Design and Simulation of Koch Fractal folded-slot Antenna for Next Generation Mobile Networks

Suman Lata
Department of Electronics and Communication Engineering,
SDDIET Barwala, Panchkula, Haryana, India

Abstract: I have designed a folded-shot fractal antenna with single iteration with help of Koch iteration technique to achieve multiband properties. Antenna simulation tool Ansoft HFSS is used to design and simulate. Antenna proposed by me work with six frequency bands with acceptable return loss. Implementation of Folded slot antenna is done over a single slot antenna. Proposed design of antenna offers less than -10dB return loss for six bands 2.37 GHz, 4.00 GHz, 5.57 GHz, 6.11 GHz, 7.27 GHz and 8.95 GHz with -22.28 dB, -18.43 dB, -14.85 dB, -25.05 dB, -18.43 dB and -11.88 dB return loss respectively. So Six application areas can be covered simultaneously using this proposed Koch folded-slot fractal antenna.

Keywords-, Folded – Slot antenna, Fractals, Koch fractal antenna, Coplanar waveguide (CPW) feed, Finite Element Method (FEM).

I. INTRODUCTION

Wireless networks are the future of the world now, so this is a challenge for antenna designers to design such an antenna that can work in many of the standards of wireless networks but also they have to minimize the size of the antenna so that it can be used in small wireless devices such as smartphones and tablet computers. So the main requirement is to make an antenna that can work with so many applications simultaneously keeping its size small [2-3]. To operate on multi-applications at a single time, multiband properties are required. Concept of a fractal antenna can help achieving these multiband properties. Irregular and broken fragments are called Fractals, generally shaped and are composition of multiple copies of themselves at different scales [4]. Fractals are also known as a rough of fragmented geometric shape which can be subdivided in parts, and these subdivided parts are reduced-size of the actual whole structure. Fractal antennas are attractive because they of their self-similarity and space filling characteristics which generate antennas with multiband properties. A self-similar copy of an object seems unchanged after shrinking or increasing its size, and this self-similar copy can be obtained while a given operation is repeated over and again, on smaller or larger scales. Repeating operation can be algebraic, geometric or symbolic, to get on the path of perfect self-similarity [5]. Space filling properties are used to decrease the size of an antenna. A fractal's space-filling property fills the area occupied by the antenna as we increase the order of iteration [4]. This also can be described as a curve that is huge in term of length but small in terms of area in which this curve can be included.

II. Koch Monopole Fractal Structure

In near past, lot of work is done in fractal antenna structures and fractal techniques like monopole, dipole, slot antenna and antenna array structures. It is proved that electric performance of a Koch fractal monopole is better than the old straight-wired monopole, when it is operated in the small frequency regime.

Swedish mathematician Helge von Koch proposed the Koch curve in 1904 with a segment of a straight line as initiator and then developing an equilateral triangle over its middle third, this obtained structure is called generator. Length of generator is four-third the length of initiator [5]. Fig. 1 and Fig. 2 shows Koch curve and Koch Snowflake respectively. When middle third of straight section is replaced with a bent section of wire that spans the original third, this generates a Koch curve. It is

a non-rectifiable curve and at new iteration its length grows $\square \left(\frac{4}{3}\right)^{n}$.

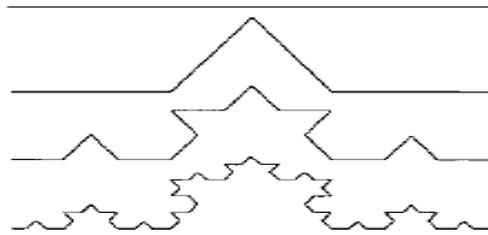$$Length_{koch} = h.\left(\frac{4}{3}\right)^{n}$$
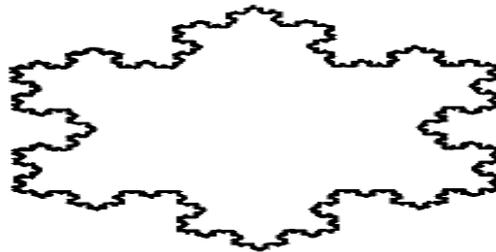
Figure 1- Koch Curve or Koch fractal

Figure 2- Koch Loop or Koch snowflake

If Koch generator is applying to an equilateral triangle, after infinite iterations, a Koch snowflake structure is obtained as shown in fig. 3.
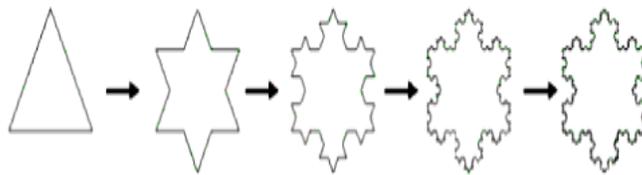

Figure 3- Infinite iterations on equilateral triangle- Koch Snowflake / Koch Loop

III.   Koch Fractal Techniques

The Koch curve or Koch snowflake is a mathematical curve and one of the initial fractal curves. Construction of The Koch fractal begins with a straight segment of length L (Initiator), then this is subdivided into three parts of equal length i.e. L/3 each, and middle segment is replaced with two other segments of same length, with intersection angle of $60^{\square}$. This is called Generator, the first iterated version of geometry. Higher iterations are generated by reusing the process. A coplanar waveguide (CPW) feed line is used to feed antenna at center.

