A NOVEL CONSTRUCTION TECHNIQUE FOR DESIGNING OF VIDEO APPLICATION USING WIRELESS 4G

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Abstract —In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-channels or subcarriers, transmitted in parallel, divide the available transmission bandwidth. The separation of the subcarriers is theoretically minimal such that there is a very compact spectral utilization. The attraction of OFDM is mainly due to how the system handles the multipath interference at the receiver. Multipath generates two effects: frequency selective fading and inters symbol interference (ISI). The "flatness" perceived by a narrow-band channel overcomes the former, and modulating at a very low symbol rate, which makes the symbols much longer than the channel impulse response, diminishes the latter. Using powerful error correcting codes together with time and frequency interleaving yields even more robustness against frequency selective fading and the insertion of an extra guard interval between consecutive OFDM symbols can reduce the effects of ISI even more. Thus, an equalizer in the receiver is not necessary. OFDM is becoming the chosen modulation technique for wireless communications. OFDM can provide large data rates with sufficient robustness to radio channel impairments. The purpose of this method is to provide visualize simulating the basic processing involved in the generation and reception of an OFDM signal in a physical channel and to provide a description of each of the steps involved. For this purpose, we shall use, as an example, one of the proposed OFDM signals of the Digital Video Broadcasting (DVB) standard in wireless 4G (3GPP-LTE).

Keywords —Multipath propagation; Inter symbol Interference; Flatness; Equalizer; Digital video broadcasting; 4G;

I. INTRODUCTION

One of the biggest challenges in wireless communication is to operate in a time varying multipath fading environment under limited power constraints. The other challenge is the limited availability of the frequency spectrum. Future commercial and military wireless systems will be required to support higher data rates with reliable communication under spectrum limitations and multipath fading environments. Military communication systems must maintain reliable communication under the conditions of hostile jamming and other interference without increasing emitted power or requiring larger bandwidth.

In order to improve the reliability without increasing the emitted power, time, frequency or space diversity could be exploited. In time diversity, the received signal is sampled at a higher rate, thus providing more than one sample per transmitted symbol. In frequency diversity, the same information is sent over a number of carriers [1]. Both diversity techniques require larger bandwidth. To exploit space diversity, the same information has been transmitted and received via many antennas. Employing multiple antennas at the receiver and/or the transmitter improves the quality of a wireless communication link without increasing the transmitted power or bandwidth [2]. Therefore, the design and implementation of multiple-input multiple-output (MIMO) communication systems is an attractive research area.

Orthogonal frequency division multiplexing (OFDM) is a widely used method in wireless communication systems. Due to its effectiveness in multipath channel conditions, OFDM has been adopted by several wireless communication standards, such as the IEEE 802.11a local area network (LAN) standard and the IEEE 802.16a metropolitan area network (MAN) standard. The combination of OFDM and MIMO systems presents better solutions by adding more diversity gain to the conventional OFDM systems employing a single antenna at both the receiver and the transmitter [3]. The robustness to fading provided by OFDM is enhanced by the spatial diversity of MIMO systems, and the resulting performance of MIMO-OFDM systems is significantly improved.

High capacity and variable bit rate information transmission with high bandwidth efficiency are just some of the requirements that the modern transceivers have to meet in order for a variety of new high quality services to be delivered to the customers. Because in the wireless environment signals are usually impaired by fading and multipath delay spread phenomenon, traditional single carrier mobile communication systems do not perform well. In such channels, extreme fading of the signal amplitude occurs and Inter Symbol Interference (ISI) due to the frequency selectivity of the channel appears at the receiver side. This leads to a high probability of errors and the system’s overall performance becomes very poor. Techniques like channel coding and adaptive equalization have been widely used as a solution to these problems. However, due to the inherent delay in the coding and equalization process and high cost of the hardware, it is quite difficult to use these techniques in systems operating at high bit rates, for example, up to several Mbps. An alternative solution is to use a multi carrier system. Orthogonal Frequency Division Multiplexing (OFDM) is an example of it and it is used in several applications such as asymmetric digital subscriber lines (ADSL), a system that makes high bit-rates possible over twisted-pair copper wires. It has recently been standardized and recommended for digital audio broadcasting (DAB) in Europe and it is already used for terrestrial digital video broadcasting (DVB-T). The IEEE 802.11a standard for wireless local area networks (WLAN) is also based on OFDM. The purpose of this project is to investigate how OFDM performs in an Additive White Gaussian Noise (AWGN) channel only. In this channel only one path between the transmitter and the receiver exists and only a constant attenuation and noise is considered. Therefore no multipath effect is taken into account. This is a basic investigation and it is intended as a basis of understanding OFDM better in order for future studies of this technique in multipath channels.

