American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-10, pp-139-148
www.ajer.org
Research Paper Open Access

Printed Planar Double Inverted-F Antenna Withlarge Frequency Reconfigurability Range

Jean Marie FLOC'H And Imen BEN TRAD
IETR, INSA, 20 avenue des Buttes de Coësmes, 35708 Rennes, France.

ABSTRACT:*The use of frequency reconfigurable antennas isextremely importantfor Cognitive Radio (CR) systems. In this paper, we propose a study and designa multiband planar double inverted F-antenna (PIFA) with frequency agility characteristic. The proposed antenna is suitable for several applications. In fact, a varactor diode has beenintegrated between the radiating element and the added floating ground plane. By applying a reverse voltage V on the varactor diode and we obtainmore than three resonance frequencies with wide tuning ranges. Frequenciescan be shifted from 700 to 1450 MHz and 1975 to 2800 MHz. The passive and active antennas have been manufactured and characterized. Simulations and measurements are presented and discussed.the novelty of this antenna is the use of a floating ground plane to realize the reconfigurability.*

KEYWORDS:*Frequency agility; reconfigurable antenna; Varactor diode; PIFA;double PIFA; large tuning frequency range*.

Date of Submission:04-10-2018 Date of acceptance: 16-10-2018

I. INTRODUCTION

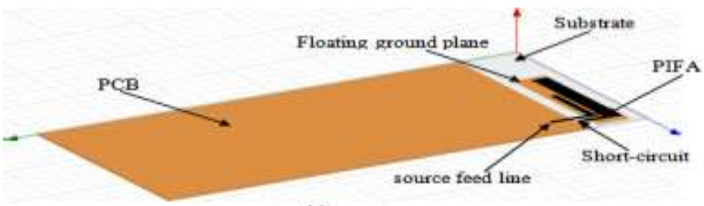
Wireless communication systems must be able to meet increasing requirements of multiple standards, higher data rates and better use of Frequency Spectrum. To overcome these challenges, antennas need to be flexible and adapt to environment changes. Frequency Reconfigurable Antennas are addressing these complex and over changing needs and are consequently becoming a hot topic triggering tremendous research interest [1-6]. This document is an extension of paper [13] listed in References at the end of this document.

The Planar inverted F-antenna (PIFA) has been extensively studied and is widely used in mobile handsets and connected objects. It is simple and cheap to manufacture and has a small footprint. Adding frequency agility property to PIFA antenna provides promising solutions to increasingly complex requirements [7-10].

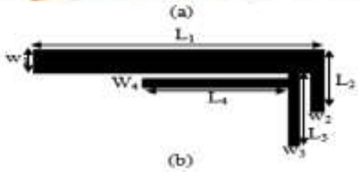
We have investigated in [11] a PIFA structure with a technique for frequency agility behavior. This technique is based on a concept developed in [12]. In this paper, we have enlarged the frequency reconfigurability ranges by using a double PIFA configuration. The new antenna design is presented in Fig. 1. The purpose of the floating ground plane is to reduce the antenna size and increase the number of resonance frequencies. This antenna can be deployed in several wireless communication applications.

II. PASSIVE ANTENNA

A. Antenna design



(a)



(b)

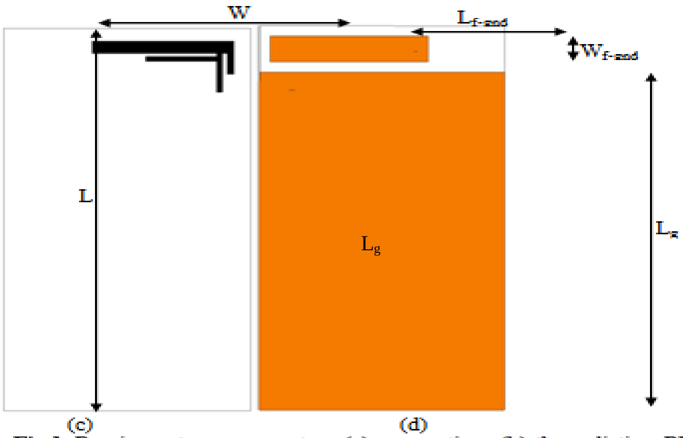


Fig.1. Passive antenna geometry: (a) perspective; (b) the radiating PIFA (c) front side and (d) back side views.