IV.   Design Technique of Koch Fractal Folded- Slot Antenna

A major component of a slot antenna is a metal surface (usually a flat plate), with a slot or hole cut out. A folded slot antenna can be designed over a single slot antenna. A folded antenna is a planner antenna having wide bandwidth and maximized radiation at the broadside. It consist of a folded slot with approximate circumference equal to one guided wavelength ($\square$g) and can be fed with a Finite Ground Coplanar (FGC) or with a CPW waveguide from one end. Fig. 4(a) is an example of simple folded slot antenna.
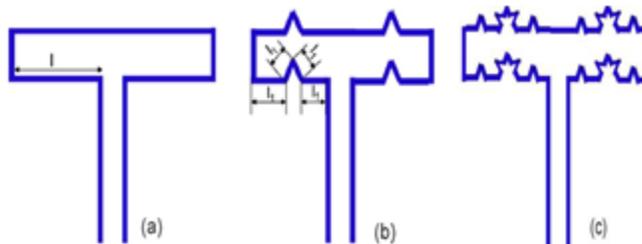

Figure 4 (a) A folded slot antenna (b) Koch folded slot antenna with first iteration
(c) Koch folded slot antenna with second iteration

Fig. 4(b) and fig.4(c) shows First iteration and second iteration of Koch folded slot antenna respectively. Antenna designing and simulator tool High Frequency Signal Simulator (HFSS) is used to design the proposed antenna, A schematic layout of simple folded-slot antenna and first iteration of Koch fractal folded-slot antenna are shown in Figure 5(a) and 5 (b).

The design of antenna starts with a slot of length 20.8 mm towards Y-axis and 35 mm towards X-axis. Then Length (L) shown in Fig. 5(b) is subdivided into three equal segments of length L/3 each, then middle segment is replaced by two other segments of the same length L/3, this is how we obtain a first iteration Koch fractal folded – slot antenna.
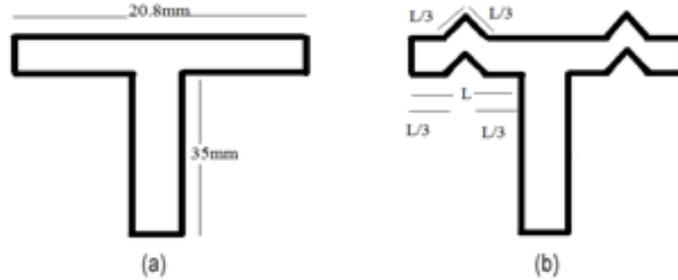

Figure 5(a)-Schematic layout of a simple folded – slot antenna
Figure 5 (b)-Schematic layout of first iteration of a Koch fractal folded – slot antenna

II. RESULT

Figure 6 shows The Koch folded – slot fractal antenna with single iteration. Finite Element Method (FEM) based designing and Ansoft HFSS simulation tool is used to design the antenna. Single iteration antenna is designed. Roger RT/duroid 5880(tm) material with dielectric constant of 2.2 thickness of 0.4mm is used as a substrate.
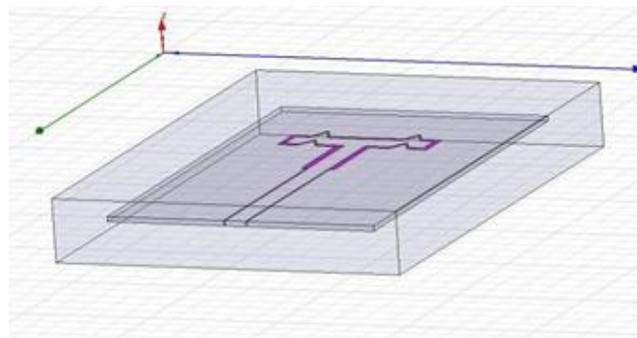

