4.4

$$
\begin{aligned}
G_t &= G_r = 29 \text{ dB} && (10)\\
P_t &= 30 \text{ dBm} && (11)\\
\lambda &= \frac{c}{f} = 0.005 \text{ m} && (12)\\
d_0 &= 1 \text{ m} && (13)\\
d_1 &= 100 \text{ m} && (14)\\
d_2 &= 1000 \text{ m} && (15)\\
PL(d_0) &= 20\log_{10}\frac{4\pi d_0}{\lambda} = 20\log_{10}\frac{4\pi}{0.005} = 68 \text{ dB} && (16)\\
PL(d_1) &= PL(d_0) + 20\log_{10}\frac{d_1}{d_0} = 108 \text{ dB} && (17)\\
PL(d_2) &= PL(d_0) + 20\log_{10}\frac{d_2}{d_0} = 128 \text{ dB} && (18)\\
& && (19)\\
P_r &= P_t + G_t + G_r - PL = 30 + 29 + 29 - PL = 88 - PL && (20)\\
P_r(d_0) &= 88 - 68 = 20 \text{ dBm} && (21)\\
P_r(d_1) &= 88 - 108 = -20 \text{ dBm} && (22)\\
P_r(d_2) &= 88 - 128 = -40 \text{ dBm} && (23)\\
& && (24)\\
V &= \sqrt{4\ P_r\ R_{ant}} && (25)\\
V(d_1) &= 0.0447 \text{ v} && (26)\\
V(d_2) &= 0.0045 \text{ v} && (27)
\end{aligned}
$$

4.5

$$
\begin{aligned}
\Gamma_{\parallel} &= \frac{-\epsilon_2 \sin\theta_i + \sqrt{\epsilon_2 - \cos^2\theta_i}}{\epsilon_2 \sin\theta_i + \sqrt{\epsilon_2 - \cos^2\theta_i}}\\
\Gamma_{\perp} &= \frac{\sin\theta_i - \sqrt{\epsilon_2 - \cos^2\theta_i}}{\sin\theta_i + \sqrt{\epsilon_2 - \cos^2\theta_i}}
\end{aligned}
$$

At $\theta_i = 30^0$

	Ground	Brick	Limestone	Glass	Water
ϵ_r	15	4.44	7.51	4	81
$\Gamma_{\parallel}$	-0.33	-0.07	-0.18	-0.05	-0.64
$\Gamma_{\perp}$	-0.77	-0.59	-0.68	-0.57	-0.89

4.12 Approximate : $P_r = \underline{\underline{P_t \cdot G_t \cdot G_r \cdot \frac{h_t^2 \cdot h_r^2}{d^4}}}$

Exact : $|E_{TOT}(d)| = \frac{E_0 \cdot d_0}{d} \sqrt{2 - 2\cos\theta_\Delta}$

$$\Rightarrow |E_{TOT}(d)|^2 = \frac{E_0^2 d_0^2}{d^2} \cdot (2 - 2\cos\theta_\Delta)$$

$$P_r(d) = \frac{|E_{TOT}(d)|^2}{120\pi} \cdot A_e = \frac{E_0^2 \cdot d_0^2}{d^2} \cdot (2 - 2\cos\theta_\Delta) \cdot \frac{A_e}{120\pi}$$

$$E_0^2 = \frac{P_t \cdot G_t \cdot G_r \cdot \lambda^2}{(4\pi)^2 d_0^2} \cdot \frac{120\pi}{A_e}$$

$$\Rightarrow P_r(d) = \frac{P_t \cdot G_t \cdot G_r \cdot \lambda^2}{(4\pi)^2 \cdot d_0^2} \cdot \frac{120\pi}{A_e} \cdot \frac{d_0^2}{d^2} \cdot (2 - 2\cos\theta_\Delta) \cdot \frac{A_e}{120\pi}$$

$$= \underline{\underline{\frac{P_t \cdot G_t \cdot G_r \cdot \lambda^2}{(4\pi)^2 \cdot d^2} \cdot 4 \cdot \sin^2\frac{\theta_\Delta}{2}}}$$

where $\theta_\Delta = \frac{2\pi}{\lambda} \cdot \frac{2h_t \cdot h_r}{d}$.

See problem 4.24 (pg. 58) for the plot.

4.13 See problem 4.24 (pg 58) for the plot

$$\Gamma = 1 \Rightarrow P_r(d) = \underline{\underline{\frac{P_t \cdot G_t \cdot G_r \cdot \lambda^2}{(4\pi)^2 \cdot d^2} \cdot 4 \cdot \cos^2\frac{\theta_\Delta}{2}}}$$

$\lambda(d_1+d_2)$

4.17 A general design rule for microwave links is 55% clearance of the first Fresnel zone. For a 1 km link at 2.5 GHz, what is the maximum first Fresnel zone radius? What clearance is required for this system ?

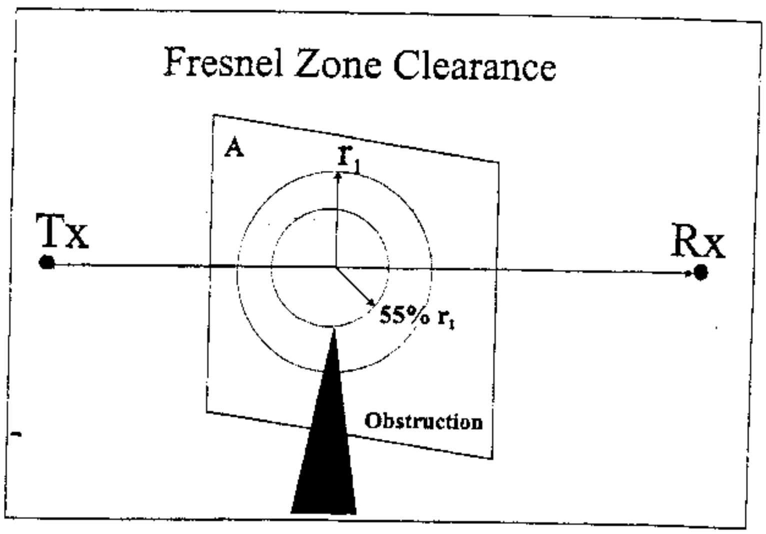
Solution

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{2.5 \times 10^9} = 0.12 \text{ m} \tag{23}$$

For the first Fresnel zone: n=1. The maximum Fresnel zone radius occurs for $d_1 = d_2 = 500m$. Using Equation (4.56), the Fresnel zone radius is found to be

$$r_n = \sqrt{\frac{n\lambda d_1 d_2}{d_1 + d_2}} = \sqrt{\frac{1 \times 0.12 \times 500 \times 500}{500 + 500}} = 5.48 \text{ m} \tag{24}$$

Thus, 55% first Fresnel zone clearance would require at least $5.48 \times 55\% = 3.01m$ above the obstruction to the LOS path as shown in the figure below.



Fresnel zone clearance.