OBJECTIVE

Students will measure the attenuation in a coaxial cable using a power meter and analyze the results.

INTRODUCTION

Decibels

Cable **attenuation** (loss) is usually expressed in **decibels** (dB), which is a logarithmic ratio of powers. Thus, it is based on the "log" function relationship, where:

$$y = \log_{10} x \quad \Leftrightarrow \quad x = 10^y$$

Let the ratio of two powers be designated by ***A***; so we have $\boldsymbol{A = P_{meas}/P_{ref}}$. The calculation of the ratio ***A*** in dB is specified by Equation 1:

$$A_{dB} = 10 \cdot \log_{10}\left(\frac{P_{meas}}{P_{ref}}\right) \qquad (1)$$

where $\boldsymbol{P_{meas}}$ is the measured power, $\boldsymbol{P_{ref}}$ is the power that $\boldsymbol{P_{meas}}$ is being compared to, and the subscript ***dB*** indicates that the resulting ratio is in decibels.

As defined, a decibel measurement provides a "**power gain**" measurement or, in other words, the increase in $\boldsymbol{P_{meas}}$ compared to $\boldsymbol{P_{ref}}$. For example, compared to a reference power of $\boldsymbol{P_{ref}}$ = 10 watts, a measured power of $\boldsymbol{P_{meas}}$ = 20 watts relates to a gain of $\boldsymbol{A_{dB}}$ = +3dB as shown in (2):

$$A_{dB} = 10 \cdot \log_{10}\left(\frac{P_{meas}}{P_{ref}}\right) = 10 \cdot \log_{10}\left(\frac{20}{10}\right) = 10 \cdot \log_{10}(2) = 3.01 \approx +3\ dB \qquad (2)$$

Note that power doubles for every additional +3dB increase. (+9dB = +3+3+3 → 2x2x2 = 8x power).

In comparison, a measured power of $\boldsymbol{P_{meas}}$ = 5 watts and a reference power of $\boldsymbol{P_{ref}}$ = 10 watts relates to a dB gain of $\boldsymbol{A_{dB}}$ = –3dB (***a negative gain relates to a positive loss or attenuation***) as shown in (3):

$$A_{dB} = 10 \cdot \log_{10}\left(\frac{P_{meas}}{P_{ref}}\right) = 10 \cdot \log_{10}\left(\frac{5}{10}\right) = 10 \cdot \log_{10}\left(\frac{1}{2}\right) = -3.01 \approx -3\ dB \qquad (3)$$

Thus, a positive dB value relates to $\boldsymbol{P_{meas}} > \boldsymbol{P_{ref}}$, and a negative dB value relates to $\boldsymbol{P_{meas}} < \boldsymbol{P_{ref}}$.

Note that decibels, as defined, provide a "power gain" measurement. Yet, it is often useful to specify a dB attenuation or loss, such that $\boldsymbol{A_{dB(attenuation)}} = -\boldsymbol{A_{dB(gain)}}$. ("negative" gain ≡ "positive" attenuation).

Some common power ratios and dB gain values include:

P_{meas}/P_{ref}	dB_{gain}	P_{meas}/P_{ref}	dB_{gain}	P_{meas}/P_{ref}	dB_{gain}	P_{meas}/P_{ref}	dB_{gain}
1	0	2	3	1	0	1/2	-3
10	10	4	6	1/10	-10	1/4	-6
100	20	8	9	1/100	-20	1/8	-9
1000	30	16	12	1/1000	-30	1/16	-12
10000	40	32	15	1/10000	-40	1/32	-15

Power Level in dBm

Absolute power values may also specified in terms of "***dBm***". A **dBm** is a decibel value of a power level referenced to **one milliwatt**. Note that the argument of the logarithm is dimensionless. Thus:

$$P_{dBm} = 10 \cdot \log_{10}\left(\frac{P}{1\text{ mW}}\right) \tag{4}$$

For example: $P = 2\text{mW} \Rightarrow P_{dBm} = 10 \cdot \log_{10}\left(\frac{P_{meas}}{1\text{ mW}}\right) = 10 \cdot \log_{10}\left(\frac{2\text{ mW}}{1\text{ mW}}\right) = +3\text{dBm}$

