PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

MICROSTRIP ANTENNA FAMILY-ANALYSIS AND DESIGN

Mohammed A. Sultan

Department of Electronics and Electrical Technology
Benha Higher Institute of Technology
Benha, EGYPT

Recently, three simple theories [1] have been introduced in the literature to solve for the main serious problems. This made it possible to correlate the sheet thickness, permittivety (including the limiting case of free space), and the patch dimensions to the required specifications. As a result, the sheet thickness that gives the largest "Figure of Merit" (Gain-Bandwidth product) was calculated with the ability to choose the antenna shape and parameters that match with the given specifications. In this paper, the author second and third theories are used to derive the experessions for radiation resistance, directivity, bandwidth and other characteristics of the standard open-ring microstrip antenna.

The open-ring microstrip antenna and the top view of the equivalent cavity model are shown in Fig.1. The model includes the effects of fringing fields, dispersion, and the microstrip curvature. Fig. 2 shows the equivalent magnetic current sources $\overline{M}$ associated with the structure. The radiation fields derived from these sources are given by [2],

$$E_\theta = -j\frac{k_o}{\varepsilon_o}\sum_{i=1}^{4} F_\phi \text{ (due to } \bar{M}_i) \qquad (1)$$
$$E_\phi = j\frac{k_o}{\varepsilon_o}\sum_{i=1}^{4} F_\theta \text{ (due to } \bar{M}_i)$$

The total power radiated by the open-ring can be evaluated either by numerically computing the surface integral of the pointing vector over a closed spherical surface

$$P_r = \frac{1}{4\eta_o}\int_0^{\pi}\int_0^{2\pi}(|E_\theta|^2 + |E_\phi|^2)\, r^2 \sin\theta \, d\phi \, d\theta \qquad (2)$$

or by making use of the author second and third theories. This leads to the calculation of the radiated power where the other radiation characteristics can be obtained in a straight forward manner. For example, the directivity for any gap angle and any annular width for all modes is found to be:

$$D = \frac{1}{2\eta_o} \frac{\mathrm{Re}(|E_\theta|^2+|E_\phi|^2)|_{\theta=0}}{P_r/4\pi r^2}$$

$$= \begin{cases} \dfrac{h^2k_o^2E_o^2}{120\,\pi^2 P_r}\left[\dfrac{K_1-K_2}{1-\nu^2} - \displaystyle\int_{r_{ie}}^{r_{ae}} E_z(\rho')|_{\phi=0}\,d\rho'\right]^2 (1\pm\cos\alpha) & (3) \\ \dfrac{h^2k_o^2E_o^2}{240\ P_r}(K_1-K_2)^2;\ \nu=1 \text{ for } \alpha=360° \text{ with } TM_{2m} \text{ modes} & (4) \\ \dfrac{h^2k_o^2E_o^2}{960\ P_r}(K_1-K_2)^2;\ \nu=1 \text{ for } \alpha=180° \text{ with } TM_{1m} \text{ modes} & (5) \end{cases}$$

where the positive and negative signs refer to the odd-and-even modes respectively and,

$$E_z = E_o\left[J_\nu(k_{\nu m}\rho) - \frac{J'_\nu(k_{\nu m}r_{ie})}{Y'_\nu(k_{\nu m}r_{ie})}Y_\nu(k_{\nu m}\rho)\right]\cos\nu\phi$$

with $\nu = n\pi/\alpha$, $K_1 = r_{ae}A_\nu(r_{ae})$, $K_2 = r_{ie}A_\nu(r_{ie})$

$A_\nu(x) = J_\nu(k_{\nu m}x) - C_1Y_\nu(k_{\nu m}x)$, $C_1 = \dfrac{J'_\nu(k_{\nu m}r_{ie})}{Y'_\nu(k_{\nu m}r_{ie})}$

The results for the antenna radiation resistance and directivity for some typical cases of a half-ring structure excited with TM_{11} mode are shown in Figs. 3 and 4 respectively. The results are found to be approximately four times and the same (respectively) as that of a closed-ring structure having the same parameters and excited with the same mode [3,4]. This is because f_r and the field distribution underneath their patches are the same and the radiated power of the half-ring is given by,

$$P_r = \frac{1}{4}\left[P_r - P_c - P_d\right]_{\text{closed-ring}} \qquad (6)$$

where P_c and P_d are the power loss in the conductor and the dielectric medium. For arbitrary structures that can not be shaped from the open-ring, new theories have been developed and examined to analyze and design any microstrip antenna for all modes. This includes the antenna family and covers the phased-array antenna system problems.

