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New and Efficient DWT SC-FDMA System for Image Transmission

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ABSTRACT

The demand for high speed and efficient wireless communication systems for image transmission has grown due to increasing demands of wireless multimedia applications such as remote sensing via satellite, nuclear medicine, telemedicine, teleconferencing, broadcast television and accessing Internet services on mobile phones with a high-bit-rate transmission and better quality of the offered services.

This paper proposes a new efficient single carrier frequency division multiple access (SC-FDMA) system which is currently adopted as the uplink multiple access scheme in 3GPP LTE because it has many advantages over OFDMA. The proposed system uses Discrete Wavelet Transform (DWT) which is widely used to transform an image from the spatial domain to frequency domain to overcome the high implementation complexity drawback of SC-FDMA due to the Discrete Fourier Transform (DFT) and Inverse Discrete Fourier Transform (IDFT) operations. Simulation of the proposed system is done using Matlab software and measurement of the reconstructed images quality is done using the Peak Signal to Noise Ratio (PSNR) at the receiver. The simulation results show that the proposed DWT based SC-FDMA system provides a better PSNR performance than the DFT SC-FDMA and the DCT SC-FDMA systems.

Keywords: *Wireless Communication, Communications, Digital Signal Processing, Digital Image Processing,*

1. INTRODUCTION

Single Carrier Frequency Division Multiple Access (SC-FDMA) is a promising technique for high data rate uplink communication. SC-FDMA is a modified form of OFDM in which the data symbols of each user are first modulated in the time domain and then DFT-spread across the data subcarriers. The main advantage of SC-FDMA over OFDMA is that the SC-FDMA has a lower Peak-to-Average Power Ratio (PAPR) than OFDM because of its inherent single carrier nature. This lower PAPR makes it suitable for uplink transmission and improves the transmit power efficiency and is therefore seen as an attractive alternative to OFDMA [1]:[7].

Two variants of SC-FDMA have emerged, that differ in the manner in which the sub-carriers are mapped to a particular user. These are the Interleaved-FDMA (I-FDMA) approach which assigns equi-distant sub-carriers to each user and the Localized-FDMA (LFDMA) approach whereby groups of contiguous subcarriers are assigned to a particular user [2], [3], [4] and [8].

Discrete Wavelet Transform (DWT) becomes more popular over traditional Discrete Fourier Transform (DFT) and Discrete Cosine Transform (DCT) in digital signal processing applications mainly because of its capability of multi-resolution signal analysis with localization in both time and frequency and better performance factors. DWT can be viewed as a multi resolution decomposition of a signal into its components in different frequency bands and analyzing each component with a resolution matched to its scale [9], [10].

The wavelet transform becomes a very important tool for many different fields of mathematics, physics and engineering, such as digital communications, remote sensing, biomedical signal processing, medical imaging, astronomy, numerical analysis, digital signal compression, noise reduction, turbulence, human vision, radar, and earthquake prediction acoustics, nuclear engineering, sub-band coding, signal and image processing, neurophysiology, music, magnetic resonance imaging, speech discrimination, optics, fractals, turbulence, earthquake-prediction, radar, human vision, and pure mathematics applications such as solving partial differential equations and etc [10].

The rest of the paper is organized as follows: Section 2 will introduce the Discrete Wavelet Transform. Section 3 will explain our proposed scheme. Section 4 is preserved for the experimental results. The concluding remarks are in Section 5.

2. DISCRETE WAVELET TRANSFORM

Wavelets are used to analyze signals for which the Fourier Transform is inadequate. The Fourier Transform is good for sinusoidal signals but has difficulty with discontinuous signals, like an image with edges. Both transforms break down a signal into simpler signals, called sinusoids for the Fourier Transform, and wavelets for the wavelet transform. These simpler signals can be added together to recreate the original. One difference between wavelets and Fourier transforms is that the wavelet exists for a few cycles, while the sinusoid cycles forever. This limited duration means that the wavelet transform is more efficient.

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Wavelet is a suitable tool for transient, non-stationary or time-varying phenomena so it provides a way where an image can be de-correlated without introducing any artifacts or distortions. The Wavelet transform is a compression algorithm that decomposes the image into sub-image of different spatial domain and independent frequency district using low-pass and high-pass filters. The image is then divided into four sub-bands. These 4 frequency districts which are one low-frequency district (LL) and three high-frequency districts (LH, HL, HH) as shown in figure 1 and figure 2 [5], [9]: [14] .

