JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

# Design of substrate integrated waveguide based self-multiplexing antennas

**A. saritha**
**B. Tech Student**
**Department of ECE**
**RVR&JC College Of Engineering**
**Guntur, India**

**B.V.S.Y.Nandini**
**B.Tech Student**
**Department of ECE**
**RVR&JC College Of Engineering**
**Guntur, India**

**G.Hemanjali**
**Department of ECE**
**RVR&JC College Of EngineeringGuntur, India**

## Abstract:

This study introduces substrate integrated waveguide (SIW)-backed antenna designs capable of self-quadruplexing and self-diplexing, offering a compact, lightweight, and efficient solution for multiplexing applications in multiband communication systems. The self- quadruplexing antenna design integrates an SIW cavity with its top side modified to create four patches of different lengths. Each patch is fed by a separate 50-Ω microstrip feed line, enabling operation at distinct frequencies: 6.08, 7.31, 11.3, and 13.4 GHz. This design achieves peak gains of 4.1 dB, 4.96 dB, 6.2 dB, and 6.1 dB at the frequencies of 6.08, 7.31, 11.3, and

13.4 GHz, respectively, with an isolation levels exceeding 29dB. Meanwhile, the self-diplexing antenna, which utilizes a similar SIW cavity modification, incorporates two patches of different lengths to operate at 8 and 10 GHz. These patches are fed by two 50-Ω microstrip feed lines. This configuration achieves peak gains of 4.8 dB and 6.4 dB at the frequencies of 8 and 10 GHz, respectively, with isolation level exceeding 24dB. Both antennas are fabricated using an RT-Duroid (5870) suited for a wide range of applications in modern multiband communications, including wireless routers, portable devices, and custom-built communication systems.

Keywords:
Antenna, SIW, Self-diplexing, self-quadruplexing

## 1| INTRODUCTION

Research on small and multiband antennas has been spurred by the recent trend in microwave communication [1,2]. There are various multi-fed multiband antennas available in the public domain. To maintain smooth isolation between any feeding ports, they do, however, need an external multiplexer, which may take up extra space [1]. Self-multiplexing antennas, which do not require additional multiplexing circuitry, are a good solution to this problem. In this sense, a self-diplexing antenna with two feed lines can serve as a better option than conventional dual-band antennas [2,3]. The researchers have made multiple attempts to display various self-diplexing antennas. Since then various multiplexing antennas such as self-diplexing[4-6], self triplexing[8], self-quadplexing antennas[8-11] have been reported for dual-band and multi-band operations, respectively. It is observed that with the increase in the number of ports it is more challenging to maintain isolation among them. However, to meet the future communication demand there is absolute need of a self-multiplexing antenna. In this prospect, recently one self-quadruplexing antenna[12] is reported in the literature, which can operate at four different frequencies simultaneously. However, design method for an all- planar fed self-quadruplexing antenna with improved port isolations and compact size is highly desirable. The proposed model for Four port and three port like SIW-based quadplexing and siw based based diplexing are used for radiation and each patch is fed individually by distinct feed lines. The proposed quadplexing antenna offers four resonant frequencies around 6.08, 7.31, 11.3,13.4 GHz band when excited by the corresponding feed and diplexing antenna offers two resonant frequencies around 8, 10.06, GHz band when excited by the corresponding feed.

The equivalent circuit model of the proposed designs are also developed, and the tuning of each frequency band is analyzed without affecting the others. The proposed antenna is producing high isolation (>24dB) among all ports and a unidirectional radiation pattern.

## 2| ANTENNA STRUCTURE

### a) SIW based Self diplexing antenna design

While SIW-based antennas may offer some advantages, such as compact size and low profile, they may also be limited in terms of bandwidth and efficiency compared to other antenna structures. Additionally, the self-diplexing design may introduce complexity and potential performance trade-offs that could impact overall antenna performance. A rectangular SIW cavity (L x W = 24 x 24) is fed with two 50-ohm feed lines . The cavity is made using an RT/Duroid 5870 substrate with a relative permittivity of 2.33, a loss tangent of 0.0012, and a thickness of 0.787 mm. The cavity is bound by an array of short metallic vias. To minimize energy leakage, the vias are strategically placed within a range of distances from 1 p to 2 times the guide wavelength (λg). This SIW technique and low loss substrate help in achieving unidirectional radiation. While the design may aim to minimize energy leakage and achieve unidirectional radiation, it is important to consider potential interference or impedance matching issues that may arise from using two separate feed lines. Additionally, the complexity of the design and precise placement of vias may increase manufacturing costs and make it more difficult to replicate in mass production. The resonant frequency (fmn0) of the cavity can be calculated as

