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Design and Implementation of Multiband Microstrip Patch Antenna for 5G-IOT Communication System

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***Abstract*— A versatile and adjustable multi-functional antenna system should be used to handle a challenging wireless communication scenario so as to ensure system quality. The multiband is attained by designing proposed length and thickness of the micro-strip patch antenna. The frequency sweeps are changed in order to obtain the multifrequency for the applications such as Internet of Things point-to-point communication etc. The patch antenna with multiband characteristics is proposed in this paper. Inset-fed structure is used to feed the microstrip antenna and fabricated and with FR4 _Epoxy substrate. The proposed structure of patch antenna achieves tri-band characteristics of S-band with 3.7-GHz and C-band X-band with 5.7GHz, 6.9GHz,7.1GHz.9.3GHz suitable for multiband applications in 5G. Using Ansys HFSS software the proposed microstrip patch antenna was simulated and the essential characteristics of the anticipated design was verified. The design bids multi-band process with stable gain and high directional radiation characteristics.**

Keywords— multiband, microstrip patch antenna(MSPA),5GHz inset-fed Ansys-Analysis of Systems, HFSS-High Frequency Structure Simulator, circularly polarized(CP).

I. INTRODUCTION

Due to the tremendous expansion of recent wireless communication systems, antennas must have the ability to be sense multiband at the same time to be used in various wireless networks. With suitable design principles, the antenna must be perform with high gain and directivity. Microstrip patch antenna may be the most practical option for Internet of Things (IOT) system. The development of microstrip antennas that can operate in several frequency bands with better radiation quality is receiving increased attention from RF experts. By using various processes, we can make the antenna to transmit and receive multiband, but there are a lot of factors to take into account, including constant radiation, high gain, efficiency, and the right impedance.

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II. LITERATURE SURVEY

In (Dr.V.Prakasam et.al. 2020) The proposed design used MSPA for wireless communication systems, they designed an Left and right hand circularly polarized antenna using a cross-coupler with a frequency of 4.85GHz which is attached to the antenna. The applications of this work can be considered for satellite interchanges, full-time satellite TV. They have utilized RMSPA and CSTMWS for the programming.

In (G. Christina 2021) The author reviewed microstrip Patch Antenna Performance enhancement methods on various applications. The size and shape of the antenna, and how important it is also briefed in this review. With the performances of the MSA the advantages and limitations of the recent techniques are also mentioned.

In (Radouane Karli et.al. 2013) a novel design of multi-frequency band patch antenna for various wireless communication is described in this work, the author designed a microstrip patch antenna using seven unique multiband frequencies for the application of GSM, cellular phone, Bluetooth, and so on. The antenna was selected on the basis of the requirement of the constraints like frequency range, gain, and cost. To enhance the bandwidth of the antenna they implemented feeding methods like L-probe feed. One of the disadvantages of the design of this antenna was its narrow bandwidth due to surface wave losses.

The author (Tanvi Dabas et.al.2020) proposed a multiband multi-polarized, feed patch antenna with a truncated patch and a complementary split resonator with a circular shape to obtain the frequency bands with multi-polarizations. It was observed that the simulated results were lower than the calculated values due to the of additional slits.

In (B. Manjurega et.al.2019) U-shaped slot patch antenna using HFSS was analyzed, and a U-Shaped patch antenna has been used. A rectangular patch over that a U-formed slot was made to which the patch was embedded. The dual band application was one of the

TABLE I. COMPARISON BETWEEN PATCH AND SLOT ANTENNA

Sr. No .	Characteristics	Microstri p Patch Antenna	Microstrip Slot Antenna
1.	Profile	Thin	Thin
2.	Fabrication	Very easy	Easy
3.	Polarization	Both linear and circular	Both linear and circular
4.	Dual-Frequency operation	Possible	Possible
5.	Shape flexibility	Any shape	Mostly rectangular and circular shapes
6.	Spurious radiation	Exists	Exists
7.	Bandwidth	2-50%	5-30%

major advantages of U-shaped. With improved gain and decrease of return loss they were able to achieve the same. The parameters used were analyzed and simulated on HFSS but achieving the U-shape slot on the antenna was a difficult process to achieve. We can compare the characteristics of microstrip patch antenna and microstrip slot antenna as shown in table 1, we can say that though characteristics such as Profile, Polarization, Dual frequency operation and Spurious Radiation these are similar, there is immense variation in characteristics such as Fabrication, Shape flexibility and Bandwidth.

