Introduction to Amateur Radio Satellites

March 10, 2025

Jerry, VE6TL

Introduction to Amateur Radio Satellites

Outline

- History of Amateur Radio satellites
- Introduction
- History
- Getting Started
- AMSAT – Your One Stop Information Source
- Antennas
- Current Satellites – Searching for one to work
- My Setup – Just one possibility
- Programming the HT
- Working the ISS and HADES-R – Mapping out passes
- Summary

Introduction

- Many ham radio satellites in orbit right now – on various bands and modes
- Allows communications over several thousand kilometers
- No need to worry about propagation!
- Satellite passes are 100% predictable in advance
- Passes last only 10 - 20 minutes, at most
- FM satellites work like an orbiting repeater with one signal access at a time
- Transmit signal referred to as *uplink*, Receive signal as *downlink*
- Most uplinks require CTCSS to access satellite
- Downlink signals are often <1W but easily heard due to line of sight
- Basic hardware required for FM satellites:
  - Dual-band HT for 2m and 70cm (or two separate transceivers)
  - Diplexer (isolates transmitted signal from receive radio)
  - Dual-band antenna (hand-held or mounted on tripod)

History

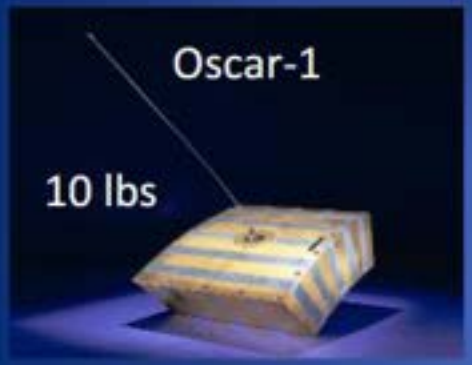
- OSCAR – Orbiting Satellites Carrying Amateur Radio was first approved for experimentation by the WARC (World Administrative Radio Conference) in 1960
- Approved bands included 10m, 2m, 70cm, 24cm and 13cm.
- OSCAR I: Launched Dec 12, 1961 by USAF. It weighed 4.5 kg, had a single monopole antenna, and a battery-powered 140 mW transmitter. The batteries died after 3 weeks and it re-entered the atmosphere Jan 31, 1962 after 312 orbits. It transmitted "HI-HI" in CW on 2m band and was heard by more than 570 hams in 28 countries.
- OSCAR III: Launched March 9, 1965. Weight 16.3 kg. First ham satellite to relay voice contacts (146 MHz up/144 MHz down). Lasted 18 days. Used by >1,000 hams in 22 countries.
- OSCAR IV: Dec 21, 1965. 18.1 kg. Four monopole antennas. 3W 10 kHz wide linear transponder. Uplink on 144 MHz, downlink on 432 MHz. Operated 85 days.

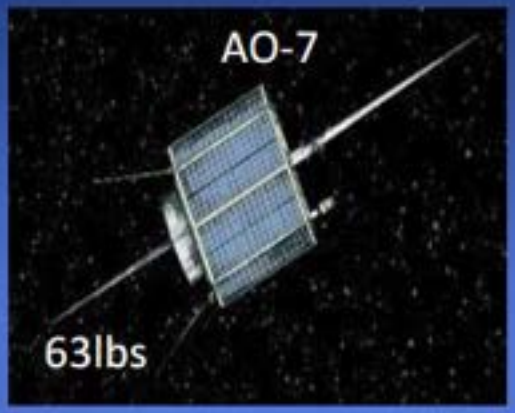
History Cont'd

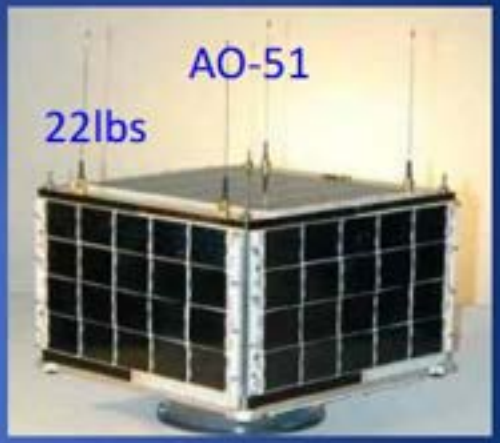
Satellite	Launch Year	Operational	Wt (kg)	Details
OSCAR I	1961	21 days	4.5	140 mW transmitter. CW "Hi-HI" on 2m
OSCAR II	1962	18 days	4.5	100 mW transmitter to extend battery life
OSCAR III	1965	50 days	16.3	First voice relays. 146 MHz up, 144 MHz down
OSCAR IV	1965	81 days	18.1	3 Watt transmitter, 2 m up, 70 cm down
Australis-OSCAR 5	1970	23/46 days	17.7	Built by U of Melbourne. 2m and 10m telemetry
AMSAT-OSCAR 6	1972	4.5 years	16.0	First complex control system using discrete logic, satellite to satellite relays via AO-7, solar panels recharging NiCd batteries
AMSAT-OSCAR 7	1974	7+ years		Battery failure in 1981 but sprang back to life 21 years later with daytime power only from solar panels. Resets each orbit.
AMSAT-OSCAR 8	1978	6 years	27.2	Built by US, Canada, Germany & Japan. 2m, 10m, 70 cm.
RS-1 and RS-2	1978	A few months	40.0	First Russian satellites - Mode A (145 MHz up, 29 MHz down)
UoSAT-OSCAR 9	1981	8 years	52.0	First on-board computer for battery and attitude management. Built by U of Surrey, UK. First to carry S-band beacon.
RS-3 to RS-8	1981			6 Russian satellites launched together. Issued QSO number upon activation.
Fuji-OSCAR 12 (FO12)	1986	3 years	50.0	Developed by JARL
AMSAT-OSCAR 13	1988	8 years	92.0	Carried 50 kg fuel. High altitude
RS-14/AO-21	1991	3 years		Functioned as "repeater in the sky".
Arsene-OSCAR 25	1993	Several months		Packet relay built by French Amateur Club de l'Espace. 2m transponder failed soon after launch,
KITSAT-OSCAR 25	1993			South Korean microsatellite (KO-25) with scientific objective

