BPSK BER with OFDM modulation

*by*KRISHNA SANKAR*on JUNE 10, 2008*

Oflate, I am getting frequent requests for **bit error rate**simulations using **OFDM (Orthogonal Frequency Division Multiplexing)** modulation. In this post, we will discuss a simple OFDM transmitter and receiver, find the relation between Eb/No (Bit to Noise ratio) and Es/No (Signal to Noise ratio) and compute the bit error rate with BPSK.

**OFDM modulation**

Let us use the OFDM system loosely based on IEEE 802.11a specifications.

|  |  |
| --- | --- |
| **Parameter** | **Value** |
| FFT size. nFFT | 64 |
| Number of used subcarriers. nDSC | 52 |
| FFT Sampling frequency | 20MHz |
| Subcarrier spacing | 312.5kHz |
| Used subcarrier index | {-26 to -1, +1 to +26} |
| Cylcic prefix duration, Tcp | 0.8us |
| Data symbol duration, Td | 3.2us |
| Total Symbol duration, Ts | 4us |

You may refer to post [Understanding an OFDM Transmission](http://www.dsplog.com/2008/02/03/understanding-an-ofdm-transmission/) for getting a better understanding of the above mentioned parameters.

**Cyclic prefix**

In an OFDM transmission, we know that the transmission of cyclic prefix does not carry ‘extra’ information in Additive White Gaussian Noise channel. The signal energy is spread over time http://www.dsplog.com/cgi-bin/mimetex.cgi?Td+Tcp whereas the bit energy is spread over the time http://www.dsplog.com/cgi-bin/mimetex.cgi?Td i.e.  
http://www.dsplog.com/cgi-bin/mimetex.cgi?E_s%20\cdot%20\left(Td+Tcp%20\right)%20=%20E_b%20\cdot%20Td.

Simplifying,

http://www.dsplog.com/cgi-bin/mimetex.cgi?E_s%20%20=%20%20\frac%7bTd%7d%7bTd+Tcp%20%7dE_b

**Frequency spread**

In OFDM transmission, all the available subcarriers from the DFT is not used for data transmission. Typically some subcarriers at the edge are left unused to ensure spectrum roll off. For the example scenario, out of the available bandwidth from -10MHz to +10MHz, only subcarriers from -8.1250MHz (-26/64\*20MHz) to +8.1250MHz (+26/64\*20MHz) are used.

This means that the signal energy is spread over a bandwidth of 16.250MHz, whereas noise is spread over bandwidth of 20MHz (-10MHz to +10MHz), i.e.

http://www.dsplog.com/cgi-bin/mimetex.cgi?20MHz\cdot%20E_s%20=%2016.25MHz\cdot%20E_b

Simplifying,

http://www.dsplog.com/cgi-bin/mimetex.cgi?E_s%20=%20\frac%7bnDSC%7d%7bnFFT%7dE_b.

**Relation between Eb/No and Es/No in OFDM**

Combining the above two aspects, the relation between **symbol energy** and the **bit energy** is as follows:  
http://www.dsplog.com/cgi-bin/mimetex.cgi?\frac%7bE_s%7d%7bN_0%7d%20=%20\frac%7bE_b%7d%7bN0%7d%20%20\left(\frac%7bnDSC%7d%7bnFFT%7d\right)\left(\frac%7bTd%7d%7bTd+Tcp%7d\right).

Expressing in decibels,

http://www.dsplog.com/cgi-bin/mimetex.cgi?\frac%7bE_s%7d%7bN_0%7ddB%20=%20\frac%7bE_b%7d%7bN0%7ddB\%20+\%20%2010\log_%7b10%7d\left(\frac%7bnDSC%7d%7bnFFT%7d\right)\%20+\%2010\log_%7b10%7d\left(\frac%7bTd%7d%7bTd+Tcp%7d\right).

**Simulation model**

The attached Matlab/Octave simulation script performs the following:

(a) Generation of random binary sequence

(b) BPSK modulation i.e bit 0 represented as -1 and bit 1 represented as +1

(c) Assigning to multiple OFDM symbols where data subcarriers from -26 to -1 and +1 to +26 are used, adding cyclic prefix, concatenation of multiple symbols to form a long transmit sequence

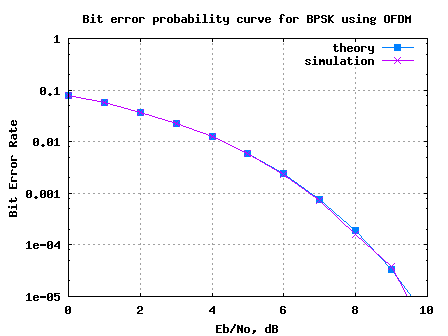
(d) Adding White Gaussian Noise

(e) Grouping the received vector into multiple symbols, removing cyclic prefix, taking the desired subcarriers

(f) Demodulation and conversion to bits

(g) Counting the number of bit errors

Click here to download: [Script for BER computation of BPSK using OFDM](http://www.dsplog.com/db-install/wp-content/uploads/2008/06/script_ber_bpsk_ofdm.m)



**Figure: Bit Error Rate plot for BPSK using OFDM modulation**

Can observe that the simulated bit error rate is in good agreement with the theoretical bit error rate for BPSK modulation i.e.  
http://www.dsplog.com/cgi-bin/mimetex.cgi?P_%7bb,BPSK%7d=\frac%7b1%7d%7b2%7derfc\left(\sqrt%7b\frac%7bE_b%7d%7bN_0%7d%7d\right). :)