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Study of Metal Strip Grating Antenna and Its Relation to Leaky Waves

Dr. Reena Kumari[1], Dr. K. B. Singh[2]

[1]Department of Physics, L. N. Mithila University, Darbhanga, Bihar, India

[2]P. G. Department of Physics, L. S. College, Muzaffarpur, B. R. A. Bihar University, Muzaffarpur, Bihar, India

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ABSTRACT

In this present paper we studied about metal strip grating antenna using Fabry-Perot Cavity design and its relation to leaky waves.

Keywords : Antenna, Metal Strip Grating, Fabry-Perot Cavity, Microstripline.

In this work we aim at showing that, when an electric dipole parallel to the strips is used as an excitation, azimuthally omnidirectional pencil beams pointing at broadside or nearly omnidirectional conical beams scanned off broadside can be produced with excellent polarization properties. For the usual FPC structures nearly omnidirectional pencil beams at broadside can be produced, but the degree of Omni directionality degrades rapidly as the beam is scanned away from broadside to become a conical beam.

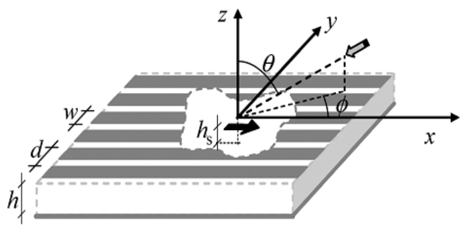

Fig. 1. Metal strip grating above a ground plane

Metal strip grating above the ground plane is excited by a horizontal electric dipole, with the relevant physical and geometric parameters; also shown is a uniform plane wave incident from the direction, used in the calculation of the far field radiated by the dipole based on reciprocity. This was among the first leaky-wave antennas, proposed by Honey in the 1950s [1-5]. It is similar in geometry, but very different in operating principle, from periodic leaky wave antennas that also use MSGs but radiate from the space harmonic [6, 7]. We would like to stress that the leaky wave excited in this structure radiates through the fundamental spatial harmonic of the periodic structure. the structure is thus in the category of a quasi-uniform leaky-wave antenna, which is physically periodic but acts as a uniform structure. We recall that there is another class of leaky-wave antennas based on using a guiding structure with periodic perturbations spaced on the order of a wavelength apart, radiating from the space harmonic. These are referred to as periodic leaky-wave antennas.

The model is based on the use of a transverse equivalent network (TEN) to represent the fields in the FPC structure. This is useful to derive and explain the peculiar features of the analyzed structure. For periodic leaky-wave antennas that radiate from a higher-order space harmonic [8-10] the period is not small relative to a wavelength and such a homogenization is not possible.

2. MATERIAL AND METHODS

An FPC antenna can generally be regarded as a leaky parallel-plate waveguide excited by a finite source. The upper plate, either in the form of a dielectric screen or of a patch or slot array, allows radiation to leak out of the region between the parallel plates. To achieve a wide effective antenna aperture, and hence a directive radiation pattern, the leakage rate should be small; this is the case if, the upper plate has a low transmission coefficient. This happens when the equivalent susceptance of the upper FPC screen is much larger than the characteristic admittance. The radiation features of the antenna shown in Fig 1 are illustrated by providing numerical results for a specific structure with parameters. The value of the thickness has been determined by maximizing at this frequency the power density radiated at broadside.

To assess quantitatively the accuracy of the approximate homogenized model of the antenna, a comparison is presented between results obtained with the TEN representations based on the temporally and spatially dispersive susceptance and full-wave results obtained with the MOM in the spatial domain. Here we have assumed an infinitesimal horizontal electric dipole source in the middle of the cavity.

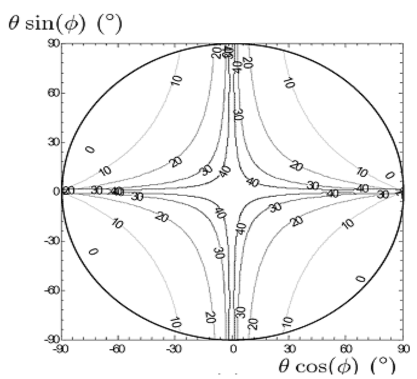

Fig. 2

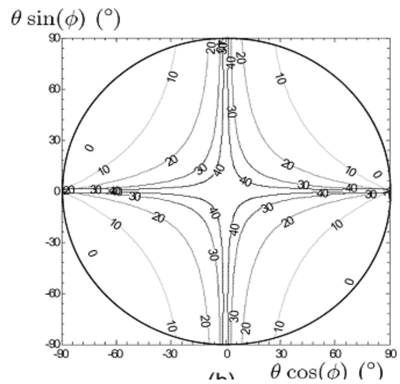

Fig. 3

The highly directive beam is produced by the excitation of one leaky mode propagating radially away from the source. This is clearly shown here by resorting to the TEN model and verified via the MOM analysis.

