Getting into Amateur Satellites

Mac Cody - AE5PH

Outline of Presenation

- First, time for a live demonstration (hopefully)!
- Introduction, a brief history, and AMSAT®
- Types of amateur radio communication satellites
- Details on FM repeater satellites
- Equipment and software to work the satellites
- Operational techniques
- Awards as a form of motivation
- Online resources
- Video demonstration (if required) and Questions

Introduction

- Satellites containing amateur radios have been orbiting the earth for years
- These satellites provide hams the means to communicate with other hams over great distances using VHF and UHF radios
- This presentation provides an introduction to how you can communicate with other hams via amateur satellites with a minimum of financial investment
- You may already have most of the equipment you will need to get started!

A very brief history of Amateur Satellites

- Amateur radio has been in space almost as long as there has been a space program
- The first satellite carrying amateur radio, OSCAR I – a beacon satellite, was launched in 1961, barely four years after Sputnik I
- Many satellites carrying amateur radio have been launched since then – the oldest operational amateur satellite is AO-7 (launched in 1974)
- See https://www.amsat.org/amsat-history for a brief history of amateur satellites

OSCAR I

Amateur-OSCAR 7 (AO-7)

Amateur Satellite Organizations

- Argentina (amsat.org.ar)
- Australia (www.amsat-vk.org)
- Belgium (www.amsat-on.be)
- Brazil (www.amsat-br.org)
- Denmark (www.amsat.dk)
- Finland (rats.fi/rats-in-english)
- Germany (www.amsat-dl.org)
- India (www.amsatindia.org)
- Italy (www.amsat.it/cms/index.php)
- Japan (www.jamsat.or.jp/index_e.html)
- Netherlands (www.amsat-nl.org)
- New Zealand (www.kiwisat.org.nz)
- Portugal (www.amsat-ct.pt)
- South Africa (www.amsatsa.org.za)
- Spain (www.amsat-ea.org)
- Sweden (www.amsat.se)
- Turkey (www.tamsat.org.tr)
- United Kingdom (amsat-uk.org)
- United States (amsat.org)*
- Venezuela (www.amsat-yv.org)

*The Radio Amateur Satellite Corporation (AMSAT®) was founded in 1969

Types of Amateur Radio Communication Satellites

- FM repeaters – The 'easy' satellites
  - A limited number of satellites that are heavily used
  - Modest equipment investment required to use effectively
  - Easy to work, but pile-ups and interference are common

The focus of this presentation

- Linear transponders – More birds, more bandwidth, more challenging
  - Over a dozen satellites that are not heavily used – more being launched
  - More significant equipment investment is required to use effectively
  - Somewhat harder to work, but learned through experience
- Digital transponders – APRS, PSK-31, Digital Voice in space...
  - A limited number of satellites, with different modes, that are moderately used
  - Modest to significant equpment investment depending upon mode
  - Can be easy or challenging depending upon mode and conditions

FM Repeater Satellites

- FM repeater satellites are cross-band repeaters
  - Provide a single channel for communcations
  - Utilize narrowband FM voice mode
- A few are available, most heavily used, but more coming!
  - SO-50 (SaudiSat-1C) – Very popular, easy to work
  - AO-85 (Fox-1A) – Turned off until further notice due to low battery
  - LilacSat-2 (CAS-3H) – Sporadic activations
  - AO-91 (RadFxSat/Fox-1B) – Very popular, easy to work
  - AO-92 (Fox-1D) – Very popular, easy to work
  - FUNcube on ESEO – In commissioning
  - PO-101 (Diwata-2) – In commissioning
  - CAS-5A – Launch date to be determined

What's recommended to work FM Repeater Satellites

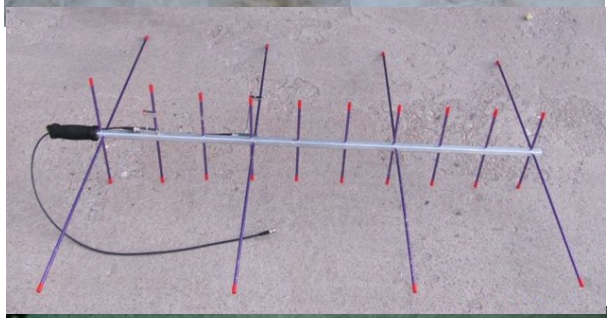
- Radio(s) sufficient for full duplex operation
- Antenna(s) supporting 2m and 70cm operation
- Speaker mic and headphones or a headset
- Audio recording equipment (or a means of taking notes or a good memory)
- Compass (unless you know your directions)
- Watch or other means of telling the time
- Know where the satellite will be during the pass

Radios for FM Repeaters Satellites

- Highly recommended to have full-duplex, crossband operations
  - Make sure you can hear yourself on the transponder
  - Situational awareness – more about this later
- Options for VHF/UHF-capable equipment
  - At a minimum, a dual-band, 5W handheld transceiver and a VHF/UHF receiver (scanner or SDR) can work – watch out for receiver desense
  - A 2m transceiver and a 70cm transceiver, or two dual-band transceivers
  - A full-duplex, dual-band transceiver – usually much more expensive
  - More wattage is useful for busting pile-ups but isn't necessary
- Can be a modest equipment investment if done carefully
  - Caution! Inexpensive transceivers can desense on recieve, especially on 70cm when another transceiver is transmitting on the 2m band
  - Baofeng handheld transceivers are notorious for this problem!

Commercial Antennas for Satellite Ops

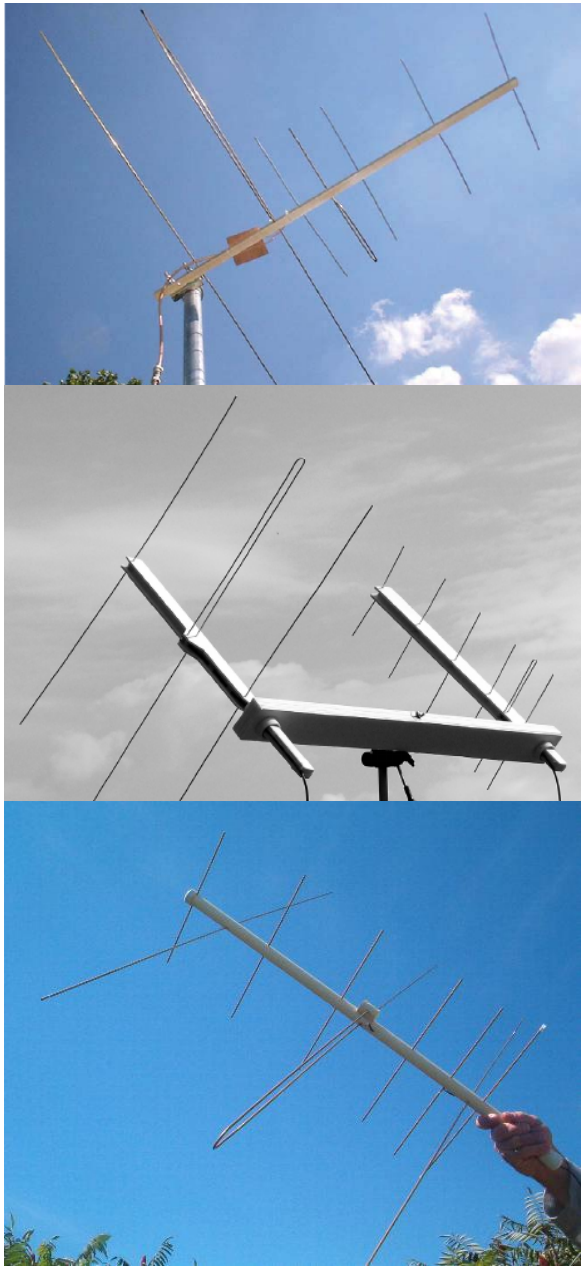
- Arrow® antenna
  - Crossed 2m and 70cm Yagi antennas
  - Purchased with or without a duplexer
  - Standard Arrows® and Alaskan Arrows® are available (has more elements, directionality, and sensitivity)
- Elk® antenna
  - 2m to 70cm Log Periodic Dipole Array antenna
  - No duplexer is needed
  - More portable, easier dis/assembly



Discussions about the superiority of Arrows vs Elks border on being 'religious'!

