Build a Satellite ‘Roving’ Station for Your Next Road Trip or POTA Activation!

Preparing for a satellite pass along a dusty road in Grasslands National Park, Saskatchewan, Canada, July 2023 (gridsquare DN69)

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Presentation available at:
https://www.deloach.net/Satellite/

AMATEUR RADIO IN SPACE
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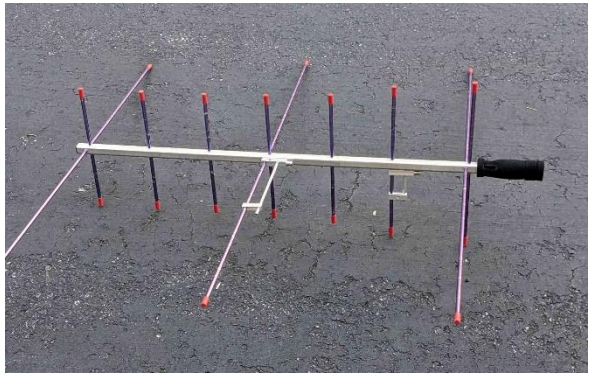
Introduction

- Add some extra fun to your next road trip or POTA activation by bringing along a simple ‘roving’ satellite station!
- A portable satellite station is easy to assemble
  - Two simple V/UHF FM rigs (or one dual-channel rig) and a small antenna does the trick!
- Apps & web sites make satellite operation easy

Two FM rigs – one for transmit and one for receive – or one dual channel FM is all you need!



The 2-meter/70-cm “Arrow” antenna is popular for satellite.

Presentation Topics

- In this presentation, I will:
  - Show you how to put together a simple yet capable portable FM satellite kit
  - Explain how to use apps and web sites to easily predict when and how satellite passes will occur
  - Describe the basics of satellite operation
  - Reveal how to make sure other operators know to look for you when you are in that rare Maidenhead gridsquare!
  - Provide links to helpful information

“Radio Amateur Satellite Corporation” (“AMSAT”)

- AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.
- Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage – (HEO/GTO/GEO activities – under development as part of the GOLF program), to continue active participation in human space missions – (ARISS, AREX on Lunar Gateway), and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups – (Fox-1 program, Fox-1 linear transponder communications module for student-led cubesat programs).
- Help keep Amateur Radio in space by joining AMSAT now at https://launch.amsat.org/ !

Simple FM
Mobile Satellite Stations

Types of ‘Two-Way’ Satellites

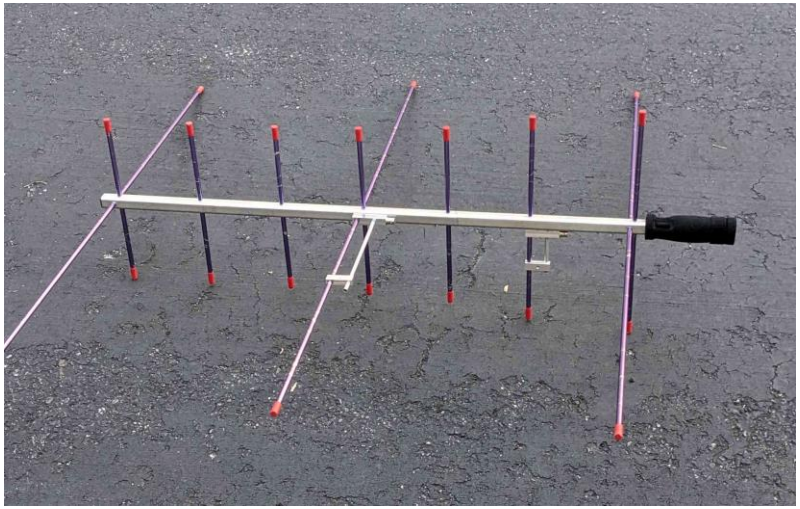
There are three basic types of satellites for QSOs:

- **FM Satellites** are flying FM crossband repeaters
  - Receive on 2m / retransmit on 70cm, or vice versa – may use CTCSS
  - **FM satellites will be the primary focus of this presentation**
- **Transponder Satellites** linearly retransmit all signals received within a passband
  - More capable, but more sophisticated equipment needed
- **Digital Satellites** “digipeat” received digital signals

Beacons, telemetry, images, videos, etc. are also transmitted by satellites and can be received

The Mobile Satellite Antenna

- Every station begins and ends with its antenna!
- Most hams leave the rotor at home and use a handheld antenna
  - Either homemade or one of these popular commercial models:



Arrow II antenna (arrowantennas.com). The 2m & 70cm Yagis can be fed separately using two coaxial cables or fed using a duplexer with a single cable.

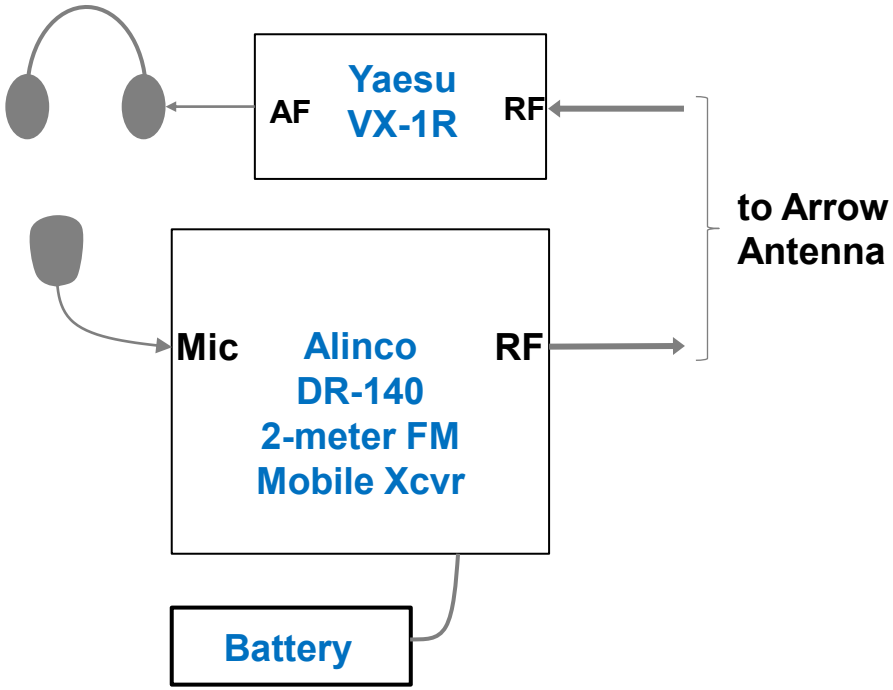
The Elk (elkantennas.com/) 2M/440L5 log periodic antenna is fed from a single coaxial cable – an advantage in some circumstances.

