# Antenna Systems For New Hams

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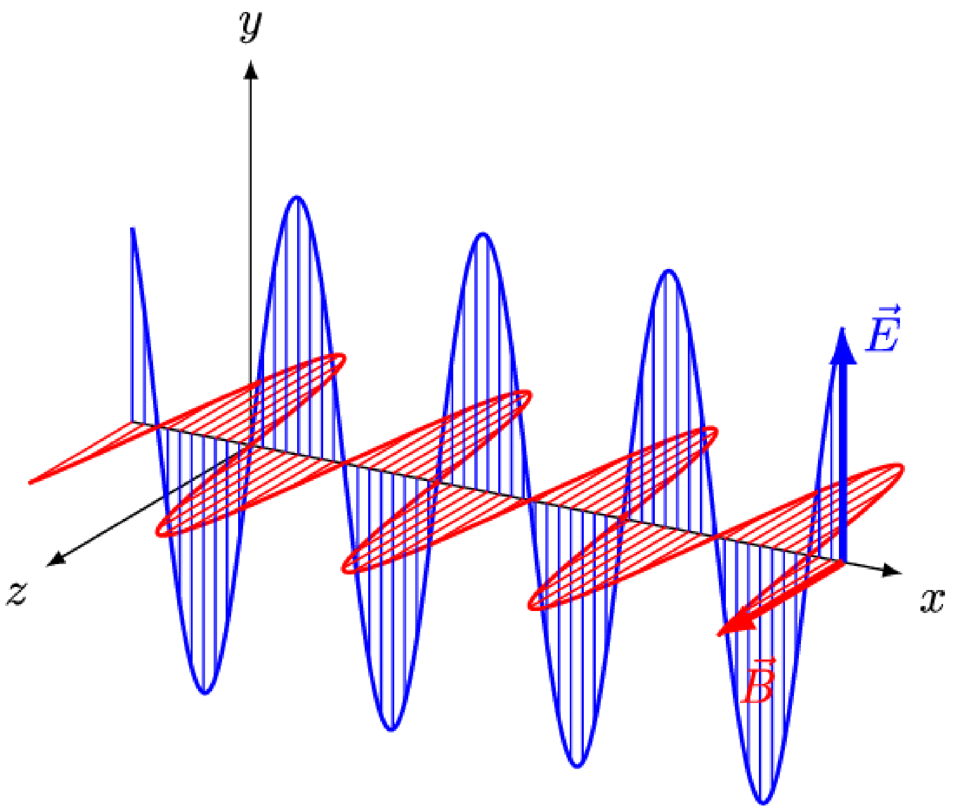
# Overview

- What this presentation is not:
  - The best antenna for a new ham is X
  - Go buy/build antenna X
  - Solution to Maxwell's equations, derivation from first principals, etc.
- What this presentation is:
  - What I wish I knew when I was starting out
  - Terminology
  - Understand the tradeoffs
- All antennas are a compromise
  - Available land
  - Available support structures
  - Available budget

# Background

# What are we trying to capture?

- Maxwell's Equations
  - Described behavior of electromagnetic waves
  - Defined before radio waves were proven to exist – work was based on visible light.
  - 20 Equations, 20 variables – later refined to 4 equations and two variables.
- Two components
  - Electric Field
  - Magnetic Field
  - Both contain the same information



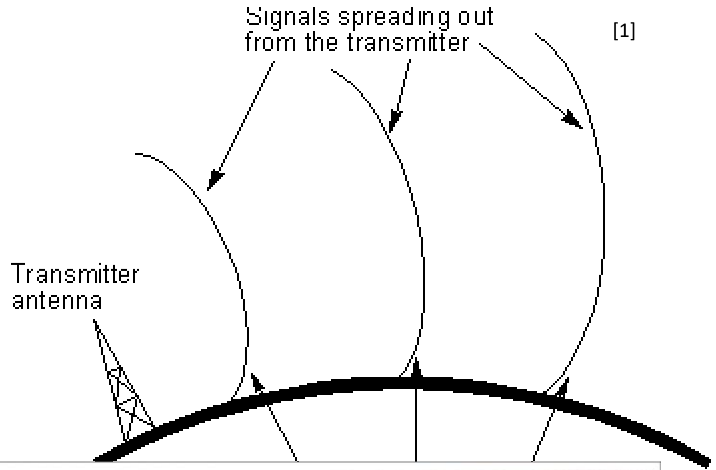

https://commons.wikimedia.org/wiki/File:EM-Wave.gif

# Terminology

- Resistance(R): an element that dissipates energy.
- Reactance (X): acts like resistance but does not dissipate energy.
- Impedance (Z): $Z = R + jX$ -> combination of resistance and reactance
- Isentropic Antenna: an ideal antenna with uniform radiation pattern.
- Directivity: degree to which the antenna pattern is not uniform.
- Wavelength($\lambda$): distanced traveled in one cycle
- Decibel (dB): relative unit of measure – always compares quantities.
- Resonance: when the reactance of an antenna is zero.
- Match: When the source and load impedances are equal.

