

WRAPS Portable Satellite Antenna Rotor

By: Mark Spencer, WA8SME

ARRL Education and Technology Program

Recent AMSAT successes in competing for CubeSat launch opportunities, (Fox1A, Fox1B, and Fox2) which will carry experimental payloads and ham communications packages, signals a paradigm shift in future ham satellite efforts and gives a significant boost in the utility of CubeSats in the classroom. In this article I will introduce the WRAPS rotor system I designed to support working the Fox constellation of satellites. The acronym comes from the Attitude Determination Experiment (which I call Wobbler) to be carried on Fox1A, the Radiation Effects experiment to be carried on Fox1B, Antenna Pointing System.

My design goals for WRAPS included:

- Develop a portable, battery operated satellite antenna rotor system.
- The rotor would be easily duplicated using commercial-off-the-shelf (COTS) parts and simple hand tools with the minimum of machine work.
- Make a rotor that is an affordable alternative to the industry standard, the Yaesu G5500 (an excellent and proven rotor for base station operations).
- A limited duty rotor for small hand held satellite antennas in the ARROW and Elk class of antennas usable to receive Fox satellite signals.
- Target the school audience that wants to access the capabilities of the CubeSat systems (reduce the costs to the ARRL Teachers Institute Program) and the portable ham satellite enthusiast.
- Finally, to fulfill a bucket list goal.

The result; WRAPS:

- Runs off a 12 volt battery source (small sealed UPS batteries work fine).
- The cost of parts is approximately \$275 versus the \$1300 for the G5500 which includes all the associated cabling and computer interfaces.
- Includes an organic USB interface that works with SatPC32 and other satellite tracking software packages running EASYCOM protocol.

What WRAPS is not:

- It will not handle large antenna arrays, it is designed for ARROW and Elk class antennas only.
- It is not weather proof nor designed for 24/7 unattended operation.

This is a brief introduction of the WRAPS rotor, more detailed information that would be required to duplicate the project is available by a simple e-mail request to m Spencer@arrl.org. You will received all the relevant files including parts list with sources, schematics, software, construction details, templates for drilling holes and other simple metal work; in other words more detail than can be printed here.

Figure 1 shows the WRAPS in operation. It is mounted on a camera tripod. The PVC base sleeve slides over the camera mounting post of the tripod.

Mechanical. What makes the WRAPS possible is the proliferation of precision parts being manufactured for the robotics community. Figure 2 illustrates how these



Figure 1.

COTS parts are assembled to make the elevation part of the rotor. The EL rotor uses a .5 RPM DC geared motor that provides excellent torque at an affordable price. Over the years of toying with the idea of a portable rotor, I have tried many alternative motors from servos to steppers, but I found these obvious alternatives to a straight DC geared motor lacking in performance for one reason or other. You will notice that the construction is basically like building an “erector set” project. There are a couple of cut outs required in the aluminum channel chassis of the EL rotor, these cuts are easy to make with a hand hacksaw and clean up the rough edges with a metal file. There are eleven holes that need to be drilled in the rotor chassis box and some hacksaw, drill, and tap work on two metal brackets made from home improvement store aluminum stock supplies. Finally there are a couple of PVC pipe fitting parts that need some drilling.

The EL and AZ rotor position is determined by the value of variable wire-wound resistors that is connected to the motors by a pair of 36:50 ratio gears. The brackets for mounting the pot precisely for the gearing are made from circuit board material. The circuit board designed for this project includes the two brackets that are outlined and have pilot-hole locations marked (figure 3). These two brackets are separated from the main circuit board using a band saw.

The AZ rotor is a 1 RPM motor and mounted inside the rotor body enclosure along with the associated position pot (figure 4).

Electronics. A block diagram of the WRAPS circuitry is shown in figure 5. The completed circuit board is shown in figure 6. The heart of the WRAPS circuit is a PIC® microcontroller that, 1. receives positioning commands from the satellite tracking program, 2. translates those commands into rotor positions (ADC values), 3. reads the current rotor positions and determine if a position change is required, if so, which direction, 4. commands the motors to turn in the proper direction, 5. monitors the motors as they move, 6. stop the motors when they reach the commanded position, and finally 7. waits for the next position update. It sounds complicated, but if taken a step at a time, it makes sense. The PIC program is written in “C” and is included in the supplementary documentation.

There is a USB to serial converter included in the circuit that shows up on your computer as a comm. port. The position switches allow you to manually position the rotor motors. The calibration button switch allows you to make adjustments in the firm ware if the system gets out of “whack” for some

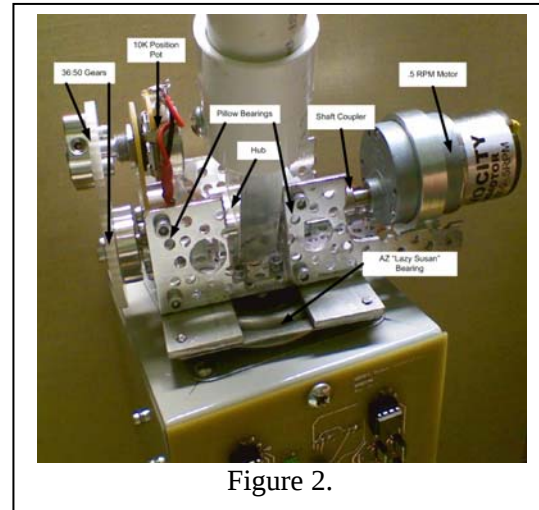


Figure 2.

