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Triple Frequency S-Shaped Circularly Polarized Microstrip Antenna with Small Frequency-Ratio

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ABSTRACT: A triple frequency single-feed S-shaped circularly polarized microstrip antenna with small frequency-ratio has been proposed for mobile communication and GPS applications. An S-shaped slot is cut at the centre of square patch of 84.5×84.5 mm^2 for multi-band operation. The proposed antenna geometry consists of an aperture-coupled feeding structure by a single microstrip line. The simulation results show that the proposed antenna can be used for multi-band operation with effective return loss of -34.34 dB, -18.23 dB and -24.75 dB at 1.193 GHz, 1.454 GHz and 1.615 GHz respectively. The measured gain of designed geometry is more than 5.0 dB over all the bands and measured frequency ratio is 1.2. The antenna design and optimization is performed with the help of commercial EM software IE3D.

KEYWORDS: Microstrip Antenna, Circular Polarization, Circularly Polarized Antenna, Slotted Patch, Slot, and GPS.

I. INTRODUCTION

Microstrip antennas (MSAs) are proven best radiators in different domains of wireless communications like satellite communication, mobile communication, radar system, global positioning system (GPS), and many other applications. Due to their operation in dual-frequency mode, the MSAs have replaced two single-frequency operated antennas in these applications. Microstrip antennas have many attractive features like low profile, conformability to planar and nonplanar surfaces, low fabrication cost, etc., the MSAs tolerate various drawbacks like poor radiation characteristics (narrow bandwidth, low gain, low efficiency, etc.), which demand more attention [1]. Microstrip patch antennas have enjoyed proliferated use in various circularly-polarized applications due to their low-profile and useful radiation characteristics [2].Now a day's circular polarization is one of the most common polarization types used in the field of wireless communication systems, for example: pulse radar and satellite systems, as it is independent of the transmitting and receiving antenna guidelines. It can also provide better mobility and weather penetration than linear polarization. Recently, circularly polarized patch antennas have the advantages of simple structure, low profile, light weight, easy impedance matching, very good radiation efficiency and wide bandwidth [3].

In many dual-band or multi-band applications as global positioning system (GPS), a small frequency ratio is needed. This poses a challenge for a single-feed, single-patch, microstrip antenna structure [4].Several circularly polarized microstrip antenna configurations have been reported during the last decade [2-13]. In this letter, triple frequency S-shaped circularly polarized microstrip antennas (CPMA) with a small frequency ratio have been investigated. The antenna consists of an S-shaped slotted square patch with an aperture coupled feeding structure. Triple frequency CP radiation is obtained by cutting an asymmetrical S-shaped slot from the radiating patch without increasing the shape and the thickness of the patch. The antenna design and optimization have been investigated with the help of commercial Electromagnetic (EM) software, IE3D [14]. Section II describes the related work on circularly polarized microstrip antennas. Section III describes proposed antenna structure and design. Section IV illustrates

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proposed methodology and discussion. Simulation study is discussed in section V. Conclusion and future work is discussed in Section VI.

II. RELATED WORK

Xiaoye Sun *et al.* have proposed a dual-band circularly polarized stacked annular-ring patch antenna for GPS application. This antenna is excited by two orthogonal H-shaped apertures fed by a 3-db hybrid and acts at both the GPS L1 frequency of 1575 MHz and L2 frequency of 1227 MHz, whose frequency ratio is about 1.28 [5]. A square-shaped dual-coupling feed circularly polarized microstrip RFID tag antenna designed for 915 MHz band is investigated by Horng-Dean Chen *et al* .[6].This antenna is excited by a dual-offset coupling feed network with one of the feed lines a quarter-wavelength greater than the other. In [7] Yunxue Xu *et al.* have investigated coaxially fed, circularly polarized microstrip antenna for harmonic suppression with the circularly symmetrical slot. The circularly symmetrical slot is etched on the radiation patch near the coaxially fed location. Chenguang Li *et al.* have proposed a novel broadband CP slot antenna. There are three CP modes in the coupling band. It is found that the 3-dB AR bandwidth of the proposed antenna can be improved by increasing the CP mode in the CP band. This antenna is excited by the proximity coupling of a microstrip line [8].

