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Bandwidth Enhancement Using Single Slot in Heptagonal Microstrip Patch Antenna

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Abstract - *FR4 is an inexpensive and easily available substrate material, which can be used to design efficient and cost effective microstrip patch antenna. This paper focuses on increasing the bandwidth of the microstrip patch antenna. Paper discusses about design of a Heptagonal patch antenna, having coaxial probe as a feed. To get the improved bandwidth, a rectangular slot has been digged on the patch, which changes the interaction of radiation. A huge increase in bandwidth is observed using the proposed design. All the simulation work is done using IE3D simulating software from Zeland has been used.*

Key Words: FR4, heptagonal antenna, slot, coaxial feed, IE3D

1. INTRODUCTION *(Size 11 , cambria font)*

A Microstrip or Patch Antenna is a low profile Antenna that has a number of advantages over other antennas. It is lightweight, inexpensive, and easy to integrate with accompanying electronics. While the antenna can be 3D in structure (wrapped around an object, for example), the elements are usually flat, hence their other name, Planar Antennas. A Planar Antenna is not always a patch antenna. But the use of conventional elliptical microstrip patch antenna alone is very difficult because of its low gain and narrow bandwidth. So to overcome these problems various methods have been tried, some of them are listed in next section. This paper proposes a method in which slots are digged in heptagonal patch antenna. Configuration of paper is as follows: Next section is literature review, which is followed by proposed design and in the last some conclusions are drown based on simulation done.

2. Literature Review

The Gordon et.al described that the band width of microstrip antennas can be increased by using thick substrate but with thick substrate coaxial probe feed introduces inductive component due to which unavoidable impedance mismatch occurs. So the solution to impedance mismatch was found in the form of capacitive feeding mechanism which can be used for annular ring MPA elements, consisted a small capacitor patch in the same layer as in the radiating element. [1]

Gordon et.al experimented on following three designs:

- Rectangular radiating elements,
- Circular radiating elements and
- Annular ring radiating elements

Feeding mechanism was common in all three designs. The position of the probe feed was decided to be in the center of the small patch. Design tool used was IE3D 12th version Zeland, substrate was FR4 with thickness 1.6 mm having dielectric constant 4.4. Height of patch from ground was taken as 15 mm, ground plane was taken as square of 150x150 mm and probe diameter 0.9 mm.

Experimental Results are shown below:

Resonant frequency- 1800MHz

10 dB return loss Band Width-

	Rectangular	Circular	Annular Ring
Simulated	25.9%	26.8%	25.9%
Measured	26.4%	27.9%	26.1%

Gain-

	Rectangular	Circular	Annular Ring
Simulated	8.5dBi	8.8 dBi	8.0 dBi
Measured	8.2 dBi	8.6 dBi	8.5 dBi

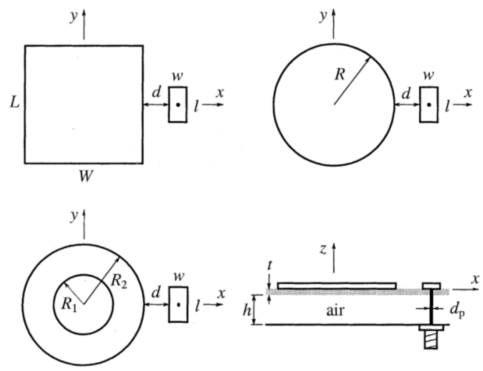

Fig- 1: Structure of proposed antenna design for (a) rectangular,(b) circular and (c) annular ring radiating elements (d) side view of anteena.

Dheeraj et. al. proposed modified circular patch antenna to achieve 50.36% efficiency together with 4.10 dBi gain and 8.38% band width. Firstly they taken a circular patch and then an elliptical slot has been cut in it, after this, parallel to major axis of the inserted elliptical slot, splitting is applied and at last this elliptical hole is filled with an elliptical patch between two split halves of circular patch.

