Antenna Target Recognition with Terahertz Radar Based on RCS Characteristics

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***Abstract*—Regarding the problem of antenna target recognition in terahertz (THz) band, this paper proposed a target recognition process based on Radar Cross Section (RCS) characteristics. Besides, it established an antenna target recognition simulation for four kinds of typical antennas with 140G narrowband radar, which verified the effectiveness of the above method.**

I. INTRODUCTION

THERE is a promising application in airborne Video Synthetic Aperture Radar (ViSAR) for terahertz (THz) radar. Additionally, research on target scattering characteristics and recognition of ground antenna can make great contribution to airborne ViSAR in THz band. Compared with microwave radar, THz radar is more beneficial for target recognition for its short wavelength, wide bandwidth and high resolution [1]. Furthermore, target scattering characteristics in THz band are much more abundant. In addition, RCS characteristics of the targets are significant for target recognition due to its stability and reliability [2]. Moreover, research on antenna target gains vital military application.

In THz band, the problem of super-large-electrical-size demands high-frequency approximation approaches to compute target electromagnetic scattering characteristics. Usual approaches includes Geometrical Optics (GO), Physical Optics (PO), Equivalent Electromagnetic Currents (EEC), Shooting and Bouncing Ray (SBR), etc. However, there is not an application in computing target scattering characteristics in THz band for antenna target recognition.

This paper is constructed as follows: first, it adopted SBR to compute antenna target scattering characteristics and the antenna RCS characteristics were extracted to design the Nearest Neighbor Classifier (NNC) [3]. Then, it proposed the general process of antenna target recognition with terahertz radar based on RCS characteristics. Eventually, simulation on antenna target recognition was established for Parabola antenna (PAR), Ground-Based radar antenna (GBR), Anti Anti-Radiation Missile antenna (AARM) and Triangle Corner Reflector (TRCR) with 140G narrowband radar, and the effectiveness of the method is verified.

II. CALCULATION

Initially, CAD models of four typical antenna targets were established. Then, Shooting and Bouncing Ray (SBR) approach was adopted to calculate electromagnetic scattering characteristics. Thorough calculations are as follows:

A. Target CAD model establishment

FEKO is a generic 3D electromagnetic field of arbitrary structure simulation software, which solves Maxwell's equations using integral equation method. Models of four kinds of target configurations established using this software are shown in Figure 1.

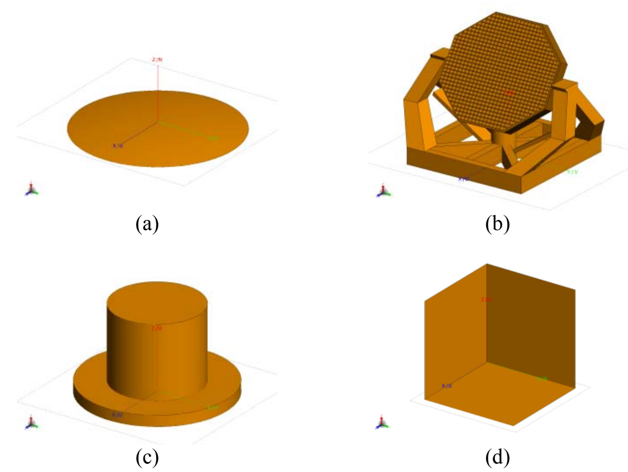

Fig. 1. 3D models of (a) Parabola antenna, (b) Ground-Based radar antenna (GBR), (c) Anti Anti-Radiation Missile antenna (AARM), and (d) Triangle Corner Reflector (TRCR).

B. Electromagnetic scattering characteristics calculation

In THz band, for super-large-electrical-size problem, this paper adopted SBR to calculate electromagnetic scattering characteristics. SBR combines GO and PO. It uses GO to describe multiple reflection of electromagnetic waves on the surface of objects, and uses PO to solve scattering field when electromagnetic waves leave objects. CST Microwave Studio (CST MWS) is developed by German CST Corporation. It can conduct simulation analysis of small-, medium- and large-electrical-size problems, fitting needs of various users, and it is specifically suitable for large-electrical-size calculation. This paper adopted CST MWS to calculate target electromagnetic scattering characteristics.

III. RECOGNITION PROCESS

This paper adopted MNC to extract, classify and recognize typical RCS sequence characteristics.

A. RCS sequence characteristics

The following RCS statistical characteristics are verified to recognize targets effectively: (1)mean value (2)variance (3)distance between centers of order r (4)median (5)extreme deviation and (6)variation coefficient.

B. Most Neighboring Classifier

For c-cluster problems, assuming there are N training samples $\boldsymbol{x}_j^{(i)}$ (j = 1,2 , … ,N_i) , $N=\sum_{i=1}^{c} N_i$ in cluster ω_i (i = 1, 2, … ,c), unrecognized mode $\boldsymbol{x}$ is classified into the cluster to which its nearest recognized sample belongs. In this case, decision function of ω_i is

$$d_j\left(x\right)=\min_{j=1,2,\ldots,N_i}\left\|\boldsymbol{x}-\boldsymbol{x}_j^{(i)}\right\| \quad \left(i=1,2,\ldots,c\right) \tag{1}$$

and decision rule is

$$\text{if} \quad d_m(\boldsymbol{x}) = \min_{i=1,2,\ldots,c} d_i(\boldsymbol{x}), \text{ then} \quad \boldsymbol{x} \in \omega_m$$

It is normally called 1-NN method. To avoid chance of single sample, k nearest samples can be taken into account and $\boldsymbol{x}$ is classified into the cluster to which most samples among those k belong. Decision function of ω_i is then defined as

$$d_i(\boldsymbol{x}) = k_i \quad (i = 1, 2, \cdots, c) \tag{2}$$

and decision rule is

$$\text{if} \quad d_m(\boldsymbol{x}) = \max_{i=1,2,\ldots,c} [\, d_i(\boldsymbol{x})], \text{ then} \quad \boldsymbol{x} \in \omega_m$$

This method is called k-NN method.

