UNIVERSITY
OF TRENTO

DEPARTMENT OF INFORMATION AND COMMUNICATION TECHNOLOGY

38050 Povo – Trento (Italy), Via Sommarive 14
http://www.dit.unitn.it

DESIGN OF A MINIATURIZED ISM-BAND FRACTAL ANTENNA

R. Azaro, G. Boato, M. Donelli, G. Franceschini, A. Martini, and A.Massa

June 2005

Technical Report DIT-05-009

Design of a miniaturized ISM-band fractal antenna

R. Azaro, G. Boato, M. Donelli, G. Franceschini, A. Martini, and A. Massa

Miniaturization techniques for antenna design based on fractal geometries are of growing interest in wireless communications. In this letter, the design of a miniaturized fractal antenna prototype is described. Towards this end, a particle swarm optimizer is used to simultaneously optimize the fractal shape as well as the input impedance by acting on the thickness of the antenna segments to avoid matching networks. The effectiveness of the approach is confirmed by means of simulated as well as experimental results.

Introduction: Several mobile systems, such as mobile telephones, use simple monopole radiators because of their simplicity, low-cost, and suitability for portable devices. The growing need of miniaturization, not only require small devices, but also small-sized radiators. Fractals, due to their geometrical properties, can be successfully used in antenna miniaturization [1] and recently some interesting applications have been studied and presented in the scientific literature [2]. In this framework, this letter deals with the design of a Koch-like fractal miniaturized antenna [3,4]. Koch-like fractal antennas can be arranged in many geometrical configurations to satisfy user-defined geometrical constraints. Unfortunately their input impedance is generally low [3,4] and active or passive networks [5] are needed to obtain a satisfactory impedance matching. As an example, in [5] a linear fractal antenna has been designed with a Genetic Algorithm (GA) based procedure able to simultaneously minimize the antenna size as well as the positions of two lumped loads in order to match the input impedance. To avoid lumped loads, this letter considers the optimization of the fractal geometry [5] together with the segment widths through a procedure based on a particle swarm optimizer (PSO) [6]. To model the body of an electronic device, a small circular ground plane has been considered both during the design phase and experimental measurements.

Antenna design and structure: As far as the requirements for the ISM band are concerned, the antenna is required to have in the overall frequency band a VSWR value lower than 2.61, which results in a reflected power at the input port lower than 20% of the incident power. From a geometrical point of view, a size reduction of about 30 % in comparison with a standard quarter-wave monopole is requested. To fit these constraints, the parameters to be optimized are the fractal geometry and the width of each fractal segment. Towards this purpose, the PSO is applied. According to the guidelines reported in [7], the optimization algorithm defines a sequence of trial configurations, which converges to an optimal antenna design by minimizing the cost function defined as the least-square difference between requirements and estimated specifications in terms of VSWR and power gain values (computed starting from the estimated parameters by means of a Method-of-Moment-based simulator **[8]**). At the end of the optimization process, the fractal antenna shown in Figure 1 has been obtained. As can be observed, the synthesized antenna satisfies the geometrical requirements in terms of linear extension since its length turns out to be lower than that of the reference monopole (the ratio between fractal and monopole antenna being of about 0.65).

Experimental Validation: The antenna prototype has been built by using a photolithographic printing circuit technology and it has been equipped with a SMA connector as shown in Figure 2. The VSWR has been measured by means of a network analyzer placing the antenna, equipped with a small circular ground plane, in an anechoic chamber. For comparison purposes, computed and measured VSWRs have been compared and the results are shown in Figure 3. As it can be observed, measured as well as simulated VSWR values satisfy the project specifications.

Finally, for completeness, Fig. 4 shows the simulated horizontal and vertical gain patterns. As expected, the radiation properties of the fractal antenna are very close to those of a conventional monopole.

Conclusion: The design of an ISM-band fractal antenna has been described. The antenna has been optimized through a particle swarm algorithm by optimizing the fractal parameters and the segments widths to comply with the geometrical specifications as well as the impedance matching constraints. An antenna prototype has been fabricated and comparisons between measured and simulated performance have been carried out in order to assess the effectiveness of the proposed design procedure.

