Comparison of a Single Carrier and Multicarrier Modulation Techniques

Project Report

EEE-5040 Data Communication & Networks

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LIST OF ABBREVIATIONS

RF	Radio Frequency
ASK	Amplitude Shift Keying
PSK	Phase Shift Keying
FSK	Frequency Shift Keying
BSK	Binary Shift Keying
QAM	Quadrature Amplitude Modulation
MIMO	Multiple Input Multiple Output
BER	Bit Error Rate
SNR	Signal to Noise Ratio
OFDM	Orthogonal Frequency Division Multiplexing
MSK	Minimum Shift Keying
AFSK	Audio Frequency Shift Keying

Abstract

In this Project (or this report present), digital modulation techniques was considered on a preferential basis. Two type of digital modulation examined. These types are ASK, FSK, PSK, QAM for single carrier and also OFDM for MCM. The difference between modulation techniques is clearly demonstrated. The Most comparisons between single carrier and multicarrier modulations assume frequency-domain linear equalization of the channel.

The idea of multi-carrier transmission has surfaced recently to be used for combating the hostility of wireless channel and providing high data rate communications. OFDM is a special form of multi-carrier transmission where all the subcarriers are orthogonal to each other. OFDM provide high user data rate transmission capability at a reasonable complexity and precision.

1.Introduction

Signal means an electric current or electromagnetic field used to convey data from one place to another. Electronic devices produce messages like analog baseband signals in the form of audio, video or even messages can be in the form of digital bits from computer. To send these messages we must have some communication channel like wires, even wireless radio waves, microwaves or infrared. We can easily transmit messages through wires or cables.

In order to achieve digital signal, the analog signal has to enter some processes which includes band pass filters, amplifiers to refine the data. Then an analog to digital converter must be use due to gathering numerical data. So that the digital data can be modulated.

Digital modulation techniques are essential to many digital communication systems, whether it is a telephone system, a mobile cellular communication system, or a satellite communication system, this topic has been decided.

Digital modulation techniques distinguish in two types; single carrier modulation and multicarrier modulation.

The single carrier transmission means one Radio Frequency carrier is used to carry the information. OFDM, also known as multicarrier transmission or modulation, uses multiple carrier signals at different frequencies, sending some of the bits on each channel.

Single Carrier Modulation separate in to four subgenres; Amplitude Shift Keying(ASK), Frequency Shift Keying(FSK), Phase Shift Keying(PSK), Orthogonal Amplitude Modulation(QAM).

Multi-carrier modulation (MCM) is a method of transmitting data by splitting it into several components, and sending each of these components over separate carrier signals. The individual carriers have narrow bandwidth, but the composite signal can have broad bandwidth.

Multicarrier Modulation has only one subtopic which is Orthogonal Frequency Division Multiplexing (OFDM)

2.DIGITAL MODULATION IN FIRST STEPS

An analog signal is modulated with binary code in techniques of digital modulation. Between the transmitter and channel, digital modulator ensures the interface. The digital modulation categorizes on the bandwidth characteristics of compaction for better modulation methods interconnect with SNR (Signal to Noise Ratio) and BER (Bit Error Rate). SNR simplifies the signal quality and suitable bandwitdh. [1]

Digital modulation techniques include different types of methods in communication systems. The essential types of digital modulation methods are Phase Shift Keying (PSK), Frequency Shift Keying (FSK), and Amplitude Shift Keying (ASK). While another genre is considered to be probable by integrating more than one digital modulation techniques of database excluding or including pulse shaping, PSK, ASK and FSK with pulse Nyquist altering on the baseband establish primary techniques of the digital modulation. [1]

The application of ASK is common but they are limited to convey low quantity of power, success a low transmission rate of data.

The PSK modulation have a discontinuous transitions phase from symbol to symbol because PSK have a regular envelope. DPSK, QPSK and MSK are derivated forms of modulation method in PSK.

