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Analysis and comparation of ISDB-T using modulations OFDM and CC-OFDCM

Análisis y comparación de ISDB-T utilizando modulaciones OFDM y CC-OFDCM

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Abstract

Digital Terrestrial Television (DTT) is focused on replacing analog television transmissions, using OFDM (orthogonal frequency division multiplexing) modulation, which enables transmitting to both fixed and mobile equipment. Nevertheless, in the case of mobile digital television receivers, such as smartphones, laptops and other devices there are reception problems due to the multipath effect. In this project, the OFDM and CC-OFDM (Orthogonal Frequency Division Multiplexing by Convolution Coding) modulation schemes are simulated for the ISDB-T (Integrated Services Digital Television Broadcasting) standard. By means of the Simulink graphical programming environment, from Matlab, the block diagrams of both schemes were implemented and the data transmission was simulated, further measuring the BER (Bit Error Rate), the delay and the number of carriers, for three types of channels, namely: AWGN (Additive White Gaussian Noise), Type A land (rural land) and Type C land (urban land). The results obtained indicate that CC-OFDM modulation has a higher efficiency, due to higher BER and reduction in the reception delay.

Keywords: CC-OFDM, ISDB-T, Multiway, OFDM, Simulink.

Resumen

La Televisión Digital Terrestre está orientada a sustituir las transmisiones de televisión analógica, al utilizar la modulación OFDM (multiplexación por división de frecuencias ortogonales), con esta modulación se puede realizar transmisiones para equipos fijos y móviles. Sin embargo, en el caso de sistemas de recepción de televisión digital como teléfonos inteligentes, portátiles y otros dispositivos móviles tienen problemas en la recepción causados por el efecto multicamino. En este proyecto se realiza la simulación de las modulaciones OFDM y CC-OFDM (Multiplexación por División de Frecuencias Ortogonales mediante Codificación por Convolución) para el estándar de televisión ISDB-T (Radiodifusión Digital de Servicios Integrado para Televisión). Por medio de Simulink del entorno Matlab, se simuló los diagramas de bloques de ambas arquitecturas para observar los resultados al transmitir datos, midiendo el BER (Tasa de Bit Errado), el retardo y el número de portadoras, bajo los siguientes canales: AWGN (Ruido Gaussiano Blanco Aditivo), Terreno tipo A (terreno rural) y Terreno tipo C (terreno urbano). De los resultados obtenidos se muestra que la modulación CC-OFDM tiene una mayor eficiencia, debido a que presenta un BER mayor y reducción en el retardo en la recepción.

Palabras clave: CC-OFDM, ISDB-T, Multicamino, OFDM, Simulink

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1. Introduction

The digital television is geared towards substituting analog television, because it has the advantage of including interactive applications, such as surveys, programming times and emergency signals, among others, as well as different types of signal quality in high definition (HD) and standard definition (SD) [1].

When digital television signals are received in mobile devices, such as smartphones and laptops, among others, there are impulsive noise issues due to multipath in the ISDB-T standard, when the usual OFDM modulation is employed [2].

The ISDB-T (Integrated Services Digital Broadcasting-Terrestrial) standard had its origin in Japan, being developed in the late 1990s. The main objective of this standard was to enable the simultaneous transmission of HDTV (High Definition Television) and SDTV (Standard Definition Television). ISDB-T was designed to operate in channels of bandwidth 6.7 and 8 MHz, respectively. In Ecuador this standard should operate in a channel of 6 MHz [3].

In the last decade, the orthogonal frequency division multiplexing (OFDM) has become the basis of telecommunication systems, and it is a technique utilized in wireless transmission [4] and fiber optic systems [5]. The advantages of OFDM are the management of multipath interference, mitigation of intersymbol interference (ISI) caused by the bit error rate (BER) in frequency selective fading [6]. On the other hand, the orthogonal frequency division multiple access (OFDMA) is a multicarrier transmission technique, which is considered as one of the best for bidirectional wireless networks is communication systems and for broadcasting digital television, especially in the ISDB-T television system being used in Ecuador; besides, it is used in satellite and space communications, reducing the errors. The BER, defined as the number of bit errors divided by the total number of transferred bits during a time interval, is the quality criterion utilized in digital transmission and data storage.

