S-72.245 Transmission methods in Telecommunication Systems

Tutorial 2

Objectives

- Get familiar with transmission channel basic properties
- Study impairments of transmission channels
- Study modeling of linear channels

Quizzes

Q1. Define by your own words and give an analytical expression for: Signal power, signal energy, and channel capacity in AWGN channels.

Q1. Briefly explain by your own words the following concepts: Attenuation, distortion, interference, and noise in data communications.

Q2. Study the concept of Group Delay as presented in Annex I. Then explain it by your own words. Can Group Delay equal phase delay - Why or why not?

Q3. a) Compare the properties of guided media and unguided media by calculating attenuation [dB] of omni-directional antenna with *n(f)* = 2.5, coaxial cable with the attenuation of 2.4 dB/100 m and optical fiber with attenuation of 0.35 dB/km at the propagation distance of 5 km. b) Select two examples of guided media and unguided media and compare their properties by giving pros and cons in some selected applications (pick the applications by yourself).

Q4. Study the concept of coherence bandwidth as presented in Annex II and in the supplied example 4.4. Explain by your own words what it means. Discuss coherence bandwidth in wide band and in narrow band channels by using some formulas.

Q5. Consider matching of a communication channel with $Z_L = 30 + j2\pi fL, L = 10\,\mathrm{nH}$ to the source of having impedance $Z_g = 10 + 1/(j2\pi fC), C = 1\,\mathrm{nF}$. Describe goodness of matching as a function of frequency. Is there a frequency where matching is optimized?

M1: Signal $x(t)$ has the duration of 10 seconds and it is defined by

$$x(t) = \begin{cases} \cos(2\pi \times 47t) + \cos(2\pi * 219t), & 0 \le t \le 10 \\ 0, & otherwise \end{cases}.$$

This signal is sampled at the sampling rate of 1000 samples per second. Find the total average power of this signal and find power-spectral density for this signal.

M2: Consider a linear transmission channel that is defined by the transfer function

$$H(f) = \frac{1}{1 + j2\pi f}$$

a) Plot its phase and frequency response up to 10 Hz based on this given expression. What is the 3 dB frequency bandwidth of the channel?
b) Create a Matlab program to estimate channel frequency response by feeding white noise to its input.

Annex I (See also Carlson's IV ed, pp. 91-94)

Group delay

- Consider a bandpass channel characterized by **group delay** t_g
$$H(f) = A\exp\left[j\left(-2\pi f t_g + \phi_0\right)\right] = \left[A\exp\left(j\phi_0\right)\right]\left[\exp\left(-j2\pi f t_g\right)\right]$$
$$\Rightarrow \arg H(f) = -2\pi f t_g + \phi_0, t_d(f) = t_g + \phi_0 / \left(2\pi f\right)$$
- Note that linear distortion is small provided that
$$\phi_0 / \left(2\pi f\right) << t_g \approx \text{constant}$$
- It can be shown [1,p. 93] that for the input* $x(t) = x_1(t)\cos\omega_c t + x_2(t)\sin\omega_c t$ channel output is
$$y(t) = Ax_1(t - t_g)\cos\left[\omega_c(t - t_d)\right]$$
$$- Ax_2(t - t_g)\cos\left[\omega_c(t - t_d)\right]$$
- Note that the modulation part is delayed by t_g and the carrier part by t_d
- For **distortionless transfer** it is thus required that
$$d\left[\arg H(f)\right] = \left(-2\pi f t_g + \phi_0\right)df$$
$$\Rightarrow t_g = -\frac{1}{2\pi}\frac{d\left[\arg H(f)\right]}{df} = \text{constant}$$

*Note that for *lowpass equivalent presentation* x_1 and x_2 would carry the *i* and *q* parts of modulation $v_i = \cos \phi_m(t)$, $v_q = \sin \phi_m(t)$

