Networks Lecture 1

csd5fa

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Course Logistics

Homework	30%
Midterm 1	15%
Midterm 2	20%
Final Project	25%
Lecture Scribing	10%

Grade Cutoffs posted on Collab
TA Hours TBD

1 Simple Network Theory

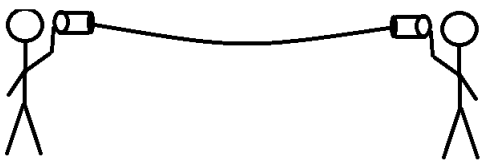
Goal: Move information from one point to the next

1.1 Four Basic Features

1. **Encoding**: convert into a form that we can "move"
2. **Decoding**: convert back to our our original information
3. **Transport**: wifi, ethernet
4. **Reliability**: strategy to move information consistently

1.2 A Simple Childhood example: the can-string phone

Information is encoded through amplitude modulation in the vibration of the string. However, no reliability here.



1.3 Network Architectures

There are three basic types of network architecture:

- **simplex**: one directional networks (TV, radio)
- **half-duplex**: two directional, however only one at a time (Walkie-Talkie, VHF Radio)
- **full-duplex**: two directional, simultaneous (cell network, landline)

Early Examples:

- The telegraph (half-duplex) encodes information with morse code, sent as a voltage spike for either a short (dot) or long (dash) amount of time. Hard to catch mistakes and terminate messages however.
- Broadcast Example: Before the internet, software was played over television shows through audio encoding. Viewers could record this, demodulate it, and use the software (unreliably, still). See video on course site.

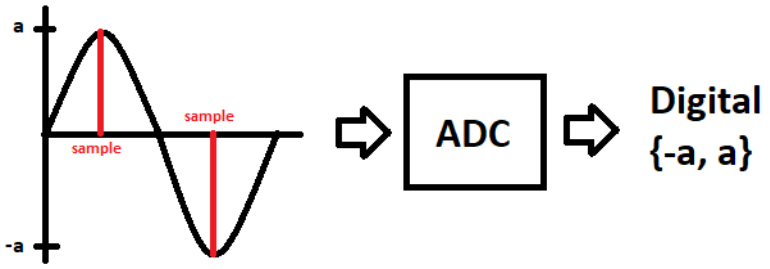
2 The Modern (OSI) Networking Model

Application Layer	The networks interaction with user software communication
Presentation Layer	Encryption, Compression
Session Layer	Authentication, Connection Management
Transport Layer	Node to Node comunication
Network Layer	Routing, Pathing through network
Data Link Layer	Framing, Reliability
Physical Layer	Physical Hardware, Software Defined Radio (SDR)

We will study this bottom-up, starting with the physical layer and SDR's.

3 Software Defined Radio (SDR)

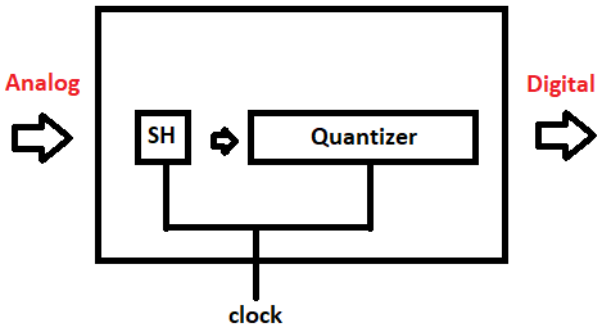
Goal: Covert audio / signal to digital values.



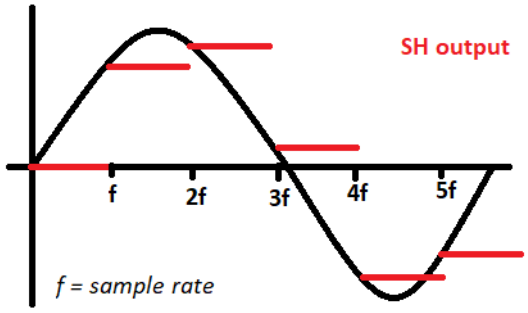
We must sample the signal through an analog digital converter (ADC) at a Hz at least twice its frequency to be able to reconstruct the wave.

3.1 The ADC

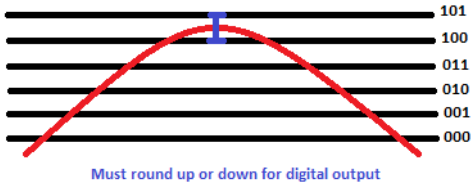
The ADC uses a sample holder (SH) and a Quantizer to produce digital output from an analog signal.



