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Analysis the Effect of Spectral Efficiency on Digitally Modulated OFDM Communication System over Realistic Channel Condition

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Abstract— In OFDM communication system, the choice of modulation technique is considered very important for good system performance. It is our primary need today to achieve high data rates in limited spectrum bandwidth to improve the performance of signal. Spectral efficiency describes the ability of a modulation scheme to accommodate data within a limited bandwidth. In this paper, the performance of spectral efficiency for different modulation techniques namely BPSK, QPSK, and 16PSK have been investigated over AWGN and Fading channel conditions. The simulation model that is build for this paper, demonstrated that 16PSK modulation scheme has a better performance than BPSK and QPSK over any channel condition. MATLAB R2010a is used as a simulation tool and synthetic data is used as input data for this research work.

Index Terms— Spectral Efficiency, OFDM, CC, AWGN, Rayleigh fading channel, Rician Fading channel, Digital Modulation.

1 INRODUCTION

Orthogonal frequency division multiplexing (OFDM) is a multicarrier modulation scheme that achieves high spectral efficiency by using minimally densely spaced orthogonal subcarriers without increasing the transmitter and receiver complexities. In modern communication systems, the highest transmission rates in the 20-200 Mb/s range are envisioned for 4G systems [1].However, with the increase of the data rate, the symbol duration educes and hence the Inter Symbol Interference (ISI) increases. The ISI is caused by the dispersive fading of the wireless channels if single-carrier modulation is used. To reduce this high ISI a multicarrier modulation technique is required that has high spectral efficiency. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation technique that is considered as one of the high spectral efficient modulation techniques. OFDM uses minimal densely spaced orthogonal subcarriers. The entire channel is divided into many narrow-band sub channels, which are used in parallel to maintain high data rate transmission and, at the same time, to increase the symbol duration to combat ISI. Although OFDM plays an important role in wide band transmission schemes, its performance is degraded by multipath fading that is very common in any wireless communication system [2]. To combat the effects of channel fading and to improve the system performance, various diversity techniques are used in one form or another.

In OFDM Communication System, choice of modulation scheme is considered very important for good performance. Different performance parameters are generally considered for selection of a digital modulation scheme depending on the channel response. Performance parameters like Bandwidth Efficiency, Bit Error Rate (BER), Signal to Noise Ratio (SNR), Bit Energy to Noise Ratio (Eb/No), cost effectiveness and ease of implementation are considered in different applications. In this paper, the main parameters spectral efficiency is considered to analyze the performance of M-ary PSK (BPSK, QPSK, 16PSK) modulation schemes in an AWGN and Fading (Rayleigh & Rician) Channel. A general theoretical approach is considered for performance analysis in which MATLAB is used to plot different curves for the comparison [3].

OFDM Communication system used digital modulation schemes because of its many advantages over the analog modulation schemes. The choice of digital modulation schemes generally depends on several factors and all the modulation schemes do not satisfy all the requirements; as some of these modulation schemes are better in bandwidth efficiency and some are better in terms of bit error rate. Therefore, trade-offs are made depending on the requirements and desired applications. The performance of the modulation scheme is generally measured in terms of spectral efficiency. Spectral Efficiency is the efficient utilization of allocated bandwidth and is defined as the throughput data rate per Hertz. Spectrum is an expensive resource in wireless communication therefore bandwidth efficient modulation schemes are always preferred [4].

The objective of this paper is to implement an OFDM communication system and simulate the spectral efficiency using MATLAB in order to have a better understanding of the standards and evaluate the system performance. This involves studying through simulation of the Convolutional encoded various PSK modulation schemes and evaluating the spectral efficiency performance of the communication system under AWGN and Fading channel.

2 SPECTRAL EFFICIENCY

Spectral efficiency, one of the crucial term for every type of network whether it is WiFi network, or WiMAX or cellular network. The main aim of the designer is to increase the spectral efficiency as much as possible and that is why there are terms like cell splitting, cell sectoring etc. in cellular system [5].Spectral efficiency is defined as the ratio of data rate to channel bandwidth. Spectral efficiency, spectrum efficiency or bandwidth efficiency refers to the information rate that can be transmitted over a given bandwidth in a specific communication system. It is a measure of how efficiently a limited frequency spectrum is utilized by the physical layer protocol, and sometimes by the media access control (the channel access protocol) [6].