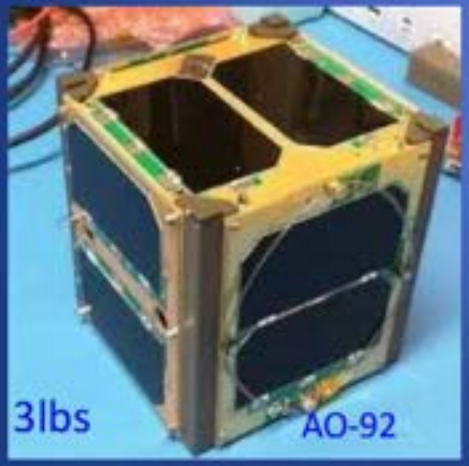
Many others were launched in this early period but many failed or were operational for short amounts of time. Since 1993, dozens of other satellites have been launch from organizations around the world, many still active

Evolution of Satellites









1U-cubesat- 10cm x 10cm x 10cm- 1.3 KG

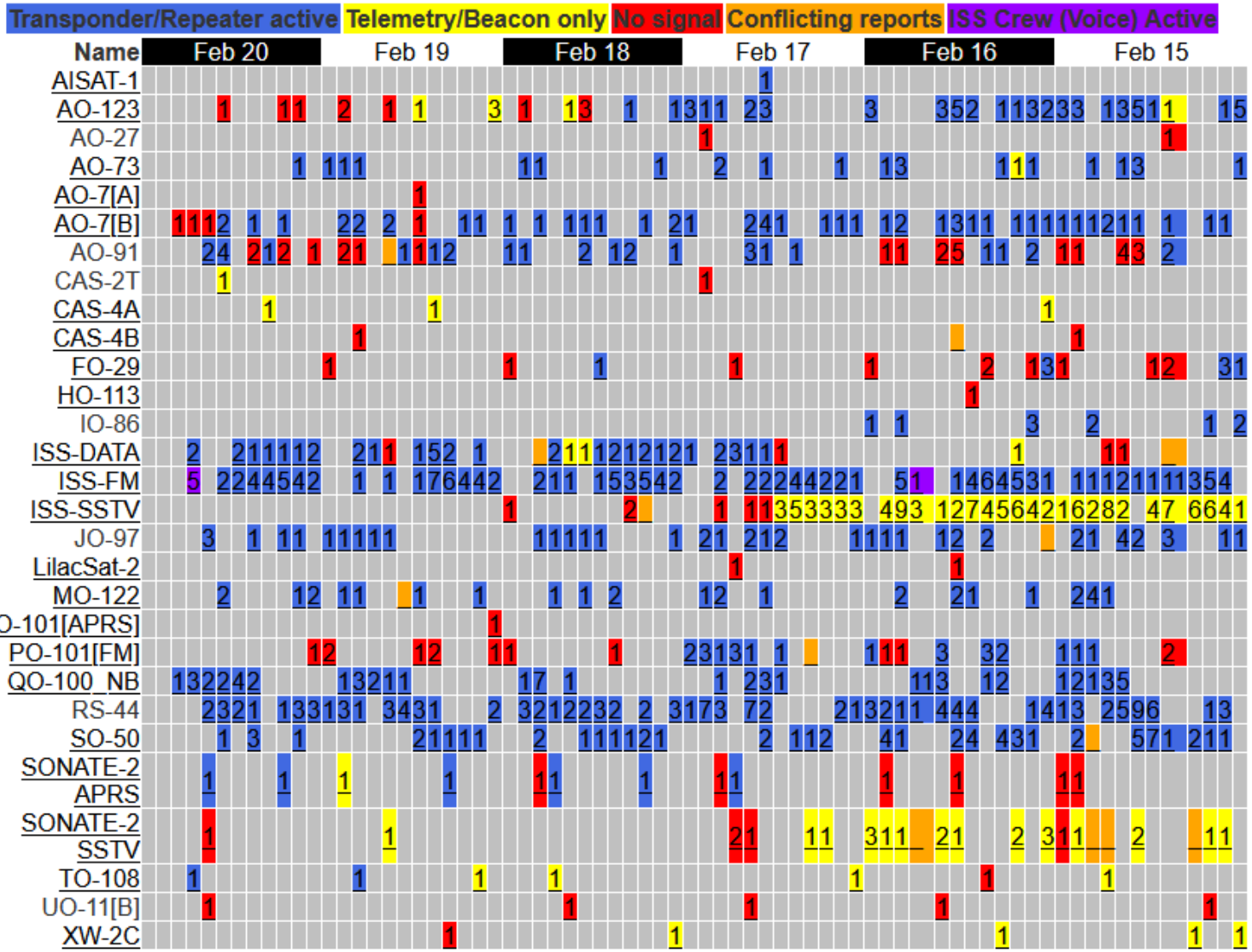
Getting Started…

- Which Satellites can I work?
  - Depends on my hardware (radios/antennas/interfaces)
  - Depends on modes available (SSB/CW/FM/Digital)
  - Depends on schedules coinciding (date/time of day/chance of success)
- Where can I find out which satellites are workable from my QTH and when?
  - AMSAT provides most of what you need to know

AMSAT

- Worldwide group of hams formed in D.C. in 1969 as an educational organization
- AMSAT maintained entirely by group of “amateur” volunteers
- Works in partnership with government, industry, educational institutions to foster ham radio participation in space research and communication
- Focus on design, construction and maintenance of communications satellites
- Manages satellites once they are in orbit to ensure availability for public use
- Promotes space education and STEM throughout the world
- Promotes speaking with ISS astronauts
- Publishes weekly bulletins online and maintains active website (amsat.org)

AMSAT Live OSCAR Satellite Status - 2025



Satellites do not appear if they have no data available.

https://www.amsat.org/status/

More Details… The Lingo

- Before accessing a particular satellite, some research is required
  - Need to know modes of operation
  - Need to know uplink and downlink frequencies (and CTCSS, if any)
  - Need to know when the satellite is accessible (making a pass)
    - AOS/LOS – *Acquisition and Loss of Signal* -time when the satellite first appears over the horizon and disappears of the horizon
    - Azimuth and Elevation of path
  - Need to know how to program your HT
  - Need to know how/where to access pass predictor information
- Doppler Effect
  - Because the satellite is moving very fast towards you or away from you, its frequency will experience a shift and need to be compensated for by your HT. The effect is more noticeable on 70cm than on 2m.
  - You need to program your HT to compensate for this effect in order to complete a QSO

