Study of small prefractal antennas in the time domain

Abstract:

This deliverable describes some results obtained analysing, using the method of moment in the time domain (MoMTD), several small pre-fractal antennas such as the Koch and the binary tree monopoles and the Hilbert and the Koch loop antennas.

Keyword list: Time domain, method of moments, pre-fractal small antennas, visualization.
RELATED WP AND TASKS (FROM THE PROJECT DESCRIPTION)

WP3: Software simulation tool.
   Task 3.4: Simulation of pre-fractal structures in the time domain.

WP1: Theory of fractal electrodynamics.
   Task 1.1: Understanding fractal electrodynamics phenomena.

1 INTRODUCTION

To simulate and analyse, in the time domain, the behaviour and characteristics of thin-wire pre-fractal antennas containing wire junctions, such as the binary tree monopole, it has been needed to develop further extensions of the DOTIG5 code to model such junctions using non-uniform segmentation of the wires. Furthermore, to simulate larger strip pre-fractal antennas, the surface code has been extended to take advantage of the symmetry of monopole antennas in front of a PEC ground in order to save computational resources. This task has been divided into two main parts:

a) Extensions of our previous code, DOTIG5, to study PEC thin-wire pre-fractal antenna geometries including wire junctions with non-uniform segmentation and to take advantage of the symmetry of strip monopole antennas in front of a PEC ground.

b) Simulation and analysis of different pre-fractal geometries. The realization of numerical experiments in the time domain allows us to isolate interactions using time range (cause and effect can be distinguished providing an easier physical interpretation of the results), possibilities of simulating transient phenomena, visualization of the time history of the physical magnitudes and possibility of obtaining, with a single run, broadband information.

2 EXTENSIONS OF THE DOTIG5 CODE

As was explained in the previous report, DOTIG5 is a computer code based on the time-domain solution of the time-domain electric field integral equation (TD-EFIE) using the MoMTD for the analysis of structures formed by PEC thin wires and surfaces.

2.1 Extension of DOTIG5 to model thin-wire junctions with non-uniform segmentation

In our previous work the code was extended to model thin-wire pre-fractal antennas formed by unconnected wires using non-uniform segmentation or structures with crossing wires (at junctions) but just with an uniform descretization. Now we have further extended it to include the possibility of modeling junctions between wires that are modelled with a non-uniform segmentation. Figure 1a shows, as an example of
prefractal antennas including junctions, several iterations of a binary tree antenna. Figure 1b shows the way of treating junctions by means of overlapping segments. The basic idea is to force the current and charge per unit length to be continuous at the junctions.

a) Binary tree dipole

b) Original thin-wire structure and overlapping segments model.

Figure 1

2.2 Extension of DOTIG5 for continuous surface structures

To save computational resources we have also extended the DOTIG5 code for surface structures in order to take advantage of the symmetry of monopole antennas in front of a perfect conducting ground. This extension makes possible, using the same computer, to analyse greater structures that was possible previously, for example the 3rd iteration.
of the one millimetres width Koch monopole, or the 1st iteration of the two millimetre width Koch monopole with a finer discretization.

The surface geometries analysed with DOTIG5 are modeled with triangular patches to solve the EFIE using the MoMTD. The sense of the surface current crossing an edge is given by the definition of the two triangles with that edge in common. Figure 2 shows two adjacent triangular patches and their mirror image where the triangles have been change so that the right mirror-image current is obtained in the lower part of the structure. For a given structure modelled with N triangular patches and located in front of a PEC ground, applying symmetry considerations greatly reduces the computational resources needed for its simulation. In particular the memory is reduced in approximately 50% and the computational time in more than 50%.

2.3 Validation

Both extensions of DOTIG5 have been validated using representative examples. Figure 3 shows for the order 4 pre-fractal thin-wire binary tree antenna of Figure 1, the input impedance (resistance and reactance) calculated using the extended version of DOTIG5 and NEC. It can be observed that there is a excellent agreement between both results.