$$f_{mn} = \frac{c}{2\sqrt{\varepsilon_e}} \left[ \left(\frac{m}{L_e}\right)^2 + \left(\frac{n}{W_e}\right)^2 \right]^{1/2} \quad (1)$$

where m = 1, 2,..., n = 1, 2,..., μ = relative permeability, εr = relative permittivity, a = cavity length, and b = cavity width. The cavity design can be fine-tuned for particular frequency ranges by modifying the dimensions and layout of the vias. Adjusting the dimensions and via arrangement is crucial for achieving precise control over the radiation pattern and efficiency of the antenna system. viability of the substrate; Leff = effective length; Weff = effective width. The structure consists of two patches of varying lengths, labeled as l1 and l2, connected to separate ports, namely Port-1 (P1) and Port-2 (P2). As a result of this perturbation, there is an increase in capacitive loading, leading to a resonant frequency below the cut-off frequency. This decrease in resonant frequency contributes to achieving a more compact design, which is advantageous. The length and width of each parameter are mentioned in the caption of Figure 1. Utilizing the finite element solver HFSS v18 software is integral to the completion of the entire antenna design process. Further analysis and validation of the design will be elaborated on in the upcoming sections

The schematic diagram provides a visual representation of the proposed model, including specific measurements for each component. This detailed information allows for a clear understanding of the design layout and facilitates accurate implementation during the development phase. While the schematic diagram may offer detailed measurements, it may not necessarily guarantee accurate implementation as other factors, such as material properties and manufacturing processes, can also impact the final product. Additionally, relying solely on visual representation may overlook potential design flaws or limitations that could arise during the development phase.

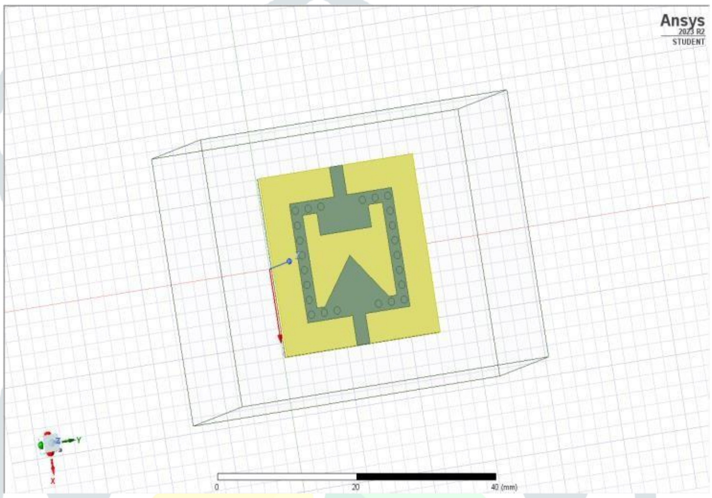


Figure 1: Schematic Diagram of the Proposed Model (L = W = 24, l = 12.5, ws = 12` = 12.5, rect = 8 w = 3, triangle = 10 w = 6.25, distance between vias = 2, diameter of via =1) All dimensions are in millimeters.

