Analysis to Find the Best MPSK Techniques to get Minimum Error Probability over Rayleigh and Nakagami-m Fading Channel

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Abstract: OFDM technique very effective for reliable communication over multipath fading environment. BPSK, QPSK & QAM are most popularly used modulation schemes. In order to find the reliability of communication system, some fading channel models has been used. Rayleigh and Nakagami-m fading channels are two such models which resemble real environmental conditions. Therefore in our work, different modulation schemes are studied over multipath fading channel models. It is found that communication systems work better in Nakagami-m environment than Rayleigh channel. In Nakagami-m model, as the value of m increases BER is reduced in all modulation schemes. It is also found that BPSK gives less BER than other modulation schemes under high value of m. the results has been potted and discussed in the paper.

Keywords: OFDM (Orthogonal Frequency Division Multiplexing), PDF (Probability Density Function), BER (Bit Error Rate), SNR (Signal-to-Noise Ratio). Rayleigh fading, Nakagami-m fading, MATLAB, FFT(Fast Fourier Transform), BPSK(Binary Phase Shift Keying), QPSK(Quadrature Phase Shift Keying), QAM(Quadrature Amplitude Modulation).

1. INTRODUCTION

In the current scenario, high data rate with reduced bandwidth is in requirement against multipath fading Environment. This issue can be solved by implementing OFDM (Orthogonal Frequency Division Multiplexing) which provides high bandwidth efficiency. The factors which affect the efficiency of the communication systems are like density of users, line of sight between the transmitter and receiver, mutual movement between the transmitter and receiver etc [1]. In order to simulate these phenomena some channel models has been created, among them the most effective are Rayleigh and Nakagami-m channel model. Performance of the wireless communication system can be estimated by considering the transmission characteristics and parameters of the channel and the device structure. It is highly believed that the OFDM results in an improved multimedia download services requiring high data rates communications, but this condition is significantly controlled by inter-symbol interference (ISI) due to the existence of the multiple paths [2].

Usually parameters like high quality, high speed, high spectrum utilization and high reliability are taken into high consideration but in actual communication environment or channel environment affects more as the signal in the process of propagation is occluded, absorbed, reflected, refracted or diffracted caused by the various objects, the receiver can receive a number of path signals components, whose superimposition may produce severe multipath fading [3]. The most important performance parameter used to study any communication system is Bit Error Rate Ratio (BER). It is important to study the error rate performance of OFDM modulation technology under different multipath fading channel characteristics for analysis of the overall performance of OFDM system.

In our proposed work, the most likely used channel models, Rayleigh and Nakagami-m fading channel are used to find error probability performance on different PSK modulation techniques. All the modulation techniques are simulated in MATLAB over fading channel model parameters.

2. OFDM TECHNIQUE

OFDM is a parallel transmission scheme, where a high-rate serial data stream is split up into a set of lowrate sub-streams, each of which is modulated on a separate sub-carrier. The bandwidth of the sub-carriers becomes small compared with the coherence bandwidth of the channel. The symbol period of the sub-streams is made long compared to the delay spread of the time-dispersive radio channel. OFDM scheme is advantageous because of high spectral efficiency, easy adaptability to severe channel conditions without complex time domain equalization, robustness against inter symbol interference (ISI) and fading caused by multipath propagation, efficient implementation using Fast Fourier Transform (FFT), less sensitive to time synchronization errors etc [1].

