Microwaves

Experiment LS11

Concept(s) Investigated: Microwaves
Time Required for Completion: Approximately 55 minutes.

OBJECTIVE

The objective of this experiment is to show that microwaves behave like any other waves by studying reflection and formation of standing waves with microwaves. Note: Due to the delicate nature of the experimental equipment, your lab instructor will be the only person touching the equipment. You will collect your data as the instructor performs the experimental steps.

EQUIPMENT NEEDED

Pasco Microwave Optics Kit (WA-9314B)

Meter Stick

THEORY

Microwaves are a form of electromagnetic radiation with a frequency range of 10^9 Hz to 10^{12} Hz. Microwaves are used for a variety of practical purposes including carrying long distance and cooking food. The waves have a wavelength of about 1 mm to 30 cm, and are the highest frequency electromagnetic waves producible by electronic devices.

PROCEDURE

Caution

The output power of the Microwave Transmitter is well within standard safety levels. Nevertheless, one should never look directly into the microwave horn at close range when the Transmitter is on.

Under some circumstances, microwaves can interfere with electronic medical devices. If you use a pacemaker, or other electronic medical device, check with your doctor or the manufacturer to be certain that low power microwaves at a frequency of 10.5 GHz will not interfere with its operation.

PART I: Introduction

1. Arrange the Transmitter and Receiver on the Goniometer as shown in Figure LS11.1, with the Transmitter on the fixed arm. Be sure the Transmitter and Receiver are adjusted to the same polarity-the horns should have the same orientation, as shown in the figure.

2. Plug in the Transmitter and turn the INTENSITY selection switch on the Receiver from OFF to 30X. (The LEDs should light up on both units.)

3. Adjust the Transmitter and Receiver so the distance between the source diode in the Transmitter and the detector diode in the Receiver (the distance labeled R in Figure LS11.1) is **40 cm**. Adjust the Intensity and Variable Sensitivity dials on the Receiver so that the meter reads 1.0 (full scale).

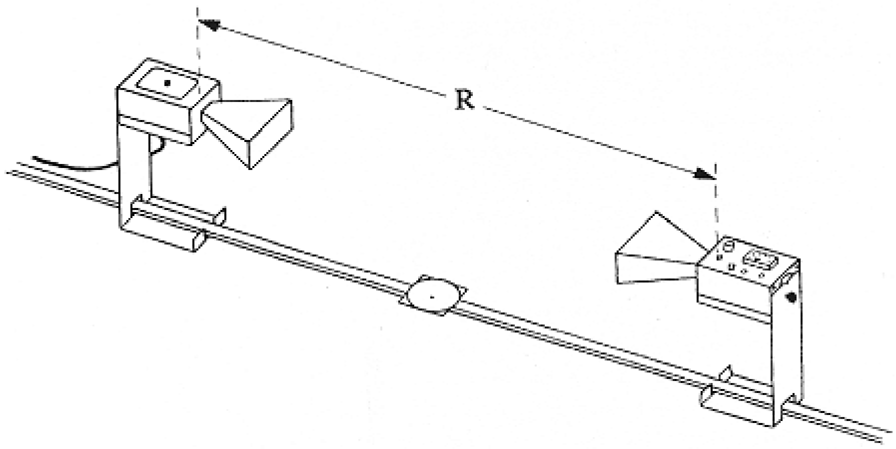

Figure LS11.1

4. Set the distance R to each of the values shown in Data Table 1. For each value of R, record the meter reading. (Do not adjust the Receiver controls between measurements.)

5. Set R to some value between 30 and 50 cm. While watching the meter, slowly decrease the distance between the Transmitter and Receiver. Does the meter deflection increase steadily as the distance decreases? Record your observations in Data Table 2.

6. Move a Reflector, with the plane of the Reflector parallel to the axis of the microwave beam, toward and away from the beam axis. Observe the meter readings. Record your observations in Data Table 3.

7. Loosen the hand screw on the back of the Receiver and rotate the Receiver. This varies the polarity of maximum detection. (Look into the receiver horn and notice the alignment of the detector diode.) Observe the meter readings through a full 360-degree rotation of the horn. Try rotating the Transmitter horn as well. When finished, reset the Transmitter and Receiver so their polarities match (both horns are horizontal or both horns are vertical). Record your observations in Data Table 4.

8. Position the Transmitter so the output surface of the horn is directly over the Degree Plate of the Goniometer arm. With the Receiver directly facing the Transmitter and as far back on the Goniometer arm as possible, adjust the Receiver controls for a meter reading of 1.0. Then rotate the rotatable arm of the Goniometer as shown in the figure. Set the angle of rotation (measured from the 180-degree point on the degree scale) to each of the values shown in Data Table 5, and record the meter reading at each setting.

