Design and Simulation of millimeter wave Mylar based flexible Antenna for 5G wireless Applications

C Ankita, Supriya A, Bhagya R

Abstract: The millimeter wave (mm-wave) is expected to play a crucial role in providing broad frequency bandwidth for large data transmission. The restrictions of wave propagation are anticipated to get eliminated in mm-wave propagation through the assistance of antenna technologies. The higher frequency spectrum prevalence of the 5G applications are likely to be dependent on a small advanced antenna technology. This paper presents an antenna design which uses Mylar as substrate for the 5G wireless applications. The structure of the antenna adopted here is of a T-shaped patch designed with ideal symmetrical slot structures. To increase the bandwidth the idea of defective ground structure (DGS) is used. The antenna model discussed here shows a high impedance bandwidth and a fair radiation pattern in the required direction with a maximum gain of 8.35dB at 28 GHz frequency. The proposed antenna is compared with the basic microstrip patch antenna which is designed at low frequency to prove that the bandwidth is enhanced and so other parameters in the proposed antenna such that it is suitable for mm-wave 5G wireless applications.

Keywords- **Directivity, HFSS, microstrip patch antenna, millimeter waves, radiation pattern, return loss.**

I. INTRODUCTION

The 4G LTE currently uses lower frequency spectrum, generally below 1GHz, to deliver data at great speed. The data speed achieved over 4G LTE have drastically changed the ways one communicate and consume the data. As society becomes increasingly digital-reliant, the demand for data-intensive applications are also increasing. But the available 4G bandwidth has limited these data intensive uses and this limitation has given rise to expanding of bandwidth and using the millimeter wave (30-300GHz) which is nothing but next generation technology i.e. 5G[4].

These 5G frequencies are capable of carrying massive amounts of data at very high speed and with a very little latency and hence the 5G networks are composed of small cells. And so the current 5G is expected to have antennas placed throughout the cities, blending in with the local environment and giving out a very high data rates. And hence it leads to a new challenging network requirements and antenna design for 5G communication systems.

These antennas should be of low cost, flexible and robust so that they can be placed in large numbers, as 5G is a dense network through which high data rates are obtained [5]. The type of antenna chosen for 5G is of at-most importance. There are many antenna types available in wireless communications, but the microstrip antennas are more popular as they have low cost, low profile and ease of fabrication.

Revised Manuscript Received on September 25, 2020.

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As microstrip antennas are commercially used for various applications. This project utilizes the advantages of microstrip antenna. In this project, with the help of a basic microstrip antenna, few of the drawbacks are noted. Considering these drawbacks a microstrip antenna is presented which is of smaller in size, overcomes most of the drawbacks of basic antenna.

Also, a low cost substrate i.e. Mylar is used to make the antenna flexible so that it can be used in various applications including wearable devices.

The main motivation of this work is to design an antenna, which is flexible in terms of weight and usage, introduce DGS concept and show that the antenna proposed is better when compared with a basic microstrip antenna. With the help of DGS concept the number of resonating frequencies are increased. The most important aspect of this work is to introduce a flexible and cost effective antenna for 5G applications so that it can be used in various applications including wearable devices.

The further sections of this work are described as follows. Section 2 details about the microstrip patch antenna. The different configurations, shapes and feeding methods used for the microstrip patch antenna.Section 3 details about the design and implementation of the proposed antenna. It defines the design specifications and implementation of the basic microstrip antenna and also the proposed antenna. Section 4 presents the results obtained upon simulation. The basic antenna results along with its drawbacks are discussed here and also the proposed antenna is better than the basic antenna which is commercially used. Section 5 presents the conclusion which briefs about the outcome of the project. Through the results obtained, the advantages of the proposed antenna over the basic antenna is highlighted here to prove that the proposed antenna is most suitable candidate for 5G applications.

