RSSI, Vol. 07, N°. 01, July 2018, 12-16

Revue des Sciences et Sciences de l'ingénieur
Journal of sciences and engineering sciences

ISSN 2170-0737/EISSN: 2600-7029
https://www.asjp.cerist.dz/en/PresentationRevue/303

Future 5G wireless communication systems: A new multicarrier shemes

Bouaziz Samir *, Mesri Mokhtaria

Department of electronics, University Amar Telidji, Laghouat, Algeria
Laboratory of semiconductors and functional materials

Article history
Submitted date: 2017-11-08
Acceptance date: 2018-01-10

Abstract

Current wireless communication networks and technologies are being pushed to their limits by the massive growth in demands for mobile wireless data services. We now stand at a turning point in the wireless communication domain where the technologies are being driven by applications and expected use cases. This paper presents an overview on the drivers behind the 5G evolution and presents the new waveforms candidates for future generation network; the FBMC for filter bank multicarrier and UFMC for Universal filtered multi carrier are a potential concept for 5G and replacing the famous multicarrier modulation OFDM used in different technologies 4G. So there is a new way for the 5G transition expected beyond 2020.

Key-words: *5G*; *FBMC*; *UFMC*; *OQAM*; *beyond OFDM*.

Résumé

Les technologies des réseaux de communication sans fil actuelles sont poussées à leurs limites par la croissance massive de la demande de services de données sans fil. Nous sommes maintenant à un point tournant dans le domaine de la communication sans fil où les technologies sont déterminées par des applications et des cas d'utilisations. Cet article présente un aperçu des facteurs qui sous-tendent l'évolution de la 5G et présente les nouvelles formes d'ondes candidates pour les réseaux de futur génération, FBMC pour Modulations Multiporteuses à base de Bancs de Filtres et l'UFMC pour Modulation Multiporteuses à base des Filtres Universels sont un concept potentiel pour la 5G et remplaçant la fameuse modulation multiporteuses OFDM utilisée dans différentes technologies 4G. Il ya donc une nouvelle voie pour la transition 5G envisagée au-delà de 2020.

Mots-clés : *5G*; *FBMC*; *UFMC*; *OQAM*; *au-delà de l'OFDM.*

* Corresponding authors. Tel. /fax: +213 670266424
E-mail address: samirbouaziz24@yahoo.fr

1. Introduction

Multicarrier modulation has marked its importance over the past several decades for the realization of broadband communication systems. Based on sending parallel streams of information in the frequency domain on different center frequencies, multicarrier modulation has exhibited its potential to transmit large amounts of data across a channel while improving the robustness of the communication system against various impairments.

Among the existing multicarrier modulation systems, the Orthogonal Frequency Division Multiplexing (OFDM) technique is widely used in the mobile communication with the good performance in multipath fading channel and the high utilization of the frequency spectrum. However, the OFDM technique has some limitations: the Cyclic-Prefix (CP) is necessary to guarantee the orthogonality of the subcarriers which reduces the spectrum efficiency; the system uses the rectangular filters, which leads to the high leakage of sidelobe and gets better time domain performance with the sacrifice of the frequency domain performance. The FBMC decreases the leakage of sidelobe by designing the prototype filter. Meanwhile, the symbols overlap in the time domain. The balance of the performance in time and frequency domains makes FBMC system more flexible in the complicated communication environment. The feature of the prototype filter reduces the demand of orthogonality which makes the CP unnecessary and raises the data rate [1], [2]. In the face of diverse service and the typical technical scenarios, in 5G, FBMC could be an effective auxiliary method for OFDM [3]. In FBMC, a set of synthesis and analysis filters are designed such that they have both adequate spectral selectivity and bandwidth efficiency. Although each filter could be designed on an individual basis, a more efficient approach is to design a single prototype low pass filter and modulate it to several specified center frequencies to generate the synthesis and analysis filters

$g^{(k)}(n)$ and $f^{(k)}(n)$, k = 0, ..., N-1.

