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Modified Half-Circle Fractal Antenna Using DC Theorem for 2.4/5.2 GHz WLAN Application

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***Abstract*—A new form of modified CPW-fed half circle fractal patch antenna is proposed for dual band 2.4/5.2 GHz Wireless Local Area Network (WLAN) application. The circular shape antenna based on the Descartes Circle (DC) theorem and iteration of self similar design. The -10 dB return loss (VSWR 2:1) impedance bandwidth in 2.4 GHz band is 28% and it covers the required bandwidth for 2.4 GHz WLAN. The 5.2 GHz resonant mode has impedance bandwidth of 40% covering 5.2/5.5/5.8 GHz WLAN bands. The EM characteristics of the antenna are presented by the current distribution. Proposed antenna maintained good radiation patterns with gain. Detailed design steps and results for the designs are studied and investigated in this paper.**

Keywords- Half Circular Fractal Slot Antenna; Dual Band; CPW-Feed; Descartes Circle theorem Antenna.

I. INTRODUCTION

Rapid progress in wireless communication promises to replace wired communication in the near future in which antenna plays a more important role. Microstrip patch antennas are widely used due to their inherent advantages of low profile, light weight, low cost [1-4] etc. The major limitation of microstrip antenna is narrow bandwidth. To overcome this limitation the patches are to be etched with slot like E-Shape [5], U-Shape [6], and Stack patch [7]. But using this type of shape the boundary condition and the cavity model are invalid for design and analysis.

Printed slot antennas are attractive because of their planar geometry and wide operating bands [8]. A coplanar waveguide (CPW) feed makes them more suitable for compact wireless communication devices owing to its features like uniplanar structure, easy fabrication and circuit integration [9]. Compact antennas can be designed using a meandered radiating structure and several antennas [10, 11] using this technique has been reported.

Fractal antennas [12], have very good features like small size and multiband characteristics. Most fractal objects have self similar shape, with different scale [13, 14]. The fractal shape carried out by applying the infinite number of iteration using multiple reduction copy machine (MRCM) algorithm [15]. On the other hand, a circular generator with a nonconstant fractal ratio dependent on the Descartes circle theorem in the CPW-fed structure is reported for dual and wideband antennas [16-17].

In this paper, we proposed the modified Half-Circle fractal slot antenna for dual band WLAN applications. Miniaturization of the antenna structure and getting of dual resonance the main aim of this paper. The design of the antenna was performed and optimized using CST Microwave Studio Suit TM 2010 based on the three dimensional finite integration time-domains (FITD) method. This antenna consist return loss, gain, EM and radiation characteristics at 2.4/5.2 GHz WLAN frequencies.

II. DESIGN OF FRACTAL PATCH ANTENNA

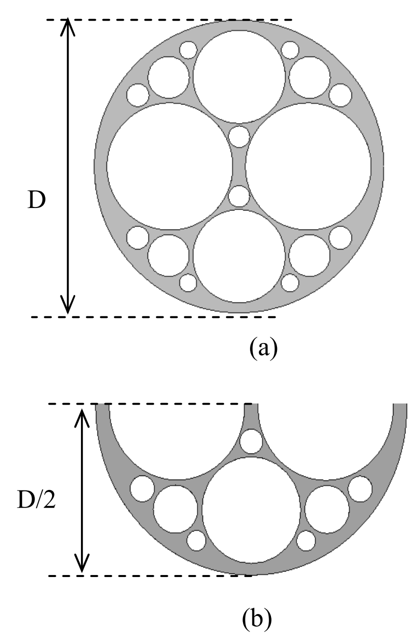

Fig.1 Geometry of Proposed Antenna Structure
(a). Full Circle Fractal Patch Antenna
(b). Modified Half-Circle fractal patch antenna

A. Descartes Cricle Theorem

If four mutually tangent circles have curvatures k_i (for $i=1,2.....4$),

Then, the curvatures satisfied the relation [16-17]

$(k_1+k_2+k_3+k_4)=2(k^2{}_1+k^2{}_2+k^2{}_3+k^2{}_4)$

Where, $k_1=1/R_{k1}, k_2=1/R_{k2}, k_3=1/R_{k3}, k_4=1/Rk4$

and radius of the circles are $R_{k1}, R_{k2}, R_{k3}, R_{k4}$.

