"Moment Method Analysis of Parallel Plate Slot Antennas"

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Abstract: *The authors propose a Moment Method Analysis for the Analysis of a Parallel Plate Slot Array, excited by a feed waveguide, based on the Flocket's Theorem. The beam tilt of the incident wave, due to the frequency dependence of the excitation wavelength. is considered by using a complex Hertzian Potential and Periodic Boundary Conditions. A phase shift, that depends on the frequency, is included in the Periodic Conditions. This analysis can also be used for beam scanning arrays.*

I. Introduction

A parallel plate slot antenna is an attractive candidate for high-efficiency and mass-produceable planar phased array antennas for millimeter-wave applications. Generally, the transmission loss in a waveguide is very small in comparison with other feedlines such as a microstrip line and a suspended line. A parallel plate slot antenna, excited by a Single-Layer Feed Waveguide consisting of posts was proposed for 40 GHz band [1]. The very high number of slots makes time consuming the analysis of this kind of antennas. With this method, a rectangular waveguide with periodic boundary conditions is analyzed in order to simulate the operation of a two dimensional slot array on parallel plates [2]. To consider the beam tilt produced by the frequency dependence of the wavelength in the feed waveguide complex Magnetic Hertzian Potential is used to calculate the electromagnetic fields inside the waveguide. This method is also useful for the analysis of phased arrays slot antennas.

II. Antenna Structure

Fig. 1 shows the structure of the antenna. The slots are placed on the upper plate, designed to get uniform amplitude and phase. The feed waveguide is fabricated by making of several via holes in a grounded dielectric substrate and metalizing them as posts. The equivalent width of the waveguide depends on the distance between two consecutive posts.

III. Analysis

The analysis of the slot structure is made using periodic boundary conditions as shows figure 2. The phase shift due to the frequency dependence of the wavelength in the postwall waveguide is considered using complex Hertzian Potential.

H Modes: $$\psi = \sqrt{\frac{\varepsilon_{mn}}{a \cdot b}} \cdot e^{-j\left(\frac{2m\pi}{a}+\sin\theta\right)\cdot\left(x+\frac{a}{2}\right)} \cdot \cos\frac{n\pi}{b}\cdot z \qquad \begin{array}{l} m = -\infty \cdots \infty \\ n = 0 \cdots \infty \end{array}$$

E Modes: $$\psi = \sqrt{\frac{\varepsilon_{mn}}{a \cdot b}} \cdot e^{-j\left(\frac{2m\pi}{a}+\sin\theta\right)\cdot\left(x+\frac{a}{2}\right)} \cdot \sin\frac{n\pi}{b}\cdot z \qquad \begin{array}{l} m = -\infty \cdots \infty \\ n = 1 \cdots \infty \end{array}$$

The analysis unit is a rectangular periodic wall waveguide terminated by a short circuit. The slot structure is divided in three regions by placing PEC walls together with magnetic currents on each slot. The three regions are the rectangular waveguide with the periodic boundary conditions a rectangular cavity for each slot whose height is the width of the upper plate and the half free space. The analysis of the feeding waveguide can be found in [1]. Considering the continuity of the magnetic field on each slot a system of equations is obtained. The system is solved using a Galerkin's Moment Method.

IV. Numerical Results

First he equivalent width of the feeding post wall waveguide is calculated, and with that value, the angle of the incident TEM wave in the parallel plate waveguide. Fig. 3 shows the equivalent width of the post wall waveguide and the incident angle.

With this value the reflection coefficient and the field on each slot can be calculated. Fig. 4 shows the reflection coefficient and Fig. 5 and 6. Show the Amplitude and Phase of the Electric Field on each slot for different frequencies. In this graphic the x-axes represents the position of each pair of slots. Each pair is separated from the next in one wavelength in the parallel plate waveguide.

The s_{11} parameter is very good for all the frequencies, as it can be observed if Fig. 4 and Fig. 7. Fig. 4 shows the reflection coeffient considering the incident angle of the signal when the frequency is different from the central one. The incident angles (Fig. 3) are smaller than 4° for that margin of frequencies. Fig 7. shows the reflection coefficient for different incident angles in a phased array. In both cases the reflection coefficient is enough good. The maximum amplitude error (Fig. 5), at the end of the antenna and the upper frequency (41 GHz) is 6 dB. This value means a small reduction in the gain of the antenna at that frequency. The phase error (Fig. 6) means a deviation of the beam in E-plane. This effect is almost neglectible, as it is showed in Fig. 8 for very large scan angles in H-plane.