II. CONCEPTS OF MICROSTRIP PATCH ANTENNA

The usage of microstrip antennas (MSA) or patch antennas usage is extending to a great extent due to their ease of fabrication that directly fabricated onto a circuit board. Patch antennas have a low profile and can be easily fabricated and it is economical and feasible. These antennas are a sub-class of planar type antennas which are in continuous research. They have become popular and most chosen choice for the antenna designers as it is used in majority wireless applications.

The half-wave dipole is the simplest of all the antenna elements and is most widely used antenna element. It includes two straight conductors of quarter wave long and are excited by a source at the center. The two different types of half-wave dipole are the quarter wave monopole and the folded dipole as shown in Fig 1.

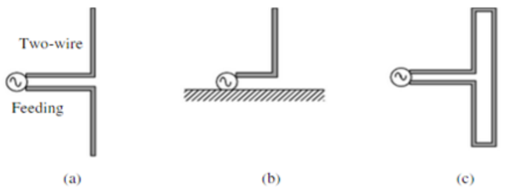

Fig 1: Illustration of (a) dipole (b) monopole; (c) folded dipole

The Defected Ground Structure (DGS) concept is used in the microstrip patch antennas for boosting the bandwidth and gain of the patch antennas. And also, to reduce high levels of harmonics and lessen coupling between adjoining elements and cross-polarization. This in turn, magnifies the radiation characteristics of the microstrip patch antenna to major extent. DGS is one of the technique available to excite multiple resonant frequencies within the antenna formation. In general, these are the slots which are cut inside the ground in order to modify the current distribution pattern at surface by generating resonant gaps. Proper placement of these DGS slots will result in multiple resonant frequencies which are merged into an uninterrupted bandwidth in the Ka-band.

III. DESIGN AND IMPLEMENTATION

The design strategy adopted here is in such a way that the return loss is minimum at the resonating frequencies. Based on the various discrete values of the material, the dielectric constant of a material is obtained as it is not a free variable. Hence, it is necessary to choose ϵ_r in advance and then vary other constraints. Also, another constraint which is important here is the thickness of the material, as common fabric materials are available only within a specified range of thickness, so, initially a continuous range of h is considered. When a suitable thickness is obtained, the value of thickness is rounded off to the nearest available thickness and then the accession resumes with the available h. Therefore, the dielectric constant and the thickness (h) of the material are considered as constant values and other design parameters are obtained as follows:

The patch width (W_{patch}) can be calculated using Eq. (1) as shown below.

$$W_{patch} = \frac{c}{2f}\sqrt{\frac{2}{\epsilon_r+1}} \quad (1)$$

where $c=3x10^8$

Then calculate the effective ϵ_r using the formula given in Eq. (2).

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \quad (2)$$

The normalized extension (ΔL) of the length is obtained as shown in Eq. (3).

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\epsilon_{reff}-0.258)(\frac{W}{h}+0.8)} \quad (3)$$

The actual length (L_{patch}) is calculated with the help of Eq. (4) using the effective length as well as the normalized extension of length.

$$L_{patch} = \frac{c}{2f\sqrt{\epsilon_{reff}}} - 2\Delta L \quad (4)$$

where $c=3x10^8$

$$L_{ground} = 6h + L_{patch} \quad (5)$$

$$W_{ground} = 6h + W_{patch} \quad (6)$$

The ground plane length (L_{ground}) and width (W_{ground}) are calculated as shown in Eq. (5) and (6).

Choosing the frequency as 24GHz and Mylar as substrate the design procedure is followed and the calculated parameters are obtained as shown in Table 1.

Table 1: Calculated parameters for the mm-wave antenna

Design Parameters	in mm	Design Parameters	in mm
Antenna Width (W)	12.8	The distance between ground and patch	2.4
Antenna length (L)	7.5	Length of CPW (flooring)	6.3
W_{patch}	12	Each slot length (L_{slot})	2.9
L_{patch}	4.7	Distance between slots (G_{slot})	5.2

The flow of the design and implementation process has been depicted in Fig 3. Final design of mm-wave antenna and basic antenna are compared.

