

# A Novel Approach for Generation of Hermite - Guassian beam Using Patch Antenna Array for High Speed Communication in Wireless Network Applications

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**ABSTRACT:** The growth in wireless network applications increased the usage of mobile phones and other transportable electronics devices. Hence there arises a need for high speed communication to avoid congestion in wireless system. This motivated us to develop a method for the generation of millimeter-wave Hermite-Gaussian (HG) beams by designing patch antenna. Due to the congestion of the frequency spectrum and the needs of higher data rates, millimeter wavelength is preferred. Four inset-fed microstrip patch elements with microstrip feed network is used for generating a HG11 beam. The antenna was designed on a FR4 (Flame Retardant) epoxy substrate. FR4 is a grade designation assigned to glass-reinforced epoxy laminate sheets, tubes, rods and Printed Circuit Board (PCB). The array is designed using HFSS (High Frequency Structured Simulator), a standard industrial tool for full wave electromagnetic simulation. The total volume of the designed antenna is 8 mm x 8 mm x 0.125 mm. The array return loss and radiation pattern both have been characterized in E-band. The VSWR (Voltage Standing Wave Ratio) and gain are also been measured.

**KEYWORDS:** E-band, inset-fed, Hermite-Gaussian (HG), microstrip patch antenna array, millimeter wave.

## I. INTRODUCTION

The rapid growth of mobile communications and wireless Internet access has created a substantial demand for advanced wireless techniques. There are some challenges in wireless communication designs such as multipath fading, Doppler effect and cochannel interference etc. that degrades the signal quality [1].

Today, information is largely exchanged through wireless channels. Though, dense coding and channel sharing techniques are utilized, the expeditious increase in the use of portable electronics has driven congestion in the available radio bands. Therefore it is very necessary to increase the channel capacity for future wireless systems also. The use of Orbital Angular Momentum (OAM) states provides a solution to the problem of congestion in radio band. In optical fibre communication, orthogonal Languerre Guassian (LG) beams have been multiplexed through Mode division multiplexing [2].

The Hermite-Gaussian (HG) beams also have the capability of increasing the channel capacity effectively. The HG modes are higher order modes that encodes large amount of information than that of LG mode [3]. The rectangular patch antennas are preferred more due to its low profile, light weight properties and ease of fabrication and have same dependency for both inset fed and probe fed in terms of feed position [4].

The demand for millimeter wave circuit has been emerging due to the development in CMOS technology that provides reduction in size and cost. The major aspect for selecting a substrate includes height, loss tangent, permittivity and cost. The FR4 (Flame Retardant -4) is known to be the best for packaging solutions of range 5

GHz and below [5]. We have calculated the results for  $HG_{11}$  beam by designing the antenna and simulating it in HFSS software.

Paper is organized as follows. Section II describes the literature survey of the other such systems designed. Section III describes the proposed method in which the antenna design and antenna specifications are detailed. The simulation and results are described in the Section IV. Finally, Section V describes the conclusion.

## II. RELATED WORK

Experimental circular phased array for generating OAM radio beams designed by Q. Bai, et.al in 2014, describes a circular phased array antenna that can generate Orbital Angular Momentum (OAM) radio beams in the 10 GHz band. The circular array consists of eight identical rectangular patches, which are excited by an asymmetrical microstrip corporate feeding network and back-fed with a  $50 \Omega$  SMA connector. The designed array has a radius of 0.6 wavelengths in order to minimise the radiation sidelobes and to keep the inter-element mutual coupling at a relatively low level. This array has an overall diameter of 60 mm and is manufactured on an FR4 substrate material with 1.6 mm thickness. The antenna consists of eight inset-fed patch elements and a microstrip corporate feeding network. The antenna was designed using commercial CAD (computer-aided design) software and the simulated performance of the antenna has been verified experimentally. The results confirm the generation of a twisted radio beam working at OAM mode  $-1$  [6].

