Building a "Poor-Man's" Amateur Radio Satellite Ground Station
Part I: Introduction

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The goal of this multi-part series is to **build up an inexpensive working amateur radio satellite ground station** -- not to "buy" one. In decades gone by, many hams built their entire stations, including all their radios, from scratch. It is beyond many of us (who have other hobbies and vocations and obligations in life) to solder together complete vhf/uhf transceivers. However, it is **well within our grasp** to piece together many parts of ham radio stations from parts or second-hand or inexpensive equipment, and still get workable performance -- and the learning that accompanies this accomplishes part of the goals expressed in Part 97.1 for the Amateur Radio Service.

<u>How I Got Interested</u>

Our local ham radio group was having a tough time in the satellite arena in summer or winter Field Day. Yet one of our crew managed an AX.25 connection to the Russian digipeater aboard the International Space Station with nothing more than our EOC VHF packet/VARA digital station! That got me thinking: "How much more could we advance with a bit more knowledge and equipment building on our own?"

It seems that success in this field requires

(1) somewhat directional/high-gain VHF and UHF antennas (or omni-directional antennas and very high-gain preamplifiers!);
(2) filter separation between the two bands, to allow full duplex operation and protect receiver front-ends,
(3) some means of aiming the antennas that is driven by mathematical models of satellite position, and
(4) full-duplex (simultaneous receive and transmit) radio gear.

Then add
(5) computerized (automated) Doppler correction of frequency control and
(6) sufficient receiver sensitivity (or low enough noise figure) to dig these incoming signals out.

Radio Signal Path Budget

Basu (VU2NSB) explains many factors affecting the received signal and calculates that reasonable received signal level are indeed possible from a low power satellite 1000 km above the ground station (https://vu2nsb.com/radio-propagation/space-radio-propagation/). This is really possible with ordinary radios!

Commercially Available Antennas/Radios

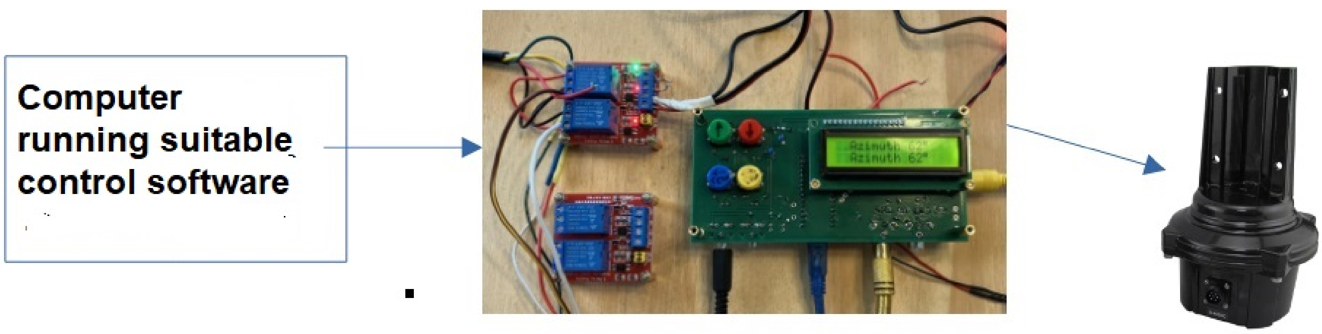
VHF and UHF directional antennas are plentiful commercially, but can also be built at home with simple tools. Second-hand transceivers, or HF transceivers with transverters and suitable preamplifier appear to be sufficient for the radio gear.

Commercially Available Rotation Systems

While one-off communications can be accomplished with hand-aimed antennas, my goal was for a repeatably successful system, so mechanical aiming is necessary..There are popular off-the-shelf dual-axis rotator systems available (e.g. Yaesu G-5500) and commercial control systems (e.g. the quite pricey Yaesu G232B interface, or the more reasonably priced S.A.T. control by CSN Technologies http://www.csntechnologies.net/sat) but even simpler and homebrew-capable systems are well-developed, particularly the K3NG Arduino-base dual-axis controller.

The method of prior years to achieve computer-control rotators looked somewhat like this:

However, the homebrew-capable Arduino-based controller reduces it to this for general purposes:



This allows low- or zero-cost satellite aiming software to be utilized with very inexpensive rotator systems -- even homebrewed rotators made from powerful linear actuators, and simple attached potentiometers for angular measurement   So I decided to go that route instead of the "off-the-shelf" purchase route.

Future parts of this multi-part series will tackle

- building the rotator controller system, using a printed circuit board I've created;
- assembling physical rotators and potentially building your own elevation system[1] (to avoid the $700 G5500 expense);
- fabricating 2-meter and 70cm directional antennas[2];
- radio equipment, sensitivity testing and improvement with an inexpensive GaAs preamp;
- duplexer filtering; and hopefully
- finding and connecting with currently available satellites.

We start off with a table explaining satellite ground station software that I've used:

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1 Many amateurs have achieved acceptable performance without elevation control by simply aiming their antennas about 20 degrees above horizon.

2 Many amateurs have succeeded with simple one-plane antennas, but adding a 2nd plane allowing circular polarization isn't that difficult.

SATELLITE GROUND STATION SOFTWARE

No.	Name	Function	Available at: Training at:
1	***gpredict*** (There are many similar programs available)	Displays chosen satellite courses and footprints; does calculations to predict Doppler, arrival of signal, loss of signal etc. Available for both Linux (raspberry pi) and Windows	Files: https://sourceforge.net/projects/gpredict/files/ Excellent manual: https://sites.science.oregonstate.edu/~hetheriw/whiki/psp/main/base/files/gpredict-user-manual-1.3.pdf
2	***rigctld*** (part of hamlib) (Keyboard user version: rigctl)	Interfaces with a variety of radios to command Doppler corrections and/or uplink/downlink frequencies. Available for both Linux (raspberry pi) and Windows. Part of the hamlib series, rigctld has workable provisions for controlling two separate radios (one transmit, one receive) and this is a viable option. Unfortunately, rigctld doesn't work well to provide full-duplex Doppler correction to the Main/Sub ICOM 820H that I used. Available modules don't appear to properly handle the "main/sub" dual-frequencies. For controlling a single duplex Icom transceiver, the AMSAT-provided **Sat32PC** software appears superior, even if slightly dated.	Comes in a package: https://sourceforge.net/projects/hamlib/files/hamlib/ Includes both rigctl files and rotctl files; multiple versions available for different operating systems. Man pages widely available. For example: https://www.mankier.com/1/rigctld
3	***rotctld*** (part of hamlib) (Keyboard user version: rotctl)	Interfaces with several different rotator computer control languages. (Doesn't actually turn the motors on or off or read the angles, just tells downstream system the angle to go to). I preferred using the G-232B language, which the K3NG Arduino-based controller (subject of a futue article) happily accepts. Available for both Linux (raspberry pi) and Windows.	Comes in the same package as ***rigctld*** Man pages widely available. For example: https://manpages.ubuntu.com/manpages/trusty/man1/rotctl.1.html

4	**Sat32PC**	This tried-and-true software package by amateur DK1TB (available on the AMSAT web page) has worked to control BOTH TX and RX frequencies of my IC-820H without problems. It also provides rotator control, 1- or 2-axis. The rotator control works with an amazing number of rotator systems, but isn't quite as "elegant" as the system inside gpredict. This package is only available for Windows PC computers.	Download the program and then send in your payment ($45/$50) to get the registration key. https://www.amsat.org/product/satpc32-by-electronic-download/