B. *Antenna Iterative Design*

Fig. 1 illustrated the design procedure of the modified half circle fractal slot antenna for dual band applications. In this design procedure the full circle radiating patch is miniaturized for utilizing the half version of circle fractal slot antenna.

The circular inner conductor is constructed with the circular fractal patterns using Descartes Circle theorem. For first stage configuration of the four circle is obtained, the Descartes circle equation can be applied in the next stage to specify the size of a smaller circle from any set of three original circles. Using the processes with stage to stage, it is designed as the self similar iteration design.

Hence, at the second stage, a set of four circles is selected from the initial three circles obtained in the first stage to determine the fifth circle.

Similarly, in the third stage, a set of two circles is selected from the initial four circles obtained in the first and the fifth circle obtained at the second stage is shown in Fig. 2. Detailed of the iterative model which is satisfied the curvature is reported in [16-18].

For modification of the proposed geometry, the circle is miniaturized by D/2 height; the full circle height is D. Finally, the antenna posses the characteristics of dual band frequency operation in the spectrum.

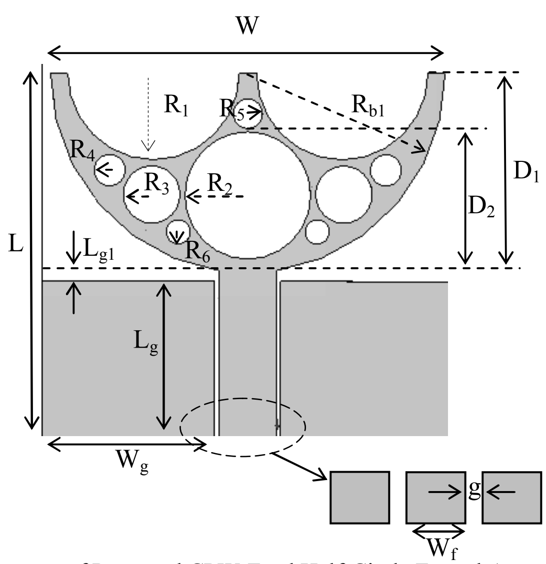

Fig.2 Geometry of Proposed CPW-Feed Half-Circle Fractal Antenna

C. *Antenna Design*

Fig. 2 shows the proposed modified CPW-fed half circle fractal patch antenna using DC theorem for dual band 2.4/5.2 GHz WLAN applications. D_1 and D_2 are the height of the patch antenna which is used for the resonant mode. The value of D_1=*21.43 mm* is acceptable for the higher resonant mode and the value of D_2=*14.66 mm* is acceptable for lower resonant mode of the antenna. The geometry of antenna printed on FR4 substrate with relative permittivity (ε_r=4.4) and thickness of the substrate (*h*) is 1.6 mm. The antenna is having overall size of $W \times L$ *(48×44* mm^2) with 50 Ω CPW-Fed technique. Radius of the outer circle (Radiating patch element) is R_{b1}=*23mm*. In this geometry, we removed the circles using DC theorem. The circles radius are $R_1>R_2>R_3>R_4>R_5>R_6$ is shown in Fig. 2. The radius of these circles are R_1=*10mm*, R_2=*7.33 mm*, R_3=*3.3* mm, R_4=*1.8 mm*, R_5=*1.7 mm* and R_6=*1.4 mm*. Dimensions of the ground plane are $W_g \times L_g$ (*20.15×18* mm^2), CPW fed microstrip line $W_f \times L_g$ (6.7×19 mm^2), gap between the ground and microstrip line is g=*0.5* mm and the gap between the radiating patch and the ground plane is L_{g1}=*1 mm*.

