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BANDWIDTH ENHANCEMENT OF A MICROSTRIP ANTENNA FOR X-BAND APPLICATIONS

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ABSTRACT

An X-band microstrip antenna for bandwidth enhancement is presented in this paper. The proposed antenna is comprised of circular and rectangular slots fed by a 50 Ω microstrip line. It is designed on 40 mm × 40 mm printed circuit board using FR4 substrate material. Commercially available high frequency electromagnetic solver HFSS based on the finite element method (FEM) is taken into account in this study. The impedance bandwidth (VSWR≤2) of the proposed antenna is 2.10 GHz (9.75 to 11.85 GHz). 1.85 dB is the average gain where maximum gain is 2.3 dB. The proposed antenna exhibits stable Omni-directional radiation pattern.

Keywords: bandwidth enhancement, microstrip antenna, X-band.

1. INTRODUCTION

Since technology is updating gradually, the demand of the miniaturization device is being increased to control the performance of the device. This concept is the same in case of antenna technology. Now a day, the demand of low profile antenna design is very high. The communicating device should be smaller in wireless communication. As a result, the antenna used in such devices should be small also but the cost should not be increased. Similarly if we want to place an antenna in space, any aircraft, parabolic reflector antenna or Yagi antenna that have high bandwidth and gain can be placed in that place but, it will affect highly on the space and aircraft because of their 3D structure, hence it becomes inefficient to plant those antenna structure on the space and aircraft. The solution is to use planner or 2D antenna configuration to this type of difficulties. These antennas can be easily mounted on the surface of any such equipment. In this case, the microstrip patch antenna plays an important role. Advances in wireless communications have introduced tremendous demands in the antenna technology. It also paved the way for wide usage of mobile phones in modern society resulting in mounting concerns surrounding its harmful radiation [1-6]. Microstrip patch antenna has attractive features such as low profile, low cost, light weight, easy integration with integrated circuits and ease of fabrication.

There are varieties of techniques to enhance the bandwidth of patch antenna such as using of a foam or a thick substrate material, cutting rectangular and circular slots or notches like U slot, M-shaped, H-shaped, Z-shaped, E-shaped patch antenna, initiating the parasitic elements either in stack configuration or coplanar and changing the shape of the radiating patch by setting up the slots. In [7-10], a wide-slot antenna with a microstrip line is proposed to enhance the bandwidth using a fork-like tuning stub. Bandwidth has been obtained 1.1 GHz (1.821-2.912 GHz) with gain variation less than 1.5 dBi (3.5-5 dBi) over the entire operating band. Here, both bandwidth and gain were low. In [11], a single layer rectangular patch antenna of wide-band has been explained where impedance bandwidth of greater than 20% has been obtained. In [12], a printed antenna with a rotated slot is narrated for bandwidth enhancement using FR4 substrate material. The antenna showed bandwidth about 2.2 GHz and gain variation less than 2 dBi. But the antenna size was very large that was 70 mm × 70 mm. In ref. [13], a tuning stub is used to increase the bandwidth for a CPW-fed loop slot antenna where dimension is 72 mm × 72 mm and gain range is from 3.75 to 4.88 dBi within the operating band. A wide bandwidth is achieved with considering the position of a widened tuning stub. 34% to 60% impedance bandwidth has been achieved with the CPW-fed slot antennas using these bandwidth enhancement techniques. In [14], two E-shaped slot antennas have been proposed for broadband applications using CPW and microstrip line as feeding technique. It has contained dimension of 85 mm × 85 mm with stable bandwidth and radiation pattern. The week point is that the size of this antenna is large.

In this study, a microstrip patch antenna for X-band applications has been proposed and investigated to increase the bandwidth and reduce the size at the same time. The bandwidth has been enhanced by adding circular slot on the patch and rectangular slots on the ground plane. The results give a hint that the proposed antenna is suitable for X-band applications covering from 9.75 GHz to 11.85 GHz.

2. ANTENNA GEOMETRY AND OPTIMIZATION

The length, width, VSWR, return loss of the patch antenna can be calculated from the equations (1) - (6) narrated in [15-20]. Where L and W are the length and width of the patch, c is the velocity of light, ε_r is the dielectric constant of substrate, h is the thickness of the substrate, f_0 is the target center frequency, ε_e is the effective dielectric constant and ρ is the radiation coefficient.

