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Research Article

Simulation of Moving Target Indication Radar System Based on VisSim/Comm Application

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ABSTRACT

Moving target indication (MTI) is mainly designed to detect moving targets while unmoving targets are filtered out. It focuses on the technique of the modern stationary target indication, using directly the signal details to determine the reflecting object's mechanical properties, after that it becomes easier to find moving or non-moving targets. This paper presents the simulation design of the MTI radar system. The main purpose of this design is to help students in understanding the radar system subject and help teachers to explain this subject in a simpler approach. Both students and teachers need to know how the signals inside the MTI radar processor are working and how they are generated and related to each other. This paper introduces a method of simulation of MTI radar signals including, A-scope radar display, transmitted and returned radar pulses with constant and multiple pulse repetition frequency, n-delay line cancellers.

Keywords: Moving Target indicator radar, pulse Doppler radars, signal processing, n-delay line canceller, multiple pulse repetition frequency.

INTRODUCTION

Radar is an abbreviation of radio detection and ranging[1] when there is no way to detect an object such as video recording for an area such as MANET.[2] The main application of the old radar was to measure the distance (or range) from the position of the radar to the place of the target and measure the azimuth angle (direction) of the required target. Nowadays, modern radars can do much more than this such as 3D-radar which can measure the height of the target. Moreover, Moving Target Indicator (MTI) radars can measure the speed of the target as well as the other stated parameters. The principle of operation of MTI radar depends on the Doppler effect, and this type of radar is considered a very useful device to measure the speed of targets as well as detecting the motion of moving targets. The plan position indicator display of MTI radars will not show the nonmoving targets as well as the very slow-moving targets, and this will make the display of the radar more cleaner and this will reduce the processing time which is required which is very important in digital radars. It also removes the return signals of stationary objects (clutters), in addition to detecting moving targets. The Delay line canceller (DLC) can be used to accomplish this. Figure 1 shows a principle of radar operation.

In this paper, a design of the MTI radar system will be simulated and analyzed, to give a deep understanding of the radar systems and overall assessment of the teaching process. The importance of this paper is to introduce a different method of simulating the MTI radar signals including, using A-scope radar display, transmitted and returned radar pulses with constant and multiple pulse repetition frequency (PRF), n-DLC.

The organizing of the rest of the paper will be as follows, in section two explanations of some other author's related work will be written, section three shows briefly explanations of the radar system design and components. In section four, the simulation of MTI radar system with VisSim/comm 6.0 will be introduced. Finally, section five will conclude the paper.

RELATED WORK

Recent papers were published that focuses on different radar system techniques, in[3] different signal processing approaches were simulated and presented by a software-defined radar (SDR), along with an overview of how SDRs are used to implement baseline radar functionality. All of these techniques

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were applied to the MTI issue, and examples of several signatures of moving target were displayed. In Ridder And Narayanan[4], the operational reliability metric is used to assess an MTI radar's ability to detect a moving target in a variety of situations. A ground-based MTI radar in the radar scenario examined might detect a small aircraft. The obtained signal is also subjected to MTI processing to eliminate the effects of stationary ground clutter. In QasMarrogy[5], the auther by evaluating throughput, retransmission attempt, and delay parameters, a thorough review of FANET will be performed to assess and improve these problems of detection and recording video for an objects with different video formats, mobility models, and IEEE 802.11 n standards for best results.

THE DESIGN OF RADAR COMPONENTS[6]

In the following section, a full explanation of the radar design components will be explained, with all the required figures, tables and equations.

The Principle of Doppler Frequency Shift

The change in return signal frequency is called Doppler shift and this occurs whenever there is a motion of two objects. This might occur between two objects one is moving and the other is stationary, or both of the objects are moving. MTI radars exploit this Doppler phenomenon. When the MTI radar transmits an electromagnetic wave of a specified frequency, the return signal (echo) frequency will be shifted. This frequency shift will depend on whether the target is closing or opening for the radar movement. The echo signal frequency will be higher if the target is closing to the radar and this frequency increment is equal to the Doppler frequency shift (fd). On the other hand, the returned signal will be lower for the case of opening (getting away from the radar) targets.

