An implementation on GNURadio of a new model to ISDB-Tb using FBMC

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***Abstract* — The modulation technique Filter Bank MultiCarrier (FBMC) is an alternative widely studied in order to replace Orthogonal Frequency Division Multiplexing (OFDM) in wireless telecommunications systems. The fact that FBMC does not use Cyclic Prefix and uses Polyphase Filters allows improvements in bit rate, bandwidth efficiency and robustness against multipath channel impairments. This implementation can bring advantages to Digital TV case in comparison to the traditional OFDM based systems because of the need to transmit higher resolution videos such as 4K and 8K. This article presents a study on the use of FBMC in Integrated System Digital Broadcasting Transmission B (ISDB-Tb), developing an application on GNURadio environment, analysing Bit Error Rate (BER) and power spectrum curves in a multipath channel.**

Keywords: FBMC, OFDM, ISDB-Tb, GNURadio, polyphase filters.

I. INTRODUCTION

The OFDM is one of the most used modulation techniques in telecommunication systems. However, the FBMC has become an alternative in order to improve the bit rate and bandwidth efficiency of wireless systems [1]. When OFDM is replaced by FBMC, the improvement in bandwidth utilization (bits/sec/Hz) may be up to 25% [2] as there is no need for Cyclic Prefix. At the same time, there is a 20% increase in robustness to interferences resulting in better bit error curve [3]. For that reasons, this article presents a modified model of ISDB-Tb using FBMC, which was implemented on GNURadio software defined radio environment. The BER curves and frequency domain are presented to evaluate the obtained improvements with different channel estimators.

II. FILTER BANK MULTI CARRIER

FBMC can be understood if Figure 1 is considered. The data to be transmitted is split into *M* different paths in a filter bank arrangement. The resulting signal *s(k)* is expressed in (1) in which $a_{m,n}$ is the symbol, g_m the filter response shifted, and *n* the time position.

$$s(k) = \sum_{m=0}^{M-1} \sum_{n \in Z} a_{m,n} \, g_m\left(k - \frac{nM}{2}\right) \qquad (1)$$

As non-orthogonal filters usually compose the filter bank, Offset Quadrature Amplitude Modulation (OQAM) is used. Hence, the symbols are transmitted in a staggered way in order to keep the orthogonality among adjacent carriers.

The complete system, transmitter and receiver, can be implemented through a combination of a polyphase filter bank and FFT blocks as explained in [4].

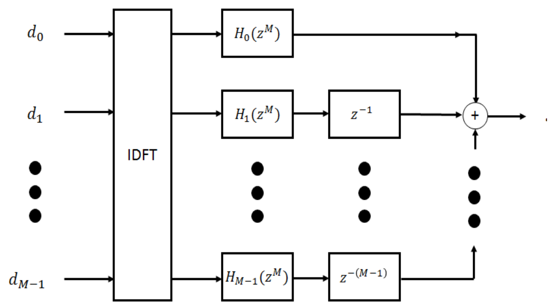

Fig. 1 FBMC modulator

III. INTEGRATED SERVICES DIGITAL BROADCASTING TERRESTRIAL VERSION B

ISDB-Tb is the terrestrial digital TV standard adopted by 15 countries in Latin America and Africa. ISDB-Tb can be transmitted on 6, 7, or 8 MHz channels with 13 segments that are multiplexed in OFDM blocks and 1 segment as guard band. The 13 segments can be arranged for operation with One Segment, Standard Definition, or High Definition modes. The standard allows the use of QPSK, 16QAM, and 64QAM modulations in each particular OFDM layer. It uses 4992 data carriers, 625 pilot tones and an 8K IFFT with zeros insertion to complete the frame. The Cyclic Prefix values can be 1/4, 1/8 or 1/16 of the useful OFDM symbol time [5].

IV. PILOT BASED CHANNEL ESTIMATION

In order to estimate the transfer function of the channel, pilot tones are sent in the ISDB-Tb. The scattered pilots have an amplitude of either +4/3 or -4/3. These values depend on a Pseudorandom Binary Sequence (PRBS) with polynomial $x^{11} + x^9 + 1$, positioned in every 12th sub channel. The starting subcarrier is either the 0th, 3rd, 6th, or 9th according to the OFDM or FBMC symbol order.

After finding the transfer function of the pilots (*Hp*) by (2), where *Y(k)* and *X(k)* (always different from zero) are the amplitudes of received and transmitted pilot respectively, an interpolation method, such as linear or cubic, is applied with the purpose of estimating the other subcarrier responses. This operation can be done not only in the frequency domain but also in the time domain.

$$Hp(k) = \frac{Yp(k)}{Xp(k)} \qquad (2)$$

V. ISDB-TB USING FBMC IMPLEMENTATION

The complete ISDB-Tb proposed system employing FBMC is depicted in Figure 2 on the bottom of the next page. As it can be seen, the source generates data which are coded, modulated, staggered (pre OQAM) and multiplied by beta. Then, an IFFT and synthesis filters are applied. The resulting signal is sent through the channel. At the receiver, the signal passes through the analysis filters and FFT. Then, the opposite steps performed at the transmitter are accomplished.