V. Application to phased arrays antennas

This analysis method can be used for the study of phased array slot antennas. If a set of phase shifters is placed at one side of the antenna, feeding the parallel plate waveguide from different points, different radiation angles can be obtained. Fig 7 shows the dependency of the reflection coefficient with the frequency and the H-plane beam angle. Fig. 8 shows the E-plane beam angle produced by each H-plane beam angle due to the phase variation of the electric field of each pair of slots.

VI. Conclussions and Next Research

We presented a Moment Method Analysis for considering the dependency of the incident angle with the frequency. This method is not very time consuming, so can be used for the analysis of very large antennas (like slot antennas) due to the utilization of Flocket's theorem and periodic boundary conditions. This method can also be used for the analysis of phased arrays slot antennas.

The calculated results show a very good reflection for small angles. It also shows a very small angle error in E-plane when large scan angles in H-Plane are obtained. This result lets us to manage in an independent way the beam scanning in both planes.

Nowadays we are fabricating an antenna in order to compare the results with the numerical analysis. The parameters of the antenna used in the Analysis are showed in Table I.

REFERENCES

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[*4*] *Robert S. Elliot. "Electromagnetics. History, Theory and Applications". IEEE Press. 1993*

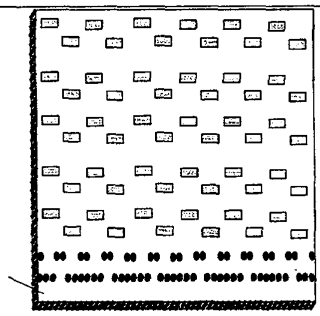
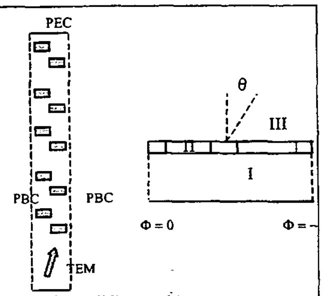


Fig.1:Geometry of the antenna



I. Periodic Wall Waveguide
II. Rectangular Cavity III. Half free space
Fig.2: Analysis Model

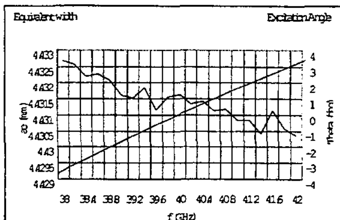


Fig. 3: Incident angle

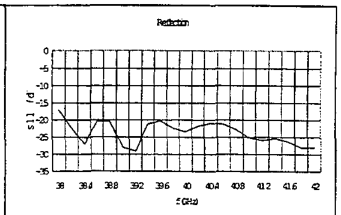


Fig. 4: Reflection Coefficient

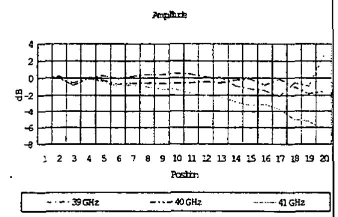


Fig.5: Amplitude of Electric Field

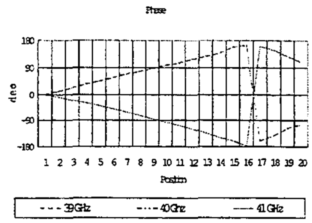


Fig. 6: Phase of Electric Field

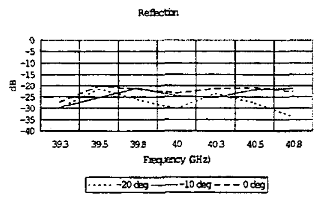


Fig. 7: Reflection Coefficient

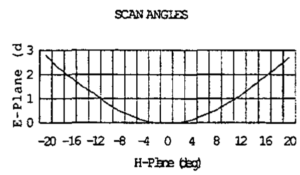


Fig. 8: E-plane and H-plane scan angles

Frequency	*f (GHz)*	40
Spacing of Periodic Boundary Walls	*a (mm)*	3.98
Height of Parallel Plate Waveguide	*b (mm)*	1.46
Dielectric Constant	ε_r	2.17
Wall Thickness	*d (mm)*	0.10
Slot Width	*w (mm)*	0.38
Distance between center of slots in one pair	*x (mm)*	2.00
Slot tilt	ϕ *(deg)*	0
Short circuit Position	*s (mm)*	92
Number of Basis Functions for Magnetic Current in Aperture	*M*	1
Number of Slot Pairs	*N*	20
Width of the Feed Waveguide	a_f *(mm)*	4.92
Post Diameter in Feed Waveguide	*d (mm)*	0.6
Distance between Posts	*s (mm)*	1
Number of Pins per Post for the Analysis	*I*	12

Table I: Antenna Parameters for the Analysis