Journal of Engineering Sciences
Assiut University
Faculty of Engineering
Vol. 42
No.4
July 2014
Pages: 983–1001

PROPOSED APPROACHES TO ENHANCE THE ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING SYSTEM

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Recieved15 June 2014; Accepted 15 July 2014

ABSTRACT

In the Orthogonal Frequency Division Multiplexing (OFDM) systems, where the data symbols are transmitted in parallel on different carriers, the length of a symbol is extended. This extension of the symbol length causes the OFDM system to be less sensitive to channel dispersion than a single carrier system transmitting data symbols at the same data rate. However, at the edges of the OFDM symbol, the channel dispersion still causes distortion, and hence introduces interference between successive symbols (i.e. Inter-Symbol Interference, ISI) and interference between different carriers within the same symbol (i.e. Inter-Carrier Interference, ICI). Different guard interval techniques for the OFDM transmission were suggested to reduce the interference between successive symbols. The most commonly used guard interval is the cyclic prefix (CP). In this paper, the impact of replacing the CP by zero insertion (ZI) before the Inverse Fast Fourier Transform (IFFT) process on the OFDM transmitter is studied. The motivation of using the ZI instead of the CP is the reduction in the transmission rate and the high performance in reducing the channel distortion. Moreover, the proposed ZI-OFDM system is suitable to minimize the effect of the fading channel when the channel characteristics are unknown or difficult to be estimated. Another approach to enhance the OFDM system is also introduced in this paper. A signal denoising approach is suggested to be added in the receiver to reduce the effect of the additive white Gaussian noise (AWGN) channel. In this approach, the Radio Frequency signal (RF) is enhanced using a wavelet thresholding technique instead of enhancing the baseband signal. The simulation results show that the proposed ZI approach provides better transmission performance than the recent techniques and achieves a 20 % reduction in the data redundancy relative to the redundancy in the CP-OFDM system. Moreover, the results show that the proposed thresholding approach significantly removed the noise and the signal power is enhanced by almost 30 db with different values of the channel signal-to-noise ratio (SNR). The overall system performance of the proposed ZI approach in the transmitter together with the thresholding approach in the receiver is tested in this paper.

Keywords: wavelet thresholding, Gaussian noise, signal denoising, Inter-Symbol Interference (ISI), Inter-Carrier Interference (ICI), cyclic prefix.

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1. Introduction

The Orthogonal Frequency Division Multiplexing (OFDM) is a special form of multicarrier modulation (MCM), where a single data stream is transmitted over a number of lower rate subcarriers. It is worth mentioning here that OFDM can be seen as either a modulation technique or a multiplexing technique. One of the main reasons to use OFDM is to increase the robustness against frequency selective fading and narrowband interference. In a single carrier system, a single fade or interferer can cause the entire link to fail, but in a multicarrier system, only a small percentage of subcarriers will be affected. Error correction coding can then be used to correct the few erroneous sub-carriers. In OFDM systems, where the data symbols are transmitted in parallel on N different carriers, the length T of a symbol is extended with a factor N (J., 1990). This extension of the symbol length causes the OFDM system to be less sensitive to channel dispersion than a single carrier system transmitting data symbols at the same data rate. However, at the edges of the OFDM symbol, the channel dispersion still causes distortion, and hence introduces interference between successive symbols (ISI) and interference between different carriers within the same symbol (ICI). To reduce the effect of the ISI, each symbol is extended with a guard interval. When the length of the guard interval is longer than the duration of the channel impulse response, ISI can completely be removed. However, as the transmission efficiency reduces with the insertion of the guard interval (during the guard interval, no new information can be transmitted); the guard interval must be chosen sufficiently small. The most commonly used guard intervals are the cyclic prefix (Prasad, 1998), the Zero Padding (ZP), and the Known Symbol Padding (KSP) [14]. Fig.1 shows the CP-OFDM block diagram. The basic concept of the OFDM system and its applications is illustrated in many references(Nee & Prasad, 2000; Noble, Sneddon, & G. Eason, 1955).Cyclic Prefix is used in OFDM system to compensate (overcome) synchronization mismatch problem in a multipath fading channel, which are typically of significant order, because every echo component of the signal is poorly synchronized signal. As a consequence, the base pulses of the original OFDM signal and the delayed version of the signal are no longer orthogonal. This leads to several ISI in time and frequency as well because the detector output $\mathcal{D}_{\mathrm{kl}}[\mathrm{s}_\tau]$ at frequency number k and time slot l of the delayed signal $\mathrm{s}_\tau(\mathrm{t}) = \mathrm{s}(\mathrm{t}-\tau)$ with $0 < \tau < T$ has ISI contributions from pulses at all subcarrier frequencies at time slot$l$ and$l-1$. The output of the detector$\mathrm{g}'_{\mathrm{k'l'}}(\mathrm{t})$, given that the pulses $\mathrm{g}_{\mathrm{kl}}(\mathrm{t})$ has been transmitted is

$$\langle g_{kl}, g'_{k'l'}\rangle = \sqrt{\frac{T}{T_S}}\delta_{kk'}\delta_{ll'}$$

The detector base pulses $\mathrm{g}'_{\mathrm{k'l'}}(\mathrm{t})$ and the transmitted base pulses $\mathrm{g}_{\mathrm{kl}}(\mathrm{t})$ are orthogonal unless both time and the frequency index are identical. It is important to note that if they are identical the output does not take the value 1 but the smaller value$\sqrt{\mathrm{T}/\mathrm{T_S}}$. This can be understood as a waste of energy by transmitting a part of the symbol (guard interval) that is not used for detection. The OFDM signal has the advantage of averaging fades when its symbol duration is longer than the length of the fades. Due to this fact, the OFDM symbols are partially destroyed under fading. This can be achieved by adopting a large number of subcarriers but at the cost of increasing the system complexity and resulting in a poor peak-to-average power (PAPR) ratio [3]. The correlation between the samples during one

OFDM symbol must be taken into consideration. A comparison among the cyclic prefix, zero padding, and known symbol padding systems is shown in [5].

Another distortion in the OFDM signal is often due to the effect of the additive white Gaussian noise (AWGN) channel. To reduce the effect of the AWGN channel, a signal denoising approach is suggested in the receiver. In this approach, the radio frequency signal (RF) is enhanced using a wavelet thresholding technique instead of the baseband signal.

