COMPACT SINGLE LAYER LOW-PROFILE MICROSTRIP PATCH ANTENNA

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Abstract—A compact low-profile differential filtering microstrip patch antenna with high selectivity and deep rejection using single-layer substrate is proposed. The proposed antenna is designed to process the wideband application. A multiband Microstrip patch antenna is designed to support different bands ranging from 1GHz to 8Ghz. The 5G technology requires low latency and high bandwidth to transmit virtual reality and augmented reality calls for HD video which requires multi band transmission. To serve this purpose a band reconfigurable Quasi H shaped patch antenna is proposed to increase the efficiency of microstrip patch antenna. The simulation will be shown in HFSS.

Index terms: Microstrip patch antenna, single layer substrate, Quasi H shaped, RF, low latency, high bandwidth, HFSS

I. INTRODUCTION

Microstrip antennas are extensively used in various applications because of its low profile, low cost and being able to effortlessly integrate with RF devices. Conventional microstrip antennas have a conducting patch printed on a grounded microwave substrate, and the attractive features of low profile, light weight, easy fabrication, and conformability to mounting hosts. However, microstrip antennas naturally have a narrow bandwidth and bandwidth enhancement is usually demanded for practical applications.

In this paper, a compact H-shaped microstrip antenna with T-shaped meandering nulls is presented. The dimension of the patch and the parameters of the shorting posts are enhanced to acquire an efficient design leading to the highest possible impedance bandwidth in the range of about 1 to 8 GHz, i.e., 81% of the center frequency. The growing demands of commercial and government communication systems have called for the development of small, Low-Profile antennas that are low cost and have high performance over a large range of frequencies. Such systems include wireless LANs, multipoint distribution networks, satellite communication systems, radar systems, personal communication systems, and automotive radars. Most of these applications require a small antenna with high performance, and commonly utilize high dielectric constant materials.

Microstrip patch antennas have been the focus of recent development because they exhibit many advantages that cannot be found in other forms of antennas. Some of these advantages are the wide variety of possible designs in terms of (operating frequency, polarization, pattern, and impedance), compactness, lightweight, simple and cost-effective fabrication, and also compatibility with the millimeter wave and microwave integrated circuits to have the ability to conform to planar and non-planar surfaces. Furthermore, for the last couple of years the trend in the communication area is the trend towards increased integration, due to the availability of Monolithic Microwave Integrated Circuits (MMIC's). Because of such circuits, microwave personal communication systems have become affordable. In the drive towards higher frequencies, integrable and smaller size components, one area that has been given particular attention is the antenna. The field of antenna engineering is the central bone to all wireless technology and plays a significant role in the successful development of such systems. Therefore, microstrip antennas are employed in a wide range of applications such as radars, satellites, GPS, mobile phone and other communication devices. The low-profile microstrip patch antenna with multiband operating frequency system is introduced with an intention to design an antenna which has multiband-frequency operation making it compatible for various applications by setting selective frequency. The proposed antenna resonates at a multiband of 1.5 GHz to 8.2 GHz frequencies for VSWR ≤ 1.32.

II. PROPOSED ANTENNA

Microstrip antennas are one of the most popular forms of printed antennas. Our objective is to design a low-profile single layer microstrip patch antenna, in the first iteration a simple rectangular patch was designed along by adding L band(1Ghz-2Ghz), S band(2Ghz-4Ghz) and C band (4Ghz-8Ghz). The desired results of the parameters were not achieved in Iteration I.

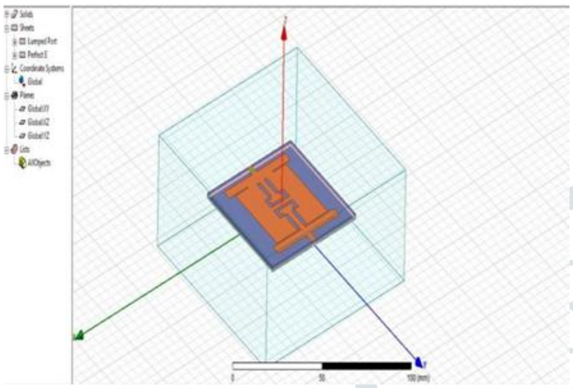

Fig 2.1: Design of the proposed system

By the next iteration, two slots were cut to make a H shaped patch from the rectangular patch by which bandwidth of the antenna was enhanced, then a lumped circuit was designed to operate the antenna at selective frequency. Finally in iteration 3 the desired results were achieved as shown in Fig.2.1 by adding T shape meandering nulls which acts as a resonator giving better radiation pattern and by lowering the losses.

