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# Analysis and Design of Low Complexity Receiver for UWB Transmitted Reference Based on Wavelets Transform

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***Abstract*** **- The Rake receiver has become very popular in wireless communication in recent years, but it has a number of drawbacks, including complexity, high noise, poor performance, and a slow transmission rate. As a result, a system with high performance, low complexity, low noise, and high efficiency is required. In this article, the idea of a new discrete wavelet transform (DWT)-based system is called Low Complexity (LC) Transmitted Reference (TR) Ultra Wideband (UWB) that achieves high performance, low complexity, higher transmission rate, and lower noise than previous discrete wavelet transform systems. High frequencies that caused noise in the system were cut off using DWT. To remove these frequencies, DWT uses two types of FIR filters. To get a better result, use three levels in this system. The simulation results show that when three levels of noise reduction are used, the effect is to remove high frequencies that cause noise in the TR UWB received signal.**

***Index Terms*** **- TR_UWB, DWT, LC_TR_UWB.**

## INTRODUCTION

The bandwidth of UWB (Ultra Wide Band) communications system from 3.1 to 10.6) GHz. The bandwidth of UWB will be given chance for very high data rate communications. There are two types of applications for UWB based on data rate known low data rate applications and other known high data rate applications. In UWB techniques, the different impulse assumed for low power, low complexity and low data rate application. There is some challenge for UWB transceiver, low power and low cost [1]. The Rake receiver of UWB is high complexity because it consists of a number of fingers so that the system performance is loss [2].

Subsequently, the proposed of new wireless system known as transmitter reference ultra wide band (TR-UWB) receiver that have some advantages such as, low complexity until it's known a low-complexity alternative to rake receiver, less noise, higher transmission rate, channel wireless estimation and no need to have transmitter of reference pulse with pulses of information data as compared with the Rake receiver [3, 4]. But this type has some disadvantages such as, cannot has the efficiency to reduce the noise of received signal so that proposed a new type of receiver to removed noise.

Many papers have been published on using Wavelet Transform (WT) to overcome low complexity for receiver. WT in UWB communication has been used to synthesize and analyze the UWB pulses in order to create the signal needed for noise detection [5, 6]. WT was also used to diagnose breast cancer using UWB contact [7]. The Wavelet Transform is a real modern mathematical technique for compressing images and signals and eliminating internal and external noises from their coefficients [8, 9]. For multi-carrier, multiple access, wideband, code division and a rake wireless receiver over additive channels as in [10, 11], the wavelet video pressure was evaluated. In [12], the used Continuous Wavelet Transform (CWT) in rake receiver that showed a significant improvement in performance and a less complex of multipath receiver.

In this paper, used DWT that contains of High Pass Filter (HPF) and Low Pass Filter (LPF) will use the part of LPF only to cut off frequencies with high values that made lnternal low level noise for TR-UWB wireless receiver and then procurement the received signal with very less deformity. These receivers depend on the decomposition algorithm for wavelet signals, which divides the signal into four steps or levels and generates approximated and advised or detailed coefficients. The gollowing rest of this article is structured as mentioned of follows: in section one, a WT analysis is presented. While section two detailed description for Transmitted Reference (TR). TR receiver performance is the subject of section 3. In the sections of four and five are dealing with analysis results with their discussions and conclusions respectively.

## WAVELET TRANSFORM PROCESS

The wavelet transform was introduced by Morletetal and displayed at the starting of 1980. Morletetal used the wavelet transform to estimate seismic data. The wavelet theory is distinguished from Fourier theory. can express a signal of Fourier theory such as the add compilation of cosines, sines and possible infinite. Fourier expansion can be expressed by this sum. Fourier expansion has great disadvantage, it hasn't time resolution but it has frequency resolution.

Problem of Fourier theory, at the same time cannot define both of frequency domain and time domain for signal [13]. later, developed different kinds of wavelet transform and found plentiful implementations such as continuous time wavelet transform (CWT). The DWT has distinguished signal compaction characteristic for plentiful proportion of real-world signals while calculation greatly active. Therefore, its utilized to nearly each technical domain inclusive pattern recognition, DE noising, numerical integration and image compression. The wavelet transform has goal, this goal is defining signals such as linear conjunction of functions for the wavelet at sundry scales and of functions for scaling of broadest asked scale. the goal of wavelet to transpose the pulses or signals from time domain to time-scale or frequency domain (time-frequency) that decided the subscriber time with frequency [14]. It involves specific kinds of waves to define the signal these called WAVELET. For CWT analysis, signal can be defined as decay into wavelets that can be expressed bellow:

$$CWT = b(s,\tau) = \int f(t).\psi_{s,\tau} * (t)dt \quad (1)$$

$$ICWT = f(t) = \int\int b(s,\tau).\psi_{s,\tau}(t)ds\,d\tau \quad (2)$$

where's,
* is the denoted difficult conjunction, f(t) is decayed into group of rule functions, $\psi_{s,\tau}(t)$ =named the wavelet signal.

