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Design and Simulation of UWB LFM Radar

Dr.A.NagaJyothi, **Dr. T. Pavani , G. Thhiagarajan, G.V. Sai Swetha**

Abstract: UWB radar signal generator requires advanced digital signal processing techniques. Direct analysis techniques often fail in designing such complex systems. Keysight SystemVue has enough models and integration capability to handle modern radar systems. A system design of UWB radar signal generator where LFM waveform is used as a source is considered and simulated using a platform in the SystemVue tool. This allows the users to reduce their system development time and cost, and also decreases the chances of unexpected system failures in the system development process.

In this paper models for signal generation transmission, reception, signal processing and measurements are used to design advanced UWB Radar. UWB Radar use low energy level for short range, high bandwidth communications.

I. INTRODUCTION

The majority of radars have narrow frequency range. This narrow frequency restricts the information capacity of the system. There is a need to expand the frequency range in order to increase information capacity. The solution to this is to increase the transmission time. Ultra Wide Band (UWB) technology uses pulses in the order of microseconds, covering a very wideband in the frequency domain [3.1 to 10.6GHz] with limited transmit power of -41dBm/MHz [1]. UWB radar can be used to monitor the traffic of vehicles, perimeter detection, and target identification and medical diagnosis. It has clutter rejection and is energy efficient device [2]. The advantages of UWB Radar are: The range measurement of the detection target is made more accurate, which results in improvement of radar resolution for all coordinates. It identifies the class and type of target, as the received signal carries information not only about the target but also its separate parts. It reduces the radar effects from rain, mist and aerosols, etc. As the effects on radar are reduced and stability is improved, so more uniform radar cross section is provided. Narrow antenna pattern is obtained by changing the radiated signal characteristics improving the radar's immunity, so that it can resist external narrowband electromagnetic radiation effects and noise. The radar "dead zone" is decreased, keeping the radar signal secret and makes it hard to detect [3].

II. PROBLEM FORMULATION

The system design of UWB radar having LFM based signal generator is taken up for simulation using SystemVue tool. The change of parameters is the chief hurdles in such designs. The SystemVue tool eliminates these hurdles and provides a user friendly approach. The LFM spectrum from the source can have a bandwidth of 50MHz. It is the objective of this Endeavor to maximize the bandwidth transmitting waveform. Such efforts can be simplified by the SystemVue tool so that

the maximum value of transmission range can be altered as per the requirement of the designer.

III. METHODOLOGY

Various aspects of design of UWB radars are investigated meticulously. The parameters of LFM waveform are judiciously selected considering the wide range offered by SystemVue. The selection of proper band pass filter amplifier as well as delay factors is critical for the overall improvement of design. Considering the importance of increase in transmitted bandwidth, simulation is carried out to maximize the same.

IV. LINEAR FREQUENCY MODULATION

This type of modulation employs sinusoidal waveforms whose instantaneous frequency increases or decreases linearly over time. Increasing the duration of a transmitted pulse increases its energy and improves target detection capacity. On the other hand, reducing the duration of a pulse improves the range resolution of the radar[4]. The LFM spectrum has a shape similar to a $sinc^2(x)$ function shown in Fig 1. It also contains an ideal spectrum with the same bandwidth. The matched filter response is the sinc function which is the autocorrelation function of the original signal. It is advisable to treat the spectrum as rectangular. (That is, being flat within the swept bandwidth)[5-6].

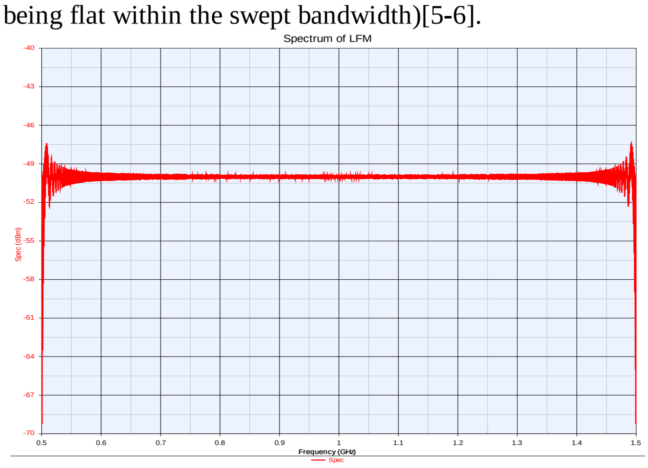

Fig1: Spectrum of LFM Waveform

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Dr. A. Naga Jyothi, ECE, VIIT, Visakhapatnam, India.
Dr. T. Pavani, Industrialist, Ambica Mart, India.
G.V. Sai Swetha, ECE, VIIT, Visakhapatnam, India.

