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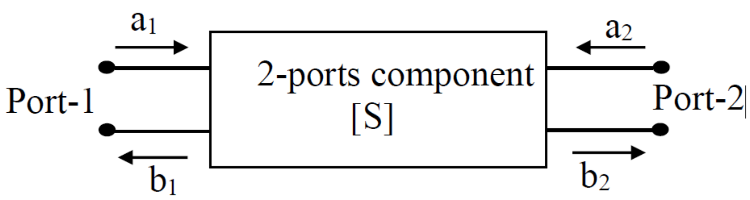
IMPEDANCE AND ATTENUATION VARIATION WITH FREQUENCY IN LINES

In this experiment, the variation of the attenuation and the input impedance of a coaxial cable with frequency will be examined using a Network Analyzer.

Preliminary Information:

S-Parameters:

S-parameters (scattering parameters) describe the input-output relationship between ports orterminals of a microwave element. For the 2-port network shown in the figure, thisrelationship is given by the equations:



$$b_1 = S_{11}a_1 + S_{12}a_2$$
$$b_2 = S_{21}a_1 + S_{22}a_2$$

In these equations, a_1 and a_2 are the normalized incident power waves, and b_1 and b_2 are the normalized reflected power waves.For a 2-port network, the S-parameters are defined as follows:

$S_{11} = \frac{b_1}{a_1}\Big|_{a_2=0}$: Reflection coefficient at Port 1, $S_{22} = \frac{b_2}{a_2}\Big|_{a1=0}$: Reflection coefficient at Port 2

$S_{21} = \frac{b_2}{a_1}\Big|_{a_2=0}$: Forward transmission coefficient, $S_{12} = \frac{b_1}{a_2}\Big|_{a_1=0}$: Reverse transmission coefficient

The conditions a_1=0 and a_2=0 imply that the respective ports are terminated with a matched load. S-parameters are generally complex quantities. A vector network analyzer can measure For a reciprocal 2-port element, $S_{22}=S_{11}$ and $S_{21}=S_{12}$. Transmission lines (e.g., a coaxial cable of length l) are reciprocal elements.

Line Attenuation:

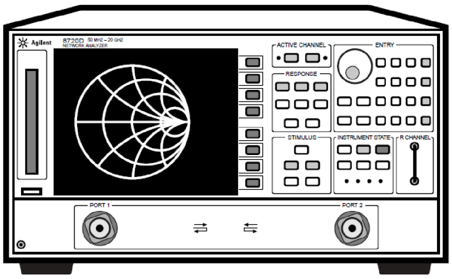
The attenuation of a transmission line is defined by the attenuation constant, α.

$$\alpha = \alpha i + \alpha d \text{ (Np/m) or } \alpha = 8{,}686(\alpha i + \alpha d) \text{ (dB/m)}$$

α_i : conductor attenuation, α_d : dielectric attenuation

The frequency variation of the attenuation of a transmission line (e.g., coaxial cable) is typically provided by the manufacturer in dB/m or dB/100m.

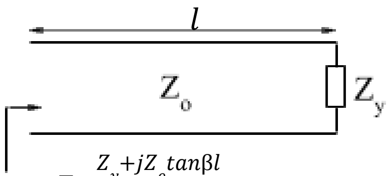
The variation of the total attenuation (αl) of a line of length l with frequency can be determined using a Network Analyzer. For this, the line, which has the same characteristic impedance Z_0 as the analyzer, is connected between the calibrated ports 1 and 2 of the analyzer. The logarithmic variation of S_{12} or S_{21} with frequency is then examined. The trace displayed on the analyzer's screen represents the frequency variation of the line's total attenuation, αl.



Network Analyzer

Variation of Input Impedance with Frequency:

As shown in the figure, the input impedance of a lossless line of physical length l, terminated with an impedance Z_L, is given by:



$$Z_{in} = Z_o \frac{Z_y + jZ_o \tan\beta l}{Z_o + jZ_y \tan\beta l}$$

If the frequency of the signal applied to the input of the line is changed, the electrical length of the line (l/λ) also changes with frequency.