S, τ are incoming simensions. The wavelet transform has t many important attributes such as the systematic, stipulations and the permissibility that express bellow.

$$\int_{-\infty}^{\infty} \frac{|\psi(w)|^2}{|w|} \quad dw < +\infty \quad (3)$$

The DWT is used to reduce the calculation time wanted and used during synthesis and analysis operation to supply information. the WT consists from two kinds of filters used to cutoff frequency that cause signal noise. there are two type of filters, HPF used to cutoff low frequencies and LPF used to cutoff high frequencies as shown in Figure (1). Used filters to confirm the signal degeneration by variation scale denoted by factor (j) as can be expressed bellow [15].

$$h[j] = \sum_{i=-\infty}^{\infty} x[j].h[j-i] \quad (4)$$

$$r[j].g[i] = \sum_{i=\infty}^{\infty} x[j].g[j-i] \quad (5)$$

where,
$h[i]$ *is impulse response of LPF* ,
$g[i]$ *is impulse response of HPF* .

$$Y_{high}[i] = \sum_j x[j].g[2i-j] \quad (6)$$

$$Y_{Low}[i] = \sum_j x[j].h[2i-j] \quad (7)$$

While inverse of the wavelet transform (IDWT) makes building on the relation between the HPF and LPF which can be defined bellow.

$$x[j] = \sum_{i=-\infty}^{\infty} \left( \left(Y_{high}(i).g[-j+2i]\right) + \left(Y_{low}(i).h[-j+2i]\right) \right) \quad (8)$$

$$g[D-1-j] = (-1)^j.h[j] \quad (9)$$

where, (-1) is translate from LPF to HPF and D is filters 'tallness.

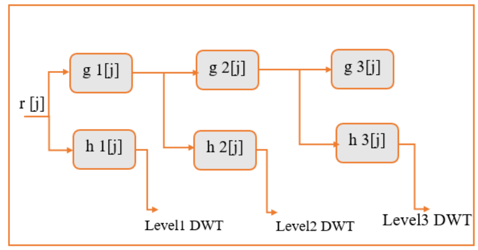



**Figure 1 HPF and LPF of DWT.**

## TRANSMITTED REFERENCE SYSTEM (TR-UWB)

In over all wirelrss system, the used pulse is based on a second derivative Gaussian pulse p(t) can express in equation (10). The Gaussian pulse has a zero DC component. The Gaussian pulse is chosen over a rectangular pulse because it has less energy outside the allocated frequency band.

$$p(t) = \left[1 - 4\pi\left(\left(t - \frac{0.35}{\tau_m}\right)^2\right)\right] \exp\left[-2\pi\left(\left(t - \frac{0.35}{\tau_m}\right)^2\right)\right] \quad (10)$$

The TR signaling technique consists of an unmodulated reference signal and a modulated data signal for each information bit. In conventional TR systems, the modulated signal is transmitted after certain delay following the unmodulated signal to ensure there is no interference between the two signals. A Binary Phase Shift Keying (BPSK) modulated TR signal pair is represented bellow.

$$s_0(t) = g_{tr}(t) + b_0 g_{tr}(t - T_d) \quad (11)$$

Where $g_{tr}(t)$ is represents an ultra-wideband pulse with a non-zero value in the interval $[0, T_m]$; the energy of $g_{tr}(t)$ is defined as $\frac{E_b}{2}$ and *b0* € {—1,1}. A binary PSK modulated TR signal pair is illustrated in Figure (2). In this research, the delay $T_d$ between the unmodulated and modulated pulses is set to equal to the data transmission time frame $T_f$ . Therefore, TR signal pairs are transmitted at intervals of $2T_f$ . To improve the transmission reliability, the same TR signal pair can be sent $N_s$ times. The circuit of TR-UWB transmitter signals can be shown in Figure (3) and represent bellow [16].