II. PROBLEM FORMULATION

The objective of this is to investigate MIMO and MIMO-OFDM systems and compare their performance to the conventional single antenna systems. The first step to achieve this goal was to study the fundamentals of MIMO systems by investigating their performance in a communication system. In this, techniques for the systems with single-carrier modulation and with OFDM were investigated. Several communication systems with various numbers of antennas utilizing both single carrier modulation and OFDM were developed in Matlab. The developed systems were simulated and shown in the results.

III. RELATED WORK

Due to their efficiency in providing an improved performance without increasing the bandwidth or the emitted power, MIMO systems are the subject of considerable research effort. Probably the most attractive scheme from the stand point of implementation and performance is the Alamouti's transmit diversity scheme [4] based on maximal ratio combining [5]. Numerous studies have been performed to investigate its performance and led to the development of several variations [6, 7]. The scheme was originally developed for flat fading channels. Subsequently, it has been Extended to frequency selective channel cases [8,9] and renamed as “the time-space block coding technique”.

MIMO Systems

In radio, multiple-input and multiple-output, or MIMO (pronounced mee-moh or my-moh), is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology. MIMO technology has attracted attention in wireless communications, since it offers 5significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity (reduced fading). Because of these properties, MIMO is a current theme of international wireless research. The block diagram is given in figure 1.

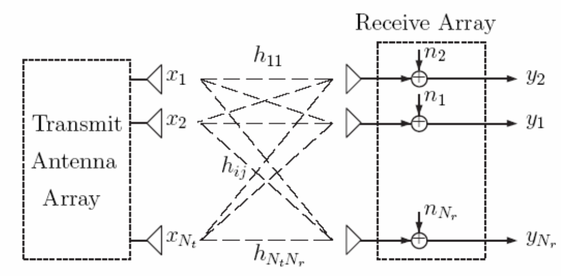

Figure 1. MIMO channel model

Space Time Block Coding

A Space-Time Block Code is generally represented by a matrix. Each row represents a time slot and each column represents one antenna's transmission over time.

$$\begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n_t} \\ s_{21} & s_{22} & \cdots & s_{2n_t} \\ \vdots & \vdots & \ddots & \vdots \\ s_{T1} & s_{T2} & \cdots & s_{Tn_t} \end{bmatrix}$$

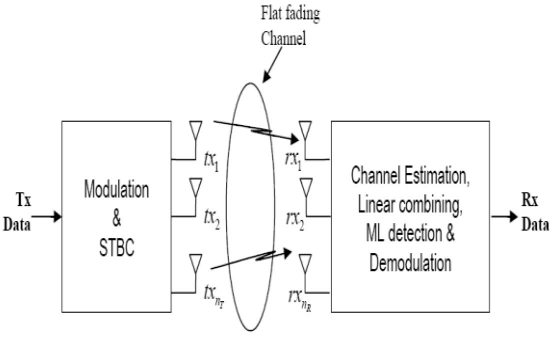

Figure 2: schematic view of a system using STBC

High rate is desirable, because it indicates that a large fraction of the transmitted symbols carry actual information, not redundancy. Suppose each input symbol to the space-time code is drawn from a QAM (or PSK) constellation of size 2^b. Then, each symbol carries *b* bits of information. Assuming a pulse shape with zero excess bandwidth, the information rate transmitted by a rate *R* space-time code with 2^b -QAM input symbols is R=K/N.

