INTERFERENCE OF SOUND WAVES

The objectives of this experiment are:

- To measure the wavelength, frequency, and propagation speed of ultrasonic sound waves.
- To observe interference phenomena with ultrasonic sound waves.

APPARATUS: Oscilloscope, function generator, ultrasonic transducers, meter stick, angle board.

INTRODUCTION

In this experiment we deal with sound waves, produced by and detected with ultrasonic transducers. We study the interference of coherent (same phase) waves. The oscillations are displayed on an oscilloscope.

Sinusoidal waves can be characterized by the following parameters:

Wavelength: .... λ
Frequency:............................ f
Period: .... $T = 1/f$
Wave propagation speed: ..... $c = f\lambda = \lambda/T$.

The speed of sound through air (at 20 C) is 344 m/s.

Ultrasonic transducer

A transducer is a device that transforms one form of energy into another, for example, a microphone (sound to electric) or loudspeaker (electric to sound). In this experiment the transducer is a "piezoelectric" crystal of barium titanate which converts electrical oscillations into mechanical vibrations that make sound. The oscillating frequency is near 40 kHz which is beyond what can be heard by the human ear (about 20 kHz).

Interference of Waves

Below in Figure 1 is a drawing of the basic concept for interference of coherent waves from two point sources. Coherent means that the waves, even though they are from separate sources, have the same frequency and are in lock-step, namely in phase, as they are being emitted. The waves will get out of relative phase because they have to travel different path lengths to reach the same point in space. There, the waves can add constructively if they are in phase, or add destructively if they arrive out of phase. Look at the diagram.

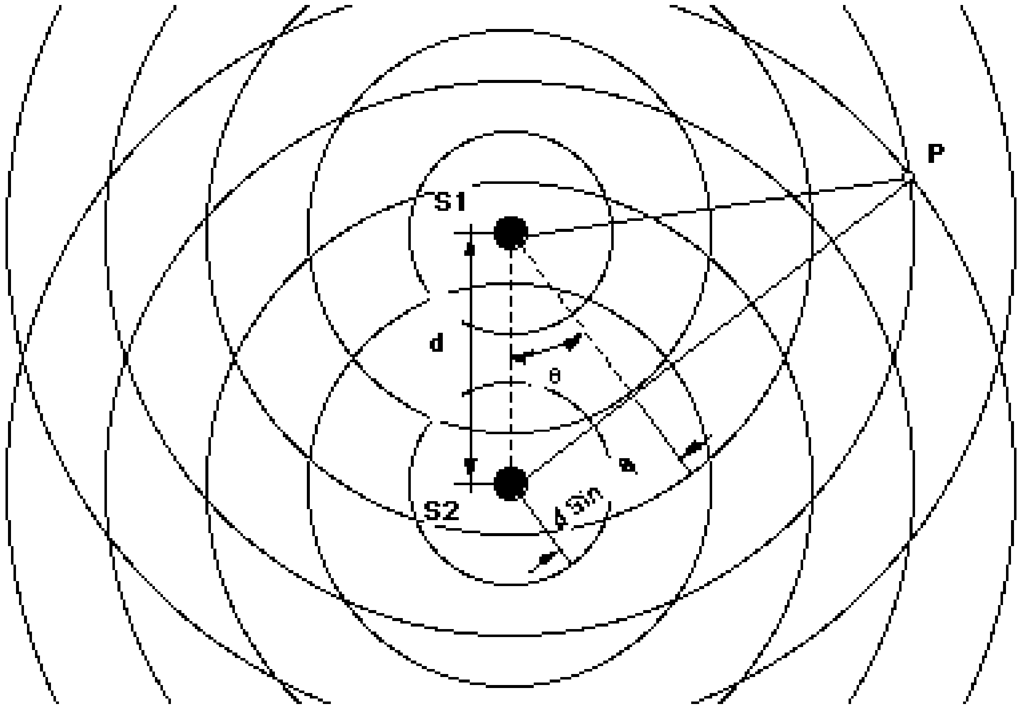

FIGURE 1

S_1 and S_2 are sound wave sources oscillating in phase because they are driven by the same voltage signal generator; they are separated by distance d. The sources also emit waves of the same frequency. P is the place where we place a detector, fairly far (in terms of d) from S_1 and S_2. At point P the path difference to S_1 and to S_2, is the distance d sin θ. When the path difference, d sin θ, is an integral multiple of the wavelength λ, waves arriving at P from S_1 and S_2 will be in phase and will interfere constructively.

