A Reconfigurable Frequency-notched UWB Antenna with Split-ring Resonators

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Abstract— **In this paper, two designs of an ultra-wideband antenna with reconfigurable band notches are presented. The first design is based on several nested complementary split-ring resonators, whereas the second has two identical split-ring resonators. Electronic switches mounted across or along these resonators serve to activate or deactivate their corresponding band notches, thus leading to band-notch reconfigurability. Prototypes of the two designs are fabricated and tested, and their results are compared.**

Index Terms— **Microstrip antennas, resonators, semiconductor diode switches.**

I. Introduction

Split-ring resonators (SRRs), originally proposed in [1], have been of great interest for the design of negative permeability and left-handed (LH) materials. Their dual counterparts, the complementary split-ring resonators (CSRRs), are used for the synthesis of negative-permittivity media. CSRRs are implemented as slots in the patch or the ground plane, whereas SRRs are implemented as conducting strips near the feed line or close to the patch edges.

In [2], CSRRs that are implemented in the ground plane of the proposed antenna are used for better matching at the resonant frequency and to obtain dual-band operation. The non-resonant property of CSRRs is exploited by the authors of [3] to design a square patch antenna with circular polarization. In [4], CSRRs etched in the ground plane are employed to eliminate the spurious harmonics associated with the original microstrip antenna structure. Ultrawideband (UWB) antennas with notched bands, introduced using SRRs and CSRRs, are presented in [5].

In this paper, two ultra-wideband (UWB) antenna designs with reconfigurable band notches are introduced. The first design features nested CSRRs etched in the patch, and electronic switches mounted across the slots of the CSRRs. By controlling the state of the switches, one CSRR is rendered active at a time, and a corresponding band notch results. Different CSRRs cause notches in different frequency bands. The second design has two identical SRRs placed symmetrically about the feed line. An electronic switch is placed along the strip of each SRR. Activating the switches would activate the SRRs, and a band notch appears. The notch disappears when the switches are OFF.

II. Antenna Configuration

The two designs, denoted Design A and Design B, are based on the same monopole antenna, printed on a $30\times30\times1.3$ mm^3 Rogers RO3006 substrate with a dielectric constant $\varepsilon_r = 6.15$. The antenna has a microstrip line feed and a partial ground plane. The patch is rectangular and is 14 mm $\times$ 15.5 mm in size, the ground is 30 mm $\times$ 10 mm, and the feed line is 2.4 mm $\times$ 10.5 mm. For better matching, the corners of the patch are rounded, by intersecting it with a circle of radius 8.75 mm, and a slit is etched in the ground below the feed. The slit is 3 mm $\times$ 1 mm. As a result, this antenna has an impedance bandwidth that covers the whole UWB frequency range.

Design A has four nested CSRRs. Three electronic switches, 1mm$\times$0.5mm in size, are mounted across the slots, as shown in Fig.1. The sequential activation (deactivation) of the switches leads to the functioning of a larger (smaller) CSRR, and thus results in a notch at a lower (higher) frequency.

The two SRRs of Design B are placed at 0.3 mm from the feed line. For each SRR, a switch is placed across the strip close to the feed line, whereas the SRR gap is at the facing side. The two switches work in parallel. When they are in the ON state, the SRRs are active and result in a wide-band notch. Switching them OFF will cancel the notch and bring back the UWB response. The dimensions of the SRRs are shown in Fig. 2.