Another technique used for 5G is Universal-Filtered Multi-Carrier (UFMC) [4], a filtering operation is applied to a group of consecutive subcarriers in order to reduce out-of-band side lobe levels and subsequently minimize the potential ICI between adjacent users in case of asynchronous transmissions.

This paper is organized as follows: Fundamental blocks for wireless communication systems based on Filter Bank Multicarrier FBMC in 5G are explained in Section 2, including architecture design and system components for next generation waveforms. In section 3 an UFMC model is explained. In Section III, we will discuss about results for both systems FBMC and UFMC compared to OFDM systems.

2. FBMC System model

FBMC system realizes the modulation and demodulation of signal though filter banks [5], which are the frequency shift of the prototype, filter. FBMC chooses the Nyquist filter (such as classical raised cosine filter) to reduce the out-of-band radiation. Actually, modulation and demodulation are coupled in the network. Consider the normalization of data, we often use half-Nyquist filter (such as the square root raised cosine filter). In this paper, we use PHYDYAS filter [6]. Table 1 shows the frequency coefficients of the prototype filter when K=4, where K denotes the overlapping factor.

Table 1: The frequency coefficients of the prototype filter when k=4

H_0	H_1	H_2	H_3
1	0.971960	$\sqrt{2}/2$	0.235147

The frequency response of the prototype filter is

$$H(f) = \sum_{k=-(K-1)}^{K-1} H_k \frac{\sin\left(\pi\left(f - \frac{k}{MK}\right)MK\right)}{MK\sin(\pi\left(f - \frac{k}{MK}\right))} \quad (1)$$

M denotes the number of subcarriers. The time response of the prototype filter is

$$h(t) = 1 + 2\sum_{k=1}^{K-1} H_k \cos\left(2\pi\frac{kt}{KT}\right) \quad (2)$$

The filter banks are the frequency shifts of the prototype filter. Figure 1 shows the filter banks in the frequency domain. The horizontal axis denotes the index of subcarriers. The adjacent subcarriers don't overlap in the frequency domain because of the raised cosine filter, which results in interference. But the sub-channels with even (odd) index don't overlap. The system can use OQAM modulation to guarantee the orthogonality of adjacent subcarriers and demodulate the data perfectly at the receiving end [7].

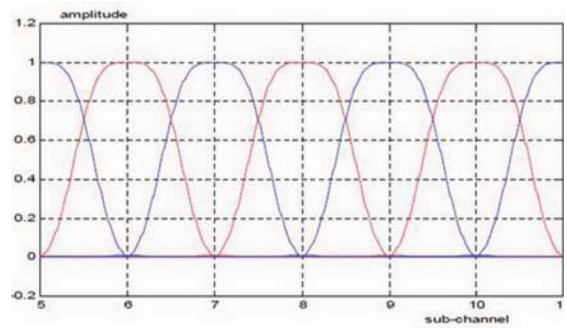

Fig. 1. Filter banks based on the prototype with K=4

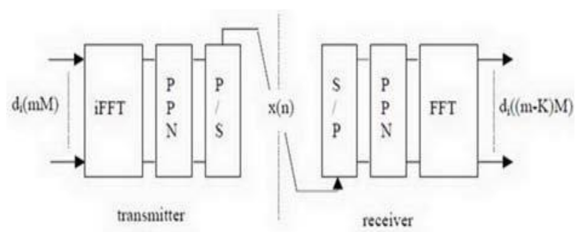

Fig. 2. FBMC system model with PPN

The computational complexity of the system increases greatly because of the prototype filter [8], Polyphase network (PPN) can simplify the calculation [9], [10]. Let h_i be the pulse response of the prototype filter with length of L=KM. H (Z) is the Z-transform version of h_i, divide the sequence into M sub-sequences with length of K, we can get

$$H(Z) = \sum_{p=0}^{M-1} H_p(Z^M)Z^{-p}, H_p(Z^M) = \sum_{k=0}^{K-1} h_{kM+p}Z^{-kM} \quad (3)$$

