

Basic RF Technic and Laboratory Manual

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Part I

Experiment-3 Transmission Lines-Part 2

Chapter 1

INTRODUCTION

1.1 Prelab Exercise

1. Refer to the following sentence " a line with series resistance $R = 0$ is a lossless line".

2. What is the frequency of :

- f_0 – electromagnetic wave, propagation in a free space, $\lambda_0 = 1m$.
- f_{coax} – electromagnetic wave, propagating in a coaxial cable with dielectric material. , $\lambda_{coax} = 1m$.
- Find the ratio $\frac{f_0}{f_{coax}}$ and show the dependence on ϵ_r .

1.2 Background Theory

1.2.1 (see part 1)

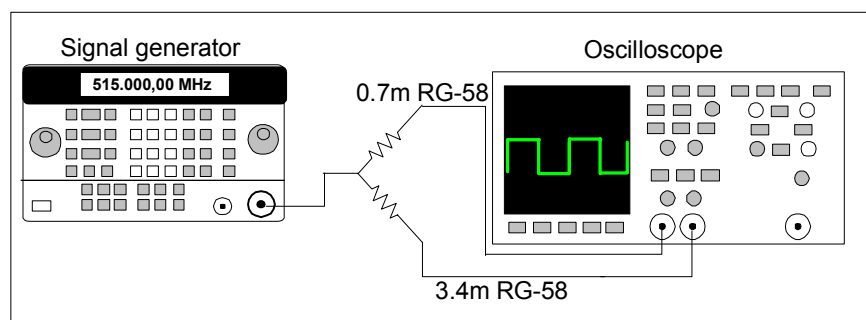


Figure 1 Phase difference between two coaxial cables

Chapter 2

EXPERIMENT PROCEDURE

2.1 Required Equipment

1. Network Analyzer *HP – 8714B*.
2. Arbitrary Waveform Generators (*AWG*) *HP – 33120A*.
3. Keysight ADS software.
4. Termination- 50Ω .
5. Standard 50Ω coaxial cable .
6. Open Short termination.
7. SMA short termination.
8. Caliber.
9. Length measuring device.

2.2 Dielectric Constant ϵ_R and Velocity Factor of Coaxial Cable.

Coaxial cable RG-58 with BNC (Bayonet Navy Connector) connectors, is the transmission line that widely used in laboratories and other application. The reason is their wide operating frequency range, physical flexibility, and their low cost.

In this part of the experiment you simulate and measure the wavelength, velocity factor of electromagnetic wave in coaxial cable. The velocity of electromagnetic wave in coaxial cable is less than free space $v_{coax} < c$ therefore $\lambda_{coax} < \lambda_0$ By taking a fixed length of short circuit transmission line at the load end, and measuring the input impedance you determine the dielectric constant ϵ_R and velocity factor of coaxial cable.

1. Measure the physical length of the coaxial cable under test.
2. Calculate the frequency for which the measured length of the coax cable would equal one wavelength in free space ($f_0 = \frac{c}{length}$) .
3. Using ADS software, simulate the system as indicated in Fig.9.

