Minkowski Fractal Yagi Antenna

Boncho Bonev[1], Zornitsa Radkova[2], Luboslava Dimcheva[3] and Peter Petkov[4]

Abstract –**In this paper Yagi antenna with elements shaped as modified Minkowski first order curve is presented. The antenna is designed and optimized for 1800 MHz frequency band. Usage of modified fractal gives possibilities for achievement of wider bandwidth and almost the same gain than in case of classical Yagi antenna with small antenna size. The return losses (SWR), antenna gain, front-to-back ratio and radiation pattern are simulated and discussed.**

Keywords – **Fractal Antenna, GSM 1800, LTE, Minkowski curve, Yagi antenna.**

I. Introduction

The interest of researchers in fractal antennas experienced significant growth in the resent years [1-4], because these antennas allow achievement of multiband and wideband performance and relatively small size. That matches with the needs of modern communications.

Yagi arrays can be used to achieve high gain with a relatively simple antenna structure [1]. Despite these incontestable advantages, these antennas have limited frequency bandwidth. Usage of fractal antenna elements in Yagi antennas could lead to wideband and multiband performance. In other hand the analysis and optimization of fractal antennas are very complicated [2], because after every adjustment of the length or width of one of the elements or the distances between elements the optimization has to start almost from the beginning.

In our previous works [5-7] have been presented our studies on fractal antennas - studies on different types of fractal antennas and antennas designed with fractal modifications. Fractal modification allows achievement of wideband performance [7]. Despite the Koch curve is most used in wired antenna design in this paper are proposed and analyzed a three element fractal Yagi antenna based on Minkowski curve. This approach represents a wideband and multiband performance and relatively small size. The main antenna parameters - radiation pattern, return loss, antenna gain and front-to-back (F/B) ratio were simulated in comparison with these of conventional Yagi antenna optimized for the same frequency band.

[1]Boncho Bonev is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria, E-mail: bbonev@tu-sofia.bg.

[2]Zornitsa Radkova is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria. E-mail: zornitsaradkova@abv.bg

[3]Luboslava Dimcheva is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria. E-mail: lddimcheva@gmail.com

[4]Peter Petkov is with the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria. E-mail: pjpetkov@tu-sofia.bg

II. Minkowski Curve

The antenna based on the Koch curves is very close in its properties to the antenna which is formed from Minkowski curve. As is shown in Fig.1 the shape of the Minkowski curve is formed by taking the initiator (a) and the generator structure (b) which is the first iteration of the recursive process.

In contrast to the Koch curve where triangles are used, the Minkowski curve uses squares (rectangles in some modifications) for its geometry. [8]

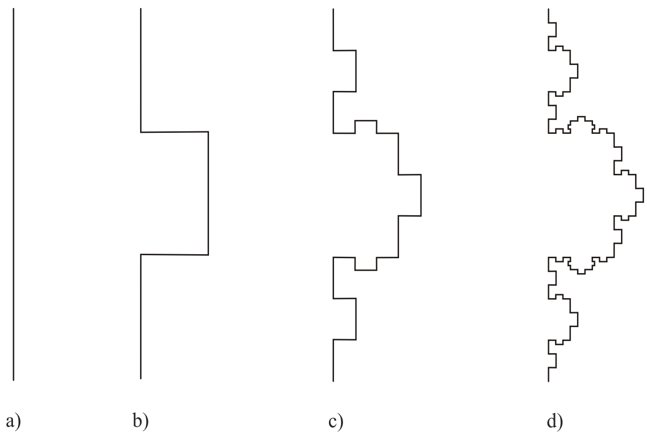

Fig. 1. Minkowski curve: a) initiator; b) first iteration; c) second iteration d) third iteration

The first iteration increases antenna gain but the next iterations do not influence the gain, they only broaden the frequency bandwidth and the antenna itself becomes more compact.

