ECC 203 : Electromagnetics and Radiating Systems

Microstrip Patch Antenna : Transmission Line Model
And
Horn Antenna

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Microstrip (Patch) Antenna

A metallic strip or patch mounted on a dielectric layer (substrate) which is supported by a ground plane

TABLE 14.1 Typical substrates and their parameters

Company	Substrate	Thickness (mm)	Frequency (GHz)	ε_r	$\tan\delta$
Rogers Corporation	Duroid®5880	0.127 1.575 3.175	0 – 40	2.20	0.0009
	RO 3003		0 – 40	3.00	0.0010
	RO 3010		0 – 10	10.2	0.0022
	RO 4350	0.168 0.508 1.524	0 – 10	3.48	0.0037
-	FR4	0.05 – 100	0.001	4.70	-
DuPont	HK 04J	0.025	0.001	3.50	0.005
Isola	IS 410	0.05 – 3.2	0.1	5.40	0.035
Arlon	DiClad 870	0.091	0 – 10	2.33	0.0013
Polyflon	Polyguide	0.102	0 – 10	2.32	0.0005
Neltec	NH 9320	3.175	0 – 10	3.20	0.0024
Taconic	RF-60A	0.102	0 – 10	6.15	0.0038

Rectangular Microstrip Antenna

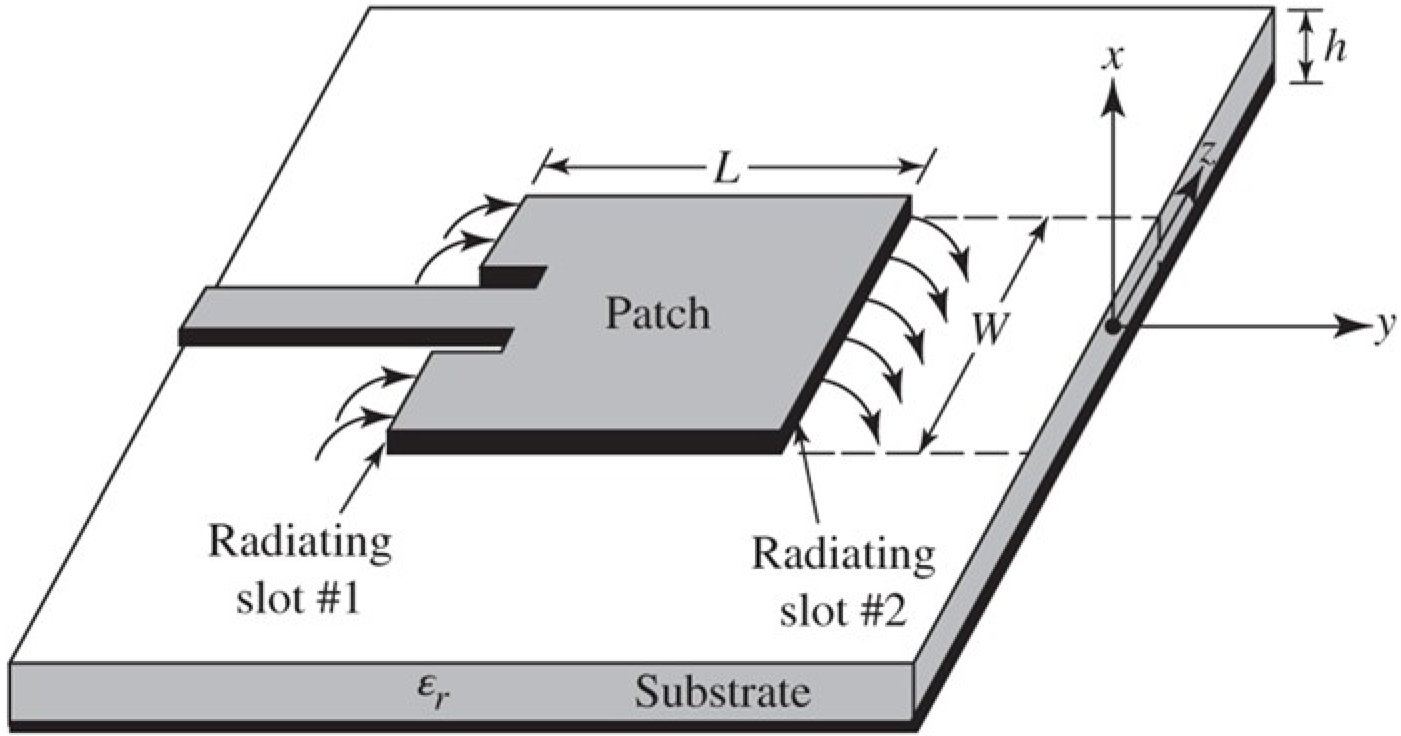


Fig. 14.1a

Side View

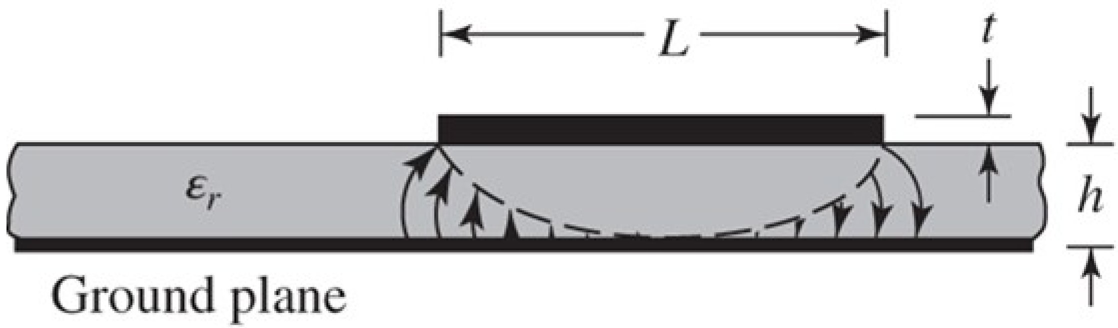


Fig. 14.1b

Patches of Various Shapes

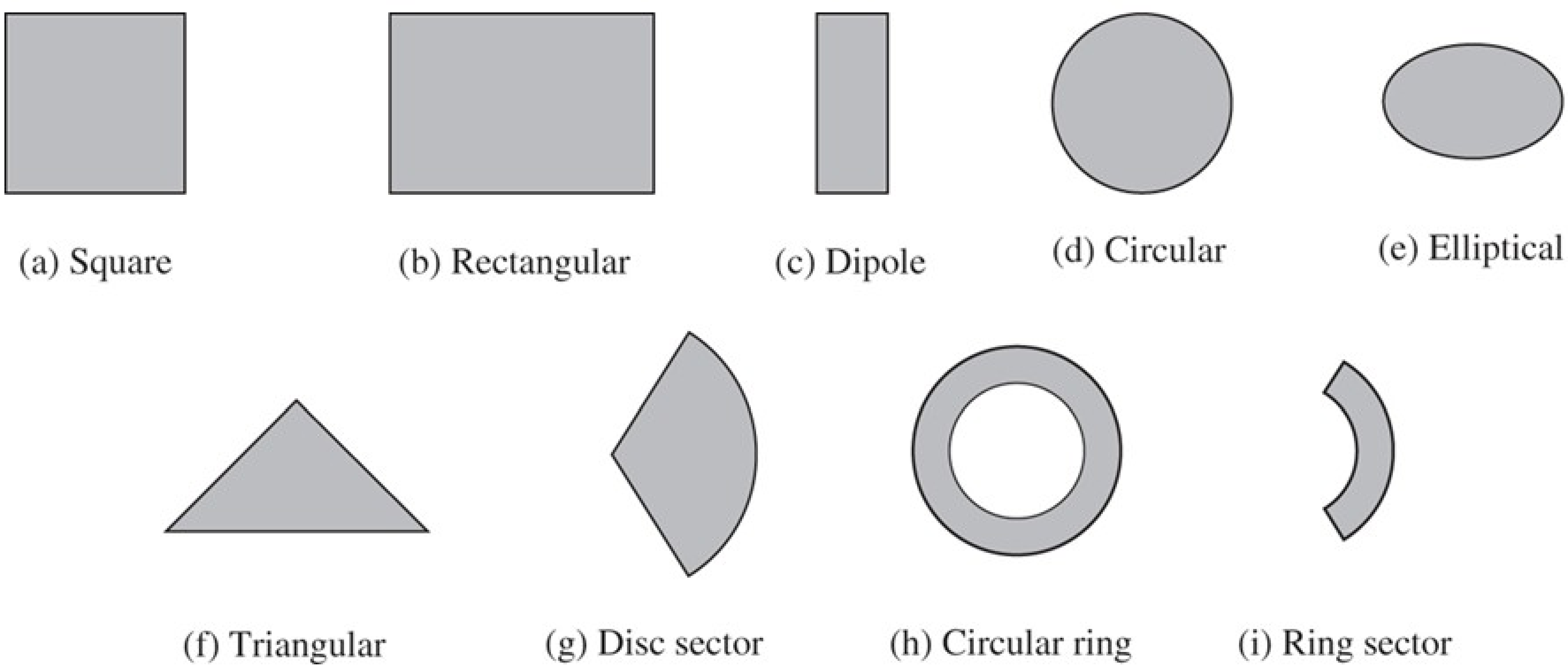


Fig. 14.2

Microstrip (Patch) Antennas

Advantages:

1. Low profile
2. Conformable to nonplanar surfaces
3. Simple and inexpensive
4. Mechanically robust
5. Compatible with MMIC designs
6. Very versatile
   a. Resonant frequency
   b. Polarization
   c. Patterns
   d. Impedance

Disadvantages

1. Low power
2. Narrow bandwidth
3. Large EM signature at certain frequencies outside operating band
4. In large arrays, tradeoff between bandwidth and scan volume
5. Large size (physical) at VHF and possibly UHF bands

Popular Feeding Techniques

1. Microstrip line
2. Probe (coaxial)
3. Aperture coupling
4. Proximity coupling

Microstrip Feed Line

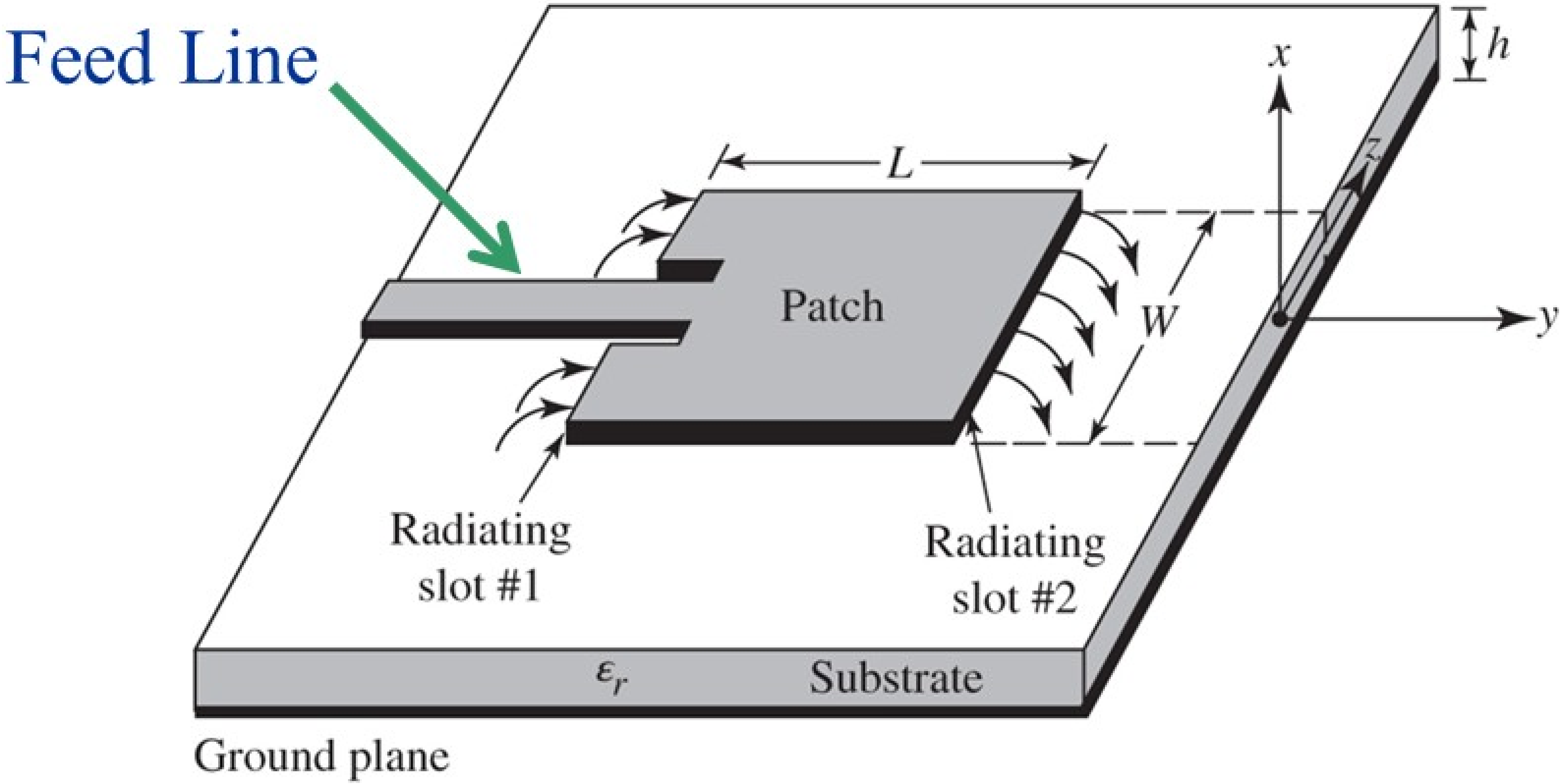
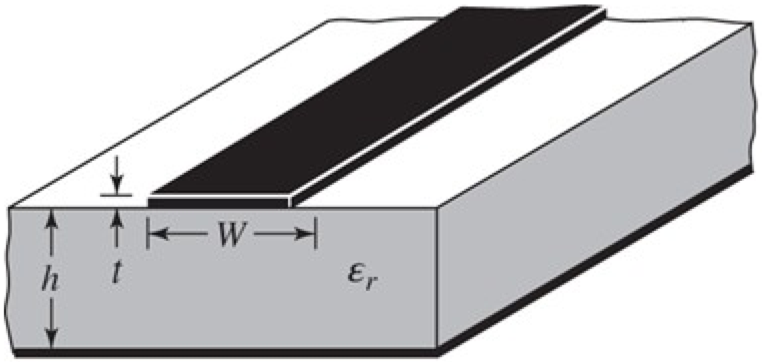


