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Construction and Implementation of Radio Detector Echo Simulation with Dynamic Scene

Lu Zhaogan, Yang Yuye and Wei Qing
School of Computer and Information Engineering,
Henan University of Economics and Law, Zhengzhou, 450002, China

Abstract: During the design and development of proximity radio detector for proximity detecting in the range about 20 m, various test and debug would be involved with dedicated echo signal. However, it's difficult to obtain. This study is devoted to the echo signal simulation for the dedicated s. One signal simulation scheme for proximity radio detector is outlined for the signal from dedicated s. According to the signal model of radio detector transceivers, the echo signal is evaluated under the case of dynamic scenes constructed by professional 3 day modeling software. The simulation scheme could realize the independency of scene modeling, movement control and simulating algorithm, and have good generalization and extensibility. The simulator was constructed into an independent echo simulating block, which could be integrated with common used system simulating software. Finally, one simulating instance indicated that the simulated echo waveform could reflect the signal changes during the process of radio detector meetings.

Key words: Radio detector, echo simulation, simulator, time waveform

INTRODUCTION

During the design of proximity radio detectors, a lot of test data must be provided so that the performance and evaluation could be verified. In fact, the working environments and scenarios are constructed, and simple entries are used for the possible targets. Then, the radio generator transmits the radio that would be used by the designed radio detectors, and receiver equipment receives the echo radio signal returned back by the possibles. Obviously, this method would take a lot of time and money, which is not economic in the current advanced computer era. At the same time, the designed radio detector has to be tested or verified in different scenarios, which is not all possible constructed by actual objects. Furthermore, the actual constructed scenarios could not be similar to the designed cases, and these data from these scenarios could not be fit the designed radio detector. So, how to construct the computer simulation platform of radio detectors is one alternative method to avoid these problems.

Here, this study was devoted to one possible simulation method and technology to set up the radio detector simulation platform, which would be very useful to improve the efficiency of radio detector design teams. Up to now, there are few studies that devoted to the radio detector simulation platforms. What's more, only several echo signal simulation methods (Anying, 2005; Tao *et al.*, 2004) of radio detectors and Radar were presented by a few studies. The presented echo simulation methods are those based statistic characteristic, and their simulated echo signals are not the data of one given targets. These simulation results don't contain any information of detector modulation modes and the Doppler frequencies. Aiming to the target model, many researchers (Hongfei *et al.*, 2006; He, 2008; Qiuju and Cuiqiong, 2010; Jinsheng and Qinwei, 2005; Xu *et al.*, 2009; Jin *et al.*, 2010) tried to use mathematics formula to describe the shapes, sizes and movements of the possible s. However, this method could not be successful for most actual target with various complex shapes and movement traces. Therefore, one is divided into large numbers of scatters and their echo signals are summed up to form its echo signal (Yang *et al.*, 2007; Li and Zhang, 2007; Peng *et al.*, 2008). The problem is how to do it, and it is not given in these studies.

Actually, there are many technologies involved in the simulation platform, i.e., the echo signal computation, space models, and the method to construct these models, the visual display blocks and so on. Thus, the common reported technologies or methods would be used in this study to set up the radio echo simulation platform, i.e., the targets are divided into scatters, the echo signal from one scatter according to the common radar equation and so on. In order to construct one detector echo simulation

Corresponding Author: Lu Zhaogan, School of Computer and Information Engineering, Henan University of Economics and Law, Zhengzhou, 450002, China

platform, two key technologies have to be overcome, i.e., the echo signal computation with low complexity and the s with scatter division. This study is mainly devoted to these two technologies, and the implementation of the echo signal simulation platform is only presented with short contents.

SIGNAL FLOW IN THE DETECTOR RADIO DETECTOR

The time echo signal simulation of radio detector is actually to simulate the signal flow between its sender and receiver. This would involve the modeling signal, carrier, radio frequency, antenna, radio signal propagation in atmosphere space, returned echo signal by s, and so on. This signal flow could be disclosed by Fig. 1 and the result of echo signal simulation obtains the differential frequency signal, which is the output of the fixer at the detector receiver.

Here, the key technology is to take account the effects of radio signal that propagates between the antenna of senders and receivers. When the radio signal is simulated by digital signal technologies, it must be sampled according to its two multiple frequency at least. Thus, its data is too large to be disposed by current ordinary computers. In order to reduce the computation complexity, one zero-intermediate echo equivalent model is deduced to compute the echo signal value. Of course, the effects of atmosphere, interfering machines, targets on the radio signal, would be considered in the fixer at the receivers.

