THz Near Field Focusing using Cassegranian Configuration for EM Side-channel Detection

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***Abstract*—This paper presents near field focusing at THz frequencies using cassegranian antenna configuration used for the electromagnetic side-channel detection. The antenna is designed to produce the focused beam 30cm away from the aperture. The focusing is done in the near field region by moving the sub-reflector from the focal point along the axis. It is observed in the simulations that the subreflector position has to shift approximately 11 wavelengths along the axis to create the focus at the required location. The 3dB focus width of the antenna is ~ 4mm. Finally, simulation results of near field gain are compared with measurements and good agreement is observed.**

Keywords— Near Field, THz propagation, EM side-channels.

I. Introduction

The existence of EM side-channels poses risk to embedded system devices [1]. Previous experiments in the microwave range involve the investigation of the reflected waves from the surface of board, when incident by the radiated field from an antenna. For the incident area of few mm^2, which can be a region on a chip, THz near field focusing is preferred which involves shorter wavelengths and hence focuses the field in a small area.

Near field focusing is used in many applications, such as imaging, short range wireless systems, or wireless power transfer. In microwave frequencies, the focusing can be done by using different antenna configurations, which includes Fresnel zone plate lens antennas, microstrip, and reflect arrays [2]. At THz frequencies, small size of the patch element poses various fabrication challenges for the planar antennas. It is known that to focus the antenna, a symmetric quadratic phase is required at the aperture [3]. One of the simple and effective ways to get the near field focus beam is to create a spherical phase front at reflector aperture [4]. It has been established previously that at microwave frequencies the prime focus reflectors focus the beam when feed is out of the focus in the axial direction [5]. This technique is used here to design a dual reflector cassegranian configuration to achieve near field focusing at 300GHz. The reason to select the mentioned reflector configuration is based on the measurement system we have in the lab, which is VDI (Tx 210) and the VDI receiver (Rx 148) system. The diagonal horn antennas are used to transmit (Tx section) and receive (Rx section) power in the system. This inbuilt horn antenna in the system is conveniently used as a feed to design the focusing antenna.

This paper presents near field focusing at THz frequencies using cassegranian antenna configuration used for the electromagnetic side-channel detection. The antenna is designed to produce the focused beam 30cm away from the aperture. The focusing is done in the near field region by moving the sub-reflector from the focal point along the axis. It is observed in the simulations that the sub-reflector position has to shift approximately 11 wavelengths along the axis to create the focus at the required location. The 3dB focus width of the antenna is ~ 4mm. Finally, simulation results of near field gain are compared with measurements and good agreement is observed.

The rest of the paper is organized as follows. Section II describes the designed near-field focusing apparatus, Section III presents simulation results and comparison with measurements, and Section IV concludes the paper.

II. Near Field Focusing

The near field focusing is illustrated in Fig. 1. Initially, the subreflector is at the focal point and the beam is focused at the infinity (in far field). To focus the beam at finite distance, subreflector is shown to have shifted axially along z-direction by Δ. This will results in focusing of the beam at Zo, which is the distance from the main reflector to the beam focus. For the present case requirement, the focusing beam region should be within 25-30cm, which is in the near field region of the antenna. By shifting the subreflector in the axial direction will focus the beam at finite distance. To focus the beam in the near field region, i.e. $Z_o < 2\frac{D^2}{\lambda}$, the feed should be displaced by more than $2(F/D)^2$ [2]. Here we have investigated the focusing by displacing the subreflector along the axis.

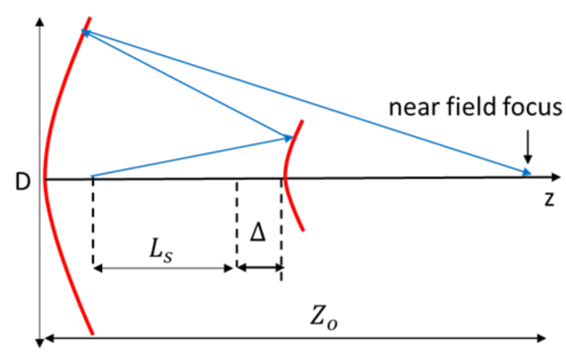

Fig. 1 Illustration of near field focusing in cassegrain configuration by shifting the sub-reflector from focal point.

