exam 2/26 coverage chap 1-4, Review

electrical version problem

ECE 6332

Class 5 1/29/14

Y TX power (Range)

large scale propagation
- path loss model: $\beta = 2\text{-}6$
- log normal: $\sigma = 3\text{-}12$ dB

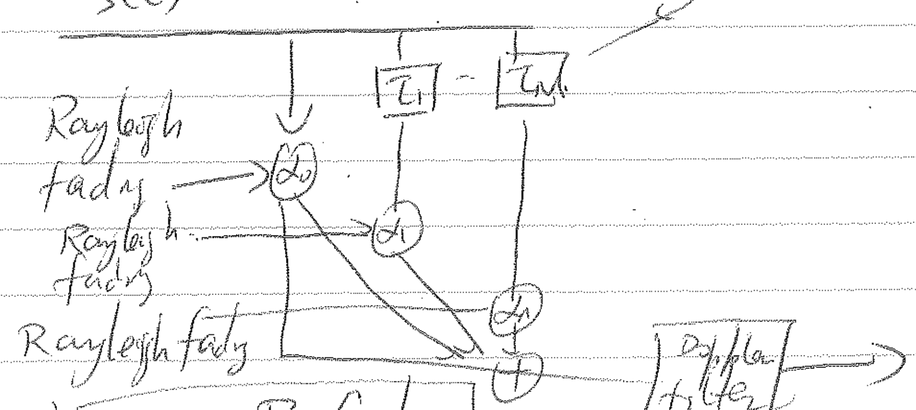
small scale fading

type I
- ① coherent bandwidth: RMS
  - flat fading v.s. frequency selective fading
- ② coherent time: doppler shift
  - slow fading v.s. fast fading

II model
- Rayleigh – NLOS
  - complex zero mean Gaussian
- Rician – LOS
  - complex nonzero mean Gaussian
- other model: Nakagami, Gilbert Elliot model

simulation:
- Doppler filter
- multipath profile $(\alpha_i \tau_i)$

$s(t)$



chapter 3 Statistical multipath channel models

3.1 Time varying channel Impulse response

Tx Signal $s(t) = Re\{u(t)\, e^{j2\pi f_c t}\}$

$u(t)$ is baseband signal f_c is the carrier fq

Rx Signal $r(t) = Re\left\{ \sum_{n=0}^{N(t)} \alpha_n(t)\, u(t-\tau_n(t))\, e^{j(2\pi f_c (t-\tau_n(t)) + \phi_{D_n})} \right\}$

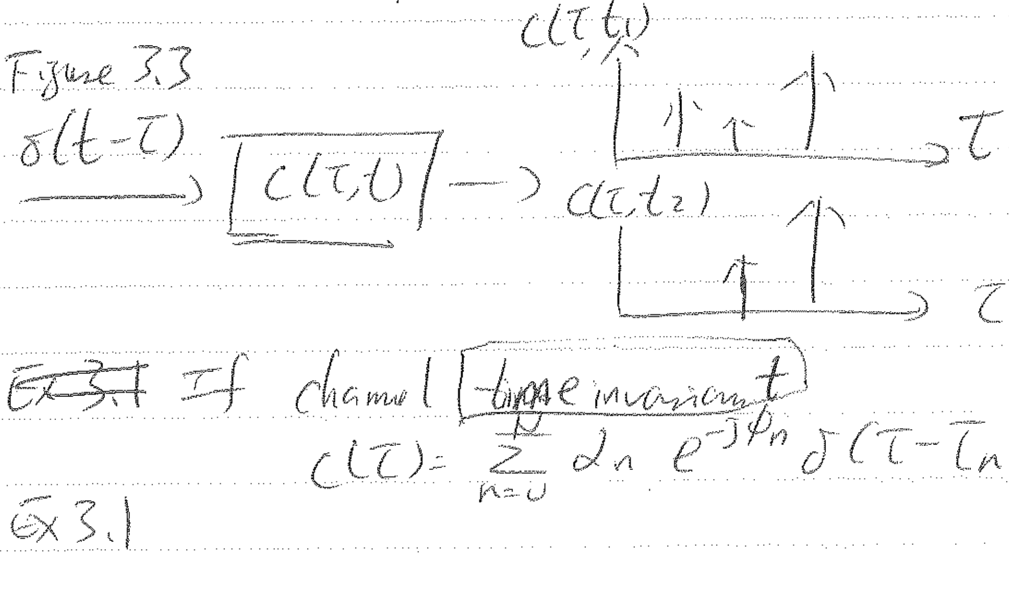
all fn of t:
- $N(t)$: no. of multipath
- $\alpha_n(t)$: multipath strength
- $\tau_n(t)$: multipath delay
- $\phi_{D_n}(t)$: doppler phase shift

~~Ex~~ We can also write $r(t)$ as a filter of channel

$$r(t) = Re\left\{ \left(\int_{-\infty}^{\infty} c(\tau,t)\, u(t-\tau)\, d\tau \right) e^{j2\pi f_c t} \right\}$$

where $c(\tau,t) = \sum_{n=0}^{N(t)} \alpha_n(t)\, e^{-j2\pi f_c \tau_n(t) - \phi_{D_n}}\, \delta(\tau-\tau_n(t))$

