Research on Reconstruction of Target Scattered Field Based on Scattering Center Model

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***Abstract*—In this paper, the radar target back-scattered field reconstruction project based on scattering center model is investigated. The project establishes a scattering center database by ISAR imaging and CLEAN algorithm. And then reconstruct the scattered field of modified radar target based on the database and field reconstruction theory. The representative geometry as an example is used to illustrate the effectiveness of the project, and the results prove the reconstructed scattered field has a perfect approximation to the actual field in frequency-spatial domain and the project works well. It is of great significance to acquire the scattered field data of electrically large size radar target.**

***Keywords*—scattering center; ISAR ; CLEAN; field reconstruct**

I. INTRODUCTION AND BACKGROUND

Scattering center theory plays a significant role in the study of radar target characteristics. In high frequencies, a radar target is usually viewed as a number of discrete point-scatters called scattering centers [1, 2, 3]. Scatter centers are often generated from special geometry such as plane, edge, corner structure and so on. Traditionally, the scattering center model can be established by ISAR, analytic and statistic approaches [4, 5]. Shan Cui and Sheng Li extracted the 3-D scattering centers from different subapertures based on ISAR images [6]. Da-hai Dai extracted the full-polarization scattering centers based on GTD model [7]. In this paper, the scattering model is constructed on the basis of ISAR images. In practice, the geometry of electrically large size radar target such as aircrafts, antennas and others are often modified due to maintenance and update. The acquisition of the scattered field is very expensive and time-consuming [8]. To avoid the expense of measuring target's scattered field, an economic method to acquire the modified target's scattered field data should be taken into consider. In this study, an approach of acquiring the scattered field of radar target based on the scattering center theory is proposed and examined. Scattering centers of a target modified can be constructed from the scattering center database established before and the scattered field can be computed based on the scattering center model. Finally, the electromagnetic characteristics of it can be analyzed further.

II. FORMULATION AND BASIC THEORY

A. ISAR imaging

ISAR images are usually formed by taking the inverse fast Fourier transform of the mass computed or measured scattered field data. FFT method applied for monostatic radar is shown in Figure 1. Assuming that the field scattered from a target is approximated from M different scattering centers on target. The field is shown in Equation (1). The image can be obtained by taking 2-D IFFT of the filed, as shown in Equation (2). A_i represents the complex amplitude of the nth scattering center, $\vec{r} = x_i \cdot \vec{x} + y_i \cdot \vec{y}$ represents the position of the nth scattering center.

$$E^s(k,\varphi) \cong \sum_{i=1}^{M} A_i \cdot e^{-j2\vec{k}\cdot\vec{ri}} \quad (1)$$

$$ISAR(x,y) = \sum_{i=1}^{M} A_i \cdot \iint_{-\infty}^{\infty} e^{j2\pi(\frac{2f}{c})x} \cdot e^{j2\pi(\frac{k_c\varphi}{\pi})y} d(\frac{2f}{c}) d(\frac{k_c\varphi}{\pi}) \quad (2)$$

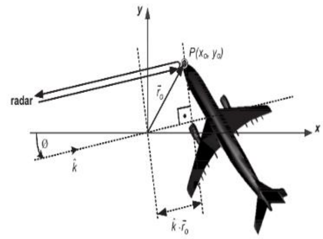


Fig. 1. Geometry for monostatic ISAR imaging

B. CLEAN algorithm

- Form image by Fourier transform of the computed scattered field data [9].
- Find the brightest spot in image and measure its complex amplitude $ae^{j\phi}$ and position x , y .
- Calculate radiation field at array due to a source $se^{j\phi}$ at location x and y .
- Subtract radiation field from computed data and form new image.
- New image is deprived of the brightest target as well as its sidelobes due to the radiation pattern of antenna.
- Repeat procedure on next brightest spot, and so on; with sidelobes of all large spots eliminated, the process works down to the noise.
- Acquire a list of targets A_n at position x_n , y_n , n =1,2,…, n .

CLEAN algorithm was first introduced to perform deconvolution on images created in radio astronomy [10, 11]. It is an iterative procedure that picks out the brightest point in the image, assumes it is a scattering center with the corresponding amplitude, and removes its point spread response from the image.

