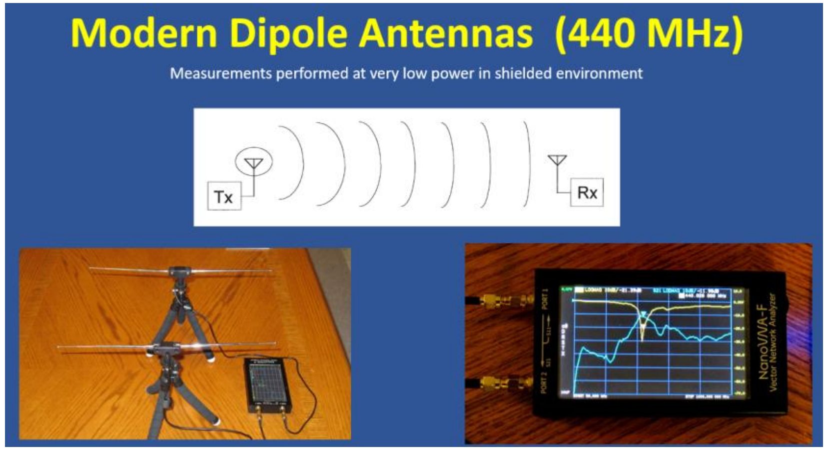
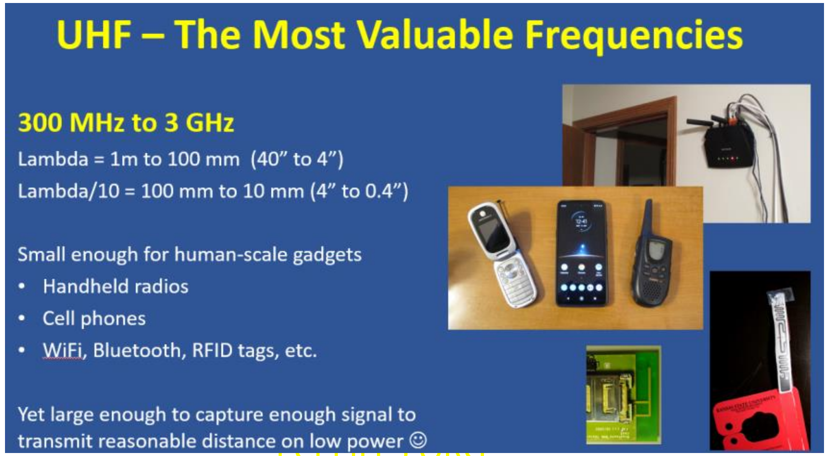
Antenna Briefs #1 -- Frequency, Wavelength, and Antenna Size

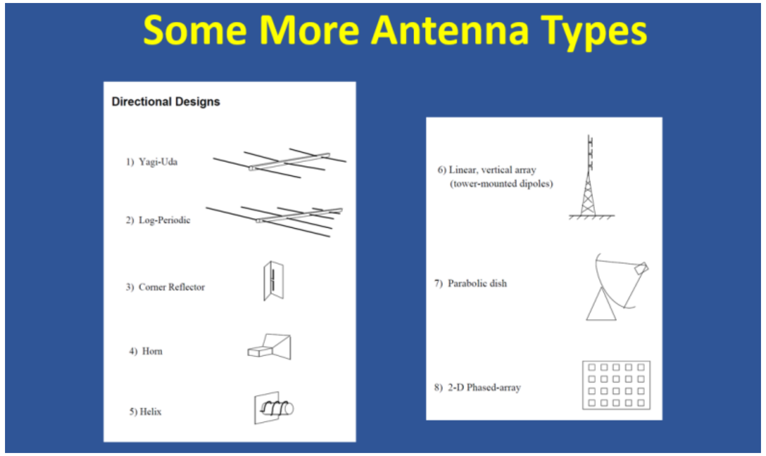
Slides downloaded from: https://ecefiles.org/rf-design/

Companion video at: https://www.youtube.com/watch?v=w2S6pbnoQew

This is the first in a series of videos on antennas and propagation. It is based on and supports a university course, but covers material without any deep math. In Episode #1 we overview key elements of radio antenna. We start with the first antennas created by Hertz and proceed to demonstrations with modern antennas - focusing initially on dipoles. Additional types including loops, monopoles, and dish antennas are covered as examples of real-world designs and are presented across the frequency range from 1 MHz to 40 GHz. The key takeaway is the formula for wavelength and how it relates to frequency, antenna size, and directivity.







