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UWB Excitation Pulse for Rectangular Patch Antenna

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***Abstract*— A design process of excitation pulse for rectangular patch antenna is presented. The Ultra Wide Band pulse generator is based on multiplying the triangular pulse envelope to a sinusoidal wave in order to generate the nanosecond pulse. This new pulse shape, having maximum amplitude of 154 mV, pulse duration about 1 ns and the pulse repetition period PRP is 10 ns, is ex- cited the rectangular patch antenna in the frequency range of 3.1 GHz to 5.1 GHz. The proposed antenna has been devise using Glass Epoxy substrate (FR4) with dielectric constant $\epsilon_r = 4.4$ and loss tangent tan δ equal to 0.02. The excitation and radiation pulse for UWB rectangular patch antenna is characterized by the bandwidth of 2 GHz, centered at frequency of 4.1 GHz, and the limited Power Spectral Density (PSD) is -41.3 dBm/MHz.**

***Index Terms*— Ultra Wide Band (UWB), pulse, transmitter, generator, multiplier, triangular pulse generator, antenna, microstrip, rectangular patch, return loss , ADS momentum.**

I. Introduction

According to Federal Communication Commission (FCC), Ultra Wide Band communication system is defined as any system that has a bandwidth larger than 500 MHz at -10dB. The FCC regulation also fixed the maximum average equivalent radiated isotropic Power Spectral Density (PSD) of –41.3dBm /MHz [1].

The radar system can be exploited in a variety and great number of various applications such as military field, detection and localization of the moving object. In later years, the radar is used for non contact measuring of some organs of parameters target such as heart motion and respiration [2].

Figure 1 makes the synoptic of UWB medical radar presenting the most important components: UWB generator sends a short duration pulse to moving in the direction of target and then detecting the reflected pulse response with a UWB receiver [3].

We can identify various shapes of UWB pulses generated: rectangular pulse, raised- cosine pulse and the pseudo-raised cosine that can be classified into two large groups.

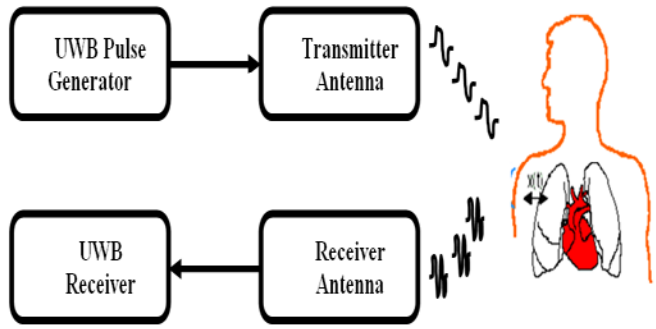

Fig.1. Block diagram of UWB radar

One category includes a pulse generated without requiring frequency translation. The pulse width is defined by delay elements that are tunable. The UWB signal generated by such transmitter is typically referred to as carrier-free impulse or mono-pulse UWB signal [4].

The other category presented a pulse generated at base band and up-convert by frequency translation using a local oscillator. In such transmitters, the bandwidth and center frequency of the generated signal can be adjusted separately by the width and the frequency of the input oscillator signal [5]. Also, by tuning the center frequency of the oscillator, the transmitter can operate over multiple frequency bands [6] [7].

In the UWB radar system, an antenna is designed to emitting a short signal and receiving echo carrying information to be processed. There are several shapes of microstrip patch antenna: circular, square radiating element, triangular, semicircular..., but the most common is rectangular element [8] [9].

In this paper, we begin first with a general architecture of the Ultra Wide Band generator. After, we study the design of some blocks of UWB generator. Then, we interested in the

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design and simulation of the rectangular patch antenna. Finally, the various simulation results of this circuit and conclusions are made.

