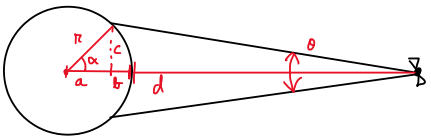
4.1) a)



$R = 6371\ Km$

$c = \frac{1000Km}{2} = 500\ Km$

$g \approx \frac{4\pi}{\theta^2} = 16090 = 42\ dB$ //

$d = 35781\ Km$ 8-PSK

$f_c = 12\ GHz$ $R_B = 96\ Mbit/s$

$tg\left(\frac{\theta}{2}\right) = \frac{c}{h+d} \approx \frac{c}{d} \Rightarrow \theta = 2 \cdot tg^{-1}\left(\frac{c}{d}\right) = 0.028\ Rad$

b)

$S = \frac{P_E}{4\pi d^2} \cdot g_E \Rightarrow S^T = P_E^S + G_E^S - 10\log_{10}(4\pi d^2)$

$S^T = -77\ dBm/m^2$ $\hookrightarrow P_E^S = S^T - G_E^S + 10\log_{10}(4\pi d^2) =$

$G_E^S = 40\ dB$ $= -77\ dBm - 40\ dB + 162.065\ dBm =$

$= 45\ dBm = 15\ dBW$

c) $\left(\frac{C}{N}\right)^T = P_E^S + G_E^S + G_R^T - L_{fs} - 10\log_{10}(KTB_W)$

$\left(\frac{G}{T}\right)^T = G_R^T - 10\log_{10}(T)$

Logo: $\left(\frac{G}{T}\right)^T = \left(\frac{C}{N}\right)^T - P_E^S - G_E^S + L_{fs} + 10\log_{10}(KB_W) = 13.21\ dB/K$ //

$P_E^S = 15\ dBW$ $L_{fs} = 32.4 + 20\log_{10}(d) + 20\log_{10}(f) =$

$G_E^S = 40\ dB$ $= 205\ dB$

$\left(\frac{C}{N}\right)^T = \frac{E_b}{N_0} + 10\log\left(\frac{f_b}{B_W}\right) = \frac{E_b}{N_0} + 10\log(\log_2 M) = 16.7\ dB$

$B_W = \frac{f_b}{\log_2(M)} = 32\ MHz$

4.2)

30 ch/ET (8 bit PCM)

$LB = 36\ MHz$

$EIRP = 30\ dBW$

4-PSK

a) 2 canais de controlo + 30 canais voz → 32 canais

8 bits PCM $\Rightarrow 2 \times 4\ KHz \times 8\ bit \Rightarrow 64\ Kbits/s$

Logo $R_b = 32 \times 64\ Kbit/s = 2.048\ Mbits/s$

$LB_{ET} = \frac{R_b}{\log_2(M)}(1+\alpha) = \frac{2.048\ Mbit/s}{\log_2(4)} \cdot (1+0.2) = 1.229\ MHz$

$N_{ET} = \frac{LB}{LB_{ET}} = \left\lfloor \frac{36\ MHz}{1.229\ MHz} \right\rfloor = 29\ ET$ //

b) $\left(\frac{C}{N}\right)^T = P_E^S + G_E^S + \quad - L_{fs} - 10\log_{10}(KT_{eq}B_w)$

$\left(\frac{G}{T}\right)^T = G_R^T - 10\log_{10}(T_{eq})_R^T$

$EIRP = P_E^S + G_E^S \quad \Rightarrow EIRP_{ET} = EIRP - 10\log_{10}(N_{ET})$

$L_{fs} = 32.4 + 20\log_{10}(d) + 20\log_{10}(f)$

$\left(\frac{C}{N}\right)^T = \frac{E_b}{N_0} - 10\log_{10}\left(\frac{B_w}{f_b}\right) = \frac{E_b}{N_0} + 10\log_{10}(\log_2 M)$

$\Rightarrow \left(\frac{G}{T}\right)^T = \left(\frac{C}{N}\right)^T - EIRP_{ET} + L_{fs} + 10\log_{10}(KB_w)$

$B_w = LB_{min} = \frac{R_b}{\log_2(M)} = \frac{2.048\,Mbit/s}{\log_2(4)} = 1.024\times10^6\,Hz$

$\left(\frac{C}{N}\right)^T = 10.5 + 10\log_{10}(2) \approx 13.5\,dB$

$EIRP_{ET} = 30dBW - 10\log_{10}(29) \approx 15.4\,dBW$

$L_{fs} = 32.4 + 20\log_{10}(40\,000) + 20\log_{10}(11.5\times10^3) \approx 205.7\,dB$

