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Research Article

Triple Frequency Fractal Patch Structure Antenna for C Band Applications

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Abstract: In this study, a triple frequency fractal triangular shape microstrip patch antenna is presented for C band applications. The proposed antenna comprises of two triangular shape patches with two triangular slots and excited by a 50 Ω microstrip transmission line. The antenna excites three separate resonant modes where lower resonant mode of the antenna has an impedance bandwidth (VSWR<2) of 50 MHz (5.64-5.69 GHz), middle resonant modes impedance bandwidth 140 MHz (6.47-6.61 GHz) and the upper resonant mode impedance bandwidth of 140 MHz (7.59-7.73 GHz). It has achieved stable radiation pattern in the operating frequency band. The proposed fractal triangular patch antenna is presented and discussed in details.

Keywords: C band, fractal, multi frequency, patch antenna, triangular

INTRODUCTION

Antennas are very significant in the area of wireless communications and the Microstrip Patch Antenna (MPA) is one of the most popular and widely used in this field. Indeed, the MPAs have attracted so much research interest, due to their light weight, compatibility, low-profile, ease of fabrication, multi-frequency capability and low cost. Other merits include ease of integration with other kinds of Microwave Integrated Circuits (MICs) on the same substrate and capability of being deployed for both linear and circular polarizations. However, MPAs have such disadvantages as low power handling capability, low gain and narrow BW. Many techniques have been developed to overcome these limitations (Wong, 2004). Now a day's wireless communication system requires antennas that have large bandwidth, multi-frequency and fewer dimensions than existed before. Various types of multiband antenna can be made depending on the idea of fractal geometry because of proving itself the Sierpinski as an attractive and excellent multiband antenna. An antenna has multiband and ultra-band characteristics on account of being self-similarity of fractal geometry (Garg *et al*., 2001; Puente-Baliarda *et al*., 1998) whereas miniaturization of antenna is constructed with the space filling properties (Khan *et al*., 2008; Lule and Babij, 2004). Fractal hexagon shape has been evaluated and found appropriate for multiband usage (Gianvittorio and Rahmat-Samii, 2002; Tang and Wahid, 2004). Circular microstrip fractal antenna has also been constructed ultra wide bandwidth reduced size using self-similarity and space filling characteristics. The antenna shows the low backscattering and radiation pattern approaches to Omni-directional (Kumar and Malathi, 2010; Samsuzzaman *et al*., 2012a). The microstrip triangular patch searches various applications with many useful MIC components such as circulators, resonators and filters. The triangular patches have been read practically and theoretically. They are got to deliver radiation properties similar to those of rectangular patches with a small size. In this study, an effort is performed to design a triangular fractal antenna of effective radiation, intact size and multiband properties. It can be seen that greater demand is created by means of quick growth of wireless communications and electronics for wireless devices that can obey different rules at different standards. It also the paved the way for wide usage of mobile phones in modern society resulting in mounting concerns surrounding its harmful radiation (Faruque *et al*., 2011, 2012a, b; Islam *et al*., 2010a). The process for decreasing the size of microstrip patch antenna are reported (Azim *et al*., 2012; Habib and Islam, 2012; Islam *et al*., 2010b; Tiang *et al*., 2011) vastly and include capacitive loading (Rowell and Murch, 1997; Samsuzzaman *et al*., 2013), LC resonator (Lui and Murch, 2001), configuration (Islam *et al*., 2009), reactive loading (Ullah *et al*., 2012). However, this process deals with antenna bandwidth or antenna efficiency to achieve the decrease in antenna size. Different processes for constructing multiband microstrip patch antennas have been disclosed such as including parasitic elements (Cho *et al*., 2005;

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Mobashsher *et al*., 2011) to make an additional resonant frequency or including more radiating elements shared with similar feed and ground (Rowell *et al*., 2006; Samsuzzaman *et al*., 2012b). This process compulsory extend the physical size to make the multiband properties. There is dealing between number of using bands and antenna size. Multiband resonance frequency is constructed and operating by balancing the number of turns of the spiral AMC ground plane (Nashaat *et al*., 2009).

