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FRACTAL ANTENNA WITH HEXAGONAL RESONATORS

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Abstract: *The paper presents a model of fractal antennae having hexagonal resonators with slots. The content highlights the principles, the calculation model and technical design features accompanied by experimental results. Covering a very wide frequency band, having a satisfactory gain and relatively small geometric dimensions, this antenna is recommended in mobile telephony and multiservice.*

Keywords: *fractal, antenna, resonator, directivity, field intensity.*

1. INTRODUCTION

A fractal element antenna uses the fractal geometric structure as a virtual combination of capacitors and inductors. This allows the antenna to have multiple resonance frequencies that can be selected and corrected by chosen fractal model. Recent years have shown in many studies [1], [2], [3] that the use of fractal element antennas in the antennas construction confers superior performances and properties, validating the idea that geometry is a key issue in unique determination of the electromagnetic behavior of antennas that are independent of frequency [6].

2. ANTENNA DESIGN

2.1 Principles and the calculation model. The theoretical model of reference is fractal with discs, while the calculation procedure of electrical quantities is similar to fractal sector antenna with disk-shaped resonators, stressing that discoid surfaces were approximated with hexagonal surfaces.

2.2 Antenna architecture. The geometrical shape used both for the fractal construction and for the radiating surface of the antenna, it is the hexagon. Fractal has in this case three iterations and the scaling factor is two. In the first iteration six new hexagons are created (one on each side of the basic shape, having the edge dimension equal to half of the generator side), and in the second iteration are kept only three hexagons, on the sides that are towards the outside of figure (Fig. 1).

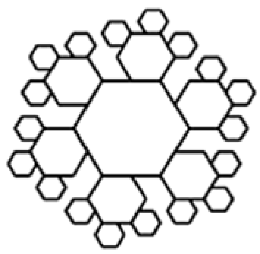

Fig. 1. The architecture of the fractal antenna with hexagonal resonators.

In the final shape of the radiating surface are placed two such fractals. Hexagonal surfaces on the top floor are approximated by discs. Each hexagonal surface contains a resonant slot disposed symmetrical on rectangular axes of the hexagonal surface. For one of fractals slots are placed horizontally and vertically to other one (Fig. 2).

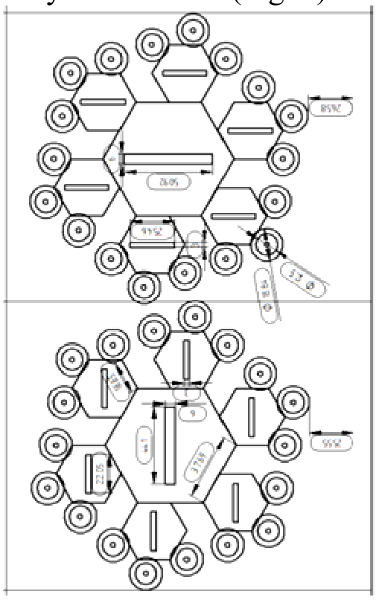

Fig. 2. Fractal antenna with hexagonal resonators – slots disposing.

2.3 Dimensioning of planar resonant slot. The electromagnetic wave equation of the planar resonant cavity is:

$$\frac{^2H_z}{x^2}+\frac{^2H_z}{y^2}+\mu\varepsilon\omega^2H_z=0 \qquad (1)$$

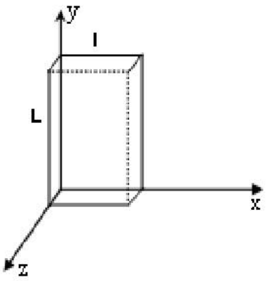

Fig. 3. Model of the planar resonant slot.

Considering the following conditions:

$E_z = 0$, $x = 0$ and $x = l$;

$E_z = 0$, $y = 0$ and $y = L$,

the H_z value can be calculated:

$$H_z = H_0\cos(n\pi\frac{x}{l})\cos(m\pi\frac{y}{L})$$

(2)

for $0 \le x \le l$ and $0 \le y \le L$.