PART II: Reflection

1. Arrange the equipment as shown in Figure LS11.2, with the Transmitter on the fixed arm of the Goniometer. Be sure the Transmitter and Receiver are adjusted to the same polarity-the horns should have the same orientation, as shown in the figure.

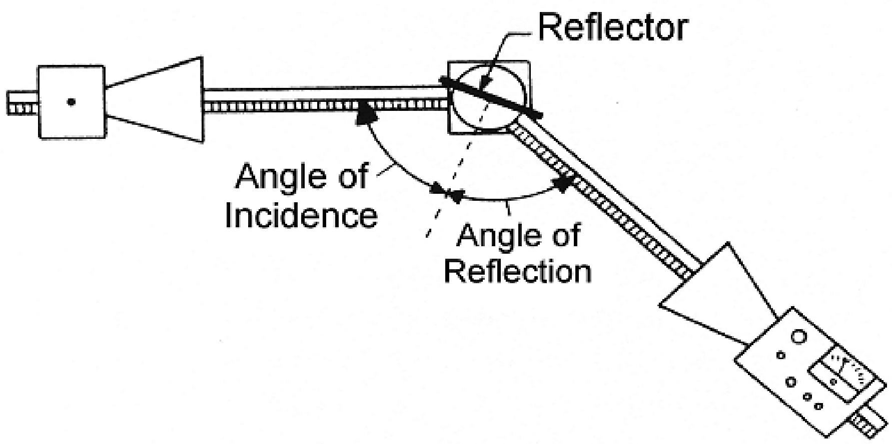

Figure LS11.2

2. Plug in the Transmitter and turn the Receiver Intensity selection switch to 30X.

3. The angle between the incident wave from the Transmitter and a line normal to the plane of the Reflector is called the Angle of Incidence (see Figure LS11.2). Adjust the Rotating Component Holder so that the Angle of Incidence equals 45-degrees.

4. Without moving the Transmitter or the Reflector, rotate the movable arm of the Goniometer until the meter reading is a maximum. The angle between the axis of the Receiver horn and a line normal to the plane of the Reflector is called the Angle of Reflection.

5. Measure and record the angle of reflection for each of the angles of incidence in Data Table 6. (Note: At some angles the Receiver will detect not only the wave that is reflected, but also the wave coming directly from the Transmitter, giving misleading results. Determine the angles for which this is true, and mark the data collected at these angles with an asterisk (*).

PART III: Standing Waves-Measuring λ

1. Setup the equipment as shown in Figure LS11.3. Adjust the Receiver controls to get a full-scale meter reading with the Transmitter and Receiver as close together as possible. Slowly move the Receiver along the Goniometer arm, away from the Transmitter. How does this motion affect the meter reading?

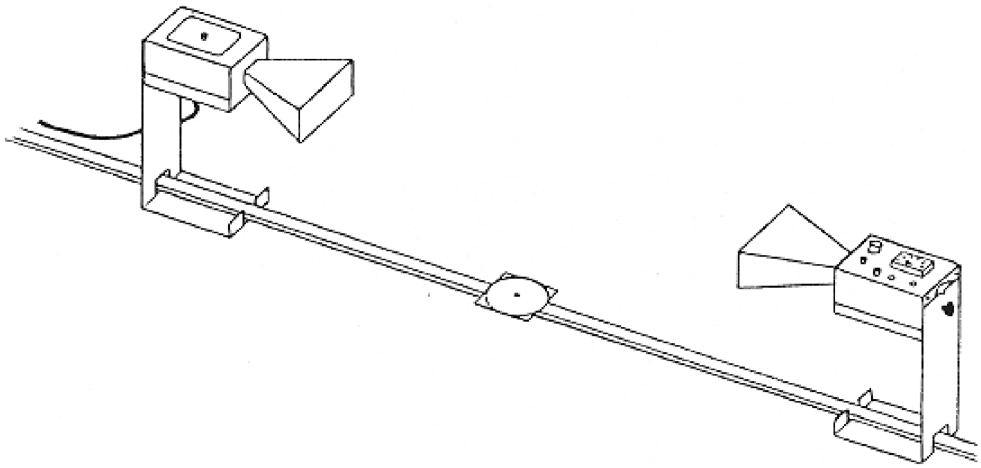

Figure LS11.3

The microwave horns are not perfect collectors of microwave radiation. Instead, they act as partial reflectors, so that the radiation from the Transmitter is reflected back and forth between the transmitter and reflector horns, diminishing in amplitude at each pass. However, if the distance between the transmitter and receiver diodes is equal to *n*l/2, where *n* is an integer and λ is the wavelength of the radiation, all the multiply reflected waves entering the receiver horn will be in phase with the primary transmitted wave. When this occurs, the meter reading will be a maximum. (The distance between adjacent positions where a maximum will be seen is therefore λ/2)

2. Slide the Receiver one or two centimeters along the Goniometer and to obtain a maximum meter reading. Record the position of the Receiver along the metric scale of the Goniometer arm in Data Table 7.