Figure 6- First iteration Koch folded – slot fractal antenna

In figure 7 a return loss versus frequency graph is used to describe multiband operation of the designed antenna. n in figure 7.
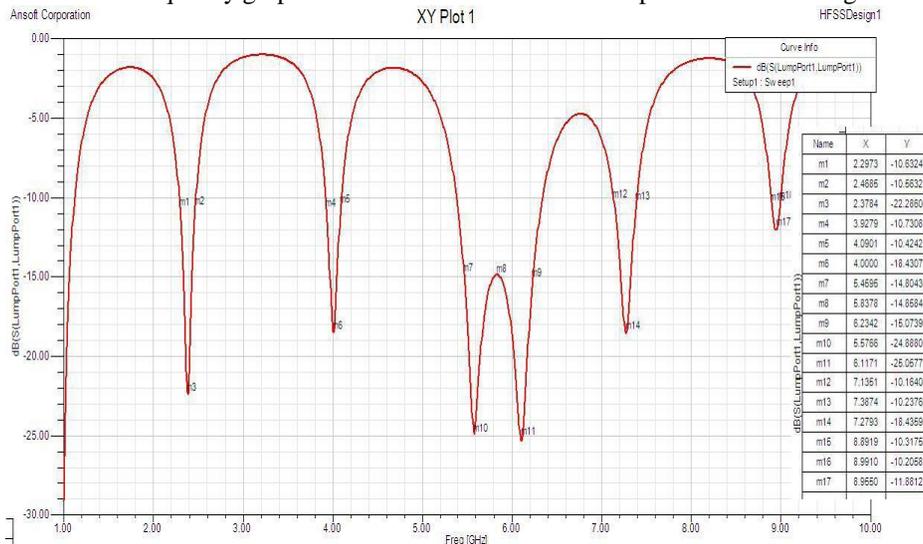

Figure 7- Frequency versus Return loss graph of the folded – slot fractal antenna

Radiation patterns are said to be perfect when return loss is less than -10dB because reflections are negligible at return loss below -10dB. In figure 7, we can see that the proposed antenna has return loss less than -10dB for six bands 2.37 GHz, 4.00 GHz, 5.57 GHz, 6.11 GHz, 7.27 GHz and 8.95 GHz, return loss - 22.28dB, -18.43 dB, -14.85 dB, -25.05 dB, -18.43 dB and -11.88 dB respectively. It proves that the proposed Koch folded – slot fractal antenna can work simultaneously for six applications. VSWR results for proposed Koch folded – slot antenna are shown in figure 8. VSWR VSWR is a standing wave ratio which gives information about impedance mismatch. The desired value of VSWR is less than 2. Figure 8 shows that all resonated frequency bands have VSWR less than 2.
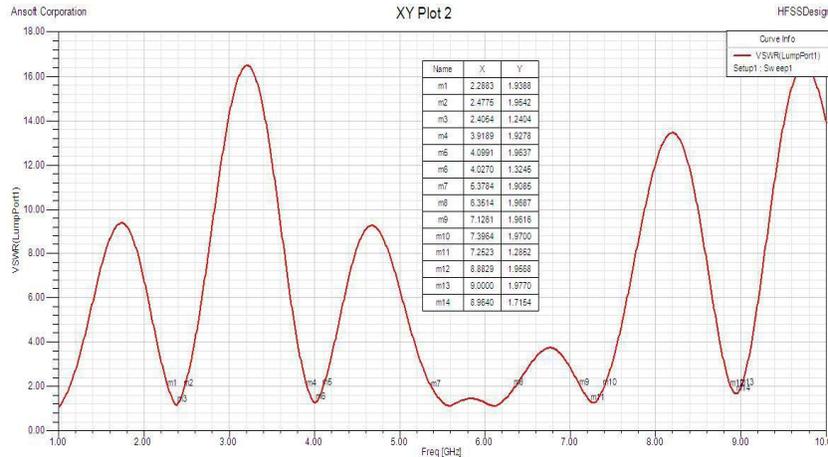

Figure 8- Frequency versus VSWR for proposed folded – slot fractal antenna.

Figure 9 shows the Radiation pattern of proposed antenna. We can illustrate by looking at fig. 9 that antenna is radiating in Omni-direction and in most of the mobile applications it is most desired feature and making it multi-application compatible because of multiband support.
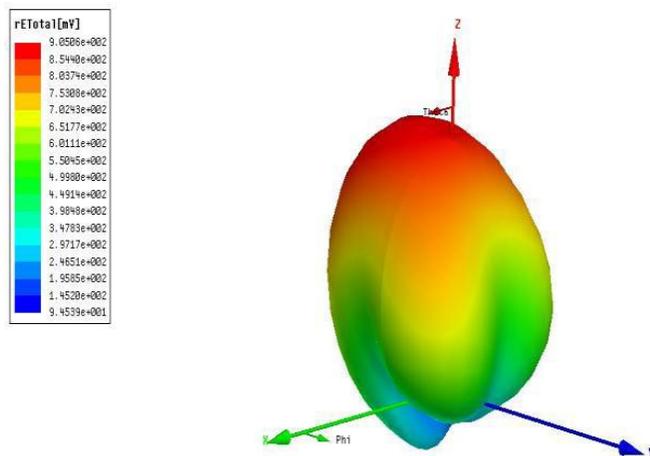

Figure 9- A 3-D view of Radiation pattern of the proposed antenna.

III. CONCLUSION

A folded – slot antenna using Koch iteration technique is designed in this paper. An antenna simulation and designing tool HFSS is used in simulation and designing of the proposed antenna. Return loss of the designed antenna is less than -10dB with six frequency bands 2.37 GHz, 4.00 GHz, 5.57 GHz, 6.11 GHz, 7.27 GHz and 8.95 GHz, return loss - 22.28dB, -18.43 dB, -14.85 dB, -25.05 dB, -18.43 dB and -11.88 dB respectively. The results leads us to a good agreement with next generation wireless / mobile applications.

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