The sample holder converts the analog signal to a step function. Every cycle of its clock, it samples the signals amplitude and holds that value until its next cycle. The quantizer converts this held value to a digital value for output.



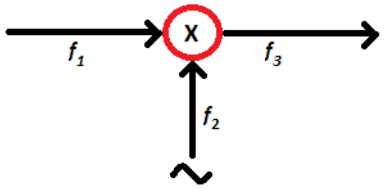
Quantizer error will affect the accuracy of the digital output however, as the quantizer must round down to the nearest whole value of amplitude.



What if we can't sample our signal at a high enough rate?

In order to convert frequencies beyond our sample rate to frequencies low enough to sample effectively, we pass the signal through a mixer. The mixer adds and

subtracts two frequencies, one from our signal and one from an oscillator, as shown below.



$$f_3 = \begin{cases} f_1 \pm f_2, & f_1 > f_2 \\ f_2 \pm f_1, & f_2 > f_1 \end{cases}$$

Consider a simple example with a radio:

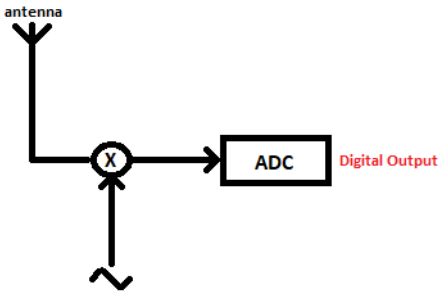
1. The input signal frequency (f_1) is 550 kHz
2. Our ADC runs at 200 kS/sec (kilo-samples per second)

What must our oscillator frequency (f_2) be at minimum? Recall that we must sample at least twice as often of the frequency, so the fastest frequency we can sample is 100 kHz.

$$\begin{gathered} f_3 = f_1 \pm f_2 \\ 100kHz = 550kHz \pm f_2 \\ 550kHz \pm 450kHz = (100khz, 1000khz) \end{gathered}$$

We must have an oscillator frequency of at least 450 kHz in order to pick up the output frequency (the 1000 kHz signal will be ignored). However, notice that an oscillator value of 650 kHz also creates one output frequency of 100KHz. We will see that this mixer property can also make two input signals indistinguishable with the same mixer frequency.

3.2 A (too) Simple SDR Design



We can build a simple SDR that can pick up a wider range of signals using just our mixer and ADC.However, we can observe that the indistinguishability problem limits this design. Consider if an SDR of this design had:

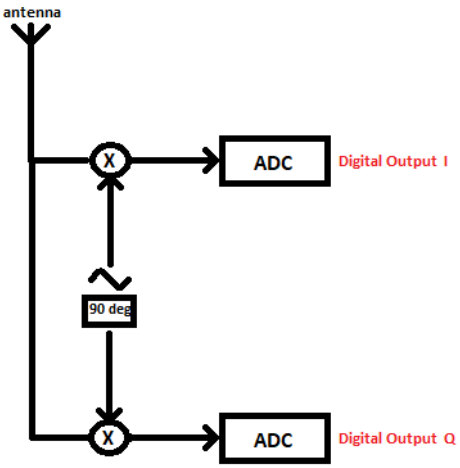
1. An oscillator frequency (f_2) of 91.1 Hz.
2. Two incoming frequencies (f_1) of 90.9 Hz and 91.3 Hz.

$$f_3 = f_2 \pm f_1$$
$$f_3 = 91.1Hz \pm 90.9Hz = (.2Hz, 182Hz)$$
$$f_3 = f_1 \pm f_2$$
$$f_3 = 91.3Hz \pm 91.1Hz = (.2Hz, 182.4Hz)$$

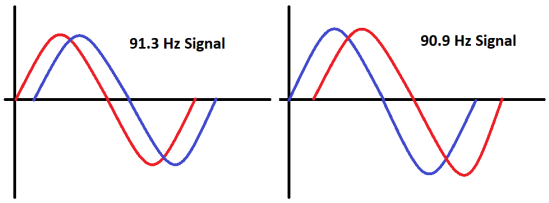
If our ADC can only pick up the .2 Hz signal, these two input signals will be **indistinguishable**. We can remedy this with the use of two mixers in 90 degree phase with each other.

3.3 The IQ SDR

The creation of a 90 degree in phase signal makes the two previously identical inputs distinguishable by creating a leading and lagging signal.



The two inputs from the previous example still create the same output waves, but the I and Q outputs will be in different phases, as shown below.



More on SDR's and the physical layer next lecture.

4 Some Latex References Used

- https://www.overleaf.com/learn/latex/Lists
- https://www.overleaf.com/learn/latex/Tables
- https://tex.stackexchange.com/questions/238037/how-to-typeset-piecewise-functions/238039