Printed Hexagonal Antenna with Dual Reconfigurable Wide Rejected Bands

Houda Ayadi[#1], Sabri Beldi[# 2], Jan Macháč[*3], Lassaad Latrach[#4]
[#]Microwave Electronics Research Laboratory, Faculty of Sciences of Tunis, University of Tunis El Manar, Tunis 2092, Tunisia
[*]Faculty of Electrical Engineering, Czech Technical University in Prague, Technicka 2, 166 27 Prague, Czech Republic
[1]ayadi_houda@hotmail.fr, [2]beldi.sabri@gmail.com, [3] machac@fel.cvut.cz, [4]lassaad.latrach@ensi-uma.tn

***Abstract*— A printed hexagonal antenna with double reconfigurable notched bands was presented and performed for modern wireless communication systems. The dismissed bands were obtained by etching a complementary split ring resonator (CSRR) on the original antenna layout. By placing two varactor diodes on the resonator, the discarded bands become easily controllable and tunable by varying the DC voltage of the diodes. Two wide continuous tuning ranges of 0.5 GHz and 1.1 GHz were achieved. The simulated and measured results show a good agreement.**

***Keywords*—Reconfigurable antenna, complementary split ring resonator (CSRR), notched band, varactor diode.**

I. INTRODUCTION

Currently, with the emergency of new standards, new telecommunication systems must be able to include a large number of features to meet the needs of cohabitation of several standards on the same antenna [1], to reduce interference with other users, to improve the transmission rate, to avoid fading phenomena and to ensure better efficiency in signal reception. Thus, the deployed antennas must be able to adapt themselves to such an evolving and variable environment. Agile antennas (in frequency, radiation patterns and polarization) are therefore potential candidates to meet the imposed requirements with a minimum of space and complexity [2-4]. The development of active components such as PIN diodes, varactor diodes, and MEMS [5-7], used to produce agility, has accelerated the rapid evolution of these antennas. In this regard, numerous efforts have been made to design printed planar ultra wideband (UWB) and wideband (WB) antennas with band-stop performance [8-10] due to their advantageous features, such as simple structure, low profile, wide bandwidth and ease of fabrication and integration. Adjustable rejected bands can be aimed to avoid interference with some wireless systems that use wide band frequencies. In this paper, a planar wideband antenna with reconfigurable dual stop-bands was designed and fabricated. Reconfigurable notched bands characteristics were obtained by integrating an agile complementary split ring resonator (CSRR) loaded by two varactor diodes. Two wide tuning ranges of notched bands were achieved and confirmed by the simulation and measurement results.

II. ANTENNA DESIGN

The proposed hexagonal wideband (WB) antenna is printed on a 0.76 mm thick Rogers substrate (RO4350B) with a dielectric constant of 3.66 and a loss tangent of 0.035. The overall dimensions of the antenna are 40×30 mm^2. The hexagonal monopole radiator is placed in a circular aperture with a radius of 14 mm etched on the ground plane. The monopole antenna is excited by a 50 Ω coplanar waveguide (CPW) feeding-line and is loaded by a complementary split ring resonator (CSRR) as shown in Fig. 1. In order to obtain the wideband performance, a pair of right angle cuts with a depth of L_1 and width of W_3 is symmetrically cut on the ground plane. Then, the CSRR is added to the antenna to obtain dual band-notched performance, with their dimensions zoomed and depicted in detail especially. The structure is printed on the top side of the substrate while the back side is empty. All dimensions are listed in table 1.

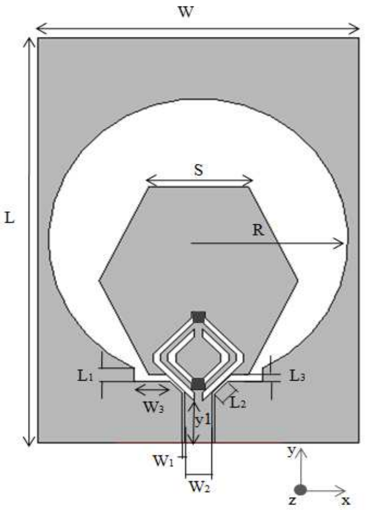


Fig. 1. Schema of the antenna with two reconfigurable reject-bands.

The designed antenna operates over the band of 2-8 GHz. The insertion of the CSRR on the radiating element closes the feeding line, creates two discarded bands (controlled by the two rings of the resonator).