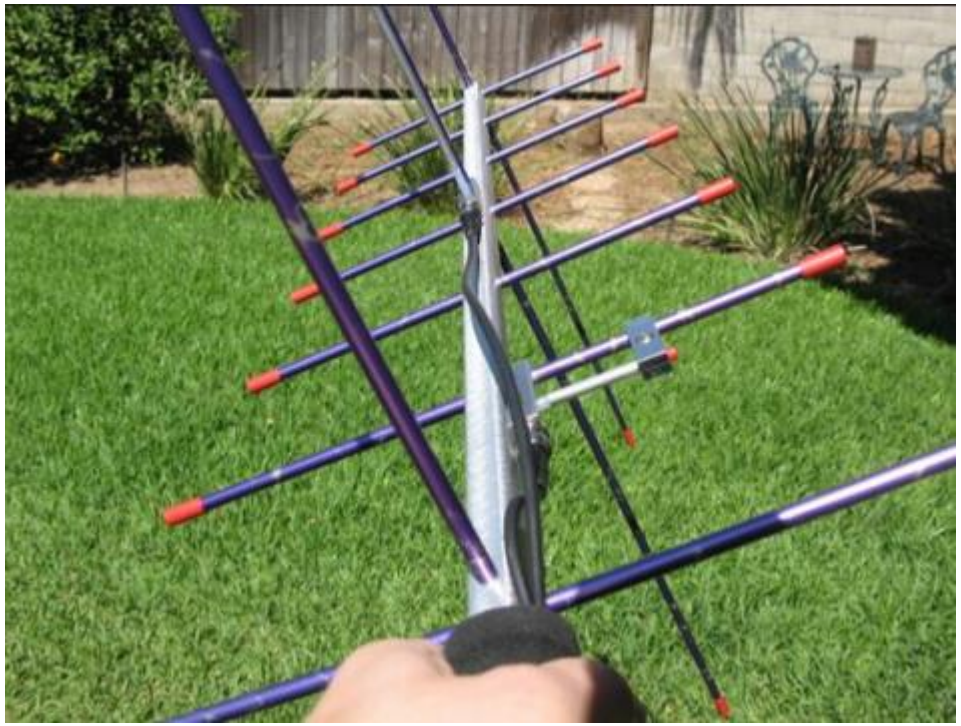
Getting to the QSO…

- Plug in your coordinates and determine next passes (Azimuths of AOS, LOS) of desired satellite to AMSAT's prediction page (up to 50 next passes)
- Listen for that satellite's beacon using appropriate freq/mode or check health on AMSAT website
- Best to use a headset with boom mike while working satellites as you may have one hand on the antenna, trying to keep it pointed at the satellite. Having separation between earphone and microphone will eliminate potential feedback, which you might experience from a speaker-microphone (if operating full-duplex).
- Having the antenna mounted on a tripod will save your arm over a 15 minutes pass
- Opening the squelch all the way on your FM receiver will allow you to hear weak signals
- Use your smartphone to record entire session audio. This avoids having to keep a paper of log of QSOs if communicating via voice
- For FM communications, the capture effect rules! The strongest uplink signals will be heard over top of the weaker signals. So power – and timing - is important. Try less busy times (mid-week) and elevation angle as high as possible. Using an amplifier (up to 25W) can help a lot.

Antennas

- Amateur satellites typically put out very low power and are in LEO (Low Earth Orbit). This means they will rarely be closer than 800 km, even when directly overhead. They'll be over 3,000 km away when they are near the horizon. This requires a sensitive receiver with an antenna that has good gain. The "rubber duck" antenna that comes with most HTs is usually not good enough for satellite communications.
- Amateur satellites tend to tumble as they orbit the earth as this process allows one side of the satellite to heat up while the opposite side cools down. This keeps batteries and onboard electronics from getting too cold or too hot, prolonging the lifespan of the satellite.
- Because of the varying polarity of the transmitted signal from the tumbling satellite changes through time, a ¼λ or 5/8 λ fixed HT-mounted whip antenna is also not recommended (except for ISS).
- Best solution is for a hand-held Yagi antenna. You can make your own or buy a commercially made one, such as the popular "Arrow" or "Elk" antennas.

Antennas Cont'd



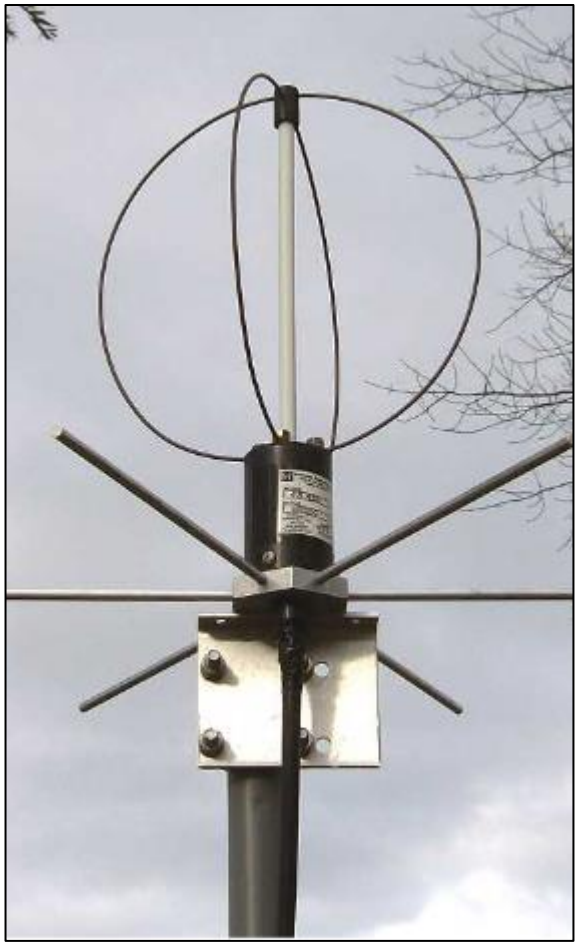
Diplexer

Arrow LEO – 3 Elements on 2 m, 7 elements on 70 cm
About US$200 with Diplexer

- Both sets of elements are linearly polarized

Antennas Cont'd

Other popular antennas



M2 "Eggbeater"

- Omni-directional – single band (2m here)
- Two full-wave loops fed 90° out of phase with each other
- Parasitic reflector elements at base to provide gain
- No need to point at satellite
  - At horizon, displays horizontally polarized linear pattern, useful for weak signals VHF/UHF terrestrial work
  - At higher elevations, exhibits increasingly right-hand circular radiation pattern, ideal for satellite work
- Other types of antennas include dish (1.2 GHz and above, due to size considerations), quadrafilar Helix (omni-directional), etc.
- Many of these antennas are easy to home brew

Current Satellites

https://www.amsat.org/two-way-satellites/

FM Repeater Satellites

(Click here for frequency chart, follow links below for satellite details)

- SO-50 (SaudiSat-1C)
- LilacSat-2 (CAS-3H) Transponder activations sporadic
- IO-86 (LAPAN-A2) In equatorial orbit, activations by schedule
- PO-101 (Diwata-2) Active by schedule, see here for schedule updates
- ISS Crossband Repeater Click here for schedule updates.

