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Design of Lens Antenna for Low Terahertz Application

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***Abstract*—This paper describes a hemi-elliptical dielectric lens antenna for Terahertz application. The design of antenna is done by integrating a hemi-elliptical dielectric lens antenna with a perforated substrate patch antenna to provide low loss, high directivity at low terahertz frequency. The initial geometry of the design is based on integral equations and ray optics which is optimized using Simulations (Ansys HFSS version 2016). The dielectric used for substrate is Rogers RT Duriod (ε_r=2.2) and for the lens we use Gallium Arsenide (ε_r=12.9) in this design. The central frequency of the designed antenna is 600GHz with a maximum directivity of 7dB and return loss of -30dB.**

***Index Terms*— Hemi-elliptical lens antenna, Terahertz, perforated substrate micro strip antenna.**

I. INTRODUCTION

With the development of technology many opportunities are available to obtain super quality images, high speed, and large data communications [1]. In recent times, terahertz (THz) region has attracted lot of interest for new opportunities in radar and satellite communication, sensing and imaging applications [2] and in infrared energy harvesting applications [3]. These applications require propagation through adverse environment with very less attenuation of the signal and low cost systems [4].

Design of antenna at Terahertz frequency range acquires many challenges. Starting from fabrication, to interaction of electromagnetic waves with its nano-antenna structures and it also involves the limitations of signal generation and detection. The recent solutions for this are horn and lens antennas in sub-millimeter wave band [5]. There are many designs operating in these bands, but effective illumination of lens antenna is a challenge.

Here, a hemi-elliptical dielectric lens antenna is being proposed which is directly fed by the perforated substrate microstrip patch antenna which acts as a primary radiator. In this context, hemi-elliptical lens has been chosen to be integrated with the microstrip antenna. The proposed antenna achieves low loss and medium gain which addresses the requirements for the Terahertz communication and for high resolution imaging.

Also, the antenna proposed is provided with a simple feed, which is easy to analyze.

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II. ANTENNA DESIGN

The proposed design is as shown in Fig.1. The structure is a hemi-elliptical lens of semi-minor axis b=0.4764mm, semi major axis a=0.5mm, which are governed by these equations [6].

$$b=\frac{a}{\sqrt{1-\frac{1}{n^2}}} \tag{1}$$

$$c_e=\frac{b}{n} \tag{2}$$

$$n=\sqrt{\varepsilon_r} \tag{3}$$

With, eq. 2 to find one of the focal point of ellipse, and eq.3 to find the refractive index of the lens. The dielectric material is Gallium arsenide with ε_r=12.9.

The perforated substrate microstrip antenna is as shown in Fig.2. The antenna is made up of substrate thickness, sh=0.01mm, the length and width sl = sw = 1mm. There are 100 perforations in the substrate of radius rad=0.015mm. The width and length of patch pw = 0.1475mm and pl = 0.08475mm respectively. The design equations of patch antenna [7].

$$\varepsilon_{eff}=\frac{\varepsilon_R+1}{2}+\frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\frac{sh}{pw}}}\right] \tag{4}$$

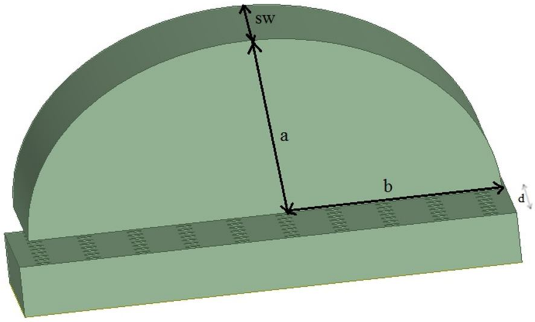


Fig 1: Illustration of the proposed hemi-elliptical dielectric lens antenna

$$\mathrm{pw}=\frac{\mathrm{c}}{2\mathrm{f}_0\sqrt{\frac{\varepsilon_R+1}{2}}} \tag{5}$$

$$pl=\frac{c}{2f_0\sqrt{\varepsilon_{eff}}}-0.824sh\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{pw}{sh}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{pw}{sh}+0.8\right)}\right) \tag{6}$$

where, c=3x10^8 the speed of light, f_0 is the operating frequency, ε_{eff} is effective refractive index.

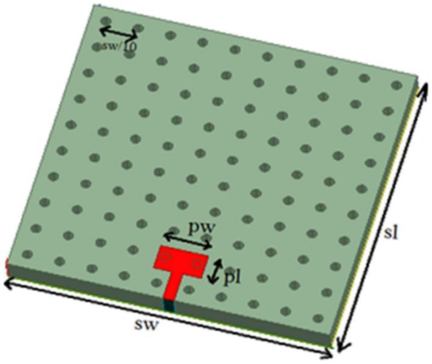


Fig 2: Schematic of the perforated substrate microstrip patch antenna

There exists an airgap between the lens and the microstrip antenna denoted as d=0.05mm. The initial calculation by geometric approach gives the elliptical lens's focal length. An optimization of the parameters a and d carried out using Ansys HFSS, considering the effects of the radiation pattern of the primary antenna.

