Multi Band Circularly Polarized Microstrip Patch Antennas for Mobile Communication

Mukesh Arora, Shubhi Jain, Abha Sharma

***Abstract:* This paper represents a circularly polarized microstrip antenna for many kind of wireless communication applications. Circular polarization can be achieved with asymmetries. The emphasis is on to increase the bandwidth of the antenna. In this paper various kinds of techniques has been used to provide circular polarization like triangular slits inserted at the corners, corners of the patch are truncated etc. The proposed antennas have been discussed with Aperture Coupled feeding. Measured results show that radiation patterns with good CP Characteristics are obtained for multi bands. HFSS software used to simulate the antennas.**

***Index Terms*: Microstrip, Bandwidth, Aperture Coupled Feed, HFSS**

I. INTRODUCTION

A microstrip patch antenna is a type of antenna that offers a low profile, i.e. thin and easily manufacturability, which provides great advantages over traditional antennas [1-2]. However, patch antennas have a main disadvantage i.e. narrow bandwidth [3]. Researchers have made many efforts to overcome this problem and many configurations have been presented to extend the bandwidth.

In modern wireless communication systems, small circularly polarized microstrip antennas with good performance are desirable mainly at low microwave frequencies. Design of the compact CPMA is attractive for handheld/portable device applications. Small size of the CPMA can be achieved at the cost of limited gain and narrow 3-dB axial ratio (AR) bandwidth/ 10 dB return loss impedance bandwidth. Using slits/slots on a radiating patch two orthogonal modes can be generated at around resonance frequency with 90^0 phase-shifts for CP radiation requirements. The single-feed circularly polarized microstrip antennas are generally compact when compared with the dual-feed CPMAs. Single feed CPMA is simple, compact structure, easy manufacture, and low-cost. Asymmetric cross-slot provides necessary perturbation to excite two orthogonal modes with 90^0 phase-shifts to generate CP radiation. Aperture coupled microstrip antenna couples patch to the feed line through a slot. In this technique the feed network is separated from the radiating patch by a common ground plane. Energy is electromagnetically coupled through an aperture in the ground plane. This aperture is usually centered with respect to the patch where the patch has its maximum magnetic field. For maximum coupling it has been suggested that a rectangular slot parallel to the two radiating edges should be used. Two very similar coupling mechanisms take place, one between the feed line and the slot and another between the slot and the patch. This technique has several advantages, which makes it suitable for widespread applications in communication systems. Also, the isolation of the feed network from the patch reduces the spurious radiations and provides more space for the feed network, being suitable for phased arrays. Wider bandwidth can be achieved by adjusting the width and length of the coupling slot and using a thicker patch substrate. The feed substrate is usually thin with high permittivity, whereas the patch substrate can be thick with low permittivity.

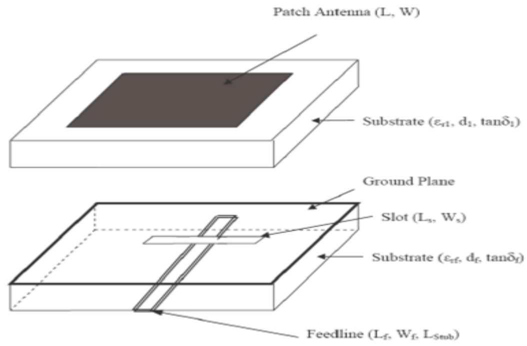

Figure 1 Microstrip Antenna with Aperture Coupled Feed

II. DESIGN OF V-SLIT MICROSTRIP ANTENNA

Designed Frequency: 2.4 GHz
Substrate Height h: 4.572mm
Ground Dimensions: 66x76 mm^2
Patch Dimensions: 50x50x4.572mm^3
Dielectric constant: 2.2
Loss tangent: .0002

There are several type of slots are inserted into the patch to reduce the size of the antenna. Now, we will discuss each antenna one by one in detail.