61

Annex II

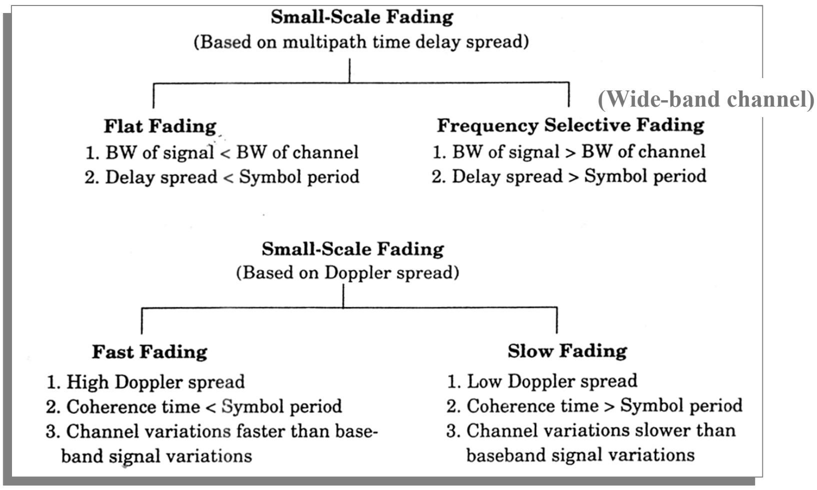
Coherence bandwidth and its relation to Doppler bandwidth

- Coherence BW defines the frequencies over which channel frequency response can be considered to be flat = passes all frequencies with the same transfer function
- In this frequency range, two separate frequencies have tendency for a strong correlation in their transfer function. If this assumed to be 50% the coherence bandwidth is [7] $B_c \approx \dfrac{1}{5\sigma_t}$
- Coherence time is defined as the time domain dual of coherence bandwidth and it can be determined by with same assumptions as above (eg. 50% correlation) as

$T_C \approx \dfrac{9}{16\pi f_m}$, $f_m = v/\lambda$ where f_m is the maximum Doppler spread

Ref: www.williamstallings.com

Small scale fading classified [7]



Ref : T.S. Rappaport: Wireless Communications

Example 4.4

Calculate the mean excess delay, rms delay spread, and the maximum excess delay (10 dB) for the multipath profile given in the figure below. Estimate the 50% coherence bandwidth of the channel. Would this channel be suitable for AMPS or GSM service without the use of an equalizer?

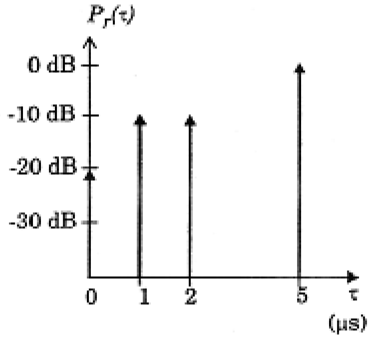


Figure E4.4

Solution to Example 4.4

The rms delay spread for the given multipath profile can be obtained using equations (4.35) — (4.37). The delays of each profile are measured relative to the first detectable signal. The mean excess delay for the given profile

$$\bar{\tau} = \frac{(1)(5) + (0.1)(1) + (0.1)(2) + (0.01)(0)}{[0.01 + 0.1 + 0.1 + 1]} = 4.38\mu s$$

The second moment for the given power delay profile can be calculated as

$$\overline{\tau^2} = \frac{(1)(5)^2 + (0.1)(1)^2 + (0.1)(2)^2 + (0.01)(0)}{1.21} = 21.07\mu s^2$$

Therefore the rms delay spread, $\sigma_\tau = \sqrt{21.07 - (4.38)^2} = 1.37\mu s$

The coherence bandwidth is found from equation (4.39) to be

$$B_c \approx \frac{1}{5\sigma_\tau} = \frac{1}{5(1.37\mu s)} = 146 \text{ kHz}$$

Since B_c is greater than 30 kHz, AMPS will work without an equalizer. However, GSM requires 200 kHz bandwidth which exceeds B_c, thus an equalizer would be needed for this channel.

Ref : T.S. Rappaport: Wireless Communications