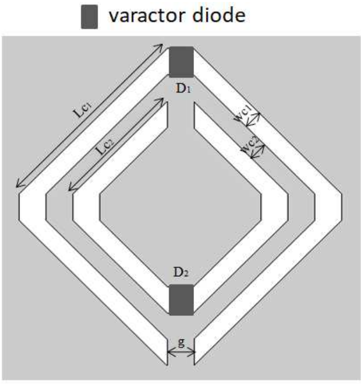


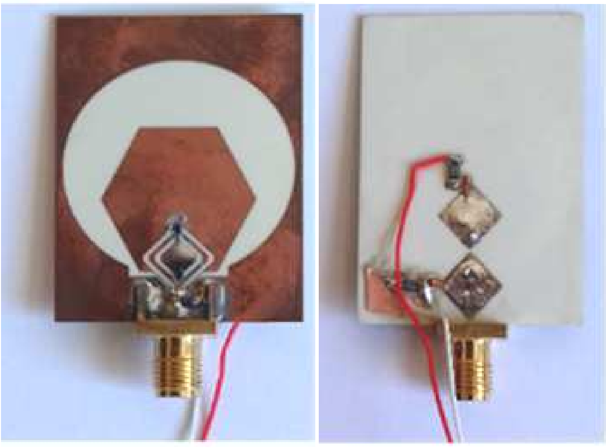
Fig. 2. Geometry of the proposed CSRR

TAB 1. ANTENNA DIMENSIONS

Parameters	W	L	S	R	L_1
Value(mm)	30	40	9.30	14	1.35
Parameters	L_2	L_3	W_1	W_2	W_3
Value(mm)	2.40	0.70	0.24	2.60	3.36
Parameters	L_{C1}	L_{C2}	W_{C1},W_{C2}	g	y1
Value(mm)	5.5	3.5	0.5	0.7	4.7

The resonator can therefore be used to monitor two notched frequencies independently. The rejection bands appear at 3 GHz and 6.8 GHz, which correspond to S-band and C-band respectively. Then, two SMV1430-040LF varactor diodes [11] are loaded on the CSRR (see Fig. 2), to obtain two wide tunable rejected bands. By varying the DC voltage of the varactors, the first and second rejected bands shift to lower frequencies.

Accordingly, a WB antenna with reconfigurable rejection bands properties was designed and fabricated; see Fig. 3. Two wide tuning ranges were well achieved. In the manufacturing phase, the diodes are connected to two insulated square patches, placed on the back side of the structure, using two metallized vias. Then, the DC voltage is connected via a CC45T47K240G5 inductor to isolate the RF signal and a 20 kΩ resistor to protect the diodes.



(a) **(b)**

Fig. 3. Realized reconfigurable reject-bands antenna: **(a)** Top view, **(b)** Bottom view.

III. EXPERIMENTAL VALIDATION

The dual reconfigurable notched bands WB antenna has been designed and performed using the computer simulation technology (CST). Fig. 4 shows that the antenna without CSRR operates from 2 to 8 GHz. The insertion of CSRR on the antenna structure as near as possible to the microstrip feed line increases the magnetic coupling and induces a total reflection of the supplied power. In this work, the best position of the resonator is at a distance of 4.7 mm from the feeding line. The S-band (3 GHz) and C-band (6.8 GHz) are well eliminated; the CSRR acts as a filter and creates a band-stop behavior around its resonant frequencies (3.5 and 7 GHz). Thanks to the negative electric permittivity properties of this structure; see Fig. 5. The WB behavior is always well maintained on the outside of these bands.

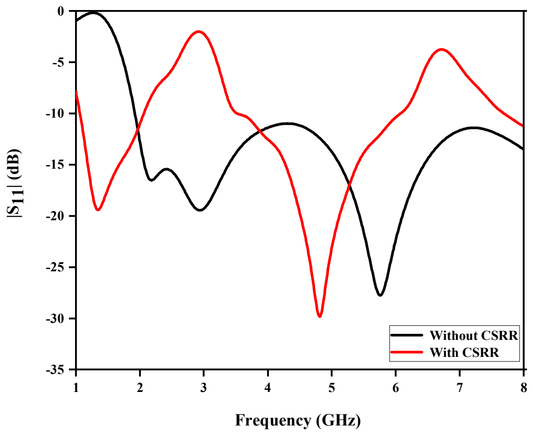


Fig. 4. Reflection coefficient magnitudes of the antenna with and without CSRR.

