



ECE 3300 LAB 3 – Pre-lab

Monopole Antenna and Single Stub Matching Network

Overview: This document is a preparation for lab 3. It is due at the start of the lab.

Equipment: A floppy disk or jump drive is needed to complete the pre-lab and lab. Txline software is needed. TLINE software is recommended.

Background:

Students should know how to use a Smith chart to design a single stub matching network.

For more information: Contact the teacher assistants or class instructor. See website for details: www.ece.utah.edu/~ece3300

Objectives

- ◆ Learn to design and build Monopole antennas
- ◆ Design and implement a matching network
- ◆ Become familiar with S11 parameter
- ◆ Learn how to measure S-parameters on a Network Analyzer

Prelab

1. Read this lab.
2. Design a quarter wave monopole in air ($h = \lambda/4$) at 440 MHz. Length = _____ cm
3. Design a single stub matching circuit for a quarter wave monopole antenna. The imaginary part of the antenna has been adjusted to “zero” by tuning the antenna, so the input impedance is approximately $Z_{ant} = 36.5$ ohms. This is Z_L of the transmission line. The matching circuit should use a parallel open circuit stub. The characteristic impedance of both the transmission line and the stub is 50Ω .
4. Determine the width of a 50 ohm microstripline. Use Txline (available on the LAB website, this is NOT the same software as TLine from the lecture site) to compute the dimensions of the microstrip using Rogers Laminate. The electrical length is not important, since the length of the stub has already been calculated using the Smith Chart.

Rogers Laminate RO4350 Properties

Dielectric constant	3.38
Loss tangent	0.0035
Thickness of the substrate	1.52 mm or 60 mils
Thickness of the metal layer	17.8 um or 0.7 mils

5. Plot the radiation pattern of a quarter wave dipole antenna. Radiation pattern is a map of the NORMALIZED POWER as a function of angle around the antenna. Use the equation for the E field:

$$\tilde{E}_\theta = j60I_o \left[\frac{\cos(\pi/2 \cdot \cos \theta)}{\sin(\theta)} \right] \left(\frac{e^{-jkR}}{R} \right).$$

Square it (to get power). Assume any value for R (since we will be normalizing the power). Divide by the maximum value (this leaves only the sine and cosine terms). Plot this as a function of angle from 0 to 180 degrees. You should get a figure eight. θ is measured from the z-axis which means that $\theta = 0$ is directly ABOVE the dipole, $\theta = 90$ degrees is directly to the side, and $\theta = 180$ degrees is directly below the dipole. Sketch your dipole on this plot. (A note, you probably won't be able to calculate 0 or 180 degrees, calculate another small value instead). Explain in WORDS what the radiation pattern of a dipole antenna is shaped like in three dimensions and where the power is the strongest and the weakest.

6. Download and read the instructions on calibrating the network analyzer for SINGLE PORT measurements.
7. Bring a floppy disk or jump drive for saving Network Analyzer data. Also bring TLIN software (from the LECTURE website) or extra Smith Charts in case you need to quickly recalculate your stub.

Dipole and Monopole Wire Antennas

A general purpose dipole antenna (long thin wire antenna) with height $h_1 = h_2 = L/2$, where L is the total length of the antenna is shown in Figure 1.

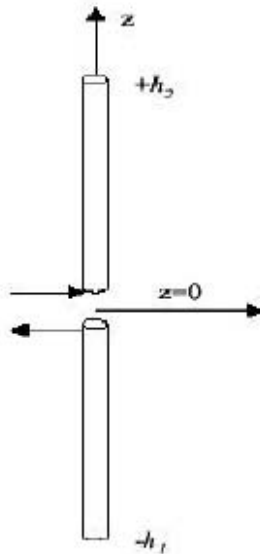


Figure 1. Thin Linear Antenna of Total Length $h_2 + h_1$

The dipole antenna is constructed with two thin linear elements that are symmetrically fed at the center by a balanced two-wire transmission line. The antennas may be of any length, but it is assumed that the current distribution is sinusoidal. Current-distribution measurements indicate that this is a good assumption provided that the antenna is thin: That is, when the conductor diameter is less than $\lambda/100$.

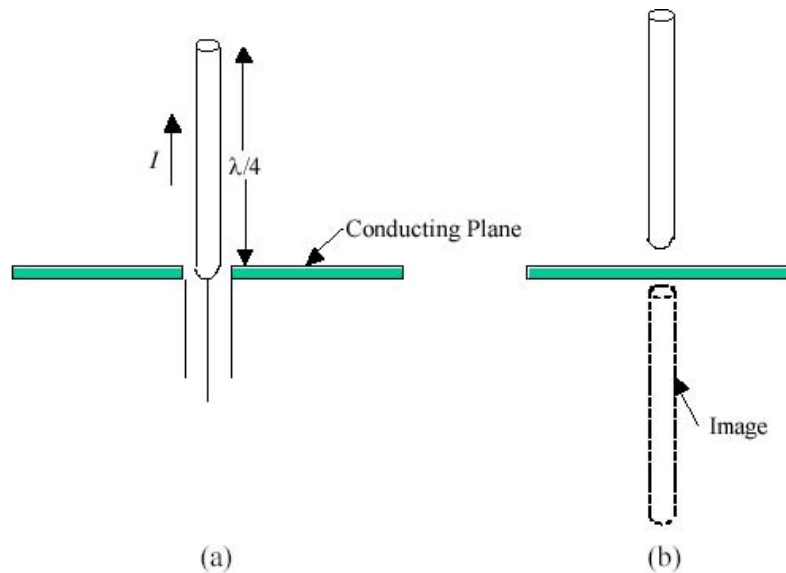


Figure 2. (a) Quarter-Wave Monopole Antenna. (b) Equivalent Half-Wave Dipole Antenna

When placed over a conducting ground plane, a quarter-wave monopole antenna excited by a source at its base as shown in Figure 2 exhibits the same radiation pattern in the region above the ground as a half-wave dipole in free space. This is because, from image theory, the conducting plane can be replaced with the image of a $\lambda/4$ monopole. However, the monopole can only radiate above the ground plane. Therefore, the radiated power is limited to $0 \leq \theta \leq \pi/2$. Hence, when fed the same input power, the $\lambda/4$ monopole radiates twice as much power as the dipole over the top half plane.

