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One General System Simulation Platform for Proximity Radio Detectors

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Abstract: In the designs and developments of current proximity radio detectors, it has important role that its improvement by function verifications and performance evaluation by the way of computer simulations. One system debug and test platform with computer simulations, is presented in this report. Based on the Matlab Simulink, the platform is designed as one open frame and its function could be expanded according to the requirements of the radio detector system models. In the form of the standard Simulink blocks, the core modules, i.e., echo evaluations, Virtual Reality Modeling Language (VRML) display, space models, are developed by C++ language, while the interfaces to other Electronic Design Automation (EDA) tools are given by the plug-ins or Software Development Kit (SDK) packages. Furthermore, one system simulation model could be set up quickly by the platform and this could reduce the complexity to construct system simulation models. Finally, one test system simulation model is also displayed in this report and the results verified the expected functions of this platform.

Key words: Proximity radio detector, simulation models, cooperation simulation, simulation platform

INTRODUCTION

The debug and test platform for the proximity radio detector systems, is one request in recent years, as the high performance computer could be used the possible simulator to associate the design and debug these systems. Here, this study presented one design and implementation scheme of the proximity radio detector systems, which are the results of his post-doctorial research plan.

Here, this report is devoted to one radio detector simulation platform used in the development and production of radio detectors. Up to now, there are few reports or reports that devoted to the radio detectors simulation platforms. What's more, only several echo signal simulation methods (Chen and Mo, 2010; Xu *et al.*, 2009) of radio detectors and RADAR were presented by a few reports. However, these few reported schemes are mostly based on the statistic characteristic of sensed radio echo signals. Furthermore, their simulated results are not the actual echo signals of actual objects. At the same time, any modulation signals from the transmitters are not also contained, i.e., the working mechanism of radio detectors and Doppler frequencies. So, with the strongpoint s of the reported echo simulation schemes, some mathematics formula were used to describe the shapes, sizes and movements of the possible targets by some researchers (Li and Wang, 2005; Hong *et al.*, 2004; Ren *et al.*, 2006). The results are obviously failed to describe the most actual targets with various complex shapes and movement traces. Therefore, one approach that divided the complex targets into large numbers of scatters and their echo signals are summed up to form the echo signal (Ma, 2005; He, 2008), were proposed. But, the detail about how to do it in actual application is not given by any public reports. Here, this report presents one the approaches to conduct one general simulation platform for proximity radio detectors.

GENERAL RADIO DETECTOR DESIGN PROCESS

From the whole design period, as shown by Fig. 1, the requirements such as detecting depth, meeting speed with targets, target types, anti-interfering ability, distance and angle resolution, working environments, reaction time, reliability and other special requirements, should be determined before the design of one proximity radio detector. These factors have the important effects on its design. Then, the re-design and test should be also repeated frequently in the following production periods. In fact, these works are not possible tested in fields, which would cost a lot of money and time. So, the

