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Frequency Reconfigurable Micro-strip Patch Antenna for Wideband Applications

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Abstract— **A frequency reconfigurable microstrip patch antenna is presented in this paper. The antenna is designed to achieve the reconfigurabilty within the band i.e. wideband(X-band). The proposed antenna is multipart eight armed star shape frequency reconfigurable antenna designed to cover the frequency band from 7.5 GHz to 14 GHz. The antenna exhibits the property of change in frequency which results in change in return loss characteristics depending upon the configuration request. The frequency reconfiguration capability of antenna is achieved with the help of metal strip line which acts as a switch to reconfigure the antenna. Small rectangular slots are cut out of patch to insert switches to obtain reconfigurability. The antenna is simulated on Ansoft HFSS software. The simulated results gives high gain & wide band of 6.3805 GHz in the range of 8.1650 GHz to 14.5455 GHz without switches. The same antenna gives multiband and wide bandwidth switches.**

Index Terms— **Reconfigurable Antenna, Microstrip antenna, Wide-Band, Multi band, MSL.**

I. INTRODUCTION

Microstrip patch antennas are of much interest in antenna applications. They are easy and cheap to manufacture. Microstrip patch antennas are capable of being designed as a single element or as part of an array. Whereas, these advantages do not hide the low efficiency and limited bandwidth of micro strip patch antenna. In recent years research has also been done to use the single antenna in many application that is antenna must exhibits the property of switching from one application to another upon configuration request and such antennas are called reconfigurable antennas. Recent trends have seen the development of wideband antennas, multi-band antennas or reconfigurable antennas receiving much attention to fulfill different applications in

just one single terminal. Single terminals or devices could have many applications such as, GPS, GSM, WLAN, Bluetooth, X band application etc. To suit such applications wideband, multi-band or reconfigurable antennas have been developed [1]. The reconfigurable approach offers significant advantages of compactness and flexibility. Moreover, when considering the interference levels at the receiver, they are the best option since only one single band is used at a given time.

Reconfigurable antenna can be used in variety of applications by changing their functionality depending upon the requirements [2]. Applications of reconfigurable antenna include multifunction wireless devices, multiple input multiple output systems(MIMO), on laptops, cellular phones, ultra wide band system and secure systems [3]-[4]. Reconfiguration of antenna can be achieved by redistribution of current in different parts of antenna. Reconfiguration of antenna can be done in multipart antenna as well as single part antenna. In multipart antenna current is distributed in some parts or all parts[4]. In single part antenna, slots are cut in the antenna to distribute the current and reconfigurable components are installed in the slots to achieve reconfiguration [4].
One could achieve reconfigurability in terms of frequency, bandwidth, and polarization and radiation pattern of these antennas by using various method. The popular method is to change the shape of the effective radiating structure to alter the radiation pattern or the frequency of operation [5, 6, 7].

This paper present an eight armed star shaped frequency reconfigurable microstrip patch antenna which provides wide band with switch.. The states of the switches changes the antenna functionality in terms of change in resonating frequency and thus return loss characteristics [2].Impedance modification of the antenna is also the another method to change the resonant frequency of the radiating antenna [8].

II.MSL SWITCH

To reconfigure the antenna in a well manner, tunable components such as Switches and Varactors have been used. Author is using Metal strip line (MSL) which act as a switch to reconfigure the antenna to be used in variety of applications. Slots are cut out of the patch where metal strip lines are to be mounted. Frequency reconfigurability is achieved via optically controlled switches with low photoconductivity that tune the resonant frequency of microstrip patch antenna [9] as depicts in figure.1 but author has used metal strip as a switch in 8 armed structure.

