WRAPS: A Portable Satellite Antenna Rotator System

The WRAPS az-el rotator system mounts on a camera tripod. [Photo courtesy Mark Spencer, WA8SME]

Build this az-el rotator system for tracking satellites.

Mark Spencer, WA8SME, ARRL Education and Technology Program Coordinator

AMSAT's recent successes in competing for CubeSat launch opportunities (such as Fox-1 and RadFxSat/Fox-1B) signal a paradigm shift in future ham satellite efforts and will give a significant boost to the utility of CubeSats in the classroom, carrying experimental payloads and ham communications packages. I introduce here the WRAPS (Wobbler RadFxSat Antenna Pointing System) rotator system that I designed to support tracking the CubeSats. "Wobbler" is my term for the Attitude Determination Experiment; it refers to the behavior of ham satellites and CubeSats while in orbit. The Attitude Determination Experiment is to be carried on Fox-1 and Fox-1B satellites along with the RadFxSat Experiment.

Design Goals for WRAPS

I wanted to develop a portable, battery operated satellite antenna rotator system that could be easily duplicated using commercial, off-the-shelf (COTS) parts, and by using simple hand tools with a minimum of machine work. This rotator system should be an affordable alternative to the industry standard — the Yaesu G-5500 system — which is an excellent and proven rotator for base station operations.[1] My limited duty rotator is intended for small handheld Arrow and Elk class satellite antennas, and can be used to receive Fox satellite signals.[2] My target audience includes school groups who want to access the capabilities of the CubeSats. The AMSAT-UK FunCube satellites provide additional exceptional educational opportunities. I also want to support the portable ham satellite enthusiasts, including hams interested in Field Day satellite operations.

My design is powered by a 12 V battery such as a small sealed UPS battery. The cost of parts, including all the associated cabling and computer interfaces, is approximately $275, compared with about $1300 for the G-5500 system. This design includes a USB interface that works with *SatPC32* and other satellite tracking software packages running the EASYCOM protocol.

The WRAPS System

WRAPS is designed for lightweight antennas only, and is not intended to handle large antenna arrays. It is not weatherproof, nor designed for continuous unattended operation. What follows is a brief introduction of the WRAPS rotator system. Detailed information, including a construction guide, is available on the *QST* in Depth web page, and also by e-mail request to **mspencer@arrl.org**.[3]

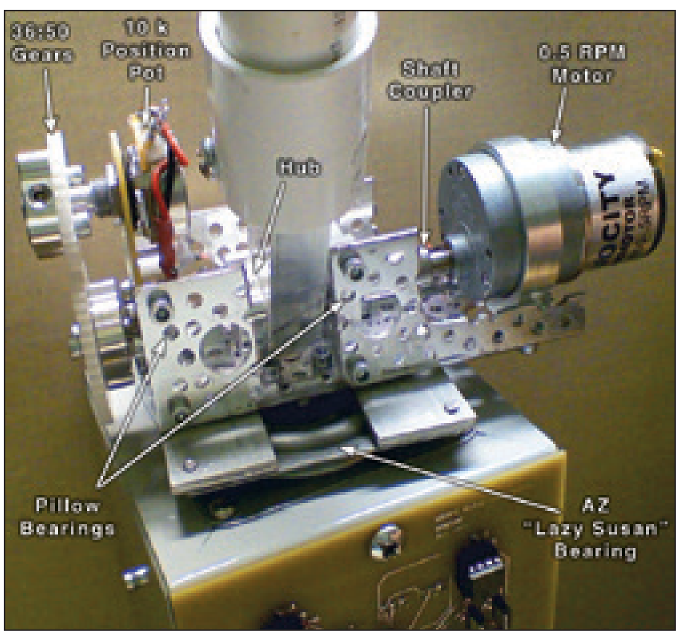

Figure 1 — The el rotator assembly. [Graphic courtesy Mark Spencer, WA8SME]

[1]Notes appear on page 45.

