A New Compact Microstrip Antenna for WSN Applications

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***Abstract* – We propose a new dual-band microstrip antenna using compact quasi-fractal resonator with a ladder-shaped slot at a fundamental frequency around 2.45 GHz for Wireless Sensor Network (WSN) appliances. It was constructed using one layer of FR4 substrate with double via ports feeds to function as dual-band at 2.45 and 2.95 GHz respectively. This antenna has compact substrate size (31 mm x 31 mm) with feasible radiation performances and return loss responses, which can be jointly adopted in WSN and other applicable wireless systems such as Internat of Thing (IoT) and Wireless Local Area Network(WLAN).**

Keywords - Microstrip Antenna, Compactness, WSN, Electronic Design Simulation

I. INTRODUCTION

Microstrip antennas possess strategic features in wireless systems including simplicity and cost-effective value of production and modeling. These features have made them highly attractive for microwave designers since the earliest days. In some circumstances, where the antenna dimensions are considered a significant constraint, if their size is outsized, they will be improper to be integrated within many wireless devices and systems. The antenna is an essential component. Subsequently, there is presently growing consideration for using microstrip antennas in the development of handheld devices and personal communications like computers, cellular phones and navigation appliances that are utilizing wireless access points. Because of end-user requirements and wireless component marketplace, the antenna has to be concealed. Because of this, it is extremely vital to design mini antennas that may be incorporated in the device configuration satisfactorily [1,2].

Microstrip antenna size doesn't rely on its manufacture techniques as in digital chips, but to some extent, it depends on their guided wavelength at its fundamental resonant frequency in mobile communications and wireless networks. Numerous approaches and techniques are presented to decrease the antenna dimensions and keep worthy radiation features. The smallness characteristics of antennas are at the significance in the current and forthcoming wireless applications [3-5] for its microwave circuit engineers.

The most commonly used tiny antennas have been Planar Inverted F Antennas (PIFAs) and shorted patches as testified in [6--10]. The supplementary decrease of antenna sizes can be accomplished through patch resonators [11,12] that is to some extent performed at the expense of bandwidth, gain, and efficiency.

Using geometry optimization and material loading along with slotted microstrip patch antennas can be taken into consideration to dropping the antenna dimensions [1,13,14]. These antennas have been diminished elements with satisfactory performance. Alternatively, fractal and quasi-fractal structures were used under desired electrical specifications in the design of compact antennas [15-17]. These structures are fundamentally identified space filling features and by their similarity.

Dual band microstrip antenna has been presented in this paper using slotted resonator in the form of the quasi-fractal resonator at 2.45 and 2.95 GHz respectively. The projected microstrip antenna has diminished sizes as well as adequate S11, phase, group delay and radiation pattern results that are possibly implemented in personal and several handheld Communication systems.

II. QUASI-FRACTAL ANTENNA TOPOLOGY

The projected microstrip patch antenna with uniform ladder-shaped slots is exemplified in Figure1. The arrangement of this antenna has been achieved by constructing uniform symmetrical resonator that is so-called quasi-fractal resonator [1, 2]. The minutest square patch generator possibly originates the structure of the antenna demonstrated in Figure 1. This generator involves length (U) of 2.5 mm. The total length (E) of this foremost microstrip quasi-fractal resonator is 21 mm. Corner patches have been inserted in upper right and bottom left of the main resonator.

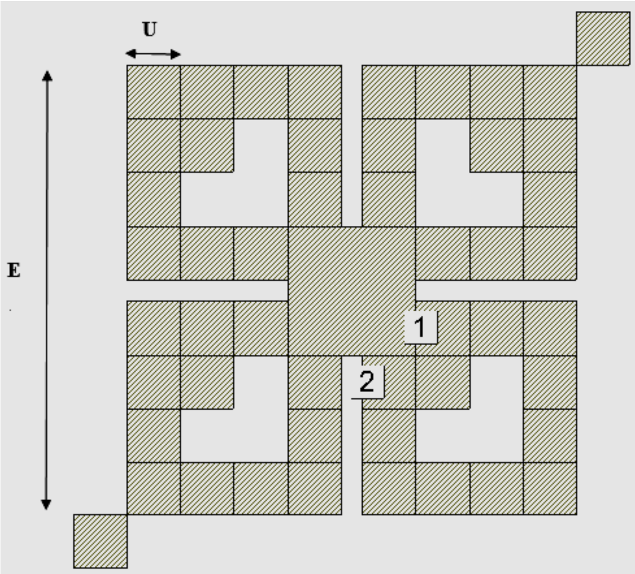

Figure 1. The top view topology of quasi-fractal antenna.

