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Design and Analysis of Miniaturized Log Periodic Antenna with Minkowski Fractal Geomtry

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Abstract: The proposed paper shows the design and analysis of printed Log-Periodic miniaturized Minkowski dipole antenna. The Minkowski curve is introduced in the linear dipoles enhancing the wider band in desired range of frequencies. Minkowski fractal is applied on 8 pairs of alternate dipoles which are electrically connected with lumped feed. The simulated results are compared with the previously published work and significant length reduction of 44.56 % and bandwidth of 90% is observed. The proposed antenna finds its application in GSM 1800, GSM 1900, Bluetooth, IEEE 802.11 b/g/n, IEEE 802.11 a/g/h, WiMax, 4G LTE and broadband communication.

Keywords: Minkowski fractal, log periodic dipole antenna, miniaturized antenna

I. INTRODUCTION

Log-Periodic Dipole Antennas (LPDA) mostly provide wide band consisting wide frequency range. These antennas fill the gap of multiple frequency ranges provided by a single antenna. Log-periodic dipole array are constructed with dipoles applied in alternate manner, connected electrically, on either faces of substrate [1]. As log periodic dipole antennas are highly directive, they are used for broadband microwaves receiver with wider range. After PCB applications, printed antennas are in concern. For the desired application of antenna size and weight is restricted, antenna must be miniaturized [3].

The self filling property of Minkowski fractals gives reduction in physical length of the dipole elements and in turn gives better S_{11} parameters, dimensions get reduced enhancing wide band. Miniaturization is applied with Minkowski fractal to the simple linear dipole. Size and weight is reduced keeping same results [1]. In [1] the proposed Log-periodic Koch dipole array (LPKDA) works in range 2-3GHz. Koch fractal is applied in the original microstrip dipole array. The proposed Microstrip Log-Periodic Dipole Antenna (MLPDA) array works in range 2.2-6.4 GHz. MLPDA used coaxial as a feeding element to the antenna. It has made simple straight dipoles without fractals. Log–periodic antenna array gives basics and fundamentals of design of proposed geometry [4][5].

In this paper, mainly Minkowski fractal is applied to the dipole and contributed for the betterment of bandwidth that is 1.6-5.5 GHz and VSWR less than 2. The proposed antenna is simulated using HFSS13.0.

II. ANTENNA DESIGN

In the proposed printed Log-Periodic Minkowski Antenna, fundamental methods are used to design the antenna [6]. To design the log-periodic dipole array, spacing factor (σ) and scaling factor (τ) are prerequisite. Spacing factor is the distance between the two dipoles and space between the dipoles increases with this factor. Scaling factor increases the length after each successive dipole length. The equation to calculate these parameters are given in [2] [3].

$$\tau = (Li-1)/Li = (Si-1)/Si = (Wi-1)/Wi \quad \ldots (1)$$

$$\sigma = Si/2Li \quad \ldots (2)$$

Where,
W_i is the width of the half of the dipole,
L_i is the length of the half of the dipole and
S_i is the spacing between the two dipoles.
i = 1, 2, 3……., 8.

The dipoles are constructed on both the faces of substrate in alternative manner which are connected electrically from the side of smallest dipole. The detailed method is given in [6].

The proposed Log-Periodic Minkowski dipole antenna has dimensions 50 X 125 X 1.5 (mm) as shown in fig.(1)(a) . The FR4 epoxy material is used as substrate with relative permittivity 4.4, loss tangent 0.002 and thickness 1.5 mm and lumped type of feed. The dimensions of the proposed antenna are given in the following table 1.

TABLE 1. DIMENSIONS OF PROPOSED ANTENNA (MM)

i	W_i	L_i	S_i	M_i
1	2.68	20.8	3	4.7
2	2.98	25.84	12.71	5.96
3	3.24	32.44	13.79	7.61
4	3.53	35.26	14.53	8.315
5	3.83	38.32	15.56	9.08
6	4.17	41.66	16.68	9.915
7	4.53	45.28	17.89	10.82
8	4.92	49.22	19.22	11.80

Minkowski fractal is applied by dividing single line that is zeroth iterator, in four sections and then making Minkowski curve. Every Minkowski dipole is designed in a way such that it is non-uniform along the width in order to achieve the improved bandwidth.

