

EVALUATION OF FAR-FIELD PATTERN FROM NEAR-FIELD MEASUREMENT USING A NEAR-FIELD IMAGING TECHNIQUE

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I. INTRODUCTION

The far-field condition requires that the distance between the object and the antenna be greater than $2D^2/\lambda$, where D is the maximum dimension of the object and λ is the wavelength. When size of the object is large and the operating wavelength is short, the test range of the anechoic chamber may not satisfy the far field condition. In that situation what we measure is the near-field scattered field rather than the far-field one.

It is known that one of the applications of microwave imaging is to locate the scattering centers or scattering sources of the object [1]. It is also known that the scattered field pattern can be obtained once the scattering sources are determined. In this paper we propose a new method based on the principle of near-field imaging developed earlier [2], where the spherical back-projection has been applied to obtain microwave images from data in the near-field region.

II. BASIC THEORY

Consider a far-field imaging scheme involving frequency sweeping and object rotation. In this imaging a target is seated on a rotating pedestal and is illuminated by plane waves spanning a wide bandwidth. The backscattered far field at each step frequency is received. The object is then rotated and measurement is repeated to obtain the multi-aspect, stepped frequency response of the scattering object. The scattered field with range corrected with respect to the rotation center is referred as the Fourier-space data. The field at a given set of frequency and aspect corresponds to a Fourier-space data point. By varying the operating frequency and aspect angle we can have various Fourier-space data points. The accessed Fourier-space data can be represented by a polar format with radius representing the operating frequency and azimuth representing the rotation angle. By the fact that the Fourier-space data (range-corrected backscattered field) and the scattering characteristic function have an approximate Fourier transform (FT) relationship, the microwave image of an object is then reconstructed by Fourier transforming the Fourier-space data directly [1]. This image reconstruction method is referred to as the Fourier transform method. On the contrary, if the complex image of an object can be obtained by other means, it is possible to obtain the range-corrected far-field (Fourier-space data) by inversely Fourier transforming the complex image. In the procedure of the FT method, an interpolation step is required to convert the Fourier-space data in polar format into a rectangular format in order to utilize the efficient FFT algorithm. The image so obtained is then in rectangular format. Similarly, if the complex image obtained by other means is represented by a rectangular format, after the inverse

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FFT, the range-corrected backscattered fields will also be in a rectangular format. If the frequency response of the backscattered field for a given aspect or the backscattering pattern for a given frequency are required, the derived backscattered fields in rectangular grids should also be converted to those in polar grids through an interpolating process.

It has been proved that the FT reconstruction method is equivalent to the back-projection method [3]. The latter method consists of two steps: First obtaining the range profile of each aspect, and then graphically back-projecting the range profile of each aspect to the image plane along directions normal to the line of sight. The back-projection method is more time-consuming, but it gives more physical insight to the image formation.

When the distance between the object and the antennas becomes much shorter than the distance required in the far-field condition, the equiphasic surface can no longer be assumed a plane. The equiphasic surface is spherical in general, the image can be reconstructed from the measured near-field data through a generalized "spherical back-projection method" [2]. Implementation of the spherical back-projection method is as follows:

1. Estimate the spherical projection of each aspect by inverse Fourier transforming the range-corrected near-field data.
2. Spherically back-project the estimated spherical projection of each aspect to each image pixel.

The image so obtained is referred to as the near-field image. It has been found that the near-field image reconstructed from the measured near-field data and the far-field image reconstructed from the far-field data have similar appearance if the frequency coverage and angular intervals of the two cases are the same [2]. In other words, the far-field image can be approximated by the near-field image which can be reconstructed from the measured near-field data. As stated earlier in this section, the range-corrected far field can therefore be obtained by inversely Fourier transforming the complex near-field image.

