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Different Multicarrier Communication Schemes For Cognitive Radio : a Survey

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Abstract – **This paper presents the different multicarrier communication methods for Cognitive Radio (CR). Now a days OFDM(Orthogonal Frequency Division Multiplexing) modulation scheme is the most widely used technique for high speed wireless data transmission. Using an OFDM low complexity modulation and demodulation can be performed by IFFT and FFT respectively. In this paper besides OFDM other three modulation schemes such as DFT-spread OFDM(DFTS-OFDM), Constant Envelope OFDM(CE-ODFM) and Filter Bank Multicarrier (FBMC) have been discussed. Each of these schemes have advantages over OFDM which makes them beneficial for use in Cognitive radio applications.**

Keywords **– Cognitive Radio, ODFM, DFTS-OFDM, CE-OFDM, FBMC, FFT, IFFT.**

I. INTRODUCTION

Multicarrier Modulation (MCM) is a process of transmitting data by splitting into several components and each component is transmitted over separate carriers. The individual carriers can have a narrow bandwidth but the composite signal is wide banded. The advantages of Multicarrier Modulation includes immunity to multipath fading, enhanced immunity to Inter Symbol Interference (ISI) and less susceptible than single carrier systems to interference caused by the impulse noise [1].

With the emerging technologies and with the increasing number of wireless devices the radio spectrum is becoming scarcer everyday and wide range of spectrum are rarely used most of the time while other bands are widely used. Those unused portions of the spectrum are licensed and thus cannot be used by the users other than licensed one's. The Cognitive Radio is a solution to this spectral crowding problem by introducing an opportunistic usage of frequency bands that are not heavily occupied by licensed users. Hence the Cognitive Radio should have ability to sense and be aware of its operational environments and dynamically adjusts its transmission or reception parameters accordingly. For CR to achieve this objective the physical layer needs to be highly flexible and adaptable. In order to do so, the multicarrier modulation techniques such as OFDM, DFTS-OFDM, CE-OFDM and FBMC have been designed.

The paper is organized as follows. In section 2 different transmitter models for multicarrier modulation are discussed. In section 3 different receiver models for multicarrier demodulation are discussed. The section 4 shows the drawbacks of the OFDM based modulation schemes and in section 5 overview of FBMC modulation scheme is discussed.

II. TRANSMITTER MODELS FOR MODULATION

A. OFDM

The block diagram of the OFDM (Orthogonal Frequency Division Multiplexing) transmitter is as shown in Fig 1. Here the input bits are initially mapped to constellation symbols X and then fed as an input to the IFFT.

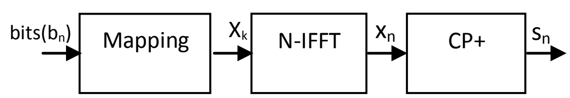

Fig 1: The Block diagram of OFDM Transmitter

The IFFT generates the time domain OFDM symbols x_n as

$$x_n = \sum_{k=0}^{N-1} X_k e^{j\frac{2\pi}{N}kn} \quad \rightarrow (1)$$

n= 0,1,….N-1

where X_k is the modulation symbol of the k^{th} subcarrier. Then the Cyclic Prefix (CP) is added to the time domain OFDM symbol x_n to form a transmitted signal s_n. OFDM based transmission results in high Peak to Average Power Ratio (PAPR) [2].

B. DFTS - OFDM

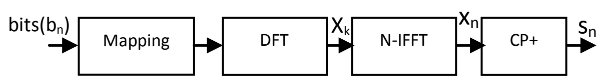

Fig 2: Block diagram of DFTS - OFDM Transmitter

The block diagram of the DFTS – OFDM (DFT Spread OFDM) transmitter is as shown in Fig 2. In this case the complex modulation dataset is preprocessed that is the complex modulation values to be transmitted are grouped and DFT operation is applied on them. Then the output of DFT is used to modulate the subcarriers. The result is slightly lower Peak to Average Power Ratio (PAPR) value compared to OFDM transmission [3].

C. CE - OFDM

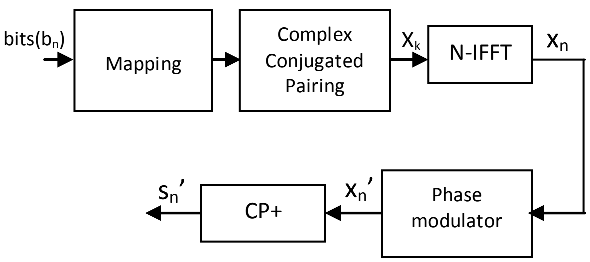

Fig 3: Block diagram of CE-OFDM Transmitter

The block diagram of the CE-OFDM (Constant Envelope- OFDM) transmitter is as shown in Fig 3. The CE-OFDM solves the high PAPR values of the OFDM signal. The basic idea is to generate a real valued OFDM signal, which can be used as an input for a phase modulator. The complex modulation symbols are aligned in a complex conjugated manner to achieve a real valued IFFT output. Subsequently the phase modulation is applied to the real valued time domain signal and Cyclic Prefix(CP) is added to form a transmitted signal. The transmitted signal s'_n before the addition of the CP is given by

$$x_n' = \sum_{k=0}^{N-1} X_k e^{j2\pi l x(n)} \quad \rightarrow (1)$$

Where l is the modulation index of the phase modulator and x(n) is the output of the IFFT [4].

