Study and Analysis of Orthogonal Frequency Division Multiplexing

RadhaKrishna Karne[1], D Rahul[2], Dr.A.Arunkumar[3], Karthik Kumar Vaigandla[4] Sravankumar Pagadala[5]

[1,2]Assistant Professor in ECE, CMR Institute of Technology, Hyderabad, Telangana, India
[3]Professor in CSE, MLRITM, Hyderabad, Telangana, India
[4]Assistant Professor in ECE, Balaji Institute of Technology and Science, Telangana, India
[5]Assistant Professor in ECE, JNTUH University College of Engineering Science and Technology Hyderabad (JNTUH UCESTH),India
Corresponding Author: krk.wgl@gmail.com,

ABSTRACT : Mobile wireless communications at high speeds are rapidly growing in popularity. Orthogonal frequency division multiplexing(OFDM) technology will emerge as a key technology for wireless communication systems to achieve spectral efficiency and high data capacity. A 4G communication system uses OFDM modulation. OFDM is a crucial enabling technology for wireless communication systems, both present and future. Various references have been used to establish a mathematical model of the performances of OFDM systems based on some factors. OFDM demonstrates high performance and is very tolerable to multipath delays and channel noise. We analyze the performance of OFDM in this paper based on power spectral density(PSD), spectral efficiency, signal- to-noise ratio(SNR), and bit error rate(BER).

Keywords: OFDM; QAM; channel noise; FFT; IFFT; PSD; PAPR; BER; SNR

1. INTRODUCTION

A faster bit rate and greater reliability seem to be the requisites for wireless multimedia communications, as they become more popular [1]. By using OFDM, we can achieve high communication speeds and high spectral efficiency, and similarly to accommodate more users. By providing multiplexing/multiple access technologies, the system supports next-generation wireless technology. The property of orthogonality allows for the transmission of several signals over a common channel without interference, so that the signals can be detected without interfering with one another [1-2]. When orthogonality is lost, information signals become distorted and transmission of low-quality information is compromised. The number of users connected to wireless communication systems is growing exponentially because of an increasing number of wireless applications. To resolve the fundamental problems, researchers and network designers need to find an efficient and low-latency way to ensure ultra-high data rates, wideradio coverage, and a huge number of interconnected devices [3]. The development of 5G wireless networks will be made easier by using intelligent and efficient technologies. As 5G prepares to meetmajor challenges, it must be prepared to meet reliability, security, and efficiency requirements [4].

We recommend high throughput and high speed for wireless communication in recent times. Since high-speed wired communications became popular decades ago, wireless communication has grown in popularity. Wireless communications degrade in many ways, including small scale fading, large scale fading, distortion, and HPA nonlinearities [4-5]. Multicarrier transmission is used instead of single carrier transmission to meet these requirements. Multiple transmission schemes, such as orthogonal frequency division multiplexing (OFDM), are used for high-speed transmission and voice communication. Long Term Evolution (LTE) improves the sensitivity and performance of wireless data networks that use various modulations. LTE has the benefit of significantly limiting the transfer latent period [6].

