Modified Fractal Super J-pole Antenna

Boncho Bonev[1],Peter Petkov[2] and Nina Spassova[3]

Abstract – **In this paper a super J-pole antenna with two modified fractal Koch curve shaped elements is proposed. In order to increase the bandwidth and to provide proper phasing of the currents in the antenna elements, the length of some elements of the fractal has been changed. The antenna performances (radiation patterns, VSWR and gain) are simulated and optimized for GSM-1800, UMTS-2100 and Wi-Fi 2,4 GHz bands. Proposed Koch curve super J-pole antenna features relatively small size and high gain.**

Keywords – **Super J-pole, Fractal, Koch curve, Wideband, Multiband.**

I. INTRODUCTION

One of the biggest problems in wireless communications is the design of the antennas. They should work in wide frequency band while being small physically. The rule in such cases, as states in [1] is that the bandwidth of an antenna enclosed in a sphere of radius r can be improved only if the antenna utilizes efficiently, with its geometrical configuration, the available volume within the sphere. Several antenna types meet this requirement and fractal antennas are one of them [2-4]. They bear such name after the concept of fractals.

In our previous works [5,6] these concepts have been presented on other types of fractal antennas - research on fractal antennas performance, fractal antennas for some specific applications - Wi-Fi hotspots, digital TV reception, etc. In this paper are proposed and analyzed a super J-pole modified fractal antenna based on Koch curve. This approach represents a wideband and multiband performance, acceptable total gain and relatively small size. The main antenna parameters - radiation pattern, return loss and antenna gain were simulated.

II. THEORETICAL ANALYSIS

A. J-pole and Super J-pole Antenna

The J-pole antenna (Fig. 1) is an omnidirectional antenna, so called because of its similarity with the letter "J". It is formed by a vertical half-wavelength radiator end-fed by a quarter-wavelength matching stub. One of the advantages of this antenna comes from the fact, that the lower end of the matching stub can be used for direct grounding. The impedance matching of the J-pole antenna is achieved by moving the feed point between the radiator and the stub short, back and forth, until point where they resonate with the transmitter frequency is reached[7,8].

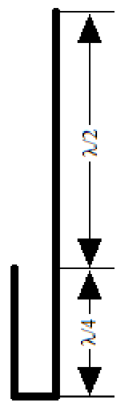

Fig. 1. J-pole antenna

When designing a J-pole antenna there are several particularities that should be taken into account [2]. First of all to achieve negligible radiation from the matching stub, the spacing between its two conductors must be commensurable with the wavelength. The current in the two parallel lines must be with phase difference of 180º and of course the open end of the stub must have infinite impedance while the connected one should be very high, but not infinite.

The Super J-pole antenna (Fig. 2) is a variation of the J-pole. It still has the basic construction of the J antenna, but also has an additional half-wavelength radiator which is connected to the first one with a quarter wave-length phasing stub. The phasing stub is used to unify the phases of the currents in the two radiators. This type of antenna provides more gain compared to the classical J-pole version.

The design of the Super J-pole antenna doesn't differ very much from the J-pole's. Same conditions, mentioned above, must be met to obtain the maximum performance from this antenna construction. Also the space between the two collinear radiators should be very small in order to derive the biggest profits of their collinear placement.

B. The Koch curve fractal

Geometrical figures which are formed by miniaturized identically scaled copies of themselves are called fractals. The operation used to obtain their form is iteration – endlessly repetition of certain steps. The more times we do these steps, the more accurate the fractal will be, but also it will become more complex [3].

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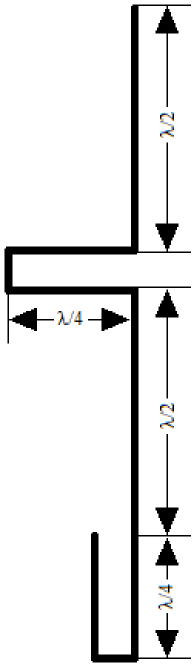

Fig. 2. Super J-pole antenna

One of the fractals used in antenna theory and design to miniaturize the antenna elements and help utilize the frequency band more efficiently is the Koch curve. To form it we start with a straight line, initiator, and split it into three equal parts. After that we build an equilateral triangle over the middle part and remove its foundation (the middle section of the line) - first iteration (n=1) in Fig.3. We do the same thing with the remaining two sides of the triangle and the two parts of the initiator, as shown below to obtain the 2-nd order Koch curve - n=2. We can continue these steps to obtain a fractal with the desired form, precision and complexity.

The total length of the Koch curve can be given with equation [4]

$$L = L_0 \left(\frac{4}{3} \right)^n , \qquad (1)$$

where L_0 is the 0-th order length, also called initiator, and n is the iteration number.