Transponder Satellites (Typically SSB/CW/Digi – 100 kHz wide passband)

(Click here for frequency chart, follow links for satellite details)

- AO-7
- FO-29 (JAS-2) Due to low battery, transponder is activated by schedule in Japan and remains active until voltage drops
- AO-73 (FUNcube-1) See AMSAT-BB or AMSAT News Service for transponder schedule updates
- JO-97 (JY1Sat)
- XW-2B (CAS-3B)
- TO-108 (CAS-6) Transponder operates intermittently
- RS-44
- MO-122 (MESAT1)
- QO-100 (Es'hail-2 / P4A) Geostationary at 25.9 degrees east.
- IO-86 (LAPAN-A2) In equatorial orbit, activations by schedule
- ISS Frequency Summary
- ISS Ham TV Currently inoperative
- AO-123 (ASRTU-1)

Saudisat SO-50

SO-50 carries several experiments, including a mode J FM amateur repeater experiment operating on 145.850 MHz uplink and 436.795 MHz downlink (+/- 10 kHz Doppler shift). The repeater is available to amateurs worldwide as power permits, using a 67.0 Hertz PL tone on the uplink, for on-demand activation. SO-50 also has a 10 minute timer that must be armed before use. Transmit a 2 second carrier with a PL tone of 74.4 to arm the timer.

The repeater consists of a miniature VHF receiver with sensitivity of -124dBm, having an IF bandwidth of 15 KHz. The receive antenna is a 1/4 wave vertical mounted in the top corner of the spacecraft. The receive audio is filtered and conditioned then gated in the control electronics prior to feeding it to the 250mW UHF transmitter. The downlink antenna is a 1/4 wave mounted in the bottom corner of the spacecraft and canted at 45 degrees inward.

The order of operation is: (allow for Doppler as necessary):
1) Transmit on 145.850 MHz with a tone of 74.4 Hz to arm the 10 minute timer on board the spacecraft.
2) Now transmit on 145.850 MHz (FM Voice) using 67.0 Hz within the 10 minute window.
3) Sending the 74.4 Hz tone again within the 10 minute window will reset the 10 minute timer.
You can set the memory channels in your handheld as follows:

Ch	TX	RX	CTCSS
1	145.850	Timer Reset	74.4 Hz
2	145.850	436.805	67 Hz
3	145.850	436.800	67 Hz
4	145.850	436.795	67 Hz
5	145.850	436.790	67 Hz
6	145.850	436.785	67 Hz

At the start of the pass tune to 436.805 and then decrease the frequency during the 10+ minute pass.

Dual Band Transceivers

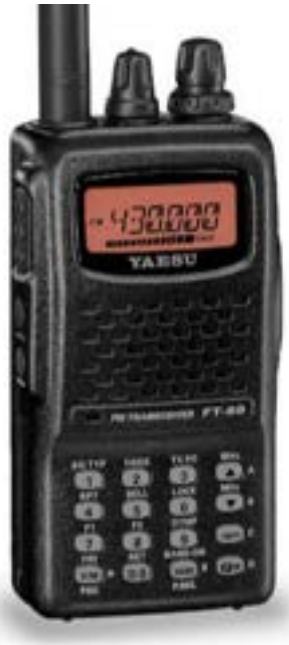
Currently, many brands and models to choose from

- Many can be programmed via free app (i.e., Chirp) through a PC and a USB cable
- Others require dedicated cables and software

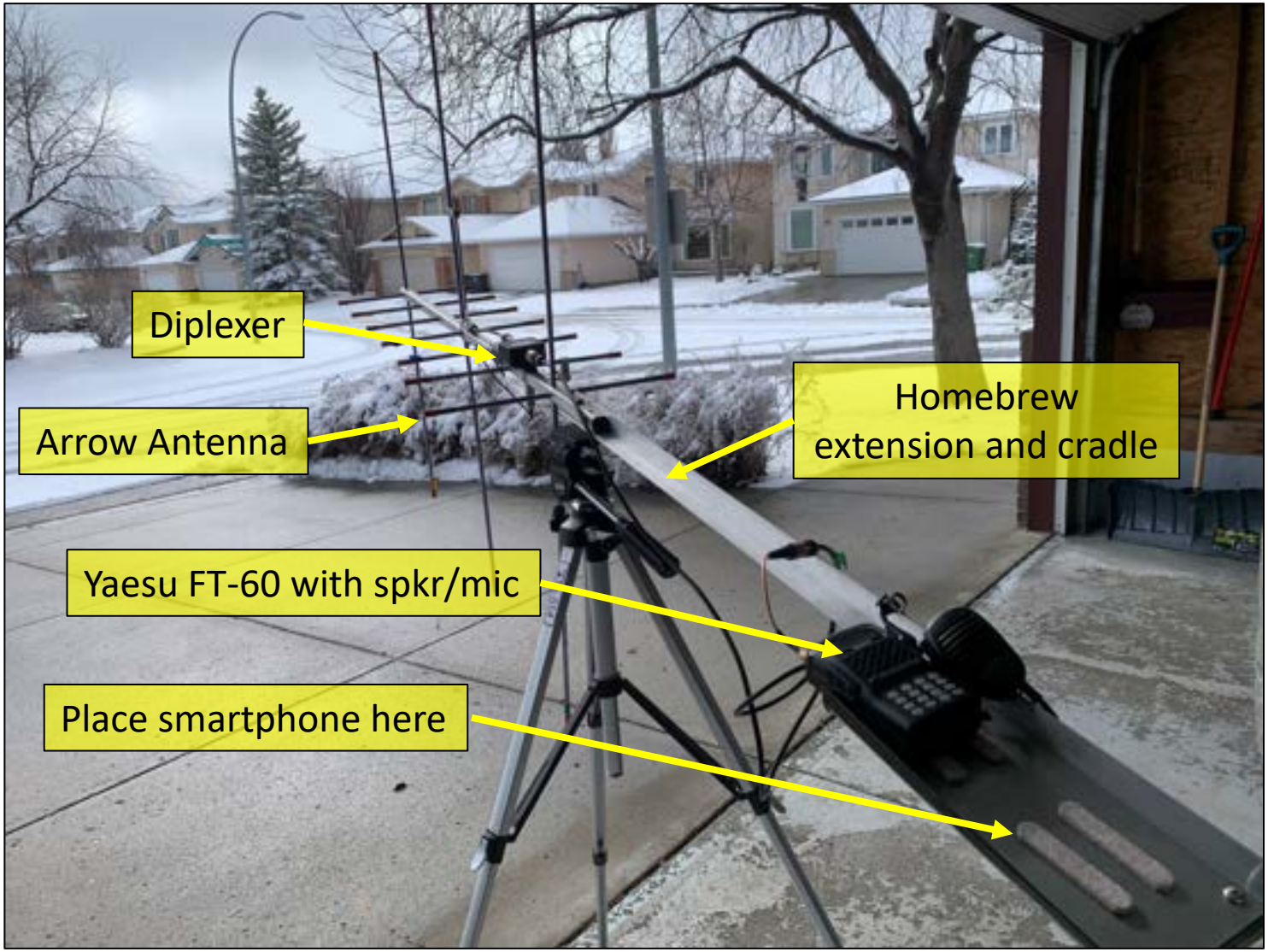
Think about modes of communication:

- FM Voice
- SSB
- Digital
- APRS

My own example: Yaesu FT-60 Handheld – 2m/70cm
- With speaker/mic



My Setup


Diplexer
Arrow Antenna
Homebrew extension and cradle
Yaesu FT-60 with spkr/mic
Place smartphone here

Workable FM Voice Birds

ISS:

- One mode functions like X-Band repeater
  - 145.990 MHz up (CTCSS 67 Hz), 437.800 MHz down

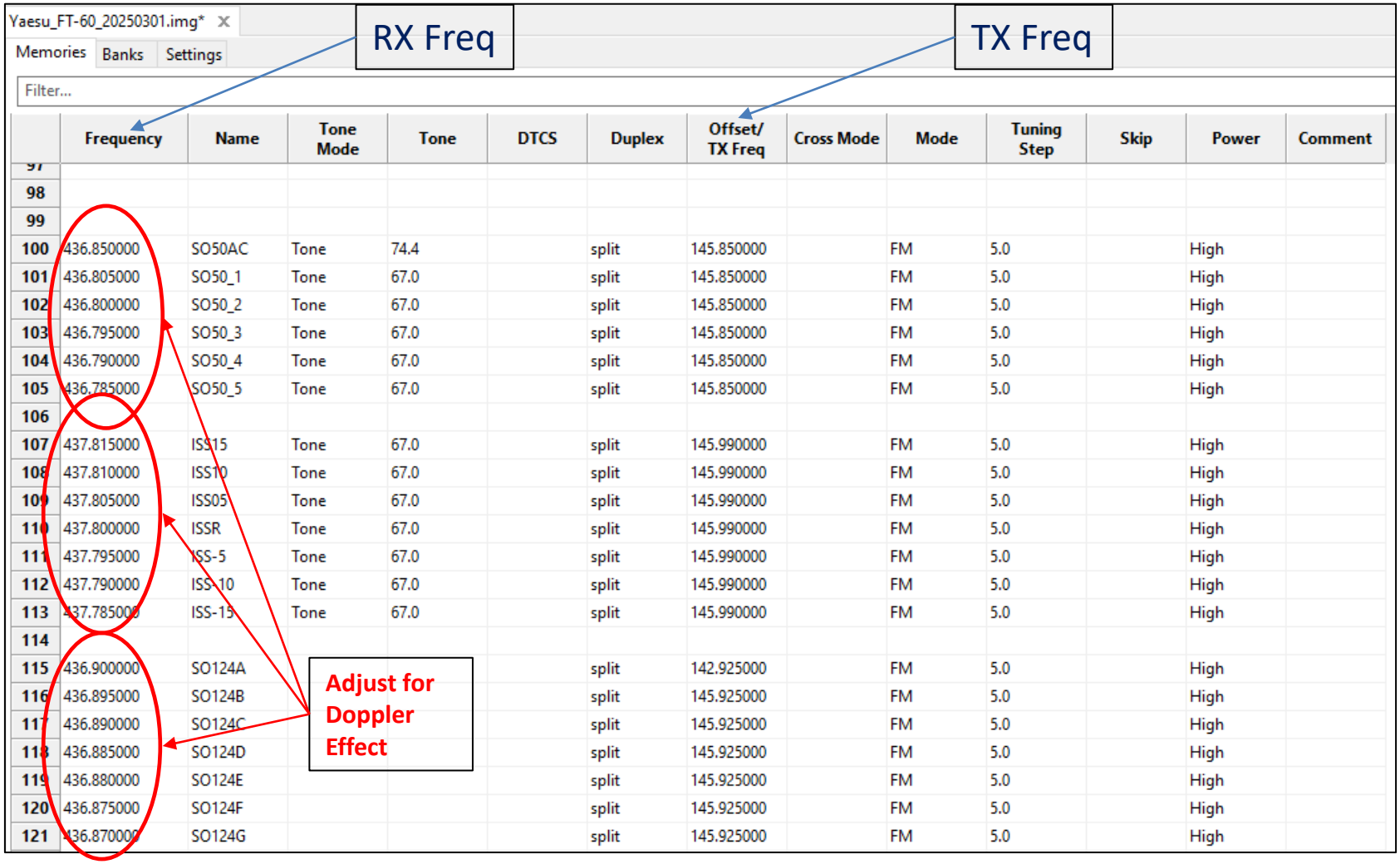
SO-124 (Pocket Cube “Hades-R”) from UK:

- 145.925MHz up (no CTCSS), 436.885 MHz down

SO-50 (250mW TX):

- 145.850MHz up (CTCSS 74 Hz for 10 min activation), 436.795 MHz down
- Requires CTCSS 67 Hz once activated

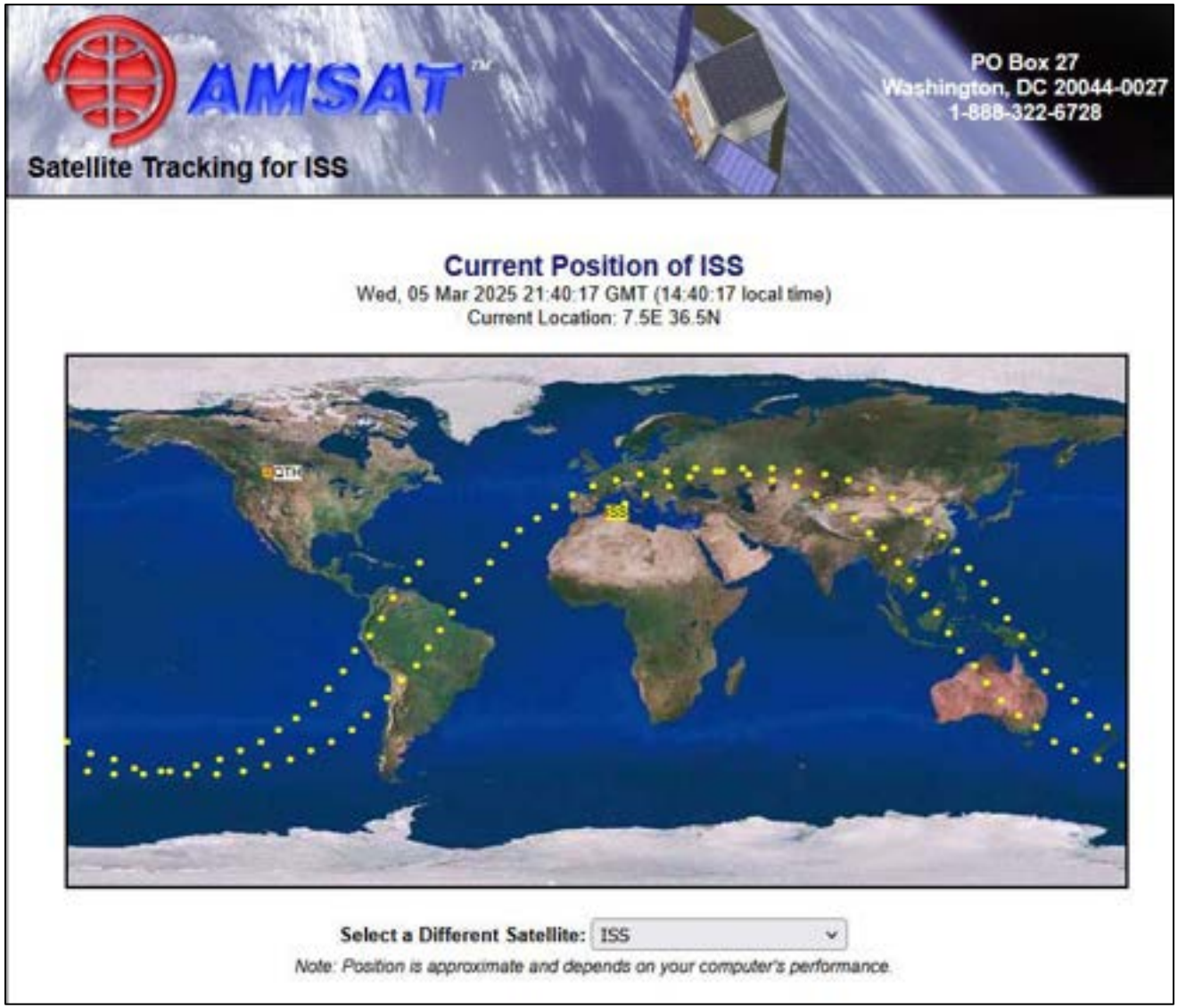
Programming the HT



	Frequency	Name	Tone Mode	Tone	DTCS	Duplex	Offset/ TX Freq	Cross Mode	Mode	Tuning Step	Skip	Power	Comment
97													
98													
99													
100	436.850000	SO50AC	Tone	74.4		split	145.850000		FM	5.0		High	
101	436.805000	SO50_1	Tone	67.0		split	145.850000		FM	5.0		High	
102	436.800000	SO50_2	Tone	67.0		split	145.850000		FM	5.0		High	
103	436.795000	SO50_3	Tone	67.0		split	145.850000		FM	5.0		High	
104	436.790000	SO50_4	Tone	67.0		split	145.850000		FM	5.0		High	
105	436.785000	SO50_5	Tone	67.0		split	145.850000		FM	5.0		High	
106													
107	437.815000	ISS15	Tone	67.0		split	145.990000		FM	5.0		High	
108	437.810000	ISS10	Tone	67.0		split	145.990000		FM	5.0		High	
109	437.805000	ISS05	Tone	67.0		split	145.990000		FM	5.0		High	
110	437.800000	ISSR	Tone	67.0		split	145.990000		FM	5.0		High	
111	437.795000	ISS-5	Tone	67.0		split	145.990000		FM	5.0		High	
112	437.790000	ISS-10	Tone	67.0		split	145.990000		FM	5.0		High	
113	437.785000	ISS-15	Tone	67.0		split	145.990000		FM	5.0		High	
114													
115	436.900000	SO124A				split	142.925000		FM	5.0		High	
116	436.895000	SO124B				split	145.925000		FM	5.0		High	
117	436.890000	SO124C				split	145.925000		FM	5.0		High	
118	436.885000	SO124D				split	145.925000		FM	5.0		High	
119	436.880000	SO124E				split	145.925000		FM	5.0		High	
120	436.875000	SO124F				split	145.925000		FM	5.0		High	
121	436.870000	SO124G				split	145.925000		FM	5.0		High	

- Chirp makes programming relatively easy
- FT-60 has 1,000 memories, so many different setups can be tried

