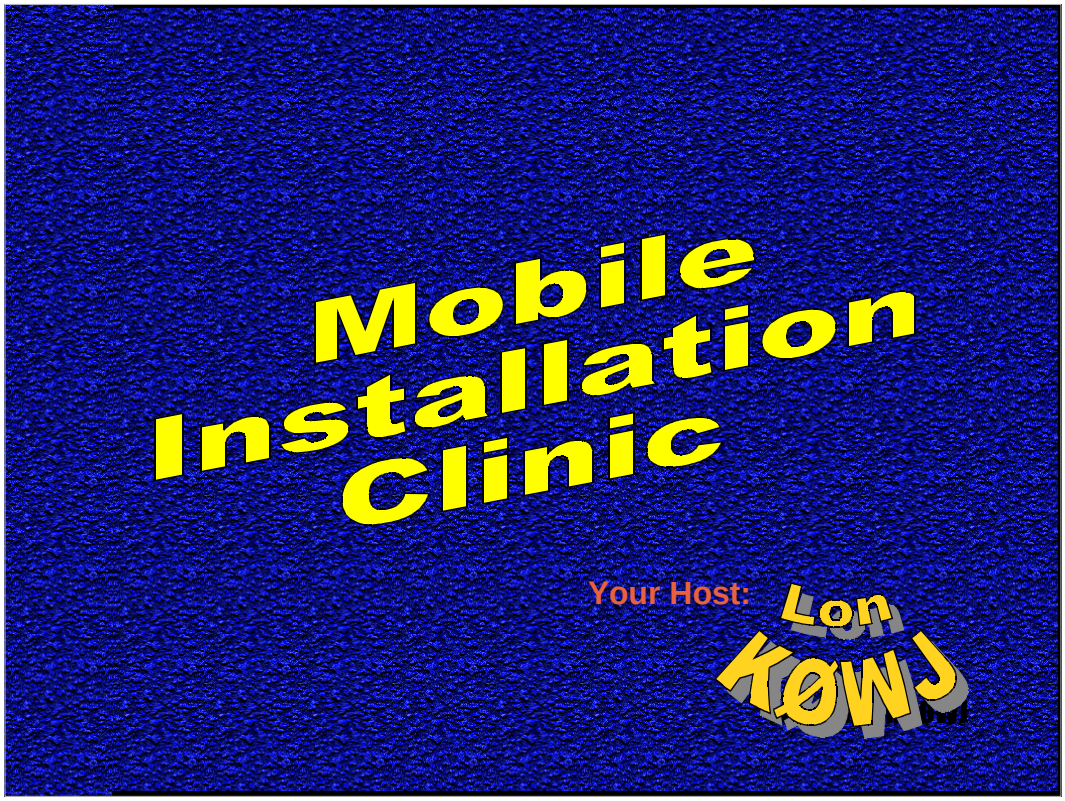
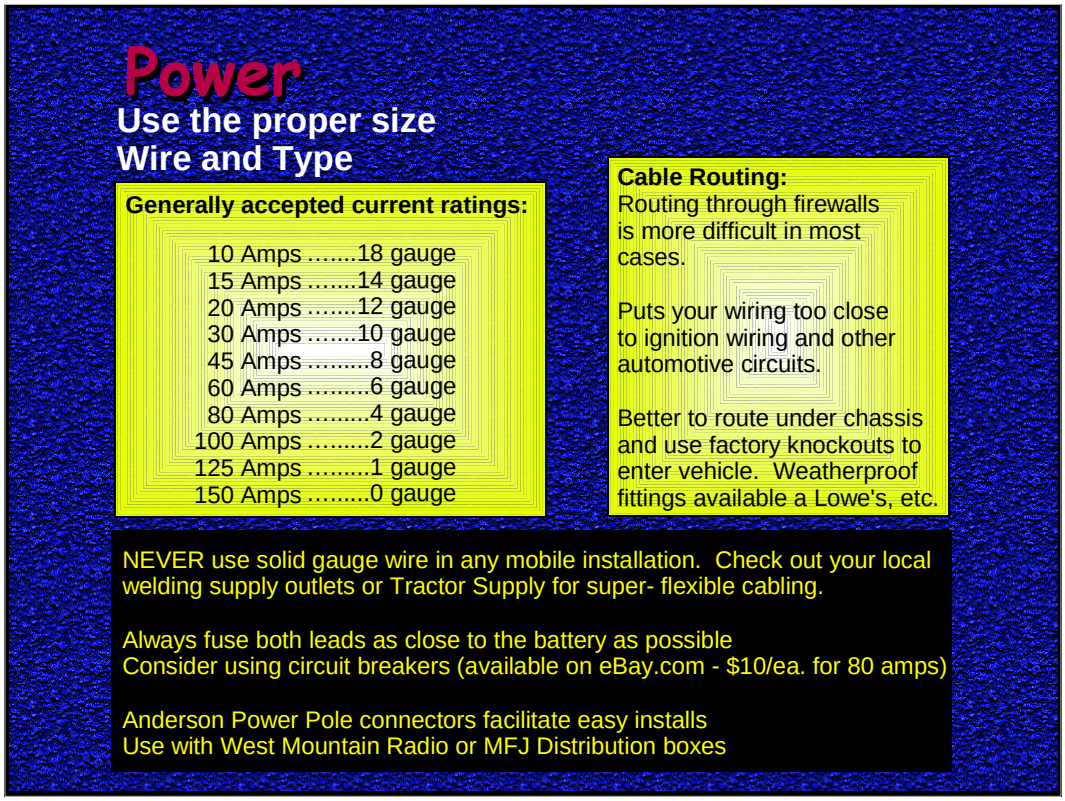