Yea Jan *et al.* have demonstrated new broadband microstrip-line-fed CP slot antenna. The spur slot can provide the perturbation into the wide slot antenna for the CP operation. Moreover, the use of open slot can improve the 3-dB AR bandwidths [9]. A single feed dual-band stacked circularly polarized microstrip antenna with a small frequency ratio have been reported by Sachin Kumar *et al.* [10].This antenna is having a dual-band frequency ratio of 1.05.A novel dual-polarized broadband frequency tuneable active electromagnetic band gap (EBG) structure has been presented, by Bin Liang *et al.* [11].Which is incorporated in the design of a frequency and polarization reconfigurable CP antenna. Chunling Chen *et al.* have demonstrated a dual-band circularly polarized microstrip patch antenna to satisfy the RFID application in China (840.5MHz-844.5MHz, 920.5MHz-924.5MHz), a parasitic patch is used to attain dual bands and slots in the ground are used to adjust frequency ratio [12]. A slot cut circularly polarized circular microstrip antenna at 900 MHz has been investigated by Amit A. Deshmukh *et al.* [13]. Circularly polarized microstrip antenna is frequently realized by cutting the slot within the patch and feeding it along the diagonal axis.

III. ANTENNA DESIGN AND STRUCTURE

The dimensions of the optimized antenna design are shown in Table I. The Proposed dual-band circularly polarized microstrip antenna (CPMA) cross-sectional view and S-shaped slotted patch radiator with aperture-coupled feeding structure is shown in Fig.1.

TABLE I
DIMENSIONS OF THE OPTIMIZED ANTENNA DESIGN

Antenna Parameters	Value (mm)
Thickness of lower substrate	1.524
Thickness of upper substrate	21.524
Length of patch	84.5
Width of patch	84.5
Length of ground-plane	115
Width of ground-plane	115
Length of aperture	50
Width of aperture	3
Width of slot W_s	4.5

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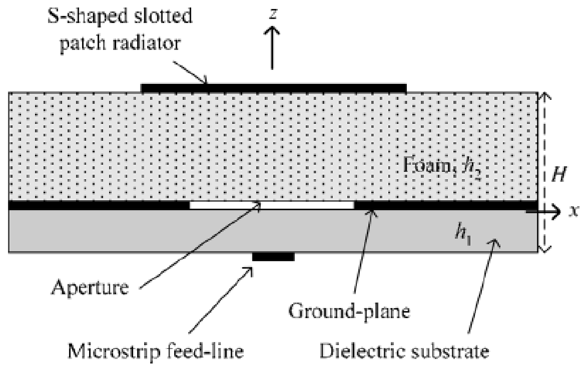
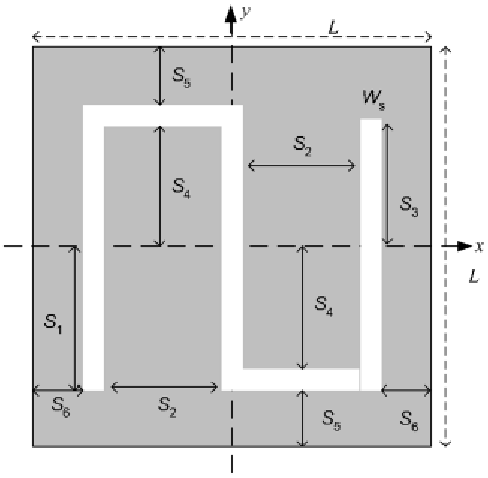
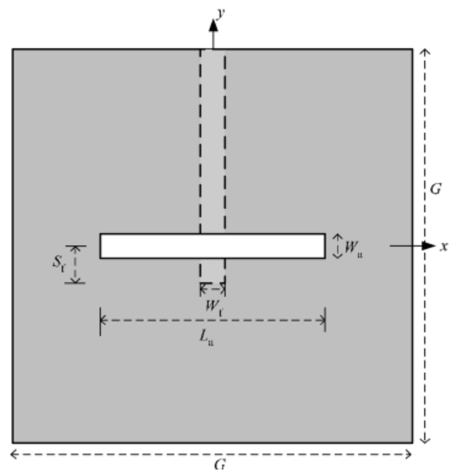


