A new design of a printed reconfigurable coplanar multiband antenna

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ABSTRACT

The demand for multi-functional components has increased enormously in recent years. Advances in integrated technology have enabled researchers to adapt diverse applications operating at different frequencies in a single wireless device. A compact broadband coplanar waveguide (CPW)-fed square aperture monopole antenna with inverted-L grounded strips is first described. The proposed antenna has a small size of 60×60×0.74 mm^3 and has excellent performances which include a good input impedance matching with a much wider operating bandwidth, an excitation of the circular polarization at 2.45 GHz, and a stable omnidirectional radiation pattern. Then, a multiband reconfigurable antenna design is developed from this structure. The frequency reconfigurable approach is obtained using a varactor diode. In this work, it is observed that frequency diversity can be obtained by varying the value of the capacity by leaving the dimensions antenna unchanged. The results are given using CST microwave studio and show good performances in terms of return loss, bandwidth, gain and radiation pattern and demonstrate that the proposed antenna offers a reconfigurable solution for multi-standard wireless communication applications.

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1. INTRODUCTION

Although reconfigurable antennas have generally been implemented in various ways during the last 40 years, in particular, reconfigurable microstrip antennas have been in existence for almost as long as the microstrip antenna itself, i.e. since the early 1980s [1], [2]. The motivation from deploying reconfigurable features in an antenna typically is straightforward- the acquisition of new capabilities which eliminate the requirement for multiple antennas and/or which provide additional degrees of operational freedom that increase system performance.

The reconfiguration of an antenna is accomplished by an intentional redistribution of the currents or, similarly, the electromagnetic fields of the effective aperture of the antenna, which leads to reversible changes in the antenna impedance and/or radiation characteristics [3]-[5]. antenna reconfiguration can be achieved by various approaches. for the implementation of miniature reconfigurable antennas, six principal reconfiguration methods can be distinguished. antennas based on radio frequency microelectromechanical devices (RF-MEMS) [6], PIN diodes [7], or varactors (varactor diodes) [8], [9] for redirecting their surface currents are called electrically reconfigurable [10]. thus, antennas that rely on photoconductive switching elements are called optically reconfigurable antennas[11], [12]. Also, reconfigurability can be achieved by a mechanical modification in the antenna structure [13], [14] this type is known as physical reconfigurability. there is another reconfigurability technique presented in the use of smart materials such as ferrites and liquid crystals [15], [16].

Besides, in this study, we are interested in electrical reconfigurability using varactors diodes. The varactor diodes are used in the tuning circuits of receivers, they allow to vary the resonance frequency of the tuning circuit by changing the control voltage applied to the diode [17], [18]. The advantage of this diode is the facility of its integration and the possibility of continual frequency reconfiguration. It is widely used in wireless communication applications [19], [20].

However, the integration of multi-band antennas having frequency reconfigurability permits frequency selectivity, downsizing, and enables the antenna to be deployed for multiple wireless standards. Changing operating scenarios can affect antenna performance [21], [22]. Most of the current multi-band antenna designs used to achieve reconfigurability can be classified into three categories: patch antennas [23], [24], wire antennas, and inverted F planar antennas (PIFA) [25].

Therefore, current work is focused on the design of a frequency reconfigurable antenna structure. This paper presents a printed multiband coplanar reconfigurable antenna. This proposed antenna design is derived from the structure of [1]. Compared to Ouberri *et al.* [1], a varactor diode is used in this antenna to generate multiple frequencies that can support certain recent wireless communication standards. Simulation demonstrates the validity of the concept. The simulation results for return loss, gain and radiation patterns are presented. The simulation is carried out by CST-MW.

2. METHOD

2.1. Design of the cpw monopole antenna with linear and circular polarizations

The topology of the basic structure is shown in Figure 1. A ground plane is etched on one side of an inexpensive square FR4 substrate with a side length G, a thickness H=0.8 mm, a dielectric constant of 4.4 and a loss tangent of 0.02. The square opening with side length L is located in the center of this ground plane with a pair of inverted L ground strips around the two opposite corners and an L-slot on the top side. the exciting is applied by a 50 Ohm CPW fed line, which has a signal band of width W_f and using two identical intervals of width g_1 for separation of the ground plane.

