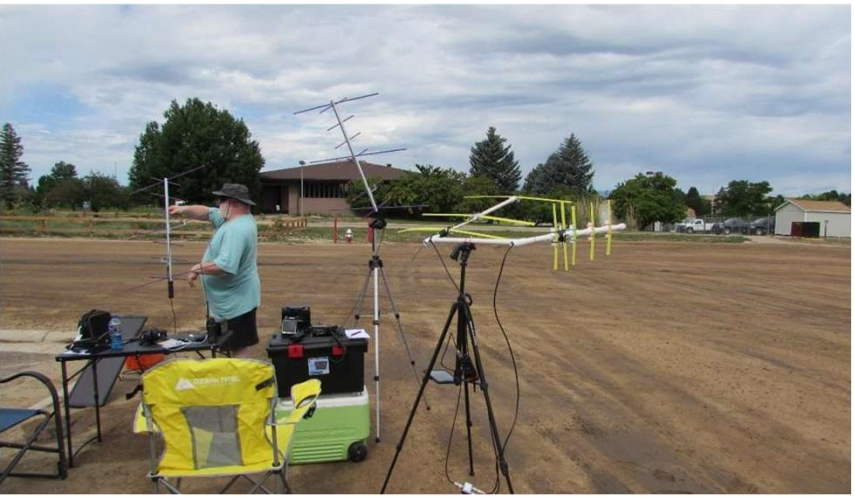


Satellite Communication on the "Cheap!"

(and much more…)

Chuck Poch - KØITP
Bryan Gonderinger - AFØW

November 20, 2019

Question

Would you like to make a QSO on a repeater that is 4 inches square, traveling 17,000 MPH, 1,400 miles away using just 5 watts?

- If the answer is "yes," today is your lucky day!
- If no, then take a nap...

Background

- We (Chuck (KØITP) and Bryan (AFØW)) had previously received SSTV transmissions from the ISS
- We were both interested in communicating via amateur radio satellites
- Chuck suggested we work together to learn the basics so we could later teach others in the club

“Learn by Doing”

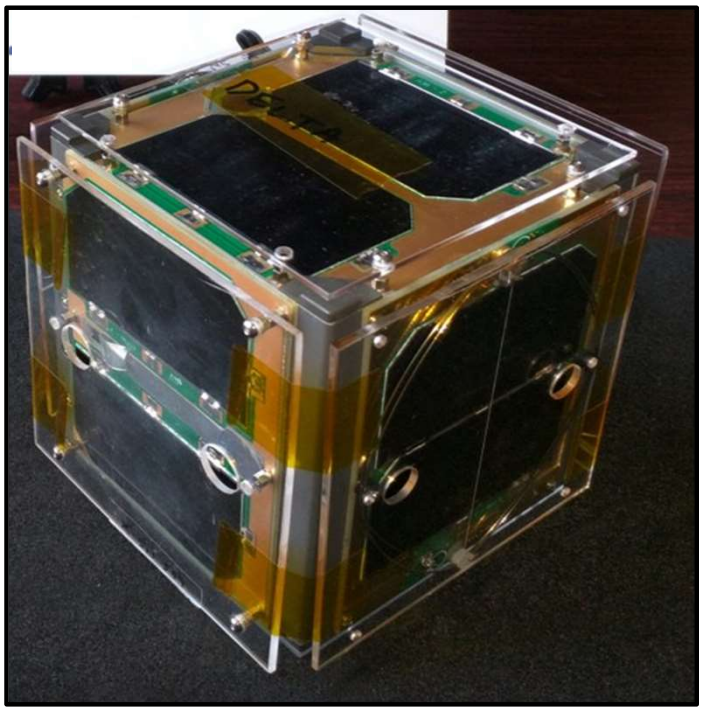
- We met on July 27th (a Saturday morning) behind the Clover Building to try it out
- Wanted to see what we could accomplish with minimal equipment and limited knowledge
- Primary goal was to be able to receive satellite voice communications

Satellites vs. Ground-Based Repeaters

- Biggest difference is that satellites are in motion
  - Tracking across the sky
    - Not visible all the time
    - Must point antenna
    - Doppler shift in frequencies
  - Tumbling / rotating
    - Must vary polarization of antenna for max signal

Fox-1D / AO-92

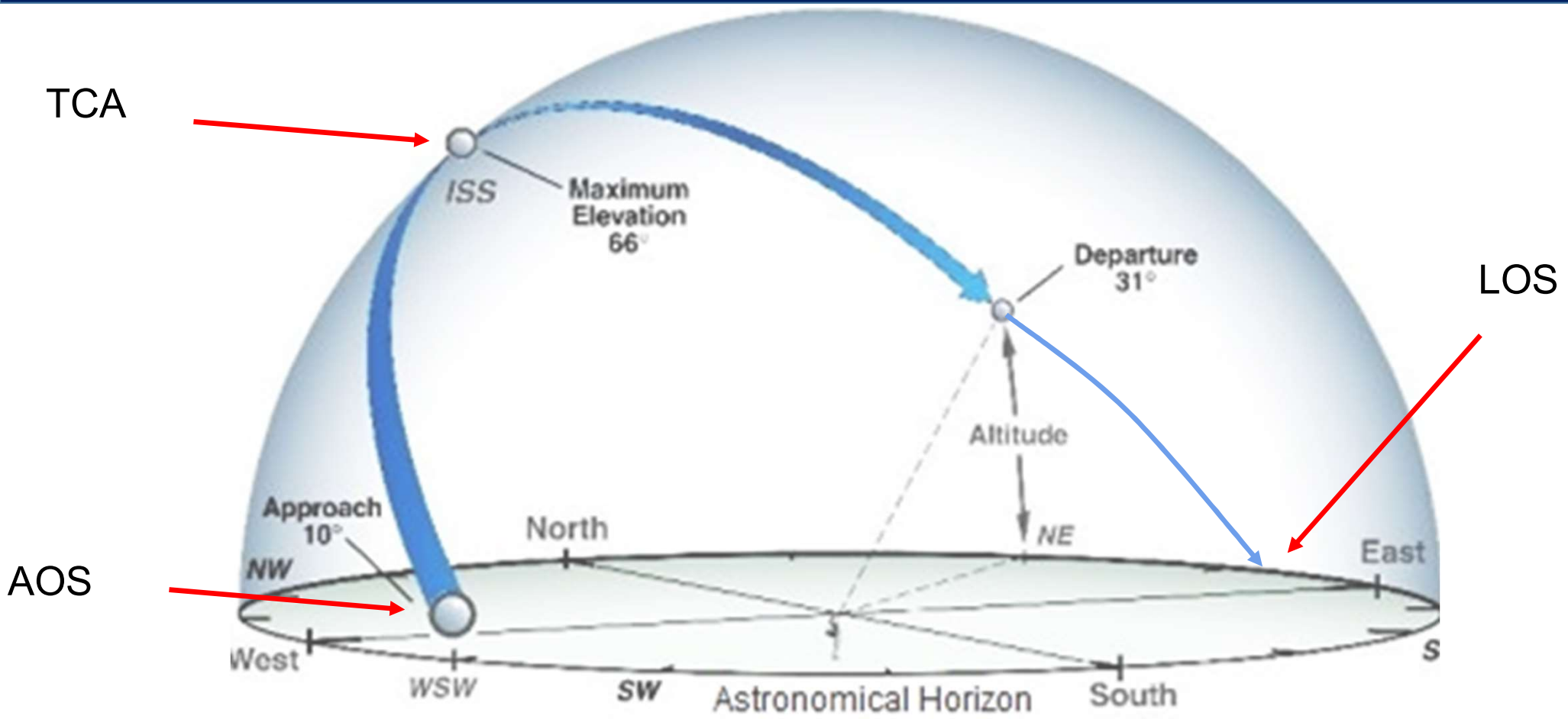
- 1U (10 cm / 4" cube), 1kg/2.2 lbs.
- Available for use Jan 2018
- 2m and 70cm whip antennas
- Power: Solar cells, NiCad battery
- 500 mW (!) EIRP



