CHAPTER 6: Analysis of BER and SNR in OFDM

This chapter presents the analysis of BER and SNR in OFDM systems considering with different channels and modulation techniques. The analysis of BER and SNR plays a crucial role in understanding and enhancing the design of OFDM systems.

6.1 Introduction:

OFDM plays a very key role in the advanced communication technology solutions being implemented across the world. It has been adopted different standards like 802.11a, 802.11n & 802.11ac etc,. OFDM is also one of the preferred technologies for mobile communications including Long Term Evolution (LTE) and Long Term Evolution –Advanced (LTE-A). OFDM is also adapted for different communications and broadcast standards including digital radio for long, medium & short wave bands.

An OFDM signal represents a complex signal format than other signals evolved using different technologies. In spite of the complexities OFDM signals provides some special advantages for data transmission especially when the data transmission rate is very high. OFDM is a form of multi carrier modulation an OFDM signal can be viewed as a signal that has a number of closely spaced modulated carriers. An OFDM signal is illustrated in the Figure 6.1.
In order to transmit an information through the signal modulation of any form like voice, data etc., is applied to the carrier. After the application the side bands spread out on either side. The specific advantage an OFDM system offer here is in spite of the presence of overlap, the signal can be still received without any interference because they are orthogonal to each other.

In order to increase the data rate of OFDM system one of the most viable options is to increase the number of sub carriers per symbol. To increase the number of sub carriers there is an eventual reduction in the frequency spacing between the subcarriers in the symbol. This factor influences the performances of OFDM by making it sensitive for inter carrier interference (ICI). Also due to the high variations in signal transmission there
is a corresponding increase in the peak average power ratio (PAPR). This also makes the signal operate in the non linear region of high power amplifier. Non linear distortion are induced when the signal operates in the non linear distortion can also give rise to inter carrier interference.

These non linear distortions has the potential to effect the BER and subsequently the SNR Figure 6.2 depicts an OFDM signal simulated for distortion owing to the non linear operation in the high power amplification.

Figure 6.2: An OFDM Signal OFDM signal simulated for distortion after HPA

SNR & BER provides meaning full indication about the quality of the signal. While the SNR, indicates the reliability of the link between the transmitter and the
receiver. OFDM being a multi carrier modulation scheme with a wider bandwidth, it is usual that the interference is not linear over entire bandwidth of use. So a meaningful criterion that can be used for the evaluation of performance of OFDM is BER.

Both Additive White Gaussian Noise and ICI affect the BER performance. Different modulation techniques influences the performances of the system and can have the wide range of variation of bit error rate for corresponding SNR. The Figure 6.3 depicts the comparison plot of BER versus SNR for different QAM types.

![Figure 6.3: BER Compared with SNR for different levels of QAM](image)

It can be observed from the figure there is a drop in BER as there is increase in SNR of the signal for different modulation types. It can also be inferred from the figure that the 16 QAM offers the better performance when compared to the 64 QAM & 256 QAM. It can be observed that the lower BER can be achieved for an SNR of 10 for 16
QAM but to achieve corresponding BER in 64 QAM the SNR has to be close to 17 and in the case of 256 QAM. The SNR has to be close to 21. It can be inferred the higher noise channel having a very low SNR 16 QAM is preferable and for those channels where the SNR is expected to be on the higher side 256 QAM is preferable.

6.2 Channel Models:

The type of the channel in which the signal is transmitted severely affects the profile of the transmitted signal. Different channel models are used to define the profile of the received and the transmitted signal. Important of these channels are AWGN and Rayleigh channels.

AWGN channel is a channel which is representative of diversity a communication signal through a linear addition of wide band or through a white noise which is having a constant spectral density with Gaussian distribution of amplitude [132]. An AWGN channel usually does not account for non linearity or dispersion, interference, frequency selectivity or fading. It contains a uniform frequency continuous spectrum that spread evenly over a particular frequency band. The usual assumption that are encountered in this type of channel model includes that the noise is additive, the noise is white and the noise complex have a Gaussian distribution.
Rayleigh channel model is usually used to describe the statistically time varying signal envelope which has a multiple path constant. When multiple components are present, signal weakening can cost the main component to be lost. So Rayleigh fading can be considered as the reasonable model when there are many objects in the channel that can be scatter a signal before it reaches the receiver [133]. A Rayleigh fading can be considered as the specialized model for stochastic fading channel is assumed to provide an amplitude gain that is characterized by Rayleigh distribution. Figure 6.4 depicts the plot of BER compared with SNR for BPSK modulation scheme over a AWGN and Rayleigh channel.

