# OPTIMISATION OF MICROSTRIP ANTENNA

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## Abstract

*When choosing the most appropriate microstrip antenna configuration for particular applications, the kind of excitation of the radiating element is an essential factor that requires careful considerations. For controlling the distribution of energy of the linear or planar array of elements and for coupling energy to the individual elements, a wide variety of feed mechanisms are available. In this paper, the coaxial antenna feeding is assumed and the best (optimised) feeding is found. Then, antenna characteristics such as radiation pattern, return loss, input impedance, and VSWR are obtained.*

## 1. Introduction

The antenna dimensions can be calculated as follows ([1]):

$$b=\frac{\lambda_d}{2\sqrt{\varepsilon_r}} \tag{1}$$

$$a=1.5\,b \tag{2}$$

where the patch dimensions are a and b, $\varepsilon_r$ is the relative permittivity, and $\lambda_d$ is the wavelength in the dielectric as shown in Fig.1. Lo et al. [2] have made a model for solving the microstrip like a cavity. The region between the microstrip and the ground plane may be treated as a cavity bounded by a magnetic wall along the edge, and by electric walls form above and below. The fields in the antenna may be assumed to be those of the cavity.

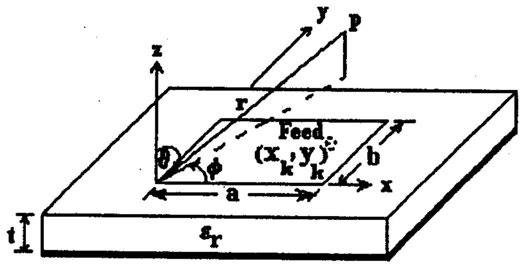


Fig.1 Rectangular patch microstrip antenna configuration

## 2. Method of Analysis

The field may be expanded in a series of resonant mode assuming that the perimeter of the microstrip antenna may be enclosed in a perfect magnetic conductor without disturbing the fields as illustrated in Fig.2. According to the Huygens' principle to the outer surface of the cavity and using [2], the z-directed electric field $E_z$ of a resonant mode in the cavity under the patch may be represented by:

$$E_z = E_o \cos(m\pi x/a).\ \cos(n\pi y/b) \tag{3}$$

where $m, n = 0, 1, 2, \ldots$

## 3. Power and Input Impedance

Consider a closed surface S shown in Fig.2, and using Huygens' principle to the outer surface of the cavity and neglecting the electric current flowing on the outer surface of the microstrip antenna, one obtains the Huygens' magnetic current source.

$$\mathbf{M} = -\,\mathbf{n} \times \mathbf{E} \tag{4}$$

where **M** is the surface-magnetic-current density [V/m] and **n** is the unit outward normal to the *H*-wall.

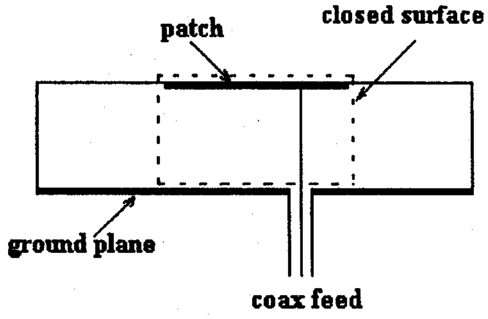


Fig.2 Application of the equivalence principle

If the substrate thickness $t \ll \lambda$, its effect on the radiation field is small and **M** may be assumed to radiate in free space. Using the free-space Green's function, the vector electric potential **F** at a point **r** is given by:

$$\mathbf{F}(\mathbf{r}) = (\varepsilon_o\, t/4\pi)\int_C \mathbf{M}(\mathbf{r}')\left[\frac{e^{-jk_0|\mathbf{r}-\mathbf{r}'|}}{\mathbf{r}-\mathbf{r}'}\right] dl\,(\mathbf{r}'), \tag{5}$$

where $\varepsilon_o$ is the permittivity of vacuum $\cong 8.85\cdot 10^{-12}$ F/m, **r** is the distance between the origin and the field point, **r'** is the distance between the origin and the source, the integration is over the patch perimeter, and the field in far-zone at **r** is given by [3],[4]:

$$E_\theta = jk_o[-F_x \,.\, \sin\phi + F_y \,.\, \cos\phi] \tag{6}$$
$$E_\phi = -jk_o\cos\theta\ [F_x \,.\, \cos\phi + F_y \,.\, \sin\phi] \quad , \tag{7}$$

where $k_o = (\mu_o\varepsilon_o)^{1/2}\cdot\omega$ and $\mu_o$ is the permeability of vacuum $4\pi\cdot10^{-7}\ \mathrm{H\cdot m^{-1}}$.

