Compact polarisation reconfigurable printed monopole antenna at 2.4 GHz

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A single feed printed monopole antenna with switchable polarisation with reduced antenna size is proposed. The radiating element is in the form of two monopole rectangular patches fed by a single microstrip line. To reduce the size of the patches and to provide dual polarised operation, each patch is perturbed by two L-shaped slots. Such a structure can produce two orthogonal linear polarisations by switching only one *pin* diode, which is the most interesting feature of the design. To further reduce the size of the antenna a meandered stub attached to the transmission line is employed. The antenna is fabricated on the low-cost FR4 substrate with an overall size of 26 × 19 mm^2.

Introduction: Recently, polarisation reconfigurable printed antennas have received a lot of attention due to their intrinsic advantages in wireless data communication networks such as reduction in multipath effects. A variety of antennas with switchable polarisation have been reported [1–4]. A microstrip patch antenna is reported in [1], where through four *pin* diodes, the polarisation is switched between two circular polarisations and one linear polarisation. In [2], a reconfigurable polarisation slot antenna is designed where by adjusting two *pin* diodes vertical and horizontal polarisation is achieved. The feed structure is such that the overall size of the design is not compact. In [3], a reconfigurable polarisation slot antenna without any additional structures is reported, but the overall size of that antenna is still large, 86 × 70 mm^2. In [4], it is shown that by only two *pin* diodes and by changing the feeding mechanism which is in the form of V, one linear polarisation and dual orthogonal circular polarisations are achieved.

All the previous works have a large dimensional size and to achieve dual orthogonal polarisations, at least two diodes should be used.

In this Letter, a compact reconfigurable monopole antenna that acts as a dual polarised structure for wireless local area network (WLAN) application is proposed. In the proposed design, only one *pin* diode to create dual orthogonal linear polarisations is required. The antenna is made compact by attachment of a meandered stub to the transmission line and by placing dual L-shaped slots on each patch.

Antenna structure: The structure of the proposed reconfigurable monopole antenna is depicted in Fig. 1. The overall antenna has small dimensions of 26 × 19 mm^2 and is fabricated on FR4 substrate with relative permittivity of 4.4 and a thickness of 1 mm. The designed structure consists of two similar rectangular monopole patches fed through a T-shaped microstrip transmission line. A *pin* diode is placed at an appropriate position within the structure and by switching it ON or OFF, vertical or horizontal polarisation can be achieved.

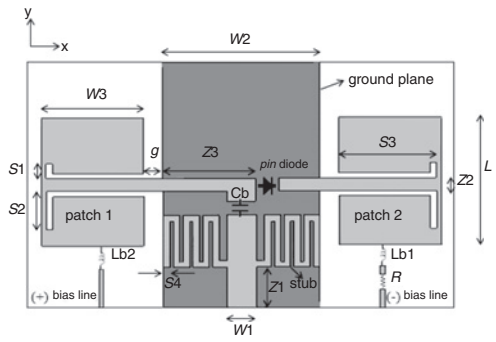

Fig. 1 *Configuration of proposed reconfigurable printed monopole antenna*

To study the operation of the proposed antenna, assume that the *pin* diode is OFF. Patch 1 is excited through the main feed line. The current distribution on this patch has *y*- and *x*-oriented components. The presence of the two L-shaped slots on the patch with different slot lengths *S*1 and *S*2 creates *y*-directed upward/downward current distribution that produces electric fields which are opposite in phase and nearly equal in amplitude and thus almost cancel each other in the far field (leaving a small cross-polarised field). The strong *x*-component of the excited current produces an *x*-polarised (horizontal) electric field. Thus, in this way, horizontal polarisation is produced by patch antenna 1.

A *y*-polarised field can be generated if the *pin* diode is set to the ON state. In this state, both patches 1 and 2 are then excited through the T-shaped microstrip feed line. As before, due to the inequality of the two slot lengths *S*1 and *S*2 upward/downward *y*-component of current distribution on each patch is produced. As compared with the single patch of the previous case, in this diode state, the two patches provide a significant downward *y*-component of current as compared with the upward component. From Fig. 1 it is obvious that the *x*-component of the electric fields due to each patch is opposite in phase and cancel each other in the far field, hence vertical polarisation is achieved in this diode state.

The size of the proposed antenna is kept small by using the following two methods:

(a) The presence of the L-shaped slots create additional current path to that of the original patch. As shown in Fig. 2, by adjusting the length *S*3 of the two L-shaped slots the resonant frequency of the patch can be tuned

(b) Use of the meandered stub. As the overall stub length (to one side of the feed line) increases, the resonance frequency decreases, as shown in Fig. 2

By adjusting the gap between the patch and the ground plane, *g*, and the position of the meandered stub relative to the feed point, *Z*1, one can improve the matching for both diode states.

