

# A Manual Reconfigurable Multiband Cavity Backed Helical Antenna

Rahul Yadav<sup>1</sup> and VinitKumar Jayprakash Dongre<sup>2</sup>

<sup>1</sup> Mumbai University

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## Abstract

The paper presents a miniaturized design of helical antenna loaded inside an impedance matching L-wall shaped cavity to achieve multi-frequency bands in the range of 5-15 GHz. A detail analysis of helix orientation inside the designed cavity is carried out. The cavity and helix arrangement is made reconfigurable by placing the helix and RF feed in such a way that it can thus be rotated manually at various angles with respect to the cavity walls. A comparative analysis of antenna gain and bandwidth is also reported. The antenna has a peak gain of 11.28dB and highest bandwidth of 2.68GHz. The maximum power handling capacity of the design is found to be 40.67MW. Computer Simulation Tool is used in the modeling of antenna. The antenna being conformal in design finds its application in aerospace, military and personal wireless communication.

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*Index terms*— l-wall cavity, 1½ turns helix, multiband, manual re-configurability, helix rotations.

## 1 Introduction

he helical antenna has always been in demand for wireless communication and has gone through various kinds modification for gain and bandwidth enhancement techniques [1][2][3] [4] to improve the overall antenna performance. Another important feature as discussed in [5][6] which make the helical antenna more demanding is its power handling capacity. But the problem in helical antenna arrived when the helical antenna designs were only limited to WLAN (2.4 GHz) and S-band frequencies. The reason being that existing equations and mathematical proofs given by Kraus [7] and other authors showed that, the stability in helical antenna at much higher frequency is not feasible.

So a demand arises to demonstrate a stable frequency response and impedance matching in helical antenna for higher range of frequencies.

The work presented in this paper aims to show that helical antenna can still be used at higher frequencies even beyond C-band. Also here attention is focused on the enhancement of bandwidth and gain along with the reduction in size of helical antenna which finds important application in communication systems.

The issue of compact size in the antenna design has always been challenging barrier. So to overcome this barrier, a conformal partial cavity has been designed which backs the helical antenna. The

## 2 Rahul Yadav

Authors :

e-mail: ryrahuladav01@gmail.com, name partial cavity is assigned because unlike the actual cavity which has its all side enclosed, the cavity designed here has opening in three different directions. To keep the system more compact, helix turns has been compromised in the design. In this paper, an L-wall partial cavity backed 1½ turn helical antenna is designed and its parameters like gain, bandwidth, radiation pattern and power handling capacity are investigated. In the design, the parameter like spacing between walls is also taken into account to carry out a detail analysis. To make the antenna reconfigurable, the helix is loaded inside the cavity in such a

43 way that it can thus be rotated manually without disturbing the feed. This is done by digging a hole at the center  
 44 of the ground plane whose diameter is 1mm extra compared to that of diameter of SMA connector. This allows  
 45 soldering of the helix feed pin and SMA connector together conveniently. The bonding connection is coated with  
 46 PTFE to prevent it from shorting with the cavity body.

47 It is important to note that the conventional helical antennas have generally a single resonant mode [8][9].  
 48 However in [10], the higher order mode can be realized by modifying the ground plane and geometry of the helical  
 49 antenna. Although the helical antenna is a three dimensional entity whose modes are characterized by half wave  
 50 variation along x, y and z axis, for simplicity the modes can be reduced to TM<sub>mn</sub> by observing the wavelength  
 51 variation in 'x' and 'y' direction only from the top view.

### 52 3 II.

#### 53 4 Antenna Design & Theory

54 The conventional design of helical antenna explains that to have proper circular polarization of electric fields, the  
 55 helix should have atleast three turns and for that its circumference (C) should be in between 0.75λ-1.33λ. However  
 56 the number of turns can be reduced to 1½ if the electric fields from the antenna can be confined with double the  
 57 intensity from conventional helix. With the decrease in helical turns, there is possibility that the higher order  
 58 modes may not be excited but this can be accounted by loading helix inside the cavity. It is important to note  
 59 that the primary reason for reducing the turns of helix is the fact that it will follow odd symmetry with respect  
 60 to each of the cavity wall and will provide greater degree of variation in the design. The pitch angle of the helix  
 61 is kept as 14 degree. The rectangular configuration of helical is chosen in order to have non-uniform distribution  
 62 of current along the antenna which will eventually help to excite higher order modes along with the fundamental  
 63 mode, whereas in case of conventional cylindrical helix only fundamental mode is excited. So a rectangular helix  
 64 is designed with a strip width of 2mm and thickness of 1mm as shown in Fig. 1.

