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Implementation of Split-Radix Algorithm for Rapid DFT Computation in CR OFDM Systems

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Abstract
Now a days, new technologies are emerging in communication systems. It's a challenging task to maintain good computational speed of DFT. The main intention of using Split-Radix algorithm is to boost up the computational speed of the system, hence resulting in saving time of the computation and increasing efficiency. OFDM method of modulation is involved in this paper in order to get better SNR v/s BER. Cognitive Radio (CR) plays a vital role in the domain of wireless communication. Now a days due to over population, people are facing many difficulties in communication there is a necessity of Cognitive Radio systems which takes off the problem of spectrum interference and offers efficiency in wireless communication. CR is the key to new technologies of dynamic spectrum access techniques. It provides sharing of wireless channel with licensed users.

Keywords
Cognitive Radio (CR), Split-Radix (SR), Discrete Fourier Transform (DFT), Fast Fourier Transform (FFT), Orthogonal Frequency Division Multiplexing (OFDM), Signal to Noise Ratio (SNR), Bit Error Rate (BER).

I. Introduction

The split-Radix FFT is the Fast Fourier Transform method used to compute DFT at faster rate. It recursively expresses DFT of length N/2 in the terms of one smaller DFT of length N/2 and another two smaller DFT's of length N/4. The structure of split radix algorithm includes several butterfly computations and twiddle factors. The two advantages of split radix algorithm are as follows

1. The forward and the inverse transforms are same
2. Hartley transformed output are real valued rather than complex data.

The split radix FFT algorithm is based on both even term radix-2 decompositions and the odd term radix-4 decompositions simultaneously. The Cognitive Radio approach [2] for usage of virtual unlicensed spectrum (CORVUS) of virtual licensed spectrum approach helped to use unlicensed spectrum for secondary users in a way without any interference to the primary users or licensed users. In this paper they have discussed regarding the functionality and general architecture. They have also proved that Cognitive Radio is having capability of sensing their spectrum environment and locating resources of the free spectrum. The CR senses spectrum of primary and secondary users periodically for occupancy and finally it traces out the available spectrum holes in the licensed bands which can be used by secondary users. CR also helps in spectrum mobility.

OFDM is a multicarrier modulation technique. It is used for high bit rate communications [6]. OFDM's underlying spectrum sensing technology is best transmission technique for the CR systems due to its high flexibility and adaptivity [8]. That's why OFDM is a good fit for Cognitive Radios.

II. Structure of Split Radix Algorithm

The fig 1 shows the block diagram of the split radix algorithm. The structure of this algorithm includes repeated butterfly computations and twiddle factors. This algorithm have four inputs and four outputs. They require only trivial multipliers other than twiddle factors. In the split radix algorithm several butterfly computations are carried out. Inputs are fed to two N/2 DFT's and computation is done. The importance of this algorithm is computational time is less since several butterfly computation takes place at one instant of time.

