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Broadband Modified Rectangular Ring Patch Antenna*

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Abstract: This paper presents a novel broadband modified rectangular ring patch antenna for wireless communication. A modified rectangular microstrip antenna with protruding semi ellipse having an air gap in between the two dielectric substrate layers of patch antenna is analyzed using the IE3D simulation software. By protruding semi ellipse of appropriate dimension close to one of the edges, the rectangular patch has been shown to realize dual-frequency broadside radiations. Once the frequency response of the dual-element can be controlled, we can get a broad bandwidth antenna configuration by overlapping the two-element frequency response. Several optimizations are performed to attain the optimum values of the antenna physical parameters which gives an impedance bandwidth more than 0.94 GHz or 27.64%. The E and H plane radiation patterns in entire impedance bandwidth are identical in shape and direction of maximum radiations is normal to patch geometry.
Keywords: Microstrip antenna, broadband, air gap, radiation pattern

1. Introduction

The increasing demand of wireless and mobile communication systems has increased the demand for smaller devices with wider bandwidth. Antennas following this trend have to be compact and must be integrated with host object with desired impedance behavior and radiation characteristics. Microstrip antennas are now finding wide applications in mobile and wireless devices due to their lightweight, low profile, planar configuration and compactness[1,2]. However, their small impedance bandwidth has always been a major constraint as it limits the frequency range over which the antenna can perform satisfactorily. Several methods were

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suggested to improve the performance of microstrip antennas in open literature. Several approaches has been proposed by several researchers, such as using an impedance matching network[3], thick substrates with low dielectric constant and multiple resonator[4, 5], parasitic patches stacked on the top of the main patch or close to the main patch in same plane[6], a capicitively probe feed structure[7], L- probe feeding[8] etc. Antennas with various shaped of microstrip feed line and rectangular wide slot have been introduced for large impedance bandwidth in[9, 10]. In most cases a thick form substrate is required. The bandwidth and gain of antenna may be significantly improved by applying low permittivity substrate materials having low loss tangent like foam material or by introducing an air gap between the patch radiator and the ground plane[11, 12]. This idea is simple and can be applied to patches of arbitrary shape. The microstrip antenna with air-gap band width enhancement technique takes the advantage of using the air gap to lower the effective permittivity of the cavity beneath the patch, resulting in, rising shift in the resonant frequency and increase the total thickness of the microstrip antenna which is essential for bandwidth enhancement. This bandwidth enhanced microstrip antenna can be deployed for the WLAN application operating at a desired frequency. In present communication we have modified the rectangular patch geometry and applied an air gap with slight variation in the technique proposed by[11, 12]. Due to limitation of fabrication, we have introduced an air gap in between the two dielectric substrate layers with spacers instead of introducing air gap between ground plane and dielectric substrate. These modifications not only increase the impedance bandwidth but also provide the mechanical strengthen to patch.

2. Antenna Design and Result

(a) Single Layer Rectangular Microstrip Antenna with Protruding Semi Ellipse

In this paper, radiation performance of a modified rectangular patch antenna with and without air gap is discussed and analyzed. The FR4 glass epoxy substrate has dielectric constant ε_r = 4.4 and thickness h =1.59 mm is chosen for the simulation.

In first step a single patch rectangular microstrip antenna having a protruding semi ellipse on one of the edge of the patch is presented. An interesting phenomenon is observed that by a simple amendment on the regular coplanar microstrip antenna the new antenna geometry can work with dual-frequency. One of the resonant frequencies is similar to the frequency with conventional patch while the other is originating due the alteration in geometry.

The proposed geometry is shown in Fig. -1, the length of rectangular patch '*L*' = 2.8cm and width '*W*' = 2.0cm. A semi elliptical patch having dimension of semi major axis a = 1.4 cm and semi minor axis b = 0.03cm is protruding with its origin at (x = 14 mm, y = 20 mm). Since there are no analytical models to solve the design problems, a simulation tool (IE3D) is used to solve this problem .The IE3D (Zeland Software) is an integrated full wave electromagnetic simulation and optimization package for the analysis and design of microstrip antennas based on method-of-moments is used to solve the problems assigned to it [13].

