The Half-Wave Dipole: Design

Developed by Kathryn L. Smith, PhD

Sources

The material presented herein is from the following sources:

"Elements of Electromagnetics," by Matthew N.O Sadiku, 5th ed. (2010)
"Engineering Electromagnetics," by Nathan Ida, 3rd ed. (2015)
"Microwave Engineering," by David Pozar, 4th ed. (2012)
"Antenna Theory," by Constantine A. Balanis, 4th ed. (2016)
"Antenna Engineering Handbook," by John L. Volakis, 4th ed. (2007)

The Half-Wave Dipole Antenna: Design

Half-wave dipole antennas are among the most common antenna topologies. They are simple to design and fabricate, and offer a rotationally symmetric radiation pattern with very clean linear polarization. They typically have a narrowband response. Their native maximum directivity is approximately 2dB, but this can be easily increased through relatively simple modifications (such as the addition of reflectors and directors, as seen in the Yagi-Uda antenna). In this module, we will focus our discussion on the following two attributes of the half-wave dipole:

The Current Structure

The Theoretical Far-Field Radiation Pattern

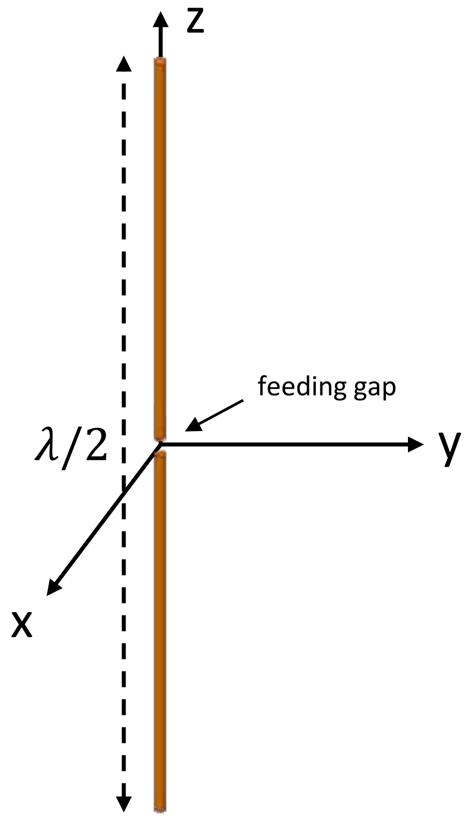
The Current Structure

A half-wave dipole antenna consists of a linear conductive element of length $L = \lambda/2$, typically fed by means of a gap inserted halfway along its length. We will base our discussion of the half-wave dipole on the diagram shown below, where the length of the dipole is oriented along the z-axis, and centered on the x-y plane.

Though the half-wave dipole is typically considered a narrowband antenna, increasing the radius of the wire used to form the body of the antenna is an effective method for increasing the bandwidth.

The major tradeoff here is that, the greater the radius of the wire, the harder it is to effect a smooth transition of current from the feed line to the antenna body.

A secondary tradeoff is that, the larger the radius is, the more strongly the antenna is affected by fringing fields (discussed in more detail on the following slide).

