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A Digital Multiband Orthogonal Frequency Division Multiplexing baseband design

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Abstract- **In Wireless communication systems, the high data transmission rate is considered to be the most important factor. The Multi-Band Orthogonal Frequency Division Multiplexing (MB-OFDM) is a suitable solution for implementation of high speed data transmission by dividing the spectrum available into multiple bands. In this paper we will take the overview of the MB-OFDM technique, and the baseband modulation of it which is considered to be a good option for secured and high data transmission rates and lowering the bit error rate and increasing flexibility in the system.**

Keywords— FPGA, IFFT, OFDM, QPSK.

I. INTRODUCTION

The multiple band orthogonal frequency division multiplexing is considered to be the best solution for Ultra wideband (UWB) Personal Area Networks (PANs). With the increase of communications technology, the demand for higher data rate services such as multimedia, voice, and data over both wired and wireless links is also increased. OFDM (Orthogonal Frequency Division Multiplexing) is an effective multicarrier technology for robust and reliable high-rate and high-speed data transmission in the wired/wireless communication systems such as DAB, DVB-T, IEEE802.11a, CMMB etc, because of its spectral efficiency and ability to mitigate the effects of delay spread and inter-symbol interference (ISI). In February 2002, the Federal Communications Commission (FCC) allocated 7,500 MHz of spectrum (from 3.1 GHz to 10.6 GHz) for use by UWB devices[3].This ruling has helped to create new standardization efforts, like IEEE 802, that focus on developing high speed wireless communication systems for personal area network (PAN). A multi-band orthogonal frequency division multiplexing (MB-OFDM) ultra wideband
(UWB) system is being considered for the physical layer of the new IEEE wireless personal area network (WPAN) standard, IEEE 802.15. The standard aims at the high data transmission rates. The MB-OFDM technology is nothing but combining multiple carrier frequencies simultaneously and at the same time providing the transmission into multiple bands, thus utilizing completely the available bandwidth.

II. WORKING OF MAJOR BLOCKS

The paper conveys the information about the grater data transmission rates using the multiple band orthogonal frequency division multiplexing using the various blocks like scrambler, encoder, QPSK etc. also to encode each and every building block and to see the results in simulation basis and possibly also on FPGA platform. The following is the basic block diagram of OFDM containing the basic building blocks which makes the baseband more secured and efficient for high data transmission.

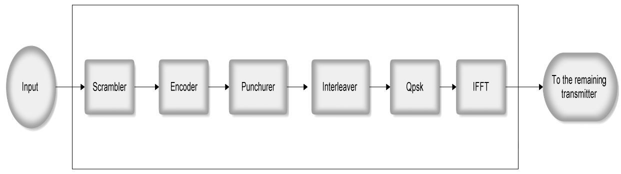

Fig 1. Block diagram of baseband

The major blocks of project are Scrambler, Encoder, Puncturer, Interleaver, QPSK and IFFT. After IFFT, whole input will be given to the remaining transmitter. The remaining transmitter will contain a digital to analog converrter (DAC) block which will convert the input digital data into analog and the output will be proceed to the RF front end transmitting antenna. Then the complete signal will be transmitted. But the project work will be to design the baseband of the transmitter which is a digital part and to check the results on FPGA platform. These all building blocks are implemented using a VHDL coding and are explained below.

A.Scrambler- In communications, a scrambler is a device that transposes or inverts signals or otherwise encodes a message at the transmitter to make the message unintelligible at a receiver not equipped with an appropriately set descrambling device. Scrambling is accomplished by the addition of components to the original signal or changing some important component of the original signal in order to make extraction of the original signal difficult. In telecommunications and recording, and scrambler is also referred as a randomizer which is a device that manipulates a data stream before transmitting. The manipulations are reversed by a descrambler at the receiving side. Scrambling is widely used in satellite, radio relay communications and PSTN modems[1]. A scrambler can be placed just before a forward error correction (FEC), or it can be placed after it, just before the modulation.

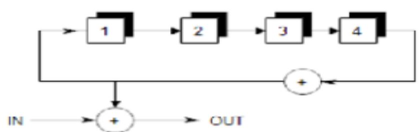

Fig 2 The scrambler circuit

In this way, the original input data can be scrambled (converted into another sequence) and another output can be shown as the output of scrambler for encryption purpose. So the scrambler is basically used for scrambling the data and providing the scrambled output to the another consecutive block.

B.Encoder – In communications , a convolution code is a type of error-correcting code in which each m-bit information symbol (m-bit string) to be encoded is transformed into an n-bit symbol, where m/n is the code rate (n,m) and the transformation is a function of the last k information symbols, where k is the constraint length of the code. This block serves to add patterns of redundancy to the data in order to improve the SNR(signal to noise ratio) for more accurate decoding at the receiver .There are two types of encoder i.e. recursive and feed forward encoder. It makes the input bit stream coming from the scrambler more secure and also provides the ways in which it should be easily decoded at the receiver side by the exact receiver party. At the receiver, Viterbi decoder is employed to decode the convolutional encoded sequence[6]. So the encoders are used to increase the data rates of the transmission system.