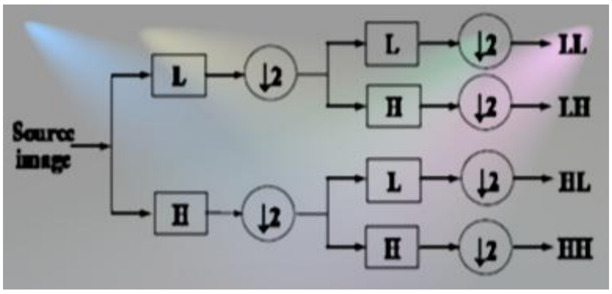


Figure 1: Structure of DWT

The information of low frequency district is an image close to the original image as it has most signal information of original the image. The frequency districts of LH, HL and HH respectively represents the level detail, the upright detail and the diagonal detail of the original image as shown in figure 3.

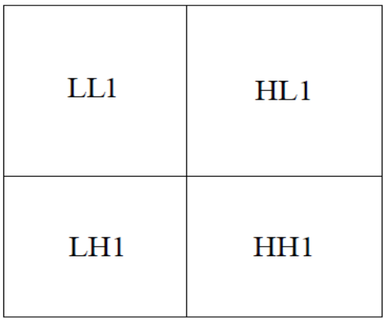
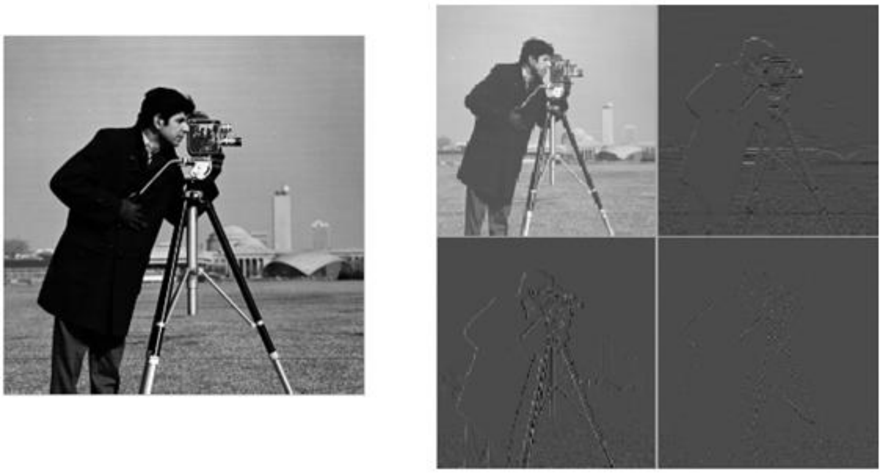


Figure 2: One Level DWT Decomposition



(a) **(b)**

Figure 3: (a) Original Image and (b) DWT Decomposed Image Structure

The discrete wavelet transform (DWT) produce a set of wavelet coefficients. These coefficients capture information from the time series at different frequencies at distinct times. For a function *f* defined on the entire real line, a suitably chosen mother wavelet function ψ can be used to expand *f* as,

$$f(t) = \sum_{j=-\infty}^{\infty} \sum_{k=-\infty}^{\infty} w_{jk}\, 2^{\frac{j}{2}} \psi(2^j t - k) \qquad (1)$$

Where the functions $\psi(2^j t - k)$ are all orthogonal to one another. The coefficient w_{jk} conveys information about the behaviour of the function *f* concentrating on effects of scale around 2^{-j} near time $k \times 2^{-j}$.

3. DWT SC-FDMA SYSTEM CONFIGURATION

Digital images and videos have become an integral part of entertainment, business, and education in our daily life as one image is worth than thousand words. So, it is important to study image communication over evolving technologies such as SC-FDMA .The proposed image communication system through DWT SC-FDMA is shown in Figure 4.

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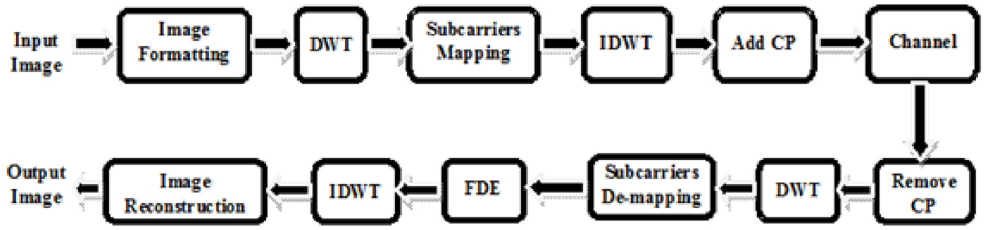

