The behavior of a CPW-Fed miscrostrip hexagonal patch antenna with H-Tree Fractal slots

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Abstract— **In this paper, a CPW-Fed microstrip hexagonal patch antenna is designed using the relationship between the design of microstrip circular and hexagonal patch antennas. Also, the setup of H-Tree fractal slot on the resonant element allows obtaining lower resonant frequencies, more -10dB bandwidths, more resonant frequencies and important gains.**
The simulation was performed with PCCAD 5.0 and FEKO 6.3.

Keywords: *antenna design, Fractal antennas, H-Tree Fractal structure, hexagonal antenna.*

I. INTRODUCTION

With the proliferation and miniaturization of telecommunications systems and their integration in restricted environments, such as smart-phones, tablets, and other embedded systems. The design of compact multi-band and broadband antennas with high gains and a good efficiency becomes a necessity.
To design this kind of antennas, a lot of techniques are used:

1-Designing multi-band antennas operating in several frequencies bands. Several studies have been made for that by using fractal geometries or adding slots to the radiating elements [1-7].

2-Designing UWB antennas operating in the frequencies bands exceeding 500MHz or having a fractional bandwidth of at least 0.20. The UWB wireless communication occupies a bandwidth from 3.1 to 10.6 GHz (based on the FCC "Federal Communication Commission") [8-17].

3-Designing antennas with a broad-band behavior, a high gain, and a good efficiency by using some special materials [18-21].

One of the interesting techniques used to design miniaturized antennas with multi-band and broad band behavior is the fractal geometry, because it's a simple technique based on the auto-similarity, the most known techniques used are: MINKOWSKI, KOCH, Tree, HILBERT, SIERPINSKI, APOLLONIUS circles, CANTOR Set… [16],[22-23].

In this paper, we study the behavior of a CPW-fed hexagonal antenna with H-Tree Fractal slots versus the iteration numbers. The simulation is done by FEKO 6.3 based on the Method of the Moment (MoM) [24].

II. ANTENNA DESIGN

A- The design of the hexagonal patch antenna

For designing the hexagonal patch antenna, First circular patch antenna design must be introduced because these two antennas are closely related to each other. According to BALANAIS [16], the fundamental resonance frequency of a circular patch antenna is given by the equation (1)

$$f_r = \frac{C.X_{mn}}{2.\pi.a_e.\sqrt{\varepsilon_r}} \qquad (1)$$

Where f_r is the resonant frequency of the patch, X_{mn} = 1.8412 for the dominant mode TM_{11}, C is the velocity of light in free space, ε_r is the relative permittivity of the substrate and a_e is the effective radius of the circular patch and which given by the equation (2)

$$a_e = a.\left[1 + \frac{2.h}{a.\pi.\varepsilon_r}\left(\ln\left(\frac{\pi.a}{2.h}\right) + 1.7726\right)\right]^{1/2} \qquad (2)$$

Where a is the radius of the circular patch and h is the height of the substrate.

The equation (1) can be applied for designing a hexagonal microstrip patch antenna by relating the areas of the circular and hexagonal patches as shown in the equation (3)

$$\pi.a_e^2 = \frac{3\sqrt{3}}{2}e^2 \qquad (3)$$

Where e is the side length of the hexagonal patch antenna as shown in the figure 1.

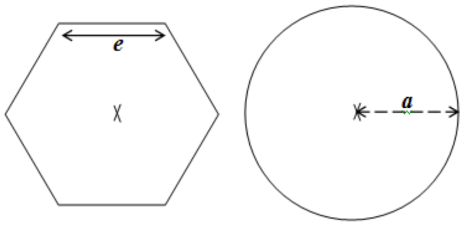


Fig. 1. The hexagonal structure and its circular equivalent structure

A simple hexagonal microstrip patch antenna is designed on a FR-4 substrate with dielectric constant ε_r=4.4, thickness h=1.6mm and size of 50mmx50mm. The side length e of the hexagonal patch antenna has been calculated using the previous equations (1)-(3) and it is found that e=15mm for the central frequency f_0=3.07GHz.
We found also that a=13.15mm and a_e=13.6mm.
As shown in figure 2, for the equivalent miscotrip circular patch antenna with the radius a=13.15, the resonance frequency is 3.07GHz. This result is exactly what we found previously. This simulation was performed with the PCCAD 5.0 based on the Transmission Lines and Cavity Models.

