ANALYSIS AND SIMULATION OF WIDEBAND FRACTAL ANTENNA USING SLOW WAVE TYPE DEFECTED GROUND STRUCTURE

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ABSTRACT

The growing demand of wireless systems (WiFi and WiMax) requires the new definition of mobility and quality for the end user. In last few decades, the miniaturization, led antenna to be conformal, low profile, multi-band, hence Fractal antenna came into existence which due to its self-similar geometry takes less area and thus its low profile. Defected ground structure plays an important role to achieve enhancement in bandwidth, reduction in size, harmonics, mutual coupling, cross polarization as well as improvement in radiation pattern, and generates various filter characteristics. Here, author has presented a fractal type rectangular patch antenna at frequency 3.5 GHz (2-6 GHz) with other resonant frequencies representing the multiband characteristics by using seven defect in the ground plane as well as introducing fractal in the patch to reduced the area to meet the requirements. FR4 substrate has been taken with perfect electric ground and patch. Analytical results have been found in close agreement with simulated results using HFSS simulation software, approximately ~ 5%.

KEY WORDS: Rectangular Patch Antenna, Fractal Symmetry, Defected Ground Structure, Return Loss, VSWR.

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1. INTRODUCTION

Patch antennas are in extreme demand in the era of WiFi and WiMax now a days and researcher are doing to lot of efforts to make it slick, thin and usable in these ranges. It has lot of advantages with limitations, which creates a bit difficulty to meet the requirement feasibilities and capabilities of this antenna. Patch antennas are available in different shapes and sizes. Basically, a rectangular patch is most simple and easy to fabricate, but frequency requirement to meet the criteria of useful bandwidth, is reducing the size of it, which is also used to get a good directivity, gain and efficiency.

As, antenna is a tranducer or electrical devices which transmits and receive the radio waves and acts a transitional part between free space and a guiding structure. It follows the reciprocity property and basic function to accelerates the [1]

charge, which generates the fringing fields to decide the radiation pattern of the antenna. Radiation pattern gives the gain, directivity, power spectral density, electric and magnetic field profiles.

Use of Fractals introduces a great change in their sizes, shapes and bandwidth. Fractals is self similar and self affine complex structures, which repeats its symmetry after a regular intervals or iterations. There are so many types of fractals available in which, most usable fractal are sierpinski carpet and sierpinski gasket. Again, these two fractals are easy to analyzed and fabricate. Some key benefits of fractal antennas area are, First, fractal antennas radically alter the traditional relationships between bandwidth, gain and size, as well as permitting antennas that are more powerful, versatile and compact. Second, fractal antennas produces fractal versions of all existing antenna types not limited for patch antenna, including dipole, monopole, patch, conformal, bi-conical, spiral, helical and others, as well as compact variants of each only possible through fractal technology. Third, fractal antennas technology affords unique improvements in gain and efficiency, to antenna arrays, for increasing their bandwidth, allowing multiband capabilities, decreasing size load and enabling optimum smart antenna technology. Fourth, increased bandwidth, multi-band and gain in addition to smaller size. Fifth, The inherent qualities of fractals enable the production of high performance antennas that are typically 50 to 75 % smaller than traditional ones. Last, fractal antennas are more reliable and lower cost than traditional antennas because antenna performance is attained through the geometry of the conductor, rather than with the accumulation of separate components or separate elements that inevitably increase complexity and potential points of failure and cost. The result is one antenna able to replace many at a high value offering to our customer [2].

Introduction of defected ground structure (DGS) is in great demands and vastly used in antennas and filters. The DGS is realized by etching a defective pattern in the ground plane, which disturbs the shield current distribution. This disturbance can change the characteristics of a transmission line, such as equivalent capacitance or inductance, to obtain the slow-wave effect, bandstop property and high characteristic impedance. The DGS applied to a microstrip line creates a resonance in the circuit, with the resonant frequency controllable by changing the shape and the size of the defects in the ground plane. With the help of DGS technique the effective 'inductance' can be increased to a high value, simultaneously the equivalent 'capacitance' can be decreased. This concept increases the impedance of the microstrip line to more than 200 (Free space impedance = 377). Due defects in ground plane, line has longer electrical length than the standard Microstrip line, for the same physical length. Also, equivalent inductive part increases due to the defect and produces equivalently the high effective dielectric constant. This produces the slow wave effect. Basically, slow wave effects generates due to periodicity of structures, parameters or circuits after a regular intervals which is called as periodicity of the basic structure, is used [3].

