Research on Dynamic Display of Radar Detection Range in Complex Electromagnetic Environment Based on GIS

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Abstract. In this paper, relevant researches are made on the system of electromagnetic environment situation and the range of radar in complex electromagnetic environment. The parameters of electromagnetic environment data calculation parameters are proposed, and the design of a 3D radar situation display algorithm is used to develop the comprehensive display system of electromagnetic environment information. A typical dynamic simulation of radar environment is given. It can display the electromagnetic environment situation more intuitively and comprehensively, and can provide analysis methods and demonstration evaluation for the increasingly complex battlefield electromagnetic environment display, laying a foundation for a certain range of battlefield electromagnetic 3D visualization environment statistical data output and situation visualization.

1. Introduction

The electronic warfare is the main form and means of the modern warfare. Whether it is a battlefield communication, a direct battlefield confrontation, or a combat command, the electromagnetic waves play an important role. However, most of the current measurement of the electromagnetic field strength uses some special receiving detection instruments to detect through the internal and external fields. But it is a huge and difficult project to detect the large-scale electromagnetic field coverage of the battlefield, and the invisibility of the electromagnetic field itself greatly increases the difficulty of electromagnetic field analysis. Therefore, the study of 3D visualization of the electromagnetic environment is important to a modern electronic warfare, and it is also a current research hot spot.

The purpose of visualizing the electromagnetic environment of the space is to help users analyze, evaluate, and make decisions, to visualize the electromagnetic field from 3D space, and to help users understand the spatial electromagnetic field situation, propagation direction, and intensity range through intuitive visualization. At present, domestic and foreign countries have made some achievements in the visualization of electromagnetic field visualization, 3D field equivalent coloring, 3D grid blanking, and stereo display. The Advanced Refraction Effect Prediction System (AREPS) developed by the United States Naval and Space Warfare Center can obtain the characteristics of radio wave propagation in complex environments. It is mainly used in electronic warfare radar and Military communication system to realize command automation and provide it with battlefield situation assessment electromagnetic environment reference data. However, the system does not realize the visualization of the 3D electromagnetic environment situation, only the two-dimensional electromagnetic environment situation spatial section representation. The virtual reality modeling language (VRML) is used to implement dynamic representation of the electromagnetic environment...
situation with directional arrows and contour lines, but the continuous situation distribution of electromagnetic field strength is lacking.

Based on the visualization of the electromagnetic environment of the GIS spherical surface and the range of radar under a complex electromagnetic environment, this paper has done related research, and realized a 3D visualization system of the electromagnetic environment situation. The methods of slice drawing, surface drawing, and direct volume rendering are used to visualize the electromagnetic data, and shows the distribution of the electromagnetic environment in three dimensions [1-2].

2. Outline Design
The research purpose of the radar electromagnetic environment situation display based on 3D GIS digital map is to provide analysis methods and demonstration assessment for increasingly complex battlefield electromagnetic environment display, and to lay the foundation for a certain range of battlefield electromagnetic environment statistical data output and situation visualization. The platform has the characteristics of flexible construction and easy expansion, and has the characteristics of high simulation accuracy, controllable parameters, strong operability and strong engineering practice, etc., which is more suitable for the complex electromagnetic environment requirements of modern battlefields.

The 3D visualization analysis method of the electromagnetic environment situation is to display the whole and comprehensive display from the time, frequency, air and energy domains; the second is to reflect the dynamic nature. The display of the space electromagnetic environment should be changed due to changes in combat targets, combat deployment methods, and combat scales, and it will change continuously as the combat process develops. Third, it is necessary to reflect both regularity and randomness [3].

3. Design instructions for complex electromagnetic environments
The comprehensive electromagnetic environment information display system consists of an interference source state control, an interference effect calculation, and an interference situation display.

Among them, the interference source state control can add and change interference platforms and equipment parameters in the configuration library, and it can set the radiation source switch, radiation source parameters, etc., as scheduled.

The interference situation display can select a single platform to individually adjust the radar status and generate a radar operating status chart, and it can generate a global radar interference map and display the status of other platforms in the current interference range and calculate the status of interference conditions of other platforms in the interference [4].

3.1. Interference effect computation
The interference effect calculation module uses a complex electromagnetic environment calculation model to perform interference analysis calculations based on distances, relative angles, interference performance parameters, radar performance parameters, and other related parameters between the jammer and the interfered platform that needs to be analyzed.

In the calculation of interference effects, relevant parameters required for the complex electromagnetic environment are extracted from the platform equipment model, and the parameters are passed to the calculation model. After the calculation model is calculated, the radar detection distance of each angle of the interfered radar is generated, and the result is transmitted back to the interference effect calculation module for subsequent interface display. The operation parameters are shown in Table 1 below[5].

| Serial number | Radar parameter category | Unit | Noise source parameter category | Unit | Environment parameter category | Unit |
|---------------|--------------------------|------|--------------------------------|------|--------------------------------|------|

Table 1. Operation parameter
|   |                                | MHz       | MHz       |                           |                           |
|---|--------------------------------|-----------|-----------|--------------------------|--------------------------|
| 1 | Frequency range                | MHz       | MHz       | Pohl this graceful       | constant                |
| 2 | Narrow band pass               | Hz        | Hz        | Ambient temperature      | K                        |
| 3 | System noise coefficient       | dB        | dB        | The radar scatters the   | M²                       |
| 4 | Average emissive power         | W         | w         |                           |                          |
| 5 | The transmitting antenna       | dB        | Range of jamming | Km                      |
| 6 | The receiving antenna          | dB        | dB        |                           |                          |
| 7 | The examination needs the      | dB        | dB        |                           |                          |
| 8 | System feed line loss          | dB        | Disturbance suppression coefficient | /                      |
| 9 | Beam width                     | °C        |           |                          |                          |
| 10| Polarized way                  | Enumeration type | |                          |                          |
| 11| Working                        | Enumeration type | |                          |                          |
| 12| Antenna pattern                |           |           |                          |                          |

