Enhancing Performance of Orthogonal Frequency Division Multiplexing (OFDM) Based on Fast Fourier Transform (FFT) in Wireless Communication System

Aimi Nabilah Ismail, Wan Zakiah Wan Ismail, Nor Azlina Abd Aziz, Nur Asyiqin Amir Hamzah and Irneza Ismail

Abstract- ***Orthogonal Frequency Division Multiplexing (OFDM) is one of the multicarrier transmission techniques used in wireless communication system. It has many benefits such as robust in channel fading and has high spectral density. The main objective of OFDM implementation in wireless communication system is to achieve less or zero Bit Error Rate (BER). However, OFDM design complexity, requirement and selection of the suitable modulation method are among the current issues. Thus, this paper aims to investigate the performance of OFDM in wireless communication by developing two OFDM based system designs. The transmitter, channel and receiver are designed based on OFDM system principles. Forward Error Correction (FEC) method is applied to reduce the BER. Both OFDM designs produce less BER with zero BER for the second OFDM design. The investigation study shows that the performance of OFDM can be enhanced by applying Fast Fourier Transform (FFT) technique. Zero BER can be achieved if the suitable modulation scheme is applied in the system. The developed designs are not complex, suitable to be applied for IEEE 802.11 standard. The BER performance can be influenced by the types of channels, signal to noise ratio (SNR) and various modulation schemes. Thus, this study can be used as a guidance to implement the OFDM in the current or future wireless communication system.***

Keywords: OFDM, enhanced BER performance, various modulation schemes and multipath channels

I. INTRODUCTION

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Orthogonal frequency division multiplexing (OFDM) is a multiplexing method to encode digital data on multiple carrier frequencies for wireless communication system that consisted of transmitter, channel and receiver [1]. In OFDM system, the input source that is in serial form is firstly converted into parallel form before the modulation technique is done. The data applied in OFDM is in frequency domain. The high data rate stream in frequency domain is serial-to-parallel converted into a data block S_k= [S_k[0], S_k[M-1]] for modulation onto *M* parallel subcarriers [1]. The Inverse Fast Fourier Transform (IFFT) converts frequency domain signal into time domain signal. Then, the signal is passed to the channel before reaching the receiver. At the receiver, the time domain signal is converted back to the frequency domain signal using the Fast Fourier Transform (FFT). Once the signal has passed through the parallel to serial converter, the original signal is recovered from the system [1-2].

OFDM has some advantages such as high spectral efficiency, low receiver complexity and has simple implementation by fast Fourier [3-4]. For 4G and 5G community, OFDM not only provides high spectral efficiency, power efficiency and immunity to frequency selective fading channels but also provides high data rate transmissions with multipath delay speed tolerance [5].

In [6], the performance of different modulation techniques in OFDM system is investigated. The modulation techniques used to see the tradeoff between system capacity and system robustness. Besides that, High Frequency (HF) OFDM performance is compared with the conventional OFDM communication system [7]. The design of conventional OFDM is similar with HF OFDM except that HF OFDM consists of several key techniques such as channel coding/decoding, windowing, interleaving/de-interleaving, synchronization, cyclic prefix and channel estimation while conventional OFDM uses IFFT/FFT, cyclic postfix and cyclic prefix [7].

In [8], OFDM has become the benchmark for physical layer implementation of these diversified digital audio and video wireless communication because OFDM is very suitable for high speed data transmission. The article also states that convolutional coding and interleaving are needed for any wireless data transmission. In [8], the simulation results in terms of bits error rate (BER) analysis for AWGN channel, Rician channel and Rayleigh fading channel are presented.