Mobile
Installation
Clinic
Your Host:
Lon
KØWJ

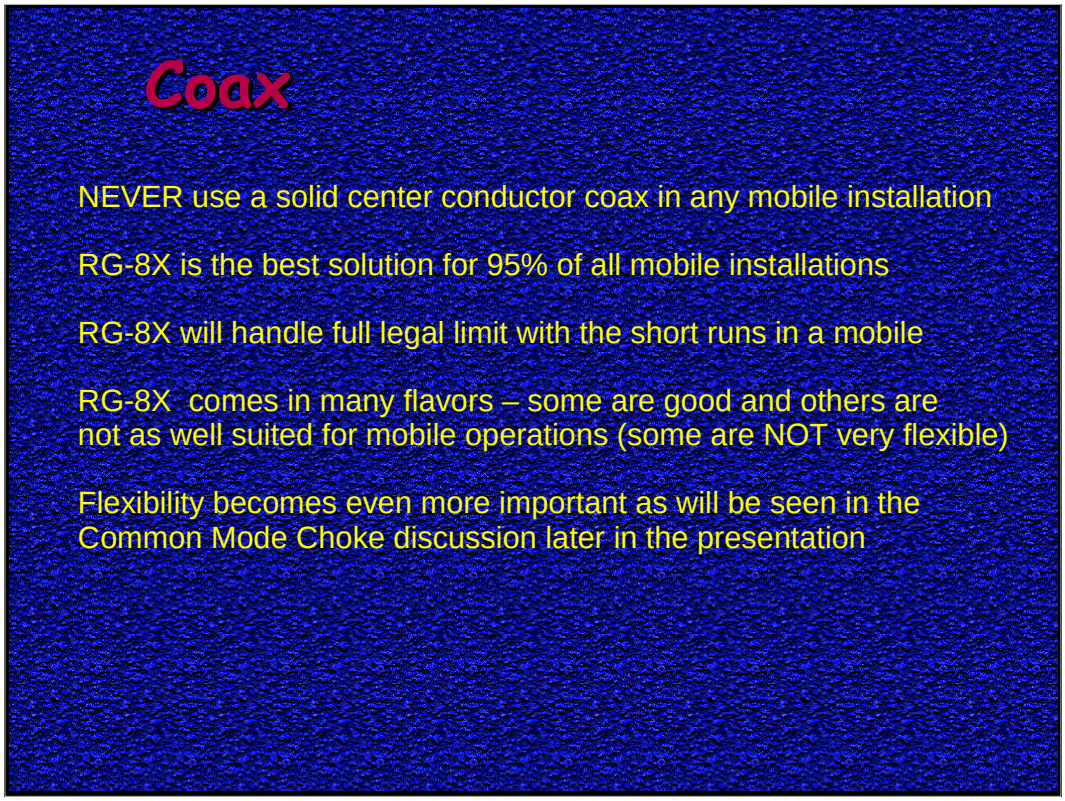
Adequately sized power cable will keep your installation safe, sometimes eliminate or reduce noise and provide trouble-free mobiling for years. Don't scrimp here...it will cost you less initially if you do it right rather than constantly fighting an ongoing nagging problem.

