Fractal Inspired High Gain and Multiband Antenna using Circular Slots and Vertical Slits for WLAN and WiMAX Applications

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Abstract- A **novel compact multiple resonating inset fed microstrip antenna with circular slots and vertical slits suitable to operate for short range wireless application is presented. This novel design has an increased gain and radiates at multiple frequencies. High gain and multiband operation are obtained by applying fractal techniques. Circular slots and vertical slits are incorporated in the design. These slots are placed over the top layer of the patch i.e., on the conducting layer which is above the substrate. Return loss at all the desired frequencies obtained is less than -10 dB, which show that the antenna radiates optimum power at ISM band 2.4 GHz and also at frequencies which can be used for short range communications. The overall gain of the antenna obtained is 7.31062 dB with the use of above-mentioned structure. The material used for the design is inexpensive material which has a relative permitivity of 2.2 and also height of the material used is 1.60 mm. Simulation tool used to carry out design and analysis is ADS (Advanced Design System) tool.**

Keywords – Fractal antenna, High gain, Multiband, Planar Antenna, WLAN, WiMAX.

I. Introduction

The rate at which the fast multiplication of different remote wireless systems, the interest towards a solitary remote stage with multi-band applications is expanding [1]. In today's wireless world, numerous antenna researchers center their inclinations towards configuration, conservative, mutltibands, omidirectional radio wires for multisystems, particularly for the WLAN and WiMAX [2]. So as to cover the above two band of frequencies, a conservative radiating wire with 2.4–5.85 GHz is profoundly required in coordinated framework. Even though a broadband transceiver covering WLAN/WiMAX groups is a decision, a multiband reception apparatus is attractive in light of the fact that it will be a savvy arrangement by removing a particular band of channels in WLAN/WiMAX framework to smother unimportant bands. Numerous kinds of antenna designs have been proposed as of late to accomplish multiband capacities and applications [2, 3].Multiband aerial devices assume a predominant job in present day remote communication frameworks [4].A few radiating devices appropriate for short range communications is presented in the literature. Some of them are double circle, a triangular aerial of size λ/4, a modified λ/4 ring-fix, opened and space joined conducting layer, excessively formed slots and slits and also a wire antenna of size λ/2 [5].

The multiband framework has become an exceptionally serious point thus much critical advancement in the plan of multiband radiating devices has been accounted for as of late such sierpenski gasket monopole antenna [6]. A novel planar monopole radio wire configuration dependent on the E-molded aerial device with the L-molded spaces cut out of the bottom conducting layer and the U-formed out of the fix, which can be used for short range applications, is presented in this paper [7]. A new methodology is proposed with a wideband fix radio wire utilizing the L-probe feeding method. By cutting openings in the fix, scores are presented inside the matching band, coming about in multi-band activity [8].

A conjugated resonator-based radiating structure, a new highly directional planar radiating patch with four different frequencies is presented for remote long distance communications are proposed in this paper. Not quite the same as the customary multiband radiating devices, the four recurrence groups are accomplished by coordinating a few resonators in the reception apparatus structure. The four recurrence groups can be balanced by adjusting the proper impedance match between the resonators [9]. Fractal radio wires are extremely minimal, multiband or wideband, and exhibits valuable applications in cell phone and microwave interchanges. The benefits of printed circuit innovation and printed radiating devices improve the plan of fractal printed planar antennas and microwave devices. The viable region of a fractal structure is essentially higher than the viable region of a normal printed aerial device. Fractal antennas may work with great execution at a few distinct frequencies all the while [10].