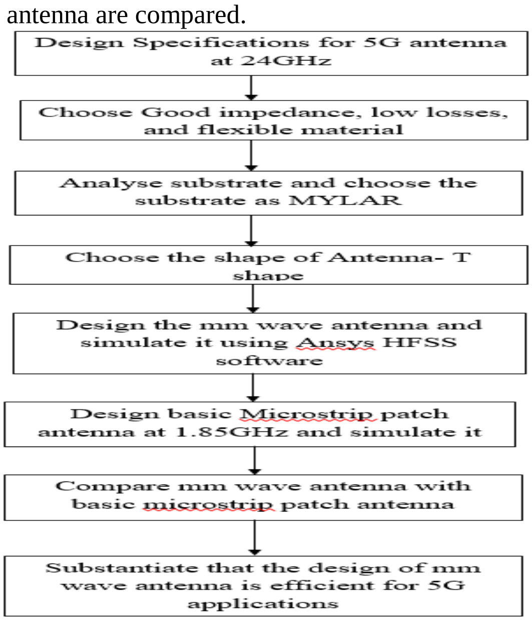

Fig 3: Flow chart of mm-wave microstrip patch antenna.

T-shape geometry is chosen for this antenna. Over the substrate the ground plane is extended and a gap is made for the proper allocation of the patch. Multiple slots with the length and gap as mentioned in the table 1 are made in order to form a DGS geometry in the patch as shown in Fig 4. These are the slots responsible for creating multiple resonant frequencies.

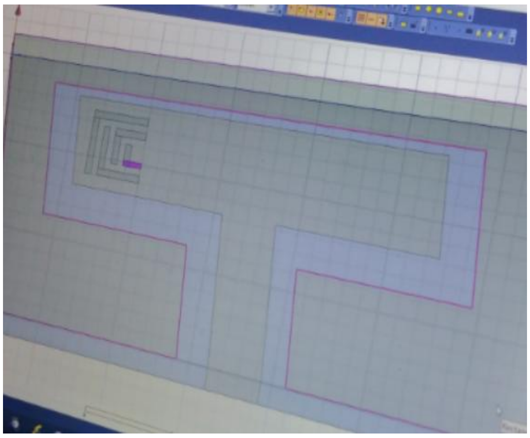

Fig 4: Antenna design with DGS slots

A coplanar waveguide feed (CPW) is given to the antenna for simulation purpose and the final antenna design is as shown in Fig 5.

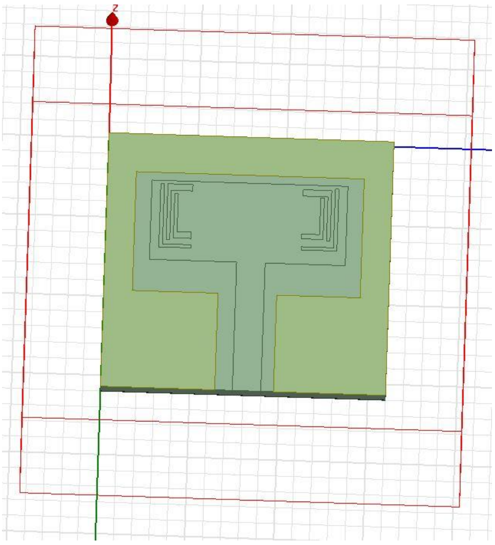

Fig 5: Final design of mm-wave microstrip patch antenna

Similarly, at lower frequency (1.8GHz), the antenna design parameters are obtained and designed. The lower frequency antenna is added with a waveguide port as shown in Fig 6 and used for comparing with the proposed antenna.

The designed antennas are simulated using Ansys HFSS software which is a commonly used solver for electromagnetic structures. Through the results the parameters are compared to prove that the proposed antenna is a good choice for the 5G applications.

