Building a "Poor-Man's" Amateur Radio Satellite Ground Station Part III: Inexpensive Antenna Rotator

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This series presents the trek toward building an inexpensive amateur radio satellite ground station.

- Part I provided an overview of what is generally required: https://www.nf4rc.club/how-to-docs/satellite-system-part-i-overview/
- Part II explained how to take advantage of K3NG Arduino publicly available software and build a very simple computer controlled rotator controller capable of running Yaesu and some other rotators: https://www.nf4rc.club/how-to-docs/satellite-system-part-ii-rotator-control-board/

In this part, I'll discuss how to get automated, computer-controlled antenna rotation. Unless you use an omnidirectional antenna (and thus give up some potential gain) you're going to need some sort of "pointing system." It doesn't have to be very sophisticated. Many users report doing very well by simply using a camera tripod and using it to manually rotate their antenna(s). Others set their elevation to approximately 15° and then arrange an azimuthal rotator system to track at least the azimuth heading of the satellite they wish to hit. The typical Yagi antenna's beam-width is broad enough that exact pointing isn't absolutely required. It is very easy to take the antenna controller explained in Part II, and have it computer controlled, and us it to control a Yaesu or other rotator.

My goal wasn't for a weather-proof permanent satellite installation. All I needed was a system that could be used occasionally outside, and allow me to get some experience making satellite-relayed contacts. So I didn't want to put in a huge amount of capital, and I didn't need it to be battleship-stout. Nevertheless, with the use of pressure-treated wood, a bit more aluminum, and some carefully chosen plastic rain-shields, the system I built would like be useful in moderate weather for some time.

There are multiple commercial systems and homebrew designs out there to create a dual-axis controlled rotator. **The go-to commercial off the shelf standard seems to be the Yaesu G5500 dual rotator assembly**, which is upwards of $700 Given what it does, that price isn't unreasonable. That fancy G5500 can be controlled by the CSN S.A.T. controller which handles almost everything (even including Doppler-correction CAT commands) ! http://www.csntechnologies.net/sat (It probably has a small microcontroller running Linux and potentially a K3NG software derivative.) One-stop shopping! It is just that your wallet will be a bit lighter afterwards and you won't have had the satisfaction of "rolling your own." Other rotator solutions include:

- Winradio dual axis rotation system (with available controller) https://winradio.com/home/arp-elaz-100.htm (appears to be high cost)
- Lightweight pan and tilt camera mount system to handle light antennas: https://k3rrr.com/el-cheapo-az-el-satellite-antenna/ (appears to be very low cost)
- Green Heron system (expensive): https://www.greenheronengineering.com/product/alfa-spid-ras-with-rt-21-az-el-controller/
- The (discontinued) SARCNET School Amateur Radio Club Network design: https://www.sarcnet.org/sarctrac-mk2.html (although discontinued, the ideas can be harvested)
- SATRAN print-it-at-home rotator system: https://satran.danaco.se/

Going More Of The Homebrew Route

I chose to purchase a used Yaesu G450ADC (dc motor) rotator for the azimuth control. I have previously rebuilt a Yaesu rotator so I have a good feel for what is inside. It can handle quite a bit of axial load. That allows for very simple homebrew elevation control construction. I mounted the Yaesu rotator on a piece of plywood using the provided bolts through the plywood and up into the threaded holes in the bottom of the rotator. Then I added some longer lumber extensions to the plywood to make it more stable and usually I put a weight on the plywood for additional anti-tipping weight.

Into the Yaesu rotator, I put a simple wood mast extending vertically and using simple deck screws, mounted a horizontal platform out of 2x6 lumber, and attached a vertical "back" again out of 2x6 lumber using deck screws to connect. This made a very stout platform on which I could mount mechanical pieces. My first attempt used a very-geared-down DC motor and a 90º gear box. https://www.amazon.com/dp/B0C64XM1NG The gear box, with 10mm shafts coming out of three sides, worked well -- the gears in the very-geared-down DC motor stripped within a few days. Not a good solution.

This I watched this fellow's solution using a **linear actuator** to control an off-center connection to a rotating boom. https://www.youtube.com/watch?v=oRMzorrm-bA&t=686s His technique looks so simple! Powered by 12VDC, the linear actuator must have a worm gear or similar system inside -- it looks like the spring/gas piston that slows down the closing of your screen door, but under power it can either extend or retract mechanically. They are made with lots of different extension lengths. I chose a small one that extends / retracts only 2 inches, at a cost of $40 (It might have been easier to have a bit more movement). https://www.amazon.com/dp/B00NM8H5TG The actuator is plenty powerful!

I then fabricated a U-bracket that could be screwed to connect to a rotating shaft, and also accept the linear actuators arm with a pin to allow movement. This can be made out of some steel from one of the Home Depot thin tie-plates. (e.g. https://www.homedepot.com/p/Simpson-Strong-Tie-LSTA-1-1-4-in-x-12-in-20-Gauge-Galvanized-Strap-Tie-LSTA12/100375120) Choose the thickness of metal suitable for your ability to saw/cut and the heft that you need to swing your antenna load. To make solid connection to the shaft possible, I used an aluminum shaft from Amazon, slightly flattened one segment and drilled a hole to allow the bracket to be connected with a screw. This worked very well. With a bit of geometry, I figure out the size of the bracket to cause the 2" stroke to make the shaft move 90 degrees. The linear actuator has to be mounted in pins on both ends, so that it can adjust its angle, but to a first approximation to allow 90 degrees of rotation, the 2 inch stroke should be close to 1/4 of the circumference of the circle inscribed by the pin in the bracket. With the pin approximately 1" from the center of the shaft, the circumference is 2pi*1" = 6.28" and 1/4 of the circumference is a bit less than 2". So I arranged the pin-hole to be about 1" from the center of the shaft that the bracket attaches to. The linear actuator comes with some brackets for each end. With a bit of trial-and-error, I figured out where the "base" of the linear actuator needed to be, and with some woodwork provided a surface to which to screw the base bracket. Wood construction makes this very easy!