Antenna Briefs #1

Frequency, Wavelength, and Antenna Size

Credit: NASA

ECEFILES.ORG

Welcome to Antenna "Briefs"

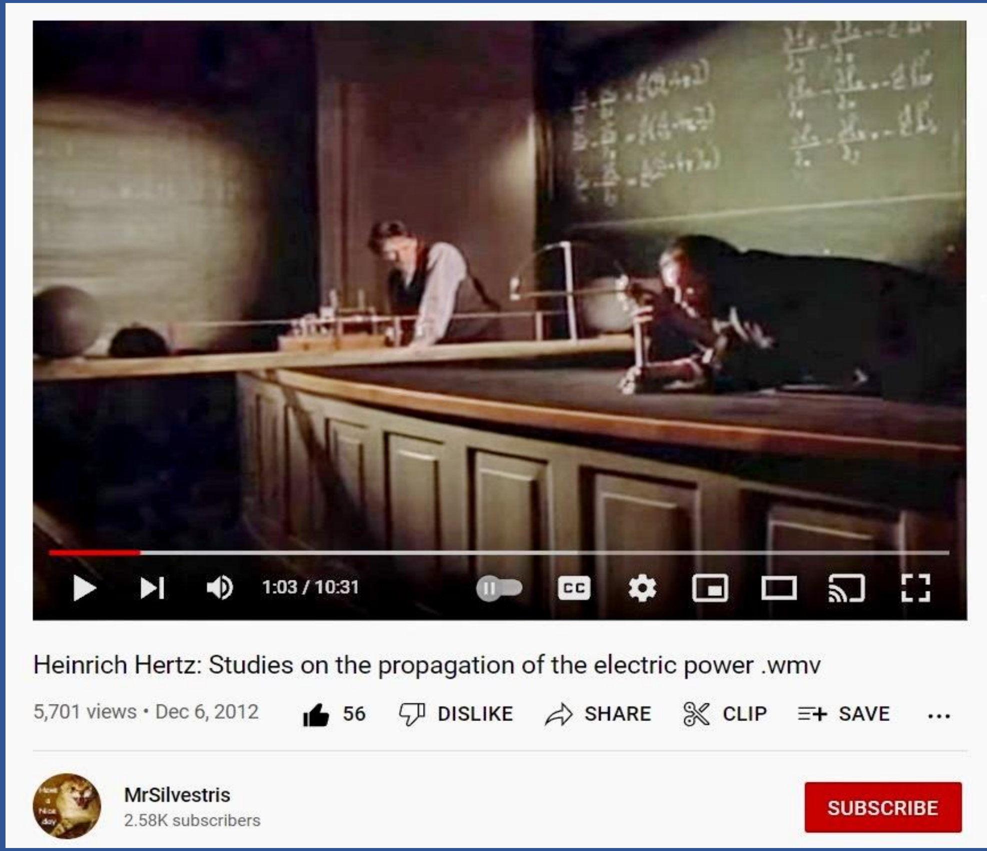
Credit: Steve S. on Facebook


Credit: NASA

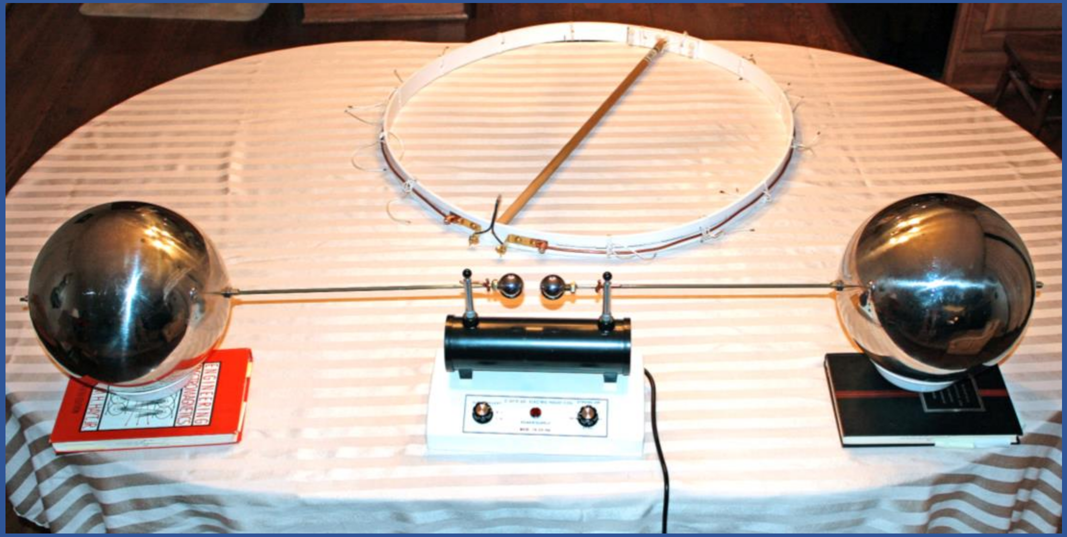
- **A new video series based on my experience with**
  - CB radios
  - Amateur Radio (Ham bands 80m through 70 cm)
  - Teaching "Antennas and Microwaves" lecture/lab course at K-State
- **Prereqs for this series**
  - An interest in how and why antennas work
  - Some familiarity with electricity / electronics
  - A general desire to learn
- **Today's topic:**
  - Frequency, wavelength, and antenna size
- **Future topics:**
  - Licensing for transmitting
  - Impedance (and return-loss/VSWR), resonance, Q, and bandwidth
  - Essentials of electric, magnetic, and electromagnetic fields
  - Lots more:
    - Antenna types, effective height and area, polarization, patterns and directivity gain, EIRP and received power, propagation, multipath, …

