A POLARIMETRIC MODEL OF HIGH FREQUENCY SCATTERING CENTERS AND IT'S APPLICATION IN MICROWAVE MULTIPATH TARGET IMAGING ANALYSES

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Abstract

At high frequencies the electromagnetic scattering from a complex object is modeled by certain scattering centers. The physical optics bistatic and monostatic scattering matrix properties of a flat plate model of such a scattering center have been developed in detail. Analyzing these model scattering matrices, a procedure for recovering the high frequency scattering centers from multi-static polarimetric scattering matrix data is reported.

The bistatic scattering matrix for a multipath scattering problem, involving an isolated scattering center over an infinite planar reflecting surface has been derived. The difference between this case and the two physical scattering center models has been clearly demonstrated.

Introduction

Electromagnetic scattering from a complex object, at high frequencies (physical optics, geometric optics), is dominated by certain specular components. The locations of these specular points on the complex object are known as the scattering centers. Generation of these scattering centers is dependent on the geometry of the object with respect to the aspect directions of the transmitter and the receiver (bistatic system). It has been suggested that the knowledge of the locations and the local geometries of these scattering centers can be useful in developing identification and pattern recognition algorithms [1].

In the present presentation, for the microwave multipath target imaging analysis, the multipath returns have been modeled as "image scattering centers" since these are not actual scattering centers, the bistatic scattering matrix will show behavior that are different from those of the physical scattering centers.

Problem Formulation

For the electromagnetic scattering analysis, the isolated scattering center is modeled as a conducting rectangular flat plate whose sides are given by vectors $\underline{s}_1$ and $\underline{s}_2$ and the unit vector to the flat surface is given by $\hat{n}$. The location of the scattering center with respect to a fixed global spherical coordinate system is given by $\underline{d}$. Determination of ($\hat{n}$, $\underline{s}_1$, $\underline{s}_2$, $\underline{d}$) from the multistatic polarimetric scattering matrix with plane wave incidence) data is known, in the context of the present work, as the "scattering center recovery" problem [1,2].

To obtain the bistatic scattering matrix (BSM) of the above defined scattering center, first the physical optics approximation is used to obtain the induced current on the flat plate due to an arbitrary directed plane wave incidence. Huygen's theory of secondary sources is subsequently used on this induced surface current to obtain the far-field BSM of an isolated scattering center.

This derived BSM has been analyzed successfully to extract the unknowns $\hat{n}$, $(\underline{s}_1, \underline{s}_2)$, and $\underline{d}$ from the radar measurable input data [1].

When an isolated scattering center is located near a reflecting surface, the receivers will not only collect the direct scattered signal from the target but will also receive scattered energy "bounced" off the reflecting surface (see Fig. 1). This situation is referred to as the multipath scattering problem. The energy reaching the receiver after bouncing off the interface (path-2 in Fig.1) can be accounted for by introducing an image of the scattering center as shown in Fig. 1. In other words, the physical problem of an isolated center on the reflecting surface is equivalent to a model consisting of the pair of scattering centers, a (physical center), and a' (image center) in the free space (this model will be called a doublet-center from here- on).

Summary of the Doublet-Center's BSM Analysis

Before the above model of the multipath scattering problem is analyzed the following difference between the two physical scattering center model and the doublet-center model must be observed:

> If a and a' were two real scattering centers, the currents induced on the two centers will have different phases and different magnitudes.
>
> If on the other hand a' was the image of a, then the currents induced on a' in $\hat{a}_s3(\underline{s}_3 = s_3\hat{a}_s3)$ and $\hat{a}_s4(\underline{s}_4 = s_4\hat{a}_s4)$ directions will be negative (-) of that induced on 'a' in $\hat{a}_s1(\underline{s}_1 = s_1\hat{a}s_1)$ and $\hat{a}_s2(\underline{s}_2 = s_2\hat{a}_s2)$ directions, respectively, i.e., the induced surface currents on a and a' ($\underline{J}_a$, $\underline{J}_{a'}$, respectively) are,

$$\underline{J}_a = (J_{s1}\hat{a}_{s1} + J_{s2}\hat{a}_{s2})\, e^{j\phi a} , \tag{1}$$

$$\underline{J}_{a'} = (-J_{s1}\hat{a}_{s1} - j_{s2}\hat{a}_{s2})\, e^{j\phi a} . \tag{2}$$

Thus it is clear that the initial formulation of the two scattering centers problem has to be modified for the doublet-center model of the multipath situation.

In Fig. 1, let $(\underline{s}_1, \underline{s}_2, \hat{n}, \underline{d})$, and $(\underline{s}_1', \underline{s}_2', \hat{n}', \underline{d}')$ define the parameters of the physical center and the image center, respectively. For an arbitrary plane wave incidence, the current induced on the physical center itself is given by (with $k = 2\pi/\lambda$),

$$\underline{J}_a = 2\hat{n}\times\underline{H}_i = 2\hat{n}\times\underline{H}_{i0}\exp(-jk|\underline{r}_i-\underline{d}| + jk\hat{k}_i\cdot\underline{r}_a') \quad , \text{or}$$

$$\underline{J}_a(\underline{r}_a') = (J_{s1}\hat{a}_{s1}+J_{s2}\hat{a}_{s2})\exp(-jk|\underline{r}_i - \underline{d}| + jk\hat{k}_i\cdot\underline{r}_a') \tag{3}$$

and the corresponding induced image curent on a' is,

$$\underline{J}_{a'}(\underline{r}_{a'}') = (-J_{s1}\hat{a}_{s1} - J_{s2}\hat{a}_{s2})\exp(-jk|\underline{r}_i - \underline{d}| + jk\hat{k}_i\cdot\underline{r}_a') \tag{4}$$

