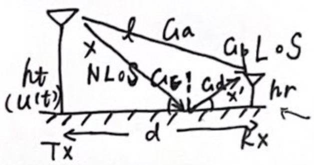
2023.09.25 无线通信 note 3

2.4.1 Two-Ray model



$(G_l = G_a\cdot G_b)$
$(G_r = G_c\cdot G_d)$
← 镜面反射

假设: LoS: $u_1(t) = \frac{\sqrt{G_l}\cdot\lambda}{4\pi l}\cdot e^{-j2\pi l/\lambda}\cdot u(t)$

NLoS: $u_2(t)$.

∴ ~~$v(t) = u_1(t) + u_2(t)$~~ (R代表反射性质).

近似: $u_2(t) = R\frac{\sqrt{G_r}\cdot\lambda}{4\pi(x+x')} e^{-j2\pi(x+x')/\lambda}\cdot u(t)$

(同上节课)

∵ $v(t) = u_1(t) + u_2(t)$

∴ $v(t) = \frac{\lambda}{4\pi}\cdot e^{-j2\pi l/\lambda}\left[\frac{\sqrt{G_l}}{l} + \frac{\sqrt{G_r}\cdot R}{(x+x')} e^{-j2\pi(x+x'-l)/\lambda}\right]\cdot u(t)$

(两条路径的时间差: $\frac{x+x'-l}{c}$)

(Delay spread).

Path Gain: ($\frac{1}{\text{Path Loss}}$). $\Delta\phi = 2\pi\frac{x+x'-l}{\lambda}$

$$P_a = \frac{P_r}{P_t} = \frac{\frac{1}{T}\int_0^T|v(t)|^2dt}{\frac{1}{T}\int_0^T|u(t)|^2dt}$$

$$= \left(\frac{\lambda}{4\pi}\right)^2\left|\frac{\sqrt{G_l}}{l} + \frac{R\sqrt{G_r}}{x+x'}e^{-j\Delta\phi}\right|^2$$

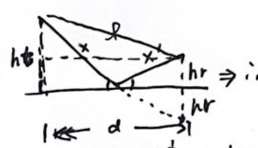
入射角→90°. 全反射. 相位翻转

近似: $\theta\to 0$, $x+x'\approx l\approx d$, $G_l\approx G_r$, $R\approx -1$

∴ $P_a \approx \left(\frac{\lambda}{4\pi}\right)^2\frac{G_l}{d^2}\left|1-e^{-j\Delta\phi}\right|^2$

$= \left(\frac{\lambda}{4\pi d}\right)^2 G_l\left|1-(1-j\Delta\phi)\right|^2$

(在零点泰勒展开) $= \left(\frac{\lambda}{4\pi d}\right)^2 G_l\cdot\Delta\phi^2$



⇒ ∴ $x+x'-l = \sqrt{d^2+(h_t+h_r)^2} - \sqrt{d^2+(h_t-h_r)^2}$

$= d\left[1+\left(\frac{h_t+h_r}{d}\right)^2\right]^{\frac12} - d\left[1+\left(\frac{h_t-h_r}{d}\right)^2\right]^{\frac12}$

$(1+x)^{\frac12}\approx 1+\frac12 x$ ⇒ $= d\left[1+\frac12\left(\frac{h_t+h_r}{d}\right)^2\right] - d\left[1+\frac12\left(\frac{h_t-h_r}{d}\right)^2\right]$

$= \frac{2h_t\cdot h_r}{d}$

∴ $P_a = \left(\frac{\lambda}{4\pi d}\right)^2 G_l\left(\frac{4\pi h_t\cdot h_r}{d\lambda}\right)^2$

$= \left(\frac{h_t\cdot h_r\sqrt{G_l}}{d^2}\right)^2$

※ V.S. Free-Space: $P_a = \left(\frac{\lambda\sqrt{G_l}}{4\pi d}\right)^2$ $\frac{P_r}{P_t}$

1. 与波长λ无关
2. 两个model, Free-Space更有利于传播.(远).

(见中文书P30)

(两路径相位差为π, 干涉, 相互抵消).

写成dB形式:

$P_a = \frac{P_r}{P_t} = \left(\frac{h_t\cdot h_r\sqrt{G_l}}{d^2}\right)^2$

$10\lg P_a = P_r\,dBW - P_t\,dBW\ (= P_r\,dBm - P_t\,dBm)$

$= 10\log_{10}G_l + 20\log_{10}(h_t\cdot h_r) - 40\log_{10}d$

读图 Figure 2.5.

后半段斜率为−40.

2.5 Empirical Path Loss Model

- Hata Model
- COST 231.

2.6 Simplified Path Loss Model

Let K be the path gain at a reference distance d_0 then: $\frac{P_r}{P_t} = K\cdot\left(\frac{d_0}{d}\right)^\gamma$

$P_r = P_t\cdot K\cdot\left(\frac{d_0}{d}\right)^\gamma$

γ: Path Loss exponent. γ=2. Free-Space.. γ=4. Two-Ray..

$P_r\,dBm = P_t\,dBm + K\,dB - 10\gamma\log_{10}\frac{d}{d_0}$

$P_L\,dB = P_t\,dBm - P_r\,dBm$

$= -K\,dB + 10\gamma\log_{10}\frac{d}{d_0}$

2.7. Shadowing (随机变量)(R.V.).

Without shadowing. $P_L = \frac{P_t}{P_r}$ (constant).

With shadowing. $\underset{R.V.}{\psi} = \frac{P_t}{P_r} \leftarrow \underset{constant}{PL}\times\underset{R.V.}{SH}$

ψ follows log-normal distribution, ($10\log_{10}\psi\sim$ normal)

$\psi\,dB \triangleq 10\log_{10}\psi \sim$ ~~normal~~ normal

∴ $\psi\,dB\sim N(\mu_{\psi dB}, \sigma^2_{\psi dB})$.

PDF of ψdB:

$$p(\psi_{dB}) = \frac{1}{\sqrt{2\pi}\sigma_{\psi dB}} e^{-\frac{(\psi_{dB}-\mu_{\psi dB})^2}{2\sigma^2_{\psi dB}}}$$

∵ $\psi = P_L\cdot P_{SH}$

∴ $\mu_{\psi dB} = E[\mu_{dB}] = E[10\log_{10}(P_L\cdot P_{SH})]$

$= E[10\log_{10}P_L + 10\log_{10}P_{SH}]$

$= 10\log_{10}P_L + E[10\log_{10}P_{SH}]$

$= \underbrace{P_L\,dB}_{随d↑增加} + \underbrace{\text{Average of (Shadowing in dB)}}_{随d↑几乎不变}$

2.8 Combined PL & SH

$$\frac{P_r}{P_t}\,dB = -\frac{P_t}{P_r}\,dB = -\psi\,dB$$

$$= \underbrace{-\mu_{\psi dB}}_{\text{equivelent PL}} \underbrace{-\left(\psi_{dB}-\mu_{\psi dB}\right)}_{N(0,\ \sigma_{\psi dB})}$$