Figure 3 shows the real and imaginary parts of the impedance for monopole antennas of different lengths. It can be observed from the figure that the impedance can vary tremendously depending on length. Note that the reactance X_a depends on the conductor radius a , whereas the feed-point resistance R_a is relatively independent of conductor radius a for thin antennas ($a/\lambda \leq 1$). The input resistance R_a of a center-fed dipole antenna of length $2h$ is twice that of an end-fed monopole of length h .

Figure 4 shows the antenna you will be working with in the lab. The antenna is made by pressing a piece of copper wire into the center hole in the connector. Be SURE to remove any varnish on the wire with sandpaper. If you are using “magnet wire”, it may appear to be a clean copper wire, but it actually has copper colored varnish on it. The open circuited PARALLEL stub is created using copper tape.

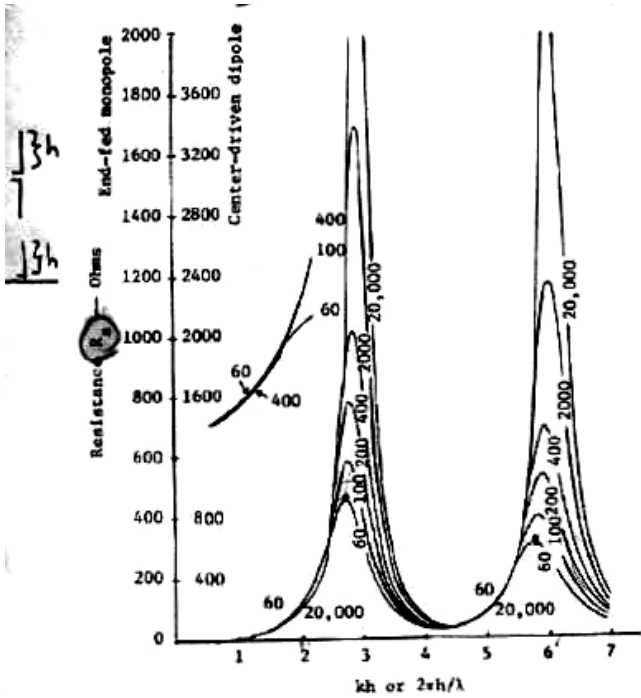


Fig. 5.4. R_r as a function of kh for various values of h/a (the ratio of length h to radius a of the antenna wire). [Source: E. C. Jordan and K. G. Balmain, *Electromagnetic Waves and Radiating Systems*, Prentice Hall, Englewood Cliffs, New Jersey, 1968.]

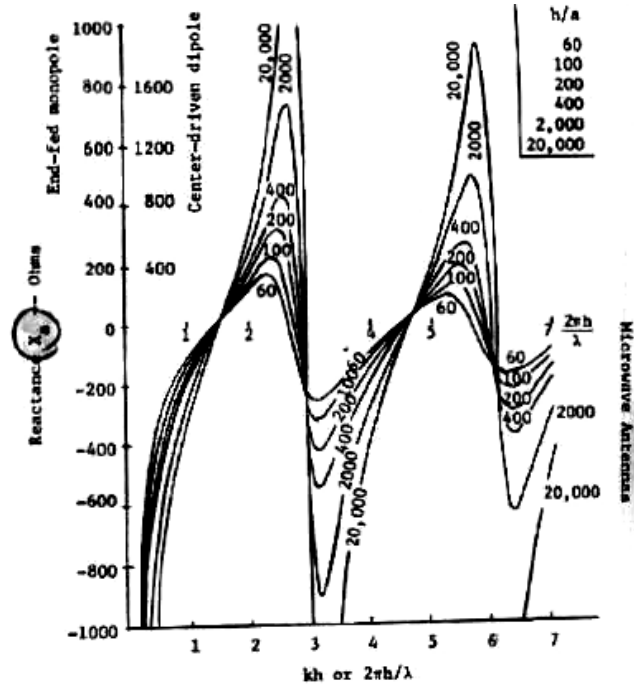


Fig. 5.5. X_r as a function of kh . [Source: E. C. Jordan and K. G. Balmain, *op. cit.*]

Figure 3 Monopole resistance and reactance plots. Dipole values are twice that of a monopole. The input impedance of an 'ideal' half wavelength dipole antenna is $73 + j 42$ ohms. From O.P. Gandhi, *Microwave Engineering and Applications*. New York: Pergamon Press, 1981, pp. 124-125



Figure 4. Monopole connected to microstrip line with open stub matching network. The antenna is made by pressing a piece of copper wire into the center hole in the connector. Be SURE to remove any varnish on the wire with sandpaper. If you are using “magnet wire”, it may appear to be a clean copper wire, but it actually has copper colored varnish on it. The open circuited PARALLEL stub is created using copper tape.

References

- [1] F. Ulaby, *Fundamentals of Applied Electromagnetics*, 6th ed., 2010, ch. 9.