Inset-fed Cantor Set Fractal Multiband Antenna Design

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Abstract- The design and analysis of a Microstrip Patch Antenna having Cantor set fractal geometry has been discussed in this paper. Inset-fed technique has been implemented in the design and the substrate material used is FR4- epoxy of relative permittivity 4.4 and thickness 1.6 mm. The design was simulated on electromagnetic simulation software Ansys HFSS (High Frequency Structure Simulator) version 13.0. MATLAB R2015a has been used for calculating the parametric design values for the proposed antenna. The various parameters of the proposed Microstrip Patch Antenna (MPA) were evaluated and analyzed such as return loss, Voltage Standing Wave Ratio (VSWR), bandwidth , gain and radiation pattern. Simulation results establish that the antenna having multi-band behavior which can effectively be utilized for Wireless applications.

Keywords – Microstrip Patch, Inset fed, cantor set, fractal, FR4-epoxy

I. Introduction

In recent years, with the rapid growth of the wireless communication technology, the future technologies needs a very small size, multi band antenna in order to avoid using of two or more antennas. Microstrip patch antenna is very useful for the future technology. Microstrip patch antenna consists of a dielectric substrate, with a ground plane on the other side. Due to its advantages such as low weight , low profile planar configuration, low fabrication costs and capability to integrate with microwave integrated circuits technology, the microstrip patch antenna is very well suited for applications such as wireless communications system, cellular phones, pagers, Radar systems and satellite communications systems. Double L-slot microstrip patch antenna array for WiMAX and WLAN applications is presented in [1]. There is a need of fractal antenna for achieving the multiband characteristics explained in [2]. Multiband microstrip antenna for wireless applications with Proximity coupled feeding technique presented in [3]. Achieving of multiband and compact size explained in [4-5]. Inset fed technique is presented in [6].Multiband fractal antenna with triangular shape explained in [7]. Rectangular Patch antenna design explained in [8]. In this project, a compact multiband design of Microstrip patch antenna is proposed which will resonate at four different frequencies of S(2-4GHz),C(4-8GHz) and X(8-12GHz) bands. The Antenna Parameters are calculated by using MATLAB software version R2021a and Antenna design by using Electromagnetic Simulation Software HFSS.

The rest of the paper is organized as follows. Proposed antenna design explained in section II. HFSS Software Simulated results are presented in section III. Concluding remarks are given in section IV.

II. Proposed Antenna Design

A. Antenna Design Equations :–

The design equations for rectangular microstrip patch antenna have been utilized to obtain the antenna geometry. The center/resonant frequency in this design is 2.4 GHz. The substrate material used is FR4-epoxy with dielectric constant 4.4 and thickness 1.6 mm. The wavelength is calculated as ratio of velocity of Wave and frequency of the wave. The patch length determines the resonant frequency and they are inversely proportional. Electrically the patch length bigger than the physical length. By taking this into account the normalized extension of length is calculated. Width of the patch and permittivity dielectric decides the characteristic impedance of antenna. The length of the ground plane is optimized to get the desired values of bandwidth and return loss.

Step 1: The wavelength(λ) is calculated as given below:

$$\lambda = \frac{c}{f_c} \tag{1}$$

where, f_c is the center frequency and $c = 3 \times 10^{11}$ mm/s.

Step 2: The width of antenna patch (W_P) calculated by the equation:

$$W_P = \frac{c}{2f_c}\sqrt{\frac{2}{\epsilon_{r+1}}} \tag{2}$$

where, ε_r represents the substrate dielectric constant.

