Experimental Investigation of CPW Fed Fractal Array Antenna

Noor Asniza Murad and Mazlina Esa

Microwave / RF and Antenna Research Group
Department of Radio Communication Engineering
Fakulty of Electrical Engineering
Universiti Teknologi Malaysia
81310 UTM Skudai, Johor Darul Ta'azim
asniza@fke.utm.my, mazlina@suria.fke.utm.my,

Abstract –This paper experimentally investigates the performance of a set of simple two element coplanar waveguide (CPW) fed fractal array antennas. The design is based on the single square microstrip patch antenna, operating at 1.575 GHz. This is the frequency of operation of a Global Positioning Satellite system receiving antenna. The basic patch antenna undergoes the first and second iteration process to form the first and second iteration fractal structures. The array elements are equally spaced between their corresponding centres. Through experimental investigations, it was found that the fractal antenna array operates at lower frequency of operations compared to the basic two element square patch antenna. The second iteration fractal array antenna has the lowest operating frequency, indicating a much more compact radiating structure. However, the reflection bandwidth decreases.

1. INTRODUCTION

Fractal antenna geometries was first classified by Mandelbrot in 1975 [1]. Fractal geometries are generated in an iterative pattern. Recursive generating methodology is involved which results in contours of intricate fine geometries. The interesting geometry of the fractals allow simultaneous reduction of the antenna radiating size. However, degradation of the antenna radiation pattern may occur and this has to be compromised with the objective of having compact structures.

Array antennas can have special characteristics compared to single antennas such as beam scanning, steering capability and high gain.

2. FRACTAL ARRAY GEOMETRIES

Most array antennas are designed with half wavelength spacing to avoid mutual coupling effect and the existence of grating lobes. Reducing the elements spacing can lead to an increase in the mutual coupling [2].

In this work, the Koch Island fractal geometry is employed by removing the Koch curve at each straight segment of the antenna radiating structure. The curve size depends on the fractal structure. The iterative generation process is repeated twice to form the first

0-7803-8129-7/03/$17.00 ©2003 IEEE.

and second iteration fractal array elements. The space-filling contours of fractals allow electrically large structures to occupy smaller area. Hence, antennas can be miniaturised and consequently the operating frequencies can be reduced.

The basic single patch antenna is designed at 1.575 GHz. The Koch Island fractal structure designed for the first fractal antenna has a 0.25 iteration factor. The Koch curve removed at the centre of each side is 25 % of the side length due to the 0.25 iteration factor. The procedure is then continued for the second iteration, i.e. for the second fractal antenna.

The antennas are named as follows:

ASCF: Two-element basic square patch array antenna
AFCF1: Two-element 1st iteration fractal array antenna
AFCF2: Two-element 2nd iteration fractal array antenna

All the designed antenna arrays are fed with CPW lines. The line is designed such that the input impedance is 50 ohm and the feed point on the fractal radiating patch is also the 50 ohm impedance location of a single patch antenna. Quarter wavelength lines are employed throughout the feed line length. The impedance calculation of the CPW line is performed with MathCAD software [3] using the formulations available in the literature [4].

3. EXPERIMENTAL INVESTIGATIONS

The antennas are implemented on the GML1000.06 microwave laminate [5] having relative permittivity = 3.05, loss tangent = 0.0009, substrate thickness = 1.524 mm, copper thickness = 0.035 mm and copper conductivity = 5.882 x 10^7 S/m. The antennas are fabricated using the standard photolithography and wet etching method. The measurements are then performed on the bench top AntennaLab set-up available at the Advanced Microwave Laboratory, Department of Radio Communication Engineering.

(a) ASCF antenna

The measurement of the ASCF antenna has been successfully carried out. The return loss response of the ASCF antenna is shown in Figure 1. The antenna resonates at 1.52 GHz with a good return loss of −25 dB. The corresponding voltage standing wave ratio, VSWR, is well below 1.5, indicating well-matched antenna at the input. The resonant frequency is lower than the desired operating frequency at 1.575 GHz. This is probably due to imperfect fabrication process available at the Electrical Process Laboratory, Faculty of Electrical Engineering. The −10 dB reflection bandwidth is approximately 9.3 % which is narrow. This is inherent with microstrip patch antennas. The 9.3 % bandwidth is broader than the corresponding single patch antenna [6].

The two port performance is measured by having a wideband log-periodic reference antenna provided by the manufacturer. The antennas are placed 500 mm apart. The frequency response plot showed a peak value of about −18 dB at the operating frequency. The far-field E and H-plane co-polarisation radiation patterns plot appear bi-directional, the former being shown in Figure 2. The pattern exhibits quite a broad beamwidth of 40^0. Cross-polarisations are at least 10 dB below that of co-polarisation patterns.

(b) AFCF1 antenna

The measurement of the AFCF1 antenna has been successfully carried out. The return loss response of the AFCF1 antenna is shown in Figure 3. The antenna resonates at 1.34 GHz with a good return loss of −18 dB. The resonant frequency is lower than that of the ASCF antenna. This value is much lower than the desired operating frequency at 1.575 GHz. The −10 dB reflection bandwidth is approximately 7.1 % which is narrower than that of the ASCF antenna. This is inherent with microstrip patch antennas. The 7.1 % bandwidth is still broader than the corresponding single patch antenna or the single first iteration fractal antenna [6].

