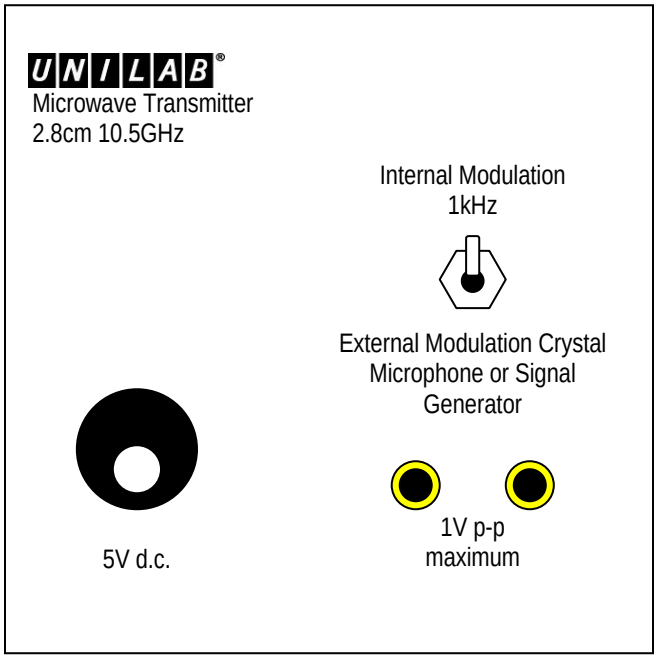
Microwave Apparatus

Transmitter Unit (Tx)

The Tx unit transmits polarised microwaves with a wavelength of 2.8cm, thus with a frequency of 10.5GHz. To turn it on, connect the 5V plug top power supply to the mains, and the jack into the 5V d.c. input of the Tx.

The Tx features a 1 kHz internal modulator. This is on when the switch on the back is in the up position.

The Tx can also be modulated by an external signal, such as a crystal microphone or signal generator. The input signal must not exceed a peak to peak voltage of 1V, so the amplitude of a sine wave, for example, must be 0.5V maximum. To enable this, the source of the signal must be plugged into the yellow sockets, with the switch in the down position. If there is no signal generator connected but the switch is in the down position, then the Tx will emit unmodulated microwaves. If desired, this can be used to turn off modulation.



The back of the Tx

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Receiver Unit (Rx)

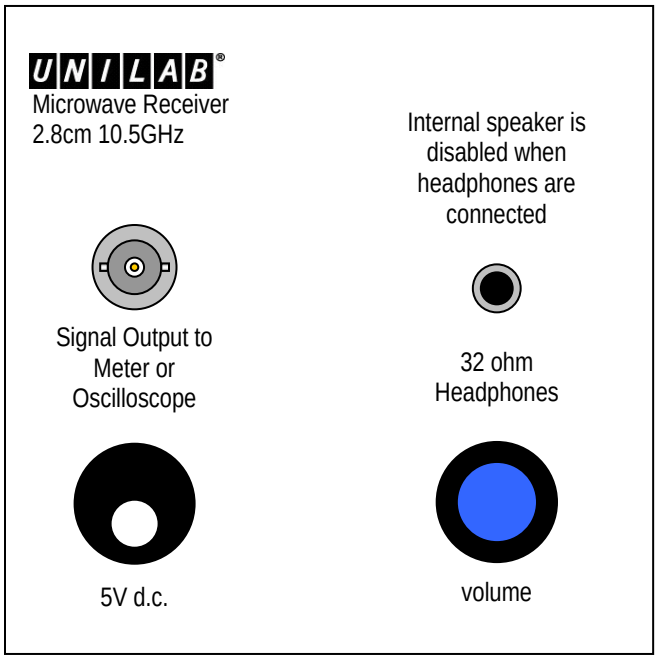
The Rx unit, detects polarised microwaves with a wavelength of 2.8cm, thus with a frequency of 10.5GHz, as produced by the Tx. To turn it on, connect the 5V plug top power supply to the mains, and the jack into the 5V d.c. input of the receiver.

