Performance of BER in OFDM System Using Different Channels and Modulation Techniques

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ABSTRACT

OFDM system suffers significant performance, when transmitted over different channels. Various channels like AWGN , Rayleigh Fading channels were taken which can be used for the transmission of OFDM signals. Different modulation techniques like QPSK, BPSK, MSK can also be used to modulate the signal before transmission. So the performance of BER can be calculated when modulated by using different modulation technique and when passes through different channels [1].

In this paper, we derive approximate closed-form expressions for BER performance in AWGN channel with different modulation techniques like BPSK,QPSK,8-PSK,16-PSK,32-PSK modulations and predict the performance of bit error rate (BER) with respect to Signal Energy per bit over noise power density ratio (Eb/N0). Simulation results show that the proposed simple analytical forms are quite accurate for different modulation techniques , which lead to the conclusion that BPSK gives the best and ideal performance as compared to other PSK in wireless communications

Keywords—AWGN, BPSK, QPSK, 8-PSK, 16-PSK, 32-PSK, BER, OFDM

I. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has been widely adopted and implemented in wire and wireless communication, such as digital subscriber line (DSL), digital terrestrial TV broadcasting (DVB-T), IEEE 802.11a wireless local area networks (WLANs) and European high performance local area network (HIPERLAN/2). When OFDM signal with different modulation technique transmitted with different channels, the performance of BER is better in some modulation technique and with some channels whereas it is worst in some other type modulation technique and other channels, It is however sensitive to modulation and channel.

II. MODULATION

PSK is a modulation scheme that conveys data by changing, or modulating, the phase of a reference signal (i.e. the phase of the carrier wave is changed to represent the data signal). A finite number of phases are used to represent digital data. Each of these phases is assigned a unique pattern of binary bits; usually each phase encodes an equal number of bits. Each pattern of bits forms the symbol that is represented by the particular phase. There are two fundamental ways of utilizing the phase of a signal in this way:

- By viewing the phase itself as conveying the information, in which case the demodulator must have a reference signal to compare the received signal's phase against; (PSK) or
- By viewing the change in the phase as conveying information – differential schemes, some of which do not need a reference carrier (to a certain extent) (DPSK).

A convenient way to represent PSK schemes is on a constellation diagram (as shown in figure 2.8 below). This shows the points in the Argand plane where, in this context, the real and imaginary axes are termed the in-phase and quadrature axes respectively due to their 90° separation. Such a representation on perpendicular axes lends itself to straightforward implementation. The amplitude of each point along the in-phase axis is used to modulate a cosine (or sine) wave and the amplitude along the quadrature axis to modulate a sine (or cosine) wave.

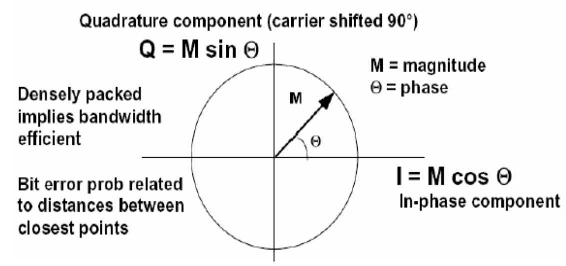

Figure1. Constellation Diagram

In PSK, the constellation points chosen are usually positioned with uniform angular spacing around a circle. This gives maximum phase-separation between adjacent points and thus the best immunity to corruption. They are positioned on a circle so that they can all be transmitted with the same energy. In this way, the moduli of the complex numbers they represent will be the same and thus so will the amplitudes needed for the cosine and sine waves. Two common examples are binary phase-shift keying (BPSK) which uses two phases, and quadrature phase-shift keying (QPSK) which uses four phases, although any number of phases may be used i.e like 8-PSK, 16-PSK,32-PSK,64-PSK. Since the data to be conveyed are usually binary, the PSK scheme is usually designed with the number of constellation points being a power of 2.

The relation between symbol energy rate Es/No and bit energy rate Eb/No is reasonably straightforward. For M-PSK modulation, the number of bits in each constellation symbol is k=log$_2$ (M). Since each symbol carries k bits, the symbol to noise ratio Es/No are k times the bit to noise ratio Eb/No. i.e.

Es/No=k(Eb/No)

Plugging to the above formula, the bit error rate vs bit energy(Eb/No) is given as,

P_b, BPSK= ½ erfc (√(Eb/No))

P_b, 16-PSK = erfc [√ (4Eb/No)sin (Π/16)]

P_b, M-PSK = erfc [√ (4Eb/No)sin (Π/M)]

III. BIT ERROR RATE FOR M- PSK

Consider a general 16-PSK modulation where the alphabets are used.