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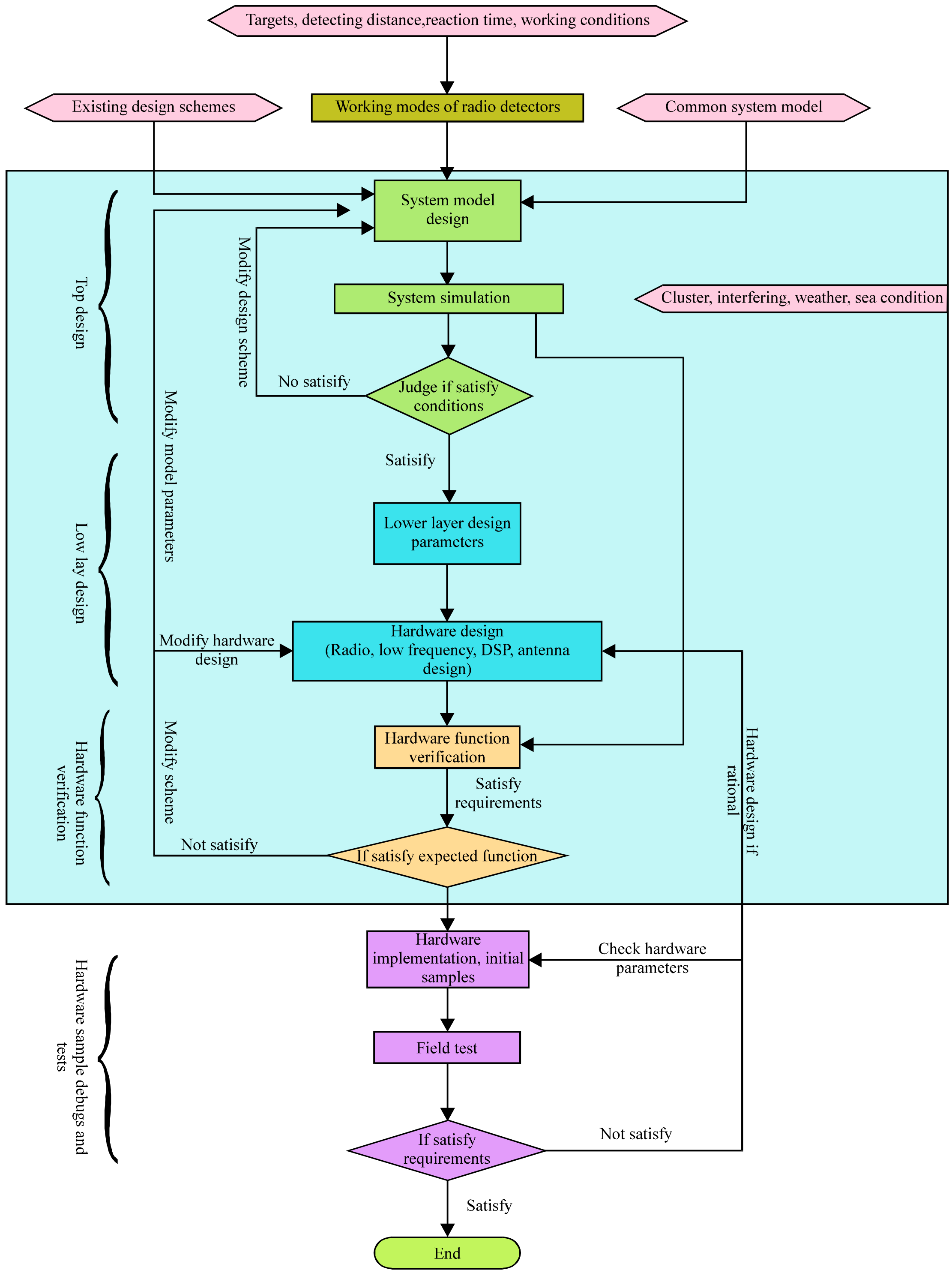

Fig. 1: Development flow of proximity radio detector

according to the proximity radio detector's system mode, if one general simulation platform could be set up, the design process would be accelerated quickly.

Thus, based on the experience design schemes, the design scheme could be given from the top design. The design scheme should be further verified by the system simulation with the platform. By the simulated system parameters, the design would be modified repeatedly according to the system design requirements. When the design scheme is perfect enough to make sample products, the simulated data could be used for the initial tests before the field tests. In fact, when new problems appear, the modification and verification are also based the platform and thus it could save a lot of cost in the form of time and money. At the same time, the platform would also be used as the evaluation platform for the performance metrics, such as detecting distance, detecting area, distance resolution, angle resolution, average transmission power, peak power, receiving sensibility, Signal to Noise Rate (SNR), virtual warning, loss warning rate, anti-interfering ability, reaction time, relative movement speed, the optimal time and so on.

With the simulation platform constructed by this report, the simulated echo waveform signal would be used as the input of proximity radio detector and evaluated according the designed disposal process as the circuit can do. The effects from the target characteristics, background interfering signal and source-interfering, are also considered in the special design war scene. The war scene is model as the general models with 3ds MAX 2010. Furthermore, by the system simulation platform, the cooperation with other EDA tools such as, OrCAD, HFSS and ADS could also be implemented according to the development requirement of proximity radio detectors. Finally, according to the results of simulation and evaluation, the optimal system parameters and design scheme could be optimal to the working environments.

