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Design of Spectrum Sensing Techniques for Multi-Carrier Waveform

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ABSTRACT

The main motive of 5G communications is to handle large amount data traffic and providing several applications like Industrial Internet of Things (IIOT), smart home, automation, D2D communication, and high data-rate. Due to this, the data consumption will increase by 30% and we need an advanced radio to handle the different applications. The advanced radio needs high spectral efficiency to provide a good quality of service. To meet the vision of 5G communication systems, orthogonal frequency division multiplexing (OFDM) is not a choice due to the cyclic prefix (CP), wastage of the spectrum, and so on. Hence, it is important to explore the spectral efficient advanced waveform techniques and combine a cognitive radio (CR) with the 5G waveform to sense the idle spectrum, which overcomes the spectrum issue. For the 5G network, out of different waveform techniques, universal filter multi-carrier (UFMC) is one of the best choices. In this study, we simulated and designed an energy detection (ED) spectrum sensing technique for the UFMC system. Further, the design and analysis of the proposed system and OFDM using CP and without CP is taken out in terms of accurate detection, false detection, peak power, bit error rate (BER), power spectrum density (PSD). It is obtained that, the performance of the ED is better for the UFMC framework as compared to the OFDM system.

Keywords: *Spectrum sensing, Energy detector, 5G, Multi-carrier waveform*

1. INTRODUCTION

Spectrum sensing is one of the major concerns in reaching an efficient character of service (QOS) in the advanced mobile communication system. The advanced engineering sciences such as 5G, device 2 device communications (D2D), Internet of Things (IoT), MIMO require a large spectrum for better service [1]. The major challenge in the carrying out of the spectrum sensing technique in the universal filter multi-carrier (UFMC) is to sense the idle spectrum in the presence and absence of primary users (PU). The quality of service (QoS) of advanced mobile communication depends on spectral efficiency, low detection delay, high data-rate, low peak power, and accessing large numbers of devices. The successful regularization of 5G depends on developing and designing an advanced modulation schemes. In this work, we focus on UFMC as one of the primary candidates for 5G [2]. The concept of UFMC and OFDM is the same. In UFMC, filtration is carried out for a cluster of sub-carriers due to which the size of the filter is reduced. In OFDM, filtration is utilized to an entire circle. One of the singular characteristics of the UFMC is its adaptability with present MIMO techniques, which do not hold for FBMC (Filter bank multi-carrier). In UFMC, the full spectrum of the subcarrier is spliced into an act of sub-spectrum. The fixed numbers of the subcarriers are assigned to a sub-band and it is not compulsory to use the entire allotted spectrum for transmitting and the response of signals. The transceiver of UFMC is designed by using an IFFT (Inverse Fourier Fast transforms) and FFT (Fast Fourier Transform) and zeros are introduced to determine the vacant subcarriers. The full spectrum is filtered to cut down the spectrum leakage and the reaction of an entire sub-set is added [3]. In [4], UFMC is designed to defeat the problem of spectrum leakage. The proposed objective was accomplished by placing interference reduction subcarriers on the boundaries, decreases the filter intervention. High computational complexity and computability with OFDM, is the drawback of the demonstrated technique. The authors introduced a novel technique to overcome the effect of spectrum leakage and ISI (Inter-symbol interference) in the UFMC system. The proposed objective was accomplished by transmitting a received to the coordinated multipoint central unit for further enhancement and better detection [5]. In [6], UFMC is designed with an active noise cancellation technique to cut the issue of spectrum leakage and ICI (Inter-Carrier interference). The outcomes of the proposed work reveal that the performance of the proposed technique is better than the OFDM and Conventional UFMC waveforms. The authors introduce an overlapped UFMC waveform to overcome the issue of spectrum leakage and ICI. The proposed objective was accomplished by designing a reduplication receiver system. The experimental results reveal that the proposed scheme outperforms the conventional UFMC. Nevertheless, the high computational complexity is an issue of the proposed design [7]. In [8], the comparison and analysis of UFMC, OFDM and FBMC are carried away. The effects are optimized by analyzing the different frameworks of the organization such as FFT, modulating waveform, and subcarriers. It is concluded that the performance of UFMC is better than the OFDM and FBMC. In [9], UFMC is designed by using an SDR (Software-defined radio) for the 5G mobile

