Journal of Engineering and Applied Sciences 13 (17): 7266-7270, 2018
ISSN: 1816-949X

Design and Simulation of Square Based Fractal Slot Antennas for Wireless Applications

[1]Yaqeen Sabah Mezaal and [2]Seham Ahmed Hashim
[1]Department of Medical Instrumentation Engineering, Al-Esraa University College,
Baghdad, Iraq
[2]Department of Technical Electronic, Technical Instructors Training Institute,
Middle Technical University, Baghdad, Iraq

Abstract: New antennas derived from square fractal slot have been printed on the ground plane of FR4 substrate with straight line feed for single and dual-band operations. Antenna scaling factor and rotation parameters have been conducted in this study. All projected antennas have considerable small dimensions and remarkable frequency responses which can be employed in a lot of wireless schemes.

Key words: Printed antenna, square based fractal geometry, single and dual band responses, CST design and simulation

INTRODUCTION

Antennas are Electromagnetic (EM) devices that transmit and receive signals by means of radiation. They present numerous advantages such as simplicity of fabrication, light weight and cost effectiveness. These features make them extremely prevalent and good-looking for the microwave circuit researchers since the premature days they come into view. In various cases, if the antenna size is a noteworthy restriction, their huge dimensions can be improper to be integrated within many wireless schemes and devices (Ali, 2008a, b; Mezaal, 2016). Besides of these features, microstrip antennas suffer from narrow bandwidth. To overcome this drawback, slot structures with different shapes have been employed to design broadband/wideband printed antennas (Ali and Abdulkarim, 2013; Ali, 2011). Therefore, it looks logical to utilize a hybrid of these techniques; Fractal geometry and slot structure to design multiband antennas with enhanced resonant bandwidths (Chen *et al*., 2009; Sung, 2011; Mirzapour and Hassani, 2008).

A variety of fractal structures are adopted to construct compacted and multi-band antennas based on fractal distinctive features of self similarity and space filling (Werner and Ganguly, 2003).

By Jawad (2008a, b), a miniature microstrip patch antenna with unbalanced slits was employed as a receiver element for Global Positioning Systems (GPS). It can be integrated in many portable wireless systems. This antenna uses somewhat square microstrip patch resonator and single probe fed with dual pairs of orthogonal slits from the edge. It was found that this antenna in size has more diminutions with high-quality radiation characteristics essential for GPS system. The resultant circular polarization bandwidth with axial ratio ≤3 dB was within the requirements for this relevance. Also it has an average gain of 4.5 dB required for the GPS L1 wireless application.

By Saini and Agarwal (2017), a single band microstrip patch antenna for 5 G wireless application is stated. This proposed antenna is suitable for the millimeter wave frequency. The single band antenna consists of new H slot and E slot loaded on the radiating patch with 50 Ohm microstrip line feed. This single band antenna is simulated based on a Rogers RT5880 dielectric substrate. It shows the return loss -40.99 dB at 60 GHz millimetre wave 5 G wireless application presented.

By Dongre and Mishra (2016) microstrip antennas are presented to operate as single or dual-band device. It is based on rectangular resonator employing FR 4 substrate and coaxial feed. Square slot loading can been constructed to acquire dual band frequency response. The simulated S11 response for each antenna has reasonable performance and they are proper for GPS, GSM and Bluetooth applications. By Abdulkarim *et al.* (2013) Co-Planar Waveguide (CPW) printed slot antenna has been designed using FR4 substrate and single feed as dual-band circuit with improved bandwidths for wireless utilities. The slot structure is derived from 2nd order of

Corresponding Author: Yaqeen Sabah Mezaal, Department of Medical Instrumentation Engineering, Al- Esraa University College, Baghdad, Iraq

Peano fractal curve and applied to the two sides of a rectangular slot. The consequential antenna has 36×45 mm size that is appropriate for portable terminal uses. The design and analysis of the projected antenna are conducted by means of CST simulator.

By Ali *et al.* (2016), a new dual-band antenna for use in wireless applications has been investigated. It uses slot structure of the 2nd iteration of Cantor square fractal geometry printed on the ground plane of an FR4 substrate. Parametrical investigations were carried out to examine the outcomes of geometrical parameters on the antenna S11 responses. Simulated and measured results demonstrate that the antenna has high-quality dual-band response with a broad variety of resonant frequency ratio.

In this study, new antennas are simulated to operate as single or dual-band devices. Five antennas are modelled using CST EM simulator based on square fractal slot printed on FR4 substrate. The modelled antennas has reasonable sizes and satisfactory electrical specifications that are suitable for numerous fixed and handheld wireless systems.

