Development And Simulation Of Koch Dipole Antenna For 868MHz

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***Abstract*—**This paper evaluates a fractal antenna based on Koch curve geometry. The antenna uses Ansys HFSS (High- Frequency Structure Simulator) software for simulation. The antenna is designed on a 1mm thick FR4 dielectric. This Koch curve antenna is designed to achieve resonance at 868MHz. The frequency choice is made as it is the approved frequency for ISM band in India and is used for LoRa communication in India. It is also used for other RFID [Radio Frequency Identification] and IoT [Internet of Things] protocols. A return loss of -15dB is obtained for 868MHz resonance frequency. A bandwidth of 60MHz is obtained considering -10dB return loss threshold. The antenna is designed on a substrate with dimension of 110mm x 20mm x 1mm. Simulated values of other parameters such as radiation efficiency and Gain are evaluated.

***Index Terms*—**Koch Fractal dipole, LORA antenna, 868MHz antenna, microstrip antenna

I. INTRODUCTION

LoRa [Long Range] communication is widely used all over the world. It has advantage of being a protocol that can be used for long range communication. It uses the chirp spread spectrum modulation which is ideal for use in low data rate wireless communication network. However the antenna required for 868MHz is generally large in size due to lower frequency. Efforts have been made to miniaturize these antennas so that they can be easily integrated in various products in the industry. As described in [2], among the variety of methods used for miniaturization, fractal design is a innovative method. Our aim is to design an antenna that can operate at 868MHz with an acceptable bandwidth, return loss and gain for LoRa or other wireless protocols for this frequency. Along with miniaturization, fractal antenna design also can provide advantages such as better impedance matching, increase in gain, multi band resonance and wide bandwidths. Some examples of fractal geometry are Koch curve, Sierpinski triangle, minkowski curve etc [2]. Each of these provide specific advantages due to their geometry. However for sub GHz LoRa application, a dipole structure serves well due to its inherent simplicity, good efficiency and omnidirectional pattern. Thus we would want to combine advantages of dipole antenna and fractal design to achieve good results in a Printed circuit board [PCB] antenna.

As shown in [3], [4], Koch dipole is a good candidate for such an antenna. when implemented on a PCB with FR4 material we can achieve resonance at 868 MHz in a relatively small size. Further sections of this paper explains the construction of antenna, theory of resonant frequency and wavelength calculations, Results and finally, conclusion.

II. ANTENNA DESIGN

A. The Koch Curve

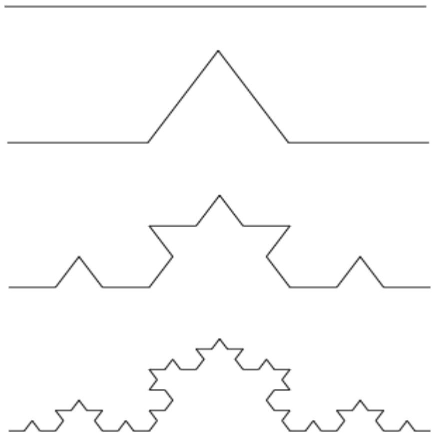

Fig. 1: Iterations of Koch curve

The fractal pattern originally conceptualized by Swedish mathematician Helge von Koch in 1904 is discussed in [6]. The Koch curve can serve as basis for several other type of fractal antennas like the snowflake, Minkowski antenna etc. and hence is a significant geometry. The geometry itself is fairly simple. the iteration 0 is a straight line, which is divided into 4 equal line segments , and the middle part forms an equilateral triangle without the base. This is the first iteration. further iterations then perform the same modifications on each of the new line segments. Thus, after N iterations, the total unfolded or stretched out length of the resulting geometry may be given as

$$L = h(4/3)N \qquad (1)$$

where h is the length measured end to end and L is the total unfolded length. since the middle part is an equilateral triangle, the angle it makes with the base is 60 degrees. This property can be used to calculate the end points of the line segments as described in the following algorithm.

Considering A and B as the end points of line segment of iteration zero. The x and y coordinates of these points are ax,ay and bx,by respectively.