First Radio Demo and Antennas !

Replicas of those made by Heinrich Hertz in 1887 (50 MHz)



https://www.youtube.com/watch?v=dHhz-rQ5WWw



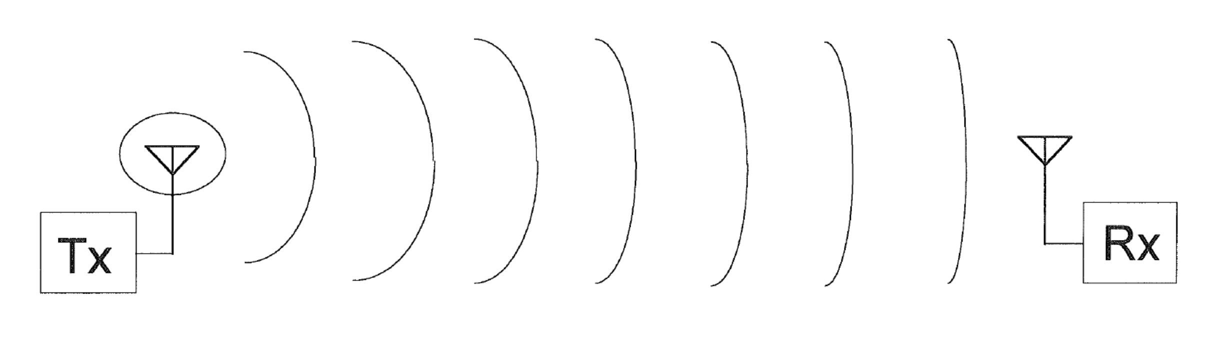
Credit for photo above:

Designing replicas of Hertz's antennas using modern computer methods
Ted L. Simpson;Milos Pavlovic;Dragan Olcan

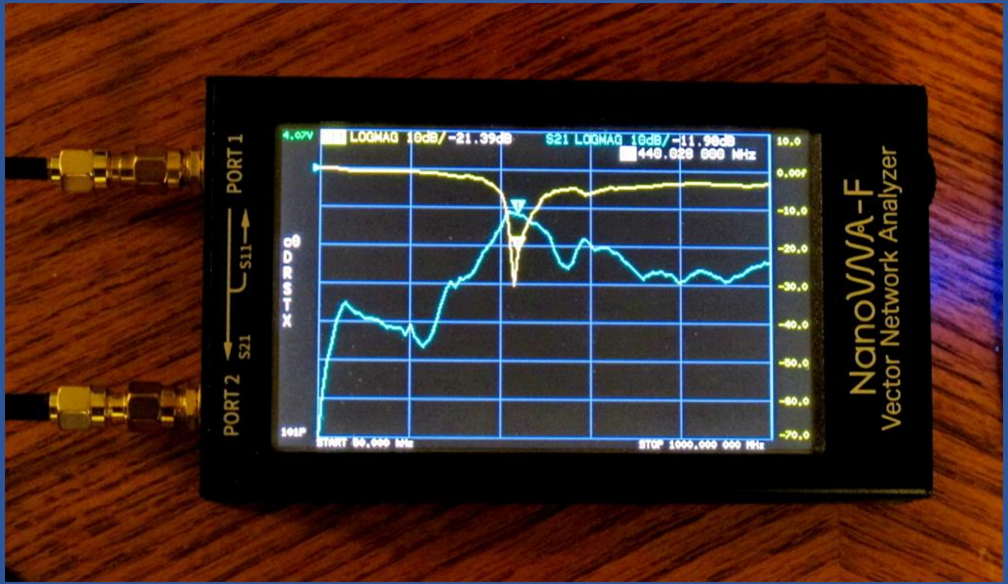
2015 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, Year: 2015 | Conference Paper | Publisher: IEEE

