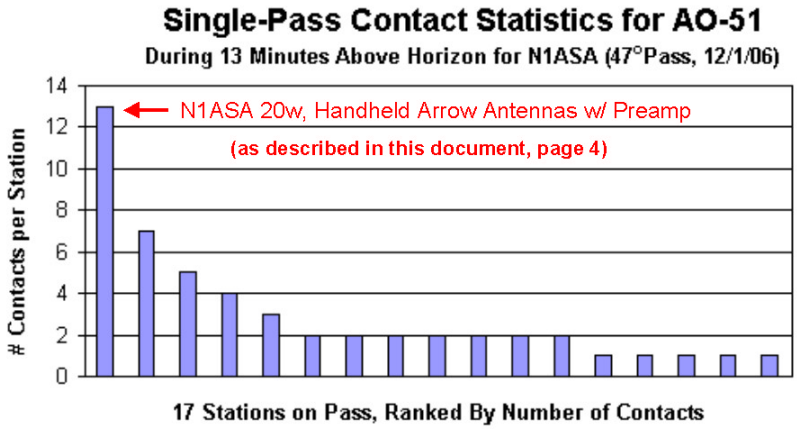
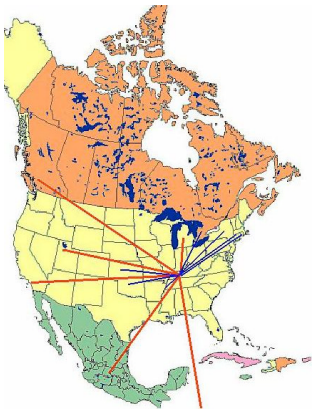
Abstract: Using a handheld antenna system to maintain maximum downlink signal and polarization match, along with a preamp for adequate gain, the number of contacts per pass can easily exceed what is achieved with computer-driven satellite-tracking antenna systems (example graph below). AO-51 passes are heard continuously, from horizon to horizon. Anyone can achieve similar results at minimal cost based on the experience, equipment, and techniques described in this document.





"Down-to-Earth" Satellite Communications

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Purpose and Goal

My interest is in sharing my experience with low-earth-orbit (LEO) FM-repeater OSCAR satellites with anyone interested in amateur communications using them. In particular, I want to cover the basics in a way that simplifies getting started, by describing simple economical systems that will get you on the air quickly. I tell what worked best in my experience, trying various levels of approach, and outline step by step how to get set up, how to operate, and the results you can expect with different setups. I do not describe computer-driven dual-rotator azimuth-elevation-rotator very-large-yagi systems that are quite expensive, and extensive in size. You can go on to build such a system later -- if desired. Other satellites and modes (e.g., VO-52, SSB linear transponders, etc.) are better facilitated with such systems. However, I show how to do as well -- *and even better* -- in making contacts using LEO FM satellites for much smaller cost, with systems that are easy to transport and use anywhere. A summary of this document is given on the final page for review and reference in operating the "FM sats." You might want to **read the last page first**, for overview, then use the rest of the document for detailed setup.

Overview of LEO Capabilities

Currently, there are two fully operational LEO satellites that are FM analog voice repeaters orbiting the earth at altitudes of about 500 miles. These are AO-51 ("Echo") and SO-50 (SaudiSat-1C). Each one passes over your location many times a day (orbital period about 100 minutes), and anywhere from 2 to 4 or so 15-minute passes (for each satellite) will have a satellite reaching elevations greater than, say, 20 degrees above your horizon. The higher the elevation, the closer the satellite is to you and the stronger its signal will be. Overhead (elevation 90 degrees) it is only about 500 miles away. The repeaters' output powers range from about 0.25 watt to just over 0.5 watt -- radiated by dipoles on the satellites. Even at these powers, each can be heard from up to 2000 miles away (line-of-sight) with easily obtainable and not-overly-expensive equipment. You can access the repeater will powers on the order of 5 watts (typical of HT's) and occasional contacts are made using 'uplink" powers less than a watt. With simple equipment, two stations up to almost 4000 miles apart can link up for a -- usually quick -- contact. This means continent-spanning, even intercontinental, multi-country DX with a 5 watt HT on a VHF uplink and UHF downlink. You need a dual-band rig that is capable of transmitting on 2 meters and receiving on 440 MHz (not necessarily simultaneously). Some operators like to use a full-duplex-capable transceiver, but it isn't necessary at all. I prefer not to bother, as it can cause problems with audio recordings that one needs to make during the pass to be able to log all the contacts afterwards. I prefer microphone recording (not direct) to have both sides of the QSO and all of the information. If you don't have a suitable dual-band HT, you can use two radios instead.

Key Factors for Success

The most important factors in reliably making contacts through LEO satellites are, in my experience:

1. Ability to **adjust the receiver frequency (on 440) for the doppler shift** throughout the pass.
2. Ability to track the satellite -- not only across the sky (**Azimuth or compass bearing** and **Elevation angle above the horizon**) -- but very importantly, keeping the **Polarization angle** aligned with the satellite's polarization.
3. Sufficient **gain in the downlink (receiving) antenna system**

I will discuss basic techniques for achieving each of the above requirements with a handheld, hand-tracked, portable system using a dual band HT (5 KHz steps stored in memories), an available handheld yagi system, and a 440 MHz preamp.

