
FRACTALCOMS



**Exploring the limits of Fractal Electrodynamics for
the future telecommunication technologies
IST-2001-33055**

Project Presentation

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Abstract:

This deliverable is a brief project presentation for the non-specialist.

Keyword list: Fractal antennas, miniature antennas

CONTRACT NUMBER: IST-2001-33055

PROJECT ACRONYM: FRACTALCOMS

PROJECT NAME:

EXPLORING THE LIMITS OF FRACTAL ELECTRODYNAMICS FOR THE
FUTURE TELECOMMUNICATION TECHNOLOGIES

KEY ACTION, ACTION LINE: IST VI.2.2 (FET)

PROJECT LOGO (IF ANY):

FractalComs

LIST OF PARTICIPANTS (ORGANISATION NAME, COUNTRY):

- **UPC**, Universitat Politècnica de catalunya, Spain: Project leader, experts on antennas and microwave devices and early developers of fractal multiband antennas. <http://www.upc.es/>
- **ROME**, Interuniversity Research Center for Disordered Systems and Fractals in Chemical Engineering and Department of Electronic Engineering of the La Sapienza University of Rome, Italy: Experts on vector calculus in fractal curves and surfaces <http://www.uniroma1.it/>
- **EPFL**, Ecole Polytechnique Fédérale de Lausanne, Switzerland: Experts on numerical analysis and miniaturization of printed antennas and microwave circuits. <http://www.epfl.ch/>
- **UGR**, Universidad de Granada, Spain: Experts on time domain modeling, with experience on simulation of fractal antennas. <http://www.ugr.es/>
- **CIMNE**, International Center for Numerical Methods in Engineering, Spain: Experts on adaptive meshing for numerical simulation. <http://www.cimne.upc.es/>

TOTAL COST (€): 882,234

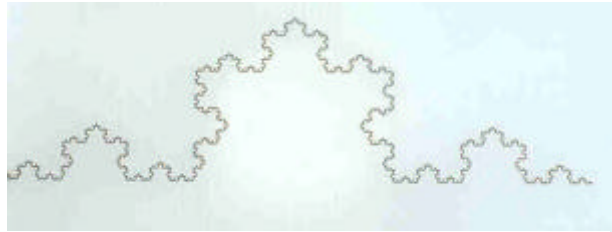
COMMISSION FUNDING (€): 379,000 (42.96%)

PROJECT MAIN GOAL(S):

The aim of this FET project is basic research on fractal electrodynamics in order to explore the performance limits (both fundamental and technological) of highly innovative fractal shaped miniature devices for future wireless telecommunication systems.

The performance of conventional antennas and microwave passive devices is highly sensitive to its size compared to the wavelength. Given a particular operating wavelength, they cannot be made arbitrarily small. However, there is a property of fractal shapes that may lead to a significant size reduction regardless the electromagnetic geometrical constraint: the fractal dimension. A fractal curve enclosed in a finite area or volume has infinite length. In practice, a fractal shaped device will not have infinite length, but it can be made arbitrarily long until the technology limit is reached. This may lead to the design of devices that, having the same length compared to the operating wavelength than their Euclidean counterparts, occupy a smaller volume.

The technological limitations are important here, since fractals are structures that have details of infinitely small size, which are obviously impossible to implement in practice. One of the objectives of the research is to study the performance of devices having a finite smallest size



Pre-fractal antenna based in Koch curve

compatible with present technology constraints. In addition to the technological limitations for the miniaturization of fractal shaped devices, there is also a fundamental limit. This limit establishes the smallest size of a device that can have a given operating bandwidth. In practice, this fundamental limit has never been reached by conventional devices. The size limitation depends on how efficiently the device occupies the volume inside the enclosing sphere, and thus fractal shapes are expected to perform much better than Euclidean ones. Another objective of this project is to explore if fractal shaped devices can reach the fundamental limit.

There is another potential limitation of fractal microwave devices that must be investigated: the loss efficiency. It has been shown that in fractal geometries electromagnetic fields and currents concentrate into very small regions. Since the power loss due to Joule effect is proportional to the square of the electric current density integrated along the device surface, current concentration in small areas produce much larger power losses than more uniform current distributions. This effect may result in antennas having much lower gain than the theoretical directivity or microwave filters or resonators having too large insertion losses.

OBJECTIVES

- 1- Increase the know-how in Fractal Electrodynamics theory and understand better the behavior of electromagnetic fields and electric currents in fractal domains, in order to acquire guidelines for the design of fractal-shaped antennas and microwave devices.
- 2- Explore if fractal-shaped microwave devices can reach the fundamental miniaturization limit, which has been never reached by Euclidean-shaped devices.

3- Develop a software tool for computer simulation of fractal-shaped microwave devices performance, including time domain visualization of the interaction between geometry and electromagnetic fields, in order to allow a physical interpretation of radiation and resonance of the proposed structures. This tool would allow also the later design and optimization of such devices.

4- Explore the impact of the technological limitations on the performance of fractal-shaped microwave devices, including minimum detail size and loss efficiency.

KEY ISSUES

It must be remarked that this is a FET project and therefore the main objective is an increase of knowledge. Fractal antennas are becoming increasingly popular and many European SMEs, driven by the need of offering up-to-date state-of-the-art products, may decide to tackle risks by including them in their production lines. This project should provide answers about the potential interest of fractal antennas, through a careful study of electrical performance vs. technological complexity trade-offs.

TECHNICAL APPROACH

Numerical simulation is necessary in this project in order to test and predict the performance of many suggested fractal geometries of potential interest. For initially successful geometries, simulation is very important in order to assess the viability of such devices in the frame of present technology constraints. Fractal-shaped devices can be simulated even beyond the technological limitations in order to predict performance in the frame of future technologies. Numerical simulation in the time domain has the added value of providing animated visualization of the interaction between geometry and electromagnetic fields, thus allowing a physical interpretation of radiation and resonance of the proposed structures.

EXPECTED ACHIEVEMENTS/IMPACT

The result, if successful, should be the basis for a new generation of miniature microwave devices such as antennas, filters and resonators. The development of miniature wireless communication sub-systems would remove one of the bottlenecks that prevent the integration of multiple information services in small user terminals, resulting in a significant breakthrough for the IST.

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