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Effect of Slot Size Variations on Microstrip Patch Antenna Performance for 5G Applications

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***Abstract*— This paper presents the design of microstrip patch antenna at 28GHz and also analyzes the effect of slot size variations on microstrip patch antenna's performance in terms of Gain, Bandwidth, Return loss and VSWR. Slots are introduced in the patch and ground plane. Substrate used is a Rogers RT Duroid 5880 with a dielectric constant of 2.2. High frequency structure Simulator (HFSS) Software is used for simulation**

***Index Terms*—HFSS,MICROSTRIP,VSWR 5G**

I. Introduction

The fifth generation of cellular wireless networks is envisaged to overcome existing challenges cellular networks such as higher rates, great performance. Moreover, indeed, 5G will need to be a paradigm shift that includes high carrier frequencies with massive bandwidths, extreme base station and device densities and unprecedented numbers of antennas. [1]

5G antenna technology will be a combination of sub 6GHz antenna systems as well as mmW antenna sytems, 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 [2].

The paper is organized as follows:

Section II discusses design of Microstrip patch antenna at 28GHz without ground plane slot, Section III discusses advantages of using slotted ground plane and slotted patch, Section IV discusses design of slotted ground plane and slotted patch microstrip antenna at 28GHz using HFSS and finally the paper is concluded with results and discussions.

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II. Design of Microstrip Patch Antenna At 28Ghz

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 as shown in the Fig.1

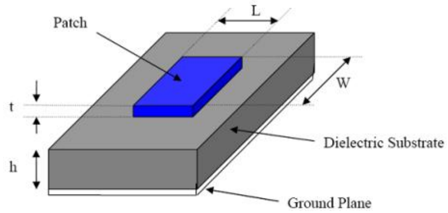

Fig.1 Microstrip patch antenna

The width and length of the patch are calculated by using the design formula

$$W = \frac{C}{2 f_r \sqrt{\frac{\varepsilon_r}{2}}} \text{ ---------------------------------------(1)}$$

Where c is the velocity of the light, f_r is the frequency of operation and ε_r is the dielectric constant of the substrate

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

Length of the patch (L) can be determined after obtaining the value of effective dielectric constant and incremental length of the patch.

$$\varepsilon_{reff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \text{ -----------------(3)}$$

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \text{ --------(4)}$$

The antenna is connected with a quarter wave transformer of 87.26 ohms having width of 0.304mm to a microstrip line of 50ohms having a width of 0.783mm [3].

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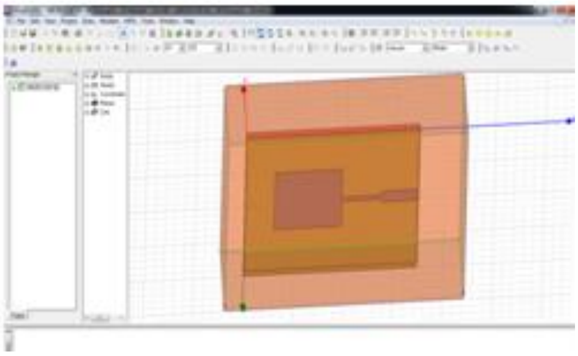

Fig. 2 Construction of Patch in HFSS

Following design specifications [4] were used for the construction of the antenna:

<u>Patch</u>
Width of the Patch : 4.105mm
Length of the patch : 3.362mm

<u>Quarter Wave Transformer</u>
Width: 0.304mm
Length : 2.007mm

<u>Microstrip Line</u>

Width : 0.783 mm
Length : 1.824 mm

<u>Substrate</u>
Rogers RT Duroid 5880
Thickness of the substrate : 0.254mm
Loss Tangent: 0.0009

III. ADVANTAGES OF SLOTTED GROUND PLANE AND SLOTTED PATCH

By using the slotted ground plane and slotted patch we get the following advantages:

- Increase in Bandwidth [3]
- Increase in Gain
- Decrease in the values of VSWR
- Decrease in the values of Return loss

IV. DESIGN OF SLOTTED GROUND PLANE AND SLOTTED PATCH MICROSTRIP ANTENNA AT 28GHz

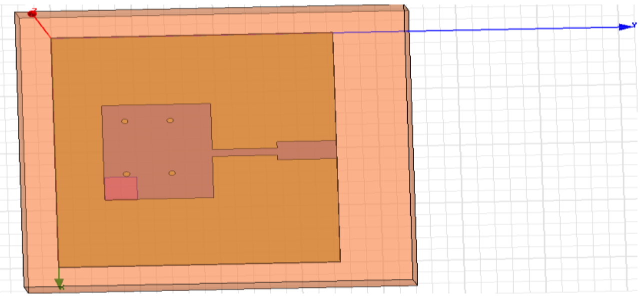

Fig. 3 Construction of Patch with Ground plane slot and slot in the patch using HFSS.

Slots in the patch are analyzed for the radius of 0.05mm,0.1mm,0.5mm without varying the size of ground plane slot and then by fixing the patch slot size the ground slot size are varied to analyze the performance of antenna.