Figure 4: DWT SC-FDMA Scheme for Image Transmission

At the transmitter, the image is firstly converted to a binary form in the "Image Formatting" block suitable to be transmitted and processed by the System. Then, the signal is transformed into frequency domain to produce frequency domain in "DWT" block. The outputs are then mapped to orthogonal subcarriers followed by the (IDWT) block to convert to a time domain complex signal sequence. The subcarrier mapping assigns frequency domain modulation symbols to sub-carriers. It also adds a set of symbols as cyclic prefix (CP) in order to provide a guard time to prevent inter-block interference due to multipath propagation. The cyclic prefix is a copy of the last part of the block. It is inserted at the start of each block. Then transmitted data propagates through the channel [15].

At the receiver, the CP is removed then the received signal is transformed into the frequency domain in "DWT" block in order to recover sub-carriers. The de-mapping operation isolates the frequency domain samples of each source signal because SC-FDMA uses single carrier modulation. Then, the samples are equalized through the Frequency Domain Equalizer (FDE). After that, the equalized symbols are converted back to the time domain through (IDWT) block. The Image reconstruction used to convert the binary form to an image to recover the original image.

4. SIMULATION RESULTS

The image transmission over conventional wireless network requires broadband and long data transmission time and moreover it even cannot be done at the low Signal-to-Noise Ratio (SNR) channel condition.

Measurement of the reconstructed images quality is done using the PSNR at the receiver as performance criteria. PSNR describes the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of this signal. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale. The PSNR is defined as follows [15]:

$$PSNR = 10log_{10}[\frac{max_f^2}{MSE}] \qquad (2)$$

Where max_f is the maximum possible pixel value of an image (f). For grayscale images; 8 bit pixels (*bits* = 8 *hence* $max_f = 2^{bits} - 1 = 255$).

MSE: is the Mean Square Error. For an N×N monochrome image, it is defined as:

$$MSE = \frac{\sum[f(i,j) - \hat{f}(i,j)]^2}{N^2} \qquad (3)$$

Where: $f(i,j)$ is the source image, and $\hat{f}(i,j)$ is the reconstructed image.

To evaluate the performance and efficiency of the proposed system (IFDMA and LFDMA) in case of AWGN channels and SUI-3 channel**,** different images are used such as cameraman image (256×256 size gray scale), which used as an input to the system at different SNR values. The system simulation parameters are as shown in table 1.

The simulation results are shown in Figure 5. The comparison between the PSNR values of the output images of the proposed DWT-SC-FDMA system and other system which based on either DCT or DFT [15] are illustrated in table 2. These PSNR comparisons are plotted in Figure 6. The results show that the proposed DWT SC-FDMA output images have PSNR values higher than that based on either DCT or DFT.

Simulation Parameter	**Value**
FFT Size	512 symbols
Input Block Size	128 symbols
Cyclic Prefix Size	20 samples
Image Size	256 × 256
Modulation Type	DWT
Subcarriers Mapping	Interleaved and Localized
Channel Model	SUI3 and AWGN channel
Noise Environment	AWGN
Equalizer Type	MMSE equalizer

Table 1: Simulation Parameters

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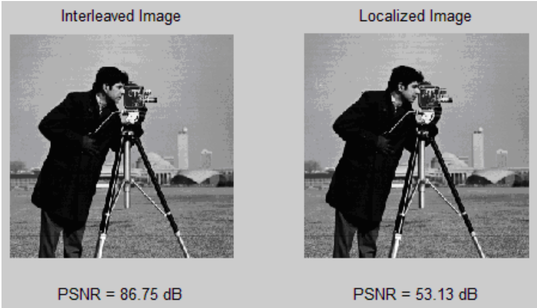
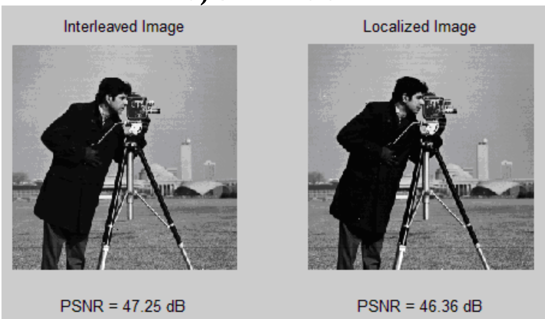
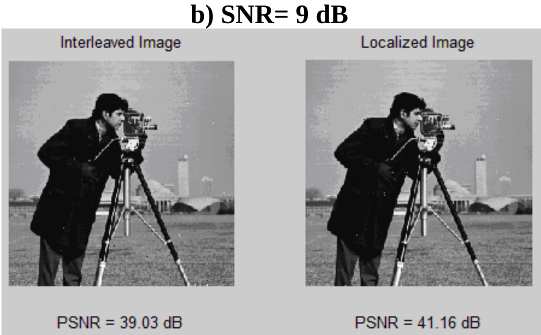


