International Journal of Engineering Research & Management Technology
ISSN: 2348-4039
November- 2014 Volume 1, Issue-6
Email: editor@ijermt.org
www.ijermt.org

Design and Simulation of Multiband Patch Antenna for Mobile Communication

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ABSTRACT:
In this paper we have analyzed and designed a Design of microstrip antenna in mobile band. The desired frequency is chosen to be 9 GHz at which the patch antenna is designed. After calculating the various parameters such a 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).

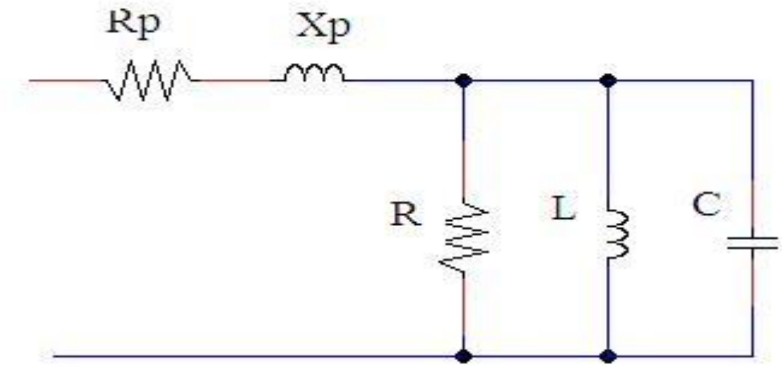
Keywords—Rectangular Microstrip Antenna, Impedance, Return loss, VSWR, radiation pattern.

1. INTRODUCTION

In recent year the area of microstrip antenna has seen much inventive work 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 circular patches are probably the most extensively used patches. A it is very easy to analyze a design of microstrip antenna using transmission and cavity model so in our paper we shall be designing a Design of Microstrip antenna using cavity model in mobile band. The detail of the designing is given in the following sections.

2. THEORETICAL CONSIDERATION

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



Here R_p and X_p are added in the model due to the effect of coaxial probe feed. According to modal expansion cavity the value of L, C, R are calculated [3].

$$C = \varepsilon_0 \frac{(\varepsilon_e l W)}{2h} \cos^{-1} \frac{(y_0 \pi)}{l} \quad (1)$$

$$L = \frac{1}{\omega^2 C} \quad (2)$$

$$R = \frac{Q_r}{\omega C} \quad (3)$$

$$Q_r = \frac{\sqrt{\varepsilon_r}.c}{4fh} \quad (4)$$

Where c is the velocity of light $\omega=2\pi f_r$, f_r 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. Parameter of Microstrip Antenna (RMSA)

The parameter of RMSA such a 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:

$$W = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (5)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{W}\right)^{\frac{-1}{2}} \quad (6)$$

$$l_{eff} = \frac{c}{2 f_o \varepsilon_{reff}}$$

Fig. 1. Equivalent circuit of RMSA (7)

$$\Delta l = 0.412h \cdot \frac{(\varepsilon_{reff} + 0.3) \cdot \left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258) \cdot \left(\frac{W}{h} + 0.8\right)} \quad (8)$$

$$l = l_{eff} - 2\Delta l \quad (9)$$

B**. Impedance**

The impedance of RMSA is obtained from Fig. 1.

$$Z_{in} = \frac{R\omega^2 L^2 + jR^2(\omega L - \omega^3 L^2 C)}{X} \quad (10)$$

Where

$$X = R^2(1 - \omega^2 LC)^2 + \omega^2 L^2 \quad (11)$$

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

$$Re(Z_{in}) = \frac{R\omega^2 L^2}{X} \quad (12)$$

$$Im(Z_{in}) = \frac{R^2(\omega L - \omega^3 L^2 C)}{X} \quad (13)$$

Hence the input impedance of the circuit is $Z_{in} = Z$. The reflection coefficient (ρ) can be calculated as

$$\rho = \left| \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \right| \quad (14)$$

Where Zin is input impedance of RMSA, Z_o is impedance of the coaxial feed (50 Ω).

