Influence of metallic target surface roughness on THz scattering characteristics

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***Abstract*—Compared to microwave and infrared, THz radar has higher resolution, stronger secrecy, stronger penetrating ability and stronger anti-interference ability. The development of THz radar system depends on the research of THz radar target characteristics. However, different from microwave band, we must take into account the influence of target surface roughness on THz scattering characteristics during developing the research of THz radar target characteristics. This paper studies the influence of metallic target surface with different roughness on THz scattering characteristics through theoretical calculations and experiment.**

I. INTRODUCTION

TERAHERTZ wave is defined by the frequency range of 0.1THz to 10THz, 1THz=10^{12}Hz. Terahertz is situated between infrared and microwave that includes their advantages and also overcomes their disadvantages. Obviously, Terahertz wave has high value both in academic and application. Terahertz has many characters, such as broad frequency band, short wavelength and large information capacity, and its application domain has been extended. Terahertz technology has been used and developed on military and defense by developed countries recently. Particularly, in contrast with microwave, terahertz radar technology not only can achieve smaller target detection and more pinpoint detection, but also has higher resolution and stronger secrecy. Therefore, terahertz radar will be the future high pinpoint radar development direction, and will play an important role on military equipment and national security.

On microwave band and millimeter wave band, most of metallic targets can be regarded as smooth-faced ideal conductor. Whereas on THz band, due to the high frequency and narrow beam of THz wave, the scattering effect of various micro structures will be enhanced, the target surface will become rough. Thus, targets on THz band are actually the objects with rough surface and relative permittivity. This paper applies methods of the combination of theoretical calculations and experiments to study the influence of metallic target surface roughness on THz scattering characteristics.

II. THEORETICAL CALCULATIONS

In theory, the solution methods of the scattering characteristics of rough surface can be divided into two classes: analytic method and numerical calculation method [1]. According to the electromagnetic calculation theory, with the increase of the frequency, the calculated amount augments significantly. Therefore, the THz electromagnetic modeling faces huge challenge. Traditional numerical calculation methods are too demanding on calculation time and calculation resource which are very difficult to put into engineering application. So THz electromagnetic calculation adopts usually high frequency calculation method. The high frequency calculation method has major advantages on THz electromagnetic calculation with two main reasons: firstly, the high frequency calculation method is very flexible on geometric modeling, while the numerical calculation method is too demanding on geometric modeling. Taking MOM as an example, it requires that each paired panel is complete joined, and each triangle is regular; Secondly, on terahertz band, the electromagnetic wave behaves more particulate and less wavelike. The high frequency calculation method is based on the particle property of electromagnetic wave.

Through theoretical calculations, we compared the RCS of terahertz band on ideal metallic plate with which on actual metallic plate. The ideal metallic plate has smooth surface, while the actual metallic plate has the millimeter level relief height because of the technical limit and the abrasion. The size of plate is 0.1m×0.1m, the mean value of relief height is 0.001m. According to the electromagnetic scattering theory, we applied physical optics method to deduce the RCS of metallic plate:

$$\sigma_{po} = \frac{64\pi}{\lambda^2} a^2 b^2 \cos^2\phi \,\mathrm{sinc}^2(2ka\sin\phi) \quad (1)$$

The signification of the parameters in formula (1) illustrates in figure 1.

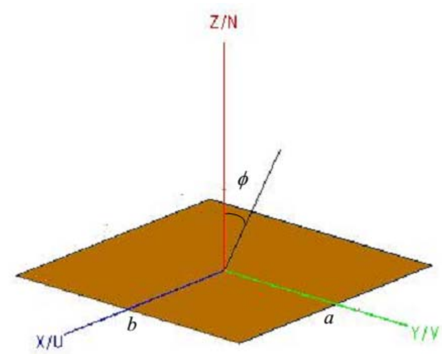

Fig. 1. The theoretical simulation coordinates of plate.

Figure 2 compares the RCS of terahertz band on ideal metallic plate with which on actual metallic plate. The simulation results show that with the increase of the frequency, the RCS on ideal metallic plate always keep the sinc function property of formula (1), while the RCS on actual metallic plate doesn't show any scattering curve property of sinc function. Due to the increase of the frequency, actual metallic plate cannot be regarded as smooth according to the Rayleigh criterion of smooth surface, and the target surface roughness will influence the target RCS.

III. EXPERIMENT

The THz-TDS system gets information such as refractivity, reflectivity and permittivity by THz electric field intensity

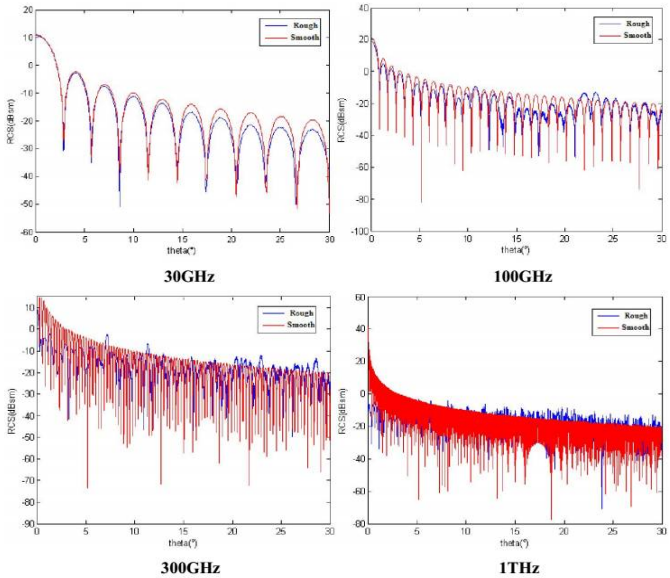

Fig. 2. Comparison of the RCS of rough metallic plate and the RCS of smooth metallic plate.