The broadcasts of digital terrestrial television tend to be reflected on buildings and mountains; as a consequence, the multipath phenomenon appears in the propagation. In order to avoid the interference, the digital television ISDB-T utilized in Ecuador is based on the Japanese system with the Brazilian patch, and employs OFDM as modulation scheme. This technique is not robust, and shows long delays in multipath transmissions which may exceed the guard interval (GI) or produce high peaks in the transmission power [7], particularly in the time-domain because many subcarrier components are added when the inverse fast Fourier transform (IFFT) is used [8]. But beyond that, OFDM systems have a high peak-to-average power ratio (PAPR) with respect to systems with one carrier. When signals with a high PAPR pass through a nonlinear element, such as a high power amplifier (HPA) [9], it is produced a signal out of the range of the spectrum of the carriers that will interfere with adjacent channels and in the carrier spectrum, thus causing distortion, attenuation and an offset in the received signal. A HPA with a big dynamic range will produce high losses in the communication system. This can be reduced using systems with low losses, but the cost will increase. The fading effect can be compensated using CC-OFDM [10].

The convolution coding based orthogonal frequency division multiplexing (CC-OFDM) modulation in orthogonal frequency division multiplexing (OFDM) systems, has become a very used tool in the current technology. Similarly, in other communication systems the OFDM system needs to use channel codification to decrease the VER, such as CC-OFDM [11]. Figure 1 shows the block diagram of the CC-OFDM modulation [12].

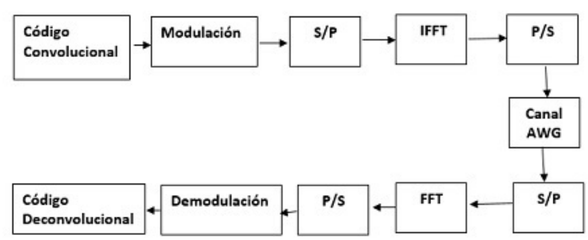

Figure 1. OFDM with convolution code.

In this paper, the CC-OFDM modulation is analyzed and simulated in ISDB-T architectures, to determine how the efficiency is improved in environments with multipath, as well as to observe the behavior of parameters such as BER, delay and number of carriers.

The block diagram in Figure 1 is constituted by: generator of the convolution code, which is a type of error correction code; modulation, which in this case is 64 QAM, even though other types of modulation such as QPSK, QAM, 16 QAM, 32 QAM can be used; a serial to parallel (P/S) converter; inverse fast Fourier transform (IFFT); AWG channel, which is the data transmission medium where attenuation, noise and signal fading will be introduced; parallel to serial (S/P) converter; fast Fourier transform (FFT); a second P/S converter, demodulation and, at last, the convolutional code decoding [13].

2. Materials and methods

Configurable parameters and values of the ISDB-T standard must be taken into account in the corresponding model, since they will completely define the operating mode of the system blocks as described in [14]. Figure 2 shows the block diagram of transmission and reception for the ISDB-T standard with OFDM modulation, created in Matlab Simulink. This block diagram is now described.

The image generator employs a Signal From Workspace block, which is in charge of importing the image data from the Matlab Workspace [15].

