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Design Of Ku-Band Hexagonal Microstrip Patch Antenna With Linear And Circular Polarizations

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Abstract: This paper presents two antennas, one is linearly polarized dual frequency hexagonal microstrip patch antenna and other is wide band circularly polarized hexagonal microstrip patch antenna. The presented antennas are designed for Ku band applications. Dual frequency is obtained by introducing a rectangular shaped slot on the hexagonal patch. Both antennas are simulated using HFSS 14.0 and performance measures of an antenna such as return loss, voltage standing wave ratio (VSWR),axial ratio, peak gain and radiation pattern are measured.

Key words: Hexagonal, slot, axial ratio, circular polarization, linear polarization.

I. INTRODUCTION

Antennas play very important role in the field of wireless communications. Some of them are Parabolic Reflectors, microstrip Antennas, Slot Antennas, and Folded Dipole Antennas. Each type of antenna is good in its own properties and usage. We can say antennas are the backbone for wireless communication without which the world could have not reached at this age of technology.

Microstrip patch antennas play a very significant role in today's world of wireless communication systems.. A Microstrip patch antenna is very simple in the construction using a conventional Microstrip fabrication technique. Rectangular and circular patch antennas are the most commonly used microstrip patch antennas. Dual characteristics, circular polarization, dual frequency operation, frequency agility, broad band width, feed line flexibility, beam scanning and triple band frequencies can be easily obtained from these patch antennas.

Micro strip antennas are widely used in the microwave frequency region because of their simplicity and compatibility with printed circuit technology, making them easy to manufacture. Generally a microstrip antenna or a patch antenna consists of a patch of metal on top of the grounded substrate. The substrate is made of a dielectric material.. Various methods are used to feed a micro strip antenna such as inset feed, coaxial feed, aperture coupled or slot coupled feed and proximity coupled feed. Microstrip patch antennas have the important advantage of being low profile and if the substrate is thin enough, they may also be comfortable. Basic structure of microstrip patch antenna is shown in fig1.

Antenna Polarization is very important parameter when choosing and installing an antenna. The most communications systems use either vertical or horizontal or circular polarization. Knowing the difference between polarization and how to maximize their benefits is very important to the antenna user. A linear polarized antenna radiates wholly in one plane containing the direction of propagation. In a circular polarized antenna, the plane of polarization rotates in a circle making one complete revolution during one period of the wave. An antenna is said to be vertically polarized (Linear) when its electric field is perpendicular to the Earth's surface.

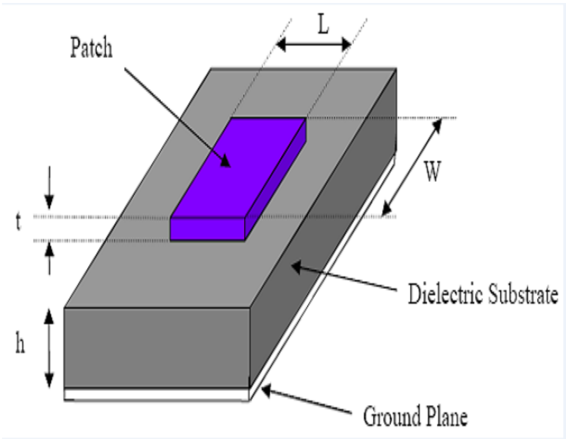

Fig.1 Micro strip patch antenna

II. ANTENNA DESIGN

The patch in the antenna is made of a conducting material Copper (Cu) or Gold(Au) and this can be in any shape like rectangular, circular, triangular, elliptical or some other common shape. The hexagonal patch antenna is designed so as it can operate at the resonant frequency. The important parameters for the design of a Hexagonal microstrip patch antenna are:

- Frequency of Operation (f_r): The resonant frequency of the antenna is depending on the application. The presented antennas are designed for Ku-band

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applications. The frequency range of Ku band is approximately 12 to 18 GHz. The resonant frequency selected for this design is 15 GHz.

- Dielectric Constant of the Substrate (ε_r): The dielectric constant of a substrate (ε_r) plays an important role in the patch antenna design. A substrate with a high dielectric constant reduces the dimensions of the antenna but it affects the antenna performance too. So, there is a trade-off between size and performance of a patch antenna. The dielectric material chosen for this antenna is FR-4 epoxy, which is having a dielectric constant of 4.4
- Height of dielectric substrate (h): For the microstrip patch antenna to be used in communication systems, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate should be less.

$$h \leq \frac{0.3 \times C}{2 \times \prod \times fr\sqrt{\varepsilon r}}$$

After the proper selection of above three parameters, the next step is to calculate the radiating patch radius and ground dimensions.

