International Journal of Electronics and Electrical Engineering
ISSN : 2277-7040 Volume 2 Issue 3 (March 2012)
http://www.ijecee.com/ https://sites.google.com/site/ijeceejournal/

BER PERFORMANCE OF OFDM SYSTEM WITH 16-QAM AND VARYING LENGTH OF GUARD INTERVAL

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Abstract. Orthogonal frequency division multiplexing scheme being spectrally efficient is used in modern communication systems. To achieve error free communication guard interval is inserted using cyclic prefix and zero padding. The Bit Error Rate (BER) performance for orthogonal frequency division multiplexing (OFDM) system with 16-QAM and varying length of guard interval (GI) is presented.

Keywords: BER, Cyclic prefix, Intersymbol interference, Virtual carriers, Zero padding

1 Introduction

An OFDM signal may incur out-of-band radiation, which causes non-negligible adjacent channel interference (ACI). It is clearly seen from Figure 1 that the first side lobe is not so small as compared to the main lobe in the spectra. Therefore, OFDM scheme places a guard band at outer subcarriers, called virtual carriers (VCs), around the frequency band to reduce the out-of band radiation. [3] The OFDM scheme also inserts a guard interval in the time domain, called cyclic prefix (CP), which mitigates the inter-symbol interference (ISI) between OFDM symbols [1]

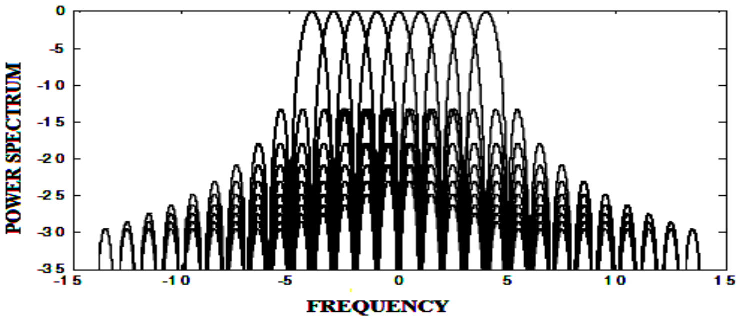


Fig.1 Power spectrum of OFDM signal (dB)

The OFDM guard interval can be inserted in two different ways. One is the zero padding (ZP), that pads the guard interval with zeros. The other is the cyclic extensions of the OFDM symbol with cyclic prefix (CP) or cyclic suffix (CS) [4].

2 Cyclic prefix and Zero padding

2.1 Cyclic Prefix

CP is to extend the OFDM symbol by copying the last samples of the OFDM symbol into its front. Let T_G denote the length of CP in terms of samples. Then, the extended OFDM symbols now have the duration of $T_{sym} = T_{sub} + T_G$. Figure 2(a) shows two consecutive OFDM symbols, each of which has the CP of length T_G, while illustrating the OFDM symbol of length $T_{sym} = T_{sub} + T_G$.Figure 2(b) illustrates them jointly in the time and frequency domains. Figure 2(c) shows the ISI effects of a multipath channel on some subcarriers of the OFDM symbol. It can be seen from this figure that if the length of the guard interval (CP) is set longer than or equal to the maximum delay of a multipath channel, the ISI effect of an OFDM symbol (plotted in a dotted line) on the next symbol is confined within the guard interval so that t may not affect the FFT of the next OFDM symbol, taken for the duration of T_{sub} .[1]

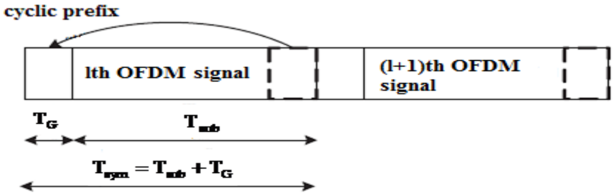


Fig.2 (a) OFDM symbols with CP

2.2 Zero Padding

Zero can be inserted into the guard interval. This particular approach is adopted by multiband- OFDM (MB-OFDM) in an Ultra Wide-band (UWB) system. Figures 3 (a) and (b) show OFDM symbols with ZP and the ISI effect of a multipath channel on OFDM symbols for each subcarrier, respectively. Even with the length of ZP longer than the maximum delay of the multipath channel, a small symbol timing offset (STO) causes the OFDM symbol of an effective duration to have a discontinuity within the FFT window and therefore, the guard interval part of the next OFDM symbol is copied and added into the head part of the current symbol to prevent ICI.[3]

