UNIVERSITY
OF TRENTO

DEPARTMENT OF INFORMATION AND COMMUNICATION TECHNOLOGY

38050 Povo – Trento (Italy), Via Sommarive 14
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M. Donelli, R. Azaro, L. Fimognari, and A. Massa

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Massimo Donelli, *Member, IEEE*, Renzo Azaro, *Member, IEEE*, Luca Fimognari, and Andrea Massa*, Member, IEEE*

Department of Information and Communication Technologies,

University of Trento, Via Sommarive 14, 38050 Trento - Italy

Tel. +39 0461 882057, Fax +39 0461 882093

E-mail: *andrea.massa@ing.unitn.it,*

massimo.donelli@dit.unitn.it, *renzo.azaro@dit.unitn.it*, *luca.fimognari@dit.unitn.it*

Web-site: *http://www.eledia.ing.unitn.it*

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Abstract

This letter presents the result of the synthesis of an horizontally polarized reconfigurable microstrip antenna. The obtained architecture is based on a parasitic structure composed by a set of microstrip elements that can be electronically reconfigured by means of RF switches. As a result, the maximum values and zeros of the antenna radiation pattern can be steer towards an interfering signal or/and desired signals allowing an optimal management of wireless resources. Representative numerical and experimental results are reported and compared for assessing the effectiveness and reliability of the proposed prototype.

Key words: Reconfigurable Antennas, Parasitic Antennas, Wireless Networks, Wi-Fi.

1 Introduction

The impressive grow of wireless applications in both telecommunication and other industrial areas has forced the designers to study suitable methodologies for the optimized exploitation of the transmissive medium in order to mitigate saturation effects and interference phenomena that inevitably occur in the increasingly crowded electromagnetic environment.

Efficient solutions resort to the smart management of the physical layer by exploiting the space selectivity functions offered by the so-called smart antenna systems [1][2][3]. These approaches implement a quasi-real-time reconfiguration of the antenna radiation properties when operating in a time varying electromagnetic scenario, thus allowing an increased wireless network throughput and improved signal-to-interference-plus-noise ratio ($SINR$) values. Moreover, thanks to the radiation pattern re-configurability, they guarantee additional functionalities to wireless networks [e.g., the detection of the direction-of-arrival (DoA) of incoming signals [4] and the localization of a node in a wireless network [5]). Obviously, the use of smart antennas with fully-adaptive properties (i.e., phased array [6]) is the optimal solution in dealing with the access to the propagation medium [7][8]. However, their complexity, dimensions, and costs usually prevent an extensive use in commercial applications and, concerning with low cost applications, switched beam antennas are generally adopted. In such a case, the continuous variation of the radiation properties, allowed by a fully-adaptive smart antenna system, is approximated with a discrete set of possible and electronically-selected configurations of the radiation pattern [2].

A good compromise between fully-adaptive and switched-beam solutions is represented by reconfigurable parasitic systems where an active radiating element interacts with an electronically reconfigurable parasitic array [9][10]. In such a framework, this letter presents the design of an horizontally-polarized Wi-Fi band reconfigurable antenna based on a planar microstrip structure. Such a radiator is intended for a reconfigurable wireless network where DoA estimation, interference suppression, and positioning functions are requested for the optimal resources management.

2 Reconfigurable Antenna Design

The antenna architecture is composed by an active and a passive reconfigurable part, respectively. With reference to Fig. 1, the former is a Z-shaped radiator [11] while the passive parasitic structure is composed by 18 identical and equally-spaced metallic radial sectors. The parasitic elements can be electrically connected in order to obtain a reconfigurable planar shielding structure. In the first stage of the synthesis process, the geometry of the active part has been designed following the guidelines reported in [11] and for operating at $f = 2.45\,GHz$. Successively, the geometrical parameters of the parasitic structure (i.e., the inner diameter D_1 and the outer diameter D_2 of the parasitic structure, the angular width θ, and the angular spacing θ_s of the radial sectors) have been optimized for generating a radiation pattern similar to that of the active element without the parasitic structure and in order to allow the isotropic behavior of the corresponding network node.

