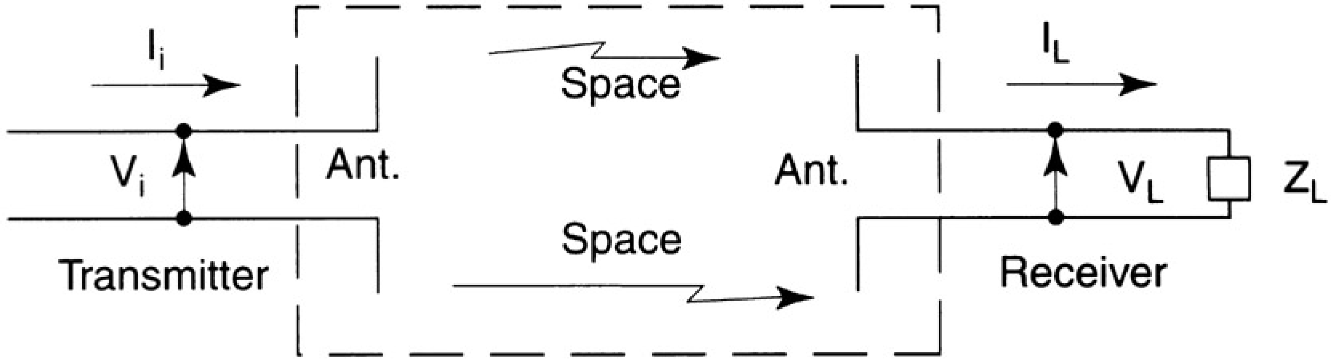
ANTENNA:

AN OVERVIEW

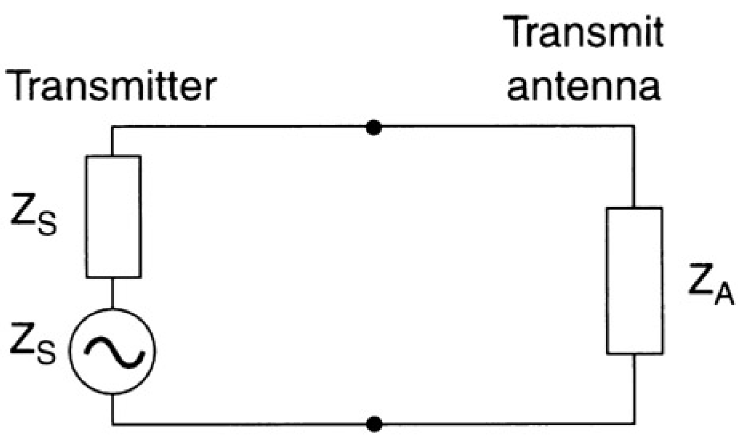
ANTENNA: METALLIC CONDUCTOR SYSTEM CAPABLE OF RADIATING & CAPTURING ELECTROMAGNETIC WAVES.
USED TO INTERFACE TRANSMISSION LINES TO FREE SPACE, FREE SPACE TO TRANSMISSION LINES, OR BOTH

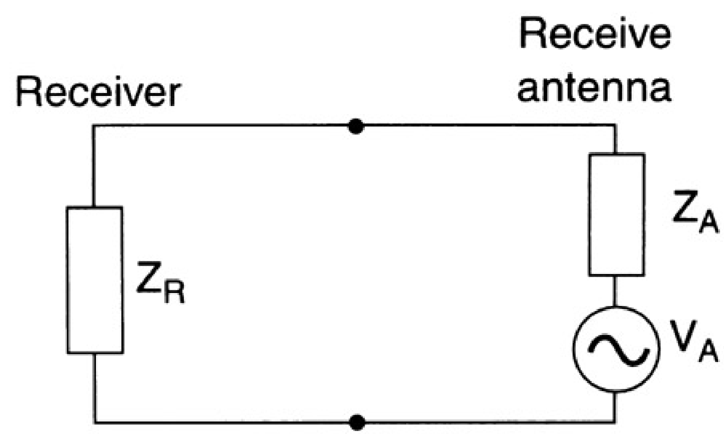
Some figures taken from Chapter 10 of W. Tomasi, *Electronic Communications Systems: Fundamentals through Advanced*, 4th Edition, Prentice-Hall, 2001.

CIRCUIT MODELS



ANTENNA AS A FOUR-TERMINAL NETWORK:



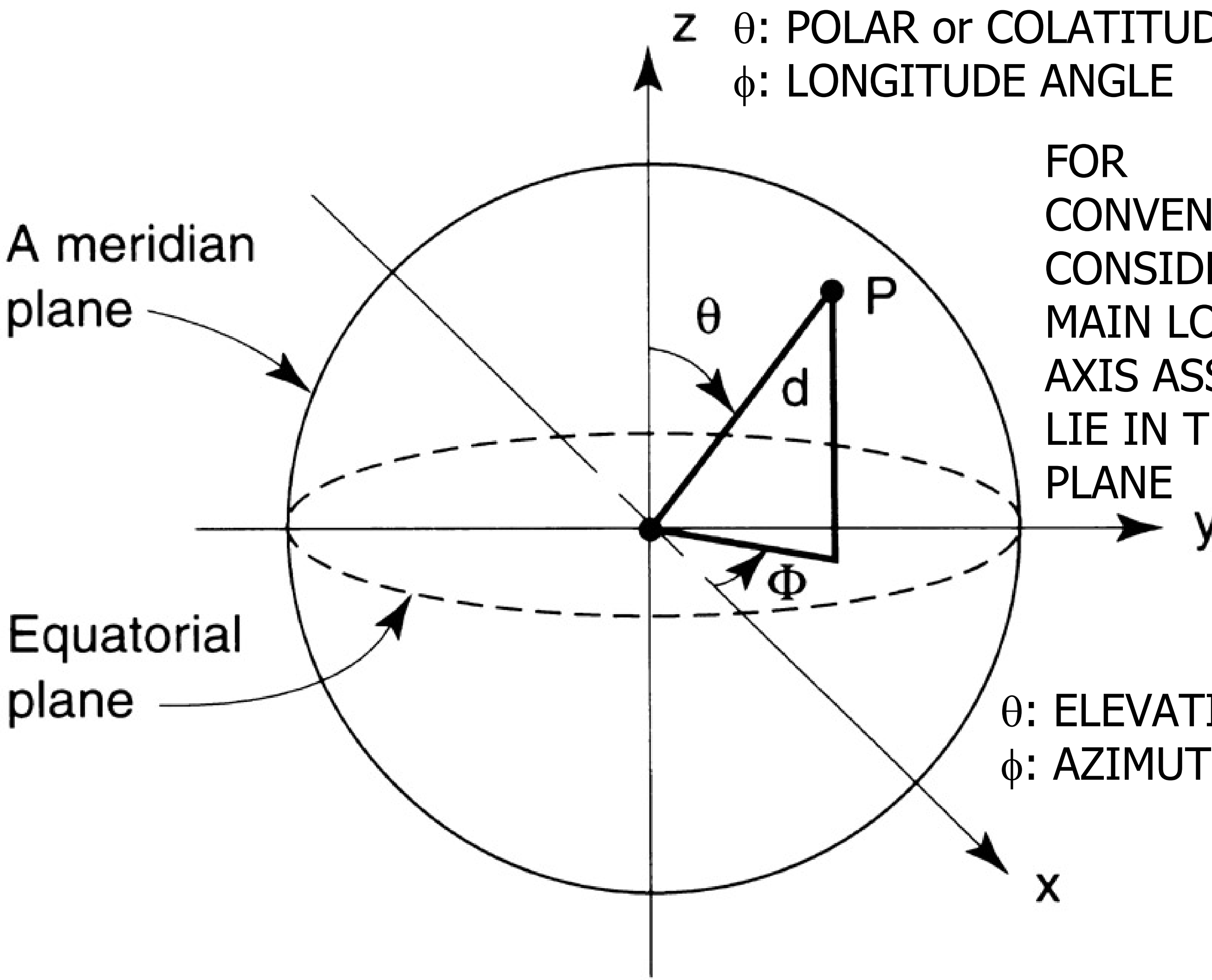


TRANSMIT ANTENNA
EQUIVALENT CIRCUIT

RECEIVE ANTENNA
EQUIVALENT CIRCUIT

SPHERICAL COORDINATES

θ: POLAR or COLATITUDE ANGLE
ϕ: LONGITUDE ANGLE

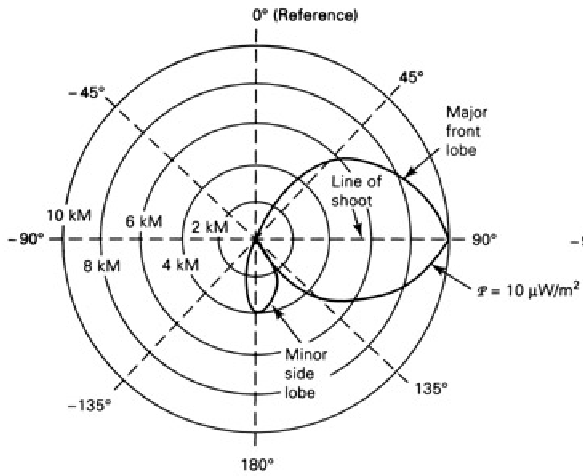


FOR CONVENIENCE, CONSIDER SINGLE MAIN LOBE WITH AXIS ASSUMED TO LIE IN THE xy-PLANE

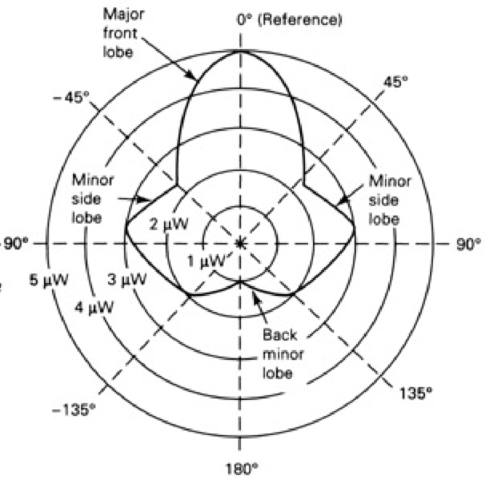
θ: ELEVATION ANGLE
ϕ: AZIMUTH ANGLE

RADIATION PATTERNS

absolute (fixed power) radiation pattern



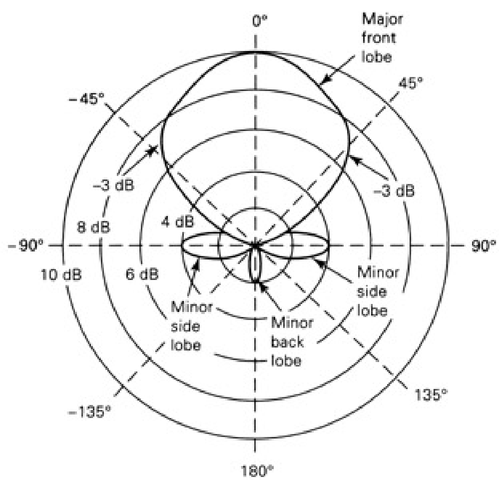
(a)



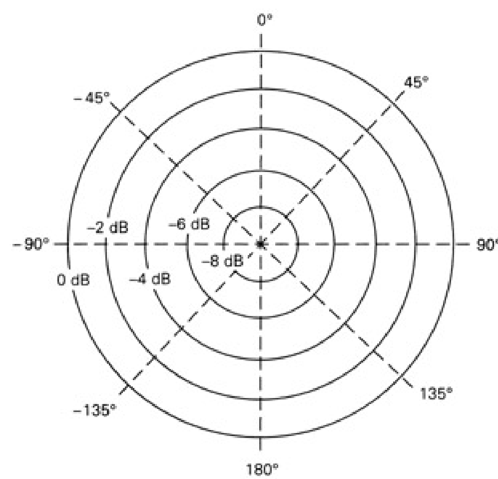
(b)

relative (fixed distance) radiation pattern

relative (fixed distance) radiation pattern in decibels



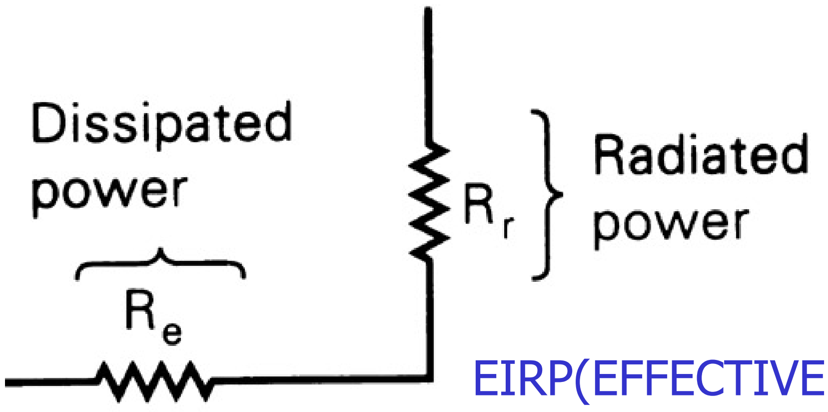
(c)



(d)

relative (fixed distance) radiation pattern in decibels for an omnidirectional (point source) antenna

SIMPLIFIED EQUIVALENT CIRCUIT OF AN ANTENNA



RF POWER TO ANTENNA:

$P_{RF(IN)}=P_D+P_R$

ANTENNA EFFICIENCY:

$\eta=P_R/P_{RF(IN)}=R_f/(R_f+R_e)$

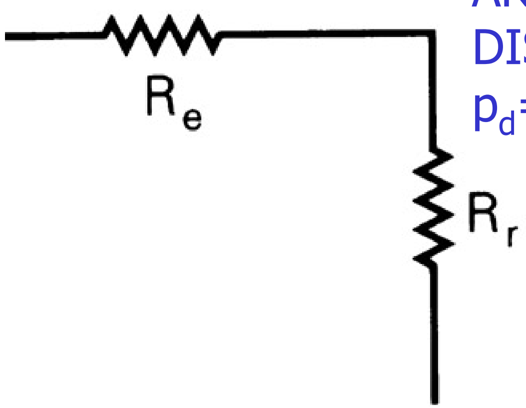
ANT **DIRECTIVITY** GAIN:

$D=P/P_{REF}$,

P_{REF} : POWER OF A REFERENCE (ISOTROPIC) ANTENNA

ANT **POWER** GAIN:

$G_{ANT}=\eta D$



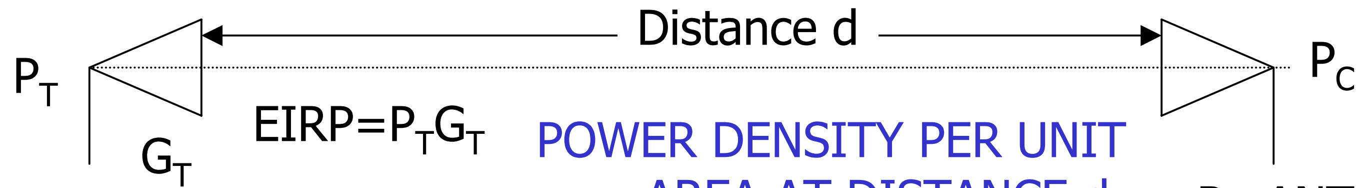
EIRP(EFFECTIVE ISOTROPIC RADIATED POWER)

$EIRP=P_R D=P_{RF(IN)}G_{ANT}$

POWER DENSITY PER UNIT AREA AT A POINT WITH DISTANCE d FROM ANT:

$p_d=(EIRP)/(4\pi d^2)$

CAPTURE AREA & CAPTURED POWER



Tx POWER P_T
Tx ANT POWER GAIN G_T

POWER DENSITY PER UNIT AREA AT DISTANCE d: $p_d=(P_TG_T)/(4\pi d^2)$

Rx ANT POWER GAIN G_R
Rx (CAPTURED) POWER P_C

p_d : AMOUNT OF POWER INCIDENT ON EACH UNIT AREA OF AN IMAGINARY SURFACE (PERPENDICULAR TO THE DIRECTION OF PROPAGATION OF THE ELECTROMAGNETIC WAVE).

EFFECTIVE CAPTURE AREA OF THE Rx ANTENNA: $A_C=(G_R\lambda^2)/(4\pi)$

where $\lambda=c/f$: wavelength

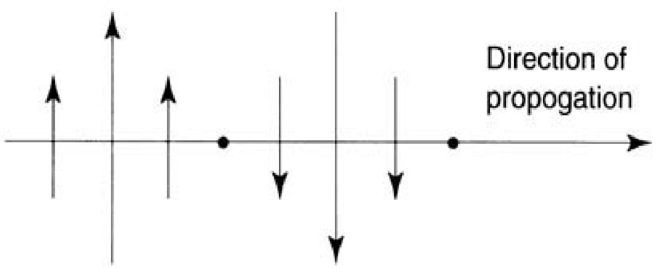
Rx CAPTURED POWER: $P_C=A_C\, p_C=(G_RP_TG_T\lambda^2)/(4\pi d)^2=P_T(G_TG_R)/(4\pi df/c)^2$

FREE-SPACE LOSS: $L_{FREE-SPACE}=(4\pi df/c)^2$

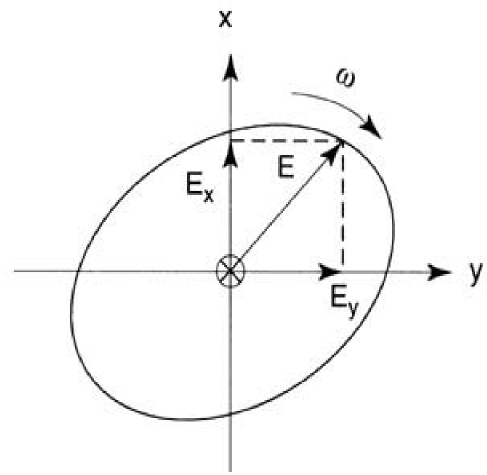
$P_{C,dBm}=P_{T,dBm}+(G_{T,dB}+G_{R,dB})-L_{FS,\,dB}$

$L_{FS,\,dB}=10\log_{10}(L_{FREE-SPACE})=92.44+20\log_{10}(f_{GHz})+20\log_{10}(d_{km})$