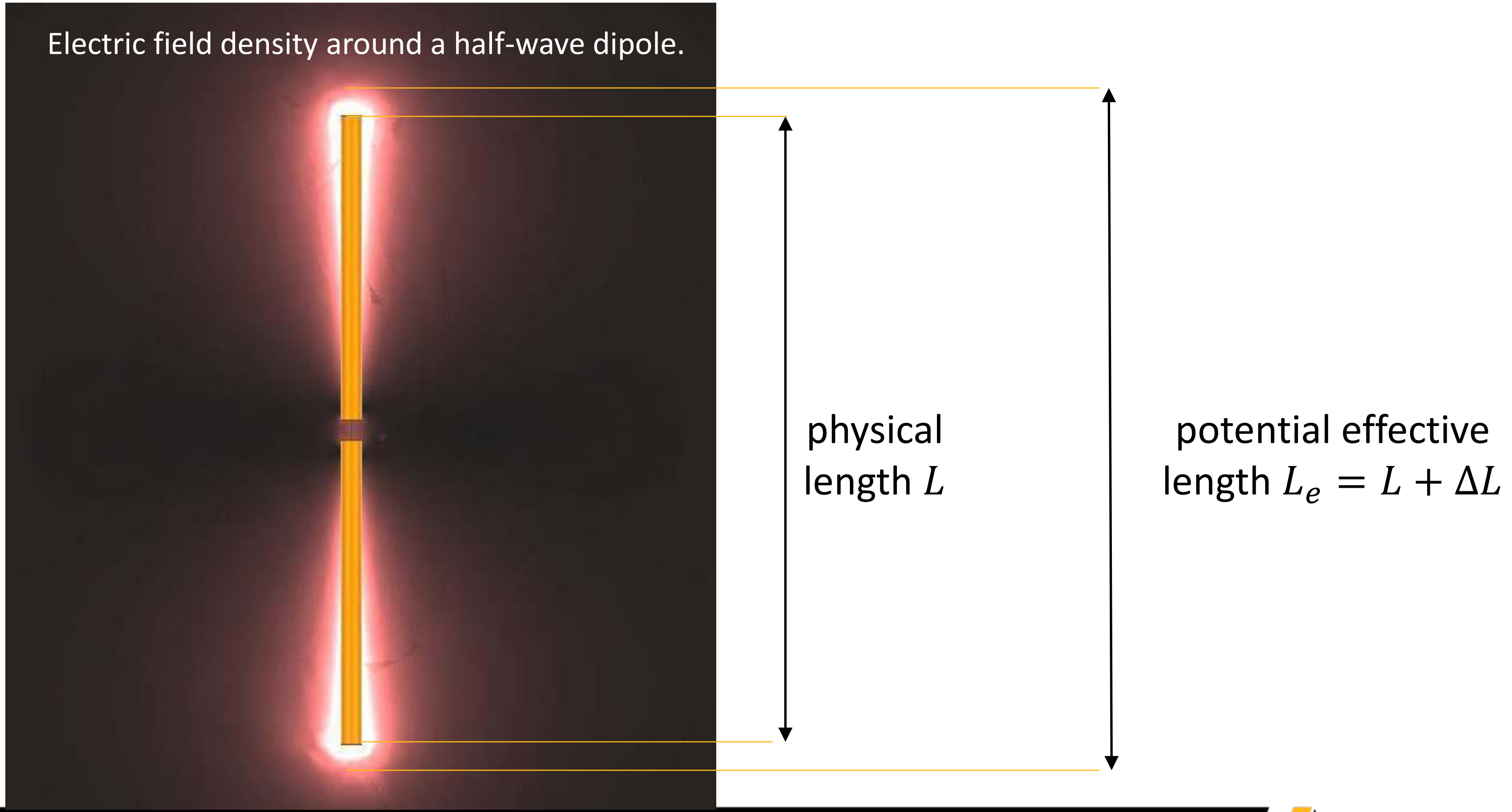


The Half-Wave Dipole Antenna

The Current Structure

Before examining the specifics of the current structure that forms on the dipole antenna, it is of practical importance to note that the abrupt truncation of the current path at either end of the dipole leads to high-density *fringing fields*, which make the *effective* length L_e of the antenna slightly longer than its *physical* length L. The effect of this apparent lengthening of the dipole is to marginally increase its inductance, and thereby reduce its resonant frequency.

