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Performance Study of Modulation Techniques over Fading Channel Using Multiple Access Technique

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Abstract: Every successful transmission need to be carefully calibrated for balancing noise interferences. Multifold increase in digital devices creates an unpredictable interference scenario. The aim of this work is to analyze the unpredictable noise interference scenarios and to choose modulation scheme according to the random interference parameters. OFDM scheme supports variety of modulation schemes like PSK and QAM techniques. A performance evaluation of various modulation techniques over varies fading environments has been studied in detail. BPSK, QPSK, M-ary QAM and PSK modulation has been employed in AWGN, RAYLEIGH and RICIAN fading channels. BER (Bit Error Rate) which is a SNR (Signal to Noise ratio) function is used to analyze the performance of data transmitted in wireless channels. The BER performance of the communication channel has been plotted for all combinations of channel parameters.

Key words: AWGN · RAYLEIGH · RICIAN · OFDM · BPSK · QPSK · PSK · QAM

INTRODUCTION

In wireless channels, several models have been introduced and used for investigating and calculating SNR [1-3]. All the models are a function of the distance between the sender and the receiver, the path loss exponent and the channel gain. Several PDF functions are available to model a time-variant parameter i.e. channel gain [4]. The three important and frequently used distributions are AWGN, Rayleigh and Rician models. The signal is detected and decoded by employing several replicas of the received signal. So, we consider multilink receiver structure. The Physical layer transmission mode consists of a specific set of modulation, binary convolution coding and data rate.

In this work, the performance of OFDM based Communication system adapting different coding scheme and digital modulation scheme is observed in using three different channels, such as Additive White Gaussian Noise, Rayleigh and Rician channel under BPSK, QPSK, 8 - PSK, 16 - PSK, 32 - PSK, 64 - PSK and 4-QAM, 8-QAM, 16-QAM, 32-QAM, 64-QAM modulation techniques. The Bit Error Rate performance over AWGN, Rayleigh and Rician channel is analyzed.

Modulation Techniques

Quadrature Amplitude Modulation: Quadrature amplitude modulation (QAM) is a modulation scheme used for both digital and analog signals. QAM doubles the effective bandwidth by combining two AM signals into a single channel. This allows multiple analog signals to be placed on a single carrier, for example, in television signals, which contain both color signals and sound. The two channels required for stereo sound signals can be carried by a single QAM. Digital QAM or quantized QAM is often used for radio communication systems from regular cellular to LTE including WiMAX and Wi-Fi. Figure 1 shows the various M-ary QAM techniques.

M-Ary QAM: The amplitude is allowed to vary with the phase and modulation scheme called Quadrature Amplitude Modulation (QAM) is obtained. It is such a class of non-constant envelope schemes that can achieve higher bandwidth efficiency than MPSK with the same average signal power.

Phase Shift Keying (PSK): PSK is a digital modulation scheme based on changing, or modulating, the initial phase of a carrier signal. PSK is used to represent digital information, such as binary digits zero (0) and one (1).

PSK is typically applied in wireless local area networks (WLAN), Bluetooth technology and radio frequency identification (RFID) standards used in biometric passport and contactless payment systems. Figure 2 shows the various M-ary PSK techniques.

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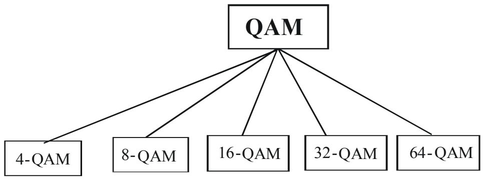

Fig. 1: M-ary QAM

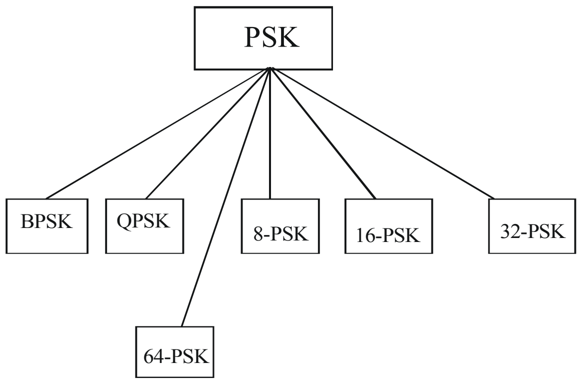

Fig. 2: M-ary PSK

M Array PSK(M-ar*ray Phase Shift Keying*): Multi-level modulation techniques permit high data rates within fixed bandwidth constraints. MPSK is a modulation where data bits select one of M phase shifted versions of the carrier to transmit the data.