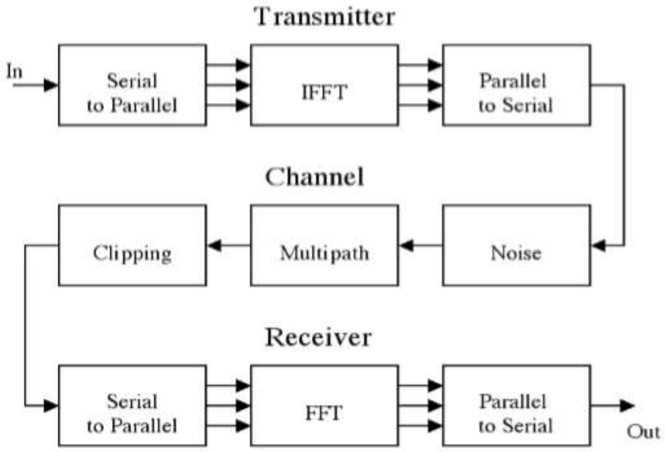

Fig. 1: OFDM Flow Chart

The Orthogonal frequency-division multiplexing (OFDM) is the modulation technique for the European standards such as the Digital Audio Broadcasting (DAB) and the Digital Video Broadcasting (DVB) systems. The Orthogonal frequency-division multiplexing (OFDM) is a process of encoding digital data on the multiple carrier frequencies. The data are transmit over parallel sub-channels with each sub-channel modulated by the modulation scheme such as BPSK, QPSK, QAM etc. The benefit of the OFDM is its ability to cope with severe channel conditions compared to a single carrier modulation scheme but still maintain the data rates of a conventional scheme with the same bandwidth. The Orthogonal Frequency Division Multiplexing has become one of the main physical layer techniques used in the modern communication systems [2]

3. CHANNEL MODELS

There are lots of channel models has been suggested to find the performance of the modulation system under real circumstances. The most frequently used channel models are Rayleigh and Nakagami-m fading channel.

A. Rayleigh channel model

The Rayleigh fading environment is described by the many multipath components, each having relatively similar signal magnitude, and uniformly distributed phase, that means there is no line of sight (LOS) path between transmitter and receiver. It can be called as a channel in which the signal takes various path to reach the receiver after getting reflect from various objects in the environment. The signal receiving at receiver is sum of the reflected signal and the main signal. The signal in the environment get diffracted or reflected from the objects like tree, building, moving vehicle etc and imposes problem when the envelope of the individual signal is added up [2].

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 [4]. It is well known that the envelop of the sum of two quadrature Gaussian noise signal obeys a Rayleigh distribution [5].

A Rayleigh PDF (Probability Density Function) is expressed as

$$p(r) = (r / \sigma^2) \exp(-r^2 / 2\sigma^2) \text{ for } r >= 0 \qquad (1)$$

Where r is the envelope amplitude of the received signal, and is the RMS (Root Mean Square) value of the received voltage signal before envelop detection. And $2\sigma^2$ is the pre detection mean power of the multipath signal. The Rayleigh faded component is sometimes called the random or scatter or diffuse component [5].

B. NAKAGAMI-m FADING

The Nakagami-m distribution has been first introduced in, which can characterize envelop of the received signal propagating in ionosphere and tropospheric environments.

The Nakagami distribution matches some empirical data better than other models. Rayleigh-fading signals have a Nakagami distributed signal amplitude, the Nakagami-m fading includes the Rayleigh fading where m =1 as special cases and m describes the fading severity. The Rician and the Nakagami model behave approximately equivalently near their mean value, it can approximate Rician fading where m>1 [8].

Nakagami-m fading models assume that the magnitude of a signal that has passed through such a communications channel will fade according to a Nakagami-m distribution, which was introduced by Nakagami in to fit empirical data gathered from high frequency ionospheric channels. It provides the best fit for the fading amplitudes of the satellite-to-indoor and satellite-to-outdoor channel. The PDF of this distribution for random variables R is given by [6], [9],

$$p(R) = \frac{2m^m R^{2m-1}}{\Gamma(m)\Omega^m} e^{-(m/\Omega)R^2} \quad (2)$$

where R ≥ 0 denotes the channel amplitude, $\Omega = E(R^2)$ is average fading power, E(·) is the expectation operator, and Γ(·) is gamma function, and m ≥ 0.5 is the inverse of the normalized variance of R^2, it is also called fading severity parameter and given by

$$m = E^2(R^2) / \mathrm{Var}(R^2) \quad (3)$$

where Var(·) is the variance operator [3].

Notice that parameter m indicates various fading conditions, e.g. m = 0.5, it represents a deeply fading channel, m = 1, it represents a Rayleigh fading channel, and m = ∞, it represents a non-fading AWGN channel. Since the value of m measures the channel quality, it is very important to obtain an accurate estimate of m, in advanced receiver implementations and in channel data analyses [2].

