DESIGN OF MULTIBAND RECTANGULAR MICROSTRIP ANTENNA FOR DCS AND WLAN APPLICATIONS USING RFTOOL IN MATLAB

Nirmala M*, Ch Anoosha[1] and Ch Padmasree[2]

*,1,2 *Asst. Prof., Dept. of ECE,ANITS Engineering College, Visakhapatnam (Andhra Pradesh) [INDIA]*

*nirmala.ece@anits.edu.in, [1] anoosha.ece@anits.edu.in, [2] padmasree.ece@anits.edu.in

Abstract

Microstrip antenna have attracted a lot of attention due to rapid growth in wireless communication area. The advantages of this antenna include light weight, low volume, low profile and low fabrication cost. Microstrip patch antenna is designed to operate at 0.9Hz, 1.8 GHz and 2.7 GHz. Designed triple-band microstrip antennas can be used in various commercial systems such as Digital Cellular System (DCS) at 900MHz, Automatic Toll Collection at 905MHz and Wireless Local Area Networks at 2.4GHz. The antenna is implemented on FR4 subtrate with ε_r=4.6 and tickness of 4.98mm. Designed antenna is simulated in rftool in MATLAB. The antenna parameters such as radiation pattern, S - parameters etc. are determined. Theoritical results are compared with the simulated results.

Keywords: Microstrip Antenna, rftool, Radiation Pattern, Return Loss (RL).

1.   Introduction

In high performance aircrafts, spacecrafts, satellites, missiles and other aerospace applications where size, weight, performance, ease of installation and aerodynamics profile are the constraints, a low/flat conformal profile antenna may be required. In recent years, various types of flat profile printed antennas have been developed such as Microstrip antenna (MSA), strip line, slot antenna, cavity backed printed antenna and printed dipole antenna. When the characteristics of these antenna types are compared, the microstrip antenna is found to be more advantageous. Microstrip antennas are conformable to planar or non planar surface, simple and inexpensive to manufacture, cost effective compatible with MMIC designs. When a particular patch shape and excitation modes are selected, they are very versatile in terms of resonant frequency, polarization, radiation patterns and impedance. In this paper, a multiband rectangular patch antenna is designed and its measurement results in terms of S11, radiation patterns for aerospace applications are presented.

2.   Microstrip Antenna

The concept of microstrip radiators[1] was first proposed by Deschamps as early as 1953. A microstrip antenna in its simplest configuration consists of a radiating patch on one side of a dielectric substrate ($\varepsilon r \leq 10$), which has a ground plane on the other side. The patch conductors, normally of copper and gold, can assume virtually any shape, but conventional shapes are generally used to simplify analysis and performance prediction. A patch antenna is a narrowband, wide-beam antenna. Feeding[2] in microstrip is achieved through use of coaxial line with an inner conductor that terminates on the patch. The placement of the feed is important for proper operation of the antenna. Microstrip antennas are among the most widely used types of antennas in the microwave frequency

range, and they are often used in the millimeter-wave[3] frequency range as well. microstrip patch antennas consist of a metallic patch of metal that is on top of a grounded dielectric substrate of thickness h, with relative permittivity and permeability εr and μr as shown in figure 1.
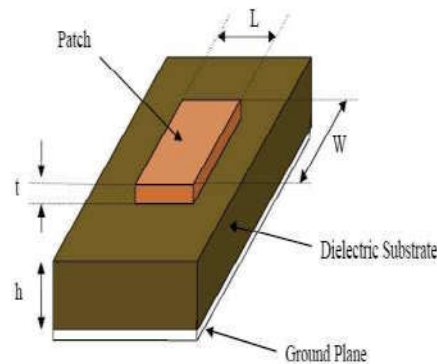

Figure 1: Structure of a microstrip antenna

One advantage of the microstrip antenna is that it is usually low profile, in the sense that the substrate is fairly thin. Other advantages include the fact that the microstrip antenna is usually lightweight (for thin substrates) and durable. Disadvantages of the microstrip antenna include the fact that it is usually narrowband, with bandwidths of a few percent being typical.

3. Aim & Objective

The main aim of the work is to design an rectangular microstrip antenna for Digital Cellular System (DCS) at 900MHz, Automatic Toll Collection at 905MHz and Wireless Local Area Networks at 2.4GHz. by using transmission line analysis model with available substrate of type FR4 with dielectric constant of 4.6 and loss tangent of 0.025 and thickness of 4.98mm of double clad copper. The dimensions of the patch W (width) and L (length) are calculated and also theoretically calculated the gain of the antenna. Then, using the specifications of the substrate, the following parameters are measured by simulating using rftool in MATLAB software[4] at 0.9Hz, 1.8 GHz and 2.7 GHz.. The overall goal of a design is to achieve specific performance characteristics[5] at a stipulated operating frequency.

