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## Design Parameters of Millimeter Wave Communication Antennas

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**ABSTRACT:** In this review paper, a study of millimeter wave and their application in 5G mobile communication has been performed. In recent years, millimeter wave spectrum has been a topic of special interest in industry experts, researchers and academicians. A lot of study of millimeter wave spectrum and millimeter wave antenna design for efficient mobile communication has been done in recent years. In this paper, various design facts and techniques have been discussed that are used in efficient antenna design. A basic microstrip antenna is also presented in this paper for illustration. The proposed antenna design has been fed by micro strip feedline. The performance of antenna has been analyzed in terms of return loss (dB), impedance bandwidth (GHz), directivity (dBi), gain (dB), VSWR. The proposed antenna design resonates at 29 GHz frequency with minimum return loss of <20dB. The proposed antenna has been designed and simulated using CST Microwave Studio 2017.

**KEYWORDS:** CST Microwave Studio 2017; directivity; dB; dBi; FR 4; gain; GHz; MHz; VSWR; DGS, MIMO; millimeter wave; spectrum, efficiency.

### I. INTRODUCTION

The coming 5G communication standard is expected to provide Internet connections 40 times faster and with at least four times more coverage worldwide than the current 4G Long Term Evolution (LTE) wireless communications standard. Even without a clear definition of 5G, testing is underway or in the works in places including Finland, Russia and South Korea. One of the most promising potential 5G technologies under consideration is the use of high-frequency signals—in the millimeter-wave frequency band—that could allocate more bandwidth to deliver faster, higher-quality video and multimedia content. Other lines of research seek to enable a single mobile device to simultaneously connect to multiple wireless networks to boost connectivity and speed. [8]

The motivation behind the search for a new telecommunication standard is the exponential growth in mobile users. Today people are using many devices (smartphones, tablets, laptops etc) that support many services and applications that require simultaneous management of multiple technologies in the same band limited spectrum. With customers base of approx. 5 billion all over the world, cellular service providers are facing global bandwidth shortage. They are limited to a carrier frequency spectrum ranging between 700 MHz and 2.6 GHz, where each major wireless provider has approximately 200 MHz across all of the different cellular bands of spectrum available to them. Also, the demand for capacity in mobile broadband communication increases dramatically every year and is expected to a thousand fold increase in total traffic by 2020. Therefore, to support the ever growing consumer data rate demand and predicted traffic volumes an efficient radio access technologies combined with more spectrum is essential. [1]-[2].

#### Millimeter Wave for future wireless communication

To support the predicted mobile traffic in future and high data rates in the order of multiple Gbps, cellular networks will need – 1- More useful radio spectrum, 2- Efficient channel access technology.

Using Millimeter waves spectrum and antennas can serve all the above purposes well.

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- 1- Solution for spectrum availability- Mm waves is the radio waves that have the wave length of the order of 10 mm to 1 mm and frequencies in the range of 30 to 300 GHz. Millimeter wave will open up more spectrums. Over 20 GHz of spectrum is available to be used for cellular or WLAN traffic in the 28, 38 and 72 GHz bands alone and hundreds of GHz more spectrum could be used above 100 GHz. It also provides the opportunity for mobile communications to use channel bandwidths of 1 GHz or more at the above mentioned bands that is far beyond the present 20 MHz channels used by 4G customers. By such a increased bandwidth for mobile radio channels, the data capacity is greatly increased while the latency for digital traffic is greatly decreased thus supporting much better internet based access and applications that require minimal latency. One disadvantage of millimeter waves has limited range. But this can overcome by designing antennas with good receiver sensitivity; high transmit power, and high antenna gains.
- 2- Today's wireless systems use MIMO systems approach. MIMO systems use multiple antennas at both ends and constructively explore multi-path propagation using different transmission paths to the receiver. These paths can be exploited to provide redundancy of transmitted data, thus improving the reliability of transmission (diversity gain) or increasing the number of simultaneously transmitted data streams and increasing the data rate of the system (multiplexing gain). The multiple spatial signatures can also be used for combating interference in the system (interferences reduction). The MIMO channel capacity is limited by the number of antennas, the antenna element spacing. At millimeter wave frequencies, very small antenna elements can be designed. Using mmwave antennas can help in building antenna arrays which contains a large number of antenna elements as compared to the present arrays because the required spacing between two antennas ( $\leq \lambda/2$ ) is very small in mm wave antennas. Hence millimeter wave antenna arrays combined with spatial multiplexing can dramatically enhance the wireless system capacity and reliability. [1],[2],[7].

**Micro strip antennas** are one of the most suitable antenna types for millimeter wave applications. The main advantages are low profile, low weight, planar configuration and lower manufacturing cost. Though there are few limitations such as narrow bandwidth and low power capability but the numerous advantages outweigh them. [3]-[4].

