Information Technology
Inside and Outside
- David Cyganski & John A. Orr

V. Bandwidth and Information Theory

10. Audio as Information

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10. Audio as Information

- Objectives:
  - the physical principles underlying sound in the natural world;
  - the idea of a signal, and examples of some specific sound signals;
  - the concept of frequency, and its relationship to bandwidth of audio signals;
  - the ways in which signals can be represented graphically and mathematically; and
  - the special characteristics of sinusoidal signals that make them very useful.

10.1 Introduction/ 10.2 The Physical Phenomena Underlying Sound

10.1 Introduction

- ***Audio signals***-electronic representations of audible information
- The concepts of *frequency* and *bandwidth*

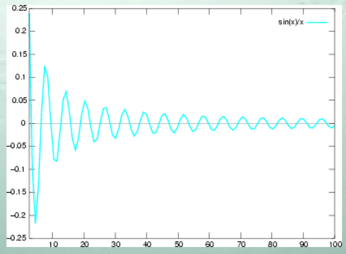
10.2 The Physical Phenomena Underlying Sound

- **Sound signal energy** is used to move air around. ***It is this motion of air that we perceive as sound.***
- To create sounds, we must provide a ***mechanical force*** to the surrounding air
- We can measure sound by recording the changes in air pressure at a particular location using, for example, a ***microphone***
- Like the human ear,a microphone has sensitive moving parts that respond to the motion of air caused as sound propagates past.

10.3 From Sound to Signals

- An electrical signal, known as an ***audio signal***

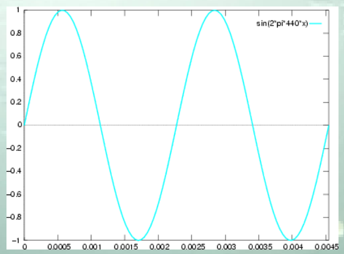
Figure 10.1: A signal such as would be created by a transient audio source upon transformation by a microphone into an electrical signal. The horizontal scale represents time in tenths of milliseconds.



10.3 From Sound to Signals(2)

- Representation of information in the form of a *voltage signal changing as a function of time* is a common one used for many types of measurable quantities that change with time

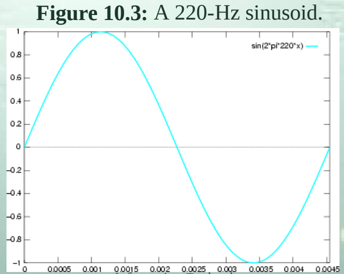
Figure 10.2: A 440-Hz sinusoid.



10.3 From Sound to Signals(3)

- Intervals of 2.27 milliseconds, or 1/440th of a second.This means that the wave repeats itself 440 times per second. We say that this wave has a ***frequency***, or rate of repetition, of **440 hertz**. The unit hertz, abbreviated Hz, is equivalent to **cycles per second**, and is used to measure the rate at which electric signals

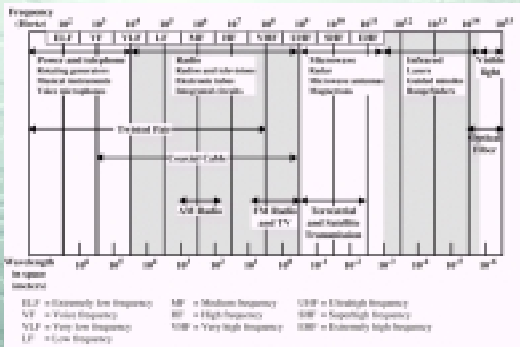
Figure 10.3: A 220-Hz sinusoid.



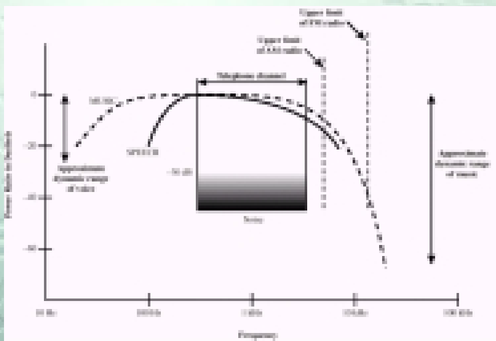
10.4 Limitations on Human Hearing

- What is the range of pitch, or frequencies, which humans can hear?
- The standard range used by manufacturers of audio systems is from **a lowest frequency of 20 Hz** to a **highest frequency of 20 kHz**,or 20,000 Hz.
  - The lowest audible frequency, **20 Hz**, is a low, rumbling``**bass**'' note, experienced as a vibration by the entire body, not just the ear.
  - The highest audible frequency, **20 kHz**, is actually beyond the range of most humans--if you listen to a lot of loud music, you probably can't hear much beyond 15 kHz--but some people and most dogs can hear this high pitch.

- **Cf. Electromagnetic Spectrum**



- **Cf. Acoustic Spectrum**



10.5 Sinusoidal Ffrequency Components

- The pure tone for A (440 Hz) above middle C
- The ***pure tone***, or sine wave, at 440 Hz
- an alto saxophone,a tenor saxophone, and a vibraphone

Figure 10.4: A 440-Hz ``A'' concert pitch sinusoid.

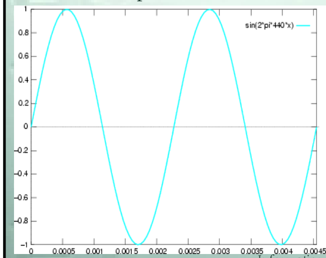
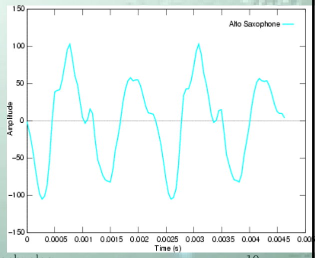


Figure 10.5: Concert ``A'' played on an alto saxophone.