Thus, the M possible waveforms all have the same amplitude and frequency but different phases. The signal constellations consist of M equally spaced points on a circle. In m-ary or multiple phase-shift keying, there are more than two phases, conventionally four (0, +90, -90 and 180 degrees) or eight (0, +45, -45, +90, -90, +135, -135 and 180 degrees). If there are four phases (m = 4), the MPSK mode is called quadrature phase-shift keying or quaternary phase-shift keying (QPSK) and each phase shift represents two signal elements. If there are eight phases (m = 8), the MPSK mode is known as octal phase-shift keying (OPSK) and each phase shift represents three signal elements.

Bit Error Rate (BER): The BER is the number of bit errors per unit time. The bit error ratio is the number of bit errors divided by the total number of transferred bits during a studied time interval.

BER= (Bits in Error) / (Total bits transmitted)

BER can also be defined in terms of the probability of error (POE) and which is represented by.

POE = ☻ (1-erf) ☻

where erf is the error function, ☻ is the energy in one bit and ☻ is the noise power spectral density (noise power in a 1Hz bandwidth). The error function is different for the each of the various modulation methods. The POE is a proportional to ☻, which is a form of signal-to-noise ratio. The energy per bit, ☻, can be determined by dividing the carrier power by the bit rate. As an energy measure, Eb has the unit of joules. ☻ is in power that is joules per second, so, ☻ is a dimensionless term, or is a numerical ratio.

If the medium between the transmitter and receiver is good and the SNR ratio is high, then the bit error rate will be very small - possibly insignificant and having no noticeable effect on the overall system However if noise can be detected, then there is chance that the bit error rate will need to be considered. BER is to evaluate the performance of the communication system, mostly expressed as a percentage. IEEE 802.11 standard has the capability to track the BER of its link and the modulation implemented to data rate and exchange to FEC, which is utilized to set the bit error rate as low error rate for data applications. BER performance more commonly affected by the noise. Quantization errors will also affect BER performance, by incorrect or uncertain reconstruction of the digital waveform.

Steps to Calculate BER for Channel:

- Initialize the various parameters such as number of subcarriers, number of pilots, guard interval and SNR.
- Initialize the USER-MOD QAM or PSK.
- Initialize the M-ary variables2, 4, 8, 16, 32 and 64
- Generate G matrix by using formula.
- Generate OFDM symbols for random input data and encode it by using trellis algorithm.
- Modulate the encoded data by USER-MOD modulation technique.
- For AWGN or RAYLEIGH or RICIAN channel, add the complex Gaussian noise to the data.
- Take variance of noise and add data to the noise.
- The channel is estimated by evaluatingthe mean square error (MSE) and Bit Error Rate(BER) using LS, LSModified, MMSE algorithm.
- Finally the received data is demodulated and decoded by using viterbi algorithm.
- Plot the graph for BER and end the process.

Signa to Noise Ratio (SNR): SNR is the ratio of the amplitude of a data signal which can either analog or digital signal to the amplitude of noise in a channel through which it is transmitted at a given point in time. SNR is typically expressed in decibels (dB). SNR measures the quality of a transmission channel or an audio signal over a network channel. Greater the ratio, it is easier to identify and subsequently isolate and eliminate the source of noise.

