class 6 2/3/14

3.3 Wideband fading models

Inter-symbol interference Figure 3.11

remember (3.6) for time varying channel impulse response $c(\tau, t)$

define deterministic scattering function

Fig 3.12 $\longrightarrow S_c(\tau, \rho) = \int_{-\infty}^{\infty} c(\tau, t) e^{-j2\pi\rho t} dt$

Auto correlation fn:

$$A_c(\tau_1, \tau_2; t, t+\Delta t) = E\{c^*(\tau_1; t)\, c(\tau_2; t+\Delta t)\}$$

if WSS $A_c(\tau_1, \tau_2; \Delta t)$, $A_c(\tau; \Delta t)$

~~3.3.1 power delay profile~~

$$S_c(\tau, \rho) = \int_{-\infty}^{\infty} A_c(\tau, \Delta t) e^{-j2\pi\rho\Delta t} d\Delta t$$

multipath delay τ and Doppler ρ

3.3.1 power delay profile

define $\Delta t = 0$, $A_c(\tau)$

rms: $\sigma_{T_m} = \sqrt{\dfrac{\int_0^{\infty} (\tau - \mu_{T_m})^2 A_c(\tau) d\tau}{\int_0^{\infty} A_c(\tau) d\tau}}$

where $\mu_{T_m} = \dfrac{\int_0^{\infty} \tau A_c(\tau) d\tau}{\int_0^{\infty} A_c(\tau) d\tau}$

~~frequency selective vs. flat fading~~

Ex 3.4. Ex 3.5

3.3.2 Coherence bandwidth

define $C(f; t) = \int_{-\infty}^{\infty} c(\tau, t) e^{-j2\pi f\tau} d\tau$

Auto correlation fn

$$A_c(f_1, f_2; \Delta t) = E[C^*(f_1; t)\, C(f_2; t+\Delta t)]$$

$\int_{-\infty}^{\infty} A_c(\tau, \Delta t) e^{-j2\pi(f_2 - f_1)\tau} d\tau = \cancel{A_c(\Delta)} A_c(\Delta f; \Delta t)$

draw Figure 3.13

frequency selective vs. flat fading

Ex 3.6

3.3.3 Doppler Power spectrum and channel coherent time

Doppler effect, taking FFT of $A_c(\Delta f;\Delta t)$ over Δt

$$S_c(\Delta f;\rho) = \int_{-\infty}^{\infty} A_c(\Delta f;\Delta t) e^{-j2\pi\rho\Delta t} d\Delta t$$

set $\Delta f = 0$ $\quad S_c(\rho) = \int_{-\infty}^{\infty} A_c(\Delta t) e^{-j2\pi\rho\Delta t} d\Delta t$

Figure 3.14, coherent time. T_c

Doppler spread $B_D \simeq 1/T_c$

Figure 3.15 Fourier transform relations

slow fading vs. fast-fading

EX 3.7

3.3.4 Transforms for Autocorrelation and Scattering fns.

$$S_c(\tau;\rho) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} A_c(\Delta f;\Delta t) e^{-j2\pi\rho\Delta t} e^{j2\pi\tau\Delta f} d\Delta t\, d\Delta f$$

four ~~chan~~ types of channel

3.4 Discrete time model

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

Figure 3.17.

over sampling.

3.5 space-time channel model.

M antenna elements, with angle of arrival

$$c(\tau,t) = \sum_{n=0}^{N(t)} a_n(t)\, e^{-j\phi_n(t)} \vec{a}(\theta_n(t))\, \delta(\tau - \tau_n(t))$$

$$\vec{a}(\theta_n(t)) = [e^{-j\psi_{n,1}}, \dots, e^{-j\psi_{n,M}}]^T$$

$$\psi_{n,i} = [x_i \cos(\theta_n(t)) + y_i \sin\theta_n(t)]\, 2\pi/\lambda$$

for (x_i, y_i) the antenna location, $\theta_n(t)$ for angle.

rms for angular spread

$$u_\theta = \frac{\int_{-\pi}^{\pi} \theta A(\theta)\, d\theta}{\int_{-\pi}^{\pi} A(\theta)\, d\theta}$$

$$\sigma_\theta = \sqrt{\frac{\int_{-\pi}^{\pi} (\theta - u_\theta)^2 A(\theta)\, d\theta}{\int_{-\pi}^{\pi} A(\theta)\, d\theta}}$$

homework: 3.1, 3.7, 3.10, 3.12, 3.15, 3.16, 3.17
due 2/19. no late submission will be accepted

overview ~~of~~ chapter 4

other materials {
- how information is quantified. what is bit?
- channel capacity in AWGN

$$C = W \log(1 + SNR)$$

$$SNR = \frac{P_t G h}{\sigma^2}, \quad \begin{matrix} W: \text{bandwidth} \\ P_t: \text{tx power} \end{matrix}$$

σ^2: thermal power level h: fading G: large scale

- h is unknown but statistically
  { flat fading 4.2
  { frequency selective fading 4.3

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exam chapter 1-4
2/26