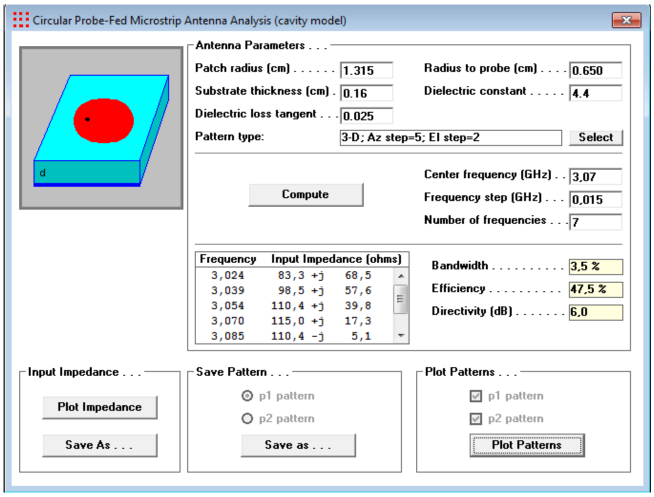
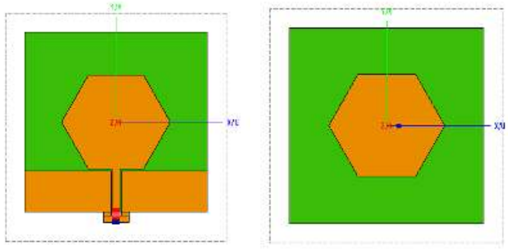


Fig. 2. Simulation with PCCAD 5.0

B- The design of the CPW-Fed hexagonal patch antenna

As demonstrated in several studies, the CPW-Feeding allows having a wide bandwidth comparing with the probe feeding [6][22]. The same microstrip hexagonal patch antenna studied in section II-A has been simulated with the CADFEKO 6.3 Solver which based on the Method of the Moment. Two configurations were simulated; the first one has been fed by a Coplanar Wave Guide the second one by a probe line (Figure 3). The figure 4 shows the difference between the S_{11} parameter versus the frequency for the two configurations. We confirm that the CPW-Feeding allows having a wide bandwidth. In the next steps, we adopt this kind of feeding for the miscrostrip hexagonal patch antenna.



(a) (b)

Fig. 3. The CPW-Fed (a) and the probe Fed (b) miscrostrip hexagonal patch antenna

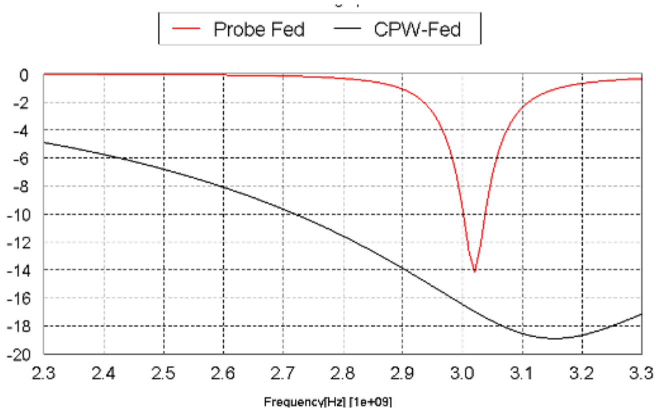


Fig. 4. The S_{11} parameter versus the frequency for the CPW-Fed and the probe Fed miscrostrip hexagonal patch antennas

The figure 5, shows the parameters of the CPW-Fed Hexagonal patch antennas with: W_s=L_s=50mm, e=15mm, W_f=2.1mm, g=0.3mm, H_g= 12mm, h=1.6mm, ε_r=4.4.

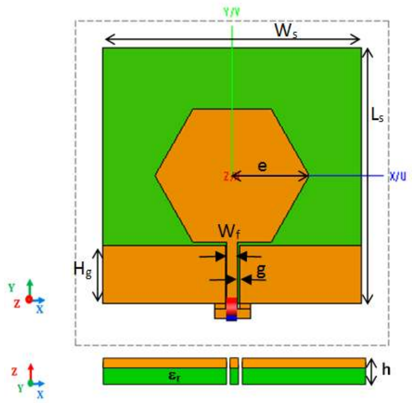
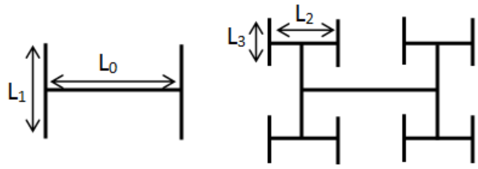


