Broadband Antenna

Chapter 4

Learning Outcome

- At the end of this chapter student should able to:
  - To design and evaluate various antenna to meet application requirements for
    - Loops antenna
    - Helix antenna
    - Yagi Uda antenna

What is broadband antenna?

- The advent of broadband system in wireless communication area has demanded the design of antennas that must operate effectively over a wide range of frequencies.
- An antenna with wide bandwidth is referred to as a broadband antenna.
- But the question is, wide bandwidth mean how much bandwidth? The term "broadband" is a relative measure of bandwidth and varies with the circumstances.

Bandwidth

Bandwidth is computed in two ways:

- (1)

$$B = \frac{f_u - f_l}{f_c} \times 100\,\%$$

where *fu* and *fl* are the upper and lower frequencies of operation for which satisfactory performance is obtained. *fc* is the center frequency.

- (2)

$$B = \frac{f_u}{f_l} \qquad (4.2)$$

Note: The bandwidth of narrow band antenna is usually expressed as a percentage using equation (4.1), whereas wideband antenna are quoted as a ratio using equation (4.2).

Broadband Antenna

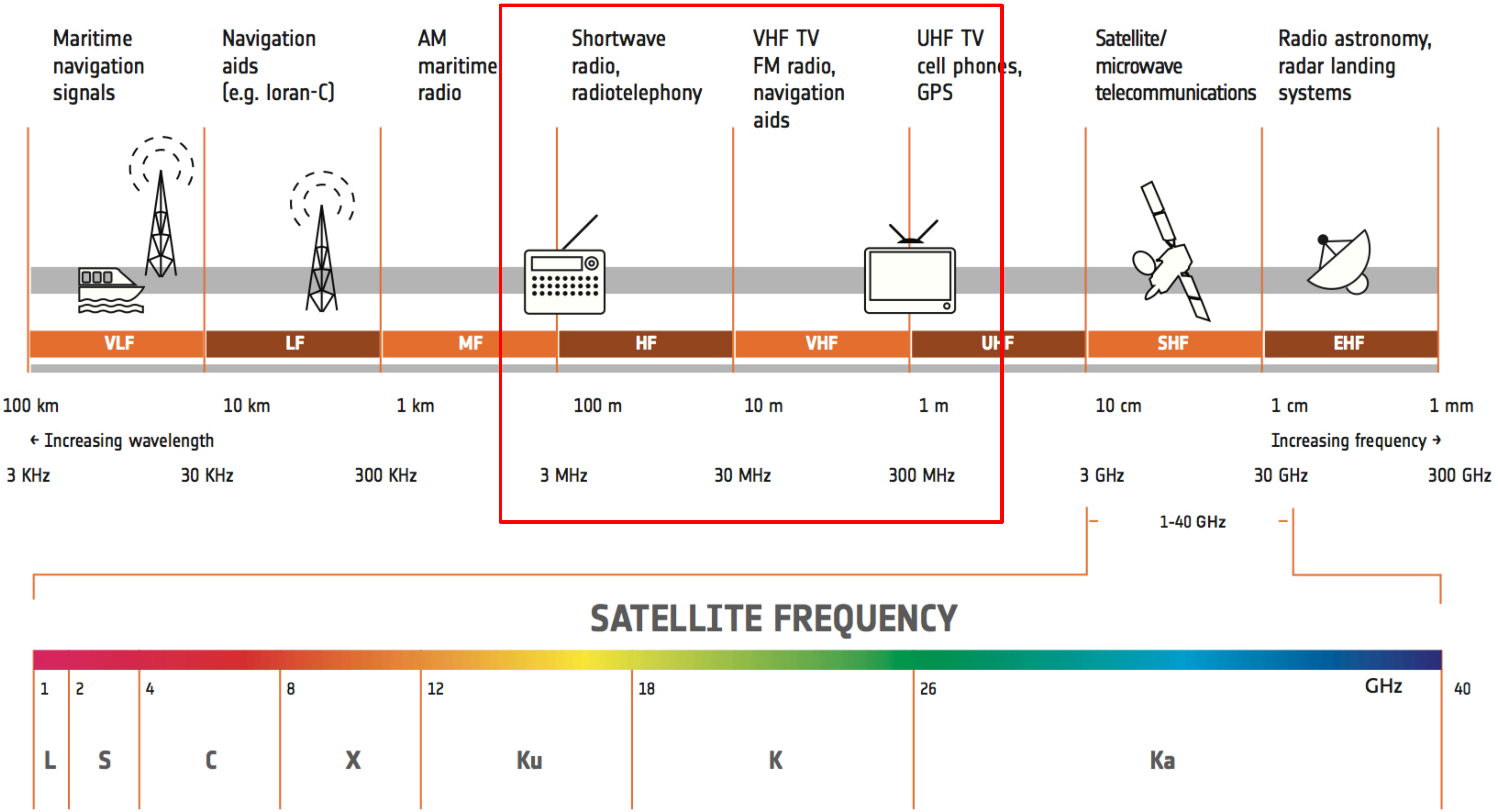
- The definition of a broadband antenna is somewhat arbitrary and depends on the particular antenna.
- If the impendence and pattern of an antenna do not change significantly over about an octave ($fu / fl = 2$) or more, it will classified as a broadband antenna".
- In this chapter we will focus on
  - Loops antenna
  - Helix antenna
  - Yagi uda antenna
  - Log periodic antenna*

LOOP ANTENNA

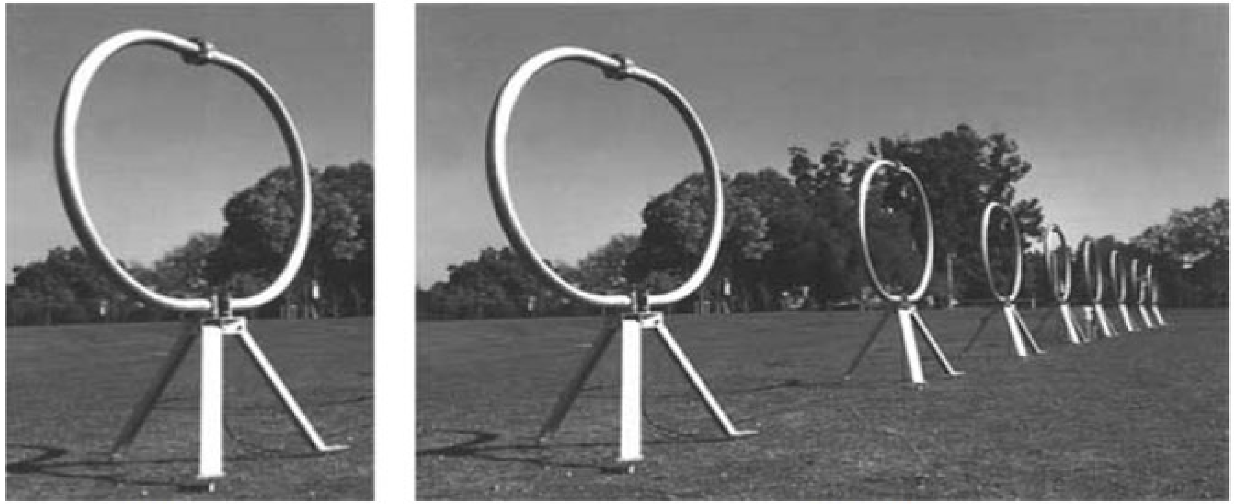
Loops Antenna

- Another simple, inexpensive, and very versatile antenna type is the loop antenna.
- Because of the simplicity in analysis and construction, the circular loop is the most popular and has received the widest attention.
- Loop antennas are usually classified into two categories, electrically small and electrically large.
  - Electrically small antennas: overall length (circumference) is usually less than about one-tenth of a wavelength ($C < \lambda/10$).
  - Electrically large : circumference is about a free-space wavelength ($C \sim \lambda$).
- Most of the applications of loop antennas are in the HF (3–30 MHz), VHF (30–300 MHz), and UHF (300–3,000 MHz) bands. When used as field probes, they find applications even in the microwave frequency range.
- Electrically large loops are used primarily indirection all arrays, such as in helical antennas, Yagi-Uda arrays and so on.

Broadband Antenna



Loops Antenna



(a) single element

(b) array of eight elements

Commercial loop antenna as a single vertical element and in the form of eight-element linear array. (Courtesy: TCI, A Dielectric Company).

- Loop antennas can be used as single elements, as shown in Figure (a), whose plane of its area is perpendicular to the ground. The relative orientation of the loop can be in other directions, including its plane being parallel relative to the ground.
- Thus, its mounting orientation will determine its radiation characteristics relative to the ground.
- Loops are also used in arrays of various forms. The particular array configuration will determine its overall pattern and radiation characteristics. One form of arraying is shown in Figure (b), where eight loops of Figure (a) are placed to form a linear array of eight vertical elements.

HELICAL ANTENNA

HELICAL ANTENNA

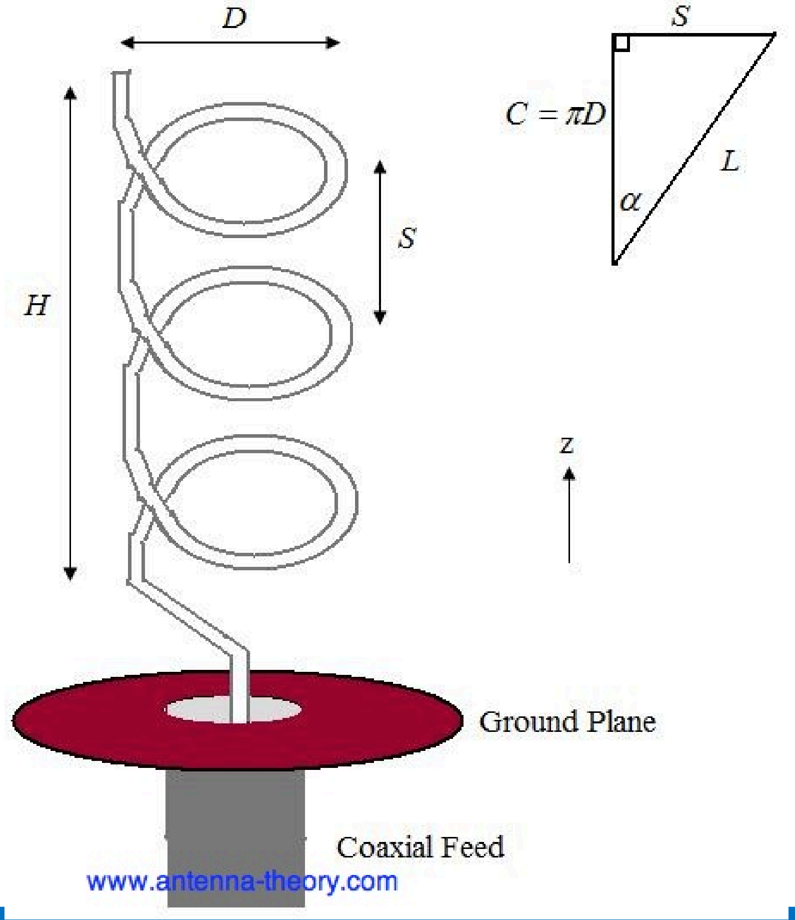
- In most cases the helix is used with a ground plane.
- The ground plane can take different forms.
- Typically the diameter of the ground plane should be at least 3λ/4.
- The ground plane can also be cupped in the form of a cylindrical cavity.
- The helix is connected to the center conductor of a coaxial transmission line at the feed point with the outer conductor of the line attached to the ground plane

Helix Antenna

- **Helix antennas** (also commonly called **helical antennas**) have a very distinctive shape, as can be seen in the picture.
- The benefits of this helix antenna is it has a wide bandwidth, is easily constructed, has a real input impedance, and can produce circularly polarized fields.

www.antenna-theory.com

- The basic geometry of the helix antenna shown in figure below.



The parameters of the helix antenna are defined below:

D - Diameter of a turn on the helix antenna.

C - Circumference of a turn on the helix antenna ($C=\pi D$).

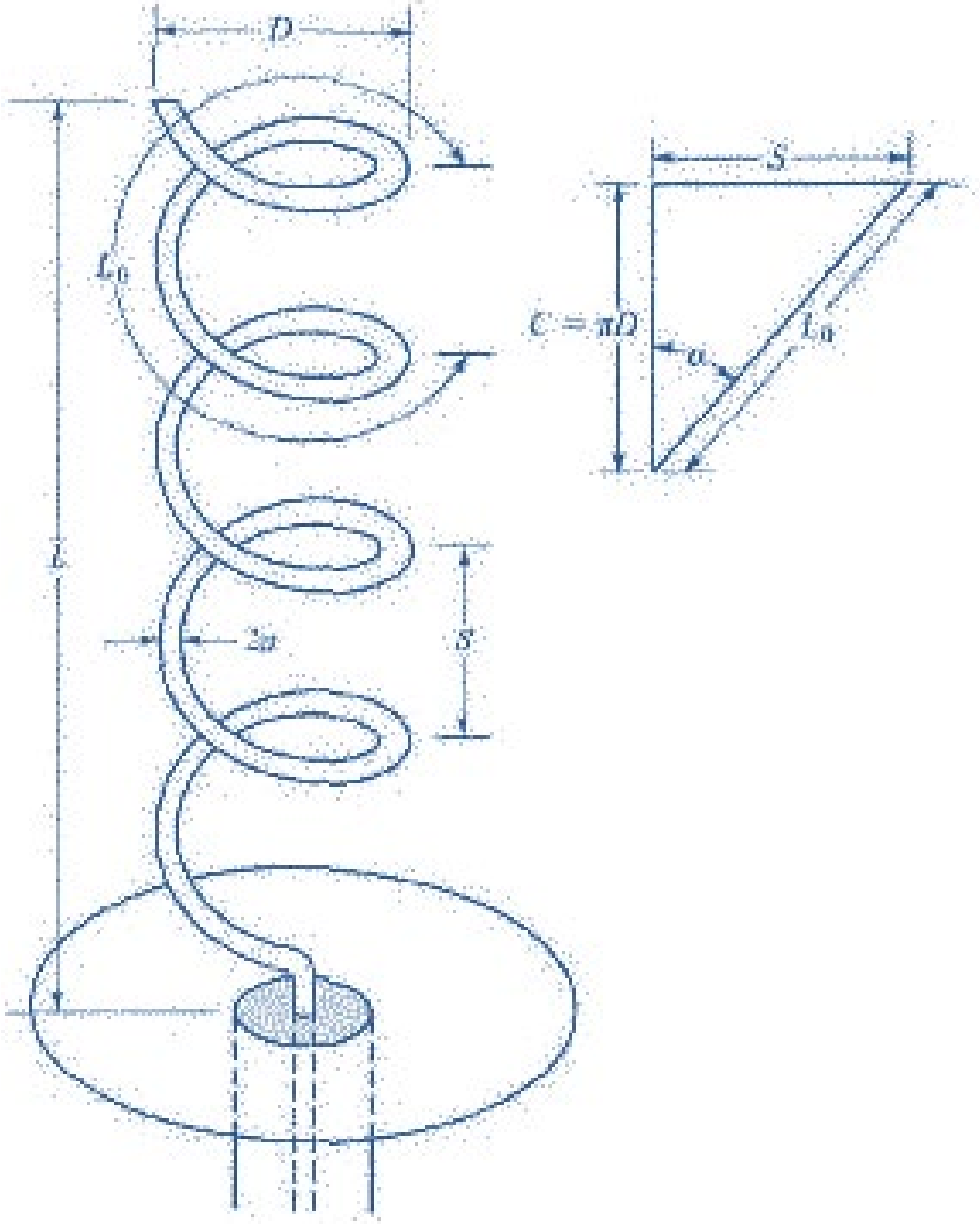
S - Vertical separation between turns for helical antenna.

