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Multiband Microstrip Patch Antenna for 5G Wireless Communication

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Abstract— In current time's an immense proliferation occurred in the user's density of wireless communication, not so far but in near past one channel was enough for the necessities of a single mobile user. Now even 4G technology is inadequate to deliver its clienteles a wider bandwidth, gain and fast communication. For need of high hasten communication technology alteration is under way and is switching from 4G to 5G. For multi-channel communication necessity, communicating gadgets are integrated with multiple bands having peculiarity to work on disparate frequency channels in a single device. In this projected work microstrip patch antenna is used as communicating tool and analyzed for one band and dual band communication at higher frequencies (mm-waves). Microstrip patch antenna is selected because of its simple design, low price, compactness and compatibility with circuit elements. A dual band U-shaped slotted Microstrip patch antenna with 28GHz and 38GHz operating bands is presented in this paper. The total area of antenna is$8.5 \times 8 \times 0.254mm^3$, the substrate used in designing is Rogers RT 5880 having a dielectric constant 2.2. The antenna resulted in return loss of -32dB at 28GHz and -40dB at 38GHz. The simulated gain of proposed dual band is 6.7dB at 28GHz and 7.92dB at 38GHz.

Keywords— MPA, Microstrip antenna array, 5G, mm-waves, Return Loss.

I. Introduction

. The user density is increasing day by day there is a big difference between the current density of users now and a few years ago after each year a large number of new users get access to the channel, therefore there is a prominent development in the arena of wireless technology, As the user density is aggregate similarly higher data rates and wide bandwidth increase the importance to accommodate that massive user density, it is indispensable to provide them multiple channels so that they can get uninterrupted service, in current era the field of 5G is emerging, now communication will takes place on higher frequencies (mm-band), therefore to allot the users high data rates various techniques are used linked with antenna to meet the requirements of higher number of users, for this purpose multiband antennas are usually used with diverse optimization approaches like using of array , slot or MIMO approach in recent era MIMO approach plays an gigantic role in providing higher emitted efficiency of the emitted EM waves both in near and far field regions and the data rate is quite high, both in 4G and now in 5G.when you have to provide access to multiusers at a time you will need a vast quantity of broad casting devices on both side via transmitter or receiver [1], by proper enactment of Slot, MIMO or Array approach, there is an extreme development in data rate, user allotting and handling aptitude. The mm frequency bands at the present time are under consideration around the globe because it is the probable sturdy entrant for meeting the congested user density [2]. Research is proceeding on the mm bands that come under the umbrella of 5G, these mm frequencies ensembles are comprised of 28GHZ, 38GHZ, 60GhHZ some even work on more than 70 GHz. In broadcasting devices antenna act as imperative player in wireless system. The radiated waves usually in mm bands agonize after atmospheric fascination, it include the issue of path loss also. Therefore the manufacturing and outline of an antenna has two main concerns, first a high gain and second a covenant size which is nothing more than a challenge. Bandwidth amplification and dimensions detraction are appropriate prevailing design politeness for the pragmatic consumption of MPA [4], it is indispensable for an antenna element to have a low profile dimension, low budget, to have the peculiarity to work on distinct mm bands. Enormous research considerations have been adopted with multiband antenna devices that utilize the mm bands [5]. A profound number of designs employed on mm bands are addressed in today era and are appropriate for 5G [5], the architecture of a circular geometrical alignment of MPA is illustrated in [6] with a slot acquainted in patch operating at 28GHz, one MIMO outline which is investigated in [7] works on three dissimilar bands. This design is composed of 2D antenna having an introduced slot designed for 28GHz band. In [8] an MPA antenna has been depicted with multiband peculiarity and used slot technique for 2x4MIMO attaining of multiband characteristics, the projected design is set up above the dielectric material made of FR4 having **k**=4.2 & 1.6mm thickness, it resonates at 7.4 GHz possess a 308 MHz bandwidth along with 9.68 GHz, 12.04 GHz & 12.86 GHz under the stag frequency range of 4.8 GHz. The antenna has return loss of -21.45 dB, -33.51 dB, -16.48 dB and - 10.78 dB at operating frequencies. For gain enhancement researches are