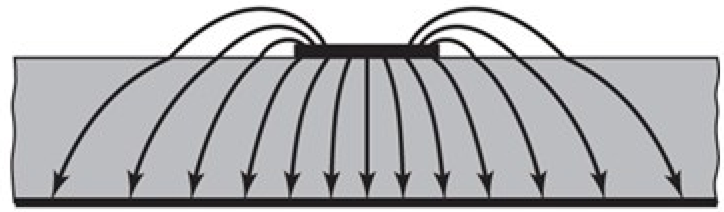
Fig. 14.3a

Transmission-Line Model

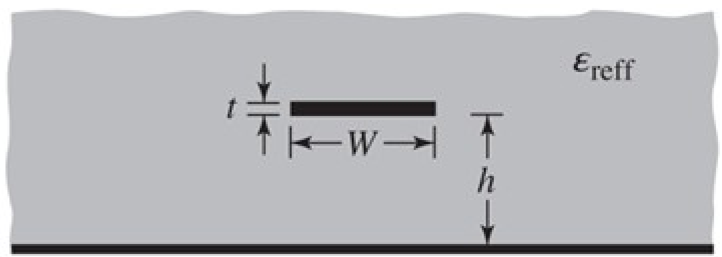
Effective Dielectric Constant For Microstrip Line



(a) Microstrip line



(b) Electric field lines



(c) Effective dielectric constant

Fig. 14.5

Effective Dielectric Constant

$$W/h > 1$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \qquad (14\text{-}1)$$

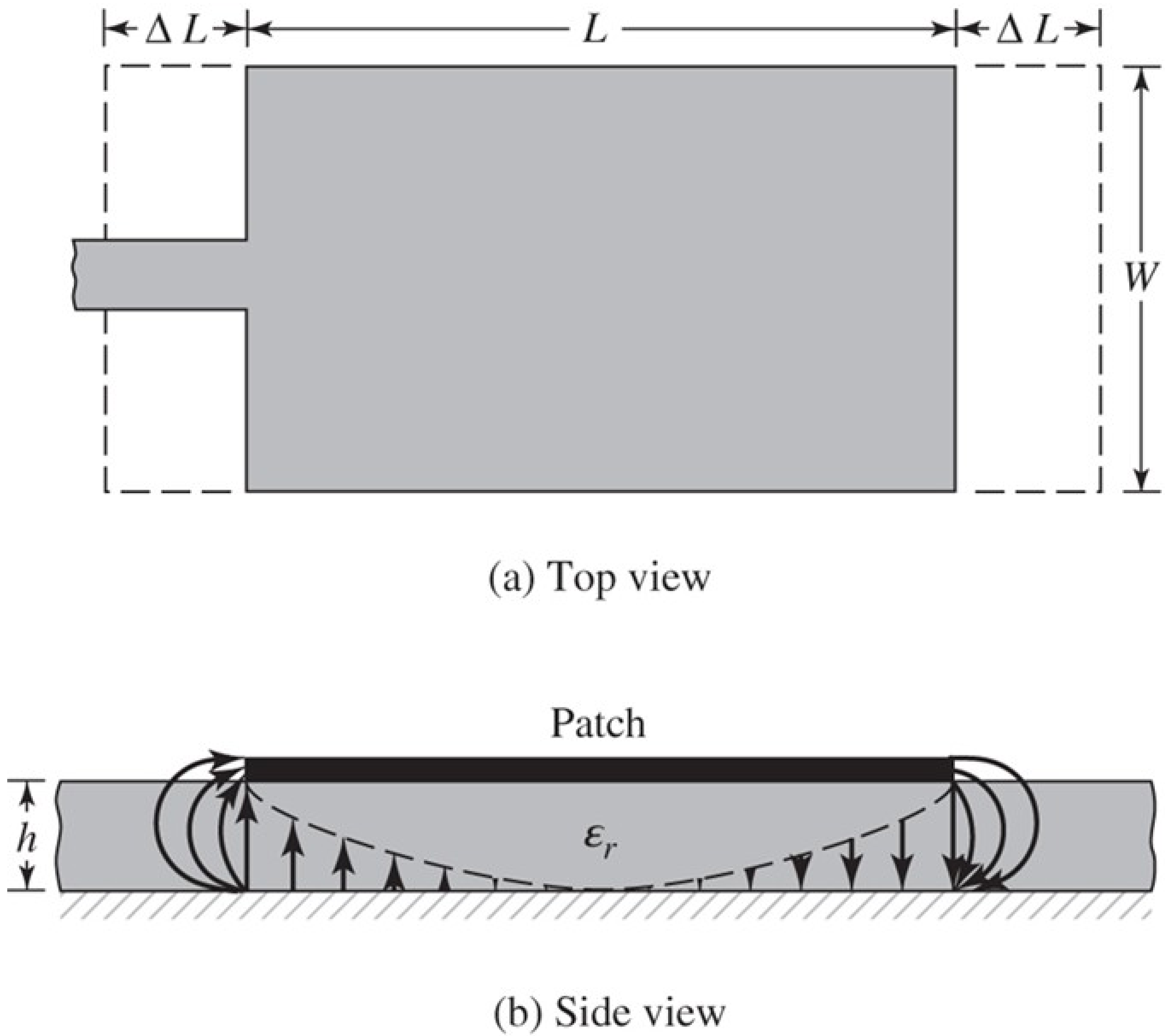


Fig. 14.7

Design Procedure

1. Specify: ε_r , f_r, h/λ_o
2. Determine: W, L

Design Procedure

1. Specify: $\varepsilon_r, f_r, h/\lambda_o$

2. Determine: W, L

A. Determine W:

For an efficient radiator, a practical width which leads to good radiation efficiencies is

$$W = \frac{\upsilon_o}{2 f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \qquad (14\text{-}6)$$

B. Determine L:

once W is known, and the effective dielectric constant and length extension have been computer, the

$$L = \frac{\upsilon_o}{2 f_r \sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (14\text{-}7)$$

$$\frac{\Delta L}{h} = 0.412 \frac{(\varepsilon_{reff} + 0.3)\left(\dfrac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\dfrac{W}{h} + 0.8\right)} \qquad (14\text{-}2)$$

Example 14.1:

Given: Duroid $\left(\text{RT/5880}\right)(\varepsilon_r = 2.2,\ h = 0.0625 \text{ in} = 0.1588 \text{ cm})$

$$f_r = 10 \text{ GHz}$$

Solution:

$$W = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{3\times 10^{10}}{2\times 10^{10}}\sqrt{\frac{2}{2.2+1}} = 1.186 \text{ cm}$$

$$= 1.186 \text{ cm} = 0.467 \text{ in}$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

$$= \frac{2.2+1}{2} + \frac{2.2-1}{2}\left[1 + 12\left(\frac{0.062}{0.467}\right)\right]^{-1/2} = 1.9726$$

$$\frac{\Delta L}{h} = 0.412\frac{(1.972+0.3)\left(\dfrac{1.186}{0.1588}+0.264\right)}{(1.972-0.258)\left(\dfrac{1.186}{0.1588}+0.8\right)}$$

$$= 0.412\left(\frac{17.7178}{14.2865}\right) = 0.511$$

$$\Delta L = 0.511(0.1588) = 0.081 \text{ cm } (0.032 \text{ in})$$

$$L = \frac{\lambda}{2} - 2\Delta L = \frac{30}{2(10)\sqrt{1.972}} - 2(0.081) = 0.906 \text{ cm} = 0.357 \text{ in}$$

Rectangular Microstrip

($L = 0.906$ cm, $W = 1.186$ cm, $h = 0.1588$ cm,
$y_o = 0.203$ cm, $\varepsilon_r = 2.2$, $f = 9.8$ GHz)

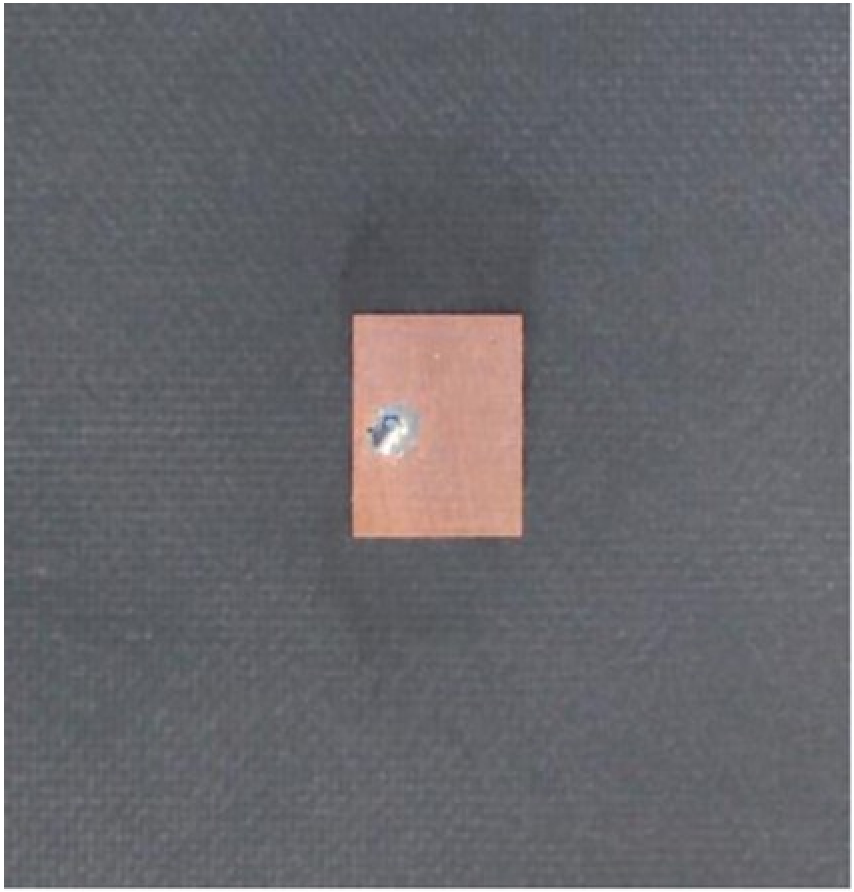
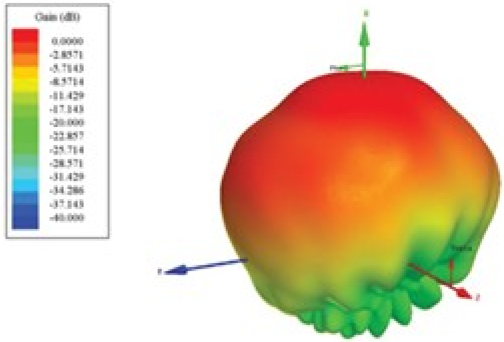
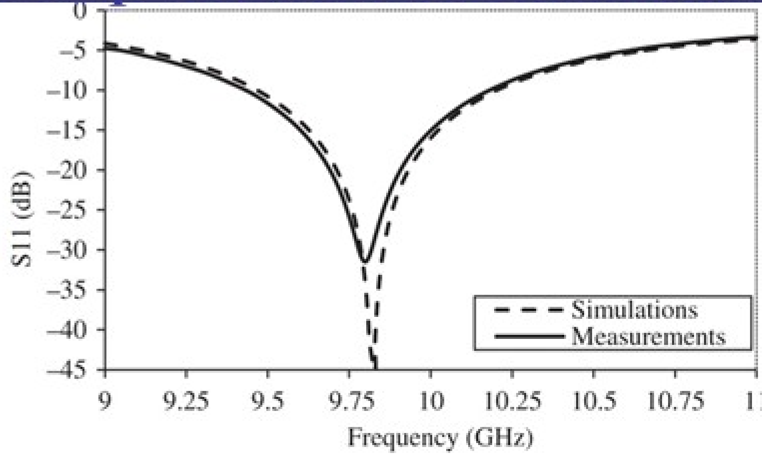


Fig. 14.8 (a)