The Rx features a demodulator and an internal speaker. If the received microwaves are modulated, then this signal will be played through the speaker. For example, if the 1 kHz internal modulator is enabled on the Tx unit, and this signal is received by the Rx, then the internal speaker will emit a 1 kHz tone. The amplitude of this will depend on the signal strength and the volume setting.

A 3.5mm headphone socket is provided on the back on the receiver. If headphones are plugged into this socket, then the internal speaker is disabled. This allows multiple experiments to be carried out in a room without the sounds interfering. Use any standard headphones as supplied with personal music players.

The volume control controls either the internal speaker volume, or that of the headphones if plugged in. The volume increases as this is rotated clockwise. The internal speaker can be turned off if desired, by rotating the volume control fully anticlockwise.

A BNC socket is provided for connection to an oscilloscope to observe any received signal. Alternatively, this could be connected to a basic voltmeter to indicate the strength of the signal received. The output voltage from this is typically 2V at a range of 17cm. An analogue meter is recommended to observe gradual changes in signal strength.



The back of the Rx

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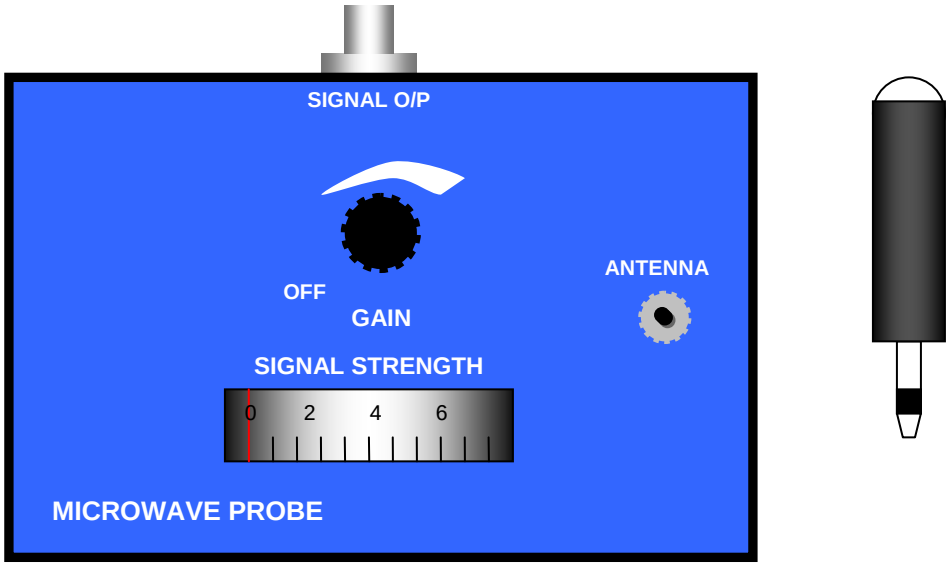
Probe Receiver Unit (PRx)
(Please note this is not included with the kit, and must be purchased separately)

The PRx is intended for more precise measurement of field strength, and features a near point detector.

Output is via an inbuilt moving coil meter, which is backlit when turned on. The unit also features a BNC output for connecting to a loud speaker via an amplifier, or to a larger voltmeter, oscilloscope or datalogger.

On the front panel are a 3.5mm socket, into which the probe is plugged, and a gain control knob. When the gain control is turned fully anticlockwise, it clicks off.

The unit is powered by an internal 9V PP3 battery, available separately. To install the battery, simply remove the sliding panel on the back, attach the battery to the internal clip, insert the battery into the space and replace the cover.



The probe receiver and probe

Accessories

Included accessories are three aluminium reflectors, which act like mirrors. A hardboard reflector, which partially reflects signal and partially transmits, and a polarisation grill. Pairs of feet are provided for each reflector to help them stand up.

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Basic Experiments

1. Standing wave

Set up the Tx and Rx facing each other at a distance of around 40-50cm. Ensure the internal modulator is switched on, and the volume on the Rx turned up so you can hear the tone.