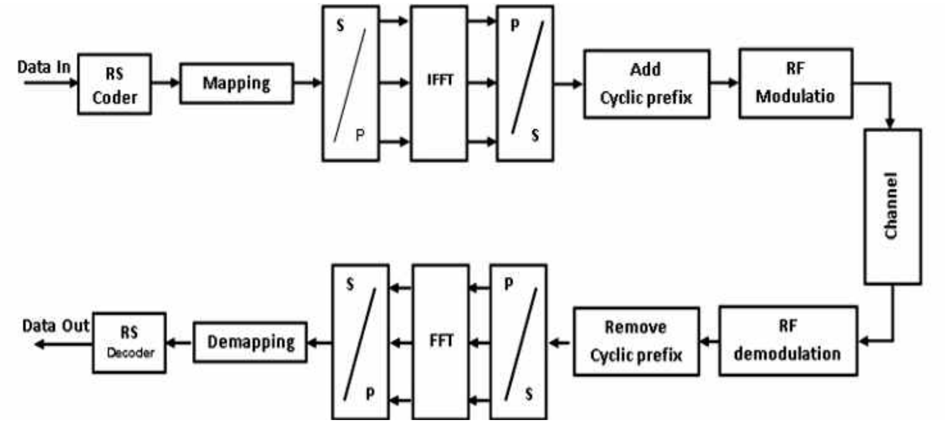

Fig.1. Original OFDM System with CP as a guard interval

The paper is organized as follows: Section 2 introduces system model and the performance analysis. Performance evaluation of the proposed system is given in section 3. Finally the conclusions are made in section 4.

2. System analysis for the proposed modified OFDM system

A new approach to enhance the performance of the OFDM system, when the channel characteristics are unknown or difficult to be estimated, is introduced.

In this paper, the codes have been written for data transmission using an OFDM technique over two types of channels. The effect of fading channel and additive white Gaussian noise (AWGN) channel are studied and suggested approaches are used to enhance the performance of the OFDM system. In this work, the impact of replacing the Cyclic Prefix (CP) by zero insertion (ZI) before the IFFT process in the OFDM is studied. Associated with each OFDM symbol, the zeros will be added in the transmitter before the IFFT process. For symmetry of the OFDM symbol, the zeros will be inserted with the same length among the OFDM frames. The ZI acts as a safe region of the high frequency component (details) of the signal where delayed information from the previous symbols freely corrupts the low frequency components, and the high frequency components are protected by giving it a high immunity (higher SNR) against the additive noise. The motivation of using the ZI instead of the cyclic prefix is the reduction in the transmission rate and the high performance in reducing of the channel distortion. The performance comparison among the proposed ZI technique, the CP, the Zero Padding (ZP), and the Known Symbol Padding (KSP) will be introduced in the simulation results. Another type of channels is the AWGN channel. The AWGN is a noise that affects the transmitted signal when it passes through the channel. It contains a uniform continuous frequency spectrum over a particular frequency band. The OFDM system has been built to reduce the effect of fading channel without the enhancement of the effect of the AWGN channel. In this work the approach of the wavelet thresholding denoising at the beginning of the receiver is used to denoise the received radio frequency (RF) signal.Fig.2 shows the proposed ZI-OFDM system.

The transmitted and the received signals for CP-OFDM, ZP-OFDM [14], KSP-OFDM, and ZI-OFDM are shown in Fig.3 and Fig.4; respectively.

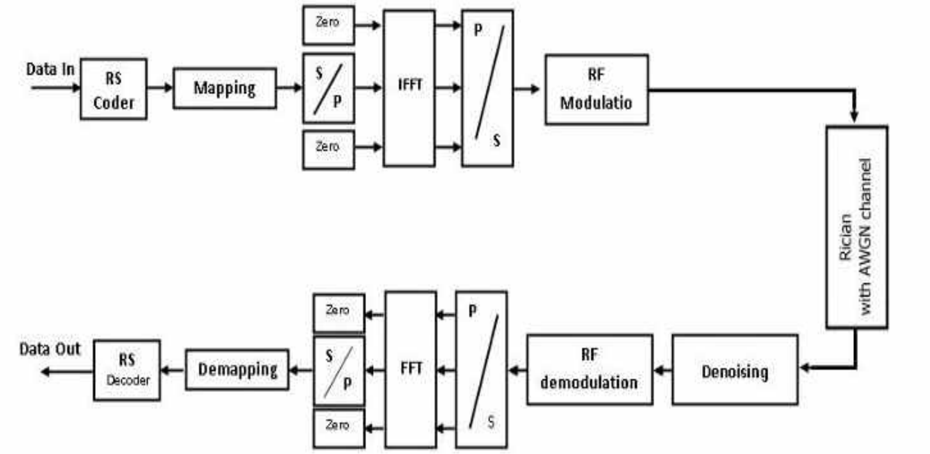

Fig. 2. Modified OFDM system

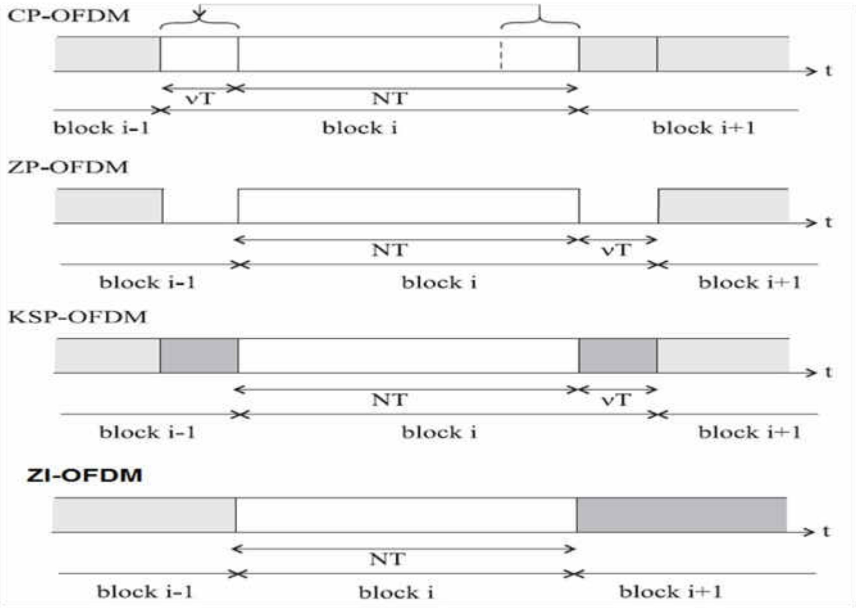

Fig. 3. Transmitted signal for CP-OFDM, ZP-OFDM, KSP-OFDM, and ZI-OFDM

The proposed Modified OFDM system can be described as follows:

1. The input signal is protected using Reed–Solomon (RS) encoder, and converting its output data to binary data stream.
2. Mapping the binary stream using Quadrature Phase Shift Keying (QPSK).
3. Passing the mapped stream through serial to parallel converter to fit the number of non-silence subcarrier (1536) (as the DAB model I standard).
4. Covering each frame with 256 zeroes at both ends.
5. The Inverse Fast Fourier Transform (IFFT) for each data frame (N=2048 bits; DAB model I) is applied (Bracewell, 2000).
6. Passing the data through a parallel to serial converter.
7. Modulating of the output data using the RF modulator is achieved.
8. In the first stage of the receiver the wavelet thresholding system is used to denoise the received radio frequency (RF) signal.

