Design of a Microstrip patch Antenna for 5G Wireless Applications

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Abstract : With the evolvement of new on-demand applications which require high data rate, can be achieved by 5G technology. The aim of this work is to design a rectangular Microstrip patch antenna which can be used in small-sized devices such as mobile phones, radios, wireless computers and operate around frequency of 4.5 GHz which is one of the frequency band for 5G. The dielectric substrate, Rogers Ultralam1217 of dielectric constant 2.17 is used for the design and the dimension of the antenna were obtained using analytical(mathematical) processes. This is implemented using transmission line method. Microstrip patch antenna is designed and simulated in High Frequency Structured simulator(HFSS).

Index Terms**- Microstrip, Dielectric substrate, Transmission line method,5G,HFSS.**

1.INTRODUCTION

An antenna is a conductor that can transmit, send and receive signals such as microwave, radio or satellite signals. As a result of the daily improvement in technology especially in the area of communication devices such as cell phone, radio sets, laptops with wireless connection, etc, there is a need for the design of a small size antennas.

Microstrip antennas are becoming very widespread within the mobile phone market. Microstrip antennas find many applications as they are low profile, light weight, comfortable to surface and inexpensive to manufacture using printed-circuit technology. There are other forms of microstrip antennas, such as circular, square, triangular, E-shape.

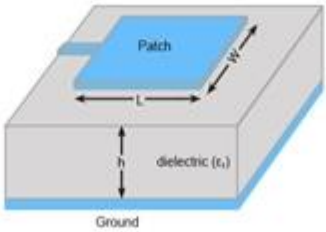

Fig.1:Single Patch

Disadvantages of single Microstrip antenna are narrow bandwidth,low gain and large ohmic losses.These disadvantages can be overcome by array configuration. An antenna array is a set of multiple connected antennas which work together as a single antenna.In this paper a single rectangular patch antenna which resonates at 4.5Ghz band is discussed.

2.ANTENNA DIMENSIONS

There are three methods for designing microstrip antennas which are: Transmission model method, cavity model method and fullwave model method, but the one used in this work is transmission line model method.

Design Calculations:

The dimensions considered in this paper are calculated using the formulae given below:

(a) Determination of patch Width:

The width of the patch is calculated using the formula given as

$$W = \frac{C}{2F_0\sqrt{(\epsilon r+1)/2}} \qquad (1)$$

where
F_0 =Operating Frequency
€r=Dielectric Constant
C=3*10^8 m/s
The width W is in mm(millimeter).

(b) Determination of effective dielectric constant:

It is calculated using the equation is given as

$$€_{erff}=\frac{€r+1}{2}+\frac{€r-1}{2}\left[1+\frac{1}{\sqrt{1+12\left(\frac{H}{W}\right)}}\right] \quad (2)$$

(c)Determination of Effective Length(L_{eff}):

It is calculated using the formula given as

$$L_{eff}=\frac{C}{2F0\sqrt{€erff}} \quad (3)$$

(d)Normalized Extension in Length:

It is calculated using the formula given as

$$\Delta L=0.412H\frac{(€erff+0.3)\left(\frac{W}{H}+0.264\right)}{(c-0.258)\left(\frac{W}{H}+0.8\right)} \quad (4)$$

(e) Length of the patch:

The length o the patch is given as

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

(f)Determination of Substrate Length and Width:

Substrate length and width are given by the formulae

$$Lg=L+6h \quad (6)$$

$$Wg=W+6h \quad (7)$$

h: here h is not the height of the substrate

$$h=\frac{0.0606ƛ}{\sqrt{€r}} \quad (8)$$

(g)Feed Line Length:

The lenth of the feed line is determined using formulae

$$L_f=\frac{ƛg}{4} \quad (9)$$

$$ƛg=\frac{ƛ}{\sqrt{\mathcal{E}reff}} \quad (10)$$

3.DESIGN CALCULATION ANALYSIS:

(a) Calculation of patch Width:

The width of the patch is calculated using the formula given as

$$W=\frac{C}{2F_0\sqrt{(€r+1)/2}}$$

$$=\frac{3*10^8}{2*4.5*10^9}\sqrt{\frac{2}{2.17+1}}$$

$$=0.2647m$$

where F_0 =Operating Frequency

$€r$ = Dielectric Constant

C=3*10^8 m/s

The width W is in mm(millimeter).

