A LONG HELICAL ANTENNA WOUND ON A DIELECTRIC ROD

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1. Introduction

A short helical antenna, consisting of an arm with a small number of turns (less than 2) printed on a holow dielectric rod, has already been analyzed [1]. The analysis shows that the helix radiates a circularly polarized (CP) wave in the axial direction with a gain of approximately 7 dB.

This paper investigates the radiation characteristics of a long helical antenna (more than 2 turns). The antenna arm is printed on a hollow dielectric rod, as in [1]. The investigation is performed using the finite-difference time domain (FDTD) method based on a cylindrical coordinate system [2].

After revealing the radiation characteristics, impedance matching is considered. The impedance is matched by modifying the helical arm near the feed point. The VSWR and gain as a function of frequency for a helix with this arm modification are revealed.

2. Configuration and analysis method

Fig. 1 shows the configuration of a helical antenna, where the strip helical arm is printed on a hollow dielectric rod of relative permittivity ε_r. The outer and inner diameters of the hollow rod are d_{out} (= C/π) and d_{in}, respectively, and hence the thickness of the hollow rod is given as $t = (d_{out} - d_{in})/2$. The strip helical arm is specified by the following parameters: width w, initial vertical element length L_0, horizontal element length L_H, vertical element length L_v, number of turns n, and pitch p. Note that a conducting plane (ground plan (GP)) of infinite extent backs the helix.

The height of the rod above the infinite ground plane, h, equals the height of the top edge of the final arm strip segment. To simplify the discussion, the thickness t (or the inner diameter d_{in}) and the number of turns n (and hence the height of the rod, h) are varied, with other configuration parameters, listed in Fig. 1, remaining unchanged. Note that λ_3 in the list is the free-space wavelength at a test frequency of 3 GHz.

Cylindrical coordinates (r, θ, ϕ) are adopted to match the configuration of the dielectric rod. Maxwell's curl equations are expressed using the cylindrical coordinates and solved using the FDTD method with Liao's absorbing boundary condition [2]. The input impedance ($Z_{in} = R_{in} + jX_{in}$) is calculated using the current at the feed point, I_{in}, where the current is obtained by integrating the magnetic field $\mathbf{H}$, obtained by the FDTD method, around the helical arm. The radiation field $\mathbf{E}_{rad}$ is obtained using the equivalence principle [3], in which the equivalent electric and magnetic currents on a surface enclosing the antenna are used. The gain is calculated using the obtained radiation field, together with the input power $R_{in}|I_{in}|^2$.

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3. Analysis results

Fig. 2 shows the gain for a right-hand CP wave as a function of the number of turns n, where three values for the thickness of the rod, t, are used. Note that a value of t = 0 corresponds to the helical arm wound in free space and a value of $t = 0.15\lambda_3$ corresponds to the helical arm wound on a solid dielectric rod. It is found that, as the number of turns n increases, the gains of the three helices increase. It is also found that the gain is affected by the thickness t. The difference in the gains between the helices with t = 0 and $t = 0.15\lambda_3$ is approximately 0.5 dB.

As n increases, the axial ratio improves. Fig. 3 shows the axial ratio as a function of the number of turns n. The axial ratios of the three helices at n = 9.75 turns are approximately 1 dB, with gains of greater than 11.5 dB.

Based on the above results, further investigation is directed towards a helix with n = 9.75 turns and a rod thickness of $t = 0.05\lambda_3$ (referred to here as the $HX_{0.05}$). The input impedance of the $HX_{0.05}$ is matched to a 50-ohm feed line by creating a matching strip section of width w_{mtc} and length s_{mtc}, as shown in Fig. 4(a). Fig. 4 (b) shows the VSWR at 3 GHz for a width of $w_{mtc} = 2w = 0.1\lambda_3$ as a function of the length s_{mtc}. It is found that the input impedance is matched to a 50-ohm feed line at $s_{mtc} = 0.16\lambda_3$.

So far, a test frequency of 3 GHz has been used. Next, the frequency response of the $HX_{0.05}$ with a matching strip section of $(w_{mtc}, s_{mtc}) = (0.1\lambda_3, 0.16\lambda_3)$ is revealed. Fig. 5 and Fig. 6 show the VSWR and gain as a function of frequency, respectively. As seen in these figures, the VSWR and gain show wide band characteristics. The VSWR bandwidth for a VSWR= 2 criterion is 59% and the gain bandwidth for a 3-dB gain drop criterion is 48%.

4. Conclusions

A helical antenna, whose arm is wound on a hollow dielectric rod of relative permittivity ε_r, is analyzed with the FDTD method using cylindrical coordinates. It is found that, as the thickness of the dielectric rod, t, increases, the gain decreases. It is also found that the input impedance is matched to 50 ohms by creating a matching strip section near the feed point. A helical antenna of $(t, n, \varepsilon_r) = (0.05\lambda_3, 9.75, 2.07)$, whose arm includes the matching strip section, shows a frequency bandwidth of approximately 48% for a 3-dB gain drop criterion.

