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INPUT IMPEDANCE OF RECTANGULAR MICROSTRIP ANTENNAS ON NON-RADIATING EDGES FOR DIFFERENT FEED SIZES

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Abstract—Closed-form expressions for the input impedance of half-wavelength rectangular microstrip antennas fed by coaxial connectors of different sizes at any point on any one of the non-radiating edges and open-circuited at the other ends are derived. Good agreement between computed and measured data is obtained.

1. SYMBOLS

R_{in} input resistance
X_{in} input reactance
$R_{in}(nr)$ input resistance on non radiating edges [8]
$X_{in}(nr)$ input reactance on non radiating edges [8]
a radiating edge
b Non-radiating edge/length of the rectangular microstrip antenna = $\lambda_g/2$
λ_g guide wavelength
ε_r relative dielectric constant
h dielectric substrate thickness
ε_{eff} effective dielectric constant
f_{rect} desired resonant frequency of rectangular microstrip antenna
f_r resonant frequency at which the rectangular microstrip antennas are to be designed for obtaining the desired resonant frequency f_{rect}
f frequency of operation
Δf_r $f_{rect} - f$

d diameter of the feed size in inches

This paper shows the effect of feeding point at the edge (specially at the non-radiating edge). When the rectangular microstrip antennas are fed inside, the input impedance decreases.

2. INTRODUCTION

Microstrip antennas of different configurations like square, rectangular, circular, trapezoidal, elliptical, etc. are widely used because of their many advantages over conventional antennas such as low cost, light weight, reproducibility, ease of fabrication, etc. Several authors have studied [1–5] different characteristics on microstrip antennas. Closed-form expressions have been developed [6–8] for the input impedance of rectangular microstrip antennas. This communication attempts the development of empirical expressions for the input impedance of half-wavelength rectangular microstrip antennas for different feed sizes.

3. DESIGN

A number of rectangular microstrip antennas of various a/h ratios and of length $\lambda_g/2$ and fed at any point on any one of the non-radiating edges by coaxial connectors, were constructed on PTFE substrates of different ε_r and h at the center frequency ranging from 1 to 10 GHz as shown in Figure 1. The values of $\lambda_g/2$ were calculated from [9].

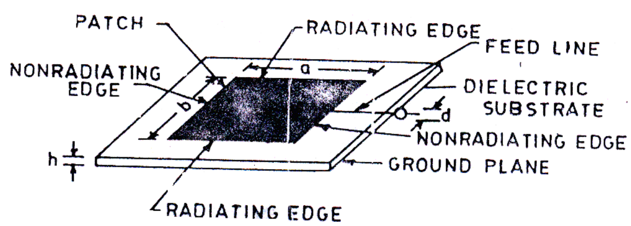

Figure 1. Rectangular microstrip antenna.

4. MEASUREMENTS

R_{in} and X_{in} of the rectangular microstrip antennas were measured over a range of frequencies centered around desired resonance frequency by an HP 8410B network analyzer connected to an HP 9000 computerized set-up.

5. EMPIRICAL EXPRESSIONS FOR f_{rect}

f_{rect} values observed from the network analyzer for different feed sizes were different from f_r because of the fringing field. f_{rect} values were plotted with the f_r values with $a/h, \varepsilon_r, |y|$ and d as parameters as shown in Figure 2. Using curve fitting technique [10], the following expression was obtained relating the f_{rect} and f_r:

$$f_{rect} = f_r \log_{10}\left(\frac{19 + a/b}{2}\right)\left(1-\frac{\varepsilon_{eff}}{14.33\varepsilon_r}\right)\left(1-\frac{b/2 - |y|}{6.32b}\right)\left(\frac{\sqrt{d}+0.157}{d^{0.32}}\right) \quad (1)$$

Equation (1) has been developed with reference to the co-ordinate axis of Figure 3. f_{rect} values calculated with $d = 1/16''$, using expression (1) were compared with the measured data of Kundu et al. [8] in Figure 4. The agreement was found to be excellent.