In (Abdullah AL-Sehemi et.al 2020) a bendable broad band antenna used for IOT application was described. An antenna with high radiation efficiency based on IOT application was proposed. A two stubs a triangular shaped and an U-shaped radiator has been designed. It is fabricated on a flexible substate and natural rubber as filler. The frequency attained is around 2GHz which used in the application of wireless communications and IOT applications. The results demonstrated that bending in the design has a lesser effect on the performance of antenna within the targeted frequency range.

III. SYTEM MODELLING

A. Calculation of Effective Dielectric Constant

The MSL has air and substate as its dielectrics. The electric fields are maximum inside the substrate than that of the air. The phase velocities changes in air and substate, hence the transmission line will not support pure Transverse Electric and Magnetic mode. Due to the fringing field around the border of the patch the value of ϵ_{eff} dielectric constant lesser than dielectric constant of the substrate.
The effective dielectric constant ϵ_{eff} is given by:

$$\epsilon^{\circ}{}_{eff} = \frac{\varepsilon^{\Delta^{\circ}}{}_{r} + 1}{2} + \frac{\varepsilon^{\Delta^{\circ}}{}_{r} - 1}{2}\left[1 + \frac{12h}{w}\right]^{-\frac{1}{2}} \tag{1}$$

where $\varepsilon^{\Delta\circ}{}_{r}$= dielectric constant of the substrate
h =Substrate height
W =Patch width

B. Calculation of length

The resonance frequency obtained by the length of the patch which is a critical factor for the design of MSL.
The L_{eff} is given by;

$$L_{eff} = \frac{C}{2f_r\sqrt{\epsilon^{\circ}{}_{eff}}} \tag{2}$$

where f_r = relative frequency
C = speed of light
$^{\circ}\,\epsilon_{eff}$ = the effective dielectric constant
The difference in length ΔL, is expressed as;

$$\Delta L = 0.412h\frac{(\epsilon^{\circ}{}_{eff} + 0.3)(\frac{w}{h} + 0.264)}{(\epsilon^{\circ}{}_{eff} - 0.258)(\frac{w}{h} + 0.8)} \tag{3}$$

the The definite length of the MSA patch which is given as;
$L = L_{eff} - 2\Delta L$

C. Calculation of Width

The width of the MSL is the determining factors for calculating efficiency, impedance of antenna and the bandwidth. The width is dependent widely on substrate dielectric constant and frequency.
The width of the MSA patch antenna is given by;

$$W = \frac{C}{2f_r\sqrt{\frac{\varepsilon^{\Delta^{\circ}}{}_{r} + 1}{2}}} \tag{4}$$

Where W= width of the patch; C=speed of light; f_r=Frequency of operation; $\varepsilon^{\Delta}{}_{r}$ *=didectirc constant of the substrate material*

IV. ANTENNA GEOMETRY AND DESIGN

For designing a microstrip antenna we require three structures namely – a ground plane, a dielectric and a patch above the substrate as shown in Figure1.The constructed design is illustrated in Table 2 that consists of the width and length of both the ground plane and microstrip patch of the antenna, along with the thickness and width of the port. The designed antenna has various application concerning the frequency bands X-band, C-band, S-band and as depicted in Table 3.
The multiband MSA is designed using the parameter shown in table 2.

TABLE II. PARAMETERS OF THE MSA

S. No	Parameter	Description	Value (in mm)
1	W_g	Width of the ground plane	30
2	L_g	Length of the ground plane	30
3	W_p	Width of the patch	23
4	L_p	Length of the patch	17.5
5	T_{pt}	Thickness of the port	1.6
6	W_{pt}	Width of the port	1

TABLE III. APPLICATIONS FOR DIFFERENT SIMULATED FREQUENCIES

S. No	Frequency (GHz)	Frequency Band	Applications
1	3.7	S band	Weather radar
2	5.7	C band	Broadcast television distribution
3	6.9	C band	Satellite downlink
4	7.1	C band	Cordless telephone
5	9.3	X band	Défense Tracking

TABLE IV. CHARACTERISTICS OF THE DESIGNED ANTENNA.

