MULTISTANDARD RECONFIGURABLE PIFA ANTENNA

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ABSTRACT: *In this article, a frequency reconfigurable antenna using the ON/OFF states of a MEMS (micro-electro-mechanical system) switch is presented. This structure is based on a planar inverted-F antenna (PIFA), designed with an L-shaped open slot etched upon its main plate. According to the switch position along the slot, the GSM operating frequency is not detuned while other standards become reconfigurable. To validate our concept, a RF MEMS switch, designed and developed at CEA-LETI, is used. The scattering parameters of the MEMS are measured and compared with simulated results from a simple model using lumped elements and transmission line sections. This active device is then inserted in the slot to validate the switching capabilities of the PIFA.* Microwave Opt Technol Lett 48: 1975–1977, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.21823

Key words: *reconfigurable antennas; PIFA; RF MEMS switch; frequency hopping*

1. INTRODUCTION

The demand for small radio receivers has been increasing along with the expansion of new communication standards (GSM900, DCS1800, UMTS, WLAN, BLUETOOTH, WIFI,. . .). From the designer's point of view, antennas having small dimensions and low profiles are the most suitable for mounting on these equipments. Consequently, small radiators covering different standards are requested in such applications. The dimensions of the radiating element can still be decreased if the specifications of the front-end module allow switching between different standards. Frequency hopping can be achieved by the use of RF MEMS, which are suitable components to perform this operation with low losses. Among all the antenna structures, the planar inverted-F antenna (PIFA), which has already been used in mobile handsets, is often employed to cover one or several of these standards. The addition of a slot in the radiating element can actually achieve the decrease of its higher-order resonant modes [1]. The modification of the length of the slot controls the resonance frequencies of these higher-order modes. We demonstrate here that this control can be carried out by the integration of an RF MEMS switch in the antenna structure.

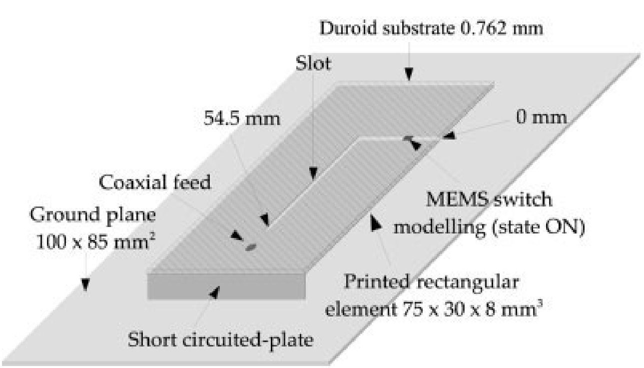


Figure 1 Slotted PIFA antenna

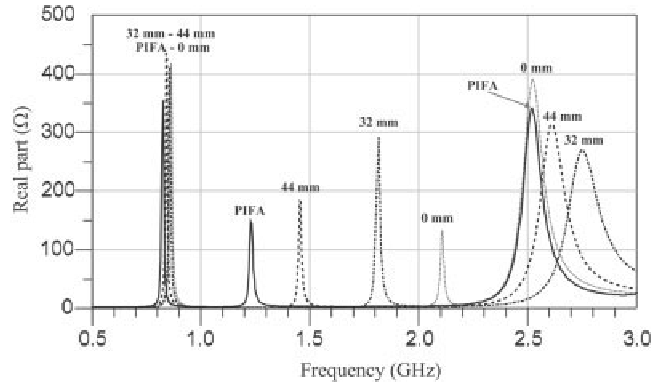


Figure 2 Simulated real part of the impedance for three switches positions (0, 32, 44 mm)

2. MULTISTANDARD PIFA ANTENNA

PIFA is typically made up of a rectangular element short circuited to a ground plane by means of a vertical metallic plate [2]. In the studied structure, this rectangular element is printed below a thin Duroid substrate (see Fig. 1). An L-shaped open slot is realized in the radiating element to decrease the resonant frequencies of its higher-order modes and to place then an interesting frequency allowing dual-mode applications. The idea is here to modify the electrical length of this slot by means of MEMS switch in different positions [3]. To study the first order frequency behavior of the antenna vs. the MEMS switch position along the slot, the Agilent ADS electromagnetic simulator [4] is used in which a perfect short circuit stands for the MEMS in ON state.

