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A Novel Design Of Single-Wall Cavity Backed Helical Antenna For Re-Configurable Gain And Bandwidth

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Abstract

A single-wall cavity backed helical antenna has been designed to achieve re-configurability on gain and bandwidth. The helix is loaded inside the single-wall cavity in such a way that it can be rotated manually and thus provides variable resonance between C-Ku bands. The antenna has peak gain of 9.2 dB and highest measured bandwidth of 5.3 GHz. Computer Simulation Tool is used for the designing.

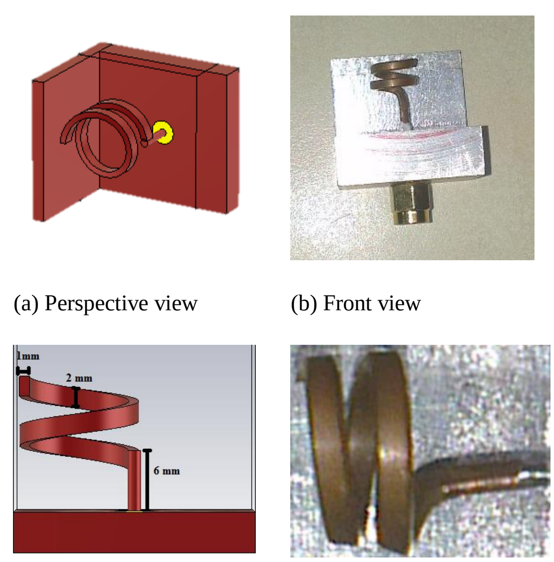
1. Introduction

The helical antenna was first introduced by Kraus in 1946 [1] and in the past five decades it has gone through various design modifications with aim of improving basic antenna parameters. Since the rigorous analysis of helix is extremely complicated, therefore radiation properties of the helix such as gain, far-field pattern and bandwidth needs to be investigated. Also now a day's, re-configurability of the antenna is playing important role in communication as it allows to use the single designed antenna in various frequency bands and thereby supporting variety of applications.

The helical antenna is one of the selective antenna which is used for military applications and therefore a demand arises to employ a design with conformal shape, reconfigurable characteristics and robustness which can significantly help in communication at various bands as and when application demands. So to incorporate all such features, a partial cavity has been designed in the shape of "Single-wall" which back a 1½ turn helical antenna. It is important to find the best suited orientation of helix inside the cavity which results in desirable resonating bands. This is done by rotating the helical antenna with an offset angle of 45^{o} degree in anticlockwise direction inside the cavity. At these various angles, the antenna response is extracted using Computer Simulation Tool.

2. Antenna Design

The design begins with the formation of Single-wall shaped partial cavity as shown in fig. 1. The cavity has a height of 22mm, width of 24mm and thickness of 2mm. Only Single-wall has been designed due to the fact that with minimum number of enclosing walls also it's possible to confine the electric field vector, which thereby helps to improve the resonance and gain of the antenna.

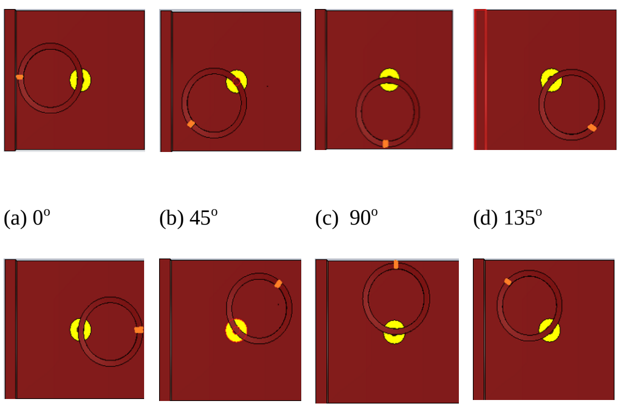


(a) Perspective view (b) Front view

(c) Helix Design (d) Implemented helix

Fig. 1 Design of Single-wall cavity backed 1½ turn helical antenna

To achieve more variations in the resonant bands, 1½ turns for the helix is chosen with the fact that it will provide odd symmetry with respect to the cavity walls in various helix rotation as shown in fig.2.