The spectral efficiency is presented in many ways in the literature. We derived the spectral efficiency using the relation [7]

$$\eta = (1 - p_e)^n \, mr \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

Where,

p_e = bit error rate

n= the number of bits in the block

m= the number of bits per symbol

and r= the code rate

In digital wireless networks, the system spectral efficiency or area spectral efficiency is typically measured in bit/s/Hz/area unit, bit/s/Hz/cell or bit/s/Hz/site. It is a measure of the quantity of users or services that can be simultaneously supported by a limited radio frequency bandwidth in a defined geographic area. It may for example be defined as the maximum throughput, summed over all users in the system, divided by the channel bandwidth. The system spectral efficiency of a cellular network may also be expressed as the maximum number of simultaneous phone calls per area unit over 1 MHz frequency spectrum in E/MHz per cell, E/MHz per sector, E/MHz per site, or (E/MHz)/m2. This measure is also affected by the source coding scheme. It may be used in analog cellular networks as well [8].

3 SYSTEM SIMULATION MODEL

The block diagram of the simulated OFDM system model is shown in Figure 1. The simulation model consists of three main sections namely transmitter, receiver and channel. At the transmitter side, generally the input binary data stream is encoded, modulated, and then transmitted through the communication channel. At the receiver side, the received signal is demodulated and decoded in order to recover the data transmitted. Transmitter and receiver components consist of channel coding and modulation sub-components whereas channels are modeled as AWGN and fading (Rayleigh and Rician) channel [9].

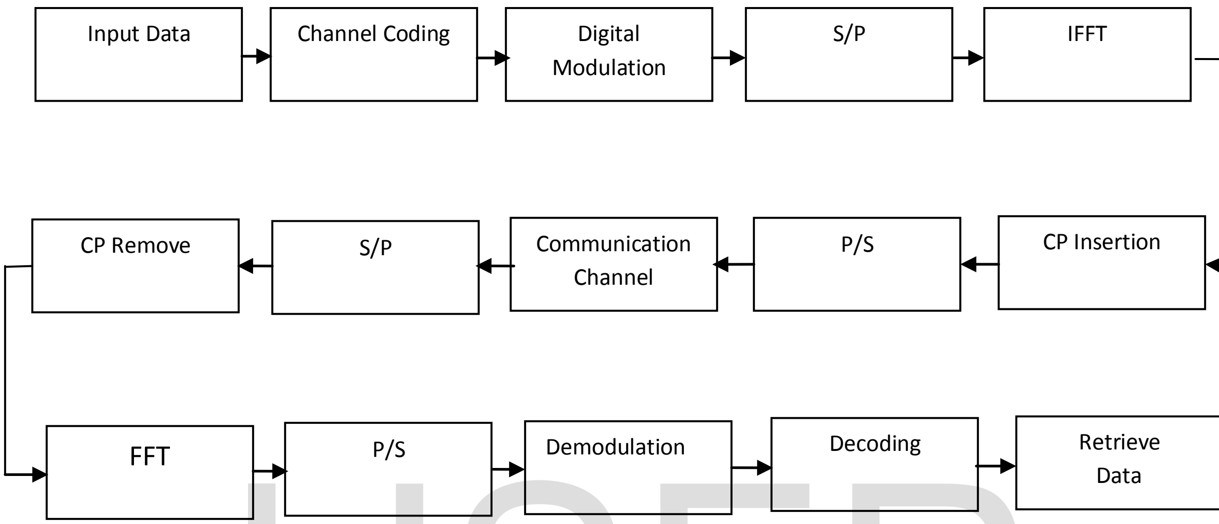

Figure 1: Communication Model of OFDM system

First, we define the parameters that were used to develop the OFDM simulator. The used parameters are listed in Table 1 as follows:

