EXPERIMENT 10
INTERFERENCE AND DIFFRACTION USING MICROWAVES

I. THEORY

In this experiment we will study interference and diffraction of microwaves, using a single slit and a double slit. The theoretical analysis is greatly simplified if we assume that the electromagnetic rays are all nearly parallel to each other as they pass through the slit system, a condition known as Fraunhofer Diffraction. Since lenses are impractical with microwaves, we could achieve such conditions only if both the source and the detector of microwaves are placed far from the slit system, in comparison with the slit dimensions. Such conditions are only approximated in this experiment.

Under Fraunhofer conditions, the intensity of radiation which has passed through a single slit is

$$I = I_0 \left(\frac{\sin\left(\beta/2 \right)}{\beta/2} \right)^2 \text{ with } \beta = \frac{2\pi a \sin\theta}{\lambda},$$

in which $\mathbf{I_0}$ is the maximum intensity, **a** is the width of the slit, λ is the wavelength, and θ is the angle from the normal at which the intensity is measured.

In the case of an ***ideal*** double slit, with each slit having infinitesimal width, the intensity is given by

$$I = I_0 \cos^2\left(\phi/2 \right) \text{ with } \phi = \frac{2\pi d \sin\theta}{\lambda},$$

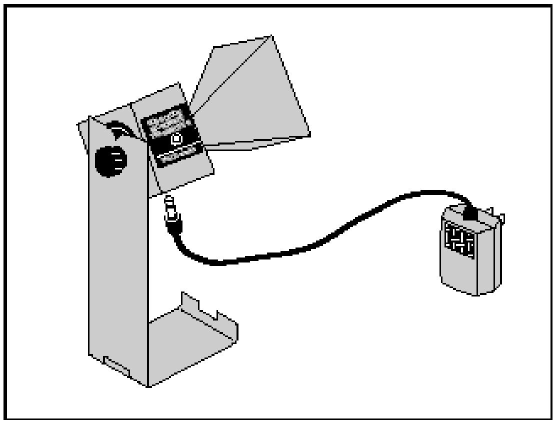
in which $\mathbf{I_0}$ is again the maximum intensity, **d** is the separation of the two slits, λ is the wavelength, and θ is the angle from the normal at which the intensity is measured.

In the case of a ***real*** double slit, consisting of two slits separated by **d** each having width **a**, the intensity is given by

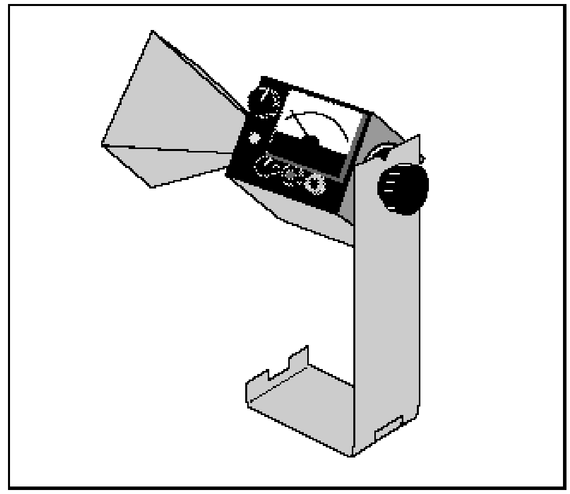
$$I = I_0 \cos^2\left(\phi/2 \right) \left(\frac{\sin\left(\beta/2 \right)}{\beta/2} \right)^2$$

with ϕ andβ defined as before.

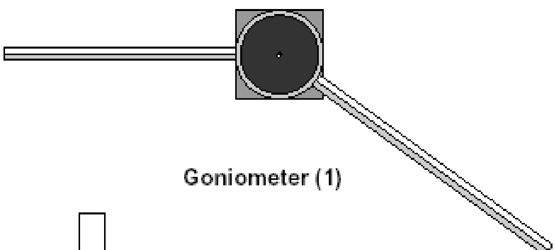
The following figures identify the equipment to be used.



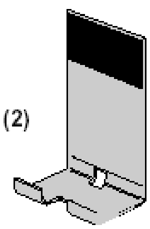
Microwave Transmitter with Power Supply



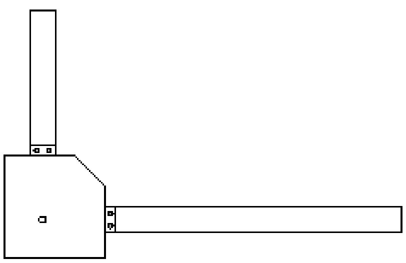
Microwave Receiver



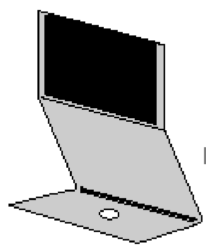
Goniometer (1)