$$s_{tr}(t) = \sum_{i=\infty}^{\infty} g_{tr}\left(t - 2iT_f\right) + b_{\lfloor \frac{i}{N_s} \rfloor} g_{tr}(t - (2i+1)T_f) \quad (12)$$

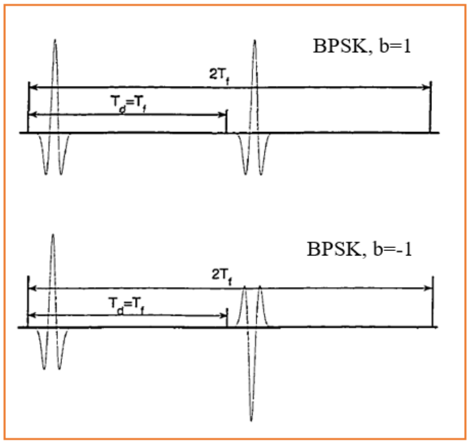



**Figure 2 The BPSK Modulated TR System Signal Pair.**

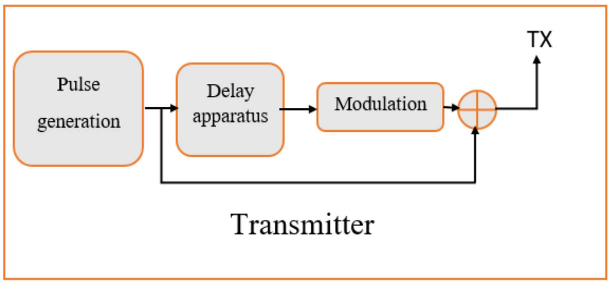



**Figure 3 TR-UWB Blocks of transmitter.**

Since the unmodulated signal is transmitted together with the modulated signal as a pair on the same channel, the unmodulated signal will undergo the same channel distortion as the modulated signal assuming the channel remains unchanged during the period $T_f$ [17]. Thus, the received unmodulated signal can be used as a noisy reference for the detection of the modulated signal and avoid the need for explicit channel estimation. The received signal pair is expressed in equation bellow. The receiver signal from channel will be gone to transmitted reference as shown in Figure (4) [18].

$$\bar{r}_{tr}(t) = \sum_{i=\infty}^{\infty} g_{tr}(t-2iT_f) + b_{\lfloor \frac{i}{N_s} \rfloor} g_{tr}(t-(2i+1)T_f) + \bar{n}(t) \tag{13}$$

Where $\bar{n}(t)$ is the zero mean AWGN (additive white Gaussian noise) with $\frac{N_0}{2}$ variance.

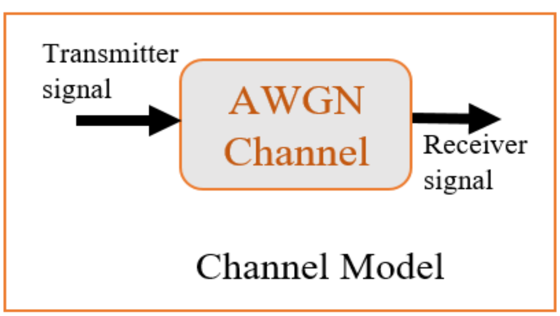



**Figure 4 Wireless Channel Model.**

## Transmitted Reference (TR) Receiver Performance

Two TR receiver designs are analyzed in this section: conventional TR receiver and Low Complexity TR receiver based on 3 levels of DWT.

*I. Conventional Transmitted Reference (TR-UWB) Receiver*

At reception side, the received pulses are then passed through or over an ideal low pass filter with a one-sided bandwidth of *W* and unit magnitude. The low pass filter output of *i*th symbol interval (with duration of *2NsTf)* can be expressed in equation bellow.

$$r_i(t) = \sum_{j=0}^{N_s-1} [g_{rx}(t-2jT_f) + b_i g_{rx}(t-(2i+1)T_f)] + \bar{n}(t) \tag{14}$$

Where $g_{rx}(t)$ corresponds to the received pulse shape. The use of different representations for pulses is to indicate the possible shape difference between the received $g_{rx}(t)$ and the transmitted pulse $g_{tr}(t)$ due to channel distortion. The dynamic bandwidth of the low pass digital filter is designed to limit the white Gaussian noise to within the filter bandwidth and allow the pulse pair to pass through without distortion. The term $n(t)$ indicates the band limited noise. In the next section, two autocorrelation detectors and their performance analysis will be presented. An autocorrelation is used to correlate the unmodulated reference transmitted signal with the modulated data signals to demodulate the data signal. The autocorrelation takes the received signal $r_{tr}(t)$ and multiply it with a $T_f$ delayed received signal and integrate it over a time period $T_{tr}(t)$[19]. The circuit of TR-UWB receiver can be shown in Figure (5). The output of the autocorrelation for one symbol duration is expressed bellow [20].

