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BER PERFORMANCE STUDY OF ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

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ABSTRACT

OFDM efficiently overcomes the problems that plague most wireless channels. Multipath propagation is a serious hazard that introduces delay spread accounting for multiple copies of the transmitted signal to reach the receiver. This causes energy of one symbol of information to spill onto several successive symbols. This phenomenon is called Inter Symbol Interference (ISI). OFDM reduces ISI through several simultaneous transmissions, thus making it possible to have an increase in the transmission time for each symbol. OFDM moves the equalization operation to the frequency domain instead of time domain as in the case of single carrier systems. OFDM is based on parallel data transmission scheme that reduces that effects of multipath fading and renders complex equalizers unnecessary. In this project will study and identify t h e Orthogonal Frequency Division Multiplexing (OFDM) technology that gives the best BER performance in a multipath fading environment using computer simulation. Orthogonal

Frequency Division Multiplexing is modeled and simulated under different channel conditions such as AWGN and Rayleigh fading. Subsequently, a comparison study is carried out to obtain the BER performance for Orthogonal Frequency Division Multiplexing under under 1-path multipath fading conditions and to identify which channel gives the best BER performance. The comparison study showed that BER for AWGN channel gives the best BER performance compared to Rayleigh channel.

INTRODUCTION

Digital multimedia applications as they are getting common lately create an ever increasing demand for broadband communications systems. Orthogonal Frequency Division Multiplexing (OFDM) has grown to be the most popular communications system in high speed communications in the last decade. In fact, it has been said by many industry leaders that OFDM technology is the future of wireless communications. The prosperous progress of mobile communications has built the main road of the history of wireless communication. The mobile wireless communications progressed from Personal Communication Services/Network (PCS/PCN) to Global System for Mobile Radio Channel (GSM) to General Packet Radio Service (GPRS) to Enhanced Data for Global Evolution (EDGE) to Universal Mobile

Telecommunication Systems (UMTS) (better known as 3G) and will continue to evolve to 4G which is under active research.

OFDM is expected to be used in future broadcasting and wireless LAN (WLAN) systems. IEEE802.11a is the technology that used OFDM concept. Since wireless technologies become a very high demand nowadays, OFDM is chosen to be a subject study.

In this paper, MATLAB computer-simulation software is used, which is produced by MathWork Inc. MATLAB, a sophisticated language for matrix calculation, and stands for MATrix LABoratory. MATLAB is chosen as the computer language to design the Orhtogonal Frequency Division Multiplexing (OFDM) systems because it is one of the most popular computer simulation languages in the world. MATLAB is used in this paper to:

- model and simulate the communication channel (AWGN and Rayleigh)
- compute and compare the BER.

In wireless communications, multipath is the propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths. Causes of mutipath include atmospheric, ducting, ionospheric reflection and refraction and reflection from terrestrial objects such as mountains and buildings. The reflected signals arrive at the receiver with random phase offsets, because each reflection generally follows a different path to reach the user's receiver. The result is random signal fades as the reflections destructively (and constructively) superimpose on one another, which effectively cancels part of the energy signal for brief periods of time. The degree of cancellation or fading will depend on the delay spread of the reflected signals, as embodied by their relative phases and their relative power. The paper studies and identifies the Orthogonal Frequency Divison Multiplexing (OFDM) that gives the best BER performance in a multipath fading environment using QPSK modulation system. This paper will identify the best BER performance between different types of communication channel. The outcome from the BER vs Signal Energy per bit over noise power density ratio (Eb/No) will be shown in the graph format.

ORTHOGONAL FREQUENCY DIVISION MULTI;PLEXING TECHNOLOGY

OFDM is the concept of MC where the different carriers are orthogonal to each other. Orthogonal in this respect means that the signals are totally independent. It is achieved by ensuring that the carriers are placed exactly at the nulls in the modulation spectra of each other. Source for OFDM spectral efficiency is the fact that the drop off of the signal at the band is primarily due to a single carrier which is carrying a low data rate. OFDM allows for sharp rectangular shape of the spectral power density of the signal. Orthogonal Frequency Division Multiplexing (OFDM) also known as discrete multitone modulation (DMT), is based upon the principle of requency division multiplexing (FDM), but it utilized as a digital modulation scheme. The bit stream that is to be transmitted is split into several parallel bit streams, typically dozens to thousands. The available frequency spectrum is divided into sub-channels and each low rate bit stream is transmitted over one sub channel by modulating subchannel by ,odulating a sub-carrier using a standard modulation scheme, for example: PSK, QAM. The sub-carrier frequencies are chosen so that the modulated data streams are orthogonal to each other, meaning that cross talk between the subchannels is eliminated.

