International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 09 September 2024
Page No: 2316 - 2321
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0317

Frequency Selective Surface Based Rasorber with T-A Response

Miss Neeharika Verma[1], Dr. Nipun Kumar Mishra[2], Mr. Deepak Rathore[3]
[1,2,3]Department of Electronics & Communication Engineering, Guru Ghasidas Vishwavidyalaya, Bilaspur, 495009, India.
Emails: *neeharikaverma1@gmail.com[1], mishranipun@gmail.com[2]*

Abstract
A brand-new switchable rasorber/absorber with double polarization is suggested. An air gap separates two FR-4 substrates in the dual-substrate design that is shown. The bottom substrate contains a copper metal layer with a slot cutout that allows for a filter response, while the top substrate has a plus-shaped copper design. The top substrate's plus-shaped absorber demonstrates an absorption response, creating a composite structure with absorption and filtering characteristics. This design achieves a distinct frequency response by utilizing the complementary effects of the slot-coupled resonator and the metal-insulator-metal (MIM) arrangement. This design is switchable since it makes use of P-i-n diodes. Radome, radar, and wireless communication all make use of this concept.

Keywords: *Absorber, Rasorber, pin diodes, CST Software.*

1. Introduction
A new configuration with two substrates is introduced. There is a new double-substrate configuration displayed, with FR-4 substrates separated by an air gap. The top substrate features a plus-shaped copper design, while the bottom substrate has a copper metal layer with a slit carved out to allow for a filter response. A switch-like diode included inside the slot controls the filter response. The structure produces a unique frequency response and acts as a rasorber when combined with the bottom substrate. An absorption reaction is seen in the plus-shaped absorber on the upper substrate. This multilayer structure utilizes the effects of the metal-insulator-metal (MIM) arrangement, slot coupled resonator, and diode switching to produce a multifunctional absorber response. The air gap improves the isolation between the two substrates, and the FR-4 substrates provide the structure a sturdy and robust foundation. The bottom substrate's slot cutout is expertly crafted to produce a superior filter response, while the top substrate's plus-shaped design is maximized for absorption. The filter response can be dynamically controlled by the diode switching mechanism, allowing the structure to adjust to shifting frequency conditions. The narrow bandwidth and high absorption level of the rasorber response make it appropriate for applications needing high-frequency selectivity. The proposed structure has numerous potential applications in microwave and millimeter-wave systems, including filter banks, switching circuits, and absorptive frequency selective surfaces. [1] The ability to control the filter response using diode switching makes it an attractive solution for adaptive frequency selection and switching applications.

2. Implementation
FR-4 substrates are employed to produce the recommended double-substrate structure, with the two layers being separated by an air gap. For best absorption, the top substrate should have a plus shaped copper pattern. [2] The copper metal layer with a slot carved out on the bottom substrate allows for a filter response. A switch-like diode included inside the slot controls the filter response. we present a novel plus-shaped Frequency Selective Surface (FSS) design, optimized for efficient electromagnetic wave filtering. [2] This rasorber configuration enables selective absorption and transmission of electromagnetic radiation, leveraging the unique properties of FSS technology. By carefully tailoring the plus-shaped geometry and FSS element parameters, our design achieves improved

transmission-absorption response, making it suitable for applications requiring precise electromagnetic control.

2.1. Materials Selection

1. **Substrate Material:** FR-4 (Flame Retardant 4) is selected as the substrate material due to its high thermal stability, low dielectric loss, and good mechanical strength. [3]
2. **Conductor Material:** Copper is chosen as the conductor material for the plus-shaped design and metal layer due to its high conductivity, flexibility, and compatibility with FR-4 substrates. [4]
3. **Dielectric Material**: FR-4 is used as the dielectric material for the combining two FR-4-layer air spacer is using, providing high isolation and low dielectric loss. FR-4 easy to cut, cost effective and give the mechanical strength of the structure. [5]
4. **Switching Element:** A PIN diode is selected as the switching element due to its high switching speed, low insertion loss, and compatibility with copper and FR-4 substrates. [6-8]
5. **Metal Layer:** Copper is used for the metal layer on the bottom substrate due to its high conductivity and compatibility with the diode switching element. Copper having good thermal handling properties, cost efficient and easily available metal. [4]

