EE 4202 Laboratory in Circuits

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***Abstract*—In this lab the speed of light was measured and familiarity with scalar RF power measurements was gained.**

I. Introduction

This document is a model and instructions for LaTeX. Please observe the conference page limits.

II. Measuring the speed of light

A. Procedure

To measure the speed of light using a microwave, the rotating plate was removed from the microwave. Sliced cheese was the placed onto a paper plate inside of the microwave. After 15 seconds in the microwave the cheese platter was examined. There were regions of soft, melted cheese and hard, cold cheese. Because the microwave forms standing waves during operation, it is implied that the hot spots correspond to the standing waves antinodes. The distance between adjacent antinodes corresponds to have wavelengths of the standing wave. Using this to determine the wavelength.

Measurement Type	Value
Frequency of microwave operation:	2.45 GHz
Distance between hotspots	5.75 cm

$$\frac{\lambda}{2} = 5.75 \times 10^{-2}\text{m}$$
$$\lambda = 11.5 \times 10^{-2}\text{m}$$
$$f = 2.45 \times 10^{9}\text{Hz}$$

$$c_{\text{measured}} = \lambda f$$
$$c_{\text{measured}} = \left(11.5 \times 10^{-2}\right)\left(2.45 \times 10^{9}\right)$$
$$c_{\text{measured}} = 2.8175 \times 10^{8}$$

$$\%\ \text{error} = \frac{|c - c_{\text{measured}}|}{c}$$
$$\%\ \text{error} = \frac{|2.99 \times 10^{8} - 2.8175 \times 10^{8}|}{2.99 \times 10^{8}} \cdot 100\%$$
$$\%\ \text{error} = 0.05 \cdot 100\%$$
$$\%\ \text{error} = 5\%$$

B. Analysis

The accuracy of the speed of light measurement was dependent on several factors. The factors likely caused the drift between the measured speed of light and the theoretical speed of light. These factors include but are not limited to:

- Tolerance of the generated frequency of the microwave
- Measurement error using the ruler
- Operator error related to the ambiguity of the exact location of the antinodes

With these in mind, the percent error of 5% is entirely reasonable. Some problems include the ambiguity with the exact location of the antinodes as it seemed as if the antinodes occurred at the seams of the cheese slices. A solution to fix this problem would be to procure a larger cheese sheet and to leave the microwave on for longer. With these 2 modifications the ambiguity of the antinode location would be minimized. Another problem is the limited sample size. This subjects the measured value to random errors. By collecting more samples, one could gain more confidence in the measurements.

C. Question to Consider

From what you learned in lab today why do microwave oven manufacturers almost always include a rotating platform?

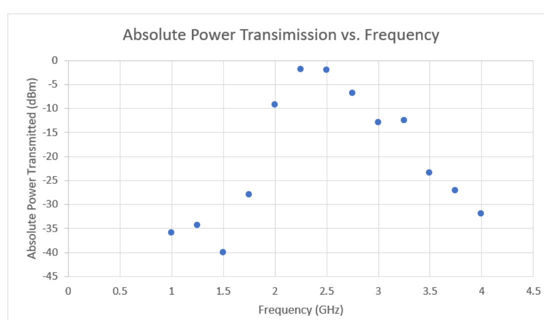
The rotating platform reduces the uneven heating that the microwave produces. From the food's perspective, the nodes/antinodes are constantly changing positions so the food cooks more evenly than it would be otherwise.

III. Scalar Power Measurements

A. Attenuators

The measured power of the signal generator's 2GHz 0dBm signal was -0.12 dBm. For a 2 GHz frequency, several measurements were made.

B. Filter



IV. Appendix

Medium	Absolute Power (dBm)	Absolute Power (mW)	Insertion Loss (dB) at 2GHz	Insertion Loss Difference Absolute (dB)	Insertion Loss Difference Percentage
RF Cable	-0.12	0.972747	-0.12	N/A	N/A
3dB SMA attenuator	-3.8	0.416869	-3.8	-0.8	26.667
10dB SMA attenuator	-10.28	0.0937562	-10.28	-0.28	2.8
20dB SMA attenuator	-20.17	0.00961612	-20.17	-0.17	0.85

Frequency (GHz)	Absolute Power (dBm)
1	-36.00
1.25	-34.42
1.5	-40
1.75	-28
2	-9.32
2.25	-1.86
2.5	-2.07
2.75	-6.94
3	-12.99
3.25	-12.6
3.5	-23.47
3.75	-27.10
4	-32.01

Fig. 1. Cheese slices that were measured to determine the speed of light