Step 3: The length of antenna patch (L_P) has been calculated by the equation:

$$L_P = L_{eff} - 2\Delta L \tag{3}$$

where, L_{eff} is the effective length of patch and ΔL indicates the normalized extension in length.

$$L_{eff} = \frac{c}{2f_c\sqrt{\epsilon_{reff}}} \tag{3a}$$

where, ε_{reff} , know as the effective dialectic constant of substrate, is given by:

$$\varepsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+\frac{12H}{W_P}\right]^{-1/2} \tag{3b}$$

and the normalized extension in the length is calculated as :

$$\Delta L = 0.412H\,\frac{(\epsilon_{reff}+0.3)}{(\epsilon_{reff}-0.258)}\,\frac{\left(\frac{W_P}{H}+0.264\right)}{\left(\frac{W_P}{H}+0.8\right)} \tag{3c}$$

Step 4 : Substrate length (L_S) and substrate width (W_S) are evaluated using the following equations

$$L_S = L_P + 6H' \tag{4a}$$

$$W_S = W_P + 6H' \tag{4b}$$

Where, $H' = \frac{0.0606\,\lambda}{\sqrt{\epsilon_r}}$

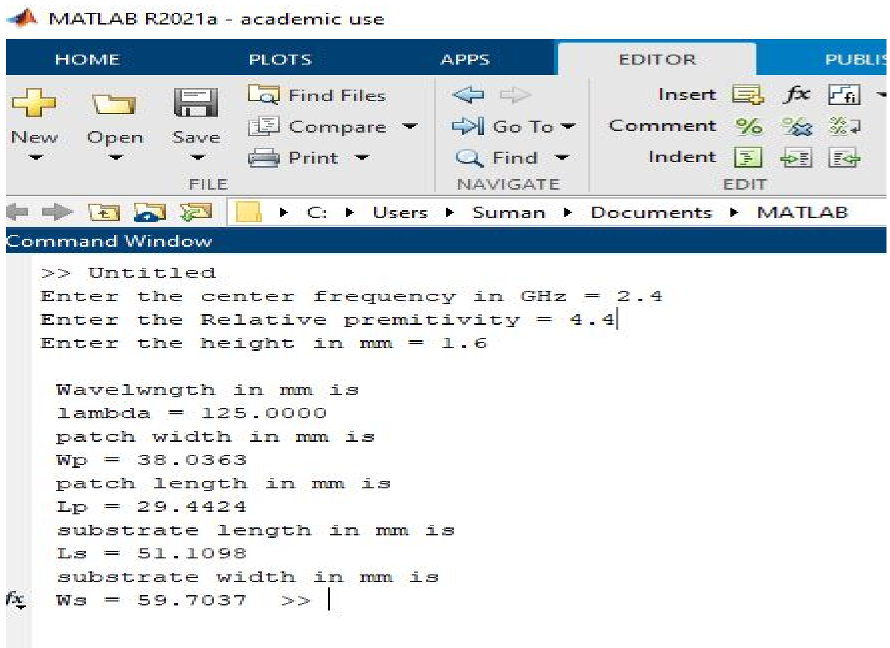

Figure 1. Antenna parameters calculated using MATLAB

TABLE I . DIMENSIONS OF ANTENNA FOR CENTER FRQUENCY (f_C) = 2.4GHz

S.No	Antenna Parameters	Values (mm)
1.	Substrate Length (L_S)	51.10
2.	Substrate Width (W_S)	59.70
3.	Patch Length (L_P)	29.44
4.	Patch Width (W_P)	38.03
5.	Feed line Length (L_F)	16.83
6.	Feed line Width (W_F)	2.0
7.	Inset-cut Length (L_i)	6.0
8.	Inset-cut Width (W_i)	1.0

B. Cantor Set Geometry -

The Cantor set is set of points lying on a line segment. It is created by taking some interval, for instance [0,1],and removing middle third (1/3,2/3), then removing the middle third of each of the two remaining sections(1/9,2/9) and (7/9,8/9) then removing the middle third of the remaining four section. This will continue untill the length is zero.

The quality factor of microstrip patch antenna is decreases with the introduction of slots. The presence of slot decreases the conduction area due to this the conduction losses can be minimized and also the dielectric loss of substrate, so that the Q factor decreases. As the Q factor value decreases the bandwidth of the patch antenna increases. The length of the ground plane has major importance because it leads to impedance matching and there by increases the bandwidth.