Figure 3.3



~~Ex 3.1~~ If channel $\boxed{\text{time invariant}}$

$$c(\tau) = \sum_{n=0}^{N} \alpha_n\, e^{-j\phi_n}\, \delta(\tau-\tau_n)$$

Ex 3.1

3.2 Narrowband Fading models

i.e. flat fading → RMS small

$$r(t) = Re\{u(t)\, e^{j2\pi f_c t} \left(\sum_n \alpha_n(t)\, e^{-j\phi_n(t)}\right)\}$$

assume $u(t) = e^{j\phi_0}$ ϕ_0 random

$$s(t) = Re\{u(t)\, e^{j2\pi f_c t}\} = Re\{e^{j(2\pi f_c t + \phi_0)}\}$$

then $r(t) = Re\{[\sum_{n=0}^{N(t)} \alpha_n(t)\, e^{-j\phi_n(t)}]\, e^{j2\pi f_c t}\}$

$$= r_I(t) \cos 2\pi f_c t - r_Q(t) \sin(2\pi f_c t)$$

where $\begin{cases} r_I(t) = \sum_{n=1}^{N(t)} \alpha_n(t) \cos\phi_n(t) & \text{Inphase} \\ r_Q(t) = \sum_{n=1}^{N(t)} \alpha_n(t) \sin\phi_n(t) & \text{quadrature phase} \end{cases}$

$$\phi_n(t) = 2\pi f_c \tau_n(t) - \phi_{D_n} - \phi_0$$

Question: $\begin{cases}\text{what is power spectrum density (PSD)} \\ \text{what is distribution}\end{cases}$

3.2.1 Auto correlation cross-correlation and PSD

mean: $E[r_I(t)] = E\{\sum_n \alpha_n \cos\phi_n(t)\} = \sum_n E[\alpha_n] E[\cos\phi_n(t)] = 0$

cross correlation: $E[r_I(t)\, r_Q(t)] = 0$

Auto correlation $A_{r_I}(t, t+\tau) = E[r_I(t)\, r_I(\tau + t)]$

$$= \frac{1}{2} \sum_n E[\alpha_n^2] \cos(2\pi v \tau \cos\frac{\theta_n}{\lambda})$$

if $f_{D_n} = v\cos\theta_n/\lambda$ is fixed, θ_n not function of t

it is wide sense stationary $A_{r_I}(\tau)$

~~cross correlation~~ for received signal

$$r(t) = r_I(t)\cos(2\pi f_c t) - r_Q(t) \sin(2\pi f_c t)$$

$$A_r(\tau) = E[r(t)\, r(t+\tau)]$$

$$= A_{r_I}(\tau) \cos(2\pi f_c \tau) + A_{r_I, r_Q}(\tau) \sin(2\pi f_c t)$$

If we assume $\Delta\theta = 2\pi/N$ $E[\alpha_n^2] = 2P_r/N$

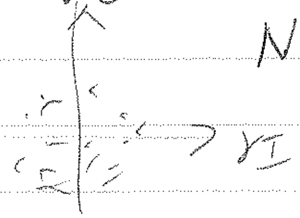
$\begin{cases} A_{r_I}(\tau) = P_r J_0(2\pi f_D t) & \text{Figure 3.5} \\ A_{r_I, r_Q}(\tau) = 0 \end{cases}$

PSD $S_{r_I}(f) = S_{r_Q}(f) = F(A_{r_I}(\tau)) = \begin{cases} \frac{2P_r}{\pi f_D}\frac{1}{\sqrt{1-(f/f_D)^2}} & f \le f_D \\ 0 & \text{otherwise} \end{cases}$

Figure 3.6

3.3.2 Envelope and Power distributions

Envelop $z(t) = |r(t)| = \sqrt{r_I^2(t) + r_Q^2(t)}$

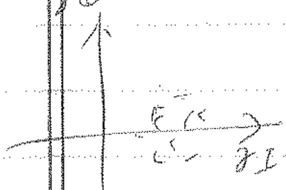


NLOS:

zero mean complex Gaussian $r_I + j r_Q$

$$p_Z(z) = \frac{z}{\sigma^2}\exp\left(-\frac{z^2}{2\sigma^2}\right) \quad z \ge 0$$

Rayleigh distribution with rx power σ^2



example 3.2

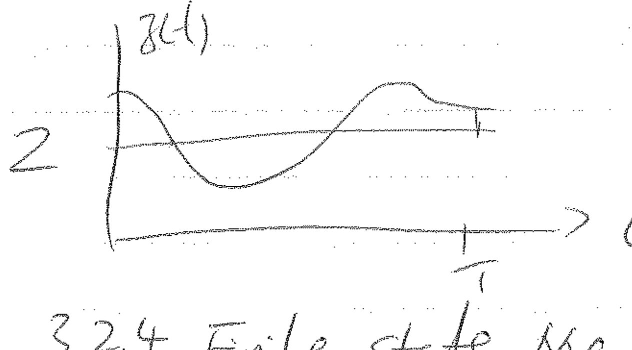
LOS: non-zero mean (s) complex Gaussian $r_I + j r_Q$

Rician distribution $p_Z(z) = \frac{z}{\sigma^2}\exp\left(\frac{-(z^2+s^2)}{2\sigma^2}\right) I_0\left(\frac{zs}{\sigma^2}\right)$

$z > 0$

Nakagami distribution (m)

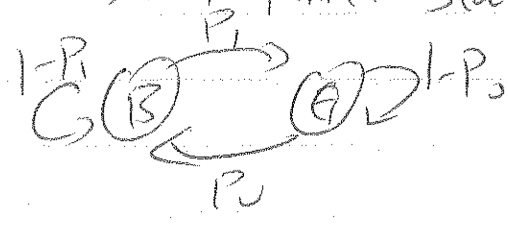
3.2.3 level crossing rate and average fade duration



$P_r(z(t) < Z)$

L_Z: level crossing rate

3.2.4 Finite state Markov channel



ex: GSM voice coder
4 state MDP