A=[ax,ay]
B=[bx,by]

We let P, Q, R, be the end points of segments of iteration 1 as shown in the figure.

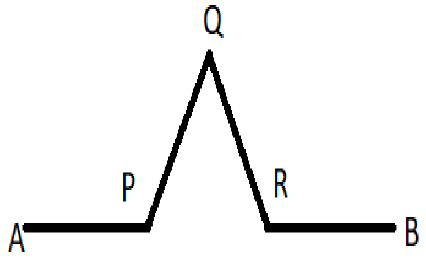

Fig. 2: finding xy coordinates of curve segments

We then define vectors along x and y axis, namely u and v. these can be calculated as

u=[bx-ax,by-ay]
v=[ay-by,bx-ax]

The x and y coordinates of points P, Q, R, can then be calculated as

P=a+(1/3)*u
Q=a+(1/2)*u+(sqrt(3)/6)*v
R=a+(2/3)*u

This algorithm is repeated for N iterations to calculate the Koch curve coordinates.

B. *Construction of Koch Dipole*

A standard dipole antenna is a construction having 2 identical wires separated by a small insulator section. with feed at the mid point. For a half wave dipole the length of the conductor is equal to half of the wavelength of interest. The diameter or width of the conductor used affects the bandwidth of the antenna. It also leads to significant changes in the input characteristics of the antenna. Hence a significant variation in resonant frequency would occur with change in radius.

[5] demonstrates and quantified the advantage of miniaturization as obtained using Koch curve. As described in [5], the resonant frequency for the first resonant band can be estimated for a Koch dipole as

$$fr = fd[1-\exp\left(\frac{N-1}{N}\right)\left(\frac{\ln D}{D}\right) \qquad (2)$$

where
fr is the resonant frequency of Koch dipole
fd is the resonant frequency of a linear dipole antenna with same end to end length as Koch dipole
D is the scaling factor given by

$$D = \frac{\log 4}{\log 3} = 1.261 \qquad (3)$$

This does not take into account other factors like dielectric or radius of the conductor but focuses solely on the Koch geometry. From the equation we can see that the relation is not linear with increase in iteration of the design. It is demonstrated that 3 or 4 iterations of the Koch curve gives optimal results. Thus, a 3rd iteration of Koch curve is used in this paper.

Since this paper aims to implement the dipole on a printed circuit board, calculation needs to be done to take into account the effects of dielectric used.

[1] discusses method to calculate wavelength for a micro strip line. Since we are designing for the first resonance to be at 868MHz , the length of linear dipole antenna can be calculated as $\lambda/2$, which is 172.7 mm for free space.

However for FR4 dielectric with dielectric constant ϵ = 4.4, the dipole length can approximated as follows.

First estimate ϵ [equivalent] = (1+4.4)/2 = 2.7 . Thus for fr4 material the length is

$$\text{length} = 172.7/\sqrt{2.7} = 108\text{mm} \qquad (4)$$

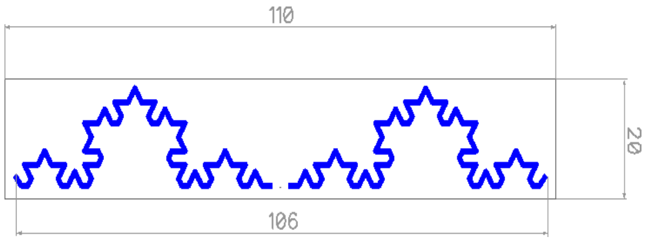

Fig. 3: Koch curve design used for simulation

This number is optimized using HFSS numerical optimization. The final optimized design is shown in Fig 3. Then end to end length is 106mm.

1 micron thickness copper on a 1mm thick FR4 substrate is

Fig. 4: Koch curve design on 1mm thick FR4

defined for simulation. The graph shows variation of frequency with changes in dielectric thickness. We can see that thicker dielectric further lowers the resonant frequency.

