A Lightweight Antenna Rotator

Jonathan Hare G1EXG describes an Experimental Lightweight 12V DC 3D Printed Rotator for Small Lightweight Antennas.

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An experimental lightweight 12V DC powered rotator is described. Many of the parts can be created on a standard 3D printer, providing ease of replacement or modification. I created this little rotator so I could rotate a small 1296MHz beam on top of a 15m telescopic fibreglass mast but I have also used it to rotate other antennas such as lightweight dipoles (10, 6 and 4m band – see header photo) and VHF HB9CV antennas. The rotator might also prove to be useful to remotely position ferrite rod receive antennas for LF and VLF reception.

Specifications

- turn time 12V (360°): ~10 sec
- turn time 6V (360°): ~20 sec
- mass of rotator: 500g
- fits 22mm mast (two clamps) and 40mm mast (side fixed, see text)
- Note: this version has no position sensor

Introduction

I live in the city and only have a relatively small back yard for antennas. I cannot go out horizontally very far, but I can go up. I have a 15m fibre mast secured using two sturdy TV antenna brackets on the yard wall.

In an ideal world I would like my antennas to be on the top section of the mast and to be raised as high as possible. This means as lightweight antenna as possible. If you use a directional antenna, you either need to turn the mast or use a rotator to position it for best signal (or lowest noise). However, rotators are heavy devices and also add a considerable wind loading to the antenna system, which means it's not really practical to raise the masts to full height.

To overcome these issues I have made a lightweight prototype 3D printed rotator, which can be fitted at the top of the mast, perhaps not with full length extension (depending on wind) but at least start to be able to have a working rotatable antenna system high up.

Many standard antenna rotators used by radio amateurs require mains power and are often quite heavy. These are ideal for a fixed mast setup or on the side of a house etc, but they are not so good for small portable use. Some cheap lightweight TV type rotators rely on the mains voltage and frequency to synchronise the rotator motor and control readout but DC to AC converters are often not very reliable in this way. Of course, you can use a generator to create mains voltages but it's a lot more effort and gear that needs to be moved around and no one really wants to have 240V mains outside in the mud and rain if they can help it.

There are few commercially made 12V portable rotators available and some are very expensive. A well-priced and well-made UK portable rotator can be found here [1].

If you are portable, you have the option of rotating the mast by hand to point an antenna but if you are in a parked car, for example, constantly going in and out can become tiresome. What we need is a small lightweight rotator that can be viewed from the car window say, that can run on 12V, is easy to put up and control and does not cost the earth.

A 3D Printed Rotator

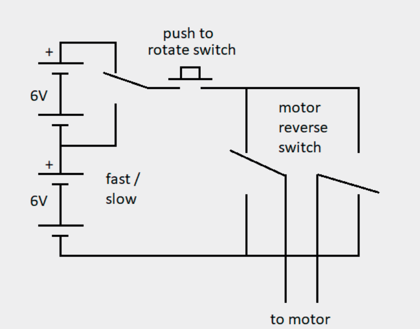
I have written before [2] of how a 3D printer can be a fantastic aid to prototyping ideas for amateur radio. Here I present a simple 12V rotator suitable for turning small antennas, many of the parts of which can be printed out economically on a standard 3D printer.

My prototype weights about 500g (including the motor but not the wiring), most of the parts are 3D printed and the motor drive is an easy to source geared motor. If a part gets broken or worn down, you can simply print another part to replace it.

Currently 1kg of filament is about £25 so the 3D printed parts for this design will cost you about £10. The DC motor was about £10 to £15.

I used a length of 8mm studding for the drive shaft of the rotator, which happens to perfectly fit standard roller skates/skateboard bearings, which are easy and cheap to obtain.

You can run the rotator motor direct from a 12V battery or use a variable voltage regulator circuit to adjust the speed for greater control. It's easy to arrange a simple push and toggle switch circuit to control the ON/OFF and rotation direction control (see diagram, **Fig. 1**).