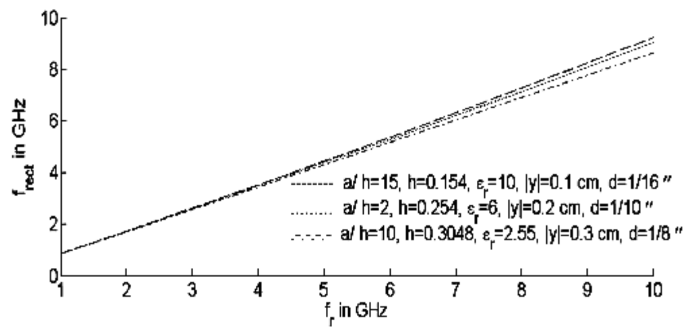

Figure 2. f_{rect} versus f_r plot for various $\varepsilon_r, a/h, |y|$, and d values.

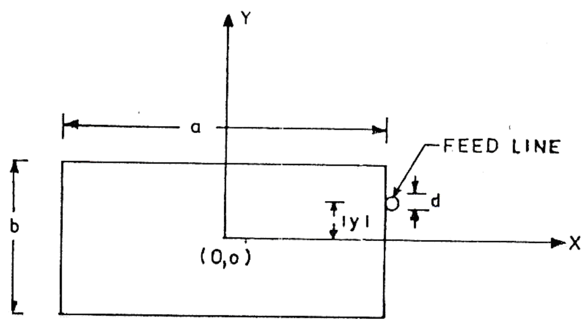

Figure 3. Coordinate system used in the analysis showing $|y|$.

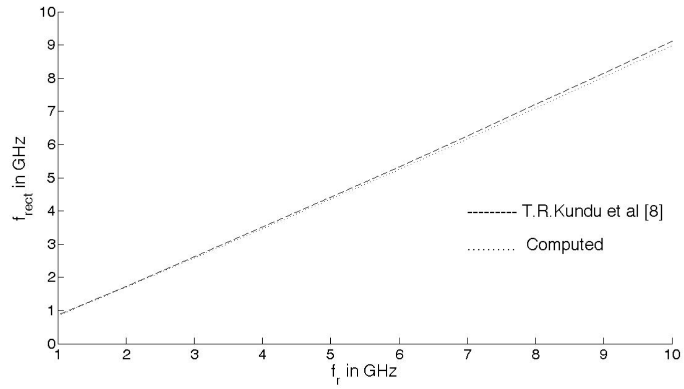

Figure 4. f_{rect} versus f_r plot for $\varepsilon_r = 2.55$, $a/h = 10$, $h = 0.3048$, $|y| = 0.3\,\text{cm}$, and $d = 1/16''$.

6. EMPIRICAL EXPRESSIONS FOR R_{in} AND X_{in}

R_{in} and X_{in} values measured from the network analyzer were plotted as a function of f, with $\varepsilon_r, f_{rect}, a/h, |y|$, and d as parameters. Some typical plots are shown in Figures 5 and 6. By the principle of curve fitting technique, the following expressions were obtained.

$$R_{in} = \left(\frac{\sqrt{d} + 0.06}{d^{0.42}}\right) R_{in}(nr) \tag{2}$$

and

$$X_{in} = \left(\frac{d - 0.15}{\sqrt{d}} + 1.35\right) X_{in}(nr) \tag{3}$$

Where,

$$R_{in}(nr) = \frac{A f_{rect} \varepsilon_r \left(\varepsilon_r^2 + 49.5\right)\left(\frac{a}{h} + 23\right)\cos(\Delta f_r)}{6123.6\left(1 + 943.98(\varepsilon_r - 2.55)|\Delta f_r|^{2.6}\right)\left(1 + \frac{2.8}{|\Delta f_r|}\right)} \tag{4}$$

and

$$X_{in}(nr) = \frac{B f_{rect} \varepsilon_r \left(\varepsilon_r^2 + 8.5\right)\left(\frac{a}{h} + 23\right)\sin(\Delta f_r)}{5588.77\left(|\Delta f_r| + 0.005\right)} \tag{5}$$

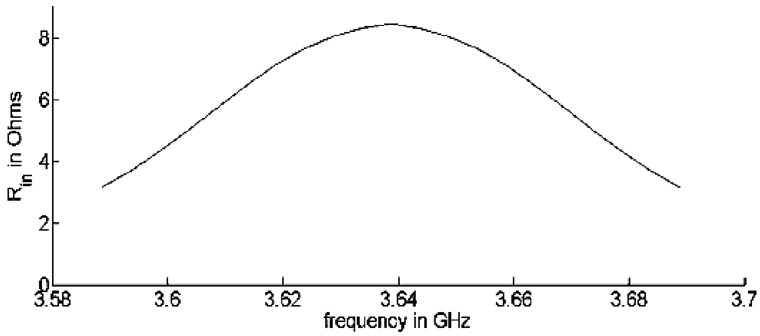

Figure 5. R_{in} versus frequency plot for $\varepsilon_r = 6$, $a/h = 8$, $h = 0.254$, $|y| = 0.2\,\text{cm}$, and $d = 1/8''$.

