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A Review Paper on Implementation of OFDM Transceiver using Mixed Radix 8-2 Algorithm

Prof. Y.D. Kapse[1], Ms. Lokhande Komal Mohan[2], Ms. Pooja Sarangpure[3]

Assistant Professor, Electronic and Telecommunication, Government College of Engineering, Jalgaon, India [1]

M.Tech, Student, Electronic and Telecommunication, Government College of Engineering, Jalgaon, India [2,3]

Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is a Frequency Division Multiplexing (FDM) technique used as a digital multi-carrier modulation method. A large number of closely spaced sub carriers which are orthogonal are used to carry data on several parallel data streams. OFDM uses the spectrum efficiently compared to Frequency Division Multiple Access (FDMA) by spacing the channels much closer and creating all the carriers orthogonal to one another. Due to rapid growth of wireless and multimedia communication, there is a tremendous need for high-speed data transmission. Telecommunication industry provides variety of services ranging from voice to multimedia data transmissions, in which speed ranges several Kbps to Mbps. Existing system, may fail to support high speed efficient data transmission. To improve the speed and maximum amount of data transmission Orthogonal Frequency Division Multiplexing (OFDM) system may be used. Orthogonality of the carriers prevents interference between the closely spaced carriers and provides high bandwidth efficiency. This work focuses on design and implementation of OFDM transmitter and receiver.

Keywords: OFDM, FPGA, Orthogonality, IFFT.

I. INTRODUCTION

Orthogonal frequency-division multiplexing (OFDM) is a method of digital signal modulation in which a single data stream is split across several separate narrowband channels at different frequencies to reduce interference and crosstalk This means symbols sent in the substreams are longer and spaced farther apart. In +0e original stream, each bit might be represented by a 1-nanosecond (ns) segment of the signal, with 0.25 ns spacing between bits. Splitting the signal across four component streams lets each bit be represented by 4 ns of the signal with 1ns spacing between. This reduces interference among symbols and makes it easier to receive each symbol accurately while maintaining the same throughput .To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonally of the carriers.

A.INTRODUCTION

In order to meet the unprecedented requirements for high quality of service (QoS) and high data rate communication as well as emerging multimedia services, telecommunication professionals are currently working towards the fourth generation (4G) wireless communication systems. The orthogonal frequency division multiplexing(OFDM), one of the most promising technologies, has raised a great deal of attention in view of the rapid development of digital signal processing technique s and circuits in recent years [9][11].OFDM was originally proposed in 1960s as a parallel data transmitting scheme. At the early development stage [12], traditional methods as that used in single carrier modulation were applied to implement OFDM modem, which require a number of sinusoidal subcarrier oscillators and multipliers in the modulator and banks of correlates in the demodulator. The implementation complexity limited the development of OFDM until 1971, whenthe discrete Fourier transform (DFT) was applied to this technology [16]. The DFT significantly simplified the modulation and demodulation processes andmade it practical to implement the baseband OFDM modem in a digital manner. From the more and more applications of OFDM have been investigated in practice

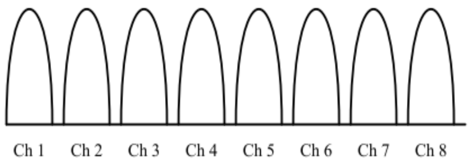

Fig. 1.1 Spectrum of FDM showing Guard Bands

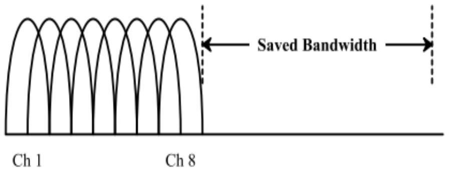

Fig. 1.2 Spectrum of OFDM showing Overlapped Subcarrier

The basic idea is to divide a single high rate data stream into a number of lower-rate data streams as shown in to Figure1.1. Each of these data streams is modulated on a