α - pitch angle, which controls how far the helix antenna grows in the z-direction per turn, and is given by $\alpha = \tan^{-1}\frac{S}{C}$

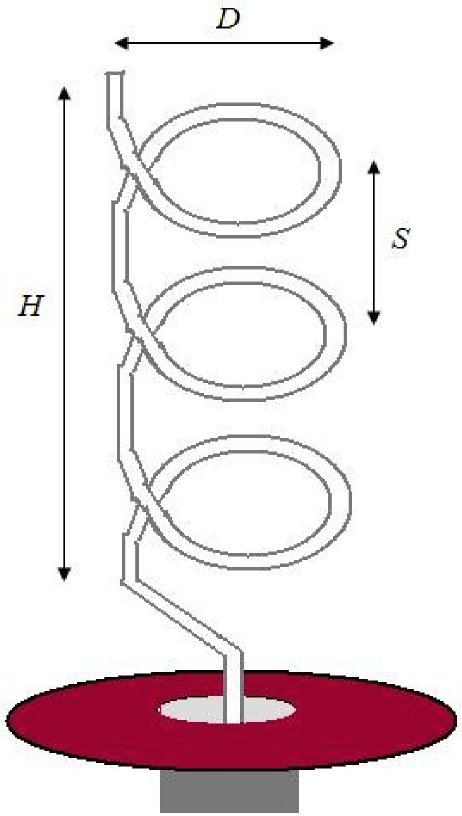
N - Number of turns on the helix antenna.

H - Total height of helix antenna, H=NS.

Broadband Antenna



Identify the left or right handed helical antenna



- This antenna is a left handed helix antenna, because if you curl your fingers on your left hand around the helix your thumb would point up (also, the waves emitted from this helix antenna are Left Hand Circularly Polarized).
- If the helix antenna was wound the other way, it would be a right handed helical antenna.

Modes of Operation

Normal (broadside)

Axial (end-fire) - Most practical modes: can achieve circular polarization over a wider bandwidth (usually 2:1), most efficient.

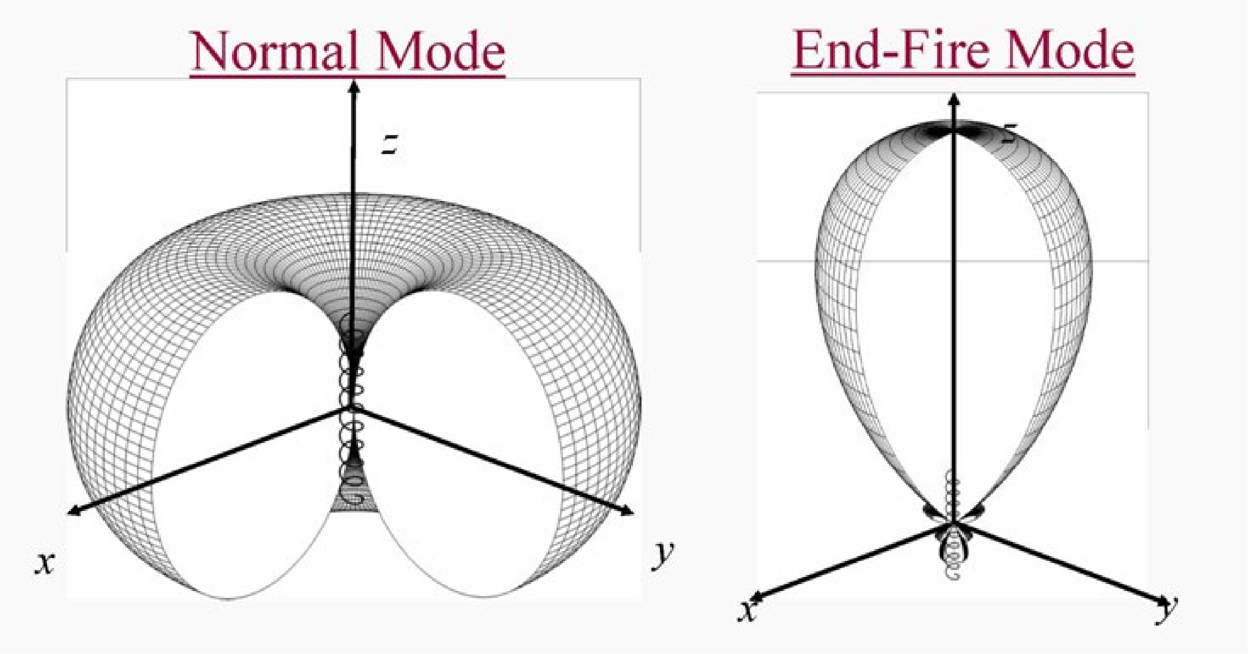


Figure 2: three dimensional normalized amplitude linear power patterns for normal and end fire modes helical design.

Helix and Its Equivalent

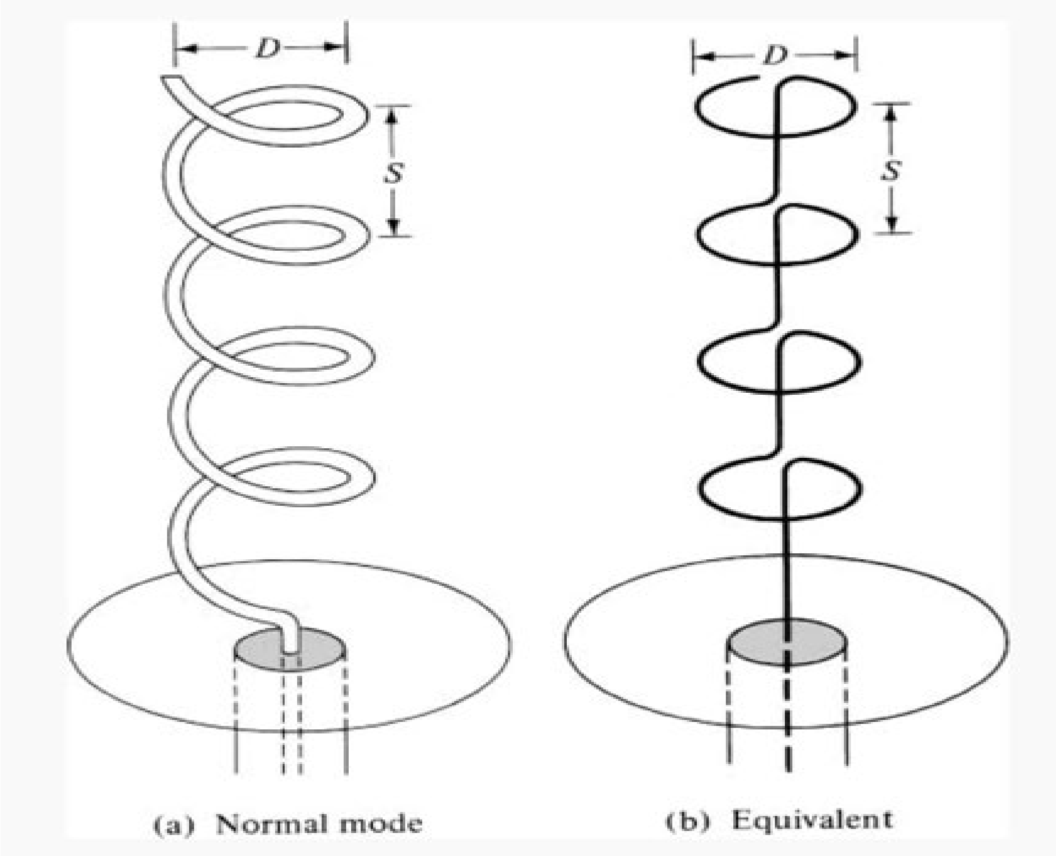
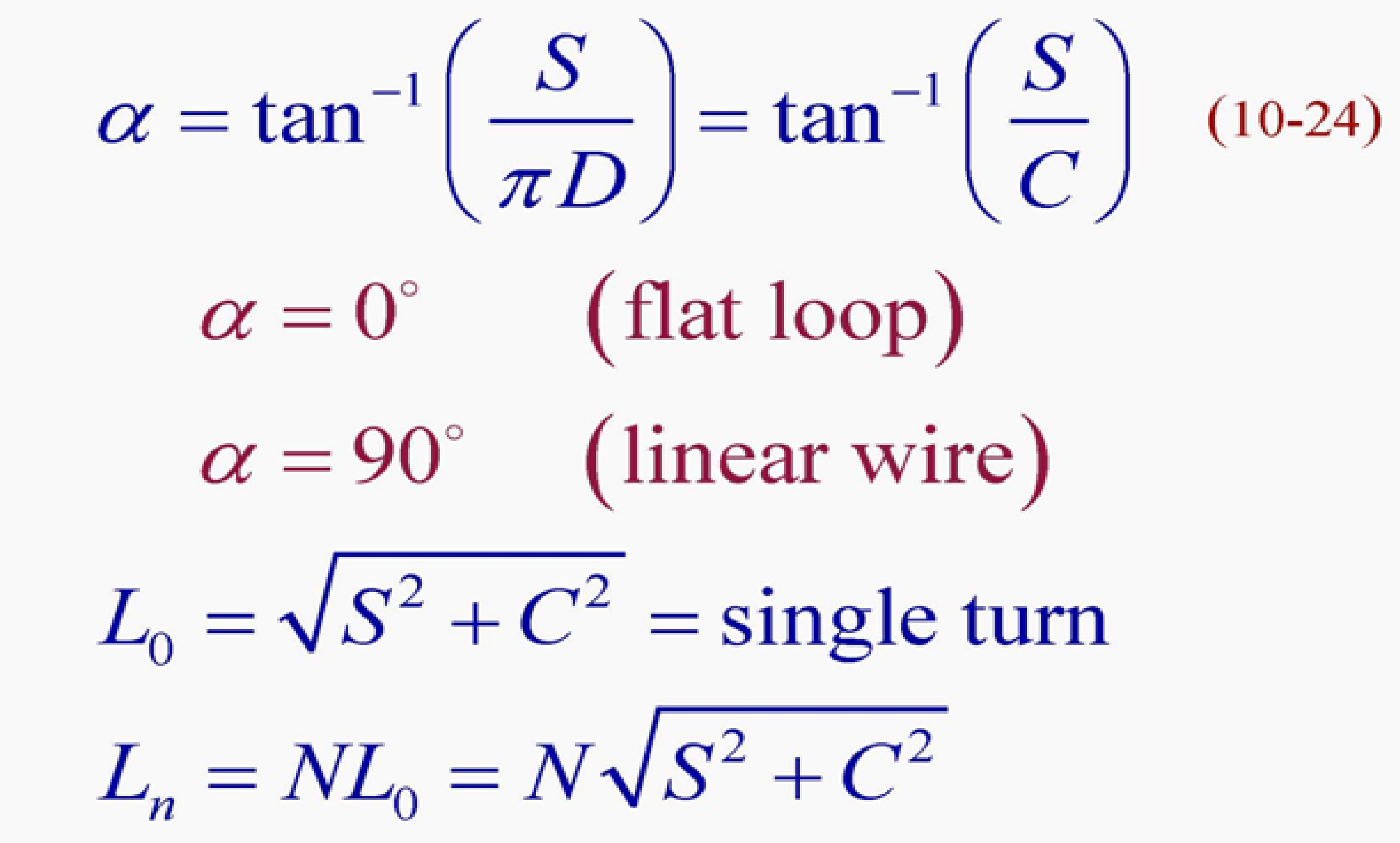


Figure 3: normal (broadside) mode for helical antenna and its equivalent.

Math of Helical Antenna



$$\alpha = \tan^{-1}\left(\frac{S}{\pi D}\right) = \tan^{-1}\left(\frac{S}{C}\right) \qquad (10\text{-}24)$$

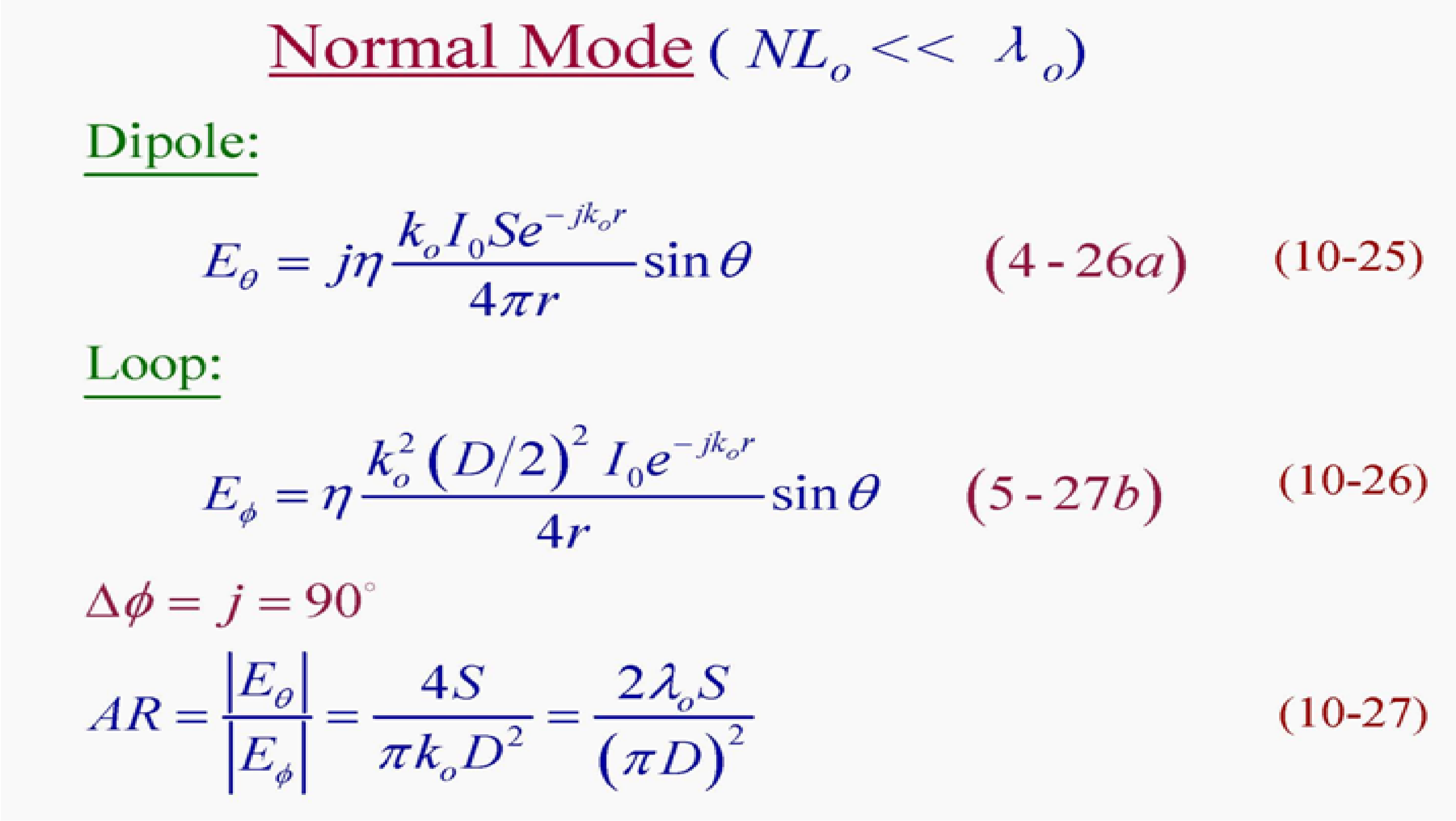
$$\alpha = 0^\circ \qquad (\text{flat loop})$$

$$\alpha = 90^\circ \qquad (\text{linear wire})$$

$$L_0 = \sqrt{S^2 + C^2} = \text{single turn}$$

$$L_n = NL_0 = N\sqrt{S^2 + C^2}$$

Normal Mode



Normal Mode ($NL_o << \lambda_o$)

Dipole:

$$E_\theta = j\eta \frac{k_o I_0 S e^{-jk_o r}}{4\pi r}\sin\theta \qquad (4-26a) \qquad (10\text{-}25)$$