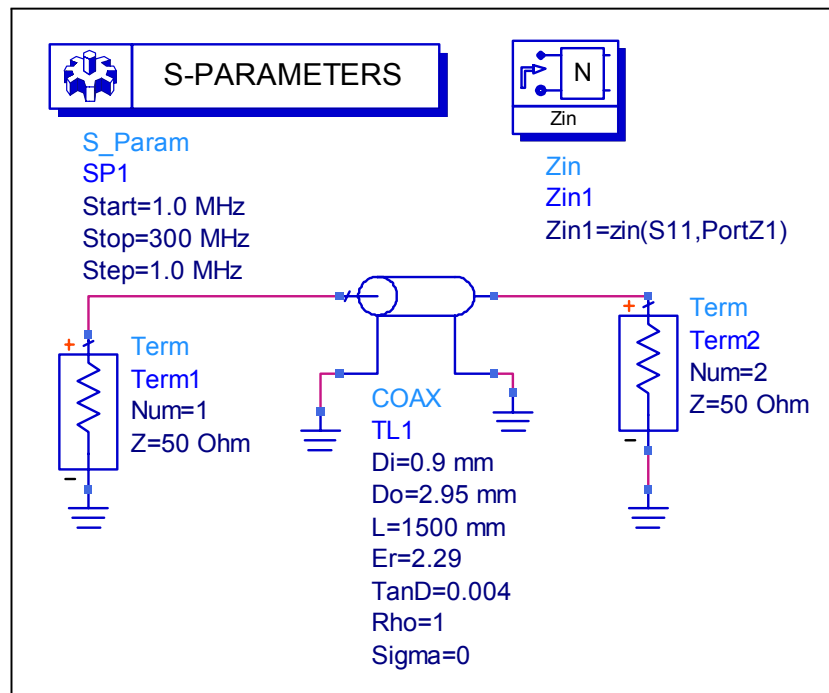


Figure 1 Simulation of short coaxial cable

Component	Name	Simulation. palette list
S-parameter	Simulation-S-parameter	Simulation-S-parameter
Zin	Simulation-S-parameter	Zin: Input port Impedance
Termination	Simulation-S-paramete	Term
Coax	Coax	TLines-Ideal
Table-4 Part list of Fig-9		

4. Simulate the system to magnitude of Z_{in} , start frequency 300kHz, stop frequency just above f_0 .

5. The magnitude of Z_{in} is the impedance transformation of short-circuit line see Fig.11, The frequency difference between two OPEN impedance points is the frequency f_{coax} , at frequency f_{coax} the wavelength in the coax is the same as physical length of the cable. **Save the data on magnetic media.**

6. Calculate ϵ_R using theory of transmission line $\epsilon_R = \left(\frac{f_0}{f_{coax}}\right)^2$.

7. Connect the coaxial cable with short at the load end to the Network Analyzer, as indicated in Fig.10.

8. Set the Network Analyzer to Impedance Magnitude Measurement, start frequency 300kHz, stop frequency just above f_0 .

9. The Network Analyzer display the impedance transformation of short-circuit line, The frequency difference between two OPEN impedance points is the

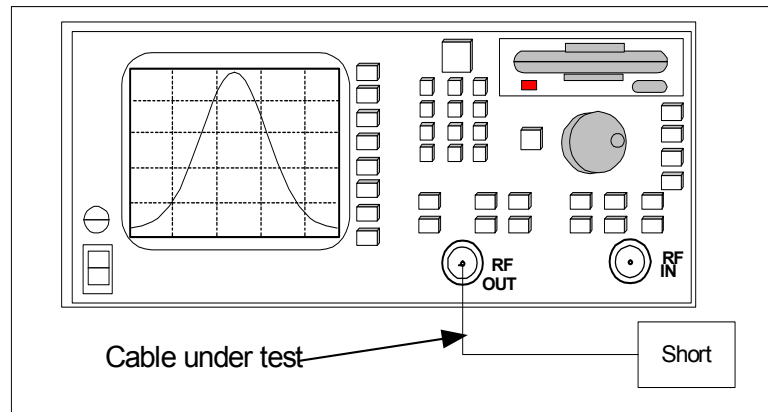


Figure 2 Measuring dielectric constant and velocity factor

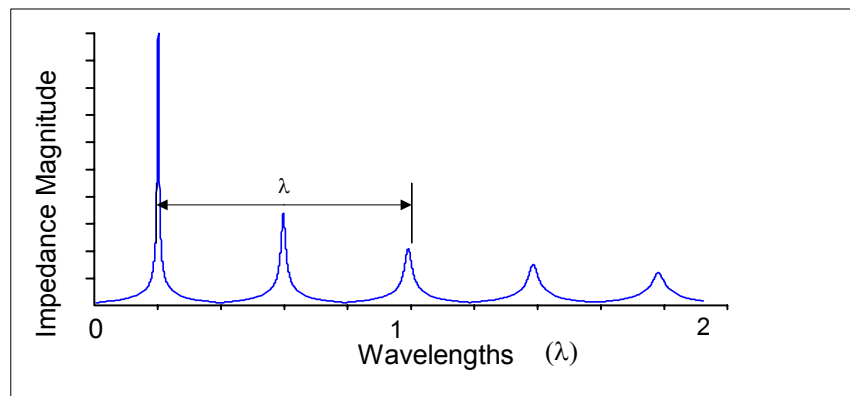


Figure 3 Input impedance of shorted low loss coaxial cable

frequency f_{coax} . **Save the data on magnetic media.**

10. Calculate ϵ_R using theory of transmission line $\epsilon_R = \left(\frac{f_0}{f_{coax}}\right)^2$.

11. Compare your results of ϵ_R to the RG-58 data sheet of RG-58 (see appendix -1).

2.3 Measuring Characteristic Impedance Z_0

In this part of the experiment you measure the characteristic impedance- two methods.

