Helical Antennas

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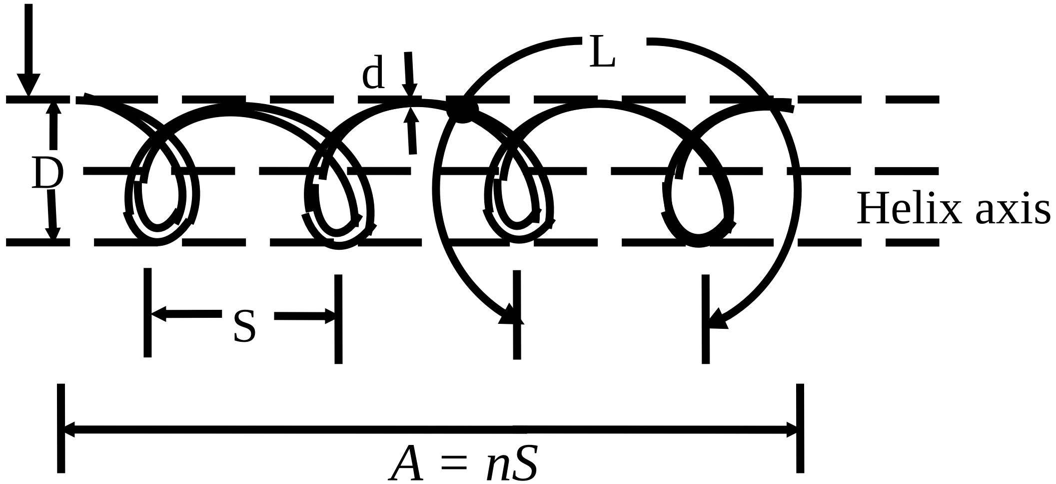
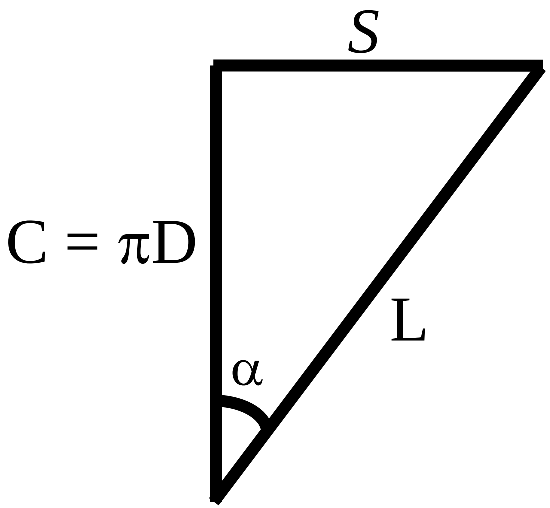
Helical Antenna





Total Length of wire = nL

Total axial length (A) = nS

$$L = \sqrt{S^2 + C^2}$$

$$\alpha = \tan^{-1}\left(\frac{S}{\pi D}\right) = \tan^{-1}\left(\frac{S}{C}\right)$$

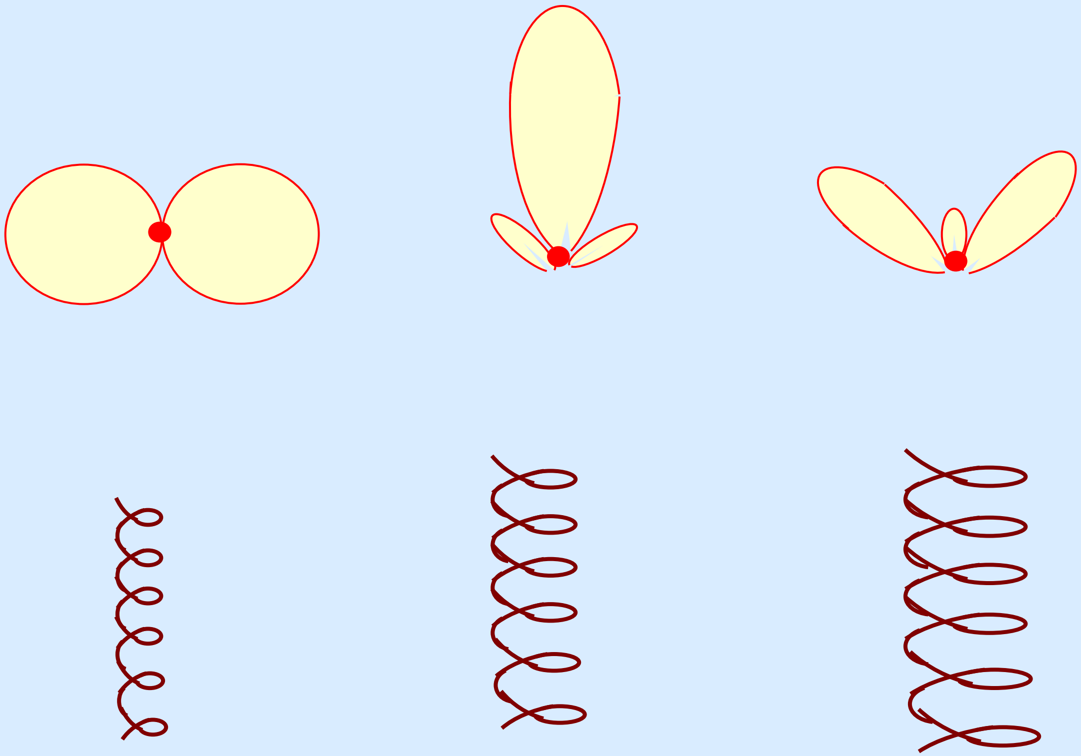
Special Cases of Helical Antenna:

Case 1: α = 0° ⇒ S = 0 ⇒ Loop Antenna

Case 2: α = 90° ⇒ D = 0 ⇒ Linear Antenna

(Reference: JD Kraus, Antennas, Tata-McGraw Hill, 1988)