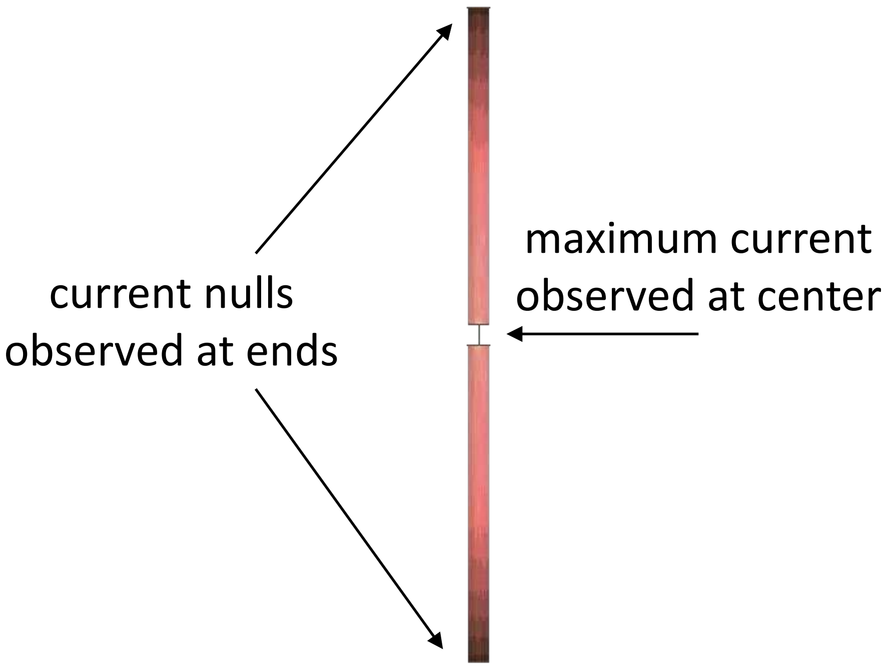
This effect is typically very small, and can be compensated for by slightly reducing the physical length of the dipole.



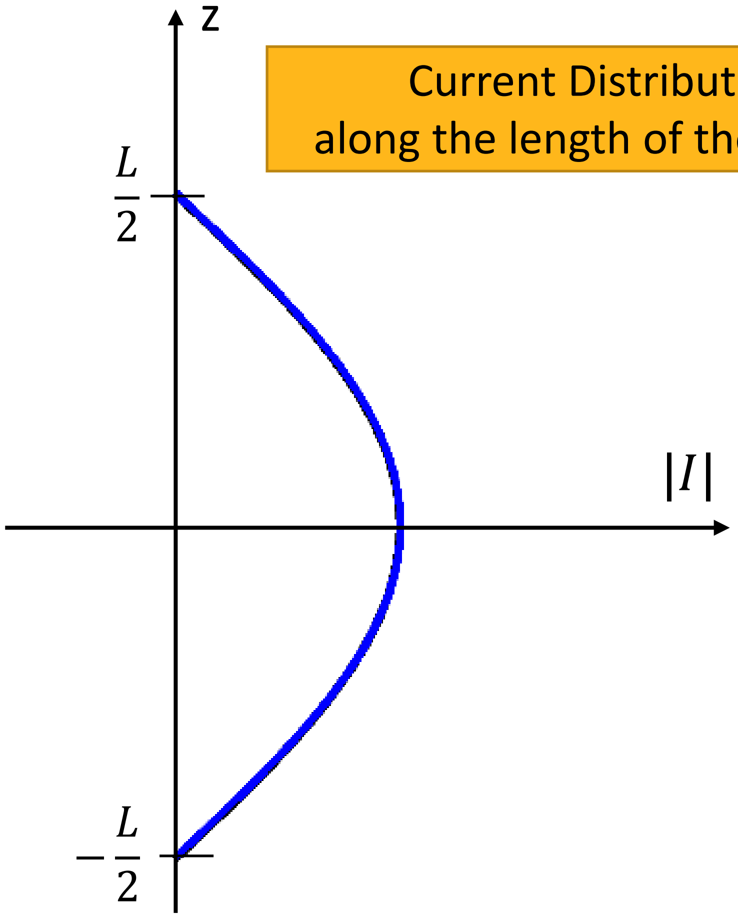
The Current Structure

The current structure on a half-wave dipole (when driven by a sinusoidal source) is approximately sinusoidal. When driven at exactly the half-wave frequency, the current magnitude forms a standing half-sinusoid along the length of the dipole, with nulls at either end of the dipole and a maximum at the center.

