Introduction to Antenna Basics

Week 1: Intro to RF for Antennas

Karen Rucker

Week 1 Class Outline

What’s an antenna?

Maxwell Equations

Electromagnetic waves

Polarization

Gain

Radiation patterns

VSWR

Impedance matching

Frequency bands

What’s an Antenna?

- Antenna: transducer that converts energy from one domain into another domain

  transducer is an electronic device that converts energy from one form to another

- Want good electrical match at antenna terminals
- Want good power transfer (efficient)

Important Antenna Properties

Radiation Properties

1) Reciprocity

2) Antenna Pattern

3) Gain

4) Polarization

Impedance Properties

1) Radiation resistance

2) Loss resistance

3) Voltage Standing Wave Ratio (VSWR)

Isotropic Antennas

Hypothetical antenna having the same radiation in all directions (i.e., uniform radiation)

Gain of 1 (0 dB) in the spherical space all around it and has an efficiency of 100%

Mathematical construct as frame of reference

Antennas generally specify gain in dBi (decibels relative to isotropic antenna)

Image: Wiki Commons

Maxwell Equations

- Gauss's law
  - relationship between a static electric field and the electric charges that cause it
- Gauss's law for magnetism
  - there are no "magnetic charges" (also called magnetic monopoles)
- Faraday's law
  - time varying magnetic field creates ("induces") an electric field
- Ampère's law with Maxwell's addition
  - magnetic fields can be generated in two ways: by electric current and by changing electric fields

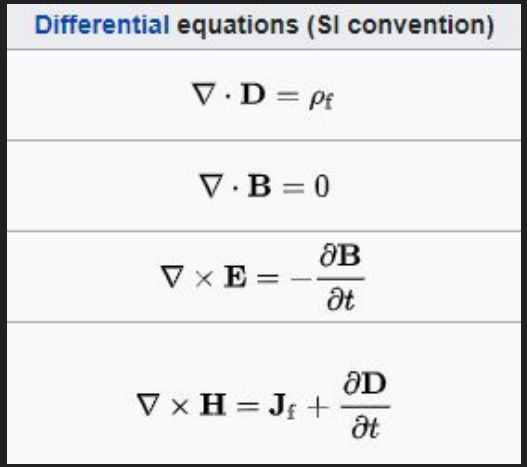
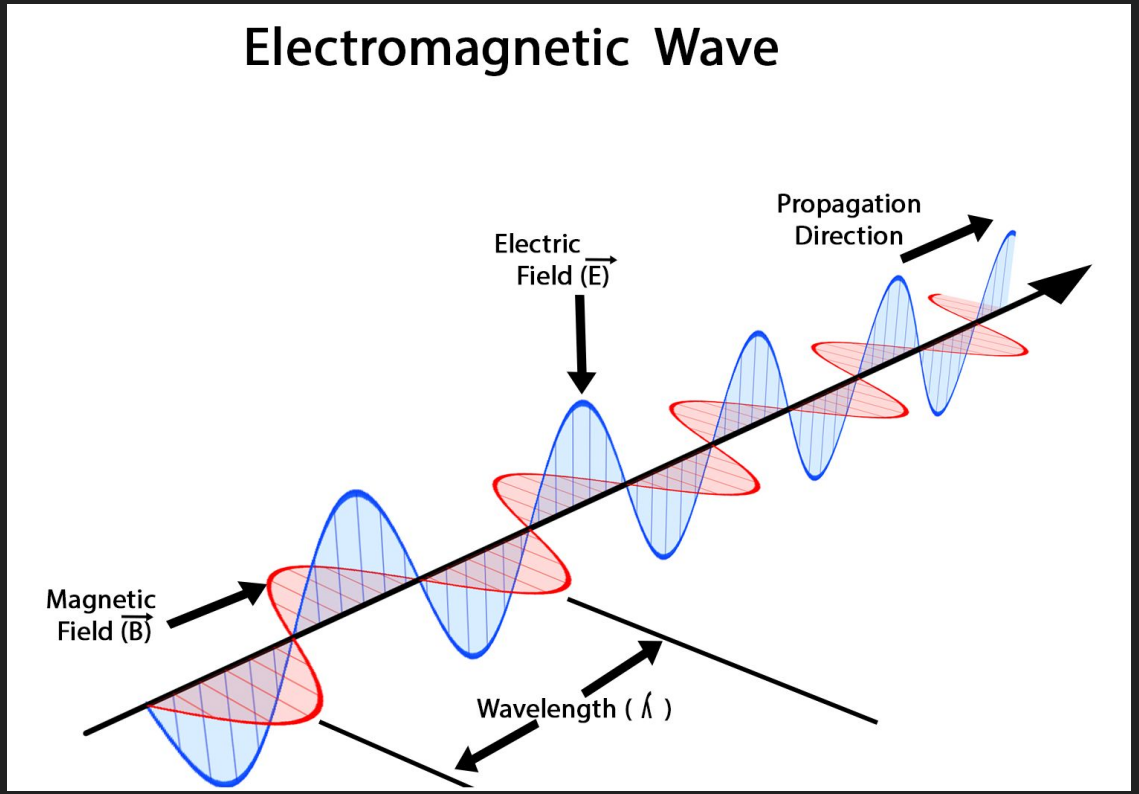