III. RECEIVER MODELS FOR DEMODULATION

A. OFDM

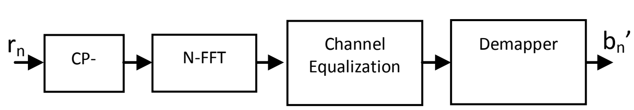

Fig 4: Block diagram of OFDM receiver.

The block diagram of the OFDM receiver is as shown in Fig 4. The received discrete baseband signal r_n is demodulated after removing the CP using N-Point FFT [5].

B. DFTS - OFDM

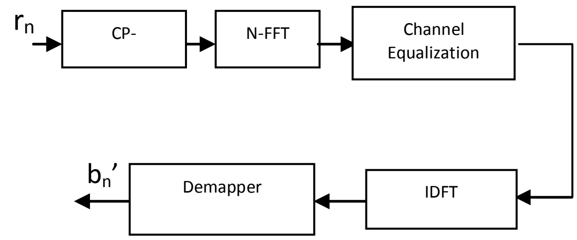

Fig 5: Block diagram of DFTS - OFDM receiver.

The block diagram of the DFTS-OFDM receiver is as shown in Fig 5. It is similar to OFDM as in Fig 4, but the difference is the IDFT operation is used to despread the information after the channel equalization [3].

C. CE - OFDM

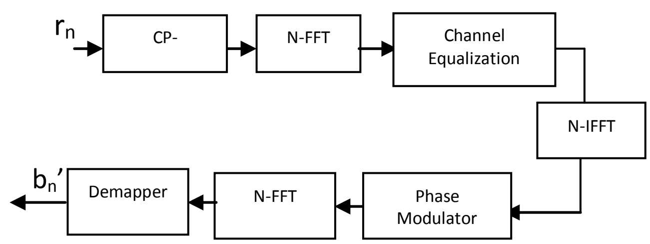

Fig 6: Block diagram of CE - OFDM receiver.

The block diagram of the CE-OFDM receiver is as shown in Fig 6. Here first frequency domain equalization is performed, then the equalized signal is transformed back to the time domain where phase demodulation is performed. After demodulation the N-FFT is applied to retrieve the complex modulation values [4].

IV. DRAWBACKS OF THE OFDM BASED MODULATION TECHNIQUES

In OFDM based modulation techniques with the use of cyclic prefix the ISI(Inter Symbol Interference) can be avoided but it reduces the data rate of the system. On the other hand the OFDM has some limitations [6] –

- Sensitivity to the nonlinear distortions due to the fluctuations in the instantaneous amplitude of the transmitted signal.
- Sensitivity to the frequency offsets caused by the local oscillator mismatch.
- High PAPR (Peak to Average Power Ratio).

In CE – OFDM the complex conjugated pairing reduces the data rate by a factor of two.

V. FILTER BANK MULTICARRIER SYSTEMS (FBMC)

FBMC systems are the class of multicarrier modulation schemes for high speed wireless communication. The FBMC systems can easily meet the Adjacent Channel Leakage Ratio (ACLR) requirements of the Cognitive Radio. The FBMC systems are more suitable for Cognitive Radio applications because of the following reasons : FBMC signals do not include the Cyclic Prefix(CP) so the data rate will be higher , better spectral shaping of the subcarriers than OFDM, better out of band radiation which is moderate in case of OFDM based modulation schemes.

In the FBMC scheme prototype filters with overlapping impulse responses fulfilling the Nyquist criterion are applied. Due to an advantageous properties of the prototype filter bank, the FBMC signal will have a better ACLR than OFDM. With the use of offset-QAM modulation, where the real and imaginary data are transmitted with a time offset of a half symbol duration, no data rate loss will occur compared to OFDM. The adjacent channel leakage is considerably lower in FBMC than in OFDM. The low out-of-band radiation makes FBMC a more suitable solution for cognitive radio applications [7].

VI. CONCLUSION

In this paper different multicarrier modulation techniques for Cognitive Radio applications are discussed. From the above discussion it can be concluded that FBMC will be the best suited modulation technique for Cognitive Radio since it does not include the Cyclic Prefix and can easily meet the strict requirements of Cognitive Radio that is low ACLR and low Out of band radiation.

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