Modes in Helical Antenna



Normal Mode

Axial Mode

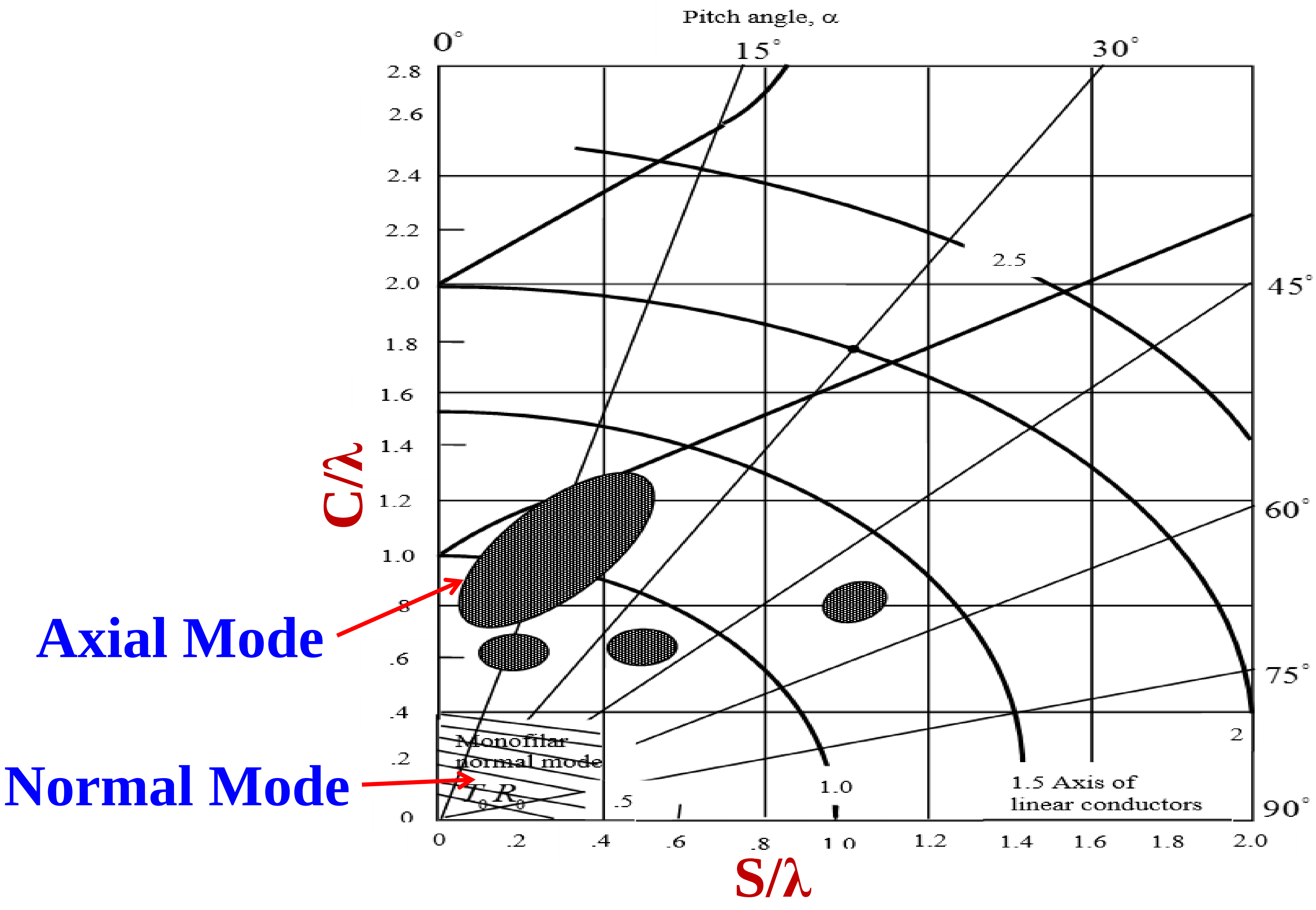
Conical Mode

$C = \pi D << \lambda$

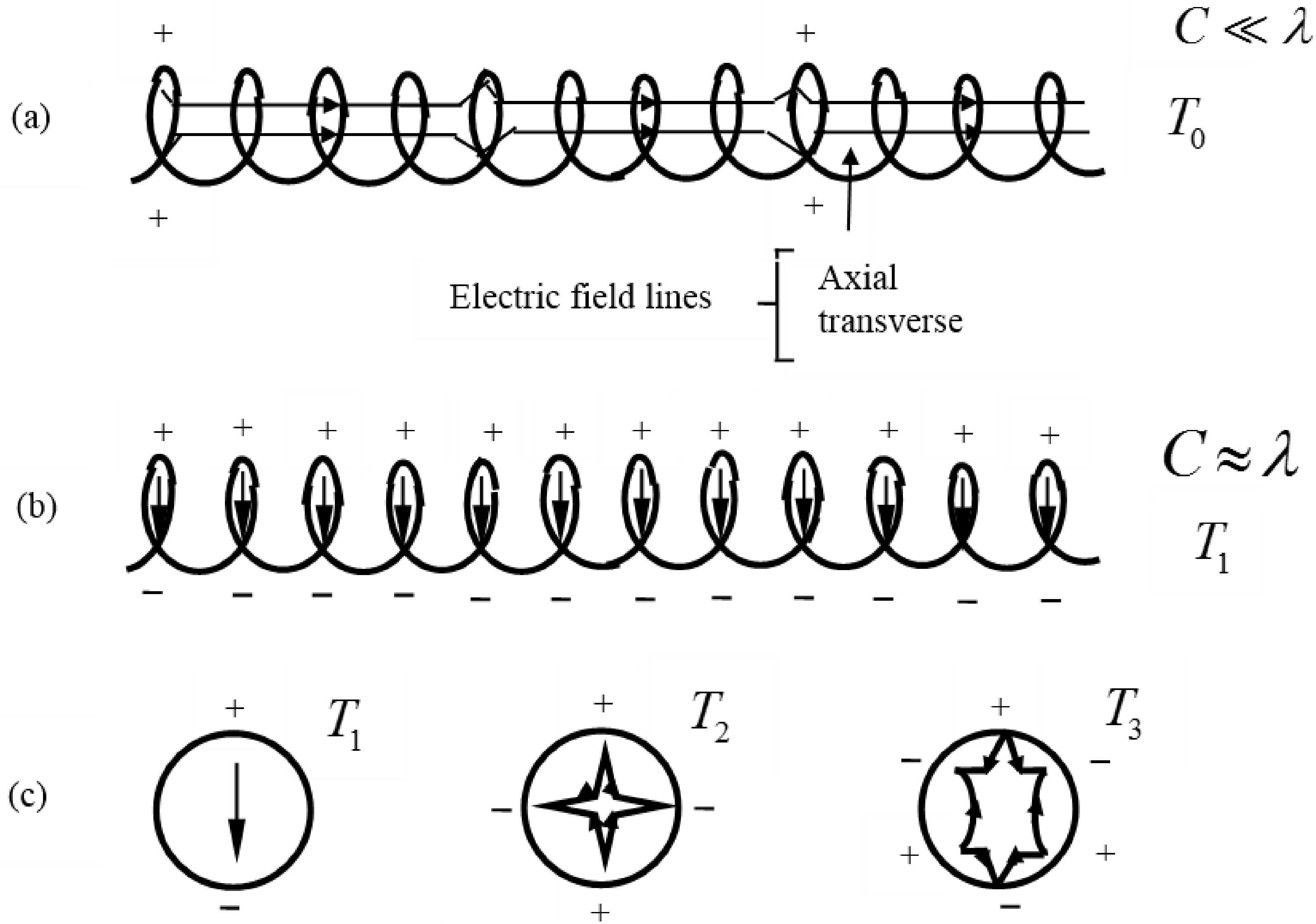
$C \approx \lambda$

$C \approx n\lambda, n = 2, 3..$

Helical Antenna Modes Chart

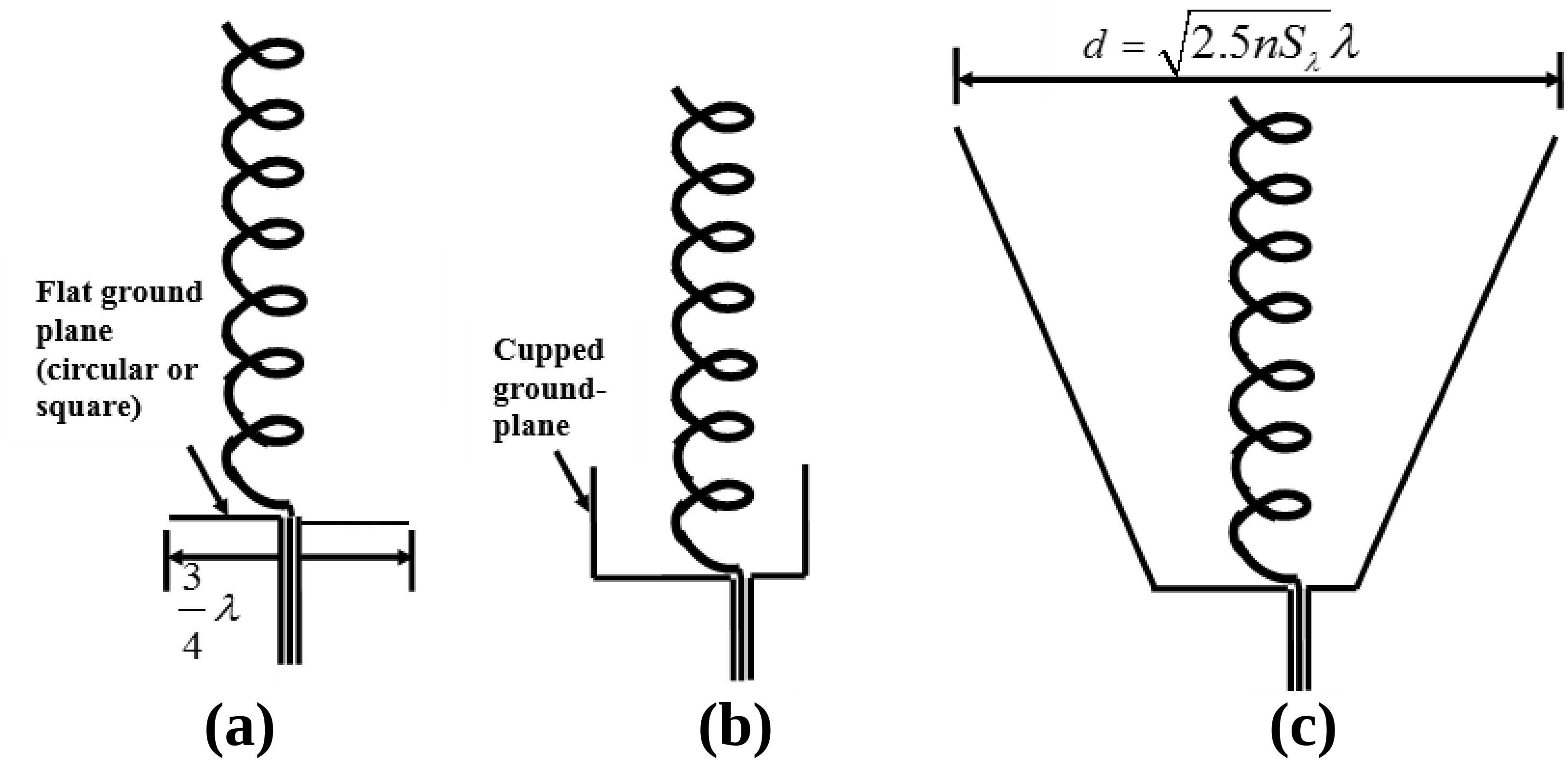


Field Distribution in Different Modes



End view of helices

Axial Mode Helical Antenna: Ground Plane



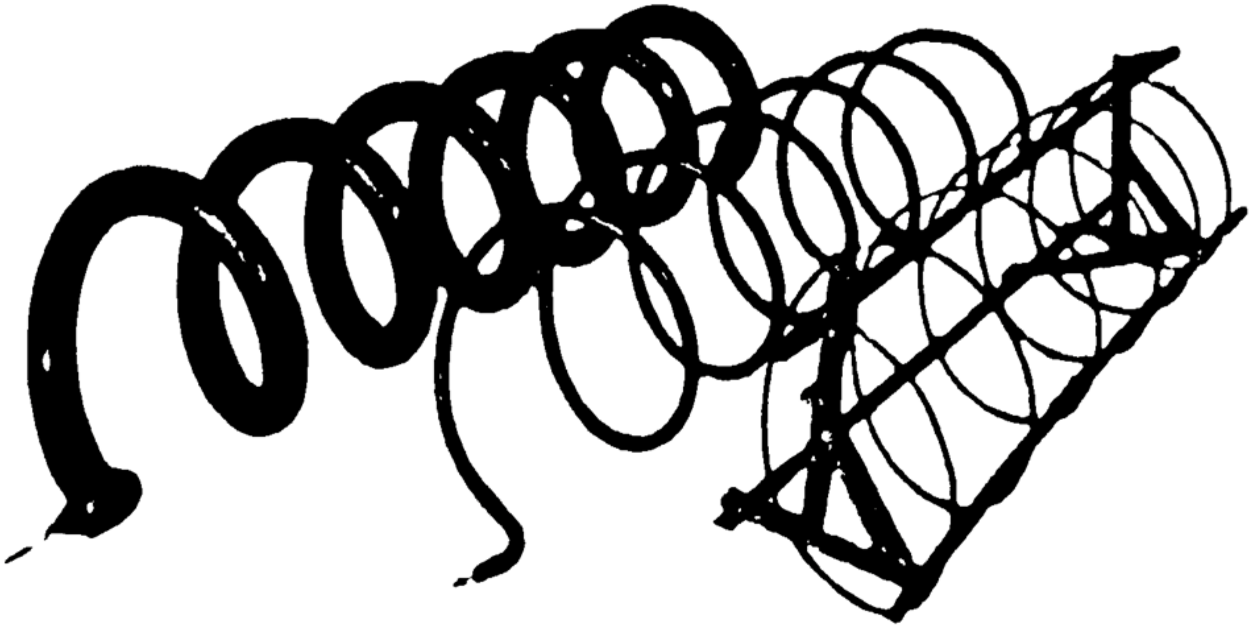
Monofilar Axial Mode Helical Antenna

a) Flat Ground Plane

b) Shallow Cupped Ground Plane

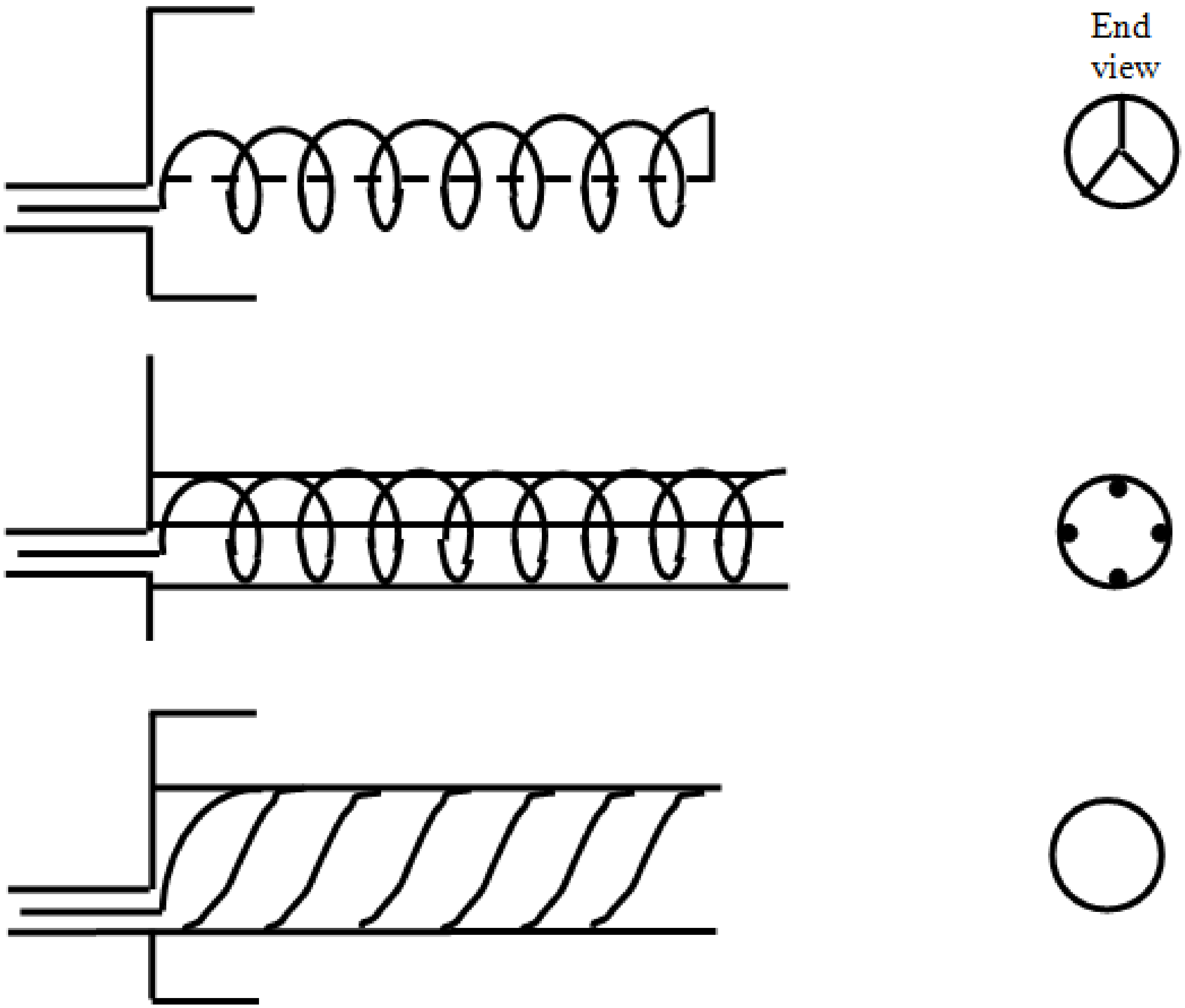
c) Deep Conical Ground Plane Enclosure.

Conductor Size of Helical Antenna



- **Monofilar axial-mode helical antennas with wire diameter of 0.055λ, 0.017λ and 0.0042λ at center frequency of 400 MHz**
