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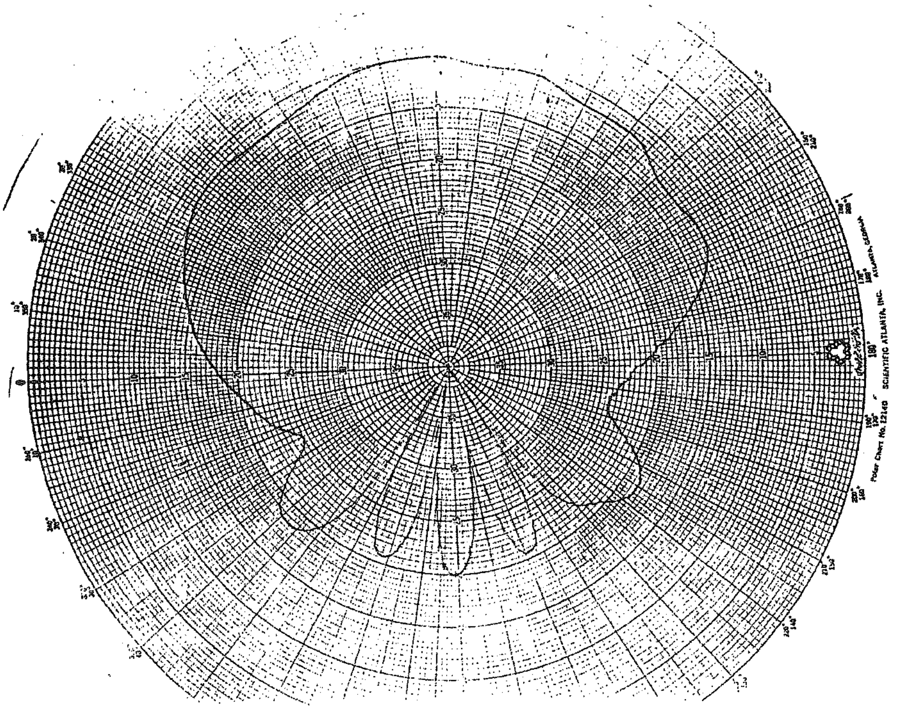