focusing on antenna arrays like one illustrated in [9] in which MPA (parasitic) comprised of 42-elements is capable of working on mm-wave frequencies, antenna provides 6.3% FBW and 1.96 VSWR for frequencies varying from 26.83-28.56GHz. Antennas intended for 5G technology is projected to be minor in size with elevated gain as compared to others that are utilized for both 3G, 4G networks. 5G antennas require extra
innovative steering and scanning approaches with the aim to act adequately. It offers the likelihood possession of extended channel frequency extent conceivably varying from 1 to 2 GHz, a 4 element double band printed antenna array with slots formation for 5G is depicted that offers an adequate impedance matching at 28/38 which are sought bands in mm waves, |S11| is lower than -10 dB, having 10.58 dB gain at 28 GHz and 12.15 dB at 38 GHz [10]. Numerous configurations are delineated in [11] and [12] for bandwidth augmentation, for instance enlarging the thickness of dielectric material (substrate), usage of a small truncated substrate, the adoption of miscellaneous tactics for impedance equivalency and patch invigorating, the adoption of diversified resonators [13], use of aperture coupling fed technique in [14], the utilization of slot antenna for gain melioration [15] or acquainting of thickened parasitic patch substrate [16].

A dual band U-shaped slotted Microstrip patch antenna is designed for 5G technology with 28GHz and 38GHz as operating bands. In first phase of designing a single band Microstrip patch antenna with Rogers RT 5880 substrate and 2.2 dielectric constant was designed and analyzed for 28GHz band, substrate has $8 \times 8.5mm^2$ dimeniosn with 0.254mm hight.The single band is fed by inset fed line approach, the projected single band antenna has a return loss of -48dB at 28GHz and VSWR less than 2. For attaining the multiband features two U-shaped slots were introduced in patch design, two distinct bands of 28GHz and 38G were attained with the help of these inserted slots, the proposed dual band slotted microstrip patch antenna has gain of 6.7dB at 28GHz and 7.92dB at 38GHz respectively. The dual band has a return loss of -32dB at 28GHz and -40dB at 38GHz band.

II. DESIGN OF SINGLE BAND MICROSTRIP PATCH ANTENNA

The substrate used in design of single band MPA antenna is Rogers RT 5880 having $\varepsilon_r = 2.2$ and $8 \times 8.5 \times 0.254\ mm^3$ dimensions, total area of radiating patch is $3.27 \times 4.09 \times 0.035\ mm^3$. For excitation of patch inset feed approach is used. The designed single band antenna is analyzed at 28GHz frequency. The parameters used for designing of said antenna is projected in table 1.

TABLE I DESIGNING PARAMETERS OF SINGLE BAND MPA

Description	Values	Parameter
Substrate length	8 mm	L_s
Substrate width	8.5 mm	W_s
Substrate height	0.254 mm	h_s
Patch length	3.27 mm	L_p
Patch width	4.09 mm	W_p
Feedline length	3.12 mm	L_f
Feedline width	0.782 mm	W_f

The width of inset feedline cut is 0.411mm.The listed mathematical equations were used in calculating the dimensions of designed single band MPA like equation (1) for width calculation, equation (2) for calculation of effective length, equation (3) for factual length, and (4) for determination of feedline width

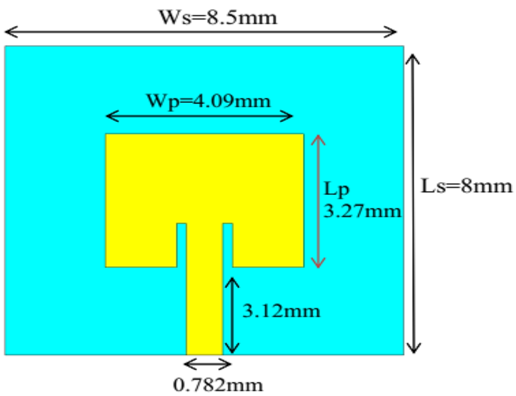
$$w = \frac{c}{2f_r\sqrt{\frac{er+1}{2}}} \ldots\ldots\ldots\ldots\ldots(1)$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \ldots\ldots\ldots\ldots(2)$$