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III. Simulation Results

The antenna configuration shown in Fig. 1 was designed and simulated in CST microwave studio. Main reflector diameter F/D is 0.6, where F is the focal length and D is the diameter respectively. The overall geometry can be derived using the procedure given in [6]. The diagonal horn antenna was used as a feed in the simulation model. Initially, the cassegrain antenna was designed for far field directivity of ~ 49dBi with 11 dB subreflector edge taper. The subreflector is positioned at 5.2 cm away from the main reflector vertex. Then, to focus the beam in the near field region, subreflector position was shifted axially, along the z-axis by Δ, as shown in Fig. 1. To get the focus, for Z_0 values between 25-35cm, simulations were done for the various values of Δ with an increment of 1mm. It is found that to focus the beam in the required region, subreflector shift Δ is around 11λ, where λ is the free space wavelength at 300 GHz.

Fig. 2 shows the normalized power density along transverse yz-plane in front of the antenna aperture. The subreflector position is at z=0, y=0. The plot shows the high power density in the region centered around 30 cm. The depth of focus along z direction is ~ 10 cm. It is observed in the simulations that the focus is sensitive with the position of the subreflector and the focusing spot size depends upon F/D of the main reflector. Fig. 3 shows the normalized power density in the focal plane (xy-plane), which is 30 cm away from the subreflector. The focal plane dimension along x and y directions is equivalent to the diameter of the main reflector, which is 10 cm. It is observed for the Fig. 3, that the simulated 3dB focus width is ~ 4mm.

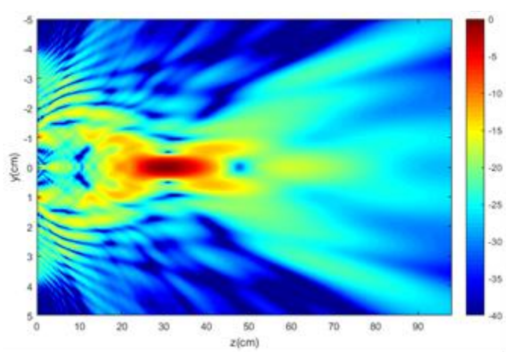

Fig. 2 Normalized power density in transverse yz plane (sub-reflector position is at z=0, y=0).

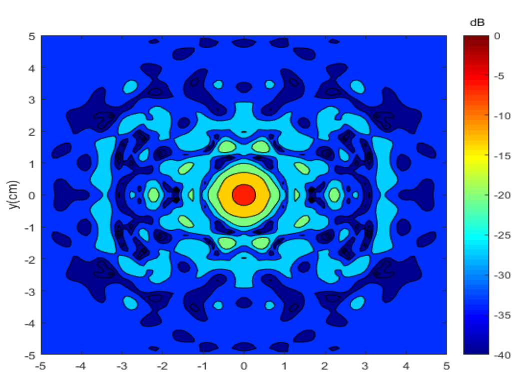

Fig. 3 Normalized power density at the focal plane (30cm away from sub-reflector).

The simulation model was fabricated using 3-D printing technology and tested. Fig. 4 shows the fabricated antenna prototype. Fig. 5 shows the comparison between measured and

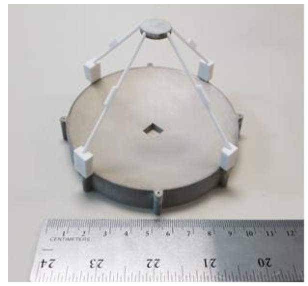

Fig. 4 Fabricated antenna prototype.

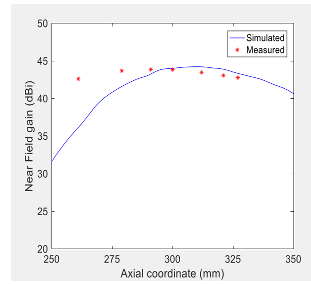

Fig. 5 Comparison of simulated and measured near field gain.

simulated near field gain (focusing gain), which shows good agreement. Gain is calculated by performing transfer measurements for finite number of points along the axial direction, between 25 to 35 cm, for both horn to horn and horn to designed antenna, using VDI Tx and Rx system. The measured results shows the maximum focus around 30cm, which is also evident from simulated results of Fig. 2. The fabricated prototype shown in Fig. 2 was used to detect the EM sidechannel from FPGA chip, by focusing the power density around the chip area.

IV. Conclusions

This paper presented the near field focusing at THz frequencies using cassegranian antenna configuration used for the electromagnetic side-channel detection. The antenna is designed to produce the focused beam 30cm away from the aperture. The focusing is done in the near field region by moving the sub-reflector from the focal point along the axis. It is observed in the simulations that the sub-reflector position has to shift approximately 11 wavelengths along the axis to create the focus at the required location. The 3dB focus width of the antenna is ~ 4mm. Finally, simulation results of near field gain are compared with measurements and good agreement is observed.

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