Comparative Analysis Of Coiflet Wavelets In OWDM With OFDM For DVB-T

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Abstract

OWDM technique is used to increase flexibility with decrease computational complexity, which is shown to be overall quite similar to OFDM but improved characteristics and with some additional features, the focus of this paper is on the performance analysis of OFDM with OWDM for DVB-T system and also analysis the performance of wavelet filters cf1, cf2, cf3 of Coiflet family in OWDM. The wavelets of Coiflet family are considered with increasing order to ascertain which wavelet transform is most suited for use in an AWGN channel in OWDM and measure the performance in terms of variance and Signal to Noise (SNR) for AWGN transmission channel. Orthogonal Frequency Division Multiplex (OFDM) is used to increase the data rate of wireless medium with high performance that uses an Inverse Fast Fourier Transform (IFFT) at the transmitter to modulate a high bit rate signal onto a number of carriers but this technique is inherently inflexible and require a more complex FFT core while wavelet theory permit more flexibility as compare to Fourier Transforms.

Index Terms*- OWDM, OFDM, SNR, cf1, cf2, cf3, DVB-T, IFFT, FFT, Variance*

1. Introduction

The world's first commercial digital terrestrial service launched by UK in 1997, Digital Video Broadcasting Terrestrial standard has been developed in Europe; it uses Orthogonal Frequency Division Multiplex and Orthogonal Wavelet Division Multiplex as modulation scheme. In OFDM, the signal is being transmitted at a high data rate in serial transmission; the signal will be affected by the channel than a lower bit rate signal. Chang proposed than an alternative to serial transmission i.e. parallel transmission, in parallel transmission, the bit rates per subcarrier were lower.The aim of this service was to facilitate the switch off in the analogue services thus potentially freeing up a large number of RF channels for more services.In OFDM,it is important that the subcarriers remain orthogonal to each other. The IFFT uses Sin c shaped carriers (Sin x/ x) which are inherently orthogonal because the nulls of adjacent carriers align with the peaks of each carrier, this causes inter-carrier interference and corruption to the received tone [1].

OFDM is underlying technology of the DVB-T standard and comprises of an IFFT (Inverse Fast Fourier Transform) at the transmitter and FFT (Fast Fourier Transform) at the receiver which performs the frequency division multiplex. One advantage of OFDM over serial transmission in DVB-T that OFDM has a natural resilience for multipath. Even with its inherent advantage, there are some drawback to OFDM being the inflexibility and increase in computational complexity of the system. This means more complex devices are needed to reduce the power consumption. Instead of the different part of the symbol in different ways, there are small numbers of parameters that can be change in OFDM. An alternative is used the wavelet to separate the sub-band components like OFDM does, the system is called OWDM. The use of filters in the wavelet domain has been used for multi carrier resolution analysis of time varying signals. With OWDM, it is possible to dynamically allocate the number of sub-bands and bandwidth of each. With all this in mind, this paper OWDM as an alternative to OFDM in DVB-T which employs a true time -frequency division multiplex using wavelet which may provide more flexibility [2]-[4].

The objective of this paper is to identify how the new OWDM system can be compared with the existing OFDM system so simulation were first run using OFDM as the RF modulation front-end. Following this, the OFDM block was replaced with the OWDM block with same tests run. This paper is to investigate three wavelets of Coiflet family with increasing order to ascertain which wavelet transform is the most suited for use in an AWGN channel and compare the performance of OWDM with OFDM in terms of Variance and SNR for an AWGN environment with DVB-T parameters of 3/4 rate convolutional encoding, 64-QAM modulation and 1/32 Guard Interval.[5]-[8].