Table-1: Parameter of the Simulator

Parameters	**values**
Number Of Bits to be Transmitted and received	61184
Number Of Subcarriers	200
FFT Size	256
CP	1/8
CC code rate	2/3
Doppler Shift	100/40 Hz
K-factor	3
Constraint length	7
SNR	0-25
Modulation	BPSK,QPSK,16-PSK
Noise Channels	AWGN, Rayleigh and Rician

In this section, a simple communication system simulation model has been discussed thoroughly and all related assumptions have been stated clearly and justified. The implemented model needs to be realistic as possible in order to get reliable results. It is ought to be mentioned here that the real communication systems are very much complicated and due to non-availability of the algorithms to simulate the performance evaluation of their various sections, generally, simulations are made on the basis of some assumptions to simplify the communication system concerned. Figure-1 shows a simulation model. This is a point-to point communication system model.

At first, the input bit is randomly generated. In CC channel coding scheme, a Convolution Coding (CC) is applied to the input binary data. The output of the encoder then converted to complex digital symbols by BPSK, QPSK & 16PSK modulations and fed to OFDM modulator for transmission where the digitally modulated symbols are transmitted in parallel on subcarriers through implementation as an Inverse Fast Fourier Transform (IFFT) on a block of information symbols followed by an analog-to-digital converter (ADC). To mitigate the effects of inter-symbol interference (ISI) caused by channel time spread, each block of IFFT coefficients is typically presented by a cyclic prefix. At the receiving side, a reverse process (including decoding) is executed to obtain the original data bits. When passing through the CC-decoder some errors may be corrected, this results in lower error rates [10].

4 SIMULATION RESULT

In this section, we have presented various BER vs. SNR plots for all the essential modulation and coding profiles in the standard on different channel models. Figure 2, 3 and 4 display the performance on Additive White Gaussian Noise (AWGN), Rayleigh and Rician channel models respectively. The Bit Error Rate (BER) plot obtained in the performance analysis showed that model works well on Signal to Noise Ratio (SNR) less than 25 dB.

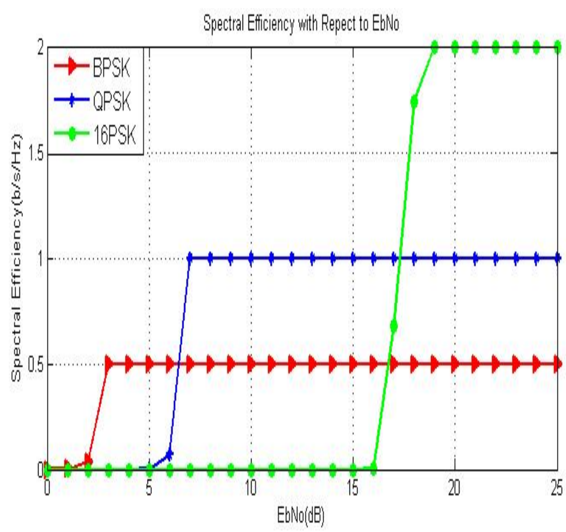

Figure-2: Effect of Spectral Efficiency on 2/3 rated Convolutional Encoded OFMD Communication System over AWGN Channel

From figure-2, we can observed the effect of spectral efficiency of convolutional encoded OFDM communication system with implementation of different modulation techniques (BPSK, QPSK, 16PSK) over AWGN channel. In this figure we have seen that, spectral efficiency is increased with increasing the signal-to-noise ratio but after particular SNR it is constant. Figure-2 also shows that, for BPSK, spectral efficiency is higher when signal-to-noise ratio (SNR) is 3dB and then it is similarly 7dB for QPSK and 19dB for 16PSK. It is seen from simulation result that, 16PSK has a better performance as compared to other; because when SNR is 19dB then it show maximum spectral efficiency which is 2 bit/sec/Hz. On the other hand, BPSK and QPSK show maximum spectral efficiency at very low SNR, but there maximum spectral efficiency is 0.5 bit/sec/Hz and 1 bit/sec/Hz respectively. Hence from all of these, 16PSK show the better performance.