The proposed antenna is printed on FR4 substrate with a thickness h=0.8mm and a relative permittivity ε_r = 4.4. The PIFA structureis printed on the topsideand short-circuited tothe grounded PCB on the backside as presented in Fig.1-a/b. The floating ground plane is added on the backside below the PIFA as shown in Fig.1-c. It enables changing the antenna effective permittivity and increases the electrical length of the radiating section. Thus, the overall size of the antenna is well reduced as explained in [11] and [12].The simulated results of antenna with (blue) and without (red) floating grounded plane are presented in Fig. 2. It illustrates very well this behavior; we generate lower frequency resonance (1250 MHz to 1150 MHz) and new frequency resonances in the same frequency band. The optimized design parameters are given in Table .I.

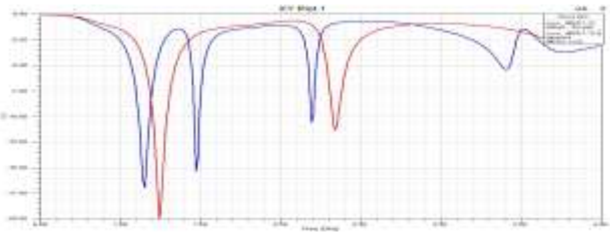


Fig.2. Simulated reflection coefficient S_{11} of the passive antenna with (blue) and without (red) floating grounded plane.

TABLE I. DESIGN PARAMETERS OF THE PASSIVE ANTENNA

Parameter	Value (mm)	Parameter	Value (mm)
L	150	w_1	5
W	70	w_2	2
L_1	40	w_3	1.6
L_2	13	L_g	132
L_3	15	$W_{f\text{-}gnd}$	10
L_4	20	$L_{f\text{-}gnd}$	45

B. Passive PIFA performances

(a) (b)

Fig.3. Photos of the prototyped passive antenna: (a) front side and (b) back side views.

The antenna prototype is presented in Fig.3. The passive PIFA has been numerically studied and optimized using the ANSYS-ANSOFT High Frequency Structure Simulator, HFSS-V15.Practically, good agreement is obtained between simulation results in red and measurements in blue as shown in Fig 4. The slight shift observed is the result of manufacturing inaccuracies (the real permittivity of FR4 per example) and we don't take into account the coaxial feeding in the simulation.
The measured resonance frequencies are F_1=1067, F_2=1602 and F_3=2278MHz.