#### 65 5 a) Design of Impedance Matching Cavity

66 To demonstrate a stable response of helical antenna for higher range frequencies, an L-wall cavity has been  
 67 designed as shown in Fig. 2a. The design of Lwall shaped partial cavity begins with the assumption that not  
 68 necessarily the cavity should always enclose the antenna to achieve more directive pattern. Instead, the proper  
 69 orientation of metallic walls around the helical antenna can significantly help to improve the overall gain and  
 70 bandwidth of the antenna. So the cavity which is basically a modified ground plane to the helical antenna is  
 71 designed assuming 13.6GHz ± 1.4GHz as the critical range of frequency. The higher range of frequency is selected  
 72 to achieve impedance matching of helical with the standard 50Ω excitation. Also this critical frequency leads to a  
 73 minimum height of cavity wall with which efficient confinement of electric field is possible. So all the dimensions  
 74 of cavity calculated here is critical? = c/f (1)

75 Where 'c' is the velocity of light and 'f' is critical frequency

76 The designed cavity has a height of 20mm and ground base as (24×24) mm. Now the cavity is actually acting  
 77 as a resonator whose inductance and capacitance per axial inch can be calculated as; antenna is placed with its  
 78 feed pin at the center of the cavity from inner dimension. The orientation of helix with respect to the cavity walls  
 79 is another potential parameter which will help to investigate the behavior of helical antenna in various directions  
 80 inside the cavity. For this, the antenna is rotated with an offset angle of 45° in anticlockwise direction and  
 81 thereby making the design reconfigurable in nature. Figure ?? shows the top view of helix rotation inside the  
 82 L-wall partial cavity.

### 83 6 III.

#### 84 7 Result Analysis & Discussion

85 The simulation is performed in CST Microwave Studio Suite using time domain solver with accuracy set to -40dB.  
 86 The boundary condition which plays an important role in the numerical analysis is kept as open space around the  
 87 antenna. To investigate the effect of cavity and its corresponding enhancement in gain and bandwidth of helical  
 88 antenna, initially a helix is simulated without the use of L-wall cavity so that a better comparative analysis can  
 89 be made.

90 The analysis begins with the simulation of helical antenna only with a rectangular ground plane of (24×24)  
 91 mm. Figure ?? shows the plot of reflection coefficient (S<sub>11</sub>) in the frequency range of 5-15 GHz. It is observed  
 92 that since the turns are too low, the result of S<sub>11</sub> is not below -10dB. From Fig. ??, it explains that the VSWR  
 93 (voltage standing wave ratio) is not below 2 indicating that there is no impedance matching in helical antenna  
 94 for higherrange of frequencies and the resonant modes are too weak. However these can be improved by loading  
 95 the designed 1½ turn helical antenna in a specially design cavity.

96 The plots of reflection coefficient for L-wall cavity backed helical antenna at various rotation angles is shown  
 97 in Fig. 6. It is observed that at 0° position, a dual band is obtained from 7.3-8.4GHz and 13.49-15GHz with a  
 98 bandwidth of 2.68GHz. This is the highest simulated bandwidth of helical antenna in this design because the  
 99 spacing between helix and wall is less which results in more reflection of electric fields from the walls and also

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100 the helix end is pointing towards the corner of the L-wall. So the bandwidth should be higher at 45 o position  
101 also, but this is not the case here because at 45 o position the helix end starts orienting slightly outward from  
102 the L-wall. Therefore at 45 o position instead of dual band only single band is resonated. Also it is noted that  
103 from 0 o to 135 o position, the bandwidth is eventually decreasing and dual band is only occurring at 0 o and  
104 90 o position. At 90 o position the helix end is outward the wall, but in 0 o position the helix end is inwards the  
105 L-section of the wall, so the bandwidth at 0 o position is high as compared to 90 o position. Rest of the angles is  
106 with single frequency band only. Beyond 180 o the bandwidth start increasing up to 270 o , this is because the  
107 spacing of the helix from the cavity wall is decreasing.

