An automatically tuned 7 to 30 MHz mobile antenna

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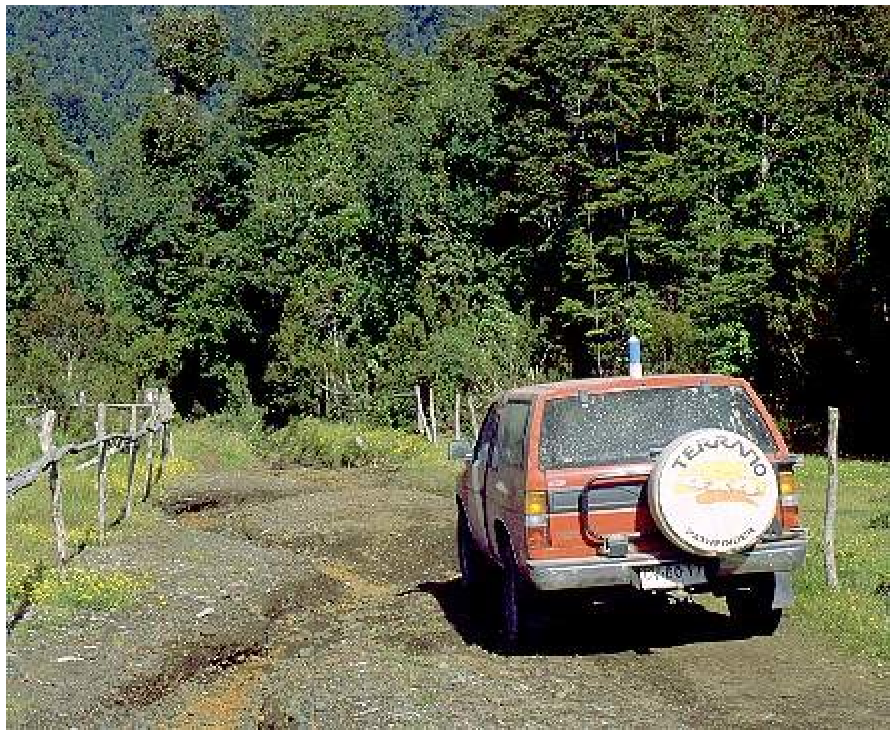


For any ham who likes to travel, and who often travels by car, a mobile installation soon becomes a necessity. This is especially true when traveling on roads like the one depicted here! And while in inhabited areas there is usually some VHF repeater coverage, in many other places VHF radios are useless. But HF can provide reliable contacts, and lots of fun, from anyplace! That led me into setting up a combined VHF-HF mobile station as soon as I got my first car.

The VHF antenna is easy enough: An NMO mount on the center of the roof takes either a quarter wave whip for modest operation in cities, or a 5/8 element for better performance when out on the highways. But the HF portion involves a lot more difficulties! Many commercial mobile HF antennas are less than practical because of their size, weight and stiffness, while others have really low performance. So I preferred homebrew antennas from the start.

Over the years (and when changing cars) I have gone through 4 iterations in my aim for a "perfect" antenna. While of course nothing can be really perfect, the antenna presented here is the result of ten years of experience in both building and using HF mobile antennas, and it has me completely happy!

Any ham who has ever operated HF mobile knows that mobile antennas, specially those for the lower bands, tend to be notoriously narrow-banded. In addition, most mobile antennas require replacing resonators, or at least plugging jumpers, in order to change bands. I used to solve the problem of insufficient bandwidth by using an automatic antenna tuner, but this did not solve the band changing problem. Much too often it happened that someone invited me over to a different band, or simply the propagation closed down on the band I was on, and not wanting to pull over, stop, get out into the rain, and change a jumper, I simply switched off the radio...

No more. The antenna presented here covers all ham bands from 40 to 10 meters, and everything in between, with a maximum SWR of no more than 1.3:1 and good efficiency. Since remotely adjusting an antenna while driving could be dangerous, I included fully automatic tuning, commanded from the transceiver. The antenna is very lightweight, tall but flexible, and looks simple while being quite sophisticated. The project involved a major amount of work, but this gave me many hours of entertainment!

