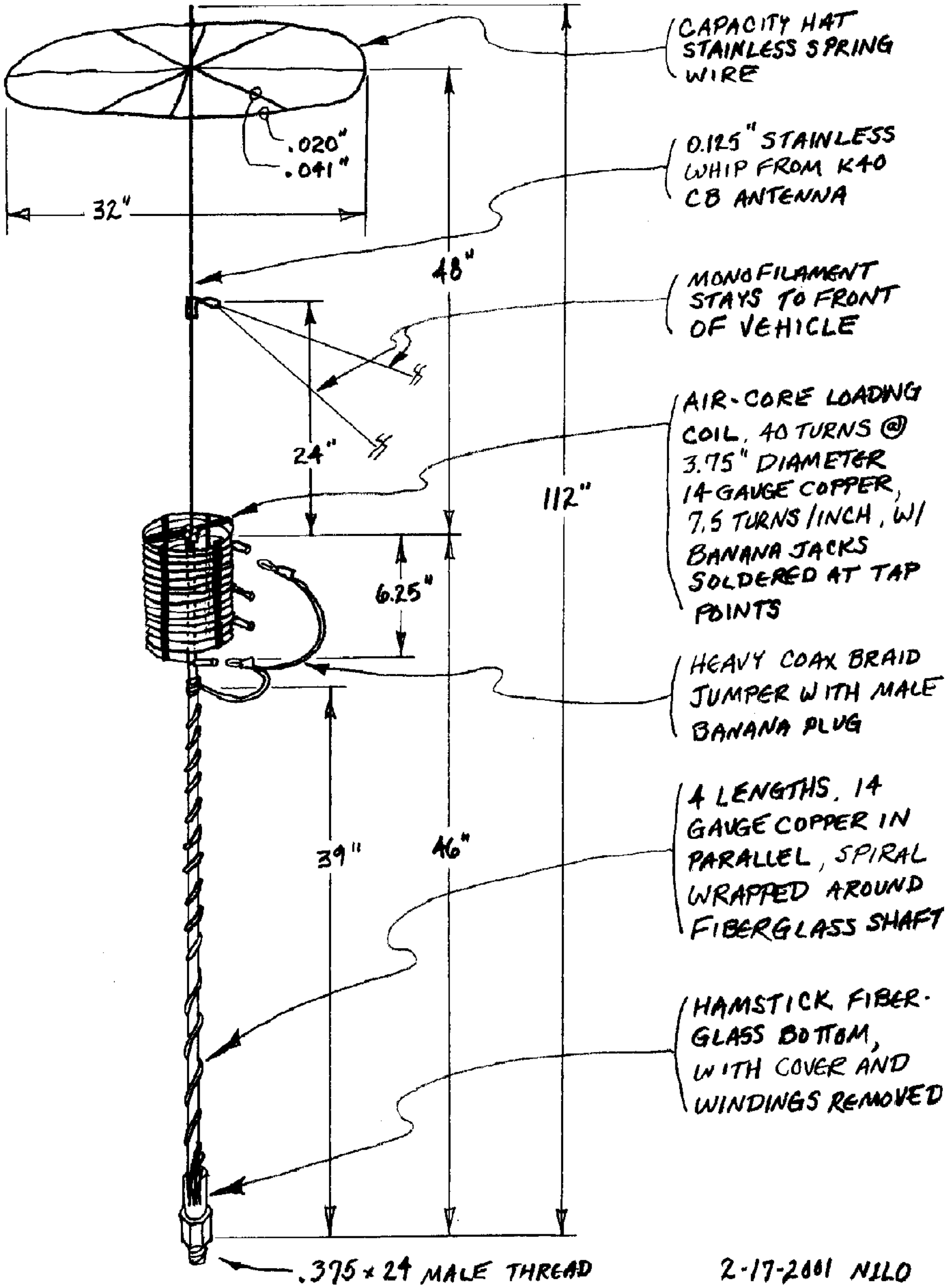
N1LO MOBILE HF ANTENNA
80-10m



2-17-2001 N1LO

10-80m MOBILE HF MULTIBAND ANTENNA PROJECT

February 17, 2001, by Mark D. Lowell, N1LO

This is a combination center and top loaded multiband antenna. It gets a good boost in efficiency from the capacity hat which, unlike the commercial bugcatcher antennas, is located where it should be: as high as practical on the whip. The low profile of the capacity hat lets it cut through the wind while still remaining effective. This is the largest diameter hat which can withstand highway speeds without using a stiffer whip. The coil construction yields the highest possible Q and least loss, since it has an air core, open spacing, and heavy gauge wire. This is a very lightweight antenna and it can also be used portable with a suitable counterpoise/radial system. Monofilament stays are required to keep the antenna upright on the highway, and this arrangement has proved suitable at speeds up to 80 mph.

