Design of Digital Simulation Based on Radar Real-time Control Computer

Ying Lei, Rui Zhang, Guangwen Chi, Lei Zhang
Xi'an Electronic Engineering Research institute
Xi'an, China, 710100
wsxadnh@126.com

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Abstract. In view of multifunctional radar characteristics such as complicated data processing, difficult debugging, this paper presents a design of digital simulation based on radar real-time control computer, analyses the principle of digital simulation, proposes the actual resolving method, including debugging system configuration and software modules, its realization process in software is described in detail. This design optimizes the radar performance and enhances the work efficiency, shortens the cycle of developing.

1 INTRODUCTION
Multifunctional radar has air defense, artillery investigation, artillery calibration shooting functions, can effectively adapt to the complex modern battlefield environment. Real-time control computer as a radar control center need to solve many problems such as complex data processing in multi-workmode, large amounts of data in real-time communication with other subsystems and difficult debugging. Target simulator can be used to debug in the laboratory in the early days, after antenna device is mounted, it can not be used. So we adopt software digital simulation based on real-time control computer which instead of target simulator to detect the status and problems of radar chief data processing link including real-time control computer, signal processor and terminal computer in later radar debugging.

2 METHODS AND PRINCIPLES
2.1 Debuging System. Real-time control computer can real-time calculate the target distance, azimuth angle, pitch angle, doppler speed and other motion state parameters according to the work mode, repetition frequencies, the target initial position and other informations to generate simulated target track datas. After that it completes the azimuth and pitch two-dimensional intersections of the next beam to control signal processor to generate the target digital echo signal. Signal processor completes the digital echo signal processing, achieves detection of the target. After target detection information send to real-time control computer, it can be deal with to target track point which is sent to terminal computer and can be observed on the terminal computer. Based on VxWorks UDP network protocol, real-time control computer can extract pivotal data in custom format and send to debugging computer. The pivotal data can be real-time monitored, collected and analysed by MATLAB to detect the status and problems of the radar chief data processing link. Debugging system structure shown in Fig. 1.
2.2 Digital simulation principle. Depending on the nature of the target, its initial position, flight characteristics are also different. Since this system is only used for debugging, the target track ideally sets. Air defense target track is approximately set in uniform motion in a straight line parallel to the ground. Artillery investigation target track is approximately set as a parabolic motion, its starting point in the floor, Z-axis direction has acceleration of gravity, gradually approaching the floor. Artillery calibration shooting target track is approximately set as a parabolic motion, its starting point in the floor, Z-axis direction has acceleration of gravity, gradually moving away from the floor. The radar is assumed to coordinate origin O, Z-axis perpendicular to the ground, X-axis points to artillery shooting direction, Y-axis direction is determined by the right hand rule, several target track shown in Fig. 2.
Among them, $V_x, V_y, V_z$ are $X, Y, Z$-axis velocity components, $c$ is ballistic coefficient, $z$ is target elevation altitude in Cartesian coordinate system, $g$ is the acceleration of gravity.

$H_z(z) = H(z) \cdot \left( \frac{\tau}{\tau_{on}} \right)$ is the correction of $H(z)$ after virtual speed instead of true speed, $H(z) = e^{-1.069 \times 10^{-4} z}$ is air specific gravity function. $G(v_r) = F(v_r) / v_r$ is resistance function,

$$F(v_r) = \begin{cases} 
0.0007454 & v_r < 250 \text{ m/s} \\
629.61 - 0.0255 & v_r + 1.8756 \times 10^{-2} v_r^2 - 1.8613 \times 10^{-5} v_r^3 \\
250 \leq v_r < 400 \text{ m/s} \\
6.394 \times 10^{-8} v_r^3 - 6.325 \times 10^{-5} v_r^2 + 0.1548 & v_r - 26.63 \\
400 \leq v_r < 1400 \text{ m/s} \\
0.0012315 & v_r \geq 1400 \text{ m/s} \\
\end{cases}$$

$v_r = \sqrt{v_x^2 + v_y^2 + v_z^2} \cdot \sqrt{\frac{\tau}{\tau_{on}}}$ is virtual speed. Among them, $\tau_{on}$ is ground standard virtual temperature, $\tau$ is the virtual temperature in height $z$ which is the real air temperature amended after taking into account the air humidity, its numerical value is dry air temperature when it has the same proportion and pressure with wet air. If the target initial position and velocity information are known, according to dynamic particle equations can calculate the target displacement in $X, Y, Z$-axis direction $S_x, S_y, S_z$, target $X, Y, Z$-axis velocity $V_x, V_y, V_z$. Radar measurement equations often given in the spherical coordinates form, as shown in Fig. 3.

![Figure 3. Target spherical coordinate system.](image-url)
R is the slope distance, \( \varepsilon \) is pitch angle, \( \beta \) is azimuth angle, dop is the doppler velocity, the measurement vector is: \( z = [R \ \varepsilon \ \beta \ \text{dop}] \), the measurement equations as follows:

\[
\begin{pmatrix}
\sqrt{x^2 + y^2 + z^2} \\
\sin^{-1}\left(\frac{z}{\sqrt{x^2 + y^2 + z^2}}\right) \\
\sin^{-1}\left(\frac{x}{\sqrt{x^2 + y^2 + z^2}}\right) \\
v_x \cdot x + v_y \cdot y + v_z \cdot z + \frac{z}{\sqrt{x^2 + y^2 + z^2}}
\end{pmatrix}
\]

According to the measurement equations, and then calculates the target simulation data including slope distance, azimuth angle, pitch angle, doppler velocity.

### 3 SOFTWARE DESIGN

Digital simulation software is divided into initialization parameter module, simulation target management module, simulation target module, and beam control module. Initialization parameter module completes the set of target simulation parameters, including work mode, frequency, target X, Y, Z-axis initial position, target X, Y, Z-axis initial speed and other information. Simulation target management module administrates multi-target, imports corresponding target initial parameters. Simulation target module completes the calculation of single target including choosing different target moving track calculation method according to different work mode, calculating the current position of target and obtaining target simulation data send to beam control module. Beam control module starts calculate target new position task, calculates radar beam current position, estimates target beam intersection according to target simulation data and beam current position, prepares simulation intersection data which will send to signal processor. Digital simulation software modules as shown in Fig. 4.

![Digital simulation software modules](image)

**Figure 4. Digital simulation software modules.**

### 4 TEST AND SIMULATION

After digital simulation, the following is the air defense, artillery investigation and artillery calibration shooting target track point observing on the terminal computer, as shown in Fig. 5, 6, 7. According to the target track point displayed on the terminal computer, the data collected from
debugging computer and the data analysis results from MATLAB, can detect the status and locate problems of chief data processing link.

Figure 5. Air defense target simulation track once point.

Figure 6. Artillery investigative target simulation track point.

Figure 7. Artillery calibration shooting target simulation track point.

5 SUMMARY

In view of multifunctional radar characteristics such as multi-workmode, complex data processing, difficult debugging and so on, real-time control computer based on VxWorks operating system, designs the digital simulation function, this function can achieve target simulation without the need of target simulator and other extra hardware and equipment. This function can detect the status and locate problems of chief data processing link. This method can reduce the debugging difficulty, shorten the development cycle.
REFERENCES