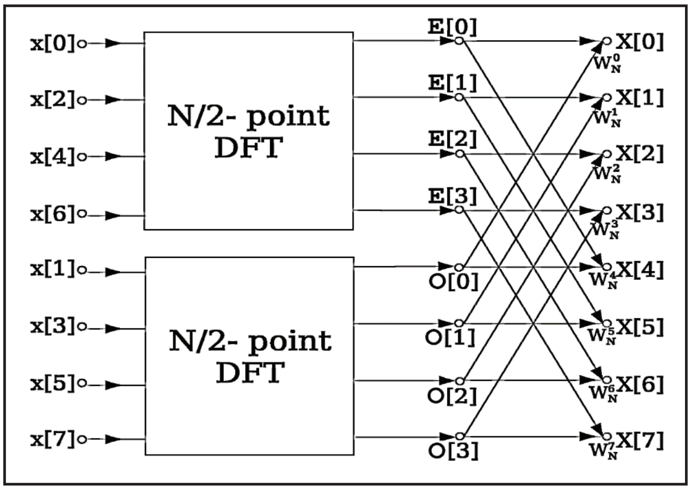

Fig. 1: Structure of Split Radix Algorithm

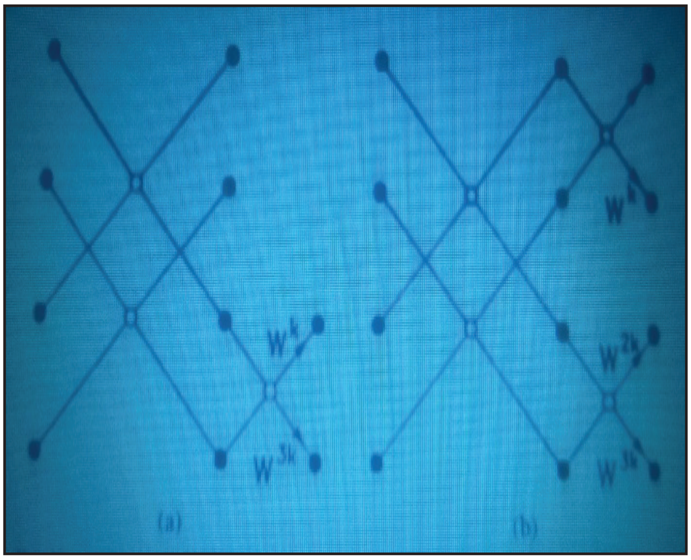

Fig. 2: Comparison of Split Radix Algorithm and Cooley-turkey Butterfly Computation (a) Cooley-turkey. (b) Split Radix FFT Butterfly Computation

The fig. 2 shows the comparison of split radix algorithm and Cooley-turkey butterfly computation. In Cooley-turkey butterfly computation the calculation of twiddle factor is taking place at only one end of the output where as in split-radix algorithm its taking place at both the ends of the output. Since split radix algorithm has better and large number of butterfly computations it yields more in decreasing computational time and hence increases the speed of computation.

III. Repeated Butterfly Computation, Encoder and Decoder

In the context of fast Fourier transforms algorithms a butterfly is a part of the computation that combines the results of smaller DFT's into a larger DFT or vice-versa. The name butterfly comes from the shape of the data flow diagram in the Radix-2 case. In the case of radix-2 Cooley-Turkey algorithm the butterfly is simply a DFT of size 2 that takes two inputs (X0, X1) and corresponding outputs are (Y0, Y1)

Y0= x0 + x1

Y1= X0 – X1

Repeated butterfly computation includes several stages of DFT's computation. May be even or uneven computations.

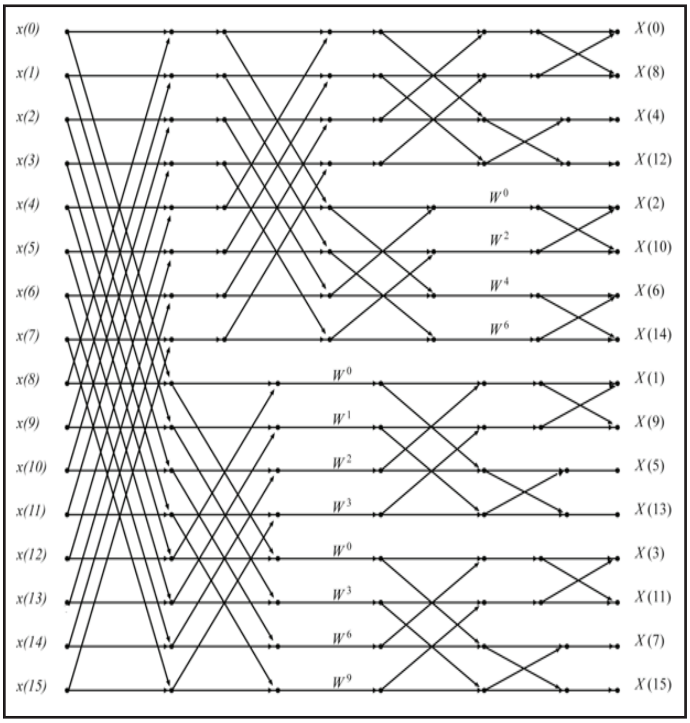

Fig. 3: Repeated Butterfly Computation

A. Encoder and Decoder of Split-Radix Algorithm

The encoder of the split-radix algorithm is shown in fig. 4, the input signal is digitized at the initial stage using analog to digital converter and resulting signal is modulated using OFDM. The OFDM modulated signal is fed to serial to parallel converter and IFFT is computed. Once IFFT is computed the signal is converted back into serial form using parallel to serial converter and cyclic prefix is calculated.