The antenna is coaxially fed to a 50 ohm system interfacing via a single coaxial SMA female connector with radius 0.62mm at an optimized feed location (X_o= 19.6mm,Y_o=16.4mm) to excite the patch. The measured and computed variation of reflection coefficient for the proposed antenna with frequency is shown in Fig. 2 and 3 respectively. The proposed antenna resonates at two frequencies 2.52GHz and 3.05GHz respectively corresponding to different modes of excitation. An excellent agreement between simulated and measured results may be seen.

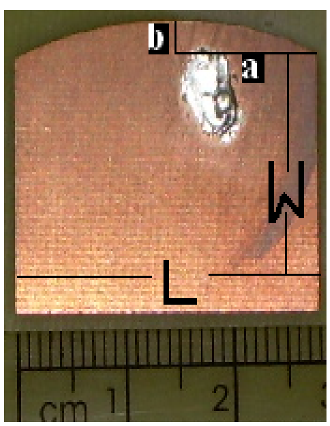


Fig. 1 (a): Top View of the Fabricated Patch Antenna

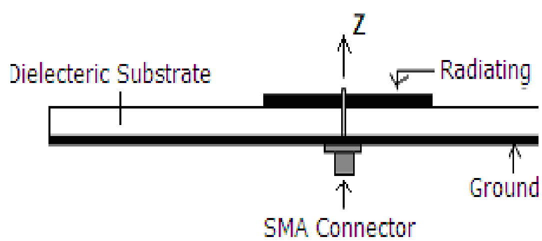


Fig. 1 (b): Side View of the Antenna Structure with Feed Network

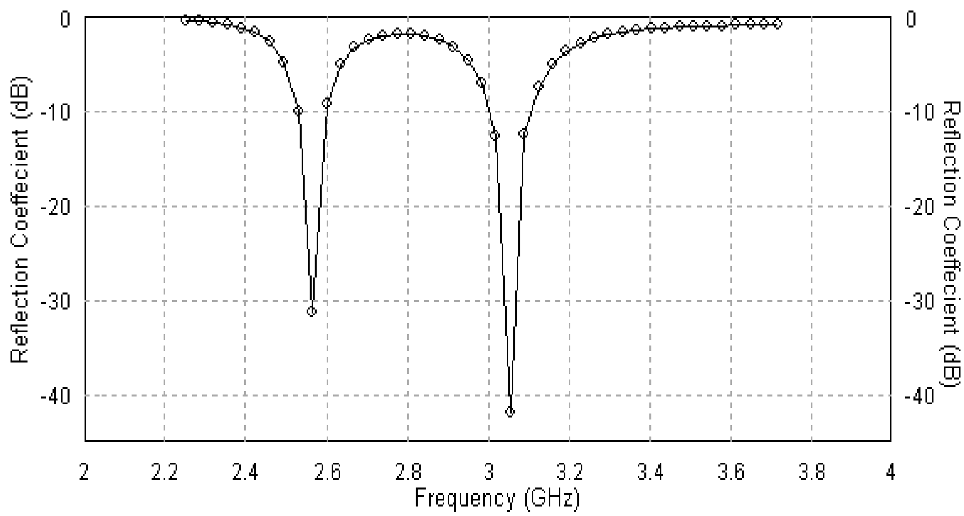


Fig. 2 Simulated Variation of Reflection Coefficient for the Proposed Antenna with Frequency

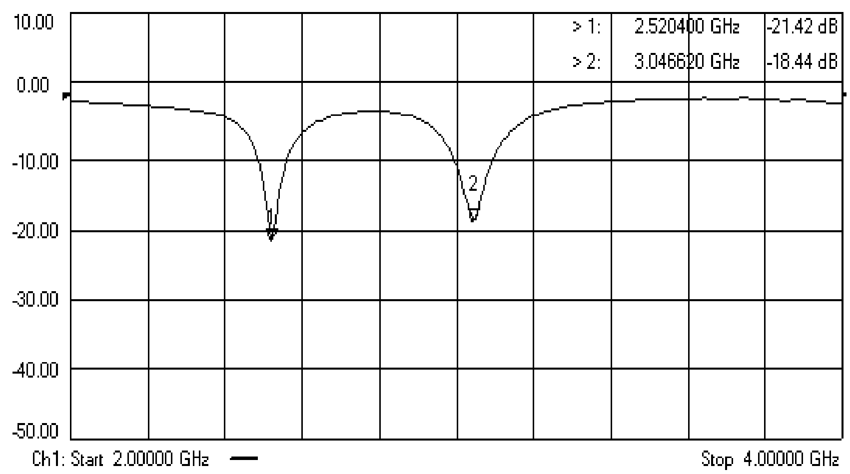


Fig. 3 Measured Variation of Reflection Coefficient for the Proposed Antenna with Frequency