Additionally, two via ports have been positioned at the main quasi-fractal layout as shown in Figure 1.

An imperative matter in the microstrip antenna smallness comes in the practicality that antennas should include absolute dimensions in accordance with the guided wavelength concerning fundamental resonant frequency (f). The guided wavelength could be calculated by:

$$\lambda_g = \frac{c}{f\sqrt{\varepsilon_e}} \qquad (3)$$

An effective relative dielectric constant ε_e, for the quasi-fractal antenna is calculated from Eq.(4) [15, 18- 19]:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1+12\mathrm{H/A}}}\right) \qquad (4)$$

Nevertheless, ε_e in this paper was determined approximately by [19]:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} \qquad (5)$$

As a result, the anticipated antenna was designed via a single FR4 layer substrate with dielectric constant (ε_r) of 4.4, a substrate height (H) of 1.6 mm and A has the total length of E of a quasi-fractal resonator with corner patch length that equals to 23.5 mm.

III. RESULTS AND DISCUSSION

Microstrip antenna has been created and adjusted by Advanced Wave Research (AWR) electromagnetic simulator depending on the method of moments. This software package calculates the antenna frequency response by meshing the resonator in diminutive close-fitting grids using linear equations solutions based on integral EM equations.The grid dimensions were chosen to be 0.5 mm. It is conducted within 1 to 5 GHz frequency range with a frequency step of 0.01 GHz. Apposite boundary settings using meshing has accomplished on the antennas to acquire the final version of meshing. In meshing, it's clear that grid size has a solution that is more exact. This condition will require supplementary time for your computer.As a result, it is required to indicate the balance between a precision level and test time. The dielectric substrate has been set as an FR4 substrate in this simulation. The enclosure dimensions (substrate dimensions) has been established by AWR simulator to 31 X 31 mm^2.

Figure 2 depicts the S11 response of the designed quasi-fractal antenna. This graph points to dual-band frequency behavior of the antenna at 2.45 and 2.95 GHz in 1 to 5 GHz frequency full range. All resonances have return losses of deeper than -15 dB. Also, it exhibits bandwidths of 503.7 and 31.1 MHz for each operating frequency respectively. As a result, it is clear that the first bandwidth at the fundamental frequency for WSN application is more advantageous than 2nd operating resonant frequency for WLAN application since the 1st bandwidth is profoundly wider than 2nd bandwidth.

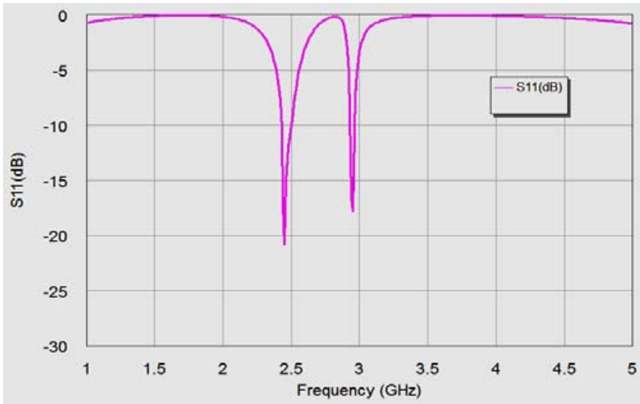

Figure 2. S11 response of the microstrip quasi-fractal antenna

Figure 3 depicts the phase response of the modeled antenna. Its results have numerous bouncings and linear paths within 1to GHz sweeping frequency change. Figure 4 illustrates the group delay of the designed antenna. It is noticeable from this graph that there is a positive delay value at 2.45 GHz and negative value at the 2nd band of 2.95 GHz operating frequency. As a result of the transmission line of the quasi-fractal resonator, resonance modes with negative group speed (akin to group delay) are possible in floating solid plates. Their interpretation comes from the broader analysis of the resonances in the structure. In the plate, a mode with negative group speed always has a companion resonance with a positive group speed. You cannot physically excite one of the pairs without exciting the other. The phenomenon is therefore not an isolated resonance with negative group speed but of resonance +/- pairs that together constitute standing waves.