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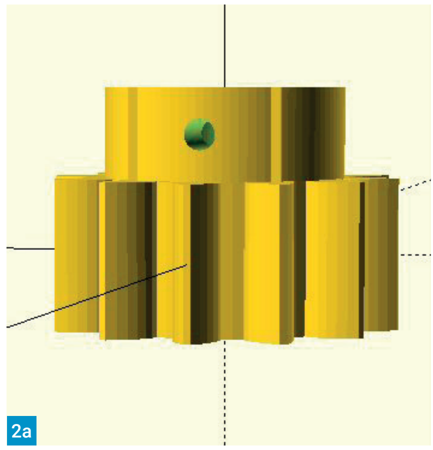

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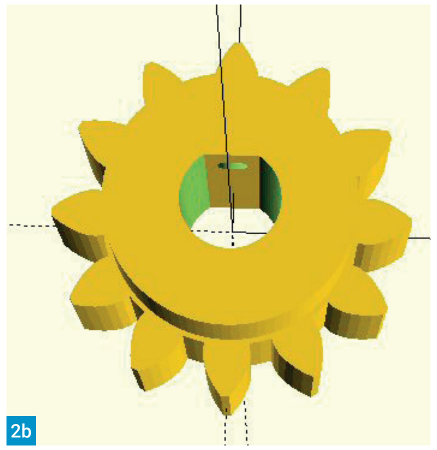

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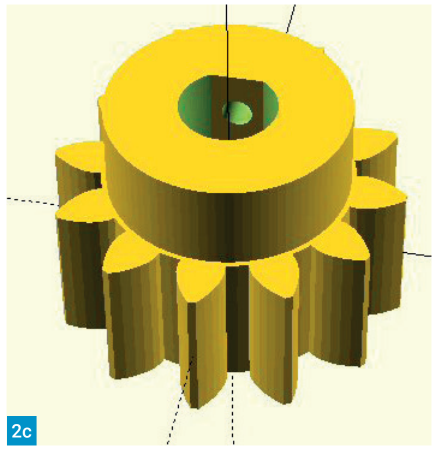

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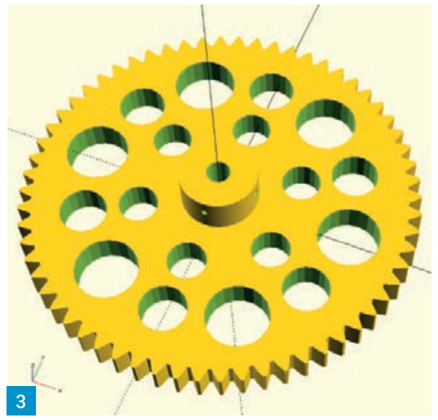

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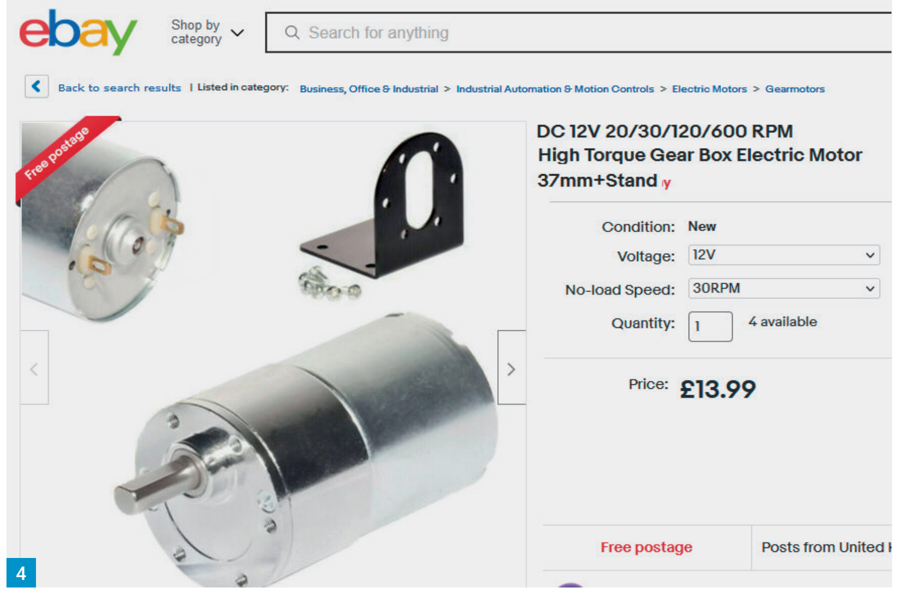