Rectangular Microstrip Radiation Characteristics

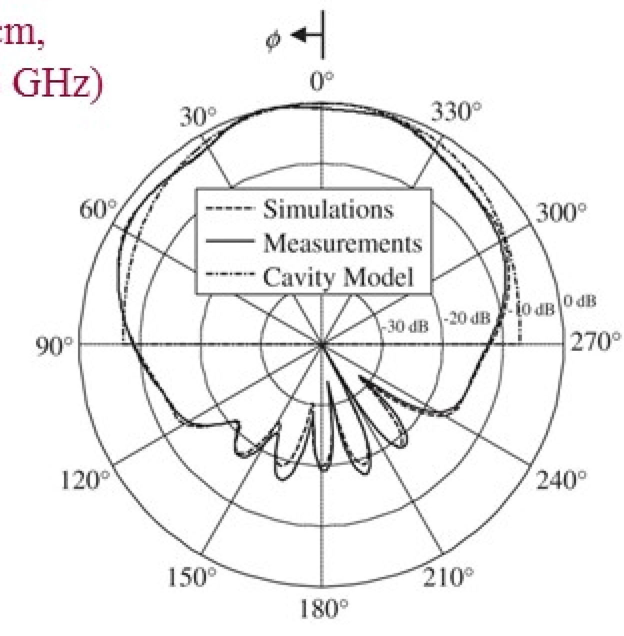


(a) 3-D

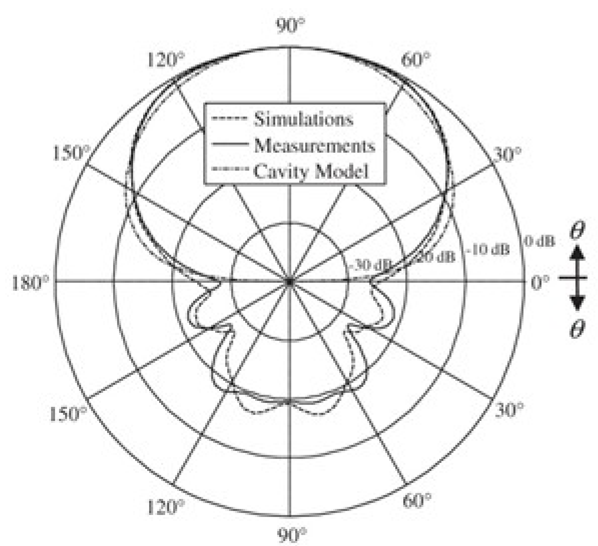


(b) S_{11}

(L = 0.906 cm,
W = 1.186 cm,
h = 0.1588 cm,
y_o = 0.203 cm,
ε_r = 2.2, f = 9.8 GHz)



(c) E-plane ($\theta = 90°$)



(d) H-plane ($\phi = 0°$)

Fig. 14.21

Microstrip Feed Line

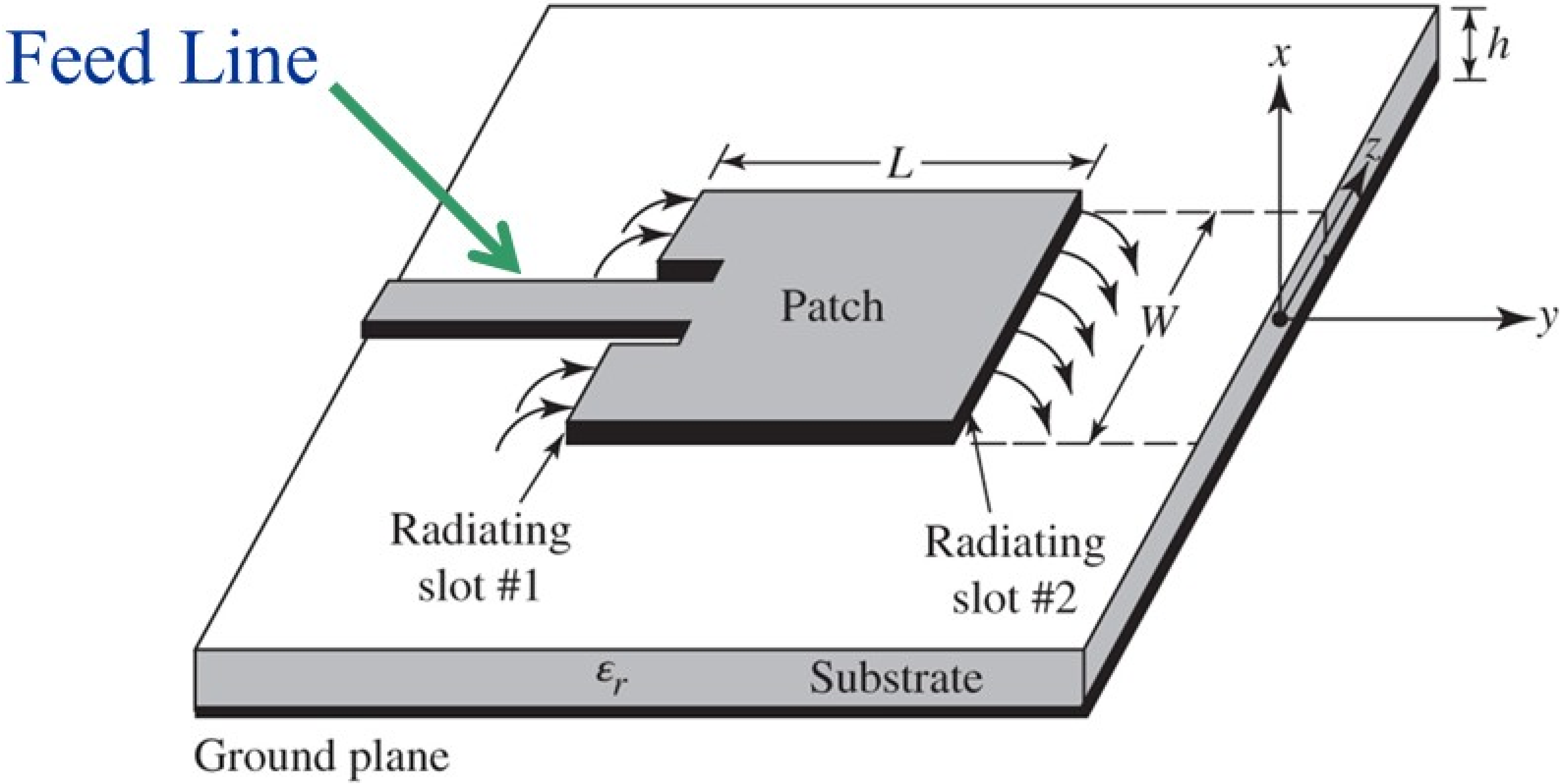
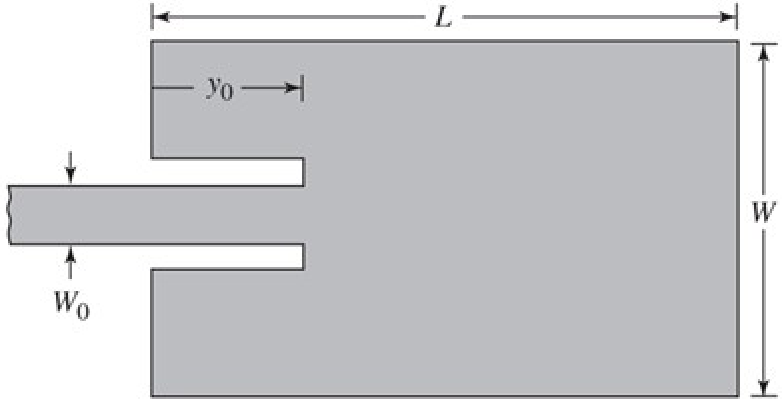
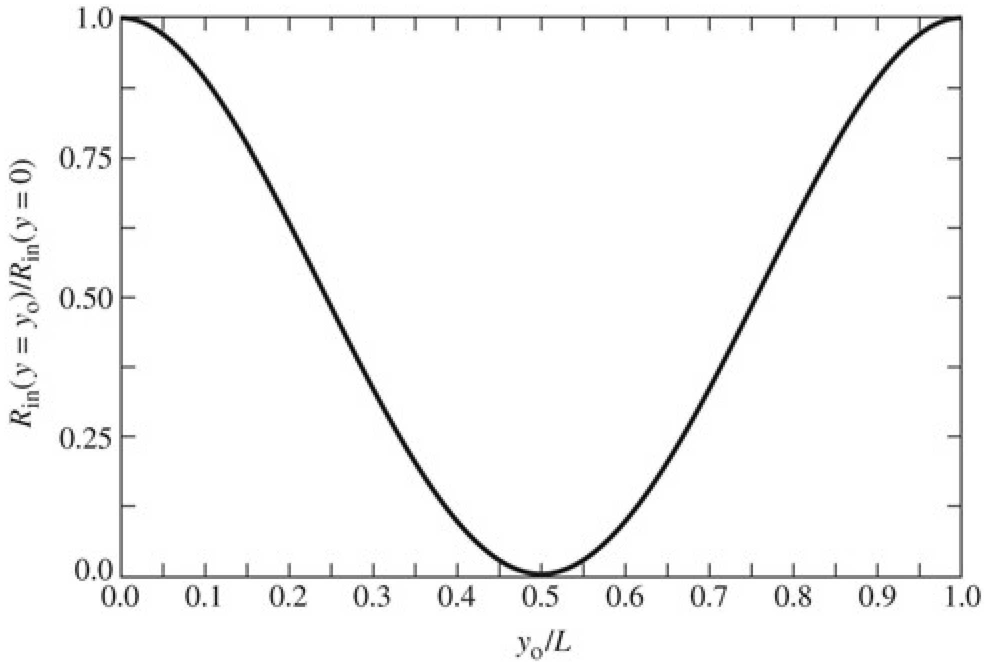


Fig. 14.3a



(a) Recessed microstrip-line feed



(b) Normalized input resistance

Fig. 14.11

Circular Polarization

1. 2 components of E-field orthogonal to each other and $\perp$ to direction of travel.
2. Equal amplitudes.
3. Time-phase difference has to be odd multiples of 90^{o}.

CP: Square Patch Driven At Adjacent Sides Through Power Divider

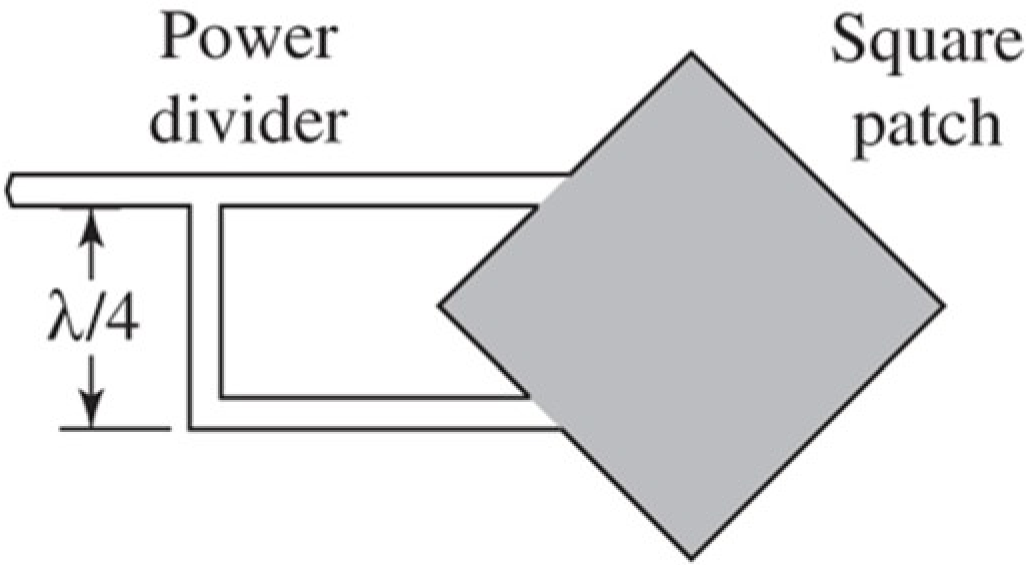


Fig. 14.34a

Introduction : Horn Antenna

- First Horn Antenna - Indian radio researcher "Jagdish Chandra Bose" in 1897.
- Modern Horn Antenna – "Wilmer Barrow and G.C. Southworth" in 1938.
- High Gain Antennas
- Also used as a feed for Large Reflector Antennas
- Broadband Characteristics – No Resonant Structure