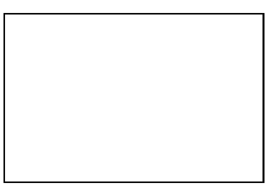
Component Holder (2)



Fixed Arm Assembly (1)

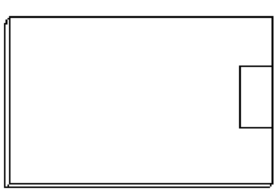


Rotating Component Holder (1)

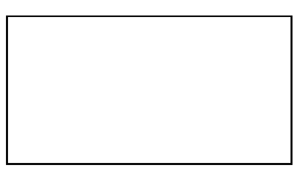


Metal Reflector (2)

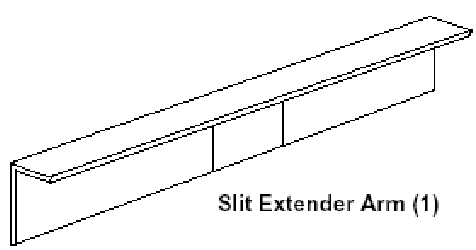
Narrow Slit Spacer (1)



Partial Reflector (2)



Wide Slit Spacer (1)



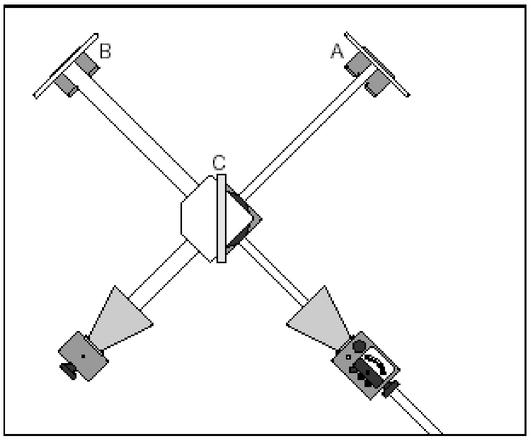
Slit Extender Arm (1)

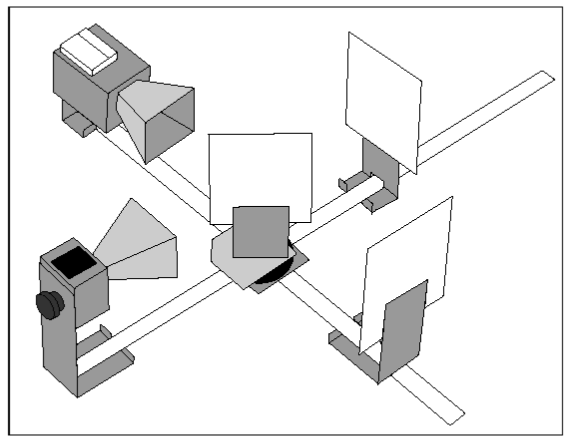
II. LABORATORY PROCEDURE

Overall Notes:
Make sure you are using the same polarization for the receiver and detector throughout the lab. Set both to 0° (vertical polarization).

If you have trouble setting the intensity reading to a specified value, seek assistances from your instructor.

1. Set up the Michelson Interferometer shown below using metal reflectors at A and B and a partial reflector at C. Plug the transmitter in and turn the INTENSITY selection switch on the receiver to "10X".





2. Move reflector A toward the partial reflector and observer the increase and decrease in the receiver signal. If you do not see this, adjust the INTENSITY and VARIABLE SENSITIVITY dials until you do. Also try adjusting the partial reflector as stated in the next step.

3. With reflector A at a position that produces a maximum in intensity (meter reading) at the receiver, slowly rotate the partial reflector (C) to a position that gives a maximum in intensity at the receiver. This should orient the partial reflector at 45° to the metal reflectors. Adjust the position of reflector A to make sure it is still at a position which gives maximum intensity at the receiver. Adjust the INTENSITY and VARIABLE SENSITIVITY dials until you get a meter reading of about 0.7. Record the position of reflector A.

4. Slowly move reflector A away from the partial reflector past at least 10 intensity minima and to an intensity maxima. Record the number of minima traversed and the position of reflector A.

5. Disassemble the Michelson Interferometer. Place the transmitter on the 0° arm of the goniometer and the receiver on the movable arm of the goniometer at 180°.