Modern Dipole Antennas (440 MHz)

Measurements performed at very low power in shielded environment

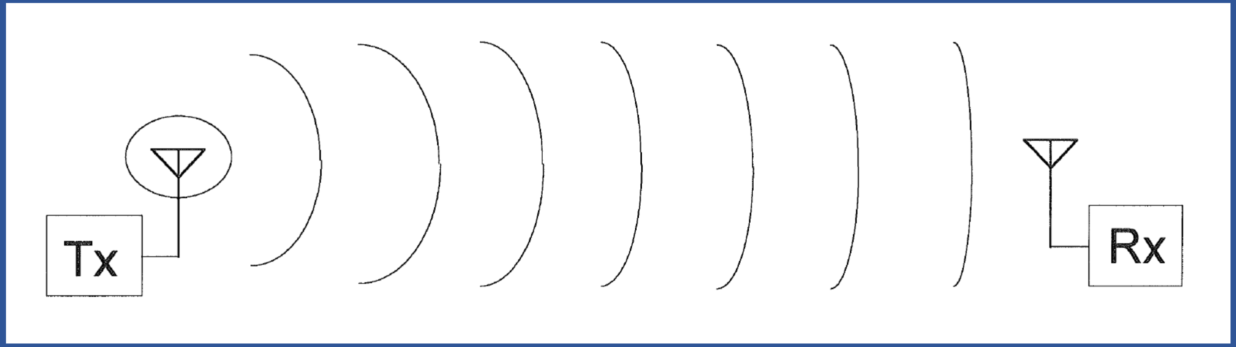


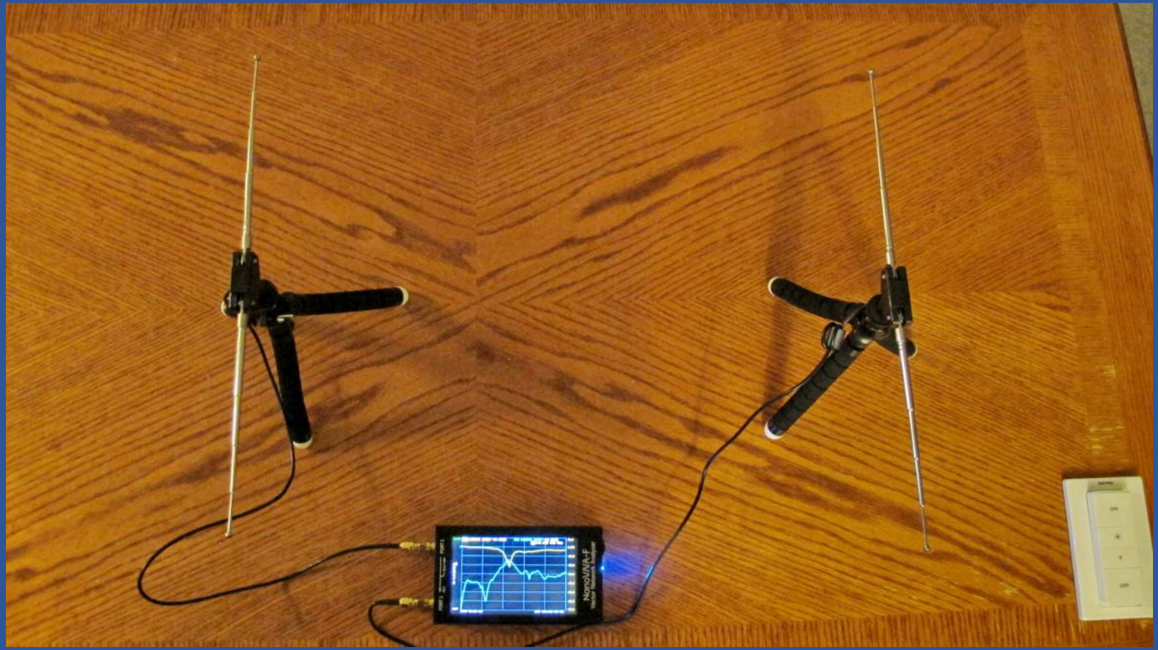
RTL-SDR Blog Multipurpose Dipole Antenna Kit (2)