Homebrew Satellite Antennas

- Kent Britain WA5JVB Cheap Yagi Antennas
  - Several designs available that are really inexpensive
  - One design even provides a duplexer circuit
- AMSAT Cheap and Easy Yagi Satellite Antennas
  - Separate 2m and 70cm Yagi antennas
  - Basis for the antennas on the AE5PH satellite battlestation
  - PDFs No longer on web site, but I have them
- VE2ZAZ Arrow-Style Satellite Antenna
  - Uses PVC as the supporting structure
  - Also provides a design for a duplexer
- Many homebrew designs can be found on the Internet



Hand-held or Tripod Support

- A lot of operators hold the antenna(s) during the satellite pass – "Builds strong bodies 12 ways"
  - More portable operations
  - 'Better' control of antenna aiming/polarization
  - Potential operator arm fatigue
  - One hand tied up holding the antenna(s)
- A lot of operators mount the antenna(s) on some form of tripod – "Wimpy, wimpy, wimpy!"
  - Less portable operations
  - 'Harder' control of antenna aiming/polarization
  - No operator arm fatigue
  - Both hands free to control the equipment

Clayton W5PFG holding an Arrow

Randy K7AGE with Arrow on a tripod

Discussions about the superiority of hand-held vs tripod border on being 'religious'!

Talking and listening

- Speaker mic and headphones
  - A speaker mic is easier to handle than a radio
  - Headphones help in hearing weak transmissions
  - Note: If two separate radios are being used for full-duplex operation, the audio output of the speaker mic should be muted
- Headset with boom mic
  - Provide hands-free mic usage
  - Needs a separate PTT switch (don't VOX!)
- Commercial headphones and headsets designed for radios can be very expensive
  - Consider adapting headphones and headsets used for computers and gaming

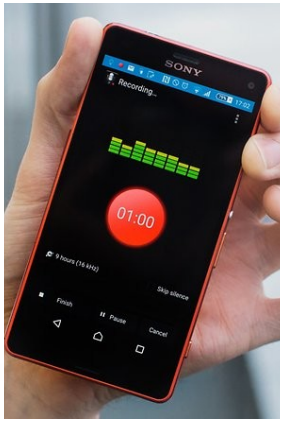
$$$

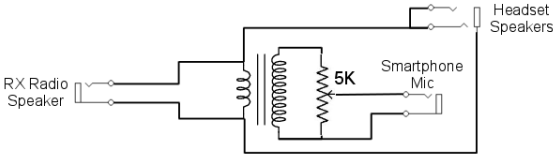
$$$

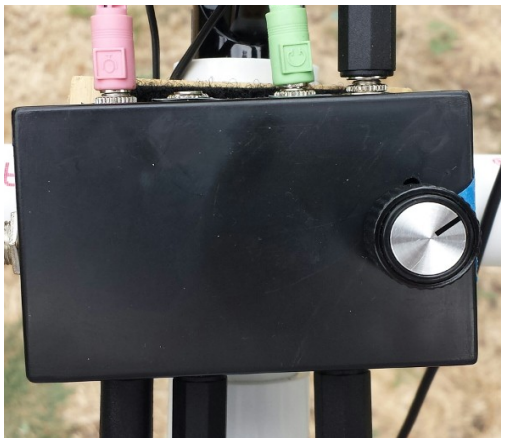
Recording for posterity

- Recommend having some form of audio recording capability – can be fun to replay!
  - Can be challenging to remember call signs and grid squares for all QSOs
  - Can be either a standalone or a smartphone-based recorder (beware of quirky behaviors!)
- Some form of audio splitter is needed to enable listening to the received audio while it is being recorded
  - Be aware of the type of audio input on the recorder (microphone vs line input)
  - Simple, passive audio splitters can be purchased or built

Smart Voice Recorder



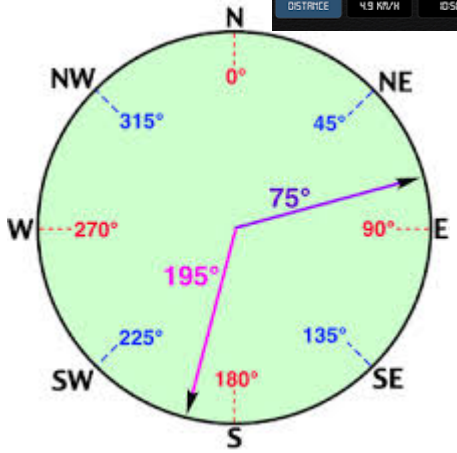


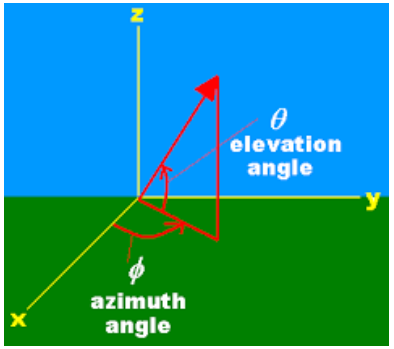


Finding your bearings

- While optional, a compass can help you know where to point the antenna (azimuth angle) during the satellite pass
- Not needed if you have a sense of direction
- Can be either traditional or a smartphone-based compass
- Usually not necessary to have a reference for pointing the antenna up towards the satellite (elevation angle)
- It is relatively easy to have a sense of the elevation angle from the horizon (0°) to directly overhead (90º)

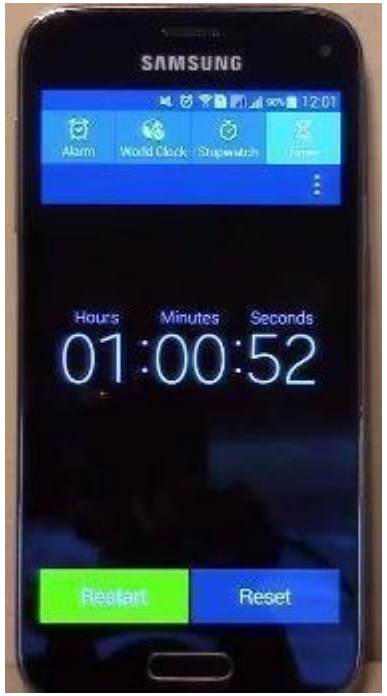
GPS Compass Explorer





Minding your time

- Watch or other timepiece with seconds display
  - Need to know when the satellite arrives
  - Need to know when to start recording
  - Need to know when a QSO occurs
- Can be a watch or a smart phone clock – suprising how few smart phone clocks have seconds display
- Keep synchronized to nearest second
- Either have it set to UTC or be able to convert – don't forget Daylight Savings Time!
  - Central Standard Time is UTC - 6
  - Central Daylight Time is UTC - 5



Other useful items

- Head-mounted flashlight for nightime operations
- Protective clothing, hat to protect from sun, cold, weather, and insects
- Additional audio splitters and headphones or powered speakers – allow others to listen to the pass
- Spare batteries for equipment


Batteries for all 2-Way Radio Models

Know where the satellite will be

- In order to successfully work the satellite, you need to know where the satellite will be during the pass
- This information can be useful before or during the pass
  - Plan ahead for when a satellite pass will occur
  - Know when and where to aim the antenna during the satellite pass
- There are a number of satellite prediction software applications available that run on various computers and smartphones

AMSAT Online Satellite Predictions

- Provides essential information
  - Select satellite to predict
  - Select number of passes to predict
  - Provide latitude, longitude, and elevation (altitude) above sea level in meters
- Information provided – note UTC times
  - UTC date of satellite pass
  - Time and azimuth at Acquistion of Signal (AOS)
  - Duration of satellite pass
  - Azimuth angle and maximum elevation angle at Time of Closest Approach (TCA)
  - Time and azimuth at Loss of Signal (LOS)
- http://www.amsat.org/track/index.php

