OFDM Based PHY Performance of IEEE 802.11a using Various Practical Channel Models

Narendra Giradkar, G. M. Asutkar, Abhijit Maidamwar

Abstract— ***Today with the advent of wireless communication and need for greater bandwidth and speed requirement with noise free reception, research has opened up a whole new market for wireless solutions. The IEEE 802.11a standards using orthogonal frequency division multiplexing (OFDM) can provide data rates up to 54 Mbps which makes good for high speed communications in wireless local area networks. In this paper, We evaluated the OFDM based PHY performance of IEEE 802.11a using various practical channel models such as Rician Fading, Rayleigh multipath Fading & AWGN. The effects of different transmission modes define in PHY on IEEE 802.11a system performance are studied using MATLAB SIMULINK. The performance is characterized in terms of 802.11a receivers bit error rates and signal to noise ratio for various modulation schemes such as 16 QAM, 64 QAM, BPSK and QPSK for different code rates as defined by the IEEE Standards 802.11a. All the Simulink models were studied using convolutional coder and Viterbi Decoder and standard OFDM format with 48 carriers, 4 pilots and a zero insertion in the middle.***

Keywords- OFDM, wireless network; 802.11

I. INTRODUCTION

The fast growth of wireless local area networks today has opened up a whole new market for wireless solutions. Released in 1999, the IEEE 802.11a is a standard for high-speed wireless data transfer that much of modern Wireless Local Area Network technology is based on. The past decade has shown major changes in the types of communications services provided to users and the infrastructure needed to support them. Besides the present-day telephony, Internet access, applications with remote servers, video on demand, and interactive multimedia are just a few examples of such services. Internet access is the service that has captured the biggest market and enjoys maximum penetration. Wire line communications networks providing these services are mostly known as wide area networks (WANs) and LANs. The overall market demand is basically for connectivity, mobility, and performance.

Wire line services can provide connectivity and performance, but not mobility together with connectivity. Wireless communications provide the solution to the requirements of mobility with connectivity. Thus, together with the growth of the Internet, there has been tremendous growth in the field of wireless communications. This has also been due to other inherent benefits of wireless, namely decreased wiring complexity, increased flexibility, and ease of installation. The main reason behind the growth of wireless has been WLANs or mobile technologies based on 2G/2.5G standards like Global System for Mobile Communications (GSM) and Personal Digital Cellular (PDC). These technologies mainly provide voice services and some data services at low data rates. 3G systems provide higher data rates with a maximum throughput of 2 Mbps. WLANs, on the other hand, provide connectivity, lower mobility, and much higher performance in terms of achievable data rate. They are many extensions of LANs providing high-speed data services with lower mobility. Complementary to WLANs are WPANs, which provide wireless data networking within a short range (~10m) at data rates of about 1 Mbps. WLANs provide a new forum of access technology in the LAN world. The new access technology fulfils several practical requirements (increased mobility, flexibility), but several technical problems remain unsolved. The problems of WLANs are tackled by researchers throughout the world.

1. Wireless technology

Wireless technologies have become increasingly popular in our everyday business and personal lives. Personal digital assistants (PDA) allow individuals to access calendars, e-mail, address and phone number lists, and the Internet. Some technologies even offer global positioning system (GPS) capabilities that can pinpoint the location of the device anywhere in the world. Wireless technologies promise to offer even more features and functions in the next few years. An increasing number of government agencies, businesses, and home users are using, or considering using, wireless technologies in their environments. Wireless technologies, in the simplest sense, enable one or more devices to communicate without physical connections, without requiring network or peripheral cabling. Wireless technologies use radio frequency transmissions as the means for transmitting and receiving data over the air, whereas wired technologies use cables. Wireless technologies range from complex systems, such as Wireless Local Area Networks (WLAN) and cell phones to simple devices such as wireless headphones, microphones, and other devices that do not process or store information.

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They also include infrared (IR) devices such as remote controls, some cordless computer keyboards and mice, and wireless hi-fi stereo headsets, all of which require a direct line of sight between the transmitter and the receiver to close the link. Wireless communications offer organizations and users many benefits such as portability and flexibility, increased productivity, and lower installation costs.

