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DESIGN OF HUT SHAPED SIW ANTENNA ON ANALOG INTEGRATED CIRCUITS FOR 60 GHZ APPLICATIONS

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Abstract: In this research article, hut shaped antenna is designed to connect wireless gigabit Ethernet communication system to optical fiber communication for providing high data rate transfer. A novel technology like Substrate Integrated Waveguide technology is used to design this hut shaped antenna. This technology gives good results in millimeter wave frequency range applications. This structure analyzed with the results of the reflection coefficient, Voltage Standing Wave Ratio, surface currents, 3D radiation patterns, polar patterns, electric and magnetic field directions. This component is most suitable for millimeter wave applications like RADAR and 5G applications. To design this hut shaped antenna RT duriod 5880 substrate material is used.

Keywords: Analog Integrated Circuit, Point to Point communication, CPW to SIW transmission, Substrate Integrated Waveguide (SIW), mm-wave, Wireless communication.

1. INTRODUCTION

Nowadays wireless communication ruled the entire world. A number of applications are increased day by day i.e many applications are connected to the internet which is nothing but Internet of Things (IOT) [1]. But it is very difficult to implement every function is connected to the internet because due to limited bandwidth, Noise interference, all the entire system are not connected to one place and transmitter and receiver are not connected at one place. To develop the IOT system all the components are connected with high data rate. It is very difficult because at high frequency only high data rates are possible. But at higher frequency noise interference is very high. For short distance applications higher frequency support for high data rate. To design this type systems one separate system is require. This system combines the wireless with optical communication for high data rate. The wireless communication system is connected to satellite directly with high directivity and high bandwidth. The wireless system converts electromagnetic wave into an electrical wave which given to optical fibres'. Which carry the high data rate signal to subsystems. But now the entire world converted to the digital side. So this electrical analog signal converted into a digital signal at 60GHz. All the near subsystems are connected by using optical fibres' and the main system is directly connected to satellite. Below Figure 1 gives block diagram of Analogy Integrated Circuit System.

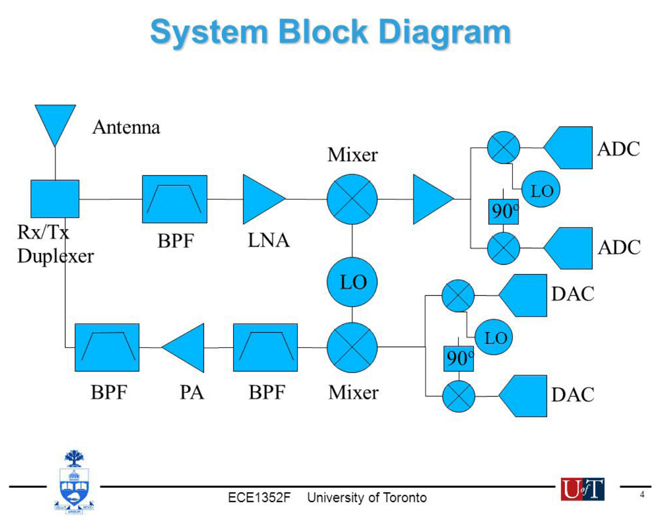


Figure 1: Analog Integrated Circuit System blocks diagram

Above circuit diagram gives the connection between satellite to the main system. Satellite sends the signal to base main station antenna, which converts electromagnetic signal into the analog electrical signal. Converted signal is given to other components Which are converted into a digital signal and given to other components to processing purposes. Here a high directivity antenna is required to receive the signal from the satellite. To receive a signal from the fixed direction high directivity antenna are required. Which are used to avoid other source interference. This high directivity antenna is mainly used in point to point communication, dish antenna and direct TV dishes. Here these antennas offer very high bit rates for connecting wireless gigabit Ethernet to optical fiber.

The millimeter wave frequency (30GHz – 300 GHz)[1] is most game challenging frequency. In this frequency range federal communication commission (FCC) announced 57GHz to 64GHz is unlicensed frequency. Because this frequency range is most suitable for short range, high data rate broadband applications. This frequency range is applied for indoor and outdoor point to point (P2P) fixed wireless communication. A new technology is required to design an antenna in the mm-wave frequency range. Substrate Integrated Waveguide (SIW) technology is most suitable technology to design any components in the mm-wave frequency range. Which gives good compatible size, high bandwidth, low losses with the good quality factory.