Large coax cables like RG-8/U, 9913 or LMR240 and LMR 400 are simply overkill for a mobile installation. In addition they are usually more difficult to run and fish through the small areas of your vehicle. Also, the smaller size of RG-8X and RG-58 provide everything you need in a mobile installation. Use RG-8X if you plan on using an amplifier.

Comments on the other topics will be with those topics.

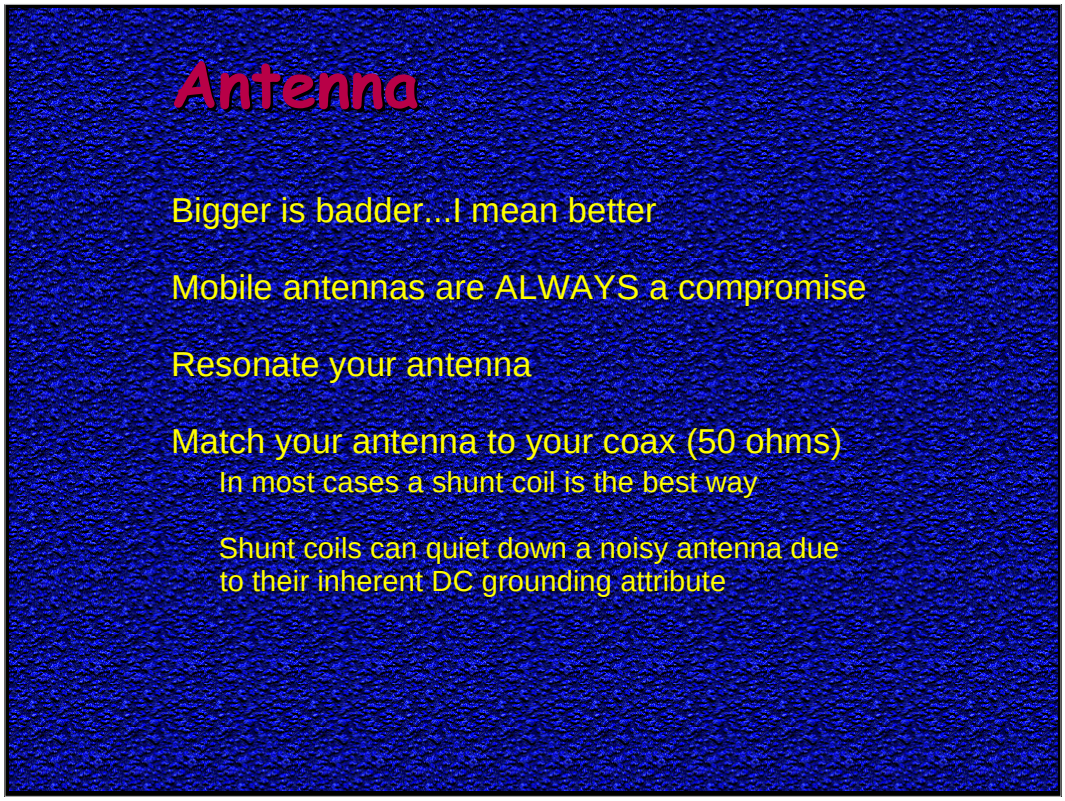


If your HF rig specifies an input current of 20 amperes, then use #10 or even larger. Give yourself some leeway in case you add another radio or accessory. I don't like doing things over, so I have installed #Ø mainly because I had some that I bought in Dayton years ago for a very low price. Copper used to be cheap. At any rate always go overboard with the sizing and be sure to fuse both leads as close to the battery as possible. Some people like to install a second battery at their radio or amplifier location. This is fine – just be sure to isolate it so you have enough juice left to start your vehicle after a prolonged period of operation. KC4YBO has done this in a very nice installation and has also added a digital meter called a "Watts Up" from http://www.rc-cars-planes.com/ that shows the state of the additional battery.