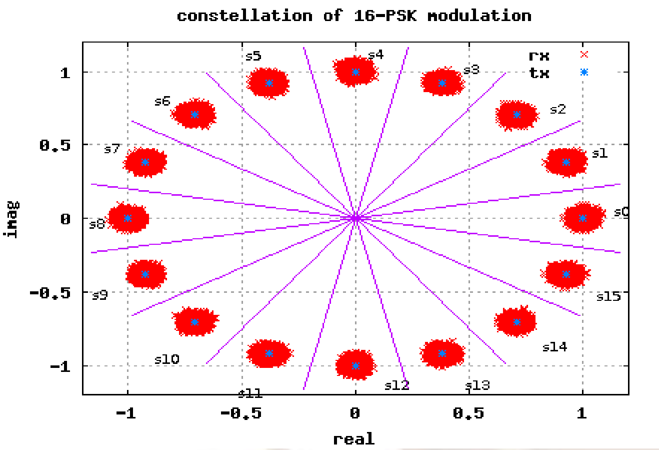

Fig- 2. 16-PSK Constellation plot.

Deriving the symbol error rate

Let us consider the bit on the real axis, i.e. S_o=√E_b

The received bit

$$y = \sqrt{E_b} + n$$

Where the additive noise n follows the Gaussian probabilit y distribution function

$$p(x) = \frac{1}{\sqrt{2\pi\sigma 2}} e^{\frac{(x-\mu)^2}{2\sigma^2}} \text{ with } \mu = 0 \text{ and } \sigma 2 - \frac{N_0}{2}$$

The conditional probability distribution function (PDF) of received symbol y given So was transmitted is

$$p(y|s_0) = \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(x-\sqrt{E_b})^2}{N_0}}$$

As can be seen from the figure above , due to the addition of noise , the transmitted symbol gets sereaded. However , if the received symbol is present within the boundary defined by the magenta lines, then the symbol will be demodulated correctly. To derive the bit error rate , the objective is to find the probability that the phase of the received symbol lies within this boundary defined by the magenta lines i.e from –Π/M to +Π/M.

For simplifing the derivation , let us make the following assumptions:

a) The signal to noise ratio Eb/No is resonable high. For a resonable high value of Eb/No , the real part of the received bit is not afected by noise.i.e.

Ry ≈ √ Eb

and the imaginary part of the received symbol is equal to noise. i.e.

Iy = n

b) The value of M is resonably high (typically M>4suffice)

For a resonably high value of M, the constellation points are closely spaced. Given so, the distance of the constellation point So to the magenta line can be approximated as

$$\sqrt{E_b}\sin\left(\frac{\pi}{M}\right)$$

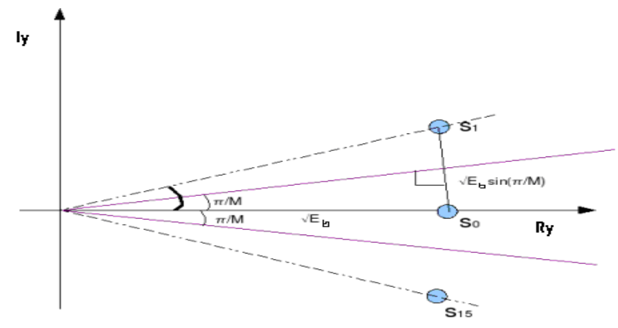

Fig:-3. Distance between Constellation Points

Given the above assumptions, it can be observed that the symbol So will be decoded incorrectly, if the imaginary component of the received symbol y is greater than $\sqrt{E_b}\sin\left(\frac{\pi}{M}\right)$ Then probability of y being greater than $\sqrt{E_b}\sin\left(\frac{\pi}{M}\right)$

Changing the variable to u = Iy/ √No, the complemantary error function is

$$erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-x^2} dx$$

Similarly , the bit So will be decoded incorrectly, if the imaginary component of received bit y is less than $-\sqrt{E_b}\sin\left(\frac{\pi}{M}\right)$. the probability of y being less than $-\sqrt{E_b}\sin\left(\frac{\pi}{M}\right)$

The total probability error given, So was transmitted is

$$p(e|s_0) = erfc\left[\sqrt{\frac{E_b}{N_0}}\sin\left(\frac{\pi}{M}\right)\right]$$

The bit will be in error , if atleast one of the bitl gets decoded incorrectly. Hence the total bit error rate from M-PSK modulation is

$$P_{e,MPSK} = erfc\left[\sqrt{\frac{E_b}{N_0}}\sin\left(\frac{\pi}{M}\right)\right]$$