(a) 0° (b) 45° (c) 90° (d) 135°

(e) 180° (f) 225° (g) 270° (h) 315°

Fig. 2 Top view of helix rotation inside Pi-wall partial cavity

3. Results and Discussion

This section illustrated the analysis of helical antenna orientations and response at various rotation angles. All the potential parameters are extracted using time domain solve of CST Microwave Studio. The analysis begins with the extraction of reflection coefficient plot as shown in fig. 3

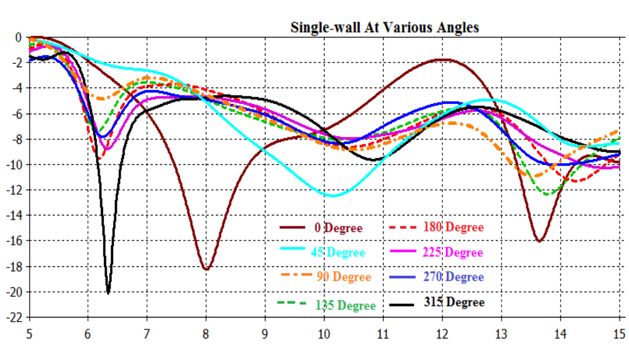


Fig. 3 Comparative plot of reflection coefficient at various helix rotation angles

It is observed that at 0° position, dual bands are resonated due to the effect of reflection from the wall. Form 315° and 45°, the effect of wall is only partially dominant which results in the bandwidth of 1.64 GHz and 0.39 GHz respectively. Now there is variation in the bandwidth of the antenna due to asymmetry in the design which is the main aspect, reflection from the single wall and different spacing between helix and wall at various helical rotations. Initially when the helical antenna is at 0° position, the distance between the wall and the antenna is closer and then later the distance increase eventually from 0° to 180° as shown in fig.3. The bandwidth at 0° position is 2.26 GHz, which is the highest bandwidth for this design. Then the bandwidth is in decreasing manner, at 315° position the bandwidth is lowest i.e. 0.39 GHz. Only at 0° position the dual band is observed. The other bands are shown in table 1.

Table 1 Bandwidth analysis of single wall partial cavity

Sr. No	Helix Position	No. of Bands	Frequency Bands (GHz)	Bandwidth(GHz)
1	0°	Dual	7.45-8.71 & 13.26-14.26	2.26
2	45°	Single	9.30-10.94	1.64
3	90°	Single	13.02-13.93	0.85
4	135°	Single	13.38-14.36	0.98
5	180°	Single	13.80-14.78	0.98
6	225°	Single	Notch	Notch
7	270°	Single	Notch	Notch
8	315°	Single	6.16-6.55	0.39

Now looking at the gain analysis which is shown in fig.5, it is found that there is variation in the gain since only single-wall is present providing an odd symmetry around the helical antenna and parameters like spacing between the walls, turn visibility are also changing with significant offset.

The turn visibility is defined here as the number of turns visible from the wall perspective view. This helps to provide an information can be used to set desired gain and bandwidth by adjusting this parameter. At 315° position, more turns are visible from the single wall perspective and this reflects the radiation from the helical antenna. Beyond 180° position the number of

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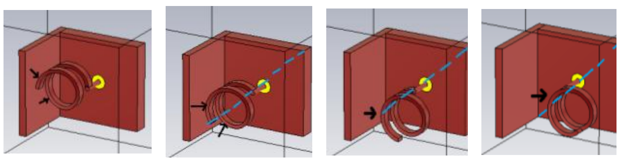
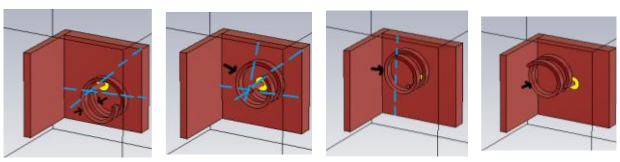
turn in from of the single wall is only one, this result in reduced gain from 180° to 270°. The perspective view of turn visibility of the helical antenna with respect to the wall is shown in fig.4.



(a) 0° (b) 45° (c) 90° (d) 135°



(e) 180° (f) 225° (g) 270° (h) 315°

Fig. 4 Turn visibility for various positions of single-wall with 1½ turns helical antenna rotation

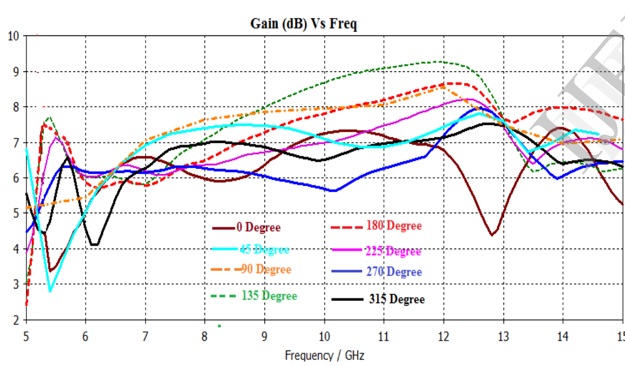


Fig. 5 Simulated gain plot for single-wall configuration at various helix rotation angles

A peak gain of 9.25 dB and minimum gain of 2.8 dB is observed for 135° and 45° respectively. Table.2 shows the values of peak gain at the respective helix rotation.