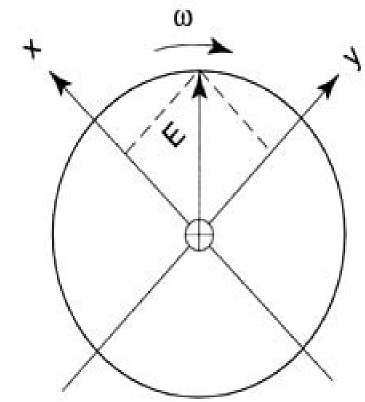
ANTENNA POLARIZATION



(a) linear

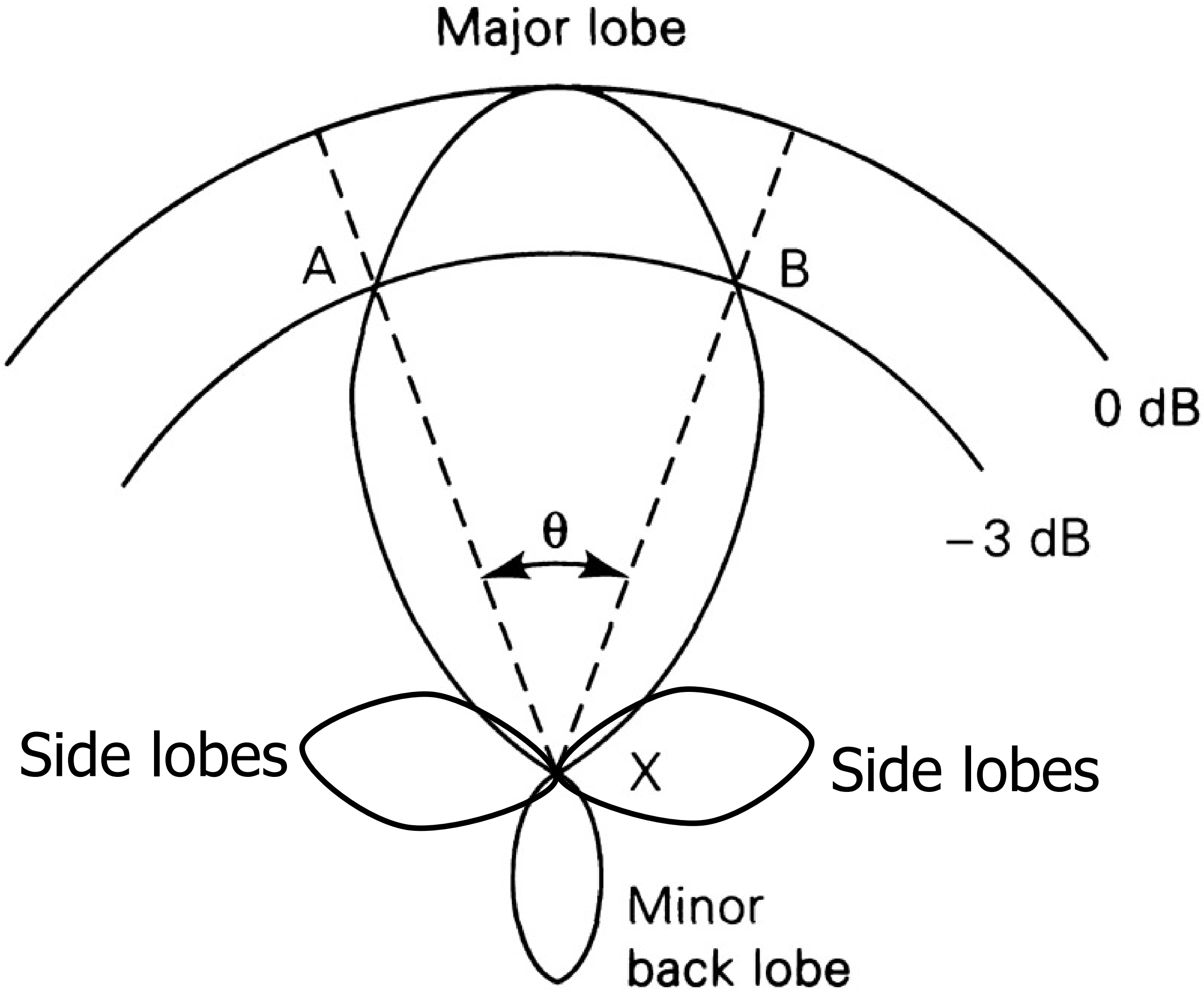


(b) elliptical polarization

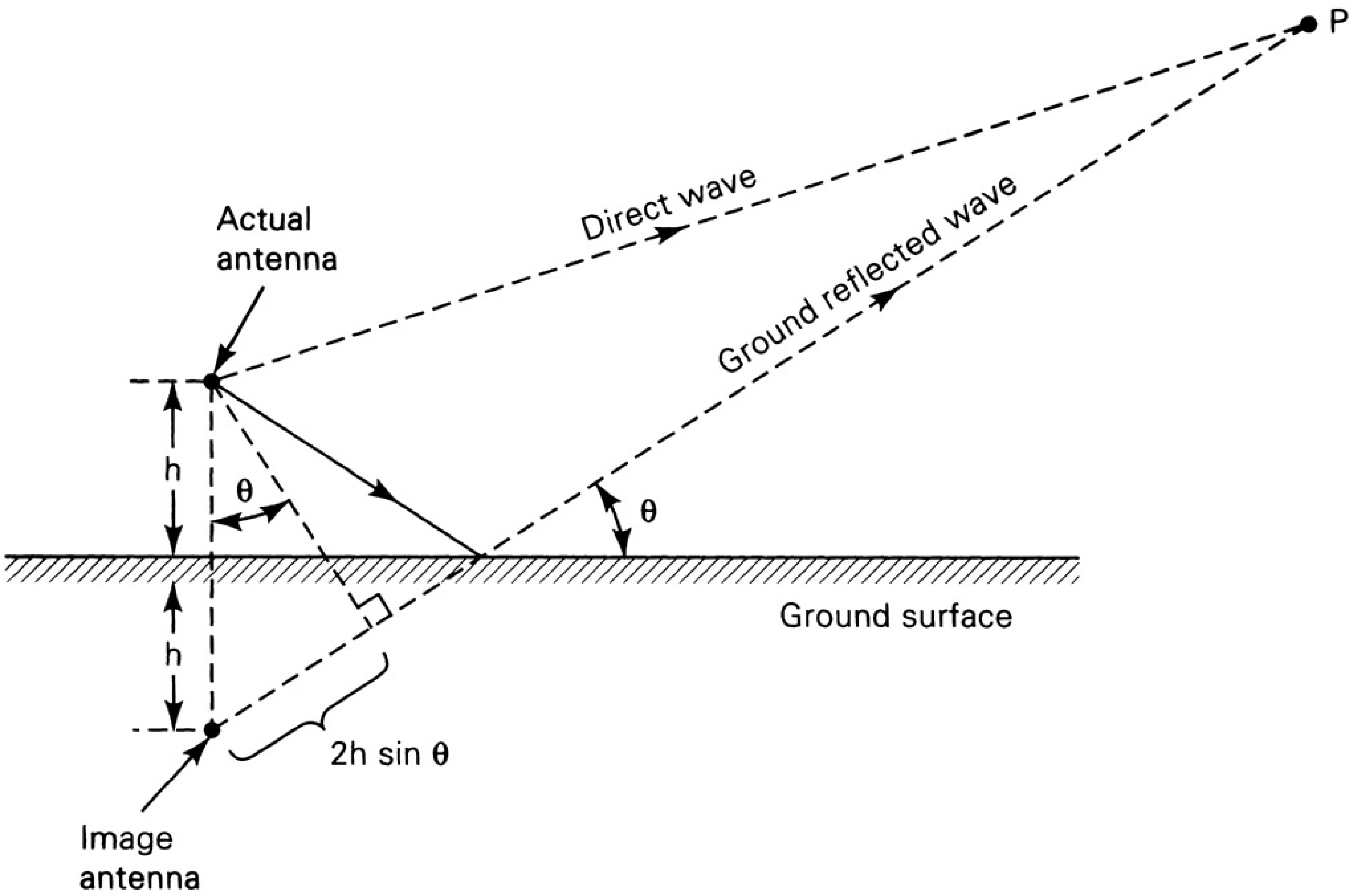


(c) circular polarization

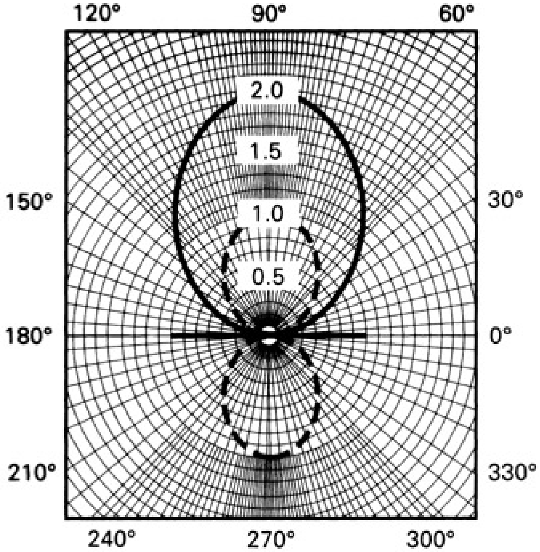
ANTENNA BEAMWIDTH

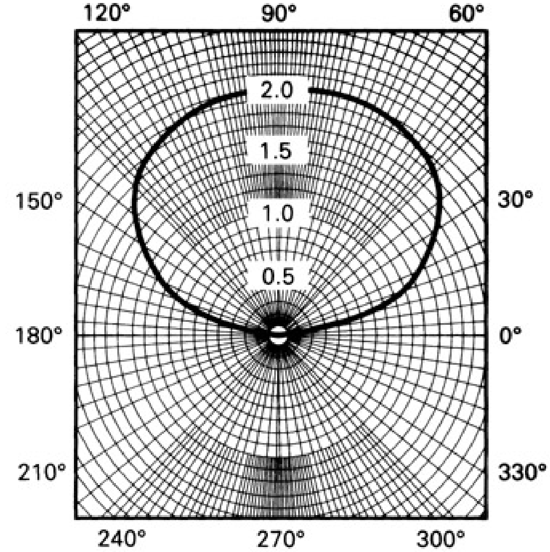


GROUND EFFECTS ON A HALF-WAVE DIPOLE



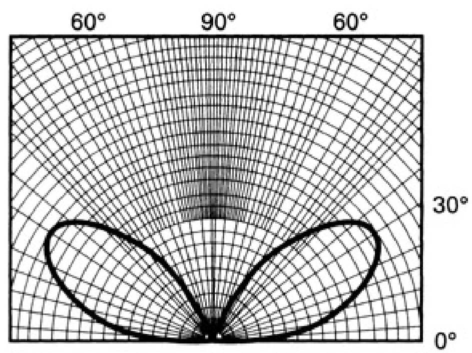
VERTICAL RADIATION PATTERN FOR A HORIZONTALLY MOUNTED HALF-WAVE DIPOLE