Fig (7) a - Radiation pattern measured in 2.682 GHz in E-plane

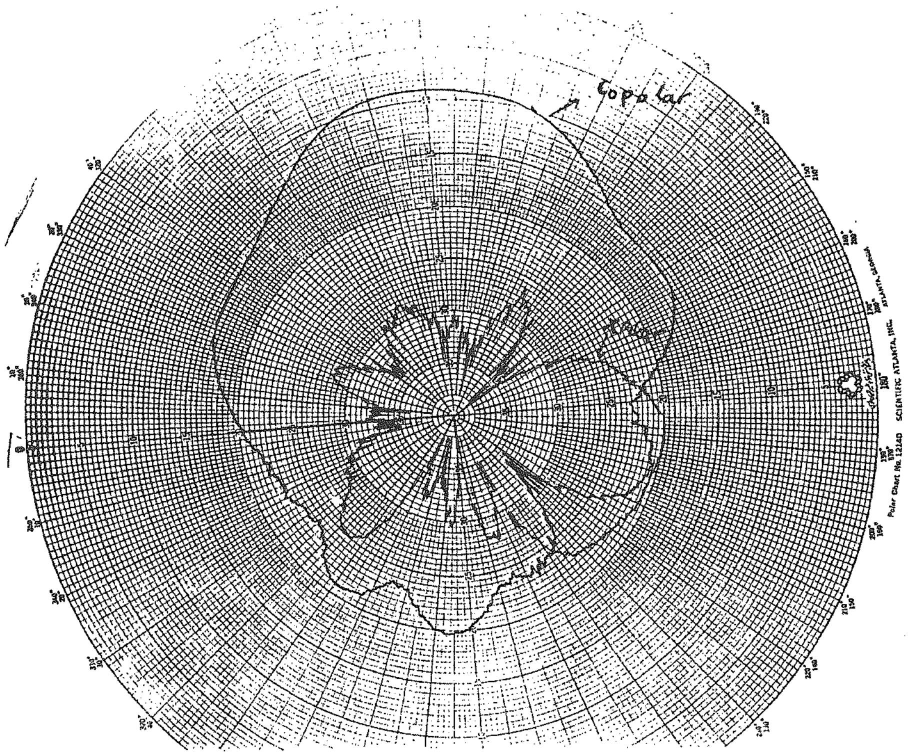

Fig (7) a - Radiation pattern measured in 2.682 GHz in H-plane

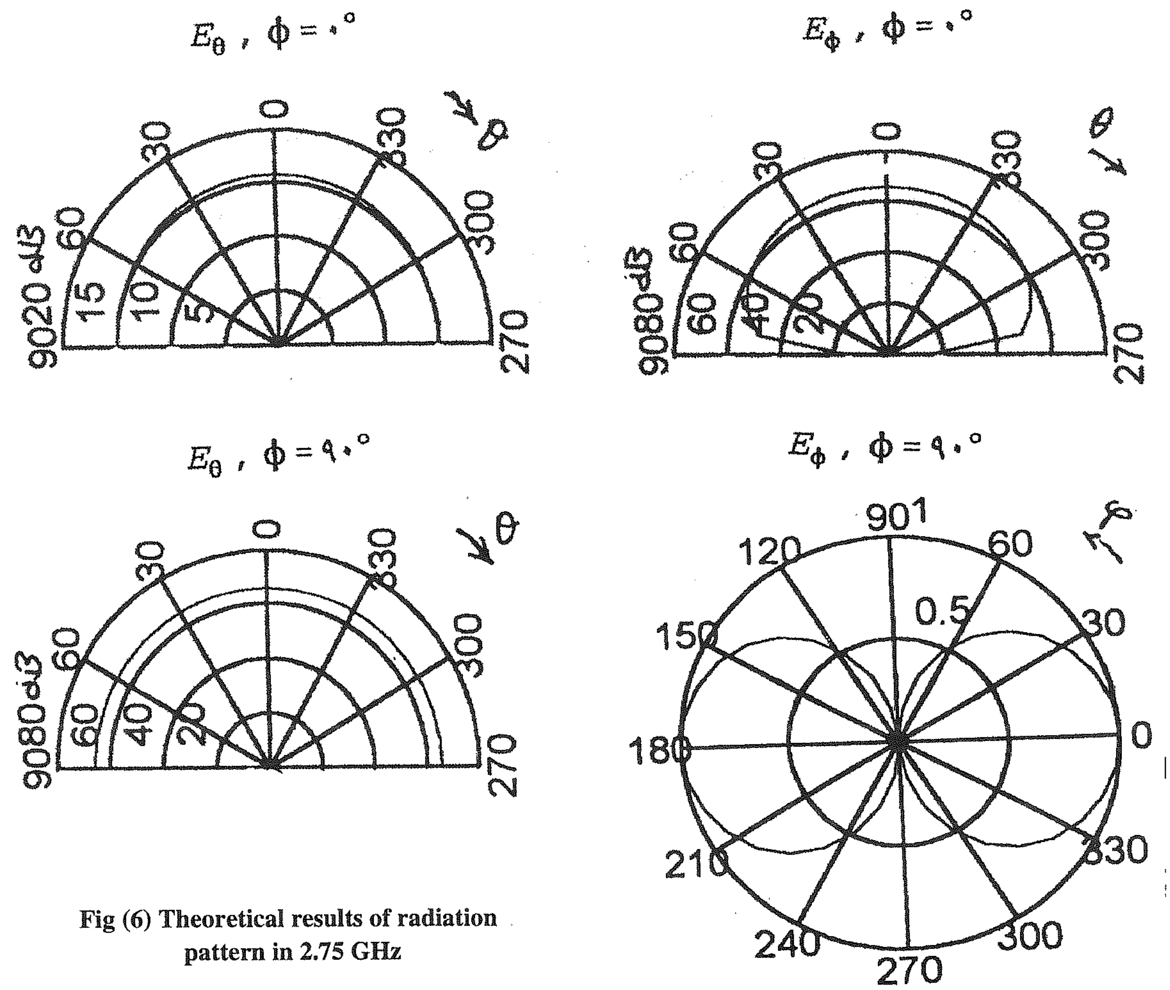

Fig (6) Theoretical results of radiation pattern in 2.75 GHz

Appendix

the spectral-domain Green functions for magnetic feed on the boundary of two layered media due to radiation of magnetic current element on a grounded dielectic with thickness h are:

$$\tilde{G}_{xx}^{HM} = -\frac{1}{\omega\mu.}\left[\frac{\varepsilon_r k_2 \mathrm{Cos}k_2h(K_0^2 - K_x^2) + jk_1 \mathrm{Sin}k_2h(\varepsilon_r k_0^2 - k_x^2)}{T_e T_m}\right]\mathrm{Cos}k_2h$$

$$\tilde{G}_{xy}^{HM} = \tilde{G}_{yx}^{HM} = \frac{k_x k_y}{\omega\mu.}\left[\frac{\varepsilon_r k_2 \mathrm{Cos}k_2h + jk_1 \mathrm{Sin}k_2h}{T_e T_m}\right]\mathrm{Cos}k_2h$$