1. The "Doppler Effect"

- When a transmitter and receiver are **approaching each other**, the **received frequency is higher** than the frequency that was transmitted. If the transmitter and receiver are **receding from each other**, the **received frequency is lower** than the frequency that was transmitted. (Recall hearing the train horn as it approaches then recedes from you.)
- In the **middle of a satellite pass**, the repeater is moving **across** the line of sight (neither toward nor away from the ground station), so **the doppler shifts are zero** at that point. Otherwise, they range through the pass from some maxima (up or down), through zero at mid-pass, to the maxima in the reversed sense (down or up).
- At the 2m uplink frequency, the doppler range is less than the 5KHz bandpass, so no adjustment of the transmitter frequency is needed for FM capture by the satellite.
- At 440 MHz, the doppler shift is three times greater, with the received signal appearing up to about 10KHz higher than nominal as the satellite rises on approach (Acquisition of Signal, or AOS), and up to 10 KHz lower than nominal as the satellite recedes and sets (Loss of Signal, or LOS). You will need to retune the receiver (one 5 KHz click at a time) during the pass as the signal begins to sound "ragged" going out of the channel passband into the next lower-frequency channel.
- The table below lists the uplink frequency and the set of downlink frequencies that should be programmed into your radio memories for each commonly used LEO repeater.

Time in Pass	**AO-51 (Echo)**		**AO-51 Second Repeater (occasionally available)**		**SO-50 (Saudisat 1C)***	
(Passes last about 15 min)	Uplink Xmt	Downlink Rcv	Uplink Xmt	Downlink Rcv	Uplink Xmt	Downlink Rcv
Start (AOS)	**145.920** (67.0Hz)	435.310	**145.880** (67.0Hz)	435.160	**145.850** (67.0Hz)	436.805
	145.920 (67.0Hz)	435.305	**145.880** (67.0Hz)	435.155	**145.850** (67.0Hz)	436.800
Mid-pass	**145.920** (67.0Hz)	**435.300**	**145.880** (67.0Hz)	**435.150**	**145.850** (67.0Hz)	**436.795**
	145.920 (67.0Hz)	435.295	**145.880** (67.0Hz)	435.145	**145.850** (67.0Hz)	436.790
End (LOS)	**145.920** (67.0Hz)	435.290	**145.880** (67.0Hz)	435.140	**145.850** (67.0Hz)	436.785

*It's a good idea in using SO-50 to also have a memory-stored VHF channel at 145.850 with a 74.4 Hz tone. Transmitting this signal will activate/re-activate SO-50's ten minute timer if it times out.

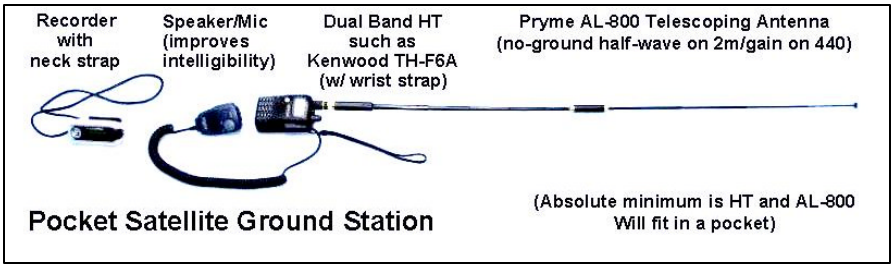
2. Tracking the Satellite Across the Sky and Maintaining Polarization Match

- Basically, you want to keep adjusting your receiving antenna's pointing direction to keep up with the satellite, as indicated by maximizing the received signal.
- Satellite antennas are usually whips or dipoles. **The satellite may slowly tumble**, changing the orientation of the antennas. If you happen to be "off the end" of its antenna, the signal may be too weak to work. Even if you remain out of its "null", the direction of the linear polarization of the satellite downlink signal changes relative to you during the pass. If the polarization at some instant happens to be perpendicular to the polarization of your receiving antenna, there is about a 20dB (100x) signal loss.