M-array modulation types are Binary Phase Shift Keying (8-PSK), Quadrature Shift Keying (16-PSK). The BPSK, QPSK, 16-QAM and 64-QAM modulation methods study for the performance related with BER values. [1]

3. WHY DIGITAL MODULATION

Digital modulation ensures more knowledge about capacity, convenience with digital data services, higher data security, better quality communications and faster system suitability.

Developers can face to face these limitations;

-Available Bandwitdh

-Allowable Power

-Actual Noise Level of the System

Every day more user increase their demands RF spectrum for communication service. Digital modulation schemes have higher capacity to deliver large amounts of information than analog modulation schemes. [2]

3.1 Amplitude Shift Keying (ASK)

ASK is one of the branch of the digital modulation techniques. The carrier wave's amplitude is based on the signal of Digital mod and the frequency with the phase of the signals are keep being constant. For expressing the logical as a 0 in this method, an amplitude of single genre is used. In a different case which is representing the Logic 1, another genre of amplitudes used. It has to be considered on and off of the carrier signal. This function of the modulation regime is able to do ON/OFF of the overlay. (A Survey Paper on Digital Modulation Techniques) [4]

3.2 Phase Shift Keying (PSK)

PSK is a digital modulation structure that delivers data by shaping, or modulating, the phase of the based signal (the carrier wave). PSK uses restricted number of phases, each assigned on its own template of binary bits. The most basic form of the phase shift keying is called binary phase shift keying(BPSK). In BPSK technique there are two phases that causes a separation on phases that are 180 degrees. Because of that it is also called 2-PSK.This modulation takes the highest grade of noise or distortion to let demodulator to took an incorrect choice. Unfortunately, it only can modulate 1 bit/symbol and unfitted for greater data-rate applications for the bandwidth restricted cases.

For the Quadrature PSK case, the constellation diagram (equally spaced around circles) uses four points by QPSK. Since QPSK has four phases, it can encode 2 bits/symbol. QPSK can transmit BPSK's data rate multiplied by two if the BER is the same. [4]

Symbol has 2 bits because of that this symbol duration has an equality with the twice duration of transmitted time gap of bits. [3]

3.3 Quadrature Amplitude Modulation (QAM)

QAM (Digital Modulation Schemes Employed in Wireless Communication: A Literature review)

QAM is a technique which includes two unlike signals to be delivered simultaneously on the same carrier frequency which means the varying with the phase is allowed to amplitude. With the unification of ASK and PSK yields greater-order modulation techniques such as QAM. It can be sub classed into varied techniques such as 8QAM, 16QAM, 64QAM etc...

This technique is generally used at greater data transferring applications. If an example should be given; if the data rate is greater than 8PSK's capacity, it is better to change the modulation technique to QAM since QAM is able to achieve greater distance between adjacent points in the planes that are called I-Q. With the distribution of those points, they become more distinct and gather reduced data rates. [5]

The most common QAM types are 16QAM, 64QAM, 128QAM.

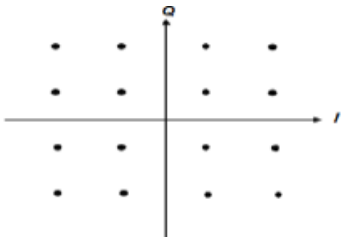

Figure 1. 16 QAM Constellation Diagram

[4] In Figure 1, 16QAM uses four different magnitude levels. The unified design would be of 4*4=16 states. It is easy to see each symbol represents four bits in this scheme.

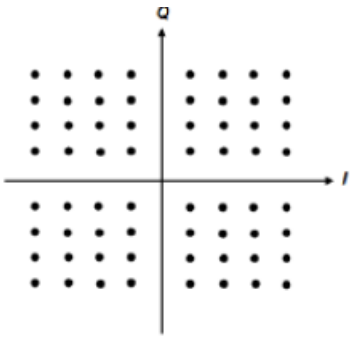

Figure 2. 64 QAM Constellation Diagram

[4] As in shown Figure 2, basically same as 16-QAM with a difference of the number of the states which is numerated as 64 and each symbol represents six bits. Even it is more complex modulation technique, it has higher efficiency rate.