Antenna Parameter Overlay1: Freq='4GHz'	
Quantity	Value
Max U	79.8315 mW/sr
Peak Directivity (dB)	6.33428
Peak Gain (dB)	4.19551
Radiation Efficiency	0.611114
Front To Back Ratio (dB)	10.2629
Total Efficiency	0.233328
System Efficiency	0.233328

V. SIMULATION TOOL USED

Simulation software used for the proposed design is Ansys HFSS. The software is known for its 3D electromagnetic (EM) simulation used for simulating high-frequency microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards.

VI.SIMULATION RESULTS

The design of a MSPA have 3 structures namely -A ground plane, dielectric substrate, patch above the substrate. In any mathematical model boundary conditions are essential component, directs the motion of flow which leads to a exclusive solution. We can observe the boundary condition of both patch and feed with perfectly E field as well as the radiation box with perfect E field as shown in Figure 2 & Figure 3 respectively.

The port excitation occurs in all 3 direction on a plane but it is most effectively used in Z plane as shown in Figure 4.

We have used Ansys electronic Desktop student 2022 R2 for simulating the microstrip patch antenna. We have designed for 4.8 GHz Frequency with a good reception of directivity and gain having a dielectric strength of 4.4 with height of 1.6mm. Hence by calculation, we get the desired length and width of the microstrip patch as 14.370 mm & 19.018 mm respectively. After calculating we use the tool to build the antenna. Setting the sweep frequency to linear count with fast sweep having the sweep from 1 GHz - 5Ghz , step size as 0.01 GHz ,the return loss for the operating frequency across the tri-band is shown in the plot. The structure along with 3-D gain plot of the MSA is shown in Figure 6, Similarly with the required sweep condition by analysis we can obtain the 3-D radiation plot and 3-D directivity plot as shown in Figure 7 and Figure 8 respectively. The Figure 11 and Figure 12 depicts the resulting graphical plot of directivity and VSWR for multiband frequency of patch antenna respectively.

With respect to Figure 12 the S parameter of S-band is -17 dB, C-band is -10.12 dB and X-band is -18.10 dB are the resulting conclusion for the microstrip patch antenna obtained.

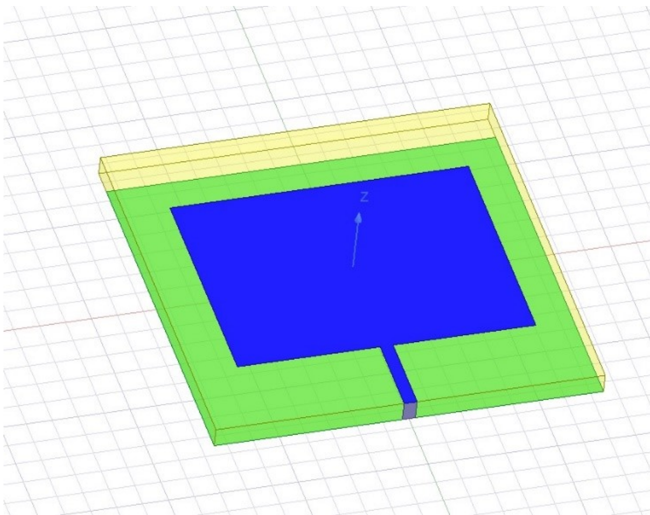

Fig. 1. Basic figure of Microstrip patch antenna.