In the case of a classic PIFA (without any slot), the fundamental resonant mode is given by the following formula:

$$f_r = \frac{c}{4(L_p + H_r)}, \tag{1}$$

where L_p and H_r are respectively the length and the height of the rectangular radiating element. Our PIFA is designed to operate in the GSM900 frequency band. The simulation curves of the real part of the impedance show two peaks corresponding to the first ($f_{r1} = 0.89$ GHz) and the third ($f_{r3} = 2.6$ GHz) resonant modes.

This quarter-wavelength structure intrinsically cancels the even resonant modes. The insertion of an open L-shape slot makes f_{r3} decrease to 1.35 GHz and f_{r5} to 2.6 GHz (Fig. 2, PIFA).

Figure 2 presents the simulated results for different positions of the switch along the slot. Positioning the MEMS at 0 mm consists to short-circuit the L-shape slot and thus creates a $\lambda/2$ frequency resonance around 2 GHz. Additionally, the third and fifth modes are moved toward the high frequencies (2.5 GHz for the third mode). For 32 mm and 44 mm position, the $\lambda/2$ resonance is rejected toward frequencies greater than 3 GHz, and we can observe a decrease of the third and the fifth resonance modes of the PIFA; the first mode decreases very slightly [5]. Experimental results for three selected positions for the switch modelled by a square piece of copper show a good agreement between measurements and simulations, proving the accuracy of our previous results in term of resonance frequencies. However, measured real parts of Zin are slightly greater than theoretical ones (see Fig. 3).

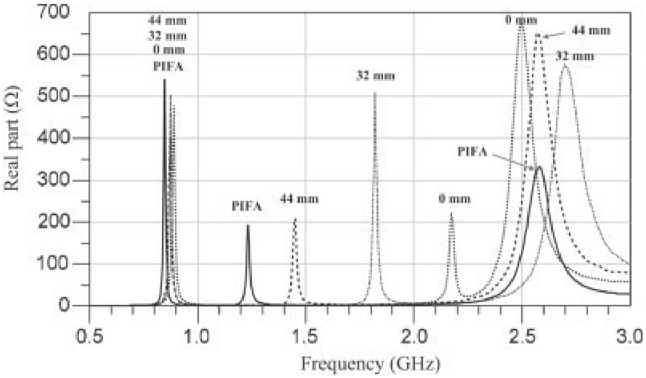


Figure 3 Measurements of real part of the impedance for three switches positions (0, 32, 44 mm)

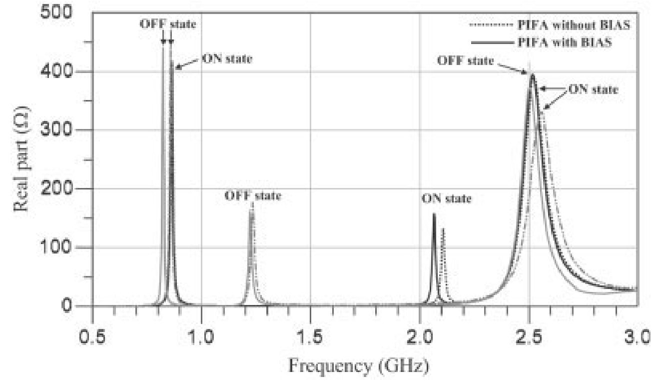


Figure 5 Simulated real part of the impedance with and without DC lines for 0 mm position in OFF and ON state

3. PIFA ANTENNA WITH DC BIAS MEMS MODELLING

To improve our model, the reconfigurable PIFA is simulated with the DC bias circuitry of the MEMS. The MEMS is still modelled by a square piece of copper. The slotted PIFA is now etched on the opposite face of the substrate and thus faces the ground plane [Fig. 4(a)]. The connection between the PIFA and the MEMS is made by two vias on each side of the piece of copper [short-circuit in Fig. 4(a)]. Moreover, we used microstrip high impedance narrow lines on each side of the L-shape slot as DC bias circuitry to minimize unwanted coupling with the antenna [Fig. 4(b)].

