FBMC transceivers for 5G mobile communication systems

Keywords : 5G systems; Filter bank based multicarrier modulation; MIMO.

François Rottenberg, Jérôme Louveaux, François Horlin

Abstract* – *One of the main challenges investigated for 5G wireless communication systems is the ability to take care of the largely increasing number of devices, establishing connections with a wide variety of requirements. Simultaneously, it is also crucial to fulfil the ever increasing demand of bit rate. The OFDM modulation (orthogonal frequency division multiplexing), used in most wireless communication systems today, forces the different devices to be synchronized in time in order to avoid interfering with each other. This might become an unaffordable burden when the number of devices and the number of cells increase. For this reason, FBMC (filter bank multicarrier) is being considered as a viable alternative. It simply separates the users in frequency and does not require any synchronization thanks to the low sidelobes of its filters. This project aims at studying the applicability of FBMC/OQAM for 5G, mainly focused on the study of the implementation of massive MIMO (systems using very large number of antennas) for FBMC/OQAM.

Orthogonal frequency division multiplexing (OFDM) is the most popular multicarrier modulation scheme nowadays. It is used for instance in systems such as WiFi, long term evolution (LTE, also known as 4G) or digital video broadcasting (DVB). OFDM has been very attractive mainly because of its low complexity of implementation. The introduction of the cyclic prefix (CP) in OFDM allows for easy channel equalization. Extension to multiple-input multiple-output (MIMO) scenarios is straightforward thanks to the OFDM orthogonality ensured in the complex domain. At the same time, due to the rectangular pulse shaping of the fast Fourier transform (FFT) filters, OFDM systems exhibit very high frequency leakage and poor stopband attenuation (see Figure 1). Furthermore, the use of the CP in OFDM significantly reduces the spectral efficiency of the system.

In the light of the shortcomings of OFDM, Offset-QAM-based filterbank multicarrier (FBMC/OQAM) modulation has been regarded as an attractive alternative. Rather than using a rectangle pulse in time, FBMC-OQAM uses a pulse shape which is more spread in time and has much larger stopband attenuation (see Figure 1). This in turn translates into higher spectral efficiency and relaxed synchronization constraints which allows the coexistence of large number of users in a very simple way. Moreover, it does not require CP overload, which allows for a larger spectral efficiency. The FBMC technique is already used in slightly different forms in some current standards (mainly in powerline communications) and has been investigated recently for several future applications such as cognitive radio (in particular in the Phydyas and Emphatic European Projects). However, it has largely been ignored in wireless communications standards up to now due to the simplicity and efficiency of OFDM for these applications. Therefore, many issues appearing in nowadays wireless context have not been investigated in the specific case of FBMC and are only receiving attention very recently.

In this project, the applicability of FBMC/OQAM for 5G is studied. The project focuses, in particular, on the study of the implementation of massive MIMO (systems using very large number of antennas) for FBMC/OQAM. Due to the particular interference structure of this modulation, many issues related to massive MIMO need to be revisited such as the design of the precoding, or the channel estimation.

Regarding channel estimation in FBMC distributed MIMO systems, we have developed several algorithms aiming at allocating pilots to the different users while avoiding inter-user interference. The results prove that an unsynchronized FBMC/OQAM system might outperform a fully synchronized OFDM system in the considered scenario. Furthermore, classical FBMC-OQAM decoders are known to suffer from the frequency selectivity of the channel, especially in multi-users MIMO scenarios. The decoders that we optimized showed that the degradation caused by the channel selectivity might be easily and efficiently mitigated using extra antennas at the base station with a very low complexity of implementation (See Figure 2).

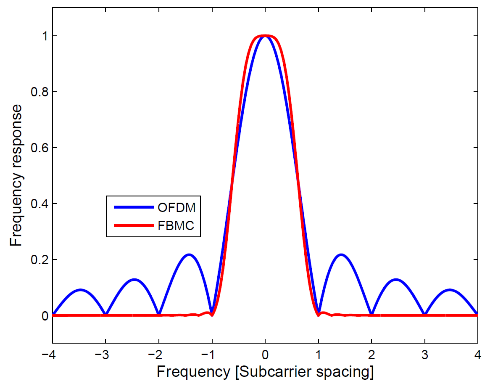

Figure 1: Frequency response of the prototype filters in OFDM and FBMC multicarrier modulations.

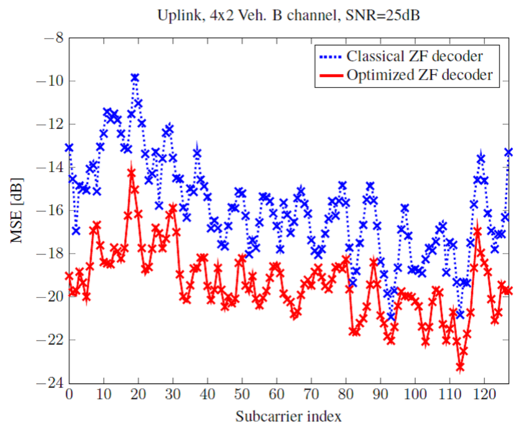

Figure 2: Frequency response of the prototype filters in OFDM and FBMC multicarrier modulations.

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