A Star-Fish Shaped Compact Dual band Antenna for Millimeter Wave Band Applications

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***Abstract*— In this paper a star fish shaped microstrip patch antenna is proposed and its design procedure and characteristics are analyzed. The shape of the antenna patch is similar to a star fish, therefore the antenna is called Star fish antenna.The proposed antenna is able to provide dual band operation in V band (40-52 GHz) and W band (77-95 GHz) which lie in the range of millimeter wave frequency. The proposed antenna has 8 branches of unequal length in order to achieve wide bandwidth in millimeter wave range. Each of the branch resonates at different frequency which ultimately results in a wide bandwidth of 30 GHz with an efficient gain of 7.9026 dBi and highly reduced return loss. Designed antenna has a very compact dimensions of 9x9x2.03 mm^3, thus it can be easily fabricated with small handset devices.**

Keywords—Star fish shape, dual band, millimeter wave band, compact, ADS.

I. INTRODUCTION

The Millimeter waves offer high speed data rate up to1Gbps which can be used for variety of services in wireless systems especially in telecommunication.With the advancement of new technology such as 5G technology,nano technology, Internet of Things (IOT) it has become more imperative to look for such smart communication tool that are expected to transfer data 1000 times faster than the present data traffic handled by the wireless device. Latest technology is the combination of cost-effective CMOS technology that performs well in the millimeter wave frequency bands(30GHz to 300GHz)[1-4].The emerging latest 5G technology is demanding such an transreceiver tool which can provide more advanced and unique feature previously unseen in the communication field.Since mm wave frequency is the ultimate solution of this demand, essential focusing has been given on the millimeter wave band frequencies in this work Moreover mm-wave carrier frequencies provide more bandwidth allocations, high data transfer rate, small emission power and very small size of antenna[5, 6]. Thus in this work, essential focusing has been given on the millimeter wave band frequencies. But operating in the very high frequency range is challenging because of high atmospheric attenuation (signals are more susceptible to signal degradation due to the absorption of radio signals by atmospheric rain or snow). Also it requires wide impedance matching, radiation stability and compact size. Hence design of such an antenna which can be operated efficiently despite of all limitations is studied here.

Microstrip Patch Antenna (MPA) is preferred over other types of antenna due to its advantageous characteristics such as they are lighter, has low profile planar configuration, has low volume, low cost, is smaller in dimension and has the ability to be integrated with microwave integrated circuits technology and easy to fabricate[7-11]. Low power handling capability and narrow bandwidth are the major disadvantages of patch antenna. Different techniques have been adopted continuously for increasing the bandwidth such as U-shaped slot and the finite ground plane used to achieve impedance matching to increase the bandwidth[12], diamond shaped radiating patch and a semicircular like ground plane[13],slotted circular shape is iterated using fractal geometry that exhibits wider bandwidth and reduced returnloss[14], two different slot resonator are embedded into the arc shaped ground plane of the circular disk patch antenna[15], rectangular patch with lower edges beveled on one side and 'V' shape partial ground having central slot with lower corner intercepted by a rectangular strip place at bottom on the other side of substrate. Lower edges beveling is done to increase the impedance bandwidth and a circular slot is etched on the patch to provide better radiation pattern and impedance bandwidth[16].To increase the bandwidth of the proposed antenna,the shape of the designed antenna is chosen as a starfish shaped having branches of unequal length.Since each branch has unequal length, each of the branch resonate at different frequency which altogether results in a wide bandwidth of 30 GHz in the simulation frequency range of 36 to 96 GHz.The length of the branch is varied continuously during simulation to get the perfectly matched resonant frequency in the expected frequency range.While designing it is also kept in mind that the antenna size should be in miniaturized form,thus it is simulated again and over for different size until perfect result on the perfect structure is found.

In this paper, a very compact sized microstrip antenna having a patch of star-fish shaped with multiple hand of varying length is considered. Proposed antenna can efficiently support a wide range of millimeter-wave frequency (30GHz to

300GHz) with highly reduced return loss. Along with its compact size it provides a wide bandwidth of 30 GHz with simplified structure than other related work.

This paper is divided into 5 sections. The first section contains Introduction. In section II, proposed antenna design is described .Discussion of simulation result has been illustrated in section III. Parametric study for optimization is shown in section IV and lastly conclusion in section V.

II. ANTENNA DESIGN

The dimensions for both the ground plane and substrate plane is 9mm×9mm. The parameter specifications for the design of the proposed antenna are as in Table I. Microstrip line feeding with 50 ohm impedance has been used. Fig.1 shows the top view of the patch which is drawn in the word document to indicate the length parameter. Actual simulation figure is shown in the Fig.2.