A SNR of zero designates that the desired signal is virtually indistinguishable from the unwanted noise, it is the ratio of the received signal strength over the noise strength in the frequency range of the operation. Noise strength, in general, can include the noise in the environment and other unwanted signals (interference). BER is inversely cognate to SNR, that is high BER causes low SNR. High BER causes increases packet loss, increment in delay and decreases throughput [5]. The exact relation between the SNR and the BER is not easy to determine in the multi-channel environment.SNR is commonly used to evaluate the quality of a communication link.

$$SNR = 20\log_{10} \text{(Signal Power / Noise Power) Db}$$

Types of Fading: According to the effect of multipath, there are two types of fading namely large scale fading and small scale fading. In the large scale fading, the received signal power varies gradually due to signal attenuation determined by the geometry of the path profile. If the signal moves over a distance in the order of wavelength, in small scale fading it leads to rapid fluctuation of the phase and amplitude of the signal. There are two types of fading according to the effect of Doppler Spread namely slow and fast fading. When the coherence time of the channel is large relative to the delay constraint of the channel then slow fading will occurred. The amplitude and phase change imposed by the channel can be considered roughly constant over the period of use. The events such as shadowing, where a large obstruction such as a hill or large building obscures the main signal path between the transmitter and the receiver, causes the slow fading. When the coherence time of the channel is small relative to the delay constraint of the channel causes the fast fading. The amplitude and phase change imposed by the channel varies considerably over the period of use.

Fading Models: There are many models that describe the phenomenon of small scale fading. Out of these models, Rayleigh fading, Ricean fading and Nakagami fading models are most widely used. The Rayleigh fading is primarily caused by multipath reception [6]. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal. It is a reasonable model for troposphere and ionospheres? signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no line of sight between the transmitter and receiver.

The Rician fading model is similar to the Rayleigh fading model, except that in Rician fading, a strong dominant component is present. This dominant component is a stationary (nonfading) signal and is commonly known as the LOS (Line of Sight Component) [7]. The simplest radio environment in which a wireless communications system or a local positioning system or proximity detector based on Time of-flight will have to operate is the Additive-White Gaussian Noise (AWGN) environment. AWGN is the commonly used to transmit signal while signals travel from the channel and simulate background noise of channel. The mathematical expression in received signal is given in equation (1)

$$r(t) = s(t) + n(t) \tag{1}$$

where s(t) is transmitted signal and n(t) is background noise.

An AWGN channel adds white Gaussian noise to the signal that passes through it. It is the basic communication channel model and used as a standard channel model. The transmitted signal gets disturbed by a simple additive white Gaussian noise process.

RESULTS AND DISCUSSION

Figure 2 to 13 shows the Bit error rate performance of AWGN, Rayleigh and Rician channel using different modulation techniques namely, M-ary PSK and M-ary QAM. When Signal to Noise ratio is high the BPSK, QPSK and 4-QAM has BER of 0.0001, 0.0354 and 0.0139 in AWGN, Rayleigh and Rician fading channels respectively.From the tabulation we can understand that for different channels like AWGN, Rayleigh, Rician SNR ratio is better for BPSK, QPSK and 4-QAM.

