Design and Analysis of Bit Error Rate Performance of Simulink based DSSS-OFDM Model for Wireless Communication

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***Abstract*—** Because of the rapid growth of Digital Communication in recent years, the need for high speed data transmission is increased. Orthogonal frequency division multiplexing (OFDM) technique is suitable for high speed communication because of its resistance to ISI (inter symbol interference) and it utilizes the bandwidth efficiently. DSSS-OFDM is a combination of OFDM and DSSS techniques suitable for design of multi-user system and robust against channel impairments. This paper compares bit error rate (BER) performance of simulink based DSSS-OFDM model for different modulation technique. Here we have used BPSK, QPSK and M-PSK, M-QAM modulation techniques.

***Keywords*—**OFDM, DSSS-OFDM, MPSK, Spread Spectrum

I. INTRODUCTION

For modern wireless communication high data rate is a most important parameter. The principles of orthogonal frequency division multiplexing (OFDM) modulation have been in existence for several decades. These techniques are extensively used now in modern communications systems. Some of the applications of OFDM are Wireless networking, data transmission over the phone line, digital radio and television. OFDM is one of the applications of a parallel-data-transmission scheme, which reduces the influence of multipath fading and makes complex equalizers unnecessary. One of the main reasons to use OFDM is to increase robustness against frequency-selective fading or narrowband interference. OFDM has been combined with spread spectrum (SS) techniques to provide reliable communications on frequency selective channels. For low symbol rates, this combination is robust enough against radio channel impairments. For high data rate applications the technique would highly suffer from interferences. There are number of methods of spreading frequency spectrum in spread spectrum communication systems. Basically, these methods include Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS), Time Hopping Spread Spectrum (THSS), and combinations of these methods. Multiband Orthogonal Frequency Division Multiplexing (MB-OFDM) is a scheme of multicarrier transmission for ultra-wideband (UWB) communication which employs the frequency hopping technique to spread its signal spectrum [3]. Both DS and FH systems reduce the average power spectral density of a signal and affects by broadband noise. Performance of both systems depends on the particular application, the space available, power, and complexity of the receiver. Narrowband interference impacts severely on an FH signal than a DS signal on the same channel. Usually DS systems uses power efficient PSK modulation and FH systems uses less power efficient FSK. The probability of error, for a given SNR, is better for PSK. DS is self synchronizing but receiver synchronization in frequency hopping is more difficult. In DSSS, higher the chip rate of PN code, the smaller will be the degradation due to multipath and in FHSS if the carrier frequency of the transmitted signal hops fast enough then only multipath effect will be diminished. We have designed simulink based DSSS-OFDM and OFDM model and tested it with BPSK, QPSK and 8-PSK modulation technique. We have obtained simulated results and compared BER performance of the model.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

OFDM is a special multi-carrier transmission technology in which high-speed serial data are converted into N channel parallel data and certain frequency band is divided into N orthogonal sub-channels. N way different sub-carriers are used to modulate the N-channel data separately, and then transmit the sub-carrier parallel [1]. The traditional frequency division multiplexing method needs a lot of filters in receiver and transmitter for the spectrum of each sub-carrier is non overlapping and the sub-carrier must maintain sufficient frequency separation to reduce the mutual interference between the sub-carrier. So the system complexity and cost increase greatly and the frequency utilization is reduced. The OFDM system uses digital signal processing technology. Digital signal processing algorithm is adopted in the process of sub-carrier generation and reception and then the structure of the system is simplified greatly. Meanwhile, in order to improve frequency spectrum utilization, each sub-carrier spectrum which meet the orthogonally throughout the symbol period to ensure the

ISSN: 2278-0181
Vol. 1 Issue 3, May - 2012

receiving end recover the signal without distortion is overlapped. The OFDM signal spectrum is shown in Figure 1. Two key points of an OFDM system are the Inverse Discrete Fourier Transform at the transmitter side and the Discrete Fourier Transform at the receiver side. By these the robustness of the sent data over a fading multipath channel is preserved [6].

