# Frequency Selective Rasorber Shielded Low Radar Cross Section Antenna

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## Abstract

This paper presents a study on low radar cross section (RCS) antenna in combination with the frequency selective rasorber (FSR) structure. The FSR exhibits a transmission notch (10 GHz) within the two-sided absorption band (3.7-9.3 GHz and 10.6-15.9 GHz). A 7 x 7 unit cell array is placed over a patch antenna having an operating frequency equal to the passband of the FSR. At the out-of-band frequencies the incoming waves are absorbed while at the antenna's in-band frequency, the FSR provides a transmission window. Compared to the typical antenna, the FSR shielded antenna shows a notable reduction in out-of-band RCS, with an average decrease of 13.18 dB in the lower band (3.7-9.3 GHz) and 15.12 dB in the upper band (10.6-15.9 GHz). Further, the beamwidth of the antenna is reduced in the broadside and an increase in gain is observed from 7.2 dBi to 11.7 dBi for the FSR shielded antenna. RCS measurements are conducted on the prototype of the FSR shielded antenna to validate the results.

## 1. Introduction

The studies on the design of frequency selective rasorber (FSR) have gained significant attention for their importance in the radar cross section (RCS) reduction applications [1]. The co-existence of transmission in addition to absorption bands allows the passage for the in-band communication while providing the out-of-band RCS reduction [2]. Among others, the A-T-A FSR having a transmission notch within the wide absorption band is suitable for providing in-band communication along with the low out-of-band RCS. In literature, numerous studies on the designs of A-T-A FSR have been reported [3]-[6]. In [7], a highly selective A-T-A rasorber is studied and its integration with the antenna is studied for designing a low RCS radiating system. Further, in [8] an equivalent circuit-guided study is reported to realize a compact A-T-A with higher passband selectivity, miniaturized unit cell, and wider absorption bands. The higher selectivity at the passband and wide absorption band of our earlier reported FSR [8] makes it suitable for realizing a narrow-band patch antenna with wide out-of-band RCS reduction bands.

In the present paper, an integration of the FSR structure with the patch antenna is carried out to study the RCS

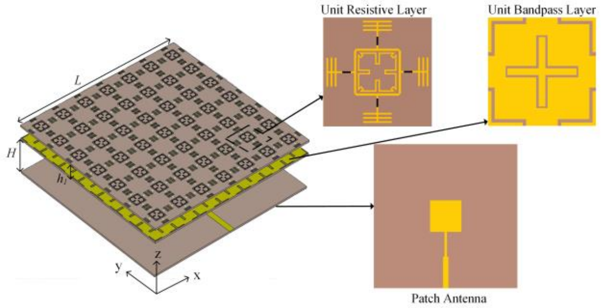



**Figure 1.** FSR shielded patch antenna ($H$ = 17 mm, $h_1$ = 5 mm, $L$ = 70 mm).

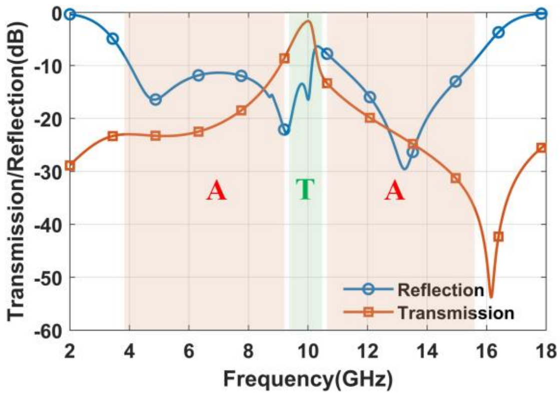



**Figure 2**. Transmission and reflection coefficient of the FSR.

reduction. The A-T-A rasorber with transmission band at 10 GHz is combined with the patch antenna with operating frequency equal to the passband of FSR. The FSR shielded antenna shows a significant reduction in RCS for the out-of-band frequency spectrum in comparison with the conventional counterpart.

## 2. Design of Low RCS Antenna

The schematic of the FSR shielded antenna is shown in Figure 1. The patch antenna is covered by a 7 x 7 array of FSR unit cells. The unit dimension of FSR is 10 mm and the overall size of the array is 70 mm x 70 mm. The FSR design [8] comprises resistive and bandpass layers at the top and bottom sides, respectively. The substrate used for the resistive and bandpass layer is Rogers Kappa ($\varepsilon_r$ = 4.3