REFERENCES

1. Sultan, M.A., "Cad of any microstrip antenna for any mode of excitation", URSI Radio Science Meeting, San Jose, California, U.S.A., June 1989, p40.

2. Sultan, M.A., "The radiation characteritics of open-and-closed ring microstrip antennas", Ph.D. Dissertation, Orgon State University, U.S.A., 1986.

3. Sultan, M.A., and Tripathi, V.K., "Radiation characteristics of annular microstrip antenna", IEEE AP-S Int. Symp. Digest, Vancouver, B.C., Canada, June 1985, pp 421-424.

4. Sultan, M.A., "Extended analysis of a closed-ring microstrip antenna", IEE Proceeding, Vol. 136, Pt.H, No.l, Feb. 1989, pp 67-69.

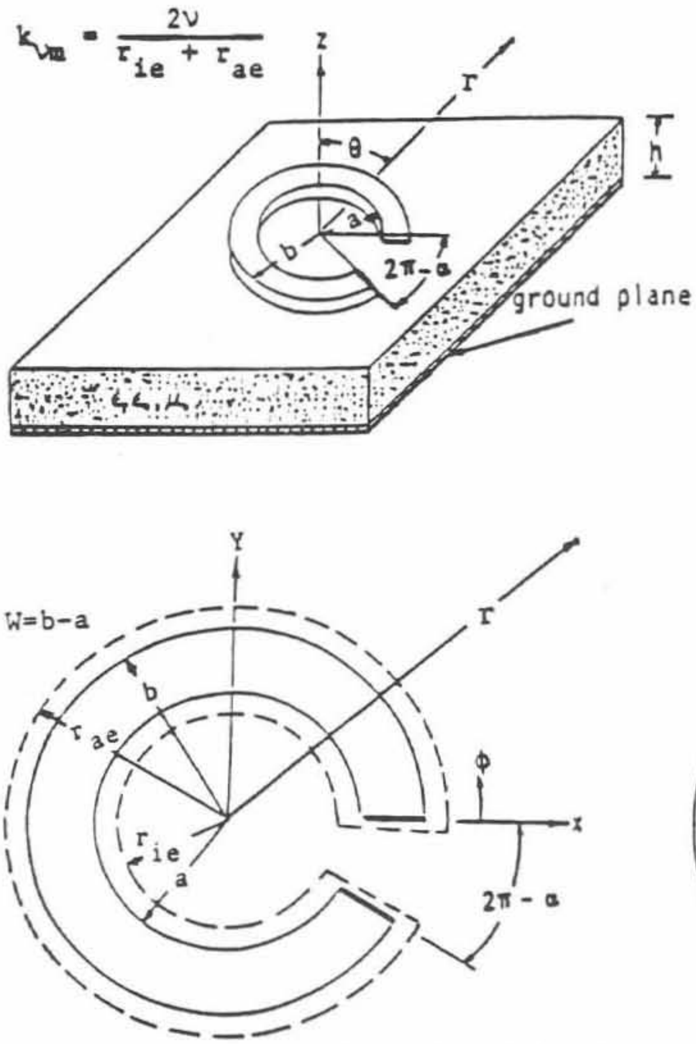

Fig. 1: Open-ring microstrip antenna and the top view of the cavity model.

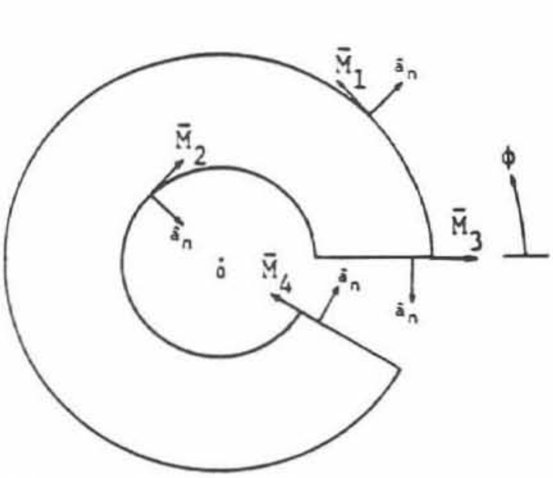

Fig. 2: The equivalent magnetic current sources of the open-ring antenna.

