



Communications: Theory

Agenda:

- Modern communications
- What is Radio?
- Analog vs Digital and Radio Wave Propagation
- Antennas
- Types of Radios & Handheld Radios
- Analog & Digital Comms and Security
- SIGINT
- High Frequency Comms
- PACE Plan and Scenarios



Modern Communications

- **Cellular Phones, Internet (via Wi-Fi) and social media are typically used for modern communications**
- Current tech is completely reliant on external systems, the **electric grid**, and **intermediate infrastructure**
 - Communications between individuals require a separate service (such as ISPs, cell phone service providers, mail service)
 - Multiple pieces of the puzzle must fit together to make it all work for a single phone call or text
 - Countries/Companies have lost these services before, leading to chaos



Modern Communications

- Radio gives one the option for talking with others without the need to rely on these services
- Radio does not require any intermediate infrastructure, paid services, or the electric grid to operate
 - However, often some intermediate infrastructure such as repeaters or satellites are used



What is Radio?

- Established in the early 20th century as a method of communication which bypassed wired telegraphs
- Use of a transmitter & receiver (combined: transceiver) to speak with other operators via Radio Frequency (RF) Radiation
- Many different frequencies may be used and all carry strengths and weaknesses
- Signals sent by manipulated RF waves to transmit human speech or data



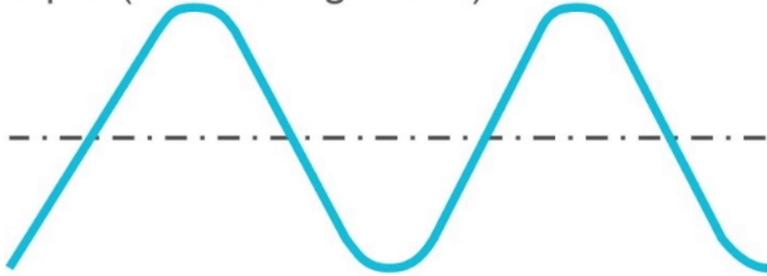
What is Radio?

- There are different classes of radio based on use and license needed.
- CB – License free radio with set channels on the 11m band (not FM)
- FRS – License free radio with set channels within UHF range (FM)
 - “Walkie-Talkies”
- GMRS – Licensed radio service with set channels within the UHF range (FM)
 - Shares some channels with FRS
- Amateur – Licensed radio service with different classes of service (All modes)
 - Technician class most common – VHF/UHF mostly
 - General and amateur classes can do all types of propagation even on HF
- Land Mobile – Licensed radio service for public service, commercial, and military
 - All types of bands, UHF and VHF most common, additionally 700-800 MHz

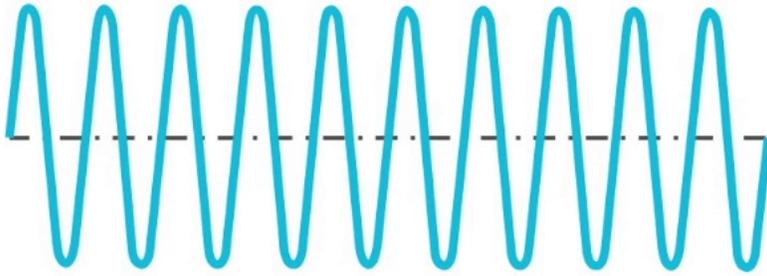
Analog vs Digital Radio Waves

Amplitude Modulation (AM)

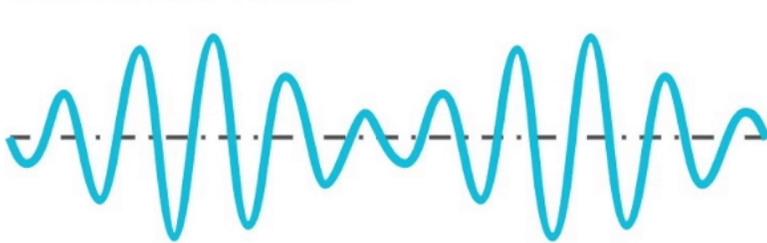
Input (Modulating Wave)



Carrier

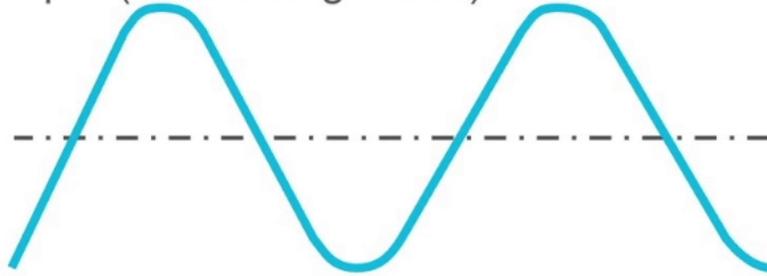


Modulated Result

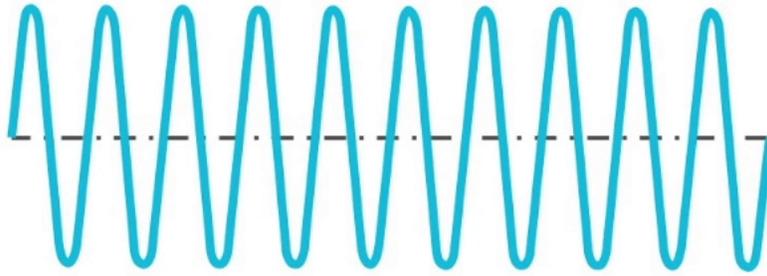


Frequency Modulation (FM)

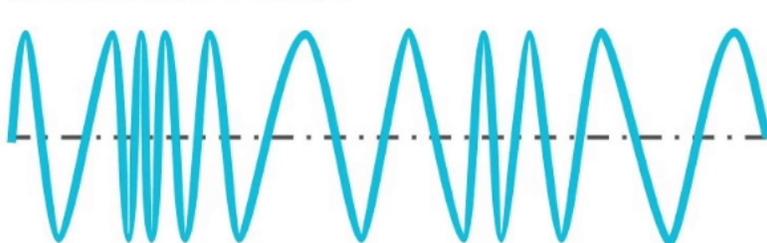
Input (Modulating Wave)