Transmitter Configuration:

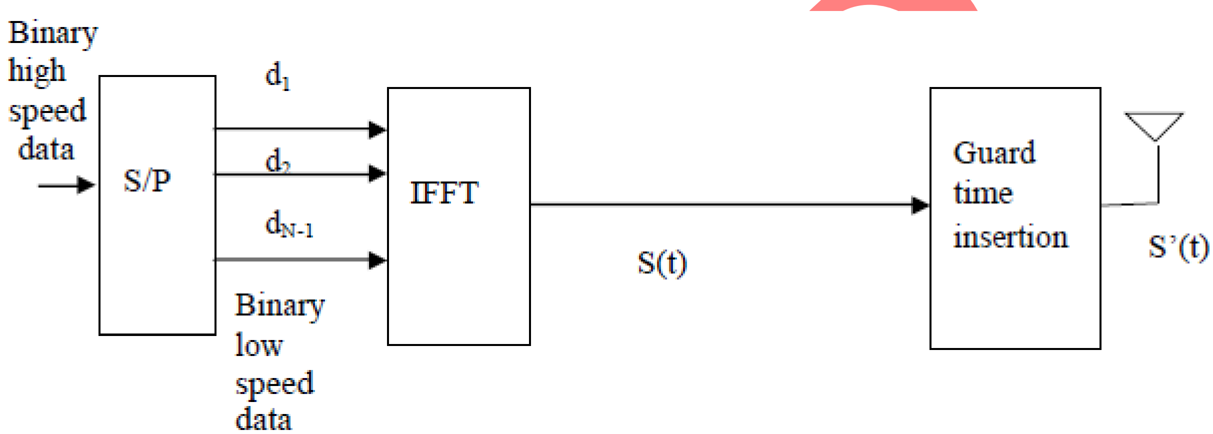

Fig.1 OFDM Transmission System: Transmitter

Fig. 1 shows the configuration of an OFDM transmitter. In the transmitter, the transmitted high speed data is first converted into parallel data of N subchannels. Then, the transmitted data of each parallel subchannel is modulated by PSK based modulation.

Consider a quadrature modulated data sequence of the N channels (d_0, d_1, d_2, .., d_{N-1}) and d_{In} and d_{Qn} are {1,-1} in QPSK and {±1,±3} in 16-QAM. These modulated data are fed into an inverse fast Fourier transform (IFFT) circuit and an OFDM signal is generated. The transmitted data is given by

$s(t) = \sum\sum d_i(k) \exp(j2\pi f_i(t-kT_s))f(t-kT_s)$

$= \sum\sum(d_{Ii}(k) + jd_{Qi}(k))(\cos(2\Omega f_i(t-kT_s)) + j\sin(2\pi f_i(t-kT_s)))\, f(t-kT_s)$

$= \sum\sum(d_{Ii}(k)\cos(2\pi f_i(t-kT_s)) - d_{Qi}(k)\sin(2\pi f_i(t-kT_s)))\, f(t-kT_s) + j\sum\sum(d_{Ii}(k)\sin(2\pi f_i(t-kT_s)) - d_{Qi}(k)\cos(2\pi f_i(t-kT_s)))\, f(t-kT_s)$ (1)

Where T_s is the symbol duration of the OFDM signal and f_i (i=0, 1, 2, …) is the frequency of the ith subcarrier given by

$fi = f0 + i/ Ts$ (2)

Here, f(t) is the pulse waveform of each of the symbols and it is defined as

$f(t) = 1\ (0\ t\ T_s)$ (3)

$= 0$ (otherwise)

Receiver Configuration:

At the receiver, received signal r(t) is filtered by a bandpass filter, which is assumed to have sufficiently wide passband to introduce negligible distortion in the signal. An orthogonal detector is then applied to the signal where the signal is downconverted to IF band. Then, an FFT circuit is applied to the signal to obtain Fourier coefficients of the signal in observation periods $[iT_{Total}, iT_{Total} + T_s]$. The output, $d_i'(k)$, of the FFT circuit of the ith OFDM subchannel is given by

$$d_i'(k) = 1/T_s\, r(t) \exp(-j2\pi f_i(t-kT_{total}))dt \quad (4)$$

If he characteristics of delayed wave, $h_i'(k)$ in a multipath fading environment can be estimated, therefore the received data also can be equalized as follows:

$$d_i''(k) = (h_i'^{*}(k)) / (h_i'(k)h_i'^{*}(k))\,(d_i'(k)) \quad (5)$$

where * indicates the comples conjugate.

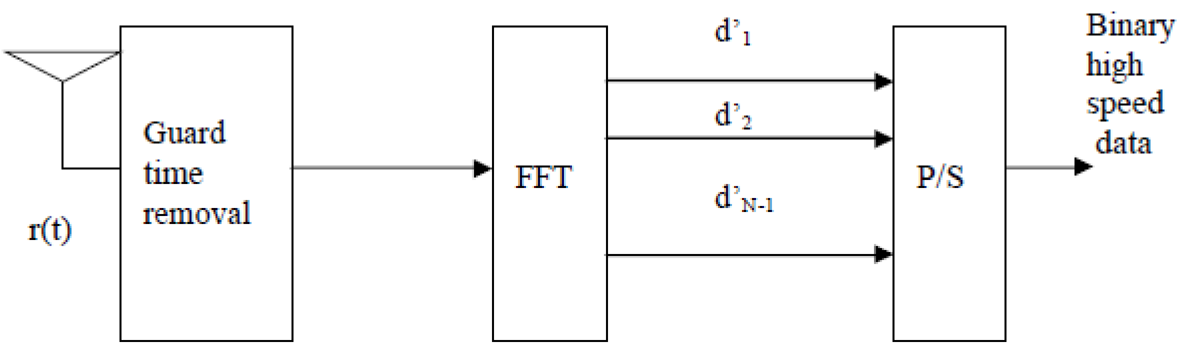

Fig. 2 OFDM Radio Transmission System: Receiver

By comparing d_k and $d_i''(k)$, the BER performance can be calculated. The BER depends on the level of the receiver's noise. In OFDM transmission, the orthogonal is preserved and the BER performance depends on the modulation scheme in each subchannel.

OFDM SIMULATION ANALYSIS

The parameter for the simulation has been defined as follows:

```
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

the above parameters, the OFDM system can be stimulated with 128 subcarriers, a 4-ms symbol time (tstp = 1./sr), and a ¼ tstp guard interval. After defining all the variables, QPSK is chosen to be modulation techniques in each channel. To start the simulation, random serial data of 0 and 1 are generated consisting of 1-by-para*nd*ml vector. This vector is called as "seridata".

seridata =rand(1,para*nd*ml)>0.5;

Then, the serial data vector,"seridata" is converted into a parallel data vector, "paradata", consistiong of a para-by-nd*ml vector to transmit the data in parallel in order to enable parallel transmission with 128 subchannels where each channel was using a QPSK modulation scheme.

paradata = reshape9seridata, para, nd*ml);

Next, the vector "paradata" is fed into the mapping circuit. In the circuit, the parallel data is converted into modulated parallel data of two channels, Ich and Qch by a predefined mapping method.

[ich,qch] = qpskmod (paradata, para,nd,ml);

Then, these data is increased kmod times to normalize the data as follows:

kmod=1/sqrt(2);
ich1=ich.*kmod;
qch2=qch.*kmod;

After the mapping, these parallel data on the frequency axis were fed into the IFFT circuit. In this circuit, the parallel data were converted into serial data on the time axis by using OFDM.

x=ich1+qch1.*I;
y=ifft (x);
ich2 =real (y);
qch2 = imag (y);

At the receiver, the received signal was first contaminated by AWGN. The noise function was introduced as a function comb.m. In this simulation, the 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 subcarriers.

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. The serial data is converted into parallel data on the frequency axis.

rx = ich5+qch5.8i;

```
ry = fft (rx);
ich6 = real (ry);
qch6 =imag(ry);
```

The converted data were divided by "kmod" in each channel to unnormalize the data and is 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 is called "demodata1".

