PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

MICROSTRIP ANTENNA ON A CONICAL SURFACE

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I. INTRODUCTION

Microstrip antennas have been intensively investigated primarily due to the inherent properties that they offer for the development of devices where low weight, reduced dimensions and conformal characteristics are important [1]. Studies concerning microstrip antennas on planar surfaces are very abundant while, on conical surfaces they are practically not available, although this type of geometry may be found in practical aerospace applications.

In this paper, a theoretical analysis of a microstrip antenna on a conical surface, fed by means of a coaxial line through the ground surface, is presented. A particular example of a microstrip patch antenna, operating in its fundamental mode, is examined.

Results for the input impedance, radiation pattern, quality factor, frequency bandwidth, efficiency and directivity are presented.

II. THEORY

The geometry used for the analysis of the microstrip antenna on a conical surface is shown in Fig. 1. Using the cavity model with magnetic side walls and assuming that (i) the dielectric substrate is very small, (ii) the curvature radius of the conical surface is very large and (iii) the distance from the patch to the cone apex is very large when compared with the wavelength in the dielectric, λ_g, the electric field in the cavity is considered as having only the component along the θ direction. The expression of this field includes spherical Bessel functions, associate Legendre functions and sine and cosine functions [2].

The input impedance is calculated following a procedure similar to that used by Luk <u>et al</u>. [3], for the antenna fed by means of a coaxial cable through the ground conical surface.

The radiated electric field, $\bar{E}(\bar{r})$ is obtained using the dyadic Green's functions formulation presented by Tai [4]:

$$\bar{E}(\bar{r}) = -j\, k_o\, \eta_o \iiint_{V'} \nabla \times \bar{\bar{G}}_{e2}(\bar{r}|\bar{r}') \cdot \bar{M}(\bar{r}')\, dV' \tag{1}$$

where $\bar{\bar{G}}_{e2}(\bar{r}|\bar{r}')$ is the dyadic Green's function of the electric type and second kind, k_o and η_o are the wave number and intrinsic impedance of free space, respectively. $\bar{M}(\bar{r}')$ is the magnetic current density of the source at the magnetic walls, calculated from:

$$\bar{M}(\bar{r}') = \frac{2}{j\omega\mu_o}\, \bar{E}_{\theta lm,1} \Big|_{walls} \times \hat{n} \tag{2}$$

For the evaluation of the input impedance and the radiated electric field, the convergence of the Gaussian hipergeometric series, associated with the Legendre polynomials of first and second kind has to be very carefully observed. In case of non convergent series, the convergence may be forced by means of Gaussian contiguous functions relations [5]. Although Tai [4] has not shown the second kind Legendre functions in the expressions of $\bar{\bar{G}}_{e2}(\bar{r}|\bar{r}')$, they have to be included in order to satisfy the finiteness condition of the radiated electric field at $\theta = 180°$.

III. RESULTS AND CONCLUSIONS

The theoretical development was applied for a particular microstrip patch antenna ($\phi_o = 9.17°$ in Fig. 1) on a conical surface with θ_o=33,9°, r_a=0.10 m and r_b = 0.129 m, fed at ϕ_1=0° and operating in the fundamental TM_{01} mode. An IBM PC CPU : 386 was used and the numerical calculations required approximately 15 hours of CPU time.

The total quality factor of the antenna was obtained as equal to Q_t = 94.69. This value included radiation, dielectric and conductor losses. Due to the small value of $\Delta\theta$ used, the losses due to the excitation of surface waves were neglected.

The input impedance of the cavity at the resonant frequency was obtained as a function of the feed position, $r = r_1$ and is shown in Fig. 2. Note that, for r_1 = 0.116 m, the input impedance is equal to zero. The introduction of a short circuit at r_1 = 0.116 m should not change much the behavior of the antenna for the TM_{01} mode, however, it would avoid the excitation of other modes, improving the spectral purity of the antenna. Note also that, for r_1 = 0.118 m the input impedance is equal to 50 ohms. With the feed point located at this position, the input impedance was calculated as function of frequency and the results are shown in Fig. 3.

The radiation pattern of this antenna in the $y = 0$ plane (half planes $\phi = 0°$ and $\phi = 180°$) is shown in Fig. 4. Note that a maximum of radiation occurs for $\theta = 138°$ and $\phi = 0°$. The influence of the cone apex is certainly present in this result. At this direction the directivity has a value of D = 5.155 (7.12 dB). The antenna bandwidth is found equal to 1.1%. The antenna efficiency, considering only radiation, dielectric and ohmic losses was found to be equal to 68.82%.

Within the framework of this approximation, the resonant frequencies are not affected by curvature. However, the radiation patterns are significantly affected.

The authors wish to express their gratitude to Professor José Busnardo Neto, from the Institute of Physics of UNICAMP, for his valuable contribution in the calculation of the Legendre functions. This work was partially supported by the following Brazilian Agencies: CNPq, CAPES, FAPESP, FINEP and TELEBRÁS.

