Design and Analysis of millimeter wave slotted Microstrip Patch Antenna for Multiband Application

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Abstract—
this paper proposes an aperture coupled micro strip antenna containing two similar substrates having thickness 1.6 mm for a millimeter wave application.The ground metal is slotted and aperture feed coupling is responsible for multibandoperations thatresonates at 113.9556, 157.1444& 187.0444 GHz whose return losses are -10.5147,-11.6695 and -13.4354 dB respectively.The antenna is useful for mm and G-band applications. The designed antenna improves the 5G communication system and their performance. Size reduction and cost-effective are also other parameter for the forth coming communication system. It also realized tunability of frequencies, stable radiation pattern with compact electrical size. The paper analysed the simulated results with the high frequency structure simulator software.

KEYWORDS—Multiband, HFSS, G band or millimeter wave, aperture feed Coupling
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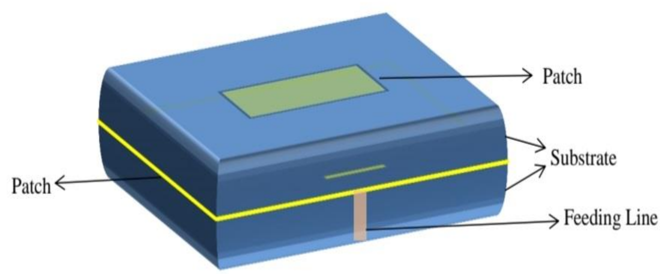
1. INTRODUCTION

Today's wireless communication companies face number of difficult issues, including the lack of suitable frequency resources for their consumers and the steadily rising Wireless services that are effective continue to be in demand. The higher frequency band like millimeter-wave band's spectrum (30-300GHz) will help to tremendous quality of bandwidth that is required for higher data transmission rates [1, 2]. It is distinguished by a tremendous quantity of bandwidth. High definition television and ultrahigh definition video, which need multi-gigabit communication services, have been proposed as applications for millimeter wave bands in the 5G mobile network [3].The proposed antenna would therefore be an appropriate component of devices operating at high- frequency covering at the 113.9556, 157.1444 & 187.0444 GHz frequency. The design of multiband resonant frequency patch antenna can be achieved by slotting on top of patch, play a crucial role in this evolution as an essential part of contemporary wireless communication systems [4, 5]. Future wireless networks will need devices with broad band capabilities operating in a variety of settings to support a wide range of applications, including smart grid, personal communications, home, automobile, and office networking. Its adaptability makes it ideal for usage in handheld devices, mobile phones, aeroplanes, ships, trains, and automobiles [6].A ground plane is located on the opposite side of the dielectric substrate from the Radiating patch of a microstrip patch antenna. Any form, including rectangular, square, circular, elliptical, triangular, etc., may be used for the radiating patch [7]. The rapid decrease in the dimensions of the mobile phone has led to the evolution of compact antenna structures. The microstrip patch antenna (MPA) has several advantages such as its small size, low cost, light weight and easy fabrication. With the advancement of wireless technologies, the need for antenna that can operate at multiple resonant frequencies is ever increasing MPAs outperforming conventional antennas. Researchers have used various dielectric substrates to make microstrip patch antennas.If the proper patch shape and mode are chosen while creating such antennas,then they are excellent in terms of return loss,compact size, high efficiency,resonant frequency, polarisation and pattern [8, 9].Micro strip patch antenna H shaped slot has been designed for millimetre wave which has multiband resonate frequency 58.95 GHz & 70.425 GHz[10]. The 5 G, small advance antenna frequency band range 28 to 38 GHz and analysed at 28 GHz the CST simulation software RT/duroid-5880 substrates material, which is demonstrated the return loss -10 dB at 28 GHz frequency [11]. A multiband horizontal wide U slotted patch antenna is proposed for wireless communication (i.e. S band, C band and X band).There are three distinct resonating frequencies i.e. 4.7 GHz, 6.8 GHz and 9.8 GHz with return loss less than -10 dB, bandwidth 111.1 MHz, 245.1 MHz, 998.6 MHz respectively. Whenresonating frequencies as 4.75 GHz, 7.1 GHz and 10.2 GHz withbandwidth 539.1 MHz,410.6 MHz and 2.08344 GHz respectively at -10 dB return loss.[12] The micro strip patch array (16*1, elements) antenna is designed for millimetre wave band applications .there is a simple edge feeding technique used. The matching network or power divider/splitter are designed for 32*16 elements are used with gain of 27dBi at 79 GHz and 26 dBi at 80GHz [13]. A coplanar waveguide fed rectangular U shape slotted patch antenna for 10 GHz is designed and simulated with HFSS, FR4 epoxy substrate used. The return loss -17 dB at 40GHz and -25 dB at 10GHz achieved [14]. The ultra-wideband micro strip antenna is designed for 5G band and compared with the same size of the conventional antenna as increased returned loss up to 16.84%, 15.7 % bandwidth and gain enhanced 9.21 dB [15]. The proposed antenna array for 5 G is designed with relative substrate 0.4 used, the antenna is tuned at 52 GHz and massive input and massive output are discussed in this work [16]. In this work different aspects of mobile communication for 5G has been discussed and a dual –polarized millimetre wave antenna has been presented and extended itself as spatial parallel parasitic patches used with 22 sub array .The centre frequency of this extended antenna observed 37.5 GHz which is less than the previous one designed antenna of 2 GHz and increased bandwidth as 6.13 % and isolation of greater than 30 dB; cross polarization of -23.6 dB gain of and 11.5 dB are obtained [17].