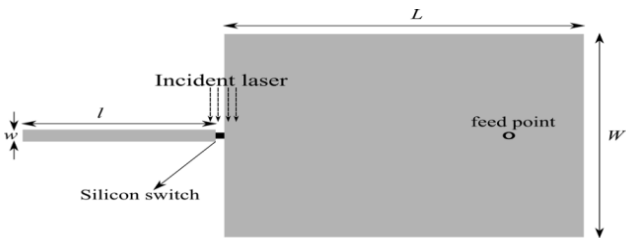

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Figure.1.Rectangular patch antenna connected to stub via photoconductive silicon switch

The eight rectangular slots of dimension 0.78 cm and 0.15 cm are cut out of the patch to incorporate switches and thus again octagon shape main patch is left at the centre of eight armed star.

III. PROPOSED ANTENNA STRUCTURE

The basic structure of the designed antenna is shown in figure 2. It is an octagon shaped patch antenna of side 1.82 cm each onto which 8 triangular slots of side 1.05 cm and 0.95 cm and base of 0.4 cm are cut out of the patch and thus, formed 8 armed star. To this 8 armed star, 8 rectangular slots of dimension 0.78cm and 0.15 cm are cut out of the remaining patch. Thus octagon shape main patch is formed at centre of 8 armed star patch as shown in fig 1 .The antenna consist of 3 layers. Bottom layer is the ground plane.

The dimension of Ground is taken according to the formula given below:

Length of ground Lg = 6h + L
Width of ground Wg = 6h + W

Where L is maximum length of patch & W is maximum width of patch and h is the height of substrate ie.. 0.0787 cm in this paper [10].

Middle Layer is a substrate of Rogers RT duroid having dielectric constant 2.2 and thickness 0.0787 cm.

The patch discussed above is fabricated at the top surface above the substrate. The antenna structure is excited using coax feed at position (-4,-4) with 50 ohms impedance. Switches are put on the rectangular slots that are cut out of patch.

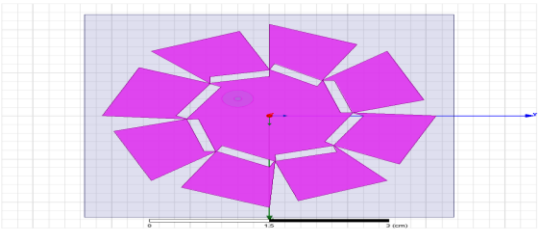

Fig 2 Basic antenna structure

IV. ANTENNA SIMULATION & RESULT

The operation of antenna depends upon the distribution of current on its surface [2]. The antenna resonates at a frequency of 9.00 GHz with a return loss of -39.7774 db. The operation of antenna depends upon the distribution of current on its surface [1]. By changing the path of current with the help of varying dimension or by using metal strip line as a switch, the return loss and radiation pattern of antenna is changed. The antenna is simulated on Ansoft HFSS software without using switches or with switches with a sweep of 7.5 GHz to 14 GHz . A wideband of 6.3805 GHz is obtained without using switches. The simulated S_{11} parameter results of antenna without having metal strip are shown in figure 5.1. The antenna resonates at frequency of 9.00 GHz with a return loss of -39.7774 db. The other resonating frequencies are in the whole band are taken as 11.05, 11.75, 12.5, 14.15 GHz which gives return loss of -30.7738 db, -27.0782 db, -28.1986 db , -21.6599 db. Maximum return loss is obtained at frequency of 9.000 Ghz. The wideband of 6.3805 GHz is obtained in the frequency range of 8.1650 GHz to 14.5455 GHz as shown in figure 3

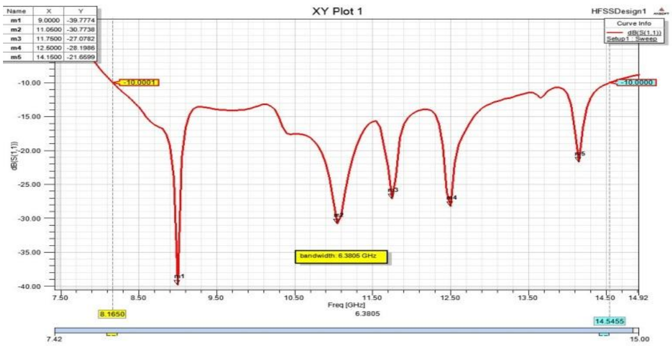

Fig 3. Simulated return loss(S11 parameter)of designed antenna (Without metal strip)

