Fractal Antenna for UWB Applications: A Review

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ABSTRACT
In this paper, A fractal geometry based Sierpinski square monopole antenna is investigated for UWB $(3.1 - 10.6\ GHz)$ application with band-notched characteristics.

UWB technology has unique features and promising applications in communications. For example, in wireless communications, the extremely wide operating bandwidth has the potential for high data-rate connections. However, the very low emission level has limited the wireless connection range to a few meters.UWB systems will coexist with other traditional communication systems in the same frequency band by using low power levels.UWB technology has received an impetus attracted academia and industrial attenuation in wider range of applications including ground plane penetrating radars, high data rate short range WLAN networks, communication systems for military purposes etc.

Keywords
Fractal antenna, UWB, MSSF

1. INTRODUCTION
The microstrip line fed modified Sierpinski square fractal (MSSF) antenna for UWB with band notch characteristics has been studied. The UWB $(3.1 - 10.6\ GHz)$ is achieved by increasing the number of iterations and rectangular grooved ground plane. The band rejection characteristic is realized by an $\cap -slot$ in feed line. The antenna consists of volume $34 \times 34 \times 1.6\ mm^3$ with square shape structure and shows omni-directional radiation patterns. The measured results dipicts that the antenna offers impedance bandwidth of 110% for (UWB $3.1 - 10.6$ GHz) and a notched at $5.5\ GHz\ (5 - 6\ GHz)$ for wireless local area network (WLAN) band.

1.1 Antenna geometry and simulation results
The recursive procedure for square Sierpinski geometry is shown in Figure 1.1. The proposed geometry is based on IFS model .IFS generates the Sierpinski square fractal gasket. It is unruffled of three similar transformations.

$$\omega_1(x,y) = \begin{pmatrix} 1/2 & 0 \\ 0 & 1/2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} 1/4 \\ 0 \end{pmatrix} \quad (1.1)$$

$$\omega_2(x,y) = \begin{pmatrix} 1/2 & 0 \\ 0 & 1/2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} -1/4 \\ 0 \end{pmatrix} \quad (1.2)$$

$$\omega_3(x,y) = \begin{pmatrix} 1/2 & 0 \\ 0 & 1/2 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} 0 \\ 1/2 \end{pmatrix} \quad (1.3)$$

Geometry of modified square Sierpinski fractal (MSSF) antenna for UWB operation is illustrated in Figure (1.2) and corresponding optimized parameters are listed in Table (1.1.) The antenna is implemented on standard $FR-4$ substrate $W \times L$ with relative permittivity $\varepsilon_r = 4.4$, thickness $h = 1.58\ mm$ and loss tangent $\tan(\delta) = 0.005$. A 50 Ω microstrip transmission line with a strip width W_f and length L_f is utilized to feed the antenna with the corresponding section over rectangular ground plane. The radiating element is placed over one side of the substrate and ridged ground plane of size $W_g \times L_g$ is located on other side of the substrate. It is noted that the grooved area of size $\omega_s \times l_s$ is located on top of the ground plane. The proposed MSSF antenna consists of two parts. In first part, the fractal geometries are generated from an original square slot x, and iterated by Generator method. The square slot is splitted into four parts with the same physical size as shown in Figure 1.3. The first iteration is achieved when the upper left part is filled with metal. Then, the same generator method is applied on the remaining portion. Repeating this generator method continuously, we can generate the n^{th} order Sierpinski square slot geometry along with similar characteristics. Figure 1.3 (e) shows the modification after 3^{rd} iteration of proposed model. This model provides a UWB performance in the range of $3.1 - 10.6\ GHz$. In second part, an $\cap -slot$ with height t_l and width t_s & t_ω has been placed on microstrip feed line. A deep band notch at $5.5\ GHz$ is provided using the $\cap -slot$. This slot prevents the interface between Wireless LAN and Ultra WB bands; meanwhile, the patterns and impedance bandwidth of the antenna are not affected using the $\cap -slot$. Figure 1.4 shows the simulated reflection coefficient characteristics for different iteration stages of MSSF antenna. The resonance frequency of MSSF antenna decreases and bandwidth increases with increase in the number of iterations. Figure 1.5 shows simulated reflection coefficients for different length l_s and width ω_s of grooved rectangular slot in ground plane. The values of length l_s and width ω_s are varying from $2.8\ mm\ to\ 3.8\ mm\ and\ 3.6\ mm\ to\ 5.2\ mm,$ respectively. The operating bandwidth of MSSF antenna is improved for length, $l_s = 4.4mm$ and width $\omega_s = 2.8mm$. From this observation, it is clear that the reflection coefficients can be controlled by changing the value of rectangular slot l_s and ω_s in top of the ground plane.

