RADAR CROSS-SECTION OF WAVEGUIDE-FED PLANAR SLOT ARRAYS

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INTRODUCTION

Waveguide-fed planar slot arrays have been used in a number of ground and space based radar and communication systems because of desirable features such as low loss, small volume and ease of deployment. The design and analysis of waveguide arrays consisting of broad wall slots for coupling and radiation have reached a mature state. Although there are a number of papers in the literature on the slot array antennas, the scattering from such arrays has not received much attention. Josefsson presented the results of scattering from a single longitudinal broad wall slot in a rectangular waveguide [1]. Recently Fan and Jin discussed the radar cross-section of a cylindrically conformal waveguide slot array and that of a planar slot array [2, 3]. In their analysis of the RCS, Fan and Jin treat each radiating waveguide end as a short or matched terminal. In this work we consider the scattering from planar arrays consisting one or more sub-arrays. Each sub-array may consist of a feed waveguide consisting of coupling slots to excite the radiating waveguides containing radiating slots as shown in Fig. 1 and 2.

METHOD OF ANALYSIS

In this work we consider a complete full wave analysis of slot scattering using integral equations and method of moments (MoM). The structural scattering is determined by the physical optics (PO) technique wherein the slots are shorted out and the induced current is approximated to the PO current which is twice the incident tangential magnetic field in the orthogonal direction. This approximation becomes poor near the edges but it is possible to augment this model with the use of the fringe currents of the physical theory of diffraction (PTD). The second component of the scattered field is the slot scattering which is obtained from the induced slot aperture fields. This requires the solution of N simultaneous coupled integral equations obtained by MoM, where N is the total number of slot apertures. i.e., twice the number of coupling and radiating slots since we assume finite slot thickness. The method of formulating and solving the integral equations and solving them by MoM is described in the literature, e.g., [4-8]. For the scattering problem, the source terms are obtained by taking the inner product of the incident plane wave magnetic field with the set of testing functions of the MoM. Feed port is assumed to be match terminated. The resulting MoM matrix consists of self terms of the radiating slots, self terms of the coupling slots, terms for external and internal coupling between radiating slots, terms for coupling between coupling slots and also terms for coupling between each coupling slot and all radiating slots. Higher order waveguide mode coupling between adjacent slots need to be accounted for. Mathematical expressions for all these terms are available in the prior literature or obtained with some modification, e.g., [3-8].

The additional matrix terms needed in this work result because of the fact that radiating waveguides contain short circuits at the two ends and the feed waveguide has a short. When invoking the equivalence principle the slot apertures are shorted and therefore these waveguides act as cavities. Thus the scattered TE10 mode waves in these cavities go through infinite reflections. We introduce an infinitesimal loss at the reflection coefficients of the two shorts to make this a tractable problem. If we have more than one sub-array, the sub-arrays are coupled through external mutual coupling between radiating slots.

NUMERICAL RESULTS AND DISCUSSIONS

The examples shown in this paper refer to a 6x12 planar array containing six radiating waveguides which are excited by alternating tilted coupling slots. The radiating aperture consists of 72 slots, 12 in each waveguide (see Figs. 1 and 2). First we consider a plane wave incident normally at the slot aperture with a polarization matched to that of the slots. Fig. 3 shows the scattered pattern in the xz plane. The induced PO currents are in the y-direction. The slot axes are parallel to the x-axis. Both the PO and the total scattered patterns peak in the broadside direction. The total scattered field is greater than that of the PO. A similar observation was made by Fan and Jin. The scattered pattern in the orthogonal direction shown in Fig. 4 is similar. At the $\theta=90^o$ direction in the yz plane the PO pattern is zero since it is in a direction parallel to the PO current. However, the slot scattering is not zero because the direction is orthogonal to the equivalent magnetic current. Fig. 5 shows the scattered field pattern in the xz plane for a plane wave obliquely incident (from $\theta=45^o$) in the xz plane. Once again the polarization is assumed to be matched to that of the slots. Both the PO and the total pattern exhibit a peak at the specular reflection direction. However, there is a significant amount of slot scattering near $\theta=32.5^o$. This corresponds to the grating lobe produced by the slot spacing of about 0.8 free-space wavelength. During the URSI General Assembly we will present and discuss additional examples.

