Hexagonal Microstrip Patch Antenna to Operate in Dual Frequency Mode

Manoj Kumar[1] Arvind Sirsath[2] Mahesh Patil[3]
[1,2,3]Department of Electronic Design and Technology
[1,2,3]NIELIT Aurangabad, Mahrashtra

Abstract— The study of Microstrip patch antennas have made great progress in recent years. Compared with conventional antennas, Microstrip patch antennas have more advantages and better prospects. Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are easily fabricated. They are lighter in weight, low volume, low cost, low profile, smaller in dimension and ease of fabrication and conformity. The Microstrip patch antennas can provide dual and circular polarizations, dual-frequency operation, frequency agility, broad band-width, feed line flexibility, and beam scanning omnidirectional patterning. In this paper a hexagonal patch antenna is proposed to produce circularly polarized radiation pattern with a single feed to operate in dual frequency mode.
Key words: Antenna, Micro strip, dual frequency, hexagonal patch

I. INTRODUCTION

Microstrip antenna have been one of the most innovative topic in antenna theory and design in recent years. And are increasingly finding application in a wide range of modern microwave system. In 1960’s microwave semiconductor device were developed. These device were fabricated on semiconductor chips of very small volume and mounted in suitably designed packages. Basic configuration of a micro strip antenna is a metallic path printed on a thin, grounded dielectric substrate. The micro strip antenna radiates relatively broad beam broad side to the plane of the substrate. Thus the micro strip antenna has a very low profile and can be fabricated using printed circuit or photolithography technique. Other advantage include says fabrication into linear or planes arrays and easy integration with microwave integrated circuit. To a large extent the development of a micro strip antenna have been driven by system requirement for antennas with low weight, low cost, easily embedded into array or with microwave integrated circuits for polarization diversity[3][5].

The size of a micro strip antenna is inversely proportional to its frequency. At frequencies lower than microwave, micro strip patches don't make sense because of the sizes required. At X-band a micro strip antenna is on the order of 1 centimeter long (easy to realize on soft-board technology). If you wanted to make a micro strip antenna to receive FM radio at 100 MHz it would be on the order of 1 meter long (which is a very large circuit for any type of substrate). For AM radio at 1000 KHz, the micro strip patch would be the size of a football field, utterly impractical. One everyday application where micro strip patches are used is in satellite radio receivers . Here the antenna is often mounted in a vehicle, where the angle in the X-Y plane relative to the satellite is not fixed (like it is for the satellite television dish mounted to your house.) Thus circular polarization is employed for satellite radio, and the angle that the patch is with respect to the satellite doesn't matter.

Micro strip antennas are commonly used at frequencies from 1 to 100 GHz and at frequencies below ultra-high frequency, UHF micro strip patch become exceptionally large. The radiating patch of antenna can be designed in various shapes according to the desired characteristics like H-shape micro strip antenna and spring shape micro strip antenna . In order to simplify the analysis and performance prediction, the patch is generally square, rectangular, circular, triangular and elliptical or some other common shape[1][4].

Hexagonal micro strip patch gives better performance than the rectangular patch antenna. Hexagonal patch supports both linear and circular polarization. The hexagonal patch antenna gives circular polarization with only one feed where as rectangular patch antenna requires multiple feeds to get circular polarization. The hexagonal patch antenna can also use multiple feeds and this type of antenna with multiple feeds can also give multiband operations.[2] [15][16]

Circular polarization is theoretically possible from a micros trip antenna excited by a single feed if two spatially orthogonal modes are excited in phase quadrature. This can be achieved in a hexagonal patch.

II. RECTANGULAR, SINGLE POLARIZATION MICRO STRIP ANTENNAS

This is by far the most popular type of micro strip antenna. The figure below shows the geometry of the rectangular micro strip antenna, not including the ground plane and dielectric which would be underneath. The dimension L is universally taken to mean the long dimension, which causes resonance at its half-wavelength frequency. The radiating edges are at the ends of the L-dimension of the rectangle, which sets up the single polarization. Radiation that occurs at the ends of the W-dimension is far less and is referred to as the cross-polarization.