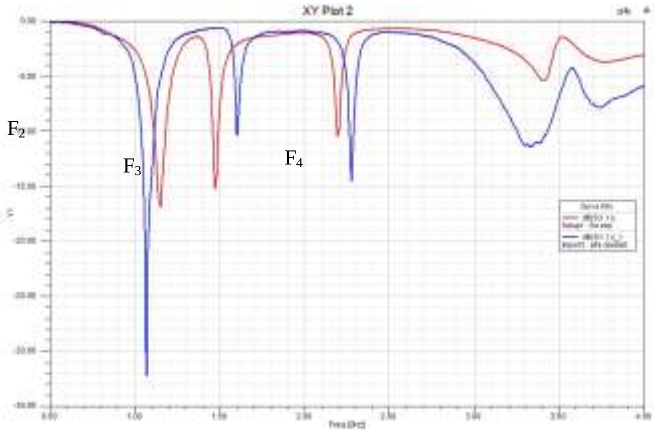
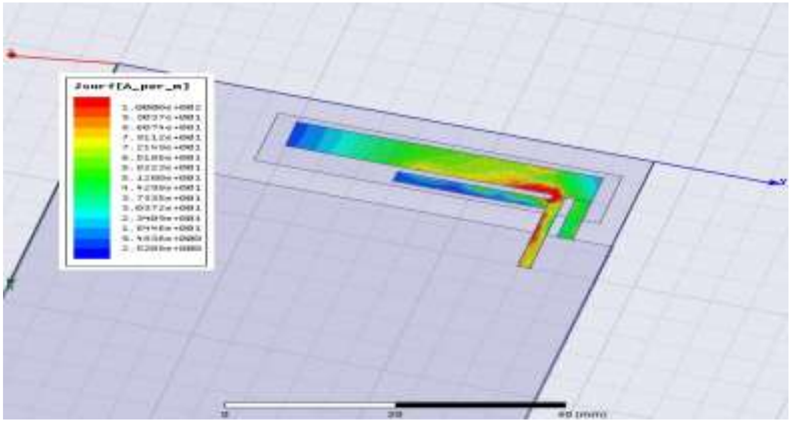
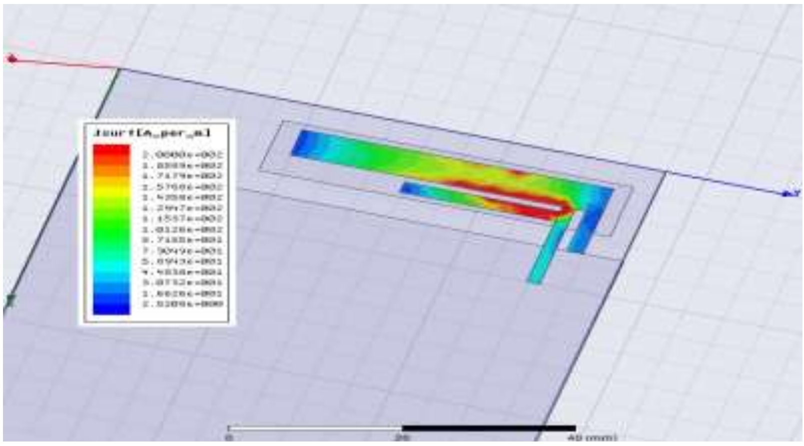


Fig.4. Measured (blue) and simulated (red) reflection coefficient S_{11} of the passive antenna.

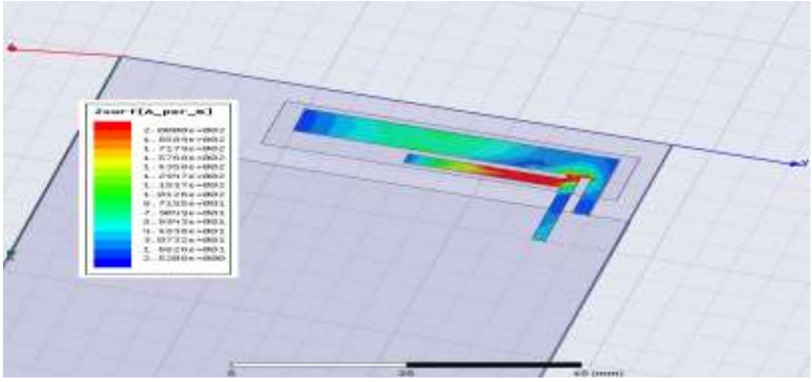
Fig. 5 shows the simulated surface current for the three resonant frequencies F1 = 1150 MHz, F2 = 1470 MHz and F3 = 2190 MHz.As expected, we observe a large current on the PIFA bigger arm for F1 = 1150Mhz, a large current on both arms for F2 = 1470MHz and a large current on the little arm for F3 = 2190 MHz



a) 1150 MHz



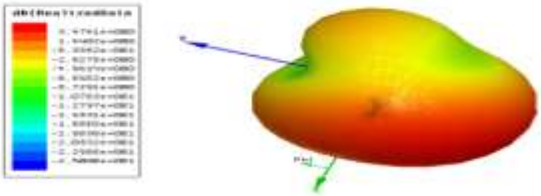
b) 1470 MHz



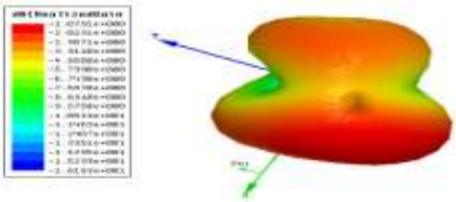
c) 2190 MHz

Fig.5. Simulated surface current of the passive antenna at the 3 resonnant frequencies.