V. SIMULATION OF UWB RADAR

There are two types of UWB signals that are impulse and modulated. The LFM UWB is of the latter variety. For this, relative bandwidth should exceed. The top level system platform structure shown in the Fig2 includes signal source, transmitter, delay, receiver and measurements. The UWB radar designed can be used as test platform for verification of the integrated system at each stage of development[7]. This is done by connecting algorithm, instruments and separate models from the library. In this method sinks are used for direct connection with various signal generators. In this model the LFM waveform generator is used in to the transmitter section. The UWB radar transmitters are extremely valuable for finding small moving targets hidden by heavily cluttered environment as the bandwidth is increased from 50MHz to 75MHz. The RF transmitter features a local oscillator which includes phase noise, modulators, mixers, amplifiers and filters. The same applies to RF receivers and it includes receiver's oscillators, demodulators, amplifiers and filters.

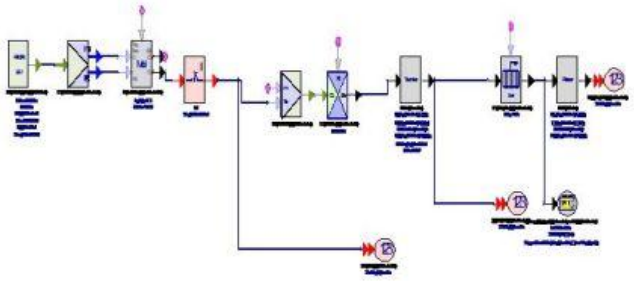

Fig 2: Block Diagram of UWB LFM Radar

A. Signal Generation

LFM have been precisely used in high resolution radar due to its Pulse Compression Ratio (PCR) >> 1 shown in (1) [8].

$$PCR = \frac{C_0 * \tau/2}{C_0/2B} = B.\tau \qquad (1)$$

Table 1: Representing parameters for generation of LFM waveform

S.No	Parameter	Value
1.	Pulse width (τ)	10μs
2.	PRI	10μs
3.	Bandwidth (B)	50MHz
4.	Sampling rate	100MHz

The generation of a LFM waveform with large product of pulse duration and bandwidth is simulated in keysight systemvue software. The rapid development in technology makes it possible to generate an LFM waveform for any given specifications. Compared to all previous ones, the keysight systemvue has distinct advantages such as good flexibility, high reliability and convenient compensation for waveform distortion[9].

B. Modulation

The Complex to Real and Imaginary converter does the conversion of input complex values to the output real part and imaginary values. It reads one sample from input and writes the sample to real part and imaginary part of every output. It implements a modulator that can perform phase, frequency, amplitude or I/Q modulation. For generating the modulated complex envelop signal (cx) the input type is set as I/Q, and this model behaves as I/Q modulator, where I signal is given at input1, Q signal is given at input2, the output as in (2)

$$cx = S_a \cdot (input1 + j \cdot input2) \qquad (2)$$

The set sample model connects the sample rate with its input signal and generates a timed signal at the output. A signal is known as timed signal when it already has sample rate associated with it. So at each execution of this model, a signal sample is read from the input and single sample is written to the output. By this technique input to the transmitter has timed signals that are redundant[10].

C. Transmitter for UWB Radar

Transmitter plays a vital role in Pulse Doppler Radar system. In radar systems a transmitter is used for the conversion of baseband signal into RF signal and this is transmitted through communication channel using an antenna. There exists various ways of simulation of Pulse Doppler radar transmitters, but the weight age is given to the simulation performed in this paper. It performs mainly two functions: frequency modulation and power amplification.

Accuracy spectral emission and output power level are the three performance matrices that are mainly considered requirements for a radar transmitter. A number of architectures are employed to design a RF transmitter which depends on form factor, cost and power required. The transmitter front end consists of various RF building blocks that carry out basic functions like frequency selection and frequency transition. The transmitter architecture is of two types which are mixer based architectures: Heterodyne & Homodyne[10]. The Fig.3 demonstrates a heterodyne architecture by Fessenden[11] in which the baseband signal undertakes two stages of up conversions with two different local oscillators. In this technique two frequencies are combined to generate a non linear device called a mixer. The newly obtained frequencies generated from the non linear mixing comprise of two frequencies, that is, its sum (f_1+f_2) and its difference (f_1-f_2). These frequencies are called beat frequencies or heterodynes. The study of the frequency spectrum from the output of the mixer shows the f1+f_2, f_1-f_2. Harmonics of f1 & f_2, beat frequencies of the various harmonics of the interactions. In many cases, only one among the two frequencies is desired and the other is filtered out at the mixer output. The heterodyning expression can be mathematically represented using trigonometric identity, while two sine wave signals, sin(2πf_1t) and sin(2πf_2t) are multiplied as shown in