Satellite Terms

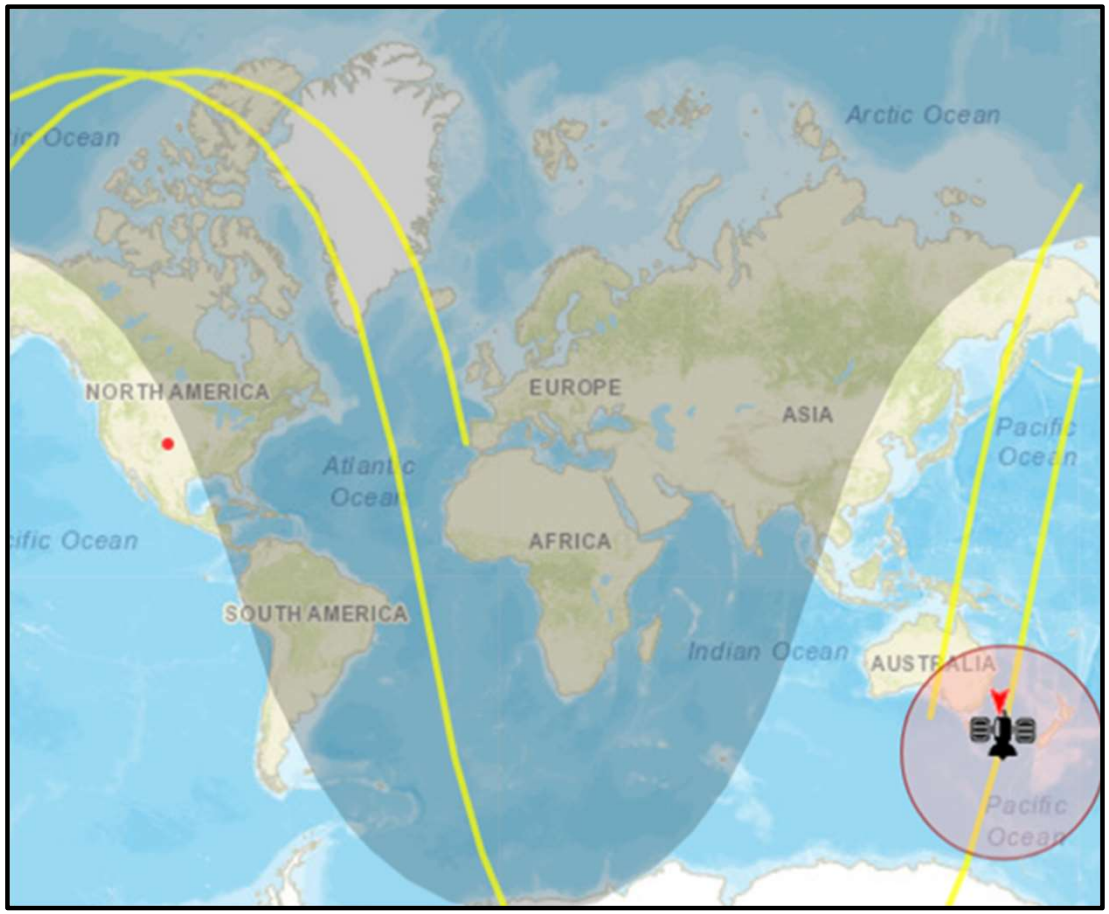
- **AOS: Acquisition of signal / satellite**
  Time when satellite rises above the horizon
- **TCA: Time of closest approach**
  Satellite closest to viewer, Doppler shift is 0
- **LOS: Loss of signal / satellite**
  Time when satellite sets below the horizon
- **Azimuth**
  Compass heading (horizontal plane)

Satellite Pass



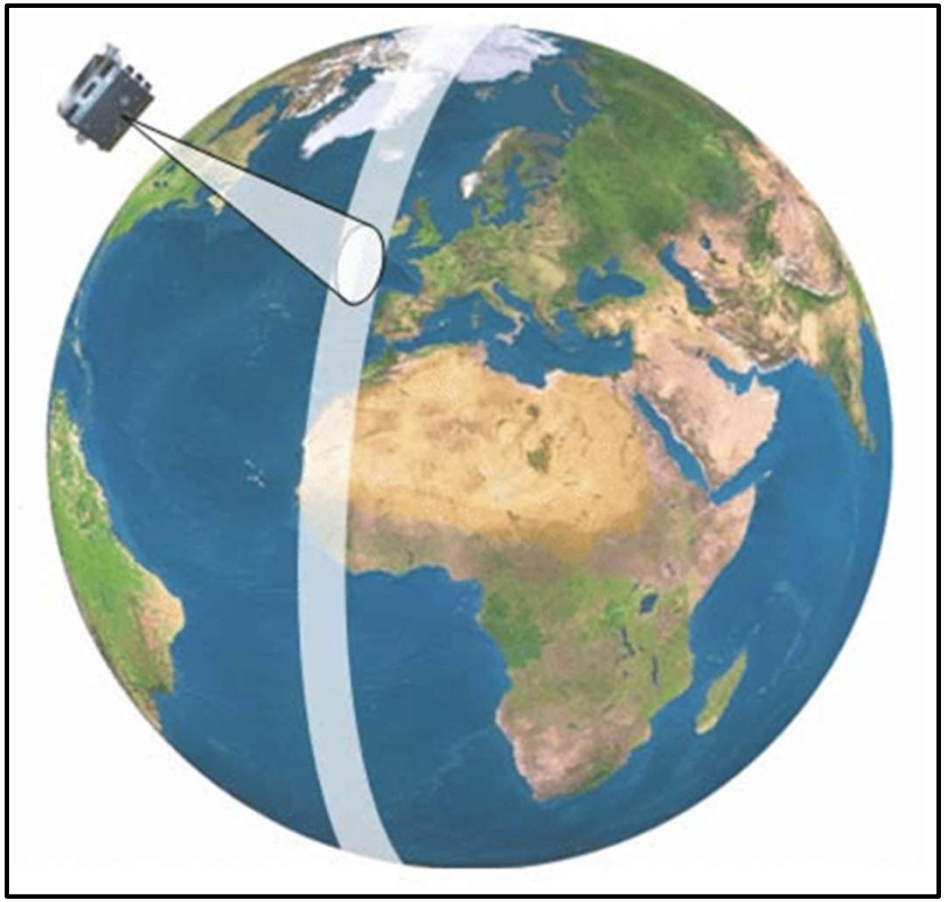
Satellite Terms

- Ground track
  - Path along Earth's surface where satellite passes directly overhead



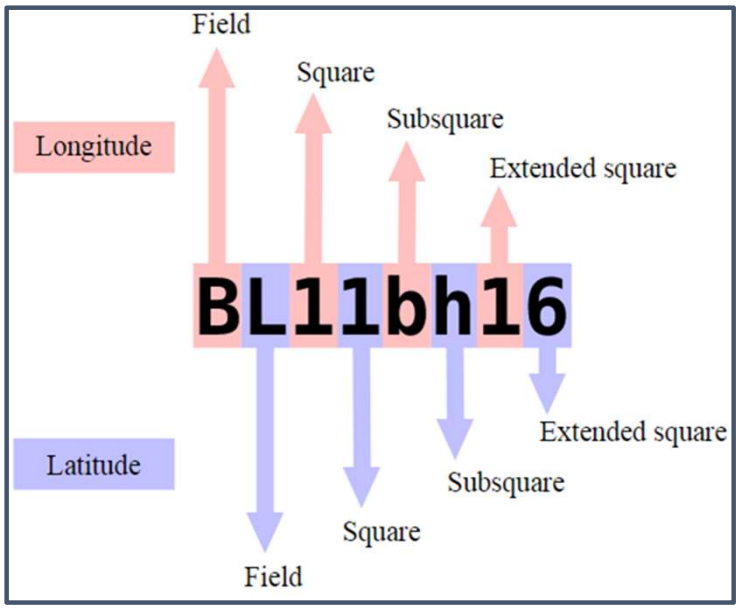
Satellite Terms

- Footprint
  - Ground coverage area of satellite's transceivers
  - Stations can communicate if simultaneously within footprint