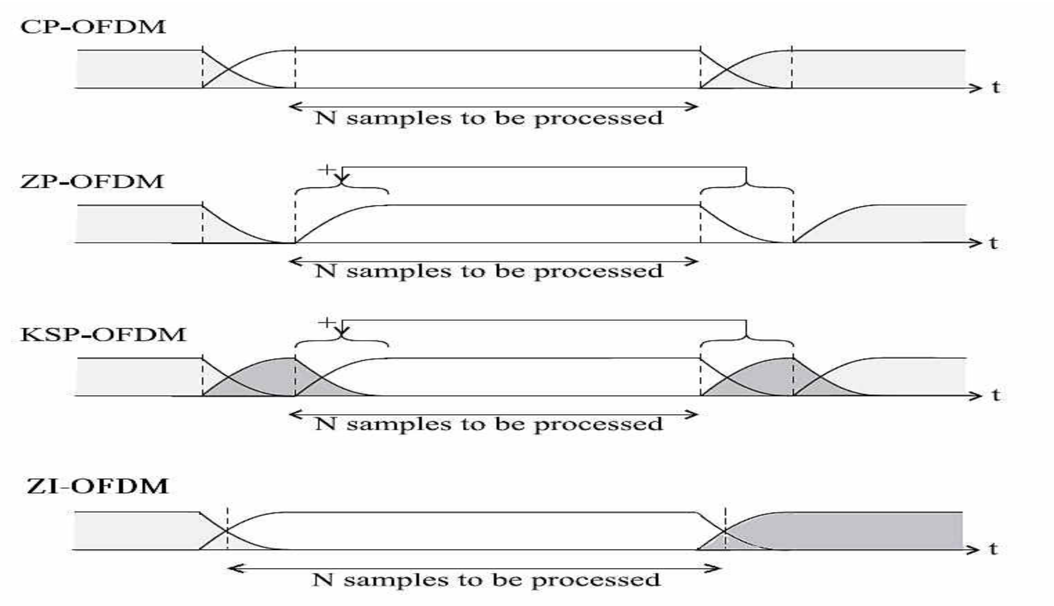

Fig. 4. Received signal for CP-OFDM, ZP-OFDM, KSP-OFDM, and ZI-OFDM

In the proposed ZI-OFDM system, data symbols $\mathrm{a_i}$ are applied to zero padding before the IFFT processing. Then, the inverse FFT is applied resulting in the time-domain samples as follows:

$$s_{i,ZI} = F^{+}(\Psi \| a_i \| \Psi)$$

Where the $(1) \times (\frac{1}{2}\nu)$ matrix $\Psi = \mathrm{zeros}\left(1\,,\frac{1}{2}\nu\right)$ is the zero-padding operator, $\mathrm{A}\|\mathrm{B}$ is the concatenation operation between A and B, and $\mathrm{s_{i,ZI}} = \{\mathrm{s_{i,ZI}}\,(\mathrm{k})|\mathrm{k} = 0,\dots,\mathrm{N}-1\}$. At the receiver, the whole N samples are applied to the FFT, and then the zeros are removed from the first $\frac{1}{2}\nu$ samples, and the last $\frac{1}{2}\nu$samples from the data part. The N outputs$\mathcal{Y}_{\mathrm{ZI}}\,(\mathrm{n})$ of the FFT can be written as follows:

$$\mathcal{Y}_{ZI} = \sum_{i=-\infty}^{+\infty} FH^{(i)} s_{i,ZI} + F\Lambda w$$

The n^th FFT output can be rewritten as

$$\mathcal{Y}_{ZI}\,(n) = \sum_{i=-\infty}^{+\infty} \sum_{n'=0}^{N-1} a_i\,(n')\gamma_{i,ZI}\,(n,n') \ + W(n)$$

Where

$$\gamma_{i,ZI}\,(n,n') = \frac{1}{N} \sum_{k=0}^{N-1} \sum_{k'=0}^{N-\nu} h(k-k'-i(N);\ k) e^{-j2\pi\frac{kn-k'n'}{N}}$$

Using a similar analysis as for CP-OFDM, it can be shown that the SINR at the FFT outputs for ZI-OFDM is independent of the carrier index *n* and yields

$$SINR \ = \frac{E_s P_U}{E_s P_I + P_N}$$

Neglecting the effect of the noise

$$SINR \ = \frac{P_U}{P_I}$$

Then, the noise component $\mathrm{P_N} \ = \ \mathrm{N_0}$, i.e. the value of the noise power is the same as in the case of the CP-OFDM. Taking into account the effect of the power efficiency loss in the CP-OFDM, it supports our clime that the ZI-OFDM system is better than the CP-OFDM system.

3. Performance evaluation of the proposed system

3.1. Performance analysis of the proposed approach with the Rician Fading channel:

Matlab will be our simulator in the performance test, path gain is varied from -0.26 to 0 dBs. However, the path delay is varied form 10^{-9} to 10^{-5} second for the same path. Fig.5 shows the mean square error (MSE) of the output signal when the channel gain was -0.16 dB with different path delays when the input signal is a random data. Fig.6 shows the same result for the same input data but when the path gain was -0.06 dB, and Fig.7 shows the relation between the averages of the MSE for the path delay against the path gain for random input signal. Fig.8 and Fig.9 show the same previous relations when the input is a speech signal. However, Fig.10 shows the relation between the averages of the MSE for the path delay against the path gain for the speech input signal. For the image data input, the same tests are done and the results are shown in Fig.11 to Fig.13. From these results, it is clear that the performance of the proposed system outperforms the original CP-OFDM system in most cases. It is clear that, for input image data, the ratio between the average of the MSE in the case of the proposed system and the average of the MSE in the case of the CP-OFDM system is 1.8231. Fig.14 shows the perceptual quality of the transmitted image (monalisa) and the received image using the CP-OFDM system and the proposed system when the path gain is -0.26 dB and the path delay is10^{-5} second. However, Fig.15 shows the transmitted speech signal and the received speech signal from the CP-OFDM system and the proposed system when the path gain is -0.26dB and the path delay is10^{-5}second.

