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WIDEBAND TRAVELING WAVE KOCH DIPOLE ANTENNA

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Abstract—In this paper, a traveling wave Koch dipole antenna is proposed. The antenna is an amalgamation of traveling wave antennas that require large elctrical lengths and fractal curves that are known for excellent form factor characteristics. The antenna is analyzed using a Mom code. The antenna exhibits an impedance bandwidth that is more than 10 : 1 for VSWR $< 3 : 1$. A comparision of simulated and measured results are presented. The traveling wave fractal antenna has many potential applications in communications and electronics warfare.

1. INTRODUCTION

With the advances in communications and military systems, there is a demand for smallest possible antennas with the widest possible bandwidths. But the fundamental limitations on size reduction of antennas [1] drive the antenna designers to search for new techniques. Some fractals are recursively generated self-similar curves that have excellent form factors. Such curves have been used [2–5] to reduce the antenna size and to get multiband performance [6–9] and high directivity elements [10]. Fractal antennas in planar forms for multiband and broadband applications are proposed [12–17] to work at higher frequencies. To a large extent the fractal antennas were used only to cover discrete non-contiguous frequency bands. Minowski loop antennas [18] and stacking of Sierpinski monopoles [5] were used earlier for wideband performance. Traveling wave antennas are antennas that have large electrical lengths and are loaded with a terminating resistance to acquire broadband performance. In this paper a fractal

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antenna generated with a Koch curve is loaded with a resistor to produce a traveling wave. The traveling wave nature of the antenna enables the antenna to operate over a wide bandwidth without nulls in the elevation pattern. In Direction Finding applications broadband antennas with omni azimuthal coverage are preferred antennas. The suitable number of broadband antennas are placed in circular bay form to achieve good DF accuracy and lesser ambiguity in phase comparison DF system. In bay form, antenna pattern distortion occurs due to mutual coupling between antenna elements of antenna bay. The proposed antenna offers some front to back ratio in azimuth plane radiation patterns with good omni directionality. This property of the antenna reduces the risk of pattern distortion upto some extent while placing the antennas in bay form in back to back fashion and hence is a good candidate for Direction Finding applications.

2. DESIGN AND REALISATION

A Koch curve [2, 11] can be generated by making four copies of the generator after scaling 1/3rd the original size and rotating two copies that are in the middle by 60° and −60° respectively. The resultant curve becomes the generator for the next iteration wherein the same step are repeated. The steps are shown in Fig. 1. Antennas made out of Koch curve [2] are shown to exhibit multiple resonances. It is also reported that a reduction in the size of the antenna depending on the number of iterations and the fractal dimension can be achieved. The photograph of the antenna is shown in Fig. 2. Two iterations of the Koch curve are simulated with the help of an MoM code (SuperNEC V2.9) keeping the length constant at 1.56 m and diameter of the wire as 4 mm. the segment length was taken as 0.1λ at the highest frequency for both the iterations. The antenna resonates at frequency f_1 after first iteration and at f_1, f_2 after second iteration. The reduction in antenna lengths at the lowest resonant frequency f_1 compared to a conventional $\lambda/2$ dipole are given in Table 1. The ratio between first and second resonant frequencies is 2.92, which is very close to 2.91 as predicted in [19]. The reduction in length for first and second iteration also corresponds very closely to the results reported in [20]. The Koch dipole after the first and second iteration are then loaded with a 240 Ω resistance as this value is optimised for minimum impedance variation in linear antennas [21]. The appropriate load locations for both the iterations were optimised by simulation to get progressive decrease in current from feed point to ends of the dipole which ensures the travelling wave nature of the antenna. These optimised locations are shown in Fig. 3(a) and Fig. 3(b). The simulated current distribution of the antenna is shown in Fig. 4 indicating current decrease in current progressively from the feed point of the dipole to the tip of the dipole. Since the antenna was loaded with 240 Ω resistor, a 4 : 1 transformer was required to match the antenna to 50 Ω impedance. The simulated VSWR curve with a 4 : 1 tarnsformer for the two iterations are shown in Fig. 5. The second order Koch dipole was fabricated with a copper wire of diameter 4 mm. A 4 : 1 balun transformer was wound on a binocular ferrite core with permeability $\mu_i = 40$. The simulated result indicated a bandwidth from 56 MHz to 226 MHz. Instead of using a transmission line balun transformer that gives a faithful 4 : 1 transformation with minimum losses, loss was incorporated in the system by using a transformer with fewer number of turns to compensate for the low radiation resistance and high capacitive reactance from 20 MHz to 56 MHz.