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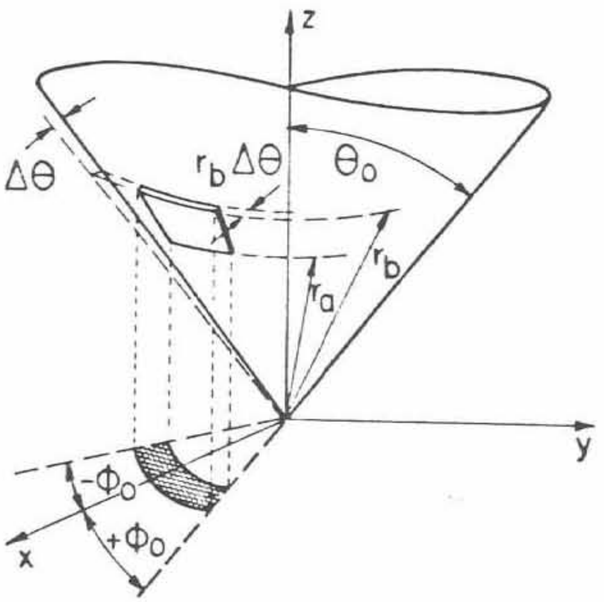

Fig. 1. Geometry of a microstrip antenna on a conical surface.

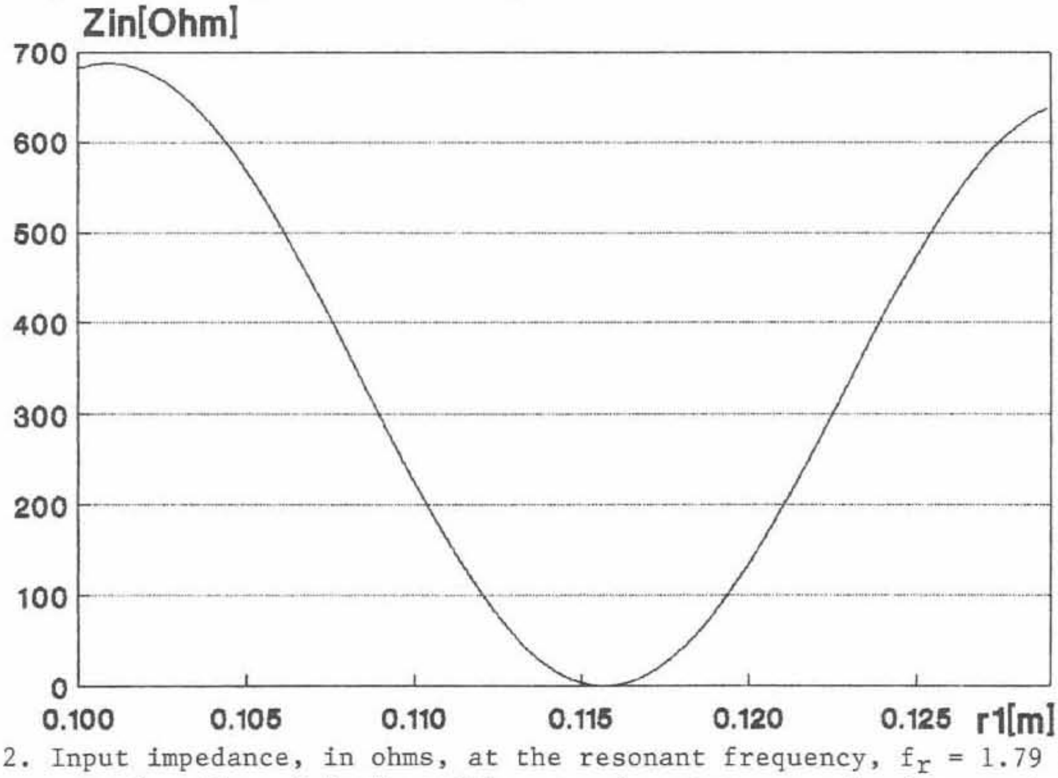

Fig. 2. Input impedance, in ohms, at the resonant frequency, f_r = 1.79 GHz, as a function of feed position r_1, in meters, varying from r_a to r_b. $\theta_o = 33.9^o$, r_a = 0.10 m, r_b = 0.129 m, $\phi_o = 9.17^o$, $\Delta\theta=1.146^o$, $\phi_1=0^o$ and ε_r = 10.68.