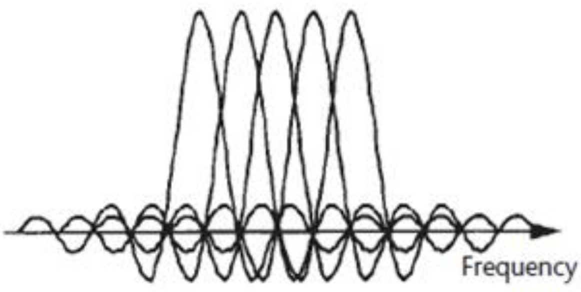

Figure 1. OFDM signal spectrum

OFDM techniques are quickly becoming a popular method for advanced communications networks. Advances in VLSI technology have made it possible to efficiently implement an FFT block in hardware. The N-point DFT and IDFT are defined as

$$DFT\{x[n]\} = X[i] = \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} x[n]e^{-j2\pi n\frac{W}{N}}, 0 \leq i \leq N-1 \quad (1)$$

$$IDFT\{X[i]\} = x[n] = \frac{1}{\sqrt{N}}\sum_{n=0}^{N-1} X[i]e^{j2\pi n\frac{W}{N}}, 0 \leq i \leq N-1 \quad (2)$$

Where N is the number of subchannels and W is the bandwidth in the OFDM system. One can think of the above expression as complex data symbols mapped to complex OFDM symbols, which make up the data symbols being sent on different subchannels. In this way the available spectrum is divided into several subchannels which are narrowband and therefore experience almost flat fading during transmission. The use of FFT technique makes OFDM computationally more fast and efficient too. Cyclic prefix is used to reduce the inter-symbol-interference (ISI) as well as inter-channel-interference (ICI) which is introduced by the multi-path channel.

III. SPREAD SPECTRUM

There are number of methods of spreading frequency spectrum in spread spectrum (SS) communication systems. Basically, these methods include Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS), Time Hopping Spread Spectrum (THSS), and combinations of these methods. Multiband Orthogonal Frequency Division Multiplexing (MB-OFDM) is a scheme of multicarrier transmission for ultra-wideband (UWB) communication which employs the frequency hopping technique to spread its signal spectrum. Here we will discuss about Direct Sequence Spread Spectrum. The basic form of the output signal of DSSS is given by equation;

$$S(t) = a(t)d(t)\cos(\omega_c t - \theta) \quad (3)$$

Where *a(t)* is a sequence of pulses to spread the data, and *d(t)* is a sequence of pulses of duration T of the digital data [4]. If the sequence d(t) is narrowband and a(t) is wideband, the product signal will have a spectrum nearly equal to that of a(t) [7].Direct sequence spread spectrum use a spreading sequence of positive and negative pulses at a very high chip rate. In this scheme the data signal is multiplied by the spreading sequence, and then modulated by the required carrier frequency as shown in (1). From Fourier Transform, we know that multiplication of two unrelated signals produces a product signal whose spectrum equals the convolution of the spectra of two individual signals. The spread signal is to be recovered by applying a "despreading" sequence at the receiver. The de-spreading sequence is just identical to the spreading sequence used at the transmitter. The type of PN sequence used its length, and its chip rate, set limits on the capability of the system. The capability can only be changed by modifying the PN sequence on above said parameters.

IV. DSSS-OFDM MODEL

The combination of Orthogonal Frequency Division Multiplexing (OFDM) with Direct Sequence Spread Spectrum (DSSS) is favorable for multi-user system. The combination named DSSS-OFDM is found robust against channel impairments and its power spectrum density remains constant. This system can also effectively reduce the peak-to-average power ratio of the transmitted signal. The DSSS-OFDM signal characterizes by much wider bandwidth than that of the conventional OFDM signal. It has also the characteristics of a white noise therefore it can realize effective ultra-wideband communication. Wideband communication efficiently reduces the interference problems. We can use the wide bandwidth characteristics of the DSSS-OFDM signal to control the received signal bandwidth by designing matched filters. The transmitted bandwidth can be selected flexibly to suit for different communication systems under different circumstances [3].

Many current efforts to develop broadband wireless capability are now concentrating towards developing systems, technologies, protocols, and even programming languages. OFDM has been combined with Direct Sequence Spread spectrum (DSSS) techniques to provide reliable communications on frequency selective channel. Multipath fading is very much influencing the performance of wireless communication link. Basic layout of DSSS-OFDM model is shown in figure 2.