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specific carrier, which is called subcarrier, and transmitted simultaneously. Such a kind of multi-carrier modulation preserves the robustness against the effects of multipath fading. Moreover, these subcarriers are orthogonal to one another so as to enhance the spectrum efficiency compared to that in conventional multi-carrier transmission. Since the data streams carried by each subcarrier are separated by frequencies, OFDM is also considered as a frequency division multiplexing (FDM) scheme shown in Figure 1.2 for the spectrum of OFDM subcarrier . A large number of closely spaced sub carriers which are orthogonal are used to carry data on several parallel data streams. OFDM uses the spectrum efficiently compared to Frequency Division Multiple Access (FDMA) by spacing the channels much closer and creating all the carriers orthogonal to one another. Due to rapid growth of wireless and multimedia communication, there is a tremendous need for high-speed data transmission.

OFDM is a special case of Multicarrier transmission, where a single data stream is transmitted over number of lower rate Subcarrier. The problem of intersymbol interference (ISI) introduced by multipath channel is significantly reduced in OFDM by using the cyclic prefix (CP) as a guard interval between OFDM blocks. The proposed work would be a brief overview of IFFT & FFT algorithm to be effectively used in OFDM system. OFDM is a special case of multicarrier transmission, where a single data stream is transmitted over a number of lower rate subcarriers

I.Orthogonality

The key to OFDM is maintaining orthogonality of the carriers. If the integralof the product of two signals is zero over a time period, then these two signals are said to be orthogonal to each other. Two sinusoids with frequencies that are integer multiples of a common frequency can satisfy this criterion. Therefore, orthogonality is defined by Eq.(1):

$$\int_0^T \cos(2\pi n f_0 t)\cos(2\pi m f_0 t)\,dt = 0 \quad (n \neq m) \qquad \text{...Eq.(1)}$$

Where n and m are two unequal integers; fo is the fundamental frequency; T is the period over which the integration is taken. For OFDM, T is one symbol period and fo set to 1/T for optimal effectiveness.

II. LITERATURE SURVEY

A. RESEARCH BACKGROUND

Ashish D. Sawant et.al [1] proposed the “Study of FPGA Based OFDM Transmitter and Receiver”. This proposed section presents relevant works related to OFDM implementation. In his work he used the radix-2 algorithm for designing the OFDM in which they have shown the results for the 64 point FFT and study the performance of OFDM, including the power spectral density, BER. Through intensive MATLAB simulation in this they optimize FFT/IFFT Length was 1024 points and the best value for the SNR was 60db.

A. S. Chavan et.al [2] proposed the work on “FPGA Based Implementation Of Baseband OFDM Transceiver Using VHDL” The system is designed using VHDL, synthesized using high level synthesis tool and targeted on Xilinx Spartan 3e device. Presented design is simulated on ISE simulator and the results are presented. Resources utilization for transmitter and receiver is given in his paper. The design utilizes the Intellectual Property (IP) cores provided by Xilinx for floating point multiplication, addition subtraction and division. DIT radix-2 butterfly approach is used to calculate IFFT and FFT. In their work they only show that the main problem of OFDM transceiver is the processing time which is consumed in the IFFT and FFT.

ManjunathLakkannavar et.al [3] proposed the work on “Design and implementation of OFDM using VHDL and FPGA”. He implemented the OFDM system on FPGA using VHDL it worked for 8-point FFT using radix-2 algorithm.

Naveen Kumar et.al[4] proposed the work on “FPGA Implementation of OFDM Transceiver using Verilog - Hardware Description Language” they shows the simulation work on vertex-4 using Verilog . Radix-4 algorithm is used for FFT and IFFT solving. They design the system for 494.841MHz and maximum frequency of OFDM system can be increased by using radix-4.