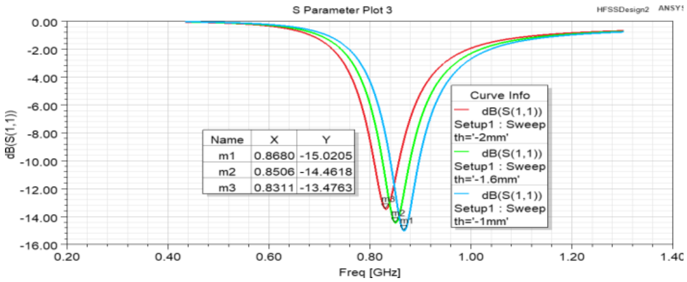

Fig. 5: Koch curve design variation with FR4 thickness

III. RESULT AND FURTHER DISCUSSION

The s11 response for the Koch dipole is shown in Fig. 4 with the bandwidth marked for -10db threshold. As can be seen from the return loss fig. 4, As can be seen a bandwidth of 60MHz is achieved. This is sufficient for LORA communication. The yellow markers on the plot show the frequencies at which the s11 curve crosses over the -10db threshold.

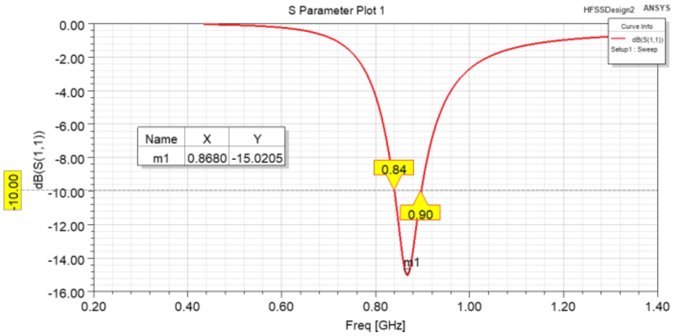

Fig. 6: S parameter plot for proposed antenna

The 3D radiation pattern for 868MHz frequency is shown fig. 5 . The gain values and radiation efficiency are calculated. Radiation efficiency is the ratio of total signal power that is radiated by an antenna to the total input power received from the generator. Thus it is an important parameter of an antenna. A radiation efficiency of 93% is obtained with this geometry, as calculated by simulation.

The antenna is fabricated and awaiting VNA repair and calibration at the time of submission of this paper.

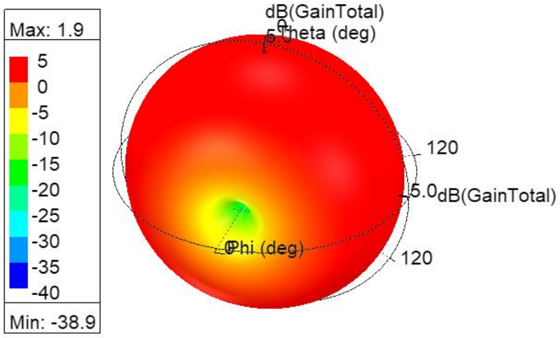

Fig. 7: 3D gain plot for proposed antenna

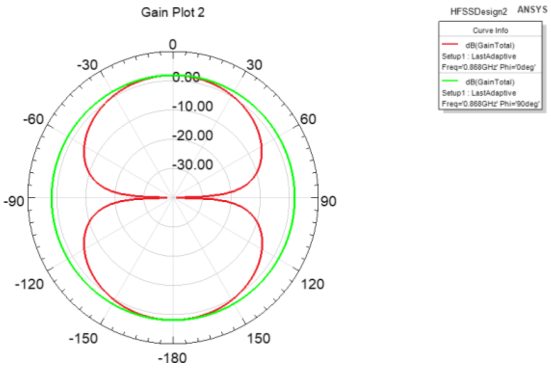

Fig. 8: E and H plain plot for proposed antenna

IV. CONCLUSION

The proposed antenna shows good results on simulation for desired ISM band frequency of 868MHz. This antenna achieves a bandwidth of 60MHz. A -10db return loss threshold is obtained for the frequencies 0.84-0.90 MHz. The geometry using fractal approach reduces the size of antenna as compared with conventional dipole antenna. The omni directional radiation pattern with gain of 1.9dB obtained with simulation is within acceptable range, and can support LORA, IoT and other RFID applications well.

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