IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Hexa-Band Generation of SIW Embedded Dielectric Resonator Antenna at THz Frequency

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ABSTRACT

This paper presents a novel design of a Substrate-Integrated waveguide-embedded Dielectric Resonator Antenna operating at terahertz frequencies, which is suitable for the next generation of wireless communication systems, including 6G applications. A novel mickey mouse shaped embedded DRA is constructed from Rogers RT5880 material. This antenna is fed by "U" with rectangular spiral feed through the cross aperture. The SIDRA provides frequencies of 6.41THz, 8.29THz, 12.07THz, 17.3THz, 20.4THz, 27.5THZ with a maximum return loss of 32dB.

INTRODUCTION

Terahertz band technology is a rapidly developing field in wireless communications. The terahertz frequency range has several advantages including higher bandwidth, lower interference, and greater security [1]. Terahertz waves can transmit data at rates of up to 1 Tbps, which is 10 times faster than the current 5G technology [2]. Terahertz waves, have shorter wavelengths and higher frequencies than millimeter waves. Terahertz waves should be able to carry more data more quickly, though they will not be able to propagate as far [3]. A Dielectric Resonator Antenna is suitable for many modern wireless applications [4]. There are various basic DRA shapes like rectangular, triangular, and cylindrical, etc [5]. A Dielectric Resonator Antenna operates based on the resonance of a dielectric material rather than a metallic conductor. DRA has received tremendous attention because of several attractive features such as its small size, lightweight, low loss, and ease of excitation [6,7]. The antenna design incorporates an embedded dielectric resonator antenna (DRA) to enhance the bandwidth and eliminate unwanted modes to stabilize the gain and radiation patterns are stable [8]. SIW is a rectangular waveguide-like structure in an integrated planar form, that can be synthesized by conducting cylinders vias or slots embedded in a dielectric substrate that is electrically integrated by two parallel metallic plates [9,10]. the SIW-fed DRA (SIW-DRA) is an excellent candidate for low-loss [11]. Because of the lack of longitudinal surface currents and the gap between the vias, the structure supports the TE mode. SIW guide can easily be integrated with active devices because the design of transition between the SIW guide and the planar technology is straightforward. [12]. The aperture in the ground plane will reduce the interference and ignore impedance mismatch due to multiple layers. Aperture design has to be taken into consideration to avoid impedance mismatch and to obtain more return loss [13]. A Novel feed, excitation method has been applied to the DRA for bandwidth improvement[14,15]. 6G is introducing more technologies and applications providing higher data rate, higher reliability, and secure efficient transmission [16].

The proposed antenna design is a substrate integrated with embedded DRA at terahertz frequency for 6G applications. This antenna will work in the frequency range of 1-29 terahertz

Design and development of antenna:

The proposed antenna design is SIW-based embedded DRA consisting of two different stages. The first stage comes with the design of SIW-based embedded DRA. The second stage corresponds to the design of feed with the cross slot. The design and development of the antenna have five-layered configurations as shown in Fig 1. It consists of two substrate materials those are Silicon and Rogers RT5880 with different thicknesses Ts1 and Ts2 and the metal is copper it is having thickness of 0.035.

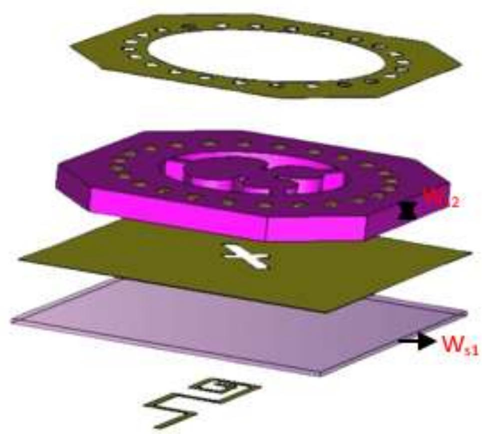


FIG :1 Five-Layered configuration

Design of SIW-based embedded DRA:

The Mickey Mouse-shaped embedded DRA is constructed from Rogers RT5880 material with a dielectric constant of $\varepsilon_r = 2.2$ and a loss tangent $\tan \delta = 0.0009$. A Dielectric Resonator Antenna (DRA) is fed by a 50 Ω feed. The Mickey Mouse-shaped embedded DRA is carried out in three different stages. The initial stage of the DRA design is a cylinder and the next stage is followed by three different slots and the first slot is placed at the top of the cylinder and remaining two slots are placed at 45^0 degrees angle from the first slot. The final stage of design comes with bending the edges of the slots with an angle of 115.50^0 degrees, and the three attachments are placed to make the DRA more stable. The SIW was designed from copper material with a substrate height of T_{s2} and vias are placed around the DRA which improves the antenna performance.