4. MODULATION SCHEMES

There are following PSK modulation schemes used with OFDM,

A. Binary Phase Shift Keying (BPSK)

The PSK uses a finite number of phases; each is assigned with a unique pattern of binary digits. Generally, each phase encodes an equal number of the bits. Each pattern of the bits generates the symbol that is denoted by the particular phase. The BPSK is the simplest type of phase shift keying (PSK). It consists of two phases which are separated by 180° and so they can also be named as 2-PSK [7]. It does not matter exactly that where the constellation points are positioned, and in the below figure they are represented on the real axis, at 0° and 180°.

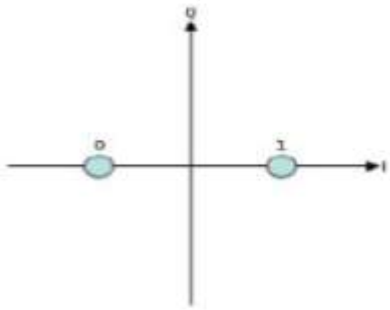

Fig. 2: Constellations for BPSK

B. Quadrature Phase Shift Keying (QPSK)

The QPSK have four points on the constellation diagram, and are equal spaced around a circle. With four phases, QPSK can encode the two bits per symbol, shown in the figure with gray coding to reduce the bit error rate (BER) — some times it misperceived as twice the BER of the BPSK. The mathematical studies shows that QPSK can used either to double the data rate when compared with a BPSK system while maintaining the same bandwidth of the signal, or to maintain the BPSK data rate but halving the needed bandwidth.

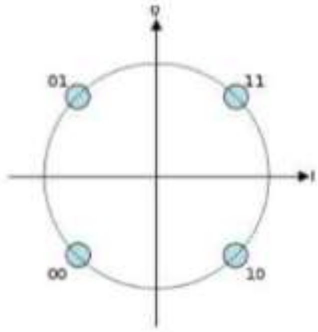

Fig.3: Constellation for QPSK

C. Quadrature amplitude modulation (QAM)

The QAM is the modulation scheme which encode the information into a carrier wave by varying the amplitude of both the carrier wave and a - quadrature carrier that is 90° out of phase with the main carrier wave in accordance with the two input signals. It means that, the amplitude and the phase of the carrier wave are simultaneously varied in accordance to the information we want to transmit. The symbol rate is one fourth of the bit rate. So this modulation format produces a more spectrally efficient transmission. It is more efficient than BPSK, QPSK.

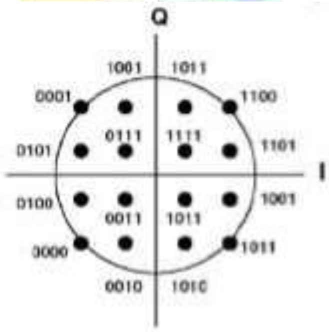

Fig. 4: Constellation for QAM

Table 1: OFDM System Specification

Parameter	**Value**
FFT Size	64
No. of Subcarriers	52
FFT Sampling Frequency	20MHz
Subcarrier Index	-26 to -1 and 1 to 26
Modulation Schemes	BPSK, QPSK, 16-QAM & 64-QAM

5. PERFORMACE PARAMTER

A. Bit error rate (BER)

The BER, or quality of the digital link, is calculated from the number of bits received in error divided by the number of bits transmitted.

BER= (Bits in Error) / (Total bits received) (5)

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors. The BER is the number of bit errors divided by the total number of transferred bits during a particular time interval. BER is a unit less performance measure, often expressed as a percentage. IEEE 802.11 standard has ability to sense the bit error rate (BER) of its link and implemented modulation to data rate and exchange to Forward Error Correction (FEC), which is used to set the BER as low error rate for data applications. BER measurement is the number of bit error or destroys within a second during transmitting from source to destination. Noise affects the BER performance. Quantization errors also reduce BER performance, through incorrect or ambiguous reconstruction of the digital waveform. The accuracy of the analog modulation process and the effects of the filtering on Signal and noise bandwidth also effect quantization errors.