2.2. Components

Resistors and Diodes are used in this structure. The structure makes use of a 250-ohm copper (Cu) thin film resistor. To ensure the best possible signal transmission, this resistor is utilized to match the impedance of the plus-shaped copper design on the upper layer to the metal layer on the bottom substrate. In addition, a silicon (Si) PIN diode is used as a switch to regulate the metal layer's filter response. Diodes working as a switch and make the structure reconfigurable. A switching time of 10 ns. In forward mode, the diode blocks signal absorption and having RON=1.5Ω and in reverse mode, it permits signal transmission and generate capacitance, it has a capacitance of 0.05 pF. The inductor use in both on and off condition of diode is L = 0.1nH. The diode is make the full structure as absorber in on condition and working as rasorber in the off condition of diodes. [9-14]

3. Structure Design

Substrate Selection uses FR-4 substrates are selected for their high thermal stability, low dielectric loss, and good mechanical strength. PlusShaped Design, a design is created on the upper layer using copper, optimized for maximum absorption. An Air gap is designed between the two substrates to provide high isolation and low dielectric loss. Metal Layer Design, A copper metal layer is designed on the bottom substrate with a slot cutting for filter response and diode is integrated into the slot, functioning as a switch to control the filter response. After the design is completed, Simulation and Optimization process is started, the structure is simulated using electromagnetic simulation software (e.g. CST) to optimize the design parameters for maximum rasorber response. Layout and Fabrication, The final design is laid out and fabricated using photolithography, etching, and copper thin-film deposition techniques. Figure 1 shows Top View of Upper Layer, Figure 2 shows Prospective View of Upper Layer

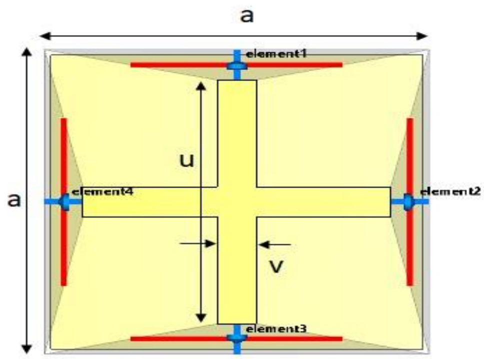

Figure 1 Top View of Upper Layer

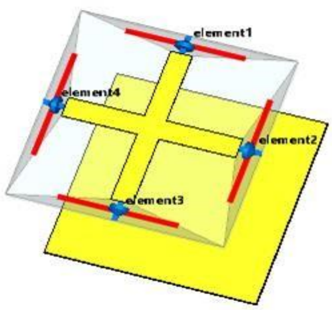

Figure 2 Prospective View of Upper Layer

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 09 September 2024
Page No: 2316 - 2321
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0317

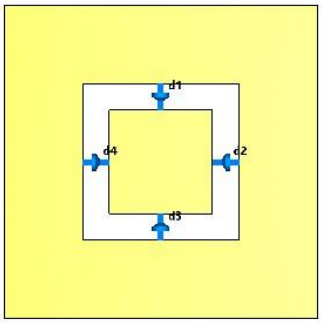

Figure 3 **Bottom Layer**

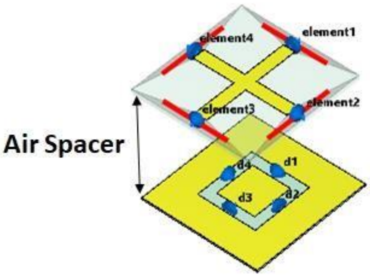

Figure 4 **Prospective View of Rasorber**

Table 1 **Parameters and Its Optimized**

Parameters	Values
Substrate (1 and 2)	Fr-4
Substrate (upper)	0.8 mm
Substrate (Bottom)	0.3 mm
Conducting material	Copper
Copper thickness	0.035 mm
Air Spacer	12 mm
Design dimension (Plus Shaped)	2x20 (vertical) 20x2 (horizontal)
Slot	10 mmx10 mm Width 1.7 mm

