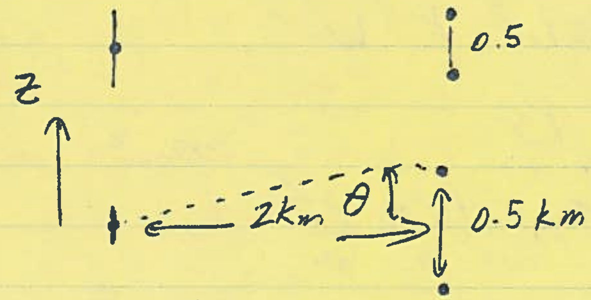
Prob. 2.1



beamwidth $= k \cdot \dfrac{\lambda}{L}$

angle between points where power density = ½ of peak

$\tan\theta = \dfrac{0.25}{2}$ $\quad\quad \theta = \operatorname{atan}\left(\dfrac{0.25}{2}\right) = 7.125°$

$\theta_b = 2\theta = 14.25°$ ← the beamwidth needed to achieve −3dB power at the antennas

$14.25° \leq 66° \cdot \dfrac{\lambda}{1\,m}$

$\lambda \geq 0.2159\,m$

$\dfrac{c}{f} \geq 0.2159\,m$

$f \leq 1.3895\,GHz$

Problem 2.2

→ isotropic antenna radiates P_o W

TX $\bullet \longleftarrow$ 2km $\longrightarrow \bullet$ RX

$$G_{r1} = 4\pi \underbrace{\eta_1}_{0.9} \frac{\overbrace{A_{e1}}^{600\,cm^2}}{\lambda^2}$$

$$P_{r1} = \frac{P_o G_t G_{r1} \lambda^2}{(4\pi)^2 d_1^2}$$

$$P_{r2} = \frac{P_o G_t G_{r2} \lambda^2}{(4\pi)^2 d_2^2}$$

$$\frac{P_{r2}}{P_{r1}} = \frac{d_1^2}{d_2^2} \frac{G_{r2}}{G_{r1}} = \frac{d_1^2}{d_2^2} \frac{\eta_2 A_{e2}}{\eta_1 A_{e1}} = 1$$

$$d_2 = d_1 \sqrt{\frac{\eta_2 A_{e2}}{\eta_1 A_{e1}}} = 7.698 \text{ km}$$

Problem 2.3

800 MHz $\Rightarrow \lambda_{800} = \frac{c}{f_{800}} = 0.375\,m$

1900 MHz $\Rightarrow \lambda_{1.9} = 0.1579\,m$

$G_{r1\,800} = 4\pi\eta_1 \frac{A_{e1}}{\lambda_{800}^2} = 4.8255 = 6.8354\,dBi$

$G_{r1\,1900} = \quad = 27.2188 = 14.3487\,dBi$

$G_{r2\,800} \quad = 71.4887 = 18.5424\,dBi$

$G_{r\,1900} \quad = 403.2409 = 26.0556\,dBi$

Problem 2.4

$k = 51°$

$L_1 = \sqrt{\frac{4A_{er1}}{\pi}} = 0.2764\,m$

$L_2 = \quad 1.1284\,m$

$BW_{1,800} = 51 \cdot \frac{\lambda_{800}}{L_1} = 69.19°$

$BW_{1,1900} = \quad = 29.13°$

$BW_{2,800} = \quad = 16.95°$

$BW_{2,1900} = \quad = 7.14°$

Prob 2.5

TX • ⟵ 5km ⟶ • RX

-87 dBm o/p

$G_t = 7.5\,dBi$ $\quad$ $G_r = 2\,dBd = 4.15\,dBi$ $\quad$ $P_r = \dfrac{P_t G_t A_{er}}{4\pi d^2}$

$\eta = -2.8\,dB$

$f = 890\,MHz$

$EIRP = P_t G_t$ effective isotropic radiated power

$$EIRP = \frac{P_r\,(4\pi d^2)}{A_{er}}$$

$d = 5\,km = 5\times10^3\,m$

$$A_{er} = \frac{\lambda^2 G_{r}}{4\pi\eta} = 0.0448\,m^2$$

$$\boxed{EIRP = \cancel{0.146}\ W}$$

0.014

$$P_r = 10^{(-87/10)} \cdot 10^{-3}$$

$$= 2.0\,pW$$

if $G_t = 7.5\,dBi$

$$P_t = \frac{EIRP}{G_t} = \frac{\overset{0.014}{\cancel{0.146}}\,W}{5.6234} = \cancel{0.03}\,W = \cancel{30}\,mW$$

$0.0025\,W = 2.5\,mW$

Prob 2.6

$EIRP = 1W$

$G_r = 5dBi \qquad d = 1km \qquad loss = 2dB = L_{sys}$

a.) $f = 900 \text{ MHz}$

$$P_r = \frac{EIRP \cdot G_r}{\left(\frac{4\pi d}{\lambda}\right)^2 \cdot L_{sys}} = -58.5dBm$$

b) $f = 1800 \text{ MHz}$

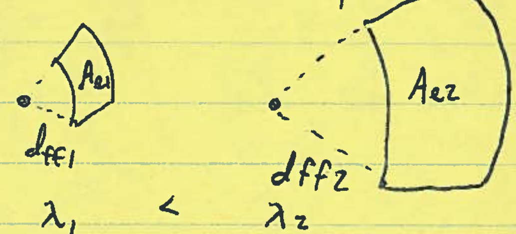
$P_r = -64.5dBm$

c) Case b has a lower received signal

→ if all the parameters don't change the aperture of the higher frequency signal is ~~slower~~ or lower, in such a scenario it effectively draws in less power

