2.19

2.16

→ we calculated an overall noise factor of

$F = 5.62$ for this receiver

total noise power referred to the input is

$P_{ni} = kT_0BF_{TS}$

$= 1.38\times10^{-23}\cdot 290 \cdot 30\times10^{3}\cdot 5.62$

$= 0.675\times10^{-15}\,W$

$= -122\,dBm$

∴ min required i/p signal is $-122+17 = -105\,dBm$

2.17 moving the LNA to before the lossy tx lines results in

$F = 1.42$ (instead of 5.62)

now $P_{ni}|_{dBm} = -128\,dBm$ (instead of $-122\,dBm$)

min. detectable signal lowered by 6 dB

∴ min req. signal level $= -128+17 = -111\,dBm$

clearly moving LNA is better

2.18 A

1.) sig. power @ i/p of rx amplifier

$$P_s|_{dB} = EIRP|_{dB} + G_r|_{dB} - L_{sys}|_{dB} - L_{path}|_{dB}$$

$$= 50\,dBm + 3 - 3 - 145 = -95\,dBm$$

2.) noise power spectrum referenced to i/p of rx amp

$$S_n = \frac{kT}{2} \underset{6.31}{F} = 12.6 \times 10^{-21} \frac{W}{Hz}$$

3.) SNR @ RX amp. o/p

→ noise power at RX o/p is

$$P_n = S_n \times 2 \times BW$$

$$= 12.6 \times 10^{-21} \cdot 2 \cdot 100 \times 10^3$$

$$= 2.53 \times 10^{-15}\,W = -116\,dBm = P_n|_{dB}$$

$$\therefore \quad SNR_{dB} = P_s|_{dB} - P_n|_{dB} = -95 - (-116)$$

$$= 21\,dB$$

3.1

A) Just plug into $P_r \approx P_t G_t G_r h_t^2 h_r^2 / L_{sys} d^4$

$$P_r|_{dB} = P_t|_{dB} + G_t|_{dB} + G_r|_{dB} + 20\log(h_t) + 20\log(h_r)$$

$$- L_{sys}|_{dB} - 4 \times 10 \log(d)$$

$$= -87.5\,\text{dBm}$$

B) $\Rightarrow$ just plug into the standard (ideal) range eqn.

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi d)^2} = -71\,\text{dBm} \qquad (\lambda = 0.25\,\text{m})$$

C)

$$(3.16) \Rightarrow \underbrace{2A_{dir}\left|\sin\left(\underbrace{\frac{2\pi h_t h_r}{\lambda d}}_{0.0754}\right)\right|}_{0.0753} \leftarrow \text{subst given vals}$$

approx. v. good in this case

~~323A~~

3.5

A) Using Hata model

$$a(h_{re}) = 3.2\left(\log(11.75 h_{re})\right)^2 - 4.97\,dB$$

$$= 0.225\ dB \quad (\text{for } h_{re} = 1.6m)$$

$$\underbrace{L_{50}(\text{urban})|_{dB}}_{\text{median path loss}} = 69.55 + 26.16\log(1200) - 13.82\cdot\log(30)$$

$$+ (44.9 - 6.55\log(30))\log(12) - 0.225$$

$$= 167\ dB$$

B) $$P_r|_{dB} = 10\cdot\log\left(\frac{15}{0.001}\right) dBm + 7 + 2 - 4 - 167$$

$$= -121\,dBm$$

c) $$P_r|_{dB} = 10\log\left(\frac{15}{0.001}\right) + 7 + 2 - 4 - 40\log(12\times10^3)$$

$$+ 20\log(30) + 20\log(1.6)$$

$$= -82.8\ dBm$$

Eq. 3.25 predicts a RX'd power ~ 10,000X greater

(v. optimistic)

3.8 repeat 3.5, but using Lee model

convert to imperial units

$h_t = 98.4$ ft, $h_r = 5.25$ ft, $d = 7.46$ mi

Eq. (3.50) gives

$$\alpha_c = 20\log\left(\frac{98.4}{100}\right) + 20\log\left(\frac{5.25}{10}\right) - 30\log\left(\frac{1200}{850}\right)$$

$$+\left[10\log\left(\frac{15}{1mW}\right) - 40\right] + (7-8.15) + (2-2.15)$$

$$= -9.77\,dB$$

from Table 3.1 on pg. 93

$P_{1\text{-mile}} = -77$ dBm $\quad \nu = 4.8$

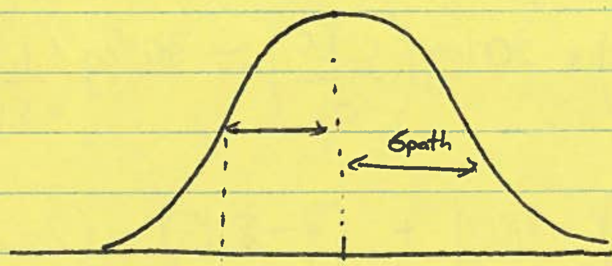
$$\therefore \quad P_{r,50} = -77 - 10\times 4.8\log\left(\frac{7.46}{1}\right) - 9.77 - 4$$

$$= -133\,dBm$$

3.10)