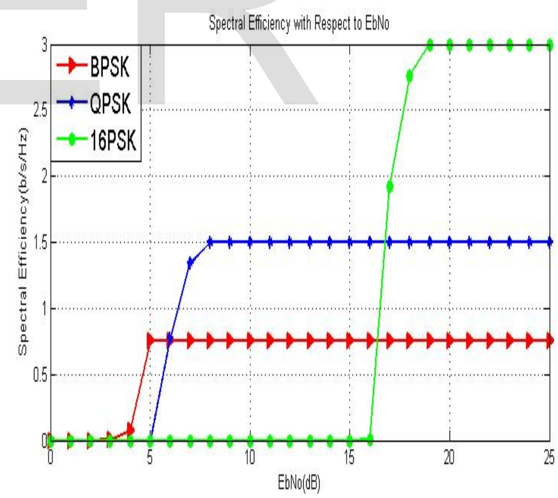

Figure-3: Effect of Spectral Efficiency on 2/3 rated Convolutional Encoded OFMD Communication System over Rayleigh Fading Channel

Similarly from figure-3, we can also observed the effect of spectral efficiency of convolutional encoded OFDM communication system with implementation of different modulation techniques (BPSK, QPSK, 16PSK) over Rayleigh fading channel. Figure-3 also showed that, for BPSK, spectral efficiency is higher when signal-to-noise ratio (SNR) is 5dB and then it is similarly 8dB for QPSK and 19dB for 16PSK. It is seen from simulation result that, 16PSK has a better performance as compared to other; because when SNR is 19dB then it show maximum spectral efficiency which is 3 bit/sec/Hz. On the other hand, BPSK and QPSK show maximum spectral efficiency at very low SNR, but there maximum spectral efficiency is 0.75 bit/sec/Hz and 1.5 bit/sec/Hz respectively. Hence from all of these 16PSK show the better performance.

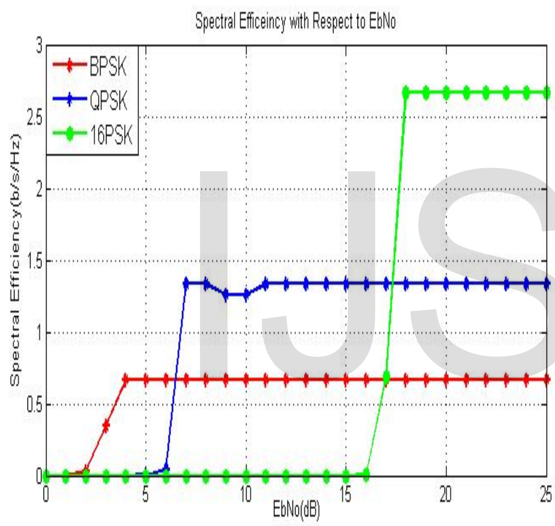

Figure-4: Effect of Spectral Efficiency on 2/3 rated Convolutional Encoded OFMD Communication System over Rician Fading Channel

Similarly from figure-4, we can also observed the effect of spectral efficiency of convolutional encoded OFDM communication system with implementation of different modulation techniques (BPSK, QPSK, 16PSK) over Rician fading channel. It is obtained from figure-3 that, 16PSK has a better performance as compared to other; because the maximum spectral efficiency 16PSK is 2.65bit/sec/Hz. On the other hand, BPSK and QPSK show maximum spectral efficiency of 0.65 bit/sec/Hz and 1.45 bit/sec/Hz respectively. Hence from all of these 16PSK show the better performance.

5 CONCLUSIONS

In this research work, it has been studied the spectral efficiency performance of an OFDM communication system adopting the 2/3 rated Convolution Coding (CC) channel coding and different digital modulation schemes. A range of system performance results highlights the impact of spectral efficiency of digitally modulated OFDM system under AWGN and fading channels (Rayleigh and Rician) channel. The research work focuses on the performance investigation by spectral efficiency (Bit/s/Hz) against Eb/No of OFDM system under AWGN, Rayleigh and Rician fading channels using different digital modulations namely BPSK, QPSK and 16PSK. By analyzing the simulation result, it has been observed that for all channel condition 16PSK shows better performance as compared with other modulation technique.

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