The Characteristics of Koch Island Microstrip Patch Antenna

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ABSTRACT

In this paper, the characteristics of Koch island microstrip patch antenna are investigated by numerical and experimental methods. The Koch patch is fractal shaped antenna which can be characterized by two properties such as space-filling and self-similarity. Due to its space-filling property of fractal structure, the proposed Koch fractal patch antennas are smaller in size than that of conventional square patch antenna. From numerical and experimental results, it is found that as the iteration number and iteration factor of Koch patch increase, its resonance frequency becomes lower than that of conventional patch, thus contributes to antenna size reduction. In particular, when the fractal iteration factor is 1/4, the fractal antenna is 45% smaller in size than that of conventional patch, while maintaining radiation patterns comparable to those of rectangular antenna and cross polarization level is about -20~-14 dB.

I. INTRODUCTION

In recent years, as the demands of portable wireless systems have increased, low-profile systems have drawn much interest from many researchers. In making such systems, the size of antenna is a critical issue. Accordingly, many kinds of miniaturization techniques, such as usage of high dielectric substrates [1], application of resistive or reactive loading [2], and increment of the effective electrical length of the antenna by optimizing its shape [3], have been proposed and applied to microstirp patch antennas. The application of fractal geometry to conventional antenna structures could in crease the electrical size of the antenna, thus leads to miniaturized radiating structure. Because fractal geometries have two features such as space-filling and self-similar properties, fractal shape antennas pose various advantages: wide bandwidth [4], multiband [5], and reduced antenna size. Among the many fractal geometries, Koch fractal geometry exhibits well-known features that have been used to construct miniaturized monopoles and loop antennas[6]. By applying the Koch fractal shape to conventional antennas, the overall electrical length of the antennas increases, and as a result the resonance frequency becomes lower than that of conventional monopole, loop, or patch type antennas [7].

In this paper, Koch fractal geometry is applied to microstrip patch antenna to reduce its overall size, and the effectiveness of this technique is then verified through numerical and experimental studies. It is found that as the iteration number and iteration factor increase, the resonance frequencies become lower than those of the zeroth iteration, which represents a conventional square patch. In other words, microstrip patch antennas employing Koch fractal island geometry can operate at a much lower frequency range while maintaining an identical overall antenna size. This make possible to obtain smaller size antenna than conventional one. In next sections, various design parameters are described and then simulation data have been documented with measurement results.

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Ⅱ. DESIGN CONSIDERATION

Koch island patch is constructed by forming a polygon with Koch curve, named after the mathematician Helge von Koch[8], is a simple example of fractal structure. This curve is characterized by two factors: iteration factor and iteration number. The iteration factor represents the construction law of fractal geometry generation, while the iteration number describes how many iterating process are carried out. For the fractal variation of conventional rectangular patch antenna, each sides are replaced with Koch fractal curves , thus forming fractal antenna. In the zeroth iteration, the curve begins as a straight line known as the zeroth iteration and this curve is mapped onto each side of the square. In the first iteration, the first Koch curve is placed on the position of zeroth iteration curve as illustrated in Figure 1 (b). If this process is repeated infinitely, the ideal Koch island fractal geometry is obtained. In this paper, due to its fabrication complexity of fractal geometry, larger than two iteration numbers are not considered, and the effect of wide variety of iteration factors 1/10, 1/6, 1/5, and 1/4 are throughly investigated. Fig. 1 and Fig. 2 show most of the fractal antennas considered in this study.

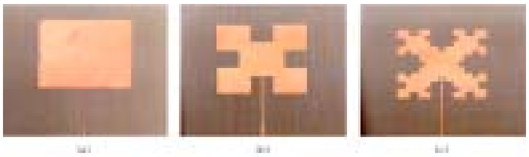


Fig. 1. Koch fractal island microstrip antennas for iteration factor 1/4 (a) the zeroth iteration (b) the 1st iteration (c) the 2nd iteration number