II. Study of UWB Transmitter

In the literature, there are different pulse shapes for UWB transmitter such as gaussian pulse and its derivatives, triangular, rectangular, and cosine envelope. The new pulses are generated by converting the triangular envelope to the 4.1 GHz center frequency via a multiplier. The description and design for UWB generator circuit is presented in Fig.2. A theoretical study of UWB pulse generated and its PSD are presented in this section. The pulse shape is characterized by some parameters, such as the period repetition pulse PRP, pulse durations (T_p), the bandwidth (B) and the maximum amplitude (V_p) [10] [11].

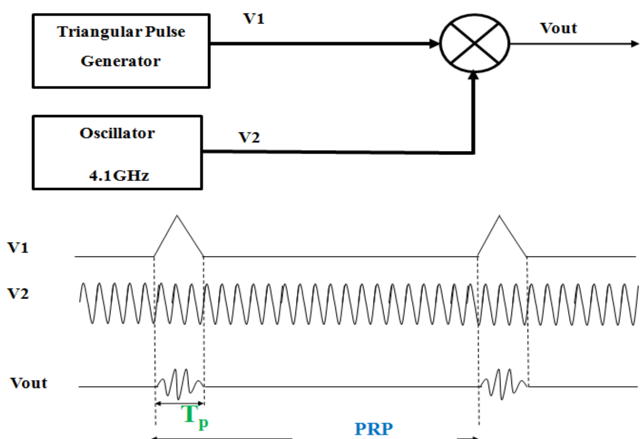


Fig.2. Proposed architecture of UWB generator

In this section, we are interested to study the three blocks of UWB transmitter: oscillator generated a sine wave at frequency 4.1GHz, pulse triangle and multiplier.
The output sine wave of oscillator circuit (V_2 (t)) is given by this expression:

$$V_2(t) = V_p \cos(2\pi f_0 t) \quad (1)$$

Where, V_p and f_0 are the amplitude and the frequency of output signal respectively. Typically, the center frequency f_0 is set equal to 4.1 GHz and the period is 244 ps.
The triangular pulse generator produces the signal (V_1 (t)) defined by the following expression:

$$V1(t) = \Delta\left(\frac{t}{T_p/2}\right) = \begin{cases} 1 - \frac{|t|}{T_p/2} & ; -T_p/2 \le t \le T_p/2 \\ 0 & ; otherwise \end{cases} \quad (2)$$

The duration of triangle envelope (T_p =1 ns) is specified by this expression:

$$\Delta f = f_H - f_L = \frac{2}{T_p} \quad (3)$$

By multiplying the output sine wave of oscillator and triangular pulse, the multiplier generates an impulse signal (V_{OUT} (t)) whose shape is defined by the following expression:

$$V_{OUT}(t) = V_p \sin(2\Pi f_0 t)\, \Delta\left(\frac{t}{T_p/2}\right) \quad (4)$$

To calculate the distance (D) between radar and obstacle, the time delay (Δt) between emission and reception is measured. This time delay is expressed by the following equation:

$$D = \frac{C\,\Delta t}{2} \quad (5)$$

Where C: speed of light (3.10^8 m/sec).
For a short distance (D=1 m), pulse should be able to move and return in 6.6 ns. According to equation (5), we deduced the value of period repetition pulse PRP=10 ns.
The maximum impulse amplitude can be calculated as a function of R, PRP and FCC limit values (Γ).
The maximum amplitude (V_p) of the UWB signal is calculated by the following expression:

$$V_p = \sqrt{\frac{2.R.PRP.10^{\frac{\Gamma-90}{10}}}{T_p^{\sqrt{\Pi}}}} \quad (6)$$

Where R is the impedance of antenna (R=50 ohm) and the maximum of the power spectral density of the FCC mask limit (Γ=−41.3 dBm/MHz). In this research, the parameters of UWB signal are bandwidth B=2 GHz, f_0=4.1 GHz, maximum amplitude is 0.154 V, pulse duration T_p=1 ns and period repetition pulse PRP=10 ns.

III. Simulation Results of UWB Pulses Generator

The proposed architecture of UWB generator depicted in Fig.3 has been designed and simulated using the tool of modeling Agilent Advanced.