The VSWR parameter graph for simulated structure without metal strip is shown below in Fig. 4

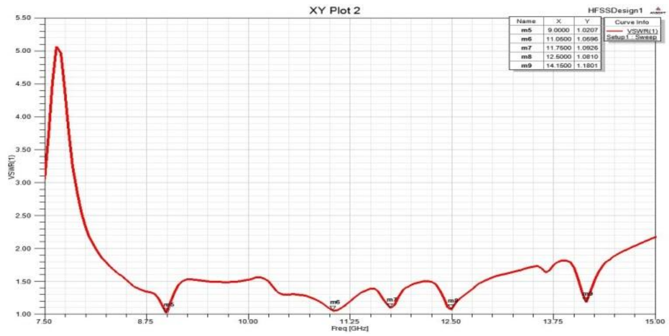

Fig 4. Simulated VSWR parameter of designed antenna without Metal Strip

The simulated elevated radiation pattern of the antenna without metal strip is presented in figure 5. Maximum Gain of 7.4318 dbi is obtained at frequency 9.00 Ghz.

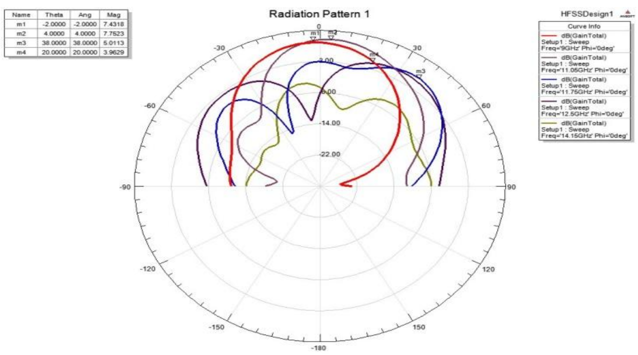

Fig 5. Simulated radiation pattern of designed antenna without having Metal Strip

The simulated azimuth radiation pattern of the antenna without metal strip line as a switche is shown in figure 6 for above stated resonant frequencies.

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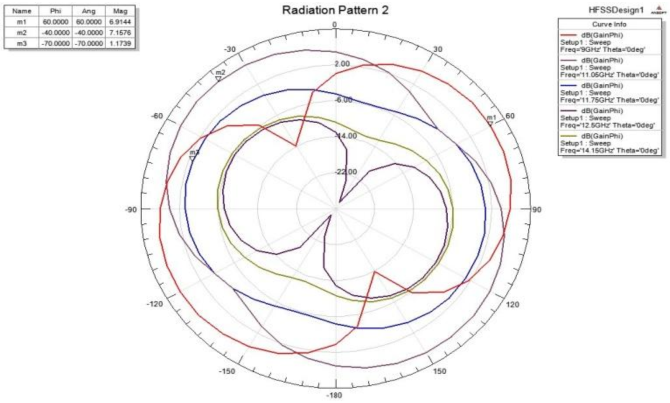

Fig 6. Simulated azimuth pattern(Gain phi) of designed antenna.

V. EXPERIMENTAL RESULTS

Figure 7 shows the photograph of the top view and back view of fabricated antenna using RT/Duroid 5880 substrate. The coaxial probe SMA connector is used to feed the antenna.

Figure 7 Top view of antenna & Back view of antenna

An antenna is characterized by a Network Analyzer, so the Return Loss, Impedance and Bandwidth can be determined. After designing and simulating the eight armed star shaped patch antenna the next step is to test its practical workability. The antenna is fabricated using RT/Duroid 5880 substrate. SMA connector is soldered with antenna to make the connection so that antenna can be tested practically.
After fabricating the proposed antenna, it is tested using Arnitsu (MS2036C) of upto 30 GHz as shown in figure 8

Fig. 8 Experimental setup using VNA (in ECE deptt., NITTTR Chandigarh)

The measured return loss characteristics of the antenna is shown in figure 9 which shows that antenna resonates at 10.74 GHz with a return loss of -10.59db and then at 12.5 GHz with a return loss of -21.31 db. The measured pattern shows two bands: one band is of 1GHz within the range of 12.2 GHz to 13.2 GHz and other is of 392 MHz within the range of 14.013 GHz to 14.405 GHz.

