IMPLEMENTATION OF OFDM SYSTEM

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ABSTRACT

Orthogonal Frequency Division Multiplexing (OFDM) is mainly designed to overcome the effects of multipath reception, by dividing the wideband channel into many narrowband sub-channels. To avoid ISI due to multipath, successive OFDM symbols are separated by guard band. This makes the OFDM system resistant to multi-path effects. This paper describes implementation of a half-duplex OFDM system using Matlab software Simulink. In this approach, Matlab and Simulink are effectively used to develop an OFDM system including transmitter, receiver and an AWGN channel. The graphical environment of Simulink enables the creation of sophisticated algorithms. The results are obtained by using MATLAB code and simulation.

Keywords FFT, FDM, IFFT, OFDM, QAM, SIMULINK

1. INTRODUCTION

The rapid growth in telecommunication market in the last decades are in need of new techniques that can provide high data rates. Wireless communications has seen enormous growth in the past few years. Wideband wireless OFDM communication systems are much popular because of their high spectral efficiency and the capability of OFDM to transmit high data rates over Broadband radio channels with frequency selective fading. Such systems are also popular due to the inherent error robustness in a multipath environment and hence has been chosen for several next generation broadband wireless local area network (WLAN) standards like   terrestrial digital audio broadcasting (DAB) and digital video broadcasting (DVB-T).OFDM is a special case of multicarrier data transmission technique in which a single data stream is transmitted over multiple subcarriers of narrow bands. The subcarriers are closely spaced and are modulated with low data rates. These subcarriers are orthogonal to each other.

Due to rapid increase in the transistor density, it is better to keep the functionality completely in a programmable Digital Signal Processor (DSP) which allows for much faster changes and upgrades. OFDM needs to compute several hundred or thousand points of Fast Fourier Transforms (FFT) within a few tens of microseconds in order to achieve high speed data transmission in narrow bands.

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2. IMPLEMENTATION

The design approach that the real time implementation of system will follow. Here, the first block shows the signal processing description that is we will begin with a concept of what should be programmed. The next step is to model the concept with blocks from Simulink's large collection of prewritten block sets. Basically, a block diagram that models the concept is built using Simulink. If a specific block required is not included in Simulink's block sets, we may choose to write the own blocks from scratch using Matlab.

3. OFDM SYSTEM

OFDM is a special case of multicarrier data transmission technique in which a single data stream is transmitted over multiple subcarriers of **narrow** bands. The subcarriers are closely spaced and are modulated with low data rates. They are made orthogonal to one another by appropriately choosing the frequency spacing between them. The orthogonality allows simultaneous transmission on a lot of sub-carriers in a tight frequency space without interference from each other. The block diagram of an OFDM system is shown in fig. The random data generator generates a bit stream. This data stream is processed using the 16-QAM modulator to map the data into complex signals. These symbols are passed to an IFFT block to perform the IFFT operation and the time domain signals are obtained. The time domain modulated OFDM symbol from IFFT block is converted back to a serial stream and a guard interval in the form of cyclic prefix is added to each OFDM symbol. This data is now passed through an AWGN channel. The reverse operation is done at the receiver to obtain the original data back. That is, the cyclic prefix is removed and processed in the FFT block and finally passed through demodulator for data recovery.
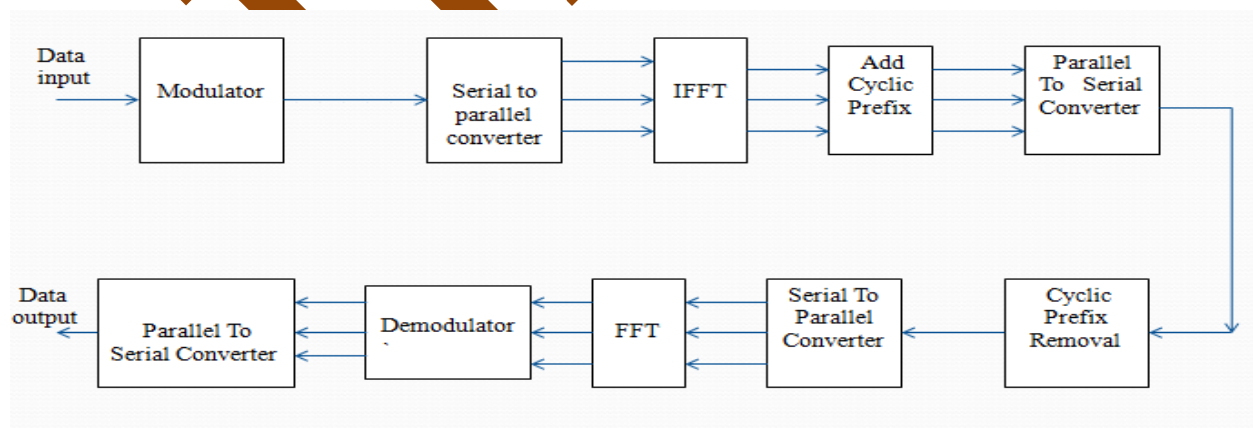