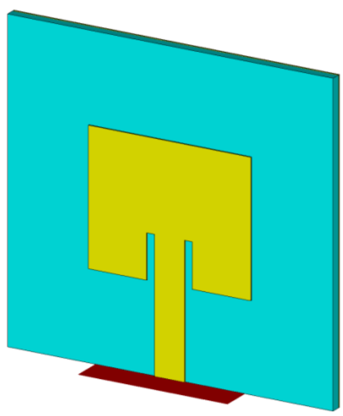
$$L = L_{eff} - 2\Delta L \ldots\ldots\ldots\ldots (3)$$

$$w_f = \left(\frac{377}{Z_o\sqrt{\varepsilon_r}}\right) h \ldots\ldots\ldots\ldots\ldots (4)$$

The front and perspective view of designed Microstrip patch antenna is delineated in figure 1



(a)Front view



(b)Perspective View

Figure 1: Front and perspective view of designed single band MPA is delineated

After simulation at 28GHz operating frequency the designed single band MPA resulted with return loss of -48dB and voltage standing wave ratio in between 1 and 2. The simulated results for both S11 and VSWR are delineated in figure 2 and 3 respectively

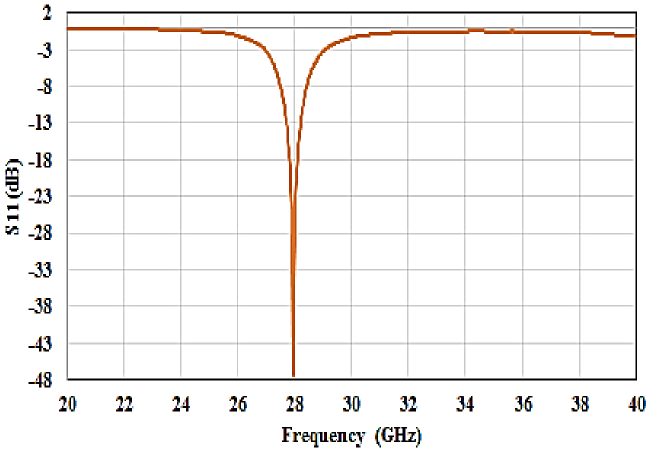


Figure 2: S11 of single band MPA at 28GHz frequency

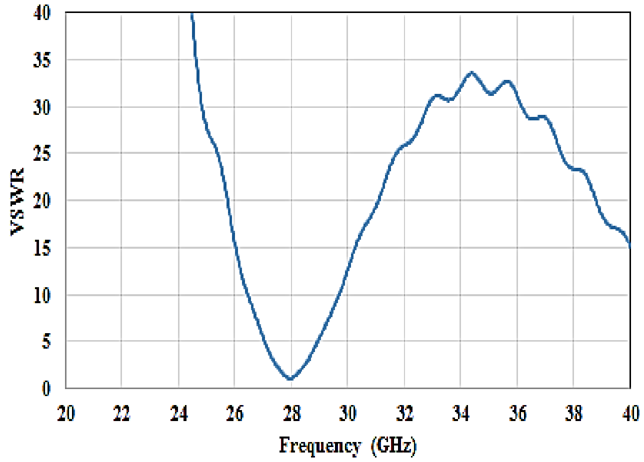


Figure 3: VSWR of single band MPA at 28GHz frequency

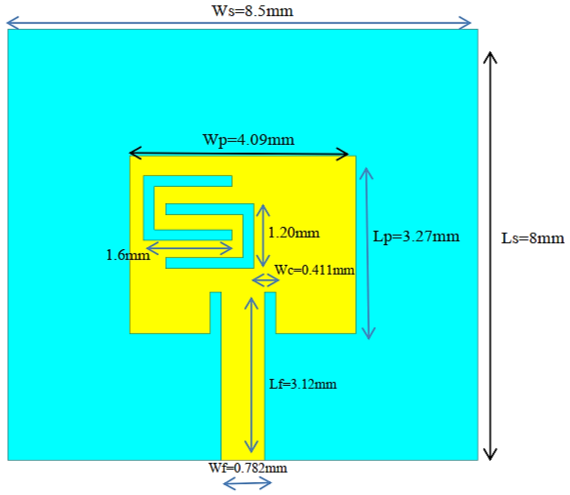
III. Insertion of U-shaped Slots in Patch

