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BER Performance Analysis of MSK-OFDM in Nakagami-*m* Channel

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***Abstract*— Ultra Wide Band (UWB) technology is one of the most promising future technologies for short-range high or low-rate wireless communications. Data or signal transmission degrades by fading channel is still a research issue for efficient digital communication system in mobile radio area. In this paper, Nakagami-*m* distribution is used to model UWB channel.BER performance of MSK-OFDM in Nakagami-*m* channel model is investigated by considering ideal MSK.BER performance is analyzed for proposed model by varying the FFT size or number of subcarriers of OFDM. Instead of using cyclic prefix as guard band zero padded is taken in this model.**

Keywords—Minimum shift keying, MSK-OFDM, Nakagami-m channel, Ultra-wide band.

I. INTRODUCTION

In the environment of the wireless mobile communications, the presence of reflecting objects and scatters in the channel creates a constantly changing environment that dissipates the signal energy in amplitude, phase and time .These effects result in multiple versions of the transmitted signal that arrive at the receiving antenna, displaced with respect to one another in time and spatial orientation. The random phase and amplitudes of the different multipath components cause fluctuations in signal strength. This kind of dispersion may cause the inter-symbol interference (ISI) [3].

There are many techniques that are proposed to suppress ISI effect. Orthogonal Frequency Division Multiplexing (OFDM) is such a technique that reduces the effect of ISI by using fast Fourier transform (FFT) [4] .OFDM is one of the multi-carrier modulation (MCM) techniques that transmit signals through multiple carriers. These carriers (subcarriers) have different frequencies and they are orthogonal to each other. After the IFFT/FFT technique was introduced, the implementation of OFDM became more convenient. OFDM techniques have been applied in both wired and wireless communications. OFDM is a Special case of Frequency Division Multiplexing (FDM).

The key idea of OFDM is that a single user can able to make use of all subcarriers which are orthogonal. This facilitates high data rates. OFDM systems can suppress the ISI effect when the entire bandwidth is divided into narrow channels of longer symbol period only [11]. This limit the data rate of OFDM however OFDM provides high data rates than other systems which are proposed earlier

Modulation schemes like QPSK, OQPSK, DPSK and FSK generate modulated waveform with phase discontinuity. The sharp phase transitions cause side lobes in the signal spectrum. These side lobes are comparable to main lobe. This leads to co-channel and inter channel interference.

Minimum shift keying (MSK) is a special type continuous phase frequency shift keying (CPFSK) which is proposed to suppress co-channel and inter channel interference. It can also be a special case of orthogonal phase shift keying (OQPSK) with half sinusoidal waveform. Modulation index corresponds to MSK is 0.5 which facilitates two FSK signals to be coherently orthogonal. The special characteristics of MSK are constant envelop, good spectral efficiency, better BER performance and self synchronizing capability [5]. MSK is well suited for Rayleigh fading environments. In digital communication MSK can be viewed as special case of continuous phase modulation (CPM).

Even though OFDM has advantages like high data rate, it has disadvantage of high side lobe level. Due to high side lobe level OFDM becomes sensitive to carrier frequency offset (CFO) which results inter carrier interference (ICI).MSK is an efficient technique to reduce side lobes. MSK-OFDM which is a combination of MSK and OFDM can able to suppress both inter carrier interference (ICI) and inter symbol interference (ISI).

Tasadduq [6] proposed a multipath channel model using AWGN distribution. The BER performance of this model with CPM-OFDM is studied by varying the CPM modulation index h.The BER performance analysis showed that at h=0.5 CPM-OFDM can perform better than PSK-OFDM.The drawback associated with this model is that less computational efficiency and limited sub carriers of OFDM. No of subcarriers value is limited to 8.

Weng et al., [4] proposed a system with 64 OFDM sub carriers along with MSK to reduce complexity of implementation at transceiver. The BER performance of this system is better than QPSK-OFDM in AWGN channel and Rayleigh fading channels at high SNR conditions. At high SNR conditions, MSK can able to suppress side lobes as result in reduction of inter channel interference (ICI) better than QPSK-OFDM.

Shaban [2] proposed a system with multi-carrier code division multiple accesses (MC-CDMA) and studied BER performance of both Rician and Nakagami-m fading channels.

In this paper, we study the BER performance MSK-OFDM in the UWB channel which is modeled by Nakagami-

m channel by varying the FFT size or number of subcarriers of OFDM system.

The rest of the paper is organized as follows. In section II, we explain about MSK-OFDM system. In section III, we describe about Nakagami-m channel model. In section IV, we illustrate about simulation results and analysis. Finally in section V, we conclude the paper.

II. MSK-OFDM SIGNALLING

A. *MSK signal generation*

According to [7], the base band MSK signal can be represented as below

$$s(t) = A\left[I(t)\cos\left(\frac{\pi t}{2T_b}\right)\cos 2\pi f_c t + Q(t)\sin\left(\frac{\pi t}{2T_b}\right)\sin 2\pi f_c t\right] \qquad (1)$$

Where $I(t)$ is the imaginary component of input data while $Q(t)$ is the quaternary component of input data. T_b is the bit period of input data. f_c is the carrier frequency. A is a constant that represents the amplitude of the signal.
The quaternary component is lagged by the imaginary component by a time equal to bit period.

