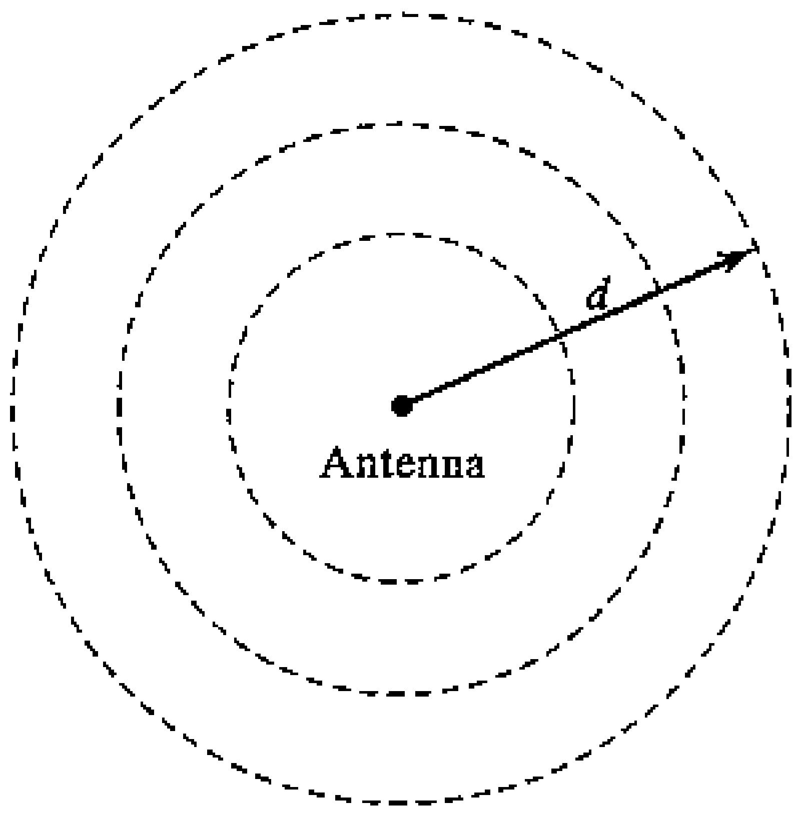


TRANSMIT AVERAGE POWER OF P_T WATTS

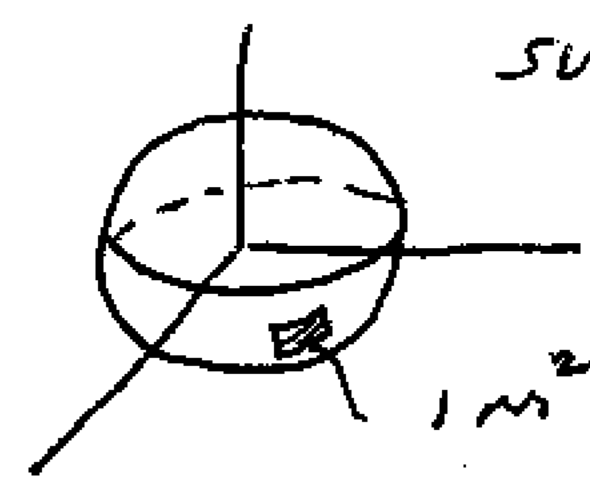
Figure 11.30 Antenna that radiates isotropically in free space.

↑ SAME IN ALL DIRECTIONS

WISH TO DETERMINE THE BIT RATE WE CAN SUPPORT FOR GIVEN AVERAGE TRANSMIT POWER.

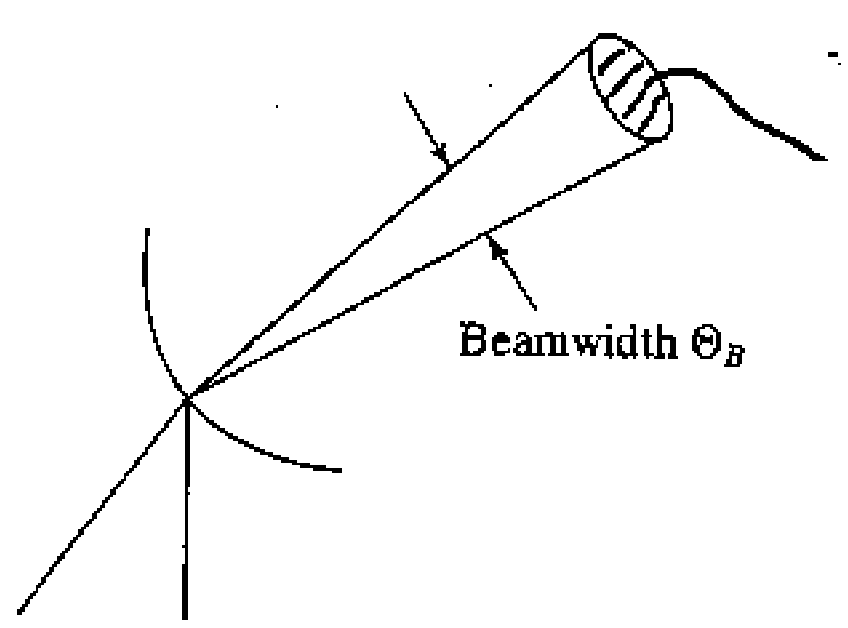
AT DISTANCE d POWER DENSITY = $\frac{P_T}{4\pi d^2}$ W/m²