AMSAT Online Satellite Pass Predictions - SO-50

View the current location of SO-50

Date (UTC)	AOS (UTC)	Duration	AOS Azimuth	Maximum Elevation	Max El Azimuth	LOS Azimuth	LOS (UTC)
08 Oct 17	02:09:50	00:13:01	318	28	234	178	02:22:51
08 Oct 17	14:40:01	00:12:04	174	20	117	46	14:52:05
08 Oct 17	16:19:47	00:13:00	230	31	316	19	16:32:47
08 Oct 17	18:05:22	00:05:46	299	2	311	350	18:11:08
08 Oct 17	23:15:21	00:09:26	359	7	40	87	23:24:47
09 Oct 17	00:54:27	00:13:50	334	65	47	146	01:08:17
09 Oct 17	02:36:03	00:10:14	302	10	263	205	02:46:17
09 Oct 17	13:29:05	00:05:02	125	2	99	80	13:34:07
09 Oct 17	15:04:25	00:13:22	198	58	118	33	15:17:47
09 Oct 17	16:46:17	00:11:24	254	13	313	9	16:57:41

Your results are shown above

Use the form below to request more pass predictions

Show Predictions for: SO-50 for Next 10 Passes

Calculate Latitude and Longitude from Gridsquare: [ ] Calculate Position

Or

Enter Decimal Latitude:* 32.9697 North

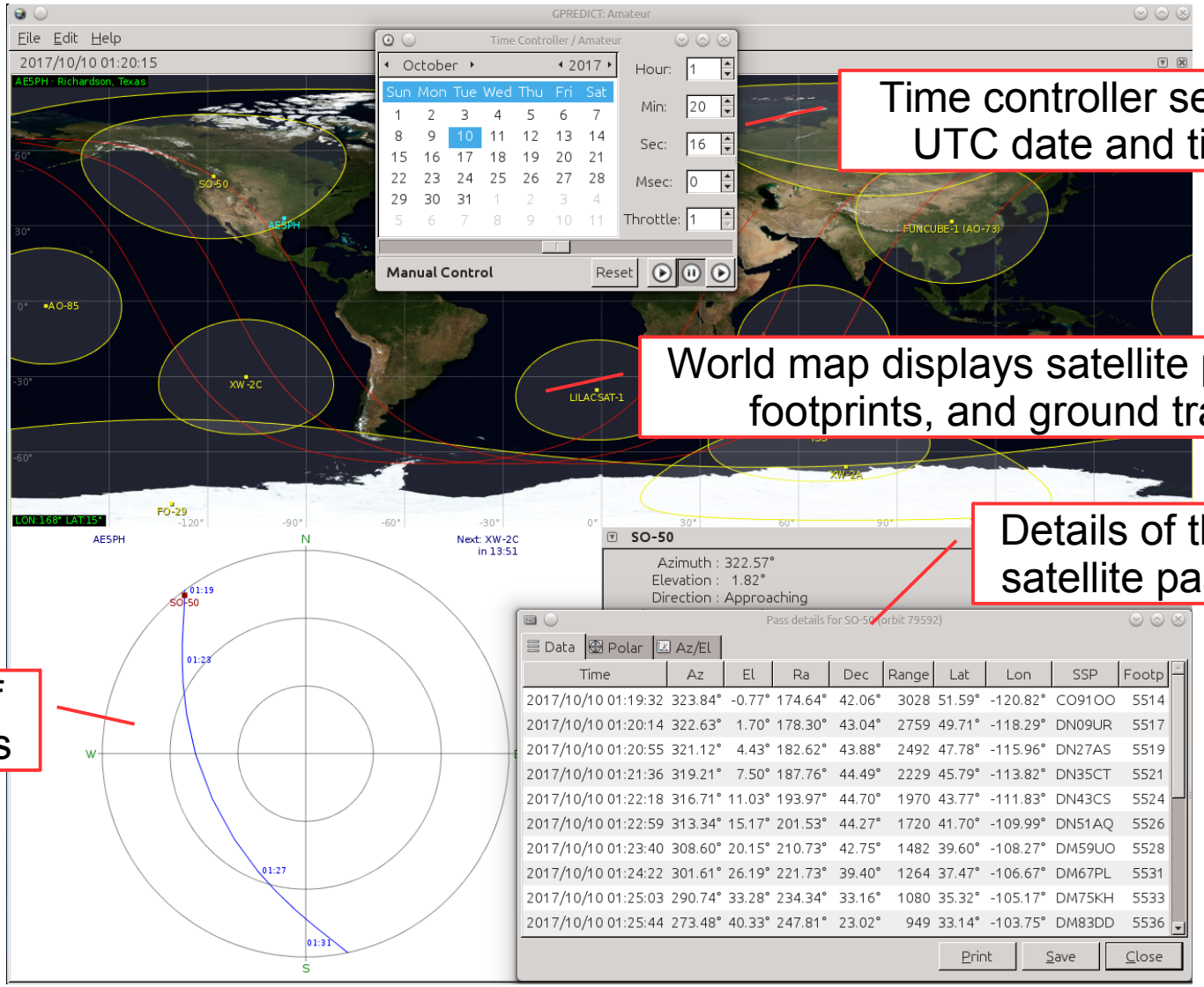
Enter Decimal Longitude:* 96.7449 West

Elevation in meters AMSL: 197.06 m

Predict

Save my location for later use

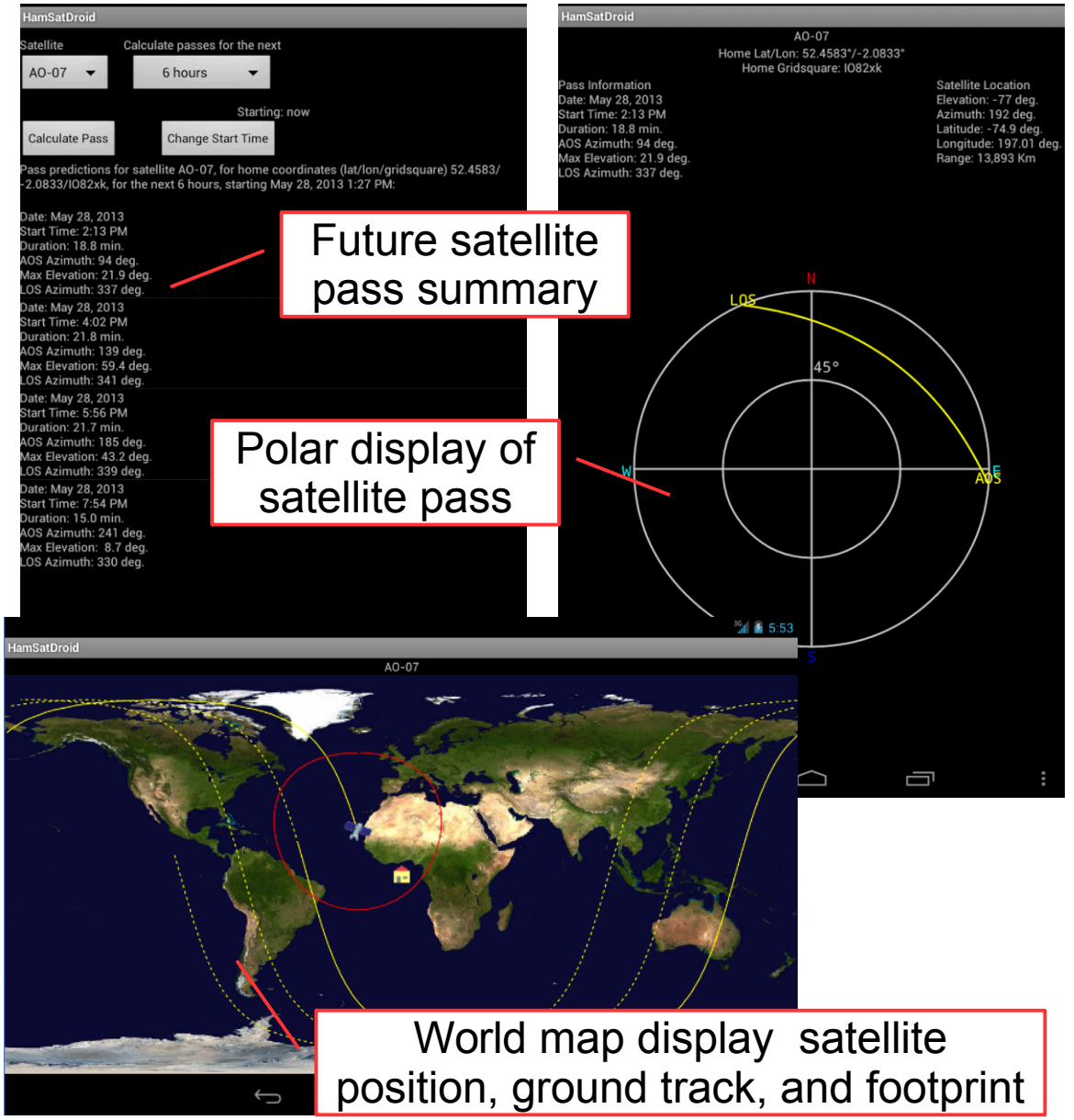
Satellite prediction software for computers