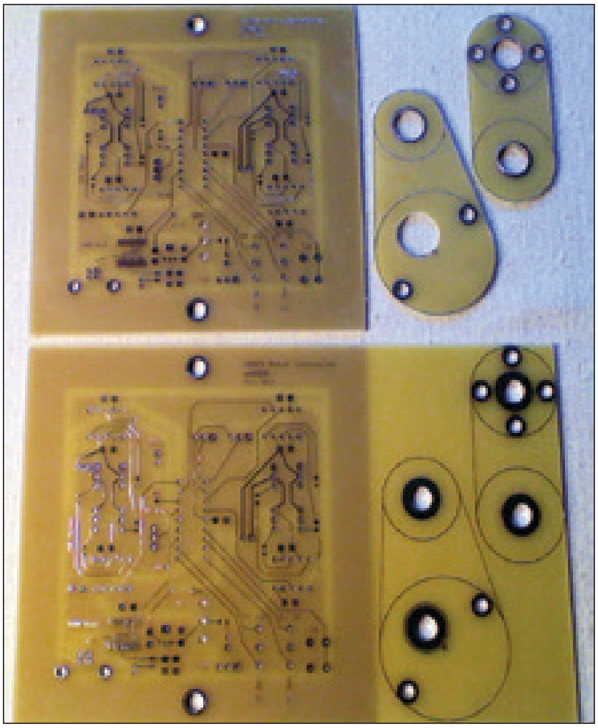

Figure 2 — WRAPS circuit boards. [Photo courtesy Mark Spencer, WA8SME]

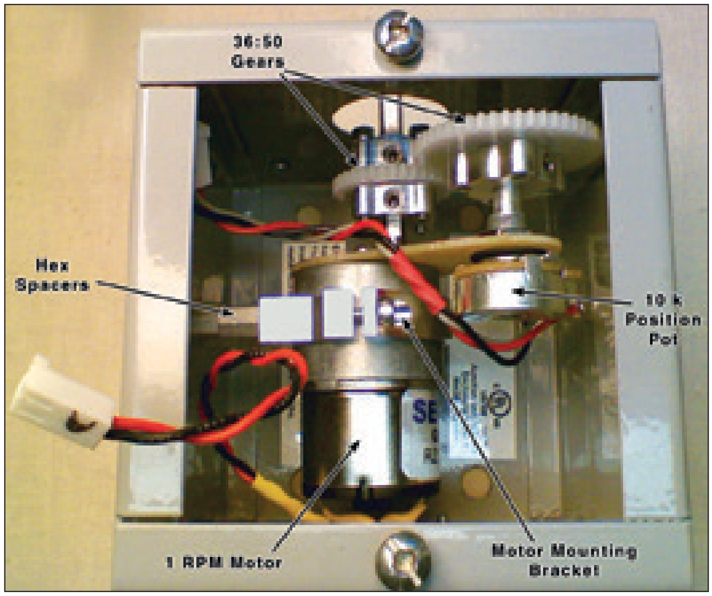

Figure 3 — The az rotator assembly. [Graphic courtesy Mark Spencer, WA8SME]

The lead photo shows WRAPS in operation, mounted on a camera tripod. The PVC base sleeve slides over the camera mounting post of the tripod.

Mechanical Considerations

The proliferation of precision parts manufactured for the robotics community makes WRAPS possible. Figure 1 illustrates how these COTS parts are assembled to make the elevation (el) part of the rotator. The el rotator uses a geared 0.5 rpm dc motor that provides excellent torque at an affordable price. Construction is similar to an "erector set" project. There are a couple of cutouts required in the aluminum channel chassis of the el rotator. These cuts are easy to make with a hand hacksaw, and the rough edges can be cleaned up with a metal file. You will need to drill 11 holes in the rotator chassis box along with some hacksaw, drill, and tap work on two metal brackets made from home improvement store aluminum stock supplies. Finally, a few PVC pipe fitting parts require some drilling.