Wireless technologies cover a broad range of differing capabilities oriented toward different uses and needs. Wireless local area network (WLAN) devices, for instance, allow users to move their laptops from place to place within their offices without the need for wires and without losing network connectivity. Less wiring means greater flexibility, increased efficiency, and reduced wiring costs. However, risks are inherent in any wireless technology. Some of these risks are similar to those of wired networks; some are exacerbated by wireless connectivity; some are new. Perhaps the most significant source of risks in wireless networks is that the technology's underlying communications medium, the airwave, is open to intruders, making it the logical equivalent of an Ethernet port in the parking lot.

The loss of confidentiality and integrity and the threat of denial of service (DoS) attacks are risks typically associated with wireless communications. Unauthorized users may gain access to agency systems and information, corrupt the agency's data, consume network bandwidth, degrade network performance, launch attacks that prevent authorized users from accessing the network, or use agency resources to launch attacks on other networks.

1.1 WIRELESS NETWORK

Wireless networks serve as the transport mechanism between devices and among devices and the traditional wired networks (enterprise networks and the Internet). Wireless networks are many and diverse but are frequently categorized into three groups based on their coverage range:

Wireless Wide Area Networks (WWAN), WLANs, and Wireless Personal Area Networks (WPAN). WWAN includes wide coverage area technologies such as 2G cellular, Cellular Digital Packet Data (CDPD), and Global System for Mobile Communications (GSM), and Mobitex. WLAN, representing wireless local area networks, includes 802.11, HiperLAN, and several others. WPAN represents wireless personal area network technologies such as Bluetooth and IR.

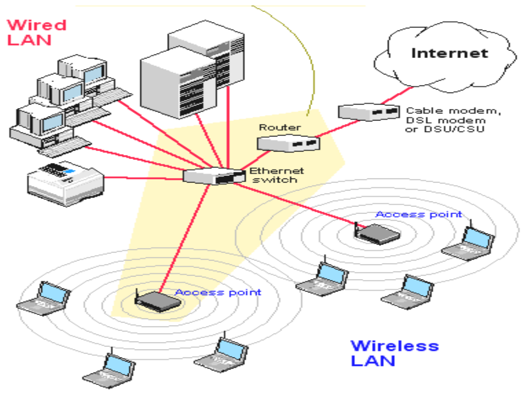

Figure 1 – An Example

1.2 WIRELESS STANDARD

WLANs are based on the IEEE 802.11 standard, which the IEEE first developed in 1997. The IEEE designed 802.11 to support medium-range, higher data rate applications, such as Ethernet networks, and to address mobile and portable stations. 802.11 is the original WLAN standard, designed for 1 Mbps to 2 Mbps wireless transmissions. It was followed in 1999 by 802.11a, which established a high-speed WLAN standard for the 5 GHz band and supported 54 Mbps. Also completed in 1999 was the 802.11b standard, which operates in the 2.4 - 2.48 GHz band and supports 11 Mbps. The 802.11b standard is currently the dominant standard for WLANs, providing sufficient speeds for most of today's applications. Because the 802.11b standard has been so widely adopted, the security weaknesses in the standard have been exposed. Another standard, 802.11g operates in the 2.4 GHz waveband, where current WLAN products based on the 802.11b standard operate.

2 ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

Orthogonal frequency division multiplexing (OFDM) is a promising technique for achieving high data rate and combating multipath fading in wireless communications. OFDM can be thought of as a hybrid of multi-carrier modulation (MCM) and frequency shift keying (FSK) modulation. MCM is the principle of transmitting data by dividing the stream into several parallel bit streams and modulating each of these data streams onto individual carriers or sub carriers (SCs); FSK modulation is a technique whereby data is transmitted on one carrier from a set of orthogonal carriers in each symbol duration. Orthogonality amongst the carriers is achieved by separating the carriers by an integer multiples of the inverse of symbol duration of the parallel bit streams. With OFDM, all the orthogonal carriers are transmitted simultaneously. In other words, the entire allocated channel is occupied through the aggregated sum of the narrow orthogonal subbands. By transmitting several symbols in parallel, the symbol duration is increased proportionately, which reduces the effects of ISI caused by the dispersive Rayleigh-fading environment.Over the past few years, there has been increasing emphasis on extending the services available on wired public telecommunications networks to mobile/movable non wired telecommunications users. At present, in addition to voice services, only low-bit-rate data services are available to mobile users. However, demands for wireless broadband multimedia communication systems (WBMCS) are anticipated within both the public and private sectors. Wired networks are cannot support extension to wireless mobile networks because mobile radio channels are more contaminated than wired data-transmission channels. We also cannot preserve the high Quality of Service required in wired networks. The mobile radio channel is characterized by multipath reception: the signal offered to the receiver contains not only a direct line-of-sight (LOS) radio wave, but also a large number of reflected radio waves that arrive at the receiver at different times.