As far as the re-configurability of the system is concerned, it has been obtained by setting proper electrical connections among each radial sector and its neighbours in order to obtain a variable configuration composed by the active element and a shield of variable extent. The electrical connection between two adjacent sectors is physically implemented by means of a couple of PIN diodes working as electronically-driven switches. The radial positions of the switches, the minimum number of radial sectors necessary for obtaining a minimum value of the front-to-back ratio (FBR) of $5\,dB$, and a maximum Voltage Standing Wave Ratio ($VSWR$) equal to 2 have been found in a third phase of the synthesis procedure and by means of an optimization procedure. More in detail and similarly to the second stage, the optimization has been carried out by means of a particle-swarm optimizer (PSO) [12] and by minimizing a suitable cost function proportional to the difference between the electrical performances of trial structures and the requirements.

After the synthesis, the dimensions of the resulting antenna were: $D_1 = 2.8\,cm$, $D_2 = 7.2\,cm$, $\theta = 17^o$, $\theta_s = 3^o$, $S_1 = 1.4\,cm$ (S_1 being the distance of the first ring of switches from the center), and $S_2 = 2.1\,cm$ (S_2 being the distance of the second ring of switches from the center). Moreover, the minimum number of connected parasitic sectors for obtaining a FBR value greater than $5\,dB$ turned out to be equal to 3. According to these results, a prototype of the reconfigurable antenna shown in Fig. 2 has been fabricated and experimentally-tested.

3 Numerical Results and Experimental Assessment

The antenna geometry resulting from the synthesis process has been numerically and experimentally tested. Concerning the experimental assessment, the antenna prototype has been placed in an anechoic chamber where both the radiation pattern and $VSWR$ values have been measured.

In Fig. 3, the H-plane normalized beam pattern of the active element radiating in free space is compared with measured and simulated radiation patterns of the same element, but surrounded by the reconfigurable parasitic structure with all the elements in the off state. As it can be observed and expected, the radiation properties of the active element are not modified, thus allowing the isotropic behavior of the system.

In the following, the configurations (activated elements in red and deactivated elements in gray color) and corresponding performances in terms of radiation patterns concerned with 3 (Fig. 4), 6 (Fig 5), and 9 (Fig. 6) activated passive elements are reported. Whatever the configuration, there is a good agreement between numerical and experimental data and the resulting front-to-back values turn out to be compliant with the requirements ($FRB > 5\,dB$).

Moreover, as far as the DoA detection and positioning functionalities are concerned, it should be noticed that both 6- and 9-activated elements configurations present deep nulls characterized by attenuation values of about $19.78\,dB$ (Fig. 5) and $22.36\,dB$ (Fig. 6), respectively.

Finally, the $VSWR$ measurements have been performed by varying the number of activated sectors and the range of variations of $VSWR$ values turned out to be between 1.1 and 1.22.

4 Conclusions

In this letter, the design of an electronically reconfigurable antenna based on a microstrip parasitic structure and characterized by an easy fabrication process, low costs, and limited hardware complexity, has been presented. The radiation properties of the proposed antenna have been adjusted by controlling the states of suitably-located radio frequency switches in order to modify the parasitic structure surrounding the central active element. The reported numerical and experimental results have demonstrated the reconfiguration capabilities of the synthesized antenna system aimed at mitigating the interference phenomena or implementing DoA detection functionalities or positioning functions.

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FIGURE CAPTIONS

- **Figure 1.** Geometry of the planar microstrip parasitic antenna.
- **Figure 2.** Photograph of the prototype of the parasitic antenna.
- **Figure 3.** Simulated and measured normalized radiation patterns in correspondence with the "fully deactivated" configuration.
- **Figure 4.** Simulated and measured normalized radiation patterns in correspondence with the 3-sectors shielding structure.
- **Figure 5.** Simulated and measured normalized radiation patterns in correspondence with the 6-sectors shielding structure.
- **Figure 6.** Simulated and measured normalized radiation patterns in correspondence with the 9-sectors shielding structure.