# How do radio waves move?

- Ground Wave – Wave follows earths curvature
  - Predominant mode for medium wave
  - 10’s KHz - ~1 MHz
  - AM broadcast in the US
- Skywave – Ionospheric bounce
  - Predominant mode for shortwave
  - ~1 MHz – 30 MHz
  - HF Ham Bands
- Line of sight – point to point
  - Predominant mode for VHF+
  - 30 MHz – light
  - Exceptions exist, sporadic E, ducting, etc.  Not reliable



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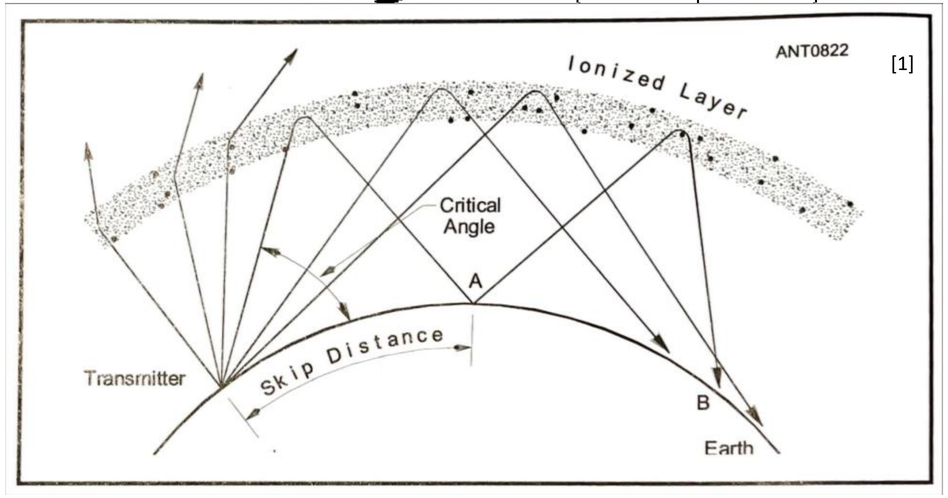

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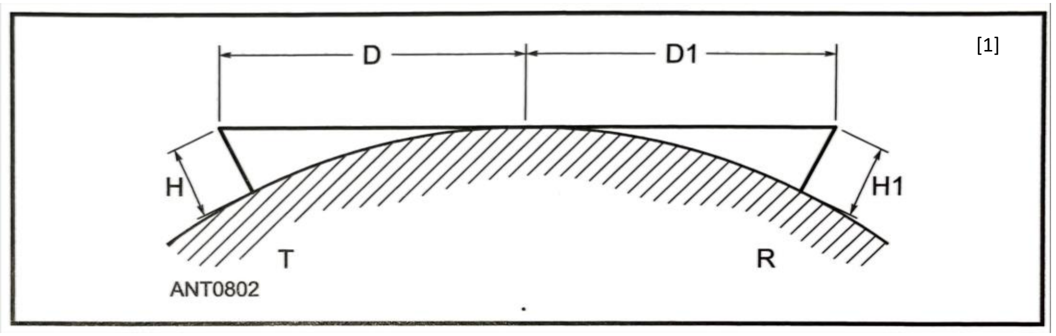


[1]


1. American Radio Relay League. *The ARRL antenna book*. 23rd Ed. The League, 2015.

# Fast Math with Decibels

- 3dB = 2x
- 6dB = 4x
- 10dB = 10x
- 1 dB = ~25%

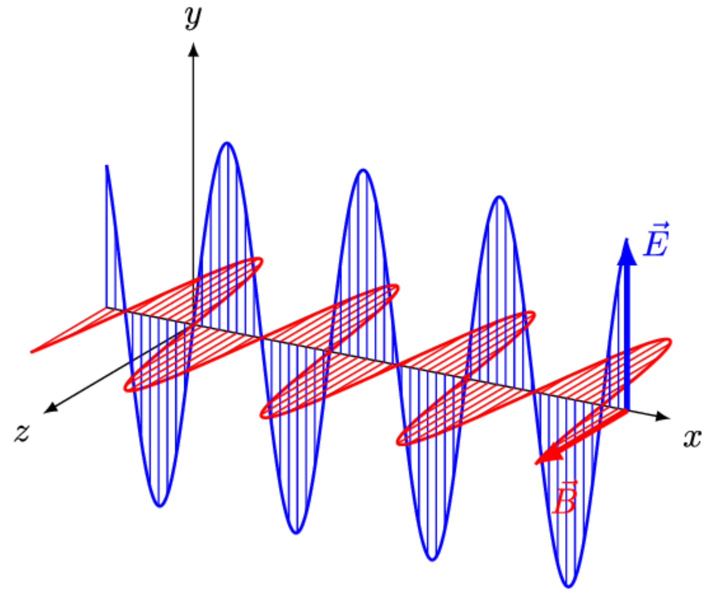
# Antenna Basics

# How do Antennas Work?

- If you place an electric potential across a conductor:
  - Electrons will be attracted to the positive end of the field
  - Moving electrons generate a current
  - Current flowing in a conductor generates a magnetic field
- If you place a conductor in a moving magnetic field:
  - Electrons will move perpendicular to the lines of magnetic force
  - Moving electrons generate a current
  - A current flowing through a finite resistance generates a voltage potential
- For radio need to interact with one of the parts of the radio wave
  - Electric Field -> dipoles, whips, etc.
  - Magnetic Field -> loop antennas
  - Both fields contain the same information
- General Properties
  - Scaling -> you can scale a design up or down to change frequency
  - Reciprocal -> Receive pattern is the same as the transmit

