Pulse 2.45 Fractal Microstrip Patch Antenna

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Abstract: - The rectangular microstrip patch is used as an initiator to all iterations. The first iterations of a Pulse 2.45 (the generator of this antenna shape is pulse and the initiator is a patch with resonant frequency 2.45 GHz) microstrip patch antenna. In order to enhance the antenna bandwidth and other antenna parameters a modified and inverted Pulse 2.45 microstrip patch antenna was proposed. The examined patch is 46.12% shorter than the simple rectangular patch. The designed antennas using the ready-made software package (Zeland IE3D) were then fabricated using thin film technology and photolithographic technique and their performances were measured in the required frequency range.

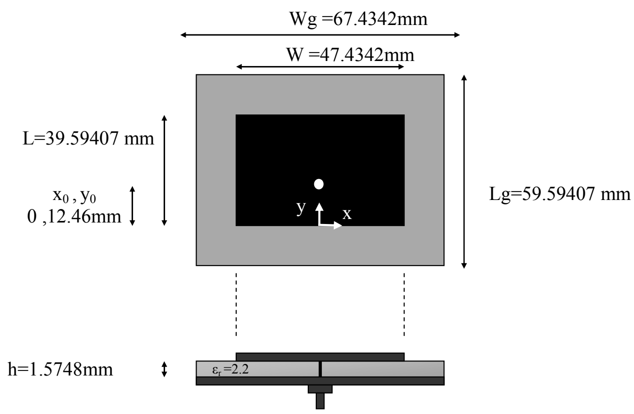
Keywords: - Fractal, Microstrip antenna, Space-filling, and Size reduction.

1 Introduction

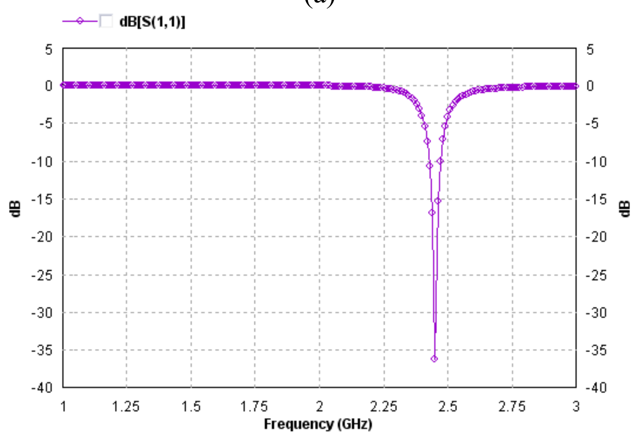
Fractals can be used to miniaturize patch elements as well as wire elements, due to their space filling properties [1-3]. The same concept of increasing the electrical length of a radiator can be applied to a patch element. The patch antenna can be viewed as a microstrip transmission line [4]. Therefore, if the current can be forced to travel along the convoluted path of a fractal instead of a straight Euclidean path, the area required to occupy the resonant transmission line can be reduced. This technique has been applied to patch antennas in various forms [5].

2 Initiator of Pulse 2.45 Antenna

A rectangular patch antenna was designed to resonate at Bluetooth frequency 2.45GHz on dielectric with substrate ε_r =2.2 (Duroid 5880) and h = 1.5748 mm. The antenna is fed by a probe coaxial feed at the position x_0 = 0 mm, y_0 = 12.46 mm from the bottom edge. Simulating the rectangle structure using Zeland IE3D [6] to obtain the reflection coefficient (| S_{11} | in dB) and the radiation pattern gives the results shown in Fig. 1 (a),(b),(c) . Tables 1 and 2 show the resonant frequency, -10dB impedance bandwidth and the performance parameters of the antenna.



(a)



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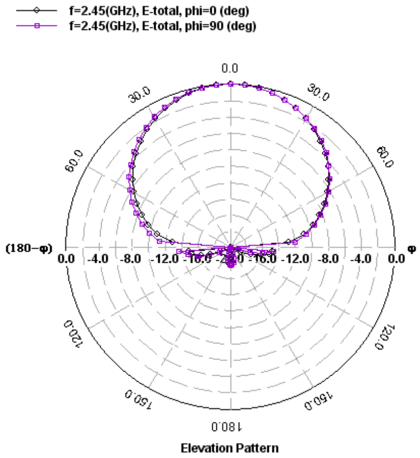


(c)

Fig. 1: (a) Initiator of Koch antenna, (b) Simulated $|S_{11}|$ in dB and (c) Simulated E- and H-plane radiation pattern.