A very narrow $\cap -slot$ is cut away from the feed line as shown in Figure 1.2 (a). It acts as a filter element to make the antenna non-responsive at the ω_s frequency. To act as a band-reject UWB antenna, the reflection coefficient of the stop-band notch should be almost 1.0. However, in the band-stop antenna design, reflection coefficient $-2.1\ dB$ is observed. The $\cap -slot$ filter element dimensions will control both the bandstop frequency f_{notch} and the rejection bandwidth of the band notched filter BW_{notch}. The $\cap - shaped$ slot filter of height t_l and widths t_s & t_ω is placed on microstrip feed line. Figure 1.6 shows the simulated reflection coefficients of the MSSF antenna for different values of slot length t_l keeping other parameters fixed. It can be seen from Figure 1.6 that the length t_l of $\cap - slot$ has an effect on $0.707\omega_c$ of the notch band. Hence, the resonance frequency can be adjusted by optimizing the length of $\cap - slot$. It is establish that the resonant frequency of the notched band decreases with increase in the value of t_l.

$$slot\ length \approx \frac{c}{2f_{notch}} \left\{ \frac{\sqrt{\epsilon_r + 1}}{2} \right\}^{-1}$$

where c is the velocity of light and ϵ_r is the relative permittivity. Figure 1.7 plots the simulated reflection coefficients of antenna with and without the $\cap - slot$. It is clear that the antenna resonances remain unaffected due to the presence of the $\cap - slot$ excluding the frequency band $5 - 6\ GHz$. Figure 1.8 shows the simulated $3D$ radiation patterns and surface current distributions of the proposed MSSF antenna at $4\ GHz$, $5.5\ GHz$, $6.2\ GHz$ and $8.7\ GHz$. It can be observed that the gain of the radiator all the frequencies is more than $2\ dBi$. $3D$ patterns are omnidirectional towards the lower frequency band and nearly omni-directional with multiple lobes towards the high frequency band. The division of current in lower frequency is on lower side of the radiating element. Further, at higher frequency, the current moves towards the initial point of the radiator. In addition, at 5.5 GHz the 3D stronger current distribution mainly concentrated at the area of $\cap - slot$. It causes the antenna to be non-reactive at that frequency.

The impedance changes making large reflection at the desired notched frequency. Table 1.2 provides the Simulated gain (dBi), Measured gain (dBi) and Total antenna efficiency for UWB antenna. From the table, some discrepancy exists between measured and simulated gains. This is not consistent in nature. However, simulated total antenna efficiency is more than 75 % throughout UWB.

Table 1.1:Dimensions of MSSF antenna

L	W	W_f	L_f	W_g	L_g	x
34mm	34mm	3.8mm	13.5mm	34mm	13mm	20mm
l	ω_8	l_8	t_8	t_ω	t_l	
22mm	2.8mm	4.4mm	0.2mm	2mm	7.4mm	

Table 1.2 : Simulated gain, measured gain and simulated total antenna efficiency of MSSF antenna