$$D = \sum_{j=0}^{N_s-1} \int_{(2j+1)T_f+T_{tr}}^{(2j+1)T_f+T_{tr}} r_i(t) r_i(t-T_f)\, dt$$

$$= \sum_{j=0}^{N_s-1} \int_{(2j+1)T_f+T_{tr}}^{(2j+1)T_f+T_{tr}} \left\{ \left[ \left[ g_{rx}(t-2jT_f) + b_i g_{rx}(t-(2j+1)T_f \right] + n(t) \right) \right] . \left[ \left[ g_{rx}(t-2jT_f) + b_i g_{rx}(t-(2j+1)T_f - T_f) \right] + n(t-T_f) \right] dt \tag{15}$$

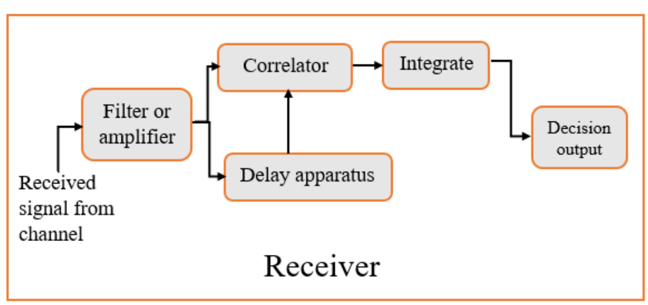



**Figure 5 TR-UWB Receiver.**

The variance exists when a=j and $v = t - (2j-1)T_f$ can express bellow.

$$\sigma_{X_4}^2 \approx \sum_{j=0}^{N_s-1} \int_0^{T_{tr}} \int_0^{T_{tr}} R_n^2(v_2 - v_1)\, dv_1\, dv_2 \quad (16)$$

$$\sigma_{X_4}^2 \approx N_s W \frac{N_0^2}{2} T_{tr} \quad (17)$$

To decision variable D can then be an approximate as Gaussian R.V conditioned on the bit and $\tau$ . Its mean and variance are expressed bellow [21].

$$E[D|b_i,\tau] = N_s b_i R(0) \quad (18)$$

$$Var[D|\tau] = N_s N_0 R(0) + \sigma_{X_4}^2 \quad (19)$$

Where,

$$R(\tau) = \int_0^{T_{tr}} g_{rx}(t)\, g_{rx}(b-\tau)\, dt \quad (20)$$

The conditional probability of error for the autocorrelation receiver can express bellow.

$$P(e|\tau) = P(D < 0 | b_i = 1, \tau) = Q\left(\frac{N_s R(0)}{\sqrt{N_s N_0 R(0) + \sigma_{X_4}^2}}\right) \quad (21)$$

*II. Low Complexity Transmitted Reference (LC-TR)Ultra Wideband Receiver*

In this system, the proposed LC-TR wireless receiver with DWT because all applications need to have systems of low cost and complexity reduced. Can show circuit of LC-TR based on DWT as shown in Figure (6). For starters, remove some components that can build a system without having to such as LPF, Amplifier, Integrator and Decision output. Thus, propose a system with no large component also, this component not expensive. An autocorrelation is used to correlate the unmodulated reference pulses or signals with the modulated required data signals to demodulate the data signal. The autocorrelation takes the received signal $r_{tr}(t)$ and multiply it with a $T_f$ delayed received signal .Can express an auto correlation bellow.

$$D = \sum_{j=0}^{N_s-1} r_i(t) r_i(t - T_f) dt$$

$$= \sum_{j=0}^{N_s-1} \{[g_{rx}(t - 2jT_f) + b_i g_{rx}(t - (2j+1)T_f)] + n(t)]$$

$$.[g_{rx}(t - 2jT_f - T_f) + b_i g_{rx}(t - (2j+1)T_f - T_f) + n(t - T_f)]\} \quad (22)$$

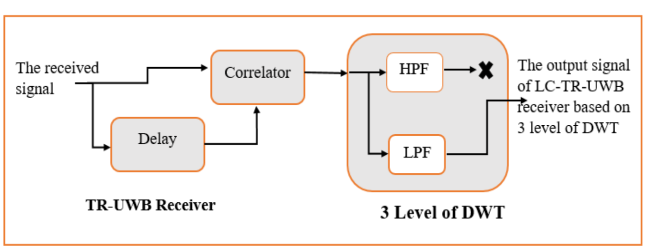



**Figure 6 The Circuit Of LC-TR-UWB Based On DWT.**

After that, removed Integrator, Decision output and used 3 levels of DWT. The DWT consist of two type filters HPF and LPF. In this receiver, need to analyze high frequencies. So that, using only LPF for 3 levels of DWT in order to remove high range of frequencies that contains or caused the noise signal, these levels can express bellow.

