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Aperture Coupled Microstrip Patch Antenna for 5G Application using HFSS at 60 Ghz

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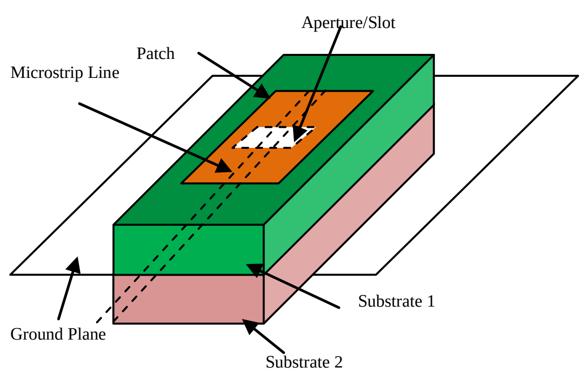
A B S T R A C T

An antenna is used in an RF system to receive or transmit radio wave signals. Without a properly designed antenna, the signal created by the RF system will not be transferred and no signal will be recognised at the receiver. Many different types of antennas have been developed to meet the demands of various applications. Antennas come in the form of microstrip patches. A wideband microstrip antenna at 60 GHz designed. Here antenna is design and simulate using ANSYS HFSS 2019R1 at 60 GHz. An Aperture coupled feed technique is used in this work. The proposed antenna resonates from f_L= 56.8630 GHz to f_H= 62.0550 GHz with a return loss ≤ -10 dB at central frequency 60 GHz. The antenna having antenna bandwidth 4.511 GHz. In this design, two substrate Roger RT/Duroid 6006 and Roger RT/ Duroid 5880, which has dielectric constant of 6.15 and 2.2 with loss, tangent 0.0009 with a height of substrate are 0.635 mm and 1.6 mm was used. Finally conclude the performance of antenna in terms of bandwidth its good agreement for 5G applications.

Keywords:Aperture coupled feed microstrip antenna, 5G.

1. Introduction

An antenna is a device used to send and receive electromagnetic waves in free space. Antennas are classified into two types: passive antennas and active antennas. The reciprocal device is the passive antenna. The reciprocal device is not an active antenna. Further Antennas are classified into nine categories. Active antennas, antenna arrays, dielectric antennas, microstrip antennas, lens antennas, wire antennas, aperture antenna reflector antennas, and



leaky wave antennas are examples of these antennas.

Figure Error! No text of specified style in document. **Aperture coupling**

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Above all, these antennas differ in terms of feeding techniques and layouts. Deschamps initially introduced the notion of microstrip radiators in 1953. Printed circuit technology may be used to create a microstrip antenna. A technology called as photolithographic process may be used to print out exact dimensions on PCB.

The microstrip antenna can be made with low cost. In the photolithographic process, fabrication can be done the same as a photocopy machine because the mask of the design can be reused as many times as possible. Microstrip antenna has narrow bandwidth. Usually for rectangular microstrip antenna, the bandwidth is below 5%. It is also has low gain.

1.1 Aperture Coupling

This is the most difficult to fabricate and it also has high bandwidth. In this coupling method use a feed line on ground on one side of PCB and other side creates a slot as shown in Figure 1.

2. Design and Analysis of Antenna

Transmission line model used for analysis. It is very simple and easy to understanding. In this method two slots represent a patch and work as line resonator that occur fringing field by variation of radiating field. Since the microstrip patch antenna consist of two slit first slot known as radiating patch and second is represent ground patch, therefore in this model width of antenna and length of antenna separated as transmission line with the thickness of antenna is h. The microstrip has no homogenous line of two dielectrics, typically the substrate and air. Figure shows the most of electric field lines reside in the substrate and some parts of lines in air. Therefore, the result of this transmission line cannot support pure TEM mode of transmission because the phase velocities would be different in the air and the substrate.The width of microstrip patch calculated by using following equations (Eqn-1-6). Where W is width of microstrip patch, C is the velocity of light, ε_r is the dielectric constant of the antenna substrate and f_0 is design frequency of the microstrip patch antenna.

$$W = \frac{C}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} \qquad \text{Eqn. 1}$$

$$\varepsilon_{eff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r+1)}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}} \qquad \text{Eqn. 2}$$

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff}+0.300)\left(\frac{W}{h}+0.262\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.813\right)} \qquad \text{Eqn. 3}$$

$$L = \frac{c}{2f\sqrt{\varepsilon_{eff}}} - 2\Delta L \qquad \text{Eqn. 4}$$

$$L_g = L + 6h \qquad \text{Eqn.5}$$

$$W_g = W + 6h \qquad \text{Eqn. 6}$$

$W_g$and L_g represent the finite ground plane width and length.