Owing to addition of two U-shaped slots in patch of prior designed single band MPA, an additional 38GHz band was attained. Due to the insertion of slots the proposed antenna got multiband characteristics. The substrate used in designing of proposed dual band antenna is of Rogers RT 5880 with epsilon 2.2. Total area of the proposed antenna is $8 \times 8.5 \times 0.254mm^3$ .An inset feedline of 50Ω is provided to patch. Designing parameters of substrate, patch, feedline and slots along with description are delineated in table 2.

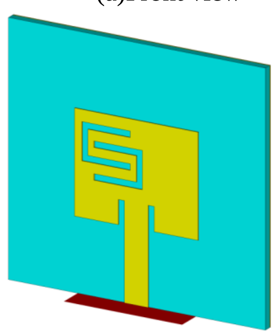
TABLE II DESIGNING PARAMETERS OF PROPOSED DUAL BAND SLOTTED MPA

Parameters	Values	Description
L_s	8 *mm*	Length of substrate
W_s	8.5 *mm*	Width of substrate
L_p	3.27 *mm*	Length of patch
W_p	4.09 *mm*	Width of patch
L_f	3.12 *mm*	Length of feedline
W_f	0.782 *mm*	Width of feedline
H	0.254 *mm*	Height of substrate
Mt	0.035 *mm*	Thickness of patch
Wc	0.411 *mm*	Width of inset feed cut
W1	1.6 *mm*	Slot width
L1	1.20 *mm*	Slot length
Mx	0.2 *mm*	Space between two slots
D1	0.245 *mm*	Distance between patch and slot length
D2	0.37 *mm*	Distance between patch and slot width
T1	0.2 *mm*	Slot thickness

The front and perspective view of proposed dual band MPA antenna is depicted in figure 4 (a and b).



(a)Front view



(b) perspective View

Figure 4: Front and perspective view of proposed dual band MPA antenna

The labeled structure of slots introduced in patch is delineated in figure 5

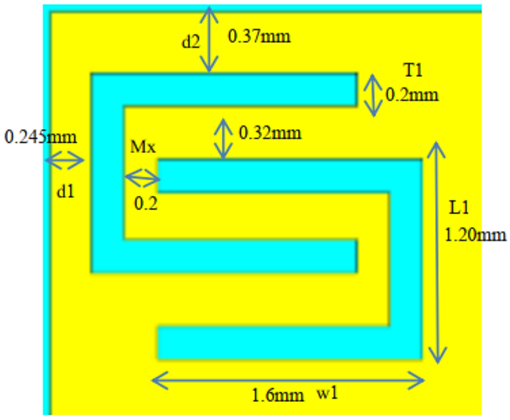


Figure 5: U-shaped slots introduced in patch for dual band peculiarity

Simulations performed on proposed dual band antenna resulted in adequate results in term of return loss, VSWR, gain and directivity both at 28GHz and 38GHz.

IV. RESULTS AND SIMULATIONS

(A) Return Loss

For an adequate wireless communication S11 should be less than -10dB. The proposed dual band gives a return loss of -32dB at 28GHz and -40dB at 38GHz respectively. S11 of dual band is depicted in figure 6

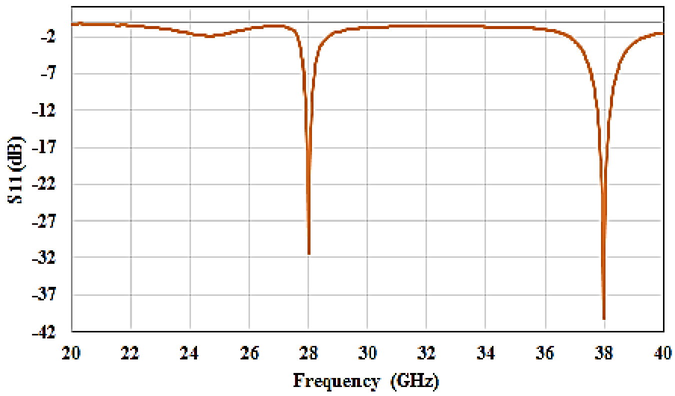


Figure 6: S11 of proposed dual band antenna

(B) Voltage Standing Wave Ratio

For an ample wireless communication VSWR must be less than 2. The proposed dual band antenna resulted in VSWR in between 1 and 2 at both bands which is quite an acceptable result at higher frequencies. The VSWR of the proposed dual band antenna is projected in figure 7.

