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# A NEW METHOD FOR CHARACTERIZING RADAR TARGET

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## 1. Introduction

From the reflected wave of a radar target, it is difficult or impossible to get the target's shape. So, it is very important how to obtain the characteristics of a radar target from the reflected wave. Up to now, there have been many methods to classify radar targets. But, most of the methods can not be used for measuring the characteristics of a target's shape. On the other hand, after Prony's Approximation (introduced by Prony in 1795) was first applied to a transient electromagnetic field [1], a number of papers dealing with aspects of Prony's Approximation have been provided. But, as for the identification of scatters from the frequencies even less is known. The present state is that such an identification can not be carried out without some a prior information [2].

In this paper, based on Prony's Approximation, a new method will be provided to describe some characteristics of a target from the reflected wave at high frequency. It will be very useful to identify the shape's characteristics of a radar target.

## 2. The Method to Describe the Characteristics of a Radar Target

### 2.1 The Method

Usually, a radar target is a complex object made up of three kinds of reflectors. The first class includes plat plate, corners (made up of two or three mutually orthogonal planes) and so on. These reflectors' *RCS* are inversely proportional to $\lambda^2$, where $\lambda$ denotes the wavelength, Another class is cylinders, which *RCS* is inversely proportional to $\lambda$. A sphere, which *RCS* is approximately equal to constant if $\lambda << 1$, belongs to the third class. This paper's appendix shows these typical reflectors, and gives the formulas of their maximum *RCS* values. So, the reflected wave of a radar target can be written as

$$E(k) = \sum_{i=1}^{r} kA_i \exp(jka_i) + \sum_{i=1}^{s} \sqrt{k}B_i \exp(jkb_i) + \sum_{i=1}^{t} C_i \exp(jkc_i) \tag{1}$$

where $k$ denotes the frequency and $j$ denotes the imaginary unit.

Suppose that $E(k)$ can be measured from $k_1$ to $k_m$. For conveniences, let $u_1 = \sqrt{k_1}$, $u_m = \sqrt{k_m}$ and $u = \sqrt{k}$. Then Eq.(1) can be rewritten as

$$E(u^2) = \sum_{i=1}^{r} u^2 A_i \exp(ja_i u^2) + \sum_{i=1}^{s} uB_i \exp(jb_i u^2) + \sum_{i=1}^{t} C_i \exp(jc_i u^2) \tag{2}$$

With the method of the approximate integration of rapidly oscillating functions. We can get

$$\int_{u_1}^{u_i} \frac{E(u^2)}{u} du = \sum_{i=1}^{r} \bar{A}_i \exp(ja_i u^2) + A_0 \qquad u_1 \le u_i \le u_m \tag{3}$$

where $\overline{A_i} = \frac{A_i}{(2ja_i)}$, and $A_0$ is approximately equal to constant if $k >> 1$. Let

$F(u_i^2) = \int_{u_1}^{u_i} \frac{E(u^2)}{u} du$ , then $F(u_i^2)$ can be known. So

$$F(k_i) = \sum_{i=1}^{r} \bar{A}_i \exp(ja_i k_i) + A_0 \tag{4}$$

where $k_i = u_i^2$ . Using Prony's Approximation, one can obtain the parameters $r$ , $a_i$ and $A_i$ .

After $r$ , $a_i$ and $A_i$ are obtained, we have from Eq.(1)

$$\frac{E(k)}{k} - \sqrt{k}\sum_{i=1}^{r} \bar{A}_i \exp(ja_i k) = \sum_{i=1}^{s} B_i \exp(jkb_i) + \sum_{i=1}^{t} \frac{C_i}{\sqrt{k}} \exp(jkc_i) \tag{5}$$

Similarly, using integration processing Eq.(5) and then using Prony's Approximation, we can obtain the parameters $s$ , $b_i$ and $B_i$ .

Finally, using similar method, the parameters $t$ , $c_i$ and $C_i$ can be gotten.

2.2 Some Notes

It should be noted that

(1) After one uses integration processing to above the Eq.s (2) (5), the errors of calculation will be reduced.

(2) If *r, s* or *t* is larger than *10*, the results of calculation will not good when this paper's method is used.

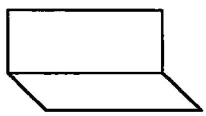
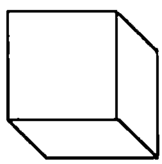
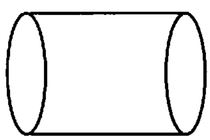
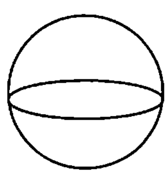
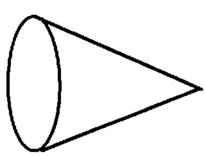
(3) Prony's Approximation is sensitive to noises (or errors). So, the combination nonlinear least square method with Prony's Approximation is desirable.

(4) If some discrete values of reflected wave $E(k_i)$ are given, one can use a similar method. Notice, in this case, that integration should be replaced by addition.

## 3. Conclusion

In this paper, a method is given for describing the characteristics of a radar target from the reflected wave at high frequency. Using this method, one can estimate the number of the reflectors, type and approximate size of each reflector of the radar target. All these characteristics can be reflected by the parameters of Eq.(1). For example, after $A_i$ , $B_i$ and $C_i$ are obtained, $|RA_i|$, $|RB_i|$ and $|RC_i|$ will determinate the section areas of the reflectors of the target, where $R$ denotes the distance from the target to the receiver. Notice that : usually, the second kind of targets may be cylinders and the third kind of targets may be spheres or cones. Next problem is how to distinguish between plates and corners. To solve this problem, we need to observe whether the average values of $|RA_i|$ and $|RC_i|$ during some time changes rapidly or not when the target moves. For example, If the average value changes quickly, one can regard that the target includes some plates; Otherwise, we can conclude that the target includes some corners. Anyway, this method will be very useful to identify the shape of a radar target.

**Appendix : three kinds of reflectors**

| reflector | shape | maximal RCS | kind |
|---|---|---|---|
| plate |  | $\sigma = \frac{4\pi a^2 b^2}{\lambda^2}$ | the first class |
| corner made up of two plates |  | $\sigma = \frac{8\pi a^2 b^2}{\lambda^2}$ | the first class |
| corner made up of three plates |  | $\sigma = \frac{12\pi a^4}{\lambda^2}$ | the first class |
| cylinder |  | $\sigma = \frac{2\pi a l^2}{\lambda}$ | the second class |
| sphere |  | $\sigma = \pi a^2$ | the third class |
| cone |  | $\sigma = \pi a^2 \tan^2 \alpha$ | the third class |

## References

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