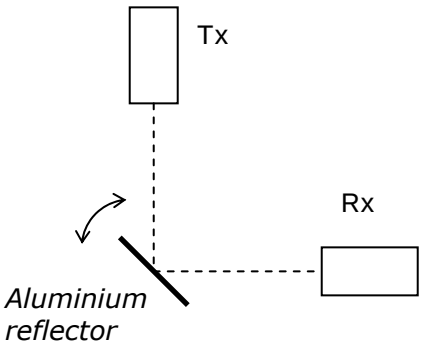
Slowly, move the Tx away from the Rx, keeping them facing one another. Without adjusting the volume control, listen carefully to the volume of the tone*. Observe how the volume goes up and down as you move the Rx away. This is due to the standing wave that is set up between the Tx and Rx, you are observing the peaks and troughs. Measure the distance between one trough and the next. This should equal half a wavelength.

If you have a probe receiver, you can set up a standing wave and observe it passively. Turn on the Tx and point it at an aluminium reflector. Place the PRx between the two and move it along slowly, observe the minima and maxima.

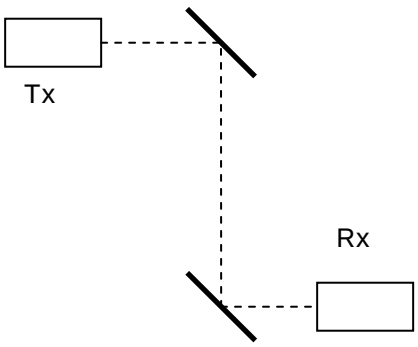
2. Reflect a wave

Set up the Tx and Rx as before, but at an angle of 90° from each other. Ensure the 1 kHz modulator is on, and the volume up.

You should hear nothing, or a very quiet tone. Place the aluminium reflector at a 45° angle as shown. The tone should now sound loud and clear. Try rotating the mirror and observe how this affects the volume of the tone*.



3. Microwave periscope



This time, set up the Tx and Rx facing each other, but offset by around 50 cm. The modulator should be on and the volume turned up.

Using the two larger aluminium reflectors, make a periscope to get the signal from the Tx to the Rx, as shown in the diagram. The tone should now sound loud and clear*.

*Alternatively, connect a meter to the Rx output and observe the changes in voltage.

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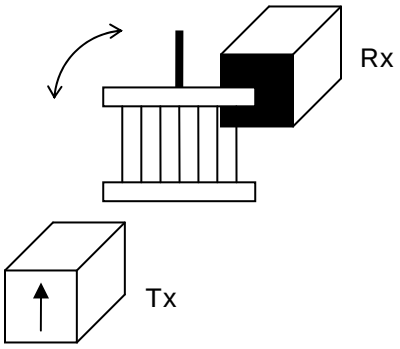
Polarisation Experiments

4. Test the polarisation

Start with the Tx and the Rx facing each other, about 40cm apart, with the modulator on and the volume up. The tone should sound loud and clear.

Keeping the Tx and the Rx facing each other, turn the Tx on its side. The sound should stop. Turn the Rx on its side, and the sound should come back. Turn the Tx back to its original position and the sound should stop. Turn the Rx back its original position to restore the sound once more.

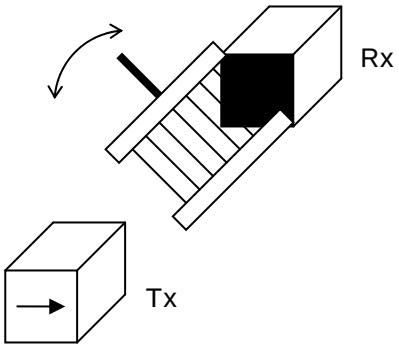
5. Apply a polaroid filter



Have the Tx and Rx face each other about 40cm apart. The modulator should be on with the volume turned up.