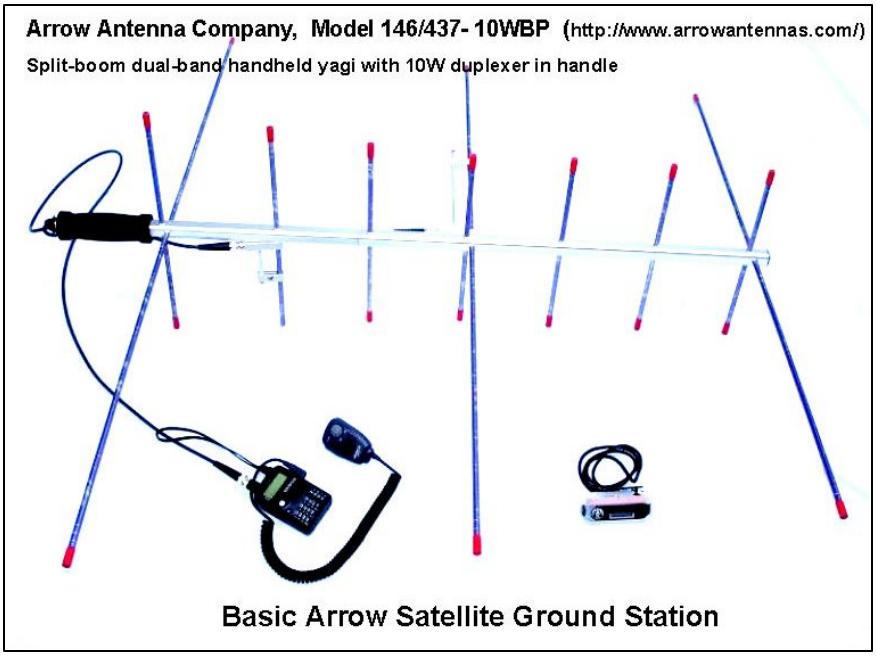
- If you use an antenna whose polarization you can't adjust (say a fix-mounted dipole, ground plane, J-pole, or yagi), you will experience **long periods of drop-out or "fades"** of the satellite signal during the pass. You may be able to make some contacts, but much of the pass time will be unusable.
- To have nearly continuous coverage of the pass, you need to frequently **adjust the polarization angle** of your receiving antenna to keep up with the current polarization of the satellite transmitter. A handheld yagi is optimum for achieving this match, as you simply twist your wrist and rotate the yagi about its boom as an axis to find the satellite polarization (stongest signal). You can easily vary the pointing direction by hand to maximize the signal as you "track" the satellite across the sky, having reviewed the predicted path of the pass beforehand, as described later in this paper.

3. Downlink Gain

- When a LEO satellite is overhead (90 degrees elevation) it is about 500 miles from you. When it is just a few degrees above your horizon, it is up to 2000 miles away (4 times further and 16 times weaker, or -12 dB compared to the signal when overhead). Thus, the signal is generally stronger for higher elevations of the satellite above your horizon. With a given receiving system, you might be able to work it only when it is at very high elevations. To work it at lower elevations and use more of the pass time, you need more gain in your receiving system.



- **Barely:** It is sometimes possible to work a LEO at high elevation angles using just the HT and a Pryme AL-800 telescoping dual-band whip antenna. To hear the satellite, I slowly move the whip through a range of orientations (sometimes slightly downward) until the polarization matches (and keep checking to maintain it). With this arrangement (shown above), I average about 1 contact per high pass (with no contacts on some of them). Adding the preamp described in a later section can result in about 2 contacts per pass. (When UO-14 was active with 2.5 watts downlink, this system easily worked an average of 4 contacts, and up to 9 per pass -- current LEOs are 7-10 dB weaker, so more gain is needed.)

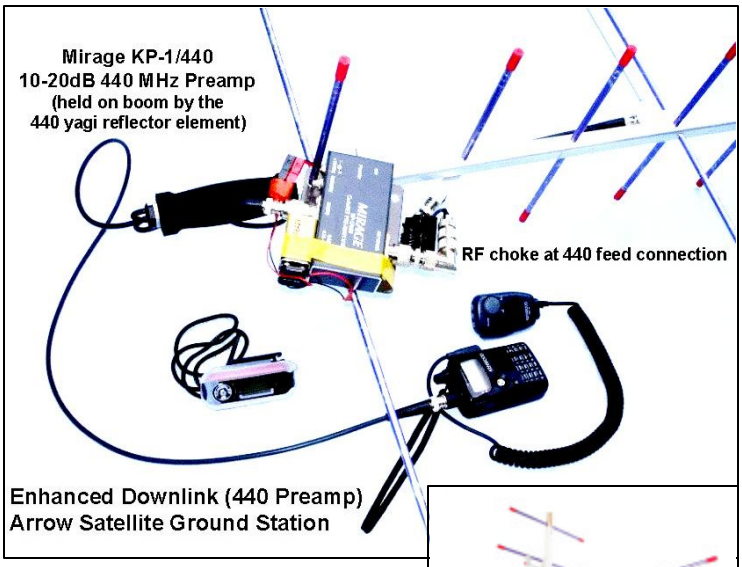


- **Better:** The Arrow Antenna Company sells a dual-band, hand-held yagi that is widely used for satellite work. The model to get is the 146/437-10WBP, which easily assembles and disassembles into transportable parts no longer than about 22 inches. They also sell a nice canvas bag, or wrap, with pockets to safely hold all the parts for carrying or packing in baggage. The above-cited model contains a 10-watt duplexer in its handle to combine both antenna signals into a single cable for attaching to the HT. This system provides about 6 dB gain on the 2m uplink and about 10 dB gain for the 440 MHz downlink. With this system, I average about 2-4 contacts per pass (with none on some passes).

- **Super:** A low-noise 440 MHz preamplifier gives a significant boost (10 to 20 dB) to the downlink sensitivity and makes much more of the pass time usable, allowing contacts when the satellite is just a few degrees above your horizon. I happen to use the Mirage KP-1/440, which can be powered by a 12 volt source (I generally use 18 volts from two 9 volt batteries in series, taped to the case of the preamp). **This setup is really an optimum system -- it is very transportable, and with it I achieve an average of about 7 contacts per pass (ranging from about 4 to 12)**.

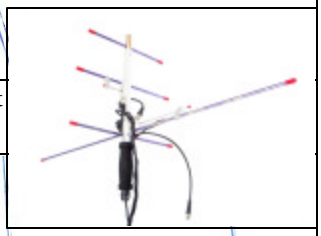
  The preamp makes a **very big difference** in making contacts. The RF choke at the 440 feed point is also important to avoid loss of the weak signal.