V-Slit microstrip antenna is proposed for circular polarized radiation and it also reduces the size of the antenna. Aperture coupled feeding technique is used for analysis. Location of four V-shaped slits are located at (P,P) along diagonal directions from center of the square microstrip patch. 1,2,3,4 are areas of the slit along the diagonal directions.. 1 and 3 are same as well as 2 and 4 are also same. For CP radiation of the patch antenna, 1/3 should be not equal to 2/4. The geometry is shown in Fig.1 and Fig 2.

This antenna is designed for 2.4 GHz frequency. The substrate material used for design is Roger RT/ duroid.

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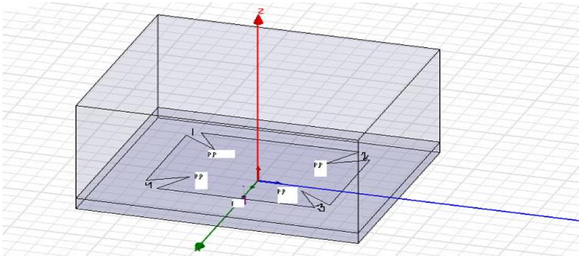

Figure2. V-Slit Patch Antenna

Figure 3 shows the variation of return loss versus the frequency of designed antenna. The return loss of antenna is -12dB and -42 dB. It is observed that, the antenna resonates at 1.12 GHz and 3.33 GHz. The percentage of experimental impedance bandwidth is calculated by using the following relation:

Impedance bandwidth (%) = $f_2 - f_1 / f_c$ x100%

Where, f_2 and f_1 are upper and lower cutoff frequency of the resonated band when its return loss reaches -10 dB and f_c is a center frequency between f_2 and f_1.

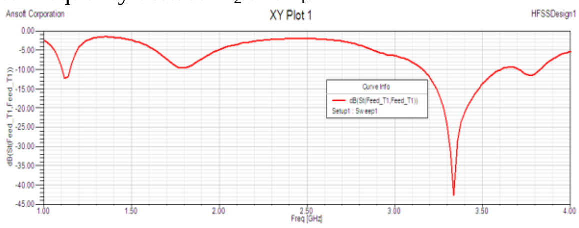

Figure3. Simulated Return loss S_{11} V/S Frequency

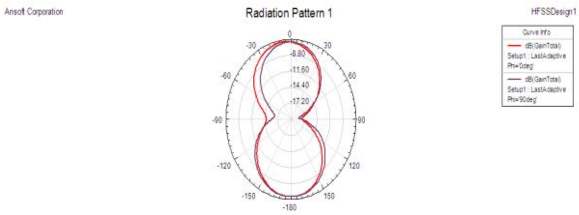

Figure 4 Radiation Pattern for V-Slit Patch

This antenna is designed with HFSS software. The measured impedance bandwidth is 12.74%.

III. PENTAGONAL SLOT MICROSTRIP PATCH ANTENNA

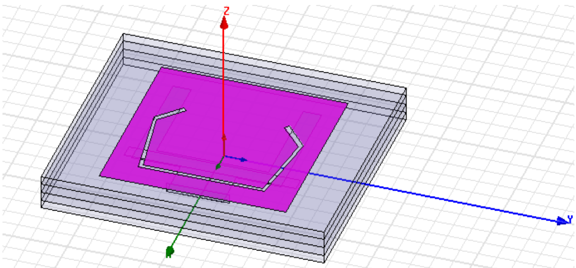

Figure 5 Pentagonal Slot Antenna with Aperture Coupled Feed

As shown in Figure 5, a pentagonal slot has been cut in the square patch. The length of the patch in x-direction is 33 mm, 14 mm in y-direction and 7 mm in z-direction. The width of pentagonal slot is 1 mm. This antenna gives circular polarization. Pentagonal slot reduced the size of antenna.

This proposed antenna resonates at two frequencies respectively at 1.73GHz and 3.63 GHz. The measured impedance bandwidths are 10.53% at 1.73 GHz and 9.14% at 3.63 GHz with return losses of -15 dB and -29 dB respectively.