### 3.2. Electromagnetic environment situation display

The situation map is developed on the basis of GIS maps and communication studies. It firstly appeared in the general combat situation map of the US military. The visualization of the situation of radar electromagnetic environment is based on 3D GIS digital map. The 3D electromagnetic environment is the same as the conventional two-dimensional electromagnetic environment. In the 3D electromagnetic environment, the situation symbols in the two-dimensional electromagnetic environment need to be reconstructed to meet the new requirements.

The symbol system in the two-dimensional situation map is relatively complete. It has been practiced for a long time, but it is not yet able to express the third-dimensional elements. In the 3D situation, it is easier for people to understand the third symbol from an intuitive understanding. The current situation can be observed from multiple angles in the 3D situation. The line of sight and direction of the viewpoint can be arbitrarily changed to avoid many blind spots in the two-dimensional situation map.

The electromagnetic environment situation display module calls the result of the interference effectiveness calculation, extracts the radar detection distance array from the calculation result, describes the radar detection range according to the array, and displays it on the interface.

In this part of the function, it can be displayed all the radar platforms that have been calculated by clicking the menu; it can be displayed the detection range of the selected radar-equipped objects by selecting and displaying the map [6].

### 4. Design process of 3D radar situation display software in typical electromagnetic environment

#### 4.1. 3D radar situation display algorithm design

This algorithm gets the antenna gain through the Sink function or the antenna pattern, loads the antenna gain, and injects it into all interference devices, and then determines whether the radar is in
the interference area or not. If the radar is in the interference area, firstly calculating the interference value of the radar within 360 degrees of the radar and the interference power at the current angle between the radar and each interference device by the interference power calculation formula. Then the system noise is calculated after superimposing the calculation results of multiple interference devices, and finally the current angle radar detection range is calculated to form a complete detection range.

4.2. Algorithm implementation

The complex electromagnetic environment operation model is the core of the electromagnetic interference calculation. It mainly includes: the antenna gain loading, the effective interference state judgment, the judgment of the radar is whether in the jammer's interference area or not, the calculation of the angle and distance between radar and jammer. This algorithm divides the radar detection area into 360 degrees, and it analyzes the interference power between the radar and each jamming device at each degree. At the same time, in drawing the radar's 3D detection range and interference range, the key is that this algorithm calculates the interference power analysis between radar interference devices and determines the range of interference [7-8]. The calculation steps are as follows:

- Getting the antenna gain \( G_{\text{pointi}} \) through the Sink function or the antenna pattern;
- Performing interference power calculations, the calculation formula is shown below:

\[
R = 10 \times (\log_{10}(P_j) + \log_{10}(\text{lam})^2 + \log_{10}(f_r)^2 - \log_{10}((4\pi)^2 - \log_{10}(R_j^2) - \log_{10}(F_j)) + G_j + G_{\text{pointi}} - Q - K_d
\]  

(1)

Among them, \( R \) is the interference power, \( P_j \) is the transmission power of the jammer, \( \text{lam} \) is the radar wavelength, \( f_r \) is the radar receiver bandwidth, \( R_j \) is the distance from the radar to the jamming equipment, \( F_j \) is the jammer bandwidth, \( G_j \) is the interference antenna gain, \( Q \) is the multi-factor radar anti-interference factor, and \( K_d \) is Polarization loss.

- Overlaying the results of multiple interference device operations as getPlatEmc;
- Performing the system noise calculations and record the results as Gnr, the calculation formula is shown below:
\[ G_{nr} = 10 \times (\log_{10}(K) + \log_{10}(T_0) + \log_{10}(B_n)) + F_n \]  
(2)

Among them, \( G_{nr} \) is the system noise, \( K \) is the Boltzmann constant, \( T_0 \) is the ambient temperature, \( B_n \) is the Doppler bandwidth of the signal processing, and \( F_n \) is the noise figure.

- Calculating the current angle radar detection range, the calculation formula is shown below:

\[
D = 10^{10\times (\log_{10}(Pav) + \log_{10}(lam) - \log_{10}(G_k) - \log_{10}(G_r + \log_{10}(G_{nr} + \log_{10}(getPlatEmc)))} + G_r + G_r - L + cita - D_0
\]

(3)

Among them, \( D \) is the radar detection range, \( Pav \) is the radar average power, \( lam \) is the radar wavelength, \( G_r \) is the transmitting antenna gain, \( G_i \) is the receiving antenna gain, \( L \) is the system loses, \( cita \) is the radar scattering area, \( D_0 \) is the minimum detectable signal-to-noise ratio[7-8].

5. Conclusion

In complex battlefields, electromagnetic situations often play a decisive role in the battlefield situation. Based on the spatial electromagnetic environment data field, with the help of a visualization technology, it is particularly important to fully represent the distribution of the electromagnetic field. This article takes electronic countermeasures as the background, and gives a dynamic simulation of a typical radar environment through the research in the three-dimensional dynamic display of the radar detection range changing under a complex electromagnetic environment. It can help users to analyze, evaluate and make decisions, and help users understand the spatial electromagnetic field situation, propagation direction and intensity range [9].

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