Table 1. Resonant frequencies and reduction in length at lowest frequency compared to conventional $\lambda/2$ dipole.

Sl. No.	Iteration No.	First Resonant Frequency f_1 (MHz)	Second Resonant Frequency f_2 (MHz)	Antenna Element Length	Reduction in length(%) for f_1 compared to $\lambda/2$ dipole
1	0	92	-	0.5λ	0
2	1	75	225	0.408λ	18.4
3	2	65	190	0.3535λ	29.3

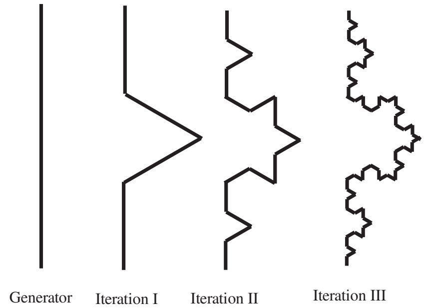


Figure 1. Generation of Koch fractal curve.

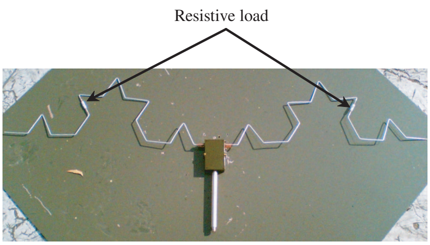
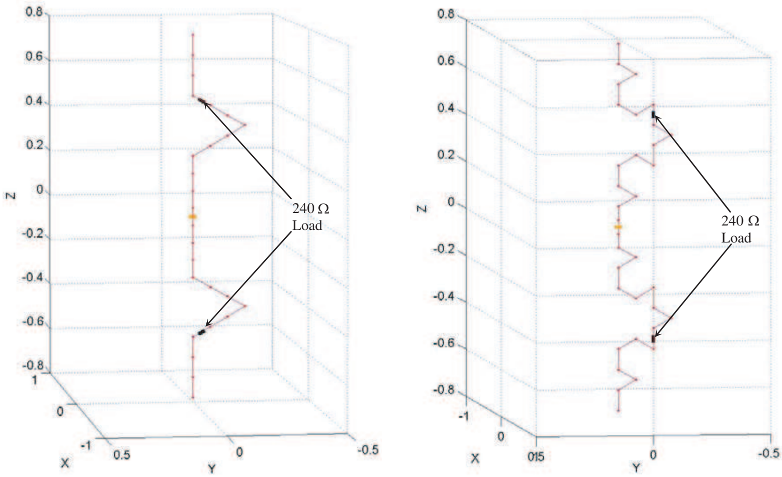


Figure 2. Photograph of Koch dipole antenna.



(a) Iteration I (b) Iteration II

Figure 3. Simulated antennas with Load locations.

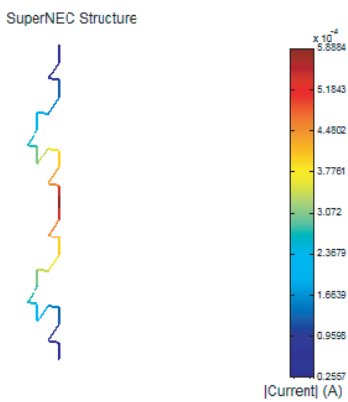


Figure 4. Simulated current distribution of the antenna.

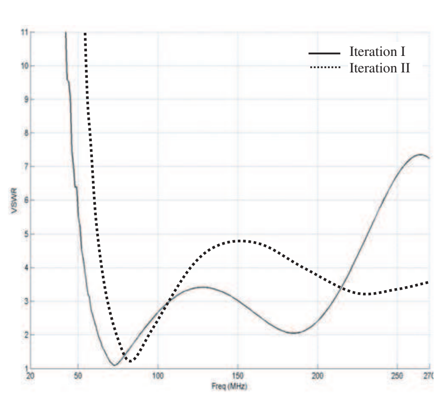


Figure 5. Simulated VSWR curves for two iterations.