In this study, the authors target is to achieve multiband characteristics antenna from fractal shape patch. By selecting shapes and dimensions of these triangular slots properly, good triple frequency impedance bandwidths and suitable radiation characteristics for use in C-band (4-12 GHz) applications can be obtained. The effects of the embedded slots to the resonance have studied. The proposed antenna not only has good triple frequency operating performance and stables radiation pattern but also a simple structure and compact size. The detailed design and simulation results for the proposed antenna are demonstrated in this study.

MATERIALS AND METHODS

Antenna design architecture: Figure 1 shows the Microstrip Patch Antenna (MPA) configuration, including a dielectric substrate located between a radiating patch and a ground plane. Generally, the patch is prepared of conducting material such as gold or copper in any shape. On the dielectric substrate, the feed lines and radiating patch are usually photo-etched. The microstrip patch antenna analysis is represented by some models such as the transmission line model, cavity model, full wave model and characteristic mode. The cavity model is more accurate and gives a good physical insight thus very complex compared to the transmission line model that is the simplest of all models and less accurate. The characteristic mode is typically performed on electrically small to intermediate size antennas for simplicity (Balanis, 2012).

However, the full wave model is the most accurate and complex of the models and can analyse single elements, arbitrary shaped elements and infinite antenna arrays. The transmission line model is used in this study because of its simplicity to implement and its output good performance in antenna designs in terms of efficiency and return loss and also it is well suited for MPAs design. By choosing operating frequency f and a substrate with the required permittivity ϵ_r and also defining the substrate thickness h, the design starts. Based on the transmission line model, the length L and width W of the patch are calculated as (Balanis, 2012):

$$W = \frac{c}{2f_o}\sqrt{\frac{\varepsilon_r+1}{2}} \tag{1}$$

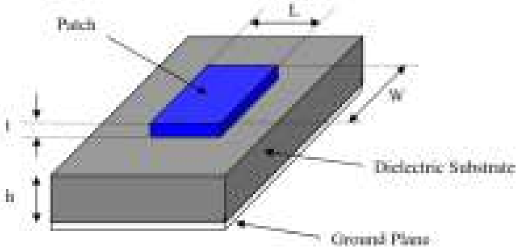


Fig. 1: Structure of MPA

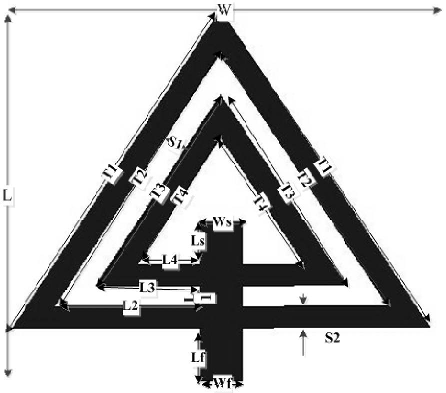


Fig. 2: Proposed antenna geometry

$$L = \frac{c}{2f_o\sqrt{\varepsilon_e}} - 2\Delta l \tag{2}$$

where,

L = The length of the patch
W = The width of the patch
f_o = Target resonance frequency
c = The speed of light in a vacuum and the effective dielectric constant can be calculated by the equation:

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r+1}{2}\sqrt{\left(1+\frac{10h}{W}\right)} \tag{3}$$

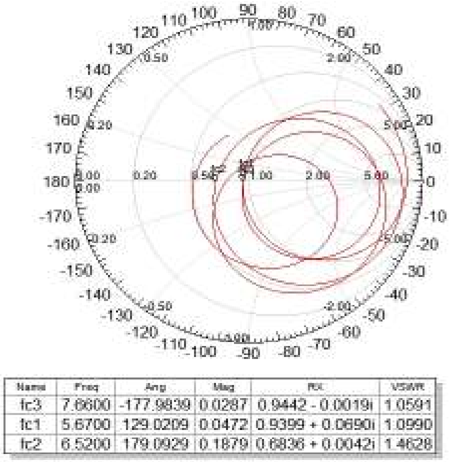
where,

h = The thickness of the substrate
ε_r = The dielectric constant of the substrate

