San Diego Mesa College

Physics 197 Laboratory Experiment

Title: Microwave Optics

Name:________________________________

Date: ________________________________

Group Members: ________________________

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Objective:

To experimentally validate the idea that all waves may form standing wave systems, including electromagnetic waves. To confirm that all materials have an index of refraction, but that this index depends upon the frequency of the incident energy. To experimentally determine the wavelength of a microwave emitter.

Theory:

The index of refraction of a material is determined by the ratio of the propagation speed of a particular wave inside and outside the material:

$$n = \frac{v_{Outside}}{v_{Inside}}$$

It may also be expressed in terms of the angles made by the incident and refracted rays with respect to the surface of the material, as long as the surface is in air or vacuum.

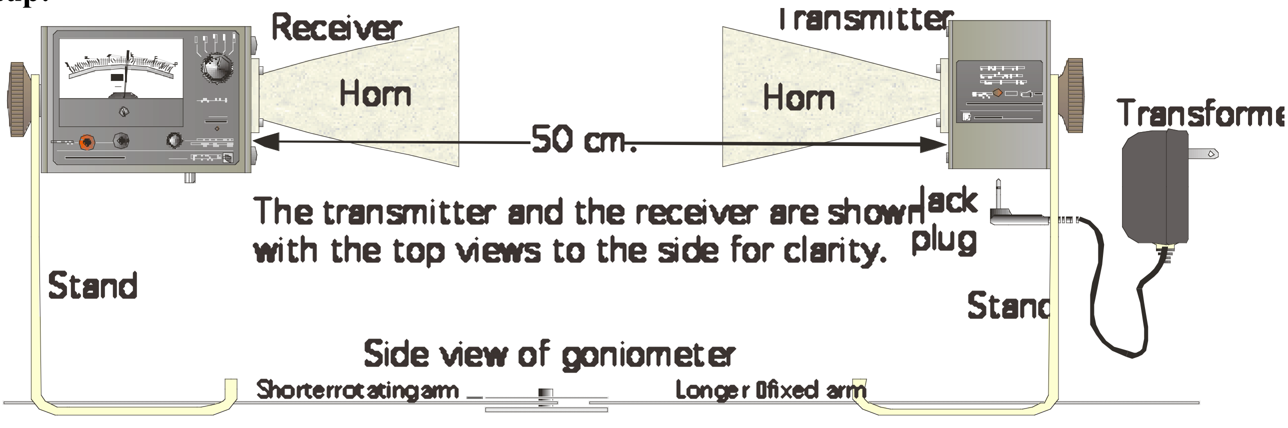
$$n = \frac{\sin\theta_{incident}}{\sin\theta_{refracted}}$$

In a wave system, the principle of superposition states that waves arriving at a point in space will interfere with each other. When perfect constructive interference is obtained, the difference in path lengths is a multiple of the wavelength. This information and the geometry of the system will lead to a relationship that will predict the location of the maximum and minimum intensities of the interference pattern.

Equipment:

- Microwave Transmitter
- Fixed and Rotating Arms
- Narrow and Wide Slit Spacers
- Partial Reflectors
- Polarizers
- Microwave Receiver
- Rotating Table
- Component Holders
- Full Reflectors

Setup:



Procedure Part I: Determination of the Microwave Wavelength

1) Attach the transmitter and receiver to their respective stands. Plug the transformer into an outlet and the insert the jack into the transmitter.
2) With the front of the receiver and transmitter separated by 50 cm, turn on the receiver by adjusting the intensity knob. Use the variable sensitivity knob on the receiver to obtain a mid-scale reading.
3) Once you obtain a mid-range reading, assemble the system by sliding the arms of the goniometer through the corresponding slots in the stands. Mount the transmitter on the longer of the two arms and the receiver on the shorter arm.
4) Place a full reflector (metal plate) on a component stand and mount it directly opposite the transmitter. This reflector will redirect the incident microwaves back towards the transmitter, creating a standing wave pattern in the space between them.
5) Place the slotted metal plate on a component stand and place it on the middle portion of the apparatus. Adjust the angle that it makes with respect to the reflector until it is approximately 45 degrees. Adjusting the slotted plate will deflect some of the energy towards the receiver, allowing you to monitor the wave pattern.
6) As you slide the reflector slowly towards the transmitter, you should see the intensity reading on the receiver rise and fall in a periodic fashion. If this is not the case, adjust the angle made by the slotted plate.
7) Slowly move the full reflector and record the positions and intensities of 12 consecutive maxima in the data table. Remember that for a standing wave system the maximum intensities are separated by a half-wavelength.
8) Once the approximate wavelength of the microwaves has been obtained, make 12 measurements over the distance of 2 wavelengths. These intensity measurements should include maxima, minima and intermediate points.