Band switching is accomplished by moving the jumper plug to different tap points on the coil. You have to stop, get out, and manually change the tap. In the top socket, the coil is effectively bypassed, and the antenna resonates in the 17m band. There is enough inductance in this coil to achieve resonance from 20m down to 80m with several turns to spare. A tuner can be used for 10-15m with the tap in the 17m position (coil bypassed). If you like, you can remove the capacity hat and select tap points for all the upper bands so that no tuner is required. I think it will tune 10-40m without the capacity hat, so you have a choice to make. If you want to operate 80m, or if you want to operate 40m with the best efficiency, you definitely need the capacity hat.

The bandwidth gets narrower as you go lower in frequency. With the capacity hat, two tap points cover the 40m band reasonably well: one for phone and one for CW. For the 80m band, you may need six or more tap points depending on the range of the tuner you have.

This design is the result of 9 months of experimentation on my part. With each improvement, signal reports would improve. I have stopped building for awhile with this latest design and have just enjoyed operating with it. I wish you good luck building yours!

I have a 1998 Toyota Camry, and I am using a Lakeview license plate mount, which fits behind the plate on the rear of the trunk, and has an arm that projects out to the rear (Lakeview is the same company that manufactures the Hamstick antenna). The arm is about 33 inches above the ground, and the antenna rides higher and quite clear of body panels. The coil assembly is about 12 inches above the roof of the car, a very desirable and added bonus for radiation. The overall height is just over 12 feet above the ground, well clear of bridges, but still subject to tree limbs!

Some notes on mobile HF antenna efficiency. The following are features that improve efficiency:

Tallest possible antenna.
Maximum top loading:
  Largest practical hat diameter.
  Small wind resistance.
  Unitized construction, minimal variation
  In contact resistance at joints.
Minimal coil turns for resonance.
Largest practical base diameter (between base and coil).
Very low ohmic losses in materials (highest conductivity).
Large contact patch in mechanical electrical joints (coil taps)
Highest possible coil efficiency:
  Largest practical diameter and wire gauge.
  Turns air spaced by one wire diameter.
  Air core
  Minimal metal inside or near coil ends.
  Length approximately equal to diameter.
Highest possible mounting on vehicle.
Centralized location of antenna (middle of vehicle)
Largest possible horizontal separation from sheet metal body parts.
Highest integrity ground plane/counterpoise:
  Large, metal car body.
  All body panels and chassis bonded together.

STEP-BY-STEP CONSTRUCTION

This section follows along with the remaining illustrations.

BASE SHAFT

Strip off the heat shrink tubing from the Hamstick antenna by scoring or slitting the tubing lengthwise and peeling it off. The reveals the helical windings. Cut the magnet wire at the base and up at the whip socket, unwind it from the shaft, and save it for your wire scrap box.

File or brush the black coating off of the brass base on one side. Cut 4, 48" lengths of 14 gauge bare copper wire. Solder these to the base, separate them slightly, and wind them in a gentle spiral up the shaft toward the whip socket. Try to keep the wires equally spaced on the shaft. This effectively increases the electrical diameter of the base radiator section.

Terminate the wrap 39" up from the base, with a tight wrap, bringing all wires next to each other so that they can all be soldered together. Form a short tail from 2 of the wires. This is where you will solder on the tap jumper wire.

JUMPER WIRE

Create the jumper with a 12" length of shield braid from large coax such as RG-8 or RG-213. You can also use the braid from RG-58 if you double it up in parallel to reduce the losses. Solder one end to the tail you created on the top end of the base radiator winding. Solder one of the male banana plugs at a right angle to the braid 3-4 inches up from the tail. This plug will connect to the very bottom of the loading coil. Solder the other plug at the far end of the jumper. This plug is the one you move to the various tap sockets on the loading coil for band switching.