Basic Station Using Two FM Rigs

This was my first satellite station in 2010

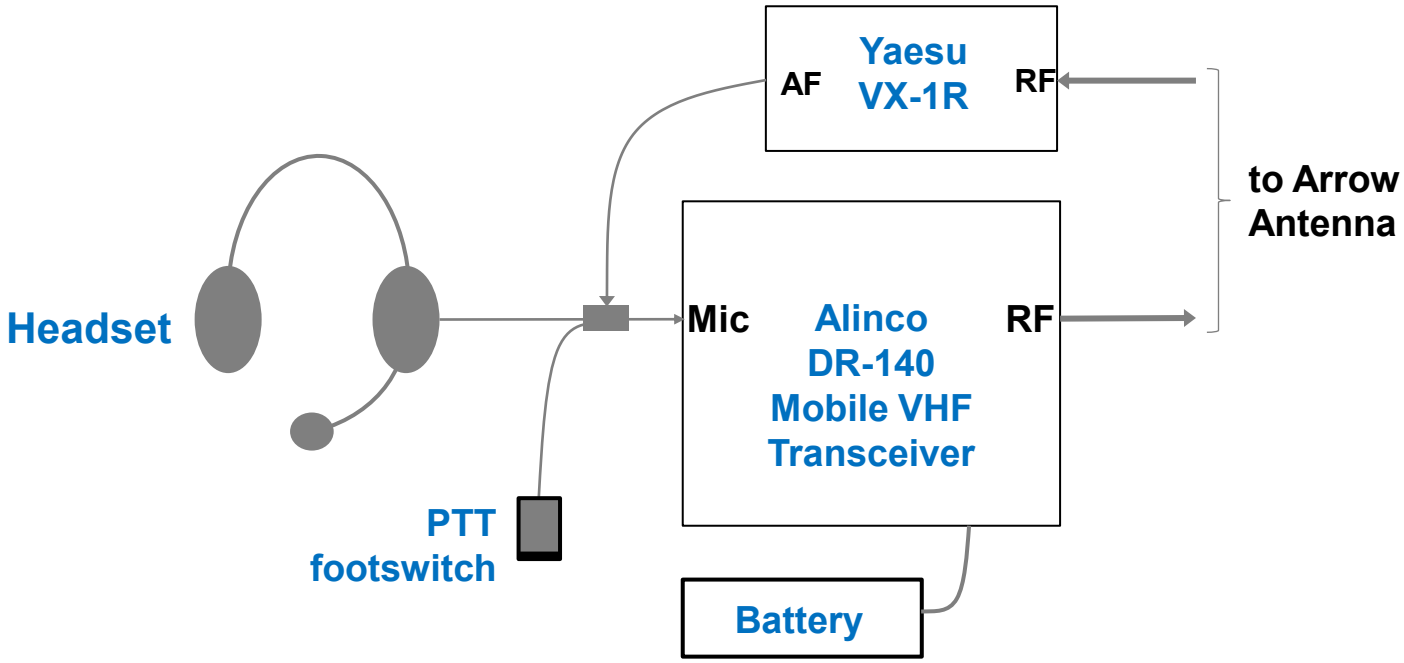
- Used FM gear I had laying around
- Tuned the VFOs on the two rigs manually, which worked fine
- Worked 4 continents with this simple setup!

ET3AA club members making satellite QSOs using this kit. Photo by Maggie DeLoach, KK6DZS.



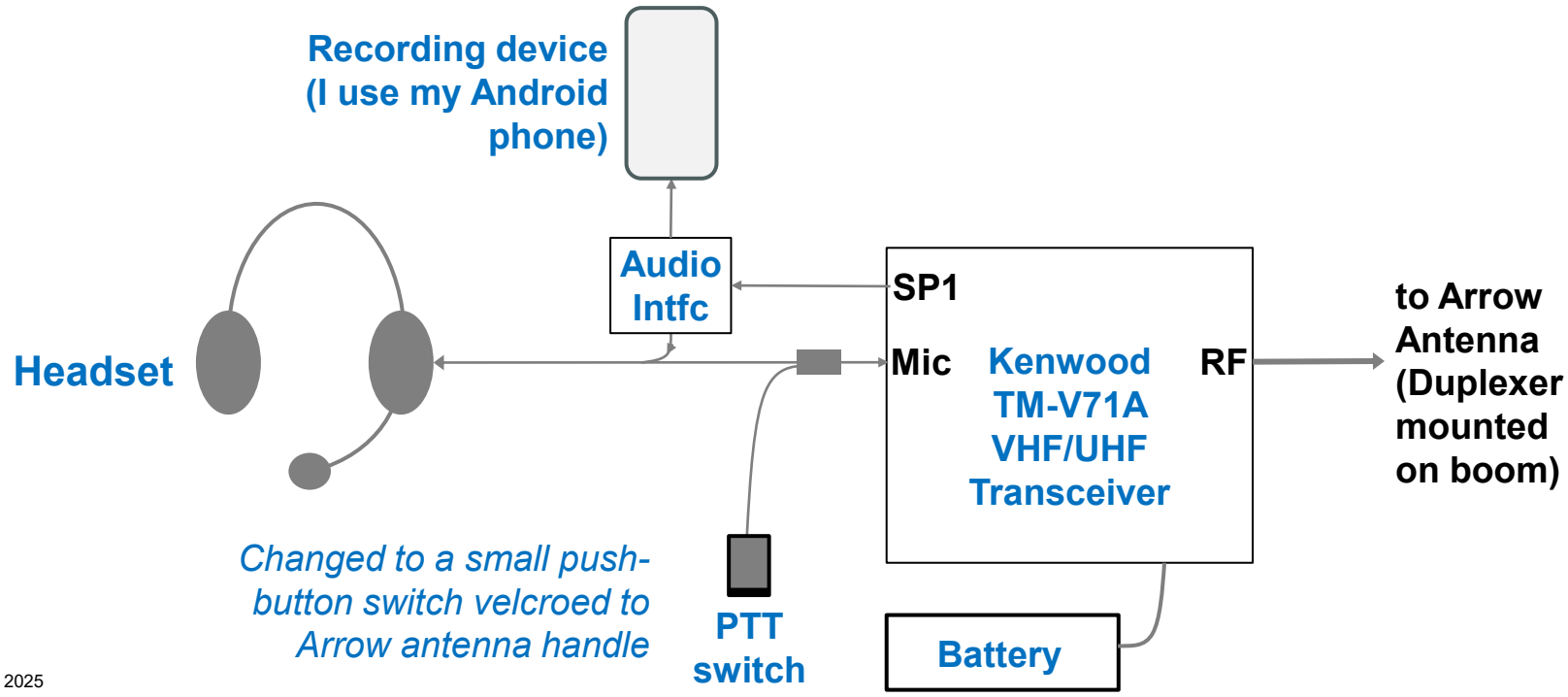
Added a Headset with Footswitch

- Pretty quickly I realized that I needed to free up a hand to log, so I added a headset with mic and a footswitch
- To key the rig, three solutions are common:
  - Place a small PTT switch on the antenna handle
  - Use a PTT footswitch
  - Use VOX



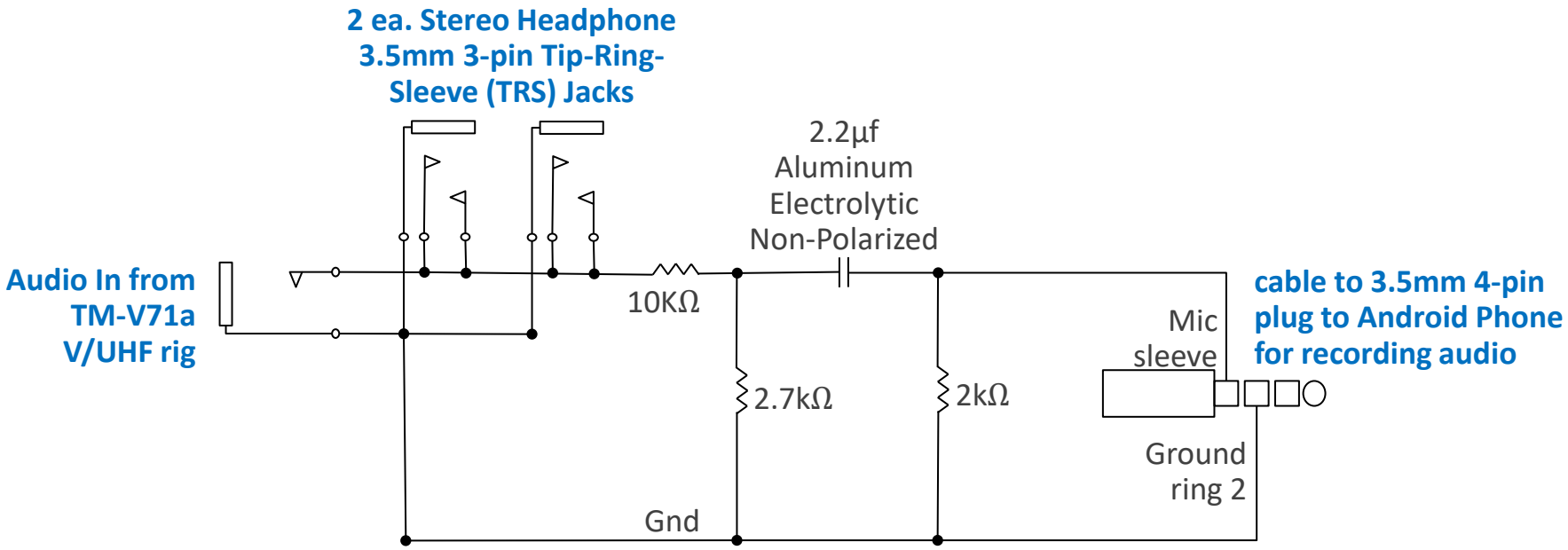
Setup Using a Dual-Channel FM Rig

- If you have a rig capable of simultaneously transmitting FM on one V/UHF band while receiving on another, you have an even simpler solution
  - My current FM kit shown here uses the popular Kenwood TM-V71A 2m/70cm rig
- I added an audio interface circuit to enable recording downlink audio – *super helpful when resolving logging questions after the pass is complete*



