

AN EXPERIMENTAL REALIZATION OF A FULLY ADAPTIVE SMART ANTENNA

R. Azaro, L. Ioriatti, M. Martinelli, M. Benedetti, and A. Massa

Department of Information and Communication Technology,
University of Trento, Via Sommarive 14, 38050 Trento, Italy;
Corresponding author: andrea.massa@ing.unitn.it

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ABSTRACT: In this letter, the structure of the prototype of a smart antenna working in the 2.4-GHz band is described. The radiating structure is composed by an eight-element linear array with a finite reflecting plane and its adaptive behavior is obtained by means of a set of electronically driven vector modulators that control the array weights. The antenna system is equipped with a control software based on a particle swarm optimizer algorithm that enables the system to adapt to the complex interference scenario. A selected set of numerical and experimental results are reported and discussed to assess the effectiveness of the proposed architecture. © 2008 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 50: 1715–1716, 2008; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.23459

Key words: smart antennas; adaptive arrays; antenna prototype

1. INTRODUCTION

The adaptive control of antennas is one of the most promising solutions to interference phenomena and saturation effects that verify in a more and more crowded electromagnetic environment. As a matter of fact, the growing diffusion of mobile devices, which employ wireless standards for data exchange, requires an efficient and complex exploitation of the communication channels to guarantee a suitable quality of service. In such a framework, smart antennas [1–3] seem to be a very effective tool for the intelligent management of the physical layer since they provide space selectivity functions useful to enhance the signal-to-noise-plus-interference ratio (SINR) at the receiver. The technological difficulties



Figure 2 Photograph of the prototype of the fully adaptive antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

arising in the experimental realization of fully adaptive antenna systems [4] prevented their development and successive application in wireless systems. Consequently, simpler architectures, such as reconfigurable [5, 6] or switched-beam antennas [3], have been proposed and implemented. In this letter, the design of a prototype of a fully adaptive antenna is described and validated through some representative numerical and experimental results.

2. STRUCTURE OF THE FULLY ADAPTIVE ANTENNA

With reference to Figure 1, the fully adaptive antenna is composed by four different modules that provide the system with the necessary hardware and software functionalities: (a) the radiating module, (b) the HW control module, (c) the combiner of the RF signals, and (d) the software control module. More in detail, the radiating system is composed by a linear array of eight equally spaced ($d = \lambda_0/2$, λ_0 being the free-space wavelength at 2.4 GHz) elements and a finite reflecting plane of extension $9\lambda_0 \times \lambda_0$ parallel to the array at a distance of $\lambda_0/4$ (see Fig. 2). The dipoles equipped with integrated baluns have been designed according to the guidelines given in [7] and printed on a dielectric substrate. A vector modulator working in the 2.4-frequency band has been used to introduce an attenuation in the range -4.5 to -34.5 dB and a phase delay from 0 up to 360° with