A. FABRICATION OF ANTENNA

The designed system is sent for fabrication which is done by photo-lithographic method. The photo-lithographic method is a chemical etching process which removes the unwanted metal regions of the metallic layer leaving the chemically etched designed region alone on the substrate. The photo-lithographically fabricated H-shaped microstrip patch antenna is shown in the Fig. 2.2.

Fig 2.2: Fabricated H-shaped Microstrip patch antenna

B. TESTING OF ANTENNA

The fabricated antenna is sent for testing the results. The Fig.2.3 shows the testing of antenna for parameters such as return loss and VSWR were tested using a 8720D Two-port Vector Network Analyzer. 8720D Vector Network analyzer is a device mainly used to measure parameters of electrical networks that are of high frequency. The return loss and VSWR of the fabricated H-shaped microstrip patch antenna was measured to evaluate signal performance and quality.

Fig 2.3: Testing of Fabricated Antenna

III. BLOCK DIAGRAM

The intended microstrip patch antenna is designed using HFSS (High Frequency Structure Simulator) which is a high-performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modelling. The proposed microstrip patch antenna consists of ground, dielectric substrate and metallic patch. First, the materials for the patch and substrate of the antenna were chosen.

For substrate FR4 (flame retardant) is used because of its excellent mechanical properties making it ideal for a wide range of electronic components application and for ground copper is used, which is known for its high conductivity and increased electrical efficiency.

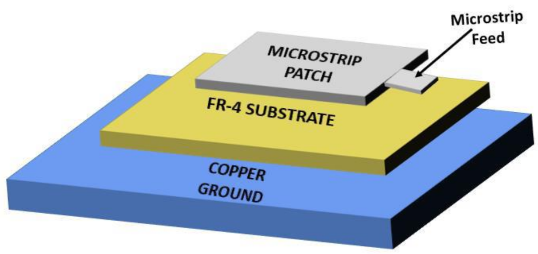

Fig 3.1: Block diagram of the Proposed system

A. COPPER GROUND

The ground plane of the microstrip patch antenna is a conducting surface to reflect the radio waves. The shape and size of the ground plane determine its radiation characteristics including gain, the designed dimension of the ground is 60 mm x 60 mm. For the ground plane to function the conducting surface must be at least a quarter of the wavelength (λ/4) of the radio waves. It is important for the ground plane to have good conductivity, any resistance in the ground plane is in series with the antenna, and serves to dissipate power from the transmitter. Considering the following factors, copper is chosen as ground plane material due to its high conductivity, increased electrical efficiency allowing RF energy to go up and out the antenna and not be trapped by creating heat energy.

B. FR-4 SUBSTRATE

Substrate is a base on which the microstrip patch (metallic sheet) is fabricated. It plays an important role in the functioning of microstrip patch antenna. The substrate is principally needed for the mechanical support of the antenna. To provide this support, the dielectric material is used as a substrate. For this system, FR-4 (Flame retardant) is used as a substrate, which is a glass-reinforced fiber epoxy laminate. The dielectric constant(εr) of FR-4 is 4.4mm. FR-4 popularly is known for having high mechanical strength, good insulating capacity in dry or humid environments and for being versatile at an affordable cost.

C. MICROSTRIP PATCH

Microstrip patch is a metal patch that radiates electromagnetic waves when current through the feed line reaches the strip of the antenna. The patch is of length **L**, width **W**, and sitting on top of a substrate (FR-4) of thickness/height **h** with permittivity having dielectric constant $\boldsymbol{\varepsilon_r}$ = 4.4mm.

C.1 Calculation of patch length and width

The dielectric constant of FR-4 $\boldsymbol{\varepsilon_r}$ = 4.4 mm
The dielectric height of FR-4 **h** = 1.6 mm
Resonant frequency **f0** = 8 GHz
Width **W** controls the input impedance larger width shows larger bandwidth.