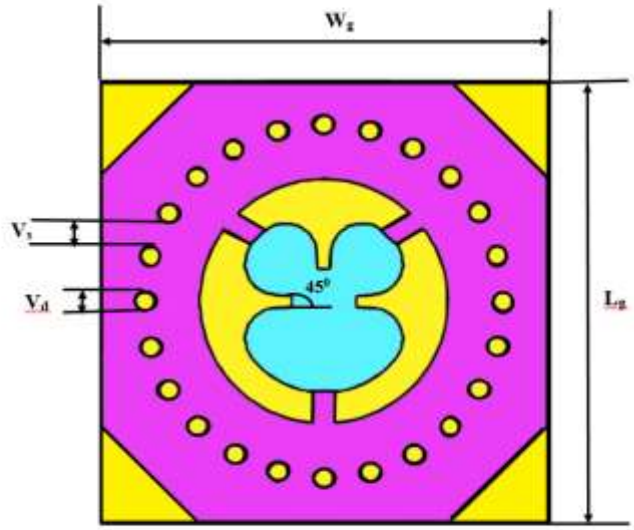


FIG: 2 Top view of proposed antenna

Dimensions of Design:

Parameter	**Description**	**Value (μm)**
L_s	Length of the substrate	13.95
W_s	Width of the substrate	13.95
T_{s1}	Thickness of the substrate 1	0.254
T_{s2}	Thickness of the substrate 2	1.27
$L_g = L_p$	Length of patch and Length of ground	13.95
$W_g = L_p$	Width of patch and width of ground	13.95
$T_p = T_g$	Thickness of patch and thickness of ground	0.035
V_d	Diameter of Vias	0.3
V_n	No. of Vias	24
Vs	Vias spacing	1.46

Design of feed:

The feed is designed in three different stages. The first stage of feed is microstrip line. And the second stage is spiral feed. Final stage of feed is comes with a “U” shaped brick is attached in between the microstrip and spiral feed. The antenna is fed by aperture feeding through the cross slot and the cross slot is placed at the ground plane with unequal lengths. The ground plane is having the length Lg and width W_g and the thickness is Tg. This feed is used to excite Dielectric Resonator Antenna, which resonates at six frequency bands.

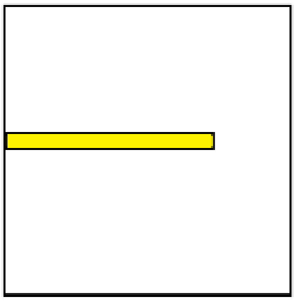


FIG: 3 Stage - 1

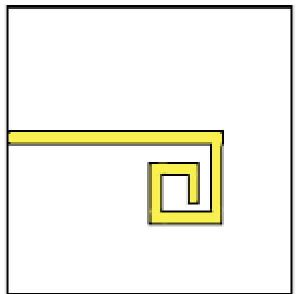


FIG: 4 Stage - 2

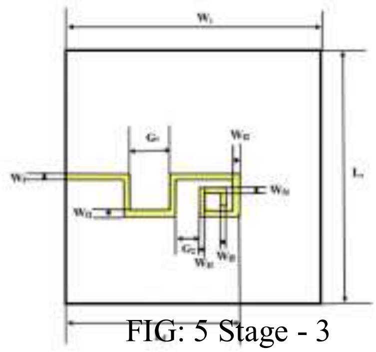


FIG: 5 Stage - 3

Feed Dimensions:

Parameter	**Description**	**Value (µm)**
$W_f = W_{f2}$	Width of the feed	0.34
L_f	Length of the feed	9.475
W_{f1}	Width of the feed at “U” shape	0.35
$W_{f3}=W_{f4}=W_{f5}$	Width of the feed at spiral	0.3
G_1	Gap at “U” shape	2.2
G_2	Gap between “U” shape and spiral	1.3

The proposed antenna is fed by novel feed shape. The design and development of feed consists of three different stages. The first stage of proposed feed design is microtrip line. The microstrip line provide single frequency band i.e. 21.8THz. The second stage comes with a rectangular spiral is attached at one end of the microstrip line. The rectangular spiral feed provides the three frequency bands i.e 4.22THz, 7.17THZ, 23THZ. The final stage of the feed is “U” with rectangular spiral. This optimized feed shape generates the six-frequency bands i.e 6.41THz, 8.29THz, 12.07THz, 17.3THz, 20.4THz, 27.5THz with different bandwidths.

Feed configurations:

Shape of the Feed	Frequency (THz)
Microstrip	21.8
Rectangular Spiral	4.22, 7.17, 23
“U” with rectangular spiral	6.41, 8.29, 12.07, 17.3, 20.4, 27.5

Results :

