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OFDM TRANSMISSION AND RECEPTION: REVIEW

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Abstract-*The paper concentrates on the review of Orthogonal Frequency Division Multiplexing (OFDM) technique, for digital data transmission and reception. OFDM is relied upon to be utilized as a part of future television and remote LAN (WLAN) systems. For instance, IEEE802.11 in the United States, ETSI BRAN in Europe [4], and ARIB MMAC in Japan have officially embraced the OFDM transmission technique as a physical layer for future broadband WLAN systems. In OFDM information transmission and reception uses IFFT and FFT in modulator and demodulator respectively. The literature review is carried from some of the journals.*

Keywords: *Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), Local Area Network (LAN), Orthogonal Frequency-Division Multiplexing (OFDM).*

1. INTRODUCTION

OFDM is a unique instance of multicarrier transmission, where a single data stream is transmitted over various lower-rate subcarriers (SCs). It merits saying here that OFDM can be seen as either a modulation technique or a multiplexing technique. One of the principle motivations to utilize OFDM is to increase robustness against frequency-selective fading or narrowband interference. In a single-carrier system, entire link can fail even if a single fade or interferer can occur, but in a multicarrier system, only a small percentage of the SCs will be affected. Error-correction coding can then be utilized to right for the couple of mistaken SCs. With the fast development of advanced digital communication, there is the need for high-speed data transmission with faster rate. The mobile telecommunication industries are confronting the issue of providing the technology that be able to support a variety of services ranging from voice communication with a bit rate of couple of kbps to wireless multimedia in which bit rate up to 2 Mbps. Couple of frameworks have been proposed to determine the issue and OFDM framework has increased much consideration for distinctive reasons. OFDM system was initially grown in the 1960s. Just lately, OFDM has been perceived as an exceptional strategy for high speed cellular data communication correspondence where its execution depends on very high speed digital signal processing applications. The strategy has just as of late get to be accessible with sensible costs versus execution performance of hardware implementation. There are a few guaranteed focal points over OFDM with time-domain statistical multiplexing

- OFDM permits concurrent low-information rate transmission from a several clients.
- Pulsed carrier can be avoided.
- It reduces maximum transmission power for low data rate clients.
- Shorter and consistent delay.
- Contention- based multiple access (collision avoidance) is simplified. It, further improves OFDM robustness to fading and interference.

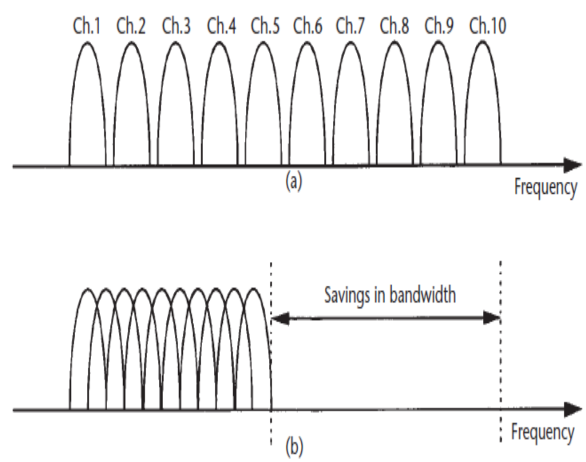

Fig-1: Concept of the OFDM signal, (a) conventional multicarrier technique, and (b) orthogonal multicarrier modulation technique.

"Orthogonal" shows that there is a precise mathematical relationship between the frequencies of the carriers in the system. In a typical FDM system, numerous carriers are divided separated in such a way that the signals can be received using conventional filters and demodulators. In

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such receivers, guard bands are introduced between the different carriers frequency, which results in a lowering of spectrum efficiency. It is possible, however, to arrange the carriers in an OFDM signal so that the sidebands of the individual carriers overlap and the signals are still received without adjacent carrier interference. To do this the carriers must be mathematically orthogonal. The receiver goes about as a bank of demodulators, translating each carrier down to dc, with the resulting signal integrated over a symbol period to recover the raw data. On the off chance that alternate carriers all beat down the frequencies that, in the time domain, have an entire number of cycles in the symbol period T, then the combination procedure brings about zero contribution from these different carriers. Thus, the carriers are linearly independent (i.e., orthogonal) if the carrier spacing is a multiple of 1/T.