- **Effect of conductor diameter on helical antenna performance - only minor changes**

Helical Antenna Support



Axial Mode Helical Antenna - Input Impedance

For Axial Feed: $R = 140 * C_\lambda \ \Omega$

For Peripheral or Circumferential Feed:

$$R \approx 150 / \sqrt{C_\lambda} \ \Omega$$

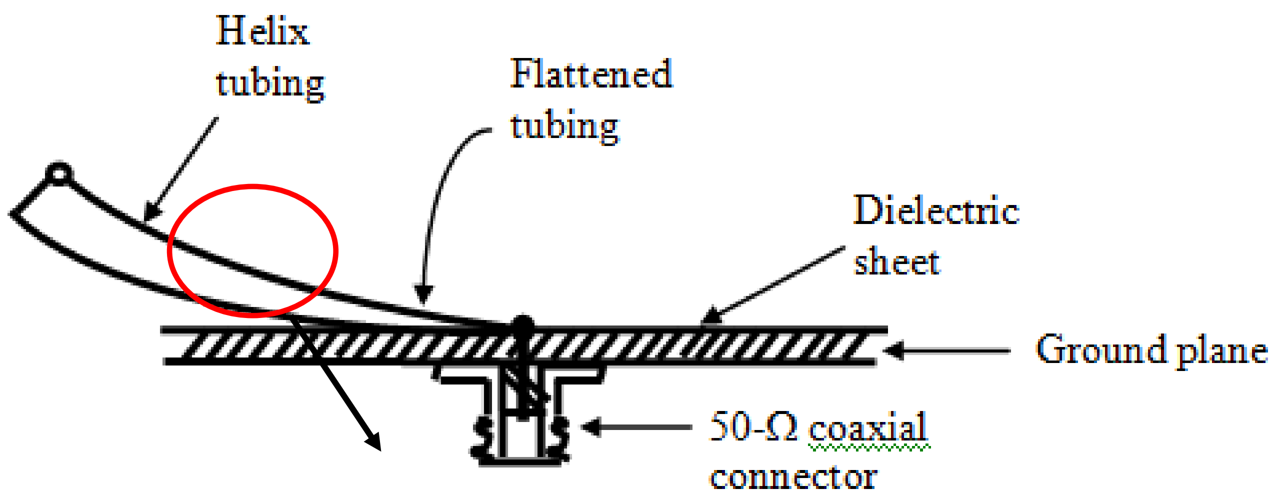
Restrictions: (a) $0.8 \leq C_\lambda \leq 1.2$

(b) $12° \leq \alpha \leq 14°$

(c) $n \geq 4$

Input Impedance Matching

1. Tapered Transition from helix to coaxial line

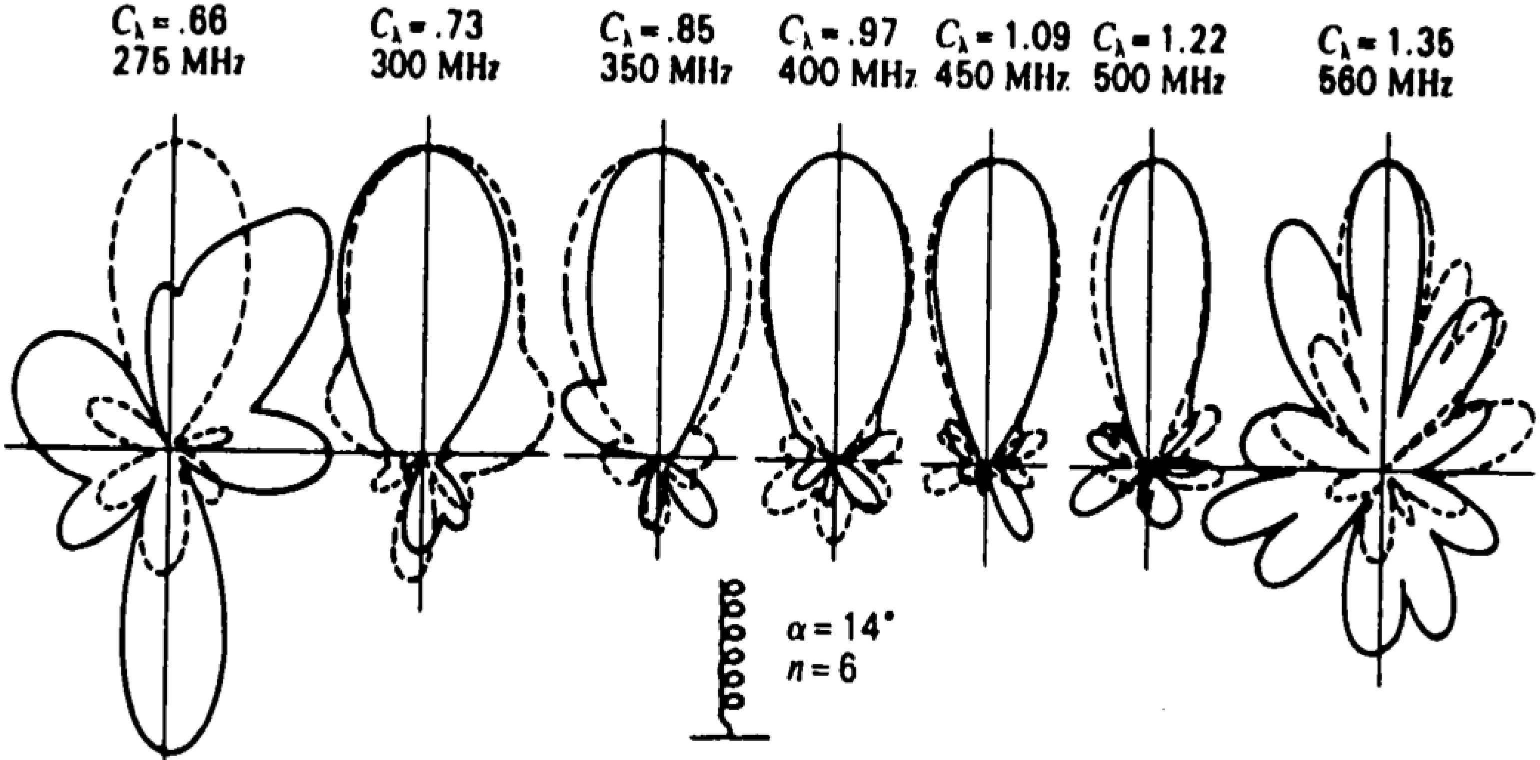


w = width of conductor at termination

2. Tapered Microstrip Transition

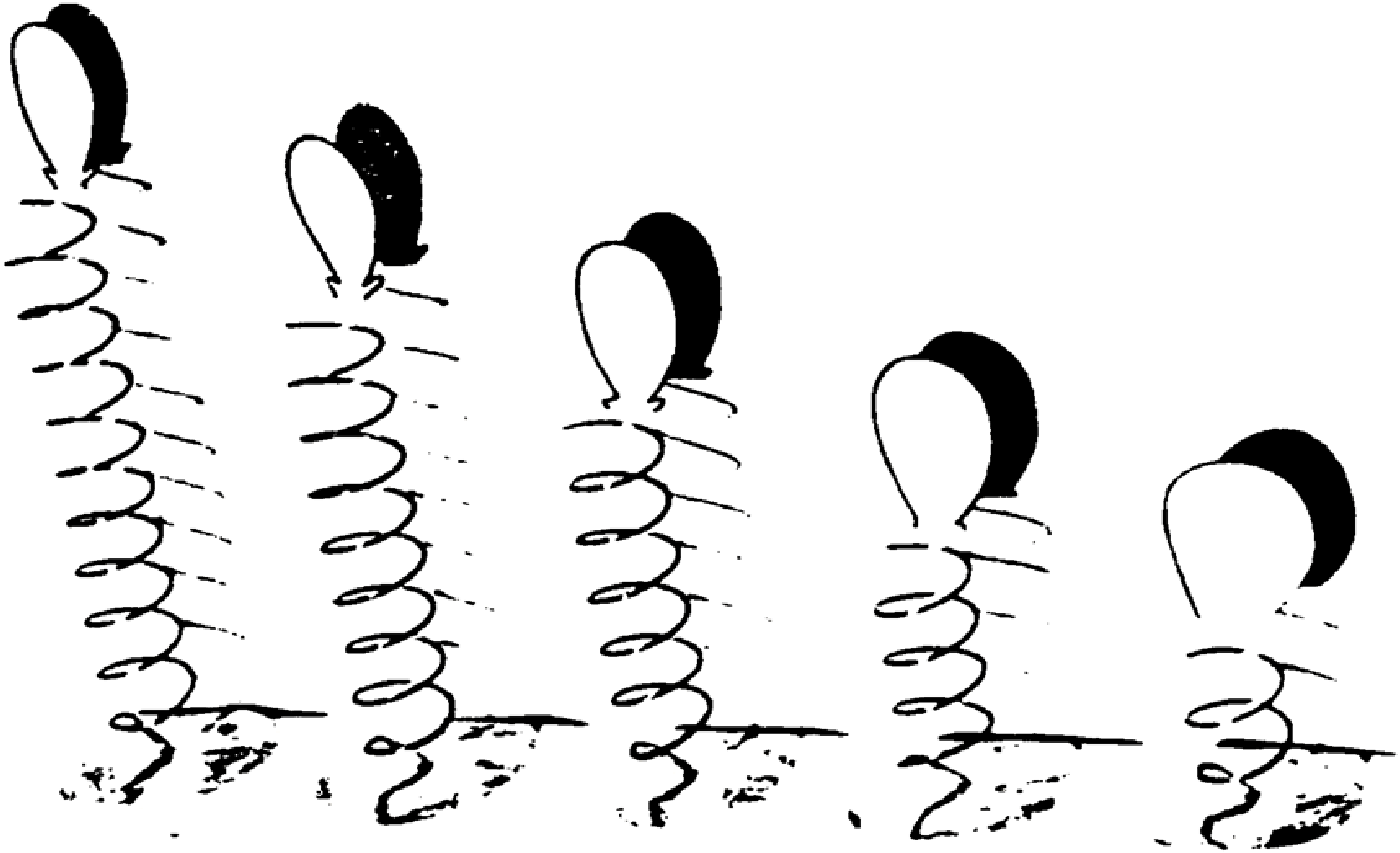
$$h = \frac{w}{[377/(\sqrt{\varepsilon_r} Z_0)] - 2}$$