Delayed signals are the result of reflections from terrain features such as trees, hills, mountains, vehicles, or buildings. These reflected, delayed waves interfere with the direct wave and cause intersymbol interference (ISI), which in turn causes significant degradation of network performance. A wireless network should be designed to minimize adverse effects. To create broadband multimedia mobile communication systems, it is necessary to use high-bit-rate transmission of at least several megabits per second. However, if digital data is transmitted at the rate of several megabits per second, the delay time of the delayed waves is greater than 1 symbol time. Using adaptive equalization techniques at the receiver is one method for equalizing these signals. There are practical difficulties in operating this equalization at several megabits per second with compact, low-cost hardware. To overcome such a multipath-fading environment with low complexity and to achieve WBMCS, the orthogonal frequency division multiplexing (OFDM) transmission scheme. OFDM is one of the applications of a parallel-data-transmission scheme, which reduces the influence of multipath fading and makes complex equalizers unnecessary.

In a classical parallel-data system, the total signal frequency band is divided into N nonoverlapping frequency sub channels. Each sub channel is modulated with a separate symbol, and then the N subchannels are frequency multiplexed. It seems good to avoid spectral overlap of channels to eliminate interchannel interference. However, this leads to inefficient use of the available spectrum. To cope with the inefficiency, the ideas proposed in the mid-1960s were to use parallel data and FDM with overlapping subchannels, in which each, carrying a signaling rate b, is spaced b apart in frequency to avoid the use of high-speed equalization and to combat impulsive noise and multipath distortion, as well as to use the available bandwidth fully. By using the overlapping multicarrier modulation technique, we save almost 50% of bandwidth. To realize this technique, however, we need to reduce cross talk between SCs, which means that we want orthogonality between the different modulated-carriers

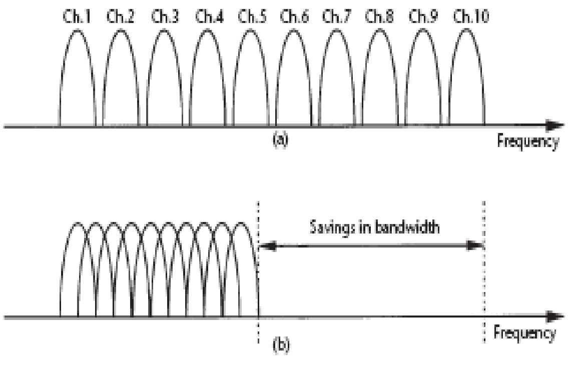

Figure 2- a) Conventional Multicarrier Technique b) Bandwidth saving using OFDM

The word "orthogonal" indicates that there is a precise mathematical relationship between the frequencies of the carriers in the system. In a normal FDM 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. It is possible, however, to arrange the carriers in an OFDM signal so that the sidebands of the individual carriers overlap and the signals are still received without adjacent carrier interference as shown in figure 4. To do this the carriers must be mathematically orthogonal. If the other carriers all beat down the frequencies that, in the time domain, have a whole number of cycles in the symbol period *T*, then the integration process results in zero contribution from all of these other carriers. Thus, the carriers are linearly independent (i.e., orthogonal) if the carrier spacing is a multiple of 1/*T*.