The design included two main specifications: one is mainly for impedance band widening by implanting two inverted L-shaped strips of earth $g_2$width, having the same length of L_x in the x-direction and $L_y$in the y-direction, around the two opposite corners of the slot, which are only cut by the extended line of the inclined feed. The other feature is for the improvement of the axial ratio band width (ARBW) which is mainly related to the inverted L-shaped slot in the upper half of the ground. Although these structures (inverted L-slot and inverted L-slot grounded metal strips) are capable of conducting the antenna to CP operation with satisfactory impedance matching, they cannot guarantee that the broadband impedance can be completely covered by the 3-dB AR band of the antenna.

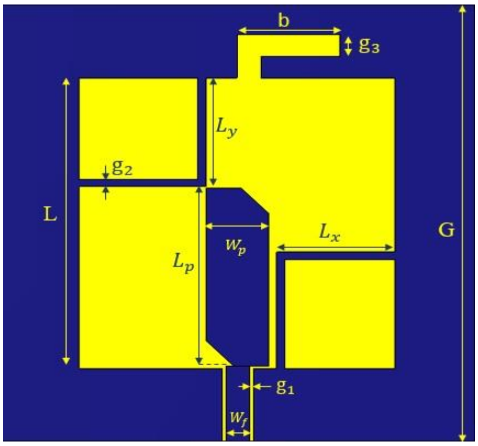


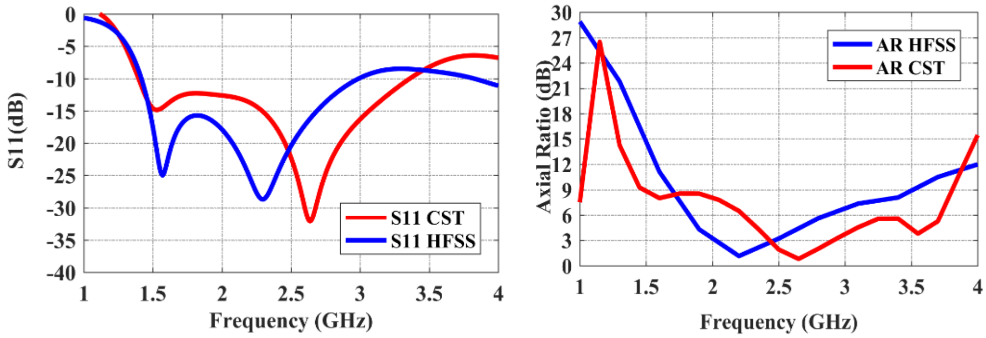
Figure 1. Geometry of the CPW monopole antenna [1]

The corresponding structural dimensions of the presented antenna have been summarized in Table 1. This antenna was designed and simulated using the CST microwave studio electromagnetic solver.

Based on the simulation results shown in Figure 2. As shown in Figures 2(a) and (b), one can clearly observe that we have a clear correspondence between the simulation on CST and the simulation on HFSS in terms of reflection coefficient and axial ratio with good input impedance matching and remarkable bandwidth. The value of the gain of this initial antenna is greater than 2 dB, as shown in Figure 3. Because both of the software tools are based on different theoretical models, the simulation results in high-frequency structure simulator (HFSS) and CST (Figure 2).

Table 1. Parameters of the CPW-fed monopole antenna

Parameters	Value (Mm)	Parameters	Value (Mm)
G	60	$L_x = L_y$	15
L	40	g_1	0.3
$\mathbf{W_p}$	8	g_2	1
$\mathbf{L_p}$	24.5	g_3	3
$\mathbf{W_f}$	1.41	b	13



(a) (b)

Figure 2. The simulation results of the initial antenna of, (a) the reflection coefficient and (b) the axial ratio