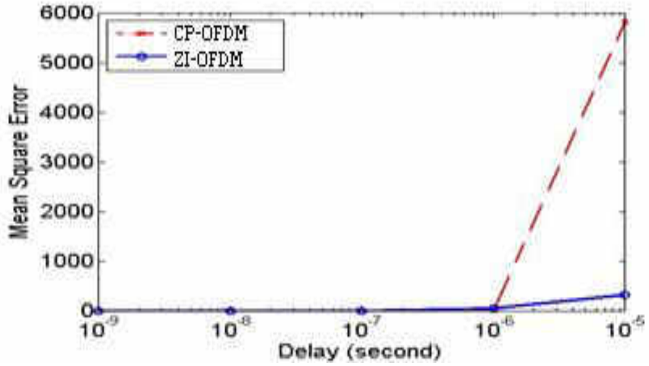

Fig. 5. MSE versus path delay in seconds, at path gain = -0.16 dB for random input data

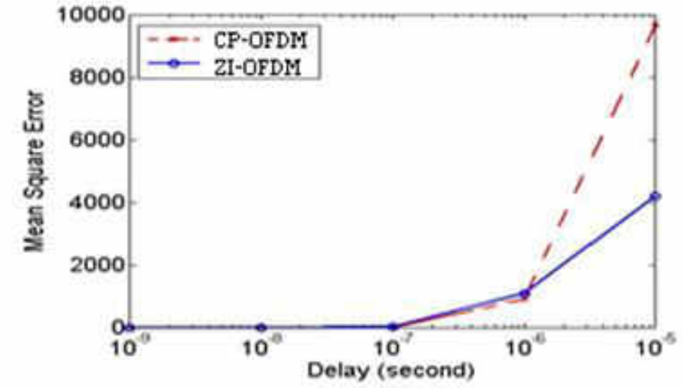

Fig. 6. MSE versus path delay in seconds, at path gain = -0.06 dB for random input data

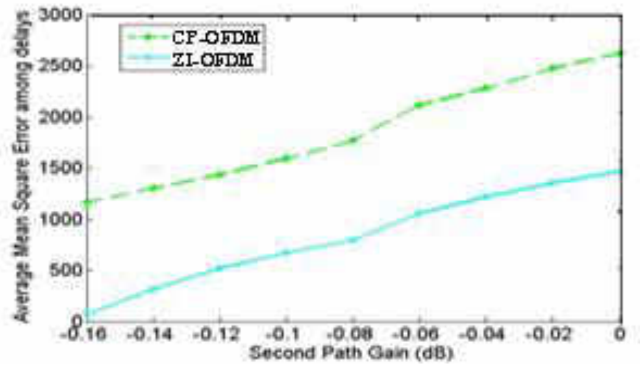

Fig. 7. Average MSE versus path gain in dB, for random input data

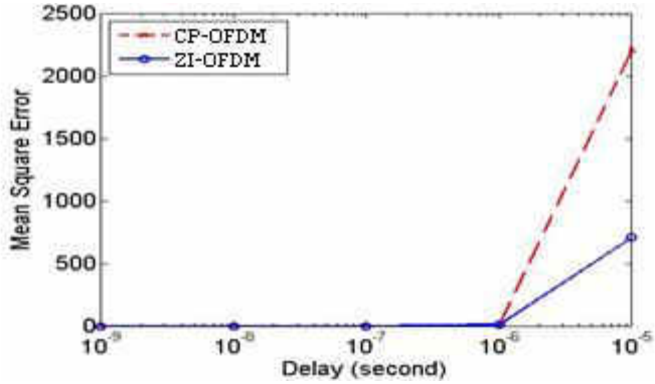

Fig. 8. MSE versus path delay in seconds, at path gain = -0.16 dB for speech input data

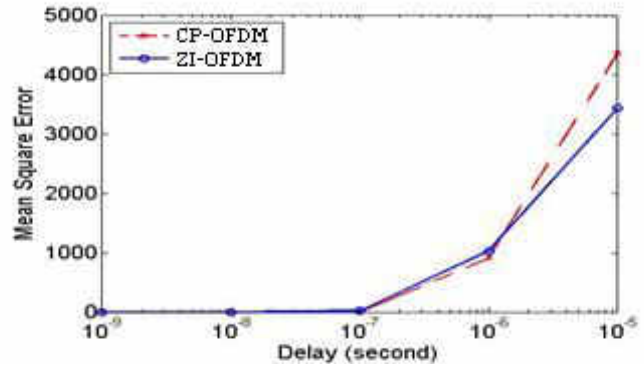

Fig. 9. MSE versus path delay in seconds, at path gain = -0.06 dB for speech input data

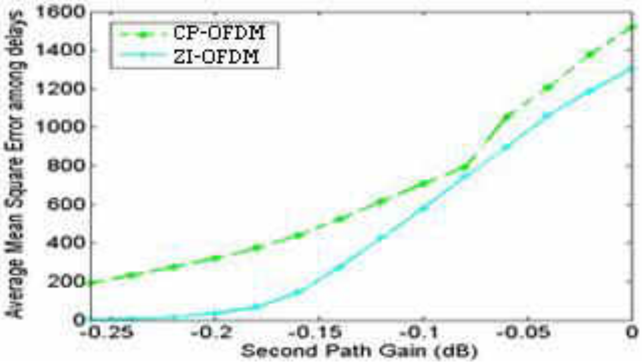

Fig. 10. Average MSE versus path gain in dB, for speech input data

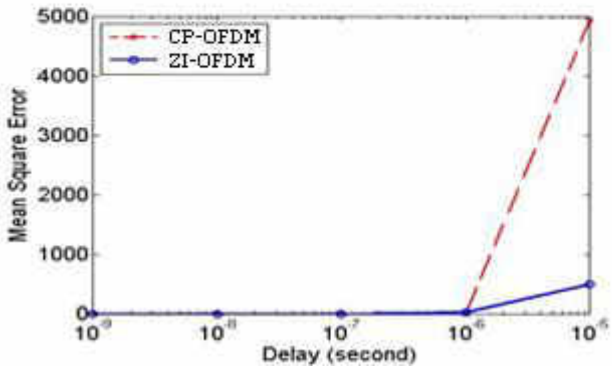

Fig. 11. MSE versus path delay in seconds, at path gain = -0.16 dB for image input data

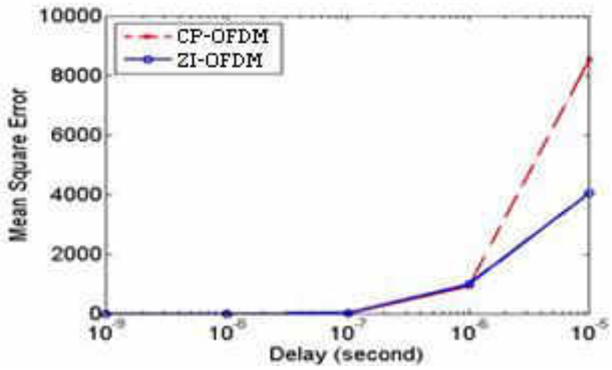

Fig. 12. MSE versus path delay in seconds, at path gain = -0.06 dB for image input data