Calculation of width:

$$W = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} = 36.5042\ mm$$

Effective substrate permittivity:

$$\varepsilon eff = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2}$$

Calculation of length:

$$\text{L}eff = \frac{c}{2f_0\sqrt{\varepsilon eff}}$$

$$\Delta\text{L} = 0.412h\frac{(\varepsilon eff+03)\left(\frac{W}{h}+0.264\right)}{(\varepsilon eff-0.258)\left(\frac{W}{h}+0.8\right)}$$

$$\text{L} = \text{L}eff + 2\Delta\text{L} = 38.5194\ mm$$

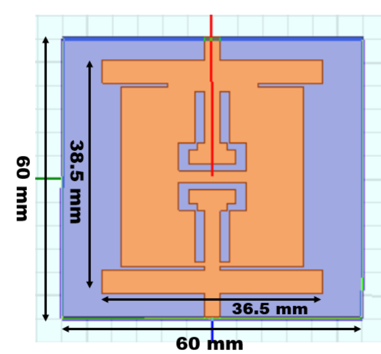

Fig 3.2: Length and width of the patch

Our objective is to design a low-profile single layer microstrip patch antenna. The calculated length and width are applied to design the patch a shown in Figure 3.2. A simple rectangular patch was designed along by adding L band(1Ghz-2Ghz), S band(2Ghz-4Ghz) and C band (4Ghz-8Ghz) in iteration 1, the desired results of the parameters were not achieved. By the next iteration, two slots were cut to make a H shaped patch from the rectangular patch by which bandwidth of the antenna was enhanced, then a lumped circuit was designed to operate the antenna at selective frequency. Finally in iteration 3 the desired results were achieved by adding T shape meandering nulls which acts as a resonator giving better radiation pattern and by lowering the losses.

D. MICROSTRIP FEED

A microstrip feed is used as a transmission line which is connected directly to the edge of the patch. To obtain a desirable VSWR it is important to have Impedance matching because impedance mismatch can lead to signal reflection and inefficient power transfer. The input impedance of the patch antenna varies with the feed location. The location of the probe is kept at 243 ohm point of the patch to achieve impedance matching. Thus, by extending the microstrip line into the patch, the impedance of the antenna is matched.

IV. RESULTS AND DISCUSSION

The proposed antenna has been designed and simulation is done by HFSS software (high-frequency structure simulator) which is a high-performance full-wave Electromagnetic (EM) Field simulator for arbitrary 3D volumetric passive device modeling.

A. RETURN LOSS

Return loss is a measure of the effectiveness of an antenna to deliver of power from source to antenna. The return loss is plotted, where frequency is given in GHz along the X axis and return loss in dB by the Y axis. Figure 4.1 shows the return loss simulation of the designed microstrip patch antenna. Figure 4.2 shows the tested result of the fabricated microstrip patch antenna.

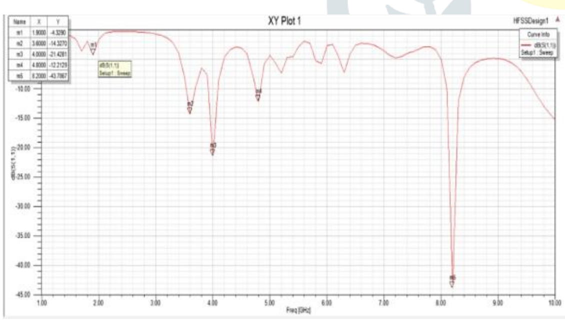

Fig 4.1: Return loss S11

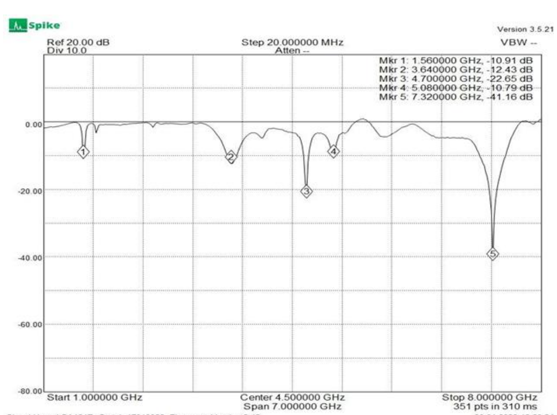

Fig 4.2: Return loss (Tested Result)

B. VSWR

VSWR is a measure that numerically describes how well the antenna is impedance matched to the transmission line it is connected to. VSWR shown in Fig.4.3 describes the reflected power from the antenna. The smaller the VSWR is, the better the antenna is matched to the transmission line and more power is delivered to the antenna. The minimum VSWR should be less than 2.0 which means no power is reflected from the antenna, making it an ideal case. The proposed antenna operates at frequency 4.8 Ghz with a return loss of -10.79 dB making it good candidate for 5G network and other high-speed communication.