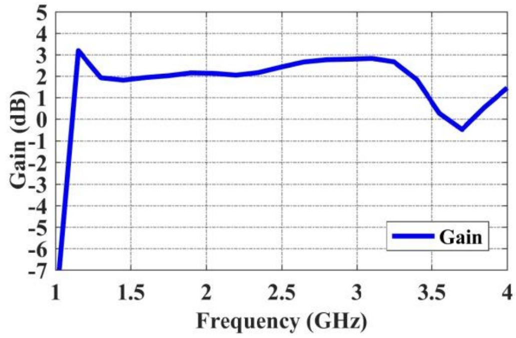
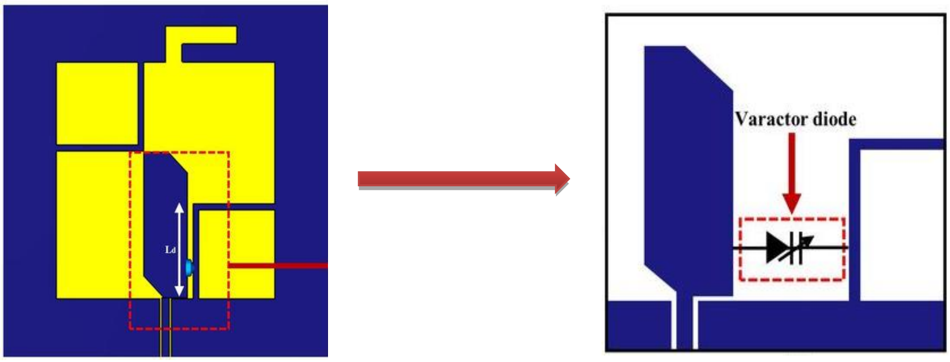


Figure 3. Simulated result peak gain of initial antenna

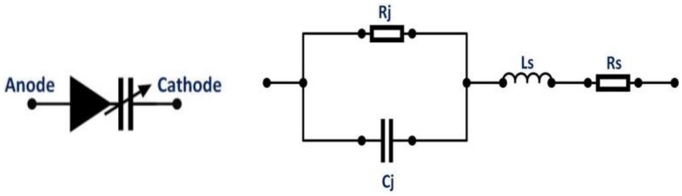
2.2. Design of a frequency reconfigurable coplanar antenna

To be used over several frequency bands, an antenna can be either wideband or narrowband and reconfigurable. Generally, in the first case, the initial antenna is well suited over a wide range of frequencies for the second case, a new configuration of the frequency agile antenna is proposed based on the structure shown in Figure 1. In order to achieve reconfigurability, a varactor diode as shown in Figure 4 is inserted between the patch and the strip in the right inverted L-shape and a distance of Ld=7.1 mm from the corner as shown in Figures 4(a) and (b). The electrical model of the varactor diode is presented in Figures 5(a) and 5(b).



(a) (b)

Figure 4. Configuration of the proposed reconfigurable antenna with varactor diode with (a) the overall configuration and (b) the presentation of the varactor diode



(a) (b)

Figure 5. The presentation of the varactor diode of (a) the equivalent scheme and (b) the equivalent circuitry

3. RESULTS AND DISCUSSION

After inserting the varactor diode and varying the reverse direct current (DC) Bias corresponding to the values of its capacitance between 0.1 pF and 0.4 pF, we notice an important effect on the range of agility of the antenna. The Figure 6 presents the reflection coefficient for different values of the diode capacitance.