$f_m|_{dB}$ : fade margin, ~~probability that received signal will~~ the amount below ~~average~~ median that can still be processed by my receiver

$$f_m|_{dB} = \overline{P_r}|_{dB} - p_r|_{dB}$$




$p_r|_{dB} = (\overline{P_r}|_{dB} - f_m|_{dB})$ $\quad \overline{P_r}|_{dB}$

$P_Q$ : probability that power available to rx will exceed the min. set by the fade margin

$$P_Q = Pr\left[P_r|_{dB} > p_r|_{dB}\right] = Q\left(\frac{p_r|_{dB} - \overline{P_r}|_{dB}}{\sigma_{path}}\right)$$

$$= Q\left(\frac{(\overline{P_r}|_{dB} - f_m|_{dB}) - \overline{P_r}|_{dB}}{\sigma_{path}}\right) = Q\left(-\frac{f_m|_{dB}}{\sigma_{path}}\right)$$

3.13

$$P_{ni} = kTBF = 3.19\times10^{-15}\,W = -115\,dBm = P_n|_{dB}$$

noise power referred to input

for SNR of 15dB need min. received power

of $p_r|_{dB} = -115 + 15 = -100\,dBm$

$$Pr\left[P_r|_{dB} > p_r|_{dB}\right] = 0.9 = Q\left(\frac{p_r|_{dB} - \bar{P}_r|_{dB}}{\sigma_{path}}\right)$$

$$= Q\left(\frac{-100\,dBm - \bar{P}_r|_{dB}}{8}\right) = 0.9$$

$$\Rightarrow \bar{P}_r|_{dB} = -89.7\,dBm$$

Lee model from 3.12

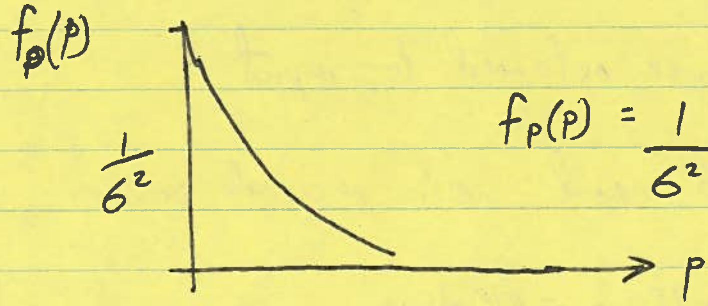
$$\alpha_c = 20\log\left(\frac{100}{100}\right) + 20\log\left(\frac{5}{10}\right) - 30\log\left(\frac{1800}{850}\right)$$
$$+(44-40) + (4-8.15) + (12-2.15) = -16.1$$

$$P_{r,50}|_{dB} = -70\,dBm - 10\times3.68\log\left(\frac{d}{1}\right) - 16.1\,dB - 2 = -89.7$$

$P_{r\text{-mile}}|_{dB}$

= ~~-125 dBm~~ $d = 1.11\,mi = 1.78\,km$

3.16 → probability density fn. of power in multipath environment is




$$f_p(p) = \frac{1}{\sigma^2} e^{\frac{-p}{\sigma^2}} \quad (3.101)$$

avg. $m_p = \sigma^2 = \overline{P}_r$

$$Pr[p_r > \overline{P}_r] = \int_{\sigma^2}^{\infty} \frac{1}{\sigma^2} e^{\frac{-p}{\sigma^2}} dp$$

$$= -e^{\frac{-p}{\sigma^2}}\Big|_{\sigma^2}^{\infty} = -0 - (-e^{-1})$$

$$= e^{-1} = 0.368$$

3.17 $Pr[SNR > SNR_{min}] = 0.95 = Pr\left[\frac{p_r}{P_n} > \frac{p_{r,min}}{P_n}\right] = Pr[p_r > p_{r,min}]$

noise pwr

$$= \int_{p_{r,min}}^{\infty} \frac{1}{\sigma^2} e^{\frac{-p}{\sigma^2}} dp = e^{\frac{-p_{r,min}}{\sigma^2}} = 0.95$$

$$\sigma^2 = \overline{P_r} = 19.5\, p_{r,min}$$

$$\overline{SNR} = 19.5\, SNR_{min}$$

$$\overline{SNR}\big|_{dB} = 12.9\text{ dB} + SNR_{min}\big|_{dB}$$

3.18 $\langle t_k \rangle = 4.86\,\mu s$

$\langle t_k^2 \rangle = 25.4 \times 10^{-12}\, s^2$

$\sigma_d = \sqrt{\langle t_k^2 \rangle - \langle t_k \rangle^2} = 1.36\,\mu s$

$B_{coh} = \dfrac{1}{5\sigma_d} = 148\, kHz$

⇒ baseband → 148 kbps

⇒ but passband req's are 2x as great ∴ ~74 kbps

3.19 A) 1.9 GHz ⇒ $\lambda = 0.158\, m$

$v = 60\, mph \Rightarrow 26.8\, m/s$

$f_d = \dfrac{v}{\lambda} = 170\, Hz$ : max Doppler shift

signals arrive at $-5°$ & $85°$ with respect to direction of travel

$f_{d1} = f_d \cos(-5) = 169\, Hz$

$f_{d2} = f_d \cos(85) = 14.8$

$T_{sig} \ll t_{n-n}$ ∴ fading is slow

$f_{d1} - f_{d2} = 154\, Hz$

B) ∴ period of fading cycle is $t_{n-n} = \dfrac{1}{154} = 6.48\, ms$

3.20 $\frac{\sigma_{path}}{v} = \frac{9}{4.2} = 2.14$

for area coveravg of 90% need $P_{psens}(R) \approx 0.75$
(Table 3.21 pg. 137)

$$0.75 = P_r\left[P_r(R)|_{dB} > p_{sens}|_{dB}\right] = Q\left(-\frac{f_m|_{dB}}{\sigma_{path}}\right) = Q(-0.67)$$

$$f_m|_{dB} = 0.67 \cdot \sigma_{path}$$

$$= 6.03\,dB$$