Generation of OAM radio waves using patch antenna designed by C. Qin, et.al in 2014, introduces a feasible patch antenna to generate OAM-carrying radio beams. Eight identical printed dipole antennas with microstrip balun feedline are arranged in an octahedron cylindrical substrate. Every printed dipole is fed with unit amplitude but with a successive phase difference from element to element. The phase difference can be changed at the steps of  $0, \pm 45^\circ, \pm 90^\circ$ , and  $\pm 135^\circ$  to obtain mode numbers  $0, \pm 1, \pm 2$ , and  $\pm 3$ . Simulation shows that the OAM states of  $\pm 1, \pm 2$  and  $\pm 3$  achieve the expected results well, while the state of  $+3$  produce a deviation due to the radiation difference of the designed antenna element and traditional tripole antenna. Furthermore, the impedance matching of every port and increase the directivity of the antenna is achieved [7].

Study of microstrip line inset-fed and two layer Electromagnetically coupled rectangular patch antennas designed by Z. Ronghui, et.al in 2005 presents the parametric study of a microstrip-line inset-fed rectangular patch antenna and a two-layer Electro Magnetically Coupled (EMC) rectangular patch antenna. The influence of the inset position and the air thickness between the two layers on input impedance, resonant frequency, and bandwidth is investigated by using software IE3D (Integral Equation Three Dimensional). The final results show that the inset depth is the primary factor affecting the matching and the air thickness mainly affects the bandwidth. The tested two-layer antenna works at 6.1 GHz with a bandwidth ( $S_{11} / \text{spl} \text{les} / -10\text{dB}$ ) of about 11%, 8dB gain. The 3-dB beamwidth in the E-plane and H-plane is  $57/\text{spl} \text{deg} /$  and  $70/\text{spl} \text{deg} /$ , respectively [9].

Microstrip-fed quasi-Yagi antenna with broad band characteristics designed by Y. Qian, et.al in 1998, provides a compact and uniplanar antenna with broadband characteristics. The novel Yagi-like printed dipole array antenna is fed by a microstrip-to-coplanar strip transition, and uses the truncated microstrip ground plane as its reflecting element. An X-band prototype measures a bandwidth of 17%, with 6.5dB gain, 18dB front to back ratio, and lower than -15dB cross polarisation level at 10GHz. This antenna should find wide applications in wireless communication systems, power combining and phased arrays as well as millimetre-wave imaging arrays [11].

## III. PROPOSED METHOD

In the proposed method, the microstrip patch antenna is designed to generate millimeter-wave Hermite-Gaussian (HG) beams at E-band. A  $HG_{11}$  antenna array is designed using high performance FR4 (Flame Retardant) laminates using HFSS software. The proposed antenna array is the first fabricated antenna array to generate a HG mode radio beam. This method is preferred because of its high performance and also more information can be encoded. In this design the antenna array consists of four identical patches, which are excited with the appropriate phase placement to generate the  $HG_{11}$  beam.

The antenna is designed on FR4 epoxy substrate. The Length and width of a patch are 1.025mm and 1.58mm respectively. The Width of a feed network is 0.66 mm and the distance between patch edges is  $0.8\lambda$ . A gap of  $0.8\lambda$  between the patch edges has been chosen in accordance with the simulation analysis using ANSYS (Analysis system) HFSS. The relative permittivity of the antenna is 3.75 and the loss tangent is 0.018. The impedance of the inset-fed antenna is approximately  $100\Omega$ . The total volume of designed antenna is 8 mm x 8 mm x 0.125 mm. The microstrip transmission line feeding network is designed to achieve impedance matching and the phase shift scheme. The designed antenna works at 32 GHz. The figure 3.1 shows the single patch dimensions of the antenna array and the figure 3.2 shows the overall design of the antenna array.

