Lab 7: Standing Waves and Diffraction of Microwave Radiation

Goal

Observe physical wave properties of Microwave Radiations

Objectives

1. Use standing waves formed between transmitter/receiver antennas to determine the wavelength of the EM waves

2. Understand the basic principles of wave diffraction using two slits experiment and determine the wavelength of the EM waves

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

Traveling and Standing Waves

The transmitting and receiving antenna have a finite size and as a results it will reflect a fraction of the microwave radiation between the two antennas. It will form a standing wave pattern the space between. Generally, a standing wave form when two waves travel in opposite directions.

Nodes appear where the fields of the two waves cancel and anti-nodes appear where the superposed fields oscillate between a maximum and a minimum. The distance between nodes in the standing wave pattern is just one-half (1/2) the wavelength, λ of the two waves.

If the distance between the Transmitter and Receiver diodes is equal to $n\lambda/2$, (where n is an integer and λ is the wavelength of the radiation), then 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 in order to see a maximum is therefore $\lambda/2$.)

Double-Slit Diffraction

Diffraction can be observed when an electromagnetic (EM) wave passes through a two-slit aperture if the slit size and separation are comparable to the wavelength of the EM wave. The wave diffracts into two waves which superpose in the space beyond the apertures. Similar to the standing wave pattern, there are points in space where maxima are formed and others where minima are formed. With a double slit aperture, the intensity of the wave beyond the aperture will vary depending on the angle of detection. For two thin slits separated by a distance d, maxima will be found at angles such that,

$$d \cdot sin(\theta) = n\lambda \tag{1}$$

where θ is the angle of detection, λ is the wavelength of the incident radiation, and n is an integer $(0, \pm 1, \cdots)$. See Figure 1.

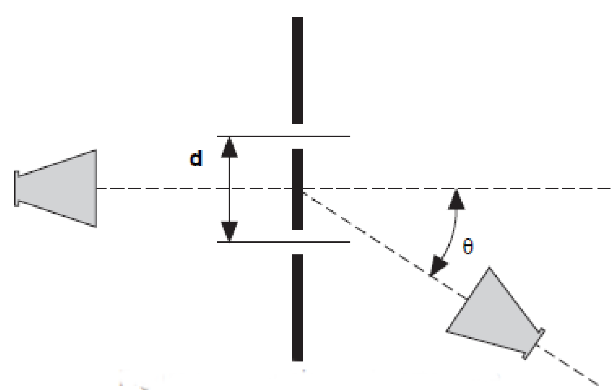

Figure 1: Double-Slit diffraction

Preliminary Lab Questions

1. Find an equations for the wavelength λ of the EM wave given no.of nodes n and length the antenna moved is L

Equipment and Parts

1. PASCO microwave optics system : Transmitter, Receiver, Goniometer, Metal Reflectors (2), Wide Slit Spacer, Narrow Slit Spacer

2. Multimeter

Procedure

Traveling and Standing Waves

1. Set up the equipment as shown in Figure 2. Adjust the Receiver controls to get a full-scale meter reading with the Transmitter and Receiver about $R \sim 40\ cm$. Slowly move the Receiver along the Goniometer arm away from the Transmitter. How does this motion effect the meter reading?

2. Adjust the "INTENSITY" and "VARIABLE SENSITIVITY" knobs on the Receiver so that the meter reads 1.0 (full scale)

3. Slide the Receiver one or two centimeters along the Goniometer arm to obtain a maximum meter reading. Record the Receiver position along the metric scale of the Goniometer arm.

4. Note down the Initial Position of Receiver

5. While watching the meter, slide the Receiver away from the Transmitter. Do not stop until the Receiver passed through at least 10 positions at which you see a minimum meter reading and it 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.