III. RESULT

The proposed printed log periodic minkowski dipole antenna works on the frequency range between 1.6-5.5 GHz as shown in fig.2(a),(b) and the radiation pattern at resonant frequency 4.3 GHz in yz and xz plane are shown in fig.3.(a),(b) .

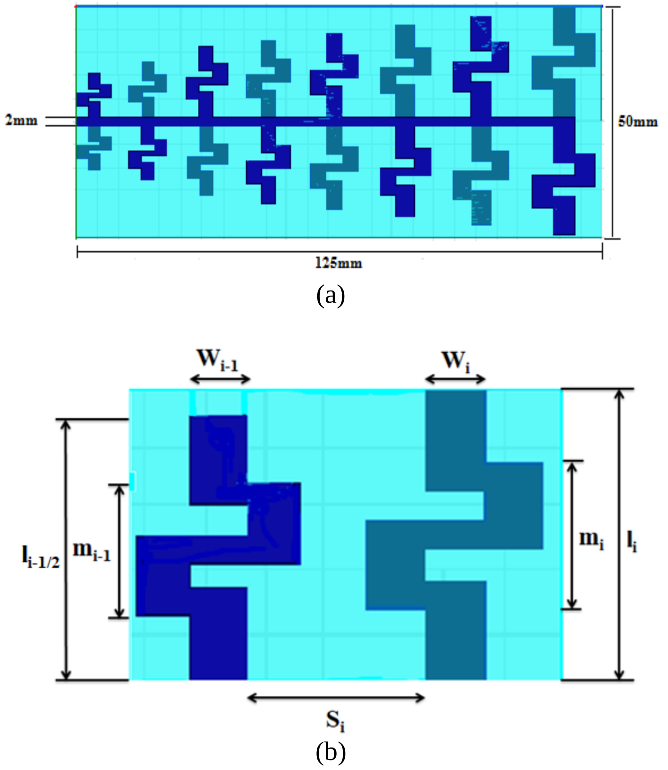

Figure.1. (a) Dimensions of proposed antenna. (b) Dimensions of Minkowski fractal.

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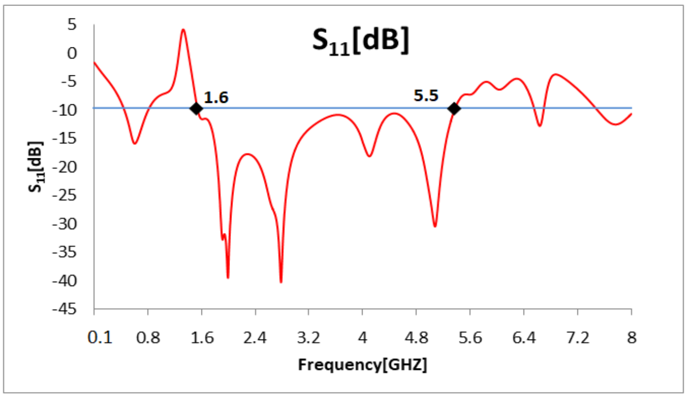
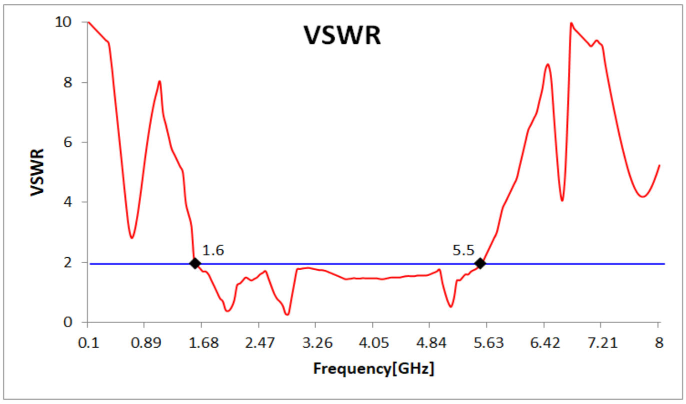
TABLE 2. COMPARISION OF PROPOSED AND PUBLISHED ANTENNAS