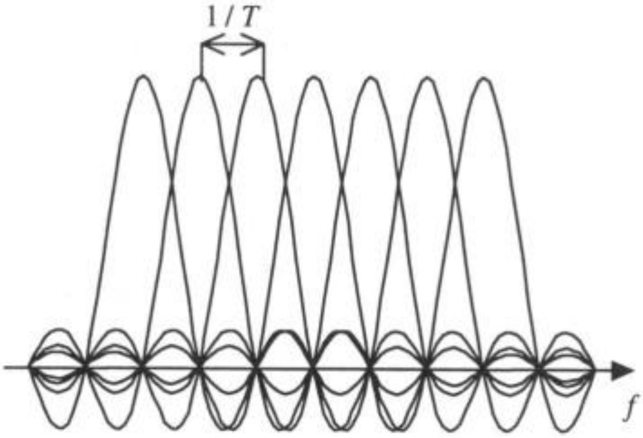

Figure 3- Spectrum overlap in OFDM

2.1 OFDM ADVANTAGES

The OFDM transmission scheme has the following key advantages:

• OFDM is an efficient way to deal with multipath; for a given delay spread, the implementation complexity is significantly lower than that of a single-carrier system with an equalizer.

• In relatively slow time-varying channels, it is possible to enhance capacity significantly by adapting the data rate per SC according to the signal-to-noise ratio (SNR) of that particular SC.

• OFDM is robust against narrowband interference because such interference affects only a small percentage of the SCs.

• OFDM makes single-frequency networks possible, which is especially attractive for broadcasting applications. On the other hand, OFDM also has some drawbacks compared with single carrier modulation:

• OFDM is more sensitive to frequency offset and phase noise.

• OFDM has a relatively large peak-to-average-power ratio, which tends to reduce the power efficiency of the radio frequency (RF) amplifier

3 OVERVIEW OF 802.11A LAN

The OFDM system used in IEEE 802.11a provides a WLAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mbps. The block diagram of 802.11a system is shown in figure 2.4.1.The system uses 52 sub carriers that are modulated using binary or quadrature phase shift keying (BPSK/QPSK), 16-quadrature amplitude modulation (QAM), or 64-QAM.

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Forward error correction coding (Convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4. At the transmitter, binary input data is encoded by the industry standard rate 1/2, constraint length 7, code with generator polynomials (133,171). The rate may be increased to 2/3 or 3/4 by puncturing the coded output bits. After interleaving, bits are mapped into complex numbers according to the modulation scheme that is being used. In order to facilitate coherent reception, four pilot values are added to each of the 48 data values, such that a total of 52 modulation values are reached per OFDM symbol. 52 values are then modulated onto 52 sub carriers by applying and Inverse Fast Fourier Transform (IFFT). A guard interval (cyclic prefix) is added to make the system robust to multipath propagation. Next, windowing is applied to attain a narrower output spectrum. The modulated and windowed digital output signals are converted to analog signals, which are then up converted to the proper channel in the 5 GHz band, amplified, and transmitted through an antenna. A typical OFDM receiver basically performs the reverse operations of the transmitter, together with additional training tasks. First, the receiver has to estimate frequency offset and symbol timing, using special training symbols in the preamble. Then, it can do a Fast Fourier Transform (FFT) for every OFDM symbol to recover 52 modulation values of all subcarriers. The training symbols and pilot subcarriers are used to correct for the channel response as well as any remaining phase drift. After taking FFT, a Viterbi decoder can be used to decode the information sequence with a trace back path of 34. A low complexity soft decision Viterbi decoder for a bit-interleaved system can be easily implemented. The preamble is composed of 10 repetitions of a "short training" sequence, and two repetitions of a "long training sequence". At the receiver end, short training sequences are used for Automatic Gain Control (AGC) convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver. Long training sequences are used for channel estimation and frequency acquisition.

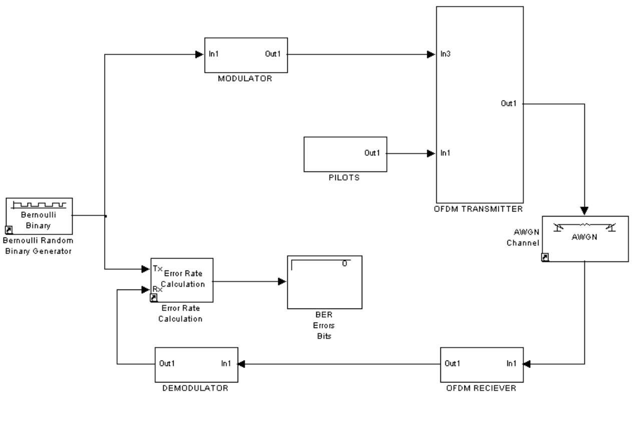


Fig.:- Wireless System and there performance

II. EXPERIMENTAL STUDY

This simulation is done with Matlab and Simulink as the tool. The simulation model is designed for AWGN channel with different modulation technique such as BPSK, QPSK,16 QAM, and 64 QAM using ½ and 3/4 code rate as per the table provided in literature review. Table 4.2 gives the main OFDM parameters in 802.11a standard, which we used in for this simulation. The 64 QAM scheme is simulated for 2/3 code rate instead of ½ code rate.