A power value in dBm can be converted to power in milliwatts as shown below for the case of a +12dBm power level:

$$12\text{ dBm} = 10 \cdot \log_{10}\left(\frac{P_{meas}}{1\text{ mW}}\right) \Rightarrow 1.2 = \log_{10}\left(\frac{P_{meas}}{1\text{ mW}}\right) \Rightarrow 10^{1.2} = 10^{\log_{10}\left(\frac{P_{meas}}{1\text{ mW}}\right)}$$

$$\frac{P_{meas}}{1\text{ mW}} = 10^{1.2} \Rightarrow P_{meas} = 1\text{ mW} \cdot \left(10^{\frac{12}{10}}\right) = 15.84 \approx 16\text{ mW} \tag{5}$$

Attenuation in Cables

In lecture you will discuss the RMS-phasor form used to represent waves traveling on transmission lines. For waves traveling in the positive ***x*** direction, the equation for the magnitude of a wave at a distance "x" down the line is:

$$\boldsymbol{E_x = E_0^+ e^{-\alpha x}} \tag{6}$$

where α is the **attenuation constant** for the line and has units of **Nepers** per unit length. In this lab you will utilize a single frequency measurement technique to measure the attenuation between the input and output of a passive two-port network and determine its attenuation constant. The "two-port network" or DUT (device-under-test) you will use is a section of coaxial cable.

To measure the attenuation (also referred to as insertion loss or one-way signal loss), you will perform a reference/insertion measurement. First, the source is adjusted to provide a measured reference power reading (P_{in}) of 0dB_m using the setup shown below. The two interconnect cables should have the same characteristic impedance as the cable to be measured and the minimum number of adapters should be used to connect the cables. See Figure 2.1.

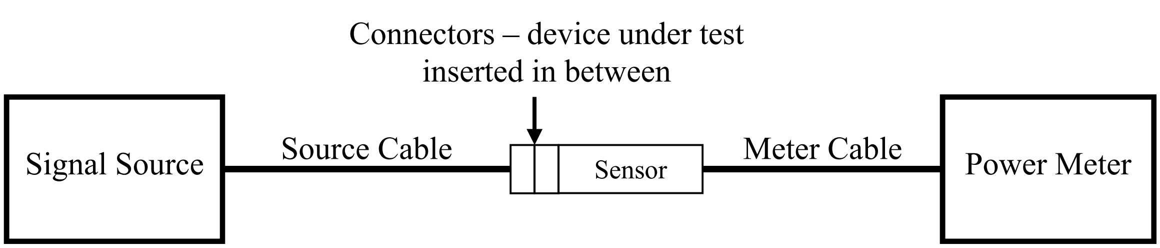

Figure 2.1 – Setup for Insertion-Loss Measurement

Then, without adjusting the signal source, the two-port network (your cable) is inserted between the signal source and meter interconnects. The power meter now indicates the power (P_{out}) that has passed through the cable. If both P_{in} and P_{out} are measured in dBm, then the dB attenuation of electrical signal caused by the coaxial cable can easily be determined as shown in (6):

$$\alpha_{dB} = P_{in(dBm)} - P_{out(dBm)} \qquad \textbf{(6)}$$

Note that this equation assumes that the signal source and power detector are matched to the network. If a signal encounters a change in the medium of propagation, some of the energy will be transmitted past this point and some will be reflected back in the direction it comes from. The most significant changes in the transmission medium occur at connectors, defective or damaged points in the cable, and/or changes in cable types. Therefore, the power reaching a detector may be reduced not only by the attenuation characteristics of the cable itself, but also by any mismatches between the signal source and the detector.

The main difference between the attenuation values you measure for the cables in the lab and those specified by a manufacturer are usually due to mismatches in cable and connector impedances.

PRELAB CALCULATIONS (To be completed before the beginning of the Laboratory Session):

Using **Table 1-3** of your textbook, calculate to two decimal places the expected dB cable attenuation for **12 feet** of RG-58/U and RG-58A/U cables at frequencies of 100, 200, 400, and 900MHz and record your results in the appropriate columns of Table 2.1.

(Use the "***RG 58/U JAN-C-17A***" and "***RG 58A/U JAN-C-17A***" specifications in Table 1-3).