(a)



(b)



(c)

Fig.1. Proposed dual-band CPMA: (a) cross-section view, (b) S-shaped slotted patch radiator, and (c) aperture-coupled feeding structure.

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The cross-sectional view of the designed antenna is shown in Fig.2. Here a square patch of dimensions 84.5×84.5 mm^2 is used with a ground plane of dimensions 115×115 mm^2. The patch is fed by an aperture-coupled 50-Ω microstrip feed-line under the ground-plane. The Designed antenna has a square patch on ground plane with S-shaped slot at the centre of patch as shown in Fig 2. The aperture is carve on the opposite side of an RO4003C substrate (h = 1.524 mm, ε_{r1} = 3.8 and tan δ_1 = 0.0027).The proposed antenna length vary from 4.5mm to 25.5mm and width from 4.5mm to 49.0mm. The results are verified on IE3D EM simulator [14] with the parameters for X-axis -30.0mm to 30.0mm, Y-axis -22.25mm to 22.25mm and Z-axis is still 21.524mm.

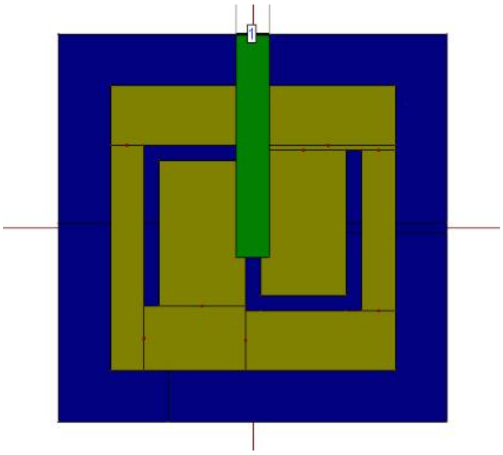

Fig.2. View of Designed Antenna

IV. Proposed Methodology and Discussion

A parametric study has been done to perceive the effect of the S-shaped slot on the multi-band CP operation. The procedure selected for the study is that only one parameter is changed at a time while all remaining parameters are kept unchanged. By varying the length of slot the operating frequency ratio of two bands can be controlled. From simulation, it is found that the dimension of the S-shaped slot significantly strike the performance of the antenna.After simulation, a procedure of the antenna design is demonstrated as follows.

1. Determine the initial dimensions of the square patch with an S-shaped slot according to the lower-band frequency and the antenna size constraint.
2. Optimize the aperture-coupled feeding structure of antenna to achieve good impedance matching over all the operating bands.
3. Select the length of one arm of the S-shaped slot and adjust the length of the other arm to generate dual band CP operation. Make certain that the 3-dB AR bandwidth falls totally within 10-dB return loss bandwidth.
4. Further optimize the antenna by changing the foam thickness and S-shaped slot parameters (S_1, S_6, and S_5).

If the desired performance over the required frequency is not obtained at the end of Step 4, change the basic parameters in Step 1 and iterate the steps.