Antenna Type	Frequency (GHz)	Simulated Gain (dBi)	Measured Gain (dBi)	Total Antenna Efficiency (%)
UWB MSSF antenna with ∩-slot	4	3.32	3.34	92.9
	5.5	4.11	4.17	83.82
	7	4.78	4.33	84.81
	9	3.78	3.26	75.14
UWB MSSF antenna without ∩-slot	4	3.10	3.39	91.5
	5.5	-4.15	-4.32	22.30
	7	4.12	4.39	81.47
	9	3.58	3.12	74.05

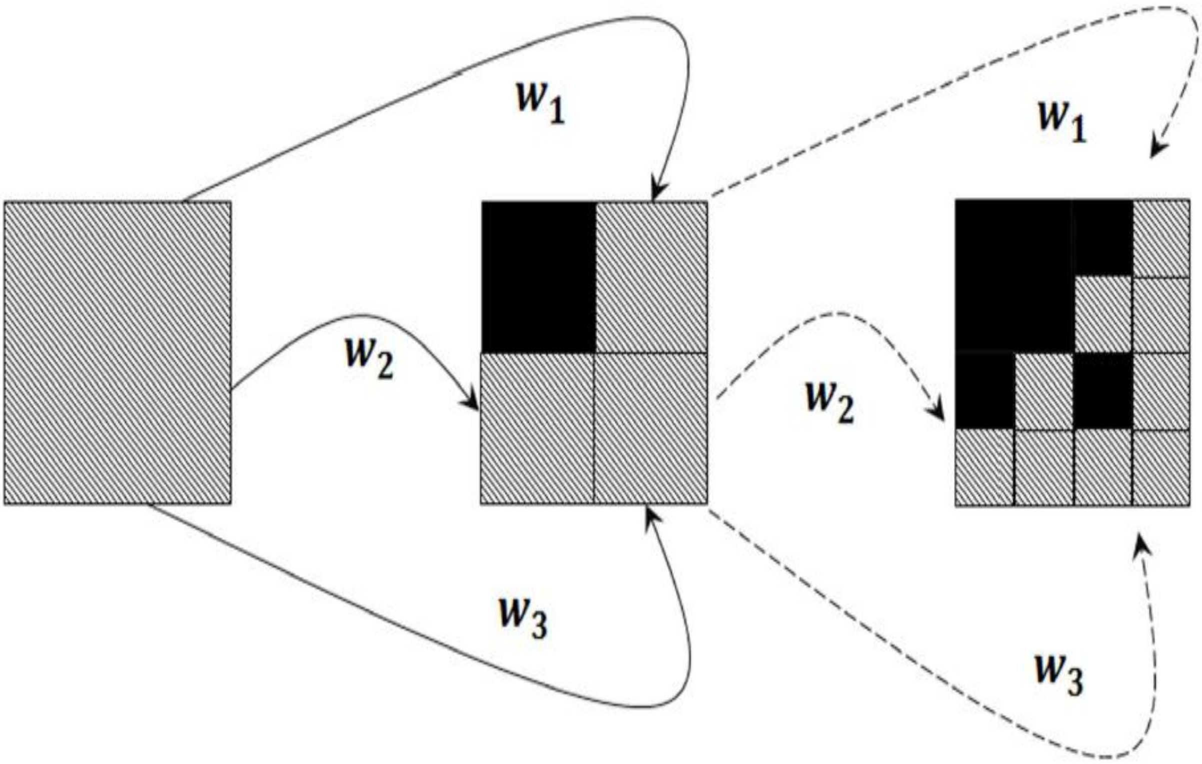

Figure 1.1: Stages of the IFS that generates the square Sierpinski.

