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INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2014
Brasov, 22-24 May 2014

FRACTAL SECTOR ANTENNA WITH RESONATORS ARRANGED IN A SQUARE SHAPE

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Abstract: *This paper presents a model of stripline fractal antenna having resonant elements in the form of a square shape. The model is presented in two versions, one with compact resonators and second with frontier resonators, highlighting technical similarities and differences through electrical parameters. In the same time, the paper emphasizes the concordance between theoretical and experimental results.*

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

1. INTRODUCTION

Development of mobile telephony and portable phones miniaturization has imposed dimensions reduction of the radiant elements (emission-receiver antenna), keeping as much as possible their gain and efficiency at an optimum level. In the same time, it is necessary to ensure a wide frequency range, directivity and a large aperture. These requirements are best satisfied by fractal sector antennas with different geometric shapes of resonators. This paper presents two versions of a fractal antenna model with resonant elements arranged in a square shape, with three levels of demultiplication. In a radiant field resonators arranged in a square shape behaves simultaneously as a magnetic antenna (loop antenna) and closed dipole.

2. ANTENNA DESIGN

The two variations of the antenna model are shown in Figure 1 - frontier resonators, respectively Figure 2 - compact resonators.

The frontier resonators are pairs, having dimensions and ecart between them as specified in Table 1 (from the edge inwards).

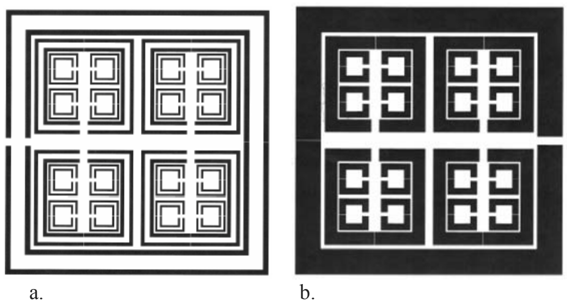

Fig. 1. Fractal sector antenna: a. with frontier resonators; b. with compact resonators

Table 1. Lengths of the frontier resonators and ecart between them

Length [cm]	Ecart [mm]
$L_{11} = 15$	10
$L_{12} = 13$	
$L_{21} = 5$	5
$L_{22} = 4$	
$L_{31} = 3$	5
$L_{31} = 2$	

Table 2. Lengths of the compact resonators and ecart between them

Length [cm]	Ecart [mm]
$L_1 = 14$	10
$L_2 = 4{,}5$	5
$L_3 = 2{,}5$	5

Compact resonator lengths were chosen as the average length of the frontier resonators to maintain the same central resonance frequency.

Figure 3 shows the resonators phasing and the feeder adaptation circuit.

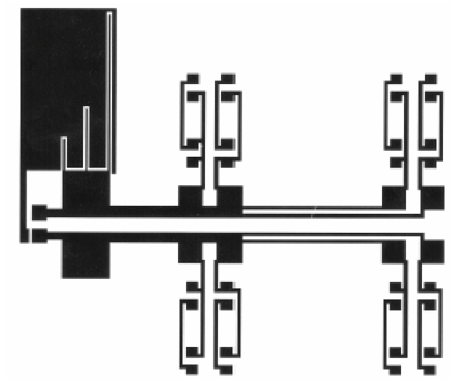

Fig. 3. Feeder adaptation circuit.

Fractal series of the radiating surface is in division with 4^n.

$$S = S_0 \sum_{n=0}^{2} \frac{1}{4^n} \tag{1}$$

where S_0 is the surface of the biggest contour.

A. Analytical calculation of the resonator for magnetic antenna regime (***, 2013)

$$\lambda = (4 + 10) \cdot 4 \cdot L \tag{2}$$

where L is edge length in meters.

$$h_e = \frac{2\pi NA \cos\theta}{\lambda} \tag{3}$$

where: h_e - effective height of antenna;
N – contours number;
A - surface area [m^2];
θ - the angle of incidence of the wave relative to antenna plane [°].

$$R_{rad} = Z_0 \frac{2}{8}\pi \left(\frac{h_e}{\lambda}\right)^2 \tag{4}$$

where Z_0 - impedance of free space.

$$U_{ef} = h_e E \tag{5}$$

where E - electric field intensity.

For stripline resonators, according to (2)

$\lambda = 16L$, and bandwidth is

$$\Delta B = (\pm 25\%) f_c \tag{6}$$

where f_c – central frequency.