A. AWGN CHANNEL

At the receiver, the received signal was first contaminated by AWGN. The noise function was introduced as a function comb.m. i.e

```
function [iout,qout] = comb (idata,qdata,attn)
iout = randn(1, length(idata)).*attn;
qout = randn(1, length(qdata)).*attn;
iout = iout + idata(1:length(idata));
qout = qout + qdata(1:length(qdata));
```

variable “attn” will vary in accordance with given Eb/No. Here, “spow” refers to the signal power per carrier per symbol. For the OFDM system, “spow” had to be divided by “para” which indicates the number of parallel sub-carriers.

```
spow = sum(ich3.^qch3./nd./para;
attn = 0.5*spow*sr/br*10.^9-ebn0/10);
attn =sqrt(attn);
```

By using “attn” and comb.m, the transmitted data was contaminated by AWGN.

```
[ich4,qch4] = comb (ich3,qch3,length(ich3), attn);
```

Then, the guard interval was removed from received signal ich4 and qch4.

```
[ich5,qch5] = girem (ich4,qch4, fftlen2, gilen, nd);
```

These data, “ich5” and “qch5” on the time axis were fed into the FFT circuit. In this circuit, the serial data were converted into parallel data on the frequency axis.

```
rx = ich5+qch5.*I;
ry = fft (rx);
ich6 = real (ry);
qch6 =imag(ry);
```

The converted data were divided by “kmod” in each channel to un-normalize the data and were fed into the demodulation function.

```
ich7 = ich6./kmod;
qch7 = qch6./kmod;
[demodata] =qpskdemod(ich7,qch7,para,nd,ml);
```

After that, the demodulated data were converted into a 1-by-para*nd*ml vector. The data were called “demodata1”.

```
demodata1 =reshape(demodata,1,para*nd*ml);
```

Since, in this paper, we need to obtain the BER under different communication channels. Therefore, the number of errors should be calculated. In this simulation, the transmitted data are referred as “seridata” and the received data are referred to as “demodata1”. The calculation will be performed as follows:

instantaneous number of errors and data bits

```
noe2 = sum(abs(seridata-demodata1);
nod2 = length(seridata);
```

cumulative number of errors and data bits in noe and nod

```
noe = noe +noe2;
nod=nod+nod2;
```

Then, BER under different communication channel can be obtained using the following operation:

```
ber = noe/nod;
```

B. RAYLEIGH FADING CHANNEL

Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal such as that used by wireless devices. It assumes that the power of a signal that has passed through such a transmission medium (also called a communications channels) will vary randomly or fade according to a Rayleigh distribution the radial component of the sum of two uncorrelated Gaussian random variables. It is reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built up urban environment on radio signals. Rayleigh fading is most applicable when there is no line of sight between the transmitter and receiver.

For BER performance under one path flat Rayleigh, we need to determine the fading parameters and the parameters to generate fading.

Generated data are fed into a fading simulator

```
[ifade,qfade]=sefade(ich3,qch3,itau,dlv1,th1,n0,itnd1,now1,length(ich3),tstp,fd,flat);
```

Update fading counter

```
Itnd1 =itnd1 + itnd0
```

IV. SIMULATION AND CONCLUSION

A. TABLES

para = 128 ; % Number of parallel channel
fftlen = 128; % FFT length
noc =128; % Number of carrier
nd = 6; %Number of OFDM symbol for one loop
ml = 2; %Modulation level : QPSK
sr = 250000; % Symbol rate
br = sr.*ml; % Bit rate per carrier
gilen = 32; %Length of guard interval
ebn0 = 100; %ebn0 : Eb/No
nloop = 100; % Number of simulation loops
noe = 0; % Number of error data
nod = 0; %Number of transmitted data