The concept:

This is a base-loaded vertical antenna that mounts on the car's roof. The loading coil is designed as a variable inductor, with a three-legged chariot that travels up and down inside the coil, with grooved brass wheels running on the coil turns, and driven by a slotted rotor tube. A modified model airplane servo, inexpensive and widely available, is used as compact and powerful motorization. Two limit switches shut off the motor current before the chariot can run off the ends of the coil. The motor is fed by positive and negative DC voltage applied to the coax cable. The bulk of the antenna can be quickly removed from the car, without any tools, while only the mounting base is left in place, protected by a cover. The entire antenna is sealed against the weather by silicone caulk in the permanently assembled threads, and O-rings at the other places. Only plastic and stainless steel get exposed to the weather. An impedance matching coil is included, resulting in very low SWR. In order to maximize the efficiency, the loading coil is large, and, to the best extent possible, metal parts are avoided in close proximity to the coil. All mechanisms and coils are inside the assembly, resulting in a smooth, simple appearance.

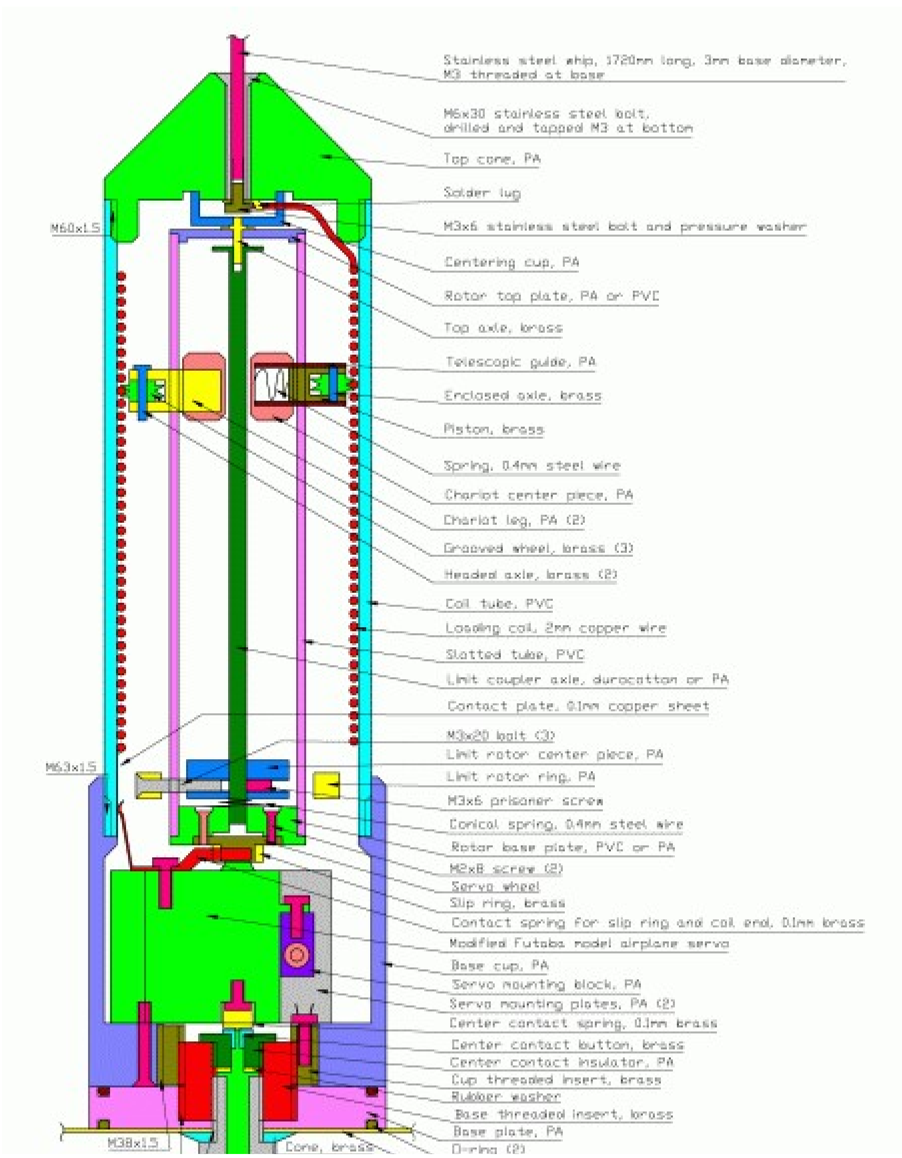
The control unit can be mounted anywhere between the antenna and the transceiver. It does not need to be mounted within the reach of the operator, since it is remotely operated from the transceiver. It is connected via one coax cable to the antenna, and one coax cable plus one power/data cable to the transceiver. It contains a Basic Stamp microcontroller, a SWR sensor, a DC-DC converter with bipolar output for powering the motor, and associated components. The microcontroller communicates with the Kenwood TS-50 transceiver, emulating an AT-50 antenna tuner as seen from the transceiver side. If a different transceiver will be used, a relatively simple software modification would be necessary. Commanding the system to tune to any frequency within the covered range is done in exactly the same way as one would do it with one of the factory-made automatic antenna tuners: Go to a nearby clear frequency and press AT TUNE!