Differences between MTI and Pulse Doppler (PD) Radars

The MTI and PD radars are in principle dependent on the Doppler frequency shift.[1] The main difference between these two radars is the PRF and other parameters. MTI radars use low PRF, while PD radars use high and medium PRF. In MTI radars, there will be in general unambiguous in range and ambiguity in velocity (Doppler shift frequency, fd), while in PD radars, ambiguity in the range may occur and unambiguity in velocity for high PRF. In medium PRF pulse radar, ambiguity in both range and velocity may occur. Other than the PRF difference between MTI and PD radars is the usual improvement factor (If) need not be improved. On other hand, in PD radars improvement in If is required. Magnetron oscillator is usually used in MTI radar transmitters, while high power Klystron oscillators are used in PD radars. Analog DLC is commonly used in MTI radars, while PD radars use an analog bank of filters. Less clutter echo signals are received in MTI radars while more clutter signals are received by PD radars.

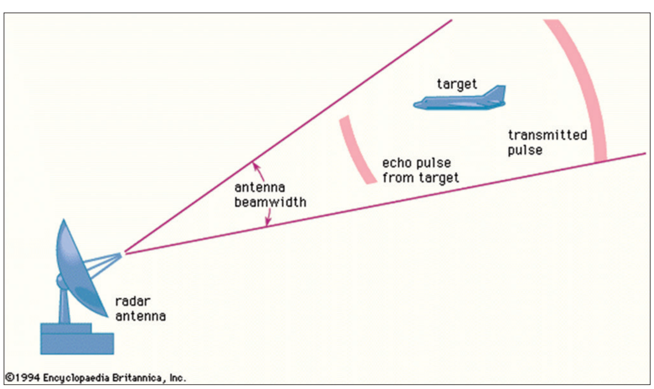

Figure 1: Principle of radar operation

Basic Principles of MTI Radar Operation[7]

An MTI radar system block diagram is presented in Figure 2. The main difference between MTI radars and other ordinary radars is the application of a reference signal generator. Figure 2 shows that there is a highly coherent oscillator (coho) is used as a reference oscillator. This coho oscillator is characterized as a stable oscillator and its frequency is the same as the intermediate frequency (IF) used in the receiver. Moreover, the output of the coho is also mixed with the local very high-frequency stable oscillator (stalo). The returned echo signal is mixed with the stalo signal so that to produce the IF signal exactly such as the superheterodyne receiver principle. It can be seen that these two oscillators serve in the receiver and transmitter modes. Incoherent MTI radar, the transmitted signal must be in phase (coherent) with the receiver reference signal. This can be performed by generating the transmitted signal from a trace of the coho reference signal as shown in Figure 2. The stalo's job is to provide the appropriate frequency conversion between the IF and the transmitted frequency. Although the phase of the stalo affects the phase of the transmitted signal, every stalo phase change is canceled at transmission because the stalo that produces the transmitted signal also serves as the receiver's local oscillator. Both the coho comparison signal and the IF echo signal are fed into the phase detector, which is a mixer. Since the phase detector's contribution is equal to

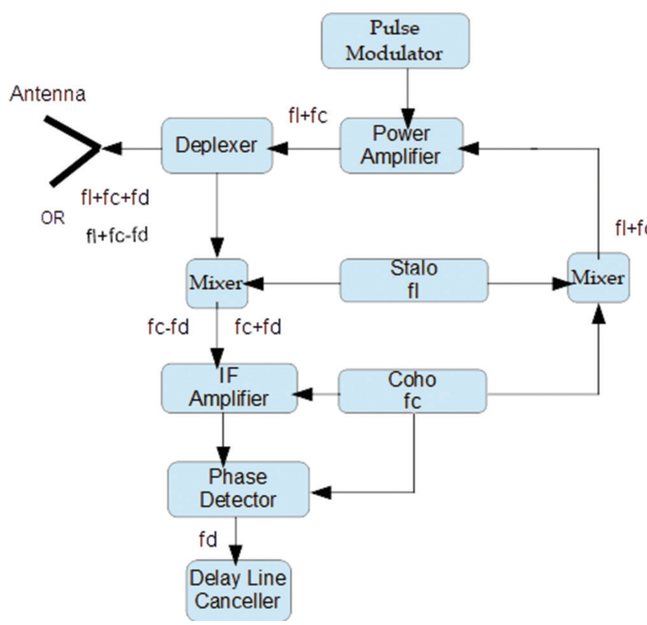

Figure 2: Block diagram of moving target indication radar

the phase difference between the two input signals, it differs from a standard amplitude detector.