108 It is observed that if the helix approaches closer to the walls, the bandwidth increases which can be seen in  
109 Table ??1. At 135 o the spacing between the helix and the base of L-wall is more, so the bandwidth is poor i.e.  
110 0.41GHz only. After the comparative analysis made for simulated and measured results of cavity backed helix,  
111 it is seen that there is an agreement in comparison made for majority of the helix rotation angle. However at  
112 positions like 90 0 , 180 0 and 225 0 , a slight shift and increase in the measured bandwidth is noticed. A detail  
113 explanation for this is illustrated in section IV.

114 The radiation pattern as shown in Fig. 7 is simulated for each of the helix position inside the cavity at peak  
115 resonance for the respective orientations in Eplane. It is observed that due to the manual reconfiguration of helix  
116 orientation, both omnidirectional and directive nature of pattern is obtained which makes the antenna suitable  
117 for point to point and point to multipoint communication. Next, to find the maximum power handling capacity  
118 of antenna, the intensity of near electric field vector is solved which is found to be 7837 V/m as shown in Fig.  
119 9. Now assuming that breakdown threshold for helical antenna which is made of copper as 50 MV/m [11], the  
120 maximum power handling capacity comes out to be 40.67 MW.

## 121 8 Experimental Observations

122 In the fabricated design of cavity backed helical antenna, the helix which is made using copper and the impedance  
123 matching L-wall cavity which is fabricated using aluminum metal as shown in Fig. 2b, it is found that the joint  
124 connection between the helix and feed pin plays an important role in the distribution of current along the helical  
125 antenna. In the modeling of antenna in Computer Simulation Tool (CST), the joint connection between the helix  
126 and feed pin is abrupt however this has been improved in the practical implementation of helix as shown in Fig.  
127 10. The geometrical operation of lofting has been employed to enhance the flow of current from the feed along  
128 the helix. The lofting certainly improves the current distribution along the antenna and thereby increases the  
129 overall bandwidth of the antenna. The measured results of reflection coefficient show improvement in bandwidth  
130 over the simulated results at some of the rotation angles.

## 131 9 Conclusion

132 A compact and conformal helical antenna design has been demonstrated with a stable frequency response. It  
133 is found that modification of ground plane which is the L-wall cavity here in the design plays an important role in  
134 confinement of near field electric vector. Also the orientation of helix inside the cavity should be appropriately  
135 adjusted to provide a multiple reflectionsof<sup>1</sup>

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Figure 1: Figure 1 :

