Sound Waves and Wave Interference

Introduction

In this laboratory, you will explore wave interference using sound waves.

Sound waves are disturbances in a medium that propagate from one place to another, without the actual transport of the particles that make up the wave. For instance, a sound wave traveling from a loudspeaker to your ear results in the successive compression and rarefaction of molecules of air between the loudspeaker and your ear, the molecules moving in the direction of wave propagation. But the molecules themselves are not transported any appreciable distance. In contrast, a breeze blowing on a warm summer day involves mass transport of air molecules, rather than wave motion.

In a fluid only longitudinal waves can occur (it is not possible to shake a fluid sideways). But in a solid, both longitudinal and transverse modes (sideways motion of the individual particles) occur. Earthquakes (or underground nuclear tests) generate both types, which propagate with different velocities, which also vary with the depth (i.e. with density and composition). These waves provide the only probe of the earth's interior and lead to our knowledge of a liquid nickel-iron region in the deep interior.

If you have two waves of very different frequency then the waves will pass right through each other, essentially ignoring each other.

When waves interact with each other, especially waves of the same (or nearly the same) frequency, interesting effects occur.

Activity 1: Understanding the Oscilloscope

EQUIPMENT

Cathode Ray Oscilloscope

The instrument most often used to measure time-varying signals is the Cathode Ray Oscilloscope (CRO). Actually "cathode ray" is just another name for an electron. This instrument uses the displacement of an electron across a fluorescent screen to indicate characteristics of an input signal. Both the amplitude (size) and the frequency (time rate of change) of the input signal can be determined from the change in position of the CRO beam.

PROCEDURE

1) Familiarization with CRO Controls

Screen -- On front panel, with a series of vertical and horizontal grid lines with 1 cm spacing used to measure the electron beam location, also note 0.2 cm hash marks

Power Switch and *3* Power Indicator -- To turn instrument on and indicate so

Focus Control -- Must be adjusted by the operator for optimum display on screen

Intensity Control -- Adjusts the brightness of the beam appearance on the screen

Vertical Section -- Controls vertical positioning of CRO beam.

VOLTS/DIV Switch -- Used to select the vertical sensitivity of the CRO channels

Note: The switch setting is determined by the 1X mark just outside the dial.

VOLTS/DIV Cal Controls -- Should be in fully clockwise position

Position Controls -- Adjusts vertical beam position on the CRO screen

Input Coupling Switches -- Used to input either AC or DC signals or ground

Input Connectors -- Used to input signals for either of the CRO channels

Vertical Mode Switches -- Used to select either one or both channels, and either inverting, alternating, or adding functions

Horizontal Section -- Controls horizontal positioning of CRO beam.

SEC/DIV Switch -- Used to select beam sweep speed, which enables us to observe the time-variation of an electrical voltage

SEC/DIV Cal Control -- Keep in a fully clockwise position

X10 Magnifier Switch -- If SEC/DIV control pulled out, then a factor of 10 increase takes place in the sweep speed; normally this would be kept pushed in

Position Control -- Adjusts horizontal beam position on the CRO screen

Horizontal Mode Switch -- Used to select the mode of operation for sweep

Delay Time -- Selects a particular delay time in measurement

Trigger Section -- Controls triggering of instrument for signal measurement.

TRIGGER Mode Switch -- Set to P-P AUTO

TRIGGER Level Control -- Set to midrange

Slope Switch -- Set to the "up" position

Source Switches -- Set left switch to VERT MODE, and right switch anywhere

INT Switch -- Set to the VERT(ical) MODE

EXT COUPLING Switch -- Set to the AC position

2) Obtaining the Baseline Trace

Whenever you use the CRO, the first thing that must be done is to establish the baseline trace. *Without turning the instrument on, preset the CRO controls as follows*:

DISPLAY section: Set the Intensity fully counterclockwise and the focus midrange.

VERTICAL section:	Position	Midrange
	Vertical Mode	Channel 2
	VOLTS/DIV	1 v
	CH 2 INVERT	Normal
	Input Coupling	AC
	Volts/Div Variable	Fully clockwise position
HORIZONTAL section:	Position	Midrange
	MAG	X1
	SEC/DIV	0.5 s

TRIGGER section: Set as indicated in the identification section above.

Now turn the power switch on and allow the instrument to warm up for a few minutes, and a solid horizontal line should appear across the screen. Adjust the Intensity control for desired brightness, but not too brightly, or you will burn the screen! The intensity setting may need readjusted later when you change the sweep speed of the CRO. Use the focus control to get a sharper view of the line. Center this trace (line) on the screen using the horizontal and vertical positioning controls.