Coaxial Cables

RG #	AWG Material	Insulation	# Shields	Jacket	Nom. O.D. (inch)	Nom. Imp. (Ohms)	Nom. Vel. Of Prop.	Nom. Cap. (pF/ft.)	Nom. Attenuation per 100' MHz	dB	Standard Spool Lengths
58/U **JAN-C-17A**	20 Bare Copper	Poly-ethylene	1	Black Vinyl	0.195	53.5	66%	28.5	100 200 400 900	4.1 6.2 9.5 14.5	100,500 1000
58A/U **JAN-C-17A**	20 Tinned Copper	Cellular Poly-ethylene	1	Black Vinyl	0.195	50	66%	30.8	100 200 400 900	5.3 8.2 12.6 20.0	100,500 1000

Data from textbook: **Table 1-3 Characteristics of Coaxial Lines Used in Communication Systems**

INSTRUMENTATION

Power Meter w/ Power Sensor and an *RF* Signal Generator (with modulation switched OFF)

PROCEDURE

1. Attenuation Measurements for both Short and Long cables

a. Select a "**short**" (**12-foot**) piece of RG-58 cable and identify its type by reading the labeling on the cable jacket. (Is it labeled RG-58/U or RG-58A/U?)

Cable type: ________________________________

b. Select a "**long**" piece of RG-58 cable and identify its type by reading the labeling on the cable jacket. (Is it labeled RG-58/U or RG-58A/U?)

Cable type: ________________________________

c. Connect the **signal source** directly to the **power sensor** using a short "launch cable". Set the source to **100 MHz** and adjust the source's output power level to obtain a **0dBm** reading on the power meter. This is a normalization/calibration step.

d. Insert the **short cable** (12-foot) between the launch cable and the power sensor. You will need to use an additional coaxial adapter to make the connection. Based on the power value shown on the meter, determine and record the cable's dB attenuation in Table 2.1.

e. Remove the short cable and insert the **long cable** between the launch cable and power sensor. Based on the power value shown on the meter, determine and record the cable's dB attenuation in Table 2.1.

f. **Repeat** steps (**c**) through (**e**) for the other frequencies specified in Table 2.1. Be sure to perform a normalization after you set the source to the new frequency but before adding the two cables.

ANALYSIS

1. Based on the (prelab) calculated attenuations for a 12-foot section of cable and your measured attenuations for the short (12-foot) cable, would you say that the short (12-foot) cable best resembles RG 58/U (JAN-C-17A) or RG 58A/U (JAN-C-17A) despite its labeling? Be sure to support your answer.

2. Plot the measured attenuation data as a function of frequency for both the short and long cables on a single graph. Use logarithmic scaling on the horizontal frequency axis. The vertical axis should be in dB and should be linearly scaled. Your plot must be electronically generated. Do not create a hand-drawn plot.

3. Use the *measured* attenuation results for the short cable at 100 MHz, 200 MHz, 400 MHz, and 900 MHz to estimate the length of your long cable. You will make four different calculations here, one for each frequency. Determine your short cable's loss in dB/ft and then use those values to estimate (calculate) the length of the long cable based on its measured attenuation. Record your results in the appropriate column of Table 2.1. Compare these calculated lengths to the actual long cable length of 116.75 feet using relative difference with actual length as reference.

4. The nominal velocity of propagation for both RG-58/U (JAN-C-17A) and RG-58A/U (JAN-C-17A) cable is 66% of the speed of light in a vacuum. Calculate the wavelength in meters for a sine wave traveling in RG-58/U or RG-58A/U cable for each of the frequencies you used for your measurements. Then calculate to two decimal places the length of the 5-meter cable in wavelengths for each of the frequencies in Table 2.1. Put these length calculations in a new table.

5. In general, the cable lengths you calculated in Analysis step 4 will not be integer numbers of wavelengths. Consider sending a 400 MHz sine wave down the cable. From your length-in-wavelengths calculation at 400 MHz, determine the relative phase shift in degrees between the sine wave measured at the beginning of the cable and the sine wave measured at the output. Make your phase shift fit within a 0° to +360° range.

LAB REPORT NOTES

Include a computer-generated version of Table 2.1 in the main body of the report. Make sure your data, calculations, figures, and tables are introduced and described properly in your report narrative. When including plots in the report, they are called figures, not plots.

Name: ____________________________________ **Section (Day/Time): _________________**
(Print Name – Last Name First)

Table 2.1 – Attenuation & Calculated Length Data

Frequency (MHz)	Prelab Calc. Atten. Short Cable **RG 58/U Jan-C17-A** (100, 200, 400, 900 MHz)	Prelab Calc. Atten. Short Cable **RG 58A/U Jan-C17-A** (100, 200, 400, 900 MHz)	Meas. Atten. Short Cable	Atten. Diff. Short Cable (for your cable type)	Meas. Atten. Long Cable	Approx. Long Cable Length (100, 200, 400, 900MHz)
100						
125						
160						
200						
250						
320						
400						
500						
620						
750						
900						
1100						
1400						
1800						