My Recording Audio Interface Circuitry

- Audio from my TM-V71A directly feeds one or two headphones
- Then, a simple passive resister network & DC blocking capacitor attenuates and isolates the recording signal while presenting a reasonably consistent impedance across audio frequencies



Kit Packaging

- Rig, battery, audio circuitry, all interconnections, and all cables mount in a satchel

Satellite Operation

Understanding Doppler Effect

- Like the pitch of a train's horn, both your 'uplink' transmission to the satellite and the satellite's 'downlink' transmission to you experience "***Doppler Effect***"
  - Positive relative speed (sat moving towards you) shifts signals ***higher***
  - Negative relative speed (sat moving away from you), shifts signals ***lower***
- Higher frequencies have MORE Doppler shift

A train's horn traveling towards you sounds higher – this is the "Doppler Effect"

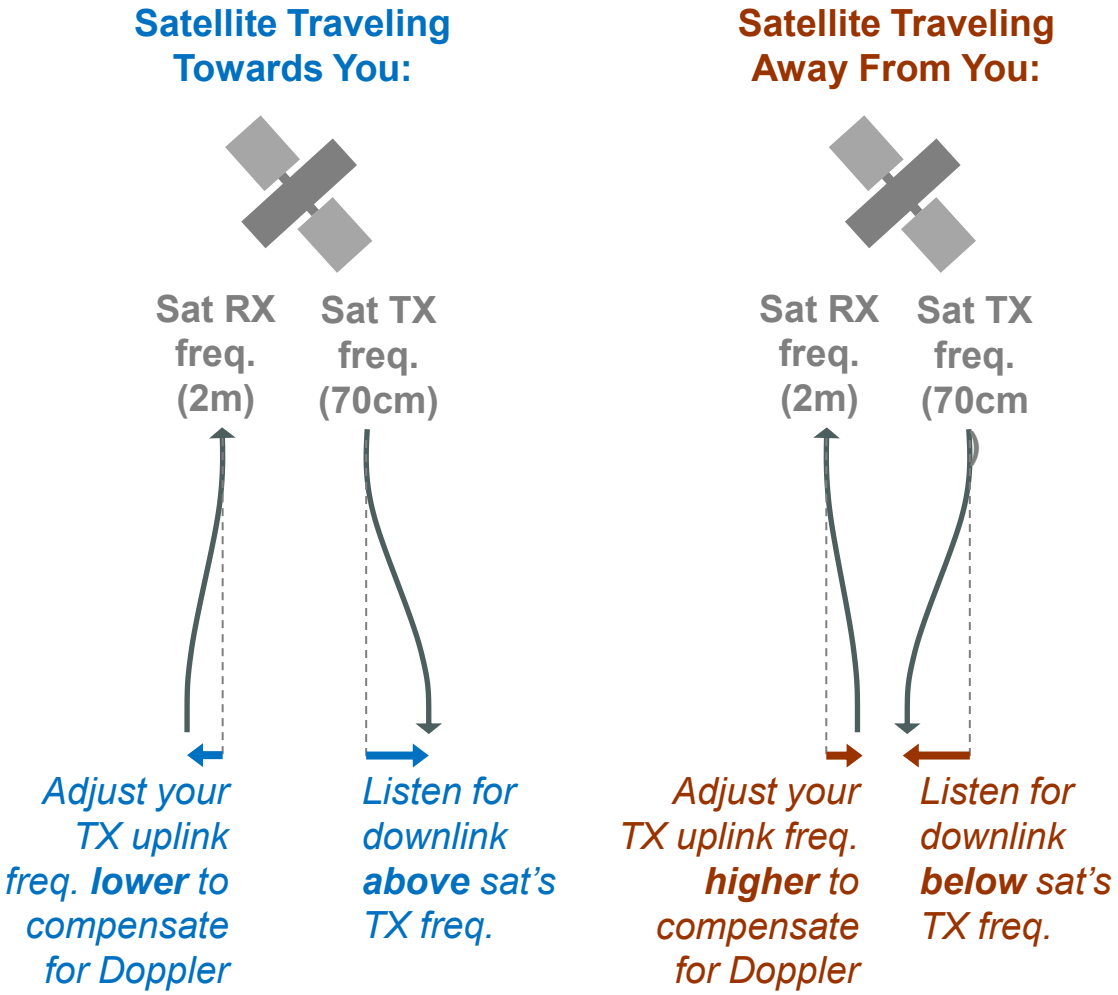
A train's horn traveling away from you sounds lower

For a satellite:

$$\textit{Doppler Shift}\ (\text{kHz}) = \frac{\text{Relative Speed (m/s)}}{\text{Speed of Light: } 3*10^8\ \text{m/s}} \text{ Emitted Freq. (kHz)}$$

Compensating for Doppler Effect

- Compensate for the uplink Doppler shift by adjusting your TX freq. so that it is received *at the satellite* at its FM receiver freq.
- Adjust your receiver freq. to account for the Doppler shift on the downlink from the satellite to you



'SO-50' Satellite Example (2m Uplink, 70cm Downlink 'V/U')