Fig 3.1: Block diagram of OFDM system

MODULATION: The input data stream is converted into N parallel data streams through a serial-to-parallel port. The duration of the data is elongated by N times. The data to be transmitted on each carrier is then differential encoded with previous symbols, then mapped

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into a Phase Shift Keying (PSK) format. Since differential encoding requires an initial phase reference an extra symbol is added at the start for this purpose. The data on each symbol is then mapped to a phase angle based on the modulation method. For example, for QPSK the phase angles used are 0, 90, 180, and 270 degrees. The use of phase shift keying produces a constant amplitude signal and was chosen for its simplicity and to reduce problems with amplitude fluctuations due to fading.

SERIAL TO PARALLEL CONVERSION: The input serial data stream is formatted into the word size required for transmission, e.g. 2 bits/word for QPSK, and shifted into a parallel format. The data is the transmitted in parallel by assigning each data word to one carrier in the transmission.

FFT: The frequency division multiplexed signal illustrates typical FFT-based OFDM system. The incoming serial data is first converted form serial to parallel and grouped into *x* bits each to form a complex number. The number *x* determines the signal constellation of the corresponding subcarrier, such as 16 QAM or 32QAM. The complex numbers are modulated in the baseband by the inverse FFT (IFFT) and converted back to serial data for transmission. A guard interval is inserted between symbols to avoid inter symbol interference (ISI) caused by multipath distortion. The discrete symbols are converted to analog and low-pass filtered for RF up conversion. The receiver performs the inverse process of the transmitter. One-tap equalizer is used to correct channel distortion.

The fast Fourier transform (FFT) is merely a rapid mathematical method for computer applications of DFT. It is the availability of this technique, and the technology that allows it to be implemented on integrated circuits at a reasonable price, that has permitted OFDM to be developed as far as it has. The process of transforming from the time domain representation to the frequency domain representation uses the Fourier transform itself, whereas the reverse process uses the inverse Fourier transform.

IFFT: After the required spectrum is worked out, an inverse Fourier transform is used to find the corresponding time waveform. The guard period is then added to the start of each symbol. y = ifft(X) returns the inverse discrete Fourier transform (DFT) of vector X, computed with a fast Fourier transform (FFT) algorithm. If X is a matrix, ifft returns the inverse DFT of each column of the matrix. ifft tests X to see whether vectors in X along the active dimension are conjugate symmetric. If so, the computation is faster and the output is real. An N-element vector x is conjugate symmetric if x(i) = conj(x(mod(N-i+1,N)+1)) for each element of x. If X is a multidimensional array, ifft operates on the first non-singleton dimension.

CYCLIC PREFIX: In wireless channel, due to multipath propagation and fading the broadening of symbol occurs. The broadening of the symbols causes the interference of one symbol with the next symbol. This is called as inter symbol interference (ISI). Due to ISI the start of the symbol will be lost. To avoid the inter symbol interference (ISI) and inter carrier interference, cyclic extensions (cyclic prefix, cyclic postfix) are used. Normally cyclic prefix

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is used. Cyclic prefix is the addition of a part of the tail of OFDM symbol at the start of the OFDM symbol. The OFDM cyclic prefix is quite straight forward. The cyclic prefix is created so that each OFDM symbol is preceded by a copy of the end part of that same symbol. Different OFDM cyclic prefix lengths are available in various systems.

DEMODULATON: At the receiver, the received signal is down-converted to form a base-band signal. Then, low-pass filters and de-subcarriers are applied to separate subcarrier waveforms. Orthogonality of sub-carriers will ensure that only the targeted subcarrier waveform will be preserved in each sub-band. Ideally, the final detected symbols will be identical to those transmitted.