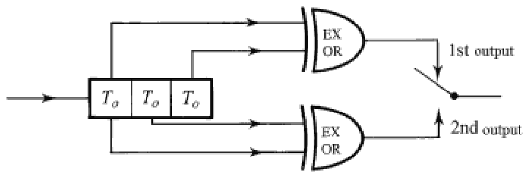

Fig 3. Convolutional encoder

So in the above diagram there is one input bit steam is applied to encoder and the convolved data is taken out. The single bit stream is applied at the input and the convolved data as output is observed, In this way the transmission becomes more secured by using convoltional encoder.

C. Punchurer –It is the process of deleting some bits from the given codeword according to the puncturing matrix .The puncturing matrix (P) consists a bit stream of zeros and ones, where the zero (0) represents an omitted bit and the one (1) represents an emitted bit. It is used to increase the rate of a given code. Puncturing can be applied to both block and convolution codes. It accepts the input bit stream and convolves it into stream of 1's and 0's and applies a puncturing matrix over it and this punchured data is provided to the remaining blocks,So the data rates will be increased and more number of bits will travel per unit time. The puchuring can be done in many ways like by using 2x2 matrix or 4x4 matrix etc. also it can be done using a simple even odd method. By choosing an appropriate method the input bit stream can be punchured for improving the bit rates. The simulations can be as below.

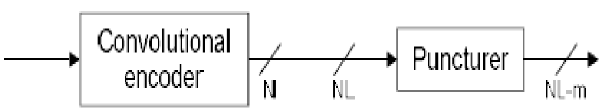

Fig..4. Punchurer circuit

D. Interleaver- An interleaver is a device that rearranges the ordering of sequence of symbols in a deterministic manner. Associated with the interleaver is a de-interleaver that applies the inverse permutation original interleaved sequence at the transmitter side.It will accept the input bit streams coming from previous blocks and will assign some special (random) values to it and then transmits that random sequence and there will be a de-interleaver block placed at the receiver side to decode those values first and then retrieve its own bit stream, making the secured data transmission. And the unknown party could not detect the original signal thus making the baseband of the transmitter more efficient and secured.

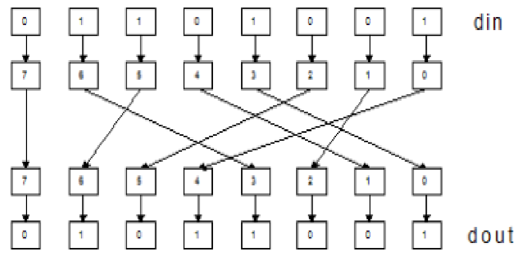

Fig. 5 The Interleaver

The above diagram shows, working of an interleaver that accepts the bit stream and assigns irrelevant values to it, provides this data to the preceding blocks for further transmission purposes.

E. QPSK - The quadrature phase shift keying is considered to be the most suitable modulation technique amongst all. The interleaved values will be given to the QPSK for the further modifications. An input binary sequence is converted into a complex valued sequence according to Gray-coded constellation mapping .The coded and interleaved binary serial input data shall be divided into groups of two bits and converted into a complex number representing one of the four QPSK constellation points.

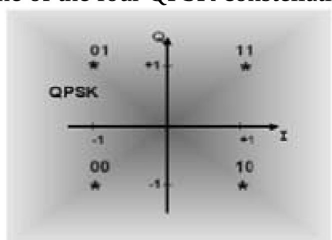

Fig. 6 The quadrant of QPSK

Based on a pair of input bits, we determine the in-phase and quadrature phase values denoted as I and Q, respectively these two bit streams I and Q are being fed to the next block IFFT.

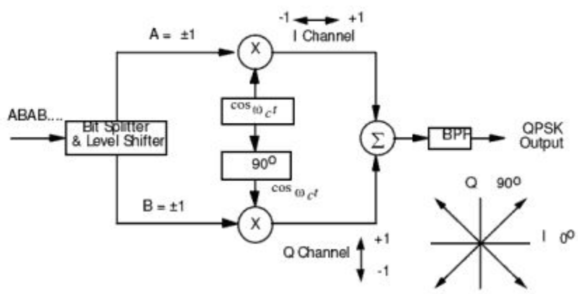

Fig 7. The QPSK block

At the input of the modulator, the digital data's even bits (i.e., bits 0,2,4 and so on) are stripped from the data stream by a "bit-splitter" and are multiplied with a carrier to generate a BPSK signal (called PSK_I). At the same time, the data's odd bits (i.e., bits 1, 3, 5 and so on) are stripped from the data stream and are multiplied with the same carrier to generate a second BPSK signal (called PSK_Q).However, the PSK_Q signal's carrier is phase shifted by 90^o before being modulated. Each adjacent symbol only differs by one bit, sometimes known as quaternary or quadric-phase phase shift keying. QPSK uses four points on the constellation diagram, equi-spaced around a circle, with four phases, qpsk can encode two bits per symbol to minimize the BER- twice the rate of BPSK. Analysis shows that this may be used either to double the data rate compared to a binary-phase shift keying system while maintaining the bandwidth of the signal or to maintain the data rate of BPSK but half the bandwidth needed.

