A MULTIBAND MIMO ANTENNA WITH REDUCED ECC FOR WLAN/WiMAX APLICATIONS

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Abstract : This paper present a novel multi-band t antenna designed on the theory of fractal geometry. The antenna is fabricated on a FR4 substrate. The performance of the proposed antenna design is investigated and the results are compared with the simulated results. The proposed multiband MIMO antenna performance parameters viz. resonant bands, return loss, bandwidth and gain are reported and discussed. The return loss is less than -10dB & VSWR of less than 2 for six resonant bands in the vicinity of 1.15 GHz, 2.0 GHz, 3.17 GHz, 3.6 GHz, 4.17 GHz and 5.91 GHz. The suitability of proposed antenna to be used in MIMO systems had been checked by calculating Envelop Correlation Coefficient (ρ) ECC, which should be less than 0.7, we have achieved much less then this i.e. 0.00123.The results exhibited makes it extremely useful for the future generation of wireless broadband communication systems based on MIMO Systems.

***Index Terms* – MIMO, Fractal Antenna, Envelop Correlation Coefficient ECC, WiMAX.**

I. INTRODUCTION

In present scenario it is very much necessary to address the problem of traffic load in context of wireless communication. MIMO antenna increases the coverage and capacity of the wireless communication. And fractal antenna increases number of resonant bands for low profile patch antenna.

'Fractal' term was first coined by Benoit Mandelbrot to classify the structure whose dimensions were not whole numbers. In Euclidian shapes, If linear dimension of the line segment is doubled then the length of the line also doubled. In two dimensions, if the linear dimensions of a rectangle for example is doubled then the characteristic size, the area, increases by a factor of 4 and so on. This relationship between dimension D, linear scaling L and the resulting increase in size S can be generalized and written as

$$S = L\,D \qquad (1)$$

If we scale a two dimensional object for example then the area increases by the square of the scaling. Rearranging the above expression we get

$$D = \frac{Log\ S}{Log(\mathrm{L})} \qquad (2)$$

This relationship holds for all Euclidean shapes. But in natural world, there are objects which appear to be curves but cannot be described with integer number. There are shapes that lie in a plane i.e. two dimensional (D=2 in the expression), but if they are linearly scaled by a factor L, the area does not increase by L squared but by some non integer amount. These geometries are called fractals.

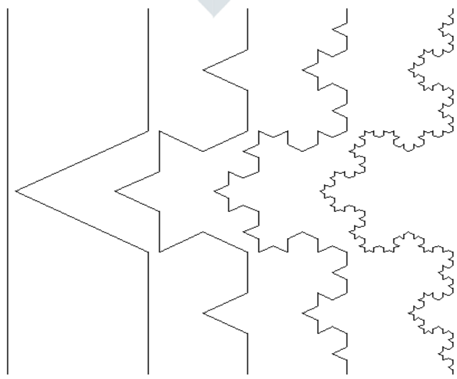

Figure 1: Geometry of Koch Curve.[5]

The Simplest example of antenna using geometry is given by the Von Koch, researcher is shown in Figure 1. The the first five iterations in the construction of the Koch curve are shown. Fractal dimension contains information about the self-similarity and the space-filling properties. The Fractal similarity Dimension (FD) is defined as [5]:

$$FD = \frac{Log\ N}{Log(1/\varepsilon)} = \frac{Log(5)}{Log(3)} = 1.46 \qquad (3)$$

Where N is the total number of distinct copies, and $(1/\varepsilon)$ is the reduction factor value, which gives the length of the new side. [5]

II. PROPOSED ANTENNA STRUCTURE

The conventional dipole design technique is adopted to design the proposed Koch loop antenna for a frequency of 2 GHz. A dipole antenna length must be half of wavelength according to basic antenna theory, hence first we have designed a fractal dipole antenna of half wavelength. Four such dipoles antennas are arranged to form a loop by which physical length is increased. For a 2 GHz frequency, wavelength is 150 mm. Dipole antenna length must be half of wavelength. The four dipoles are then arranged in the form of loop.

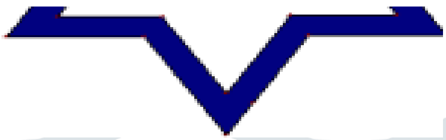

Figure 2: Koch Dipole designed after 2nd iteration.