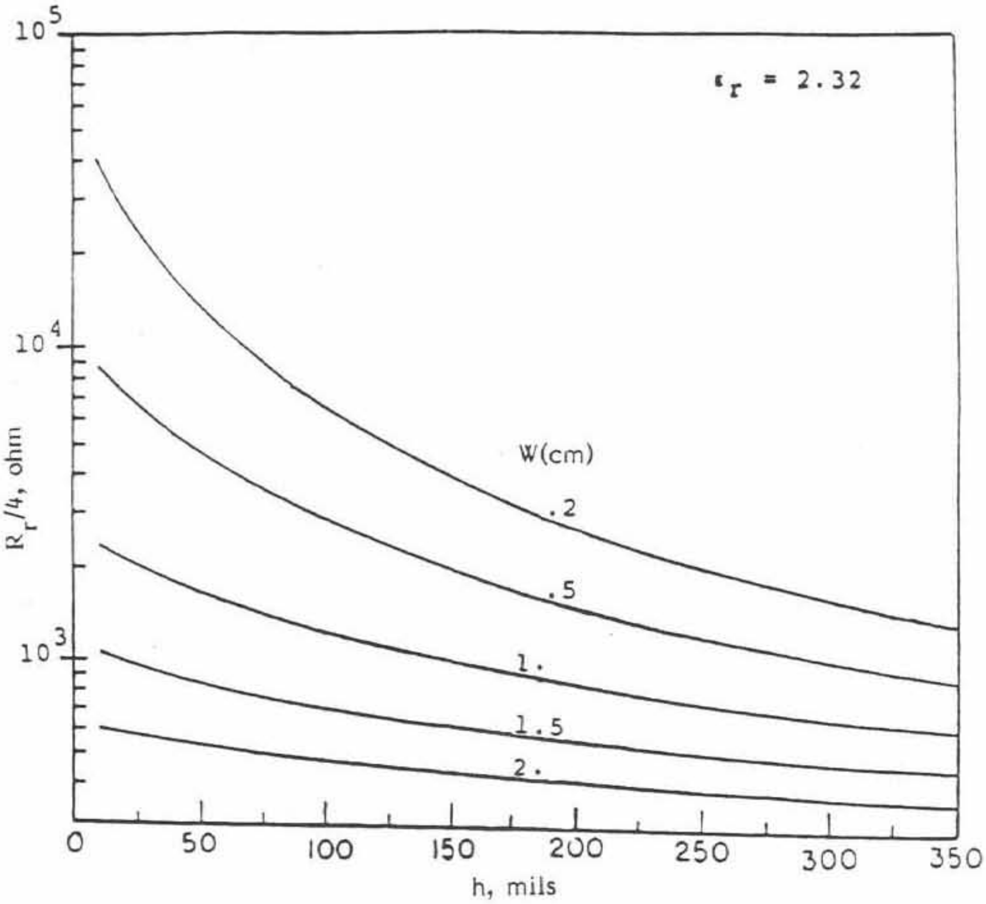

Fig. 3: Radiation resistance of a half-ring antenna for the TM_{11} mode, outer-edge fed elements.

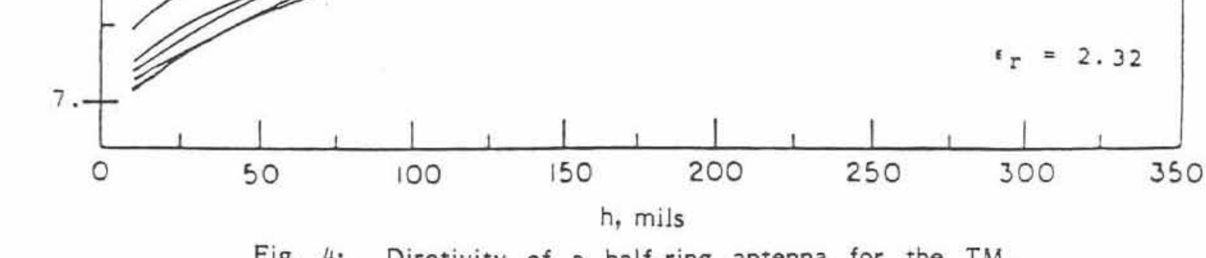

Fig. 4: Diretivity of a half-ring antenna for the TM_{11} mode, outer-edge fed elements.