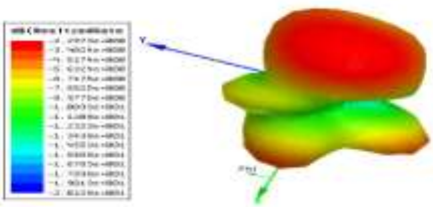
In the next section we present the measured and simulated radiation patterns at the different resonnant frequencies.



a) 1150 MHz



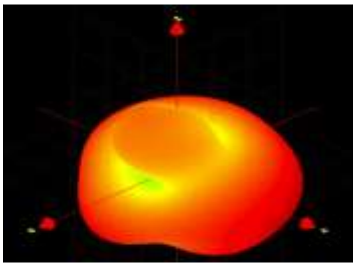
b) 1470 MHz



c) 2190 MHz

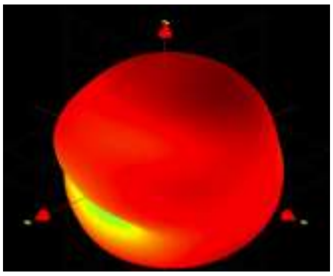
Fig.6. Simulated radiation patterns of the passive antenna at the 3 resonnant frequencies.

GAIN	
Min	- 25 dBi
Max	3.1 dBi



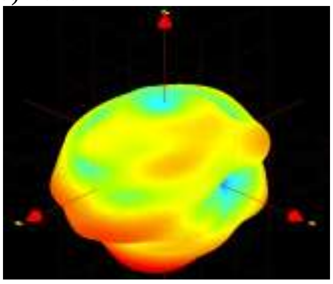
a) 1090 MHz

GAIN	
Min	- 27 dBi
Max	0.27 dBi



b) 1610 MHz

GAIN	
Min	- 24 dBi
Max	0 dBi



c) 2290 MHz

Fig.7. Measured radiation patterns of the passive antenna at the 3 resonant frequencies.

III. FREQUENCY RECONFIGURABLE ANTENNA

The varactor diode used in the active antenna is a BB833 device from Infineon. It is integrated in the corner of the bigger line of the PIFA, to connect it later to the floating ground plane as can be seen on Fig.5.The agility is obtained by applying a variable reverse voltage V to the varactor diode. A 1 KΩ resistor is used to polarize the diode. The measured reflection coefficient S_{11} for different cases (voltage between 0 to 17 V) are shown in Fig.9.

Fig.8. Photos of the fabricated frequency reconfigurable double PIFA: (a) front side and (b) back side views.

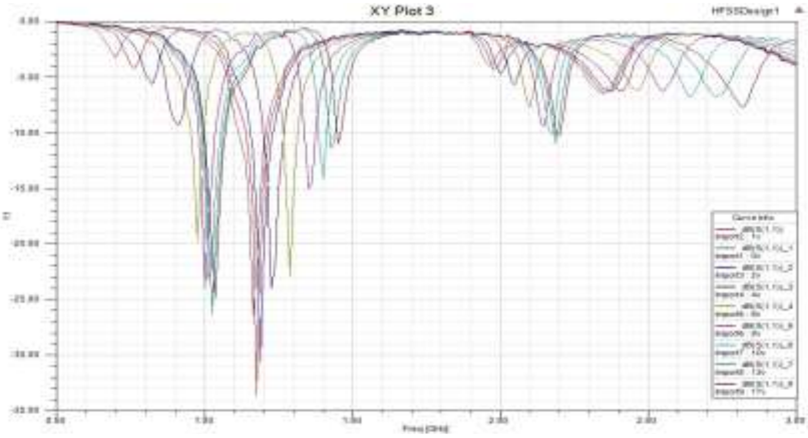


Fig.9. Measured reflection coefficient S_{11} of the frequency reconfigurable antenna.