As is the case with the Koch curve, only the first 5 or 6 iterations are effective. Increasing the iterations leads to reducing the diameter of the conductors which in its own way increases the resistance, i.e. that results in gain loss. [9]

There is a modification of Minkowski fractal which is based on rectangular form of the curve rather than square. This modification is called Fractal Rectangular Curve – FRC and it is shown on Fig. 2. The length of the rectangle is $L/3$ and height is $L.r/3$, where L denotes length of original antenna and r denotes ratio coefficient. [8, 10]

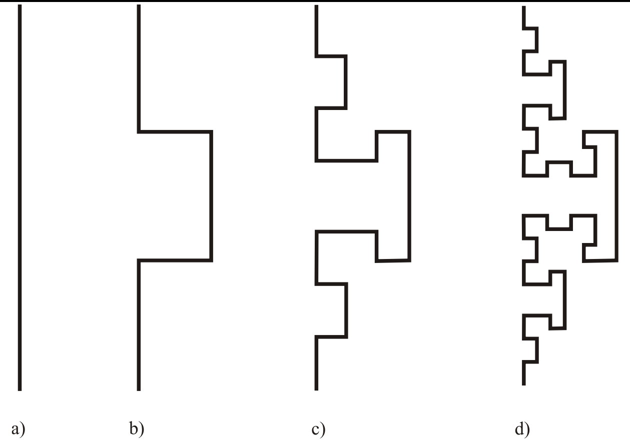

Fig. 2. Fractal Rectangular Curve: a) initiator; b) first iteration; c) second iteration d) third iteration

III. The Minkowski Fractal Antenna Design

The proposed Yagi antenna (Fig. 3) is designed with a plane structure in order to save space and easiness of manufacturing. It is optimized for GSM 1800 MHz band which is also widely used in 4G technology. The physical dimensions of the antenna are given in Table 1, where the small letters from *a* to *d* designate the fractal segments, without digit for dipole element, with 0 for director and with 1 for reflector, the capital letters *D*0 and *D*1 designate the distance between driving element and reflector and driving element and director (Fig. 3). Wire diameter is 1.5 mm.

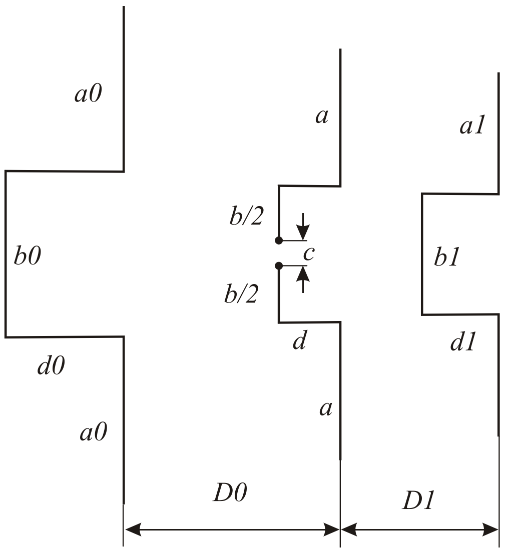

Fig. 3. Proposed antenna design

Table 1. Antenna dimensions

Design parameters, mm					
a	***b***	***c***	***d***	***a0***	***b0***
23.35	22.58	2	7.3	25.92	20.24
d0	***a1***	***b1***	***d1***	***D0***	***D1***
11.32	20.16	17.74	10.84	33.22	22

The first order of Minkowski fractal is used, since as was already written higher orders do not improve the antenna gain, but lead to decrease in the usable bandwidth. The new in the design are the each of three antenna elements is shaped as first iteration of Minkowski curve and feeding is in the middle of the central element of the driving element. Also each part of the fractal curve is with different length which allows better antenna performance. For optimization and simulation of proposed antenna is used 4nec2 software [11] which is based on Moment Method.

Return losses of the Modified Koch Fractal Yagi Antenna are displayed on Fig 4. It shows a distinctive minimum (i .e. the structure is tuned to) at 1818 MHz with a bandwidth of 12,2% (217 MHz) in compare with 11,1 % for conventional Yagi antenna. Proposed antenna has also second frequency band with return losses lower than -10 dB – from 5140 to 5230 MHz but it is not in interest for this design.