Working the ISS



Working the ISS – Cont'd

AMSAT Online Satellite Pass Predictions - ISS

View the current location of ISS

	Date (UTC)	AOS (UTC)	Duration	AOS Azimuth	Maximum Elevation	Max El Azimuth	LOS Azimuth	LOS (UTC)
	06 Mar 25	05:22:11	00:08:53	192	12	132	82	05:31:04
	06 Mar 25	06:57:24	00:10:43	235	45	141	75	07:08:07
A	06 Mar 25	08:33:58	00:10:56	265	82	346	85	08:44:54
B	06 Mar 25	10:10:47	00:10:54	282	78	197	108	10:21:41
	06 Mar 25	11:47:34	00:10:22	284	24	227	143	11:57:56
	06 Mar 25	13:25:25	00:05:56	266	4	240	198	13:31:21
	07 Mar 25	04:34:53	00:07:41	178	7	137	87	04:42:34
	07 Mar 25	06:09:26	00:10:30	226	32	133	75	06:19:56
C	07 Mar 25	07:45:48	00:10:49	259	89	241	81	07:56:37
D	07 Mar 25	09:22:36	00:10:50	279	88	294	101	09:33:26

This prediction should not be used for precise scientific analysis

Use the form below to request more pass predictions

Show Predictions for: ISS for Next 10 Passes

Calculate Latitude and Longitude from Gridsquare: DO21wd Calculate Position

Or

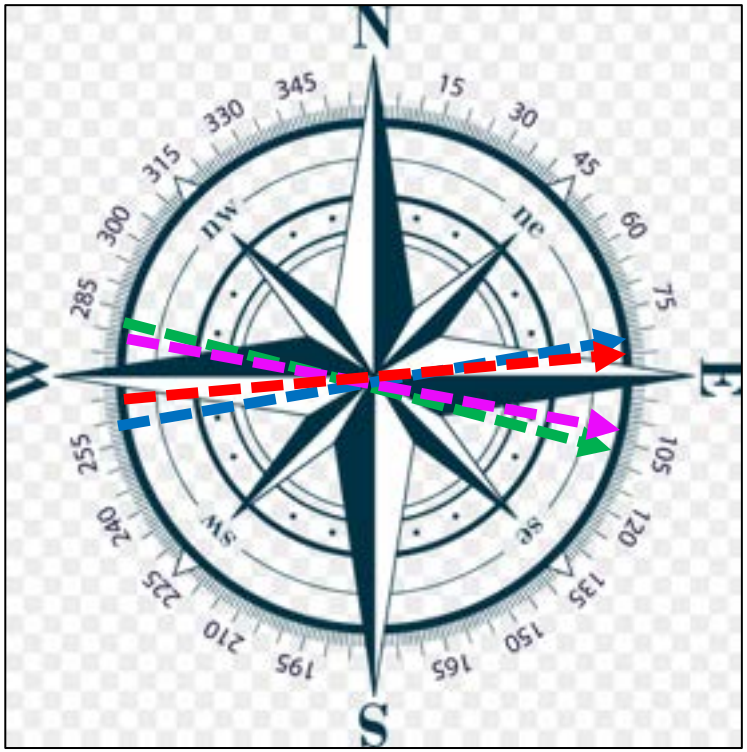
Enter Decimal Latitude: 51.1459 North

Enter Decimal Longitude: 114.125 West

Elevation in meters AMSL: 1200

Predict

Save my location for later use



Max El Azimuth = Maximum Elevation Azimuth half way through duration.

Example: Path A Begins 08:33:58 UTC Half Duration = 10:56/2 = 5:28. So at 8:33:58 + 5:28 = 8:39:26, the ISS will be at max elevation 82° at azimuth 346 °

Unfortunately, the next 50 passes (until March 14, 2025) all occur in the middle of the night!

Working the ISS – Cont'd

W1FRD Making Contact with ISS Using Arrow Antennas, 2 HTs, Headphones
https://www.youtube.com/watch?v=yUOkkOZKU_I

Working HADES-R – SO-124

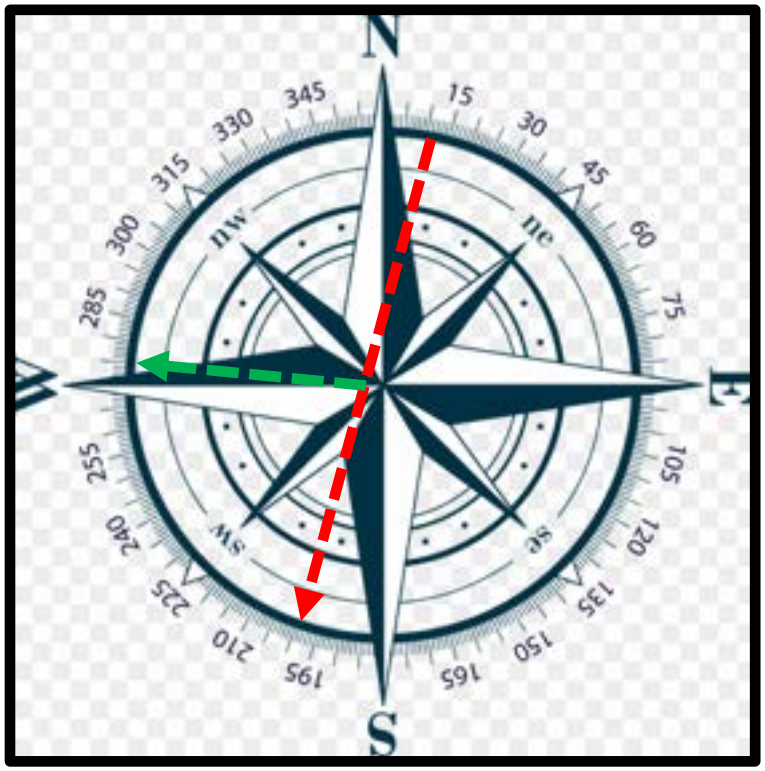
AMSAT Online Satellite Pass Predictions - HADES-R (SO-124)

View the current location of HADES-R (SO-124)

Date (UTC)	AOS (UTC)	Duration	AOS Azimuth	Maximum Elevation	Max El Azimuth	LOS Azimuth	LOS (UTC)
12 Mar 25	06:26:05	00:11:11	189	30	248	339	06:37:16
12 Mar 25	08:04:50	00:03:55	264	1	277	304	08:08:45
12 Mar 25	17:50:46	00:10:16	27	17	91	154	18:01:02
12 Mar 25	19:24:20	00:11:23	8	45	269	210	19:35:43
12 Mar 25	20:59:12	00:07:32	349	6	306	267	21:06:44
13 Mar 25	04:34:49	00:10:15	124	18	60	359	04:45:04
13 Mar 25	06:07:42	00:11:28	178	48	279	343	06:19:10
13 Mar 25	07:44:49	00:06:30	243	4	270	313	07:51:19
13 Mar 25	17:32:50	00:09:23	32	11	74	142	17:42:13
13 Mar 25	19:06:06	00:11:25	12	75	276	199	19:17:31

Best chance to work SO-124 in next 50 passes is Thursday, March 13, 2025 at 13:06:06 MDT

Note: Next 50 passes for SO-50 are all in the middle of the night. Need to wait for better times.