Because of the fringing field around the periphery of the patch, electrically the antenna looks larger than its physical dimensions. Δl takes this effect in account and can be expressed as:

$$\Delta l = 0.412h\frac{(\varepsilon_r+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_e-0.258)(\frac{W}{h}+0.8)} \tag{4}$$

The geometry of the proposed antenna is portrayed in Fig. 2. The antenna consists of two triangle slot with two triangular patches which are connected with a microstrip line. The slot and tuning stub are printed on the opposite side of a Rogers/RT Duroid 5870 substrate



Name	Freq	Ang	Mag	RX	VSWR
fc3	7.6600	-177.9839	0.0287	0.9442 - 0.0019i	1.0591
fc1	5.6700	129.0209	0.0472	0.9399 + 0.0690i	1.0990
fc2	6.5200	179.0929	0.1879	0.6836 + 0.0042i	1.4628

Fig. 3: Smith chart of the proposed antenna

Table 1: Parameters of the proposed antenna

Parameter	Value (mm)	Parameter	Value (mm)
L	30	S1	2
W	40	S2	2
Ws	4		
s	4	W_{Gnd}	40
Wf	4	L_{Gnd}	35
Lf	5	T4	14.42
T1	36.05	L1	2
T2	28.84	L2	18
T3	21.63	L3	14
L4	10	L5	6

of thickness 1.575 mm with low dielectric constant 2.33 and less tangent loss. A SMA connector that contains 50 Ω is conducted at the end of antenna feeding line for input Radio Frequency signal. The feed position is also important to achieve the desired impedance bandwidth. Figure 2 represents the input impedance of three resonance frequency by using smith chart where VSWR<2. By properly selecting the slot and tuning stub, a good impedance bandwidth with multiband characteristics is achieved. The essential parameter specifications for the design of the proposed microstrip antenna are arranged as in Table 1 and Fig. 3.

RESULTS AND DISCUSSION

High frequency electromagnetic solver HFSS is applied to explore and optimize the performance of the proposed patch antenna. As far as the electric features are concerned, simulated VSWR values from 5.5 GHz up to 8 GHz are depicted in Fig. 4. By setting the operating bands to the frequency ranges where VSWR = 2, it turns out that the antenna has an evident triple frequency behaviour. From the simulated data, one can notice that the project requirements in terms of impedance matching are fully satisfied at centre frequency 5.67, 6.52 and 7.66 GHz, respectively. The impedance bandwidth of (VSWR<2) 50 MHz ranges from 5.64 to 5.69 GHz, 140 MHz from 6.47 to 6.61 GHz and 140 MHz from 7.59 to 7.73 GHz, respectively are clearly obtained.