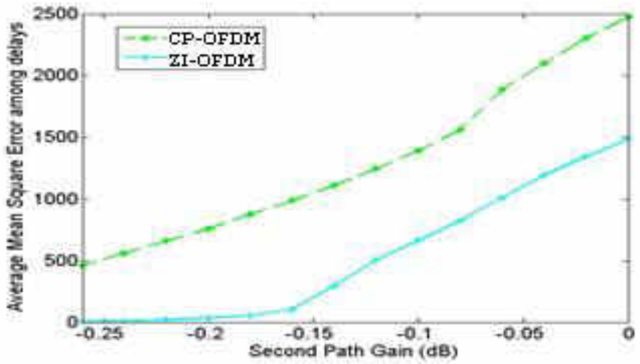

Fig. 13. Average Mean Square Error versus path gain in dB, for image input data

Fig. 14. Monalisa Image as a source and received images from CP-OFDM and ZI-OFDM systems at path gain= -0.26 dB and delay = $\mathbf{10^{-5}}$

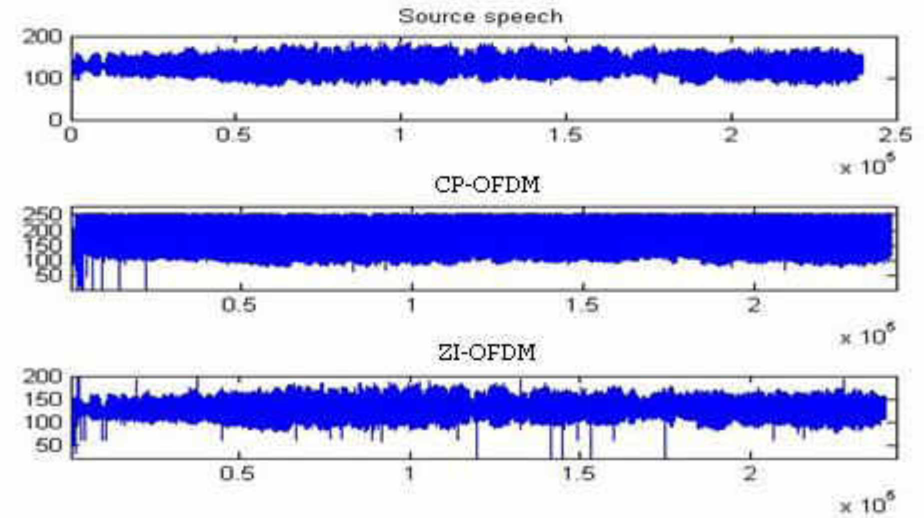

Fig. 15. TransmittedSpeech signal and received speech signal from the CP-OFDM and ZI-OFDM system at path gain= -0.26 dB and delay = $\mathbf{10^{-5}}$

3.2. Performance analysis of the proposed approach with the AWGN channel only:

In general, the OFDM system is not proposed to deal with this type of channel, so our proposed denoising technique work with the OFDM systems and give a good result in the AWGN environment. With the birth of the wavelet theory and multi-resolution analysis, a signal denoising technique based on the wavelet transform has been extensively studied and tremendously improved. The denoising and feature detection of signals using the wavelet transform is done by representing the signal by a small number of coefficients. This wavelet shrinkage is based on thresholding, as developed by Donoho and Johnstone (Donoho & Johnstone, 1994). The signal is composed into L levels before thresholding is applied. Fig.16 demonstrates the two types of thresholding, hard and soft thresholding, with thresholdδ.Hard thresholding zeroes out small coefficients, resulting in an efficient representation.

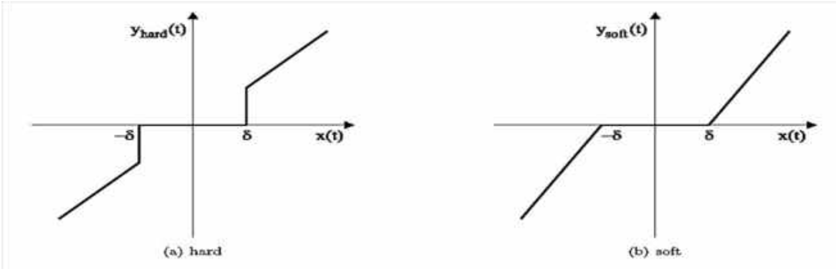

Fig. 16. Thresholding technique

Soft Thresholding softens the coefficients exceeding the threshold by lowering them using the threshold value. Soft thresholding gives better compression performance. When the thresholding value is applied, no perfect reconstruction of the original signal is possible. The outputs of soft and hard thresholding can be written as

$$y_{\text{hard}} = \begin{cases} x(t), & |x(t)| > \delta \\ 0, & |x(t)| \le \delta \end{cases}$$

$$y_{\text{soft}} = \begin{cases} \operatorname{sign}\left(x(t)\right)(|x(t)| - \delta), & |x(t)| > \delta \\ 0, & |x(t)| \le \delta \end{cases}$$

The denoising is not limited to a special kind of noise; different kinds of disturbances can be filtered out of the images. Thresholding generally gives a low-pass version of the original signal. An appropriate threshold δ (the noise variance in the wavelet domain is used in this work) can suppress noise present in a signal. For denoising applications, generally soft thresholding is used. It is assumed that the noise power is smaller than the signal power. If this is not the case, the denoising by thresholding removes, besides the noise, a large part of the signal or leaves a larger part of the noise in the signal. In general, removing noise from the original signal is still a challenging problem for researchers. Most of the denoising techniques work at the baseband signals; they use image denoising as a major field to apply them researches (Kaur, Gupta, & R.C. Chauhan, 2012). Adaptive (reconfigurable) (Latha & M., 2011)(Liu, Teng, & Chen, 2010), nonlinear (Gao, Sultan, Hu, & Wen-wen, 2010), and fixed thresholding (Kim & Barner, 2005) are the most common techniques to perform the denoising at this band. In the OFDM system, the wavelet OFDM (OFDM-DWT) (M & Dr.B.V.Uma, 2013)gives an OFDM system with high immunity against the AWGN channel and performs the denoising for OFDM signals. The following simulation results prove that the proposed system outperform the performance of the OFDM-DWT.

To select the best mother wavelet function, the RF modulated OFDM signal is processed by some wavelet functions to select the best denoising technique.