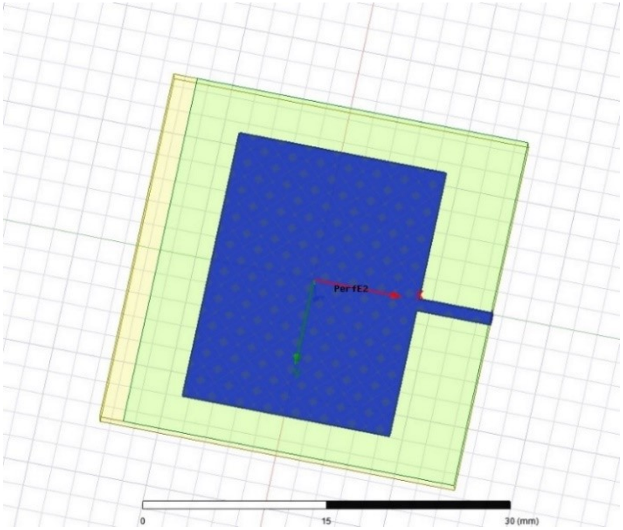

Fig. 2. Boundary condition of patch and feed with perfectly E field

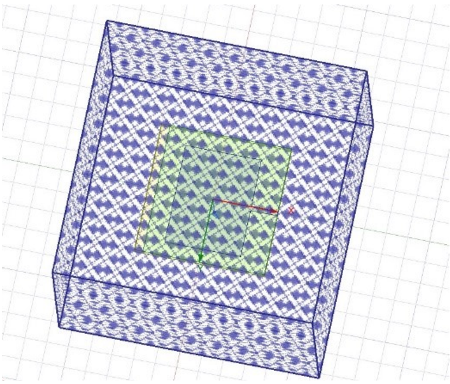

Fig. 3. Boundary condition of radiation box consisting of Microstrip patch antenna placed inside it with perfectly E field.

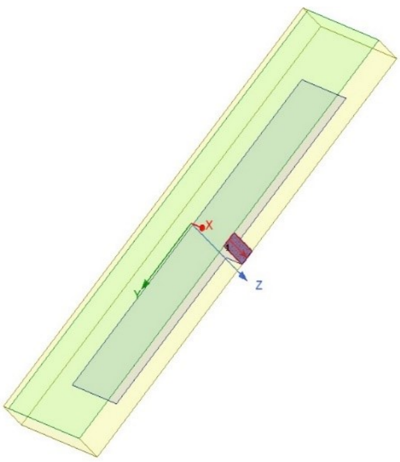

Fig. 4. Port excitation towards z direction

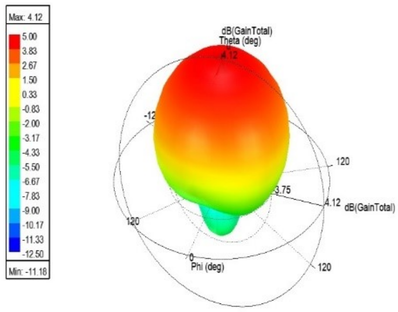

Fig. 5. 3-D polar plot of total gain in dB.

as per the antenna specification, for effective transmission and reception the most important parameter is gain of an antenna. These values are plotted as a function of frequency for the validation as observed in Figure 5.

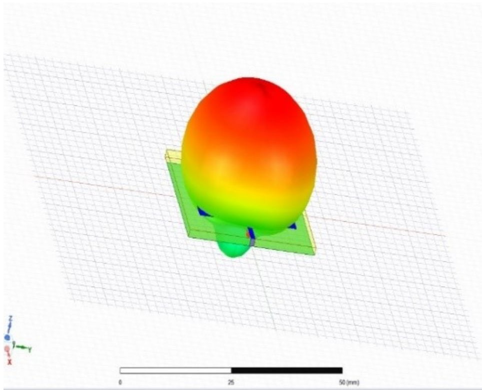

Fig. 6. 3-D gain plot of the antenna with structure of microstrip patch antenna.

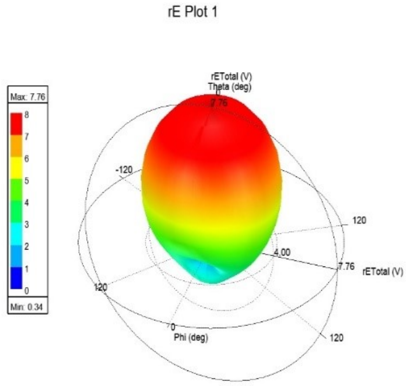

Fig. 7. 3-D Radiation plot of microstrip patch antenna.