Note that constructive interference gives maximum intensity:

$$d \sin \theta_{\max} = n\lambda$$

where n = 0, 1, 2,-- is referred to as the order of the particular maximum.

PROCEDURE: 1. Measuring frequency

The setup is shown in Fig. 2: a variable frequency signal generator drives one ultrasonic transducer; its output is also applied to channel B of the oscilloscope. (Later in the experiment two transmitting transducers will be connected to channel B.) The output of a second receiving ultrasonic generator is applied to channel A of the scope. Channel B trace (pattern of the oscilloscope) shows the sinusoidal voltage applied to the transmitting generator; channel A's trace shows the sinusoidal voltage coming out of the receiving ultrasonic crystal.

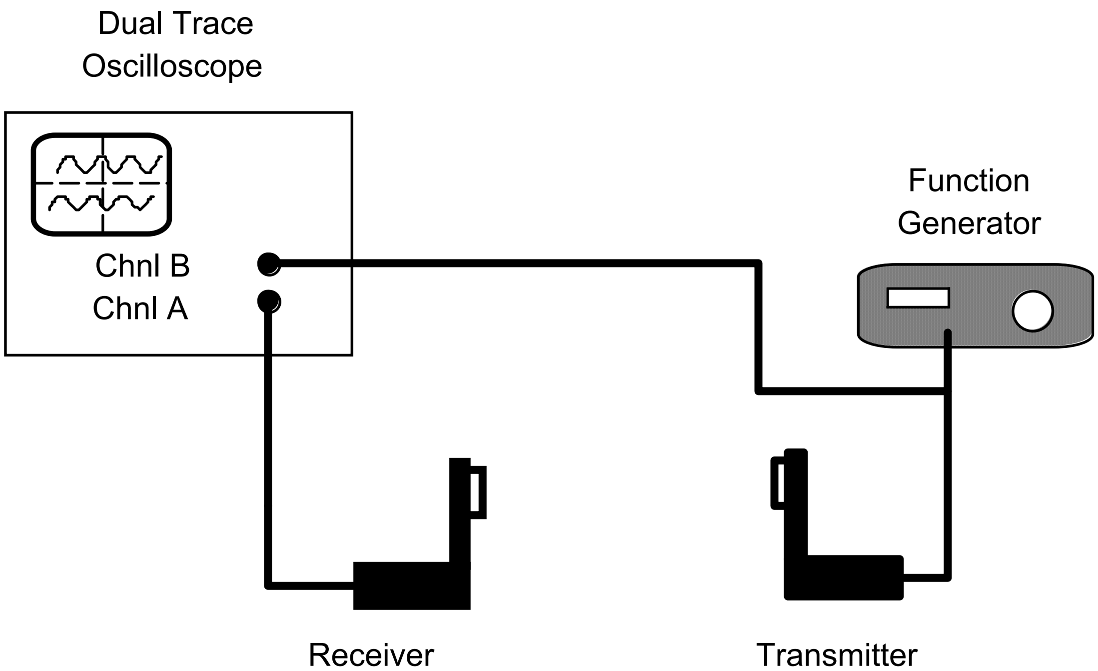

FIGURE 2

Adjust the scope controls, intensity, vertical amplification and horizontal sweep rate so that trace A shows several, steady sine curves. Place the transmitting transducer facing the receiver at a distance of a few centimeters. If you think the transducers are not functioning (nothing on trace A), it is most likely that the function generator is not at the exact resonance frequency. You should tune to resonance when the signal getting through to the receiving transducer (trace A) reaches a maximum. Do this by varying the frequency around 38 to 42 kHz.

Warning: Do not exchange your transducers with those from other tables; your three transducers are a matched set.

Measure the period of oscillation directly from the oscilloscope's screen, using the sweep rate (milliseconds per centimeter) marked on the oscilloscope's sweep control. To make the period measurement as accurate as possible, measure the time interval corresponding to several complete oscillations. The reciprocal of T is f. Compare the frequency f_o determined with the oscilloscope with the frequency f_{sg} of the signal generator.

