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Design and Analysis of Low Profile Coplanar Waveguide Fed Monopolar Patch Antenna

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***Abstract* – A new low profile and broadband monopolar patch antenna is proposed. Generally monopolar patch antennas are built using circular or square patches to obtain the required radiation pattern but these antennas have low gain in the horizontal plane. Rectangular patch antennas have been designed for high gain but they have broadside radiation pattern. We propose a low profile patch antenna with wide bandwidth, high gain and monopole like radiation pattern. The proposed antenna has a bandwidth of 13.38% and gain of 4.48 dBi with monopole like radiation pattern.**

***Keywords* – Annular Ring, Excitation Modes, Low Profile, Omnidirectional, Method of Moments (Mom), Monopolar Patch.**

I. Introduction

Monopole antennas are widely used in wireless communication system, since they can provide omnidirectional radiation patterns [1]. In recent years the demands on mobile communication have grown rapidly. So, indoor wireless networks consisting of numerous indoor base station antennas have been mounted on the ceilings of many buildings and malls, thus there are stringent requirements on an antennas impedance bandwidth and physical size. Many types of monopole antenna are attractive for present wireless communication systems.

A typical monopole antenna is the quarter wavelength monopole antenna, whose length is equal to a quarter of the wavelength at the resonance frequency. The profile of a conventional monopole antenna is too high for some devices that have limited space for hiding the antenna. Microstrip antennas are popular for their low cost, light weight, easy fabrication, mass production and planar structure with low profile [1][2]. Because of the merits it is expected that microstrip antennas can be used to replace monopole antennas that have a high profile of about quarter wavelengths. A microstrip patch antenna in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. Radiation from the patch can occur from the fringing fields between the periphery of the patch and the ground plane.

This paper is organized as follows. Section I mentions a brief introduction to the applications of monopole antenna. Various methods that have been implemented to design monopolar patch antennas and their drawbacks, is mentioned in Section II. Section III explains the design of a novel low profile monopolar patch antenna. The simulation and results are shown in Section IV. The paper is concluded in Section V.

II. Monopolar Patch Antenna

Monopole antennas are widely used since they provide a vertical polarization and a conical radiation pattern. However, the profile of a conventional monopole antenna that has a quarter wavelengths is too high for some devices or applications that have limited space for hiding the antenna. Many excitation modes have been studied for circular disc and annular ring patches. A circular microstrip antenna can be used to replace vertical wire monopole [3]. However, the radius of this antenna is very large. Microstrip antennas including ground wire which connects the patch of the antenna to the ground plane can be used to obtain monopole like radiation pattern [4].Such an antenna has total height much less than a quarter wavelength of the centre operating frequency. However, this type of monopolar wire patch antenna has a narrow impedance bandwidth. To improve the bandwidth a planar rectangular monopole top-loaded with a shorted square or circular patch can be used [5]. The wire monopole and the ground wires [4] can be replaced by a planar rectangular monopole and ground rectangular plates respectively [5]. The profile of such an antenna is around $0.09\lambda_0$, which is much lower as compared to the quarter wavelength dipole. The bandwidth can further be increased by using a circular patch, because of the relatively large patch size. The bandwidth of a probe fed patch antenna is limited by the inductance introduced by the coaxial feed in case of thick substrate. To improve the bandwidth and avoid drilling or soldering of the patch, a L-probe fed circular patch antenna can be used [6]. Such an antenna provides wide bandwidth and high gain with a profile of 0.13 λ_0. However, such antennas consist of air substrate, which are difficult to implement.

Another inconvenience is that such antennas are larger in size as compared to quarter wavelength monopoles. The profile of the L-probe fed circular patch can be reduced to 0.092 λ_0 by shorting the circular patch to the ground plane by four copper wires [7]. The radius of this patch is also reduced due to the presence of shorting wires. The bandwidth can further be enhanced by connecting four trapezoidal plates orthogonally to the circular patch which is shorted to the ground plane by four copper wires [8]. A

