Design of Millimeter-Wave Patch Antenna for 5G Applications

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Abstract – In recent trends there is an ever-growing increase in demand 5G Wireless applications. This letter presents the design of MMW-MPA which has the low complexity, planar structure, small size, ease of fabrication and easily compatible with the hand-held wireless devices. The MMW patch antenna at 28GHz is designed and applicable to the 5G wireless networks .The results are discussed in terms of S11 [dB] , VSWR , Gain [dB], ,radiation pattern & Surface-Current distribution.

Index Terms – Millimeter-wave Microstrip Patch Antenna [MMW-MPA], Microstrip Patch Antenna [MPA].

1. INTRODUCTION

The development of a 5G network was introduced to provide the effective solution for bandwidth scarcity which is due to demand of the hand-held devices , frequency 28GHz was chosen as it is suitable for the 5G applications , high data transfer and low latency. FCC has approved the licensed frequency band of 28,37-39GHz ,and un- licensed frequency range of 64-71GHz.

These frequency band is suitable for the 5G wireless applications since there is less loss of propagation.[1-3].Another added advantages of MMW is shorter wavelength which adds an advantage reduced size of an antenna so that multiple antennas can be incorporated in Due to the compact size of an antenna ,it allows the multiple patches to be integrated in form of an array to increase gain.

MPA have become attractive for mobile applications. The advantages of using the MPA is due to thin-profile, low volume ,and less weight, cavity is not required ,circular and linear polarization can be easily achieved by using the simple feeding techniques ,it can be easily integrated with the RF circuits due to the compact size of the antenna ,less cost and triple and dual band can be obtained by using the slotting techniques.[5]

The limitations of the MPA are it has the lower gain , narrow bandwidth and high ohmic losses can be observed near the feed of the antenna structure .These antenna structure must be fabricated with substrate materials with low di- electric losses since at high frequency the propagation losses should be less and observed excitation of the fringing field effects[6].

2. DESIGN OF MMW-PA

A MMW-PA is designed and simulated by using HFSS Software at 28GHz. The substrate is selected based on the dielectric constant .For the design of MM-PA ,RT-Duroid 5880 with the ε_r-2.2 is selected. The MMW-PA length and width are calculated by using design equations.

The design formulae for MPA are as follows:

The width of the patch antenna is given by the formulae

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad (1)$$

Effective di-electric constant is given by

$$\varepsilon_{reff} = \frac{\varepsilon r+1}{2} + \frac{\varepsilon r-1}{2}\left(1+12\frac{h}{W}\right)^{-1/2} \quad (2)$$

Effective-length of patch is calculated by

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (3)$$

Fringing length of the patch is calculated by

$$\Delta L = 0.421h\frac{(\varepsilon reff+0.3)(\frac{W}{h}+0.264)}{(\varepsilon reff-0.258)(\frac{W}{h}-0.8)} \quad (4)$$

Where h is the substrate height in mm

To find the actual length L of the rectangular

-patch

$$L = L_{eff} - 2\Delta L \quad (5)$$

Where L_{eff} is the effective length of patch

To calculate width [W_g] and ground length [L_g]

$$L_g = 2 * L \quad (6)$$

$$W_g = 2 * W \quad (7)$$

3. ANTENNA STRUCTURE OF MMW-MPA

Design specifications of the chosen substrate is shown in the tabular form

Table 1 :Design Specification of the Substrate

Substrate Parameters	**RT-Duroid**
Dielectric-constant εr	2.2
Loss-Tangent	0.009
Height of the substrate	0.8
Conductor	Copper Cu
Conductor thickness	35.0µm

The structure of MMW-MPA antenna at 28GHz is depicted in the figure 1.1 .The antenna is tuned and optimized by varying width of transmission line. The MPA is finely tuned to meet the desired results.