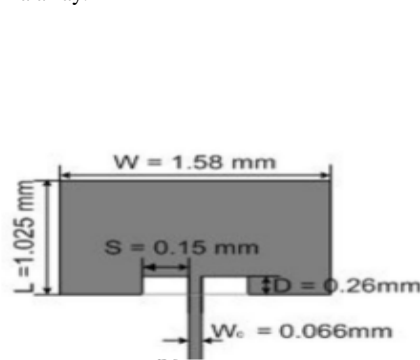


Fig 1 Single inset-fed patch antenna dimensions

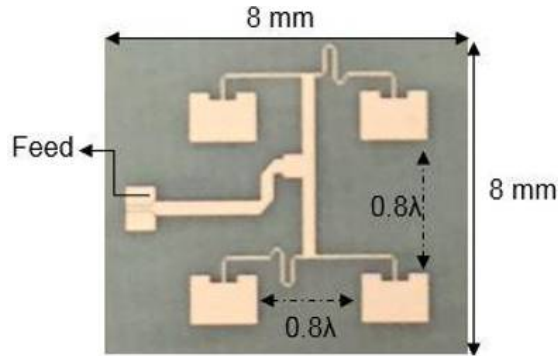


Fig 2 Designed antenna array

#### IV. EXPERIMENTAL RESULTS

The antenna array radiation patterns were simulated using ANSYS HFSS where the operating frequency was set to 32GHz. The simulated results are shown in the figures 4.1 to 4.5.

##### S – Parameter

It represents the input – output relationship between ports (or terminals) in an electrical system. Here  $S_{11}$  is measured, where  $S_{11}$  represents how much power is reflected from the antenna, and hence it is called as reflection coefficient or return loss. The return loss is shown in the figure 4.1 that operates at 32GHz.

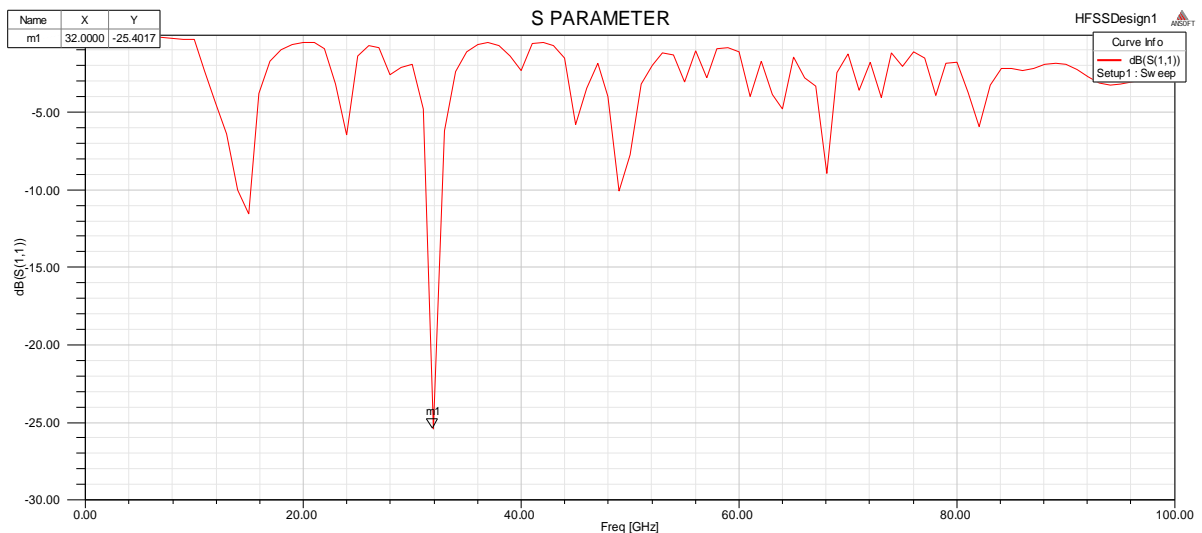


Fig 3 S – Parameter

**Radiation pattern**

Radiation pattern (or antenna pattern or far-field pattern) refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source. The antenna radiates at -47 dB at 0 degree that is shown in the figure 1.4. In this far field radiation pattern is measured which is represented graphically as a plot of the field strength and the directive gain.

