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WIRELESS COMMUNICATION USING OFDM BASED ON DUAL TREE COMPLEX WAVELET TRANSFORM

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***ABSTRACT*—Orthogonal frequency division multiplexing is used in wireless communication systems is to create and detect the subcarriers. Wireless communication requires high performance and high speed integrated services. This performance can be improved by using wavelet based OFDM system compared to FFT based OFDM system in terms of ISI and spectral efficiency. The wavelet based OFDM system are DWT-OFDM and Dual Tree-Complex Wavelet Transform (DT-CWT) based OFDM system. The new approach proposes a 5/3 wavelet filter OFDM based on DTCWT using QAM modulation. An alternative model DT-CWT based OFDM system using FSK modulation. Here the wavelet based OFDM are modeled using MATLAB software. The performance of different OFDM models are evaluated in terms of BER and the simulation results show that both the DWT and DTCWT based OFDM system outperform standard FFT-OFDM system with the gain more than 3db.**

***Index terms*—OFDM, FFT, DWT, DT-CWT, FSK, MATLAB, BER.**

I.INTRODUCTION

OFDM is a multicarrier modulation technique used in modern wired and wireless communications systems. An Orthogonal Frequency Division Multiplexing (OFDM) system utilizes a parallel processing technique which allows the simultaneous transmission of data closely spaced in orthogonal sub-carriers. Traditionally, OFDM is implemented using FFT. Inverse Fast Fourier Transform and Fast Fourier transform used in a conventional OFDM system are to multiplex the signals together and decode the signal at the receiver respectively. This transform has disadvantages is that it uses a rectangular window, that creates high side lobes. The pulse shaping function which is used to modulate the subcarriers extends to infinity in frequency domain. This leads to high interference and hence lower performance level. The Inter symbol interference (ISI) and Inter channel interference can be avoided by appending a cyclic prefix (CP) to OFDM symbol, it requires more bandwidth due to redundant CP. This reduces the spectral efficiency.

The numbers of modulation schemes based on wavelets have been proposed. The OFDM implemented by using IFFT and FFT have some problems. One of a major problem of this system is the high bit error rate (BER). Due to this problem we look at other type of modulation to generate the carrier. The proposed method a new wavelet based OFDM system which uses DT-CWT instead of FFT. DT-CWT has the same advantages as the DWT, but DT-CWT produces better results of BER reduction than DWT. In the OFDM system based on DT-CWT the FFT and IFFT are replaced by the DT-CWT and the inverse DT-CWT (IDT-CWT) respectively.

In this paper is organized as follows: In section II we discuss DWT; in section III we discuss the DT-CWT; in section IV we discuss the Bit Error Ratio; in section V DT-CWT BASED OFDM SYSTEM; in section VI EXPERIMENTAL RESULTS; in section VII we conclude this paper in simulation results.

II. DISCRETE WAVELET TRANSFORM

DWT is a multi-resolution analysis tool. The wavelet series is simply a sampled version of the CWT, and the information it provides is highly redundant as far as reconstruction of the signal is concerned. This redundancy on the other hand it requires a sufficient amount of computation time and resources. The discrete wavelet transform (DWT), it provides sufficient information for both the analysis and the synthesis of the original signal, with a significant reduction in the computation time. The DWT replaces the infinitely oscillating sinusoidal basis functions of the Fourier Transform with a set of locally oscillating basis functions called wavelets. These wavelets are stretched and shifted versions of a real-valued band-pass wavelet $\Psi(t)$. When carefully chosen and then combined with shifts of a real valued low-pass scaling function ϕ(t), it forms an orthonormal basis expansion for one dimensional real valued continuous time signals. The limited energy analog signal x(t) can be decomposed in terms of wavelets and scaling functions obtained.

$$x(t) = \sum_{n=-\infty}^{\infty} c(n)\,\phi(t-n) + \sum_{j=0}^{\infty}\sum_{n=-\infty}^{\infty} d(j,n)2^{\frac{j}{2}}\,\psi(2^{j}t-n)$$