3. RESULTS

The measured VSWR curve with fabricated balun transformer is shown in Fig. 6. The VSWR of the antenna is below 3 : 1 from 20 MHz to 200 MHz. The efficiency of the antenna was expected to be low below 50 MHz because of the lossy transformer and the electrically small size of the antenna. The efficiency plot of the antenna is shown in Fig. 7. The elevation plane and azimuth plane radiation patterns of the antenna were measured in a Ground Reflection Range with the help of digital pattern recording system and are depicted in Figs. 8(a) and

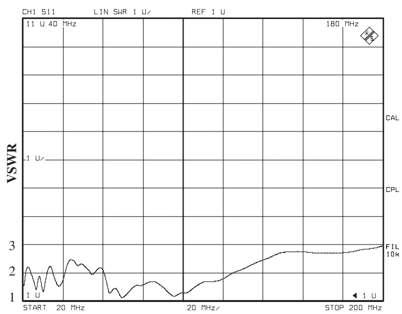


Figure 6. Measured VSWR of the loaded traveling wave Koch dipole antenna (II Iteration).

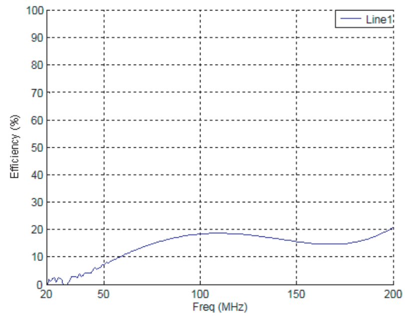
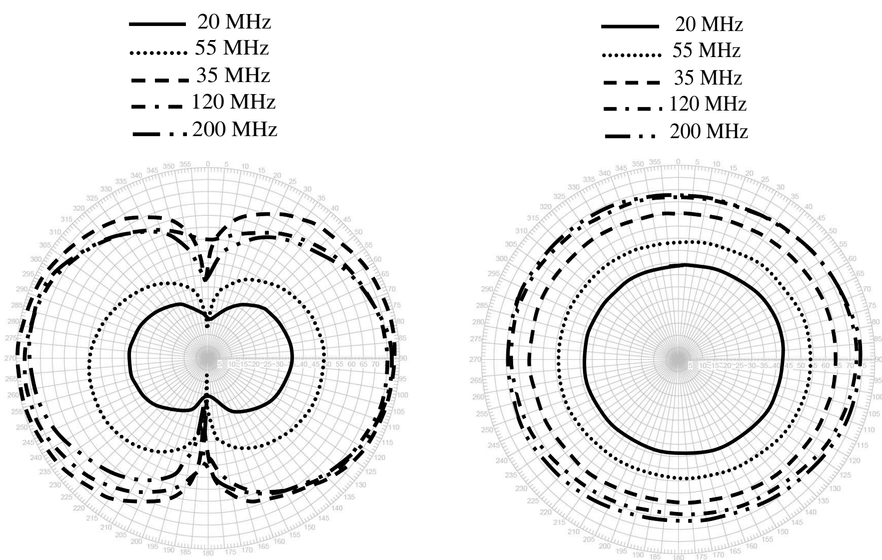


Figure 7. Simulated efficiency of the antenna.



(a) (b)

Figure 8. (a) Measured elevation plane radiation patterns of the antenna. (b) Measured azimuth plane radiation patterns of the antenna.

8(b) respectively. The omnideviation of the antenna is less than ± 3 dB throughout the band and the elevation beamwidth of the antenna is greater than 30°. The azimuth pattern of the antenna exhibits a front to back ratio of 5 dB in the high frequencies, which is useful for Direction Finding systems. The front to back ratio reduce the mutual coupling between the antenna bays of different sub-bands stacked in a wedding cake arrangement. The gain of the antenna was measured in a Open Ground Reflection range in comparison with standard gain dipoles from M/s Scientific Atlanta and M/s EMCO and varies from −24 dBi at 20 MHz to 0 dBi at 200 MHz. Such antennas do possess low gain at the lower frequencies because of severe size reduction.

4. CONCLUSIONS

A traveling wave fractal antenna is proposed for the first time to operate over a bandwidth of over 10 : 1. The antenna can be used effectively either in commercial communication systems with high data rates requiring small antennas or in tactical communications where small antennas are required to intercept the hostile communication. The antenna can further be used as a broadband dipole element for direction finding systems with better performance because of reduce mutual coupling between antenna bays. The antenna can also be termed as a prefractal antenna as only two iterations have been carried out. Axial resistive loading was found to be effective in increasing the bandwidth of the antenna. Similar loading of other antennas having good form factor characteristics such as meander line antennas can further be carried out to make a comparative study.

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