The filter banks at the transmitting end are frequency shift of the prototype filter. Let M be the numbers of subcarriers, 1/M be the sub-carrier spacing, and W= exp (−j2 π/M), we can get all the Z-transform verisons of the pulse response of filters in the bank by polyphase decomposition

$$\begin{bmatrix} B_0(Z) \\ B_1(Z) \\ \vdots \\ B_{M-1}(Z) \end{bmatrix} = \begin{bmatrix} 1 & 1 & \cdots & 1 \\ 1 & W^{-1} & \cdots & W^{-M+1} \\ \vdots & \vdots & \cdots & \vdots \\ 1 & W^{-M+1} & \cdots & W^{-(M-1)^2} \end{bmatrix} \begin{bmatrix} H_0(Z^M) \\ Z^{-1}H_1(Z^M) \\ \vdots \\ Z^{-(M-1)}H_{M-1}(Z^M) \end{bmatrix} \quad (4)$$

Figure 2 shows the system model of FBMC with iFFT-PPN structure. The system can use iFFT-PPN to modulate the data, and use FFT-PPN to demodulate the signal at receiving end. Comparing with OFDM, FBMC only adds PPN, which reduces the computational complexity and enhance the compatibility with OFDM.

3. UFMC System model

Figure 3 illustrates the operating principle of the UFMC transceiver. Universal Filtered Multi-Carrier (UFMC) is a novel modulation technique [11], which is a generalization of filtered OFDM and FBMC (in its filtered multi-tone (FMT) variant). UFMC is seen as a generalization of Filtered OFDM and FBMC (Filter Bank Multi-carrier) modulations. The entire band is filtered in filtered OFDM and individual subcarriers are filtered in FBMC, while groups of subcarriers (sub bands) are filtered in UFMC.

This subcarrier grouping allows one to reduce the filter length (when compared with FBMC). Also, UFMC can still use QAM as it retains the complex orthogonality (when compared with FBMC), which works with existing MIMO schemes.

The full band of subcarriers (*N*) is divided into subbands. Each subband has a fixed number of subcarriers and not all subbands need to be employed for a given transmission. An *N*-pt IFFT for each subband is computed, inserting zeros for the unallocated carriers. Each subband is filtered by a filter of length *L*, and the responses from the different subbands are summed. The filtering is done to reduce the out-of-band spectral emissions. Different filters per subband can be applied, however, in this example; the same filter is used for each subband. A Chebyshev window with parameterized sidelobe attenuation is employed to filter the IFFT output per subband [12].

The transmit-end processing is shown in the following diagram given in Figure 3.

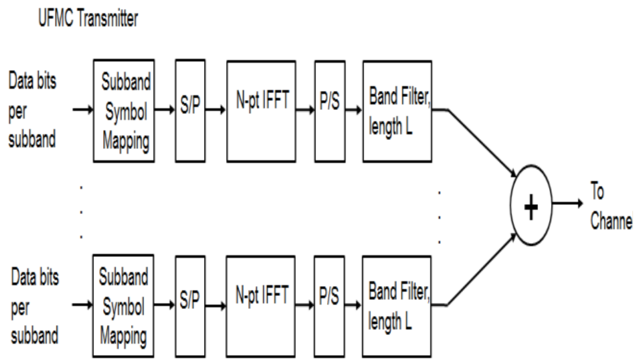

Fig. 3. UFMC Transmitter model

4. Discussion and Results

Figure 4 shows the magnitude response of the prototype filter in OFDM and FBMC system .When carriers where modulated in an OFDM system, side lobes spread out either side, with a filter bank system, the filters are used to remove these and therefore a much cleaner carrier results. FBMC has a much better usage of the available capacity and is able to offer higher data rates within a given radio spectrum. Cyclic Prefix is not required in FBMC; his usage reduces the overall data rate and causes loss in spectral efficiency, (See fig.5 and fig.6).