Dimensions of the Ground Plane slot is initially fixed for the size of 1mm*1mm

CONSTRUCTION OF ANTENNA WITH SLOT IN HFSS:

A. Microstrip Patch Antenna with fixed Ground Plane Slot size and Slotted Patch with Different Radius:

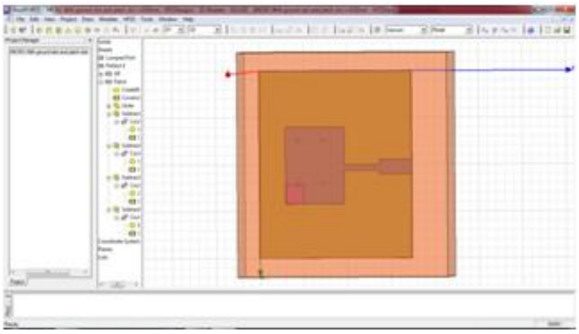

Fig. 4 Slotted patch(r=0.05mm) and fixed Ground plane slot

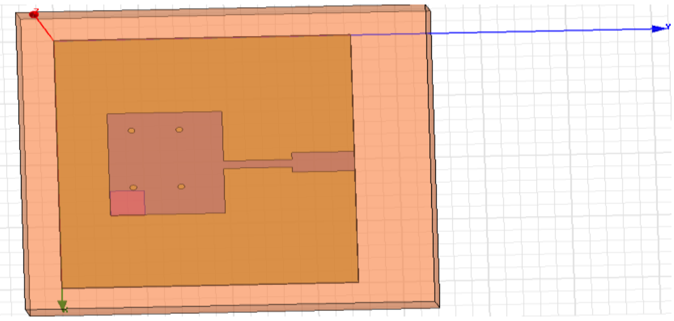

Fig. 5 Slotted patch(r=0.1mm) and fixed Ground plane slot

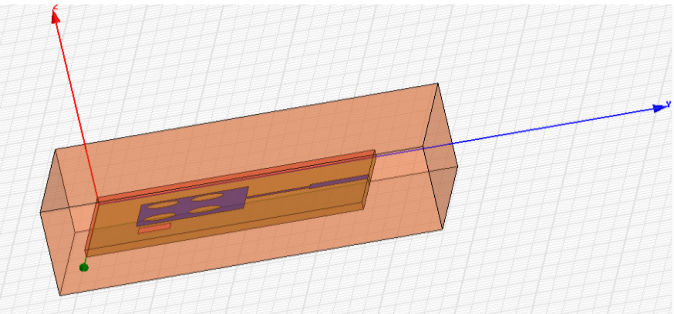

Fig 6 : Slotted patch (r=0.5mm) and fixed Ground Plane

B. Microstrip Patch Antenna with fixed Slotted patch and different dimensions of Ground plane slot

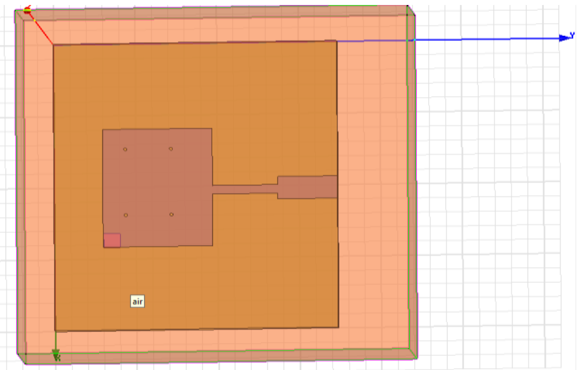

Fig 7 Ground plane dimensions (0.5*0.5) mm

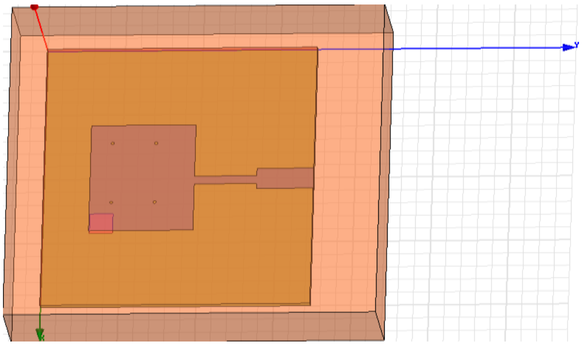

Fig 8 Ground plane dimensions (0.75*0.75) mm

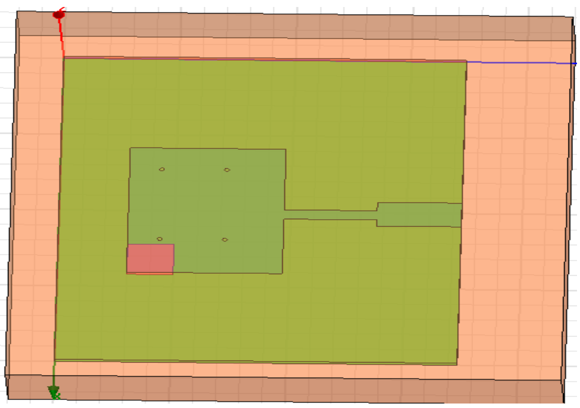

Fig 9 Ground plane dimensions (1*1) mm

V. Simulation Results

A. Graphical Results

Simulation results are shown for the slot radius of r=0.05mm and ground plane slot dimension 1*1mm