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rectangular planar monopole with a bevel can further increase the impedance bandwidth. Nevertheless, owing to the asymmetry of the planar structure, its radiation patterns in the azimuth plane do not keep omnidirectional as the operating frequency increases [9]. A disk-loaded monopole reduces the profile to 0.08 λ_0. A monopole can also be created by connecting six triangle plates together. The regular hexagon is shorted to the ground plane by six wires [10]. The height of such an antenna is equal to 0.1 λ_0 at resonance frequency. Another type of monopolar patch is the sleeve monopole antenna [11]. This antenna is composed of a circular patch and a disc-conical sleeve, both of which are shorted to the ground plane through four shorting probes. The antenna has a low profile of 0.1 times the free space wavelength of the centre operating frequency. A circular sleeve structure can be added to improve the matching condition of the upper operating frequency edge and thus enhance the bandwidth [12].

The bandwidth enhancement for monopolar patch antennas were demonstrated [3] - [13] with/ without shorting wires. All these antennas have a profile of about 0.1 λ_0 (or even higher); nonetheless it is too thick for some applications such as the installation to an aircraft. Besides these antennas adopt an air substrate and their structures are not simple to be fabricated. A centre-fed circular microstrip patch with a coupled annular ring provides monopole-like radiation pattern [14], [15]. Such antennas have low profile of 0.03 λ_0.

III. Antenna Design

Fig. 1 shows the geometry of the proposed antenna. The patch was first designed with the dimension L_1= 20 mm and W_1= 12 mm, on a substrate with dielectric constant 4.4 and thickness 1.6 mm. The patch is mounted over the ground plane of the size Lg =10 mm, Wg= 30 mm and is fed with the help of microstrip line of 50 ohm impedance.

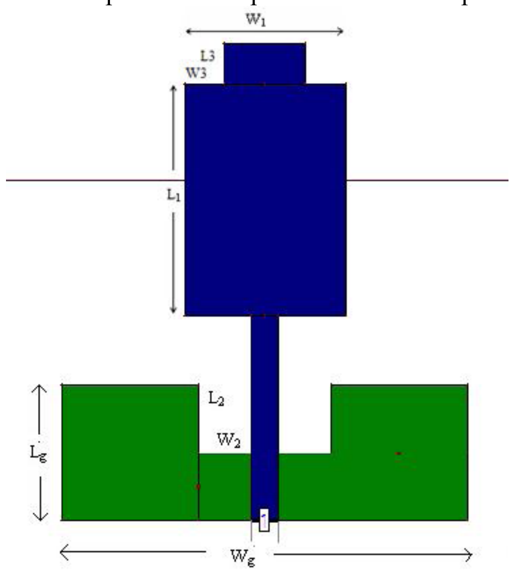

Fig.1. Geometry of proposed antenna

Initially the gap (Gw) between the patch and the ground plane was fixed to 1.5 mm. The simulations were performed using IE3D software, a commercial full wave simulator based on Method of Moments (MOM). It was found that the impedance matching is not proper over the entire range of desired frequency.

To improve the impedance matching a slit with the dimension L_2 X W_2 was introduced in the ground plane. Following a number of iteration L_2, W_2 and Gw were fixed to 4.26 mm, 2.28 mm and 1.5 mm respectively. To improve the impedance matching at the lower frequency two notches with length L_3 and width W_3 were introduced at the upper corner in the patch. It was seen that the notches in the patch helps in improving the impedance matching in the lower frequency range.

IV. Results and Discussions

A slit in the ground plane and two slots at the upper corner of the radiating patch were introduced. The dimension of the slit and slots were optimized using the iterative method. With these optimized dimensions antenna was modelled and simulated. The return loss obtained for the designed antenna is shown in fig. 3. The return loss is below -10 dB between 5.93 to 6.78 GHz, which gives an approximate bandwidth of 13.38%. The designed antenna has a low profile of 0.034 λ_0. The VSWR of the designed antenna is shown in fig. 3. The VSWR is well below 2 between, 5.93 to 6.78 GHz. Fig. 4 and 5 depict the radiation pattern of the designed antenna. The proposed antenna has monopole like radiation pattern in the elevation plane and omnidirectional pattern in the azimuth plane. Maximum gain of 4.48 dBi is obtained at the resonant Frequency as shown in fig. 6, which is approximately twice the gain obtained by a circular monopole with annular ring.