$$\tilde{G}_{yy}^{HM} = \frac{-1}{\omega\mu.}\left[\frac{\varepsilon_r k_2 \mathrm{Cos}k_2h(K_0^2 - K_y^2) + jk_1 \mathrm{Sin}k_2h(\varepsilon_r k_0^2 - k_y^2)}{T_e T_m}\right]\mathrm{Cos}k_2h$$

$$T_e = k_2 \mathrm{Cos}\, k_2 h + jk_1 \mathrm{Sin}\, k_2 h$$

$$T_m = \varepsilon_r k_1 \mathrm{Cos}\, k_2 h + jk_2 \mathrm{Sin}\, k_2 h$$

$$K_1^2 = K_0^2 - \beta^2 \qquad (I_m(K_1) < 0)$$

$$K_2^2 = \varepsilon_r K_0^2 - \beta^2 \qquad (I_m(K_2) < 0)$$

$$\beta^2 = K_x^2 + K_y^2$$

One can find the details in refrence [4]

6-Conclusion

This paper presents a moment solution and implementation of a slot loop printed antenna. Exact Green functions in spectral domain and pulse expansion functions are used in Galerkein procedure. Delta and pulse functions are used for feed model. Good agreement between calculated and measurement results has been observed.

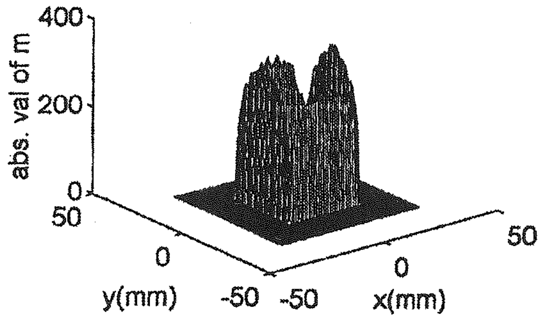

Fig (2) Absolute value of magnetic current distribution in the slot (f = 2.75GHZ)