The structure and its parameters are showing in Fig 3. The upper layer gives the absorption response and bottom layer produce the filter response. When combining both the layer, the structure produces the rasorber response. This rasorber give the absorption transmission response i.e. showing by simulation results. Figure 4 shows Prospective View of Rasorber. Table 1 shows Parameters and Its Optimized.

4. Simulation Results

The double-substrate structure exhibits a rasorber response, combining the absorption characteristics of the plus-shaped copper design on the upper layer with the filter response of the metal layer on the bottom substrate. Measured Results:

- Frequency Range: 2.3 GHz – 8.4 GHz
- Absorption Coefficient: 0.9 – 1.0
- Absorption Bandwidth: 6.1 GHz
- Filter Response: 1 GHz
- Switching Time: 10 ns
- Insertion Loss: 1 dB

Simulation Software (CST): confirms the rasorber response and predicts a high absorption coefficient and filter response. The provided graph illustrates the reflection coefficient (S11) and transmission coefficient (S21) of a device or system under two different conditions: "On" and "Off". The x-axis represents frequency in GHz, while the y-axis indicates the reflection/transmission coefficient in dB. The upper layer gives the absorption and covers the frequency range from 2.3 GHz to 8.4 GHz, bandwidth is 6.1 GHz. The upper layer structure result shows in Fig. 5, its absorptivity is more than 90%.

4.1. Upper Layer Simulation Result

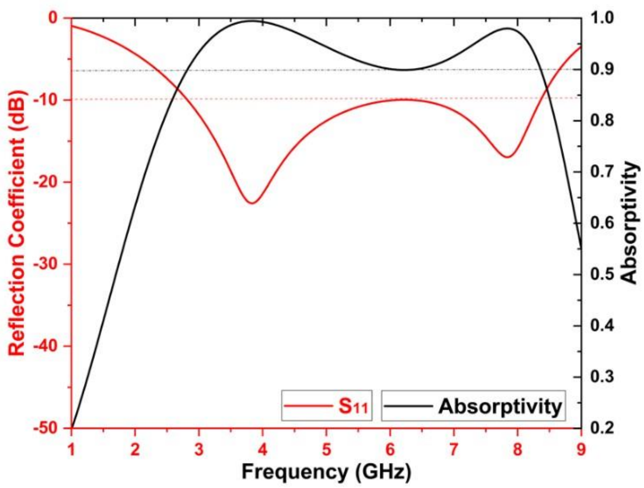

Figure 5 **Upper Layer Simulation Result**

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 09 September 2024
Page No: 2316 - 2321
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0317

4.2. Bottom Layer Simulation Result

The bottom layer having slot cutting method and produce filter response, i.e. band pass response. In this slot PIN diodes are placed in symmetrical manner, its provide the structure switchable properties by its on and off conditions.