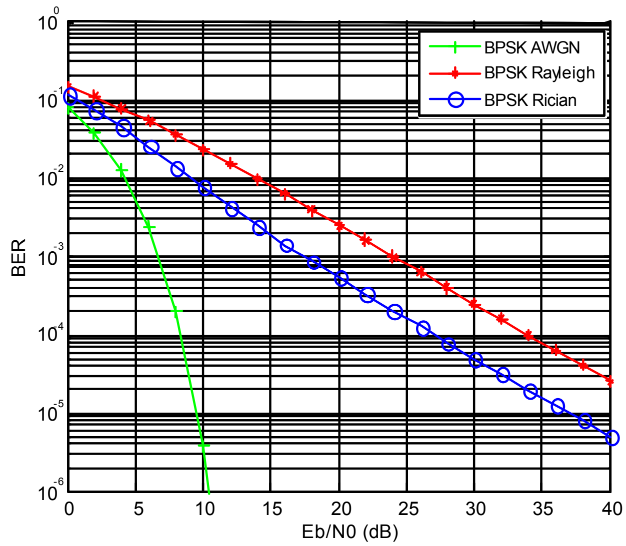

Fig. 3: Output of BPSK for AWGN, RAYLEIGH and RICIAN channels

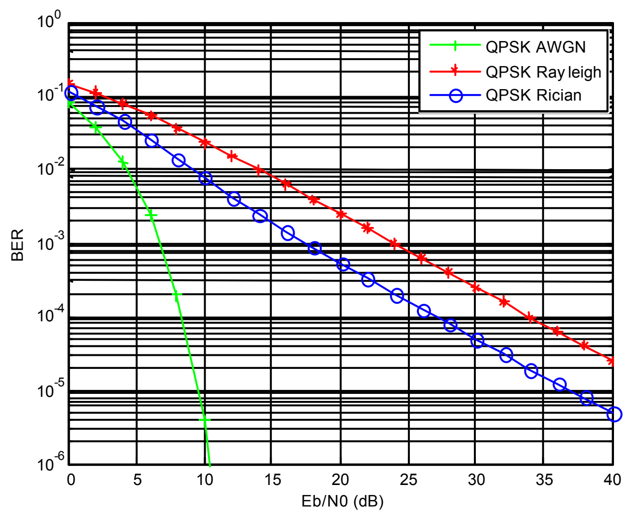

Fig. 4: Output of QPSK for AWGN, RAYLEIGH and RICIAN channels

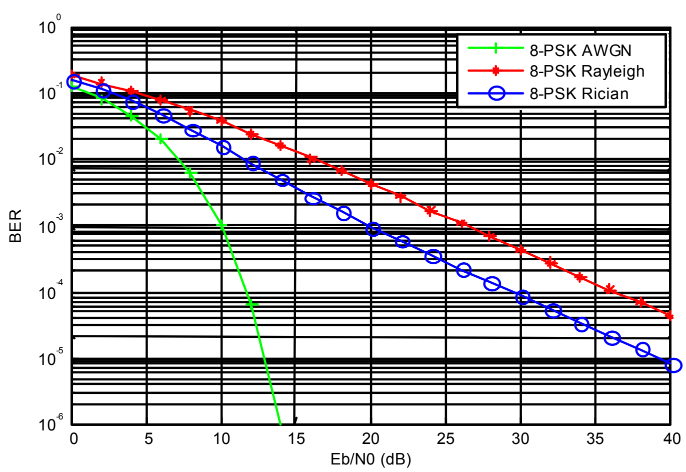

Fig. 5: Output of 8-PSK for AWGN, RAYLEIGH and RICIAN channels

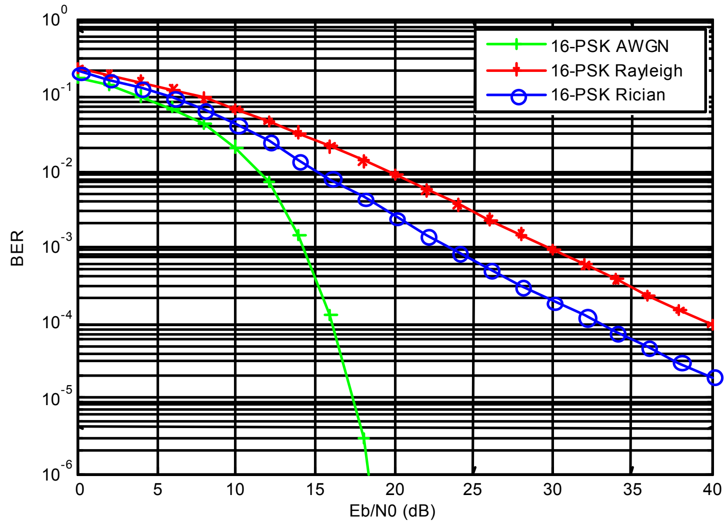

Fig. 6: Output of 16-PSK for AWGN, RAYLEIGH and RICIAN channels

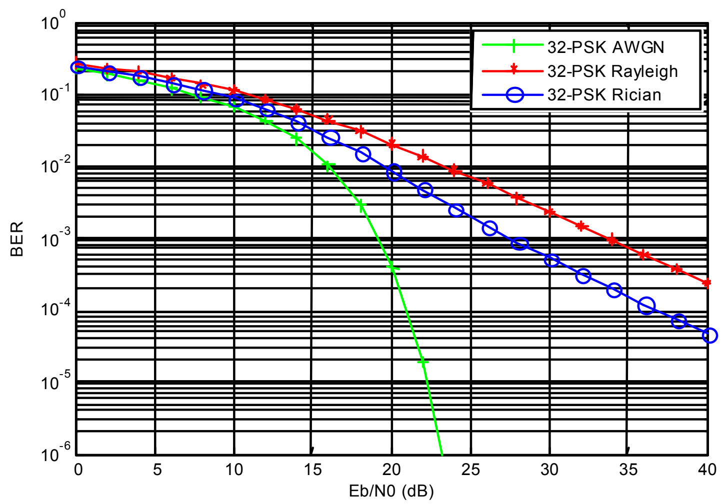

Fig. 7: Output of 32-PSK for AWGN, RAYLEIGH and RICIAN channels

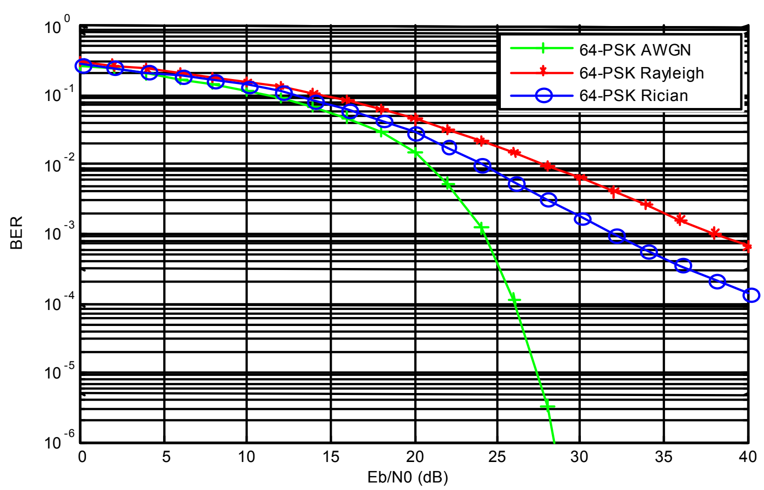

Fig. 8: Output of 64-PSK for AWGN, RAYLEIGH and RICIAN channels

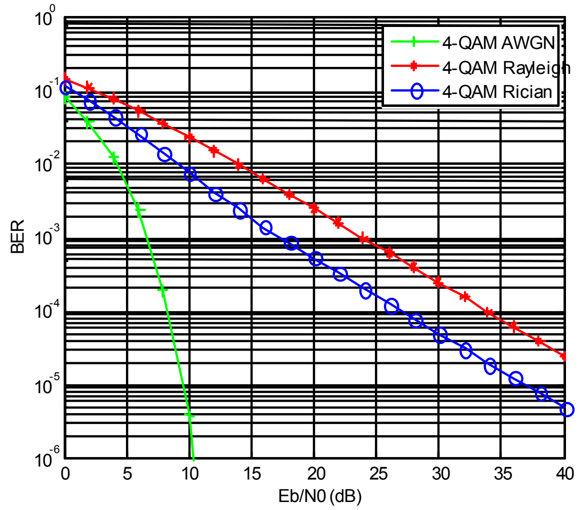

Fig. 9: Output of 4-QAM for AWGN, RAYLEIGH and RICIAN channels

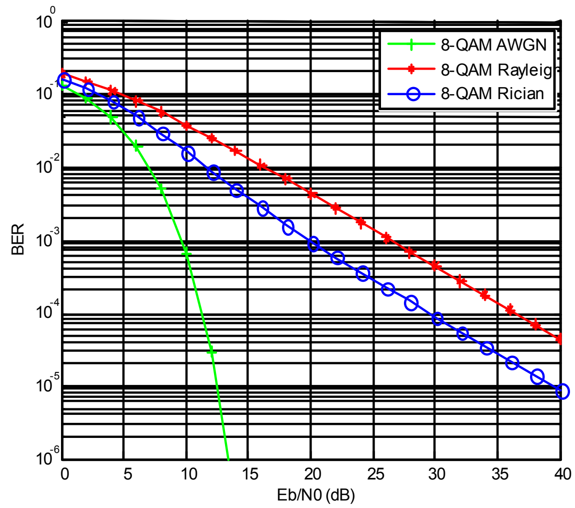

Fig. 10: Output of 8-QAM for AWGN, RAYLEIGH and RICIAN channels

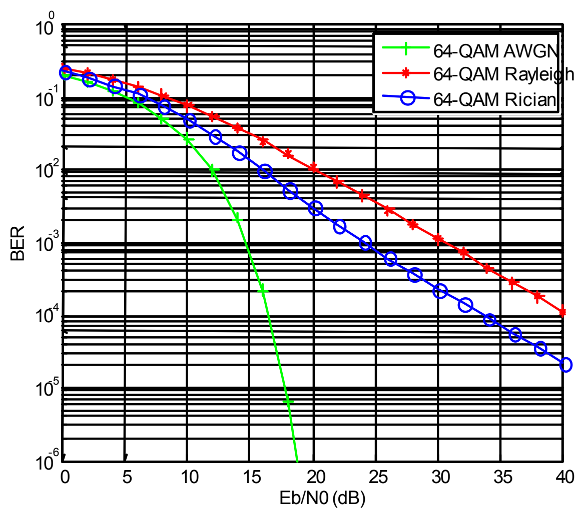

Fig. 11: Output of 16-QAM for AWGN, RAYLEIGH and RICIAN channels