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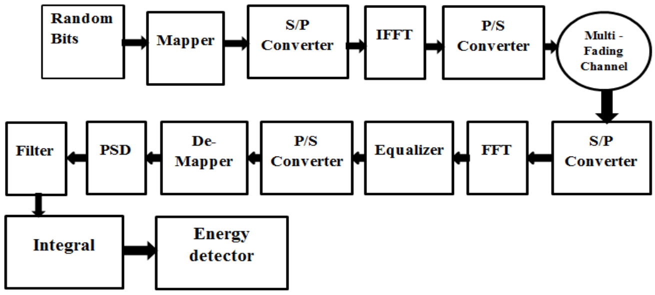
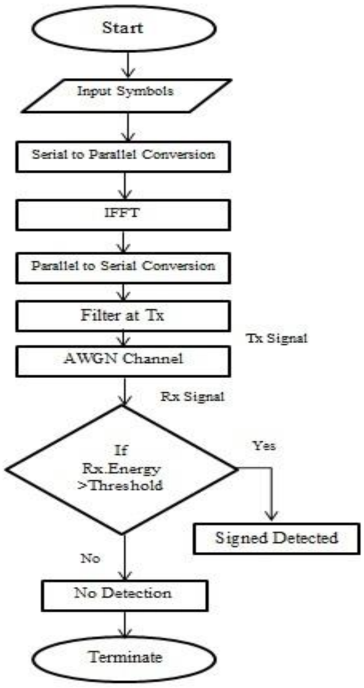
communication system. Additionally, subcarriers synchronization and channel estimation are also improved in the projected scheme. In [10], UFMC is implemented by using a scrambling technique. The simulation result shows that the BER and PAPR of the proposed system are efficiently improved. Design complexity and high noise are the drawbacks of the delivered system. The work in [11] proposed a fuzzy logic based scheme for spectrum management for cognitive radio, where the radio can share unused spectrum depending on parameter like load velocity, signal strength, distance and availability of unused spectrum and tabulate a rules for taking the decision. The presented work give better result in terms of SNR and BER as compared to conventional fuzzy logic spectrum based technique. The work in [12] studied and describes the security concern in cognitive radio as the bandwidth is shared between PU and SU. The work also described the malicious attack in cognitive radio, which is considered to be one of the greatest challenges in implementation of CR. The first part of the work has analysed the physical layer safety from any attacks and it is a convincing thought of using the PHY properties of the radio channel to give protected wireless infrastructure. In second part of the work malicious user detection is implemented to reduce the interference and the Pfa and missed detection. Finally, cynical approach against different attacks in cognitive radio is introduced and analysed. The work in [13] proposed a matched filter detection technique for cognitive radio. This manuscript mainly focused on detection of vacant spectrum by using matched filter spectrum sensing method, which minimizes the spectral overcrowding problem. The work in [14] proposed a detection technique by using Cyclostationary feature detection in cognitive radios. In this proposed method, they uses of Cyclostationary feature detection approximation for spectrum sensing. It is less prone to noise and robust for low SNR in comparison to energy detection method. The work in [15] proposed a GFDM modulation for cyclostationary feature detection in cognitive radio system. In proposed method GFDM has circular detection properties GFDM has circular detection properties which is compared with OFDM. Cyclostationary detection of GFDM has examined and compared with OFDM technique. The work in [16] proposed a multiband joint recognition for CRNs, which together sense the major indications over multiple frequency bands. Here author proposed a spatial spectrum joint detection, which improves the spectrum performance and provides flexible power allocation by introducing conservative factor α and β. The work in [17] proposed a co-operative wideband sensing for multiple users by using Cyclostationary spectrum sensing. Although in all wireless communication malicious users are the biggest problem it will affect the throughput of system. Author introduced two methods to avoid the malicious users and improve the system efficiency. Experimental results are carried out with 0.01 Pfa and 0.9 Pd. It shows that co-operative wideband sensing with cyclostationary detection will be best method for multiple cognitive users. In the present study, we aim to integrate UFMC with Cognitive Radio (CR) to utilize the spectrum in an effective way. To accomplish spectrum sensing, we consider energy detection. To the best of my knowledge and given literature, UFMC-Energy detection has not been explored so-far**.** The block diagram of UFMC with ED is shown in fig.1.



(a)



(B)

FIGURE. 1. A) PROPOSED MODEL B) FLOW CHART

2. SYSTEM MODEL

ED is a famous strategy in CR for range detecting and it distinguishes the nearness of range gap and streamlines the recognition likelihood [18-19]. It contrasts the got signal vitality and limits esteem (λ) following the SNR to get two speculations regardless of whether the signal is missed or detected [20-21].

$$R(t) = \{n(t)\} : H_0$$

$$R(t) = \{h * U(t) + n(t)\} : H_1$$

Where R(t) = Secondary signal

U(t) = Primary User's transmitted signal

n(t) = Additive White Gaussian Noise

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h = Amplitude gain of the channel