Data: Part I

Determination of λ		Intensity as a function of position	
Position	Intensity	Position	Intensity

Analysis:

From the 'rough' measurements made, what is the approximate wavelength of these microwaves?

λ_1 = ________________

Either by hand, or using Excel or a similar program, produce a graph of intensity as a function of distance and use this information to determine an approximate wavelength of the microwaves. Calculate the percent difference in the results obtained by these two methods.

λ_2 = ________________

$$\%Difference = \frac{2|\lambda_2 - \lambda_1|}{\lambda_2 + \lambda_1} * 100 =$$

Using the information about the wavelength and the fact that the speed of light is $3 \bullet 10^8$ m/s, calculate the frequency of your microwave transmitter.

f = ________________

Part II: Determination of the Index of Refraction for Microwaves in Paraffin

Procedure:

1) Position the half-cylinder of Styrofoam encased paraffin on top of the rotating table assembly and use masking tape to secure it in position. Align the flat face toward the transmitter and center the receiver behind the curved side. Record the intensity.
2) Rotate the table upon which the paraffin is attached through a few degrees and adjust the position of the receiver until a location of maximum intensity is found.
3) Repeat this process for a total of 4 angles of incidence. Make sure each angle is larger than the previous one.
4) Rotate the paraffin in the opposite direction of that used in 2). Gather intensity data at each of the same angles used in 3).

Data: Part II

Angle of Incidence (+θ)	Intensity	Angle of Incidence (-θ)	Intensity
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	
7		7	
8		8	

Analysis:

1) Either by hand, or using Excel or a similar program prepare a graph of the Angle of Refraction as a function of the Angle of Incidence. Then, prepare a graph of the sin of the Angle of Incidence as a function of the sin of the Angle of Refraction.

2) Using one of these graphs, determine the index of refraction for microwaves in paraffin. Justify your choice of graphs with a brief statement.

$n_{paraffin}$ = _______________

3) Using the information obtained, determine the approximate wavelength of a microwave inside the paraffin.

$\lambda_{paraffin}$ = ________________

Part III: Double Slit Microwave Interference

Setup:

1) Assemble the double slit by placing two reflectors and a narrow slit spacer on the 'Slit Extender Arm' and mounting this assembly on the rotating component holder.
2) Try to make sure that the slit spacer is positioned on the central axis and that the slits are of equal width. The slit width should be ~1.5 cm.
3) Measure the distance between the slits and the slit width. Record these values in the data table.
4) Position the transmitter and receiver on opposite sides of the double slit setup. The transmitter and receiver should be about 20 cm from the slits.

Procedure:

1) Starting with the receiver directly behind the slits, record the transmitted intensity at 5 degree increments. Record intensities on both sides of the central axis, calling one direction (+θ), the other (-θ).

Data:

+θ	Intensity	-θ	Intensity
0			
5		5	
10		10	
15		15	
20		20	
25		25	
30		30	
35		35	
40		40	
45		45	
50		50	

Analysis:

Either by hand, or using Excel or a similar program, prepare a plot of intensity as a function of angular position on polar graph paper. In Excel this is called a radar plot. Prepare a second plot using standard graph paper showing the same information. Place the vertical axis at the middle of the paper so you can show the intensities on either side of the central maximum.

Using the theoretical expression for the intensity distribution for a double slit system, plot the expected locations of the maxima on top of your actual data that you plotted on the second of the graphs. Use a different color or some other means of differentiating the data.

Conclusion: Briefly discuss the physics involved in the experiment, summarize the data, address potential sources of error and methods to reduce or eliminate them, and state whether or not the experimental results validate the theory.