3.4 Frequency Shift Keying (FSK)

Digital information is pass through discrete frequency changes of a carrier wave which is a frequency modulation scheme. The simplest FSK is binary BFSK pass through using a couple of discrete frequencies to transmit binary knowledge. (1s and 0s). 1s are called the mark frequency and 0s are called the space frequency in this scheme. MSK (minimum shift keying) is a specific spectrally influential form of suitable FSK. In MSK, higher and lower frequency is same to half the bit rate and Audio frequency-shift keying (AFSK) is a modulation technique related with which digital data is exemplify by the changes in the frequency (pitch) of an audio tone, yielding an encoded signal availability for transmission in radio or telephone.

Hence, AFSK is different from regular frequency shift keying in performing the modulation at baseband frequencies and it cannot use all the time in high-speed data communications because AFSK is less efficient in both power and bandwidth than most other modulation techniques.

4.OFDM

It is a technique that enciphering digital data on multiple carrier frequencies. OFDM has improved into a popular structure for wideband digital communication. A huge number of close gapped orthogonal sub-carrier signals is able to carry data on quite a few parallel data streams or channels. Conventional modulation scheme which is modulated with each sub-carrier, such as QAM or PSK at low symbol rate, gathering total data rates which are similar to conventional single-carrier modulation schemes in the same bandwidth. OFDM has a significant essential advantage over single-carrier schemes which is the ability to cope with sever channel state. Due to OFDM might be viewed as using many slowly modulated narrowband signals rather than a speedy modulated wideband signal, the channel equation is simplified.

5.SIMULATIONS

The code that we wrote for the simulation according to the 6th Reference:

```
clc;
close all;
EbN0dB=-4:1:24;
EbN0lin=10.^(EbN0dB/10);
colors={'k-*','g-o','r-h','c-s','m-s','y-*','k-p','b:s','m:d','g:p'};
index=1;

%BPSK

BPSK = 0.5*erfc(sqrt(EbN0lin));
plotHandle=plot(EbN0dB,log10(BPSK),char(colors(index)));
set(plotHandle,'LineWidth',1.5);
hold on;

index=index+1;

%M-PSK

m=2:1:5;
M=2.^m;
for i=M
    k=log2(i);
    berErr = 1/k*erfc(sqrt(EbN0lin*k)*sin(pi/i));
    plotHandle=plot(EbN0dB,log10(berErr),char(colors(index)));
    set(plotHandle,'LineWidth',1.5);
    index=index+1;
end


%Binary DPSK
Pb = 0.5*exp(-EbN0lin);
plotHandle = plot(EbN0dB,log10(Pb),char(colors(index)));
set(plotHandle,'LineWidth',1.5);

index=index+1;

%QPSK
x=sqrt(2*EbN0lin*(1-sqrt(1/2)));
y=sqrt(2*EbN0lin*(1+sqrt(1/2)));
Pb = marcumq(x,y)-1/2.*besseli(0,x.*y).*exp(-1/2*(x.^2+y.^2));
plotHandle=plot(EbN0dB,log10(Pb),char(colors(index)));
set(plotHandle,'LineWidth',1.5);
index=index+1;

%M-QAM

m=2:2:6;
M=2.^m;
for i=M
    k=log2(i);
    berErr=2/k*(1-1/sqrt(i))*erfc(sqrt(3*EbN0lin*k/(2*(i-1))));
    plotHandle=plot(EbN0dB,log10(berErr),char(colors(index)));
    set(plotHandle,'LineWidth',1.5);
```

```
    index=index+1;
end

legend('BPSK','QPSK','8-PSK','16-PSK','32-PSK','D-BPSK','4-QAM','16-
QAM','64-QAM');
axis([-4 24 -8 0]);
set(gca,'Xtick',-4:1:24);
ylabel('Probability of BER-log10(Pb)');
xlabel('Eb/N0 (dB)');
title('Probability of BER Error log10(Pb) vs Eb/N0')
```

The Graphical Result:

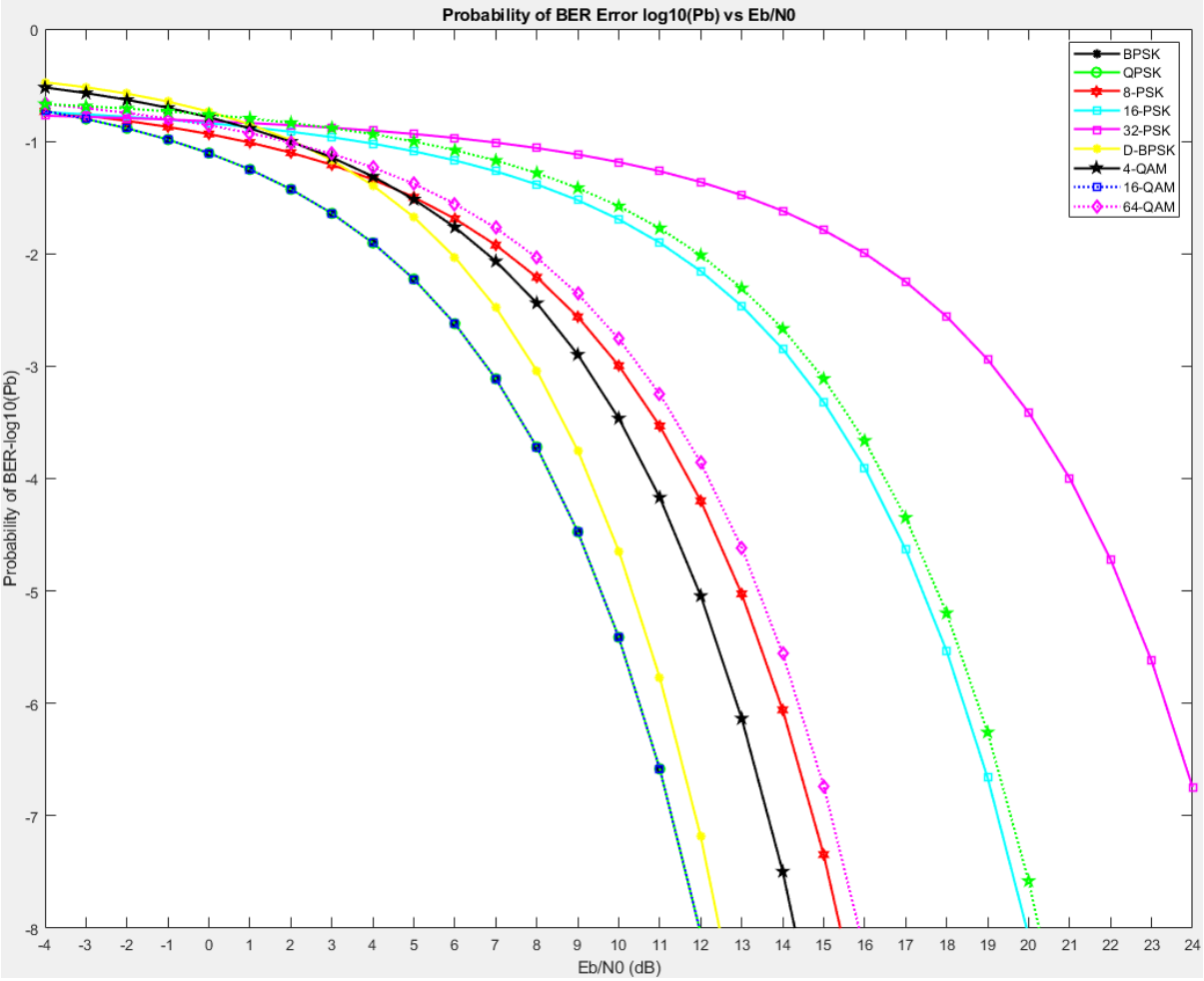

Figure 3: Probability of BER Error with Logarithmic Values

As it shown in this Figure 3, QPSK modulation technique gives less error when it is compared with QAM and the graphical results that we found on the Reference 6.