## II. LITERATURE SURVEY

A lot of study has been done on millimeter wave frequency bands and antenna design in recent years. A detailed survey on millimeter wave mobile communication at 28 GHz and 38 GHz bands for 5G mobile communications has been presented in [2], [6] and [9]. In [7], basic theory and application is given. On millimeter wave frequencies various planar antenna designs has been experimented. A description on designing a Microstrip antenna is given in [1], [3], [4] and [6]. A detailed design and analysis of rectangular, circular and antenna arrays is given in [5].

## III. DESIGNING A MILLIMETER WAVE RECTANGULAR MICROSTRIP ANTENNA

The design of an efficient printed antenna requires a good understanding of how different design parameters affect the antenna performance. These parameters, for printed antennas, include the selection of substrate with appropriate dielectric constant ( $\epsilon_r$ ), dielectric loss tangent ( $\tan\delta$ ), substrate thickness (h), antenna shape and feeding technique. This paper presents the simulation results of a parametric study of these parameters at mm-Wave frequencies (27 - 29 GHz).

1 – **Selection of substrate** – A suitable substrate for a microstrip antenna has low dielectric constant and low loss tangent material with considering the cost, space available for an antenna element etc. A lower value of ( $\epsilon_r$ ) for the antenna substrate means lower capacitance to ground. This will increase the fringing field at the patch periphery, and thus the radiated power. On the other side, a high value of ( $\epsilon_r$ ) results in higher capacitance from the patch antenna to the ground plane and therefore more energy storage and less power radiation. Few suitable choices for substrate are listed in Table 1. [5], [9]

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Substrate	Dielectric Constant ( $\epsilon_r$ )	Loss tangent ( $\tan\delta$ )	Cost
Alumina	9.8	0.001	Very High
GlassEpoxy	4.4	0.02	Low
Duroid/ Arlon	2.2	0.0009	Very High
Foam	1.05	0.0001	Low/ Medium
Air	1	0	NA

**2 – Substrate thickness** - The antenna substrate thickness is limited on the lower and upper boundaries by different mechanisms. On the lower end, the substrate thickness is limited by the fact that smaller substrate thickness means higher capacitance to ground. This results in reduced fringing fields and lower radiation. It also results in higher Quality factor (Q) and reduced bandwidth. On the upper end, the substrate thickness is limited by two mechanisms. The first one is the excitation of unwanted substrate modes. The higher the antenna substrate thickness, the more power is lost and coupled to the substrate modes which in turn lower the antenna radiation efficiency. The second mechanism that limits the maximum allowable substrate thickness for microstrip line-fed antennas is the fact that the width of a 50  $\Omega$  microstrip line increases as the substrate thickness increases and it can be wider than the width of the microstrip antenna itself.

However for optimum antenna performance, the substrate thickness recommended as given in [5] is defined by equation (a)

$$\frac{h}{\lambda_0} \leq \frac{0.3}{2\pi\sqrt{\epsilon_r}} \quad \text{---- (a)}$$

**3 – Calculation of patch width, length** – After the selection of substrate for the antenna, patch width, patch length, ground plane dimensions has to be calculated. In this paper, the following equations has been used for the design of proposed RMSA, [5] –

$$W = \frac{c}{2f_0\sqrt{\frac{(\epsilon_r + 1)}{2}}} \quad \text{----- (b)}$$

Effective dielectric constant -

$$\epsilon_e = \frac{(\epsilon_r + 1)}{2} + \frac{(\epsilon_r - 1)}{2} \left[ 1 + \frac{10h}{W} \right]^{-1/2} \quad \text{----- (c)}$$

Effective length and length of patch –

$$L_e = L + 2\Delta L = \frac{\lambda_0}{2\sqrt{\epsilon_e}} = \frac{c}{2f_0\sqrt{\epsilon_e}} \quad \text{----- (d)}$$

**4 – Feeding technique** – There are many feeding technique available for MSAs like coaxial feed, stripline feed: inset feed, gas coupled feed, quarter wave transformer etc. In this proposed design microstrip feed line is used due to its simple geometry and easy to fabricate.

The feed line width is calculated by the following formula

$$Z = 377 / (\sqrt{\epsilon_r}W/h + 2) \quad \text{----- (e)}$$

Using the above equations from (a) to (e), a RMSA is designed and simulated using CST MWS 2017. The calculated values are given in table 2 and simulated results in table 3. Figure 1 shows the top view of the designed RMSA.

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**Table 2 Antenna Dimensions:**

Antenna Dimensions	Dimension (mm)
Patch Width, $W_p$	4
Patch length, $L_p$	2.45
Substrate thickness, $h$	0.24
Ground plane width, $W_g$	6.188
Ground plane length, $L_g$	5.378
Feed line width, $W_f$	0.390
Patch & ground plane thickness	0.1

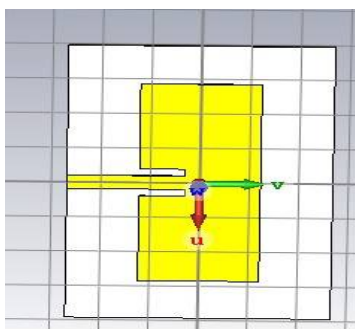


Figure – 1 Patch antenna (top view)

## IV. SIMULATED RESULT AND DISCUSSION

The performance of the designed antenna has been analyzed in terms of return loss (dB), directivity (dBi), gain (dB), bandwidth (GHz), VSWR shown in table 4.