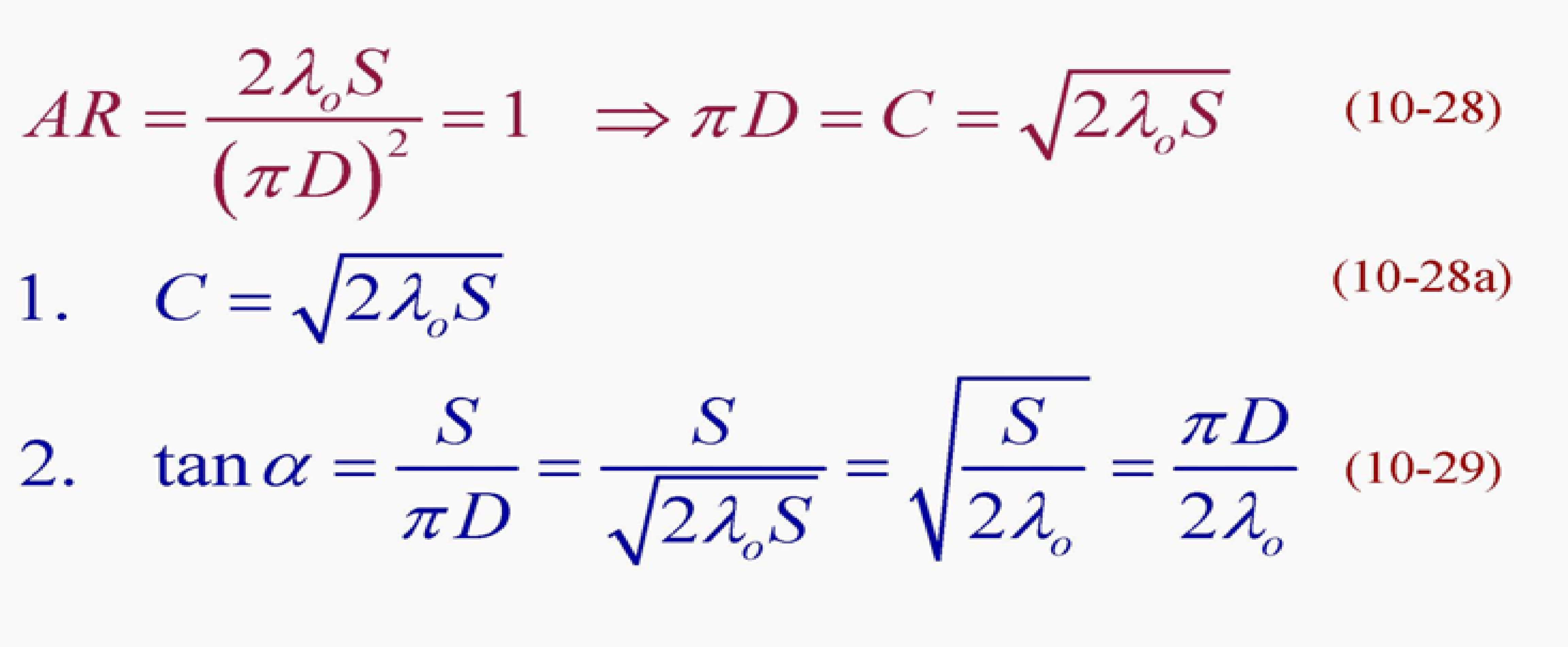
Loop:

$$E_\phi = \eta \frac{k_o^2 (D/2)^2 I_0 e^{-jk_o r}}{4r}\sin\theta \qquad (5-27b) \qquad (10\text{-}26)$$

$\Delta\phi = j = 90^\circ$

$$AR = \frac{|E_\theta|}{|E_\phi|} = \frac{4S}{\pi k_o D^2} = \frac{2\lambda_o S}{(\pi D)^2} \qquad (10\text{-}27)$$

Normal Mode

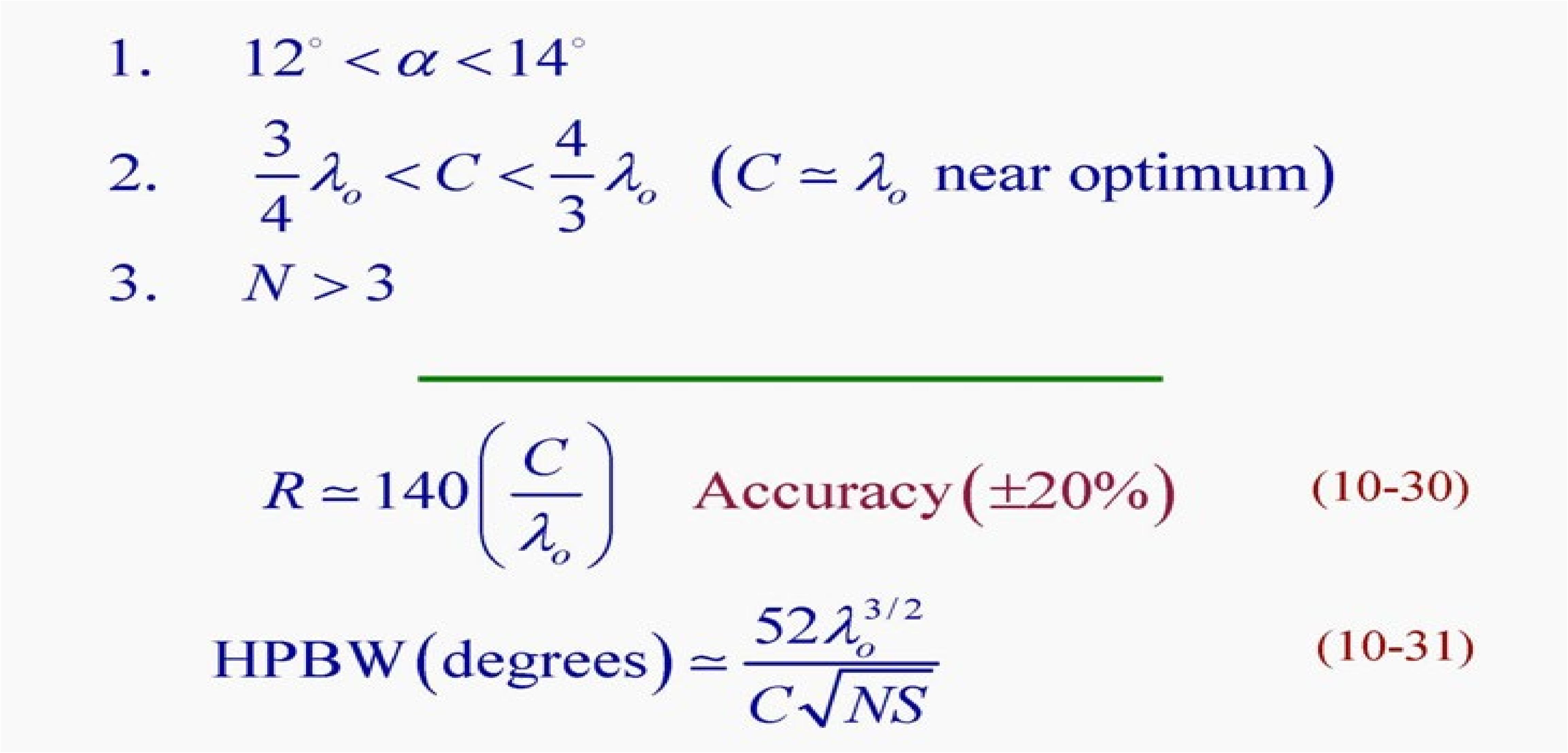


$$AR = \frac{2\lambda_o S}{(\pi D)^2} = 1 \quad \Rightarrow \pi D = C = \sqrt{2\lambda_o S} \qquad (10\text{-}28)$$

1. $$C = \sqrt{2\lambda_o S} \qquad (10\text{-}28a)$$

2. $$\tan\alpha = \frac{S}{\pi D} = \frac{S}{\sqrt{2\lambda_o S}} = \sqrt{\frac{S}{2\lambda_o}} = \frac{\pi D}{2\lambda_o} \qquad (10\text{-}29)$$

End –Fire @ Axial Mode



1. $12^\circ < \alpha < 14^\circ$
2. $\frac{3}{4}\lambda_o < C < \frac{4}{3}\lambda_o \quad (C \simeq \lambda_o \text{ near optimum})$
3. $N > 3$

$$R \simeq 140\left(\frac{C}{\lambda_o}\right) \quad \text{Accuracy}(\pm 20\%) \qquad (10\text{-}30)$$

$$\text{HPBW}(\text{degrees}) \simeq \frac{52\lambda_o^{3/2}}{C\sqrt{NS}} \qquad (10\text{-}31)$$

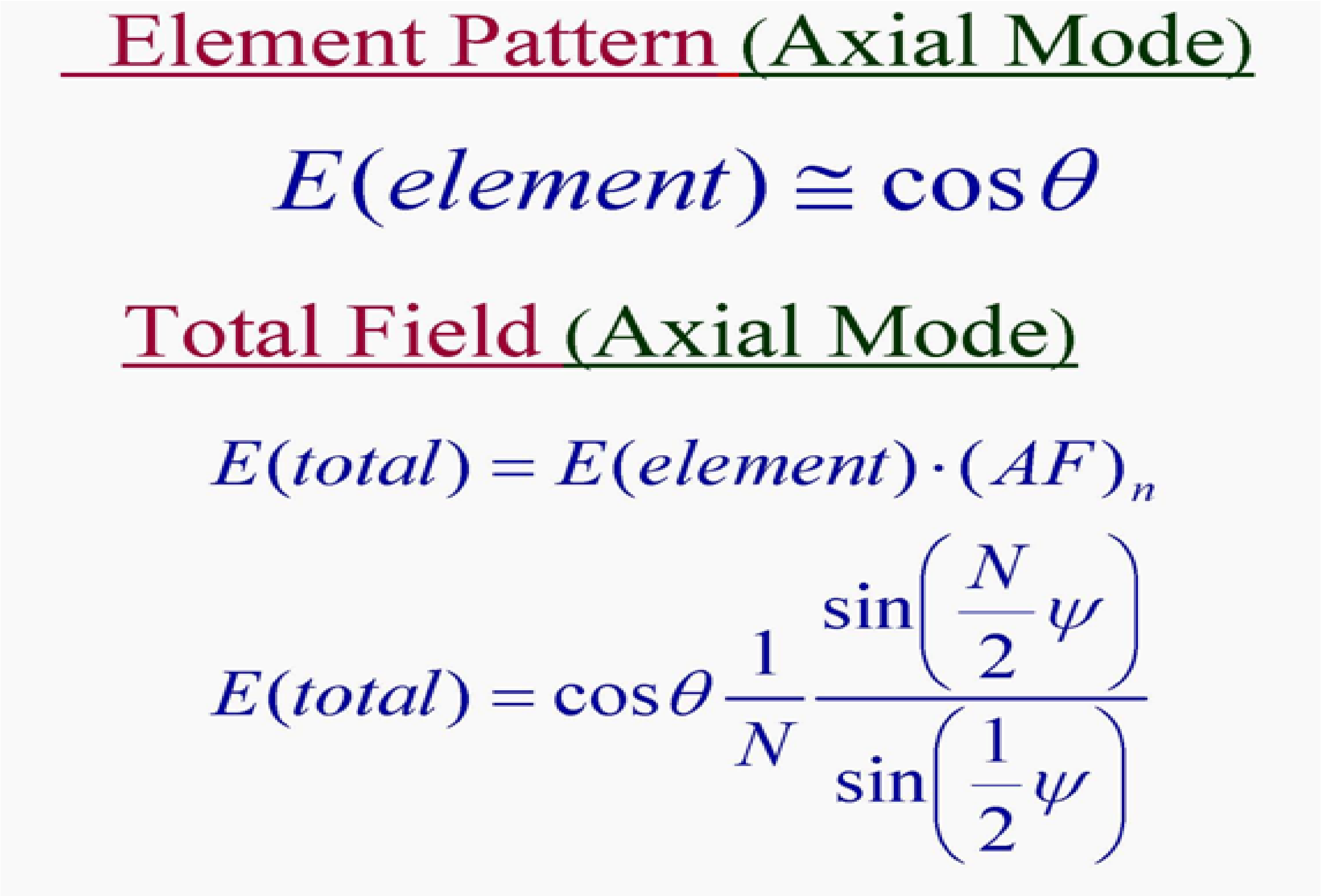
Broadband Antenna

$$FNBW\,(\text{degrees}) \simeq \frac{115\lambda_o^{3/2}}{C\sqrt{NS}} \qquad (10\text{-}32)$$

$$D_o\,(\text{dimensionless}) \simeq 15N\,\frac{C^2 S}{\lambda_o^3} \qquad (10\text{-}33)$$

$$AR = \frac{2N+1}{2N} \qquad (10\text{-}34)$$

Broadband Antenna



Element Pattern (Axial Mode)

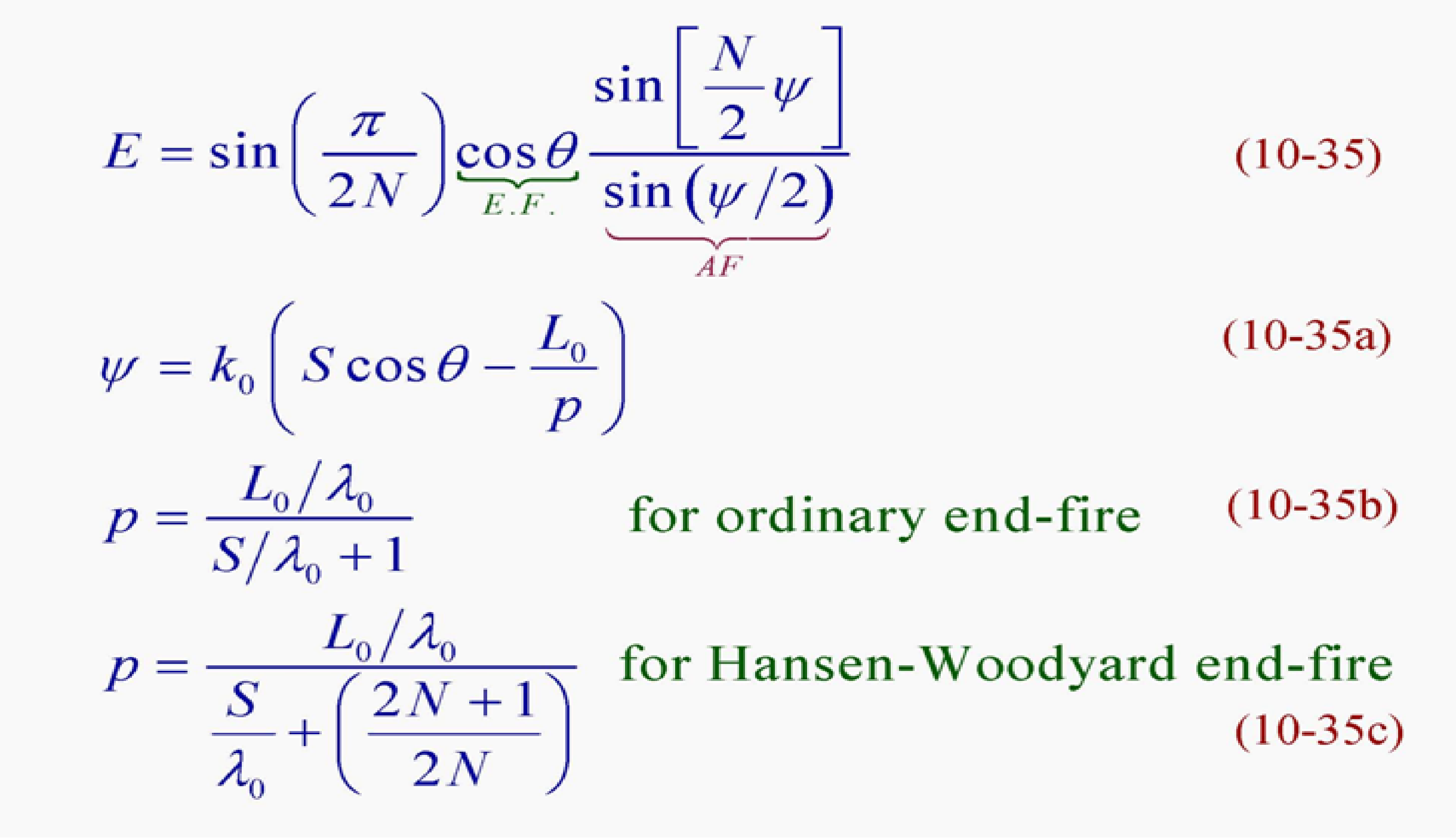
$$E(element) \simeq \cos\theta$$

Total Field (Axial Mode)

$$E(total) = E(element)\cdot(AF)_n$$

$$E(total) = \cos\theta\,\frac{1}{N}\,\frac{\sin\left(\frac{N}{2}\psi\right)}{\sin\left(\frac{1}{2}\psi\right)}$$