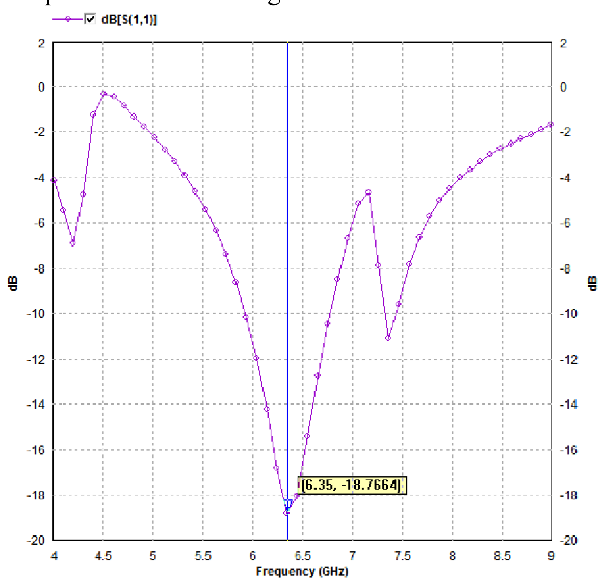

Fig.2. Return Loss of proposed antenna

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High directivity of 8.3 dBi is obtained at the resonant frequency as shown in fig. 7, which is again comparatively higher than the previously designed monpolar patch antennas. The performance of the proposed antenna is compared with that of centre fed circular patch with annular ring in table 1.

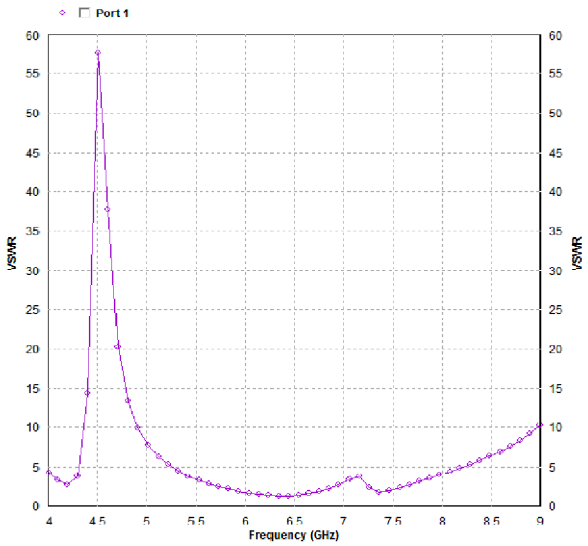

Fig.3. VSWR of the proposed antenna

Table 1: Comparison of centre fed circular patch with annular ring with the proposed rectangular onopolar patch antenna

Parameters	Centre Fed Circular Patch with Annular Ring	Proposed Antenna
Dielectric	RT Duroid	FR4
Bandwidth	12.28%	13.38%
Gain	2.33 dBi	4.48 dBi
Directivity	4.86 Bi	8.3 dBi
Profile	0.05 λ0	0.034 λ0

V. Conclusion

A monopole patch antenna with slit in the ground plane and two slots at the upper corners of the radiating patch has been proposed to improve the impedance matching. Slit in the ground plane helps to improve the matching at higher frequencies, where as the notch on upper corner improves the matching at the lower frequencies. It has been shown that the performance of the proposed antenna is superior to the performance of centre fed circular patch with annular ring.

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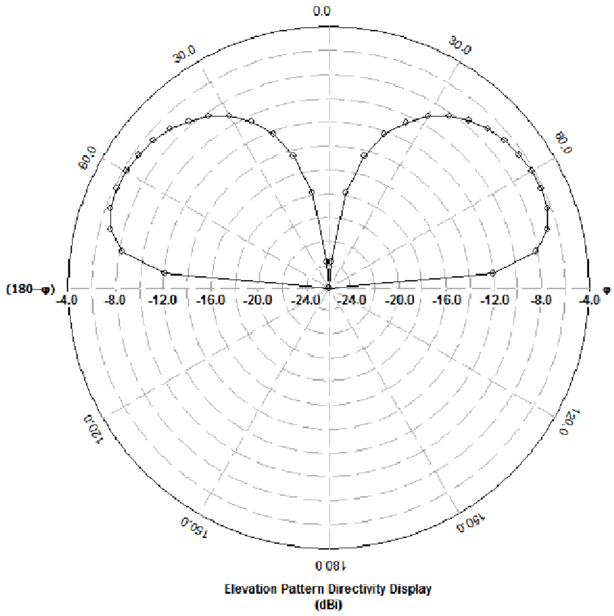

