1(a)

Distance between Tx and Rx need to be at least Rayleigh distance $d_R = \frac{2L_a^2}{\lambda_c}$

$d_R = \frac{2\cdot 400}{1/5} = 4000 \qquad d = 500 < 4000$

$\cdot\ L_a = 20 \quad \cdot\ \lambda_c = \frac{3\times10^8}{1.5\times10^9} = \frac{1}{5}$

Ans: No, 至少須 4000m #

1(b)

$G_{par} = \frac{4\pi}{\lambda_c^2}A_e = 100\pi\cdot 50\pi \Rightarrow 46.9\,dB$

$\cdot\ \lambda_c^2 = \frac{1}{25} \quad \cdot\ A_e = 0.5A = 50\pi$

$A = \left(\frac{L_a}{2}\right)^2\pi = 100\pi$

Ans: $G_{par} \simeq 46.9$ dB #

1(c)

$\cdot$ if $G_{BS} = G_{par} = 48.4\,dB$

$P_{RX.dB} \approx P_{TX.dB} + \underline{46.9 + 46.}\ - 20\log_{10}\left(\frac{4\pi d}{\lambda_c}\right)$

$= P_{TX.dB} + 93.8 - 32 - 20\log_{10}(1.5\times 500)$

$= P_{TX.dB} + 93.8 - \underline{32 - 57.5}$

$= P_{TX.dB} + 4.3$ #

$\cdot$ if $G_{MS} = G_{par} = 0$

$P_{RX.dB} \approx P_{TX.dB} + 46.9 + 0 - 20\log_{10}\left(\frac{4\pi d}{\lambda_c}\right)$

$= P_{TX.dB} - 42.6$ #

1(d)

$\cdot$ Rayleigh distance $d_R = \frac{2L_a^2}{\lambda_c}$

$\cdot\ G_{par} = \frac{4\pi}{\lambda_c^2}\times\frac{A}{2} = \frac{\cancel{4}\pi}{\cancel{\lambda_c}^2}\cdot\frac{1}{\cancel{2}}\left(\frac{\cancel{L_a}}{2}\right)^2\pi$

$= \frac{2L_a^2}{\lambda_c^2}\cdot\frac{\pi^2}{4} = \frac{\pi^2}{4\lambda}d_R$

Ans: $d_R = \frac{4\lambda}{\pi^2}G_{par}$ #

2(a)

- $\overline{r^2} = 2\sigma^2$
- $r_{50} = \sigma\sqrt{2\ln 2}$

$2\sigma^2 = \overline{r^2} = \frac{r_{50}^2}{\ln 2}$

$$cdf(r) = 1 - e^{-\frac{r^2}{2\sigma^2}} = 1 - e^{-r^2/\overline{r^2}} = 1 - e^{-\left(\frac{r^2 \ln 2}{r_{50}^2}\right)} \#$$

Ans: $cdf(r) = 1 - e^{-\left(\frac{r^2 \ln 2}{r_{50}^2}\right)}$ #

2(b) · The fading margin relative to "mean power" is:

$$P_{out} = P(r \le r_{min}) = cdf(r_{min}) = 1 - e^{-\left(\frac{r_{min}^2}{2\sigma^2}\right)}$$

$$\exp\left(-\frac{r_{min}^2}{2\sigma^2}\right) = 1 - P_{out}$$

$$\frac{r_{min}^2}{2\sigma^2} = -\ln(1 - P_{out}) = \frac{r_{min}^2}{\overline{r^2}}$$

∘ $M_{mean} = \frac{\overline{r^2}}{r_{min}^2} = \frac{\overline{P}}{P_{min}}$; 意思是 $\overline{P}$ 需比 P_{min} 高出某個倍數，即為 M_{mean} : Fading margin