2. LITERATURE REVIEW

The number of complex multiplication and addition operations required by the simple forms of both the Discrete Fourier Transform (DFT) [1] [2] and Inverse Discrete Fourier Transform (IDFT) [5] is of order N^2 as there are N data points to calculate, in which each requires N complex arithmetic operations. For the length of n input vector x, the DFT is a length n vector X, is given by equation 1 with n elements

$$f_j = \sum_{k=0}^{n-1} x_k e^{-\left(\frac{2\pi i}{n}\right)jk}, Where j = 0, 1, .., n-1 \quad (1)$$

In software engineering language, it may say that they have algorithmic complexity O (N^2) and consequently is not an extremely effective strategy. Is it conceivable to have better than then the DFT won't be exceptionally helpful for the greater part of useful DSP applications? Essentially, there are a number of 'Fast Fourier Transform' (FFT) algorithms that empower the calculation of the Fourier transform of a signal much faster than a DFT. FFTs are algorithms for quick computation of discrete Fourier transform of a data vector. The Fast Fourier transform (FFT) is a DFT algorithm which reduces the number of computations needed for N points from O (N^2) to O ($N\log_2 N$) [1] [3] . If the function to be transformed is not harmonically related to the sampling frequency, the response of an FFT looks like a 'sinc' function (sin x) / x.

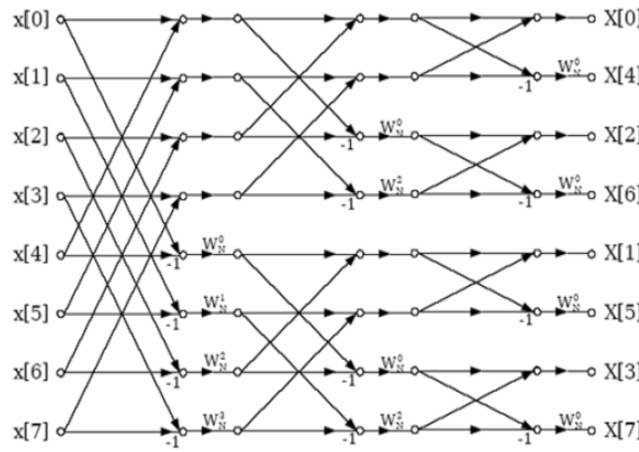

Fig-2: Implementation of DIF FFT

The 'Radix 2' algorithms are useful if N is a regular power of 2 and ($N=2^p$). If it is considered that algorithmic complexity provides a direct measure of implementation time and that the relevant logarithm base is 2 then, the ratio of implementation times for the (DFT) vs. (Radix 2 FFT) increases tremendously with increase in N. The term Fast Fourier Transform is actually slightly ambiguous. The reason of it is that, there are various commonly used 'FFT' algorithms and strategies. There are two different Radix 2 algorithms, which are called 'Decimation in Time' (DIT) and 'Decimation in Frequency' (DIF) algorithms. Both of the algorithms rely on the recursive decomposition of an N point transform into 2 (N/2) point transforms. The same decomposition process can be applied to any composite (non-prime) N. This strategy is particularly simple if N is divisible by 2 and if N is a regular power of 2, the decomposition structure can be applied repeatedly until the trivial '1 point' transform is reached. Consequently, the computation of N-point DFT via this algorithm requires $(N/2) \log_2 N$ complex multiplications. For understanding and illustrative purposes, the 8-point decimation-in frequency algorithm is shown in the fig. 2. It is observed that the output sequence occurs in bit-reversed order with respect to the input values in discrete order. Furthermore, if there is an abandon to change the requirement that the computations occur in place, then it is also possible to have both the input and output in normal order.

The detailed literature review can be explained with the help of following papers

Chandrakanth.V, et al. [1], presented a simple and novel architecture for executing hardware effective real time configurable variable point FFT implementation. This architecture is of generic in nature and its application can be elongated beyond radars. It can also used on custom

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designed FFT's in contrast to their usage of Altera IP core. But first the obtained data from the receiver has to be reorganized from range cell wise to Pulse repetition Interval (PRI) wise before providing as input to the FFT block, which is done with the help of ping pong memory architecture.