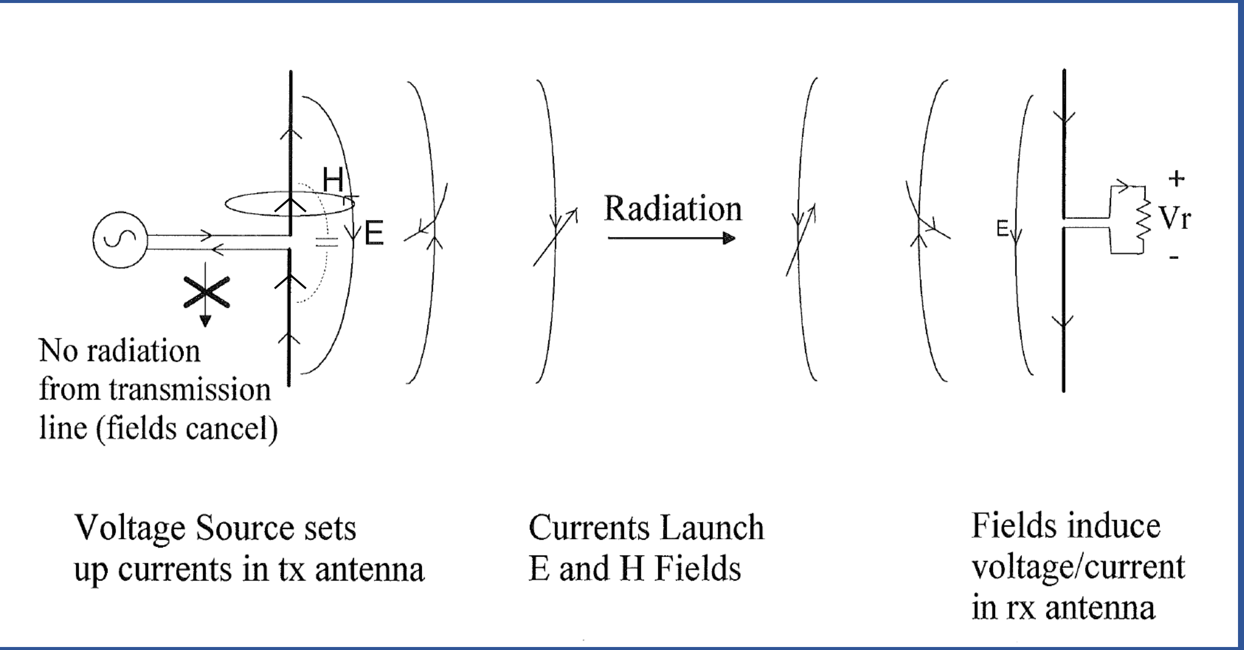


NanoVNA

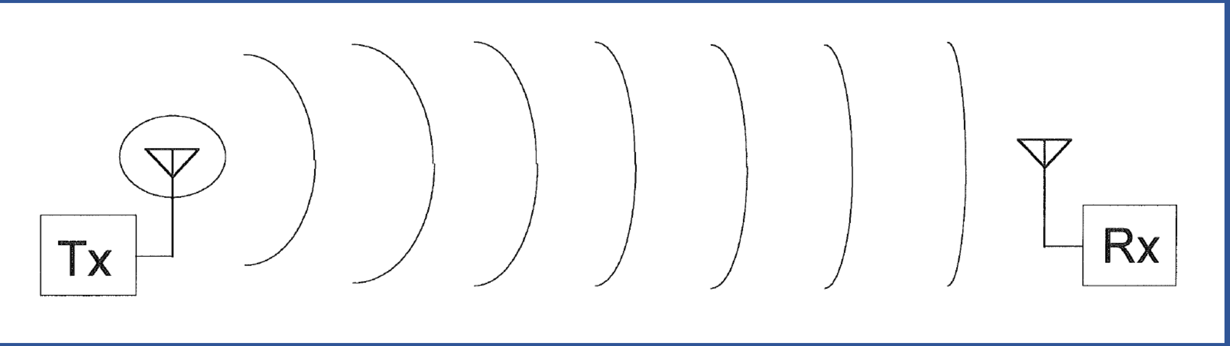
What's Going On Here ?