# Polarization

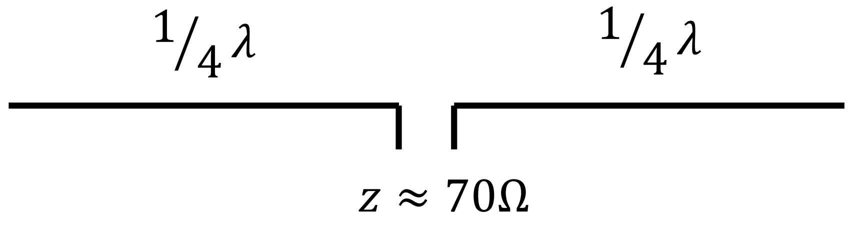
- Orientation of Electric Field
    - Vertical: Electric field is perpendicular to the earth
    - Horizontal: Electric field is parallel with the earth
    - Circular: Electric field is rotating at a constant rate
- Cross polarization loss
    - Vertical -> Horizontal ≈ 30 dB
    - Circular -> linear ≈ 3 dB



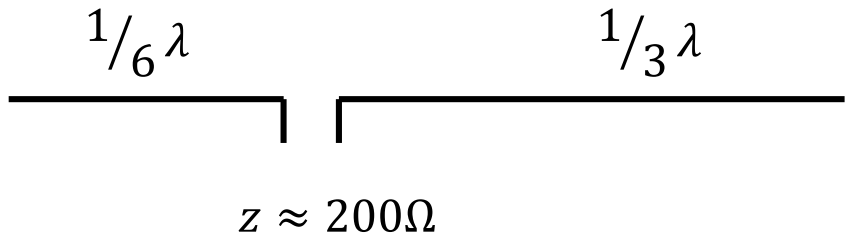
# Antenna Impedance (Z)

- Ratio of current to voltage
- Comprised of Resistance and Reactance
- Not constant across an antenna
- Three impedances to in an antenna system
  - Radio (usually 50Ω).
  - Transmission line (varies).
  - Antenna Feed point.

Center Fed Dipole*



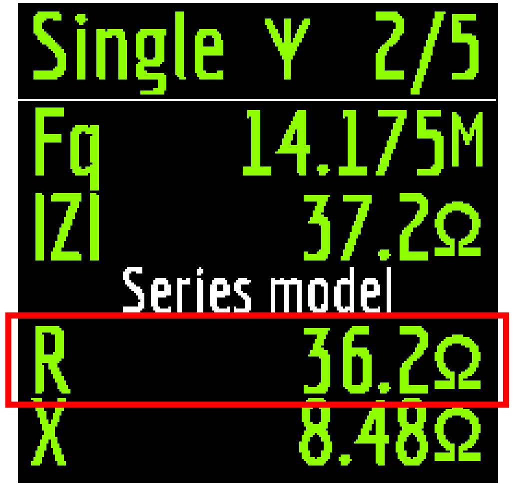

Off-Center Fed Dipole*

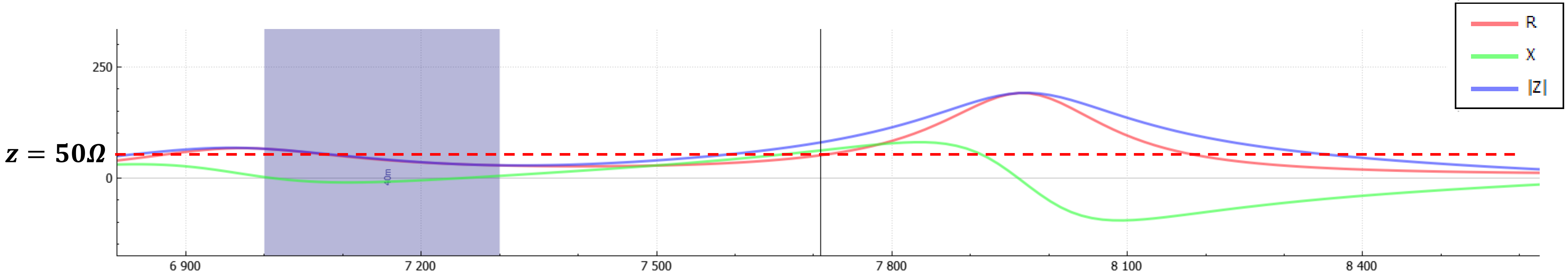



$*\ in\ free\ space$

# Resistance (R)

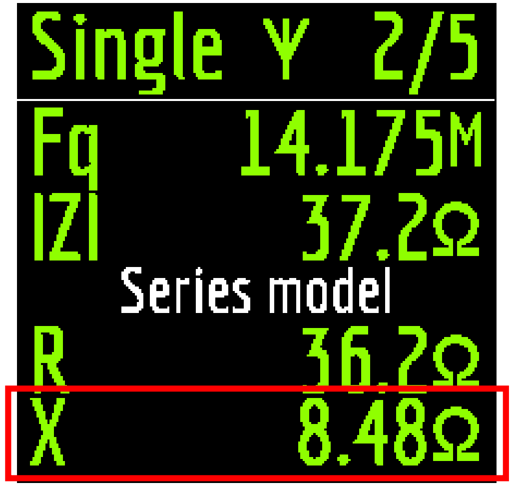
- Two components:
  - Ohmic Loss -> due to imperfections (typically milli-ohms)
  - Radiation Resistance -> energy dissipation due to radiating.
  - Indistinguishable from a measurement standpoint.
- Radiation Resistance is Frequency Dependent
- Ohmic loss is independent of Frequency
- Effected by any conductive object near the antenna
  - HF: Reflections from the ground, nearby metal objects
  - VHF+: Reflections from nearby metal objects



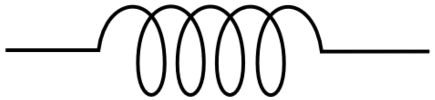
# Reactance

Acts like resistance, BUT no energy dissipated.