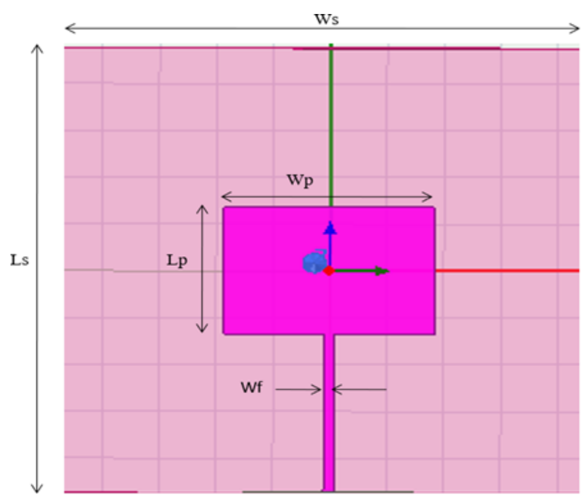

Figure 1 : Structure of the MMW-MPA at 28GHz

The design specifications MMW-MPA antenna is shown in the table 2

Table 2 :Design Specifications of MMW-MPA

Antenna Parameters	**Symbols**	**Dimensions (mm)**
Length of the Patch	Lp	2.7
Width of the Patch	Wp	3.7
Substrate Height	h	0.8
Feed line-Width	wp	0.2
Substrate-Length	Ls	9.5
Substrate-Width	Ws	9.5
Ground-Length	Lg	9.5
Ground-width	Wg	9.5

4. SIMULATION RESULTS OF THE MMW-MPA

The performance of an antenna is characterized in terms of S-parameters, VSWR, Gain, Radiation Pattern and current distribution.

Return loss: For an ideal case, the antenna is said to work as good radiating structure if the return loss is less than -10dB over the required band of frequency. From the plot 2 , it shows , resonating frequency of an antenna at 28GHz with the return loss of -27.57dB

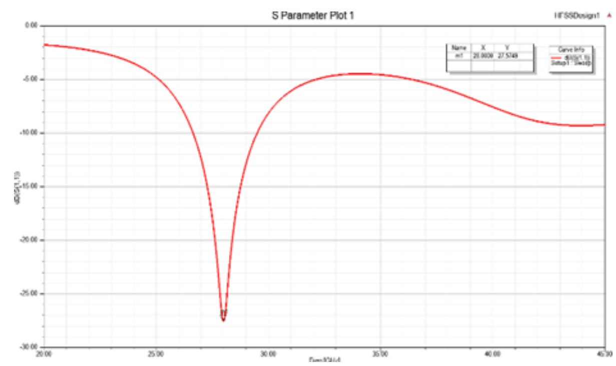

Figure 2: Return loss plot of MMW-PA at 28GHz

For an ideal case, the VSWR of antenna should be less than or equal to 2.0 .It indicates the antenna has a good radiation structure with the good impedance match. From the plot 3, the VSWR of the proposed antenna at the resonating frequency 28GHz is 1.08, it indicates that 100% of the power is transmitted and signifies there is no loss .The obtained results meets the requirements of the antenna.

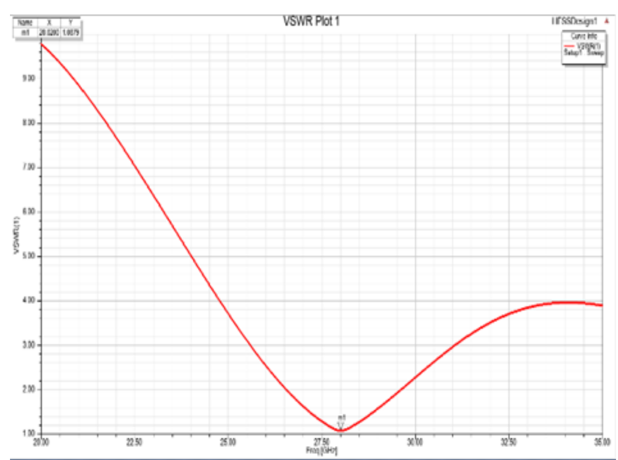

Figure 3: Plot of VSWR MMW-MPA at 28GHz

Antenna gain of the patch antenna for an ideal case, should provide the maximum gain of 6-9dBi. The antenna gain can be increased by choosing the appropriate dielectric material i.e low dielectric constant ,effective area of an antenna to be increased by using the parasitic patch and meandering of the edges. From the Fig 4 it is seen peak gain is 6.382 dBi at 28GHz which meets the requirements of the antenna .Fig 5 depicts the 3-D gain plot of the antenna. Red color indicates the highest gain.