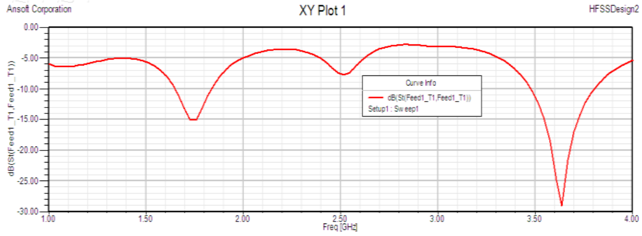

Figure 6 Simulated Return loss S_{11} V/S Frequency

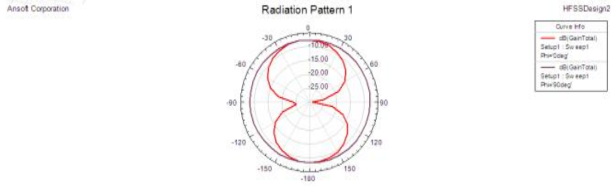

Figure 7 Radiation Pattern for Pentagonal Slot

IV. PENTAGONAL SLOT WITH V-SLITS MICROSTRIP PATCH ANTENNA

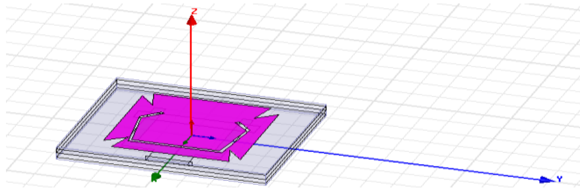

Figure 8Pentagonal Slot with V-Slit Microstrip antenna with Aperture Coupled feed

In previous, pentagonal slot has been reduced from the patch. Now V-shaped slits has been also cut out at the corners of the patch. Thus this antenna may be said as a combination of two previous designs.

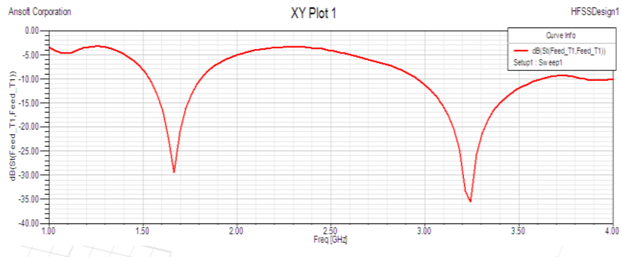

Figure 9 Simulated Return loss S_{11} V/S Frequency

The resulted design as shown in Fig 9 gives dual bands of 1.65 GHz and 3.24 GHz. Compared to previous design, this antenna is more compact in size .The bandwidth also increases. The measured bandwidth is 15.85% and 18.80% with return losses of -29 dB and -35 dB. When feed point is changed, as shown in Fig 10, the antenna gives three resonant frequencies 1.08 GHz, 1.77 GHz and 4.82 GHz, which shows multi bands. The bandwidth is increased by 12.90%, 10.83% and 11.02%. Thus we observe multi-bands.

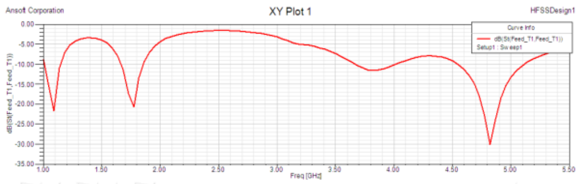

Figure 10 Simulated Return loss S_{11} V/S Frequency

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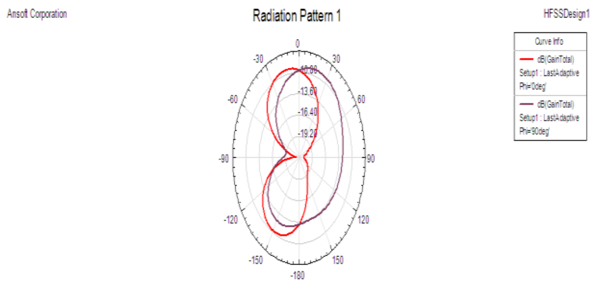

Figure 11 Radiation Pattern for Pentagonal with V-Slit

V. TRUNCATED SLOT PENTAGONAL MICROSTRIP ANTENNA

In this design, the pentagonal slotted antenna is now truncated at the opposite corners, which provides two orthogonal modes for circular polarized radiation due to the unequal size of truncated corners. A pentagonal shaped slot is cut in the truncated patch. The width and length of the truncated slot is 7mm and 8mm respectively. The designed antenna is shown in Fig 12.

