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An UWB to Narrow Band and Bi-bands Reconfigurable Octogonal Antenna

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Abstract—The main objective of this article is to design, realize and measure the performance of a reconfigurable antenna for wireless applications. The designed antenna will be able to switch among several modes, from the ultra-wideband mode (UWB mode) to narrow band mode (NB mode) and then to dual-band mode (Bi-bands mode) and vice versa in order to combine the maximum functionality. BBy incorporating two resonators into the octagonal antenna, the initial antenna can be covered by one wideband (UWB mode), one narrow sub-band (NB mode), or two narrow sub-bands (Bi-bands mode). The ultra-wideband mode is obtained by deactivating the two resonators (so the antenna operates as a classical octagonal antenna), while the one narrow band mode is obtained by activating just one resonator. In the bi-bands mode, the two resonators are activated at a time to be used as a coupling-bridge to very narrow frequency bands. To present the work, simulated and measured results are given and discussed.

1. INTRODUCTION

The multitude of different standards in cell phones and other personal mobile devices requires compact and smart antennas. Several antennas for multiservice radios have been proposed and can be classified as either ultra-wideband [1–3], or multi-bands [4], or frequency reconfigurable antennas [5–7]. Recently, many frequency reconfigurable antennas have been proposed which comprise three major features: the switching between a wideband mode and one of its sub-bands or vice versa [8, 9]; the switching between narrow band mode and another narrow band mode [10, 11] , and the switching between narrow band mode to bi-bands mode or vice versa [12].

This paper presents analysis, design, and simulation of an octagonal reconfigurable antenna for applications wireless such as WiMAX and Wi-Fi. A tree-resolution is presented. The different simulated antennas were realized with microstrip technology. The experimental results corroborate those obtained by simulation and characterize a reconfigurable frequency behavior, necessary for wireless applications.

2. INITIAL ANTENNA

The idea of covering a maximum bandwidth that allows the use of several known frequencies for different wireless applications led us to choose an antenna whose shape of its main radiating element is octagonal. This antenna was proposed in [13], where the authors designed this antenna to work in the band [3.2 GHz–12 GHz], for a bandwidth of 115.79%.

The needs of design, which come later on the prototype, force us to enlarge the dimensions of this antenna (Figure 1), where they will be larger than those presented by [13]. The new dimensions of our initial antenna ($L_{sub} = 56\,\text{mm}$, $W = 60.8\,\text{mm}$) are shown in Table 1.

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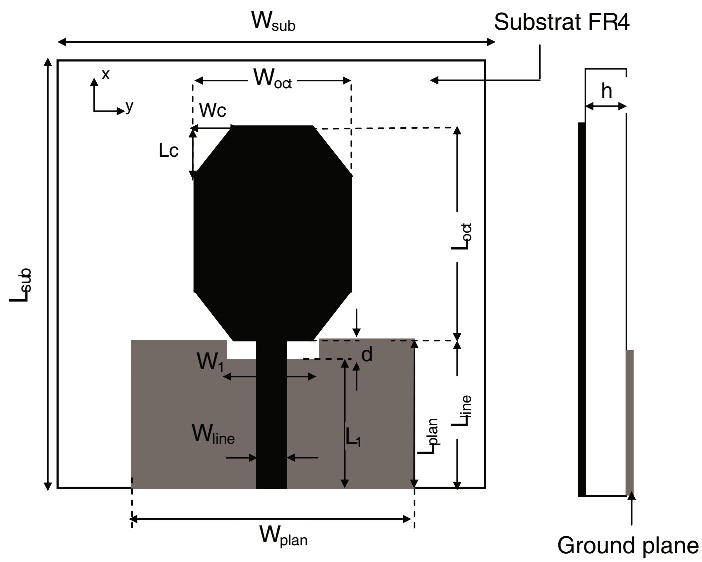


Figure 1. Schematic of the initial antenna.

Table 1. Values of the dimensions of our Octogonal antenna after modification.