⇒ refer back to the far-field distance expression

$$d^{*}_{far field} = \frac{2l^2}{\lambda} = d_{ff}$$



at bigger λ's my antenna window for radiative power is bigger allowing me to draw more radiation

Prob 2.7

$P_t = 5W \qquad f = 1.9 GHz$

$A_{et} = 0.9 m^2 \qquad A_{er} = 100 cm^2 = 0.01 m^2$

b) $G_t = \frac{4\pi A_{et}}{\lambda^2} = 453.6 \qquad G_r = \frac{4\pi A_{er}}{\lambda^2} = 5.04$

a) $L_{path} = \frac{4\pi d^2}{\lambda^2} = 5.04 \times 10^{10}$

$d = 10 km$

c) $EIRP = P_t \cdot G_t \qquad EIRP|_{dBm} = 10 \cdot \log\left(\frac{P_t \cdot G_t}{10^{-3}}\right)$

$= 63.6 dBm$

d) $\cancel{P_r} \; \cancel{2 P_t}$

$$P_r|_{dBm} = P_t|_{dBm} + G_r|_{dB} + G_t|_{dB} - L_{path}|_{dB} - \overset{2dB}{L_{sys\,loss}}$$

$= -38.4 dBm$

Prob 2.8

$P_t = 5W$ $\quad f = 1.8\,GHz$ $\quad p_{sens}\big|_{dBm} = -80\,dBm$

$A_{et} = 4\pi\left(\frac{0.3}{2}\right)^2$ $\quad G_r = 2.15\,dBi$

$p_{sens} = \left(10^{\frac{-80}{10}}\right)\cdot 10^{-3}$

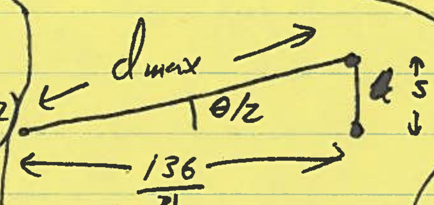
a) $G_t = \frac{(4\pi)^2}{\lambda^2}(0.15)^2 = 127.9$

$$d = \sqrt{\frac{P_t G_t G_r \lambda^2}{p_{sens}(4\pi)^2}} = 136\ km$$

c) beamwidth $\approx k\cdot\frac{\lambda}{L} = 55\cdot\frac{\lambda}{0.3} = 30.56° = \theta$

b) $d_{max} = \frac{d}{4}\,\frac{1}{\cos(\theta/2)}$

$= 35.2\ km$



make distance 4x as small if you want central power 2x as big (the drops off by 2x at beam edges)

$\frac{s}{136/4} = \tan^{-1}\left(\frac{\theta}{2}\right)$

$\boxed{2\cdot S = 17.1\,km}$

max separation

2.13 $NF = 9\,dB$

$G = 50\,dB$

$B = 1\,MHz$

a) $P_{ao,i} = k \cdot T \cdot B \cdot G \cdot (F-1)$

$= 2.78 \times 10^{-9}\,W$

b) $P_{ao} = 10 \cdot \log\left(\frac{k \cdot T \cdot B \cdot G \cdot F}{10^{-3}}\right)$

$= -55\,dBm$

c) $P_{ai}\big|_{dBm} = P_{ao}\big|_{dBm} - G\big|_{dB}$

$= -105\,dBm$

2.14

$T_o + T_e = T_o\,(F)$

$= 290 \cdot 10^{0.9}$

$= 2304\,K$

2.15

$$F = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3}$$

$$= \cancel{40}\ 4.077$$

a) $T_{eff} = 290 \times F$

$= 1182.4\,K$

b) $NF = 10 \cdot \log(F) = 6.1\,dB$

c) $P_{ai} = k \cdot T \cdot B \cdot F$

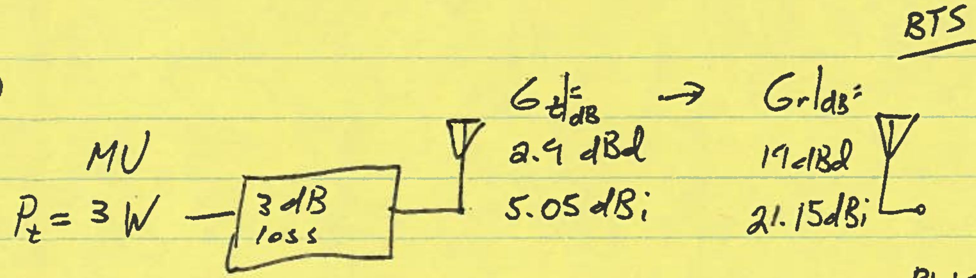
$= -107\,dBm$

$\therefore$ min. det sig is ~~xxxx~~ $-92\,dBm$

d) F becomes 2.5

$\therefore$ min. det sig is $-95\,dBm$

2.20



$BW = 30\,kHz$

$F|_{dB} = 7\,dB$

$T_0 = 290\,K$

AMPS $f = 850\,MHz$

6 dB marging

17 dB rx sensitivity

2 antennas

$$P_{ai} = 2 \cdot k T_0 \cdot B \cdot F$$ ← ~~effective~~ equivalent input noise

$$= \cancel{2.395}\ 4.8 \times 10^{-11}\,W = \cancel{-103\,dBm} \quad -73.2\,dBm$$

$$P_{sense}|_{dBm} = P_{ai}|_{dBm} + 6 + 17 = -\cancel{80}\,50.2\,dBm$$

$$P_t' = P_t \times 10^{-0.3} = 2.5\,W$$

loss

$$d = \sqrt{\frac{P_t' G_t G_r \lambda^2}{(4\pi)^2 P_{sense}}}$$

$$= 9.28\,km$$