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

$$L = \frac{c}{2 f_o \sqrt{\varepsilon_r}} - 2\Delta l \qquad (2)$$

$$\varepsilon_e = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{2}(\varepsilon_r - 1)\sqrt{(1 + \frac{10h}{W})} \qquad (3)$$

$$\Delta l = 0.412h \frac{(\varepsilon_e + 0.3)[\frac{W}{h} + 0.8]}{(\varepsilon_e - 0.258)[\frac{W}{h} + 0.8]} \qquad (4)$$

$$\text{VSWR} = \frac{1+\rho}{1-\rho} \qquad (5)$$

$$\text{Return loss} = -10\log(\frac{1}{\rho^2}) \qquad (6)$$

The proposed antenna geometry is shown in Figure-1. The antenna consists of radiating patch, dielectric substrate material and ground plane. One circular slot and four similar lateral slots are placed on the radiating patch. It is printed on FR4 dielectric substrate material whose thickness is 1.6 mm, relative permittivity 4.55, relative permeability 1 and dielectric loss tangent 0.02. Ground plane contains four similar rectangular slots. Microstrip line is used as feeding technique. A 50 Ω Sub Miniature version A (SMA) connector is used at the feeding line for input radio frequency (RF) signal. Finally, the proposed antenna design is achieved.

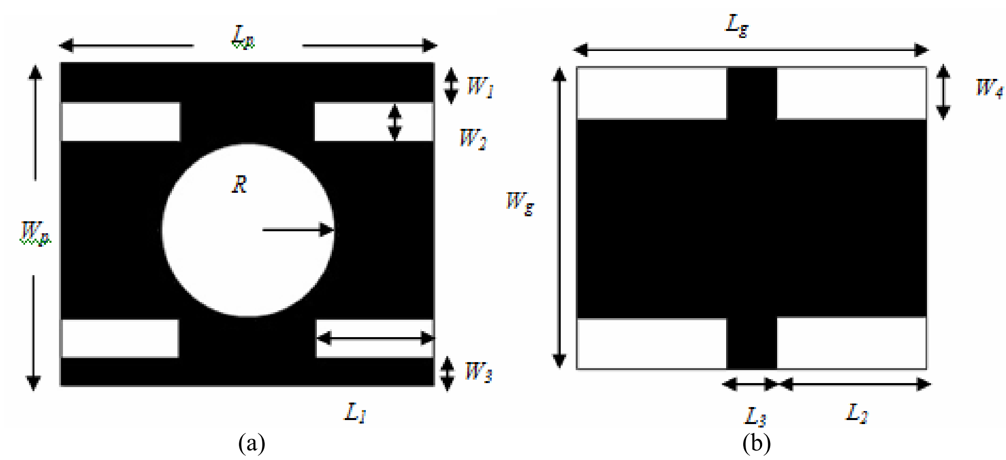

Figure-1. Proposed antenna a) Top view b) Bottom view.

The antenna design and dimensions were investigated by using the Ansoft HFSS software, which is based on the finite element method (FEM), and finally the optimal dimensions were determined as follows: L_p = 40 mm, L_g = 40 mm, L_1 = 12 mm, L_2 = 17 mm R = 11.5 mm, W_p = 40 mm, W_g = 40 mm, W_1 = 5 mm, $W2$ = 4 mm and W_3 = 4 mm.

3. RESULTS AND DISCUSSIONS

The simulation has been carried out applying Finite Element Method (FEM) based high frequency electromagnetic solver HFSS to execute the resonant demands of the proposed antenna design. Figure-2 depicts the simulated return loss of the proposed microstrip antenna. Return loss of -57.26 dB has been achieved at resonant frequency 10.88 GHz. We have obtained 2.10 GHz (11.85 GHz-9.75 GHz) bandwidth.

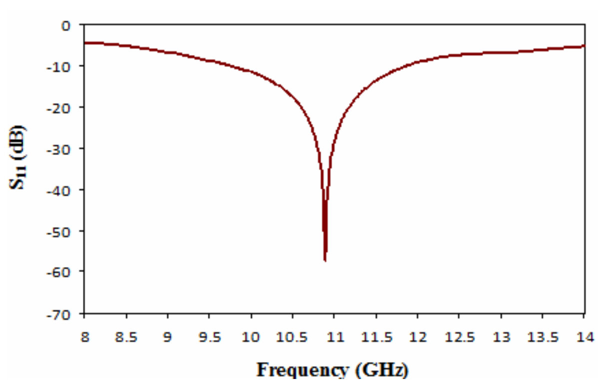

Figure-2. Return loss of the proposed antenna.

