AIR-DIELECTRIC MICROSTRIP ANTENNAS ON INFINITE AND FINITE SIZE GROUND PLANES

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INTRODUCTION:

Integrated or printed circuit antennas are a natural evaluation of integrated circuit components and are finding increase use in the microwave, millimetre and for infrared frequency ranges. Therefore, the development of antennas which are amenable to integration with other printed circuit elements is of significant technological importance.

In recent years the analysis of electromagnetic problems has been tremendously helped by the digital computer and use of two powerful theories, the method of moments (MM) and the geometrical theory of diffraction (GTD). Here, the moment method is used to calculate the input impedance and the radiation pattern of an air-dielectric microstrip antenna on an infinite size ground plane. Also, the hybrid technique (MM+GTD) is applied to calculate the effect of a finite ground plane on the air-dielectric microstrip antenna characteristics. Experimental work is carried out and compared with the theoretical results. The agreement of presented theoretical results with experiment is markedly better than obtained by previous investigators.

1. MICROSTRIP ANTENNA ON INFINITE SIZE GROUND PLANE.

Consider a rectangular patch air-dielectric microstrip antenna as shown in Fig. (1). The radiating patch has a length L, width W and at a height H above the ground plane. The antenna is coaxially fed at distance L_1 from one edge. Using image theory, the ground plane is removed and the images of the patch and feed probe are isnerted. The current on the feed probe I_i is assumed constant along the proble, since $H << \lambda_o$ and this constant current will be chosen as 1 Ampere. Applying the reaction theorem [1], and using the notation in Fig.(1), one had,

$$-\iint_S J_s . E_m ds = \int_{-H}^{H} I_i . E_m \, dx \tag{1}$$

where the left hand integral is over the surface of the patch S and the right hand one is along the feed probe.

The integral equation (1) is solved using the Galerkin form of the moment method where the bais and testing functions are taken as pulse and sinusoidal distribution in breadth and length respectively over the surface patch dipoles. Thus the unknown current J_s is expanded in a set of N-basis functions or modes,

$$J_s = \sum_{n=1}^{N} C_n J_n \tag{2}$$

where, J_n is the nth mode and C_n is its unknown complex amplitude. Use of the same set of functions as test functions leads to a system of linear algebraic equations to be solved for the unknown constants C_n. Equation (1) may be rewritten as,

$$[Z_{mn}] \, [C_n] = [V_m] \quad , \quad m = 1, 2, \ldots, N \tag{3}$$

where Z_{mn} is known as the impedance matrix with elements,

$$Z_{mn} = -\frac{1}{I_{nn} \, I_{mm}} \iint_{S_n} J_n . E_m \, ds_n \tag{4}$$

V_m is the voltage vector whose elements are given by,

$$V_m = \frac{1}{I_{mm}} \int_{-H}^{H} I_i . E_m \, dx \tag{5}$$

J_{nn} and I_{mm} are the terminal currents of modes m and n respectively, I_i is the feed probe curent and E_m is the electric field due to the test source J_m on the patch surface of the antenna.

When the coefficients of the current modes on the surface of the patch, C_n, are determined, the antenna's input impedance is calculated as,

$$Z_{in} = -0.5 \frac{1}{|I_i|^2} \int_{-H}^{H} E . I_i \, dx + j X_L \tag{6}$$

where the 0.5 is introduced for the monopole configuration, E is the total electric field due to the N-expansion modes J_n, $n = 1,2,\ldots,N$ on the surface of the patch and X_L is a reactance component to show the effect of the probe [2]. The effect on the input impedance of fringing capacitances at the edges of the microstrip antenna can be accounted for by assigning equivalent lengths to be added to both length and breadth dimensions of the antenna [1].

A comparison will now be made between the theoretical and experimental results. Two structures are taken to show this comparison. The first one is the air-dielectric narrow strip antenna as shown in Fig. (2). The second one is the air-dielectric microstrip antenna as shown in Fig. (3). The ground plane has length a = 275 Cm and width b = 122 Cm and is made from aluminium sheet of thickness 0.2 Cm. Fairly good agreement between the measured data (covering the range f = 0.92 - 0.975 GHZ) and the theory is manifested in both cases.

The radiation pattern is calculated from the surface current along the patch and from the current along the feed probe. Figures (4,5) show E and H-plane patterns for narrow and wide patch microstrip antennas.

2. MICROSTRIP ANTENNA ON FINITE SIZE GROUND PLANE.

A hybrid method combining GTD and MM is developed to study the effect of a finite ground plane upon the input impedance and radiation pattern of an air-dielectric microstrip antenna. The equivalent current edge method is used to calculate the effect of finite ground plane [3,4]. Electric or magnetic currents or both are taken along the edges of the ground plane.