Satellite prediction software is available for MS Windows, Apple OS, and Linux – this is the Linux program GNOME Predict

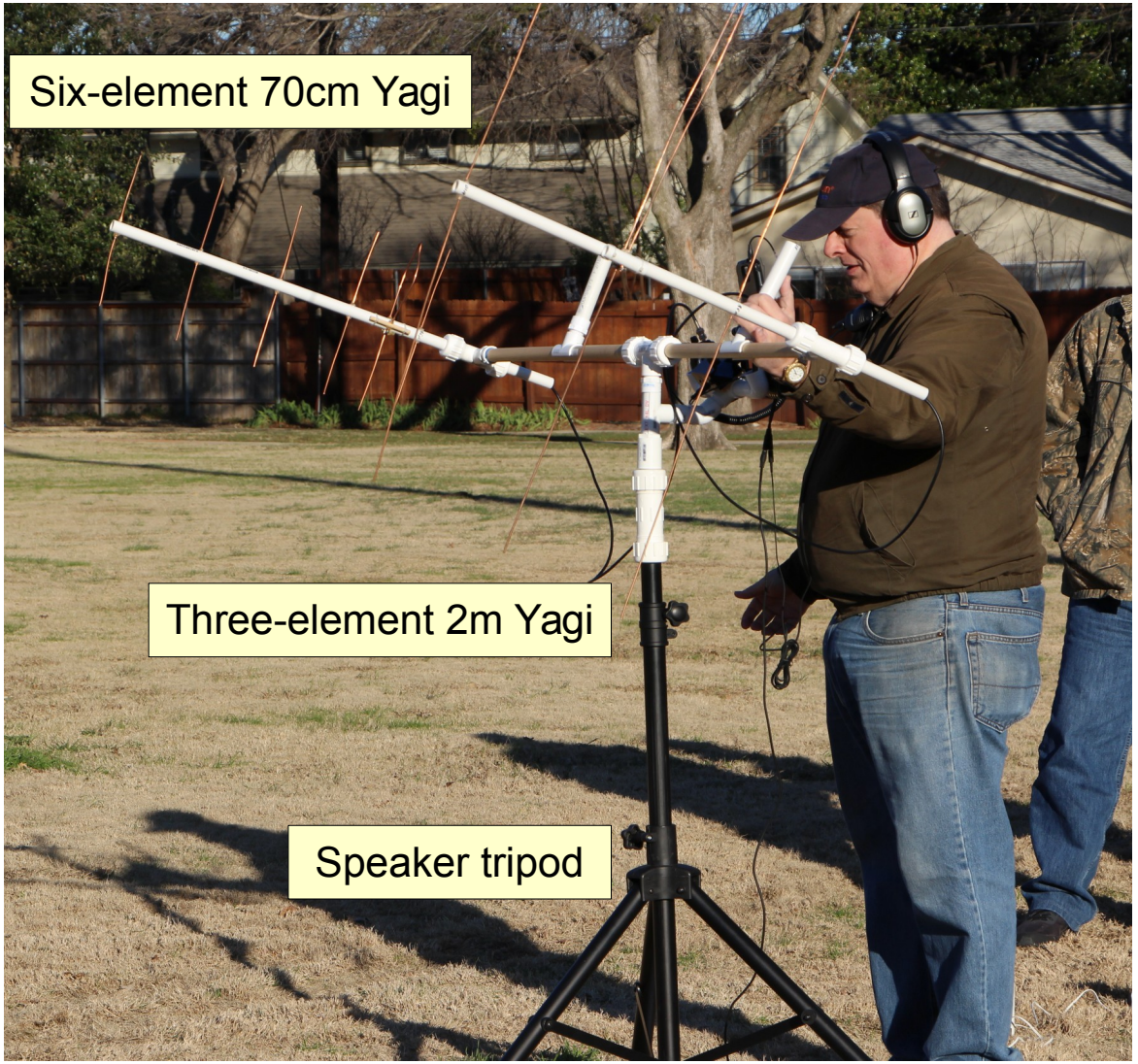
Satellite predictions software for smartphones

- Satellite prediction apps are available for both Android and Apple phones – this is AmsatDroid Free
- A smartphone can be turned into a portable 'satellite operations' device by installing applications for satellite prediction, audio recording, compass, and time!

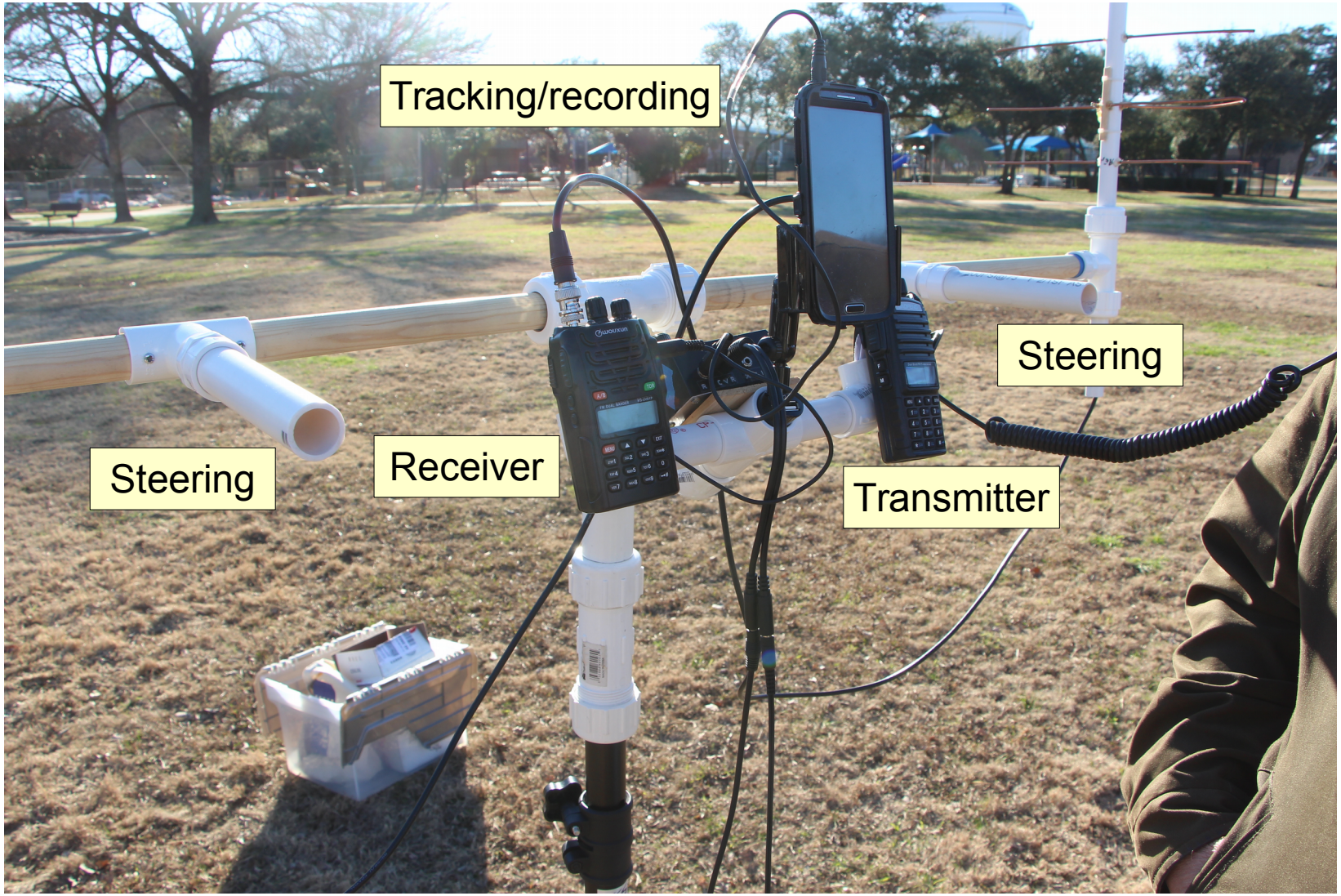


AE5PH Satellite Battlestation

- Speaker tripod provides stable support
- PVC pipe and fittings
  - AZ-EL mount for crossboom
  - Supports for radio equipment
  - Antenna clamps
- Wooden dowel for stable crossboom