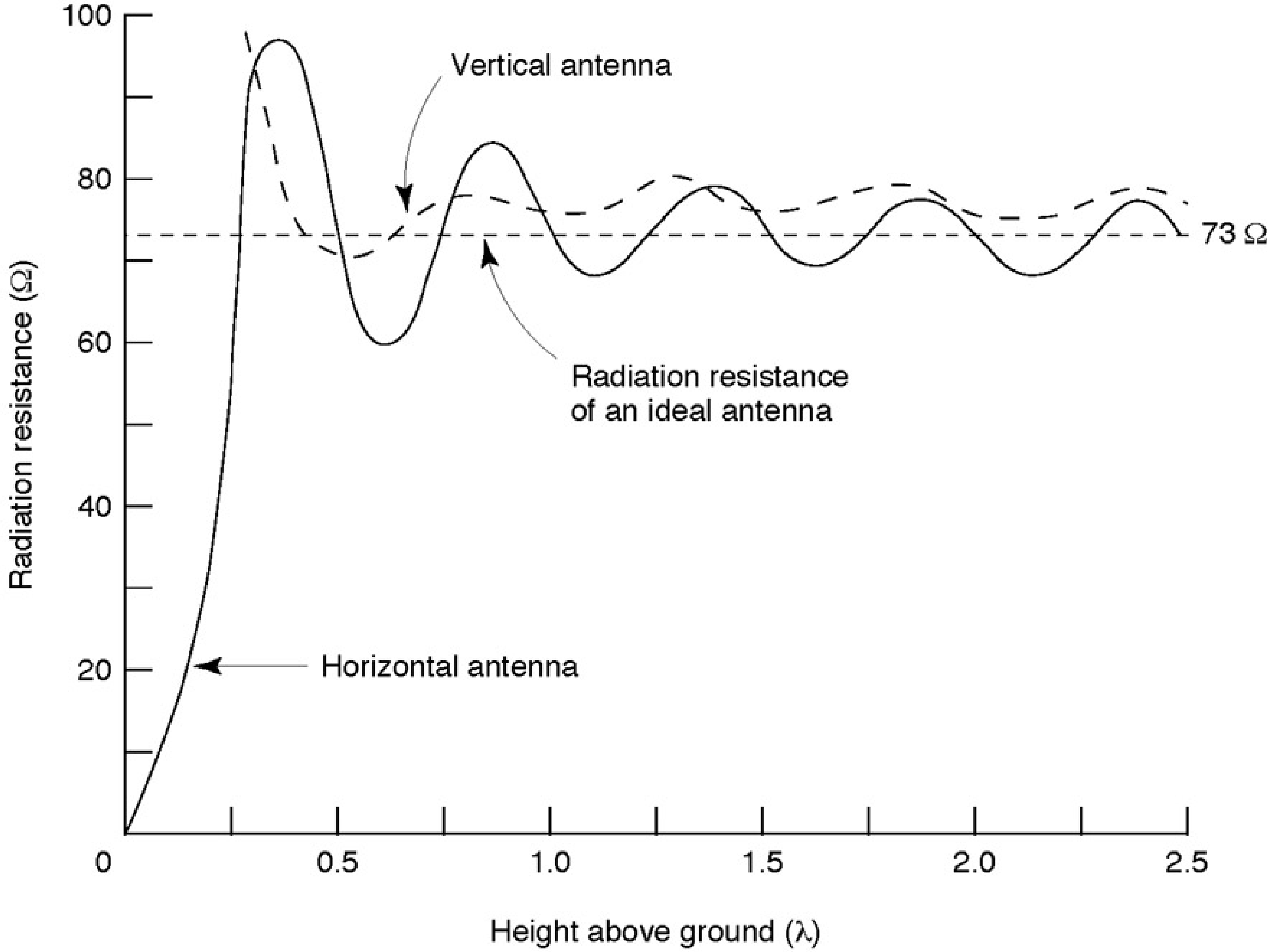
(a,b) **¼** wavelength above ground

(a) In a plane through antenna (b) in a plane at right angles to antenna



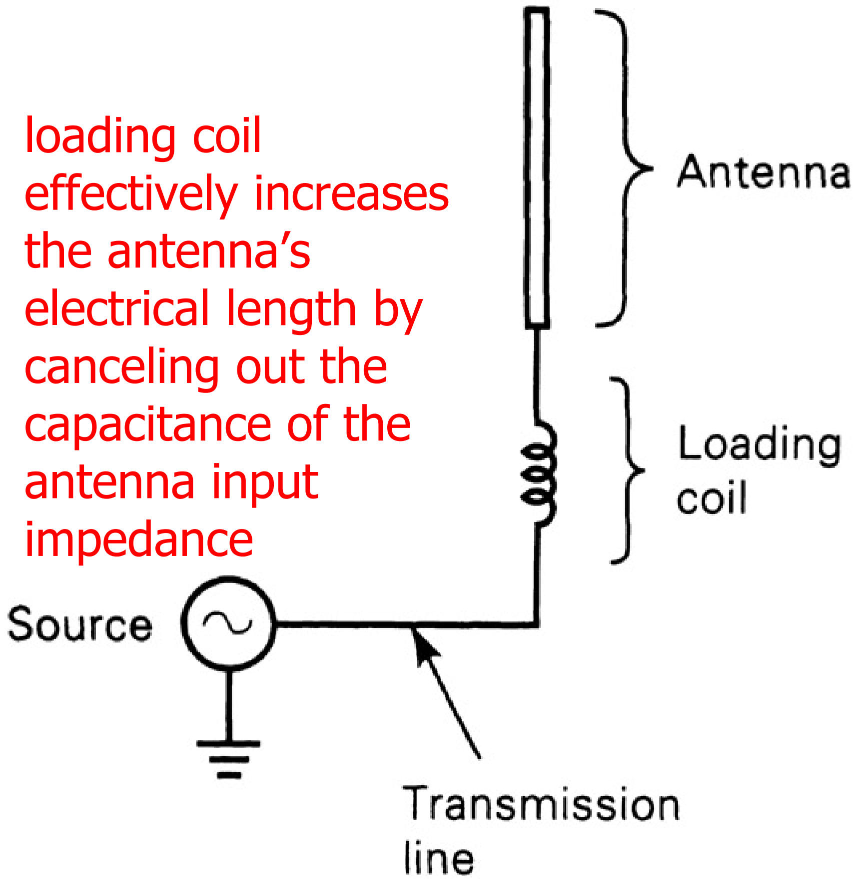
(c) **½** wavelength above ground

RADIATION RESISTANCE VERSUS HEIGHT ABOVE GROUND

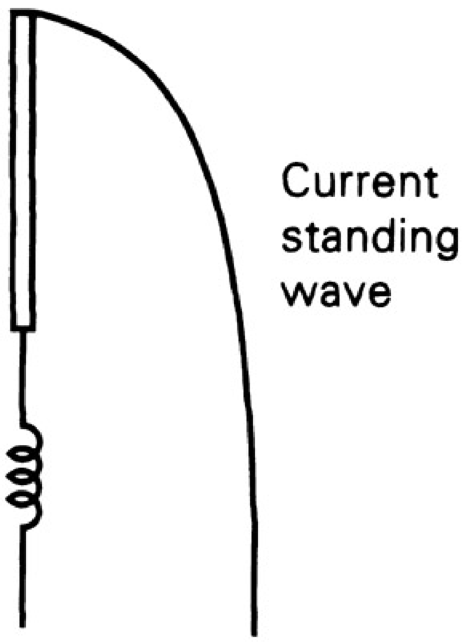


LOADING COIL

loading coil effectively increases the antenna's electrical length by canceling out the capacitance of the antenna input impedance