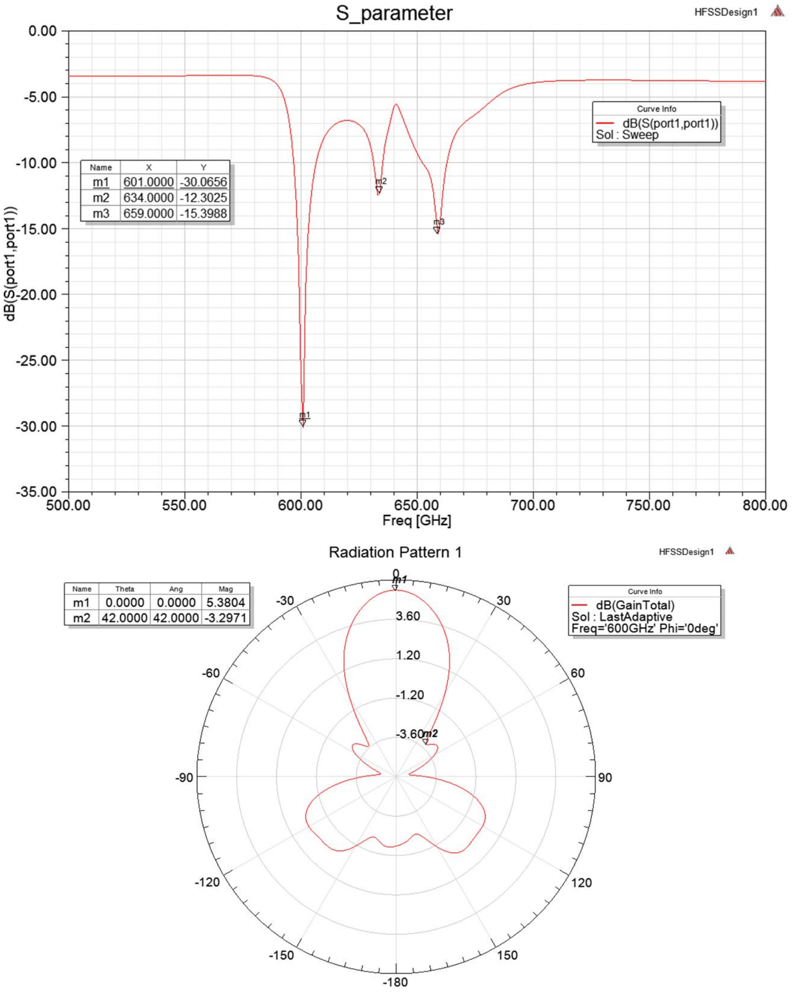
III. RESULTS

A maximum realized directivity of 6.99dB at 601GHz has been obtained with a return loss of -30dB and a gain of 5.3804dB as shown in Fig.3. The return loss, gain (radiation pattern), and directivity for a center frequency of 600GHz are shown in Fig.3. It is can be observed that the side lobe levels for the main beam is -3.29dB. Initial design without the lens yielded a return loss of -8.4782 at 630GHz, maximum gain of 2.4101dB at ±15° and directivity of 5.86dB as shown in Fig.4.

The results when compared with a dielectric lens antenna in a lower band of frequency of 0.25THz, the proposed antenna produced a return loss of -30dB at 0.6THz, whereas, the dielectric antenna gave a minimum of -18dB.

The gain and directivity of the proposed antenna is optimized by varying the gap length l. By doing so, the directivity and gain increased, but the loss also increased. So, the lowest loss was obtained in this proposed design.

In the simulation results, it can be observed that multiple band radiation is possible at 634GHz an also at 659GHz.