A Koch curve is developed and designed by dividing a line into three equal parts and replacing the middle part with a bent section of wire. Design of Koch dipole structure after 2nd iteration is as shown in Figure 2; length of this structure is 25 mm. A final antenna is designed with the dimension further reduced to 3rd iteration. A loop of these lines is made to design Koch Loop Antenna which is a novel design. The line that is used to represent the fractal can meander in such a way as to effectively fill the available space, leading to curve that is electrically long. This overcomes the limitations of the small dipole antenna in terms of Bandwidth, Efficiency & Gain of an antenna. This Koch dipole is then arranged in the form of a loop by using four arms. The width of dipole strip is chosen to be 2mm. Ground plane practically is taken as 80mm X 80mm.

This antenna is a simple planar structure and is designed using commercially available software. The parameters for designing and simulation are effective permittivity of 4.4 for FR4 substrate, height of substrate is 1.588mm and loss tangent of 0.0025. A CPW feed is chosen for this antenna for simulation. A SMA connector of @50 ohms impedance is connected at feed port 1 and 2. The complete design of Koch Loop antenna is shown in Figure 3. This antenna is fabricated as shown in Figure 4.

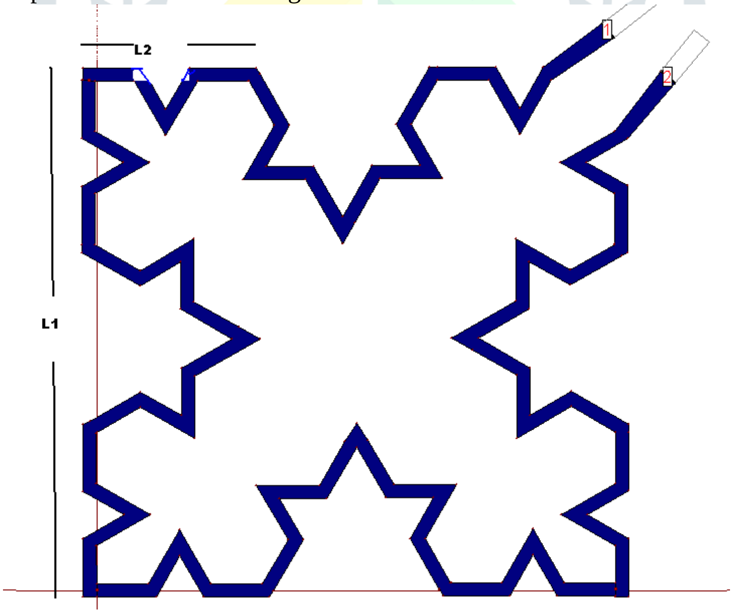

Figure 3: Koch Loop Antenna with Lengths L1 = 75mm, L2=25m

The dimensions of the designed and fabricated Koch Loop Antenna are as given by Table 1.

Table 1: Dimensions of Koch Loop Antenna

Length of Substrate	Width of Substrate	Width of Strip	Length of Loop Arm L1	Length of Element L2
80mm	80mm	2mm	75mm	25mm

Figure 4: Koch Loop Antenna fabricated on FR4 substrate as per dimension in Table 1.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

Using commercially available EM tool IE3D, simulation results are obtained. The return loss obtained is as shown in Figure 5, It was observed that seven resonant frequency bands are obtained where return loss is well below -10 dB. The central frequencies of these bands are mentioned in the Table 2. Multiband are obtained results are due to self similarity in the geometry. A wide band is also obtained for frequency range of 500 MHz to 2.5 GHz & 5.5GHz to 6.1GHz.This bands are used in WLAN Bluetooth, WiMAX wireless communications.