Current Density
on the surface of the dipole



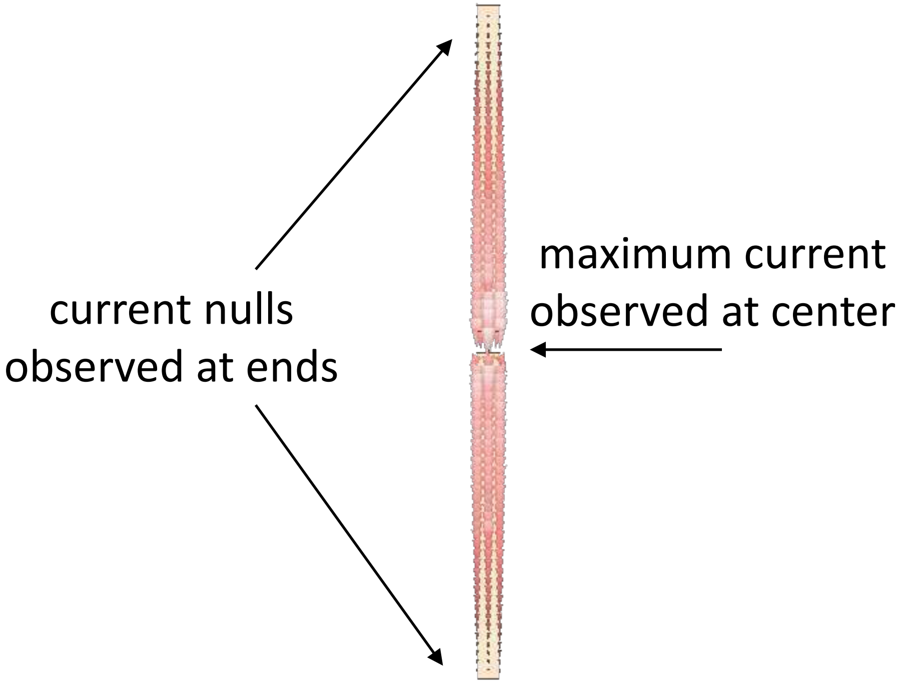
Current Distribution
along the length of the dipole



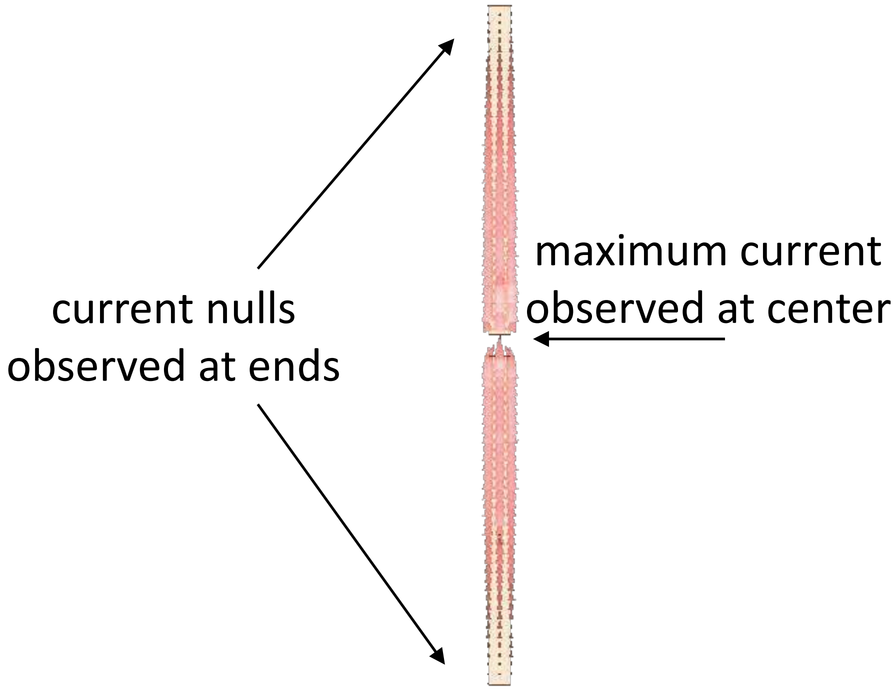
The Current Structure

The direction of the current on a half-wave dipole (when driven by a sinusoidal source) is along the z-axis, and is alternately upward-directed or downward-directed, depending on the phase of the cycle.