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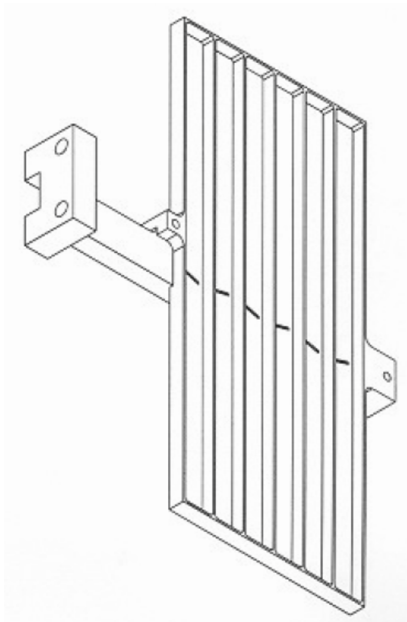

Figure 1 A planar array of six radiating waveguides

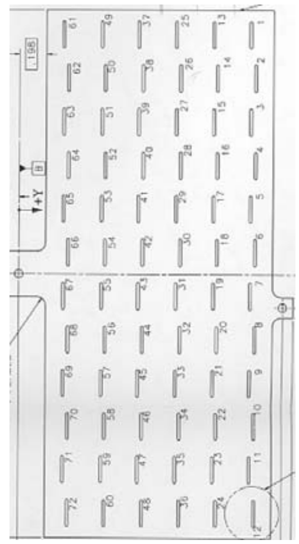

Figure 2 Radiating aperture (6x12 slots)