2. DESIGN AND STRUCTURE OF THE ANTENNA

The proposed antennas are designed on High frequency structure simulator with dielectric substrate FR4 epoxy of dielectric constant 4.4 and the thickness of the substrate h = 3.2 mm which is a combination of two 1.6 mm substrate having same dielectric constant . The ground has the dimensions of 6 mm × 9 mm with height of substrate 3.2 mm. Antennas is excited with aperture coupled Feed having characteristics impedance of 50 Ω. Here aperture coupled feed is used to transfer the signal as current on the patch. The slots are utilized to generate multiple resonant frequencies. 1031



The geometry of slotted micro strip patch antenna (3.2mm width substrate) is shown in Figure 1.

Table 1.Design specification for double width substrate slotted micro strip patch antenna

3. CHARACTERISTIC DESCRIPTION OF DESIGNED ANTENNA

1. The Width of the patch

$$W=\frac{c}{2f_0\sqrt{\frac{(\varepsilon_{r+1})}{2}}}$$

Where c is the velocity of light in free space, f_o is the resonant frequency, εr is the dielectric constant of substrate

2. Calculation of the Effective Dielectric Constant. This is based on the height, dielectric constant of the dielectric and the calculated width of the patch antenna (ε_{eff}):

$$\varepsilon_{eff}=\frac{\varepsilon_{r+1}}{2}+\frac{\varepsilon_{r-1}}{2}[1+12\frac{h}{w}]^{\frac{-1}{2}}$$

3. Effective length (L_{eff}):

$$L_{eff}=\frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$$

4. Length extension (ΔL):

$$\Delta L=0.412h\frac{(\varepsilon_{eff+0.3})(\frac{W}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{W}{h}+0.8)}$$

5. Calculation of actual length of patch (L):

$$L=L_{eff}-2\Delta L$$

4. Result and discussion

A. Return loss

In telecommunications the return loss is the loss of power in the signal returned i.e., the reflecteing by a discontinuity in a transmission line. The proposed antennas have configured with low return loss, the return loss must be greater than -10 dB. MPA at operating frequency 113.9556, 157.1444 & 187.0444 GHz the return loss is -10.5147,-11.6695 and -13.4354 dB respectively, which isdesirable

S. No.	Parameters	MPA's, values are in mm
1	Substrate Length	6
2	Substrate Width	9
3	Total Substrate thickness (h)	3.2
4	Patch length	4
5	Patch width	6
6	Slot length	0.25
7	Slot width	1
8	Feed line Length	3
9	Feed line Width	0.295
10	Relative dielectric Constant (εr)	4.4

1032

forgood performance ofantenna.