Doppler Adjustments Timing

‘SO-50’ Satellite Pass Example

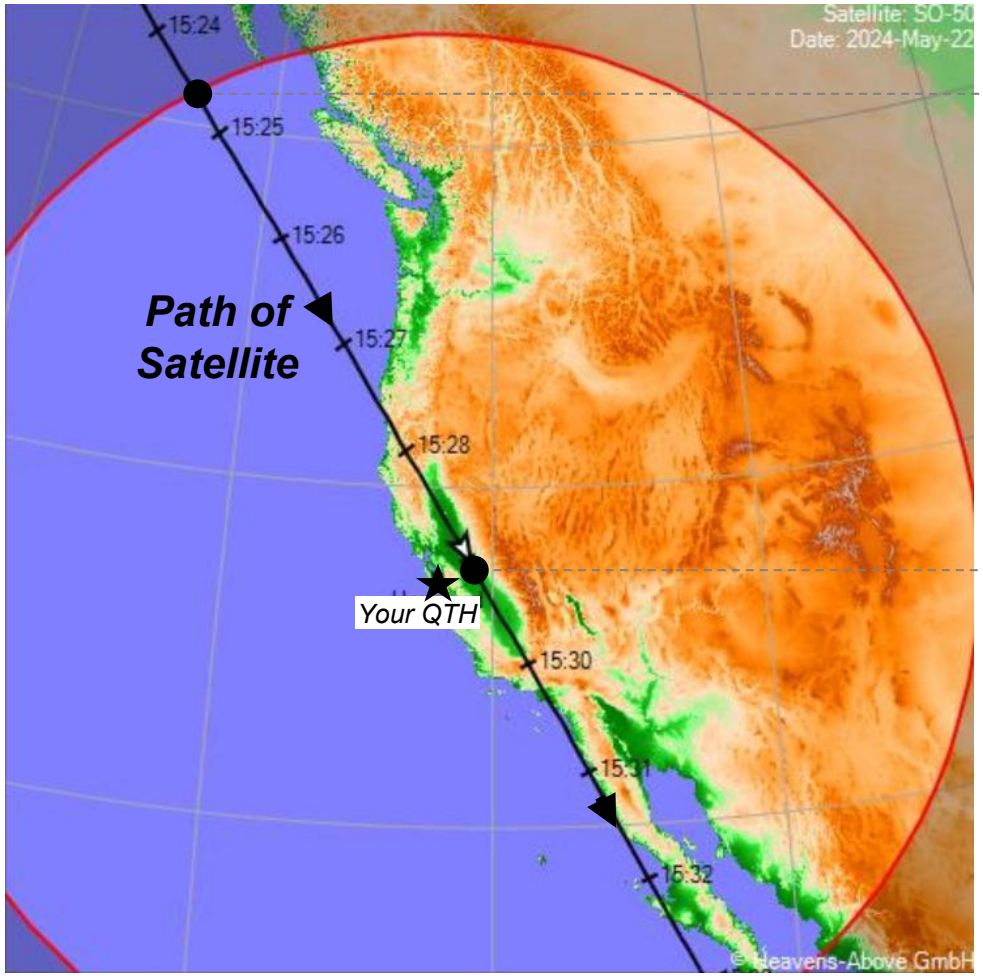
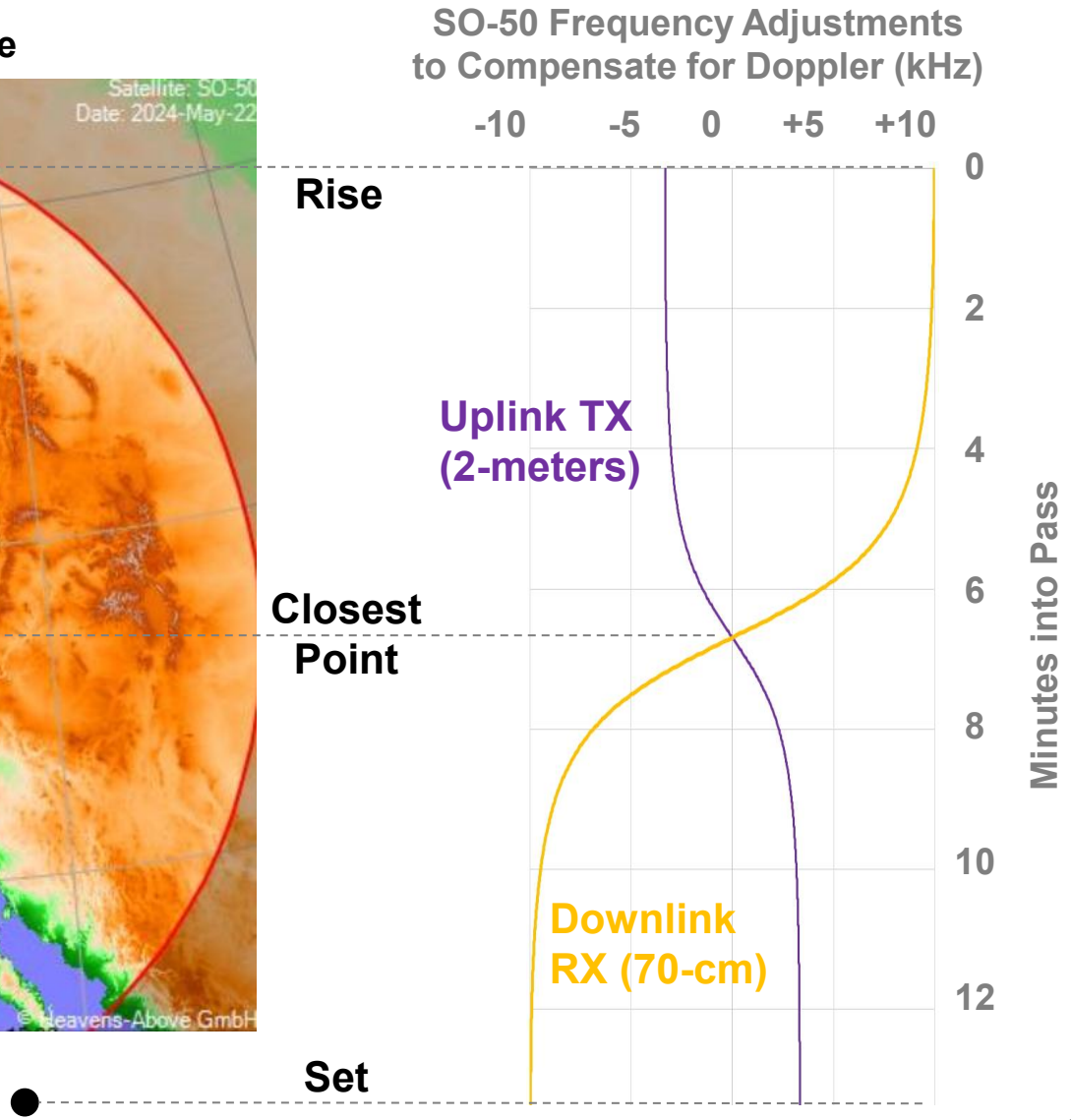


Image courtesy of the excellent heavens-above.com website.

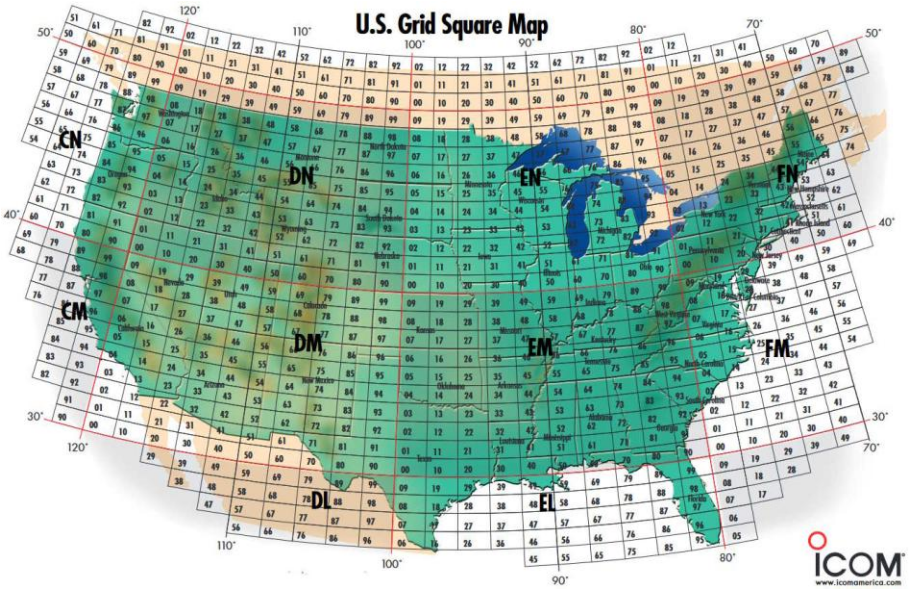


Frequency Management Methods

- There are three practical methods to adjust frequencies during pass:
  - **Manually turn your TX and RX VFO knobs**
    A little tricky because the RX and TX frequency changes are going in different directions, but you get used to it!
    - For 2m uplinks, the amount of Doppler shift may be small enough (e.g., ±3kHz or less) that you don't need to bother to tune the TX
  - **Set up memories for the different phases of the pass**
    Set up memories in your rig(s) to manage TX & RX frequencies – Chirp programming example at: https://www.deloach.net/Satellite/
  - **Use rig control software**
    Use software to predict the Doppler shifts based on your position and set the rig(s) automatically
- IMHO, *you must be able to listen to your own downlink signal to know when and how much to adjust frequencies!*
- *Be sure and turn your squelch OFF!*

Maidenhead Gridsquares

- Each grid is one degree of latitude by two degrees of longitude
- Many hams ‘collect’ gridsquares
  - Prestigious AMSAT Gridmaster Award for ops who have worked all 488 Continental US grids
- Mobile “roving” stations help others collect grids – filling in the many grids where there are few or no satellite operators
- I personally prefer to collect grids *from which I have operated!*

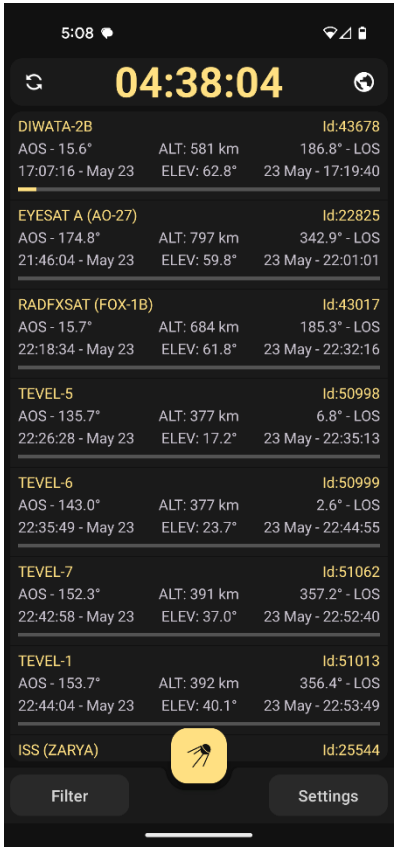


Maidenhead gridsquare map of the Continental US, courtesy of Icom.