```
demodata =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 ti 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;
```

Then, 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
```

RESULTS AND DISCUSSION

Comparison of OFDM under AWGN Channel Theory and Simulation:

Fig 3 shows the result after simulation when comparing between theory and simulation.

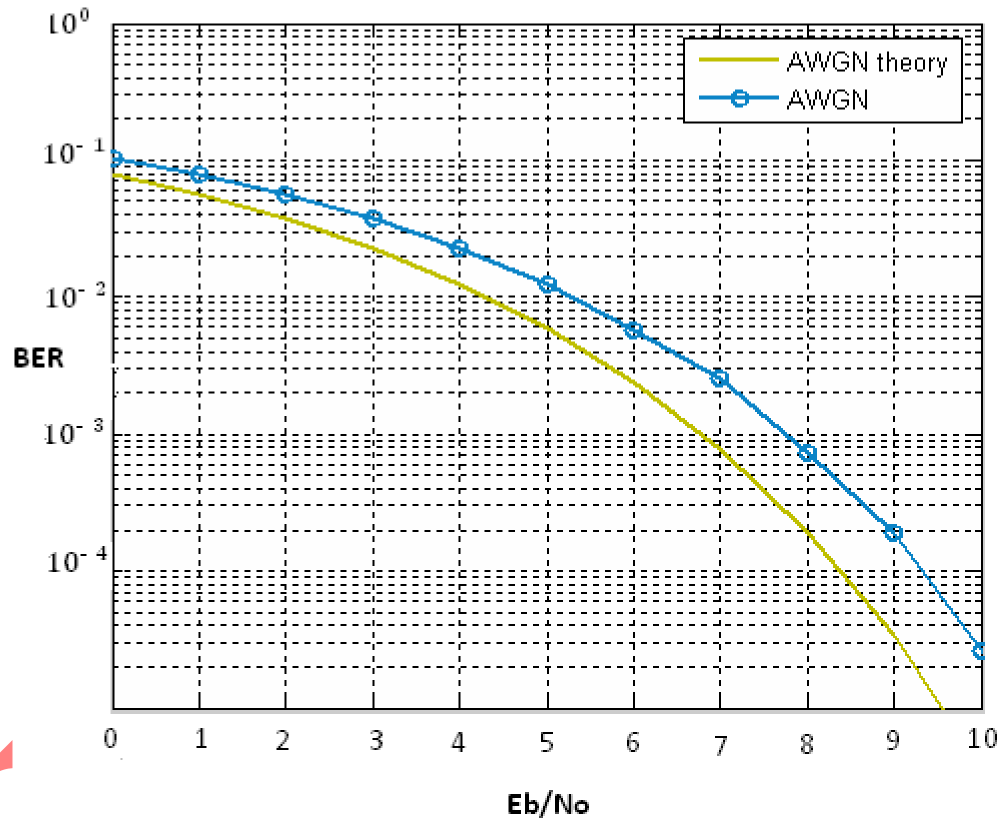

Fig 3 Comparison between AWGN Theory and Simulation

The result shown that AWGN under simulation gives 0.9691 db shifts from the theoretical value. This shift was caused by the cutting off of the guard interval power from the received signal. It can be calculated as follows:

shift value(dB) = -10log 10(gilen/fftlen2)

Comparison between theory and simulation (OFDM under one path Rayleigh)

Fig 4 shows the result after simulation when comparing between theory and simulation.