Fig.4. Elevation pattern of the proposed antenna

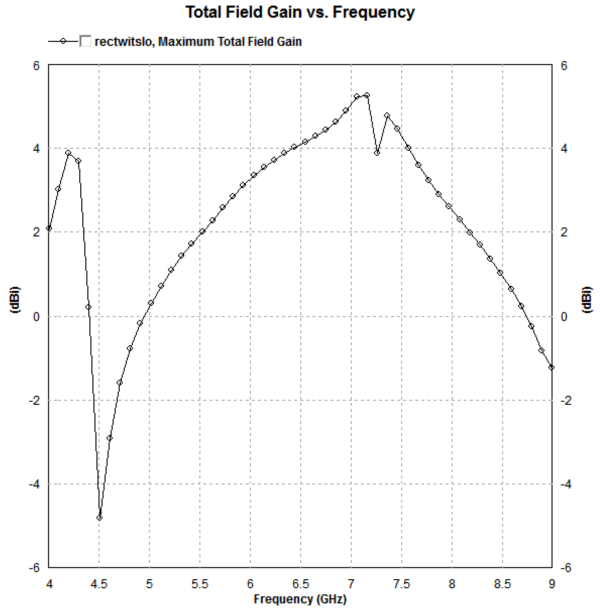

Fig.6. Gain of the proposed antenna

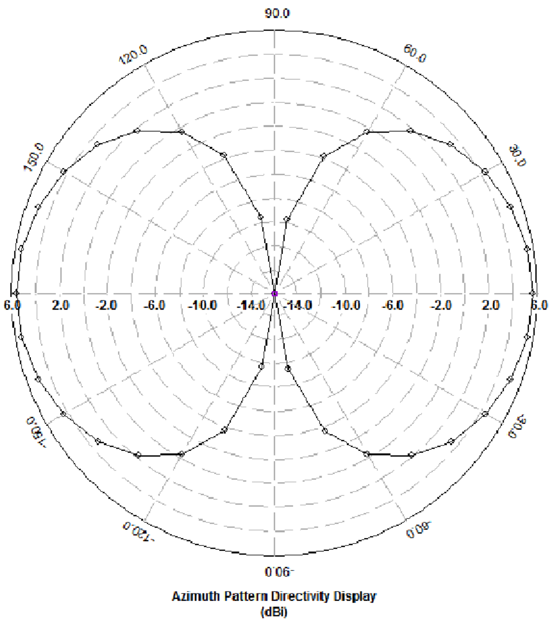

Fig.5. Azimuth pattern of the proposed antenna

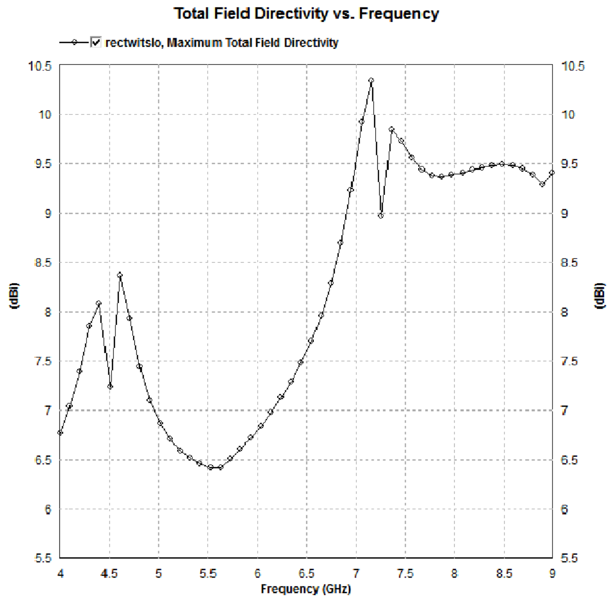

Fig.7. Directivity of the proposed antenna