V. Simulation Results

The proposed structure of circularly polarized microstrip antenna (CPMA) is shown in Fig.1. This antenna structure consists of an S-shaped slotted square patch on the top of ground plane. An S-shaped slot is cut at the centre of square patch radiator. Here, a single microstrip feed-line is beneath the centre of the coupling aperture ground-plane. The designed antenna structure is shown in fig. 2. Here a square patch is placed on the top of ground plane and fed by the help of aperture coupled 50 Ω microstrip line below the ground plane. The designed antenna resonates at triple frequencies i.e. 1.193 GHz, 1.454 GHz and 1.615 GHz at the return loss values of -34.34 dB, -18.23 dB and -24.75 dB respectively which are shown by Fig.3. Return loss is used in modern practice in preference to SWR because it has

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superior resolution for small values of reflected wave. The designed antenna with an S-shaped slot has obtained appropriate impedance matching, high gain and wide CP beamwidth. Fig. 4 shows the measured and simulated gain of three resonant frequencies at the boresight. The measured and simulated gain of designed geometry is more than 5.0 dB which is suitable for GPS application [4]. Fig. 5 shows the results for the measured and simulated axial-ratio at the boresight. The proposed geometry has good axial-ratio for all the bands.The frequency-ratio of the measured minimum AR for triple-band is 1.2.