According to (2), (3) $N=1$, $A=L^2$ and

$$h_e = \frac{2\pi A \cos\theta}{\lambda} = \frac{\pi L \cos\theta}{8} \tag{7}$$

In case of frontier resonators the lengths are given by

$$L_i = \frac{L_{i1} + L_{i2}}{2} \tag{8}$$

It is resulting in

$$h_{e1} = \frac{\pi \cos\theta}{8} \cdot 14 = \frac{7\pi}{4} \cos\theta \tag{9}$$

$$h_{e2} = 4, \frac{5\pi}{8} \cos\theta \tag{10}$$

$$h_{e3} = 2, \frac{5\pi}{8} \cos\theta \tag{11}$$

According to (4), radiation resistance is

$$R_{rad} = Z_0 \frac{2}{3} \pi^3 \frac{\cos^2\theta}{128^2} \tag{12}$$

Resonance frequencies of the resonators are:

$$f_{c1} = \frac{c}{\lambda_1} = \frac{3 \cdot 10^8}{16L_1} = 135MHz \quad (13)$$

$$f_{c2} = \frac{c}{\lambda_2} = \frac{3 \cdot 10^8}{16L_2} = 420MHz \quad (14)$$

$$f_{c3} = \frac{c}{\lambda_3} = \frac{3 \cdot 10^8}{16L_3} = 750MHz \quad (15)$$

Taking into consideration (8) bandwidth of frontier resonators is given by

$$\Delta B = (\pm 30\%) \cdot f_c \quad (16)$$

Calculation methodology presented is valid also for compact resonators with the observation that the bandwidth is different – eq. (6).

B. Analytical calculation of the resonator

for closed dipole (λ/2) regime

$$\lambda = 2 \cdot L \quad (17)$$

$$h_e = \frac{2}{\pi} h_d \quad (18)$$

where h_d – height of the dipole.

For $h_d = \lambda/2$,

$$h_e = \frac{\lambda}{\pi} \quad (19)$$

$$R_{rad} = Z_0 \frac{2}{3} \pi \frac{h_e}{\lambda} = Z_0 \frac{2}{3\pi} \quad (20)$$

Central resonant frequencies are:

$$f_{c1} = \frac{c}{\lambda_1} = \frac{3 \cdot 10^8}{0},3 = 1GHz \quad (21)$$

$$f_{c2} = \frac{c}{\lambda_2} = \frac{3 \cdot 10^8}{0},09 = 3,4GHz \quad (22)$$

$$f_{c3} = \frac{c}{\lambda_3} = \frac{3 \cdot 10^8}{0},05 = 6GHz \quad (23)$$

3. EXPERIMENTAL RESULTS

Experimental data obtained by spectral analysis (scalar) and vector analysis (with VNA) are shown in Fig. 4 – 8 (experimental diagrams).

Fig. 4 and 5 are shown the directivity diagrams.

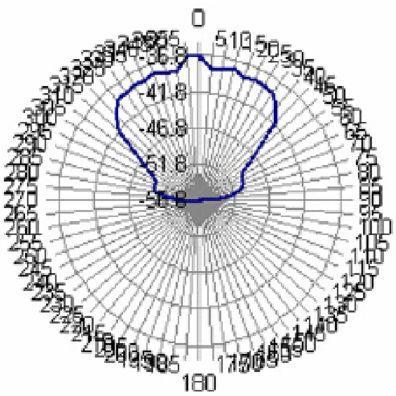

Fig. 4. Fractal sector antenna with compact resonators: Directivity diagram – E field.

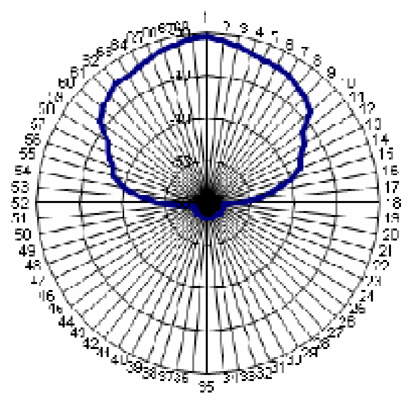

Fig. 5. Fractal sector antenna with frontier resonators: Directivity diagram – E field.

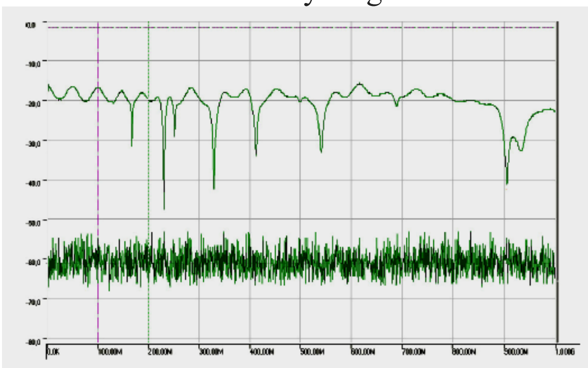

Fig. 6. Fractal sector antenna with frontier resonators: The reflection coefficient.

