Free-Space Propagation

Exercise 1: If the effective area of an antenna is 1 m^2, what is the path loss, in dB, at a distance of 100 m? At the distance to a geo-stationary satellite ($\approx 36,000$ km)? How does it increase (in dB) with distance?

$A_e = 1$

for $d = 100m$

$$\frac{P_R}{P_T} = \frac{A_e}{4\pi d^2} = \frac{1}{4\pi 10^4}$$

$$\simeq -51 \text{ dB } (?)$$

for $d \doteq 36 \times 10^6$ m

$$\frac{P_R}{P_T} = \frac{1}{4\pi (36 \times 10^6)^2}$$

$$= -162 \text{ dB}$$

$$\frac{P_R}{P_T} \propto \frac{1}{d^2} \qquad \frac{P_R}{P_T} (\text{dB}) \propto -20 \log(d)$$

Exercise 2: What is the directivity of an isotropic radiator?

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Exercise 3: What is the maximum value of k?

1 (100%) $U_o = U_r$

Exercise 4: A point-to-point link uses a transmit power of 1 Watt, transmit and receive antennas with gains of 20dB and operates at 3 GHz. How much power is received by a receiver 300m away?

$P_T = 1$ W

$G_T = 20\text{ dB} = 10^{\frac{20}{10}} = 10^2$

$G_R = 20\text{ dB} = 10^2$

$f = 3 \times 10^9 \quad \lambda = \frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^9} = 0.1\text{ m}$

$d = 300\text{ m}$

$$P_R = P_T\, G_T\, G_R \left(\frac{\lambda}{4\pi d}\right)^2$$

$$= 1 \cdot 10^2 \cdot 10^2 \left(\frac{0.1}{4\pi\, 300}\right)^2 \approx 7\,\mu W$$

Exercise 5: What is the far-field distance for an cell phone antenna operating at 3 GHz that has a physical size of 1 × 1 × 3 cm? For a 100 m diameter antenna?

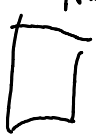
$$\frac{L^2}{\lambda} = \frac{(3\times10^{-2})^2}{0.1} \quad \frac{9\times10^{-4}}{0.1} \approx 9\,mm$$

$$\frac{(100)^2}{0.1} = \frac{10^4}{0.1} = 10\,km.$$

Exercise 6: If we kept the *effective aperture* constant at one end of a link (transmitter or receiver), how would the path loss change as a function of frequency? What if we kept it constant at both ends? Is this a feasible approach for mobile systems?

$A_e \rightarrow G = \frac{4\pi A_e}{\lambda^2}$ $\quad G$

path loss decreases (G increases)^2 with frequency



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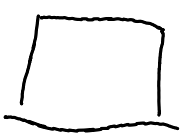

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