Acknowledgments

This work has been partially supported **by the *Center of REsearch And Telecommunication Experimentations for NETworked communities* (CREATE-NET).**

References:

1 WERNER, D. H., and MITTRA, R.: 'Frontiers in electromagnetics' (IEEE Press, Piscataway, NJ, 2000).

2 GIANVITTORIO, J., and RAHMAT-SAMII, Y.: 'Fractals antennas: A novel antenna miniaturization technique, and applications', IEEE Antennas Propagat. Mag., February 2002, Vol. 44, pp. 20–36

3 BALIARDA, C. P., ROMEU, J., and CARDAMA, A.: 'The Koch monopole: A small fractal antenna', IEEE Trans. Antennas Propagat., November 2000, Vol. 48, pp. 1773–1781

4 BEST S. R.: 'On the performance properties of the Koch fractal and other bent wire monopoles', IEEE Trans. Antennas Propagat., June 2003, Vol. 51, pp. 1292–1300

5 WERNER, D. H., WERNER, P. L., and CHURCH K. H.: 'Genetically engineered multiband fractal antennas', Electron. Lett., September 2001, Vol. 37, pp. 1150–1151

6 KENNEDY, J. , EBERHART, R. C., and SHI, Y.: 'Swarm Intelligence' (Morgan Kaufmann Publishers, San Francisco, 2001)

7 ROBINSON, J., and RAHMAT-SAMII, Y.: 'Particle swarm optimization in electromagnetics', IEEE Trans. Antennas Propagat., February 2004, Vol. 52, pp. 397–407

8 BURKE, G. J., and POGGIO, A. J.: 'Numerical Electromagnetics Code (NEC) - Method of Moments' (Lawrence Livermore Nat. Lab., Livermore, CA, Tech. Rep. UCID-18834, 1981)

Authors' affiliations:

R. Azaro, G. Boato, M. Donelli, G. Franceschini, A. Martini, and A. Massa (Department of Information and Communication Technology, University of Trento, Via Sommarive 14, 38050 Trento – ITALY)

Corresponding Author:

A. Massa
Department of Information and Communication Technology
University of Trento
Via Sommarive 14
38050 Trento
ITALY
E-mail: andrea.massa@ing.unitn.it

Figure captions:

Fig. 1 - Geometry of the synthesized fractal antenna.

Fig. 2 - Photograph of the fractal antenna prototype.

Fig. 3 - Comparison between measured and simulated VSWR values.
- - - - - - - - Measured Data
——— Simulated Data
- - - - - - - - Requirements

Fig. 4 - Horizontal and vertical gain patterns.