In 1980s, OFDM was widely studied in such areas as high-density recording, high-speed modems, and digital mobile communications [17]. Since 1990s, OFDM has been employed in wideband data transmission. Applications of OFDMtechnology include asymmetric digital subscriber line (ADSL), high-bit-rate digital subscriber line (HDSL), and very-high-speed digital subscriber line (VDSL) in wired systems, and digital audio broadcasting (DAB), digital video broadcasting (DVB) in wireless systems. Furthermore, it has also been recognized as the basis of the wireless local area network (WLAN) standards , among which the IEEE 802.11a standard is one of the most important ones. Recently, high data rate and high QoS have been two main topics in wireless and mobile communications, which require communication systems to be capable of adapting to fast varying channel conditions and providing a steady communication environment to various kinds of users at a high speed of data transmission

The proposed architecture has three main advantages: fewer butterfly iteration to reduce power consumption, pipeline of radix–2butterfly to speed up clock frequency, and even distribution of memory access to make utilization efficiency in SRAM ports. They coded this design in Verilog hardware description language with increase in speed & performance of OFDM. In 2010, Mounir Arioua et. Al. [2] proposed an optimized implementation of 8-point FFT processor with radix-2 algorithm in R2MDC architecture.

In 2011, K. Harikrishna and T. Rama Rao proposed Pipeline architecture for Wi-MAX technology using Radix-4Decimation in frequency FFT algorithm [1]. They proposed a memory based recursive FFT design which has much less gate counts, lower power consumption and higher speed.

B. SUMMARY

In all previous work we can see that it works on OFDM using FPGA they simulate the results on Matlab and Xillinx. In all previous system to solve the FFT and IFFT they commonly used the radix-2 algorithm which required more time to solve. So In this work I am going to make the system fast and to reduce the power consumption, we choose the mixed radix 8-2 algorithm to solve the FFT and IFFT which take minimum time to solve. mixed-radix FFT algorithm is capable of producing efficient hardware with structural regularity. It is more efficient than radix-2 FFT algorithm and applicable to all 2n-point FFT systems. It is therefore selected for implementation of the OFDM systems.In this proposed system I am going to improve the speed, reducing the power consumption, reducing the noise, increasing the SNR and Frequency.

III. SYSTEM DESIGN

Wireless communication using OFDM has many advantages. Channel equalization using OFDM is easy as compare to adaptive equalization. Also spectrum available can be used more efficiently with help of OFDM. Applications such as DAB, HDTV, Wireless LAN (IEEE 802.11a, g) where high baud rate & less noise are essential features, OFDM can be efficiently used. FPGAs can used to implement the hardware of any system at very less cost.

A. PROPOSED SYSTEM

The proposed work will be to design the 48-point FFT & IFFT blocks for OFDM by using mixed radix8-2 algorithm and to achieve the efficient multiplication. The design would be coded in Verilog and synthesis will be done in Xilinx ISE 13.2 software. Then the design will get implemented on FPGA Spartan 3E device kit. Therefore, we can get the efficient multiplication of FFT and IFFT block to be used in OFDM receiver and transmitter respectively. I have chosen the Verilog over VHDL because it is easy to learn and easy to use. The main problem in OFDM is to minimize the processing time and power consumption of OFDM system and that are only due to the FFT processing so to minimize the FFT processing time I have chosen the Radix8-2 algorithm to solve the FFT by which FFT time will reduces in OFDM system.

Initially transmitter and receiver is implemented independently and tested on kit, and then both the subsystems were merged to form one system. The system is designed for two sets of subcarriers one is using 4 subcarriers and the other using 8 subcarriers. Design flow for both the system is same. Then the algorithm is developed for the sequential and concurrent operations. To make the design more parallel the operations are broken in to processes and independently written in VHDL. Some blockscontain floating point complex operations, for that Intellectual Property (IP) cores provided Xilinx are used.

B. OFDM SYSTEM DESIGN

All The OFDM system was model using MATLABTM to allow various parameters of the system to be varied and tested. The aim of doing the simulations was to measure the performance of OFDM under different channel conditions, and to allow for different OFDM configurations to be tested. Four main criteria were used to assess the performance of the OFDM system, which were its tolerance to multipath delay spread, peak power clipping, channel noise and time synchronization errors. To generate OFDM successfully the relationship between all the carriers must be carefully controlled to maintain the orthogonally of the carrier

