Lab 5: EM Wave Properties using Microwaves

Goal

Reflection and refraction of microwaves.

Objectives

1. Explores the relationship of reflected microwaves to incident microwaves
2. Use the law of refraction to measure the index of refraction for Styrene pellets.

Expectations

1. You are expected to take detailed notes during each step outlined in the procedure that can be used during the lab report write-up.
2. You are expected to provide a neat table of the data that you measured where you clearly label what each data set is and include units for all measured quantities.
3. You are expected to clearly record the measured values of any components that you use.
4. You are expected to clearly record the detail related to images captured by the oscilloscope.
5. You are expected to make your final plots in a program such as Excel. Make sure that your data points appear clearly on the plots, that all axes are clearly labeled and have units.
6. If it is possible to compare your measurements with an expectation or a prediction, you are expected to do so in your lab report
7. You are expected to answer the questions encountered in this manual as well as discuss exercises given during the lectures in your lab write up.

Introduction to Concepts

Reflection and Refraction of Microwave Radiation

The relationship of reflected microwaves to incident microwaves is given by law of reflection where incident angle is equal to reflected angle.

When an electromagnetic wave crosses a boundary between two different media, the direction of propagation of the wave changes. This change in direction is called Refraction, and it is described by a mathematical relationship known as the Snell's law or the law of refraction.

$$n_1 sin\theta_1 = n_2 sin\theta_2 \tag{1}$$

Where n_1 is the index of refraction of the medium 1, θ_1 is the incident angle, n_2 is the index of refraction of the medium 2, and θ_2 is the refracted angle (Figure 2) .

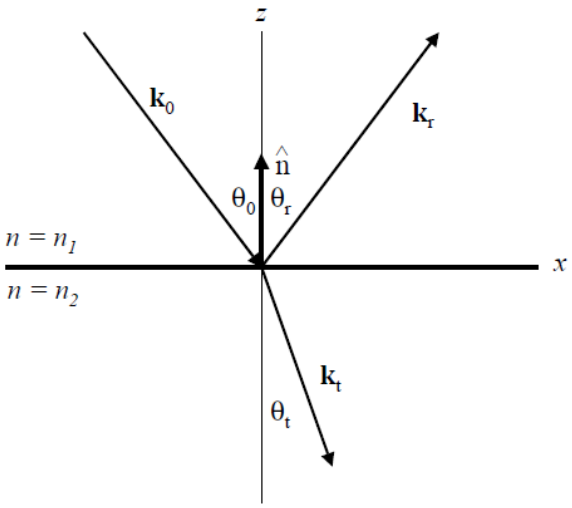

Figure 1: The $\vec{k}$ of incident, reflected and refracted wave at the interface between two media of index of refraction n_1 and n_2

Preliminary Lab Questions

1. Find an equations for index of refraction using speed of light in the medium?

Equipment and Parts

1. PASCO microwave optics system : Transmitter, Receiver, Goniometer, prism mold, styrene pellets, and reflector
2. Protractor

Procedure

Reflection of Microwave Radiation

1. Arrange the equipment as shown in Figure 3 with the Transmitter attached to the fixed arm of the goniometer.
2. Adjust the transmitter and receiver to the same polarity;
3. The horns should have the short side oriented horizontally.
4. Set the both transmitter and receiver 40 cm from the center of the goniometer
5. Adjust the "INTENSITY" and "VARIABLE SENSITIVITY" knobs on the Receiver so that the meter reads 1.0 (full scale)
6. Connect the reflector at the center of the goniometer as shown in Figure 4
7. The angle between the incident wave from the transmitter and a line normal to the plane of the reflector is the angle of incidence (see Figure 5).

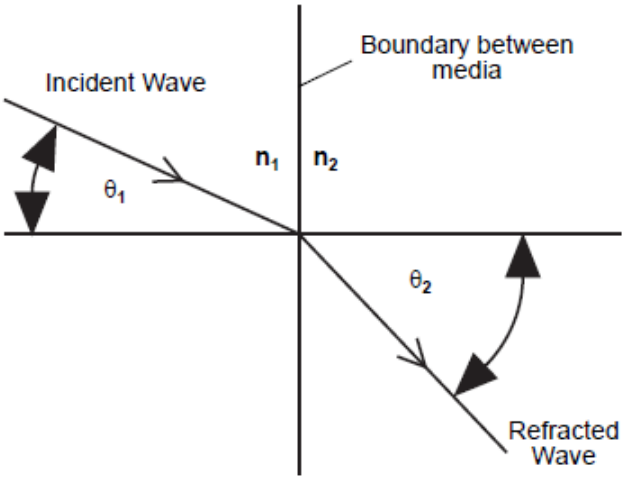

Figure 2: Angles of incident and refraction when crossing the interface of two media.

8. Adjust the rotating component holder where the reflector is mounted so that the angle of incidence can be set to desired value.