The VSWR presented by antenna at both the frequencies are lower than 2:1 value and close to unity as shown in Fig.4. This result confirms excellent matching of this antenna geometry with the feed network. The input impedance variation of antenna is shown in Fig.-5. The measured value of input impedance at both the frequencies is (44.3 – j 5.2) ohm and (41.89 + j 6.8) ohm respectively, which is very close to 50 ohm and reactive parts are also close to desired values. The impedance bandwidths of this antenna at both the frequencies are very narrow of order of 2.33% and 3.25% corresponding to frequencies 2.565 GHz and 3.055 GHz respectively; hence antenna in its present form is not suitable for modern communication systems and requires some technique which can improve the impedance bandwidth of present structure.

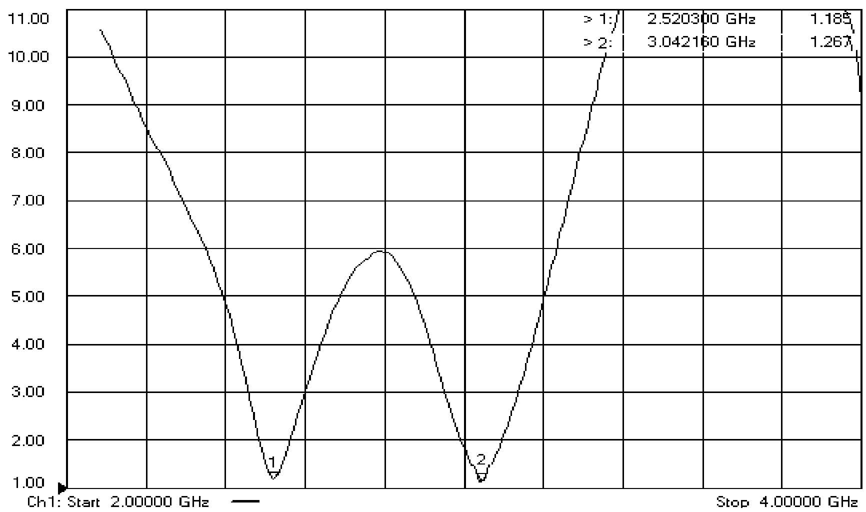


Fig. 4 Measured Variation of *VSWR* for the Proposed Antenna with Frequency

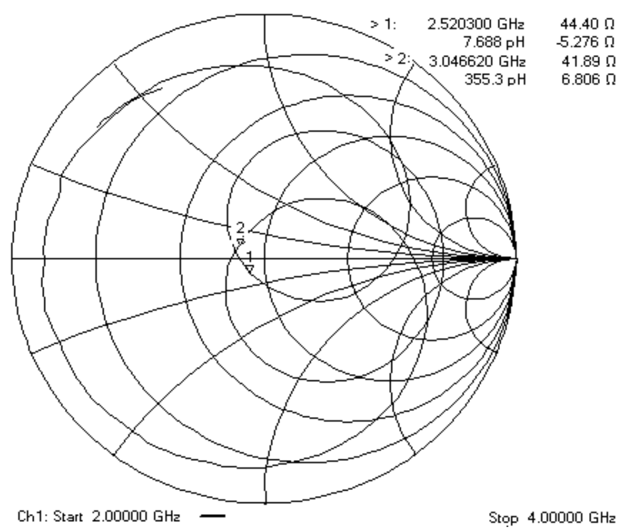
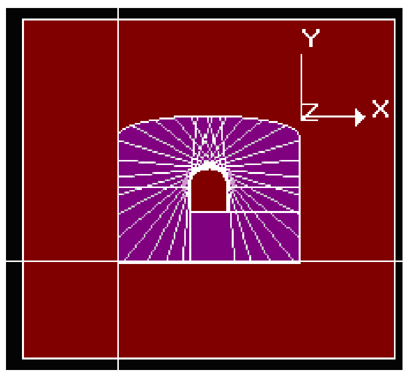