Parameter	$\mathbf{W_{sub}}$	$\mathbf{W_{plan}}$	$\mathbf{W_{oct}}$	$\mathbf{W_{line}}$	$\mathbf{W_1}$	$\mathbf{W_c}$	**d**
Value (mm)	60.8	48	24	3	14.4	6	0.8
Parameter	$\mathbf{L_{sub}}$	$\mathbf{L_{plan}}$	$\mathbf{L_{oct}}$	$\mathbf{L_{line}}$	$\mathbf{L_1}$	$\mathbf{L_c}$	**h**
Value (mm)	56	25	30	25	24.2	6	1.6

The design and parameter optimization of the proposed antenna have been done using CST software package. The representation of the reflection coefficient S_{11} as a function of frequency shows the presence of a wide frequency band of 151.2% (Figure 2), with good adaptation applied for different standard wireless: DCS (1.8 GHz), UMTS (1.9 GHz), Bluetooth (2.4 GHz–2.45 GHz), Zigbee (2.4 GHz–2.48 GHz), WiMAX (3.2 GHz–3.5 GHz), Wi-Fi (5 GHz–5.825 GHz).

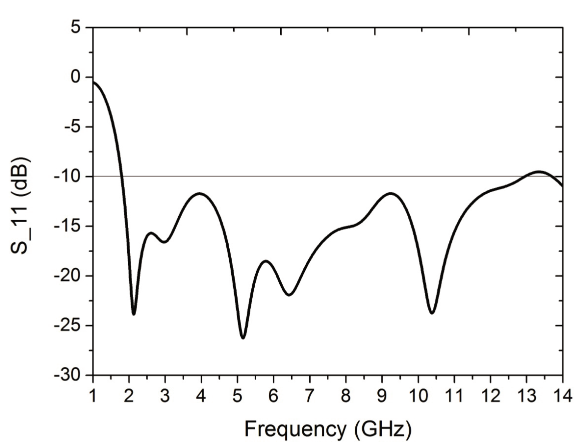
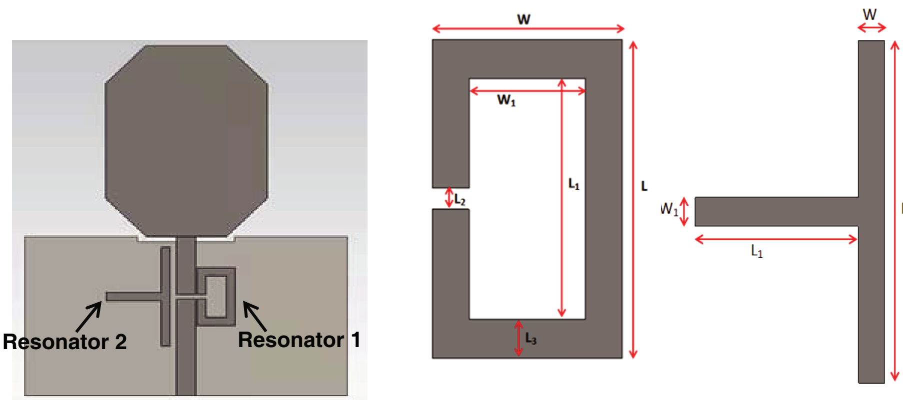


Figure 2. Simulated S_{11} of the initial antenna.

3. PROPOSED APPROACH

Several elements are generally used to make the reconfiguration: sections of lines (resonators) or slot. Their main effect is either the creation of new frequencies of operation of the antenna or the filtering of unwanted bands (notched). These elements are introduced into the antenna using ideal switches, where their connection is made when adding a metal conductor, and their disconnection is done by removing the metal (presence or absence of copper).

In order to make our antenna reconfigurable to a single narrow band and perform the function of passband, a "C-shaped" resonator (or open-loop (resonator 1)), having the dimensions shown in Figure 3(b) (Table 2(a)), is introduced next to the feed line with a very small gap "g1" to have more coupling between the antenna and the resonator. Also, an opening at the power line is made at the same level of the resonator location, with a gap of 0.6 mm, in order to allow the surface current to bypass its path inside the resonator.



(a) (b) (c)

Figure 3. Schematic of the proposed antenna; (a) proposed antenna, (b) Resonator 1, (c) Resonator 2.

After the first step of reconfiguration, we will now go to the second technique in order to make our antenna dual bands, where we will introduce a second resonator "T elongated" (resonator 2), different from the first by its shape and dimensions, but it keeps the same filtering characteristics (Figure 3(c) (Table 2(b))).

