FRACTAL SECTOR STRIPLINE ANTENNA WITH DISKS

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Abstract: *The paper presents a model of fractal antennae having as resonant elements stripline disks with resonant slots. The content highlights the analysis of resonance phenomenon and technical design features accompanied by experimental results. Covering a very wide frequency band, having small geometric dimensions and satisfactory gain, this antennae is recommended in mobile telephony, RFID and multiservice.*

Key words: *antenna, fractal, stripline, Bessel function*

1. INTRODUCTION

The need for miniaturization of communication devices, particularly mobile ones, led to the use of antennas as small as possible.

Along with the reduction in size, these antennas must ensure high bandwidth coverage, keeping as much as possible their gain and efficiency at an optimum level. Another requirement imposed in the realization of such an antenna is the low cost price.

Stripline fractal antenna disc sector described in this article meets those requirements.

Contents of the paper refer to analysis of the phenomenon of resonance, technical realization of the antenna and experimental results.

2. DYNAMICS OF RESONANT FREQUENCY

Take into consideration (as reference) the analyze of the electric field resonance in a discoid cavity with radius r (Best, 2003) (Morariu, 2009), particularly the expression of the resultant electric field E_T, and extrapolating to a finite and tidy string of radius r_i, it is deducted the global variation of the electric field for a fractal segment or fractal sector, as are briefly presented in the following.

$$E_T = E\left(1 - \left(\frac{\omega r}{2c}\right)^2 \frac{1}{(1!)^2} + \left(\frac{\omega r}{2c}\right)^4 \frac{1}{(2!)^2} - \left(\frac{\omega r}{2c}\right)^6 \frac{1}{(3!)^2} + \cdots\right)$$

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(1)

$$E_{T_i} = E\left(1 - \left(\frac{\omega r_i}{2c}\right)^2 \frac{1}{(1!)^2} + \left(\frac{\omega r_i}{2c}\right)^4 \frac{1}{(2!)^2} - \left(\frac{\omega r_i}{2c}\right)^6 \frac{1}{(3!)^2} + \cdots\right)$$

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(2)

By noting:

k - fractal multiplier coefficient;

j - multiplication fractal level;

r_0 - reference disc radius (the lowest disc radius),

it results:

$$r_i = r_0 k^i r_i = r_0 k^i \quad (3)$$

$$i = 0 - n i = 0 - n \quad (4)$$

$$\frac{x_i}{2} = \frac{wr_i}{2c} = \frac{wr_0}{2c} k^i \frac{x_i}{2} = \frac{wr_i}{2c} = \frac{wr_0}{2c} k^i \qquad (5)$$

Applying the electric field superposition property results:

$$E_T = \sum_{i=0}^{n} E_{T_i} = \sum_{i=0}^{n} E_i J_{0_i}$$

$$E_T = \sum_{i=0}^{n} E_{T_i} = \sum_{i=0}^{n} E_i J_{0_i} \qquad (6)$$

where:

$$J_{0_i} = J_0(x_i) J_{0_i} = J_0(x_i) \qquad (7)$$

and

$E_{T_i} E_{T_i}$ – the evolution of the border electric field on the disc level i;

J_0 - zero-order Bessel function.

Arranging in matrix form parameters in the above relationship is obtained:

$$J_0 = j_{00} + j_{01} + j_{02} + \cdots j_{0n} = \sum_{i=0}^{n} j_{0i}$$

$$J_0 = j_{00} + j_{01} + j_{02} + \cdots j_{0n} = \sum_{i=0}^{n} j_{0i} \qquad (8)$$

$$j_{0i} = \left(\frac{x}{2i}\right)^{2i} \frac{1}{(i!)^2} (-1)^i$$

$$j_{0i} = \left(\frac{x}{2i}\right)^{2i} \frac{1}{(i!)^2} (-1)^i \qquad (9)$$

$$K = [k_{ij}] K = [k_{ij}] \qquad (10)$$

$$k = k^{i2j} k = k^{i2j} \qquad (11)$$

$$E = E_{00} + E_{01} + E_{02} \ldots + E_{0p} = [E_{0j}]$$

$$E = E_{00} + E_{01} + E_{02} \ldots + E_{0p} = [E_{0j}] \qquad (12)$$

$$E_{0i} = E_{Ti} E_{0i} = E_{Ti} \qquad (13)$$

The matrix representation of the electric field global evolution on an arm of the antenna is:

$$E_T = [E_{0j}] \prod_{i=0}^{n} [j_{0i}] [k_{ij}]$$

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3. TECHNICAL REALIZATION OF THE ANTENNA