- Side of a hexagonal patch is given by

$$S = \frac{C}{23.1033\ fr\sqrt{\varepsilon r}}$$

- Radius of hexagonal patch antenna is given by

$$r = S \times \sqrt{\frac{2.598}{\prod}}$$

- Calculation of the ground plane dimensions (Lg and Wg)
  L_g = 6h+ λ
  W_g= 6h+ λ
  Where,

$$\lambda = \frac{C}{fr\sqrt{\varepsilon r}}$$

III. ANTENNA PARAMETERS

Before discussing the simulation of the hexagonal microstrip patch antenna, it is important to discuss the parameters in detail that are to be analyzed in simulation.

- Return Loss: It is the difference between forward and reflected power, in dB If the power transmitted by the source is P_t and the power reflected back is P_r , then the return loss is given by Pr. The reflection coefficient is also known as s11 or return loss. For maximum power transfer the return loss should be as minimum as possible. This means that the ratio of Pr/Pt should be as small as possible, or expressed in dB, the return loss should be as large a negative number as possible.
- Gain: It is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna is radiated isotropically.
- Radiation pattern: A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field. The radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna. Antenna radiation patterns are taken at one frequency, one polarization, and one plane cut.
- VSWR: For a radio (transmitter or receiver) to deliver power to an antenna, the impedance of the radio and transmission line must be well matched to the antenna's impedance. The parameter VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line it is connected to.

IV. PROPOSED ANTENNAS

A. Linearly polarized dual frequency hexagonal patch microstrip antenna

The above parameters are analyzed and used in design of hexagonal patch antenna. Linearly polarized dual frequency hexagonal microstrip patch antenna is shown in Figure:2 . This antenna is designed to operate at 15GHz. The radius of an hexagonal patch antenna is 2.75mm.Dimension of this antenna are 12.42×12.42×0.48 mm.FR-4 epoxy is selected as substrate material ,which is having dielectric constant of 4.4.The size of rectangular shaped slot is 2.4×0.6 mm.

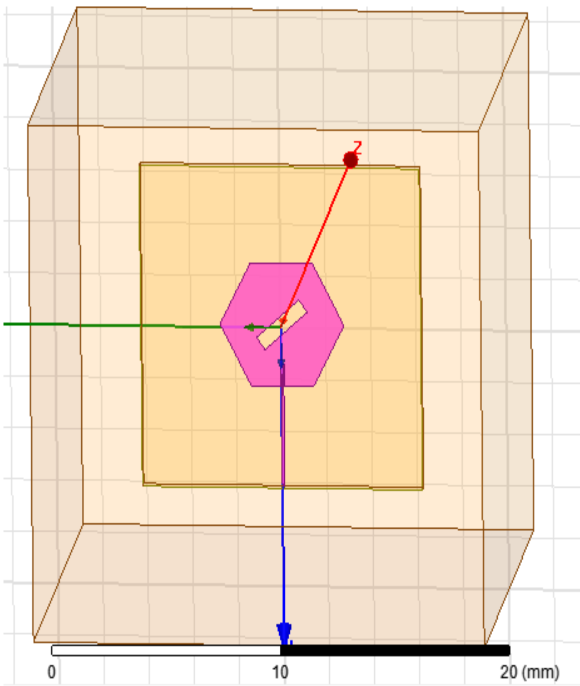

Fig.2 linearly polarized dual frequency hexagonal patch antenna

B. wide band circularly polarized hexagonal microstrip patch antenna

Wide band circularly polarized hexagonal microstrip patch antenna is shown in Figure:3. This antenna covers the frequency range in Ku band from 14.38 GHz to 15.28 GHz. The radius of an hexagonal patch antenna is 2.75mm. Dimension of this antenna is 12.42×12.42×0.48 mm.FR-4 epoxy is selected as substrate material ,which is having dielectric constant of 4.4.The size of rectangular slot is 2.03×0.4 mm .

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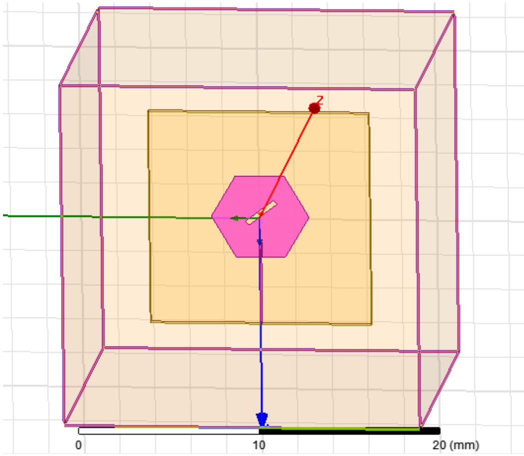

Fig.3 circularly polarized wide band hexagonal patch antenna

VI. SIMULATION

The simulation of these antennas is done using HFSS (High Frequency Structural Simulator) 14.0. HFSS uses finite element method (FEM) for solving electromagnetic structures and design of antennas, RF electronic circuit elements such as filters and transmission lines.