H_0= No Primary user

H_1= Primary user is present

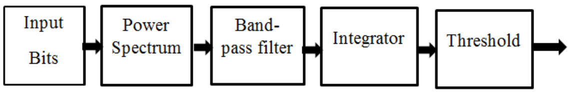


Figure 2. Cr in ED

In the proposed work, for each user dual sub-bands are carried out for transmission, mathematically represented as follows:

$$v^s = \begin{pmatrix} v + {}^{V}/_{2}, & 1 \le v \le {}^{V}/_{2} \\ v - {}^{V}/_{2}, & {}^{V}/_{2} + 1 \le v \le V \end{pmatrix} \quad (1)$$

The discrete time UFMC signal is determined by:

$$Y_v = I_v * \left(\frac{1}{\sqrt{N}} \sum_{k \in O_v} \sqrt{\beta P_v}(k) e^{\frac{i2\Pi kl}{N}}\right) + I_{v^s} * \left(\frac{1}{\sqrt{N}} \sum_{k \in O_{v^s}} \sqrt{1 - \beta P_v}(k) e^{\frac{i2\Pi kl}{N}}\right) \quad (2)$$

Where $P_v(k)$ is the frequency domain signals, I_v and I_{v^s} are the response of the filter, O_v and O_{v^s} are the subcarriers subsets, β and $1-\beta$ are power ratio, N is the length of IFFT and l= 0, 1, 2… N+$N_f - 2$, where N_f is the size of filter.

The received signal is given by:

$$Z(t) = \sum_{v=1}^{V} Y_v \, h(t) + N \quad (3)$$

The channel coefficient h (t) is represented by:

$$h(t) = \sum_{j=0}^{P-1} a_j \, \delta(t - \tau_j) \quad (3.1),$$

Where $a_j$the attenuation is factor and τ_j is the delay.

The energy detection comparator is represented by following equation:

$$E = |Z(t)|^2 \quad (4)$$

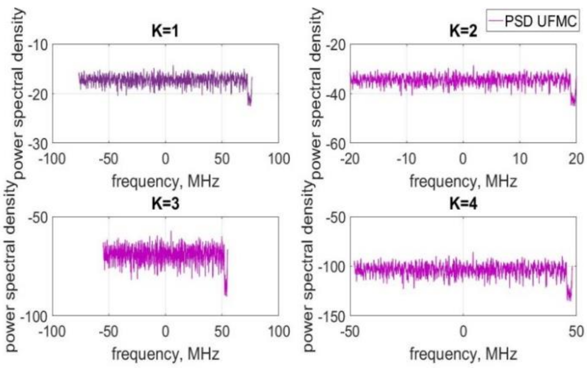
The received signal is compared with the threshold value and the following assumptions determine the presence and absence of the signal:

$$Y(t) = \begin{pmatrix} N(t), & H_0 \\ Z(t) + N(t), & H_1 \end{pmatrix}$$

Where H_0 means no spectrum is detected and H_1 indicates the detection of idle spectrum.

3. RESULTS AND DISCUSSION

We have designed and simulated UFMC and OFDM systems with the ED spectrum sensing technique by using Matlab-2014. In this work, we considered bandwidth of 4MHz, CP= 11% of 4 MHz, 10 sub-band, 64 subcarrier (utilized subcarrier = 52), 64 FFT size, length of Chebyshev filter = 73 and overlapping factor (K) = 1, 2, 3 and 4.The Power Spectrum density **(**PSD) of the UFMC and OFDM for k = 1, 2, 3 and 4 are indicated in fig.3. Analyzing the PSD graph, the side lobe of UFMC is smaller than the OFDM system. It is concluded that UFMC can efficiently utilize the assigned bandwidth, enhancing spectrum efficiency. The graph of accurate detection for UFMC and OFDM, with and without CP is given in fig.4. The proposed technique (UFMC without CP) gives an accurate detection at low SNR as compared to other frameworks. It is concluded that the proposed technique outperforms all other sensing techniques for $SNR \ge -0.5\ dB$. The probability of detection is 1 at SNR of -0.5 dB, 2.2 dB, 4 dB and, 6 dB for UFMC without CP, OFDM with CP, UFMC with CP and OFDM without CP**.** It is also noted that the performance of OFDM without CP degrades due to the interference between the symbols. The Probability of false alarm (PFA) means the misinterpretation of noise as the desired signal. Fig.5. compares the PFA for the proposed technique (UFMC without CP), OFDM with CP, UFMC with CP and OFDM without CP. The false detection performance of UFMC without CP and OFDM with CP is similar and better than the other reflected methods. It is also concluded that the detection is false at high PFA. Fig. 6 shows the Bit Error Rate (BER) performance of UFMC without CP, OFDM with CP, UFMC with CP and OFDM without CP. It is concluded that the OFDM and UFMC marginally underperform at low SNRs because the channel fading directs the BER at low SNRs. However, for high and moderate SNRs, the UFMC without CP is better than the other deliberated methods. Fig.7. compares the peak power performance of the deliberated schemes. At CCDF (complementary cumulative distribution function) 10^{-3}, the SNRs of the proposed technique (UFMC without CP), OFDM with CP, UFMC with CP and OFDM without CP are 9 dB, 9.8 dB, 10 dB and 14 dB. It is also noted that the PAPR decreases with the increase of SNR. The PAPR of UFMC without CP is better than the other reflected methods excluding for the OFDM with CP, with the difference of 0.8 dB