For the input impedance calculation, equation (3) becomes,

$$[Z'_{mn}]\,[C'_n] = [V'_m] \quad , \qquad m = 1, 1, \ldots ,N \tag{7}$$

where,

$$Z'_{mn} = Z_{mn} + Z^d_{mn} \tag{8}$$

$$V'_m = V_m + V^d_m \tag{9}$$

Z^d_{mn} and V^d_m are the additional impedance and excitation terms due to the diffraction from the ground plane edges. Equation (7) is used to calculate the coefficients (C'_n) for the surface current J_n, and input impedance can be calculated from equation (6). Fig. (6) shows a comparison between the experimental and theoretical results based on the hybrid technique. Good agreement between calculated and experimental values is seen.

The radiation pattern of air-dielectric microstrip antenna is calculated for different sizes of the ground plane. The effect of the height of the patch from the ground plane and also the radiation from the feed probe are considered. Again, the equivalent currents along the edges are proposed to calculate the diffracted field from the edges of the ground plane.

For air-dielectric microstrip antenna, the measurements are carried out and compared with the theory to calculate E-and H-plane patterns as in Figures (7,8). The agreement is quite good.

CONCLUSION.

The reaction integral equation for an air-dielectric microstrip antenna has been solved by using the moment method technique. The surface patch modes are used as testing and expansion functions (Galerkin's method). The moment method solution has been used to calculate the input impedance and radiation pattern of the antenna on an infinite size ground plane. Experimental results are compared with the theoretical results.

A hybrid technique based on the moment method and the geometrical theory of diffraction has been used to calculate the input impedance and the radiation pattern for an air-dielectric microstrip antenna on a finite size ground plane. The equivalent current edge method is used to calculate the effect of the finite size ground plane. Markedly better agreement between the measured and the present theoretical results has been found, compared with results of previous investigators [1].

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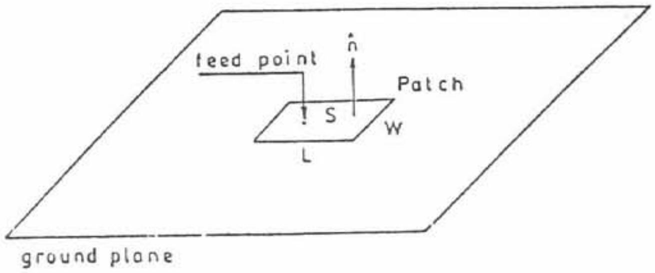


(a) Top View.

(b) Side View.

Fig.(1): Air-dielectric Microstrip Antenna Structure.

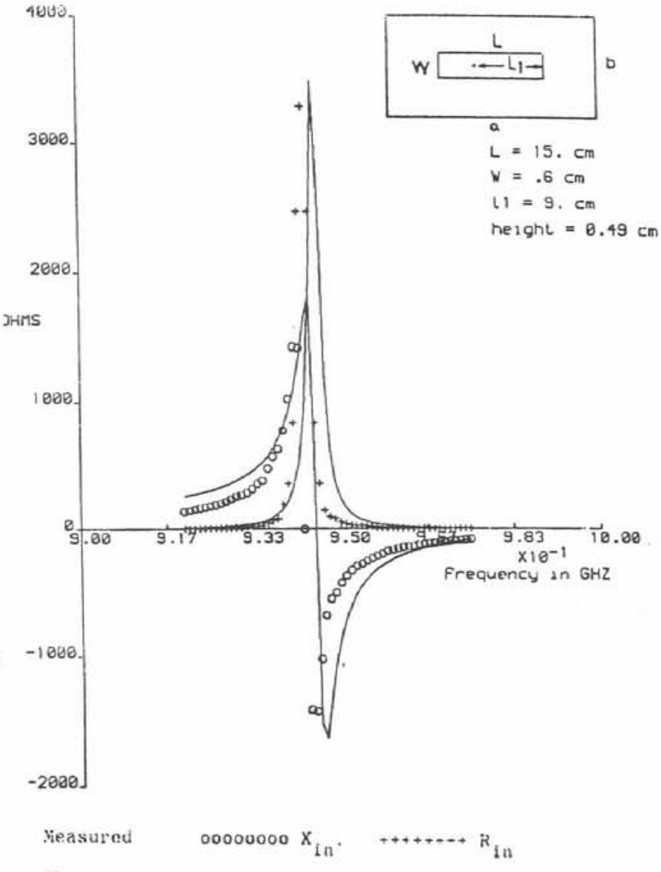


Fig.(2): Input Impedance of Air-dielectric Narrow Strip Antenna.