III. Design and Simulations

As initial step a super J-pole antenna is designed using a known calculation approach [2]. The two elements of the antenna is shaped as 1-st order Koch curve. Then the length of the elements in two triangle parts of each radiator of the antenna has been changed to provide the proper phasing of the currents in the antenna elements. The optimizations and simulations of antenna parameters (VSWR and antenna peak gain) are performed with 4nec2 moments-method software (www.qsl.net/4nec2) for the frequency band 1,71-2,49 GHz. The simulated and optimized antenna model is presented on

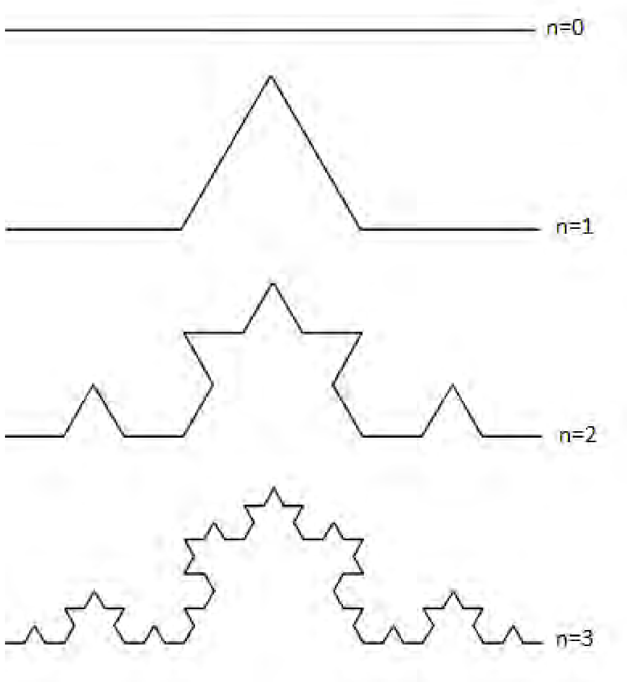

Fig. 3. Generation of the Koch curve

Fig. 4 and the elements length in mm are given in Table I. The antenna elements are round wires with radius 1.75mm.

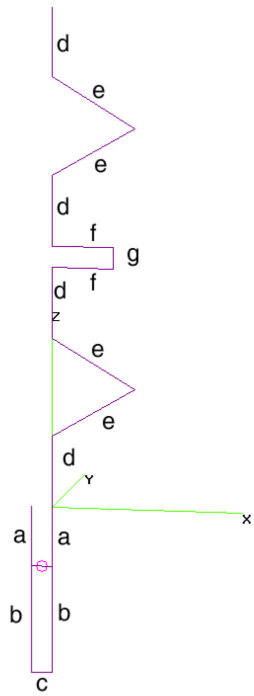

Fig.4. Proposed design of super J-pole fractal antenna

TABLE I
ANTENNA ELEMENTS LENGTH

a	b	c	d	e	f	g
30	54	11	36	50	32	11

In simulations up to 200 segments per half wave length are used which provides the necessary accuracy of the simulations.

The proposed antenna has two frequency bands of

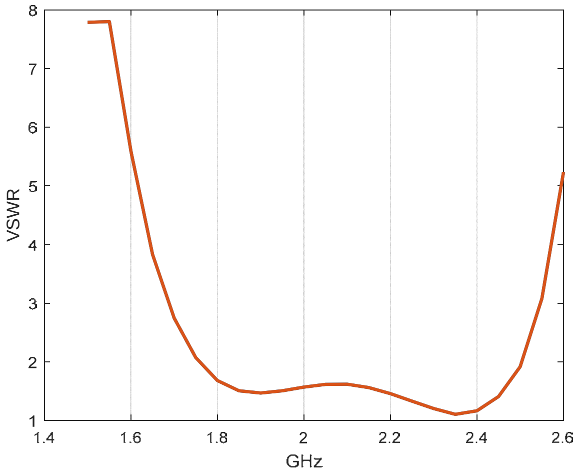

Fig. 5. Simulated VSWR for 1-st frequency band

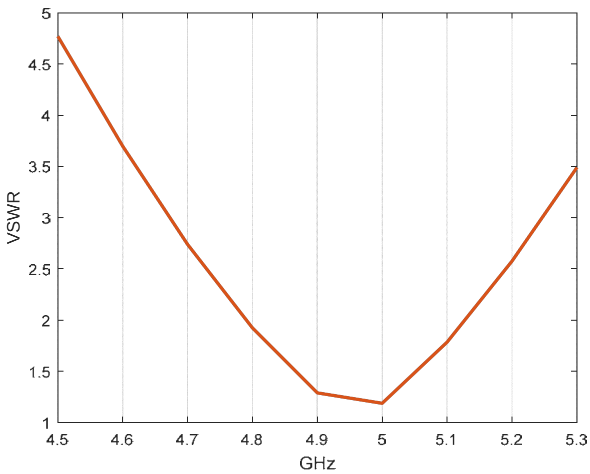

Fig. 6. Simulated VSWR for 2-nd frequency band

operation where the VSWR is lower than two (see Fig. 5 and Fig. 6). The first one (Fig. 5) is from 1.735 GHz to 2.52 GHz and the second one (Fig. 6) is from 4.785 GHz to 5.125 GHz. The bandwidth for the 1-st frequency band is 37,4 % and 6,9 % for the 2-nd one for the proposed fractal antenna while the classical antennas (non fractal) in most cases has not usable 2-nd frequency band of operation.

