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SIMULATIONS AND MEASUREMENTS OF DUAL-BAND 2-D PERIODIC LEAKY WAVE ANTENNA

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ABSTRACT

A dual band 2-D leaky wave antenna is presented. The antenna is constructed from a double layer partially reflective surface suspended above a metallic ground plane, forming two Fabry Perot cavities corresponding to the two different resonant frequencies. The paper demonstrates the successful operation of the antenna through simulation and measurement.

I. INTRODUCTION

Highly directive antennas have been realized, in the past, using Fabry Perot Cavities (FPCs) [1], [2], [3], [4], [5], [6]. A structure of this nature is also known as a Leaky Wave Antenna (LWA). A FPC is formed when a Partially Reflective Surface (PRS) is suspended half a wavelength above a conducting ground plane. The PRS is generally a Frequency Selective Surface (FSS). The resonant cavity supports a mode which propagates along the transverse direction. A highly directive beam is obtained due to the leakage through the PRS. Radiation emitted by an antenna, located within this cavity, will undergo multiple reflections between the ground plane and PRS. The entire cavity operates as a radiator leading to a significant increase in the effective aperture area, and hence in the antenna gain and directivity. Depending on the substrate thickness a LWA antenna can either produce a pencil beam at broadside or a conical beam at a desired scan angle. The height of PRS above the ground plane is chosen to ensure that rays leaking through the PRS have equal phases in the normal direction. Simple design formulas for LWAs were proposed in [7]. In this paper those formulas are used to design a pair of nested LWAs for two different operating frequencies. This is achieved by using two complementary PRS, one made by an FSS of slots and the other by an FSS of dipoles. These two PRS are stacked, one on top of the other, in order to form two different FPCs. They are complementary, which means that in theory one FSS should be highly reflecting when the other is in its stop band. Full-wave simulations are presented in Section III. A prototype antenna was fabricated and measured to demonstrate the validity of this novel proposal for a dual frequency highly directive LWA.

II. ANTENNA STRUCTURE AND DESIGN

The first part of Fig. 1 depicts the two PRS, whilst the second part provides a side view of the dual band LWA. Inspection of the figure reveals that a dipole FSS constitutes the PRS for the first cavity, whilst a slot array, positioned above the dipole FSS, constitutes the PRS of the second cavity. Fig. 1 also defines the various symbols used when referring to different geometrical features of the structure. Table I gives the dimensions of each PRS. The distance between the PRS and ground plane determines the resonant frequency of the cavity and was obtained using an approximate equation [7, equation (32)]. The slot and dipole array PRS were designed to

operate at frequencies of $f_L = 10$ GHz, and $f_U = 14.6$ GHz, respectively. The overall size (270mm^2) of the structure was determined, using knowledge of the attenuation coefficient of the leaky mode launched by the dipole excitation. It was set to ensure that the leaky mode electric field, at the edges of the substrate, was attenuated by 30 dB, compared to its value in the centre.

Table I. The height of each FPC and dimensions of each PRS

PRS Type	L (mm)	w (mm)	a (mm)	b (mm)	Height (mm)
Dipole array	7.0	1	10	10	$h_1 = 10.50$
Slot array	7.5	3	10	10	$h_2 = 13.96$

Fig. 1. (a) dimensions of the slot and dipole PRS, (b) a side view of the dual frequency FPC (not to scale).

The reflection coefficient for each PRS was determined using in-house code. The code is based on the Periodic Method of Moments (PMM) and assumes that the PRS is infinite in extent and illuminated by a normally incident plane wave [8]. The susceptance of the PRS is then determined, and from this it is possible to calculate the distance of each PRS above the ground plane. The two PRS must be complementary at their operating frequencies f_L and f_U (as mentioned above), i.e. at $f_L = 10$ GHz the slot FSS must have a high value of reflection coefficient, whilst the patch FSS must have a low value reflection coefficient in order to ensure that it does not effect the size of FPC₂. However, we shall see, that interaction between the two PRS causes a shift in the operating frequencies.

III. SIMULATION RESULTS

This section presents simulation results for the dual band antenna. These electromagnetic computer simulations were performed using version 7 of Micro-Stripes, from Flomerics Ltd. Micro-Stripes is based on the well

established full wave Transmission Line Modelling (TLM) method. Fig. 2 is a graph of peak directivity as a function of frequency. Maxima in the directivity curve, occur at frequencies 8.23 GHz, and about 14.64 GHz. It is important to note that the antenna will not necessarily exhibit peak directivity at broadside, for every value of input frequency. Some of the values plotted in the figure will therefore pertain to non zero scan angles. However, for the two operating frequencies of the antenna, the directivity corresponds to maximum beam at broadside. This is shown in Fig. 3 where the co-polar radiation patterns of the antenna at each of the operating frequencies are illustrated. Each graph depicts two curves corresponding to the H- and E-plane radiation patterns. At both of these frequencies the antenna exhibits a directivity of approximately 17.5 dB.

Fig. 2. Directivity as a function of frequency

Fig. 3. Co-polar radiation patterns at (a) 8.2 GHz, and (b) 14.6 GHz (Black line = H-plane, gray line = E-plane)

IV. MEASUREMENT RESULTS

An antenna prototype has been fabricated and tested experimentally. Each PRS is formed from a sheet of Taconic microwave substrate material (TLX-8-0600). The substrate thickness, permittivity, and loss tangent of this material are 1.58mm, 2.55 and 0.0022 (at 10 GHz), respectively. The metallic array geometries are etched on the copper surface of the substrates which is suspended above the ground plane. The correct separation distances

are achieved by using plastic spacers. A simple thin wire dipole provides the source of excitation and is fed by a co-axial cable inserted through a hole drilled into the ground plane.

Fig. 4 shows the co-polar H- and E-plane radiation patterns obtained, through measurement. These patterns were recorded at frequencies for which the antenna exhibits maximum directivity. The measurements were performed using a HP 83650L signal generator together with a HP 8757D Scalar Network Analyser.

Fig. 4. Co-polar radiation patterns at (a) 7.64 GHz, and (b) 13.14 GHz

In the measurements, the antenna exhibits maximum directivity values at 7.64 GHz and 13.14 GHz. The positions of maxima in the directivity curve obtained through simulation do not agree with those derived by measurement. Further research will be required to reduce these differences, which are believed to be principally attributable to fabrication tolerances.

V. CONCLUSIONS

This paper has demonstrated the feasibility of a low profile, dual frequency antenna, formed from a pair of nested Fabry Perot Resonant cavities. The antenna was designed using simple theoretical formulas derived during previous studies. The antenna's operation was confirmed through full-wave simulations and measurements. The proposed antenna provides the desired directivity and radiation pattern. These preliminary results are encouraging and show that our novel design is a valid one for a dual frequency planar antenna with high directivity. However further work is required in order to analyze the small disagreement between measurement and simulation.

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