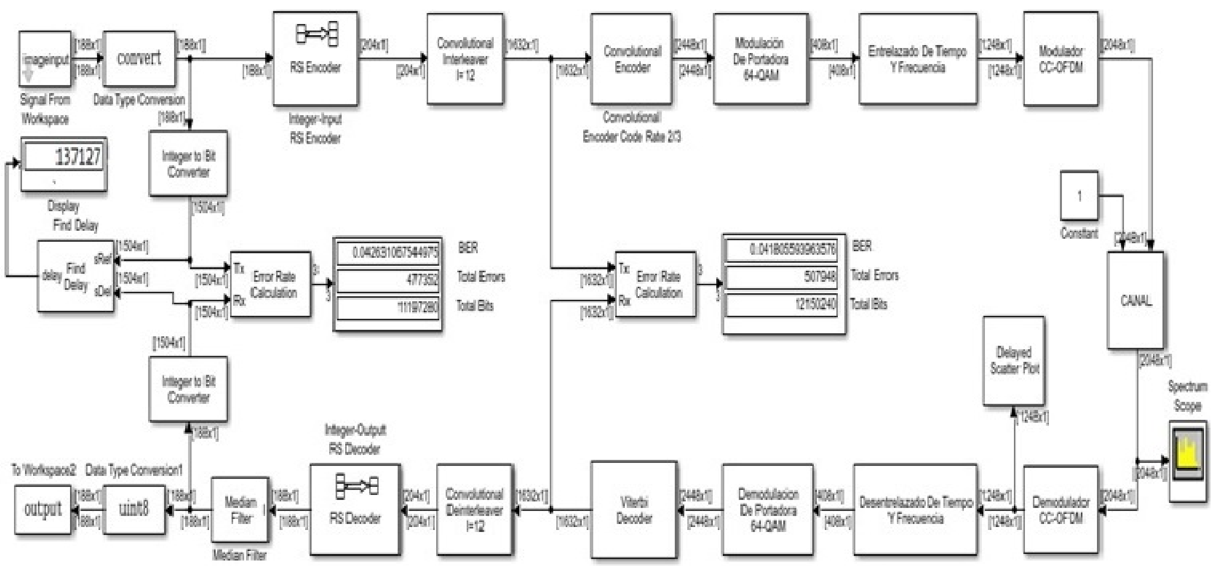

Figure 2. Block diagram of the ISDB-T standard with OFDM modulation, created in Matlab Simulink.

The Reed Salomon encoder carries out a block-based error correction process, for block processing a certain amount of data symbols. A code of the form k/n = 188/204 is employed in this case [16].

The integer to bit converter uses a value of 8, to obtain a total value of 1632 bits, as required by the norm [17]. The carrier modulation employs a block known as matrix interleaver, which will do the process of bits interleaving. Then, a mapping process is carried out; this process comprises two blocks, namely a bit to integer converter and a rectangular QAM modulator. In order to obtain a 64-QAM modulation, it is necessary to enter a value of 6 in the bit to integer converter, and also a value of 64 in the QAM modulator [18].

The time and frequency interleaving comprises a buffer, in which the number of rows and columns indicated by the standard (96 × 204) are entered, to further carry out the serial to parallel conversion. The matrix interleaver block contains the aforementioned rows and columns in order to correctly transmit the data. At last, a second buffer stores the 1248 data that belong to the standard [19].

In the OFDM modulation, the total number of carrier (2048) is assigned, and then the parameter number of guard bands [400;400] is entered which will enable obtaining the 1248 used by the simulator. Figure 3 shows the block diagram of transmission and reception for CC-OFDM [20].

In addition, a 3 taps line was implemented in the AWGN channel, known as Stanford University Interim (SUI) channels, to incorporate the effect of multipath; besides an AGWN block was added to introduce additive white Gaussian noise. The selected radio frequency communication model can be used in Wimax, digital television, and long distance wireless communication [21]. The OFDM demodulator performs the inverse process of the OFDM modulation. In the time and frequency deinterleaving an inverse process is conducted, in which the obtained output vector of [272×1] should be equal to the indicated in the transmission process, in order to proceed with the following stage [22].

