An Overview of Radar Clutter Simulation

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Abstract. Radar is known as an important sensor in modern warfare. The complex electromagnetic environment of the battlefield has adverse effects on the survivability and working ability of the radar battlefield. Clutter is the main interference in radar signal processing. It is the key for radar development, test and performance detection to simulate the clutter environment that radar is facing. This paper summarizes the research status of radar clutter simulation technology, and highlights the clutter simulation method based on reverberation chamber. It is also pointed out that there is still a long way to go for the mechanism analysis and experimental research of radar clutter simulation in reverberation chamber.

1. Research Background and Significance
Modern warfare is a form of multi-dimensional joint operations, and its form will also transform from the physical dominated by hard weapons to information fields with soft and hard combination[1]. The electromagnetic environment of complex battlefield is composed of distributed, varied, complex and dynamic superimposition of radiation sources. This omnidirectional, large, deep, multi-dimensional electromagnetic environment will not only threaten the safety of electronic equipment and personnel, but also interfere with the decision making of the command system, influence the process of battle, and master wars situation [2]. Radar is known as an important sensor in modern warfare, playing a vital role in air defense warning, detection and firefighting. Radar echo is the product of electromagnetic wave modulated by the target and its surrounding environment, which the signals scattered by the environmental scatterers are called clutter. Clutter is one of the main electromagnetic environments of radar. What’s more, clutter is the main interference in radar signal processing, and its scattering characteristics directly affect the performance of radar system. Therefore, simulating the clutter environment faced by radar reasonably and realistically is the key in radar development, testing and performance detection.

2. Research status of radar clutter simulation technology
As mentioned above, clutter is the main interference in radar signal processing. Target signal is submerged in the clutter, when the target is hidden in the surrounding environment. And the presence of clutter causes serious interference to the radar target detection and extraction. So clutter simulation is very important for detecting the working ability of radar system under clutter background. Several clutter simulation techniques will be introduced following in the passage.
2.1. External Field Simulation Method Based on Real Loading
The field test is to use real weapon to build the battlefield environment, and put the test radar in it to test the performance of the radar in the real battlefield. The advantage of this method is that the built battlefield environment is close to actual combat, and the detection of radar performance is more real and accurate. The famous NATO POLYGON electronic range is the main base of outfield training. Before the Kosovo war, the US army sent radar to the range for training to improve the performance of the radar on the battlefield [3]. But there are some shortcomings in the field test. Firstly, it needs to coordinate a large number of electronic equipment, and the cost of single test is high. Secondly, the test results are easily affected by the weather and the geographical environment of the outside field. It needs to wait for a certain time to test. Besides, the single experiment period is very long, and the repeatability is poor. In addition, with the increase of radar system classes, the role of radar becomes more and more pertinent. According to the working mode and system of radar, the clutter environment it faces is quite different.

2.2. A Clutter Simulation Method based on Computer Simulation
In order to overcome the shortcomings of the actual simulation method and improve the flexibility and repeatability of the clutter simulation, people begin to rely on the unique advantages of the computer and the simulation software. ZMNL and SIRP are the two most mainstream methods of clutter simulation at present. With these two methods, this software based clutter simulation technology has been greatly developed.

2.3. A Clutter Simulation Method based on Semi Physical
The semi physical clutter simulation is fed into radar by means of cable injection or space radiation to realize radar clutter signal simulation. Injection clutter simulation and radiation clutter simulation are two main simulation methods at present. The injection simulation can be divided into radio frequency, intermediate frequency and video simulation which generated by radar clutter signal simulator are injected into the radio frequency, intermediate frequency and video input terminals through the feeder line accordingly. Radiation simulation is the signal generated by the radar clutter signal simulator, which is received into the radar via the antenna after direct or environmental reflection in the form of space radiation. Usually there are two modulation processes of the radar clutter analog signal and the superposition of the external signal. Radiation radar clutter simulation is more realistic, but more complicated.

2.4. A Clutter Simulation Method based on Microwave Anechoic Chamber
The simulation of large microwave anechoic chamber is to place the whole radar or part of the machine in a closed microwave anechoic chamber, and use one or more radiation sources to produce a realistic radar clutter environment. The radiation direction, polarization direction, signal intensity and purity of clutter can be well controlled. However, the cost is very high, and the range of the radiation direction and polarization direction of clutter is limited. The quality of analog signal in microwave anechoic chamber mainly depends on the spatial superposition of each signal simulator, and there is no reflection or multipath signal in principle.

2.5. A Clutter Simulation Method based on Reverberation Chamber
The simulation in reverberation chamber is to place the whole radar or part of the machine in a closed radio reverberation chamber. One or more radiation sources are used to produce single frequency or specific modulation signals. After mixing, modulation and multipath reflection in the reverberation chamber, the radar is entered from the antenna. Compared with the open field, the reverberation chamber is a shielding chamber with strong sealing. The system has higher controllability, stronger anti-interference ability and shorter experimental period. Compared with the microwave anechoic chamber, the cavity wall of the reverberation chamber is made up of a good conductor metal plate, which does
not require a large number of absorbing materials. The cost of the experiment and the difficulty of making process are greatly reduced, and the utilization rate of space is greater.