$M_{mean|dB}(P_{out}) = -10\log_{10}(-\ln(1 - P_{out}))$

· The fading margin relative to "median value" is:

$$P_{out} = P(r \le r_{min}) = cdf(r_{min}) = 1 - e^{-\left(\frac{r_{min}^2}{2\sigma^2}\right)} = 1 - e^{-\left(\frac{r_{min}^2 \cdot \ln 2}{r_{50}^2}\right)}$$

$$\exp\left(-\frac{r_{min}^2}{r_{50}^2}\ln 2\right) = 1 - P_{out}$$

$$\frac{r_{min}^2}{r_{50}^2} = \frac{-\ln(1 - P_{out})}{\ln 2}$$

∘ $M_{medium} = \frac{r_{50}^2}{r_{min}} = \frac{P_{50}}{P_{min}}$

$$M_{medium|dB}(P_{out}) = 10\log_{10}\left(\frac{\ln 2}{-\ln(1 - P_{out})}\right) = -1.59 - 10\log_{10}(-\ln(1 - P_{out}))$$

Ans: $\begin{cases} M_{mean|dB}(P_{out}) = -10\log_{10}(-\ln(1 - P_{out})) \\ M_{medium|dB}(P_{out}) = -1.59 - 10\log_{10}(-\ln(1 - P_{out})) \end{cases}$ #

2(c)

$$\begin{cases} M_{mean|dB}(P_{out}) = -10\log_{10}(-\ln(1 - P_{out})) \\ M_{medium|dB}(P_{out}) = -1.59 - 10\log_{10}(-\ln(1 - P_{out})) \end{cases}$$

$\rightarrow M_{medium|dB}(P_{out}) = -1.59 + M_{mean|dB}(P_{out})$ #

3. • $f_c = 2GHz$

• $d_{break} = 15m$

• pathloss factor $n = 3.7$

• distance between Tx and Rx : 900m

• Rayleigh distribution

(i) Calculate the Pathloss at $d_{break} = 900\,m$

$$PL(d) = 20\log_{10}\left(\frac{4\pi d_{break}}{\lambda_c}\right) + 10n\log_{10}\left(\frac{d}{d_{break}}\right)$$

$$= 20\log_{10}\left(\frac{4\pi}{\lambda}2\times15\right) + 37\log_{10}(60)$$

$$= 32 + 29.54 + 65.79$$

$$= 127dB$$

(ii) Determine the Fading margin

$$M = \text{Maximum Loss} - PL(d)$$

$$= 140 - 127 = 13\,dB \Rightarrow 20 = \frac{\overline{P}}{P_{min}} = \frac{2\sigma^2}{r_{min}^2}$$

(iii) Compute the Pout :

$$P_{out} = P(r \le r_{min}) = cdf(r_{min}) = 1 - e^{-\left(\frac{r_{min}^2}{2\sigma^2}\right)} = 1 - e^{-\frac{1}{20}}$$

$$= 0.048$$

Ans: $P_{out} = 0.048$ ※

4. Find Fading Margin :

$$M_{total,dB} = M_{Rayleigh,dB} + M_{large\text{-}scale,dB}$$

- $P_{out} = 0.05$

1. Calculate the fading margin for small-scale Rayleigh fading.

$$P_{out} = P(r < r_{min}) = 1 - e^{-\frac{r_{min}^2}{2\sigma^2}}$$

$$\frac{r_{min}^2}{2\sigma^2} = -\ln(1 - P_{out})$$

$$M_{Rayleigh,dB} = 10\log_{10}\left(\frac{2\sigma^2}{r_{min}^2}\right) = -10\log_{10}(-\ln(1-P_{out}))$$

$$= -10\log_{10}(-\ln(1-0.05)) \approx 12.9 \text{ dB}$$

2. Calculate the fading margin for large-scale log-normal fading.

$$P_{out} = P(r < r_{min}) = P(L_{min} + L_{dB} > L_{max,dB})$$

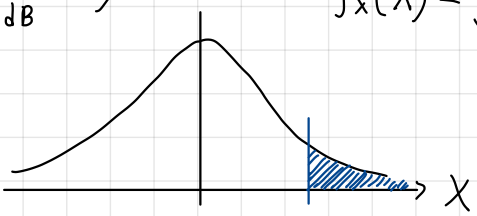
$$= P\left(\frac{L_{dB}}{\sigma_{p,dB}} > \frac{L_{max,dB} - L_{mean,dB}}{\sigma_{p,dB}}\right)$$

$$= P\left(X > \frac{M_{l,dB}}{\sigma_{p,dB}}\right),$$

$$= Q\left(\frac{M_{large,dB}}{\sigma_{p,dB}}\right)$$

$$= 0.05$$

- $r \sim X \sim N(0,1)$
- $f_X(x) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x^2}{2}}$



$$\frac{M_{large\text{-}scale,dB}}{\sigma_{p,dB}}$$

$$\rightarrow \frac{M_{large\text{-}scale,dB}}{\sigma_{p,dB}} \approx 1.645,$$

$$M_{large\text{-}scale,dB} = 8.22 \text{ dB}$$

Ans : $M_{total,dB} = 12.9 + 8.22 = 21.12$ dB

5.(a)