The addition of avaractor diode to PIFA allows an electronic control of the four resonance frequencies that shift to higher values when increasing the applied reverse bias voltage via a decrease of the capacitor values.We will focus on the first three frequencies F_1, F_2 and F_3. The resonance frequencyF_1 can be easily moved from 700 to 1037 MHz. Noteworthy is that the input impedance matching was greatly improved while decreasing the capacitor values.For the second frequency F_2, we obtain a frequency range between 1162 to 1450 MHz. A tuning frequency range of 1975 to 2200 MHz is achieved for the Third resonance frequency F_3.Measured resonant frequencies are summarized in Table II.Fig.10 presents the measured and simulated reflection coefficient S_{11} for reverse bias voltage V=13V (C=1pF). A good agreement can be observed between simulated and measured results.

TABLE II. MEASURED RESONANT FREQUENCIES

Voltage (V)	**Capacitor value (pF)**	**Frequency F_1 (MHz)**	**Frequency F_2 (MHz)**	**Frequency F_3 (MHz)**
without varactor	- -	1067	1602	2278
0	**≈20**	700	1162	1975
1	**9.8**	762	1175	1987
2	**7**	825	1187	2000
4	**4**	908	1220	2050
6	**2.8**	975	1287	2100
8	**1.8**	1000	1350	2150
10	**1.4**	1025	1400	2175
13	**1**	1030	1425	2185
17	**0.9**	1037	1450	2200

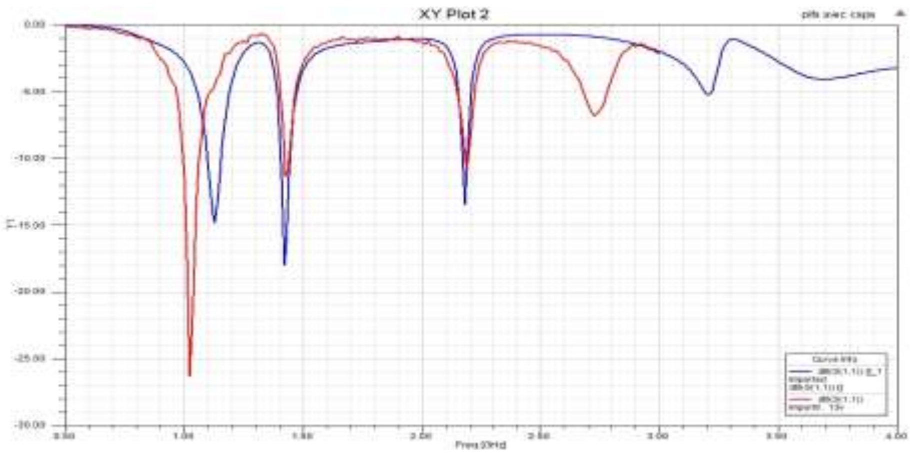
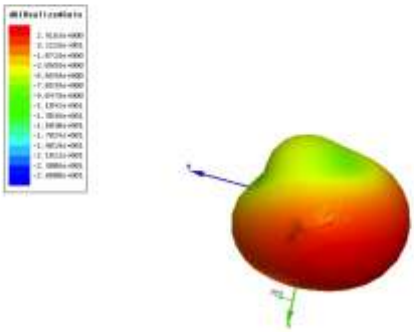
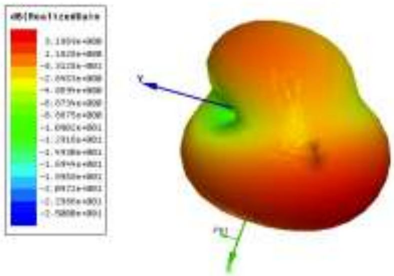


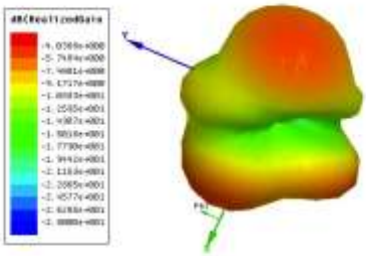
Fig.10. Measured and simulated reflection coefficient S_{11} for V = 13V (C=1pF).