V. RESULTS

A. Dual frequency linearly polarized hexagonal microstrip patch antenna

The position of the slot is modified randomly until a specific return loss values S11< -10 dB. Return losses -20 dB at 13.81 GHz and -21 dB at 14.97GHz are observed. This antenna got over all gain of 4.4 dB and axial ratio of 13 dB. Simulated results are shown in following figures.

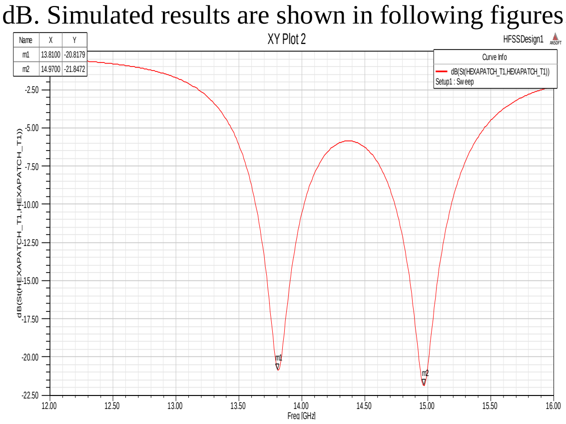

Fig.-4: Return loss plot

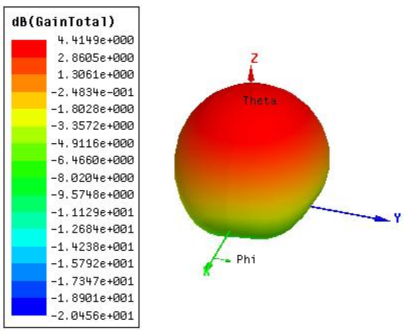

Fig-5:Gain plot

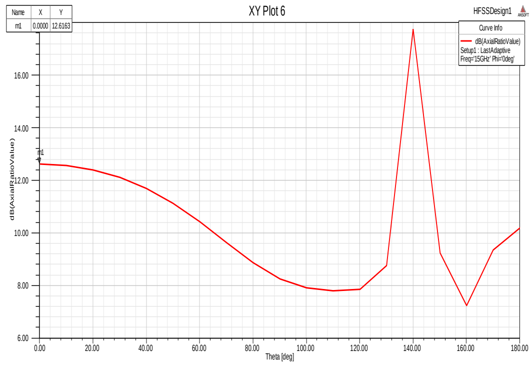

Fig-6: Axial ratio plot

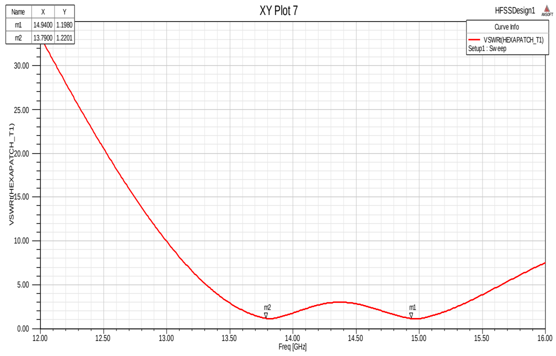

Fig-7: VSWR plot

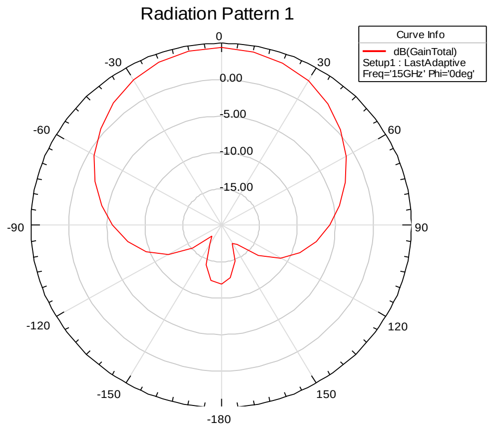

Fig-8: Radiation pattern

TABLE-1Design specifications for linearly polarized hexagonal patch antenna

Type of antenna	Dual frequency Hexagonal patch antenna
Dielectric constant of substrate	FR-4 Epoxy (2.4)
Operating frequency	15 GHz
Height of substrate	0.48mm
Feeding method	Inset feed
Gain	4.41 dB
Polarization	Linear polarization
Return loss	-20 dB at 13.87 GHz and -21 dB at 14.97 GHz

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B. Wide band circularly polarized hexagonal microstrip antenna

This wide band antenna covers frequency range from 14.38 to 15.28 GHz .Return losses -18.6 dB at 14.68 GHz and -17 dB at 14.99 GHz are observed. This antenna got over all gain of 4.37 dB and axial ratio of 2.77 dB. Simulated results are shown in following figures.

