

BER Calculation Using Matlab Simulation for OFDM Transmission

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Abstract—Orthogonal frequency division multiplex (OFDM) modulation is being used more and more in telecommunication, wired and wireless. DVB and DAB already use this modulation technique and ADSL is based on it. The advantages of this modulation are the reason for its increasing usage. OFDM can be implemented easily, it is Spectrally efficient and can provide high data rates with sufficient robustness to channel imperfections.

The purpose of this paper is to use a Matlab simulation of OFDM to see how the Bit Error Ratio (BER) of a transmission varies when Signal to Noise Ratio (S/N Ratio) and Multipropagation effects are changed on transmission channel.

Index Terms— BER, FFT, ISI, OFDM, S/N

I. INTRODUCTION

In an OFDM [4] scheme a large number of sub-channels or sub-carriers are used to transmit digital data. Each sub-channel is orthogonal to every other. They are closely spaced and narrow band. The separation of the sub-channels is as minimal as possible to obtain high spectral efficiency. OFDM is being used because of its capability to handle with multipath interference at the receiver.

These two are the main effects of multipropagation [3]. Frequency selective fading and Inter Symbolic Interference (ISI) [5]. In OFDM the large number of narrow band sub-carriers provides sufficiently “flat” channels. Therefore the fading can be handled by simple

equalizing techniques for each channel. Furthermore the large amount of carriers can provide same data rates of a single carrier modulation at a lower symbol rate.

The symbol rate of each channel can be dropped to a point that makes each symbol longer than the channel’s impulse response. This eliminates ISI.

The two main drawbacks of OFDM are the large dynamic range of the signals being transmitted and the sensitivity to frequency errors.

Using a Matlab simulation we can implement an OFDM transmission. Using the simulation we can easily change the values of S/N ratio [2] and change the multipropagation effects on the transmission. Then we can analyze the results of each transmission and see how the BER [1] is changed.

II. OFDM SIMULATION

A. The Matlab source code

The Matlab code used in this paper was developed by Alan C. Brooks and Stephan Hoelzer [8]. This implementation is used to transmit a computer file in binary data form modulated by OFDM and 16- QAM modulation. A scheme of every part of the implementation can be seen in Fig 1. As it can be seen in the figure channel imperfections are modeled in this implementation. In the end of the transmission, when the receiver receives the data, a comparison of the transmitted and the received messages is done in order to calculate the Bit Error Ratio (BER).

This paper does not explain in detail the simulation code. It uses it to create results and see the behavior of OFDM under different channel properties. Nevertheless some of the main variables of the code are described, because the choice of them has a critical effect on the results.

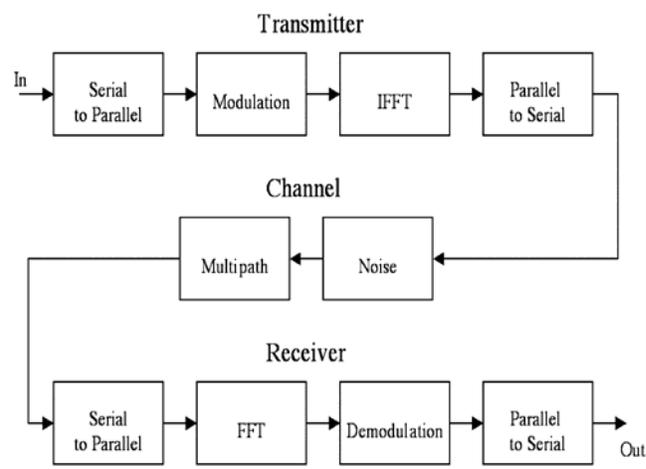


Figure 1. Matlab Flow Chart

B. General Options in the Simulation

The general options of each transmission are in the *setup.m* file of the simulation. Two of the most important variables are analyzed.

One of the main characteristics of every simulation model of OFDM is the size of the fast Fourier transformation (FFT) used to generate the signal. In the

simulation it is equal to the number of samples for the transmission signal. In the code this variable is named *fft_size*. The more the size of the FFT is increased the more samples there are for each signal. The more samples there are the smoother and more accurate the signal is.

Another very important variable is the number of the carriers (or the sub – channels) being used in every simulation. This variable is named *num_carriers*. According to the number of sub – carriers the data is cut into pieces, which are called chunks. Each carrier transmits 2 data bits. The first is coded in the real part of the Fourier transformation of signal and the second in the imaginary.