SIMULATION PLATFORM FUNCTIONS

As the description above, the system simulation platform has an important role during the development of proximity radio detectors. Meanwhile, there are many Electronic Design Automation (EDA) tools used in its design, debug and test. So, the platform has to be implemented with relative interfaces to these EDA tools so that their results could be integrated into the simulation platform. Thus, the cooperation simulation with these tools could be set up with the platform. With considering the design EDA tools in the lower layer design, the platform architecture is realized in the form as shown by Fig. 2.

According to the platform architecture, it has interfaces to low frequency circuit design tool (OrCAD Pspice), high frequency circuit tools (ADS), antenna design tool (HFSS), the famous space model tool (3DS MAX 2010), virtual reality display (VRML) and other digital signal processing tool, i.e., Field Programmable Gate Array (FPGA), Single System on Chip, Digital Signal Processing (DSP), Complex Programmable Logic Device

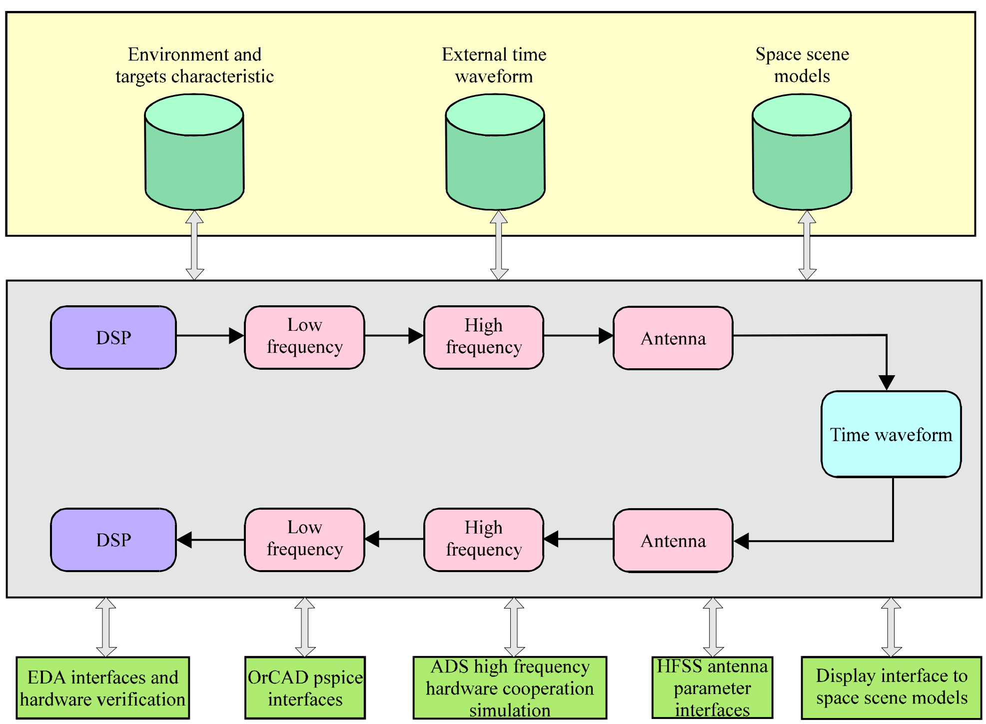

Fig. 2: System simulation chart of proximity radio detectors

(CPLD), Acorn RISC Machine (ARM) and so on. At the same time, the parameters of target characteristics, background cluster, external interfering sources, are input into the platform by their special interfaces. The implemented modules by different EDA tools could be embedded into the platform and their cooperation simulation could be also realized. The echo simulation module is used to simulate the echo signal from targets and clusters and it also used as the input to the modules that worked as the receiver of proximity radio detectors. Obviously, the function is verified by the cooperation simulation platform and it displays good extension, customization and high efficiency.

Furthermore, the platform could be customized according to the working theories, digital signal processing and simulation targets. Different modules in the simulation platform have also different simulation entries. According to the requirements, different simulation modules and verification modules could be combined to form the corresponding system models. This trait procures the good expansibility and the function that conducted by each modules, are described as followings.

Digital signal processing: At the sending end of the simulation platform, its input signal about the modulating data source would be further disposed and its output waveform as the input of hardware low frequency design and verification tools. While, at the receiver end, the discrete signal data would be filtered, de-noised, detected according to the judgments given by the designer. Finally, the out signal would be used as judgment signals for other disposal algorithms.