The two port performance is similarly measured over a wideband log-periodic reference antenna placed 500 mm apart. The frequency response plot showed a peak value of about −20 dB at the operating frequency. The far-field E- and H-plane co-polarisation radiation patterns appear bi-directional, similar to that of the ASCF antenna. The former plot is given in Figure 4. The pattern exhibits quite a broad beamwidth of 40^0, similar to that of the ASCF antenna. Hence, both the ASCF and AFCF1 antennas are equally directive.

(c) AFCF2 antenna

The measurement of the AFCF2 antenna has been carried out. The return loss response of the AFCF1 antenna showed that the antenna resonates below 1.2 GHz. The resonant frequency is lower than that of the AFCF1 antenna. This value is much lower than the desired operating frequency at 1.575 GHz, indicating that the AFCF2 antenna is more compact at the same designed frequency of operation. Since the resonant frequency is below that of the AntennaLab setup frequency range, no return loss value can be recorded. Hence, no two port measurements are carried out on the AFCF2 antenna. However, the antenna is expected to have similar bi-directional far field co-polarisation patterns.

4. CONCLUSION

A set of simple fractal array antennas having two radiating elements has been designed and tested. In addition, a corresponding two-element square array antenna has also been designed and tested for comparison. The antennas are shown in Figure 5. The performance indices are tabulated in Table 1.

5. ACKNOWLEDGEMENTS

The authors would like to thank the Malaysian Government for funding the research, under UTM vote 72293.

6. REFERENCES

[1] J P Gianvittorio and Y Rahmat-Samii, "Fractal antenna: A Novel Antenna Miniaturisation Technique and Applications", *IEE Proc.-Microw. Antennas Propag.* Vol. 44, No. 1, February 2002.

[2] R R Ramirez, L Jofre and F de Flaviis, "Small Size Single and Multiband Antenna Arrays with Diversity Capabilities for Portable Antennas", *IEEE Trans* 2001.

[3] MathCAD 2000 Reference Manual, Mathsoft Inc. Massachusetts, USA, 1999.

[4] Constantine A. Balanis, "*Antenna Theory: Analysis and Design* ", Second Edition, John Wiley and Son, Inc., New York, USA, 1997.

[5] http://www.gil.com

[6] Noor Asniza Murad, Performance of Fractal Structure in Planar Array Antenna Design, Masters Dissertation, Universiti Teknologi Malaysia, March 2003.

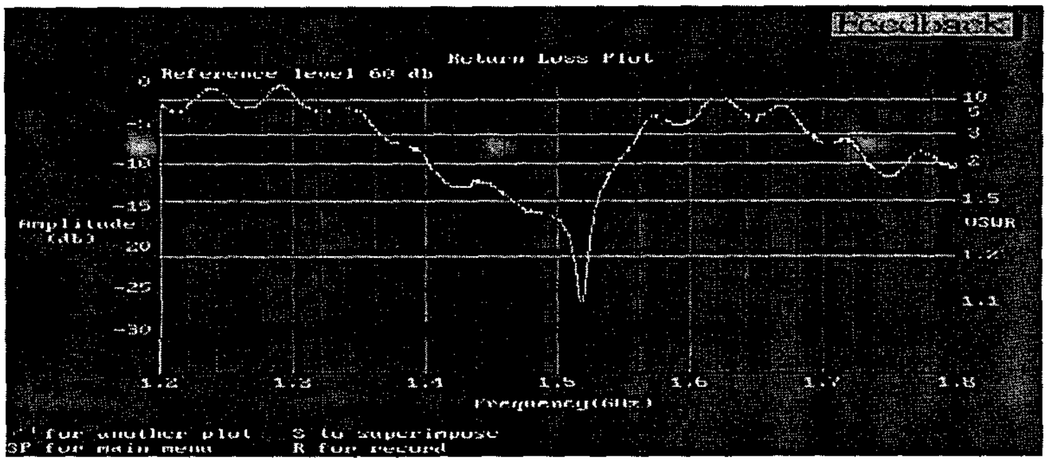


Fig.1 Measured Return Loss Response of the ASCF Antenna.

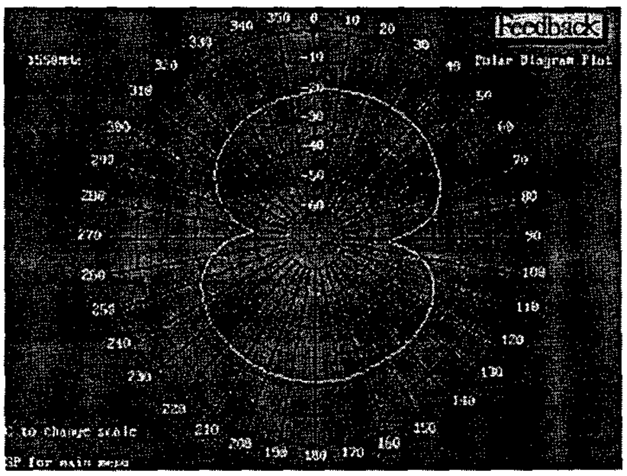


Fig. 2 Measured E-Plane Co-Polarisation Radiation Pattern of the ASCF Antenna.