B. *MSK – OFDM Transmitter*

The following shows the block diagram of MSK-OFDM transceiver.

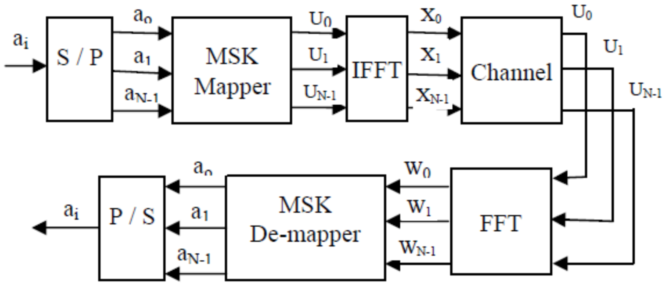

Fig 1: MSK- OFDM transceiver

At the transmitter, a_i is the input serial data of length N bits. This serial data is converted into parallel data to generate MSK carrier and to perform OFDM. The MSK-OFDM is designed based on FFT by using no of subcarriers and guard band can be taken as either zero padded or cyclic prefix.

The resultant transmitted signal of MSK-OFDM transmitter is [1]

$$x(i) = \sum_{i=0}^{F-1} x(k)\sin\left(\frac{2\pi ki}{F}\right) - j\sum_{i=0}^{F-1} x(k)\cos\left(\frac{2\pi ki}{F}\right) \qquad (2)$$

Where $x(k)$ represents the FFT coefficient of index k. i and k are the indices of frequency and time respectively.

C. *MSK – OFDM Receiver*

At the receiver, the received signal is converted back to frequency domain by using FFT. The operation of MSK-OFDM receiver is represented by following equation.

$$x(k) = \sum_{i=0}^{F-1} x(i)\sin\left(\frac{2\pi ki}{F}\right) - j\sum_{i=0}^{F-1} x(i)\cos\left(\frac{2\pi ki}{F}\right) \qquad (3)$$

Equations (2) and (3) are almost similar only difference is coefficients are being used.

III. NAKAGAMI-m CHANNEL MODEL

Nakagami distribution can able to represents various wireless channels using the parameter m. When m=1 Nakagami distribution follows Rayleigh distribution. It closes to worst case fading like one sided Gaussian distribution when m=1/2 .If m>1, it tends Rician distribution [10]. Nakagami distribution is more flexible because of one or more free parameters. It provides good fit for modern wireless communications. Nakagami-m distribution is used to model ultra wide band (UWB) systems to study BER performance [9]. The probability density function (PDF) of Nakagami distribution is given below

$$p(r) = \frac{2m^m r^{2m-1}}{\Omega^m \Gamma(m)}\exp\left(-\frac{mr^2}{\Omega}\right), m \geq \frac{1}{2}, r \geq 0 \qquad (4)$$

Where $\Omega = \mathbb{E}\,(r^2)$ denotes average power of multipath scatter field. m is the fading parameter or shape factor to represent the degree of fading. The signal envelope for Nakagami distribution is defined as sum of envelopes of Rayleigh and Rician distributions as follows

$$r_{nak}(t) = r_{ray}e^{1-m} + r_{rice}(1 - e^{1-m}) \qquad (5)$$

The signal envelope for Rayleigh distribution is given by

$$r_{ray}(t) = \sum_{k=1}^{K} r_k(t) = \left[r_{ik}(t) + j\, r_{qk}(t)\right] \qquad (6)$$

Where $r_k(t)$ is the complex signal envelop of the received MSK signal, $r_{ik}(t)$ and $r_{qk}(t)$ are in phase and quadrature components. The signal envelope of Nakagami simulation signal is given by

$$\begin{aligned} r_{nak}(t) = {} & a_1 e^{\frac{1}{2}-m}(e^{1-m} - 1)n(t) \\ & + a_2\left(1 - e^{\frac{1}{2}-m}\right)\left[(1 - e^{1-m})C \right. \\ & \left. + r_{ray}(t)\right] \end{aligned} \qquad (7)$$

Where $a_1 = 1/(\sqrt{e} - 1), a_2 = \sqrt{e}/(\sqrt{e} - 1)$,

$n(t)$ is noise signal of type white Gaussian, C is a constant which is termed as correction factor and $r_{ray}(t)$ is the complex envelop of Rayleigh fading channel. The correction factor can be found by using minimum mean square error (MMSE) algorithm which corresponds to m=1.

IV. EXPERIMENTAL RESULTS

The proposed model implemented and simulated using MATLAB and execution time for simulation 40 sec. The following table shows the parameter settings

TABLE I
PARAMETER USED IN MSK-OFDM SYSTEM

No of subcarriers(n)	**128**	**256**	**512**
G	1/4	1/8	1/8
Zero padded	32	32	64
N	244 x 10^3		
m	1		
C	1.147-1.18cos(9.801m)+0.1318sin(9.801m)		

The utilized simulation model which is MSK-OFDM in Nakagami-*m* channel model was generated based on the parameters mentioned in above table. The values of n was 128,256, and 512 and the sub-carriers employed the same input signal for all transmitted data N (which was to244×10^3) .For n= 128 and 256, 32 sub-carriers of zero padded was used, for n=512, 64 sub-carriers of zero padded was used for the extracted OFDM symbols. According to the WiMAX specifications the guard band size G was chosen, G for both n=128 and 256 was 1/4 whereas for n=512, G was 1/8.