In this article next section explains the design of the antenna. The third section explains the results of hut shaped antenna. The fourth section explains comparisons between literature survey antennas with any proposed antenna. The last section gives the conclusion of proposed antenna.

2. DESIGN OF SIW AND CPW STRUCTURE

1. CPW Design

To connect the antenna to other components a transmission path is required. Here coplanar waveguide (CPW) path is used because which is best suitable for impedance matching perps. In the design of System on Substrate (SOS), System on Chip (SOC) and System in Package (SIP) crosstalk occurs because components are very near to each other. To avoid cross talk in between components CPW to SIW transmission good one. In CPW design space width (S) between ground and signal carrying conductor and signal carrying conductor path width (W) parameters are important. Which are calculated by using below formulas. Here grounded CPW method is used because which gives good results compared with normal CPW connection [1-4].

$$0.2 \le \frac{W \quad W}{W+2S W+2S} \le 0.8 \qquad (1)$$

Here below Figure 2 shows the CPW structure. This fig gives all the parameters of CPW. Here tapering section is used for good impedance matching. The length of this tapering section is calculated using below formula 2.

$$\lambda_g = \lambda_o / \sqrt{\varepsilon r} \qquad (2)$$

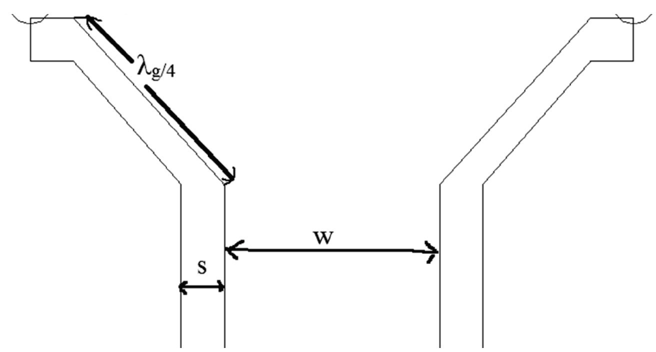


Figure 2: GCPW structure

2. SIW Design

SIW structure is just like rectangular waveguide structure but in the place of sir in rectangular waveguide substrate is placed and two periodic arrays of metallic vias are used to connect the top and bottom conductor which shown in Figure 3. SIW design parameter is via diameter (d) and spacing between two vias (P) and width between two conductor vias (Wsiw) are decided the losses in the structure which are calculated by using below formulas [1-4].

$$W_{eff} = W_{siw} - d^2/(0.95\ p) \qquad (3)$$

$$W_{eff} = a/\sqrt{\varepsilon r} \qquad (4)$$

$$p \le 4d \qquad (5)$$

Here "a" is the standard dimension of normal width rectangular waveguide. εr is relative permittivity of the substrate. RT duriod 5880 substrates is used. Which having $\varepsilon r = 2.2$ with dissipation factor tan $\delta = 0.0009$. The height of the RT duriod 5880 substrate $h = 0.508$ mm. The top and bottom of the substrate are coated with a copper layer with a thickness of 0.035mm

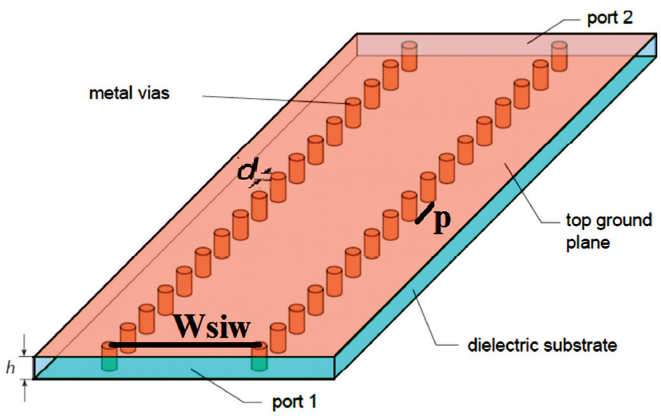


Figure 3: SIW structure

3. ANTENNA STRUCTURE

In the antenna structure design hut and ohm-shaped structures are developed. To increase the resonance peak at 60GHz numbers of slots are increased. To insert the slots in structure nickel material is used.