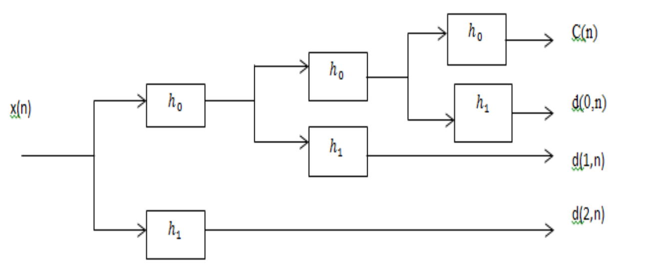
The scaling coefficients c (n) and the wavelet coefficients d(j-n) are computed via the inner products

$$c(n) = \int_{-\infty}^{\infty} x(t)\phi(t-n)$$

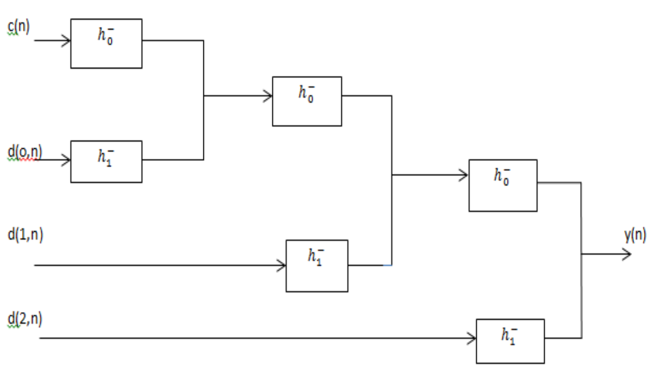
$$d(j-n) = \int_{-\infty}^{\infty} x(t)\psi(2^{j}t-n)dt$$

They provide a time-frequency analysis of the signal by measuring its frequency content (controlled by the scale factor j) at different times. There exists a very efficient, linear time complexity algorithm to compute the coefficients c(n) and d(j-n) from a fine-scale representation of the signal.

A discrete-time FB low-pass filter, high-pass filter, up-sampling and down-sampling operations. Fig. 1 show the FB trees implementation, the analysis (forward) and synthesis (inverse) DWT.



(a)



(b)

Fig 1:Filter bank tree implementing the(a)analysis(forward)

and (b)Synthesis (inverse)DWT

III. DUAL TREE COMPLEX WAVELET TRANSFORM (DTCWT)

Complex wavelet transform is complex-valued filtering that decomposes the real or complex signals into real and imaginary parts in transform domain. Complex wavelet transform (CWT) is applied in digital image processing perfectly. The DTCWT inspires a new filter pairs ($h_0(n)$,$h_1(n)$ the low-pass/high-pass filter pair for the upper FB respectively) and ($g_0(n)$, $g_1(n)$ the low-pass/high-pass filter pair for the lower FB respectively) are use to explain the sequence of Ψ(t) and ϕ(t) as follows

$$\psi_h(t) = \sqrt{2}\sum_{n} h_1(n)\phi_h(t)$$

$$\phi_h(t) = \sqrt{2}\sum_{n} h_0(n)\phi_h(t)$$

Where $h_1(n) = (-1)^n h_0(d-n), \psi_g(t), \phi_g(t)$and $g_1(n)$are explained. The two real transforms are $\psi_h(t)$ and$\psi_g(t)$. $\psi_g(t)$ is approximately the Hilbert transform of $\psi_h(t)$. $[\psi_g(t) = H\{\psi_h(t)\}]$

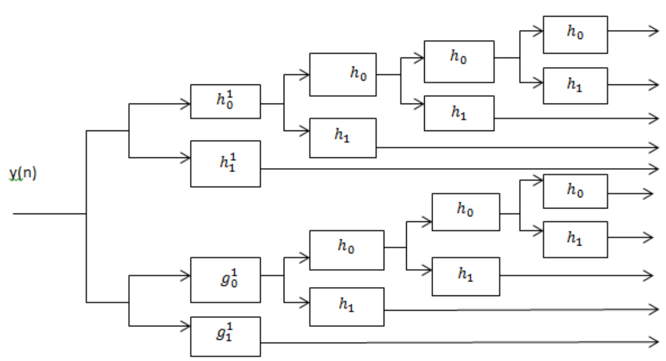


Fig 2: The dual tree discrete CWT (DT-DCWT) Analysis (demodulation) FB.