C. Shashikanth & B. Kedarnath [2], deals with the design and implementation of Fast Fourier Transform (FFT) algorithm which can be used for wireless-communication and its applications in real time environment. The computational strategy is two dimensional and implementation of this strategy on VIRTEX 5 LX330 FF1145 based XILINX's FPGA. The algorithm is written in VHDL language, which is verified and simulated on MODEL SIM SE tool, this provides new methodology to design and develop the processor for the Digital Signal processing prospects, and is implemented on the fundamental of pipelined architecture and Fast Fourier Transform approach.

Kai-Jiun Yang & Shang-Ho Tsai [3], presents a multipath delay commutator (MDC)-based architecture and memory scheduling to implement fast Fourier transform (FFT) processors for multiple input multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) systems with variable length. Based on the above architecture, they propose to utilize radix-Ns butterflies at each stage, where Ns are the number of data streams, so that there is simply one butterfly demand in each stage. Due to the simple control mechanism of the MDC, they propose simple memory scheduling scheme for input data and output bit/set-reversing. To apply the proposed method in practical applications, they use Ns = 4 and implement a 4-stream FFT/IFFT processor with variable length including 128, 512, 1024 and 2048 for MIMO-OFDM systems.

K. Harikrishna et al. [4], they presented a high level implementation of a high performance FFT for OFDM Modulator and Demodulator. The Verilog HDL coding is used for design and targeted into Xilinx Spartan3 FPGA's (a family of FPGA technology). They proposed a Radix-2^2 Algorithm and used it for the OFDM communication system. In proposed algorithm it has been examined that it uses the similar multiplicative complexity as the radix-4 algorithm, and it retains the butterfly structure of radix-2 algorithm.

Lokesh C & Dr. Nataraj K. R [5], focuses on the OFDM Kernel which advert to the inverse fast Fourier transform and cyclic prefix insertion blocks in the downlink flow and the FFT and cyclic prefix removal blocks in the uplink flow. An elongation to the OFDM kernel is required to affirm orthogonal frequency-division multiple access (OFDMA) that permits each user to be allocated with a portion of the available carriers. This technique is referred to as sub channelization and channel division. In this paper an additional controller is required for the cyclic prefix addition block that buffers the output packets from the FFT, which adds the appropriate proportion of the end of the output packet to the beginning of the output packet. A moderately significant memory resource is required; the hardware architecture has been designed so that the embedded memory may be shared with the uplink OFDM kernel if the modem is operating in time division duplex (TDD) mode.

M. Merlyn [6], focused on design and implementation of a variable-length prototype FFT/IFFT processor to cover various specifications of OFDM applications which is implemented on FPGA using Verilog HDL. He proposed a scheme for SDF (Single-path delay feedback) FFT architecture that employs a method of adding counter to achieve the purpose of programmable and without increasing the hardware complexity. The above proposed programmable SDF FFT processor can be applied to several OFDM communication systems. On the other hand, he also proposed a simple memory control method for shared-memory FFT architecture by acquiring the effective mixed-radix algorithm, and all of the calculation related to FFT will be discriminated in to three types: fixed-R-2^3, mixed-R-2 & R-2^3, and mixed-R-2^2 & R-2^3. The above two proposed methods of this paper can perform all FFT-point calculation in power of 2.

Paul H. [7], OFDM is a bandwidth efficient signaling scheme for digital communications that was first proposed by Chang. The main difference between frequency division multiplexing (FDM) and OFDM is that in OFDM the spectrum of the individual carriers mutually overlap, giving therefore an optimum spectrum efficiency (asymptotically Q b/Hz for modulation of each carrier). OFDM carriers exhibit the property of orthogonality on a symbol interval if synthesized such that they are spaced in frequency exactly at the reciprocal of the symbol interval. There are two deleterious effects caused by frequency offset, out of which one is the reduction of signal amplitude in the output of the filters matched to each of the carriers and the second is introduction of ICI from the other carriers which are now no longer orthogonal to the filter. Because, in OFDM, the carriers reinherently closely spaced in frequency compared to the channel bandwidth requirement, the tolerable frequency offset becomes very small fraction of the channel bandwidth requirement. Maintaining sufficient open loop frequency accuracy can become difficult with links, such as satellite links with multiple frequency

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channels estimations and translations or, as mentioned previously, in mobile digital links that may also introduce significant Doppler shift.