The n-Delay-Line Canceller[6,8]

The output of the phase detector of MTI radar is shown in Figure 2, and this is sent to a DLC. Figure 3 shows an example of a block diagram for a time-domain filter.[6] The application of the delay-line canceller is found in MTI radars that use pulse modulation. The typical value (maybe several milliseconds) of the delay line is set to be equal to the pulse repetition time PRT, Tp (1/PRF). The magnitude of these values of delay lines cannot be achieved with electromagnetic wave transmission lines. Therefore, one can achieve these values by converting the electromagnetic waves to an acoustic wave. This technique is adopted in analog DLC, and this is mainly because the velocity of acoustic waves is much less than the electromagnetic waves. When the required delay is achieved by the acoustic delay line, the signal is converted back to an electromagnetic signal for further signal processing. The acoustic delay lines were made using delay lines filled using liquid material with either water or mercury and they were large and inconvenient, and they were replaced by another technique that utilizes solid fused-quartz line which uses multiple internal reflections and they get a compact component. With the revolution of digital electronics, these analog delay lines are replaced by storage devices using digital signal processors. The application of digital delay lines requires changing the output of the MTI radar receiver phase detector to be quantized first in such a way to get a sequence of digital words. Using digital signal processing, delay lines become compact as well as convenient to use in MTI radars. Moreover, in analog DLC, it was very difficult to get more than two delay cancellers, while using digital techniques; one can obtain more complex DLC that were not possible with analog. Other techniques that might be used in some forms of MTI radars instead of DLC are by adopting a bank of contiguous Doppler filters.

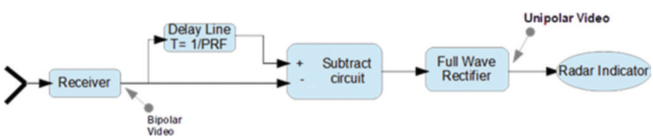

Figure 3: Delay canceller block diagram

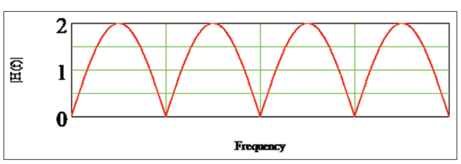

Figure 4: Frequency response of single delay line canceller

Frequency Response of Single SDLC[1,9]

The received signal from a target at range Ro at the output of the phase detector.[1]

$$V_1 = k \sin(2\pi f_d t - \phi_o) \quad (1)$$

where fd = doppler frequency shift, φo is a constant phase = 4πRo/λ, Ro = target range at time equal to zero, λ = wavelength, and k = is the amplitude of the signal. The signal from previous radar transmission is similar, but it is delayed by a time Tp = pulse repetition interval and can be written as:

$$V2 = k \sin(2\pi f_d(t-T_p) - \varphi_o)) \quad (2)$$

The delay-line canceler subtracts these two signals, and we

$$V=V1-V2=2k \sin(\pi f_d T_p) \cos(2\pi fd(t-T_p/2) - \varphi_o)) \quad (3)$$

The frequency response function of the SDLC is:

$$H(f) = 2 \sin (\pi\, fd\, Tp)\ (a) \quad (4)$$

$$H(f) = 2 \sin (\pi\, fd/f_p)\ (b)$$

where fp = is the PRF.

The frequency response magnitude function is sketched in Figure 4.