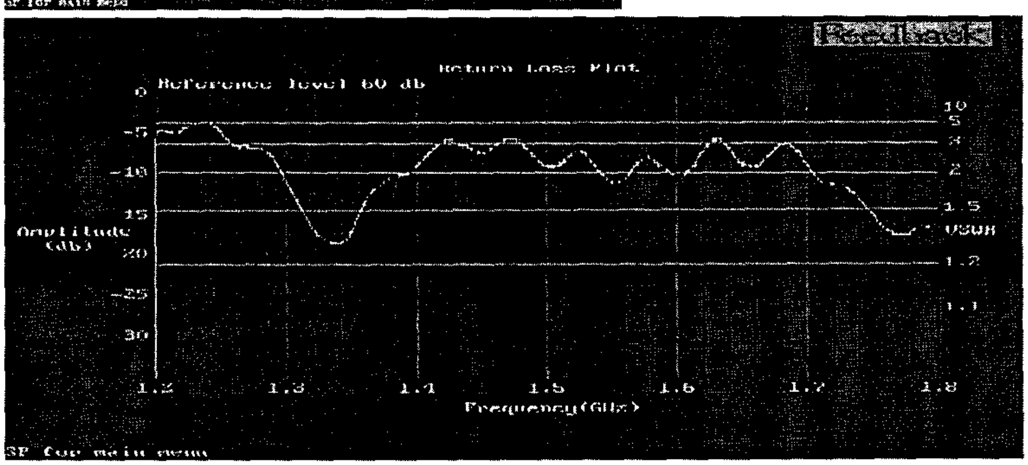


Fig.3 Measured Return Loss Response of the AFCF1 Antenna.

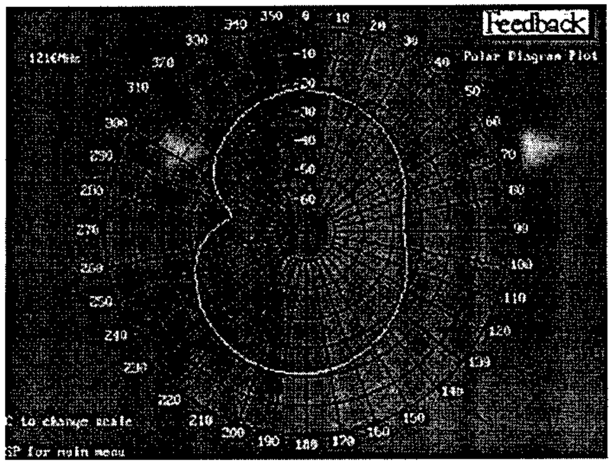
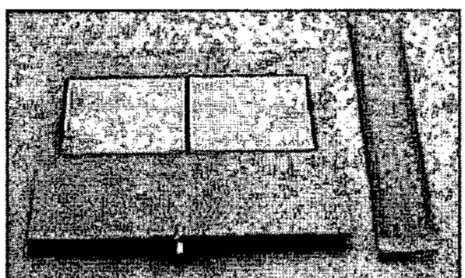


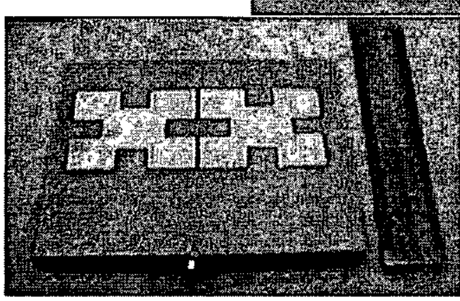
Fig. 4 Measured E-Plane Co-Polarisation Radiation Pattern of the AFCF1 Antenna.

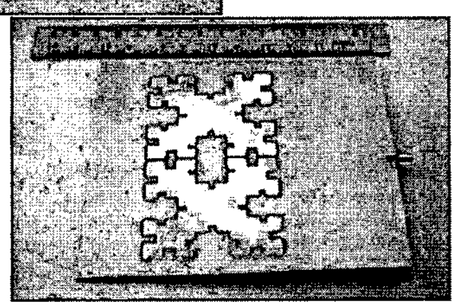
Table 1 Performance Indices of the ASCF, AFCF1 and AFCF2 Antennas.

Antenna	f_0,GHz	$\|S_{11}\|$, dB	BW, %	HPBW, ^{0}
ASCF	1.52	-25.0	9.3	40
AFCF1	1.34	-18.0	7.1	40
AFCF2	<1.20	Not available	Not available	Not available

(a) ASCF antenna







(b) AFCF1 antenna **(c) AFCF2 antenna**

Fig. 5 Fabricated CPW Fed Antenna Array Structures.