Different mothers wavelet are used to test the RF modulated signal. The RF modulated OFDM signal for color image is analyzed using various mothers wavelet functions as Daubechies (db5), Symlets (sym2), Coiflets (coif1), Biorsplines (bior2.2), reversebior (rbio4.4), DMeyer (dmey), and Haar (haar) functions; as an example in Fig.17 to Fig. 20. In these figures, s is the signal, d is the detail component, and a is the approximate component; the sub-scripted number is the decomposition level of the wavelet transform.

For noise free signal, the simulation results prove that both the approximate and the detail coefficients at level 3 have zero value when the Haar wavelet function is used as shown in Fig.20 and Fig. 21. We exploit this feature and propose the denoising technique for the OFDM signal. The proposed algorithm is based on soft and hard thresholding. Fig.21 shows the analysis of the same RF modulated OFDM signal using the Haar wavelet at level 3 but after adding AWGN. It's clearly that we have information about the noise at the approximate and detail coefficients in level 3. Both the approximate and detail components in level 3 can be combined together to create the approximate component of level 2. So all the information can be gotten from this component will describe the noise characteristics. This characteristic (noise standard deviationσ) is used to perform the signal denoising process.

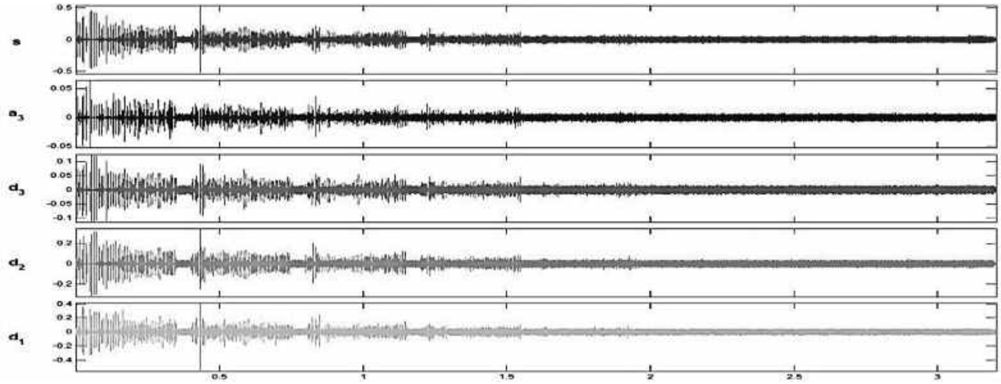

Fig. 17. OFDM signal level 3 decomposition using Daubechies (db5) wavelet

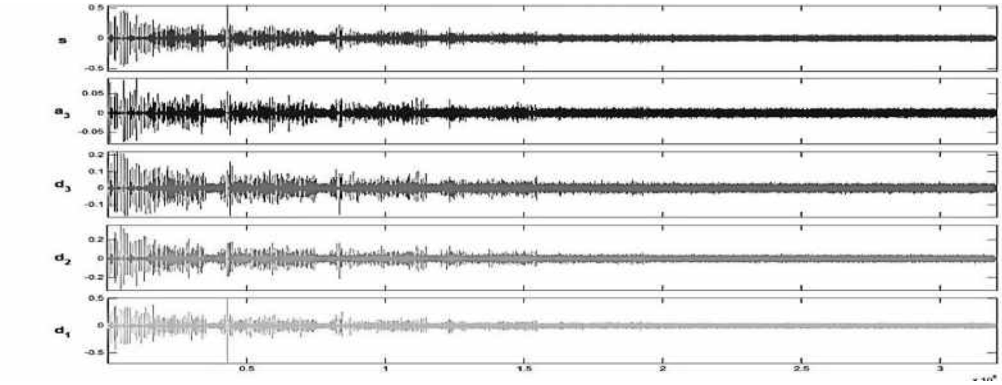

Fig. 18. OFDM signal level 3 decomposition using Symlets (sym2) wavelet

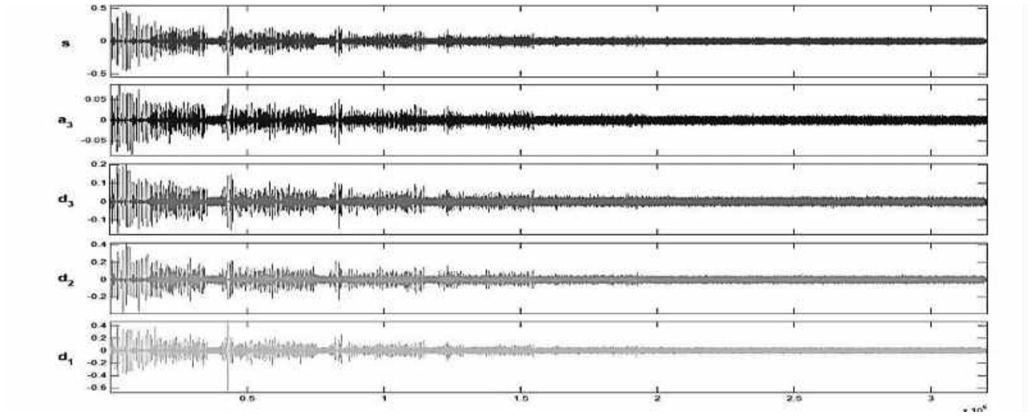

Fig. 19. OFDM signal level 3 decomposition using Coiflets (coif1) wavelet

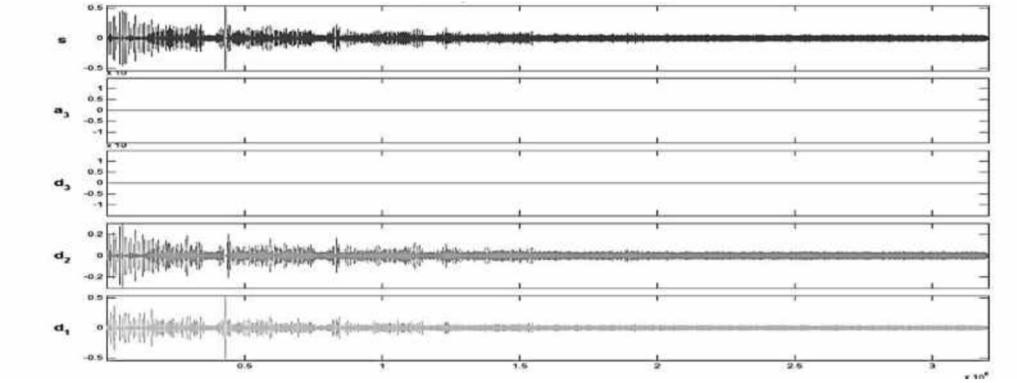

Fig. 20. OFDM signal level 3 decomposition using Haar (haar) wavelet

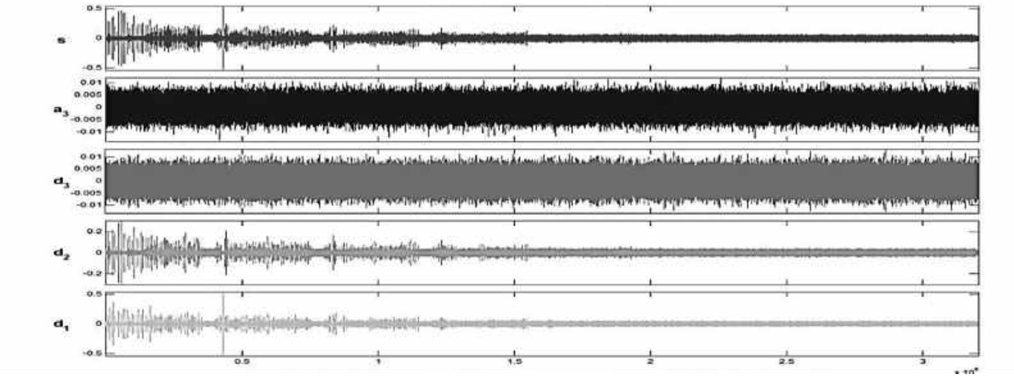

Fig. 21. Noisy OFDM signal with level 3 decomposition using Haar wavelet

The steps of the proposed technique in the wavelet domain after using the Haar wavelet transform are described as follows:

1. The noise standard deviationσ_2 will be estimated from the approximate coefficients in level 2.
2. Using σ_2 to perform the signal denoising process for the detail components in level 2.

3. Set the approximate coefficients at level 2 to zero.
4. Combine level 2 coefficients together to get the denoised approximate wavelet coefficients at level 1.
5. Calculate the value of σ_1 of the wavelet coefficients at level 1 from the difference between the denoised wavelet coefficient at level 1 and the noisy approximate coefficient at the same level.
6. Using σ_1 to denoise the detail wavelet coefficients at level 1.
7. The last approximate and detail coefficients are combined together to get the denoised signal.