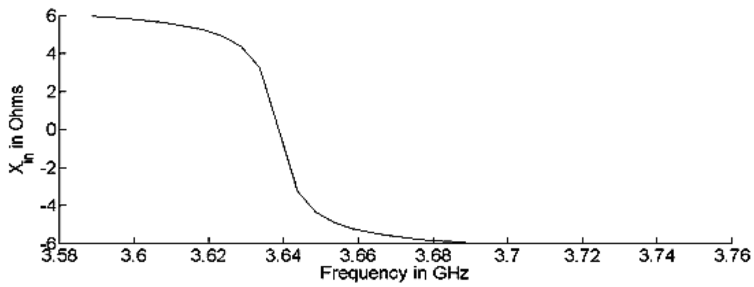

Figure 6. X_{in} versus frequency plot for $\varepsilon_r = 6$, $a/h = 8$, $h = 0.254$, $|y| = 0.2\,\text{cm}$, and $d = 1/8''$.

$$A = \left(1 - \frac{\frac{b}{2} - |y|}{3.83b}\right) \tag{6}$$

and

$$B = \left(1 - \frac{\frac{b}{2} - |y|}{7.21b}\right) \tag{7}$$

In the above equations f_{rect} and Δf_r are expressed in GHz and

$$-0.05 \leq \Delta f_r \leq +0.05$$
$$2.55 \leq \varepsilon_r \leq 10$$
$$1.0 \leq f_r \leq 10.0$$
$$1/16'' \leq d \leq 1/6''$$

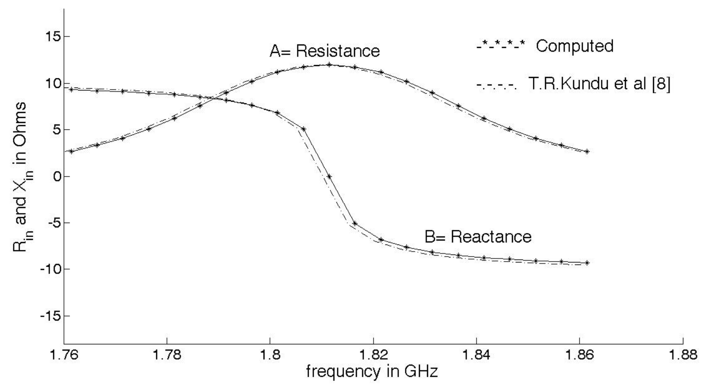

Figure 7. $R_{in}$and X_{in} versus frequency plot for $\varepsilon_r = 10$, $a/h = 15$, $h = 0.154$, $|y| = 0.3\,\text{cm}$, and $d = 1/16''$.

7. CALCULATION OF R_{in} AND X_{in}

R_{in} and X_{in} values of a rectangular microstrip antenna fabricated on a dielectric substrate having ε_r within a certain range of values and for a frequency range of ± 0.05 Ghz around f_{rect}, fed at any point on any one of the non-radiating edges by coaxial connectors of different sizes may be calculated as follows :

Step 1. Substitute the value of the $f_r, |y|$ and d and obtain the corresponding value of f_{rect} from equation (1).

Step 2. Compute the values of R_{in} and X_{in} from equations (2) and (3) respectively, with the known values of f_{rect} calculated in step 1.

8. RESULT

The theoretical values of R_{in} and X_{in} for the rectangular microstrip antennas were calculated using equations (1)–(3) and were compared with the measured data of Kundu et al. [8]. One typical plot is shown in Figure 7. The agreement was found to be excellent.

9. CONCLUSIONS

Empirical expressions for the computation of the input impedance of half-wavelength rectangular microstrip antennas fed by coaxial connectors of different sizes at any point on any one of the non-radiating edges have been developed. The advantages of this method are that it can be used by practically any antenna designer without any background in this area and that the computation time is negligible small.

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