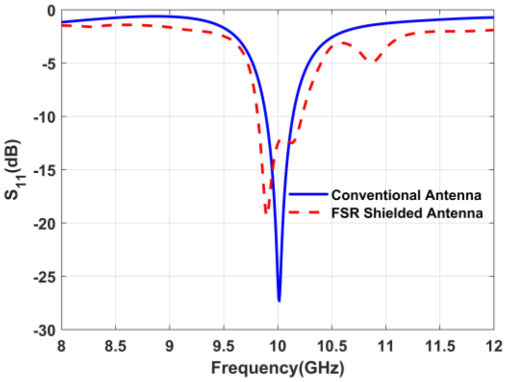



**Figure 3**. Reflection coefficient of the FSR shielded antenna.

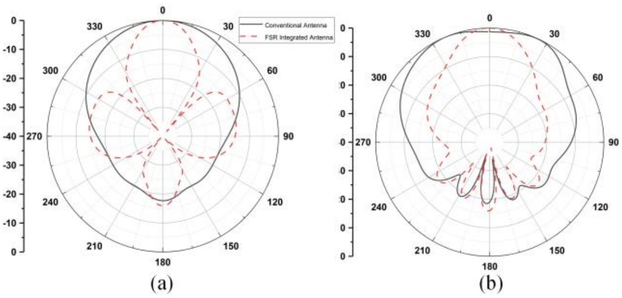



**Figure 4**. Radiation pattern for FSR shielded Antenna at 10 GHz: (a) xz-plane, and (b) yz-plane

and tanδ = 0.005). The transmission and reflection response of the FSR structure can be observed in Figure 2. There occurs a center transmission notch at 10 GHz within the two-sided broad absorption bands ranging from 3.7-9.3GHz and 10.6-15.9 GHz. A patch antenna with the operating frequency of 10 GHz (i.e the passband frequency of FSR) is designed on a 0.762-mm thick Rogers Diclad substrate ($\varepsilon_r$ = 2.2 and tanδ = 0.0009) with the substrate dimensions of 70 mm x 70 mm. The FSR array is placed over the patch antenna with a separation distance nearly of the order of λ/2.

## 3. Results and Discussion

A study on FSR shielded patch antenna is carried out compared with the normal antenna and the results are discussed in this section. The $S_{11}$ of the antenna is shown in Figure 3, in which a -10 dB reflection bandwidth is realized between 9.8-10.2 GHz for the FSR shielded antenna. It is observed that the operating band of the patch antenna remains maintained in the FSR shielded case as compared to the typical patch antenna. The comparative radiation pattern of the patch antenna with and without FSR integration is shown in Figure 4. A decrease in the beamwidth for the FSR shielded antenna is observed in comparison with the typical antenna. However, from Figure 5, it can be observed that integration of the antenna with the FSR structure increases the gain in the main beam direction from 7.2 dBi to 11.7 dBi at 10 GHz.

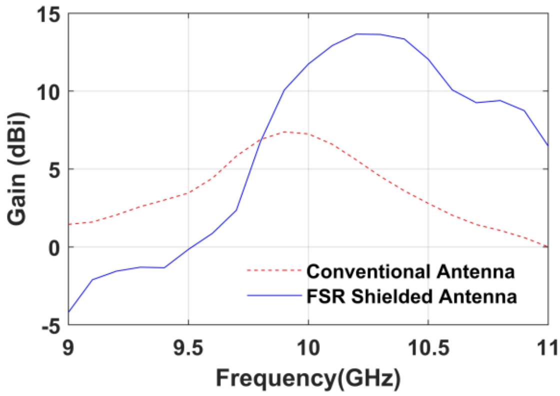



**Figure 5**. Gain of the FSR shielded Antenna.

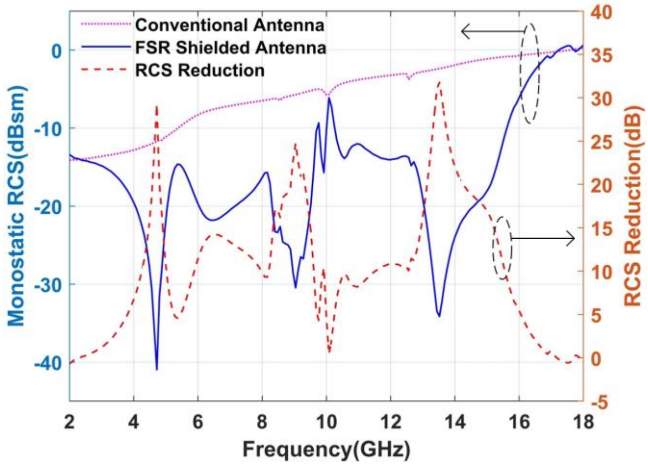
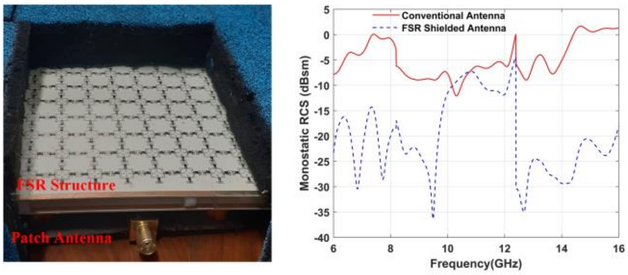



**Figure 6**. Mono-static RCS of the FSR shielded Antenna for the y-polarized incident plane wave.

The monostatic RCS of the FSR shielded antenna in comparison with the typical antenna for the y-polarized plane wave is shown in Figure 6. It can be observed that there is a significant decrease in the RCS in the out-of-band region while at the operating frequency of 10 GHz the monostatic RCS is nearly same. In the lower band of 3.7-9.3 GHz, the average RCS reduction is around 13.18 dB, and the maximum reduction of 29.2 dB is observed at 4.7 GHz. In the upper band of 10.6-15.9 GHz, the average RCS reduction is around 15.12 dB, and the maximum reduction of 31.7 dB is observed at 13.52 GHz.