In the simulation test, the AWGN channel is simulated by adding a Gaussian noise to the transmitted signal without affecting the signal synchronization. The simulation will be done by varying the Signal-to-Noise Ratio (SNR) from 5 to -10 dBs. The Peak Signal to Noise Ratio (PSNR) is used to measure the received image quality, and the MSE for the audio signal evaluation.Fig.22shows the PSNR against SNR for Monalisa color image, and Fig.23 shows the MSE against SNR for the input audio signal.

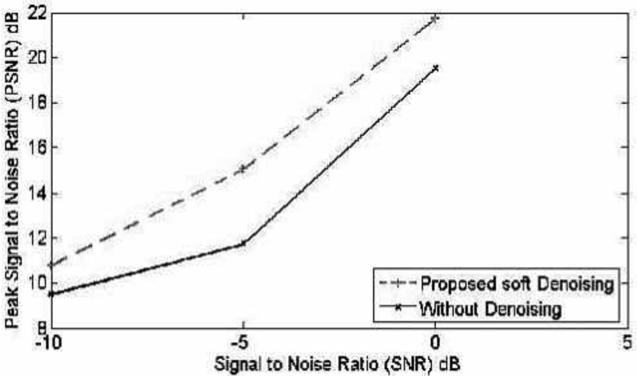

Fig. 22. PSNR against SNR for Monalisa color image signal

A comparison between the CP-OFDM and the proposed system performance for the denoising wavelet techniques shows that a little improvement in PSNR is achieved due to the short length of the modified OFDM symbol relative to the length of the CP-OFDM symbol. Fig. 24shows the perceptual quality of the transmitted image and the received image with SNR= 0 dB.

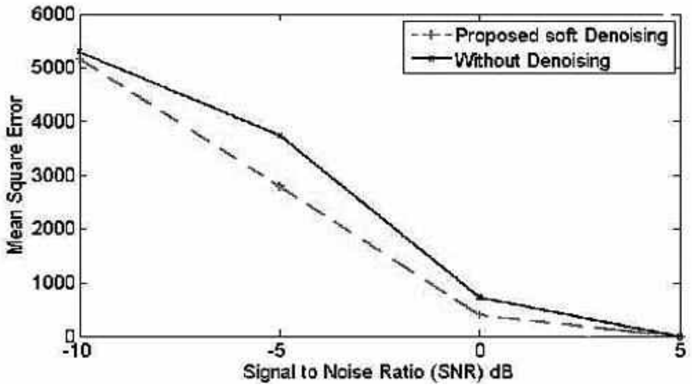

Fig. 23. MSE against SNR for audio signal

To demonstrate the performance of the proposed denoising system, the comparison between the proposed system and the OFDM-DWT proposed in (M & Dr.B.V.Uma, 2013) is introduced. The OFDM-DWT system (M & Dr.B.V.Uma, 2013) uses the Inverse Discrete Wavelet Transform (IDWT)/Discrete Wavelet Transform (DWT) instead of IFFT/FFT in the OFDM system. A generated PN sequences is used in the comparison to test the two systems performance. Table.1 illustrates the performance of the proposed approach relative to the OFDM-DWT.

Fig. 24. A Performance comparison between the proposed system and the CP-OFDM after using soft denoising when SNR=0db(a) received image without denoising PSNR=19 .3617 (b) received image with the proposed system PSNR=21.7884 (c) received image with the CP-OFDM denoising PSNR=21.3 .56

It's clear that the proposed system outperforms the performance of the OFDM-DWT. The comparison is used the absolute difference between the denoisy and the transmitted signal with the channel noise of SNR=22db.

3.3. Performance analysis of the proposed system withthe AWGN and the fading channel together

In this Section, the proposed system is tested with the combination of Rician and AWGN channel. To evaluate the performance of the system, Lena image is used as a test signal. The fading criteria will be varied from 0% to 25% with the OFDM frame length of2048.The SNR of the AWGN channel is varied from 5 to -5 dB. Fig.25 shows the received image without denoising, and with the denoising technique when 1% fading delay and SNR=5db Gaussian noise are added. The same result is shown in Fig.26when 25% fading and SNR=0db is used. Table.2 shows the SNR for the received signal at the input of the receiver after the transmission over the Rician fading channel, the SNR of the received signal after the transmission over the AWGN, the SNR of the denoised signal, and the PSNR of the received image.