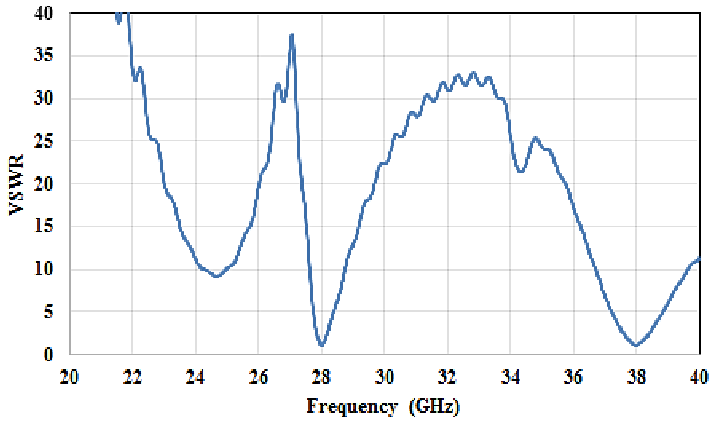
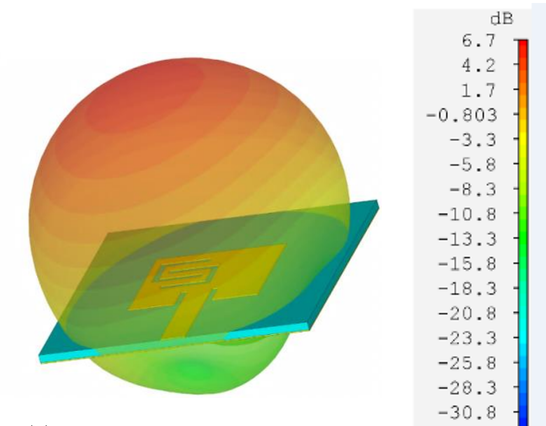


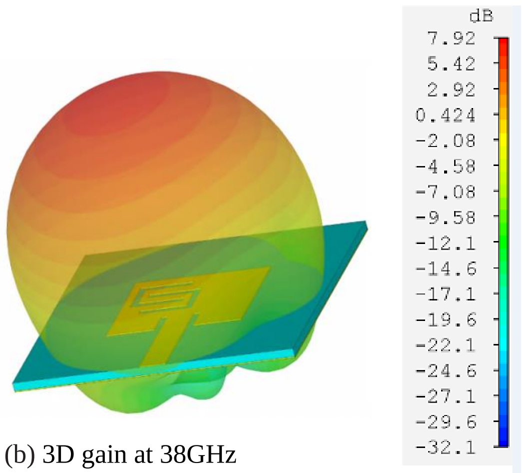
Figure 7: VSWR of proposed dual band antenna

(C) 3-D gain of proposed dual band Antenna

The proposed dual band slotted MPA resulted in a gain of 6.7dB at 28GHz and 7.92dB at 38GHz. The 3D gain at both bands is delineated in figure 8.



(a) 3D gain at 28GHz



(b) 3D gain at 38GHz

Figure 8: 3-D gain at 28GHz and 38GHz is delineated in this figure.

The gain at both bands in graphical form is depicted in figure 8.