Image: Wikipedia

Electromagnetic Waves

EM waves are composed of oscillating magnetic and electric fields



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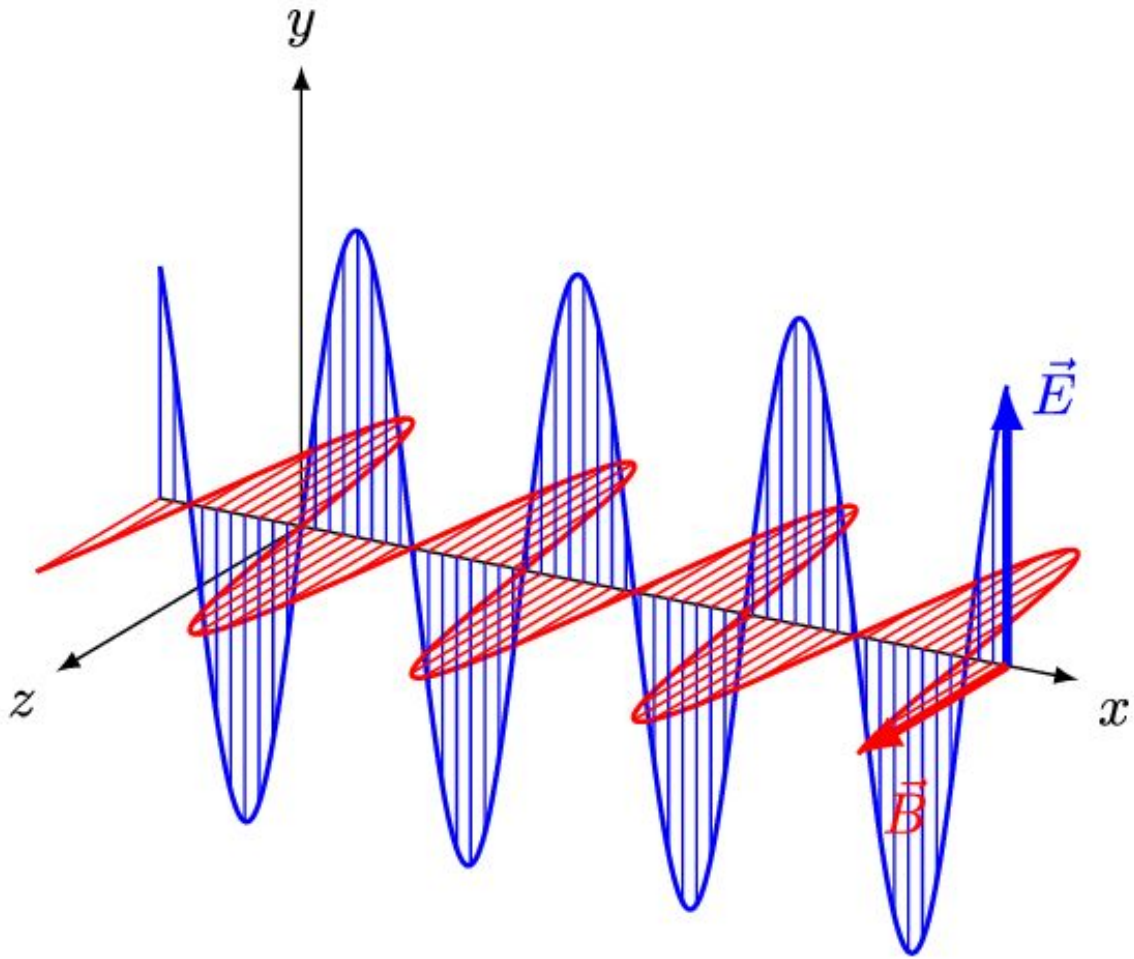