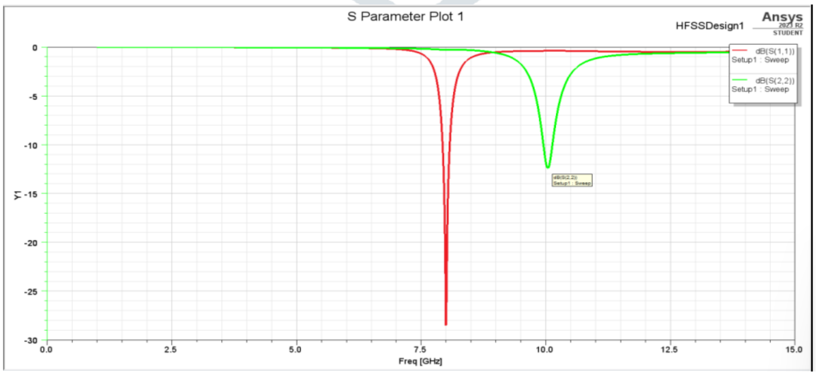


Figure2: S parameter responses of the antenna

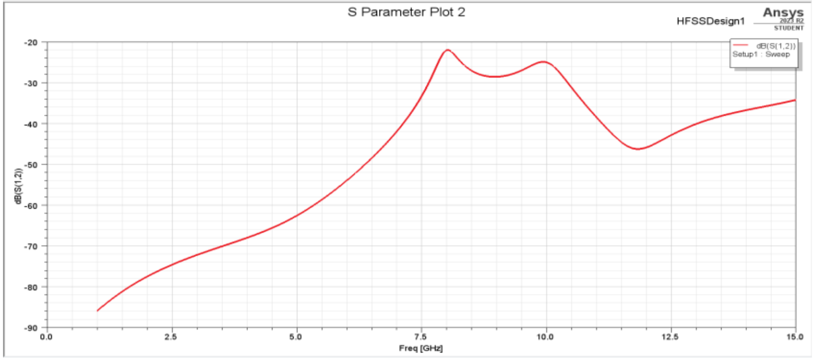


Figure3: S12 parameter response

## b) SIW based self-quadruplexing antenna

uses a special waveguide technology for high directivity and gain. This design boosts signal strength and enhances performance in communication systems. It is also followed by a self diplexing antenna design, but approached with different dimensions and different frequencies. The top view of the antenna structure is shown in figure . The layout is very simple. A rectangular SIW cavity (L x W = 27 x 27) is fed with four 50-ohm feed lines. The cavity is made of an RT/Duroid 5870 substrate with a relative permittivity of 2.33, a loss tangent of 0.0012, and a thickness of 0.787 mm. The cavity is bounded by an array of short metallic vias. To minimize energy leakage, the vias are positioned, ensuring that the distance between them satisfies 1p ≤ d ≤ 2 λg. This special technique and low-loss substrate help in directing radiation in one direction. The antenna design supports multiple feed points for various frequencies and uses shorting metallic vias to reduce energy leakage. These techniques create a straightforward layout with effective one-way radiation. You can find the resonant frequency (fmn0) of the cavity using the formula (1). As seen in Figure 4, the top side of the cavity is perturbed with an irregular slot. It forms four patches of different lengths and is connected to four separate ports, that is, Port 1 to Port 4, respectively. Due to this perturbation, capacitive loading increases, and as a result, the resonant frequency is obtained below the cut-off frequency. This decrease in resonant frequency benefits achieving high compactness. The length and width of each parameter are mentioned in the caption of Figure4.

Figure4 : schematic diagram of the proposed model(L=W=27 ,ls=15.5 ,ws=15.5 ,rect1: l=6.5 w=4.7 ,rect2:l=5, w=4.7 ,triangle1: l=13 w=3.75 ,triangle2:l=7.75 w=2.75 ,diatance between vias=2,diameter of via =1)All dimensions are in millimeter.