- $\lambda_c = \frac{3\times10^8}{12\times10^8} = 0.25$
- $d_{break} \geq \frac{4h_{TX}h_{RX}}{\lambda_c} = \frac{4\times10\times3}{1/4} = 480m$

- For BS Antenna. $d_{far,BS} = \frac{2\cdot0.5^2}{0.25} = 2m$

For MS Antenna: $d_{far,MS} = \frac{2\cdot0.2^2}{0.25} = 0.32m$

$\Rightarrow d_{far} = 2m$

Ans: $d_{break} = 480m$, $d_{far} = 2m$ #

5.(b) Eq 4.24: $P_{RX} = P_{TX}G_{TX}G_{RX}\left(\frac{h_{TX}h_{RX}}{d^2}\right)^2$

- For BS-MS:

$$P_{RX} = P_{TX.BS} + G_{TX} + G_{RX} + 20\log_{10}\left(\frac{h_{TX}h_{RX}}{d^2}\right)$$
$$= 10\log_{10}(40\times10^3) + 7 + 3 + 20\log_{10}\left(\frac{30}{d^2}\right)$$
$$= 46 + 10 + 29.54 - 40\log_{10}(d)$$
$$= 85.56\,dBm - 40\log_{10}(d)$$

- For MS-BS

$$P_{RX} = P_{TX.MS} + G_{TX} + G_{RX} + 20\log_{10}\left(\frac{h_{TX}h_{RX}}{d^2}\right)^2$$
$$= 10\log_{10}(0.1\times10^3) + 7 + 3 + 20\log_{10}\left(\frac{30}{d^2}\right)$$
$$= 20 + 10 + 29.54 - 40\log_{10}(d)$$
$$= 59.54\,dBm - 40\log_{10}(d)$$

Ans: BS-MS: $85.56\,dBm - 40\log_{10}(d)$

MS-BS: $59.54\,dBm - 40\log_{10}(d)$ ※

5.(c)

Eq 4.26: $\boxed{P_{RX}(d) = P_{RX}(1m) - 20\log_{10}(d_{break}/m) - n10\log_{10}\left(\frac{d}{d_{break}}\right)}$ O