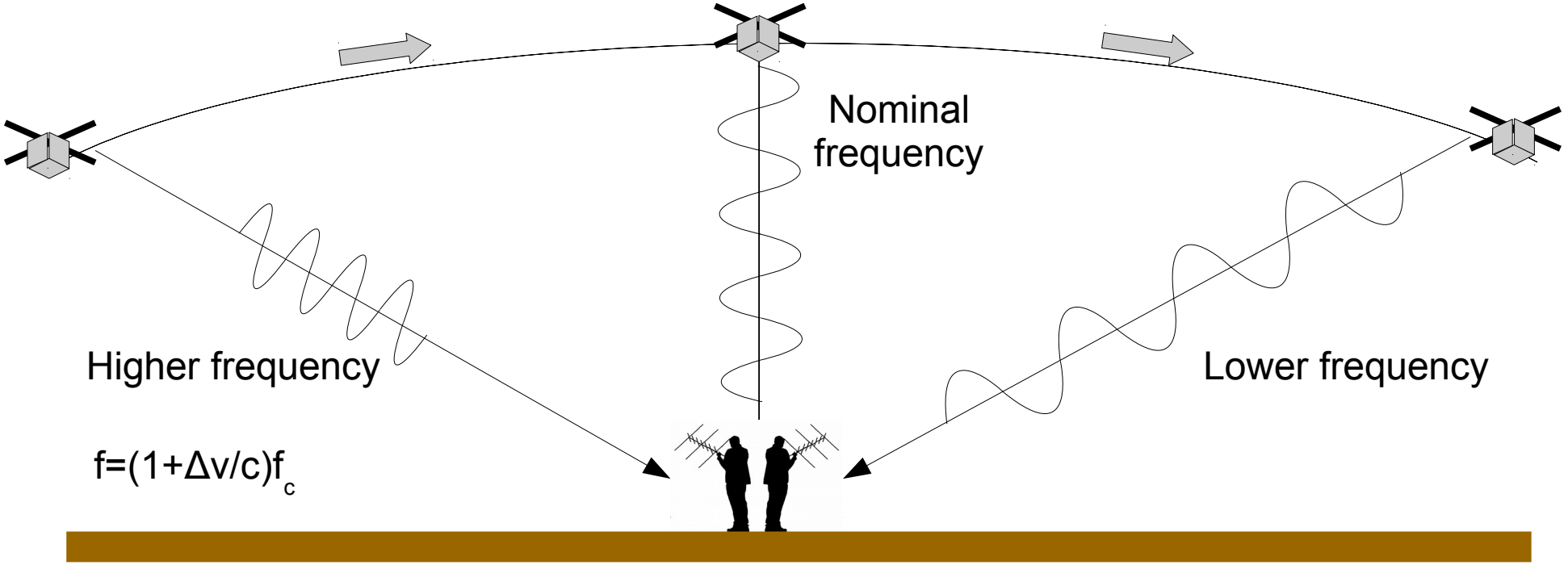
The 'Bridge' of the Battlestation



Some Amateur Satellite Lingo

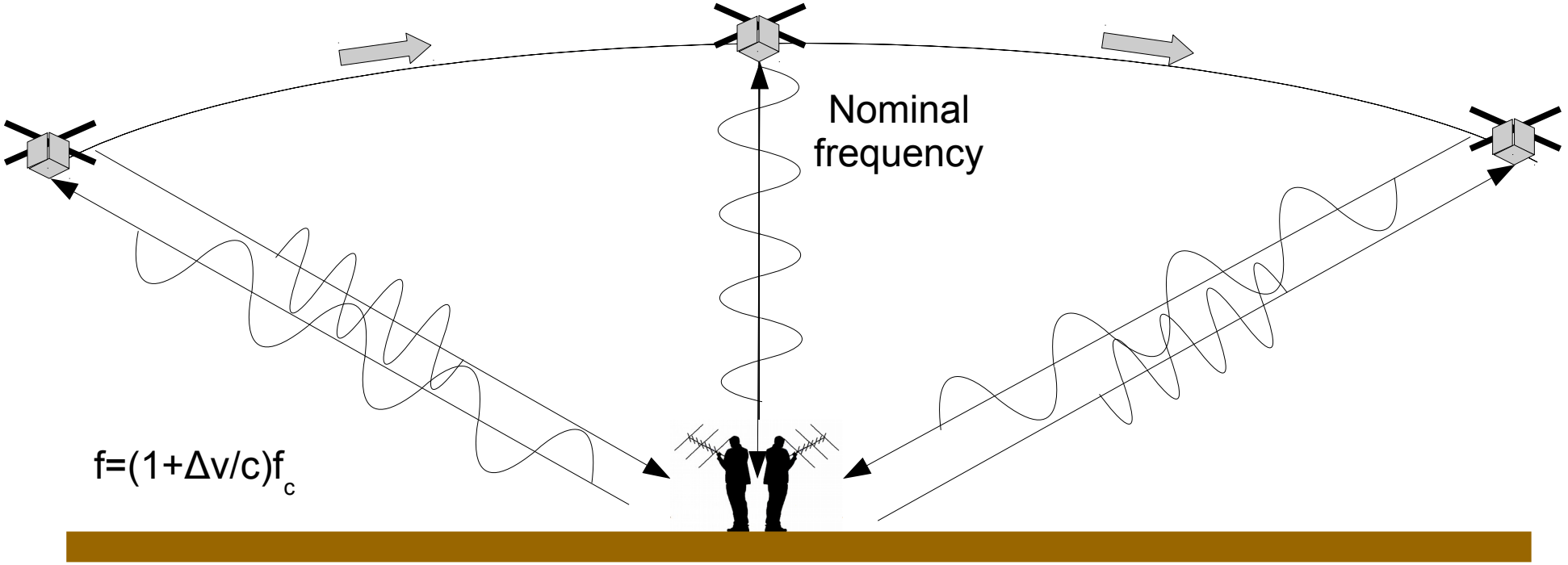
- Uplink (uppercase)/downlink (lowercase) bands of operation, e.g. U/v – UHF uplink, VHF downlink
- Doppler shift – Received frequency change caused by relative motion between the transmitter and receiver
- Azimuth – Direction angle clockwise from North in degrees
- Elevation – Direction angle upwards from the horizon in degrees
- LEO – Low Earth Orbit (usually 1000 km altitude or less)
- AOS – Acquistion Of Signal (coming up over the horizon)
- LOS – Loss Of Signal (going down below the horizon)
- TCA – Time of Closest Approach (highest elevation angle)
- UTC – Coordinated Universal Time

What is Doppler Shift?