(Note, the exponential term is the same in $\underline{J}_a$, $\underline{J}_{a'}$)

Here $\underline{r}_a'$, and $\underline{r}_{a'}'$ are the position vectors to a general observation point on a and its image on a', with respect to the local coordinate systems ($\hat{a}_{s1}$, $\hat{a}_{s2}$, $\hat{n}$) on a and ($\hat{a}_{s'2}$, $\hat{a}_{s'1}$, $\hat{n}$) on a', respectively. Using the image relationship, the correspondence between the position vectors $\underline{r}_a'$ and $\underline{r}_{a'}'$ can be expressed as follows:

if the local position vector to a point on a, ($\underline{r}_a'$) is given by

$$\underline{r}_a' = x_a\hat{a}_{s1} + y_a\hat{a}_{s2} \ , \tag{5}$$

then the local position vector to the corresponding point on a' will be given by

$$\underline{r}_{a'}' = x_a\hat{a}_{s'1} + y_a\hat{a}_{s'2} \ . \tag{6}$$

Using the problem formulation described earlier, the vector potentials due to the currents given in (3) and (4) can be obtained. Using these vector potentials the elements of the BSM can be calculated. A detail derivation of these results is documented in [2].

Summary of the Results

The BSM for a multipath scattering problem involving an isolated scattering center over an infinite planar reflecting surface, has been derived. The difference between this multipath model (doublet-center) and the two scattering center model has been clearly established. A scheme to recover the parameters of a doublet-center from its BSM model is being studied currently. For this recovery, the distinct nature of the expressions for the co- and cross-polarized elements in the BSM are being exploited. Once the recovery model for the doublet-center is established, it can be used as a building block towards the solution of the multiple doublet-center problems.

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References

[1] S.K. Chaudhuri and W-M. Boerner, "Polarimetric Recovery of the High Frequency Scattering Centers from Bistatic/Monostatic Scattering Matrix Data", Report for Westinghouse Electric Corp., Baltimore MD, Contract No. 86EJ-HA-30690 OV, Nov., 1984.

[2] S.K. Chaudhuri and W-M. Boerner, "Polarimetric Treatments of Microwave Multipath Target Imaging Analyses", Report for General Dynamics, Pomona, CA, P.O. #614972, Dec. 1984.

[3] S.K. Chaudhuri, and W-M. Boerner, "A Polarimetric Model of High Frequency Scattering Centers and it's Application in Microwave Multipath Target Imaging Analyses", Submitted to IEEE Trans A&P for Publication, 1985.

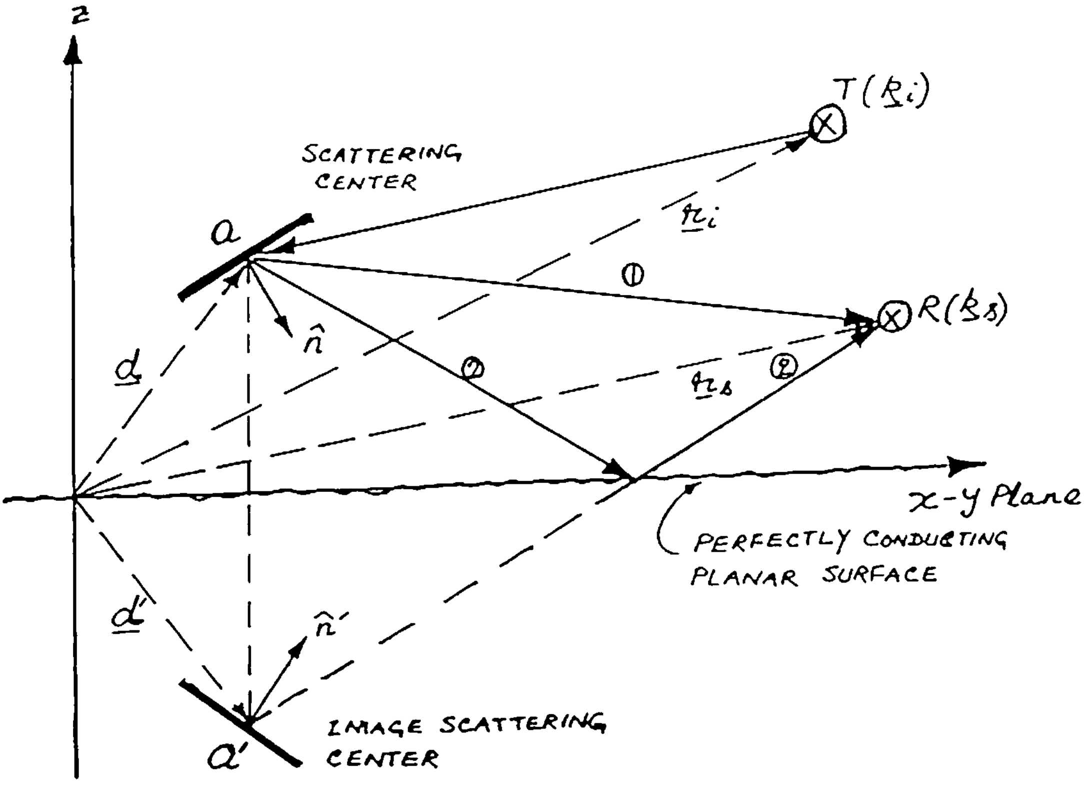

Figure 1: Geometry of the Multipath Scattering Problem