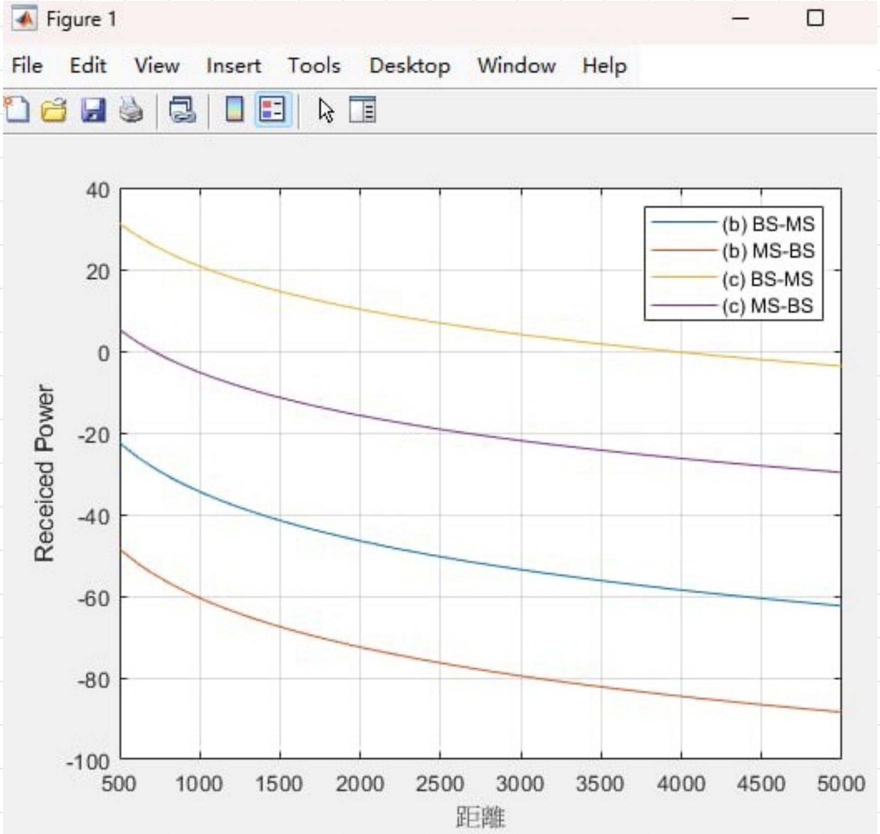
- For BS-MS,

$$P_{RX} = 85.56 - 20\log_{10}(480) - 35\log_{10}\left(\frac{d}{480}\right)$$
$$= 85.56 - 20\log_{10}(480) + 35\log_{10}(480) - 35\log_{10}(d)$$
$$= 85.56 + 40.22 - 35\log_{10}(d) = \underline{125.77\,dBm - 35\log_{10}(d)}$$ ※

- For BS-MS,

$$P_{RX} = 59.54 - 20\log_{10}(480) - 35\log_{10}\left(\frac{d}{480}\right)$$
$$= 59.54 - 20\log_{10}(480) + 35\log_{10}(480) - 35\log_{10}(d)$$
$$= 59.54 + 40.22 - 35\log_{10}(d) = \underline{99.76\,dBm - 35\log_{10}(d)}$$ ※

5.(d)



5(e)

(i)

BS-MS

- $P_{RX} = P_{TX} + G_{TX} + G_{RX} + 20\log_{10}(h_{tx}h_{Rx}) - 40\log_{10}(d)$

$= 46 + 7 + 3 + 29.54 - 120 = -34.4\,dBm$

- $P_N = -174 + 10\log_{10}(20\times10^6) + 15 = -86\,dBm$

$P_{RX} - P_N = -34.4 - (-86) = \underline{51.6 > 10}$ satisfy require SNR

MS-BS

- $P_{RX} = P_{TX} + G_{TX} + G_{RX} + 20\log_{10}(h_{tx}h_{Rx}) - 40\log_{10}(d)$

$= 20 + 7 + 3 + 29.54 - 120 = -60.5\,dBm$

- $P_N = -174 + 10\log_{10}(20\times10^6) + 3 = -98\,dBm$

$P_{RX} - P_N = -60.5 - (-98) = \underline{37.5 > 5}$ satisfy require SNR

Ans: Both satisfied required SNR #

5(e)

(ii)

BS 為 Receiver

$$\begin{array}{l} \\ \end{array}$$

- $P_{RX} = P_{TX} + G_{TX} + G_{RX} + 20\log_{10}(h_{TX} h_{RX}) - 40\log_{10}(d) \geq \underbrace{-174+73}_{N_0B} + \underbrace{3}_{F} + \underbrace{5}_{SNR}$

$$= 20 + 7 + 3 + 29.54 - 40\log_{10}(d) \geq -174+73+3+5$$

$$\Rightarrow 152.54 \geq 40\log_{10}(d)$$

$$\Rightarrow 10^{152.5/40} \geq d$$

$$\Rightarrow \underline{6508 \geq d}$$

MS 為 Receiver

- $P_{RX} = P_{TX} + G_{TX} + G_{RX} + 20\log_{10}(h_{TX} h_{RX}) - 40\log_{10}(d) \geq \underbrace{174+73}_{N_0B} + \underbrace{15}_{F} + \underbrace{10}_{SNR}$

$$= 46 + 7 + 3 + 29.54 - 40\log_{10}(d) \geq -174+73+15+10$$

$$\Rightarrow 161.54 \geq 40\log_{10}(d)$$

$$\Rightarrow 10^{161.54/40} \geq d$$

$$\Rightarrow \underline{10927 \geq d}$$

<u>Ans: maximun feasible d ≈ 6500 m</u> ※