Performance Analysis of Microstrip Patch Antenna at 28GHz over Rogers RT/Duroid 5880(tm) and Neltec NY9220 (IM)(tm) Substrates with different thicknesses

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***Abstract* - 5G is the fifth generation Cellular network technology and always designing the antenna for this high frequency cellular network is a challenging task. Microstrip patch antenna can be designed for this 5G frequency band. But selecting a proper substrate material for this design is very important as it provides mechanical support and must satisfy electrical and mechanical requirements. The objective of this paper is to design a Microstrip patch antenna at 28GHz over RT/Duroid 5880(tm) and Neltec NY9220 (IM)(tm)substrates and to analyze its performance over different substrate thicknesses (0.127mm,0.254mm,0.381mm,0.508mm,0.787mm). Software used is High Frequency structure Simulator (HFSS).**

***keywords* - Microstrip Patch, Substrate, HFSS.**

I. INTRODUCTION

5G is the fifth generation of mobile networks designed to meet the high speed data connectivity required for many applications.5G uses massive MIMO (Multiple Input, Multiple Output) antennas at millimeter wave frequency bands to send and receive more data simultaneously. The primary technologies include millimeter wave bands (26, 28, 38 and 60GHz) offer performance as high as 20 Gigabits per second [1]. Massive MIMO (Multiple Input multiple output) offers performance upto ten times current 4G networks [2][3][4].

5G antenna technology will be a combination of sub 6GHz antenna systems as well as mmW antenna systems, the latter will work just below 30GHz and also from 30GHz to 77GHz.There is particular emphasis from a hardware and network deployment viewpoint on the 28GHz.[5]

The paper is organized as follows:

Section II discusses design of Microstrip patch antenna at 28GHz (5G Frequency). Section III discusses the details of Rogers RT/Duroid 5880(tm) and Neltec NY9220(IM)(tm)Substrates. Section IV discusses simulation results in both graphical and Tabular form. Section V Concludes the paper.

II. DESIGN OF MICROSTRIP PATCH ANTENNA AT 28GHZ (5G FREQUENCY BAND)

A Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side.

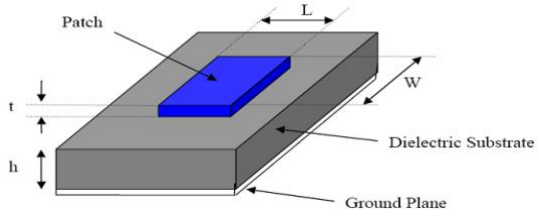
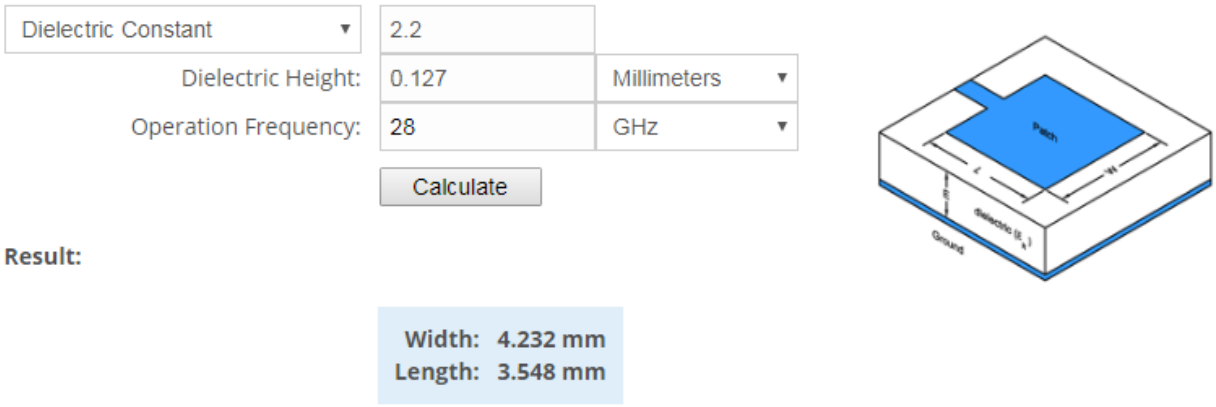