Table 1.
Difference between denoised signal and the Transmitted signal for SNR=22 dB for both OFDM-DWT and proposed systems

4-Bit	Transsignal const.	OFDM-DWT			Proposed Denoising		
		Received signal constellation after Denoising	Difference		Received signal constellation after Denoising	Difference	
			Real	Imag.		Real	Imag.
0000	-3+3i	-3.0272 +2.8808i	0.0272	0.1192	-2.8105 + 2.8263i	0.1895	0.1737
0001	-1+3i	-1.0804 + 2.9525i	0.0804	0.0475	-0.8872 + 2.8946i	0.1128	0.1054
0010	3+3i	3.1469 + 2.9503i	0.1469	0.0497	2.8215 + 2.8712i	0.1785	0.1288
0011	1+3i	0.8712 + 3.1746i	0.1208	0.1746	0.9457 + 2.7797i	0.0543	0.2203
0100	-3-3i	-2.9841 - 2.9337i	0.1592	0.0663	-2.8156 - 2.7247i	0.1844	0.2753
0101	-1-3i	-0.9514 - 3.0205i	0.0486	0.0205	-0.8954 - 2.9330i	0.1046	0.0670
0110	3-3i	3.0258- 3.0272i	0.0258	0.0272	2.7976 - 2.8537i	0.2024	0.1463
0111	1-3i	0.5585 - 2.8909i	0.4415	0.1091	0.9972 - 2.8201i	0.0028	0.1799

Table.2 proves that the SNR improvement by 30 dBs with the proposed approach relative to the CP-OFDM system is achieved.

Fig. 25. CP-OFDM, and the proposed system when 1% fading delay and SNR=5db Gaussian noise is added (a) received image without denoising PSNR=21.7663 (b) received image with the CP-OFDM denoising PSNR=24.3318 (c) received image with the proposed system PSNR=25.4752

Fig. 26. CP-OFDM, and ZI-OFDM with denoising when 25% fading delay and SNR=0db Gaussian noise(a) received image without denoising PSNR=14.8022 (b) received image with the CP-OFDM denoising PSNR=17.7931 (c) received image with the proposed system PSNR=18.2096

Table 2.
The performance of the proposed system with the fading and the AWGN channels

Fading delay (%)	**SNR (dBs) after**		**PSNR (dBs)**			**SNR (dBs) after denoising**
	Fading	**AWGN**	**Without denoising**	**CP-OFDM with denoising**	**ZI-OFDM with denoising**	
1	-6.22	-7.66	21.76	24.33	25.48	13.32
		-9.72	14.62	17.633	18.48	6.91
		-13.15	10.95	12.95	13.33	2.81
12.5	-24.11	-25.31	22.75	22.91	23.22	10.87
		-27.13	15.016	18.1	18.37	6.69
		-30.32	10.92	13.02	13.3	2.84
25	-27.11	-28.31	22.4	22.88	22.9	10.95
		-30.12	14.8	17.8	18.21	6.84
		-33.31	10.92	12.84	13.15	2.59

In general, the performance of the denoising algorithm is measured using quantitative performance measures such as peak signal-to-noise ratio (PSNR), signal-to-noise ratio (SNR) as well as in terms of visual quality in the case of the images. An ideal denoising procedure requires a priori knowledge of the noise, whereas a practical procedure may not have the required information about the variance of the noise or the noise model. Thus, most of the algorithms assume known variance of the noise and the noise model to compare the performance with different algorithms. It is obvious from the results that, the proposed approach works well in both AWGN channel and fading channels even if the channel characteristic is unknown.

4. CONCLUSIONS

It is proved that the complexity in the OFDM system can be reduced by replacing the CP by zero insertion (ZI) before the IFFT process on the OFDM transmitter. Moreover, a signal denoising approach is suggested to be added in the receiver of the OFCM system to reduce the effect of the AWGN channel. The performance analysis with different types of data and channels proved that the performance of the proposed system outperforms the performance of the CP-OFDM system. Random, speech, and images signals are used as an input signal for the system to test the performance. The proposed modification approach provides a reduction in the data redundancy by approximately 20% of the original redundancy with the CP-OFDM system in the fading environmental. Performance of denoising algorithms for the AWGN channel is measured using quantitative performance measures such as peak signal-to-noise ratio (PSNR), signal-to-noise ratio (SNR) as well as in terms of visual quality in the case of the images. The simulation results of the proposed scheme indicate that the proposed system provides a signal enhanced with about 30dbs, according to the SNR for the received signal.

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اتجاهات جديدة لتحسين أداء نظام التقسيم المتعدد للترددات المتعامده

الملخص العربى

يعتبر نظام التقسيم المتعدد للترددات المتعامدة (OFDM) هو احد نظم الاتصالات متعددة الترددات الحاملة (MCM) وهى التى تستخدم عدة ترددات فى حمل الاشارة المرسلة على خلاف نظم التردد الوحيد الحامل(SCM).ومن احد اهم الاسباب فى استخدام هذا النوع من الانظمة هو انه لديه مناعية عالية اتجاه الشوشرة المضافة وخصوصا من الانواع محددة التردد (Frequency Selective) حيث اننا نستطيع من خلال تشفير الاشارة (Channel coding) ان نسترد ما فقد نتيجة التشويش فى احد الترددات الحاملة للاشارة ولكن فى حالة نظم التردد الوحيد فاننا قد نصل الى فقدان الاشارة تماماً ومن مميزاته انه يوفر حماية ومناعية للاشارة المرسلة من القنوات ذات المسارات المتعددة والمتداخلة (Fading Channel).ومن اهم عيوب هذا النظام اننا نفقد جزء من الطاقة المرسلة نتيجة استخدامها فى ارسال فترات الحماية (Guard Intervals) بعد كل رمز وهو ما لا يمثل اى نوع من المعلومات للمستقبل وايضا من عيوب هذا النظام أننا نحتاج الى معرفه جيدة الى طبيعة وخواص القناة ما بين المرسل والمستقبل (Channel Characteristic's) وانه لا يضيف اى مناعة للاشارة المرسلة من القنوات من نوع AWGN.

فى هذه المقالة تم اقتراح طريقتين جديدتين لتحسين عمل نظام التقسيم المتعدد للترددات المتعامدة (OFDM) وذلك باستبدال فترات الحماية (Cyclic Prefix) بوضع اصفار فى بداية كل رمز ونهايته وذلك قبل عملية تحويل فورير العكسى (IFFT) فى المرسل مع عمل تعديل فى المستقبل لإزالة تأثير هذا التعديل. كما تم إضافة نظام جديد لإزالة الشوشرة فى دائرة المستقبل وذلك لتفادى تأثير نوعان من القنوات وهما قناة AWGN وقناة Fading.وقد تم عمل محاكاة للنظام المقترح وكذلك للنظام الأصلى المستخدم حالياً وعمل مقارنة لأداء كل منهم مع وجود اشارات دخل مختلفة. وقد أثبتت نتائج المحاكاه أن النظام المقترح يعطى نتائج أفضل من النظام الأصلى مع جميع أنواع الأشارات المستخدمة دون الحاجة الى معرفة خواص القناة.