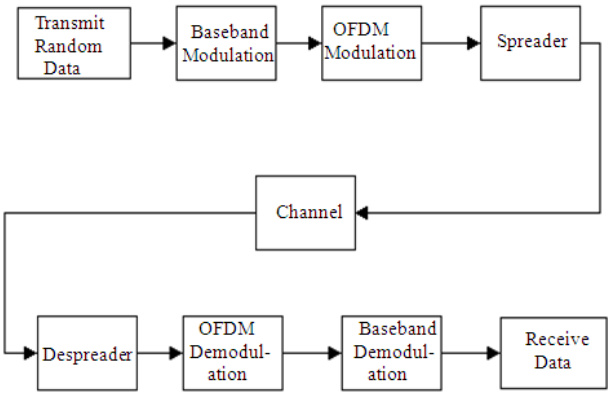

Figure 2. Basic layout of DSSS-OFDM model

Let see how spreading help us to improve the performance over noisy channel. The Shannon's capacity theorem is

$$C = B\log\left(1 - \frac{P_S}{P_N}\right) \quad (4)$$

Shannon's channel capacity formula describes the principle of spread spectrum system, shown in equation 4. Where C is the channel capacity, B is the signal bandwidth, P_S is the signal power and P_N is the noise power [3]. The amount of information that can be transmitted over a given channel is proportional to the product of the channel bandwidth and the time of operation. This indicates that when the signal to noise ratio of the transmission system drops in a Gaussian channel, the channel capacity can remain unchanged by increasing the transmission bandwidth. Shannon's theory also indicates that with the presence of Gaussian noise interference, the optimum signal for reliable communication is the signal with the statistical characteristics of a white noise. The power spectral density of (both sided signal) a white noise is

$$\Phi(\omega) = \frac{N_0}{2} \quad -\infty < \omega < \infty \quad (5)$$

where N_0 is the single-sided power spectral density. Its autocorrelation function is

$$\varphi(\tau) = \frac{1}{2\pi}\int_{-\infty}^{\infty} \Phi(\omega) e^{j\omega\tau} d\omega = \frac{N_0}{2}\delta(\tau) \quad (6)$$

where

$$\delta(\tau) = \begin{cases} 1, & for\ \tau = 0 \\ 0, & elsewhere \end{cases} \quad (7)$$

Autocorrelation function of a white noise is an impulse function. The signal transmitted on the AWGN channel should be designed so that its autocorrelation function is an impulse function, it has been also proved theoretically that to overcome multipath interference the optimum transmitted signal is also a signal with the statistical characteristics of a white noise.

V. IMPLEMENTATION

A. Simulink based DSSS-OFDM model with MPSK modulation

We have implemented DSSS-OFDM model using simulink as shown in Fig. 3. Random binary data is generated by Random Integer block. This randomly transmitted data is then modulated by MPSK modulator (Here we have used M=2, 4, 8 for BPSK, QPSK, 8-PSK respectively). This MPSK modulated data is again modulated by OFDM modulator. Inside the OFDM modulator we have used zero padding, IFFT blocks and cyclic prefix blocks in sequence. Zero padding blocks append zeros to the specified dimension if it is not available at the input of IFFT block. Ultimately it decides the number of subcarriers to be used. Now OFDM signal is spreaded using PN sequence and transmitted and after passing through the AWGN channel is first despreaded using same PN sequence which was used at transmitter side and then demodulated by the OFDM demodulator which is consist of Remove Cyclic Prefix, FFT, Remove Zero Pad blocks in sequence. Cyclic prefix which is attached to OFDM signal before transmission is to be removed by Remove Cyclic Prefix block. Then FFT will process the data to get the data same as that of input given to the IFFT block. After this one has to remove the zero padding. Now MPSK demodulator is used to demodulate this data to obtain random integer data transmitted by the random integer generator block.

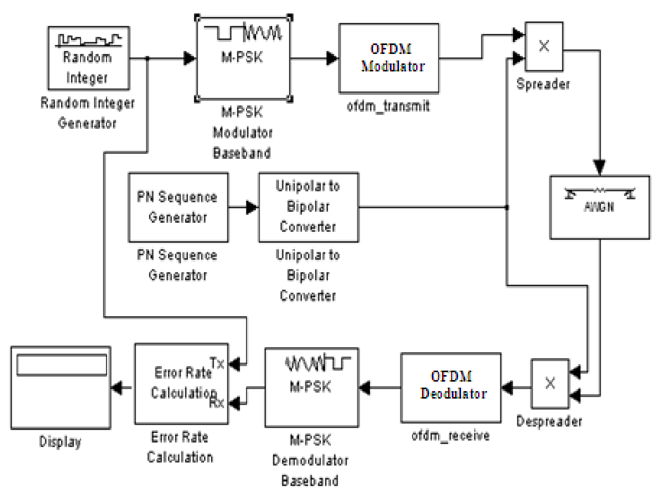

Figure 3. Simulink based DSSS-OFDM model using MPSK modulation

In MATLB 7.8 following toolboxes are required to implement above simulink model (1) Signal Processing Toolbox (2) Communication Toolbox. Following shows the blocks and parameter used in above simulink model.