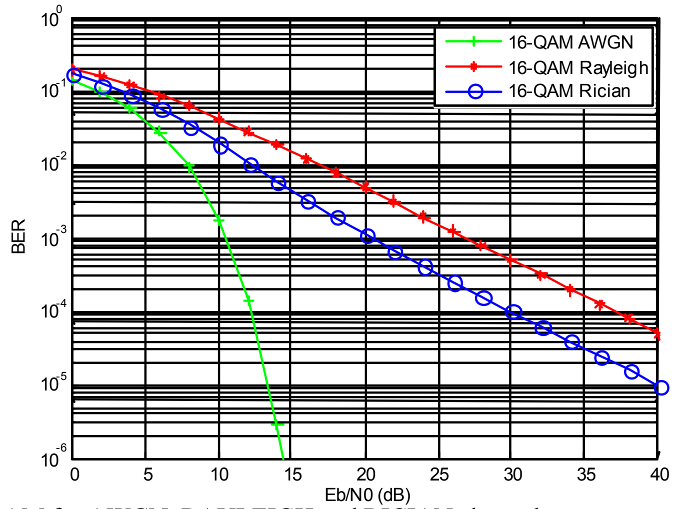

Fig. 12: Output of 32-QAM for AWGN, RAYLEIGH and RICIAN channels

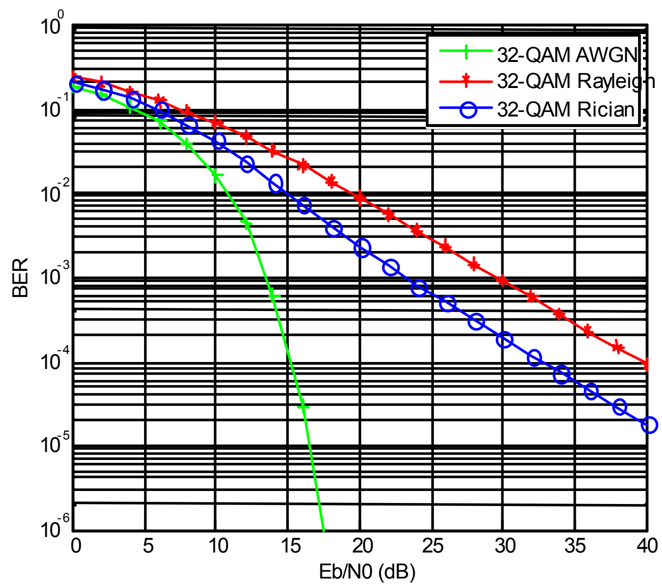

Fig. 13: Output of 32-QAM for AWGN, RAYLEIGH and RICIAN channels

Table 1: BER versus SNR comparison over AWGN channel with M-array PSK and M-array QAM

	Bit Error Rate(BER), AWGN										
SNR (db)	BPSK	QPSK	8-PSK	16-PSK	32-PSK	64-PSK	4-QAM	8-QAM	16-QAM	32- QAM	64- QAM
2	0.0375	0.0375	0.0806	0.1338	0.1892	0.2521	0.0375	0.0867	0.0977	0.1461	0.157
4	0.0125	0.0125	0.0458	0.0986	0.1538	0.2223	0.0125	0.0474	0.0586	0.1066	0.1185
6	0.0023	0.0023	0.0204	0.0681	0.1207	0.1926	0.0023	0.0191	0.0278	0.0702	0.0838
8	0.0001	0.0001	0.0061	0.0414	0.0914	0.1452	0.0001	0.005	0.0092	0.0387	0.0523

Table 2: BER versus SNR comparison over RAYLEIGH channel with M-array PSK and M-array QAM

	Bit Error Rate(BER), Rayleigh										
SNR (db)	BPSK	QPSK	8-PSK	16-PSK	32-PSK	64-PSK	4-QAM	8- QAM	16- QAM	32- QAM	64- QAM