Carrier

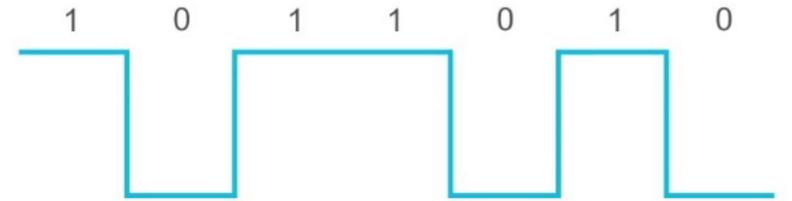


Modulated Result

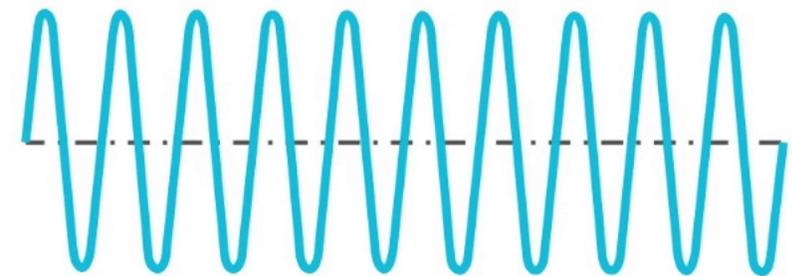


Digital Modulation

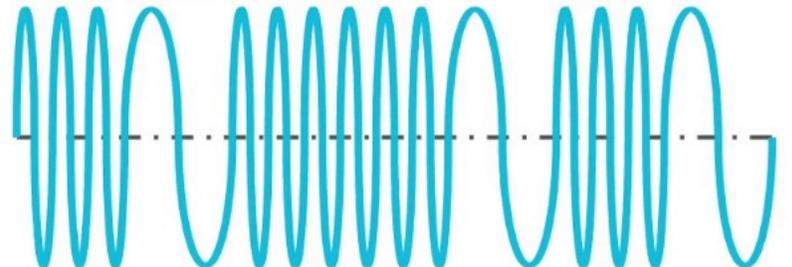
Input (Modulating Wave)