The azimuth (az) and elevation (el) rotator positions are determined by the wiper positions of wire-wound potentiometers that are connected to the motors by a pair of 36:50 ratio gears. Make the brackets for accurately mounting the potentiometers from circuit board material. The circuit board designed for this project includes outlines and pilot hole locations marked for the two brackets, as seen in Figure 2. Separate these two brackets from the main circuit board using a band saw. The az rotator is a 1 rpm motor mounted inside the rotator body enclosure along with the associated position potentiometer as seen in Figure 3.

The Electronics

Figure 4 shows a block diagram of the WRAPS circuitry. The completed circuit board is shown in Figure 5. The heart of the WRAPS circuit is a PIC® microcontroller that:

- Receives positioning commands from the satellite tracking program. [Which runs on the personal computer (PC) in Figure 4. — *Ed.*]
- Translates those commands into rotator positions (analog to digital converter values).
- Reads the current rotator positions and

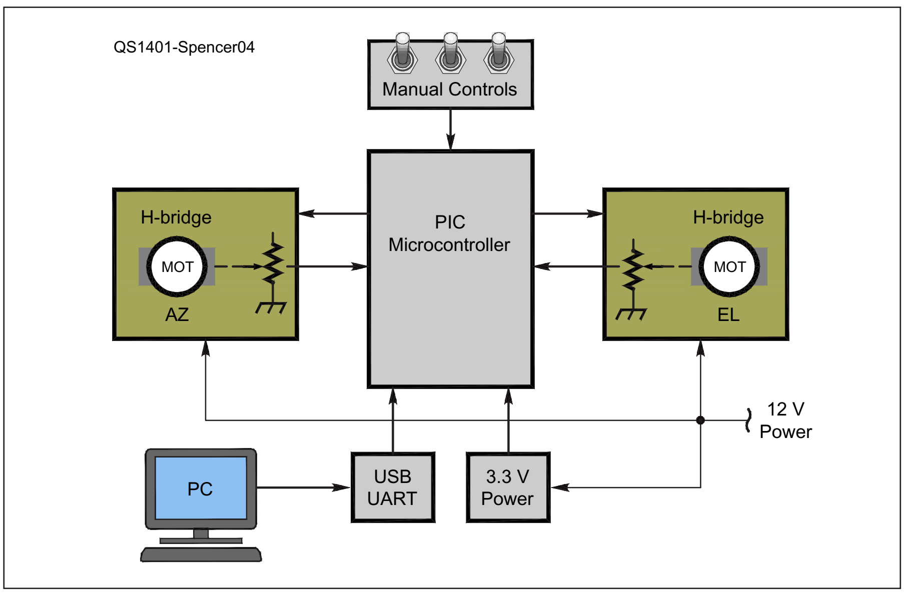

Figure 4 — Block diagram of the WRAPS rotator system.

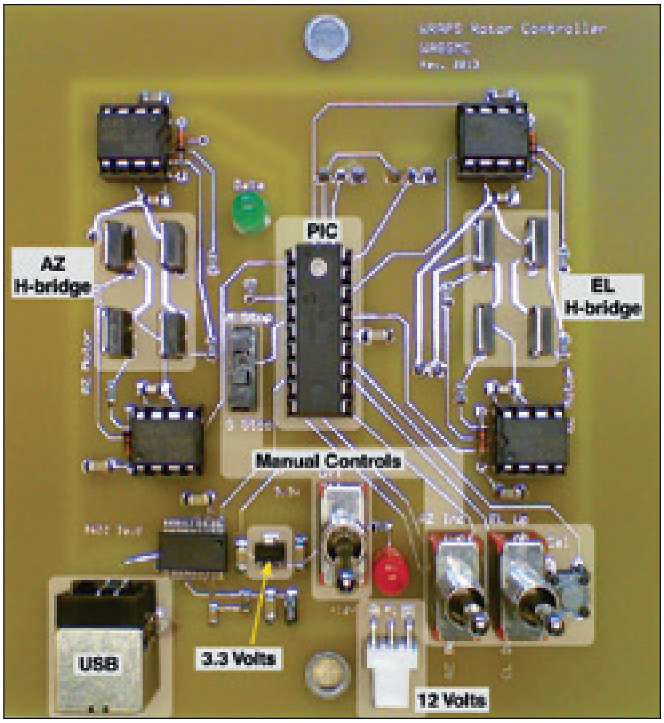

Figure 5 — A completed WRAPS printed circuit board. [Graphic courtesy Mark Spencer, WA8SME]

determines if a position change is required, and if so, in which direction.