Solid conductors will fatigue quickly and the result will be an open circuit if you're lucky. If you're not so lucky, you'll experience intermittent connectivity which will sometimes be difficult to diagnose. Things like erratic SWR or your transceiver power varying between high and low power can be misdiagnosed as a transceiver malfunction when, in fact, your coax continuity is the problem.

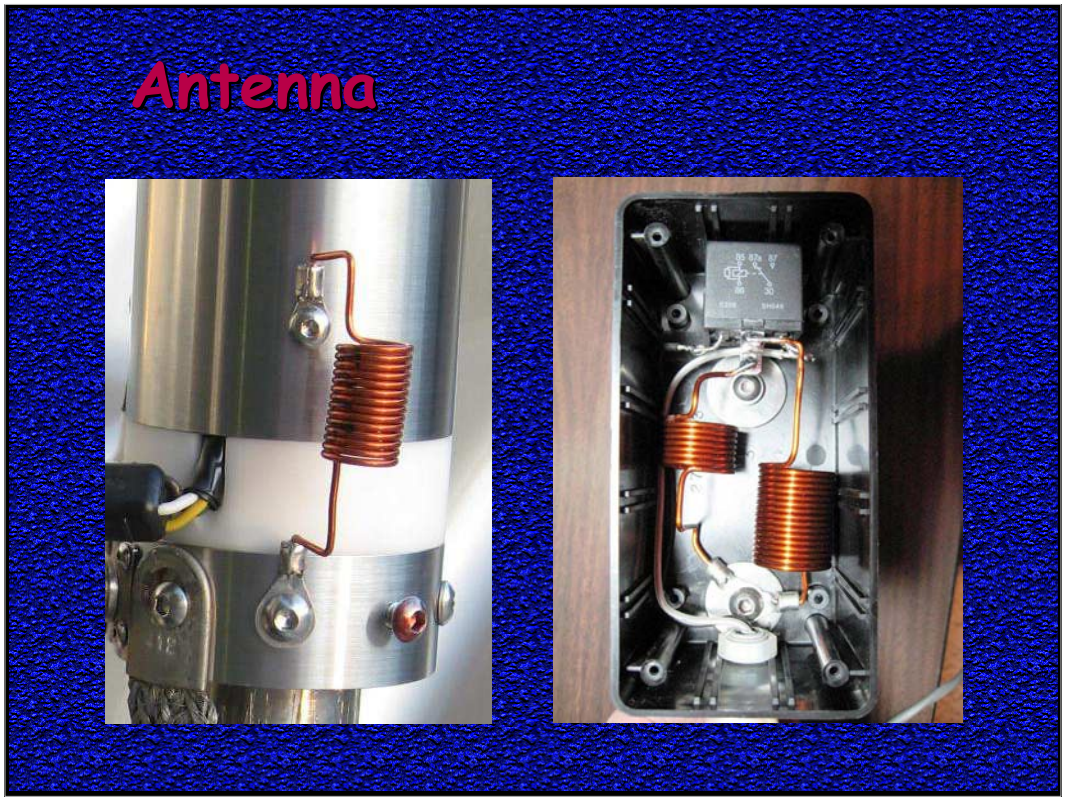
Don't think you can adequately tie-wrap your solid conductor coax to eliminate this fatigue – you can't. The ever-present vibration in all vehicles will take its toll.



Get the antenna that meets your needs. If you only routinely work a couple of bands, there are many fine single band antennas to choose from. Mounted correctly, they will radiate RF quite well. Remember, even the best antenna money can buy will be no better than a dummy load if installed incorrectly.

Also remember, most of the radiated RF happens below the main coil in a center loaded antenna, so make your mast is as long and fat as possible to maximize efficiency.