Name	X	Y
m1	601.0000	-30.0656
m2	634.0000	-12.3025
m3	659.0000	-15.3988

Name	Theta	Ang	Mag
m1	0.0000	0.0000	5.3804
m2	42.0000	42.0000	-3.2971

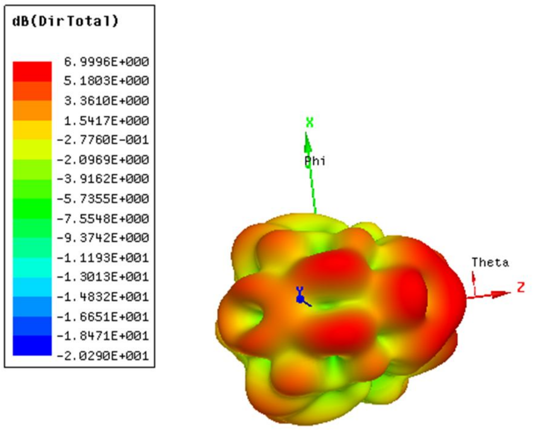
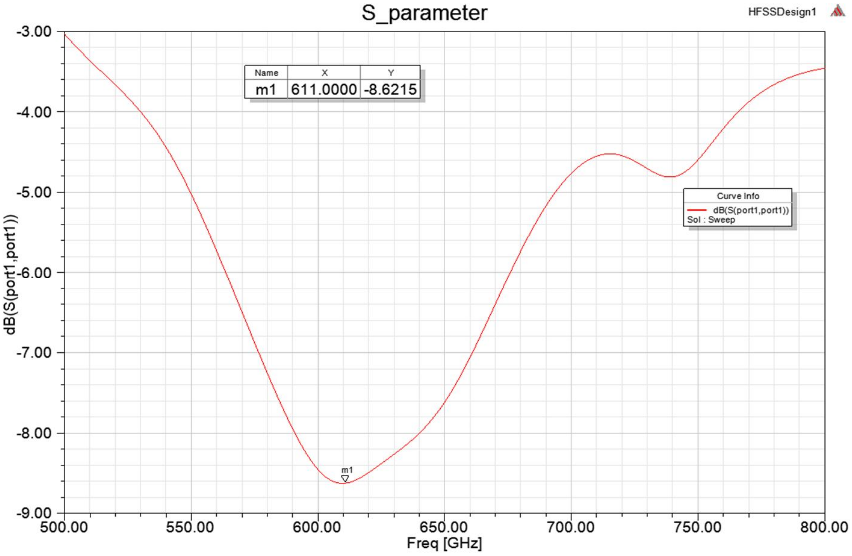
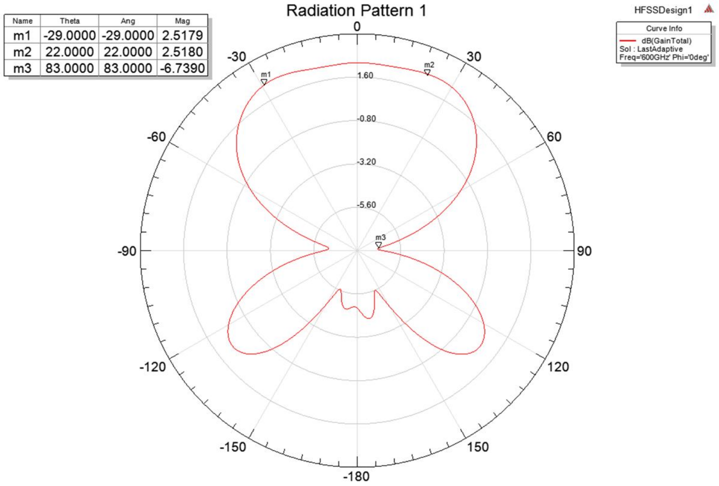


Fig. 3. (a) Return loss (b) Gain and (c) Directivity of the Proposed antenna at 600GHz





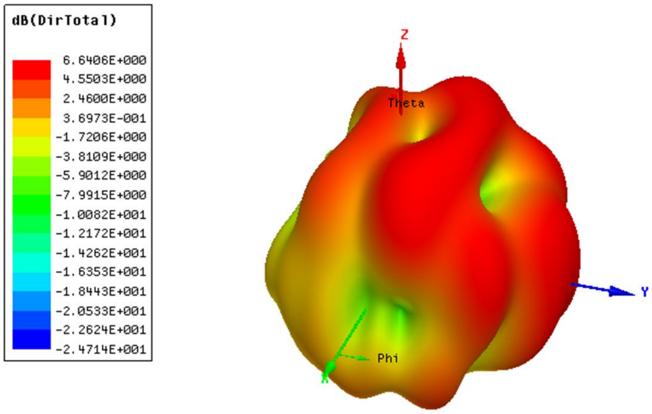


Fig. 4. (a) Return loss (b) Gain and (c) Directivity of simple microstrip patch antenna at 600GHz

IV. CONCLUSION

A directive hemi-elliptical antenna at low terahertz frequency is proposed, that is integrated with a microstrip antenna as a primary source. The design based on simulations and geometric optics, with the simulated results showing a maximum gain of 5.38dB, maximum directivity of 6.99dB, and very low return loss of -30dB at 601GHz overcoming the shortcomings of just a single patch antenna. The shortcomings are that for the microstrip antenna, the return loss is -8.47dB but for an antenna to radiate it should be a minimum of -10dB. Also for this antenna the gain and directivity is low. The gallium arsenide lens placed on top of the microstrip antenna improves the loss by 21.3885dB, the gain by 2.87dB, and the directivity by 0.35dB. In the future, the integrated hemi-elliptical antenna is to be fabricated and tested. Then, it should to be integrated with embedded systems to test for high rate data transfer communication applications.

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