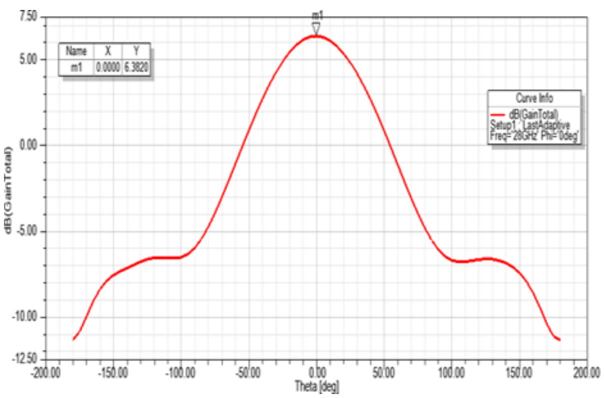

Figure 4: Rectangular Gain plot MMW-MPA at

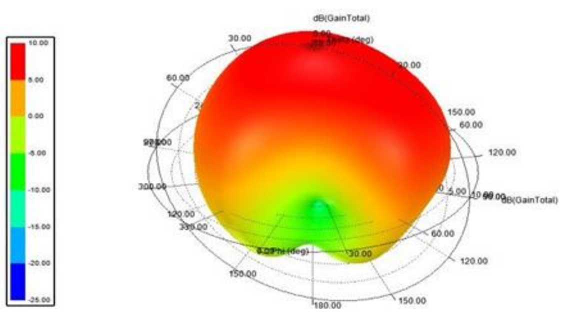

Figure 5 : 3-D Gain plot of MMW-PA at 28GHz

From the Fig 6,. RP of an antenna indicates the distribution of the electromagnetic energy in all direction between the 0 to 360 deg. The radiation pattern of the MMW antenna at resonating frequency 28GHz.

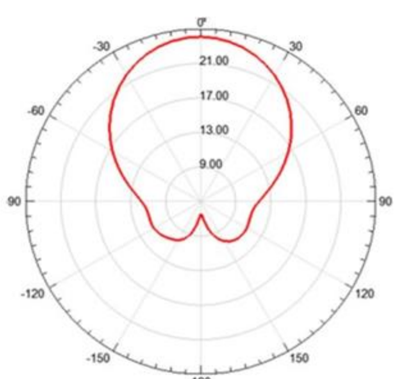

Figure 6 : Radiation-pattern of the MMW-PA at 28GHz

Surface current distribution in the MMW-PA is shown in Fig 7.it is observed that the current distribution is higher the radiating edges and at the feed point.

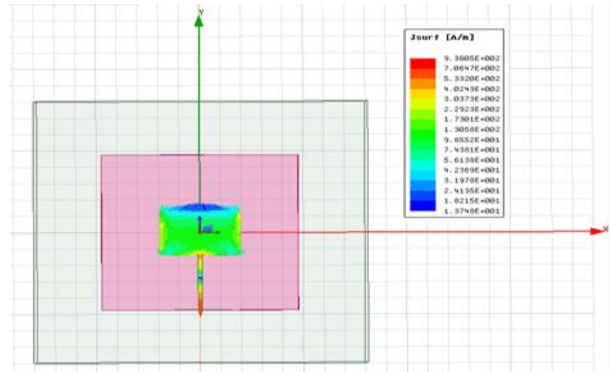

Figure 7 :Surface-Current-distribution of the MMW- MPA at 28GHz

5. CONCLUSION

Proposed MMW-MPA antenna is best suitable for the 5G Applications as the simulated results meets the ideal requirements of MMW antenna .The peak gain of 6.3280db , return loss of -27.57dB ,VSWR of 1.028 and the broad-sided radiation pattern is observed and higher density of current distribution is observed at radiating edges and at the feed line. The simulated results meet the requirements of the ideal antenna, and signifies at 28GHz is suitable for 5G wireless applications.

6. FUTURE SCOPE

To fabricate and validate the practical and measured values of designed antenna MMW-PA. 1 x 2 and 1 x 4 array can be designed to increase the gain.

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