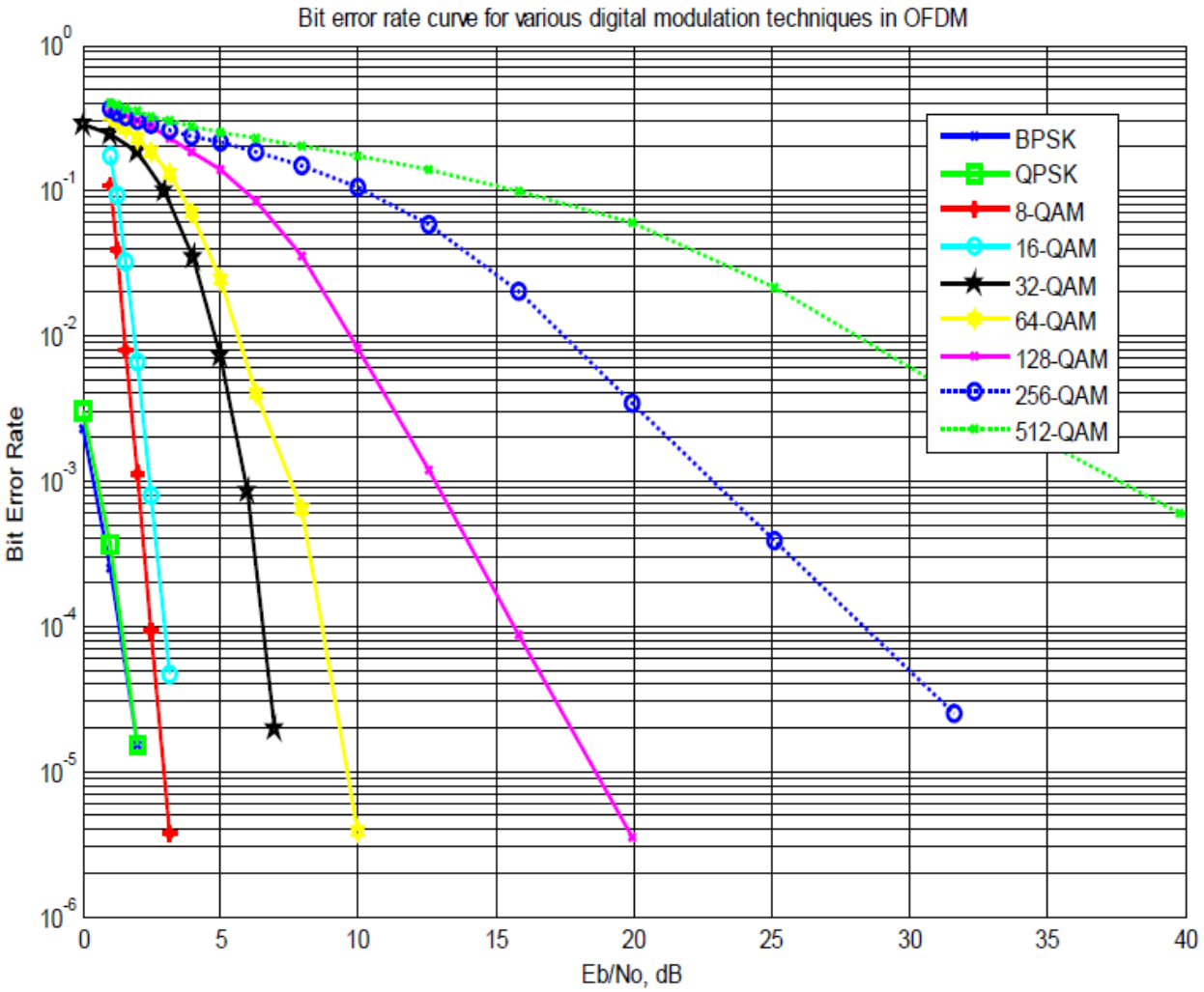

Figure 4: BER Error Rate Curve

6.CONCLUSION

In these academic article shows that differences between modulation types especially include a comparison of the single carrier and multicarrier modulation techniques. After these comparisons, simulation part shows clearly with help of the graphical verification.

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