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Fig. 1: Using a toggle switch for ON/OFF and direction control. Fig. 2: The small cog. Fig. 3: The large cog. Fig. 4: Listing for suitable motor on eBay. Fig. 5: Various views of the completed rotator. Fig. 6: The controller. Fig. 7: Dipole centre. Fig. 8: Dipole arrangement and rough lengths. Fig. 9: The motor.

Waterproofing

I am only using the rotator for a few hours each time in my experiments, so I haven't made any attempt to waterproof it. However, silicon grease could be used on the plastic cogs and simple box arrangements could be fitted around the motor to protect from water.

3D Parts

Once the 3D prints are ca. 5mm or greater in thickness they are surprisingly strong. However, sunlight and heat are a problem for thermoplastics used in 3D printing. Hence, I am not suggesting this rotator be used permanently outside. My prototype used PLA filament but for outside use other filament types may be preferred, for example ABS, nylon or ASA.

When you have such a range of 3D filament colours to choose from, what colour is best? Black absorbs heat but some white pigments degrade over time. As these parts are all experimental and are not designed for longevity, I don't think it really matters. Bright colours show up well 'out in the field' and so might be worth considering, to minimise the chance of leaving things behind after going out portable for example.

3D Printed Cogs

Plastic cogs are not as strong as metal cogs, but they are re-printable and cheaper. You can of course modify the 3D printed cogs to your own specification and application. I take no credit for the design of the cogs used in this article. The Cog design (type of teeth etc.) was downloaded from Thingiverse [3] and I have modified the OpenScad code in this application. They are 3D printable customisable Involute Spur Gears, and I used the code to create the small and large cogs used here. I included a collar for self-tap screws to fix the cog in place. I also included additional circular cut-outs to removed much of the unnecessary plastic to save on filament and weight but keep strength.

Small and Large Cog

The small cog, **Fig. 2**, goes on the motor gearbox drive shaft and consists of a 20mm diameter, 10mm thick, 12 toothed gear. I designed it with a D-type shaft hole to fit the motor shaft. It has a collar that has a pilot hole to take a self-tap screw so that it can be locked onto the motor shaft. The large cog, **Fig. 3**, is a 100mm diameter, 10mm thick, 62 toothed gear. It has a central hole to take the 8mm studding rotator shaft and the collar has two pilot holes for self-tap screws to fasten the cog onto the rotator shaft.

Once printed, both gears might need a little cleaning up to remove the odd bit of stray filament. The parts printed closest to the printer bed tend to be slightly wider (to get a good first layer grip on the bed) so this part of the gear teeth may need to be filed down a little.

Motor Drive

I used a small motor easily sourced from online outlets such as eBay, **Fig. 4**. Search for 'DC 12V 20/30/120/600 RPM High Torque Gear Box Electric Motor'. I have also experimented with stepper motors but decided here on the simplicity of the standard motor. I chose a 30 RPM motor, but a lower speed (e.g. 20 RPM) motor might be preferable.