Steps of Simulation:

1. Designed eight simulation models for AWGN channel conditions, four for ½ code rate and four for ¾ code rate of all four modulation scheme. Simulated these entire eight simulation model using MATLAB programming code and evaluated the performance using BER Vs SNR plot.
2. Simulated two simulation models for different code rate of each modulation scheme for same channel conditions using programming and evaluated the performance using BER Vs SNR plot.

The different simulink models for AWGN channel condition are shown below including, (The subsystems for the visible blocks in the figure are not shown)

1. AWGN Channel

The various parameters set for the simulation for different modulation schemes are shown below. According to the code rate the Puncture vector was changed and the number of bits per frame was altered. The insert zero block parameters and the block interleaver parameters were set accordingly.

III. RESULT AND DISCUSSION

AWGN Channel for 1/2 Code Rate

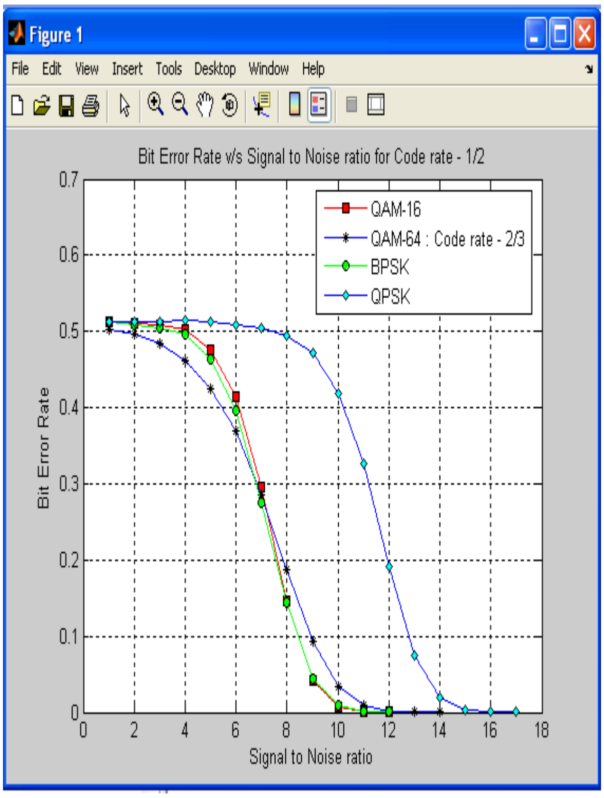


Figure 6 – BER Vs SNR plot for ½ code rate

AWGN Channel for 3/4 Code Rate

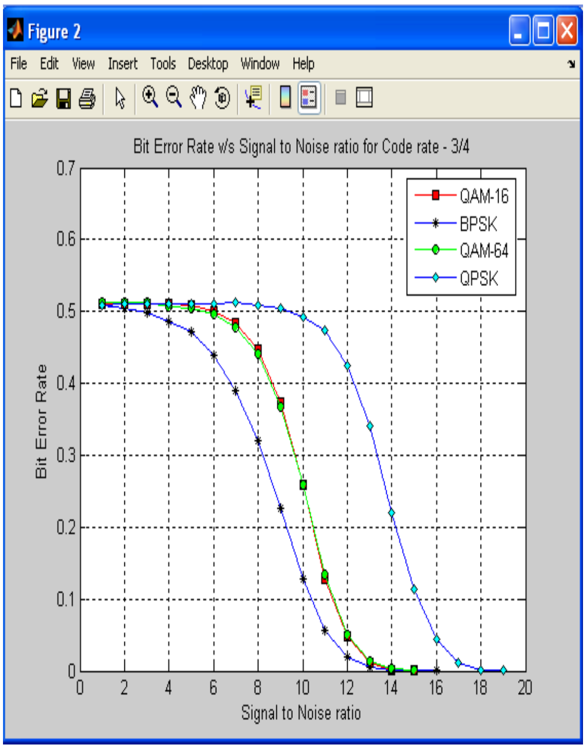


Figure 7 – BER Vs SNR plot for 3/4 code rate

BPSK Performance

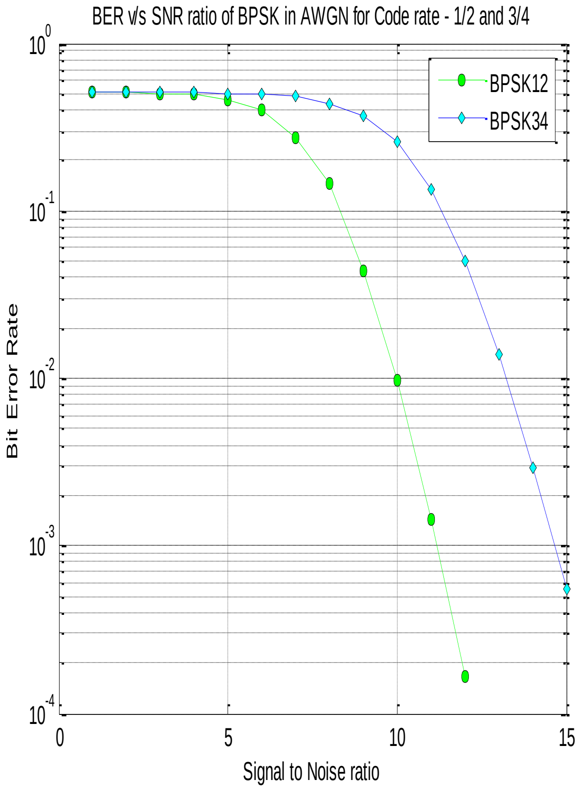


Fig-8 – BER Vs SNR plot of BPSK for 1/2 and 3/4 code rate

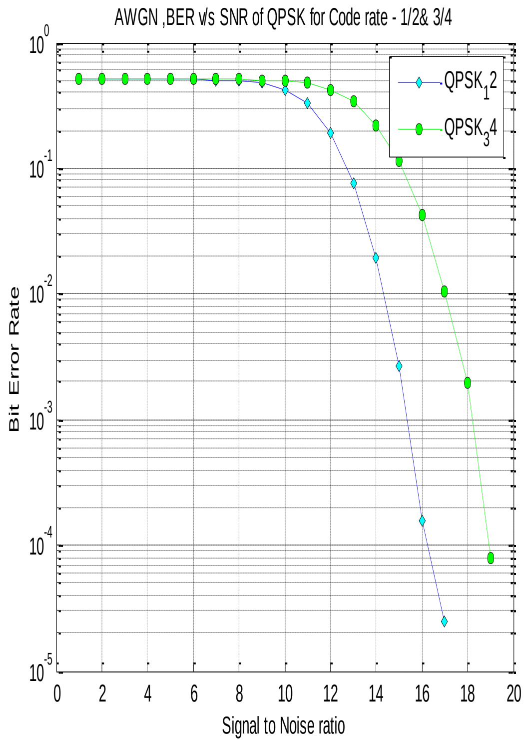
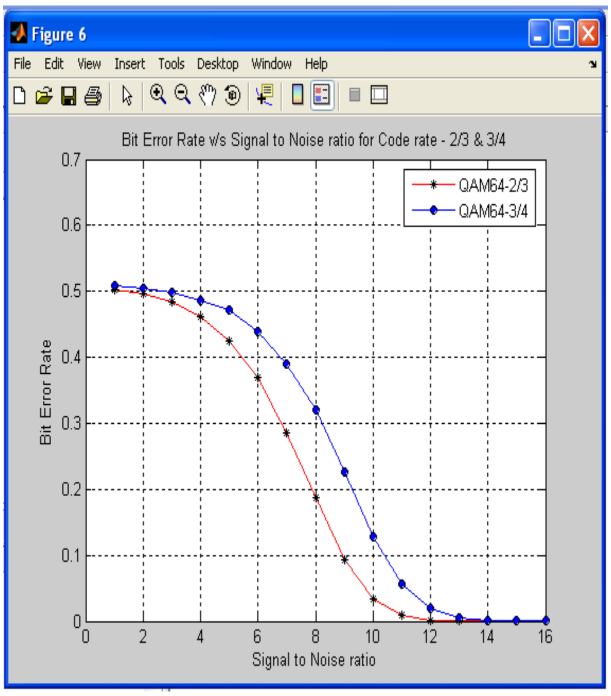