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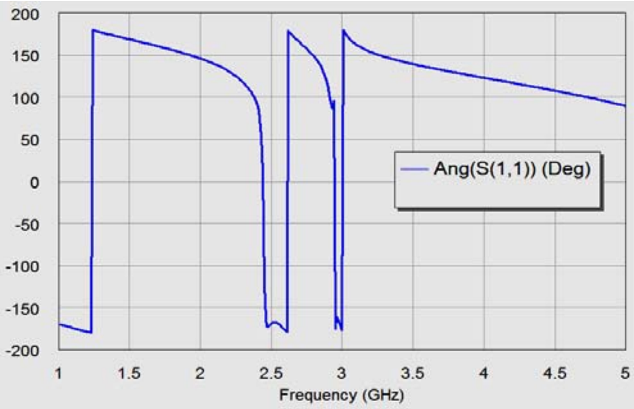

Figure 3. The phase response of the microstrip quasi-fractal antenna

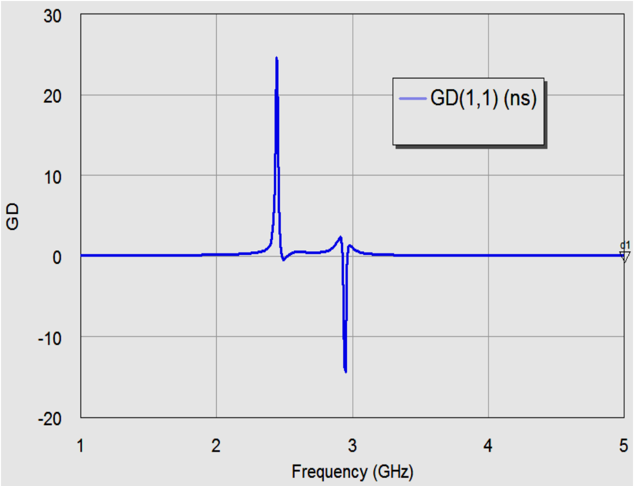

Figure 4. The group delay response of the microstrip antenna

The result parameters for microstrip antenna are outlined in Table I concerning return loss, bandwidth, frequency ratio, phase and group delay. It's clear in the table that frequency ratios of 2nd operating frequency to the fundamental frequency is not an integer (1.2) that signifies for no harmonic is existing, and this antenna exhibits classic dual band with adequate performance.

TABLE I. RESULTS FOR SIMULATED MICROSTRIP ANTENNA.

	f1=2.45	f2=2.95
Return Loss(dB)	-20.815	-17.813
10dB Bandwidth Range (GHz)	2.4294-2.9331	2.9312-2.9623
Frequency Ratio	…….	1.2
Phase magnitude(Degree)	-123	-176
Group Delay(ns)	24.58	-14.41

In theory, there is a connection between guided wavelength and antenna measurements. This relation defines if antenna sidelength is less than 0.25 λ_g, then the antenna is unfeasible for the reason that radiation immunity, bandwidth, and gain are going to be diminished [1,2, 19]. Incidentally, the size of a simulated antenna concerning guided wavelength was (0.416 x 0.416) λ_g at its fundamental frequency of 2.45 GHz for WSN application that is feasibly incorporated within numerous portable and personal communication devices.

Results of PPC-LHCP are illustrated by Figures 5-6 regarding principle plane cut left-hand circular polarization and also PPC RHCP regarding main principle plane cut right-hand circular polarization at φ = 0◦. RHCP And LHCP frequencies can be feasibly evaluated by:

$$RHCP = \frac{E\theta + jE\varphi}{\sqrt{2}}$$

and

$$LHCP = \frac{E\theta - jE\varphi}{\sqrt{2}}$$

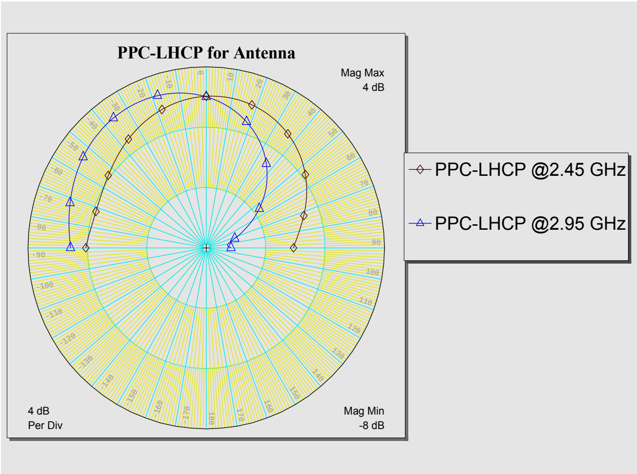

Figure 5. PPC-LHCP radiation results for microstrip antenna.

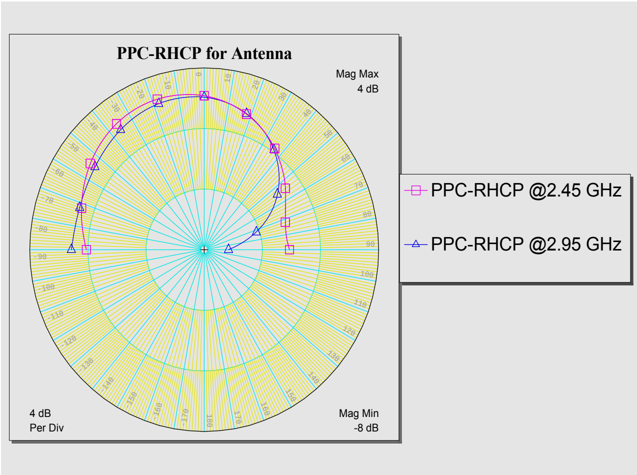

Figure 6. PPC-RHCP radiation results for quasi fractal antenna

PPC-LHCP and PPC-RHCP results in Figures 5-6 are within -90 to 90 degrees at predetermined φ and resonant

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frequency. This antenna owns a particular radiation pattern in accord with band frequency. Nonetheless, they are unobjectionable in antenna conception theoretically.

Figure 7 describes PPC total power (PPC-TPWR) from Eφ and Eθ fields irrespective of polarization under φ = o degree and operated resonant frequencies conditions.

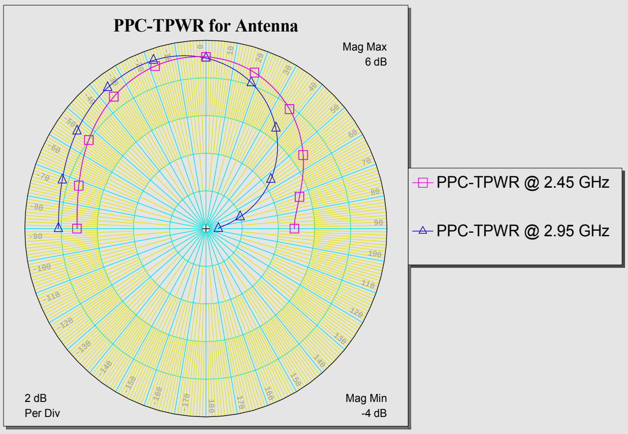

Figure 7. PPC-TPWR radiation results for quasi fractal antenna

Exchanging of via port feed places has massive consequences on S11 responses of the designed antenna along with PPC-LHCP and PPC-RHCP radiation results. The most excellent antenna performances are predicted with AWR electromagnetic software package in feed places as exemplified in Figures 1. The prime frequency of the microstrip antennas may be altered by rescaling the general size of the foremost slotted patch resonator as portrayed in [1,2, 20, 21] to reach the planned frequency. Corner patches dimension could be tapped for trivial frequency dropping.

IV. CONCLUSION

New microstrip patch antenna using quasi-fractal resonator with ladder slots was introduced in this paper designed at 2.45 and 2.95 GHz for WSN and WLAN wireless applications. This antenna operates as dual-band device utilizing solitary layer FR4 substrate and two via ports with adding corner square patches in up right and bottom left of a quasi-fractal resonator. The anticipated antenna has streamlined simulation results concerning S11, phase response, group delay, and radiation patterns. Also, it has a compact substrate size that can be integrated within many wireless instruments and systems including wireless sensor networks and Internet of Thing (IoT) wireless systems.

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