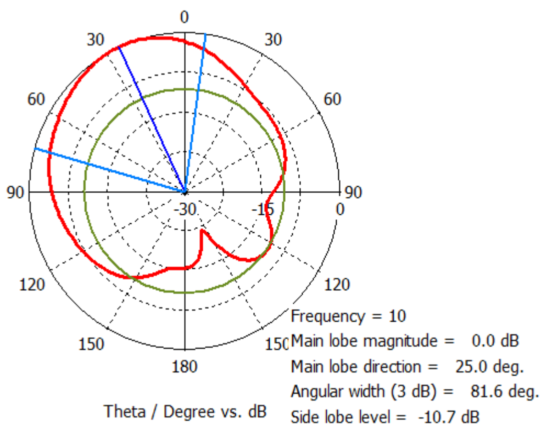
Table 2 Gain analysis of Single wall partial cavity

Sr. No	Helix Position	Turns Visibility	Peak Gain (dB)
1	0°	1.5	7.4
2	45°	2	7.8
3	90°	2	8.5
4	135°	2	9.2
5	180°	1.5	8.6
6	225°	1	8.2
7	270°	1	8
8	315°	1	7.5

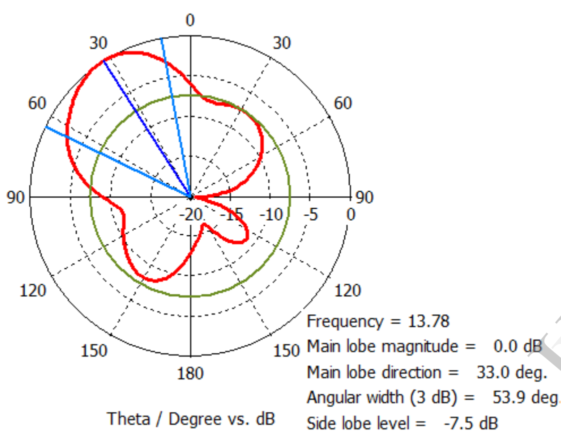
The antenna has been tested at 135° position. Fig.6 shows the measure results for 135° position of helix with respect to the wall. It is observed that, the measured bandwidth for 0° helix rotation is 5.3 GHz whereas the simulated bandwidth is found to be 0.98 GHz only. This increase in the measured bandwidth is due to the lofting of helix base and feed pin joint in practical implementation whereas in simulation, the joining point between feed pin and helix base is abrupt, which can be clearly seen in fig.1c-1d. So a peculiar observation has been noted down that, lofting between helix base and feed pin helps to improve the geometry continuity and thereby improves the current distribution along the antenna.

Fig. 6 Measure results of single –wall cavity backed helix at 135° position

The radiation pattern of electric field vector for 0° and 135° position is shown in fig.7



(a) 0° Position



(b) 135° Position

Fig. 7 E-field polar plot for Single-wall cavity at phi = 0

Moreover, the electric field intensity of the antenna system is also investigated to obtain the maximum power handling capacity which is given as [2]

$$Power\ handeling\ capacity = \left(\frac{Breakdown\ Threshold}{Electric\ field\ intensity}\right)^2 \quad (1)$$

The electric field distribution is shown in fig.8.

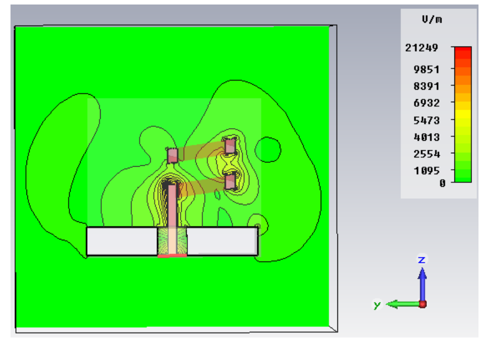


Fig. 8 Near E-field distribution

So, here electric field of 21249 v/m is observed in the near field zone of the single-wall cavity loaded helical antenna and thus maximum power handling capacity is found to be 5.53 MW assuming that breakdown threshold for helical antenna which is made of copper as 50 MV/m.

4. Conclusion

The designed Single-wall partial cavity backed 1½ turn helical antenna meets the requirement of re-configurable gain and bandwidth, conformability and robustness making it suitable to use for various microwave bands. It is found that by varying the spacing between helical antenna and the walls, an application dependent response can be achieved. Also it observed that the practical result is having a remarkable improvement over simulated results.

5. References

[1] J. D. Kraus and R. J. Marhefka, *Antenna: For All Applications*, 3rd ed. New York: McGraw-Hill, 2002.

[2] Xiang-Qiang Li, Qing-Xiang Liu, Xiao-Jiang Wu, Liu Zhao, Jian-Qiong Zhang, Zheng-Quan Zhang, “A GW Level High-Power Radial Line Helical Array Antenna”, *IEEE Trans. Antennas Propag.*, vol.56, pp. 2943 – 2948, 2008.