Normalized far-field pattern



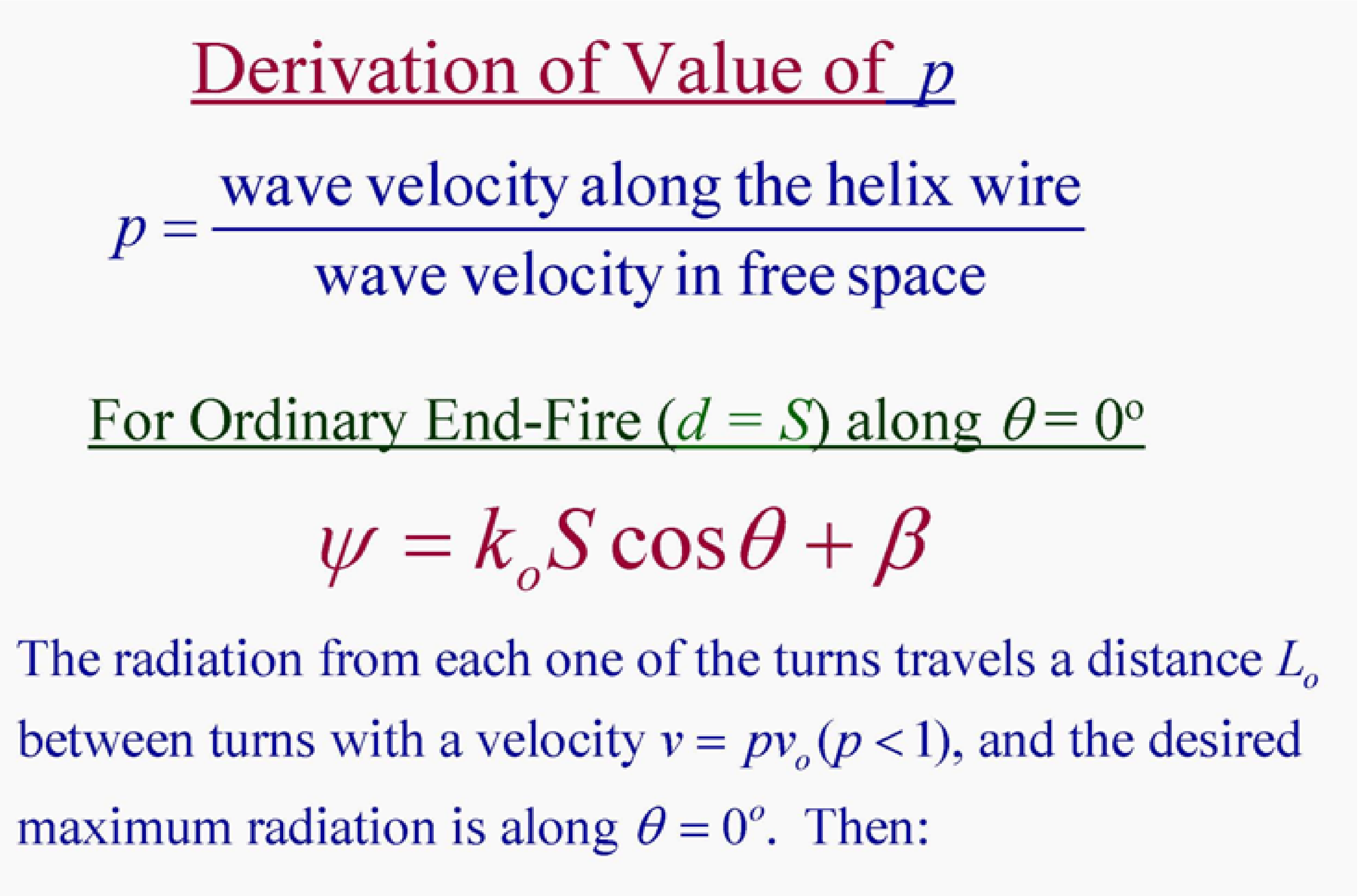
$$E = \sin\left(\frac{\pi}{2N}\right)\underbrace{\cos\theta}_{E.F.}\underbrace{\frac{\sin\left[\dfrac{N}{2}\psi\right]}{\sin(\psi/2)}}_{AF} \qquad (10\text{-}35)$$

$$\psi = k_0\left(S\cos\theta - \frac{L_0}{p}\right) \qquad (10\text{-}35a)$$

$$p = \frac{L_0/\lambda_0}{S/\lambda_0 + 1} \quad \text{for ordinary end-fire} \qquad (10\text{-}35b)$$

$$p = \frac{L_0/\lambda_0}{\dfrac{S}{\lambda_0} + \left(\dfrac{2N+1}{2N}\right)} \quad \text{for Hansen-Woodyard end-fire} \qquad (10\text{-}35c)$$

HELICAL ANTENNA [HELIX]



Derivation of Value of p

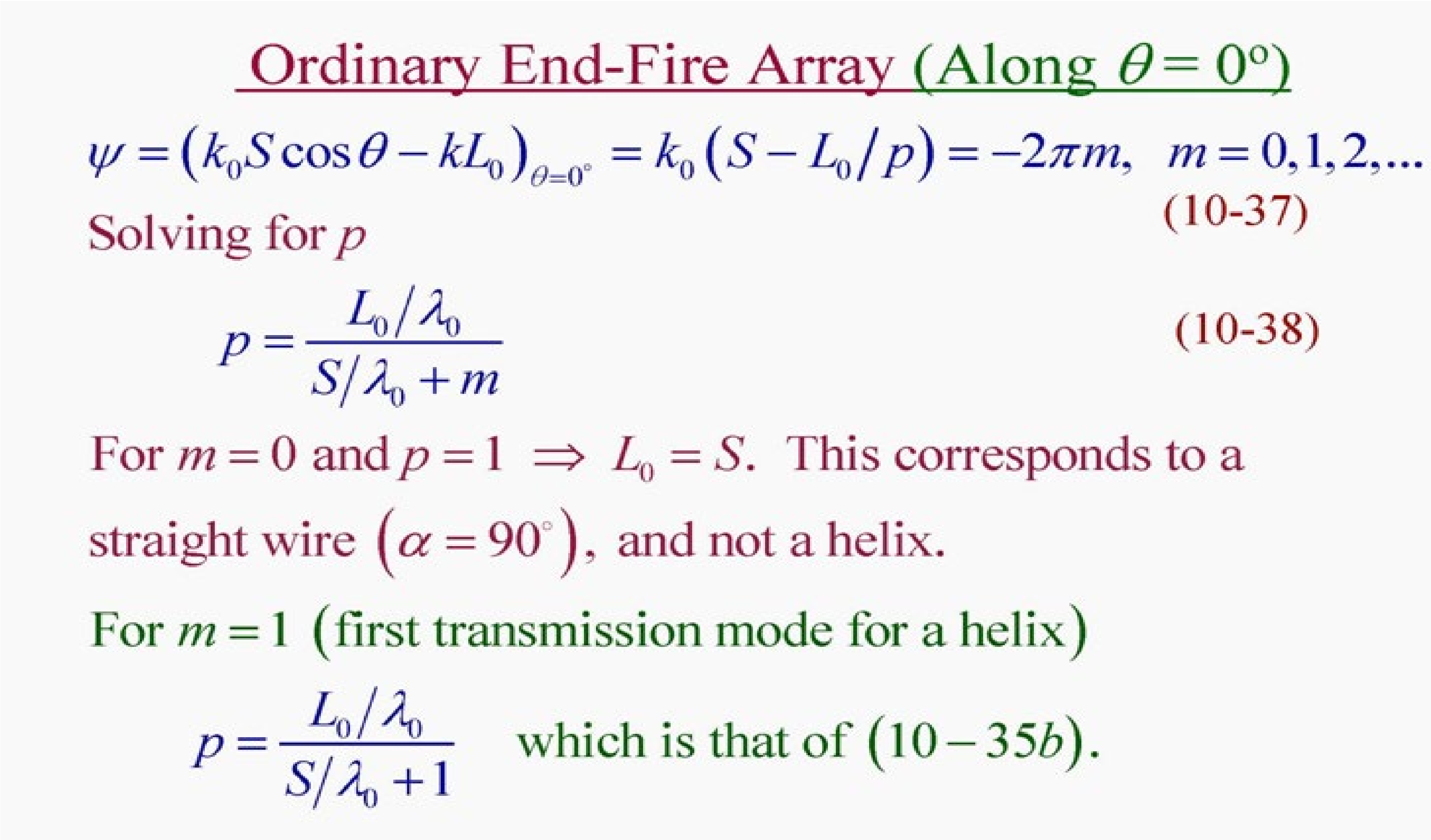
$$p = \frac{\text{wave velocity along the helix wire}}{\text{wave velocity in free space}}$$

For Ordinary End-Fire ($d = S$) along $\theta = 0^{o}$

$$\psi = k_{o} S \cos\theta + \beta$$

The radiation from each one of the turns travels a distance L_o between turns with a velocity $v = pv_o (p < 1)$, and the desired maximum radiation is along $\theta = 0^{o}$. Then:

HELICAL ANTENNA [HELIX]



Ordinary End-Fire Array (Along $\theta = 0^o$)

$$\psi = \left(k_0 S\cos\theta - kL_0\right)_{\theta=0^\circ} = k_0\left(S - L_0/p\right) = -2\pi m, \quad m = 0,1,2,\ldots \tag{10-37}$$

Solving for p

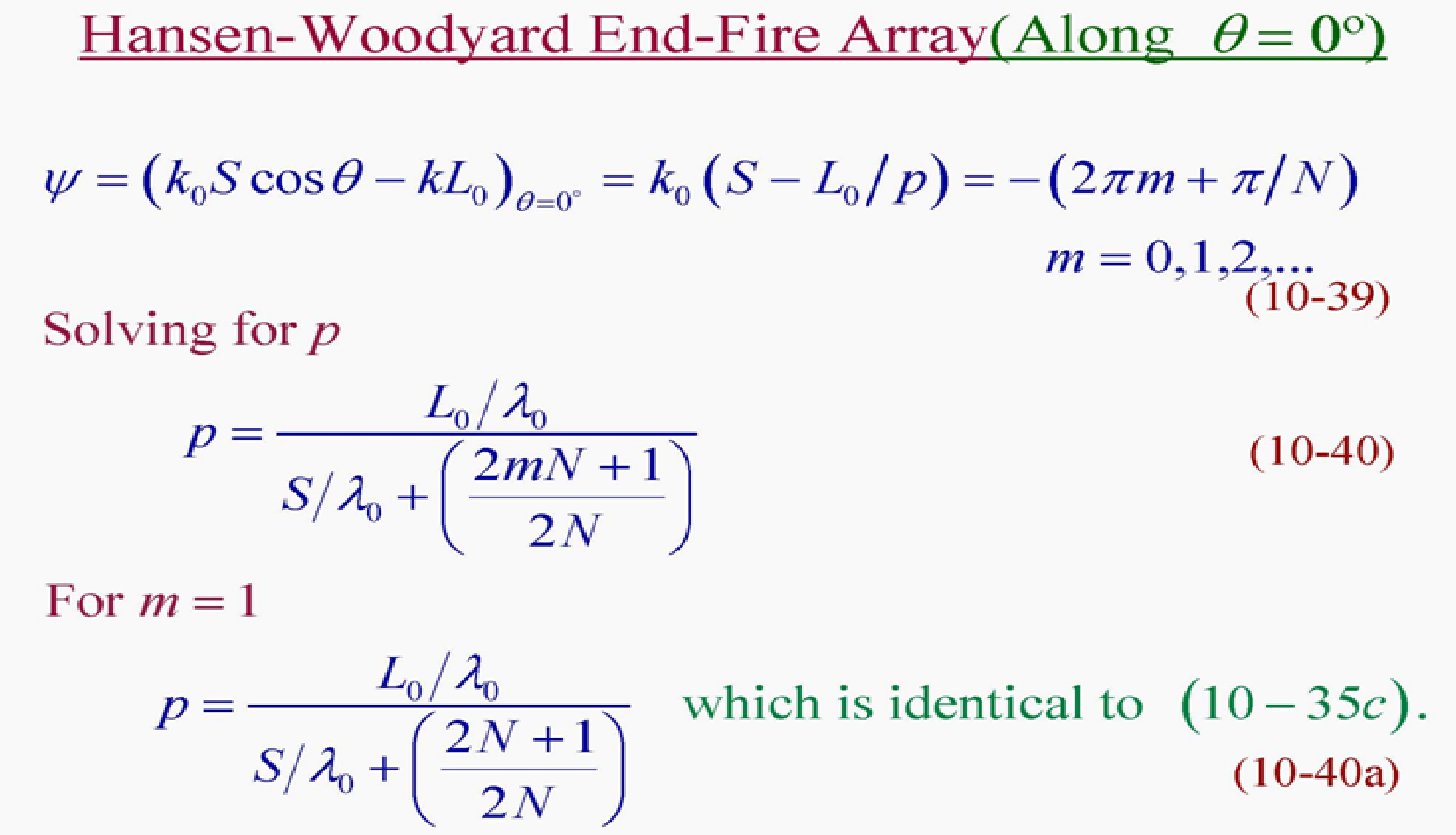
$$p = \frac{L_0/\lambda_0}{S/\lambda_0 + m} \tag{10-38}$$

For $m = 0$ and $p = 1 \;\Rightarrow\; L_0 = S$. This corresponds to a straight wire $\left(\alpha = 90^\circ\right)$, and not a helix.

For $m = 1$ (first transmission mode for a helix)

$$p = \frac{L_0/\lambda_0}{S/\lambda_0 + 1} \quad \text{which is that of } (10-35b).$$

HELICAL ANTENNA [HELIX]



Hansen-Woodyard End-Fire Array(Along $\theta = 0^\circ$)

$$\psi = \left(k_0 S \cos\theta - kL_0\right)_{\theta=0^\circ} = k_0\left(S - L_0/p\right) = -\left(2\pi m + \pi/N\right)$$

$$m = 0,1,2,\ldots \qquad \text{(10-39)}$$

Solving for p

$$p = \frac{L_0/\lambda_0}{S/\lambda_0 + \left(\dfrac{2mN+1}{2N}\right)} \qquad \text{(10-40)}$$

For $m = 1$

$$p = \frac{L_0/\lambda_0}{S/\lambda_0 + \left(\dfrac{2N+1}{2N}\right)}$$

which is identical to $(10-35c)$.