The DTCWT employs two real DWT the upper one gives the real part of the transform and the lower one gives the imaginary part. The analysis and the synthesis FB used to implement the DTCWT and its inverse are illustrated in fig. 2 and fig. 3.

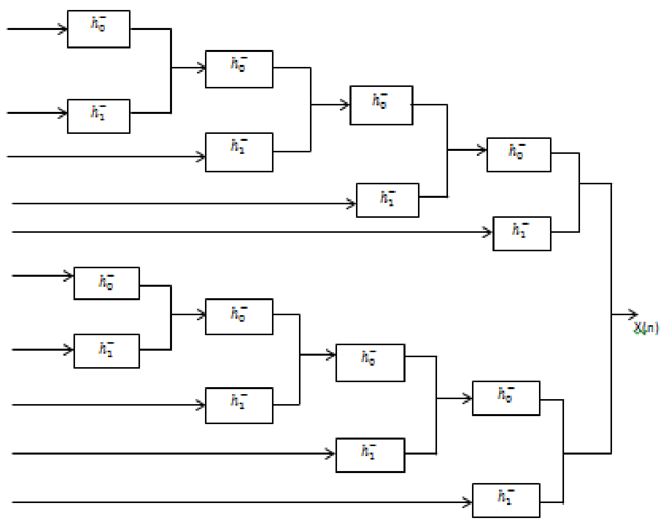


Fig 3: The Inverse dual tree discrete CWT (IDTDCWT) Synthesis (modulation) FB.

If the two real DWTs are represented by the square matrices F_h for the upper part and F_g for the lower part, then the DTCWT can be represented by the following form.

$$F_C = \frac{1}{\sqrt{2}}\begin{pmatrix}1 & jI\\ 1 & -jI\end{pmatrix}\begin{pmatrix}F_h\\ Fg\end{pmatrix}$$

And the IDTCWT is given by

$$F_c^{-1} = \frac{1}{\sqrt{2}}\left(F_h^{-1}\,F_g^{-1}\right)^{-1}\begin{pmatrix}I & I\\ -jI & jI\end{pmatrix}$$

The complex sum/difference matrix in (6) is unitary

$$\frac{1}{\sqrt{2}}\begin{pmatrix}I & jI\\ I & -jI\end{pmatrix}.\frac{1}{\sqrt{2}}\begin{pmatrix}I & I\\ -jI & jI\end{pmatrix} = I$$

Note that the identity matrix on the right hand side is twice the size of those on the left hand side. Therefore if the two real DWTs are orthonormal transforms, then the DTCWT satisfies$F_c^*.F_c = I$,where * denote the conjugate transpose.

IV. BIT ERROR RATIO

The two parameters which are related and necessary to evaluate the performance of the OFDM system are PAPR and BER .It proved that the PAPR obtained for DWT-OFDM system outperforms the FFT-OFDM. In our work the performance of OFDM system is evaluated with respect to its BER (Bit Error Ratio). Here, the BER is calculated for FFT, DWT and DT-CWT based OFDM system then it is compared with each other.

