High-Directivity Fractal-Vee Dipoles

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1. Introduction

Shaping of linear dipoles is a technique to achieve higher directivity. If the arms of a dipole are tilted to make a vee dipole, higher directivity and lower side lobes can be achieved [1]. Another way of shaping dipoles for higher directivity by using a piecewise parabolic approximation is described in [2]. In [3], it is shown that by also letting the two arms in a dipole antenna configuration be fractal elements based on the Minkowski motif, higher directivity can be achieved. A variation of the vee dipole referred to as the double-vee dipole is presented in [4] where it is shown that this type of antenna have higher directivity, lower side lobes and less back radiation than the conventional vee dipole.

In this paper an optimization search of a vee antenna based upon the Koch fractal curve is presented. In the next section this design optimization search is described and in section 3 the numerical results are presented. It is shown that by replacing the arms of the ordinary vee dipole with the Koch fractal curve higher directivity can be obtained. It is also shown that by increasing the number of fractal iterations, smaller antennas with significantly higher directivity compared to the conventional vee dipole can be achieved.

2. Design Optimization

In Fig. 1 is a vee dipole with its arms replaced with the Koch fractal curve shown. The Koch fractal curve is generated by an iterative process described in [6]. The length l, referred to as the projected arm length, is the shortest distance from the feed point to the end of an arm. The half apex angle α is the half angle between the arms. An exhausted optimization search is performed by varying the parameter l over a range of $0.4\lambda \leq l \leq 1.5\lambda$ in steps of 0.02λ and the parameter α between $6^{0} \leq \alpha \leq 148^{0}$ in steps of 1^{0}. The first four iterations of the Koch fractal vee-dipole are simulated. For each iteration optimum angles α_m that give maximum directivity are found for different values of l. The antenna is modelled as a thin wire structure and simulated with the Numerical Elecromagnetics Code (NEC2) based upon methods of moments techniques [5]. The wire radius used is 0.0005λ at a frequency of 2.45GHz.

Fig. 2(a) shows α_m as a function of l for the second and fourth iteration Koch fractal-vee dipole. Iteration 0 corresponds to the ordinary vee dipole and is included for comparison purposes. In Fig. 2(b) is the maximum directivity plotted. Solutions obtained at the optimum angles for different values of the projected arm length will from now on be referred to as optimum solutions. Optimum solutions obtained at iteration 0 agree well with in [1] predicted values.

3. Radiation Characteristics

In Fig. 2(b) one can see that when the arms of the vee dipole are replaced with the Koch fractal curve higher directivity compared to the ordinary vee dipole can be achieved and that series of local maxima are holding up. As the number of iterations increases the number of maxima in the investigated interval increases. For the first four fractal iterations the antenna parameters and its characteristics at the major maximas are listed in Table 1. For

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optimum solution 4 from Table 1, the impact on the directivity due to shaping the antenna with the Koch fractal curve seems to be largest. At this solution the directivity is 2.72dB larger than the conventional vee dipole. The highest directivity obtained in the investigated interval is 8.47dBi and that is achieved with optimum solution 2. The input impedance of the above mentioned solutions have however a very large negative imaginary part. From Table 1 and Fig. 2 it is apparent that for higher iteration Koch fractal-vee dipoles, the optimum angles as a function of projected arm length and the corresponding maximum directivity appears roughly as compressed versions of optimum solutions obtained with lower number of fractal iterations. This agrees well with observations made in [3] where it is stated that it is the application of the first iteration fractal that is responsible for optimized gain. As the number of fractal iterations increases, the directivity at the major maximas decreases and appears at lower projected arm lengths, except for the directivity at the third peak which increases slightly when the third iteration Koch fractal curve is replaced with a fourth iteration curve. However, even though the directivity at the major directivity peaks in overall decreases as the number of fractal iteration increases, higher directivity compared to the ordinary vee dipole with same projected arm length can be obtained by increasing the number of iterations. For example, all the first major directivity maximas for each iteration are situated over an interval where the maximum directivity, as a function of the projected arm length, of the ordinary vee dipole decreases with higher rate than the directivity at the first major directivity maximas, as a function of iterations, decreases. All solutions in Table 1 with projected arm length greater or equal to 0.745λ have high back lobe radiation compared to the conventional vee dipole with same arm lengths. The increase in directivity for these solutions seem instead mainly be due to reduced side lobes and beamwidth. For the other solutions in Table 1 the increase in directivity seem to be due to lower back lobe radiation. All solutions in Table 1 except optimum solution 7 and 10 have the main beam along the x-axis. The later two solutions, which have a completely bidirectional radiation pattern, have maximum radiation along the z-axis.