Table 1Optimized dimension of the patch antenna

Parameter	Dimension(mm)
Ground Plane & Substrate Length (G_x)	12
Ground Plane& Substrate Width (G_y)	12
Patch Length (L_p)	0.55
Patch Width (W_p)	1.98
Height of substrate(h_1)	0.635
Height of substrate(h_2)	1.6
Width of feedline (W_f)	0.9563
Length of Stub(ΔL_S)	0.15
Length of slot L_a	0.9646
Width of slot W_a	0.0986

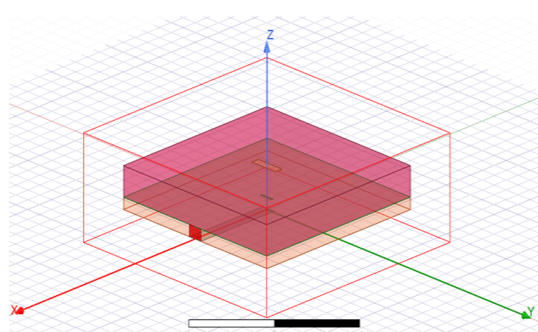

Figure 2 an aperture coupled microstrip antenna

2.1 Aperture coupled patch antenna

In this section, antennas designed at resonance frequency 60 GHz with help of previous section parameter explain and considered in previous section. ANSYS HFSS 2019R1 full wave EM software is used for all simulation work. All simulated result compare and analyzed for bandwidth, gain, directivity and efficiency of antenna point of view

Draw Ground Substrate

Draw the box and rename as ground substrate with the dimension of G_x = 12 mm and G_y = 14 mm. Height of box is h_1= 0.635 mm with dielectric constant (ε_{r1}) = 6.15 RT/duroid 6006 and set position as centre.

Draw Feed Line and Position of Stub

Draw a rectangular and rename as feedline with W_f= 0.9563 mm. Now add the fringing stub length ΔL_S = 0.15 mm at the centre axis that is $G_x/2+\Delta L_S$ =6.15 mm. Now set the color and transparency of element up 70%. Feed line and stub position of antenna.

Draw Ground Slot

For structure of ground slot is combination of two planes. First draw a rectangular with size 12 mm x 12 mm and second with size 2.2 mm x 0.23 mm. Then subtract the second element with first element. Now set the color and transparency of element up 70%.

Draw Patch Element

Draw the box and rename as ground substrate with the dimension of G_x = 12 mm and G_y = 12 mm. Height of box is h_2= 1.6 mm with dielectric constant (ε_{r1}) = 2.2 RT/Duroid 5880 and set position as centre. Now draw a rectangular with size of L_P = 0.55 mm and width W_P = 1.98 mm. Now set the color and transparency of element up 70%.

Draw Source Element

Change the position of axis from xy plan to xz plane and draw a rectangular with size 0.9563 mm x 0.635 mm.

Assign Boundary Condition and Excitation of Source

Check the position of axis as xy plain. Now assign the boundary condition for all conductor plain as perfect E. Assign the radiating surface as vacuum and solution type considers as terminal. Now assigns excitation with lump port.

2.2 Analysis and Simulation Setup

Assign the analysis at frequency 60 GHz, maximum number of passes 20 and maximum delta s = 0.02. Now assign the sweep as fast and distribution for linear step start from 55 GHz to 65 GHz with step size 0.001 GHz.

Check validation and click analyze all. After the completion of simulation work plot some parameters like as, S11, VSWR, Smith chart, radiation patterns as well as radiation efficiency.

3. RESULT

This section present the simulation result of the antenna and summary of the result.

Return Loss, Smith Chart and VSWR

The proposed antenna resonates at 60 GHz with a return loss of -20.4438 dB. Impedance bandwidth obtained 4.511 GHz from f_L= 56.467 GHz to f_H= 60.978 GHz shown in Figure 3. The matching impedance at resonance frequency at 60 GHz is real as shown in Figure 4.