For Nakagami-*m* channel, the value of m was chosen to be unity so that the Nakagami distribution will be reduced to Rayleigh distribution as in equation (6).The correction factor; C for all n was acquired using the minimum mean square error (MMSE) algorithm which can produce the best value of C which corresponds to m value [9].

Figure 2 shows the simulation results follows the theoretical results for all cases (i.e. BER of MSK in proposed channels). BER performance simulation of the MSK signal (which is considered to be ideal) in Rayleigh fading channel and Nakagami-*m.* From simulation of Rayleigh and Nakagami-*m* channel, it can be seen that at Eb/No equal to 0 dB to 5 dB, both channels have almost the similar trends of BER performance which slightly differ in its values.

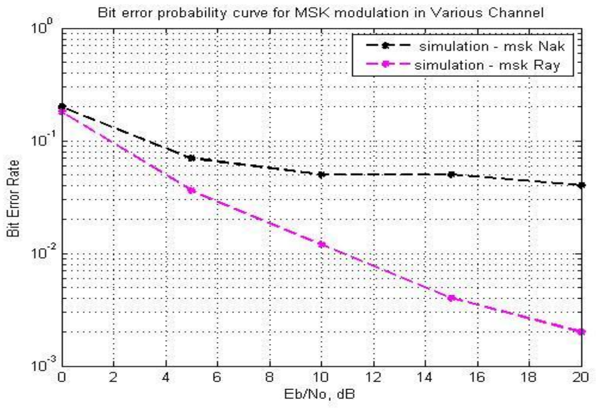

Figure 2. BER performance in various channels

However, for Eb/No equals to 5 dB until 20 dB, the BER graph for Nakagami-*m* channel is disperse away from Rayleigh channel up to 1.5x10^{-2} which makes Rayleigh fading channel outperformed Nakagami-*m* channel at high SNR.

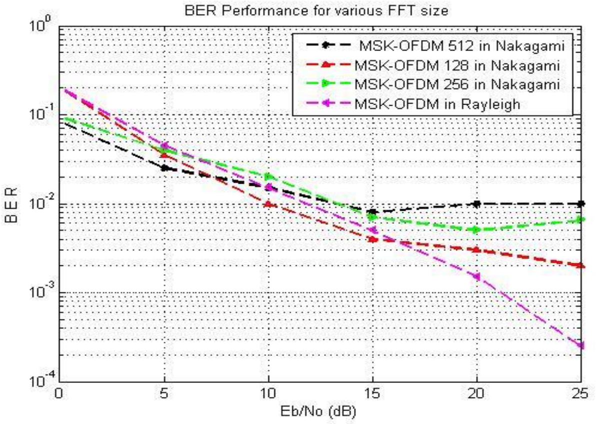

Figure 3. BER performance in various FFT size

The BER performance of MSK-OFDM for n=128, 256 and 512 for all three channels is shown in Figure 3. This graph shows the BER performance of MSK -OFDM for all sizes of n where these graphs do not follow the same trends as in Figure 2. For simulation result of n=128, at Eb/No equal to 0 dB until 5 dB, the BER of Nakagami-*m* channel is close to that of Rayleigh channel, however, the difference in BER between these channels increases when Eb/No is 15 dB to 25 dB.

The simulation results obtained for n=256 and 512 are also not the same as n=128 for Eb/No equals to 0 dB to 5 dB where Nakagami-*m* channel is outperformed Rayleigh channel. This indicates that both n=256 and 512 give better BER performance at low Eb/No. However, in Nakagami-*m* channel, there is a difference between the BER of MSK-OFDM for value of n at high Eb/No. This is also true for n=512 where the BER does not experience a lot of changes in its value at high EbNo which makes n=128 have the best performance in Nakagami-*m* channel compare to other sizes of FFT points. It is because zero padded cannot resolve multipath effect efficiently which causes BER to be saturated when Eb/No is above 15 dB

V. CONCLUSION

In this paper the basic MSK and MSK-OFDM signaling has been discussed and the wireless channel which is Nakagami-*m* channel model was introduced. The BER performance of MSK-OFDM has been evaluated. By using linear combination of AWGN and Rayleigh fading channel Nakagami channel was constructed. The system employed was assumed to be ideal and compatible with OFDM. From the simulation results, for m=1 at low Eb/No , the BER performance of MSK in Nakagami-*m* channel is almost similar to Rayleigh fading channel. The performance comparison between MSK and MSK-OFDM for various FFT sizes has shown that by using n=128, the MSK-OFDM provided the best performance compared to other FFT points at high value of Eb/No but n=256 and 512 give better BER performance at low Eb/No. This is due to zero padded could not resolve multipath effect efficiently which made BER to be saturated when Eb/No was above 15dB.

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