S2.1: 100 W of power is being transmitted from an isotropic antenna at a frequency of 1 GHz. What is the power density at a distance of 10 km from the antenna?

S2.2: A circular antenna with a radius of 0.5 m is being used to receive the electromagnetic signal being transmitted in the previous problem. How much power is received? (Assume the effective area of the antenna is equal to its physical area.)

S2.3: A circular antenna of radius 0.2 m is being used to transmit an electromagnetic signal. a) What is the beamwidth of the antenna if a 100 MHz signal is being transmitted? b) If a 2 GHz signal is being transmitted? (The antenna has a beamwidth factor of \( k = 10^\circ \). Calculate the beamwidth using beamwidth = \( k \lambda / D \) where \( D \) is the antenna diameter.)

S2.1) \( p = 79.58 \text{ nW/m}^2 \)

S2.2) \( P_r = 62.5 \text{ nW} \)

S2.3)

a) beamwidth = 75°

b) beamwidth = 3.75°

2.2) \( d_s = 7.698 \text{ km} \)

2.3)

\[
\begin{align*}
f & = 800 \text{ MHz: } G_{r1} = 6.835 \text{ dBi, } G_{r2} = 18.54 \text{ dBi} \\
& = 1.9 \text{ GHz: } G_{r1} = 14.35 \text{ dBi, } G_{r2} = 26.06 \text{ dBi}
\end{align*}
\]

2.4)

\[
\begin{align*}
f & = 800 \text{ MHz: beamwidth}_1 = 69.19^\circ, \text{ beamwidth}_2 = 16.95^\circ \\
f & = 1.9 \text{ GHz: beamwidth}_1 = 29.13^\circ, \text{ beamwidth}_2 = 7.139^\circ
\end{align*}
\]

2.6)

A) \( P_r = -88.53 \text{ dBW} = 1.403 \text{ nW} \)

B) \( P_r = -94.55 \text{ dBW} = 0.3510 \text{ nW} \)

C) The power level is a factor of 4 (6 dB) smaller at the higher frequency.

Typically \( G_r \) would increase by a factor of 4 when the frequency doubles (wavelength halves) since \( G_r = 4 \pi A_e / \lambda^2 \) and the received power would be the same at both frequencies. We kept
the received antenna gain the same at both frequencies in this problem which means the effective area of the antenna must be smaller at the higher frequency (by a factor of 4). This means that the received power will decrease.

2.7)  
A) $L_{\text{path}} = 118.0$ dB  
B) $G_t = 26.57$ dBi, $G_r = 7.025$ dBi  
C) $EIRP = 63.56$ dBm  
D) $P_r = -49.41$ dBm  

2.8)  
A) $d = 68.03$ km  
B) $d = 48.03$ km  
C) $x = 25.32$ km