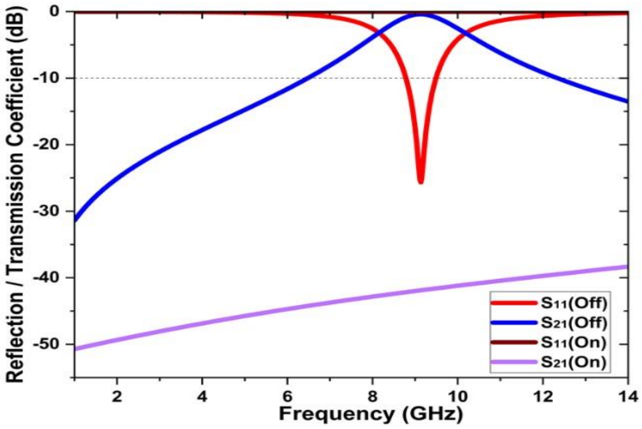

Figure 6 Simulation Result of Bottom Layer

The Fig. 6 shows the simulation result of the bottom layer. This bottom layer gives the transmission response, when the diodes in off condition. While the diodes in the on condition, structure gives full reflection and minimum transmission. The transmission band covers the frequency from 8 GHz to 10 GHz with low insertion loss dB. Combining both the layers by using air spacer the structure of rasorber is showing in Fig. 4 and its simulation result shows by the sparameter is the below Fig.7, the full structure of rasorber having both lossy layer and the lossless layer. Pin diodes and resistors are used.

4.3. Rasorber Simulation Results

The Rasorber structure gives both absorption and transmission response. PIN diode make the structure switchable. In on condition of diodes it gives absorption and in off condition of diodes it gives both absorption and transmission response. Fig. 7 shows the on and off condition of diodes and presented by the s-parameters. The both reflection coefficient and transmission coefficient are minimum while the structure absorb the Electromagnetic wave and for transmission the reflection coefficient is minimum and the transmission coefficient is maximum.

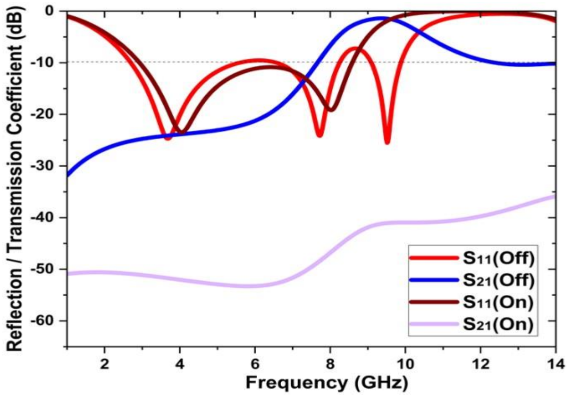

Figure 7 Simulation Result of Rasorber

The rasorber structure having the polarization and angular properties. [3] This property shows by the analysis of the structure.

5. Analysis of Polarization Angle and Incidence Angle [15-16]

5.1. Polarization Angle

The polarization angle variation from 0° to 75° shows in Fig. 8.

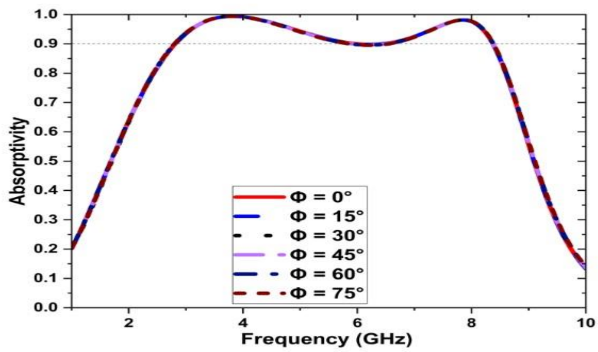

Figure 8 Polarization Angle Variation in On Condition of Diodes

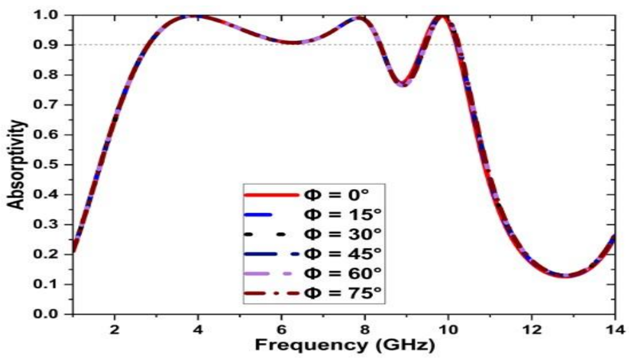

Figure 9 Polarization Angle Variation in Off Condition of Diodes

International Research Journal on Advanced Engineering Hub (IRJAEH)
e ISSN: 2584-2137
Vol. 02 Issue: 09 September 2024
Page No: 2316 - 2321
https://irjaeh.com
https://doi.org/10.47392/IRJAEH.2024.0317

The Fig. 8 shows the structure is polarization insensitive for all the angle of phi, the absorptivity of the structure is more than 90% for full absorption bandwidth. Fig. 8 shows the polarization angle variation in on condition of diodes and Fig. 9 shows the polarization angle variation in off condition of diodes.