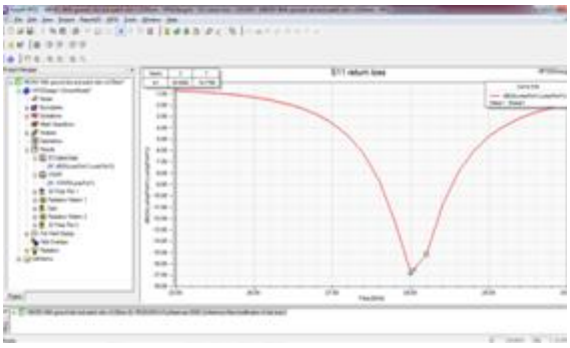

Fig 10:Plot of Return loss versus Freq.

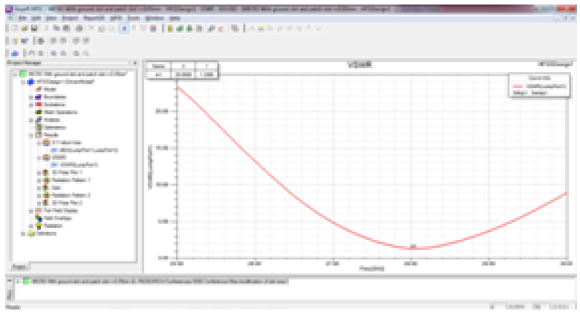

Fig 11:Plot of VSWR versus Freq.

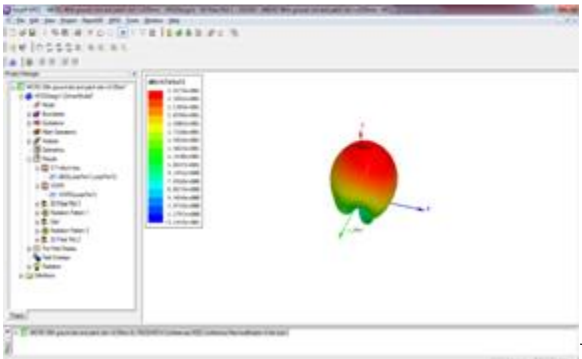

Fig 12:Plot of Gain(dB).

B. Numerical Results

The below Table (1) shows the numerical results of the antenna performance in terms of S11, VSWR, Gain and Bandwidth without any slots.

Table 1:

S11	VSWR	GAIN(dB)	BW
-13.2	1.559	2.5*e+001	600MHz

The below Table(2) shows the performance of the microstrip patch antenna in terms of S11,VSWR,Gain(dB) and Bandwidth by varying the radius of the slot in the patch and by keeping the fixed size of the ground plane slot.

Table 2: Performance of the microstrip patch antenna for different slot radius of patch and fixed ground plane slot size

Radius of the slot in the patch	S11	VSWR	GAIN(dB)	BW
r=0.05 mm	-16.7	1.3390	2.5175*e+001	2610 MHz
r=0.1mm	-16.7	1.3414	2.5207*e+001	2610 MHz

Table 3: Performance of the microstrip patch antenna for different ground plane slot dimensions and fixed slot radius of patch

Dimensions of Ground Plane slot	S11	VSWR	GAIN(dB)	BW
(0.5*0.5)	-13.53	1.534	2.5125*e+001	2570 MHz
(0.75*0.75)	-14.061	1.49	2.5110*e+001	2600 MHz
(1*1)	-16.77	1.3390	2.5175*e+001	2610 MHz

VI. CONCLUSION

From the above Graphical and numerical results it is clearly understood that the introduction of slots in the Patch and Ground plane improves the performance of the antenna in terms of gain, bandwidth, VSWR and return loss**.** Varying the slot radius of the patch produces slight improvement in the gain and by varying the dimensions of the ground plane slot VSWR is reduced and Bandwidth is increased.

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Dr.Swaminathan Ramamurthy completed his PhD, ME and BE in the field of Electronics & Communication Engineering .He has over ten years Teaching,Industrial and Research Experience. He has published papers in International Journals and Conferences.His area of Interest are Antenna, Mobile Communication and Image Processing.

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He has received the **prestigious National Scientist award "VASVIK" for the design and development of "Sonobuoy Processor and Optical fiber data bus" in 1990** for the contribution made during DRDO service. He also received the **"Best Paper award"** in Rail Road Electrical Information in an International Conference in **May 2006** at Korea.. Further served as**" Korean Expert Professor (only non-Korean)"** for setting up a **National University at Laos,** fully funded by Government of Korea between 2004 – 2007. In this connection **Laos Government has given him a "Certificate of Gratitude"**

He has carried out research in the field of **Sonar, Radar, Sonobuoy, Sonar Simulators, cryptography, Ethernet traffic Investigation, Expert Systems, Telemedicine, Adaptive Equalizers, Internet Telephony, VoIP etc. He has good number of research publications to his credit.**