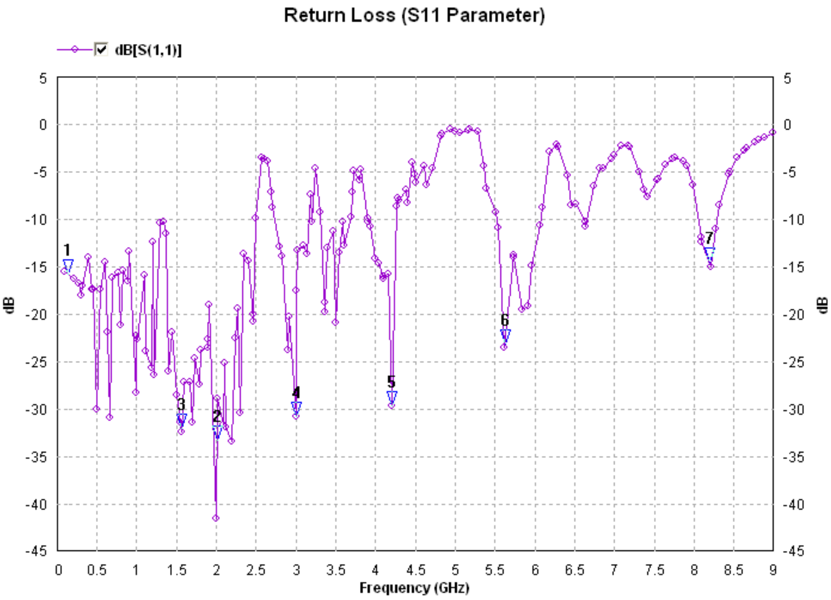

Figure 5: Simulated Return Loss of Koch Loop Antenna.

Table 2: Resonant Frequencies of Koch Loop Antenna

Points	Frequency	S11 in dB
1	0.50	-30.76
2	2.01	-42.30
3	1.56	-32.04
4	3.00	-30.84
5	4.2	-29.70
6	5.625	-23.13
7	8.19	-14.55

Corresponding the return loss and the design proposed the VSWR obtained is also less than 2,as shown in Figure 6. This antenna is linearly polarized since the axial ratio is found to be zero.

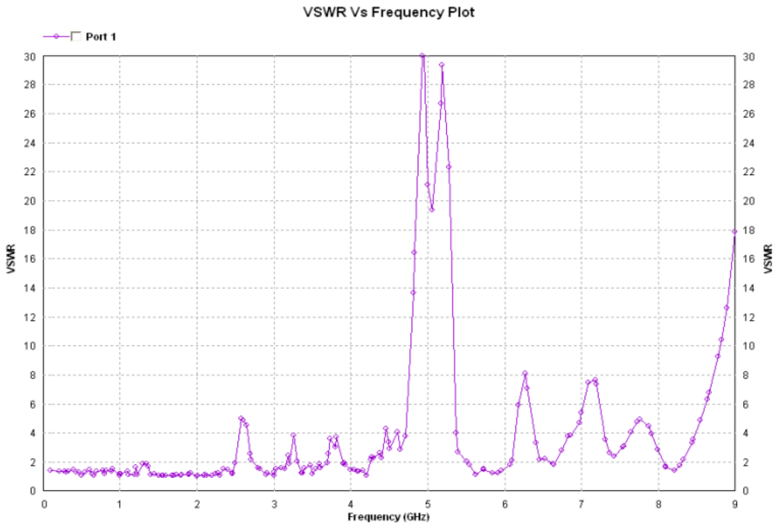

Figure 6: VSWR obtained by simulation

The experimental set up for testing the antenna performance is shown in Figure 7, which includes Vector Network Analyzer (VNA) of Anritsu, Signal Generator, Computer system and antenna under test. The VNA was first calibrated using calibration device and then coaxial feed is given to this antenna through SMA connector.

Figure 7: Experimental setup for measurement of parameters of Koch Loop Antenna.

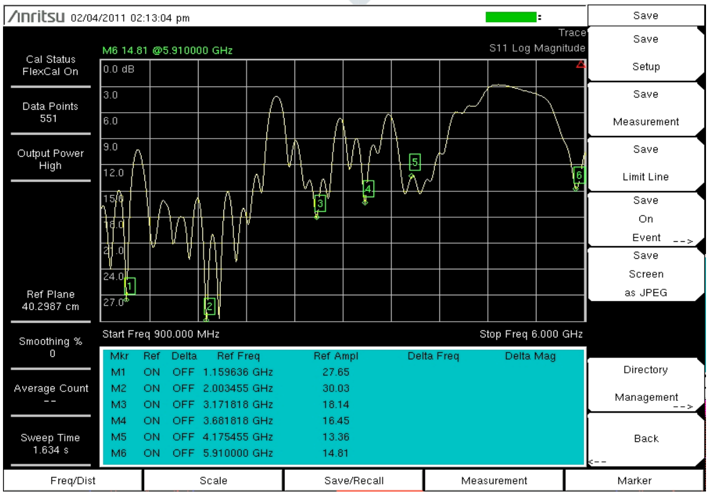

Figure 8: Measurement of return loss of Koch Loop Antenna on VNA.