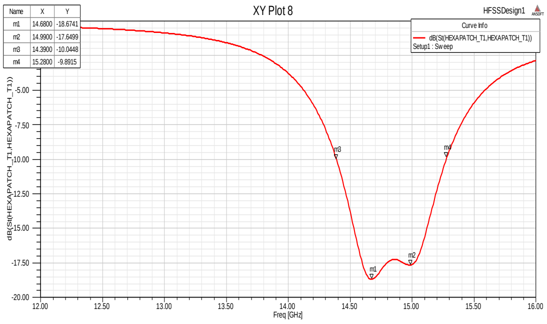

Fig-9: Return loss plot

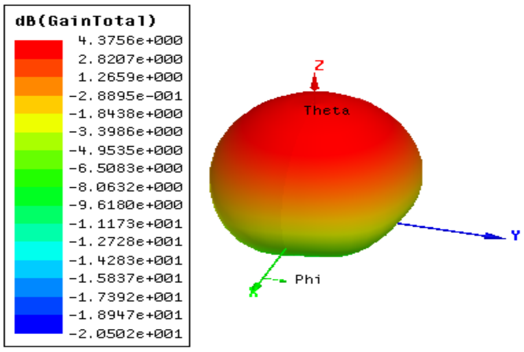

Fig-10: Gain plot

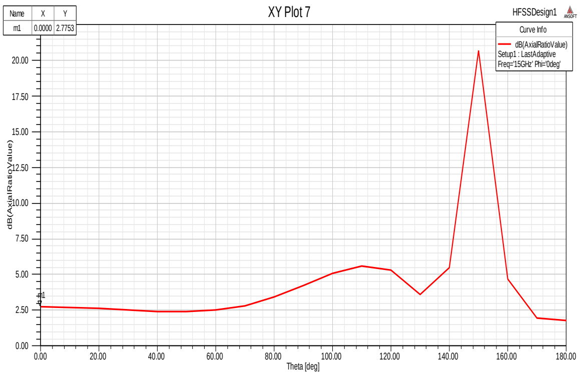

Fig-11: Axial ratio plot

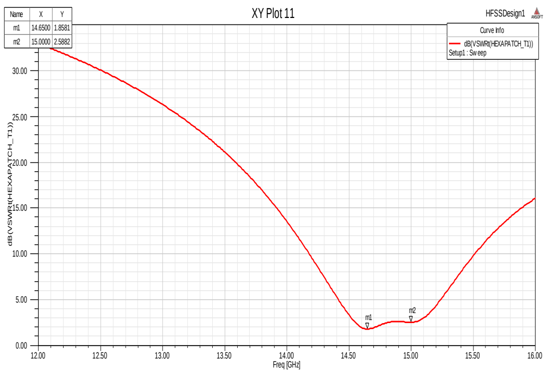

Fig-12: VSWR plot

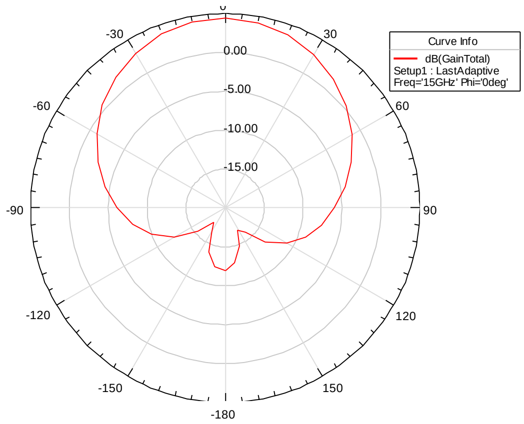

Fig-13: Radiation pattern

TABLE-2Design specifications for circularly polarized hexagonal patch antenna

Type of antenna	Wide band Hexagonal patch antenna
Dielectric constant of substrate	FR-4 Epoxy (2.4)
Operating frequency	15 GHz
Height of substrate	0.48mm
Feeding method	Inset feed
Gain	4.3 dB
Polarization	Circular polarization
Return loss	-18 dB at 14.68 GHz and -17 dB at 14.99 GHz
Bandwidth	0.9 GB(14.3-15.2 GHz)

VII. CONCLUSION & FUTURE WORK

Linear and circular polarized hexagonal microstrip patch antennas with inset feed are designed and simulated using HFSS 14.0, after that performance measures such as return loss, peak gain, VSWR, axial ratio and radiation pattern are observed. The resonant frequency selected for these antennas is 15GHz. Linear and circular polarizations are obtained by changing the dimensions of a rectangular slot. These antennas are designed for Ku band applications such as satellite and radar communications. Both antennas are designed only for single band. Dual and triple bands can be carried out in future.

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BIOGRAPHIES

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