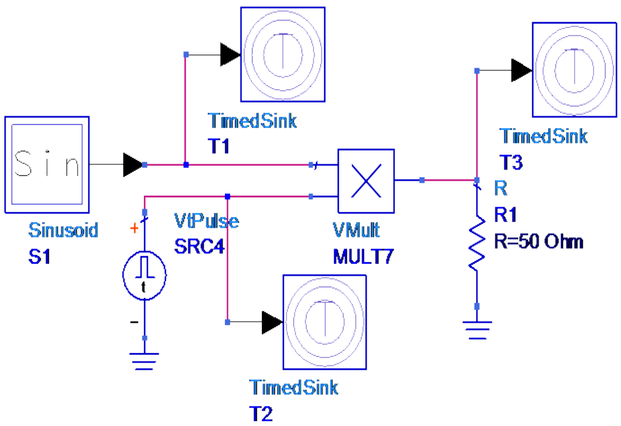


Fig.3. UWB generator model

Figure 4 illustrates the output signals of oscillator (T1) and the triangular pulse (T2). The oscillator circuit generates a signal at 4.1 GHz with amplitude about 154 mV. The triangular signal produced a pulse of 1 ns duration and the pulse repetition period of 10 ns which satisfy the required parameters of our UWB generator architecture.

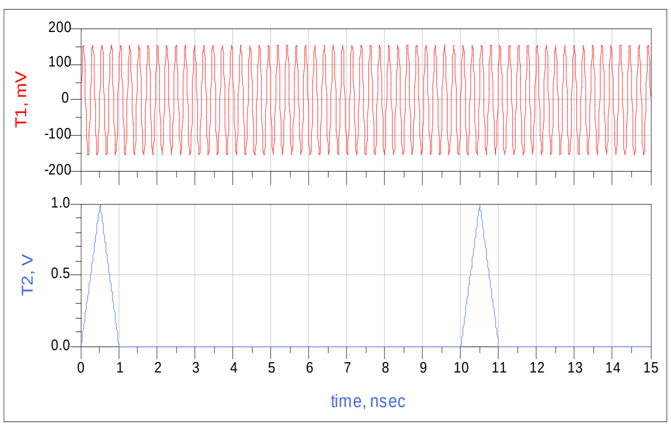


Fig.4. Input signals of UWB generator

The output signal of generator (T3) is illustrated in Fig.5. The amplitude of the output signal generator is 76 mV, the pulse width is 1 ns and the pulse repetition period is 10 ns.

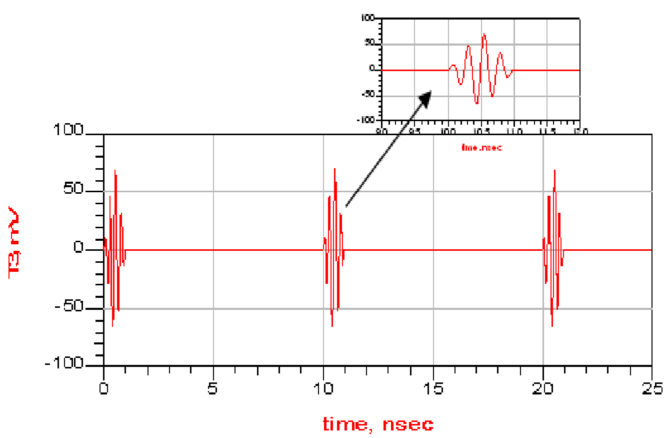


Fig.5. Output signal of UWB generator

The PSD of the UWB pulse generated is shown in Fig.6. The maximum PSD is equal to -41.3 dBm/ MHz and the band width is 2 GHz. From the spectral shape, it is clear that, the output impulse generated complies with FCC mask with high spectral efficiency.