S.No.	parameters	Simple dipole [1]	Koch [2]	Minkowski (proposed antenna)
1	Freq. range	2-5.5 GHz	2-5.8 GHz	1.6-5.5 GHz
2	S_{11}[dB]	81.39%	88.3%	90%
3	Fractal used	No fractal	Koch	Minkowski
4	Total length	28.4	30.3	75.01
5	Vertical length	28.4	25.6	41.66
6	Length reduction	0	9.86%	44.56%

Miniaturization helps in physical size reduction and on the same time enhancing the percentage bandwidth of S_{11}[dB] and VSWR less than 2, gradually as shown in Table2. In the previously published simple log-periodic dipole antenna, frequency range is 2-5.5 GHz [2]. When Koch fractal is applied over the simple dipoles, its frequency range becomes 2-5.8 GHz [3].There is a slight increase in the percentage bandwidth. The maximum percentage bandwidth among the previous both antennas, is found when Minkowski fractal is applied over simple dipoles. The percentage bandwidth is found to be 90%. The proposed antenna also has multiple bands of frequencies which find its applications in broadband communication. The proposed antenna results are shown below in terms of S_{11}[dB] and VSWR :



(a)



(b)

Figure.2.(a) Simulated S11[dB] plot,(b) Simulated VSWR for proposed antenna.

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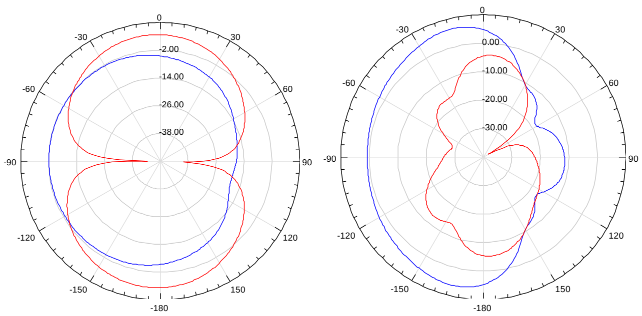
Cross-polarization

Co-polarization



(a) (b)

Figure.3. Radiation patterns at Freq.=4.3GHz (a) yz plane (b) xz plane.

IV. CONCLUSION

The proposed antenna introduces a printed log periodic Minkowski dipole antenna .The first iteration of Minkowski fractal is applied over the simple dipoles to design the proposed antenna. The antenna works over a frequency range of 1.6-5.5 GHz. The comparative analysis of simulated results for the proposed design is done with the previously published papers. The performance is improved by applying the Minkowski fractal with increase in S_{11}[dB] bandwidth of 90% and VSWR bandwidth of 90.94%. A significant length reduction of 44.56 % could be observed as compared to the previous published work.

The application of Koch dipole and Minkowski dipole shows that when fractals are applied to the simple dipole geometry of antenna miniaturization occurs reducing the physical length of the dipole keeping the electrical length intact. This in turn enhances bandwidth of S_{11}[dB] and antenna resonates on multiple frequencies as shown in fig.2(a). The designed antenna finds applications in GSM 1800, GSM 1900, Bluetooth, IEEE 802.11 b/g/n, IEEE 802.11 a/g/h, WiMax, 4G LTE and broadband communication.

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NOMENCLATURE OF SYMBOLS USED

Symbol	Nomenclature
τ	Scaling factor
σ	Spacing factor
W_i	Width of the half of the dipole
L_i	Length of the half of the dipole
S_i	Spacing between the two dipoles
M_i	Vertical length of minkowski fractal
i	No. of dipoles