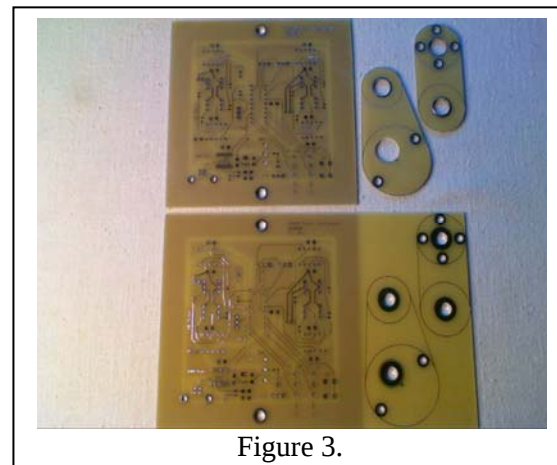


Figure 3.

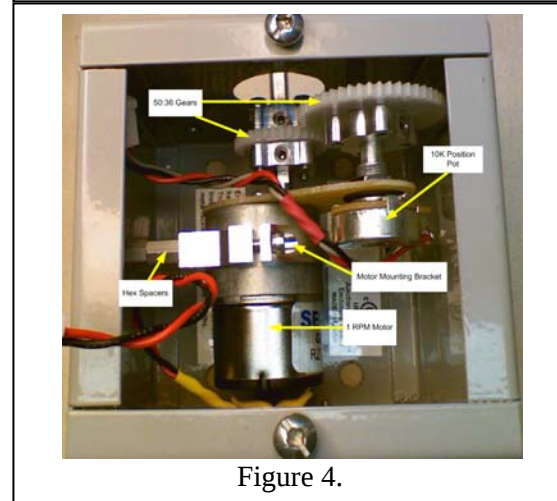


Figure 4.

reason. You set the rotor to 0 degrees AZ and 0 degrees EL, press the CAL button, and that location is stored in the PIC. Conversely, set the rotor to 359 degrees AZ and 90 degrees EL, press the CAL button, and this stores the other stop in the PIC. The motors are controlled through the individual H-bridge circuits with pulse width modulation (PWM) produced by the PIC to set the motor speed. If you find that the motor performance is not to your liking, you can go into the software and change the PWM characteristics.

Operational considerations. Notice that the rotor is set up for 90 degrees maximum elevation. The ideal situation would be to have the EL rotor set up for 180 degrees maximum elevation to avoid the problem of flipping the antenna over when the satellite passes through the AZ stop or turn point. For instance, if the EL rotor is limited to 90 degrees elevation, and the AZ turn point is set to South, if a bird were to pass through your Southern horizon; at 179 degrees, the AZ rotor would have to rotate around 360 degrees to pick up the bird on the other side of South - 180 degrees. This would result in a loss of signal and is a problem with a fixed rotor installation.

This problem is mitigated in the WRAPS by its portability. There is a switch in the circuit that allows the user to select if the AZ rotor stop is North or South. With a little planning, if the satellite is going to pass through South, set the switch to a North turn point. Change the rotor setting to a North turn point in SatPC32 rotor setup, command a position to a known heading, pickup and rotate the rotor 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 rotor setup menu. This scheme simplifies the mechanical set up of the WRAPS, puts less strain on the EL rotor (the system could be mechanically modified to produce 180 degrees of EL rotation however), but also accommodates an Elk like antenna which would be difficult to operate with a 180 degree EL system.

Rolling your own. Though the design is intended for duplication by the interested ham, I anticipate there will be requests for boards, kits, and completed units. (I will be duplicating a number of the WRAPS rotors to support the ARRL Teachers Institute-2 Space program.) If you need to go a step beyond the request for the detailed information as suggested earlier, check the AMSAT store for availability of a limited number of complete WRAPS rotors (<http://store.amsat.org/catalog>). The units will be sold at cost of parts plus some delta that will be used to support current and future AMSAT CubeSat development efforts. Be assured you will be supporting the future of ham satellites if you go this route.

The WRAPS rotor project was motivated by the Fox CubeSat launches, but it was made possible in part by a grant from the ARRL Foundation and through an award from the YASME Foundation. I hope you will participate in the Fox CubeSats and join the ranks of the ham satellite enthusiasts. For more information, contact me at mspencer@arrl.org.

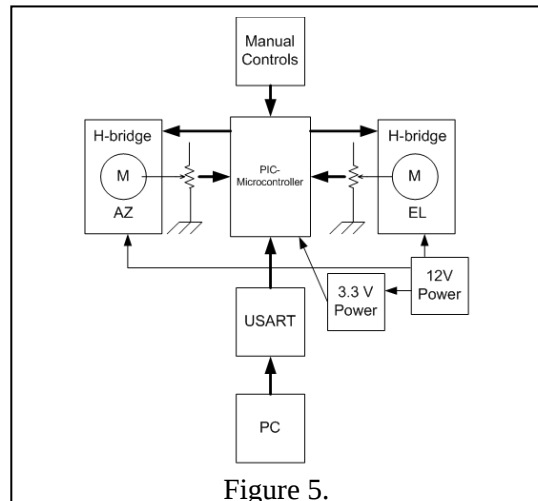


Figure 5.

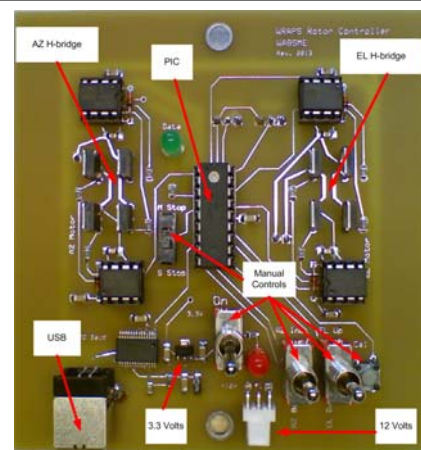


Figure 6.