Antenna Solution for Millimeter Wave Mobile Communication (MWMC):5G

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Abstract
As today's cellular providers endeavor to deliver high quality, low latency video and multimedia as well as all upcoming applications for wireless devices, they are limited to a carrier frequency spectrum ranging between 700 MHz and 2.6 GHz. Obtaining this information is extremely important for the design and operation of future generation cellular networks that use 5G (Fifth Generation) technologies. But there are few challenges to deploy 5G wireless communication systems in enormous carrier spectrums in which sufficient bandwidth present. It's possible when millimeter wave (mmW) is used and design an antenna which operates in millimeter wave. In addition, this paper presents a microstrip patch antenna designed for the unlicensed millimeter-wave (30GHz to 300GHz) band applications for 5G and discussed in details.

Keywords*—5G, microcell, mm-wave (mmW) communication, Microstrip Antenna and coaxial feed.*

I. INTRODUCTION

Demand for cellular data has been growing at a full swing pace, with conservative estimates ranging from 45% to 65% year upon year increase in traffic according different surveys. The rapid increase of mobile data growth implies that within the next decades, cellular networks may need to deliver as much as a thousand times the capacity, relative to current levels. So, mobile cellular networks need to support ever-growing consumer data rate demands and will need to tackle the exponential increase in the predicted traffic volumes.

The significant growth in the customer's demand for wireless communication using handsets has created the need for important developments of antenna design as a basic part of any wireless systems. The user and service providers demand wireless units with antennas that are small and compact, cost effective for manufacturability, low profile and easy to integrate with the wireless communication system. Our proposed microstrip antenna can fulfill most of the wireless systems requirements using *mm-wave*.

Our work contemplates a wireless future where mobile data rates expand to the multi gigabytes-per-second (Gbs) range, made possible by the use of our proposed microstrip antenna acts in mm-wave spectrum that could simultaneously support mobile communications and backhaul, with the possible convergence of cellular and Wi-Fi services. The proposed antenna configuration achieved a wide bandwidth of 14.98GHz (25.193 %) covering the frequency range from 58 to 62.5 GHz. The lowest return loss of the antenna is -44.99 dB and the maximum gain obtained at the 59.5 GHz resonance frequency. This antenna can be selected for 59.5 GHz wireless communication system in microcell for high speed data rate considering the size, bandwidth, and gain. The available bandwidth spectrum at these higher frequencies can easily be five hundred times greater than all cellular allocations today. Despite of unique capability of millimeter-wave technology to offer such a high data rate demand, a number of technical challenges need to be overcome or well understood before its full deployment. We represent in this paper below how to utilize millimeter-wave (mmW) for 5G wireless communication systems with Microstrip Antenna.

II. MILLIMETER WAVE SOLUTION FOR FUTURE 5G CELLULAR NETWORKS

The life cycle of every new generation of cellular technology is generally a decade or less, due to the natural evolution of computers and communication technologies. The combination of cost-effective CMOS technology that can now operate well into the mm-wave frequency bands, and high-gain microstrip antennas at the mobile and base station, strengthens the viability of mm-wave wireless communications. Furthermore, mm-wave carrier frequencies allow for more bandwidth allocations, which translate directly to higher data transfer rates. Mm-wave spectrum would allow service providers to significantly expand the channel bandwidths far beyond the present 20 MHz channels used by 4G customers **[1-2]**. By expanding the RF channel bandwidth for mobile radio channels, the data capacity is greatly increased, while the latency for digital traffic is greatly reduced, thus supporting much better internet-based access and applications that require minimal latency. Mm-wave frequencies, due to the much smaller wavelength, may exploit polarization and new spatial processing techniques, such as mmW based microstrip antenna. Given this major bound in bandwidth and new capabilities offered by mm-waves, the base station-to-device links, as well as backhaul links between base stations, will be capable to manage much greater capacity than today's generation of networks in large populated areas. Also, as operators continue to reduce cell coverage areas (microcell) to exploit spatial reuse, and implement new cooperative architectures such as relays and interference mitigation between base stations, the cost per base station will drop as they become ample and more closely distributed in urban areas, making wireless backhaul essential for quick deployment, flexibility, and decreased ongoing operating costs.