In fact, the echo signal received by receivers, used by other object detecting modules, is the output of the fixer with carrier signal at the receiver. The radio returned to the receiver by the possible targets in the form of radio energy, could be computed according to the principle of the radar equation. It would be captured by the receiver antenna, and would activate the high frequency current at the receiver antenna, i.e., the received radio frequency signal in the form of current or voltage. The relation of the received radio energy and the magnitude of high frequency current or voltage would be decided by the input resistance of the receiving antenna. According to the energy conservation theory, the radio energy would be converted into the current or voltage signal. At the same time, the high current or voltage would be feed to the fixer with carrier signal.

If A_{eo} is denoted as the effective area of one target, i.e., the scattering cross area, P_{rad} the transmission power, the echo energy P_r captured by the antenna of radio detector, could be given by the following formula:

$$P_r = \frac{1}{4\pi} G_t G_r A_{eo} \left[\frac{\lambda}{4\pi R^2}\right]^2 P_{rad} \quad (1)$$

Here, G_t is the gain of sender antenna, G_r is the gain of receiver antenna, λ is the wave length of electromagnetic wave, while R is the distance between the target and the radio detector. When the sender and receiver share the same antenna, one has the conclusion $G_t = G_r$.

COMPUTATION OF ECHO SIGNAL

According to the system theories of radio detector, there are several system mode (Zhanzhong and Shihe, 1998) i.e., Doppler, frequency modulation, pulse modulation, coding system, and so on. In order to set up the echo signal simulation platform, the computation complexity of echo signal must be simple enough to be realized in current performance computers. Inspired by the base-band system in wireless communication systems, the zero-intermediate echo signal model is deduced according to the signal flow of radio detectors. The model gets rid of radio signal simulation, and the effects of radio propagation in atmosphere and surroundings are also considered.

But, the processes as described in following sentences, is involved by the radar equation with s and surroundings in the simulation scenarios. The modulating signal is used to modulate the carrier, which was then sent out by the sending antenna in the form of radio frequency wave. The echo radio signal from the possible s and surroundings is further fixed with carrier at receiver. It's the output of fixer at receiver that one need for simulation.

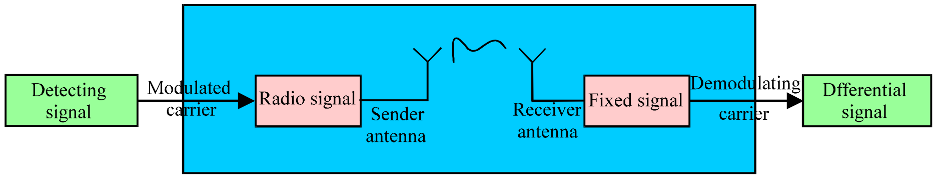

Fig. 1: Signal flow in the radio detector

When the three possible modulation signal, f_{am} (t), f_{pm} (t) and f_{fm} (t) are given for special radio detector, the echo signal that received by the radio detector, i.e., the so-called echo signal, could be evaluated according to the formula as following steps:

- Assumed that the transmitting signal at the radio detector is given by f_{am} (t) its square is considered as the instantaneous power
- Then, the power density p_1 (t) at the scatter s_1, that radiated by the sent instantaneous signal, is given by the radar equation according to the distance between the scatter and the radio detector
- Next, with the consideration of the cross angle ϕ_i between the radio incidence and the external normal at the scatter surface, the projected area s_i cos ϕ_i of the scatter surface on the incident vertical direction of the incidence would be further used as the effective area that could capture the radio by the scatter. Therefore, according to the formula (1) the total energy p_r (i) captured by the receiver antenna from the scatter, could be calculated when the antenna gain and effective area were given. Then, based on the input resistance of the received antenna, the magnitude $P_{rad}f_{r,am}^{(i)}(t)$ of the sensed high frequency current activated by the captured radio energy from the scatter s_i could be determined as shown by the following formula:

$$I_L(i)=\sqrt{\frac{p_r(i)}{2R_A}} \tag{2}$$

- In the following, based on the phase modulating signal f_{pm} (t), frequency modulating signal f_{fm} (t), the distance r (t) between the radio detector and the scatter s_i, the echo signal v_i^o (t) without carrier at the fixer receiver, would be computed by:

$$v_i^o(t)=\frac{f_{r,am}^{(i)}(t)}{2}\cos\left[f_{fm}(t)\left(t-\frac{2r_i(t)}{c}\right)+f_{pm}(t)-\varpi\frac{2r_i(t)}{c}\right] \tag{3}$$

- At last, the echo signals from all the scatters would be summed together as the final echo output signal of the receiver fixers, i.e., where:

$$v_o(t)=\sum_{i=1}^{N}v_o^i(t) \tag{4}$$

IMPLEMENTATION OF ECHO SIMULATION PLATFORM

The Matlab Simulink is used as the simulation platform, which function was expanded according to the requirement of echo signal simulation theories. Thus, it keeps the good expansibility, easy realization. In order to realize the cooperation simulation with other simulation tools or Electronic Design Automation (EDA) software such as Or CAD, High Frequency Structure Simulator (HFSS) and so on, the echo evaluation module is constructed as one block that could be used as the common block in Simulink. This would make it possible to quickly set up one radio detector simulation system in the Matlab Simulink environments by the usable blocks.

