Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

$f_c = \dfrac{c}{2a} = \dfrac{3.0 \times 10^8}{2 \times 0.04755} =$ **3.15 GHz**; 3.0 GHz is below cutoff, so it **cannot** travel; WR-284: **2.08 GHz**, so 3.0 GHz travels in it

2.2

$\lambda = 25$ mm; $\lambda_g = \dfrac{25}{\sqrt{1 - (6.56/12)^2}} =$ **29.9 mm**; $v_p = c\dfrac{\lambda_g}{\lambda} =$ **3.6 × 10⁸ m/s**; $v_g = \dfrac{c^2}{v_p} =$ **2.5 × 10⁸ m/s**

2.3

$A_e = 0.60 \times \dfrac{\pi \times 0.60^2}{4} =$ **0.170 m²**; $G = \dfrac{4\pi \times 0.170}{0.025^2} = 3410 =$ **35.3 dBi**

2.4

$\lambda = 0.20$ m; $FSPL = 20\log\dfrac{4\pi \times 100}{0.20} =$ **76.0 dB**; doubling d adds $20\log 2 =$ **6.0 dB**

3.1

$v = \dfrac{c}{\sqrt{2.1}}$, so $f_c = \dfrac{6.56}{\sqrt{2.1}} =$ **4.52 GHz**

empty $f_c = 6.56$ GHz is above 6.0 GHz, so the wave is cut off; filled, 6.0 GHz is above 4.52 GHz

$\lambda = \dfrac{c}{f\sqrt{2.1}} = 34.5$ mm; $\lambda_g = \dfrac{34.5}{\sqrt{1 - (4.52/6.0)^2}} =$ **52.5 mm**

TE_{20} starts at $2 \times 4.52 =$ **9.05 GHz** (below TE_{01}), so single mode up to there

3.2

$FSPL = 20\log\dfrac{4\pi \times 3.6 \times 10^7}{0.025} =$ **205.2 dB**

$P_r = 50 + 35.3 - 205.2 = -119.9$ dBW = **−89.9 dBm**

$N = 10\log(1.38 \times 10^{-23} \times 150 \times 27 \times 10^6) = -132.5$ dBW

$C/N = -119.9 - (-132.5) = 12.6$ dB, a margin of only **2.6 dB**; heavy rain at 12 GHz can take more than this

3.3

(a) $FSPL = 20\log\dfrac{4\pi \times 10}{0.10} = 62.0$ dB; $P_r = 0 + 6 + 6 - 62.0 =$ **−50 dBm**; margin $-50 - (-85) =$ **35 dB**

(b) allowed $FSPL = 0 + 12 + 85 - 20 = 77$ dB, which is 15 dB more than at 10 m; $d = 10 \times 10^{15/20} =$ **56 m**

(c) losses $2 \times 1.0 + 10 = 12$ dB, so allowed $FSPL = 65$ dB; $d = 10 \times 10^{3.0/20} =$ **14 m**

(d) reflections from walls, benches and people add with different phases, so the signal can drop by 20 dB or more at some points (multipath fading)

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