Koch Fractal Loop Antenna using Modified Ground

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ABSTRACT
In the present paper a Koch fractal loop antenna is described using modified ground techniques for the multiband applications. A Koch fractal loop antenna is printed on dielectric substrate. The return loss value at each multiple resonating frequencies have been studied and improved for higher iterations of the Koch fractal loop antenna with the use of modified ground feed techniques. Theses antennas have been modeled and simulated using CST microwave studio software. The results of the simulations have been shown and compared for every iteration of Koch fractal loop antenna.

General Terms
R.F and Microwave, Koch fractal loop Antennas, Communication.

Keywords
Fractal antenna, Koch fractal loop, multiband antenna, antenna design.

1. INTRODUCTION
A class of broadband, multiband and small size antenna is in great demand in the area of RF and wireless communication systems [1]. Nowadays users are looking for antennas that can operate over multiple frequency bands or are reconfigurable as the challenges on the antenna system changes. Furthermore, the design of the antenna systems is always significant to be as miniaturized as possible in many applications. Fractal antennas are the excellent methods to find the way for the miniature and multi-band antennas. The concept of Fractal theory in antenna engineering has been playing a great role at the present time. The term fractal was initially discovered by Benoit Mandelbrot to define a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structure. The term 'fractal' was discovered in 1975 from the Latin word "fractus" which means broken or irregular. Fractals has the property of space filling contours or curve that means the electrically large features that can be efficiently packed into small areas [2]. The large electrical lengths can be efficiently packed in the small area as a viable miniaturization technique. The Iterated function system [3, 4], which represents a versatile tool to generate wide variety of useful fractal structures and based on a series of affine transformation was used to generate the infinite number of fractal geometries.

There are varieties of fractal geometries that have been investigated to be useful in developing new and innovative design for miniatured and multiband /broadband antennas. Some of these old known fractal geometries e.g. Sierpinski gasket, Sierpinski carpet and Koch fractal geometry have been studied for the multiband antennas. Fractal antennas based on Koch fractal shape have been widely explored for the size miniaturization and multiband purposes [5-9]. The effective length of the Koch fractal curve increases at each iteration of fractal results in shifting the frequency response of the antenna as well as the antenna size miniaturization. Some of the fractal geometries with loop antennas have been used for the multiband/broadband purpose. Classical Loop antennas have some disadvantages as low input resistance and larger in size. The Koch fractal loop antenna based on Koch island curve has the advantage that the increased effective length of the Koch island loop at higher iteration can be packed into a small space of the antenna as well as increases the input resistance of the simple circular shaped loop antenna.

In the present work, the Koch fractal geometries with circular shaped loop antennas have been designed and simulated using CST microwave studio software for the study of the multiband/broadband behavior. The reason for study of Koch fractal island geometry is to see the effect of changing the dimensions of the Koch fractal loop on its resonating frequency and bandwidth. A new feed technique has been implemented for the designed model. A modified ground based feed techniques on Koch fractal loop antenna shows the improvement in the return loss at each resonating frequencies for the higher iteration of the fractal antenna due to better impedance matching. Although the higher iterations of Koch fractal loop antenna can be useful to design the miniaturized size of antenna.

2. DESIGN OF KOCH LOOP ANTENNA
A Koch fractal island with circular shaped loop antenna has been designed using CST software [10]. Various iteration of the Koch fractal island is generated by the IFS tool. Multiple iterations of the Koch fractal island are shown in Figure 1. These Koch fractal loop/island are superimposed on circular shaped patch antenna to analyze the frequency and bandwidth response of the antenna.

In the present work, the higher iterations of Koch loop fractal have been used for the multiband antenna. The structure of the 3^{rd} iterated Koch circular loop patch antenna of radius *r =10 mm* is printed on a FR-4 substrate with thickness of *h* = 1.5 mm and relative dielectric constant $\varepsilon_r = 4.7$ as shown in Figure 2 (a). Where W_s and L_s represents the width and length of the substrate. A microstrip feed line on modified ground has been employed for the designing of Koch loop antenna for the better impedance match at each resonating frequency of the antenna. Where the L_f = 20.3 mm and W_f = 2.6 mm are the length and width of the feed line. The modified ground has dimensions of $L_g \times W_g = 1.6 \times 42$ mm as shown in Figure 2 (b).