Table 1: Resonant frequency, reflection coefficient and bandwidth for the initiator of Koch antenna.

F in GHz	$\mid S_{11} \mid$ in dB	BW in MHz	BW %
2.45	-36.15	44.1	1.8

Table 2: Antenna parameters for the initiator of Koch antenna.

Parameters	2.45 GHz
Gain (dBi)	7.12
Directivity (dBi)	7.6
Maximum (deg.)	(0 , 10)
3dB Beam Width (deg.)	(79.9 , 83.1)
Radiation Efficiency (%)	89.03
Antenna Efficiency (%)	89

From Tables 1 and 2 we can notice that the rectangle microstrip patch antenna may operate at the Bluetooth band, which has many applications. The rectangle microstrip patch antenna has narrow bandwidth and good radiation efficiency, gain and directivity.

3 Pulse 2.45 antenna Iterations

The first four iterations of the Pulse 2.45 microstrip patch antenna are shown in Fig. 2 (a),(b),(c),(d). Zeland IE3D simulator was used to obtain the reflection coefficient ($|S_{11}|$ in dB) and the radiation pattern, shown in Fig. 3 and Fig. 4 (a),(b),(c),(d). Tables 3 and 4 show the antenna figure-of-merits.

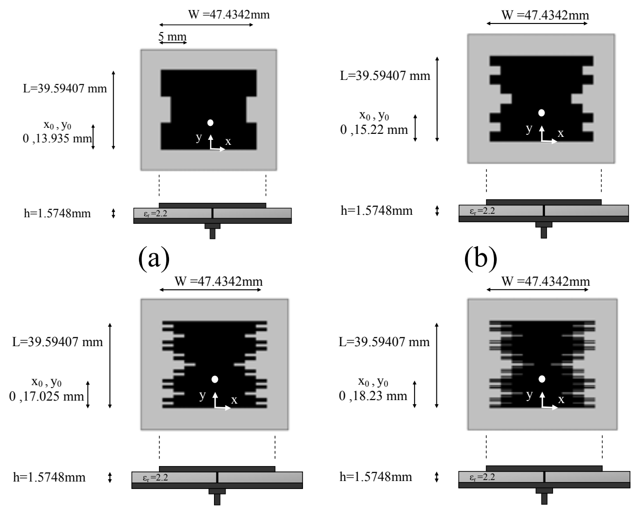


Fig. 2: (a) 1st iteration, (b) 2nd iteration, (c) 3rd iteration and (d) 4th iteration of Pulse 2.45 antenna.

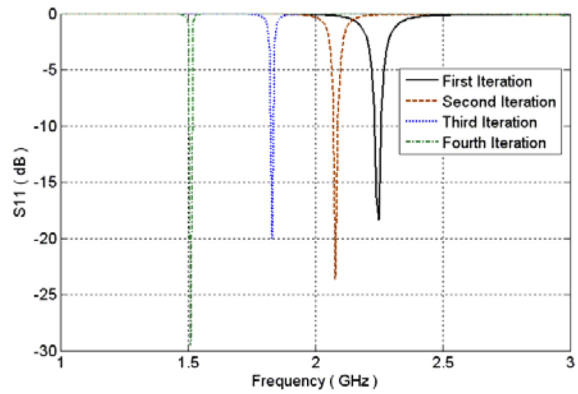
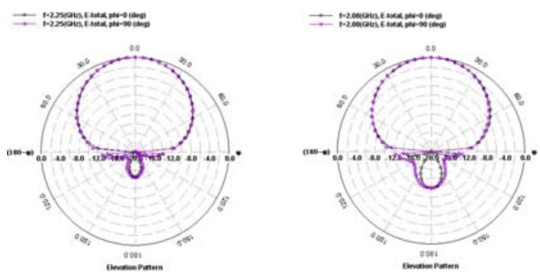


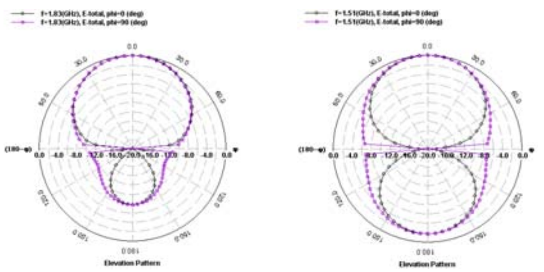
Fig. 3: Simulated $|S_{11}|$ in dB for the first four iterations of Pulse 2.45 antenna.