DGS helps to reduce the size, harmonics, and mutual coupling to enhance the bandwidth, efficiency and radiation properties of antennas or filters [4]-[6].

Feeding technique, which is using in present paper, microstrip feeding. Rather than this, there are three more feeding techniques are available, but that are quite complicated in uses [7]. Microstrip feed has two basic forms, edge and inset. Here, in this paper, edge fed is used.

2. DESIGN AND ANALYSIS

As discussed above in section 1, about the patch antenna, it act as resonant cavity with four wall, two are upper and lower short walls (patch and ground) and other two are open ends of antenna (left and right) [1]. If the antenna is excited at a resonant frequency, a strong field is set up inside the cavity, and a strong current on the surface of the patch. This produces significant radiation due to fringing fields. Fringing field patterns can be demonstrated by Figure 1.

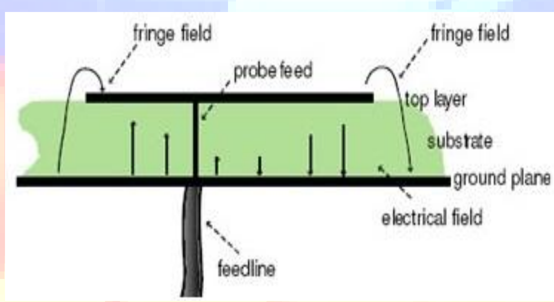

Fig. 1 Fringing Field Pattern in Microstrip Antenna [8].

There are certain formulas, which is basically used to calculate the size of antenna, width, length, effective length, effective dielectric constant, height and width of the air boundary to find out the radiation pattern.

$$W = \frac{v_0}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad , \qquad (1)$$

$$L = \frac{v_0}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L, \quad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}, \quad (3)$$

$$\Delta L = 0.412h \frac{(\varepsilon_r + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_r - 0.258)\left(\frac{W}{h} + 0.8\right)}, \quad (4)$$

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\varepsilon_{eff}}}, \quad (5)$$

$$L = L_{eff} - 2\Delta L, \quad (6)$$

$$L_g = 6h + L, \quad (7)$$

$$W_g = 6h + W, \quad (8)$$

Where, W is the width, L is length ΔL is increment in length and L_{eff} is effective length of antenna after fringing is obtained. Lg and Wg are defines the air boundaries. ε_{eff} , c and f_0 are the effective dielectric constant, velocity of light and desired frequency respectively.

Characteristics impedance of microstrip line is given as [1]:

$$Z_0 = \frac{60}{\sqrt{\varepsilon_{eff}}} \ln\left(\frac{8h}{W} + \frac{W}{4d}\right) \quad \text{for,} \quad \frac{W}{h} \le 1 \quad (9)$$

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}\left[\frac{W}{h} + 1.393 + 0.667 \ln\left(\frac{W}{h} + 1.444\right)\right]}} \quad \text{for,} \quad \frac{W}{h} \ge 1 \quad (10)$$

where W/h, can be calculated as,

$$\frac{W}{h}=\frac{8e^{A}}{e^{2A}-2},$$ for W/h <2

(11)

$$\frac{W}{h}=\frac{2}{\pi\left[B-1-\ln(2B-1)+\frac{\varepsilon_r-1}{2\varepsilon_r}\left\{\ln(B-1)+0.39-\frac{0.61}{\varepsilon_r}\right\}\right]}$$ for W/h >2

