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Experiment 17
Electromagnetic Waves

Activity 1

To measure the wavelength of a standing electromagnetic wave.

Equipment

- Cenco microwave transmitter (catalog 80422).
- Cenco electric field detector.
- Meter stick.
- Microwave reflector plate.
- Oscilloscope.

Theory

The electromagnetic waves predicted when Maxwell collected and combined the basic equations of electricity and magnetism come in a wide variety of frequencies and wavelengths, all related by the speed of propagation c:

$$c = f\lambda.$$

Just like sound waves, electromagnetic waves can form standing waves when two waves travelling in opposite directions interfere with each other. The distance between successive nodes of the standing wave is equal to half a wavelength.

Procedure

Set up the microwave transmitter and reflector plate about a meter apart on the table-top. Connect the electic field detector to the oscilloscope input, taking care that the connection is tight (both the connection of the coax fastener to the scope, and the banana plugs to the coax fastener).

Set the scope sweep speed to a fairly low value (50 ms/div is good). Turn on the microwave transmitter. (The transmitter requires a few seconds to warm up). Holding the probe with the receiver axis parallel to the transmitter axis, slowly move the probe along a meter stick placed between the transmitter and reflector. Record the locations of as many nodes (minimum pulse height) as you can find along the meter stick (at least 8). Since our analysis will be based on the separation of **adjacent** nodes, it is not necessary that we find the one closest to the reflector or transmitter, only that we be careful not to miss any in the region we do explore. For a variety of reasons (diverging beam, reflections off of other objects in the room, etc.) the intensity will not be quite zero at the nodes.

Node number	position of node

Analysis Prepare a graph of the positions of the nodes versus the node number. (You may use Excel to do this, if you wish.) Since the successive nodes of the standing wave are a half wavelength apart, the slope of this graph will be the number of centimeters per half-wavelength:

$$slope = \frac{\lambda}{2}.$$

Q1. From the slope of your best-fit line on the graph (Excel may be used to determine this slope), what value do you infer for the wavelength of the microwaves produced by the transmitter?

Measured wavelength, λ:	

Q2. Using the known frequency of the microwave transmitter (f = 2.5 GHz) and your measured wavelength, what value do you deduce for the speed of light?

Measured speed of light, c:	

Activity 2

To study the polarization of an electromagnetic wave.

Equipment

- Cenco microwave transmitter (catalog 80422).
- Cenco microwave receiver.
- Microwave polarizer.

Theory

Polarization of an electromagnetic wave refers to a situation where the electric field associated with the wave has a particular orientation at all times (such as pointing along the $\pm x$ axis). For the microwaves generated by a simple dipole antenna, the electric field will be parallel to the antenna. Likewise, the dipole antenna in the microwave receiver should be parallel to the direction of the electric field in the incoming wave to pick up the maximum signal.

Observations

Turn on the microwave generator and hold the receiver a few feet away, with the receiving antenna in a vertical position. Adjust the gain control on the transmitter so that the receiver signal is approximately 75 μA.*

Turn the receiver by 90° (lay it on its side) without changing the distance to the transmitter. What happens to the reading on the meter?

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* When the receiver switch is set to "100 microamps", the full scale of the meter is 100 μA. Since this is labelled "20", this indicates that we should multiply all readings by 5 when the switch is in this position. So, a meter reading of "15" corresponds to 75 μA.

Put the receiver back in the upright position and insert the polarizing "filter" (it looks like a cooling rack used in the kitchen). The filter prohibits the passage of electric fields which are parallel to the bars (the electrons in the bars can move about in response to any incoming field, cancelling it out).

What meter reading do you get with the bars in the horizontal orientation?

What meter reading do you get with the bars in a vertical orientation? Is this consistent with the expectation outlined above? What might be the cause of any difference you observe?

Carefully hold the filter so that the bars are at a 45° angle with respect to the table top. What meter reading do you get in this case? What value do you expect in this orientation? How does your actual reading compare to the expected one?