FREQUENCY AGILE CIRCULAR MICROSTRIP ANTENNAS

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ABSTRACT

A method to control the operating frequency of circular microstrip antennas has been investigated theoretically and experimentally. The method consists in the placement of shorting posts at appropriate locations within the input region of the antenna. The analytic and measured results have been compared to prove the validity of the models developed.

INTRODUCTION

Recently, Schaubert et al [1] described a technique for controlling the operating frequency of a rectangular microstrip antenna by using passive conducting posts at appropriate locations within the antenna's boundary. However, there are no satisfactory theoretical models which can adequately describe the performance of such antennas. It seems possible that circular microstrip antennas may also be tuned by using passive posts. However, no such information is presently available. The objective of this paper has been to gain sufficient understanding of the performance of such antennas and to develop theoretical models so that their design may be carried out efficiently.

THE NONUNIFORM TRANSMISSION LINE MODEL OF CIRCULAR MICROSTRIP ANTENNAS

Although various theoretical models are already available to predict the behavior of circular microstrip antenna, it is difficult to apply to tunable antennas having an arbitrary number of internal discontinuities. This restriction is removed in the present analysis which uses a nonuniform transmission line model for the input region of the antenna. In this model, the antenna is simulated as an asymmetrically excited radial waveguide loaded with passive posts and terminated by an equivalent boundary admittance at the radiating edge. Consider an untuned circular microstrip antenna with radius a and thickness d, as shown in Fig. 1, excited by a coaxial probe loaded at $\rho = \rho_0$, $\phi = 0^\circ$. The normalized mode admittance in the two regions can be shown as [2,3]

$$y_{m_1}(x) = j\frac{J_m'(x)}{J_m(x)} \tag{1}$$

in Region I where $0 \le \rho < \rho_0$, and

$$y_{m2}(x) = \frac{j + y_{t2}(y)ct_r(x,y)k_r(x,y)}{Ct_r(x,y) + jy_{t2}(y)k_r(x,y)} \tag{2}$$

in Region II where $\rho_0 < \rho \le a$, where

$$ct_r(x,y) = \frac{N_m'(x)J_m(y) - J_m'(x)N_m(y)}{J_m(x)N_m(y) - N_m(x)J_m(y)},$$

$$Ct_r(x,y) = \frac{J_m(x)N_m'(y) - N_m(x)J_m'(y)}{J_m'(x)N_m'(y) - N_m'(x)J_m'(y)},$$

$$k_r(x,y) = \frac{J_m(x)N_m(y) - N_m(x)J_m(y)}{J_m'(x)N_m'(y) - N_m'(x)J_m'(y)}, \tag{3}$$

$$x = k\rho_0,\ y = ka.$$

$y_{t2}(y)$ is the normalized boundary admittance and was reported elsewhere [3]. J_m and N_m represent the Bessel function of the first and second kind, and the prime sign represents differentiation with respect to the argument. The input impedance of the antenna is given by

$$Z_{in} = \sum_{m=0}^{\infty} Z_m(\rho_0)\frac{1}{y_{m_2}(\rho_0) - y_{m_1}(\rho_0)} \tag{4}$$

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where

$$Z_m = \frac{\eta d}{(1 + \delta_m)\pi\rho} = \text{normalizing impedance factor},$$

$$\eta = \sqrt{\mu_0/\varepsilon},$$

where μ_0, ε are the permeability and permittivity of the substrate material.

$$\delta_m = \begin{cases} 0 & m \neq 0 \\ 1 & m = 0 \end{cases}$$

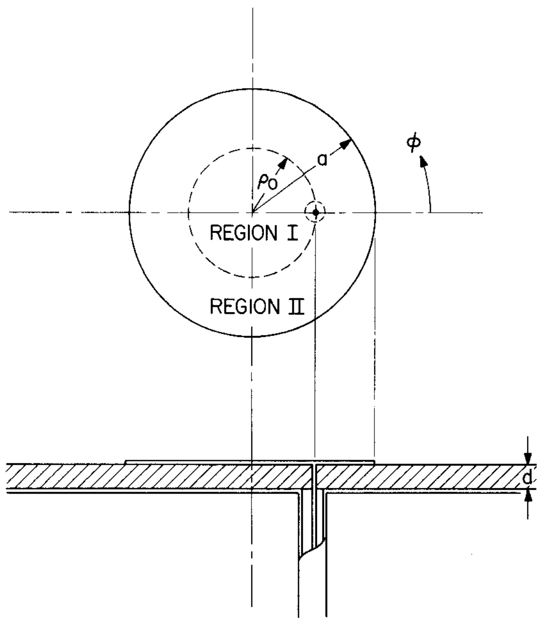

Fig. 1. A circular microstrip antenna showing the coaxial feed location and two source-free regions.