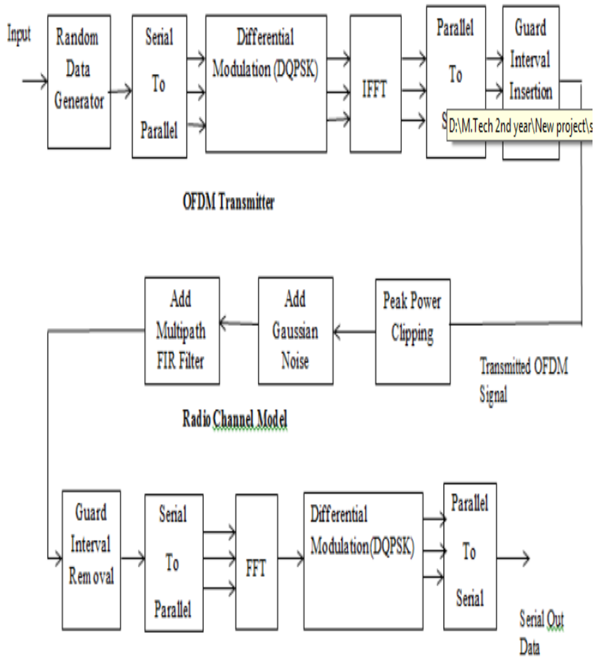

Fig. 3.1 OFDM System

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 QPSK, or QAM) The Block diagram of OFDM system is shown in above Figure 3.1.The explanation of each block is as follows:

➢ 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 then transmitted in parallel by assigning each da ta word to one carrier in the transmission.

➢ Modulation of Data:
The data to be transmitted on each carrier is then differentially encoded with previous symbols, and then mapped into a 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.

➢ Inverse Fourier Transform:
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.

➢ Guard Period:
The guard period used was made up of two sections. Half of the guard period time is a zero amplitude transmission. The other half of the guard period is a cyclic extension of the symbol to be transmitted. This was to allow for symbol timing to be easily recovered by envelope detection. However it was found that it was not required in any of the simulations as the timing could be accurately determined position of the samples. After the guard has been added, the symbols are then converted back to a serial time waveform. This is then the base band signal for the OFDM transmission.

➢ Channel:
A channel model is then applied to the transmitted signal. The model allows for the signal to noise ratio, multipath, and peak power clipping to be controlled. The signal to noise ratio is set by adding a known amount of white noise to the transmitted signal. Multipath delay spread is then added by simulating the delay spread using an FIR filter. The length of the FIR filter represent s the maximum delay spread, while the coefficient amplitude represents the reflected signal magnitude.Using this cyclic extended symbol the samples required for performing the FFT (to

➢ Receiver:
The receiver basically does the reverse operation to the transmitter. The guard period is removed. The FFT of each symbol is then performed to find the original transmitted spectrum. The phase angle of eachtransmission carrier is then evaluated and converted back to the data word by demodulating the received phase. The data words are then combined back to the same word size as the original data.

➢ OFDM Generation:
To generate OFDM successfully, the relationship between all the carriers must be carefully controlled to maintain the orthogonally of the carriers. For this reason, OFDM is generated by first 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 DQPSK. The required spectrum is then converted back to its time domain signal using an Inverse Fourier Transform. In most applications, an Inverse Fast Fourier Transform (IFFT) is used. The IFFT performs the transformation very efficiently, and provides a simple way of ensuring the carrier signals produced are orthogonal.

➢ Adding a guard period to OFDM:
OneOne of the most important properties of OFDM transmissions is its high level of robustness against multipath delay spread. This is a result of the long symbol period used, which minimizes the inter-symbol interference. The level of multipath robustness can be further increased by the addition of a guard period between transmitted symbols. The guard period allows time for multipath signals from the previous symbol to die away before the information from the current symbol is gathered.

The most effective guard period to use is a cyclic extension of the symbol. If a mirror in time, of the end of the symbol waveform is put at the start of the symbol as the guard period, this effectively extends the length of the symbol, while maintaining the orthogonality of the waveformUsing this cyclic extended symbol the samples required for performing the FFT (todecode the symbol), can be taken anywhere over the length of the symbol. This provides multipath immunity as well as symbol time synchronization tolerance.