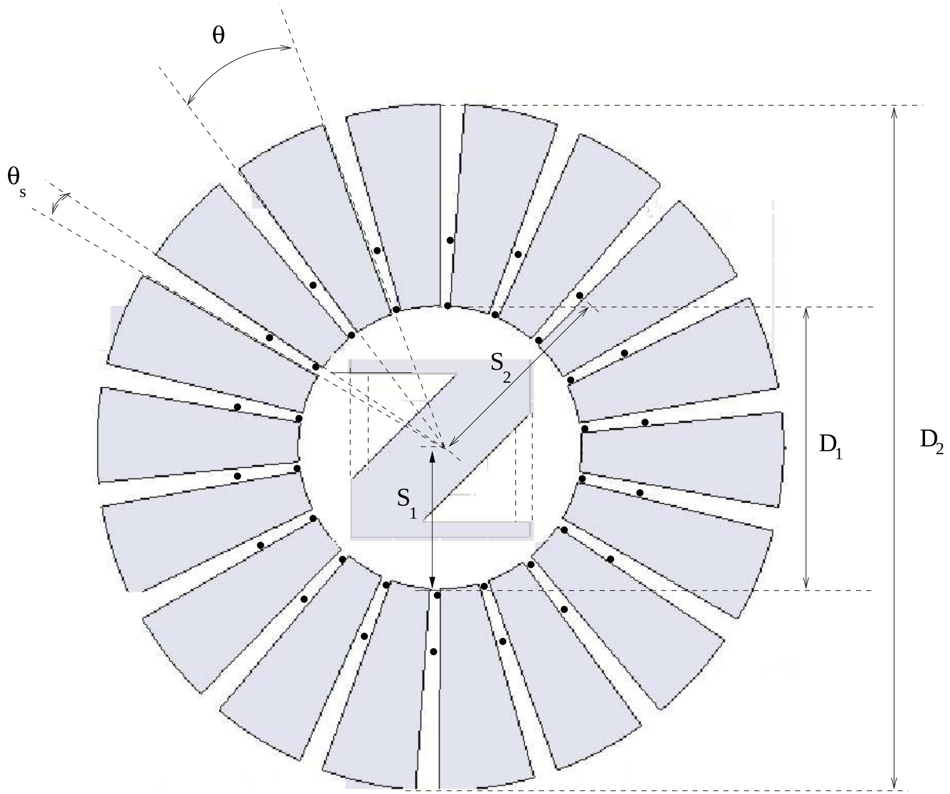

Fig. 1 - M. Donelli *et al.*, "A planar electronically reconfigurable..."