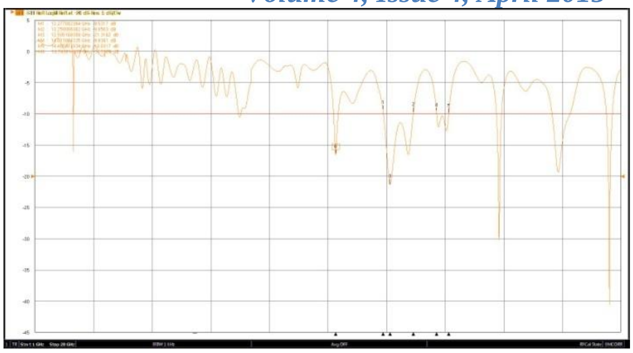

Fig. 9. Experimental S_{11}Parameter of antenna without switches using VNA

The measured VSWR of the designed antenna is shown in figure 10 which is similar to the simulated VSWR of the proposed antenna.

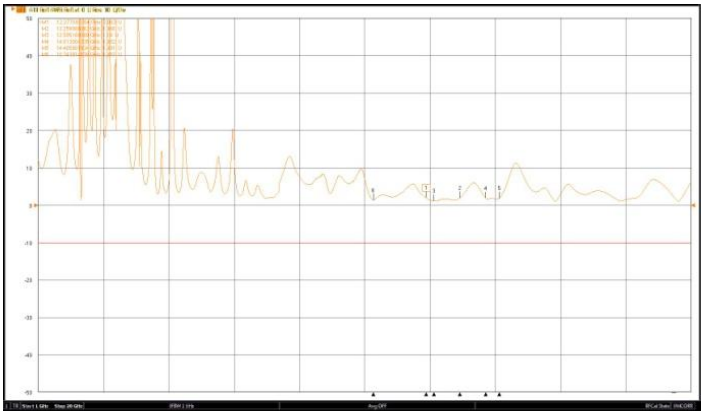

Fig. 10. Measured VSWR using VNA

VI. COMPARISON BETWEEN SIMULATED & MEASURED RESULTS

The measured results show the similar trend in experimental results as compared to the simulated results. The frequency **m6 ie 10.74GHz** to **m5 ie 14.405 GHz** of figure 9 is matched with frequency **8.16 GHz** to **14.5455 GHz** of the simulated S_{11} parameter as shown in figure 3. There is a small variation in resonating frequencies from both left and right direction and some frequency shifts upward which are due to cheaper quality of SMA connector available in the market which do not have good frequency response. Also there are some fabrication error due to which frequency shifting takes place
Also Simulated VSWR as shown in figure 4 is perfectly matched with the measured VSWR as shown in figure 10 with a little variations due to poor quality of SMA connector being used.

VII. RECONFIGURABLE ANTENNA DESIGN

The antenna was designed to achieve frequency reconfigurability within the band i.e. wide-band. In this design, Author discuss the design of new eight armed star shaped microstrip patch antenna. The antenna exhibits the property of frequency tuning upon configuration request. In general, a slotted geometry is taken to which switches can be incorporate to make it reconfigurable. Slotted geometry usually provides wide bandwidth. In this work, octagon shape slotted geometry is taken for the design of multiband and wideband antenna with high gain. the designed antenna is multipart in nature means it has many parts that are to be connected to main patch via reconfigurable components which is metal strip line in this design as shown in figure 11