4. OFDM SIMULATION

The OFDM model has been developed in Simulink using 16-level QAM as shown in fig 4.1 The blocks included in this model are random integer generator, Integer to Bit Converter, Bit to integer converter, general 16 level QAM modulator, selecting rows and obtaining complex conjugate, IFFT (Inverse Fast Fourier Transform), FFT (Fast Fourier Transform), frame status conversion, general 16 level QAM de-modulator and a time scope to observe the simulation results.
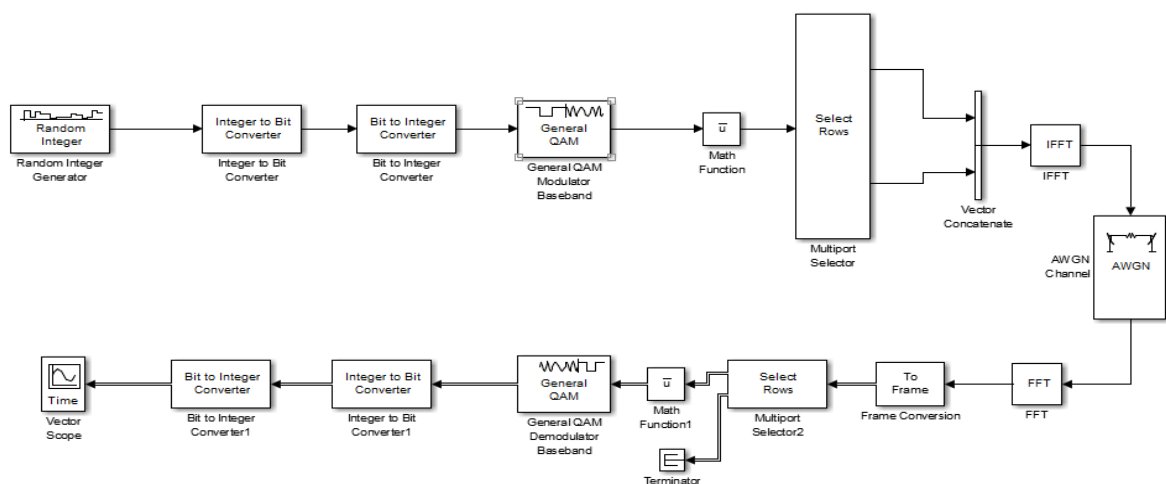

Fig4.1: simulink model of complete ofdm system

SIMULATION:

RANDOM INTEGER: The Random Integer Generator block generates uniformly distributed random integers in the range [0, M-1], where M is the M-ary number defined in the dialog box. The M-ary number can be either a scalar or a vector. If it is a scalar, then all output random variables are independent and identically distributed (i.i.d.). If the M-ary number is a vector, then its length must equal the length of the Initial seed; in this case each

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output has its own output range. If the Initial seed parameter is a constant, then the resulting noise is repeatable.

The output signal can be a frame-based matrix, a sample-based row or column vector, or a sample-based one-dimensional array. These attributes are controlled by the Frame-based outputs, Samples per frame, and Interpret vector parameters as 1-D parameters. The number of elements in the Initial seed parameter becomes the number of columns in a frame-based output or the number of elements in a sample-based vector output. Also, the shape (row or column) of the Initial seed parameter becomes the shape of a sample-based two-dimensional output signal.

INTEGER TO BIT CONVERTER: The Integer to Bit Converter block maps each integer or fixed-point value in the input vector to a group of bits in the output vector. The block maps each integer value (or stored integer when a fixed point input is used) to a group of M bits, using the selection for the Output bit order to determine the most significant bit. The resulting output vector length is M times the input vector length. For integer-valued inputs, if M is the Number of bits per integer and Treat input values as is set to Unsigned, then the input values must be between 0 and 2^M-1. If M is the Number of bits per integer and Treat input values as is set to Signed, then the block maps each group of M bits to an integer between -2^{M-1} and $2^{M-1}-1$.

BIT TO INTEGER CONVERTER: The Bit to Integer Converter block maps groups of bits in the input vector to integers in the output vector. For unsigned integers, if M is the Number of bits per integer, then the block maps each group of M bits to an integer between 0 and 2^M-1. As a result, the output vector length is 1/M times the input vector length. For signed integers, if M is the Number of bits per integer , then the block maps each group of M bits to an integer between -2^{M-1} and $2^{M-1}-1$.

VECTOR SCOPE: The input to the Vector Scope block can be any real-valued M-by-N matrix, column or row vector, or 1-D (un oriented) vector, where 1-D vectors are treated as column vectors. Regardless of the input frame status, the block treats each column of an M-by-N input as an independent channel of data with M consecutive samples. The block plots each sample of each input channel sequentially across the horizontal axis of the plot.