In principle, OFDM is a multicarrier transmission technique that divides the bandwidth into countless carriers which each of them is modulated by a low data rate stream [9]. The term 'orthogonal' shows a precise mathematical relationship among frequencies of carriers in the system [9]. This orthogonality condition can be seen when each sub-carrier frequencies and spacing are chosen so that they are orthogonal to one another. No guard bands are required as their spectra do not interfere with one another. OFDM is like Frequency Division Multiplexing in which many user accesses are attained by subdividing the accessible spectra into several number of channels which are assigned to users [6]. Besides that, the concept of orthogonality is introduced when integral product of the signal is zero in given time interval as shown in (1)[10].

$$\int_0^T \cos(2\pi mft)\cos(2\pi nft)\,dt = 0, n \neq m \qquad (1)$$

Recent studies of OFDM in wireless communication system involves hybrid system combining OFDM and free-space optics (FSO) [11], OFDM based on Non-Orthogonal Multiple Access (NOMA) [12] and OFDM for wireless communication systems in underwater [13]. The hybrid OFDM and FSO system [11] uses a channel coding scheme and trellis code modulation which gives less decoding complexity and reasonable delay, suitable for weak turbulence. OFDM based on NOMA [12] is created to serve the fifth generation (5G) wireless communication which allows many users to operate using the same frequency band leading to massive connectivity. Lian *et. al* [13] discuss optical OFDM such as DC-biased optical OFDM, asymmetrically-clipped optical OFDM and unipolar OFDM for underwater wireless communication system. Issues such as bandwidth limit of the light source, peak power constraint and turbulence are also discussed in [13].

Most of the new OFDM systems introduce issues such as delay, stability and complexity. Eventhough the hybrid OFDM systems currently exist, the principle of OFDM is still the same. Thus, this paper introduces two OFDM designs to study the performance of Orthogonal Frequency Division Multiplexing in wireless communication in terms of Bit Error Rate (BER) and Signal to Noise Ratio (SNR). The designs are simple and not complex but able to achieve less or zero BER. The effects of various modulation schemes and multipath channels on OFDM are also analyzed.

II. METHODOLOGY

Study on performance of OFDM is implemented based on two designs: (1) OFDM Modulation and Demodulation system and (2) OFDM based Model. Both designs are developed according to basic components of digital communication system which consists of transmitter, channel and receiver. Both designs are created to enhance the performance of bit error rate (BER) in wireless communication system. The parameters used in both designs such as number of carriers, IFFT/FFT period, sequence duration, coded bits and data bits per OFDM symbols are based on [14-16] according to IEEE 802.11 standard.

A. Design 1: OFDM Modulation and Demodulation in a basic communication system.

The design is created in order to analyze the performance of OFDM modulation and demodulation in a basic wireless communication system as shown in Fig. 1. In the transmitter block design, the Bernouli Binary Generator is used to generate random binary numbers using a Bernoulli distribution and the bit is modulated in digital modulator (Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK), M-ary Phase Shift Keying (MPSK) or Quadrature Amplitude Modulation (QAM)) to modify the input carrier signal based on the information as the message signal. The bit is normalized before it goes through OFDM transmitter block design to ensure that the output has similar dimensions as the input. OFDM transmitter is a subsystem consists of combination of several block diagrams like PN sequence generator, multiport selector, matrix concatenate, zero pads for OFDM, IFFT and cyclic prefix. The information from the generator creates a bit stream. The modulator scheme is used to delineate information into symbols. Then, symbols are sent through IFFT block design in order to perform IFFT operation to create *N* parallel information streams. IFFT/FFT is applied in the system to reduce cost, complexity and size of the system. FFT converts signal from time domain to frequency domain while IFFT converts back the signal from frequency domain to time domain. To reduce the Inter Symbol Interference (ISI), cyclic prefix (CP) is included before transmission [14-16].

The normalized bit goes through the noisy Multipath Rician Channel with AWGN and received by the receiver block design consists of OFDM receiver, denormalizer and QAM demodulator. In OFDM system receiver, zero pads and cyclic prefix which are added at the transmitter will be removed. The FFT block diagram then converts back signal from time domain to frequency domain. To use the retrieved signal for further processing, the pilot carrier is removed. The generated output after the pilot carrier removal is in a parallel form [15]. The receiver signal is demodulated and compared with the signal in the transmitter then the error rate can be measured. The constellation diagrams are used to compare the information before the OFDM transmitter and after the OFDM receiver. The detection and correction processes of the received information errors from the multipath fading channel are done using the Forward Error Correction (FEC) technique where the error control is done by ensuring the receiver only recognizes the part of information which contains no obvious errors [17-19].