C. Variables which have an effect on S/N ratio

In this implementation noise is added to the transmission signal. In the *setup.m* file there is the variable called *noise_level*. This variable changes the level of the noise of the channel. The level of the noise is given by the following equation:

$$A_n = A_s \cdot \text{noise_level} \quad (1)$$

Where A_n is the level of the noise

A_s is the level of the signal

We know that the S/N ratio is given by the following equation [2]

$$S/N = \frac{1}{\text{noise_level}^2} \quad (2)$$

The noise produced is uniformly distributed in the closed space:

$$[-\text{noise_level} \cdot A_s, \text{noise_level} \cdot A_s]$$

The noise after being generated is added to the signal. This is done in the *ch_noise.m* file.

D. Variables which have an effect on multipropagation

Adding two delayed and attenuated copies of the signal to itself simulates multipath propagation. The copies are named echoes. The first echo is delayed less and has a higher level than the second.

The time of the delay of the two echoes are changed by the variables d_1 and d_2 . But it is also a function of the number of carriers. Actually the time of the delay for both echoes is analog to the number of carriers. So each time the number of carriers changed in the tests, to keep the time of delay stable, d_1 and d_2 variables were divided by the change. This is done in order to make the tests equivalent.

The level of the echoes is changed by the variables a_1 and a_2 and it is given by the following equation.

$$A_{\text{echo1}} = a_1 A_s \quad (3)$$

$$A_{\text{echo2}} = a_2 A_s$$

Where A_{echo1} is the level of the first echo

A_{echo2} is the level of the second echo

III. PLOTS OF BER AS A FUNCTION OF S/N RATIO AND MULTIPROPROPAGATION

A. BER and S/N ratio

To make the plots of the BER as a function of the S/N ratio a file was transmitted for many S/N ratios. As mention before the S/N ratio can be changed by the *noise_level* variable, which changes the S/N ratio according to the equation (2).

Each time a transmission took place the *noise_level* variable changed. The lowest S/N ratio was decided to have the value 0.1 and the highest 10. Therefore, by solving the equation (2), the *noise_level* variable varies from 0.3162 to 3.162.

The transmission was simulated for 5 sets of carriers. 32, 64, 128, 256 and 512 carriers. For each set of carriers a BER curve as a function of S/N ratio was plotted.

There are two plots. In the first the echoes have high level and in the second low levels. To be exact, in the first plot the two echoes have a level of 0.50 and 0.40 times and in the second 0.10 and 0.05 times the level of the signal. The results can be seen in Fig 2. and Fig 3.

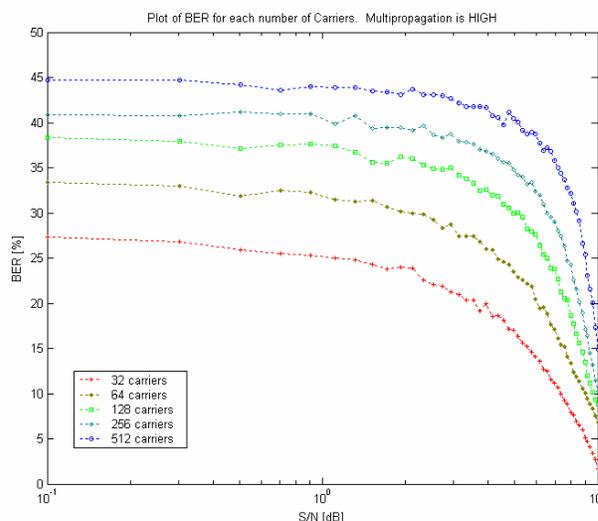


Figure 2. BER as a function of S/N ratio. Multipropagation effects are high

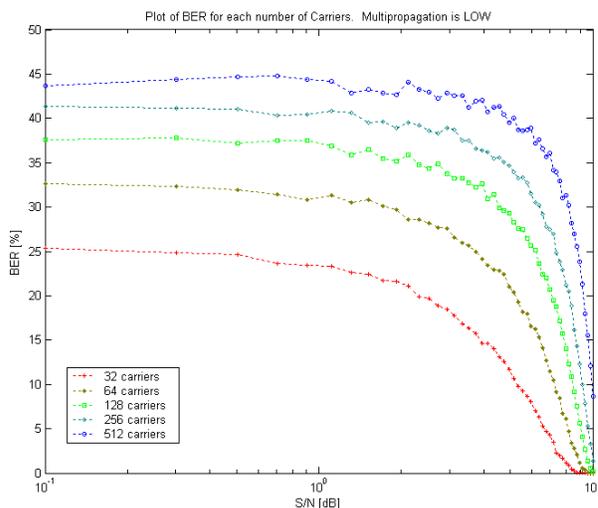


Figure 3. BER as a function of S/N ratio. Multipropagation effects are low

B. BER as a function of Multipropagation

In these plots the behavior of the BER of OFDM can be seen as a function of the level of the signals.