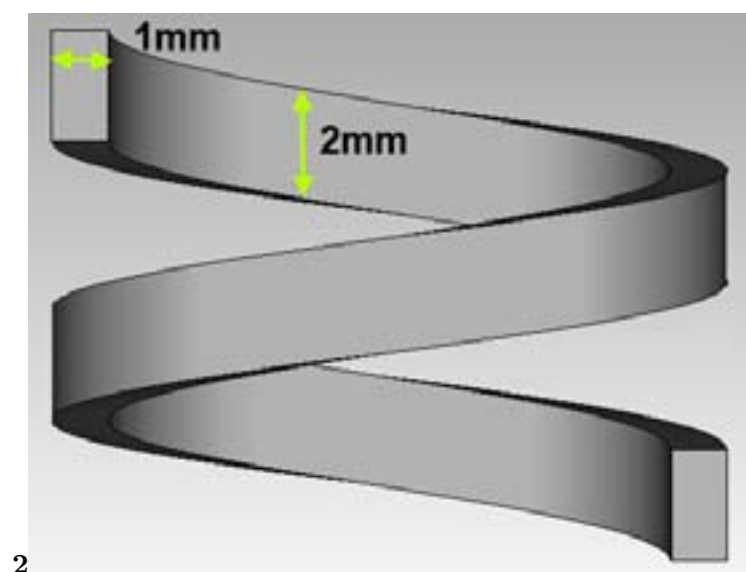
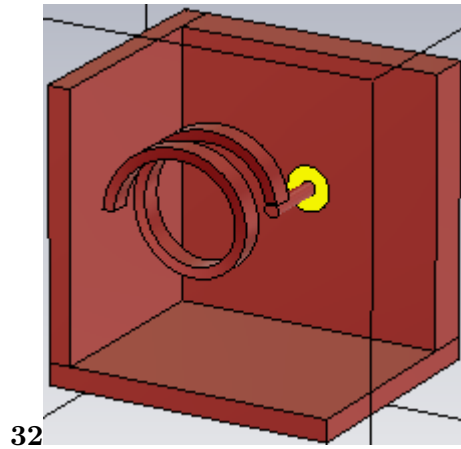
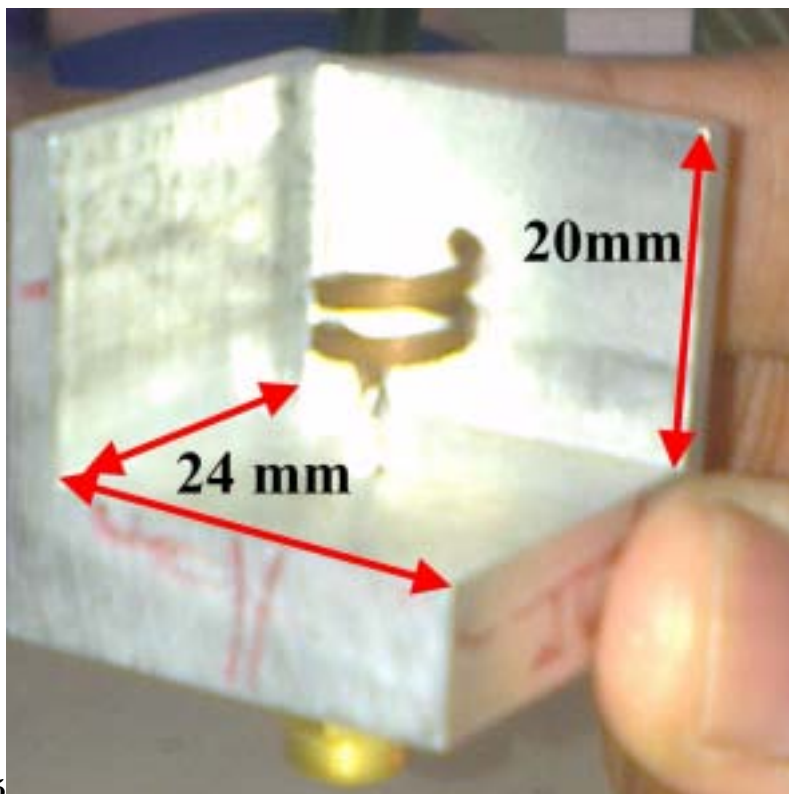


Figure 2: Figure 2 :



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Figure 3: Figure 3 : 2 (



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Figure 4: Figure 4 :Figure 5 :

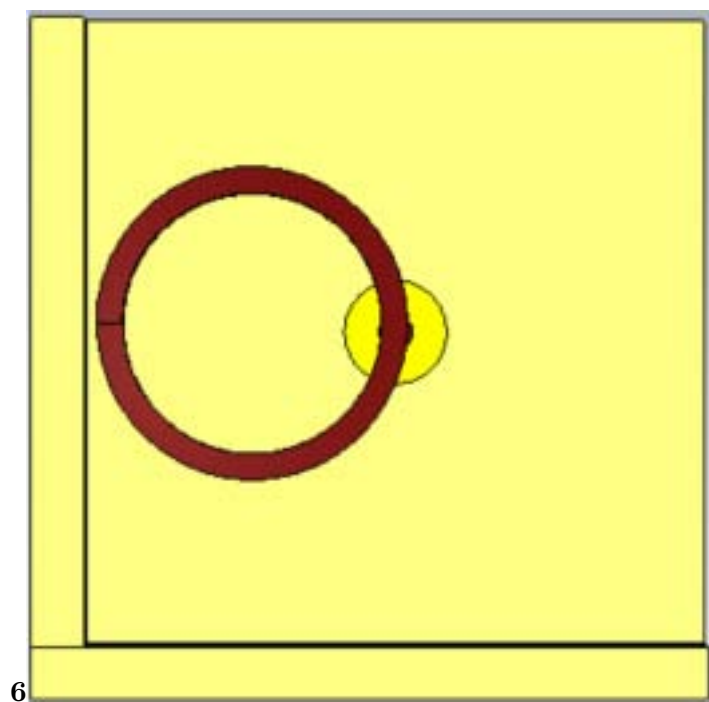


Figure 5: Figure 6 :