A further disadvantage of OFDM is that spectral localization of the subcarriers is weak and this results in spectral leakage and interference issues with unsynchronized signals

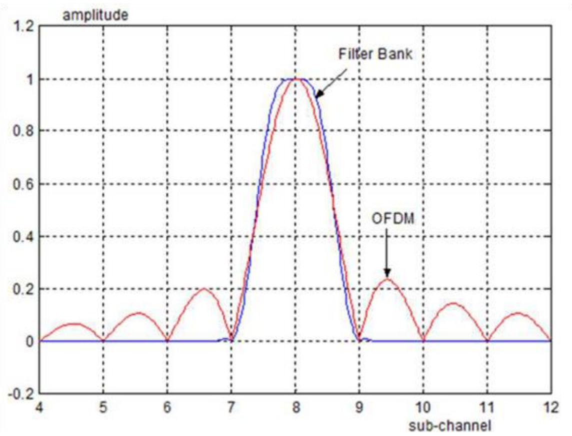

Fig. 4. Magnitude response in OFDM and FBMC system

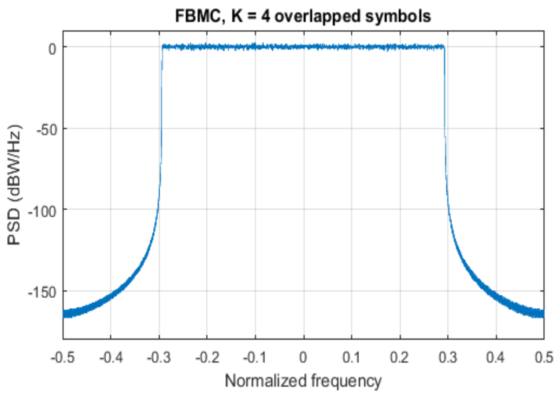

Fig.5.The power spectral density of the FBMC

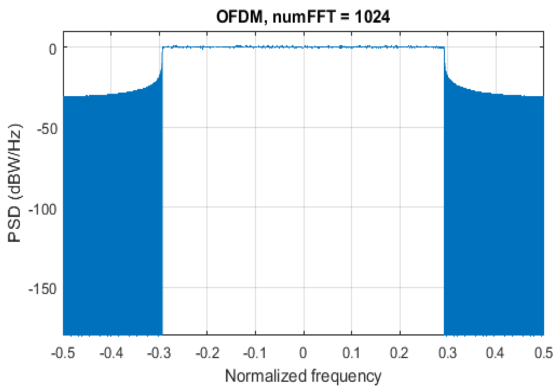

Fig.6.The power spectral density of the OFDM

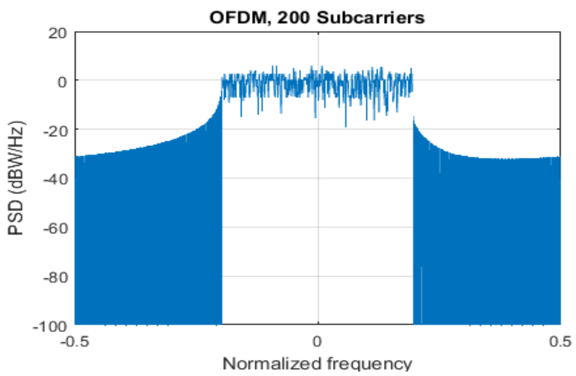

Fig.7. Spectral density of the OFDM

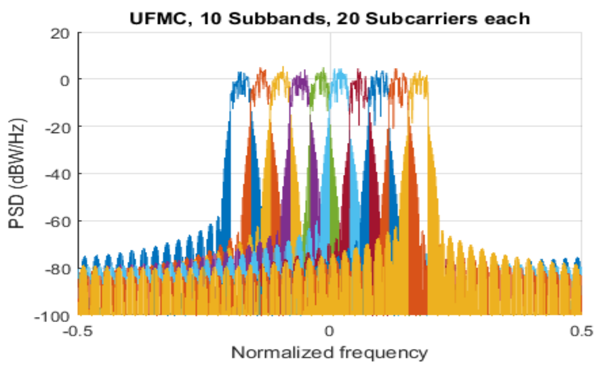

Fig.8. Spectral density of the UFMC

The example presents the basic characteristics of the UFMC modulation scheme at both transmit and receive ends of a communication system.Exploring different system parameter values for the number of subbands, number of subcarriers per subband, filter length, and sidelobe attenuation is shown in fig.7 and fig.8. UFMC is considered advantageous in comparison to OFDM by offering higher spectral efficiency. Subband filtering has the benefit of reducing the guards between subbands and also reducing the filter length, which makes this scheme attractive for short bursts. The latter property also makes it attractive in comparison to FBMC, which suffers from much longer filter length.