A common consideration in the wireless engineering community is that rain and atmosphere make mm-wave spectrum useless for mobile communications. However, when one considers the fact that cell sizes in urban environments are on the order of 200 m, it becomes clear that mm-wave cellular can avoid these issues. In figure-1 shows the atmospheric absorption characteristics of mm-wave propagation. It can be seen that for cell sizes on the order of 200 m, atmospheric absorption does not create significant additional path loss for mm-waves, particularly at 59.5 GHz. Work by many researchers has confirmed that for small distances (less than 1 km), rain attenuation will present a minimal effect on the propagation of mm-waves for microcell **[3].**

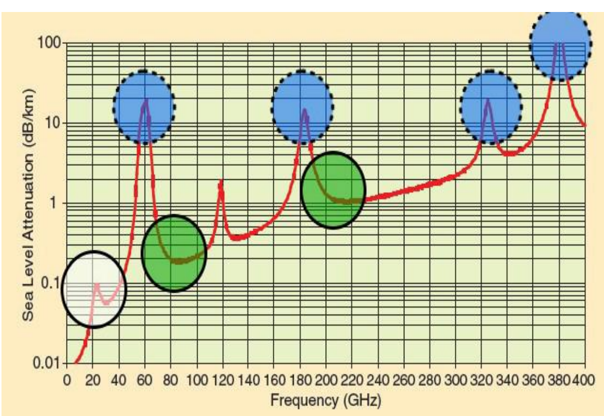

Figure-1: Atmospheric absorption across mm-wave frequencies in dB/km **[4],** The attenuation caused by atmospheric absorption is 10 dB over 200 m at 60GHz .Frequencies from 70 to 100 GHz and 125 to 160 GHz also has small loss.

III. MICROSTRIP ANTENNA

Due to enhancement of mobile phone technology, the antennas used for mobile devices have to be small, light weight, and have an omni-directional radiation pattern in the horizontal plane. However, still there are challenges in the antennas performance during interaction with the user's head and head. One type of antenna that fulfills most of the wireless systems requirements are the microstrip antennas. These antennas are widely used on base stations as well as handsets. Microstrip structure consists of a thin sheet of low-loss insulting material called the dielectric substrate. It is completely covered with a metal on one side called ground plane, and partly metalized on the other side, where the circuit or antenna patterns are printed. Components can be included in the circuit by implanting lumped components or by realizing them within the circuit.

A microstrip antenna is basically a conductor printed on top of a layer of substrate with a backing ground plane as shown in figure-2.

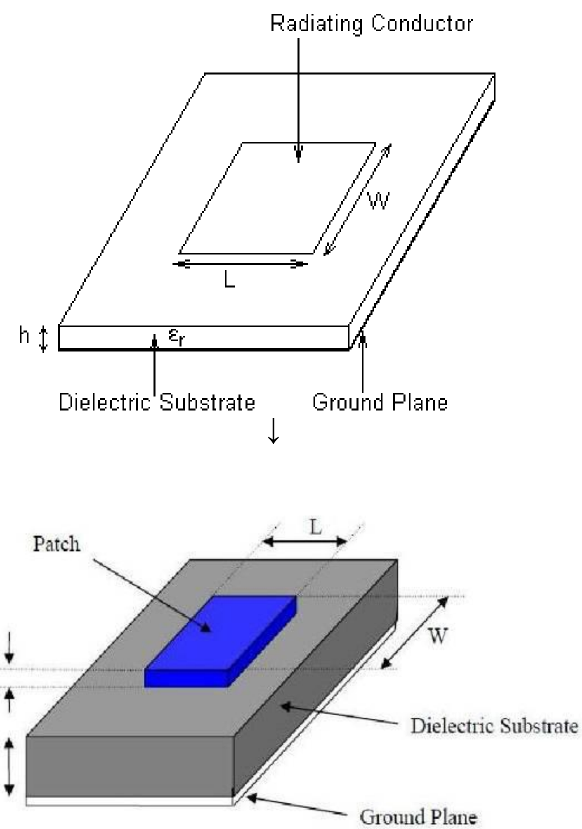

Figure-2: Basic Structure of Microstrip Patch Antenna

The length of the radiating conductor or patch is made approximately $\lambda g/2$, so the patch starts to radiate. The design of a microstrip antenna begins by determining the substrate used for the antenna and then the dimensions of the patch. Due to the fringing fields along the radiating edges of the antenna there is a line extension associated with the patch.

IV. METHODOLOGY OF PROPOSED MICROSTRIP ANTENNA

4.1. Substrate selection

As the substrate is one of the most important materials in the design of microstrip, its selection must be treated with care. The key parameters to take note when selecting a substrate are dielectric constant, loss tangent and substrate thickness. A low loss tangent substrate will increase antenna efficiency and reduces microstrip losses.

So therefore it is best to choose a substrate with the lowest possible dielectric constant if space permit, with a low loss tangent. Table-1 below lists some common substrate materials used in the design of microstrip antennas.

