

# S-72.245 Transmission methods in Telecommunication Systems

## General Guidelines for Tutorials, Fall 2004

- All tutorials are voluntary. Tutorials are divided into two sections:
  - Quiz-part reviews lecture contents in a rather general level. Due to this generality, it is recommended that you use Internet to investigate backgrounds.
  - Matlab-part focuses on mathematical contents of lecture and strives to illustrate lecture topics in practical, engineering level.
- Tutorial solutions will not be published, but you need to come to tutorials to discuss solutions. Course closed-book exam will have at least half of its assignments based directly on tutorials.
- Your course grade is formed by: (closed book exam grade) + (number of tutorials participated)/(number of all tutorials). Therefore, participation to tutorials can increase your grade maximum by 1.
- Participation to tutorials is controlled by participation list circulated in tutorials. You need to return all your tutorial solutions at the end of all tutorials in a bundle. These bundles are returned by lecture assistant before exam. NOTE: Your tutorial solutions are not graded - only your participation to tutorials counts.
- Lecture assistant will discuss tutorial solutions in tutorials. Therefore, your 'activity-factor' in tutorials is totally up to you - you may just come to listen solutions, or you may come to make questions and to suggest own solutions.

## **Tutorial 1**

### Objectives

- Study conversion between time and frequency domain presentations of periodic, analog signals
- Recognition of pros & cons of in time and frequency domain presentations
- Properties of linear, time-invariant transmission channel
- Sinc-function: Properties, applications, and limitation

Note: Sometimes you need to make web searching. If there are no references after the question consult lecture notes, Google or other material in web. Many universities as University of Rice (<http://cnx.rice.edu/>) and MIT (<http://ocw.mit.edu/index.html>) offer nice on-line courses for further information (ref. to electrical and communications engineering type of courses)

### Quizzes

Q1.1: Give your *verbal arguments* what is the logic in definition of self-information by

$$\begin{cases} I_i \geq 0, 0 \leq P_i \leq 1 \\ I_i > I_j, P_i < P_j \end{cases} \begin{cases} P_i \rightarrow 0, I_i \rightarrow \infty \\ I_{ij} = \log_b \frac{1}{P_i P_j} = \log_b P_i^{-1} + \log_b P_j^{-1} = I_i + I_j \end{cases}$$

Q1.2: Discuss coaxial cable and optical fibre as a transmission medium with respect of their bandwidth, attenuation and linearity. Mention/justify applications [1,2].

Q1.3: How can you convert continuous signal into discrete signal? What about vice versa? What happens to the information contents of the signal in these conversions and why? [3] [4, Chapter 6]

Q1.4: Are all the signals in real world real-signals or are there also complex-signals in real world? Any examples? [5]

Q1.5: Define channel linearity - Why channel non-linearity is especially harmful in frequency multiplexed (FDM) systems, as in Cable TV distribution? [4, Chapter 3]. Keywords: CATV, Nonlinear distortion

Q1.6: Show that linear channel can not generate new frequency components (that don't exist in its input) to its output.

Q1.7: Draw a block diagram of an AWGN channel! How would you define additive, white, and Gaussian noise?

Q1.8: Why statistical multiplexing is applied often in data communications?

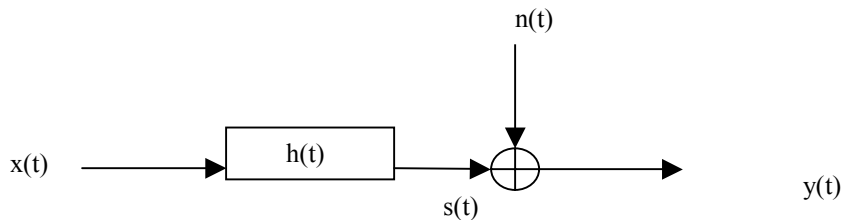
Matlab assignments

M1.1. Signal  $x(t)$  has a duration of 10s and is the sum of two sinusoidal signals of unit amplitude, one with frequency 47 Hz and the other one with frequency of 147 Hz:

$$x(t) = \begin{cases} \cos(2\pi \times 47t) + \cos(2\pi \times 147t), & 0 \leq t \leq 10 \\ 0, & \textit{otherwise} \end{cases}$$

This signal is sampled at a sampling rate of 1000 samples per second. Plot its time-domain representation and positive spectrum in the same page. In order to make comparison with the result of the following questions, only 0.4 duration of the time-domain signal is OK.

