Design of miniaturised ISM-band fractal antenna

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Miniaturisation techniques for antenna designs based on fractal geometries are of growing interest in wireless communications. Described is the design of a miniaturised fractal antenna prototype. To this end, a particle swarm optimiser is used to optimise simultaneously the fractal shape and the input impedance by acting on the thickness of the antenna segments to avoid matching networks. The effectiveness of the approach is confirmed by simulated and 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 for miniaturisation, not only requires small devices, but also small-sized radiators. Fractals, owing to their geometrical properties, can be used successfully in antenna miniaturisation [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 miniaturised 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, a linear fractal antenna has been designed [5] with a genetic algorithm (GA) based procedure able to minimise simultaneously the antenna size and the positions of two lumped loads in order to match the input impedance. To avoid lumped loads, this Letter considers the optimisation of the fractal geometry [5] together with the segment widths through a procedure based on a particle swarm optimiser (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 required. To fit these constraints, the parameters to be optimised are the fractal geometry and the width of each fractal segment. To this purpose, the PSO is applied. According to the guidelines reported in [7], the optimisation algorithm defines a sequence of trial configurations, which converges to an optimal antenna design by minimising the cost function defined as the least-squares 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-moments-based simulator [8]). At the end of the optimisation process, the fractal antenna shown in Fig. 1 has been obtained. As can be observed, the synthesised 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 about 0.65).

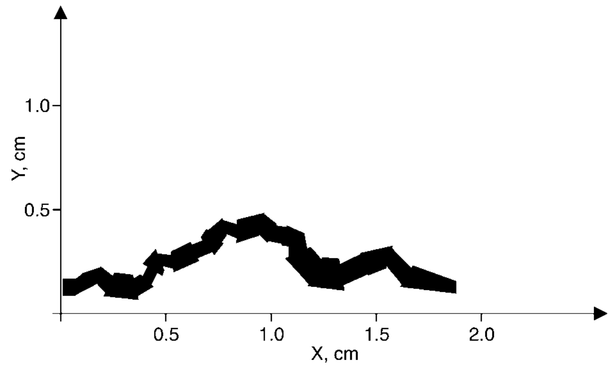

Fig. 1 *Geometry of synthesised fractal antenna*

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

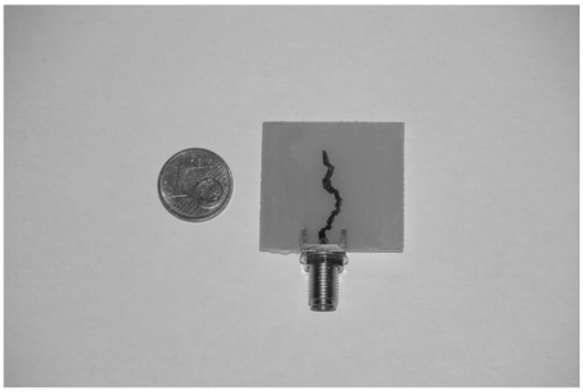

Fig. 2 *Photograph of fractal antenna prototype*

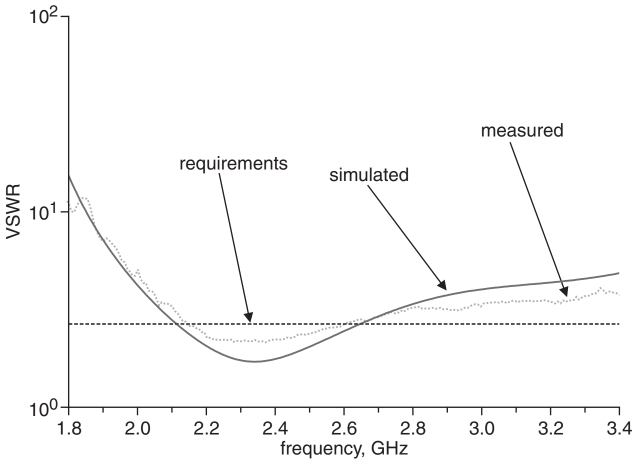

Fig. 3 *Comparison between measured and simulated VSWR values*

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.

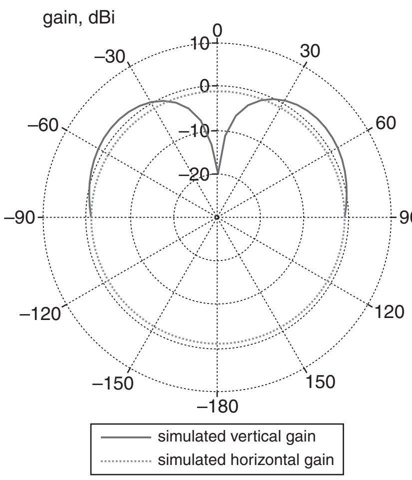

Fig. 4 *Horizontal and vertical gain pattern*

Conclusion: The design of an ISM-band fractal antenna has been described. The antenna has been optimised through a particle swarm algorithm by optimising the fractal parameters and the segment widths to comply with the geometrical specifications and 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.

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