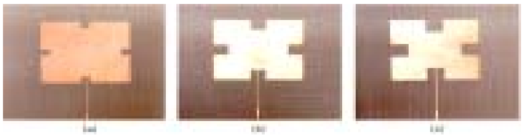
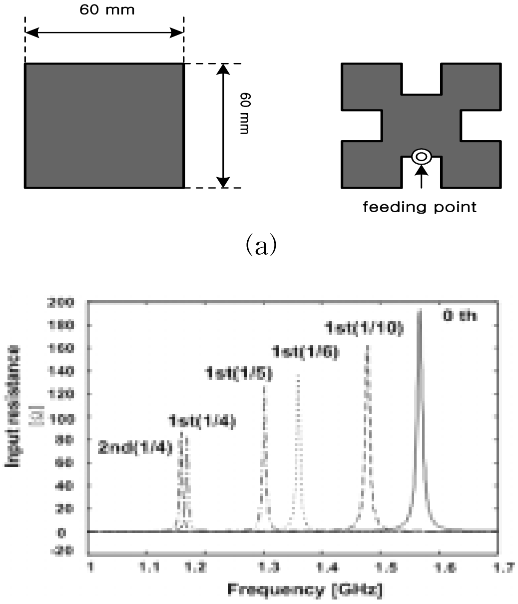


Fig.2. 1st iteration Koch fractal island microstrip patch antenna with different fractal factor:(a) 1/10 iteration factor (b) 1/6 iteration factor (c) 1/5 iteration factor

Ⅲ. SIMULATION DATA

The input impedance of proposed Koch patch is analyzed using commercial MOM based simulator. As shown in Fig. 3(a), the dimension of the patch is 60 mm by 60 mm and substrate thickness is 0.508 mm with permittivity 2.5. The feeding point is located at the edge of each patch as shown in Fig. 3 and the input impedances are calculated as shown in Fig. 3 (b).



(a)

(b)

Fig. 3 The configuration and numerical result of patch (a) dimension and location of feeding point (b) input impedance of the proposed patch antenna.

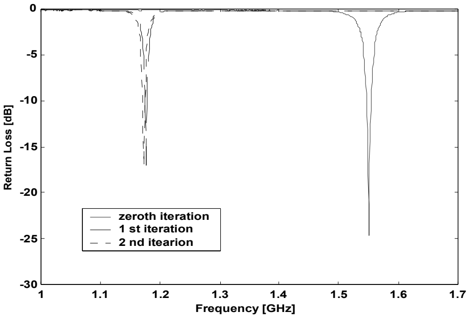
As shown in Fig. 3 (b), it is clear that as the iteration number and the iteration factor of Koch island patch increase, the resonance frequency and the input resistance become lower than that of conventional one, thus miniaturized antenna is possible to obtain.

Ⅳ. MEASUREMENT RESULTS

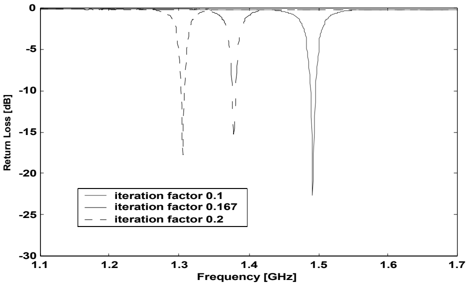
Six different Koch patches antennas are fabricated on Teflon substrate and input matching is performed by placing λ/4 transformer. The length and width of the rectangular patches are 60 mm by 60 mm, and fractal iterations and reductions of all the proposed fractal antenna are start from this dimension. As shown in Fig. 1 and Fig. 2, notches are located at each side of the patch and as the iteration number and iteration factor increase, the average electrical length of the patch boundaries also increases, thus lowering the resonant frequency of Koch fractal microstrip patch antennas.

The return losses and radiation patterns of the proposed fractal patch antennas are measured as shown in Fig. 4 and Fig. 5. It is observed that the resonant frequency of the zeroth iteration (conventional rectangular) patch is 1.55 GHz. In the case of the first iteration patch, the resonant frequencies are 1.493 GHz, 1.379 GHz, 1.305 GHz, and 1.176 GHz for iteration factors 1/10, 1/6, 1/5, and 1/4, respectively. The resonant frequency of the second iteration patch is 1.173 GHz. After the second iteration, the shift in the resonant frequency becomes insignificant.