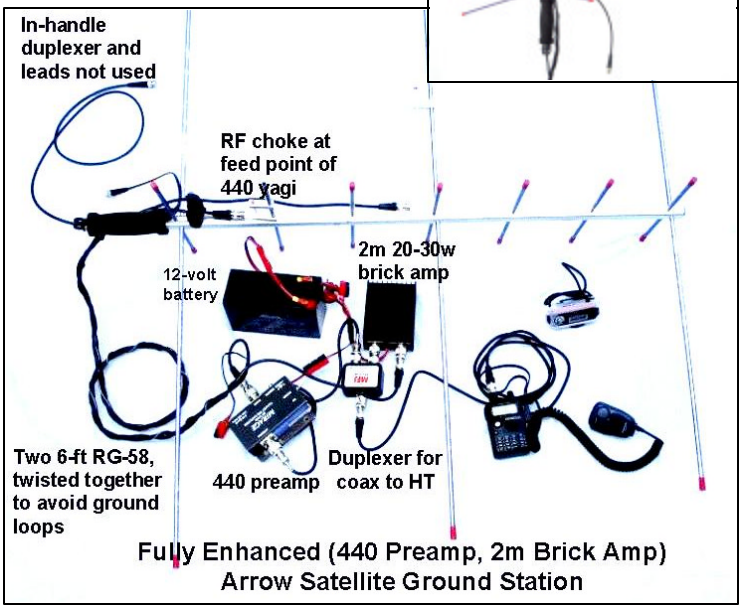
- **Awesome:** If you want to pretty much make contacts at will, you can be noticed more often with a better signal using a small VHF "brick" amplifier. I use one that produces about 20 watts out with the HT running 5 watts into it. The connection scheme is described in the photo at right. All of the electronics can be contained in a camera bag (about 10" across) and operated from there, as shown below. The amp should be turned off when using the QRP-reserved AO-51 second repeater.



Enhanced Downlink (440 Preamp)
Arrow Satellite Ground Station

(Short version also works -- slight compromise in performance) →

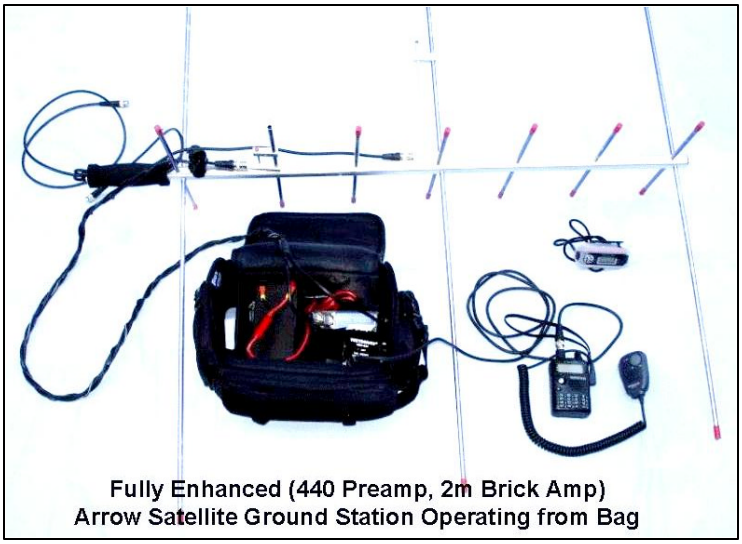




Fully Enhanced (440 Preamp, 2m Brick Amp)
Arrow Satellite Ground Station


Fully Enhanced Ground Station in a Bag


Fully Enhanced (440 Preamp, 2m Brick Amp)
Arrow Satellite Ground Station TO GO


Fully Enhanced (440 Preamp, 2m Brick Amp)
Arrow Satellite Ground Station Operating from Bag

Finding When the Satellites Pass Over and Where to Point Your Antenna

Use the NASA Marshall Space Flight Center's web-based program "**J-Pass**" to predict passes of AO-51 and SO-50 -- all containing simple FM voice repeaters. Most convenient is the J-Pass **email service**, which can regularly email pass information in the form of three-day predictions, sent every Monday, Wednesday, and Friday. To subscribe to the free service:

1. Go to: http://sccience.nasa.gov/RealTime/JPass/20/
2. Select: J-Pass E-Mail
3. Give your email address, and proceed with the most advanced options, asking for ALL PASSES of AO-51 and SO-50 (or Saudisat 1C.)
4. Choose M/W/F as the frequency of emails.

Below is a **sample** of emailed AO-51 pass predictions for Bowling Green, KY, for 9/30-10/03/2005:

The first entry tells us that --

- On 9/30 at 10:05:58pm CDT,
- AO-51 rises in the S.
- It will set in the NNW after 15m 14s.
- (It is sun-lit for 2m 59s, which doesn't matter because it's too faint to see)
- Its maximum elevation is 54 degrees, looking in the WSW direction.

In preparation for the pass, I carry a small note card that simply reads:

AO-51 9/30 10:06pm S (54 WSW) NNW

(Maximum elevation 54° will occur in the WSW direction, about halfway through the pass, ~7 minutes after rising.)