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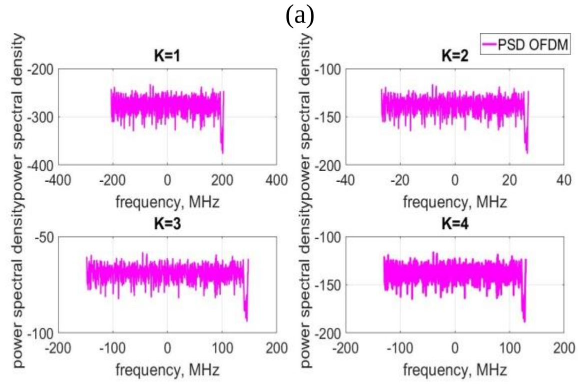

(b)

Figure 3. PSD, a) UFMC and b) OFDM

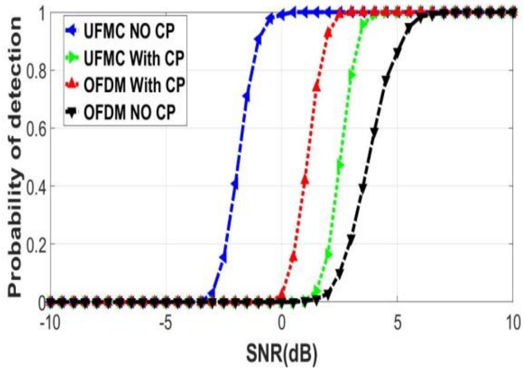

Figure 4. Detection graph

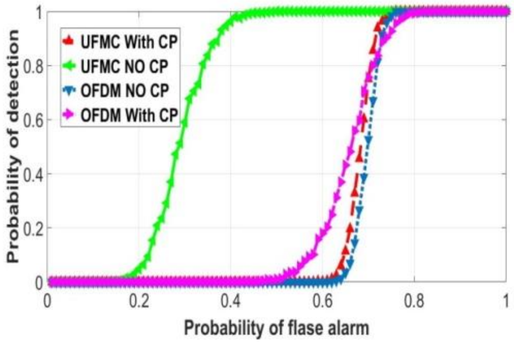

Figure.5. False alarm graph

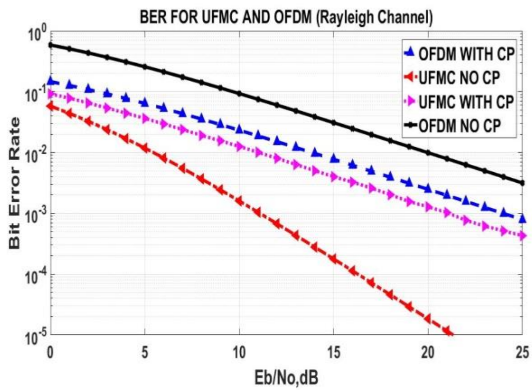

Figure.6. BER graph

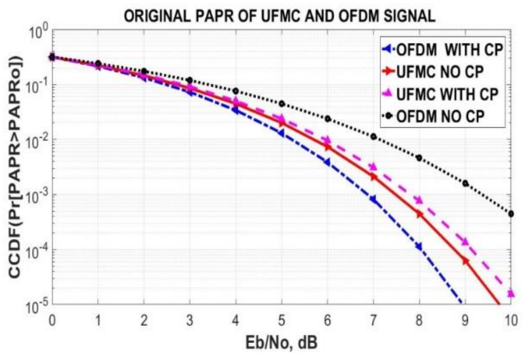

Figure.7. PAPR graph

4. CONCLUSION

We propose spectrum sensing in advanced waveform scheme, integration of CR, and UFMC system for enhanced spectral efficiency supporting detection of spectrum in the absence of PU. The proposed technique renders an efficient BER, PAPR, Pd (probability of detection) and, PFA (probability of false alarm) performance in the multipath fading channel as compared to the OFDM system. The proposed method is suitable for the 5G mobile, IoT, D2D requiring high spectral efficiency.

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