TABLE I. Design Parameter Specifications Of The Antenna

Parameter	Value
Patch Shape	Star fish
Dielectric Substrate	Teflon
Dielectric Constant of the Substrate	2.0
Loss Tangent	0.00914
Thickness of the Substrate	1.67 mm
Conductor Thickness	0.18 mm
Width of substrate	9mm
Length of substrate	9mm
Ground Plane(width ×length)	9×9mm^2
Total Antenna Profile	9×9×2.03 mm^3
Feed position	(-1,-2)

The length of the patch for the designed antenna is illustrated in Table II . The feed position in which the designed MPA is simulated is shown in Fig.2

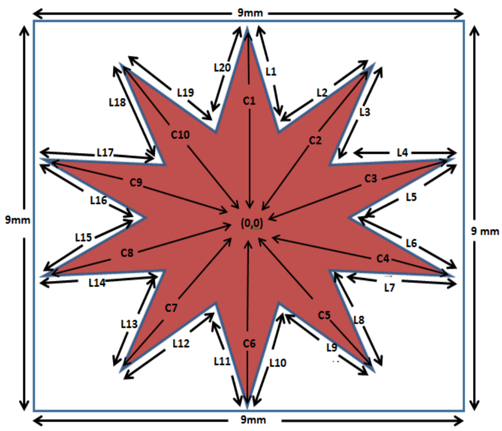

Fig. 1. Top view of the proposed antenna

TABLE II. LENGTH SPECIFICATIONS OF THE PATCH

Param eters	Dimensi on(mm)	Param eters	Dimensi on(mm)	Param eters	Dimensio ns(mm)
L1	3.046	L11	1.838	C1	4.301
L2	3.701	L12	2.884	C2	5.590
L3	3.808	L13	2.941	C3	4.704
L4	2.518	L14	2.247	C4	5.111
L5	2.596	L15	2.702	C5	5.482
L6	3.041	L16	2.236	C6	4.30
L7	2.625	L17	2.280	C7	5.220
L8	2.915	L18	3.585	C8	4.36
L9	2.842	L19	3.50	C9	4.001
L10	2.163	L20	2.192	C10	5.091

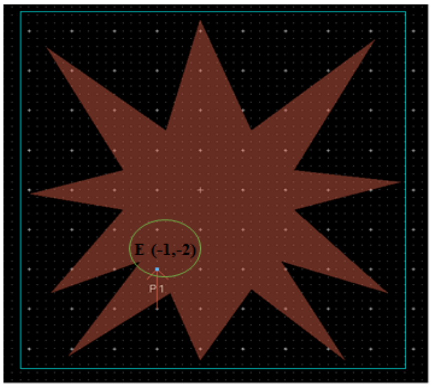

Fig. 2. Indicating feed position of the Designed MPA

III. SIMULATION RESULTS

Fig.3 shows the return loss (RL) for feed position E. There are two resonating frequency of operation of 44.74 GHz and 84.84 GH with RL of -43.863 dB and -31.059 dB respectively. The effective angle is 2.03581 Steradians, Directivity is 7.90473 dBi and Gain is 7.9026 dBi. From 36 to 96 GHz, antenna covers total 30 GHz bandwidth with satisfied RL response.

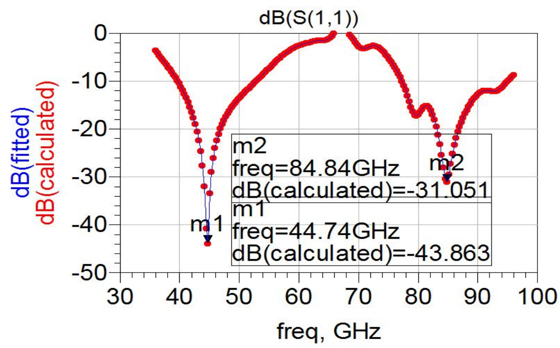

Fig. 3. RL for the frequency of (36-96GHz)

Fig.4 shows the smith chart for the feed position E. The impedance obtained for center frequency of 44.74 GHz is Z0 * (0.997+ j0.012). Fig.5 demonstrates the EM Far Field Cut of designed MPA (Theta = 90 degree). Fig. 6.shows the radiation pattern of the proposed antenna.