Orthogonal Frequency Division Multiplexing

Orthogonal frequency division multiplexing is a technique for transmitting data in parallel by using a large number of modulated sub-carriers. These sub-carriers (or sub-channels) divide the available bandwidth and are sufficiently separated in frequency (frequency spacing) so that they are orthogonal. The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. Due to this, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. This results in no interference between the carriers, although their spectra overlap. The separation between carriers is theoretically minimal so there would be a very compact spectral utilization. OFDM systems are attractive for the way they handle ISI, which is usually introduced by frequency selective multipath fading in a wireless environment. Each sub-carrier is modulated at a very low symbol rate, making the symbols much longer than the channel impulse response. In this way, ISI is diminished. Moreover, if a guard interval between consecutive OFDM symbols is inserted, the effects of ISI can completely vanish. This guard interval must be longer than the multipath delay. Although each sub-carrier operates at a low data rate, a total high data rate can be achieved by using a large number of sub-carriers. ISI has very small or no effect on the OFDM systems hence an equalizer is not needed at the receiver side.

In the OFDM system, Inverse Fast Fourier Transform/Fast Fourier Transform (IFFT /FFT) algorithms are used in the modulation and demodulation of the signal. The length of the IFFT/FFT vector determines the resistance of the system to errors caused by the multipath channel. The time span of this vector is chosen so that it is much larger than the maximum delay time of echoes in the received multipath signal.

OFDM is generated by firstly choosing the spectrum required, based on the input data, and modulation scheme used. Each carrier to be produced is assigned some data to transmit. The required amplitude and phase of the carrier is then calculated based on the modulation scheme (typically differential BPSK, QPSK, or QAM).

IV. IFFT/FFT IMPLEMENTATION

This project is based on the 2k mode of the DVB-T standard, intended for mobile reception of digital TV. In this mode, the transmitted OFDM signal is organized in frames, each having duration T_F. Each frame consists of 68 OFDM symbols. Four frames make one super-frame. Each symbol is constituted by a set of K=1705 carriers (actually sub carriers) and transmitted with a duration of T_S, composed of a useful part with a duration T_U and a guard interval with a duration Δ In addition to the data, the DVB-T signal contains reference information (scattered pilot cells, continual pilot carriers, TPS carriers), defined by the standard, which can be used by the receiver for e.g. synchronization and channel estimation. Since this project deals only with AWGN channel there is no need for those and all sub carriers are used for data modulation.

OFDM Transmitter

A practical implementation became a reality due to the availability of digital signal processors that made the FFT affordable [1]. The OFDM spectrum is centered on f_C. This means that sub-carrier 1 is located (7.61/2) MHz to the left of the carrier and sub-carrier 1705 is located (7.61/2) MHz to the right of the carrier. A simple way to achieve centering is to use a 2N-IFFT [1] and T/2 as the elementary period. As you can see from the table, the OFDM symbol duration T_U is specified considering a 2048-IFFT (N=2048); thus we will use a 4096-IFFT. Next, a suitable simulation period must be selected. T is defined as the elementary period for a baseband signal; however, since the simulation is of a passband signal, a relationship between T and 1/Rs, a time- period that considers at least twice the carrier frequency, must be found. For simplicity, an integer relation was chosen, namely $R_S=40/T$. This gives a carrier frequency of around 90 MHz, which is in the range of a VHF channel five, a common TV channel in any city. The block diagram below shows the generation of one OFDM symbol:

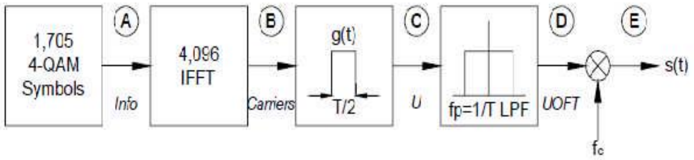

Figure 3: OFDM symbol generation simulation

In the figure above, step specified are as follows: The total number of sub-carriers in this system is 1705.However, the size of IFFT/FFT vector is 4096.Therefore, and we add 4096-1705=2391 zeros to the signal *info* at (A) to achieve over-sampling and to center the spectrum.