$10\log_{10}(KLB_{Min}) = 10\log_{10}(1.38\times10^{-23}\cdot1.024\times10^6\,Hz) \approx -168.5\,dB$

$\left(\frac{G}{T}\right)^T = 13.5 - 15.4 + 205.7 - 168.5 = 35.3\,dB/K$

4.3) $\left(\frac{G}{T}\right)^T = 40.7\,dB/K$

$F_{REC} = 9\,dB$

$T_A = 40K$

$A_{wg} = 0.3\,dB$

$T_{PA} = 10K$

$f = 60\,GHz$

$\eta = 0.5$

a) $\left(\frac{G}{T}\right)^T = G^T - 10\log_{10}(T)$

$G^T = \left(\frac{G}{T}\right)^T + 10\log_{10}(T) =$

$= 40.7 + 10\log_{10}(71.46) =$

$= 59.2\,dB$ //

$G^T = 20\log_{10}\left(\frac{\pi\cdot D}{\lambda}\right) + 10\log_{10}(\eta) \Leftrightarrow$

$\Leftrightarrow g^T = \left(\pi D\frac{f}{c}\right)^2\cdot\eta \Leftrightarrow$

$\Leftrightarrow D = \sqrt{\frac{g^T}{\eta}}\cdot\frac{c}{\pi f} = 20.53\,m$

$T = ?$

$T = T_a + T_{eq}$

$T_{eq} = T_{wg} + \frac{T_{PA}}{g_{wg}} + \frac{T_{REC}}{g_{wg}\cdot g_{PA}} \approx T_{wg} + \frac{T_{PA}}{g_{wg}}$ ($T_{REC} \ll$)

$F = 1 + \frac{T}{T_0}$ onde $T_0 = 290K$

$F_{wg} = \frac{(S/N)^i}{(S/N)^o} =$ atenuação $= 0.3\,dB$

$\Rightarrow T_{wg} = T_0\times(F_0 - 1) = (10^{\frac{0.3}{10}} - 1)\times290 = 20.74K$

$T = T_a + T_{wg} + \frac{T_{PA}}{g_{wg}} = 40 + 20.74 + \frac{10}{10^{-0.03}} = 71.46K$ //

$g_{wg} = \frac{1}{a_{wg}} = 10^{-0.03}$

b) $g \approx \frac{4\pi}{\theta^2} \Rightarrow \theta = \sqrt{\frac{4\pi}{g^T}} = 3.89\times10^{-3}\,rad \Rightarrow 0.22°$

4.4 a) $30\,ch/ET$ $d = 40\,000\,Km$ 8-PSK $LB_T = 30MHz$ $f_c = 12\,GHz$

a) $N_{ET} = 38\,ET$

$N_{ET} = \frac{LB}{LB_{ET}} \Rightarrow LB_{ET} = \frac{LB}{N_{ET}}$

R_b voice/ch $= 64\,Kbit/s$

$R_b = N_{ch}\times R_b$ voice/ch $= 32\times64\,Kbit/s = 2.048\,MHz$

$N_{ch} = 30$ voice + 2 controlo

$LB_{ET} = \frac{R_b}{\log_2(M)}\cdot(1+\alpha) \Rightarrow \frac{LB}{N_{ET}}\cdot\frac{\log_2 M}{R_b} - 1 = \alpha = 0.16 \Rightarrow \alpha < 0.16$

b) $EIRP = ?$ $\left(\frac{G}{T}\right)^T = \left(\frac{C}{N}\right)^T - EIRP_{ET} + L_{fs} + 10\log_{10}(K\cdot LB_{min}) \Rightarrow EIRP_{ET} = \left(\frac{C}{N}\right)^T - \left(\frac{G}{T}\right)^T + L_{fs} + 10\log_{10}(K\cdot LB_{min}) \approx 11.31$

$\left(\frac{C}{N}\right)^T = \frac{E_b}{N_0} + 10\log_{10}(\log_2 M) = 10.5 + 10\log_{10}(3) \approx 15.27\,dB$

$L_{fs} = 32.4 + 20\log_{10}(40\,000) + 20\log_{10}(12\times10^3) \approx 206.03\,dB$

$10\log_{10}(K\cdot LB_{min}) = 10\log_{10}\left(K\cdot\frac{R_b}{\log_2(M)}\right) = 10\log_{10}\left(1.38\times10^{-23}\cdot\frac{2.048\,MHz}{3}\right) \approx -170.26\,dB$

$EIRP_{ET} = EIRP - 10\log_{10}(N_{ET}) \Rightarrow EIRP = EIRP_{ET} + 10\log_{10}(N_{ET}) = 27.11\,dB$

c) Seria igual!