Figure:1 Microstrip patch antenna

The width and length of microstrip patch antenna are calculated based on the Transmission line method of Analysis and the following calculator (https://www.pasternack.com/t-calculator-microstrip-ant.aspx) is used to perform this calculation. The calculated values are given in the section IV numerical results.



$$Width = \frac{c}{2f_o\sqrt{\frac{\varepsilon_R+1}{2}}}; \quad \varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right]$$

$$Length = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right)$$

The antenna is connected to a quarter wave transformer of 87.26 ohms having width of 0.304mm to a microstrip line of 50ohms and a width of 0.783mm.[6]

III. RT/DUROID 5880 AND NELTEC NY9220(IM) SUBSTRATES

The **Rogers 5880** high-frequency laminate families are glass microfiber reinforced with PTFE compounds. These microfibers are statistically oriented to maximize the benefits of fiber gain in the most valuable direction for circuit producers and in end-use applications. The dielectric constant of these high-frequency laminates is the lowest of all products, and the low dielectric loss makes them suitable for high frequency/broadband applications where dispersion and losses must be minimized. Due to its extremely low water absorption properties, the **RT Duroid 5880** is ideal for applications in high humidity environments. [7]

Properties of RT Duroid 5880

- The very low electrical loss chances for any reinforced PTFE material
- Lower moisture absorption
- Isotropic
- Uniform electrical properties on the frequency
- Excellent chemical resistance, including solvents and reagents used in printing and coating

The N9000 PTFE laminate system is for microwave components, antennas, power amplifiers and subassemblies. Superior mechanical and electrical performance make it suitable for low loss high frequency applications.

IV. SIMULATION RESULTS

Simulations are performed using HFSS Software.

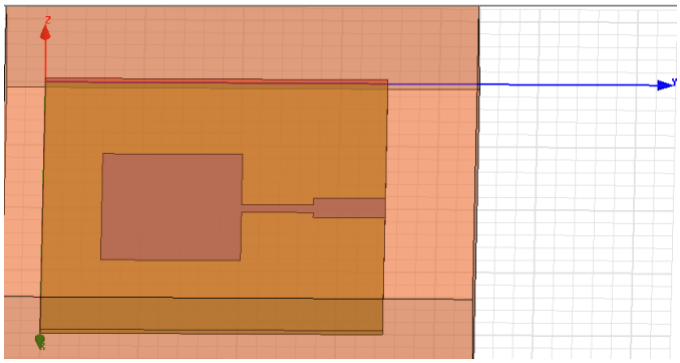


Figure:2 Microstrip Patch Antenna Simulation 28GHz

Simulations were performed by using two different substrates RT/Duroid 5880 and Neltec NY9220™ with thicknesses of 0.127mm, 0.254mm, 0.381mm, 0.508mm and 0.787mm.
Values of the following parameters like S11, Bandwidth, VSWR, Maximum Directivity, Peak Directivity, Peak Gain,Radiated power,Radiation efficiency are measured.

The following Graphical results shows the simulation of microstrip patch antenna at 28GHz over Neltec NY9220™ substrate of 0.127mm thickness and other results are obtained in the same manner.