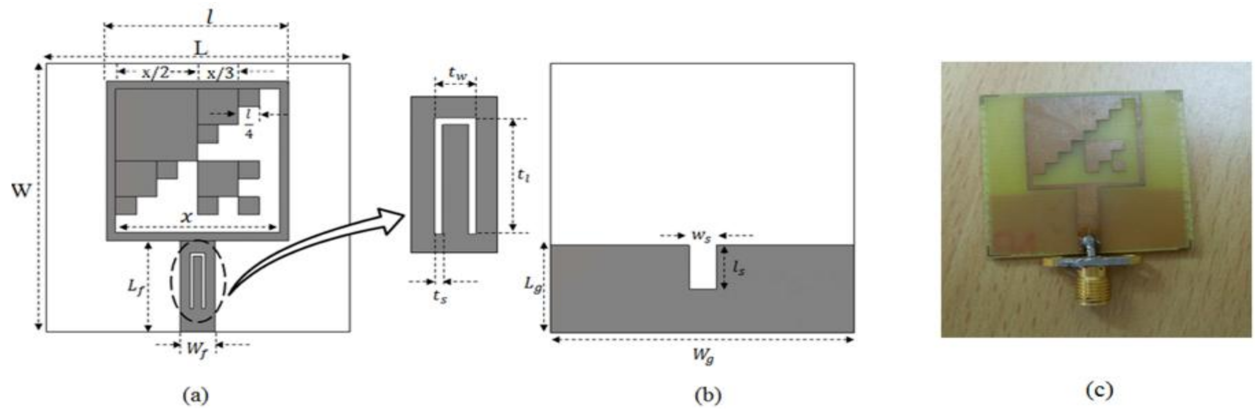

Figure 1.2: Geometry of MSSF antenna (a) Front view (b) Rear view (c) Photograph.

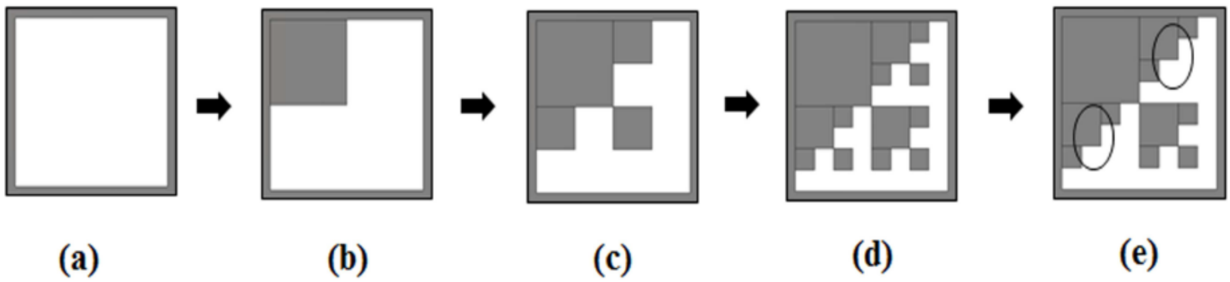

Figure 1.3: MSSF geometry and its different stages (a) Basic geometry (b) First iteration (c) Second iteration (d) Third iteration (e) Modified geometry