TABLE II. SLOT LENGTH AND WIDTH OF CANTOR SETS

S.No	Segments	Length of slot (mm)	Width of the slot (mm)
1	Initial Segment	24.3	1
2	1st Iteration	8.1	1
3	2nd Iteration	2.7	1
4	3rd Iteration	0.9	1

III. EXPERIMENT AND RESULTS

The Antenna is designed in HFSS as per parameters obtained in section II. The antenna performance is evaluated by its Bandwidth, Return loss, Gain, VSWR and radiation pattern. The resonance frequency of an antenna is estimated by observing its return loss and VSWR.

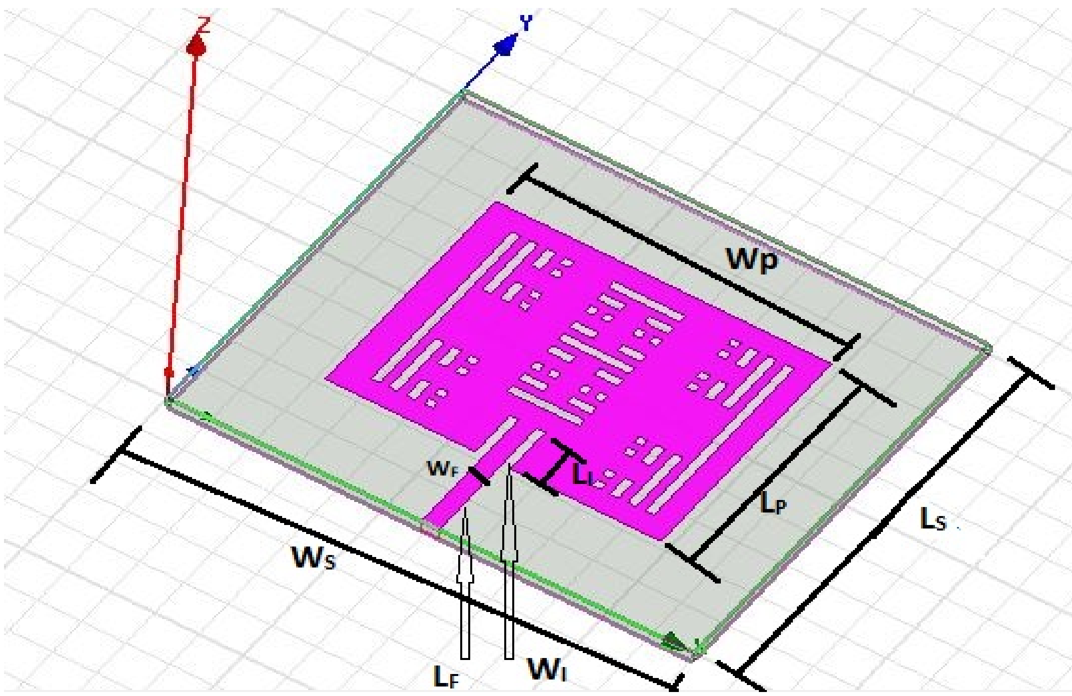

Figure 2. Antenna Design in HFSS

A. *Return Loss (S11):-* Return loss is a measure that indicates the amount of energy reflected by the antenna owing to impedance mismatches. . A good radiating element must have its S(1,1) should be below -10 dB at the resonant frequencies. The plot shows the variation of Return loss in dB with frequency is as depicted in Figure 3 indicating that the antenna has much lower than -10dB Return losses at frequencies 2.3GHz,4.7GHz,8GHz and 9.8GHz.