(a)



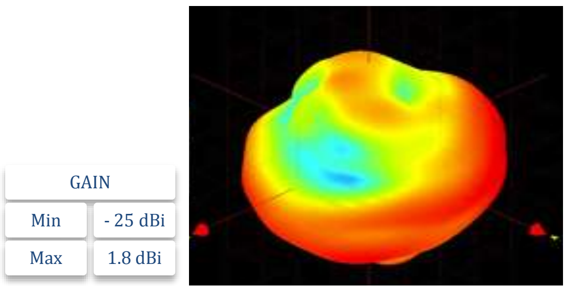
(b)



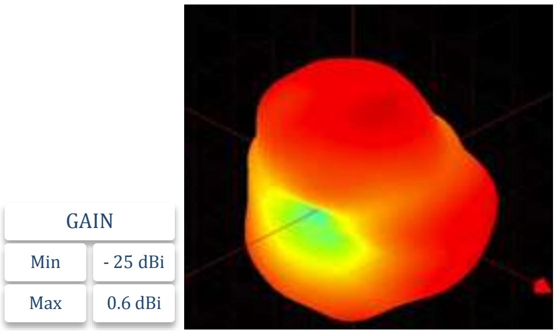
(c)

Fig.11. Simulated 3 D radiation patterns for V = 4V (C=4pF) at: (a) 1050 , (b) 1300 and (c) 2050 MHz.

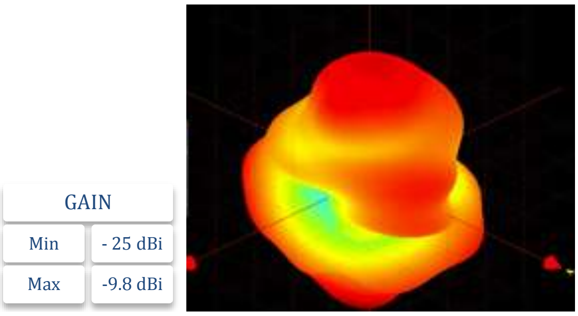
The simulated and measured 3D radiation patterns for V=4V (C=4pF) are shown in Fig. 11 and Fig. 12, respectively. It can be concluded that the frequency reconfigurable double PIFA presents stable radiation properties with maximum simulated gain of 2.9 dBi at 1050 MHz, 3.2dBi at 1300 MHz and -4 dBi at 2050 MHz. Actual measured gains are G_{max} = -1.8 dBi at 908 MHz, 0.6 dBi at 1220 MHz and -9.8 dBi at 2050 MHz. The differences between simulated and measured results can be explained by the fact that we only consider the varactor diode like a capacitance without taking into account the diode losses. Besides, the maximum frequency for the diode is 2 GHz.



(a)



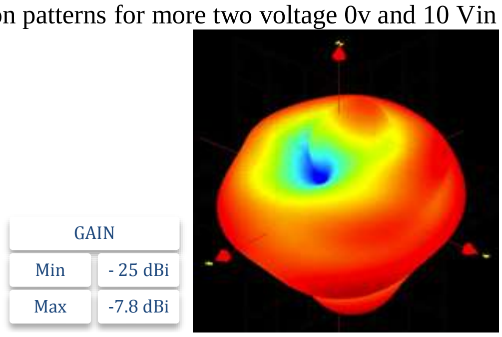
(b)



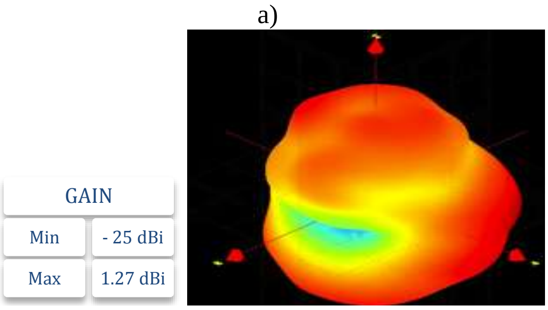
(c)

Fig.12. Measured 3 D radiation patterns at: (a) 908; (b) 1220 and (c) 2050 MHz for V = 4V (C = 4pF).