MATERIALS AND METHODS

Basic antenna design: All the printed antennas are square slot based . All of these structures have dimensions of substrate (Wg×Lg) of 50×50 mm^2 with inner slot dimention (Ws×Ls) of 24×24 mm^2, single feed coupled beneath slot structure has been employed in the antenna design. The first projected slot antenna is shown in Fig. 1. This antenna is obviously rooted in Euclidian slot shape printed on the ground plane of FR4 substrate.

Th second printed slot antenna is obtained from adding four square slots to every corner of the antenna, each has a side length of 12 mm to produce the 1st iteration of fractal antenna topology as in Fig. 2.

To determine the compression of the designed antennas, these circuits should include absolute dimensions in terms of guided wavelength that can be calculated at the fundamental frequency (f) by Waterhouse (2003):

$$\lambda_g = \frac{c}{f\sqrt{\varepsilon_e}} \quad (1)$$

Where:

c = The light speed

ε_e = Effective dielectric constant

The value of ε_e in this study is evaluated by Waterhouse (2003):

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} \quad (2)$$

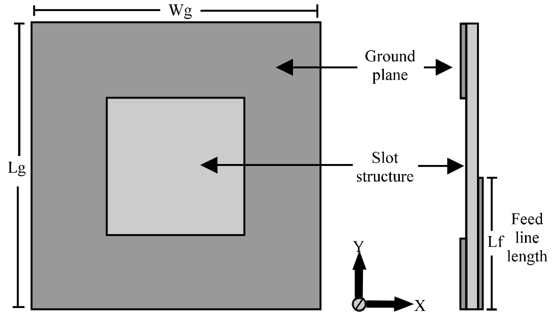

Fig. 1: Square based slot antenna (Antenna 1)

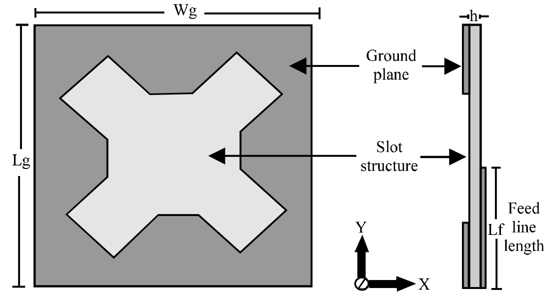

Fig. 2: 1st iteration of square based slot antenna (Antenna 2)

In this framework, the proposed antennas are simulated and verified using an FR4 substrate with a dielectric permittivity (ε_r) of 4.4 and a substrate thickness of 1.6 mm.

RESULTS AND DISCUSSION

All antenna designs have been modelled using Computer Simulation Technology (CST) software package. CST simulator has precise, capable computational solutions for EM design and investigation. It performs EM analysis using finite difference time domain technique.

For the proposed antenna depicted in Fig. 1, its performance is determined within the swept frequency range of 1-9 GHz using a substrate of 4.4 dielectric constant and 1.6 mm dielectric thickness with feed line lengths of 21-33 mm as shown in Fig. 3. It can be seen that the antenna offers a dual-band response with feedline length (Lf) of 23 mm which is suitable for WiMAX and satellite wireless applications at resonant frequencies of 3.6 and 8.3 GHz.

Figure 4 gives an idea about the return loss response for the illustrated antenna in Fig. 2. As it is noticeable from this Fig. 4, this antenna has a dual-band response when the feedline length is 33 mm at resonant