C. Field reconstruction

The scattered electric field in frequencies and angles can be reconstructed easily by using the extracted scattering centers with Equation (3):

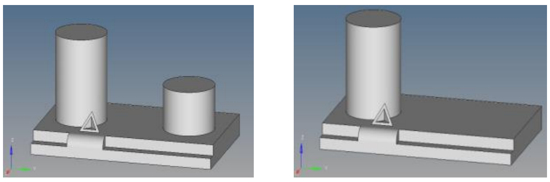
$$E_r^s(k,\phi)=\sum_{n=1}^{M} A_M \cdot e^{-j2k(\cos\varphi \cdot x_n+\sin\varphi \cdot y_n)} \tag{3}$$

III. Numerical and Experimental Results

In this part, two typical PEC geometries named SLICY_1 and SLICY_2 are introduced to test the field reconstruction project [12, 13].

A. Scattering centers database based on SLICY modle

SLICY model is a combo of some typical reflectors, such as planes, cylinders, corner structures, and edges. The scattering centers of this model are generated from these structures. The geometry is 0.3m by 0.5m by 0.25m along x-, y-, z-directions respectively. Compared with SLICY_1, only the short cylinder is removed for SLICY_2. As shown in Figure 2.

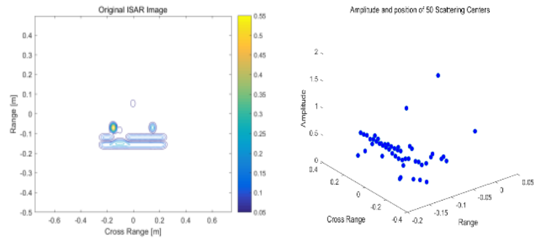


(a) (b)

Fig. 2. (a)Geometry of SLICY_1; (b)Geometry of SLICY_2

To establish the database, firstly acquire the computational back-scattered field data of SLICY_1 and form the ISAR image of it by FFT method. Then the scattering centers can be extracted from ISAR image utilizing CLEAN algorithm. The radar parameters are set as following: 50 frequency sampling between 71.25 GHZ and 78.75 GHZ in a step of 15 MHZ. Azimuth angle varies from -2.865° to 2.865° in a step of 0.076°, 75 elevation angles in total. Elevation angle is 90°. In the help of electromagnetic computing software, the scattered field of SLICY_1 is easy to get.

The ISAR image of SLICY_1 is shown in Figure 3, and 50 scattering centers extracted are shown in Figure 3, the scattering centers are numbered according to the complex amplitude and comprise the basic scattering center database. All the amplitude and position information are stored in the database. If SLICY_1 will be modified into another geometry, the database can provide useful and enough scattering center information for the new model.



(a) (b)

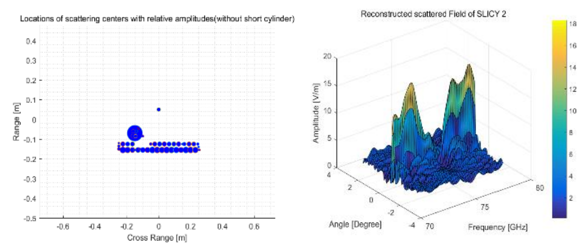
Fig. 3. (a) ISAR image of SLICY_1; (b) Scattering centers of SLICY_1

B. Field reconstruction of SLICY_2

- Meshing the ISAR image by the 0.02m × 0.025m gridding. And the scattering centers all drop in the different gridding.
- Identify the location of the short cylinder, it’s in the region of -0.1m~0.1m along range- direction and 0.08m~0.22m along cross-range- direction.
- Identify the scattering centers located in this region from the database, eventually, No. 2, No. 42, No. 46, No. 49 scattering centers are identified in this area, the information are shown in Table one. All the scattering centers except for these four are consisted of the scattering center model of SLICY_2.
- The scattering center model of SLICY_2 is constructed by last two steps. It includes all the scattering centers generated on SLICY_2
- Eventually, the scattered field of SLICY_2 in different frequencies and azimuth angles can be reconstructed based on the model, as shown in Figure 4.