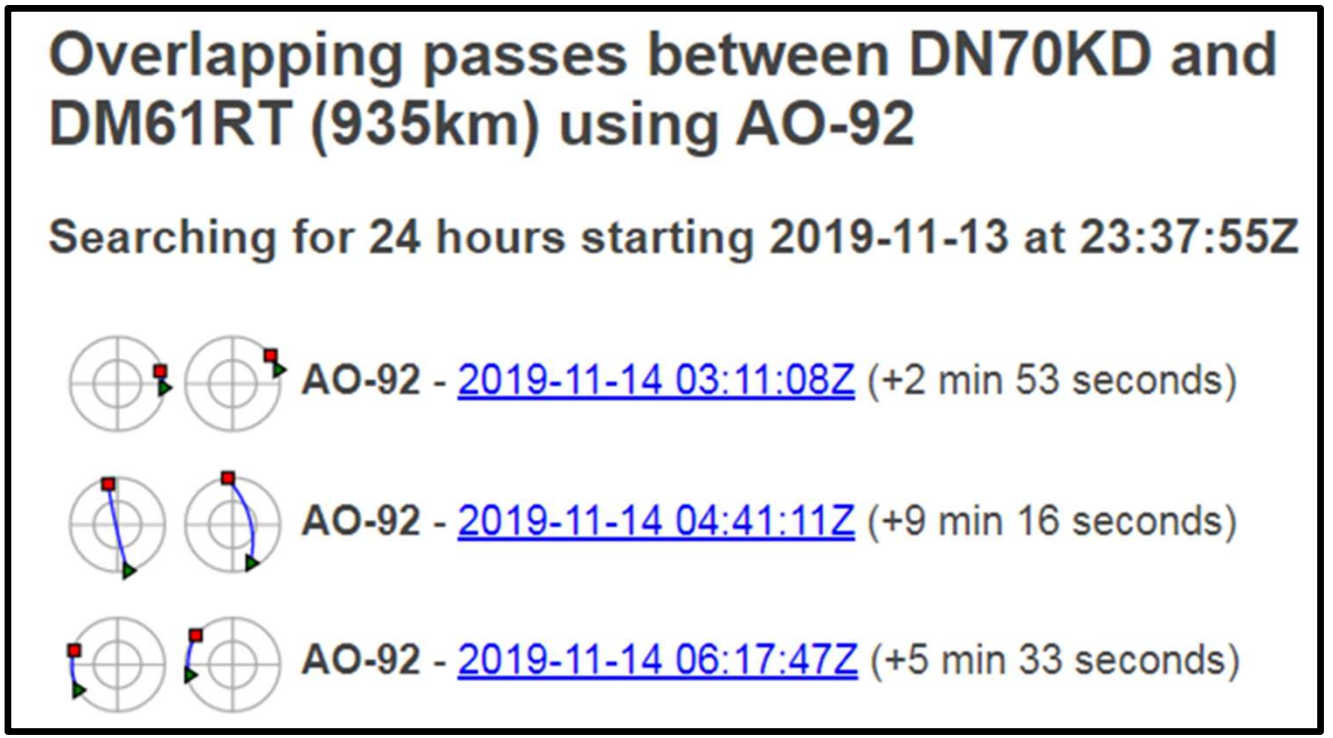
Grid Squares

- Maidenhead grid squares (grid squares) represent a position on the earth based on latitude and longitude



Satellite Terms

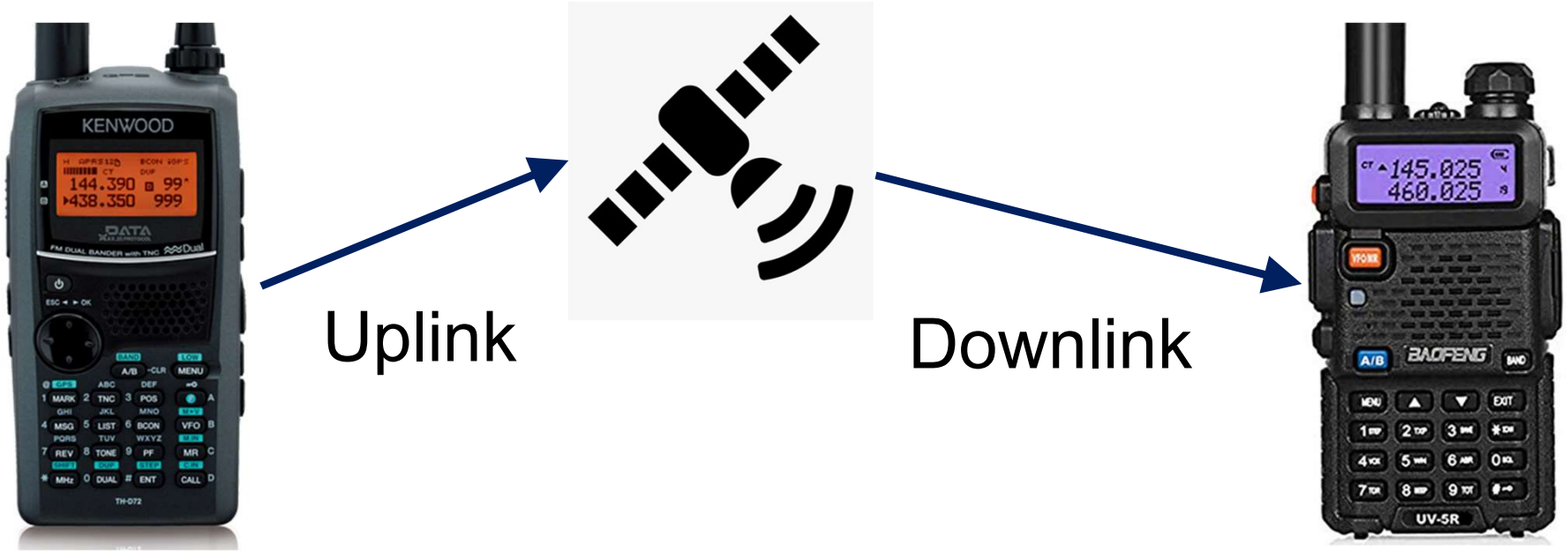
- Can select passes based on grid squares
- Note 2nd pass is much better than 1st and 3rd



https://www.satmatch.com/

Satellite Terms

- **Uplink:** Transmission from ground to satellite
- **Downlink:** Transmission from satellite to ground



Satellite Terms

- Doppler shift
  - Frequencies vary during pass due to motion of satellite

Band	Shift
2m	± 3 kHz
70cm	± 10 kHz

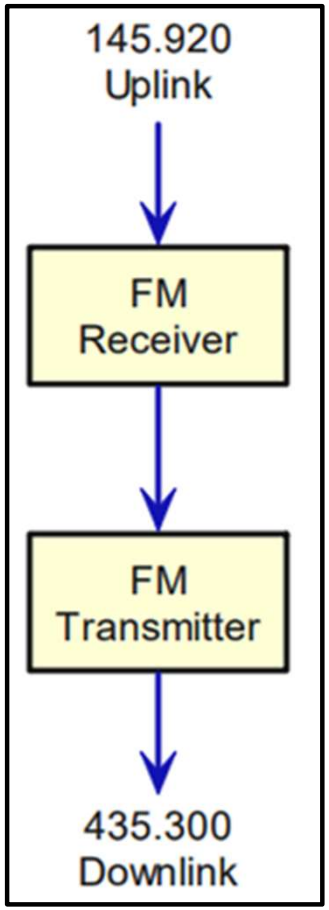
Satellite Terms

- Mode
  - U/V, V/U, L/V, etc.
  - Uplink / Downlink ***bands***, not modulation

Designator	Band	Frequency
V	**2 m**	**145 MHz**
U	**70 cm**	**435 MHz**
L	23 cm	1.2 GHz
S	13 cm	2.4 GHz
X	3 cm	10 GHz
K	1.2 cm	24 GHz
R	6 mm	47 GHz

Satellite Transponders

- FM Repeater
  - Single input frequency retransmitted on single output frequency
  - One QSO at a time
  - Can be worked with HT or mobile