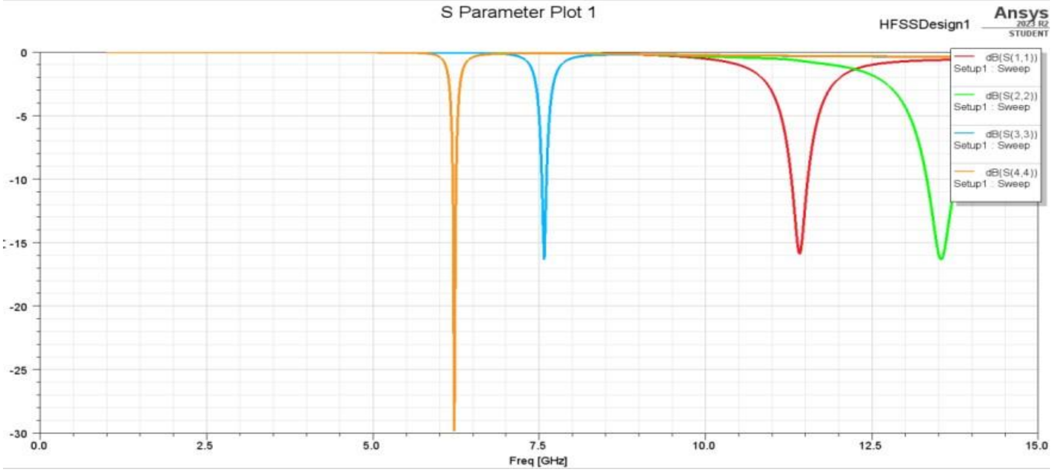


Figure5: S parameters responses of the antenna

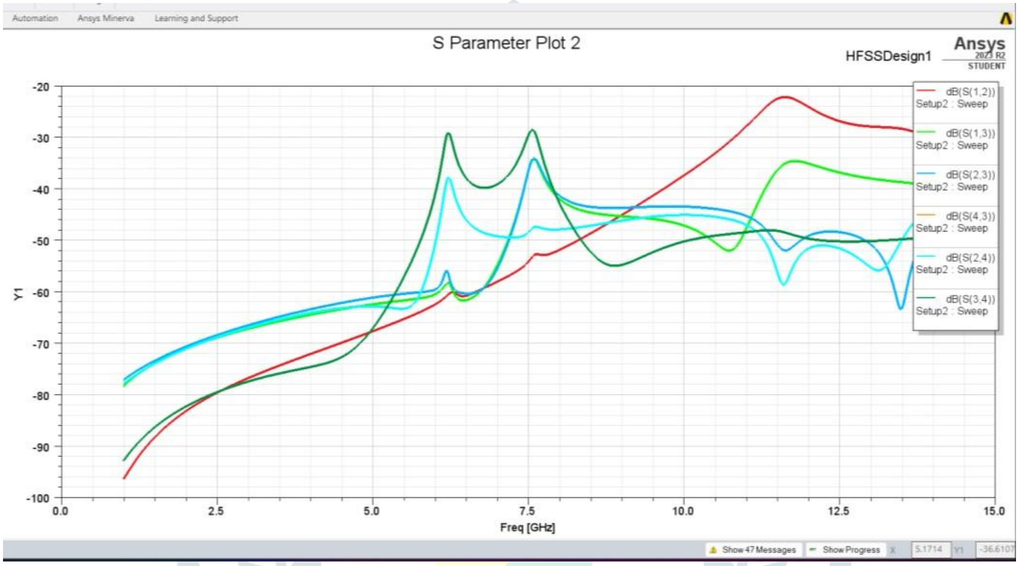


Figure6: S12,S13,S23,S43,S24,S34 parameter responses

## 3| ANTENNA DESIGN ANALYSISANTENNA DESIGN ANALYSIS

antenna design analysis is important for optimizing performance, it is also crucial to consider real-world variables such as environmental interference and user behaviour that may impact overall effectiveness. Simply focusing on theoretical design without practical application may lead to suboptimal results in real-world scenarios. The design begins with a basic rectangular SIW cavity, as per Equation (1). First, it is modified in such a way that two different patches (lengths l1 and l2) are created in the A-A' axis and associated with two separate ports, namely, P1 and P2, respectively. This is denoted as diplexing antenna 1 and shown in Figure 1. In multiport devices, >20 dB isolation is recommended. In this geometry, the length (ls) and width (ws) of the major slot and the distance between two resonating patches are the keys to controlling electromagnetic wave leakage from one port to the other. As per observation, for better isolation, ls and ws should neither be equal nor close to the vias boundary, whereas "g1" should be more than 2mm. The resonant frequencies of the cavity can be changed slightly by the modified slot dimensions. Hence, after a series of observations, the dimensions are fixed as mentioned in figure1. This led the antenna to operate at fS11 = 8 GHz and fS22 = 10 GHz with minimum isolation (S12) ≥ 24 dB, as shown in Figure 1. Following this, we also created four port antennas with the other two sets of resonant patches (lengths 1, 2, 3, and 4) created in the A-A0 and B-B0 axes and denoted as quadraplexing antennas as shown in Figure 4. Here, the four patches are associated with P1, P2, P3, and P4, respectively. The gap g2 was maintained high to allow high isolation and adequate space for future integration. Keeping this in mind, lengths l1 and l2, l3, and l4 are fixed as mentioned in figure4. This enables the antenna to radiate at fS11 = 6.08 GHz, fS22 = 7.31 GHz, fS33 = 11.3 GHz, and fS44 = 13.4 GHz, as shown in Figure 4. They are well isolated by |S34| ≥ 35.4 dB. Here, the cavity is excited by four ports (P1, P2, P3, and P4) from four sides and radiates at four different frequencies.

## 3 |EXPERIMENTAL VALIDATION

Radiation patterns of the siw based self-diplexing antenna followed with this respective figures.

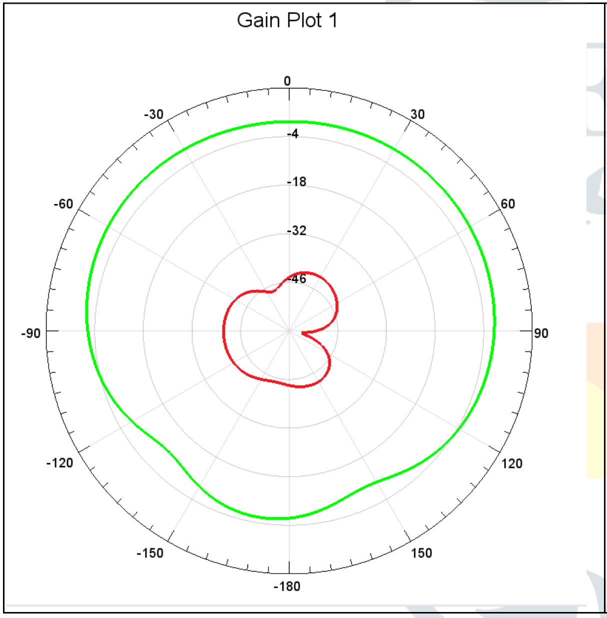


Figure6(a) at 8GHZ($\phi=0^{o}$)