Directional Pattern of a Horn

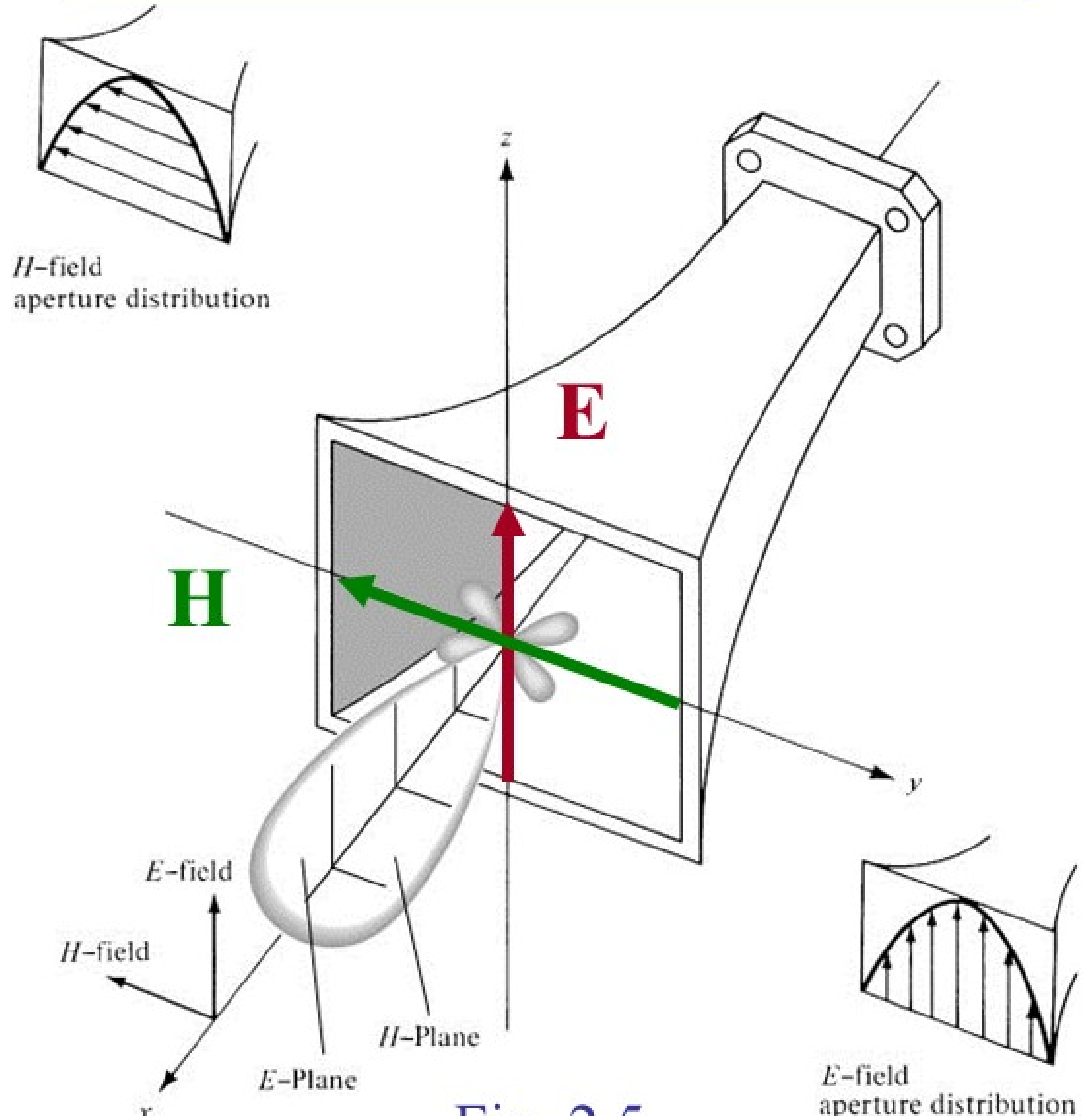


Fig. 2.5

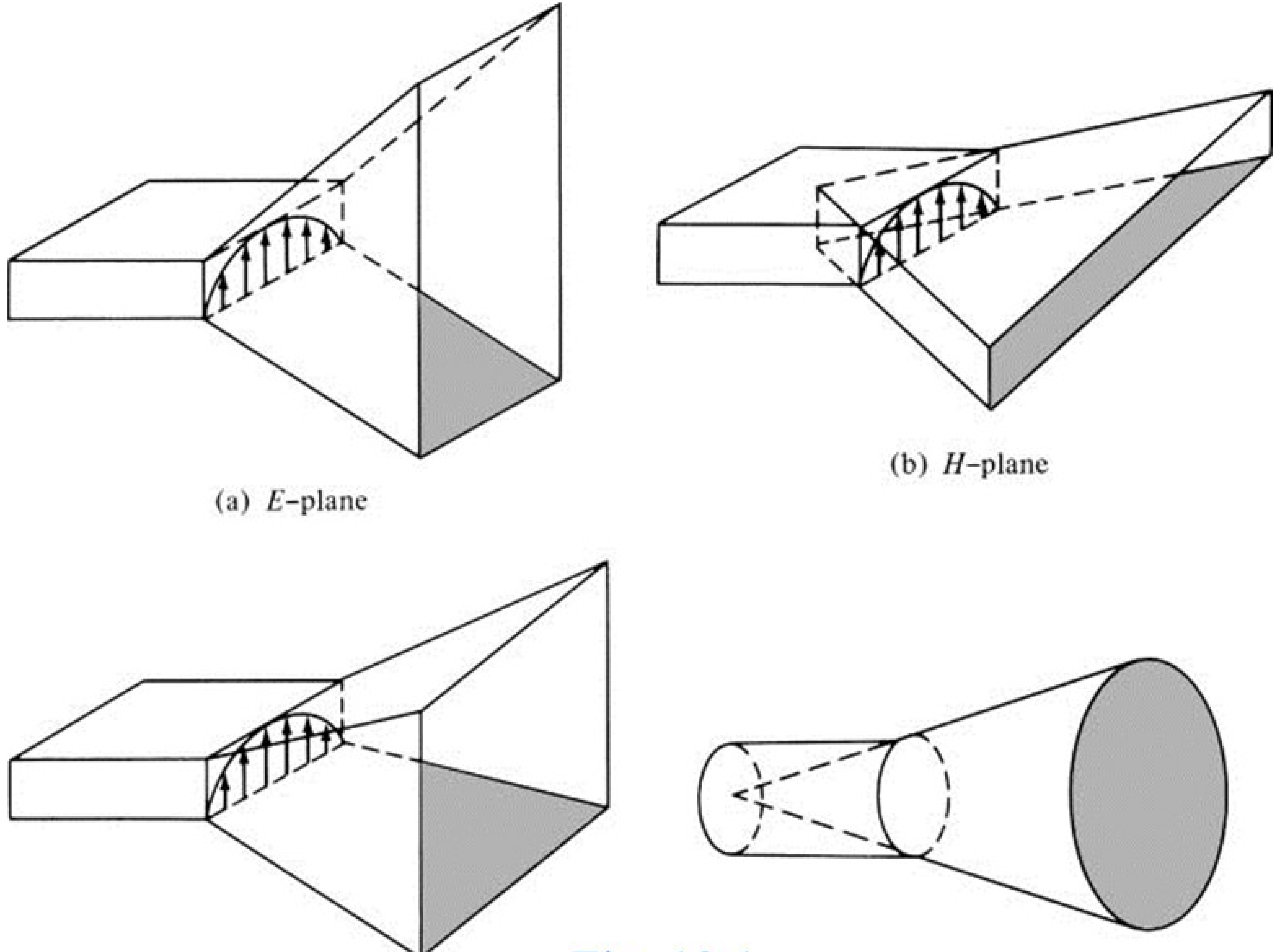
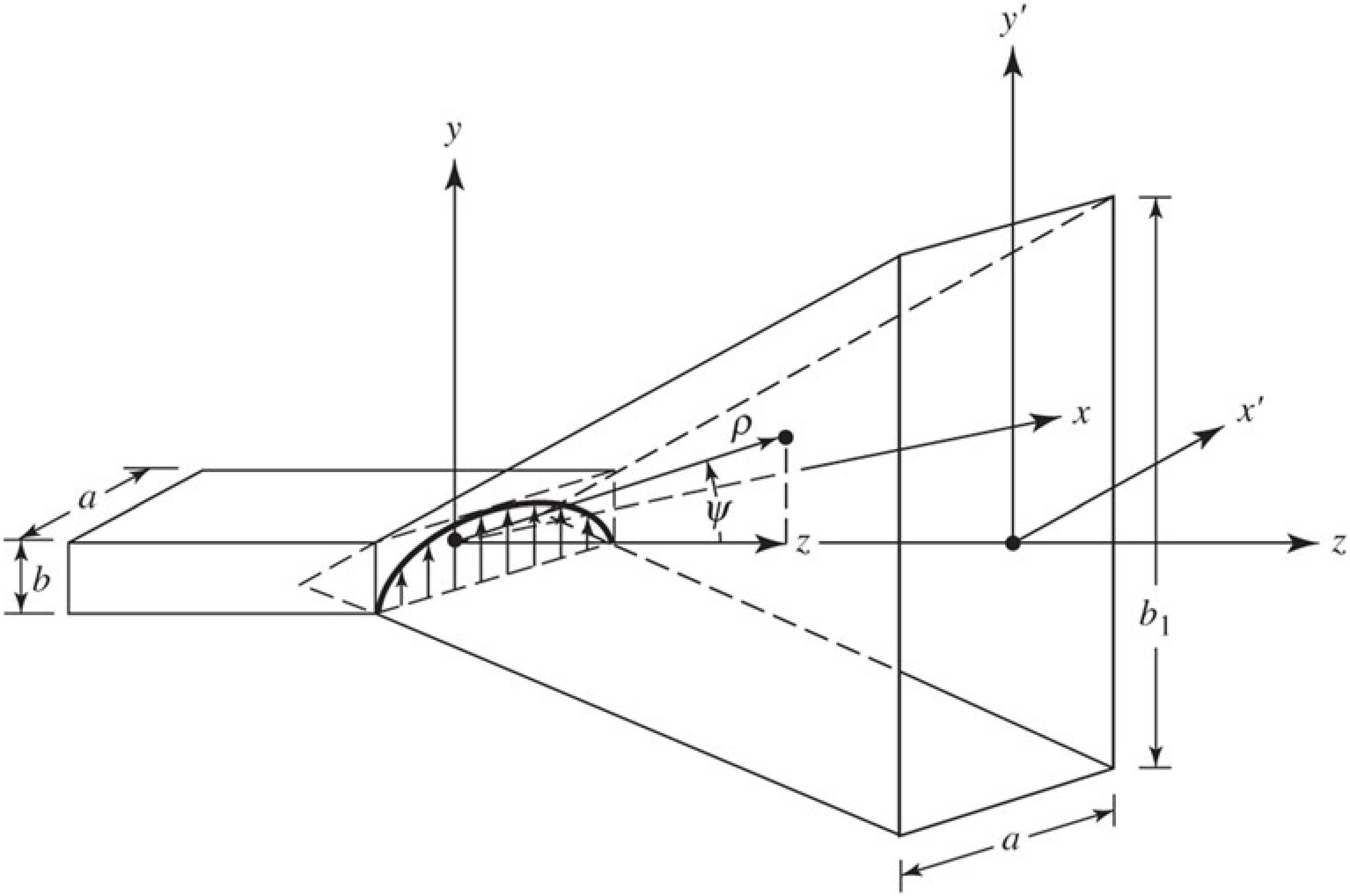


Fig. 13.1

(c) Pyramidal

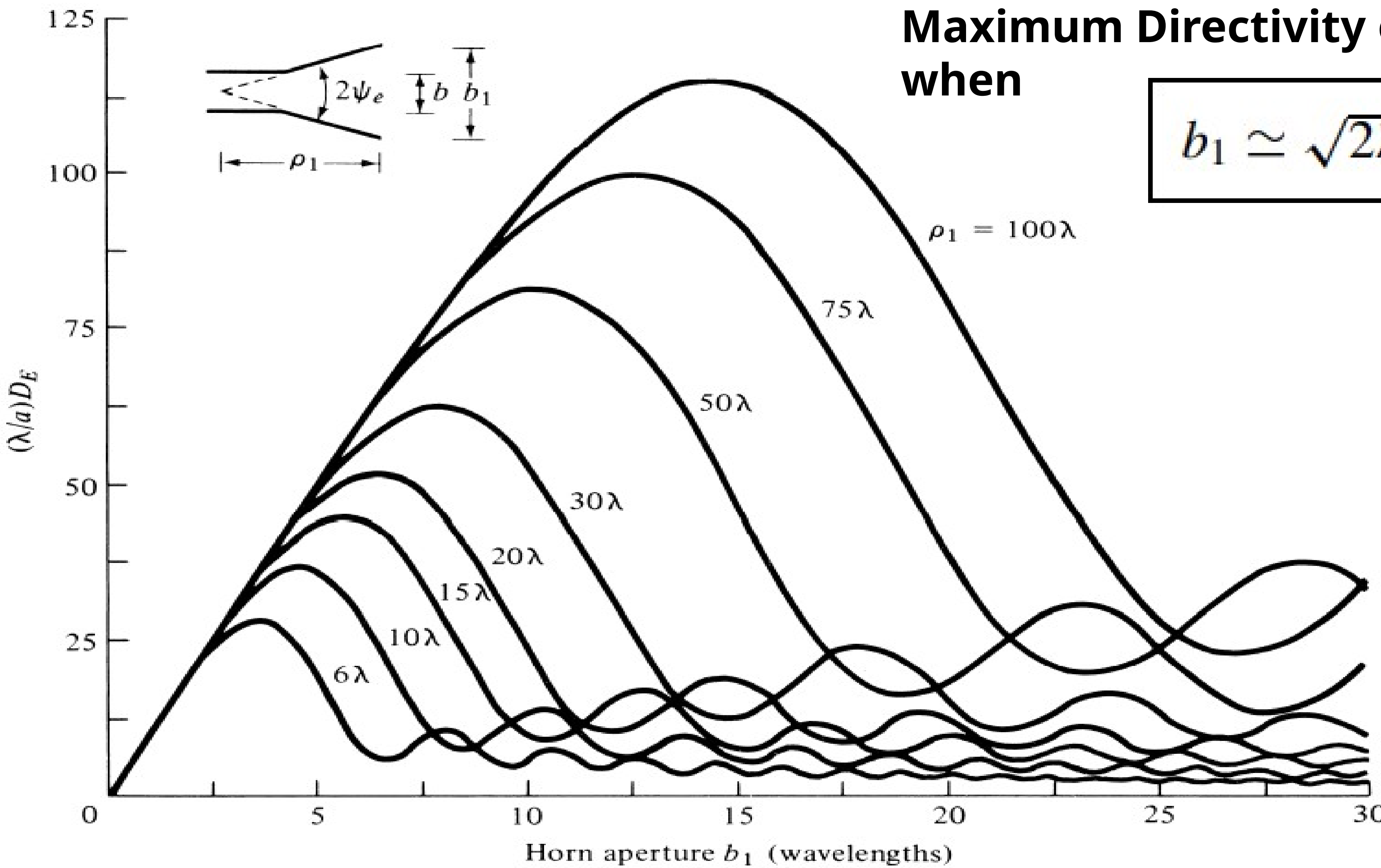
(d) Conical

E-Plane Horn



$$E'_y(x', y') \simeq E_1 \cos\left(\frac{\pi}{a}x'\right) e^{-j[ky'^2/(2\rho_1)]}$$