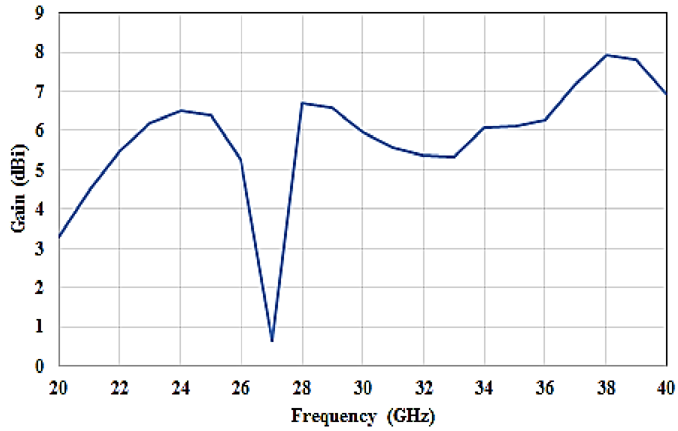
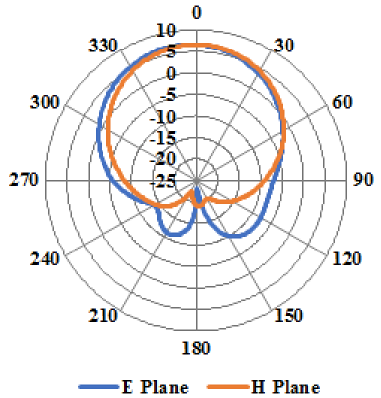


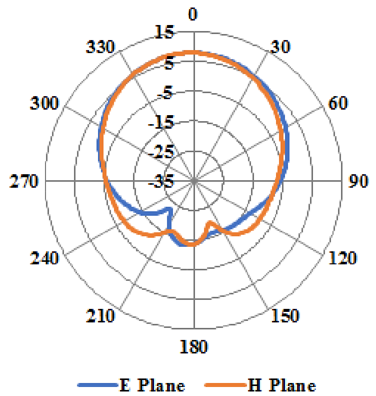
Figure 9: Simulated gain at both bands of proposed dual band antenna

(D) E and H plane of proposed dual band Antenna

The simulated results for E and H planes in polar form at both bands are depicted in figure 9.



(a) E and H plane at 28GHz



(b) E and H plane at 38GHz

Figure 10: E-plane and H-plane at 28GHz and 38GHz is depicted in this figure

The results of proposed dual band slotted MPA is delineated in table 3.

TABLE III RESULTS OF PROPOSED DUAL BAND SLOTTED ANTENNA

Operating Frequencies	S11	VSWR	Gain
28GHz	-32dB	1-2	6.7 dB
38GHz	-40dB	1-2	7.92dB

V. V. Parametric Analysis of Proposed Dual Band Antenna

A parametric study carried out on three different antenna parameters to check their impact on performance characteristics of antenna. The first parameter that was altered from its proposed value was patch length (L_p). Patch length was changed from its proposed value 3.27mm to 3.17mm and 3.37mm. At 3.27mm the antenna gives S11 of -32dB at 28GHz and -40dB at 38GHz, when changed to 3.17mm from its proposed value, antenna resulted in a return loss of -22dB at 28GHz and -27dB at 38GHz. At 3.37mm patch length antenna resulted in S11 of -22dB and -24dB.

The second parameter that was carried out for parameter study is width of patch element (W_p). The patch width is altered from its 4.09mm proposed value to 3.99mm and 4.19mm respectively. At 4.09mm proposed patch width antenna gives S11 of -32dB at 28GHz and -40dB at 38GHz whereas at 3.99mm patch width antenna gives S11 of -32dB at 28GHz and -22dB at 38GHz and at 4.19mm antenna gives a return loss of -32dB at 28GHz and -25dB at 38GHz. The third parameter which was investigated for parametric analysis is the distance between slots (Mx), the slots distance was altered from its proposed 0.2mm value to 0.1mm and 0.3 mm. At 0.2mm proposed distance antenna gives -32dB S11 at 28GHz and -40dB S11 at 38GHz, when the distance was changed to 0.1mm, return loss got changed and at 28GHz antenna has given an S11 of -31dB and -25dB at 38GHz similarly at 0.3mm distance S11 are -40dB at 28GHz and -21dB at 38GHz respectively. The parametric analysis of patch length, patch width and distance between slots for S11 is delineated in graphical form in figure 11, 12 and 13.