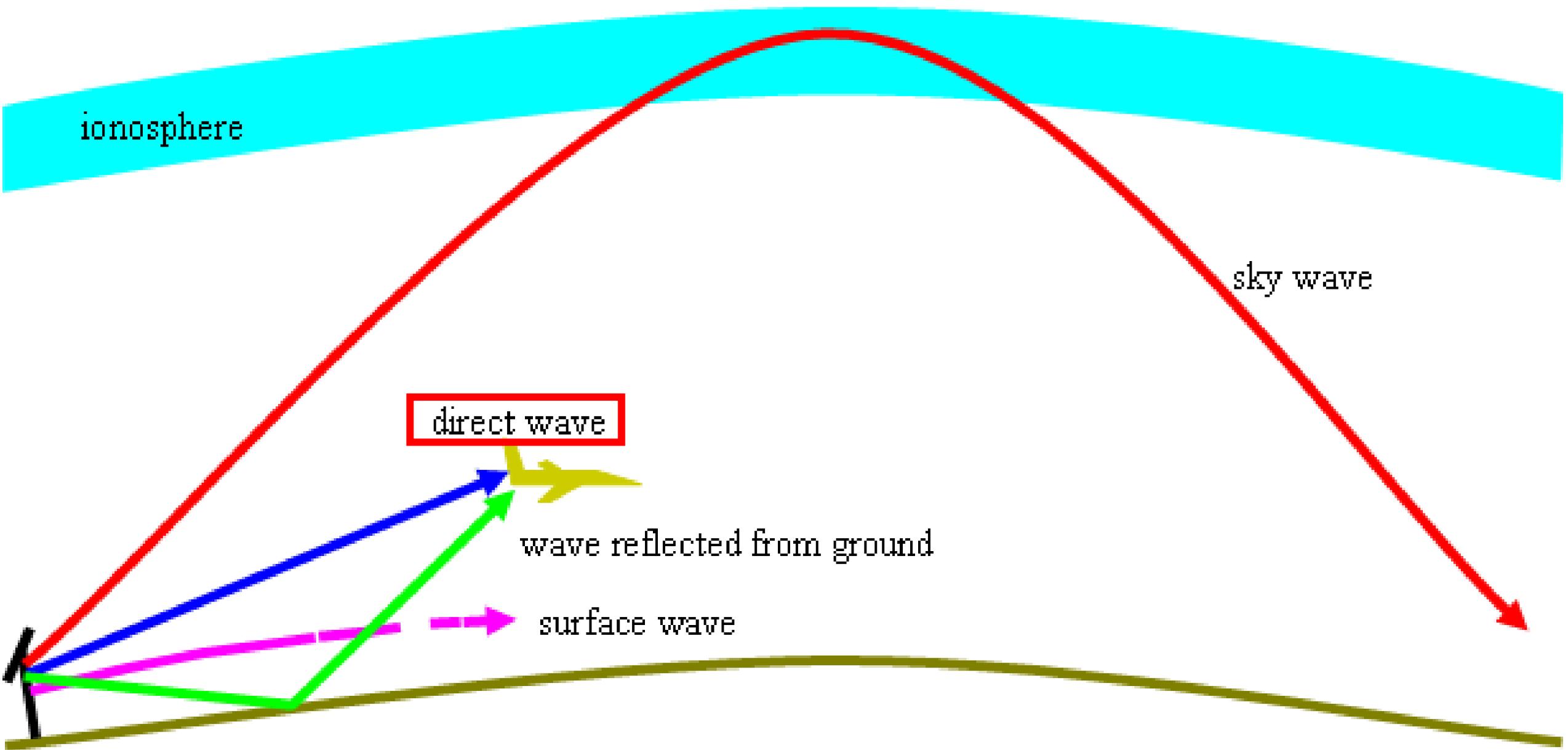
Carrier



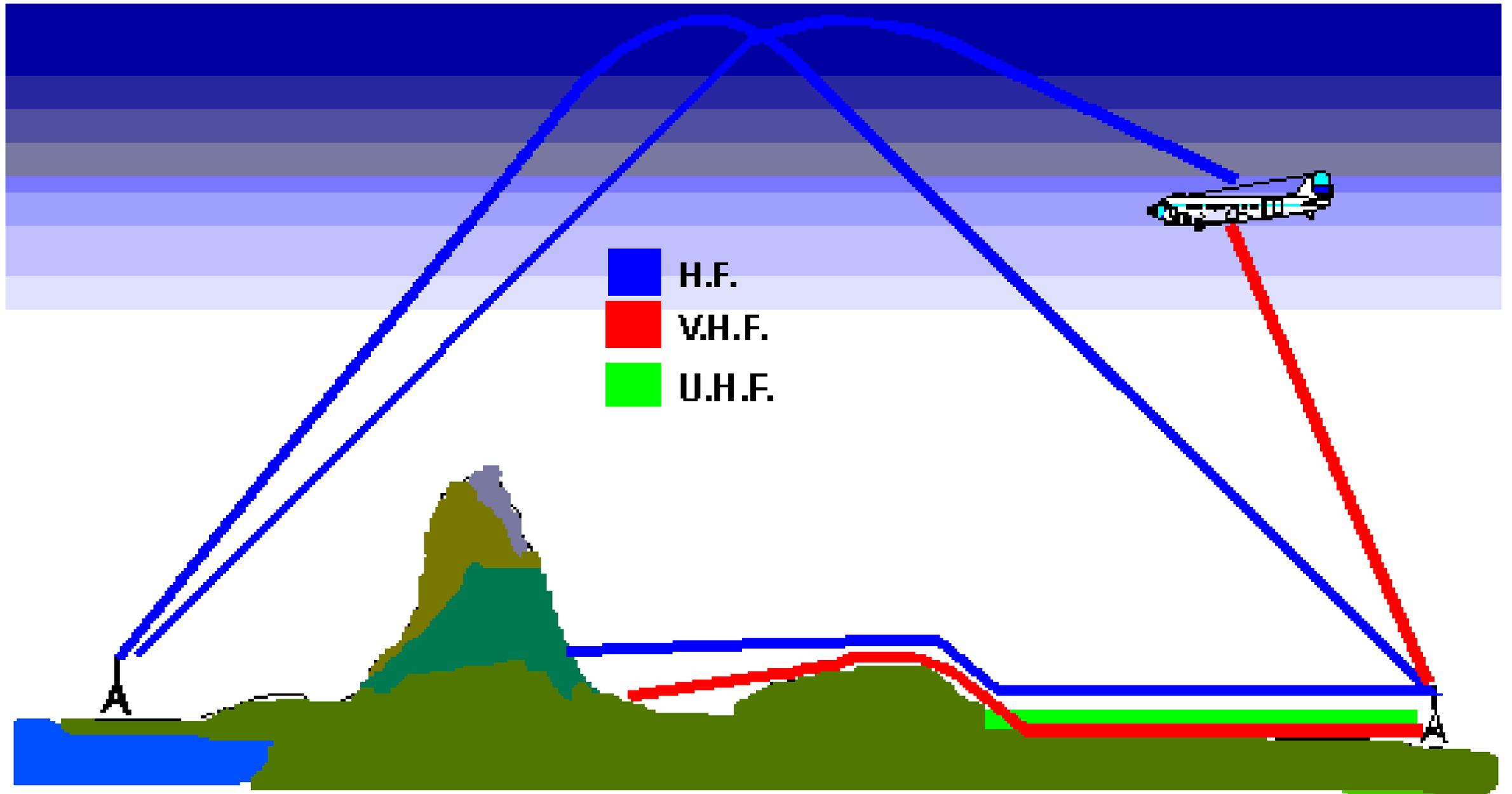
Modulated Result



Radio Wave Propagation



Radio Wave Types and Behavior



Antennas: Directionality

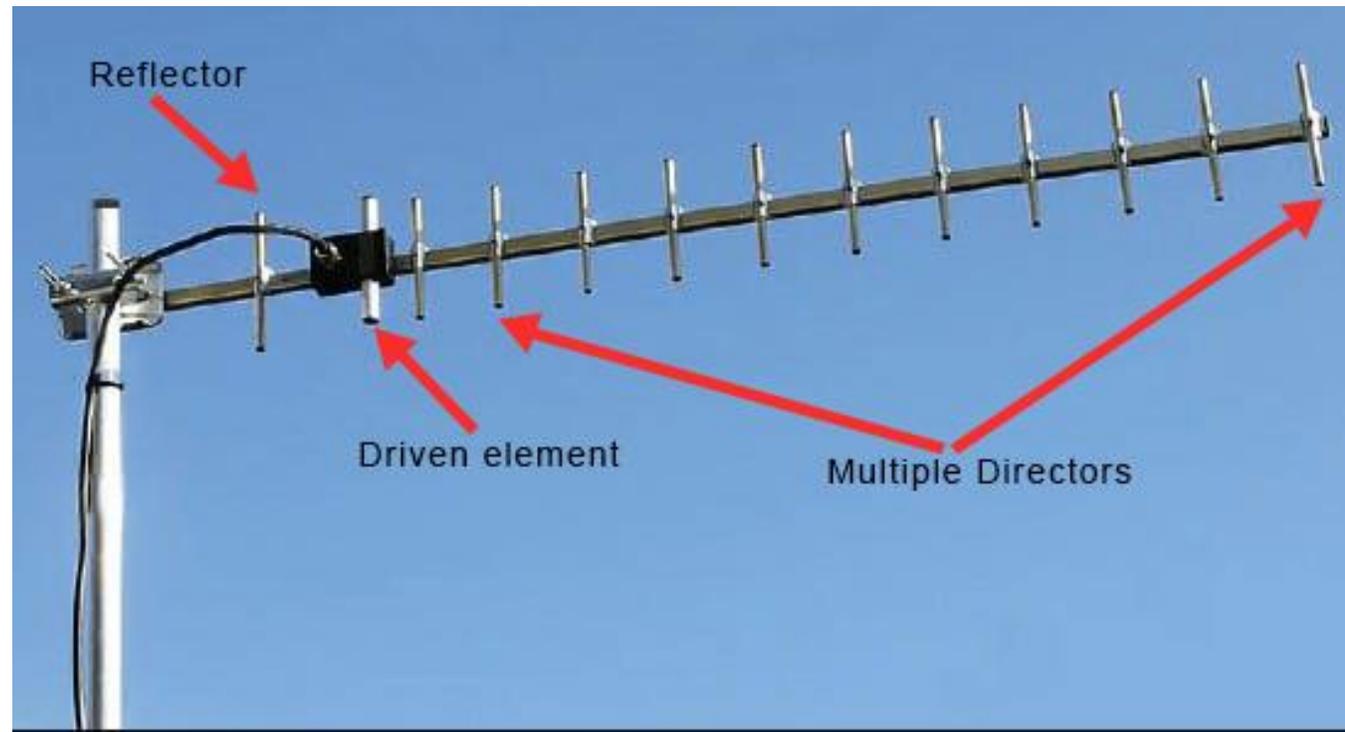
- Most antennas used are omni-directional, thus equally send RF out in all directions (less efficient).
- A directional antenna allows for greater range/clarity of signals as well as preventing easy interception
- Directional antennas are easy to see based on their use of reflective elements to concentrate the signal....think a lamp vs a flashlight.