## Inductive Reactance

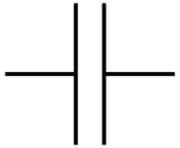
$$X = 2\pi f L$$



- Gets larger as frequency increases
- Always positive
- All wires have a little inductance (parasitic)
- Inductance gets larger as wires get longer

## Capacitive Reactance

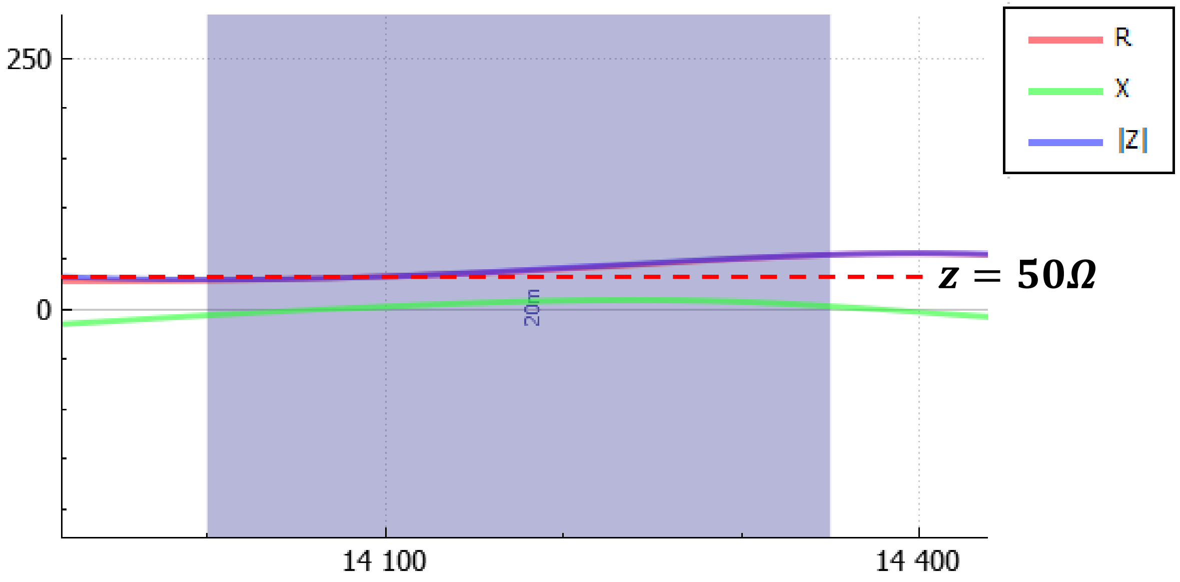
$$X = -\frac{1}{2\pi f C}$$

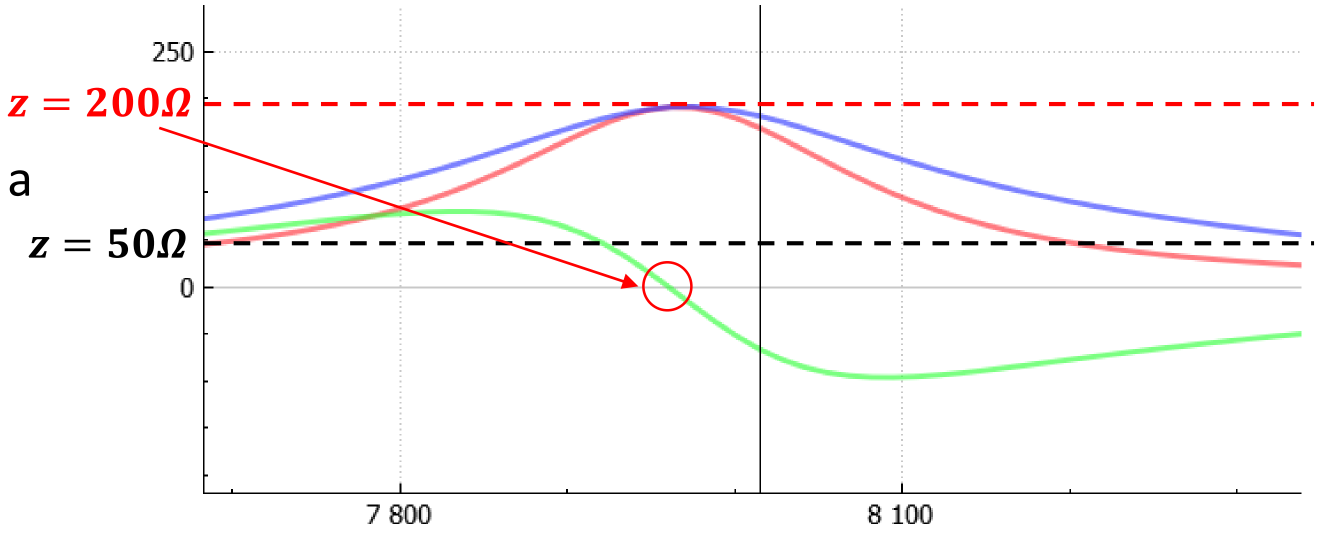


- Gets smaller as frequency increases
- Always negative
- All conductors have a little capacitance (parasitic)
- Capacitance gets larger as conductors get closer