CAPACITY HAT

The capability of soldering stainless steel is the key to the whole success of the capacity hat portion of this project. Any intermittent contact between the elements while transmitting will cause wild fluctuations in SWR and the transmitter will fold back. Crimped connections with sleeves may work a little better while the wires are fresh and shiny but corrosion will eventually take its toll. The solder and flux combination that I have listed in the bill of materials is nothing short of dynamite for this stainless wire. A dab of the liquid flux on the joint before applying the silver bearing solder will do the trick.

Cut off the portion of the tang on one of the ground clips where the drilled hole is, as shown on the illustration. This leaves the copper bearing plate intact between the end of the setscrew and the groove where the whip will pass. Brighten up one side and solder on the four radial wires as shown. If you use the silver bearing solder here, the joint will be mechanically stronger and the electrical conductivity will improve.

In bending the radial arms out to position, take care that you do not block screwdriver access to the set screw. Form small eyes in the radial ends, just big enough to pass the small perimeter wire. One easy way to hold the assembly is to clamp a short rod in the ground clip and clamp the rod vertically in a vise. This effectively simulates the way the hat rides on the whip and puts the hat in a horizontal plane where you can access all the radial ends. String the perimeter wire through all radials and hook the ends of the perimeter wire to themselves. Keep the radial ends evenly spaced. Minor variations will be of no consequence. Solder all joints, taking care to completely fill them with solder. Remember that an intermittent joint here will disrupt the stability of the antenna's resonance while transmitting.

In testing, I determined that this hat was equivalent to five more feet of vertical whip above the coil.

LOADING COIL

Thanks to a tip from George, K0FF, I learned about grommet strips, the most perfect structure available for making high Q, air-core coils! They are essentially, extruded U-channel, made from nylon, a strong insulator, having castellated cutouts at a spacing of approximately 7.5 turns-per-inch. When several of these strips are arranged around the outside of a section of pipe, with the grooves turned out, they become the ideal wire guides for winding a coil of wire in a spiral. The grommet strips are available in several sizes. I have selected the largest size available, which is perfectly suited for 16 and 14 gauge wire.

For stronger coils that must bear mechanical strain, you can simply glue the strips to the PVC pipe. However, we desire the lightest weight possible, and minimal material surrounding the wire turns. Therefore we need to slip the finished assembly off of the pipe. This is harder than it sounds! I found a trick that makes it a snap. Cut a saw kerf along the length of the pipe, as shown, using a hacksaw, and wedge a length of 14 gauge wire in the kerf. When you finish making the coil, fish out the wire from the kerf, which will instantly reduce the pipe's diameter, and the coil assembly will slip right off neatly. By the way, the 3" PVC pipe will result in a coil diameter of approximately 3.75 inches, which is nearly one full foot of wire per turn. Surprising how much wire is there, isn't it?

Don't worry if the free ends of the grommet strips bend out of position slightly while you are winding the coil. Just be sure to straighten them back up before you secure the turns with the glue. Speaking of glue, I use a high temperature variety of hot glue that sets a little more rapidly and has a bit more strength.

The hot melt glue could become a weak link if you are running enough power to heat the coil. I have not noticed the slightest bit of coil heating while running 100W on 80m. However, at 500W or more, there is the possibility that the coil may heat enough to soften the glue.

40 turns was more than enough to resonate the antenna down to 3.5 MHz on my car, with several turns to spare. Clip off excess grommet strips with diagonal cutters. You will find that the coil assembly is remarkably strong, even without the supporting pipe. A single cross bar made from copper tubing soldered across the top coil winding has been quite sufficient in holding my coil assembly on the antenna. By flattening the cross bar ends, you increase the joint area, making the solder joint stronger.