comparison and phase change. It has been adopted by many researchers to develop the research field of target electromagnetic scattering characteristics [2][3]. The paper applies the THz-TDS system to carry out THz reflectivity measurement on metallic target surface with different roughness. Figure 3 shows the diagram of THz-TDS system.

In order to simulate metallic target surface with different roughness, we sprayed metal conductive paints on sandpapers

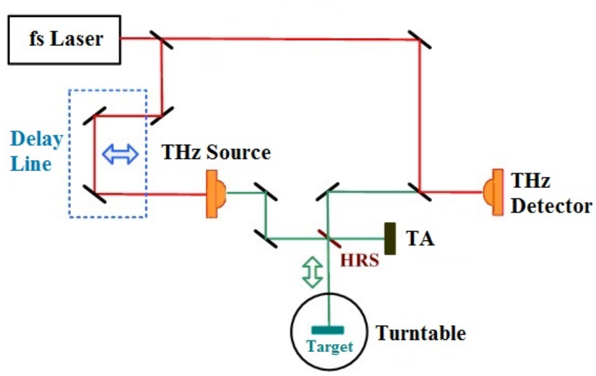

Fig. 3. Diagram of THz-TDS system.

with different grits and relative results are presented as below. In figure 4, P120, P150, P500 and P600 represent sizes of sandpaper grits respectively, which mean the amount of grit on every square inch. The grade is smaller, the size of sandpaper grit is larger, and the surface of sandpaper sprayed by metal conductive paints is rougher. With the THz-TDS system we obtained THz reflectance spectrums on four different rough metallic target surfaces with the frequency range of 0.2 THz to 2 THz. Testing results are presented in figure 5.

Testing results show that if the surface of sandpaper sprayed by metal conductive paints is rougher, the changing of measurement frequency has more significant effect on THz reflectance characteristics. For example, when the measurement frequency is 1.5 THz, the THz reflectivity of P120 sandpaper tends to be 0, but the THz reflectivity of P600 sandpaper still exceeds 0.6. In the case, the roughness of metallic target surface leads to the change of THz reflectance

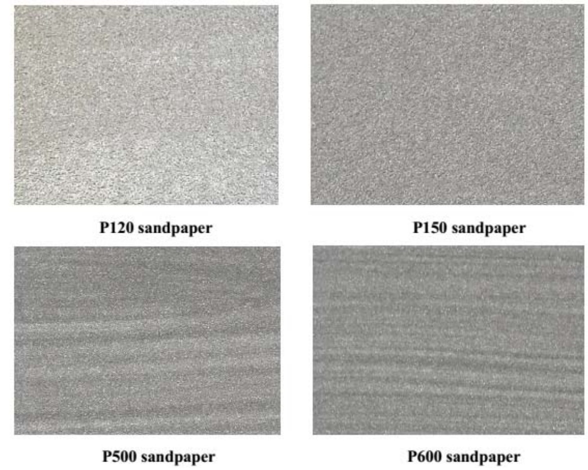

Fig. 4. Sandpapers with different roughness sprayed by metal conductive paints.

signal from targets, and influences the target RCS.

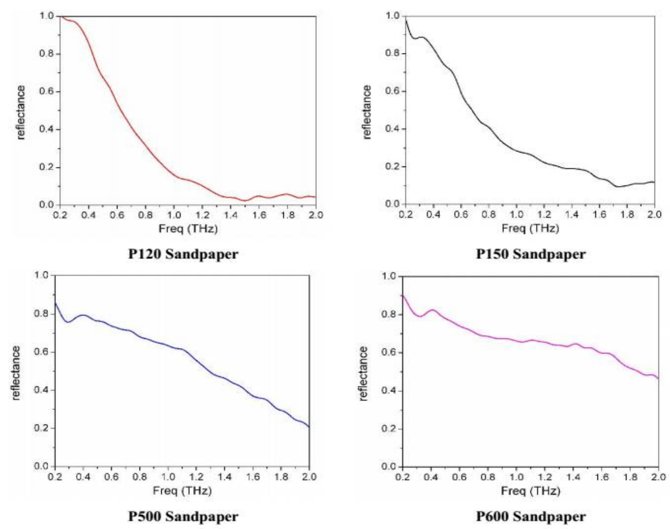

Fig. 5. Reflectance spectrum of metallic surface with different roughness (sandpapers with different grits).

IV. Summary

Conclusions are drawn from results of theoretical calculations and experiments that the surface roughness of metallic targets has significant effect on THz target scattering characteristics, which should be taken in account when we carry out the research of THz target scattering characteristics.

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