Table-1: Comparison between Dielectric Constant and Loss Tangent of several Dielectric Materials.

Materials	**Dielectric Constant**	**Loss Tangent**
Teflon (Rogers RO4232™)	2.2	0.0009
Rexolite 1422	2.55	0.0007
Noryl	2.6	0.0011
FR4	4.7	0.0190
Alumina	9.8	0.0003

4.2. Antenna Dimension

The rectangular patch antenna parameters are calculated from the equations given below,

$$\frac{\Delta L}{h} = 0.412\left[\frac{\varepsilon_{eff}+0.3}{\varepsilon_{eff}-0.258}\right]\left[\frac{W/h+0.264}{W/h+0.813}\right],\ W/h > 1$$

And patch length, $L = \frac{c_0}{2 f_0 \sqrt{\varepsilon_r}} - 2\Delta L$

Where, An initial guess at the patch width, $W = \frac{c_0}{2 f_r}\sqrt{\frac{2}{\varepsilon_r+1}}$,

c_0 is the speed of light

The effective dielectric constant (ε_{eff}) due to the air dielectric boundary is given by:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r+1}{2}\left(1+\frac{10h}{W}\right)^{-\frac{1}{2}}$$

The resonant frequency can be estimated by using the formula:

$$f_r = \frac{1}{2\,(L+2\Delta L)\sqrt{\mu_0 \varepsilon_0 \varepsilon_{eff}}}$$

Where: ε_o is permittivity of free space, $\mu_o$is permeability of free space, ΔL is line extension, $\varepsilon_{eff}$is effective dielectric constant, ε_r is Dielectric constant of substrate, *h is* Height of dielectric substrate and *W* is Width of the patch.

4.3. Feed technique and probe position

Microstrip patch antennas can be fed by a variety of methods. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes). But we have selected coaxial probe feed because of this type of feeding scheme the feed can be placed at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and has low spurious radiation. the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

After calculating the parameters of patch dimension from the above equations we find out the probe position at our desired resonance frequency 59.5 GHz with respect to return loss.

Table -2. Comparison of bandwidth, return loss and resonant frequency for different probe positions.

Feed Position (x, y)	**Return Loss (dB)**	**Resonant Frequency (GHz)**	**BW (%)**
(1, 1.55)	-39.89	60.60	14.96
(1.1, 1.5)	-24.23	57.14	17.61
(1.1, 1.55)	-41.23	59.50	18.22
(1.1, 1.6)	-20.33	56.80	19.30
(1.2, 1.55)	-30.52	58.16	20.65

4.4. Impedance matching

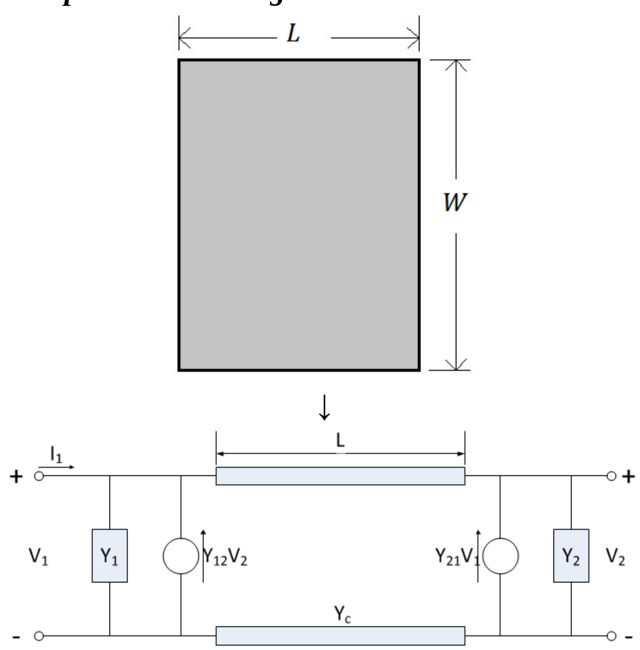

Figure-3: Equivalent circuit of antenna

Input impedance.

$$\left.\begin{array}{l} Y1 = G1 + jB1, Y2 = G2 + jB2 \\ G_1 = \frac{W}{120\lambda_0}\left[1-\frac{1}{24}(k_0 h)^2\right], k_0 = \frac{2\pi}{\lambda_0} = \frac{2\pi f_r}{c} \end{array}\right\} G2 = G1,$$

*B*2= *B*1;

Where G_1 *is* the equivalent radiation conductance and B_1 is the susceptance of the fringing field capacitance of the microstrip and k_o is the free-space wave number.

$$B_1 = \frac{W}{120\lambda_0}\left[1 - 0.636\ln(k_0 h)\right]$$

Via admittance transfer function,

$$\widetilde{(Y2)} = \widetilde{G_2} + j\widetilde{B_2} = G_1 - jB_1$$

$$Yin = Y1 + \widetilde{Y2} = 2G1$$

$$Z_{in} = \frac{1}{Y_{in}} = R_{in}$$

Where, Z_{in} is input impedance and mutual effects have been ignored.