2. Digital video broadcasting- terrestrial

DVB-T is multi carrier system where each carrier modulated digitally and it has been adopted or proposed for digital television broadcasting by many countries, using mainly VHF 7 MHz and UHF 8 MHz channels whereas Taiwan, Colombia, Panama, Trinidad and Tobago and the Philippines use 6 MHz channels. DVB-T standard uses coded Orthogonal Frequency Division Multiplexing (COFDM) as modulation scheme. In COFDM, forward error correction is applied to the signal before transmission. Except this property, COFDM is same as OFDM. This is to be overcome a errors in the transmission due to lost carriers from channel noise, frequency selective noise and other propagation effects. The main focus of this project is on OFDM and OWDM, but in real-life application any practical system will be use forward error correction thus would be COFDM.The DVB-T network operator can choose one of the two modes of operation. First is 2K mode which is suitable for single transmitter operations and small single frequency networks (SFN) with limited transmitter distance. It employs 1705 carriers. 8K mode is suitable for single transmitter operations and small and large single frequency networks (SFN). It employs 6817 carriers. Existing DVB-T modes produce a transport capacity of 5-15 Mbps (1-3 TV Programs) suitable for mobile receivers. A simplified block diagram of the European DVB-T standard is shown in the figure below. A digital signal processor (DSP) performs most of the processes described in this diagram.

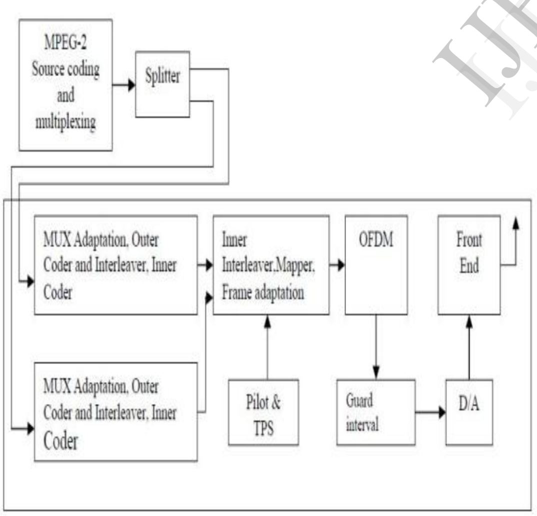

Fig.1.0 Digital Video Braodcasting Terrestrial

2.1 Ofdm

In the OFDM system, Inverse Fast Fourier Transform/Fast Fourier Transform (IFFT /FFT) algorithms are used in the modulation and demodulation of the signal. The length of the IFFT/FFT vector determines the resistance of the system to errors caused by the multipath channel. OFDM has been adopted in a number of wireless applications including Digital Audio Broadcast (DAB), Digital Video Broadcast (DVB), and Wireless Local Area Network (WLAN) standards such as IEEE802.11g and Long Term Evolution (LTE). OFDM is a technique widely used in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and also its robustness to multi-path fading without requiring complex equalization techniques. The DVB-T Orthogonal Frequency Division Multiplexing system uses multi carrier transmission. The common modulation for the carrier is QPSK, 16 QAM or 64- QAM, in case of using 16 QAM modulations, the no. of states is 16, and so 1 symbol represents 4 bits. If we simulate all the carriers in the constellation diagram we get not just one discrete point but many points forming a “cloud” and representing each state. In case of Additive Guassian White Noise (AGWN) the “cloud” gets bigger and the receiver may decide incorrectly resulting in bit error. The big difference between OFDM and OWDM is that in OFDM, the FFT performs sub band decomposition with a specific number of sub bands at well defined intervals, with OWDM; it is possible to dynamically allocate the number of sub bands and the bandwidth of each. Of course, if there were sufficient levels, the OWDM would start to resemble the OFDM Symbol.

2.2 Owdm

OWDM using the discrete wavelet transform is a multiplexing transmission method in which data being assigned to wavelet sub bands having different time and frequency resolution. Wavelet based system establishes a small bit error rate probability than that of the Fourier transform based system. In DWT -OWDM, the modulation and demodulation are implemented by wavelets rather than by Fourier transform. Wavelet modulation is modulation scheme to make use of wavelet transformations corresponding to the data being transmitted. The advantage of wavelet transform than other transforms such as Fourier transform is discrete both in time as well as scale. By increasing the order of the wavelets, the effect of aliasing can be decreased and therefore the orthogonality between the sub bands. The other advantage of OWDM is increase in resilience to frequency selective fading by increasing the error correction on the effected sub-bands and decrease in computational complexity from:

$$O\ N = N \log 2N \quad \text{to} \quad O\ N = N$$

OWDM allows each subcarrier to have different coding and different modulation depending on the channel requirements so increase in flexibility.