9. Without moving the transmitter or the reflector, rotate the movable arm of the goniometer until the meter reading is a maximum. Note : The angle between the axis of the receiver horn and a line normal to the plane of the Reflector is the angle of reflection

10. Read the **angle range** at which the meter reading is at maximum.

11. Calculate the average angle of reflection and error

12. Measure and record the angle of reflection for each of the angles of incidence shown in Figure 6 ★

13. What is the relationship between the angle of incidence and the angle of reflection based on your results? Does this relationship hold for all angles of incidence? ★

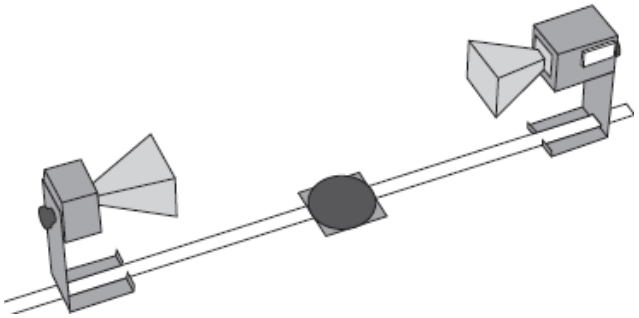

Figure 3: Equipment setup to measure linear polarization with no polarizer

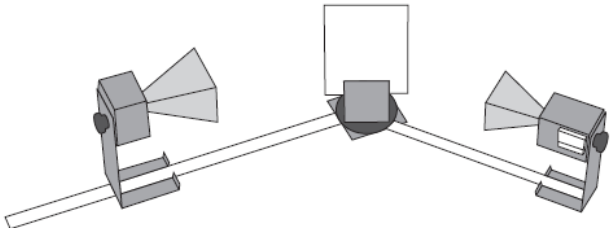

Figure 4: Initial equipment setup

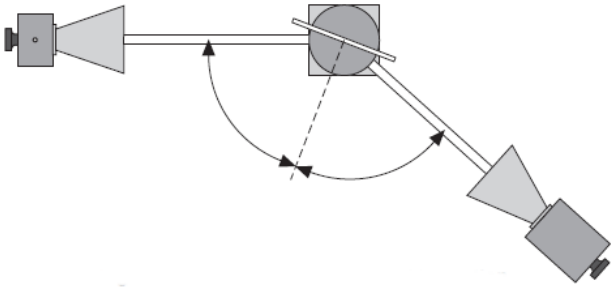

Figure 5: Angles of incident and reflection

Refraction of Microwave Radiation

1. Arrange the equipment as shown in Figure 7
2. Before the empty prism mold is placed, align the transmitter and receiver inline
3. Adjust the "INTENSITY" and "VARIABLE SENSITIVITY" knobs on the Receiver so that the meter reads 1.0 (full scale)
4. Fill the prism mold with the styrene pellets.
5. Align the face of the prism that is nearest to the transmitter so it is perpendicular to the incident microwave beam. See Figure 8 to better understand the alignment of the prism.
6. Rotate the movable arm of the goniometer and locate the angle θ at which the refracted signal is a maximum.
7. Read the **angle range** at which the meter reading is at maximum.
8. Calculate the average angle and error
9. θ is just the angle that you read directly from the degree scale of the goniometer.
10. Using the diagram shown in Figure 8, determine θ_1. You will need to use a protractor to measure the Prism angles.
11. Use your value of θ to determine θ_2.
12. Repeat the measurements three times ★

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

Figure 6: Data table for reflection measurements

13. Calculate the average angles (θ_1 and θ_2) and errors ★
14. Use the Snell's law (equation 1) to determine the ratio of refraction indices. ★
15. Assume index of refraction for air is equal to 1.00 and determine n_1 , the index of refraction for the styrene pellets. ★
16. Find out about index of refraction for the styrene pellets (Google search)
17. Estimate the error of the measurement of n_1 ★
18. Calculate the speed of light inside the styrene ★

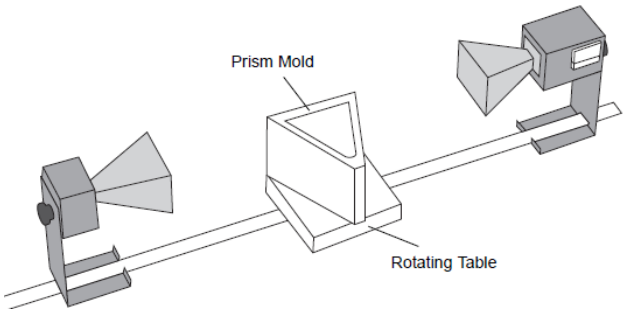

Figure 7: Equipment setup

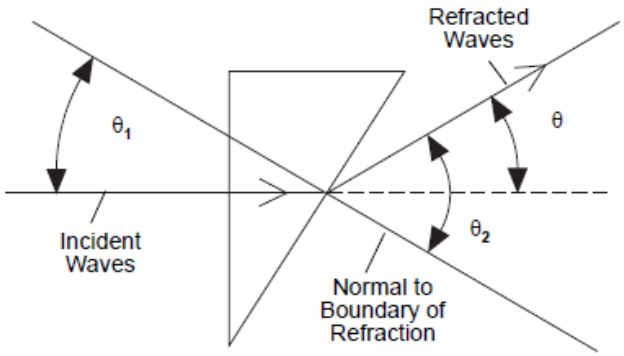

Figure 8: Geometry of prism useful for refraction measurement