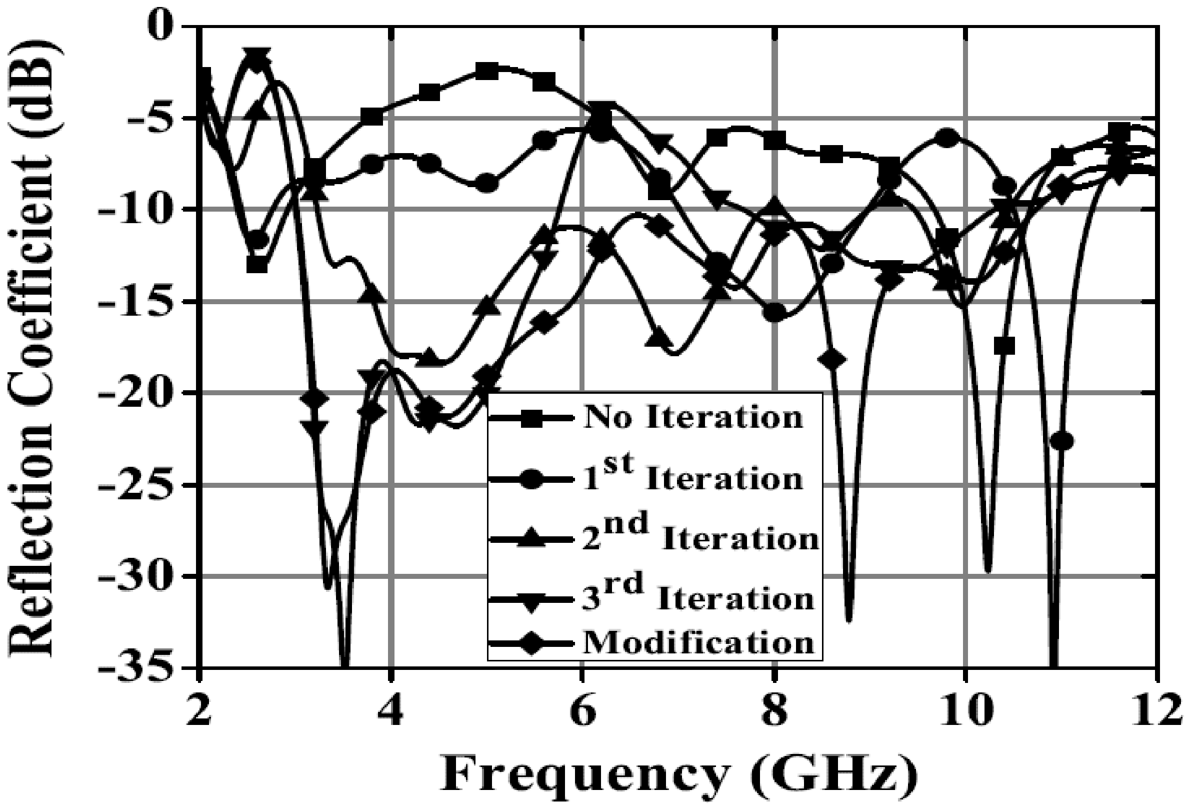

Figure 1.4: Simulated reflection coefficients of MSSF antenna for different iteration.

