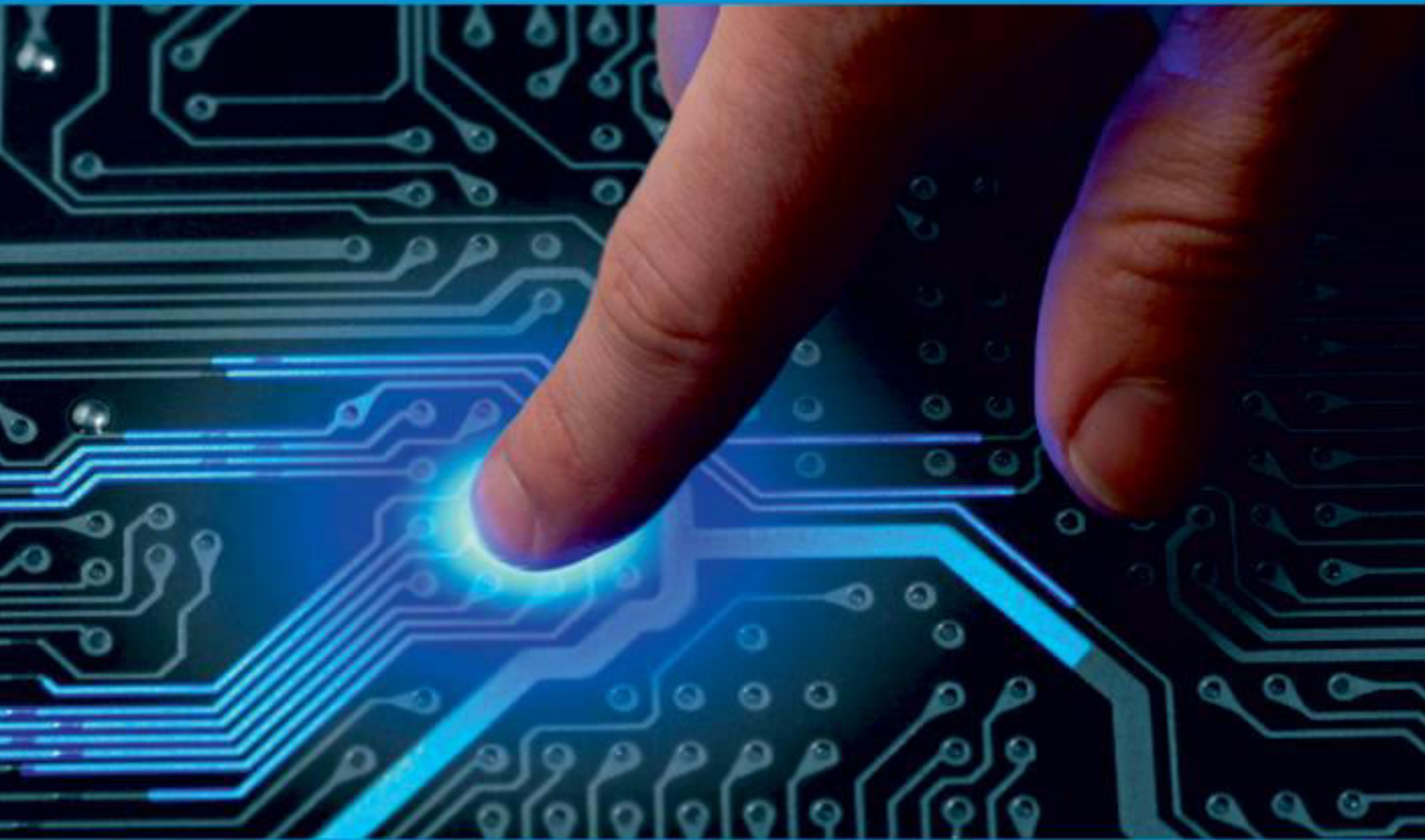
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 10, Issue 5, May 2022

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.165

International Journal of Innovative Research in Computer and Communication Engineering

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.165 |

|| Volume 10, Issue 5, May 2022 ||

| DOI: 10.15680/IJIRCCE.2022.1005206|

Design and Analysis of Fractal Loaded MIMO Radiator for Thz Applications

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ABSTRACT: A compact Super Wide Band (SWB) four element multiple-input-multiple-output (MIMO) antenna having an overall dimension of 125 μm × 125 μm is presented for application in Terahertz (THz) frequency spectrum. This SWB MIMO antenna configuration consists of orthogonally placed four coplanar waveguide (CPW) fed half elliptical patch antennas with connected ground planes. Three types of fractal curves are suitably applied on this MIMO configuration to obtain enhanced impedance bandwidth and good isolation between antenna elements. The proposed design exhibits an impedance bandwidth (S11≤ −10 dB) from 0.72 THz to 10 THz and an isolation more than 20 dB between all four antenna elements is obtained over the entire band of operation. Stable radiation characteristics with moderate amount of gain are also observed. The proposed design consists of more number of antenna elements with relatively smaller physical dimension compared to the existing SWB MIMO antenna designs available in literature in THz frequency range. Therefore, this proposed MIMO antenna design can be used for THz applications in future beyond the fifth generation (B5G) technology.