# Resonance

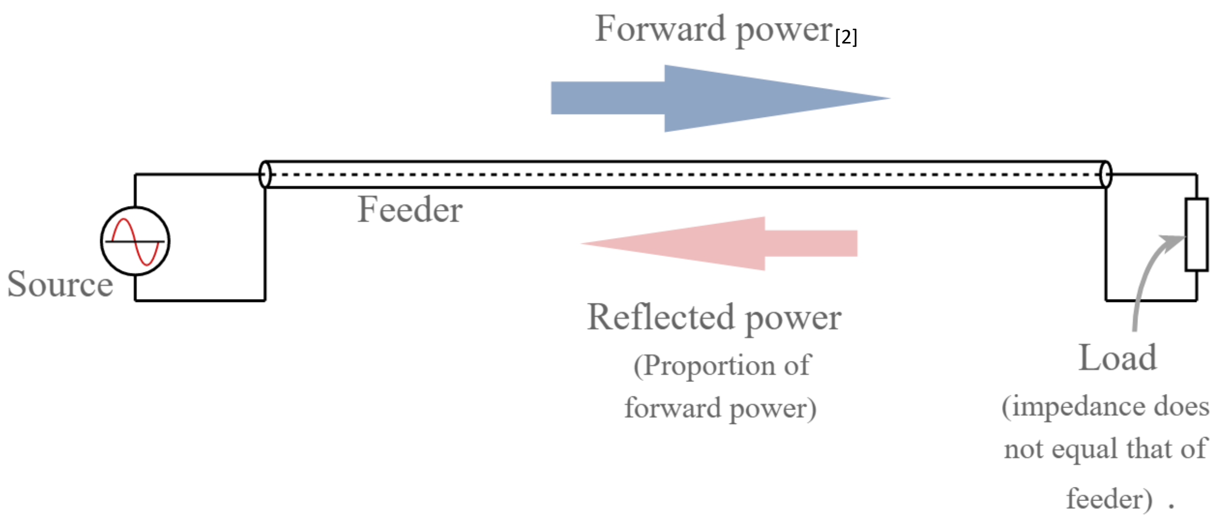
- Frequencies where the reactance is zero
  - Happens every harmonic (multiple of frequency)
  - Where your antenna is most efficient -> all energy is dissipated
- Resonance is <u>NOT</u> the same as matching
  - An antenna can be resonant, but have a very high or low impedance



# Standing Wave Ratio (SWR)

- What it is:
  - Indication of how well your antenna is matched
  - A measure of power that is being reflected into your radio
  - A rabbit hole -> needs more than a few slides
- What it isn't:
  - How 'good' your antenna is
  - A dummy load has a 1:1 SWR
  - A showstopper
- It can be affected by things other than your antenna
  - Transmission line loss
  - Water intrusion




2. https://www.clarke.com.au/clarke-and-severn-rf-blog/what-is-the-effect-of-vswr-on-transmitted-power

# What is a good SWR?

- Why do you need to worry about it?
  - Loss in coaxial cables
  - Transistor Power amplifier damage
- Your radio has SWR limits
  - IC-7300 1:1.5, power reduction at 1:2
- Antenna tuner doesn't tune your antenna
  - Matches your radio to impedance measured at the antenna port
  - Mismatch still exists after tuner
- Tube amplifiers are not as sensitive
- HT antennas….
  - Low power
  - No transmission lines
  - Your body is part of the system

RG-58 [3]

| Attenuation/ 100 ft. | Power Rating |
|---|---|
| 0.5 dB @ 1 MHz | 1000 W |
| 1.5 dB @ 5 MHz | 600 W |
| 2.8 dB @ 30 MHz | 350 W |
| 3.0 dB @ 50 MHz | 250 W |
| 4.0 dB @150 MHz | 150 W |

LMR-400 [3]

| Attenuation/ 100 ft. | Power Rating | Efficiency % |
|---|---|---|
| 0.3 dB @ 5 MHz | 6.9 kW | 93 % |
| 0.5 dB @ 10 MHz | 4.8 kW | 90 % |
| 0.8 dB @ 30 MHz | 2.8 kW | 83 % |
| 1.1 dB @ 50 MHz | 2.1 kW | 79 % |
| 1.8 dB @ 150 MHz | 1.2 kW | 65 % |
| 3.3 dB @ 450 MHz | 0.7 kW | 47 % |