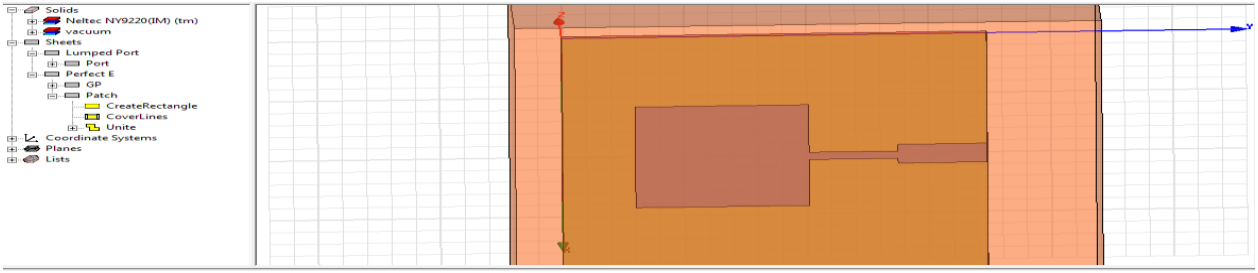


Figure:3 Microstrip patch Antenna at 28GHz over Neltec NY9220 substrate

Figure:4 Graph of Return loss(S_{11}) versus frequency

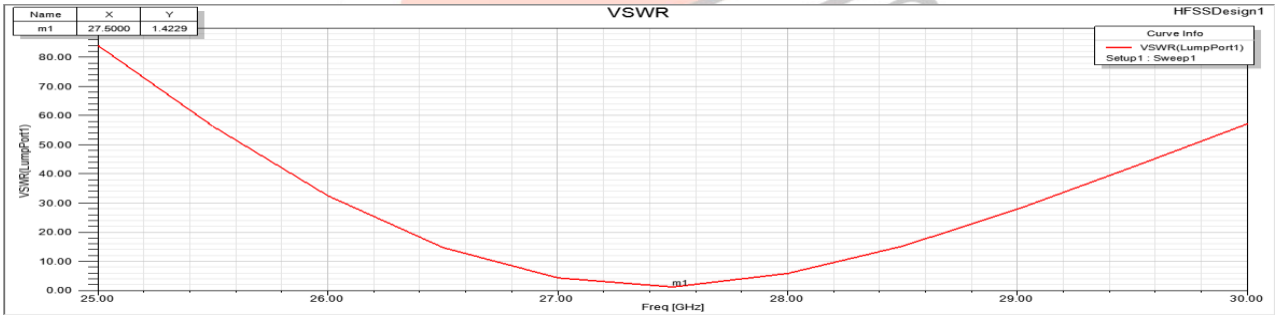


Figure:5 VSWR Versus Frequency

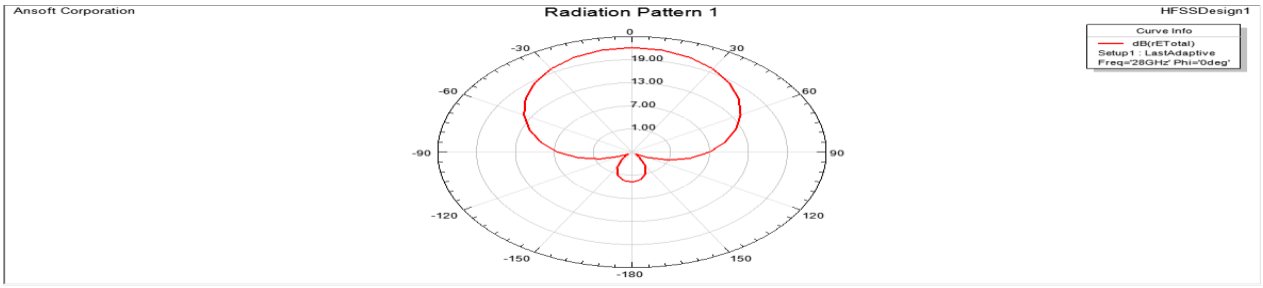


Figure:5 Radiation Pattern of Antenna

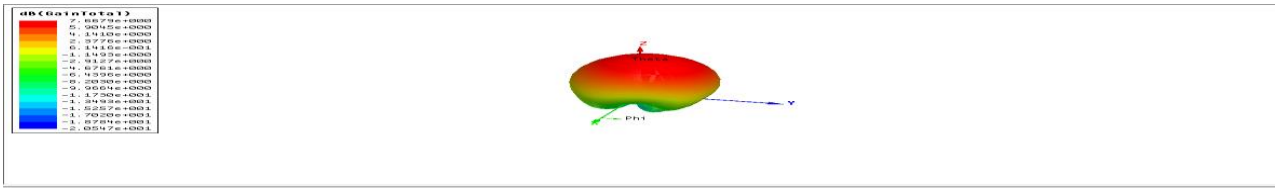


Figure:6 Gain of Antenna

Table 1 PERFORMANCE PARAMETERS OF MICROSTRIP PATCH ANTENNA AT 28GHZ OVER ROGERS RT/DUROID SUBSTRATE WITH ϵ_R=2.2

Thickness of the Substrate (mm)	Width of the Patch (mm)	Length of the Patch (mm)	S_{11}	Resonating Frequency (GHz)	Bandwidth (MHz)	VSWR	Max.UW/Sr	Peak Directivity	Peak Gain	Radiated Power (Watts)	Radiation Efficiency
0.127	4.232	3.548	-15.5826	27.5	464.4	1.3989	0.22814	6.0931	5.8408	0.47053	0.95859
0.254	4.232	3.466	-11.1032	27.5	655	1.7720	0.33124	5.9154	5.7999	0.70369	0.98046
0.381	4.232	3.375	-12.0210	27.5	791.7	1.6687	0.38902	5.7464	5.6733	0.85066	0.9872
0.508	4.232	3.279	-12.9730	27.5	1583.6	1.5792	0.41074	5.5194	5.4523	0.93517	0.98784
0.787	4.232	3.060	-24.2392	29	2772.3	1.1308	0.39144	5.1316	5.0949	0.95859	0.99284

Table 2: PERFORMANCE PARAMETERS OF MICROSTRIP PATCH ANTENNA AT 28GHZ OVER NELTEC NY9220(IM)™ SUBSTRATE WITH ϵ_R=2.2

Thickness of the Substrate (mm)	Width of the Patch (mm)	Length of the Patch (mm)	S_{11}	Resonating Frequency (GHz)	Bandwidth (MHz)	VSWR	Max.UW/Sr	Peak Directivity	Peak Gain	Radiated Power (Watts)	Radiation Efficiency
0.127	4.232	3.548	-15.1617	27.5	444.8	1.4229	0.22625	6.1078	5.8451	0.4655	0.95698
0.254	4.232	3.466	-11.1327	27.5	661.4	1.7684	0.33138	5.9099	5.7911	0.70571	0.97989
0.381	4.232	3.375	-11.5485	27.5	914	1.7196	0.37765	5.6968	5.6082	0.83306	0.98445
