Microwave Experiments: Fun with big electromagnetic waves

PHY344 Jan 25, 2007 (Preliminary Draft)

We are most familiar with electromagnetic (EM) waves as visible light. This microwave laboratory explores EM waves in both similar and different ways than the optical laboratory. Young's double slit interference experiment and the Lloyd's Mirror experiments are essentially similar. Otherwise it is easier to see some EM wave properties with microwave because the waves are so large (centimeters) relative to the visible light variety (380 to 770 nm) which are less than one micrometer. They are a convenient way to understand evanescent waves, diffraction, polarization, interference, etc.

Day One

The first four experiments in the Lab Manual are to get to know the apparatus and introduce a few basic concepts.

So do 1-4 experiments, they don't take long at all. Answer all the questions before proceeding.

For experiment 3, we have the detector probe. It is not very efficient so it will require observation with the receiver at its most sensitive setting and with a multimeter connected to voltage to observe the small signal. You will need this later as well so no time to learn like the present.

Then do 5, 6, and 7 before calling it a day. Answer all questions. If you have lots of time left over you can do 8 if you wish.

Be sure to unplug the power from the transmitter before you leave.

Day Two

Begin with **Expt 9**

P.28 has an alternate suggestion for doing more. Read the suggestion, but instead take the greyish plastic sheet and measure its path length, its thickness and hence its refractive index as it suggests for the boxed styrene chips. To do it well actually takes a lot of care, and several repetitions and you can calculate the error in your estimate. You can make use of the plate holder.

Expt 10

This experiment introduces fiber optics which is great for projecting light where you need it and also introduces total internal reflection a technique used to visualize single molecules.

Expt. 10A

As a supplement to this lab, take the large blue prism and bring the microwaves perpendicular to the short side of the prism so that the ray path grazes the hypothenuse of the prism. Using the diode probe used in Expt3 investigate how the signal decays as you move away from the surface of the prism. Plot this intensity on a mm distance scale away from the surface. What is so total about the "total internal reflection"? Why is this there? It is called the evanescent wave. Look up evanescent waves and compare to your experimental determination. Why do you think you got what you did?

Expt 11

is self explanatory

Be sure to unplug the power from the transmitter before you leave.

DAY Three

Expt 12

This is one of the most worthwhile experiments here, because the use of diffraction has many practical applications such as the determination of 3D structure of molecules or materials. It is worthwhile to go through the lab thoroughly and slowly so that you come away from it understanding reciprocal space, where diffraction spots come from and how to interpret X-ray images in a simple case.

Supplementary Experiment

A quarter-wave stack reflector or shaped-beam dielectric antenna

Laser mirrors, coupling light to some photomultipliers, and micro and small biological organism eyes are optimized with this technique. Cats eyes also reflect light, although the interference producing the reflection is derived differently.

Place the transmitter and the receiver facing each other at least 30 cm apart. Measure the received intensity, you will need that as a reference for the next measurements.

Place the transmitter and receive along side each other and place a single 3mm thick plastic sheet reflector in its wood holder at least 30 cm away from the receiver so that the reflection off the surface maximizes the signal at the receiver, i.e. angle and distance from receiver. It would be most handy if the front surface of the plate was at the center of rotation of the goniometer. Keeping the reflector and transmitter in the same positions measure the intensity as a function of the angular position of the receiver (go to at least 60 degrees from the normal).

Choose the spacer combination that gives the largest net reflection.

Without moving the first 3mm thick plastic sheet, take a window spacer (you can try each spacer or together in combination) then take a second plastic sheet and behind it (further from the transmitter) at such a distance that the signal is maximum at the receiver. Measure the intensities as a function of receiver positions again.

Take a third plastic sheet separated by a spacer similarly behind the second and measure the intensities again.
Take a fourth sheet, etc
And a fifth.

Now measure the sum of the air paths between the five sheets. Divide by 4 and this gives an estimate of the optimum wave path length for the air for the composite reflector. Compare to what you might expect from looking up and understanding this device.

Plot the intensities as a function of the angles for the different number of plates on the same graph. What properties do you note?

Look up the structure of a cats eyes reflector and design (draw a scale drawing) a microwave target to demonstrate it.

Be sure to unplug the power from the transmitter before you leave.

NOTE:
If there are any additional instructions that you think might be useful for the next student doing this lab, please bring it to the attention of a TA or professor. This is a new lab, the equipment just arrived, and has not yet been student tested.