Design of Miniaturized Compact Multi-Band Microstrip Patch Antenna

Mukesh R Chaurasia[1] Shobhit K Patel[2]
[1,2]Department of Electronics & Communication Engineering
[1,2]Charotar University of Science & Technology, Changa, Gujarat

Abstract— The present day Systems are operating in two or more frequency bands, requiring Dual or even triple band operation with narrowband antennas. This requirement is demanding a lot more of research in the field of antenna design. These include GPS, Satellite navigation system, wireless cellular system and LANs. Recent advances in the software defined and reconfigurable radio networks allow the multiple band operation of the systems. One of the specific advantage of the software defined reconfigurable radio network is that the operating frequency can be changed even after the device is manufactured. A multiband Microstrip patch antenna is simulated by meandering the slots to reduce the overall dimensions of the patch and to make the system much more embedded, the performance of the antenna is optimized and analyzed using the Ansoft high frequency structure simulator (HFSS). The antenna is designed to function satisfactorily in the radio band of L, S, C and X, Covering a wide range of radio frequency. Antenna has the six active frequency bands and the Centre frequency of the bands are 1850 MHz, 2910 MHz, 5580 MHz, 6880 MHz, 8340 MHz, 9430 MHz respectively. Out of frequency bands L and S are employed in mobile communication while the C and X band are used in the satellite communication purpose. The proposed antenna provides good return loss S11 and VSWR in the range of 1 < VSWR < 1.5 for all the operating band of frequencies.

Key words: Antenna, Multi Band, Embedded, VSWR

I. INTRODUCTION

With the ever increasing demand for the miniaturization of the mobile communication devices, there is a great role to be played by the technocrats to design the antenna which will possesses the features like low profile, low cost, and ease of integration with system and have the compatibility with the MMICs. Adhere to all these requirement, Microstrip patch antenna possesses all such qualities and hence it has been the center of attraction for many researchers across worldwide.

A Microstrip patch antenna (MPA) consists of a conducting patch of any planar or non-planar geometry on one side of a dielectric substrate with a ground plane on other side. It is a popular printed resonant antenna for narrow-band microwave wireless application. Microstrip patch antennas are small in size, light in weight and are used in all hand held devices as well as in aircraft including satellite and RADAR application. In spite of all these stated advantage patch antenna lacks in the bandwidth, these antennas are most commonly known as narrowband antennas. A number of techniques are employed to enhance the operating bandwidth of the antenna. There are numerous and well-known methods to increase the bandwidth of antennas, including increase of the substrate thickness, the use of a low dielectric substrate, the use of various impedance matching and feeding techniques, the use of multiple resonators, and the use of slot antenna geometry (Pozer). There is always some trade-off between the operating frequency and the size of the structure. However S.K Patel and Y. P Kosta proposed the bandwidth enhancement using the Meta material is providing the substantial result [1-3].

II. ANTENNA DESIGN

The basic structure of the proposed antenna, shown in Fig. 1, consists of 3 layers. The lower layer, which constitutes the ground plane, covers the partial rectangular shaped substrate with a side of 36.98×45.53 mm. The middle substrate, which is made of FR4 epoxy resin, has a relative dielectric constant $\in r = 4.4$ and height 1.5 mm. The upper layer, which is the patch, covers the rectangular top surface. The rectangular patch has sides 29.47×38.03 mm that covers the middle portion of the substrate. Two rectangular slots are cut out from the patch near the feeding Microstrip line for impedance matching. The patch is fed by a coaxial feeding technique.