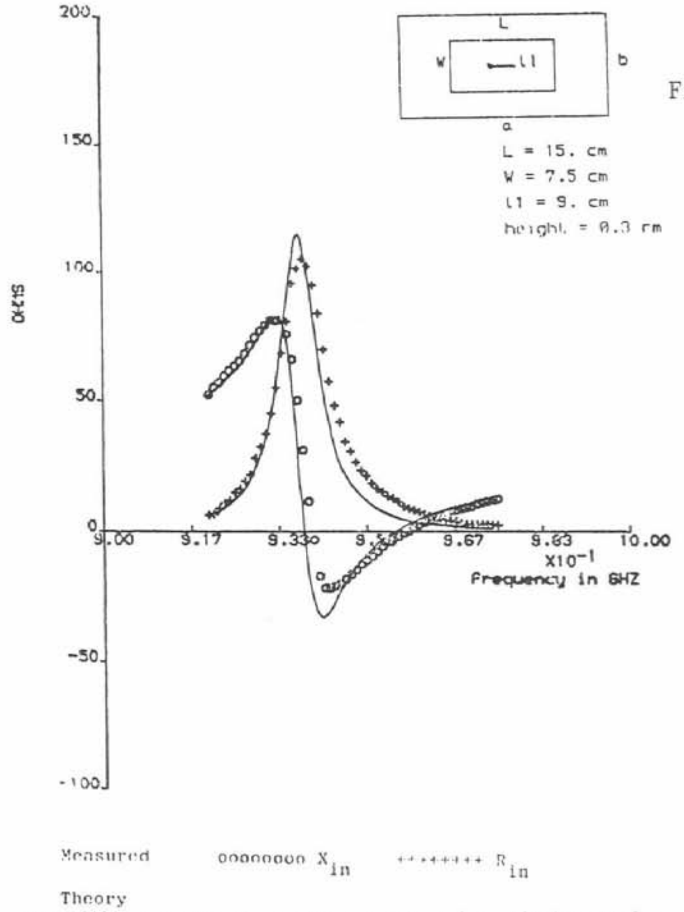
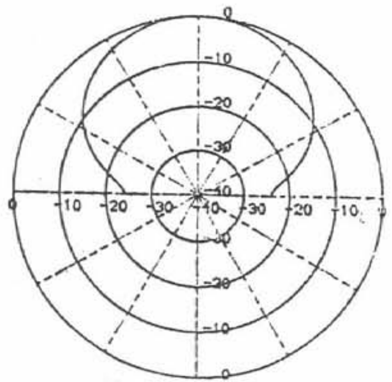
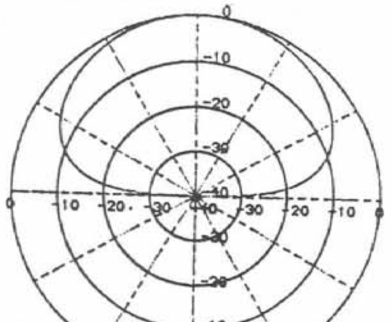


Fig.(3): Input Impedance of Air-dielectric Microstrip Antenna.

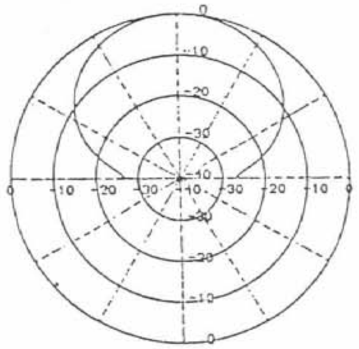


E-Plane.

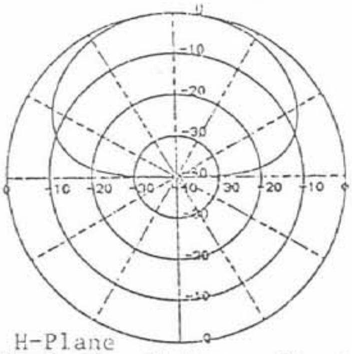


H-Plane

Fig.(4): Radiation Pattern. The antenna Dimensions are L 1.5 Cm, W=0.2Cm, H=0.15 Cm, y_1=0.15 Cm and f=8.29 GHz.



E-Plane.



H-Plane

Fig.(5): Radiation Pattern. The Antenna Dimensions are L=1.5Cm, W=0.75Cm, y_1=0.15Cm and f = 8.46 GHz.