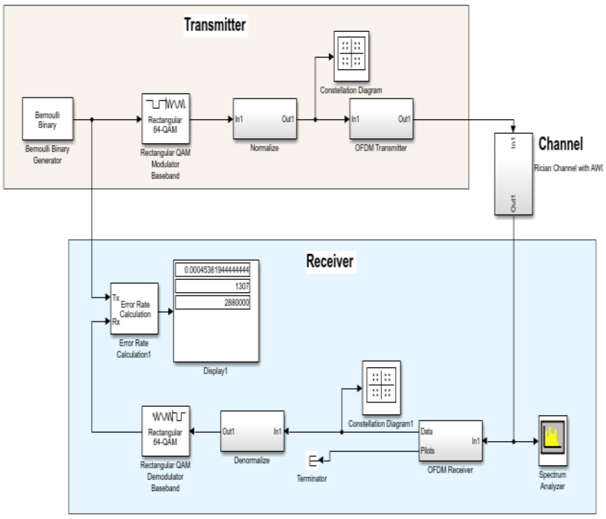


Fig. 1. OFDM system 64-QAM in a noisy Multipath Rician Channel

B. Design 2: OFDM based Model

The purpose of the second design (Fig. 2) is to analyze the BER using different modulation techniques (BPSK, QPSK MPSK and QAM) based on OFDM system.

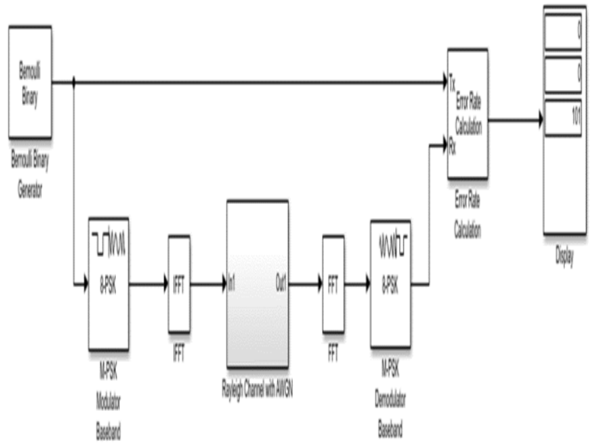


Fig. 2. OFDM based system using BPSK Modulation

In both designs, signal from Multipath Rician and Multipath Rayleigh Fading Channels are compared and the signal to noise ratio (SNR) is increased up to 60 dB.

III. RESULTS AND DISCUSSION

Two designs of OFDM based systems are developed to study OFDM in wireless communication which can generate less bit error rate (BER). BER of various modulation schemes (BPSK, QPSK, MPSK and QAM) based OFDM system are compared. BER is one of the performance parameters for wireless communication system where the possibility of errors during the signal transmission is measured based on (2) and (3) [16].

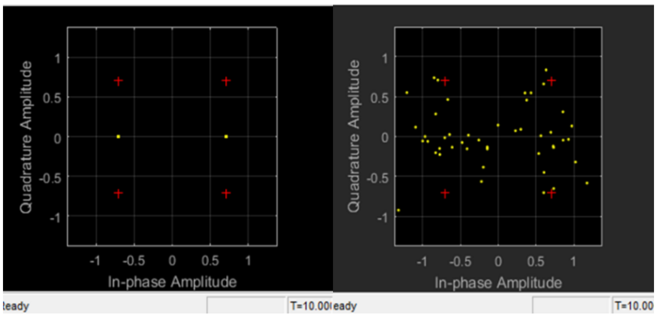
BER= No of errors / Total no. of transmitted bits (2)

$$A = \frac{1}{2}(1 - erf)\sqrt{\frac{E_b}{N_0}} \quad (3)$$

where *erf* is the error function, E_b represents the energy in one bit and N_0 refers to the noise spectral density.