5a


5b


5c


5d


5e

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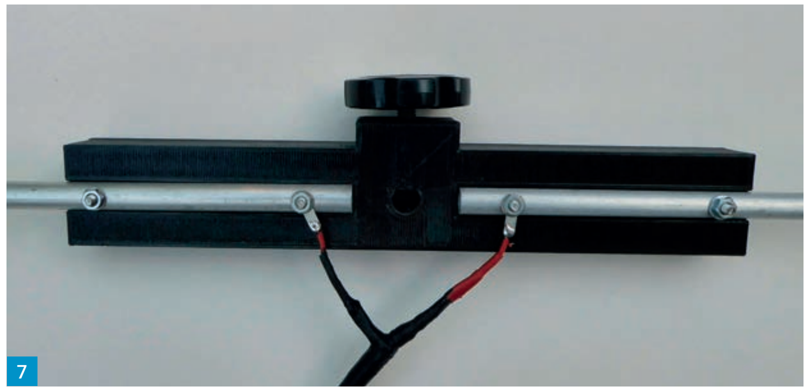
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Putting the Bits Together

Note: you may need to drill out some of the position and pilot holes in the 3D printed parts. For example, the self-tap screws holes etc. but be careful not to widen them out too far before trying them out.

Once you have all the 3D printed parts printed out and the other bits of hardware, you can assemble the rotator. To help hold everything I built a stand from a piece of wood and a short length of 22mm tube. Fit the two thumb screws/bolts into the mast clamp holes. Depending on the size of the bolts you may need to drill these out a little but there is no need to tap holes. Slide the main base onto the stand, tighten the thumb screws, then you can work on everything easily.

Depending on the motor you purchased it may, or may not, fit the six holes I printed on the main base. You may need to drill these out. I only used three of the holes. You can then fit the small cog onto the motor shaft and secure using a self-tap screw.

Put a bearing into the top bearing support part, **Fig. 5d**, and, at this stage, very lightly fit it into place under the main unit using two 3M nuts, bolts and washers. Pop the other bearing into the L shaped 'lower bearing support' and fix it into place using two self-tap screws into the side of the tube support, **Fig. 5e** (there are two holes printed for this, but you might need to open them up depending on the size of the self-tap screw you use).

Note: I have made the 3D printed 'cups' that take the bearings a little large. This is much better than too small as it would be very difficult to open them out. Although I didn't need to, you might find a small amount of packing (e.g. tape) or glue might be needed to secure them in place.

Using a 30cm length of 8mm studding for the rotator shaft, slide it down into the two bearings (you will need to add washers and nuts as you do so). Adjust the nuts so they sit on the bearings, so to take the weight evenly. Then add one or two washers on top, slide the large cog onto the shaft and fix in place using two self-tap screws (the collar under the cog). I filed down parts of the 8mm studding where the self-tap screw goes so the cog can't slip. Adjust the top bearing unit so the two cogs interlock properly and tighten the two 3M bolts to secure. Finally add a large washer and two 8M nuts to the bottom of the studding to secure the shaft in place. That's basically the rotator made. The photos, **Fig. 5**, may help to see what you need to do/what's going on.

Wiring Up

The next step is to connect suitable length wires to the motor and wire it up to the control switches and (if used) the variable regulator. Everything should move around nicely when voltage is applied (>6V). The rotation speed will of course depend on the voltage applied to the motor and the gearbox drive ratio that you chose to use. Rotation speed will also be dependent on the size and wind loading of the antenna you are using as well as the wind speed.

The combination of the gear ratio on the motor and the two 3D printed cogs means that the antenna is quite stable and movement of the antenna is unlikely to go back along the cogs and move the motor so you don't need a brake. But obviously bear in mind that this is a plastic setup and eventually with enough wind loading or wind speed some damage will be done. If this happens, you can easily print out spare parts.