Table 3: Resonant frequencies, reflection coefficient, bandwidth and size reduction of the Pulse 2.45 antenna.

Iterations	F in GHz	$\mid S_{11} \mid$ in dB	BW in MHz	BW %	Size reduction %
1	2.25	-18.32	27	1.2	8.2
2	2.08	-23.61	18.096	0.87	15.1
3	1.83	-19.85	15.738	0.86	25.3
4	1.51	-29.49	12.382	0.82	38.4



(a) (b)



(c) (d)

Fig. 4: (a) 1st iteration, (b) 2nd iteration, (c) 3rd iteration and (d) 4th iteration of Pulse 2.45 antenna simulated E- and H-plane radiation patterns.

Table 4: Antenna parameters for the Pulse 2.45 antenna

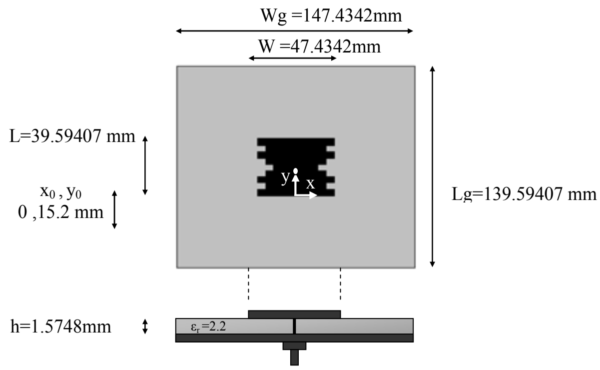
Parameters	Frequency (GHz)			
	2.25	**2.08**	**1.83**	**1.51**
Gain (dBi)	6.69	6.34	5.09	0.56
Directivity (dBi)	7.37	7.16	6.76	5.12
Maximum (deg.)	(0 , 240)	(0 , 110)	(0 , 20)	(0 , 350)
3dB Beam Width (deg.)	(84.4 , 85.55)	(85.99 , 87.93)	(88.19 , 89.69)	(86.18, 94.67)
Radiation Efficiency (%)	86.76	83.04	68.8	35.03
Antenna Efficiency (%)	85.48	82.68	68.12	34.99

From Tables 3 and 4 we can notice that the 4th iteration has very poor gain and radiation efficiency. The 2nd, 3rd and 4th iterations have approximately the same bandwidth (very narrow bandwidth). The maximum reduction size is 38.4 % but on the expense of antenna parameters. The back radiation is very large comparable to the front one and increases with the iteration order. A bow-tie antenna with the same dimensions as that of the second iteration of Pulse 2.45 antenna was simulated and the results of the two antennas were found to be very close.

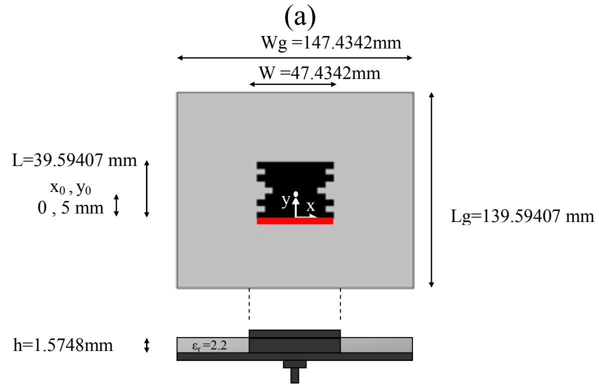
4 The 2nd Iteration of Pulse 2.45 Antenna Modification

4.1 Modified 2nd Iteration of Pulse 2.45 Antenna

We modified the 2nd iteration of the pulse 2.45 microstrip patch antenna by using a shorting wall. The simulated | S_{11} | and radiation patterns without and with shorting wall are shown in Fig. 5 (a),(b), Fig. 6 and Fig.7 (a),(b). Tables 5 and 6 show the resonant frequencies, -10dB impedance bandwidth, percentage size reduction and the performance parameters of the antenna namely gain, directivity, half-power beamwidth, radiation efficiency and antenna efficiency.