M1.2. Assume a base band signal transmission using a communication link for the band limited AWGN channel where  $x(t)$  is the input signal,  $y(t)$  is the output signal, and  $n(t)$  is white Gaussian noise.



The channel transfer function employs a sinc function which has the spectrum following rectangular pulse shape:

$$H(f) = \frac{1}{2W} \text{rect}\left(\frac{f}{2W}\right) = \begin{cases} \frac{1}{2W} & |f| < W \\ 0 & \textit{otherwise} \end{cases}$$

Note that the factor  $1/2W$  is required for scaling pulse peak to unity in time domain. Respective time-domain waveform can be obtained via inverse Fourier transform yielding  $h(t) = \text{sinc}(2Wt)$ .

Let the channel bandwidth be  $W = 100$  Hz. We truncate the sinc function (for plotting) to extend from -0.1 seconds to 0.1 seconds and normalize its amplitude to unity. This signal is sampled at a sampling rate of 1000 samples per second. Plot its time-domain representation and positive side of spectra in the same page.

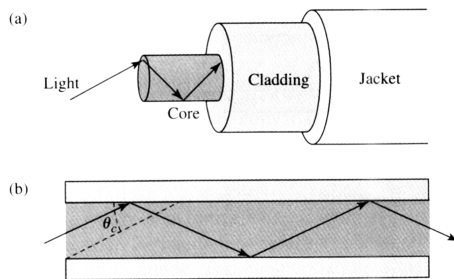
M1.3. By using the transmission system of M1.2, let the signal  $x(t)$  in M1.1 be the input and  $s(t)$  to be the transmitted signal. Plot  $s(t)$ 's time-domain (the first 0.4 s) representation and positive side spectrum representations in the same page. Compare the figures of  $x(t)$  and  $s(t)$  in time and frequency domains.

## References

1. <http://www.epanorama.net/documents/wiring/coaxcable.html>
2. See the figure below
3. <http://www.ericsson.com/support/telecom/index.shtml> (A.2.7.2)
4. A. Bruce Carlson: Communication Systems IV ed
5. <http://cnx.rice.edu/content/m11529/latest/>

## Reference 2

3.8 Properties of Media and Digital Transmission Systems 157

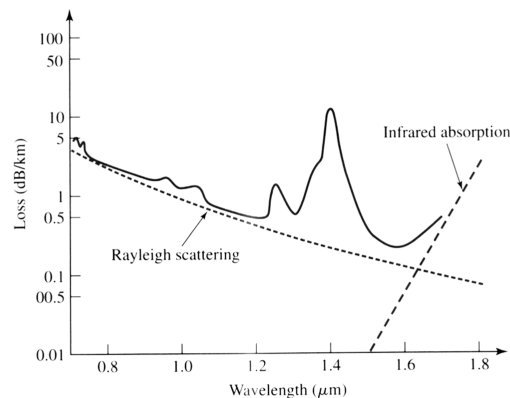


**FIGURE 3.54** Transmission of light waves in optical fiber: (a) geometry of optical fiber; (b) reflection in optical fiber.

interference from external sources. Thus compared to electrical transmission, optical fibers are more secure from tapping and are also immune to interference and crosstalk.

**Optical fiber** consists of a very fine cylinder of glass (core) surrounded by a concentric layer of glass (cladding) as shown in Figure 3.54. The information itself is transmitted through the core in the form a fluctuating beam of light. The core has a slightly higher optical density (index of refraction) than the cladding. The ratio of the indices of refraction of the two glasses defines a critical angle  $\theta_c$ . When a ray of light from the core approaches the cladding at an angle less than  $\theta_c$ , the ray is completely reflected back into the core. In this manner the ray of light is guided within the fiber.

The attenuation in the fiber can be kept low by controlling the impurities that are present in the glass. When it was invented in 1970, optical fiber had a loss of 20 dB/km. Within 10 years systems with a loss of 0.2 dB/km had become available. Figure 3.55 shows that minimum attenuation of optical fiber varies with the wavelength of the



**FIGURE 3.55** Attenuation versus wavelength for optical fiber. A. Leon-Garcia: Communication Networks, 2th ed, pp. 157.