FR4 of thickness 1.59 mm and dielectric constant 4.4 was taken as substrate which had loss tangent of 0.0148. Main circular patch radius was taken 12 mm. For inside elliptical patch semi major axis is of 9 mm, semi minor axis is of 4.8 mm and eccentricity is 0.846. Splitting width of circular patch in two halves is 0.25 mm. Ellipse filling the elliptical slot has a = 8 mm and b = 3 mm.

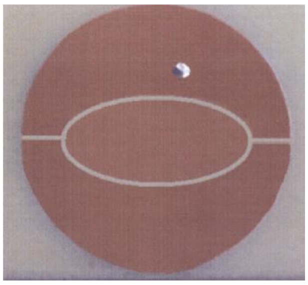

Fig- 2: Split circular patch antenna with elliptical slot and filled with elliptical patch

Experimental Results are shown below:

Geometries	Resonance Frequency, GHz	Radiation Efficiency %	Directivity dBi	Gain dBi	Bandwidth %
Circular elliptical ring	4.96	22.48	6.30	1.11	6.02
Gap coupled split circular patch antenna with circular slot	5.16	53.35	7.61	4.87	6.64
Gap coupled split circular patch antenna with elliptical slot and filled with elliptical patch	5.01	50.36	7.08	4.10	8.38

Garima et. al. proposed concentric diamond shape slotted circular patch microstrip antenna which is useful for C band and space communication systems. Main disadvantage of microstrip antennas is efficiently at a single resonance frequency corresponding to their dominant mode, narrow bandwidth (1-2%) and low gain. They proposed antenna useful for satellite communication systems as it presents the desired performances, viz. improved bandwidth, gain and multiple operating frequencies needed for satellite communication systems. FR4 with having thickness of 1.59 mm, dielectric constant of 4.4 and loss tangent of 0.025 was used as substrate. Circular patch radius is 16.2 mm was fabricated. To improve bandwidth path of the patch current has been increased by digging a diamond shape slot having dimensions a= 6 mm and b= 10 mm as shown in figure

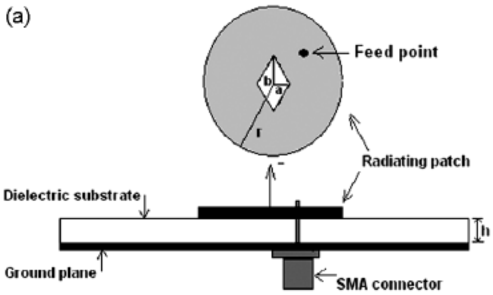

Fig- 3: Design of proposed antenna

As a result resonating frequencies of 6.23GHz and 6.859GHz (simulating) and 6.66GHz and 7.42GHz (measured) were observed and bandwidth of 15.99% (simulated) and 13.58% (measured) along with Gain of 5.84 at 6.66GHz and 5.71 at 7.42GHz were observed, which is huge improvement over non-slotted design. [3]

To obtain improved bandwidth and circularly polarized radiation over conventional elliptical antenna, in this paper the elliptical shape patch antenna with truncated edges has been introduced. In [4] tow antennas were studied (1) a conventional elliptical antenna and (2) edges truncated elliptical antenna. FR4 with having thickness of 1.59 mm, dielectric constant of 4.4 and loss tangent of 0.025 was used as substrate. Ellipse patch with semi major axis a = 15 mm and semi minor axis b = 14.43 mm after truncation L_1= L_2=7.75 mm as shown in figure.

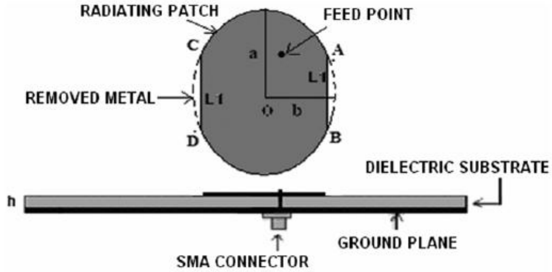

Fig- 4: Edge truncated elliptical patch antenna

Results showed resonating frequency =2.71 GHz and 2.80 GHz (simulated) and 2.692 GHz and 2.802 GHz (measured) were measured. Input impedances = (62.30+ j11.71) ohm corresponding 2.692 GHz and (48.49+ j5.34) ohm corresponding 2.802 GHz resonant frequency, Minimum Axial ratio = 0.68 dB at 2.751 GHz, Gain = 1.71 dB at 2.751 GHz