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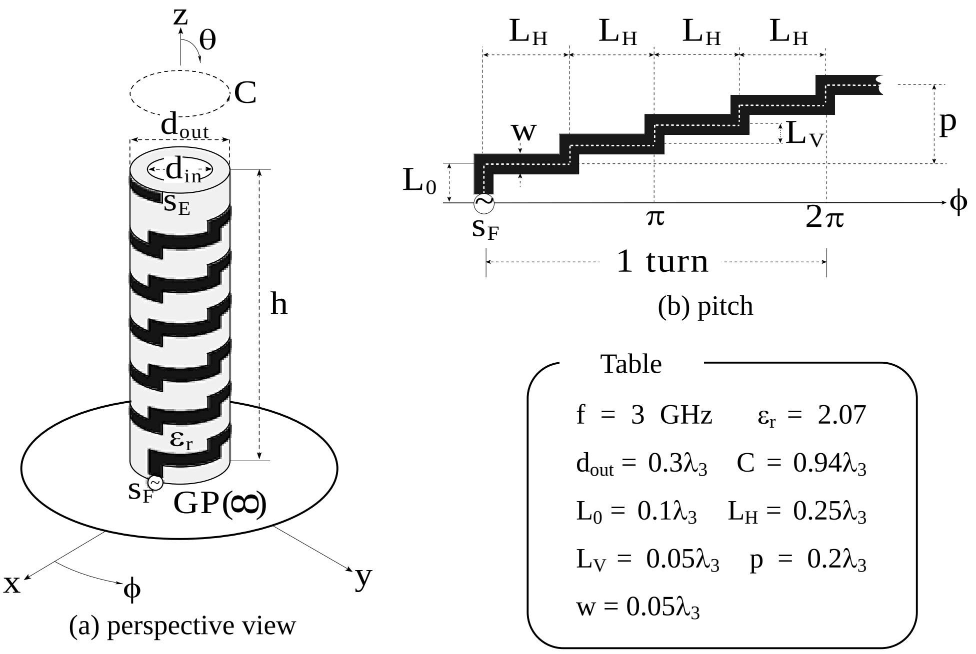


(b) pitch

(a) perspective view

Table

$f = 3$ GHz $\varepsilon_r = 2.07$

$d_{out} = 0.3\lambda_3$ $C = 0.94\lambda_3$

$L_0 = 0.1\lambda_3$ $L_H = 0.25\lambda_3$

$L_V = 0.05\lambda_3$ $p = 0.2\lambda_3$

$w = 0.05\lambda_3$

Fig. 1 A helical antenna wound on a dielectric rod.

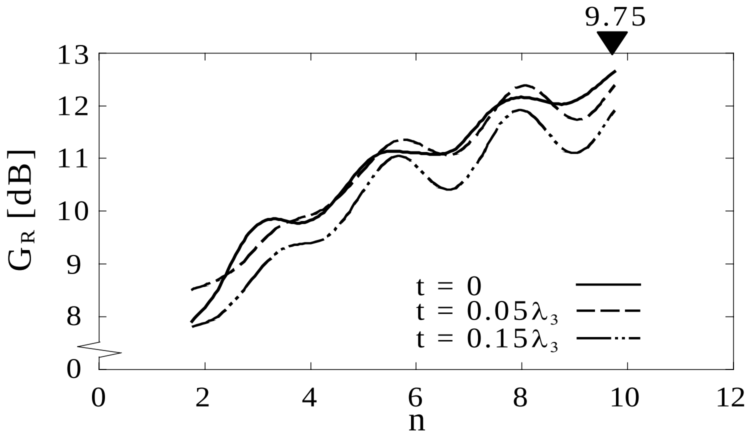


Fig. 2 Gain for a right-hand circularly polarized wave as a function of the number of turns n.

