Reconfigurable Rasorbers
A New Era of Stealth Technology

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Introduction

Traditionally, the antennas of communication systems and radars can be covered by a passive radome to protect the antennas against environmental conditions. Functionality can be added to a radome, and the resulting device is called a rasorber, offering combined advantages of radomes and absorber. A basic rasorber acts as a transparent radome at the operating frequency of the communication system or radar and behaves as an absorber at other frequencies. To address these requirements, so called frequency selective rasorbers have been proposed [1]. In recent times, additional functionalities are considered for the rasorber. The first such functionality is the ability to switch the transmission band of the rasorber on or off. The second functionality is to increase the reflection in a certain band by adding a notch band. And the third functionality is to make the transmit band and the notch band tunable. These functionalities are illustrated in Fig. 1 for the "rasorber state" and "absorber with notch band" state. The tuning range of the transmission window is indicated by Δf_T, and the notch tuning range is indicated by Δf_N. Here, a multifunctional rasorber with switchability and tunability (in both modes) is presented.

Design of Multi-Functional Rasorber

The rasorber presented here, introducing the required multi-functionality, offers 'switchability' to control the state of operation between transmit state and notch state, and 'tunability' to tune the transmission window or the notch band within a frequency range.

A three-dimensional view of the proposed rasorber with its three individual layers is shown in Fig. 2 and its equivalent circuit model is presented in Fig. 3. To understand the performance, first the bottom lossless structure is simulated for the OFF state of the diode (Fig. 4(a)). It is observed that the entire layer can be made transparent for an incident electromagnetic (EM) wave and thereby realize a passband around 3.88 GHz. However, in the ON state of the diode, the resonance in the R-side vanishes due to introduction of R_{ON}. Now the R-side will no longer allow transmission of EM waves. So, the entire layer now mimics a near perfect reflector (Fig. 4(b)), Consequently, a separate series resonance is purposefully realized by C_V, L_V, L_{22}, and R_{22}, and optimized near the bandpass frequency to introduce a transmission zero around 4.7 GHz irrespective of the state of the PIN diodes. The top layer is accurately modelled (Fig. 5(a)) and then simulated in the circuit simulation and the full wave EM environment.

It is observed from Fig. 5(b) that the real part of the impedance is very high and the imaginary part crosses zero around the desired passband frequency ensuring the possibility of realization of maximum transmission with a low insertion loss. Secondly, the real part of impedance around the passband frequency shows a good impedance matching with free space around the two possible absorption band regions.

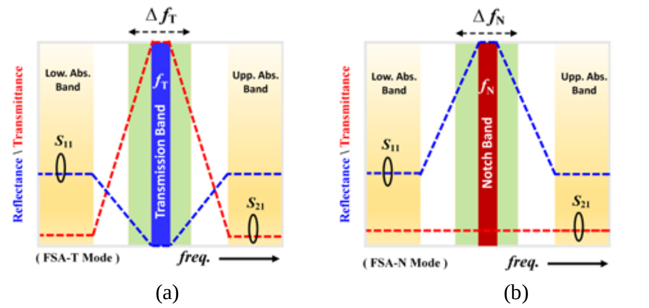


Fig. 1. States of the proposed multi-functional rasorber. (a) Transmit state. (b) Notch state.

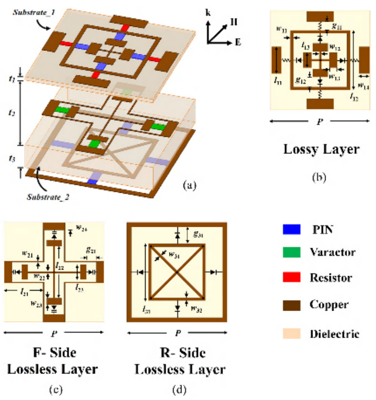


Fig.2. Proposed multifunctional rasorber. (a) Perspective view of the unit cell. (b) Lossy layer. (c) Front side. (d) Rear side of the lossless layer.

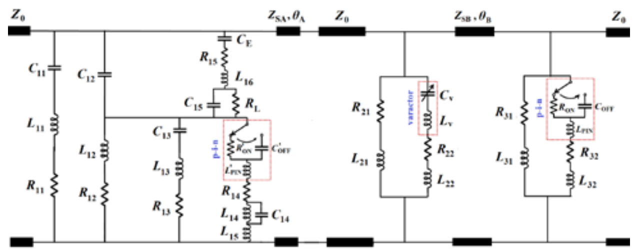


Fig. 3. Equivalent circuit model (ECM) of the multifunctional rasorber.