As before, a file was transmitted, each time with a different level for the echoes. The level of the echoes has a start value of 0.05 for the first and 0 for the second times the level of the signal. They have a final value of 0.50 and 0.40 times the level of the signal.

Again the transmission was simulated for 5 sets of carriers. 32, 64, 128, 256 and 512 carriers. For each set of carriers a BER curve was plotted. The x – axis of the plots represents the factor by which the level of the signal is to be multiplied to equal the first echo.

There are two plots. In the first the transmission takes place with a low S/N ratio - 0.1 - and in the second with a high – 10.

The results of the BER as a function of multipropagation for each set of carriers can be seen in the Fig 4. and Fig 5.

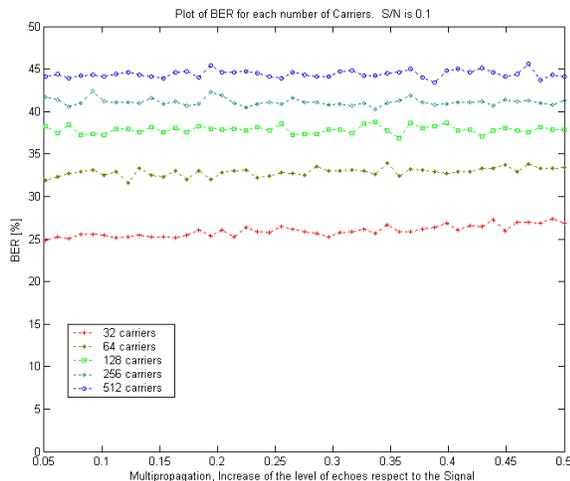


Figure 4. BER as a function of Multipropagation. S/N Ratio is 0.1

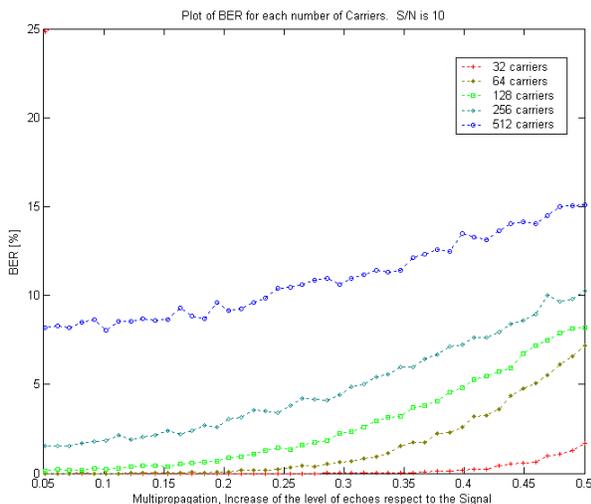


Figure 5. BER as a function of Multipropagation. S/N Ratio is 10

IV. CONCLUSION

The first and obvious thing we can notice from all the Plots is that the more we increase the number of carriers for certain S/N Ratio and Multipropagation effect the more the BER increases. This is to be expected, because the more we increase the number of carriers the more we increase the symbol rate and therefore the data rate.

From the plots of the BER as a function of the S/N ratio we can see that when the S/N ratio is very low (0.1) multipropagation does not have any impact on the BER. Furthermore, it has an impact when the S/N ratio has high values, for example 512 carriers have 15% BER when Multipropagation is low and the S/N ratio is 10 but it drops to 8% BER when Multipropagation is high and the S/N ratio is again 10.

This can be seen from the plot of BER as a function of Multipropagation when we have the S/N ratio is equal to 0.1. The BER by every set of carriers stays constant though the multipropagation effects are increased.

From the Plot of BER as a function of Multipropagation with a high S/N ratio we can notice that the less the number of carriers, the more immunity the transmission to the Multipropagation effects.

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