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EM Spectrum

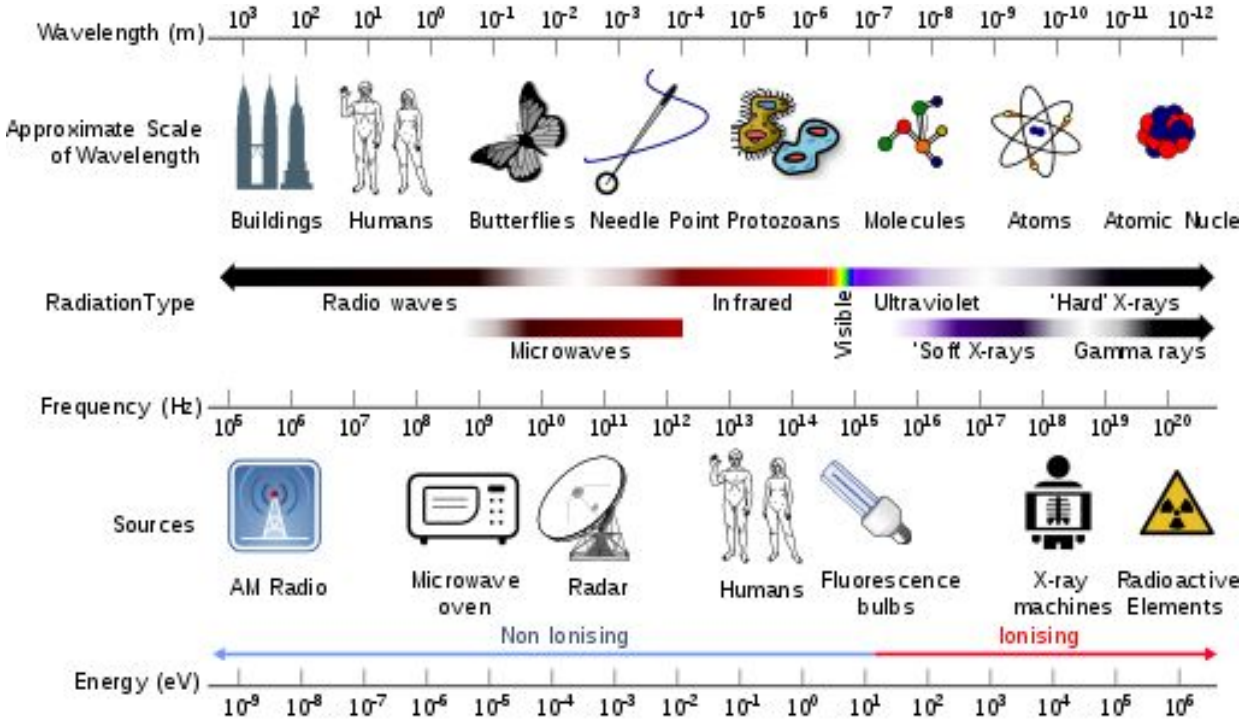


Image: Wiki Commons

Polarization

Polarization characterizes the direction of the Electric Field, E-field.