1) Random integer generator: Here we have set sample time to 1/10 and sample per frame to 10. So that we can get the frame output of vector matrix with dimension 10×1.

2) Modulator baseband: Here we have used M-PSK baseband modulatator.

3) OFDM modulator: This blocks includes zero padding, IFFT block, cyclic prefix block in sequence. Zero padding is done at the end of data to match with required FFT length i.e. 16 (which we have used). IFFT is performed to convert frequency domain signal into time domain. Cyclic prefix is added to combat inter carrier interferences (ISI). Here we have added last 7 bits of each symbol as cyclic prefix.

4) AWGN channel: Here we have used AWGN channel for communication medium.

5) OFDM demodulator: In this block we first remove cyclic prefix then 16 point-FFT is used to convert time domain data into frequency domain and then zero padding is removed which we have added before transmitting

6) Demodulator baseband: Here we have used M-PSK baseband demodulatator.

7) Error rate calculation : This block is used to caculate numbrer of bit compared, number of bit in error and bit error rate.

8) PN sequence generator: In this block we have set sample time to 1/100.

9) Unipolar to bipolar convertor: Here we have set M-arynumber to 2.

B. Simulink based DSSS-OFDM model with M-QAM modulation

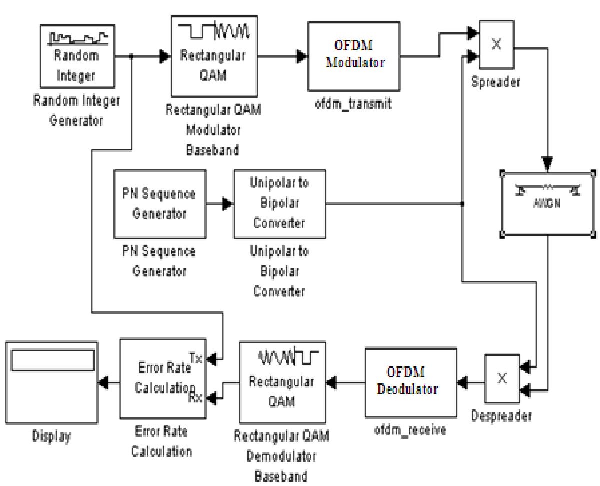

Figure 4. Simulink based DSSS-OFDM model using M-QAM modulation

Simulink model shown in figure 4 is same as shown in figure 3 only the difference is here we have used rectangular M-QAM modulator and demodulator.

VI. SIMULATION RESULT

Figure 3 shows the implementation of DSSS-OFDM using M-PSK modulation. Any number of phases may be used to construct a PSK constellation but 8-PSK is usually the highest order PSK constellation deployed. With more than 8 phases, the error-rate becomes too high and there are better, though more complex, modulations available such as quadrature amplitude modulation (QAM). Although any number of phases may be used, the fact that the constellation must usually deal with binary data means that the number of symbols is usually a power of 2; this allows an equal number of bits-per- symbol. Figure 3 shows the implementation of the OFDM model with the higher order PSK modulation. We have simulated the DSSS-OFDM model with selected BPSK, QPSK, 8-PSK, 16-PSK, 64-PSK modulation Techniques. Simulation results for OFDM with 8-PSK is found suitable for long distance communication link. BER for 8-PSK found rapidly falls above 40 dB SNR for DSSS-OFDM. From the simulated results we can observe that spreading makes system able to handle at more SNR levels for higher order modulation used, meaning that higher order modulation cannot be handle at smaller distances. As shown in simulated results one can recommend DSSS-OFDM with BPSK and QPSK modulation for short distance communication. We may select specific higher order PSK modulation over the long distance keeping the limit of affordable SNR levels. From the simulated results we can easily observe that as we go on selecting the higher order PSK modulation scheme, the poorer BER we have to bear.