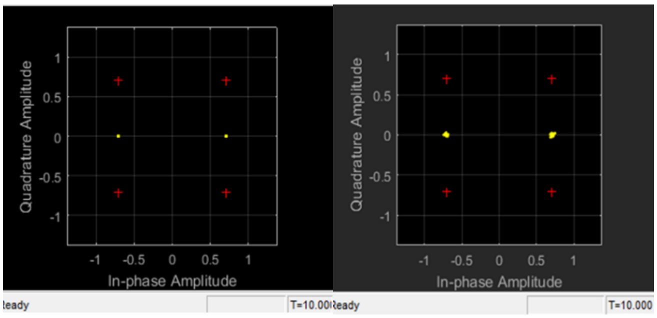
A. Design 1: OFDM Modulation and Demodulation complete system.

The signal from the OFDM transmitter and the OFDM receiver for Binary Phase Shift Keying (BPSK), Quadrature Phase Shift Keying (QPSK) and 64 Quadrature Amplitude Modulation (64 QAM) is compared based on constellation diagram. The noise decreases as the signal to noise ratio (SNR) increases. Fig. 3 shows the constellation diagram of the signal entering the OFDM transmitter and exiting the OFDM receiver for SNR~30 dB. Fig. 3(b) shows that the symbols are mapped outside of the ideal reference point areas due to higher noise or interference levels. When the SNR increases up to ~60 dB (Fig. 4), the symbols mapped on the reference points which indicate that the receiver has very low noise and interference. Higher SNR will generate symbols at the receiver similar with the symbols at the transmitter. It is due to less bit error rate (BER). The relationship between SNR and BER can be seen in Table-I and II. The similar phenomena are also observed for QPSK and QAM.



(a) (b)

Fig. 3 Constellation diagram (a) at transmitter and (b) at receiver when SNR = 30 dB.



(a) (b)

Fig. 4 (a) Constellation diagram (a) at transmitter and (b) at receiver when SNR = 60 dB.

Table-I presents bit error rate (BER) for BPSK, QPSK, 16-QAM and 64-QAM in OFDM system using noisy Multipath Rayleigh channel. The bit error rate (BER) decreases when the signal to noise ratio (SNR) increases as shown in Table-I and Fig. 5. Fig. 5 shows that the decreasing pattern of BER is quite similar for QPSK, 16-QAM and 64-QAM whereas the BER decreases sharply for BPSK. When BER ~10^{-3}, the SNR values for BPSK, QPSK, 16-QAM and 64-QAM are 50 dB, 55 dB, 56 dB and 58 dB respectively. At 60 dB, the BER for BPSK is almost zero. These results show that BPSK has lower BER for specific SNR value than other modulation techniques leading to the most suitable modulation technique for data transmission in the noisy Multipath Rayleigh Channel.

Table- I Generated BER for Different Modulation Techniques in Noisy Multipath Rayleigh Fading Channel

SNR (Eb/No) dB	Bit Error Rate (BER)			
	BPSK	**QPSK**	**16-QAM**	**64-QAM**
0	0.4748	0.4875	0.4676	0.4586
10	0.4196	0.4595	0.4499	0.4539
20	0.2693	0.3748	0.3827	0.3541
30	0.0700	0.1808	0.2048	0.1692
40	0.0082	0.0315	0.0450	0.0363
50	0.0010	0.0034	0.0051	0.0041
60	0.0001	0.0004	0.0006	0.0005