A. Step 1: Calculation of the Width (W)

The width of the Microstrip patch antenna is given as:

$$w = \frac{c}{2f0\sqrt{\frac{\epsilon r+1}{2}}}$$

Where c is velocity of light, f_0 is Resonant Frequency & ε_r is Relative Dielectric Constant

B. Step 2: Calculating the Length (L)

1) Effective dielectric constant (ε_{eff})

Once 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

$$\in reff = \frac{\in r+1}{2} + \frac{\in r-1}{2}\left(\frac{1}{\sqrt{\frac{1+12h}{w}}}\right)$$

2) Effective length (Leff)

The effective length is: which is found to be

$$Leff = \frac{c}{2fo\sqrt{\in reff}}$$

3) Length Extension (ΔL)

Because of fringing effects, electrically the micro strip antenna looks larger than its actual physical dimensions. [4] For the principle E – plane (x-y plane), where the dimensions of the path along its length have been extended on each by a distance, ΔL, which is a function of the effective dielectric constant and the width-to-height ratio (W/h).The length extension is:

$$\Delta L = 0.412h\,(\frac{(\in reff+0.3)\left(\frac{w}{h}+0.264\right)}{(\in reff-0.258)\left(\frac{w}{h}+0.8\right)})$$

Because of inherent narrow bandwidth of the resonant element, the length is a critical parameter and the above equations are used to obtain an accurate value for the patch length L. The actual length is obtained by:

$$L = L_{eff} - 2\Delta L$$

In this design, the thickness of the substrate is kept smaller so that the shorter co-axial probe will be used and thus less probe inductance will be induced. From the above equations, the length and width were calculated as 29.47×38.03 mm.

However for the substrate.

$$X = L + 5h$$
$$Y = L + 5h$$

where X is the substrate length, Y the substrate width and h the substrate thickness, is kept at 1.5 mm. Putting the calculated value for the length and width of the patch (29.47×38.03 mm) and the thickness of substrate (1.5 mm) into above Equations , the substrate length (X) and width (Y) are 36.98 mm and 45.53 mm respectively.

III. MEANDERING CORNER SLITS

Meandering technique is one of the effective methods to lower resonant frequency and allow turning surface current paths in the patch [7-11]. Meandering can be made by slitting in patch's edges, or slotting the patch, or truncating patch's angles. A corner meandered design is shown in figure 1. As the Excited surface currents are meandered and their paths are lengthened, keeping patch dimensions are fixed, and fundamental resonant frequency is decreased which is suitable for broadband application. [6].

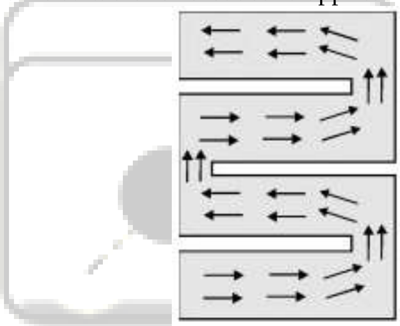

Fig-1. The current distribution at the surface of the meandered Microstrip patch antenna (adopted from ref. [22]).

The substrate is very thin and its thickness is 1.5 mm. Here the patch is meandered at the corners, as shown in Figure-2 the design has four meandered slits, all having dimensions of $12\times2mm^2$.

Microstrip line feed is one of the easier methods to fabricate it is a conducting strip connecting to the patch and therefore can be considered as extension of the patch due to which the thickness of the substrate increases which result in increase of surface wave and spurious radiation, which leads to reduction of the bandwidth. This is the greatest disadvantage of Microstrip line feed which could not be tolerated. In Coaxial probe feeding Method, the inner conductor of a coaxial line is attached to the radiation patch of the antenna through the substrate while the outer conductor is connected to the ground plane.

The main advantages of this method are easy to fabricate, ease of impedance match and low spurious radiation from the feed line and hence increase in bandwidth.

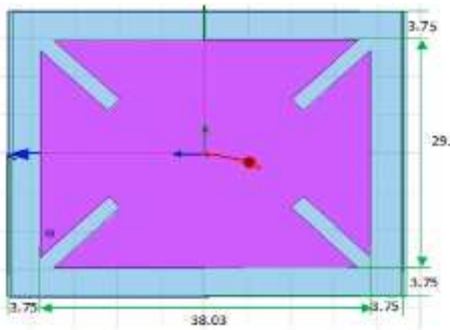

Fig. 2: Top view of the meandered corner micro strip patch antenna (all dimensions are in mm).

