ECE355: Signal Analysis and Communications

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0.1 Introduction and Course Information

This document offers an overview of the ECE355 course. They comprise my condensed course notes for the course. No promises are made relating to the correctness or completeness of the course notes. These notes are meant to highlight difficult concepts and explain them simply, not to comprehensively review the entire course.

Primary course topics include:

1. Signals and Systems (Chapter 2).
2. Frequency Domain Analysis (Chapters 3-5).
3. Sampling (Chapter 9).
4. Introduction to Communication Systems (Chapter 8).

Course Information

- Professor: Ben Liang
- Course: Engineering Science, Machine Intelligence Option
- Term: 2020 Fall

Chapter 1

Signal Basics

1.1 Definitions

Two types of signals: Continuous ($f(x)$ defined $\forall x \in \mathbb{R}$) and Discrete $f(n)$ defined $\forall n \in \mathbb{Z}$.

Power and Energy of a signal:

- Power of $x(t)$ is $|x(t)|^2$.
- Energy of $x(t)$ is defined on interval $[t_1, t_2]$ as

$$E_{[t_1,t_2]} = \int_{t_1}^{t_2} |x(t)|^2 dt$$

$$E_{n_1 \leq n \leq n_2} = \sum_{n=n_1}^{n_2} |x[n]|^2$$

- Average power of in $[t_1, t_2]$:

$$P_{[t_1,t_2]} = \frac{E_{[t_1,t_2]}}{t_2 - t_1}$$

$$P_{[n_1,n_2]} = \frac{E_{n_1 \leq n \leq n_2}}{n_2 - n_1 + 1}$$

- Total Energy:

$$E_\infty = \lim_{T \to \infty} \int_{-T}^{T} |x(t)|^2 dt$$

$$E_\infty = \lim_{N \to \infty} \sum_{n=-N}^{N} |x[n]|^2$$

1.2 Signal Transformations

Time Shifting: *Shifts t_0 units RIGHT*

$$y(t) = x(t - t_0)$$

$$y[n] = x[n - n_0]$$

Time Scaling: *Speeds original signal up by factor a)* (or slowed down by factor $\frac{1}{a}$). Time reversal occurs when $a < 0$.

$$y(t) = x(at)$$

Continuous Scaling AND Shifting: It is important to remember the following steps for $y(t) = x(at + b)$

1. **SHIFT**: $v(t) = x(t + b)$.
2. **SCALE**: $y(t) = v(at)$.

Discrete Time Scaling AND Shifting: Remember to IGNORE fractional indexes. Interpolation for 'slowing down' a signal is a poorly defined process that will be covered later.

1.3 Periodic Signals

Definition: A signal is periodic iff $\exists T > 0$ s.t. $x(t + T) = x(t)\ \forall t \in \mathbb{R}$.

- T is the period of the signal.
- **Fundamental** period is the smallest possible T.
- If $x(t)$ is constant, then the fundamental period is undefined.

1.4 Even and Odd Signals

Even: $x(t) = x(-t)$

Odd: $x(-t) = -x(t)$

ANY SIGNAL can be decomposed into an even and odd component.

$$x_{even}(t) = \frac{1}{2}(x(t) + x(-t))$$

$$x - odd(t) = \frac{1}{2}(x(t) - x(-t))$$

$$x(t) = x_{even}(t) + x_{odd}(t)$$

1.5 Complex Exponential

Function Family: $x(t) = ce^{at}$, $c, a \in \mathbb{C}$