TAP SOCKETS AND PROBE

I was fortunate enough to obtain a bag of silver-plated, 5-way binding posts at a hamfest. The ends have sockets for banana plugs. I chose these for their relatively large, and circular contact patch, just what we need for a low resistance, RF joint... if the joint can't be soldered, that is! By cutting the shank through the through hole, you can thread off the plastic binding head, leaving a beautiful, silver-plated, female banana socket with a stub shank on the other end. The stub has a groove across it, as a result of sawing through the hole, and is a perfect fit over the 14 gauge coil wire. File the edges as shown on the illustration, to reduce the width and to help keep the tap from touching adjacent coil turns. Solder one of the sockets onto the very top turn of the coil. Solder another one on the free wire end at the very bottom turn of the coil.

You will need a probe that can be attached and removed quickly from a single coil turn when hunting for resonant tap points. The alligator clip fits the bill for the limited current from your antenna analyzer. Solder on a socket to a clip so you can plug the tap jumper wire into the clip for making temporary coil taps.

ASSEMBLY

Now for the fun part! Slide the whip through the clip groove in the hat and secure the hat about 49.5 inches above the bottom of the whip. Slide the clip groove of the coil assembly over the bottom of the whip and secure it with about 1.5 inches of whip extending below the clip. Slide the base shaft up through the bottom of the coil and insert the 1.5 inch tail into the whip socket. Spin the coil around in the socket until you can easily plug the bottom plug of the tap jumper into the bottom coil socket on the last coil turn. Next, insert a small screwdriver horizontally through the coil turns to tighten and secure the set screws in the whip socket. Plug the free end of the tap jumper into the alligator clip probe. Now you have the complete antenna assembly, ready for tuning!

TAP POINT DETERMINATION

Install the antenna on your vehicle. If you intend to use a quick-disconnect adapter fitting on the base, go ahead and install it now, as it will affect tuning. If you do not have a tuner in your mobile setup, you should consider purchasing Lakeview's inducti-match to help transform the feedpoint impedance on 40 and 80m from a low value up much closer to 50 ohms. If you are setting the antenna up for portable use, set up the mount and radial system exactly as you intend to use it.

I highly recommend an antenna analyzer that shows antenna resistance and reactance instead of just SWR, such as the MFJ 259B or 269. It is more important to make the antenna resonant than to have the best SWR, especially if you have a tuner to make the match. Resonance and SWR are two independent qualities of the antenna. The secret for the best performance of the *antenna itself* is to make it resonant. Matching it for best SWR is another matter entirely. At resonance, the reactance of the antenna drops to zero as the inductance and capacitance of the antenna exactly cancel each other out, leaving a purely resistive feedpoint resistance that is rarely equal to 50 ohms. Your tuner will match a resonant antenna much more easily. On 20m and up, the frequencies of resonance and best SWR are very close together, and the match will typically be good enough where no tuner or inducti-match is required. However, on 40 and 80m, the feedpoint resistance at resonance drops fairly low. In my case, at resonance in the 80m band, the MFJ-269 indicates that the resistance is about 12 ohms, with a reactance of 2-3 ohms. If you are using the inducti-match, you will have the unique opportunity to match both the resonance and the SWR at the same frequency. You may have to go back and forth between the loading coil and the inducti-match in several iterations to find the best combination of taps. Record the settings of the inducti-match in a notebook as you will need to change these every time you change bands.

If you don't have an analyzer, you can use the SWR indicator in your radio and perform the tuning with lowest power, 5W or less. It won't be quite as optimal at finding resonance below 20m, but it should still be satisfactory. Keep in mind that a low SWR doesn't always insure antenna resonance.

Move the probe clip around until you find the position of best resonance in the band of interest. Mark the coil with tic marks, using a marker. Take care that the clip is only touching one coil turn during your measurements. It may help to squish the alligator jaw teeth flat with pliers to keep them from touching adjacent turns. Once you have found all of the tap points, disassemble the antenna and solder jacks at each tap point. Take care not to short out turns when you solder the jacks. Reassemble the antenna and check out the tuning on each band by plugging the male plug on the end of the jumper into your newly installed jacks. Note that the bottom plug of the jumper stays plugged into the bottom of the coil at all times.

For 20m, my tap point is about 2 turns down. For 40m, I use about 10 turns. For 80m, I have 6 taps on turns 32-37. This should give you some idea of where to look for these bands. The best tap points also have different positions around the coil, using only portions of a turn in some instances. When you are satisfied with the tuning, dab a bit of antioxidant paste, such as NoAlox, in each of the tap sockets, the set screws and clip grooves of the coil and hat clips, and the threads of the base stub.