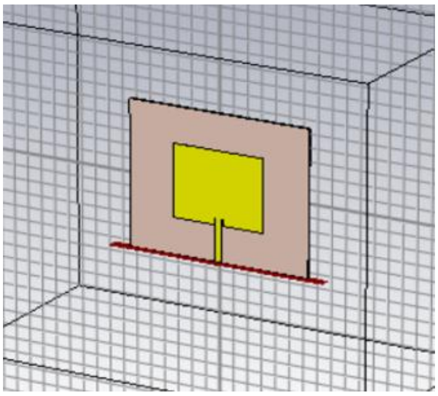

Fig 6: Basic microstrip patch antenna design

IV. RESULTS AND DISCUSSIONS

The basic antenna is first simulated and the results obtained are used to verify the antenna characteristics. The S_{11} vs frequency response is shown in Fig 7 and VSWR plot obtained is depicted in Fig 8.

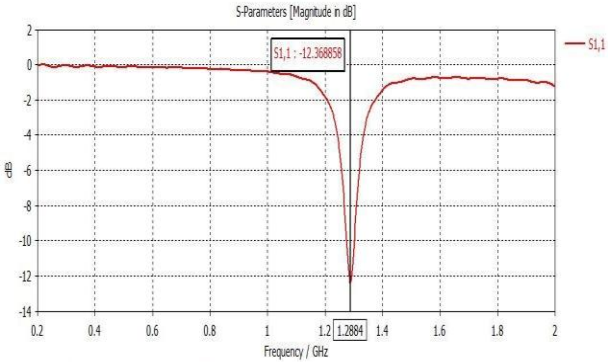

Fig 7:S_{11} vs frequency plot of basic antenna

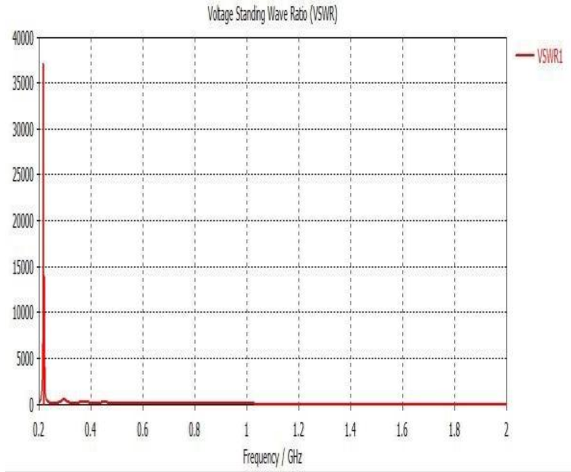

Fig 8: VSWR plot of basic antenna

From the S_{11} vs frequency response of basic antenna it is seen that the return loss is obtained at a frequency of 1.2884GHz and this is the resonating frequency of the basic antenna. There is a slight deviation in the center frequency and the reason behind it is the fringing fields around the antenna. Through the VSWR plot it is possible to know how efficiently RF power is transmitted from power source from a transmission line. VSWR value under 2 is considered as suitable for most of the wireless applications. From the Fig 8 it is seen that the VSWR of the basic antenna is not under 2 and so it is not suitable for wireless applications.

The simulated result of S_{11} vs frequency response for the mm-wave antenna is presented in Fig 9. From the plot we can infer that the mm-wave microstrip antenna has a return loss at the resonating frequency which is at 24.7GHz covering a bandwidth around 548MHz. Fig 10 shows the VSWR plot which shows a value <2 for the antenna designed, which is the required condition for good impedance matching.