Table 2. Values of the dimensions of the two resonators; (a) Resonator 1, (b) Resonator 2.

(a)

Parameter	**W**	**L**	**W1**	**L1**	**L2**	**L3**	**Gap "g_1"**
Value (mm)	5.7	9	4.4	7.7	0.6	1.3	0.13

(b)

Parameter	**W**	**L**	**W1**	**L1**	**Gap "g_1"**
Value (mm)	1.3	15.5	1.5	9.5	0.9

The final design of the antenna is shown in Figure 3(a) which illustrates the final prototype of our technique in the two-band case, with the presence of two resonators.

3.1. Operating Principle of the Approach

Our final prototype consists of an octagonal antenna of five switches (switch 1–switch 5 (Figure 4)) and two resonators having two different physical lengths, in order to have two different applications and a tree-resolution (UWB to NB, then to Bi-bands or vice versa among the three modes). These switches are modeled by the presence and absence of a conductor.

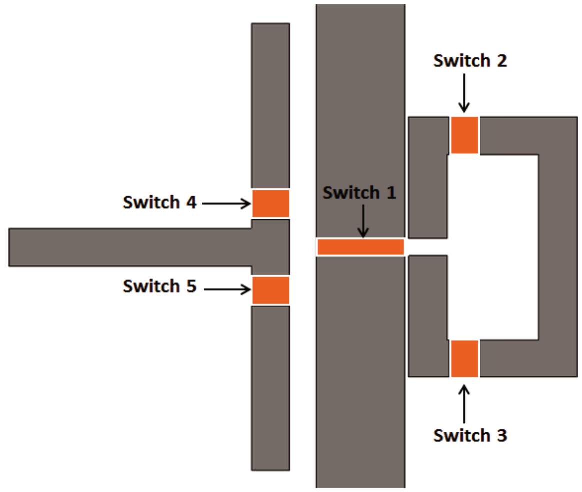


Figure 4. Switches positions.

- To activate the "UWB mode", it is necessary to open the location of switches 2, 3, 4 and 5, to deactivate their operations; however, we close the switch 1 to let the current flow to cross just along the radiating elements of our antenna.
- To activate the "NB mode", for F1 = 3.31 GHz, it is necessary to open the location of switches 4 and 5 of the "T elongated" resonator, switch 1 of the power supply line, and close switches 2 and 3 on resonator C. For F2 = 5.1 GHz, switches 4 and 5 are activated, while leaving switches 1, 2 and 3 deactivated.
- To activate the "Bi-bands mode", we close the location of switches 2, 3, 4 and 5 (activated mode), representative of the two resonators, 1 and 2, and we open switch 1 to allow the surface current to bypass its trajectory inside the two resonators, for the selection of the two frequencies F1 and F2 (bandpass and bandstop modes are used in the same way as in [5]).

Table 3. Resonators configuration: (a) UWB. (b) NB1 mode. (c) NB2 mode. (d) Bi-bands mode.

Switch / Mode	Switch 1	Switch 2	Switch 3	Switch 4	Switch 5
UWB	**Activated**	Deactivated	Deactivated	Deactivated	Deactivated
NB1 à $F_1 = 3.31$ GHz	Deactivated	**Activated**	**Activated**	Deactivated	Deactivated
NB2 à $F_2 = 5.1$ GHz	Deactivated	Deactivated	Deactivated	**Activated**	**Activated**
Bi-bands	Deactivated	**Activated**	**Activated**	**Activated**	**Activated**

In this phase, the design is based mainly on the visualization of the surface currents on the antenna structure in its various operating states. To illustrate this coupling-bridge operation mode, the in-band surface currents of the two narrow bands are given in Figure 5. As can be noted from this figure, at the operating frequencies of the antenna in the NB mode, the current at the active resonator is dense which proves that all the radiated electromagnetic waves are transited by this resonator.

4. SIMULATED RESULTS

Based on this approach, an antenna with two resonators has been designed for different configurations. As can be seen from Figure 6, the antenna has the capability to operate in a UWB mode or one of the three other modes.

