EEE 6109 Wireless Communication.

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11th April, 2019

Today's Lecture

1. Wideband and directional channel characterization
2. Channel Models
3. Channel Sounding

Introduction

- The transfer function of the channel varies over the channel bandwidth - frequency selectivity
- The impulse response of the channel is not a delta function - delay dispersion
- Wideband channels suffer from intersymbol interference
- Using appropriate signal processing techniques, the detrimental effects of fading can be overcome

Delay Dispersion

- Consider the two-path model where the transmit signal gets to the RX via two paths with run times $\tau_1 = d_1/c_0$ and $\tau_2 = d_2/c_0$
- Let's assume the RX, TX and IOs are stationary. The system is LTI and

$$h(\tau) = a_1\delta(\tau - \tau_1) + a_2\delta(\tau - \tau_2) \tag{1}$$

- We can show that the transfer function of this channel depends on frequency resulting in frequency selective fading.
- There are dips in this transfer function at the notch frequencies

See figure 6.1 in Molisch

Delay Dispersion

- Channels with frequency selective fading also experience phase distortion.
- Group delay is given by

$$\tau_{Gr} = -\frac{1}{2\pi}\frac{d\phi_H}{df} \tag{2}$$

where $\phi_H = \arg(H(f))$

See figure 6.2 in Molisch

Description of Wireless Channels

- If the RX, TX and IOs are static, the channel is time invariant with impulse response $h(\tau)$
- In general the impulse response is time variant $h(t, \tau)$
- t is absolute time and τ is delay
- In general we have

$$y(t) = \int_{-\infty}^{\infty} x(t-\tau)h(t,\tau)d\tau \tag{3}$$

- If the impulse response is shorter than the time over which the channel varies, we can model the channel as an LTI system

Power Delay Profile

- The PDP measures how much power from a transmitted delta pulse with unit energy arrives at the RX with a delay between $\tau, \tau + d\tau$
- We have

$$P_h(\tau) = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} |h(t, \tau)|^2 dt \tag{4}$$

- The PDP is summarized using the zeroth-order moment

$$P_m = \int_{-\infty}^{\infty} P_h(\tau) d\tau \tag{5}$$

Power Delay Profile

- The mean delay is

$$T_m = \frac{\int_{-\infty}^{\infty} P_h(\tau)\tau d\tau}{P_m} \tag{6}$$

- The rms delay spread is

$$S_\tau = \sqrt{\frac{\int_{-\infty}^{\infty} P_h(\tau)\tau^2 d\tau}{P_m} - T_m^2} \tag{7}$$

Example 6.1 in Molisch

Channel Models

- Stored channel models
- Deterministic channel models
- Stochastic channel models

Narrowband Models

- For a narrowband channel we have

$$h(t, \tau) = \alpha(t)\delta(\tau) \tag{8}$$

Path Loss Models

- Okumura-Hata model

$$PL = A + B\log(d) + C \tag{9}$$

  A, B, and C are factors that depend on frequency and antenna height
- COST 231-Walfish-Ikegami model
- Motley-Keenan Model - for indoor environments

$$PL = PL_0 + 10n\log(d/d_0) + F_{wall} + F_{floor} \tag{10}$$

Wideband Models - Tapped Delay Line Models

- The N-tap Rayleigh-fading model

$$h(t, \tau) = \alpha_0 \delta(\tau - \tau_0) + \sum_{i=1}^{N} c_i(t) \delta(\tau - \tau_i) \tag{11}$$

- $c_i(t)$ is a zero-mean complex Gaussian random process

Wideband Models - Power Delay Profile

- The PDP can be approximated by a one-sided exponential function

$$P_h(\tau) = P_{sc}(\tau) = \begin{cases} \exp(-\tau/S_\tau) & \tau \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

- Typical values of delay spread
  - Indoor residential building 5-10ns
  - Microcell 100-500ns
  - Hilly Terrain: $18\mu_s$

Deterministic Channel Modelling

- Ray Launching
- Ray Tracing
- Geographical databases

Channel Sounding

- Measurement of the impulse responses of channel
- The TX sends out a signal $s(t)$ that consists of periodically repeated pulses

$$s(t) = \sum_{i=0}^{N-1} p(t - iT_{rep})$$

- The impulse response is estimated from the received signal

See figure 8.3 in Molisch

Readings

- Molisch - Chapter 6, 7, 8, 10