6. Note down total Minima Traversed (n)

7. Note down the Final Receiver Position

8. Calculate the distance the Receiver travelled.

9. The distance between the transmitter and final position of the receiver is proportional to the wavelength of the microwave times the no.of nodes

10. Use the data you have collected to calculate the wavelength (λ) of the microwave radiation. ★

11. **Repeat the wavelength measurement three times★**

12. Calculate the final measurement of wavelength (λ) and standard deviation using three measurements.

13. Compare results using theoretical value of wavelength, λ

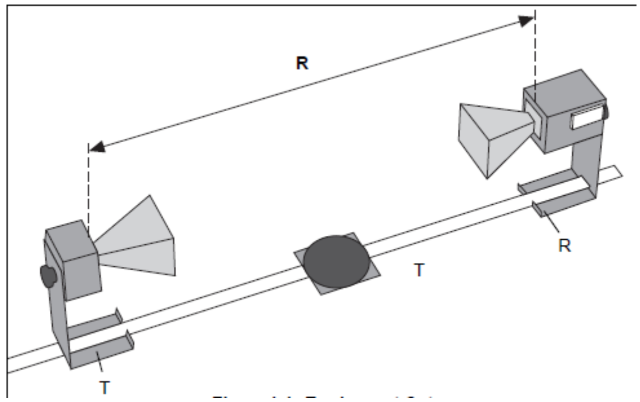

Figure 2: Equipment setup

Double-Slit Diffraction

1. Arrange the equipment as shown in Figure 3. The Receiver must rest on the rotatable Goniometer arm
2. Keep Receiver and Transmitter about 40 cm to 50 cm from the center of the Goniometer degree plate
3. Use the Slit Extender Arm or metal stands, two Reflectors, and the Narrow Slit Spacer to construct the double slit.
4. **Note:** A slit width of about 1.5 cm is recommended
5. Be precise with the alignment of the slit and make the setup as symmetrical as possible
6. Adjust the Transmitter and Receiver for vertical polarization (both at 0^o)
7. Adjust the Receiver controls to give a full-scale reading at the lowest possible amplification
8. Connect the multimeter to measure the voltage from the Receiver
9. Rotate the rotatable Goniometer arm (on which the Receiver rests) slowly about its axis.
10. Observe and note the meter reading.
11. Reset the Goniometer arm so the Receiver directly faces the Transmitter.
12. Adjust the Receiver controls to obtain a meter reading of 1.0.
13. Note down the angle when the the Receiver directly faces the Transmitter (at angle $\theta = 0^o$).
14. Move the Goniometer arm to find the first maxima on both sides of 0^o
15. Measure the meter reading and the absolute angle reading

16. Move the Goniometer arm to find the second ($n = 2$) maxima on both sides of 0^o
17. Measure the meter reading and the absolute angle reading
18. Note down the angle when the the Receiver directly faces the Transmitter (at angle $\theta = 0^o$).
19. Tabulate the result with a table for each run ★
20. Calculate the wavelength, λ using the maxima angles measured using equation 1 ★
21. show results in the table itself by adding another column ★
22. Find average and the standard deviation for the wavelength, λ measurement ★
23. Plot your data for each run and find the wavelength, λ using the slope of this graph ★
24. The equation 1 will tell you what is X and Y of the graph that will give wavelength, λ from the slope
25. Find the standard deviation of the slope ★
26. Compare results using theoretical value of wavelength, λ ★

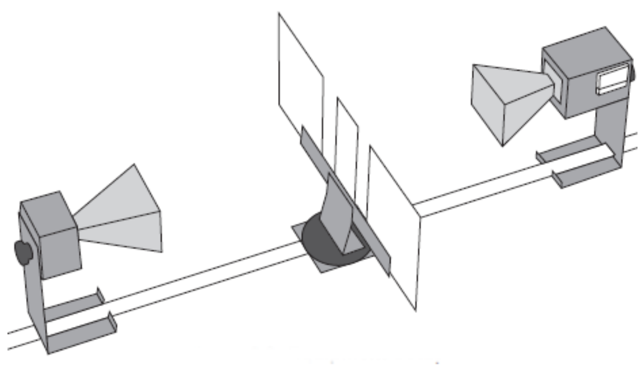

Figure 3: Equipment Setup. You may have to setup the experiment differently than shown in the Figure. The basic idea is to have the two slit made using Metal Reflectors and Slit Spacer