International Journal of Engineering Works
Kambohwell Publisher Enterprises
ISSN: 2409-2770 Vol. 4, Issue 1, PP. 5-9, January 2017
www.kwpublisher.com

Adaptive Investigating Universal Filtered Multi-Carrier (UFMC) Performance Analysis in 5G Cognitive Radio Based Sensor Network (CSNs)

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***Abstract*—**Latest trend in research tend to fulfill requirements of the most talked about 5G networks. These networks need to be be engineered in terms of cost, energy and spectral efficiency, number of connected devices and latency. Cognitive Radio (CR) is one of the promising techniques to meet the above mentioned requirements that operates at microwave frequencies and exploits underutilized spectrum bands. Universal Filtered Multi-Carrier (UFMC) is a new channel judgment method that use multicarrier modulation scheme. UFMC is consider like an applicant for the 5th Generation of wireless communication systems and replaces OFDM .Latest research indicates that cellular networks are better operated with the novel UFMC with enhanced performance in terms of improved spectral efficiency, less usage of energy as well as latency. However, an emerging area of Information and Communication technology (ICT) are Cognitive radio based Sensor Networks (CSNs). Even basic observations using empirical approach can reveal important observations, especially if the above mentioned latest channel estimation technique (UFMC) , is tried and observed for CSNs. The option of CSNs as test bed is based on abundant use of the supporting in various social and military setups. In this work, part of frequency synchronization and channel estimation are explore and correlate with OFDM and UFMC systems with CSNs as testbed, primarily with a computer-aided software simulator and also with real time experimentation in special laboratory if resources permit.

***Keywords*—** Adhoc Wireless Network Routing Protocols, Wireless Sensor Network (WSN), Energy efficiency, Random mobility model.

I. Introduction

This Long term evolution (LTE) which comes forth in the cellular system of wireless communication started to bloom in 2010. The technologies of LTE and its advance version are enhanced to pass on high-rate data organizations to wireless user utilizing stern of collaboration and orthogonality [1]. Nowadays it is common to deliver high- traffic to top of the line device like cell phones and tablets. Despite that as it may, such a methodology is impractical for new sorts of wireless service, for example, IOT and the material internet. Through the rapidly creating machine-kind of correspondence and the presence of (IOT), a central framework update is essential for upcoming 5G wireless communication frameworks. Moreover, the severe worldview of collaboration and orthogonality as connected in LTE is most certainly not reasonable to accomplish efficiency and versatility [2]. An exceptionally differing assortment of traffic type range from general high-rate traffic, sporadicsm all parcel and critical low inertness transmission must exist managed in upcoming 5G wireless communication frameworks.

In classify to decrease the signal transparency as well as the utilization of battery for the low-end device (e.g. simple sensor component). Presently 5G needed to exist permit to convey with loose synchronization situation in regards to time frequency misalignments. In any case, the most noticeable method used for the modulation of Multi-carrier is Orthogonal Frequency Division Multiplexing (OFDM) that is exceptionally to time frequency misalignments because of its high relatively side-lobe spectral level. Filter bank based multi-Carrier (FBMC) [3] is thought to be an upcoming 5G applicant innovation to supplanting OFDM. Each sub-carrier be exclusively filtered in FBMC to upgrade heartiness against inter-carrier interference (ICI) impacts. Anyhow, expected FBMC frameworks use fiters, whose length is diverse times of tests per multi-carrier image. Thus, the faults are being of its higher filter length. which really make it unfavorable for communication in small uplink blasts, as vital in possible use situations of 5G frameworks [1], similar to low inertness correspondence or energy effective Machine-Type Communication (MTC). universal Filtered Multi-Carrier (UFMC) is new multi-transporter tweak method [4],that is shown in the theory of speculation of OFDM and FBMC (in its sifted multi-tone (FMT) variety). Here the full band is sifted in separated OFDM and all subcarrier is sifted independently in FBMC, social occasions of subcarriers (sub band-piece) are sifted in UFMC. By sifting a get-together of subcarriers, the length of channel is able to lessen impressively, contrasted with FBMC. Another preferred standpoint of UFMC frameworks is that quadrature amplitude modulation (QAM) is fix material in UFMC (as opposed in the FBMC part [3]), assembly UFMC perfect nearly a wide range of Multiple Input Multiple Output (MIMO). FFT base get handling as it may be additionally

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connected in UFMC frameworks, consequently per-subcarrier adjustment is fix material like in OFDM frameworks. The characteristic of UFMC is near to OFDM, thus why it is also called as Universal Filtered OFDM (UF-OFDM) [5].