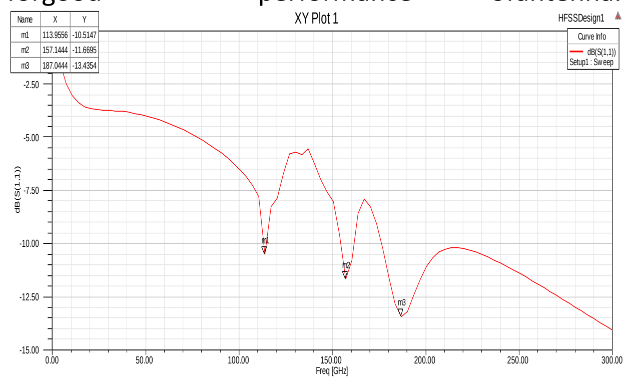


Figure2: Represents return loss at various frequencies

B. Gain

Gain is a signal strength as the signal is processed by the antenna at a given incident angle. The gain of proposed MPA varied from -10.5147,-11.6695 and -13.4354 dB at operating frequency 113.9556, 157.1444 & 187.0444 GHz respectivelythe gain of proposed antenna has been shown in the figure (3)

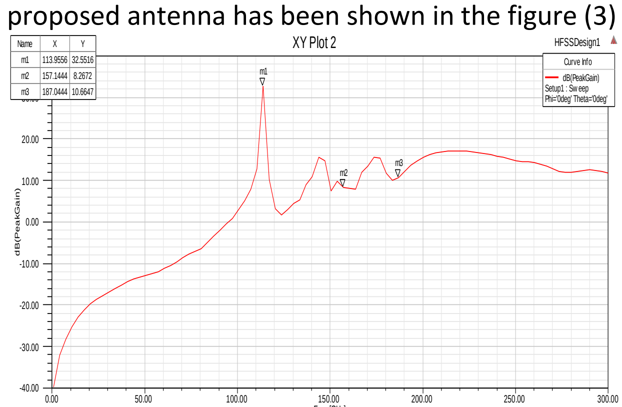


Figure 3: Represents Gain at various frequencies

C. Directivity

The ratio of maximum radiation intensity to its average radiation intensity assigns the directivity of an antenna. In this proposed work the directivity of MPAa is 0.4296,2.6033 and 2.6863 dB at 113.9556, 157.1444 & 187.0444 GHz &In general, the value of directivity is from 1 to ∞ for various operated frequency, Figure (4) represent graph between operated frequency range and obtained directivity.

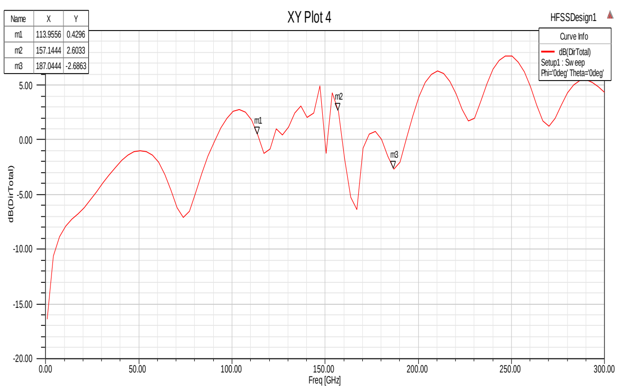


Figure 4: Represents directivity at various frequencies

D. Voltage Standing Wave Ratio

In this work, the designed MPA having 5.3394,4.6401 and 3.7564 VSWR at 113.9556, 157.1444&187.0444 GHz respectively.