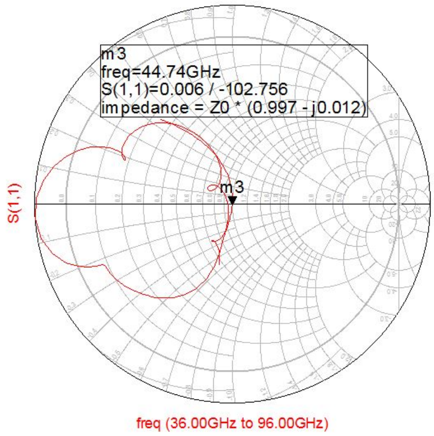

Fig. 4. Smith Chart of Designed MPA fo the frequency range 36 to 96 GHz

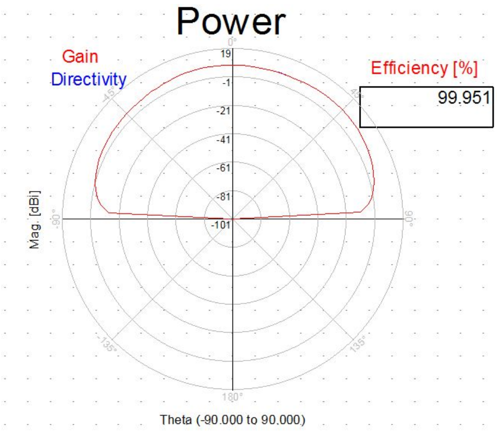

Fig. 5. EM Far Field Cut of designed MPA (Theta = 90 degree) in the frequency range of 36 to 96 GHz

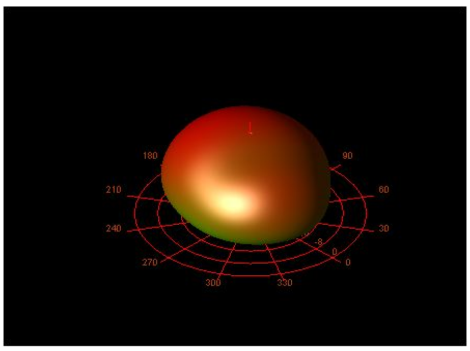

Fig. 6. Radiation pattern for the designed antenna in the frequency range of 36 to 96 GHz

Designed antenna is simulated briefly for having illustrated view of the operating frequency band.

A. For V band(40-52) GHz

Fig.7 shows the return loss (RL) for frequency range 40 to 52 GHz with a BW of approximately 12 GHz with the resonating frequency of 44.03 GHz and RL is -52.576 dB. The effective angle is 1.04407 Steradians, Directivity is 10.8048 dBi and Gain is 6.83376 dBi .

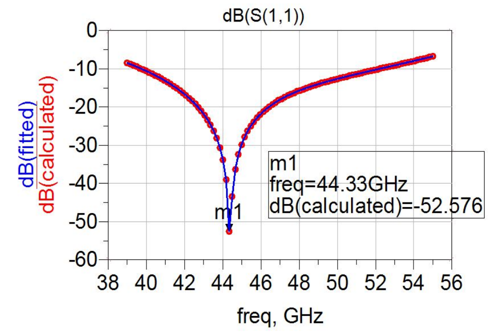

Fig. 7. Return Loss for Frequency 40 to 52 GHz

B. For W band(77-95) GHz

Fig. 8 shows the return loss for frequency range 77 to 95 GHz with a BW of approximately 18 GHz with the resonating frequency of 84.76 GHz and RL is -31.123 dB . The effective angle is 2.28351 Steradians ,Directivity is 8.83075 dBi and Gain is 8.82589 dBi .

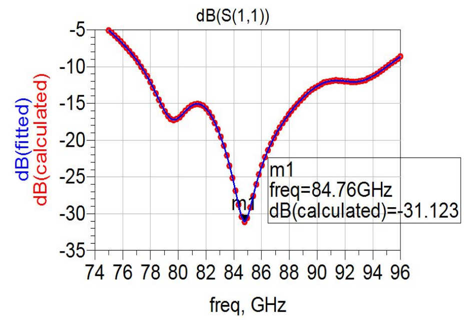

Fig.8. Return Loss for Frequency 77 to 95 GHz

IV. PARAMETRIC STUDY

A. Change of substrate height and its effect

The layout is simulated at different substrate height of Teflon and then the results obtained are analyzed below in Table III to get the comparison of apropriate substrate height.

Fig. 9 shows the effect of varying substrate height. For substrate height of 1.72 mm.,there are two resonating frequency of operation of 44.48 GHz and 84. 48 GHz with RL of -36.095 dB and -27.640 dB respectively. For substrate height of 1.69mm there are two resonating frequency of operation of 44.48 GHz and 84.48 GHz with RL of -40.196 dB and – 29.708 dB. For substrate height of 1.67 mm, there are two resonating frequency of operation of 44.74 GHz and 84.84 GHz with RL of -43.863 dB and – 31.051 dB . For substrate height of 1.50 mm, there are two resonating frequency 44.48 GHz and 86.30 GHz with RL of -28.423 dB and -32.423 dB .