E-Plane Sectoral Horn Directivity Curve



Maximum Directivity occurs when

$$\boxed{b_1 \simeq \sqrt{2\lambda\rho_1}}$$

$\rho_1 = 15\lambda$

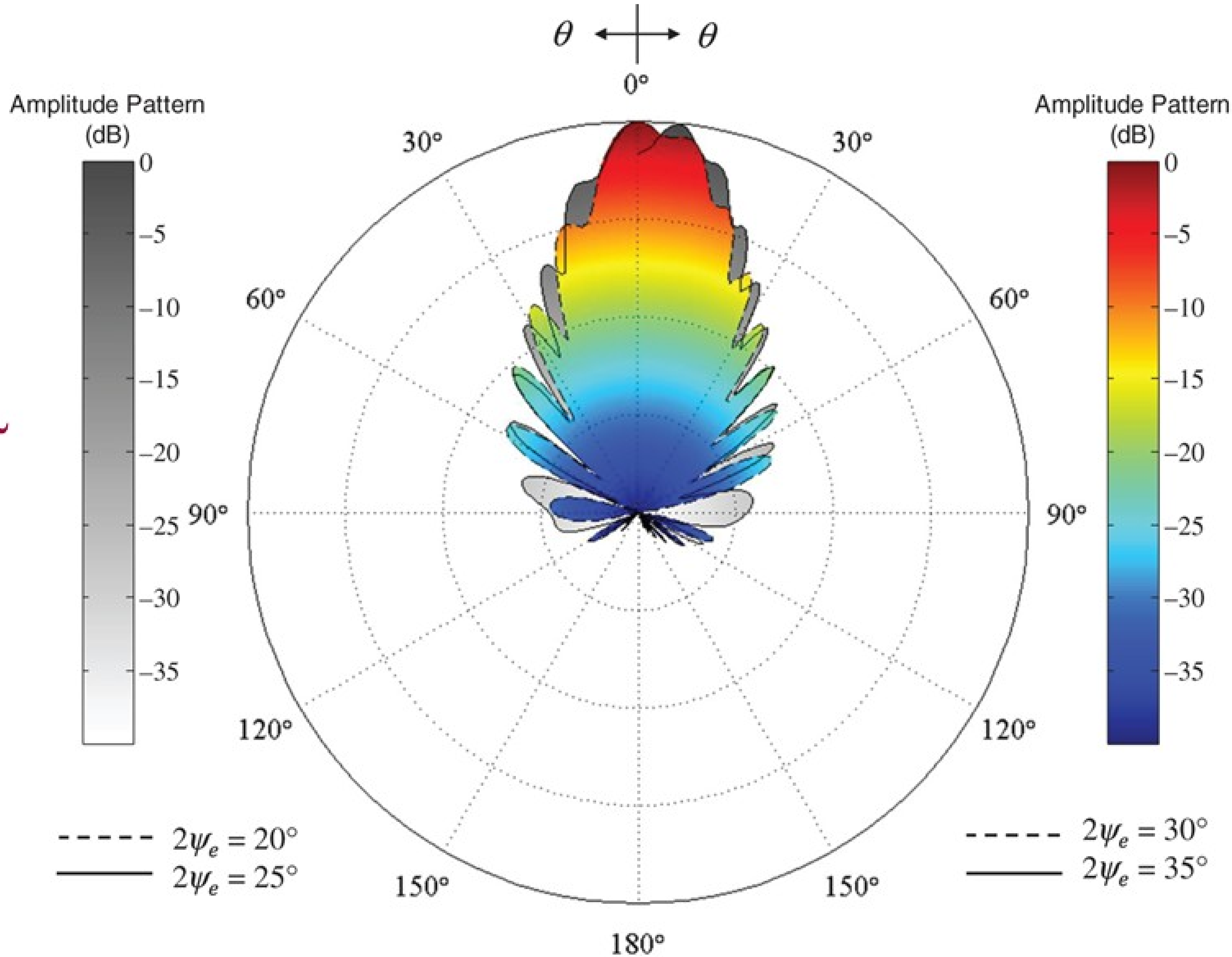
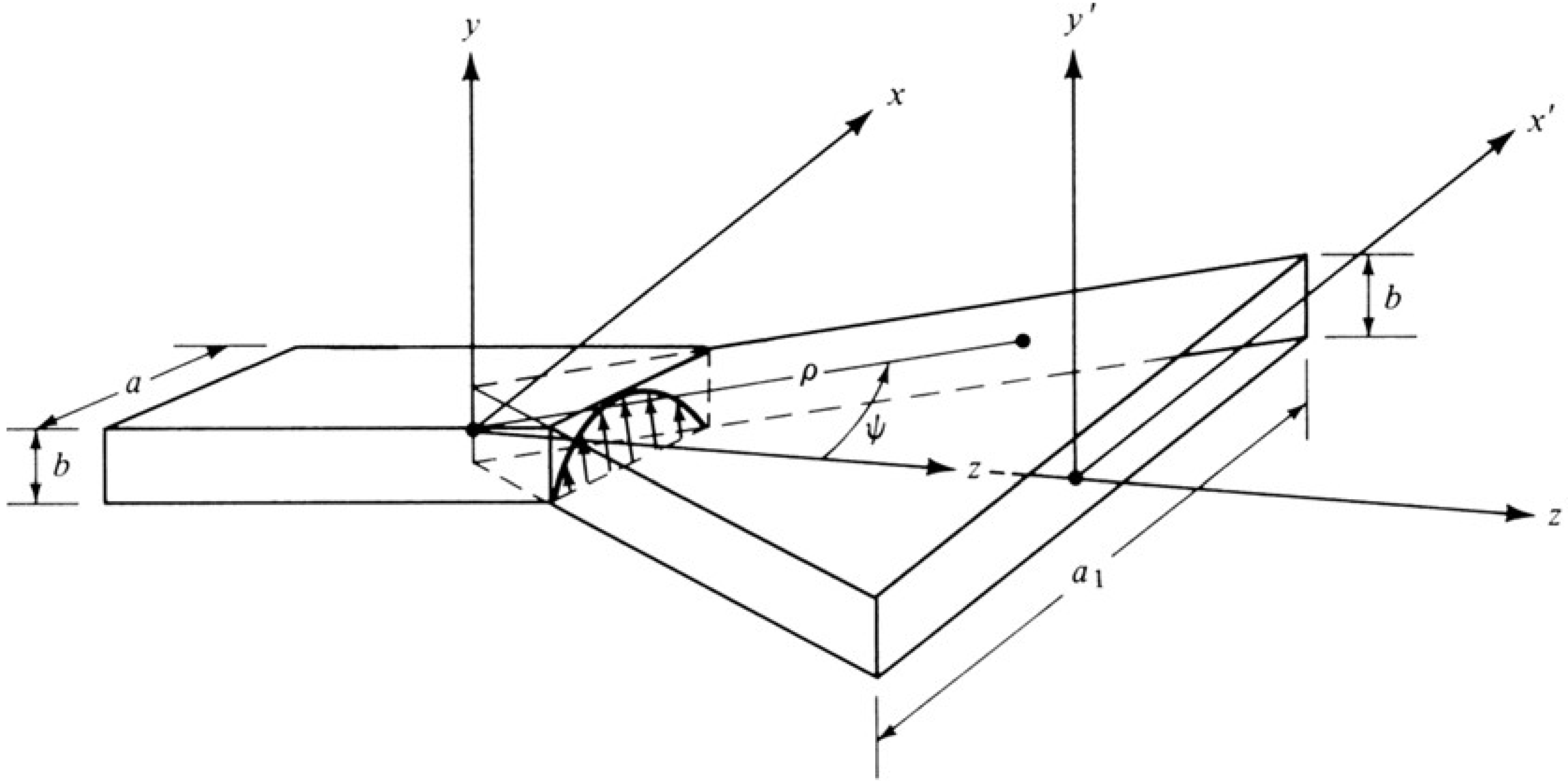