Bandwidth of Koch patches becomes narrower than that of conventional patch. For VSWR 2:1, fractional bandwidth of zeroth iteration patch is about 0.484% and the bandwidth of 1st and 2nd iteration is about 0.32%. This is due to high Q-value of Koch island patch.



(a)



(b)

Fig. 4. The measured return losses of fabricated antenna (a) zeroth, 1st, 2nd iteration (iteration factor 1/4) (b) 1/10, 1/6, 1/5 iteration factor (1st iteration)

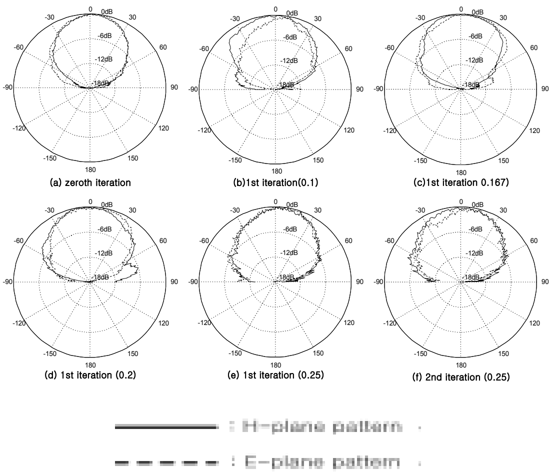
Table 1. summarizes the resonant frequencies of the fractal antennas and size reduction effect.

The column 3 of the Table shows the resonant frequencies of the zero, first (iteration factors 1/10, 1/6, 1/5, and 1/4) and second order (iteration factor 1/4) Koch island patches.

Column 4 shows the required dimensions for the conventional patch antenna to have the same resonant frequency, and Column 5 shows the percent reduction in size of the Koch patch. Fig. 5 depicts the radiation patterns of the Koch fractal patch antennas and all patterns reveal characteristics very similar to those of the zeroth iteration patch. The cross polarization levels of the Koch patch antennas are summarized in Table 2. The cross polarization level varies from -14 to -20 dB and becomes higher as the iteration factor and iteration number increase.

Table 1. Summary of Experiment Results

Iteration number	Iteration factor	Resonant Freq [GHz]	Equivalent rectangular patch size [mm×mm]	Percent reduction in size[%]
Zeroth	0	1.55	60.0×60.0	0
First	1/10	1.493	64.3×64.3	13
	1/6	1.379	70.0×70.0	27
	1/5	1.305	72.7×72.7	32
	1/4	1.176	81.4×81.4	45
Second	1/4	1.173	80.6×80.6	45



(a) zeroth iteration (b)1st iteration(0.1) (c)1st iteration 0.167)

(d) 1st iteration (0.2) (e) 1st iteration (0.25) (f) 2nd iteration (0.25)

Fig. 5 Measured radiation patterns of the proposed fractal antennas

Table 2. Cross-polarization level

Iteration Number	Iteration Factor	Freq [GHz]	Plane	Cross polarization level [dB]
Zeroth	0	1.55	H	-20
			E	-20
First	1/10	1.49	H	-20
			E	-18
	1/6	1.38	H	-19
			E	-22
	1/5	1.305	H	-15
			E	-17
	1/4	1.176	H	-14
			E	-14
Second	1/4	1.173	H	-16
			E	-17

Ⅴ. CONCLUSION

In this paper, Koch island fractal microstrip patch antenna geometry is proposed in order to acheive miniaturized antenna. This fractal patch antenna has a lower resonant frequency compared to that of conventional patch, and this property contributes to reduction in antenna patch size. For the first iteration patch, as the iteration factor increases, the resonant frequency of the patch decreases. However, the resonant frequency of patches higher than the first iteration patch remains almost the same. The radiation pattern of the Koch patches are similar to that of the square patch. Especially, for the 1/4 iteration factor, the patch antenna size can be reduced to about 45% of the normal one (the zeroth iteration) without degrading the radiation patterns and as the iteration factor increases, the cross polarization level varies from -14 dB to -20 dB. This type of patch can be used in low-profile microwave communication as well as radar systems.

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