Fig.5 Measured Variation of Input Impedance for the Proposed Antenna with Frequency
(b) Modified rectangular microstrip antenna with protruding semi ellipse with an air gap

The proposed antenna geometry in the previous section however resonates at two frequencies but it represents a narrow bandwidth. In this section, this prototype antenna is modified to achieve a much-improved performance not only in terms of impedance bandwidth but also with other parameter like gain, directivity and stable E and H plane patterns. Following the method adopted by Lee and Dehele[12] with a variation in technique is used in this communication to achieve the broad bandwidth.

The layout of design of a modified rectangular microstrip antenna with protruding semi ellipse with an air gap is shown in Fig. -6. The structure is consist of three layers, having two substrate layer of material glass epoxy FR-4 separated through a middle layer of air gap of thickness '*h*' = 1.5 mm by applying screws between these two substrate layer. The rectangular microstrip patch with protruding semi ellipse is etched on surface of top layer. The overall thickness of proposed structure is 4.18 mm. A ring of dimension equivalent to 30% of outer dimension of patch is dig at the center of the patch. The patch element is fed through single inset feed arrangement through SMA connector at feed location (X_0 = 18.5 mm, Y_0 = 15.0 mm). In order to avoid reflections, the antenna is fed with appropriate source impedance in the simulation. The performance of this antenna is also simulated using IE3D simulation tool [13].



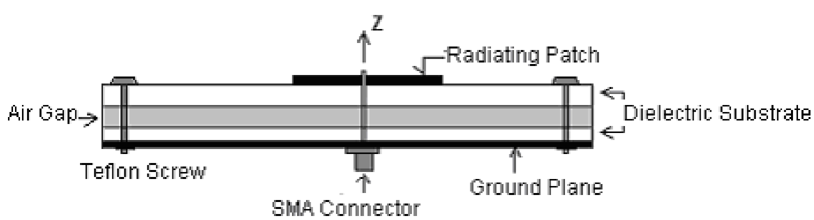


Fig. 6 Geometry of Modified Rectangular Patch Antenna with Semi Elliptical Portion with Coordinate System

Many IE3D (Momentum) simulations have been done by changing the parameter like air gap (*h*) between the substrate layers and the dimension of inner slot to obtain the maximum bandwidth without changing other parameters. On basis of this optimization it is observed that when the dimension of inner slot is 30% of the dimension of outer patch best optimum result is obtained. The simulated results shows that for this case the proposed antenna presents two clear resonances at frequencies 3.10GHz and 3.64GHz and presents an impedance bandwidth nearly 0.94 GHz or 27.64% with respect to central frequency 3.35 GHz, which is ten times more than that, obtained with the geometry without air gap and modification. The variation of reflection coefficient with frequency for different dimension of inner slot is presented in fig. 7. It is noted that both resonance frequencies shifts to higher frequency side on application of air layer between the substrates when compared with antenna without air gap since the presence of air gap reduces the effective permittivity of the substrate material under the patch, which in turn increases the resonance frequency of antenna.