F. IFFT- The IFFT converts the signals from frequency domain to time domain. IFFT is a core of the baseband of MB-OFDM transmitter. The bit streams will be modulated on various frequencies carrier by IFFT. The IFFT module mainly consists of several parts: internal receive unit, computation unit, address generate unit and central control unit. The IFFT is considered as most important block of the OFDM circuit. After QPSK modulation and IFFT the single bit stream is converted into multiple bands and is then given to the remaining analog part for the rest of the transmission purposes and finally to the transmitting antenna which will transmit the those frequencies into multiple bands .

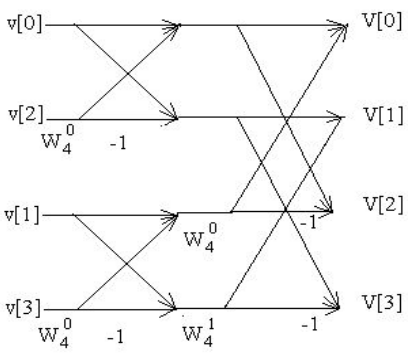

Fig.8 The basic IFFT

Forward FFT takes a random signal, multiplies it successively by complex exponentials over the range of frequencies, sums each product and plots the results as a coefficient of that frequency. The coefficients are called a spectrum and represent "how much" of that frequency is present in the input signal. In this way the outputs of the qpsk block is being fed to the IFFT and bit streams will be modulated on various frequency ranges.

III. RESULT AND ANALYSIS

The result and analysis part is shown below containing the total output waveforms of each working major block for the complete mb-ofdm system model. The basic binary input and the scrambled output are shown below.

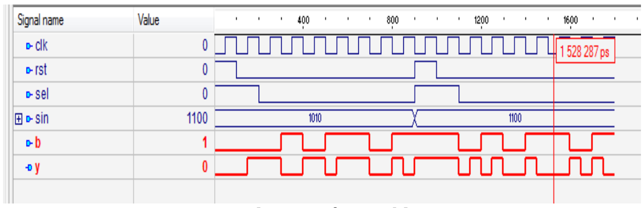

Fig 9. Simulations of scrambler

In This way we can conclude that the original bit stream (b) is different and the output displayed (y) is scrambled bit stream which is totally different from the original one in sequence thus making the secured communications.

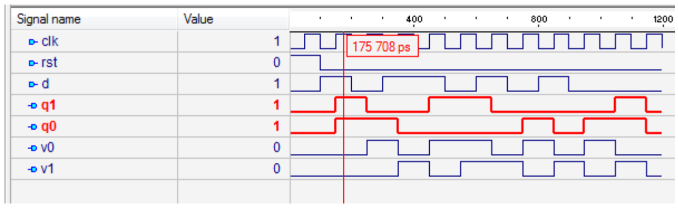

Fig.10 Simulations of encoder

The output coming from the scrambler is encoded as shown above using convolutional encoder.

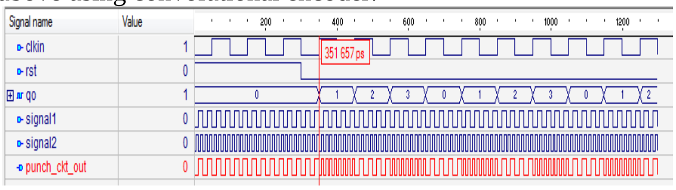

Fig. 11 Simulations of punchurer

The two incoming bit streams are punchured in a way that the two bit streams are punchured into one. And the output punchured bit stream is shown above as punch-ckt out. The total output waveforms of the OFDM baseband are shown below containing the two inputs and rest of the output. These outputs are also validated on FPGA platform.

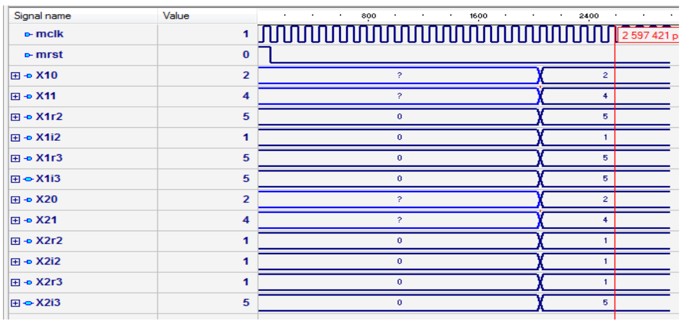

Fig.12. Final simulation of baseband

IV. CONCLUSION

The MB-OFDM technique is proved to be the best technique for wired and wireless communications having the less complexity, more efficiency and improving grater transmission rates. The above designed ofdm baseband can be considered to be more secured and efficient.

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