PORT SELECT: The Input Port block is a connecting port from the Simulink, or mathematical, part of the model to an RF physical part of the model. The Input Port block lets you provide the parameter data needed to calculate the modeling frequencies and the baseband-equivalent impulse response for the physical subsystem. It also lets you specify information about how to interpret the incoming Simulink signal. For more information about how the Input Port block converts the mathematical Simulink signals to RF Block set physical modeling environment signals. When you set the Select parameter to Rows, the block uses the one-dimensional indices you specify to select matrix rows, and all elements on the chosen rows are included.

QAM: The first QAM-related so-called orthogonal frequency division multiplexing (OFDM) scheme was proposed by Chang in 1966 [142] for dispersive fading channels, which has also undergone a dramatic evolution due to the efforts of Weinstein, Peled, Ruiz, Hirosaki, Kolb, Cimini, Sch¨ussler, Preuss, R¨uckriem, Kalet *et al.*OFDM was standardised as the European digital audio broadcast (DAB) as well as digital video broadcast (DVB) scheme. These OFDM systems - often also termed as frequency division multiplexing (FDM) or multi-tone systems - have been employed in military applications since the 1960s, for example by Bello, Zimmerman, Powers and Zimmerman, Chang and Gibby and others. Saltzberg studied a multi-carrier system employing orthogonal time–staggered quadrature amplitude modulation (O-QAM) of the carriers.

FRAME CONVERSION: The Frame Conversion block passes the input through to the output and sets the output sampling mode to the value of the Sampling mode of output signal parameter, which can be either Frame-based or Sample-based. The output sampling mode can also be inherited from the signal at the Ref (reference) input port, which you make visible by selecting the Inherit output sampling mode from <Ref> input port check box.

QAM MODULATION: The simplest type of digital modulation involves transmitting a sequence of waveforms ("symbols") of equal duration T where each waveform is chosen independently from a set of M. This allows us to transmit up to b = $\log_2$ (M) bits per symbol. Common sets of such symbols are those where the real and imaginary parts of the complex baseband signal are each modulated in amplitude. This known as Quadrature Amplitude Modulation (QAM).

QAM DEMODULATOR: The qam demodulator is very much the reverse of the qam modulator. The signals enter the system, they are split and each side is applied to a mixer. One half has the inphase local oscillator applied and the other half has the quadrature oscillator signal applied. The basic modulator assumes that the two quadrature signals remain exactly in quadrature.

AWGN Channel: The AWGN channel is the simplest channel model used in most communication systems. The thermal noise in the receivers can be characterized as an additive white Gaussian process. Although there are other factors inducing channel noise, such as antenna temperature, receiver filter, and multipath fading, only multipath fading. The AWGN Channel block adds white Gaussian noise to a real or complex input signal. When the input signal is real, this block adds real Gaussian noise and produces a real output signal. When the input signal is complex, this block adds complex Gaussian noise and produces a complex output signal. This block inherits its sample time from the input signal.

Math function: All supported modes accept both real and complex inputs, except for reciprocal, sqrt, and 1/sqrt, which do not accept complex fixed-point inputs. Also, sqrt and 1/sqrt do not accept fixed-point inputs that are negative or have nontrivial slope and nonzero

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bias. The block output is real or complex, depending on what you select for Output signal type. For 1/sqrt, the output is always real and you cannot change the setting for Output signal type.

Vector concatenation: The Concatenate block concatenates the signals at its inputs to create an output signal whose elements reside in contiguous locations in memory. This block operates in either vector or multidimensional array concatenation mode, depending on the setting of its Mode parameter. In either case, the block concatenates the inputs from the top to bottom, or left to right, input ports. In vector mode, all input signals must be either vectors or row vectors [1xM matrices] or column vectors [Mx1 matrices] or a combination of vectors and either row or column vectors. The output is a vector if all inputs are vectors. The output is a row or column vector if any of the inputs are row or column vectors, respectively.

Terminator: The Terminator block can be used to cap blocks whose output ports are not connected to other blocks. If you run a simulation with blocks having unconnected output ports, Simulink software issues warning messages. Using Terminator blocks to cap those blocks avoids warning messages. The Terminator block accepts real or complex signals of any data type supported by Simulink software, including fixed-point and enumerated data types.