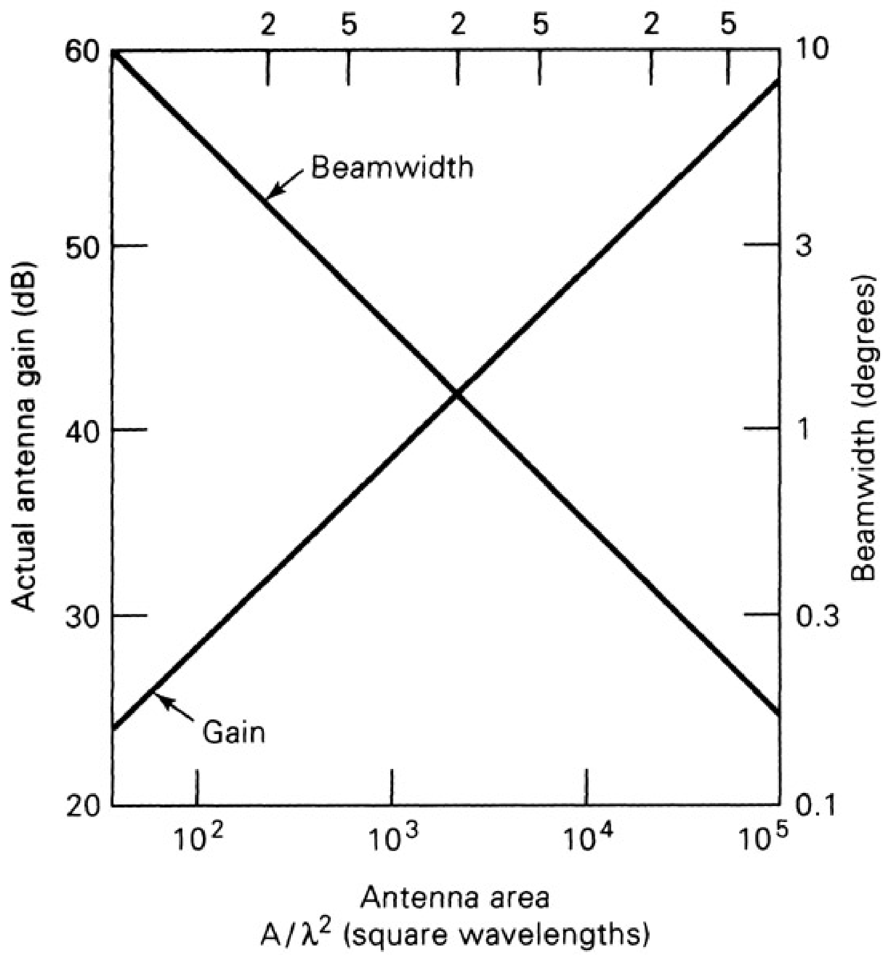


(a) antenna with loading coil

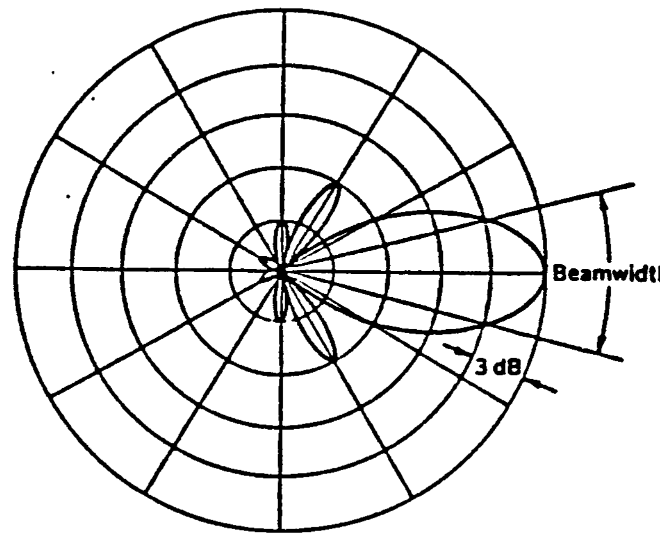


(b) current standing wave with loading coil

ANTENNA POWER GAIN AND BEAMWIDTH RELATIONSHIP



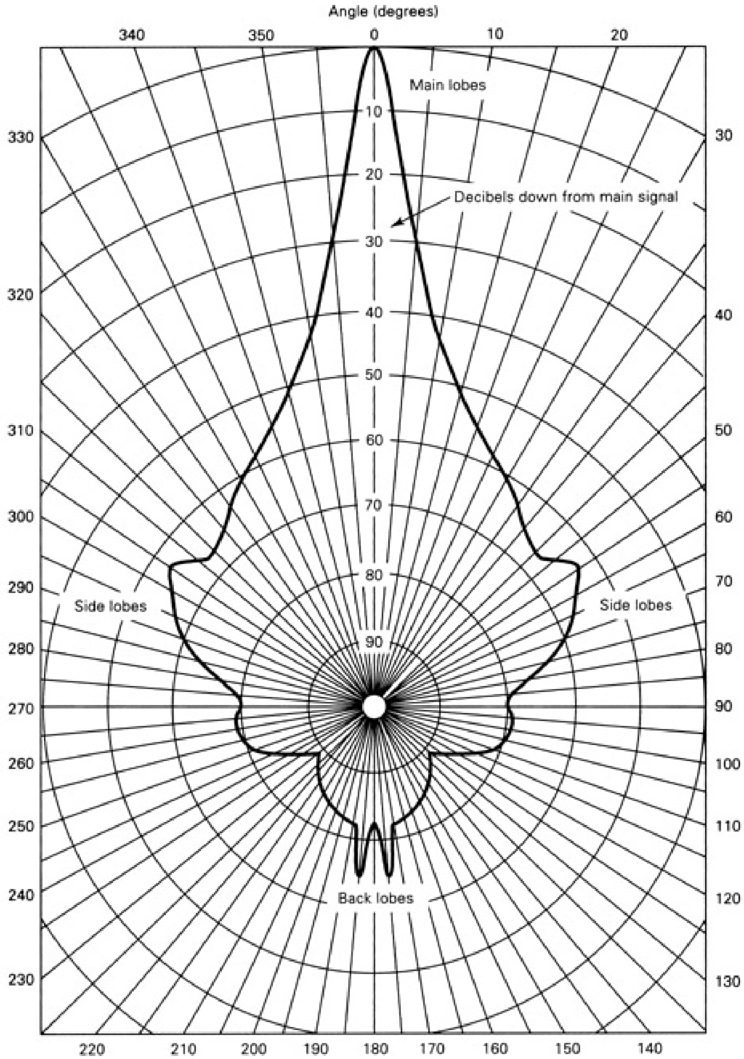
Note: Abscissa is actual antenna area, and actual antenna gain is taken to be 3 dB below theoretical.



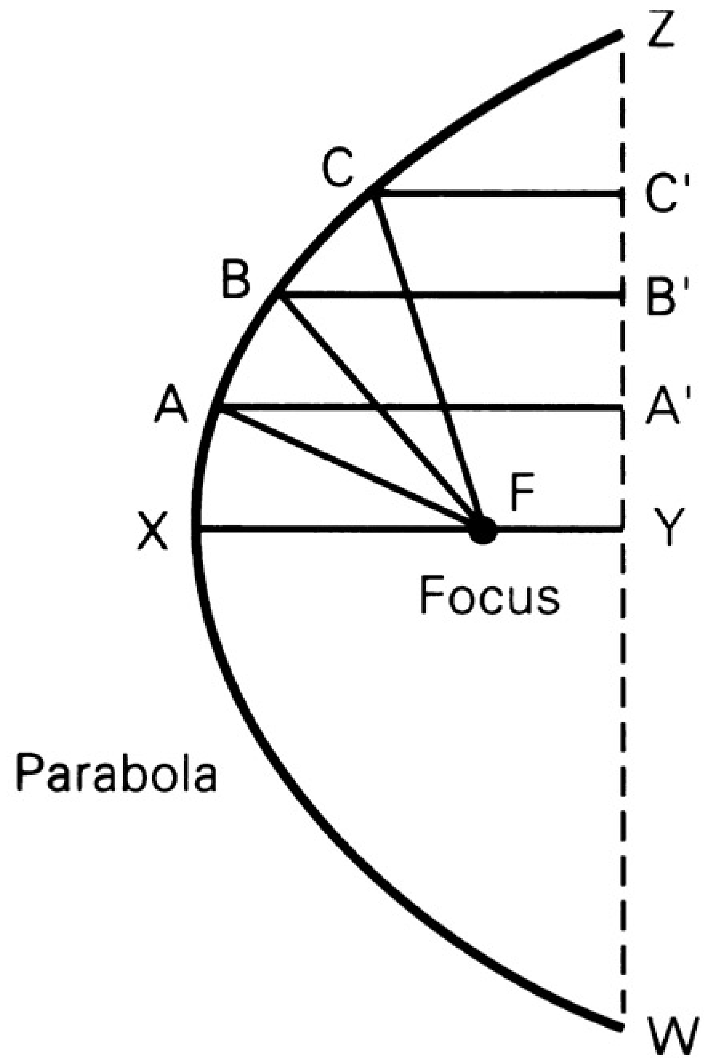
$$G = \frac{4\pi A}{\lambda^2}$$

$$\theta = \frac{142^\circ}{\sqrt{G}}$$

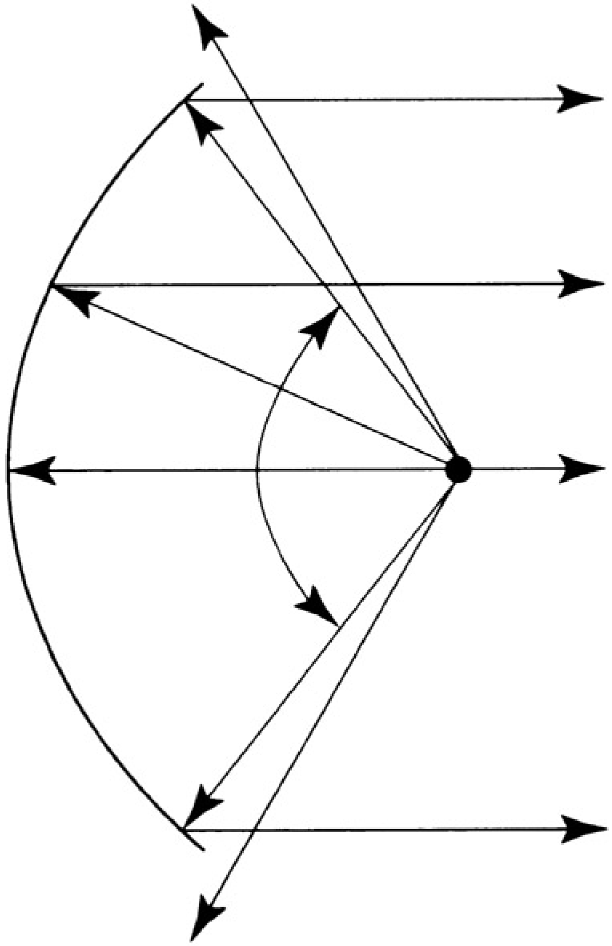
MAIN BEAM AND SIDE LOBES FOR A TYPICAL PARABOLIC ANTENNA