A modified Koch slot antenna which is fabricated on a low loss material is proposed in this paper. The essential geometry of the space is a symmetrical triangle of side, in which rehashed emphases are completed to obtain multiple resonances. [11]. The structural arrangement of this new fractal bend begins with a narrow conducting wire, called the initiator is proposed and it is observed that the feeding locating of has numerous impacts on antennas and with evolving it, we can change radiation characteristics, for example, data transfer capacity and resistance [12].
A planar monopole antenna with L-shaped slot in the bottom metal layer and U-shaped slot on the top conducting layer to operate at WLAN frequencies with proper power coupling is proposed in this paper. L-shaped slot is for band notched feature and U-shaped slot is to match the excitation input with slot location at 1.9 GHz [6, 13]. The method of embeddings a cut, for example, an L-molded cut, in the transmitting patch of the planar radiating device to accomplish a double band activity is presented. The new design with slits are used to operate at different resonating frequencies utilizing a microstrip feed line having a stage formed segment over the two openings. The energized resonating modes incorporate the quarter-frequency space modes and higher order modes [14]. The best method to actualize double band antenna is moving coaxial feed point to the askew of rectangular radiation fix. Likewise, apply space design is another basic way to deal with acquire double band feature and also L-shaped slot is placed at the edges which results into multiband characteristics around 2 GHz and 3 GHz [15].

In this paper, a geometry planar radiating element is proposed to increase the gain with only one layer of dielectric substrate which in turn helps to abide complete patch. With the use of coaxial probe feeding a proper impedance matching is provided, so that there are minimum losses which make the antenna to radiate with high gain. But here in this technique the antenna radiates at only one frequency. A single dielectric layer with two slots etched on the top layer which is symmetrical about the center of the patch. This helps the patch to radiate in higher order TM_{50} mode [16]. A planar aerial element with slot loaded on top of the conducting layer is proposed in this paper. The feeding technique used is half width microstrip line which makes the antenna to resonate at four different frequencies for WLAN & WiMAX applications. The most important section in the antenna design is feeding technique, in which here it is fed through a tapered line. The tapered lines are optimized through some parametric studies which results into a proper impedance matching at the feed location so there are minimum reflection losses [17]. Another approach to increase the gain of the antenna is by array of radiating elements. Multiple radiating elements with a very less radiations in undesired directions and with a increased gain is proposed in this article. The design consists of 32x8 element array which radiates 9.37 GHz. But the drawback of the array approach is, it increases the dimension of the planar structure which cannot be used for all commercial applications [18]. A circular patch with a very low dielectric constant for mmw imaging applications is proposed in this paper. In order to obtain TM_{010} mode this low profile structure feeds circular waveguide. But the drawback of this approach is, there is a drift in the operating frequency by 0.5 GHz due to loading effect and the overall gain of the antenna is approximately 3dB [19].

This novel design approach and its variants are studied using ADS tool and the various radiation characteristics, such as, reflection coefficient, Gain, Directivity and also the effective angle in steradians is analyzed to examine the performance of the designed structure.

II. PLANAR RADIATING STRUCTURE

2.1 Watermark embedding algorithm –

The radiating structure which plays a crucial role in the design of planar antenna is placed on a substrate which has the dielectric constant of 2.2 and the height of the substrate is 1.6mm below which a ground conducting plane placed on the other side. The thickness of the top and bottom conducting layer is approximately 35 um. This copper or gold conducting patch is itched on the top and bottom of the substrate layer. Based on the resonant frequency of operation, the physical dimensions of the patch like length and width of the patch is calculated. The thickness of the radiating aerial component is t. The rectangular planar radiating element is constructed such that it radiates at the designed frequency. The dimensions of the radiating element like length and width of the planar conducting layer, inset feed location, feed length and also width of the feed is calculated below for the assumed material with the relative permitivity of 2.2 and thickness of 1.6 mm. The top and bottom layers of the antenna which is a metal layer is chosen such that the loss tangent is far less than 35µm.

2.2. Watermark Extraction algorithm –

The design consists of the calculation of the following parameters [20].

1. Width (W) of radiating element:

$$\text{Width}=\frac{c}{2fr\sqrt{\frac{(\varepsilon r+1)}{2}}}$$

Where c = 3×10^8 meter/sec, Relative Permitivity =4.4 & fr = 2.4 GHz,

We obtain: Width = 46.8 mm

2. Effective Relative Permitivity, ε_{reff}

$$\varepsilon_{reff}=\frac{\varepsilon r+1}{2}+\frac{\varepsilon r-1}{2}\left[\sqrt{\left(1+12\frac{heigth}{width}\right)}\right]$$