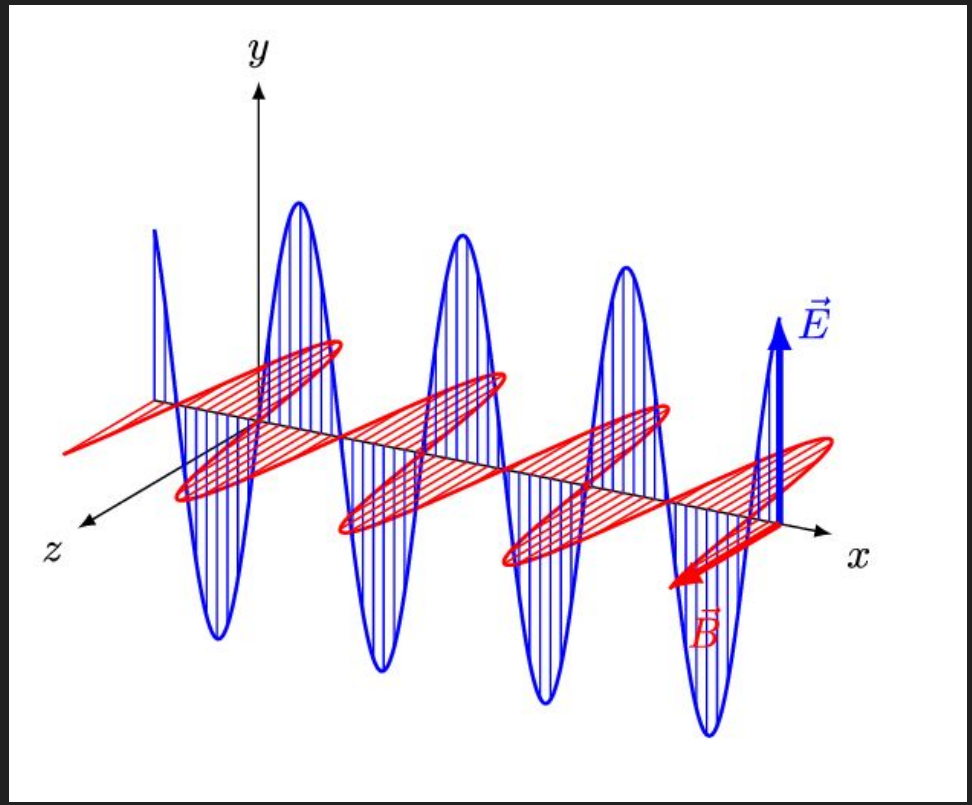
The vector E and B must be orthogonal.

k points in the direction of propagation (x-axis).

At any point along the propagation path,

the pattern ‘traced’ by the E-field in the

z-y plane is the wave’s polarization.