2.3 Wavelets

Wavelet theory is a powerful mathematical tool for analysis and synthesis of signals, wavelet technique permits much more flexibility as compare to Fourier Techniques. When performing a frequency analysis of a signal, often, if there is minimal variation in time, Fourier transform with appropriate windowing will provide accurate information. If however, there are fast fluctuations in the time domain or the time domain contains information that is relevant to how the frequency domain information is reacting, a time-frequency analysis is necessary. There are several mechanisms that can be used to do this but the most common three are the Short-Time Fourier Transform (STFT) that works by sweeping a window over the time-domain signal and presents a three dimensional spectrograph; the wavelet transform and wavelet packets.[9]-[15]. The wavelet transform maps a time function into a two dimension function of α instead of w - frequency, where α is called the scale and is the translation of the wavelet function along the time axis. The continuous waveform transform of a signal s (t) can be defined as

$$CWT(a,\tau) = \frac{1}{\sqrt{a}} \int s(t).\psi \frac{(t-\tau)}{a} dt \quad \text{.... (1)}$$

Where CWT is the Continuous Wavelet Transform, t is the time, Ψ (t) is the basic (or mother wavelet) and the $\Psi(t-\tau)/\alpha^{\sqrt{\alpha}}$ is the baby wavelet made by either stretching or compressing the mother wavelet[1].

4. Proposed System

The use of filters in the wavelet domain has been predominantly used for multi-resolution analysis of time varying signals, the big difference between OFDM and OWDM is that in OFDM. The FFT performs sub band decomposition with a specific number of sub bands at well defined intervals. Whereas OWDM, it is possible to dynamically allocate the number of sub bands and the bandwidth of each sub bands.

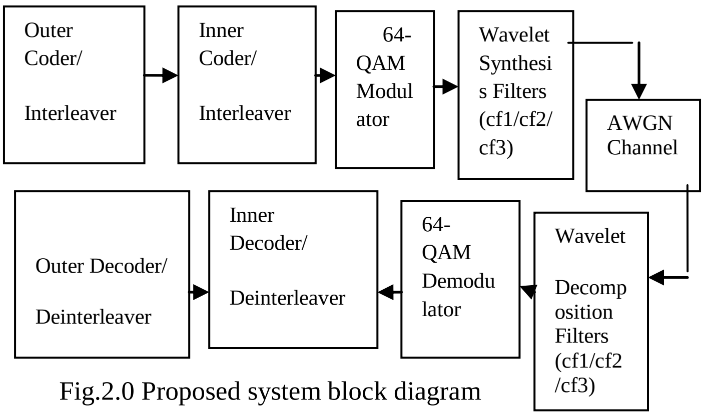

Fig.2.0 Proposed system block diagram

3. Simulation parameters & results

Now the system is simulated, the effects of showing different wavelets in the OWDM as compare with OFDM and analysis their response to Additive White Gaussian Noise (AWGN). Proposed model was considered taking in a binary sequence, 64-level Quardature amplitude modulation (64-QAM) on the stream, buffer up the results into a fixed symbol size and then pass the buffer through the OWDM modulator. The decision to present the results without coding was to demonstrate the error correction capabilities of the wavelet transform themselves. To compare the different wavelets, the buffered Quardature modulated block (containing the same information for eachtrial) was passed through the different wavelet filters. The output from the filter was passed through the AWGN channel with decreasing Signal to Noise Ratio (SNR) and then demodulated. The overall buffer size was set to 2048 symbols as per the DVB-T 2K system and only 2 levels of decomposition were used at this time. OFDM parameters in the 2k mode are given in the table below:

Parameter	2kmode			
Elementary period T	7/64 µs			
Number of carriers K	1705			
Value of carrier number K_{min}	0			
Value of carrier number K_{max}	1704			
Duration T_U	224 µs			
Spacing between carriers K_{min} and K_{max} $(K-1)/T_U$	7.61 MHz			
Carrier spacing $1/T_U$	4464 Hz			
Allowed guard interval Δ/T_U	1/4	1/8	1/16	1/32
Duration of symbol part T_U	2048xT 224 µs			
Duration of guard interval Δ	512xT 56 µs	256xT 28 µs	128xT 14 µs	64xT 7 µs
Symbol duration $T_s=\Delta+T_U$	2560xT 280 µs	2304xT 252 µs	2176xT 238 µs	2112xT 231 µs

Table 1: Parameters of 2K mode for DVB-T

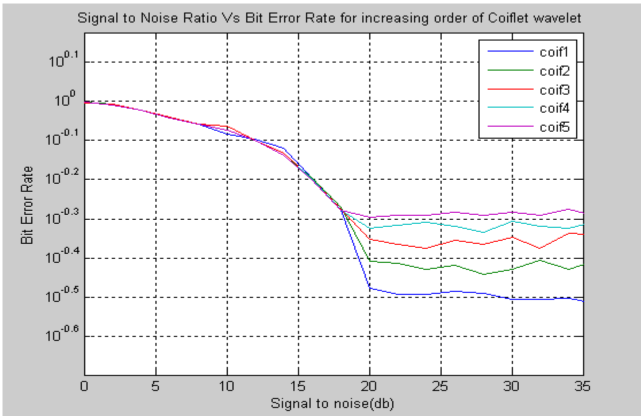

Fig.1.0 Signal to Noise Ratio Vs Bit Error Rate for increasing order of Coiflet wavelets in OWDM for DVB-T for 64-QAM.

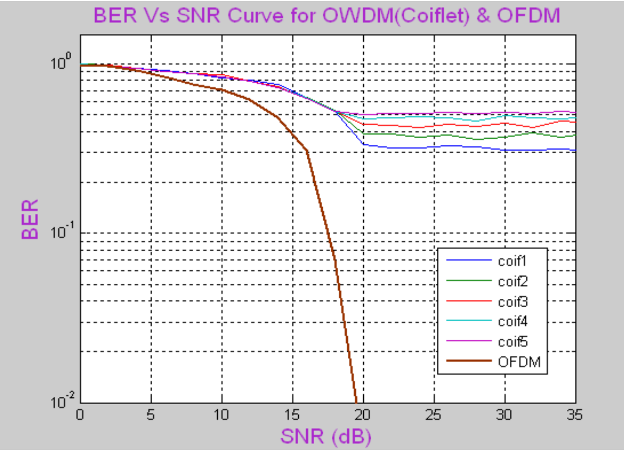

Fig.2.0 Signal to Noise Ratio vs Bit Error Rate for increasing order of Coiflet Wavelets in OWDM with OFDM for DVB-T.

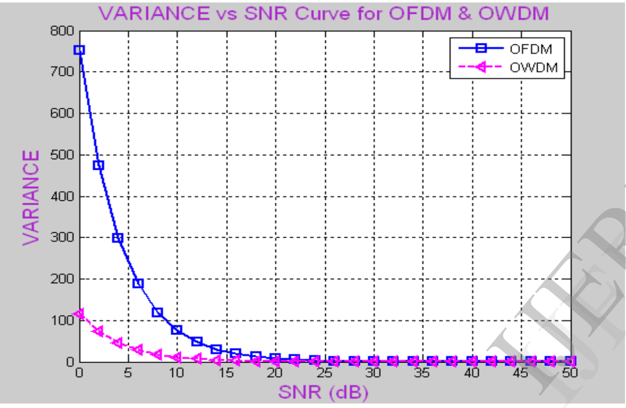

Fig.3.0. Variance vs SNR for OFDM and OWDM (cf1 wavelet filter in OWDM)