(b) Calculation of effective dielectric constant:

It is calculated using the equation is given as

$$€_{reff}=\frac{€r+1}{2}+\frac{€r-1}{2}\left[1+\frac{1}{\sqrt{1+12\left(\frac{H}{W}\right)}}\right]$$

$$€_{reff} = \frac{2.17+1}{2} + \frac{2.17-1}{2}\left(1 + \frac{12*1.58}{26.47}\right)^{\frac{-1}{2}}$$

$$=2.3513mm$$

(c)Calculation of Effective Length(L_{eff}):

It is calculated using the formula given as

$$L_{eff} = \frac{C}{2F0\sqrt{€reff}}$$

$$= \frac{3*10^8}{2*4.5*10^9\sqrt{2.3513}}$$

$$=21.73mm$$

(d)Calculation of Normalized Extension in Length:

It is calculated using the formula given as

$$\Delta L = 0.412H\frac{(€erff + 0.3)\left(\frac{W}{H} + 0.264\right)}{(c - 0.258)\left(\frac{W}{H} + 0.8\right)}$$

$$= (0.412)(1.58)\frac{(2.3513+0.3)(\frac{26.47}{1.58}+0.264)}{(2.3513-0.3)(\frac{26.47}{1.58}+0.264)}$$

$$=0.8165mm$$

(e) Calculation of length of the patch:

The length of the patch is calculated as

$$L=L_{eff} -2\Delta L$$

$$L=21.73-2*0.8156=20.09mm$$

(f)Calculation of Substrate Length and Width:

The length and width of the patch are calculated by using formulae

$$Lg=L+6h=37.3675mm$$

$$Wg=W+6h=42.9232mm$$

$$h=\frac{0.0606\lambda}{\sqrt{\epsilon r}} = 2.7422mm.$$

(g)Feed Line Length:

The length of the feedline is given by formula

$$L_f = \frac{\lambda g}{4} = 4.73928$$

$$\lambda g = \frac{\lambda}{\sqrt{\mathcal{E}reff}}$$

TABLE 1
ANTENNA DIMENSIONS

Parameters	Rogers Ultralam1217
Solution Frequency(f_0)(GHz)	4.6
Dielectric Constant(€r)	2.17
Height of Substrate(h) (mm)	1.58
Width of Patch (Wp)(mm)	26.47
Length of Patch (Lp)(mm)	20.09
Width of Ground (Wg)(mm)	42.9232
Length of Ground (Lg)(mm)	37.3675

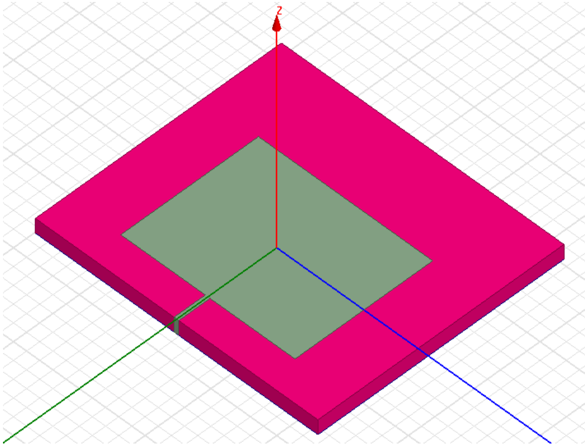

Fig.2 : Microstrip Patch Antenna with Rogers Ultralam1217 as substrate

4.RESULTS AND DISCUSSION

Under this topic we discussed different plots when we simulated a single Rectangualar Miccrostrip Patch in High Frequency Structure Simulator(HFSS) like Return loss vs frequency plot, VSWR plot, Diectivity plot, Gain plot and Radiation E field plot.

Results of Single Patch:

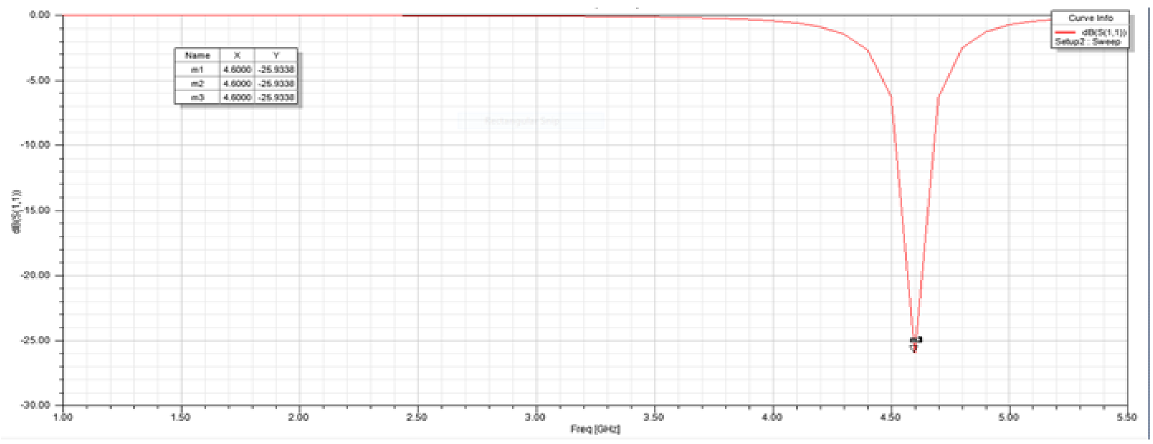

Fig.3 : Return loss

The Return loss of the antenna theoritically should be less than -10dB.Here,In this plot we obtained a gain of -25.9338 at 4.6 GHz frequency.

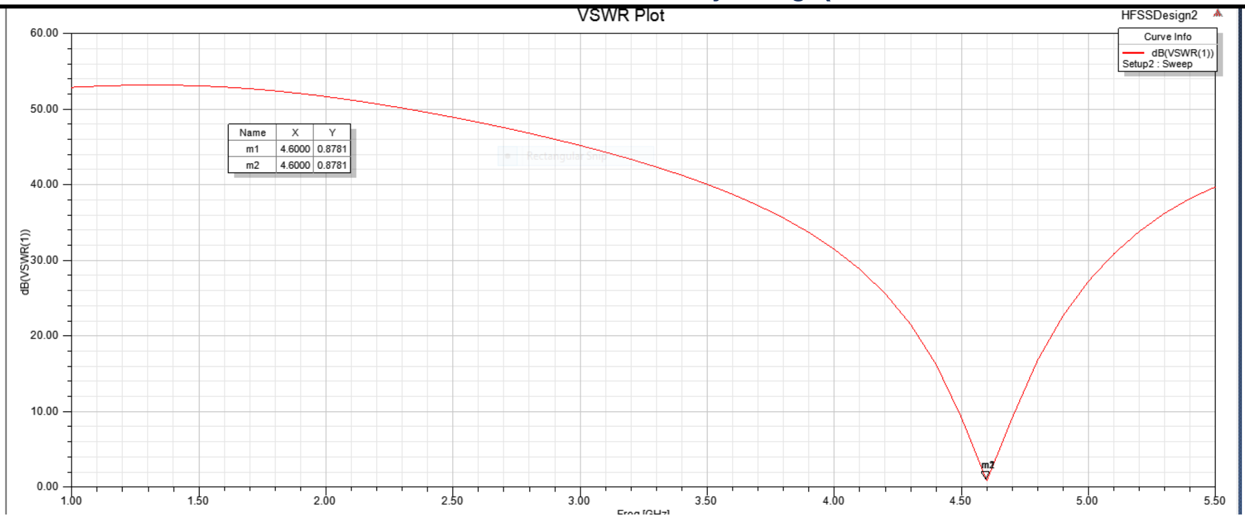

Fig 3:VSWR Plot

Voltage Standing Wave Ratio(VSWR) also referred as Standing Wave Ratio is a function of reflection coefficient, which describes the power reflected from the antenna and should be in range of 0-2.Here,In the simulation of a single patch we obtained a VSWR of 0.8781

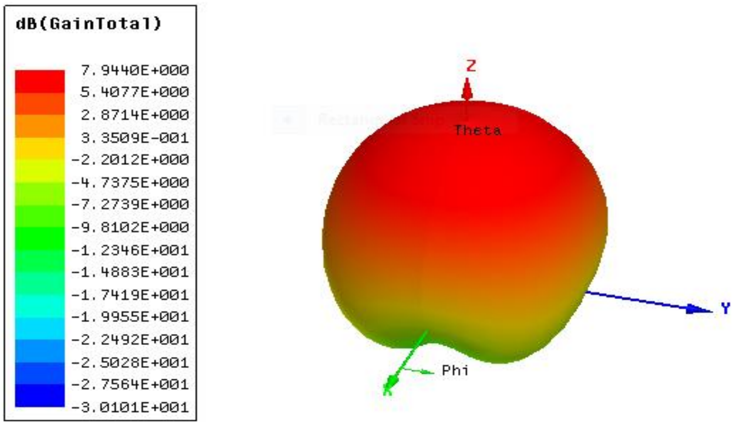

Fig.5: Gain Plot

In a antenna, the gain describes how well the antenna converts input power into radio waves headed in a specific direction. The normal gain of the antenna can be 3dB and more. Here ,in the gain plot we obtained a gain of 7.944dB.