PARAMETERS - Wi-Fi / IEEE 802.11a which is a system based on OFDM so that parameter as follows:
➢ Data Rates: 6 Mbps to 48 Mbps
➢ Modulation: BPSK, QPSK, 12 QAM and 48 QAM
➢ FFT Size: 48 with 52 sub-carriers uses, 48 for data and 4 pilots.
➢ Subcarrier frequency spacing : 20 MHz divided by 48 carriers or 0.3125 MHz
➢ FFT Period: Also called symbol period, 3.2 µs
➢ Guard Duration: One quarter of symbol time, 0.8 µs
➢ Symbol Time: 4 µs

C.INTERNAL BLOCK DIAGRAM OF OFDM SYSTEM
For designing of the OFDM system there are several block are design are as follows. The Figure 3.4 are shows the internal block diagram for OFDM system.

➢ Scramble/Descramble
Data bits are given to the transmitter as inputs. These bits pass through a scrambler that randomizes the bit sequence. This is done in order to make the input sequence more disperse so that the dependence of input signal’s power spectrum on the actual transmitted data can be eliminated. At the receiver end descrambling is the last step. Descrambler simply recovers original data bits from the scrambled bits.

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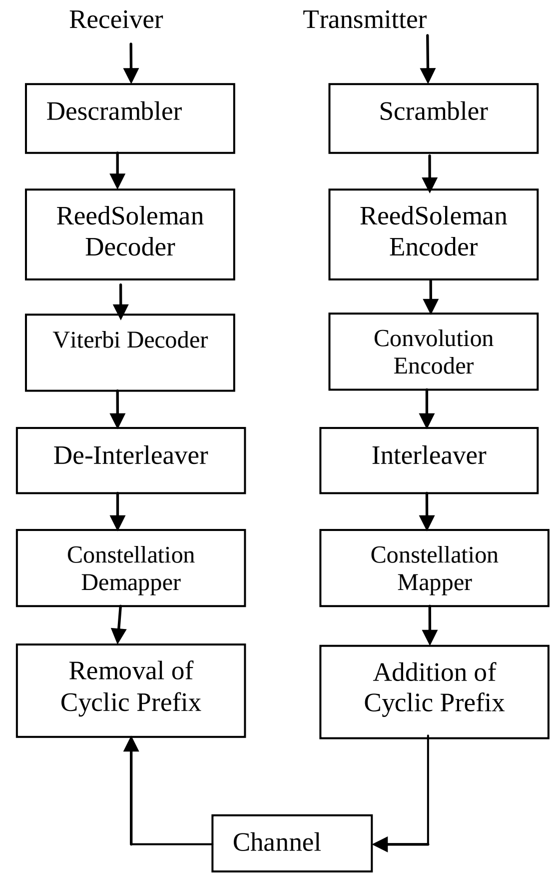

Fig.3.2 Internal Block Diagram of OFDM System

➢ Reed-Solomon Encoder/Decoder

The scrambled bits are then fed to the Reed Solomon Encoder which is a part of Forward Error designing the or Correction (FEC). Reed Solomon coding is an error-correction coding technique. Input data is over-sampled and parity symbols are calculated which are then appended with original data [3]. In this way redundant bits are added to the actual message which provides immunity against severe channel conditions. A Reed Solomon code is represented in the form RS (n, k), where n= 2m −1 (1) k = 2m −1− 2t (2) Here m is the number of bits per symbol, k is the number of input data symbols (to be encoded), n is the total number of symbols (data + parity) in the RS codeword and t is the maximum number of data symbols that can be corrected. At the receiver Reed Solomon coded symbols are decoded by removing parity symbols.

➢ Convolutional Encoder/Decoder

Reed Solomon error-coded bits are further coded by Convolutional encoder. This coder adds redundant bits as well. In this type of coding technique each m bit symbol is transformed into an n bit symbol; m/n is known as the code rate. This transformation of m bit symbol into n bit symbol depends upon the last k data symbols, therefore k is known as the constraint length of the Convolutional code. Viterbi algorithm is used to decode convolutionaly encoded bits at the receiver side. Viterbi decoding algorithm is most suitable for Convolutional codes with k<10.