3. Proposed Design and Results

Design specification: To design this antenna, IE3D simulating software from Zeland has been used. The FR4 substrate having thickness of 1.59mm, dielectric constant of 4.4 and loss tangent of 0.025 is used. We have chosen FR4 because it is inexpensive and easily available substrate material.

Design dimensions: The heptagon patch has the radius 8 mm. We used coaxial probe for connecting microstrip patch antenna at coordinates (2.5mm, 1.5mm) and same arrangement is used the conventional as well as the Slotted heptagon microstrip patch antenna. To get the improved bandwidth, a rectangular slot of dimensions 7.25mm×1mm at point (-3, 0) has been digged.

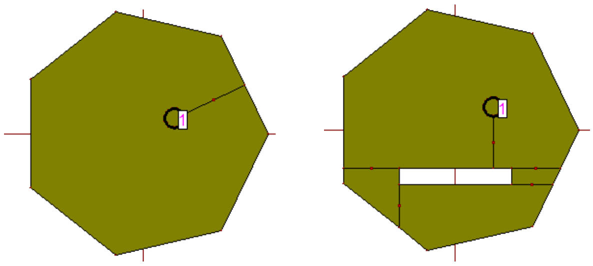

Fig- 5: (a) Conventional Heptagon patch (b) Slotted Heptagon patch

Return loss and bandwidth: After simulation on optimized slot area with different coordinates of the patch the simulated results of return loss and bandwidth are shown in figures below. As shown in fig 6 general heptagon patch has return loss of -30.81 dB with 5.17GHz resonant frequency, whereas return loss of single slotted heptagon patch is -26.83dB on 5.08GHz resonant frequency. Bandwidth is taken 10 dB down of return loss curve. Conventional patch has bandwidth 4.11% and after modification enhanced bandwidth 10.07% is obtained.

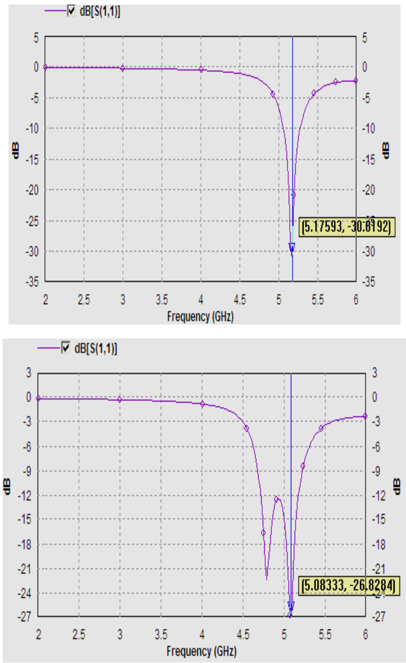

Fig- 6: (a) and (b) Simulated frequency v/s bandwidth of conventional and single slotted heptagonal Patch

Smith Chart: The smith chart corresponding to conventional heptagonal and slotted heptagonal patch is shown in figure 7(a) and (b). The figure 7 (a) shows the input impedance for conventional heptagon patch is obtained as (49.64 – j1.26), this shows that the antenna is linearly polarized. Figure 7 (b) shows that the 46.19 +j0.28 input impedance is obtained for the single slotted heptagonal microstrip patch antenna and the antenna is circularly polarized but with some impurities.