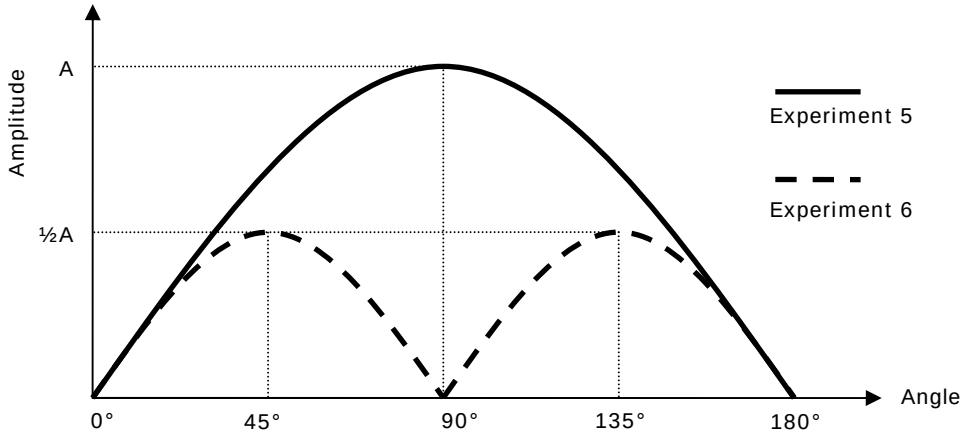
Place the polarisation grille between the Tx and Rx, such that the bars of the grille are vertical. The sound should stop. Rotate the grille as shown in the diagram slowly. Observe the volume of the sound. At 45°, the volume should be half. At 90°, the volume should be fully restored.

6. Rotate the Polarisation



Have the Tx and Rx face each other as before, but with the Tx on its side. The modulation should be on, and the volume turned up, but there should be no sound.

Place the polarisation grille as before, and rotate. Observe this time how the volume peaks when the grille is at 45°. The grille is rotating the plane of polarisation of the microwaves.



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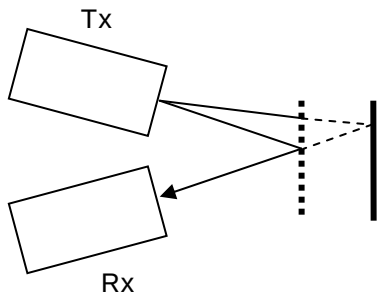
Interference Experiments

7. Simple interferometer



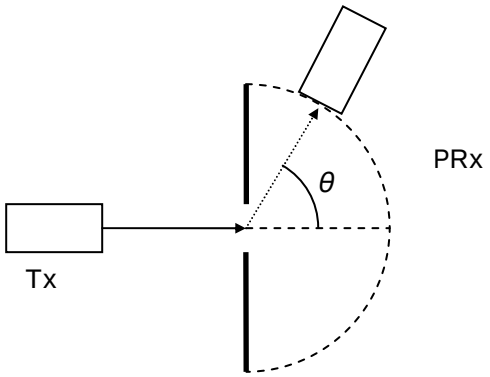
Place the Tx and Rx next to each other, a few cm apart, facing a large aluminium reflector. Turn on the Tx with internal modulation, and turn up the volume on the Rx. Rotate the Tx and Rx towards each other by a few degrees, until you can hear the tone on the receiver – that is the signal reflected from the aluminium reflector.

Now, between the Tx/Rx and the aluminium reflector, place the hardboard reflector. The signal may or may not die. Move the aluminium reflector backwards, slowly, and observe the tone's volume – it should oscillate as you move. Next, move the hardboard reflector back or forward in the same fashion, and observe the same effect. Finally, move the receiver further away from the reflectors, point in the same direction, and observe the oscillation once again.

This happens because the hardboard mirror splits the signal, which is then reflected back by the aluminium sheet and recombined to create an interference pattern.

8. Single slit diffraction (PRx)

Place the two large aluminium reflectors next to each other, with a gap between them of 5.6cm. Align the Tx such that its centre lines up with the gap, approximately 10 cm away. Place the PRx on the other side of the gap, 12-15cm away, facing the Tx.