>> AO-51 approx. vis. mag. 10

Date mm/dd	Rise Time	Rise Dir.	Set Dir.	Dur. mm:ss	Lit Dur. mm:ss	Max. Elev	/Dir
9/30	08:28:39pm	ESE	N	13:01	03:30	17	ENE
9/30	**10:05:58pm**	**S**	**NNW**	**15:14**	**02:59**	**54**	**WSW**
10/01	10:15:55am	NNE	S	15:15	15:15	61	E
10/01	11:55:30am	N	WSW	12:45	12:45	15	WNW
10/01	07:51:44pm	E	NNE	09:54	02:59	6	NE
10/01	09:26:47pm	SSE	N	15:24	03:30	62	E
10/01	11:07:19pm	SW	NNW	12:39	01:15	13	W
10/02	09:37:08am	NNE	SSE	14:15	14:15	25	E
10/02	11:15:46am	N	SW	14:45	14:45	35	WNW
10/02	08:48:20pm	SE	N	14:19	03:30	26	ENE

So, at the given start time, I point my antenna to the ESE horizon and listen, rotating about the boom as an axis to match the polarization. Sometimes the signal appears just after the satellite rises, but more often it may take two or more minutes before signals begin to be heard. Be patient, move and twist the antenna about in the general direction of the rising point. After a few minutes of waiting with nothing heard, test the next doppler frequency, which may be becoming appropriate. When I acquire the signal, I follow it across the sky, maintaining the strongest received signal by adjusting the pointing direction and rotating the boom to match the polarization. Iin the example above, it reaches its maximum elevation of 17° in the ENE direction halfway (about 6-7 minutes) into the pass. I continue following it until it sets on the horizon in the N. All along, I am calling and listening, to make contacts (see later suggestions on techniques). In preparation for the pass, it helps me to imagine the path before the pass, and to practice sweeping the antenna from the rising point, to the maximum elevation point, to the setting point. In the list from J-Pass, plan ahead which passes you want to try. That depends on your schedule, and to some extent, the maximum altitude of the passes. Passes above about 10° usually work with the Arrow yagis and preamp, and higher passes will probably yield more contacts. When I've selected the passes, it helps me to **set a timer or alarm clock** to remind me, because it is easy to work on other projects and forget to work a pass.

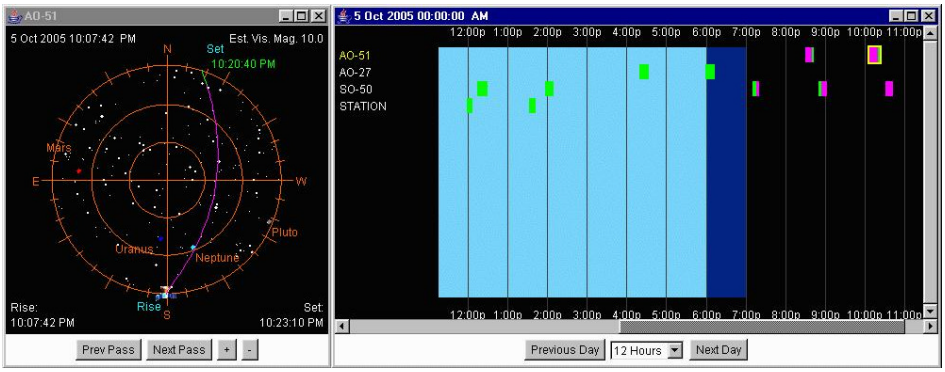
Important: There are other constraints that determine which passes you can work. For example, AO-51 is sometimes operated in modes other than V/U (L-band, S-band), so you periodically need to go the **AMSAT website** (below) for current schedules to know which passes will be useful.

Some Very Useful Websites for Planning and Scheduling:

AMSAT -- Main Page: http://www.amsat.org/amsat-new/index.php
AMSAT -- Satellite Status Page: http://www.amsat.org/amsat-new/satellites/status.php
AO-51 (Echo) Scheduled Ops: http://www.amsat.org/amsat-new/echo/ControlTeam.php
AMSAT NEWS: http://www.amsat.org/amsat-new/news/
J-PASS 2.0: http://science.nasa.gov/Realtime/Jpass/20/

Emailed predictions, or **immediate predictions** (if you have Java enabled in your browser):

The sky chart on the left describes the 10:37pm pass of AO-51 that is selected on the day's chart to the right.