3) Sweep Speed

In order to see the sweeping action of the electron beam, the SEC/DIV switch needs to be moved to a different setting. Set this control to 0.5 s and observe the beam move slowly and repeatedly across the screen. The beam should traverse one grid line in 0.5 s, or across the screen (10 divisions) in 5 seconds. Check this out with a stopwatch and verify the rate of beam sweep.

Now change the SEC/DIV setting to 0.2 seconds and observe what happens. Continue to decrease this setting until the beam appears to you as a continuous line across the screen.

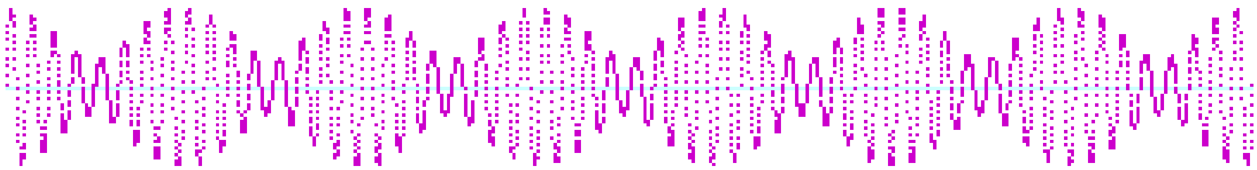
Record the SEC/DIV setting at which this first occurs here. ______

Beat Frequency

Beats result from combining at a point in space (e.g., your eardrum) two waves of different frequency. They are a periodic slow temporal variation (modulation) in the_amplitude of the resulting wave, with periodic slow temporal variation in the perceived loudness. The resulting waveform increases and decreases in amplitude in a periodic way, i.e., the sound gets louder and softer in a regular pattern.

The frequency of the beats is called the beat frequency. Suppose we have two waves with frequencies f1 and f2. If these two frequencies are combined then the frequency of the beating sound is given by:

$$f_{beat} = | f_1 - f_2 |$$



Activity 2: Beat Frequencies

Equipment:

Two speakers

Two frequency generators

Oscilloscope

Microphone with amplifier

Various connectors to get everything going

1. Use the banana plugs to connect each speaker to a signal generator: red to red and black to black plugs.
2. Plug the microphone with amplifier into the oscilloscope using the adapter.
3. Plug in the signal generators and the oscilloscope
4. Turn on the oscilloscope, if it is not on from before. Ensure that you have a solid line trace across the screen.
5. Have your instructor check your setup.
6. Turn on one signal generator and turn on the amplifier on the microphone. Place the microphone near the speaker and observe the signal on the oscilloscope. (Do not use too high of an amplitude because you can damage the speakers.)

   What is the value on the signal generator? __________________

   Verify that the oscilloscope is displaying the correct frequency.

   Explain how you determined the frequency displayed by the oscilloscope.

   Sketch the image on the oscilloscope.

7. Position the two stereo speakers so that they are standing right next to each other. Place the microphone in front of the speakers, roughly in between them.
8. Turn on the second signal generator and change the frequency slightly (no more than 2-3 Hz difference.)

Walk back and forth around the speakers. **Note that you can hear beats at any position – this is because beats are a temporal interference of two different frequencies, not a spatial interference.**

Try frequencies closer to each other, and farther apart. How does this change what you hear?

How far apart do the frequencies have to be before you no longer hear the pulsing?

Does it matter of the speakers are right next to each other or not?

9. Check your signal generator calibration.
    a. Set both signal generators to the exact same frequency. Do you hear beats?
    b. If you hear beats then this indicates that one of the signal generators is not indicating frequency exactly right! Adjust one signal generator until the beats go away.

    What is the value shown on the top signal generator? __________

    What is the value shown on the bottom signal generator? _________

    What is the difference between the two displayed frequencies? __________

    Any difference here indicates that the signal generators are no producing the exact same frequency.