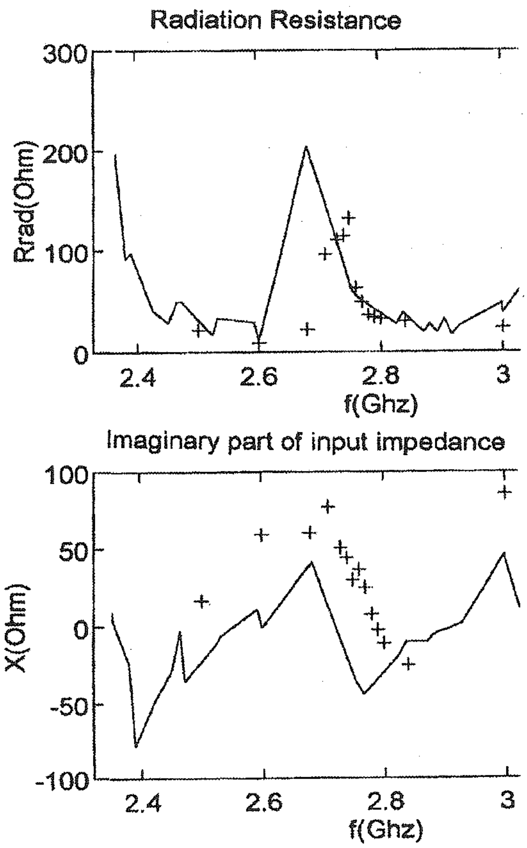

Fig (3) Real and imaginary part of input impedance
--- Measurement + Theory

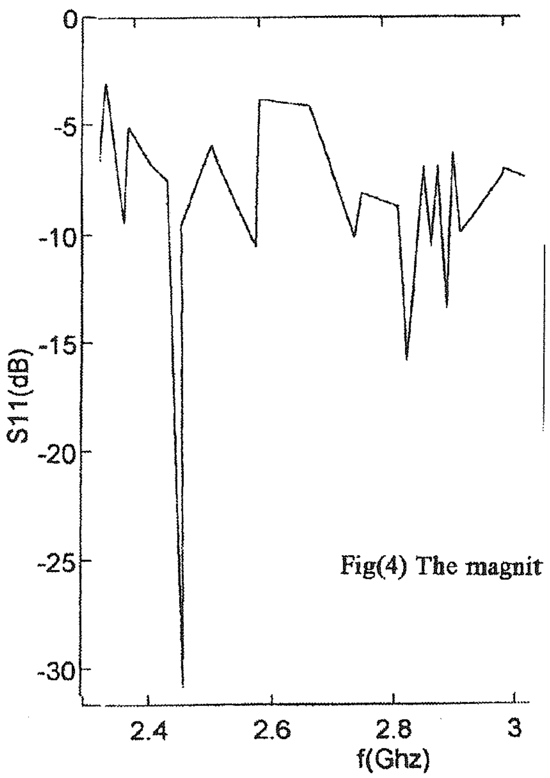

Fig (4) The magnitude of S_{11} par neter

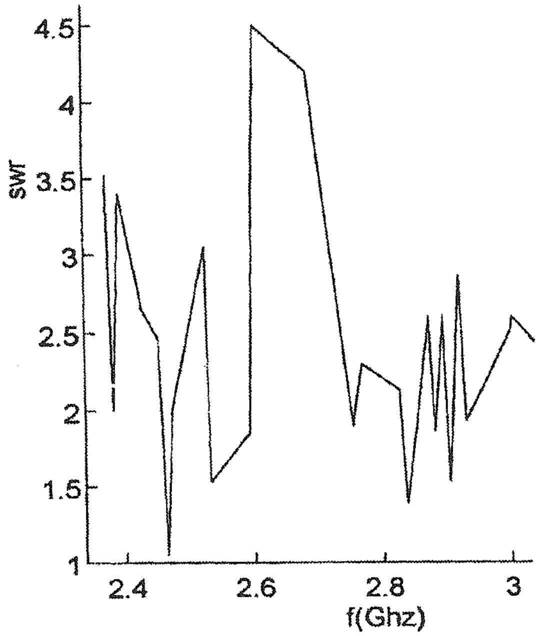

Fig (5) Measured SWR

The integrands are singular functions, so for the evaluation of equations 7, residue method is used for integration along real axis of β [5]. Also the integration region of $[o, \infty]$ can be divided into 3 [5-6] or 4 [7] intervals. For 3 interval case, regions of $[0, k_o]$, $[K_0, \sqrt{\epsilon_r}\, K_0]$, $[\sqrt{\epsilon_r}\, K_0, A]$, are considered. The accurate estimation of the upper limit, A, would minimize the truncation error, and several methods have been proposed for this purpose [5-7], taking $A=150^* \beta_0$ seems to be sufficient for the procedure.