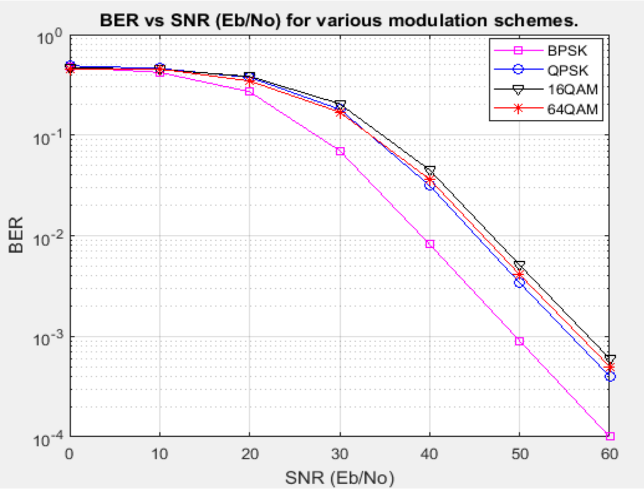


Fig. 5. BER plot for various modulation schemes in noisy Multipath Rayleigh Fading Channel

Besides that, the performance of OFDM is also studied through a noisy Multipath Rician Fading using BPSK, QPSK, 16-QAM and 64-QAM respectively. Table-II and Fig. 6 shows that BPSK gives the best performance compared to other modulation techniques. Data in Table-II and Fig. 6 indicate that BPSK modulation is the most suitable modulation technique for signal transmission in the noisy Multipath Rician Channel. We notice that the BER performance for both Multipath Rayleigh and Rician Channels is quite similar.

Table-11: Generated BER for Different Modulation Techniques in Noisy Multipath Rician Fading

SNR (Eb/No)	Bit Error Rate (BER)			
	BPSK	**QPSK**	**16-QAM**	**64-QAM**
0	0.4735	0.4867	0.4673	0.4582
10	0.4168	0.4577	0.4496	0.4347
20	0.2614	0.3707	0.3796	0.3402
30	0.0625	0.1698	0.1960	0.1613
40	0.0089	0.0284	0.0405	0.0329
50	0.0013	0.0042	0.0059	0.0047
60	0.0001	0.0005	0.0008	0.0006

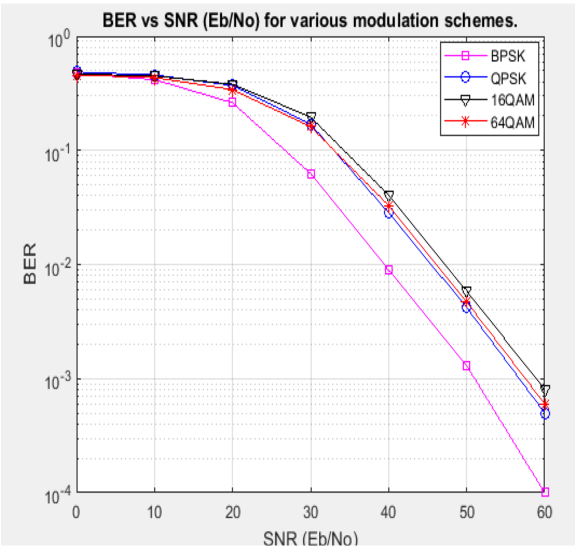


Fig. 6. BER plot for various modulation schemes in noisy Multipath Rician Channel

B. Design 2: BER Analysis for BPSK, QPSK, MPSK and QAM based OFDM System

In modulation based OFDM system, the BER is also analyzed using BPSK, QPSK, 8-PSK, 16-PSK, 16-QAM and 64-QAM through Rayleigh and Rician Fading Channels respectively. In the OFDM based system design through Rayleigh Channel, the value of SNR is varied from 0 dB up to 20 dB. It can be clearly seen in Table-III and Fig. 7 that the BER reduces as the value of signal to noise ratio (SNR) increases. BPSK shows the least BER indicating the best performance of OFDM based system whereas 16-PSK shows the highest BER signifying the worst performance of OFDM based system. BER for both BPSK and 16-QAM reach 0 at SNR~12dB showing the best performance of OFDM based design in wireless communication system. These results show that BPSK and 64-QAM introduce less interference and noise to the system. The worst performance of OFDM based system is by using 8-PSK where the system needs SNR~20 dB to obtain zero-bit error rate. Eventhough BPSK has good performance in the OFDM based system design, it is preferable to use the 64-QAM modulation technique for data transmission in the noisy Multipath Rayleigh Fading Channel. This is because 64-QAM modulation technique can carry large amount of data which is 288 coded bits per OFDM [9].