- Commands the motors ["M" in Figure 4 — *Ed.*] to turn in the proper direction.
- Monitors the motors as they move.
- Stops the motors when they reach the commanded position.
- Waits for the next position update.

A USB to serial converter (a USB UART) shows up on your PC as a COM port.

The Software

The PIC® microcontroller program, included in the supplementary documentation on the *QST* in Depth web page, is written in the C programming language. Position switches allow you to manually position the rotator motors. A calibration (CAL) button switch allows you to make adjustments in the firmware if the system gets out of calibration. You set the rotator to 0 degrees az and 0 degrees el, press the CAL button, and that location is stored in the PIC microcontroller program. Then, set the rotator to 359 degrees az and 90 degrees el, press the CAL button to store the other stop position in the PIC program. The motors are controlled through the individual H-bridge circuits using a pulse width modulation (PWM) produced by the PIC microcontroller to set the motor speed. If you find that the motor performance is not to your liking, you can make changes to the software to change the PWM characteristics.

Operational Considerations

Notice that the rotator is set up for 90 degrees maximum elevation. The ideal situation would be to have the el rotator set up for 180 degrees elevation rotation to avoid the problem of flipping the antenna over when the satellite passes through the az stop or turn point. For example, suppose that the el rotator is limited to 90 degrees elevation, and the az turn point is set to South. If a satellite were to pass through your southern horizon at 179 degrees, the az rotator would then have to rotate 360 degrees to pick up the satellite on the other side of South — at 180 degrees in az. This would result in a loss of signal, and is a problem with a fixed rotator installation.

This problem is mitigated in the WRAPS by its portability. A switch in the circuit allows the user to select whether the az rotator stop is North or South. Plan ahead; if the satellite is going to pass through South, set the switch to a North turn point. Change the rotator setting to a North turn point in *SatPC32* rotator setup, command a position to a known heading, pickup and rotate the rotator to that heading, and you're all set. Alternatively, if the satellite is going to pass through the North, set the switch to the South turn point and make the appropriate change in the *SatPC32* rotator setup menu. This scheme simplifies the mechanical set up of the WRAPS system, puts less strain on the el rotator, but also accommodates an Elk-like antenna which would be difficult to operate with a 180 degree el system. The system, however, could be mechanically modified to produce 180 degrees of el rotation if desired.

Availability of Prebuilt Rotators

Although this design is intended for easy duplication by the interested ham, I anticipate that there will be requests for boards, kits, and completed units. I will be duplicating a number of the WRAPS rotators to support the ARRL Teachers Institute-2 Space Program. Check the AMSAT store for availability of a limited number of complete WRAPS rotators.[4] The units will be sold at cost of parts plus an amount that will be used to support AMSAT CubeSat development efforts. Be assured, you will be supporting the future of ham satellites.

The WRAPS rotator system project was motivated by the Fox CubeSat launches, and was made possible in part by a grant from the ARRL Foundation and through an award from the YASME Foundation.[5] I hope you will participate in the Fox CubeSats and join the ranks of the ham satellite enthusiasts.

Notes

[1]Yaesu G-5500 Az-El rotation system, **www.yaesu.com**.
[2]**www.arrowantennas.com** and **www.elkantennas.com**.
[3]**www.arrl.org/qst-in-depth**.
[4]**store.amsat.org/catalog**.
[5]**www.arrl.org/the-arrl-foundation** and **www.yasme.org**.

You can contact Mark Spencer, WA8SME, ARRL Education and Technology Program Coordinator, at **mspencer@arrl.org**.

For updates to this article, see the *QST* Feedback page at www.arrl.org/feedback.