3- Excitation Modeling

Delta-gap model has been used for the feed modeling of coplanar waveguide [8]. In this paper, the model used for probe feed of waveguide is adopted for excitation by coaxial line. The current distribution on the inner conductor may be considered as a cosine (The same as the feed of waveguides [9]) or a pulse function. As the electric current at the feed line is only y directed, all the I^x_m elements of moment's excitation vector become zero and I^y_m, for the pulse distribution of current on the inner conductor, is written as:

$$I^y_m = 4\int_0^{\frac{\pi}{2}}\int_0^{\infty} \tilde{J}_{yi}\, \tilde{M}_x \mathrm{Cos}\,(K_x(x_p - x_m))\, \mathrm{Cos}\,(K_y(y_p - y_m))\, \beta\, d\beta\, d\theta \tag{8}$$

where (x_p, y_p) is the feed position and J_{yi} is the y directed current distribution.

4- Radiation pattern and Input Impedance

By solving the matrix equation (6), the magnetic current distribution on the slot in the spectral domain is obtained.

Using $\vec{E} \times \hat{a}_z = \vec{M}$ we get the fourier transform of tangential electric on the slot and the far field E components are [10]:

$$E_\theta = K_0(-F_x\, \mathrm{Sin}\varphi + F_y\, \mathrm{Cos}\varphi) \tag{9-a}$$

$$E_\varphi = -K_0(F_x\, \mathrm{Cos}\varphi + F_y\, \mathrm{Sin}\varphi)\, \mathrm{Cos}\theta \tag{9-b}$$

Where F_x and F_y are fourier transforms of electric field on the slot.

The input impedance can be evaluated by considering the input voltage in the subsection where probe is located. So

$$Z_{in} = -\frac{1}{I_{in}}\int_0^{w_y} E_{yp}\, dy = \frac{-1}{I_{in}}\int_0^{W_y} \frac{M_{xp}}{W_y}\left(\int_{X_P-\varepsilon}^{X_P+\varepsilon} \delta(x - x_p)\, dx\right) dy \tag{10}$$

Where E_{yp} is the tangential electric field in feed location which is obtained from magnetic current in that section. I_{in} is the input electric current.

5-RESULTS

The moment method program is written in fortran 77 on a 486 DX2, 66 MHZ computer. The periphery of the patch is nearly one wavelength. The inner patch is a square with 29 mm side. The widths of slot is 1mm. the slot is divided into 124 subsections, 62 for M_x and 62 for M_y. The resonant frequency is the one in which the maximum input resistance occurs. The magnetic current distribution on the slot is shown in figure (2). The antenna is built on a 30.63x34.7cm, 0.625 in. thick RT/duroid 5870 with dielectric constant 2.33. The computed and measured input impedance in frequency range of 2.2-3.6GHz are shown in figure (3). The measured S_{11} parameter and SWR are shown in figures (4) and (5). It is seen that from nearly 2.73 to 2.91 GHz the SWR is between 1.38-2.8. The resonant frequency is 2.682 GHz by measurement, with about 70 MHz less than the theoretical value which is due to numerical errors and probe's reactance. The bandwidth of this antenna at the resonant frequency without a match circuit is about %3, and the crosspolar radiation is 20 dB less than the coplar radiation. The theoretical results of radiation pattern in 2.72 GHz is shown in figure (6). The measured pattern in resonant frequency is shown in figure (7). The crosspolar is high in 2.47 GHz. The difference between measured and theortical patterns is because of infinite ground plane assumption in the analysis.