3. https://static.dxengineering.com/global/images/chartsguides/d/dxe-8x.pdf

The answer to every antenna question

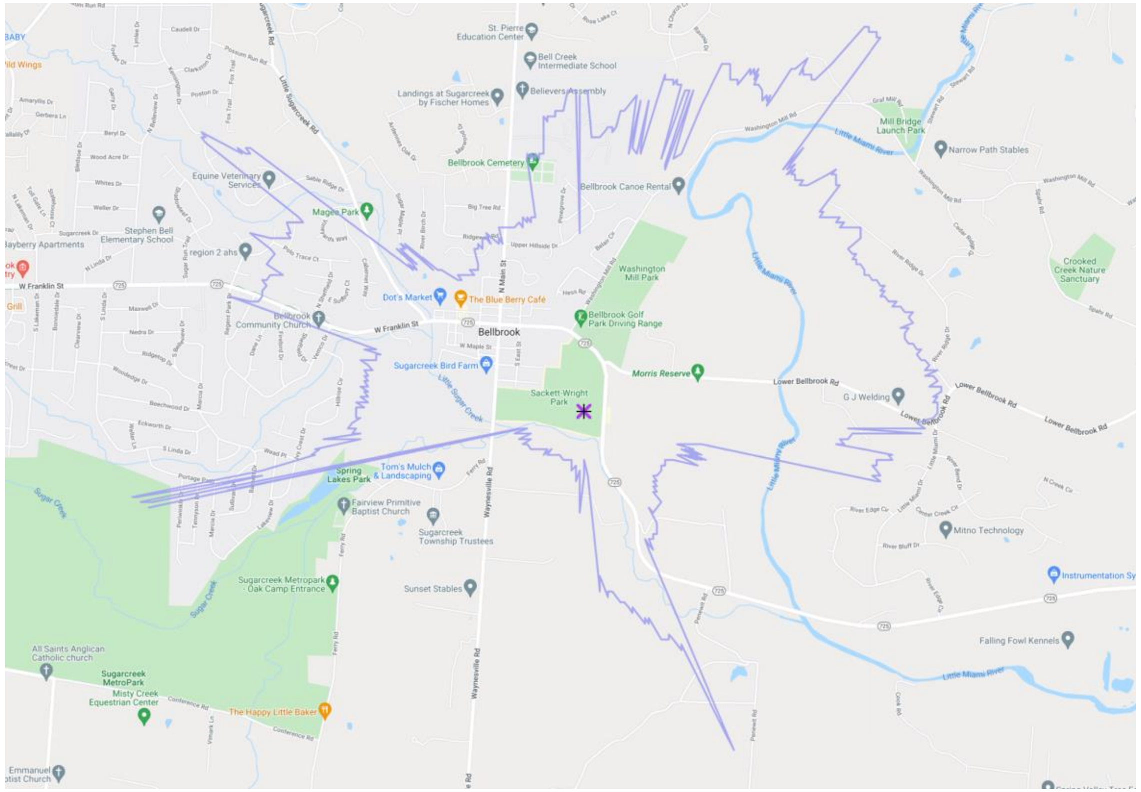
It Depends…

# VHF/UHF Antennas

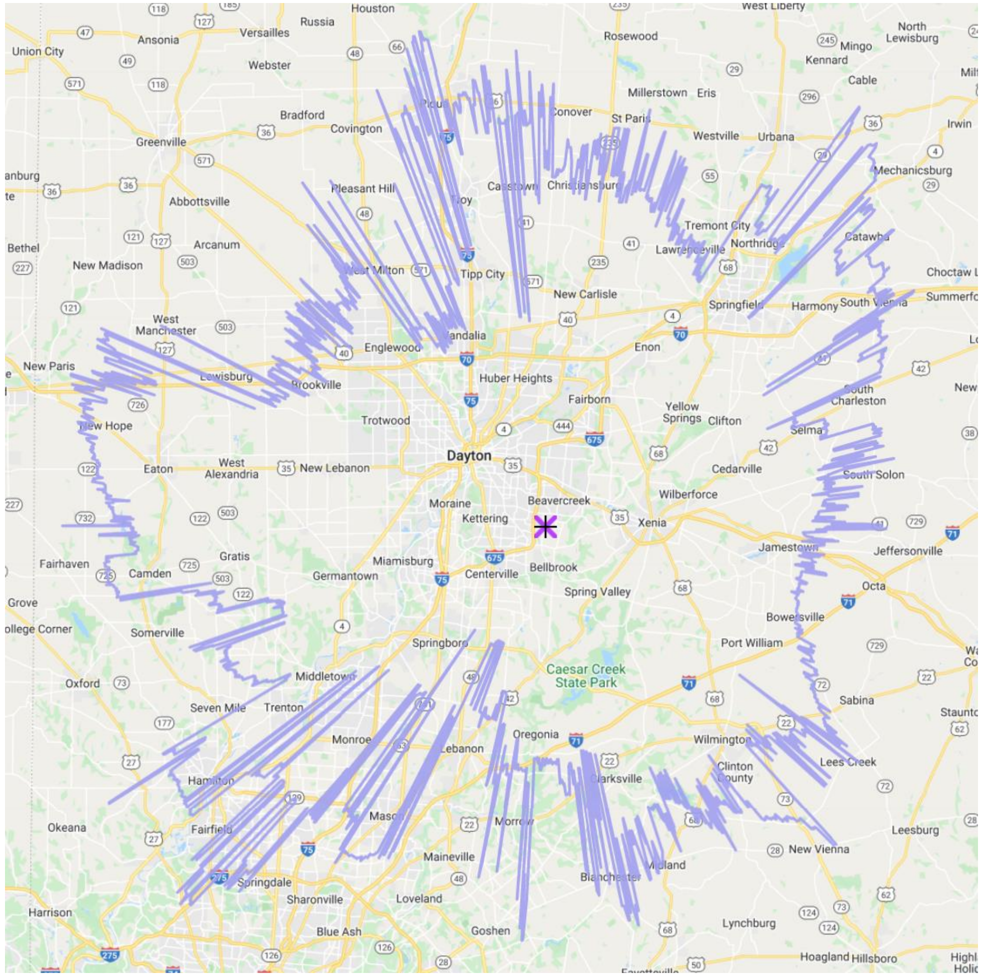
# Line of Sight

## Hight above ground is critical

Antenna at 5’