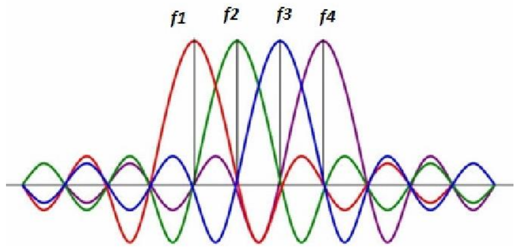

Figure 1. OFDM spectrum

In the modern wireless communication era, speed and throughput are critical. Since wired communications became popular decades ago, wireless communications have grown in popularity. OFDM is a common downlink protocol used by wireless networks. Because of their ability to adjust to channel conditions, it makes them ideal for difficult channels. OFDM is a great choice for 4G communications, its main disadvantage is its PAPR [7-8].
A more efficient modeling method that is less time consuming and more efficient than OFDM, is orthogonal multiplexing division (OFDM). In order to facilitate mail-order correspondences, OFDM is used in multiple remote correspondence benchmarks, such as digital video broadcasting (DVB). OFDM, however, poses several challenges for its development [8]. One of the major challenges is the higher PAPR. Thus, the OFDM receiver is able to detect nonlinear gadgets such as Digital Antennas(DA) and High Power Amplifiers(HPAs) with remarkable precision given their circuitry. As most remote frameworks make use of HPA, the HPA is typically implemented at the sender to obtain adequate transmission power, hence the HPA is normally placed near areas of saturation to generate the largest output power. The underlying band power of an HPA cannot be maintained if it does not operate linearly with a high power back-off. Inefficiency results in expensive transmission and high amplification costs. In order to make use of the features of OFDM, PAPR reduction techniques should be explored [9].

2. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

In terms of data connections, orthogonal frequency division multiplexing offers several major advantages. The OFDM technology is the technology that many modern wide-band and high-speed wireless networks use such as Wi-Fi, cellular phones, as well as many others[12]. In fact, as a result of OFDM using a large number of carriers each carrying low baud rate data, it is highly susceptible to specific fading, interruption, and spanning tree effects, while also delivering a high level of spectral efficiency [4]. OFDM is a form of Multicarrier Modulation that divides a frequency selective channel into a number of narrowband flat fading channels using overlap signals. Instead of transmitting the data sequentially on one carrier at a high symbol rate, the FFT encodes the block of symbols. By increasing the symbol time, the subcarriers are spaced orthogonally[19]. It is possible to eliminate multipath fading by making the symbol period of sub-channels longer as compared to multipath delay spread. Consequently, interference and fading effects are reduced when signal noise is deactivated. A complex signal processing technique is used in the transmitter and receiver sections of the radio to generate the OFDM modulation [8-10]. These techniques are known as Fast Fourier Transforms (FFTs) and Inverse FFTs. An OFDM system has the advantage of reducing the possibility of inter-symbol interference in a channel as a result of combating the adverse effects of multipath propagation[18]. Due to the overlap and contiguous nature of the channels, OFDM is also spectrally efficient.

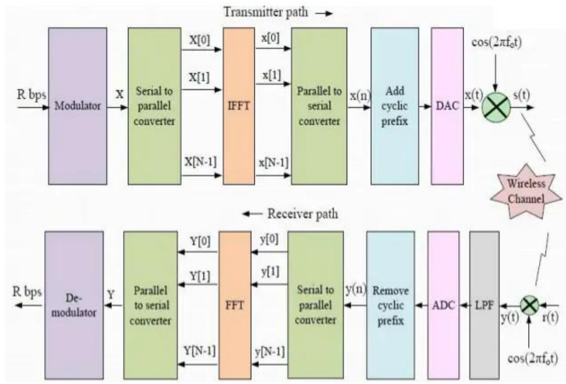

Figure 2 .OFDM - Block diagram

Figure 2 shows the OFDM block diagram. A convolution code is used in this system for encoding input data using FEC. Interleaving codes the bit stream results in diversity gain. Several channels bits are grouped together to map constellation points[11]. Specifically, complex numbers represent serial data. It is then mapped using techniques such as pilot mapping. In IFFT, serial to parallel data is converted using a serial to parallel converter. A digital modulation scheme (i.e. M-array QAM) is used to map the input binary sequence to constellation points. A serial-to-parallel converter converts the modulated baseband symbols into frames of length N, which are then performed on using an IFFT algorithm [14]. IFFT blocks are used to generate the baseband OFDM signals from the stream of baseband modulated symbols X(k). If there are N subcarriers in an OFDM signal, then the nth sample of the signal can be described as follows:

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} X(k) e^{\frac{j2\Pi kn}{N}} ; 0 \le n \le N-1$$

3. MULTIPATH FADING CHANNELS

Wireless communication fading is caused by various variables occurring during signal propagation that reduce the strength of the transmitted signal. There are many variables that can affect atmospheric conditions, such as rainfall and lightning, geographical location, time, radio frequency, etc[13]. It is possible for the channel between a transmitter and receiver to change with time as well, either because the transmitter and receiver are stationary or moving relative to one another, which may cause fading. A signal is propagated through the environment and encounters multiple reflectors before it reaches the receiver[20]. A result of this is that multiple routes are created and the receiver receives multiple copies of the transmitted signal. Each copy travels in a different route.

