ofdm.i," Communications, IEEE Transactions on, vol. 47, no. 11, pp. 1668–1677, 1999.

[8] X. Wang, T. Tjhung, Y. Wu, and B. Caron, "Ser performance evaluation and optimization of ofdm system with residual frequency and timing offsets from imperfect synchronization," Broadcasting, IEEE Transactions on, vol. 49, no. 2, pp. 170– 177, 2003.

[9] C. Y. Wong, R. Cheng, K. Lataief, and R. Murch, "Multiuser ofdm with adaptive subcarrier, bit, and power allocation," Selected Areas in Communications, IEEE Journal on, vol. 17, no. 10, pp. 1747 –1758, oct 1999.

[10] K. Nehra and M. Shikh-Bahaei, "Spectral efficiency of adaptive mqam/ofdm systems with cfo over fading channels,"
Vehicular Technology, IEEE Transactions on, vol. 60, no. 3,pp. 1240–1247, 2011.

P D Ashok received his B.E. degree in Electronics and Communications Engineering in 1999 from the Malaviya National Institute of Technology, Jaipur - India and M.E. degree in Electronics Engineering (spl. Digital Communication) from Devi Ahilya University Indore in 2008. He has been Assistant Professor at Devi Ahilya University Indore. Currently he his pursuing his Ph.D.