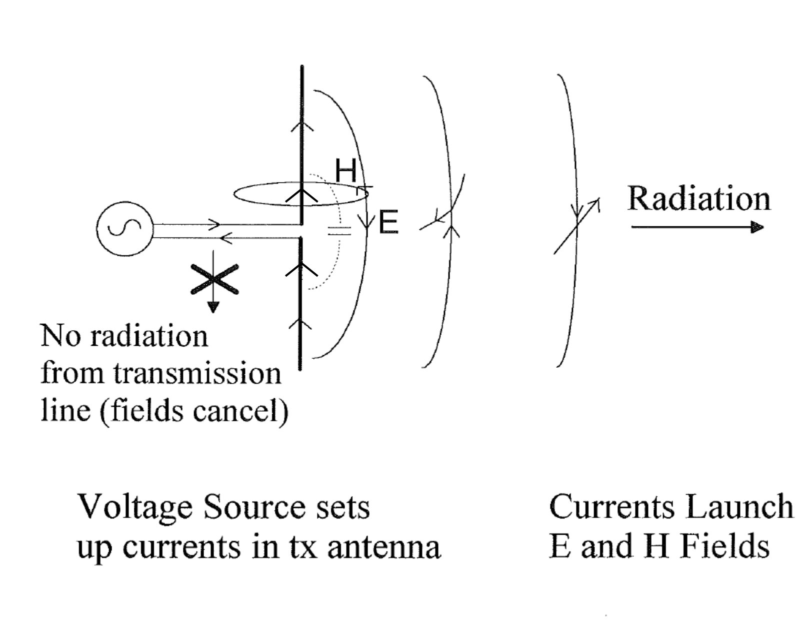






Physics





Maxwell's Equations (source free):

$$Curl\ E = -\frac{\partial B}{\partial t}$$

$$Curl\ H = \frac{\partial D}{\partial t}$$

$$B = \mu H \quad D = \varepsilon E$$

=>

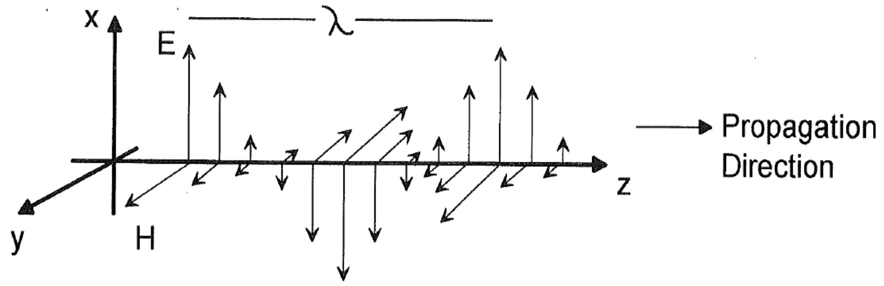
Plane Wave Solution:

$$E = E_x(z)\cos\left(\omega_o\left(t - \frac{z}{v_p}\right)\right)$$

$$H = H_y(z)\cos\left(\omega_o\left(t - \frac{z}{v_p}\right)\right)$$

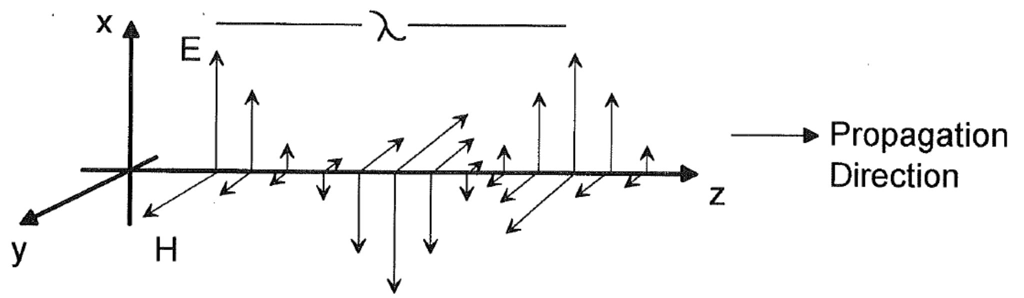
where v_p = velocity of propagation

Snapshot
of Field
Intensity



Engineering

Snapshot of Field Intensity



Wavelengths

$$\lambda = \frac{v_p}{f}$$

$$v_p = \frac{1}{\sqrt{\mu\varepsilon}}$$

$v_p = c = 2.997E8$ m/s in free space

Frequency	Wavelength
1 kHz	300 km
1 MHz	300 m
1 GHz	0.3 m

IMPORTANT TAKEHOME:

- Needed antenna size depends on wavelength and hence frequency !
- For efficient transmit (and receive), dipole needs dimension of lambda/2

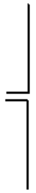
  (or lambda/4 or lambda/10 with a “tuner” – but not lambda/100 or lambda/1000)
- Lambda times 2 or times 100, etc is OK, but antenna becomes directional…

Some Antenna Types

"Non-directional" Types

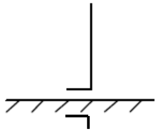
Antenna

1) Halfwave Dipole

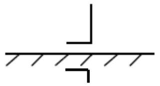


2) Folded (halfwave) Dipole

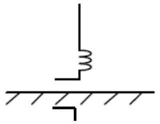
3) Quarterwave Monopole



4) Short Monopole

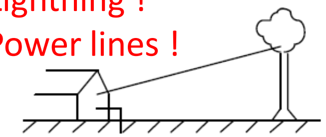


5) Loaded monopole

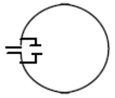


CAUTION: Lightning !
Power lines !

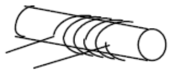
6) Simple longwire



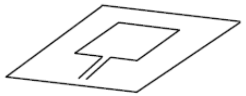
7) Simple large loop
or smaller resonant loop



8) Small ferrite-core loop



9) Microstrip patch



10) Other

Inverted F, small loaded patches, etc.

Examples

AM Broadcast:

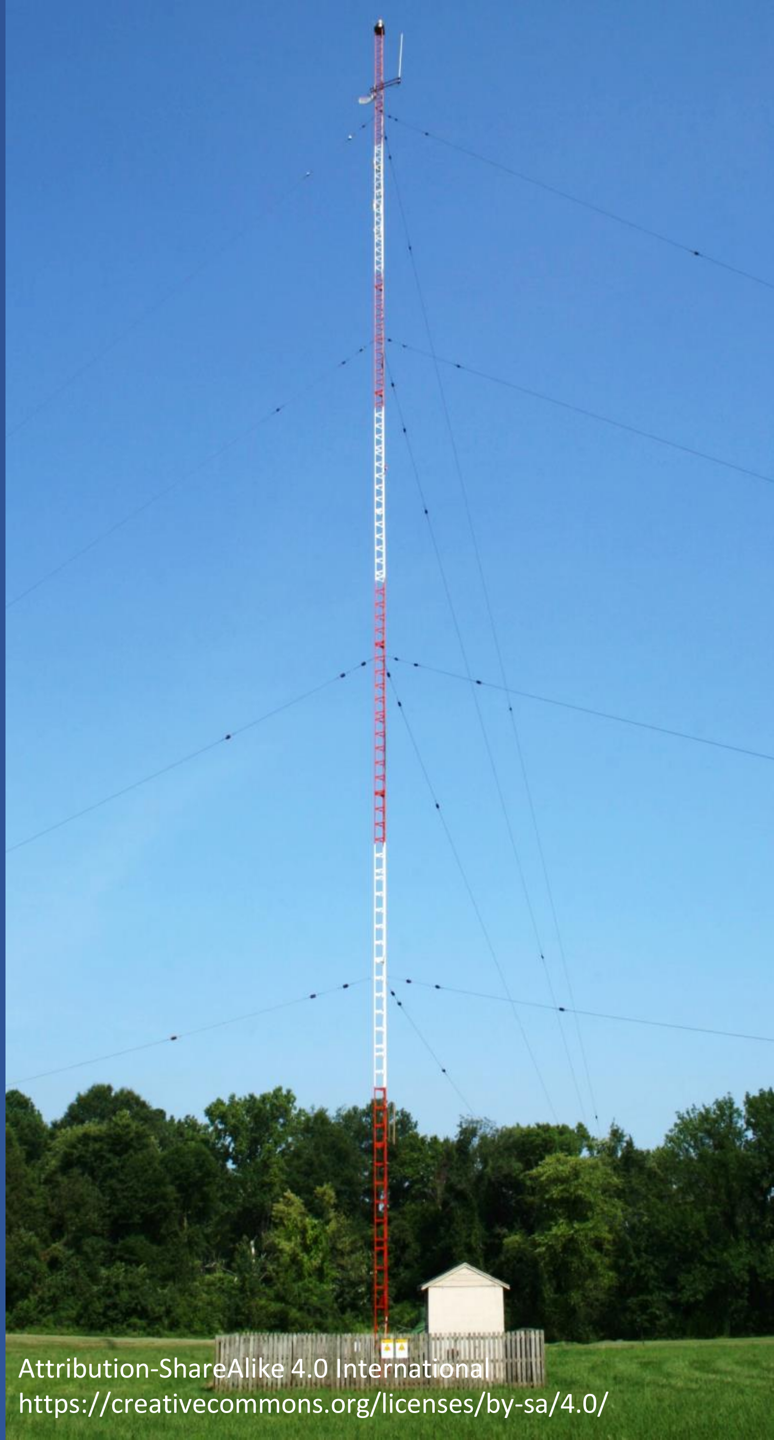
0.53 to 1.6 MHz (MF)