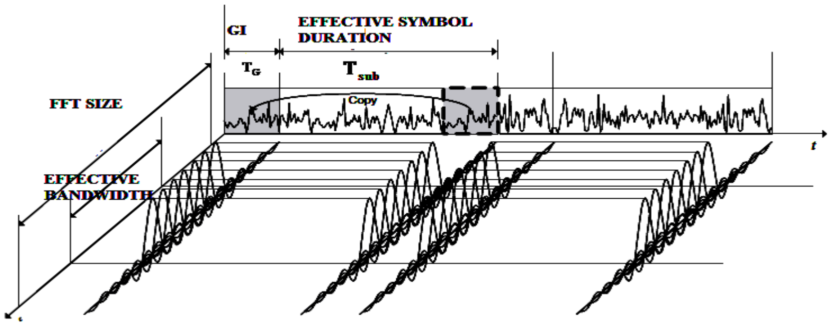


Fig.2 (b) Time/frequency domain description of OFDM symbol with CP

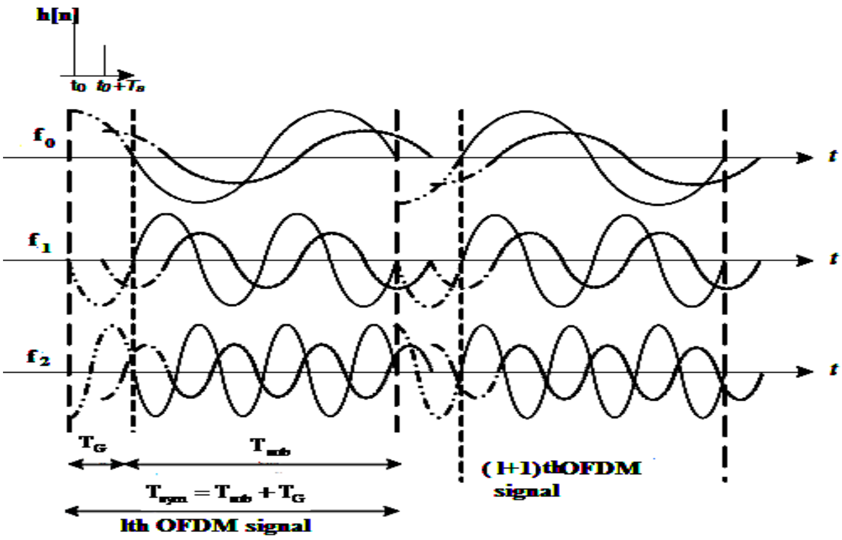


Fig.2 (c) Effect of multipath channel for each subcarrier

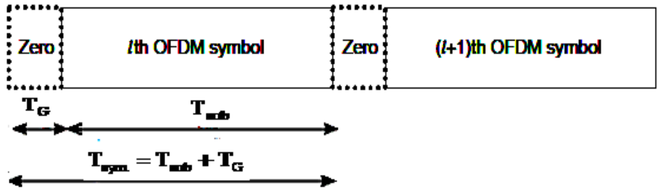


Fig.3 (a) OFDM signal with zero padding

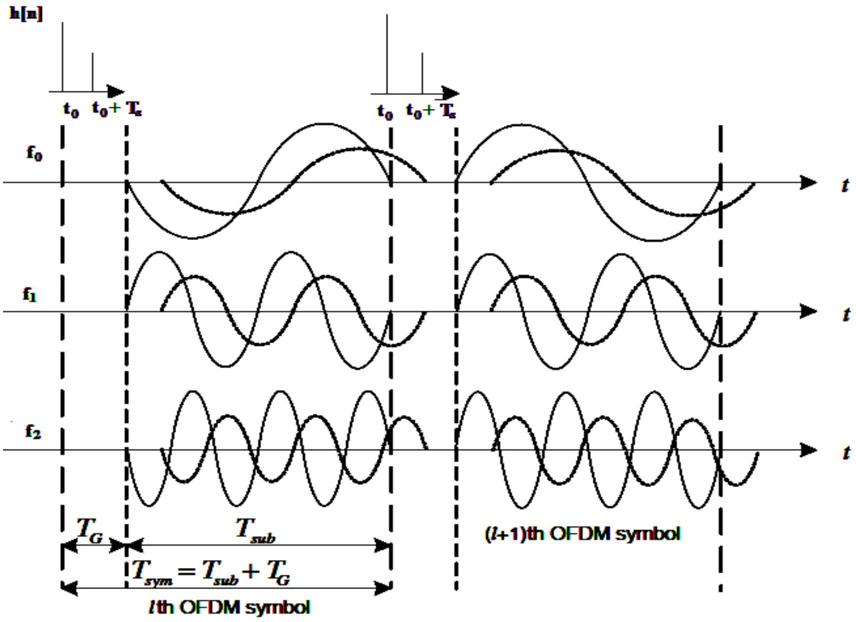


Fig.3 (b) The ISI effect of a multipath channel for each subcarrier

3 BER of OFDM scheme

The analytical BER expressions for M-ary QAM signaling in AWGN and Rayleigh channels are respectively given as

$$P_e = \frac{2(M-1)}{M\log_2 M} Q\left(\sqrt{\frac{6E_b}{N_o} \cdot \frac{\log_2 M}{M^2-1}}\right) \tag{1}$$

For AWGN channel and for Rayleigh fading channel its

$$P_e = \frac{M-1}{M\log_2 M}\left(1-\sqrt{\frac{3\gamma\log_2 M/(M^2-1)}{3\gamma\log_2 M/(M^2-1)+1}}\right) \tag{2}$$

Where γ and M denote $\frac{E_b}{N_o}$ and the modulation order, respectively. [2] Q(.) is the standard Q function defined as

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-t^2/2} dt \tag{3}$$