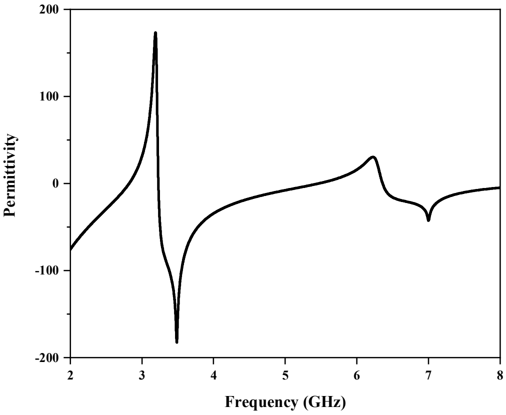
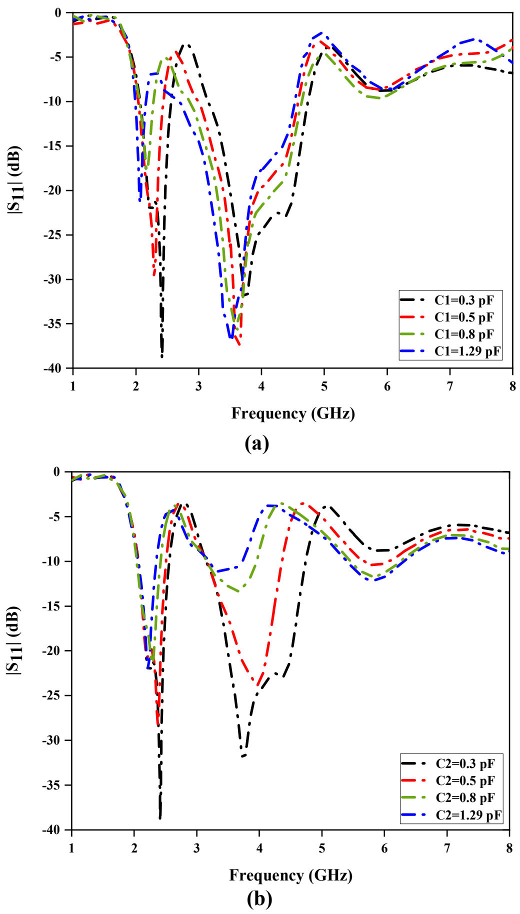


Fig. 5. The effective permittivity produced by the CSRR.

After that, one varactor diode was loaded to each ring of the resonator to control one notched band separately, hence offering more reconfigurability to the proposed design.
From datasheet of the diode, the capacitance can be controlled by varying its value C = [0.3, 0.5, 0.8, and 1.29] pF that corresponds to a reverse bias voltage V = [30, 6.6, 1.6, and 0] V, respectively. Fig. 6 (a) depicts the simulated reflection coefficient magnitudes of the antenna for C1 variable (0.3, 0.5, 0.8, and 1.29) pF and C2 fixed at 0.5 pF. The figure shows a remarkable shift of the first rejection band while the second remained fixed. Likewise, Fig. 6 (b) presents the opposite case, i.e., the reflection coefficient magnitudes for C1 fixed at 0.3 pF and C2 variable (0.3, 0.5, 0.8, and 1.29) pF. The figure highlights a shift in the second band while the first band remained unaffected.

Therefore, two continuous tuning ranges of 0.5 and 1 GHz have been obtained for the first and second rejection bands, respectively.



(a)

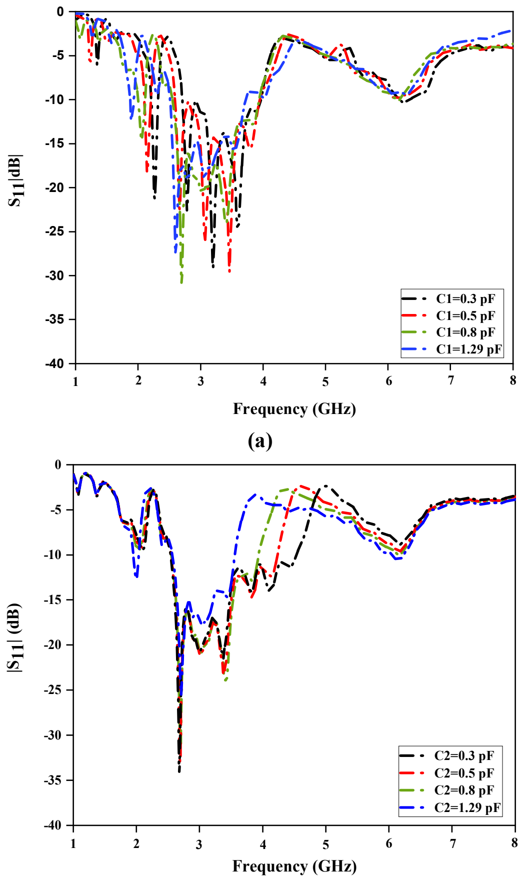
(b)

Fig. 6. Simulated reflection coefficient magnitudes: **(a)** C1 variable and C2 fixed at 0.5 pF, **(b)** C1 fixed at 0.3 pF and C2 variable.