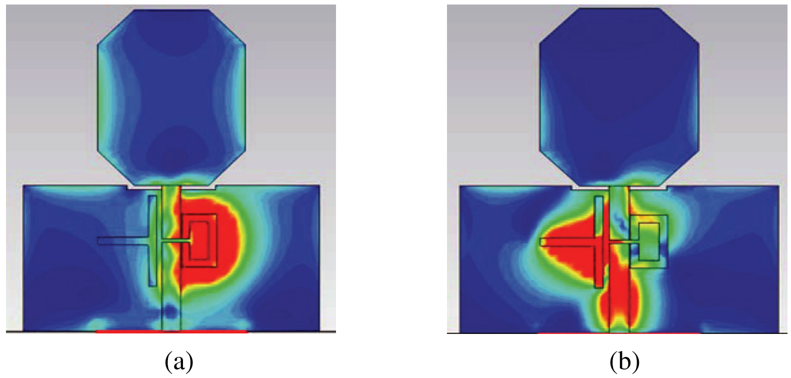


Figure 5. Surface current of antenna; (a) Narrow band 1 mode at F1 = 3.31 GHz; (b) Narrow band 2 mode at F2 = 5.1 GHz.

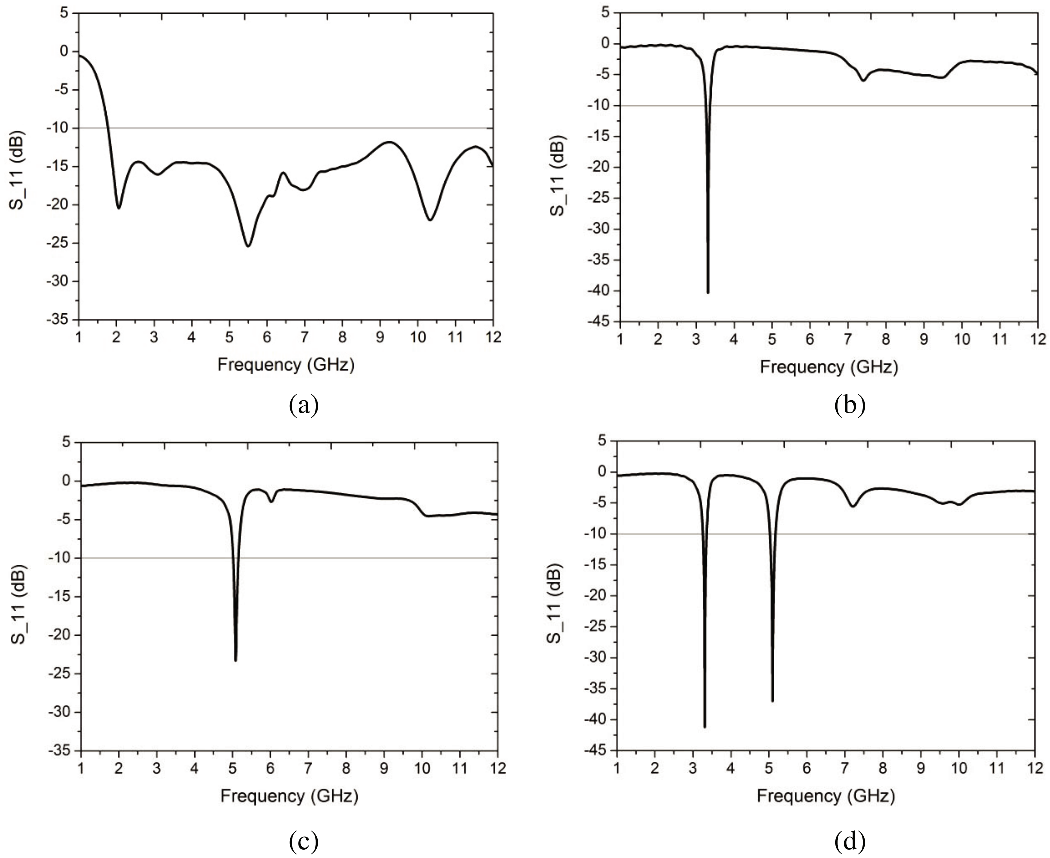


Figure 6. Simulated S_{11} of the antenna; (a) UWB mode, (b) NB1 mode at F1 = 3.31 GHz, (c) mode NB2 at F1 = 5.1 GHz, (d) Bi-bands mode.