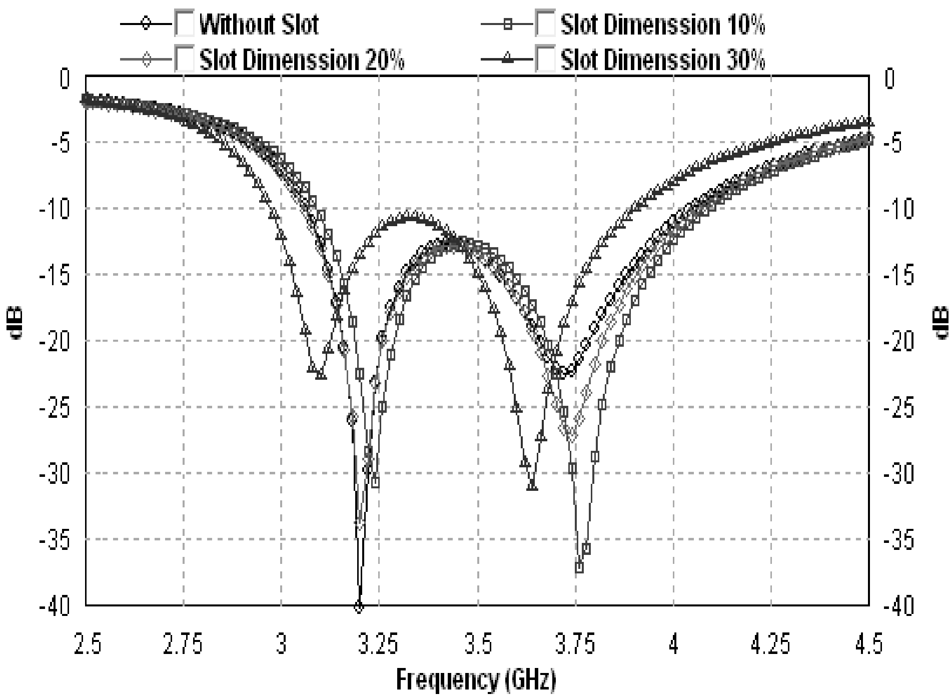


Fig. 7 Computed reflection coefficient of rectangular microstrip patch with protruding semi ellipse with frequency having an air gap h = 1.5 mm

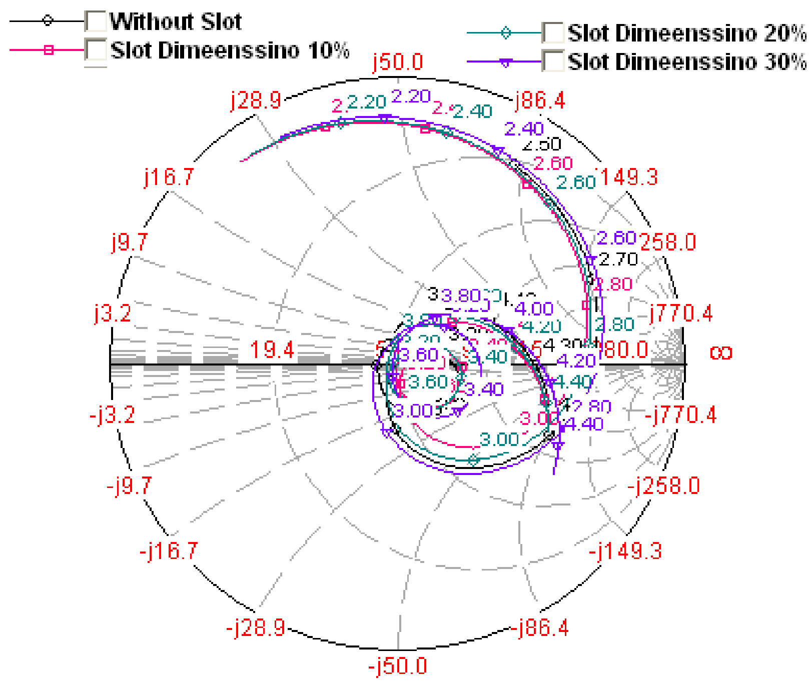


Fig. 8 Measured input impedance of rectangular microstrip patch with protruding semi ellipse with frequency having an air gap *h* = 1.5 mm

The variation of input impedance for the proposed antenna without slot and with slot for various dimensions of inner slot is shown in fig. 8. The input impedance value of antenna at frequency 3.10GHz and 3.64GHz are 49.75 – j 0.5 and 47.5 + j 1.19 respectively, which indicates that the input impedance of antenna is close to 50 ohm impedance of the feed line.

The computed variation of directivity and gain with frequency is shown in fig. 9 and 10 respectively. It is observed that there is no significant variation in directivity and gain of antenna when compared for without slot and with slot. The peak value of directivity and gain are 8.11dBi and 5.96dBi respectively.