Radiation Pattern of Axial Mode Helical Antenna



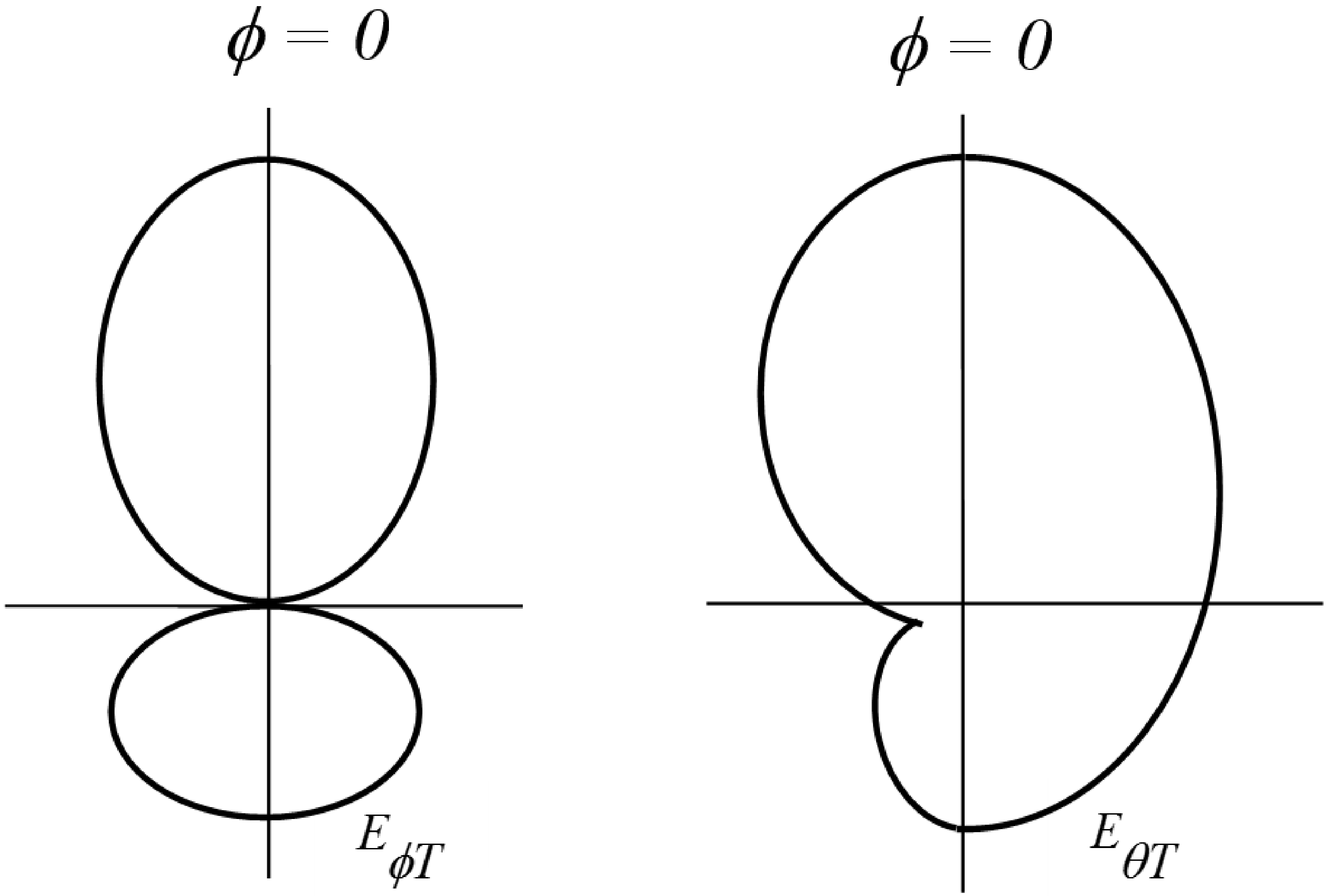
- ❑Measured Field Patterns of Axial Mode Helical Antenna of 6 turns and pitch angle α = 14°.
- ❑**CP Radiation Pattern for C/λ from 0.73 to 1.22.**
- ❑ (—) Horizontally polarized field component and (- - -) Vertically polarized.

Effect of No. of Turns (n)



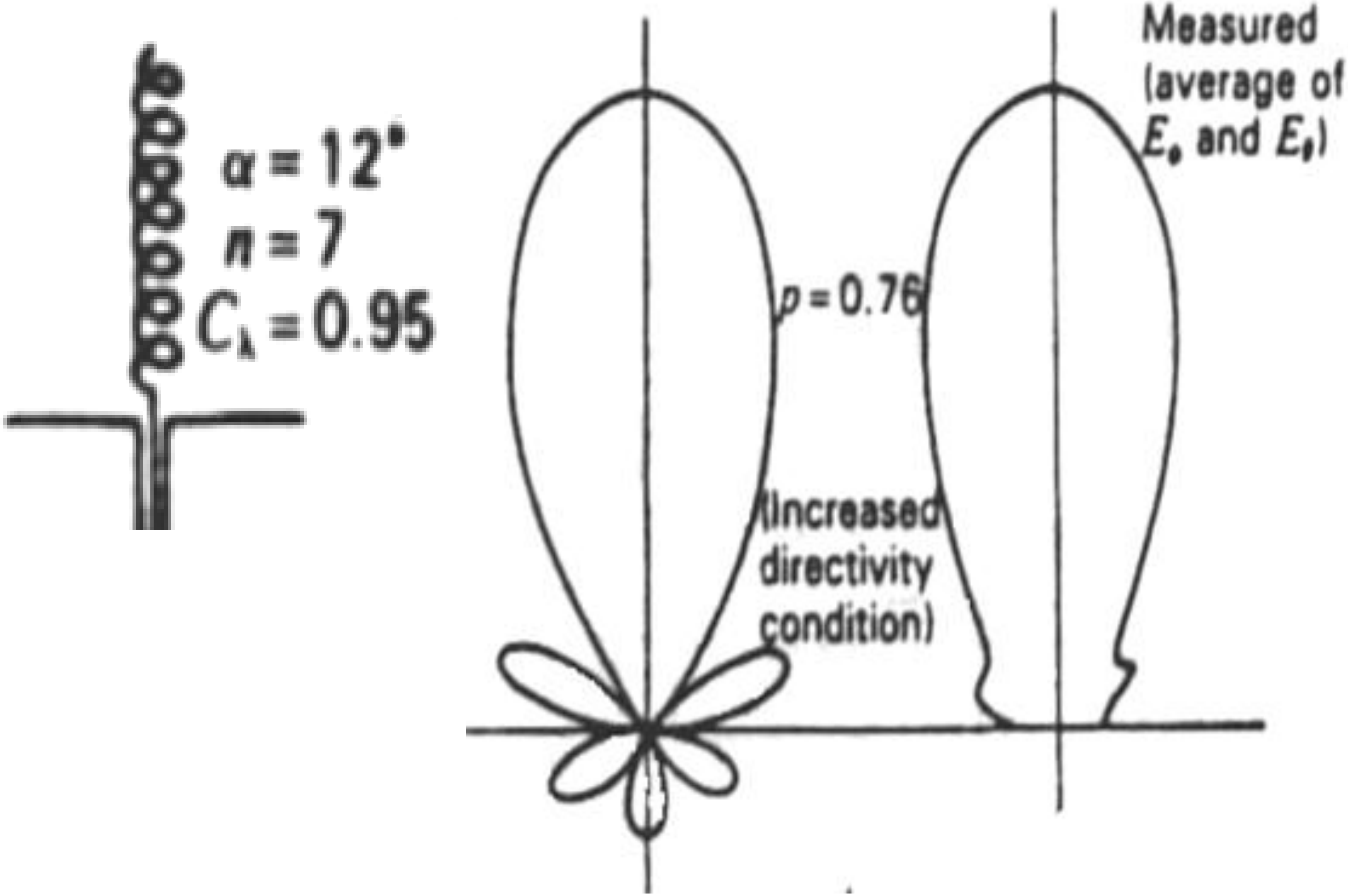
Helical Antennas: α =12.2° and 10, 8, 6, 4, 2 turns.