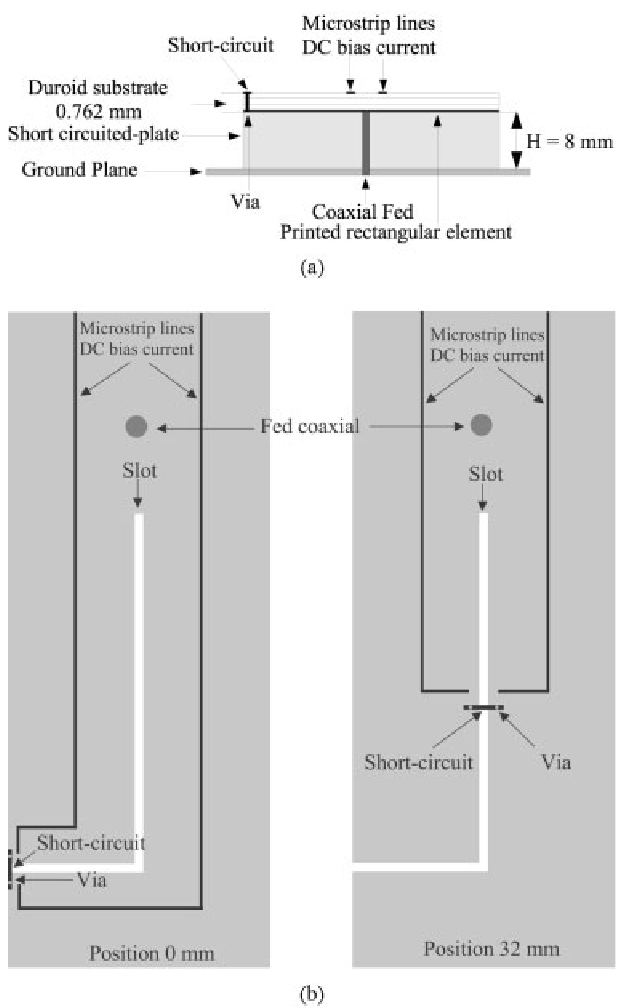


Figure 4 (a) Side view of the PIFA antenna with DC bias and vias (MEMS at 0 mm); (b) top view

To observe the reconfigurability of the third mode, we choose two MEMS switch positions, 0 and 32 mm [Fig. 4(b)]. In the first case (0 mm position), Figure 5 shows the simulated real part of the impedance of the PIFA with and without the DC bias lines when the MEMS is alternatively OFF or ON. In OFF state (open-circuit), the resonant mode of the slot is rejected toward frequencies greater than 3 GHz. The third and the fifth modes resonate at 1.35 and 2.5 GHz, respectively. When adding the DC bias lines, we can observe very little disturbances of the antenna's resonances.

In ON state, the resonant frequency of the slot becomes f_{rslot} = 2.06 GHz, and we can see that all the resonances are no longer affected by the DC lines.

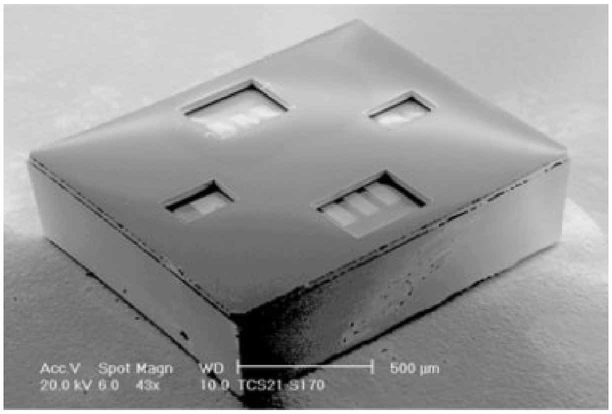
For position 32 mm (not shown here for the clarity of the plots), the same effect is obtained. For both states, good results are obtained as the antenna resonances are very lightly affected by DC lines.

4. PACKAGED MEMS DC-CONTACT SERIES SWITCH

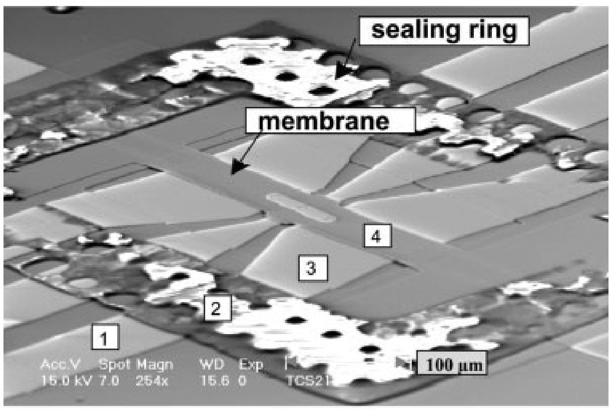
The MEMS switch, designed at CEA-LETI, is a packaged RF-MEMS DC-contact series switch [Fig. 6(a)]. The switch is made of a dielectric membrane supporting a gold contact and is suspended above CPW input/output lines [6]. A simple model can be derived using lumped elements and transmission line sections. For this purpose, the component can be symmetrically split into different sections as numbered in Figure 6(b). Each symmetrical part is made of (1) CPW access line (Z_0 = 50 Ω), (2) CPW line running through the sealing ring (Z_0 = 36 Ω), (3) tapered CPW line, separated by the switch element, which is a resistance in the ON state and capacitance in OFF state. This circuit model has been fitted to S-parameters measurements under probe to extract the ON-state contact resistance R_{ON} = 2 Ω and the OFF-state capacitance C_{OFF} = 5 fF. These packaged devices exhibit an insertion loss of 0.1–0.3 dB and an isolation over 20 dB from DC to 30 GHz. The actuation is electrostatic with a pull-down voltage of 20 V.

