Helical Antennas

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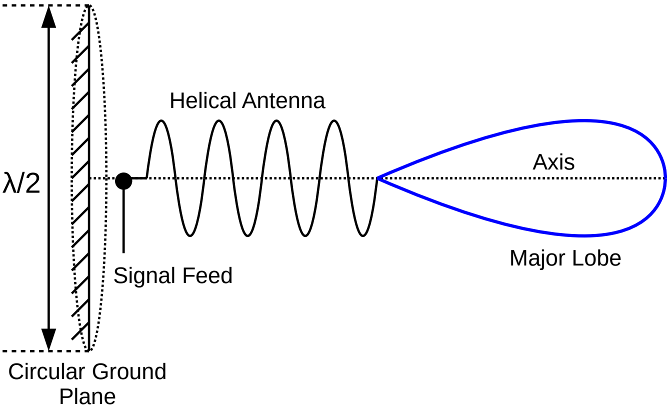
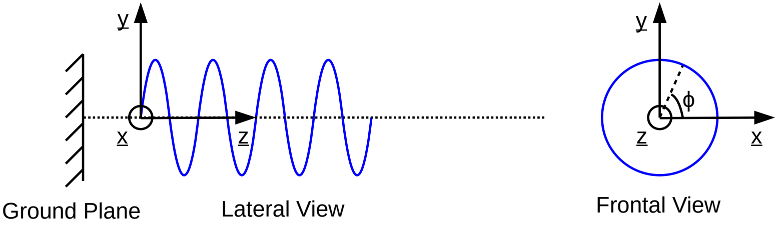
Introduction



Overview

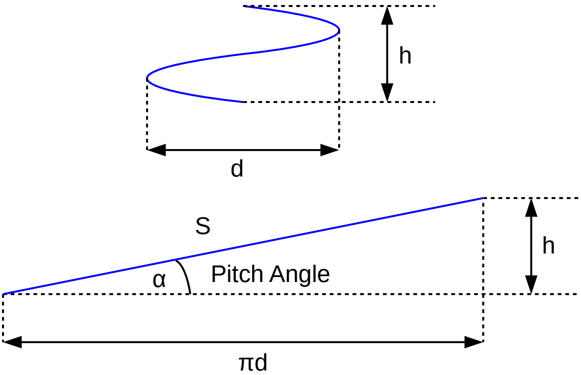
- 3D current distribution
- Elliptic or circularly polarized
- Two modes of operation
  - Normal mode which is infeasible at microwave frequencies
  - Axial mode

Analysis



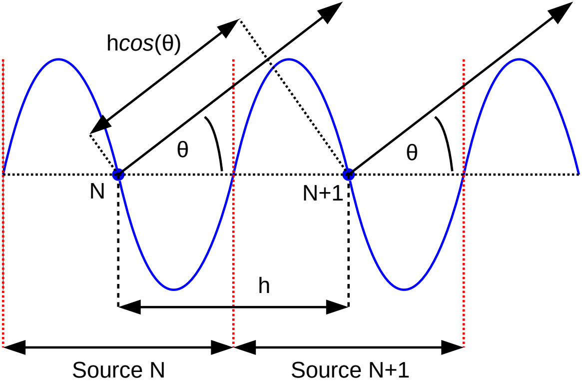
- The z axis is along the axis of the helix
- Analyzed in terms of a single helix element which is expanded to an array of N elements

Helix Parameters

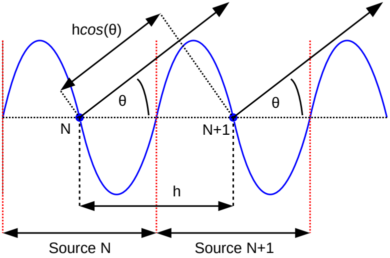


Axial Mode Operation

- Wavelength is small compared to helix dimensions
- Helix element taken as an element of an N element array



Axial Mode Operation (Contd..)



- Path difference $\Delta S = h\cos(\theta)$
- Phase difference due to *path difference* and *propagation*

$$\psi \quad = \quad \Delta\alpha + \Delta\zeta = \frac{2\pi hcos(\theta)}{\lambda} - \frac{2\pi S}{p\lambda} = \frac{2\pi}{\lambda}\left(hcos(\theta) - \frac{S}{p}\right)$$

Axial Mode Operation (Contd..)