Omni

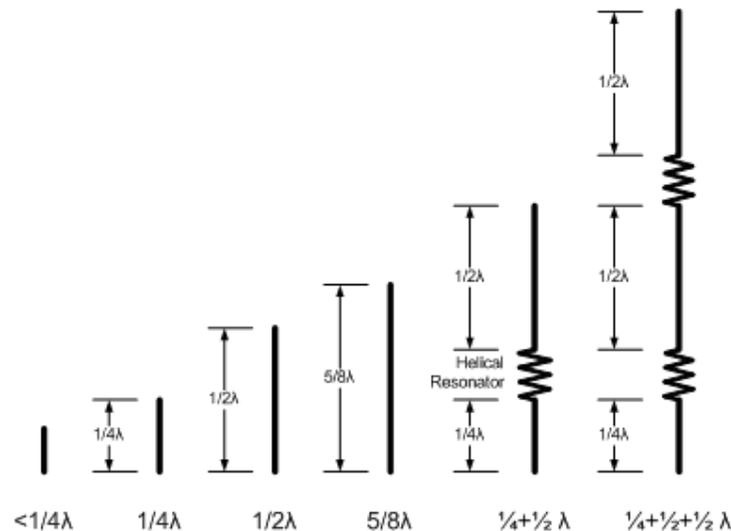


Directional



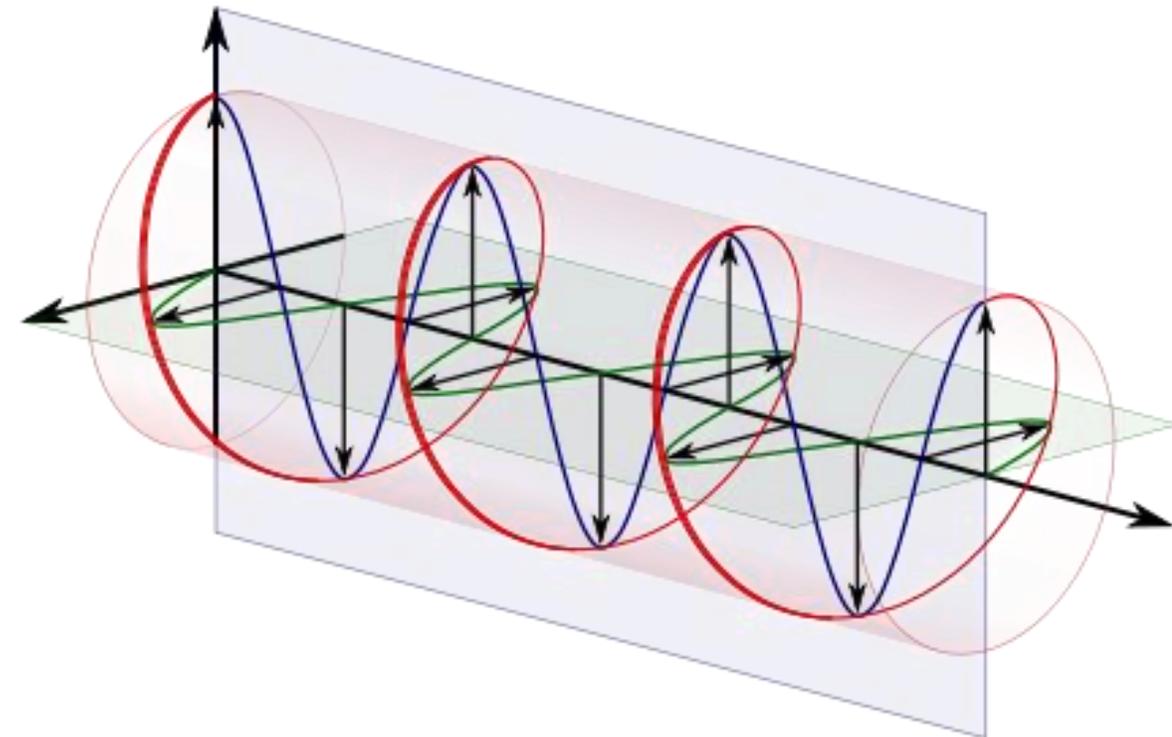
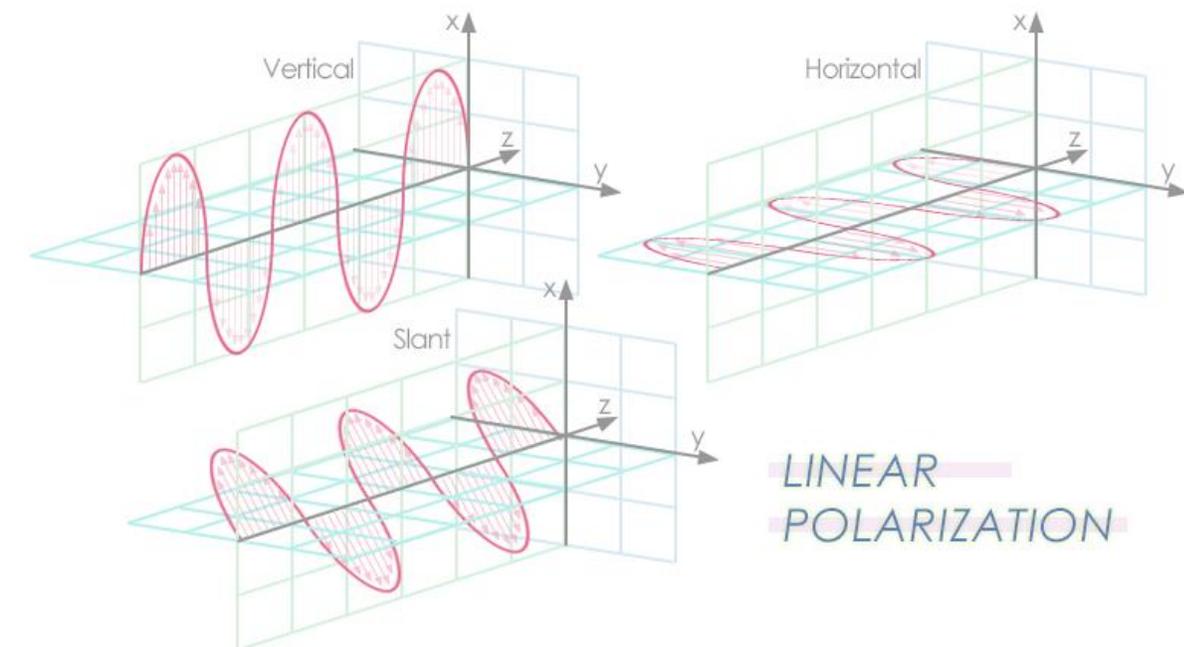
Antennas: Length and polarization