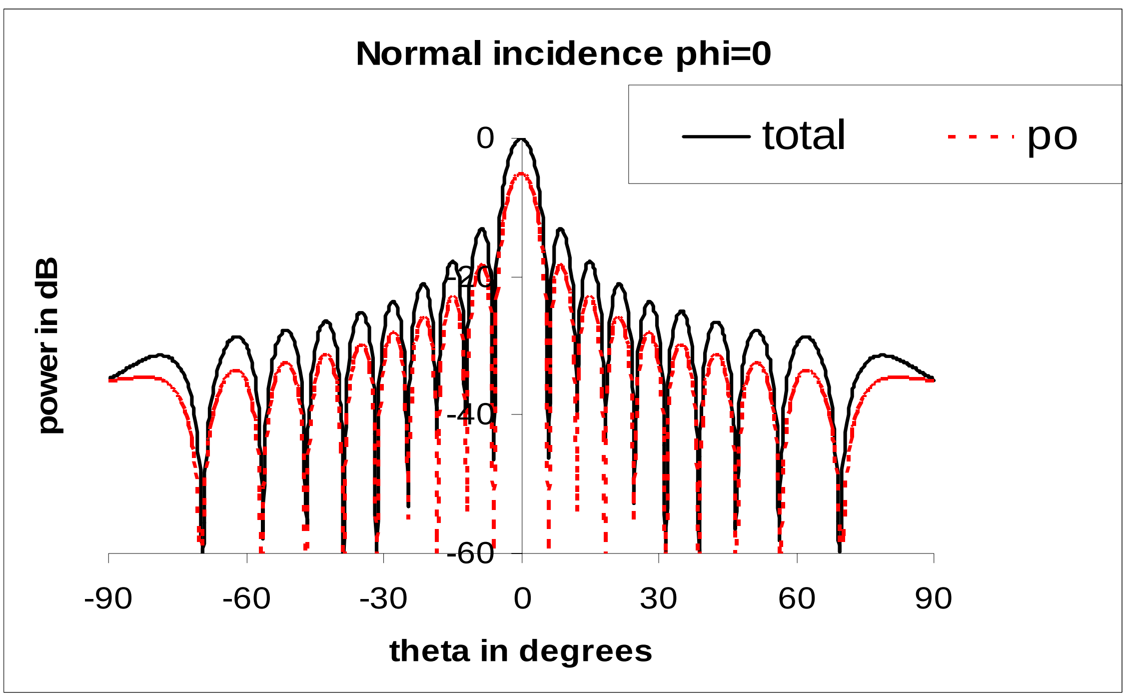

Figure 3 Scattered pattern in the phi=0 plane for normal incidence

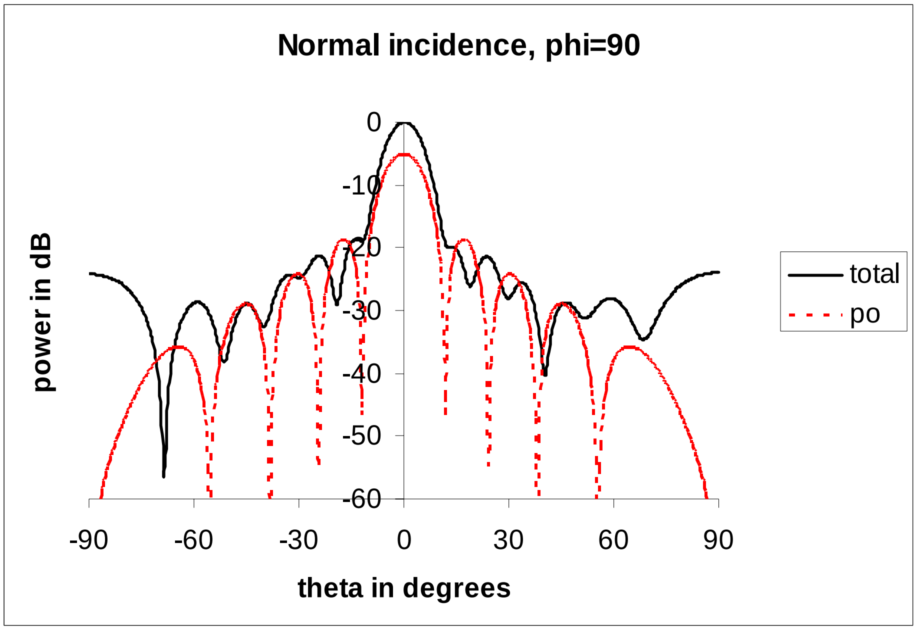

Figure 4 Scattered pattern in the phi=90 deg. plane for normal incidence

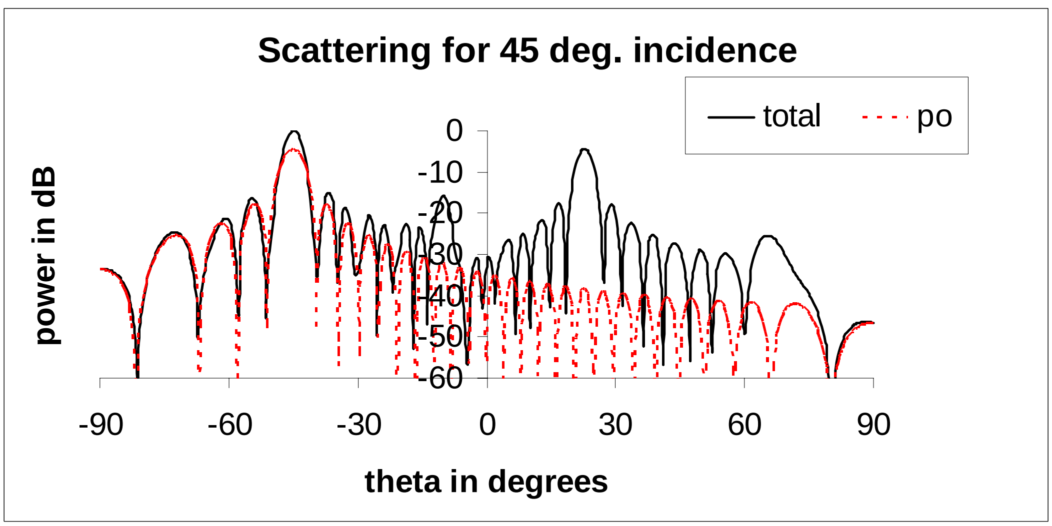

Figure 5 Scattering in the phi=0 plane for an obliquely incident plane wave