0.508	4.232	3.279	-12.9730	27.5	1590.4	1.5792	0.41074	5.5194	5.4523	0.93517	0.98784
0.787	4.232	3.060	-24.2392	29	2764.4	1.1308	0.39144	5.1316	5.0949	0.95859	0.99284

From the above two tables the values of Width and Length of the patch is calculated based on the Transmission line method of Analysis. The substrate thickness of 0.127mm, 0.254mm, 0.381mm, 0.508mm, 0.787mm are standard thickness of Rogers RT/Duroid and Neltec NY9220(IM)™ .

Increasing the height of the substrate increases the Bandwidth and efficiency which is evident from the above two table's. There is a drastic increase in Bandwidth and slight increase in the values of Radiation efficiency.

The value of VSWR obtained for all the cases of substrate thicknesses is between 1 and less than 2 .The smaller the VSWR is , better the antenna is matched to the transmission line and more power is delivered to the antenna.

Maximum Radiation intensity measured in Watts/Steradian increases, as the substrate thickness increases.

Typical Directivity for Microstrip patch antenna is between 3.2 to 6.3 [8] and from the above tables the values of peak diecrtivity obtained is in this range. Increased Directivity implies a more focused or directional antenna.

V. CONCLUSION

Microstrip patch antenna is designed at 28GHz over two substrates Rogers RT/Duroid 5880 and Neltec NY9220(IM)™. Graphical and tabulation results are mentioned above. From the results it is understood that by increasing the substrate thickness Bandwidth and Radiation efficiency increases. Effect of surface waves is not considered in this analysis. Designing of patch over these two substrates produces satisfactory results.

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