- At frequencies where the line length is $l = n\lambda/2$, $Z_{in} = Z_L$.
- At frequencies where $l = (2n+1)\lambda/4$, $Z_{in} = Z_0^2/Z_L$.

If the line is terminated with a resistive load $Z_L = R_L$:
And if $R_L > Z_0$, then $Z_{max} = Z_0 S = R_L$ and $Z_{min} = Z_0/S$.

In this case:

- For frequencies where $l = n\lambda/2$, $Z_{in} = R_L = Z_{max}$
- For frequencies where $l = (2n+1)\lambda/4$, $Z_{in} = R_L/S^2 = Z_{min}$ (where n=0, 1, 2,...)

The frequencies at which the input impedance of a line of a certain length, terminated with a resistive load R_L, is Z_{max} and Z_{min} can be determined by observing the frequency variation of the S_{11} parameter or the impedance on a Smith chart using a network analyzer calibrated for one-port measurements.
The velocity factor of the M17/084-RG223 coaxial cable to be used in the experiment is 66%.

Experimental Procedure:

1. Determining the Attenuation of the M17/084-RG223 Coaxial Cable
1.1 Turn on the HP8719D Network Analyzer by pressing the Line button on the front panel.
1.2 Press the Save/Recall button on the analyzer, select the calibration file REG14 from the screen, and press the Recall State button. Then, press the Measure button and select the appropriate softkeys to display the S_{21} parameter.
1.3 Connect the long coaxial cable (l=2m) to the ports of the device. Press the Marker button on the analyzer.
1.4 From the displayed variation of the S_{21} parameter, read the S_{21} values for the frequencies listed in the table below and record them.

Frequency (MHz)	Attenuation α(dB/m) Catalog (typical)	Attenuation α(dB/m) Catalog (max)	Measured Attenuation $\alpha l = -S_{21}$ (dB)	Calculated(dB/m) $\alpha = -S_{21}/l$
100	0,13	0,21		
400	0,269	0,394		
1000	0,439	0,689		

2. Variation of Line Input Impedance with Frequency
2.1 Press the Save/Recall button on the analyzer, select the file REG16, and press the Recall State button. Then, press the Measure button and select the softkeys to display the S11 parameter.
2.2 Connect a 100-ohm resistor to one end of the approximately 32 cm coaxial cable. Connect the other end to port 1 of the analyzer.
2.3 Press the Format button and select the Smith Chart view. Press the Marker button.
2.4 Vary the frequency from 500 MHz to 1000 MHz and observe the change in impedance.
2.5 Record your readings in the appropriate places in the table below.

Reading from Horizontal Axis :		Calculated	
Impedance (Ω)	Frequency (MHz)	λ=0,66c/f	l/λ

The distance between the end where the 100-ohm load is connected and the measurement end is approximately l≈43.3 cm.

Pre-Laboratory Preparation Questions:

1. What are S-parameters? For a two-port microwave device, define the parameters S_{11}, S_{21}, S_{12}, and S_{22}, and explain their physical meanings.
2. What does it mean for a two-port device to be reciprocal? Explain in terms of S-parameters why a transmission line is reciprocal.
3. How is the attenuation constant α defined in transmission lines? What are conductor loss and dielectric loss? Provide general information about how attenuation varies with frequency.
4. By which expression is the input impedance of a lossless transmission line defined? How does the input impedance change when the line length is $\ell = n\lambda/2$ and $\ell = (2n+1)\lambda/4$?

Requirements for the Laboratory Report:

1. Compare the results you obtained in Experiment 1 with the given catalog values and provide your interpretation.
2. By relating the measured and calculated values in Experiment 2, compare the obtained results with the expected values and provide your interpretation.
3. Why does the input impedance of an approximately 32 cm long coaxial line terminated with a 100 Ω load vary with frequency?