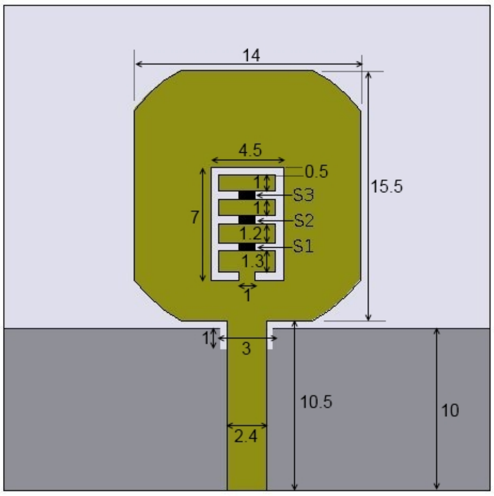

Fig. 1. Configuration of Design A

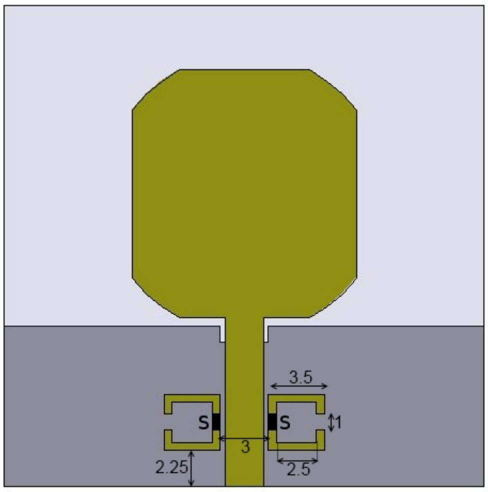

Fig. 2. Configuration of Design B

III. Results and Discussion

Ansoft HFSS is used for the design and simulations. Prototypes of the two designs are fabricated, and the return loss is measured for each switching case. A photo of a prototype of Design A is shown in Fig. 3. Without loss of accuracy, copper tapes are used in each prototype to represent the switches in their ON state.

For Design A, the following cases are considered: Case 1 when all three switches are ON, Case 2 when only S3 is deactivated, Case 3 when only S1 is ON, and finally Case 4 when all switches are OFF. The simulated and measured return loss plots for these four cases are given in Figs. 4 and 5, respectively. Clearly, a frequency notch reconfiguration is attained using this setup. Case 4 results in a weak notch in a band of very low S11 values, and thus corresponds to a notch-free UWB response. Adequate analogy is present between simulated and measured results.

Two switching scenarios are considered for Design B: the first corresponds to both switches being ON, and the second to both being OFF. The simulated and measured return loss plots for these two cases are shown in Fig.6. When the switches

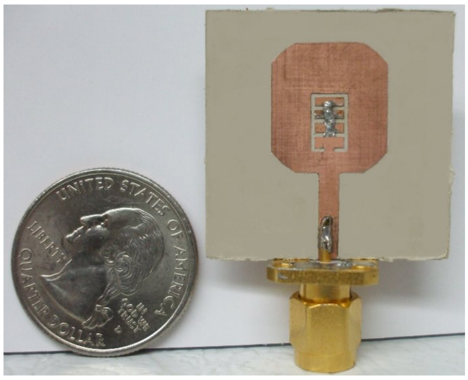

Fig. 3. Photograph of a Design A prototype

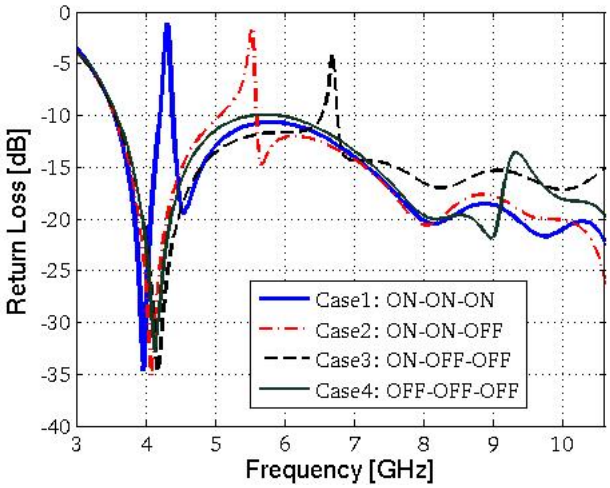

Fig. 4. Simulated return loss of Design A

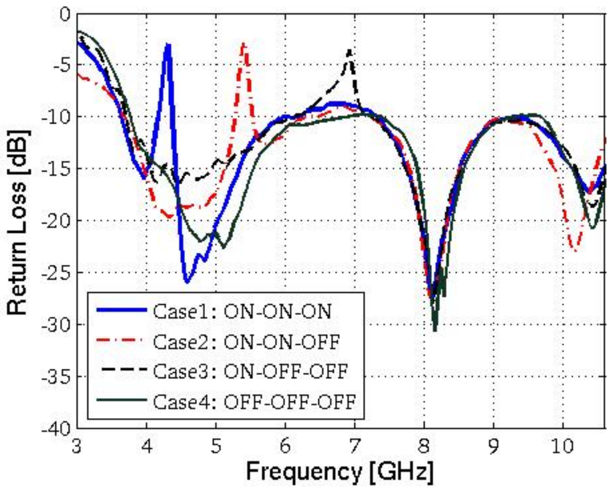

Fig. 5. Measured return loss of Design A

are put to their OFF state, the SRRs stop to resonate, and the notch disappears. The UWB response, retrieved in this case, is guaranteed by the design of the original antenna.