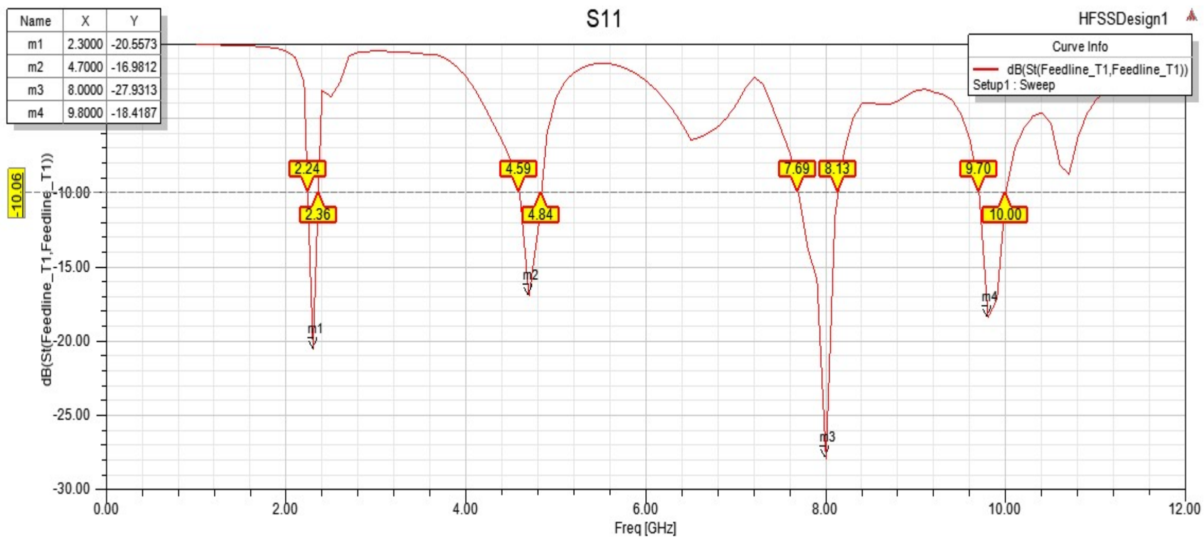

Figure 3. Plot shows the variation of return loss in dB with frequency

B. *VSWR:-* VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line to which it connected. A VSWR of 2 is considered to be marginally acceptable. The plot shows the variation of VSWR with frequency is as depicted in Figure 4 showing that the VSWR values at at frequencies 2.3GHz,4.7GHz,8GHz and 9.8GHz are below 1.4 that indicates that antenna matched to transmission line.

