RF Lab Module #1 - Scalar Measurements

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***Abstract*—In this lab, the speed of light was measured with method utilizing household materials and tools. Next, familiarity with scalar radio frequency power measurements was gained. Several cables, attenuators, and filters were measured to affirm their specification.**

I. Introduction

TO gain understanding of radio frequency (R.F.) power measurements and standing waves, several measurements were conducted and analyzed. First, the speed of light was measured by utilizing a microwave's ability to generate a standing wave with a particular frequency. To measure different R.F. components, a R.F. signal generator, power sensor, and power meter were utilized. With a proper introduction and basic understanding of these tools, several components were measured including cables, attenuators, and a filter.

II. Speed of Light Experiment

A. Procedure

To measure the speed of light using a microwave, the rotating plate was removed from the appliance. 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 half wavelengths of the standing wave. With the half wavelengths known, the full wavelength can be determined. The measurements taken are recorded in Table I.

TABLE I
Observations and measurements for calculating the speed of light

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

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

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

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

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 factors in mind, the percent error of 5% is entirely reasonable. Some problems include the ambiguity with the exact location of the antinodes. 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.

III. Power Meter Experiment

A. Attenuators

The measured power of the signal generator's 2GHz 0 dBm signal (2.c) was -0.12 dBm. For a 2 GHz frequency, several measurements and calculations were made for different attenuators as shown in Table II.

B. Filter

A R.F. bandpass filter attenuation was measured at frequencies well below its nominal pass band through frequencies above the pass band. These measurements recorded and appear in Table III and Fig. 1.

IV. Conclusion

A. 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 foods perspective, the nodes/antinodes are constantly changing positions so the food cooks more evenly than it would be otherwise.

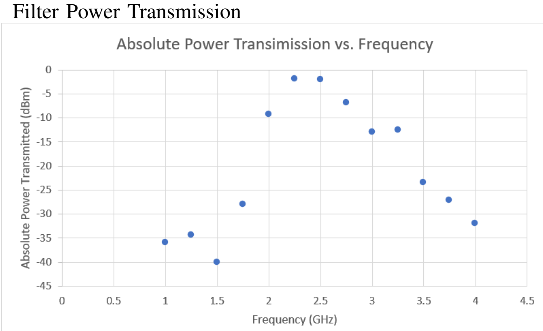
TABLE II
ATTENUATOR SCALAR POWER MEASUREMENTS AND CALCULATIONS PERFORMED DURING THE LAB SESSION

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

TABLE III
BAND PASS FILTER SCALAR POWER MEASUREMENTS PERFORMED OVER FREQUENCY RANGE

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. Filter Power Transmission



APPENDIX A
EXTRA PHOTOS

Fig. 2. Cheese slices that were measured to determine the speed of light