2. Theory

For analysis of this antenna, boundary condition for the tangential magnetic field is considered:

$$\hat{a}_z \times (\vec{H}_1 - \vec{H}_2) = \vec{J}_i \qquad \text{on the slot} \qquad (1)$$

Where J_i is the excitation electric current in the slot and $\vec{H}_1$ and $\vec{H}_2$ are respectively magnetic field in air and dielectric. By using dyadic Green function in both media and convolution integrals one finds:

$$\hat{a}_z \times \iint_S [\overline{G}_1^{HM} + \overline{G}_2^{HM}] \cdot \vec{M}_s(\vec{r}^{\,1})\, d\vec{s}^{\,1} = \vec{J}_i \text{ on the slot} \qquad (2)$$

Where s is the surface of slot and $\vec{M}_s$ is the magnetic current. The calculation of Green functions are given in details in reference [4] and the final functions in Z=h are shown in appendix.

Applying spectral domain to equation (2) and considering $\overline{G}^{HM} = \overline{G}_1^{HM} + \overline{G}_2^{HM}$, the following matrix equation results:

$$\hat{a}_z \times \begin{bmatrix} \tilde{G}_{xx}^{HM}\, \hat{a}_x \hat{a}_x & \tilde{G}_{xy}^{HM}\, \hat{a}_x \hat{a}_y \\ \tilde{G}_{yx}^{HM}\, \hat{a}_y \hat{a}_x & \tilde{G}_{yy}^{HM}\, \hat{a}_y \hat{a}_y \end{bmatrix} \begin{bmatrix} \tilde{M}_x\, \hat{a}_x \\ \tilde{M}_y\, \hat{a}_y \end{bmatrix} = \begin{bmatrix} \tilde{J}_{yi}\, \hat{a}_y \\ -\tilde{J}_{xi}\, \hat{a}_x \end{bmatrix} = \hat{a}_z \times \begin{bmatrix} \tilde{J}_{yi}\, \hat{a}_x \\ \tilde{J}_{xi}\, \hat{a}_y \end{bmatrix} \qquad (3)$$

Where ~ means that the parameter is given in spectral domain.

Pulse functions is used to expand magnetic currents in both longitudinal and transversal directions.

$$\vec{M}_s = \overrightarrow{MS}_x + \overrightarrow{MS}_y$$

$$M_x = \sum_{n=1}^{N_x} V_{xn} MS_x,\ MS_x = P(x'-x'_n)\, P(y'-y'_n) \qquad (4\text{-a})$$

$$M_y = \sum_{n=1}^{N_y} V_{yn} MS_y,\ MS_y = P(x'-x'_n)\, P(y'-y'_n) \qquad (4\text{-b})$$

Where

$$P(x'-x'_n) = \begin{cases} \dfrac{1}{W_x} & \text{if } |x'-x'_n| \le \dfrac{W_x}{2} \\ 0 & \text{otherwise} \end{cases} \qquad (5\text{-a})$$

$$P(y'-y'_n) = \begin{cases} \dfrac{1}{W_y} & \text{if } |y'-y'_n| \le \dfrac{W_y}{2} \\ 0 & \text{otherwise} \end{cases} \qquad (5\text{-b})$$

Approximating the M_s Current with a finite number of expansion functions, makes an error in equation (3) which can be minimized by using Galerkin testing functions. The following matrix equation results:

$$\begin{bmatrix} Y^{xx} & Y^{xy} \\ Y^{yx} & Y^{yy} \end{bmatrix} \begin{bmatrix} V_x \\ V_y \end{bmatrix} = \begin{bmatrix} I^y \\ I^x \end{bmatrix} \qquad (6)$$

$\tilde{G}_{xx}^{HM}$ and $\tilde{G}_{yy}^{HM}$ are even functions of K_x and K_y. Fourier transform of expansion pulses is also even function of its variable and $\overline{G}_{xy}^{HM} = \overline{G}_{yx}^{HM}$ are odd functions of K_x and K_y (See appendix). The elements of moment admittance matrix can be written as:

$$Y_{mn}^{xx} = 4\int_0^{\frac{\pi}{2}}\int_0^{\infty} \tilde{G}_{xx}^{HM} \left|\tilde{MS}_x\right|^2 \cos(K_x(x_n - x_m)) \cos(K_y(y_n - y_m))\, \beta\, d\beta\, d\theta \qquad (7\text{-a})$$