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Types of Polarization

Linear polarizations

– Horizontal & vertical polarization

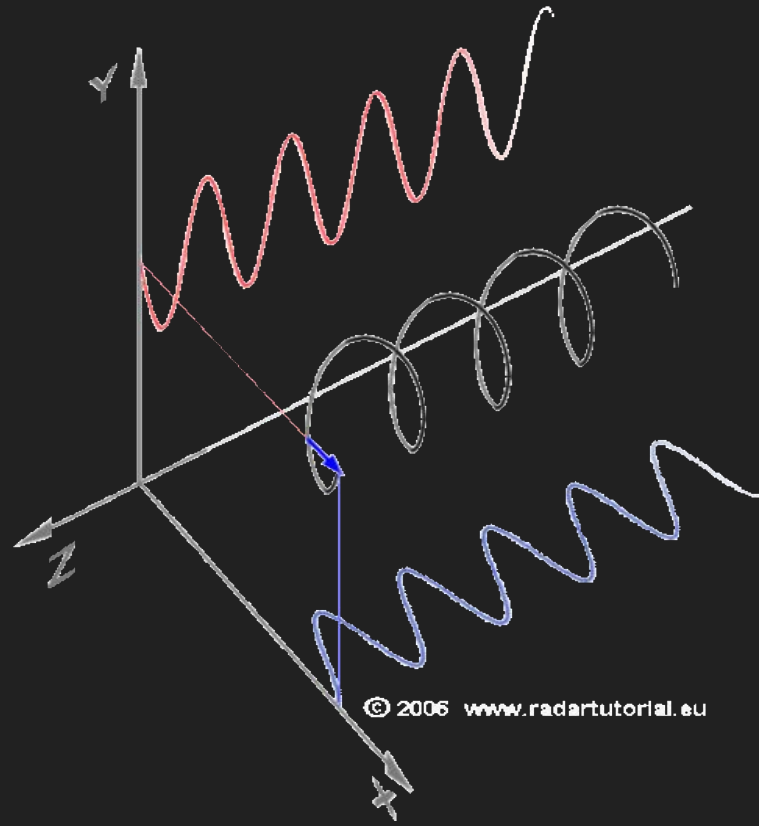
– Slant polarization

Circular polarization

– Right hand circular (counterclockwise rotation)

– Left hand circular (clockwise rotation)

– Elliptical polarization



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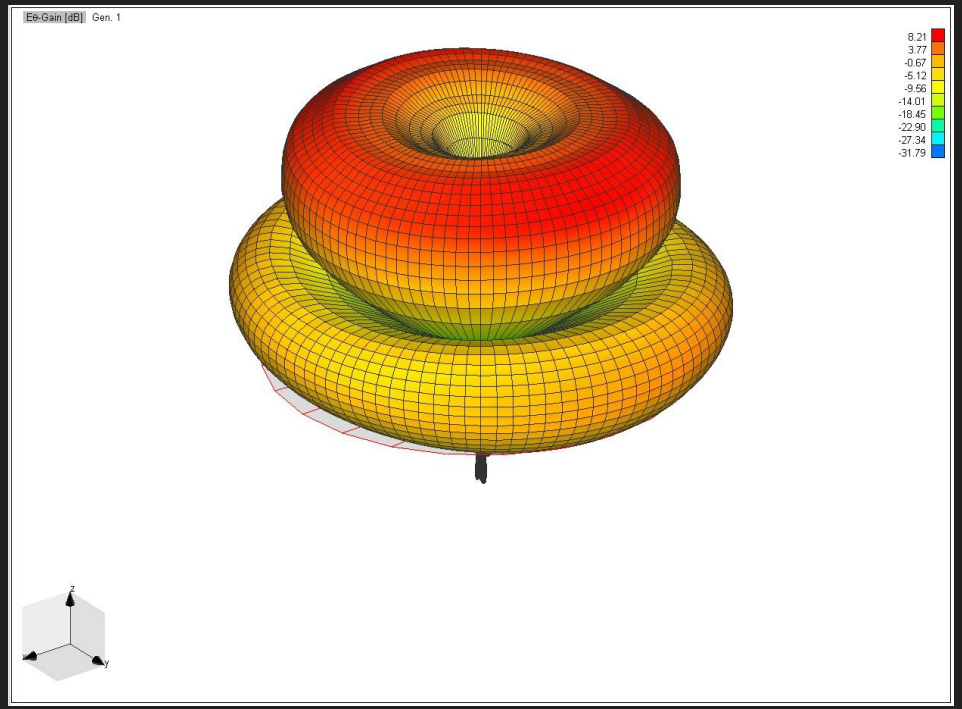
Gain

Antenna Gain is based on power at the antenna terminals and accounts for antenna losses.

