A Reconfigurable Slot Antenna With Switchable Polarization

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***Abstract*—A novel reconfigurable slot antenna architecture allowing polarization switching is presented. The antenna shape consists of a slot-ring with perturbations which are switched on and off using pin-diodes. Two antennas allowing switching either between linear and circular polarization or between two circular polarizations are demonstrated. The antenna architecture is interesting for commercial wireless applications because it is compatible with modern fabrication processes and can be realized on low cost dielectric materials.**

***Index Terms*—Diversity method, microstrip antennas, polarization, slotline components.**

I. Introduction

POLARIZATION diversity is gaining importance in modern wireless communication systems. In wireless local area networks (WLAN), e.g., polarization diversity is used to avoid the detrimental fading loss, caused by multipath effects [1]. In microwave tagging systems it is used as a modulation scheme such as the circular polarization modulation [2]. Several antenna architectures, offering polarization diversity, have been proposed. In [3], a patch antenna that allows switching between two linear and two circular polarizations has been presented. The switching was achieved by using several pin-diodes mounted between the patch and the groundplane at different locations. By shortening one or several of these diodes using a dc-bias circuit a specific polarization can be excited in the patch antenna. However, this solution requires a relatively complex biasing network and, in addition, needs mounting of the diodes between patch and groundplane, which is inconvenient for fabrication. In [4] a probe-fed patch antenna was presented whose polarization can be switched between right hand circular polarization (RHCP) and left hand circular polarization (LHCP). The circular polarization is excited by a slot which is cut in the patch. The switching is achieved by alternatively shorting this slot at two different locations with a pin-diode mounted across the slot. However, the design of the dc-bias network is delicate because the dc-connection between patch and groundplane must not interfere with the rf-signals. In [5] a circularly polarized microstrip-fed aperture-coupled patch antenna was introduced. Here, the polarization was switchable between LHCP and RHCP by changing the length of the coupling slot in the ground plane of the antenna utilizing pin-diodes.

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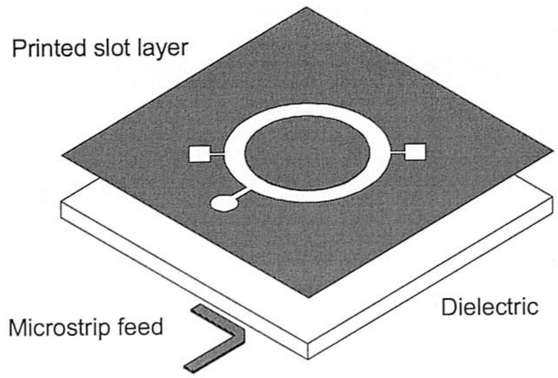

Fig. 1. Microstrip-fed circularly polarized slot ring.

Besides, polarization diversity antennas for modern communication systems should be of low-cost. We will present two novel pin-diode switched planar slot-loop antennas, which allow switching either between linear and circular polarization or between two circular polarizations. The antennas are designed for the 2.4 GHz range, achieve excellent performance with both polarizations at the same frequency and are built on a low-cost FR4 dielectric. Furthermore, the antenna allows easy integration of active elements due to its uniplanar architecture.

II. Antenna Topology

The slot-ring (also called slot-loop) uniplanar antenna is well known in rectangular as well as in circular form. It exhibits linear polarization and can be fed by a slotline. In [6] it was shown that by introducing two discontinuities in the slot-ring located at 45° and $-135°$ with respect to the feed point circular polarization can be excited. The discontinuity used in the present work consists of a rectangular opening in the groundplane (3.2×4.4 mm) which is connected to the slot-ring by a very narrow slotline section (0.4×2 mm), as shown in Fig. 1. By shorting the narrow slotline section, the rectangular opening in the groundplane (the slot discontinuity) is not seen by the slotring and the antenna becomes linearly polarized. The polarization sense of the antenna can thus be switched between linear and circular polarization if a diode switch is mounted across the narrow slotline section. In the forward biased state the diode behaves almost as a short circuit and the antenna exhibits a linear polarization. In the reverse biased state the diode behaves almost as an open circuit and the antenna exhibits circular polarization. The dc-bias voltage is directly supplied through a divided groundplane. As shown in Fig. 2(a), the groundplane is dc-wise separated into two parts using two thin slots connected to the respective discontinuities. RF grounding is accomplished