5. PIFA REALIZATION WITH CEA-LETI MEMS SWITCH

Figure 7 shows a partial RF MEMS switch view of the final structure. The MEMS was bonded at the CEA-LETI. The gold bond wires have a diameter of 25 μm. The whole structure is protected by a resin. The final results are shown in Figure 8 for position 32 mm in OFF and ON states. The measurements are compared with the simulation of the PIFA with DC bias. We can



(a)



(b)

Figure 6 (a) Photograph of the packaged RF MEMS switch and (b) view of the uncapped device

observe that for the two positions and the two MEMS states, the antenna resonances are affected by the MEMS itself and more particularly by the effect of the bonding. The same observations can be done for 0 mm position. However, the switching between frequency resonances can be observed.

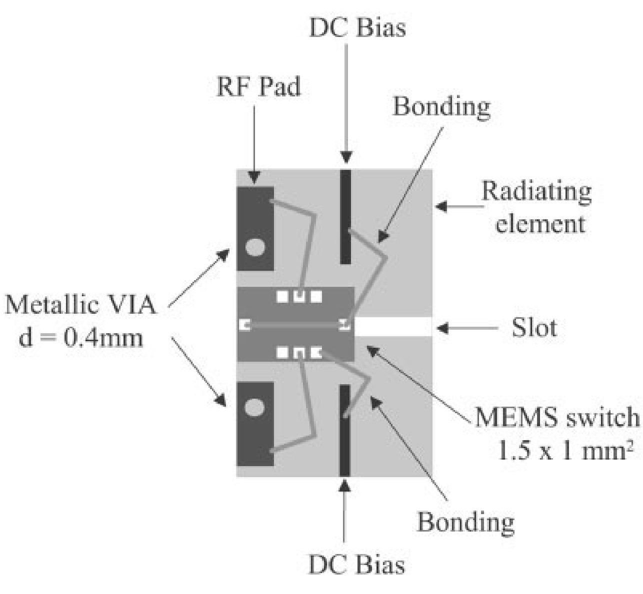


Figure 7 RF MEMS switch implantation on PIFA antenna

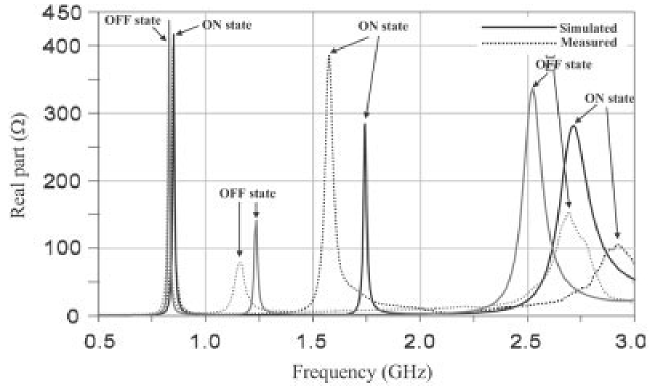


Figure 8 Measured real part of the impedance with RF MEMS switch for 32 mm in OFF and ON states

6. CONCLUSION

The design of a reconfigurable PIFA, by using the ON/OFF states properties of an electrostatically-actuated MEMS switch was presented. Probate experimental verifications have been made by comparing measured results obtained using a 1×1 mm^2 small piece of copper to model the ON state, and theoretical results calculated using an equivalent electrical RLC model for the MEMS in the CAD tool ADS. The last results present the complete structure including DC bias, real MEMS with good agreement between measurements and simulations. Some improvements must still be done to enhance the accuracy in terms of resonance frequencies and real part values.

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SHORT DISTANCE DETECTION OF FIXED TARGET UNDER NEAR FIELD CONDITIONS

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ABSTRACT: *Detection of a fixed metallic target (sheet) can be done by using two antennas in a side by side arrangement (one for Tx and one for Rx) and treatments based on amplitude level. However, for short*