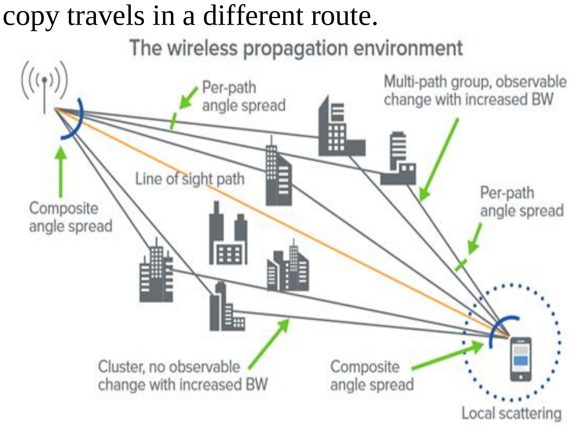

Figure 3. Wireless Propagation Environment

3.1 AWGN channel

By using AWGN Channel block, the AWGN channel block adds white Gaussian noise to complex signals or real signals. As the result of summing together real Gaussian noises, a real output signal is produced [15]. The block generates a complex output signal from a complex input signal by summing complex Gaussian noise. This block's sampling time is determined by the input signal. AWGN channels are commonly used to study OFDM. White noise with constant spectral density is linearly mixed with Gaussian noise having an amplitude distribution. Also, the choice of frequency, interference and fading are unconsidered. It is, however, still recognized as an ideal computational model due to its simplicity.

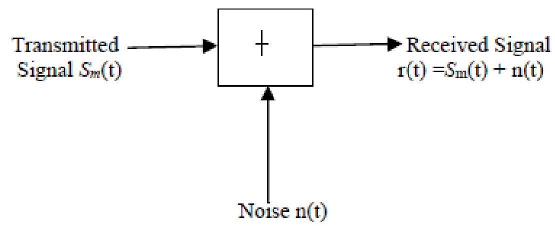

Figure 4. AWGN channel

3.2 Rayleigh Fading Channel

Rayleigh fading is primarily caused by multipath reception. Rayleigh fading channels have multipath components, each with a random amplitude and phase. Rayleigh distributions are commonly used for mobile radio channels. In order to assess the effects of propagation environments on radio signals, this statistical model can be used. Radio signals propagate at both the troposphere and ionosphere in this model, which can also be used to study the effects of densely populated urban areas on radio signals [16]. As far as we know, Rayleigh distributions govern the envelopes of the output of Gaussian noise signals in quadrature. Rayleigh distributions are time-dependent. This method is particularly useful when there is no line of sight between transmitter and receiver.

3.3 Rician Fading Channel

Stochastic processes, such as radiation propagation, are referred to as Rician fading. When the signal arrives at the receiver, at least one path changes. Rician fading is characterized by a stronger signal along a line-of-sight path. When Rician fading occurs, an amplitude gain is described by Rician distribution [17]. Rician fading occurs when there is more than one direct line of sight between transmitters and receivers.

4. SIMULATION RESULTS

Fig. 5 shows the spectral densities of OFDM. A Frequency spectrum of the original OFDM and OFDM baseband signal, where there is a padding of zeros in the middle shows in the fig. 6 and fig. 7.