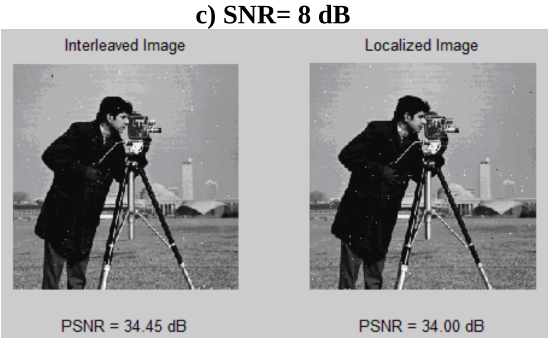
a) SNR= 10 dB



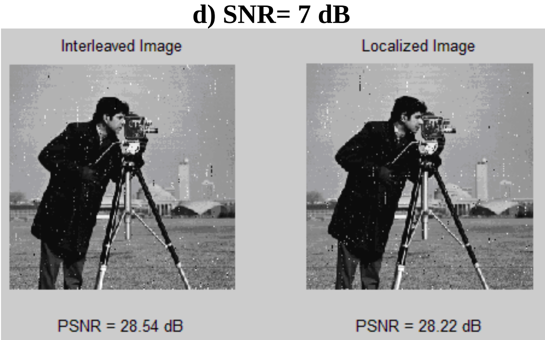
b) SNR= 9 dB



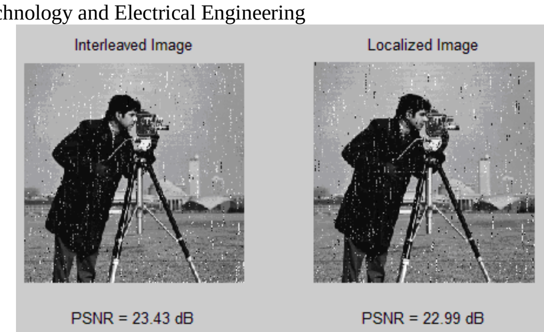
c) SNR= 8 dB



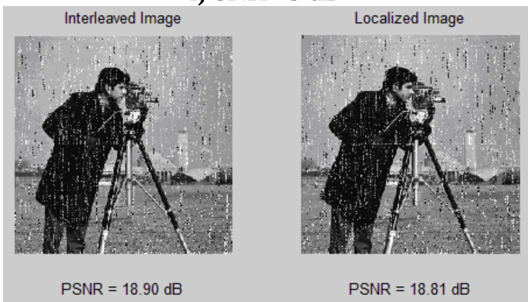
d) SNR= 7 dB



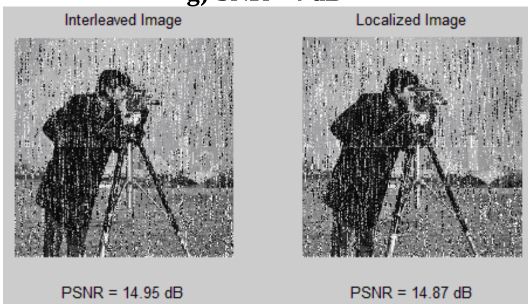
e) SNR= 6 dB



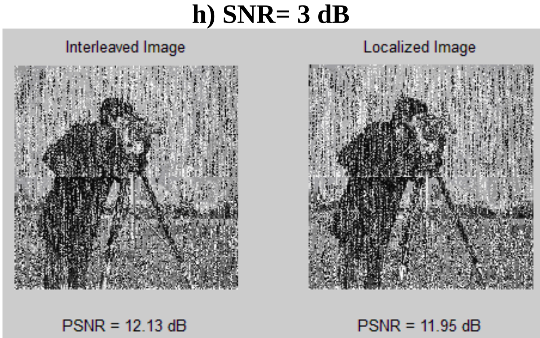
f) SNR= 5 dB



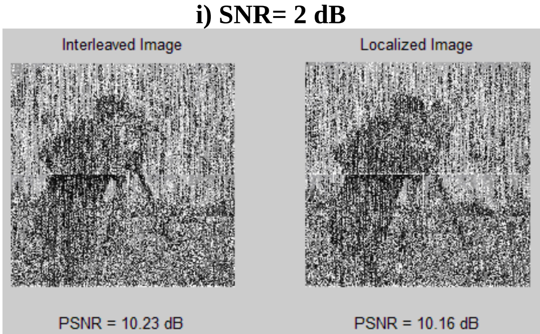
g) SNR= 4 dB



h) SNR= 3 dB



i) SNR= 2 dB



k) SNR= 1 dB

Figure 5: Simulation Experimental Results at Different SNR Values

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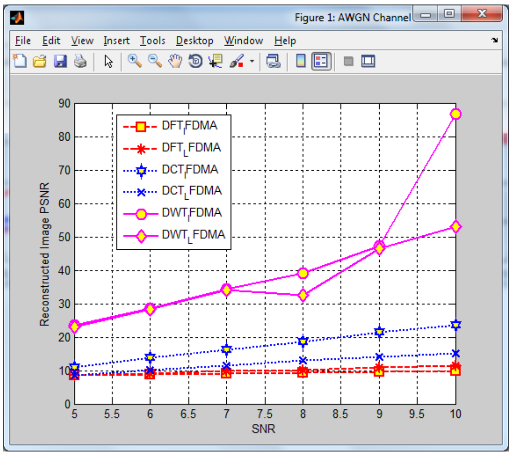
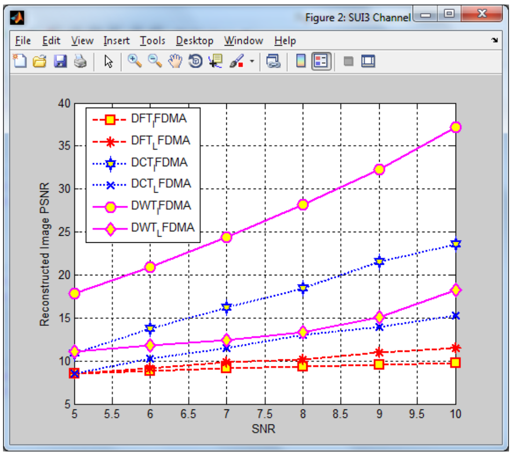
5. CONCLUSIONS

SC-FDMA has been adopted as the uplink multiple access scheme in Long Term Evolution (LTE) mainly due to its low peak-to-average power ratio (PAPR) which greatly improves the transmit power efficiency.

A new efficient SC-FDMA system using Discrete Wavelet Transform (DWT) to be used for efficient image transmission is proposed. The Proposed system is simulated using Matlab software and the simulation results showed that the proposed DWT based SC-FDMA system provides a better Peak Signal to Noise Ratio (PSNR) performance than the DFT SC-FDMA and the DCT SC-FDMA systems.