The radiated power $P_{rad}$ is calculated from the far-zone electromagnetic field is given by:

$$P_{rad} = Re\int_0^{2\pi}\int_0^{\pi/2} (E_\theta H_\phi^* - E_\phi H_\theta^*)\, r^2 \sin\theta\, d\theta\, d\phi \quad . \tag{8}$$

The conductor loss $P_c$ and the dielectric loss $P_d$ are calculated from the electric field inside the cavity

$$P_d = (\omega\varepsilon\delta/2)\iiint |E|^2\, dV \tag{9}$$

$$P_c = R_s \iint |H|^2\, dS \quad , \tag{10}$$

where $\delta = (2\omega\mu/\sigma_c)^{1/2}$ is the loss tangent of the dielectric and $R_s$ is the surface resistivity of the conductors ( $\sigma_c$ is the conductivity of the conductor $5.8\cdot10^7\,\Omega\cdot\mathrm{m}^{-1}$).

James and et al. [5] estimated that surface-wave excitation is not important if $t/\lambda_o < 0.09$ for $\varepsilon_r \cong 2.3$ and $t/\lambda_o < 0.03$ for $\varepsilon_r \cong 10$, where $\lambda_o$ is the free-space wavelength (i.e. surface-wave power loss = 0), then the total power loss $P_{Tod}$ can be defined as:

$$P_T = P_d + P_c + P_{rad} \quad . \tag{11}$$

The electric energy stored at resonance is :

$$W_E = (\varepsilon/4)\iiint |E_z|^2\, dV = P_d/2\omega\delta \quad . \tag{12}$$

From equations (11) and (12) the input impedance at the feed point of the antenna can be computed by [4]:

$$\frac{1}{Z} = \frac{P_T + j2\omega(W_E - W_M)}{|V|^2} \quad , \tag{13}$$

where $W_M$ is the magnetic energy stored. The voltage $V = E\cdot t$, where $E$ is the z-component of the electric field strength at the feeding point.

## 4. Rectangular Diagonal Fed Antenna

Using (1), (2) we can find the antenna dimensions. The diagonal of the patch must be determined. From the diagonal centre, we can move a very short distance to the right or left, up or down searching for a point of input impedance 50Ω of $Z_0$ of the coaxial feeding line.

Using (13) the input impedance for different feeding points was calculated to obtain the optimum feed location. The criterion was the VSWR. Fig.3 shows the impedance locus on different frequencies. The input impedance 50.2 - j0.02 Ω at the centre frequency (4 GHz) was found. The return loss is -53.35 dB (Fig.4) and the VSWR is 0.04 dB (Fig.5.)

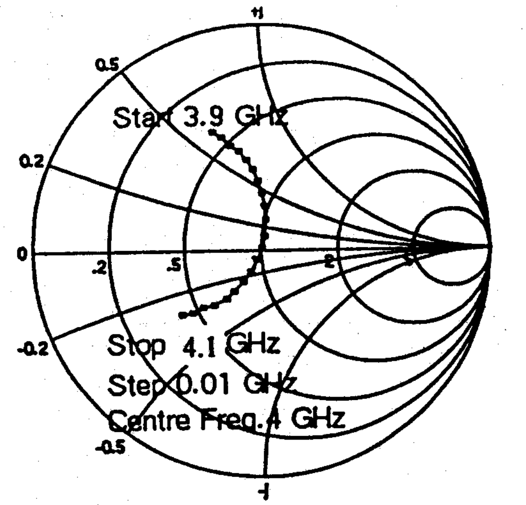


Fig.3 Input impedance locus ( $Z_0$=50 Ω )

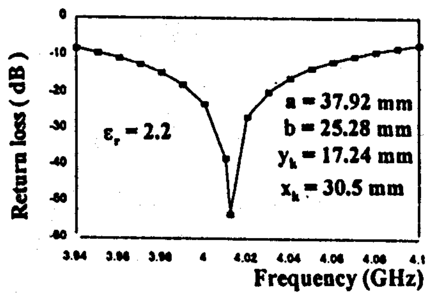


Fig.4 Return loss against frequency

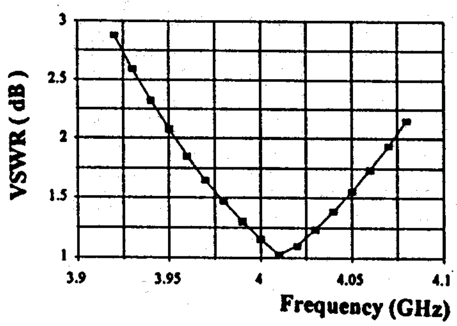


Fig.5 VSWR against frequency

The radiation pattern of the antenna is shown in Fig.6 for $\phi$ = 0°, 90° and $\theta$=90°.