Table-III: Generated BER for different modulation techniques in noisy Multipath Rayleigh Fading Channel

SNR (Eb/No)	Bit Error Rate (BER)					
	BPSK	**QPSK**	**8-PSK**	**16-PSK**	**16-QAM**	**64-QAM**
0	0.2276	0.5623	0.7129	0.8218	0.4950	0.4829
2	0.1833	0.4237	0.6436	0.7822	0.4000	0.3959
4	0.1015	0.3484	0.5842	0.7624	0.2732	0.2676
6	0.0560	0.2793	0.4455	0.7327	0.1356	0.1347
8	0.0240	0.1580	0.3762	0.6634	0.0510	0.0530
10	0.0050	0.0699	0.2574	0.5743	0.0170	0.0140
12	0	0.0170	0.2277	0.4455	0.0010	0
14	0	0.0050	0.0990	0.3762	0	0
16	0	0	0.0594	0.2376	0	0
18	0	0	0.0099	0.1089	0	0
20	0	0	0	0.0594	0	0

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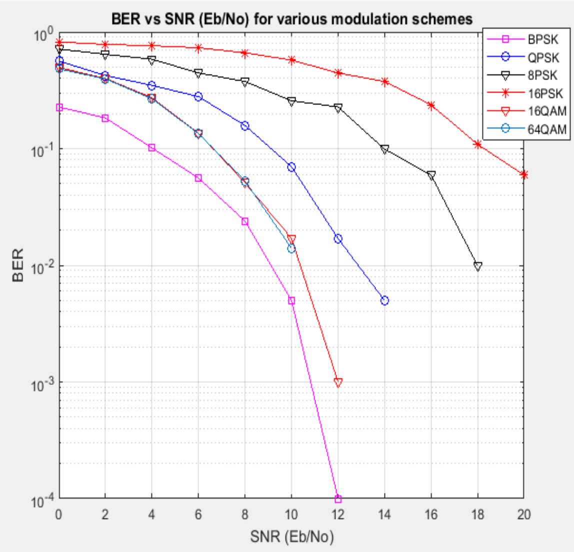

Fig. 7. BER plot for various modulation schemes in noisy Multipath Rayleigh Fading Channel

The OFDM based system is also designed for Multipath Rician Fading Channel as shown in Table- IV. It can be seen clearly that the BER also reduces as the value of signal to noise ratio (SNR) increases. BPSK still gives the best performance compared to other modulation techniques by reaching zero-bit error rate at 10 dB. Meanwhile, 16-QAM and 64-QAM need 14 dB to reach zero-bit error rate. The worst performance is shown by 8-PSK and 16-PSK where the modulation techniques need ~20 dB of SNR value to reach zero BER. This information can be clearly seen in Fig. 8. BPSK modulation technique is more preferred to transmit data in the noisy Multipath Rician Fading Channel. OFDM system using BPSK gives less noise and interference but carrying less data. For a complex and large data transmission system, QAM is highly preferred. From this data, the performance of BER between these two different noisy multipath fading channels are analyzed. The results show that the OFDM based system using noisy Multipath Rician Fading Channel performs better than OFDM based system using noisy Multipath Rayleigh Fading Channel. The BER generated from all modulation techniques in noisy multipath Rician Fading Channel is less than in noisy multipath Rayleigh Fading Channel. It is because Line of Sight (LOS) is more applicable in Rician Channel than Rayleigh Channel. In the Rayleigh Channel, there are many objects in the environment which interfere or scatter the signal before the signal can reach the receiver [17-20].