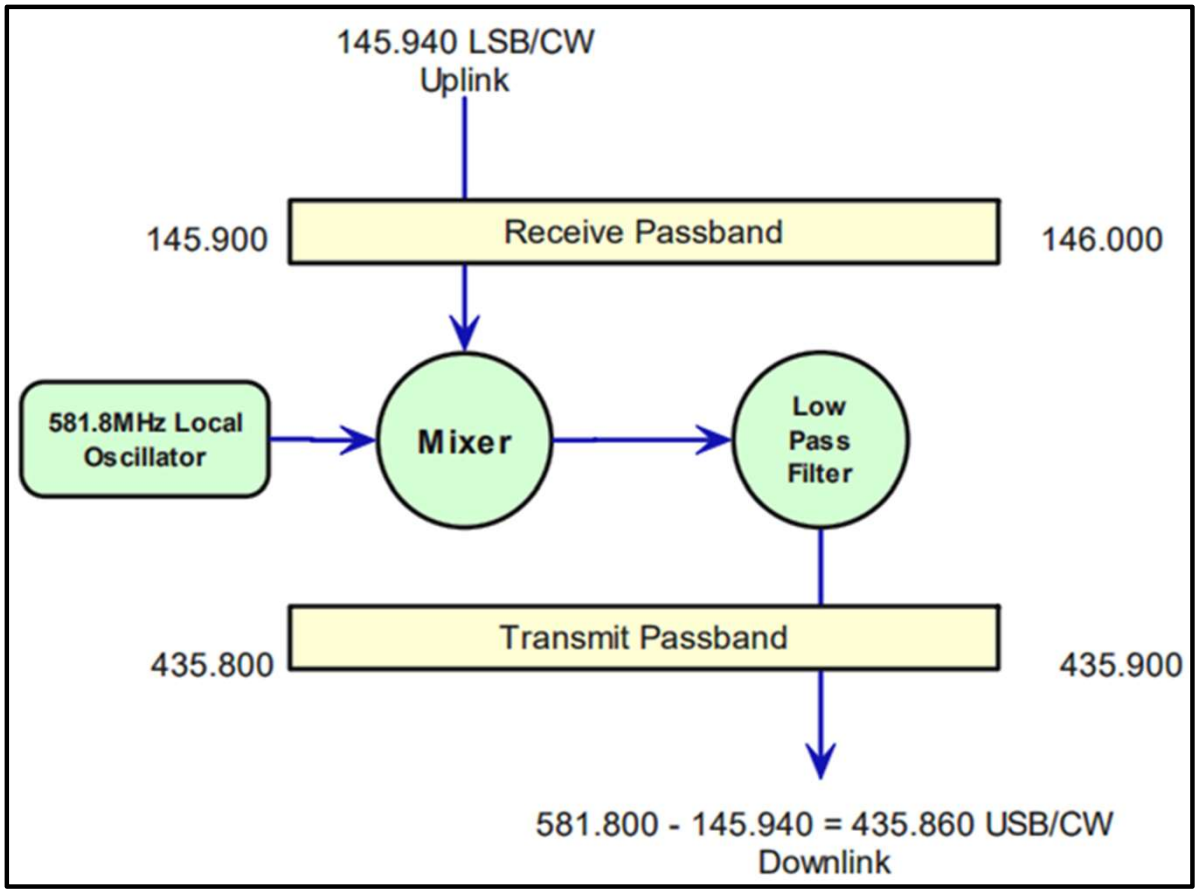
Satellite Transponders

- **SSB / CW**: Range of input frequencies retransmitted on range of output frequencies
  - Linear: TX goes up, RX goes up
  - Non-Linear: TX goes up, RX goes down
  - Inverting: Modulation not same (e.g. USB on TX, LSB on RX)
- Requires multi-mode radio
- Multiple simultaneous QSOs possible

Satellite Transponders

100 KHz wide V/U Inverting Transponder

- 145.94 LSB → 435.90 USB
- Signals have bandwidth
    - Leave space
- Output power proportional to input power
    - Use minimum power necessary

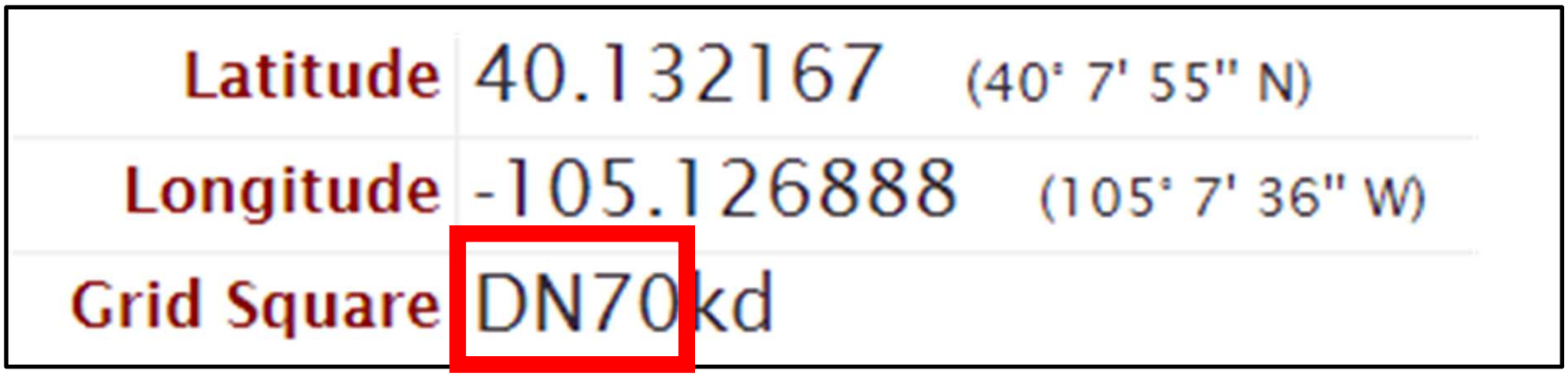


Preparation

- Find your grid square
- Determine satellite(s) you want to use
  - Your equipment
  - Capabilities (voice, data, telemetry, beacon)
  - Mode
  - Modulation
- Program frequencies into radio
- Obtain satellite pass information

Your Grid Square

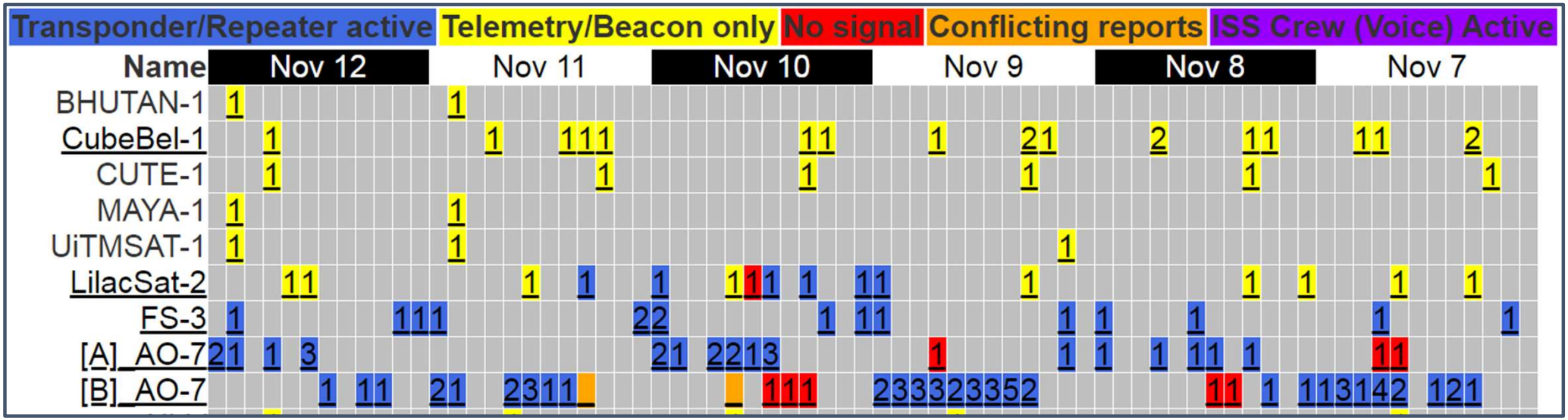
- Can lookup by address or call sign: https://www.levinecentral.com/ham/grid_square.php
- Also shown on your QRZ detail page



- Satellite and VHF contests usually use 4 characters

Satellite Selection

- Links at end of slides for apps / websites
- https://www.amsat.org/status/ to determine active satellites