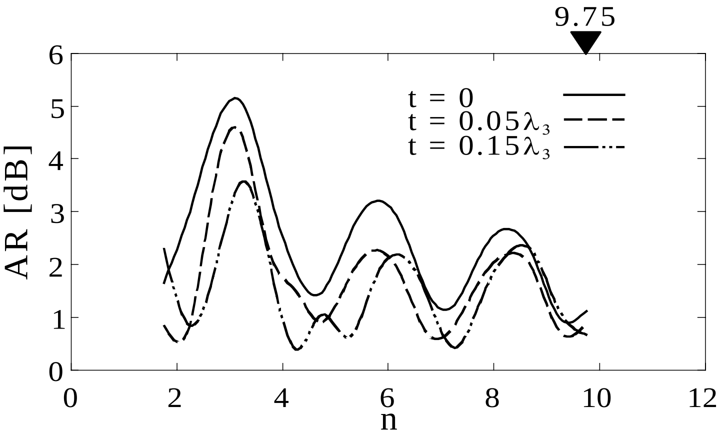
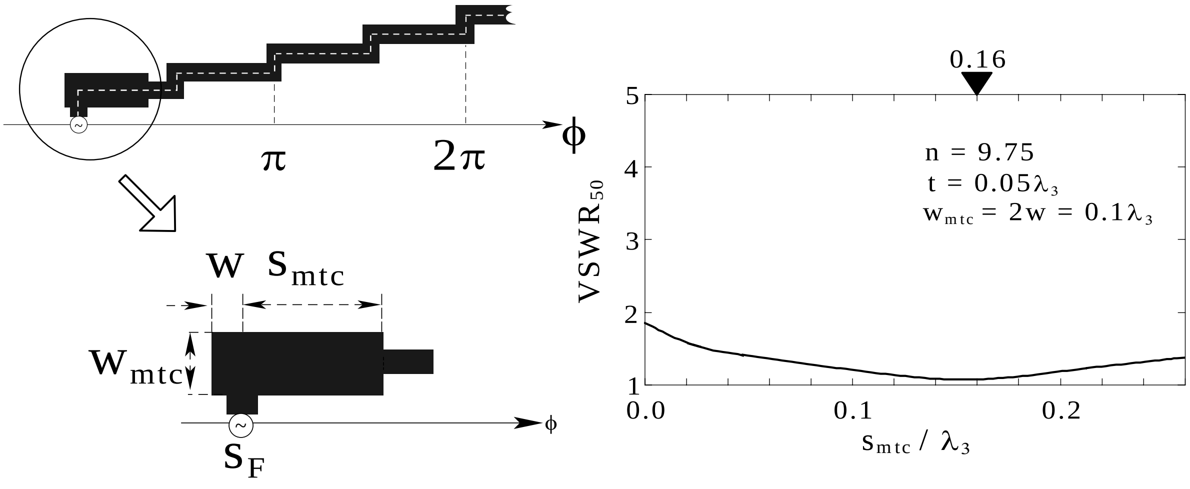


Fig. 3 Axial ratio as a function of the number of turns n.



(a) (b)

Fig. 4 VSWR as a function of length s_{mtc}.

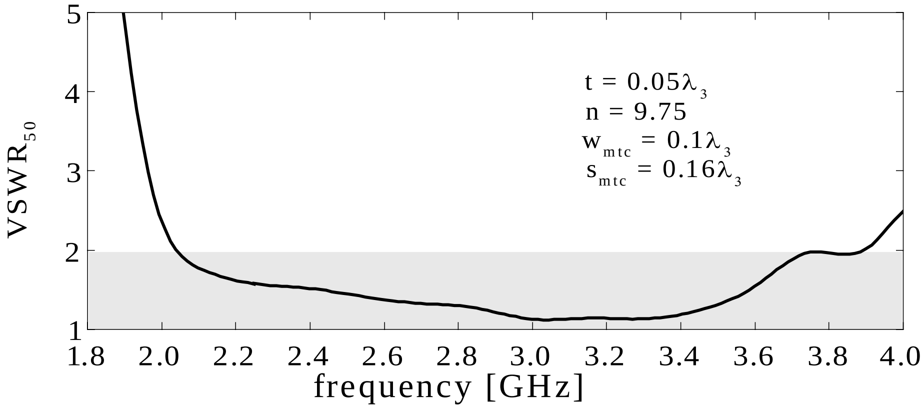


Fig. 5 Frequency response of the VSWR.

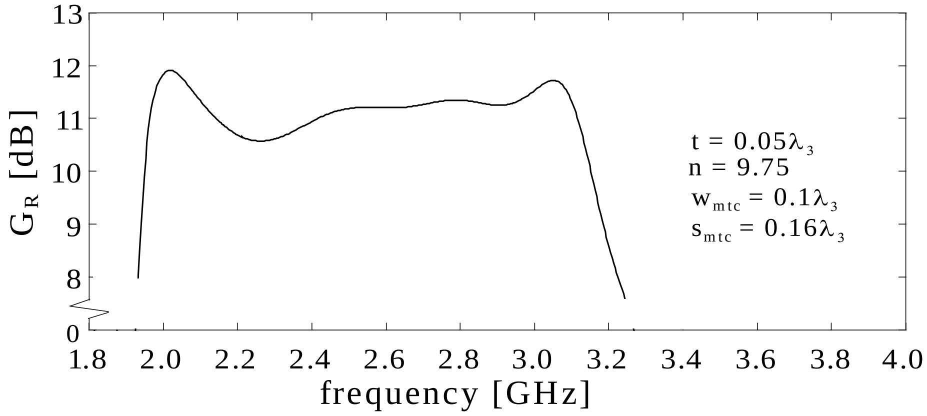


Fig. 6 Frequency response of the gain for a right-hand circularly polarized wave.