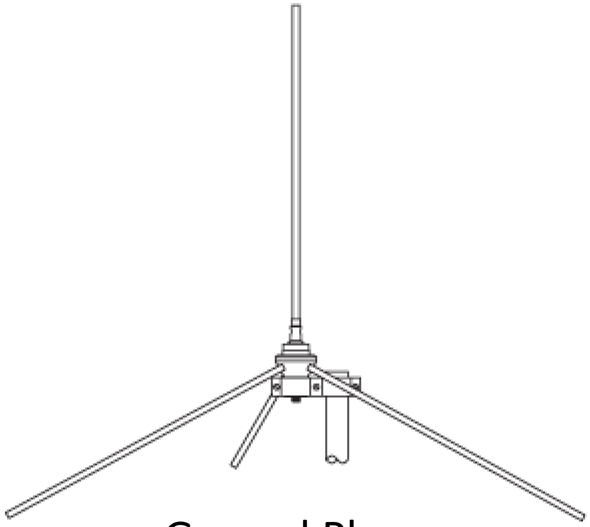

Repeater Antenna at 300’




https://www.heywhatsthat.com/

# Antennas for FM

- By convention Use Vertical Polarization
  - Easier to install on vehicles
  - Easier for HT antennas
- Ground Plane Antenna
  - Close to unit gain
  - Easy to build
- Co-linear array
  - Multiple wavelengths long
  - Higher Gain – omni pattern
  - Good for base installations
- Yagi / Beam
  - Directional – needs to be aimed
  - Useful for FM satellites
  - Won't overcome terrain



Ground Plane

Yagi Array

Colinear Array

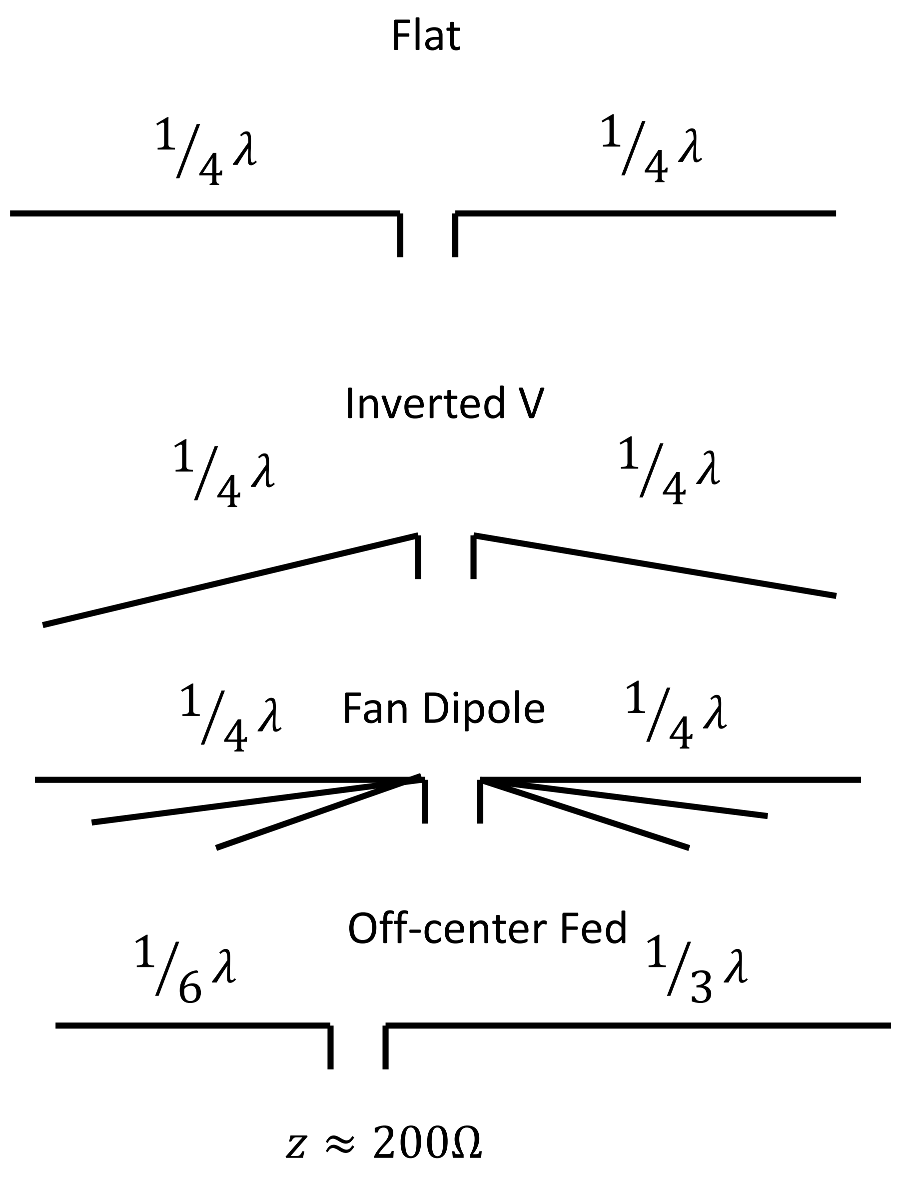
# Antennas for SSB / Weak Signal Digital