Table IV: Generated BER for different modulation techniques in noisy Multipath Rician Fading Channel

SNR (Eb/No)	Bit Error Rate (BER)					
	BPSK	QPSK	8-PSK	16-PSK	16-QAM	64-QAM
0	0.2000	0.4545	0.7228	0.8119	0.4667	0.4605
2	0.1800	0.3953	0.6535	0.7822	0.3474	0.3736
4	0.1100	0.3125	0.5644	0.7624	0.2225	0.2276
6	0.0500	0.2353	0.4455	0.6634	0.1200	0.1145
8	0.0300	0.1211	0.3456	0.5743	0.0440	0.0420
10	0	0.0630	0.2673	0.5347	0.0120	0.0130
12	0	0.0180	0.1188	0.4455	0.0001	0.0010
14	0	0.0001	0.0495	0.3618	0	0
16	0	0	0.0297	0.1881	0	0
18	0	0	0.0001	0.0792	0	0
20	0	0	0	0.0594	0	0

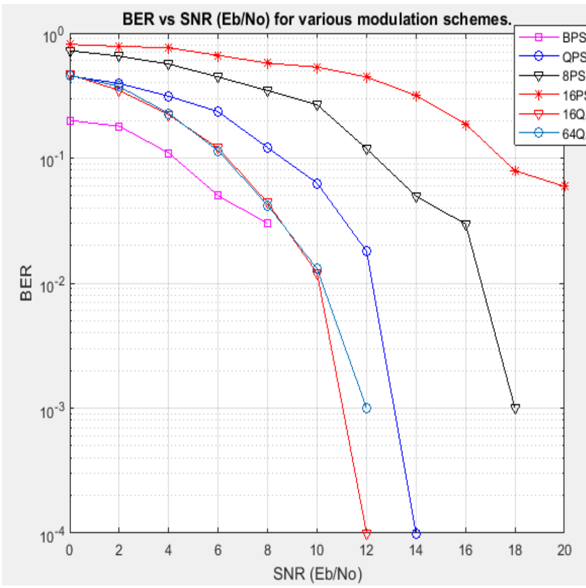

Fig. 8. BER plot for various modulation schemes in noisy Multipath Rician Fading Channel

C. Comparison of OFDM design 1 and OFDM design 2.

The BER performance of OFDM based systems are analyzed based on two developed designs. Design 1 is more complex than design 2 but the BER can be reduced using suitable modulation scheme. However, the BER cannot reduce to zero even for high SNR, 60 dB. For OFDM design 2, the BER can be reduced to zero when SNR above 12 dB. For both designs, BPSK shows the best BER performance compared to other modulation schemes. The BER performance via Rayleigh and Rician Channels is similar in the OFDM design 1. But, the BER performance via Rician Channel is better than Rayleigh Channel in OFDM design 2.

IV. CONCLUSION

In conclusion, the BER performance in OFDM modulation and demodulation complete system and OFDM based system over noisy Multipath Rayleigh Fading and Multipath Rician Fading are modelled and analyzed.

The standard of 802.11a for OFDM system is constructed and simulation process is done on the system. The study does analysis on the effects of different channels and modulation techniques on OFDM system performance. The studied parameters consist of multipath channels, signal to noise ratio (SNR) and modulation techniques. The simulation models show that the BER performance can be influenced by types of channels, signal to noise ratio (SNR) and various modulation schemes. In addition, simplest modulation scheme like BPSK produces less BER compared to QPSK and MPSK. From the above analysis, the enhanced performance of OFDM in wireless communication can be achieved. The OFDM designs can be improved by changing the parameter and the system requirement. Thus, OFDM is a potential candidate for fifth generation (5G) system or future generations of wireless communication.