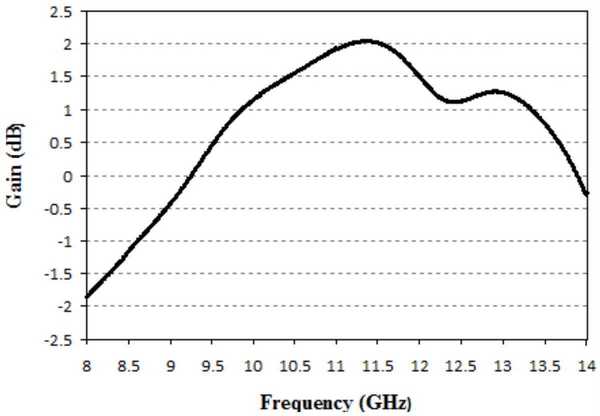

Figure-3. Gain of the proposed antenna.

In [7], achieved bandwidth is only 1.1 GHz and size is larger. But our design is compact and better bandwidth that [7]. Figure-3 shows the gain of the proposed antenna. The average gain of the proposed antenna has been achieved 1.65 dB where the maximum gain is 2.04 dB that is better than [11] and [12].

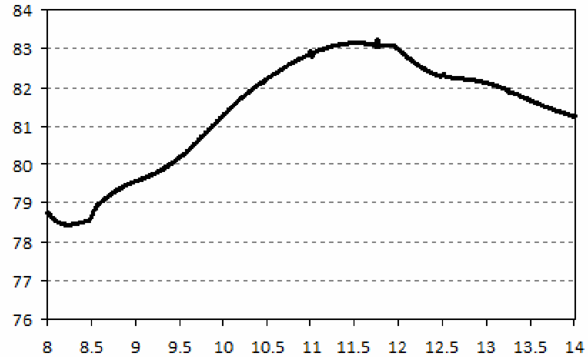

Figure-4. Radiation efficiency of the proposed antenna.

Radiation efficiency of the proposed antenna has been demonstrated in Figure-4. It can be seen that radiation efficiency is 82.4% that is better than conventional. Radiation pattern of the proposed antenna has been shown in Figure-5. From the graph, it can be observed that omni-directional radiation pattern has been achieved along the E-plane and H-plane.

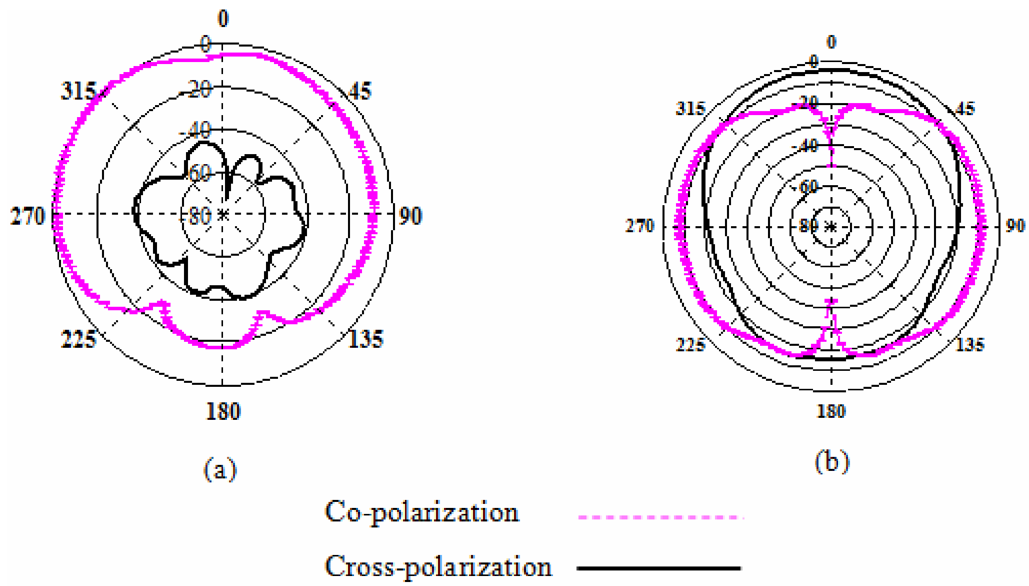

Figure-5. Radiation pattern of the proposed antenna; a) E-plane at 10.88 GHz b) H-plane at 10.88 GHz.

4. CONCLUSIONS

An X-band microstrip antenna for bandwidth enhancement has been demonstrated in this study. Simulation results indicate that the bandwidth of the proposed microstrip antenna has considerably been improved by placing circular slot on the patch and rectangular slots on the ground plane. The proposed antenna exhibits a 10 dB return loss impedance bandwidth of 2.10 GHz (9.75 GHz-11.85 GHz), omni-directional radiation patterns. This proposed X-band antenna can be appropriate for bandwidth enhancement depending on this characteristic.

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