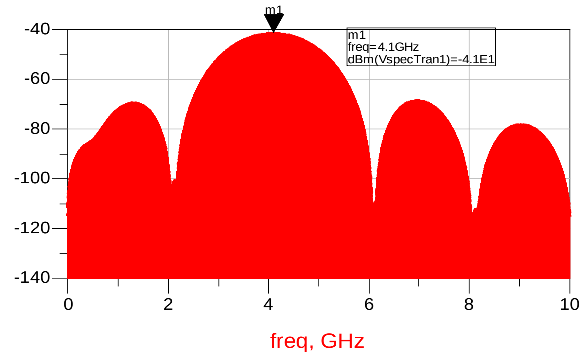


Fig.6. Pulse PSD in compliance FCC Mask

IV. MICROSTRIP ANTENNA FOR UWB COMMUNICATIONS

This section describes the design and analysis of a rectangular microstrip patch antenna for UWB application (Fig.7). The microstrip antenna is designed using electromagnetism ADS Momentum with various specifications such as a resonant frequency equal to 4.1 GHz, frequency range [3.1-5.1] GHz, dielectric of Glass Epoxy substrate (FR4) ε_r = 4.4, height of substrate h= 1.6 mm, loss tangent = 0.02 [12].

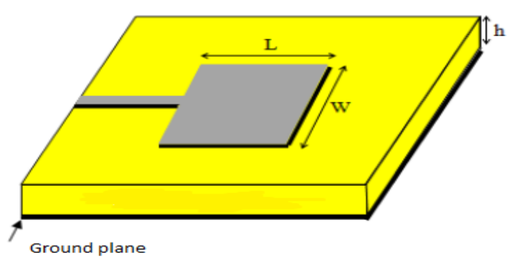


Fig.7. Microstrip patch antenna

Before designing a rectangular patch antenna, there are several parameters needed to be considered which will affect the antenna bandwidth as well as the resonant frequency. The length (L) and the width (W) are essential parameters of the rectangular patch antenna which calculated by the following expressions [13] [14]:

$$L = L_{eff} - 2\Delta L \tag{7}$$

$$W = \frac{C}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{8}$$

Where:

C: Velocity of light, $3*10^8$m/s;

ε_r : Dielectric constant of the substrate;
f_r : Resonant frequency;
L_{eff}: Effective length;
ΔL: Extended length;
The effective length, effective dielectric constant and extended length of the microstrip antenna are calculated using the following equations:

$$L_{eff} = \frac{C}{2\, fr\sqrt{\varepsilon_{eff}}} \qquad (9)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1+\frac{2h}{W}}}\right) \qquad (10)$$

$$\Delta L = h * 0.412 * \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (11)$$

A. Simulation Results

In this section, the proposed Ultra Wide Band microstrip antenna was designed using ADS momentum based on rectangular patch with dimensions of width and length 22.26 mm and 16.95 mm respectively. The width and length of the feeding line is 3.1 mm and 10.4 mm. The proposed geometry design of rectangular patch antenna using ADS Layout is illustrated in Fig.8.

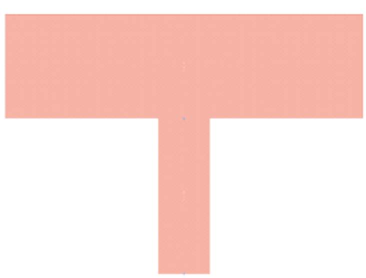


Fig.8. Basic geometry of the rectangular patch antenna

Figure 9 shows the return loss amplitude as a function of the frequency (S11) of the designed UWB antenna. The obtained result indicate that the antenna has UWB characteristics with a return loss below -10 dB in the frequency band from 3 GHz to 5 GHz and the resonance frequency is centered at 4.3 GHz.