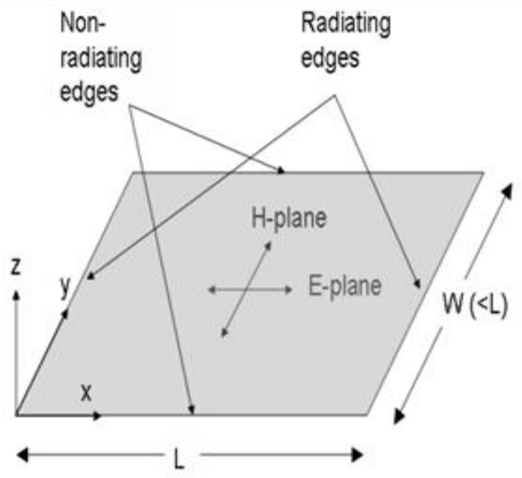

Fig. 1:

The image above is a side view which attempts to show a snapshot of the E-field under the patch. Note that the fields under the L-edges are of opposite polarity (due to the half-wave nature of the patch) and when the field lines curve out and finally propagate out into the direction normal to the substrate they are now in the same direction (both facing left). In the far field perpendicular to the substrate, the radiation from the two sides adds up because the fields are in phase.[7][8][11]

Thus the microstrip patch radiation intensity depends on what direction you are facing it from (it has gain and directivity). To make effective micro strip antenna firstly, the structure needs to be a half-wavelength resonator. Second, use a low dielectric constant under the patch. Third, use a thicker dielectric t, but the height must still be just a fraction of a wavelength.[9]

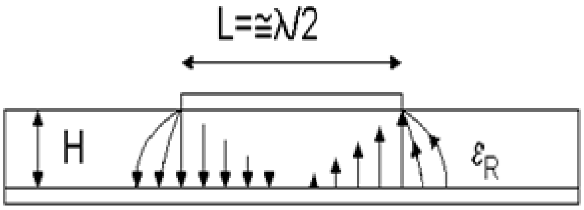

Fig. 2:

III. HEXAGONAL PATCH DESIGN

Hexagonal micro strip antenna (HMSA) are studied and it was observed that HMSAs distribution is similar to the modal distributions of circular micro strip antenna (CMSA). Therefore by equating the areas of HMSA and CMSA the resonance frequency formulation for HMSA is proposed. The formulations obtained using this method agrees closely with the simulated results for fundamental as well as higher order modes.

The HMSA is shown in Fig.4. It is obtained from equivalent rectangular micro strip antenna (RMSA) by changing the side length S as shown in Fig. 3. In this all the side lengths are not equal. A regular HMSA has all equal side length as shown in Fig. 4. For the dimensions shown in Fig. 4, the first and second order resonance frequencies are 1113 and 1425 MHz as shown in their current distributions in Fig. 5. Similarly for regular HMSA, the frequencies are 915 and 1516 MHz as shown in their surface current distributions in Fig. 6. These current distributions are similar to the current distributions of TM11 and TM21 modes in CMSA. Due to this similarity between the distributions of HMSA and CMSA, the resonance frequency formulation for HMSA is derived using frequency equation for CMSA as given below.

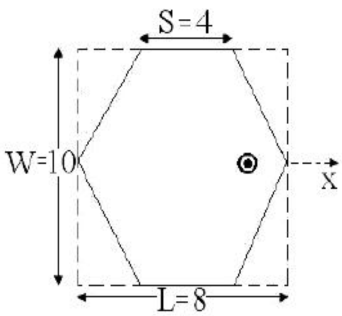

Fig. 3:

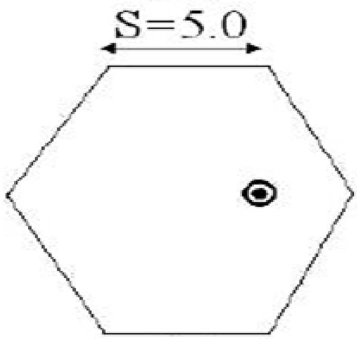

Fig. 4:

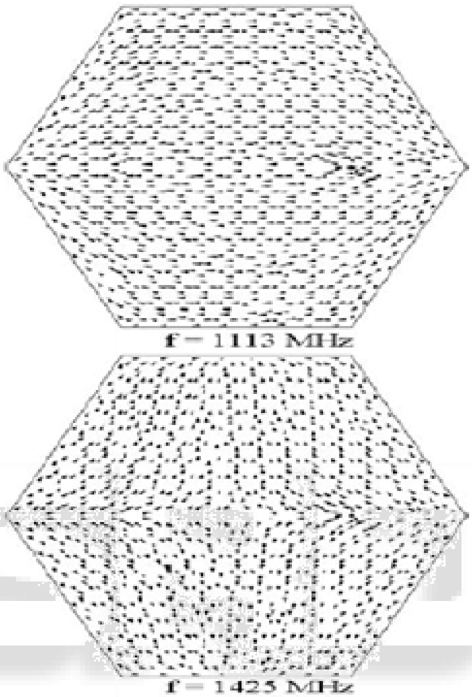

Fig. 5:

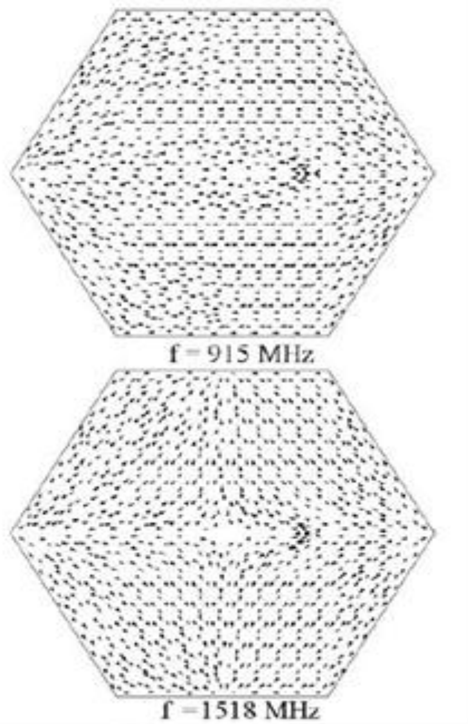

Fig. 6:

The formulation is proposed for HMSA as well as regular HMSA. The area of HMSA (ah) is first calculated and it is equated with the area of equivalent CMSA (ac). Further the equivalent radius of the CMSA in terms of side length of HMSA is calculated. This equivalent radius is used in the resonance frequency equation of CMSA to formulate the resonance frequency of HMSA as given in equation For regular HMSA.

$$a_H = 2.598S^2$$

$$a_C = \pi r_c^2$$

Equating the two areas gives,

$$r_c = S\sqrt{2.598/\pi}$$

for HMSA,

$$a_H = SW + \frac{(L-S)W}{2}$$

$$a_C = \pi r_c^2$$

$$r_c = \sqrt{a_H/\pi}$$

$$f_r = \frac{K_{mn}c}{2r_c \pi\sqrt{\varepsilon_r}}$$

IV. Antenna Design

In this project, the modal distributions of HMSA are studied and it was observed that HMSAs distribution is similar to the modal distributions of circular MSA (CMSA). Therefore by equating the areas of HMSA and CMSA the resonance frequency formulation for HMSA is proposed. The formulations obtained using this method agrees closely with the simulated results for fundamental as well as higher order modes. Also the dual band dual polarized configuration of HMSA by cutting the rectangular slot in the center of the patch is proposed. The formulation in resonant length for dual polarized response is also proposed. The frequency values obtained using the proposed formulations agree closely with simulated results. All these MSAs were first analyzed using the IE3D software followed by experimental verification in dual band and dual polarized HMSA[12][14][10].

The Neltec NX9320 substrate (ε_r = 3.2, h = 0.76 mm, tan δ = 0.0024) is used for the simulations as well as the measurements. The HMSAs are fed using micro strip line of width 1.8246 mm.