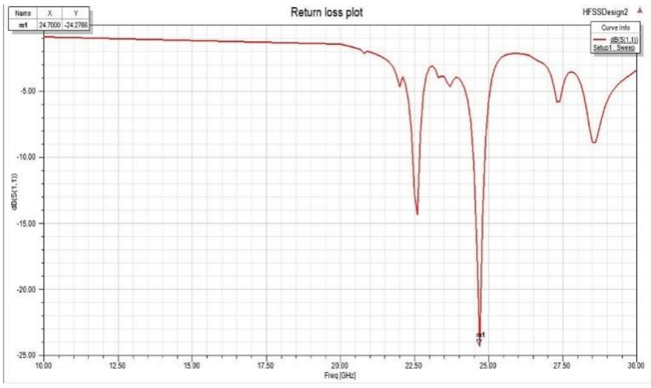

Fig 9: S_{11} vs frequency plot of mm-wave microstrip antenna at 24GHz

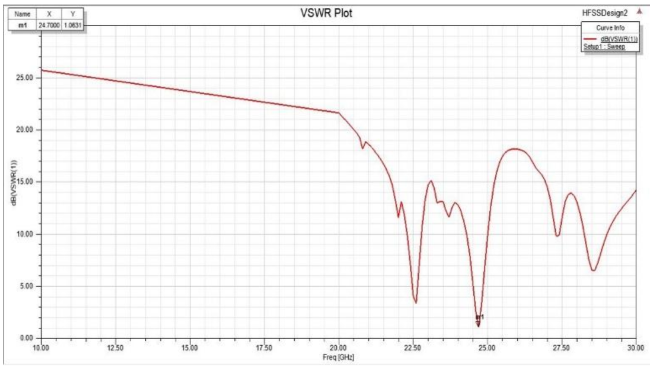

Fig 10: VSWR plot of mm-wave microstrip patch antenna at 24GHz

From the radiation pattern of mm-wave microstrip antenna shown in Fig 11, it gives an idea on which all directions the radiation happens. It can be varied based on the theta angles as well as phi angles.

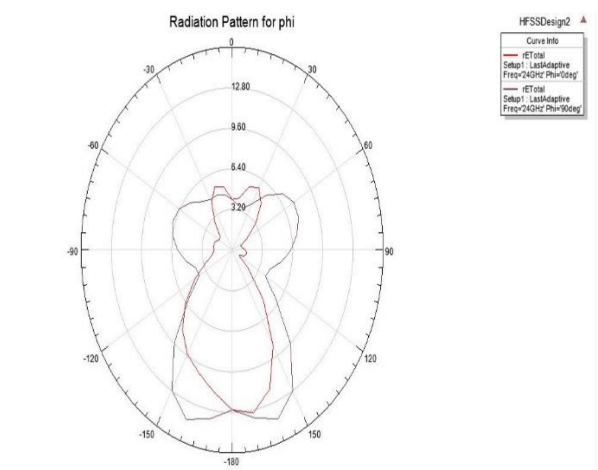

Fig 11: Radiation pattern of mm-wave microstrip patch antenna at 24GHz

The peak gain and directivity are measured for various frequencies in the range of 24-28GHz and the results show that as frequency increased the peak gain also increased and a maximum of 8.35dB is obtained at 28GHz.

Table 2: Various parameters in the range of 24-30GHz

Antenna Parameters	24GHz	27GHz	28GHz
Max U (mW/Sr)	291.9	333.94	409.3
Peak Directivity	5.6412	7.2273	7.7991
Peak Gain(dB)	6.0583	7.7366	8.3513
Radiated power(mW)	650.4	580.64	659.5
Incident power(mW)	1	1	1

V. CONCLUSION AND FUTURE WORK

A millimeter wave microstrip antenna is designed to eliminate the drawbacks which a basic antenna faces in terms of bandwidth for wireless applications. The results obtained as shown in table 2 from the proposed antenna proves that the parameters like directivity and gain are enhanced with a wide range of frequency which covers the 5G band. Considering Mylar as substrate the antenna is considered to be a low cost candidate in terms of fabrication and also due to the miniaturized structure (millimeter), the proposed antenna is flexible in use and can be used in applications varying from hand held mobile phones to hand worn wearable devices.

Future Work

By using the design, the proposed antenna can be fabricated and used for various high security applications. By using a suitable mode of fabrication technique like inkjet printing the cost of production of antenna can be reduced, thereby, making the proposed antenna feasible and economical.

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