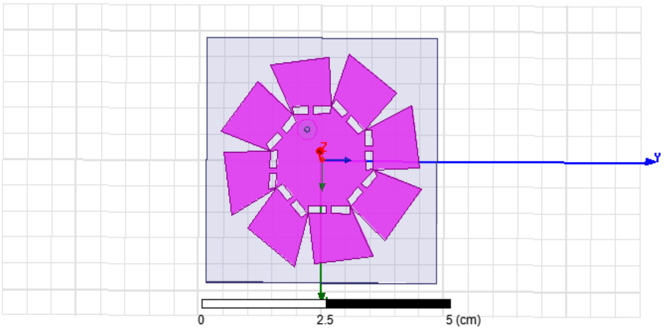

Fig. 11. Structure of antenna using switches

. Switches are put on the rectangular slots that are cut out of patch. The antenna structure is excited using coax feed at position (-4,-4) with 50 ohms impedance

VIII. ANTENNA SIMULATION & RESULT

In this antenna the presence of metal strip line indicates switch is ON otherwise switch is in OFF state. The S_{11} parameter of the antenna having switches shows that antenna is multiband in nature as shown in figure 12. In this three bands are obtained of which one is of 4.0118 Ghz in the range of 8.2666 Ghz to 12.2784 Second is of 902 Mhz in the range of 12.65Ghz to 13.5525 Ghz and third is of 1.5938 Ghz in the range of 14.6664 Ghz to 16.2602 Ghz .

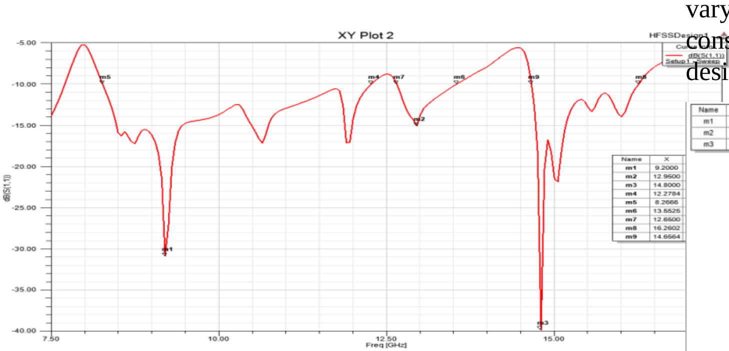

Fig.12 .Simulated S_{11} parameter of antenna with metal strip.

The simulated gain total of antenna having switches is shown in figure 13 which shows gain total of 7.2524 dbi, 5.3123 dbi, and 4.2819 dbi at above stated resonant frequencies.

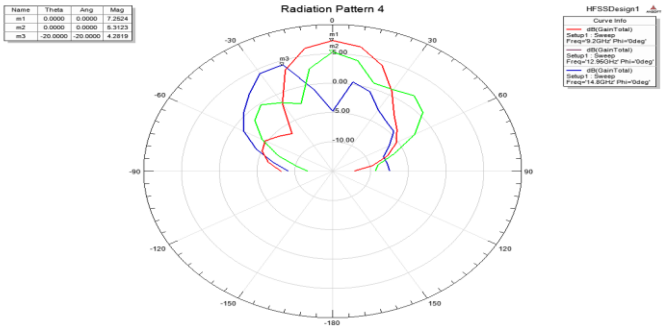

Fig.13. Simulated total gain of antenna with metal strip..

The gain in azimuth plane is measured in the entire x-y plane around the antenna under test and termed as gain phi. Gain Phi pattern is plot by varying the values of phi from 0 deg to 360 deg for the constant value of theta 0 deg.

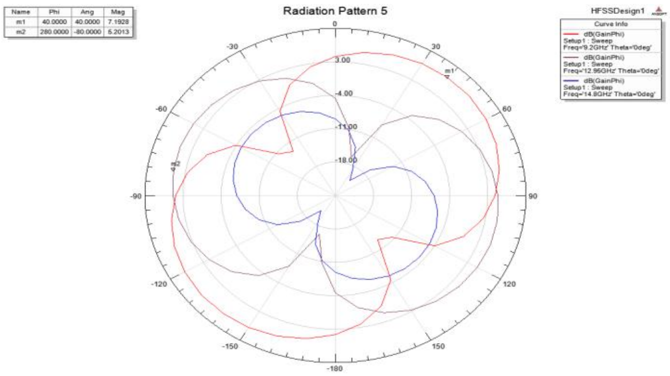

Fig.14. Simulated azimuth pattern of antenna with metal strip

For the designed antenna , gain theta pattern is plotted by varying the values of theta from -90 deg to 90 deg for the constant value of phi 90 deg. Figure.15 shows gain phi of the designed antenna at theta = 0 deg.