Hence VSWR is calculated as

$$VSWR = \frac{1 + \rho}{1 - \rho} \quad (15)$$

The Return loss of antenna is given by

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

(16

C. Radiation Pattern

The radiation pattern of microstrip antenna is calculated using Equation 17 and 18

.

$$E_\theta = -jVk_0 \frac{We^{-jk_0 r}}{\pi r}\left(\cos(kh\cos\theta)\right) \times \left[\frac{\sin\left[\left(\frac{k_0 \cdot W}{2}\right)\cdot \sin\theta\sin\phi\right]}{\left(\frac{k_0 \cdot W}{2}\right)\cdot \sin\theta\sin\phi}\right] \times \left[\cos\left[\left(\frac{k_0 \cdot l}{2}\right)\cdot \sin\theta\sin\phi\right]\right]\cos\phi$$

(17)

$$E_\phi = -jVk_0 \frac{We^{-jk_0 r}}{\pi r}\left(\cos(kh\cos\theta)\right) \times \left[\frac{\sin\left[\left(\frac{k_0 \cdot W}{2}\right)\cdot \sin\theta\sin\phi\right]}{\left(\frac{k_0 \cdot W}{2}\right)\cdot \sin\theta\sin\phi}\right] \times \left[\cos\left[\left(\frac{k_0 \cdot l}{2}\right)\cdot \sin\theta\sin\phi\right]\right]\cdot\cos\theta\cos\phi$$

(18)

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

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1. Design Consideration

The parameter of Microstrip Antenna is calculated using Matlab and the following table is obtained .

Table I

Parameter of RMSA

Parameters	Values
Substrate material	RT Duroid 5870
Relative permittivity of the Substrate	2.23
Thicknes 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

2. Result And Discussion

The theoretical result was 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 wa designed to match 50 ohm of the coaxial probe feed. A glance at the model designed in CST software can be done in Figs. 2, 3 & 4 given below.

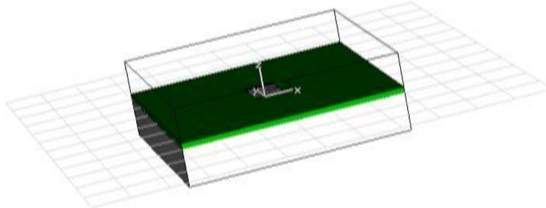

Fig. 2. RMSA model designed using CST

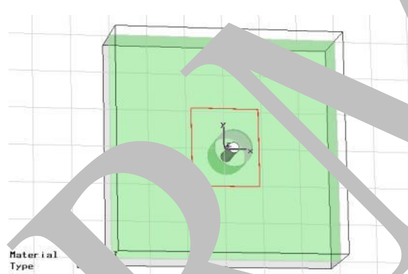

Fig. 3. Top view showing patch, coaxial feed of the model

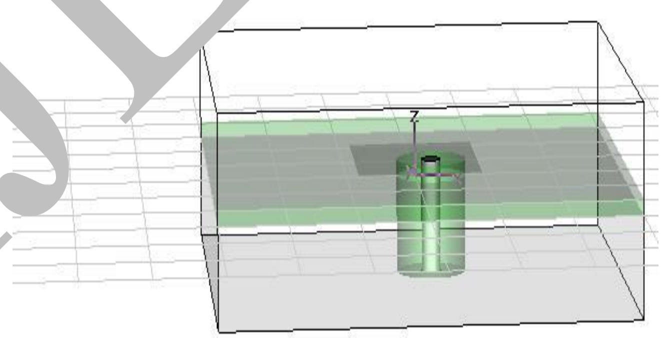

Fig. 4. Lateral view of the model

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

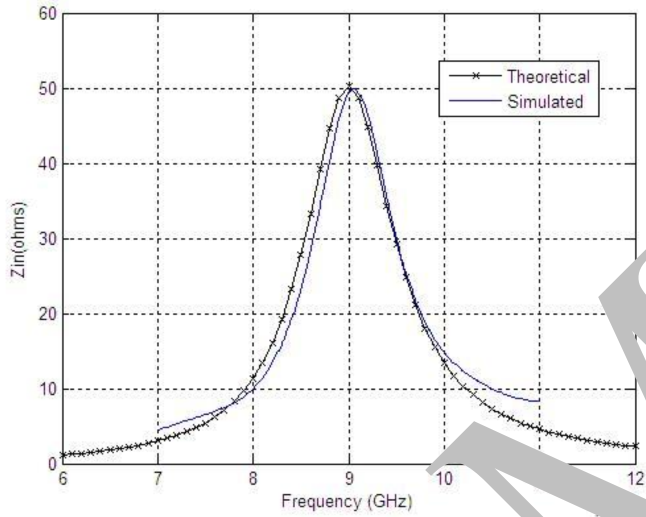

Fig. 5. Variation of Real [Zin] with frequency

The impedance of RMSA is matched with the coaxial feed of 50 ohm. And the result are seen in Figs. 5 & 6. From Fig. 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 Fig. 6. It is also observed that the theoretical result and simulated result are perfectly matched.