To insert ohm shape structure in the antenna, first insert rectangular shape slot with 2 mm as width 0.4 mm as length. Next insert two circles with inner radius 0.2 mm and outer side radius as 0.4 mm near rectangular shape which is shown in Figure 4.

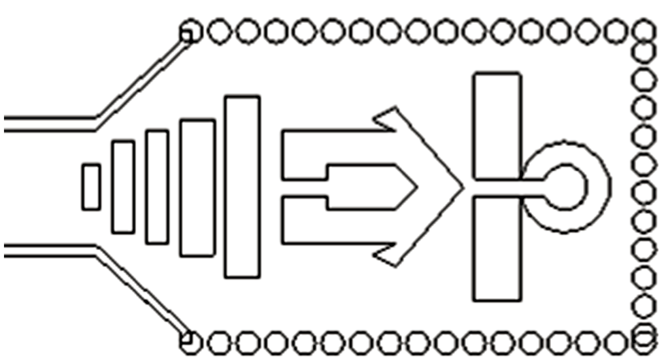


Figure 4: Proposed Antenna structure.

To insert hut shape, first insert square shape with each side dimension of 1 mm. Next insert triangular shape with base 1.4 mm and the side length of 0.6 mm which is shown in Figure 4. To insert rectangular shape inside of hut shape conductor material is used. Inside rectangular shape dimensions are 0.4 mm as width and 0.6mm as length. Insert triangular shape inside of hut shape used dimensions are, base 0.4 mm and each side of the triangular shape is 0.2 mm. which also filled with a copper conductor. Now inside copper of hut shape and outside hut shape coppers are connected using copper slot shown in Figure 4. copper slot dimensions are 0.5mm as length and width of 0.15mm.

Table 1
Proposed Antenna Design structure parameters

Parameter	*Value (mm)*
L	6
W	4
d	0.2
P	0.25
Wsiw	2.72
λg	3.371
Wc	1.008
S	0.1
Lc	0.85

4. RESULTS

The software simulation result of the proposed hut shaped antenna is shown in Figure 5. In the resulting graph red color line indicates as reflection coefficient (S_{11}). Which gives maximum resonance peak occurs at 60GHz with −28.69dB. In this graph −20dB taken as a reference to calculate the bandwidth of the structure. This −20dB line touches the S11 at $f_1 = 58.16$ GHz and $f_2 = 61.71$ GHz which shown in Figure 5. The bandwidth of the structure is calculated as $f_2 - f_1$ which gives 3.55GHz.

Voltage Standing Wave Ration (VSWR) of hut shaped antenna shown in Figure 6. Throughout the band VSWR is maintained in between 1 to 2.

The 3D radiation pattern of hut shaped antenna shown in Figure 7. This gives 5.49dBi as directivity and 1.6dB as gain. Which are occurs at 60GHz shown in below Figure.

