High Gain Antenna Design For Inter Satellite Link At Millimeter Range

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Abstract: A Novel high gain antenna at millimeter band (57-74 GHz) is presented. In this paper, two antenna designs are proposed one is Taper slot structured antenna and other is 3D waveguide structured horn antenna. Both these models achieved the high gain. Taper slot antenna with an array achieved a gain of 11 dB and single element horn antenna with a gain of 13 dB. The radiation pattern is found with narrow beam width of 20 degree. Wilkinson power divider is used in taper slot antenna with linear array of 1X4 arrangement to achieve a gain of 24 dB. For Horn antenna radiation efficiency of 86 is achieved. Taper slot antenna incorporated substrate integrated waveguide (SIW) structure as a vias to achieve better radiation efficiency. 7GHz is the bandwidth. Further Link budget calculations are presented. |S11| is less than -12 dB. Isolation of 15 dB is achieved. Impedance of 50 ohm micro strip line is considered. RT duroid 5880 material is used in designing an antenna. These designs are well suitable for small satellites with are operated above the earth surface and can create a radio links to form a satellite network. Theoretically analyzed the performance of tapered slot Linear Array and assumed that it is mounted on the small satellite

1 INTRODUCTION

Recent past there is a huge scope for high speed radio links capable to achieve high data rates. The main function of a transmitter is to match the characteristic of message to the characteristics of the channel. Here channel is wireless. Antenna plays a vital role to achieve better efficiency of characteristic of the channel. The function of the receiver is to match the channel characteristics to the message. Performance of receiver sensitivity is depend upon antenna functioning. Antenna unit converts the message into EM signal and radiates in free space. The important task of the antenna is how to radiate the signal with better efficiency and it depends upon the frequency of operation, input power, and impedance of the micro strip line. Advancement of wireless communication enhanced to scale up the frequency band towards the millimeter range. When frequency increases, wavelength decreases results in short range communication. But here there is a scope for high data rates with shorter wavelength. Gigabit communication is possible in millimeter technology. 57 GHz – 64 GHz is the best suitable band for millimeter technology. Therefore, 7GHz is the bandwidth and 60 GHz is the operating frequency. This paper proposed the basic antenna simulation designs at 60 GHz. One key issue to be considered is at 60 GHz attenuation due to atmospheric absorption.

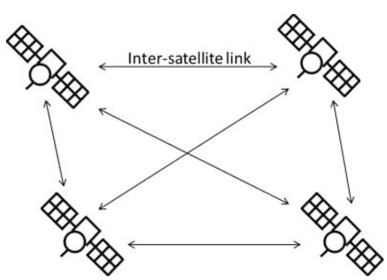

Figure 1

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Millimeter technology is widely used in the indoor communication and in space where atmosphere level is vacuum i.e. beyond the LEO (Low Earth Orbit). Wireless HD is best application for millimeter technology possible to achieve 5 Gbps data rate. Apart from these applications the mentioned designs are suitable for inter satellite links. Since there is no oxygen molecules in atmosphere at higher altitudes considered frequency of operation is best suitable for establishing high data links between satellites. In vacuum, there is no possibility of refraction and reflection. Signal directly penetrates in the medium. The factor to be considered is scattering because shorter the wavelength signal cannot transmit to long distance due to this phenomenon leads to scattering in deep space. To overcome this problem antenna is designed such a way that it should have a narrow Beam width. Choice of material is a key role because antennas are deployed on the surface of satellites .Humidity, sun temperature is plays a vital role and may cause damage to the antenna. So to overcome these problems need to select a antenna with a permittivity and tangent loss in a acceptable range. RT duroid materials are suitable for antenna design at this frequency which can sustain at different temperatures.

TABLE I

Inter-satellite Linking System

Satellite Launch	*Satellite Name*	*Frequency used for ISL*
1972-1978	*OSCAR 6,7,8*	*146 MHz*
1976	*LES-10*	*35, 38 GHz*
1983-2013	*TDRSS*	*C, Ku, Ka*
1997	*Iridium*	*23 GHz*
1998	*Spot-4*	*Optical*

Over the past there are different planar structured antennas suitable for inter satellite links. Micro strip antenna is the basic version among planar structure. The Theoretical result of this antenna shows poor gain and efficiency decreases with increase in power. Additional drawback is on-chip and MMIC leads to higher cost. In case of array side lobe levels are not in acceptable range. Further yagi antenna is another simple design with high gain and the distance between elements is half the wave length. The problem encountered is gain and efficiency are in inverse relation. In this work, planar antenna and horn antenna is proposed. Tapered slot antenna with single element result in gain of 12dB and beam width of 40 deg. Later with an array of slot antenna gain is improved to 16 dB with a beam width of 25 deg. Further, horn antenna is designed which obtained a result of gain 21 dB and beam width of 21 deg. Many papers stating that for inter-satellite links best suitable is parabolic reflectors and horn antennas instead of planar structure but these planar antennas is best suited in case of small satellites operated at low earth orbits.

