Construction of a Table-Top Antenna Range for Learning Electromagnetics Concepts

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Abstract

The University of Scranton's EE 448 Electromagnetics II class is creating a table-top antenna range at 2450 MHz to enhance learning of electromagnetic and antenna concepts. This frequency was chosen for its relevance to practical applications like Wi-Fi and Bluetooth. The class is building three types of antennas - dipoles, dipoles with corner reflectors, and loops over ground planes. We showcase the use of NanoVNA for antenna measurements and suggest future project ideas.

Fig. 1: A) Completed dipole antenna with superb soldering job. B) Steve Cerwin's pro-tip to straightening and strengthening copper.

Introduction

The NanoVNA offers a portable and affordable solution for analyzing and optimizing RF circuits, including 2450 MHz dipole antennas, through precise measurement of complex impedance. Engineers utilize handheld tests to fine-tune physical dimensions and feeding mechanisms, ensuring efficient radiation patterns and impedance matching, making it vital for RF circuit design.

The half-wave dipole, among various types of dipole antennas, is fundamental and easily constructed. It features nearly omnidirectional radiation and can be fed from any point along its length, with a center-fed radiation resistance of 73 ohms in free space, and adaptable matching schemes for diverse environments.

Method/Experiment

Calibration: Utilized short circuit, open loop, and loaded attachments on NanoVNA to calibrate within 2-3 GHz range, achieving 2450 MHz SWR for impedance matching and signal reflection.

Antenna Fabrication:

- Cut and stripped coax to desired length
- Soldered coax to connector, ensuring proper resistivity
- Formed copper piece for antenna, soldering it to coax
- Tested antenna using NanoVNA for performance evaluation