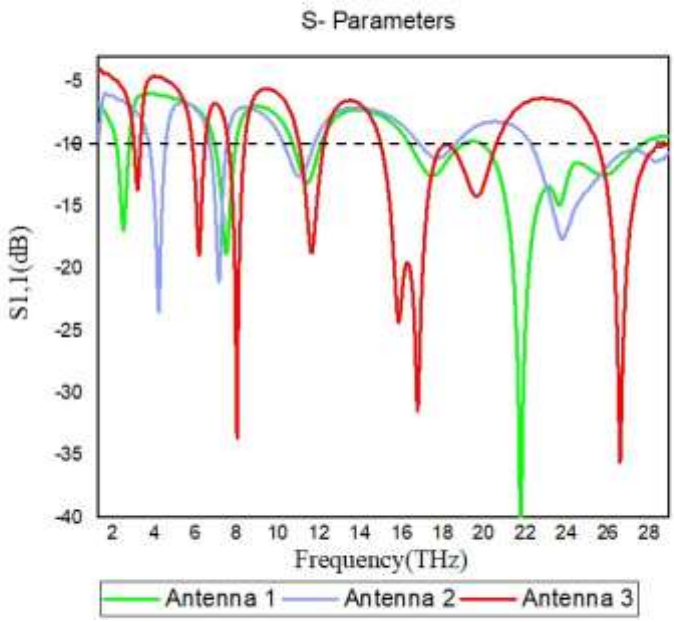
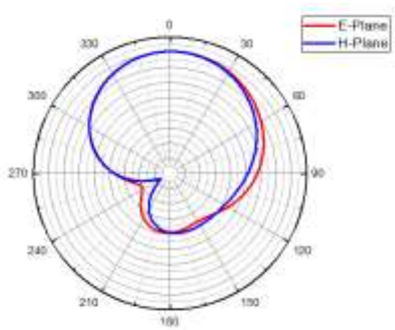
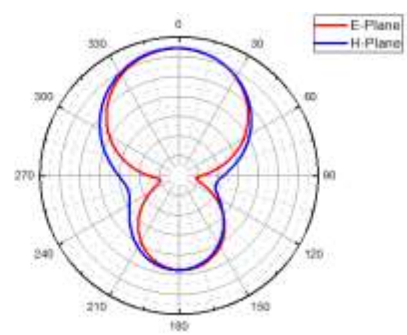


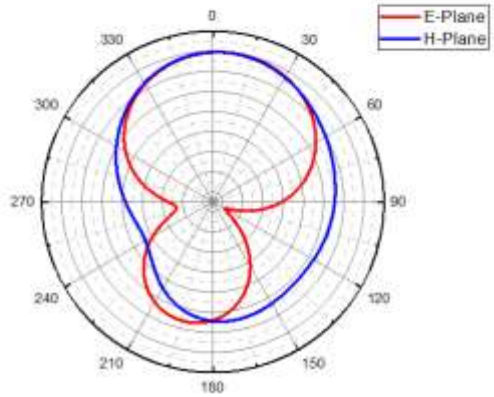
FIG : 6 . Parametric analysis of Feed



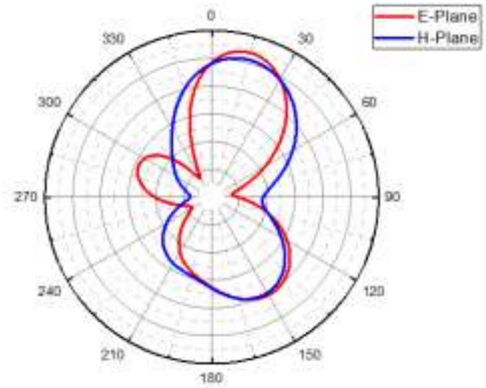
(a)



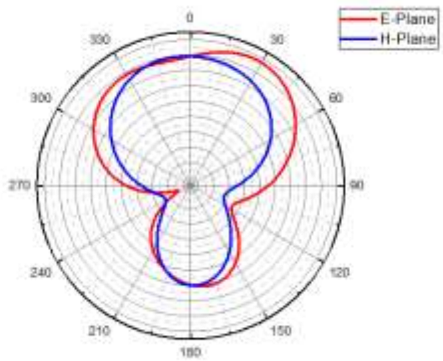
(b)



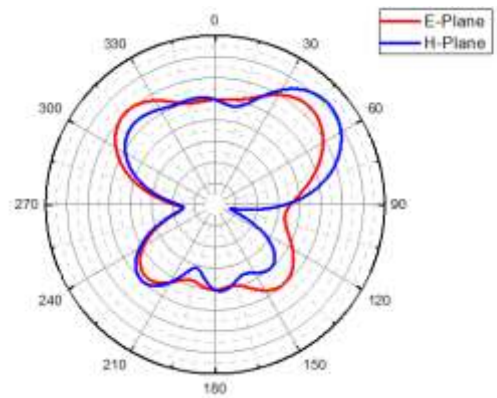
(c)



(d)



(e)



(f)

FIG : 7 . E-plane and H-plane radiation patterns at (a) 6.41 THz, (b) 8.29 THz, (c) 12.07 THz (d) 17.3 THz (e) 20.4 THz , and (f) 27.5 THz.

Conclusion:

A novel-shaped DRA embedded in Substrate Integrated Waveguide(SIW) with a novel feed configuration for the generation of 6 different frequencies with bandwidths is reported in the paper. The proposed design offers a compact size with a very low profile in the terahertz frequency range of 1-29 THz operating at 6 frequency bands 6.41, 8.29, 12.07, 17.3, 20.4, and 27.5 with bandwidths of 6.7%, 6%, 6.1%, 4.1%, 3.6%, 5.75%. So, the proposed embedded DRA is a potential candidate for 6G applications

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