In a summary, implementation for obtaining the far-field pattern from the measured near-field data using the near-field imaging technique can be proceeded as follows:

1. Given a frequency and angular coverage, obtain the near-field complex image from the measured near-field data by applying the spherical back-projection algorithm. The image so obtained is in rectangular format.
2. Inversely Fourier transform the complex near-field image to derive the Fourier-space data. The data so obtained are also in a rectangular format.
3. Apply an interpolation algorithm to convert the data in a rectangular format into a polar format. The frequency response of the backscattered far field for a given aspect is then the Fourier-space data along a radial line corresponding to that aspect, while the far-field scattering pattern for a given frequency is the pattern of the Fourier-space data of a constant radius corresponding to that frequency.

It is noted that the far-field data so derived are valid only for those points contained in the original frequency and angular windows.

III. EXAMPLE

Consider a flat plate with dimension of 50 cm in length and 5 cm in height seated on a rotating pedestal. Let the distance between the rotational center and the antenna be 4m, which is about 24% of $2D^2/\lambda$. Zero degree is defined as the aspect normal to the plate. The uniform theory of diffraction (UTD) is used to evaluate the backscattered near field over a frequency coverage from 10 GHz to 13 GHz and an angular interval from $\varphi = -16^\circ$ to $\varphi = 16^\circ$. The calculated near-field pattern at 10 GHz is shown in Fig. 1. The near-field image reconstructed from the calculated near-field data by the spherical back-projection method is shown in Fig. 2. The derived far-field pattern at $f = 10$ GHz employing the near-field imaging technique and the far-field pattern calculated by the UTD method are plotted with the solid and dashed curves respectively as shown in Fig. 3.

IV. DISCUSSION AND CONCLUSION

We have proposed a method to evaluate the far-field scattering pattern from the measured near-field data. The basic concept of this method is that the far-field data (or the Fourier space data) and the complex far-field image have a FT relationship, and the complex far-field image and the near-field image reconstructed by the spherical back-projection method have similar appearance. In other words, the far-field image can be approximated by the near-field image and the far-field scattering pattern can then be evaluated by inversely Fourier transforming the complex near-field image. The primary advantage of this method is that the far-field scattering patterns for different frequencies can be achieved simultaneously. However, this method is an approximate method. The far-field data so derived are valid only for those points contained in the original frequency and angular windows; and the scattering mechanisms of the object and the interpolation procedure can affect accuracy of the derived results.

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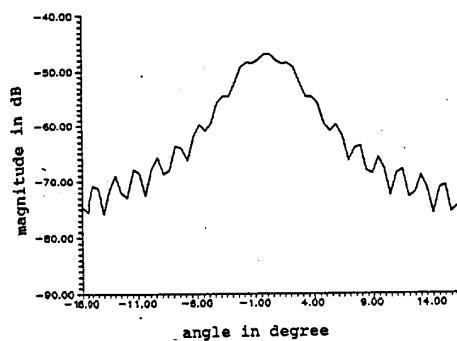


Fig.1 Near-field pattern of a rectangular plate at 10 GHz.

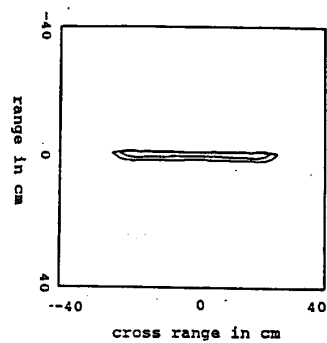


Fig.2 Microwave image of the rectangular plate reconstructed from the near-field data.

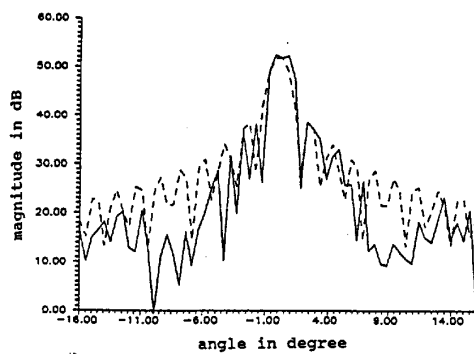


Fig.3 Derived and calculated far-field pattern.

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