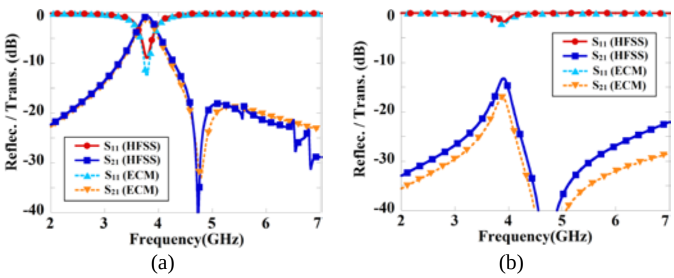
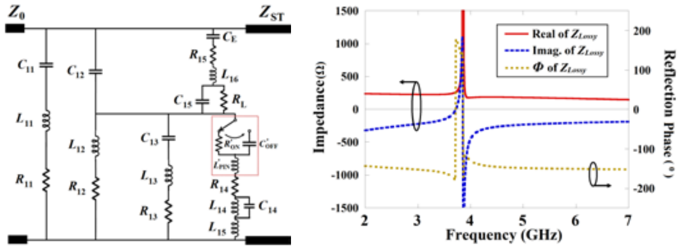
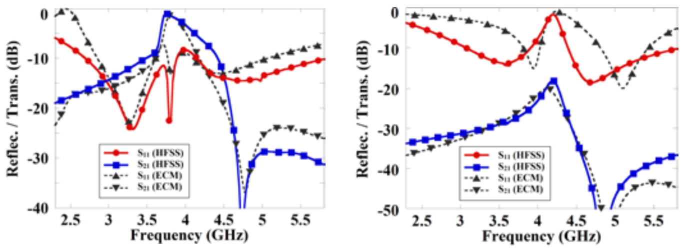


Fig. 4. Simulated response of the lossless layer. (a) Diode OFF. (b) Diode ON.



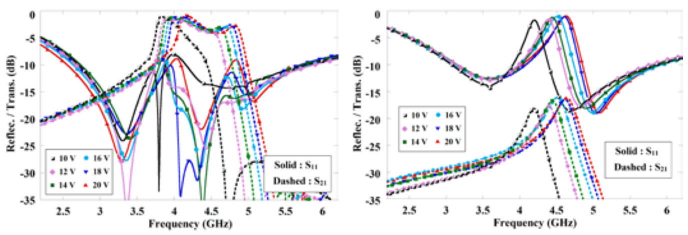
(a) (b)

Fig. 5. The top lossy layer. (a) Circuit model. (b) Simulated response.



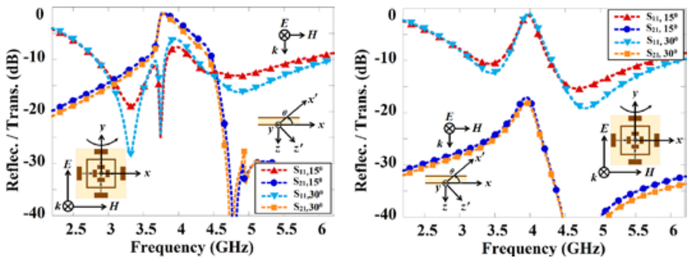
(a) (b)

Fig. 6. Simulated response of the multifunctional rasorber with varactor reverse voltage of 10 V. (a) OFF state of PIN diode (transmit state). (b) ON state of PIN diode (notch state).



(a) (b)

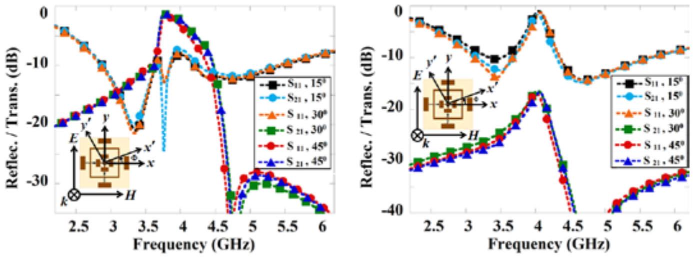
Fig. 7. Simulated response under 10 V-20 V reverse bias voltage of the varactor. (a) Transmit state. (b) Notch state.