OFDM Receiver

The design of an OFDM receiver is open since there are only transmission standards. Most of the research and innovation is done in the receiver. For example, the frequency sensitivity drawback is mainly a transmission channel prediction problem, something that is done at the receiver. In this report, I will present only a basic receiver structure that follows the inverse of the transmission process. The block diagram is presented in Figure 4.1.

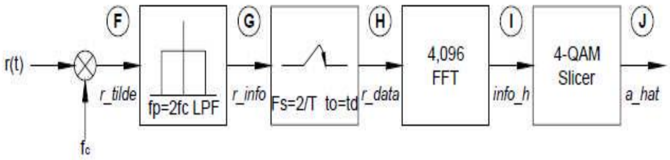

Figure 4: OFDM Reception simulation

OFDM is very sensitive to timing and frequency offsets. The delay produced by the reconstruction and demodulation filters is about t_d = 64/Rs for my program. This delay was taken care of when I did the simulation. As you can see from the block diagram in the Figure 4.1, the reception process is straightforward: the received OFDM signal is first low- pass filtered to get the corresponding baseband signal and sampled. The output of the FFT modulation block is the received constellation. This one passes through a 4QAM slicer, which assigns the received symbols into the four possible constellation points. The error, which is a symbol error, is calculated by comparing the original constellation with the one that is outputted by the 4QAM slicer. As in the case of the transmitter, the names of the variables used in the simulation and the output processes in the reception.

V. SIMULATION RESULTS

In Figure 5.1 and Figure 5.2, you can observe the result of this operation and that the signal carriers at (B) have a time period of T/2.

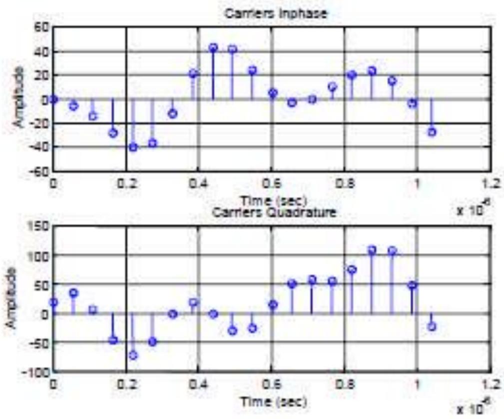

Figure 5.1: Time response of signal carriers

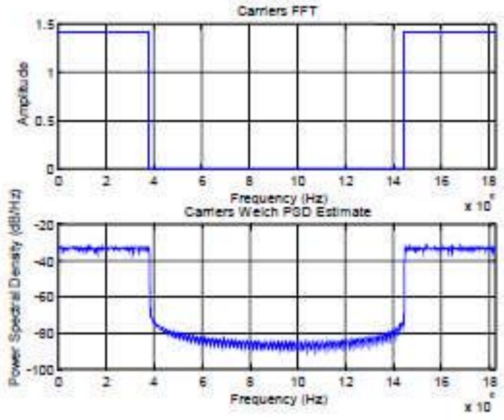

Figure 5.2: Frequency response of signal carriers

The signal carriers are a discrete-time baseband signal. The next step is to produce a continuous-time signal.

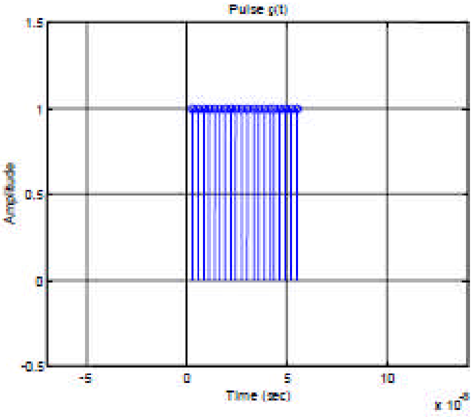

Figure 5.3: Impulse response of g(t).

In order to achieve this, a transmit filter g (t) is applied to the complex signal carriers. The impulse response of this filter is shown in figure 5.3 and figure 5.4. The output of the filter is shown in the following figures, both in time-domain and frequency-domain.