5. RESULTS

The simulation results for MATLAB code are shown in the below figures
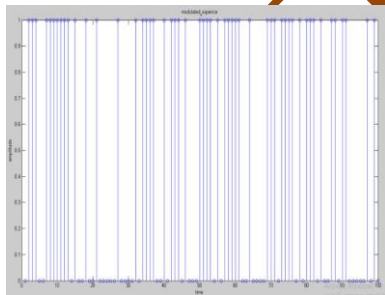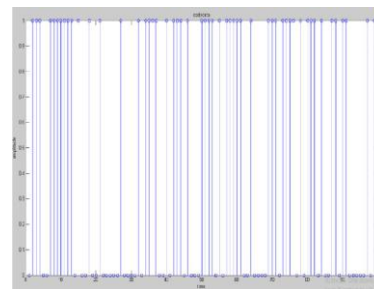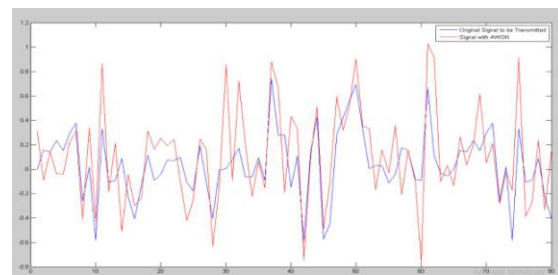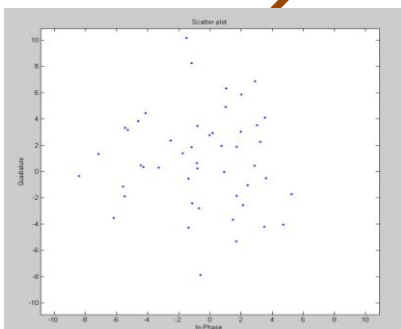

Fig5.1: Original Message

Fig5.2: Recovered message

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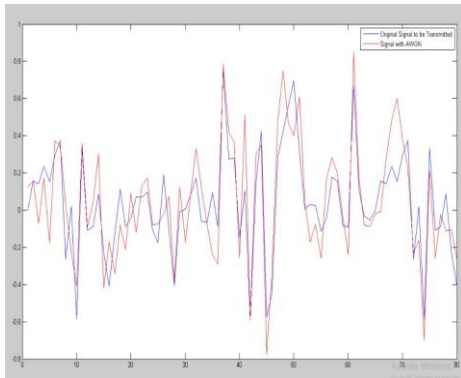**Fig5.3: Scatter plot**   **Fig5.4: OFDM transmitted signal**

Fig5.5: Received OFDM signal
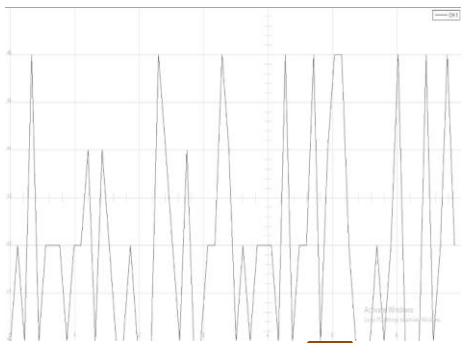
Simulink Results

Fig5.6: OFDM transmitted signal
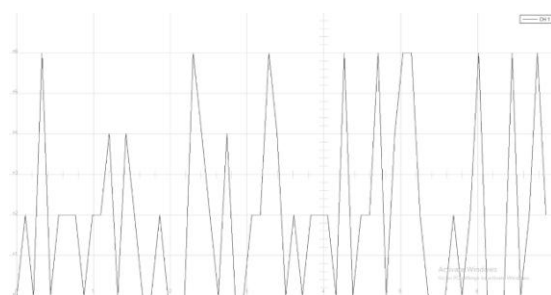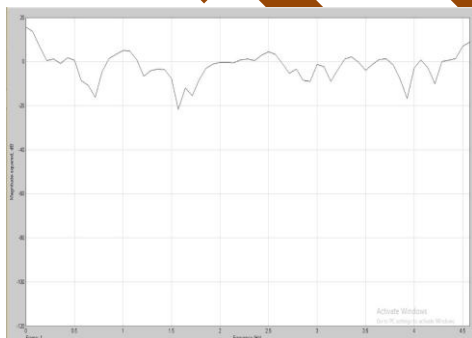
Fig5.7: OFDM received signal

Fig5.8: spectrum of OFDM signal   **Fig5.9: simulation results for simulink model of OFDM system**

6. CONCLUSION

In this paper we introduced the simulation and implementation of a complete OFDM SYSTEM through a graphical programming language, Simulink. Making use of graphical environment in the simulation and implementation stages, the designer's mind is dedicated

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most of the time in developing and enhancing the algorithm and less time on coding. Moreover using a graphical programming language makes the algorithm very clear and can be easily modified and debugged.

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