(b)



(a)

Figure 6: Output Image PSNR versus Channel SNR for the DWT-SC-FDMA through (a) SUI-3 Channel and (b) AWGN Channel

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SNR	Proposed DWT SC-FDMA AWGN Channel		Proposed DWT SC-FDMA SUI-3 Channel		Ref. [15] Without Randomization				Ref. [15] With Randomization			
					DFT		DCT		DFT		DCT	
	lFDMA	LFDMA	lFDMA	LFDMA	lFDMA	LFDMA	lFDMA	LFDMA	LFDMA	lFDMA	IFDMA	LFDMA
5	23.43	22.99	17.86	11.07	8.49	8.53	10.84	8.49	8.58	8.81	13.97	9.85
6	28.54	28.22	20.93	11.79	8.8	9.1	13.80	10.25	9.4	10.2	17.8	12.5
7	34.45	34.00	24.44	12.45	9.1	9.9	16.2	11.5	9.9	12.0	21.9	13.8
8	39.03	32.39	28.17	13.38	9.4	10.2	18.5	13	10.0	13.6	24.8	15.6
9	47.25	46.36	32.29	15.09	9.6	11	21.5	14	10.2	14.8	28.2	17.8
10	86.75	53.13	37.22	18.26	9.78	11.5	23.56	15.25	10.69	15.65	31.6	18.98

Table 2: Comparison between the Results of the Proposed DWT-SC-FDMA System and the Results of DCT and DFT based SC-FDMA Systems in Ref. [15]