Figure 8 shows the measured return loss of the antenna. At frequency range of 500MHz – 2.5 GHz & 5.5GHz – 6.1GHz, it is obtained well below -10 dB. Since electrical length of an antenna becomes variable due to fractal geometry, it resonates on multiple frequencies.

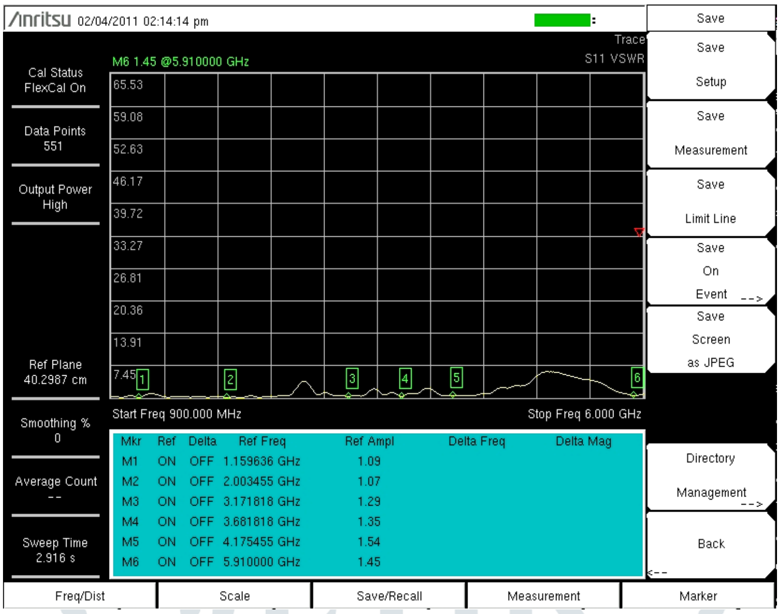

Figure 9: Measurement of VSWR on VNA

In Figure 9, the VSWR is measured on VNA is in the arrange 1-2.

Comparisons of the simulated and experimental results are made and it was found that there is good agreement between the two. Comparison between simulated results and measured return loss is as shown by Table 3.

Table 3: Comparison between Simulated and Measured Return Loss

Band No	**Simulated results**		**Measured Results**	
	Centre Freq.	S11 in dB	Centre Freq.	S11 in dB
I	0.135	-15.761	0.135	-15.04
II	2.01	-33.304	2.03	-30.04
III	1.56	-32.047	1.16	-27.85
IV	3.00	-30.845	3.17	-18.14
V	4.2	-29.70	4.17	-13.36
VI	5.625	-23.13	5.91	-14.01
VII	8.19	-14.554	8.19	-13

Using these S – Parameters, envelope correlation coefficient (ECC) can be calculated by formulas given in Equation 4 under the assumption that the antenna system operates in a uniform multipath environment. The correlation coefficient (ρ) is an important parameter to evaluate the diversity performance of the multi-antenna systems. The lower (ρ), results in better MIMO system performance. If ECC is below 0.5, it means that the antenna is feasible and good candidate for MIMO system application.

$$|\rho_{ij}| = \frac{|S_{ii}{}^{*} S_{ij} + S_{ij}{}^{*} S_{jj}|}{\sqrt{\left|\left(1 - |S_{ii}{}^{2}| - |S_{ji}{}^{2}|\right)\left(1 - |S_{jj}{}^{2}| - |S_{ij}{}^{2}|\right)\eta_i \eta_j\right|}}. \quad (4)$$

Array of the antenna is been simulated and correlation coefficient (ρ) is calculated using program developed in MATLAB. The value of ρ is found to be 0.00123 for the d= λ/8, where d= Spacing between two antenna elements.

IV. Conclusion

It may be concluded that more than one resonant band is obtained due to the facts, first, each small element acts as a separate radiating dipole element; second, entire loop as a radiating element. Besides, each small element contributes towards the increase in electrical length of antenna to increase radiating field Eθ. The range of the frequency bands is within the wireless communication bands of Wi-fi, WiMAX, Bluetooth and wireless LAN etc thus proposed antenna is a potential candidate for the use in these application. Besides, seven resonant bands at frequencies 1.56 GHz, 2.00 GHz, 3.00 GHz, 4.2 GHz, 5.6 GHz and 8.2 GHz are obtained.

This antenna can be used in MIMO systems because the value of envelope correlation coefficient ECC (ρ) is significantly reduces to 0.00123 for the d= λ/8, where d= Spacing between two antenna elements.

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