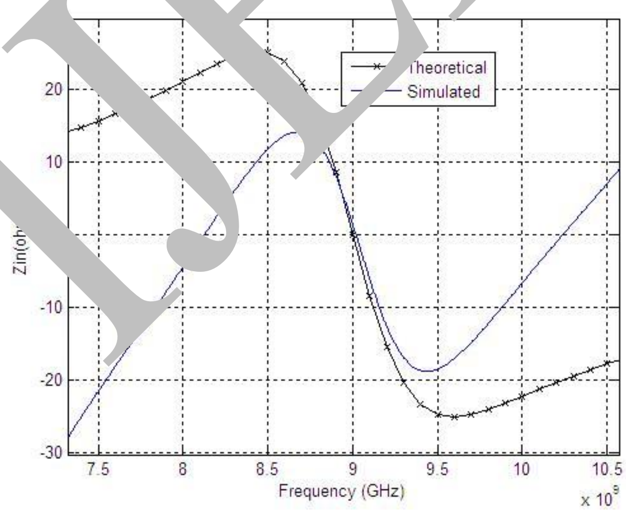

Fig.6. Variation of Imaginary [Zin] with frequency

From Fig. 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 los 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)).

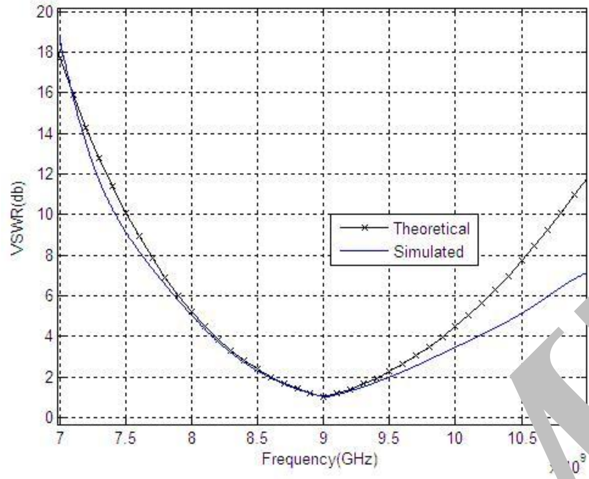

Fig. 7. Variation of VSWR versu frequency

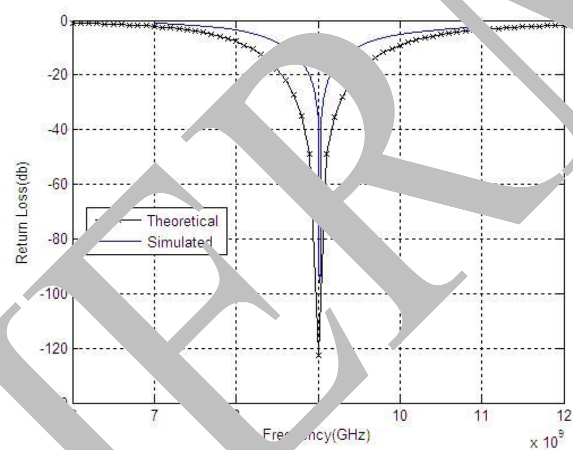

Fig. 8. Variation of Return loss versu Frequency

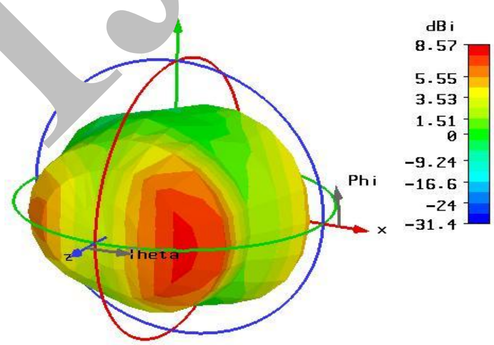

Fig. 9. The Radiation pattern of the designed antenna

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

3. CONCLUSION

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

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