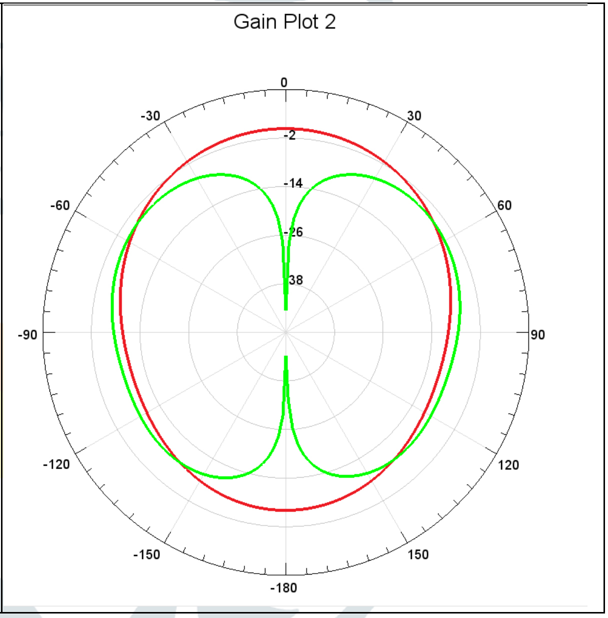
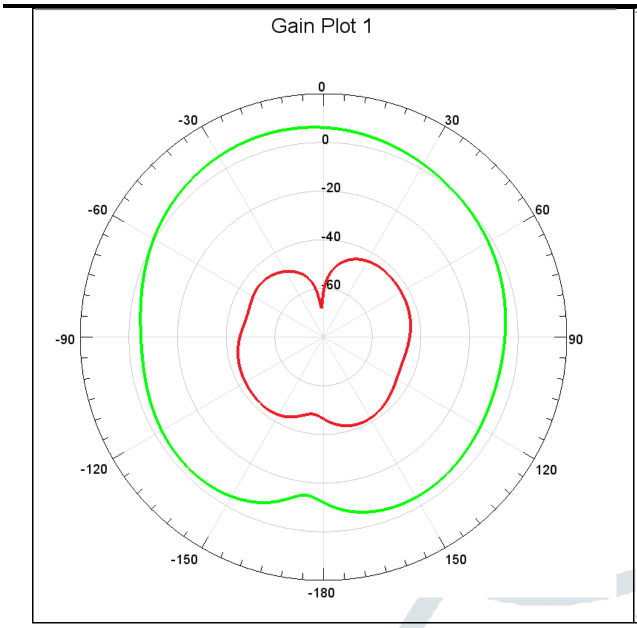


figure6(b) at 8GHZ($\phi=90^{o}$)



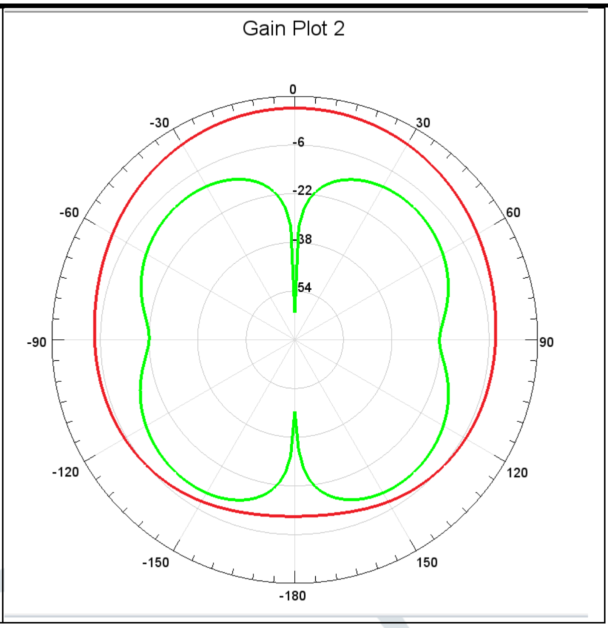
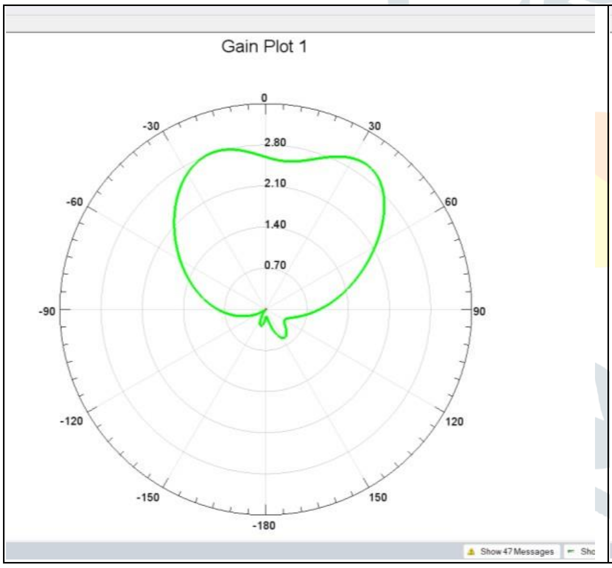