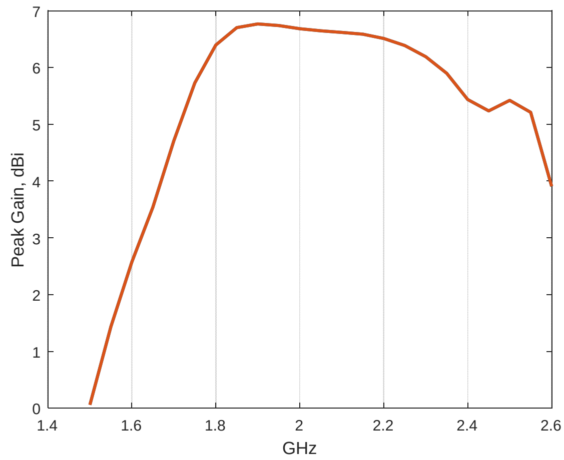

Fig. 7. Simulated antenna peak gain for 1-st frequency band

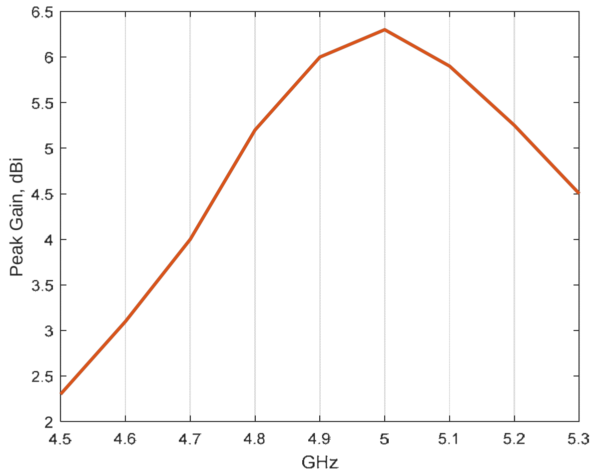

Fig. 8. Simulated antenna peak gain for 2-nd frequency band

The peak antenna gain for both bands of operation is displayed on Fig. 7 and Fig. 8. It is noticeable that the gain easily exceeds 5.2dBi, which is almost the maximum achievable with a single wire antenna. The maximal gain for first operation band is 6.8dBi and for the 2-nd one is 6.3dBi. It is obvious that the peak gain stays relatively constant.

In other hand the antenna shows directional properties (Fig.9 and Fig.10), because of the specific current distribution, especially in the upper band.

It has almost omnidirectional horizontal radiation pattern for the lower band of operation and directional vertical pattern. In the vertical plane, the antenna acts as a linear antenna array formed by several dipoles. The phasing section and fractal elements length modification provides a proper phase shift in a large frequency band, therefore the vertical pattern doesn't vary a lot with the frequency.

For the upper frequency band the antenna construction acts also as linear array, however the identical phase distribution of the currents is provided by more not tightly controlled manner (i.e not optimized).

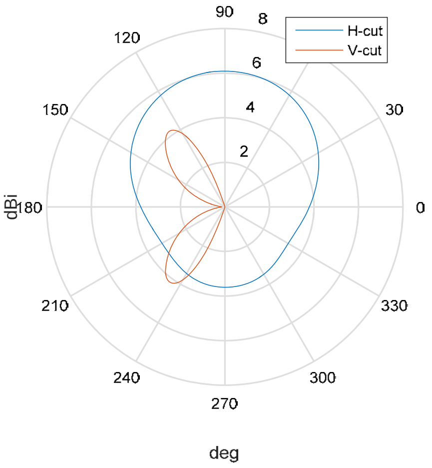

Fig. 9. Simulated radiation patterns for 2GHz.
(Z-axis of the antenna is aligned with 180-0 deg line)

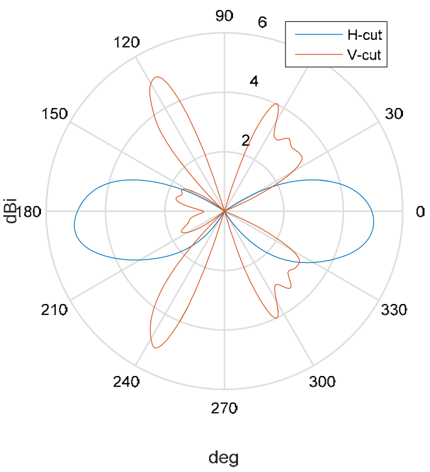

Fig. 10. Simulated radiation patterns for 5 GHz.
(Z-axis of the antenna is aligned with 180-0 deg line)

IV. Conclusion

A fractal super J-pole antenna with radiation elements shaped as Koch curve is introduced in this paper. Fractal shape is used in order to reduce antenna size and to achieve the multiband performance. For increasing the main operation frequency band fractal elements with different length is used. In this case the 37.4 % frequency band is achieved. The second advantage of the proposed fractal antenna is the dual-band performance.

With additional frequency tuning the proposed antenna can be used, among many others, for cellular repeaters - GSM 1800, UMTS 2100, Wi-Fi hotspots, etc.

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