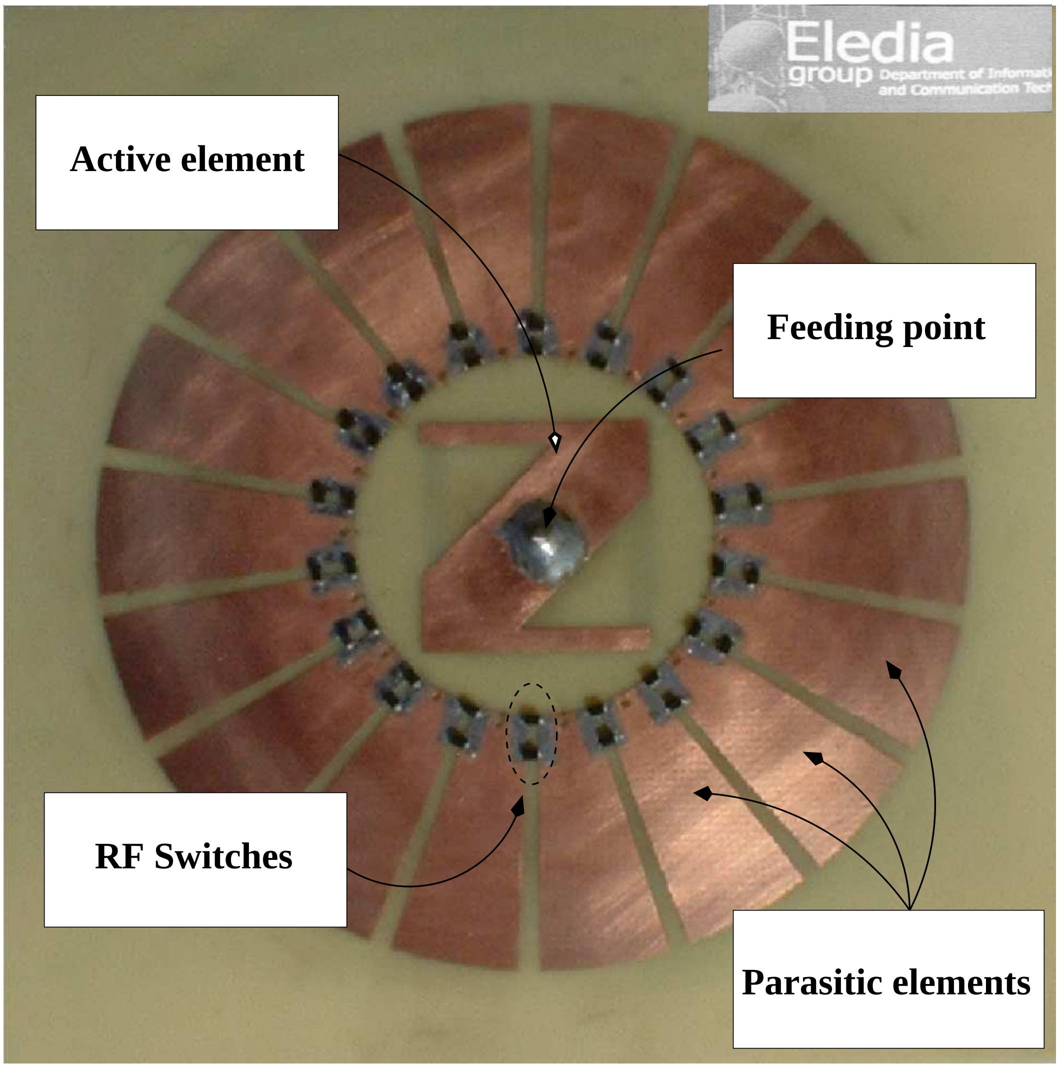

Fig. 2 - M. Donelli *et al.*, "A planar electronically reconfigurable ..."

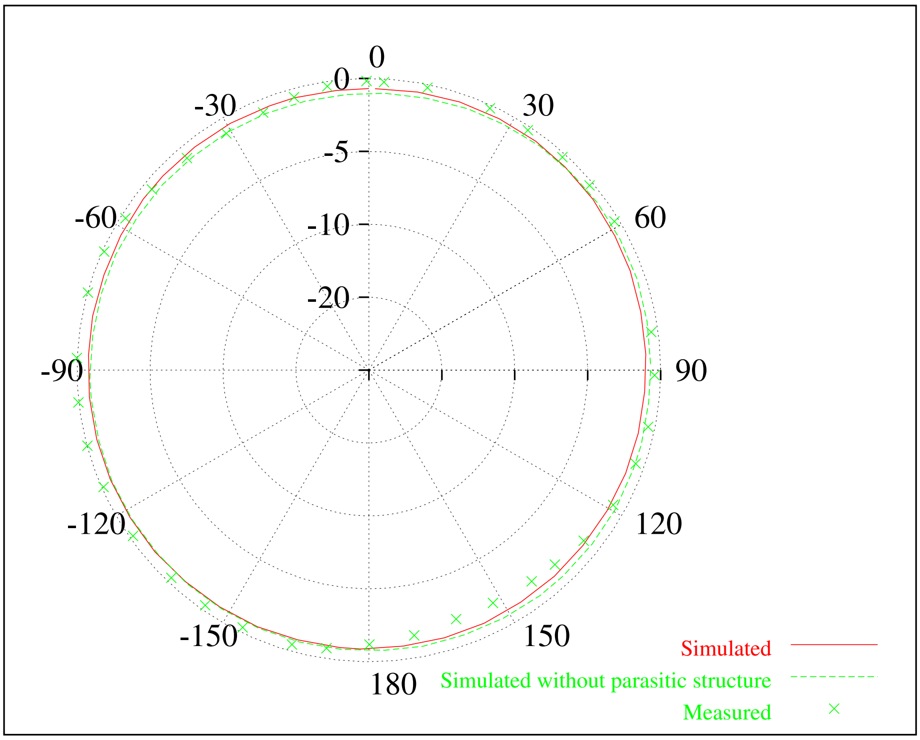

Fig. 3 - M. Donelli *et al.*, "A planar electronically reconfigurable ..."

