TIME-FREQUENCY PROCESSING OF BACKSCATTERED SIGNAL FROM A SLOTTED WAVEGUIDE ARRAY

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INTRODUCTION

Electromagnetic signals backscattered from targets provide information useful to classify and identify the targets. It was recently reported that the time-frequency processing of wideband backscattered signals gives us additional insights into the scattering physics of targets not available in either the time domain or the frequency domain alone [1-2]. In the two-dimensional time-frequency plane resonance frequencies, scattering centers and dispersive behavior can be clearly visualized simultaneously.

The time-frequency analysis has already been applied to investigate the backscattering signals from grating structures [3]. For 2-D finite dielectric gratings, it was shown that the Floquet frequencies due to the periodicity of the structure, the scattering centers due to the edges of the grating and the dispersive characteristics due to surface waves can be individually identified..

In this work the backscattering from a 3-D rectangular slotted waveguide array will be analyzed by the use the short-time Fourier transform (STFT). The data, generated in the frequency domain, was obtained by the use of the moment method together with a connection scheme [4].

COMPUTER SIMULATION

The structure analyzed is shown in Fig. 1, where we have a long finite rectangular waveguide under an infinite conducting plane with 16 rectangular slots opened on its narrow wall. To solve this problem we divided it into an inside and an outside region having the slots as a common boundary, and with the electric field on them as the unknown. By matching the magnetic field on these apertures an integral equation can be formulated and then discretized, using the standard moment method procedure, so that we obtain a matrix equation of the form

$$\{[Y_{in}]+[Y_{out}]\}[V]=[I]$$

where $[I]$ is the incident magnetic field over the aperture and $[V]$ is the unknown electric field. The computation of $[Y_{out}]$ involves only the outside region and can be easily found by applying the equivalence principle and the method of images. The computation of $[Y_{in}]$ on the other hand would involve the discretization of the magnetic and electric fields on all waveguide walls and therefore will demand a lot of computation resources, since the length of the waveguide will reach 32 λ at 10 GHz.

In order to reduce these requirements a connection scheme [4] was used, dividing the waveguide into 16 equal sections. By doing so, only a single section needs to be analyzed. The identical sections were then connected two by two to obtain the final admittance matrix that relates the electric and magnetic fields on the slots. For the discretization, triangular patch basis functions [5] were used, resulting in a total of 464 triangular patches per section, and 16 per slot.

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TIME-FREQUENCY ANALYSIS

The geometry of Fig. 1 was excited, using the computational algorithm described above, by a plane wave incident at an angle of 30° with respect to the normal of the plane, having the magnetic field parallel to the slots, from 2 to 10 GHz in 0.05 GHz steps. The medium inside the waveguide was assumed to have $\varepsilon=(1-j\ 0.01)\varepsilon_0$ and $\mu=(1-j\ 0.01)\mu_0$. The time response of the structure, obtained by inverse Fourier transforming the data obtained in the frequency domain, is plotted in Fig. 2. We can see that at t=0, corresponding to the time when the wave reaches the first slot, a strong signal appears. It corresponds to the exterior scattering from the 16 slots, within a time frame of about 3 nsec. We can verify this by noticing the presence of exactly 16 pulses, and by verifying that the signal that reaches the last slot should be delayed 3 nsec with respect to the first one. We see also that after the scattering from the last slot there is still a disturbance in the time response, due to internal resonance of the waveguide.

If we now look at the frequency response in Fig. 3, we see that there are two peaks, one at 5 GHz and another at 10 GHz, corresponding to the grating frequencies of the structure at 30° incidence. These peaks are broad and have many sidelobes due to the fact that the structure is finite (16 slots), but besides these two peaks and its sidelobes we also notice other peaks, even though it is very difficult to correctly distinguish them. These other peaks correspond to frequencies for which there is a mode excited in the waveguide that radiate in the given direction (30°) as a slotted array antenna, and can be predicted by:

$$k_0 d \sin\theta \pm \sqrt{k_0^2 - (\pi m/a)^2 - (\pi n/b)^2} = 2\pi p \qquad p = \cdots,-2,-1,0,1,2,\cdots$$

where d is the distance between slots, $\theta=30°$ and a and b are the dimensions of the guide. Since the only modes excited in the waveguide are the TM_{mn} modes (m, $n > 0$), the possible frequencies that satisfy the above equation are: (6.08, 6.65, 7.68, 8.23, 8.77, 9.29, 9.92) GHz.

If we now look at the time-frequency image, obtained via STFT, we can easily locate some resonant frequencies approximately at (6, 7.7, 8.3, 9.3) GHz, which are very close to the predicted ones, that decay with time due to radiation and losses in the guide. We should also add that even though the precise location of these frequencies cannot be determined by the simple inspection of Fig. 4 due to computation noise and low resolution, the figure gives us a clear understanding of the phenomena involved.

