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PLANAR BOWTIE ANTENNA WITH A RECONFIGURABLE RADIATION PATTERN

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Abstract—This paper presents a novel planar antenna with a reconfigurable radiation pattern. The proposed layout consists of $N \geq 2$ monospaced planar bowtie antennas selected one by one by means of a pair of PIN diodes. Experimental results referring to the case of $N = 2$ and $N = 4$ are reported and discussed demonstrating the feasibility and effectiveness of the proposed design approach.

1. INTRODUCTION

The rapid development of wireless communications, in particular of MIMO techniques, has led to growing interest in reconfigurable antennas.

Accordingly, in the last years several approaches for the design of antennas providing diversity functions in operating frequency [1, 2, 6], polarization [3–5] and radiation pattern [1, 5–20] have been proposed. Among them, antennas able to modify their radiation pattern while preserving the working frequency and polarization are key components for improving the performance and security of MIMO (Multiple-Input-Multiple-Output) architectures [5, 9]. Indeed, the use of pattern-reconfigurable antennas is crucial to minimize the system power consumption and the reception of unwanted signals.

Most of the design strategies proposed in the literature for planar antennas with a pattern reconfiguration ability can be classified into two main categories: adaptive/phased arrays [11–15] and switched parasitic array antennas [7, 10].

In adaptive and phased array antennas, the signal-to-noise ratio is improved by applying the appropriate weight to the signal received

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by each array element. The main disadvantage of these architectures is related to the fact that they use multiple RF input ports or power dividers and phase-shifters.

This shortcoming is overcome by switched parasitic arrays that obtain the pattern reconfigurability by means of parasitic elements of variable dimensions which alter the current paths [16, 17].

Usually, these antennas allow the steering of the main beam in a plane while maintaining its shape.

Similarly to switched parasitic arrays, the antenna here proposed has a single RF input port and does not require additional power dividers and/or phase-shifters.

More specifically, the proposed design approach uses PIN diodes to select one out of N planar bowtie antennas. This way a dipole-like radiation pattern with a tunable H-plane is obtained.

The paper is organized as follows: in Section 2 the geometry of the proposed antenna is briefly described; in Section 3 some experimental results are given and discussed; finally some conclusions are drawn in Section 4.

2. ARCHITECTURE OF THE PROPOSED ANTENNA: NUMERICAL AND EXPERIMENTAL RESULTS

The layout of the antenna here proposed is illustrated in Fig. 1. It consists of $N \geq 2$ bowtie antennas uniformly arranged on a plane.

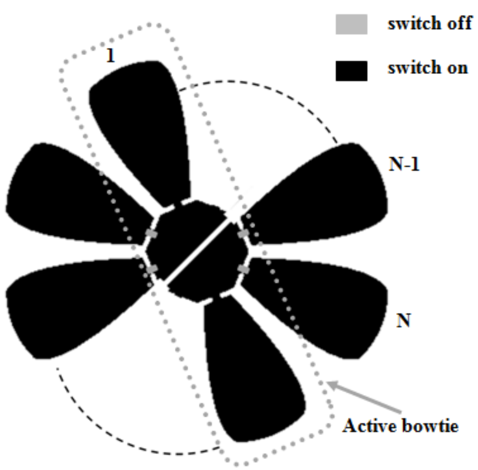


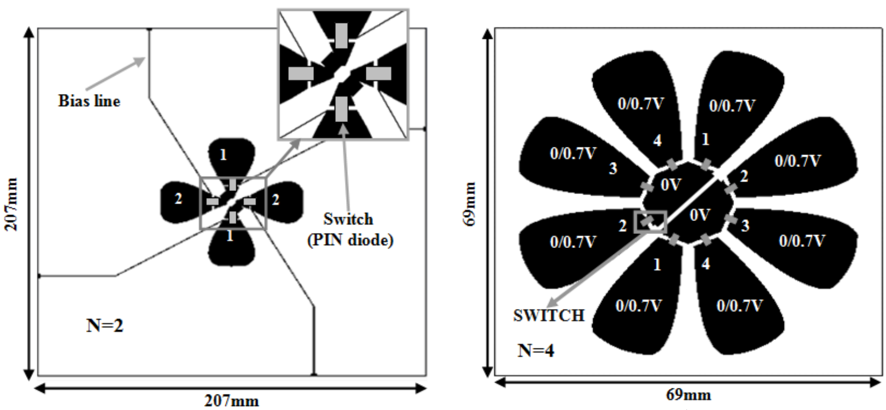
Figure 1. Design approach: N bowtie antennas are uniformly arranged on a plane and activated one by one by means of a pair of PIN diodes.