Lower frequency: For the lower modules in the receiver end, it receives the discrete time waveform signal from the digital processing modules and is used as the verification and simulation to the low frequency hardware design schemes. In the same way, it could also receive the output signal from the high frequency hardware simulation and verification modules and verifies or simulates the functions of low frequency hardware design. The final discrete output data is then input into the digital signal processing modules.

High frequency: At the sender of system models, it receives the output of low frequency simulation/verification modules. It could verify/simulate the signal loss, low frequency conversion, high frequency conversion, system noise and interfering at the high frequency disposal modules. The results are further used to verify and simulation the antenna simulation modules. Similarly, the frequency simulation/verification modules could also receive the high frequency input signal from the antenna simulation/verification modules. The results of high frequency simulation/verification modules would be sent to the low frequency simulation/simulation modules.

Antenna: The module could simulate the sending/receiving process with various losses, temperature noise and other relative factors. Here, the input resistance, radiation resistance, loss resistance, antenna efficiency, effective area, effective length, stationary wave and reflection power.

Time echo waveform: In the views of possible time waveform sources, there are three type time wave sources, i.e., (1) The waveform from the external field test data of special targets, clusters and active jamming, (2) The combined echo signal for the given radio frequency with consideration of landform, sea condition, weather and the target characteristics and (3) The simulated echo signal under the constructed special war field environments, which is computed by special simulation methods with the factors such as background clusters, target echo signal and the active jamming.

Meanwhile, various external interfaces are also implemented in this simulation platform and the system simulation among different hierarchies could be verified the design schemes. Thus, the cooperation simulation could be realized between different simulation/verification tools. The following contents show these interfaces that given in the simulation platform.

EDA digital processing interface: The digital processing modules designed by the professional EDA tools, could be integrated into the system simulation models and the simulated time waveform would also be used to verify and evaluate the digital processing modules. The hardware modules would be further modification and optimized according to the simulation results.

OrCAD low frequency hardware interface: By the interface, the low frequency circuit module designed by OrCAD, could be integrated into the system simulation model and it could call the OrCAD Pspice core and conduct the circuit simulation with the time waveform signal as its input data. Thus, the simulated echo signal is loaded into the design low circuit models and verifies the corresponding circuit functions.

ADS high frequency hardware interface: With the high frequency circuits designed by ADS, they are mainly used at the sender to conduct up-conversion and obtain radio frequency signals, while they could convert the radio frequency into low frequency signal by fixing with the carrier frequency signal. Thus, the interfaces to ADS design tools could bridge to the simulation platform for the ADS designed schemes and verify its functions by loading the simulated echo signal. This would reduce the complex process to verify the designed results by special EDA instruments. Based the verified results, one could further modify and optimize these design schemes for high frequency hardware modules.

HFSS antenna interfaces: Up to now, as one common antenna design and simulation tools, the HFSS is bridged to the constructed simulation platform by its HFSS interfaces. The antenna parameters, i.e., input resistance, radiation resistance and hardware performance metrics, could be exported into the platform and is used further to set one integrated system models. The effects of the designed antenna on the system performance could be evaluated according to the simulation results with the simulated echo signal waveform.

Display interface to space scene: According to the principle of proximity radio detectors, the echo signal should be evaluated in the virtual scene similar to their working environments. By the display interfaces, the whole meeting process of the radio detector to targets could be observed by the display windows, which adds the visual interface to the platform.

Interfaces to space models: General speaking, the scene models are commonly constructed in 3ds Max 2010 and are exported into the file formats that could be loaded in this platform. Meanwhile, the configuration to the scene models should be done by these interfaces, i.e., setting the electronic parameters, material information. With the consideration of electronic parameters or back ground clusters in the scenes, the time echo signal waveform would be computed according to the common radar equation. Thus, the 3ds Max designed 3D space models could be used the echo simulation modules to conduct the computation of echo signals.

Interfaces to target characteristics: In order to configure the working environments of proximity radio detectors, the environment factors, i.e., clusters, interfering, sea conditions, weather and terrain characteristics, should be set with the Radar Cross Section (RCS) of targets in the scenes. This interface is presented as the visual configuration windows and could be accessed by special operations.

Interfaces to external time waveform: In fact, the actual test data in fields, i.e., the cluster, active jamming and target echo signals, are very useful. When imported into the platform, these data in fields could also be used in the system simulation, which is further to simulate the echo signal that received by the receiver.