The computed radiation pattern at both the resonant frequencies 3.10GHz and 3.64GHz respectively as well as frequencies correspond to -10dB reflection coefficient 2.96GHz and 3.90GHz are shown in Fig. (11-14). Computed pattern at all four frequencies have one well-defined lobe in broadside direction i.e. right angles to the plane of the radiating element. These patterns suggest that in entire bandwidth range, radiation patterns are identical in shape and direction of maximum radiations is directed normal to the patch geometry.

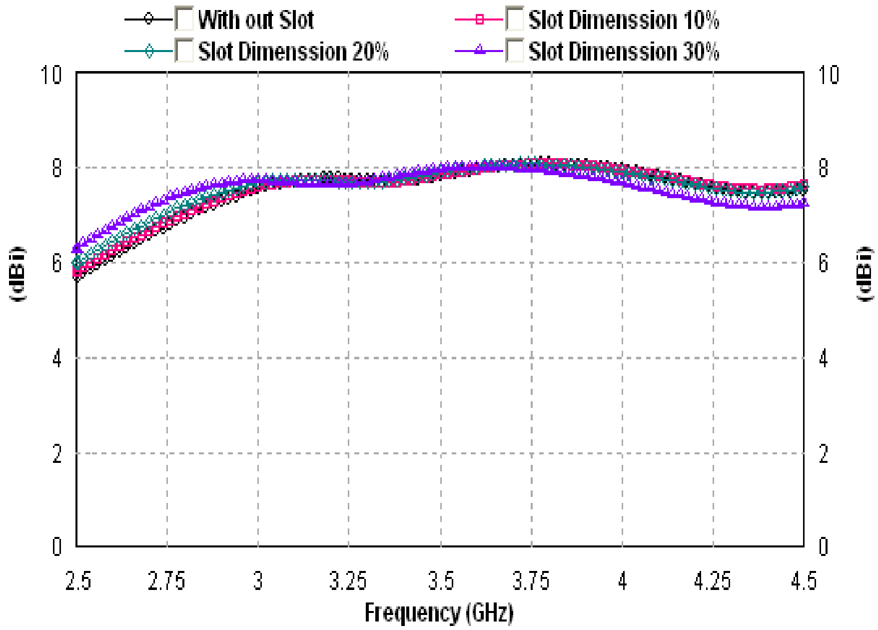


Fig. 9 Variation of directivity with frequency for rectangular microstrip patch with protruding semi ellipse having air gap h = 1.5 mm

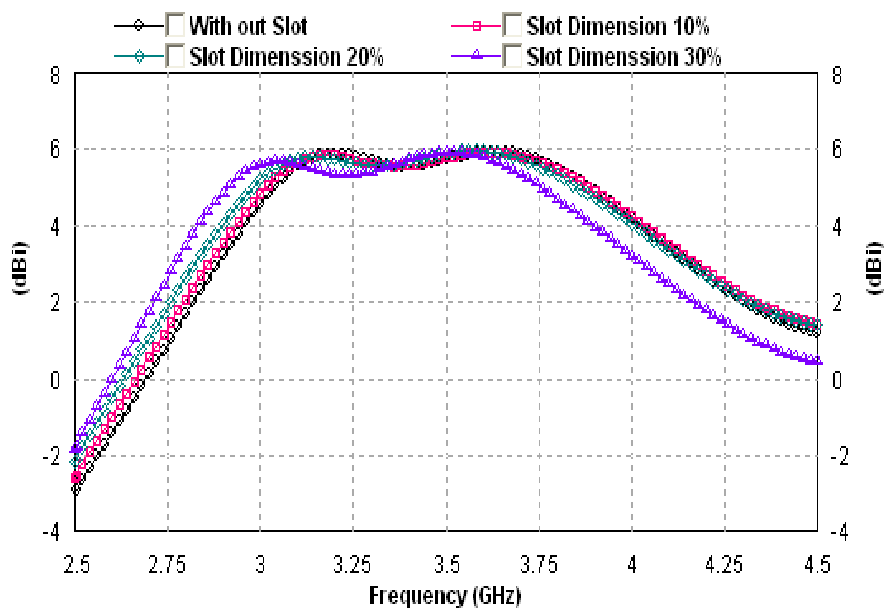


Fig. 10 Variation of total field gain with frequency for rectangular microstrip patch with protruding semi ellipse having air gap h = 1.5 mm