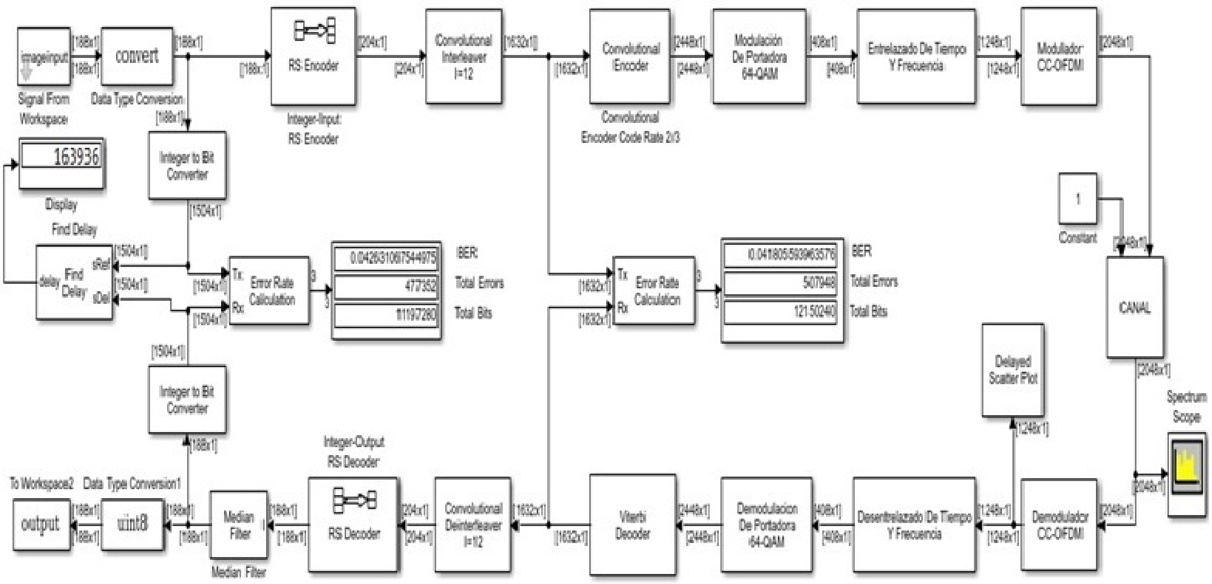

Figure 3. Block diagram of the ISDB-T standard with CC-OFDM modulation, created in Matlab Simulink.

In this subsystem, the carrier demodulation performs the bits deinterleaving, to further demodulate the 64-QAM with the rectangular demodulation block. The bit to integer converter converts the 1632 bits entered in the matrix deinterleaver, to 204 integers required in the following block [23]. In the values of the parameters in the Reed Solomon decoder match the values entered in Reed Salomon encoder, the recovered binary message vector will be equal to the message sent [24]. The median filter block was used to diminish the salt and pepper effect present in the received images, which was introduced in the communication channel; this filter calculates the mean of the pixels of the processed image, and uses a kernel to approximate the closer pixels thus reducing the noise [25]. In order to present the transmitted image, a To Workspace block is used in the ISDB-T standard with modulation CC-OFDM.

The Simulink blocks with CC-OFDM modulation use bits interleaving and de-interleaving for error correction. In addition, a convolutional encoder and its inverse, a Viterbi decoder, are added to obtain a smaller BER [26]. The Convolutional Interleaver block carries out a convolutional interleaving of bytes, to improve the performance against errors. The convolutional encoder was applied to a punctured vector, choosing a coding rate of 2/3 with an extension of 7 bits of convolution [**?**]. The Viterbi Decoder block decodes the signal coded by the convolutional encoder, using the Viterbi algorithm. This decoder uses the Trellis features of the convolutional code, and the Viterbi algorithm reduces the difficulty in the calculation to avoid taking into account all possible sequences [27]. The convolutional deinterleaver rearranges the symbols of the signal, which was interleaved using shift registers with fixed delay.

3. Results and discussion

Table 1 shows the bit error rate (BER) for different TDT standards and the corresponding modulations with a SNR of 19 [dB], since this value will enable to obtain a clear image with low noise.

Table 1. Bit Error Rate results

Standard	**ISDB-T (BER)**	
SNR[dB]	**OFDM**	**CC-OFM**
19	0,04333	0,04263

Calculations were conducted with a SNR = 16 [dB] [22], since this value will yield the best efficiency in the presence of multipath, both in sites A and C.

Table 2 shows the delays, given in seconds, for each of the modulations schemes of the TDT standards under consideration.