1. Refer to Fig-12 measure with Caliber the inner conductor radius **a** and outer conductor (shielding) radius **b** of the coaxial cable.
2. Calculate the characteristic impedance of the coax cable, using the mea-

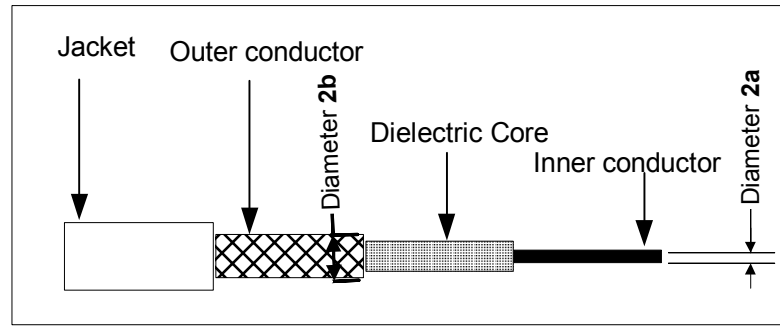


Figure 4 Physical dimension of coaxial cable

sured ϵ_R value and the following equation

$$Z_0 = 138 \sqrt{\frac{1}{\epsilon_R}} \log \frac{b}{a} \text{ (assuming } \mu_R = 1\text{)}.$$

2.3.1 Open Short Method

1. Simulate Z_{in} of 1.5m coaxial cable RG-58 with a short end, start frequency 1MHz, stop frequency 300MHz.(see Fig, 13)
2. Simulate Z_{in} of 1.5m coaxial cable RG-58 with an open end, start frequency 1MHz, stop frequency 300MHz.
3. Calculate Z_0 according to $Z_0 = \sqrt{Z_{short}Z_{open}}$. **Save the Data on magnetic media .**

Component	Name	Simulation. palette list
S-parameter	Simulation-S-parameter	Simulation-S-parameter
Zin	Simulation-S-parameter	Zin: Input port Impedance
Termination	Simulation-S-paramete	Term
Coax	Coax	TLines-Ideal
Table-5 Part list of Fig-13		

4. Terminate the coaxial cable with SHORT and connect it to the Network Analyzer as indicated in Fig.8.
5. Set the Network Analyzer to **IMPEDANCE MAGNITUDE** measurement, Start frequency 300 kHz, stop frequency to 500 MHz, average on.
6. Notice that every $\frac{\lambda}{4}$ the impedance transform the Open to Short and vice versa. Set the marker to 200 MHz and record the impedance. **Save the Data on magnetic media** for further analysis.
7. Replace the SHORT termination with OPEN termination at the end of the coaxial cable, the network analyzer measure the impedance of OPEN termination. **Save the Data on magnetic media.**