In wireless communication the bit error is calculated based on the received bit stream. Any alteration in the received signal shows some error is present in the signal. So, the bit error ratio is defined as follows

$$\text{BER}=\frac{\text{Bit errors}}{\text{total number of transmitted bits}}$$

V. DT-CWT BASED OFDM SYSTEM

DT-CWT using OFDM system is a non-redundant wavelet transform achieves approximately shift invariance Similar to the FFT- OFDM and DWT systems, a functional block diagram of OFDM based on DT-CWT is shown in fig. (4). At the transmitter an inverse DTCWT (IDT-CWT) block is used in place of inverse FFT (IFFT) block in conventional OFDM system or in place of inverse DWT (IDWT) block in WPM systems. At the receiver side a DT-CWT is used in place of FFT or in place of DWT block. Data to be transmitted are typically in the form of a serial data stream. FSK modulation can be implemented in proposed system .It depends on various factors like bit rate and sensitivity of errors. The transmitter accepts modulated data. The data stream is passed through a serial to parallel (S/P) converter, giving N lower bit rate data stream, then the stream is modulated through an IDT-CWT it realized by an N-band synthesis FB. Before the receiver can demodulate the subcarriers, and the synchronization operation is performed. For the proposed system, known data interleaved and unknown data are used for channel estimation. Then, the signal is down sampled by N and demodulated using elements of the DT-CWT matrix it realized by an N-band analysis FB. The signal is equalized after DT-CWT stage.

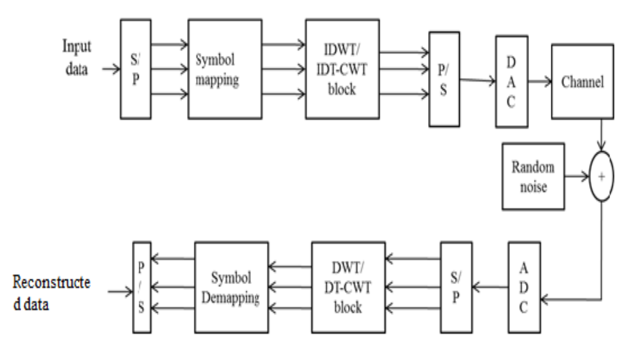


Fig 4: Functional block diagram of OFDM based on DT-CWT

IDT-CWT works in a similar fashion to an IFFT or IDWT. It takes as the input FSK symbols and outputs are in parallel time-frequency "subcarriers". The synthesis process, the transmitted signal, x_n is constructed as the sum of M waveform and it can be modulated with the FSK and PSK symbols.Let ψ_t be the scaling function, ψ_t be the waveletfunction, a_i is k-th symbol, i=1,2,……,N as follows:

$$x(n) = Re[x(n)] + jIm[x(n)]$$

$$Re[x(n)] = a_{1,k}\Psi_{1,k}(n) + \sum_{j=2}^{\frac{N}{2}} a_{j,k}\Psi_{j,k}(n)$$

$$Im[x(n)] = a_{\frac{N}{2}+,K}\Psi_{\frac{N}{2}+1,K}(n) + \sum_{j=\frac{N}{2}+2}^{N} a_{j,k}\Psi_{j,k}(n)$$

Where$a_{i,j}$ is an encoded i-th data symbol modulating the j-th DT-CWT function.The IDT-CWT synthesis a discrete representation of the transmitted signal as sum of M waveforms shifted in time. Those waveforms are built by j successive iterations ofh_0, h_1 and g_0, g_1.

The DT-CWT at the receiver recovers the transmitted symbols$a_{i,j}$ through the analysis formula exploiting orthogonality properties of DT-CWT.

In the baseband equivalent OFDM transmitter with m-th frame of N FSK symbols, a_k^m, k=0,1,….,N-1, the OFDM frame is given by:

$$x^m(n) = \sum_{k=0}^{N-1} a_k^m \, e^{j2\pi nk/N}$$

The transmitted signal x[n] is constructed as the sum of M wavelet packet function $\phi_j[n]$ individually modulated with the FSK symbols.

$$x[n] = \sum_i \sum_{j=0}^{M-1} a_{i,j} \, \Psi_j[n - iM]$$

The construction of discrete versions of transmitted waveforms for the conventional OFDM and DWT systems using the above equations are quite similar. For any time index n, both waveforms are sum of random symbols a_k or $a_{i,j}$.