Fig. 13.5

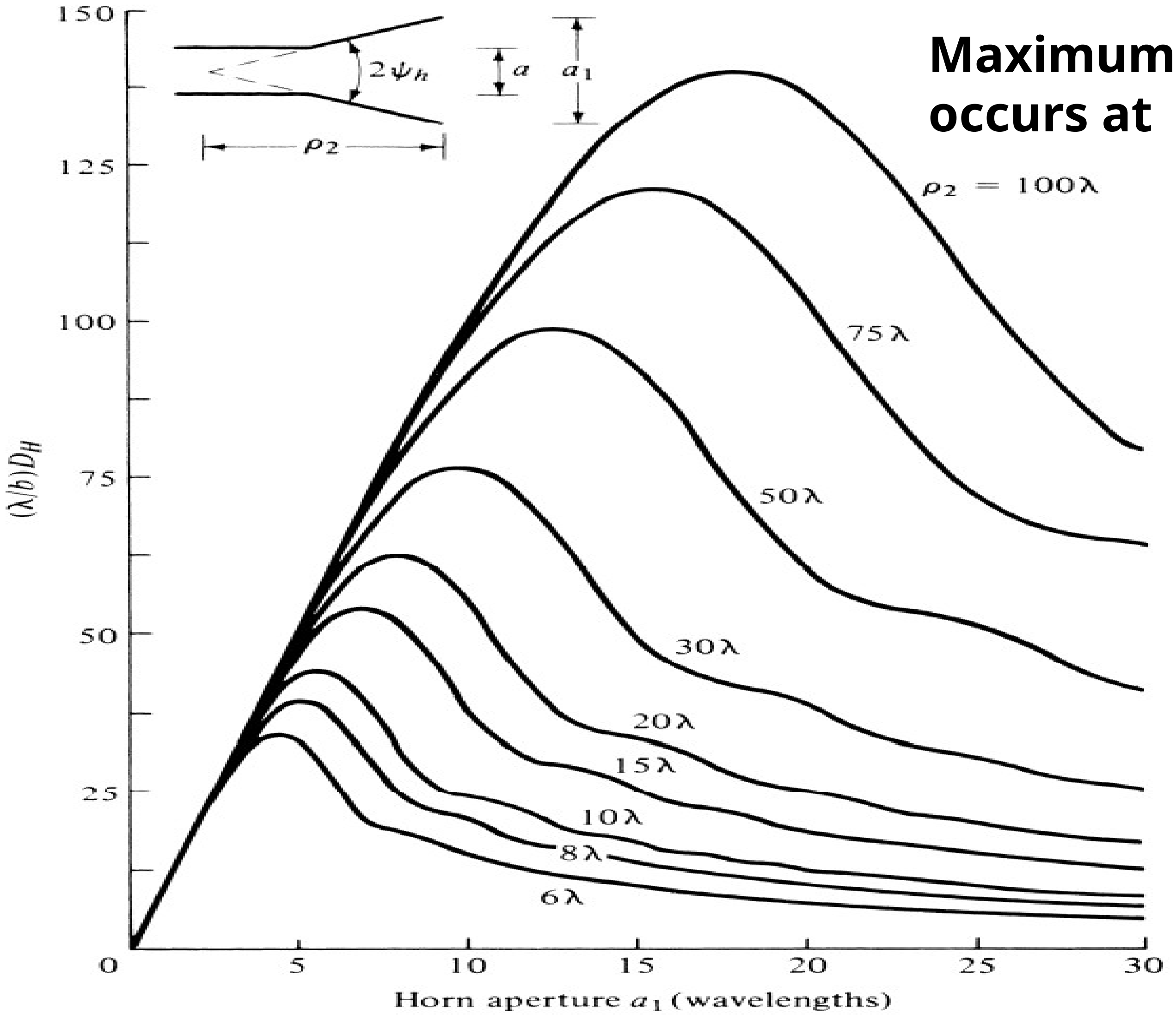
H-Plane Sectoral Horn



$$E'_y(x') = E_2 \cos\left(\frac{\pi}{a_1}x'\right) e^{-jk\delta(x')}$$

$$\delta(x') = \frac{x'^2}{2\rho 2}$$

H-Plane Sectoral Horn Directivity Curve



Maximum Directivity occurs at

$$a_1 \simeq \sqrt{3\lambda\rho_2}$$

$\rho_2 = 15\lambda$

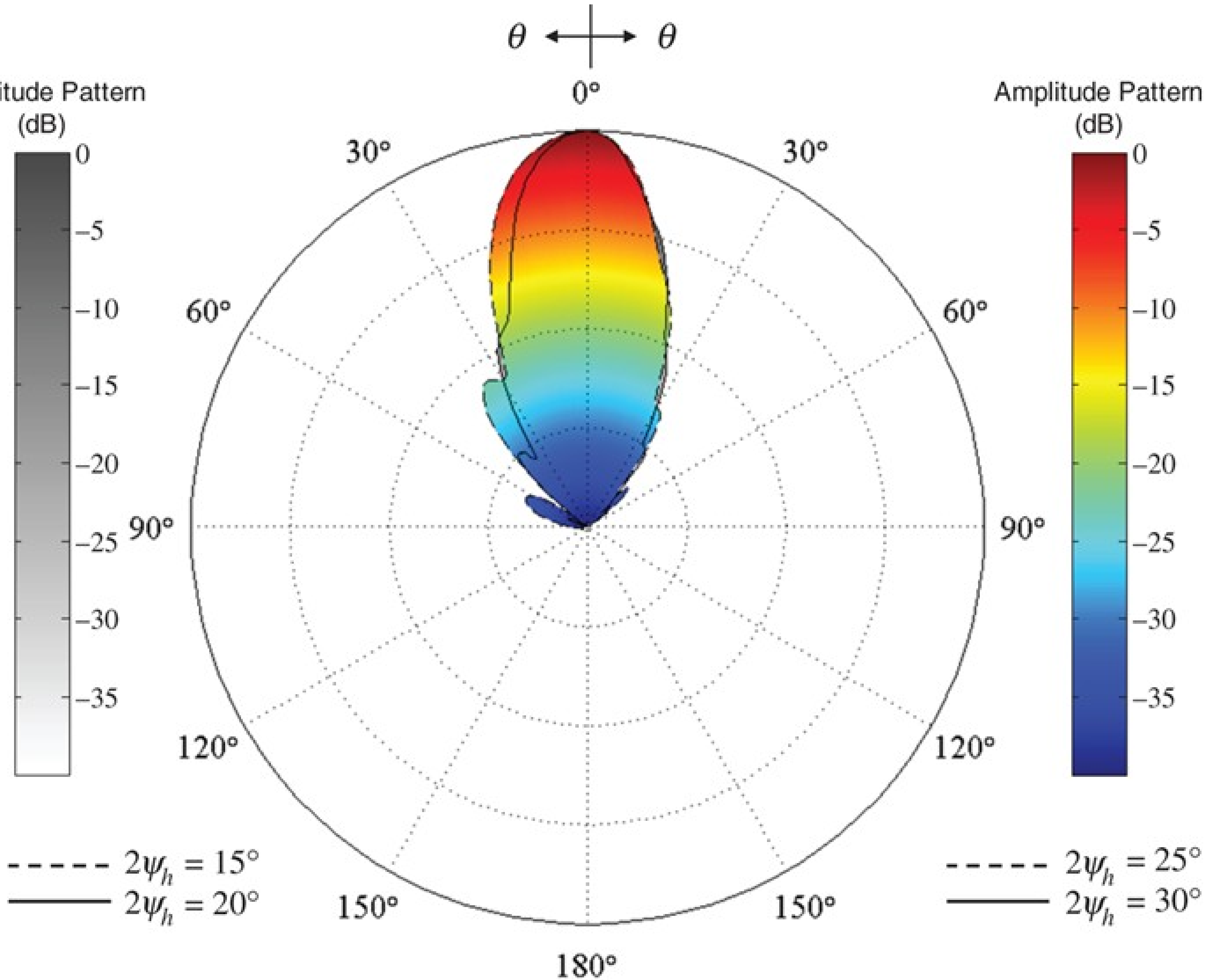


Fig. 13.12

Pyramidal Horn

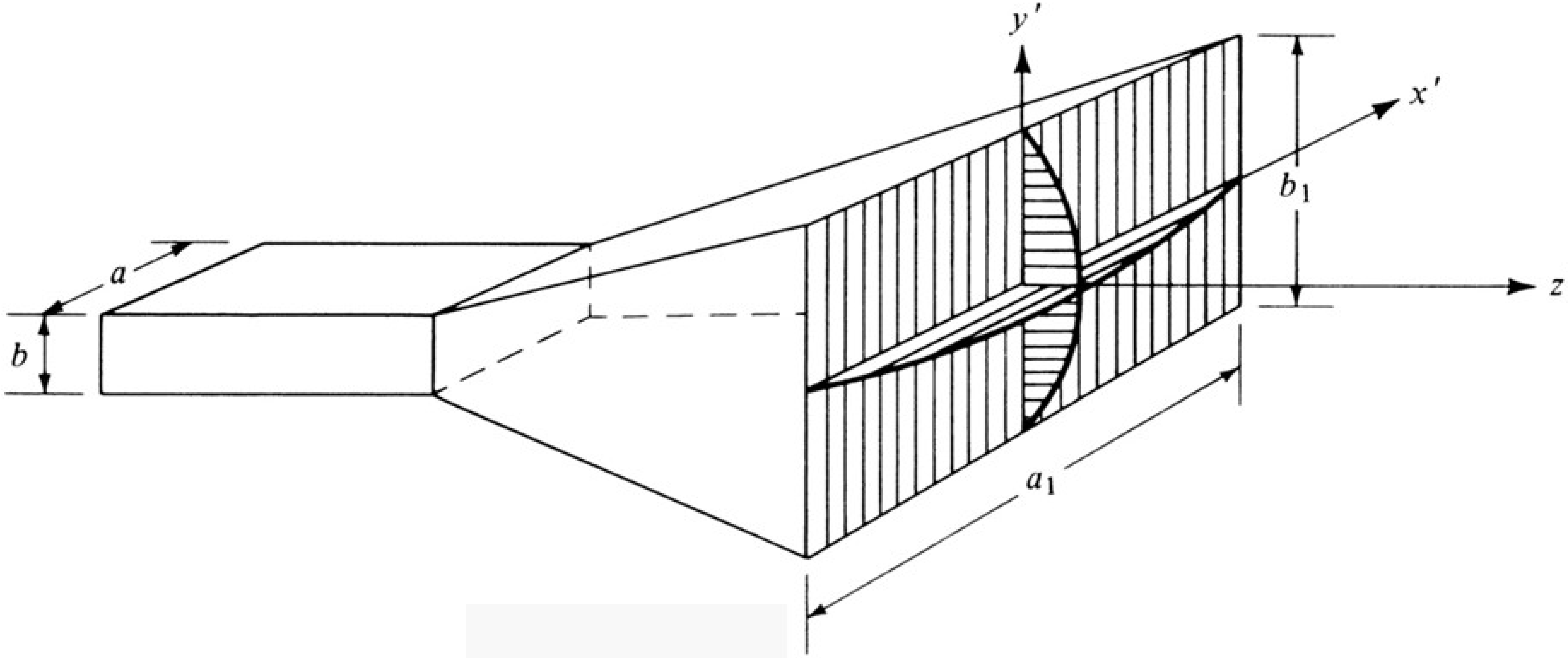
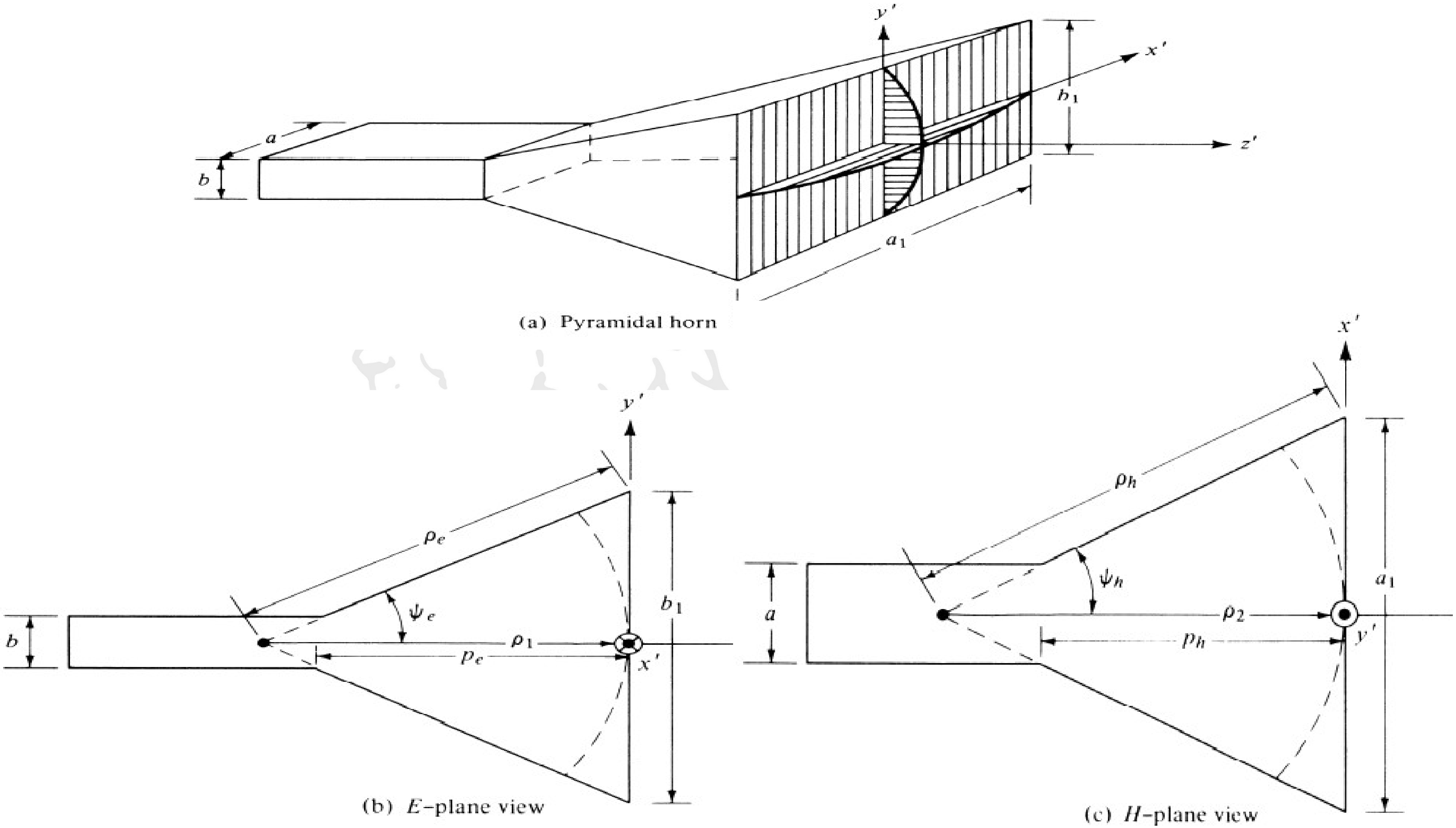


Fig. 13.16a

Pyramidal Horn Antenna

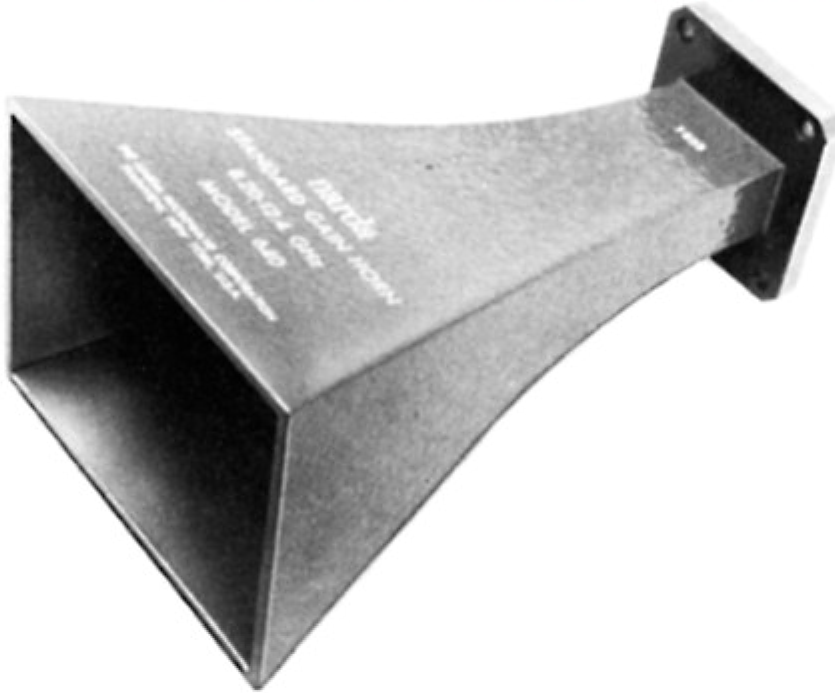


(a) Pyramidal horn

(b) E–plane view

(c) H–plane view

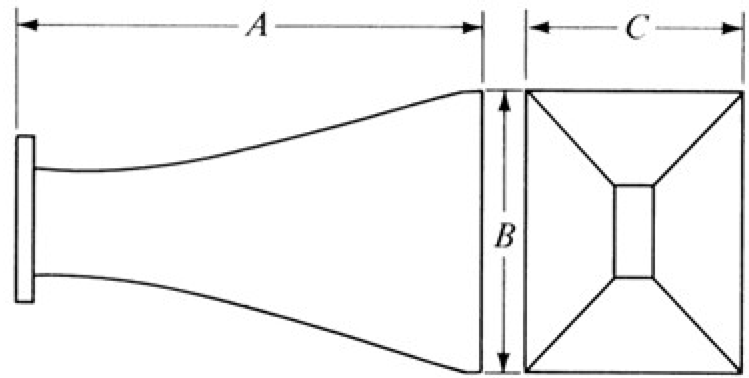
Typical Standard X-Band Pyramidal Horn



$A = 5\frac{1}{16}$ in. (12.86 cm)