(a)



(b)

Fig. 5: (a) 2nd iteration without shorting wall and (b) 2nd iteration with shorting wall.

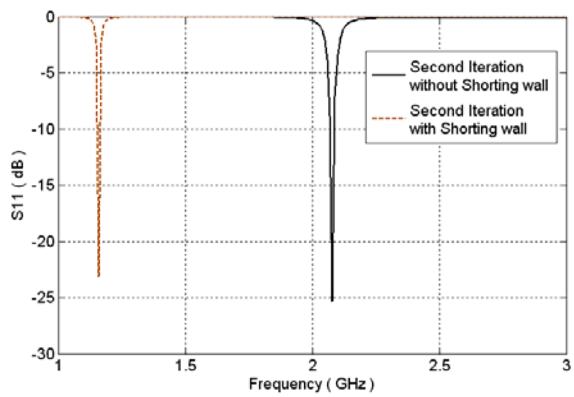
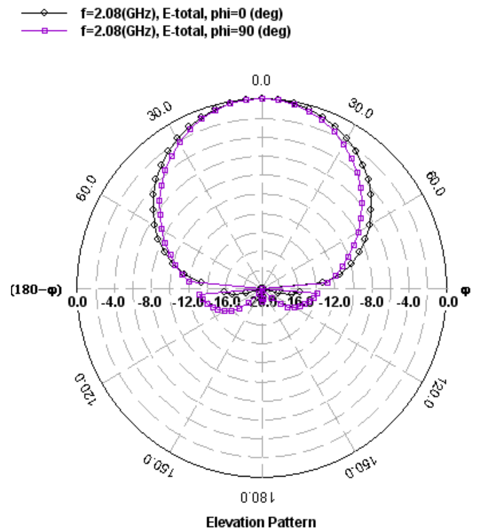


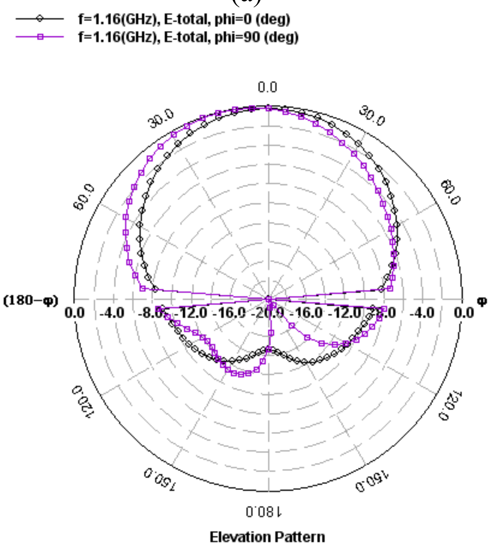
Fig. 6: Simulated | S_{11} | in dB for 2nd iteration without and with shorting wall of pulse 2.45 antenna.

Table 5: Resonant frequencies, reflection coefficient, bandwidth and size reduction of the 2nd iteration of the pulse 2.45 microstrip patch antenna without and with shorting wall.

2nd Iteration	F in GHz	$\lvert S_{11} \rvert$ in dB	BW in MHz	BW %	Size reduction %
Without shorting wall	2.08	-25.32	17.68	0.85	15.1
With shorting wall	1.16	-23.11	12.644	1.09	52.6



(a)



(b)

Fig. 7: (a) 2nd iteration without shorting wall and (b) 2nd iteration with shorting wall of pulse 2.45 antenna simulated E- and H-plane radiation patterns.

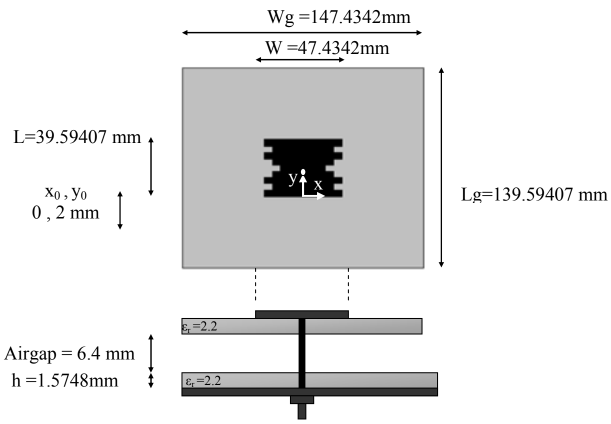
Table 6: Antenna parameters for the 2nd iteration of the pulse 2.45 microstrip patch antenna without and with shorting wall.