For this implementation, a system model was created on GNURadio utilizing the C++ programming language, in order to form a Flow Graph. This model was constructed in a way that both the traditional OFDM and FBMC-based ISDB-Tb can be simulated in real time. The configuration used was the full segment, Mode 3, 64QAM, 4992 useful subcarriers, 8K IFFT and 1/16 CP in the OFDM system.

Four channel estimators were implemented: two of them only in the frequency domain with linear or cubic interpolation, one in the frequency and time domain with cubic method [6] and the last one specifically to FBMC in the frequency domain with cubic using 3 taps equalizations [4].

VI. RESULTS

In order to obtain this results it was used a 64-QAM random source. Then, by analyzing the spectrum representation in Figure 3, it is possible to observe that the spectrum of FBMC has a decay of about 70dB more than OFDM.

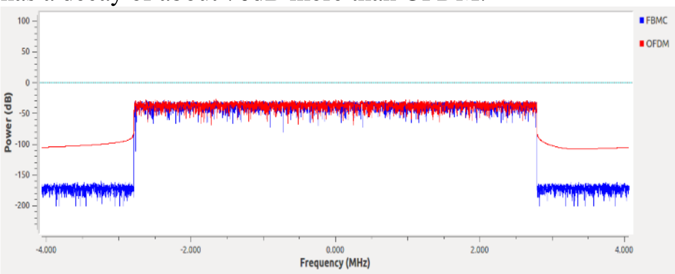

Fig. 3 FBMC and OFDM spectra

Figure 4 presents the BER curves found for the introduction of Gaussian noise in a Brazil A digital TV channel model [7], which encompasses 6 paths with 0, 0.15, 2.2, 3.05, 5.86, and 5.93 microseconds of delay and 0, 13.8, 16.2, 14.9, 13.6, and 16.4dB of attenuation respectively. Four estimators were used for FBMC and OFDM systems as explained in the Figure 4. The estimators used were chosen according to most common applied on OFDM and FBMC systems.

From Figure 4, the FBMC based system presents a better robustness to Gaussian Noise in a multipath channel even in the absence of a Cyclic Prefix, using the same estimators. Other important aspect is the fact that the equalization using 3-taps designed in order to avoid the adjacent channel interference in the case of FBMC allows a great improvement in the robustness to impairments, resulting in a bit rate increase of 6% for CP equal to 1/16.

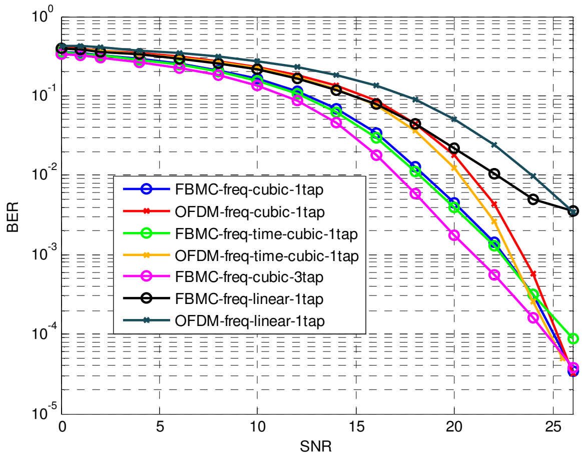

Fig. 4 BER curves using diferent estimators in a multipath channel

VII. CONCLUSION

This study has proved that the implementation of ISDB-Tb digital TV system employing FBMC instead of OFDM is viable and brings some advantages. Among them the increase of bit rate and bandwidth efficience in terms of bits/sec/Hz around to 25% if the CP is ¼. In addition, due to the decay of spectrum, reducing the interferences among adjacent sub channels, there is an improvement in terms of BER in multipath channels.

When the estimators are analyzed, it is possible to verify that 3 tap equalization it is necessary in order to cancel the interference among adjacent channels, which makes the system more robust to interferences with a little more computational complexity.

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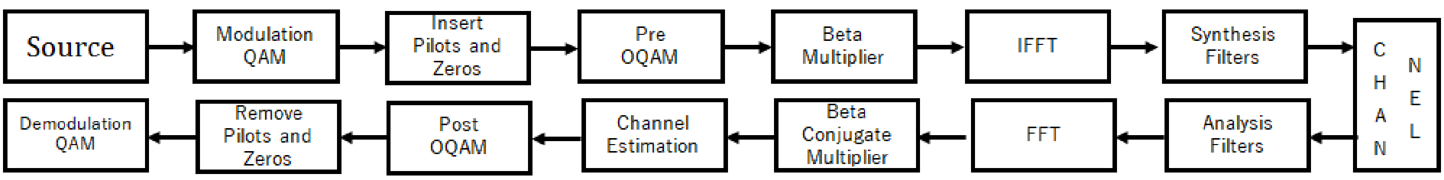

Fig. 2 Schematic of ISDB-TB FBMC