Experiment
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Communication Channel Effects

Hardware Experimentation

Objectives

The main objectives of this experiment are:

1. To obtain a better understanding of the impact of channel bandwidth limitation on the performance of communication systems.

2. To learn how to measure channel bandwidth.

3. To experiment with channel distortion impact on PAM and PCM transmission using the DCB platform.

Pre-Lab Work

You should read the relevant material in your textbook, and answer the following questions:

1. By referring back to basic Fourier theory results, explain why the time duration of a pulse signal and its bandwidth are inversely proportional, i.e., if time duration is large, bandwidth is small, and vice-versa.

2. What is Inter-symbol Interference (ISI)? Is it caused by channel bandwidth limitation, external noise interference, or other factors? Explain.

Overview

A typical communication system consists of 3 main parts: the transmitter, the receiver, and the communication channel. This channel is a physical propagation medium used to carry signals between the transmitter and the receiver. For example, a propagation channel can be a twisted copper pair, an optical fiber, a coaxial cable, or a wireless RF link.

The propagation channel has many characteristics that can introduce distortion and pause a sever limitation to the proper reception of the transmitted signal. Some of these limitations include:

- Bandwidth limitation: where, for instance, a channel with poor high frequency characteristics (i.e., similar to a low-pass filter) will affect a digital pulse rise and fall times. Thus, limited bandwidth increases the time a pulse needs to attain the full amplitude required by the receiver. Also, if the channel has poor low-frequency characteristics, it will affect the top and bottom of the transmitted pulses, which no longer maintain a stable voltage, and become more difficult to detect.

- Additive noise: coming in the form of undesirable, random-like interference that corrupts the transmitted signal, and affects the ability of the receiver to detect it properly.

- Timing variations: also known as timing jitter, which is due to random variations in the channel time delay. As a result, the received signal is delayed by a varying amount of time from one signal period to the next, and become therefore difficult to track properly.

- Channel resonance: if the channel contains reactive elements, then oscillation can arise and cause amplitude ringing effects, with overshoots and undershoots than can lead to signal detection errors at the receiver.

In this experiment, we focus on bandwidth-related aspects of digital communication channels. For a digital transmitted pulse to be detected at the receiver, the significant frequency components of the pulse must pass undistorted through the channel. Bust since practical channels have limited bandwidth, only the frequency components inside the channel passband will be received properly. The elimination of some frequency components will change the shape of the received pulse, and may cause loss of information at the receiver.

To get a basic idea of how to assess channel bandwidth, consider for example the case where the channel can be approximated by a simple low-pass filter of 1st order (e.g., an R-C circuit). It is then found that the 3-dB pass-band of this channel (which can taken as a measure of bandwidth) is given by $BW = 1/(2\pi RC)$ or $1/(2\pi\tau)$, where τ is the time constant of the circuit. Recall also from electrical circuit theory that one RC time constant is required for the output voltage to reach 63% of the input voltage (when the input is a stair-case pulse).

The concept of *rise time* can be linked to signal bandwidth as well. Rise time, denoted by T_r , is the time required for a pulse to rise from 10 to 90% of its final value. It can be shown that bandwidth is given by: $BW = 1/(\pi T_r)$. Notice that for a pulse to reach its full amplitude at the receiver, the pulse duration (or period) must be greater than the rise time imposed by the channel. This clearly shows that the pulse rise time (or, equivalently the channel bandwidth) sets a practical limit on the minimum signal pulse duration and, therefore, the maximum permissible symbol transmission rate.

In this experiment, you will be using the DCB board with the PAM, PCM and Channel Simulator blocks. The Channel Simulator is simply a configurable filter that emulates the response of a real communication channel. Additionally, the DCB channel block is also capable of including additive noise, but this is outside our scope at this time.

Lab Work

1) Part 1: PAM Transmission through a band-limited channel

- Launch WinFACET software and select the "Channel Effects" experiment under Digital Communications 1.
- Go through the overview section, then start Exercise 1: Channel Bandwidth. Notice that this lab does not cover Exercise 2 (with noise effects).

  Important Note: Do NOT follow the procedures for using the PAM-TDM block (bottom left of the DCB board) to connect this experiment setup. Instead, use the PAM block (top left of the DCB). Make sure you observe the output PAM signal from the channel (and not from the RX filter).

- Apply the sinusoidal input signal M2 from the PAM block to the Sampler input and follow the rest of the procedure steps up to Step 19 (on Slide 12). Notice also that you will be using the receive filter of the PAM block (and not the Filter 1 in the PAM-TDM block).
- Follow all steps, and use the software control for toggling the CM switch to change the channel simulator bandwidth. Record all your observations, and report your answers to the questions.
- As an additional question, when the channel bandwidth is not limited, does the channel still have some attenuation in its pass-band (i.e., within 80 kHz)? Give measurements and explain whether this is considered as distortion or not?

2) Part 2: PCM Transmission through a band-limited channel

- Disconnect the previous setup, and proceed from Step 21 (slide 14) in the Exercise 1 procedure using the PCM block of the DCB board.
- Now, use CODEC 1 as a transmitter and CODEC 2 as a receiver, with the channel simulator in between. Connect the M1 signal to Input AX of CODEC 1, the PCM output DX to the channel IN, and the Channel OUT to DR of CODEC 2. The analog recovered signal is obtained at AR of CODEC 2.
- Follow all steps, and use the software control for toggling the CM switch to change the channel simulator bandwidth. Write your observations and answers to the questions.
- Finally, go through the five review questions after finishing the experimental procedure, and report your answers.

Additional Questions

Q1. In the lab procedure you went through, can you reliably transmit the PCM signal through a channel with 80 kHz bandwidth? Why? What should be the required channel bandwidth (approximately) to allow adequate reception?

Q2. Can you suggest a typical method for controlling the bandwidth of a transmitted signal? Explain how. Hint: think of the Fourier transform of various pulse shapes!