$$Y_{mn}^{xy} = -4\int_0^{\frac{\pi}{2}}\int_0^{\infty} \tilde{G}_{xy}^{HM'}\, \tilde{MS'}_x\, \tilde{MS}_y\, \sin(K_x(x_n - x_m)) \sin(K_y(y_n - y_m))\, \beta\, d\beta\, d\theta \qquad (7\text{-b})$$

$$Y_{mn}^{yx} = -4\int_0^{\frac{\pi}{2}}\int_0^{\infty} \tilde{G}_{yx}^{HM'}\, \tilde{MS'}_y\, \tilde{MS}_x\, \sin(K_x(x_n - x_m)) \sin(K_y(y_n - y_m))\, \beta\, d\beta\, d\theta \qquad (7\text{-c})$$

$$Y_{mn}^{yy} = 4\int_0^{\frac{\pi}{2}}\int_0^{\infty} \tilde{G}_{yy}^{HM} \left|\tilde{MS}_y\right|^2 \cos(K_x(x_n - x_m)) \cos(K_y(y_n - y_m))\, \beta\, d\beta\, d\theta \qquad (7\text{-d})$$

Fullwave Analysis and Implementation of a Micro-strip Slot Loop Antenna with Coplanar Coaxial Feed Using Moment Method In Spectral domain

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M. S. Student

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Abstract

This paper presents fullwave analysis of a printed slot loop antenna on a conductor backed one layer dielectric which is coplanarly fed through coaxial line. The magnetic field integral equation on the slot is chosen for theoretical analysis and Galerkin procedure in spectral domain is applied. The numerical results of input impedance and far field pattern of the antenna are compared with measurements and good agreement is observed.

1- Introduction

This radiator is a kind of printed slot antenna with two ground planes connected together, figure (1). The top ground plane provides simpler installation of electrical elements and better concealment in the large metallic structures like vehicles and planes.

Greiser proposed coplanar antenna with coplanar feed [1] and Liu et al. analyzed it in 1995 [2]. A nearly similar structure; designed for an automobile windshield is analyzed by Torres et al. [3] by solving the complementary problem. This article presents a fullwave analysis of this antenna fed by coaxial line, using spectral domain moment method. An integral equation for the printed slot loop antenna in an infinte ground plane for an ideal case is developed and exact dyadic Green's function is obtained in spectral domain.

Two dimensional subdomain expansion functions are used to approximate the magnetic current distribution. Delta-gap model is considered for excitation. The radiation pattern and resistance are measured and computed, theoretical and measurement result are discussed.

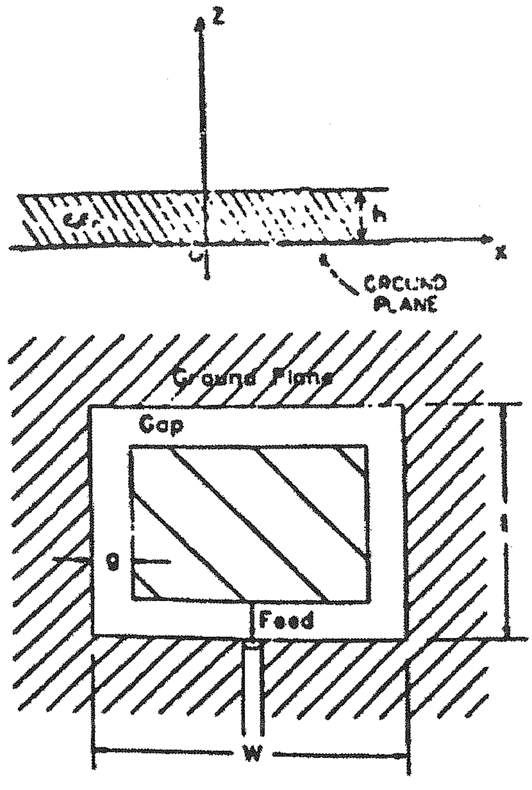

Fig (1) side and plane view of microstrip slot loop antenna