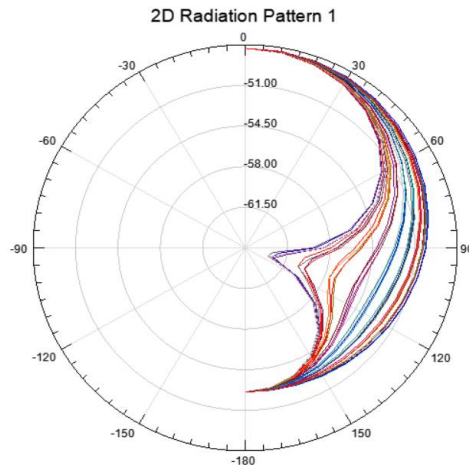


Fig 4 Radiation pattern

**VSWR**

VSWR is a function of reflection coefficient, which describes the power reflected from the antenna. It is determined from voltage measured along a transmission line leading to an antenna. The value of VSWR at 32 GHz is 0.936 dB that is shown in the figure 4.3

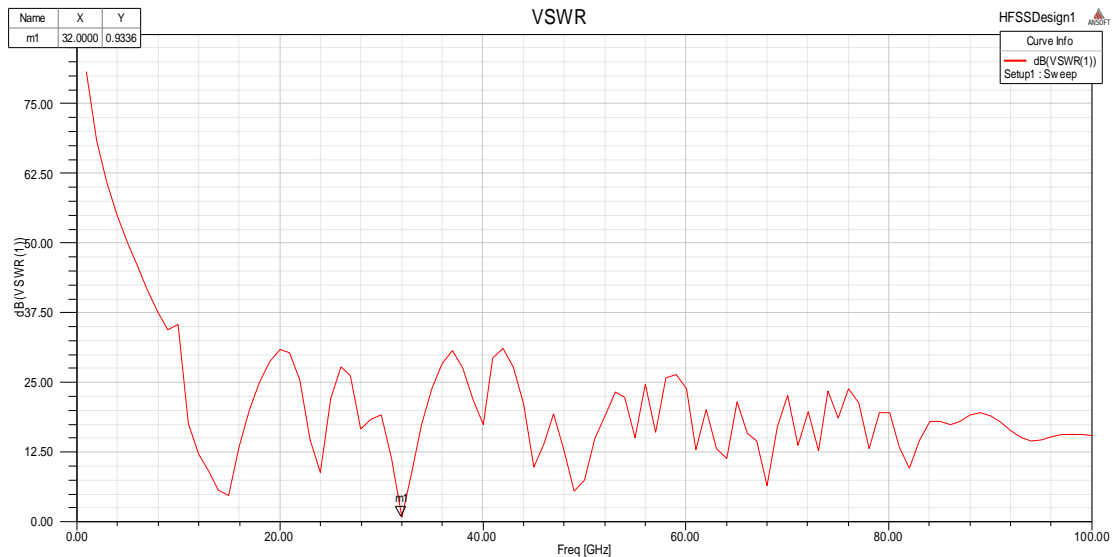


Fig 5 VSWR

**Gain**

Gain is a key performance number which combines the antenna's directivity and electrical efficiency. A plot of the gain as a function of direction is called the radiation pattern. The peak gain of the antenna is -27.69 dB, that is shown in the figure 4.4.