Figure 1

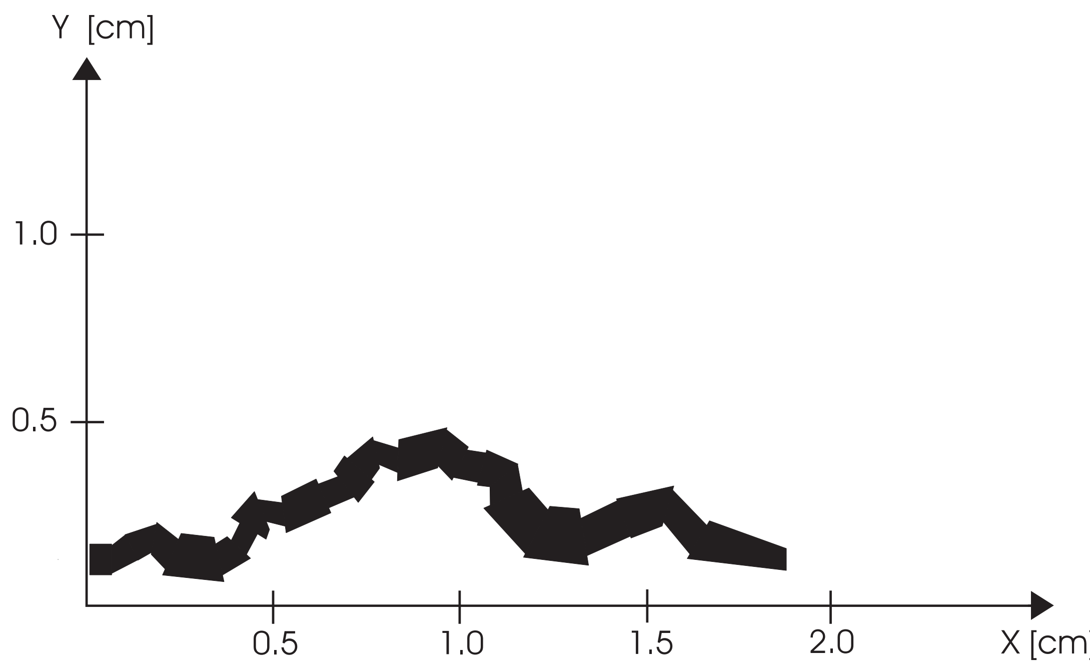


Figure 2

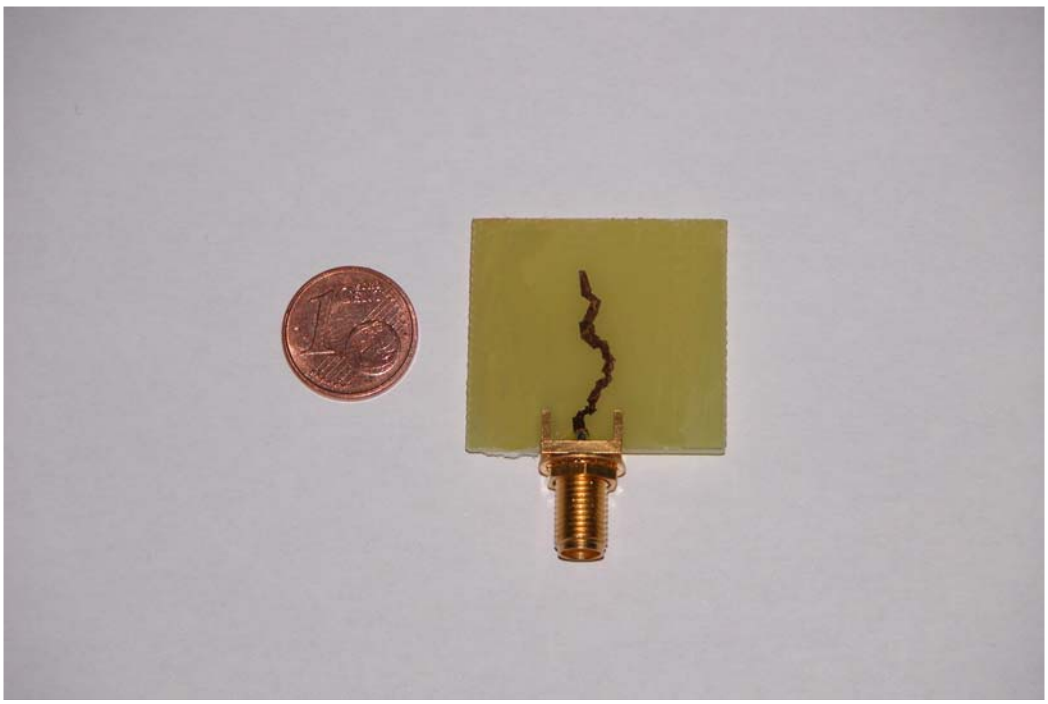
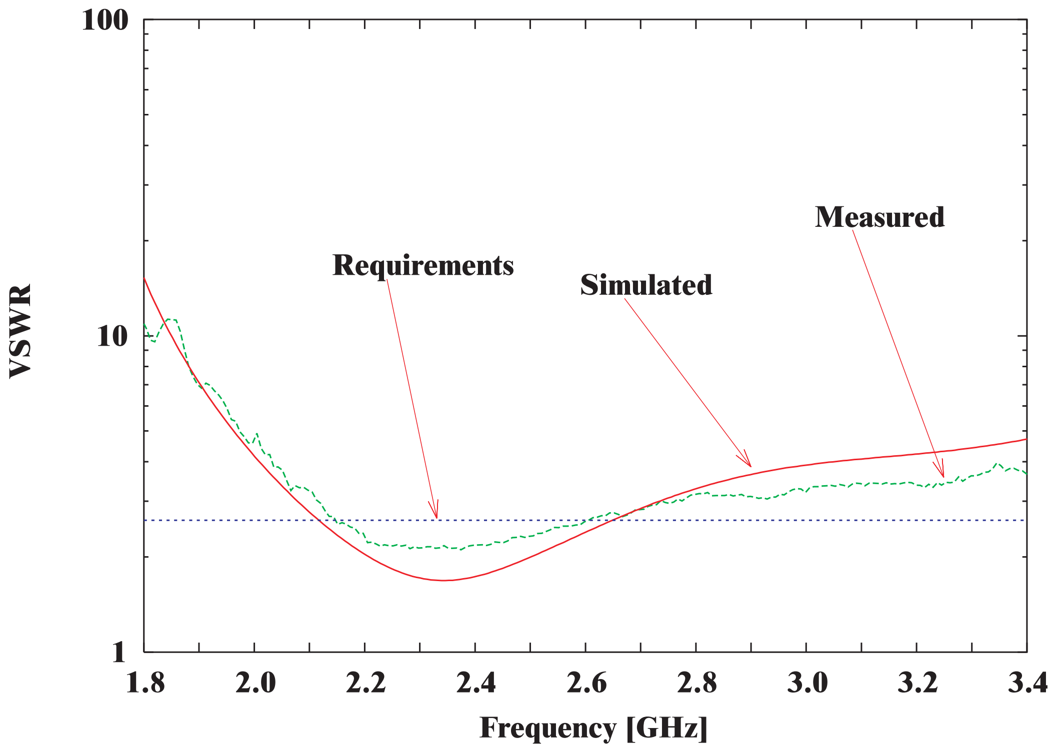
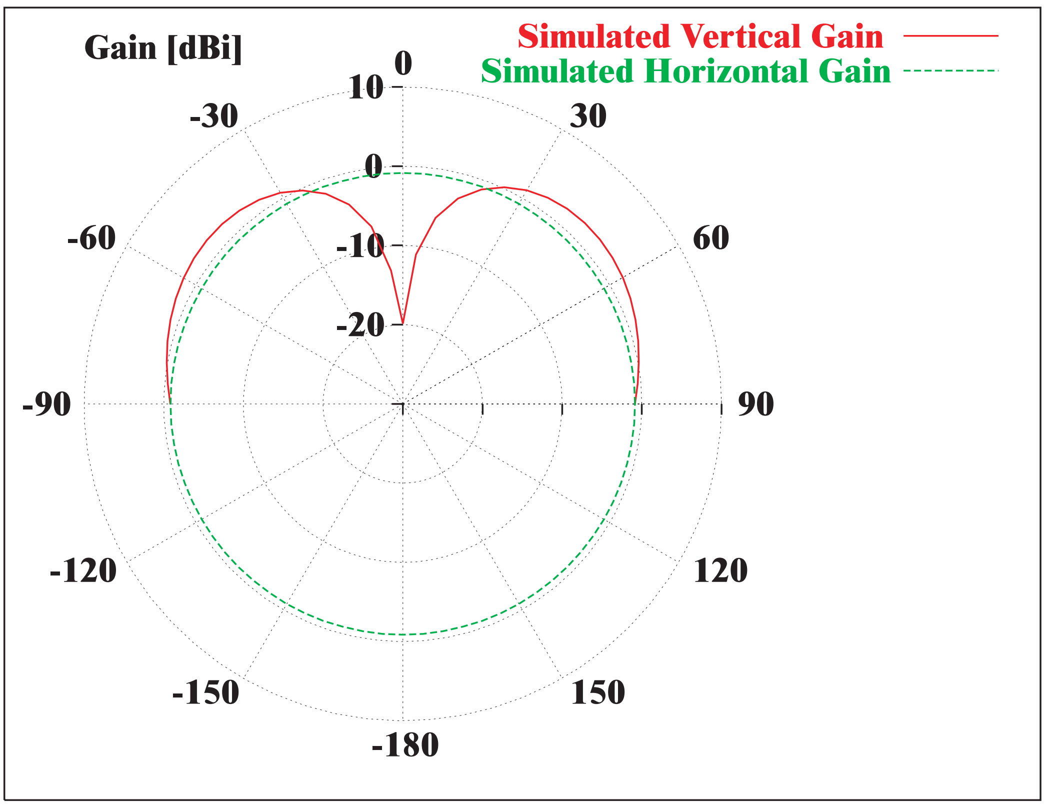


Figure 3



100
10
1
VSWR
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
Frequency [GHz]
Requirements
Simulated
Measured

Figure 4



Gain [dBi]
Simulated Vertical Gain
Simulated Horizontal Gain
0
30
60
90
120
150
-180
-150
-120
-90
-60
-30
10
0
-10
-20