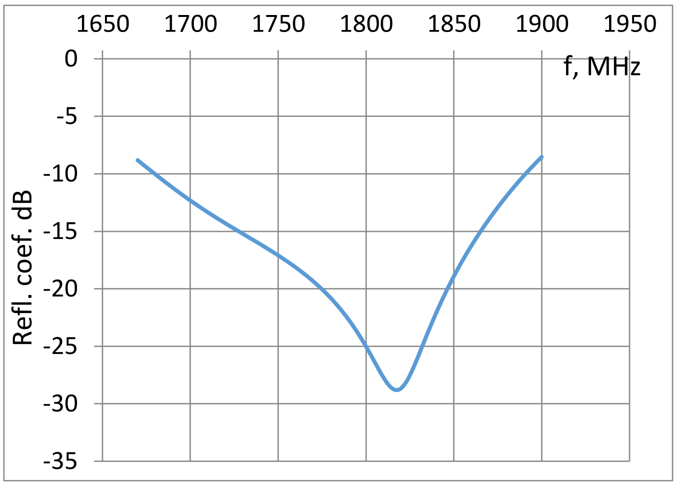

Fig. 4. Return losses

Antenna gain and F/B ratio for simulated model are given in Fig. 5 and Fig. 6 respectively. The antenna gain is higher than 6.48 dBi for the whole operating band which is on par with classical Yagi antenna with straight elements radiating in free space. The F/B ratio for the frequency band from 1710 to 1880 MHz (GSM 1800) is higher than 12.97 dB.

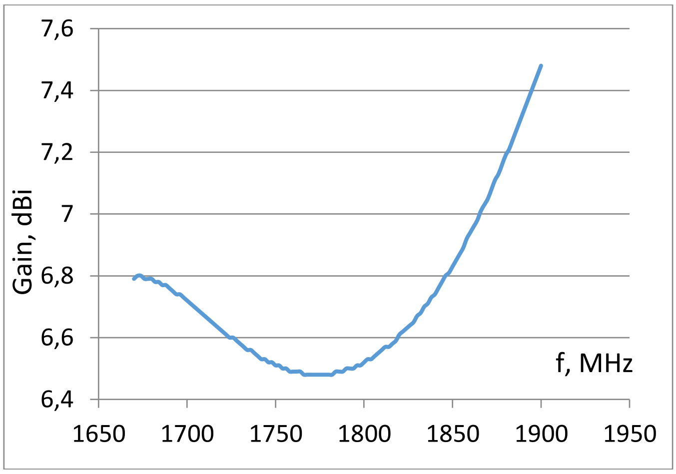

Fig. 5. Antenna Gain

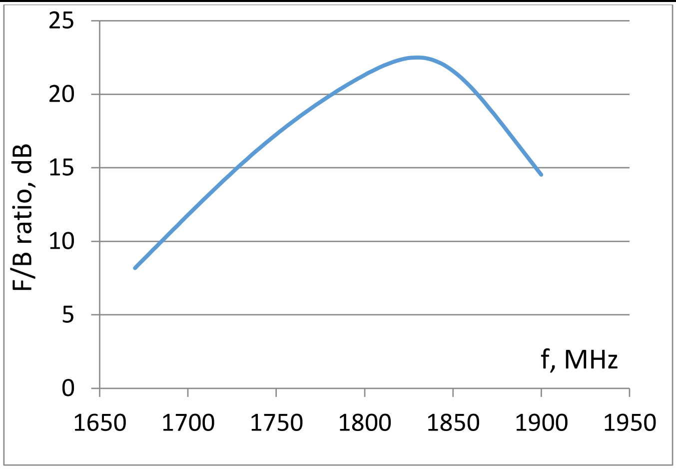

Fig. 6. Front-to-back ratio

The radiation patterns in H and V plane (antenna elements are oriented horizontaly) for frequencies 1710 MHz, 1800 MHz and 1880 MHz are shown on Fig.7, Fig. 8 and Fig. 9 respectively. For these frequencies antenna has a pattern similar to a classical Yagi antenna with gain of 6,68 dBi, 6,52 dBi and 7,19 dBi for three frequencies (6,9 dBi for conventional one).