10.5 Sinusoidal Ffrequency Components(2)

- An alto saxophone,a tenor saxophone, and a vibraphone
- Each waveform *repeats at a rate of 440 times per second*.

Figure 10.6: Concert ``A'' played on a tenor saxophone.

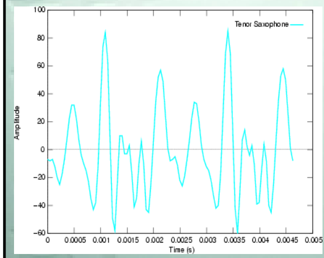
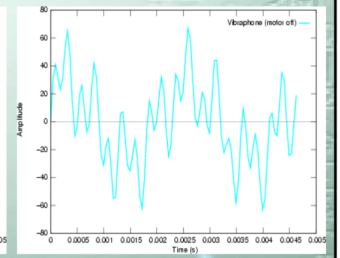


Figure 10.7: Concert ``A'' played on a vibraphone.



10.5 Sinusoidal Ffrequency Components(3)

- In the early 19th century, the French mathematician **Fourier** proved that ***all waveforms***, whether musical or not, ***can be constructed out of a sum of pure tones***.
- The implications of this are that ***every audio waveform--whether speech, music, or any other sound--can be built out of sinusoids at certain frequencies***. The different frequency components (or pure tones) which are added together to produce a complex waveform are called *the* ***frequency spectrum*** of that waveform.

10.6 The Frequency Content and Bandwidth of Audio Signals

- **Every signal is made up of a sum of simple sinusoidal tones**--known as the ***Fourier decomposition*** of the signal
- The sinusoidal tones **between 20 Hz and 20 kHz**, *the system can reproduce any* ***audible waveform***.
- **Human voices** can be recreated nicely by systems that can handle frequencies **between 100 Hz and 3 kHz**

10.6 The Frequency Content and Bandwidth of Audio Signals

- The highest frequency component in an audio signal is referred to as the ***bandwidth of the signal***.
- Thus, the **bandwidth of voice** signals is about **3 kHz**, and the **bandwidth of high fidelity music signals** is about **20 kHz**.
- The term ``bandwidth refers to the width of the range--or *band*--of frequencies that the signal occupies

10.7 Frequency Content of Audio Signals

- **The *time-domain description* of the signal**
- **The *frequency-domain description* of the signal**

10.7 Frequency Content of Audio Signals

- The time-domain signal ←→ The Frequency-domain signal

Figure 10.8: A concert ``A" 440Hz sinusoid.

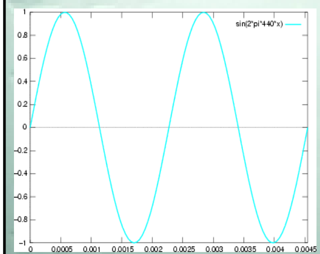
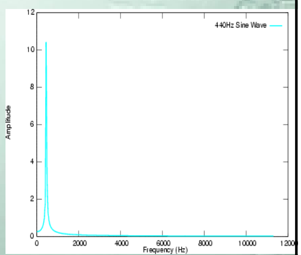


Figure 10.10: The frequency spectrum of a concert ``A" 440Hz sinusoid.



10.7 Frequency Content of Audio Signals(2)

- The time-domain signal ←→ The Frequency-domain signal

Figure 10.9: Concert ``A" played on a vibraphone.

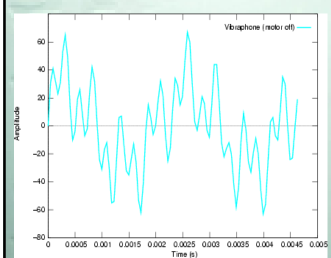
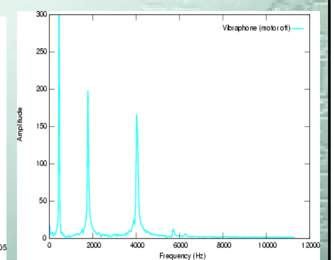


Figure 10.11: The frequency spectrum of a concert ``A" on a vibraphone.



10.7 Frequency Content of Audio Signals(3)

- The time-domain signal   The Frequency-domain signal

Figure 10.12: A **male** saying ``**information**."

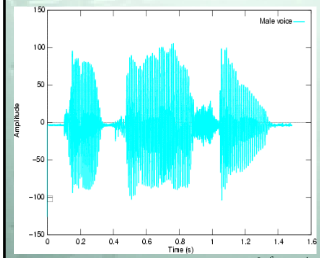
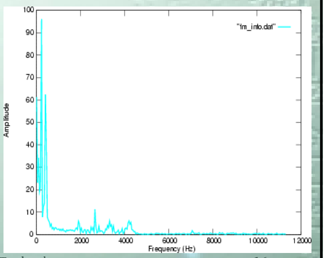


Figure 10.13: The frequency spectrum of a male saying ``information."



10.7 Frequency Content of Audio Signals(4)

- The time-domain signal ←→ The Frequency-domain signal

Figure 10.14: A **female** saying ``**information**."

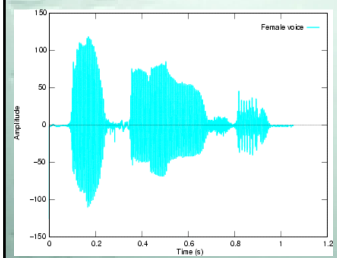


Figure 10.15: The frequency spectrum of a female saying ``information."