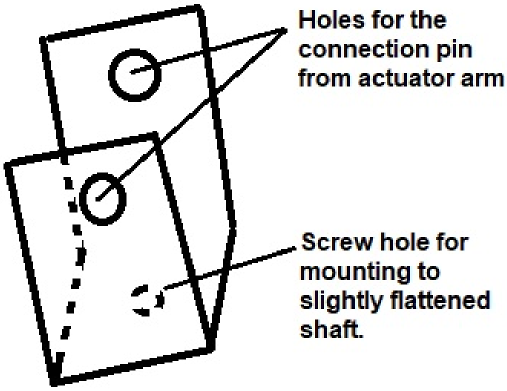

Figure: Drawing of the U bracket construction for the extending rod to connect to the rotating shaft. Adjust dimensions for your particular actuator arm.

The linear actuator comes with built-in limit switches at both full extension and full retraction, so it isn't going to wreck anything as long as your rotation system is able to move freely. This also makes the wiring even simpler.

The use of the 90° gearbox wasn't necessary in this case, but it made it easy to connect a potentiometer to the end of the driven shaft to give a measurement of the elevation angle. A bit of trial and error and the proper coefficients were entered into the K3NG code to match properly the movement to the potentiometer readings, using the control board described in Part II.

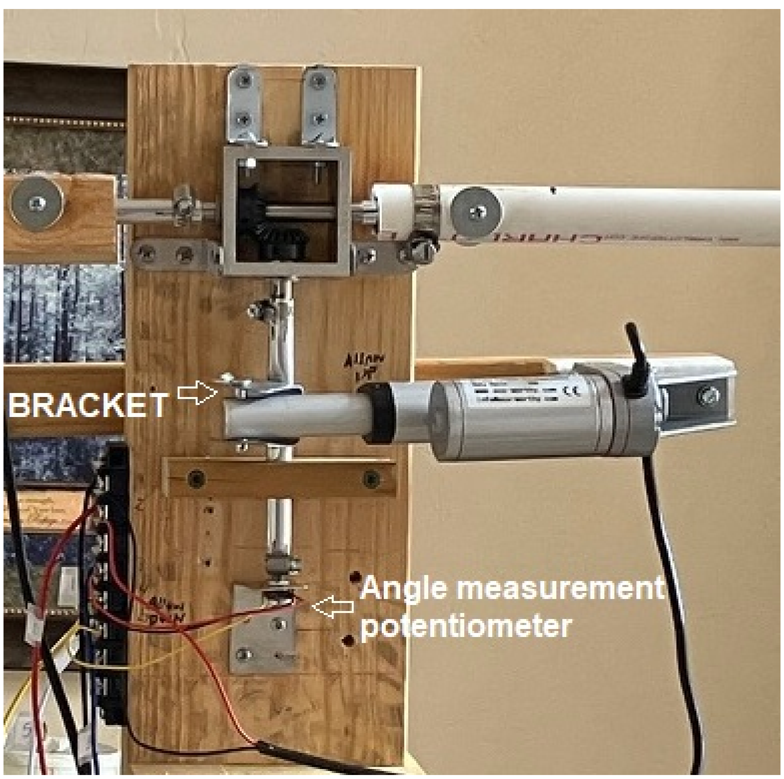

Figure: Positioning of Linear Actuator, and Bracket Connection to Shaft.

This proved to be a very simple elevation system, much simpler than the previous geared-motor design, and also quite robust! The biggest problems I had were getting solid connections between my "booms" and the 10mm shafts coming from the gearbox. Those shafts are stainless steel and I wasn't able to drill any holes through them for pins. However, cutting a few slits in the PVC, using rubber tubing inside (to make up for diameter discrepancies), and then using an automotive hose clamp proved to be a reasonably successful way to keep the angles fixed.

The horizontal boom rotates under the control of the linear actuator, to adjust elevation. It is useful to be able to get down to at least approximately 15 degrees above the horizon, and up to at least 75 degrees. I did not attempt to deal with elevations beyond 90º (on the "back side"). Because the beam-width of the Yagi's are not going to be "pinpoint", these are generally adequate and I was able to get more than this amount of rotation easily.

Control connections for the elevator rotator are through a 5-wire #18gauge cable back to the homebrew antenna controller board previously described. You could provide a connector if you want it more easily connected; I just used a terminal block.

It is important to understand that the ENTIRE top assembly is rotated in the horizontal plane (azimuth) by the bottom rotator. The Yaesu G450ADC easily handles all of this weight and easily spins it around the compass directions. It has its own internal potentiometer to measure azimuthal rotation and its own connector for all its signals I simply soldered up a cable and the connector to handle the azimuthal control.

With my homemade circular polarization Yagi's attached, the entire assembly worked very well!

Figure: dual axis antenna rotator system with antennas