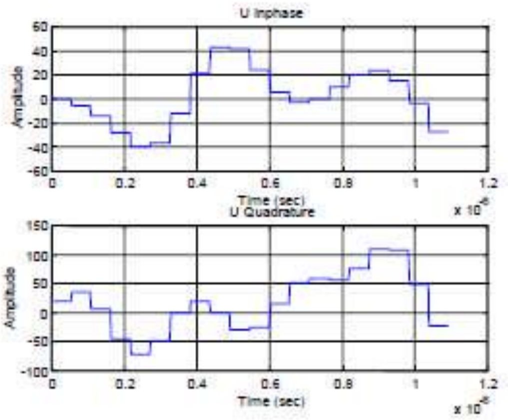

Figure 5.3: Time response of signal at ©.

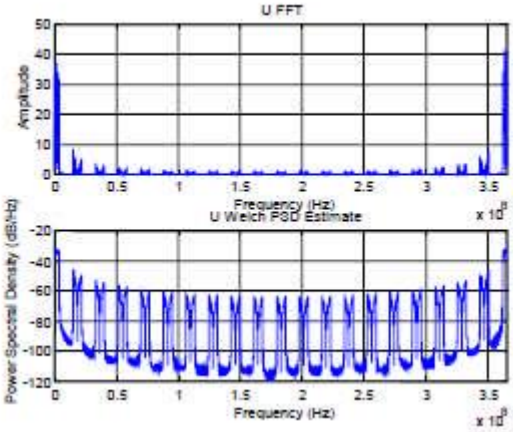

Figure 5.4: Frequency response of signal at ©.

The frequency response of Figure 3.7 is periodic, since it is of a discrete-time system. The bandwidth of the spectrum shown in this figure is given by Rs.

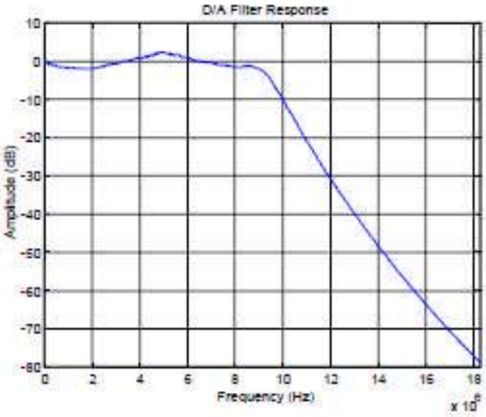

Figure 5.5: Digital to Analog filter response

The period of the signal *U* is 2/T, thus the transition bandwidth for the reconstruction or digital-to-analog (D/A) filter is (2/T=18.286)-7.61=10.675 MHz If a 2048-IFFT (N-IFFT) was used, the transition bandwidth would have been only (1/T=9.143)-7.61=1.533 MHz, which requires a very sharp roll-off, hence high complexity, in the D/A filter to avoid aliasing. The digital-to-analog (D/A) filter chosen is a Butterworth filter of order 13 and cut-off frequency close to 1/T. The filter's response is shown in figure 5.5 and also the outputs filter response is in figures 5.6 and 5.7.

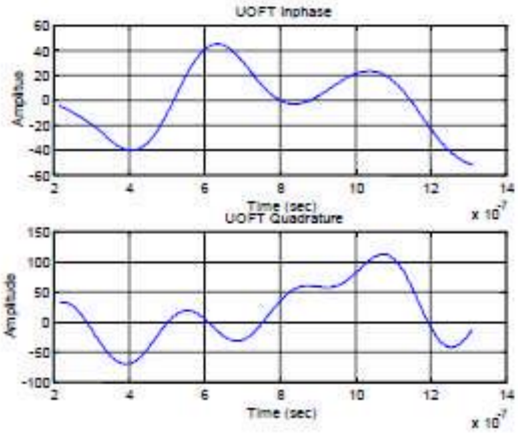

Figure 5.6: Time response of signal at (D).