Fig.7 shows the antenna efficiency against frequency. We noticed that the efficiency begins to increase to reach its maximum near the centre, and again decreases away from the centre depending upon the thickness of the dielectric material.

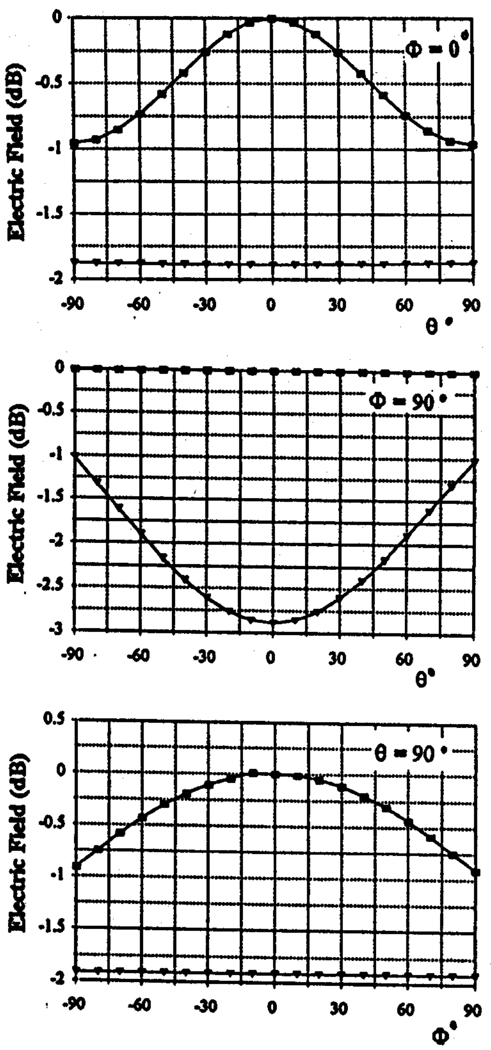


Fig.6 Radiation pattern of a rectangular microstrip antenna

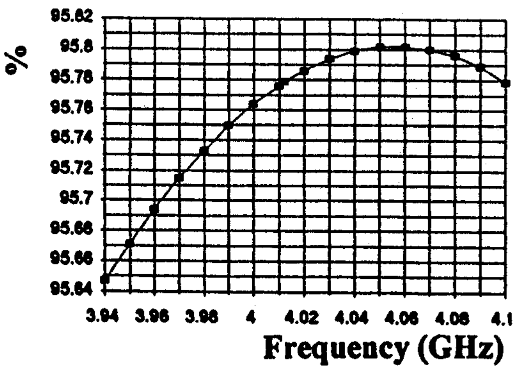


Fig.7 Efficiency

## 5. Conclusion

The optimum good match coaxial-feed location was studied for different materials $\varepsilon_r$ = 2.2, 2.62 and 4 of thicknesses t = 1.57, 1.59, and 1.50 mm respectively and in a frequency range 1.5-5.5 GHz. The position of the optimum feed is in Fig. 8.

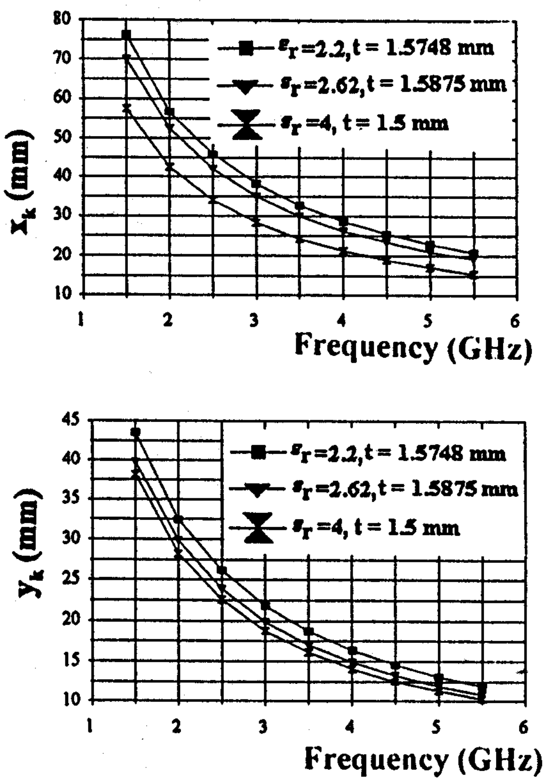


Fig.8 Optimum feed position ($x_k$, $y_k$) against frequency

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## About author ...

**Hassan El HAMCHARY** received M.Sc. degree from the Faculty of Engineering Cario Univiversity, Egypt in 1987 and he worked at the electronics research institute, Scientific Research Academy in Cario. He is interested in microwave components , integrated circuits, and microstrip antennas.