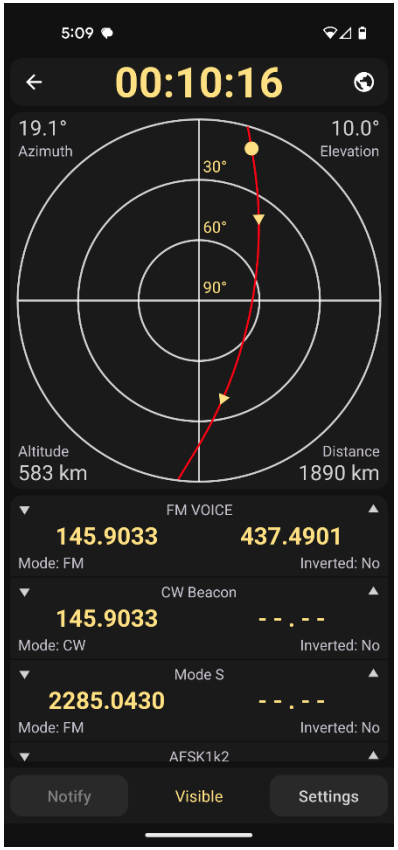
Finding Satellite Passes

- PC, tablet, or mobile apps make it easy to know when satellite passes occur and where to point the antenna
- I use Android 'Look4Sat' app
  - Set position with phone's GPS
  - Download satellite position information ("Keplerian Elements" or "Keps") over the Internet
  - Display upcoming passes
  - Illustrate satellite's current azimuth & elevation during a pass

Look4Sat App Examples



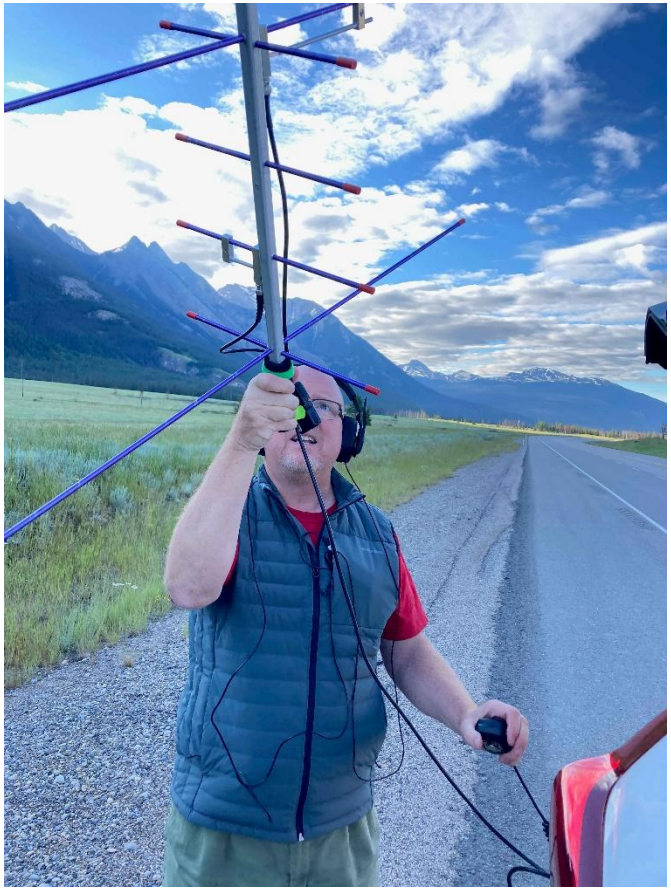
Main screen shows a list of upcoming passes



Click on a pass to show an az/el plot and other helpful info

Pointing the Antenna

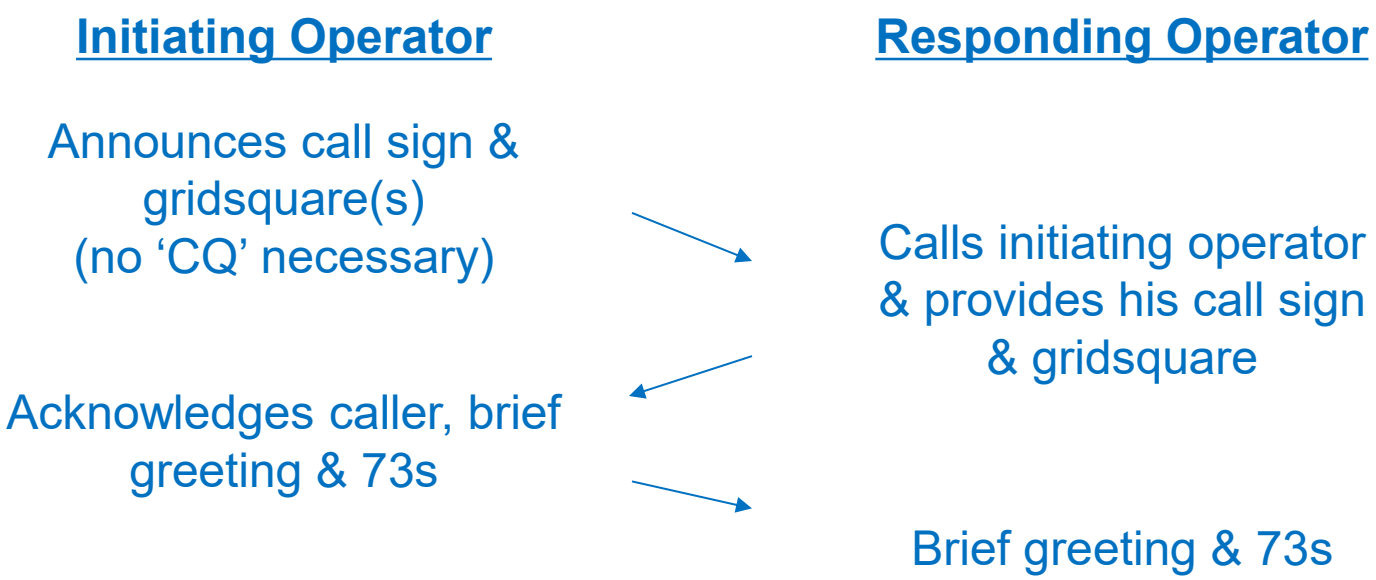
- Just point the antenna manually!
- Move antenna around in direction predicted by the app until you hear others or yourself
  - The antenna's broad beamwidth makes this easy
- Once you hear signals, gently move the antenna for maximum audio quality to 'track' the satellite across the sky
  - Also rotate antenna for maximum audio quality to optimize polarization



From a July 2022 QSO north of Jasper, Alberta, Canada (grids DOØ2/DOØ3). Photo by Maggie DeLoach, KK6DZS.