- For end-fire operation,

$$\psi = \frac{2\pi}{\lambda}\left(hcos(\theta) - \frac{S}{p}\right) = -2\pi m$$

- Therefore, when $\theta = 0$,

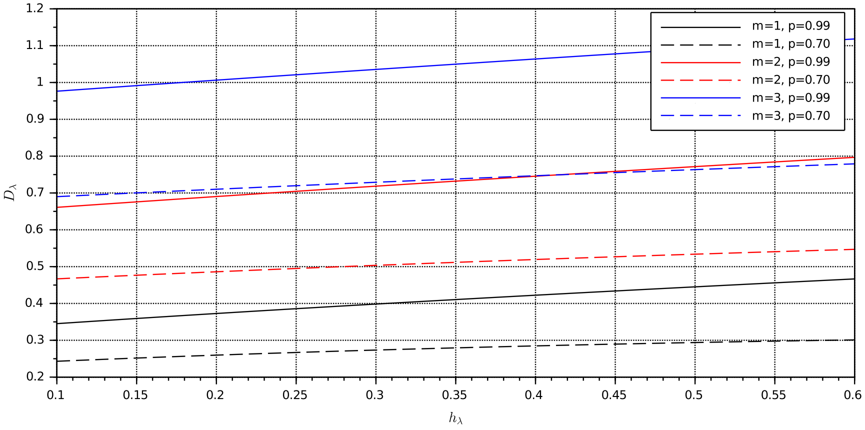
$$p = \frac{S}{h + m\lambda} \approx 0.7 \sim 0.99$$

where m is the mode of current distribution. When $m = 1$, the current between two elements will undergo a single cycle.

Effect of Parameter p

- Parameter p is a tolerance parameter
  - How much of the current cycle is within the helix
- Difficult to theoretically model
  - Therefore, it has to be taken into account into the design
- It affects helix parameters d and h and can result in *overlapping modes* which have to be avoided

Effect of Parameter p (Contd..)



Polarization

- For circular polarization
  - $|E_x| = |E_y|$
  - A phase difference of $\pm\frac{\pi}{2}$
- Therefore,

$$\frac{E_x}{E_y} = \pm j = \frac{j}{k} \Rightarrow k = \pm 1$$

- When the polarization is elliptic, $k \neq \pm 1$ where

$$k = h_\lambda - \frac{S_\lambda}{p} = h_\lambda - \frac{\sqrt{h_\lambda^2 + (\pi D_\lambda)^2}}{p}$$

Polarization (Contd..)

- From this it is possible define the eccentricity of the polarization

$$\chi = \begin{cases} \sqrt{1-k^2} & -1 < k < 0 \\ \sqrt{1-\frac{1}{k^2}} & k < -1 \end{cases}$$

- In terms of wavelength λ

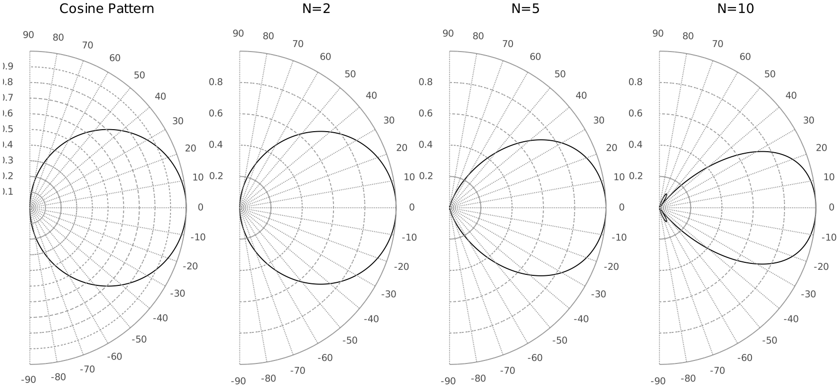
$$k = \frac{h}{\lambda} - \frac{\sqrt{h^2 + (\pi D)^2}}{p\lambda}$$

Radiation Pattern

- A single element has a basic cosine radiation pattern
- This is pattern multiplied with the array factor
- N turn helix radiation pattern,

$$E = \cos(\theta) \left[\frac{\sin\left(\frac{N\psi}{2}\right)}{\sin\left(\frac{\psi}{2}\right)} \right]$$

Radiation Pattern (Contd..)



Matching

- Krauss formula for feed impedance

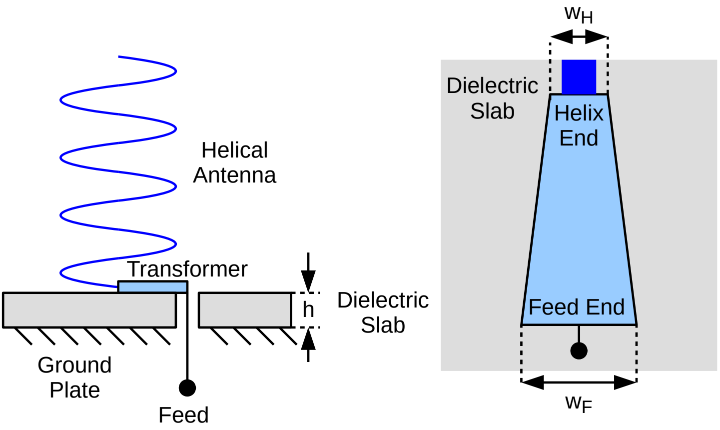
$$R = \frac{140\pi D}{\lambda}$$

- For circular polarization

$$D \approx \frac{\lambda}{\pi} \Rightarrow R \approx 140\Omega$$
$$h \approx \frac{\lambda}{4}$$

This will give a pitch angle of around 14^o (0.245rad) but a *fixed feed impedance*

Matching Transformer



a) Cross Section

b) Plan

Matching Transformer (Contd..)