- Antenna length is based on the frequency used: The lower the frequency the longer the antenna needed
- 1/4 wave or 1/2 wave?
 - The ideal antenna is 1/2 of the wavelength. While half-wave antennas are most-efficient, they take up a lot of room and have differing propagation characteristics (think on the move).
 - Quarter-wave antennas are compact and work well enough for HTs



Antennas: Length and polarization

- The RF radiation must be sent out some way, and that is based on polarization
- Most radio antennas used are linear polarized, specifically vertically
 - Vertical polarization has better ground wave propagation, horizontal skywave propagation
- Circular and dual polarization allows for both sending and receiving RF in waves easily as orientation does not matter.
 - Typically used for SATCOM



Types of Radios



Handheld



Mobile



Base Station

Handheld Radio Communications

- Communication via direct wave path or reflection (limited range – Line of Site aka LOS)
- Range may be extended by using directional or higher gain antennas, height, and clearer terrain
- Our primary method of communication – portability



Handheld Radios – VHF/UHF/Higher UHF

- Band Selection is always an important consideration but with handhelds it matters as many are limited to only 1 band, sometimes 2-3.
- VHF has the best range (especially with flat terrain) but lacks operability in urban/wooded environments
- UHF is a favorite for handhelds - compromise regarding range and capabilities
- 700/800 MHz & GHz bands are excellent for urban, underground, and high-data digital comms – however range and even weather can severely impact use



**VHF/UHF
Log Periodic**

**High UHF
& GHz**



Accessories

- The following accessories should be added to your handheld radio
 - **Spare battery**
 - **Battery Charger**
 - **Speaker mic or some other type of connector**
 - *These 3 at a minimum*
 - Programming cable
 - Wrist strap and/or belt clip
 - Spare/other type of antenna
 - Car power adapter (replaces battery)



Microphones & Receiving



Throat Mic & Covert Earpiece



Headset & PTT



Speaker Mic

Handheld Antennas

- Greater antenna length and gain make transmissions clear and give longer range
- 4 common antenna types: “Rubber Ducks”, Flexible, Whip, & Cat Tail
 - Each have advantages but generally whip and folding antennas give the best signal, rubber ducks are the most durable, and whip & cat tail antennas work best with a kit



Rubber Duck



Whip



Folding



Cat Tail

Handheld Antennas

- Most antenna connections are either SMA male or SMA female. Fine for use but can break the connector if the antenna is moved too much.
- Solution is to use a BNC connector with adaptor. Helps with switching to mobile.



Mobile Antennas for Handhelds

- Vehicles act as RF shielding and dramatically reduce the range of radios
- For convoys, using a magnet-mount antenna connected to the radio on the roof and highly increases the range of the radio



Mobile Radios

- Mobile radios greatly enhance the capability of comms
 - Much greater power – 25-100+ Watts vs only 5W
 - This gives some greater range on the edge, but mainly allows for clearer transmissions especially in urban or forested environments
- Non-portable (usually) but easier to use while driving



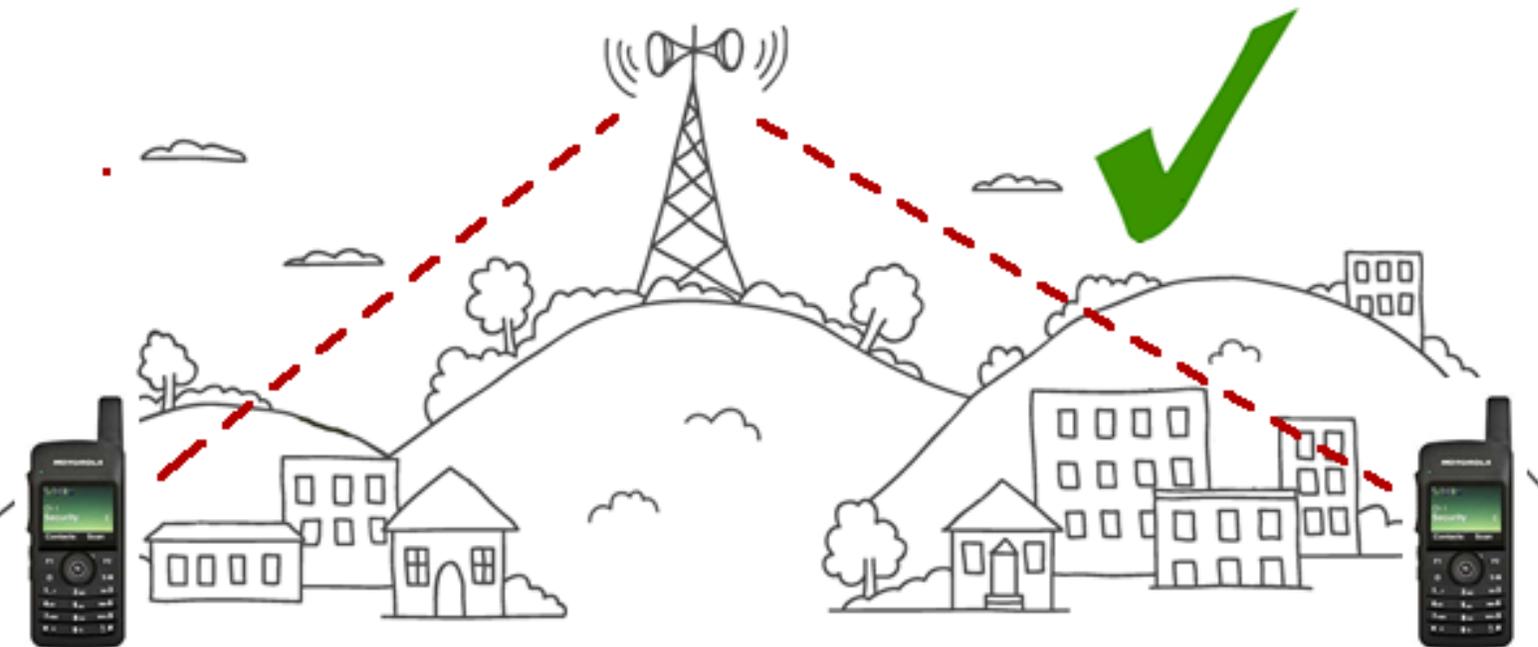
Base Station Radios

- Non-portable, but can use a mobile radio for the setup
 - Power can range from 100W to over 1000W – Usually only 50W for VHF/UHF
 - Cost, bulkiness, and reliable power are the biggest drawbacks
- Permanence allows for better antenna setups and advanced digital modes via computers
- Often use backup power via batteries and solar