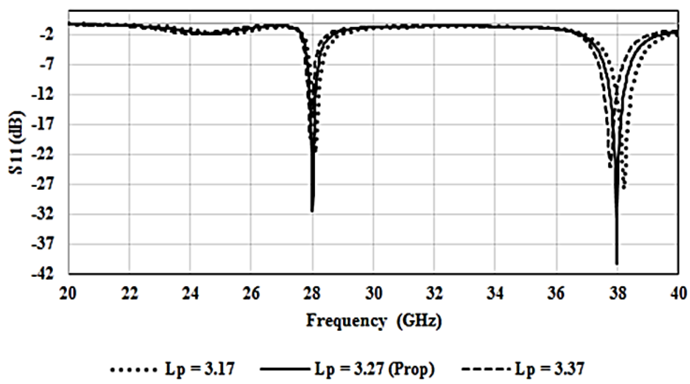


Figure 11: S11 owing to parametric analysis of length of patch element.

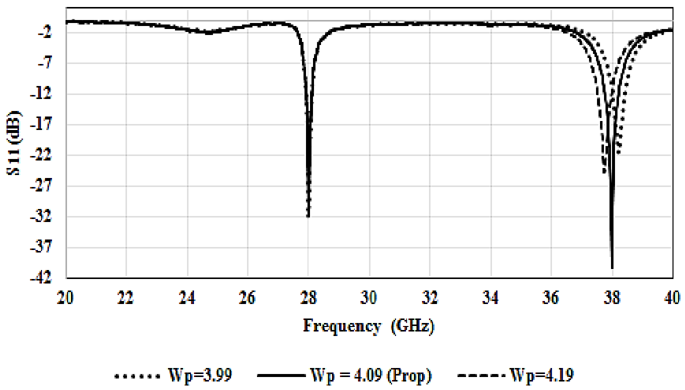


Figure 12: S11 owing to parametric analysis of width of patch element

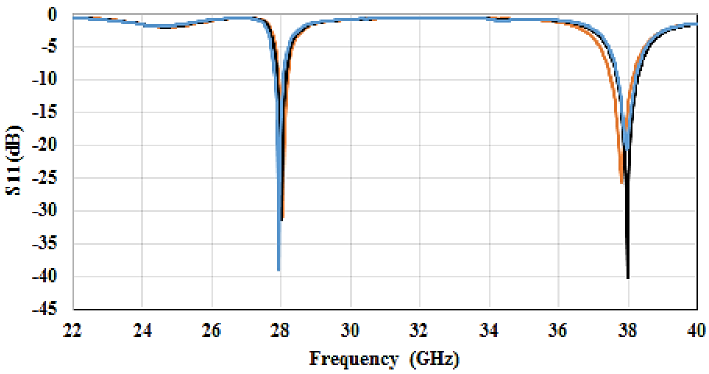


Figure 13: S11 owing to parametric analysis of slots distance

Return loss resulted due to parametric analysis of L_p, W_p and M_x are depicted in table IV.

TABLE IV TABLE COMPRISED S11 RESULTED FROM PARAMETRIC STUDY CONDUCTED ON Lp,Wp AND Mx.

Parameters	Values	S_{11}(dB)	
		28GHz	38GHz
L_p	3.27 *mm* (proposed) 3.17 *mm* 3.37 *mm*	-32 -22 -22	-40 -27 -24
W_P	4.09 *mm* (proposed) 3.99 *mm* 4.19 *mm*	-32 -32 -32	-40 -22 -25
M_x	0.2 *mm* (proposed) 0.1 *mm* 0.3 *mm*	-32 -31 -40	-40 -25 -21

CONCLUSION

A dual band U-shaped slotted Microstrip patch antenna with the peculiarity to operate at two distinct frequency bands i.e. 28GHz and 38GHz is delineated in this paper. The design comprised of two stages, in first phase a single band MPA was designed for 28GHZ band using Rogers RT 5880 substrate, later that antenna was further enhanced to multiband antenna by addition of two U-shaped slots, owing to insertion of slots communication was enabled on two different bands which are 28GHz and 38GHz. For single band, antenna resulted in S11 of -48dB at 28GHz whereas for dual band, antenna resulted in S11 of -32dB at 28GHz and -40dB at 38GHz. The VSWR for dual band is in acceptable range. The dual band resulted in an acceptable gain of 6.7dB at 28GHz and 7.92dB at 38GHz.

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