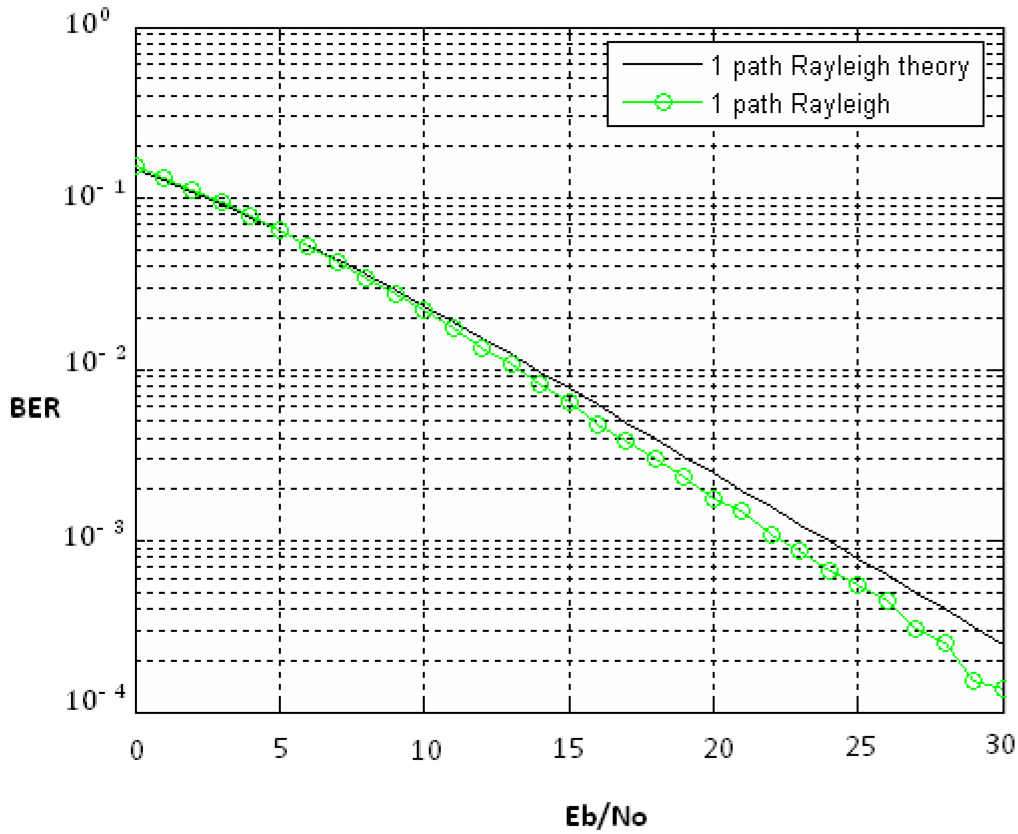

Fig 4 Comparison of OFDM under one path Rayleigh between Theory and Simulation

From the BER performance under one path Rayleigh fading, it shows that if we can compensate for the amplitude and phase fluctuations caused by fading perfectly, 0.9691 dB shifted can be obtained from the theoretical value.

COMPARISON OFDM UNDER TWO DIFFERENT CHANNELS: AWGN AND ONE PATH RAYLEIGH FADING

After simulating all the matlab code individually, now is the comparison OFDM under two different channels, AWGN and one path Rayleigh Rayleigh Fading is made. AWGN communication channel gives the best and ideal performance as compared to Rayleigh fading. In other words, Rayleigh fading is the worst communications model in wireless communications.

SUMMARY OF RESULTS

- OFDM BER performance for AWGN simulation is differed from the AWGN theory with 0.9691 dB shift.
- OFDM BER performance for one path Rayleigh simulation also gives 0.9691dB shift as compared to theoritcal value.
- OFDM BER performance for the AWGN communication channels is the ideal communication channel model
- OFDM BER performance for one path Rayleigh is the worst communication channel model in wireless communication

CONCLUSION AND FUTURE WORK

This paper has outlined all the work done on studying the BER performance of Orthogonal Frequency Division Multiplexing (OFDM) under two different types of communication channels in wireless communications.

In order to achieve the objectives of this paper, first, the concept of Orthogonal Frequency Division Multiplexing (OFDM) is studied. Then, communication channel models for ideal (AWGN) and worst case (multipath fading) channels are studied. AWGN is fairly simple to implement in Matlab using its built-in function. This is then implemented in Matlab to simulate multipath fading channel. The digital modulations are studied and the best modulation that suite with OFDM technology is selected. After selecting the entire main component in OFDM, the Matlab codes are written respectively. Once, the programs are written, they are simulated and verified by obtaining instantaneous waveforms of the transmission scheme. The output is compared against the theoretical models and equations.

Simulation up to higher N-path fading channel level to identify at which N does the BER performance is no longer lowered and what is the lowest (i.e. the best) BER performance that it would give can be done. Besides that, Simulation under different digital modulations to identify the best modulation scheme that can be used in OFDM.

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