Error Probability of Different Modulation Schemes for OFDM based WLAN standard IEEE 802.11a

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Abstract

Orthogonal Frequency Division Multiplexing (OFDM) is a key technique for achieving high data rates and spectral efficiency requirements for wireless communication systems. This paper presents a modeling and simulation of OFDM based on WLAN standard (IEEE 802.11a). Performance of OFDM is evaluated for different modulation schemes such as PSK, QAM, DQPSK, and OQPSK. The performance of OFDM is compared in terms of BER vs SNR for different modulation formats.

Keywords: Additive white Gaussian noise (AWGN), QAM, OQPSK, and DPSK.

1. INTRODUCTION

Wireless Local Area Networks (WLAN) and the exponential growth of the Internet have resulted in an increased demand for new methods of obtaining high capacity wireless networks. OFDM is a modulation scheme that allows digital data to be efficiently and reliably transmitted over a radio channel, even in multipath environments [1, 2, 3]. In OFDM, the digital data is sent using many carriers, each of a different frequency and these carriers are orthogonal to each other. All these carriers transmit in unison using synchronized time and frequency, forming a single block of spectrum. OFDM has found its application in a number of wireless and wireline systems. OFDM has been adopted into several European wireless communications applications such as the digital audio broadcast (DAB) and terrestrial digital video broadcast (DVB-T) systems [4, 5]. In the United States, OFDM has been adopted in multipoint multichannel distribution services (MMDS).Both wireless LAN applications-using standards such as IEEE 802.11a and the new European Telecommunications Standard Institute's (ETSI) HiperLAN/2 specification have also installed OFDM as the modulation scheme[6,7].

Most WLAN systems currently use the IEEE802.11b standard, which provides a maximum data rate of 11 Mbps. Newer WLAN standards such as IEEE802.11a and HiperLAN2 are based on OFDM technology and provide a much higher data rate of 54 Mbps. However systems of the near future will require WLANs with data rates of greater than 100 Mbps, and so there is a need to further improve spectral efficiency and data capacity of OFDM systems in WLAN applications [8]. One of the main reasons for using OFDM for Wireless LANs is relatively small amount of delay spread encountered in such applications [9].

The paper presents the performance comparison results of the various digital modulation techniques for OFDM in WLAN standard IEEE802.11a so as to obtain the most efficient modulation technique for the same.

Digital data is transferred in an OFDM link by using a modulation scheme on each subcarrier. A modulation scheme is a mapping of data words to a real (In phase) and imaginary (Quadrature) constellation, also known as an IQ constellation. For example 64-QAM (Quadrature Amplitude Modulation) has 64 IQ points in the constellation, constructed in a square with 8 evenly spaced columns in the real axis and 8 rows in the imaginary axis. The number of bits that can be transferred using a single symbol corresponds to log2 (M), where M is the number of points in the constellation, thus 64-QAM transfers 6 bits per symbol. Each data word is mapped to one unique IQ location in the constellation.

Differential Phase Shift Keying (DPSK) is the most common method of sending differential information. Instead of mapping data to an absolute phase angle, as in the case of coherent modulation, DPSK maps the data to a phase difference between symbols. For example, for differential QPSK each symbol transmits 2 bits of information, corresponding to 4 different phase differences.

2. OFDM GENERATION AND RECEPTION

OFDM signals are typically generated digitally. Figure 1 shows the block diagram of a typical OFDM transceiver. The transmitter section converts digital data to be transmitted, into a mapping of subcarrier amplitude and phase by using modulation techniques. It then transforms this spectral representation of the data into the time domain using an Inverse Fast Fourier Transform as it is much more computationally efficient, and so is used in all practical systems [10, 11]. The addition of a cyclic prefix to each symbol solves both ISI and ICI [12, 13, 14]. If the channel impulse response has a known length L, the prefix consists simply of copying the last L-1 values from each symbol and appending them in the same order to the front of the symbol. Digital data is then converted to serial form and transmitted over the channel.