I. INTRODUCTION

With the increase in services and users of wireless communication day-by-day, the demand for utilizing Terahertz (THz) and Sub-terahertz (S-THz) spectrum in the foreseeable future is growing specifically for preventing congestion and traffic in microwave and radio frequency spectrum. Terahertz communication band which is least explored in wireless communication services can be explored to fulfil these demands[1].This band shows rich potentials in imaging, communication, screening and sensing applications[2]. Due to these notable and profitable features of this band, antenna engineers have come up with various antenna designs for THz systems.

THz frequency spectrum has wide range of applications and various advantages. However, it suffers from lack of practical compact sources for which the widespread use of this technology have been restricted [3]. Apart from this a high attenuation path loss in THz spectrum is another factor for limiting its widespread application. Several researchers have designed different high gain antenna structures to overcome this attenuation problem such as Yagi-Uda antenna [4], Bowtie antenna [5], On-chip antenna [6], MEMS helix antenna [7], Metamaterial based antenna Journal Pre-proof [8], Surface Integrated Waveguide antenna [9], reconfigurable leaky-wave antenna [10], lens antenna [11] and corrugated Horn antenna [12]. Antenna which supports more than a decade ratio bandwidth (10:1) is termed as Super Wideband (SWB) antenna [13]. At lower frequencies, the bandwidth is enhanced by utilizing fractal antenna geometries. The challenge faced by wideband antenna structures is fading. This challenge was tackled by exploring multiple-input-multiple-output (MIMO) techniques [14].

In this paper, a four element MIMO antenna system with an overall physical dimension of 125 μm x 125 μm has been reported for SWB operation. A co-planar waveguide (CPW) fed half elliptical patch antenna has been designed on which elliptical fractal slots are etched along with Minkowski fractal curve loaded ground plane. As a result of that, the proposed antenna design operates from 0.72 THz to 10 THz and the isolation between the antenna elements is obtained better than 20 dB for the entire frequency range of operation. This design has been simulated by CST microwave studio simulation software.

II. ANTENNA GEOMETRY

Structure of proposed method design consists of ground, substrate, patch and feed. The proposed antenna is designed by using polymide lossy substrate material with relative permittivity 3.5 and loss tangent of 0.0027 the substrate. The thickness of designed substrate material is 20μm, length of 125μm and width of 125μm. The dielectric constant (εr) of the substrate material is direct effect upon the antenna size and performance. This design starts by modifying a CPW

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fed elliptical patch antenna element where half of the radiating patch is cut. The ground plane on that side of patch, where radiating element has been removed, is modified. In this ground plane, firstly a narrow rectangular slot is etched and then the rest of the ground plane is extended vertically, which acts as a reflector and the omnidirectional elliptical patch antenna is converted into a directional antenna element. The ground plane at the other side of antenna element is truncated in triangular shape for better impedance matching purpose. The broadband behavior of the antenna is maintained with this type of modification in ground plane. The feedline, radiating patch and ground plane are made of 1µm thick copper sheet. Using high conductivity copper material, the ground plane and radiating patch of the antenna are designed. So, overall dimensions of proposed antenna is 125 x 125 x 20μm^3, which is shown in Fig. 1. To feed the antenna different techniques, i.e., microstrip line, coaxial coupling, and proximity coupling, coplanar waveguide feeding are available. In the proposed antenna coplanar waveguide feeding technique is used for a ease of fabrication procedure and good impedance matching and radiation pattern. In this MIMO antenna, waveguide port excitation sources are chosen. The geometric parameters of antenna are tabulated in Table 1. As per the mentioned measurements a fractal loaded SWB four element MIMO antenna are designed and simulated.