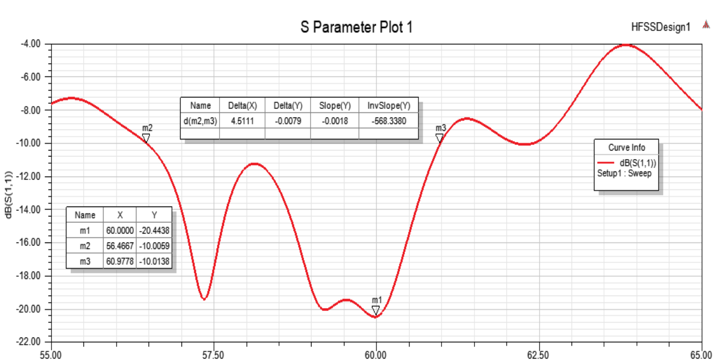

Figure 3Return loss of the antenna

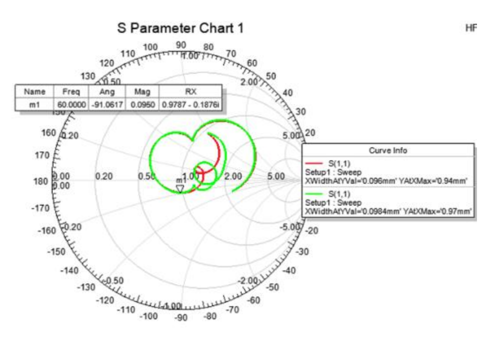

Figure Error! No text of specified style in document. **Smith chart of the antenna**

For a microstrip antenna, the VSWR should be between 1 and 2 along the bandwidth of efficiency. The proposed antenna voltage standing wave ratio (VSWR) can be observing 1.21 at 60 GHz shown in Figure.5.

Antenna has the maximum gain 3.5 dB shown in Figure 7 and Directivity of aperture coupled antenna is 3.55 dB shown in Figure.6.

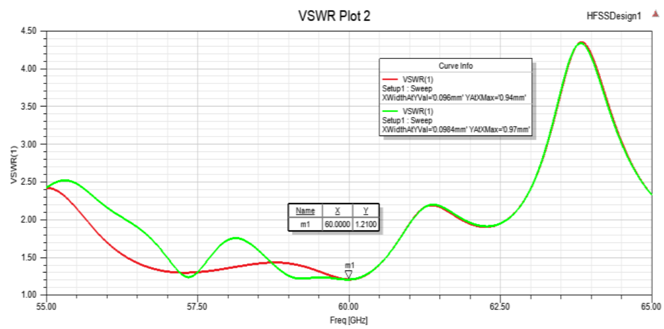

Figure 5 VSWR of antenna

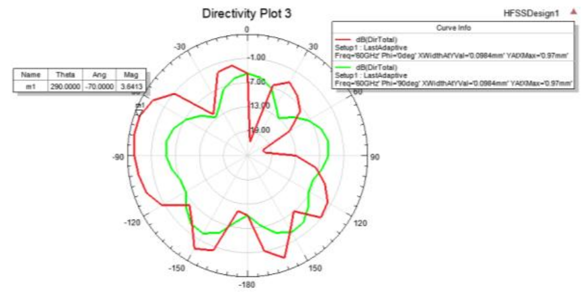

Figure 6 Directivity of antenna

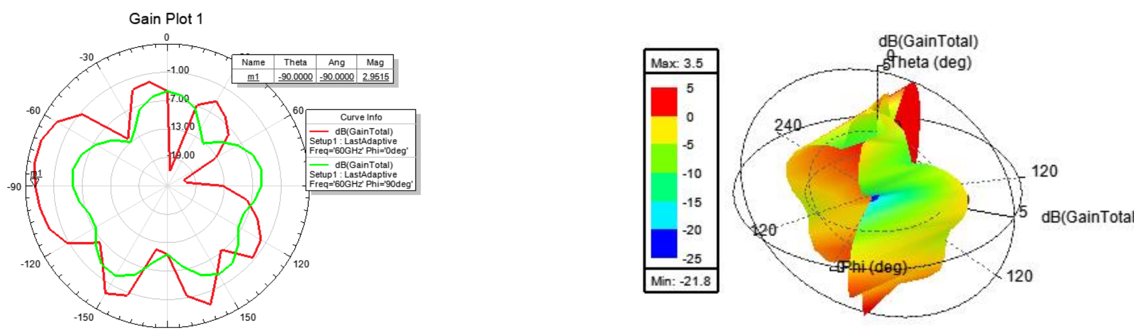

Figure 72D and 3D Gain plot of antenna

Table 2Summary of simulated result

Antenna Parameter	Values
f_0	60 GHz
S_{11}	-20.4438
VSWR	1.21
Bandwidth	4.511 GHz
Gain	3.5 dB
Directivity	3.55dB
Efficiency	93.27%

Conclusion

Concluded the modeling, design and simulated result point of view. An antenna designed at resonance frequency 60 GHz. ANSYS HFSS 2019R1 full wave EM software is used for all simulation work. An aperture coupled rectangular microstrip antenna has been proposed for 5G application. The antenna has bandwidth bandwidth 4.511 GHz. The Gain of antenna is 3.5 dB. Here, it can be observed that the antenna having wide band more than 780 MHz and gain is also high 3.5 dB, which are requirements of 5 G applications. Therefore, proposed antenna as a good option for 5G applications.

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