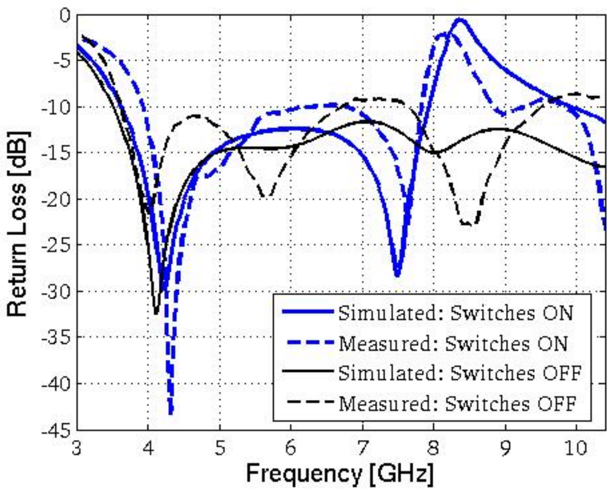

Fig. 6. Return loss of Design B

Compared to Design A, the use and configuration of the SRRs in Design B lead to wider and stronger band notches. Employing a single SRR in Design B would lead to a less wide band notch, but still wider than that attained with Design A. The CSRRs and SRRs setup of both designs can be joined in one design, thus combining the advantages of both.

Since both designs are based on printed monopoles, they are expected to exhibit omnidirectional radiation patterns. However, these patterns are subject to slight degradation at high frequencies. The computed gain patterns of Design A at 4.2 GHz are shown in Fig. 7 for switching Case 2. The chosen frequency (4.2 GHz) is that where the notch occurred for switching Case 1. A clear omnidirectional pattern is revealed, having equal gain in the H-plane and a pattern with the shape of '8' in the E-plane. The computed peak gain at this frequency is 3.12 dB. The gain patterns of Design B, computed at 8.4 GHz, are shown in Fig. 8 for the case when both switches are OFF. The frequency of 8.4 GHz is that of the notch peak when both switches are ON. A slightly degraded omnidirectional pattern is revealed. Due to this degradation, the computed peak gain mounts to 5.9 GHz.

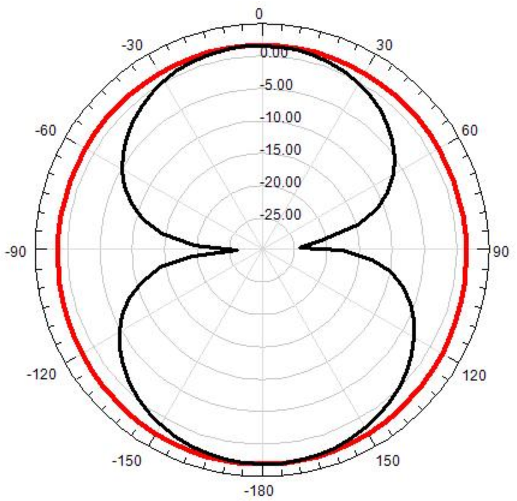

Fig. 7. Gain patterns of Design A in the H-plane (red) and E-plane (black) for switching Case 2 and f = 4.2 GHz

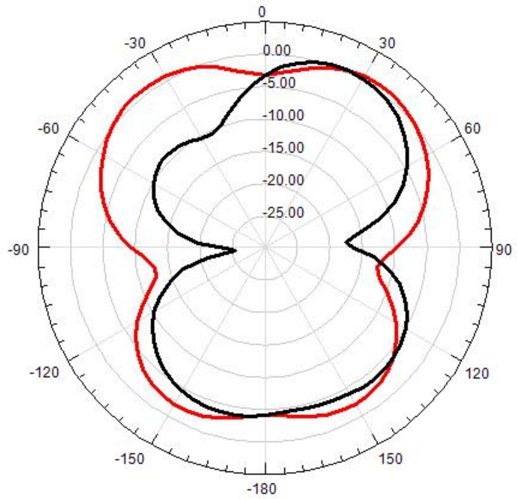

Fig. 8. Gain patterns of Design B in the H-plane (red) and E-plane (black) when both switches are OFF and f = 8.4 GHz

IV. Conclusion

Two designs of an ultra-wideband antenna with reconfigurable band notches are presented in this paper. Design A is based on nested CSRRs etched in the patch, whereas Design B features two identical SRRs placed symmetrically around the feed line.

Electronic switches mounted across each CSRR in Design A help select which CSRR is active and is causing a band notch. Since the nested CSRRs are different in size, notch reconfigurability is obtained. One of the switching cases results in a non-notched UWB response. In Design B, the activation/deactivation of the two switches placed along the SRRs enables/disables the notch they cause. A UWB response is retrieved when both switches are OFF.

Compared to Design A, Design B offers a stronger and a wider band notch. The CSRRs and SRRs setup of both of them can be joined in one design.

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