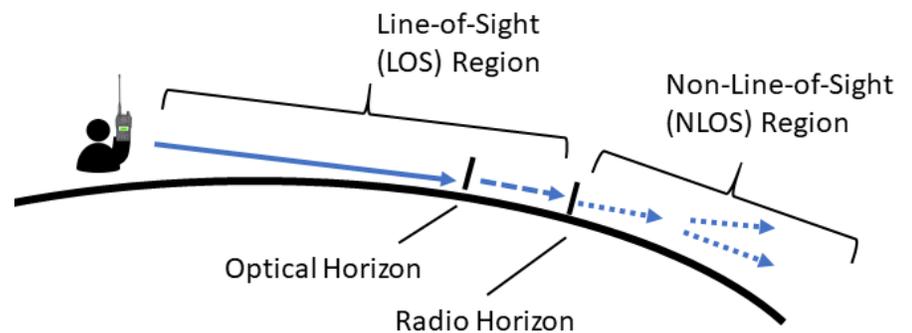


Repeaters

- Allow an RF signal to transmit much farther by repeating it.
 - Best used with handheld or mobile setup
 - Separate receive and transmit frequencies – two antennas
- Programmed ahead of time and usually require CTCSS tones to unlock and speak/hear transmissions from the repeater



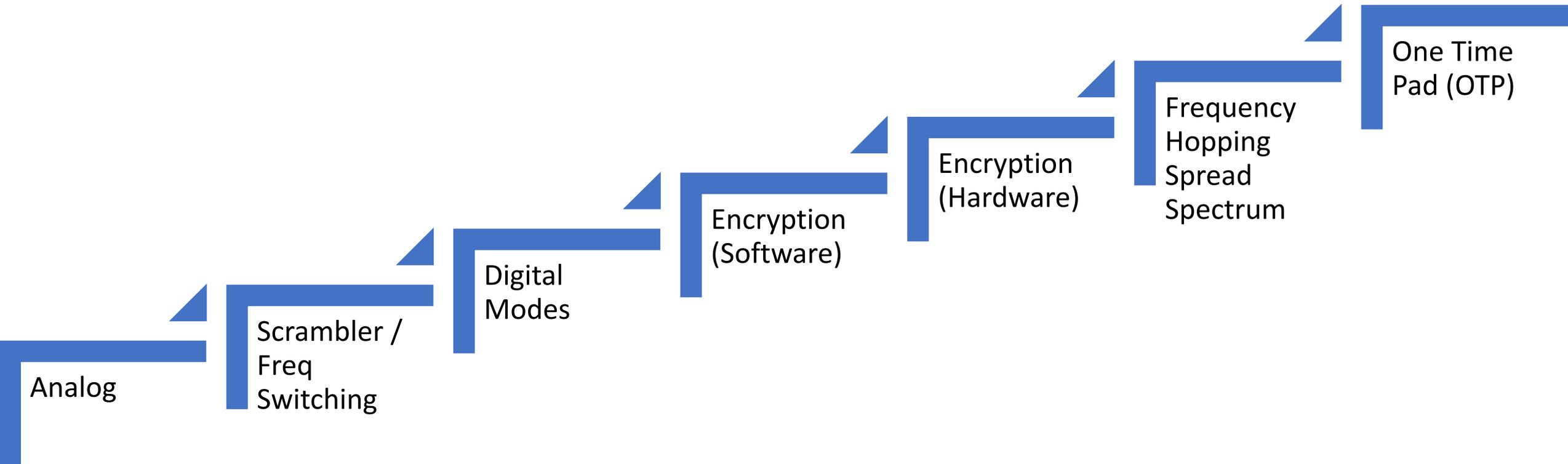
Line-of-Sight Model



Analog v Digital – Pros & Cons

- Within the last 30 years digital communication has become common
- Analog is still standard – any radio device can use analog on the same frequencies
 - Cheapest and most available
 - Lack of security – scramblers and frequency shifting are only options minus coding
- Digital has multiple benefits, namely in clarity, obscurity, data transmission, etc.
 - Digital has packet transmission vs power of pure waves – clear comms until edge of range
 - Digital nearly rids of noise floor/static from the background
 - Digital uses “packets” for transmission – missed packets may be requested re-sent
 - Digital has smaller bandwidth and requires decoding software to hear messages
 - **Digital transmissions may be encrypted – high security**
 - Digital allows for trunked systems
 - Digital has less bandwidth (harder to find)

Security Levels



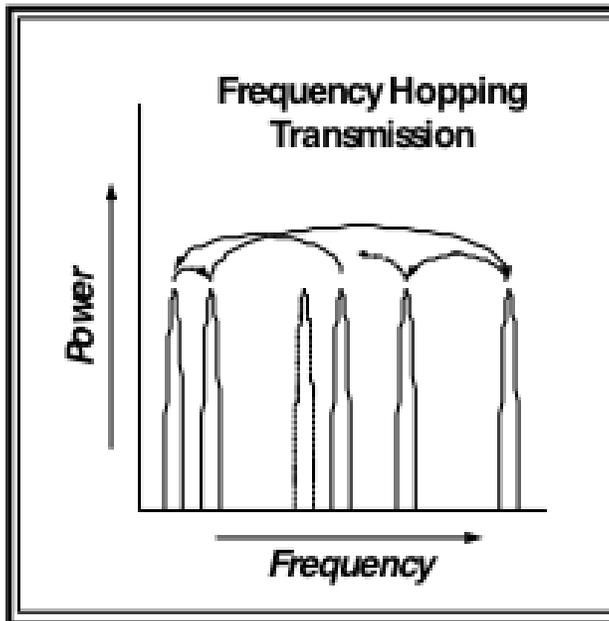
Digital Mode Types

- DMR (Digital Mobile Radio)
 - A commercial standard used for amateur and commercial communications
 - Cons: Software based encryption only, open-source standard
- P25 (Project 25)
 - A land mobile standard made for public and military communications
 - Cons: Hard to find, mostly only can buy new commercially
 - Pros: Allows for Hardware based encryption, can send data only 6.25 kHz bandwidth