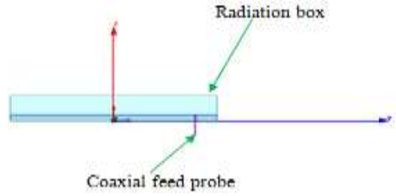

Fig. 3: Side view of the antenna showing the coaxial feed point and radiation box.

IV. SIMULATION RESULT AND DISCUSSION

The entire simulation process is tested and verified on Ansoft HFSS Software. The result of the same are discussed here.

A. Return Loss

Return loss is the loss of signal power resulting from the reflection caused at a discontinuity in transmission line. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line

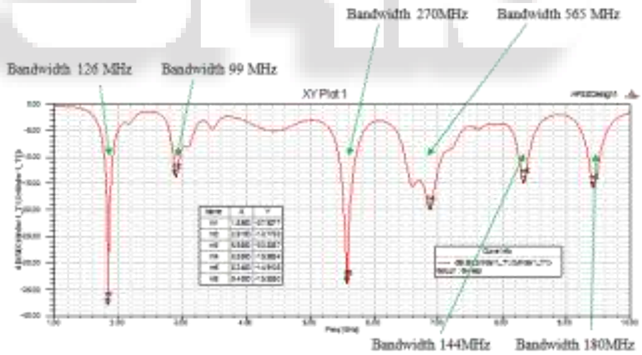

Fig. 4: Return Loss (S11) of the Antenna.

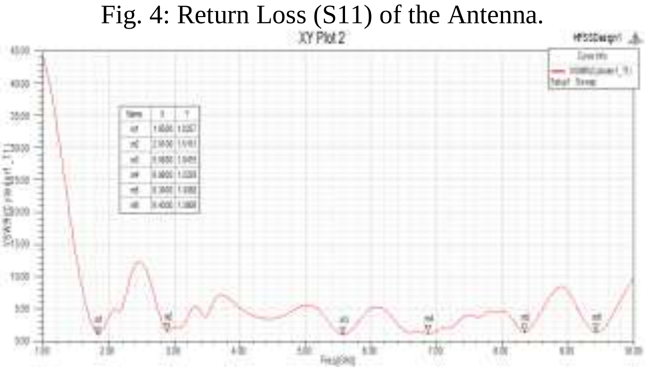

Fig. 5: VSWR of the antenna.

B. VSWR

VSWR stands for Voltage Standing Wave Ratio, and is also referred to as Standing Wave Ratio (SWR). VSWR may be express in terms of the reflection coefficient, which describes the power reflected from the antenna. The VSWR is always a real and positive number for antennas. The smaller the VSWR is, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. The minimum VSWR is 1.

C. Radiation Pattern

The Radiation pattern can be defined as the representation of the angular distribution of radiated power density in the far field region. The antenna's pattern explains how the antenna radiates energy out into space. It is important to state that an antenna radiates energy in all directions, at least to some extent, so the antenna pattern is actually three-dimensional. This radiation pattern shows that the antenna radiates more power in a certain direction than another direction. This is commonly expressed in dB.

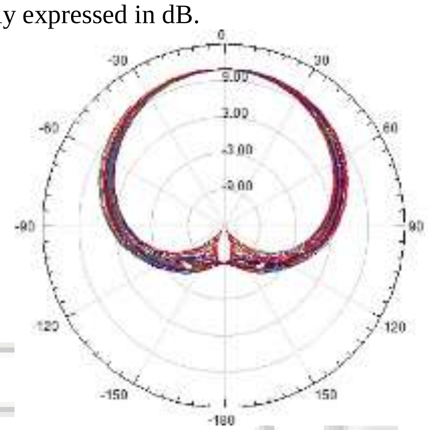

Fig. 6: Radiation Pattern of the antenna

V. CONCLUSION

In this paper, design of a meandered Corner slits Microstrip Patch antenna printed on FR4 substrate with dielectric constant 4.4 has been Analyzed and Verified. The simulation results of the antenna show that enhanced impedance bandwidth can be achieved by using slot at corners. It is seen that the proposed antenna achieved good performance and compact size, which well meets the requirements of High Frequency Satellite applications.

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