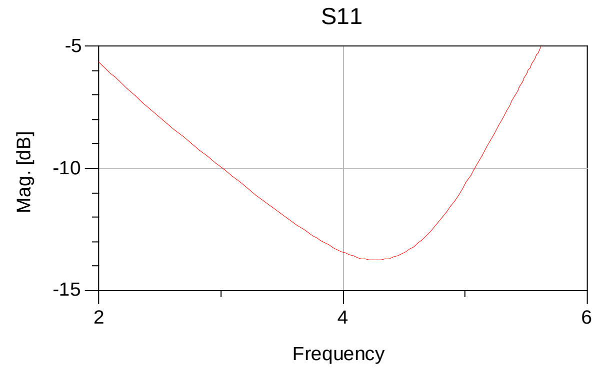


Fig.9. Return loss (S11)

Figure 10 shows the simulated result of Voltage Standing Wave Ratio (VSWR) which varies generally from 1.5 to 2. Starting at simulated result, the rectangular patch antenna presented the best characteristics of VSWR in the frequency range 3 GHz to 5 GHz. It complies with the VSWR equal to1.8.

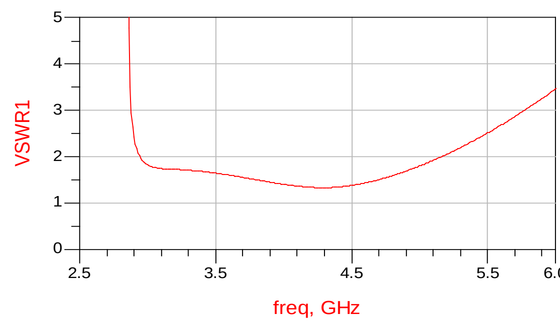
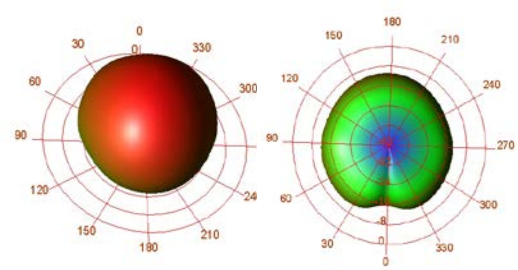


Fig.10. VSWR simulation result

The radiation pattern of UWB antenna is depicted below (Fig .11). We are getting one lobe (main lobe) which corresponds to the theoretical radiation pattern of patch antenna radiant.



(a) (b)

Fig.11. 3D radiation pattern: (a) Front view, (b) Opposite view

Table 1 shows the simulation of directivity and gain of microstrip antenna of the rectangular patch. Directivity, Gain and power radiated are important parameters to determine the efficiently of antenna. Gain of 3.48 is achieved.

Table 1. Antenna Parameters

Power radiated (Watts)	*0.4949*
Effective angle (degrees)	159.60
Directivity (dB)	6.5430
Gain (dB)	3.488
Maximum intensity (Watts/ Steradian)	0.17762

B. Time - Frequency Domain Characteristics of Microstrip Antenna

UWB Radar system is used to determine the velocity, range or detection of any target. UWB radar transmits a short pulse that reflects from range any target in the channel and detected by UWB receiver to find the properties of target. The UWB pulse generator is connected to the microstrip antenna (Fig.12). The radiated pulse is reflected by the object and detected with the receiver antenna.

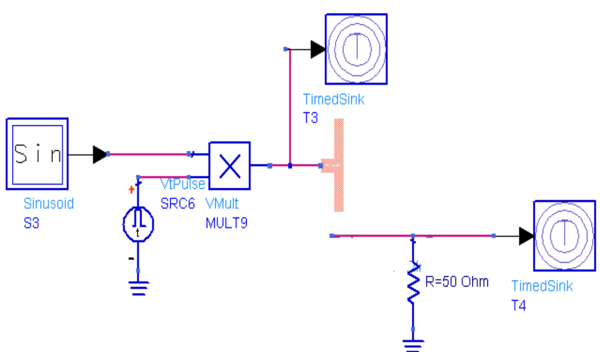


Fig.12. Microstrip antenna connected to UWB pulse generator

In this simulation (Fig.13), the excitation pulse is characterized by amplitude about 70 mV, duration of the pulse is approximately 1 ns and the frequency range [3-5] GHz.