(3)

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$$\sin(2\pi f_1 t).\sin(2\pi f_2 t) = \frac{1}{2}\cos[2\pi(f_1 - f_2)t] - \frac{1}{2}\cos[2\pi(f_1 + f_2)t]$$

(3)

In transmitters, a number of correction and equalization stages are used after modulation, in the process of direct modulation the correction and equalization stages must be developed individually for every output RF. The form of multiplication can be extended or expanded on all stages have to be returned for the latest or new RF. On the other hand, in heterodyning only output stages need to be returned[12].

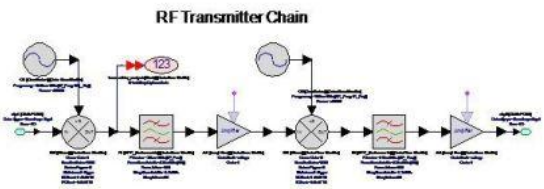

Fig3: Schematic of Transmitter

1. Local oscillator

It is a device which generates a reference signal to be used as one of the mixer inputs. It also serves for up conversion. The local oscillators are utilised for frequency conversions[10].

2. Mixer

A mixer is a non-linear device with 3 ports allowing the frequency translations. This is mostly used to get the LFM signal into RF carrier level. Mixing of two signals will generate both sum and difference of the input signal. Giving the higher and lower translations a local oscillator is used as the input which allows up conversion. So to select the desired frequency component a filter is required. The mixer combines the RF signal (at RF input), with signal generated from the local oscillator (at LO input). This produces an intermediate frequency (at IF output). The main properties of RF mixer are: Conversion gain or loss, Intercept point, Isolation, Noise[10].

3. Band pass filter

These RF filters are the devices that carry out the selection of frequency by only passing the desired range of frequencies. The signals that are unwanted are strongly attenuated. An ideal band pass filter will pass the desired signals with no losses and eliminates the desired ones perfectly[10]. This paper deals with the band pass filter which passes signals only between a range of two given frequencies. Passband and stopband attenuation are the most outstanding performances features of the filter, besides bandwidth and group delay. Butterworth is one of the standard filters, which is used, as it has no ripple in the passband or stopband. It has the best trade off between attenuation and phase response. It is with wide transition region having relatively good transient characteristics.

4. Amplifier

It is a device which enhances the level of power of a signal given. In a transmitter, amplifier is called as power amplifier as it is required to strengthen the signal at the utmost allowed linear output. On the other hand, in a receiver, it is necessary to get the input signal to a suitable level for processing with least noise to avoid degrading. These include general performance parameters such as gain, gain compression, noise Fig, inter modulation and harmonic distortion[10].

D. Delay

The delay model is introduced between the output and input. The code generated does not have any instance of this model. A delay of 1ms is introduced for the transmitted signal and it is considered as received signal. The Delay model can be selected as per the requirement[10].

E. Receiver for UWB Radar

The receiver is used to detect target with received echoes[13]. By using mixing of superhetrodyne the block diagram for receiver is shown in Fig 3.

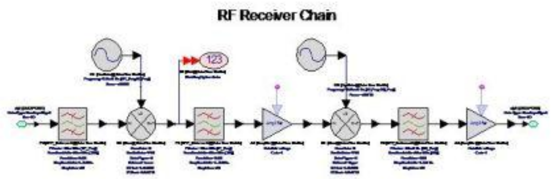

Fig4: Schematic of Receiver

VI. SIMULATION RESULTS

In this section, the simulated transmitter section Fig 3 results are compared with the received one. The radar parameters and platform on which the radar is operated suggests that there is an increase of 50% bandwidth shown in this section. The LFM spectrum from the source has a bandwidth of 50MHz. The UWB radar is transmitting the waveform whose bandwidth is 100MHz and is shown in Fig 5.