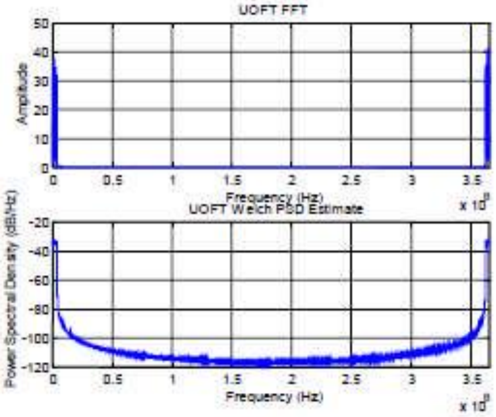

Figure 5.7: frequency response of signal at (D).

The delay produced by the filtering operation is of approximately $2x10^{-7}$, as it is obvious when comparing Figure 5.3 and Figure 5.6. Disregarding this, the filtering performs as expected since we now have only the baseband spectrum. Recall that carriers 1 to 852 are located to the left of 0Hz and carriers 853 to 1705 are to the right. This signal is a baseband signal. The next step is to convert it to a pass band signal using quadrature multiplex double-side band amplitude modulation.

$$S(t) = m_I(t)\cos(2\pi f_c t) + m_Q(t)\sin(2\pi f_c t)$$

In this type of modulation, an in-phase signal $m_I(t)$ and a quadrature signal $m_Q(t)$ are modulated using the above formula.

The in-phase signal corresponds to the real part of the complex modulation symbols, whereas the quadrature signal corresponds to the imaginary part of the same complex modulation symbols. For this project, these are 4QAM symbols. Using the formula above, the signal out of the transmitter s (t) becomes:

$$S(t) = uoft_I(t)\cos(2\pi f_c t) + uoft_Q(t)\cos(2\pi f_c t)$$

The time and frequency response of the complete OFDM signal s(t) is shown in the figures 5.8 and 5.9.

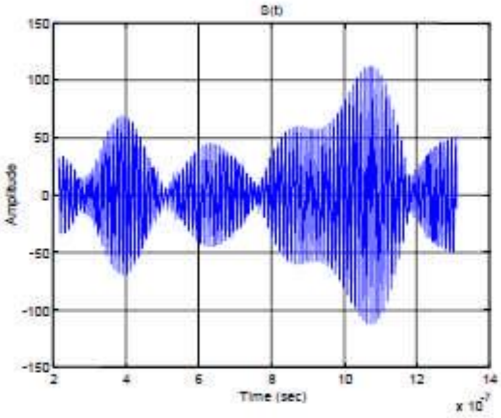

Figure 5.8: Time response of signal at (E).

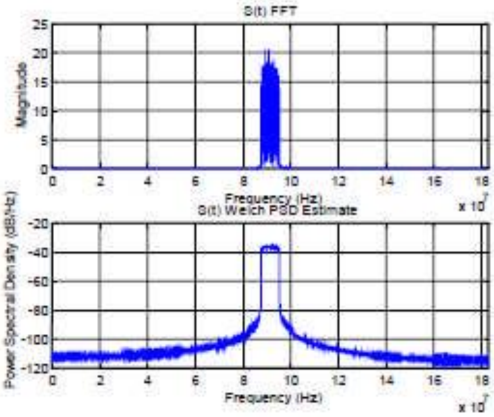

Figure 5.9: Frequency Response of signal at (E).

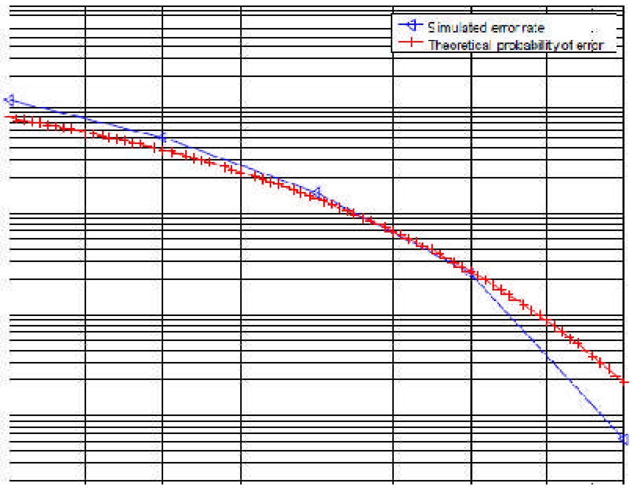

Figure 6: simulated and theoretical symbol error rate

The next step is to transmit the signal through an AWGN channel, receive it and check the errors. The simulation is based on multiple signals to noise ratio (SNR) meaning the signal is performed for various SNR values and error check is performed. The figure is shown in 6.