## 4. Experimental Measurement

A prototype with 7x7 unit cell FSR is fabricated consisting of a bandpass layer (at the bottom) and resistive layer (at the top) using the 0.76 mm thick Rogers Kappa Substrate which has a dielectric permittivity of 4.3 and loss tangent equal to 0.005. Chip resistors (100 Ω) are soldered on the resistive layer. The two layers are air-separated at 5 mm distance using plastic spacers. A patch antenna fabricated using Rogers Diclad substrate ($\varepsilon_r$ = 2.2 and tanδ = 0.0009) is placed below the FSR array at the distance of 17 mm. The photograph showing the fabricated FSR antenna is shown in Figure 7(a). Mono-static RCS measurements are




(a) (b)

**Figure 7**. (a) Fabricated prototype, and (b) measured mono-static RCS of FSR shielded Antenna.

carried out on the fabricated structure using the time domain gating application in which transmitter and receiver function is performed using a single horn antenna. Keysight PNA Network Analyzer (N5224B) along with three standard gain horn antennas in the separate J (6-8 GHz), X (8-12 GHz), and Ku (12-18 GHz) frequency bands are used for carrying out the measurements. The measured mono-static RCS of the antenna with and without the FSR array is shown in Figure 7(b). The measured results validated the out-of-band RCS reduction while at in-band frequency (around 10 GHz) the RCS remains nearly the same. A minor fluctuation in the measured response can be attributed to soldering and fabrication imperfections.

## 6. Conclusion

This paper presents a study on the patch antenna shielded with the A-T-A type FSR structure for realizing out-of-band RCS reduction. A 7 x 7 FSR structure is used as a shield on the narrowband patch antenna with equal substrate dimensions. The operational band of the patch antenna matches with the transmission notch of the FSR array. Due to the absorption phenomenon of FSR, the reduction in RCS is achieved for the out-of-band frequency, and for the in-band frequency the antenna maintains the radiation. The average RCS reduction for the FSR shielded antenna is 13.18 dB in the lower band while in the upper band an average RCS reduction of 15.12 dB is realized in comparison with the typical antenna. Further, an increase in gain is observed from 7.2 dBi to 11.7 dBi for the FSR shielded antenna.

## 6. Acknowledgements

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## 7. References

1. Y. Han, Y. Chang and W. Che, “Frequency-Selective Rasorbers: A View of Frequency-Selective Rasorbers and Their Application in Reducing the Radar Cross Sections of Antennas,” *IEEE Microwave Magazine*, **23**, 2, pp. 86-98, Feb. 2022, doi: 10.1109/MMM.2021.3125463.

2. A. A. Omar, H. Huang and Z. Shen, “Absorptive Frequency-Selective Reflection/Transmission Structures: A Review and Future Perspectives,” *IEEE Antennas and Propagation Magazine*, **62**, 4, pp. 62-74, Aug. 2020, doi: 10.1109/MAP.2019.2943302.

3. R. Shi, S. Yu and N. Kou, "A Miniaturized Frequency-Selective Rasorber With Absorption Bands on Two Sides of Passband for Antenna Dome," *IEEE Antennas and Wireless Propag. Lett.* , **21**, 11, pp. 2161-2165, Nov. 2022, doi: 10.1109/LAWP.2022.3187958.

4. W. Wan et al., "Chiral Absorber-Based Frequency Selective Rasorber With Identical Filtering Characteristics for Distinct Polarizations," *IEEE Trans. Antennas Propag.* , **70**, 5, pp. 3506-3514, May 2022, doi: 10.1109/TAP.2021.3137467.

5. B. Jiang et al., “A Switchable A-T-A Rasorber With Polarization Selectivity and High Roll-Off Characteristics,” *IEEE Antennas and Wireless Propag. Lett.*, **22**, 9, pp. 2075-2079, Sept. 2023 , doi: 10.1109/LAWP.2023.3274766.

6. Y. Jia, Y. Wang, J. Yin, C. Guo, H. Zhai and C. Liu, "Design of a Hybrid Frequency Selective Rasorber With Wideband Reflection Suppression," *IEEE Antennas and Wireless Propag. Lett.*, **22**, 2, pp. 293-297, Feb. 2023, doi: 10.1109/LAWP.2022.3209549.

7. M. M. Zargar, A. Rajput, K. Saurav and S. K. Koul, "Frequency-Selective Rasorber Based on High-Q Minkowski Fractal-Shaped Resonator for Realizing a Low Radar Cross-Section Radiating System," *IEEE Trans. Electromagn. Compat.*, **64**, 5, pp. 1574-1584, Oct. 2022, doi: 10.1109/TEMC.2022.3179514.

8. M. M. Zargar, A. Rajput and K. Saurav, "Equivalent Circuit Aided Miniaturized High-Q Frequency Selective Rasorber," *IEEE Letters on Electromagnetic Compatibility Practice and Applications*, Early Access, doi: 10.1109/LEMCPA.2024.3424390.