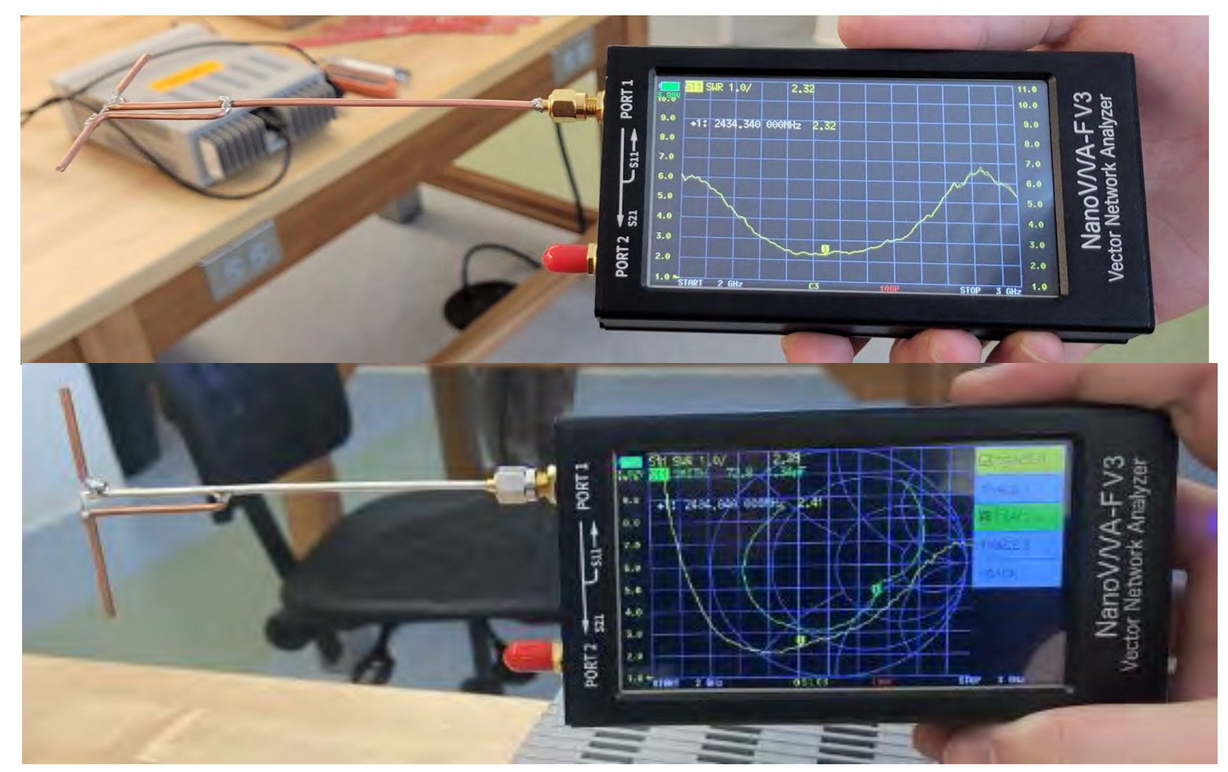

Fig. 2: Matthew Dittmar's dipole antenna being tested using a NanoVNA.

Polarization

Polarization in electromagnetics refers to the orientation of the electric field component of an electromagnetic wave concerning the Earth's surface. It describes the direction in which the electric field oscillates as the wave propagates through space.

Antennas emit and receive electromagnetic waves with a specific polarization. For optimal signal transfer, it's ideal for the polarization of the transmitting and receiving antennas to match. Mismatched polarizations can result in signal degradation or loss. Some antennas, particularly tabletop antennas used in radio communication or wireless networking, may feature adjustable polarization. This allows the antenna to be aligned to match the polarization of other antennas or to accommodate changing signal conditions.

The surrounding environment, including obstacles and reflections, can affect the polarization of electromagnetic waves. Signals may become depolarized or change polarization due to reflection and scattering. The characteristics of the transmission medium, such as the presence of atmospheric conditions or physical obstructions, can influence polarization.

Fig. 3: Full team working on developing antennas.

Theory

Radiation resistance is an important part of our analysis and construction of half-wave dipole antennas. Radiation resistance is the resistance caused by the emission of electromagnetic waves.

$$Z_{in} = 73 + j42.5\Omega$$

Equation 1: Radiation Impedance

When the antenna is resonant, we can drop the imaginary part. This is where we derive the 73 ohms used to test the antennas.

Dipole Orientation and Coupling

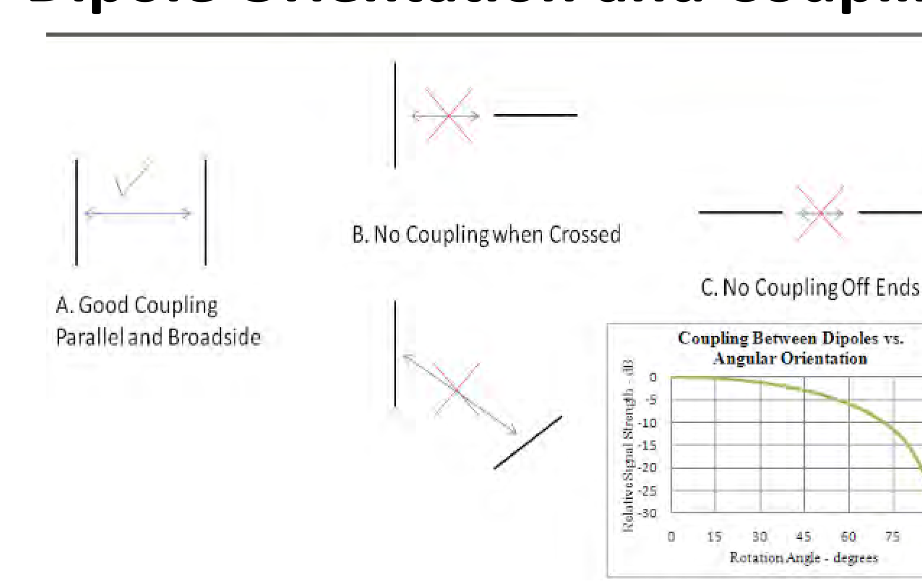

Fig. 4: Dipole Orientation and Coupling. Reprinted from Cerwin (2019).

References

Cerwin, Steve. *Radio Propagation and Antennas: A Non-Mathematical Treatment of Radio and Antennas*. AuthorHouse, 2019.

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