STAYS

Now you're ready to enjoy the performance of your creation. But before you go driving down the highway, you will need to install the monofilament stays. Without these, the lightweight antenna will bend way over at speeds above 30-35 mph. I use another ground clip with a small wire loop soldered to it as an attachment point, as shown in the main illustration. This position works best and keeps the antenna upright quite nicely. At speeds over 55 or so, the upper portion of the whip with the hat starts to bend back noticeably, but performance doesn't seem to be affected.

I attach the stays to points on opposite sides of the car, near the front. In my case, I have a plastic deflector over the sunroof that provides ideal attachment points. With this scheme, the stays form a triangle and the antenna actually becomes more stable as the vehicle speed increases. I use 30 pound test monofilament, which is complete overkill. I have reached up through the open sunroof at highway speeds and tugged on the stays to see how much tension develops on them. I would estimate that it is 2-3 pounds at most on each one.

Good luck and happy building! If you build this project and have good luck with it, I'd love to hear from you.

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MATERIALS LIST
(McMaster-Carr has a terrific online hardware store at http://www.mcmaster.com)

1 - Hamstick antenna, new or used, bottom section only, or similar fiberglass antenna with 3/8-24 male threaded fitting at bottom and whip socket at top.

1 - 1/8” diameter, non-tapered, stainless steel whip, available as a replacement whip for the K-40 CB antenna.

60 feet of 14 gauge (0.064”) bare copper wire (1 lb roll McMaster-Carr #8873K51)

22 feet of 0.041” diameter stainless steel spring wire (1/4 lb roll McMaster-Carr #9495K84)

9 feet of 0.020” diameter stainless steel spring wire (1/4 lb roll McMaster-Carr #9495K64)

materials to solder stainless steel wire: Kester #66 acid flux silver solder (96% tin, 4% silver), (1 lb roll McMaster-Carr #7791A22) and LA-CO flux paste #22404, (4oz jar McMaster-Carr #7696A2)

3 - 0.323” X 0.23” X 12.5” nylon serrated grommet strips, Catamount #GSNY-192-9 (pkg of 25 McMaster-Carr #85085K8)

1 - 7” long section of 3”, schedule 40 PVC pipe

1 - 12” section of clean, bright copper shield braid from RG-8 or RG-213 coaxial cable
or
1 - 24” section of braid from RG-58 coaxial cable

10-12 5-way, silver-plated binding posts with female banana sockets, depending on how many taps you want to have

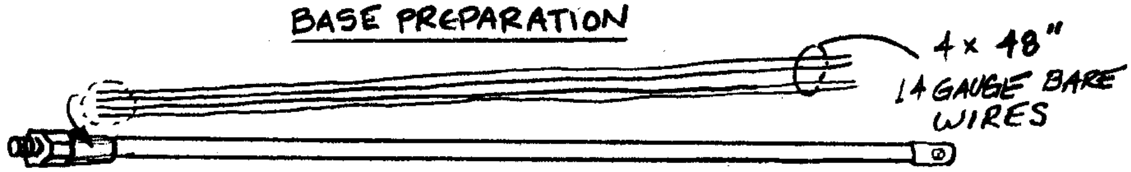
2 - Male banana plugs, silver plated, if possible

2 - Copper ground lug clips with set screw clamp, Ilsco model GSLU-35, 6-14 gauge

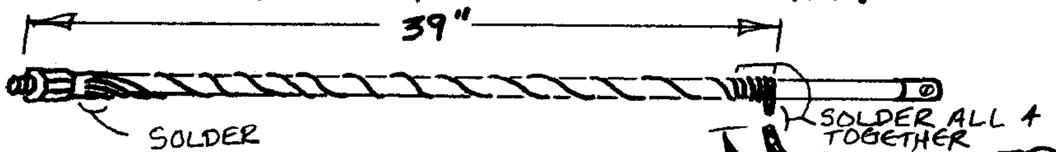
1 - 5” long piece of 3/16” diameter copper hobby tubing. Brass will work, although copper has much better conductivity