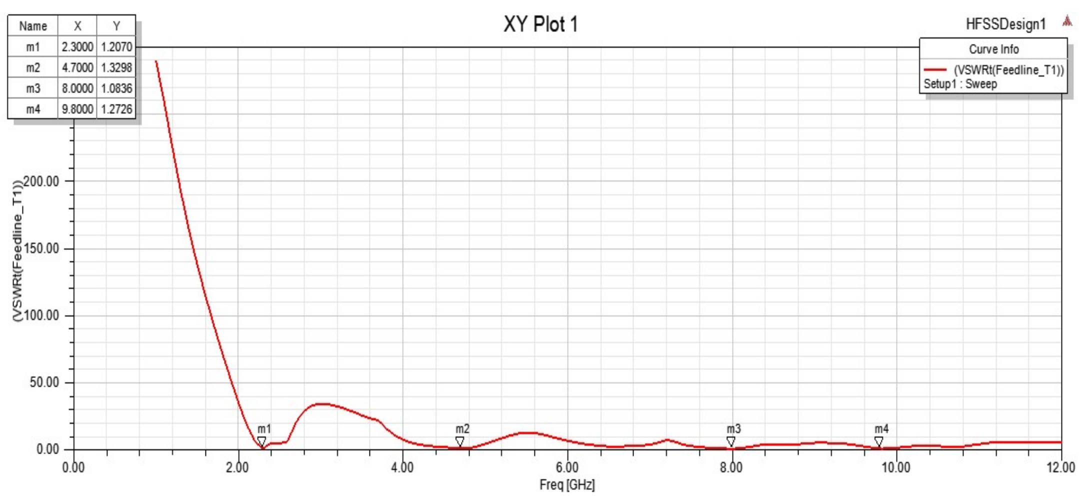

Figure 4. Plot shows the variation of VSWR with frequency

C. Radiation Pattern **:-** The directional variation in intensity of the radiation from an antenna or other source. The power when radiated from the antenna has its effect in the near and far field regions. Graphically, radiation can be plotted as a function of angular position and radial distance from the antenna. the main lobe(bigger) shows in that direction signal strength is more .The back lobe shows some energy radiated backside.

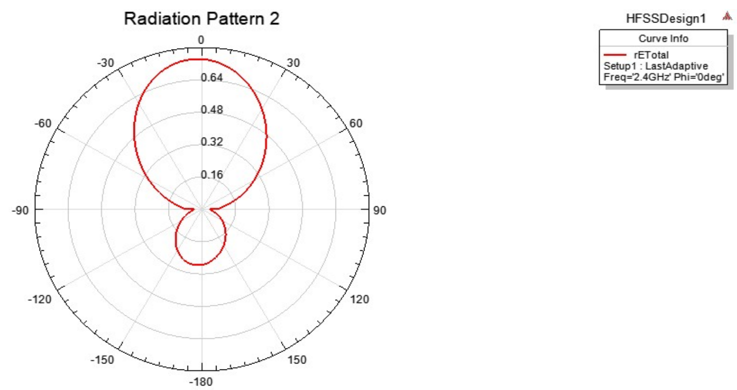

Figure 5. Plot shows the variation Radiation Pattern

D. Gain :- The gain of an antenna relative measure of an antenna's ability to direct or concentrate radio frequency energy in a particular direction or pattern. A minimum gain is required to achieve a minimum carrier-to-power-noise ratio. This design achieved the gain of 2.5dB,3.7dB,1.9dB,1.49dB corresponding to the resonant frequencies 2.3GHz,4.7GHz,8GHz and 9.8GHz.

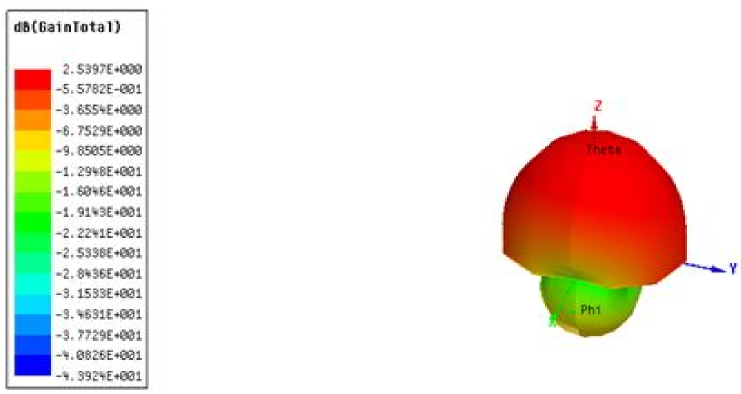

Figure 6. Plot shows the Gain of Antenna

TABLE III. Achieved results for different Resonate frequencies

S.No	Resonate Frequency (GHz)	Return Loss (dB)	VSWR	Band Width (MHz)	Gain (dB)
1	2.3	-20.55	1.20	120	2.5
2	4.7	-16.98	1.32	250	3.7
3	8.0	-27.93	1.08	440	1.9
4	9.8	-18.41	1.27	300	1.49

IV.CONCLUSION

The fractal multiband antenna with cantor sets geometry exhibits multiband characteristics. The simulation results are found to be at acceptable levels. By using various gain improvement techniques improved values of gain can be obtained. The antenna can be used for wireless applications in the S, C and X bands like Wi-Fi, mobile communication, surveillance, weather radar systems and satellite communication. This antenna can also be employed in several wireless devices owing to its small size, low profile and light weight.

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