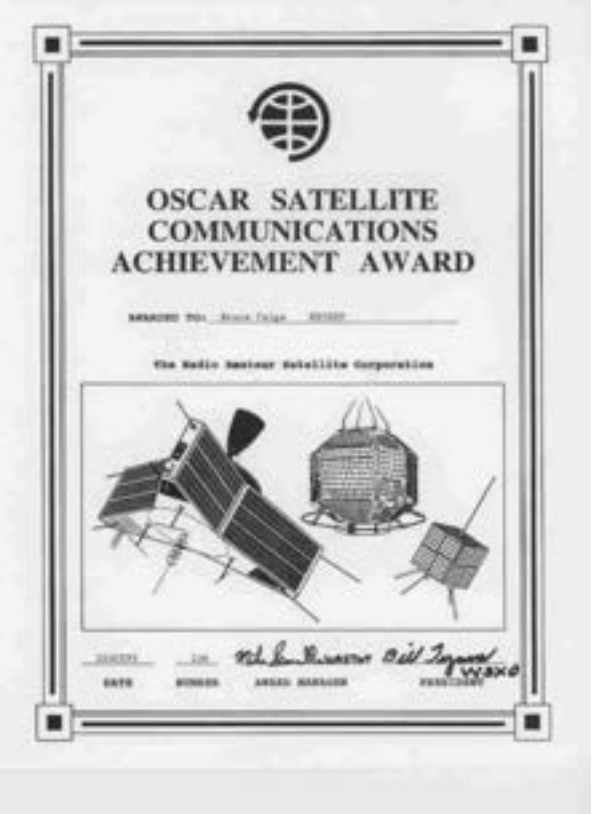
Path Begins 19:06:06 UTC.
Half Duration = 11:25/2 = 5:43. So at 19:06:06+ 5:43 = 19:13:49, the sat will be at max elevation 75° at azimuth 276 ° (shown by green arrow).

Making the QSO

- Make sure your squelch is wide open
- Using compass as a guide, point antenna just above horizon and towards desired azimuth/bearing
- Continue adjusting antenna until signal breaks squelch and you start to hear voice activity
- Activate audio recording device/app
- Answer any CQ/QRZ? with your callsign and grid square – give twice slowly and clearly
- If/when called, acknowledge other callsign with “Roger” or “QSL”, followed again by your callsign and grid square
- Call QRZ? With your callsign and grid square if no activity
- Remember to change frequencies for Doppler shift during pass
- Remember, FM subject to capture effect based on strongest signal so best chance will be when nearly directly above (shortest path)

Awards

- AMSAT offers an award to any operator for having made their first contact.
- AMSAT also offers the “OSCAR SATELLITE COMMUNICATIONS ACHIEVEMENT AWARD” for working 20 contacts on any satellite. Contacts must be between your state/province and between another state/province/DXCC country.
- RAC offers CANADAWARD for working all 13 Canadian Call Areas
- ARRL offers WAS with satellite endorsement
- ARRL offers DXCC with satellite endorsement



Breaking News...

The International Space Station (ISS) is currently scheduled for retirement in 2030, but Elon Musk has called for an earlier retirement, as soon as 2027. Musk has described the space station as having served its purpose. With the ISS potentially being deorbited in as few as two years, that leaves hams with only 24 months to continue taking advantage of the FM repeater and APRS digipeater onboard the space station.

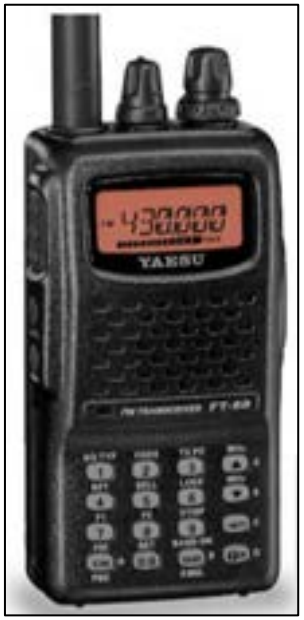
Astronauts onboard the ISS have suggested honoring agreements to keep the ISS in orbit until 2030.

Summary

What is needed to get started with the FM satellites?

Amateur Radio Certificate

Dual band yagi for 2m/70cm with diplexer



Portable Dual Band Transceiver

AMSAT Online Satellite Pass Predictions - ISS

View the current location of ISS

Date (UTC)	AOS (UTC)	Duration	AOS Azimuth	Maximum Elevation	Max El Azimuth	LOS Azimuth	LOS (UTC)
06 Mar 25	05:22:11	00:08:53	192	12	132	82	05:31:04
06 Mar 25	06:57:24	00:10:43	235	45	141	75	07:08:07
06 Mar 25	08:33:58	00:10:56	265	82	346	85	08:44:54
06 Mar 25	10:10:47	00:10:54	282	78	197	108	10:21:41
06 Mar 25	11:47:34	00:10:22	284	24	227	143	11:57:56
06 Mar 25	13:25:25	00:05:56	266	4	240	198	13:31:21
07 Mar 25	04:34:53	00:07:41	178	7	137	87	04:42:34
07 Mar 25	06:09:26	00:10:30	226	32	133	75	06:19:56
07 Mar 25	07:45:48	00:10:49	259	89	241	81	07:56:37
07 Mar 25	09:22:36	00:10:50	279	88	264	101	09:33:26

AMSAT info table from website

Smartphone with compass app (helpful)

Speaker/Mic Accessory (helpful)

Working ISS - Digital

And now a presentation from Syd, VE6SYD…


THE END