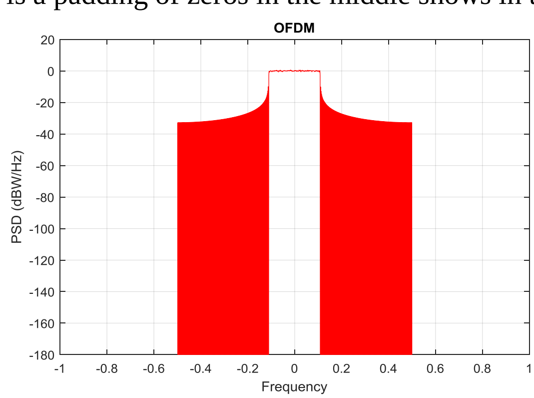

Fig. 5 PSD of OFDM

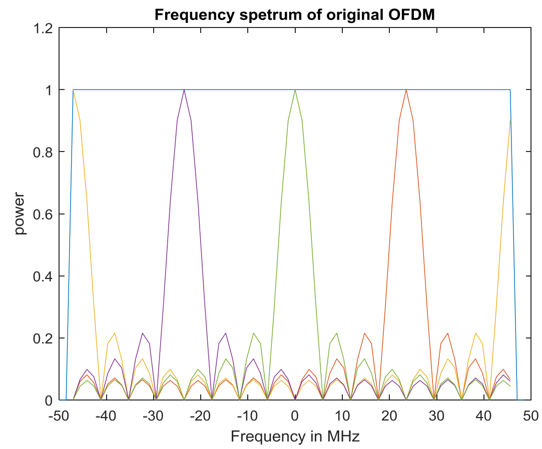

Fig. 6 Original OFDM - Spectrum

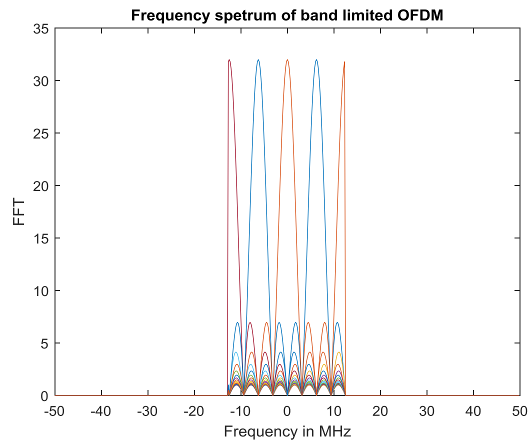

Fig. 7 OFDM baseband signal -Spectrum

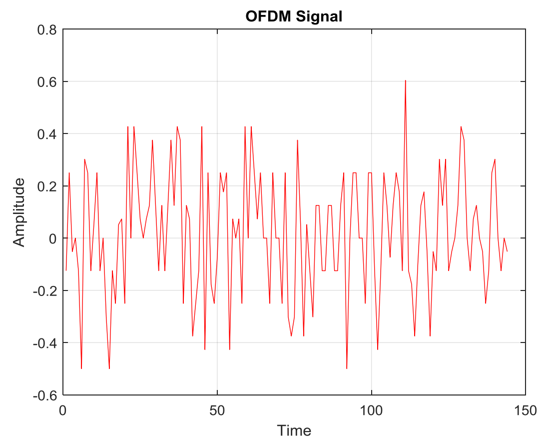

Fig. 8a OFDM signal

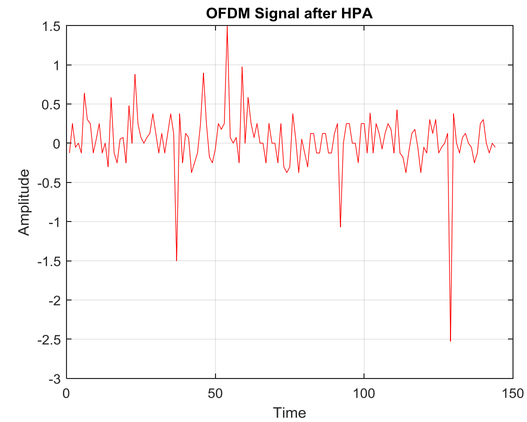

Fig. 8b OFDM signal after HPA

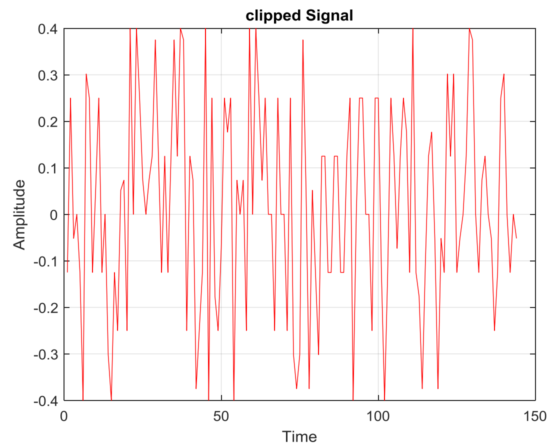

Fig. 9a Clipped OFDM Signal

Fig. 9b Clipped OFDM Signal after HPA

In fig. 10, simulation results demonstrate the relationship between BER versus SNR in decibels. Due to the increase in SNR, the BER is decreased.