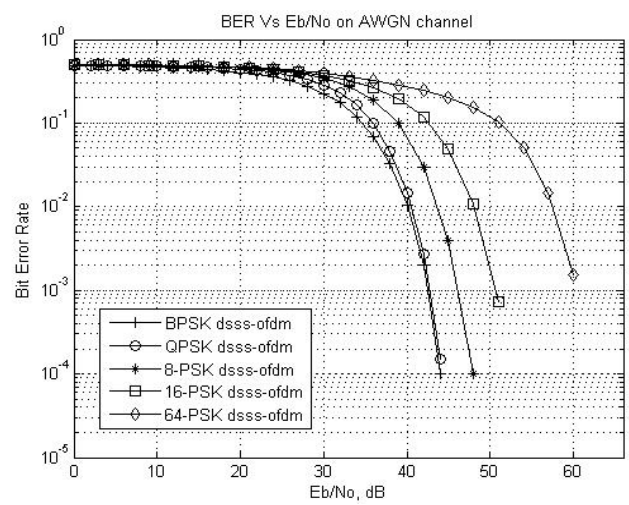

Figure 5. BER performance of DSSS-OFDM using 2, 4, 8, 16, 64-PSK modulation

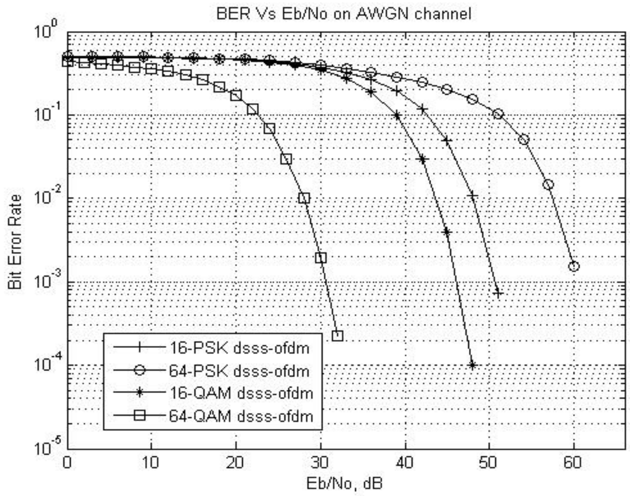

Figure 6 Comparative BER performance of DSSS-OFDM using PSK and QAM modulation

From overall comparison it is proved that DSSS-OFDM with QAM modulation have better BER performance than that of DSSS-OFDM with M-PSK. It increases complexity. To have perfect comparison over the range of PSK we have simulated our model on M-PSK range. Simulated results are shown in Figure 5. One can easily view from the comparative study that spreading requires to be handled on the increased level of SNR for getting lower value of BER. But it would give us remarkable improvement in multipath environment. This is the point where we can choose DSSS-OFDM for wireless broad band Application.

We have also tested our DSSS-OFDM model shown in figure 4 with M-QAM modulation. The simulated results are shown in figure 6 which shows the tremendous improvement in BER performance compared with M-PSK modulation used where 16, 64 QAM is compared with the 16, 64 PSK modulation used for testing BER performance of DSSS-OFDM model after combing OFDM with DSSS. We have found that system can be effectively handle communication on short as well as long distances using M-QAM modulation with the efficiently reduced interference, that too with improved BER rate. DSSS-OFDM model has another advantage of inherent security due to use of DSSS.

VII. CONCLUSION

A concept of OFDM modulation combined with DSSS results in DSSS-OFDM. The resulted signal characterizes by wide bandwidth spectrum. It has statistical characteristics of a white noise. In a proposed method, each carrier is itself spread by means of the pseudo-noise sequence. We have simulated the DSSS-OFDM model with selected BPSK, QPSK, 8-PSK, 16-PSK, 64-PSK and 16-QAM, 64-QAM modulation techniques. Simulation results for DSSS-OFDM with BPSK, QPSK modulation is found suitable for short distance communication whereas 8-PSK modulation can be used for long distance communication. From overall comparison it is proved that DSSS-OFDM with M-QAM modulation has comparatively better BER performance than of DSSS-OFDM with M-PSK. We conclude that the use of M-QAM instead of M-PSK is recommended for better BER performance of DSSS-OFDM simulink based model. all the above analysis is done for AWGN channel only. If the channel is not gaussian, we need to estimate the channel first and then use a different combining process. For future work, we can consider practical multipath channel and research on effective combining and equalization techniques.

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