TABLE I. PARAMETERS

No.	Amplitude and Position		
	range-axis/m	***Cross range-axis/m***	***Amplitude/(V/m)***
2	-0.070	0.150	-0.822 + 0.416i
42	-0.085	0.165	-0.095-0.206i
46	-0.060	0.160	-0.104-0.147i
49	-0.060	0.140	-0.067-0.143i



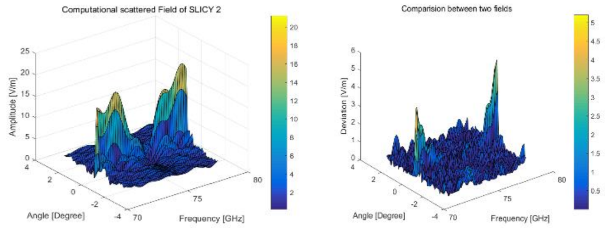
(a) (b)

Fig. 4. (a) Scattering centers model of SLICY_2; (b)Reconstruced scattering field of SLICY_2

To estimate the approximation degree of the reconstructed scattered field, a practical SLICY_2 geometry model is constructed to compute the actual scattered field data. Relevant computation parameters are the same as SLICY_1.

C. Comparision of two fields in muliple frequencies

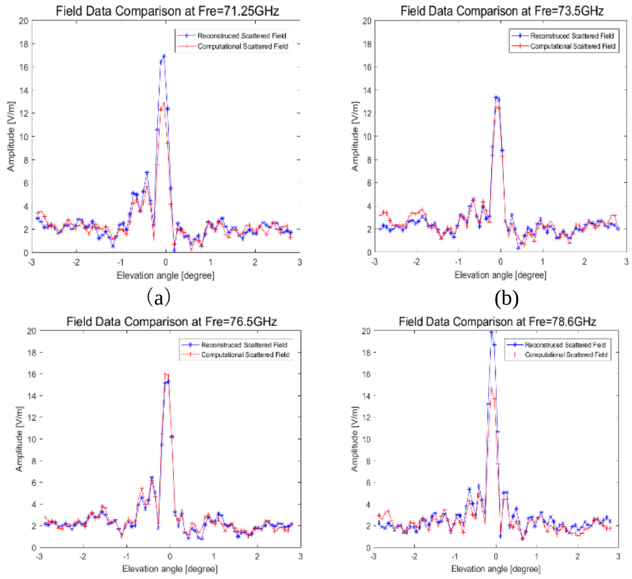
The computational scattered field and the deviation between two fields are shown in Figure 5.



(a) (b)

Fig. 5. (a) computational field of SLICY_2; (b) deviation between two fields

From Fig 5, it is clear that the deviation between two field is smaller than 1.5 V/m.To illustrate the deviation more clearly, multiple groups of data choosen from two fields are compared in various frequencies. The comparision results are shown in Figure 6.



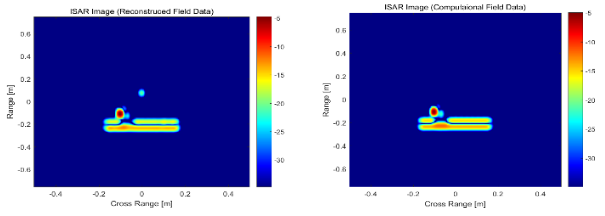
(a) (b) (c) (d)

Fig. 6. (a) Fre=71. 25GHz; (b) Fre=73.5GHz; （c） Fre=76.5GHz; (d) Fre=78.6GHz

The correlation coefficeient of the four groups are r1=0.9812; r2=0.9897; r3=0.9356; r4=0.9902. It proves the two field anastomose perfectly and the field reconstruction project works well. And noticeablely, the approximation is perfect in most frequencies and angles, while the deviation would be larger in the higher frequency and the lower frequency on the $\varphi=0°$ direction. And Research on this part will be the work in the next stage.

D. ISAR image formed by reconstruced field

To examine the reconstructed field more visibly, the ISAR images of SLICY_2 formed by reconstructed field data and computational field are shown in Figure 7 respectively. Although the scattering centers caused by coupling are included, the two ISAR images are almost the same.



(a) (b)

Fig. 7. (a) ISAR image of SLICY_2 by reconstructed field data; (b) ISAR image of SLICY_2 by computational field data

IV. Conclusion

The method of reconstructing the scattered field of modified radar target based scattering center database are fast, accurate, and convenient in this paper. Especially for these electrically large size targets that are not easy to obtain the measured scattered field, the method can get the reconstructed scattered field data by theoretical calculation and the reconstructed scattered field data can be used to analyze the target's characteristics further.

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