IMPLEMENTATION TECHNOLOGY

In recent years, Matlab is used widely in the development of various electronic products, as the plentiful blocksets in its Simulink simulation platform. Furthermore, any new design blocks could also be added to the Simulink open platform with its good expansibility. Based on the blocksets in the Simulink library, the system simulation models could be set up very quickly. Meanwhile, it also has plentiful interfaces to the common used EDA design tools. Thus, the cooperation simulation could be realized with their design modules respectively. So, the Matlab Simulink is one perfect simulation platform. However, the current blocksets in Simulink is not fit for the simulation platform of proximity radio detectors. Many function in form of blocks, would be developed to extend the Simulink library.

Here, the interfaces to HFSS, ADS and OrCAD are implemented by their SDK tools. What's more, the echo simulation module is developed by C++ language and embedded into the standard block as that in Simulink library. In order to export the 3ds Max scene models, the export plug-in 3ds MAX 2010 is developed according to the data that required in the echo signal evaluation models. And, the import modules in the platform based on Simulink, is also programmed with loading the space model data, i.e., locations, coordinate transform matrix, material information and so on. The virtual scene display module is also presented by the VRML display ActiveX controls, which would be embedded into the general block. With these designed blocks, the existing blocksets, i.e., Signal Processing Blockset_ARF Blockset_ASimulink HDL Coder_ALink for Analog Devices VisualDSP_ALink for Cadence® Incisive®_ALink for Code Composer StudioTM_ALink for ModelSim®, could also be integrated into the simulation platform.

SIMULATION CASE

With the use of 3ds MAX 2010 as the professional scene model tools, one constructed one scene with two simple objects, i.e., F15e aircraft and one Missile with radio detector. The F15e aircraft model is the existing

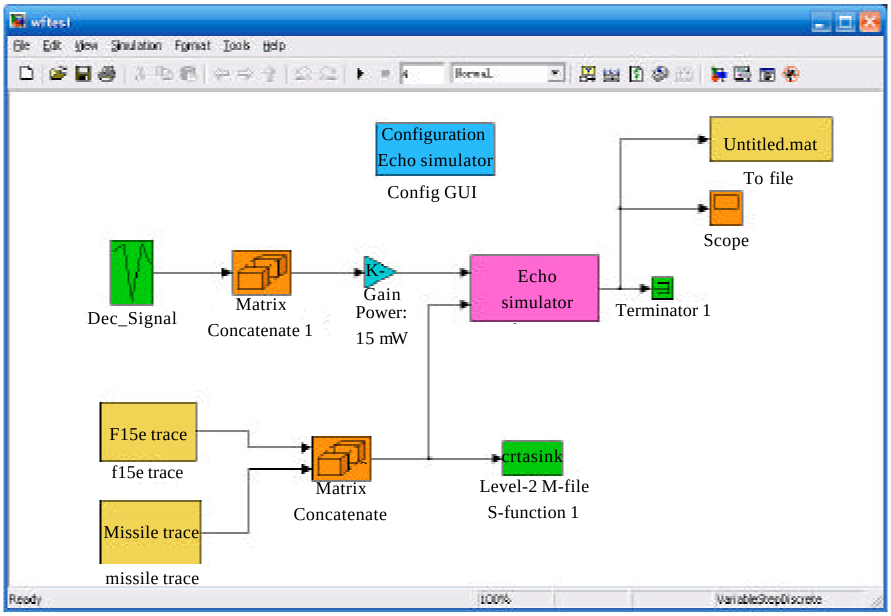

Fig. 3: Simulink model for the doppler radio detector with sequent wave mode

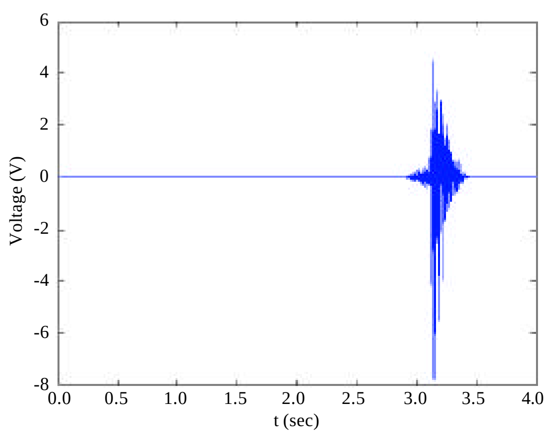

Fig. 4: Waveform with output sample frequency 1kHz

model that could be found in the Internet, while the Missile is set up by us in the 3ds MAX 2010. 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 0.01m, their position in the space scene would be considered static and the input sample frequency was set to 148 kHz. Meanwhile, if the distance distinguishing accuracy of radio detector is 1m, 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 given as 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 4 sec. 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 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_Signal 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 that with 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