Parameters	Frequency (GHz)	
	2.08	***1.16***
Gain (dBi)	7.54	2.78
Directivity (dBi)	8.29	5.99
Maximum (deg.)	(0 , 330)	(15 , 270)
3dB Beam Width (deg.)	(69.48 , 79.33)	(57.02 , 96.39)
Radiation Efficiency (%)	84.24	47.98
Antenna Efficiency (%)	83.99	47.74

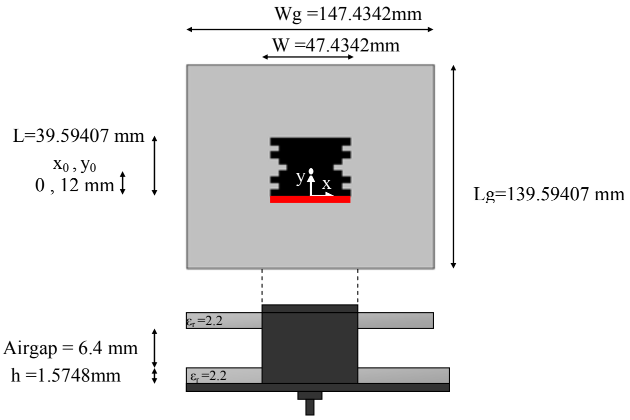
From Tables 5 and 6 we can notice that the shorting wall gives reduction in size by approximately 52.6% but on the expense of other antenna parameters (efficiency, directivity and gain).

4.2 Modified 2nd Iteration of Pulse 2.45 Antenna with air-gap

We modified the 2nd iteration of the pulse 2.45 microstrip patch antenna by using the shorting wall and adding air gap with thickness 6.4mm. The 2nd iteration of the pulse 2.45 microstrip patch antenna without and with shorting wall , shown in Fig. 8 (a),(b) was simulated which gives the results shown in Fig. 9 and Fig.10(a),(b). Tables 7 and 8 show the resonant frequencies, -10dB impedance bandwidth, percentage size reduction and the performance parameters of the antenna.



(a)



(b)

Fig. 8: (a) 2nd iteration without shorting wall and (b) 2nd iteration with shorting wall.

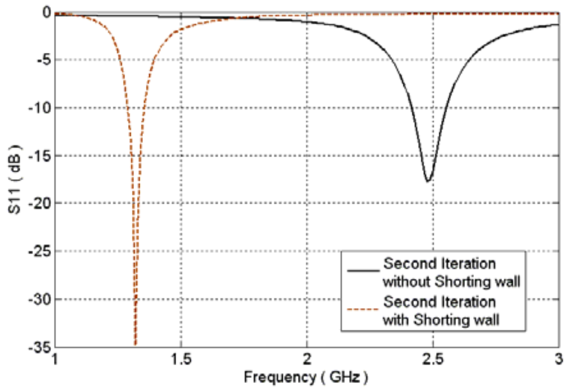
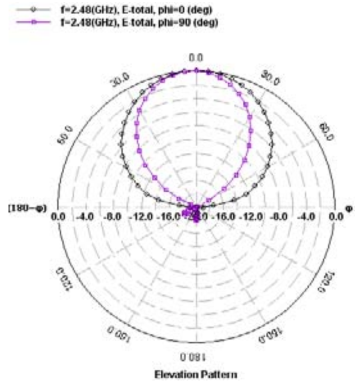


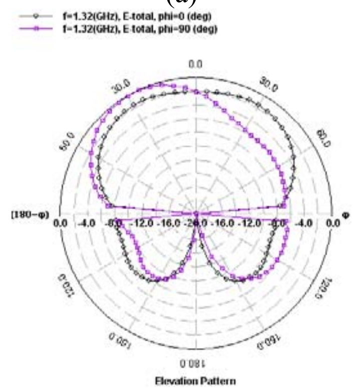
Fig. 9: Simulated | S_{11} | in dB for 2nd iteration without shorting wall and with shorting wall of pulse 2.45 antenna with air gap.