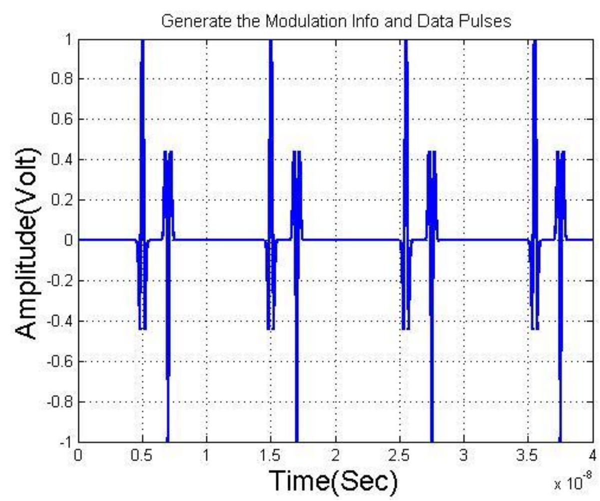
$$cA1 = \sum_{K=0}^{L} h(k)\, D(2n+k), \text{level 1 of DWT} \quad (23)$$

$$cA2 = \sum_{K=0}^{L} h(k)\, cA1(2n+k), \text{level 2 of DWT} \quad (24)$$

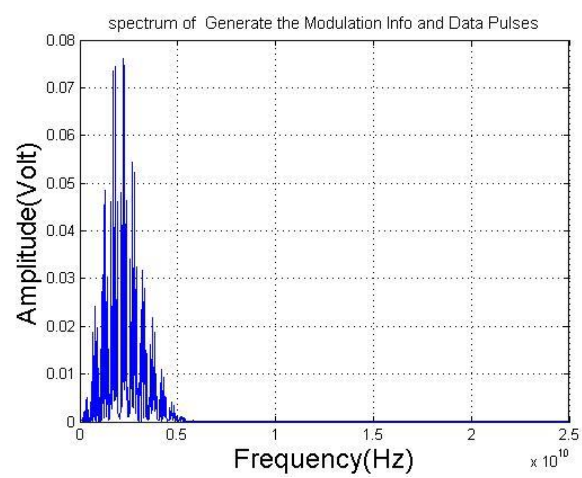
$$cA3 = \sum_{K=0}^{L} h(k)\, cA2(2n+k), \text{level 3 of DWT} \quad (25)$$

## SIMULATION RESULTS AND DISCUSSION

The proposed system produces reference pulses and two types of pulse data, with only the reference pulse being modulated. Figure (7) depicts the output transmitter signal.




**(A)**

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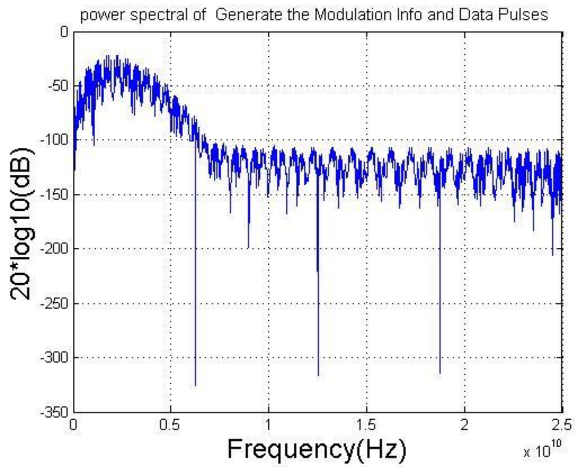
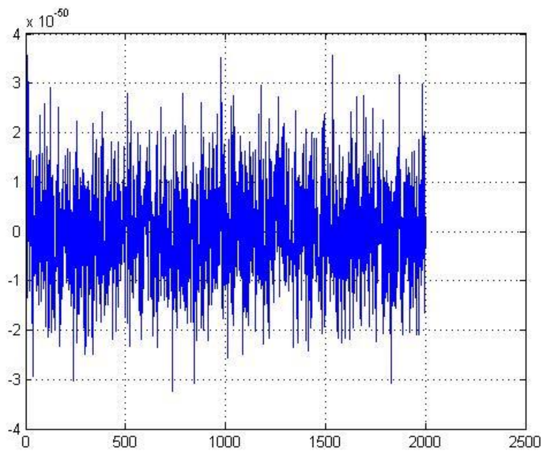