$B = 3\frac{3}{32}$ in. (7.86 cm)

$C = 2\frac{11}{32}$ in. (5.95 cm)



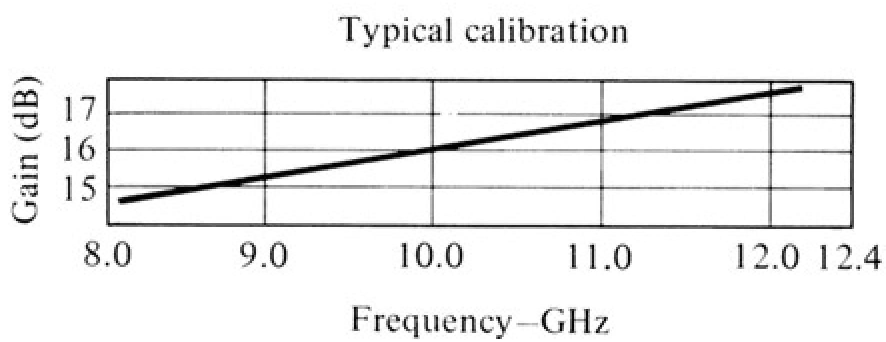


Fig. 13.22

Pyramidal Horn Design Steps

Step-1

$$\boxed{\left(\sqrt{2\chi}-\frac{b}{\lambda}\right)^2(2\chi-1)=\left(\frac{G_0}{2\pi}\sqrt{\frac{3}{2\pi}}\frac{1}{\sqrt{\chi}}-\frac{a}{\lambda}\right)^2\left(\frac{G_0^2}{6\pi^3}\frac{1}{\chi}-1\right)}$$

Step-2

$$\chi\,(\text{trial})=\chi_1=\frac{G_0}{2\pi\sqrt{2\pi}}$$

$\frac{\rho_e}{\lambda}=\chi$
$\frac{\rho_h}{\lambda}=\frac{G_0^2}{8\pi^3}\left(\frac{1}{\chi}\right)$

Step-3

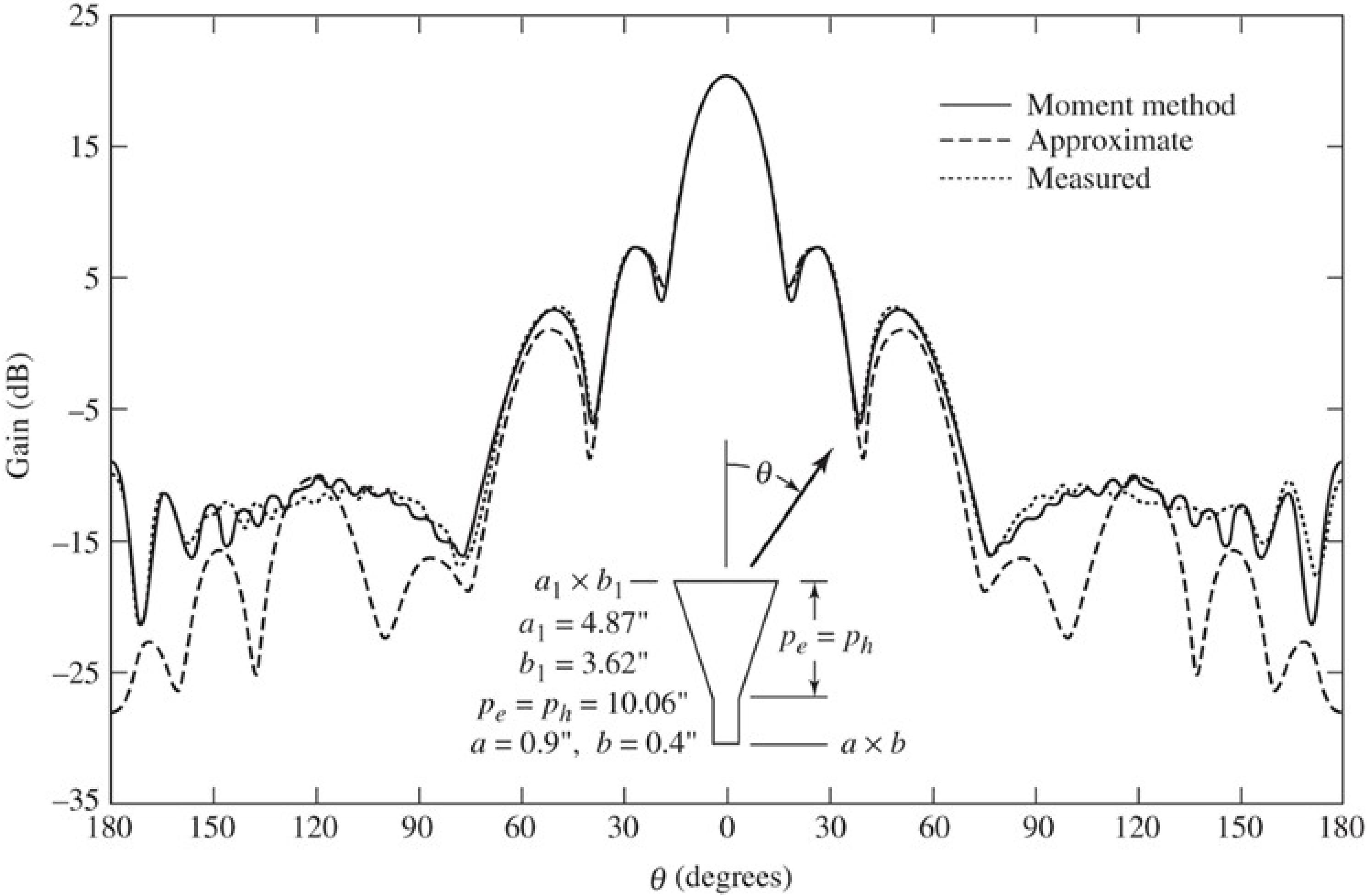
$$a_1=\sqrt{3\lambda\rho_2}\simeq\sqrt{3\lambda\rho_h}=\frac{G_0}{2\pi}\sqrt{\frac{3}{2\pi\chi}}\lambda$$