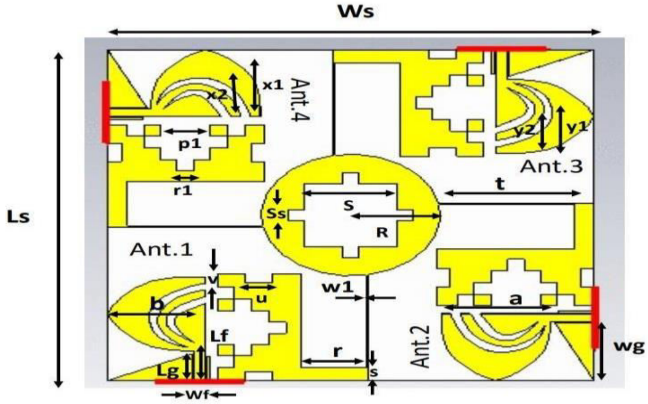

Fig 1: Structure of proposed method

Parameter	Dimensions(µm)
Ls	125
Ws	125
Lf	9
Wf	3
Lg	8.5
Wg	23.2
a	30
b	25
r	17.25
x1	18.5
x2	12.5
y1	12.5
y2	11.5
Ss	3
S	24
r	30
t	35.75
u	7
v	3.5
s	5
r1	4.33

Table 1: Geometric parameters of proposed method

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III. RESULTS AND DISCUSSION

The proposed antenna is simulates using electromagnetic simulation software CST (Computer simulation Technology) microwave studio. In terms of return loss, VSWR, input impedance, E-field and H-field radiation pattern, surface current distribution and radiation efficiency the radiation characteristics of proposed antenna is designed and investigated.

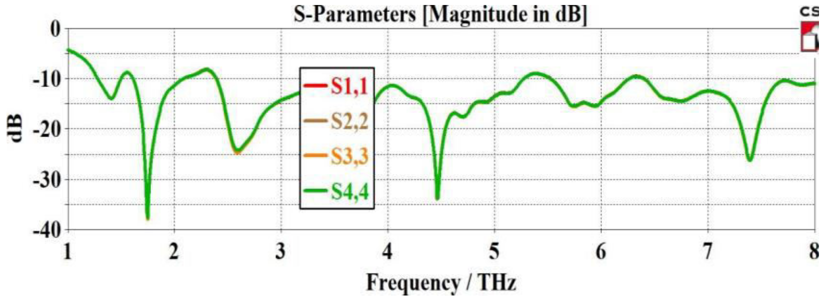


Fig. 2: The return loss characteristics of proposed method

Return loss which is measured in decibels (dB) is the ratio of incident power to the reflected power of the antenna. This return loss should be less than -10 dB and represented in S11 (dB) for an effective antenna. The simulated return loss graph of the proposed antenna is shown in Figure 2. The designed antenna has a reflection coefficient or return loss of -33.66 dB and bandwidth of 0.39 THz at the resonant frequency 4.47 THz. The wide impedance bandwidth of designed antenna is 14.4% ranging from 4.26 THz to 4.65 THz. Between the transmission line and antenna, impedance matching is the key factor to evaluate antenna performance.

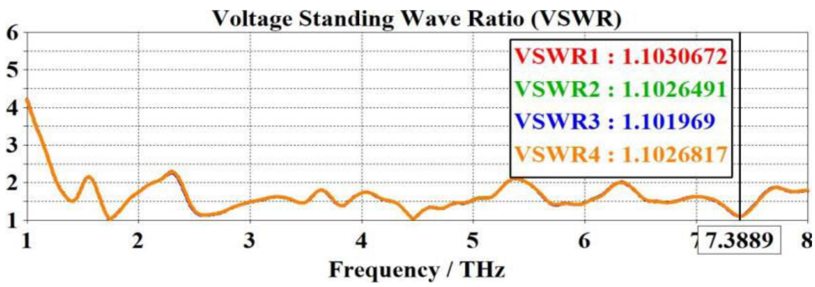
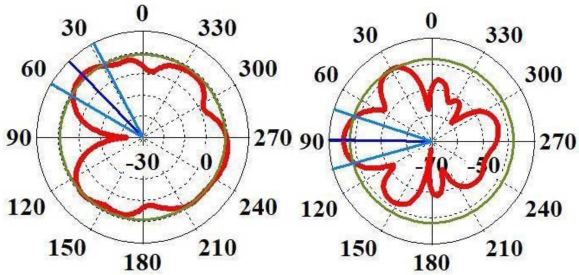


Fig. 3: The VSWR characteristics of proposed method

VSWR (voltage standing wave ratio) defines how much signal is reflected back to the source due to mismatch between source impedance and antenna impedance. VSWR for the proposed antenna is plotted as shown in Figure 3. VSWR values always should be less than 2 for good impedance matching. The signal reflected cause standing wave voltage to be present in the feed where it degrades the performance of antenna. The proposed antenna VSWR has a value of 1.10 at resonance frequency 7.34 THz. Preferably, the value of VSWR should be equal to 1 which means 100% power accepted, and having zero reflection.



a. E-Field pattern b) H-Field pattern

Fig. 4: The radiation pattern characteristics of proposed method

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The radiation pattern in both E-plane ($\Phi=0^0$) and H-plane ($\Phi=90^0$) of the proposed antenna is depicted in Figure 4.16. The orientation of antenna in order to that bore- sight direction toward the vertical direction by varying theta (θ) from 0^0 to 360^0 for fixed value of phi (Φ). The magnitude of the main lobe magnitude, main lobe direction, sidelobe level, and angular width respectively, are obtained at resonant frequency 4.46 THz. The antenna exhibits an almost bidirectional pattern in the E-plane and an omnidirectional circle-shaped pattern in the H- plane. However, changes are observed at the radiation patterns at a higher resonant frequency, 4.46 THz. The radiation pattern slightly deteriorates with the increase in operating frequency. At 4.46 THz, the E plane patterns look like a sectorial pattern with a shift in the direction of the main beam while the H-plane pattern is almost similar to omnidirectional oval-shaped.