The Exchange

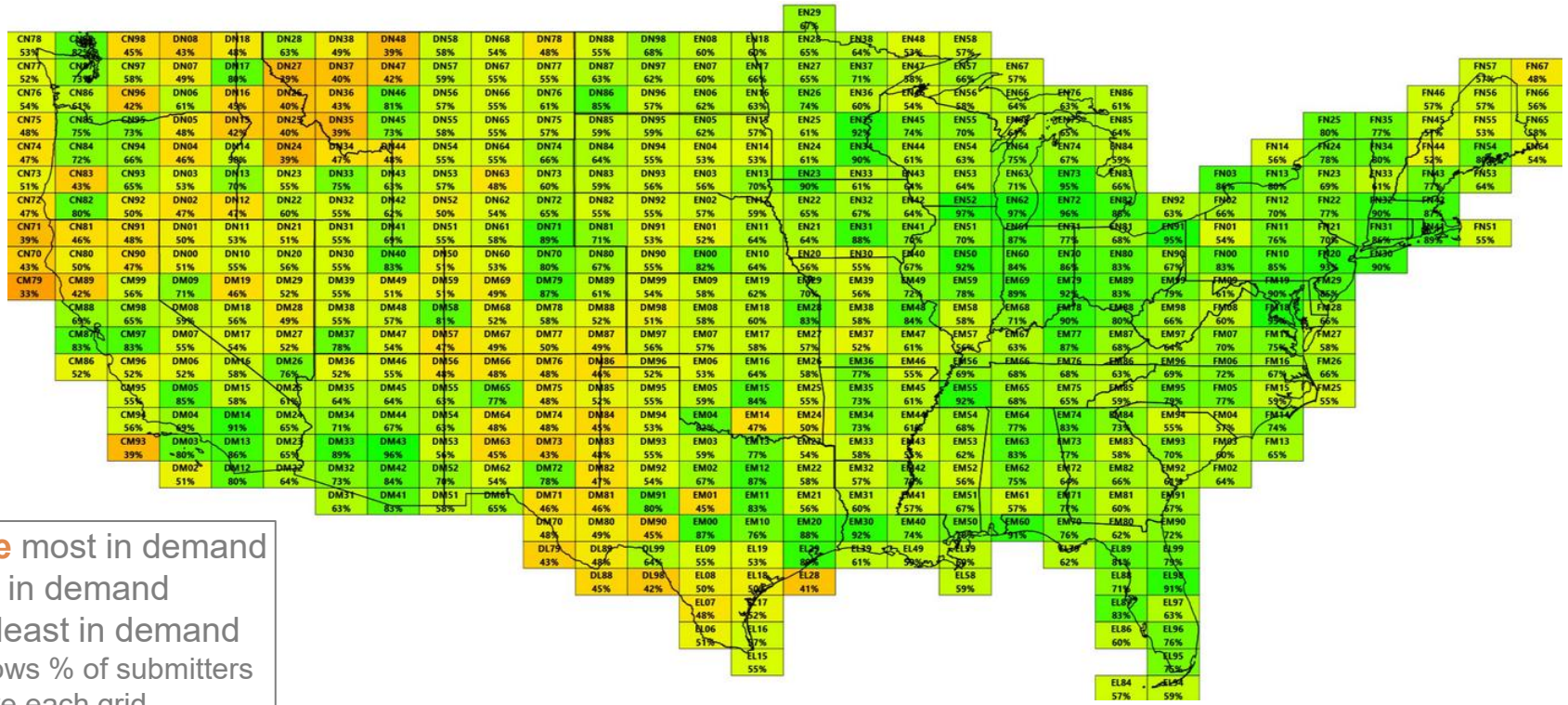
- Not a lot of time for chit-chat on the active FM birds!
- The typical exchange is based on call sign & gridsquare:



That's it! On less busy passes, more dialog can occur

Use Gridmaster Heat Maps to Plan Travel

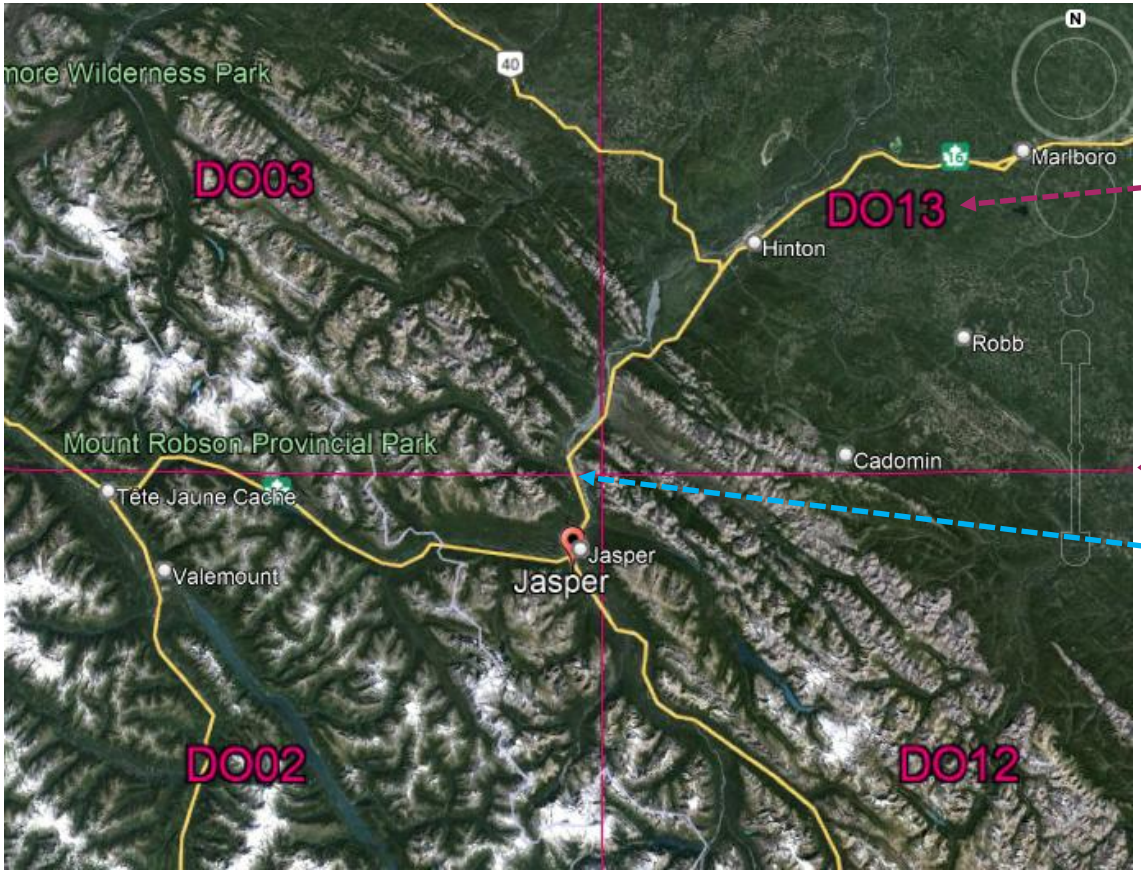
- Ian, K5ZM, publishes https://x.com/gridmasterheat?lang=en
  - Hams chasing the Gridmaster and other awards submit their logs, which are turned into color-coded ‘heat maps’ showing most needed grids
  - When planning travel, I go out of my way if I know a rare grid is close



Orange most in demand
Yellow in demand
Green least in demand
Also shows % of submitters who have each grid.

Activating Two Grids At Once

- You can activate 2 grids at once by operating from a grid boundary line
- I use Google Earth to scout operating locations on grid boundaries



Use my kml file to add gridsquare labels & boundary lines in Google Earth

Zoom & pan to explore accessible locations along boundaries

- *I found an accessible road with clear views ~15km north of Jasper, Alberta on the DOØ2/DOØ3 line*

Current Active FM Satellites

- https://www.amsat.org/fm-satellite-frequency-summary/ lists frequencies & CTCSS values, describes status & operational restrictions, etc.
- https://www.amsat.org/status/ shows up to date availability of every Amateur Radio satellite based on reports from hams across the world
- Current FM satellites:

Bird	Uplink CTCSS	Uplink (MHz)	Downlink (MHz)	Notes
AO-91 (RadFxSat / Fox-1B)	67 Hz	435.250	145.960	Operational – Don't use while in eclipse.
SO-50 (SaudiSat-1C)	67 Hz	145.850	436.795	74.4 Hz CTCSS for 2 seconds to arm.
PO-101 (Diwata-2)	141.3 Hz	437.500	145.900	Schedule: https://twitter.com/Diwata2PH
CAS-3H (LilacSat-2)		144.350	437.200	Operational, but less active
International Space Station (ISS) Repeater	67 Hz	145.990	437.800	https://www.ariss.org/current-status-of-iss-stations.html
SO-124 (HADES-R)		145.925	436.885	Operational
HADES-ICM		145.875	436.666	Active weekends beginning Mid-June
TEVEL 2 Constellation		145.970	436.400	Constellation of 9 nanosatellites coming soon!

Let the Community Know When You Activate a Grid!