Substituting ε_r = 4.4, W =46.8 mm and h = 1.6 mm

We get: Effective Relative Permitivity = 4.08

3. Length:

Substituting ε_{reff} = 4.08, W = 49.4 mm and h = 1.6 mm

4. Actual Length of patch: (L_{eff}):

$$\text{Effective Length: } L_{eff}=\frac{c}{2fr\sqrt{\varepsilon reff}}$$

Where $L = L_{eff} - 2\Delta L$

Substituting L_{eff} = 30.86 mm and ΔL = 0.73 mm

We get: L = 39.5 mm

5. Calculation of inset feed point:

Conductance (G):

$$G=\frac{1}{90}\left(\frac{W}{\lambda o}\right) = 0.00101$$

Calculation of resonant input resistance (R_{in}):

$$R_{in} = \frac{1}{2G} = 492\ \Omega$$

$$R_{in}(y=y_o) = R_{in}(y=0)\cos^2\left(\frac{\lambda o}{L}yo\right)$$

$$y_o = 13.8\ \text{mm}$$

The parameters for the patch in ADS simulation tool are the following:

- Dielectric constant = 2.2
- Operational Frequency (fr) = 2.4 GHz.
- Substrate height = 1.6 mm.
- Speed of light (c) = 3×10^8 ms^{-1}.
- Practical width (W) of patch = 46.8mm.
- Loss Tangent (tan δ) = 0.019
- Actual Length (L) = 39.5mm.
- Width of feed = 4.5mm.
- Length of feed = 46.6mm
- Inset Feed Point = 13.8mm

TABLE I: BASIC PATCH PHYSICAL DESIGN

Attributes	**Values (mm)**	**Attributes**	**Values(mm)**
Width of the Patch	46.8	Feed Location	13.8
Length of the Patch	39.5	Feed Width	4.5
Inset Feed Gap	2.25	Feed Length	46.6

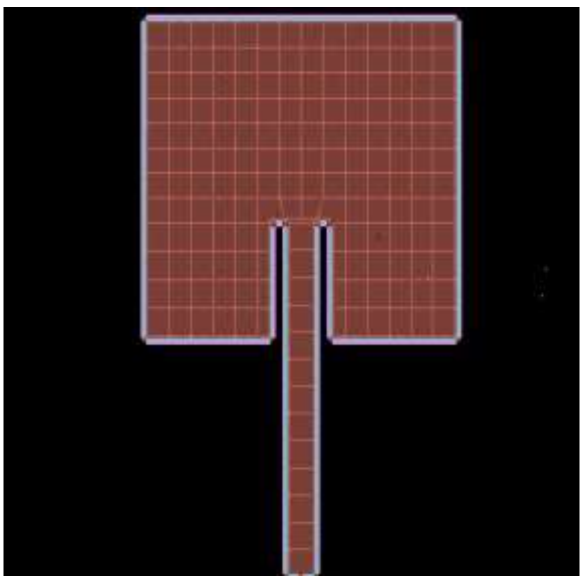

Figure. 1 Structural Top View of Patch

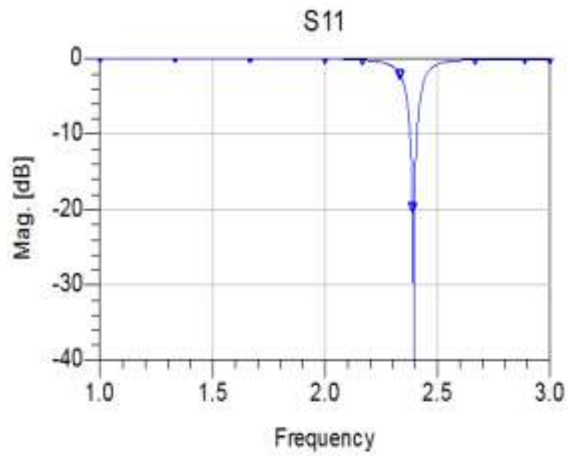

Figure. 2 Reflection Co-eff Vs Frequency for the basic antenna

A basic patch is designed at ISM band frequency. The length and width of the patch is obtained using design equations. In order to make patch radiate effectively, the input impedance of the patch is properly matched with the impedance at the feed location using inset feed technique. The simulated result obtained is -40 dB, it means only 1% of the power is reflected back to the source and 99% of the power is radiated by the antenna.