**(C)**

**Figure 7 (A) THE SIGNAL TRANSMITTER OF LC-TR-UWB, (B) THE LC-TR SPECTRUM FOR THE TRANSMITTER SIGNAL, AND (C) THE POWER SPECTRAL OF THE TRANSMITTER SIGNAL FOR LC-TR.**

Furthermore, the channel's noise signals and the channel's output signals can be seen in Figure (8).

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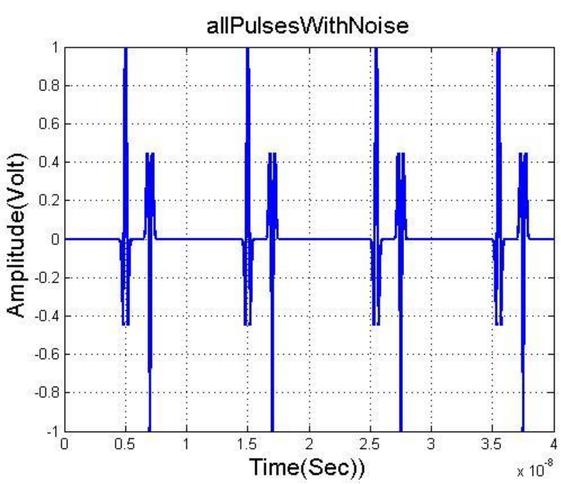


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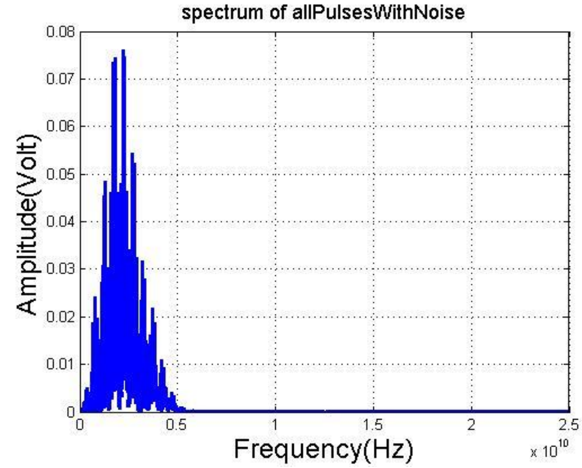


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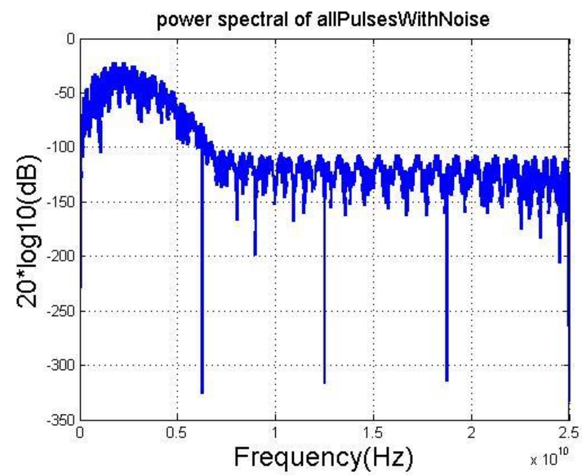
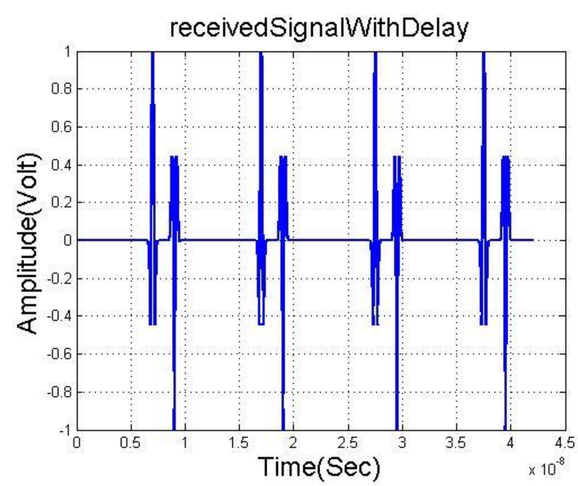