(12)

where,

$$A=\frac{Z_0}{60}\sqrt{\frac{\varepsilon_r+1}{2}}+\frac{\varepsilon_r-1}{\varepsilon_r+1}\left(0.23+\frac{0.11}{\varepsilon_r}\right), \quad (13)$$

$$B=\frac{377\pi}{2Z_0\sqrt{\varepsilon_r}}. \quad (14)$$

Here, author has used slow wave shape in the ground plane by using seven periodical gaps and each and every gap has its own inductance, capacitance and resistance to create a defect in the lower part of antenna. Those parameters can be calculated as:

$$C=\frac{\omega_c}{Z_{0g1}}\left(\frac{1}{\omega_0^2-\omega_c^2}\right),$$

(15)

$$L=\frac{1}{4\pi^2 f_0^2 C},$$

(16)

$$R=\frac{2Z_0}{\sqrt{\frac{1}{|S_{11}(\omega)|^2-\left(2Z_0\left(\omega C-\frac{1}{\omega L}\right)\right)^2}-1}}.$$

(17)

3. RESULTS AND DISCUSSION

Using the equations which are given section 2, all parameters can be calculated and designed the structure of proposed antenna using HFSS simulation software and MATLAB coding to find out the return loss and VSWR for patch antenna.

Here, the substrate length and height are 100 mm and 3.2 mm respectively. Patch has length 40 mm and height 30 mm. FR 4 substrate is used as a dielectric with dielectric constant 4.5 and loss tangent is 0.021. By using Eq. (3), effective dielectric constant can be calculated and effective length is easily obtained from Eq. (4), which decides the total length of radiating patch. Now, the length and height can be obtained from Eqs. (7) and (8). Defected ground parameters are in parallel in each gap with the same values. So, inductance, capacitance and resistance can be find out using equations given above, which makes slow wave components. These gaps are at equal space in ground plane.

Figure 2, shows the basic designed of proposed antenna with edge fed line.

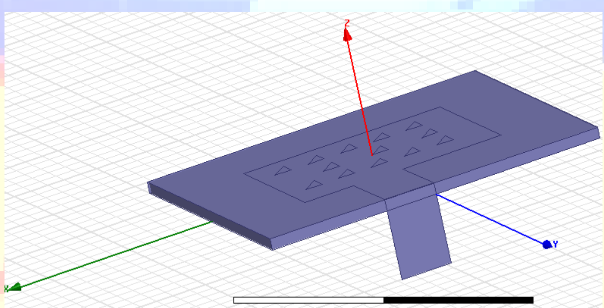

Fig. 2 Proposed Antenna Design with fractal symmetry.

Figure 3, represents the top and bottom view of antenna, in which top is for fractal and bottom view is for defected ground structure, introducing seven slow wave structures.

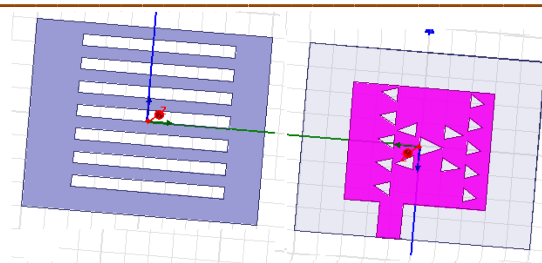

Fig. 3 First one represents defected ground structure, second one represents fractal symmetry in designed antenna.

Now, the proposed antenna is designed for wideband, so it covers the WiFi and WiMax range (2-6 GHz). Designed antenna is basically works for 3.55 GHz. But, in Figure 4, the return loss (-24 dB) is minimum at 3.15 GHz without fractal and defect ground structure, due to fringing effect and position of probe for excitation to the antenna and Figure 5, is showing the VSWR (1.2 dB) at that particular postion of frequency. This can be performed on HFSS simulation software.