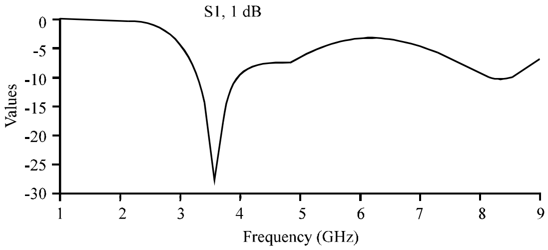

Fig. 3: Return loss response for antenna depicted in Fig. 1

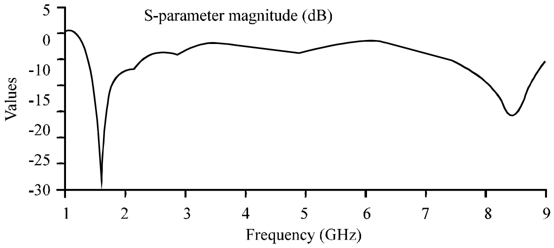

Fig. 4: Return loss response for antenna depicted in Fig. 2

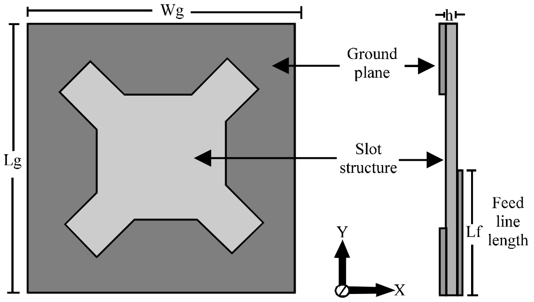

Fig. 5: The resultant antenna after the four square in the corner is scaled by 0.25 (Antenna 3)

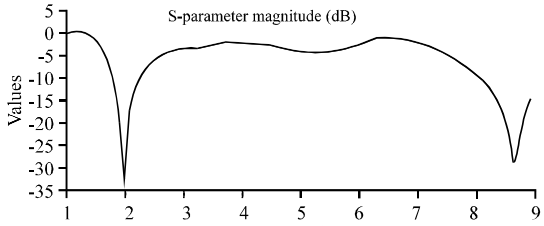

Fig. 6: The return loss response of antenna depicted in Fig. 5

frequencies of 1.6 and 8.5 GHz. This antenna is suitable for numerous wireless schemes like GPS, AWS and DCS applications.

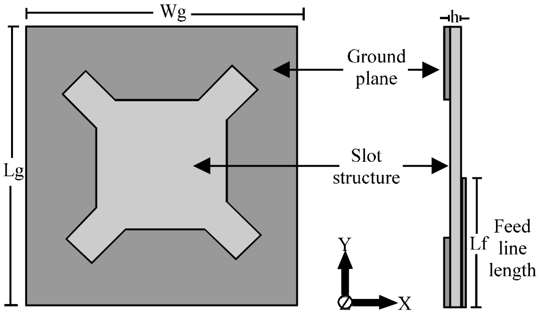

Fig. 7: The resultant microstrip antenna after the four square in the corner is scaled by 0.33 (Antenna 4)

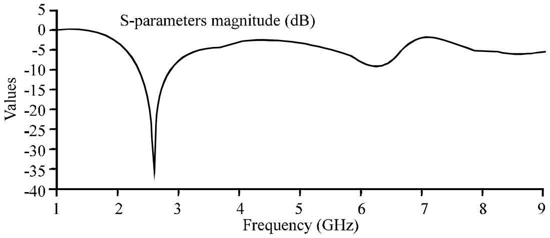

Fig. 8: The return loss response of antenna depicted in Fig. 7

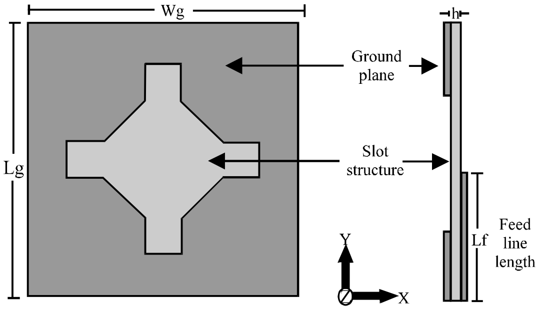

Fig. 9: The rotated antenna structure by 90° (Antenna 5)

Figure 5 explains other variation of simulated antenna after the four squares in the corner is scaled by 0.25. The return loss response of this designed antenna is depicted in Fig. 6. This device clearly exhibits dual-band response by using feedline length of 31 mm at operating frequencies of 2 and 8.7 GHz. It is suitable for DECT, PCS, G SM, PHS, WCDMA, UMTS I, IMT-2000 and WiMAX application. Figure 7 illustrates the 1st iteration fractal antenna after the four square in the corner is scaled by 0.33.

Accordingly, Fig. 8 illustrates the return loss response of antenna depicted in Fig. 7. As it can seen from this Fig. 8, the antenna offers a single band response at 2.6 GHz using feedline length of 27 mm which is proper for SDAR-S, Wi.Bro, Bluetooth ISM, WLAN, RFID, LTE, UMTS II, DMB and WiMAX applications.