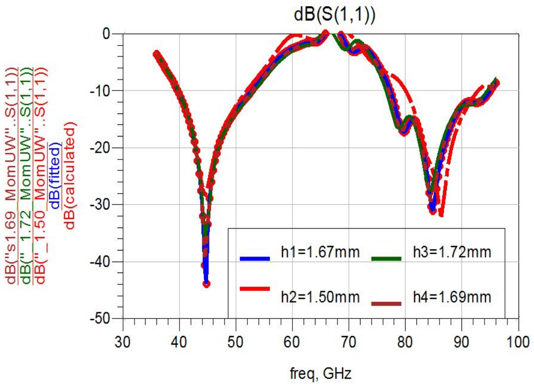

Fig.9 Effect of varying substrate height

TABLE III. CHANGE OF SUBSTRATE HEIGHT AND ITS EFFECT

Substrate height	Max.RL(dB)	Gain (dBi)	Directivity (dBi)	Effective angle (Steradians)
1.72 mm	-36.095	7.81405	7.81427	2.07865
1.69 mm	-40.196	7.86767	7.86945	2.05242
1.50mm	-32.423	7.17641	7.17689	1.91215
1.67 mm	**-43.863**	**7.9026**	**7.90473**	**2.03548**

After comparison it is proved that Teflon substrate height of 1.67 mm at the feed position E provides better result than any other height of the Teflon substrate.

B. Change of feed position and its effect

The layout is simulated at substrate height of 1.67 mm for different feed position

Fig.10 indicates the different feed position where the designed layout is simulated to get the best feed matching point.

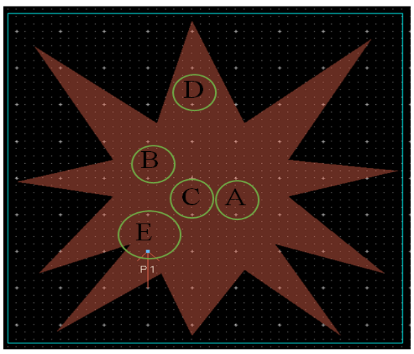

Fig.10. Designed MPA indicating different feed position

Fig. 11. shows the effect of various feed position at substrate height of 1.67 mm. For feed position A , there are two resonating frequency of operation of 67.52 GHz and 90.55 GHz with RL of -32.672 dB and - 17.161 dB. For feed position B, there are two resonating frequency of operation of 57.21 GHz ,80.85 GHz with RL of -15.432 dB and – 25.541 dB . For feed position C, there are two resonating frequency of operation of 79.64 GHz, 90.55 GHz with RL of -26.388 dB and -11.764 dB . For feed position D there are one resonating frequency of operation of 50.50GHz with RL of -21.703 dB. For feed position E there are two resonating frequency of operation of 44.74 GHz and 84.84 GHz with RL of -43.863 dB and – 31.051 dB respectively .

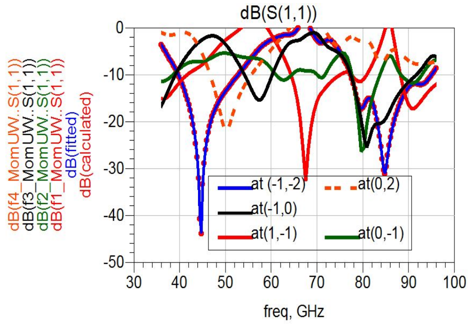

Fig.11. Effect of various feed posit

Result obtained for different feed position are analyzed below in table IV to get the summerized result for feed point.

TABLE IV. CHANGE OF FEED POSITION AND ITS EFFECT

Feed Position	No. of Resonating Frequency	Max. RL (dB)	Gain (dBi)	Directivity (dBi)	Effective angle (Steradians)
A (1,-1)	2	-32.672	7.259	7.26104	2.36105
B(-1,0)	2	-25.541	7.109	7.494	2.238
C(0,-1)	2	-26.388	7.464	7.4707	2.2408
D(0,2)	1	-21.703	7.951	7.951	2.014
E(-1,-2)	**2**	**-43.863**	**7.903**	**7.905**	**2.036**

Compared to other position, E(-1,-2) position proves to be the best matching point.

The designed star fish shaped antenna with Teflon substrate height of 1.67 mm at the feed position E(-1,-2) provides better result than any other height of the Teflon substrate and also than any other feed position in most of the aspects.

V. CONCLUSION

In this paper a compact star fish shaped micro strip patch antenna is presented for millimeter wave band application .Wide bandwidth and higher gain made the proposed antenna to be compatible for use in V and W -band applications. Optimized feed point is selected in such a way that impedance matching takes place.This antenna is easy to fabricate with its very compact and simple design. Demanding of highly improved and previously unseen features in the communication device can be utilized easily with this proposed design structure.

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