5.2. Incidence Angle [1]

The variation in incidence angle from 0° to 75°.

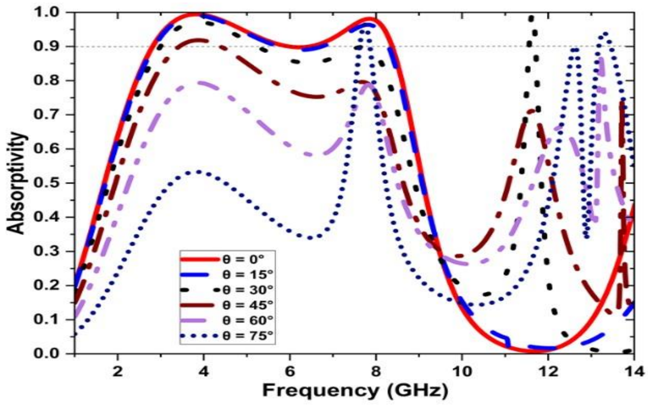

Figure 10 **Incidence Angle Variation in Off Condition of Diodes**

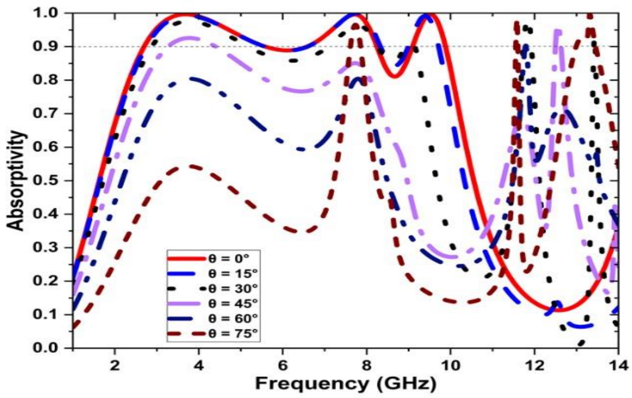

Figure 11 **Incidence Angle Variation in Off Condition of Diodes**

The incidence angle variation showing in Fig. 10 The incidence showing the performance of structures angular stability, the presented structure angular stable upto 30° and its absorptivity is more than 90%. Angular variation of incidence angle in the on condition of diodes showing Fig. 10 and incidence angle variation in off condition of diodes showing in Fig. 11.

Conclusion

This innovative double-polarized switchable absorber/rasorber system provides an adaptable way to manage electromagnetic radiation. By integrating a metal-insulator-metal configuration with a slot-coupled resonator, the dual-substrate structure attains a distinct frequency response that possesses both filtering and absorption properties. Switchability is made possible by the use of P-i-n diodes, which lends this design versatility for use in radome, radar, and wireless communication systems, among other applications. This creative idea may greatly improve electromagnetic wave control systems' usefulness and performance, opening the door for further developments in these domains.

References

[1]. S. Ghosh and K. V. Srivastava, "An angularly stable Dual-Band FSS with closely spaced resonances using miniaturized unit cell," IEEE Microwave and Wireless Components Letters, vol. 27, no. 3, pp. 218–220, Mar. 2017, doi: 10.1109/lmwc.2017.2661683.

[2]. F. Costa and A. Monorchio, "A frequency selective radome with wideband absorbing properties," IEEE Transactions on Antennas and Propagation, vol. 60, no. 6, pp. 2740–2747, Jun. 2012, doi: 10.1109/tap.2012.2194640.