III. Results And Discussion

A. *Effect of CPW-fed Line*

Fig. 3 shows the return loss of the simulated modified proposed half circle fractal slot antenna with changing the microstrip line width (W_f). It is observed that with increase the value of W_f, the simulated -10 dB impedance bandwidth of half circle fractal shape antenna increases but the resonant frequency shift. Therefore, the -10 dB return loss is matching at W_f=*6.7 mm*.

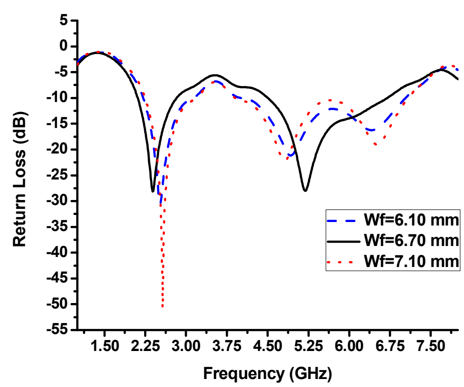

Fig.3 Effect of CPW-fed microstrip line Half-Circle Fractal Antenna

B. *Retrun Loss characteristics(S_{11})*

Fig. 4 shows the return loss of the simulated modified proposed half circle fractal slot antenna. It is printed on FR4 substrate with relative permittivity (ε_r) of *4.4* and the thickness of the substrate (*h*) is 1.6 mm. The simulation result is obtained from CST microwave Studio Suit ™ 2010. The height of the antenna is chosen to be D_1 and D_2. The iterative model of the antenna is based on the DC theorem. Proposed antenna is resonating at two frequencies. For first frequency -10 dB impedance bandwidth is from 2 GHz to 2.85 GHz with resonance at 2.4 GHz and the second frequency -10 dB impedance bandwidth is from 4.5 GHz to 6.6 GHz with resonant at 5.2 GHz. Both resonating frequencies cover the *IEEE standard 802.11b/g* and *802.11 a*, 2.4/5.2 GHz WLAN.

C. *Radiation Pattern Characteristics*

Fig. 5 shows the Far field radiation pattern characteristics of proposed modified half circle fractal slot antenna. Proposed antenna resonating in broad side direction at *V=0°* and *V=90°* at 2.4 GHz and 5.2 GHz frequencies. The results show very monopole like radiation pattern with omnidirectional radiation.

The 3 dB beamwidth at these two frequencies are 83.1°and 83.7°.

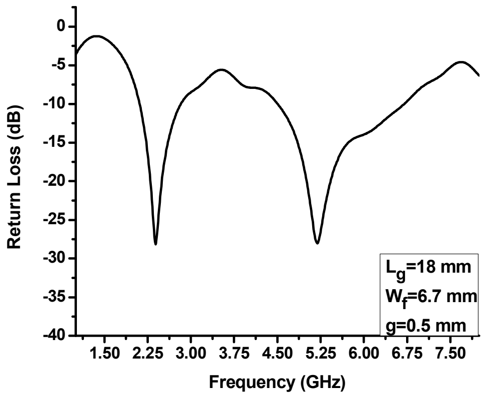

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Fig.4 Return loss of CPW-Fed Half-Circle Fractal Antenna

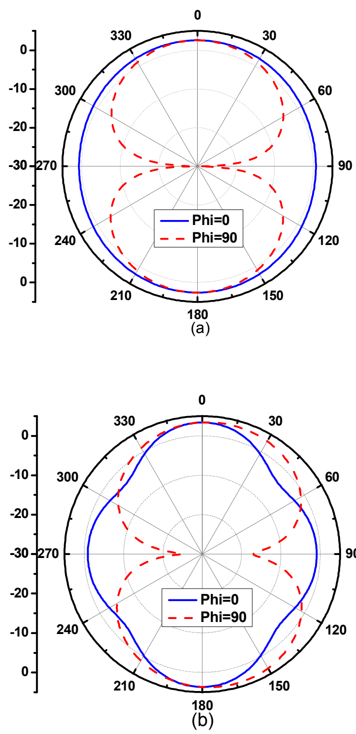

Fig.5 Radiation pattern of CPW-Fed Half-Circle Fractal Antenna at (a) 2.4 GHz (b) 5.2 GHz