Figure6(a) at 10.06GHZ(ɸ=0$^{o}$) figure6(b) at 10.06GHZ(ɸ=90$^{o}$)

Radiation patterns of the siw based self-quadplexing antenna followed with this respectivefigures.



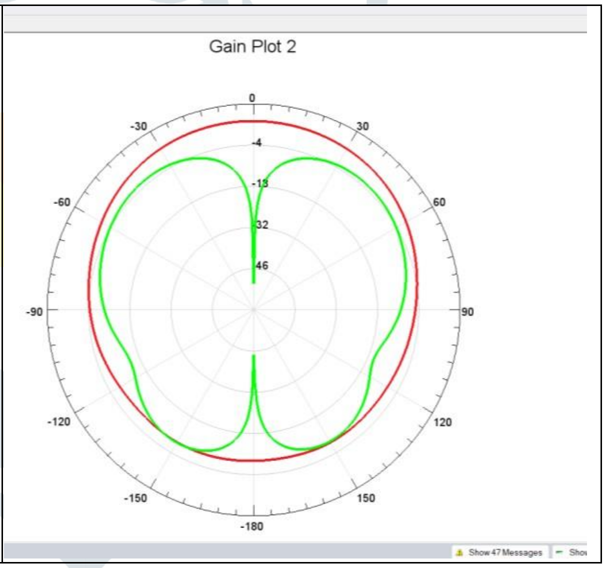


Figure6(a) at 11.33GHZ(ɸ=0$^{o}$) figure6(b) at 11.33GHZ(ɸ=90$^{o}$)

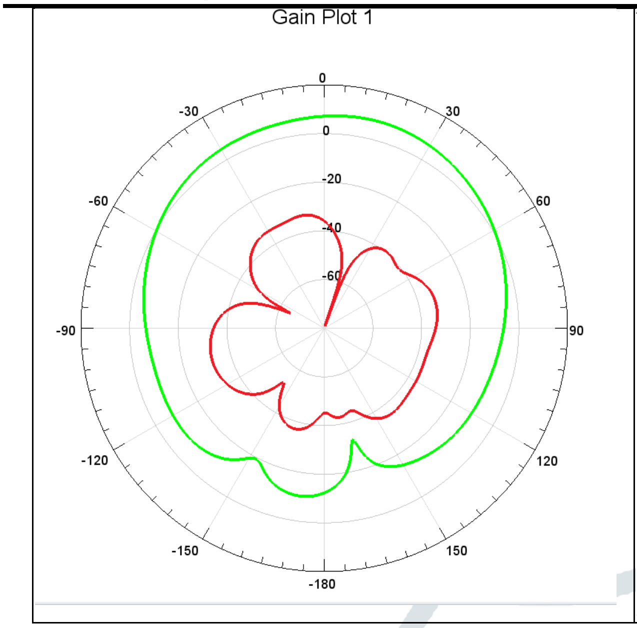


Figure6(a) at 13.46GHZ(ɸ=0$^{o}$)

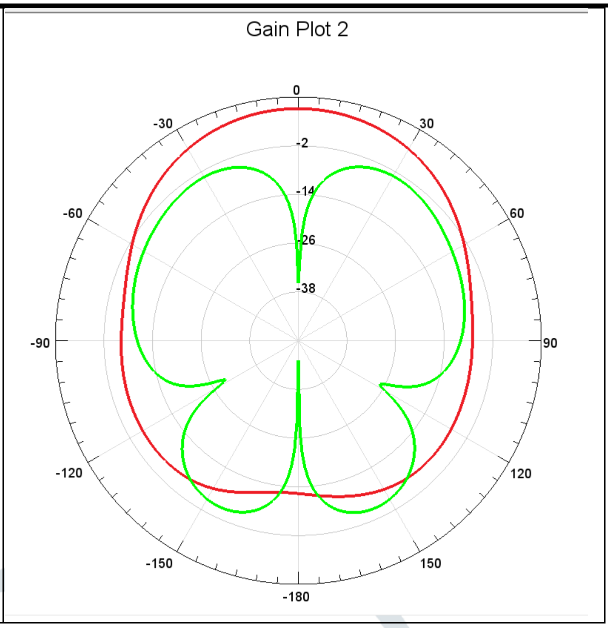


figure6(b) at 13.46GHZ(ɸ=90$^{o}$)