Lambda = 300 meters @ 1 MHz

Ideal lambda/2 dipole: 150m (500 ft.)

Lambda/8 loaded monopole 37m (125 ft.)

Ferrite Loop antenna in receiver



Examples

HF Ham Radio / Shortwave:

3 – 30 MHz
Lambda = 100 - 10 meters
Ideal antenna 50 to 5 meters
Multiband “Trap” vertical shown

DX Engineering 5-BTV
with ground-radial plate

Examples

FM Broadcast:
88 – 108 MHz (VHF)
Lambda = 3 meters at 100 MHz
Ideal lambda/2 dipole is 1.5m

Transmitter antenna is a vertical array
at the top of the tower.

Tower is shared with other services …

From Radio Design 101 video series
On this channel

Some FM receive antenna options

ECEFILES.ORG


RTL-SDR.COM

UHF – The Most Valuable Frequencies

300 MHz to 3 GHz

Lambda = 1m to 100 mm (40” to 4”)

Lambda/10 = 100 mm to 10 mm (4” to 0.4”)

Small enough for human-scale gadgets

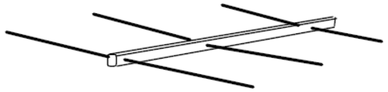
- Handheld radios
- Cell phones
- WiFi, Bluetooth, RFID tags, etc.

Yet large enough to capture enough signal to transmit reasonable distance on low power ☺

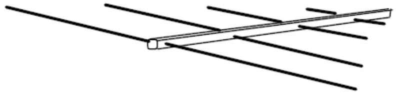
Some More Antenna Types

Directional Designs

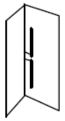
1) Yagi-Uda



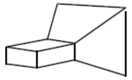
2) Log-Periodic



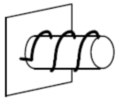
3) Corner Reflector



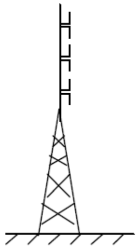
4) Horn



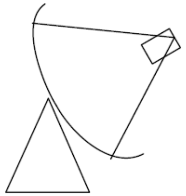
5) Helix



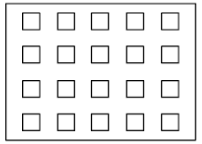
6) Linear, vertical array (tower-mounted dipoles)



7) Parabolic dish



8) 2-D Phased-array



Example

“K-Band” Satellite TV and Internet

10 - 40 GHz

Lambda = 7.5 mm at 40 GHz !

Lambda/2 dipole = 3.75 mm (0.3 inches)

Use a dish or an array to intercept sufficient signal power

“Dishy McFlatface” aperture size = 19” ($0.2m^2$)

Size >> lambda, so antenna is highly directional (and steered electronically)

https://www.youtube.com/watch?v=iOmdQnIlnRo

https://arstechnica.com/information-technology/2021/11/starlink-unveils-2nd-generation-satellite-dish-and-new-wi-fi-router/

IMPORTANT TAKEHOME: $\boldsymbol{\lambda = \frac{c}{f}}$

$c = 3.00E8\ m/s$ (In free-space)

$f = 1\ MHz \quad \lambda = 300m$

$f = 100\ MHz \quad \lambda = 3\ m$

$f = 10\ GHz \quad \lambda = 30\ mm$

- Antenna size is related to wavelength "lambda" and hence frequency
- For efficient transmit (and receive), dipole needs dimension of lambda/2 (lambda/10 can work with a "tuner" – but lambda/100 or lambda/1000 is generally very lossy)
- Lambda times 2 (or times 100, etc) is OK, and even provides "gain", but antenna becomes (highly) directional…

Thanks for Watching !