After the time-domain signal passes through the channel, it is broken back into the parallel symbols and the prefix is simply discarded. The receiver performs the reverse operation of the transmitter. The amplitude and phase of the subcarriers is then picked out and converted back to digital data.

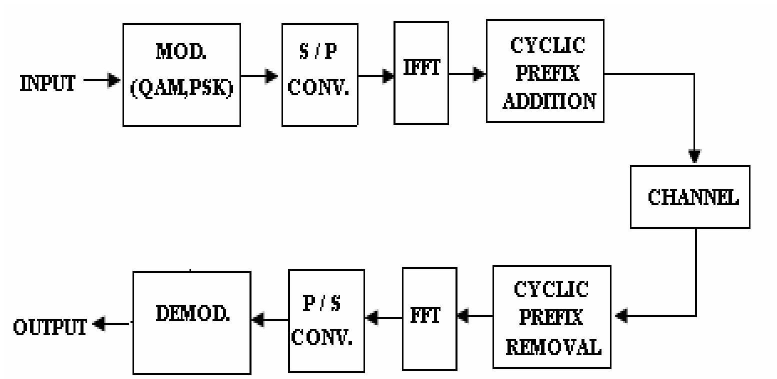

FIGURE 1: Block diagram showing a basic OFDM transceiver

When an OFDM transmission occurs in a multipath radio environment, frequency selective fading can result in groups of subcarriers being heavily attenuated, which in turn can result in bit errors.

3. SIMULATION RESULTS

OFDM for WLAN IEEE 802.11a system using different modulation schemes in the presence of AWGN and Rayleigh fading channel was simulated using Matlab. The OFDM signal parameters for the system are given in table 1.

Channel Spacing	IFFT	No. of Subcarriers	Carrier Spacing (Fc)
20 MHz	64	52	312.5 kHz (=20 MHz/64)

TABLE 1: Simulation Parameters

Two different types of subcarrier modulation i.e. Coherent and Differential (for M=2, 4, 16) are used. In addition to these, OQPSK is also used. The results presented show the BER performance as a function of the channel SNR. In log scale the SNR for a given Eb/No can be found with:

$$E_s/N_o dB = E_b/N_o dB + 10*\log_{10}(nSC/nFFT) + 10*\log_{10}(Td/Td + Tc) + 10*\log_{10}(k)$$

Where

nSC is No. of subcarriers
Tc is cyclic prefix duration
Td is Data symbol duration
Ts is Total Symbol duration and k equals $\log_2$ (M).

The graphs of BER vs Eb/No for Coherent PSK, QAM, OQPSK and DPSK for M=4 in AWGN channel are shown in figure 2 whereas figure 3 shows BER for same modulation techniques with M=16 in AWGN channel.Similarly the graphs of BER verses Energy per bit to Noise ratio for PSK, DPSK, OQPSK (M=2, 4, 16) in Rayleigh channel are shown in figure 4.

The SNR for each modulation takes into account the number of bits per symbol, and so the signal power corresponds to the energy per bit times the number of bits per symbol. The higher Eb/No required for transferring data means that more energy is required for each bit transfer.

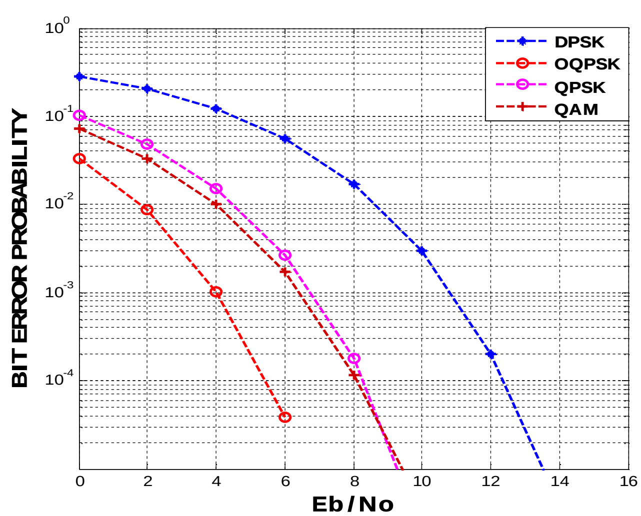

FIGURE 2: BER vs SNR for AWGN channel (M=4)