- Doppler shift is the change in frequency or wavelength for an observer that is moving relative to the wave source
- Positive relative velocity occurs when the source moves towards the observer, negative relative velocity occurs when the source moves away from the observer
- The higher the relative velocity, proportional to the speed of light, the more pronounced the Doppler shift
- The higher the carrier frequency, the more pronounced the frequency change for a given Doppler shift

Doppler Shift Correction



- Satellite transponders have fixed transmit and receive frequencies, so Doppler shift correction must all be done at the ground station (That be you!)
- As the satellite approaches, the ground station must receive at a higher frequency and transmit at a lower frequency to accomodate for the Doppler shift
- As the satellite receeds, the ground station must receive at a lower frequency and transmit at a higher frequency to accomodate for the Doppler shift
- For FM repeater operations, Doppler shift correction is usually not needed on the 2m band, but must be done on the 70cm band

Radio Programming for Doppler Shift

SO-50 (V/u)

Ch.	TX	PL	RX
1	145.850	74.4*	436.805
2	145.850	67	436.805
3	145.850	67	436.800
4	145.850	67	436.795
5	145.850	67	436.790
6	145.850	67	436.785
7	145.850	74.4*	436.795

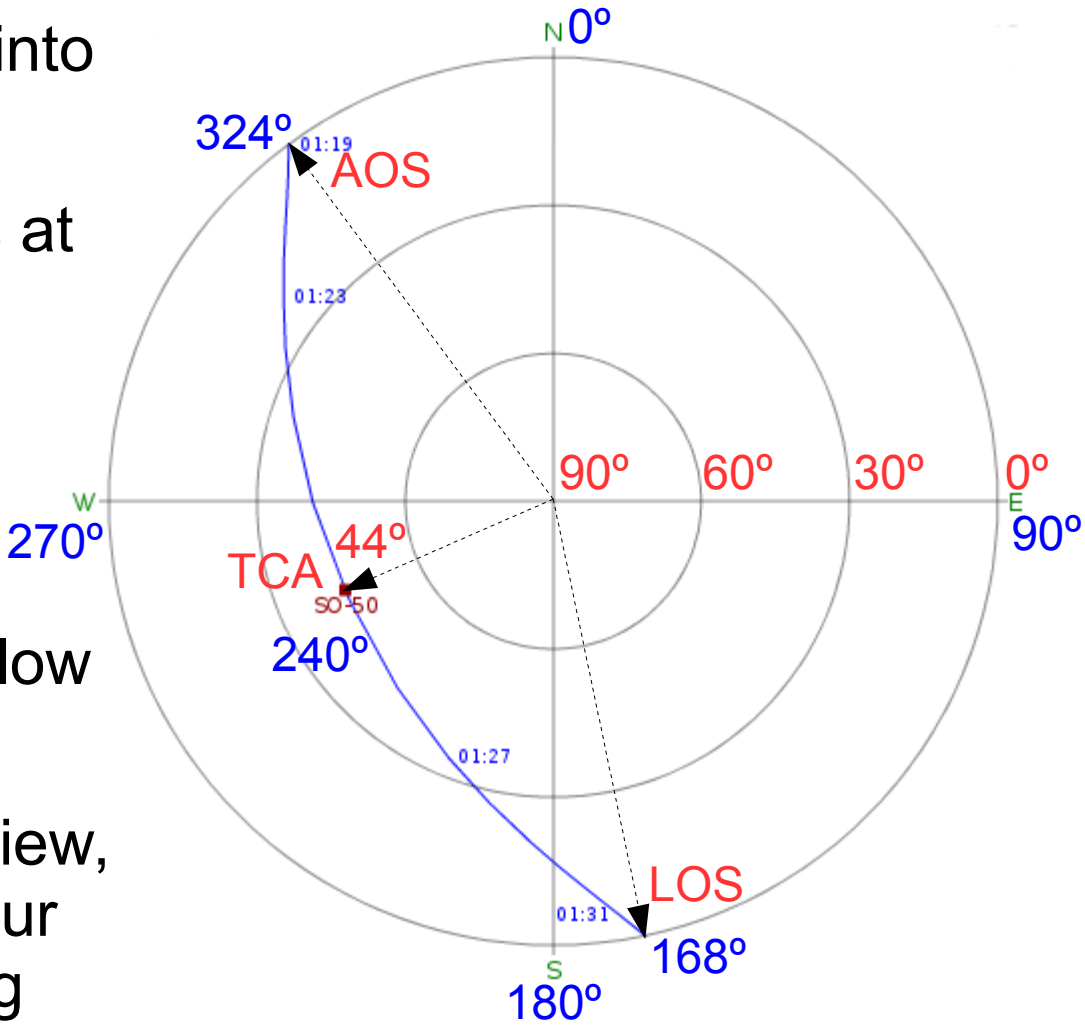
*PL tone to activate transponder if 'asleep'

AO-85 (U/v)

Ch.	TX	PL	RX
1	435.160	67	145.980
2	435.165	67	145.980
3	435.170	67	145.980
4	435.175	67	145.980
5	435.180	67	145.980

Polar View of Satellite Pass

- The polar view is looking up into the celestial hemisphere
- At AOS, the satellite appears at the horizon
- At TCA, the satellite is at maximum elevation and is closest to the ground station
- At LOS, the satellite goes below the horizon
- By understanding the polar view, you'll know where to point your antenna at the satellite during the pass



Basic Satellite Techniques

- Full duplex operation is necessary, so you can hear that you are hitting the repeater and not interfering
- Listen first, so as not to interfere – Situational Awareness!
- Keep QSOs to a minimum – exchange call sign and grid square phonetically (Example: "AE5PH EM12", "AE5PH this is KF5DAF EM13", "KF5DAF this is AE5PH QSL 73")
- Constantly adjust the antenna(s) to point towards the satellite and account for signal polarity – maximize effectiveness of received and transmitted signals
  - Atmospheric bending can distort the signal's polarization
  - A satellite can tumble, changing the antenna's orientation
- Don't forget to adjust radio for Doppler shift

Why Situational Awareness?

- Is a rover working a rare grid square or is a special event station operating? Let everyone have a chance!
- New operator? Help them out – be patient!
- Intentional interferers? Don't call them out – don't feed the trolls!
- Don't keep asking for 'fill-ins'. If you missed information from a station, listen when they work another station
- Only use the power necessary to get into the repeater
  - 5 Watts and often less is needed for the FM repeater satellites
  - Sometime use more power under bad condidtions or in pile-ups, but use with great discression!
  - More power adds to the interference, can potentially damage the repeater frontend, and nobody likes getting 'stomped on'

AMSAT® Award Chasing

- Satellite Communicators' Club
  - Make first contact via amateur satellite
  - Really easy to achieve with FM repeater satellites
- South Africa AMSAT Satellite Communication Achievement Award
  - Make contact with twenty-five different amateur stations
  - Easy to achieve with FM repeater satellites
- Oscar Satellite Communications Achievement Award
  - Work stations in 20 different United States, Canadian Call Areas (Provences), or other countries
  - Easy to achieve with FM repeater satellites

AMSAT® Awards Received

AMSAT™

Affiliated with ARRL

The Radio Amateur Satellite Corporation

THIS IS TO CERTIFY THAT

Mac Cody, AE5PH

IS A MEMBER-STATION OF THE

SATELLITE COMMUNICATORS' CLUB

AND IS ENTITLED TO ALL THE PRIVILEGES, PREROGATIVES, RIGHTS, FAVORS, GLORY, RANK, FAME, NOTORIETY, POPULARITY, AND HONOR OF MEMBERSHIP IN THAT WORTHY ORGANIZATION.

In accepting this certificate, the member-station certifies proficiency in satellite communication by having made a successful contact via a radio amateur satellite.

AMSAT PHASE III

Bruce Paige K5DO

AWARD MANAGER

SA AMSAT

SATELLITE COMMUNICATION ACHIEVEMENT AWARD

Mac Cody, AE5PH

This award is made in recognition of having made twenty-five two-way contacts through Phase II Satellites.

Bruce Paige K5DO

AWARDS MANAGER

AWARD NUMBER US 199

OSCAR SATELLITE COMMUNICATIONS ACHIEVEMENT AWARD

AWARDED TO: **Mac Cody, AE5PH**

The Radio Amateur Satellite Corporation

13 November 2016 — 572 — Bruce Paige K5DO — [signature]

DATE — NUMBER — AWARD MANAGER — PRESIDENT

More AMSAT® Award Chasing

- Oscar Sexagesimal Award
  - Work stations in 60 different United States, Canadian Call Areas (Provences), or other countries
  - Can be achieved with FM repeater satellites
- Oscar Century Award
  - Work stations in 100 different United States, Canadian Call Areas (Provences), or other countries
  - Can be achieved with linear transponder satellites
- Robert W. Barbee Jr., W4AMI Satellite Operator Achievement Award
  - Have QSOs with 1000+ amateur stations via satellite
  - Can be achieved with FM repeater satellites