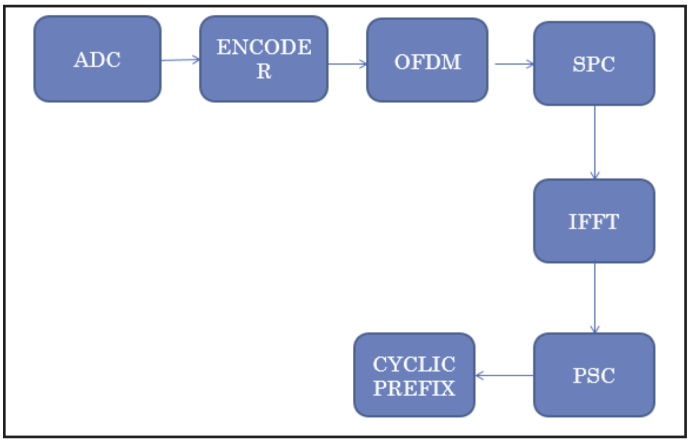

Fig. 4: Encoder of Split-Radix Algorithm

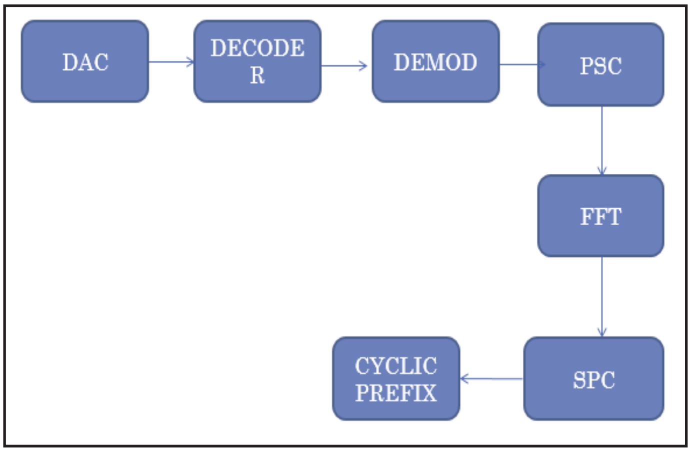

Fig. 5: Decoder of Split-Radix Algorithm

The fig. 5 shows the decoder part of split-radix algorithm. The process of decoding is followed by encoding the signal. Before demodulation the signal should be converted to digital form. FFT is computed only after converting signal from parallel to serial form and then after cyclic prefix is calculated.

IV. Orthogonal Frequency Division Multiplexing (OFDM)

It is the method of encoding digital data on multiple carrier frequencies. In this system a large number of closely spaced orthogonal sub – carrier signals are used to carry data on several parallel data streams or channels. Each sub – carrier is modulated with a conventional modulation scheme. The primary advantage of OFDM over single carrier schemes is its best ability to cope up with severe channel conditions. OFDM also offers other benefits like high data rate, reliability and robustness to multipath. A highly flexible OFDM system is considered for the Cognitive Radio in which the individual carriers can be switched off for those frequencies which are already occupied by the primary users. Theoretically, an OFDM CR system optimally approaches [5] the Shannon capacity in the segmented spectrum by adaptive resource allocation on each sub-carrier.

The main principles of OFDM system are as follows

1. Error correction of codes and mapping of bits to symbol
2. To modulate the symbols onto the orthogonal sub carriers by using IFFT method
3. While the channel transmission orthogonality is maintained which can be achieved by using a cyclic prefix to OFDM frame
4. To demodulate the signal FFT is computed.

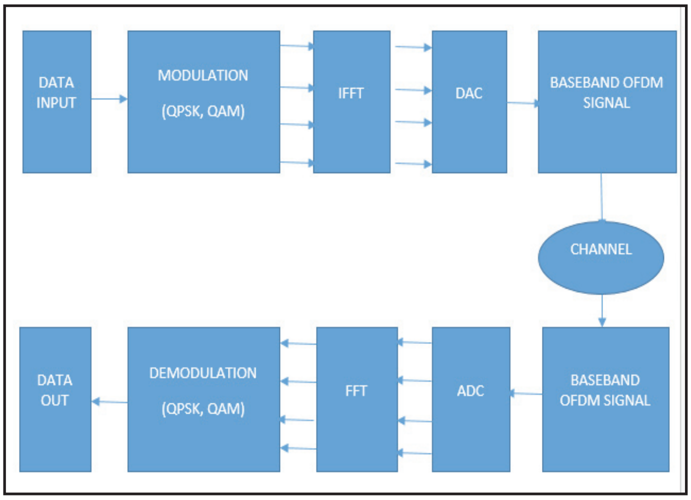

Fig. 6: Block Diagram of OFDM System

In the fig. 6 input data is modulated and later symbol sequences are converted to the parallel format and again the same sequence is converted into serial format by applying IFFT. The output of the sequence obtained is converted into analogue form by using DAC and then it is fed into RF modulation stage. The digitized signal is retrieved at the receiver end using ADC. FFT is computed and output data is obtained.