Fig. 5. The geometry of the CPW-Fed miscrostrip hexagonal patch antenna

C- The setup of the H-Tree Slots on the CPW-Fed hexagonal patch antenna

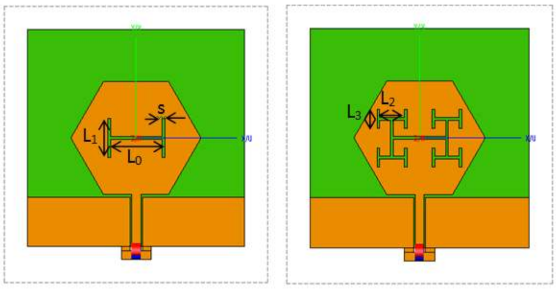
As shown in figure 6, the H-Tree is a fractal structure generated using the letter "H" with $L_i = \frac{L_0}{\sqrt[i]{2}}$ [26].



(a) 1st iteration (b) 2nd iteration

Fig. 6. The two first iterations of the H-Tree

The two first iterations of the H-tree fractal structure has been setup as slots on the Hexagonal patch antenna. The section of the slots is s=0.6mm and L_0=12.5mm (Fig. 7).



(a) 1st iteration (b) 2nd iteration

Fig. 7. The CPW-Fed microstrip Hexagonal patch antennas with the two first iterations of the H-Tree fractal slots

III. RESULTS AND DISCUSSIONS

A- The CPW-Fed microstrip Hexagonal patch antenna

For the CPW-Fed microstrip Hexagonal patch antenna, the analysis of the S_{11} parameter (Fig.8) shows that, for the band of 1 – 8GHz, the antenna have two resonant frequencies f_{r1}=3.07GHz anf f_{r2}= 5GHz, the -10dB bandwidth is 3.06GHz (2.7 – 5.76GHz).

Also, the total gain of this antenna varies between 1.8dB and 5.8dB in the -10dB bandwidth (Fig. 9). The figure 10 shows the 3D Total gains for the two frequencies 2.7 and 5 GHz.

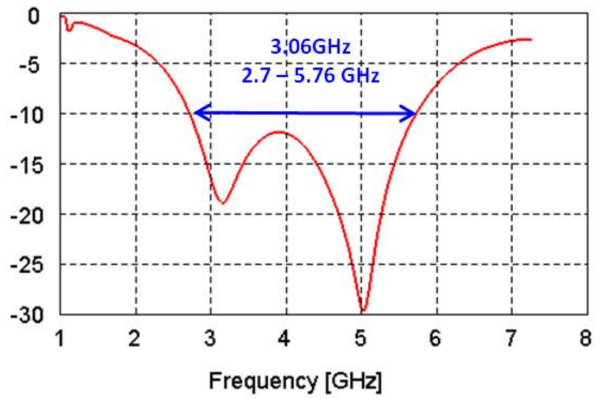


Fig. 8. The simulated S_{11} versus the frequency of the CPW-Fed microstrip Hexagonal patch antenna

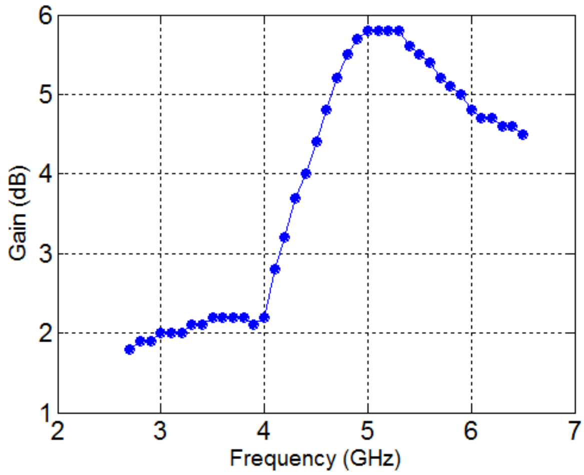
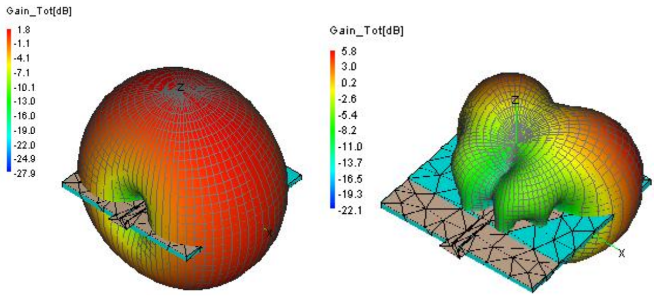