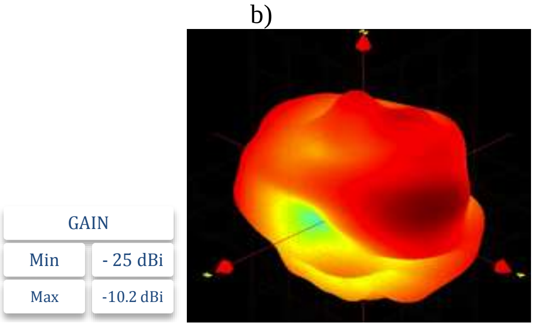
We present the measured radiation patterns for more two voltage 0v and 10 Vin the fig. 13 and 14.



a)



b)



c)

Fig.13. Measured 3 D radiation patterns at: (a) 678; (b) 1160and (c) 1968 MHz for V = 0V (C = 20pF).

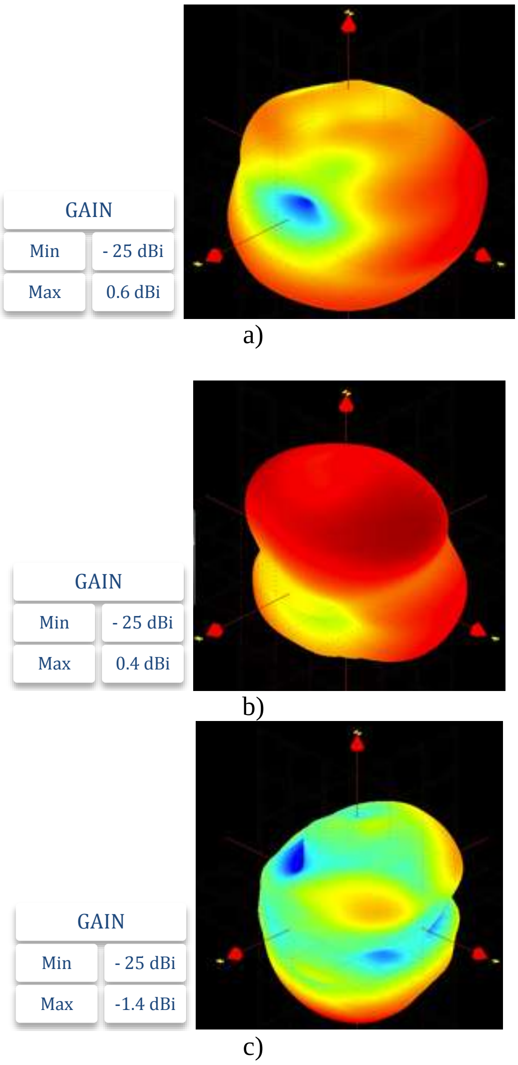


Fig.14. Measured 3 D radiation patterns at: (a) 1020; (b) 1440 and (c) 2110 MHz for V = 10V (C = 1.4pF).

The antenna efficiency at different voltages and resonance frequencies is shown on this next table:

TABLE III. MEASURED EFFICIENCY

Voltage (V)	Capacitor value (pF)	F_1	F_2	F_3
Without varactor	- -	66%	45%	21%
0	**≈20**	7%	38%	4%
4	**4**	19%	37%	4%
10	**1.4**	30%	27%	10%

We note a degradation of the efficiencies when the capacitance value increases and a better efficiency for the second resonance frequency.