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REFERENCES

1. J. Tiwari, "Simplified Channel Estimation Techniques for OFDM Systems with Realistic Indoor Fading Channels," *Int. J. Adv. Res. Ideas Innov. Technol*. ISSN, vol. 4, pp. 2573–2581, 2018.
2. P. Manhas and M. K. Soni, "BER Analysis of BPSK, QPSK and QAM Based OFDM System Using Simulink," *Int. J. Electr. Electron. Eng.*, vol. 7, pp. 54–60, 2015.
3. L. Xu, "BER Performance of MC-DS-CDMA Systems in the Presence of Timing Jitter Master of Engineering," *Thesis Rep*., 2010.
4. S. Karkare, "Wireless system using MIMO-OFDM," *Int. J. of Comp. and Comm. Eng. Research*, vol. 1, pp.53-55, 2013.
5. G. B. Umesha and M. N. Shanmukha Swamy, "Techniques for Improving Performance of OFDM System for Wireless Communication," *Ijarcce*, vol. 6, no. 3, pp. 812–816, 2017.
6. R. Rathore and B. P. Sharma, "Performance Analysis of Different Modulation Techniques for OFDM System," *Int. Conf. Recent Trends Issues Eng. Technol.*, pp. 95–99, 2014.
7. V. Gopinath, "Enhanced Performance of HF OFDM in Wireless Communication*," KIET Int. J. of Comm. &Elect.*, vol. 2(1), pp. 46–50, 2014.
8. A. Agarwal and K. Agarwal, "Implementation and Performance Evaluation of OFDM System in Diverse Transmission Channel Using Simulink," *Am. J. Electr. Electron. Eng.* Vol. 3, 2015, pp. 117-123, vol. 3, no. 5, pp. 117–123, 2015.
9. S. Kaur and G. Bharti, "Orthogonal Frequency Division Multiplexing in Wireless Communication Systems : A Review," *Int. J. Adv. Res. Comput. Eng. Technol*., vol. 1, no. 3, pp. 125–129, 2012.
10. D. Kajaree and R. Behera, "A Survey on Machine Learning: Concept, Algorithms and Applications," *Int. J. Innov. Res. Comput. Commun. Eng.*, vol. 5, no. 2, pp. 1302–1309, 2017.
11. R. Gupta, T. S. Kamal and P. Singh, " Performance of OFDM: FSO Communication System with Hybrid Channel Codes during Weak Turbulence," *J. of Comp. Net. And Comm*., 1306491, 2019.
12. V. K. Trivedi, K. Ramadan, P. Kumar, M. I. Dessouky and F. E. A. El-Samie, "Enhanced OFDM-NOMA for next generation wireless communication: A study of PAPR reduction and sensitivity to CFO and estimation errors," *AEU-Int. J. of Elec. and Comm.*, vol 102, pp. 9-24, 2019.
13. J. Lian, Y. Gao, P. Wu and D. Lian, "Orthogonal Frequency Division Multiplexing Techniques Comparison for Underwater Optical Wireless Communication Systems," *Sensors (Basel)*, vol. 19, pp. 160, 2019.
14. K. M. Shaikh, " The Performance Evaluation of OFDM based WLAN (IEEE 802.11a and 802.11g)," *Master thesis*, Blekinge Institute of Technology, Sweden, 2009.
15. C. D. Parekha, J. M. Patel, " OFDM Synchronization Techniques for 802.11ac WLAN," *Int. J. of Wireless and Microwave Tech.*, vol. 4,page 1-13, 2018.
16. A. U. Haque, M. Saeed, F. A. Siddiqui, "Comparative Study of BPSK and QPSK for wireless networks over NS2," *Int. J. of Comp. App*., vol.41, pp.8-12, 2012.
17. T. S. Rappaport, *Wireless Communications: Principles and Practice*, Prentice Hall PTR, 2002.
18. A. I. Mohammed and K. H. Bilal, "Impact of AWGN, Rayleigh and Rician FadingChannels on BER Performance of a Cognitive Radio Network," *Int. J. of Scietific and Eng. Reseach*, vol. 8 (4), pp. 1365-1368, 2017.
19. R. Yadav, "Design and Analysis of OFDM System Employed in 5G MIMO Wireless Communication by using NI Hardware : USRP and Lab VIEW Software," *Int. J. Comput. Appl.*, vol. 180(14), pp. 41–46, 2018.
20. S. Varade, K. Kulat, "BER Comparison of Rayleigh Fading, Rician Fading and AWGN Channel using Chaotic Communication based MIMO-OFDM System, *Int. J. of Soft Comput. and Eng*., vol.1, pp.107-115, 2012.

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