III. PROPOSED NOVEL DESIGN AND RESULT

In order to obtain multiband operation, a fractal inspired, and periodically arranged circular slots is placed on the top layer of the patch. The narrow width rectangular slots are also placed on either side of the patch. The dimensions of the circular slots and vertical rectangular slits is shown in the below tabular form. The frequency at which an aerial device is operated depends on the length of the patch. With the dimensions given below in the tabular form, the current distribution of the radiating patch is altered as shown in the figure 5, with that the electrical length change the antenna resonates at multiple frequencies which can be used for ISM band applications, WLAN and WiMAX applications.

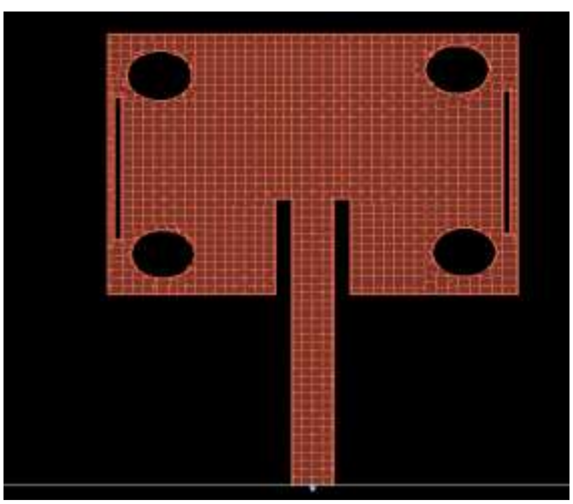

Figure. 3 Modified Patch with Circular slots and Vertical Slits

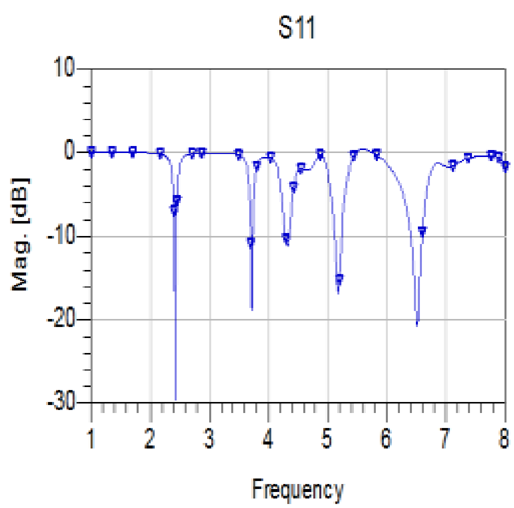

Figure. 4 Reflection Coefficient (S11) plot for proposed design

The dimensions of the rectangular slots which are place at the two ends of the patch are of length 21.4 mm and width 0.76 mm. There are four circular slots which are placed across four corners of the patch with same radius of 3.9 mm. with this geometrical arrangement which are arranged regularly changes the current distribution of the radiating patch which in turn radiates the antenna at multiple frequencies. This arrangement does not alter the actual radiation characteristics like radiation of the planar element at ISM band frequency. From the simulation results, it is observed that the reflection coefficient at 2.4 GHz is -30 dB, and also at 3.6 GHz, 4.2 GHz, 5.3 GHz and 6.4 Hz is -19 db, -11 dB, -17 dB and -20.5 dB respectively. The directive gain of the antenna is approximately -7dB.

IV.CONCLUSION

A fractal inspired patch radiating structure with periodic arrangement of circular slots along with the two narrow rectangular slits on either side of the patch is analyzed and presented in this paper. The proposed design is made on a substrate with relative permitivity of 2.2 and the height of the substrate material used is 1.6 mm. A basic planar radiator is designed to operate at ISM band of frequencies and the same radiating element is modified to operate at multiple resonate frequencies. It is observed that the modified patch is radiating at 3.6 GHz, 4.2 GHz, 5.3 GHz and 6.4 GHz along with 2.4 GHz. The return loss parameter at all these frequencies is below -10 dB, that is very less amount of power is being reflected back and optimum amount of power is radiated by the patch. The radiation characteristics of the modified patch is also calculated, where is observed that the gain and directivity is approximately 7 dB. The simulated radiating structure can be best used for short range communications like ISM band applications, WLAN and WiMAX applications.

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