[3]. Dewangan, L., & Mishra, N. K. (2023). Multiband polarization insensitive metamaterial absorber for radar cross-section reduction. AEU-International Journal of Electronics and Communications, 168, 154706.

[4]. Liu, L. G., Li, Y. Q., Meng, Q. Z., Wu, W. W., Mo, J. J., Fu, Y. Q., & Yuan, N. C. (2013). Design of an invisible radome by frequency selective surfaces loaded with lumped resistors. Chinese Physics Letters, 30(6), 064101.

[5]. Li, B., & Shen, Z. (2014). Wideband 3D frequency selective rasorber. IEEE Transactions on Antennas and Propagation,

62(12), 6536-6541.

[6]. Q. Chen, L. Chen, J. Bai, and Y. Fu, "Design of absorptive frequency selective surface with good transmission at high frequency," Electronics Letters, vol. 51, no. 12, pp. 885–886, Jun. 2015, doi: 10.1049/el.2015.0228.

[7]. Q. Chen, S. Yang, J. Bai, and Y. Fu, "Design of Absorptive/Transmissive Frequency-Selective surface based on parallel resonance," IEEE Transactions on Antennas and Propagation, vol. 65, no. 9, pp. 4897–4902, Sep. 2017, doi: 10.1109/tap.2017.2722875.

[8]. Y. Shang, Z. Shen, and S. Xiao, "FrequencySelective rasorber based on Square-Loop and Cross-Dipole arrays," IEEE Transactions on Antennas and Propagation, vol. 62, no. 11, pp. 5581–5589, Nov. 2014, doi: 10.1109/tap.2014.2357427.

[9]. A. Sharma, M. Saikia, S. Malik, S. Ghosh, and K. V. Srivastava, "A polarization-insensitive broadband rasorber with in-band transmission response," Microwave and Optical Technology Letters, vol. 62, no. 12, pp. 3668–3676, Jun. 2020, doi: 10.1002/mop.32484.

[10]. R. Ranjan, A. Sharma, M. Saikia, A. Dhumal, and K. V. Srivastava, "Design of microwave rasorber using resistive ink," 2019 IEEE Indian Conference on Antennas and Propogation (InCAP), Dec. 2019, doi: 10.1109/incap47789.2019.9134454.

[11]. B. Wu, Y. Yang, H. Li, Y. Zhao, C. Fan, and W. Lu, "Low-Loss Dual-Polarized FrequencySelective rasorber with Graphene-Based planar resistor," IEEE Transactions on Antennas and Propagation, vol. 68, no. 11, pp. 7439–7446, Nov. 2020, doi: 10.1109/tap.2020.2998173.

[12]. M. Qu and S. Li, "Graphene-based polarization insensitive rasorber with tunable passband," Results in Physics, vol. 14, p. 102172, Sep. 2019, doi: 10.1016/j.rinp.2019.102172.

[13]. S. Ghosh, "Polarization-Insensitive Switchable Frequency-Selective Rasorber/Absorber," Ieee, Dec. 2019, doi: 10.1109/apmc46564.2019.9038546.

[14]. L. Dewangan and N. K. Mishra, "Broadband Wide angle Polarization insensitive Metamaterial Absorber for K band application," Ieee, Dec. 2022, doi: 10.23919/ursircrs56822.2022.10118480.

[15]. F. Ding, Z. Wang, S. He, V. M. Shalaev, and A. V. Kildishev, "Broadband High-Efficiency Half-Wave Plate: A Supercell-Based plasmonic metasurface approach," ACS Nano, vol. 9, no. 4, pp. 4111–4119, Apr. 2015, doi: 10.1021/acsnano.5b00218.

[16]. L. Dewangan, M. S. Patinavalasa, J. Acharjee, Y. Solunke, S. Ghosh, and N. K. Mishra, "Broadband metamaterial absorber for stealth applications at K-band," AEÜ. International Journal of Electronics And Communications, vol. 170, p.154828, Oct. 2023, doi: 10.1016/j.aeue.2023.154828.