- Horizontal Polarization
  - By Convention
- Yagi Arrays are most common
- You can use the same Yagi, turned on its side

# HF Antennas

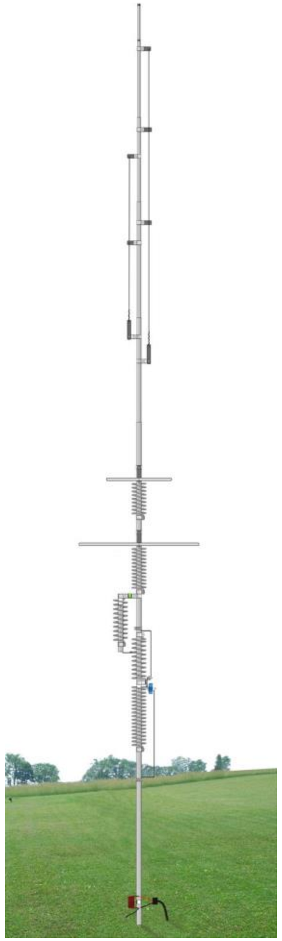
# Dipoles

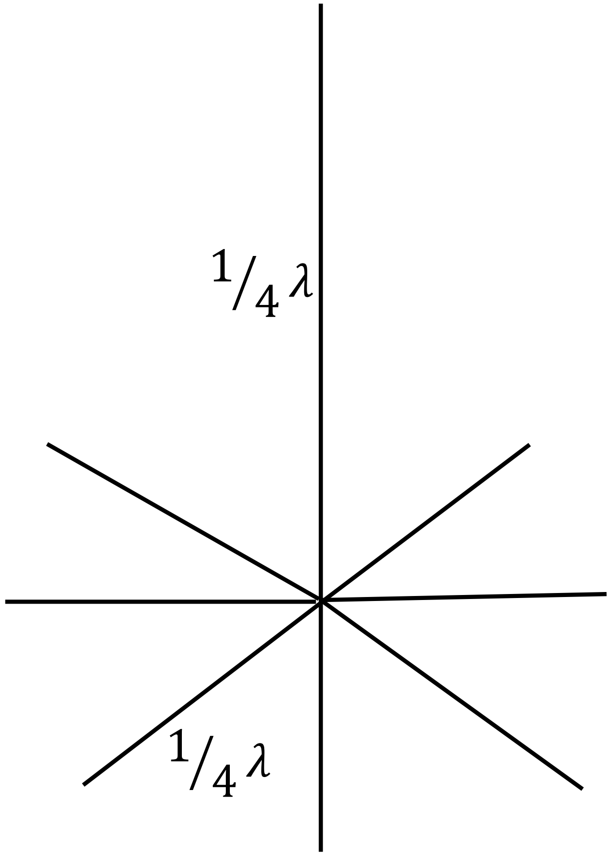
- Easy to build
- Operate on odd harmonics
- Add multiple elements for multiple bands
  - Can be difficult to tune - interactions
- Strongly affected by the ground
  - 'Ideally' 1/2λ above the ground
- Don't have to be straight
  - Ends can bend
  - Center most critical



# Vertical Antennas

- Most require radials
  - Less effected by ground
- Don’t require height above the ground
- Radials can require a lot of wire
- Can be quite tall

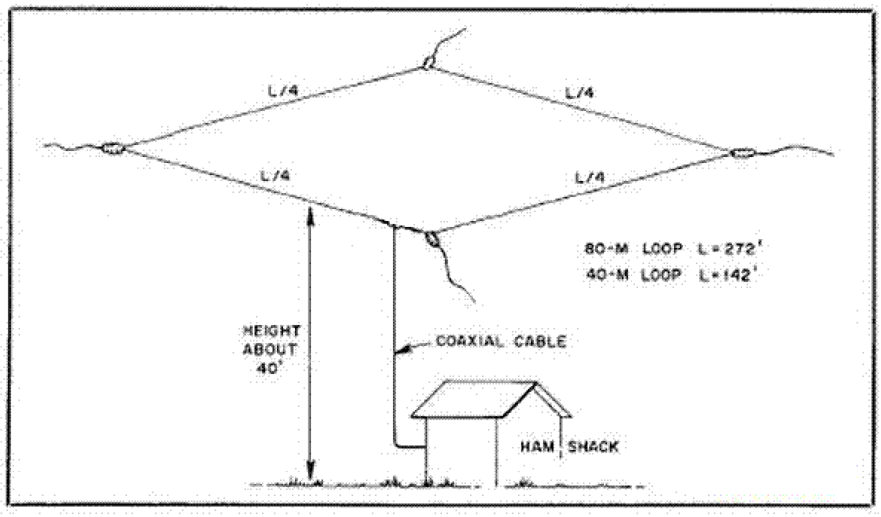





Vertical

# Loop Antennas

- Large Loops
  - Circumference is ~1λ
  - Horizontal or vertical
  - Multi-band (every harmonic)
- Small Loops
  - Circumference is ≈.1λ
  - Very narrow bandwidth
  - Tuning capacitor – limits power
  - Require specialized tuner
- Hight above ground not as critical
- Lower noise



The Loop is erected horizontal to the earth.

# Questions?