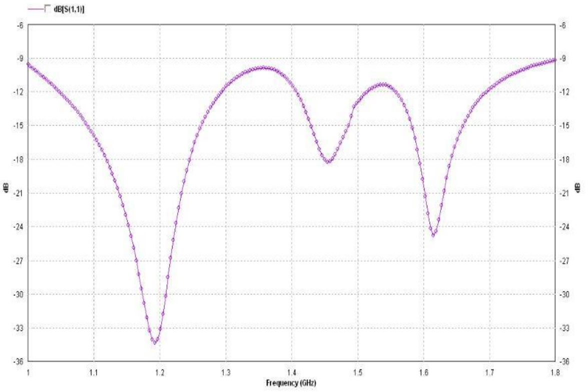

Fig.3. Return-Loss (dB) vs. Antenna Frequency

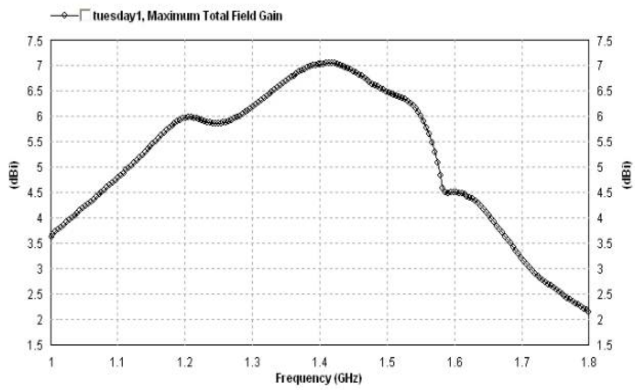

Fig.4 Total field gain vs. Frequency

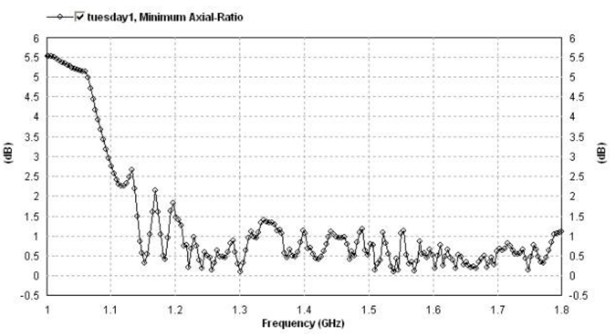

Fig.5 Axial Ratio vs. Frequency

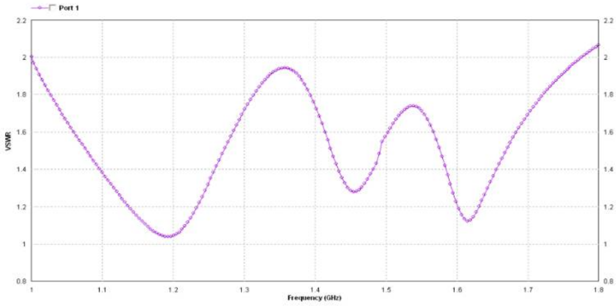

Fig.6 VSWR vs. Frequency

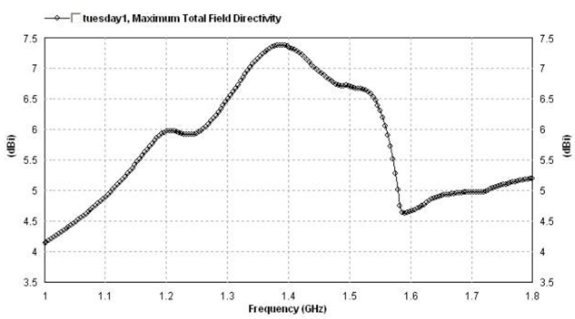

Fig.7 Directivity vs. Frequency

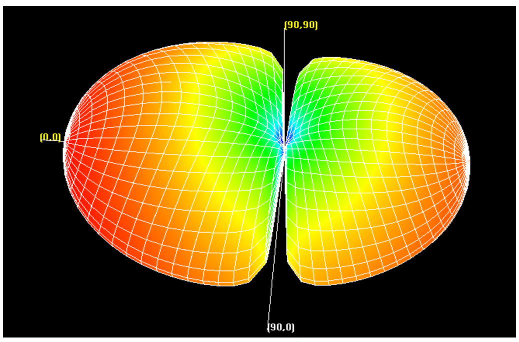

Fig.8 3D Radiation Pattern

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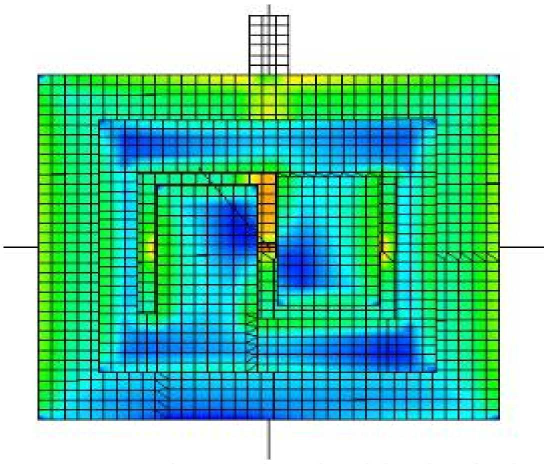

Fig.9 3D Current Distribution on the S-Shaped slotted Patch radiator

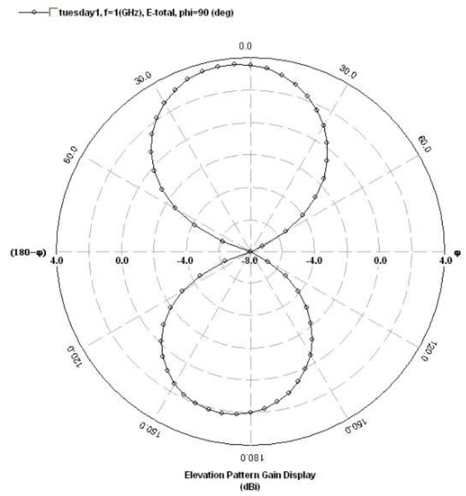

Fig.10 2D Polar-Plot Pattern

Fig. 6 shows VSWR of triple resonant frequencies. The values of the VSWR at 1.193 GHz, 1.454 GHz and 1.615 GHz are 1.039, 1.279 and 1.123 respectively. The smaller the value of VSWR is, the better the antenna is matched to the transmission line and the spacious power is delivered to the antenna. The minimal VSWR is 1.0. In this case, no power is reflected from the antenna, which is ideal. This figure shows that the antenna has good VSWR performance (VSWR <2) which is required for circularly polarized microstrip antenna. The values of Return-Loss and voltage standing wave ratio (VSWR) are tabulated in following Table II.