**(D)**

**Figure 8 (A) THE ORIGINAL NOISE SIGNAL THROUGH THE AWGN CHANNEL, (B) THE OVER CHANNEL SIGNAL, (C) THE CHANNEL SPECTRUM, AND (D) THE CHANNEL POWER SPECTRAL.**

Figure (9) illustrates the received siganl at delay interval and correlation for both data pulses and refernce pulses

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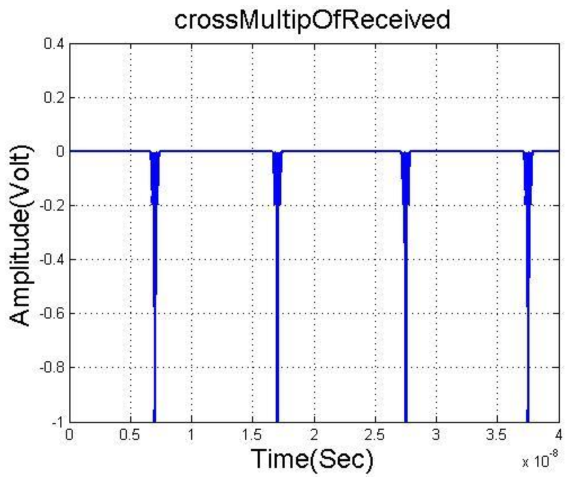


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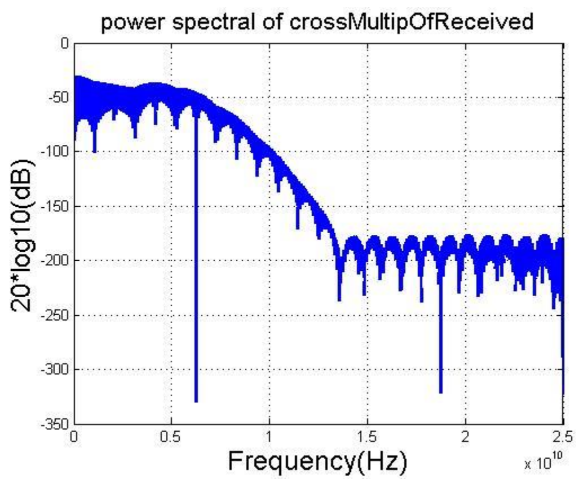


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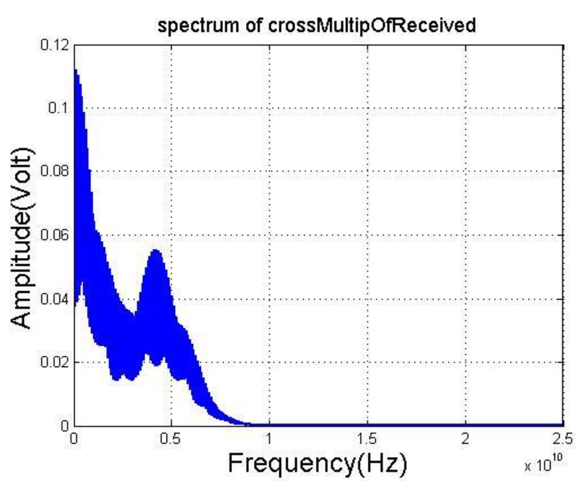
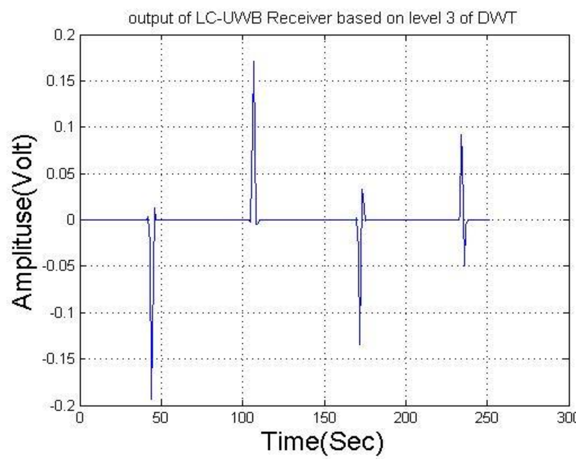