(10-40a)

HELICAL ANTENNA [HELIX]

Helical Designs

Ordinary End-Fire

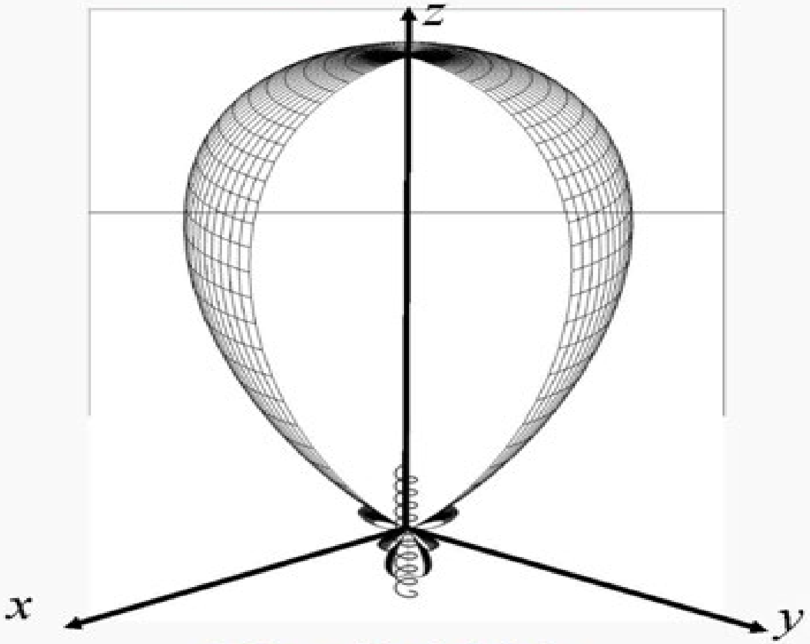


Fig. 10.16(a)

H-W End-Fire

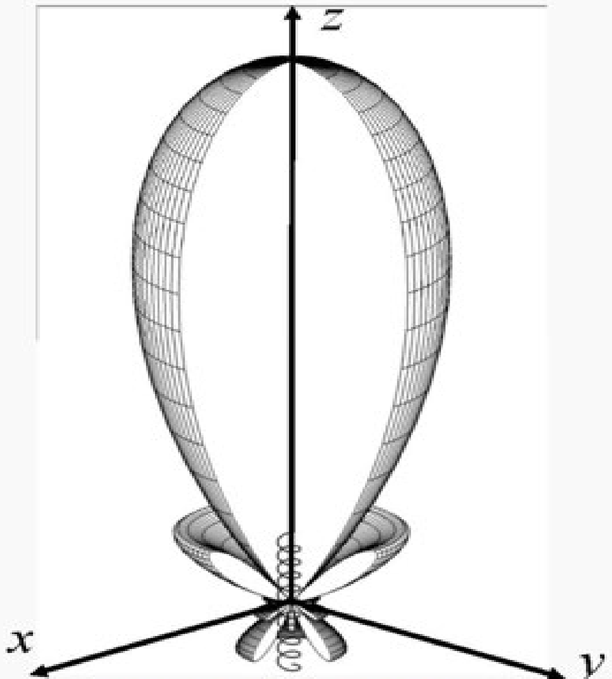
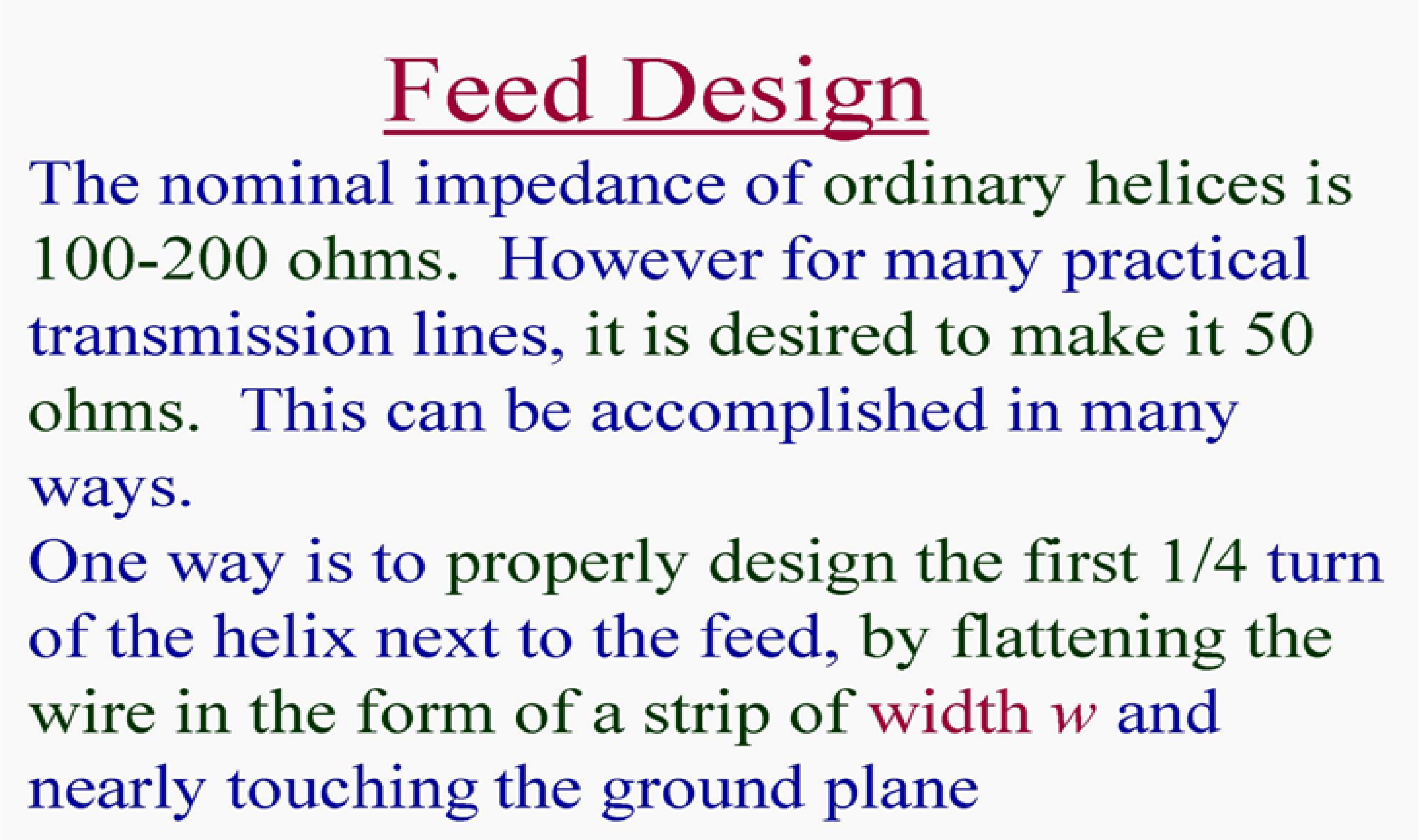


Fig. 10.16(b)

HELICAL ANTENNA [HELIX]

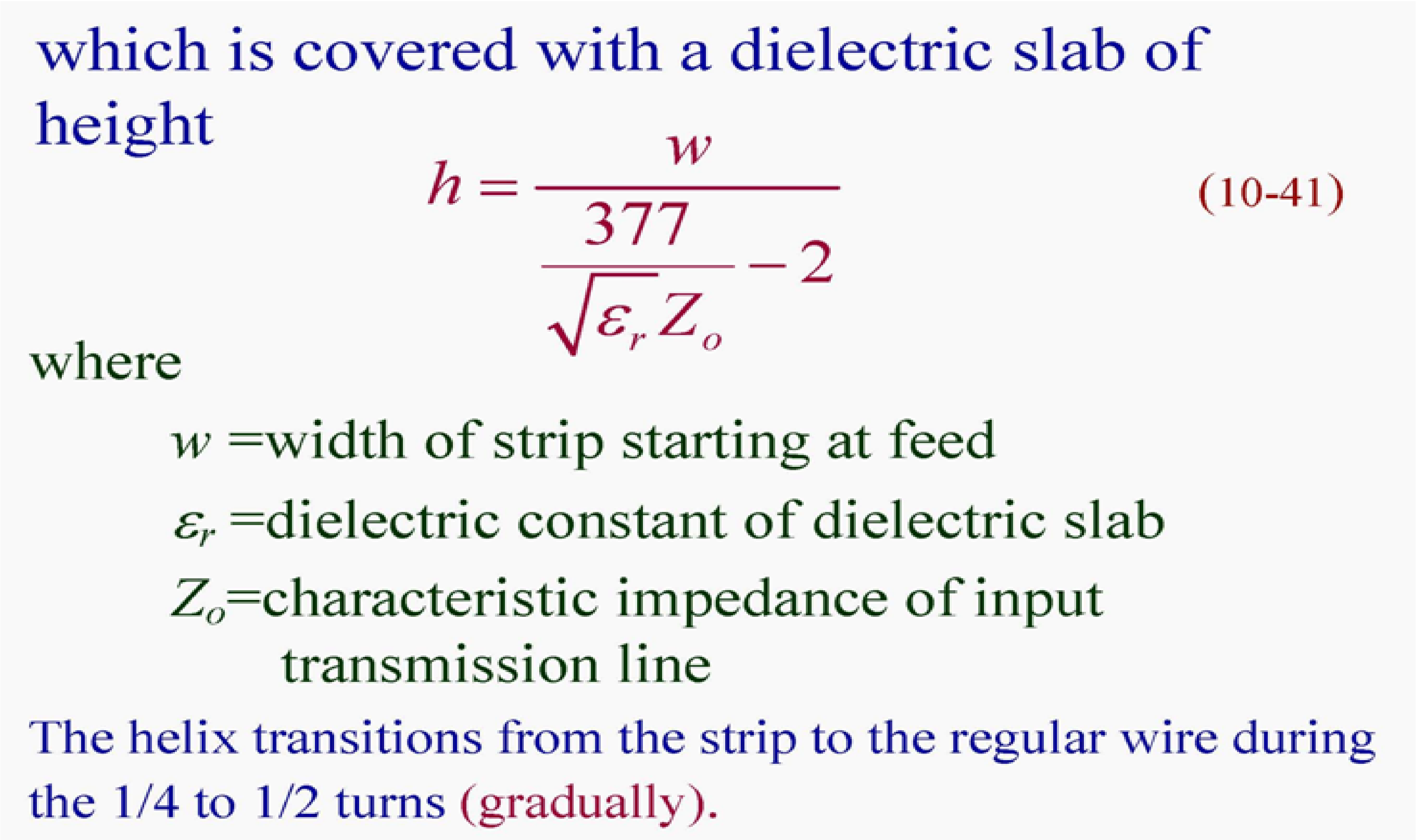


Feed Design

The nominal impedance of ordinary helices is 100-200 ohms. However for many practical transmission lines, it is desired to make it 50 ohms. This can be accomplished in many ways.

One way is to properly design the first 1/4 turn of the helix next to the feed, by flattening the wire in the form of a strip of width *w* and nearly touching the ground plane

HELICAL ANTENNA



which is covered with a dielectric slab of height

$$h = \frac{w}{\frac{377}{\sqrt{\varepsilon_r} Z_o} - 2} \qquad (10\text{-}41)$$

where

w =width of strip starting at feed

ε_r =dielectric constant of dielectric slab

Z_o=characteristic impedance of input transmission line

The helix transitions from the strip to the regular wire during the 1/4 to 1/2 turns (gradually).

HELICAL ANTENNA [HELIX]

Commercial RH Helical Antenna (100-160 MHz)

(Courtesy: Seavey Engineering Associates)

Fig. 10.17

Tutorial Helix Antenna (1)

Design a five turn helical antenna which at 300 MHz operates in the axial mode an possesses circular polarization in the major lobe. Determine,

a) Near optimum circumference (in λ and meter).
b) Spacing (in λand meter) for near optimum pitch angle design.
c) Input impedance.
d) Half power beamwidth and first null beamwidth.
e) Directivity (dimensionless and in dB).
f) Axial ratio.

Tutorial Helix Antenna (2)

Design an end fire polarized helix antenna having a half-power beamwidth (HPBW) of 45°, pitch angle is 13°, circumference of the helix is 60 cm at a frequency operation of 500 MHz. Determine,

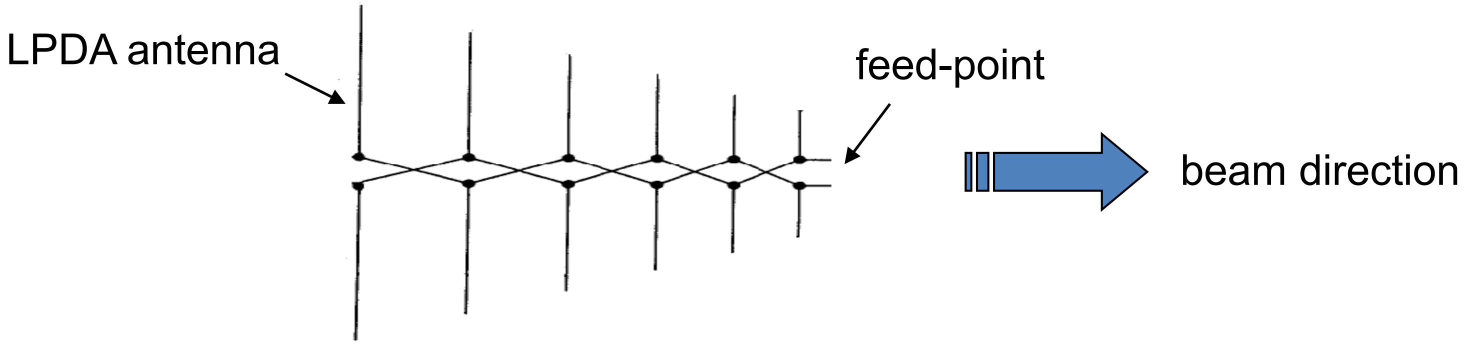
a) Number of turns needed.
b) Diameter of a turn on the helix antenna.
c) Total height of helix antenna.
d) Directivity in decibel.
e) Axial ratio.

LOG-PERIODIC ANTENNAS

LPDA: Application Examples

- VHF and UHF TV reception
- MATV (master-antenna-TV) and CATV (community-antenna-TV)
- HF long-distance radio communications
- EMC radiated emission measurement
- EMC radiated RF immunity measurement

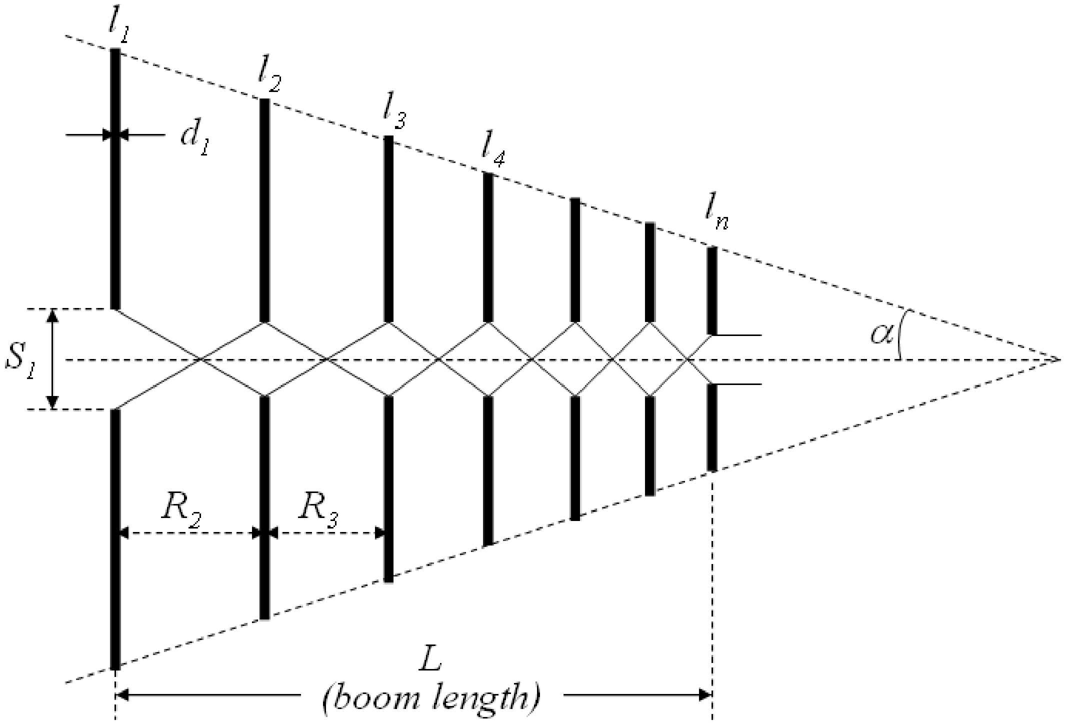
LPDA: Features



- LPDA is the most common log-periodic antenna structure
- Basic structure is an array of dipoles with criss-cross connection at feed-points (to produce a beam towards the shorter elements)
- When plotted against log(frequency), its input impedance is periodic (i.e., repeats itself at regular frequency intervals) → wideband
- Bandwidth (constant gain and input impedance) of up to 30:1
- End-fire radiation pattern
- Typical gain between 6 to 12 dB
- Compared with a Yagi antenna, a LPDA has larger bandwidth but smaller gain

LPDA: Structure

- Physical dimensions are:
  l_n = length of n^{th} element
  d_n = diameter of n^{th} element
  R_n = position of n^{th} element
  (relative to *(n-1)*th element)
  s_n = gap spacing at feed-point
  of n^{th} element
- Derived parameters:
  α = half apex angle
  L = boom length of LPDA
- In practice, d and s can be kept constant without significantly degrading the overall performance
- Construction accuracy is not critical as it is wideband



LPDA: Structure (2)

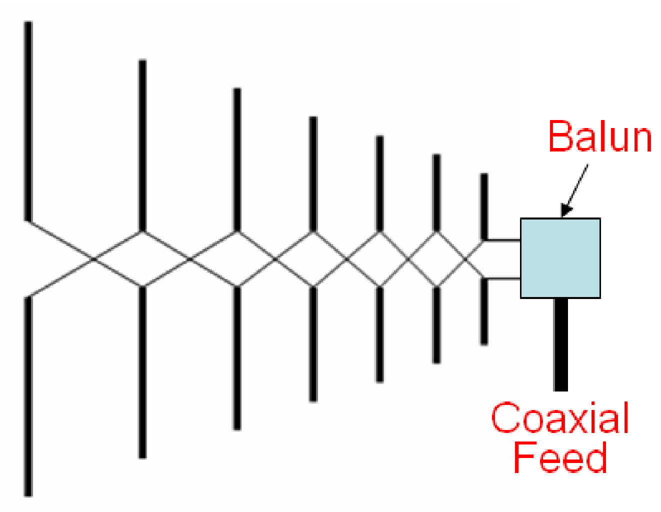
- The physical dimensions l_n, d_n, R_n, and s_n are related to the geometric ratio τ and spacing factor σ:

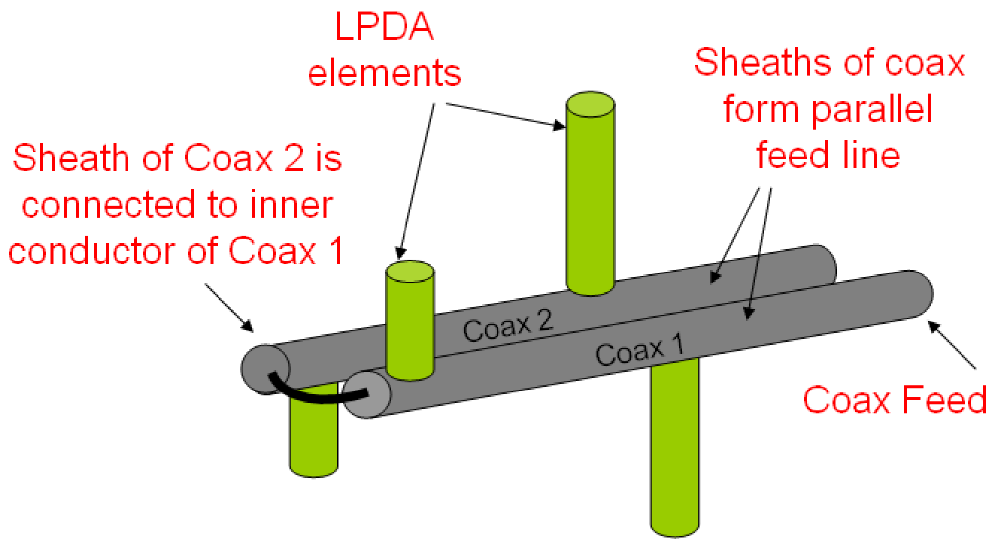
$$\boxed{\tau = \frac{l_{n+1}}{l_n} = \frac{d_{n+1}}{d_n} = \frac{R_{n+1}}{R_n} = \frac{s_{n+1}}{s_n} < 1} \qquad \boxed{\sigma = \frac{R_n - R_{n+1}}{2l_n}}$$

- Due to criss-cross connection, adjacent elements are fed 180^o out-of-phase by transposing the feed line.
- Radiation occurs at elements ~ $\lambda/2$ (Active Region).

LPDA: Balun/Coaxial Feed

- LPDA is a balanced structure.
- Balun is required for connection to a coax cable.
- Another practical arrangement using a coax-sheath parallel feed line provides a built-in broadband balun.



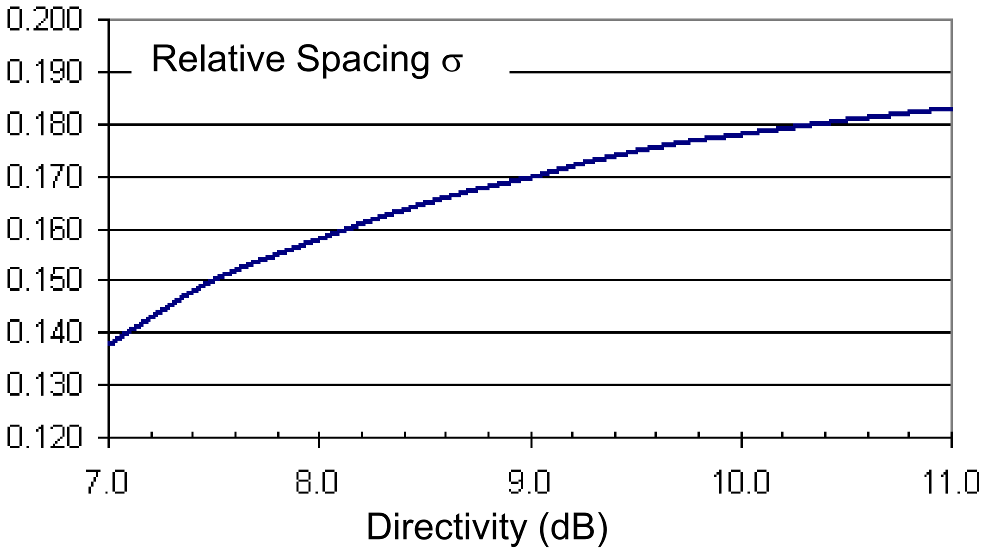


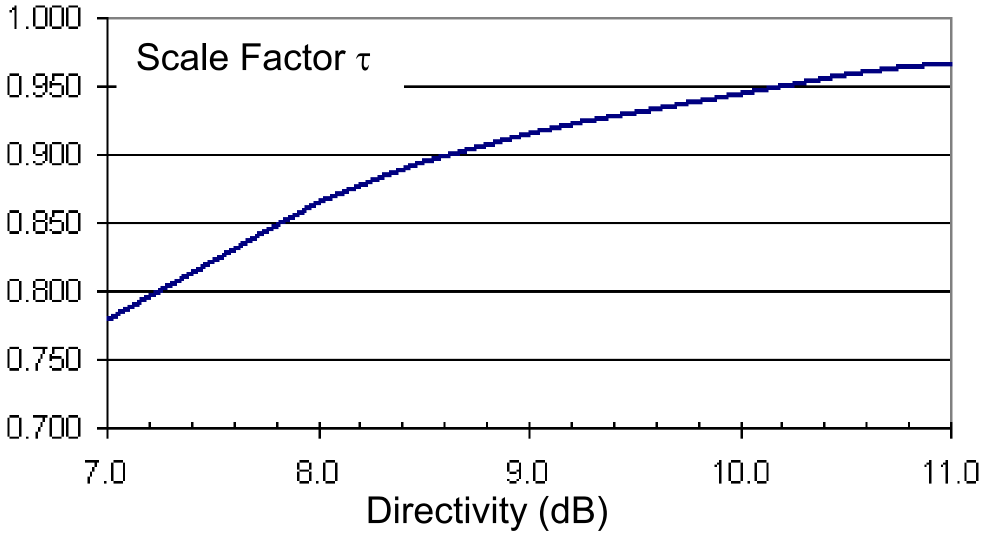
Design Procedure: Specifications

- Specifications:
  - Specify lowest operating frequency f_{min}
  - Specify highest operating frequency f_{max}
  - Specify desired directivity D
  - Specify input impedance R_{in}
  - Specify diameter of 1st element d_1
  - Specify diameter of parallel feed line d'
  - Decide *constant* or *variable* diameter for antenna elements

Design Procedure: Calculation (1)

- For an “optimum σ” design, determine σ (relative spacing) and τ (scale factor) from graphs for a given Directivity between 7 and 11 dB.
- For a non-optimum σ design, refer to published graphs [e.g., Figure 11.13 in CA Balanis, “Antenna Theory”, 3rd Ed.,Wiley 2005.]





Design Procedure: Calculation (2)

- Cal half apex angle α : $\alpha = tan^{-1}\left[\frac{1-\tau}{4\sigma}\right]$
- Cal bandwidth of operation: $B = f_{max} - f_{min}$
- Cal bandwidth of active region: $B_{ar} = 1.1 + 7.7(1-\tau)^2 \cot\alpha$
- Cal bandwidth of design: $B_s = B.B_{ar}$
- Estimate boom length: $L = \frac{\lambda_{max}}{4}(1 - \frac{1}{B_s})\cot\alpha$ where $\lambda_{max} = \frac{3x10^8}{f_{min}}$
- Number of elements: $N = 1 + \frac{ln(B_s)}{ln(1/\tau)}$

Design Procedure: Calculation (3)

- Cal average Z_a of elements: $\boxed{Z_a = 120\left[ln\left(\frac{l_n}{d_n}\right) - 2.25\right]}$
- Cal relative mean spacing: $\boxed{\sigma' = \sigma / \sqrt{\tau}}$
- With Z_a / R_{in}, find Z_o / R_{in} from published graph [eg, Figure 11.14 in CA Balanis, “Antenna Theory”, 3rd Ed.,Wiley 2005.]

  (Z_o = characteristic impedance of parallel feed line)
- Alternately, *Zo* can be calculated from: $Z_o = R_{in}(x + \sqrt{x^2 + 1})$

where $x = \dfrac{R_{in}}{8\sigma' Z_a}$

Design Procedure: Calculation (4)

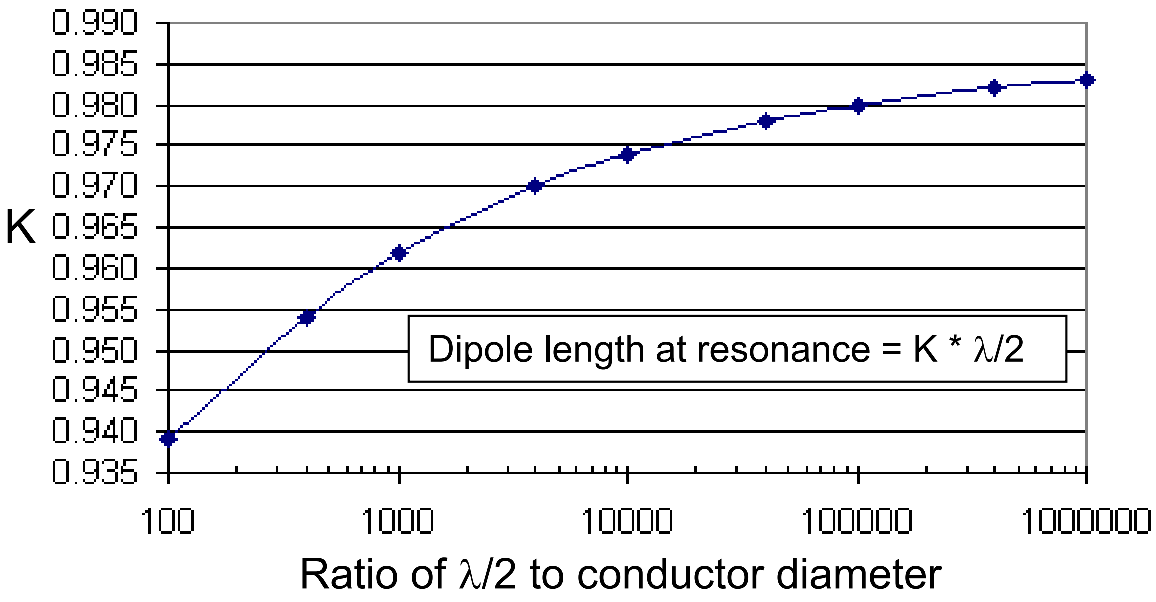
- Calculate centre-to-centre spacing s of feed line:
- Calulate all element lengths, diameters, and spacings;
- Apply K-factor correction to element lengths.

$$s = d'.\cosh\left(\frac{Z_o}{120}\right)$$

$$l_1 = \frac{\lambda_{max}}{2} \qquad l_{n+1} = \tau.l_n$$

$$d_1 = given \qquad d_{n+1} = \tau.d_n$$

$$R_2 = \frac{1}{2}(l_1 - l_2)\cot\alpha \qquad R_{n+1} = \tau.R_n$$



Dipole length at resonance = K * λ/2

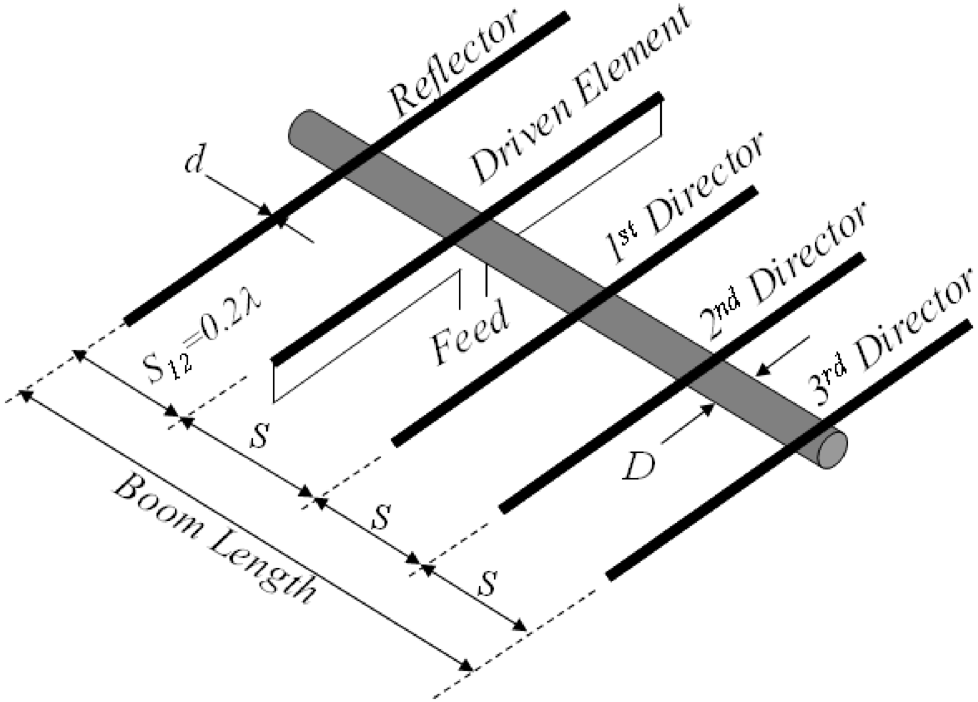
YAGI-UDA ANTENNA DESIGN

Yagi-Uda: Application Examples

- Often referred to as "Yagi" antennas
- VHF and UHF TV & FM radio reception
- HF-VHF-UHF (30 MHz – 3 GHz) point-to-point wireless communications
  - long-range wireless communications
  - base-station for two-way voice and/or data communications
  - telemetry of sensor data

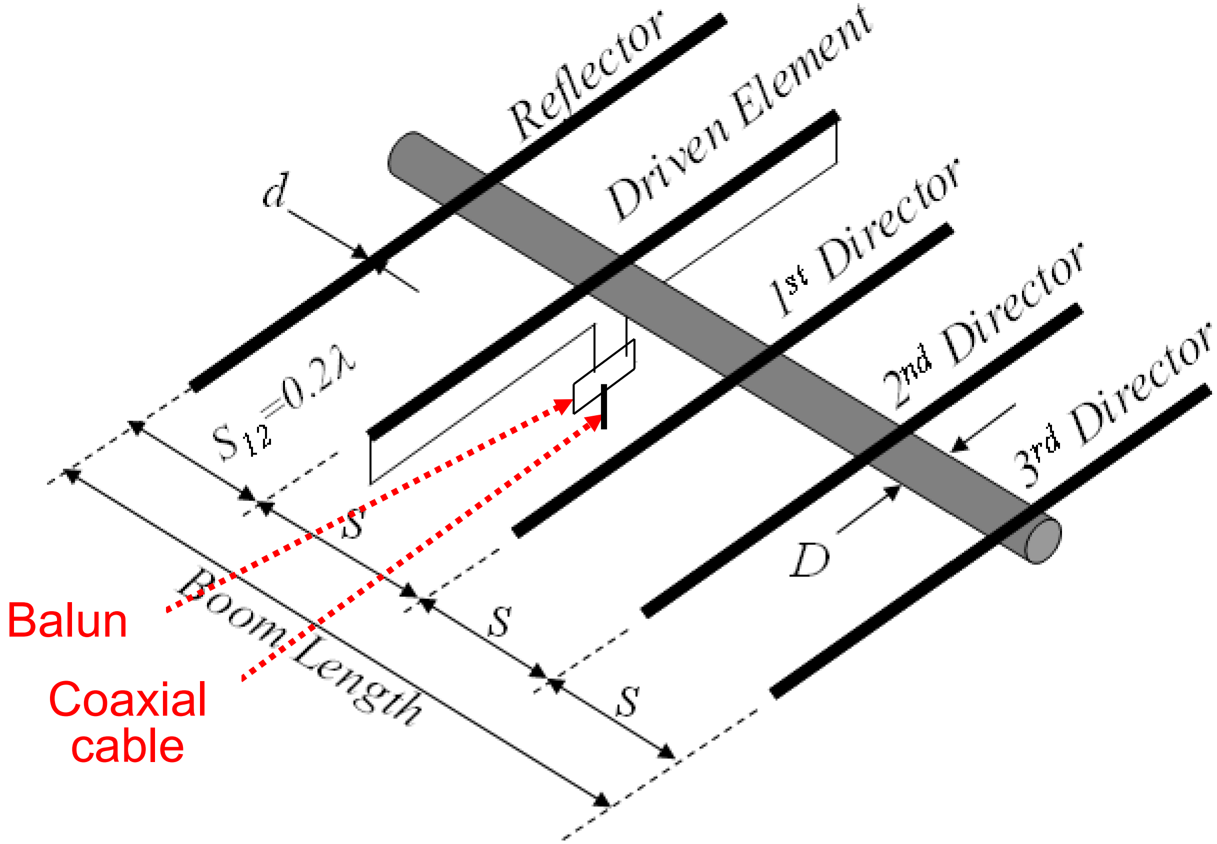
Yagi-Uda: Structure

- Basic structure is an array of dipoles made up of:
  - usually one reflector element (parasitic)
  - a driven element
  - one or more director elements (parasitic)