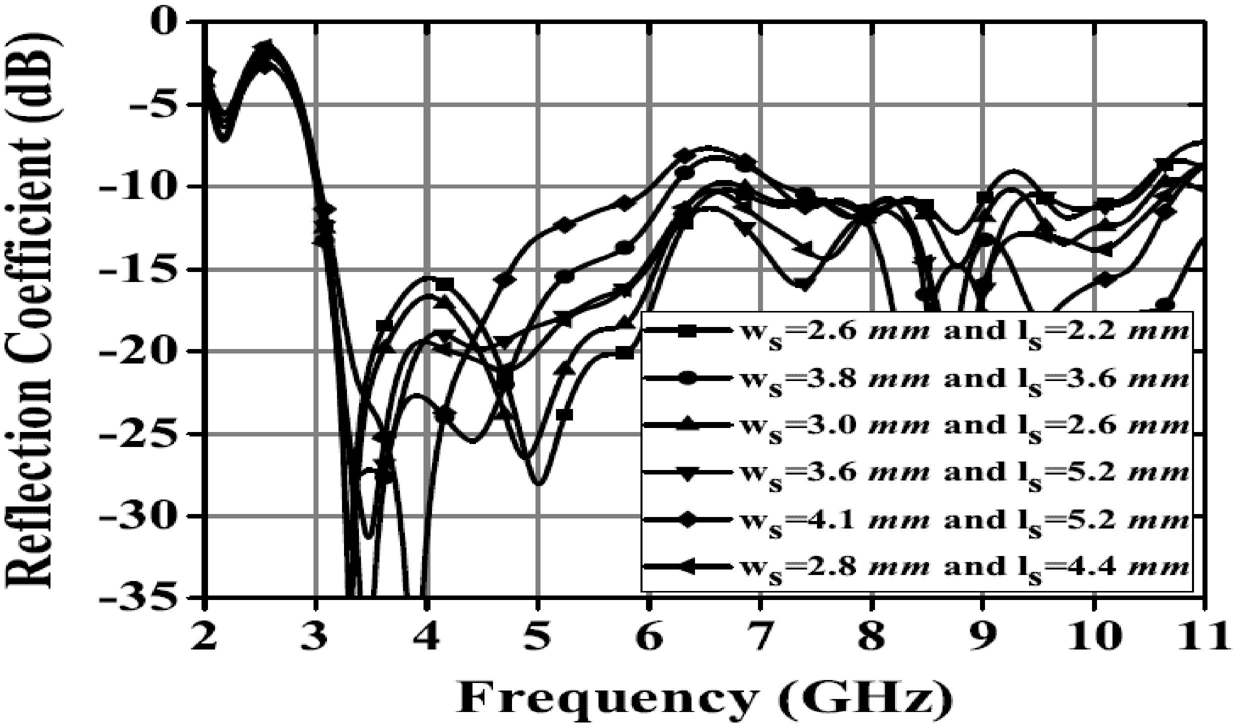

Figure 1.5: Simulated reflection coefficients of MSSF antenna for different configuration of grooved ground plane.