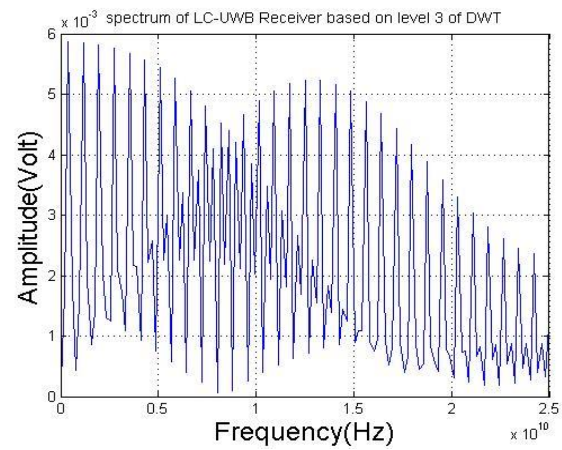

**(D)**

**Figure 9 (A) THE RECIPIENT WITH DELAY SIGNAL, (B) THE CORRELATOR PULSE, (C) THE SPECTRUM OF THE CORRELATED PULSE, AND (D) THE SPECTRAL POWER OF CORRELATED PULSE.**

Three levels of DWT were used to normaly attenuate the noise in the output of the received pulses. Figure (10) shows the output signal of the LC -TR ultra wideband receiver.




**(A)**

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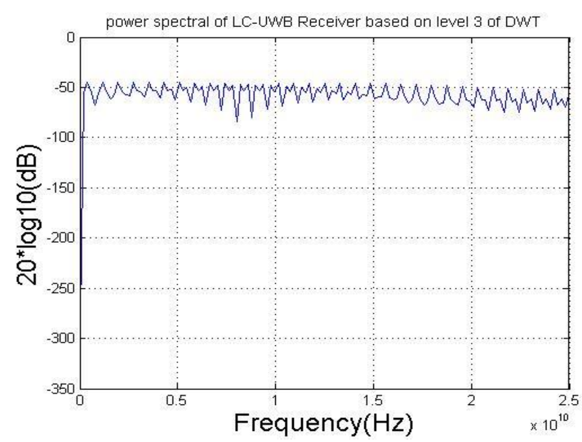


**(C)**

**Figure 10 (A) THE SIGNAL RECEIVER OF LC-TR-UWB BASED ON 3 LEVELS, (B) SPECTRUM OF THE SIGNAL RECEIVER OF LC-TR-UWB BASED ON 3 LEVELS OF DWT AND (C) POWER SPECTRAL OF LC-TR-UWB RECEIVER BASED ON 3 LEVELS OF DWT.**

Finally, the data pulse in the receiver contains both noise and information signals, whereas the reference pulse only contains noise signals; as a result, the transmitter signal can be obtained by seperating take away the reference pulse out of data signals. The results show and proved the proposed system has a high BER efficiency, low power, and low complexity, and does not include channel estimation. Furthermore, the BER value is reduced, as well as the number of incorrect bits.

**TABLE I**
**BER AND ERROR BITS OF LC TR ULRA WIDEBAND RECEIVER**

| LC TR ultra wideband transceiver with levels of DWT | No. of wrong bits | BER value |
|---|---|---|
| LC TR Ultra Wideband Conventional Transceiver | 97.4461 | 0.0487 |
| LC TR ultra wideband with 1 level of DWT | 54.8130 | 0.0274 |
| LC TR ultra wideband with 2 levels of DWT | 27.4548 | 0.0137 |
| LC TR ultra wideband with 3 levels of DWT | 13.7789 | 0.0069 |

## CONCLUSION

As can be seen from the output received signal, it contains noise, bit error, and is very fuzzy. As a result, a new system based on the DWT known LC TR UWB system was proposed. This system employs DWT, which is made up of two types of filters: LPF and HPF. The LPF was then used in all levels of DWT to obtain the output of the received signal with very little, high relief, and minimal disruption. Also, because there is no need for an integrator, amplifier, or LPF, this system does not require any large or expensive components. Furthermore, it is low in cost, low in power, light in weight, and does not require channel estimation. Finally, instead of using LPF and FFT to weaken noise, a DWT was used. LPF only reduces noise. However, DWT is more effective than other methods at reducing noise. FFT is also used to convert generated signals from the time field or domain to the frequency range or domain. As a result, some data will be lost. In addition, DWT was used to reduce the manufucturing complexity of the designed TR ultra wideband receiver.

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