ACKNOWLEDGMENT

This work is supported by the Joint Services Electronics program. L. C. Trintinalia is also sponsored by CNPq and University of São Paulo, São Paulo, Brazil.

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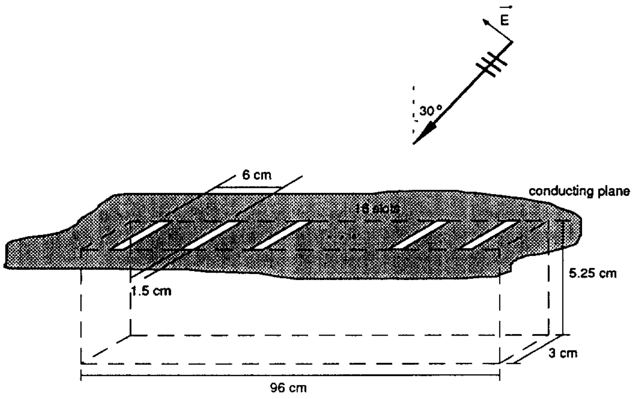

Fig. 1 - Geometry of the slotted waveguide array

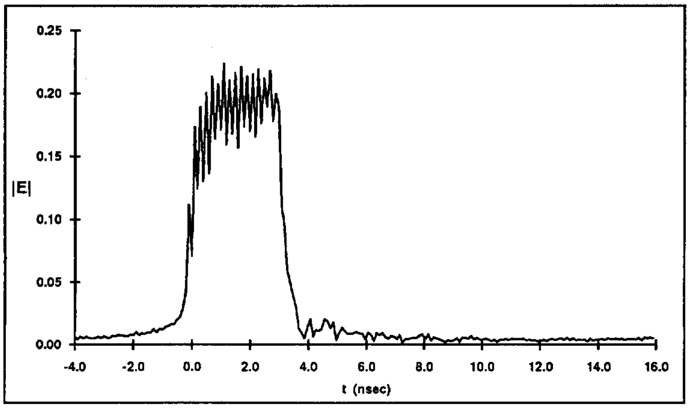

Fig. 2 - Backscattering from the slotted waveguide array in the time domain.

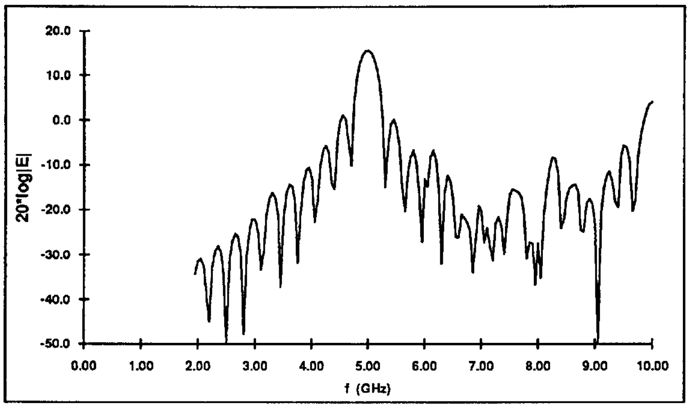

Fig. 3 - Backscattering from the slotted waveguide array in the frequency domain.

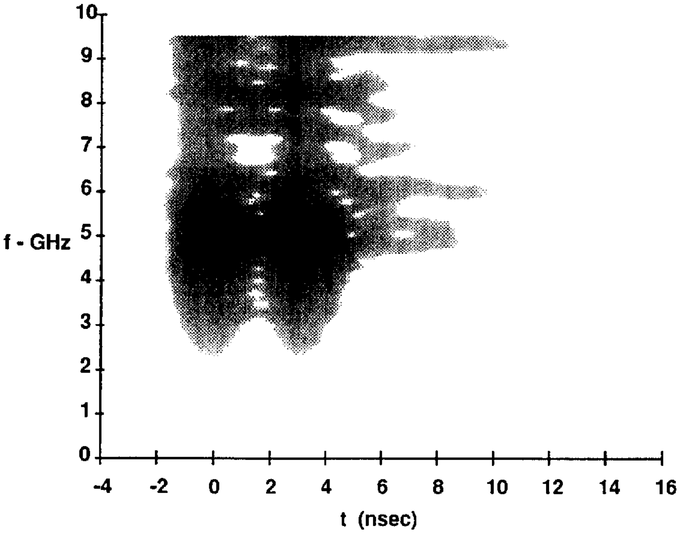

Fig. 4 - Time-frequency image of the backscattered data
(obtained via STFT)