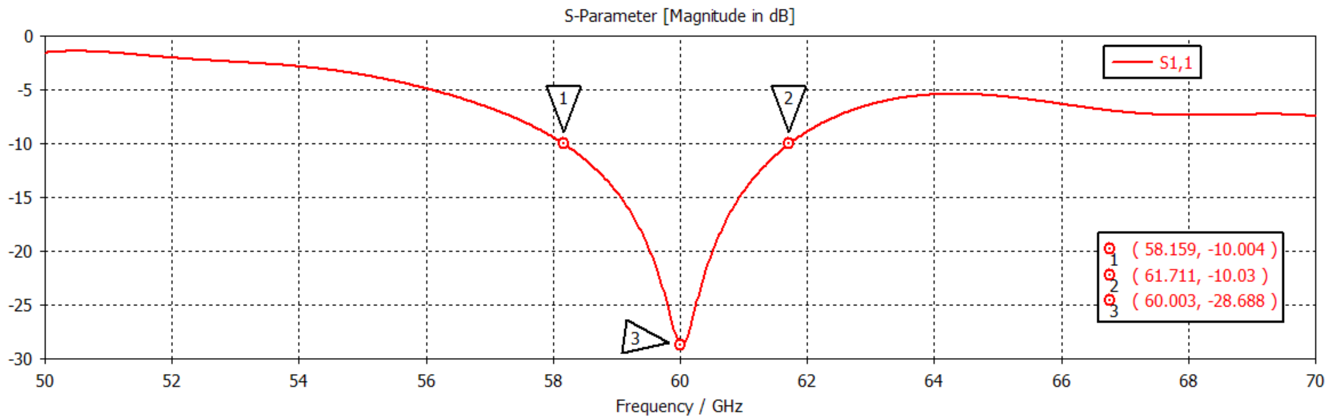


Figure 5: **Simulation results of the Proposed antenna.**

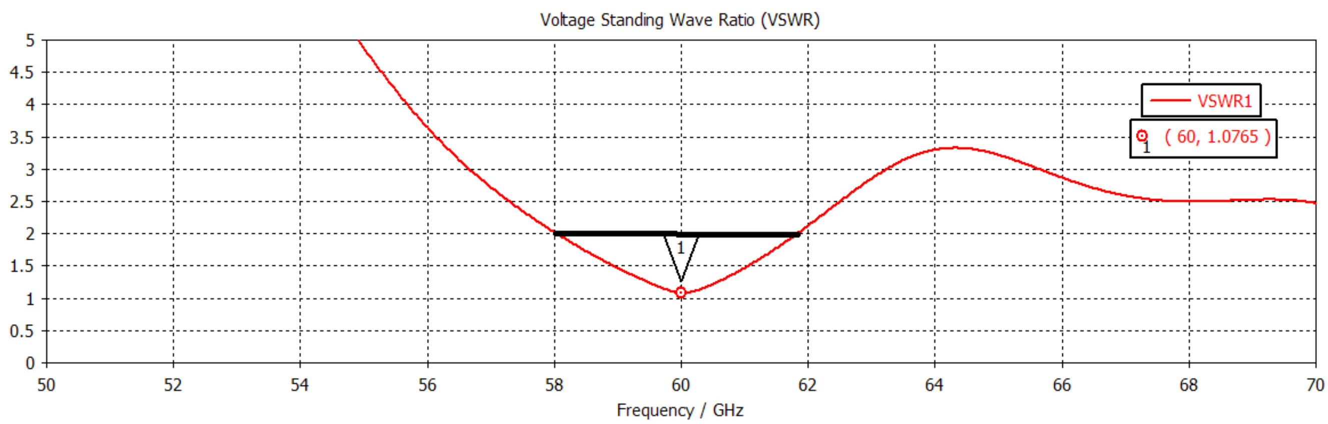


Figure 6: **VSWR curve of Proposed Antenna.**

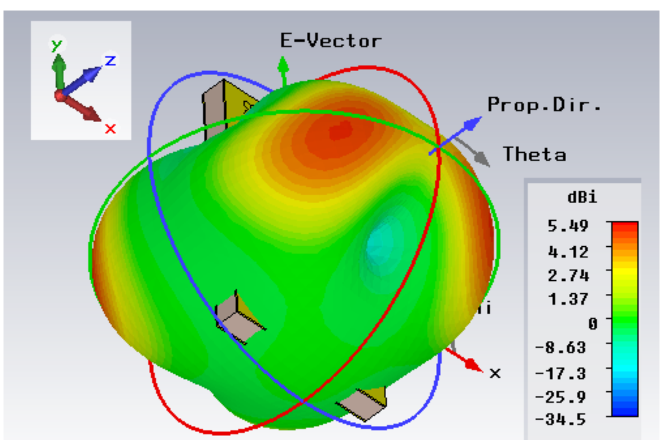


Figure 7: **3D radiation pattern.**

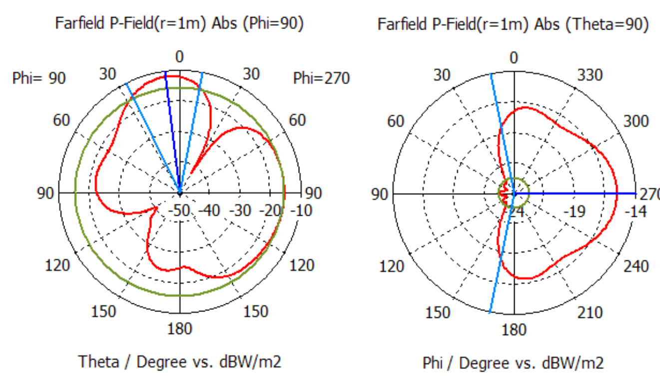
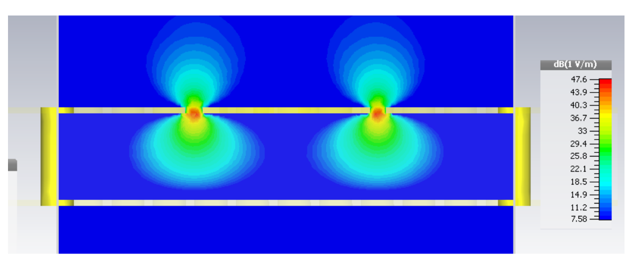


Figure 8: **2D Radiation patterns (a) E-plane (b) H-plane**

Polar pattern of hut shaped antenna shown in Figure 8. Which are occurs at 60GHz below figure shown constant phi and constant theta radiation pattern at 60GHz.

Electric field and magnetic field directions at the input port of the hut shaped antenna at 60GHz are shown in Figure 8.

Surface current distribution of the proposed antenna structure is shown in below Figure 10. These results occur at 60GHz which is shown in below figure.



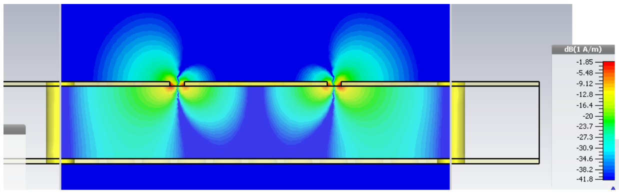


Figure 9: Field distribution at input side: (a) E-plane (b) H-plane

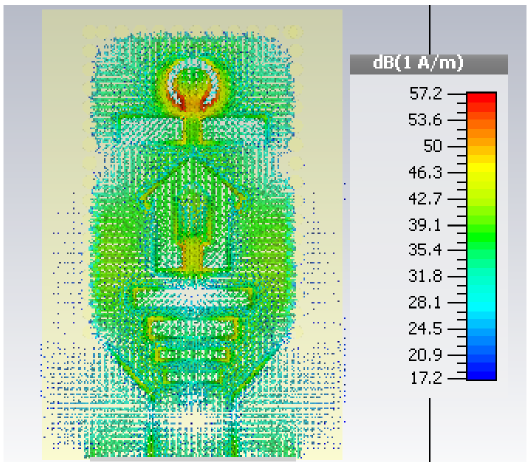


Figure 10: Surface Current distribution of antenna.

5. COMPARISION

Here below table represent the comparisons between exist structure with proposed structure.

Table 2
Comparisons between existing structure to Proposed Antenna

Parameters	*Ref. [5]*	*Ref. [6]*	*Ref. [7]*	*Proposed Design*
Frequency (GHz)	60	61	60	60
Bandwidth (–20dB)	1.85	2.144	1.5	3.55
Refl. coefficient (dB)	–35	–41.1	–40	–28.69
Size (all in mm)	4 * 4 * 0.381	4 * 20.26 * 0.381	9.93 * 43.29 * 0.381	4 * 6 * 0.508

6. CONCLUSION

Hut shaped antenna is designed for an analog integrated circuit which is used to connect optical fiber cables and wireless Gigabit Ethernet at 60GHz. This design structure given a bandwidth of 3.55dB, VSWR of 1.07 and maximum reflection coefficient resonance peak occurs -28.69dB at 60GHz. This hut shaped antenna gives 5.49dBi as directivity and 1.6dB as gain. In an unlicensed band of 57 GHz to 64 GHz antenna covers 50.71% of bandwidth. If extend these software results into a prototype and measure the results which are suitable to millimeter wave application of Analog integrated circuit used in satellite communication. This antenna is used in long distance high data rate satellite communication application.

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