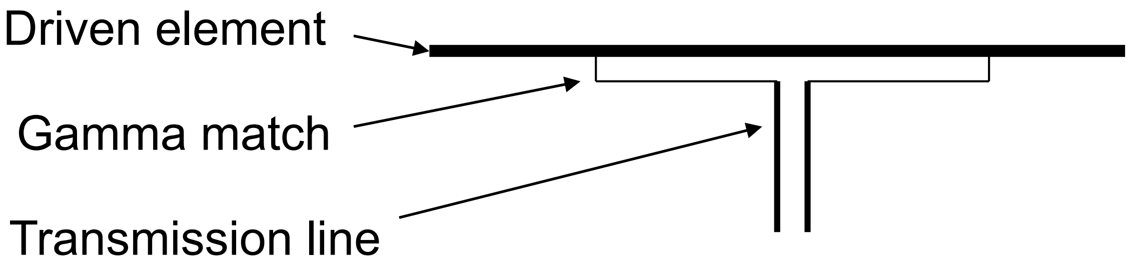
Yagi-Uda: Balun/Coaxial Feed

- The Yagi antenna is a balanced structure, similar to LPDA.
- A "balun" is required for connection to a coax cable.



Yagi Antenna Impedance Matching

- Feed-point impedance of Yagi can be estimated using computer simulation software packages
- Alternatively it can be measured (usually with the balun in place)
- If the feed-impedance is unacceptable, a gamma match is commonly used to improve the impedance matching



Yagi-Uda: Features

- High-gain (up to 17 dBi), low cost, low-wind resistance
- Typical gain vs number of elements:

No. of Elements	Typical Gain (dBi)
3	7
4	9
6	10.5
8	12.5
12	14.5
15	15.5
18	16.5

Yagi-Uda: Features

- Unidirectional (end-fire) radiation pattern with moderately low side and rear lobes.
- Normally there is only one reflector which may be just a single parasitic dipole (slightly longer than $\lambda/2$), or several parasitic dipoles forming a reflecting screen.
- Front-to-back ratio (usually about 15 dB) can be improved by the addition of a reflector screen
- The number of directors can be increased to 20 or more. Each additional director will contribute to the gain, particularly the first few directors.
- Yagi antenna are usually narrowband.
- Broadband and multi-band Yagi antennas will have lower gain.

Design Procedure: Single-Frequency

- Specifications:
  - Specify operating frequency f
  - Specify desired directivity D
  - Specify input impedance R_{in}
  - Specify diameter of elements d

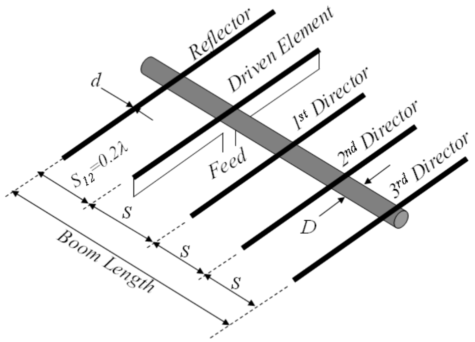
Design Procedure: Single-Frequency

- Design/Calculation:
  - For a given directivity D, determine the number of elements (N) required, usually by referring to published graphs or tables.
  - From published design examples (e.g. by the National Bureau of Standards NBS) determine the spacing between elements.
  - Determine the type of feed required – usually a folded dipole or a normal dipole.
  - Determine the type of balun to suit the transmission line impedance.

Reference Design

- P.P. Viezbicke, "Yagi Antenna Design", NBS Tech. Note 688, National Bureau of Standards, Washington, December 1968
- Assumptions:
  - Driven-element is a $\lambda/2$ folded dipole
  - All elements have diameter $d = 0.0085\lambda$
  - Spacing between reflector and driven element is 0.2λ
  - A metallic boom is used

Optimized Uncompensated Lengths (in λ) of Parasitic Elements for Six Yagi-Uda Antennas



Conditions:

(a) element diameter: $0.001\lambda \leq d \leq 0.04\lambda$ (e.g. $d = 0.0085\lambda$)

(b) reflector-driven element spacing, $s_{12} = 0.2\lambda$

(c) driven element is a $\lambda/2$ folded dipole

dBi = dB dipole + 2.15 dB

[Source: P.P Viezbicke, "Yagi Antenna Design", NBS Technical Note 688]

		Length of Yagi-Uda (λ)					
Element	**No.**	**0.4**	**0.8**	**1.2**	**2.2**	**3.2**	**4.2**
reflector	1	0.482	0.482	0.482	0.482	0.482	0.475
driven	2	0.500	0.500	0.500	0.500	0.500	0.500
director	3	0.442	0.428	0.428	0.432	0.428	0.424
director	4		0.424	0.420	0.415	0.420	0.424
director	5		0.428	0.420	0.407	0.407	0.420
director	6			0.428	0.398	0.398	0.407
director	7				0.390	0.394	0.403
director	8				0.390	0.390	0.398
director	9				0.390	0.386	0.394
director	10				0.390	0.386	0.390
director	11				0.398	0.386	0.390
director	12				0.407	0.386	0.390
director	13					0.386	0.390
director	14					0.386	0.390
director	15					0.386	0.390
director	16					0.386	
director	17					0.386	
spacing between directors (sik/λ)		0.20	0.20	0.25	0.20	0.20	0.308
Directivity (dBdipole)		7.1	9.2	10.2	12.25	13.4	14.2
Design curve (see Figure 10.27)		(A)	(B)	(B)	(C)	(B)	(D)

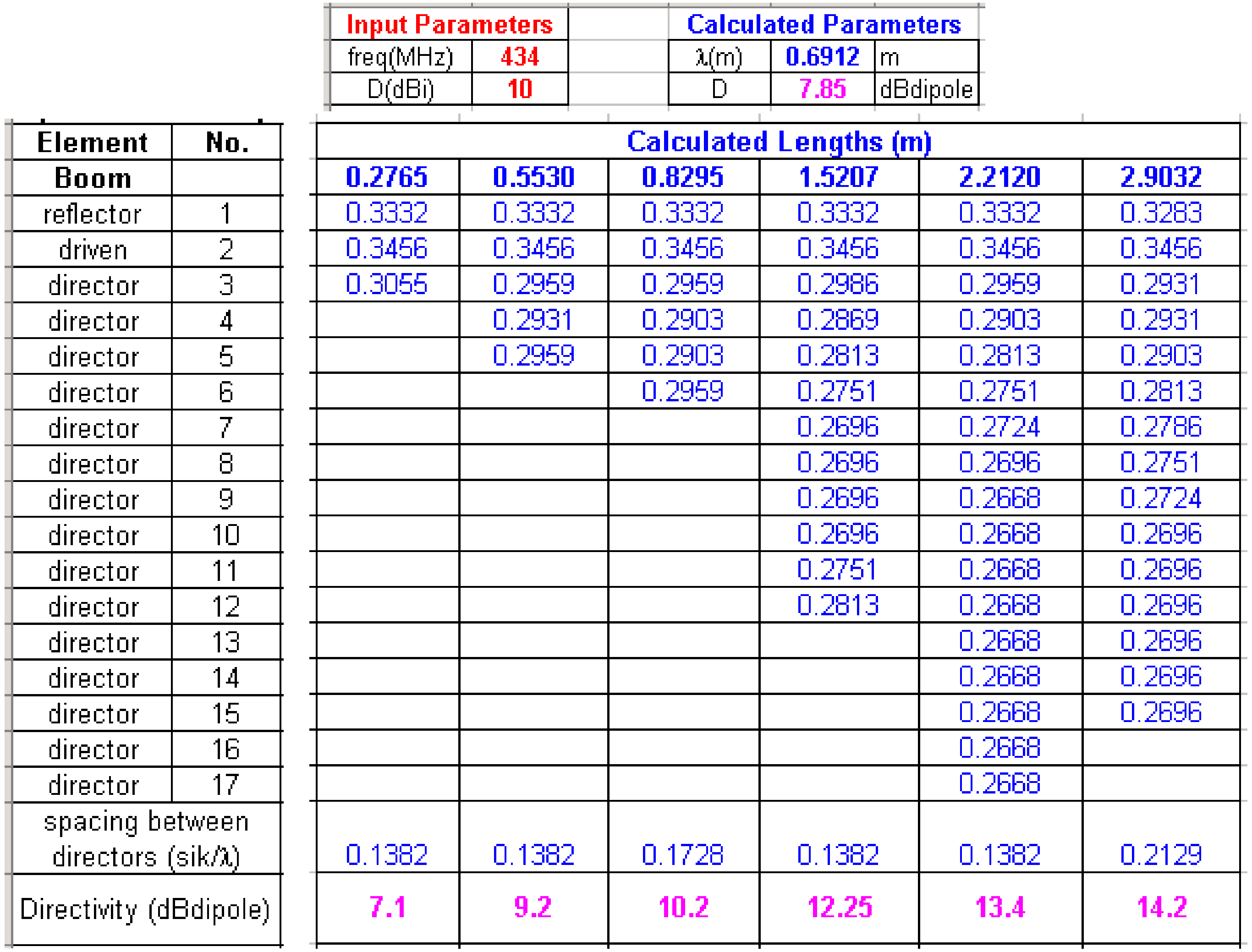
Element Length Adjustments

- For element diameter not equal to 0.0085λ, the lengths of the reflector and directors should be adjusted according to the design curves published in [PP Viezbicke, “Yagi Antenna Design”, NBS Tech. Note 688, US Department of Commerce-National Bureau of Standards, October 1968. The same graph can also be found in CA Balanis, “Antenna Theory”, Wiley 2005.
- Similarly, the lengths of the reflector and directors should be adjusted if a metallic boom is used, according to the design curve published by NBS Tech. Note 688 above.

Yagi Design Example

- Design Specifications:
  - Frequency range = 434 MHz
  - Directivity = 10 dBi (or 7.85 dB dipole)
  - Input impedance = 50 Ω
  - Diameter of elements = 8 mm
- Design with Yagi Antenna Design spreadsheet
- Simulation (e.g., with MININEC)
- Construction & Testing

Yagi Design Spreadsheet



Input Parameters	
freq(MHz)	434
D(dBi)	10

Calculated Parameters		
λ(m)	0.6912	m
D	7.85	dBdipole

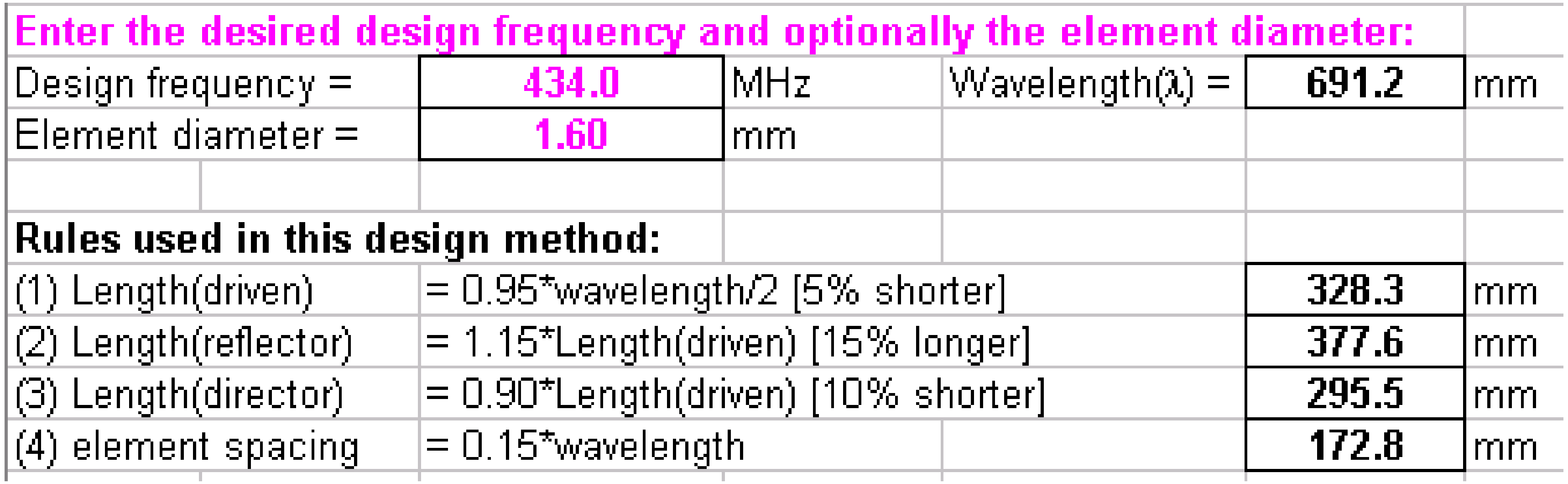
Element	No.	Calculated Lengths (m)					
Boom		**0.2765**	**0.5530**	**0.8295**	**1.5207**	**2.2120**	**2.9032**
reflector	1	0.3332	0.3332	0.3332	0.3332	0.3332	0.3283
driven	2	0.3456	0.3456	0.3456	0.3456	0.3456	0.3456
director	3	0.3055	0.2959	0.2959	0.2986	0.2959	0.2931
director	4		0.2931	0.2903	0.2869	0.2903	0.2931
director	5		0.2959	0.2903	0.2813	0.2813	0.2903
director	6			0.2959	0.2751	0.2751	0.2813
director	7				0.2696	0.2724	0.2786
director	8				0.2696	0.2696	0.2751
director	9				0.2696	0.2668	0.2724
director	10				0.2696	0.2668	0.2696
director	11				0.2751	0.2668	0.2696
director	12				0.2813	0.2668	0.2696
director	13					0.2668	0.2696
director	14					0.2668	0.2696
director	15					0.2668	0.2696
director	16					0.2668	
director	17					0.2668	
spacing between directors (sik/λ)		0.1382	0.1382	0.1728	0.1382	0.1382	0.2129
Directivity (dBdipole)		7.1	9.2	10.2	12.25	13.4	14.2

A Simple Method to Design a 3-Element Yagi Antenna

- Rules used in this design method:
  - Length of driven element, $L_{drv} = 0.95 * \lambda/2$
  - Length of reflector, $L_{ref} = 1.15 * L_{drv}$
  - Length of director, $L_{dir} = 0.90 * L_{drv}$
  - Element spacing, $s = 0.15 * \lambda$
- For a given design frequency, the wavelength λ and the above four parameters are calculated.
- Expert MININEC simulation is used to determine the minimum-VSWR (or S_{11}) frequency.
- The frequency calculated by the simulation is used to scale the above four parameters to the design frequency.
- Another Expert MININEC simulation is carried out to confirm the design. Usually, only one iteration is required.

Example of a 3-Element Yagi Antenna Design

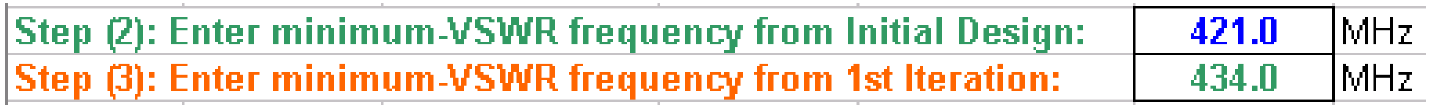
- The desired design frequency is 434.0 MHz.
- The diameter of all antenna elements is 1.60 mm.