Table 1. Parameters and radiation characteristics for optimum directivity solutions of the Koch fractal-vee dipole.

Optimum Solution	Iterations	l/λ	α_m (°)	Directivity (dBi)	Input Impedance (Ω)
1	1	0.565	122	6.09	74.2-j99.1
2	1	1.195	87	8.47	557.3-j863.2
3	2	0.495	121	5.75	48.5+j47.4
4	2	0.970	85	8.44	298.1-j945.5
5	3	0.450	121	5.54	38.5+j126.3
6	3	0.825	85	7.94	308.9-j1152.7
7	3	1.165	26	7.85	114.1+j20.1
8	4	0.425	121	5.53	33.5+j173.9
9	4	0.745	85	7.62	360.2-j1350.5
10	4	1.050	30	8.00	94.7+j65.2
11	4	1.335	130	8.02	543.3-j1652.0

As the number of fractal iterations increases more optimum solutions at resonance appears in the investigated interval. The input impedance for the optimum solutions of the fourth iteration Koch fractal-vee dipole is shown in Fig. 3. It is interesting to see that optimum solutions 8 and 10 from Table 1 for the fourth iteration Koch fractal-vee dipole is relatively close to resonate.

Possible multiband behaviours for this type of antenna has also been investigated for an optimum solution at resonance at a frequency of 2.45GHz with the parameters l=0.4057λ and α_m=118°. At this solution the directivity is 5.43dBi and the input impedance is about 24.8Ω. In the analysis the antenna is assumed to be matched to 24.8Ω. In Fig. 4 is the input return loss versus frequency plotted. As shown in the figure, the input return loss is very low at 875MHz, approximately -15dB. Also at 3925MHz is the input return loss relatively low, around -8dB. However, it should be noted that in the 875MHz band the radiation pattern is almost omnidirectional and very similar to the ordinary short dipole antenna and that in the 3925MHz band the main beam has changed from the negative x-direction to be along z-axis and the maximum directivity has decreased with 0.68dB.

4. Conclusions

In this presentation an optimization search of the Koch fractal-vee dipole has been presented. It has been suggested that the Koch fractal-vee dipole have potential to provide higher directivity than the ordinary vee dipole. By increasing the number of fractal iterations, smaller antennas with significantly higher directivity compared to the conventional vee dipole can be obtained. Possible multiband behaviours has also been investigated. It has been shown that this type of antenna has potential to operate at more than one frequency band in terms of low input return loss due to impedance mismatch. Measurements to verify these results will be made.

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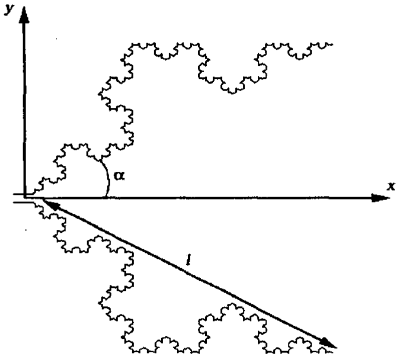

Fig. 1. Fourth iteration Koch fractal-vee dipole.

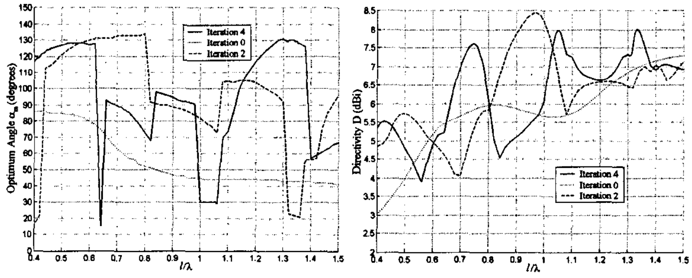

Fig. 2. (a) Half apex angles for maximum directivity as a function of projected arm length.

(b) Maximum directivity as a function of projected arm length.

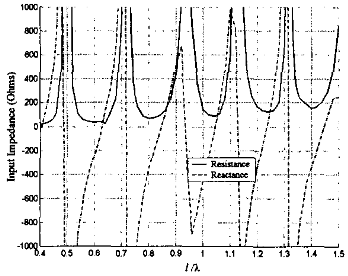

Fig. 3. Input impedance for optimum solutions of the fourth iteration Koch fractal-vee dipole.

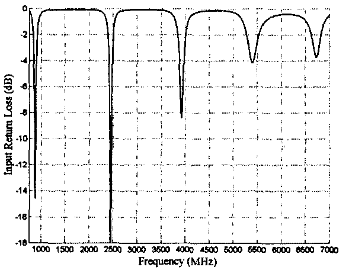

Fig. 4. Input return loss of a fourth iteration Koch fractal-vee dipole matched to 24.8Ω.