V. ANTENNA MODEL

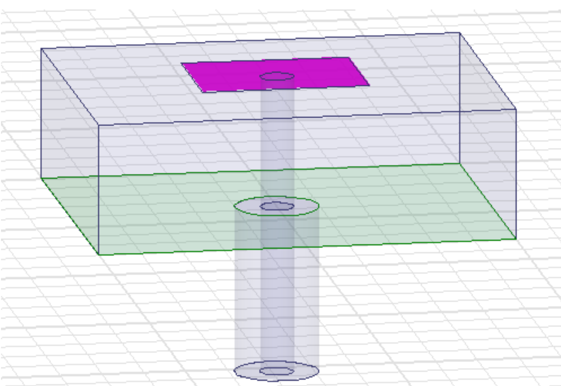

Figure-4: Rectangular Patch antenna designed for 59.5GHz

5.1. Design Specification

Table-3: Dimensions of proposed antenna

Parameters	Values
Length of the patch (L_p)	1.5 mm
Width of the patch (W_p)	2 mm
Dielectric substrate (ε_r)	2.2
Height of substrate	1.56mm
Width of substrate	5mm
Length of substrate	4mm
Feed Position(X,Y)	(1.1, 1.55) from the table-2
Loss Tangent	0.0009
Ground Plane (Wg*Lg)	5×4 mm^2
Total Antenna Profile	5 x 4 x 1.56 mm^3

VI. RESULT AND DISCUSSION

The designed antenna dimontion with following parameters in Table-3 is simulated using em-Gine simulator, the designed model of the antenna is optimized. The designed antenna model is shown in figure-4 and the resonance frequency at 59.5GHz with return loss -44.99 dB is in figure-5. The radiation pattern of the antennea is shown in figure-6 using MATLAB simulator also. The measured results show wide bandwidth in the frequency band of interest. A millimeter wave microstrip also cover a large millimeter wave range for different dielectric constant of the substrate. Millimeter systems of 5G offer tremendous potential with orders of magnitude greater spectrum and further gains from high-gain microstrip antenna technology.

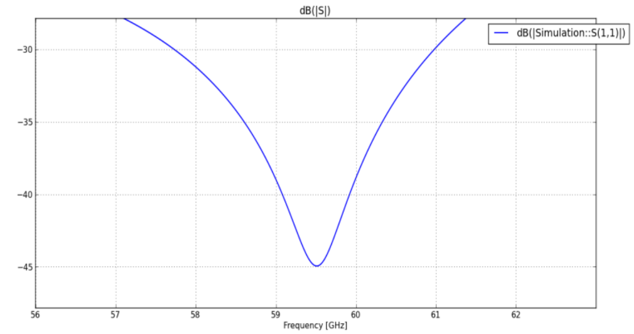

Figure-5: Antenna Resonance Frequency vs. Inserted Signal Frequency

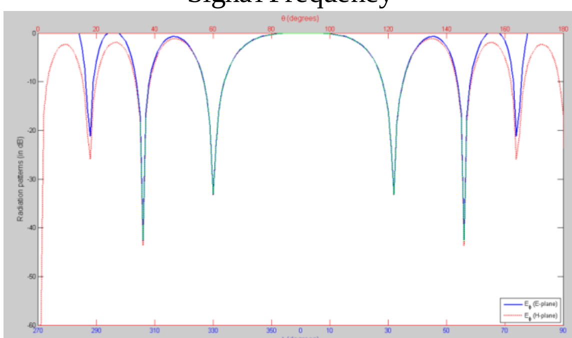

Figure-6: Radiation pattern

VII. CONCLUSIONS

In this paper, a millimeter wave microstrip antenna with high gain and more BW that can be operated within millimeter wave communications for 5G, is presented. The antenna configuration is designed and analyzed by using the HFSS and emGine simulator simultaneously based on the finite element method as well as MATLAB simulator. This low profile structure is very simple and easy to fabricate but required some highly precise fabrication facilities for such a high profile antenna. In particular, the heavy reliance on directional transmissions and 5G technologies will necessitate reconsideration of many basic procedures such as cell search, synchronization, random access and intermittent communication.

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