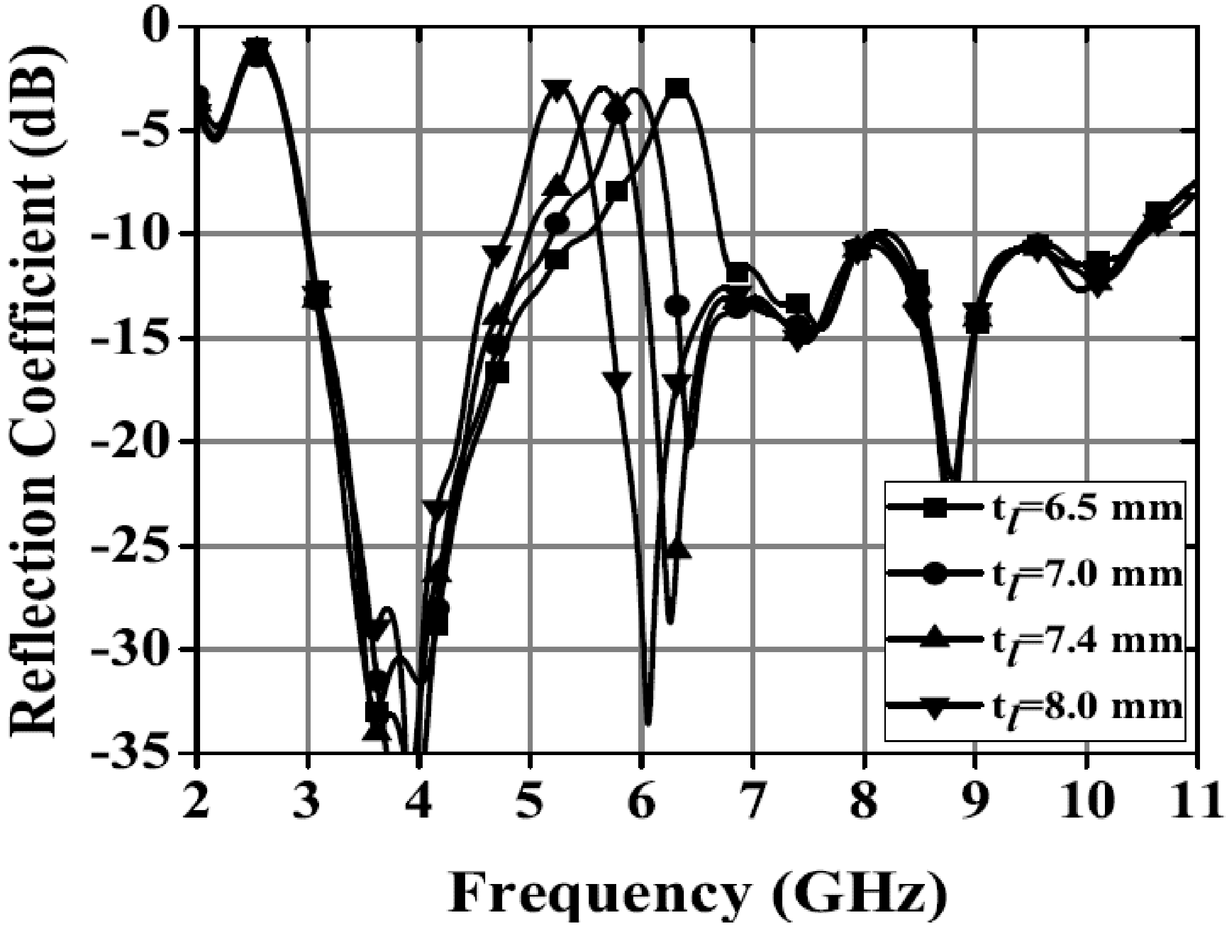

Figure 1.6: Simulated reflection coefficients of MSSF antenna for length tl of band notch slot.