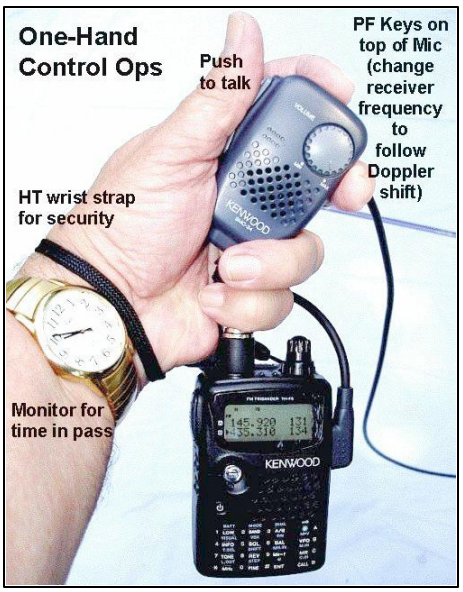


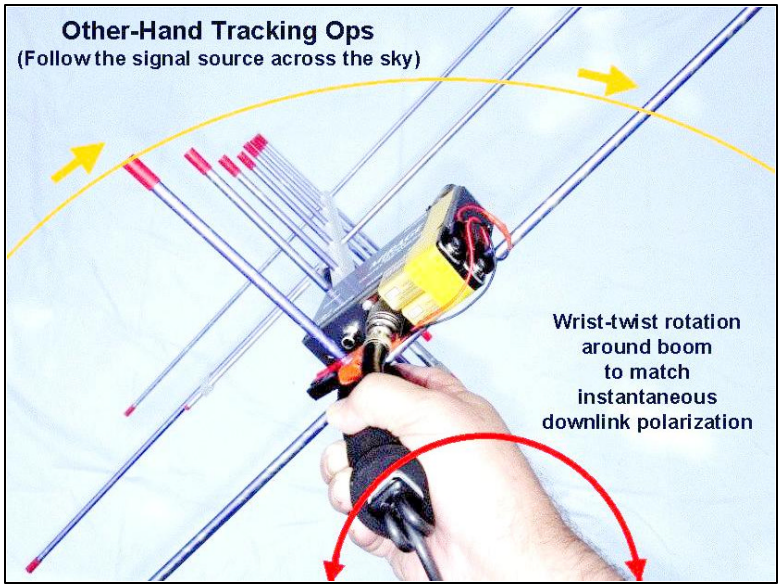
LEO and ISS Repeater Protocol and Technique

- **Call only when signals have been heard!**
- **Never call "CQ Satellite"** (and those who do are usually not hearing anything)
- **Simply repeat your call, often, and wait for someone to return to it**.
- Call **during gaps** or anticipated gaps in received activity.
- Give your **callsign**, and perhaps **grid-square** (mine is EM67), as exchanged information.
- At low power, you may have better luck just **calling repeatedly**, with others coming back to you.
- For LEOs, change the 440 MHz receiver frequency (downward) as signals slide out of the passband.
- Many signals received from the "moving hot spot in the sky" are from 5 watt, handheld stations.

Getting Started

Practice on a few passes by just listening, developing your tracking and doppler frequency adjustment techniques. Observe the rhythm and protocol of the contacts and exchanges. Test your recording system to make sure the results are intelligible. When you are comfortable after a few passes -- jump in!





Example 1 -- Kenwood TH-F6A & AO-51

Dual Transceivers --
Xmt on A (upper)
Rcv on B (lower)

Program all frequencies and tones into memories

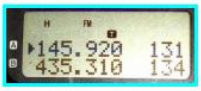
Programmable Keys:
A/B - MemUp - MemDn

Speaker-mic helps with clarity and control

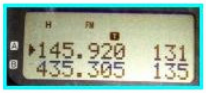
Set rcvr audio balance to band B only, Squelch OFF

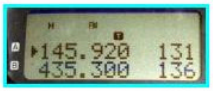
Always ***Select A*** for Xmt -- Freq 145.920, Tone 67.0 Hz

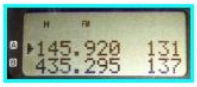
During pass, change receiver frequency as signal shifts out of the channel.

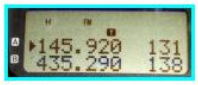


Listen on 435.310 → **Select B 435.305 Select A** → **Select B 435.300 Select A** → **Select B 435.295 Select A** → **Select B 435.290 Select A**

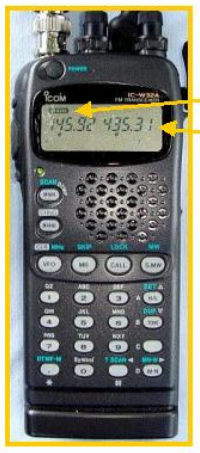








Example 2 -- Icom IC-W32A & AO-51



Dual Bands -
Xmt on A (left)
Rcv on B (right)

Squelch OFF
Volume down on Xmt Band
Volume up on Rcv Band

Always ***Select A*** ("Main") for Xmt
Freq 145.920, Tone 67.0 Hz

Speaker-mic helps with clarity

During pass, change receiver frequency as signal shifts out of the channel.

Listen on 435.31^{0} → **Dial to 435.30^{5}** → **Dial to 435.30^{0}** → **Dial to 435.29^{5}** → **Dial to 435.29^{0}**