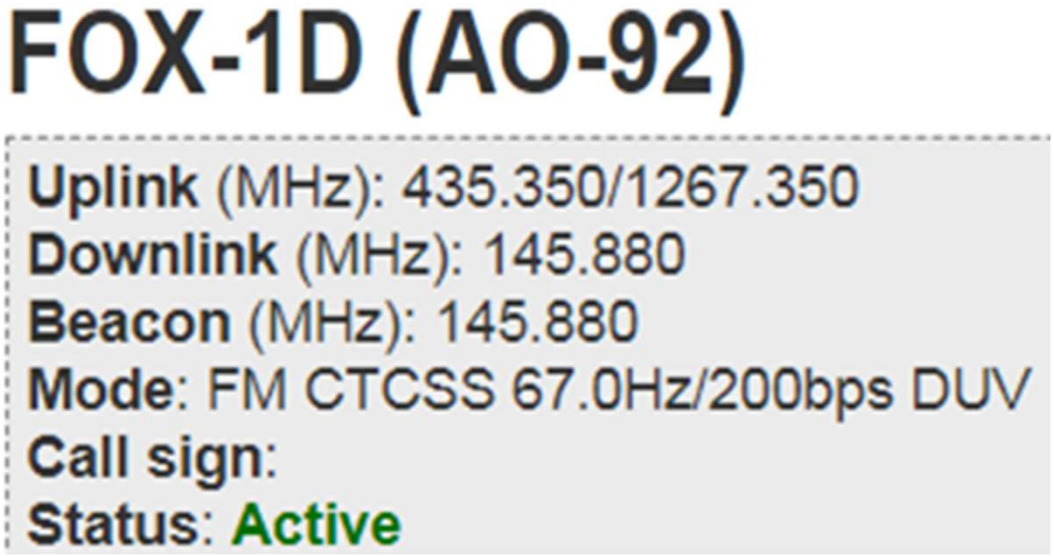


Satellite Selection

- Satellite detail pages to determine operating characteristics

https://www.n2yo.com/?s=25544

- **DUV: Data-under-voice** FSK data sent along with audio



Program Radio

- Use memories with Doppler-shifted frequencies

Memory	Name	TX Freq	TX Tone	RX Freq
911	AOS 2	435.240	67.0	145.960
912	AOS 1	435.245	67.0	145.960
913	**AO-91**	**435.250**	**67.0**	**145.960**
914	LOS 1	435.255	67.0	145.960
915	LOS 2	435.260	67.0	145.960

Pass Information

- Update Keplerian Elements ("keps" or "TLEs") if using software / app
- These numbers define an ellipse, orient it about the earth, and place the satellite on the ellipse at a particular time

```
FOX-1D (AO-92)
1 43137U 18004AC  19317.73217739  .00001006  00000-0  44859-4 0  9992
2 43137  97.4727  25.0949 0010903  96.6280 263.6199 15.23708351102036
```

Pass Information

Visible passes | AM/PM time | UTC | Print as PDF

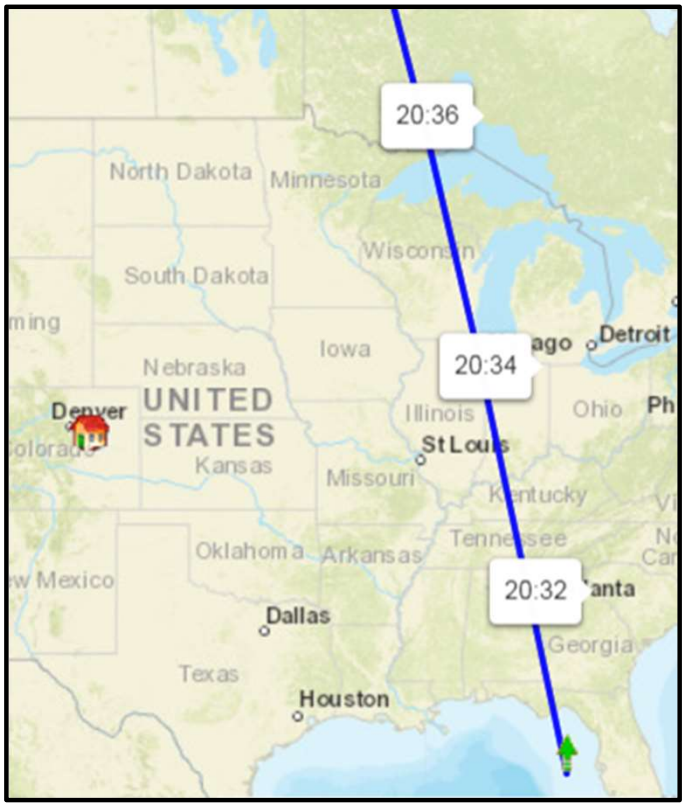
Start		Max altitude			End	
Date, Local time	Az	Local time	Az	El	Local time	Az
12-Nov 20:30	ESE 119°	20:34	ENE 67°	12°	20:39	N 13°
12-Nov 22:02	S 181°	22:08	W 261°	43°	22:13	NNW 341°
13-Nov 09:31	NE 32°	09:36	E 92°	15°	09:41	SSE 152°

Pass Information

Pass beginning	Max altitude	Pass ending
Date: 12-Nov 20:30:30	Date: 12-Nov 20:34:50	Date: 12-Nov 20:39:20
Az: 119.06° (ESE)	Az: 67.42° (ENE)	Az: 12.66° (N)
El (alt): 0.44°	El (alt): 11.75°	El (alt): 0.59°
Mag: -	Mag: -	Mag: -
Dist to sat: 2519.1 km	Dist to sat: 1577.8 km	Dist to sat: 2499.6 km
Eclipsed?: YES	Eclipsed? YES	Eclipsed? YES

Invisible pass

Add this pass on your notifications list



Equipment

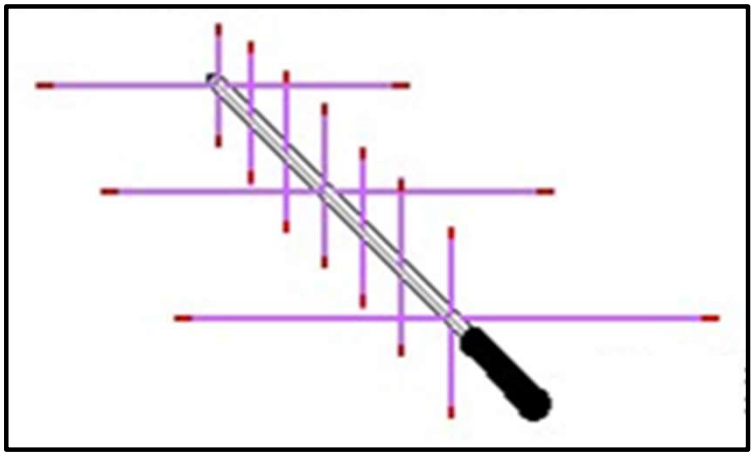
- Basic
  - Dual band (2m / 70cm) HT
- Recommended
  - Yagi antenna
  - Second radio (or duplex-capable radio)
  - Voice recorder
  - Headphones

Radio(s)

- Ideally want to be able to listen to your transmission to make sure you are getting into satellite
  - Requires either duplex-capable radio or a second radio
  - Must be true duplex radio, not "dual watch" (i.e. Baofeng)
- Mobile radios also work, but extra power is not needed for satellites (5 W is plenty!)