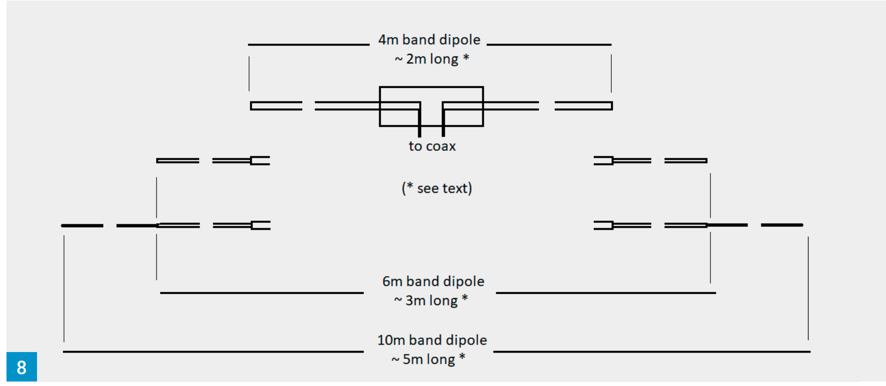
Speed and Power Control

A nice aspect of using a 12V motor is that you can easily use a voltage regulator to control the speed. I made up a simple 0-12V regulator using a LM317 regulator chip with a TO3 case, which I mounted to the side of the controller's metal box as a heatsink. As the current was under 1A, a smaller TO220 LM317 (on a heatsink) would probably work fine.

I used a push switch on the input from the 12V battery so that there was no current drain by the controller when the motor was not in use. I also fitted a large diode on the power line to prevent accidental incorrect wiring. The regulator output goes via a DPST toggle switch wired so it reverses the power to the motor: you can get clockwise or anti-clockwise rotation when the 'rotate' button is pressed.

Alternately two 6V batteries wired in series could be used (see diagram, Fig. 1 again and the photo, **Fig. 6**) to provide a fast and slow option with just the two switches.

The 3D printed rotator turns faster (10-20s) than a standard antenna rotator (60s). It's probably about the speed that you might turn a portable mast by hand if you didn't have a rotator, so I think that's acceptable. As we are turning smaller and lighter antennas with this setup we can afford go a bit faster. I found that my motor would run fine on 6V so could easily be slowed down. However, much lower voltages might not have the power to turn against wind.



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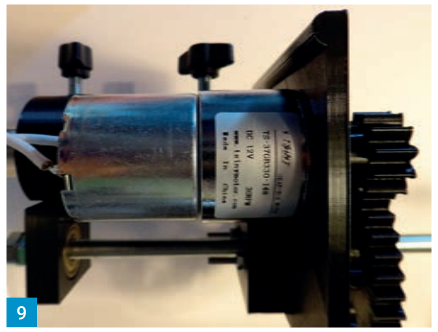
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Remember this rotator is designed for low weight antennas; it won't reliably turn a full-sized HF antenna or even a 7-element 144MHz long Yagi, for example.

Rotator Mast Fixing

The top section of my fibre mast is a 22mm diameter tube so I designed the main 3D printed base for this diameter, but I have also included a semi-circular cut-out on the side, **Fig. 5b**, so that the rotator could be attached to a 40mm diameter mast. If this is used, you will need cable ties or hose clips to hold the rotator to the mast.

Lightweight 3D Printed Dipole Centre & Elements

I also designed a 3D printed dipole centre to fit the 8mm rotator shaft to create a lightweight rotatable dipole for the 4, 6 and 10m bands [**2**]. A side of the 8mm rotator shaft will need to be filed flat to form a D shape to fit the 3D printed part. A thumb screw secures in place.

For strength, I have made the dipole centre as large as possible (ca. 200mm long), so it prints along a diagonal on the 3D printer bed.

The centre has semi-circular channels to take 100cm long 8mm diameter tubes to form a 4m band dipole. Smaller tubes and rods can then be slid into these 8mm tubes (and secured using small hose clips or wire loops tightened up) to lengthen the dipole for other bands. Obviously, the tubes and rods need to be able to slide into the holes in the adjacent tubes comfortably (not too snug otherwise over time they tend to get stuck with corrosion or when dirt gets in).