3. The Clutter Simulation in Reverberation Chamber

3.1. Reverberation Chamber
The reverberation chamber is a multimode shielding cavity with electrically large and high Q value[1]. The transmitting antenna of the Reverberation chamber injected the electromagnetic wave into the Reverberation chamber in the form of a beam. Agitating and the strong reflecting of the cavity would form a random field with high field strength and uniform statistics in the Reverberation chamber. The reverberation chamber technology has broken the traditional method to improve the field uniformity by sacrificing the electromagnetic wave reflection, and opened up a new way for the uniform field simulation technology.

3.2. Structure of Reverberation Chamber
A typical Reverberation Chamber is made up of main parts and auxiliary devices. as is shown in Figure 1.

![Figure 1. Typical Reverberation Chamber structure](image)

Apparently, the main part is constitute of shielded cavity, mixing equipment, transceiver antenna and test equipment (EUT). Composing of six good conductor metal walls, the shielding cavity which high conductivity makes the energy loss very little after the reflection of the cavity wall, ensures the high energy utilization of the Reverberation Chamber. The material of the mechanical stirrer is the same as that of the cavity wall. The location in the Reverberation Chamber is generally perpendicular to each other, so that the independent stirring position can be increased as much as possible. The role of transceiver antenna is to provide signal source and to acquire data. The working frequency, bandwidth and polarization state of antenna are generally considered when selecting and sending antennas. In addition to low frequency limitation, the Reverberation Chamber has a wide range of frequency bands, so there are many kinds of antennas for transceiver antennas selection such as logarithmic periodic
antennas, horn antennas and so on. The IEC standard stipulates that the distances between EUT and cavity wall and the distance between EUT and agitator are 1/4 working wavelengths at least, so in the course of the experiment the test equipment is generally taken up with a certain height of non conductive material, as shown in Figure 1.

3.3. Unique Advantages of the Reverberation Chamber

In addition to the advantages of the above comparison with anechoic chamber, the reverberation chamber has the following unique advantages. The electromagnetic environment of unidirectional radiation, the full domain characteristics of a more real analog clutter, strong energy utilization and so on. Therefore, the electromagnetic environment simulation based on reverberation chamber has good prospects for development. However, the difficulty of signal simulation in reverberation chamber is that the modulation characteristics of the signal depend not only on the radiation source, but also in the modulation of the mixing, resonance and multipath reflection in the reverberation chamber, and the mechanism of the signal formation is not yet clear.

3.4. Current situation of clutter simulation in reverberation chamber

At abroad, in the 90s of last century, a large number of experts and scholars began to study the electromagnetic field statistics and Doppler broadening in reverberation chamber. In field distribution, B. Boverie and others adopted the method of goodness of fit detection (GOF) to analyze the experimental data, and found that the field distribution in the reverberation chamber obeys the Rayleigh distribution [4, 5]. After that, L. R. Arnaut used the model theory to analyze the distribution of the reverberation chamber under different modes. It is considered that the Bessel K distribution can truly reflect the distribution characteristics of the reverberation chamber. However, some scholars believe that the distribution of Weibull is more consistent with that [6]. In recent years, people have used reverberation chamber as Rician and Rayleigh fading channels [7-9]. In the early 90s of last century, some scholars began to pay attention to the frequency domain characteristic [10] of reverberation chamber, such as Doppler. In document [11], the author proposes a method for calculating the maximum Doppler shift in a continuous stirring reverberation chamber under a stepwise stirring. Jung-Hwan Choi studies the influence of the size of the agitator, the position of the transceiver antenna and the polarization mode on the Doppler broadening in the same year [12]. Then, the Italy scholar Antonio Sorrentino discovered the connection between the radar clutter environment and the electromagnetic environment of the reverberation chamber, and successfully simulated the clutter power spectrum characteristic in the reverberation chamber [13]. In recent years, some scholars began to focus on the study of Doppler spectrum shape in reverberation chamber [14, 15]. In addition, the combination of reverberation chamber technology and radar field has been highly valued by the US military [16].

Reverberation chamber started late in China, especially in combination with radar field, but also achieved certain results. In document [17], the authors use the complex cavity theory to analyze the electromagnetic field spatial distribution model in reverberation chamber. In the same year, Wang Xuming analyzed the feasibility and theoretical basis of radar clutter in reverberation chamber [18]. Tan Wuduan proposed a model [19] which accords with the statistical characteristics of the electric field amplitude of the loss cavity. Wang Hao and others used the reverberation chamber to simulate the radar echo environment effectively in document [20]. Since then, on the basis of predecessors, Tu Peng et al has preliminarily simulated the amplitude and frequency domain characteristics of the measured radar clutter in the reverberation chamber [21].

4. Conclusion

In a comprehensive view, the use of reverberation chamber for radar clutter environment simulation has been paid great attention by domestic and foreign scholars and military, and great progress has been made in experimental research and verification in the short term. However, the simulation mechanism of reverberation chamber clutter is not clear, which restricts the development of reverberation simulation
technology in reverberation chamber. Therefore, the mechanism analysis and experimental research of radar clutter simulation in reverberation chamber still have a long way to go.

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