5. MEASURED RESULTS

To validate the proposed design, different prototypes, implemented with ideal switches, have been fabricated. A photograph of the antenna in the bi-bands mode is given in Figure 7(a).

The measured and simulated results are given in Figure 8.

It is clear that the results obtained in measurement for different modes of reconfiguration (Figure 8) are very satisfactory and acceptable. On the other hand, the frequency shift of a few MHz compared to the simulation is due to small manufacturing errors.

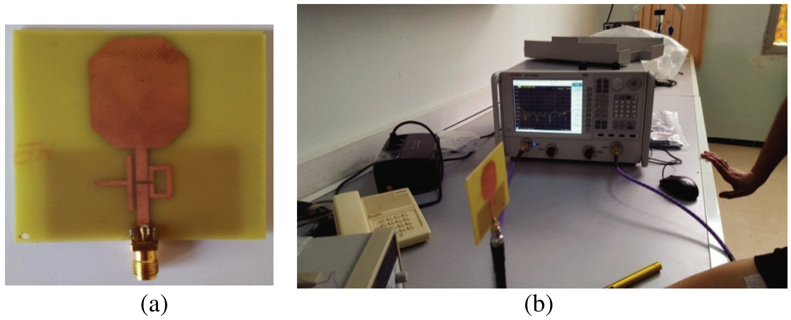


Figure 7. Photograph of a realized prototype antenna in bi-bands mode and antenna measurement with network analyzer.