Pattern of Single Turn Helical Antenna



$\alpha = 12°, \text{n} = 1$

Axial Mode Helical Antenna - Increased Directivity Endfire Array



Gain of Axial Mode Helical Antenna

HPBW (Half-Power Beamwidth) $\cong \dfrac{52}{C_\lambda \sqrt{n\,S_\lambda}}$ **(deg)**

BWFN (Beamwidth Between First Nulls) $\cong \dfrac{115}{C_\lambda \sqrt{nS_\lambda}}$ **(deg)**

Directivity = 32,400 / HPBW^2

$$Directivity = 12\,C_\lambda^2\,nS_\lambda$$

Gain = η x Directivity, η ≈ 60%

Design of Axial Mode Helical Antenna

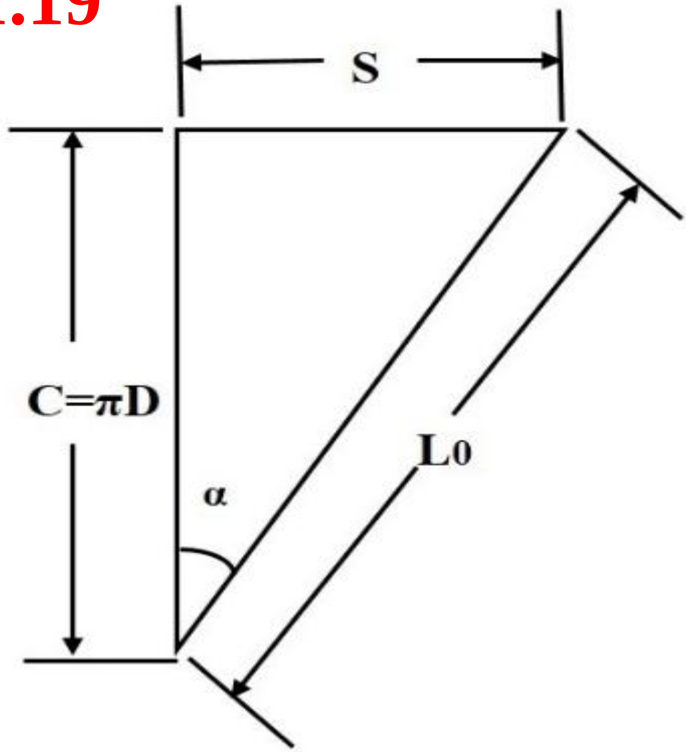
Desired: Directivity = 24 dB = 251.19

For Axial Mode Helical Antenna:

Assume: C_λ = 1.05 (0.8 to 1.2)

α = 12.7° (12° to 14°)

Calculate: $S_\lambda = C_\lambda \tan\alpha = 0.2366$



$$Directivity = 12\, C_\lambda^2\, n S_\lambda$$

$$n = \frac{251.19}{12(0.2366)(1.05)^2} = 80$$

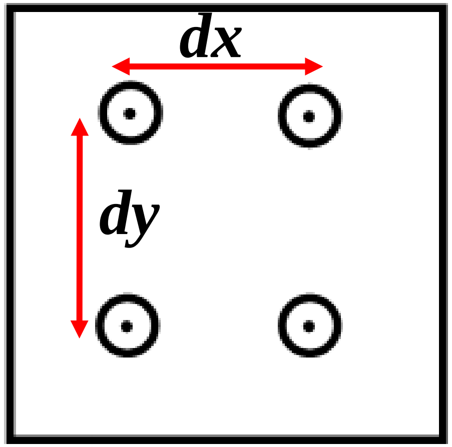
2x2 Helical Antenna Array

Instead of single 80-turns helical antenna, four 20-turns helical antennas can be used

Directivity of each 20-turns helical antenna
= 251.19/4 = 62.8

Effective Aperture $= D_o \dfrac{\lambda^2}{4\pi} \approx 5\,\lambda^2$

Assuming Square Aperture
Side Length = √5λ = 2.236 λ



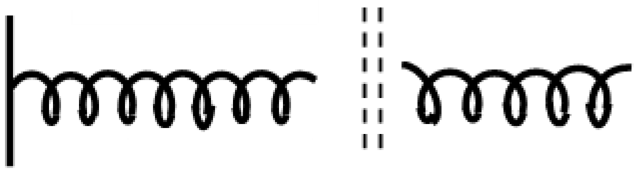
2x2 Array

Each Helix is placed at the center of its aperture.