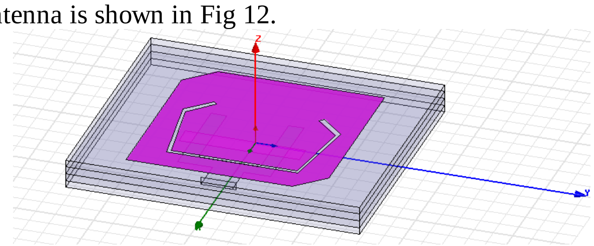

Figure12. Truncated corner Pentagonal- slot Patch Antenna

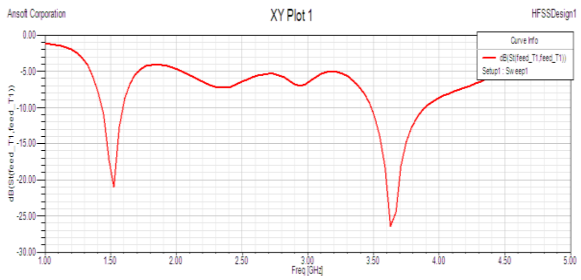

Figure 13 Simulated Return loss S_{11} V/S Frequency

The above graph shows the return loss of -21dB at 1.52 GHz and-26 dB at 3.62GHz. The measured impedance bandwidths are 11.35% at 1.52 GHz and 10.92% at 3.62 GHz. When this antenna is truncated at all corners as shown in Figure 14, the bandwidth is improved and the size also reduced. In this design the opposite end of corners are equal in size but unequal from each other, which provide us two orthogonal modes to produce CP radiation. The measured impedance bandwidth is 8.25% at 1.56 GHz and 13.28% at 3.67 GHz.

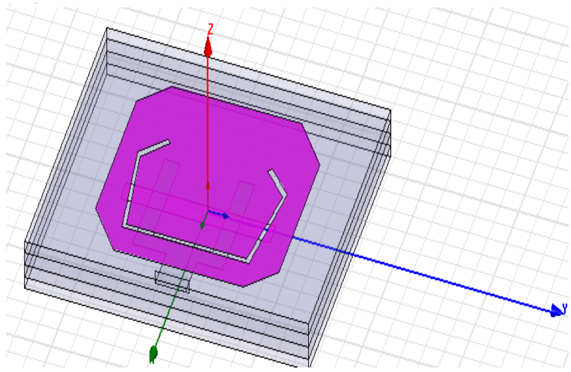

Figure14. Truncated corner Pentagonal- slot Patch Antenna

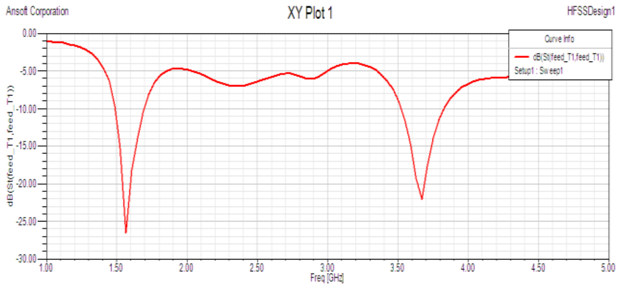

Figure 15 Simulated Return loss S_{11} V/S Frequency

VI. T-SLIT PENTAGONAL SLOT MICROSTRIP ANTENNA

Due to the inserted T-shaped or Y-shaped slits, the excited patch surface current path of theTM10 mode is greatly lengthened, which effectively lowers its resonant frequency and gives the proposed designs a reduced patch size for the fixed lower frequency of dual-band CP radiation. For the TM30 mode, the inserted slits not only considerably lower its resonant frequency, but also modify its three-lobe radiation pattern [12] to become similar to that of the TM10 mode. This arrangement is very effective for fine tuning the perturbed TM30 mode (upper operating band in this design) into two near-degenerate modes with equal amplitudes and a 90◦ phase shift for CP radiation. The splitting of the perturbed TM10 mode (lower operating band) into two near-degenerate modes for CP radiation is mainly achieved by selecting suitable dimensions of the center slot.