- More grid chasers will show up and they will be listening for you!
- Use these sites to announce your satellite activations:
  - Post each activation here: https://hams.at/
  - Email roving plans to k5zm@comcast.net, for placement on AMSAT site https://www.amsat.org/satellite-info/upcoming-satellite-operations/
  - Gridmaster Map on X: https://x.com/gridmastermap?lang=en
- If you happen to be in a state, provincial, or national park, spot your activation on POTA as well!

POTA & Satellite Operation

- POTA locations are often remote thus tend to be great satellite gridsquares as well!
- A satellite QSO counts for POTA!
  - Just submit the log like you do for other POTA QSOs

Logging Satellite QSOs

- Most hams QSL satellite QSOs with Logbook of the World (LoTW®) using the TQSL program
- Two tricky bits encountered by satellite rovers:
  - Each distinct callsign used requires a LoTW certificate, including Canadian slashed callsigns (e.g., 'WUØI/VE6') and special event 1x1 callsigns
  - Each roving position needs its own TQSL 'station location'
  - Detailed TQSL instructions shown below

Satellite Resources

AMSAT Links

- The AMSAT Website (www.amsat.org) should be your first stop for all things satellite!
  - Getting Started With Amateur Satellites online e-book (*updated May 2025!*): www.amsat.org/product/2020-edition-of-getting-started-with-amateur-satellites-digital-download/
  - Compilation of beginner tutorial articles from 'The AMSAT Journal': www.amsat.org/wordpress/wp-content/uploads/2023/06/For_Beginners_Compilation.pdf
  - Station and Operating Hints page (has lots of interesting, useful links): www.amsat.org/station-and-operating-hints/
  - Intro Material: https://www.amsat.org/introduction-to-working-amateur-satellites/
  - Bulletin Board: https://mailman.amsat.org/hyperkitty/list/amsat-bb@amsat.org/
  - List of Satellites: https://www.amsat.org/two-way-satellites/
  - FM Frequencies: https://www.amsat.org/fm-satellite-frequency-summary/
  - Satellite Status: https://www.amsat.org/status/
  - And much more!
- Help keep Amateur Radio in space by joining AMSAT now at: https://launch.amsat.org/ !

Other Helpful Links

- My satellite web page contains this presentation & other materials: https://www.deloach.net/Satellite/
- Fun utility for finding visibility between two grids: www.satmatch.com
- KEØPBR's useful page: ke0pbr.wordpress.com
- Amateur Radio on ISS: www.amsat.org/amateur-radio-on-the-iss/
- N5DUX's FM Satellite Guide: www.n5dux.com/ham/satellites/fm.php
- N6UA's comprehensive satellite presentation: https://www.rmham.org/wp-content/uploads/2020/04/Working_Satellites.pdf
- N2YO path prediction: https://www.n2yo.com/
- Heavens Above path prediction: https://www.heavens-above.com/
- 'SatPC32': www.dk1tb.de/indexeng.htm
  - Rig & rotor control program that dominates the home QTH market
- CSN Technologies 'Self-contained Antenna Tracker (S.A.T.)': http://www.igatemini.com/sat (rig & rotor control in a small package)

Conclusion

- Make a portable satellite kit and bring it along on your next road trip or POTA activation!
- You'll have a great time operating this fun new mode!

Acknowledgements

- I would like to thank:
  - Frank Hoonhout, KJ7DZ, for his roving help and for assisting my transition into the linear satellites
  - Bo Lowrey, W4FCL, for signing me up as an AMSAT Ambassador and encouraging me to write this presentation

Questions?

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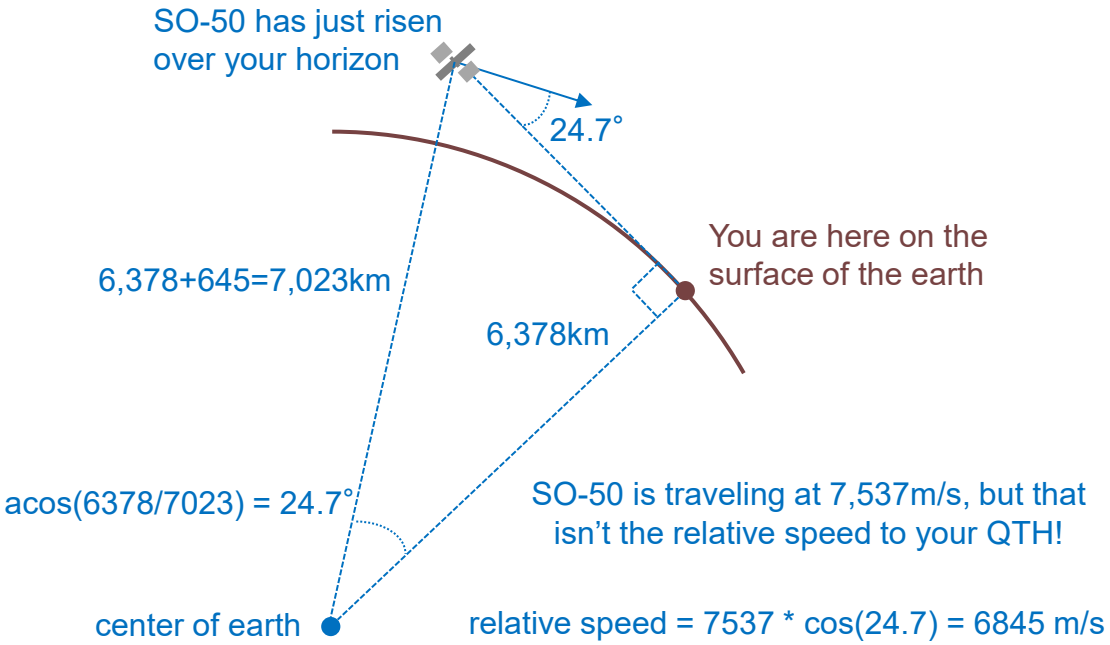
Backup Slides & Supplemental Material

Satellite QSO Logging Detailed Instructions

- Most hams QSL satellite QSOs with Logbook of the World (LoTW®)
- I take notes with paper, then after reviewing the recorded audio I log the QSOs into LoTW using the TQSL program
- Each distinct callsign used requires a LoTW certificate, including *1x1 callsigns* and *Canadian slashed callsigns* (e.g., 'WUØI/VE5')
  - To request additional certificates, in the TQSL app, under '*Callsign Certificate*', click '*Request New Callsign Certificate…*' then enter the call sign, first QSO date, and optionally last QSO date
- Each roving position (or at least each grid) needs its own TQSL 'station location'
  - To add a Station Location in TQSL, select the appropriate callsign then click '*Create a new Station Location*'
  - In the '*Add Station Location*' pop-up, fill in the information requested, including gridsquare
    - Note that up to four gridsquares can be entered in the grid box by delimiting with a comma and space – e.g., 'CN91, CN92, DN01, DN02'

Satellite Doppler Calculation Example – SO-50 at Acquisition

- Assumptions:
  - SO-50 satellite is in a near circular orbit ~645km above the earth traveling ~27,133km/h (~7,537m/s)
  - Earth's radius is ~6,378km
  - Radio wave propagation speed = speed of light = $3x10^8$ m/s
  - Pass directly overhead



$$Doppler\_shift = \frac{relative\_speed}{wave\_propagation\_speed} emitted\_freq = \frac{6845}{3*10^8} emitted\_freq$$