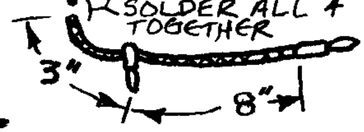
2 - 8-12’ long pieces of 20 or 30 pound test monofilament fishing line

BASE PREPARATION



STRIP SHEATH & WINDINGS OFF HAMSTICK BOTTOM.
FILE BARE SPOT ON BRASS BASE & SOLDER ALL 4 WIRES DIRECTLY TO BASE. WRAP THEM IN A GENTLE SPIRAL UP THE SHAFT & TERMINATE WITH A TIGHT WRAP ABOUT 39" ABOVE BASE. FORM A SHORT TAIL.

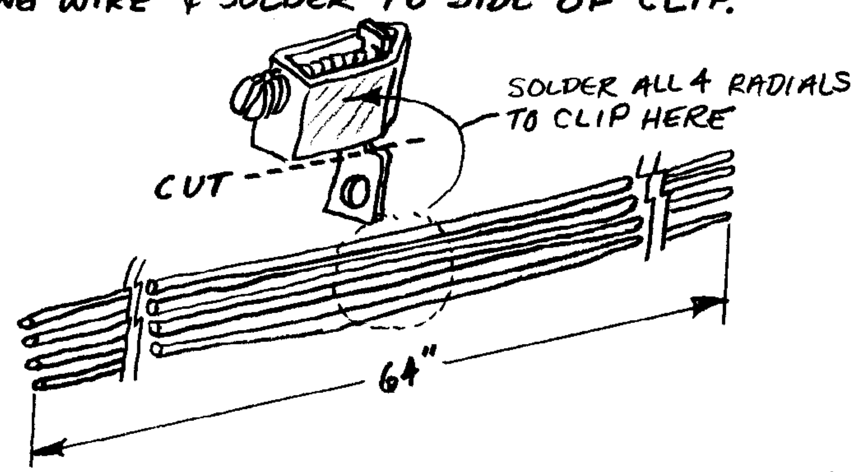




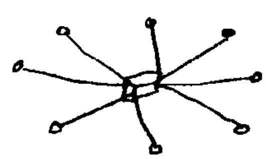
MAKE JUMPER WITH BRAID FROM RG-213/RG-8 OR 2x RG-58. SOLDER TO TAIL ON SHAFT & ADD MALE BANANA PLUGS AS SHOWN. COVER ENTIRE SHAFT WITH UNIFORM WRAP OF SCOTCH SUPER-88 UV RESISTANT TAPE.

CAPACITY HAT PREPARATION

CUT BOLT TANG OFF GROUNDING LUG CLIP & CLEAN COPPER BODY. CUT 4 64" PIECES OF 0.041" STAINLESS SPRING WIRE & SOLDER TO SIDE OF CLIP.

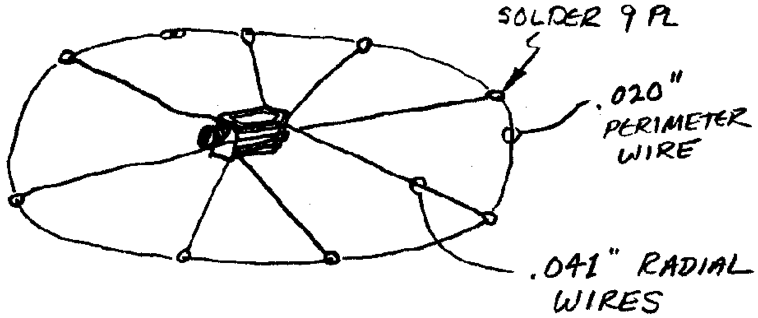


FAN OUT RADIAL ENDS & FORM LOOP IN EACH END



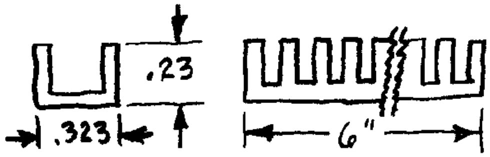
CAPACITY HAT CONT'D

SOLDER .020" STAINLESS SPRING WIRE PERIMETER WIRE IN LOOP ENDS OF RADIALS



COIL PREPARATION

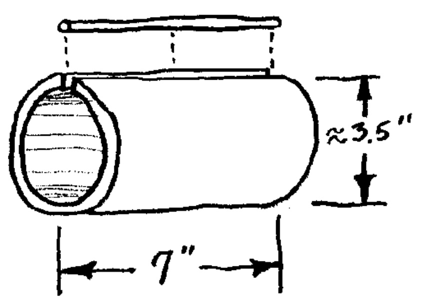
CUT 3 NYLON GROMMET STRIPS IN HALF TO 6" LONG