2. Measuring wavelength

The transmitting and receiving transducer stands fit over, and can slide along, a meter stick. With both transducers fixed in position, the two sinusoidal traces on the scope are steady. What happens to the scope trace from the receiving transducer when you move the receiving transducer away from the transmitting transducer?

Measure the wavelength by slowly shifting the receiving transducer a known distance away from the transmitter while noting on the oscilloscope screen by how many complete cycles of relative phase the wave pattern shifts. Don't choose just one cycle, but as many cycles as can conveniently be measured along the meter stick.

Use the measured period of ultrasonic oscillations from Part 1 and the wavelength from Part 2 to compute the speed of sound through air. The oscillation period measured with the scope sweep calibration is more accurate than the frequency readings on the signal generator. Compare your computed value with the standard value of 344 m/s for dry air at a temperature of 20 C .

3. Double Source Interference

The setup is similar to Fig. 2, but another transmitting transducer is added. The pair of transmitters is placed side-by-side and driven in phase by a signal generator; a third receiving transducer is at an angle θ which can be varied. See Fig. 3, which duplicates the arrangement shown in Fig. 1.

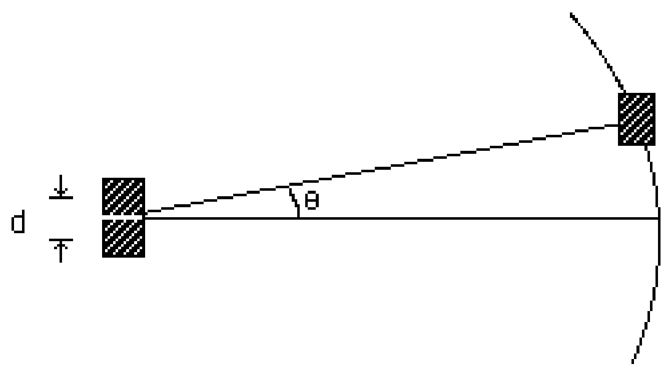

FIGURE 3

We are interested in observing the amplitude of the resultant ultrasonic wave reaching the receiving transducer. When you move the detector you are receiving the combined intensity of the two interfering waves. Sometimes you will see a strong signal while other times little or none. Move the receiving transducer along a circular arc, maintaining a constant distance from the two transmitting transducers. Record the transmitter separation d which should be kept as small as possible, and the angular positions θ_{max} for interference maxima. Suggestion: rather than plotting θ_{max} readings directly from the protractor, try taking corresponding left-side and right-side values and average them, eliminating any error in judging where the center line is.

Confirm the constructive interference relation, $n\lambda = d \sin \theta_{max}$, by plotting $\sin \theta_{max}$ as a function of the integer n. (**Take values for n and θ_{max} on the right side as positive and those on the left as negative** so your plot is a straight line ($\sin\theta = -\sin\theta$) rather than a "V"). The slope of your best straight line will enable you to calculate (d/λ), and then the separation d in terms of the theoretical wavelength $\lambda = c/f$. Compare this with the value of d directly measured.

INTERFERENCE OF SOUND WAVES

Name: ____Date:_________

Partner: ____

1) Frequency Measurement

Oscilloscope Time Base per Div (TB): __________
Number of Waves Counted on Screen (NW):_________
Number (& fractional parts) of Divisions Covered by Waves (ND): ________

Period of One Wave = TB * ND / NW = _________ Frequency = _________

2) Wavelength Measurement

Number of Waves Moved on Oscilloscope N_W: _________
Initial Position of Movable Sensor P_i: __________
Final Position of Movable Sensor P_f: ___________
Distance sensor moved, P_i - P_f = D: _____________

Length of One Wave, Wavelength = D/N_W : ___________

3) Speed of Sound: use your wavelength and frequency to calculate c.

$c = \lambda f$ = __________

4) Interference of Sound Separation of Sources, d: ________

θ_{max}	$\sin(\theta_{max})$	n (maximum #)

Graph $\sin(\theta_{max})$ vs. n. Measure slope of line fitted to data.

slope λ/d _____ use measured d to get λ _____

Compare wavelength measured on the oscilloscope (Part 2) with the value from interference (Part 4):

R (ratio) = λ osc / λ int = __________

NOTES