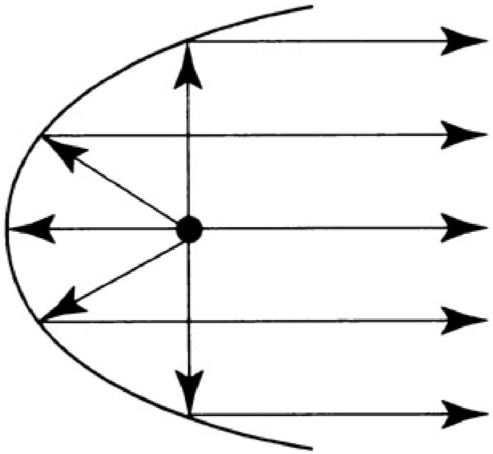
GEOMETRY OF A PARABOLA



RADIATION DIRECTIONS FOR PARABOLIC REFLECTORS

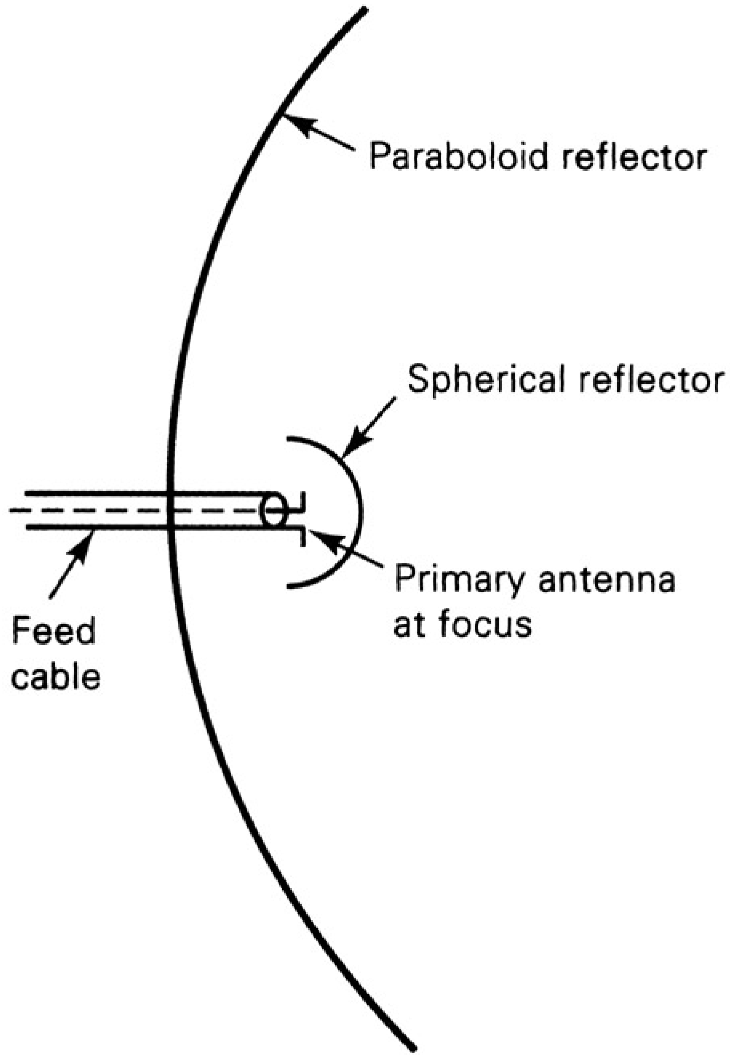


(a) focal point outside the reflector

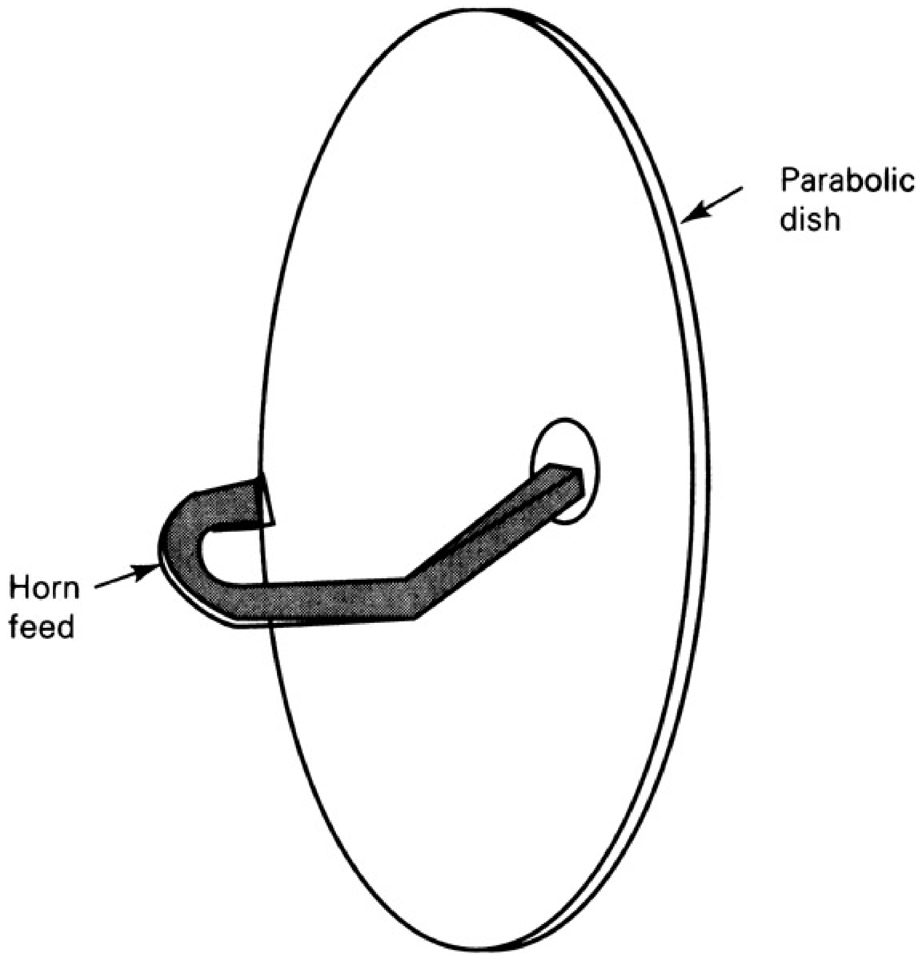


(b) focal point inside the reflector

PARABOLIC ANTENNA WITH A CENTER FEED

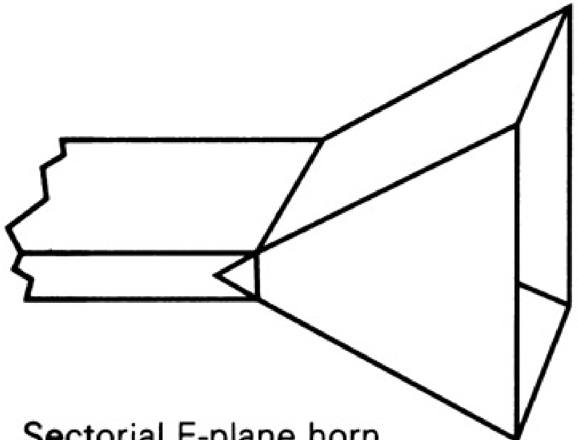


PARABOLIC ANTENNA WITH A HORN FEED

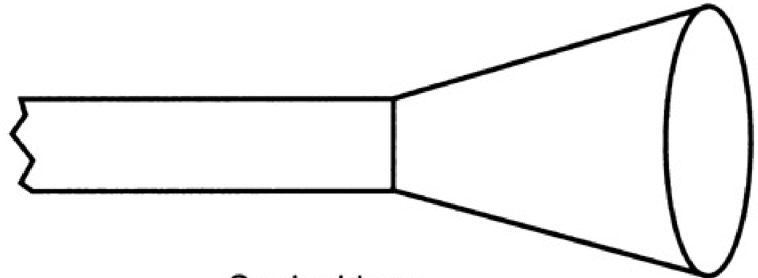


(a)

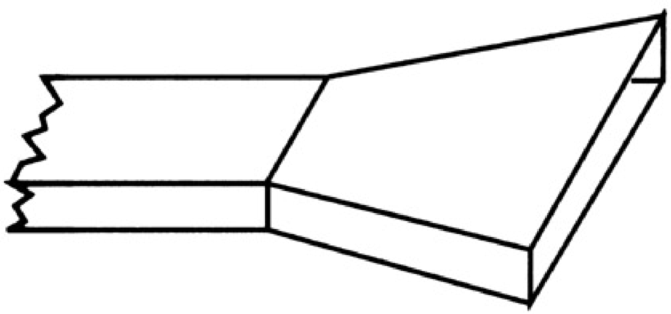
PARABOLIC ANTENNA WITH A HORN FEED: WAVEGUIDE HORN TYPES