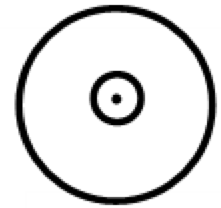
Helical Antenna and Arrays

Side View

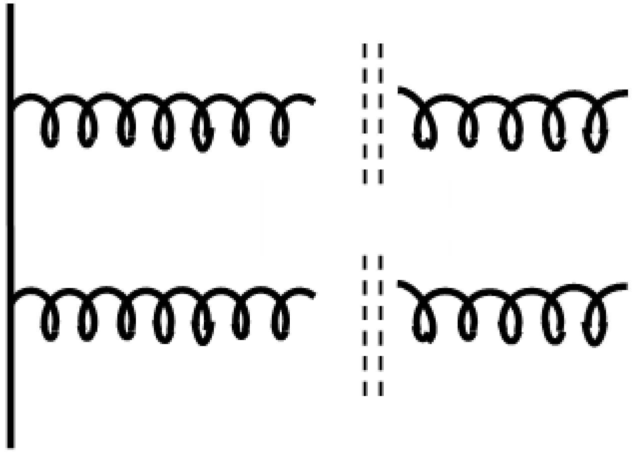
Front View



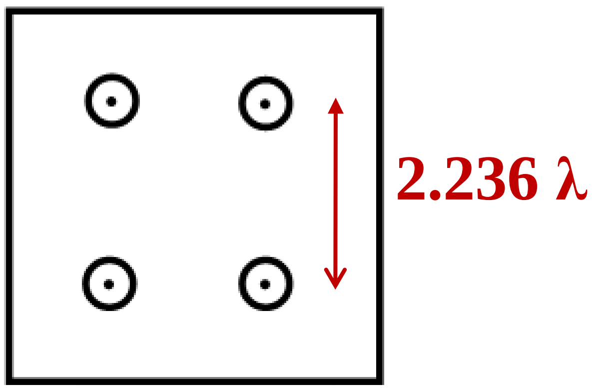
n = 80



1 Helix



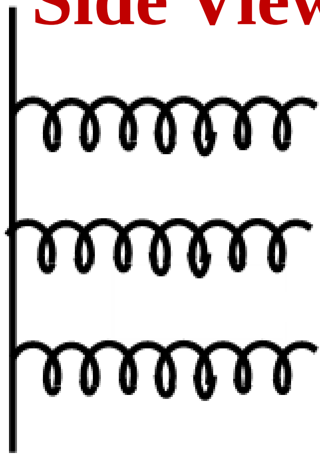
n = 20



4 Helices

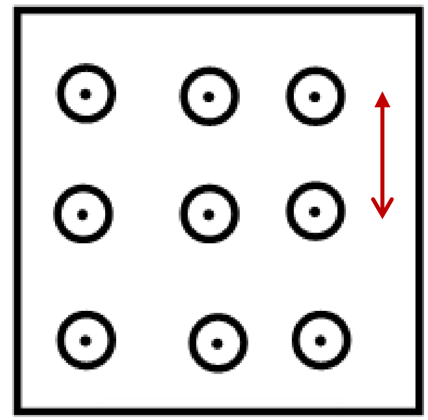
Arrays of Helical Antenna

Side View



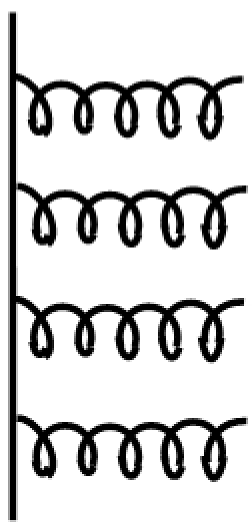
n = 9

Front View

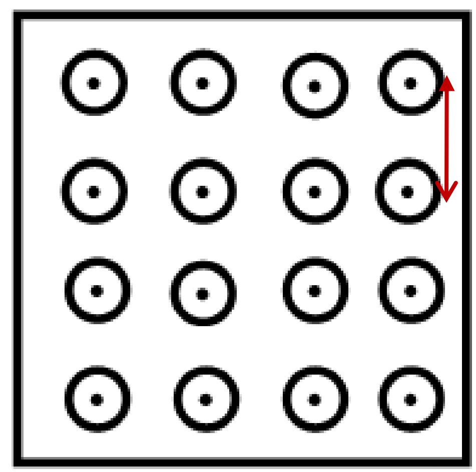


1.49 λ

9 Helices



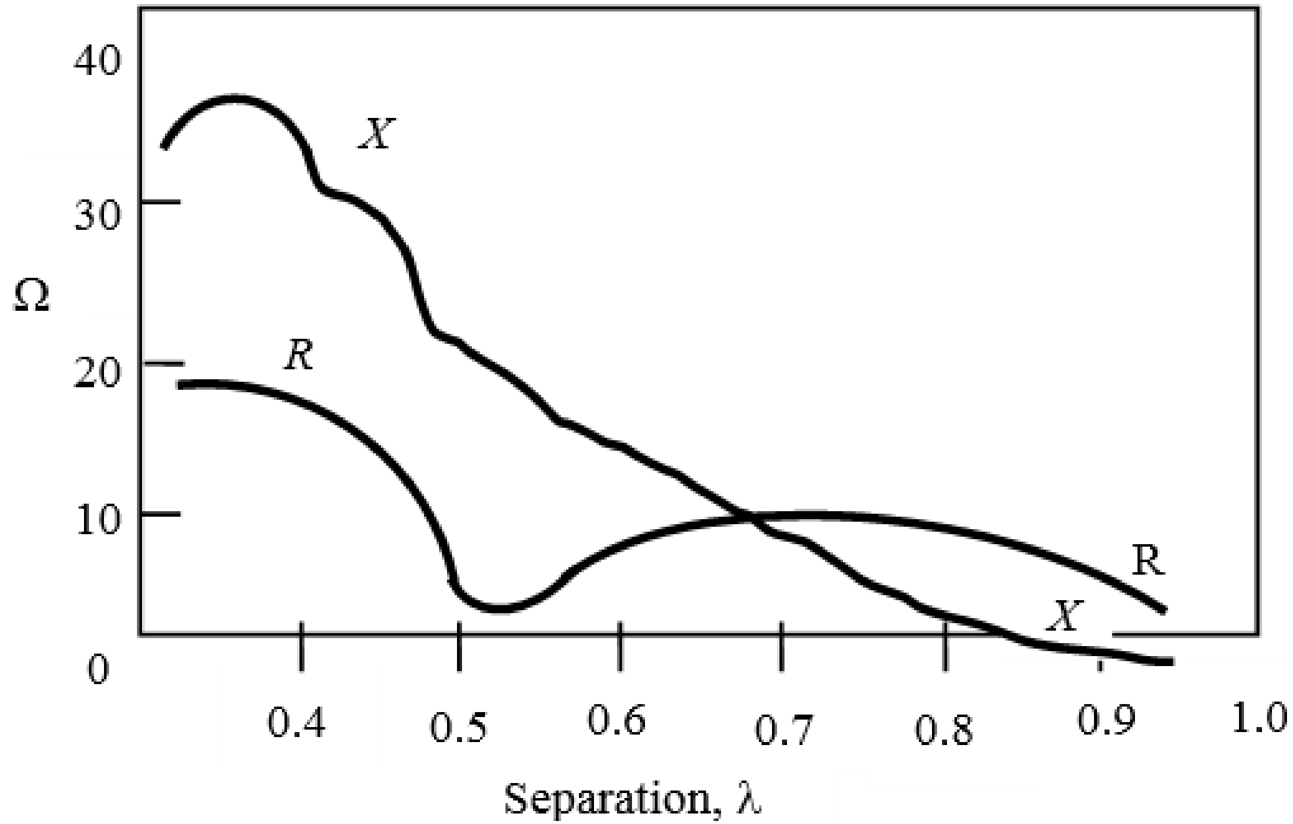
n = 5



1.18 λ

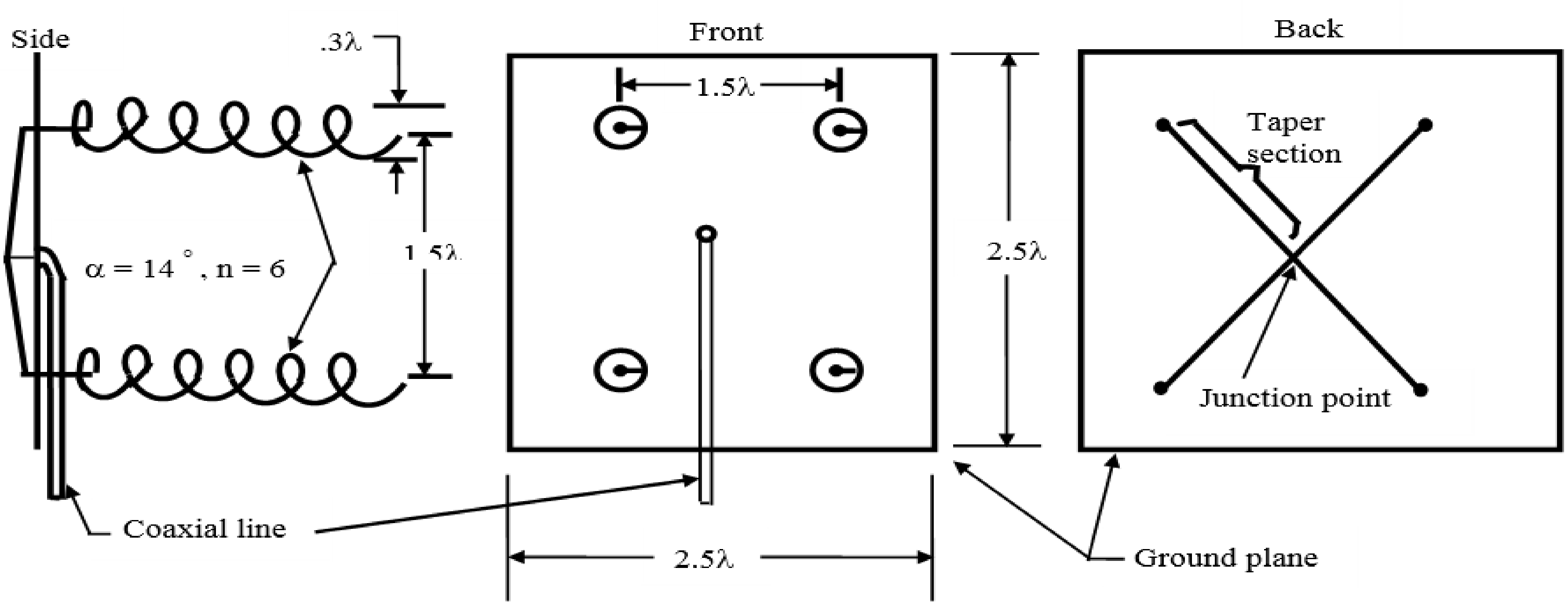
16 Helices

Mutual Impedance between Arrays of Helical Antennas

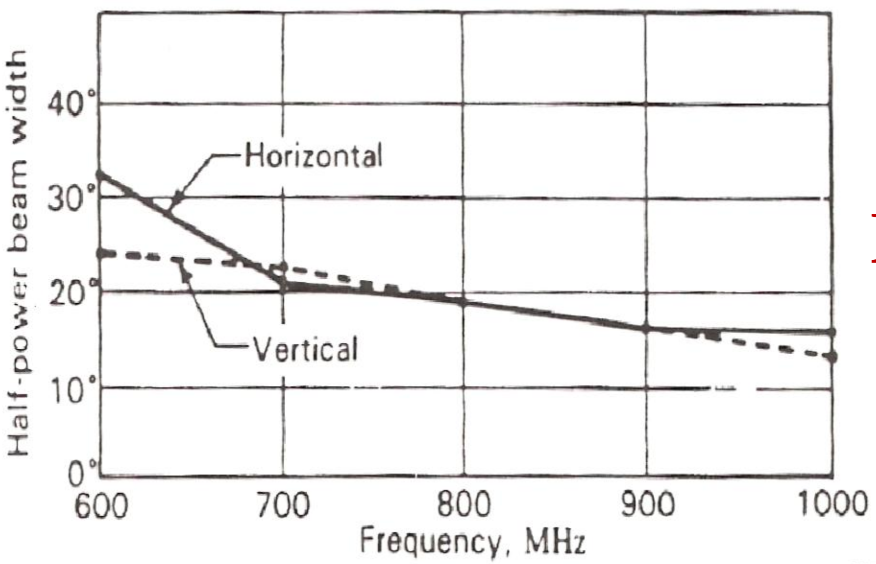


Resistive (R) and Reactive (X) components of the mutual impedance of a pair of same-handed 8-turn axial-mode helical antennas of 12° pitch angle

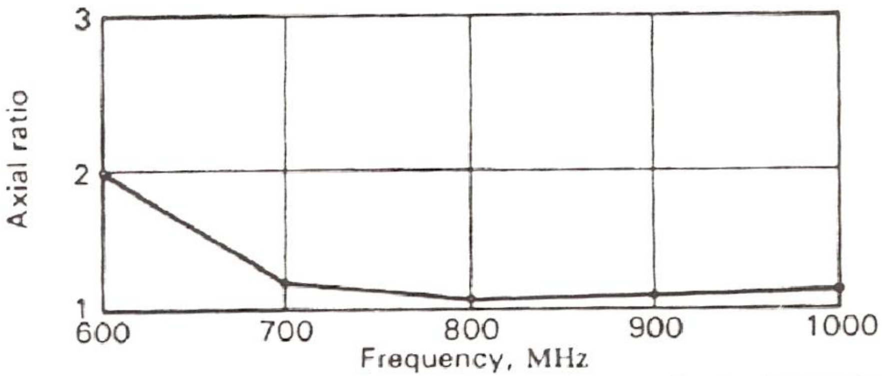
2x2 Array of Helical Antenna at 800 MHz

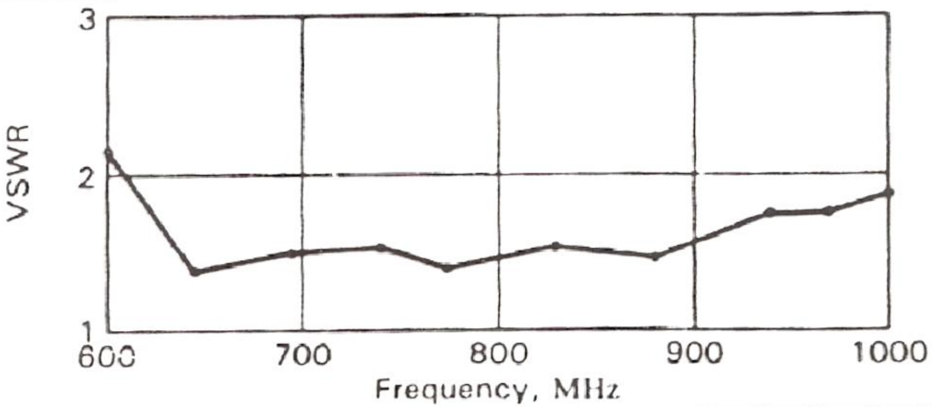


Results of 2x2 Array of Helical Antenna



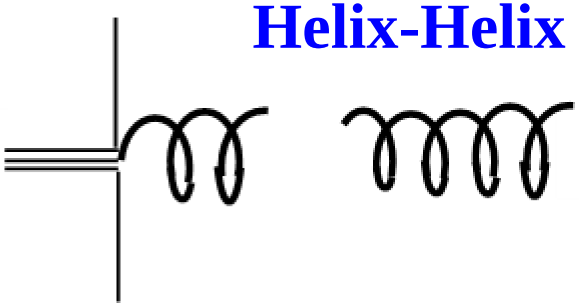
Directivity = 18.5 dB at 800 MHz



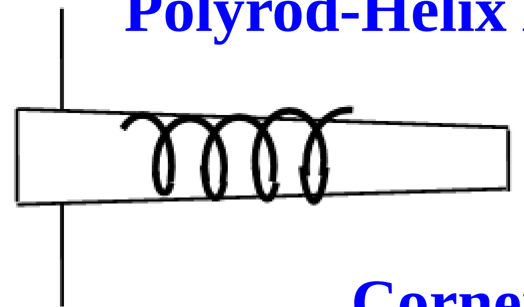


Helix as a Parasitic Element

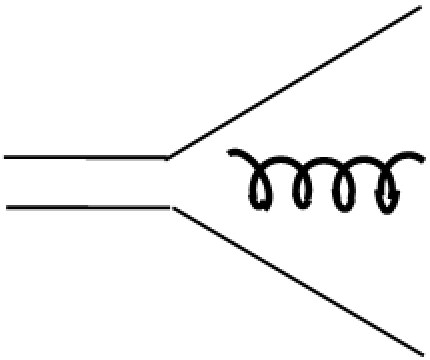
Helix-Helix



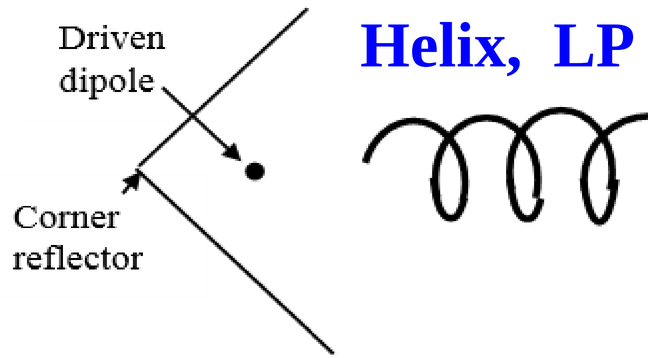
Polyrod-Helix LP to CP



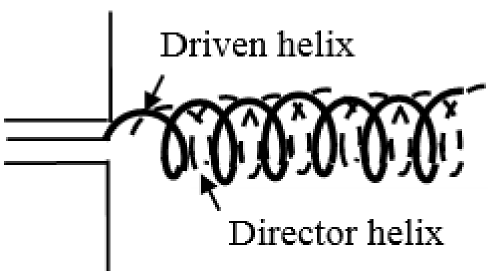
Horn-Helix LP to CP



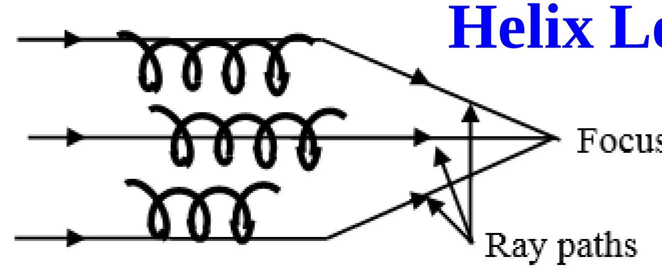
Corner-reflector Helix, LP to CP



Helix-Helix More Gain



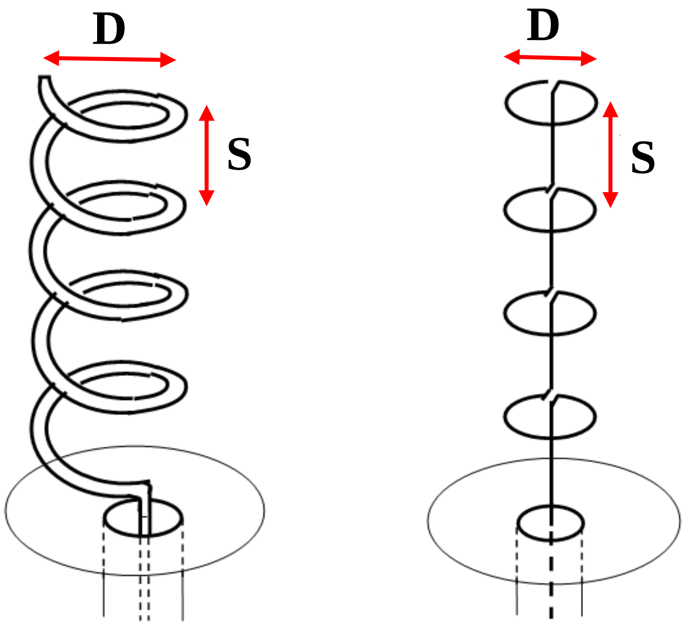
Helix Lens



Normal Mode Helical Antenna

Small Dipole:

$$E_\theta = j\eta \frac{kI_o S e^{-jkr}}{4\pi r}\sin\theta$$

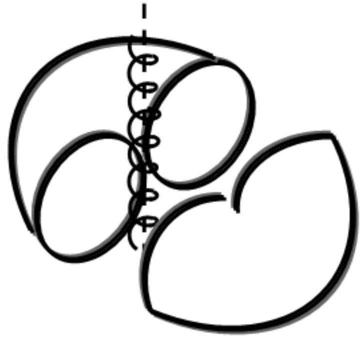


Small Loop:

$$E_\phi = \eta \frac{k^2 I_o \left(\frac{D}{2}\right)^2 e^{-jkr}}{4r}\sin\theta$$

Therefore, Axial Ratio is:

$$AR = \frac{|E_\theta|}{|E_\phi|} = \frac{2S\lambda}{C^2} = \frac{2S_\lambda}{C_\lambda^2}$$



For Circular Polarization, AR = 1 ⇒ $C_\lambda = \sqrt{2S_\lambda}$

Design of Normal Mode Helical Antenna

For Infinite Ground Plane:

Wire length ≈ λ / 4 – text book

> λ / 4 – in reality

Radiation Resistance (R_s)

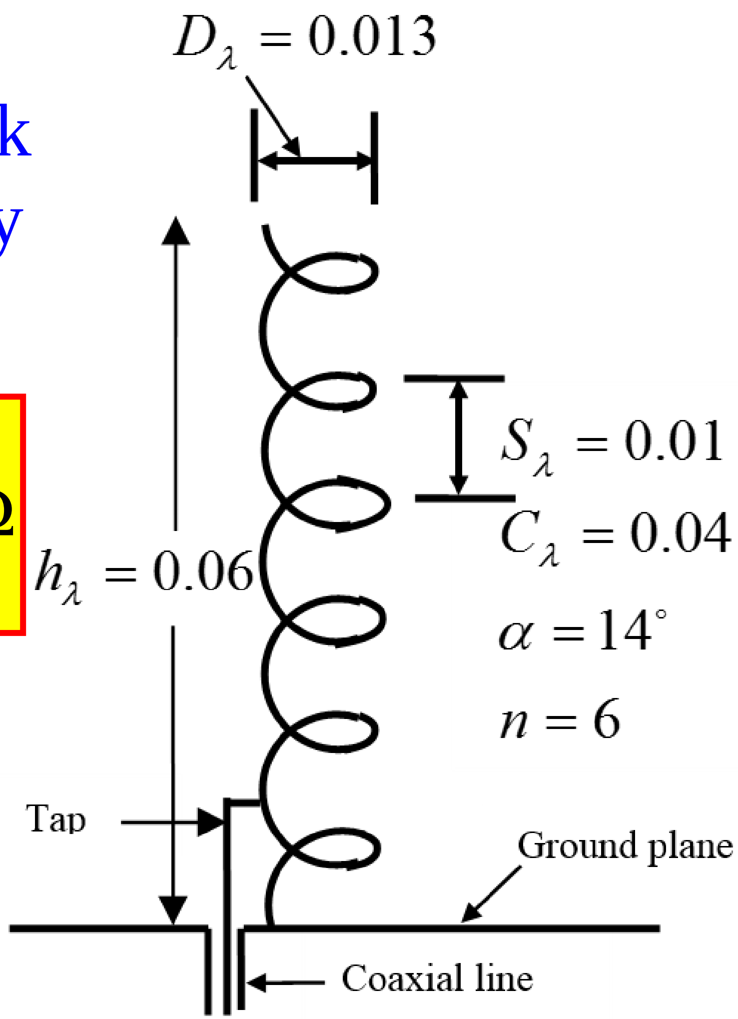
$$R_s = \frac{1}{2}(790)\left(\frac{I_{av}}{I_o}\right)^2 h_\lambda^2 \Rightarrow R_s = 0.6\ \Omega$$

Axial Ratio (AR)

$AR = 2\ S_\lambda / C_\lambda^{\ 2}$

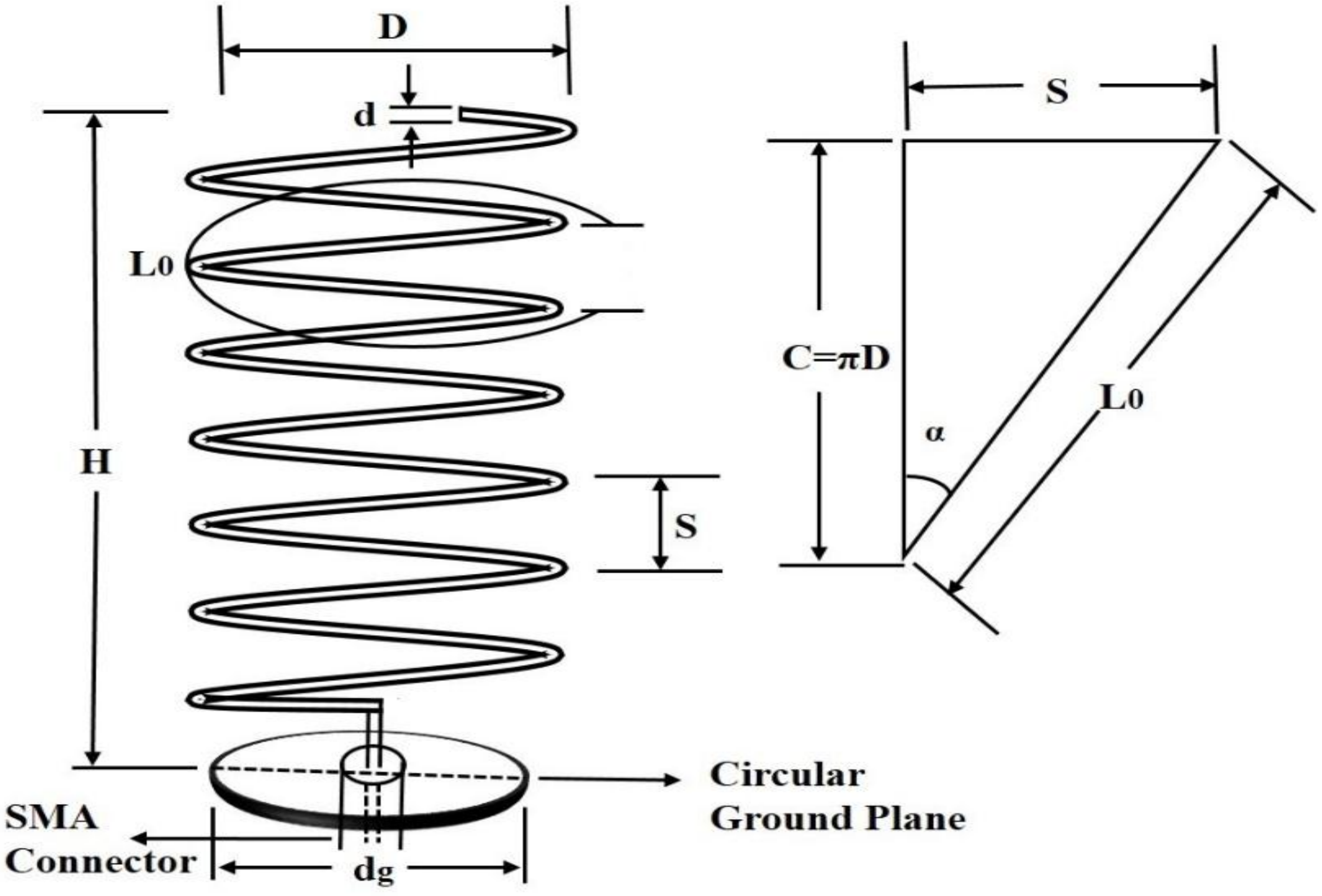
$= 2 \times 0.01/0.04^2$

$= 12.5 = 21.94$ dB



Feed is tapped after one turn for impedance matching

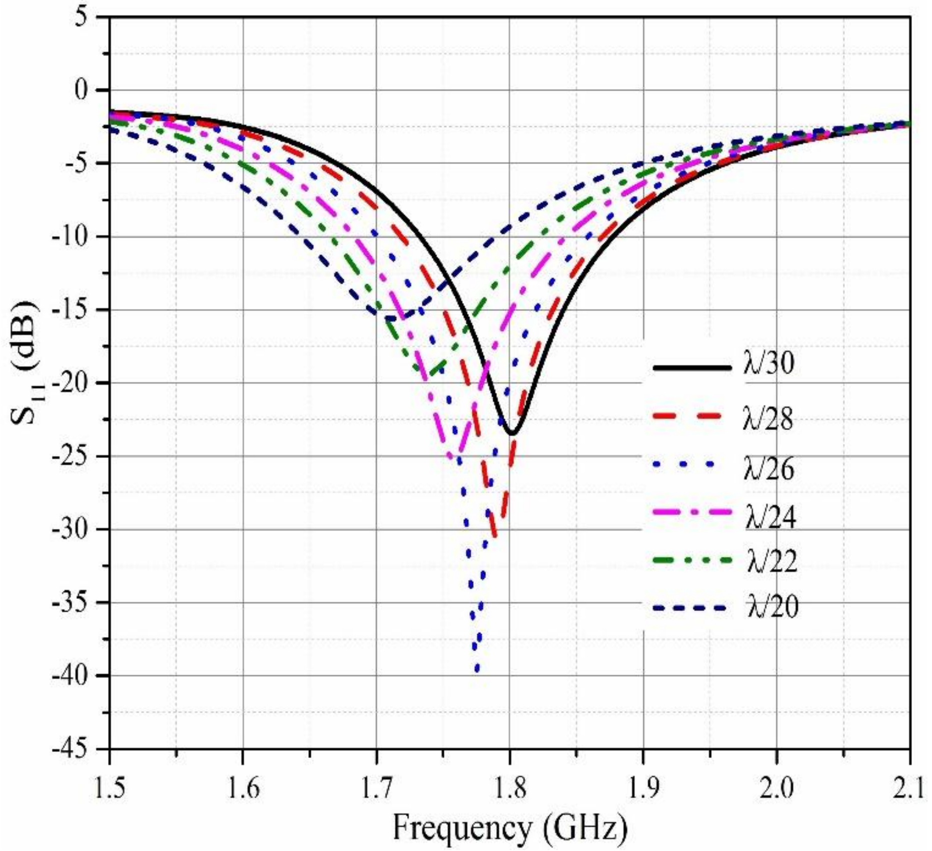
Normal Mode Helical Antenna (NMHA) on Small Circular Ground Plane