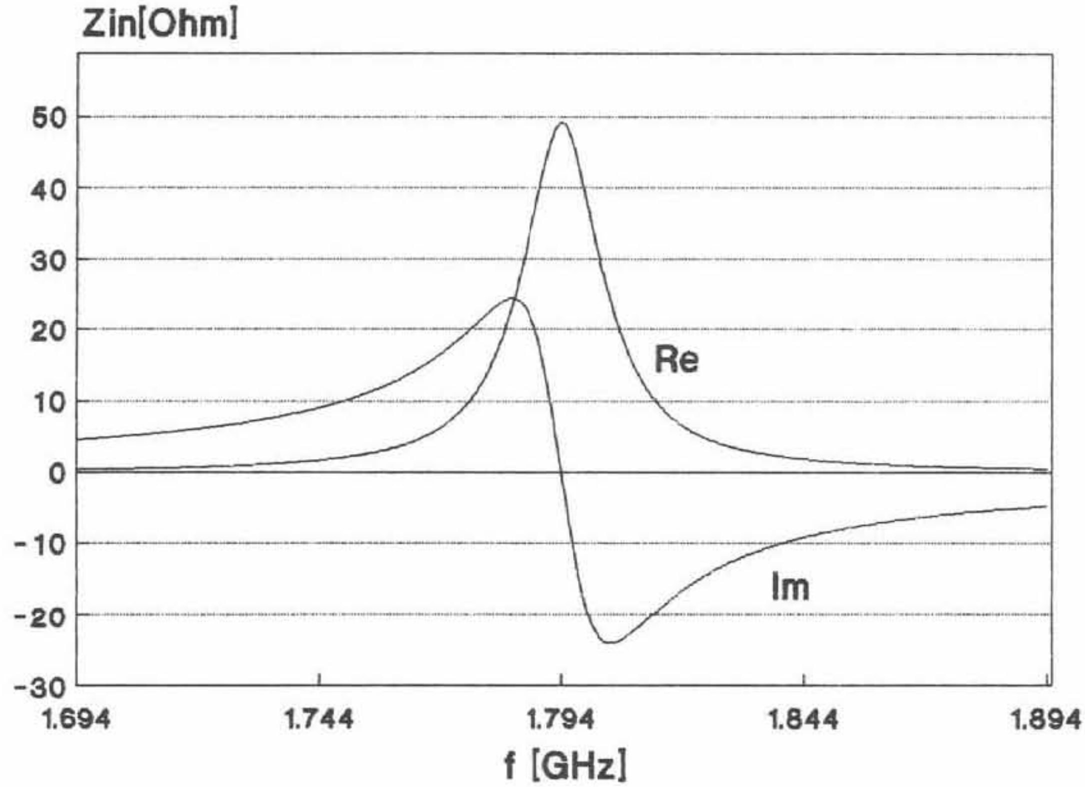

Fig. 3. Resistive and reactive components of the input impedance, in ohms, as a function of frequency, in GHz. θ_o=33.9°, r_1 =0.118 m, ϕ_o=9.17°, $\Delta\theta$=1.146°, ϕ_1=0° and ε_r=10.68.

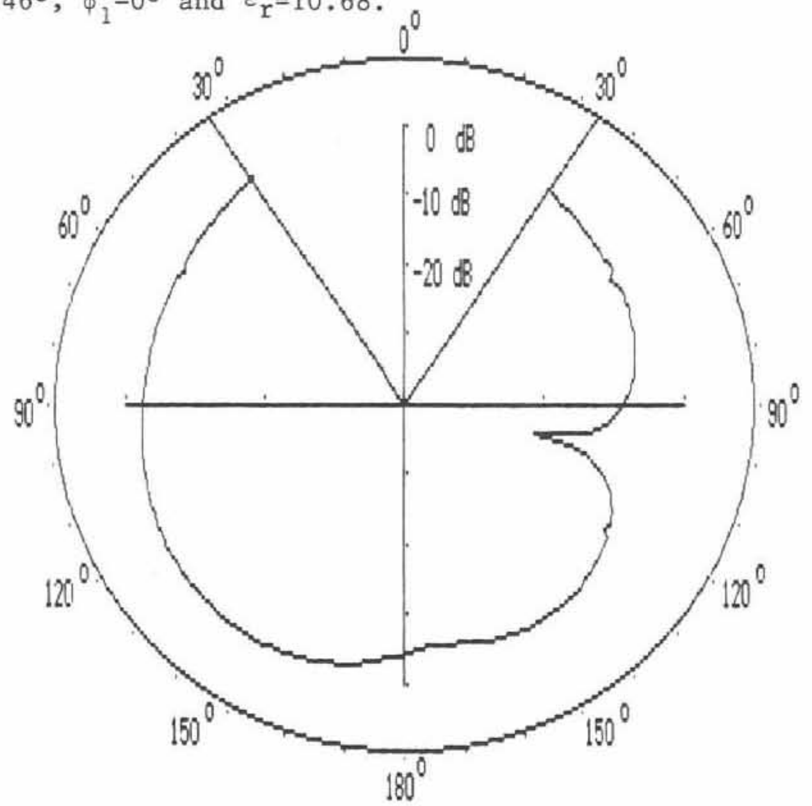

Fig. 4. Radiation pattern, in decibels, in the y=0 plane (half planes ϕ=0° and ϕ=180°) for the antenna operating in the TM_{01} mode. θ_o = 33.9°, r_a = 0.10 m, r_b = 0.129 m, ϕ_o = 9.17°, $\Delta\theta$ = 1.146° and ε_r = 10.68.