2	0.1085	0.1085	0.1424	0.1879	0.2326	0.2521	0.1085	0.1482	0.157	0.1997	0.2089
4	0.0771	0.0771	0.1071	0.1521	0.1992	0.2409	0.0771	0.1114	0.1199	0.1613	0.1715
6	0.053	0.053	0.0774	0.1192	0.167	0.2118	0.043	0.0803	0.0878	0.1256	0.1362
8	0.0354	0.0354	0.0541	0.09	0.1365	0.1831	0.0354	0.0559	0.0619	0.0939	0.1042

Table 3: BER versus SNR comparison over RICIAN channel with M-array PSK and M-array QAM

	Bit Error Rate(BER), Rician										
SNR (db)	BPSK	QPSK	8-PSK	16-PSK	32-PSK	64-PSK	4-QAM	8- QAM	16- QAM	32- QAM	64- QAM
2	0.0743	0.0743	0.1118	0.1614	0.2109	0.2521	0.0743	0.1177	0.1271	0.1735	0.1837
4	0.0447	0.0447	0.0761	0.0986	0.1762	0.2223	0.0447	0.0796	0.0889	0.1336	0.1449
6	0.0253	0.0253	0.0481	0.0681	0.1435	0.1926	0.0253	0.0496	0.0575	0.0971	0.1091
8	0.0139	0.0139	0.0284	0.0414	0.1133	0.1634	0.0139	0.0289	0.0345	0.0657	0.0772

CONCLUSION

A detailed analysis of the performance scopes of various OFDM modulation schemes has been found using MATLAB communication tool block set and the analysis results has been tabulated for better understanding. A combination of OFDMA Phase shift keying along with its M-ary modulation index variations (4, 8, 16, 32, 64) and a combination of Quadrature amplitude modulation along with its M-ary modulation index variations has been experimented with signal gain(EBN_0) variations. The corresponding BER curves for the actual SNR have been predicted as initial research. To test the real time performance scope of these modulation schemes, the performance evaluation has been tested with different real time noise condition like static Additive white gaussion noise and the frequency selective fading Rayleigh and rician noise fading. By analysing all the combination 2-MaryPSK (BPSK) modulation scheme is proven to be a better alternative than all other modulation schemes even in fading conditions.

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