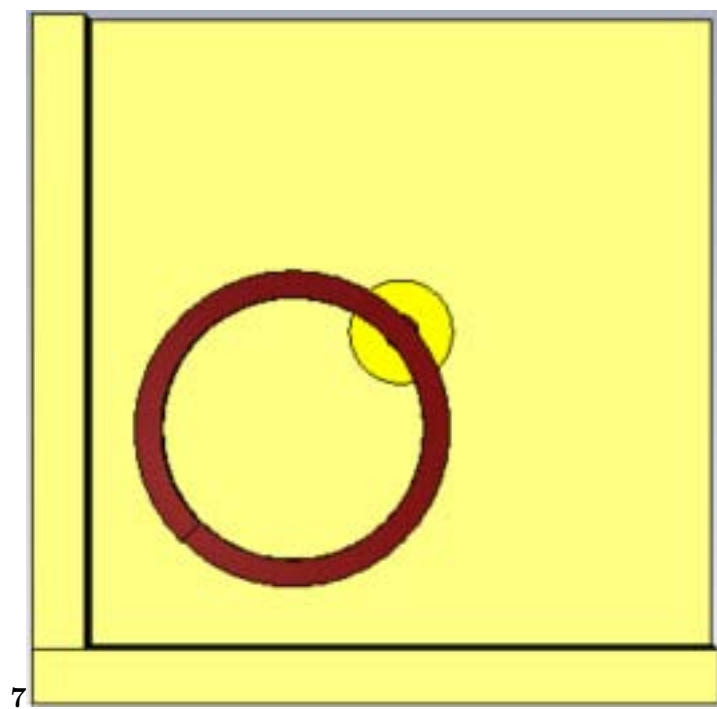


Figure 6: Figure 7 :

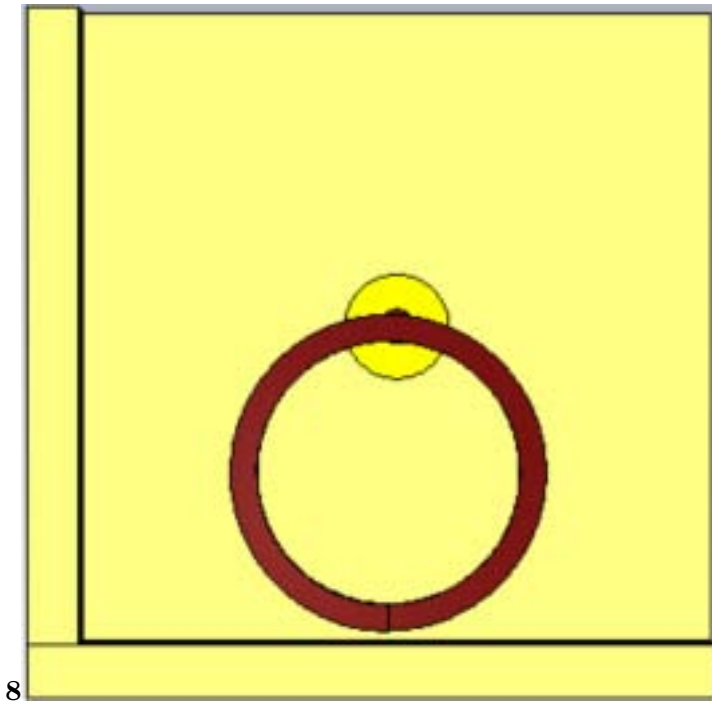


Figure 7: Figure 8 :