(POWER PASSING THROUGH



SURFACE AREA = $4\pi d^2$)

USUALLY ANTENNA DESIGNED TO TRANSMIT MORE POWER IN SPECIFIED DIRECTION



(a) Beamwidth

ALL POWER RADIATED, EG,

IF AREA = $\frac{1}{10} 4\pi d^2$

ANTENNA HAS GAIN OF $\frac{4\pi d^2}{AREA} = 10 = G_T$

G_T = GAIN RELATIVE TO OMNIDIRECTIONAL ANTENNA FOR WHICH $G_T = 1$

RECEIVING ANTENNA COLLECTS POWER PROPORTIONAL TO ITS AREA (EG, SATTELITE PARABOLIC DISH).

AREA OF DISH ↙

$$P_R = \frac{P_T}{4\pi d^2} G_T A_R \qquad W/m^2$$

TO FIND A_R USE RESULTS FROM EM THEORY - GIVES EFFECTIVE AREA AS

$$A_R = \frac{G_R \lambda^2}{4\pi} \; m^2$$

G_R = RECEIVE ANTENNA GAIN

WHERE λ = WAVELENGTH

$= c/f_c \qquad c = 3 \times 10^8 \, m/s$

$$\Rightarrow \quad P_R = \frac{P_T}{4\pi d^2} \frac{G_T G_R \lambda^2}{4\pi} = \frac{P_T G_T G_R}{(4\pi d/\lambda)^2} \quad W/m^2$$

$\mathcal{L}_s = (4\pi d/\lambda)^2$ CALLED FREE SPACE PATH LOSS

EXAMPLE: PARABOLIC DISH 

$$A_R = \frac{\pi D^2}{4}\eta \qquad D = \text{DIAMETER}$$

↑ EFFICIENCY FACTOR $\quad 0.5 \le \eta \le 0.6$

$$\Rightarrow \frac{\pi D^2}{4}\eta = \frac{G_R \lambda^2}{4\pi}$$

$$\Rightarrow G_R = \eta\,(\pi D/\lambda)^2$$

CRITICAL FACTOR IN ARRAY GAIN IS PHYSICAL SIZE IN WAVELENGTHS, D/λ.

$$10 \log_{10} P_R = 10 \log_{10} P_T + 10 \log_{10} G_T + 10 \log_{10} G_R - 10 \log_{10} L_S \quad dBW/m^2$$

CAN BE USED TO DETERMINE NECESSARY TRANSMIT POWER FOR GIVEN ERROR RATE.

EXAMPLE: RECEIVED POWER FOR SATTELITE LINK, P_R

TRANSMIT FROM SATTELITE 100 W (20 dBW) WITH ANTENNA HAVING $G_T = 18$ dB GAIN. EARTH STATION USES 3 m PARABOLIC ANTENNA. TRANSMIT FREQ = 4 GHz

$$P_R)_{dBW} = P_T)_{dBW} + G_T)_{dBW} + G_R)_{dBW} - \mathcal{L}_s)_{dBW}$$

$$P_T)_{dBW} = 20$$
$$G_T)_{dBW} = 18$$

$$G_R = \eta\,(\pi D/\lambda)^2 \qquad \text{LET } \eta = 0.5$$

WHERE $D = 3$

$$\lambda = c/f_c = \frac{3\times10^8}{4\times10^9} = 3/40 = 0.075\text{ m}$$

$$G_R = 0.5\left(\frac{\pi\,3}{0.075}\right)^2 = 7895 \Rightarrow \approx 39\text{ dB}$$

$$\mathcal{L}_s = (4\pi d/\lambda)^2$$

NEED d - DISTANCE FROM SATTELITE TO EARTH $= 36000$ Km (≈ 22000 MILES)

$$\mathcal{L}_s = \left(\frac{4\pi(3.6\times10^7)}{0.075}\right)^2 = 3.6\times10^{19}$$

≈ 195 dB NOTE LARGE LOSS!

$$P_R = 20+18+39-195 = -118\text{ dBW}$$
$$\approx 1.38\times10^{-12}\text{ W}$$

CONTINUING WE CAN NOW DETERMINE THE BIT RATE.

ASSUME 1) $\left(\frac{E_b}{N_o}\right)_{REQ} = 10\ dB$

2) $N_o = 4.1 \times 10^{-21}\ W/Hz$ TYPICAL

$\Rightarrow \quad \frac{E_b}{N_o} = 10$ (LINEAR QUANTITIES)

$E_b = 4.1 \times 10^{-20}$

$= P_R T_b = P_R / R_b$ (ASSUMES BPSK FOR EXAMPLE)

$R_b = \frac{1.38 \times 10^{-12}}{4.1 \times 10^{-20}} = 3.36 \times 10^{7}$

$= 33.6$ Mbps