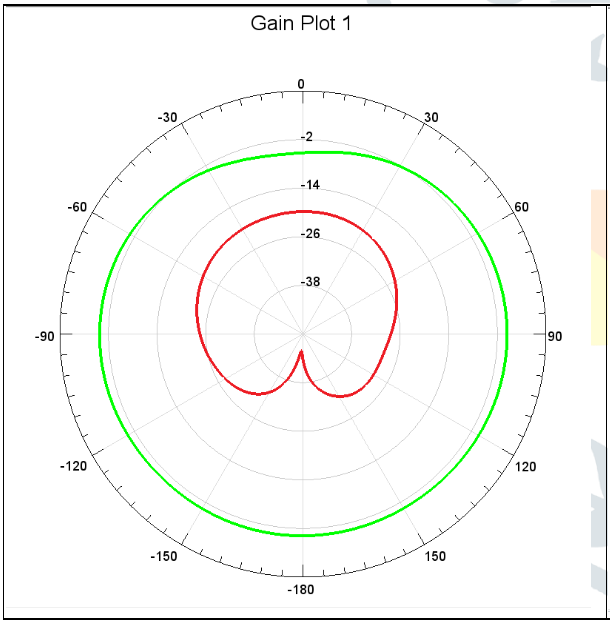


Figure6(a) at 7.31GHZ(ɸ=0$^{o}$)

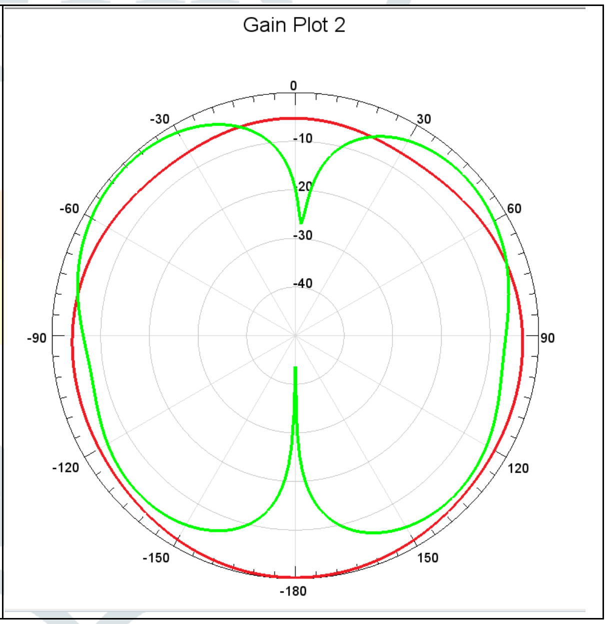


figure6(b) at 7.31GHZ(ɸ=90$^{o}$)

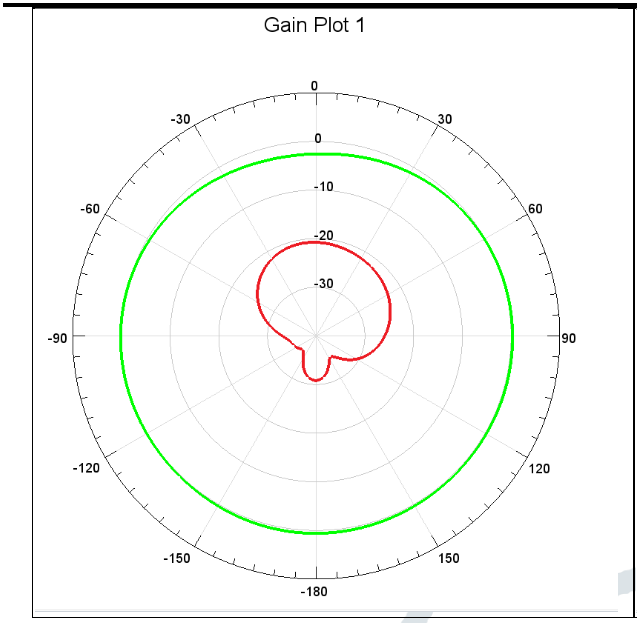


Figure6(a) at 6.08GHZ(ɸ=0°)

