SY310

Networking & Wireless Communications

Free Space Loss Worksheet

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You have been asked to design a 1 Gbps microwave link to interconnect the LANs on two different ships. The distance between the ships is 2 km and the microwave link would operate at 5 GHz using two omnidirectional antennas (which would be a horrible design decision, but it simplifies the problem, so just "go with it" for today!). The available bandwidth for the channel is 100 MHz.

(1) Using Shannon's Capacity Theorem and building in a 20% margin (i.e., you know you cannot achieve the Shannon limit so you pick a Shannon limit that is higher than your desired capacity. In this case, your desired capacity is 80% of the Shannon Capacity you design for → $R_b = 0.8*C$). What is the minimum SNR (in dB) required at the receiver?

Capacity = 80%

$R_b = 0.8 \cdot C$

minimum SNR

$B = 100MHz$

$P_{sig} = 5GHz$

$SNR_{dB} = 10 \log_{10} \frac{\text{Signal Power}}{\text{noise Power}}$

$C = B \log_2 (1 + SNR)$

$0.8 \times 10^9 = 100 \times 10^6 \cdot \log_2 (1 + SNR)$

SNR = 255dB

$P = \frac{V^2}{R}$

$C = 0.8 \times 1 \text{ Gbps}$

$C = 0.8 \text{ Gbps}$

(2) Considering only thermal noise, you decide to design to a 68°F (20°C) day and recall that Boltzmann's constant is 1.38×10^{-23} J/K. What is the minimum required signal power (in dBm) at the receiver?

$T = 68° \quad 20° + 273.15 = 293.15 K$

$N = KTB$

$N = (1.38 \times 10^{-23} J/K)(293.15 K)(100 \times 10^6 Hz)$

$N = 4.04 \times 10^{-13}$

$10 \log_{10}(4.04 \times 10^{-13}) = -123.94 dB$

$-93.94 dBm$

(3) Using the free space model, what path loss can you expect at the receiver in dB?

$d = 2\,km$

$f = 5GHz$

$C = 3.0 \times 10^8$

$L_{dB} = 20\log_{10}(f) + 20\log(d) - 147.56\,dB$

$193.98 + 66.05 - 147.56$

$L_{dB} = 112.4\,dB$

(4) Keeping in mind that omnidirectional antennas are being used (G = 1), what is the minimum transmission power required for this link in dBm?

$G = 1$

$\lambda = 0.059\,m$

$P_r = 4.04 \times 10^{-13}\,W$

$$P_t = \frac{(4\pi^2)(d^2)}{1\ \lambda^2} \cdot P_r$$

$$P_T = \frac{(4\pi)^2 (2\times10^3)^2}{(0.059)^2} \cdot 4.04 \times 10^{-13}\,W$$

$P_T = 0.0733\,W \Rightarrow 18.651\,dBm$

(5) If you assume that one antenna is at ground level, how high does the other antenna need to be? Use 4/3 for K.

$d = 3.57\sqrt{Kh}$

$$h = \frac{d^2}{(3.57)^2 \cdot K} = \frac{(2\,km)^2}{(3.57)^2 \cdot 4/3} = 0.23538\,m$$