Table 2. Delay results

Standard	**ISDB-T (BER)**	
Modulations	**OFDM**	**CC-OFM**
Delay	6,9963 [ms]	8,3640 [ms]

Table 3 shows the results corresponding to BER *vs.* SNR, having as input a RGB image. The results are different because of the variation in the SNR, which is produced in the 2 channels SUI implemented in the simulation, in order to determine which of the standards exhibits the best performance in the presence of multipath. It can be seen that the BER is smaller for the CC-OFDM modulation.

Table 3. BER *vs.* SNR [dB] results with multipath

ISDB-T				
	OFDM VER		**CC-OFM VER**	
SNR Db	**Terrain A**	**Terrain C**	**Terrain A**	**Terrain C**
10	0,13040	0,11866	0,32612	0,24866
12	0,10997	0,09436	0,20365	0,09556
14	0,09357	0,07342	0,10164	0,04618
16	0,08112	0,05699	0,05799	0,04277
48	0,07194	0,04702	0,04650	0,04263
20	0,06546	0,04291	0,04439	0,04263

Figure 4 shows the results corresponding to the ISDB-T standard, where it is observed that the plots corresponding to sites A (urban) and C (rural) with CC-OFDM modulation, of color gray and yellow, respectively, show a better BER for SNR 16 dB, tan their OFDM counterparts. In the presence of multipath, the images transmitted using CC-OFDM modulation exhibit lower salt and pepper noise.

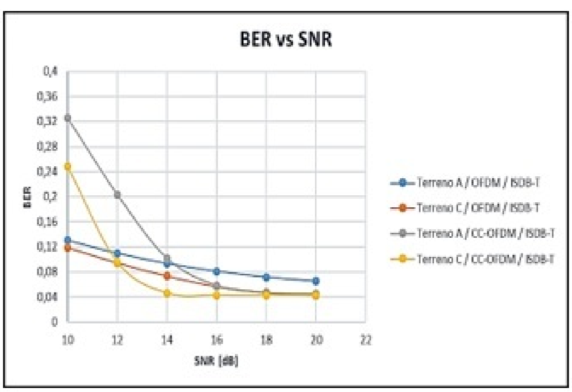

Figure 4. BER *vs.* SNR for a RGB input image applying the effect of multipath for the ISDB-T standard.

Table 4 confirms that CC-OFDM is more efficient in both sites.

Table 4. Approximate values of efficiency for the ISDB-T standard, with a SNR = 16 [dB]

ISDB-T				
	OFDM VER		**CC-OFM VER**	
SNR Db	**Terrain A**	**Terrain C**	**Terrain A**	**Terrain C**
16	91,887	94,300	94,201	95,273

At last, the results obtained for an image with SNR=16 [dB] for a site of type C (urban) are shown. Figure 5 is the original transmitted image, Figure 6 is the image received using OFDM, and Figure 7 is the image received with CC-OFDM.

Table 3 shows the results corresponding to BER vs. SNR, having as input a RGB image. The results are different because of the variation in the SNR, which is produced in the 2 channels SUI implemented in the simulation, in order to determine which of the standards exhibits the best performance in the presence of multipath. It can be seen that the BER is smaller for the CC-OFDM modulation.

Figure 5. Original input image.

Figure 6. Output image after passing through site C with SNR=16 [dB] and OFDM modulation.

Figure 7. Output image after passing through site C with SNR=16 [dB] and CC-OFDM modulation.

4. Conclusions

An OFDM system has many carriers for the ISDB-T standard, because the bandwidth allocated for each carrier is narrow. This reduces the symbol velocity in a proportional manner, thus increasing the time to transmit each symbol. As a consequence, this system is more susceptible to interferences due to multipath.

It is concluded that a CC-OFDM modulation is more 24.95% more efficient than OFDM for the ISDB-T standard, according to the BER obtained in the simulation of an urban site with a delay of 8.3640 [ms]. It is also more reliable, but with a delay 16.35% greater as compared to the OFDM modulation.

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