5. Conclusions

This paper provided an extensive comparison of the main new waveform contenders for an application in the 5G air interface. We compared OFDM, FBMC, and UFMC in terms of time-frequency containment (spectral efficiency and magnitude response). Their performances were compared to OFDM used in LTE. Presenting the best energy efficiency after OFDM and the best time-frequency containment among all contenders, FBMC seems the most suited waveform for an application in 5G. UFMC remain attractive because of their easier backward compatibility than FBMC with legacy OFDM systems, especially for MIMO techniques.

references

[1] FARHANG-BOROUJENY, Behrouz. OFDM versus filter bank multicarrier. *IEEE signal processing magazine*, 2011, vol. 28, no 3, p. 92-112.

[2] ESTELLA, Iñaki, PASCUAL-ISERTE, Antonio, et PAYARÓ, Miquel. OFDM and FBMC performance comparison for multistream MIMO systems. In: *Future Network and Mobile Summit, 2010*. IEEE, 2010. p. 1-8.

[3] SCHAICH, Frank et WILD, Thorsten. Waveform contenders for 5G—OFDM vs. FBMC vs. UFMC. In: *Communications, Control and Signal Processing (ISCCSP), 2014 6th International Symposium on*. IEEE, 2014. p. 457-460..

[4] WANG, Xiaojie, WILD, Thorsten, SCHAICH, Frank, *et al.* Universal filtered multi-carrier with leakage-based filter optimization. In: *European Wireless 2014; 20th European Wireless Conference; Proceedings of*. VDE, 2014. p. 1-5.

[5] YLI-KAAKINEN, Juha et RENFORS, Markku. Optimization of flexible filter banks based on fast convolution. *Journal of Signal Processing Systems*, 2016, vol. 85, no 1, p. 101-111.

[6] BELLANGER, Maurice G. Specification and design of a prototype filter for filter bank based multicarrier transmission. In: *Acoustics, Speech, and Signal Processing,*

2001. Proceedings.(ICASSP'01). 2001 IEEE International Conference on. IEEE, 2001. p. 2417-2420.

[7] SCHAICH, Frank. Filterbank based multi carrier transmission (FBMC)—evolving OFDM: FBMC in the context of WiMAX. In: *Wireless Conference (EW), 2010 European*. IEEE, 2010. p. 1051-1058.

[8] SANDBERG, Stuart D.. et TZANNES, Michael A.. . Overlapped discrete multitone modulation for high speed copper wire communications. *IEEE Journal on selected areas in communications*, 1995, vol. 13, no 9, p. 1571-1585.

[9] YIM, W. et COAKLEY, F. Polyphase matrix and lattice decomposition for multirate filters and filter banks. In : *Acoustics, Speech, and Signal Processing, 1992. ICASSP-92., 1992 IEEE International Conference on*. IEEE, 1992. p. 625-627.

[10] VAIDYANATHAN, Parishwad P. Multirate digital filters, filter banks, polyphase networks, and applications: a tutorial. *Proceedings of the IEEE*, 1990, vol. 78, no 1, p. 56-93.

[11] WUNDER, Gerhard, JUNG, Peter, KASPARICK, Martin, *et al.* 5GNOW: non-orthogonal, asynchronous waveforms for future mobile applications. *IEEE Communications Magazine*, 2014, vol. 52, no 2, p. 97-105.

[12] SCHAICH, Frank, WILD, Thorsten, et CHEN, Yejian. Waveform contenders for 5G-suitability for short packet and low latency transmissions. In: *Vehicular Technology Conference (VTC Spring), 2014 IEEE 79th*. IEEE, 2014. p. 1-5.