A point by point examination among OFDM, FBMC and UFMC accessible in [6]. A few preferences of UFMC are appear in [5, 7, 8].

UFMC act exceptionally gorgeous for the upcoming 5G communication frameworks along with the properties of lessened out-of-band radiation, contrasted with OFDM. Despite that as it may, a few vital issues, for example, time-frequency synchronization and channel estimation have no more examined yet. Synchronization be needed at the recipient for multi-transporter frameworks near decide beginning position of the symbol and to revise the carrier frequency counterbalance brought on with Doppler-impact and frequency mismatch of neighborhood oscillator. Moreover, beyond channel situation data, the channel information can't be recuperated at the recipient. Absence regarding cyclic prefix in UFMC frameworks, the synchronization and channel estimation get to be testing and intriguing errands. This is on the grounds that the postponement spread impact of channel cause between transporter impedance and between representations interfering for UFMC systems, that is fully mitigate with extended sufficient cyclic prefix in OFDM frameworks.

Orthogonal frequency division multiplexing (OFDM) generally received in broadband remote frameworks as far back as two decades. A generally straightforward equalization and hugh spiritual effectiveness enclose so far the basic inspirations for utilizing OFDM when information is to be spread by a wireless multi path medium. They join of collected narrow band transporters, a cyclic prefix and channel summarizing has been prompted to a solid frameworks. Numerous entrance OFDM or orthogonal frequency division different gets to (OFDMA) has supplemented OFDM to give synchronous contacted to various user.

Modulation frameworks, the estimation are normally performed by sending a preparation information succession on an arrangement of carrier frequencies familiar to the recipient. The channel is suddenly assessed above the frequencies of pilot utilizing either least squares (LS) or least mean-square error estimation [9]. Since multicarrier symbol and adjoining carrier are non-orthogonal, the signal got since a known arrangement consist of obstruction from back to back multicarrier symbol (inter symbol impedance) and neighboring bearers (inter carrier interference) while considering FBMC.As the estimation procedures roused by OFDM accept orthogonality amongst symbols and carrier, a few adjustments ought to be prepared. Channel estimation strategies in favor of FBMC adjusted to offbeat approach in a divided range environment ought to be contemplated for the 5G of network systems. Interference approximation methods (IAMs) have been examine in the written work to conquered the non orthogonality of the waveform [10]. In any case, the system ought to be returned to while pilot tones are circulated above divided range. Besides, while pilot tones are no more appropriated on each transporter, a procedure of insertion is desired to recuperate the channel reaction on each dynamic bearer recurrence [11]. The interjection might be done in the time domain a period space channel motivation reaction is acquired utilizing an opposite fourier transform of the channel evaluated at the pilot frequencies. A filter may then be connected with decrease noise impacts as well as outskirt impacts. The establishment of the frequency domain is then handle by Fourier transform. Another arrangement might be added to the direct channel in the frequency domain. Numerous algorithm, for example, linear tangent, low-pass filtering and spline cubic interpolation have been examined [12, 13]. Most of the addition plans, the channel is ineffectively introduced on the transporter situated to the joining of frequency band. Such impact might have disregarded with the quantity of transporters per touching recurrence band is vast yet may prompt important execution corruption to the general framework when the multicarrier tweak is connected to a divided range. A powerful insertion plan to the whole range, plus the edges is in this way basic. An answer has as of now been proposed in [14] utilizing insertion as a part of the time area. Execution is expanded at the cost of higher intricacy. Besides, precariousness issues are not tended to and may prompt clamor upgrade.