The basic idea is to select one active antenna by means of a pair of PIN diodes. In this way, a dipole-like radiation pattern, whose H-plane can be rotated with a step-angle of $180°/N$, is obtained.

More specifically, as highlighted in Fig. 1, a pair of PIN diodes is used to connect each bowtie antenna to the RF input port which consists of two patches separated by a gap. These patches are at a fixed 0 V DC voltage, so that the selection of the active bowtie is obtained by applying to the corresponding arms a 0.7 V DC voltage whilst the other ones are at 0 V.

The use of a bowtie layout for the antennas (i.e., a triangular shape with rounded corners) instead of the rectangular shape of a standard dipole allows improving the antenna impedance bandwidth [21, 22].

Figure 2 shows the layouts corresponding to the proposed approach for the case of $N = 2$ and $N = 4$. It can be noticed that in the case of $N = 2$ four lines coplanar to the dipoles have been designed for the DC biasing of the PIN diodes.



(a) (b)

Figure 2. Layouts corresponding to the proposed design approach for $N = 2$ (a) and $N = 4$ (b).

In order to avoid spurious parasitic effects, in the case of $N = 4$, PIN diodes have been biased by means of shielded conductors connected to the dipole arms by means of via-holes. Referring to a realization on a 1.6 mm thick FR4 laminate with a relative permittivity of 3.7 and a loss tangent of 0.019, the antenna dimensions have been optimized to obtain a working frequency of 1.8 GHz.

The full-wave simulator CST-Microwave Studio [23] has been used for optimizations and full-wave simulations. Corresponding results are illustrated in Figs. 2, 3. The antenna occupies an area of $(69 \times 69)\ \mathrm{mm}^2$,

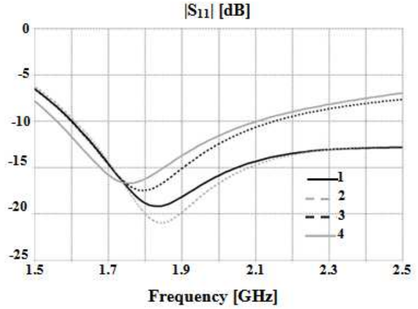


Figure 3. Reflection coefficient calculated by means of full-wave simulations for the four possible configurations of the antenna illustrated in Fig. 2(b).

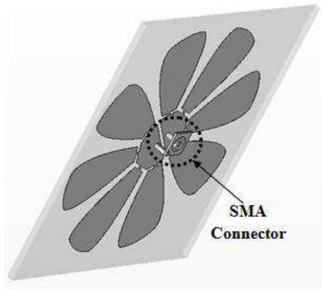


Figure 4. Perspective view of the antenna illustrated in Fig. 2(b). The SMA connector was included in full-wave simulations.

which at 1.8 GHz corresponds to $(0.413 \times 0.413)\ \lambda^2$. Fig. 3 shows the reflection coefficient calculated by means of full-wave simulations for the antenna of Fig. 2(b). The four possible configurations of the antenna have been simulated by replacing with a short- and an open-circuit the diodes in on- and off-state, respectively. More specifically, the short-circuit condition has been implemented by means of a 1×1 mm strip of copper. From Fig. 3, it can be noticed that, at the working frequency, a good level of matching has been obtained for all configurations. It is worth underlining that the presence of the SMA connector was included in simulations (see Fig. 4). This explains the differences among the reflection coefficients calculated for the four antenna configurations. In fact, from Fig. 2 it appears that configuration 1 is identical to configuration 2 and that configuration 3 is identical to configuration 4. However, from Fig. 4 it is evident that all these configurations are not perfectly identical.

As for the antenna radiation pattern, full-wave simulation results are given in Fig. 5. It can be seen that the proposed antenna exhibits the expected reconfigurability with an almost dipole-like radiation pattern. More specifically, Fig. 6 illustrates the radiation pattern in the H-plane of the antenna of Fig. 2(b) when it is in configuration 4 (see Fig. 5). It can be seen that it is slightly different from the one corresponding to a simple dipole; in fact, a small dependence on theta can be observed. This dependence is due to the presence of the parasitic bowties (i.e., the bowties that are not active) which, with respect to the radiation pattern of a simple dipole, determines higher values of the gain at Theta $= 0°$.

