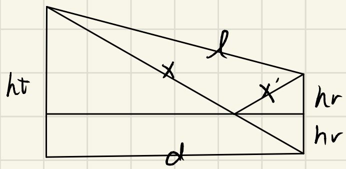
2-2. For the two-ray model with transmitter–receiver separation $d = 100$ m, $h_t = 10$ m, and $h_r = 2$ m, find the delay spread between the two signals.



$$l = \sqrt{d^2 + (ht - hr)^2} = 4\sqrt{629}$$

$$x + x' = \sqrt{d^2 + (ht + hr)^2} = 4\sqrt{634}$$

$$\therefore \text{Delay spread} = \frac{x + x' - l}{c} = 1.33 \times 10^{-9}\,s = 1.33\,ns$$

2-3. For the two-ray model, show how a Taylor series approximation applied to (2.13) results in the approximation

$$\Delta\phi = \frac{2\pi(x + x' - l)}{\lambda} \approx \frac{4\pi h_t h_r}{\lambda d}.$$

$$x + x' - l$$

$$= \sqrt{d^2 + (ht + hr)^2} - \sqrt{d^2 + (ht - hr)^2}$$

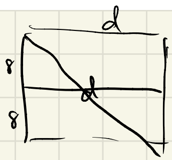
$$= d\left[1 + \left(\frac{ht + hr}{d}\right)^2\right]^{\frac{1}{2}} - d\left[1 + \left(\frac{ht - hr}{d}\right)^2\right]^{\frac{1}{2}}$$

According to Taylor series. $(1+x)^{\frac{1}{2}} \simeq 1 + \frac{1}{2}x$

$$\therefore x + x' - l \simeq d\left[1 + \frac{1}{2}\left(\frac{ht + hr}{d}\right)^2\right] - d\left[1 + \frac{1}{2}\left(\frac{ht - hr}{d}\right)^2\right] = \frac{2ht \cdot hr}{d}$$

$$\therefore \Delta\phi = \frac{2\pi}{\lambda}(x + x' - l) = \frac{4\pi ht\,hr}{\lambda d}$$

2-7. Consider a two-ray channel with impulse response $h(t) = \alpha_1\delta(t) + \alpha_2\delta(t - .022\ \mu s)$. Find the distance separating the transmitter and receiver, as well as α_1 and α_2, assuming free-space path loss on each path with a reflection coefficient of -1. Assume the transmitter and receiver are located 8 m above the ground and that the carrier frequency is 900 MHz.



$$0.022 \times 10^{-6} = \frac{\sqrt{d^2 + 16^2} - d}{c}$$

$$\therefore \sqrt{d^2 + 16^2} - d = 6.6 \Rightarrow d = 16.09\,m$$

$$\because \tau = \frac{d}{c} = 5.36 \times 10^{-8}\,s. \quad \lambda = \frac{c}{f_c} = \frac{1}{3}\,m.$$

$$\therefore \alpha_1 = \frac{\lambda}{4\pi}\frac{\sqrt{G_l}}{l} = 1.65 \times 10^{-3}$$

$$\alpha_2 = \frac{\lambda}{4\pi}\frac{R\sqrt{G_r}}{x + x'} = -1.17 \times 10^{-3}$$