➢ Interleaver/De-Interleaver

Interleaving is done to protect the data from burst errors during transmission. Conceptually, the in-coming bit stream is re-arranged so that adjacent bits are no more adjacent to each other. The data is broken into blocks and the bits within a block are rearranged. Talking in terms of OFDM, the bits within an OFDM symbol are rearranged in such a fashion so that adjacent bits are placed on non-adjacent subcarriers. As far as De-Interleaving is concerned, it again rearranges the bits into original form during reception.

➢ Constellation Mapper/De-Mapper

The Constellation Mapper basically maps the incoming (interleaved) bits onto different sub-carriers. Different modulation techniques can be employed (such as QPSK, BPSK, QAM etc.) for different sub-carriers. The De-Mapper simply extracts bits from the modulated symbols at the receiver.

➢ Inverse Fast Fourier Transform / Fast Fourier Transform

The Fast Fourier transform (FFT) and Inverse Fast Fourier transform (IFFT) are derived from the main function, which is called discrete Fourier transform (DFT). In DFT, the computation for N-points of the DFT will be calculated one by one for each point. While for FFT/IFFT, the computation is done simultaneously and this method saves quite a lot of time. The equations for FFT/IFFT function can be derived from the general DFT equation is as below Eq.(2)

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{\frac{-j2\pi k}{N}} \quad \ldots\text{Eq.(2)}$$

X(k)- the DFT frequency output at the k-the spectral point k 0 to (N-1).

This is the most important block in the OFDM communication system. It is IFFT that basically gives OFDM its orthogonality. The IFFT transform a spectrum (amplitude and phase of each component) into a time domain signal. It converts a number of complex data points into the same number of points in time domain. Similarly, FFT at the receiver side performs the reverse task i.e. conversion from time domain back to frequency domain.

➢ Addition/Removal Of Cyclic Prefix

In order to preserve the sub-carrier orthogonality and the independence of subsequent OFDM symbols, a cyclic guard interval is introduced. The guard period is specified in terms of the fraction of the number of samples that make up an OFDM symbol. The cyclic prefix contains a copy of the end of the forthcoming symbol. Addition of cyclic prefix results in circular convolution between the

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transmitted signal and the channel impulse response. Frequency domain equivalent of circular convolution is simply the multiplication of transmitted signal's frequency response and channelfrequency response, therefore received signal is only a scaled version of transmitted signal (in frequency domain), hence distortions due to severe channel conditions areeliminated. Removal of cyclic prefix is then done at the receiver end and the cyclic prefix–free signal is passed through the various blocks of the receive.

D.WORKING oF SYSTEM

Mixed-Radix 8-2 FFT With Bit Reversing Output Sequences For 48 Points FFT..The Signal Flow Graph (SFG) of the proposed butterfly structure is shown in the Figure 3.3

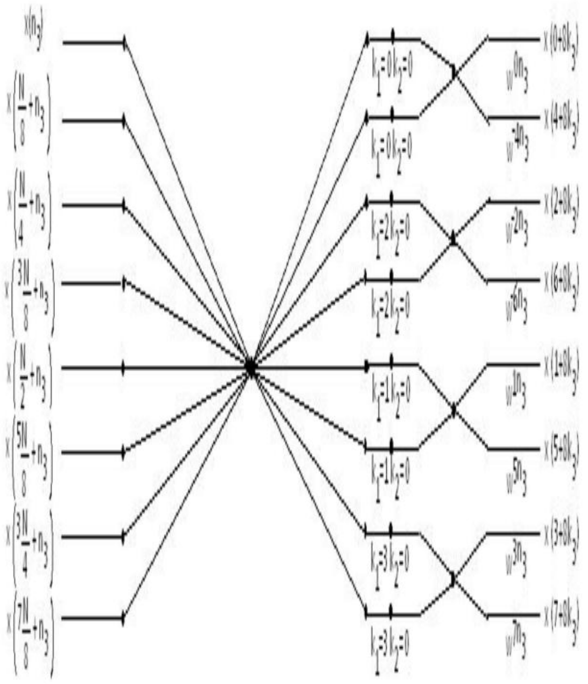

Fig 3.3The Basic Butterfly for Mixed-Radix 8-2 FFT

Algorithm

The proposed Mixed-Radix 8-2 is derived from Mixed-Radix 4-2 butterfly withsimple bit reversal for the output sequence.[12] It is composed of one radix-8butterflies and four radix-2 butterflies. In order to verify the proposed scheme, 48-points FFT based on the proposed Mixed-Radix 8-2 butterfly with simple bit reversing for ordering the output sequences is considered..