B. Signal to Noise Ratio (SNR)

SNR is the ratio of the received signal strength over the noise strength in the frequency range of the operation. It is an important parameter of the physical layer of Local Area Wireless Network (LAWN). Noise strength, in general, can include the noise in the environment and other unwanted signals (interference). BER is inversely related to SNR, that is high BER causes low SNR. High BER causes increases packet loss, increase in delay and decreases throughput. The exact relation between the SNR and the BER is not easy to determine in the multi-channel environment [5]. Signal to noise ratio (SNR) is an indicator commonly used to evaluate the quality of a communication link and measured in decibels and represented by

SNR = 10 log10 (Signal Power / Noise Power) dB (6)

The OFDM system is developed, simulated and analyzed in MATLAB version 7. Bit Error Rate is calculated for different modulation schemes under AWGN and Rayleigh Fading channel model. The symbol to noise ratio can be calculated using,

$$\frac{Es}{No}dB = \frac{Eb}{No}dB + 10log10\left(\frac{No.of\ data\ Subcarries}{No.of\ FFT\ Symbols}\right) + 10log10\left(\frac{Data\ Symbol\ Duration}{Total\ Symbol\ Duration}\right) \tag{7}$$

C. RESULTS AND PLOTS

BER vs SNR is plotted for different modulation schemes over Rayleigh and Nakagami-m fading channel. Fig. 5 shows the plot for different modulation schemes over Rayleigh channel. It is found that BPSK is better than other modulation scheme over the Rayleigh channel.

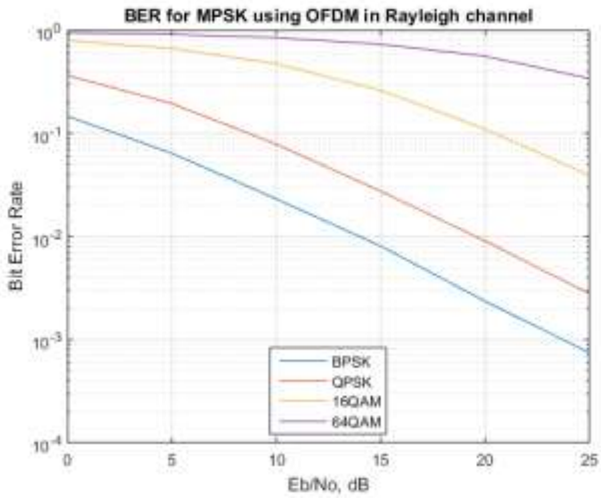

Fig. 5: BER vs SNR using OFDM over Rayleigh channel

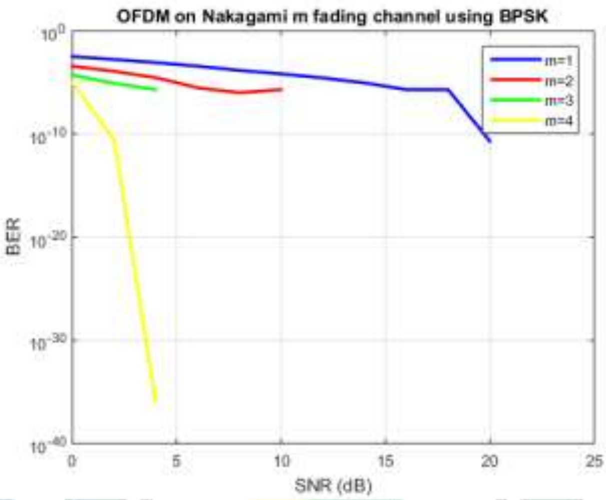

Fig. 6: BER vs SNR using OFDM over Nakagami channel using BPSK

Fig. 6 is the plot of BPSK modulation scheme over Nakagami-m channel. It is plotted by changing the value of parameter m. it is found that as value of m increases, bit error rate decreases. Thus it is concluded from this plot that BPSK modulation works better with higher value of m over Nakagami channel.