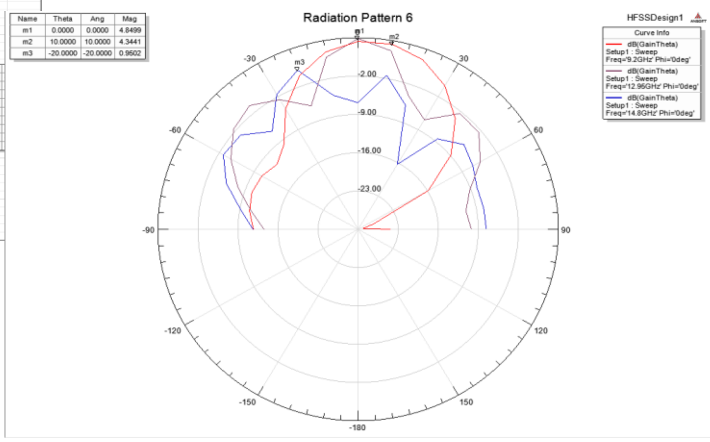

Fig. 15. Simulated Gain theta of designed antenna.

Voltage standing wave ratio (VSWR) is a measure of the impedance mismatch between the transmitter and the antenna. Higher the value of VSWR more the mismatching and minimum the VSWR more perfect it matches i.e. unity. An input impedance of either 50 Ω or 75 Ω must be there for practical antenna design as most radio equipment is built for this impedance.Figure.16 shows the VSWR of designed antenna with having switches. It is clear from the figure that VSWR satisfy the range in the whole band.

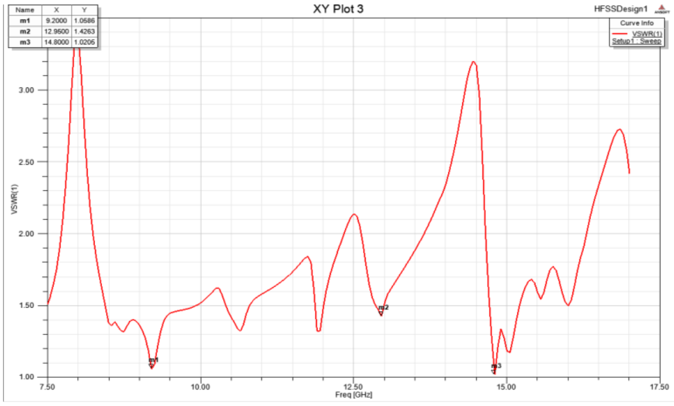

Fig. 16. Simulated VSWR of antenna

IX. CONCLUSION

During the last few years there has been increasing demand in modern telecommunication system of antennas with wide, multiple bandwidths, high gain and smaller dimensions than conventionally possible. Also there is a need of that type of radiator that can switch from one application to another upon request. This has initiated the research in new antenna fields ie.. reconfigurable antennas. Reconfigurable antennas are the solution to fulfill these requirements

In this work new eight armed star shape reconfigurable microstrip patch antenna for C, X , Ku -band applications is designe and presented. Reconfigurable antenna has the ability to switch from one application to another upon the configuration request. It is a new idea in the field of antenna. To achieve reconfiguration switches are incorporated in the antenna design.

The antenna is first simulated and tested without using switches ie simple microstrip patch antenna which shows some changes in the results with similar trend in both simulated and measured S_{11} Parameter due to poor quality of SMA connector and some fabrication error.

Then switches are used to achieve reconfiguration and antennas with switches is designed and simulated.

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