Mini Satellite-Antenna Rotator MkII

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In the May 2016 edition of Amateur Radio magazine, we described the design and construction of a mini satellite-antenna rotator. It used some small DC motors and a novel combination of 3D magnetometers and accelerometers to provide absolute azimuth and elevation feedback. Since then, we have received over 90 requests from readers for additional construction details and we know of a handful of units which have been successfully built and tested.

The original rotator was designed for quick set-up and portable operation at our primary school Amateur Radio clubs. It is very light-duty and can only be used with a small, dual-band, hand-held antenna. Some readers asked us if the rotator could be scaled up for a larger, permanent satellite antenna installation at home. Specifically, one which could handle two, much longer, cross-polarised Yagis, for 2m and 70cm, mounted on either side of the rotator.

This article describes the mechanical design and construction of the MkII mini satellite-antenna rotator including some improvements to the original electronics and software packages.

Design

We determined that this "medium-duty" rotator needed to have a horizontal through-shaft about 2 metres long, capable of handling balanced loads weighing up to 20kg.

Keeping with the simple, low cost design approach, we decided to use the same motors and drivers, but to add proper bearings, sprockets and roller chains to both the horizontal and vertical shafts. The size and gear ratio of these sprockets was selected for the maximum reduction that would fit inside the available enclosure.

A new motor speed of 2.0 RPM was selected instead of 0.6 RPM to account for the 10-to-32 sprocket gear-ratio.

The proposed design was carefully reviewed by more experienced members of the Amateur Radio Victoria, Homebrew Group before we began construction.

Figure 1 – Mini satellite-antenna rotator MkII

Components

Component selection was the key to keeping the overall cost down. As in the previous design, the enclosure was the most expensive part. However, we were surprised to find a small, IP66, steel enclosure that would do the job for around $50. It had a lockable door, internal baseplate and a cable-entry panel.

Although the enclosure was steel, the horizontal and vertical shafts were made of aluminium tubing to reduce any hard-magnetic interference close to the sensor mounted on the antenna boom. The shafts had to be stiff enough to handle the antenna weight. We decided the minimum tube size would be 25mm diameter with a 3mm wall thickness. Note: Most "25mm" tube sold in hardware stores is actually 25.4mm (i.e. 1-inch) in diameter. This will definitely not fit the selected bearings. The correct tube must be purchased from a specialist aluminium supplier. For a little extra cost, you can get a smooth "bright finish" tube instead of the standard "mill finish" tube. This tube works better with the 25mm hydraulic shaft seals that we used to keep the weather out of the enclosure.

Next, we had to source the ball bearings. There were two flange bearings for the horizontal shaft. For the vertical shaft, which only enters the enclosure through the cable-entry panel at the base, we needed a pillow-block bearing and another flange bearing. Again, we were surprised to find just the right parts on eBay, from China of course, for around $8 each.

Figure 2 – Shaft seals and flange bearings

The sprockets and chain parts proved to be far more difficult to source. The choice was between various local products, with high bore-machining costs, or overseas finished-bore products with high freight costs. However, by purchasing all the parts in quantity from one US on-line store for around $70 a set, the freight cost was minimised. Unfortunately, only 1-inch bores were available in the US, so they had to be shimmed to fit the 25mm shafts.

Construction

After all the parts arrived from around the world, construction proceeded as follows:

Tube, plate and angle stock

The thick aluminium shafts were cut using a tube cutter. The plate and angle stock was cut using an angle grinder with a thin disk.

Enclosure

The enclosure was marked out using digital callipers and then centre-punched before drilling pilot holes. The three (3) shaft cut-outs through the enclosure's 1.5mm steel plate were made using a 30mm hole punch (well worth getting).

The six (6) 10mm flange-bearing mounting holes in the enclosure were cut using a step-drill.

Unfortunately, the enclosure had an internal earth-stud too close to one of the flange bearings: It had to be ground flush using an angle grinder inside the small enclosure – a tight squeeze.

All machined steel in the enclosure was then treated with cold-galvanising paint.

The door and enclosure earth studs were connected using a ground wire with round crimp lugs.

Flange bearings

The three (3) flange bearings were fastened to the inside of the enclosure using M10x25mm stainless steel bolts, flat washers, spring washers and nuts. A flat nylon washer was used on the outside surface of the enclosure. Some silicon sealant was applied to both surfaces of the washer for added ingress protection.

Baseplate assembly

The enclosure baseplate was removed and two 10mm holes were drilled for the pillow-block bearing and four slotted 3mm holes for the motor brackets.

The pillow-block bearing was installed using M10x50mm stainless steel bolts, flat washers, spring washers and nuts. Additional flat washers and nuts were used to raise the bearing off the baseplate 22.5mm.

The small sprockets were attached to the keyed motor shafts. Note: The grub screws on these did not screw in all the way. A 3/16 inch tap was required to finish the threads properly.

The motors were attached to the motor brackets and the brackets were mounted on the baseplate, all using M3x6mm CSK bolts, flat washers, spring washers and nuts. The baseplate assembly was then re-installed into the enclosure.