According to this principle, the echo simulation systems are designed as that shown by Fig. 2 where the time waveform evaluation module is the core in this implementation. The echo signal computation is implemented by C++Program into one standard block as

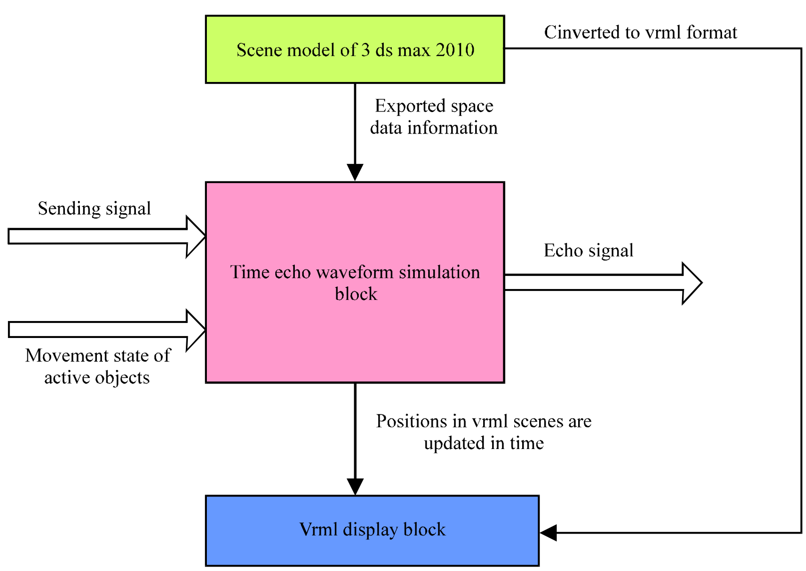

Fig. 2: Implement scheme of the waveform simulation for radio detector

that in Matlab Simulink. The trace or movement parameters of active object and radio detectors are input into the block as the predefined formats. Meanwhile, the 3 days Max (2010) scene model data file would be provided to both the block and the vrml display. When the objects and radio detectors change their positions according to the setting of movement parameters and traces, their new position would also be updated in time in the vrml display. For one simulation time point, the echo signal is computed according to the transmission power, relative positions in the scenes and given as the output signal of the block.

SIMULATION RESULTS

With the use of 3 days Max 2010 as the professional scene model tools, this study constructed one scene with two simple objects, i.e., F15e aircraft and one Missile with radio detector. In the dedicated scene, the two scene objects are active s during the simulation scene, and their initial positions are given by Table 1. There is one radio detector attached to the 'Missile', whose working parameters are further described by the property item in the Table 1.

As there are only two objects, the speeds of the F15 aircraft and Missile are set to 680 and 800 m sec^{-1}, respectively. When they move in the face to face direction, the maximal possible movement speed is 1480 m sec^{-1}. Furthermore, if the relative distance difference of 0.01 m their position in the space scene would be considered static and the input sample frequency could be set to 148 kHz. Meanwhile, if the distance distinguishing accuracy of radio detector is 1 m, the output sample frequency of the echo simulation block is given as 150 MHZ. With the consideration of the missile working frequency 3.5 GHz, the output sample frequency is 170 kHz.

However, when the initial distance between the F15e and the missile is about 4667 m they would meet each other after about 4 sec. Furthermore, there are about 9751 scatters in the space scene, i.e., triangle patches, and this scale would lead to the long time to finish the total simulation progress.

Here, in order to observe the time waveform, the input sample frequency is given as about 1 kHz with shelter angle 0.00175. At the same time, the propagation speed of electromagnetic wave in atmosphere circumstance is given as the light speed, i.e., 3×10^8 m sec^{-1}, while the minimal detecting power is -50 dbm and the simulation time is 4s. The total simulation system was constructed according to the blocks in Matlab Simulink, as shown by Fig. 3.

The traces or movement parameters are provided to the echo simulation block by the F15e trace block and the Missile trace block, respectively, as shown the corresponding blocks in Fig. 3. Furthermore, the

Table 1: Detector parameter setting and initial position of scene objects in the simulation system

Scene objects	F15e	Missile
Interfering	-	-
Detector	-	Yes
Initial position	(26, 1203,-2)	(5.6, -3464,-1.9)
Move direction	(-0.0044,-1.0000,0.0000)	(0.0044,1.0000,-0.0000)
Move speed	680 (m sec^{-1})	800 (m sec^{-1})
Transmission power	-	15 (mw)
Antenna gain	-	Ellipse
Initial phase	-	0
Radiation resistance	-	50 (ohm)
Carrier frequency	-	3.5 (GHz)
System mode	-	Sequent wave