3. While watching the meter, slide the Receiver away from the Transmitter, until the Receiver has passed through at least 10 positions at which you see a minimum meter reading and returned to a position where the reading is a maximum. Record the new position of the Receiver and the number of minima that were traversed in Data Table 7. Return all of the microwave equipment to the storage box.

ANALYSIS

PART I: Introduction

1. Calculate and record the values of $M \times R$ and $M \times R^2$ for each of the entries in Data Table 1.

2. Answer questions 1 – 3 under Part I, starting on page 163.

PART II: Reflection

1. Answer questions 1 – 5 under Part II, starting on page 164.

PART III: Standing Waves - Measuring λ

1. Calculate and record the wavelength from the data in Data Table 7.

2. Answer question 1 under Part III on page 165.

ENDING THE EXPERIMENT

1. **(a.)** Unplug the receiver and transmitter power supplies from the electrical outlet. **(b.)** Return all of the microwave equipment to its storage container.

Old Dominion University
Physics 104N Laboratory Report

Experiment LS11:
Microwaves

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Student Name

Lab Section	Date of Lab
Lab Instructor	Date Submitted

Lab Partners:

Lab Partner Name	Lab Partner Name
Lab Partner Name	Lab Partner Name
Lab Partner Name	Lab Partner Name

Summary of the Experiment: (Include your conclusions and note any problems encountered during the experiment.)

Questions

PART I: Introduction

1. The electric field of an electromagnetic wave is inversely proportional to the distance from the source of the wave (i.e.; $I = I_0/R^2$). Use your data from Data Table 1 to determine if the meter reading of the Receiver is directly proportional to the electric field of the wave.

2. The intensity of an electromagnetic wave is inversely proportional to the square of the distance from the source of the wave (i.e.; $I = I/R^2$). Use your data from Data Table 1 to determine if the meter reading of the Receiver is directly proportional to the intensity of the wave?

3. Considering your results in the previous questions, to what extent can the output of the Transmitter be considered a spherical wave? A plane wave?

PART II: Reflection

1. What relationship holds between the angle of incidence and the angle of reflection? Does this relationship hold for all angles of incidence?

2. In measuring the angle of reflection, you measured the angle at which a maximum meter reading was found. Can you explain why some of the wave was reflected into different angles? How does this affect your answer to question 1?

3. Ideally this experiment would be performed with a perfect plane wave, so that all the radiation from the Transmitter would strike the Reflector at the same angle of incidence. Is the microwave from the Transmitter a perfect plane wave? Would you expect different results if it were a perfect plane wave? Explain.

4. How does reflection affect the intensity of the microwave? Is all the energy of the wave that strikes the Reflector reflected? Does the intensity of the reflected signal vary with the angle of incidence?

5. Metal is a good reflector of microwaves. Investigate the reflective properties of other materials. How well do they reflect? Does some of the energy pass through the material? Is some absorbed by the material? Compare the reflective properties of conductive and non-conductive materials.

PART III: Standing Waves - Measuring λ

1. Use the relationship velocity = λν to calculate the velocity of microwave propagation in air.
   (ν = the frequency of the microwave radiation-10.5 GHz).

Data Table 1

Distance R (cm)	**Meter Reading** M	**Calculation** $M \times R$	**Calculation** $M \times R^2$
50			
60			
70			
80			
90			
100			

Data Table 2

Observations while moving Receiver slowly: (Record at least 4 distances and corresponding intensities, including the distance at which the intensity is at maximum)

Data Table 3

Observations while moving Reflector slowly: (Record at least 4 distances and corresponding intensities, including the distance at which the intensity is at maximum)

Data Table 4

Observations while rotating polarity of receiver slowly: (Record the relative orientation for the minimum and maximum intensities)

Data Table 5

Angle	Meter Reading
0°	
10°	
20°	
30°	
40°	
50°	
60°	
70°	
80°	
90°	

Data Table 6

Angle of Incidence	Angle of Reflection
20°	
30°	
40°	
50°	
60°	

Data Table 7

Standing Waves - Measuring λ	
Initial probe position	
Final probe position	
Distance traversed	
Antinodes traversed	
λ	