II. Planar antenna: Design and simulation

Compact size is possible when antenna is designed in a planar structure. Comfortably can place a antenna or mount on the dielectric sheets. In this paper planar anti podal slot antenna and horn antenna is designed. The basic structure reference

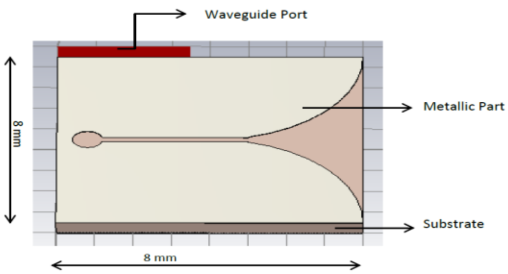

Figure 2

Table II represents the basic simulation results under the ideal conditions, but these results are not in acceptable range.

TABLE II

PATSA	Gain	Main lobe	Minor lobe	S11
Dielectric loaded	9 dB	73 deg	-1.7 dB	-14.6 dB
Without Dielectric loading	3 dB	74 deg	-3.7 dB	-12.9 dB

Further extension to this basic design mentioned above single element TSALA is proposed in Figure 3 and design dimensions as shown in Table III.

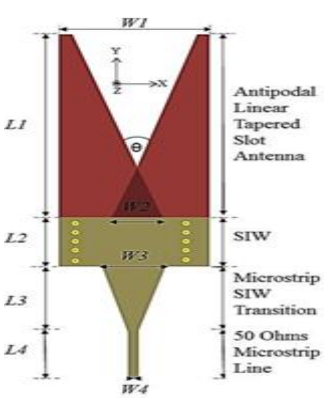

TABLE III

Antenna Dimensions for single element TSLA

Parameter	DielectricSubstrate:RT/duriod (ε_r=2.20, h=0.381mm)	
	Symbol	Value mm
ALTSA Length	L1	41.45
SIW Length	L2	22.36
Taper Length	L3	4.93
Microstrip Line Length	L4	1.5
ALTSA Width	W1	10.43
Area Width	W2	1.8
Taper Width	W3	4.12
Microstrip Line Width	W4	0.5
SIW Effective Width	Ws	9.2
Diameter of Vias	D	0.6
Pitch of Vias	P	0.90
Width of corrugation	RCw	0.9
Space between Corrugation	RCs	1.7
Length of corrugation	RC1	2.25

HFSS simulation tool is used to simulate these designs. Mathematical formulas are referred from [4] and further these are optimized.

R=2(R+H) cos(A/2)

$$0.007 \le t\left(\sqrt{RC_{substrate}} - 1\right)/\lambda_0 \le 0.05$$

$$Dvia < \lambda/5$$

Single element antenna is not suitable for the inter satellite link. This act as a basic reference to enhance the suitable antenna at high frequency. Gain and beam width is the major role at 60 GHz.Array of antenna is designed as shown in the figure 4. Mutual coupling is the key to be consider in array. The distance between the antenna elements is choosen to be half the wavelength or even less than to it. Spacing can be linear or non-linear but in this experiment spacing is equal distance. For each element power distribution is done with power divider. The figure shows the

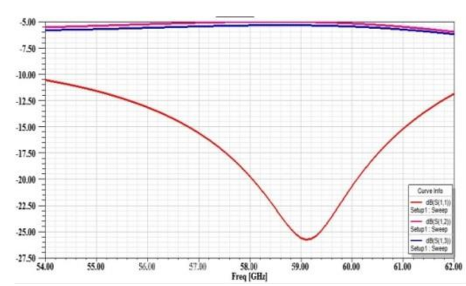

Figure 4 – *Return loss of power divider*

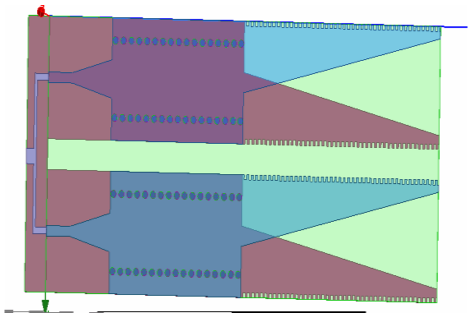

Figure 5- *Two Element array of TSLA*

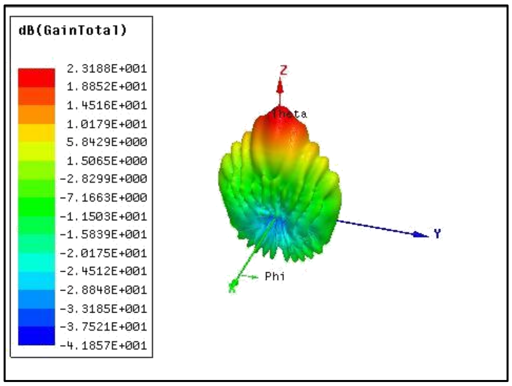

Figure 6- *radiation pattern for array*

Observe the gain tremendously increased. Array of antenna is desired when we need a high gain

2 CONCLUSION

High gain and efficient TS antenna based on SIW technology with power divider was presented in this research for satellite communications at 60GHz. The simulated gain of single element antenna is 18 dB, while 23 dB is obtained for the 1x2 antenna array.

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