Fig. 9. The simulated Total gain versus the frequency of the CPW-Fed microstrip Hexagonal patch antenna



(a) f=2.7GHz (b) f=5GHz

Fig. 10. The simulated 3D-Total gain for the frequencies 2.7GHz and 5GHz

B- The CPW-Fed microstrip Hexagonal patch antenna with H-Tree fractal slot

The setup of the H-Tree first iteration slot allows having 4 resonant frequencies: f_{r1}=2.66GHz, f_{r2}=3.05GHz, f_{r3}=3.95GHz and f_{r4}= 4.88GHz, we note that the first resonant frequency is lower than the first resonant frequency obtained with the hexagonal patch antenna without the slot. Also, the two -10dB bandwidths are 810MHz (2.45 – 3.26 GHz) and 1.92GHz (3.7-5.62GHz). (Fig. 11)

The setup of the H-Tree Second iteration slot allows having 3 resonant frequencies f_{r1}=1.92GHz, f_{r2}=3.57GHz and f_{r3}=5.65GHz, we note that the first resonant frequency is lower than the first resonant frequency obtained with the antenna with the H-Tree first iteration slot. Also, the three -10dB bandwidths are 100MHz (1.88-1.98GHz), 950MHz (2.9-3.8GHz) and 1.75GHz (4.4- 6.15GHz). (Fig. 11)

We observe also that for the antenna with the H-tree first iteration in the band of 2.6-3.7GHz, the gain is lower than the gains of simple and the H-tree second iteration antennas and higher in the band of 3.7 – 4.9GHz. for the antenna with the H-Tree second iteration in the band of 2.6 -3.5GHz and for the band of 4.8 – 6GHz, the gain is higher than the gains of simple and the H-tree first iteration and lower in the band of 4 – 4.8GHz. (Fig 12).

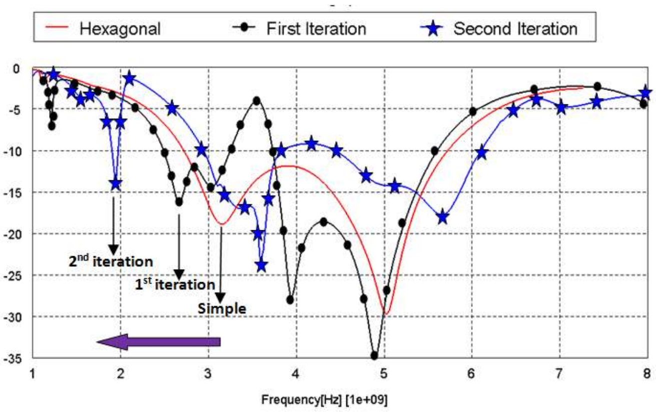


Fig. 11. The simulated S_{11} of the Hexagonal patch antenna and for the two first iterations of H-Tree slotted antennas

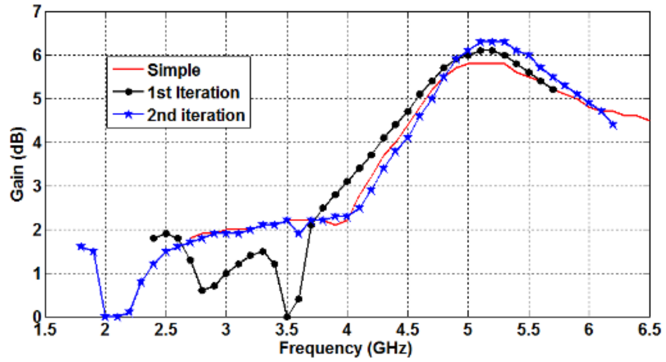


Fig. 12. The simulated Gain of the Hexagonal patch antenna and for the two first iterations of H-Tree slotted antennas

IV. CONCLUSION

In conclusion, the design of the CPW-Fed microstrip hexagonal patch antenna can be based on the methodology of design of the CPW-Fed microstrip circular patch antenna. Also, the setup of H-Tree fractal slot on the resonant element allows obtaining lower resonant frequencies, more -10dB bandwidths, more resonant frequencies and important gains.

A realization and practical measurements will be done in the next works to confirm those important results.

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