Doppler Shift at uplink frequency (145.85 MHz) = +3.3 kHz

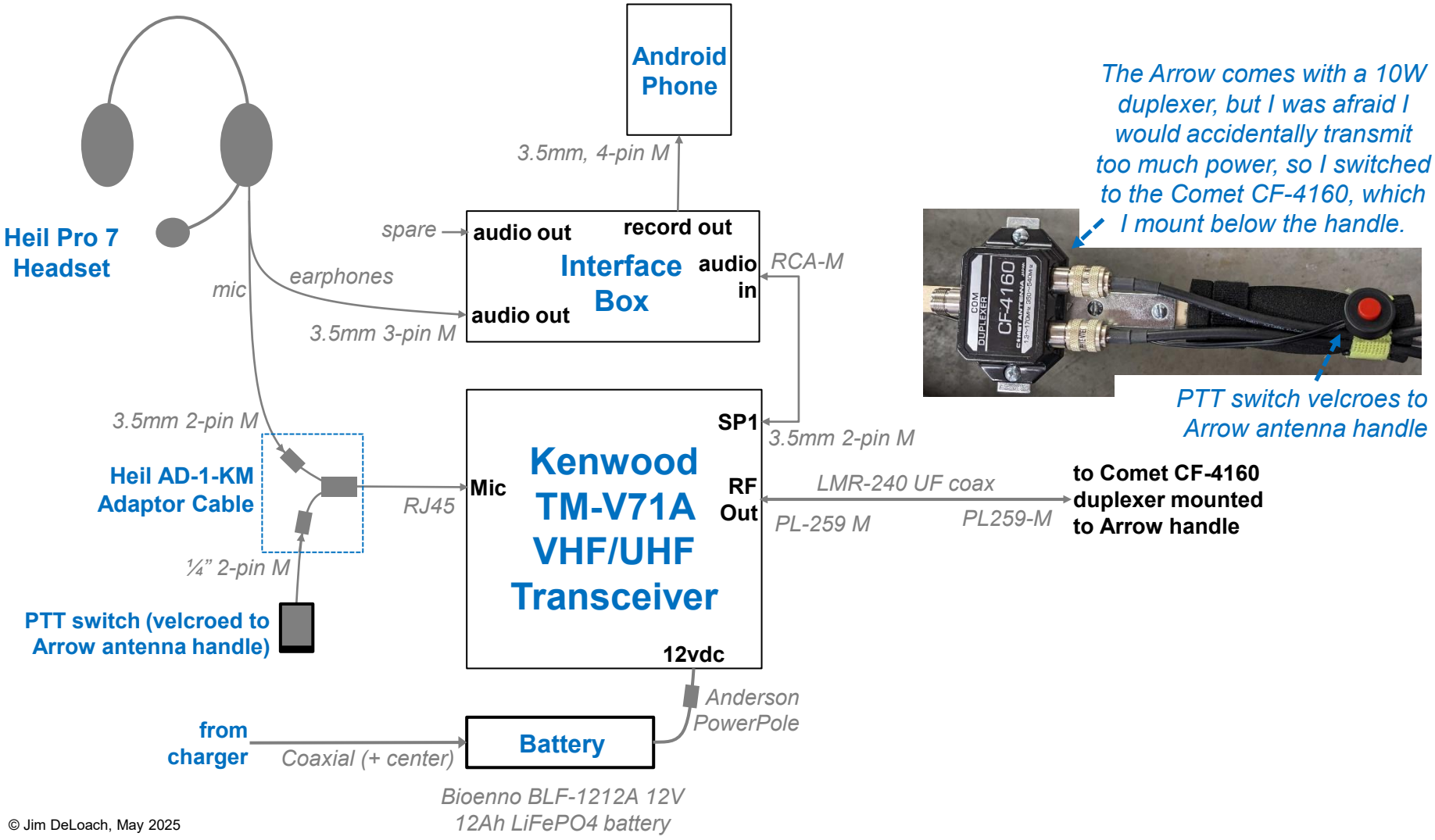
Doppler Shift at downlink frequency (436.795 MHz) = +10 kHz

This represents the maximum Doppler shift. If the pass is off to either side, instead of directly overhead, relative speed is lower still, reducing Doppler Shift.

Kenwood TM-V71A Setup for Satellite

- Configuration settings for satellite operation:
  - Menu 002 (EXT.SP) set to ‘Mode 1’ – audio from both channels output to ‘SP1’ when plugged in
  - Set Menu 508 [PF2] to ‘CTRL’ (default) – toggles channel which is controlled by tuning control using PF2 button
    - Needed to switch back and forth between the TX and RX channels
  - Menu 111 (mic sensitivity) set to ‘High’ for use with Heil Pro 7
- User Interface controls for satellite operation:
  - [F] [LOW] to turn Speaker Mute OFF – essential for hearing receive channel when transmitting
    - Make sure ‘MUTE’ not shown on screen
  - [PF2] to toggle between TX and RX channels when tuning

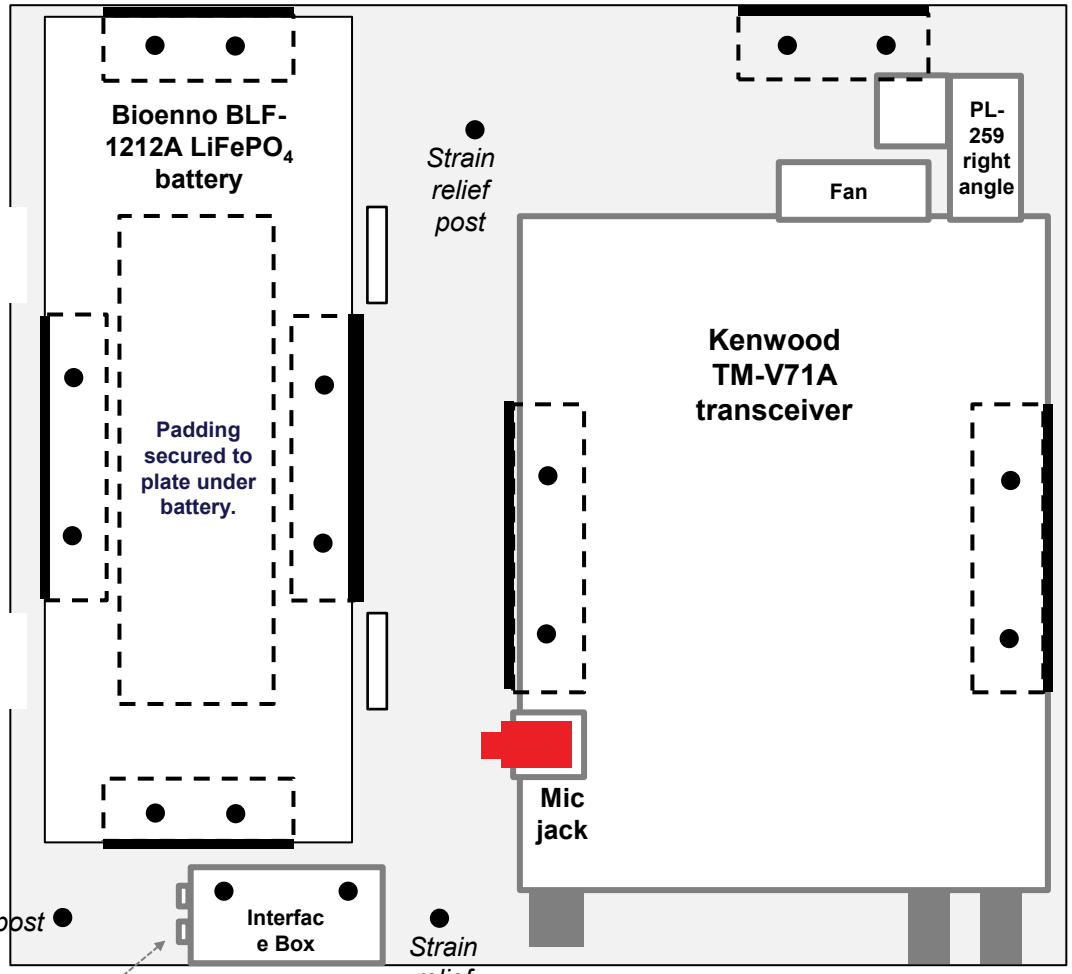
Detailed Block Diagram of my Kenwood TM-V71A Based FM Satellite Kit



Kenwood TM-V71A Based FM Satellite Kit Base Plate Layout

11” side x 10” long plastic plate (from a cutting board)

Use another bracket at the end of the plate.



Bioenno battery fits into a slot formed by 4 angle brackets. Note that the mounting holes are under the battery to keep them out of the way.

Cut 1” x ¼” notches on side and holes in the center then secure battery with two 1” x 18” Velcro looping straps.

Battery is 57mm (2.25”) tall..

Audio out 3.5mm TRS 3-pin plugs.

Angle brackets should be 2.5 to 3” wide and ~2.5” high so that the rig is suspended above the plate to allow cooling.

The TM-V71 has two mounting threaded holes ~47mm (1.85”) apart in the center of the rig.

Holes are ~3/4” up from bottom and ¾” down from top.

Screw size: M4 x 10 mm