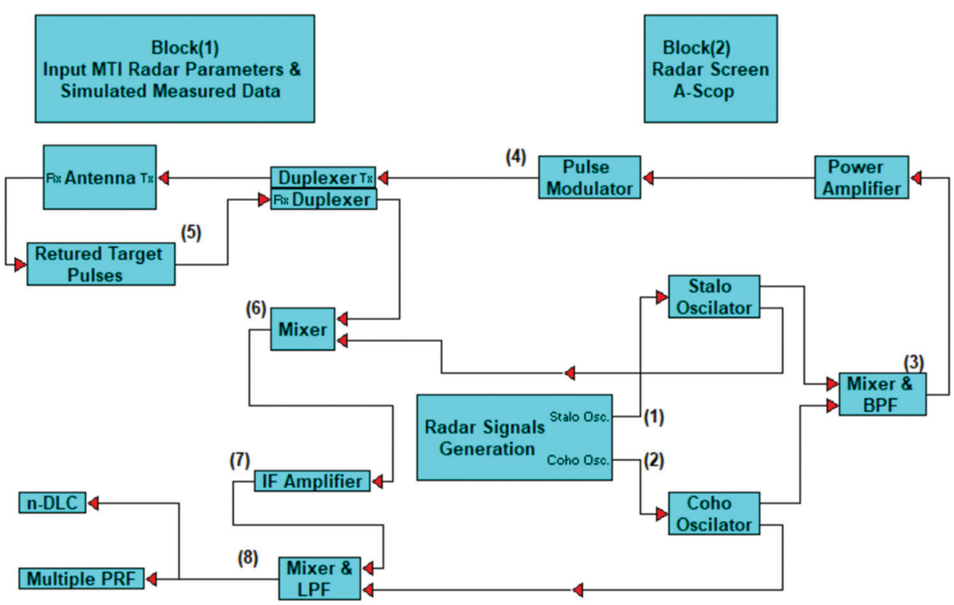

Figure 5: Moving target indication radar simulated blocks using VisSim/comm 6.0

Target Blind Speeds

The output of SDLC will be zero whenever the value of *sin (π fd/f_p)* is zero and this will occur when

$$\pi fd/fp = 0, \pm\pi, \pm 2\pi, \pm 3\pi, \quad (5)$$

Therefore

$$fd = 2\ \frac{vr}{\lambda} = \frac{n}{Tp} = n\ fp \quad (6)$$

The blind speed can be found as:

$$v_n = n\lambda f_p/2 \quad n= 1,2,3 \quad (7)$$

When two or more PRFs are used in radar, the blind speeds at one PRF generally are different from the blind speeds at the other PRFs. Thus, targets that are highly attenuated with one PRF might be readily seen with another PRF. This technique is widely used with air-surveillance radars, especially those for civil air-traffic control. A disadvantage of a multiple-PRF waveform is that multiple-time-around clutter echoes (from regions beyond the maximum unambiguous range) are not canceled.

Figure 6: Sub-blocks of Figure 5

SIMULATION OF MTI RADAR SYSTEM WITH VISSIM/COMM 6.0

VisSim/comm software was originally designed for modeling and simulating end-to-end communication networks at the signal or physical level. VisSim/Comm offers swift and reliable solutions for analog, wireless, and mixed-mode communication device designs with a complete complement of communication blocks and an efficient time-domain simulation engine. In this paper, the VisSim/comm 6.0 software is used for simulating MTI radar signal processing. The simulated MTI radar block diagram is shown in Figure 5, while the subblocks of MTI radar parameters diagram is shown in Figure 6.

Generation of Simulated MTI Radar Signals

Figure 5 shows the simulation blocks of MTI radar using VisSim/comm 6.0 software. Block (1) shown in Figure 5 illustrates how the input data of the simulated MTI radar is entered using VisSim software. Block(1) includes two sub-blocks: Block(1.1) & Blok(1.2):

The details of these two sub-blocks are illustrated in Figure 7.