POST-TUNED ANTENNAS

To obtain the variation of the resonant frequency for antennas with tuning post(s), the transmission line circuit of the corresponding untuned antenna needs to be modified to account for the effects of the tuning post. This is done by inserting an equivalent post impedance to the modified transmission line circuit. The equivalent impedance of metallic posts in a radial waveguide has been previously determined by Sengupta et al. It is shown [3,4] that the existence of shorting posts produce pure inductive impedance in the equivalent transmission line at the position corresponding to the radial locations of the posts. By changing the number and locations of the posts, the resonant frequency can be tuned over a wide range. This frequency tuning effect may provide a method for multi-band frequency operation. In order to keep the radiation fields of different bands in the same polarization plane, shorting posts must be placed along radial lines at $\phi = 0^\circ$ or 180° (Fig. 1). To minimize the cross polarization induced by the posts, in practical application of tuned antennas, posts are arranged in diametrically opposed positions. [3]

EXPERIMENTAL RESULTS: COMPARISON WITH THEORY

Measurements and theoretical computations were performed for a 3.8 cm radius circular microstrip antenna. The antenna was made on a 1/16 inch, double-clad, Rexolite 1422 printed circuit board. The relative dielectric constant and loss tangent in the frequency range

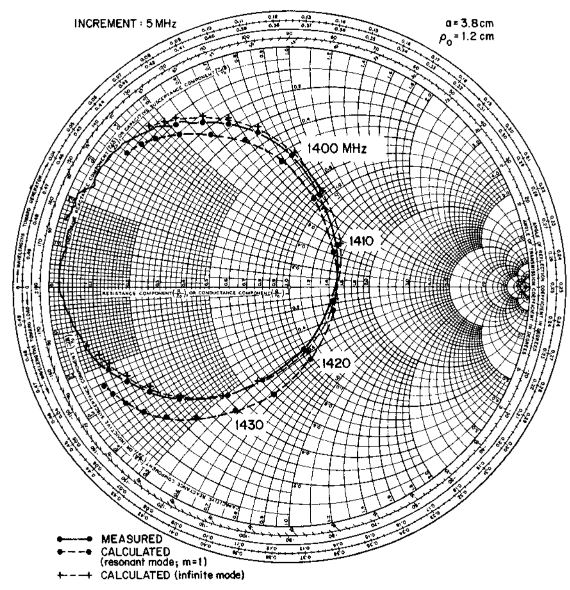

Fig. 2. First-mode input impedance of a circular microstrip antenna (without tuning posts).

considered (1.0-2.0 GHz) was approximately 2.54 and 0.001 respectively. Fig. 2 shows the measured impedance locus (solid line) for the lowest - order mode of an untuned antenna. The calculated values were obtained from eg (1) to (4) by varying the frequencies. The same antenna configuration is then used to study the post-tuned antenna. This is done by first drilling a small hole through the substrate, then inserting a metallic pin of radius 0.045 cm in the hole, and soldering the pin to both the patch and the ground plane. Theoretical and experimental resonant frequency vs. radial post locations for antenna with one and two diametrically opposed posts are shown in Fig. 3. Results of two pairs of diametrically opposed posts have also been computed by successive application of transmission line equations and are shown in table I where the corresponding measured results are also given.

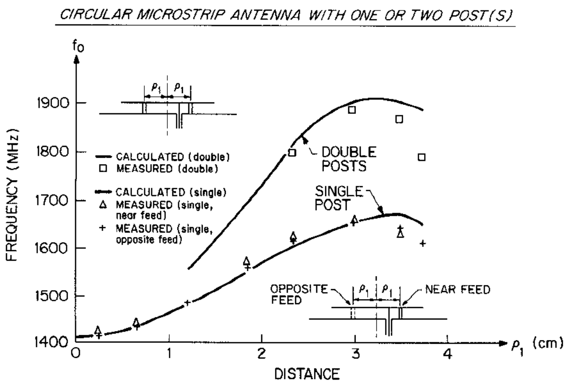

Fig. 3. The variation of resonant frequency with distance ρ_1. (ρ_1 is the distance between the post and the center line).

CONCLUSION

In summary, we have developed a simple but accurate analytical models for an untuned circular microstrip antenna. The model is then modified to represent the corresponding tuned antennas. The validity of the theory is proved by comparing the calculated results with the experimental results.

Table I. Calculated and Measured Values of Resonant Frequency and Input Resistance for a Circular Microstrip Antenna with Four Shorting Posts

(a = 3.8 cm, ρ_o = 1.2 cm, d = 0.159 cm, ε_r = 2.54, ρ_2 = 2.35 cm, ϕ_o = 0^o and 180^o, ρ_1 variable)

ρ_1 (cm)	CALCULATED		MEASURED	
	f_0 (MHz)	R_{IN} (Ω)	f_0 (MHz)	R_{IN} (Ω)
3.0	2050	48	2050	32.5
3.5	2108	62	2099	43.0
3.75	2080	42	2053	50.0

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