Measured return losses of the planar reconfigurable antenna are presented in Fig. 7 (a) and (b). Some small discrepancies between the simulated and measured results may be due to the approximate boundary conditions used in the simulation as well as the non-accuracy of the diode model. As shown in the figures, increasing the capacitance causes the notched bands to shift towards lower frequencies. The first band shifted from 2 to 2.5 GHz, leading to a tuning range of 0.5 GHz, while the second band is shifted from 3.9 to 5 GHz leading to a tuning range of 1.1 GHz. This makes the antenna a good candidate for multimode and multi standard applications such as Wi-Fi and WiMAX.

Controlling the two rejection zones separately offers more flexibility and adds more reconfigurability to the proposed antenna. These effects make the antenna advantageous in terms of wide double tuning ranges. The measured results agree well with the simulations since almost the same reconfigurable wide bands have been obtained.

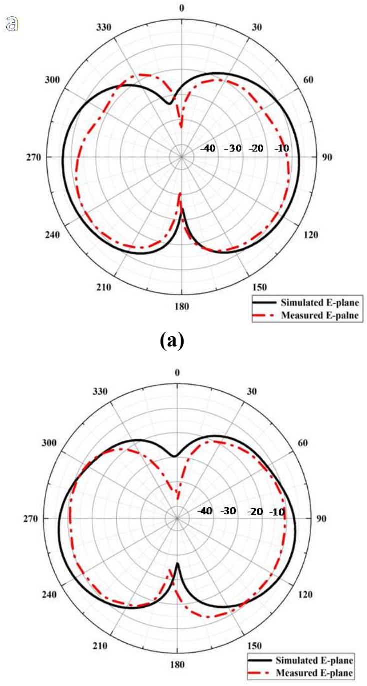
The measured radiation patterns of the double reject-band antenna at frequencies of 2.2 and 3.8 GHz in the E-plane (yoz), are shown in Fig. 8. For different DC biasing voltages 30 and 6.6 V correspond to 0.3 and 0.5 pF respectively, the antenna exhibits a stable omni-directional radiation pattern.



(a)

(b)

Fig. 7. Measured reflection coefficient magnitudes: **(a)** C1 variable and C2 fixed at 0.5 pF, **(b)** C1 fixed at 0.3 pF and C2 variable.

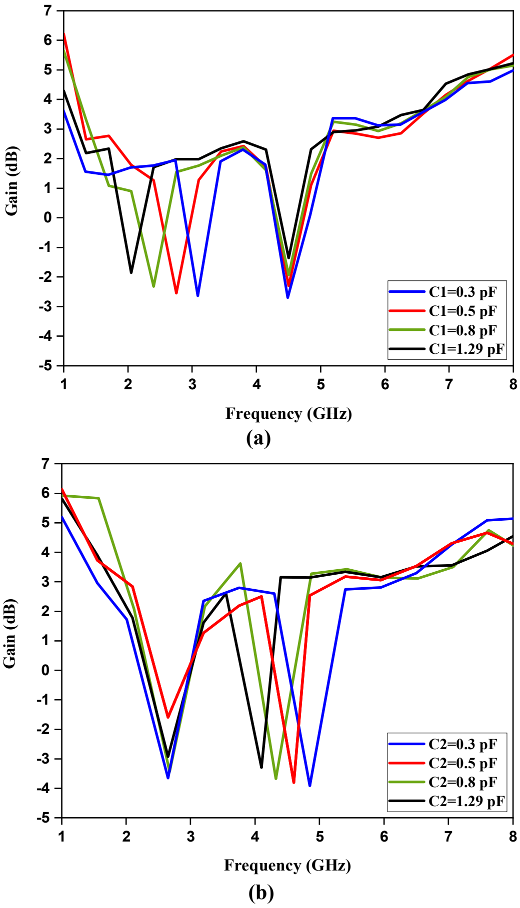


(a)

(b)

Fig. 8. Measured radiation patterns for: **(a)** (C1, C2) = (0.3, 0.3) pF at 3.8 GHz, **(b)** (C1, C2) = (0.5, 0.5) pF at 2.2 GHz.