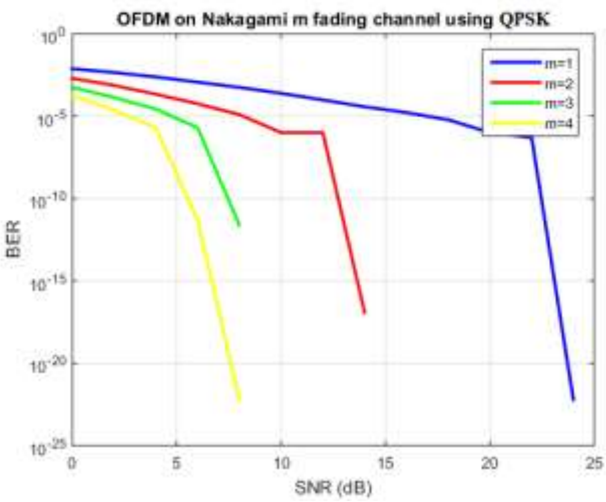

Fig. 7: BER vs SNR using OFDM over Nakagami channel using QPSK

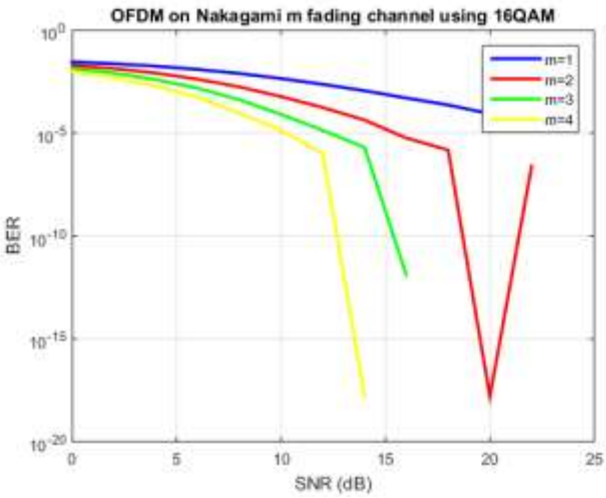

Fig. 8: BER vs SNR using OFDM over Nakagami channel using 16-QAM

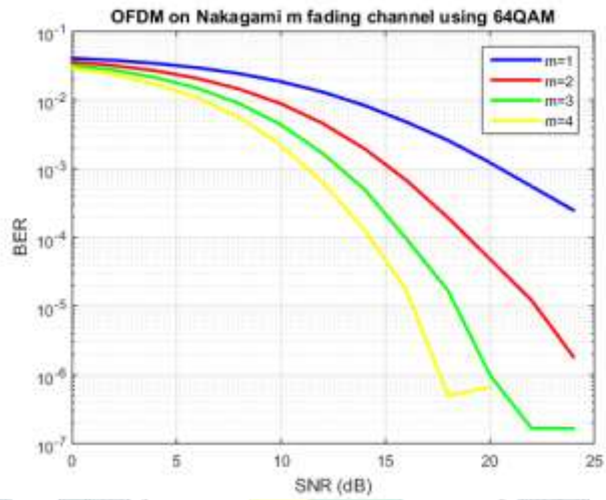

Fig. 9: BER vs SNR using OFDM over Nakagami channel using 64-QAM

Fig. 7, 8 & 9 are the plots for QPSK, 16-QAM, 64-QAM over Nakagami-m channel. It is found from all these plots that increase in value of m decreases bit error rate that means better communication.

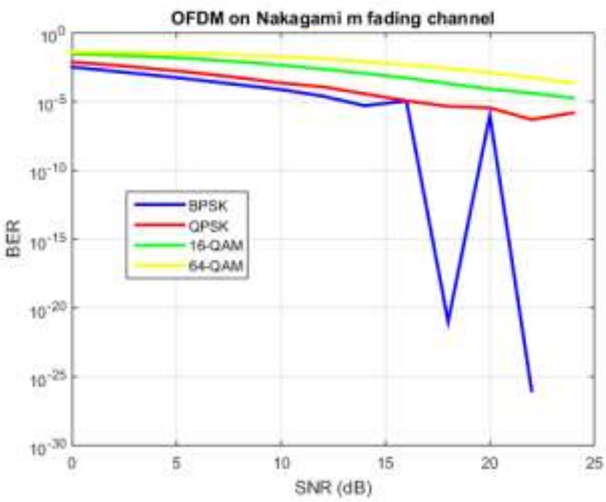

Fig. 10: BER vs SNR using OFDM over Nakagami channel for m=1

Fig. 10 shows the plot of all modulation schemes over Nakagami channel for value m=1. It is found in the above plot that BPSK is better than other modulations schemes at m=1 value in terms of lower probability of error.