R. Sai Brunda & M.V.R. Vittal [8], designed a variable point FFT processor using FPGA to meet the requirements of OFDMA system. They select 2D Fourier transform algorithm as the kernel algorithm. The detail design of two stage pipeline structure is presented using VHDL language, simulation is done on the Modelsim(SE) and verify on Spartan3E FPGA. The design can be utilized in real-time signal processing applications, which completes the principal computing modules in OFDM and OFDMA system.

3. OFDM TRANSMISSION AND RECEPTION

The block diagram of the OFDM system is shown in fig. 3. As shown in figure the high speed serial data is coming from the input side and serial to parallel mapper converts the serial data into parallel form, which is given as the input to IFFT module and the output of IFFT module is further converted in to serial form with the help of parallel to serial converter. Now this data is passed on the channel from the transmitter side, at the receiver side first the received data is converted in to parallel form with the help of serial to parallel converter and given to the FFT module and then demapper maps the actual data.

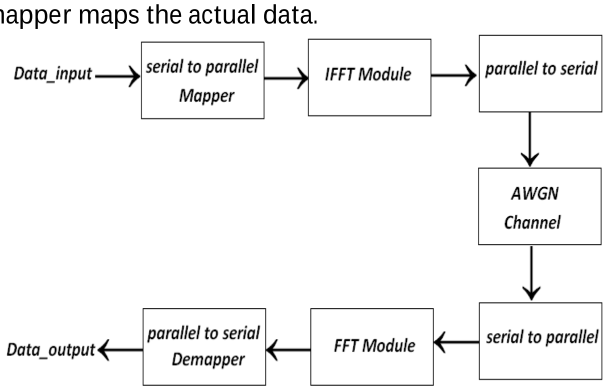

Fig-3: OFDM transmission and reception

The symmetrical arrangement about the vertical axis is essential for using the IFFT to manipulate input data. An inverse Fast Fourier transform (IFFT) converts the frequency domain data set into samples of the corresponding time domain representation of this data. IFFT is very useful for OFDM because it generates samples of a waveform with frequency components satisfying orthogonality conditions among its carriers. After the subcarrier modulation stage each of the data subcarriers is set to an amplitude and phase based on the data being sent and the modulation strategy and all unused subcarriers are set to zero. This kind of sets up is used for the OFDM signal in the frequency domain. An inverse FFT is then used to convert this signal to the time domain, allowing it to be transmitted over channel. Figure 4 shows the IFFT section of the OFDM transmitting end. In the frequency domain, each of the discrete samples of the IFFT corresponds to an individual subcarrier before applying the IFFT. Most of the subcarriers are modulated with data and outer subcarriers are unmodulated and set to zero amplitude values. These zero subcarriers provide a frequency guard band before the nyquist frequency and effectively act as an interpolation of the signal and allows for a realistic roll off in the analog anti -aliasing reconstruction filters.

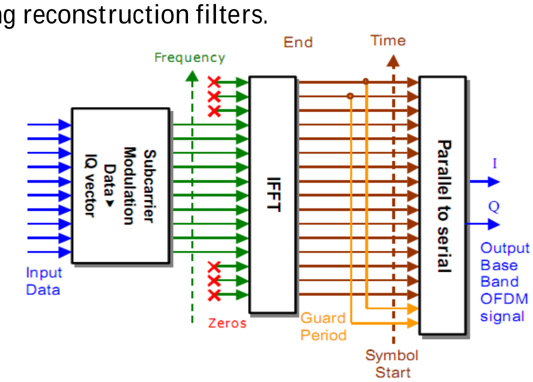

Fig-4: IFFT use in OFDM

4. CONCLUSION

This research paper is a literature survey carried out in the FFT & its application in OFDM system. The paper presents the authors contributions towards the implementation of FFT and its applications in Wifi, Wimax and wireless communication systems. OFDM is especially suitable for high-speed communication due to its resistance to ISI. As communication systems increase their information transfer speed, the time for each transmission necessarily becomes shorter. Since the delay time caused by multipath remains constant, ISI becomes a limitation in high-data-rate communication. The implementation of FFT logic and Transceiver can be a great research for OFDM and OFDMA and multiple input multiple output (MIMO) OFDM systems.

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