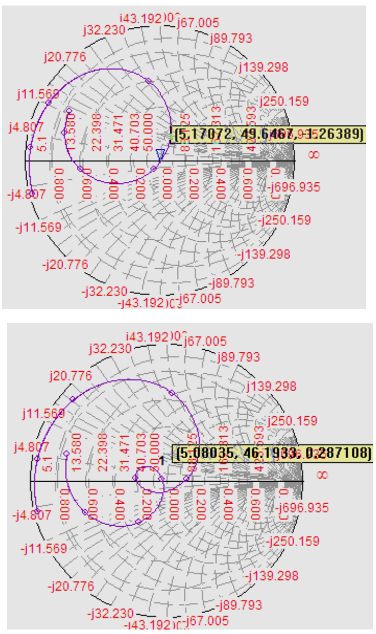

Fig- 7: (a) and (b) simulated smith chart of general and single slotted heptagonal patch

Radiation Pattern: The plot of radiation pattern of both, general heptagonal patch and slotted heptagonal patch is shown in figure below. Figure 8 shows that the radiation pattern is uniform and smooth over the large band of frequencies.

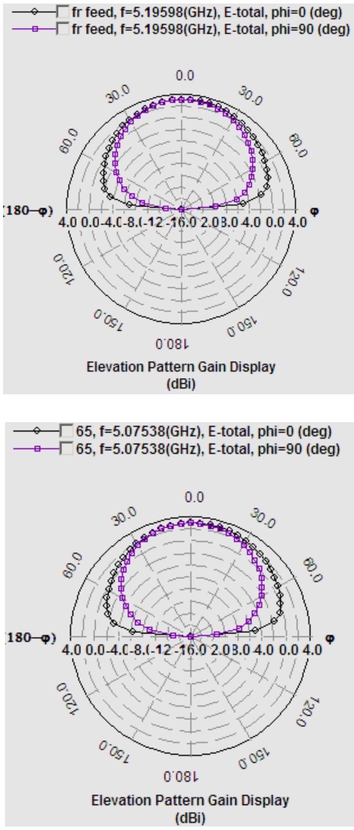

Fig- 8: (a) and (b) Simulated radiation pattern of conventional heptagon patch and single slotted heptagonal patch

Table 1: Comparison of simulated result of conventional heptagon and proposed slotted heptagon

Sr. No.	Characteristics	Conventional Heptagon Patch	Single Slot Heptagonal Patch
1.	Resonant Frequency	5.17GHz	5.08GHz
2.	Return Loss	-30.81dBi	-26.83dBi
3.	Bandwidth	4.11%	10.07%

4. Conclusions:

The FR4 substrate with aforesaid properties and dimension has been used. To optimized the output different location of the slot have been tried, maximum bandwidth was observed for slot dimension 7.25mm×1mm at point (-3, 0). For the same dimensions conventional heptagon patch had bandwidth 4.11% and proposed design had bandwidth of 10.07%. Radiation pattern is uniform and smooth over a large band of frequencies and infinite ground plane would prevent any radiation towards back of the antenna.

Table 2 shows the variation in results on optimizing the area of slot in terms of wavelength. The best results are found when length of slot is λ/8 (= 7.25).

S. No.	Position of feed point (x, y)	Resonant frequency (GHz)	Return loss (dB)	Bandwidth (%)	Gain (dB)	Efficiency Radiation, antenna (%)	Position (x, y) and size of slot (mm)
1.	(2,1)	4.896	-16.98	8.66	2.28	37, 38	(0,-3) 7.25*0.25
2.	(2,1)	4.856	-17.64	9.55	2.77	37, 38	(0,-3) 7.25*0.5
3.	(2,1)	5.12	-30.94	4.5	2.93	43, 43	(0,-1) 3.62556*0.5
4.	(2,1.5)	4.936	-32.20	8.00	2.56	39, 39	(0,-4) 7.25*0.5
5.	(2.4,1.1)	5.096	-34.43	7.69	2.89	42, 42	(0,-3) 3.62556*0.5
6.	(2.5,1.5)	5.096	-25.04	9.1	2.84	42, 42	(0,-3) 7.25*0.5
7.	(2.5,1.5)	5.08	-26.83	10.07	2.83	42, 42	(0,-3) 7.25*1.0

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BIOGRAPHY

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