Table 7: Resonant frequencies, reflection coefficient, bandwidth and size reduction of the 2nd iteration of the pulse 2.45 microstrip patch antenna without and with shorting wall.

2nd Iteration	F in GHz	| S_{11} | in dB	BW in MHz	BW %	Size reduction %
Without shorting wall	2.48	-16.9	133	5.4	-1.2 (increased by 1.2)
With shorting wall	1.32	-34.8	66	5	46.12



(a)



(b)

Fig. 10: (a) 2nd iteration without shorting wall and (b) 2nd iteration with shorting wall of pulse 2.45 antenna with air gap simulated E- and H-plane radiation patterns.

Table 8: Antenna parameters for the 2nd iteration of the pulse 2.45 microstrip patch antenna without and with shorting wall.

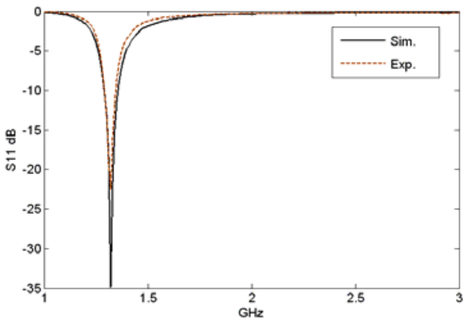
Parameters	**Frequency (GHz)**	
	2.48	***1.32***
Gain (dBi)	9.2	4.85
Directivity (dBi)	9.7	5.45
Maximum (deg.)	(0 , 160)	(30 , 270)
3dB Beam Width (deg.)	(51.35 , 70.78)	(61.91 , 107.13)
Radiation Efficiency (%)	91.45	87.12
Antenna Efficiency (%)	89.6	87.1

From Tables 7 and 8 we can notice that the shorting wall gives reduction in size approximately 46.12%. The directivity is reduced in the case of shorting wall as compared to the case without shorting wall, which is the reason for decreasing gain. The radiation pattern is distorted and become asymmetric due to the existence of the shorting wall at the antenna edge.

5 Results

The 2nd iteration with shorting wall of pulse 2.45 antenna with an air gap = 6.4mm as shown in Fig.11 (a) is fabricated on a dielectric substrate covered with copper clad from both sides. The thickness of the copper layer is 35 μm. The dielectric substrate is RT/Duroid 5880, with relative permittivity ε_r = 2.2 , dielectric height = 0.062 inch (1.5748 mm) and loss tangent tan δ = 0.0019. The antenna performance was measured using Agilent 8719ES (50MHz - 13.5GHz) vector network analyzer and was simulated using electromagnetic field solver IE3D (ZELAND) which adopts the method of moments. The computed and measured results were found to be in good agreement as shown in Fig.11(b) and Table 9.

(a)



(b)

Fig. 11: (a) Fabricated 2nd iteration with shorting wall of pulse 2.45 antenna with an air gap=6.4mm. (b) Comparison between the simulated and measured $|S_{11}|$.

Table 9: Resonant frequencies and BWs of the 2nd iteration with shorting wall of pulse 2.45 antenna with air gap=6.4 mm

Simulated Results				
f_n (GHz)	**$\|S_{11}\|$ (dB)**	**BW %**	**Zin (Ω)**	
			Real	**Imag.**
1.32	-34.858	5	51.77	-0.5
Experimental results				
f_n (GHz)	**$\|S_{11}\|$ (dB)**	**BW %**	**Zin (Ω)**	
			Real	**Imag.**
1.3198	-22.25	4.09	43.55	-2.7

As shown in Table 9, the measurement and simulation results give good agreement with average normalized error equal to 0.02 % in calculating F and the size reduction is 46.12 % as compared to the initiator. The measured reactive part of the input impedance of the antenna (capacitive due to the air gap) is larger than that simulated, while the radiation resistance is lower. The simulated value of the reflection coefficient is much better than the measured value due to many factors which were not taken into account.

6 Conclusion

This paper described the space-filling property of the fractal microstrip patch antenna. The iterations give maximum reduction in size equal to 46.12%. The fundamental limitation in fabricating the antenna is given by the resolution of the photo etching process. The fundamental resonant frequency decreases when the number of iterations increases. The difference between the resonant frequencies of the 3rd and 4th iterations is so small.

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