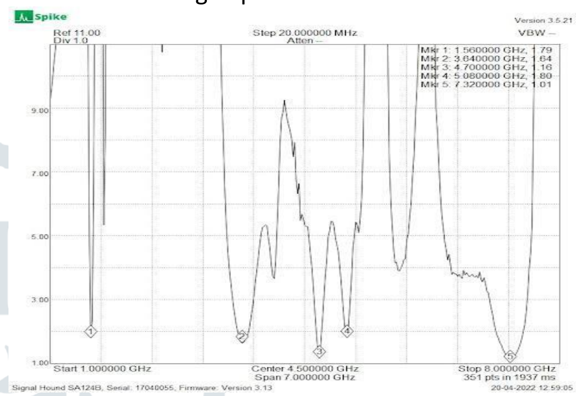

Fig 4.3 VSWR (Tested Result)

Fig 4.1: Tabulation of Return loss and VWSR of the operating frequencies.

S.NO	FREQUENCY(GHz)	RETURN LOSS (dB)	VSWR
1.	1. 56 GHz	-10.91 dB	1.79
2.	3.64 GHz	-12.43 dB	1.64
3.	4.70 GHz	-22.65 dB	1.16
4.	5.08 GHz	-10.79 dB	1.80
5.	7.32 GHz	-41.16 dB	1.01

C. GAIN AND DIRECTIVITY

Figure 4.4 shows the gain of the designed H-shaped microstrip patch antenna. Gain gives the characterization of the radiation. Gain of the antenna is simply defined as the total power given by the antenna, to the total power delivered to the destination. The gain achieved for the designed H-patch microstrip patch antenna is 3.23 dB.

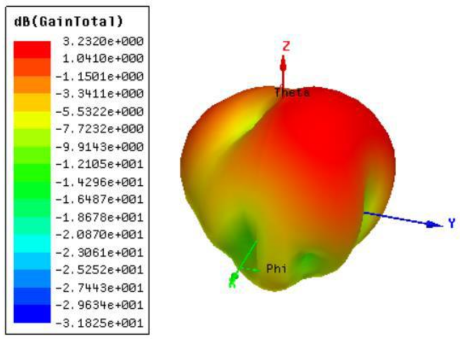

Fig 4.4: Gain of Proposed Antenna

Directivity of an antenna is defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not strictly specified, the direction of maximum radiation intensity is implied. The directivity of the proposed antenna is shown in fig 4.5.

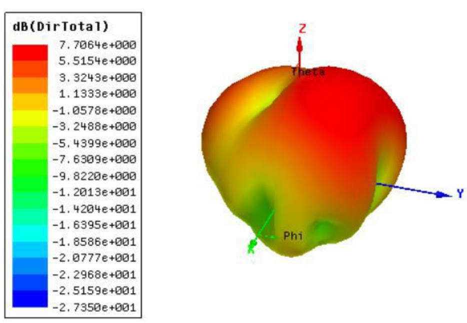

Fig 4.5 Directivity of proposed antenna

The relationship between gain and directivity is given by $\boldsymbol{G}=\boldsymbol{eD}$, where e is the efficiency of the antenna. Gain is always less than directivity because it ideal for efficiency to be in the range of 0 to 1.

D. RADIATION PATTERN

The radiation pattern of antenna pattern is the graphical representation of the radiation properties of the antenna as a function of space. That is, the antenna's pattern describes how the antenna radiates energy out into space (or how it receives energy). The radiation pattern of the proposed antenna is shown in Fig 4.6.

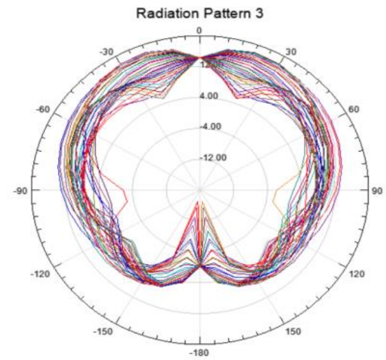

Fig 4.6: Radiation pattern

V. CONCLUSION AND FUTURE SCOPE

A compact low-profile H-shaped microstrip patch antenna patch have been designed to enhance gain, bandwidth and return loss. The proposed antenna was designed and parameters such as return loss, VSWR, gain, directivity and radiation pattern were simulated and tested. The proposed model antenna operates at frequency 4.8 Ghz with a good return loss of -10.79 dB making it good candidate for WLAN, 5G network and other high-speed communication.

In future, the designed H-shaped microstrip antenna will play an important role in wireless communication. The growth of technology comes along with the need of high-speed network. In order to meet this requirement, the proposed model will play a vital role in the advancement of 5G network devices by providing universal and uninterrupted access to information and communication.

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