Figure 9 – BER Vs SNR plot of QPSK in

AWGN Channel for 1/2 and 3/4 code rate

QAM-64 Performance



BER Vs SNR plot of QAM-64 in AWGN Channel for 2/3 and 3/4 code rate

QAM-16 Performance

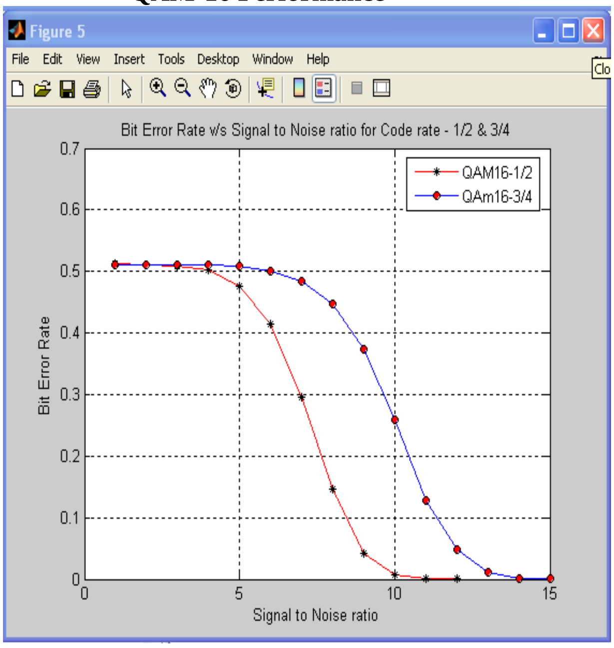


Figure 11 – BER Vs SNR plot of QAM-16 in AWGN Channel for 1/2 and 3/4 code rate

1. By simulation using AWGN Channel for ½ and ¾ code rate , it is found that the performance of BPSK modulation scheme is better than other modulation scheme such as QPSK, 16QAM and 64QAM as per the BER Vs SNR plot obtained shown in figure

2. comparing the result with two different coding rate for BPSK, QPSK, QAM16 and QAM-64 for coding rate ½ (2/3 for QAM-64) and ¾ as shown in figure , it is found that the performance of all the systems is better for ½ (2/3 for QAM-64) code rate as compared to ¾ code rate.

IV. CONCLUSION

In this project , We have examined the performance of the OFDM based IEEE 802.11aWLAN under AWGN fading channel condition with different modulation scheme (BPSK, QPSK, 16 QAM, 64 QAM) and code rate (1/2, 2/3, 3/4). While transmitting the signal in practical fading environmental condition, multipath fading effects occurs which causes the inter symbol interference. The effect of intersymbol interference can be reduced by using Guard interval and system performance can be improved .However from the performance, it concludes that BPSK performance is superior as compared to other schemes in noisy channel. The tolerable delay spread matches the time of the cyclic extension of the guard period, the BER rises rapidly due to the inter symbol interference. From the obtained experimental and simulation results, one can see that the outdoor multipath characteristics at 5.2 GHz with moving units cannot be considered constant over the one OFDM frame and, consequently, updating the channel estimates at the beginning of each frame, as currently recommended by the IEEE 802.11a standard, is not enough to accurately compensate multipath effects. Researchers had suggested two possible approaches that can be implemented to cope with the problem of inadequate channel compensation in 802.11a. The first approach calls for more advanced channel estimation equalization technique as compared to what is currently implemented in the commercially available 802.11a wireless cards. The second approach involves modifications at the upper layers of the OSI model. In IEEE 802.11a WLAN, basic coding rate is 1/2. By increasing coding rate, number of bits is to be punctured at the transmitting section and at receiving section, that punctured bits are filled by zero bits. As a result of this, distortion occurs at the receiver which causes the bit error rate degradation as seen from the results.

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