Lloyd's Mirror

1 Objective

- Understand the nature of sound-waves.
- Calculate the frequency of ultrasonic sound-waves by Lloyd's Mirror Interference.

2 Prelab Questions

1. What is meant by an ultrasonic sound-wave and what is the difference between a sound-wave and an electromagnetic wave?
2. Do you expect sound-waves to behave similarly to electromagnetic waves in terms of interference/diffraction/reflection/refraction despite the difference in their inherent characteristics and origins?
3. What are the conditions for constructive interference based on the difference in path length Δ?
4. Consider the graph below:

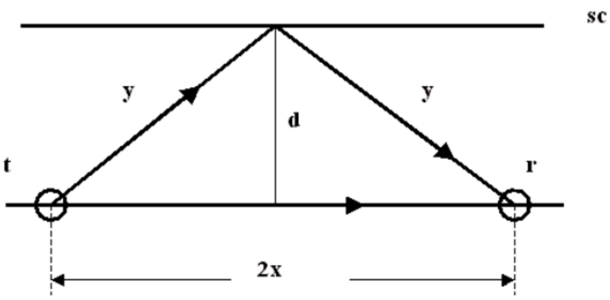

Fig 1. Schematic representation of the interference setup showing the path difference $\Delta = 2y$.

t: Transmitter (source).
r: Receiver (where the interference occurs).
sc: Screen (reflective surface).

Using the graph, derive the following constructive interference equation $\Delta = n\lambda = 2(\sqrt{d^2 + x^2} - x)$.

3 Principles

A packet of ultrasonic sound-waves is emitted from a fixed ultrasonic transmitter. Part of the packet strikes a metal screen positioned parallel to the line of propagation between the transmitter and the receiver, and is reflected in the direction of the receiver. The two packets of radiation arrive at the receiver and interfere with each other. When the reflector is moved backwards/forwards, the difference in the path lengths of the two packets changes. According to this difference, either constructive or destructive interference occurs.

4 Apparatus

- Ultrasonic production unit.
- Ultrasonic transmitter and receiver.
- Digital multimeter.

- Optical bench.
- Various mounts.
- Metal screen.
- Swinging arm and sliding device.
- Measuring tape.
- Cords.

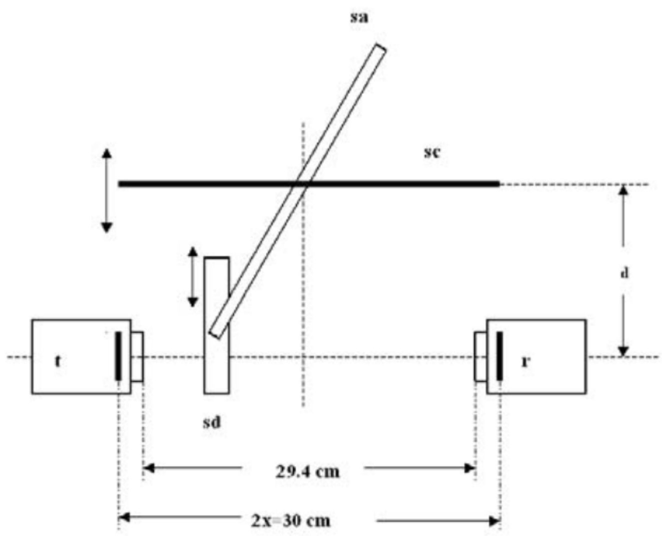

Fig 2. Experimental set-up of Lloyd's Mirror apparatus:

t: Transmitter.
r: Receiver.
sd: Sliding device.
sa: Swinging arm.
sc: Screen.

5 Precautions

1. Make sure to mount the transmitter and receiver at the same heights.
2. Orient the two devices so that their centres are concordant and parallel to the optical bench.

3. Make sure that the reflector screen is parallel to the optical bench and reset the scale.
4. If the *OVL* diode lights up, reduce the transmitter amplitude or the input amplification.

6 Experimental Steps

1. Mount the ultrasonic transmitter and the ultrasonic receiver in their slide mounts and set them at a distance of 29.4 cm. Keep in mind that the active parts of the ultrasonic elements are actually behind the protective grids, which makes the effective distance $2x$ between the two devices 30 cm.
2. Set the reflector screen at a distance of 2 cm from the middle axis which connects the transmitter and receiver, not the optical bench.
3. Connect the transmitter to the TR1 diode socket of the ultrasonic unit and set it to operate under continuous mode Con.
4. Connect the receiver to the left BNC socket.
5. Connect the receiver to the analog output of the digital multimeter.
6. Use the sliding device to move the screen backwards/forwards and locate the first maximum of the interference pattern, where $n = 1$. Record the voltage V from the multimeter and the distance d.
7. Move the screen away from the optical bench in steps of $\Delta d = 0.5$ to 1 mm, reading off the voltage and distance.

7 Evaluation

1. Plot a graph between the voltage V and the distance d. What does your graph represent?
2. Using your graph, read off the distances d that correspond to $n = 1, 2, 3...$ etc.
3. Using the equation below, calculate the wavelengths of the ultrasonic waves:

$$n\lambda = 2(\sqrt{d^2 + x^2} - x) \tag{1}$$

For $n = 1, 2, 3...$ etc.

4. Find the average wavelength λ_{avg}.
5. Using the average wavelength, calculate the frequency f of the ultrasonic waves.

8 Postlab Questions

1. Briefly describe the process by which sound-waves undergo refraction and reflection.
2. What is the speed of sound and its relation to temperature?
3. Describe the reflective surface you used in this experiment. Would a regular mirror do the same job?