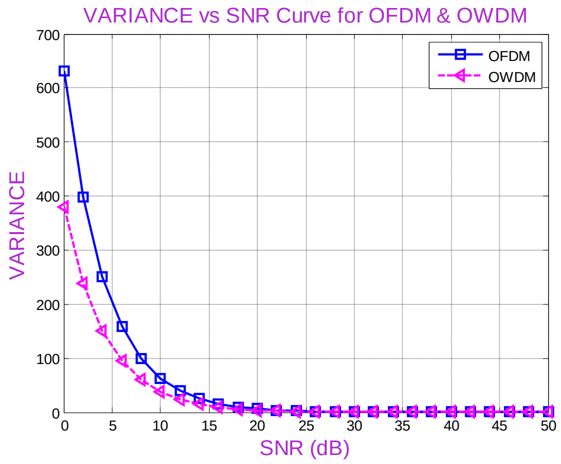

Fig.4.0 Variance vs SNR for OFDM and OWDM (cf2wavelet filter in OWDM)

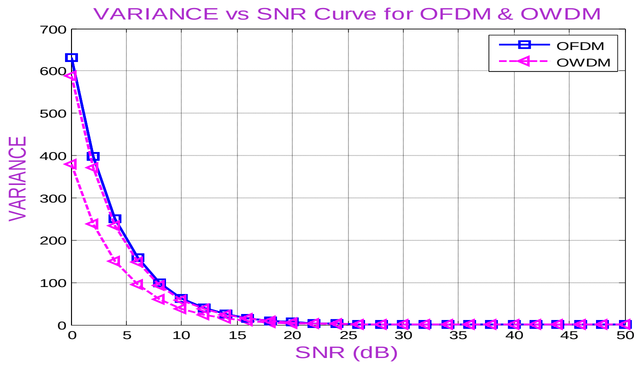

Fig.5.0 Variance vs SNR for OFDM and OWDM (cf2/cf3)

Fig.1.0 depicts the results of simulating the OWDM with Coiflet wavelet filters and comparing the Bit Error Rate (BER) at the output of the QAM demodulator against the channel Signal to Noise Ratio (SNR). From Fig.1.0 and Fig.2.0 it can be seen that as the order of filters of Coiflet family decreases, the resilience to noise increases. From Fig. 1.0 and Fig .2.0, itcan be seen that the least resilient wavelet is Coiflet 5 (cf5) then followed by Coiflet 4 (cf4), the Coiflet 3(cf3), Coiflet 2(cf2) and Coiflet 1 (cf1), as the order of filters increases, the tolerance to noise decreases, Coiflet 5 wavelet representing the weakest wavelet for use in OWDM.

Fig.5.0 shows the relationship of the Variance to the SNR for the wavelet transform where the different trace lines in Fig 5.0 depict the two different wavelet filters (cf2/cf3) of Coiflet family and OFDM. Fig.4.0 and Fig.5.0 depict the results of simulating the OWDM with different wavelet filters and comparing the variance at the output of the QAM demodulator against the channel signal to noise ratio (SNR). From Fig.5.0 it can be seen that as order of the filter increases in Coiflet family, their variance increases, it means performance of system decreases. The variance versus the SNR of the cf1 in OWDM is less as compare to cf2,cf3 and OFDM as well, this means OWDM system has lower computational complexity, increases flexibility and low multipath propagation loss.

5. Conclusion

In this paper we have demonstrated a set of simulation and comparison has been succeeded of Coiflet wavelet filters of OWDM with OFDM. From these results, it is suggested that the cf1 wavelet (the first wavelet of Coiflet family) is the most suited for OWDM because of the lower variance to

Noise in channel followed by Coiflet family, while cf2 and cf3 (the second wavelet of Coiflet family and the third wavelet of Coiflet family) is the least suited because it has high variance, this means as the order of wavelet filters increasing in a family, the variance is also increasing. The results showed that there were some OWDM scheme whose variance outperformed that of OFDM and cf1 wavelet achieved the best performance compared to other wavelet cf2, cf3 and OFDM as well. The system presented has no error correction coding, although in a practical system, coding would be included. In this paper, no error correction codes have been incorporated. However, these codes can be considered later on.

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