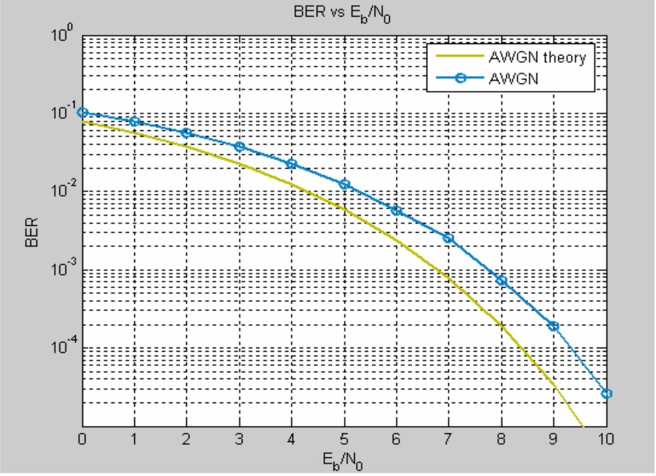

Fig-4. Comparison between AWGN theory and simulation

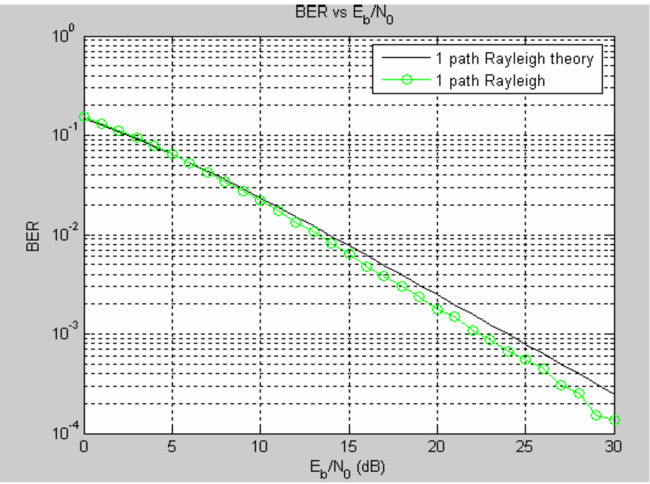

Fig-5. Comparison OFDM under Rayleigh fading between theory and simulation

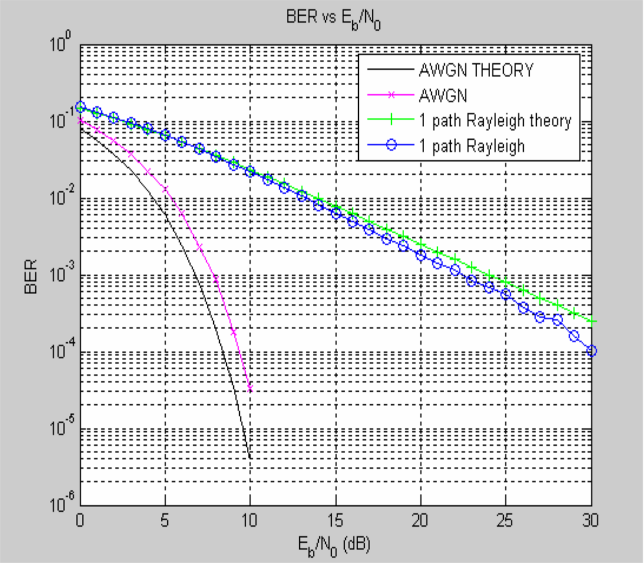

Fig-6. OFDM Comparison between AWGN and One Path Rayleigh

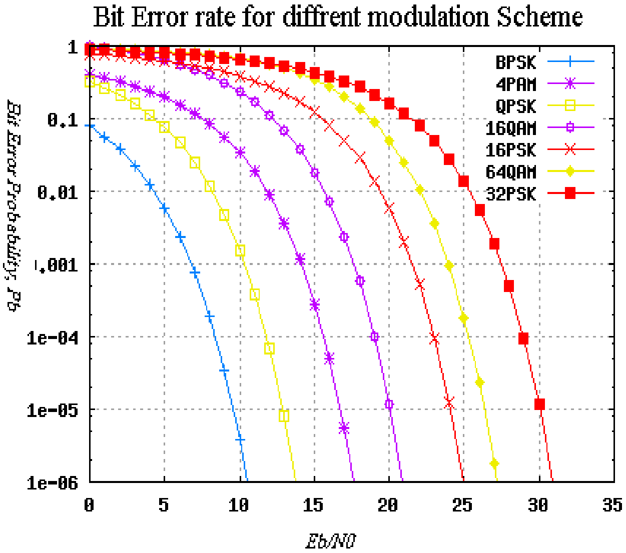

Fig-6. Symbol Error Rate vs Es/No (dB) in AWGN

From the results, it's showed that the OFDM BER performance under AWGN channel gives 0.9691 db shift. The shift of the value was caused by guard interval power for the received signals. The OFDM BER performance for one path Rayleigh fading also gives 0.9691dB shift. This value can be obtained if the amplitude and phase fluctuations caused by fading can be compensated perfectly. Lastly, from the simulations, AWGN communications channels give the best/ ideal communication as compared to one path Rayleigh fading.

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