Building this antenna requires the use of a lathe. However, it doesn't need to be a particularly large or complex lathe. I built my antenna using a simple, relatively inexpensive desktop hobby lathe, and the antenna was the first major mechanical project I attempted, which shows that no unusual mechanical skills are necessary to successfully build it! On the other hand, this definitely isn't a weekend project...

The mechanical design

Please refer to the drawing in order to be able to follow. The 172cm long stainless steel whip, which has a base diameter of 3mm and tapers out to a slim 1.5mm, screws into a drilled and tapped stainless steel bolt, which in turn is permanently screwed into the top cone, made from polyamide (PA, also known under the tradenames of Nylon and Technyl, among others). This top cone screws into the coil tube, which has the loading coil wound on its inside, with a pitch of 3mm. The coil tube is simply a piece of polyvinylchloride (PVC) water pipe of 63 mm outer diameter and 3mm wall thickness. In countries that use inch-size water pipes, there are almost exactly equivalent pipes available, of 2 1/2 inch outer diameter and 1/8 inch wall thickness. Winding the coil on the inside of the pipe is one of the more challenging parts of building this antenna, but the step by step instructions are given further down.

The chariot travels on the coil by means of three grooved wheels which run on the wire. Two of these wheels are fixed on their respective legs, while the third one has a spring-loaded telescoping mount, which compensates for the unavoidable imprecision in the dimensions. The chariot is supported only by the three wheels, floating freely inside the rotor tube, which has three lengthwise slots through which the chariot legs poke. Just like the coil tube, the slotted tube is also made from standard PVC water pipe. This pipe has 32mm outer diameter and 2mm wall thickness, being equivalent to the 1 1/4 inch pipe of non-metric countries. The top of the rotor tube is terminated by a PVC plate which has a brass axle inserted, that engages in a cup-shaped piece which centers the rotor assembly by engaging in a circular groove in the top cone. The lower end of the rotor tube is terminated in a PVC base plate, which is in turn fixed to the output wheel that comes with the model aircraft servo, a Futaba FP-S148, which provides the motion. As the servo turns the rotor, the edges of the three slots in the rotor tube push against the chariot legs, making it turn. The chariot then will be guided up and down by the coil turns. The lowermost of the grooved wheels doubles as moving tap on the coil.



When the chariot reaches the upper end of the allowable range, the chariot center piece will lift the limit coupler axle, which has a longitudinal play of 2mm both up and down from the resting position. The axle will carry along the limit rotor center piece, and with it will lift the limit rotor ring, which will activate the lower limit switch and stop the servo motor. Likewise, when the chariot reaches the lower end of the range, it will push down the limit rotor, so that the ring will activate the other limit switch. To avoid confusion, the limit switches are not shown in this drawing; instead a detail drawing is provided further down. Use that one, and the photos, to visualize this part.

Also not shown in this drawing is a flexible wire that connects the axle of the lowermost chariot wheel to the slip ring, passing through a slanted hole in the rotor base plate. A contact spring slides on the slip ring, providing the connection to the movable tap on the coil. The same contact spring connects to a contact plate soldered to the lower end of the

coil, thus the unused part of the coil is shorted out. From this contact spring a toroidal impedance matching coil is connected to ground, and a bypass capacitor is connected from the spring to the center contact spring, which has direct contact to the coax feed center conductor on the base.