Table-4 Simulated results	
S – parameter, $S_{11}$	-20.117 dB
VSWR	1.22
Directivity	2.524 dBi
Realized Gain	-3.449 dB
Total Efficiency	-5.973 dB

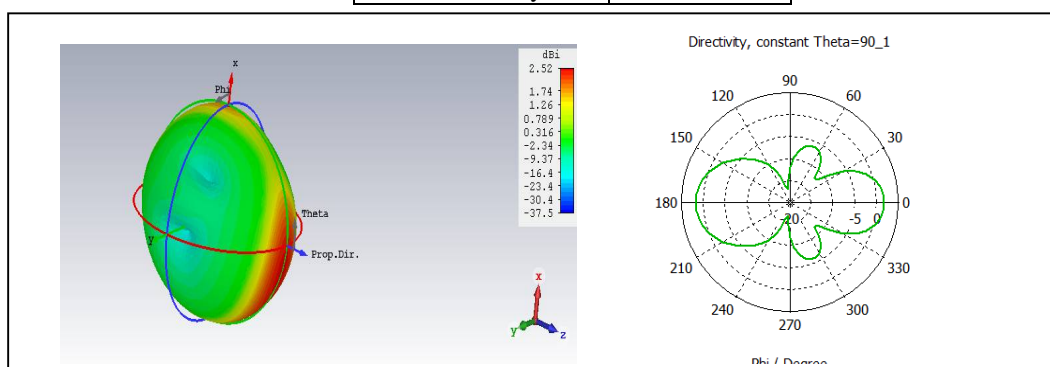


Figure 2a and 2b

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Figure 2a & 2b shows the radiation pattern. In the 3D pattern, it can be seen the main lobe radiation is in the z direction i.e. perpendicular to the patch. Figure 3a and 3b shows the S11 parameter and VSWR of the designed antenna.

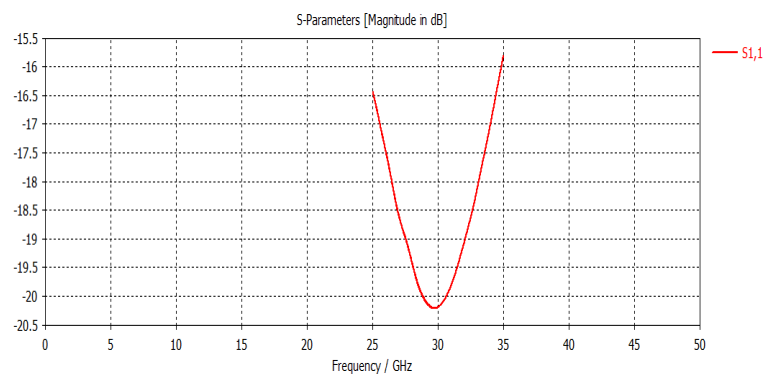


Figure 3a.

It can be seen in the above figure that the value of S11 parameter is less than -16 dB which shows that the reflected power is very low for the simulated antenna. A value less than -10 dB of S11 is considered as good for practical antennas.

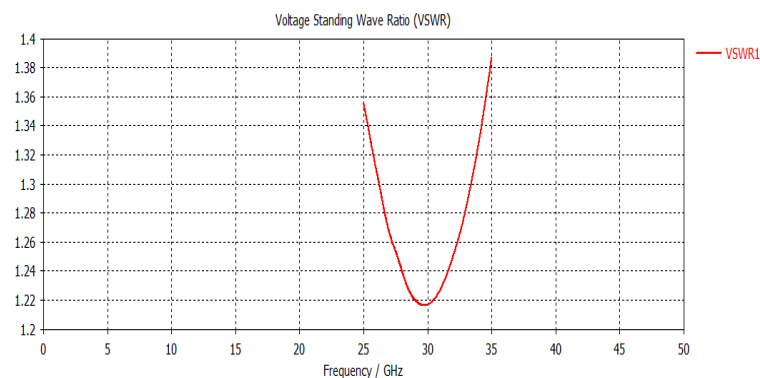


Figure 3b.

The value of VSWR is 1.22 which is within the acceptable range. The practical values of VSWR vary between 1 to 2.

## V. CONCLUSION

The antenna designed in this paper has been simulated using CST MWS 2017. The simulated antenna has directivity of 2.524 dBi, realized gain of -3.449 dB, total efficiency -5.973 dB, return loss of -20.117 dB and VSWR 1.22. The values of return loss and VSWR are found in acceptable range. The proposed antenna is suitable for 5G mobile communication.

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