(a) (b)

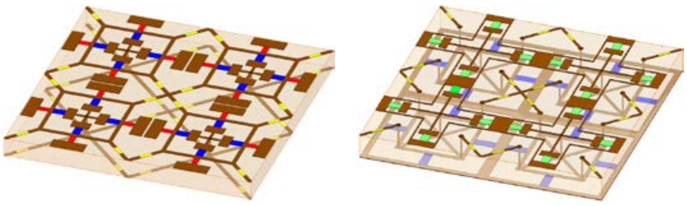
Fig. 8. Simulated response for different incident angles (a) Transmit state. (b) Notch state.

For the simulation of the full rasorber, first the PIN diodes in both layers are considered in their OFF state and the varactor diode is considered at the minimum applied reverse bias voltage. Fig. 6(a), shows the rasorber operation with a passband at 3.8 GHz surrounded by two absorption bands around 2.6-3.48 GHz and 4.46-5.8 GHz. Around the lower absorption band and the upper absorption band, the entire structure performs as a circuit analog absorber, delivering wideband absorption. Next, PIN diodes in both layers are considered in the ON state. The combined effect produces a notch band around 4.16 GHz. Good impedance matching is present around the upper and lower notch bands and this produces two separate absorption bands from 3.1-3.9 GHz and 4.4-5.9 GHz as observed in Fig.6(b). To check the tunability performance of the structure, the DC bias voltage across the varactor is continuously varied and a tunable transmission response from 4.24-4.76 GHz is noted. Also, in the lower and upper absorption bands, the refection remains less than -10 dB. In the ON state of the PIN diodes (in both layers), a continuously tunable notch band is also obtained from 4.17-4.71 GHz by regulating the reverse bias voltage from 10 V-20 V as observed from Fig. 7(b).



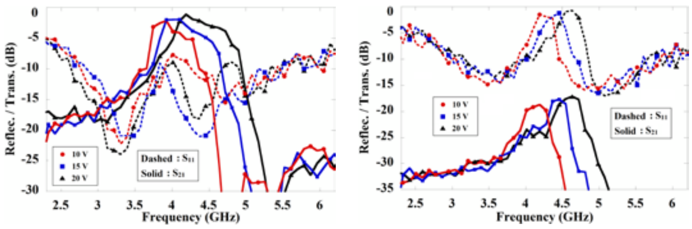
(a) (b)

Fig.9. Simulated response for different polarization angles. (a) Transmit state (b) Notch state.



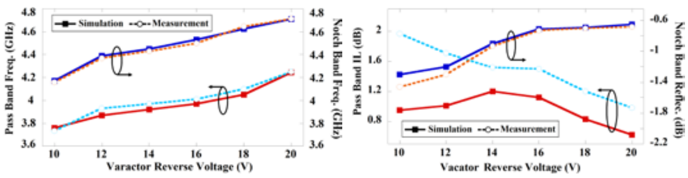
(a) (b)

Fig. 10: Biasing methodology. (a) Top layer. (b) Bottom layer.



(a) (b)

Fig. 11: Measured tunability performance. (a) Transmit state. (b) Notch state.



(a) (b)

Fig. 12. Simulated and measured result. (a) Notch-band frequency. (b) Insertion Loss.

Sustained absorption bands above and below the notch band are present during the tuning operation. Next, the performance of the structure for an oblique incident EM wave is tested for both states (Fig. 8). The structure, for both of its states of operation, is also studied for different polarization angles to confirm its low sensitivity to a change in polarization as presented in Fig. 9. To bias the entire structure, an innovative biasing is proposed and implemented as shown in Fig. 10. Note that this kind of biasing has never been implemented in rasorber design. Proposed parallel biasing also ensures fast operating speed.

Measured Results

Finally, the structure is fabricated using standard PCB techniques where diodes are mounted using SMD technology. The measured results are in good agreement with simulations, as shown in Fig. 11. The variation of centre frequencies for the transmission band (transmit state) and the notch-band (notch state) are also studied (Fig. 12(a)). It is found that this variation is not linear. Further, higher deviation of the measured insertion loss is noted in low reverse bias voltage from Fig. 12(b).

Reference

[1] A. A. Omar, H. Huang and Z. Shen, "Absorptive Frequency-Selective Reflection/Transmission Structures: A Review and Future Perspectives," in *IEEE Antennas and Propagation Magazine*, vol. 62, no. 4, pp. 62-74, Aug. 2020.