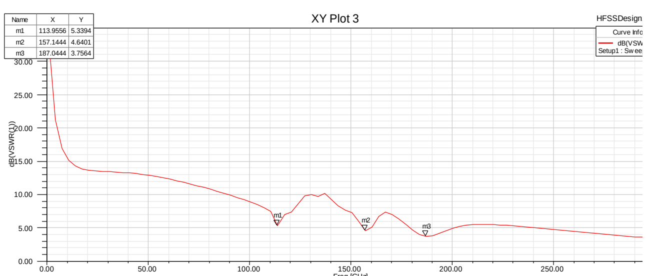


Figure 5: Represents VSWR at various frequencies

E. Radiation Pattern:

The radiation pattern decides the coverage area in free space and it has ability to receive and transmitin different directions.In the present work, Figure (6) represent optimized E – plane and H – plane at various frequencies. The better directivity gives high radiation efficiency in all possible direction.

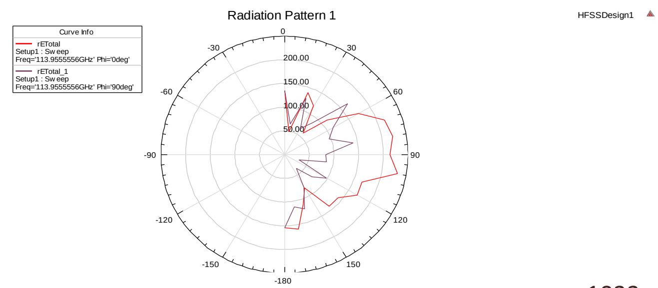


Figure 6(a): Represent optimized E – plane and H – plane at frequency 113.95 GHz

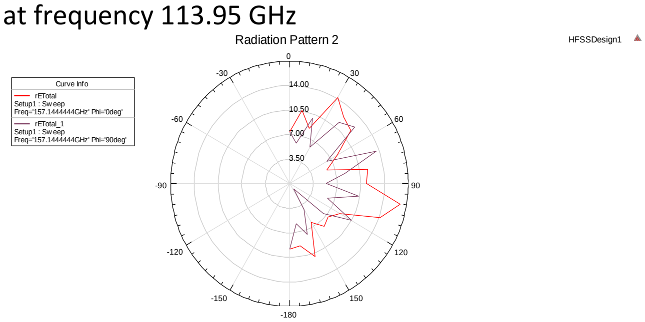


Figure 6(b): Represent optimized E – plane and H – plane at frequency 157.14 GHz

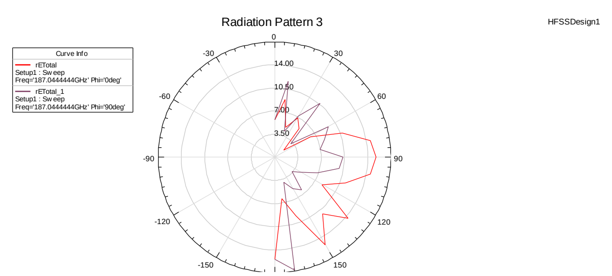


Figure 6(c): Represent optimized E – plane and H – plane at frequency 187.04 GHz

5 .CONCLUSION

The design and analysis of a micro strip patch antenna operating at 113.95,157.14& 187.04 GHz with the return loss of -10.5147,-11.6695 and -13.4354 dB presented in this paper proved the theoretical study of MPA's properties in relation to the structure profile as well as type of substrate material and the feeding technique used. The designed antenna is an excellent option for next level communication devices that would be operating on the proposed for G band. Future research and construction of more advanced patch antennas operating in the millimeter wave bands employing a variety of bandwidth improvement techniques is advised in order to fulfill the demand and specifications for 5G networks.

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