Figure 10 shows the return loss response of the illustrated antenna in Fig. 9 by rotating the structure in Fig. 5 by 90°. As it can be seen from this response, the

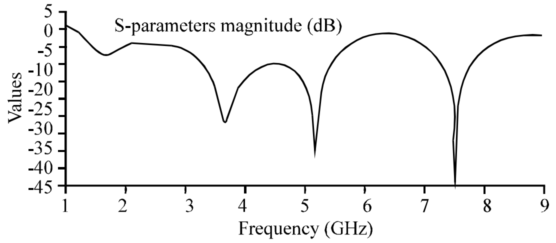

Fig. 10: The return loss response of antenna by rotating the structure by 90°

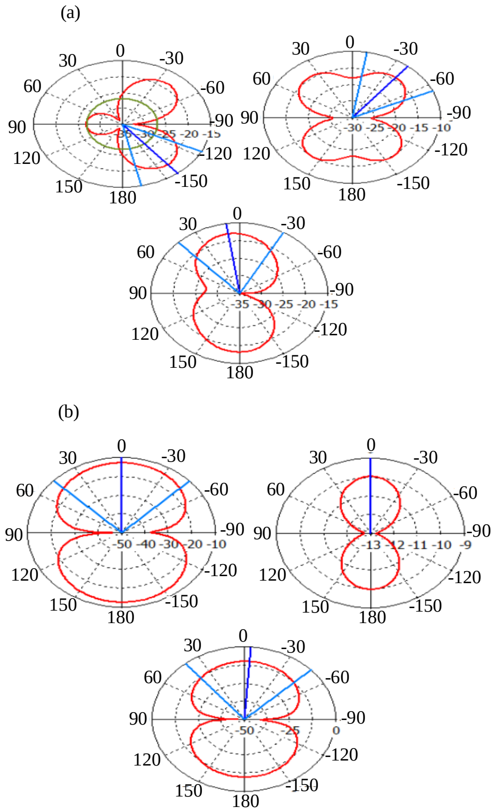

Fig. 11a, b): The simulated radiation patterns for the total electric field in the x-y plane, the x-z plane and the y-z plane at 3.6and 1.6 GHz

antenna offers dual-band response at centre frequencies of 4.4 and 7.5 GHz when the adopted feedline length is 35 mm. Based on these design frequencies, the rotated antenna by 90° is suitable for WLAN, WiMAX and Hiper-LAN applications.

Table 1 clarifies the simulated results of operating frequency, return loss, bandwidth range as well as the adopted feedline length for all previous five modelled antennas.

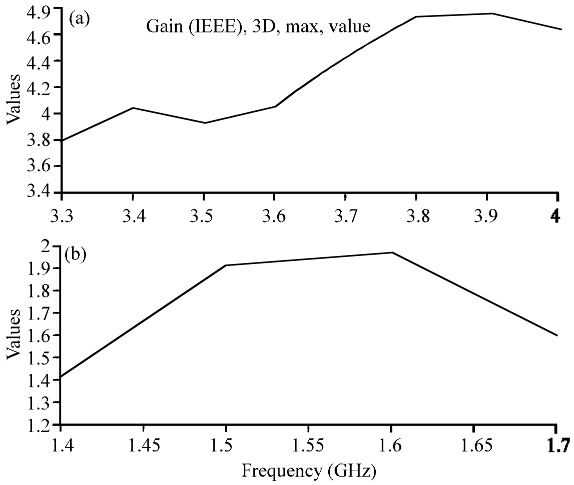

Fig. 12a, b): The peak gain values at 3.6 and 1.6 GHz

Table 1: Simulation results and details for all designed antennas in Fig. 1, 2, 5, 7, 9

Antenna #	Feed length	f1 (GHz)	f2 (GHz)	S11 (f1) dB	S11 (f2) dB	BW1 range (GHz)	BW2 range (GHz)
1	23	3.6	8.3	-27.8	-11	3.26-4	8-8.5
2	33	1.6	8.5	-28.5	-16	1.47-1.81	8-8.77
3	31	2	8.7	-32.3	-29	1.8-2.3	8.1-9.5
4	27	2.6	-	-35.6	-	2.34-2.8	-
5	35	4.4	7.5	-35.7	-44.5	3.3-5.5	7.3-7.8

**

Figure 11a and b explains the simulated far field radiation patterns for the total electric field in the x-y plane, the x-z plane and the y-z plane at 3.6 and 1.6 GHz for antennas 1 and 2, respectively. For all radiation patterns, the x-y plane (θ = 90°, φ is variable), the x-z plane (φ = 0°, θ is variable) while in the y-z plane (φ = 90°, θ is variable). All of them are fitting for WLAN applications.