4. Antenna Design

The design of a rectangular microstrip antenna involves the following process: 1. Selection of substrate and 2. Calculating length, width and feed point of the patch. 3. Selection of connector. The three essential parameters for the design of a rectangular Microstrip Patch Antenna are

4.1 Frequency of operation (f_0)

The resonant frequency[6] of the antenna must be selected appropriately. Since there are developing an antenna for microwave applications, choose design an antenna in S-band and X-band which ranges from 2 GHz to 4 GHz and 1GHz to 2GHz respectively. microstrip antenna is designed for 0.9GHz, 1.8GHz and 2.7GHz.

4.2 Dielectric constant of the substrate (ε_r)

There are many dielectric substrates[7] available in the market having different dielectric constant and thickness. The dielectric material selected for design is FR4 (Fiberreinforced plastic) which has a dielectric constant of 4.6. This substrate is selected since it can obtain better results and is cost effective.

4.3 Height of dielectric substrate (h)

The height of the selected dielectric material is 4.98mm which is optimal for having maximum radiation and has less leaky waves. This provides a balance between conductor and dielectric loss and hence we choose FR4 material dielectric substrate with 4.98mm thickness.

4.4 Design

Transmission line analysis method is used for antenna design. There are several steps to design an antenna.

Step1: Calculation of the Width (W): The width of the Microstrip antenna is given as

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \qquad \text{...} (1)$$

Where,
C is velocity of light
f_o is Resonant Frequency
ε_r is Relative Dielectric Constant

Step 2: Calculating the Length (L) & Effective dielectric constant (ε_{eff}): Once width W is known the next step is the calculation of the length which involves several other computations; the first would be the effective dielectric constant. The effective value of ε_{eff} will be closer to the value of the actual dielectric constant ε_r of the substrate. The ε_{eff} is also a function of frequency (f_0). As the frequency of operation increases the ε_{eff} approaches the value of the dielectric constant of the substrate is given by

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\sqrt{1+12\frac{h}{W}} \qquad \text{...} (2)$$

Where
h is height of the substrate
Effective length (Leff): The effective length is given by

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} \qquad \text{..} (3)$$

Length Extension (ΔL): Because of fringing effects, electrically the micro strip antenna looks larger than its actual physical dimensions. ΔL, which is a function of the effective dielectric constant and the width-to-height ratio (W/h). The length extension is

$$\Delta L = 0.412h\frac{(\varepsilon_{eff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)} \qquad \text{...} (4)$$

Calculation of actual length of patch (L): The actual length is obtained by

$$L = L_{eff} - 2\Delta L \text{...} (5)$$

Step 3: Feed Point Position (y_0): The feed point[8] y_0 gives a good impedance match between the generator impedance and the input impedance[9] of the patch element. The position of the inset feed point is calculated using the formula

$$y_0 = \frac{L}{h}\cos^{-1}\sqrt{\frac{R_{in}}{R_{ino}}} \qquad \text{..} (6)$$

Where
R_{in}= required input resistance.

R_{in0} = resonant input resistance before the application of the feed.

L = Length of the antenna.

Step 4: Calculation of Gain (G): Gain of the microstrip antenna can be calculated by using the formula

$$G = \frac{4\pi A}{\lambda_g^2}$$ ………………………………………………………………………… (7)

5.   SIMULATION RESULTS

A rectangular microstrip patch antenna designed in MATLAB for 0.9GHz, 1.8GHz and 2.7GHz and after simulation in RF Tool, it is observed that, the impedance bandwidth (VSWR ≤ 2) below -10 dB return loss obtained are observed for 0.9GHz, 1.8GHz and 2.7GHz.

5.1 The operating frequency of 0.9GHz

Length = 76.5mm, Width = 99.6 mm, the inset feed point is y_0= 3.04cm and the obtained Gain value is 5.98 dB.
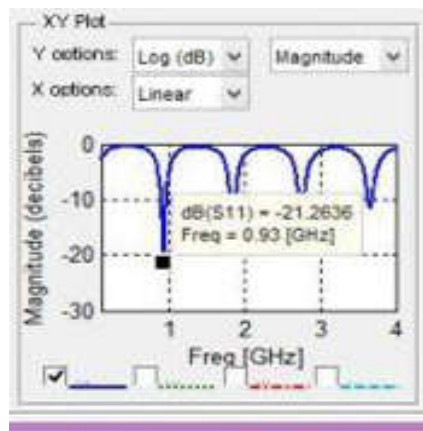
Figure 2: Return loss with frequency

Figure 2 shows the variation of return loss with frequency and the return loss obtained by using rftool for operating frequency of 0.9GHz is -21.26dB.
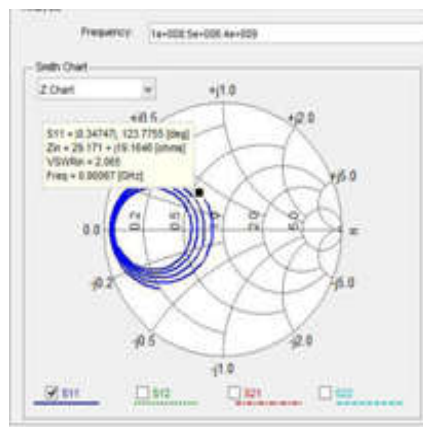

Figure 3: Impedance versus frequency

Figure 3 indicates the variation of impedance with respect to frequency which is plotted using smithchart in the rftool and at operating frequency of 0.9GHz the input impedance and VSWR are Zin= 29.171+j19.1646Ω & VSWR= 2.065.

