RCS SCALE-MODEL-TESTING METHOD BY VARIANCE IN THE SIZE FOR SIMPLY SHAPED SCATTERERS

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Abstract According to a general representation of physical scale factor of RCS for variance in the size of simply shaped scatterers, a novel RCS model-testing method is described. The computed results of the prototype scatterers by this method from the model-testing agree well with their measured values both for two kinds of simply shaped scatterers, cylinders and ladder-shaped plates.

Key words Radar-cross-section(RCS); Model-testing; Scale factor; Physical-optic approximation

I. Introduction

As well known, the model-testing technique plays an important role in study for RCS of scatterers. In the case of the geometrical size and testing wavelength are both scaled down, it is easy to obtain the RCS of the prototype in terms of the RCS of the model and the geometrical scale factor. But in practice, it is not easy to scale down the testing wavelength with the geometrical size of scatterer proportionally for lack of testing equipments. Therefore, it is developed that model-testings must be made under the conditions of geometrical size scaled down but testing wavelength unchanged.

In our method, a physical scale factor $q$ has been suggested to replace the geometrical scale factor $p$. After the $q$ is determined by scale models, the RCS of prototype can be evaluated by the $q$ and the model-testing values directly. For the purpose of verifying, two kinds of simply shaped scatterers, cylinders and ladder-shaped plates, are measured at 9.37 GHz. After data processing, the evaluated results of prototype from the models are in good agreement with the experimental values for both cylinders and ladder-shaped plates, respectively.

II. Basic Theory

In order to describe the effects of variance in size of the scatterers, it is suggested that the RCS of prototype ($\sigma_p$) and model ($\sigma_m$) are related by

$$\sigma_p = q^2 \sigma_m$$  \hspace{1cm} (1)

where the $q$ is referred to the physical scale factor between the prototype and the model. For the simply shaped scatterer, and which there is not two or more than two departed scattering
centers, usually has three types of geometrical characteristics of scattering surfaces. The RCS of them can be expressed from Ref.[2] as

\[
q^2 = \begin{cases} 
  p^4 f^2(p, x_m) f^2(p, y_m), & \text{(for plate)} \\
  p^3 f^2(p, x_m), & \text{(for cylinder)} \\
  p^2, & \text{(for curved surface)}
\end{cases}
\]  

(2)

In order to apply Eq.(2) to common situations and to get a general representation of scale factor $q^2$ for arbitrarily shaped simple scatterers we extend Eq.(2) to the following form

\[
q^2 = p^n f^2(p, x_m)
\]  

(3)

where $p$ is the geometrical scale factor between model and prototype, $n$ is an unknown configuration parameter to be determined and $x_m$ in the function $f(p, x_m)$ is determined by wavelength, wave directions and the size of model. Both $n$ and $x_m$ must be measured by model testing. If $p$ is chosen as an integer, the $f(p, x_m)$ can be written as[2]

\[
f(p, x_m) = \cos^{p-1}(\pi x_m) - \frac{(p-1)(p-2)}{3!} \cos^{p-3}(\pi x_m) \sin^2(\pi x_m) \\
+ \frac{(p-1)(p-2)(p-3)(p-4)}{5!} \cos^{p-5}(\pi x_m) \sin^4(\pi x_m) - \cdots
\]  

(4)

In our testing, three models are chosen for each kind of scatterer, whose geometrical scale factor with respect to model 1 are $p = 1, 2, 3$, respectively. By the testing RCS results $\sigma_1, \sigma_2$ and $\sigma_3$ of the model 1, 2, and 3, we can get

\[
\frac{\sigma_2}{\sigma_1} = 2^n f^2(2, x_m) = 2^n \cos^2(\pi x_m)
\]  

(5)

and

\[
\frac{\sigma_3}{\sigma_1} = 3^n f^2(3, x_m) = 3^n \left[ \frac{4}{3} \cos^2(\pi x_m) - \frac{1}{3} \right]
\]  

(6)

From Eqs.(5) and (6), it is easy to know

\[
\frac{\sigma_3}{\sigma_1} = 3^n \left[ \frac{4}{3} \left( \frac{\sigma_2}{\sigma_1} \right) \right] \left( \frac{2^n - 1}{3} \right)
\]  

(7)

By the optimization technique, the parameter $n$ can be determined from Eq.(7). Then, the RCS of the prototype with the geometrical scale factor $p = 4$ with respect to the model 1 can be computed by

\[
\frac{\sigma_4}{\sigma_1} = 4^n f^2(4, x_m) \\
= \sigma_1 4^n \left[ \frac{2}{3} \left( \frac{\sigma_2}{\sigma_1} \right) \right] \left[ \frac{2^n - 1}{2^n} \right]
\]  

(8)

III. Testing Results and Conclusions

In order to verify this method, four cylinders and four ladder-shaped plates with the geometrical size ratio 1:2:3:4 are fabricated and measured at 9.37 GHz. The measured data (solid line) of the cylinder 4 and plate 4, and the computed results (dashed line) by