Area of a Regular hexagon (A_h) $= \frac{3\sqrt{3}}{2}s^2$

Area of a Circle (A_c) $= \pi r_c^2$

Equating Both the Area,

$$r_c = s \times \sqrt{\frac{2.598}{\pi}}$$

We know that the resonance frequency of circular patch antenna,

$$f_r = \frac{X_{mn}c}{2\pi r_c\sqrt{\epsilon_r}}$$

The Resonance frequency of regular hexagon,

$$f_r = \frac{X_{mn}c}{2\pi s\sqrt{\frac{2.598}{\pi}}\sqrt{\epsilon_r}}$$

$$s = \frac{c}{3.1033 f_r\sqrt{\epsilon_r}}$$

- For TM_{11} Mode X_{11} =1.84118
- For TM_{21} Mode X_{21} =3.05424

The Operating Frequency (f_r) of the Hexagonal Patch is taken to be 3.8 GHz

Putting this in the above Eq we get,

Radius of the patch, $s = 14.22\,mm$

Inset Feed width, $W_l = 1.8246\,mm$

Cut Width, $2W_l = 3.6492\,mm$

Transmission Line Length $\left(\frac{\lambda}{4}\right) = 19.7368$

After finding the patch size the antenna feed line should be designed. The patch antenna was matched to Z_o = 50 Ω transmission lines where two matching methods were considered: inset feed and quarter wave transformer. Matching reduces the loss of the signal and reflected power towards the transmission line that supplies a smooth transition of energy from the antenna input impedance to the feed line. The program also provided the input impedance at the edge of the patch antenna Z_{in} = 204.75 Ω. The quarter wave transformer was designed theoretically by first calculating its characteristic impedance as:

$$Z_1 = \sqrt{Z_0 Z_{in}} \approx 101.181\,\Omega$$

Inserting the appropriate collected data into the transmission line calculator, the desired length and width of the quarter wave transmission line was calculated. Furthermore, utilizing the inset-feed length was found as:

$$y_0 = \frac{W}{\pi}\cos^{-1}\sqrt{\frac{Z_0}{Z_1}}$$

Putting the value of $W = 24.629\,mm$

We get $y_0 = 6.2031\,mm$

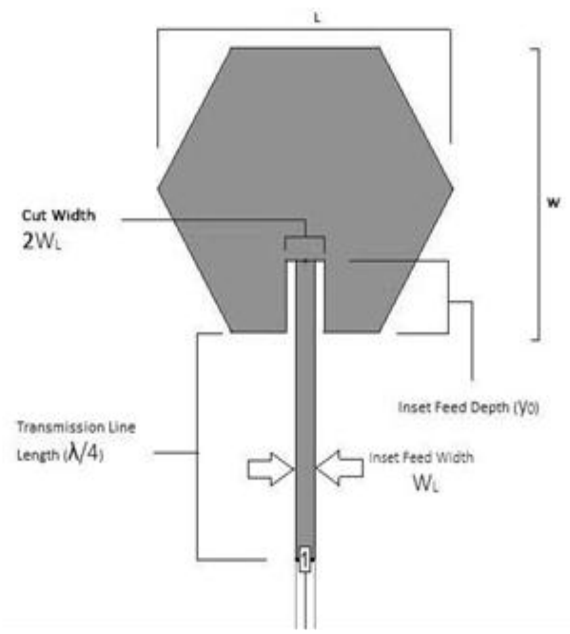

Fig. 7: Hexagonal Microstrip Patch Antenna Feed

V. Simulated Results and Discussion

The Above design of Hexagonal Microstrip Patch Antenna was simulated using Zeland Ie3D 14.0.