VI. SIMULATION RESULTS

The result given in the section compare the BER in the OFDM based on DT-CWT, with that for FFT and DFT based OFDM. Also, same simulation parameters are used to achieve a comparison between the results. The results of BER

The results for BER shown that the proposed scheme gives excellent improvements in BER over FFT and DWT systems. At the same time the DWT outperform the FFT system in term of BER. The simulation results for BER using FFT-OFDM, DWT-OFDM, DTCWT-OFDM is shown in fig 5,6 and 7.

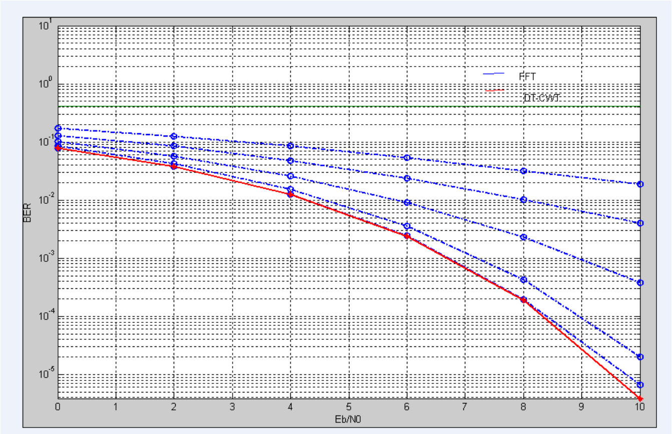


Figure 5: BER performance of FFT-OFDM and DTCWT -OFDM

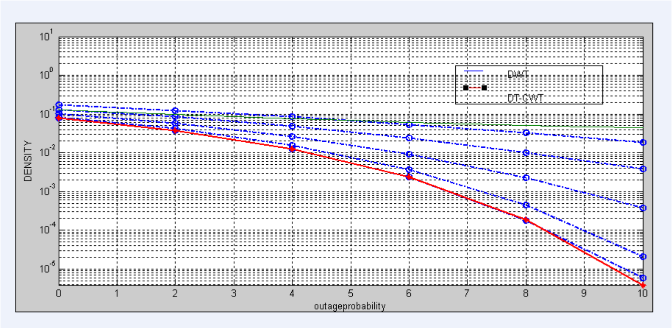


Figure 6:BER performance of DWT-OFDM and DTCWT-OFDM

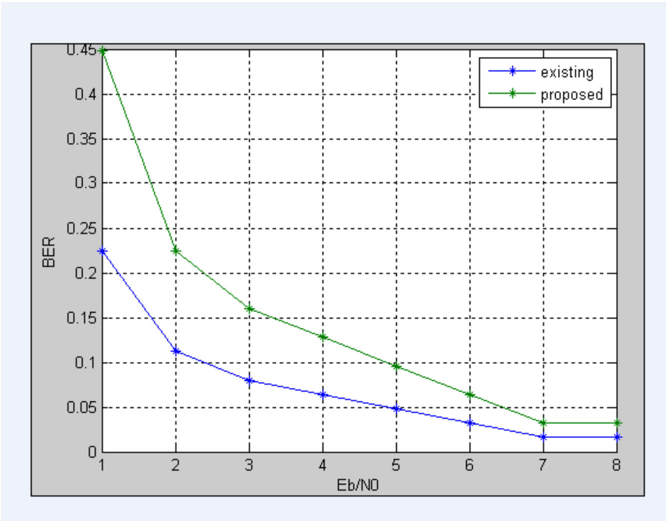


Figure 7: The effect of using the different modulation schemes in BER

VII. CONCLUSION

In this paper a new OFDM model using DT-CWT is proposed. The DT-CWT based OFDM which is more advantageous than FFT-OFDM in terms of spectral efficiency, PAPR and BER. DWT based OFDM system has lower bit error rate compared with FFT-OFDM but it does not meet some properties which are important for processing the signal in efficient way. The properties which are not meet by DWT based system are shift invariant, directional selectivity and phase information are achieved by using DT-CWT based OFDM system due to its FSK modulation. Here, this DTCWT is modeled using the selesnick's filter. Simulation result also proved that BER value is lower for DT-CWT based OFDM system provides the gain of 3dB for FSK modulation with FFT based OFDM system.

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