Surface current vectors during downward-directed half of cycle



Surface current vectors during upward-directed half of cycle

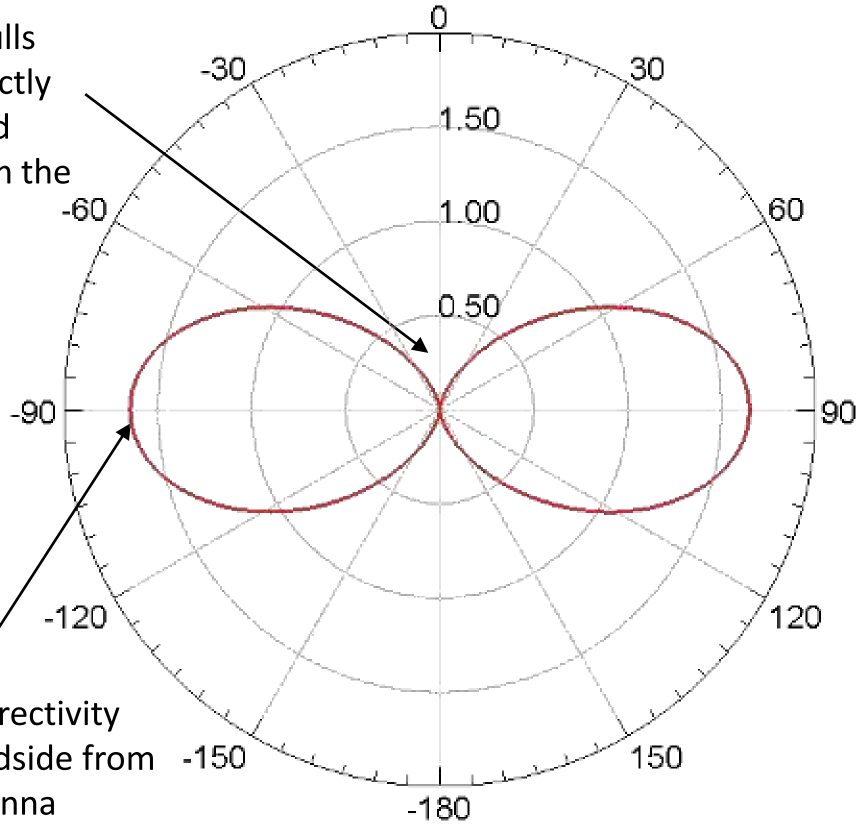


The Theoretical Far-Field Radiation Pattern

The theoretical far-field radiation pattern of a half-wave dipole has perfect rotational symmetry with respect to ϕ (rotationally around the z-axis). It has nulls at $\theta = 0°$ and $\theta = 180°$, and its maximum is in the plane $\theta = 90°$.

Antenna Directivity on the $\phi = 0°, \phi = 180°$ plane, in linear scale.

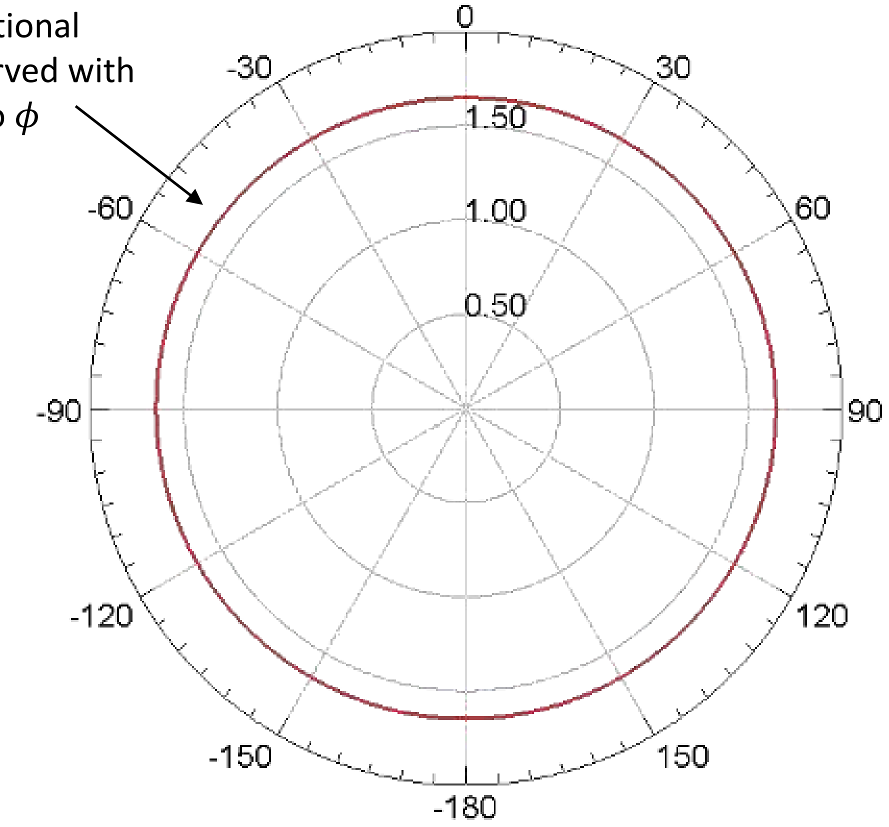
directivity nulls observed directly upward and downward from the antenna