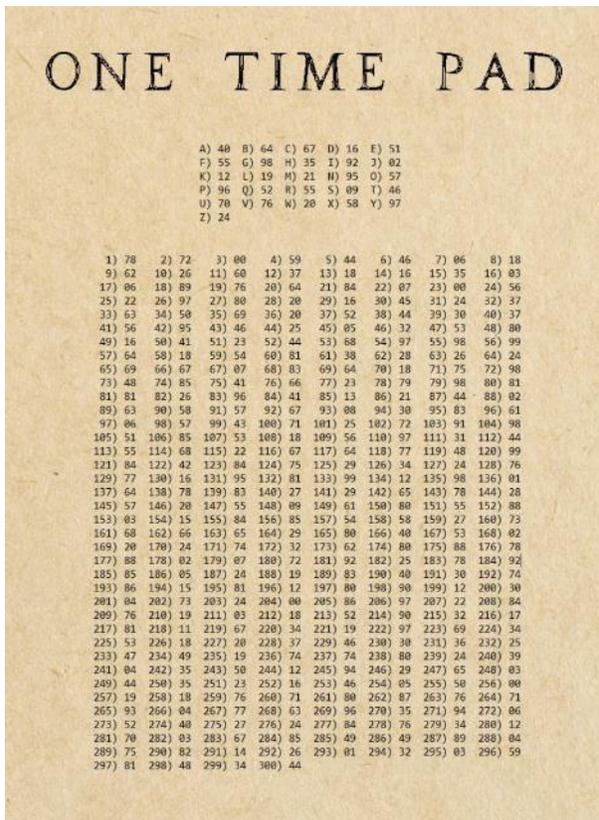
Frequency Hopping Spread Spectrum (FHSS)

- Trunked radio systems are often mistaken for this. While yes, trunked systems DO shift radio frequencies it is to make efficient use of a small frequency space on the Land Mobile Spectrum – Not switching for obscurity
- Frequency hopping can be as simple as changing channels, advanced military radios do it automatically
 - Prevents jamming being effective
 - Prevents listening in on communications easily



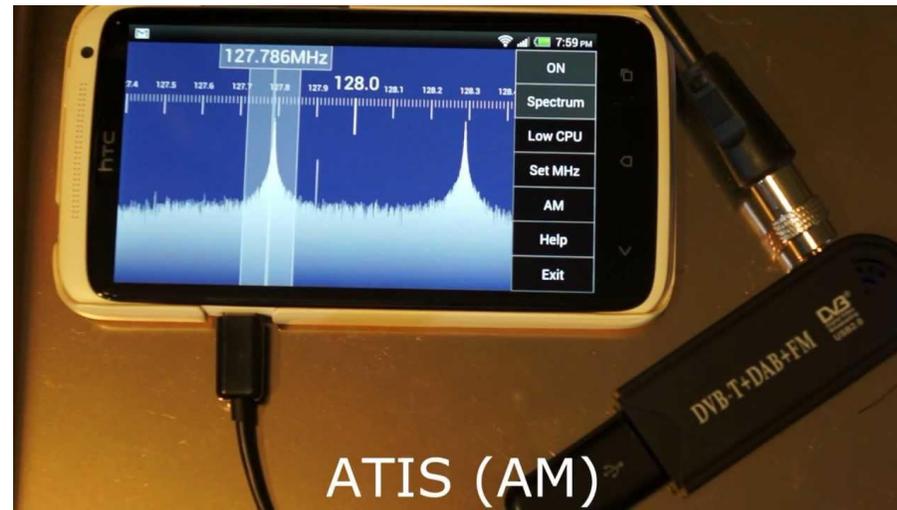
One-Time Pad (OTP)

- Uncrackable code, the receiver has a pad with the a crypt. When given the message over radio, the listener uses the cipher (pad) to decode the message.
- Can even be sent via analog as the encryption isn't of the voice but the message itself. Commonly used with number stations.



Reception - SIGINT

- Listening is just as important (arguably more) as transmitting. Listening can still yield a lot of intelligence from other radio sources. Whether this be weather radio, enemy forces, or government broadcasts.
- Listening does not require you to send out any signals (can remain invisible).
- Typical a Software Defined Radio (SDR) can be used to receive signals across the spectrum for cheap and portable SIGINT ability.
 - Con: Dedicated units are expensive, and needs plug-ins or special software to decode digital signals



Reception - SIGINT

- Radio direction finding may be accomplished with an SDR and directional antenna (such as a Yagi)
- A Cellphone with SDR dongle and adaptor is a cheap setup to accomplish this
- Requires practice and an understanding of polarity, power levels, and one to expose themselves
 - Amateur radio operators typically have field days where this is practiced.



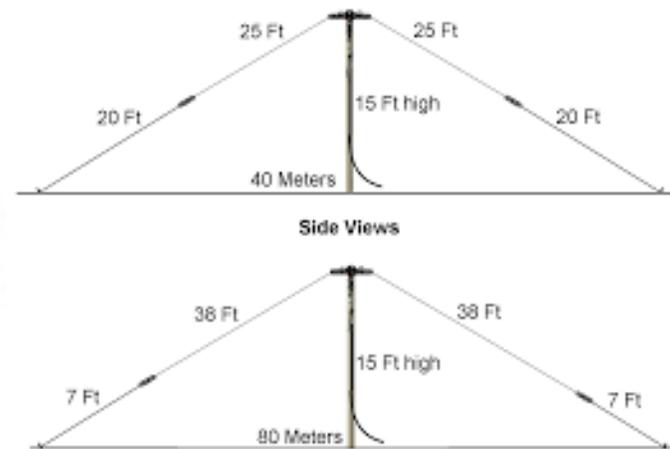
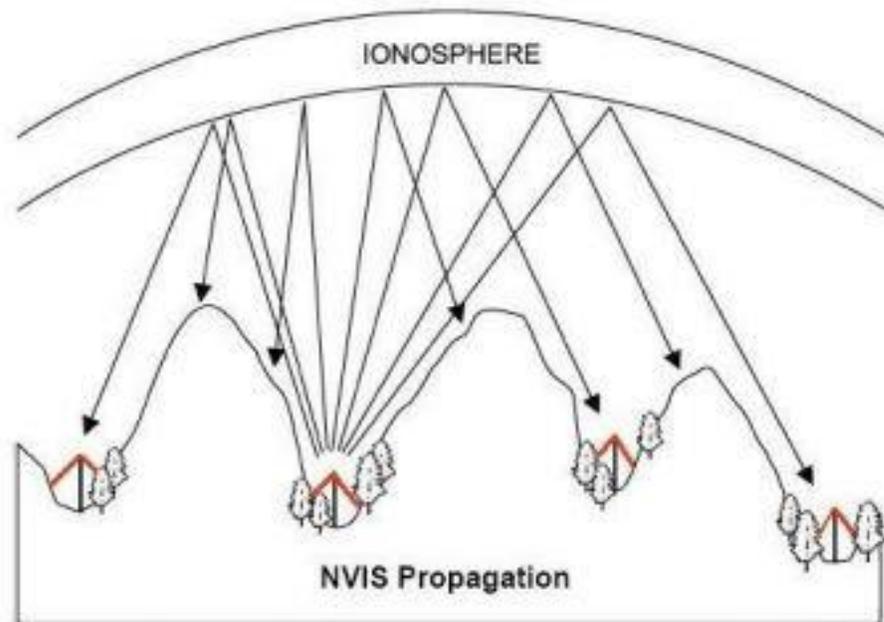
High Frequency (HF) – Operations and Uses

- High Frequency (HF) aka shortwave radio gives a powerful ability: Communication out of the region and across state/country boundaries.
- HF radios also have digital modes – encryption not possible right now
 - HF works well with morse code (CW) to be harder to find as the bandwidth is much smaller.
- Burst Data transmission modes (such as JS8Call, Winlink, etc.) allow data and emails to be sent without needing intermediate infrastructure.
 - However, to store messages to be sent out to users later it requires a node to exist
- HF radios use much different antenna setups which take up a lot of space.