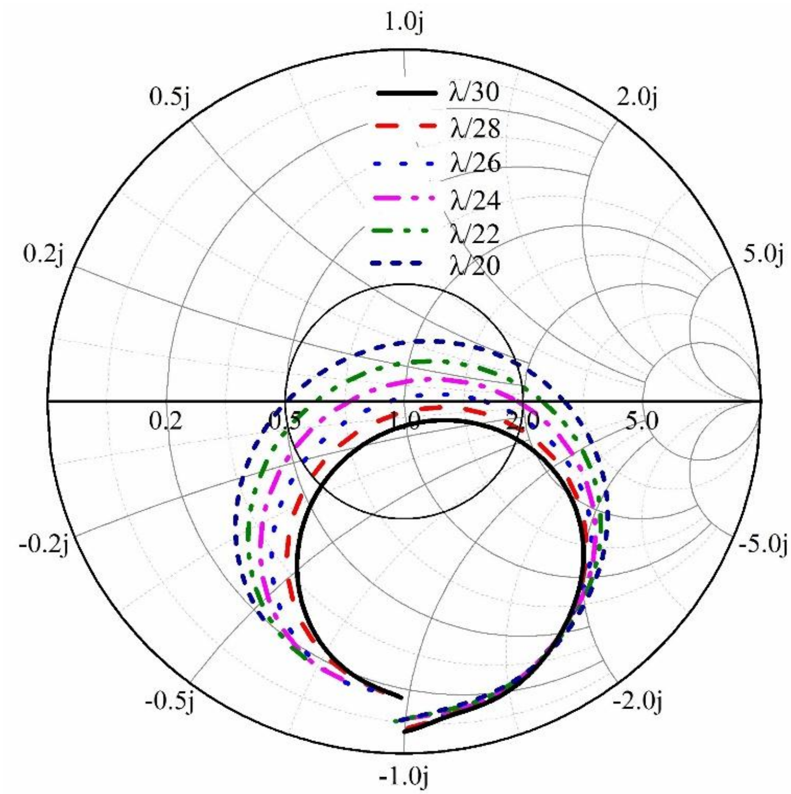


NMHA Design on Small Circular Ground Plane

Resonance Frequency	1.8 GHz
Wavelength	166 mm
Spacing = 0.027λ	4.5 mm
Diameter of Helix = 0.033λ	5.5 mm
No of Turns (N)	7
Pitch Angle (α)	14.6 Degree
Length of Wire = 0.75λ	124.5 mm

Effect of Ground Plane Size on NMHA

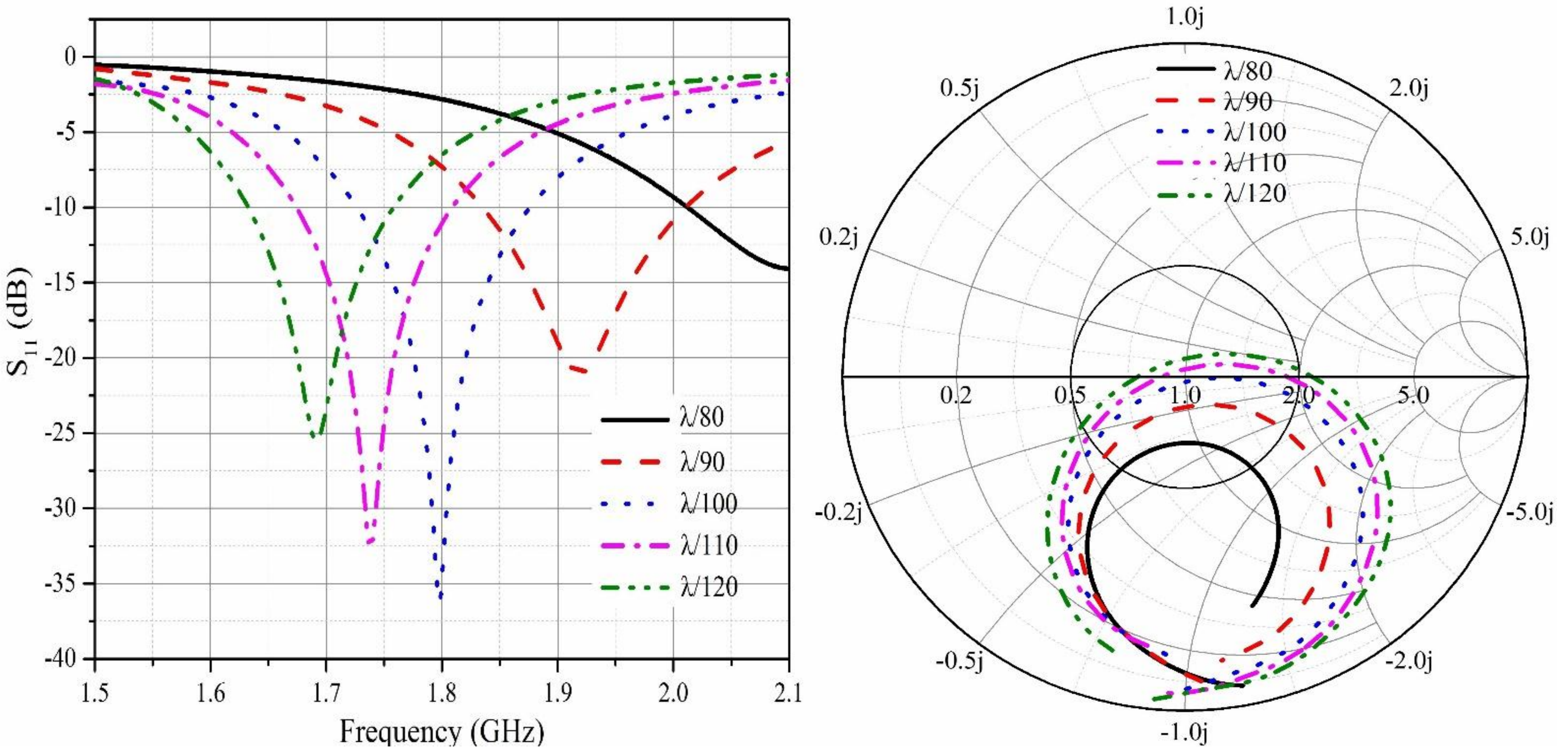




As ground plane radius increases from λ/30 to λ/20, resonance frequency decreases and the input impedance curve shifts upward.

NMHA designed for 1.8 GHz and r_{wire} = 1.6 mm (λ/100)

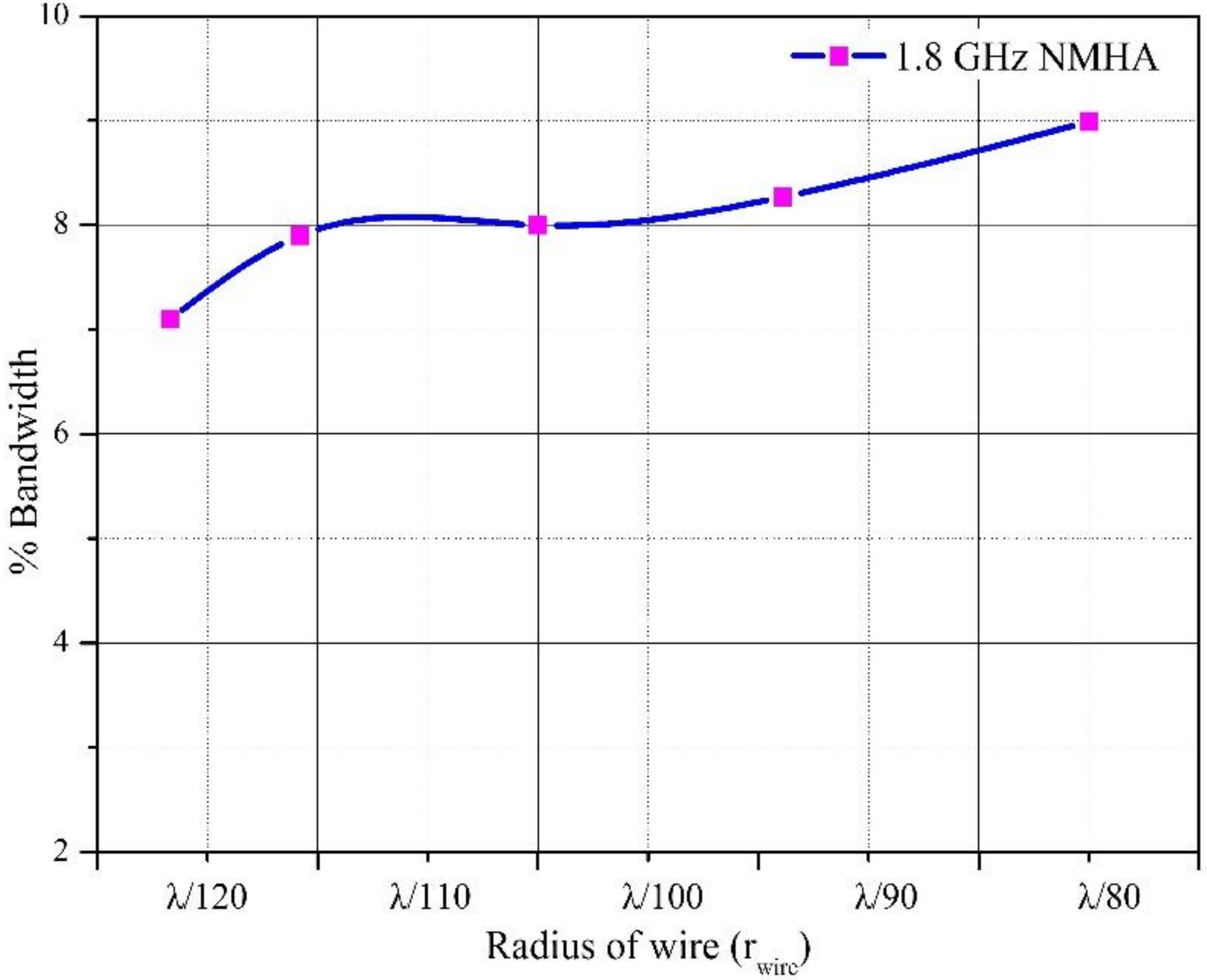
Effect of Wire Radius on NMHA



As radius of wire decreases from λ/80 to λ/120, its inductance increases so resonance frequency of NMHA decreases and its input impedance curve shifts upward (inductive region).

NMHA designed for 1.8 GHz and r_g = 5.5 mm (λ/30)

Effect of Wire Radius on Bandwidth of NMHA



Fabricated NMHA on Small Ground Plane and its Results