II. Orthogonal Frequency Division Multiplexing (OFDM)

Orthogonal frequency division multiplexing technique is a multi-carrier transmission scheme which was chosen for LTE and LTE-A systems. A multi-carrier transmission scheme for this technology was chosen because it divides the available channel bandwidth into several parallel sub-channels that are called subcarriers. This enables the multiplexing between users in both time and frequency domain. Ideally the frequency spacing between these subcarriers is chosen in such a way that they are non-frequency selective. For this reason, these subcarriers experience a flat gain in the frequency domain that can be easily remunerated for at the receiver side. In the case of OFDM, several subcarriers are spaced at $\Delta f = 1/T\_Symbol$, causing minimum cross talk. This phenomenon is also referred to as orthogonality.

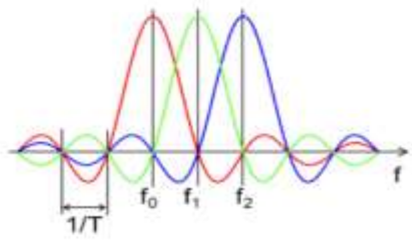


Figure 1: Orthogonality between Subcarriers

In an OFDM transmitter, the digital data is mapped to complex symbols such as QPSK, 16QAM, 64QAM or 256QAM. A serial to parallel conversion turns the data streams into N data streams, which corresponds to the different carrier frequencies f_0,f_1 〖,f〗_2 etc. The central carrier is set to zero. The unused subcarriers are added to achieve a total of 2N subcarriers, which can be converted from frequency to time domain by an inverse fast fourier transform. To increase robustness against inter symbol interference (ISI), the total symbol duration is further increased by adding a cyclic prefix (CP).

Despite of beingused for LTE/LTE-A, OFDM has certain limitations. The addition cyclic prefix (CP) in OFDM adds redundancy to the transmission since the same content is transmitted twice because CP is a copy of the tail of a symbol placed at its beginning. This overhead can be expressed as a function of symbol duration and duration of cyclic prefix β_Overhead= T_cp/(T_cp+T_symbol). Aside from the issue of cyclic prefix, the orthogonality in OFDM is based on the assumption that transmitter and receiver are using the same reference frequency. In terms of frequency offsets the orthogonality is lost consequently causing inter carrier interference (ICI). The errors in frequency usually arise due to drift of the local oscillator which are typically a function of voltage changes and temperature variations. Phase noise also adds up to this error and its true impact mainly depends upon the design approach to generate the signal. Another concern that should be dealt with regarding OFDM is the high peak to average power ratio (PAPR) and resulting crest factor. This high PAPR occurs due to the summation of many individual subcarriers. At each instant these subcarriers have a different phase as compared with respect to each other. However sometimes they could all have the same value at the same time which leads the output power to peak. Due to very high number of subcarriers in OFDM system the peak value should be much higher then to compared the average value.

III. UNIVERSAL FILTER MULTI CARRIER (UFMC)

Universal filtered multi carrier (UFMC) is a new technology which combines the features of OFDM and FBMC. It is based on frequency division multiplexing FDM. In UFMC, the incoming data stream is distributed into many sub-streams with comparatively lower data rate. This new candidate provides reduced out of band emission and better time frequency synchronization.

To see the properties and features of UFMC, a MATLAB based simulation was carried out. The simulation parameters are Filter Length = 74, Bits Per Symbol = 2, FFT length = 1024 and modulation = QPSK.

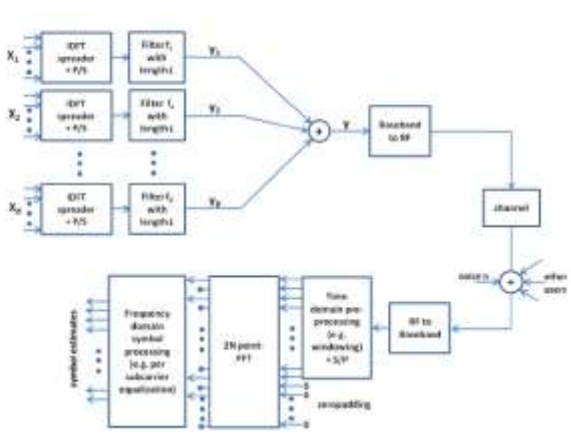


Figure 2: Block Diagram for UFMC.