Turn on the Tx.. Keeping the PRx 10 cm from the gap, move the PRx in a circle around the gap as illustrated.

You should detect a signal despite the reflector in between the Tx and PRx. To demonstrate the single slit is causing the diffraction, remove one or both of the aluminium reflectors.

The minima, or quiet zones, will occur at:

$$\theta = \arcsin\left(\frac{m\lambda}{a}\right)$$

m: order
λ: wavelength (2.8cm)
a: slit separation

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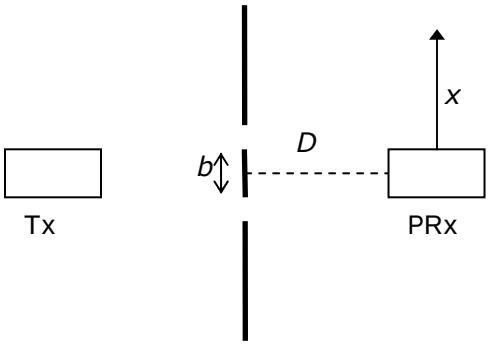
9. Young's double slit (PRx)



Set up the apparatus as in experiment 7. Then, separate the two reflectors and place the third, smaller reflector between them. Ensure there is a gap between each reflector of 2.8cm.

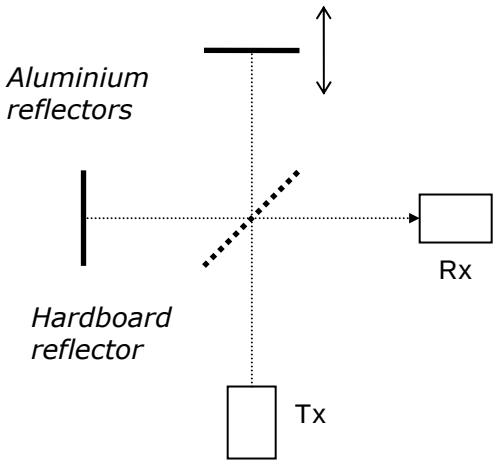
This time, move the PRx along parallel to the reflectors. You should observe the signal strength oscillate. This is due to the interference pattern set up by two circular wave fronts.

Maxima occur at: $x = \frac{nD\lambda}{b}$

n: order
λ: wavelength (2.8cm)
b: slit separation (8.8cm)

10. Interferometer

Have the Tx and Rx at 90° to each other. Place the hardboard reflector at 45° between the two to reflect the signal from the Tx to the Rx. Place the large aluminium reflectors behind the hardboard reflector, one parallel to the the Tx and the other parallel to the Rx.



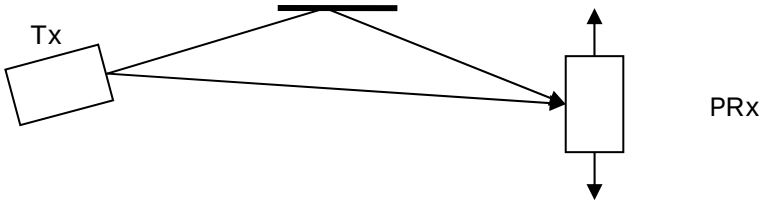
This set up is a Michelson-Morley interferometer, where the hardboard mirror acts as a semi-silvered surface.

Turn the Tx and Rx on, with internal modulation on the Tx and the volume audible on the Rx. You should hear the tone on the Rx. Move one of the aluminium reflectors back or forward along the line of the signal. You should hear the tone get louder and quieter. This is because of the path difference between the two signals as they are split and recombined.

11. Lloyd's mirror (PRx)

Point the transmitter at an aluminium reflector at an angle of about 80° and a distance of around 10cm. Place the probe receiver opposite the transmitter as shown in the diagram. Now, move the probe up and down and observe the signal strength oscillate.

This is due to some of the interference between the radiation from the transmitter and the reflected signal at the position of the probe receiver.



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