The original constellation is shown in Figure 7.1 whereas the received constellation is shown in Figure 7.2, Figure 7.3 and Figure 7.5 for corresponding SNR values of 2 dB, 6 dB and 12 dB.

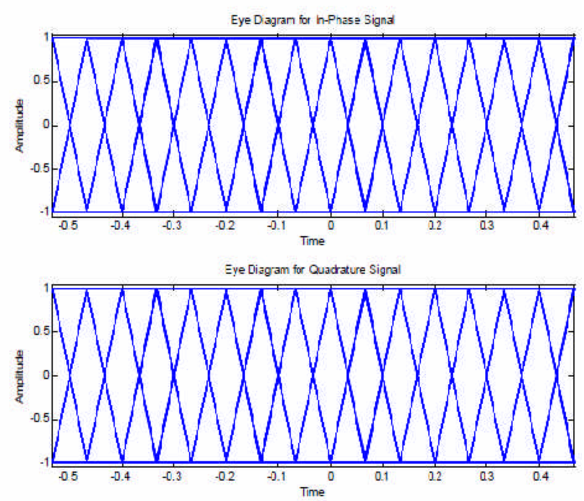

Figure 7.1: Eye pattern for the received constellation in an ideal channel

It is clear that as the SNR is increased the received constellation gets less affected by the noise, hence there will be less errors. However, for low values of SNR we have ISI introduced by the noise at the receiver side.