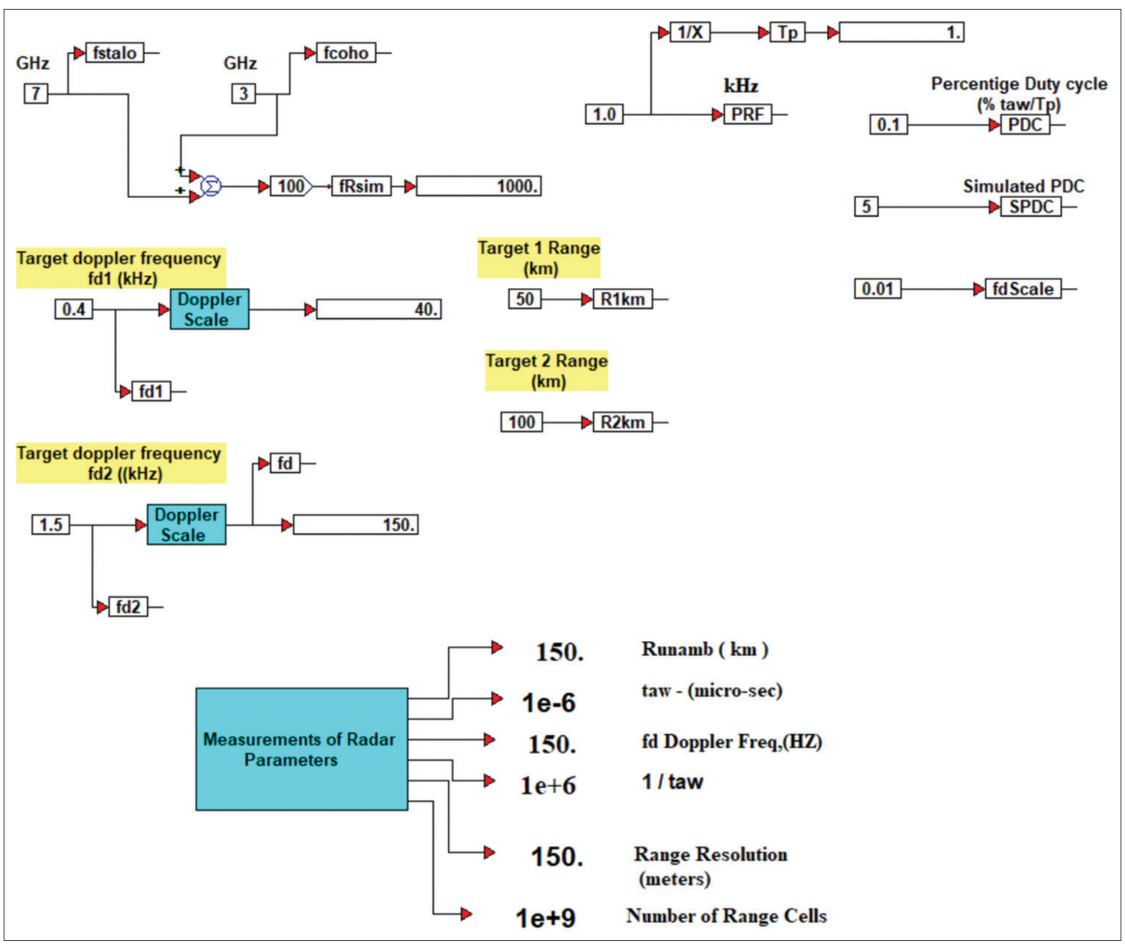

Figure 7: Details of block diagrams of Block (1.1) and Block (1.2)

In this simulation, all values of frequency shown are scaled up and not actual. Moreover, the Doppler frequency values are exaggerated, so that the Doppler frequency, *fd*, can be displayed on a frequency spectrum analyzer (usually *fr* >> *fd*).

Simulation of A-Scope MTI Radar Display

Figure 8 shows the simulation result of the A-scope MTI radar. It simulates two targets at two different ranges 50 and 100 km and moving with different velocities, represented by two Doppler frequencies fd1 and fd2.

Simulation of Various MTI Radar Signals

Simulation of MTI radar signals is presented in Figure 5 as blocks. One of the major evaluations of signals is the frequency spectrum. The frequency spectrum at specified blocks is shown in Figure 9.

Simulation of DLC and Multiple PRF in MTI Radar

Referring to the simulated MTI block diagram, Figure 5, the last blocks are n-DLC and Multiple PRF.

Simulation of n-DLC

In this paper, three types of DLC are simulated and two targets of different speeds fd1 = 1500 Hz and fd2 = 2500 Hz. It is also assumed that the radar is transmitting pulses of PRF, PRF = 1 kHz. Figure 10 shows the simulation of n-Delay canceller, for n = 1, 2, and 3. In

Simulation of Multiple PRF MTI Radar

Most airport radars use multiple PRF so that to avoid blind speeds. Simulation for this case is shown in Figure 11. It is assumed in this case that we have three PRFs values, namely, 1.5 kHz, 2.5 kHz, and 3.5 kHz.