Antenna(s)

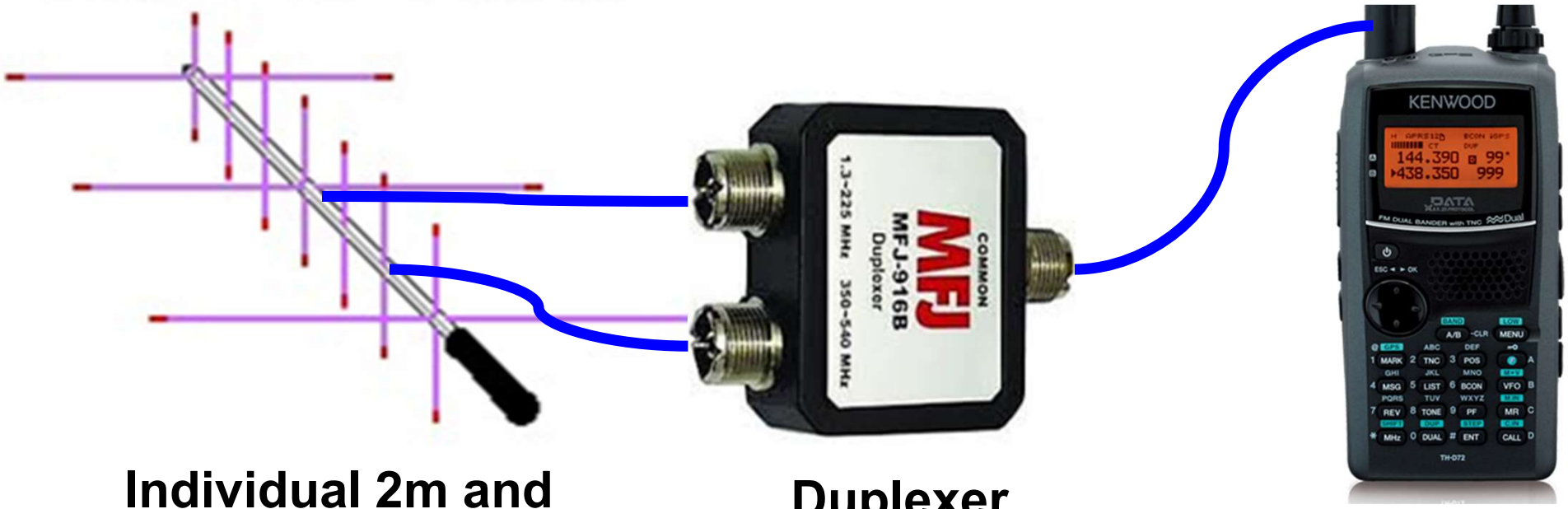
- Directional antenna better than omni-directional
- Have to be able to aim and rotate (polarization)
- Can build or buy!
  - Arrow Antennas -
    Arrow II Satellite Antenna
  - Elk Antennas -
    2M/440L5 Dual-Band Antenna
  - Tape Measure 2m / 70cm



Antenna(s)

Antenna(s)

- Depending on antenna and radio, may need duplexer to split (or join) antenna(s) to radio(s)



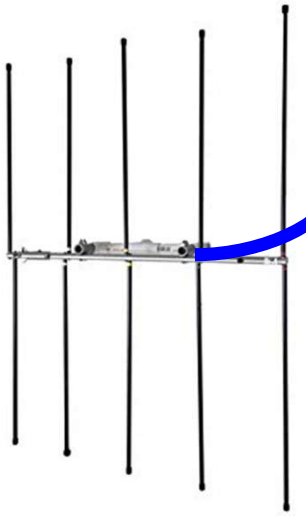
Individual 2m and 70cm Antennas

Duplexer

Full-Duplex HT

Antenna(s)

U/V Mode Satellite



Dual-band (2m / 70cm) Antenna

Duplexer

TX HT (UHF)

RX HT (VHF)

Voice Recorder (Optional)

- Passes are short and QSOs are quick!
  - Recording lets you focus on operating and log later
- Helpful if recorder interfaces to PC via USB
  - Faster to transfer audio
- May need splitter to direct audio to recorder and headphones

Voice Recorder (optional)

NOTE: Radio speaker jack may be 2.5mm, recorder is likely 3.5 mm

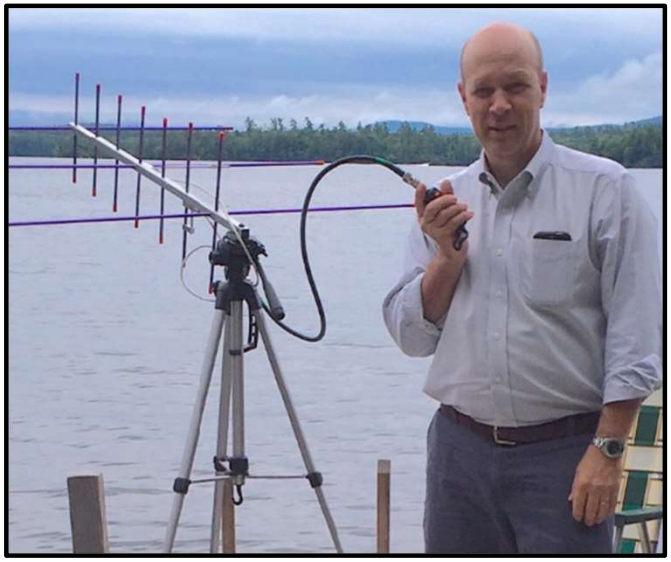
Voice Recorder (optional)

Headset (optional)

- When listening to your transmission on satellite downlink, don’t want to feed back into microphone
  - Headset will prevent this from happening
- Just need headphones (earbuds)
  - Can use radio mic for transmitting
- Sound isolation is good if in noisy surroundings
  - Can use earbuds under "ear muff“ hearing protectors

Satellite QSOs

- Due to short passes, usually just exchange call signs and grid squares
  - Don't transmit if you can't hear the satellite
  - Don't call CQ
  - No rag chewing
  - Some satellites require CTCSS tone to turn on repeater



Satellite QSO

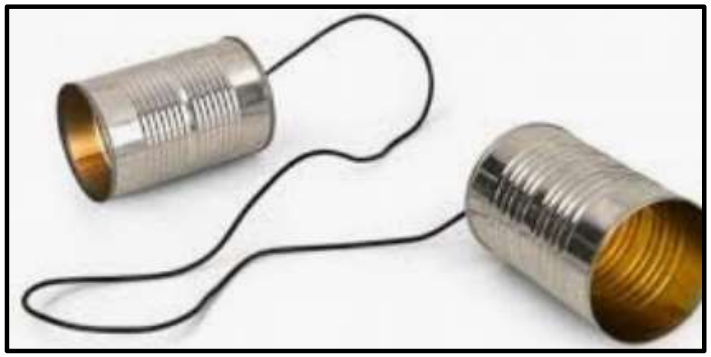
W6JW: “W6JW, DM04”

W1AW: “W6JW, this is W1AW, FN31, QSL?”

W6JW: “W1AW FN31,Thanks. Echo DM04, QSL?”

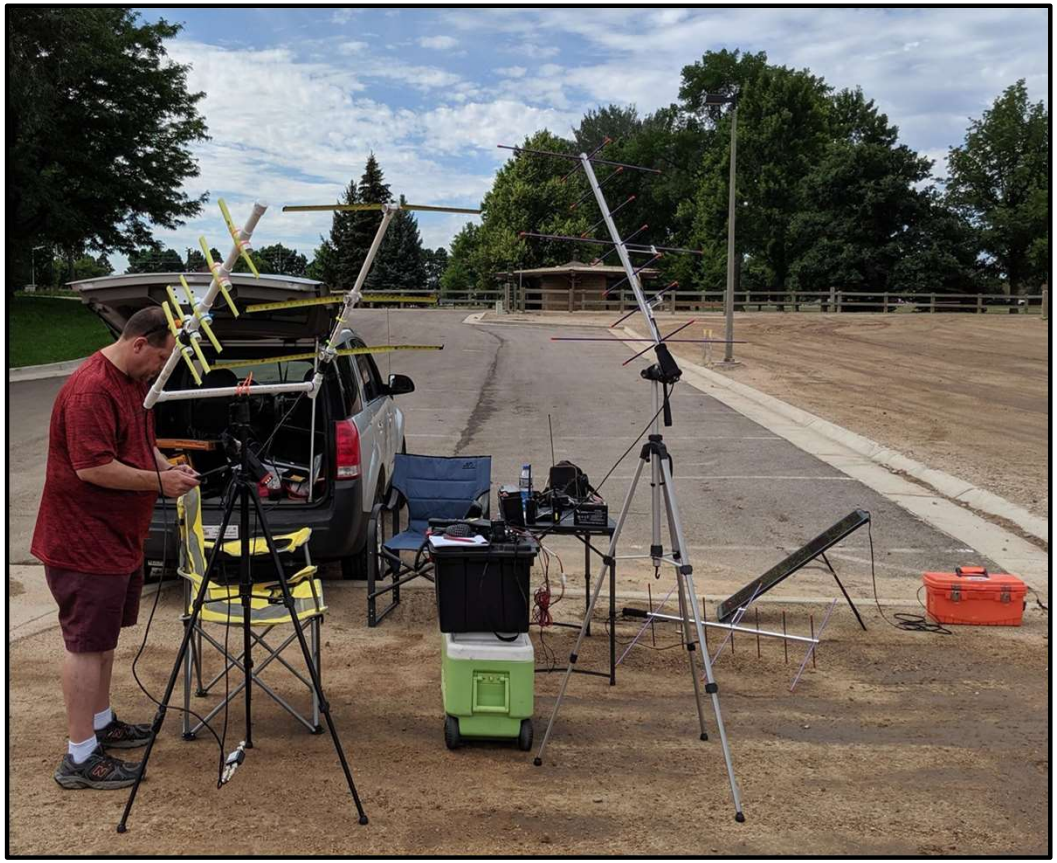
W1AW: “QSL DM04. Thank you, 73”