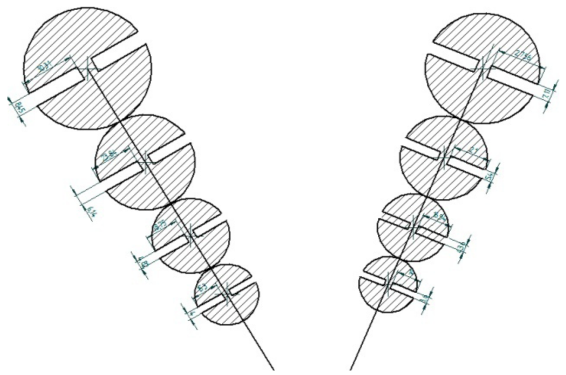

Fig. 1. Design scheme of the radiating surface

The discs have lateral parallel slots. The figure does not show total symmetry because both the corresponding circles on the two axes, as well as afferent slots have different sizes. By connecting the fractal elements creates a radiating surface network that works both independently and in combination, extending the frequency range of the antenna.

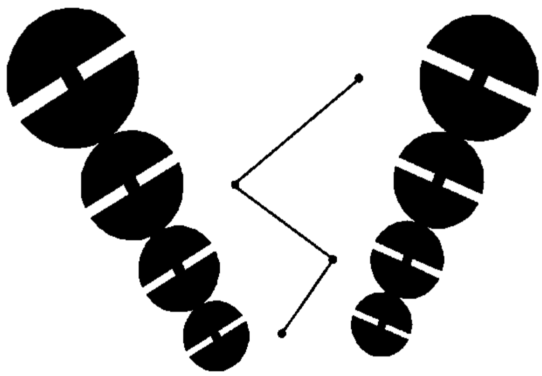

Fig. 2. Antenna radiating surface

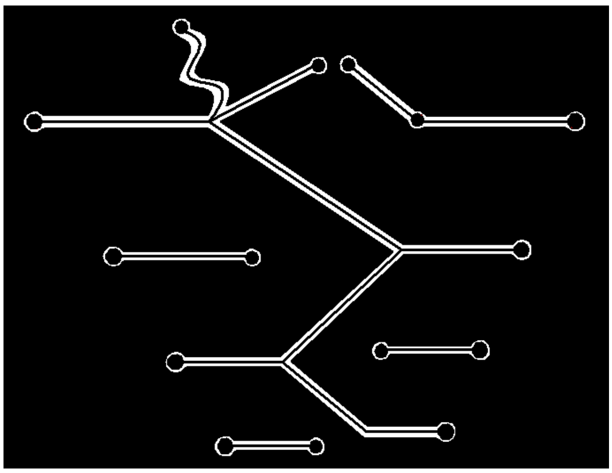

Fig. 3. The rear part of the antenna (connecting elements and feeder matching)

Determination of dimensions. Taking into account the parameters of the stripline support that will accommodate antenna network, the size of each element must be taken so as to ensure a minimum distance λ between each element located in the same direction. Also, due to the number of elements in the network, 8, their arrangement will be on two oblique arms, symmetrical ($\Phi = \pi / 8$) as will be seen later on. For a correct layout ensures framing of the frequencies of each dipole within 2GHz- 5GHz. Thus for each element is calculated wavelength, length of lateral slots and socket median length.

If the above mentioned range (3GHz) is divided to the 8 elements, we obtain the necessary step of the wavelength calculation for each dipole (375MHz). For the first dipole the start frequency is 2GHz.

$$\lambda = \frac{c}{f} \Rightarrow \lambda_1 = \frac{c}{f_1} = \frac{3\cdot10^8}{2\cdot10^9} = 0.15\text{m}$$

$$\lambda = \frac{c}{f} \Rightarrow \lambda_1 = \frac{c}{f_1} = \frac{3\cdot10^8}{2\cdot10^9} = 0.15\text{m} \qquad (15)$$

$$\frac{\lambda_1}{2} = 7.5\text{cm}\frac{\lambda_1}{2} = 7.5\text{cm} \qquad (16)$$

Dipoles are λ / 2, and the size of the socket and slot must be a division as small as the wavelength.