SERRATIONS ARE SPACED APPROX 7.5 OPENINGS PER INCH
MFD BY CATAMOUNT
PN GSNY-192-9

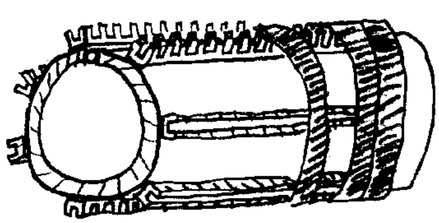
AVAILABLE FROM MCMASTER-CARR, PKG OF 25, # 85085K8

SAW A KERF IN A 7" LONG PIECE OF 3" SCH 40 PVC PIPE AND WEDGE A SECTION OF 14 GAUGE WIRE IN THE KERF



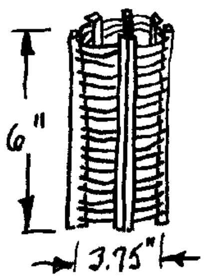
THIS PIPE WILL BECOME THE COIL FORM. PULLING THE WIRE OUT OF THE SLOT ALLOWS THE FORM TO SHRINK IN DIAMETER, RELEASING THE COIL WHEN IT IS FINISHED.

TAPE THE 6" LONG COIL GUIDES (GROMMET STRIPS) IN 2 PLACES ON THE FORM, EQUALLY SPACED

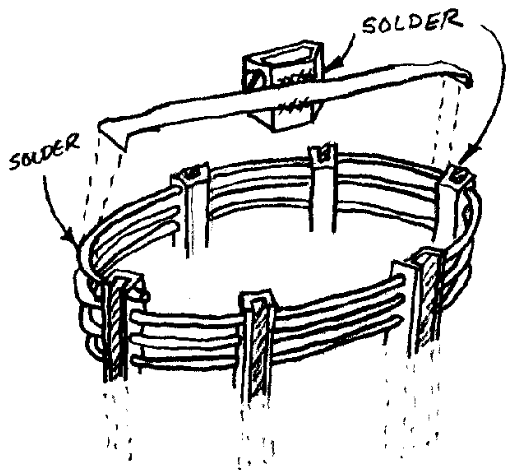


WIND 14 GAUGE COPPER COIL INTO THE FORM, UP TO THE TAPE, AND SECURE BY FILLING GROMMET STRIP CHANNELS WITH HOT MELT GLUE OVER THE TURNS. REMOVE TAPE & FINISH COIL.

COIL CONT'D

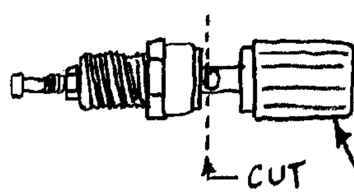


AFTER GLUING THE FINAL TURNS, REMOVE THE WIRE FROM THE KERF IN THE FORM AND SLIDE IT OUT FROM THE COIL. TRIM OFF EXCESS COIL GUIDE, LEAVING 40 TURNS

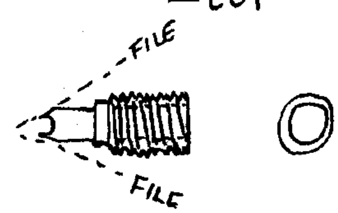


CUT A 1/8" OR 3/16" DIAMETER PIECE OF COPPER HOBBY TUBING TO A LENGTH SLIGHTY LONGER THAN COIL DIAMETER. FLATTEN THE ENDS & FORM LIPS TO FIT OVER TOP TURN OF COIL. SOLDER ANOTHER COPPER GROUND LUG CLIP TO BAR & SOLDER BAR TO TOP TURN OF COIL.