If N_{used} subcarriers out of total N (FFT size) subcarriers (except $N_{vc} = N - N_{used}$ virtual subcarriers) are used for carrying data, the time-domain SNR, SNR_t , differs from the frequency-domain SNR, SNR_f ,[2] as

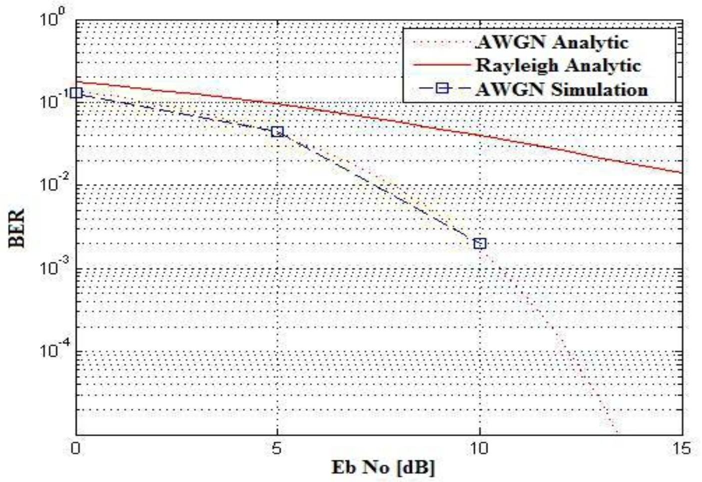
$$SNR_t = SNR_f + 10\log\frac{N_{used}}{N}[dB] \tag{4}$$

4 Simulation results

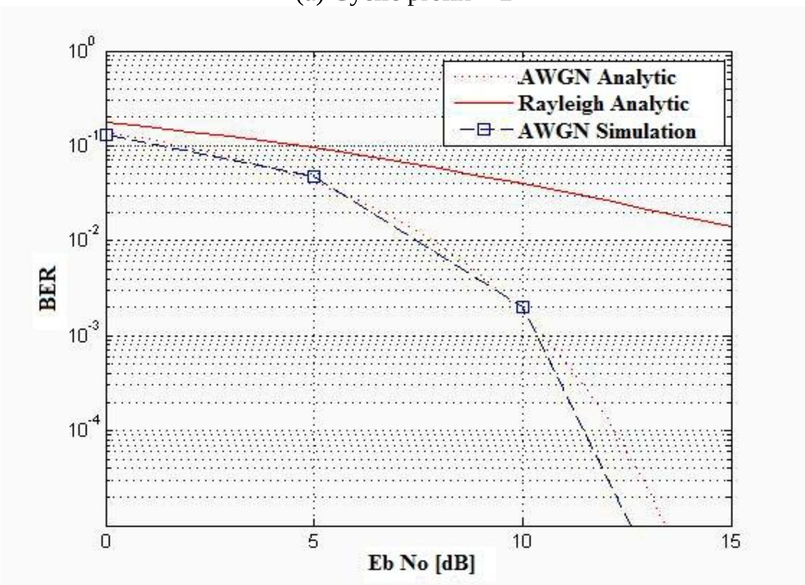
The effect of ISI (inter symbol interference) can be simulated as the length of a guard interval (CP or ZP) varies. The BER performance of an OFDM system with 64-point FFT (N=64) and varying guard interval in the AWGN or a multipath Rayleigh fading channel is presented in the below simulation results.The BER performance with CP of length 16 samples, as shown in Fig.4 (d), is consistent with that of the analytic result in the Rayleigh fading channel. This implies that the OFDM system is subjected to a flat fading channel as long as CP or ZP is large enough. Table 1 shows the effect of ISI on BER performance at different SNR with different length of GI in AWGN channel. The effect becomes significant as the length of GI decreases.