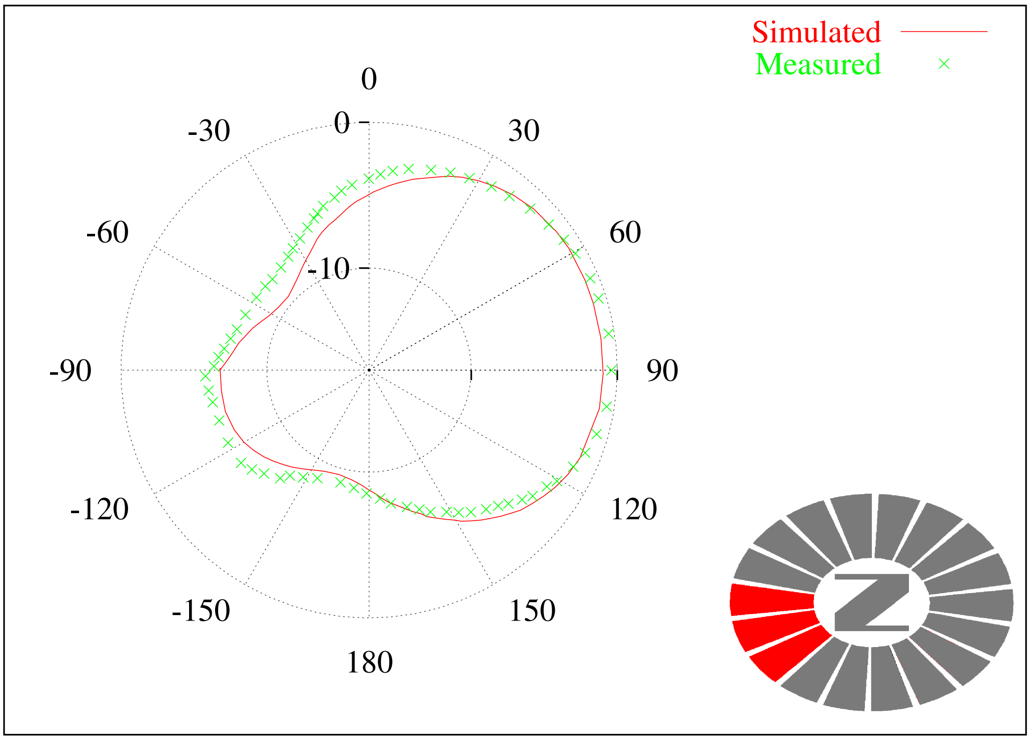

Fig. 4 - M. Donelli *et al.*, "A planar electronically reconfigurable ..."