6. You will need to construct the single slit from the two metal reflectors and the slit extender arm. Attach the two metal reflectors to the magnetic strip on the slit extender arm. Use the meter-stick caliper jaw to set the spacing, so that you can use the same spacing for the double-slit experiment. Use the dimension of the caliper jaw that gives a slit spacing between 2 and 3 cm. Place the metal plates so that the single slit is as close

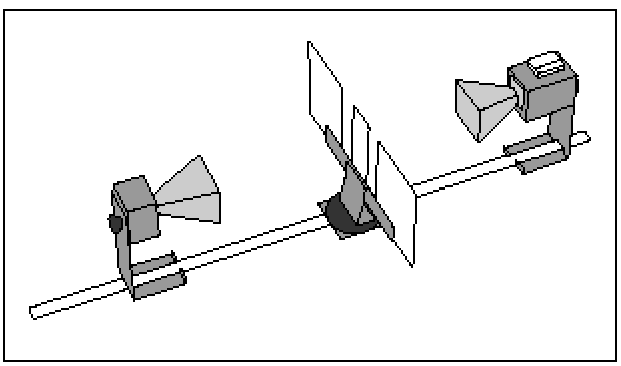
to the center of the extender arm as possible. Attach the extender arm to the rotating component holder and place the holder on the goniometer.

7. Move the transmitter slightly toward or away from the single slit to maximize the intensity at the detector. Repeat this procedure for the receiver. Record the position of the receiver. Slowly rotate the receiver arm from 120° to 240° to locate the global maximum. Place the receiver at this maximum. Set the INTENSITY to "10X" and adjust the VARIABLE SENSITIVITY dial until you get a meter reading of about 1.00 or as large as possible. After this setting, **do not move** the VARIABLE SENSITIVITY dial until you have completed all measurements with the single slit. Record the intensity as 10 times the scale reading.

8. Keeping the receiver at the same distance from the slit, rotate the receiver arm from 114° to 256° recording the angular position and the intensity at 3° increments. Record the angular positions of the receiver as the position of the arm minus 180°. Be sure to multiply the meter reading by the multiplier that the INTENSITY dial is set on. The INTENSITY dial should be set for the largest meter reading on the receiver.
For example, if the reading on the meter is 0.08 with a multiplier of 10X (a reading of 0.8), the multiplier should be turned to 3X which may give a meter reading of 0.28 (a more accurate overall reading of 0.84).

9. Return the receiver arm to 180° and remove the single slit.

10. You will need to construct the double slit from the two metal reflectors, the narrow slit spacer and the slit extender arm. Attach the two metal reflectors and the narrow slit spacer to the magnetic strip on the slit extender arm as shown below. Use the meter-stick caliper jaw to set the width of both slits, so that they are the same as was used in the single-slit experiment. Place the metal plates so that the slit spacer is as close to the center of the extender arm as possible. Attach the extender arm to the rotating component holder and place the holder on the goniometer.



11. Repeat Step 7 for the double slit. Leave the VARIABLE SENSITIVITY unchanged for the following **two** steps.

12. Repeat Step 8 for the double slit.

13. Record the angular position and intensity of each relative minimum and relative maximum between 90° and 270°. Record the angular position as the position of the receiver arm minus 180°.

14. Use the vernier caliper to measure the width of the meter-stick caliper jaw. Record this value as the slit width for both the single and double-slit. Also measure the width of the narrow slit spacer.

III. CALCULATIONS AND ANALYSIS

1. Using the data from the Michelson Interferometer, determine the wavelength of the microwaves.

2. Using the intensity recorded in Step 7 of the procedure, calculate the theoretical value of the intensity for the single slit at 10° intervals between 0° and 90°. Record these values in a table along with β and $\left(\frac{\sin\left(\beta/2\right)}{\beta/2}\right)^2$.

3. Make a graph showing the theoretical intensity vs. observation angle for the single slit from -90° to 90°. It is recommended that you make this graph with the aid of a computer program and plot at least 181 points to create the curve. On the same graph, plot all of the experimental intensity data measured in Step 8 of the procedure. Using a different color than the theoretical curve, draw a smooth curve that fits your experimental data. As with all graphs, the data on your graph should cover most of the page both vertically and horizontally.

4. Determine the angles between 0° and 90° for which the theoretical intensity is **zero** for the double slit. Show in detail how the angles were found.

5. Determine the angles between 0° and 90° for which the theoretical intensity is a **relative maximum** for the double slit. Show in detail how the angles were found.

6. Using the intensity recorded in Step 11 of the procedure, calculate the theoretical value of the intensity for the double slit at 10° intervals between 0° and 90° and for the angles found in Calculations 4 and 5. Record these values in a table along with β, $\left(\frac{\sin\left(\beta/2\right)}{\beta/2}\right)^2$, ϕ and $\cos^2\left(\phi/2\right)$.

7. Make a graph showing the theoretical intensity vs. observation angle for the double slit from -90° to 90°. It is recommended that you make this graph with the aid of a computer program and plot at least 181 points to create the curve. In a different color as the theoretical curve, plot the angles found in Calculations 4 and 5 along with the calculated theoretical intensity.

8. On the same graph, plot all of the experimental intensity data measured in Steps 12 and 13 of the procedure. Using yet another color, draw a smooth curve that fits your experimental data.