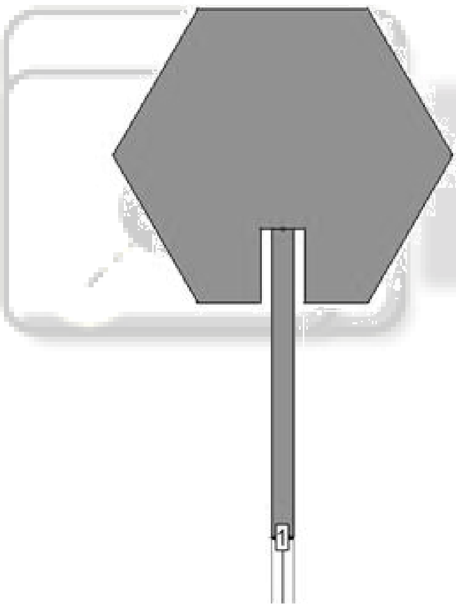

Fig. 8: Hexagonal Microstrip Patch Antenna

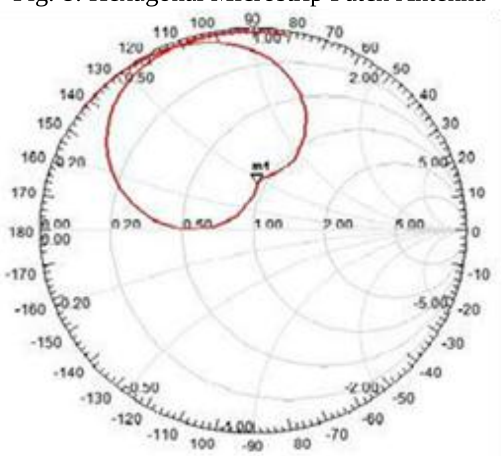

Fig. 9: Hexagonal Micro strip Patch Impedance curve

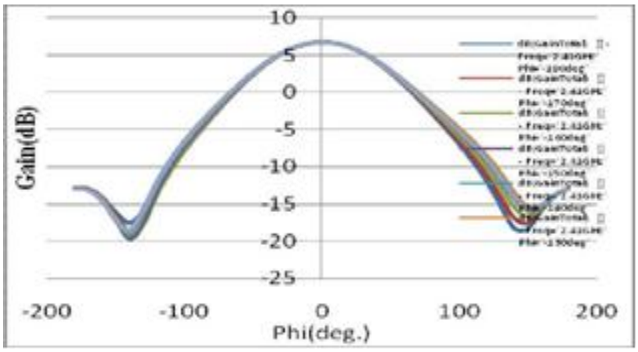

Fig. 10: Hexagonal Micro strip Patch Antenna Gain

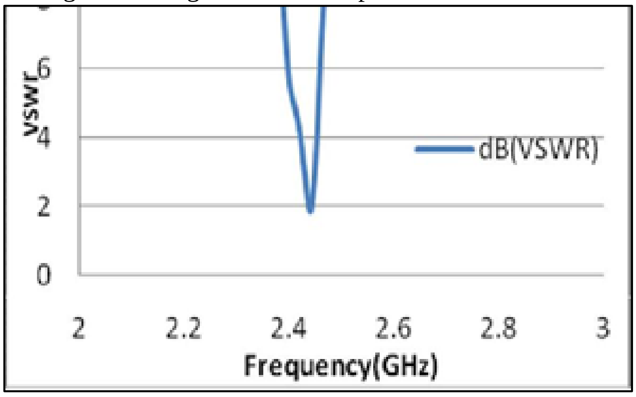

Fig. 11: Hexagonal Micro strip Patch VSWR

VI. Conclusion

The resonance frequency formulations for HMSA is proposed. The frequency obtained using them closely matches with the simulated HMSA results. The dual polarized HMSA is proposed. The resonance frequency formulation in terms of slot dimension is proposed at f1. The frequency obtained using them closely matches the simulated frequency. Since these antennas are analyzed using Neltec NX 9320 substrate they have lower gain which can be increased using slots.

The impedance bandwidth of slotted patch is achieved more in comparisons to simple hexagonal patch antenna. The average gain achieved in slotted hexagonal patch more than simple hexagonal patch antenna and radiation efficiency achieved more in simple patch against slotted patch antenna.

