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 $= \frac{\lambda_g}{2}$
$\lambda_g$ guide wavelength
$\varepsilon_r$ relative dielectric constant
$h$ dielectric substrate thickness
$\varepsilon_{eff}$ 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
$\Delta f_r$ $f_{rect} - f$
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 \( \varepsilon_r \) 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.](image)

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.

d diameter of the feed size in inches
5. EMPIRICAL EXPRESSIONS FOR $f_{\text{rect}}$

$f_{\text{rect}}$ values observed from the network analyzer for different feed sizes were different from $f_r$ because of the fringing field. $f_{\text{rect}}$ 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 $f_{\text{rect}}$ and $f_r$:

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

Equation (1) has been developed with reference to the co-ordinate axis of Figure 3. $f_{\text{rect}}$ 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](image)

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

![Figure 3](image)

**Figure 3.** Coordinate system used in the analysis showing $|y|$. 
6. EMPIRICAL EXPRESSIONS FOR \( R_{\text{in}} \) AND \( X_{\text{in}} \)

\( R_{\text{in}} \) and \( X_{\text{in}} \) values measured from the network analyzer were plotted as a function of \( f \), with \( \varepsilon_r, f_{\text{rect}}, a/h, |y|, \) 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.

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

and

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

Where,

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

and

\[
X_{\text{in}}(nr) = \frac{B f_{\text{rect}} \varepsilon_r (\varepsilon_r^2 + 8.5) \left( \frac{a}{h} + 23 \right) \sin(\Delta f_r)}{5588.77 (|\Delta f_r| + 0.005)} \tag{5}
\]
Figure 5. $R_{in}$ versus frequency plot for $\varepsilon_r = 6$, $a/h = 8$, $h = 0.254$, $|y| = 0.2$ cm, and $d = 1/8''$.

Figure 6. $X_{in}$ versus frequency plot for $\varepsilon_r = 6$, $a/h = 8$, $h = 0.254$, $|y| = 0.2$ 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 $\Delta f_r$ 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 $\varepsilon_r = 10$, $a/h = 15$, $h = 0.154$, $|y| = 0.3$ 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 $\varepsilon_r$ within a certain range of values and for a frequency range of $\pm 0.05$ 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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REFERENCES