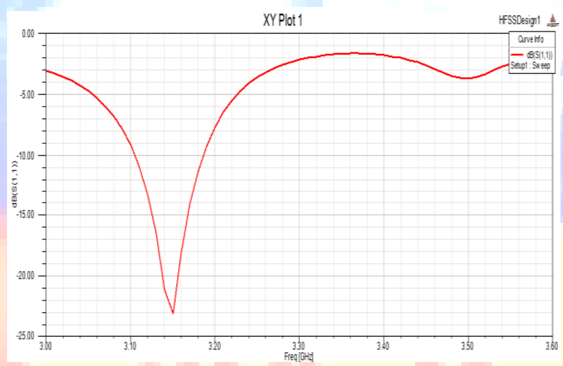

Fig. 4 Return Loss (S11) of proposed antenna without Fractal and Defected Ground structure.

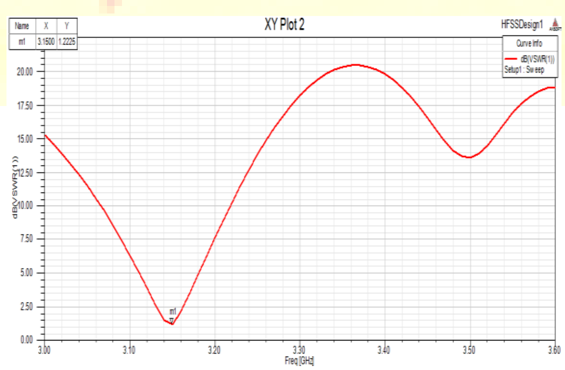

Fig. 5 VSWR of proposed antenna without Fractal and Defected Ground structure.

After introducing the fractal and DGS in proposed antenna, the return loss (Figure 6) is minimized at the required frequency as well as VSWR (Figure 7) is near to the desired value. Here, simulation as well as analytical values of return loss and VSWR is in close agreement of ~5%. Return loss is -40 dB by analysis and VSWR is 1.1 dB.

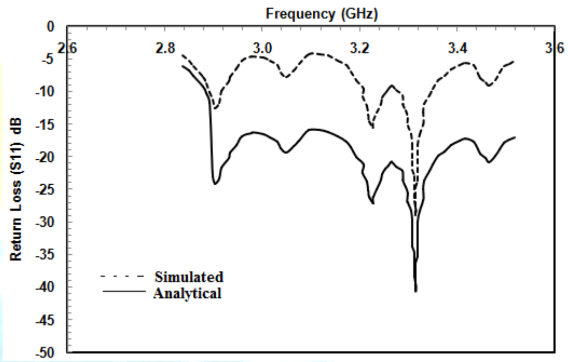

Fig. 6 Return Loss (S11) of proposed antenna with Fractal and Defected Ground structure.

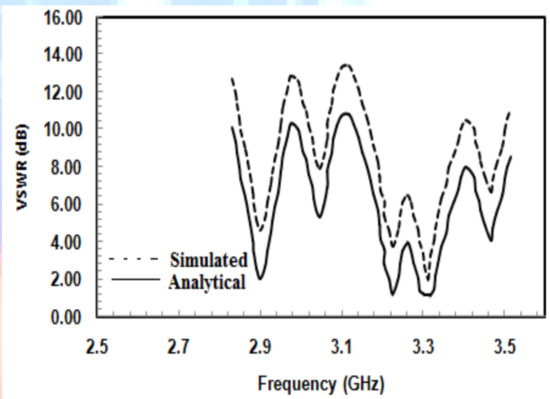

Fig. 7 VSWR of proposed antenna with Fractal and Defected Ground structure.

These results have been carrying out by calculating the incident power, output power and reflected power, which can be easily calculated from the source being in used. From the above plots, it can easily detect that the proposed antenna is working at several resonant frequencies, so it is usable for wideband applications.

4. CONCLUSION

The rectangular microstrip antenna with fractal and defected ground structure proposed for wideband applications. The return loss has been found out very less at the required frequency and similarly the VSWR has come closely near to 1. This antenna could be better than that of initially proposed antennas by other one. It is used for not only GSM, but also for WiFi and WiMax range. The bandwidth requirement is been fulfilled, which is appromately, 4-6 MHz. The antenna can be used for variety of microwave applications.

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