Example 3 -- Yaesu FT- 817 & AO-51

Dual VFOs --
Use "Split" Mode
FM Mode
Squelch Off

Set VFO A (Xmt) fixed on 145.920 with Tone 67.0 Hz

Split Mode -- activates on PTT, switches to VFO A

Set to VFO B to receive during the pass

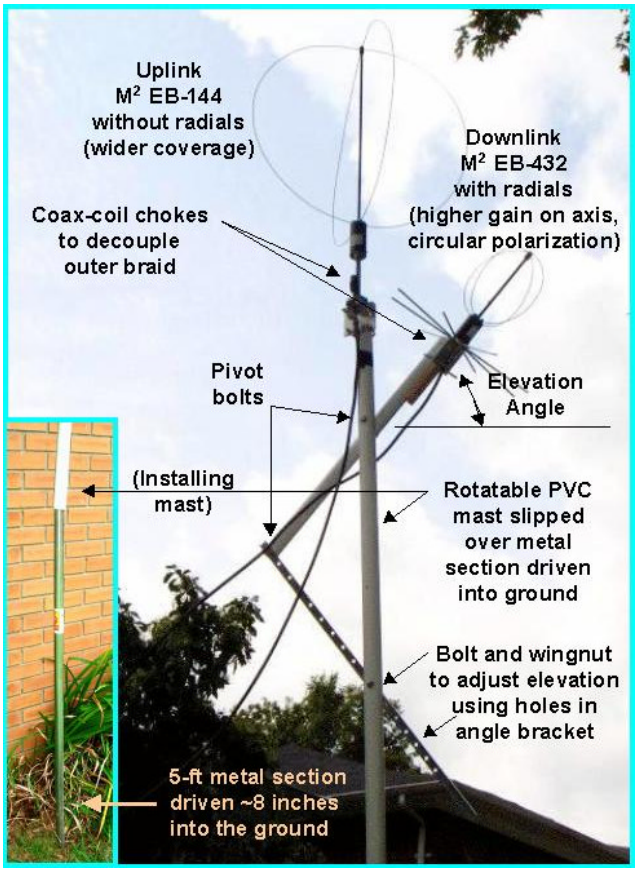
VFO B (Rcv) starts at ~ 435.310

Tune downward to follow signal during pass

The photo-diagram at right illustrates a simple, "non-tracking" antenna system for a fixed location or portable installation. It provides a form of fixed station operation without the expense of el-az rotators and computer tracking.

The "eggbeaters" are circularly polarized in the direction of their axis (and linear perpendicular to axis). The downlink antenna uses radials to increase the gain in the axial (circularly polarized) direction. It overcomes the varying polarization of the downlink, but needs a preamp to provide adequate overall gain.

Because the 440 eggbeater is set up for maximum axial gain, it will work well for the central 4-5 minutes of the pass, typically providing 2-4 contacts on AO-51. It works best for higher passes, above 30 degree maximum elevation or so. Prior to an upcoming pass, the elevation angle of the downlink antenna should be adjusted about midway between 30 degrees and the maximum elevation for the pass. The mast should be rotated to point the eggbeater axis in the compass direction of the high point of the pass. Using a bit more power for the uplink can also help with this system.

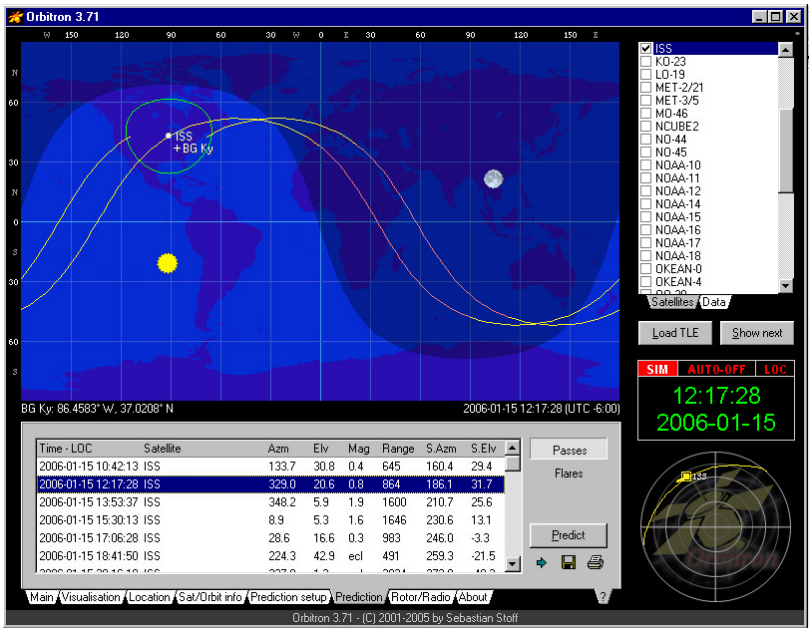


Optional Enhancements for Convenience or Better Reception

The following aids are not absolutely essential, but they can add to the convenience and pleasure of operating handheld, as described below. Don't wait until you have them all to get on the air. Begin operating and you will see how each can help in its own way.

1. **External speaker/microphone**, will generally improve the intelligibility of the reception and the logging recording (see below). Mine also has three programmable function (PF) keys that enable me to perform memory-channel changes to follow the doppler channel shifts directly with the hand holding the microphone.
2. **Recorder**, either tape or digital. Satellite work is continuous and fast-paced. In handheld mode, **logging contacts** is impractical (both hands are occupied), and one will not likely remember the calls (and times) of the contacts. After the pass, replay the tape to log the contacts. I use a tiny MP3 player that features a high-quality voice recorder mode, and I just hang it around my neck by its lanyard. It makes excellent quality recordings with its microphone picking up both the HT's audio and my voice.
3. **Headlamp** – a small light held on a headband is helpful at night for checking things visually during the pass, including the band-switching/downlink doppler-frequency adjustment maneuver several times during the pass.
4. **440 MHz Pre-Amp** -- As discussed, a preamp can really make a difference in the quality of reception and make a larger portion of the pass time usable -- resulting in larger numbers of contacts per pass on average.
5. **Gloves** -- If operating outside in the winter, a pair of thin cotton gloves will be very helpful.
6. **Indoor Operations** -- Keep in mind that it may be possible to work from inside your house as well (with slightly reduced numbers of contacts). When I was confined to bed with a lengthy illness in 2004, I gave it a try. That's when I first tried the preamp enhancement. I was able to make hundreds of contacts this way over several months confinement. It is an attractive alternative in winter.
7. **Kitchen Timer or Alarm Clock** -- A very useful aid for reminding you to when a pass is coming up.