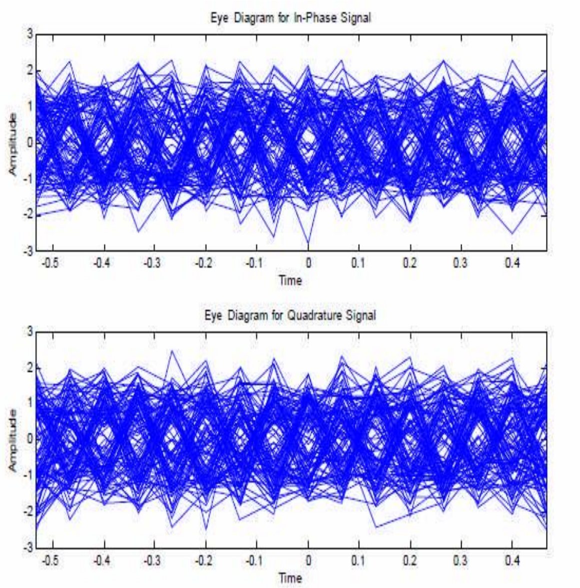

Figure 7.2: Eye pattern for the received constellation for SNR=2dB

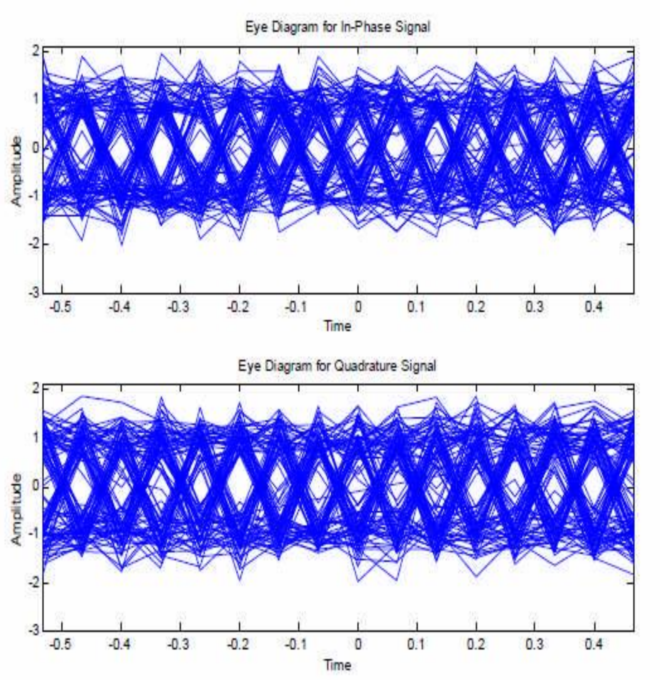

Figure 7.3: Eye pattern for the received constellation for SNR=6dB

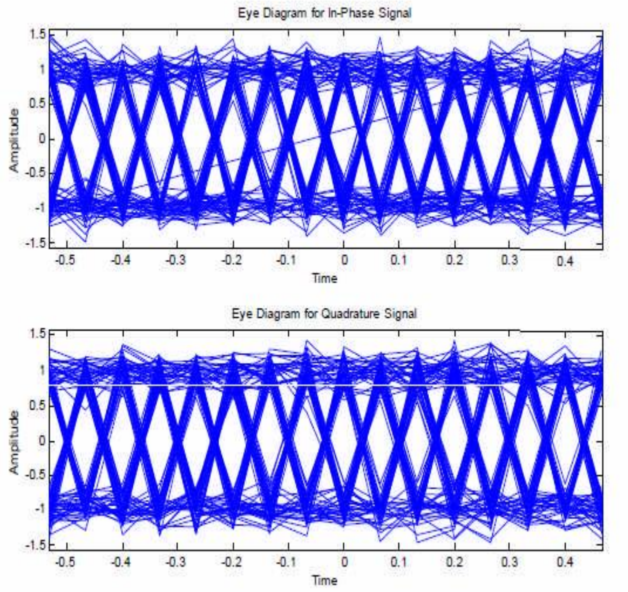

Figure 7.4: Eye pattern for the received constellation for SNR=12dB

I will provide a description of the steps involved in the generation and reception of an OFDM signal, more precisely the signal used in the 2k mode of the DVB-T standard. The generation of the OFDM signal will concentrate only on the blocks labeled OFDM, D/A, and Front End. The numerical values for the OFDM parameters in the 2k mode are given in the table below:

Parameter	2k mode			
Elementary period T	7/64 µs			
Number of carriers K Value of carrier number K_{min}	1,705 0			
Value of carrier number K_{max}	1,704			
Duration T_U Carrier spacing $1/T_U$	224 µs 4,464 Hz			
Spacing between carriers K_{min} and $K_{max}(K-1)/T_U$	7.61 MHz			
Allowed guard interval Δ/T_U	1/4	1/8	1/16	1/32
Duration of symbol part T_U	2,048xT 224 µs			
Duration of guard interval Δ	512xT 56 µs	256xT 28 µs	128xT 14 µs	64xT 7 µs
Symbol duration $T_S=\Delta+T_U$	2,560xT 280 µs	2,304xT 252 µs	2,176xT 238 µs	2,112xT 231 µs

VI. CONCLUSION AND FUTURE WORK

The simulation done in MATLAB worked well. The Additive White Gaussian Noise (AWGN) corrupted the transmitted signal and this resulted in a different received 4QAM constellation than the original constellation. For small SNR values the calculated error rate was quite large and ISI was produced due the relative high power of noise. As SNR was increased the error rate was decreasing, as expected. In fact, for a SNR value greater than 8 dB, the error was zero. This is a quite different than expected and it is due to the fact that the program is simulating only 68 OFDM symbols (i.e. one frame), sent one by one. If the number of transmitted OFDM symbols is increased, than a more accurate error rate can be obtained, but this necessitates a high processing power PC and time. Letting this aside, the system’s performance was good since the simulated error rate for small SNR values was a little bit above the theoretical probability curve. The difference between the two curves is less than 0.5 dB. As the SNR is increased we observe that the simulated symbol error rate intersects and then drops below the theoretical error curve. There are more aspects of OFDM that need to be researched since this simulation was only a basic one. As an example, there are a lot of improvements that can be brought to the program, such as the addition of guard interval, coding the original information, simulation over a multipath channel etc.

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