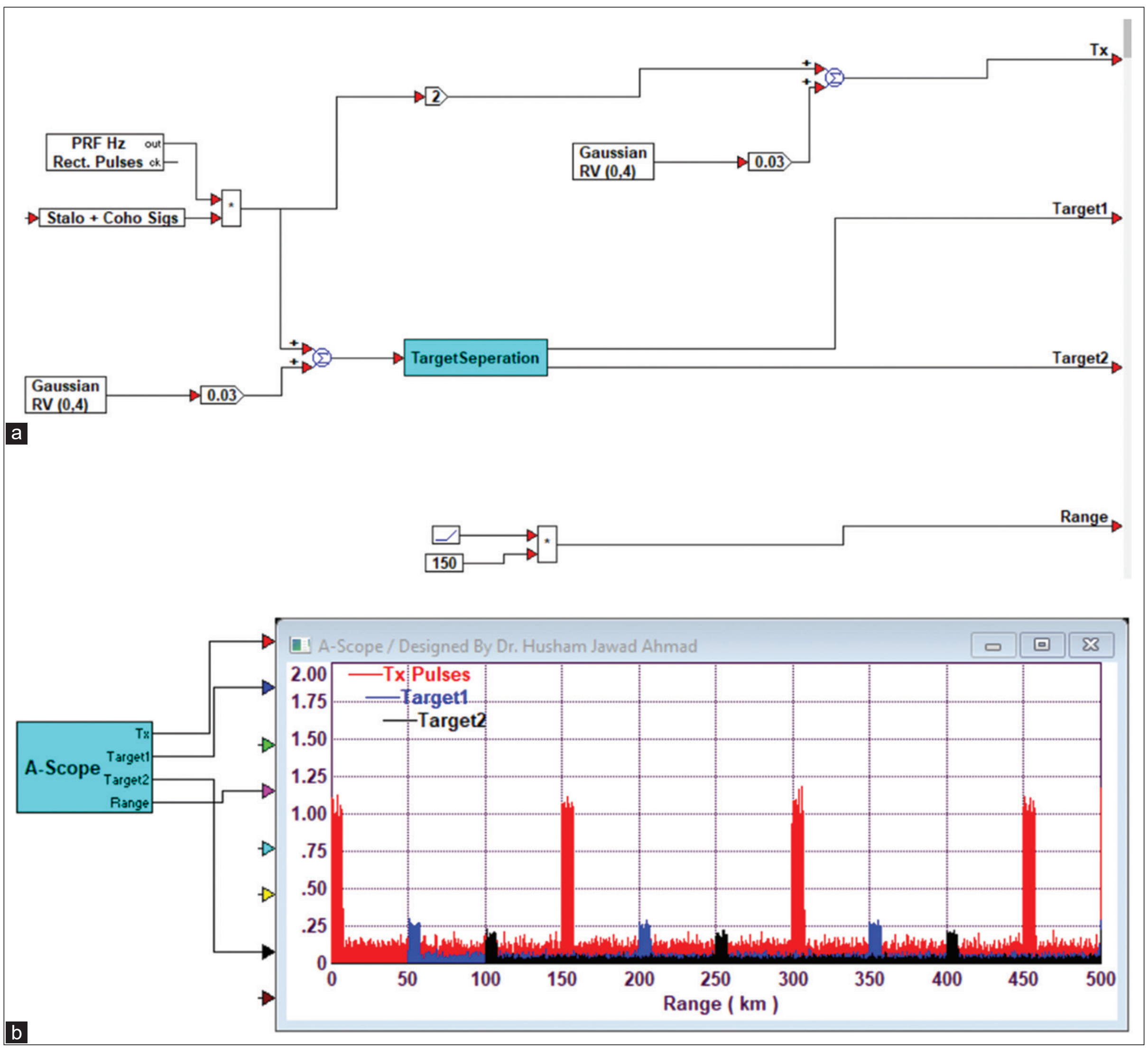

Figure 8: Simulation of A-Scope moving target indication Radar Display

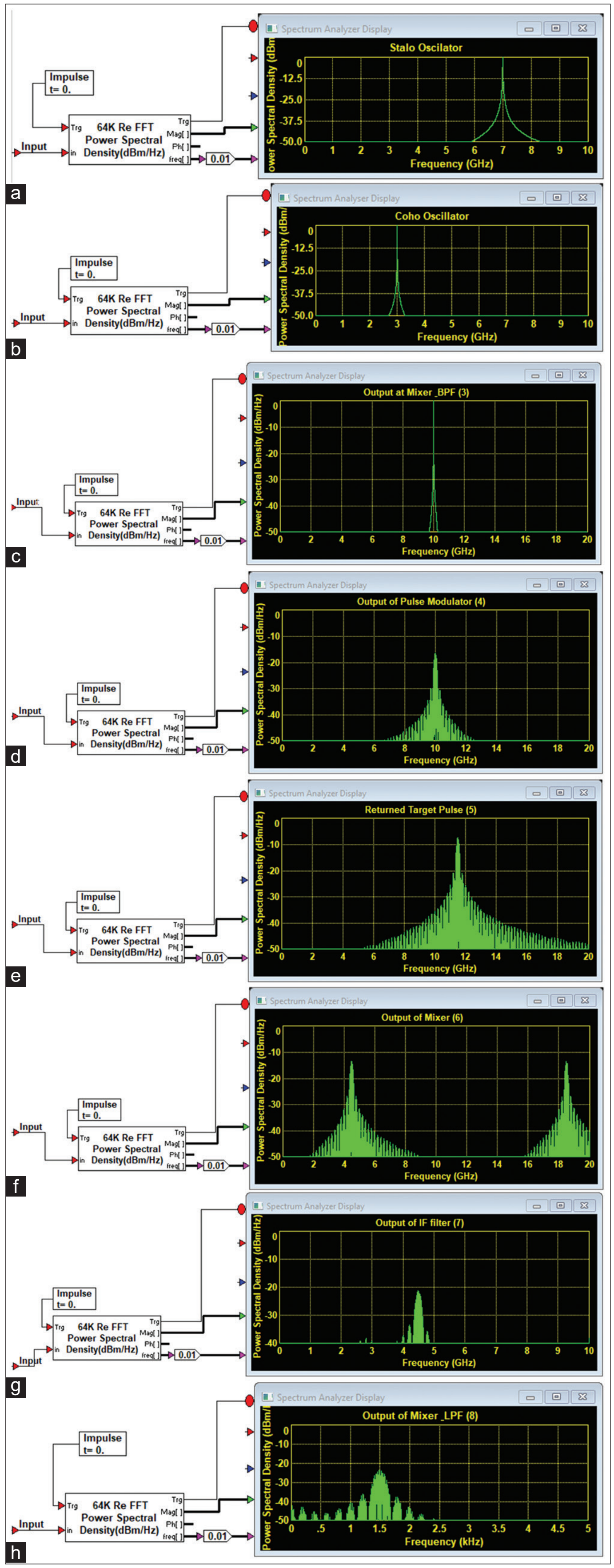

Figure 9: Frequency spectrum (a-h) at points indicated in Figure 5

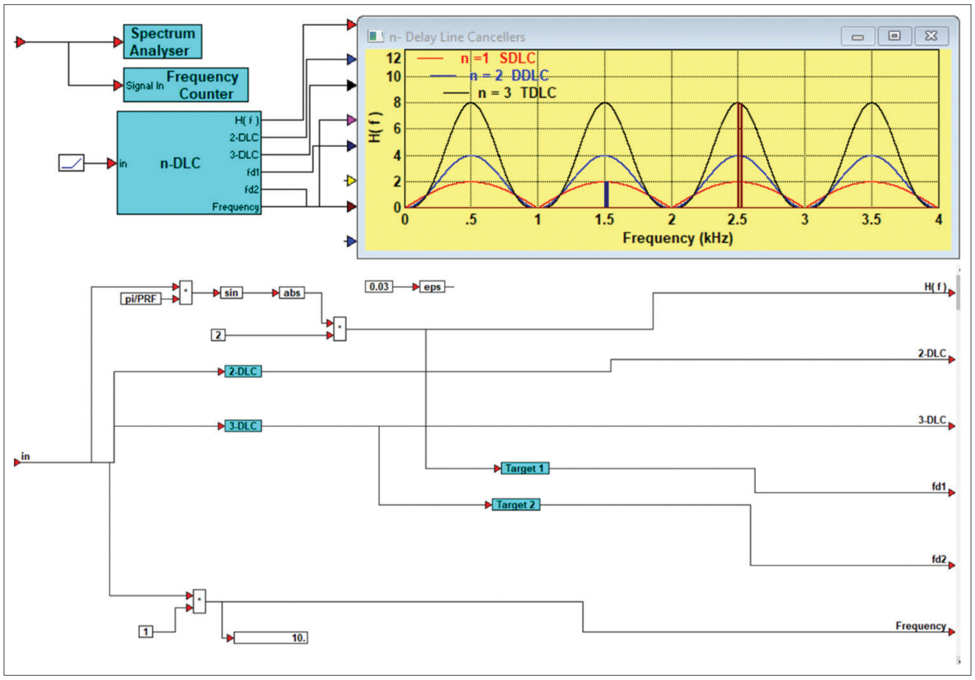

Figure 10: Results of simulation of n-delay line cancellers and the sub-block of n-DLC.

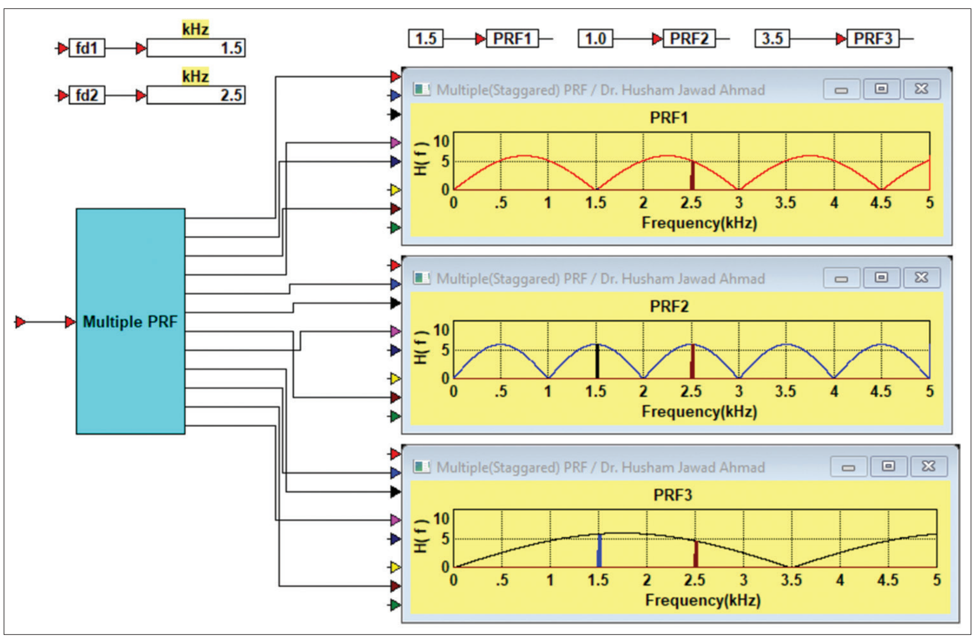

Figure 11: Simulation of multiple pulse repetition frequency of moving target indication radar

In this case of simulation, it is seen that one of the targets is blinded (target with fd = 1.5 kHz), and this obviously because it has the same value of PRF1. When the radar switched to other PRFs, this target appeared.

CONCLUSIONS

In the simulation of a radar signal processing system using VisSim/comm, a system model can be formed rapidly, and the design concept can be reflected in each step of the simulation. Simulation of radar signals with VisSim/comm software is featured by a short modeling time and a high calculation accuracy. The simulated MTI radar model is mainly designed for educational purposes to help undergraduate as well as graduate students to a better and fast understanding of the subject. The model and evaluation result can be revised, and the system behavior can be verified at any phase of the design. In this paper, the staggered (multiple PRF) methods are simulated to give more insight into the subject of blind speeds in MTI radar systems. As a future work, the simulation may include the effect of external (or deliberate) noise on the performance of MTI radar system. Moreover, simulation of constant false alarm (CFAR) could be simulated in MTI radars.

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