The simulated gain of the antenna for C1 different from C2 and for several values of varactor diodes capacitance is presented in Fig. 9. The evaluation of the simulated gain curves for the frequency reconfigurable antenna shows a drop at the notched bands, a local imbalance is caused by the CSRR. The gain decreases significantly in the vicinity of the resonant frequency bands of the CSRR, while maintaining the same performance outside. The significant drop in gain for each value of capacitance attests that a reconfiguration of the frequency notch is clearly achieved using the varactor diode.



(a)

(b)

Fig. 9. Simulated gain: **(a)** C1 variable and C2 fixed at 0.5 pF, **(b)** C1 fixed at 0.3 pF and C2 variable.

IV. CONCLUSION

A hexagonal wideband antenna with double tunable notched bands characteristics was designed for modern wireless communication systems. The integration of reconfigurable CSRR on the antenna provides electronic control of the rejected bands while keeping the WB behavior outside. The tuning of the rejected bands was obtained using two varactor diodes included on the antenna structure. Each diode controls one rejected band separately. By varying the capacitance values of the varactor diodes, two wide continuous tuning ranges of 0.5 and 1.1 GHz were achieved.

ACKNOWLEDGMENT

The experimental work and fabrication have been supported by the Grant Agency of the Czech Republic under Project No. 20-02046S.

REFERENCES

[1] LI, T., ZHAI, H., WANG, X., et al. “Frequency-reconfigurable bow-tie antenna for Bluetooth, WiMAX, and WLAN applications,” IEEE Antennas and Wireless Propagation Letters, vol. 14, pp. 171–174, 2014.

[2] YANG, X. X., SHAO, B. C., YANG, F., et al. “A polarization reconfigurable patch antenna with loop slots on the ground plane,” IEEE Antennas and Wireless Propagation Letters, vol. 11, pp. 69-72.X, 2012.

[3] CAI, X., WANG, A., LENG, W., et al. “Novel radiation pattern reconfigurable antenna using shorting probe,” In : 2011 International Conference on Electronics, Communications and Control (ICECC). IEEE, 2011. pp. 2727-2730.

[4] MANSOUL, A., GHANEM, F., HAMID, M. L., et al. “A selective frequency-reconfigurable antenna for cognitive radio applications,” IEEE Antennas and Wireless Propagation Letters, vol. 13, pp. 515-518, 2014.

[5] FAKHARIAN, M. M., REZAEI, P., OROUJI, A. “A. A Multi-Reconfigurable CLL-Loaded Planar Monopole Antenna” Radioengineering, vol. 29, no. 2, pp. 313–320, 2020.

[6] CHAABANE, G., MADRANGEAS, V., CHATRAS, M., et al. “High-Linearity 3-bit frequency-tunable planar inverted-F antenna for RF applications,” IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 983-986, 2017.

[7] AGHDAM, S. A. “A novel UWB monopole antenna with tunable notched behavior using varactor diode,” IEEE Antennas and Wireless Propagation Letters, vol. 13, pp. 1243-1246, 2014.

[8] BEN TRAD, I., FLOCH, J. M., RMILI, H., et al. “Planar Elliptic Broadband Antenna with Wide Range Reconfigurable Narrow Notched Bands for Multi-Standard Wireless Communication Devices,” Progress In Electromagnetics Research, vol. 145, pp. 69–80, 2014.

[9] KINGSLY, S., THANGARASU, D., KANAGASABAI, M., et al. “Tunable Band-Notched High Selective UWB Filtering Monopole Antenna,” IEEE Transactions on Antennas and Propagation, vol. 67, no. 8, pp. 5658–5661, 2019.

[10] ORAIZI, H., SHAHMIRZADI, N. V. “Frequency-and time-domain analysis of a novel UWB reconfigurable microstrip slot antenna with switchable notched bands,” IET Microwaves, Antennas & Propagation, vol.11, pp. 1127–1132, 2017.

[11] Skyworks. SMV121x Series: Hyperabrupt Junction Tuning Varactors. 2016.07.28. [Online]. Available at: https://datasheet.lcsc.com/szlcsc/Skyworks-Solutions-SMV1213-001LF_C150866.pdf.