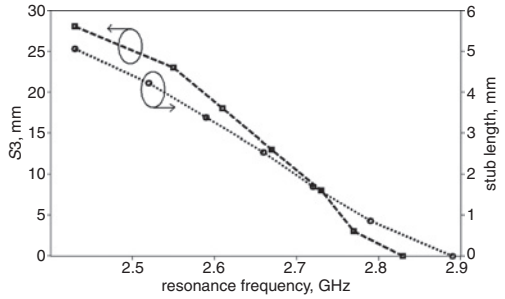

Fig. 2 *Relation between slot length S3 and stub length with resonance frequency*

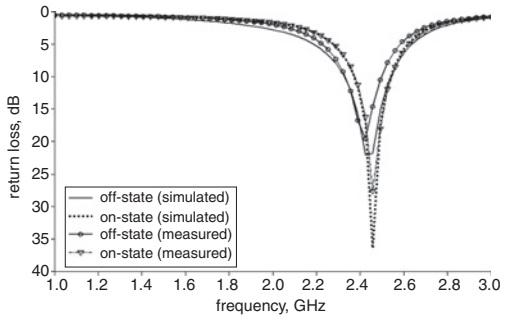

Fig. 3 *Measured and simulated return loss of proposed antenna for both states of diode*

Experimental results: The antenna is simulated through software package HFSS and a prototype of the antenna was fabricated and tested. The optimal antenna parameters for the proposed monopole antenna are: *W*1 = 1.8, *W*2 = 9.6, *W*3 = 6.3, *S*1 = 0.8, *S*2 = 2.6, *S*3 = 5.6, *S*4 = 0.4, *Z*1 = 3.2, *Z*2 = 1, *Z*3 = 5.7, *L* = 10.1 and *g* = 1.2 mm. The gap considered for the position of the *pin* diode in Fig. 1 is proportional to the MA4P789 *pin* diode with the SC79 package. To control the state of the *pin* diode, a DC-bias network is required which includes: two inductors each 56 nH to prevent the RF signal from flowing to the DC trace, a DC block capacitance of 47 pF and a resistance of 100 Ω. It should be noted that a direct bias voltage of 1.7 V is used to drive the *pin* diode.

Fig. 3 shows the simulated and measured return loss of the antenna for both diode states. At a centre frequency of 2.44 GHz the measured

return loss is about 17 and 23 dB for horizontal and vertical polarisations, respectively. As shown in this Figure, the 10 dB return loss of the design covers the 2.4–2.484 GHz band which is suitable for WLAN application.

Fig. 4 shows the normalised measured far-field radiation patterns of the antenna at 2.44 GHz. The results show that a very good omnidirectional pattern as well as low cross-polarisation levels, below −12 dB, for both horizontal and vertical polarisations, are obtained. From the measured results, the peak gains of the antenna are about 1.65 and 1.45 dBi for horizontal and vertical polarisations, respectively.

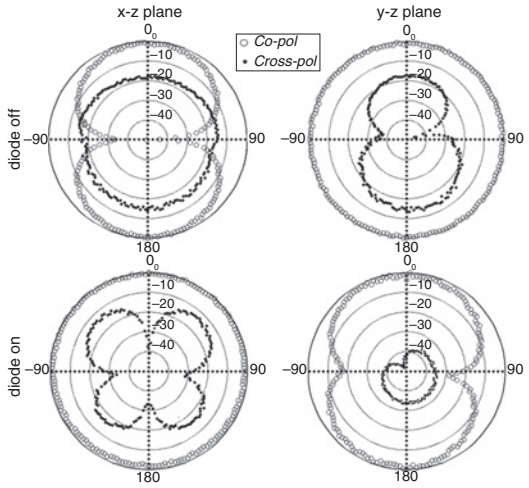

Fig. 4 *Measured co- and cross-polar radiation patterns for both diode states*

Conclusion: A compact polarisation reconfigurable printed monopole antenna for WLAN application is designed and tested. The antenna consists of two rectangular monopole patches, each of which is perturbed by dual L-shaped slots. Such a design can produce dual orthogonal linear polarisations through only one *pin* diode. The measured results show a very good omnidirectional pattern as well as a low, −12 dB, cross-polarisation level in both polarisation states.

13 June 2013
doi: 10.1049/el.2013.1979

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