First dipole socket:

$$p_1 = \frac{\lambda_1}{16} = \frac{15}{16} = 0.9375cm$$

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Its slot will be calculated as a fraction of 1/12 of the wavelength, relative to shortening factor. Let s_1 slot size:

$$s_1 = \frac{\lambda_1}{12}\cdot\frac{1}{\sqrt{\varepsilon_r}} = \frac{15}{12}\cdot\frac{1}{1.48} = 0.8446cm$$

$$s_1 = \frac{\lambda_1}{12}\cdot\frac{1}{\sqrt{\varepsilon_r}} = \frac{15}{12}\cdot\frac{1}{1.48} = 0.8446cm \qquad (18)$$

Analogously will be calculated the dimensions for the other dipoles, based on the wavelength determined taking into consideration the previous dipole frequency and adding the necessary step.

The table 1 presented below, contain the design parameters of each dipole.

Table 1. The design parameters of the dipoles

Dipole	Frequency [GHz]	λ [cm]	λ/2 [cm]	Socket [cm]	Slot [cm]
1	2	15	7.5	0.9375	0.844594595
2	2.375	12.632	6.316	0.78947	0.711237553
3	2.75	10.909	5.4545	0.68162	0.614250614
4	3.125	9.6	4.8	0.6	0.540540541
5	3.5	8.571	4.2855	0.53571	0.482625483
6	3.875	7.742	3.871	0.48387	0.435919791
7	4.25	7.059	3.5295	0.44118	0.39745628
8	4.625	6.486	3.243	0.40541	0.365230095

Data on electrical measurements obtained from experiments are presented in sequential order as follows: directivity diagrams, characteristic impedance variation, E field border diagram, Smith charts obtained for diferent frequency domains (through vector analyzer - VNA).

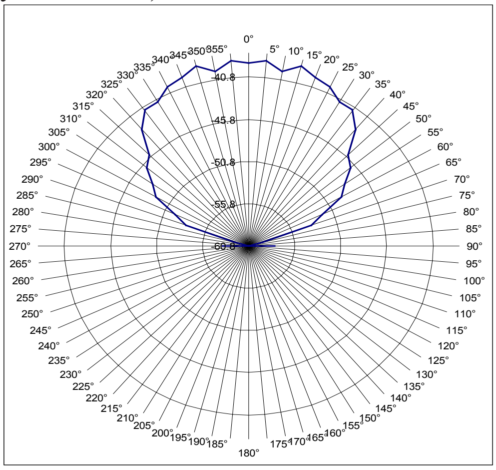

Fig. 4. Directivity diagram - horizontal polarization

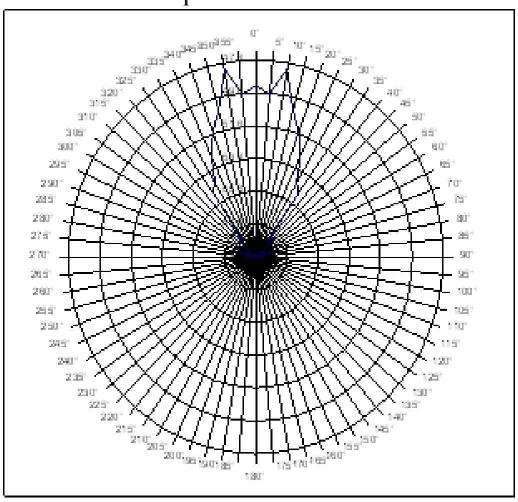

Fig. 5. Directivity diagram - vertical polarization

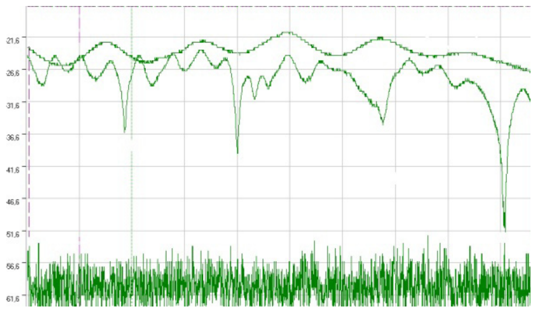

Fig. 6. Characteristic impedance variation

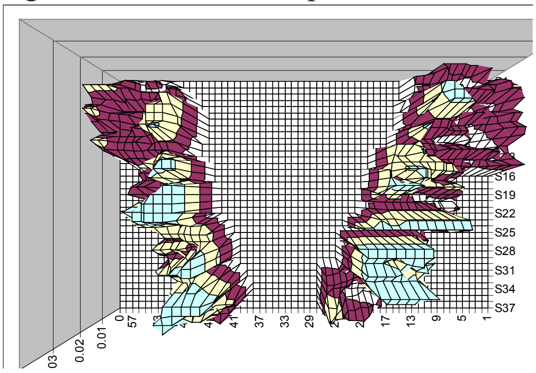

Fig. 7. E field border diagram (mapped)