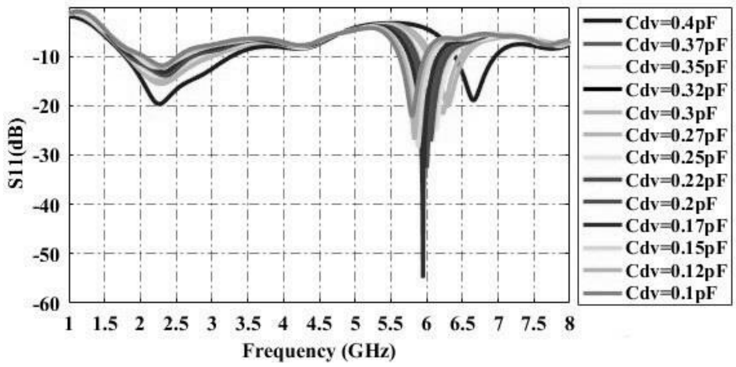


Figure 6. Reflection coefficient of the tunable capacitance

The obtained results show that the antenna covers two frequency bands. For the first band, we can clearly see the variation of the bandwidth as a function of the values of the tunable capacitance; Therefore, we can control the bandwidth. For the second band, the variation of the band makes it possible to correspond to the different standard frequencies. The proposed antenna is a suitable candidate for several applications including ISM (2.45 GHz, 5.8 GHz), LTE, UMTS, WIFI, WIMAX, RFID and 5G applications (6 Ghz). The gain is a crucial parameter that allows to judge the miniaturization of the antenna. Figure 7 shows the evolution of the gain as a function of the capacitance values, it can be seen that the gain is stable and remains above 2 dB for the first band and above 5 dB for the second band.

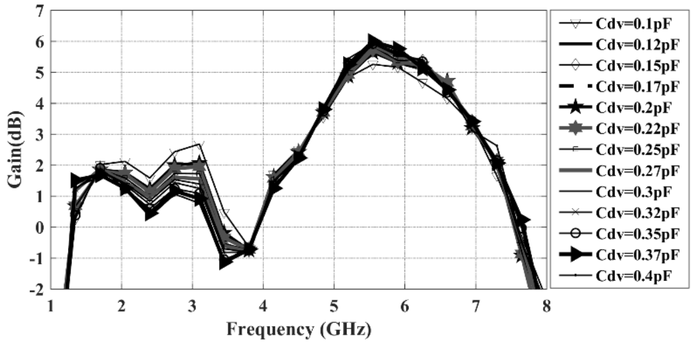
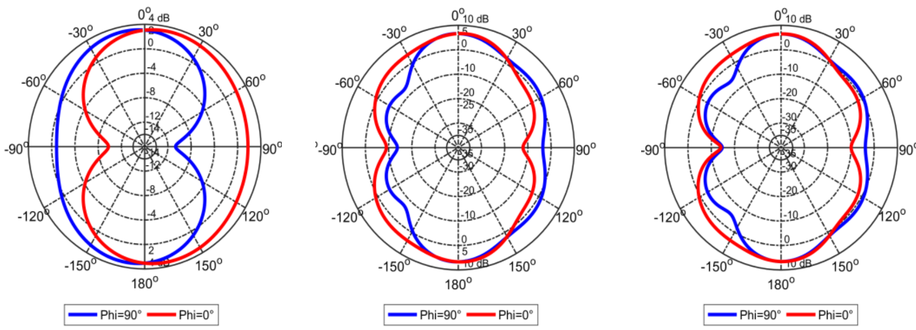


Figure 7. The variation of the gain according to the values of the capacitance

The radiation patterns according to the H-plane (Phi=0) and the E-plane (Phi=90) as shown in Figure 8 for different capacitance values are presented in Figures 8(a) and 8(b). Patterns are plotted at the frequencies for 3 cases, as shown in:

- 2.45GHz for C_{dv}=0.1pF.
- 5.8GHz for C_{dv}=0.4pF.
- 6GHz for C_{dv}=0.32pF.

for the first frequency, the form of the patterns is not affected by the presence of the varactor diode, we find the same radiation pattern as the initial patch antenna. However, in the two remaining frequencies, the radiation pattern appears to take on an omnidirectional appearance.



(a) (b) (c)

Figure 8. Radiation patterns for 3 frenquencies of different capacitance values for the (a) 2.45 GHz, (b) 5.8 GHz, and (c) 6 GHz

4. CONCLUSION

Nowadays, frequency reconfigurable antennas remain the most widely used solution to meet the increasingly diverse standards of telecommunications systems. In general, frequency reconfigurable antennas have several advantages. Not only the ability to operate at different frequency bands using the simplest possible structure, but also significantly increase the lifetime by switching quickly between the different frequencies it allows access to new standards that did not exist when the antenna was created. In this paper, a new compact printed reconfigurable coplanar multiband antenna using varactor diode has been presented. The proposed antenna achieves good performance with respect to input impedance matching and gain. The advantages of the presented antenna are its compact prototype with compact size of 60×60×0.74 mm^3, cost effective, low-profile structure and wide frequency reconfigurability using only one varactor diode.

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