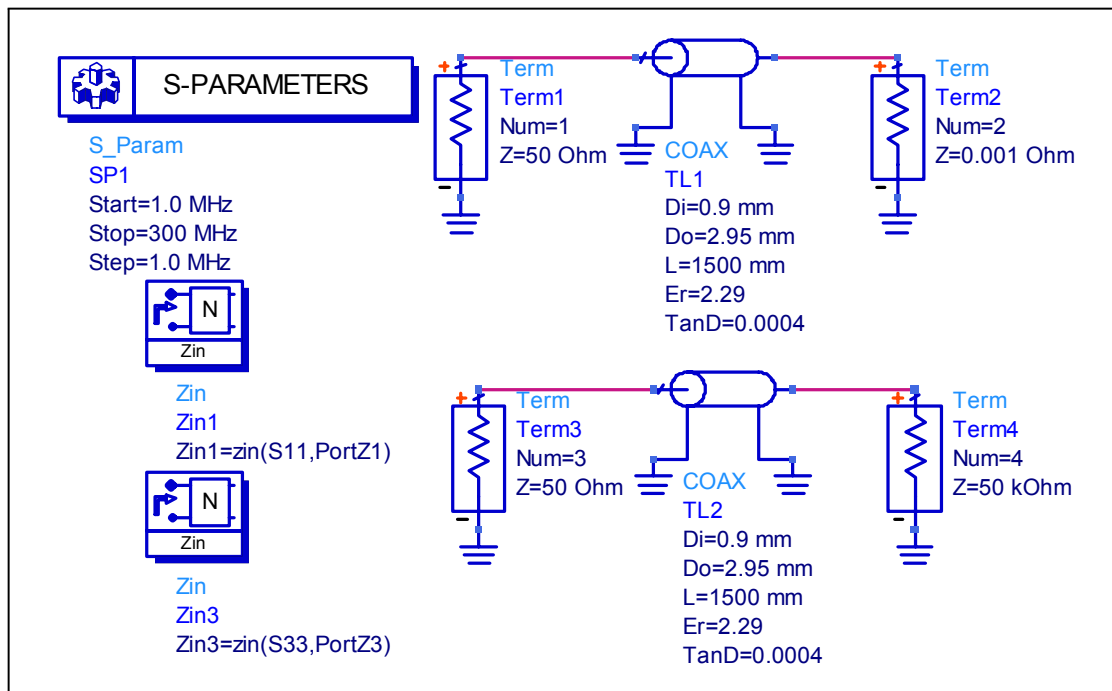


Figure 5 Simulation of Z_0 measurement using open short method

8. Set the marker to 200 MHz and record the impedance. Calculate the Characteristic impedance at 200 MHz using the equation

$$Z_0 = \sqrt{Z_{short} Z_{open}}$$

2.4 Measuring Propagation Constant of Coaxial cable.

2.4.1 Attenuation Constant α of coaxial cable

In this part of the experiment you'll measure attenuation of the coaxial cable line to 1 GHz.

1. Connect a coaxial cable Rg.-58 length at least 5m. to the Network Analyzer as indicated in Fig.14.

2. Set the Network Analyzer to Transmission measurement, Start frequency 300 kHz, stop frequency to 1 GHz

3. Measure the physical length of the cable.

4. Set the marker to 1 GHz, and read the Attenuation. Find the total Attenuation constant (due to conductor loss and dielectric loss) per unit length. (Remember the measured unit is $\frac{dB}{m}$). Compare your result to the data sheet at the cable (see appendix-1). **Save the Data on magnetic media .**

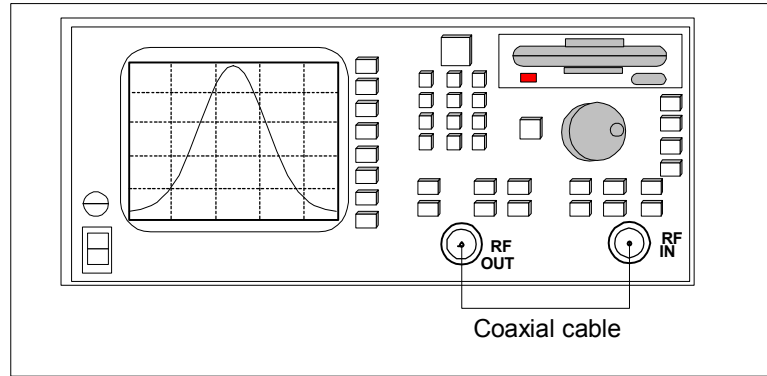


Figure 6 Attenuation and phase constant measurement

2.4.2 Measuring Phase Constant β of coaxial cable

1. Connect a short coaxial cable to the Network Analyzer, as indicated in Fig.14. Set the Network Analyzer to Transmission measurement, Start frequency 300 kHz, stop frequency to 250 MHz. perform normalized calibration.

2. Connect a coaxial cable $> 1m$. to the network analyzer. Set the Network Analyzer to Transmission measurement, Start frequency 300 kHz, stop frequency to 250 MHz.