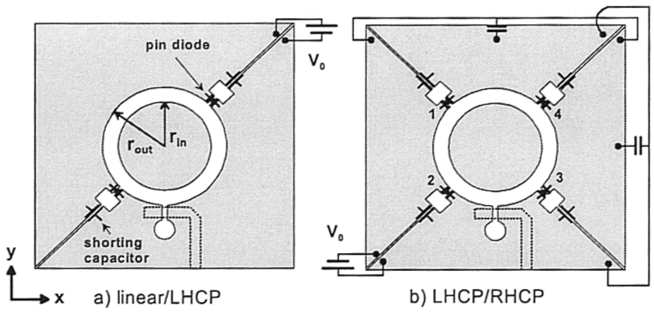

Fig. 2. Microstrip-fed slot ring antennas with switchable polarization: (a) switchable between linear polarization and LHCP; (b) switchable between LHCP/RHCP; $r_{\rm in} = 13.4$ mm, $r_{\rm out} = 15.4$ mm.

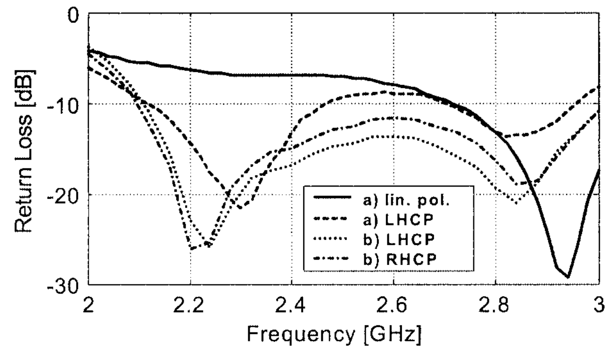

Fig. 3. Measured return loss of both antennas in both polarization states.

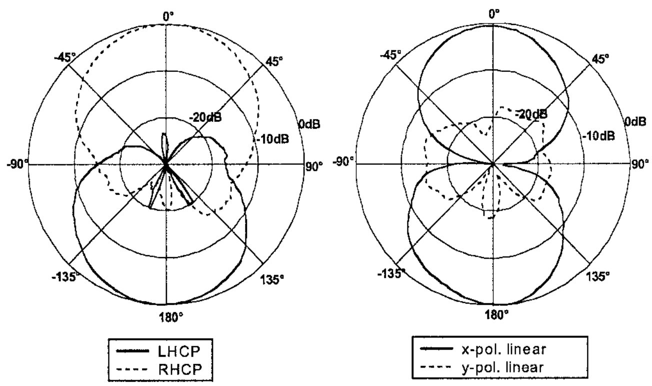

Fig. 4. Radiation pattern of antenna A at 2.4 GHz.

by shorting both slots with a large capacitor. The antenna is built on a 0.8 mm thick FR4 dielectric ($\varepsilon_r = 4.3$, $\tan\delta = 0.02$) and fed by a microstrip line as explained in [6]. Beam lead pin-diodes (HPND-4050) are used for the switching requiring 10 mA of bias current. For the rf-signal the diode represents an ohmic resistance of 1.3 Ω in the forward biased state and a capacitance of 0.12 pF in the reverse biased state.

While the structure of Fig. 2(a) allows switching between linear and circular polarization, the extension to four stubs as shown in Fig. 2(b) allows switching between RHCP and LHCP. Instead of two switching diodes four are now required. To change from one polarization state to the other always the pair of opposite diodes must be switched. If one pair is shorted the other must be open. Shortening diodes 1 and 3 produces LHCP whereas shortening diodes 2 and 4 produces RHCP. To supply the diodes with the switching voltage the groundplane must now be divided into four parts and, again, rf-wise shorted by large capacitors. The same dc-voltage is applied to those parts of the ground plane which lie opposite to each other [Fig. 2(b)]. Both antennas were designed to exhibit circular polarization at 2.4 GHz.