The IEEE gain magnitudes in the single band have been computed in Fig. 12a and b for the Antennas 1 and 2. For Fig. 12a, peak gain is plotted as large as 4.8 dBi. While for Fig. 12b the highest gain is 2 dBi. These gain magnitudes are adequate for mainly communication services in use within these design frequencies.

CONCLUSION

In this study, a fractal square based antennas are presented to produce single and dual-band frequencies for different wireless applications. Firstly, square based slot antenna is investigated to operate as dual-band antenna. Then, the second printed slot antenna is obtained from adding four square slots to every corner of the antenna, each has a side length of 12 mm to produce the first iteration of fractal antenna structure operating also with dual-band response.

Other variation investigations of first iteration of fractal antenna are carried after the four squares in the corner is scaled by 0.25 and 0.33. Their S11 responses are found to be dual and single band responses for each of them, respectively. The last simulated design was by rotating the first iteration of fractal antenna by 90° to operate as dual-band device. All five simulated antennas have considerable responses at strategic resonant frequencies that are fitting for a variety of the recently communication systems. Also, their substrate sizes have good level of compactness with 5 cm by 5 cm for all designed antennas that can be interfaced within various wireless systems.

REFERENCES

Abdulkarim, S.F., A.J. Salim, J.K. Ali, A.I. Hammoodi and M.T. Yassen *et al.*, 2013. A compact Peano-type fractal based printed slot antenna for dual-band wireless applications. Proceedings of the IEEE International Conference on RF and Microwave (RFM'13), December 9-11, 2013, IEEE, Penang, Malaysia, ISBN:978-1-4799-2214-7, pp: 329-332.

Ali, J., S. Abdulkareem, A. Hammoodi, A. Salim and M. Yassen *et al.*, 2016. Cantor fractal-based printed slot antenna for dual-band wireless applications. Intl. J. Microwave Wirel. Technol., 8: 263-270.

Ali, J.K. and S.F. Abdulkareem, 2013. A circle-based fractal slot antenna for dual-band wireless applications. Proceedings of the 13th IEEE Conference on Mediterranean Microwave Symposium, MMS Vol. 13, September 2-5, 2013, IEEE, Saida, Lebanon, pp: 1-6.

Ali, J.K., 2008a. A new compact size microstrip patch antenna with irregular slots for handheld GPS application. Eng. Technol., 26: 1-7.

Ali, J.K., 2008b. A new fractal multiband microstrip patch antenna design for wireless applications. Univ. Babylon J. Sci., 16: 555-573.

Ali, J.K., 2011. A new dual band E shaped slot antenna design for wireless applications. Proceedings of the Progress in Electromagnetics Research Symposium, September 12-16, 2011, South China Normal University, Suzhou, China, pp: 1258-1261.

Chen, W.L., G.M. Wang and C.X. Zhang, 2009. Bandwidth enhancement of a microstrip-line-fed printed wide-slot antenna with a fractal-shaped slot. IEEE. Trans. Antennas Propag., 57: 2176-2179.

Dongre, V. and A.K. Mishra, 2016. Design of single band and dual band microstrip antennas for GSM, GPS and Bluetooth applications. Proceedings of the 2016 International Conference and Workshop on Electronics Telecommunication Engineering (ICWET'16), February 26-27, 2016, IET, Mumbai, India, ISBN:978-1-78561-307-4, pp:1-6.

Mezaal, Y.S., 2016. New compact microstrip patch antennas: Design and simulation results. Indian J. Sci. Technol., 9: 1-6.

Mirzapour, B. and H.R. Hassani, 2008. Size reduction and bandwidth enhancement of snowflake fractal antenna. IET. Microwaves Antennas Propag., 2: 180-187.

Saini, J. and S.K. Agarwal, 2017. Design a single band microstrip patch antenna at 60 GHz millimeter wave for 5G application. Proceedings of the 2017 International Conference on Computer, Communications and Electronics (Comptelix'17), July 1-2, 2017, IEEE, Jaipur, India, ISBN:978-1-5090-4709-3, pp: 227-230.

Sung, Y.J., 2011. Bandwidth enhancement of a wide slot using fractal-shaped Sierpinski. IEEE. Trans. Antennas Propag., 59: 3076-3079.

Waterhouse, R.B., 2003. Microstrip Patch Antennas: A Designer's Guide. Kluwer Academic Publishers, Dordrecht, the Netherlands, ISBN:1-4020-7373-9, Pages: 423.

Werner, D.H. and S. Ganguly, 2003. An overview of fractal antenna engineering research. IEEE. Antennas Propag. Mag., 45: 38-57.