On Optimization of The Ground Conductor of Helical Antennas

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Abstract— Helical antennas may be considered a combination of two kinds of radiators, the dipole and loop antennas. Hence, many parameters control the operation of helical antennas such as circumference of helix, spacing between turns, pitch angle, and number of turns. Some of these parameters have important impact on the performance of helical antennas like maximum gain, operating bandwidth, radiation mode, and 3dB beamwidth. In this paper, we examine the effect of the size of ground plane on the performance of helical antenna. It is shown that the ratio of the diameter of the helix to the diameter of the ground plane has significant impact on the performance of helical antennas.

I. INTRODUCTION

Since the invention by Kraus in 1947 [1], helical antennas draw great attention as broadband antennas. Axial-mode helical antennas have been widely used in mobile and satellite communication ever since. However, there are many empirical equations for designing helical antennas as in [2] and [3], and these equations were not consistent for many practical designs [4], [5]. In 1980, King and Wong [3] reported that Kraus’s gain formula overestimates the actual gain and proposed a new gain expression using a much larger experimental data base. Many researchers reinvestigated the effect of helical parameters in an attempt to remove discrepancies of in the literature of helical antennas [6], [7]. These discrepancies have motivated us to investigate the effect of the size of ground plane on helical antennas. We believe that the ratio of the diameter of the ground conductor to the helix's diameter affects the operating bandwidth, maximum gain, and axial-mode operation. In this paper, we prove that the ratio of the diameter of the ground conductor to the helix's diameter affects the operating bandwidth, maximum gain, and axial-mode operation. The proposed investigation on a ground plane of the helical antenna is intended for narrow-band axial-mode operation.

II. DESIGN PARAMETERS OF HELICAL ANTENNA

Each proposed antenna considered here consists of a conductor wound in the form of a helix (spiral) with a constant pitch (α). The number of helix turns is N, and by increasing the number of turns, the main radiation beam becomes sharper. The diameter of the helix (center to center) is D which is crucial in determining the operating frequency and mode, the circumference of one turn is obtained by \( C = \pi D \). The diameter of the circular ground is Dg and the spacing between turns is referred as S. The geometry of the designed helical antenna is depicted in Fig. 1. The input impedance of helical antenna can be calculated within 10 percent using [8].

\[
R = \frac{150}{\sqrt{C_\lambda}}
\]

(1)

where \( C_\lambda \) is the circumference of one turn in terms of wavelength. This relation has restrictions that 0.8 ≤ \( C_\lambda \) ≤ 1.2, 12° ≤ α ≤ 14°, and N ≥ 4. The impedance of the designed helical antenna is found to be 147Ω, so a quarter wavelength transformer is needed to match it to a 50Ω-SMA connector. The quarter wavelength transformer is chosen to be a coaxial line with impedance of 85.5Ω as calculated from:

\[
Z_{\text{Coax}} = \sqrt{50\Omega \times Z_{\text{Helical}}}
\]

(2)

Fig. 1. (a) Geometry of helical antenna, (b) Structure of feed network.

III. PARAMETRIC STUDY ON THE INFLUENCE OF THE GROUND PLANE

In this study of the effect of the diameter of a cylindrical ground conductor, the number of turns is 4, the diameter (D) of helix is 19.5cm, and the space (S) between each consecutive turns is 14.35cm. Fig. 2 shows the effect of varying the Dg/D ratio on the operating bandwidth and the center frequency.

The bandwidth is ranging from 30.3% to 70.67%. It reaches its peak when Dg/D=1 while the center frequency slightly varies from 0.63GHz to 0.73GHz against the same ratio of
Dg/D. Fig. 3. Exhibits the effect of varying the Dg/D ratio on the maximum achieved gain. It is shown that the maximum gain ranges between 7.7dBi to 9dBi and it is proportional to the size of the ground plane. The maximum gain is attained when the ratio of Dg/D equals 1.25. Fig. 4 shows the ratio C/λ against the ratio Dg/D where C is the circumference of one turn and λ is the wavelength at the center frequency. The ratio C/λ varies from 1.35 to 1.5.

The axial mode operating bandwidth was identified so that the axial ratio is between 0dBi and 3dBi, and the maximum radiation is along the axis of the helical antenna. Table I summarizes the frequency bands of axial mode at different ratios of Dg/D.

Table I. Operating frequency bands of helical antenna at axial mode for different ratios of Dg/D.

<table>
<thead>
<tr>
<th>Dg/D</th>
<th>FL (GHz)</th>
<th>FH(GHz)</th>
<th>HPBW (Degrees)</th>
<th>Max gain(dBi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.3</td>
<td>0.5</td>
<td>0.57</td>
<td>48.6</td>
<td>4.77</td>
</tr>
<tr>
<td>0.5</td>
<td>0.55</td>
<td>0.57</td>
<td>50</td>
<td>5.3</td>
</tr>
<tr>
<td>0.75</td>
<td>0.58</td>
<td>0.61</td>
<td>44.7</td>
<td>4.8</td>
</tr>
<tr>
<td>1</td>
<td>0.55</td>
<td>0.65</td>
<td>42.9</td>
<td>7.1</td>
</tr>
<tr>
<td>1.25</td>
<td>0.58</td>
<td>0.69</td>
<td>39</td>
<td>8.3</td>
</tr>
</tbody>
</table>

Fig. 2. The Center frequency and BW% against the ratio Dg/D.

Fig. 4. The ratio, C/λ against the ratio, Dg/D.

IV. CONCLUSION

A study is made on the effect of the size of a ground conductor on helical antennas. The study showed that the perfect ratio to obtain the widest bandwidth is when the diameter of the ground disk equals the diameter of the helix. While the maximum gain increases as we increase the diameter of the ground disk, because it results in directing the main beam and reducing back reflection. The study also pinpointed the exact operating bandwidths in axial mode, as we vary the ratio of Dg/D.

REFERENCES