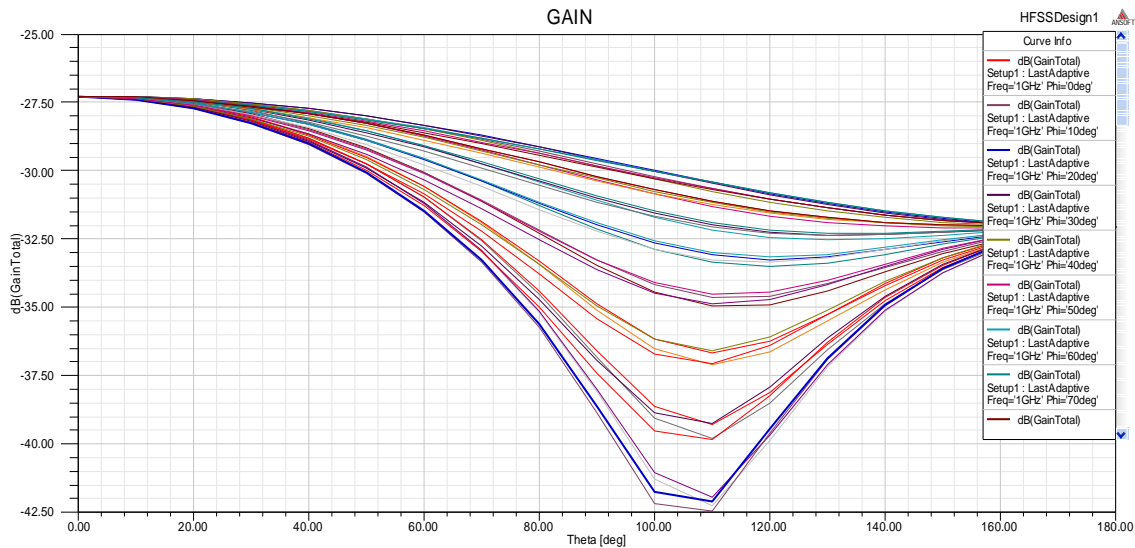


Fig 6 Antenna gain

**Directivity**

Directivity is a fundamental antenna parameter which is a measure of how 'directional' an antenna's radiation pattern is. An antenna that radiates equally in all directions would have effectively zero directionality. The peak directivity of antenna is -26.023 dB which is shown in the figure 4.5.

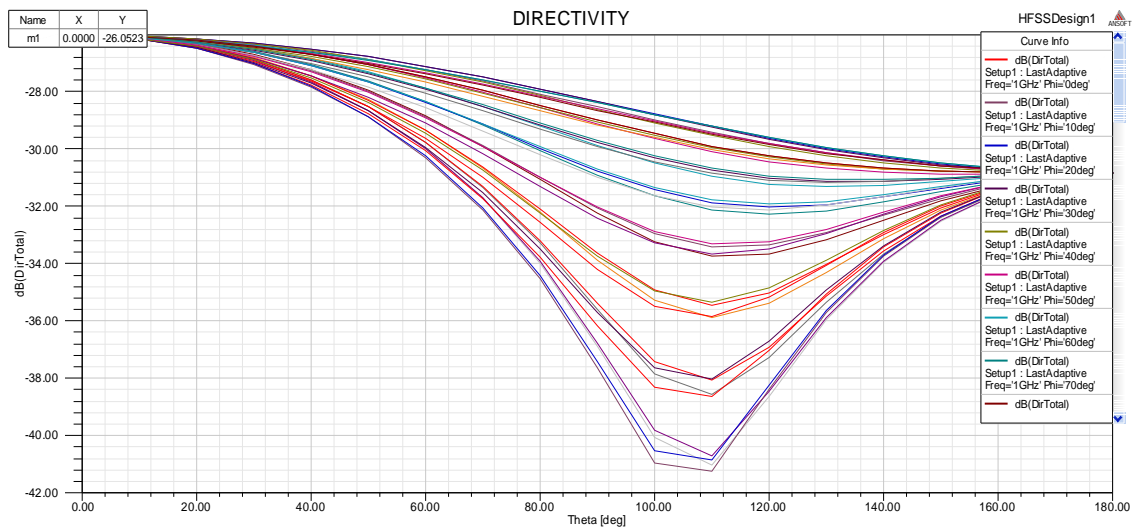


Fig 7 Directivity

## V. CONCLUSION

We have implemented an effective method for the generation of Hermite-Gaussian beams at millimeter wave. The return loss and radiation pattern have been characterized in E-band. The simulated results are in good agreement with each other, confirming that the antenna array can generate the HG<sub>11</sub> mode radio beam. The radiation efficiency of the HG<sub>11</sub> array calculated is 68.12% that is calculated from peak value of gain and peak value of directivity obtained from simulation. The proposed antenna array is the first antenna array to generate a HG mode radio beam. In future some better algorithms can be proposed that provides even more efficiency with easy implementation in hardware.

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