Figure 2. Triangular patches and their mirror images
Figure 3. Input impedance (resistance and reactance) of the order 4 pre-fractal thin-wire binary tree antenna.

Regarding the surface version of DOTIG5, this code have been validated solving the same structure with and without using the extension that takes advantage of the symmetry for a monopole in front of a PEC ground and the results were identical.

3 SIMULATIONS AND VISUALIZATION.

To continue our study about the physical behavior of pre-fractal antennas, the resulting code has been applied to carry out new simulations and numerical experiments to facilitate the understanding of the behavior of pre-fractal antennas. To this end we have studied the time history of physical magnitudes such as the current induced in several fractals antennas and the fields created by these currents. The main difference between the results presented in this report and the ones of the previous report is that now, the study has been focused on electrically small pre-fractal antennas and more geometries than the Koch monopole have been considered.
Figure 4. a) Space-time diagram for a Koch monopole of order 2 excited by a wide Gaussian signal. b) The arrows indicate the segments where the shortcut effects take place.

As a first example, Figure 4a shows the space-time diagram for a Koch monopole of order 2 excited by a wide Gaussian signal whose maximum spectral component is such that the monopole is an electrically small antenna even for that frequency. It can be observed that current suddenly appears at certain zones of the structure at times before the pulse of current propagating along the structure does. These shortcuts, as happened in electrically large pre-fractal antennas, play a significant role in the behavior of electrically short pre-fractal antennas. The shortcut effects take place mainly at certain segments, which are indicated with arrows in Figure 4b, with a specific orientation tangential to the wave front originated at the feed point. In consequence, it is clear that the orientation of the segments in the pre-fractal antennas plays also an important role that need further investigation.

After performing different numerical experiments it has been found that, for low frequencies, the shortcut is almost exclusively due to the field created at the feed points and that this effect increases, for wire antennas, with the electric size of the radius of the wire or, and for strip antennas, with the width of the trip. For example Figure 5
shows the resonance frequency corresponding to two Koch monopole strip antennas of order 3 and the same length but different widths. It can be observed that the resonance frequency increases with the width, the reason is that the effect of the shortcuts is stronger for the wider strip because there exists a greater coupling between the radiated field and the strip. The same results have been found for Koch monopoles of higher order.

4 ANALYSIS OF OTHER THIN-WIRE PREFRACTAL ANTENNAS.

Other pre-fractal geometries studied are the binary tree monopole, the Hilbert antenna and the Koch loop antenna. For example, Figure 6 shows the comparison of these two antennas and the Koch monopole in terms of the resonance frequency and total length. Figures 6a and 6b give, for these antennas, the resonance frequency and the input resistance at the resonance frequency as a function of their total length. Figure 7 presents the results obtained for the Koch loop where it can be observed that in this pre-fractal geometry, the resonance frequency presents a similar behavior than that of the other pre-fractal antennas previously analyzed, that is, it decreases as the order of the iteration increases but it stagnates as the iteration increases.
Figure 6. Comparison of the binary tree monopole and the Hilbert antenna and the Koch monopole in terms of the resonance frequency and total length.
During this period several algorithms, to improve the capability of simulating prefractal geometries of the computer program DOTIG5, have been developed and validated. The resulting code has been applied to study the behavior of several small pre-fractal antennas and, in particular, of the influence of the interaction of the field radiated by the antenna with other parts of the structure (shortcuts). The shortcut is a complex effect that strongly depends on the geometrical details of the structure and that plays an important role in the behavior of small antennas.

5 FUTURE WORK

More studies of different pre-fractal geometries will be carried out during the next period and some effort will be focused to obtain a deeper knowledge of the role played by the shortcuts. Another important task will be to develop appropriate genetic algorithms to design efficient small antennas either pre-fractal or with Euclidean
geometry. Moreover the behavior of small antennas in front of arbitrary inhomogeneous bodies, as a simplified human head, will be analyzed.
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