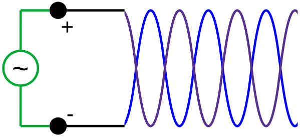
- The tapering matching transformer matches to the 50 Ω transmission line at the wide end and the 140 Ω antenna at the narrow end
- Width is given by

$$w = t\left(\frac{120\pi}{\sqrt{\varepsilon_r}z_0} - 2\right)$$

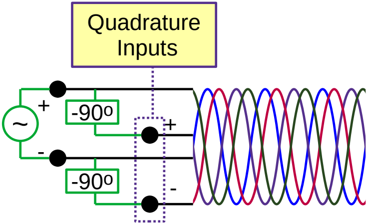
where t is the thickness of the dielectric with relative permitivity ε_r separating the conductor and ground plane and z_0 is the requied characteristic impedance of the end

- To be feasible must satisfy $\sqrt{varepslion_r}z_0 < 60\pi$

Bifilar and Quadrifilar Helical Antennas

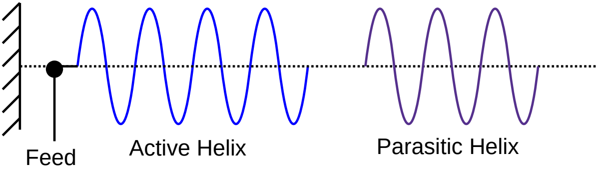


a) Bifilar Helix

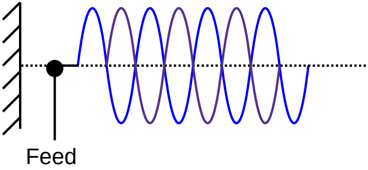


b) Quadrifilar Helix

Parasitic Helical Antennas

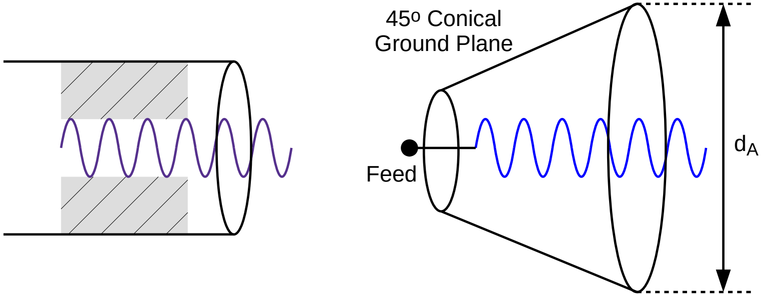


a) Front Mounted Configuration



b) Parasitic Bifilar Configuration

Cylindrical Waveguide Accessories



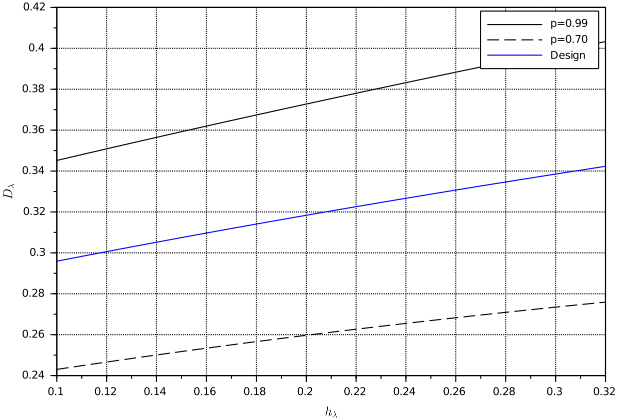
a) Circular Waveguide Parasitic Helix

b) The Helicone Antenna

Exercise 1

By taking $p = 0.85$ as a nominal value of p, determine the values of k and ratio $|E_x|/|E_y|$ of the resulting elliptical polarization of a realized helical antenna when $h = \lambda/4$ at the extreme values of $p = 0.7$ and $p = 0.99$. Assume that the antenna operates at fundamental mode.

Exercise 1 (Contd..)



Exercise 2

An axial mode helical antenna has $d = \frac{\lambda}{\pi}$. Determine the widths of either end of the required matching transformer if the dielectric slab above the ground plane has a thickness of 4 mm and ε_r of 1.2.