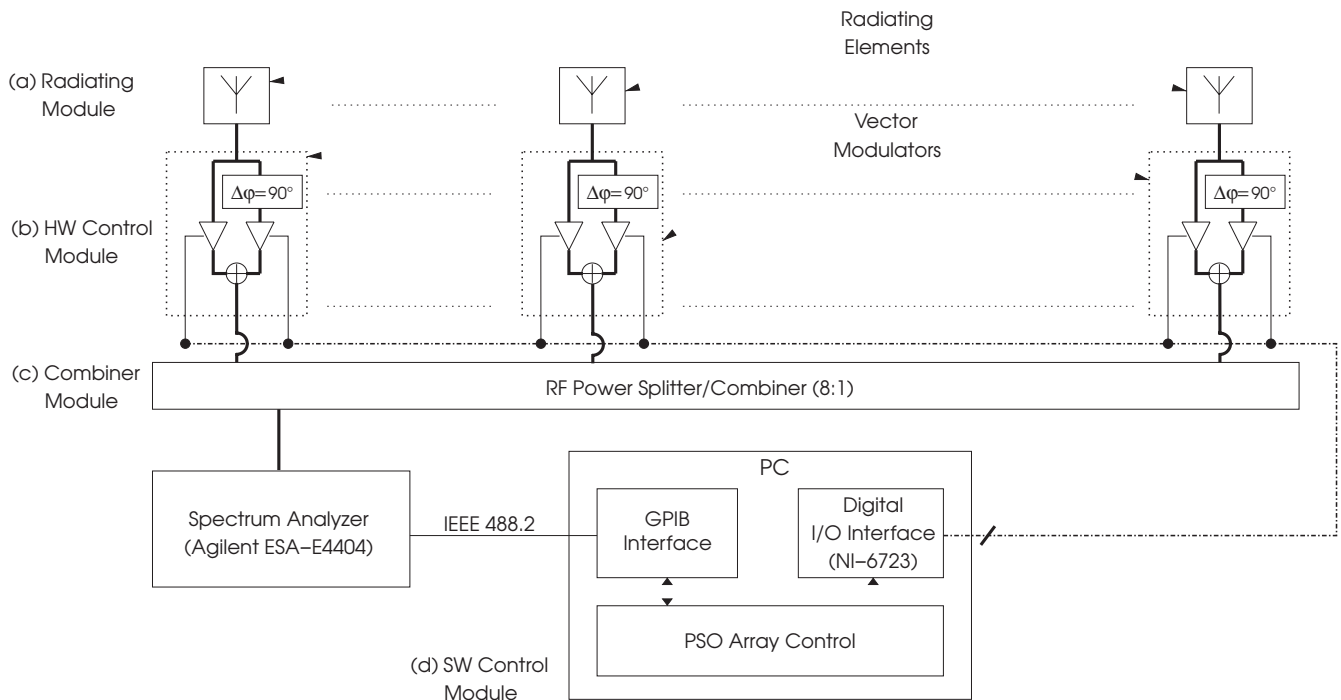


Figure 1 Fully adaptive antenna architecture

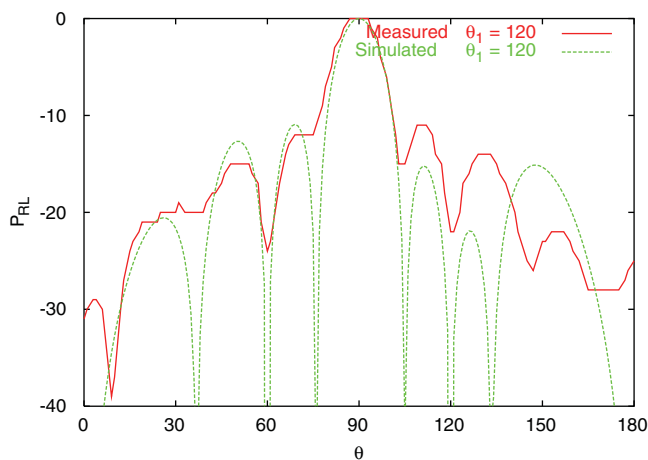


Figure 3 Radiation pattern of the fully adaptive antenna when $\theta^{\text{des}} = 0^\circ$ and $\theta_1 = 120^\circ$: (—) measured; (---) simulated. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

a value determined by a couple of low-frequency differential voltages (-500 to 500 mV). The outputs of the control module are then grouped in a passive RF power combiner (eight way, 0°), built on an Arlon dielectric substrate, which employs seven-microstrip Wilkinson power combiners. The combined signal is then processed by a spectrum analyzer that emulates a receiver able to estimate the SINR value. The whole system is controlled by a personal computer hosting the particle swarm optimizer-based software control. Starting from the current status of the system (i.e., the SINR value) and according to the particle swarm evolution strategy [8, 9], such a module defines the array coefficients to maximize the SINR. Thus, the radiation pattern of the system is continuously modified by placing a maximum value of attenuation in the direction of arrival (DoA) of the interference signals. As far as the hardware interfaces are concerned, there is a GPIB interface between the PC and the spectrum analyzer. Moreover, a digital to analog I/O interface has been used to drive the vector modulator with the required differential voltages. Finally, to avoid/minimize the electromagnetic interferences between the radiating elements and other HW components, the modules (a) and (b) have been placed just behind the rectangular reflecting surface (see Fig. 2) to shield the array elements and the RF modules.

3. NUMERICAL AND EXPERIMENTAL RESULTS

Both hardware and software modules have been separately tested and then integrated to assess the adaptive behavior of the antenna system. The preliminary assessment has been aimed to verify whether the system is able to control the angular positions of the attenuation maxima in the radiation pattern. Toward this end, an exemplificative interference scenario characterized by a jamming signal coming from $\theta_1 = 120^\circ$ and the desired signal impinging at $\theta^{\text{des}} = 0^\circ$ has been considered. Figure 3 resumes the obtained results in terms of radiation patterns. Both simulated and measured quantities are reported. As it can be noticed, the system prototype is able to place a minimum of the beam pattern at $\theta_1 = 120^\circ$ and, at the same time, to maintain the main beam oriented along the DoA of the desired signal ($\theta^{\text{des}} = 0^\circ$).

4. CONCLUSIONS

In this letter, the prototype of a smart antenna composed by a eight-element linear array with a finite reflecting plane and working in the 2.4-GHz band has been described. A selected set of preliminary numerical and experimental results have been reported to assess the

effectiveness of the proposed architecture in shaping the antenna beam pattern to maximize the reception performance of the system.

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ERRATUM: ITERATIVE IMPLEMENTATION OF APPROXIMATE SOLUTIONS FOR ELECTROMAGNETIC SCATTERING

M. Nakhkash

Department of Electrical Engineering, Yazd University, P.O. Box 89195-741, Yazd, Iran; Corresponding author: nakhkash@yazduni.ac.ir

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It has been brought to our attention that there were a number of typographical errors in Eq. (24) of this manuscript.

The equation should be corrected as:

$$\mathbf{W}_n(\mathbf{r}) = -\frac{g_n(\mathbf{r})}{1 - g_n(\mathbf{r})} \mathbf{W}_{n-1}(\mathbf{r}) + G_D \left(\frac{\chi(\mathbf{r})}{1 - g_n(\mathbf{r})} \mathbf{W}_{n-1}(\mathbf{r}) \right) \quad (24)$$

We apologize for any inconvenience these errors may have caused.

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