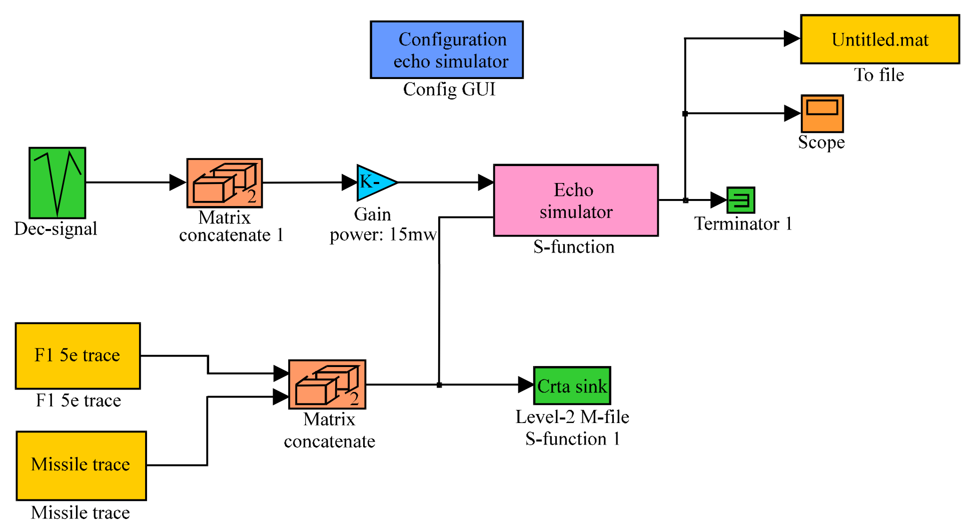

Fig. 3: Simulink model for the doppler radio detector with sequent wave mode

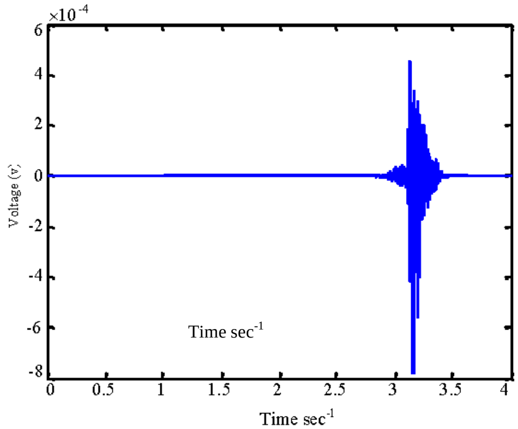

Fig. 4: Simulated waveform (1kHz)

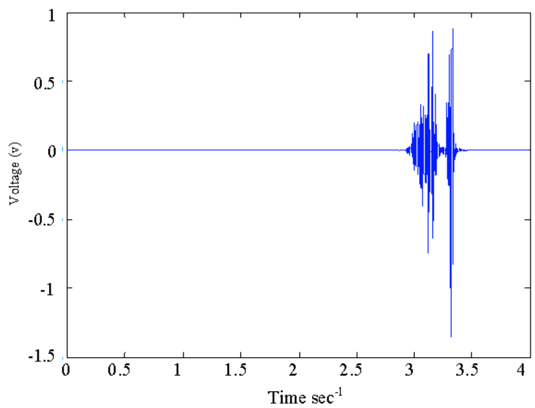

Fig. 5: Simulated waveform (10kHz)

modulating phase and frequency signals are set to zero, while the magnitude signal is set to constant. Thus, the zero-intermediate modulating signal that would modulate the carrier is constructed in the form of Dec-ignal Block, and the Gain block is used to set the transmission power from the sending antenna.

When the antenna gain of the radio detector is given as the ellipse shape, the final output signal with 1 kHz sample frequency is displayed in the form of waveform as Fig. 4 showed. The dynamic scene display window is disclosed by Fig. 4 which is actually one vrml display control and used in Matlab Simulink as one common block. As the output sample frequency is equal to that of input sample signal, which is not high enough to obtain the waveform when they meet and depart. When this study improved the output sample frequency as ten multiple that of input sample frequency, the corresponding waveform could disclose the process and the result is given by Fig. 5.

CONCLUSION

In order to construct one general echo signal simulation platform with dynamic scene, this study described one method that uses the 3 days Max (2010) as the scene modeling tool. The echo signal is evaluated according to the zero-intermediate equivalent signal model of the radio detector. At the same time, the real-time positions of all the objects in scene would be updated in time and further used to evaluate the echo signals according to the echo mathematical formula. Thus, the updated positions are also displayed in the scene display block, and the dynamic scene could be implementation. The simulation result of one simple scene verified the obtain results, whose characteristic is consistent to that of waveform in field.

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