TABLE II
OBTAINED RETURN-LOSS AND VSWR

Frequency (GHz)	Return-Loss (dB)	VSWR
1.193	-34.34	1.039
1.454	-18.23	1.279
1.615	-24.75	1.123

According to the values of S-parameters of proposed antenna structure, there is a good impedance matching between transmission line and the square radiating element at triple frequencies. Fig. 7 shows the directivity vs. frequency for the designed antenna configuration. The directivity of an actual antenna can vary from 1.76 dB for a small dipole, to as much as 50 dB for a huge dish antenna. For the designed antenna, directivity is more than 6 dB over all the bands. The 3D radiation pattern is shown by Fig. 8. It is important to state that an antenna radiates energy in all flanks, at least to some extent, so the antenna pattern is actually three-dimensional. It is common, however, to depict this 3D pattern with two planar patterns, called the principal plane patterns. These principal plane patterns can be acquired by making two slices through the 3D pattern through the maximal value of the pattern or by apparent measurement. The 3D Current Distribution on the S-Shaped slotted patch radiator for multi-band operations is shown in Fig. 9. It is found that, the current is much stronger around the edges of the S-shaped slotted patch at 1.193 GHz, 1.454 GHz and 1.615 GHz. Fig. 10 represents the 2D polar plot pattern i.e. elevation pattern gain display (dB). The term azimuth is normally found in reference to “the horizontal” whereas the term elevation generally refers to “the vertical”. The antenna patterns (azimuth and elevation plane patterns) are frequently demonstrated as plots in polar coordinates. This allows the viewer the ability to easily visualize how the antenna radiates in all directions. Occasionally, it may be adjunct to plot the antenna patterns in Cartesian (rectangular) coordinates, particularly when there are several side lobes in the patterns and where the levels of these side lobes are important.

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VI. Conclusion and Future Work

A triple frequency single-feed single-patch S-shaped circularly polarized microstrip antenna with small frequency-ratio has been reported. The proposed antenna geometry with an S-shaped slot at the centre of square patch radiator has achieved very good impedance matching, high gain, and wide circular polarization. The proposed antenna has small triple frequency ratio of 1.2. The proposed aperture-coupled feed single-patch S-shaped slotted microstrip antenna is usable for small frequency-ratio multi-band CP antenna and GPS applications. In this paper we try to minimize the return loses with the help of varying slot length by using the IE3D EM simulator version 12.0. Our results indicate that the bandwidth around the three operating frequencies (1.193 GHz, 1.454 GHz and 1.615 GHz) is sufficient. Modifying the antenna structure will help us to get more number of frequency bands. Cutting slots, adding parasitic elements, usage of tuneable materials are some of the experiment to get desired operating bands. Extensions can be done on the designed model to support more bands in the wireless spectrum.

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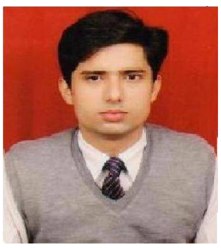
BIOGRAPHY



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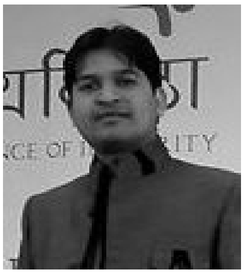

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Aadesh Kumar Arya received his B. E degree in Electrical and Electronics Engineering from Dr. B. R. Ambedkar University, Agra and M.Tech degree in Communication Engineering from Shobhit University, Meerut in 2003 and 2009 receptively. Presently he is now pursuing Ph.D in Electrical Engineering in Department of Electrical Engineering at National Institute of Technology, Kurukshetra. He is working as Assistant Professor in the Department of Electrical & Electronic Engineering at COER, Roorkee. He has 13 years teaching experience. He has been received Best Faculty Award for academic excellence in 2013. He has published many research papers in reputed national, International Journal and International conferences. His main interests focus on Smart Grid technology, Distributed Generation, FACTS applications, DR, DSM and smart appliances.
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