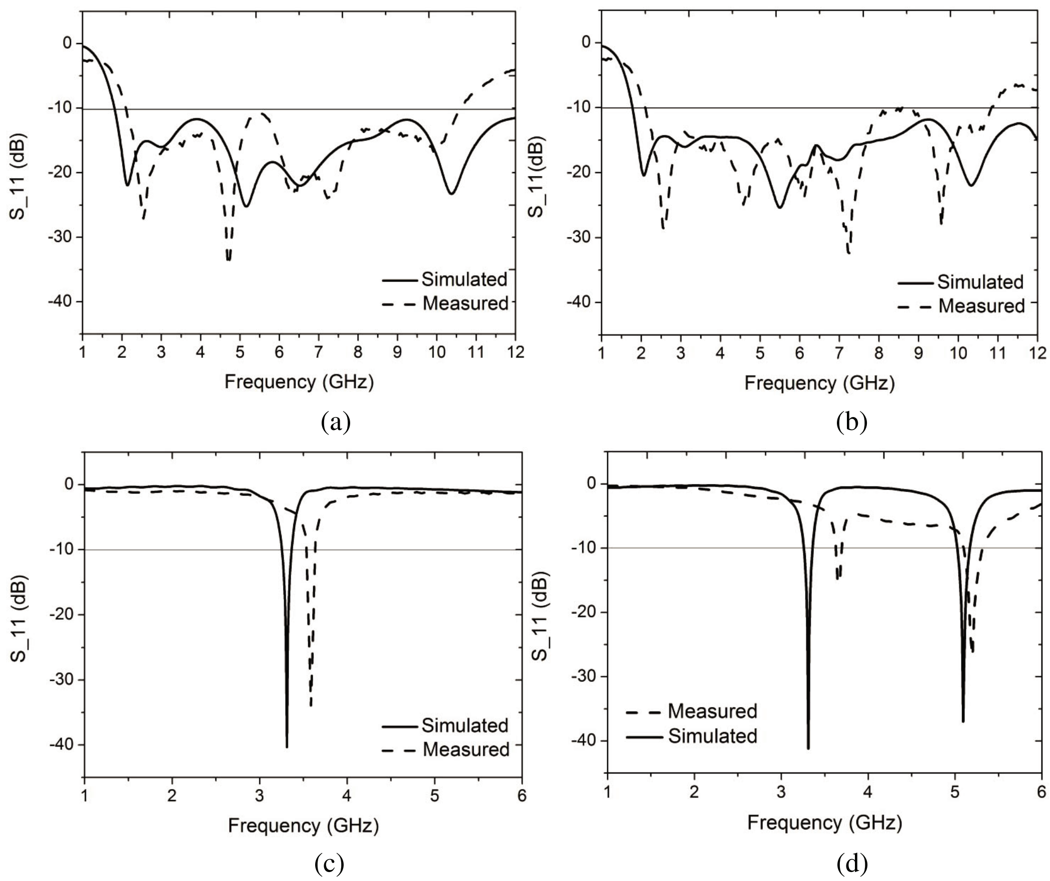


Figure 8. Measured and simulated S_{11} in different modes. (a) Initial antenna, (b) UWB mode, (c) Narrow band (NB1) mode at F1 = 3.31 GHz, (d) Bi-bands mode.

6. CONCLUSION

In this paper, we present a technique of reconfiguration on our octagonal antenna, illustrating each technique with its parametric study; Ultra-wideband (UWB) mode to narrow band (NB) mode, to dual-band mode. The antenna is capable of covering the frequency range 3–10.6 GHz in UWB, narrow band, or bi-bands mode, which allows it working in any part of the considered band. It is believed that this type of multi-resolution antennas can be a good candidate for cognitive radios and various communication standards.

REFERENCES

1. Bao, X. L. and M. Ammann, "Investigation on UWB printed monopole antenna with rectangular slitted groundplane," *Microwave and Optical Technology Letters*, Vol. 49, No. 7, July 2007.
2. Choi, S. H., J. K. Park, S. K. Kim, and J. Y. Park, "A new ultra-wideband antenna for UWB applications," *Microwave and Optical Technology Letters*, Vol. 40, No. 5, 399, 2004.
3. Chen, D. and C. H. Cheng, "A novel compact ultra-wideband (UWB) wide slot antenna with via holes," *Progress In Electromagnetics Research*, Vol. 94, 343–349, 2009.
4. Kimouchee, H., M. Bitchikh, and B. Atrouz, "Novel design of a fractal monopole antenna for wireless communications," *14th Conference on Microwave Techniques*, Prague, 2008.
5. Shynu Nair, S. V. and M. J. Ammann, "Reconfigurable antenna with elevation and azimuth beam switching," *IEEE Antennas and Wireless Propagation Letters*, Vol. 9, 367–370,2010.
6. Janne Ilvonen, Risto Valkonen, et al., "Multiband Frequency Reconfigurable 4G Handset Antenna with MIMO Capability," *Progress In Electromagnetics Research*, Vol. 148, 233–243, 2014.
7. Bemani, M. and S. Nikmehr, "A novel reconfigurable multiband slot antenna fed by a coplanar waveguide using radio frequency microelectro-mechanical system switches," *IEEE Microwave and Optical Technology Letters*, Vol. 53, 751–757, 2011.
8. Wang, Y., "An integrated narrowband-wideband antenna," *Loughborough Antennas* & *Propagation Conference*, Loughborough, UK, 11–12 November 2013.
9. Bitchikh, M. and F. Ghanem, "An UWB to three sub-bands frequency reconfigurable antipodal Vivaldi antenna," *Proc. IEEE AP-S Int. Symp. Antennas Propagation*, 670–671, Orlando, Floride, États-Unis, USA, 2013,.
10. Madi, M. A., M. Al-Husseini, A. H. Ramadan, K. Y. Kabalan, and A. El-Hajj, "A reconfigurable cedar-shaped microstrip antenna for wireless applications," *Progress In Electromagnetics Research C*, Vol. 25, 209–221, 2012.
11. Laheurte, J. M., "Switchable CPW-fed slot antenna for multifrequency operation," *Electronics Letters*, Vol. 37, No. 25, 1498–1500, December 2001.
12. Iqbal, A., S. Ullah, U. Naeem, A. Basir, and U. Ali, "Design, fabrication and measurement of a compact, frequency reconfigurable, modified T-shape planar antenna for portable applications," *J. Electr. Eng. Technol.*, Vol. 12, No. 4, 1611–1618, 2017.
13. Bithikh, M., R. Aksas, H. Kimouche, and A. Azrar, "New UWB antenna design for wireless communications," *Microwave Opt. Technol. Lett.*, Vol. 54, 692–697, 2012.