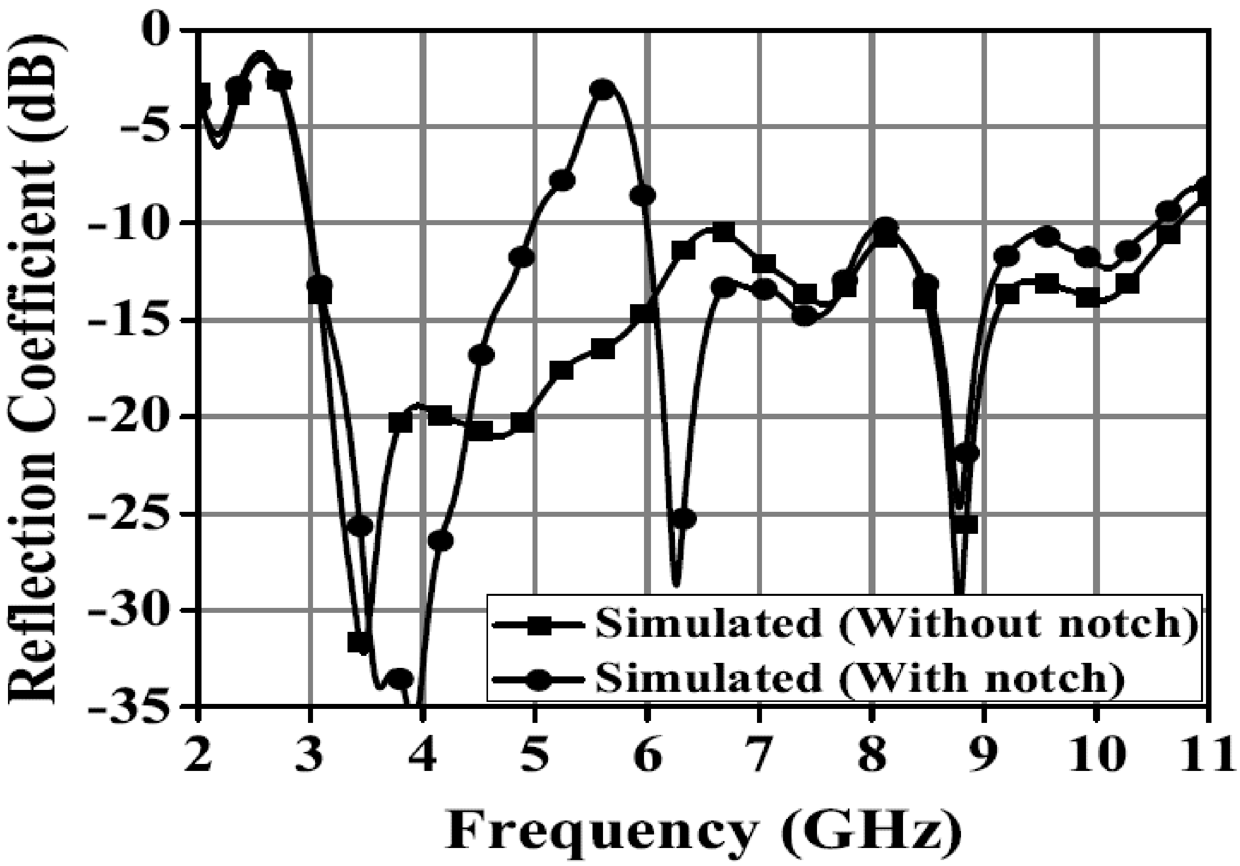

Figure 1.7: Simulated reflection coefficients of MSSF antenna for with and without notch.

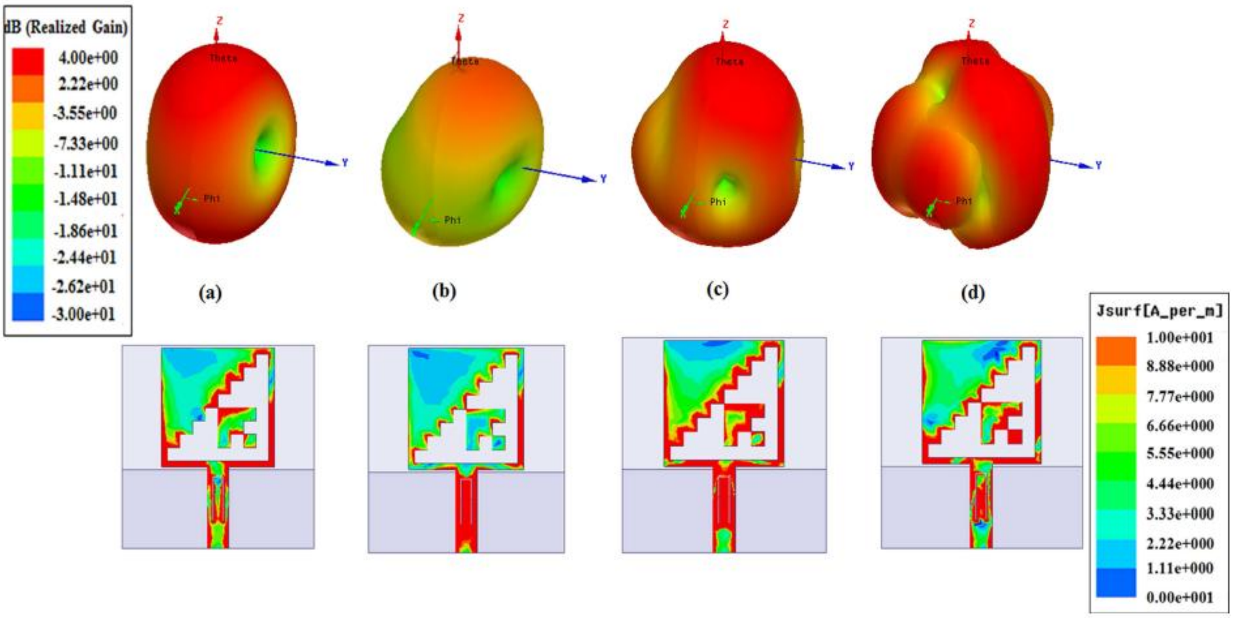

Figure 1.8: Simulated 3D radiation patterns for MSSF antenna at (a) 4 GHz (b) 5.5 GHz (c) 6.2 GHz (d) 8.7 GHz.

2. SUMMARY

For UWB application, a modified square Sierpinski fractal (MSSF) antenna is studied. The MSSF antenna is useful for UWB application $(3.1 - 10.6)$GHz with band notch characteristics at 5.5 Ghz $(5 - 6)$GHz. The band rejection is achieved by using $\cap -slot$ in micro strip feed line. The measured radiation patterns are stable throughout the operating band. The gain of MSSF antenna is $2 - 5\ dB$ in

UWB frequency range and decreases in band rejection frequency.

3. ACKNOWLEDGMENTS

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