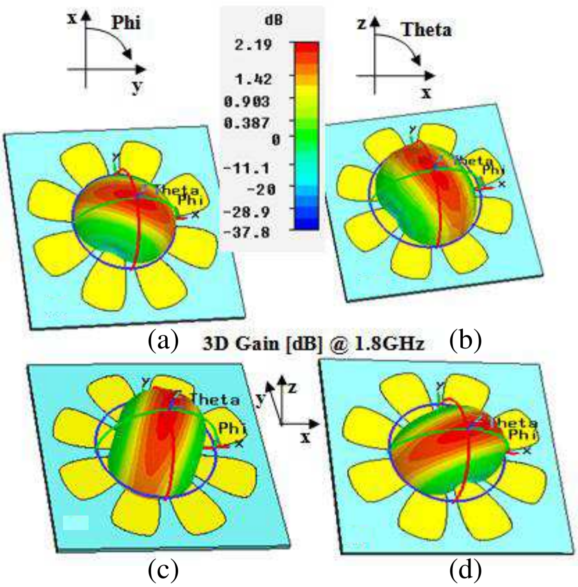


Figure 5. Radiation pattern calculated by means of full-wave simulations performed with CST Microwave Studio. (a)–(d) Three-dimensional gains obtained for configurations 1–4 of the antenna illustrated in Fig. 2(b).

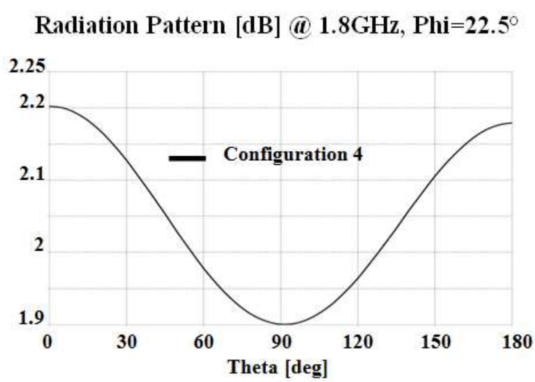


Figure 6. Full-wave simulations results obtained for the radiation pattern corresponding to configuration 4 of the antenna illustrated in Fig. 2(b). The value set for Phi identifies the H-plane of the proposed antenna when it is in configuration 4.

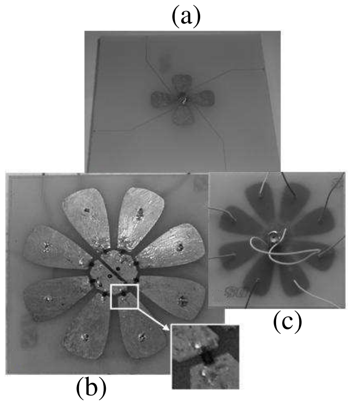


Figure 7. Photographs of the realized antennas. (a) Prototype realized for the case of $N = 2$, (b), (c) front- and back-view of the prototype realized for the case of $N = 4$.

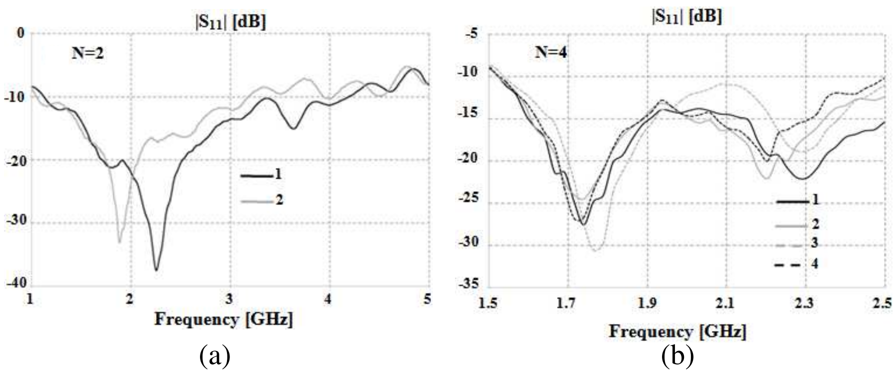


Figure 8. Measurements of the reflection coefficient for the antennas illustrated in Fig. 5. (a) Experimental data obtained for the two possible configurations of the antenna of Fig. 5(a). (b) Experimental data obtained for the four possible configurations of the antenna of Fig. 5(b).