The UFMC system was implemented in MATLAB using the parameters mentioned above. The total bandwidth is separated into B sub-bands. Each sub-band can be assigned to N_B successive sub-carrier. There are a total of N subcarriers. To transform from frequency to time domain, a N-point inverse discrete fourier transform is taken. To perform IDFT data symbols are regulated in the dispensed sub carrier positions for sub-groups and zeros are cushioned in frequency domain in the un allocated sub carrier positions.

The output signal $x_i$is then filtered using an FIR filter with length L which in our case would be 74. Therefore, the output signal can be represented by using the equation

$$y_i(k) = x_i * f_i = \sum_{l=0}^{L-1} f_i(l) x_i(k-l), \quad k = 0, \cdots, N+L-1.$$

Equation 1Mathematical Representation of the Output Signal

Due to the linear convolution of $x_i and\ f_i$ the resultant symbol length becomes N+L-1. The FIR filter used here is a Dolph-Chebyshev filter. The figure below shows the time domain wave form of the filter.

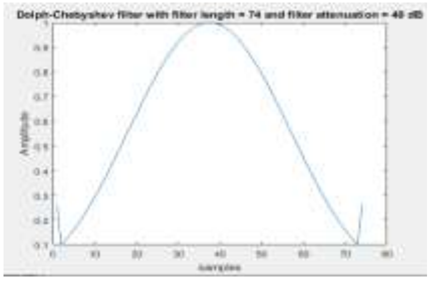


Figure 3: General Waveform of Doph-Chebyshev filter

The reason why this filter is being used to filter each sub-band is because it reduces the out of band radiation. The rectangular filter used in OFDM is not well center in time or in frequency domain. The sinc function which comes from the fourier transformation of the rectangular symbol shape cause hugh spectral side lobe level. Due to this high spectral side lobe level the out of band radiation to the neighboring sub-bands is significantly increased which is why the orthogonality between the subcarriers is destroyed.

Using the parameters described earlier BER, PER, PAPR and PSD were measured. The transmission and reception waveforms along with the BER plotted for different values of SNR and compared with OFDM. The simulation results show clearly that UFMC being a modified form of OFDM has an edge over it.

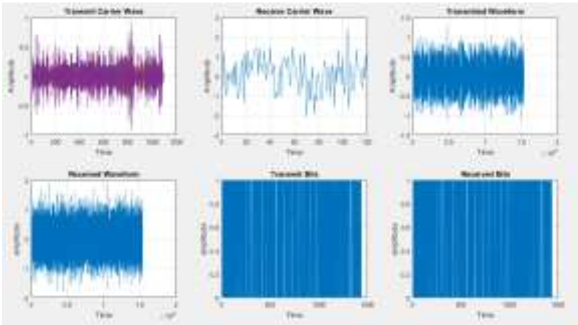


Figure 4: UFMC Matlab Simulation Output Waveforms

A transmission and receiver for UFMC was simulated in MATLAB. The designed channel only contained AWGN noise. The transmitted and carrier waveforms were then plotted. By calculating the bits at transmission and then at reception the BER was calculated.

The figure above shows different waveforms of MATLAB simulation. The results that are to be compared with OFDM are shown in the next section.