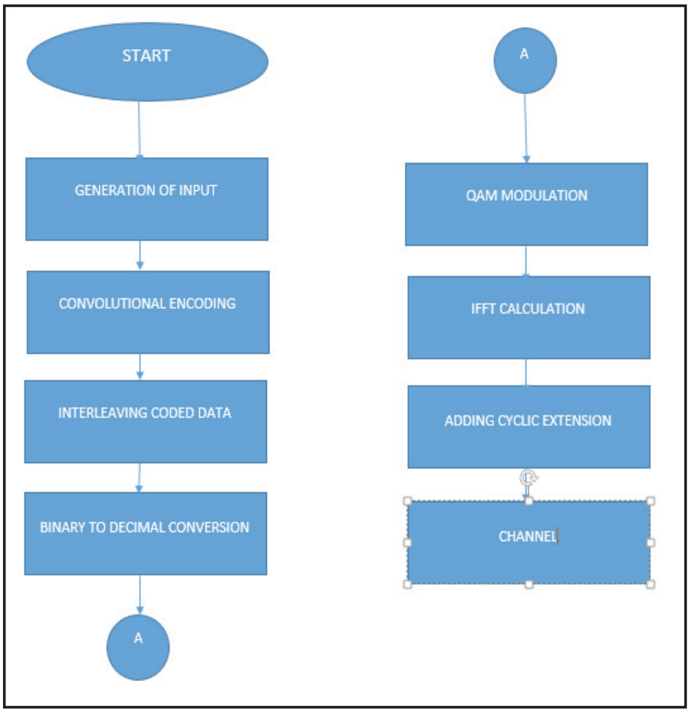

Fig. 7: Flowchart of OFDM

The fig. 7 shows the MATLAB code flow chart for the operation at receiver side. In the first stage convolutional encoding of the signal is done followed by the conversion of binary signal into decimal. QAM modulation is done and output is obtained at the end of the process.

V. Cognitive Radio

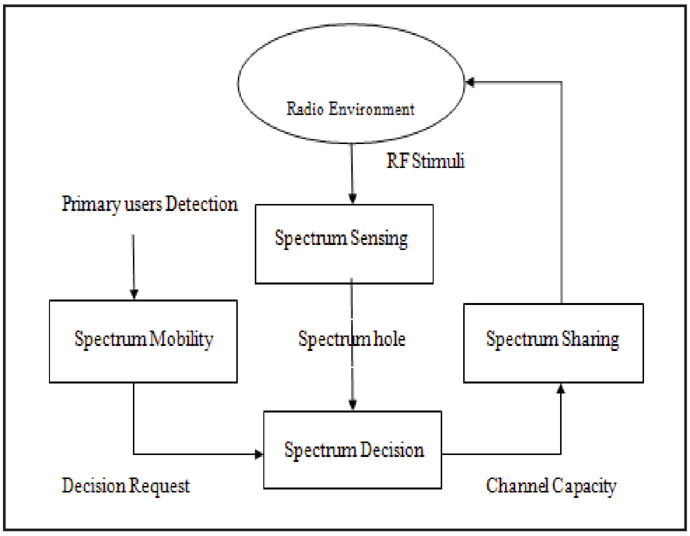

Fig. 8: Tasks of Cognitive Radio

The three major tasks of the CR are: Radio Scene Analysis, Channel Identification and Dynamic Spectrum management. In the Radio Scene Analysis, spectrum holes are detected. The Channel Identification is used for estimation of the channel state information. In the Dynamic Spectrum Management uses the radio scene analysis and channel identification to select the transmission power levels and frequency holes for transmission. At the receiver first two tasks are carried out while in the transmitter a third task is carried out with some form of the feedback between the transmitter and receiver. The CR can be extended to cognitive networks. A CR network [3] can provide intelligent multiuser communication system, it will adapt according to the environmental variations, that perceives the radio scene and it can control communications through proper allocation of resources. The cognitive network can plan, decide and act based on the perceived current network conditions. Cognitive network's functionality depends on the software adaptable network to implement the actual network and allows the cognitive process to adapt the network.

VI. Results

The following figures explain the results of split radix algorithm as well as OFDM system. The result correspond to Split radix algorithm explains about the computational time and computational speed, whereas the result corresponding to OFDM explains the comparison of BER and SNR.

