The actual distance will be $d_1' + d_2'$, assuming the heights of transmitter and receiver are the same. We have

$$d_1' = \sqrt{d_1^2 + h^2} = d_1 \sqrt{1 + \frac{h^2}{d_1^2}}$$

$$d_2' = \sqrt{d_2^2 + h^2} = d_2 \sqrt{1 + \frac{h^2}{d_2^2}}$$

Recall Taylor's series Prof. Rappaport taught in the class.

$$(1+x)^n = 1 + \frac{nx}{1!} + \frac{n(n-1)x^2}{2!} + \cdots$$

Therefore, $1 + (\frac{h}{d_1})^2 \approx 1 + \frac{1}{2} (\frac{h}{d_1})^2 + \frac{\frac{1}{2} \cdot (-\frac{1}{2})}{2} [\frac{h}{d_1}]^4 + \cdots$

Since $h << d_1$, so the equation above can be transformed approximately as

$$\sqrt{1 + (\frac{h}{d_1})^2} \approx 1 + \frac{1}{2} (\frac{h}{d_1})^2$$, Thus $d_1' = d_1 + \frac{1}{2} \frac{h^2}{d_1}$

Similarly, $d_2' = d_2 + \frac{1}{2} \frac{h^2}{d_2}$.

So the excess path distance $\Delta$ is

$$\Delta = d_1' + d_2' - d_1 - d_2 = \frac{1}{2} \frac{h^2}{d_1} + \frac{1}{2} \frac{h^2}{d_2} = \frac{h^2 (d_1 + h_2)}{2d_1d_2} \quad (4.54)$$
Recall the wavelength of a signal is \( \lambda = \frac{\pi}{d} \).
Thus the phase difference shall be
\[
\phi = \frac{2\pi \Delta}{\lambda} = \frac{2\pi \frac{h(axdx)}{\Delta}}{\lambda \Delta d dx} \quad (4.55)
\]

According to the property of triangle, we have
\[
\alpha = \beta + \gamma
\]
and \( \tan \beta = \frac{h}{d_1}, \tan \gamma = \frac{h}{d_3} \), recall the property of trigonometric function,
when \( \frac{h}{d_1} \ll \frac{h}{d_2} \) and \( \frac{h}{d_3} \ll \frac{h}{d_2} \) (recall \( h \ll d_1, h \ll d_3 \))
\[
\tan \beta = \frac{h}{d_1} \approx \beta, \quad \tan \gamma = \frac{h}{d_3} \approx \gamma, \quad \therefore
\]
\[
\alpha = \beta + \gamma = \frac{h(axdx)}{d_3 dx}
\]

The Fresnel-Kirchhoff diffraction parameter \( \nu \) is expressed as
\[
\nu = h \sqrt{\frac{x(axdx)}{\Delta d dx}}, \quad \text{take } \alpha = \frac{h(axdx)}{d_1 d_2} \text{ into the equation, then }
\]
\[
\nu = h \frac{(axdx)}{d_1 d_2} \sqrt{\frac{x(axdx)}{\Delta d dx}} = \lambda^{\frac{2(axdx)}{x(axdx)}} = \lambda^{\frac{2(axdx)}{x(axdx)}} \quad (4.56)
\]
The parameter is used to normalize the phase difference \( \phi \).