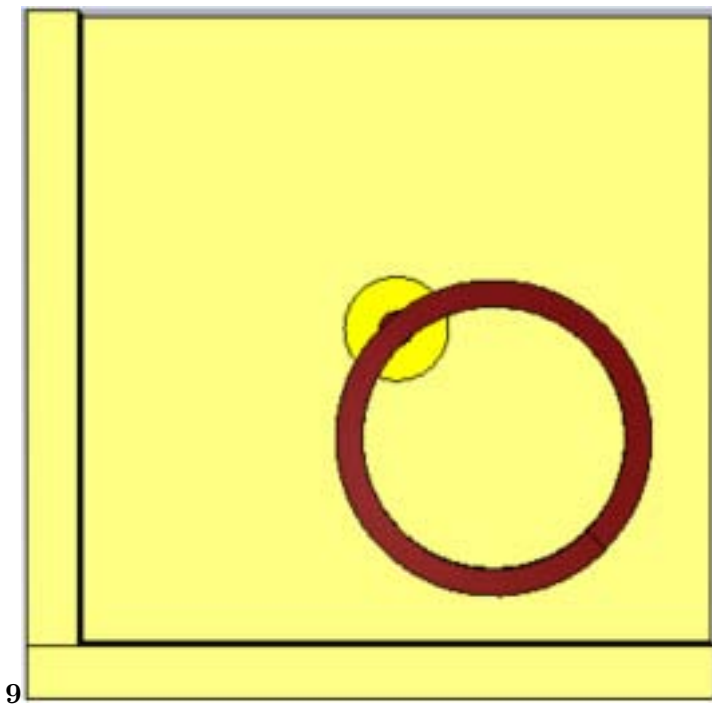


Figure 8: Figure 9 :

## 9 CONCLUSION

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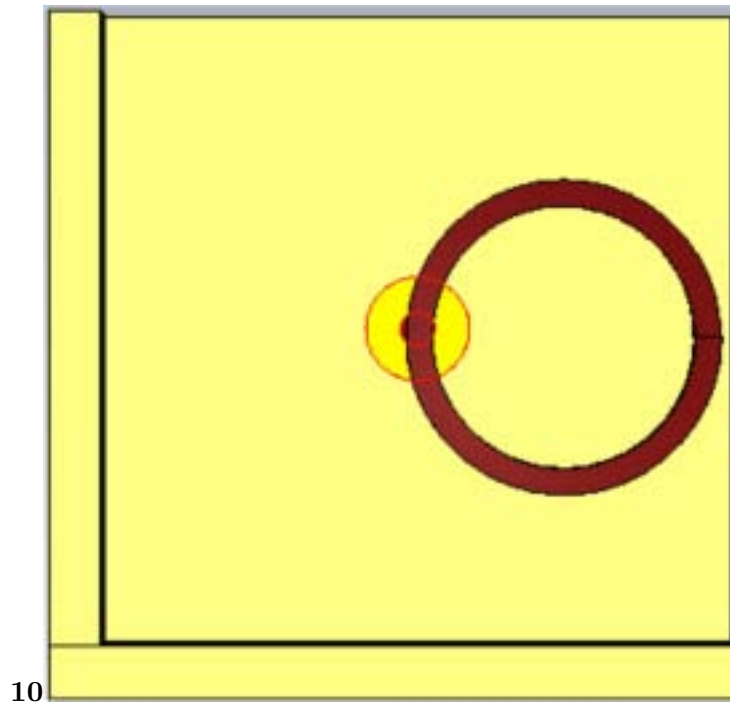


Figure 9: Figure 10 :

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Helix Position	No. of Bands	Resonant Bands(GHz)	Bandwidth (GHz)
0 0	Dual	7.3-8.44 & 13.49-15	2.68
45 0	Single	9.58-11.91	2.33
90 0	Dual	7.21-7.93 & 13.42-13.93	1.22
135 0	Single	13.5-14.44	0.94
180 0	Single	13.15-14.33	1.18
225 0	Single	13.44-14.82	1.38
270 0	Single	3.49-15.03	1.54
315 0	Single	6.18-6.59	0.41

Figure 10: Table 1 :

2

Helix Position	Peak Gain(dB)
0 0	11.28
45 0	11.2
90 0	10.7
135 0	9.7
180 0	10
225 0	8.8
270 0	8.2
315 0	10.7

Figure 11: Table 2 :

136 The authors would like to thanks all the experts for their contribution in this work.  
 137 electric field from the walls of cavity and thereby increasing the number of resonant bands.

138 .1 VI.

139 .2 Acknowledgement

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