A. Result of OFDM

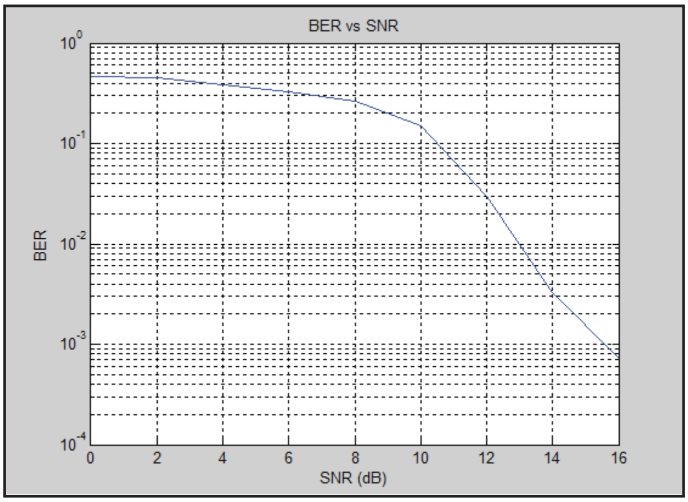

Fig. 9: Output of OFDM code (BER V/S SNR)

The graph of Bit Error Rate (BER) and signal to noise ratio (SNR) is plotted. X- axis is SNR in DB and y- axis is BER. The graph explains that SNR is high with less BER.

Hence OFDM modulation yields more efficiency by providing high SNR with low BER.

Analysis of OFDM CODE

1. Total number of carriers used = 64
2. Type of coding = convolutional coding
3. Single frame size = 96 bits
4. Total number of frames = 100
5. Modulation = 16 bit QAM
6. Number of pilots = 4
7. Cyclic extension = 25%
8. Convolutional encoding type = trellis code
9. Binary to decimal conversion = by interleaving data
10. Plot type = scatter plot
11. Result = BER vs SNR

B. Results of SR Algorithm

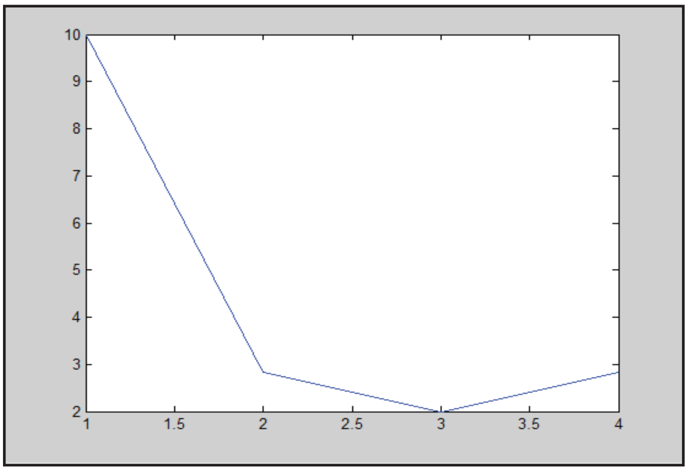
Fig. 10: Output of Split Radix FFT (N/2 Point and N/4 Point)

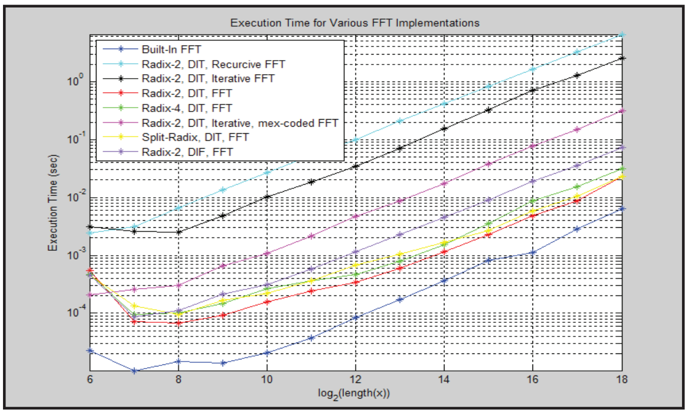

Fig. 11: Benchmark FFT

The fig. 11 shows the relation between execution time and computational speed of split radix FFT. In the above figure blue color graph indicates the original FFT signal, cyan color indicates the computation of radix- 2 DIT recursive FFT, black color indicates radix- 2 DIT iterative FFT, red color plot indicates radix- 2 DIT FFT, green color indicates radix- 4 DIT FFT, yellow color indicates the split radix DIT FFT. From the analysis of above figure it is inferred that execution time is reduced and hence speed is increased.

VII. Conclusion

From the above results we can conclude that efficiency of the CR OFDM system is increased by using split radix algorithm. From the figure 8 we can conclude that OFDM gives better signal to noise ratio and bit error rate. Fig 9 shows the n/2 and n/4 point DFT computations using split radix algorithm and fig 10 explains the several radix DIT FFT methods. By looking at the output of split radix FFT algorithm we can conclude that computational time is reduced and gives better efficiency. By designing the cognitive radio based on OFDM technique using split radix algorithm the problem of spectrum sharing can be avoided.

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