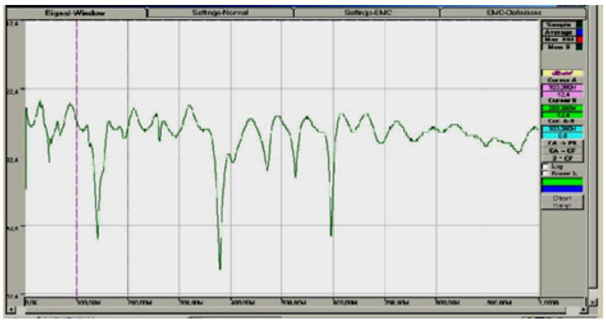

Fig. 7. Fractal sector antenna with compact resonators: The reflection coefficient.

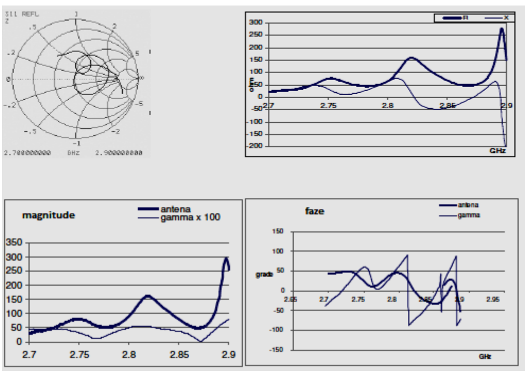

Fig. 8. Fractal sector antenna – VNA analysis in the frequency band 2.7-2.9 GHz.

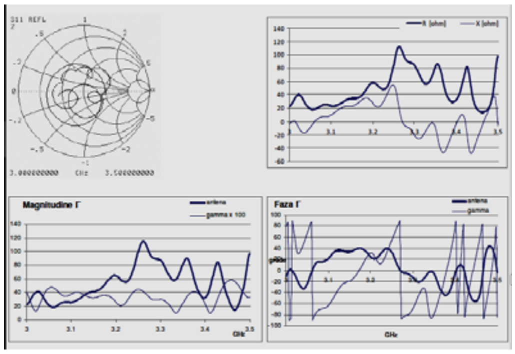

Fig. 9. Fractal sector antenna – VNA analysis in the frequency band 3-3.5 GHz.

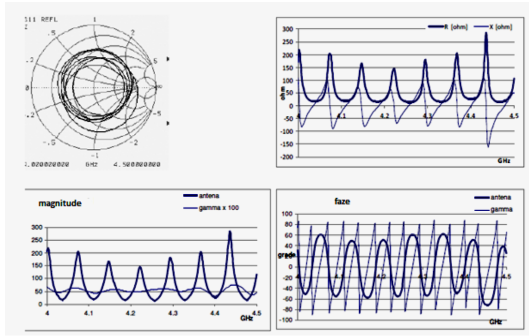

Fig. 10. Fractal sector antenna – VNA analysis in the frequency band 4-4.5 GHz.

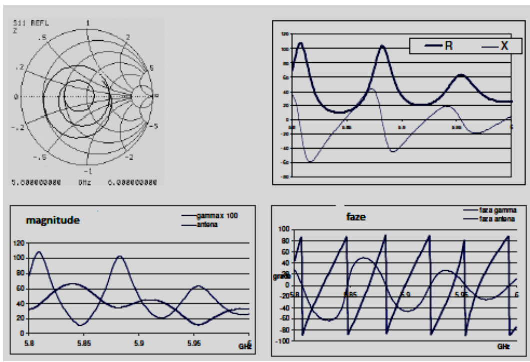

Fig. 11. Fractal sector antenna – VNA analysis in the frequency band 5.8-6 GHz.

4. CONCLUSIONS

Due to the dual behavior, both the magnetic resonator and closed dipole ($\lambda/2$), fractal sector antenna allows operation in a very wide frequency band with a gain around 10dB.

The small size and relatively simple technical realization, it is recommended for 4G and 5G mobile telephony.

Through a judicious choice of fractal dimensions, antenna can cover frequency bands with quasi-constant gain for the entire spectrum of mobile telephony.

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