IV. CONCLUSION

A multiband frequency reconfigurable double PIFA has been successfully designed and numerically studied. A varactor diode has been inserted between the double PIFA and the floating ground plane in order to produce the agility property. Four resonance frequencies are electronically controlled and reconfigurable behavior is well obtained between 700 to 1450 MHz and 1975 to 2800 MHz. Measurement results agree well with simulations. The proposed antenna can be used for a large range of applications.This study shows the potential for reconfigurabilityusing a floating ground plane. We are now studying other floating grounded plan structures inorder to improve performance in efficiency.

REFERENCES

[1]. I. Ben Trad, H. Rmili, J. M. Floch, W. Zouch and M. Drissi, "Planar Square Multiband Frequency Reconfigurable Microstrip fed Aantenna with Quadratic Koch-Island Fractal Slot for Wireless Devices," Microwave and Optical Technology Letters, Vol. 57, No. 1, pp.207-212 January 2015.

[2]. M. Konca and P. A. Warr, "A Frequency-Reconfigurable Antenna Architecture Using Dielectric Fluids," IEEE Transactions on Antennas and Propagation, Vol. 63, No. 12, pp 5280-5286, December 2015.
[3]. J.M. Floch, I. Ben Trad, I. Rouissi, “Mechanically Tunable Meander Antenna for Cognitive Radio,” 10th European Conference on Antennas and Propagation (EuCAP), 2016.
[4]. J.A. Byford, K.Y. Park, P. Chahal and E.J. Rothwell, "Frequency reconfigurable patch antenna array," Electronics Letters, Vol. 51 No. 21 pp. 1628–1630, October 2015.
[5]. X. L. Yang, J. C. Lin, G. Chen and F. I Kong, "Frequency Reconfigurable Antenna for Wireless Communications Using GaAs FET Switch," IEEE Antennas and Wireless Propagation Letters, Vol. 14, pp 807-810, 2015.
[6]. I. Ben Trad, J. M. Floch, H. Rmili, L. Laadhar and M. Drissi, “Planar Elliptic Broadband Antenna with Wide Range ReconfigurableNarrow Notched Bands for Multi-Standard WirelessCommunication Devices,” Progress In Electromagnetics Research, Vol. 145, pp. 69–80, 2014
[7]. L. M. Feldner, C. T. Rodenbeck, C. G. Christodoulou and N. Kinzie, “Electrically Small Frequency-Agile PIFA-as-a- Package for Portable
[8]. Wireless Devices”, IEEE Transactions on Antennas and Propagation, Vol. 55, No. 11, November 2007.
[9]. M. N. M. Kehn, Ó. Q.Teruel and E. R. Iglesias, “Reconfigurable Loaded Planar Inverted-F Antenna Using Varactor Diodes,” IEEE Antennas and Wireless Propagation Letters, Vol. 10, pp. 466 - 468 2011.
[10]. J. H. Lim, C. W. Song, Z. J. Jin, T. Y. Yun, “Frequency reconfigurable planar inverted-F antenna using switchable radiator and capacitive load,” IET Microwaves, Antennas & Propagation,Vol 7, No 6, pp 430 - 435, 2013.
[11]. S. Lee, Y. Sung, “Reconfigurable PIFA with a parasitic strip line for a hepta-band WWAN/LTE mobile handset,” IET Microwaves, Antennas & Propagation,Vol 9, No 2, pp 108 - 117, 2015.
[12]. J. M. Floch, I. Ben Trad, “Printed Frequency Reconfigurable Planar Inverted-F Antenna for ISM Applications", LAPC 2016, Lougborough, 14 -15 November 2016
[13]. J. M. Floch, A. Singh, L. Desclos, "Set of New Compact Antennas Suitable for Integration on PCB," Loughborough Antennas and Propagation Conference (LAPC), pp 40-43, 2014.
[14]. J.M. Floch, I. BEN TRAD « Printed Planar Double Inverted-F Antenna with Large Frequency Reconfigurability Range » EuMC 2017, Nuremberg, 9-13 October 2017

Jean Marie FLOC’H "Printed Planar Double Inverted-F Antenna Withlarge Frequency Reconfigurability Range "American Journal of Engineering Research (AJER), vol. 7, no. 10, 2018, pp. 139-148