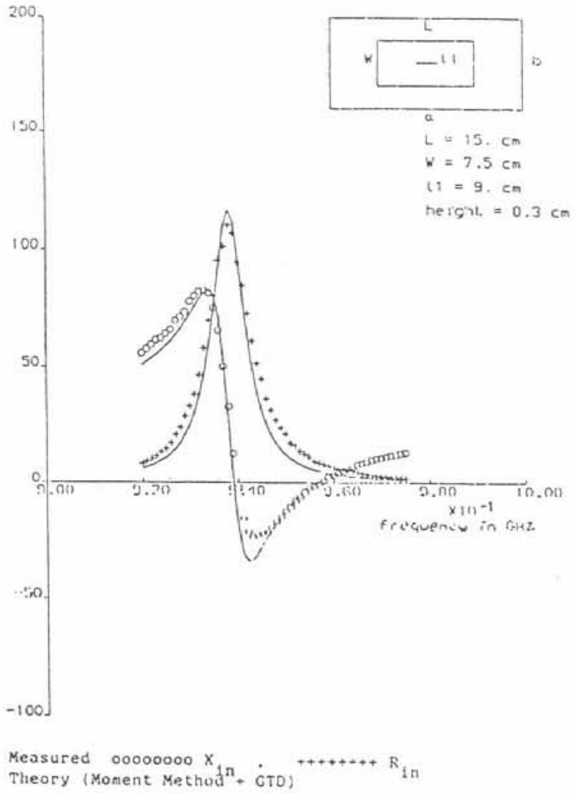
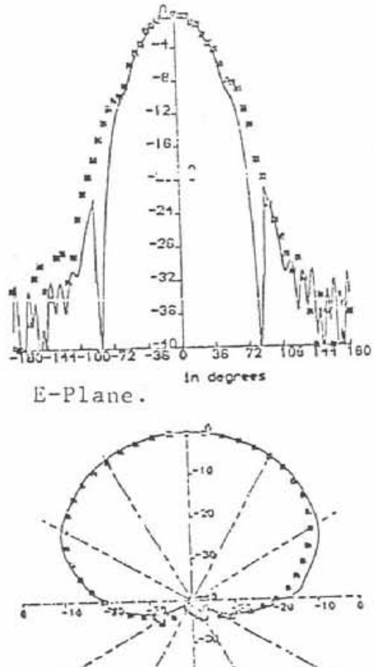
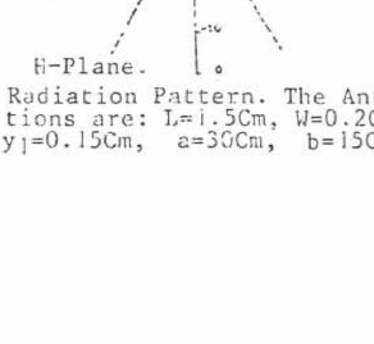


Fig.(6): Input Impedance of Air-dielectric Microstrip Antenna on Small Ground Plane (a=25 Cm , b=17.5 Cm).

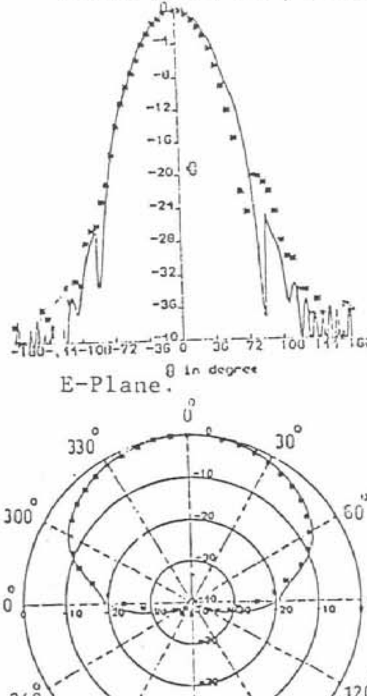


E-Plane.

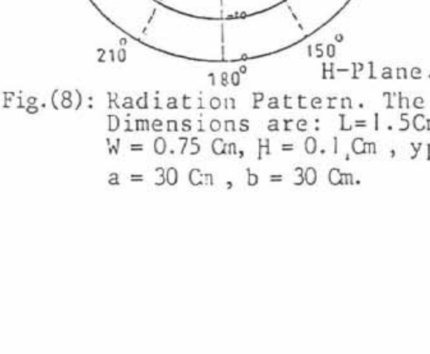


H-Plane.

Fig.(7): Radiation Pattern. The Antenna Dimensions are: L=1.5Cm, W=0.2Cm, H=0.15Cm, y_1=0.15Cm, a=30Cm, b=15Cm.



E-Plane.



H-Plane.

Fig.(8): Radiation Pattern. The Antenna Dimensions are: L=1.5Cm, W = 0.75 Cm, H = 0.1 Cm , y_1=0.15 Cm, a = 30 Cm , b = 30 Cm.