$$b_1=\sqrt{2\lambda\rho_1}\simeq\sqrt{2\lambda\rho_e}=\sqrt{2\chi\lambda}$$

Step-4

$$\rho e=\rho h$$

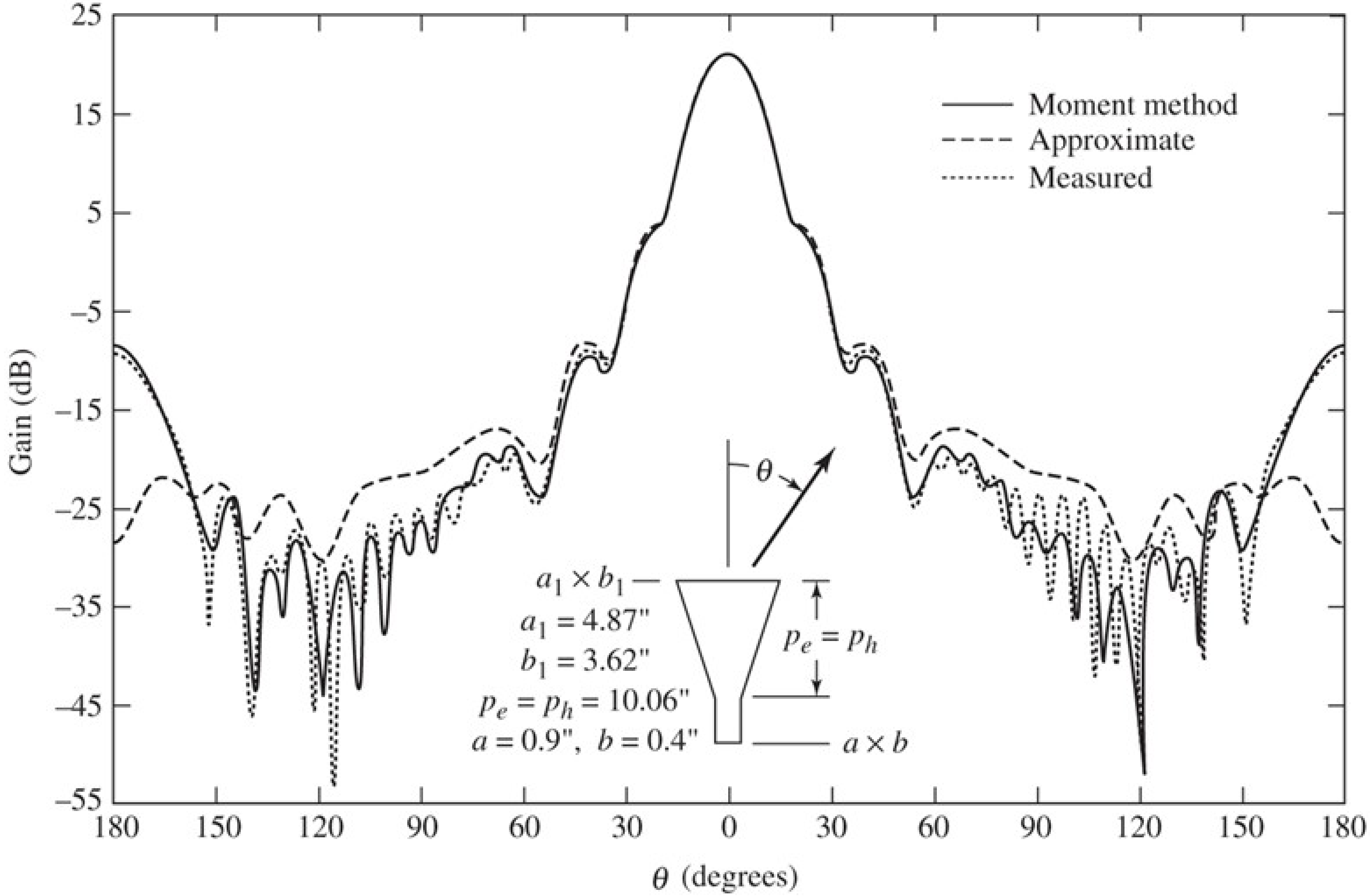
E-Plane: MoM, Approximate, Measured



(a) *E*-plane

Fig. 13.20a

H-Plane: MoM, Approximate, Measured



(b) *H*-plane

Fig. 13.20b

Conical Horn

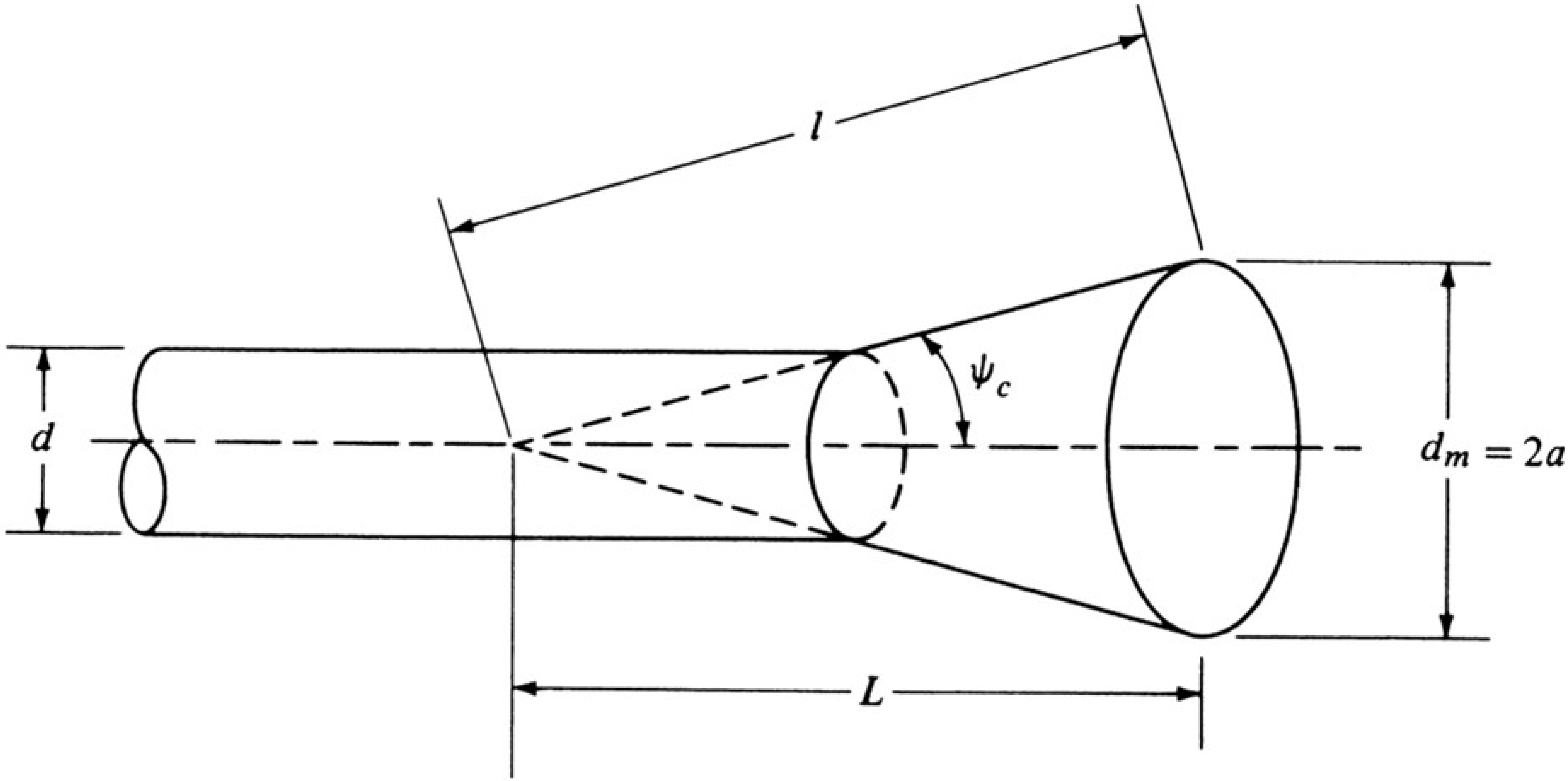
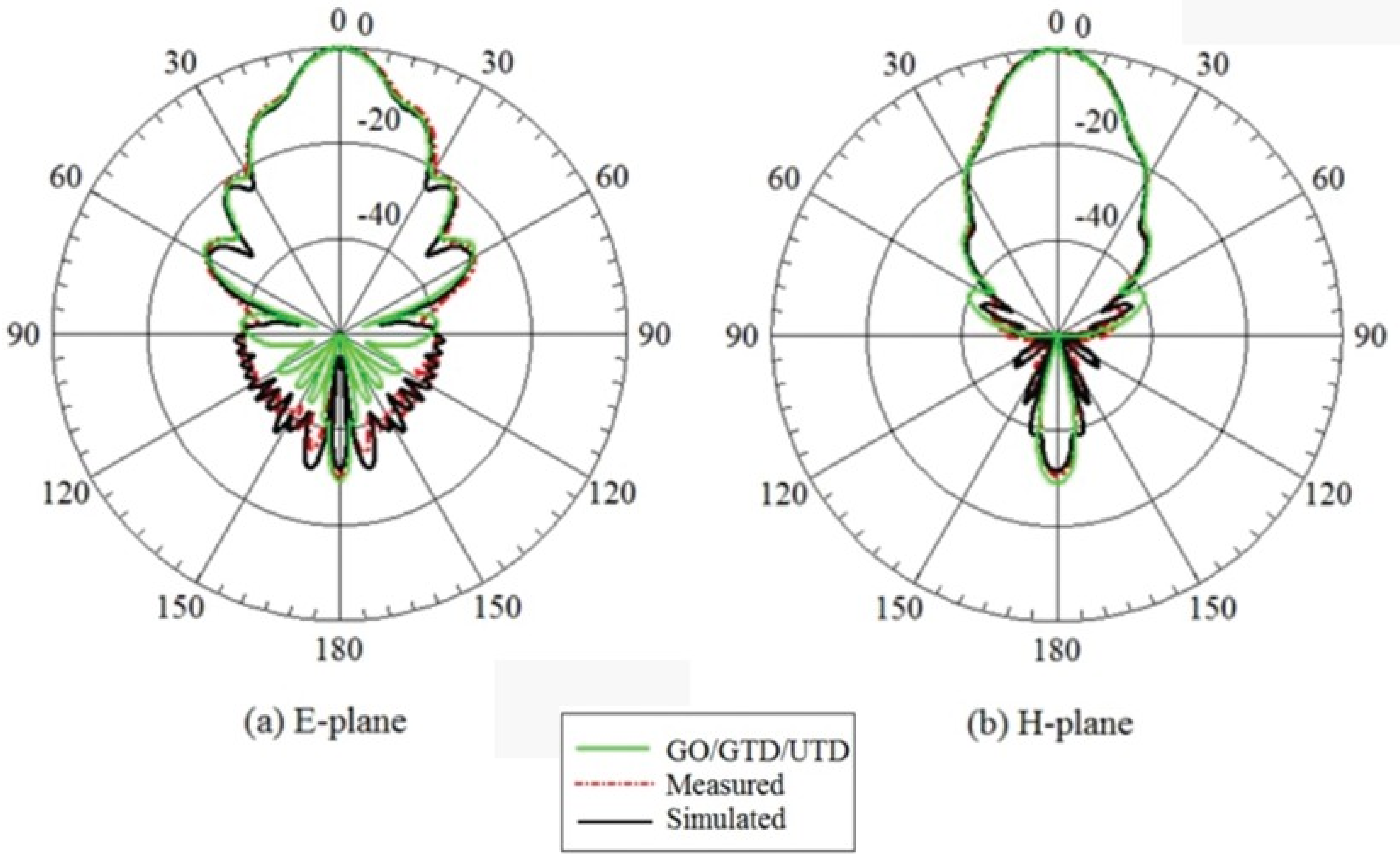


Fig. 13.24

Conical Horn

Fig. 13.25

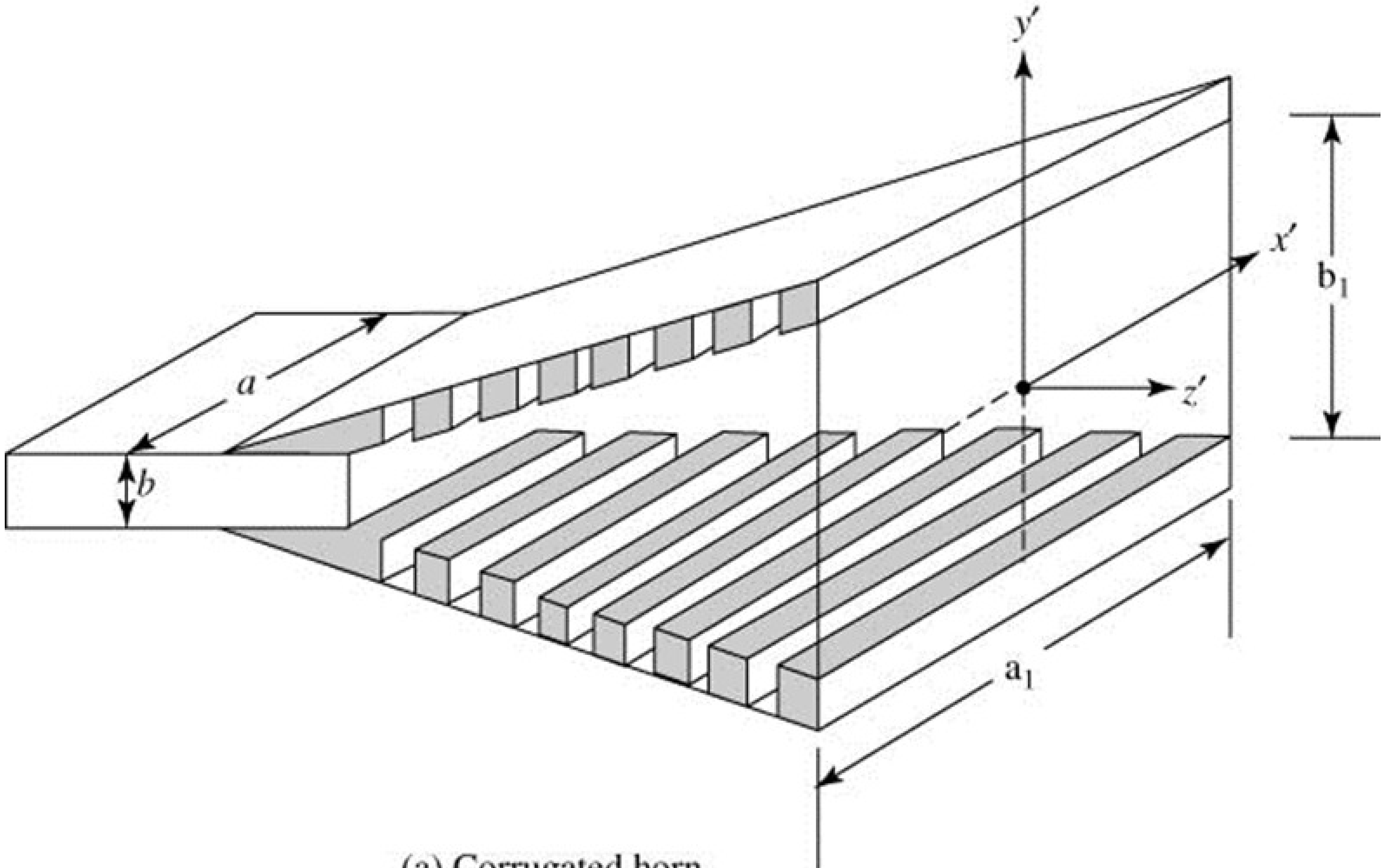


(a) E-plane

(b) H-plane

Fig. 13.28

Corrugated Horn



(a) Corrugated horn

Fig. 13.29a

Corrugated Conical Horn

Fig. 13.31

E-Plane Amplitude Pattern: (8.2λ x 8.2λ Horn)

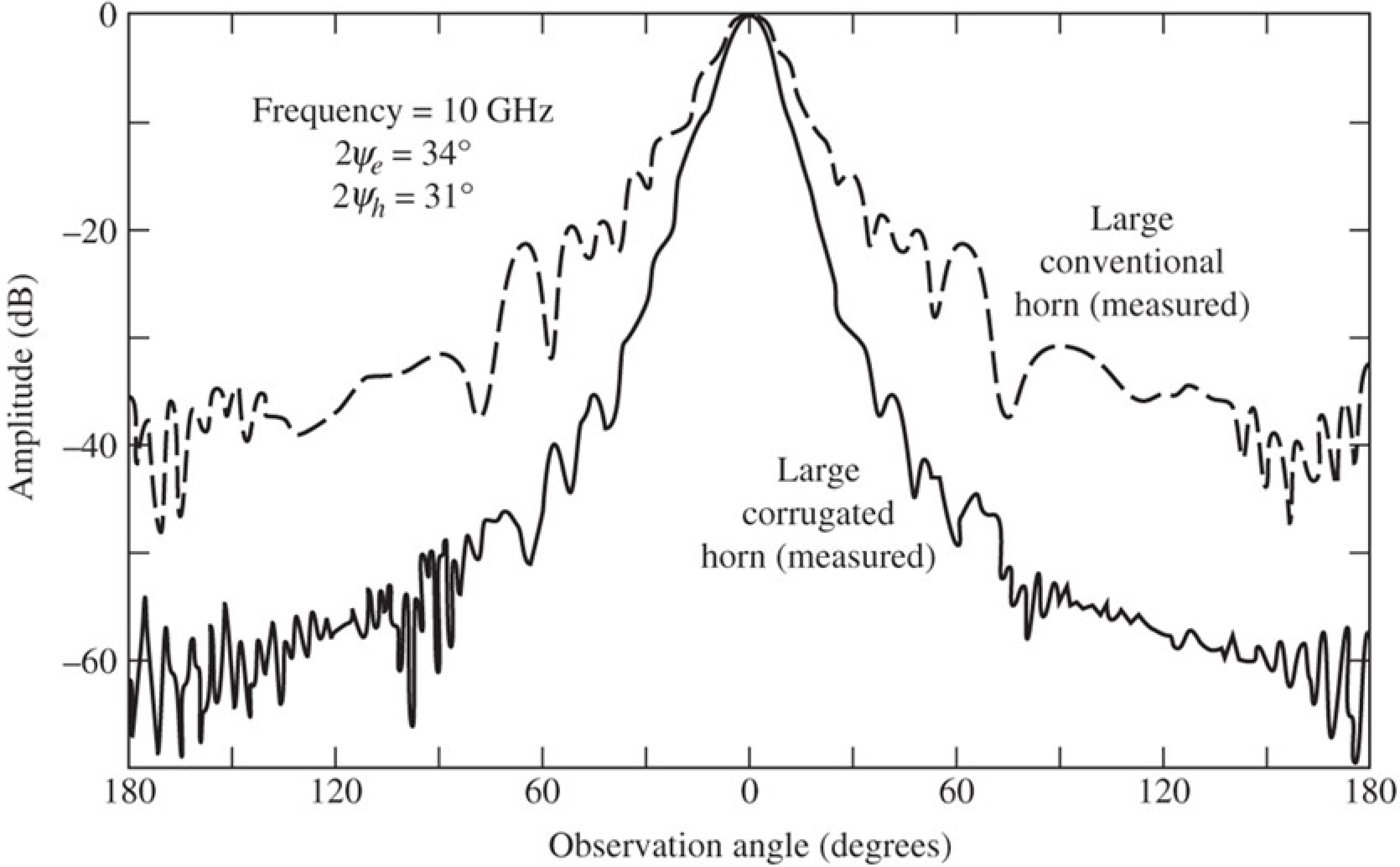


Fig. 13.32(b)

Thank You