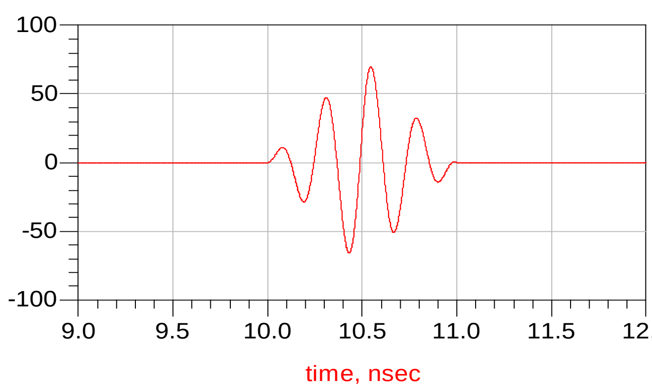
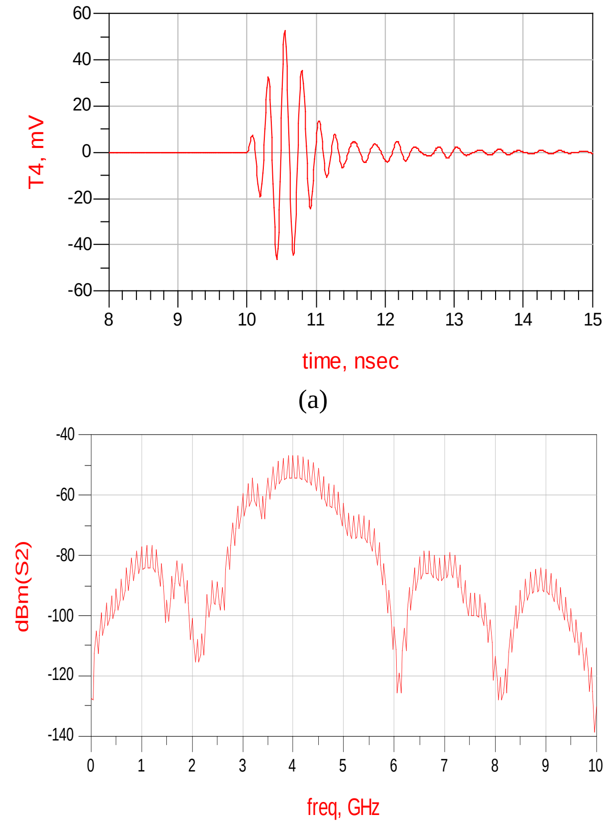


Fig.13. Excitation signal

Figure 14 (a) shows, in time domain, the radiated UWB pulse for rectangular patch antenna which is characterized by maximum amplitude of 53 mV. Figure 13(b) presented, in frequency domain, the PSD of the pulse radiated by the patch antenna .We note the maximum PSD is less to -41.3 dBm /MHz that complies with the FCC mask and the band width is 2 GHz at -10 dB.



(b)

Fig .14. Radiation pulse : (a) time domain, (b) frequency domain

V. CONCLUSION

Ultra Wide Band radar is a detection system which used a short pulse in order to detect or identify a moving target. The proposed UWB pulse generator has been studied at the frequency of 4.1 GHz and frequency range from 3.1 to 5.1 GHz. This new shape of UWB generator contains a triangular pulse, sine wave oscillator and multiplier. Firstly, we have designed a pulses generator circuit using the tool Advanced Design system. Secondly, the design and simulation of rectangular microstrip patch antenna that operates in UWB frequency range |3.1–5.1 GHz] was successfully designed using advanced design system Momentum. When this antenna is implemented it could be used to transmit or receive signals in the frequency range of the UWB system.

Thus, we have simulated the global architecture of UWB transmitter containing the designed generator circuit and UWB microstrip antenna. The results shows the performance of this circuit which is generated and radiated a UWB signal centered at frequencies of 4.1 GHz, the bandwidth of 2 GHz and the PSD of -41.3 dBm/MHz.

The biomedical applications of Ultra Wide Band radar system promise a very important means to remotely monitor physiological signal. As future research work, we interested on the design of UWB pulse propagation into a layered model of the human body using the microstrip transmission lines in the tool of modeling Agilent Advanced Design System.

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