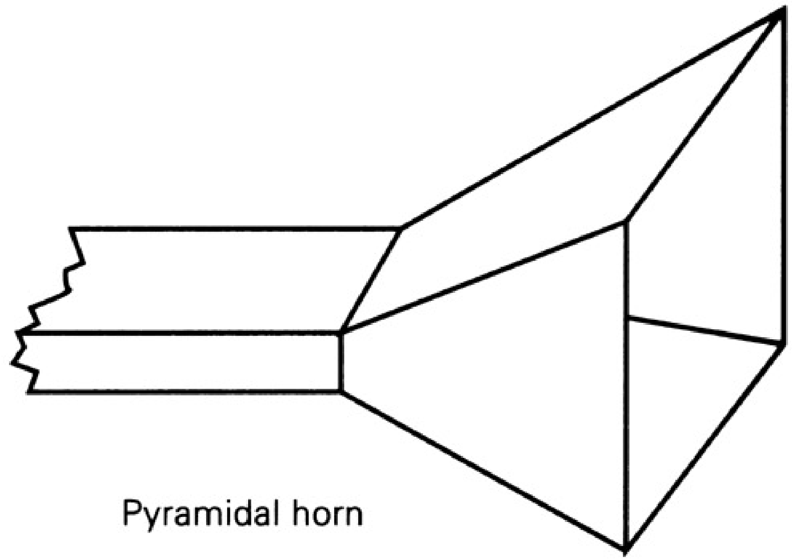
Sectorial E-plane horn



Conical horn

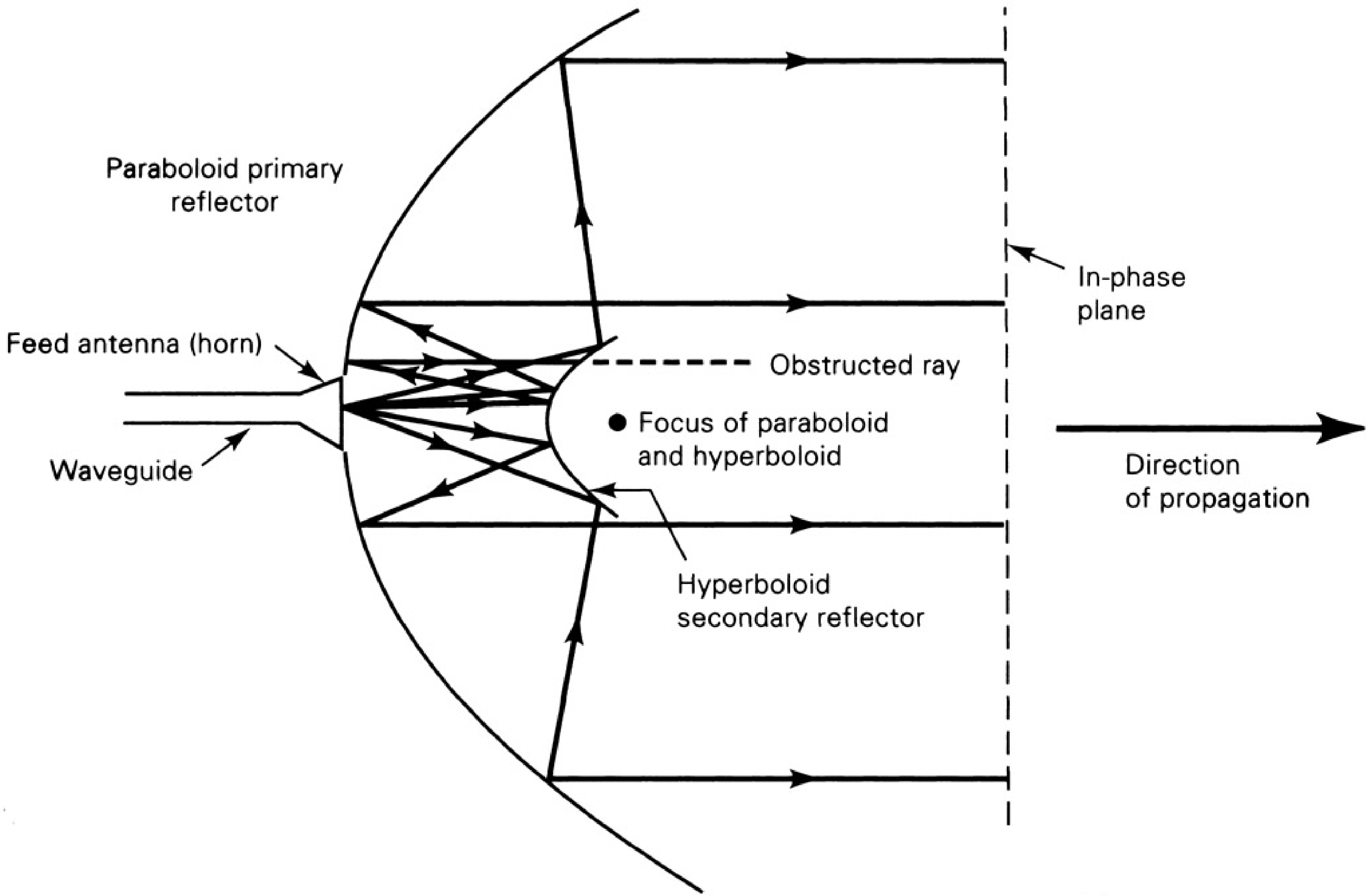


Sectorial H-plane horn

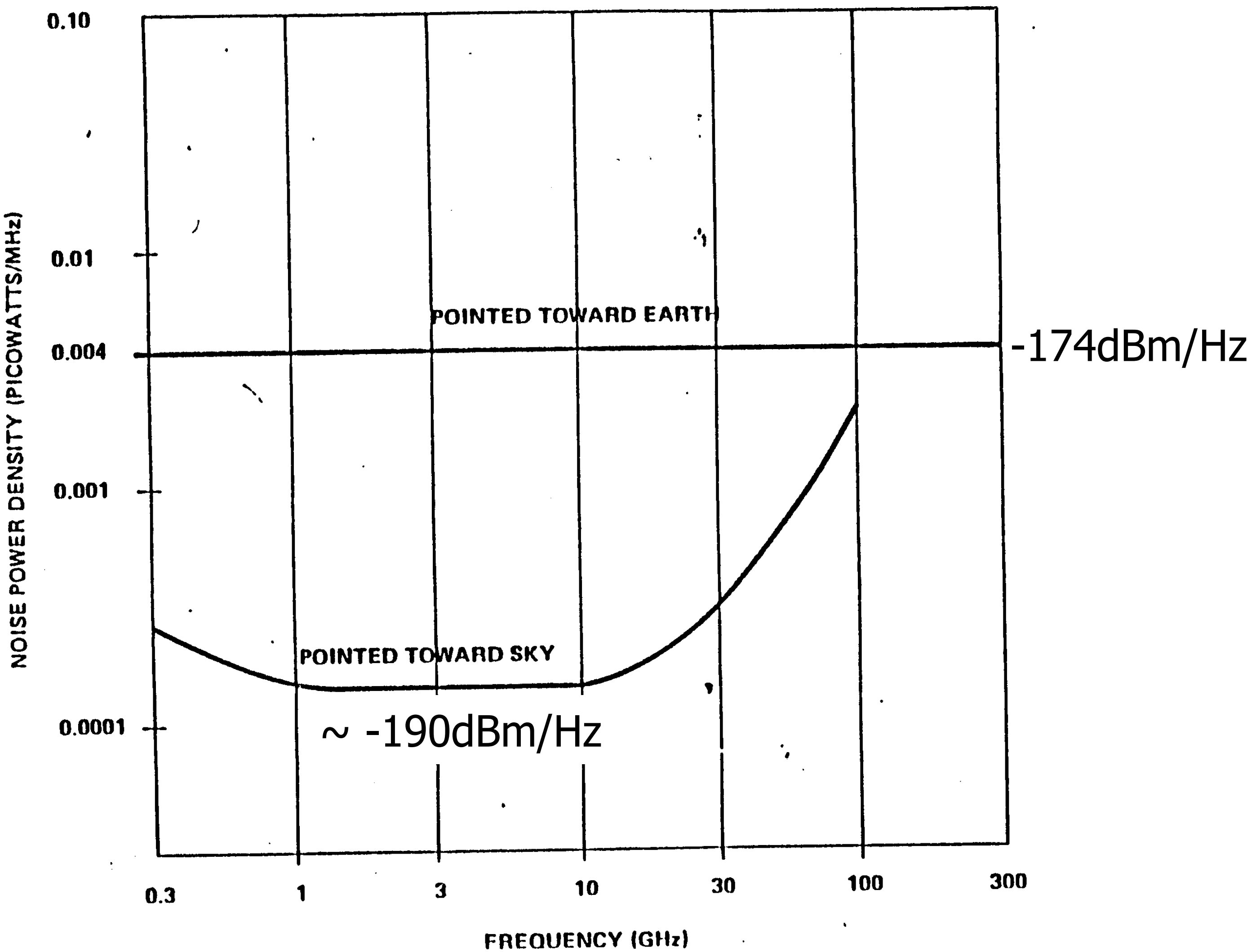


Pyramidal horn

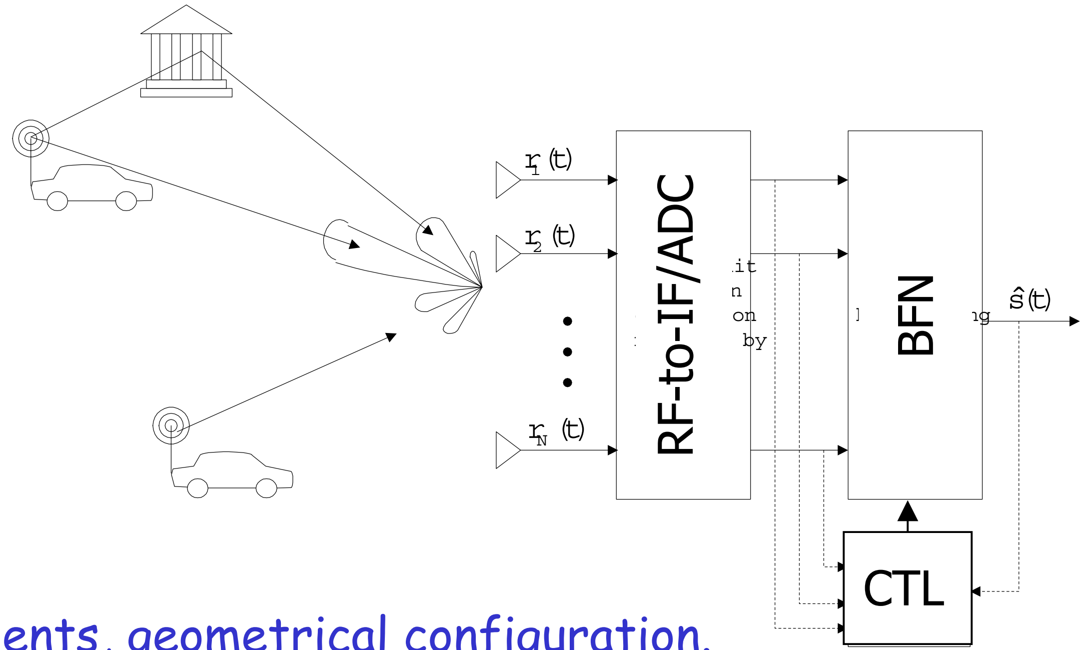
PARABOLIC ANTENNA WITH A CASSEGRAIN FEED



ANTENNA NOISE

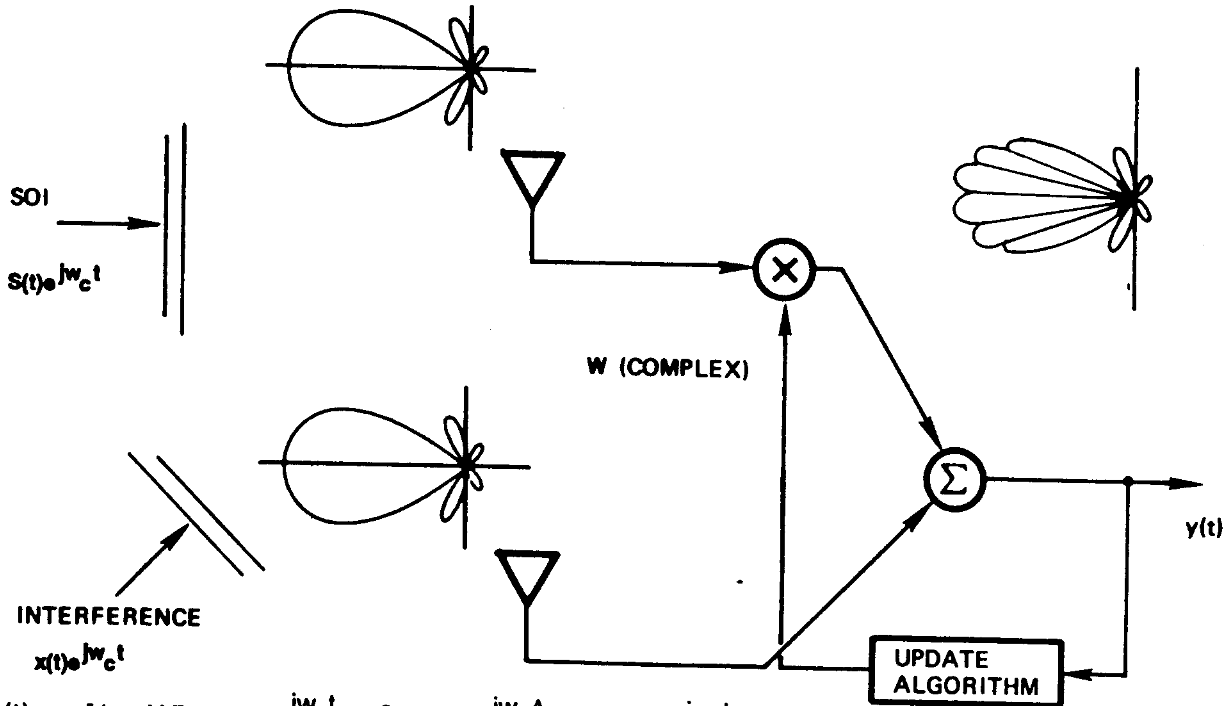


Smart Antenna Principles



- Smart antenna (SA) systems can be used for Rx and Tx.
- They exploit the spatial dimension via spatial sampling and coherent processing of the EM wave field.
- Four main system components (Rx mode):
  - Antenna array: N elements, geometrical configuration.
  - Radio unit: RF down-conversion, A/D conversion.
  - Beam-forming (BF) network (BFN): signal weighting followed by summation.
  - Control unit: adjusts BF weight to achieve desired spatial response.