W6JW: “QSL, Thank you, 73”



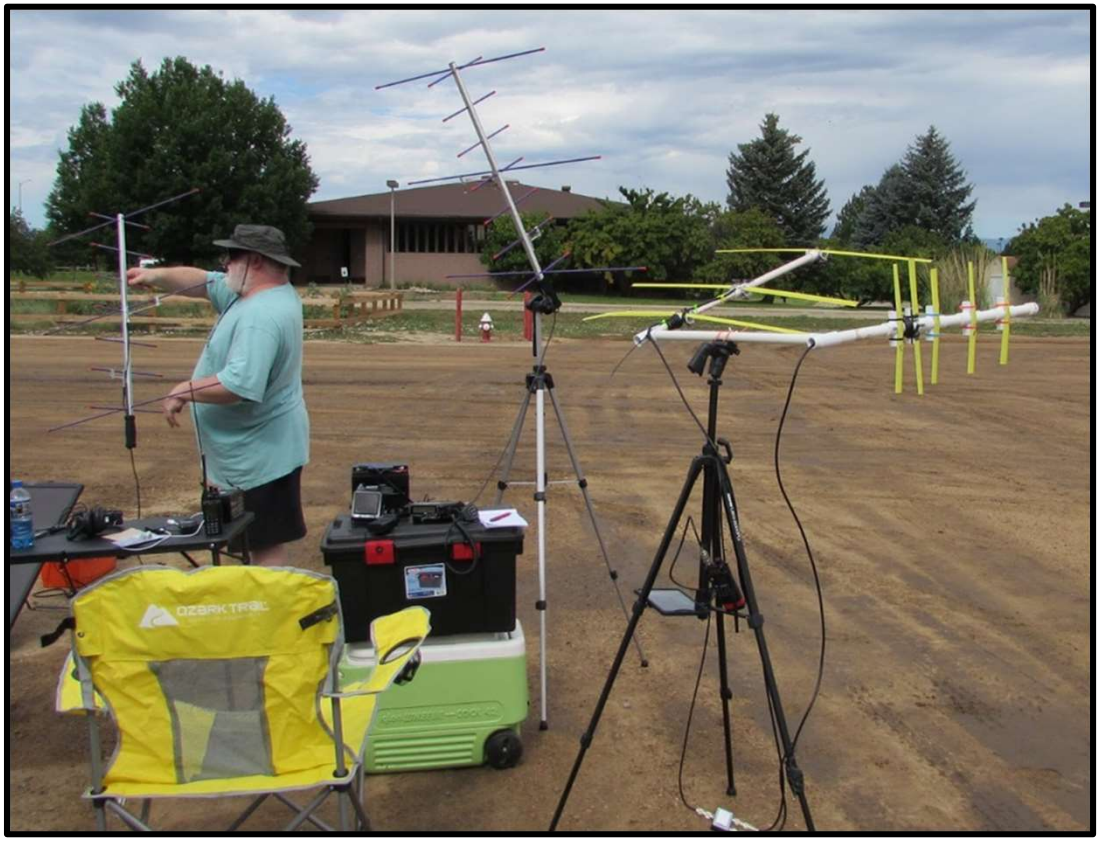
Equipment Used - Chuck

- TYT 7800 mobile with Arrow antenna (w/built-in duplexer)
- Baofeng HT with homemade Yagis & Antenna TW-720D duplexer



Equipment Used - Bryan

- Kenwood TH-D72A HT on handheld Arrow antenna (w/built-in duplexer)
- Voice recorder
- Headphones
- Camera bag for holding HT and recorder



Results

- Accomplished our goal - we heard several satellites:
  - NOAA 18 - Receive only
  - NOAA 15 - Receive only
  - SO-50 – Big pile-up

- Unfortunately, were not able to make any contacts this time

Lessons Learned

- Not as simple as making terrestrial repeater contacts!
- Improve list of satellites to track and hopefully make contacts
- Having a table was extremely helpful
- Bring shade or at least sunscreen (can still get sunburn with low sunspots!)
- Look for location with no obstructions to horizon

Next Steps…

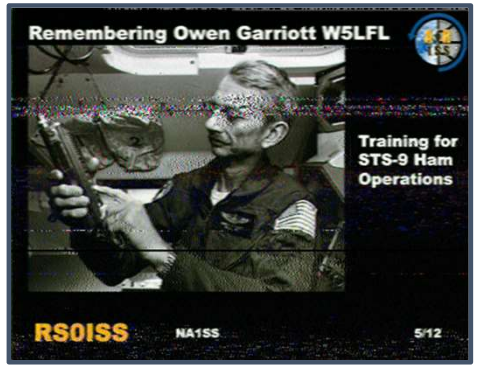
- Planning another event soon!
- Stay tuned to the LRAC website and emails for additional information
- People did show up and were curious about what we were doing...

  ...and also tried it!


WASHED

So What Else?

- Other activities using the same equipment
  - SSTV images from ISS (when available)
  - APRS with external TNC
  - Ham nets on terrestrial repeaters
  - Simplex with a friend
  - Take a walk in the mountains & make a QSO
  - Use for a “fox hunt”



Q & A

Any *(easy)* questions?

Thanks for listening!
Chuck Poch – KØITP
Bryan Gonderinger - AØFW

Youtube Videos

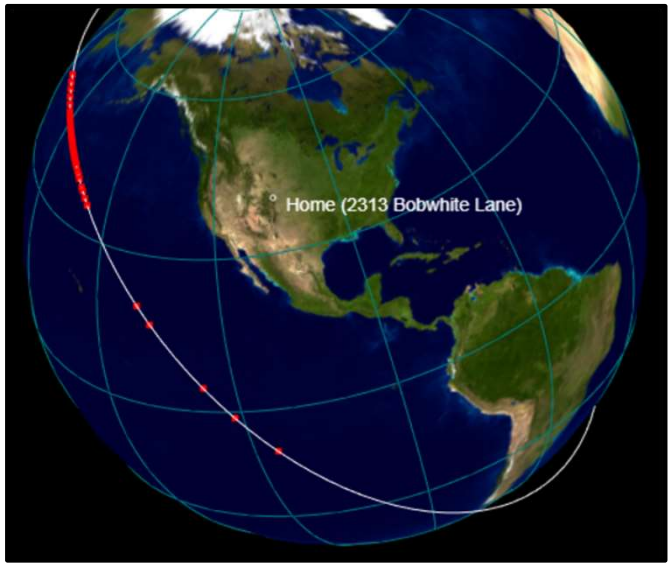
- SO-50 Satellite Contact
  - https://www.youtube.com/watch?v=YFVTtNk_f38
- Ultimate Guide to Working Ham Radio Satellites
  - https://youtu.be/aAE8NiJ6tGA
- The Story Behind the $50 SAT
  - https://www.youtube.com/watch?v=q00Fm-ij02M