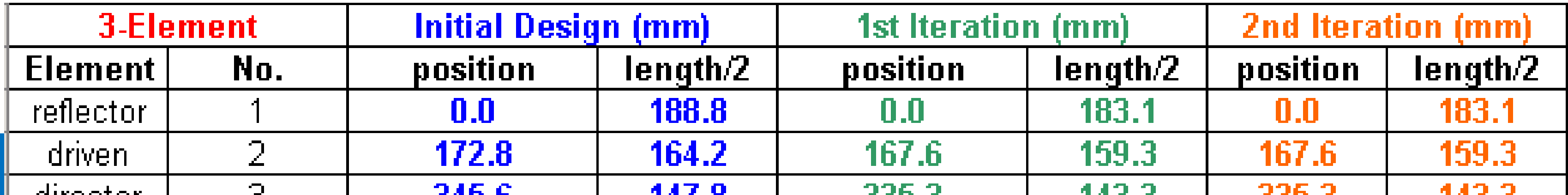
Enter the desired design frequency and optionally the element diameter:					
Design frequency =	434.0	MHz	Wavelength(λ) =	691.2	mm
Element diameter =	1.60	mm			
Rules used in this design method:					
(1) Length(driven)	= 0.95*wavelength/2 [5% shorter]			328.3	mm
(2) Length(reflector)	= 1.15*Length(driven) [15% longer]			377.6	mm
(3) Length(director)	= 0.90*Length(driven) [10% shorter]			295.5	mm
(4) element spacing	= 0.15*wavelength			172.8	mm

Example of a 3-Element Yagi Antenna Design

- The desired design frequency was 434 MHz.
- The minimum-VSWR (or minimum-S11) frequency was found to be 421 MHz. This value was entered into the spreadsheet.
- Adjusted values of the three antenna elements and spacing were calculated in the "1st Iteration (mm)" columns.
- A second run of the Expert MININEC simulation confirmed the desired design frequency of 434 MHz was obtained.



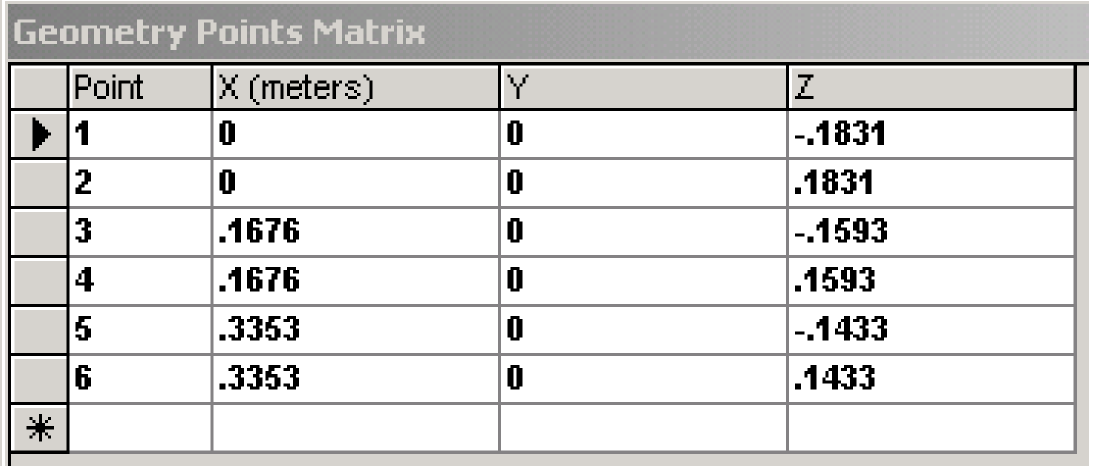
Step (2): Enter minimum-VSWR frequency from Initial Design:	421.0	MHz
Step (3): Enter minimum-VSWR frequency from 1st Iteration:	434.0	MHz



3-Element		Initial Design (mm)		1st Iteration (mm)		2nd Iteration (mm)	
Element	No.	position	length/2	position	length/2	position	length/2
reflector	1	0.0	188.8	0.0	183.1	0.0	183.1
driven	2	172.8	164.2	167.6	159.3	167.6	159.3
director	3	345.6	147.8	335.3	143.3	335.3	143.3

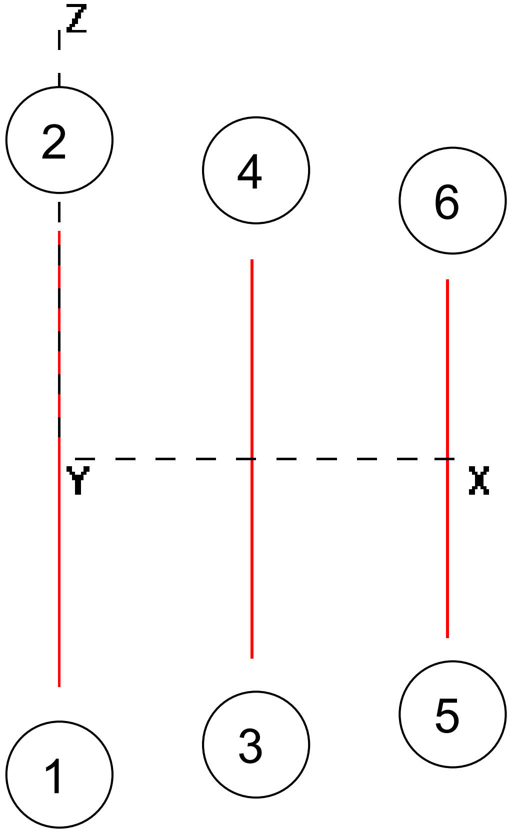
Coordinates of 3-Element Yagi

- The desired design frequency was 434 MHz.



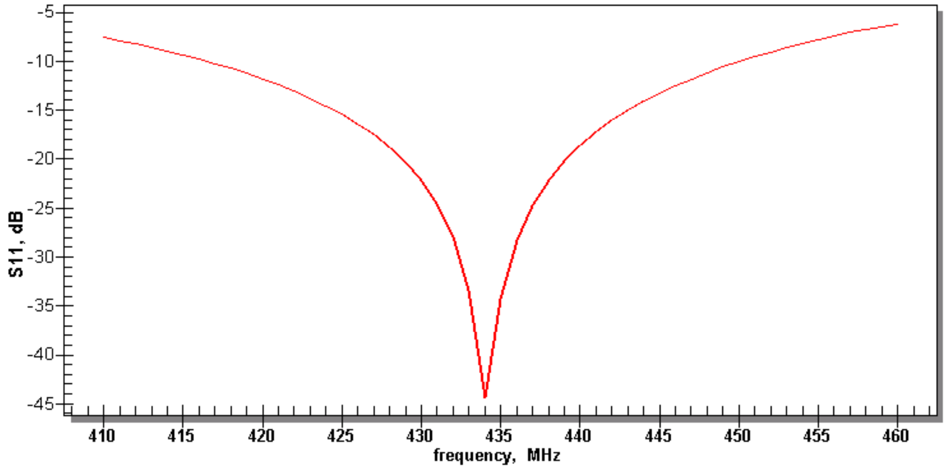
Geometry Points Matrix

Point	X (meters)	Y	Z
1	0	0	-.1831
2	0	0	.1831
3	.1676	0	-.1593
4	.1676	0	.1593
5	.3353	0	-.1433
6	.3353	0	.1433

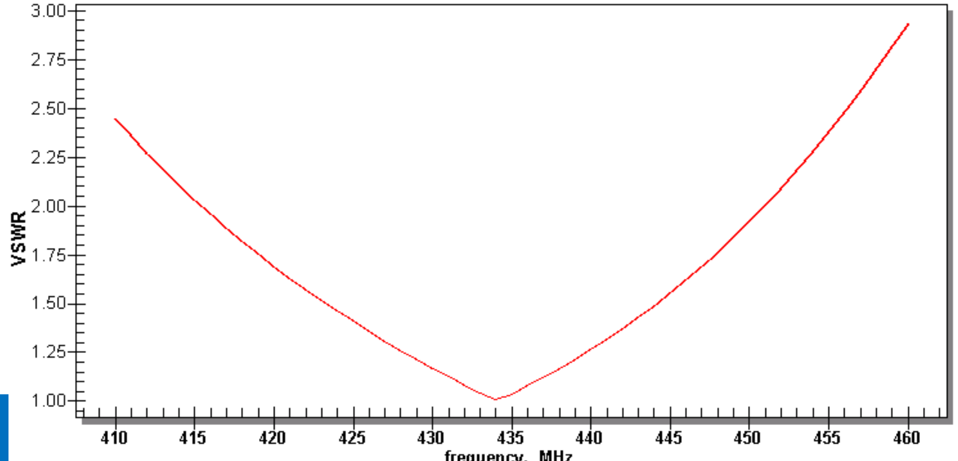


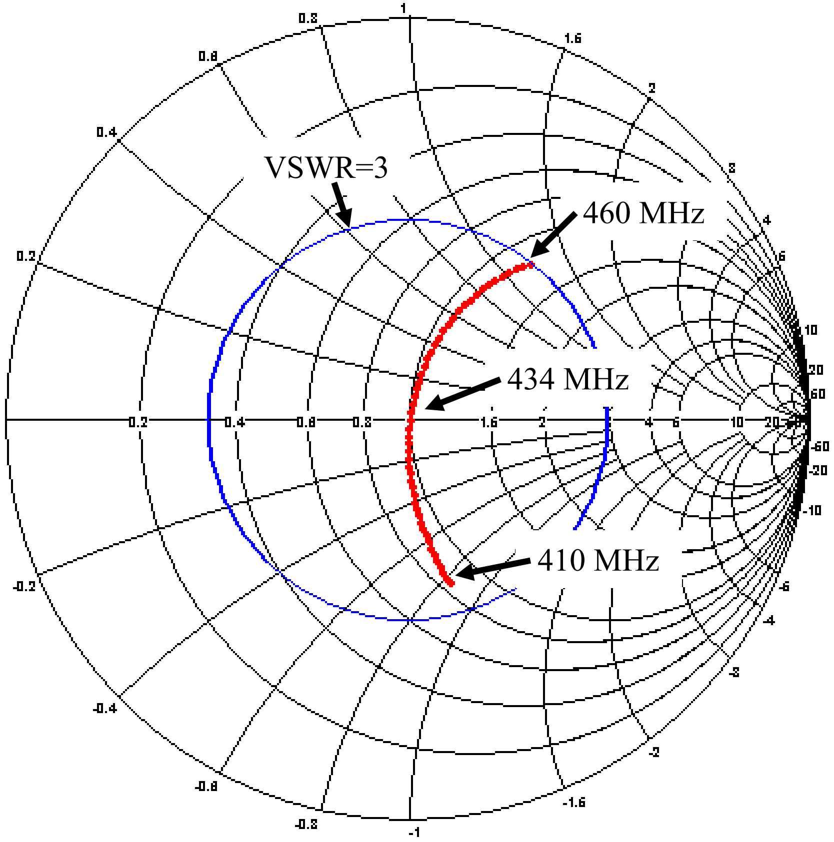
S11, VSWR, and Impedance of 3-Element Yagi

- The desired design frequency was 434 MHz.

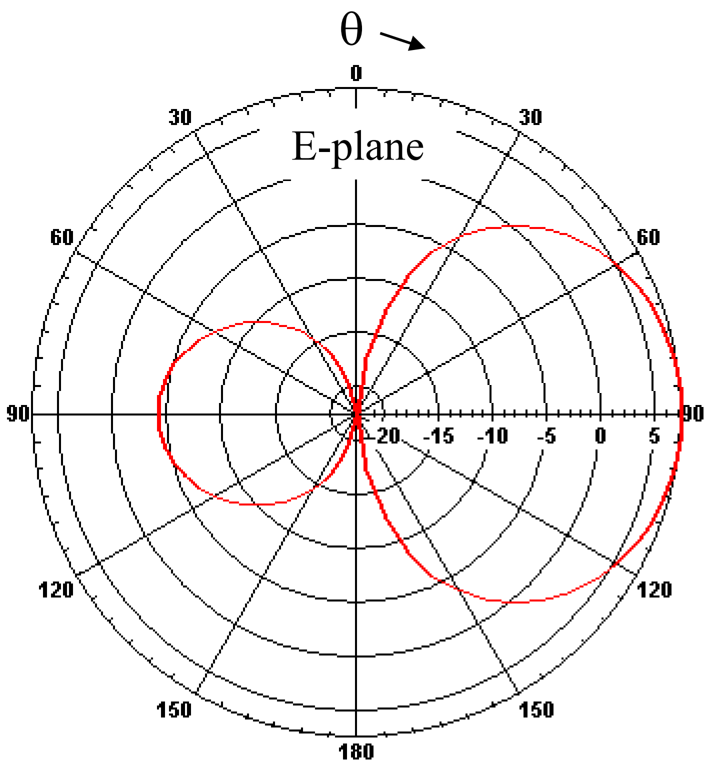


C:\Expert_MPRO\Files\TTYAGI434E3, 08-19-2007, 21:39:59
source node 21 of sector 1

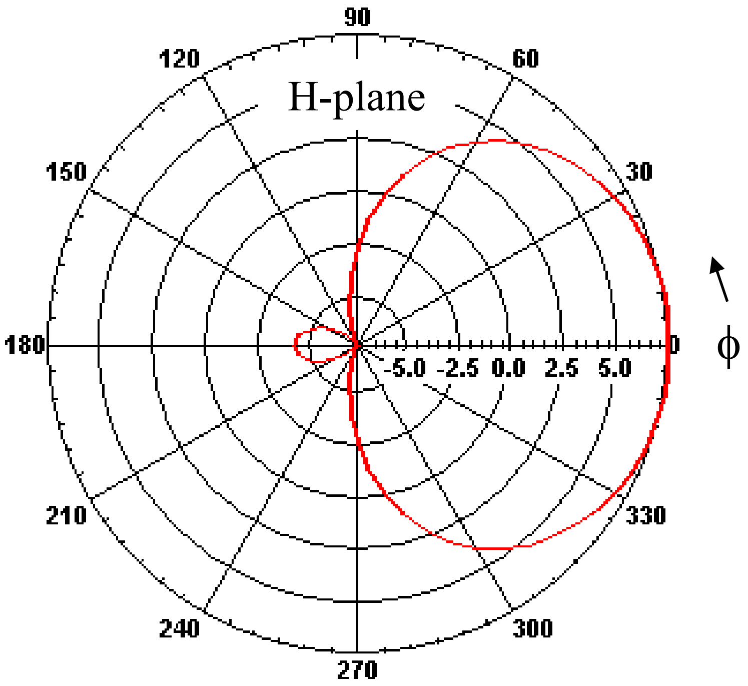




Radiation Pattern of 3-Element Yagi



E-theta, dB
azimuth = 0, 180. degrees
Scale = 1
434. MHz



E-theta, dB
zenith = 90. degrees
Scale = 1
Maximum gain: 7.4159 dB at 0 deg
-3 dB (lower, upper): 304.46, 55.54 deg
Front to back ratio: 11.749 dB
434. MHz

S-parameters

- Describe the input-output relationship between ports (or terminals) in an electrical system.
- For instance, if we have 2 ports (intelligently called Port 1 and Port 2), then S12 represents the power transferred from Port 2 to Port 1.
- S21 represents the power transferred from Port 1 to Port 2. I
- n general, S_{NM} represents the power transferred from Port M to Port N in a multi-port network.

S_{11}

- In practice, the most commonly quoted parameter in regards to antennas is S_{11}.
- S_{11} represents how much power is reflected from the antenna, and hence is known as the **reflection coefficient**(sometimes written as gamma, τ or **return loss**.
- If S_{11}=0 dB, then all the power is reflected from the antenna and nothing is radiated.
- If S_{11}=-10 dB, this implies that if 3 dB of power is delivered to the antenna, -7 dB is the reflected power. The remainder of the power was "accepted by" or delivered to the antenna.
- This accepted power is either radiated or absorbed as losses within the antenna. Since antennas are typically designed to be low loss, ideally the majority of the power delivered to the antenna is radiated.