Analysis and Design of Rectangular Microstrip Antenna in X Band

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Abstract – In this paper we have analysed and designed a rectangular microstrip antenna in X band. The desired frequency is chosen to be 9 GHz at which the patch antenna is designed. After calculating the various parameters such as width, effective dielectric constant, effective length and actual length, the antenna impedance is matched to 50 ohm of coaxial feed. The VSWR and return loss are observed followed by the radiation pattern. These results are obtained through MATLAB which are later on verified using Computer software simulation (CST).

Keywords – Rectangular Microstrip Antenna, Impedance, Return loss, VSWR, radiation pattern.

I. INTRODUCTION

In recent years the area of microstrip antenna has seen many inventive works and is one of the most dynamic fields in communication field. For simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common. Among these the rectangular and circular patches are probably the most extensively used patches. As it is very easy to analyze a rectangular microstrip antenna using transmission and cavity model so in our paper we shall be designing a rectangular microstrip antenna using cavity model in X band. The details of the designing are given in the following sections.

II. THEORETICAL CONSIDERATIONS

The equivalent of Rectangular Microstrip Antenna(RMSA) is represented as a parallel combination of resistor R, inductor L, and capacitor C as shown in figure 1. The values of R, L and C are given below which are based on model expansion cavity modal [2].

![Fig. 1 Equivalent circuit of RMSA](image-url)

Here Rp and Xp are added in the model due to the effects of coaxial probe feed. According to modal expansion cavity the values of L, C, R are calculated [3]

\[
C = \frac{\varepsilon_r \varepsilon_0 W}{2h} \cos^{-1} \left( \frac{\sqrt{\varepsilon_r} \pi}{2} \right) \\
L = \frac{1}{\omega \varepsilon_0 \varepsilon_r C} \\
R = \frac{Q_r}{\omega C} \\
Q_r = \frac{\sqrt{\varepsilon_r} c}{4f_c h}
\]

(1) (2) (3) (4)

Where c is the velocity of light \(\omega = 2\pi f_c\), \(f_c\) the designed frequency, the effective permittivity of the substrate material, \(l\) is the length of the patch, \(W\) the width of the patch, and \(h\) the thickness of the substrate.

A. Parameters of Rectangular microstrip Antenna (RMSA)

The parameters of RMSA such as width, effective dielectric constant, effective length, length extension and actual length are shown in equation 5,6,7,8, and 9 respectively.

The width of the Microstrip patch antenna is given by equation (5) as:

\[
W = \frac{c}{2 f_c \sqrt{\varepsilon_r + 1}}
\]

(5)

\[
\varepsilon_{\text{eff}} = \frac{\varepsilon_r - 1}{2} + \frac{\varepsilon_r - 1}{2} \left( 1 + \frac{12h}{W} \right)^{-1}
\]

(6)

\[
l_{\text{eff}} = \frac{c}{2 f_c \varepsilon_{\text{eff}}}
\]

(7)
B. Impedance

The impedance of RMSA is obtained from figure 1

\[
Z_{\text{in}} = \frac{R_0 L^2}{X} + jR_0^2(\omega L - \omega^3 L^2 C)
\]

(10)

Where

\[
X = R^2 \left( 1 - \omega^2 LC \right) + \omega^2 L^2
\]

(11)

Separating the real and imaginary parts of the impedance of RMSA one gets

\[
\text{Re}(Z_{\text{in}}) = \frac{R_0 L^2}{X}
\]

(12)

\[
\text{Im}(Z_{\text{in}}) = \frac{R_0^2(\omega L - \omega^3 L^2 C)}{X}
\]

(13)

Hence the input impedance of the circuit is \( Z_0 = Z \). The reflection coefficient (\( \rho \)) can be calculated as

\[
\rho = \frac{Z_{\text{in}} - Z_0}{Z_{\text{in}} + Z_0}
\]

(14)

Where \( Z_{\text{in}} \) is input impedance of RMSA, \( Z_0 \) is impedance of the coaxial feed (50 \( \Omega \)).

Hence VSWR is calculated as

\[
\text{VSWR} = \frac{1 + \rho}{1 - \rho}
\]

(15)

The Return loss of antenna is given by

\[
\text{RL} = -10 \log \left( \frac{1}{\rho^2} \right)
\]

(16)

C. Radiation pattern

The radiation pattern of Rectangular microstrip antenna is calculated using equation 17 and 18.

\[
E_\theta = -jV k_0 \frac{W e^{-j k_0 r}}{\pi r} \cos(k_0 \cos(\theta))
\]

(17)

\[
E_\phi = -jV k_0 \frac{W e^{-j k_0 r}}{\pi r} \cos(k_0 \cos(\theta))
\]

(18)

Where \( V \) is the radiating edge voltage, \( r \) is the distance of an arbitrary point; \( k \) is the \( k_0 \varepsilon_r \), \( k_0 \) is the \( 2\pi/\lambda \); \( W \) is the width of the patch; and \( l \) is the length of the patch.

II. DESIGN CONSIDERATION

The parameters of Rectangular Microstrip Antenna is calculated using Mat lab and the following table is obtained

| TABLE I |
| PARAMETERS OF RMSA |
| Parameters | Values |
| Substrate material | RT Duroid 5870 |
| Relative permittivity of the substrate | 2.23 |
| Thickness of the dielectric substrate | 0.159 cm |
Design frequency | 9GHz
---|---
Effective dielectric constant | 2.0075
Effective length | 1.18cm
Length extension | 8.1283e-002cm
Length(actual) | 1.01 cm
Width | 1.39 cm
Resistance | 50.2Ω
Inductance | 11.3 nH
Capacitance | 2.756pF

### III. RESULTS AND DISCUSSION

The theoretical results were obtained by considering an equivalent circuit of RMSA and using MATLAB for calculating various parameters. The design was then simulated on CST software. The model was designed to match 50 ohm of the coaxial probe feed. A glance at the model designed in CST software can be done in figure 2, 3 and 4 given below.

The results obtained from MATLAB programming were then compared with the results from simulated model using CST and verified. The experimental results matched closely with the theoretical values.

![Fig. 2 RMSA model designed using CST](image)

![Fig. 3 Top view showing patch, coaxial feed of the model](image)

![Fig. 4 Lateral view of the model](image)

![Fig. 5 Variation of Real [Zin] with frequency](image)

![Fig. 6 Variation of Imaginary [Zin] with frequency](image)

The impedance of RMSA is matched with the coaxial feed of 50 ohm. And the results are seen in Figure 5 and 6. From figure 5 it is observed that the impedance matching is perfect. The real part of impedance is equal to the 50 ohm of coaxial feed. The imaginary part of impedance is zero at resonant frequency which can be seen in figure 6. It is also observed that the theoretical result and simulated result are perfectly matched.
From figure 7 it can be seen that the matching is perfect and the value of VSWR are 1.004 which is close to the ideal value of 1. The return loss is also found to be minimum. At our designed frequency of 9 GHz RMSA return loss is minimum found to be -122.7 dB (theoretical).

The Radiation pattern of the designed antenna is shown using CST software.

IV. CONCLUSION

It is therefore concluded that our Rectangular microstrip antenna is perfectly designed at 9 Ghz with a Bandwidth of 2.9%.

REFERENCES