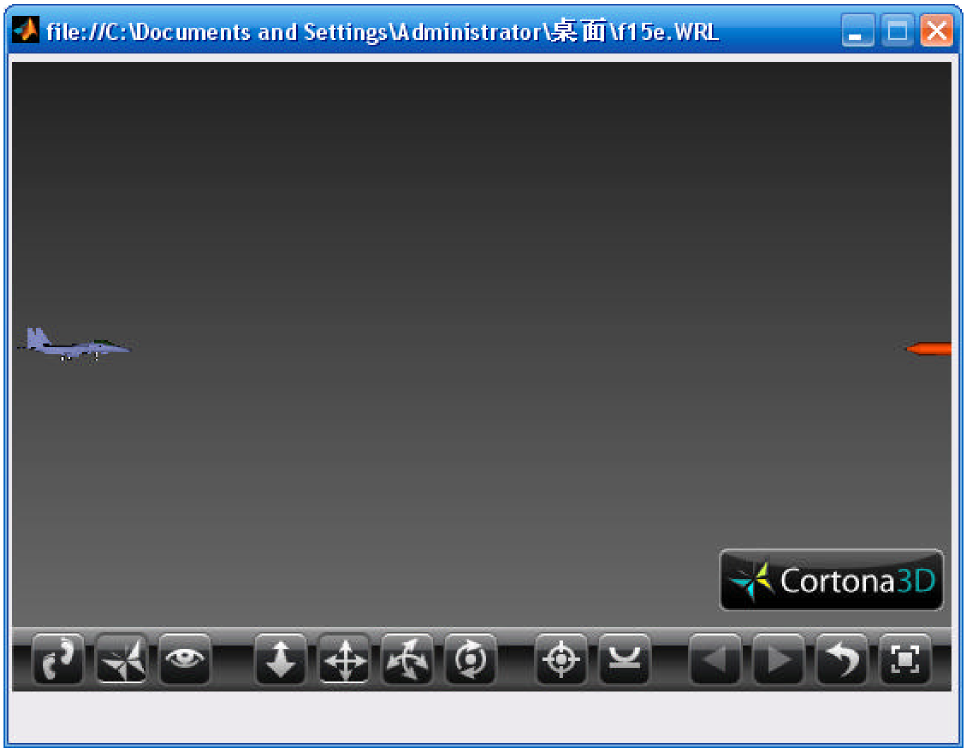

Fig. 5: Display windows with dynamic scene

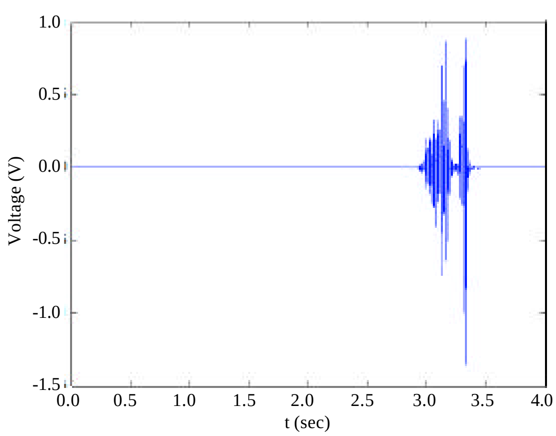

Fig. 6: Waveform with output sample frequency 10 kHz

window is disclosed by Fig. 5, 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 one 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. 6.

CONCLUSION

In this report, one system simulation platform for proximity radio detectors, is presented, which could be used to quickly construct the system simulation model. With the platform, one could realize the collaborations of various EDA design tools and verify their results. As one open platform, it has good expansibility with different simulation requirements.

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