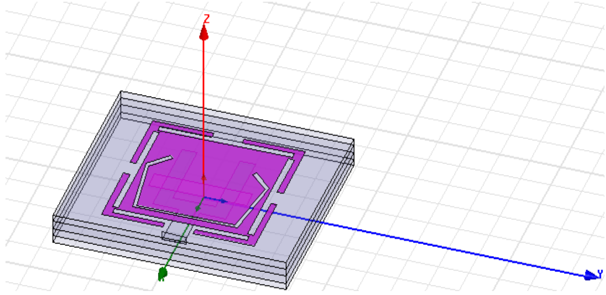

Figure16. T- Shaped Slit with Pentagonal- slot Patch Antenna

In this design T-shaped slits are inserted at all boundaries of the square patch and then pentagonal slot cut out from the patch. T-slits are equal at opposite sides of the patch, but are unequal from each other. These unequal sizes of slits introduce a phase shift of 90 degree to create circular polarized radiation. This design reduces the size of the antenna as well as gives better radiation pattern than the other discussed previous.

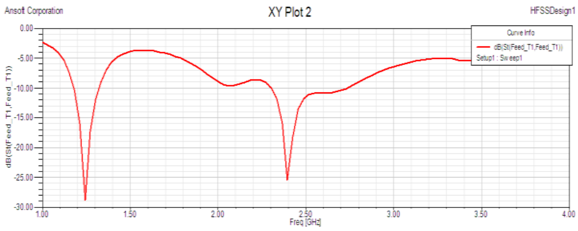

Figure 17 Simulated Return loss S_{11} V/S Frequency

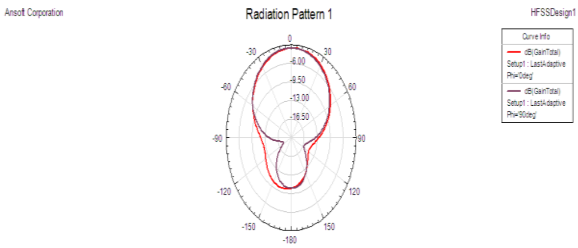

Figure 18 Radiation Pattern for Pentagonal with T shaped-Slit

The measured impedance bandwidth is 11.57% and 17.60% at resonating frequency of 1.25 GHz and 2.40 GHz with return losses of -29 dB and -25 dB respectively.

VII. COMPARATIVE ANALYSIS

Table 1

	Frequency	Return Loss	Bandwidth
V- Slot	3.33GHz	-42dB	12.74%
Pentagonal	1.73 GHz 3.63 GHz	-15dB -29dB	10.53% 9.14%
Pentagonal with V- Slot	1.08 GHz 1.77 GHz 4.82 GHz	-22dB -21dB -30dB	12.90% 10.83% 11.02%
Pentagonal Slot with Two-sided Truncated Corners	1.52 GHz 3.62 GHz	-21 dB -26 dB	11.35% 10.92%
Pentagonal Slot with Four-sided Truncated Corners	1.56 GHz 3.67GHz	-25 dB -22 dB	8.25% 13.28%
T-Slit Pentagonal slot	1.25 GHz 2.40 GHz	-29 dB -25 dB	11.57% 17.60%

VIII. CONCLUSION

The all above designed antenna reduces the size of the antenna as well as provide increased bandwidth with multi band circular polarization. These small antennas can be used for various wireless communication applications. Thanks to its compactness and multi band circular polarized radiation which can be used in mobile communications.

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