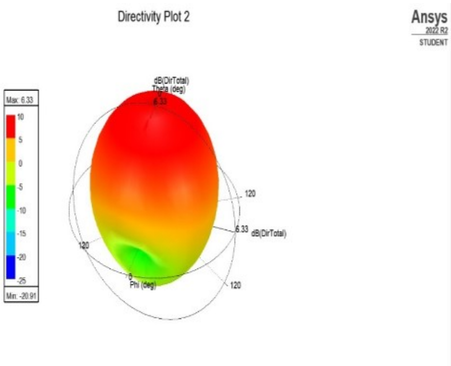

Fig. 8. 3-D polar plot of Directivity.

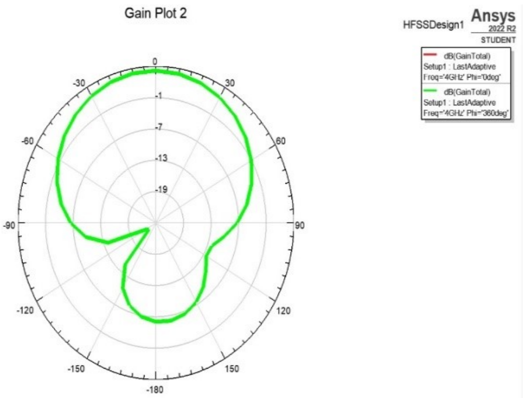

Fig. 9. Radiation of Gain plot.

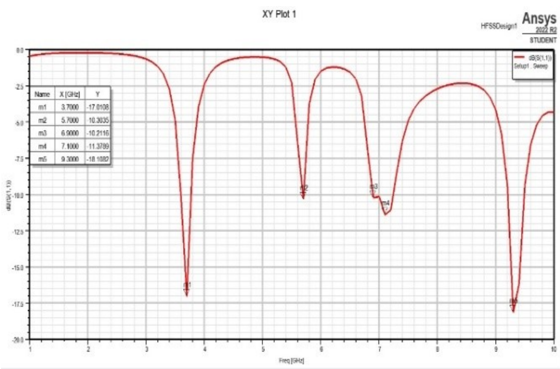

Fig.10 VSWR plot

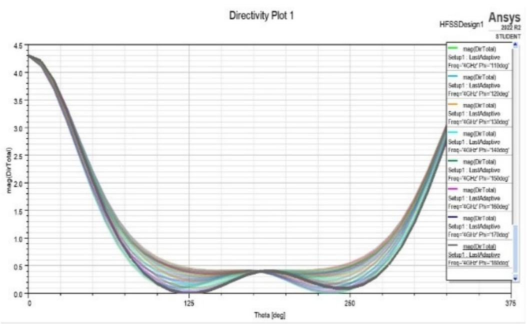

Fig. 11. Maximum directivity of multiband microstrip antenna is at 4GHz having 1800 phase

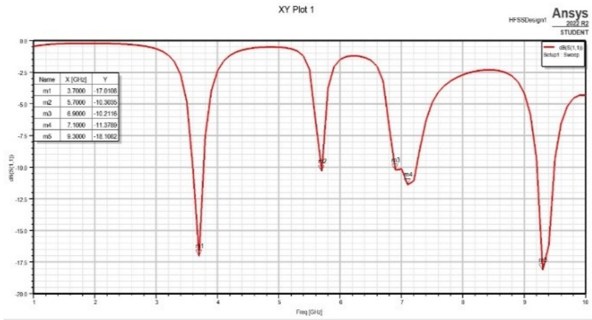

Fig. 12. Sparameter for gain plot in Db

VII. TABULATED RESULT

The resulting Table below illustrates the return loss and VSWR in dB for different frequency bands .

Band	Operating Frequency Range in GHz	Return loss in dB	VSWR
S	3.7	-17.01	2.4672
C	6.9	-10.21	5.4796
X	9.3	-18.10	2.1711

VIII. CONCLUSION

The proposed MSA is designed and simulated using Ansys HFSS software. The patch designed with width =1.6mm and length of patch as 1mm respectively is designed . The length and width of both ground and substate are 30mm,30mm and 23mm,17.5mm respectively. After simulation the required gain, directivity, VSWR and radiation pattern is obtained with an antenna efficiency in the range of 85% - 92%. This proposed microstrip patch antenna is useful for multiband frequencies such as X-band, C-band and also S-band. The application of this antenna is found in WiMax, weather radar etc. The future scope of this proposed work can be reconfigured using multiband.

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