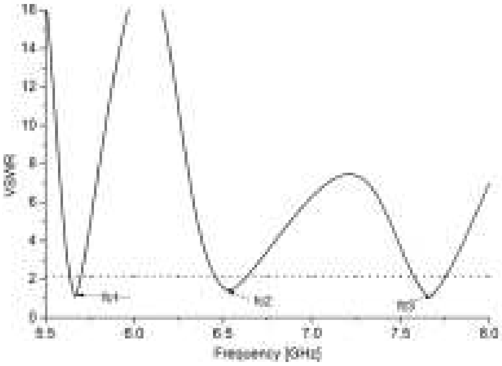


Fig. 4: VSWR values against frequency

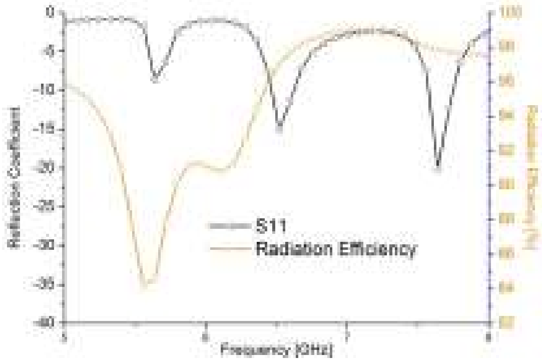
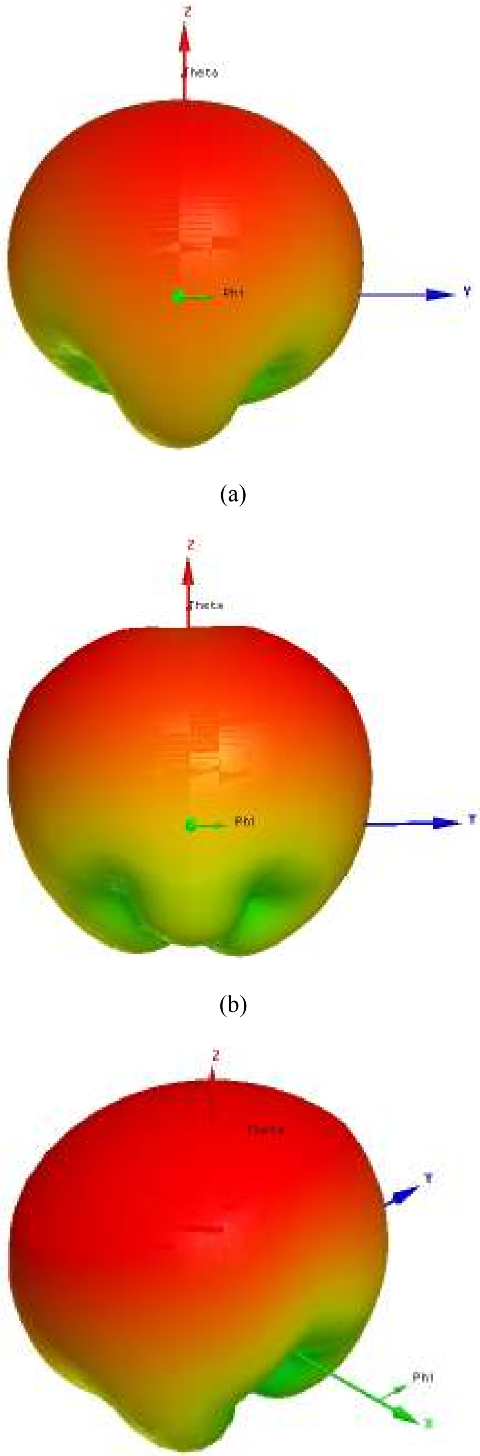


Fig. 5: Radiation efficiency with frequency

The radiation efficiency of the proposed shape antenna at difference band is shown in Fig. 5. Average radiation efficiency of the different band is 85.78, 97.30, 98.80 and 95.66%, respectively.

As for the radiation properties, Fig. 6 give an overview of the antenna behaviour. More specifically, Fig. 6a shows the three-dimensional total gain radiation pattern of the optimized antenna at fc1 = 5.67 GHz. As expected from the surface current analysis, the antenna behaves as a standard quarter-wave monopole with anomnidirectional behaviour along the H-plane, while a minimum appears in the z-direction. When the operating frequency increases to fc2 = 6.52 GHz Fig. 6b, the antenna radiates differently and it does not exhibit anymore the null along the vertical direction, but it mostly radiates along the x-axis because of the modification of the active region (i.e., the slanted sides vs. the triangular slot). Although the radiation pattern in the H-plane turns out to be slightly compressed along the y-direction, it does not present any minima, still making the antenna suitable for communication applications. Figure 6c shows the three-dimensional total gain radiation pattern of the optimized antenna at fc3 = 7.66 GHz. As expected from the surface current analysis, the antenna behaves as a standard quarter-wave monopole with an omnidirectional behaviour along the H-plane, while a minimum appears in the z-direction.



(a)

(b)

(c)

Fig. 6: Radiation pattern of the proposed shape antenna at a) 5.67 GHz b) 6.52 GHz c) 7.66 GHz

CONCLUSION

A triple frequency fractal triangular shape microstrip patch antenna are demonstrated for C band applications. Return loss of -29.69, -15.12 and -7.82 dB, bandwidth 50, 140 and 140 MHz are obtained at three resonant frequencies 5.67, 6.52 and 7.66 GHz, respectively. These simulated results are found reasonably good. The average radiation efficiency of the antenna for the different band is 85.78, 97.30, 98.80 and 95.66%, respectively. Since the antenna layout is simple and straightforward, so fabrication is more easier.

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