- Ideally, a set of weights is maintained and updated for each individual mobile user.
- SA can adapt to current radio conditions and tailor individual user beam-patterns so as to maximize SIR:
  - Communication link continually optimized.

EXAMPLE OF BEAMFORMING TO IMPROVE SIR



$$y(t) = [1 + W]\, s(t)\, e^{jw_c t} + [1 + We^{jw_c \Delta}]\, x(t)\, e^{jw_c t}$$

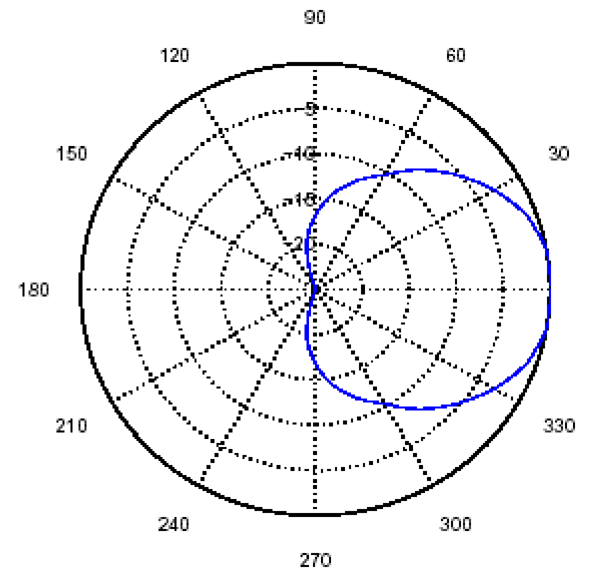
assuming $x(t - \Delta) \approx x(t)$

where Δ = propagation delay between antennas

Choose W to maximize SINR $\approx \dfrac{1 + W}{1 + We^{jw_c \Delta}}$

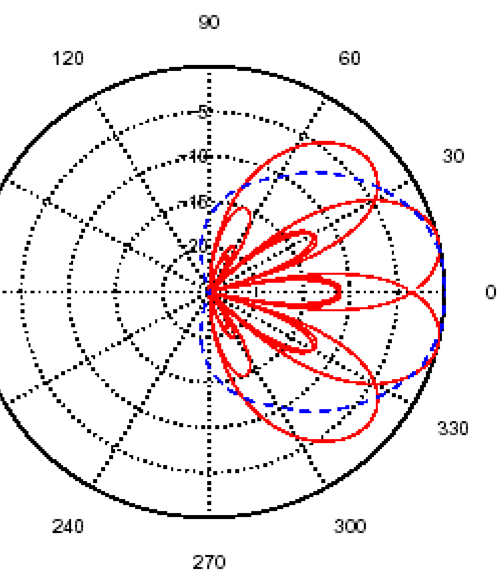
examples of beamforming antenna patterns

sector antenna

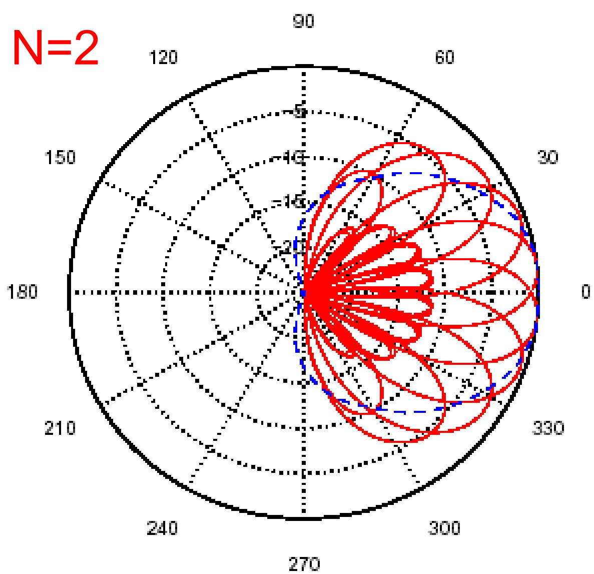


N sets of four orthogonal beams from a four-column antenna array with a 0.5λ horizontal element spacing

N=1



N=2



N=3