A prototype has been realized for both the layouts illustrated in Fig. 2. The Avago HMPP-3890 RF PIN diodes have been used to implement the switching operations. Photographs of the realized prototypes are given in Fig. 7. The measured reflection coefficients are reported in Figs. 8(a) and 8(b); it can be noticed that, with respect to a $50\,\Omega$ termination, both prototypes exhibit a good matching in all configurations.

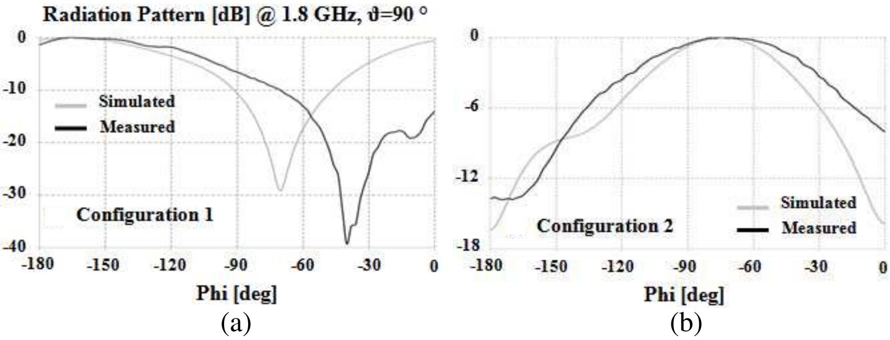


Figure 9. Experimental results obtained for the radiation pattern of the antenna illustrated in Fig. 5(a) corresponding to the application of the proposed approach for the case $N = 2$. Radiation patterns measured for configuration 1 (i.e., vertical bowtie activated) (a) and configuration 2 (b) (i.e., horizontal bowtie activated).

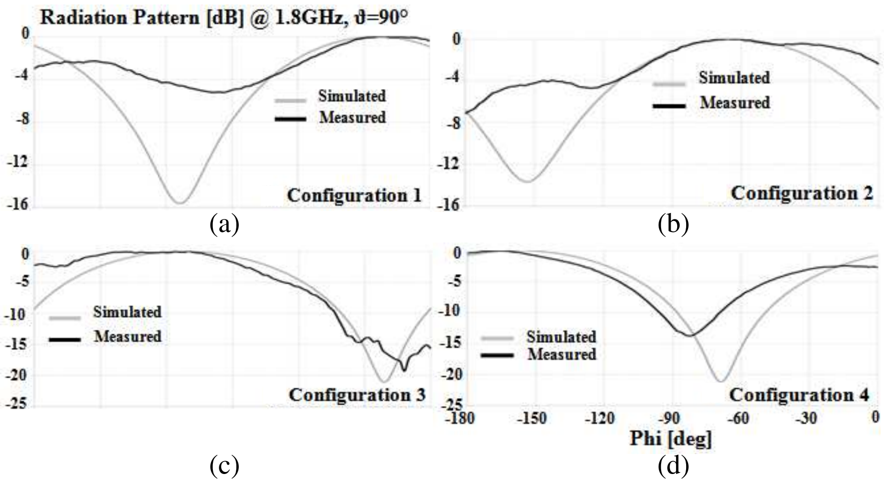


Figure 10. Experimental results obtained for the radiation pattern of the antenna illustrated in Fig. 5(b) corresponding to the application of the proposed approach for the case $N = 4$. (a)–(d) Radiation patterns measured for configurations 1–4.

Radiation pattern measurements have been also performed and corresponding results are given in Figs. 9 and 10. It is evident that a good agreement has been obtained between full-wave simulations and experimental data. In particular, from Fig. 10 it can be deduced that in the plane Theta = 90° (which is the xy plane containing the four bowtie antennas), the four configurations of the antenna illustrated in

Fig. 2(b) allow tuning the maximum of the radiation pattern with a step-angle of about 45°.

3. CONCLUSIONS

A pattern-reconfigurable planar antenna has been presented. The proposed design strategy uses N bowtie antennas uniformly arranged on a plane; by selecting one active bowtie antenna at a time, by means of a pair of PIN diodes, a dipole-like radiation pattern with a tunable H-plane is obtained.

Experimental results, referring to two prototypes working at 1.8 GHz and referring to the case of $N = 2$ and $N = 4$, have been reported and discussed. It has been demonstrated that by using N bowtie antennas, a tuning angle of $180°/N$ can be obtained for the H-plane of the dipole-like radiation pattern.

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