5.2 The operating frequency of 1.8GHz

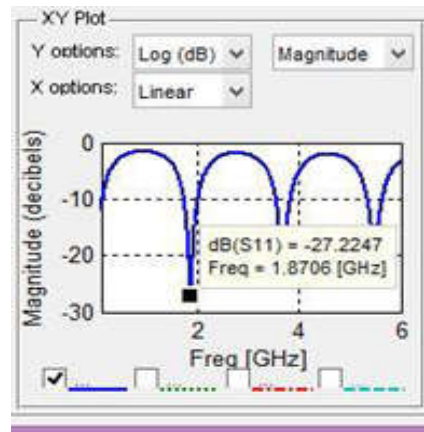Length = 37.1mm, Width = 49.8mm, the inset feed point is y_0 = 1.48cm and the obtained Gain value is 5.88 dB.

Figure 4: Return losses versus frequency

Figure 4 shows the variation of return loss with respect to frequency at operating frequency of 1.8GHz and the obtained return loss using rftool is -27.2247dB.
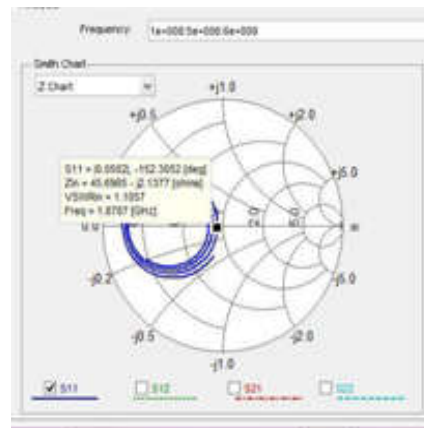

Figure 5 Impedance versus frequency

Figure 5 shows the variation of input impedance with respect to frequency at operating frequency of 1.8GHz and it is plotted using smith chart in RF tool .The obtained values of input impedance and VSWR at this frequency are Zin: =45.8965+j2.1377 Ω & VSWR=1.1057.

5.3 The operating frequency of 2.7GHz

Length = 25.9 mm, Width = 33.2 mm, the inset feed point is y_0 =1.03 cm and the obtained Gain value is 6.04dB.
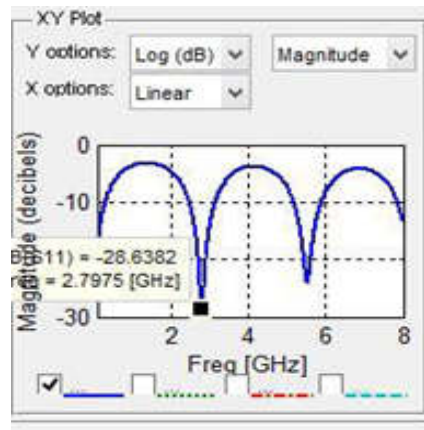
Figure 6: Return losses versus frequency

Figure 6 shows the variation of return loss with respect to frequency at operating frequency of 2.7GHz and the obtained return loss using rftool is -28.6382dB.
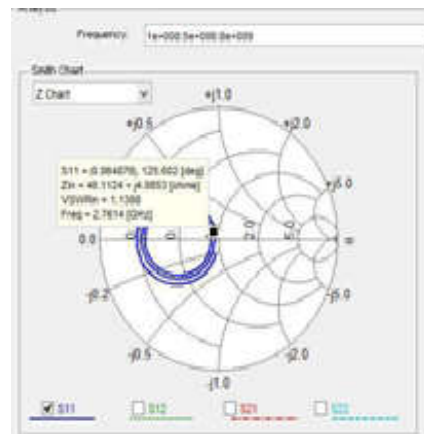

Figure7: Input impedance versus frequency

Figure 7 shows the variation of input impedance with respect to frequency at operating frequency of 2.7GHz and it is plotted using smith chart in RF tool .The obtained values of input impedance and VSWR at this frequency are Zin =46.1124+j4.8853 Ω & VSWR=1.1388.

Conclusion

The antenna for multiband operation is designed. By simulating, the antenna parameters such as radiation pattern, S - parameters etc. are determined. The simulated values are compared with the values calculated theoretically and are found to be nearly equally. The S-parameters of the designed antenna are calculated using rftool in MATLAB and in the S-band, it is found that the antenna resonates at 3 frequencies 0.9 GHz, 1.8GHz and 2.7GHz used for in various commercial systems such as Digital Cellular System (DCS) at 900MHz, Automatic Toll Collection at 905MHz and Wireless Local Area Networks at 2.4GHz with an acceptable gain value.

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