3. Measure the phase insertion at 100 MHz , (pay attention to the special display format).

4. Find β by ($l(m) = \text{coaxial cable length} - \text{short cable length}$)

$$\beta (\text{degree}) = \frac{\text{Phase insertion}^\circ}{l(m)} \left(\frac{\text{deg ree}}{\text{m}} \right)$$

5. Compare your result to the calculated β

$$\beta (\text{radian}) = \frac{2\pi}{\lambda}$$

2.5 Final Report

1. Simulate a $1m$ coaxial cable RG-58 based on distributed elements model of transmission lines(see Fig.3 theory part), operating frequency $DC - 1GHz$. (Each element should represent a length of $1/50$ of the wave length).

- Simulate S_{11} and S_{21} of one distributed element dz using figure 3 and the calculated value of L,R,C,G. (Verify that the input and output impedance is 50Ω).
- Calculate the number of dz elements required to simulate $1m$ cable. (dz should be $1/50$ of the short wavelength of operating frequency).

- Draw a graph of S_{11} and S_{21} of 1m coaxial cable and compare your results to the measurement.
2. Using distributed parameter R,l,C,G at 100 MHz find the attenuation α (dB) at 100 MHz , which part of the attenuation is due to Ohmic loss and which part is due to dielectric loss.
 3. Draw a graphs of characteristic impedance of coaxial cable versus frequency based on:
 - a. Physical properties of the cable
 - b. Open short method. based on measurement and simulation.

2.6 Appendix-1 Engineering Information RF Coaxial Cable RG-58

Component	Construction details
Inner conductor	Nineteen strands of tinned copper wire. each strand 0.18 mm diameter Overall diameter: 0.9 mm.
Dielectric core	Type A-1: Solid polyethylene. Diameter: 2.95 mm
Outer conductor	Single screened of tinned cooper wire. Diameter: 3.6 mm .
Jacket	Type Ila: PVC. Diameter: 4.95mm.

Engineering Information:

Impedance: 50Ω

Continuous working voltage; 1,400 V RMS, maximum.

Operating frequency: 1 GHz, maximum.

Velocity of propagation: 66% of speed light.

Dielectric constant of polyethylene- 2.29

Dielectric loss tangents of polyethylene- $\tan \delta = 0.0004$

Operating temperature range: -40 C to +85 C.

Capacitance: $101 \frac{pF}{m}$.

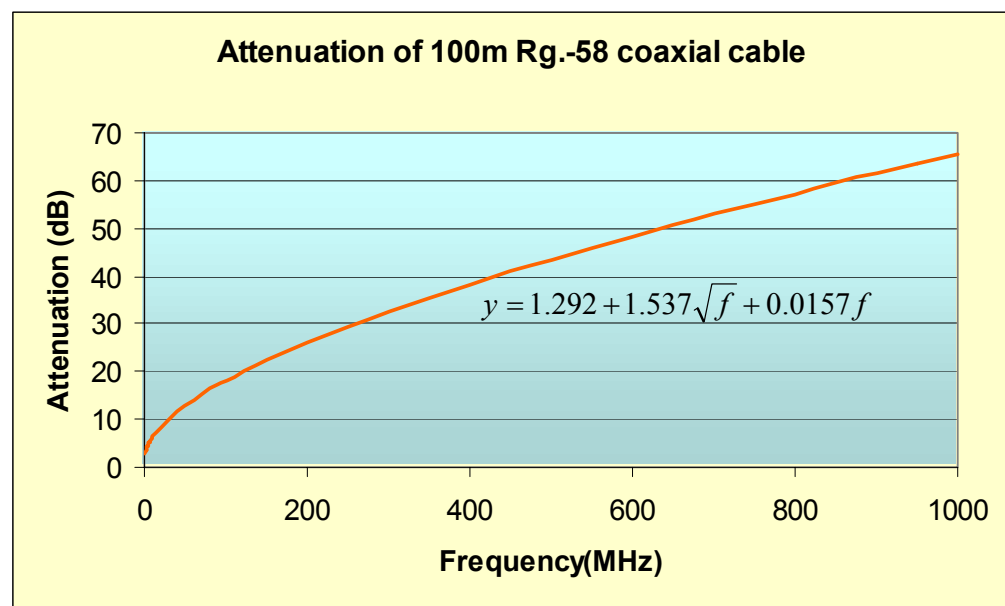


Figure 7 Attenuation versus frequency of coaxial cable RG-58