D. Surface Current Distribution

The excited surface current distribution proposed fractal antenna, obtained from the CST microwave Studio Suit ™ 2010. Fig. 6 shows the surface current distribution at 2.4 GHz and 5.2 GHz. It is clear that these two frequencies have very similar surface current distributions. This characteristic agrees with the radiation patterns characteristics of these frequencies shown in Fig 5. Moreover, it has also been found that in this design the surface current on the feed line is strong and dominates the main radiation performance of the antenna. This results in a very linear polarization pattern and also agrees with the simulated radiation pattern results.

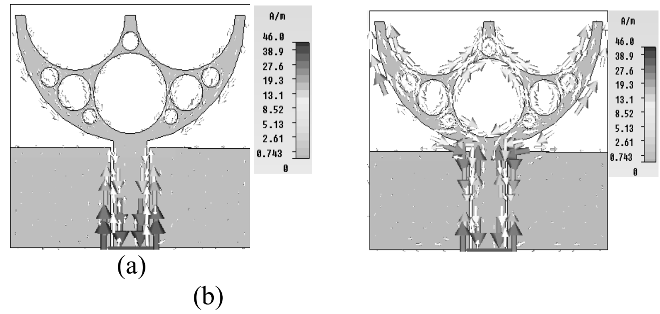

Fig.7 Current distribution of CPW-Feed Half-Circle Fractal Antenna at (a) 2.4 GHz (b) 5.2 GHz

E. Antenna Performance

The peak antenna gain against frequency for the proposed antenna across the dual operating bands are shown in fig.7. It should be noted that the gain across the lower band of 2.4 GHz is ~3dBi and for higher band of 5.2 GHz is ~4dBi. The antenna gain is well matched in both the frequencies.

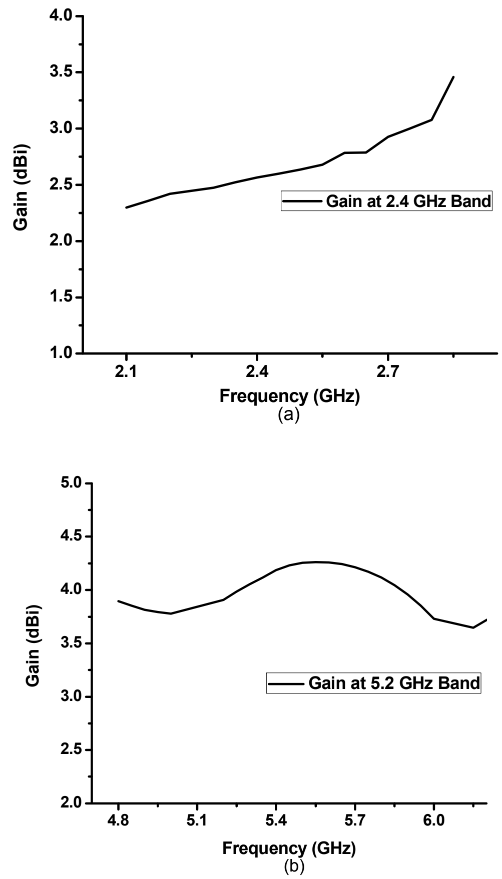

Fig.5 Gain of CPW-Feed Half-Circle Fractal Antenna at (a) 2.4 GHz Band (b) 5.2 GHz

IV. CONCLUSION

The single layer CPW-Fed modified half circle fractal slot antenna is designed for dual band operation. The iterative model is presented using the Descartes Circle theorem. The simulated results show the antenna is suitable for 2.4/5.2 GHz WLAN application. The current distribution is simulated to clarify the EM characteristics of the antenna. The proposed antenna having good radiation characteristics and gain at 2.4 GHz and 5.2 GHz frequencies.

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