maximum directivity observed broadside from the antenna

Antenna Directivity on the $\theta = 90°$ plane, in linear scale.

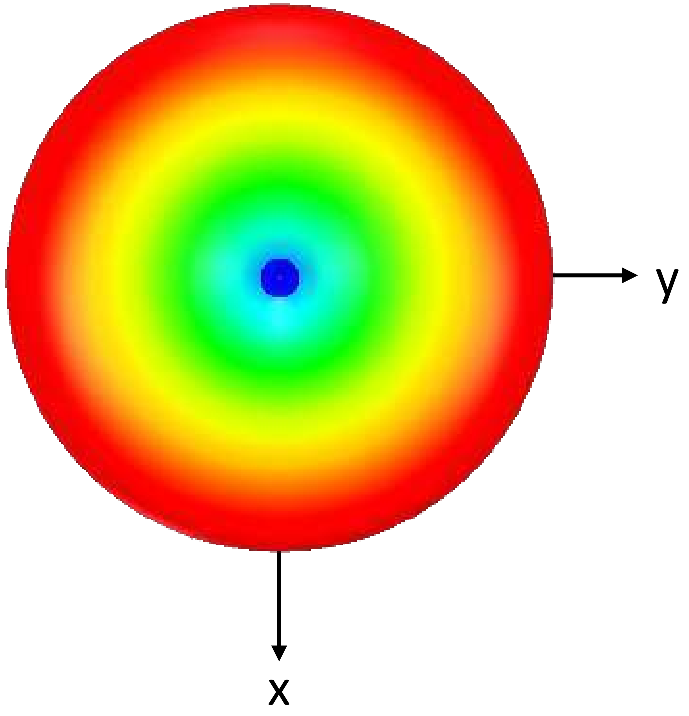
perfect rotational symmetry observed with respect to ϕ



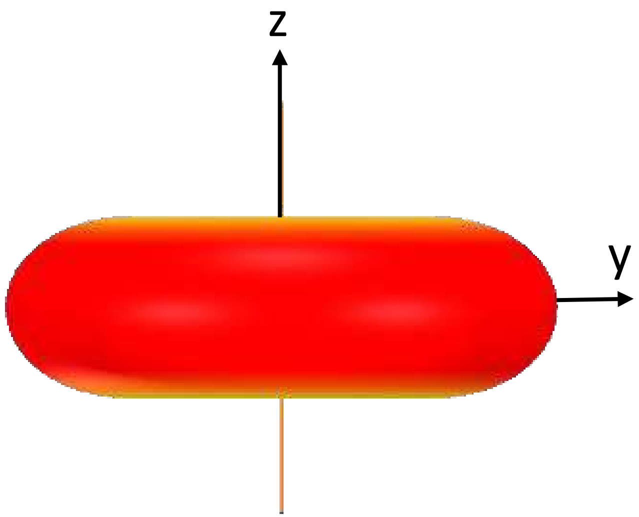
The Theoretical Far-Field Radiation Pattern

Plotted in three dimensions, the linear-scale gain of the antenna looks like this:

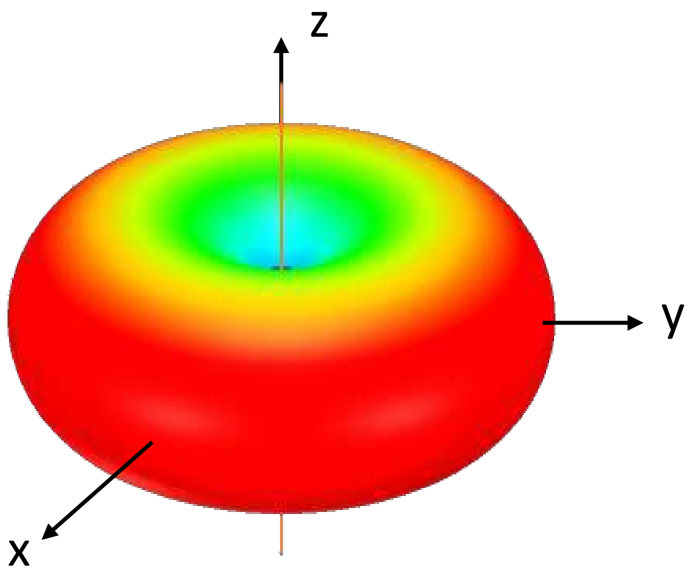
Viewed from the +z axis



Viewed from the +x axis



Viewed at an oblique angle



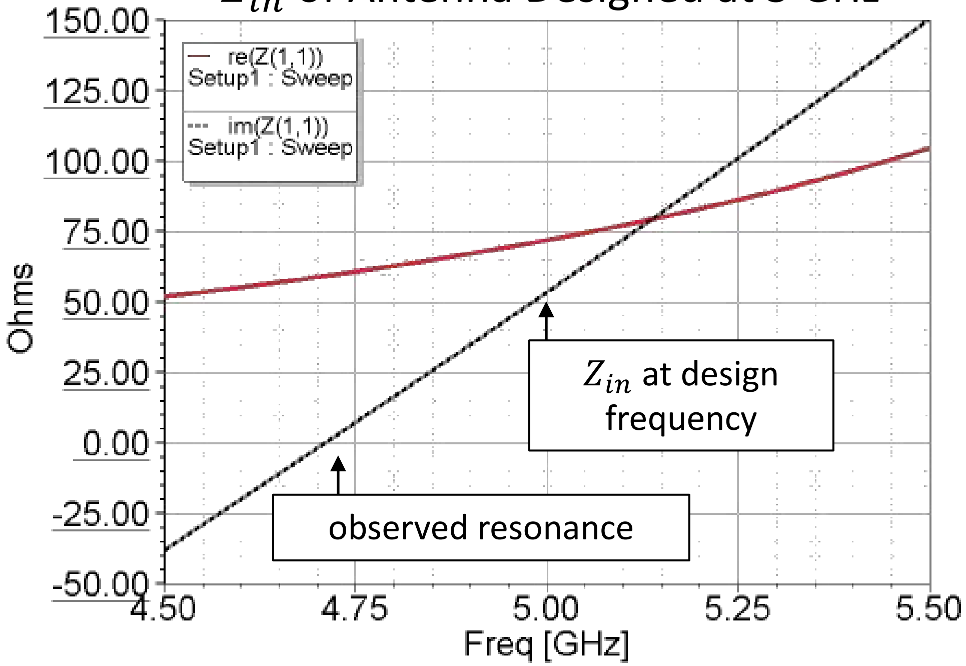
The Theoretical Far-Field Radiation Pattern

At the design frequency (where $L = \lambda/2$), some typical antenna characteristics for a half-wave dipole are:

Antenna Characteristic	Approximate Value at $L = \lambda/2$
Input Impedance	$73 + j42.5\Omega$
Maximum Directivity	1.64 linear, or 2.16 dB

**Note the positive reactance of the input impedance at the $L = \lambda/2$ frequency.

Z_{in} of Antenna Designed at 5 GHz



This plot shows the input impedance of a dipole designed to have $L = \lambda/2$ at 5GHz. Note that, at the design frequency, the input impedance is inductive, causing the resonance frequency to be *below* the design frequency.

To overcome this discrepancy, the antenna may be shortened slightly.

Ansys