General Satellite Communication Info

- https://www.amsat.org/introduction-to-working-amateur-satellites/
- https://www.onallbands.com/satellite-basics-part-1-guide-to-ham-radio-satellite-operating/
- https://www.onallbands.com/satellite-basics-part-2-making-qsos-via-satellite/
- http://w6jw.org/wp-content/uploads/2019/08/Ham-Radio-Satellites-N6JJ.pdf
- https://spacecomms.wordpress.com/satellite-setup-tips/
- https://makezine.com/2009/07/22/catching-satellites-on-ham-radio/
- Operating the Amateur Radio Satellites
  - https://slideplayer.com/slide/15394303/
- Getting Started with Satellites
  - https://slideplayer.com/slide/14408032/

Satellite Tracking

- https://www.n2yo.com/?s=25544
- http://amsat.org.ar/pass#top
- http://www.satview.org/
- https://www.heavens-above.com
- http://www.satflare.com/track.asp#TOP
- https://in-the-sky.org/satmap_worldmap.php
- https://en.wikipedia.org/wiki/List_of_satellite_pass_predictors
- https://www.amsat.org/amsat-new/tools/softwareArchive.php

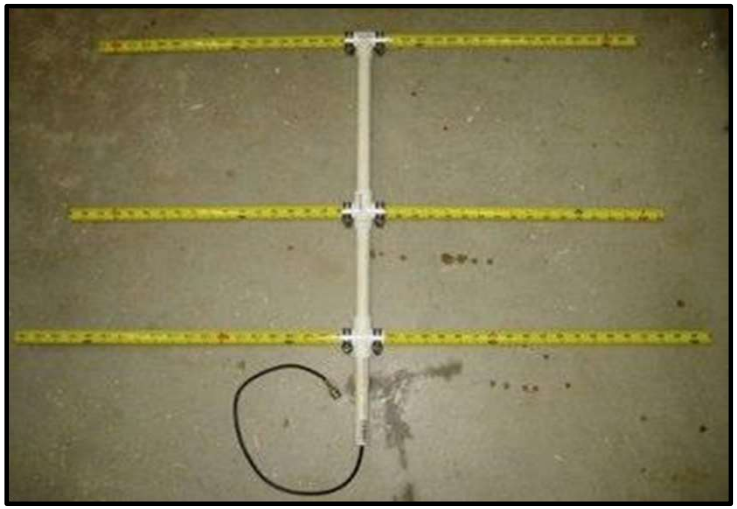


Satellite Rotator / Tracking Videos

- https://youtu.be/BDTjnJm41mc
- https://youtu.be/sIE0mcOGnms
- https://youtu.be/00SW1ExS2es
- https://youtu.be/HE09wMaTUpU
- https://youtu.be/K5Xx6K7tM0Y
- https://youtu.be/5p5XiZ_IA98

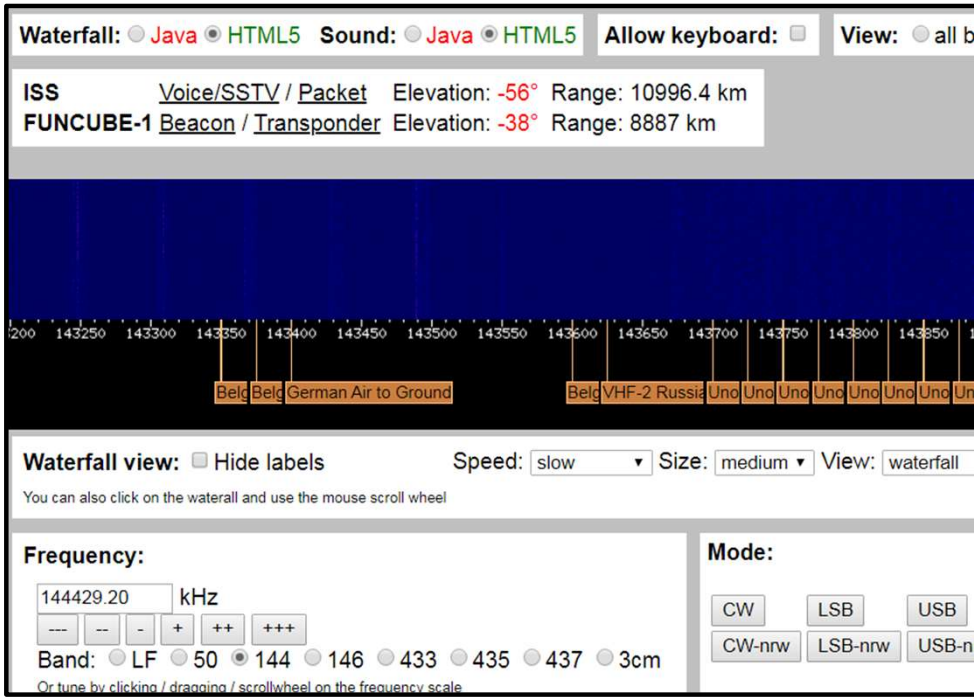
Antennas for Satellite Communication

- http://www.arrowantennas.com/arrowii/146-437.html
- https://elkantennas.com/product/dual-band-2m440l5-log-periodic-antenna/
- http://w6nbc.com/articles/2011-12QSTtapemeasure.pdf
- https://www.amsat.org/amsat/articles/w6shp/ant_tips.html
- https://www.rfwireless-world.com/calculators/3-element-Yagi-Antenna-Calculator.html
- http://w6nbc.com/articles/2011-12QSTtapemeasure.pdf



Web-Based SDRs for Satellite Reception

- https://vhf-goonhilly.batc.org.uk/
- https://eshail.batc.org.uk/nb/
- http://farnham-sdr.com/



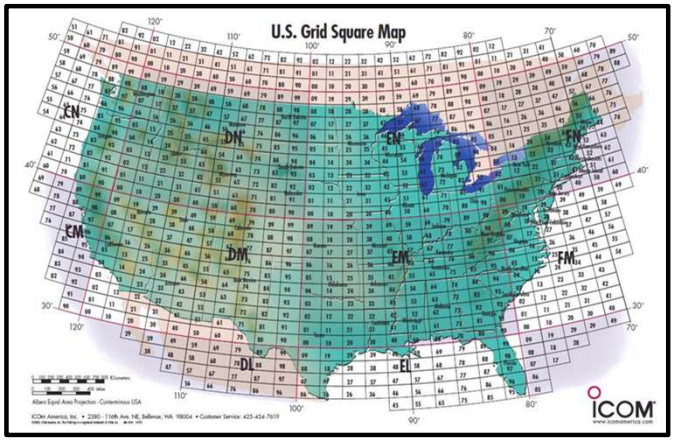
Keplerian Elements / TLEs

- TLE format description
  https://www.celestrak.com/NORAD/documentation/tle-fmt.php
- TLE/Keplerian Element Resources
  https://www.amsat.org/keplerian-elements-resources/
- Keplerian Elements
  https://marine.rutgers.edu/cool/education/class/paul/orbits.html
- NORAD TLE Current Data
  https://www.celestrak.com/NORAD/elements/

Johannes Kepler

Maidenhead Grid Squares

- VHF Grid Locators
  http://www.k0nr.com/wordpress/my-articles/vhf-grids/
- Grid Squares
  http://www.arrl.org/grid-squares
- Maidenhead Locator System
  https://en.wikipedia.org/wiki/Maidenhead_Locator_System
- GridMaster Map
  https://ke4al.wordpress.com/2018/06/29/new-and-improved-gridmaster-map/
- Satellite Grid Maps
  https://www.papays.com/sat/gridmaps/gridmaps.html



Misc Satellite-Related Sites

- School Amateur Radio Club Projects (antenna rotator) https://www.sarcnet.org/projects.html
- FoxTelem Software (Fox satellite telemetry decoder) https://www.amsat.org/foxtelem-software-for-windows-m
- ARISS (Amateur Radio on the ISS) https://www.ariss.org/

Full Duplex-Capable HTs

- Kenwood TH-D7A, TH-D72A, TH-D78, TH-D79
- Wouxon 8D Plus / 9D Plus (not for SO-50)
  - https://youtu.be/vljeh4tv-i0
- Alinco DJ-580
- ICOM IC-W2a, IC-W31a, IC-W32a
- Yaesu FT-470, FT-51, FT-530

Full Duplex-Capable Mobiles

- Kenwood TM-D710GA, TM-V71A
- Yaesu FT-8800, FT-8900
- ICOM IC-2730A

The End