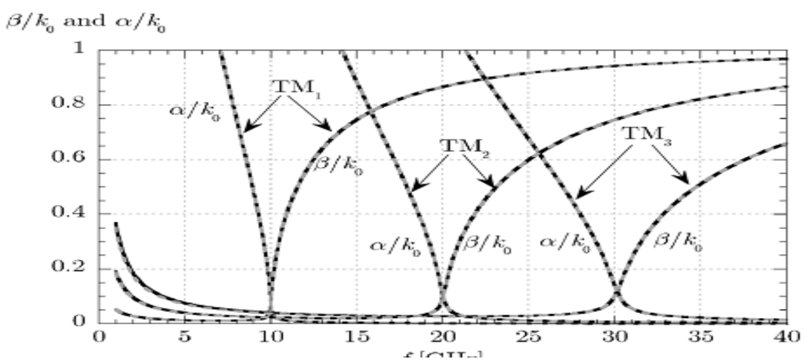

Fig.4. Dispersion diagrams obtained with MoM for the dominant mode. The dispersion equation for modes propagating at an arbitrary angle along the structure can be obtained by enforcing the condition of resonance on the TEN .

$$Y_{c0}^{TM_x} + jB_S - jY_{c0}^{TM_x}\cot(k_{z0}h) = 0$$ ---------------------------------- 1

where $k_{z0} = \sqrt{k_0^2 - k_\rho^2}$. -- 2

The functional dependence is exhibited by and is the same, (1) is a function of only K_o; hence, this proves the remarkable result that the propagation wavenumber does not depend on the propagation angle. In other words, the wavenumber of a mode does not depend on its azimuthal direction of propagation, i.e., modal propagation is omnidirectional in the plane. Since the structure is transversely open and comprises only one dielectric medium (air), no guided (real) modes exist. All modes are then leaky, and they are excited in the form of omnidirectional cylindrical waves by the horizontal dipole source. When one such leaky mode with a small attenuation constant is dominant within a region extending a few wavelengths from the source, an azimuthally symmetric directive beam is radiated. Dispersion diagrams are reported for the dominant and first higher-order leaky modes supported by the structure in Fig. 4, obtained with the MoM. Propagation in the principal planes is considered, i.e., In these planes the modal wavenumber is found to be the same, thus confirming that the wavenumber is essentially independent of the propagation angle, as predicted by the TEN model. It is to be noted that the dispersion curves obtained with the homogenized model are in excellent agreement with the full-wave results. As is well known, the main behavioral features of the radiation pattern of a leaky-wave antenna are determined from the values of the phase and attenuation constants of the involved leaky modes. In the considered structure, the azimuthal omnidirectionality of the pattern allows for considering one elevation plane only. In particular, it is convenient to consider the plane (i.e., the plane orthogonal to the dipole and the strips), since reciprocity shows that in that plane the normalized radiation pattern is the same as the pattern radiated by an infinite electric line source in place of the dipole [11]. A line source excites a 1-D leaky wave, in contrast to the 2-D leaky wave excited by a dipole; the beam angle and beam width in the plane can thus be calculated through the simple formulas available for 1-D leaky-wave radiation. In particular, when a scanned beam is produced. Then:

$$\theta_p \simeq \sin^{-1}\left(\frac{\beta}{k_0}\right)$$

$$\vartheta_{3\ \mathrm{dB}} \simeq \frac{\frac{2\alpha}{k_0}}{\cos\theta_m}.$$ --- 3

On the other hand, when a broadside beam is produced. If the power density radiated at broadside is maximum then the beam width is: A

$$\Delta\theta_{3\ \mathrm{dB}} \simeq 2\sqrt{2}\frac{\alpha}{k_0}.$$ --- 4

It can be verified from Fig. 2 that the main beam in Fig. 3 is due to the excitation of the fundamental leaky mode, whereas the secondary lobe visible at the highest frequencies (20, 30, 35 GHz) is due to the excitation of the second higher order leaky mode. The first higher-order leaky mode is very weakly excited by the source since at the component of the modal electric field is close to zero.

3. CONCLUSIONS

Remarkable omnidirectionality and polarization purity of the directive radiation patterns have been studied. due to the excitation of a single leaky mode along the antenna aperture that propagates omnidirectionally and has current flow only in the direction. This makes the considered MSG unique among the class of partially-reflecting surfaces employed in this type of antenna. An accurate equivalent network has also been adopted to model the antenna, based on the representation of the grating through an equivalent homogenized admittance that is both temporally and spatially dispersive.

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