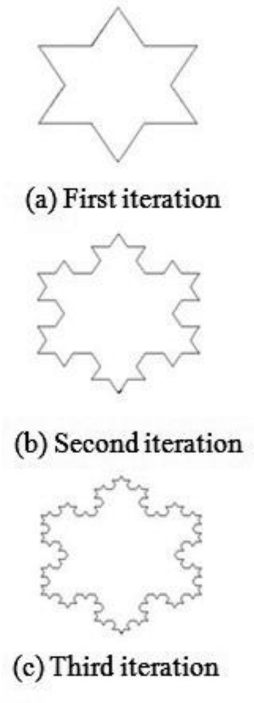

Fig 1: Various iterations of Koch fractal loop geometries.

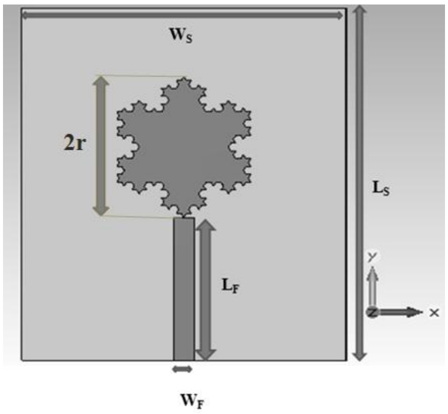

Fig 2: (a) Front view of the 3rd iterated Koch fractal circular loop antenna

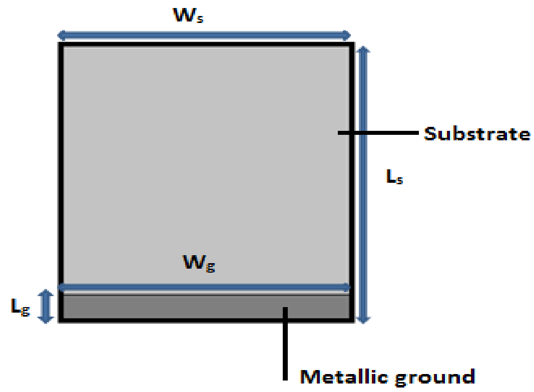

Fig 2: (b) Back view of the modified ground structure

3. RESULTS AND DISCUSSION

In order to analyze the multiband frequency resposne of the Koch fractal loop antenna, second and third iterations of koch fractal loop antennas was simulated. In figure 3, The return loss plot shows the multiband nature of the second iterated Koch loop antenna for radius *r* of 10 mm. This second iterated Koch loop antenna has three resonating frequencies at 4.43 GHz, 8.78 and 11.85 respectively. It has been observed from the plots, all the three frequencies resonates within the -10 dB return loss level. The first three frequenices have acceptable bandwidths at -10 dB tolerance level for the proper functioning of antennas. The resonance nature of the second iterated Koch loop antenna for three frequencies are tabulated in Table 4.1.

In order to verify the improvemnet in S_{11} or return loss plot with the use of modified feed, third iterated koch fractal loop antenna of same radius is simulated. Figure 4 shows the three fequencies for the third iterated Koch loop antenna. The third iterated Koch loop antenna has three resonating frequencies. It has been seen from the plots, all the three frequencies resonates within the -10 dB reference return loss level. The last two frequenices shows the improvement in return loss at frequency 8.75 GHz and 11.68 GHz. The first three frequenices have enough bandwidths at -10 dB tolerance level for the functioning of antennas. The resonance nature of the third iterated Koch loop antenna for three frequencies are tabulated in Table 4.2. It has been noticed from the third iterated Koch loop structure that the higher iterations of Koch loop fractal reduces the size or area of the antenna.