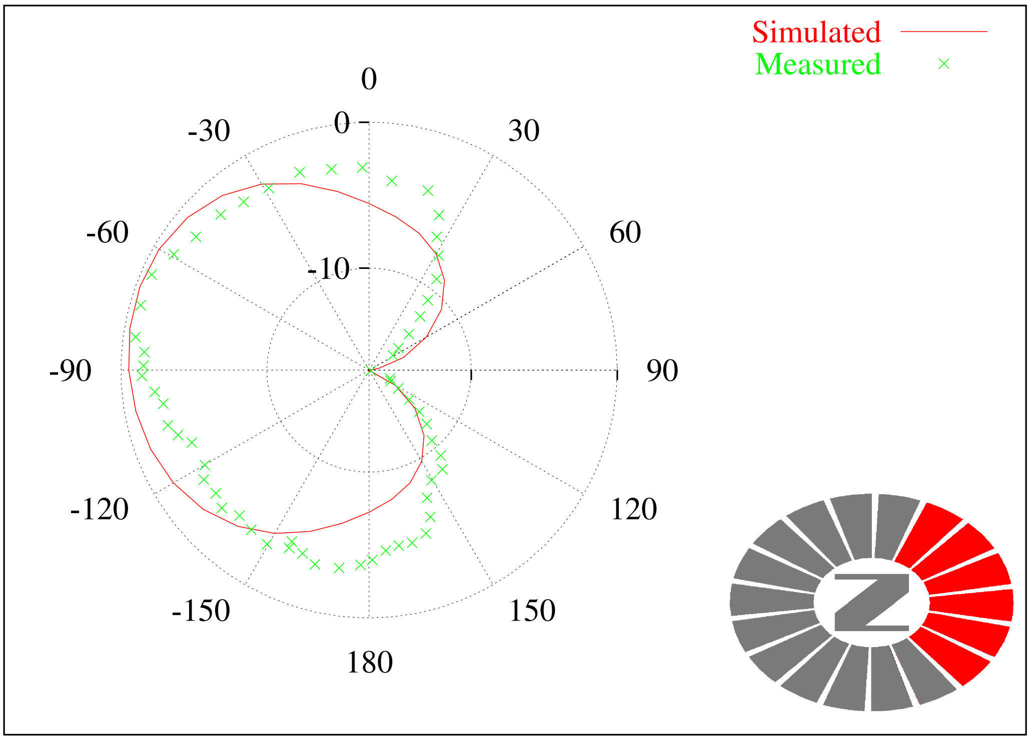

Fig. 5 - M. Donelli *et al.*, "A planar electronically reconfigurable ..."

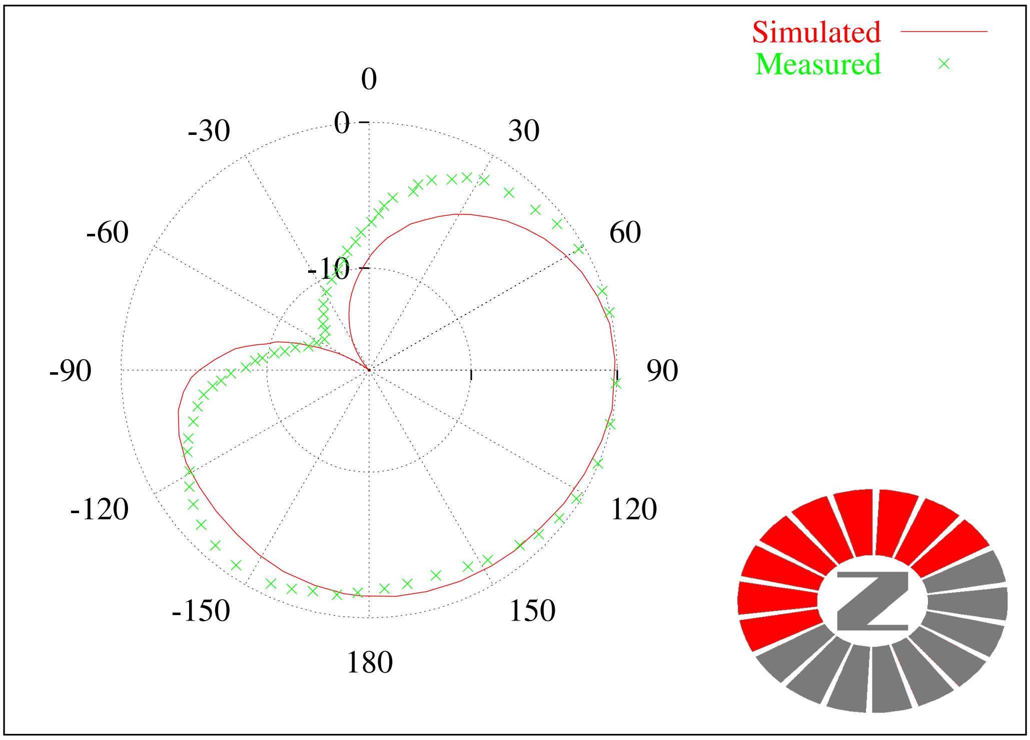

Fig. 6 - M. Donelli *et al.*, "A planar electronically reconfigurable ..."