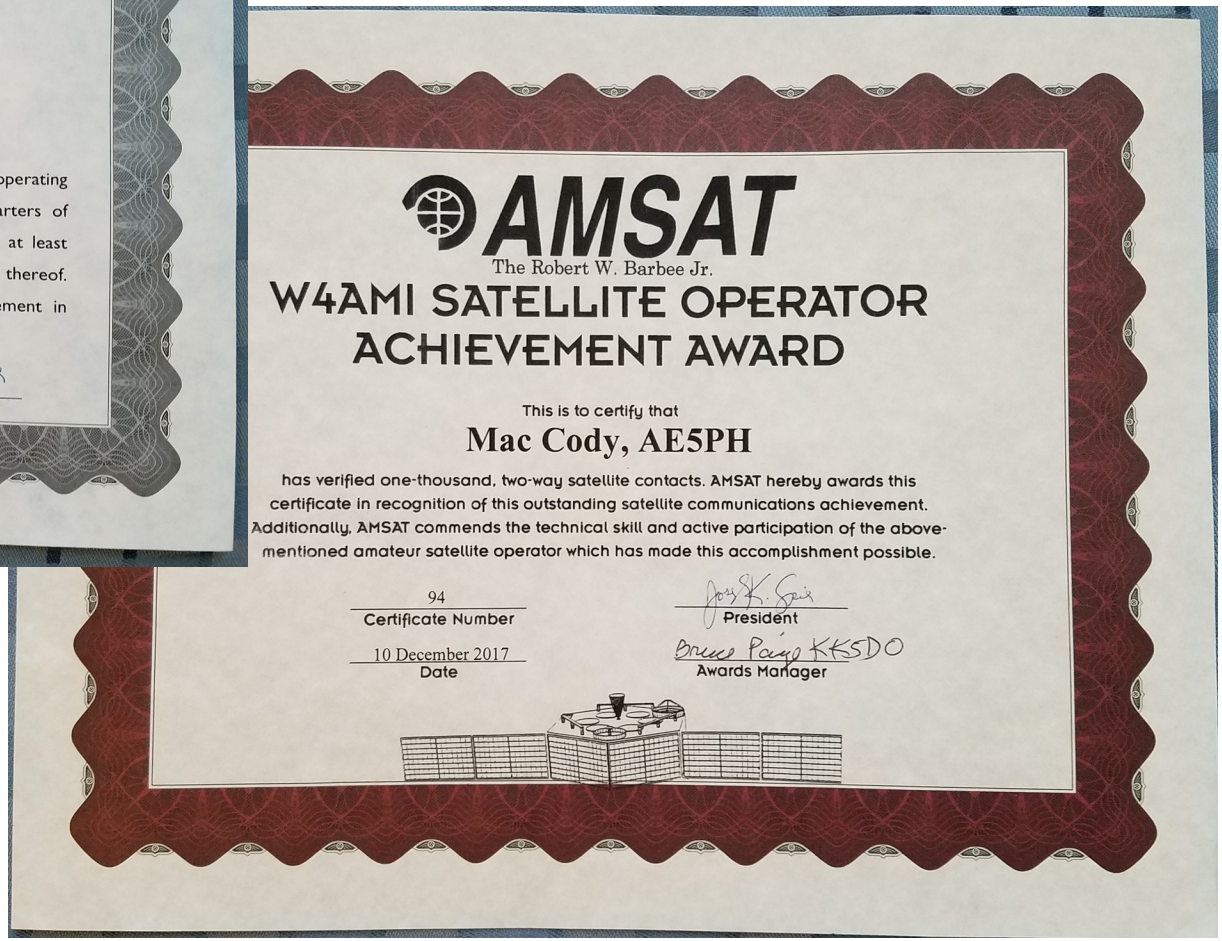
AMSAT® Awards Received

OSCAR SEXAGESIMAL AWARD

AMSAT

This certifies that Mac Cody, operating Amateur Radio Station AE5PH has submitted evidence to AMSAT Headquarters of having conducted two-way Satellite Communication with other Amateur Stations in at least sixty different Canadian call-areas, United States, other countries, or any combination thereof. This certificate is awarded by AMSAT in recognition of this outstanding achievement in Amateur Satellite Communication.

10 December 2017 (Date) 181 (Number) Bruce Paige KK5DO (Award Manager) (President)



AMSAT

The Robert W. Barbee Jr.

W4AMI SATELLITE OPERATOR ACHIEVEMENT AWARD

This is to certify that

Mac Cody, AE5PH

has verified one-thousand, two-way satellite contacts. AMSAT hereby awards this certificate in recognition of this outstanding satellite communications achievement. Additionally, AMSAT commends the technical skill and active participation of the above-mentioned amateur satellite operator which has made this accomplishment possible.