Figure 6.4: BER compared with SNR Plot for BPSK over AWGN and Rayleigh
It can be observed from the figure there is a sharp decrease in bit error rate in the case of Rayleigh channel with an increased signal to noise ratio where as in the case of AWGN channel it can be observed from the Figure 6.4 the rate of change of BER as a SNR increases is very less when compared with Rayleigh channel. The observations can be arrived at include

1. A Rayleigh channel has more predominated influence on the BER when compared with AWGN channel.

2. The BER of AWGN channel remains high even in high SNR’s as compared to the equivalent SNR, BER value for a Rayleigh channel.

BER which signifies the number of error bits in the total number of transmitted bits over a period of time. Signifies the quality of transmission as discussed earlier a variety of factors like the operation range of the OFDM signal, the type and nature of the modulation, the type of the channel (AWGN / Rayleigh) affects BER. The BER is computed, by comparing the transmitted signal and received signal. By calculating the error count over total number of bits is usually expressed in terms of SNR. BER Vs SNR performance plot has become the norm for analysing and depicting the performance of the various components of the OFDM systems. When the SNR is high which represents the signal power is relatively higher than the noise power.
It can be seen from the figure, even though influenced by different other parameters there is a reduction in BER as there is an increase in the SNR. Especially in the Rayleigh fading channel there is a non linear relationship between the SNR and the BER. This signifies a better performance of Rayleigh channel can be achieved higher SNR and also there is a linear variation between the SNR and BER in the case of Rayleigh fading channel.

OFDM systems being multi carrier systems are more sensitive to frequency synchronization errors than single carrier system. The frequency mismatch between the receiver and transmitter oscillator is modelled using carrier frequency offset.
The CFO also gives rise to ICI and affects the orthogonality of the OFDM data. The Figure 6.6 depicts the influence of CFO on the performance of the BER the performance is studied for a signal i.e., transmitted over an AWGN channel.

![Figure 6.6: BER sensitivity for CFO in an AWGN channel](image)

It can observe from the Figure 6.6 that it increases the CFO value there is a considerable decrease in the BER. It can be inferred from the plot for CFO of 0.05 there is a substantial decrease in the BER as SNR increases but with increase of CFO the improvement in the performance of BER reduces. It can be observed for CFO of 0.2 the improvement in the performance of BER with the increase in SNR is very minimal. The figure illustrates the significance of CFO in influencing the channel performance. A high CFO value can substantially decrease the performance of the channel by producing high
BER even with signals having a very high SNR values. It should also be noted the performance degradation is more severe at lower SNR values.

Another offset that also encounter in OFDM is symbol time offset (STO). The STO can also be attributed the difference in frequencies between the transmitter oscillator and the receiver oscillator.

Figures 6.7 and 6.8 depict the achievable capacity of different receiver structure of an n*n Rayleigh fading MIMO.

![Figure 6.7: Capacity plot in comparison with SNR in a Rayleigh Fast Fading MIMO System](image)

Figure 6.7: Capacity plot in comparison with SNR in a Rayleigh Fast Fading MIMO System
Figure 6.8: Achievable capacity of different receiver structures in Rayleigh Fading MIMO

With the advent of mobile devices and pervading computing platforms MIMO systems are becoming integral part of OFDM environment. It is also imperative to analyse the performance of these systems. The capacitive plot of different Rayleigh fast fading channel is illustrated using the above figures.

6.3 Conclusion:

The convenient and battery worked gadgets are getting incorporated to the greater part of the everyday applications. OFDM being boss player in these gadgets must be overhauled and advanced constantly. This offers specialists abundant opportunities and difficulties alike in enhancing the execution of the OFDM frameworks. BER and SNR
play an extremely vital part in execution examination. This paper draws out the multifaceted nature in BER and SNR investigation and their significance being developed of better OFDM frameworks.