References

[1] V.R. Gupta and N. Gupta, “Two compact microstrip patch antennas for 2.4 GHz band – a comparison,” Microwave Review, pp. 29-31, November, 2006.

[2] M. T. Torres et al., “Heaxgonall microstrip antenna equivalent to a circular microstrip antenna for GPS operation frequency,” Memorias del 7º Congreso Internacional de Cómputo en Optimización y Software, CICOS 09. UAEM, Cuernavaca, Morelos, México. pp. 200-208, 2009.

[3] G. Kumar and K.P. Ray, “Broadband microstrip antennas,” Artech House Publishers, London, 2003.

[4] I. Bahl, P. Bhartia and S. Stuchly, "Design of microstrip antennas covered with a dielectric layer," IEEE Transactions on Antennas and Propagation, Vol. 30, No. 2, pp.314-318, Mar 1982.

[5] Wen-Shyang Chen and Horng-Dean Chen- “Compact circularly polarized hexagonal shaped microstrip antenna with bent losses” Antenna and propagation society international symposium, 2001 IEEE, Page(s):424-426, vol.3.
[6] Noro, T.and Kazama, Y.”A novel wideband circular polarization microstrip antenna - combination of different shaped antenna element”. Antennas and Propagation Society International Symposium, 2005 IEEE Volume: 3A Publication Year: 2005, Page(s): 467 - 470 vol. 3A.
[7] Rasouli, M.Kencana, A.P. Van An Huynh Kiat, E. Lai, J.C.Y. Phee, L.S.J.,”Wireless Capsule Endoscopes for Enhanced Diagnostic Inspection of Gastrointestinal Tract” Conference on Robotics Automation and Mechatronics (RAM), 2010 IEEE Publication Year: 2010 , Page(s): 68 – 71.
[8] Performance of H-shaped microstrip antenna using IE3D, Kant Singh.R,Dhubkarya.P, D.C. Emerging Trends in Electronic and Photonic Devices & Systems, 2009. International Conference on. 2009, on page(s): 364 – 366.
[9] A novel wide beam circular polarization antenna - microstrip-dielectric antenna, He Haidan, Proceedings in Microwave and Millimeter Wave Technology, 2002. On page(s): 381 – 384.
[10] Sang Heun Lee and Young Joong Yoon, “Fat Arm Spiral Antenna for Wideband Capsule Endoscope Systems” Conference on Bioinformatics and Biomedical Engineering (iCBBE), 2010 4th International Publication Year: 2010 , Page(s):1 – 4.
[11] Natarajan and D. Chatterjee-”Effects of Ground Plane Shape on Performance of Probe-Fed, Circularly Polarized, Hexagonal Patch Antenna” Antennas and propagation Society International Symposium, 2003. IEEE, Page(s): 720 - 723.
[12] Ravindra Kumar Yadav, Jugul Kishor, and Ram Lal Yadava, “Compensation of Dielectric Cover Effects on CP Hexagonal Microstrip Antenna,” IJECET Volume 4, Issue 1, pp. 43-54, January- February (2013).
[13] Moglia, A. Menciassi, M. O. Schurr, and P. Dario., "Wireless capsule endoscopy: from diagnostic devices to multipurpose robotic systems," Biomedical Microdevices, vol. 9, pp. 235-243, 2007.
[14] Noro, T.and Kazama, Y.”A novel wideband circular polarization microstrip antenna - combination of different shaped antenna element”. Antennas and Propagation Society International Symposium, 2005 IEEE Volume: 3A Publication Year: 2005, Page(s): 467 - 470 vol. 3A.
[15] R.K.Yadav et al., “Performance analysis of superstate loaded patch antenna and abstain from environmental effects,” International Journal of Engineering Science and Technology (IJEST) Vol. 3 No. 8 August 2011.
[16] L. Economou et al, “Circular microstrip patches antennas on glass for vehicle applications”, IEE Proc. Microwave Antennas Propagation, Vol. 145, pp. 416-420, 1998.