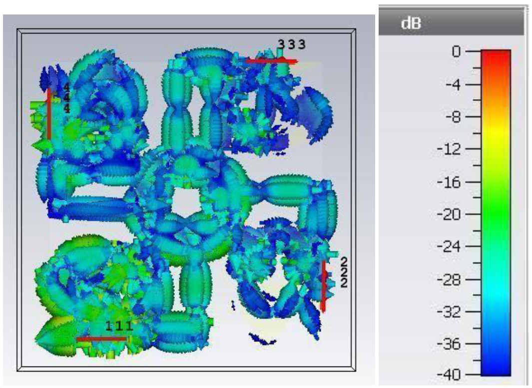
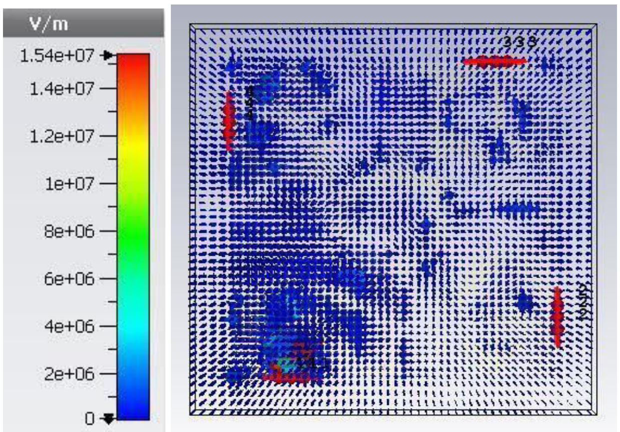


Fig. 5: The surface current distribution characteristics of proposed method

The surface current distributions of the proposed antenna at the resonating frequencies (1.75 THz, 4.47 THz and 7.38 Thz) are examined and presented in Fig. 5 at resonance frequency 4.47 THz. As observed, the distributed surface currents are highly concentrated along the edge of the feed line. Also, a high surface current concentration is noticed on the edges of the proposed patch structure.

However, the surface current distribution on the rectangular shaped structure is stronger and prominent at the higher resonant frequency which verifies its effect on the proposed antenna structure for the improvement of characteristics at the high resonance.



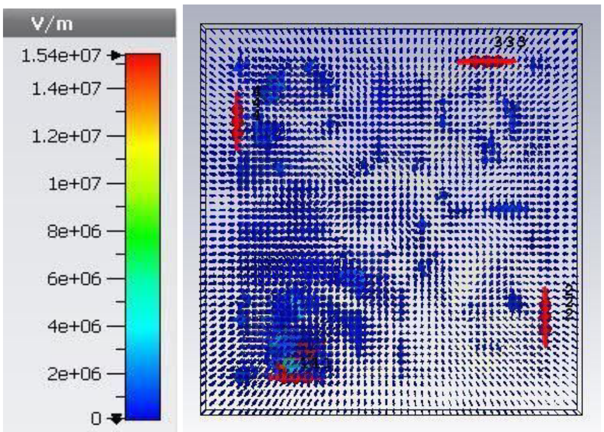


Fig. 6: The E-Field distribution characteristics of
characteristics of proposed method

Fig. 7: The H-Field distribution
proposed method

The e-field distributions of the proposed antenna at the resonating frequencies (1.75 Thz, 4.47 Thz and 7.38 Thz) are examined and presented in Fig.6 at resonance frequency 4.74 Thz. The h-field distributions of the proposed antenna at the resonating frequencies (1.75 Thz, 4.47 Thz and 7.38 Thz) are examined and presented in Fig. 7 at resonance frequency 4.74 Thz.

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IV .CONCLUSION

A four element MIMO antenna system has been designed and analyzed for Super Wide Band operation in THz frequency region. Due to the combined effect of all the fractal curves the required bandwidth enhancement for SWB operation and improvement in isolation between the antenna elements is obtained and the proposed MIMO antenna has an operational impedance bandwidth ranging from 0.72THz to 10THz. This proposed SWB MIMO antenna system can be a good candidate for different application in THz frequency range like sensing, imaging, communications and screening for weapons, explosives and biohazards as well as water content and human skin.

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