Specific resonance pulsation for the propagation mode is:

$$\omega=\frac{\pi}{\sqrt{\varepsilon\mu}}\sqrt{\frac{n^2}{l^2}+\frac{m^2}{L^2}} \qquad (3)$$

$$\lambda_{rez}=\frac{2\pi\sqrt{\varepsilon_r}}{\sqrt{\frac{n^2}{l^2}+\frac{m^2}{L^2}}} \qquad (4)$$

The H_{01} propagation mode is dominant, rendering n=0 and m=1.

$$L=\frac{\lambda_r}{2} \qquad (5)$$

$$\omega_r=\frac{4\pi}{\lambda_r\sqrt{\varepsilon\mu}}=\frac{4\pi}{\lambda_r\sqrt{\varepsilon_r}\sqrt{\varepsilon_0\mu_0}}=\frac{4\pi c}{\lambda_r\sqrt{\varepsilon_r}} \qquad (6)$$

$$f_r=\frac{2c}{\lambda_r\sqrt{\varepsilon_r}} \qquad (7)$$

The resonant frequencies of the slots for H wave propagation mode (obtained for $\varepsilon_r \cong 2.25$ and expressed in GHz) are shown in the following table.

Table 1. The resonant frequencies of the slots; Propagation mode H_{i0}, i = 1÷3.

i	L_1 [mm]	L_2 [mm]	$\square_{r1}$ [mm]	$\square_{r2}$ [mm]	f_{1n} [GHz]	f_{2n} [GHz]
1	51	25.4	162.56	81.28	1.84547	3.69094
1	44	22	140.8	70.4	2.13068	4.26136
2	51	25.4	81.28	40.64	3.69094	7.38189
2	44	22	70.4	35.2	4.26136	8,52272
3	51	25.4	54.187	27.09	5.53641	11.0728
3	44	22	46.933	23.47	6.39204	12.7840

2.4 Dimensioning of resonant surfaces having hexagonal shape. To calculate the resonance frequencies was used the calculation method of the resonant frequencies of disc resonators [4], [5] weighted by equivalent radius of the hexagonal surface (Fig. 4) for fundamental mode E_{110}.

Corresponding to this resonant mode, the fundamental frequency was calculated using the first solution of Bessel function J_0 - X_{01} = 2.402, resulting in resonance wavelengths:

$$\lambda_{rez}=\frac{2\pi r_{ef}}{X_{01}}\sqrt{\varepsilon_r} \qquad (8)$$

where r_{ef} is the circle radius with surface area equivalent to hexagon surface area having value 0.91r (r - hexagon edge).

The successive resonant wavelengths λ_{rez} have divided by two.

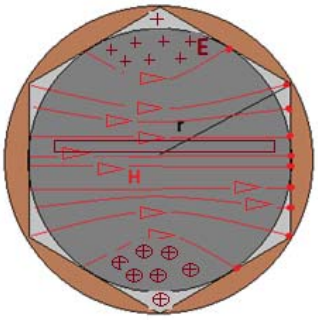

Fig. 4. Hexagonal resonator surface.

Fig. 5. The antenna radiant surface.

Figure 6 shows the resonators phasing and the feeder adaptation circuit.

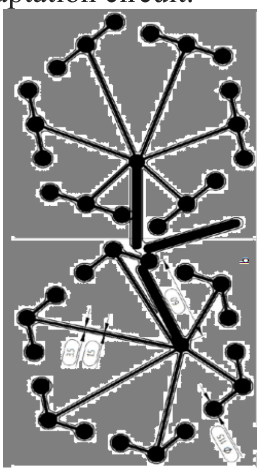

Fig. 6. Phasing and adaptation circuits.

3. EXPERIMENTAL RESULTS

The most representative experimental data results were obtained by spectral analysis (scalar) and vectorial analysis (with VNA) and are shown in Fig. 7 – 11 (experimental diagrams).

Fig. 7 shows the directivity diagrams for both type of polarization: horizontal and vertical.

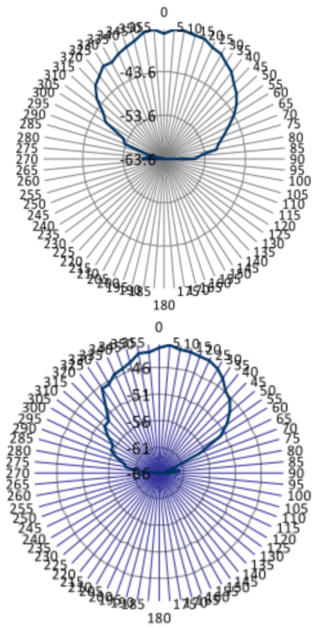

Fig. 7. Fractal antenna with hexagonal resonators: Directivity diagram for horizontal and vertical polarization.

