EEL 4514
Spring 05 HW #1
Rappaport

2) $P_r(d) = \dfrac{P_t \lambda^2}{(4\pi)^2 d^2} = P_t \cdot \dfrac{1}{d^2} \cdot \dfrac{1}{f^2} \cdot \dfrac{3E8\ m/s}{(4\pi)^2}$

thus: $|P_r(d)|_{dBW} = |P_t|_{dBW} - 20\log(d) - 20\log(f) + 20\log\left(\dfrac{3E8}{(4\pi)^2}\right)$

$= |P_t|_{dBW} - 20\log(d) - 20\log(f) + 147.6$

$A = 20$ $\quad B = 20$ $\quad C = 147.6$

3) $\lambda = \dfrac{c}{f} = \dfrac{3E8\ m/s}{f}$

a) 3.95×10^6 m b) 231 m c) 15.78 m d) $f = 89.1$ MHz $\rightarrow \lambda = 3.36$ m

e) $f = 850$ kHz $\rightarrow \lambda = 352$ m f) $f_c = 794$ MHz $\rightarrow \lambda = 3.79$ m g) $f_c = 605$ MHz $\rightarrow \lambda = 0.49$ m

h) $f = 195$ MHz $\rightarrow \lambda = 1.54$ m i) $\lambda = 3.53$ m j) 0.19 m

k) 0.33 m l) 0.157 m m) 0.025 m

4) a) $d = 200$ m $f = 2.4$ GHz for 802.11g $\rightarrow \lambda = 0.125$ m

Friis Eqn : $P_r(d) = \dfrac{P_t G_t G_R \lambda^2}{(4\pi)^2 d^2}$ $\quad G_t = 10^{1.5/10} \approx 1.4$ $\quad G_R = 10^{-1.5/10} \approx 0.7$

$P_r(200) = \dfrac{(20E\text{-}3\ W)(1.4)(0.7)(0.125)^2}{(4\pi)^2 (200)^2} = 4.85E\text{-}11\ W = \boxed{4.9E\text{-}8\ mW}$

$10\log\left(\dfrac{4.85E\text{-}11\ W}{1\ W}\right) = -103.14$ dBW

$10\log\left(\dfrac{4.85E\text{-}8\ mW}{1\ mW}\right) = \boxed{-73.14\ dBm}$

b) Apply Friis Eqn again; $d = 2000$ m

$P_r(2000) = \dfrac{(20E\text{-}3)(1.4)(0.7)(0.125)^2}{(4\pi)^2 (2000)^2} = 4.85E\text{-}13\ W = \boxed{4.9E\text{-}10\ mW}$

$= -123$ dBW

$= \boxed{-93\ dBm}$

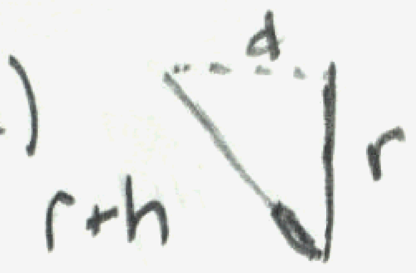
c) $P_r(10) = \dfrac{(20E\text{-}3)(1.4)(0.7)(0.125)^2}{(4\pi)^2 (10)^2} = 1.94E\text{-}8\ W = -77.1\ dBW = -47.1\ dBm$

say $d_0 = 10$ m $(PL)_{dB} = 10n\log\left(\dfrac{d}{d_0}\right)$ $\quad n = 3.5$ $d = 200$ m

$PL\,dB = 35\log\left(\dfrac{200}{10}\right) = 45.53$ dB

$P_r(200)_{dB} = P_r(10)_{dB} - 45.5$ dB $\rightarrow P_r(200m) = -47.1 - 45.5 = \boxed{-92\ dBm}$

$= \boxed{5.49E\text{-}10\ mW}$

5) a) 

$(r+h)^2 = d^2 + r^2 \rightarrow d = \sqrt{(r+h)^2 - r^2} = \sqrt{2rh + h^2}$

b) neglect h^2 term: $d = \sqrt{2hr} = \sqrt{2(4/3)(3960)\left(\frac{1}{5280}\right)h} = \sqrt{2h}$ miles, h in ft

c) $2d = 30 \text{ miles} = 2\sqrt{2h}$

$15 = \sqrt{2h} \rightarrow \frac{225}{2} = h = \boxed{112.5 \text{ ft}}$

d) $h_t = 50$ ft $\quad h_r = 5$ ft

$d_{tower} = \sqrt{2 \cdot 50} = 10$ mi $\quad d_{user} = \sqrt{2 \cdot 5} = 3.16$ mi $\rightarrow$ LOS radius $= 10.0 + 3.16 = \boxed{13.16 \text{ miles}}$

6) case 1: $h_t = 30$m $\quad h_r = 1.5$m $\quad d = 450$m

$d' = \sqrt{(h_t - h_r)^2 + d^2} = \sqrt{(30-1.5)^2 + 450} = \boxed{450.901 \text{ m}}$

$d'' = \sqrt{(h_t + h_r)^2 + d^2} = \sqrt{(30+1.5^2)^2 + 450^2} = \boxed{451.101 \text{ m}}$

$\Delta = 451.101 - 450.901 = \boxed{0.2\text{m}}$

$\Theta_\Delta = \frac{2\pi\Delta}{\lambda} \quad \boxed{\lambda = \frac{c}{f} = \frac{3E8 \text{ m/s}}{2E9 \frac{1}{s}} = 0.15\text{m}}$

$\Theta_\Delta = \frac{2\pi(0.2)}{0.15} = 8.37 \text{ rad} \xrightarrow{2\pi \text{ difference}} \boxed{2.09 \text{ rad}} = 120^\circ$

case 2: $h_t = 40$m $\quad h_r = 2$m $\quad d = 10$ Km

$d' = \boxed{10,000.072\text{m}}$

$d'' = \boxed{10,000.0882 \text{ m}}$

$\Delta = 10,000.0882 - 10,000.072 = \boxed{0.0162\text{m}}$

$\Theta_\Delta = \frac{2\pi(0.0162)}{0.15\text{m}} = \boxed{0.6786 \text{ r}} = 38.4^\circ$

Two Ray Model: $P_{r_2} = \frac{P_t G_t G_R h_t^2 h_r^2}{d^4}$

LOS: $P_{r_{LOS}} = \frac{P_t G_t G_R \lambda^2}{(4\pi d)^2}$

$\frac{P_{r_{2\text{-}r}}}{P_{r_{LOS}}} = \frac{h_t^2 h_r^2 (4\pi)^2}{\lambda^2 d^2}$

★ NOT USED, ALT SOLN

★ use this

$$\frac{P_{2\text{-ray}}}{P_{LOS}} = \frac{1 + \cos\left(2\pi\left(\frac{d_2 - d_1}{\lambda}\right)\right)}{\frac{1}{2}}$$

case 1

$\frac{P_{2\text{-ray}}}{P_{LOS}} \approx 1$

case 2

$\frac{P_{2\text{-ray}}}{P_{LOS}} \approx 3.56$