HF Antennas – NVIS and Vertical

- Many HF antennas exist, but sometimes we only want to talk to people outside of our immediate area but not the entire region.
- 2 options exist: A Near Vertical Incident Skywave (NVIS) and vertical antenna (ground wave). NVIS allows for communication from a valley over mountains and is very hard to radio direction find especially without aircraft.



NVIS Dipole

**Vertical
Antenna**



HF - Portability

- HF Radios are not portable by design. However, many portable options now exist with the rise of amateur radio competitions.
- QRP style radios are low-power output, compact radios that often have built-in batteries and antenna tuners. Portable style NVIS antennas exist too.
 - Can be powered by solar cells and batteries – additional long-term capabilities
 - Tablet or Phone to run digital modes
 - Con: WEIGHT, expense, and volume (ideally a separate bag or kit to transport).

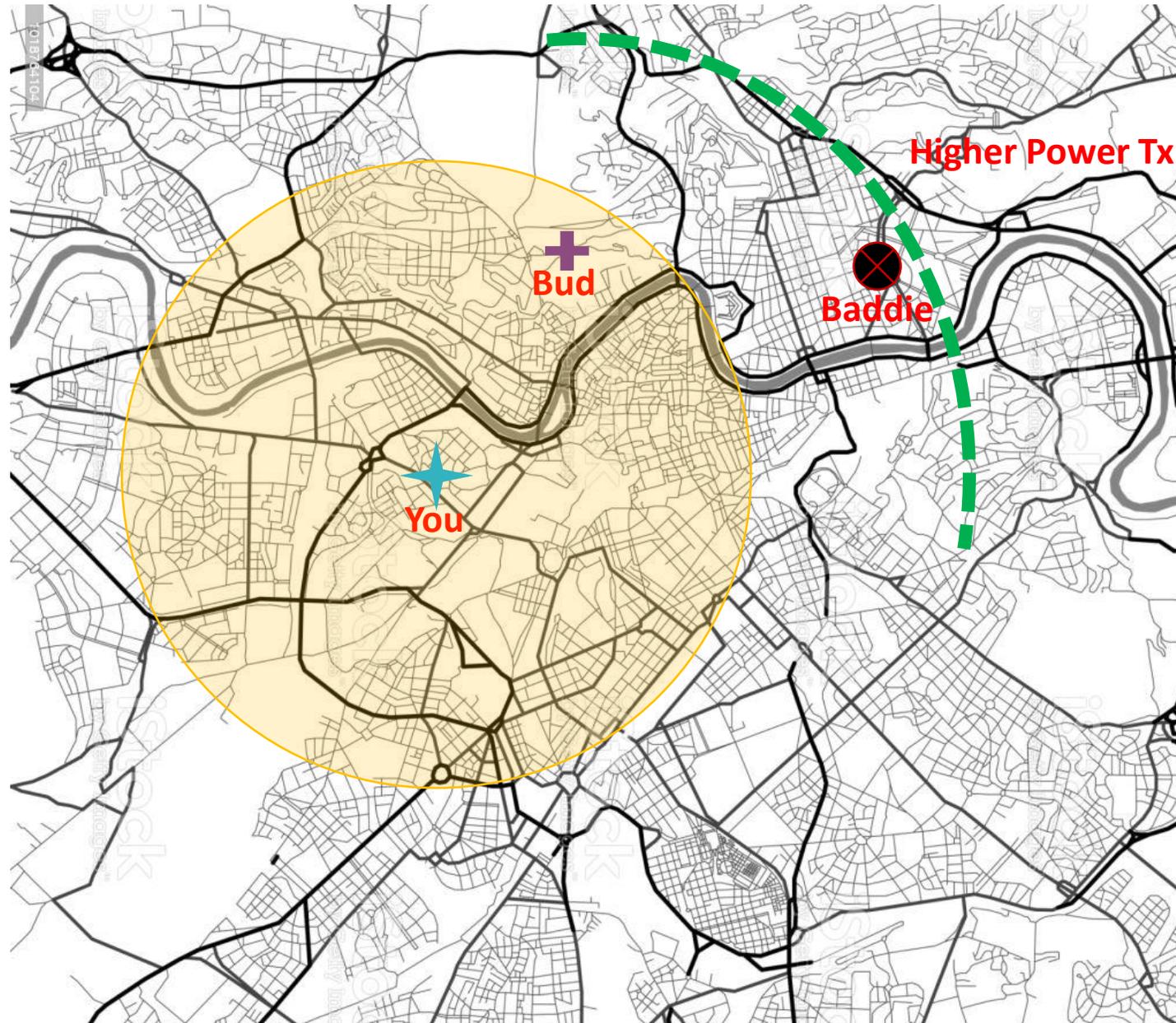


PACE PLAN - Comms

- Primary, Alternate, Contingency, Emergency
- As communications methods are compromised, whether by external forces or enemy interference, everyone must know what to turn to in-order to keep communications active.
- Cellphones should always be used as a last resort, and HF comms, even one-way, should be an Alternate or Contingency option (not everyone will have access and it is condition based)



Simplex Comms: Avoid detection via power



General Rules for Comms

- LISTEN before transmitting
- When transmitting, hit PTT button and wait at least a second before speaking
- -Be **CLEAR and CONCISE** - Know what you are going to say before transmitting
- Speak slowly and in natural phrases while enunciating each word
- Always use low-power when able and always assume someone you don't want is listening and can possibly direction find you
- Use the phonetic alphabet

Phonetic Alphabet

A – Alpha

B – Bravo

C – Charlie

D – Delta

E – Echo

F – Foxtrot

G – Golf

H – Hotel

I – India

J – Juliet

K – Kilo

L – Lima

M – Mike

N – November

O – Oscar

P – Papa

Q – Quebec

R – Romeo

S – Sierra

T – Tango

U – Uniform

V – Victor

W – Whiskey

X – X-Ray

Y – Yankee

Z – Zulu