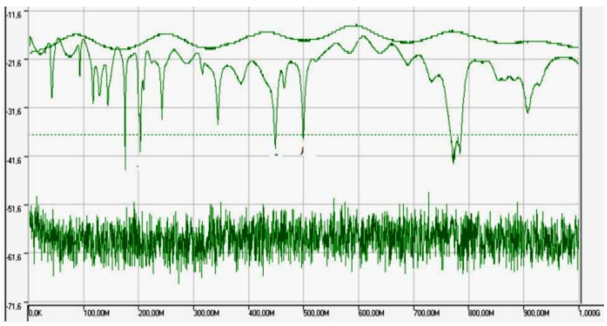

Fig. 8. Fractal antenna with hexagonal resonators: The reflection coefficient variation.

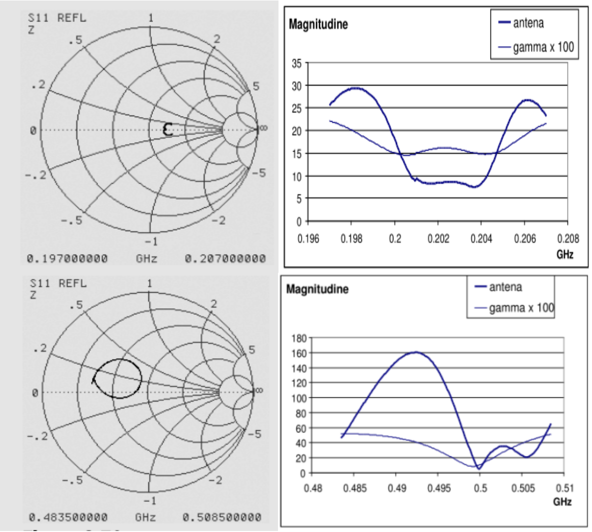

Fig. 9. Fractal antenna with hexagonal resonators – VNA analysis in the frequency band 0.19 - 0.51GHz.

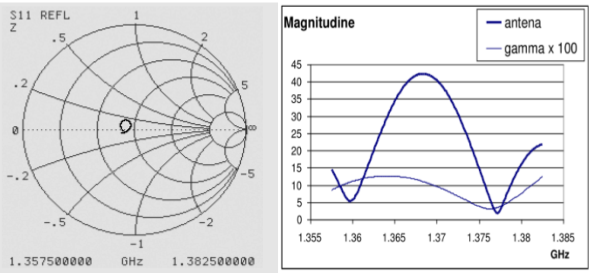

Fig. 10. Fractal antenna with hexagonal resonators – VNA analysis in the frequency band 1.35- 1.39 GHz.

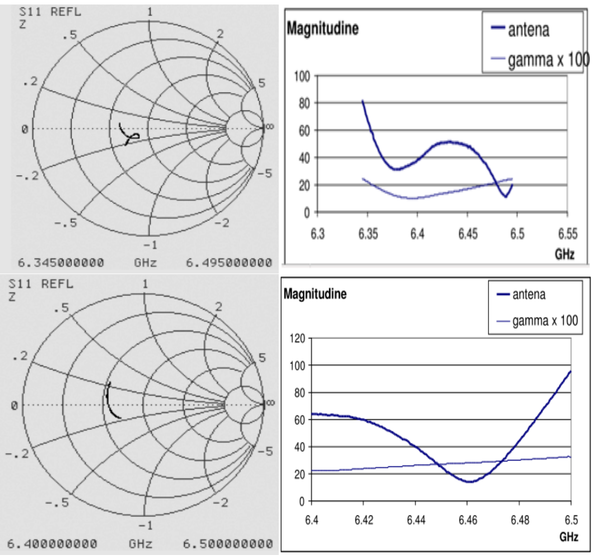

Fig. 11. Fractal antenna with hexagonal resonators – VNA analysis in the frequency band 6.34 - 6.5GHz.

4. CONCLUSIONS

This fractal antenna belonging to the class of fractal antennas (theoretically independent of frequency antennas) operate in 100MHz - 6GHz frequency band with a 3 - 9dB gain.

Through a narrower adjustment of the phasing lines between fractal radiating elements and the feeder adaptation, can be obtained a narrower frequency band with a gain of 8 - 10dB.

The antenna operates with small differences in circular polarization and vertical/ horizontal. Due assessment results, this model of antenna achieved at a smaller scale can be used in mobile phones or base stations respecting the dimensions determined in the paper.

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