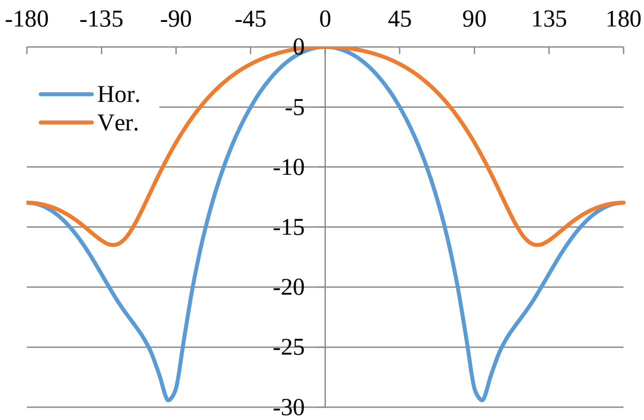

Fig. 7. Radiation pattern for 1710 MHz

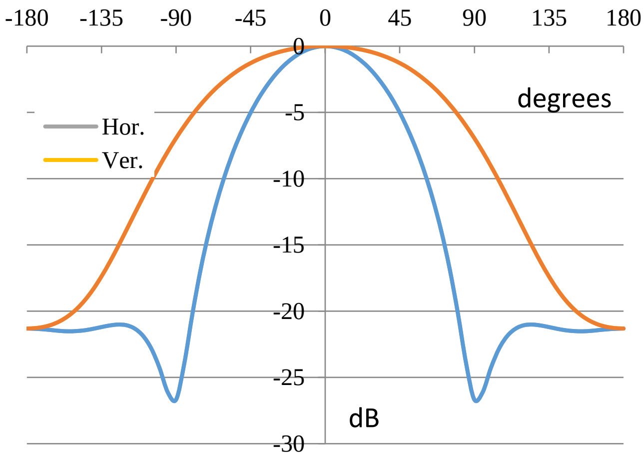

Fig. 8. Radiation pattern for 1800 MHz

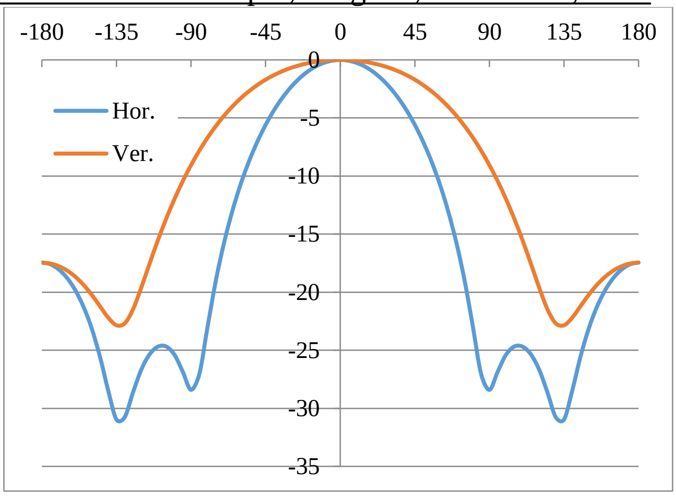

Fig. 9. Radiation pattern for 1880 MHz

The beamwidth at half power in horizontal plane is around ±35° and in vertical plane is around ±60° for these three frequencies. Front-to-Back ratio are 12.97 dB, 21.31 dB and 17,63 dB respectively.

IV. CONCLUSION

A modified fractal Yagi antenna with elements shaped as Minkowski fractal curve has been developed and examined in this study. It shows typical Yagi antenna and fractal antenna features with wideband performance enhanced by new element in the design – different fractal parts length. Modified Fractal Antenna has very good electrical parameters and compact size, which makes it also a candidate for practical applications. It can be used for point-to-point and point-to-multipoint applications as well (GSM 1800, LTE). The proposed antenna will be used as base for future development and design of antennas with wider bandwidth performance by using of additional fractal modifications.

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