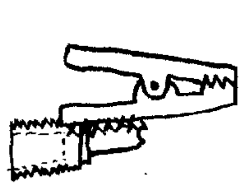
TAP PREPARATION



CUT SHANK OF 5-WAY BINDING POST THROUGH HOLE & THREAD PLASTIC HEAD OFF OF JACK PORTION, LEAVING FEMALE SOCKET WITH GROOVED END.

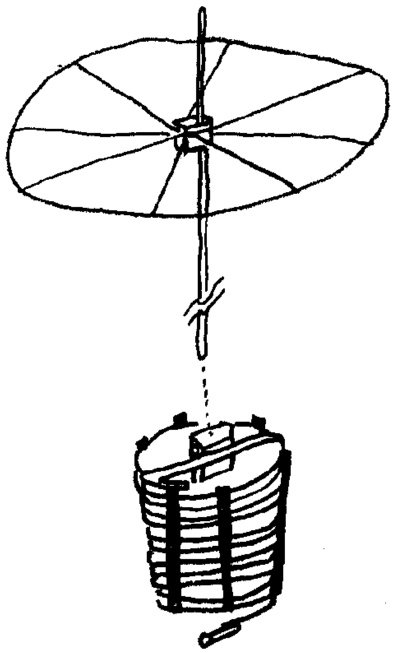


FILE EDGES OFF OF SHANK TO FORM POINT WITH GROOVE. THIS END WILL GET SOLDERED TO COIL TURNS.



MAKE A PROBE BY SOLDERING ONE JACK TO A SMALL ALLIGATOR CLIP.

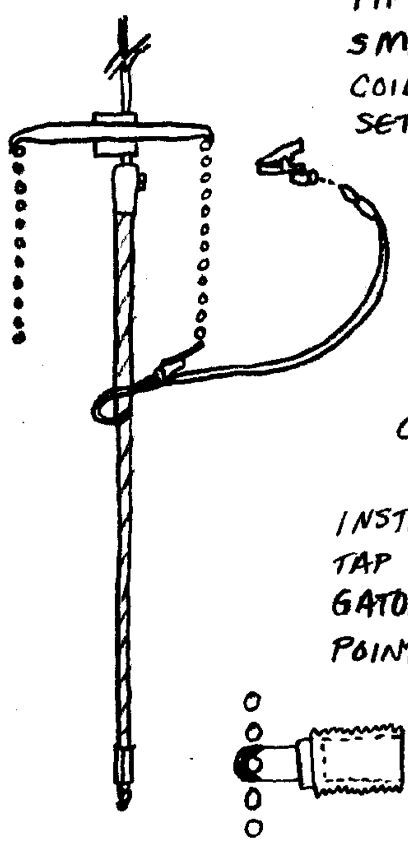
ASSEMBLY & TAP DETERMINATION



SLIP HAT OVER WHIP & TIGHTEN SET SCREW TO SECURE. FOLLOW THE DIMENSIONS ON MAIN DRAWING FOR POSITIONING.

SLIDE WHIP ABOUT 1.5" PAST CLIP IN TOP OF COIL & SECURE COIL. WHIP SHOULD EXTEND 1.5" BELOW BOTTOM OF CLIP.

SOLDER A JACK ON THE END OF THE BOTTOM TURN.



INSERT BOTTOM END OF WHIP INTO TIP OF SHAFT ASSEMBLY. SLIP A SMALL SCREWDRIVER BETWEEN COIL TURNS AND TIGHTEN THE SHAFT SET SCREWS.

PLUG THE BOTTOM JUMPER PLUG INTO THE BOTTOM COIL TURN JACK. PLUG THE UPPER JUMPER PLUG INTO THE PROBE AND CLIP THE ALLIGATOR PLUG TO INDIVIDUAL COIL TURNS TO TEST FOR RESONANCE.

INSTALL ANTENNA ON VEHICLE & FIND TAP POINTS FOR BEST MATCH USING ALLIGATOR PROBE. SOLDER JACKS ONTO TAP POINTS FOR FINAL CONSTRUCTION.

SOLDER GROOVE END OF JACK TO COIL TURN, TAKING CARE NOT TO SHORT TURNS.