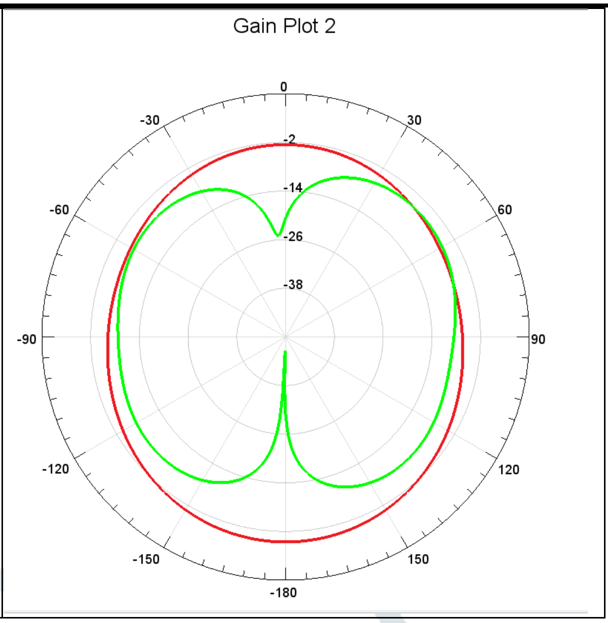


figure6(b) at 6.08GHZ(ɸ=90°)

## 4| CONCLUSION

The self-quadruplexing antenna, featuring four patches of different lengths fed by separate microstrip feed lines, demonstrates impressive performance across four distinct frequencies:
6.08 GHz, 7.31 GHz, 11.3 GHz, and 13.4 GHz. With peak gains ranging from 4.1 dB at 6.5 GHz to 6.2 dB at 13 GHz and isolation levels surpassing 24 dB, this antenna design showcases efficiency and versatility, meeting the demands of modern communication applications.

The self-diplexing antenna, utilizing a modified SIW cavity for dual-frequency operation, demonstrates robust performance, with peak gains of 4.8 dB at 8 GHz and 6.4 dB at 10 GHz. Both antennas, fabricated using the RT-Duroid (5870) substrate known for its high performance in RF applications, demonstrate suitability for a wide range of applications. Their compact, lightweight, and efficient designs address the challenges posed by multiplexing applications, providing reliable solutions for modern multiband communication needs. Overall, the introduced SIW-backed antenna designs represent a significant contribution to the field, offering improved performance, compactness, and versatility.

## REFERENCES

1. Zhang, Z., An, K., & Chen, A. (2020, August). A Diplexing Antenna for Dual-band Dual-Sense Operation wih High Isolation. In 2020 9th Asia-Pacific Conference on Antennas and Propagation (APCAP) (pp. 1-2). IEEE.

2. Dash, S. K. K., Cheng, Q. S., Barik, R. K., Pradhan, N. C., & Subramanian, K. S. (2021, January).

3.A compact substrate integrated self-diplexing antenna for WiFi and ISM band applications. In 2020 50th European Microwave Conference (EuMC) (pp. 232-235). IEEE.

4. Dash, S. K. K., Cheng, Q. S., Barik, R. K., Khan, T., & Subramanian, K. S. (2021). A compact dual-fed highly isolated SIW based self-diplexing antenna. AEU-International Journal of Electronics and Communications, 132, 153613.

5. Nandi, S., & Mohan, A. (2018). SIW-based cavity-backed self-diplexing antenna with plus- shaped slot. Microwave and Optical Technology Letters, 60(4), 827-834.

6. Kiani, N., & Afsahi, M. (2019). Design and fabrication of a compact SIW diplexer in C-band. Iran. J. Electr. Electron. Eng.(IJEEE), 15(2), 189-194.

7. Dash, S. K. K., Cheng, Q. S., Barik, R. K., Pradhan, N. C., & Subramanian, K. S. (2020). A compact triple-fed high-isolation SIW-based self-triplexing antenna. IEEE Antennas and Wireless Propagation Letters, 19(5), 766-770.

8. Dash, S. K. K., Cheng, Q. S., & Barik, R. K. (2020). A compact substrate integrated waveguide backed self-quadruplexing antenna for C-band communication. International Journal of RF and Microwave Computer-Aided Engineering, 30(10), e22366.

9. Kumar, A. (2019). Design of self-quadruplexing antenna using substrate-integrated waveguide technique. Microwave and Optical Technology Letters, 61(12), 2687-2689.

10. PourMohammadi, P., Naseri, H., Melouki, N., Ahmed, F., Iqbal, A., Vandenbosch, G. A., & Denidni, T. A. (2023). Compact SIW-based self-quadruplexing antenna for microwave and mm-wave communications. IEEE Transactions on Circuits and Systems II: Express Briefs.

**11.** Agrawal, M., & Kumar, T. (2023). A substrate integrated waveguide (SIW) based self- quadruplexing antenna for Ku-band applications. International Journal of Microwave and Wireless Technologies, 15(2), 289-297**.**

12. 7. Kumar, A. (2019). Design of self-quadruplexing antenna using substrate-integrated waveguide technique. Microwave and Optical Technology Letters, 61(12), 2687-2689.