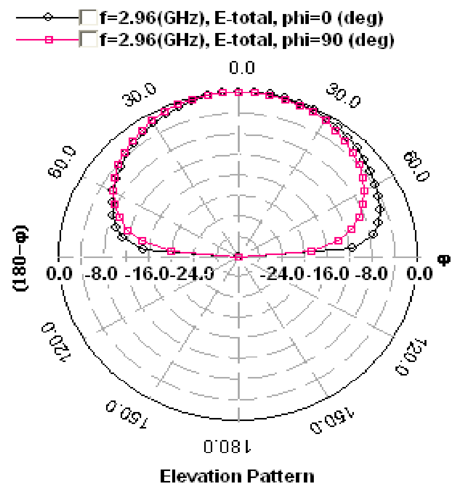


Fig. 11 Variation of two dimensional elevation patterns at 2.96GHz

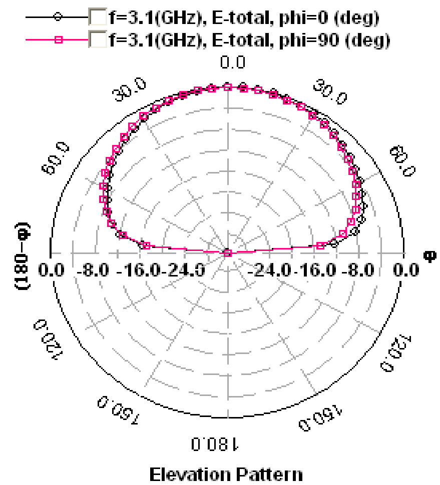


Fig. 12 Variation of two dimensional elevation patterns at .3.10GHz

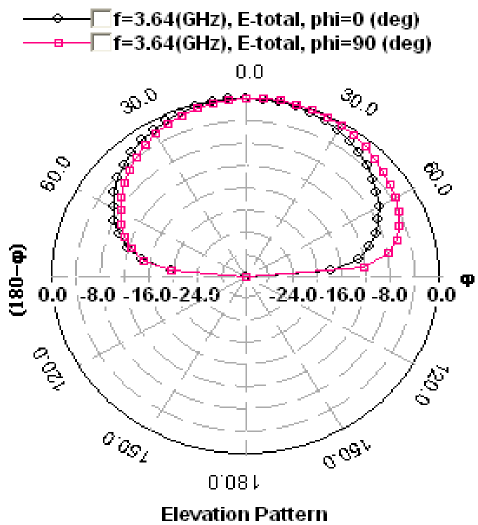


Fig. 13 Variation of two dimensional elevation patterns at 3.64GHz

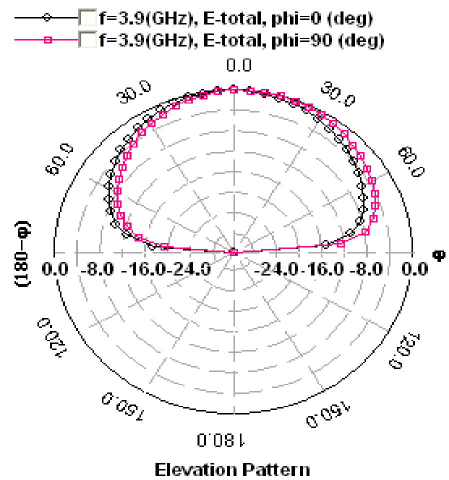


Fig. 14 Variation of two dimensional elevation patterns at 3.90GHz

3. Discussion and Conclusion

This paper presents the simulation investigations of a novel printed modified rectangular microstrip patch antenna having protruding semi ellipse with and without air gap for broadband operation. The simulation results for the proposed antenna shows a wide impedance bandwidth of order of 27%. In addition to being small in size, the antenna exhibits stable far field radiation characteristics in the entire operating bandwidth and relatively high gain. The gain is increased by the three times that is from 2.42dBi to5.96dBi in comparison to a normal patch antenna. An appreciable increment in directivity is also achieved. It was observed that by choosing optimum dimension of protruding semi ellipse, an optimum operating bandwidth could be obtained. Based on these characteristics, the proposed antenna can be useful for wideband satellite and communication applications in S band.

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