10. Set the frequencies a little bit apart so you hear pulsing.

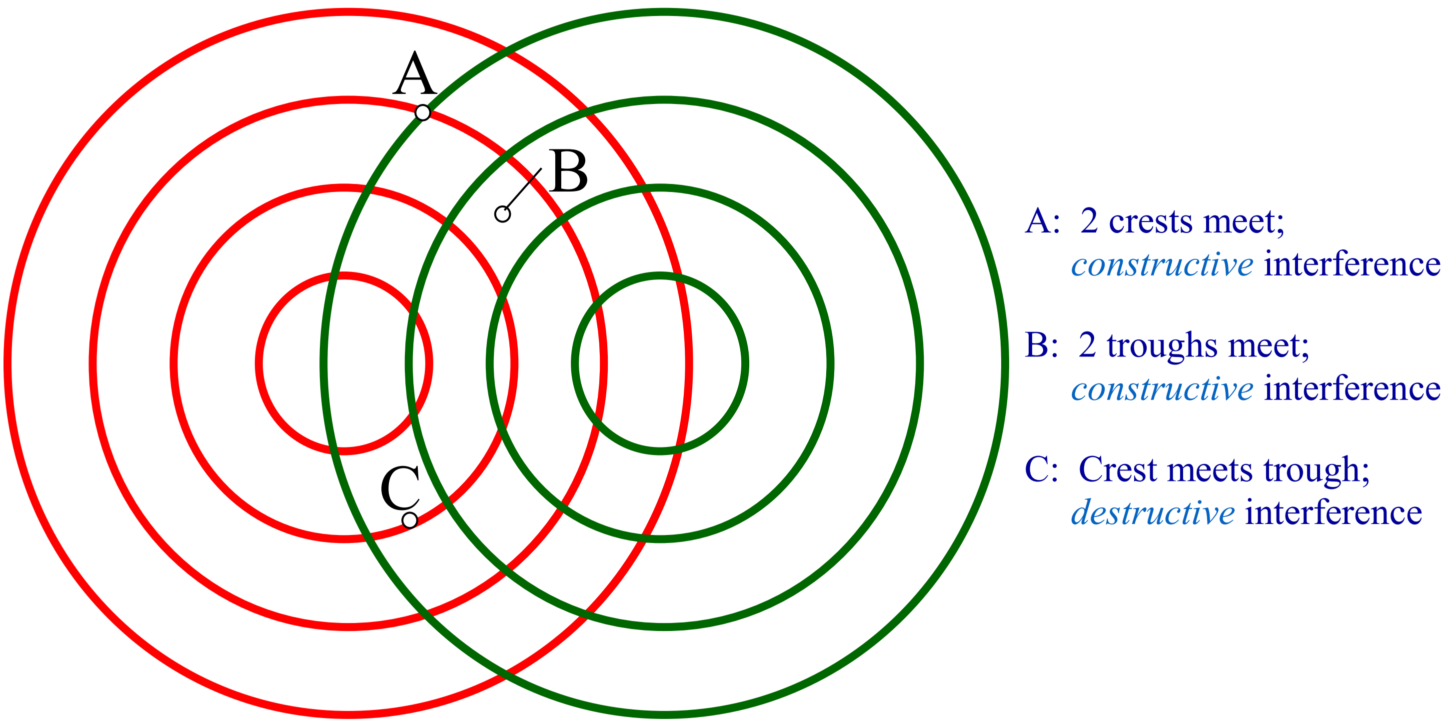
Describe how you would determine the beat frequency of the sound wave. How would you minimize errors?

Using your procedure, what is the beat frequency?

Does this match the beat frequency predicted by your model (equation)?

Activity 3: Interference

In lab on Monday we drew pictures of waves that had been added together. Constructive interference happens when two waves add together to form a maximum (positive or negative) amplitude. Destructive interference happens when two waves add together to form no wave (the waves cancel each other out.) Sound wave interference is similar to what is shown in the figure below.



The speed of sound in dry air is given by:

$v \approx 331.4 + 0.60\ T$, where T is air temp in °C.

1. Place two speakers side by side and set their frequencies to 300 Hz. Careful with the volumes!
   For this frequency, what is the wavelength?

2. Lay a ruler in front of the speakers so that it stretches outward from the space between the two speakers.
3. Use the microphone and record the locations of constructive and destructive interference. Be sure to record the distance from the speakers, not the distance measured on the ruler.

4. This experiment doesn't work very well. Why not?

5. What are some ways to improve this experiment?

6. Now try it with a much higher frequency (7100 Hz, for example.) Did this work better? Why or why not?

Activity 4: Interference again!

1. Place the speakers in the configuration above.
2. Place a meter stick, metric face up, so that it is supported by a speaker at each end. The meter stick should be approximately centered such that it juts out over each speaker by an equal amount. Exact centering is not necessary – you will take differences in minima positions – but don't move the meter stick.
3. Record the locations of constructive and destructive interference.

4. Which speaker configuration (Activity 3 or Activity 4) worked best? Why?