III. Simulation

All the simulations were performed with Ansoft HFSS 8.0TM. Good agreement between simulation and measurement was found. The pin-diodes were simulated as lumped element capacitor for the open state and as lumped element resistor in the shorted state in order to take the nonideal behavior of the diodes into account. The shorting capacitors and the thin separation slots were included in the simulation as well.

IV. Experimental Results

A. Matching

The input impedance of antenna A [Fig. 2(a)] in the linearly polarized state differs significantly from the circularly polarized state. Due to the reactive loading of the slot ring in the circular polarization case, exciting two orthogonal modes, the input impedance at the feed point is different from the one in the linear polarization case because now the stubs are shorted. At present, a good impedance match can only be achieved for one polarization. For this application the feed was matched for the circular polarization. For the second antenna a broad matching can be achieved for both polarization states, because in this case the slot ring is always loaded by two stubs.

Fig. 3 shows the measured return loss of both antennas in both polarization states. For the circular polarization, the antennas exhibits a $-$ 10 dB impedance bandwidth of more than 20%. In linearly polarized state the return loss does not exceed $-$ 8 dB in the 2.4 GHz range. However, the $-$ 7 dB impedance bandwidth which is acceptable for many applications, is wider than 30%.

B. Radiation Characteristics

The antenna radiates the same amount of energy in both directions: the front- and the back-side. Fig. 4 shows the measured radiation patterns of antenna A at 2.4 GHz. In the linearly polarized state the main polarization to both sides is x-polarization. The cross polarization (y-polarization) lies 17 dB below the main polarization. In the circularly polarized state the antenna radiates LHCP to the front-side and RHCP to the back-side. This is due to the fact that the antenna seen from the back-side corresponds to the mirror image of the same antenna seen from the front-side. RHCP radiation to the front-side could be achieved by mirroring the antenna geometry around the y-axis. The radiation pattern of antenna B [Fig. 2(b)] looks similar to the circularly polarized radiation pattern of antenna A. A gain of 4 dBi and 3.2 dBi was measured for the circularly polarized state (both antennas) and the linearly polarized state (antenna A), respectively. Although a lossy dielectric is used for the construction of the antenna the losses are low because the electromagnetic field resides mostly in the air and not in the dielectric. Fig. 5 shows the measured axial ratio of the antennas in the circularly polarized

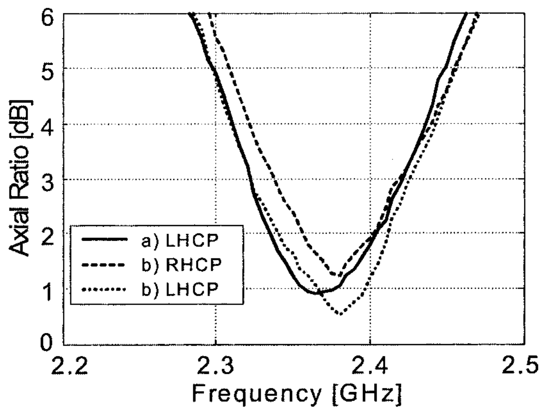

Fig. 5. Measured axial ratio of both antennas in broadside direction.

state. It shows that in all three cases the axial ratio bandwidth (ARB) is centered around the same frequency. For antenna A the achieved 3-dB ARB is 4.2% and the minimum axial ratio is 0.9 dB. In the case of antenna b) the achieved ARB's are 4.3% and 3.4% for the LHCP and the RHCP, respectively. This allows to cover the entire ISM band. The slight difference in the axial ratio is due to coupling of the radiated fields with the dc-lines.

V. Conclusion

A printed slot-ring antenna with switchable polarization at 2.4 GHz was presented. It was shown that using pin-diodes the polarization can be switched between circular and linear polarization or between two circular polarizations. Switching between different kinds of polarization can be achieved by using only a few active and passive elements. The agreement between the simulation and the measurements are good as the nonideal characteristics of the diodes were taken into account in the field simulation. Due to its uniplanar design, which allows an easy integration of active elements, the antenna is well suited for mass production. Furthermore the architecture of the antenna allows the use of a low-cost dielectric without deteriorating the antenna performance.

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