C. Process of target recognition algorithm

Process of recognition algorithm based on RSC sequence is as follows.

Step 1: training statistics are obtained, and then RCS sequence of each target is calculated.

Step 2: general statistical and other characteristics of RCS sequence are extracted.

Step 3: characteristics extracted from Step 2 are trained using NNC.

Step 4: target RCS sequence is obtained and characteristics are extracted.

Step 5: characteristics obtained from Step 4 are imported into NNC and target is classified.

Flow chart of recognition algorithm is shown in Figure 2.

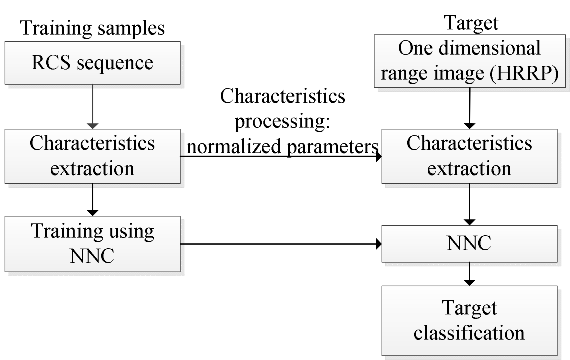

Fig. 2. Flow chart of recognition algorithm.

IV. RESULTS

Figure 3 shows the RCS estimation results under the condition of in reality, SNR=5dB, 10dB, 15dB, 20dB and 25dB respectively. Compared with RCS in reality, when the SNR is less than 15 dB, RCS estimation is incredible for loud noise. RCS tends to be steady in 20 dB. When SNR rises to 25 dB, RCS becomes more accurate and reliable.

Table 1 shows the recognition result based on RCS characteristics. Target recognition is low in 15dB except for the TRCR. In 20dB, only the recognition rate of AARM is low. Besides, all target recognition has a high level of reliability in 25dB. In conclusion, the proposed approach is effective.

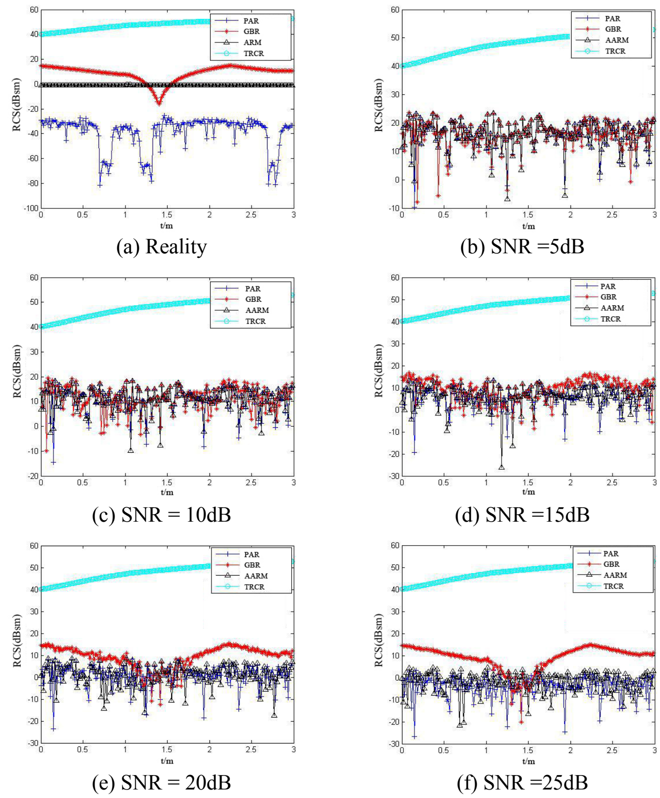

Fig. 3. RCS sequence of the four typical antennas under the condition of (a)in reality, (b)SNR=5dB, (c)10dB, (d)15dB, (e)20dB and (f)25dB.

Table. 1. Recognition Result based on RCS

Item / SNR	5dB	10dB	15dB	20dB	25dB
	Correction Number/ Total Number				
PAR	0.474	0.736	0.582	0.75	0.816
GBR	0.236	0.198	0.652	0.814	1
AARM	0.098	0.022	0.012	0.066	0.788
TRCR	1	1	1	1	1

V. SUMMARY

First, 3D models of four typical antennas, Parabola antenna (PAR), Ground-Based radar antenna (GBR), Anti Anti-Radiation Missile antenna (AARM) and Triangle Corner Reflector (TRCR) respectively, were established, and SBR was adopted to calculate electromagnetic scattering characteristics of above models. Then, using general statistical characteristics of target RCS, NNC were designed, and target recognition process based on RCS sequence were proposed. Finally, taking 140G narrowband radar as an example, by using the above method to conduct simulation analysis of above four typical antenna target, the effectiveness of the method is verified.

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