The 6mm tubes I used were about 60cm long. For the 6m band dipole about 10cm was slid into the end of the 8mm tubes to create a 3m long dipole. You can of course adjust the length for best match. For the 10m band dipole I also used 3mm aluminium welding rods pushed into the 6mm rods. About 3cm or so of the rods were fitted into the 6mm tubes (see **Table 1**).

In free space a dipole should have an impedance of 70-75Ω, which when connected to a 50Ω cable should give an SWR of about 75/50 = 1.5:1 (a lower SWR than this probably means something is not right). I fed the dipole with mini-8, which is relatively lightweight and for 10-15m lengths is good to 144MHz. Losses on a 10-15m length of mini-8 at 70 MHz (and below) for this SWR, should be relatively small. I made up a simple choke balun by winding ca. 10 turns of the coax on a piece of 40mm diameter plastic tube fitted as close to the feedpoint as practical.

I used two of the tube securing bolts as points to join the coaxial cable using solder tags (see photo, **Fig. 7**). The wires and end of the coax were painted with flexible rubber sealant to help keep moisture out.

The SWR can be adjusted by sliding the tubes in and out. The exact lengths will depend on the diameter tubes you happen to use, which is why I have only given rough lengths in the diagram, **Fig. 8**. For the 4m band you can either try the dipole with just the two 100cm long 8mm tubes or you can add length by sliding in short lengths of 6mm tubes. You get a little bit of extra length added in from the end wires coming from the coaxial cable to the solder tag connections on the tubes, but this may only be significant on the 4m band dipole.

Final Thoughts

There are no stops on the rotator. It can continually turn so it's not limited to 360° rotation. You will need to look at where the antenna is pointing.

There is no rotation position feedback potentiometer built into this design but a multiturn potentiometer could be fitted to the bottom of the 8mm studding and I may work on a prototype in which case I will add details to my web pages later on.

3D Printed Parts List

- (all the files can be found on my 3D printing web page [2])
- main body/base unit, Large cog, small motor drive cog
- bearing holder for bottom of axial, bearing holder for top (base)

Other Parts

- 1 x 12V DC motor with built-in gearbox (I used a 12V 30 RPM motor, see screen grab image, **Fig. 9**)
- 12V variable voltage supply (ca. 6-12V)
- 3 x 10mm 3M bolts for motor
- 2 x standard skate bearings (8mm shaft)
- 2 x thumb bolts 4M (as used for action cams etc)
- 3 x ca. M3 15mm self-tap screws (for cogs)
- 1 x 30cm long 8mm studding (rotator shaft)
- 2 x 3M bolts and washers (top bearing support)
- 2 x 4M self-tap screws (bottom bearing support)
- Wiring cable for rotator
- 3 x 10 mm 3M nuts, bolts and washers for motor
- 2 x 3M nuts, bolts and washers (top bearing support)

Here are the details and weights* for three dipoles:

- 4m band dipole: 200g, 3D centre + 2 x 100cm 8mm tube
- 6m band dipole: 225g, 3D centre + 2 x 100cm 8mm tube + 2 x 60cm 6mm tube
- 10m band dipole: 250g, 3D centre + 2 x 100cm 8mm tube + 2 x 60cm 6mm tube + 2 x 100cm 3mm aluminium welding rod.

(*not including weight of coax and choke/balun)

Table 1: Dimensions and weights for each band.

I have had some positive experience using ferrite rod antennas for LF and VLF reception and I plan to use this 3D printed rotator to locate the ferrite rod in a far spot in the garden to remotely rotate the receive antenna. The whole setup would be small enough to cover with a storage crate or even a bucket, to provide some simple weatherproofing.

Updates and improvements on the design will be posted on my website [**2**].

References & Links

[1] **https://tinyurl.com/fmat8h96**
[2] for details of this and my other 3D printed articles see my website: **www.creative-science.org.uk/3D.html**
[3] cog ref: e.g. **www.thingiverse.com/thing:41246**