Proposed mixed radix 8-2 butterfly with simple bit reversing output sequence include one radix8, three radix2 butterflies, one multiplier and additional shift unit for twiddle factor. In first stage the 48 point sequence are divided by the 8 groups whichcorresponds to n3=0 ,n3=1, n3=2, n3=3, n3=4, n3=5, n3=6,n3=7 respectively. After the grouping each group is input sequence for the Mixed Radix 8-2 Butterfly stage . From the SFG of Mixed–Radix 8-2 in the first stage, the input data of one radix-8 butterflies which are expressed with the B4 (o, n3, kj) , B4(i,n3,k1)[12],arex(n3),x(N/4±n3),x(N/2±n3),x(3N/4±)andx(N/8±n3),x(3N/8±n3),x(5N/8±n3),x(7N/8±n3) respectively. Each input group passes the first radix-8 butterflies, the outputted data sequence is multiplied by special twiddle factors. Then ,these outputted data are input to the second radix 2 butterflies. After passing the second radix-2 butterflies, the outputted data are multiplied by twiddle factors These twiddle factor WQ(1+K) is unique multiplier unit in proposed Mixed radix8-2 butterflies. As shown in the Figure 3.4 the SFG diagram for 48-points FFT is composed of total twelve Mixed-Radix 8-2 Butterflies are required.

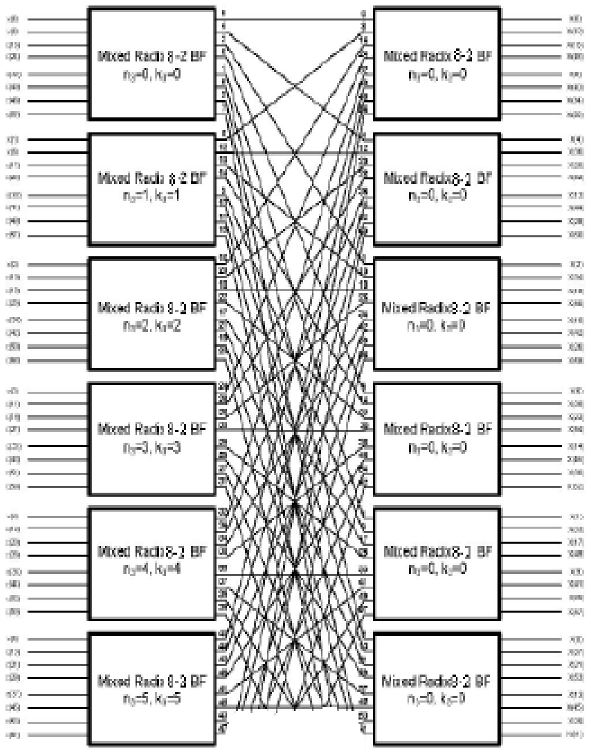

Fig.3.4 Mixed Radix8-2 Butterfly For 48-Point

IV. CONCLUSION

In this project work, the design of an OFDM transmitter and receiver is modified with mixed radix algorithms and that are implemented using VLSI design process. It was found during the algorithm design that many blocks need complex multipliers and adders and therefore special attention needs to be given to optimize these circuits and maximize reusability. In particular, the models have been applied to analyze the performance of mixed-radix FFT architectures used in OFDM. Actual hardware resource requirements were also presented and simulation results were given for the synthesized design. The 48-point Mixed-Radix 8-2 FFT based OFDM architecture was found to have a good balance between its performance and its hardware requirements and is therefore suitable for use in OFDM system.

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