Horizontal shaft assembly

The horizontal shaft and its large sprocket was assembled first. All bearings are the "self-centring" type. If they are out of alignment they can be re-aligned by gently tapping the shaft using a wooden block. The large sprockets, with the 1-inch bores, have to be shimmed to fit the 25mm shaft. A rectangular piece of aluminium drink can, cut out with scissors, worked just fine.

All bearing and sprocket grub screws were hand tightened initially, but later required a thread-locking fluid.

Vertical shaft assembly

The vertical shaft and its large sprocket was assembled on the cable-entry panel in the same manner.

The vertical shaft assembly was then installed into the enclosure and secured by the cable-entry panel screws.

Figure 3 – Cable-entry panel

Chain installation

With the sprockets mounted firmly in place, the chain had to be broken using an angle grinder, threaded over the sprockets and then re-connected using joining links.

The chain tension can be adjusted by re-positioning the motors using the slotted mounting holes.

Figure 4 – Internal mechanical assembly

Electronics package

The electronics package, which comprised two, 3-Amp, DC motor drivers, the Arduino compatible Pro-Micro controller and a new serial adapter module, was mounted on a 100x100x1.6mm aluminium plate. The motor drivers were mounted using tapped nylon spacers. The rotator controller and serial adapter module, which have no mounting holes, were epoxied to special feet cut from two strips of fibreglass PCB or prefboard, respectively. The mounting plate was finally attached to the inside of the enclosure's front door using self-adhesive Velcro strips.

The electronics package was wired to a 12-way screw-terminal block, mounted on a piece of 25x25x1.6mm aluminium angle attached to the door-hinge bolts. The terminal bock provided a convenient breakout point for the station and sensor cables entering the enclosure through two metal cable glands on the cable-entry panel.

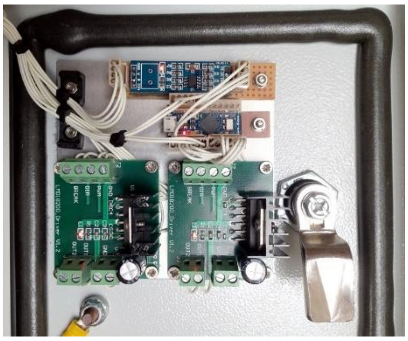

Figure 5 - Electronics package inside door

Station and sensor cables

The station cable was made from standard CAT5 UTP cable and comprises: +12VDC, TXD+, TXD-, RXD+, RXD- and GND. The sensor cable was made from standard flat telephone cable and comprises: +5V, DATA, CLOCK and GND. The sensor cable is part of an I2C bus, which did not tolerate the extra capacitance of a screened cable very well.

The sensor, was soldered to the sensor cable and was encapsulated in heat-shrink tubing sealed at each end with silicone.

Data communications

The MkII version of the rotator controller no longer uses the built-in Arduino Pro-Micro USB port for communications back to the satellite tracking PC, which would now be located in the shack. There were two reasons for this: A limitation with the Windows USB serial port hand-shaking implementation; and a limitation with the maximum length of the USB cable.

Instead, for rotator control and position feedback, the spare TTL serial port of the Arduino controller was connected to a homemade, 4-wire, full-duplex, RS422 adapter. The latter was fashioned from two, readily available, 2-wire, half-duplex, RS485 transceiver modules. Note: RS422/485 uses differential line drivers and receivers that work over twisted pair cables to provide high noise immunity and extended range. This solution required a small modification to the original rotator controller software, but it was tested to work reliably over 1000ft/300m of CAT5 Unscreened Twisted Pair (UTP) cable. Two whole pairs of this cable also provides DC power to the rotator. Incidentally, a home WiFi solution was also considered, but not expected to have sufficient range. In any case a physical DC power cable would still be required.

Back in the shack: An RS422 to USB adapter for the controller pc was fashioned using two of the same RS485 modules and a TTL to USB converter module, all housed in a small prototyping enclosure. The unit also provides a breakout for the rotator 12V DC power supply.

Figure 6 - RS422 to USB converter

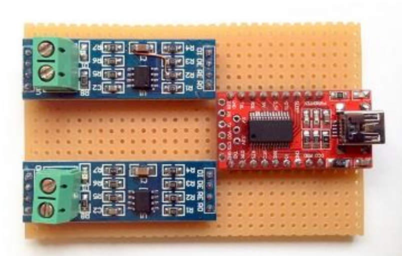

Figure 7 - RS485-TTL & TTL-USB modules

Software modifications

Several, backwards-compatible software modifications have been made since the original software release. The main change was better filtering of the sensor data. This makes the sensor calibration process much easier and more accurate; and the antenna positioning is smoother as well. Note: A fully automatic, self-calibration procedure using an adaptive, ellipsoid-fitting algorithm was considered, but discounted since the rotator only has 2 degrees of freedom while the sensor requires 3 degrees of freedom for a full calibration.

Conclusion

The scaled-up, MkII version of our original mini satellite-antenna rotator is rugged, weatherproof and will handle a couple of medium sized Yagis without any problems. No, it is not accurate enough for narrow-beamwidth microwave or EME work, as we are frequently asked, but it is just fine for Amateur satellites. The total parts cost was under $350.

Figure 8 - Tracking FO-29

For free source code, detailed engineering drawings, electrical schematics, parts list and further construction information please email us at info@sarcnet.org.