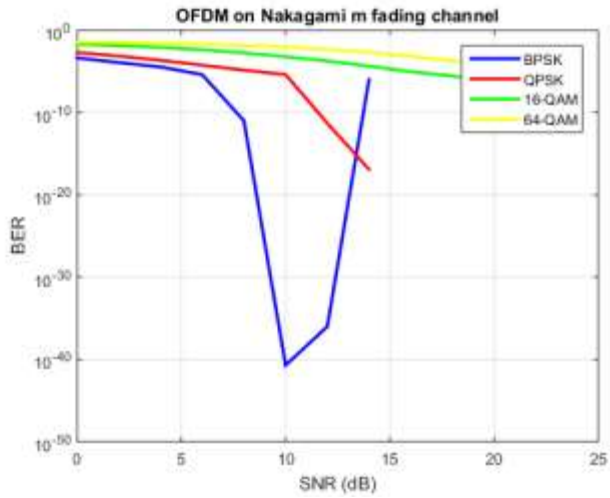

Fig. 11: BER vs SNR using OFDM over Nakagami channel for m=2

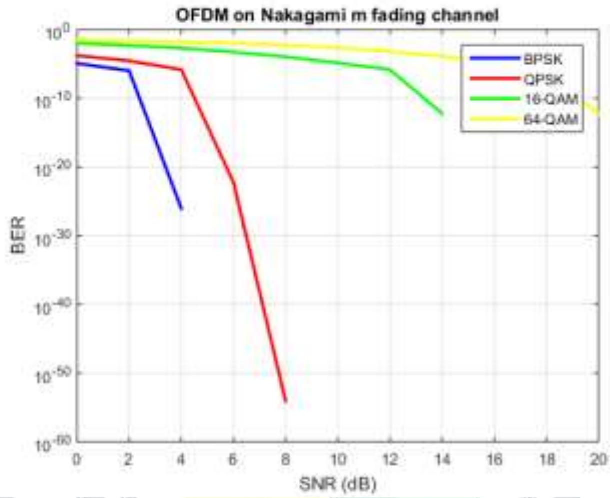

Fig. 12: BER vs SNR using OFDM over Nakagami channel for m=3

Similarly Fig. 11 & 12 shows the plot of all modulation schemes over Nakagami channel for value different value of m. It is found in the above plots that BPSK is better than other modulations schemes at all the value of m in terms of lower probability of error over Nakagami channel.

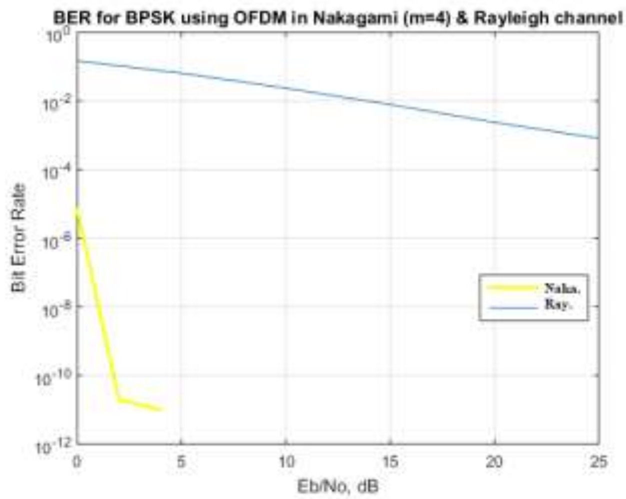

Fig. 13: BER vs SNR over Rayleigh & Nakagami channel using BPSK

Fig. 13 above is the BER vs SNR plot for BPSK technique over Nakagami channel for m=4. It is concluded from all the above plots that BPSK is better over both Rayleigh and Nakagami fading channel as compare to other modulation schemes as well as higher value of m favors BPSK modulation by providing lower probability of error.

D. CONCLUSION

OFDM technique is very effective in providing high data rate as well as bandwidth efficiency. In our proposed work, OFDM with modulation schemes like BPSK, QPSK & QAM are tested over Rayleigh and Nakagami-m fading channel. It is found that communication systems work better in Nakagami-m environment than Rayleigh channel. In Nakagami-m model, as the value of m increases, BER is reduced in all modulation schemes including BPSK, QPSK, 16-QAM & 64 QAM. The conclusion comes out of experimentation is that BPSK gives less BER than other modulation schemes under high value of m.

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