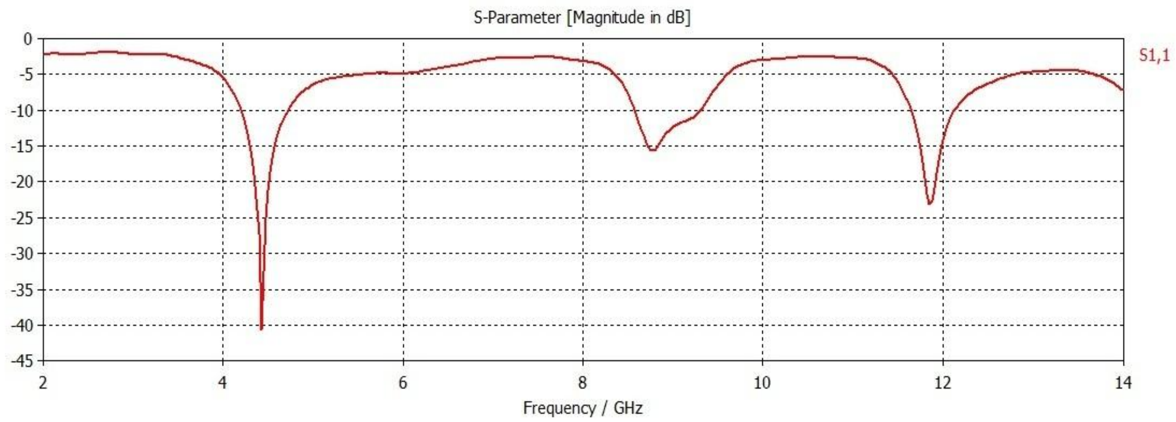

Fig 3: Resonating frequency for 10 mm 2nd iterated Koch fractal loop antenna

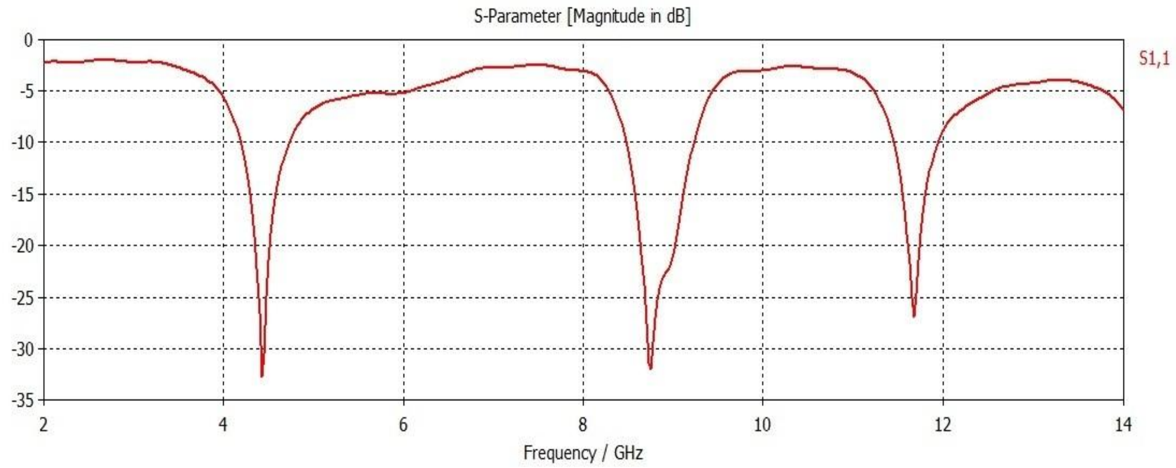

Fig 4: Resonating frequency for 10 mm 3rd iterated Koch fractal loop antenna.

Table 4.1 Resonance nature of 2nd iterated Koch loop antenna for 10 mm radius.

No. of resonance	Resonating Frequencies (GHz)	Band-width (GHz) at -10dB tolerance level	S_{11} (dB) or Return loss
First	4.43	0.53	-40.66
Second	8.78	0.73	-15.72
Third	11.85	0.49	-23.16

Table 4.2 Resonance nature of 3rd iterated Koch loop antenna of 10 mm radius

No. of resonance	Resonating Frequencies (GHz)	Band-width (GHz) at -10dB tolerance level	S_{11} (dB) or Return loss
First	4.43	0.53	-32.69
Second	8.75	0.75	-31.96
Third	11.68	0.49	-26.86

4. CONCLUSION

This paper discussed the role of Koch fractal loop in antenna as multiband antenna for WLAN band hand set applications, radar and navigation and other higher frequencies of microwave communication. Fractal antenna resonates properly at each resonating frequencies with the introduction of modified ground in feed method. The role of effective feeding techniques improves the impedance matching at each resonating frequencies of the antenna in terms of better return loss. Each resonating frequencies have acceptable range of frequencies for the broadband communication. The higher iterations of Koch fractal geometries would be useful in the size miniaturization of the antenna system.

Similar approach can be useful to design the other new kind of fractal geometries for multiband and miniaturized antennas. Bandwidth enhancement can be done with the introduction of better impedance matching devices for the ultra wide band (UWB) application. The more number of fractal iterations would generate the multiple number of fractal frequencies to cover up the wide area of RF and microwave and optical communication.

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