IV. Comparison Between OFDM and UFMC

In the previous two sections we were able to see the characteristics of OFDM and UFMC waveforms. Since UFMC is a derivative of OFDM, a lot of similarities can be seen in their properties. It is a known fact that OFDM being already used for LTE and LTE-A systems is taken into consideration for future 5G networks also. But the advanced form of OFDM definitely has several advantages over its predecessor. The foremost and obvious difference between the two candidates is that of Cyclic prefix CP. The absence of CP in UFMC reduces the filter length but at the receiver side zero padding is done before applying 2N FFT. For OFDM, orthogonality in time domain is ensured by the use of cyclic prefix. The advantage of adding CP is that it transforms the convolution of the channel in a circular one. Aside from this advantage the biggest disadvantage that OFDM suffers is the loss of spectral efficiency as shown in Figure 5. Instead of CP, UFMC uses additional per sub-band filters which reduce the spectral side lobe levels outside the sub-band. This increases robustness beside any sources of inter carrier interference. UFMC filters are in the order of an OFDM CP.

OFDM has efficient implementation of (FFT/IFFT) and has simple equalization schemes but spectral efficiency is lost due to cyclic prefixes. The main advantage of UFMC over OFDM is the use of Dolph-Chebyshev filter. Indeed, according to its filter properties the effect of side lobe interference with the adjacent subcarrier can be significantly reduced. By using this filter two OFDM issues are solved. On one hand there is no need to add guard band because other UFMC symbols would not be disturbed by the side lobe interference. On the other hand, UFMC is more robust to inter-carrier interference and loss of orthogonality would not be a problem anymore.

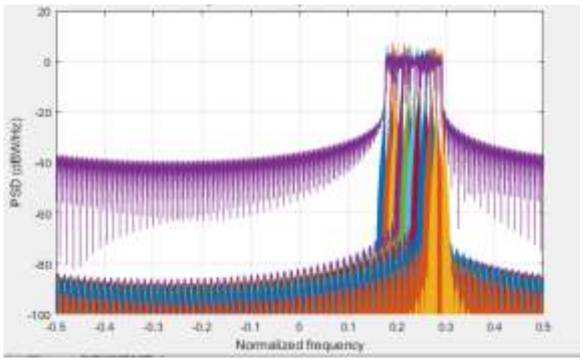
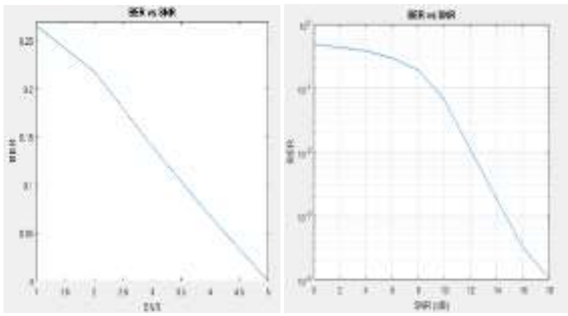


Figure 5: Power Spectral Density Waveform of OFDM (above) and UFMC (below) Candidates

In terms of PAPR, in the simulation it was seen that OFDM gives relatively higher PAPR than UFMC. High PAPR is also a draw back and the reason why PAPR should be low is because peaks may be cut-off by transmitter amplifier. In the end, BER vs SNR graphs were plotted for both the waveforms and then compared as shown in the figure 6



UFMC OFDM

Figure 6: SNR versus BER plots for UFMC and OFDM

By plotting Bit Error Rate (BER) for different values of SNR it was seen that UFMC gives better performance as compared to OFDM in terms of low values of SNR. In order for OFDM to give better results, it must have its SNR greater than 14. On the other hand, UFMC reduces the BER to almost zero at near 5 dB SNR.

Conculsion

To conclude, the study and the implementation of both the waveforms shows that clearly UFMC has better performance than OFDM in terms of PAPR, spectral efficiency, inter carrier interference or inter symbol interference. The main advantage of UFMC is the use of Dolph-Chebyshev filter. Indeed, according to these filter properties, the spectral OFDM effects of side lobes interference on the immediate adjacent subcarrier can be reduced significantly. By these properties two OFDM issues are solved. The need of a guard band is no longer required because other UFMC symbols would not be disturbed by the side lobe interference. Also, UFMC is more robust to

ISSN: 2409-2770

inter carrier interference and the loss of orthogonality can no longer be an issue.

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