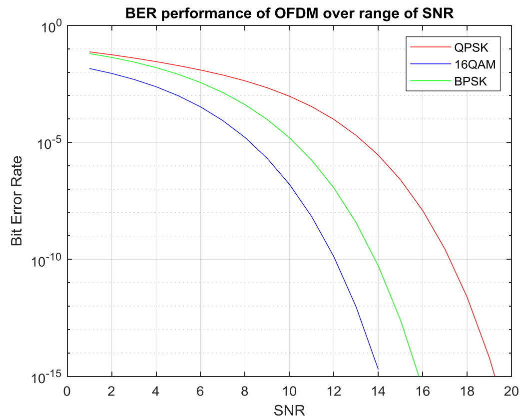

Fig. 10 BER vs SNR

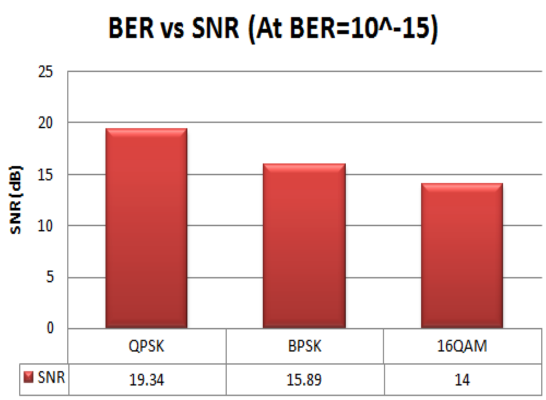

Figure 11. Comparison of BER & SNR

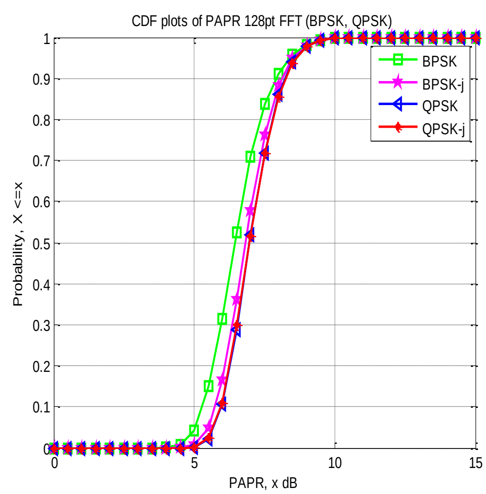

Figure 12. PAPR Comparison

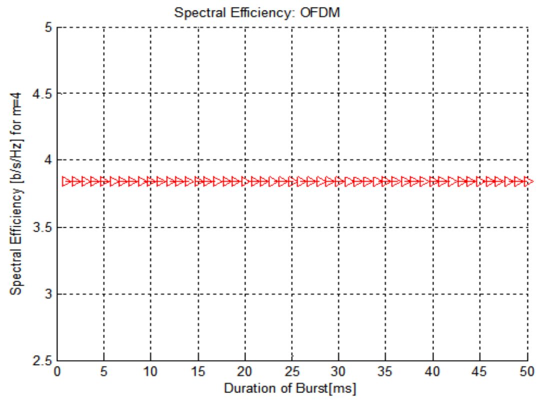

Figure 13. Spectral Efficiency

5. CONCLUSION

OFDM seems to be a suitable modulation technique for high-performance wireless communication. Compared to the usual single carrier transmission method, OFDM proves to be much more appropriate for multipath channels. Through the last decade, there has been an increase in demand for high speed wireless communication. It has been shown in this paper how OFDM plays an important role in wireless communication. In this paper, OFDM is discussed. A comparison was done for BER, SNR, frequency response, and power spectral density. The Spectral Efficiency, PSD, BER and SNR parameters have been simulated.

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