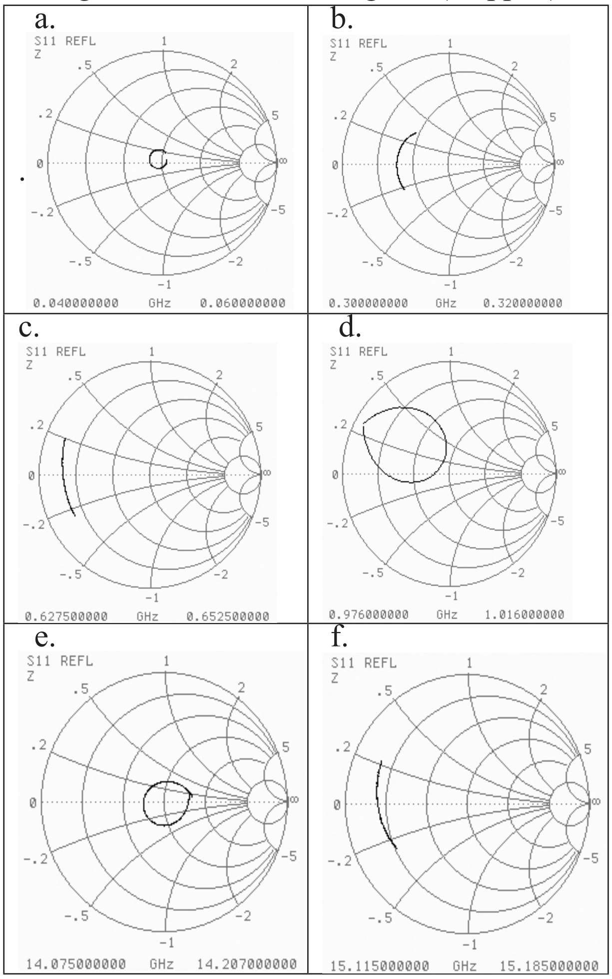

Fig. 8. Smith charts obtained for the frequency domains: a. 0.04-0.06GHz; b. 0.3-0.32GHz; c. 0.6275-0.6525GHz; d. 0.976-1.016GHz; e. 14.075-14.207; f.15.115-15.185

Notable frequency bands are between 50MHz and 100MHz, around the frequency of 150MHz, 310MHz, 465MHz, 600MHz, 1GHz, 13GHz, 14GHz and up to 16GHz.

Antenna gain shows values from 4.4dB to 5.9dB for transmission and from 4.4dB to 5,4dB for reception (outcomes from experiments).

CONCLUSIONS

Remarkable results below 1GHz recommended antenna for use in the 433MHz ISM band. Other applications could include RFID and multi-service applications.

The production cost of the antenna is a small one.

The modest gain in some portions of frequencies spectrum can be considered as a disadvantage of this type of antenna.

BIBLIOGRAPHY

1. Albers, D. J., Alexanderson, G. L. (2008). *Benoit Mandelbrot: In his own words*. Mathematical people: profiles and interviews. Wellesley.
2. Best, S. (2003). *A Comparison of the Resonant Properties of Small Space-Filling Fractal Antennas*. IEEE Antennas and Wireless Propagation Letters (1): 197–200.
3. Kumar, R., Malathi, P. (2010). *On the Design of CPW - Fed Ultra Wideband Triangular Wheel Shape Fractal Antenna*.
IJMOT, vol. 5 no. 2, p. 89-93
4. Morariu, Gh., Alexandru, M., Miron, M., Romanca, M., Machedon-Pisu, M., Dobrescu, A. (2009). *Experiment-supported study on the bipolar disk microstrip antenna*. EU Annals of DAAAM & Proceedings, Vienna, Austria.
5. *fractal_antenna.html* [online]. Available: http://www.m0wwa.co.uk/page/M0WWA [2014]