Gain vs directivity: gain accounts for ohmic losses in the antenna, whereas the directivity does not

Gain = Efficiency × Directivity

Radiation patterns



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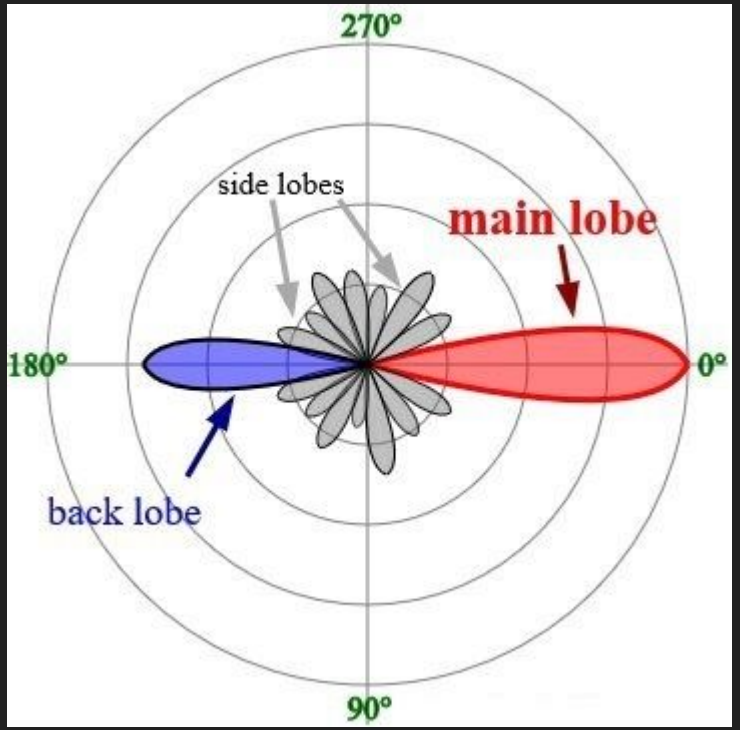

Image: Timothy Truckle (own work) [GFDL]

Voltage Standing Wave Ratio (VSWR)

SWR (Standing Wave Ratio) meters measure the ratio of transmitted to reflected energy, with the idea to have the ratio be as close to 1:1 as possible.

- varies from 1 to (plus) infinity and is always positive

S11 represents how much power is reflected from the antenna, and hence is known as the reflection coefficient

- varies from 0 to (negative) infinity

VSWR= (1 + | S11 |)/(1 - | S11 |)

$$RL = -10 \log\left(\left|\frac{P_{ref}}{P_{inc}}\right|\right)$$

Image: Wikipedia

Impedance

Impedance: amount of opposition that a circuit presents to current or voltage change

- an inductor resists changes to the current
- capacitor resists changes to the voltage

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

Z = impedance
R = resistance
X_L = inductive reactance
X_C = capacitive reactance

Image: Wikipedia

Impedance matching

introducing passive circuit components between the final circuit amplification stage and the antenna

- Baluns, capacitors, inductors

maximizes the power transfer

minimizes signal reflection from the load

Common microwave frequency bands

Frequency band	Frequency range (GHz)	Wavelength range (cm)
L band	1–2	15–30
S band	2–4	7.5–15
C band	4–8	3.75–7.5
X band	8–12	2.5–3.75
Ku band	12–18	1.67–2.5
K band	18–27	1.11–1.67
Ka band	27–40	0.75–1.11
V band	40–75	0.4–0.75
W band	75–110	0.27–0.4