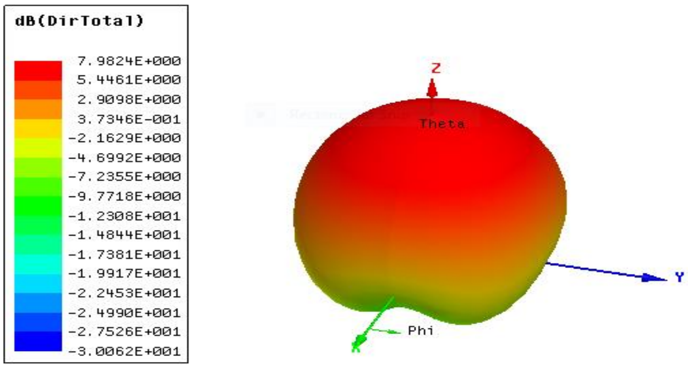

Fig.4: Directivity Plot

Directivity is a fundamental antenna parameter .It is a measure of how 'directional' an antenna's radiation pattern is.The directivity of an antenna theoritically can vary from 1.76dB to as much as 50dB.The obtained directivity in this plot is 7.982dB.

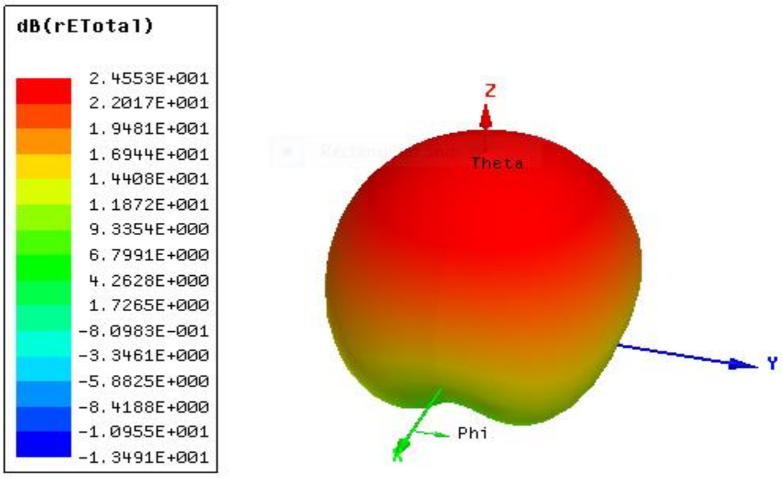

Fig.6: Total Radiation E Field Plot

CONCLUSION

A single patch antenna for around 4.5Ghz is designed and the output is verified .A 2X1 array is also designed but resonating at 4.3GHz,So still we need to go for optimization. The future work is designing a higher order array antenna for MIMO systems which resonates around 4.5Ghz which 5G wireless technology.

REFERENCES

[1]. http://www.iosrjournals.org/iosr-jece/papers/Conf.15010/Volume%201/A.%20ECE-129.pdf.
[2] http://www.iosrjournals.org/iosr-jece/papers/Conf.15010/Volume%201/A.%20ECE-129.pdf.
[3] Antenna Theory ,C.Balanis,Wiley,2nd edition (1997),chapter 14,ISBN 0-471-59268-4.
[4]] Mok WC, Wong SH, Luk KM, Lee KF. Single-layer single-patch dual-band and tripleband patch antennas.IEEE Trans Anten Propag 2013;61(8):4341–4.
[5] Zayed ASA, Shameena VA. Planar dual-band monopole antenna with an extended ground plane for WLAN applications. Int J Antennas Propag 2016;2016:1–10.
[6] shafai L, Chamma W, Seguin G, Sultano N. Dual-band dual polarized microstrip antennas for SAR applications. In: Proceedings of IEEE antennas propag int symp, Canada; 1997. p. 1866–9.
[7] Arora C, Pattnaik SS, Baral RN. Metamaterial inspired dual band patch antenna array, In: Proceedings of 5th international conference on signal processing and integrated networks (SPIN-2018), India; 2018.
[8] Kouzaev GA, Deen MJ, Nikolova NK, Rahal AH. Cavity models of planar components grounded by via-holes and their experimental verification. IEEE Trans Microw Theory Tech 2006;54(3):1033–42.
[9] Pozar, DM (1998), 2nd Ed., "Microwave Engineering" John Wiley and Sons, Inc. New York.
[10]https://www.ijert.org/research/analysis-and-design-of-rectangular-microstrip-patch-antenna-at-2.4ghz-wlan-applications-IJERTV3IS081043.pdf.
[11]www.emtalk.com.