Study of advanced signal processing techniques for extended Digital Video Broadcasting-Terrestrial Second Generation

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Abstract

In the present days, the increase of system requirements in high-capacity and limited frequency resources also affects the Digital Terrestrial Television (DTT) market as the continuous increase of image quality and screen size corresponds to an increase of bit rate to transmit.

Among worldwide DTT standards, DVB-T2 (Digital Video Broadcasting Terrestrial second generation) is the second generation of European terrestrial broadcasting standard published by the European Telecommunication Standard Institute in 2009 and mainly adopted or deployed in many European and African countries due to its higher performance than the first-generation DVB-T. While many European countries which already deployed DVB-T one decade ago, are planning (Belgium) or deploying DVB-T2, most African countries directly implemented (Benin, Burkina Faso) or adopted DVB-T2.

Since the day DVB-T2 was standardized, several types of research were undertaken on this system to further improve its performance in the objective of a potential third generation. They have all the aim to bring this system further closer to the Shannon limit. They present either initial signal processing optimization (Multiple Input Single Output technique, Signal Space Diversity technique, Peak to Average Power Ratio moderation techniques, advanced channel equalization, …) or signal processing substitution by other advanced techniques. Generally, the authors present a single improvement at a time.

In this thesis, the focus is mainly on DVB-T2 signal processing blocks substitution, e.g., Orthogonal Frequency Division Multiplexing is substituted by Filtered bank Multicarrier (FBMC) or Universal Filtered Multicarrier (UFMC), classical uniform QAM is substituted by advanced Non-Uniform Constellation (NUC) shaping technique. Also, focus is also set on low complexity demapper algorithms proposed for rotated constellation in DVB-T2.

The novelty is firstly on the application of such advanced techniques on high density subcarrier systems and deep fading channels, like the case of DVB-T2, which can reach up to 32768 subcarriers on an 8 MHz bandwidth.

Secondly, as there is a gap in the literature on the maximum reachable gain when several techniques are jointly substituted by other advanced techniques, this research aims to combine by simulations several techniques and to evaluate the maximum reachable gain by substituting one approach or combining two of them. The choice of the DVB-T2 suitable and compatible techniques has been the challenge. 5G candidate's waveforms have been proven to be hardware compatible with OFDM existing in the native DVB-T2 and are studied and implemented in DVB-T2. Additionally, an advanced geometrical constellation technique called NUC previously proposed in ATSC 3.0 (only worldwide DTT standard closer to the Shannon limit) is studied and highlighted a good performance in DVB-T2. As these techniques distinctly improved DVB-T2 system capacity, UFMC and NUC have been mutually substituted by OFDM and QAM in DVB-T2. It is noticeable that the UFMC NUCs association is a primer in the literature, whatever the envisaged system.
Besides the maximum reachable gain, the complexity and spectral efficiency induced by these techniques (FBMC and UFMC) have also been studied to provide a compliant detail about these advanced signal processing techniques employed in DVB-T2. Furthermore, as the channel is the relevant element during the signal transmission whose characteristics are unpredictable, this work studies the impact of uncertainty error that appeared during DVB-T2 channel measurement. Several performance evaluations tools (Bit Error Rate, Modulation Error Ratio and Error Vector Magnitude) have also been considered during this work and in different applications: Single Frequency Network (SFN) and urban environment, either with a generic channel model or a measured channel.
As a summary, the main conclusions of this research work are that the linear phase filter UFMC is the lowest complex algorithm which may provide a complexity equal to OFDM. Moreover, with the best parameters and in the frame of a DVB-T2 evolution, FBMC and UFMC are respectively 133.43% and 128.52% spectrally more efficient than OFDM. They also outperform OFDM by respectively a 1 dB and a 1.2 dB SNR gain in the case of a BER equals to 10^{-3}. These gains respectively correspond to the additional network coverage of up to 9.18% and 11.20%. Therefore, it can be concluded that UFMC is the best candidate in term of improvement if a next generation of DVB-T2 would be developed. UFMC and 2D-NUCs performance have been jointly evaluated in DVB-T2. It was shown that their performance (1dB SNR at a BER of 310^{-3}) compared to DVB-T2 performance in urban environment is equal to the summation of the performance of UFMC (0.8dB SNR at a BER of 310^{-3}) and NUCs (0.2dB SNR at a BER of 310^{-3}) in the same simulation conditions and using the same parameters. The classical DVB-T/T2 measurement equipment have PDP (Power Delay Profile) uncertainty ranges of up to +/- 50 ns and +/- 0.5 dB which are value that have been shown to present negligible performance losses in DVB-T2 simulation.