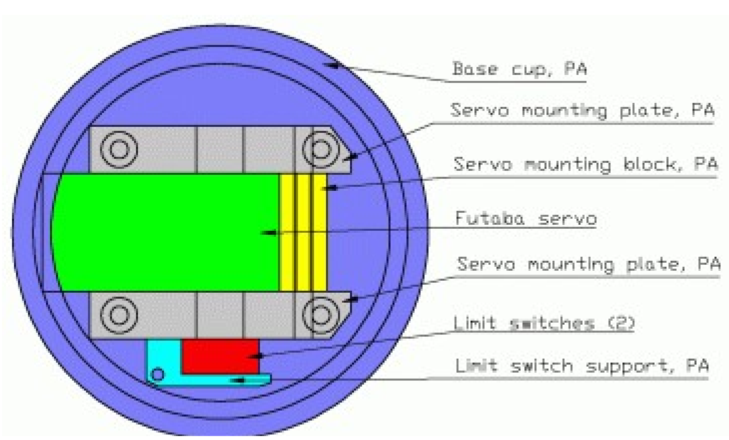
The servo, limit switches, all associated components, impedance matching coil, bypass capacitor, and the contact springs form a compact unit that mounts with four bolts inside the base cup, made from PA like most of the parts. The coil tube screws into the base cup, closing the assembly. The base cup carries a brass threaded insert, which engages to a similar but smaller threaded insert in the mounting base. This brass-to-brass thread is the one that is unscrewed to take the main part of the antenna off the car roof; The brass-to-brass contact is electrically safe and mechanically wear-resistant. The base cup threaded insert is locked in place by a single M3 bolt, which also carries a solder lug for the ground connection of the antenna innards. The other threaded insert screws into the base plate, and is fixed by a brass M12 bolt through a 12mm hole from below the car roof. This bolt has a center hole through which the RG-58 coax cable enters the base. A PA insulator, which is also M12-threaded, presses the coax shield against the drilled bolt, using a rubber washer or small O-ring to assure good contact. The dielectric of the coax cable enters the hole of the center insulator, and the center conductor is soldered to a small brass center contact button, on which the contact spring of the main antenna unit rests.

The base plate is sealed against the car roof using an O-ring. A 2mm plastic layer acts as a cushion between the brass threaded insert and the surface of the car roof, avoiding damage to the paint, so that when reselling the car the hole can be closed with a little cap, making it almost invisible. The base plate also has another O-ring embedded, that seals it against the main antenna unit.

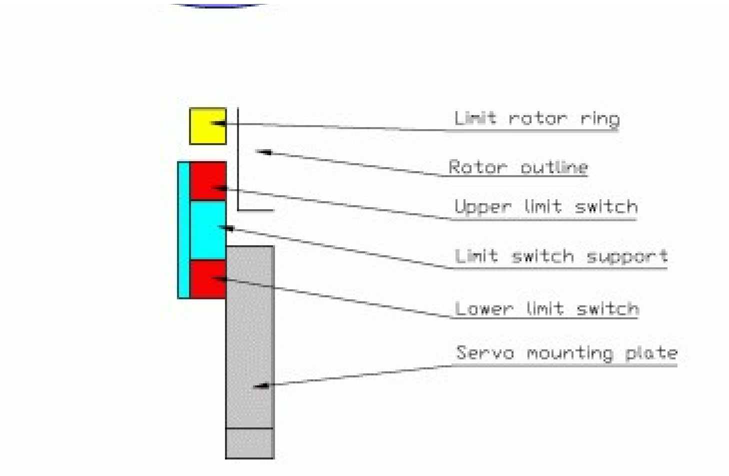
The all-important ground connection to the car roof is made by a brass cone that encloses a toothed washer, which bites into the car roof from below. This connection of brass to steel is vulnerable to galvanic corrosion, so it is very important to apply a coating of thermally stable grease (I used silicone grease) before assembly. This grease will avoid corrosion and contact problems.

You will probably want to print this drawing. Here is a full resolution file in GIF format. It is dimensioned so that if you print it at 600dpi, you should end up with a true-sized print. It will fit on either a DIN A4 sheet, or on a US legal size one, but not on a letter size one. Be aware that some viewers, and specially some browsers, may have trouble handling a file of this resolution (27 megapixels), so you may have to get a better viewer. IrfanView, available for free from Download.com, is highly recommended for such purposes.

The best way to get the exact dimensions is by downloading the original AutoCAD R14 DWG file. You will need AutoCAD, or some compatible software, to open this file, but then you can get all dimensions, easily and in full precision. Otherwise, you can measure them on the print. It helps to know that most dimensions are exact multiples of one millimeter.



And this is the detail drawing. You can click it to get the full resolution version, and here is the AutoCAD drawing file. The upper half shows a cross sectional view through the base cup, from which the dimensions and positions of the servo mounting parts can be extracted. The lower half shows the exact location of the limit switches relative to the other parts. The lower switch is mounted by two M2 bolts going through the limit switch support and the switch, self-tapped into the servo mounting plate, while the upper switch is



held in place by two bolts self-tapped into the support. The location of the bolts depends on the exact type of microswitches you find, so I didn't draw them.

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