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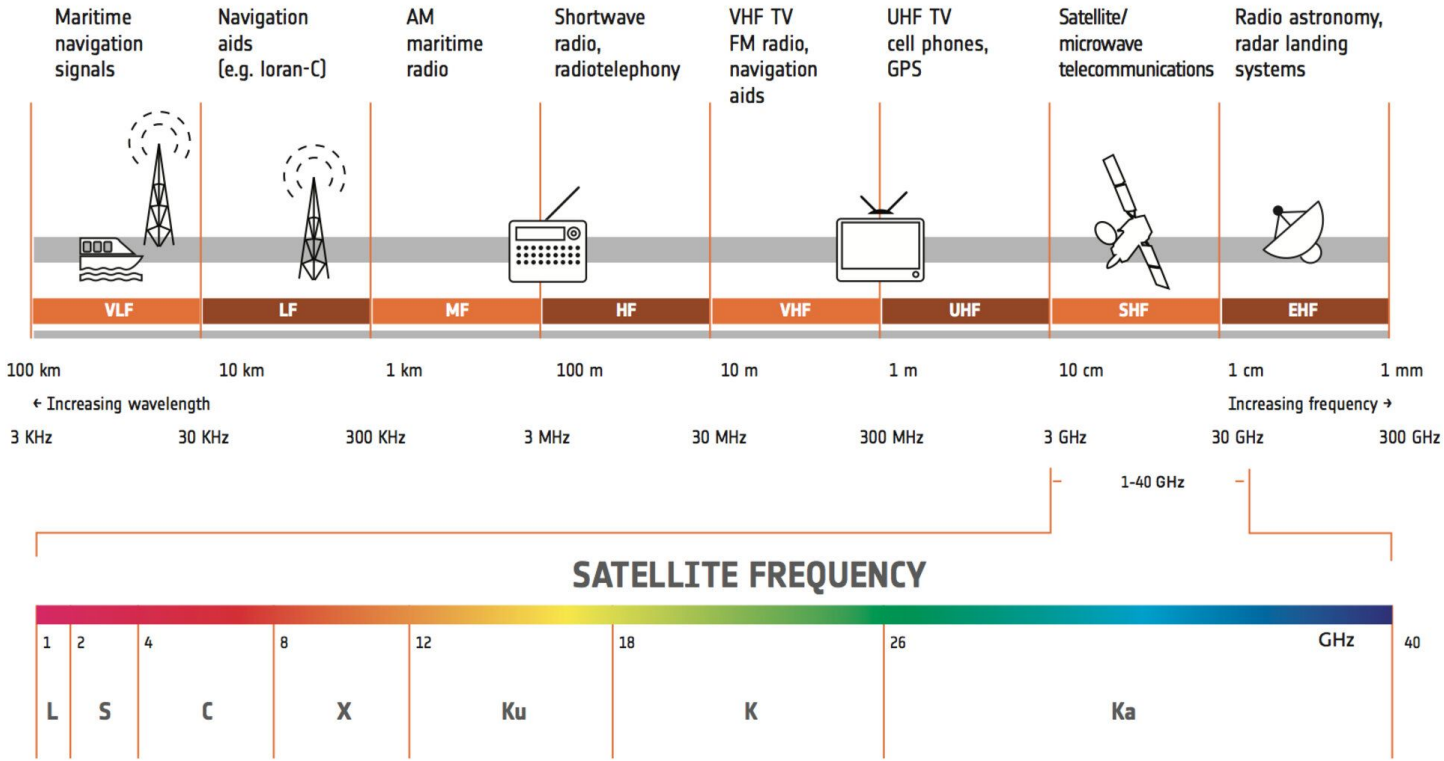

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What’s a dB?

Changes in power are measured in decibels (dB)

dB value is a *relative* unit

dB = 10 log (Pout/Pin)

dBm: absolute power measured relative to 1 mW

Additional Resources

https://www.everythingrf.com/

https://www.allaboutcircuits.com/textbook/radio-frequency-analysis-design/#rf-principles-components

https://www.allaboutcircuits.com/technical-articles/an-introduction-to-antenna-basics/

https://www.microwaves101.com/

Coming up next class

Introduction to antenna testing. Topics covered will be, but are not limited to: the far field, VSWR, network analyzers, and s-parameters.

Questions?