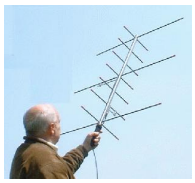
Making Your Own Pass Predictions



Eventually, you may want to be able to generate pass predictions at will using your computer. This capability is also useful for studying the characteristics of passes, such as seeing how the doppler frequencies vary and how long it takes to traverse various portions of the path. A variety of commercial software exists for these purpose, and for controlling the tracking antenna and rig frequencies during a pass. For most purposes when starting out, everything you need can be done with **Orbitron**, which is **freeware** that can be downloaded from **http://www.stoff.pl/**

In any case, you will need to obtain tables of the current "Keps", or Keplerian orbital elements, for the satellites of interest. For amateur radio satellites, go to http://www.amsat.org/amsat-new/tools/keps.php and select the NASA two-line elements (TLE). Highlight just the data portion of the display, copy, and then paste into a text editor and save the file. It can be loaded into Orbitron to facilitate currently accurate orbital calculations. The data are updated about once per month.

To the Heart of the Matter -- Distilled Basics Summarized and Reviewed



1. **Antenna:** Get an Arrow Antenna Company 146/437-10WPB (dual-band portable yagis on one boom) or home-brew equivalent, and a 440 preamp. Hand-hold the antenna and follow the (invisible) track across the sky, pointing and rotating the polarization as needed to keep the received signal as strong as possible. The track is found in step 3.

2. **Transceiver:** Try to adapt what you have, if it has dual-band capability (duplex operation is not required). (Also, two radios could be used.) Keep power to 20 watts or less if holding the antenna by hand. Program modes and memories to correct for doppler effects on the 440 MHz band. Various transceivers differ in how to transmit on one band and then receive on the other (and not necessarily at the same time). Read the manual and program the following frequencies (and tones) into memories once and for all:

Time in Pass	**AO-51 (Echo)**		**AO-51 Second Repeater (occasionally available)**		**SO-50 (Saudisat 1C)***	
(Passes last about 15 min)	Uplink Xmt	Downlink Rcv	Uplink Xmt	Downlink Rcv	Uplink Xmt	Downlink Rcv
Start (AOS)	**145.920** (67.0Hz)	435.310	**145.880** (67.0Hz)	435.160	**145.850** (67.0Hz)	436.805
	145.920 (67.0Hz)	435.305	**145.880** (67.0Hz)	435.155	**145.850** (67.0Hz)	436.800
Mid-pass	**145.920** (67.0Hz)	**435.300**	**145.880** (67.0Hz)	**435.150**	**145.850** (67.0Hz)	**436.795**
	145.920 (67.0Hz)	435.295	**145.880** (67.0Hz)	435.145	**145.850** (67.0Hz)	436.790
End (LOS)	**145.920** (67.0Hz)	435.290	**145.880** (67.0Hz)	435.140	**145.850** (67.0Hz)	436.785

3. **Pass Predictions -- Schedules and Directions:** Use NASA's J-PASS 2.0 for emailed or immediate pass information for AO-51 and SO-50. Verify current operation modes from the given web references. Carry a note giving the pass information in a convenient form such as: **AO-51 9/30 10:06pm S (54 WSW) NNW.** Set up a few minutes before the pass, and briefly practice the path by moving the antenna back and forth a few times between the rising and setting points on the horizon, passing approximately through the maximum altitude point. Remember, there are 90 degrees between the horizon and the point directly overhead.

4. **LEO and ISS Repeater Protocol and Technique**
   - **Call only when signals have been heard!**
   - **Never call "CQ Satellite"** (those who do are usually not hearing anything)
   - **Simply repeat your call, often, and wait for someone to return to it**.
   - Call **during gaps** or anticipated gaps in received activity.
   - Give your **callsign**, and perhaps **grid-square,** as exchanged information.
   - At low power, you may have better luck just **calling repeatedly**, with others coming back to you.
   - For LEOs, change the 440 MHz receive frequency downward as signals slide out of the passband.

5. As needed, add enhancements such as extension speaker/microphone, small voice recorder (for logging), headlamp for night passes, and 440 MHz preamp for improved reception.

After the initial setup and a few contacts, it becomes easier and easier. This document is meant to get you started quickly. **Best wishes, and good V/U DX'ing on the LEOs!**

(Copies of this document may be freely downloaded from the following URLs, all lowercase: http://www.wku.edu/ksgc/sats.pdf or http://www.wku.edu/ksgc/sats.doc To hear what to expect, a sample recording of a typical pass of AO-51 (76 degree elevation, Arrow yagis with preamp, 20 watts, 9 contacts ending with a contact with Mexico) is downloadable from: http://www.wku.edu/ksgc/sats.mp3)

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