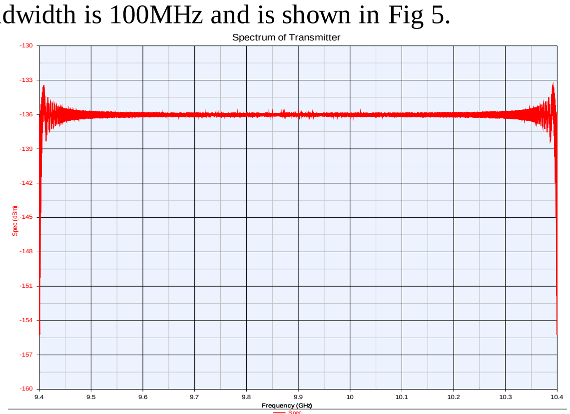

Fig5: Spectrum of the transmitter

The comparison of the transmitter and receiver results with a delay of 10ns is shown in Fig:

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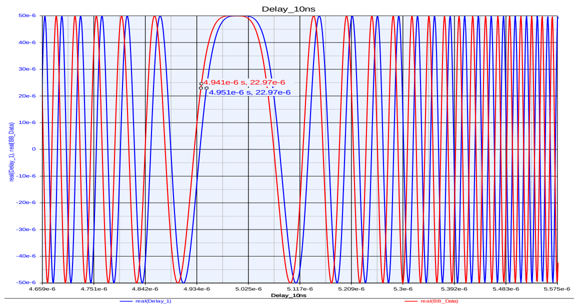

Fig.6: Transmitted and Received Signal after passing through the Delay Circuit.

The parameters for the design of transmitter and receiver are given in table2 and table3. From the Fig: 1 to Fig: 5 it is assured that the UWB is designed as an integrated system with more than increase in bandwidth. The signal after delay is given to a receiver section stated 3.5. The spectrum of the receiver after converting from RF to IF is shown in Fig 7. The Fig7 conforms the reception of signals and finally it can be said the layout designed in Fig 2 works as LFMUWB radar.

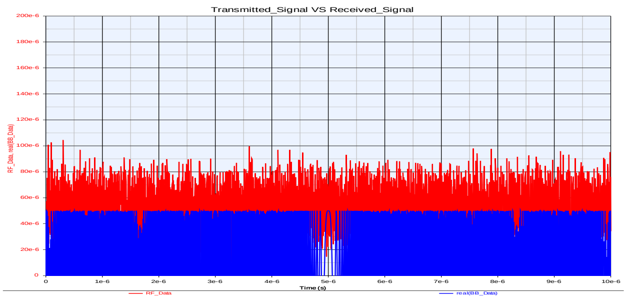

Fig7: Spectrum of Receiver

Table 2: Representing the output results

S. No	Parameter	Output (dBm)
1.	Transmitter out	$100e^{-6}$
2.	Receiver out	$50e^{-6}$

VII. CONCLUSIONS

A unified approach to UWB radar signal generation design that relies on SystemVue offers a viable means of creating effective systems for advance radar studies. This UWB radar signal generation provides a user friendly environment for design and simulation of the system performance. This UWB radar signal generators are critical for high performing advanced radar systems. The goal of achieving high bandwidth of transmission has been achieved by selection of optimum parameters with desirable features.

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AUTHORS PROFILE

Dr.A.NagaJyothi was born in 1982 at Visakhapatnam. She received her B.Tech (ECE) from Nagarjuna University and M.Tech(Radar & Microwave Engineering) from Andhra University College of Engineering(A). She completed Ph.D in Radar Signal Processing from Andhra University College of Engineering (A). She has a teaching and research experience of 12 years. Presently working as an Associate Professor in the department of ECE, VIIT, Visakhapatnam. She has published papers in various National , International journals and conferences. Her areas of interest include Radars, Antennas and Nano technology.Completed project sanctioned under WoS-A. Presently working for a project sanctioned under ECRA –SERB New Delhi with sanction order no. ECR 2017-000256 DATED 15/07/2017**.**

Dr. T. Pavani received her AMIE with first class from The Institution of Engineers (India), M.Tech and Ph.D. from Andhra University College of Engineering, Andhra University. She is having 10 years of teaching and research experience. Her areas of interest are Antennas, Electromagnetics, EMI/EMC.and Applications of Soft computing. She is a life member of Institution of Engineers and SEMCE.

G. Thiagarajan was born in 1959 in Tamil Nadu. He has done his BE at A.C College of Engineering and Technology at Tamil Nadu in 1977. He has industrial experience of 15 years and teaching experience of 18 years 9 months. Presently working as Associate Professor in Dept of ECE at VIIT, Visakhapatnam.

G.V. Sai Swetha was born in 1991 in Visakhapatnam. She received her B.Tech degree in ECE from NSRIT, Visakhapatnam in 2009-13. M.Tech in VLSI from BITS, Visakhapatnam in 2014-16. Presently working as SRF in a project sanctioned by Science And Engineering Research Board (SERB), with the grant no: ecr 2017-000256 dated 15/07/2017.