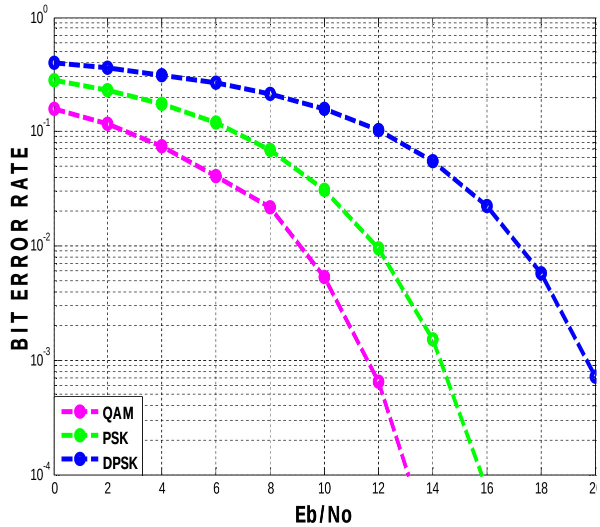

FIGURE 3: BER vs SNR for AWGN channel (M=16)

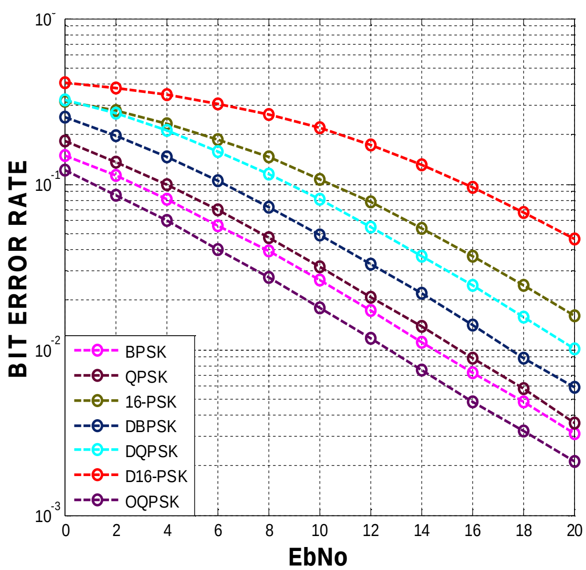

FIGURE 4: BER vs SNR for Rayleigh channel using PSK, DPSK, and OQPSK (M=2, 4, and 16)

4. CONCLUSION

All wireless communication systems use modulation schemes to map the information signal to a form that can be effectively transmitted over the communication channel.

We presented a performance study of M-ary modulation schemes viz. PSK, OQPSK, QAM and DPSK for FFT-OFDM technique using the system parameters for WLAN standard (IEEE 802.11a).The performance analysis of the WLAN system is based on BER versus SNR for above mentioned modulation formats in Additive white guassian noise channel and the Rayleigh fading channel which is one of the channel scenarios as found in most of the wireless applications.

The SNR for each modulation takes into account the number of bits per symbol, and so the signal power corresponds to the energy per bit times the number of bits per symbol. The higher Eb/No required for transferring data means that more energy is required for each bit transfer.

From the performed simulations, it was found that in AWGN channel, Coherent QAM performs best in that it shows the least bit error rate requiring the least SNR for M=16 while differential PSK is the worst for the same value of M. Whereas for M = 4, OQPSK performs the best as it requires least SNR and DPSK performs the worst in AWGN channel.
Similarly, for Rayleigh channel, OQPSK modulation done on the transmitted bits performs the best of all the other modulation techniques i.e. PSK and DPSK for the various values of M. The low efficiency of PSK in AWGN channel is a result of under utilization of the IQ vector space. As it is a known fact that PSK only uses the phase angle to convey information, with amplitude being ignored, QAM uses both amplitude and phase for information transfer and so is more efficient than PSK in AWGN channel for an OFDM system.

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