94 Certificate Number

10 December 2017 Date

President

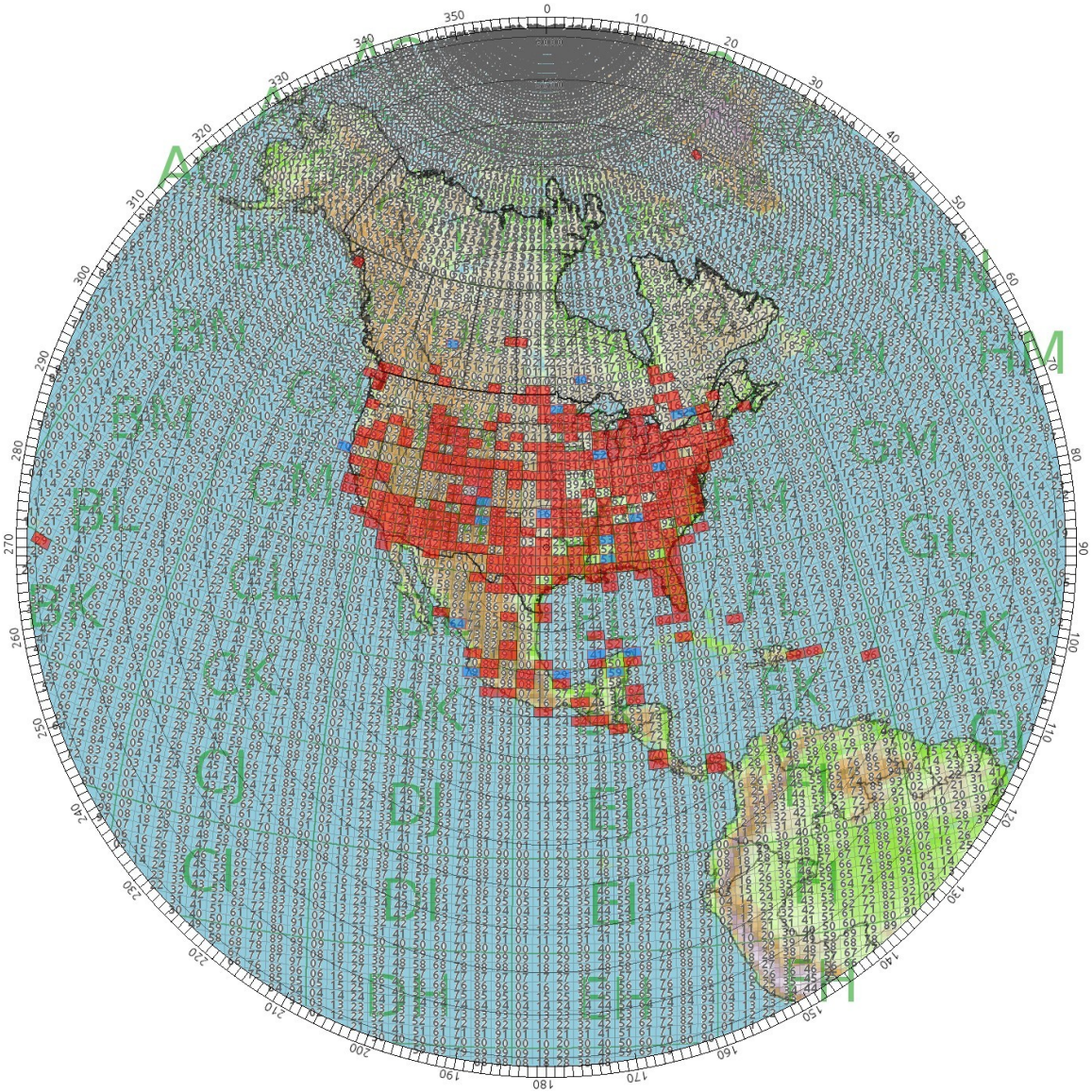
Bruce Paige KK5DO Awards Manager

ARRL Award Chasing for Satellites

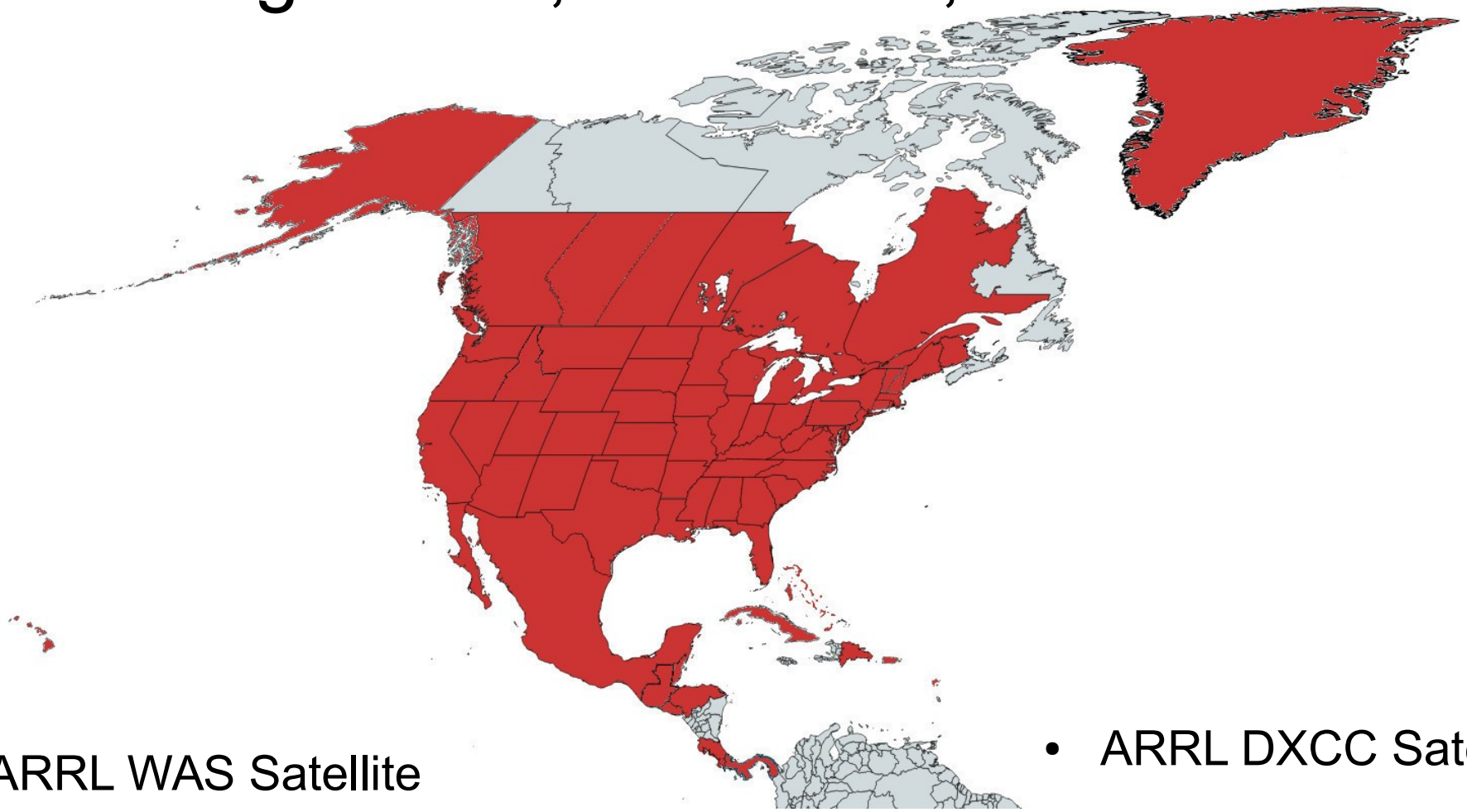
- DX Century Club (DXCC) Satellite
  - Contact one-hundred countries via satellite
  - Impractical to achieve - no Highly Elliptical Orbit satellites available
- Worked All Continents (WAC) Satellite
  - Contact all eight continents via satellite
  - Can be done using linear transponder satellites
- Worked All States (WAS) Satellite
  - Contact all fifty United States via satellite
  - Can be done using FM repeater satellites, but easier with linear transponder satellites
- VHF/UHF Century Club (VUCC) Satellite
  - Contact one-hundred Maidenhead grid squares via satellite
  - Can be easily done using FM repeater satellites

Chasing Grid Squares

- ARRL VUCC Satellite
  - Currently have 337 grid squares confirmed
  - An additional 20 worked but not yet confirmed
  - Have not claimed the award yet – not an ARRL member
- Grid square chasing is a good way to keep motivated to regularly work satellites
- There are a number of satellite operators ('rovers') that travel to activate rare grid squares



Chasing States, Provinces, and Countries



- ARRL WAS Satellite
  - 50 states worked
  - 50 states verified
  - Need to redo Hawaii for valid WAS, though
- AMSAT Sexagesimal Award
  - 60 Canadian call areas, United States, or other countries
  - Working towards Century Award
- ARRL DXCC Satellite
  - 16 entities worked
  - Greenland was on the 'hairy edge' for SO-50!
  - Hawaii via AO-91 was a thrill!

WA4NVM / WA4HFN Grid Awards

- GRID MASTER AWARD
  - Confirmed satellite contacts with all 488 US grids
  - Only ten hams have achieved this award as of April 2019
- GOT GRIDS AWARD
  - One satellite contact in each of the 10 Maidenhead grids squares in the US
- 5 in EM55 AWARD
  - Five satellite contacts with operators in grid square EM55
- For details, see Squirt the Birds (https://sites.google.com/view/squirtthebirds/home) or email squirtthebirds@gmail.com

General Resources

- ARRL – http://arrl.org
- AMSAT-NA – http://www.amsat.org
- AMSAT–UK – http://amsat-uk.org
- Work FM Amateur Radio Satellites – http://www.work-sat.com
- Amateur Radio Ham Radio Maidenhead Grid Square Locator Map - http://www.levinecentral.com/ham/grid_square.php

Antenna Resources

- Kent Britain Cheap Yagi Antennas
  - http://www.wa5vjb.com/references/Cheap%20Antennas-LEOs.pdf
  - http://www.repeater-builder.com/antenna/pdf/cheap-yagis.pdf
- AMSAT Cheap and Easy Yagi Satellite Antennas
  - https://www.amsat.org/cheap-and-easy-yagi-satellite-antennas/
- VE2ZAZ Arrow-Style Satellite Antenna
  - http://ve2zaz.net/Arrow_Ant/Arrow_Style_Ant.htm

Software Resources

- GNOME Predict - http://gpredict.oz9aec.net/
- AmsatDroid FREE - https://play.google.com/store/apps/details?id=uk.me.g4dpz.HamSatDroid&hl=en
- Smart Voice Recorder - https://play.google.com/store/apps/details?id=com.andrwq.recorder&hl=en
- GPS Compass Explorer - https://play.google.com/store/apps/details?id=com.gpsnav.evo.gps2&hl=en

Backup Slides

Linear Transponder Satellites

- Linear transponder satellites recieve a relative wide bandwidth of frequencies that are converted to another frequency range for retransmission
- Over a dozen linear transponder satellites
  - AO-7
  - FO-29 (JAS-2)
  - AO-73 (FUNcube-1)
  - XW-2A (CAS-3A)
  - XW-2B (CAS-3B)
  - XW-2C (CAS-3C)
  - XW-2D (CAS-3D)
  - XW-2F (CAS-3F)
  - EO-79 (QB50p1 and FUNcube-3)
  - UKube-1 (FUNcube-2)
  - EO-88 (Nayif-1 / FUNcube on Nayif-1)
  - CAS-4A
  - CAS-4B
  - JO-97 (JY1Sat)
- Most uplink on UHF and downlink on VHF

Digital Satellites

- International Space Station
  - APRS digipeater (V/v), 1200 bps
  - SSTV (-/v), currently inoperative
- NO-84 (PSAT) – (V/v)
  - PSK31 , supports dozens of users simultaneously
  - APRS digipeater, 1200 bps, available with power permits
- NO-44 (Pcsat)
- AISAT-1
  - APRS digipeater
- FalconSAT-3 (V/u)
  - Released by US Air Force Academy for use for amateur radio operations
  - APRS digipeater, 9600 bps
  - PACSAT Broadcast Protocol (PBP)