Table 1 BER at different SNR with different CP for AWGN channel

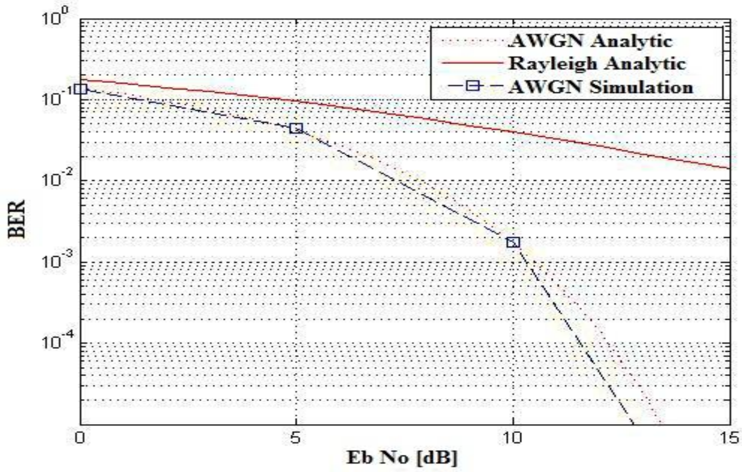
Cyclic prefix length	CP-2	CP-4	CP-8	CP-16
Signal power	9.377e-002	4.688e-002	2.344e-002	1.172e-002
BER at 0	0.1285	0.1308	0.1354	0.1432
BER at 5	0.0447	0.04815	0.04384	0.04688
BER at 10	0.001979	0.01987	0.001728	0.001946
BER at 15	0.0	6.944	1.736	1.389



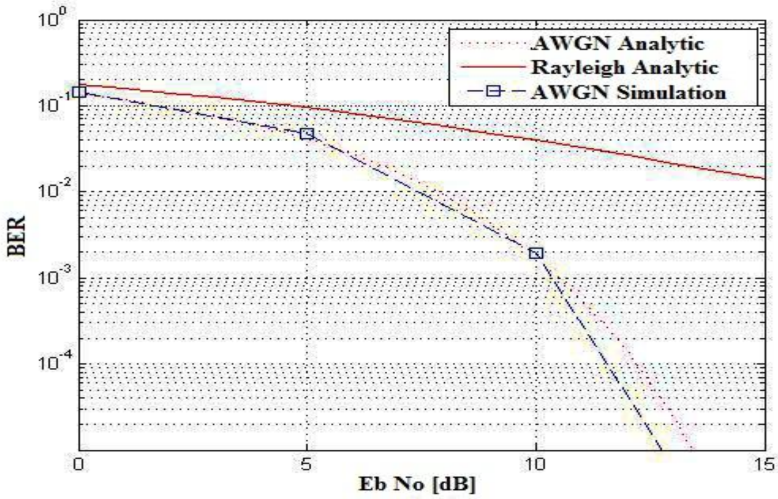
(a) Cyclic prefix = 2



(b) Cyclic prefix = 4



(c) Cyclic prefix = 8



(d) Cyclic prefix = 16

Fig.4 BER performance for OFDM system with 16-QAM and varying CP

5 Conclusions

The OFDM system is subjected to a flat fading channel as long as guard interval is large enough. Also the BER performance in an AWGN channel is consistent with the analytical results, regardless of how long GI is, because there is no multipath delay in the AWGN channel. The effect of ISI on the BER performance becomes significant in the multipath Rayleigh fading channel as the length of GI decreases, which eventually leads to an error.

5 References

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