If your new installation has a low SWR without a shunt matching coil, it was not installed correctly or you need a better antenna. For instance, that dummy load in your shack needs no matching coil to work, but it won't radiate RF worth a lick.



Shunt coils not only provide a good match between your antenna and coax, they can eliminate static buildup on your antenna, because they provide a DC path to ground for the static and many types of other noise as well.

If you find you don't need a shunt coil, you need a new antenna, installation help or both.

Generally speaking, a shunt coil should be nearly the same dimensions in diameter and length. Try a ¾" to 1" diameter and 7 to 9 turns of solid, number 12 or 14 gauge enameled wire. Try building three of them (a 7 turn, an 8 turn and a 9 turn) and see which one works best for you. The value will usually be between .5µH and 1.5µH (1.5µH for 160 Meters).

Antenna

Mount it in the best location possible – higher is better

In the case of center loaded antennas, make sure
the coil is above the roof line and clear of metal objects

Make sure shunt coils are away from body sheet metal

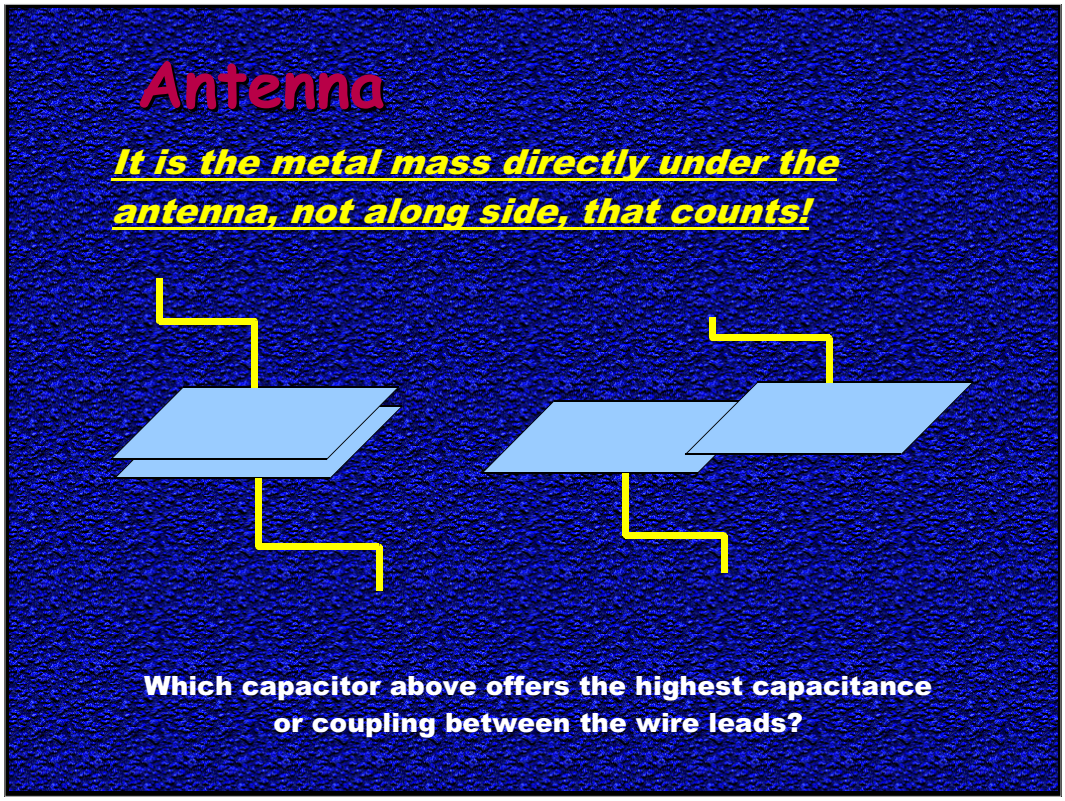
Antenna

" A vehicle is not a ground plane. Rather it acts like a capacitor between it, and the surface under the vehicle which is the true ground plane. Since the surface in question is a poor conductor of RF, ground losses occur."
- ***Alan Applegate, KØBG***

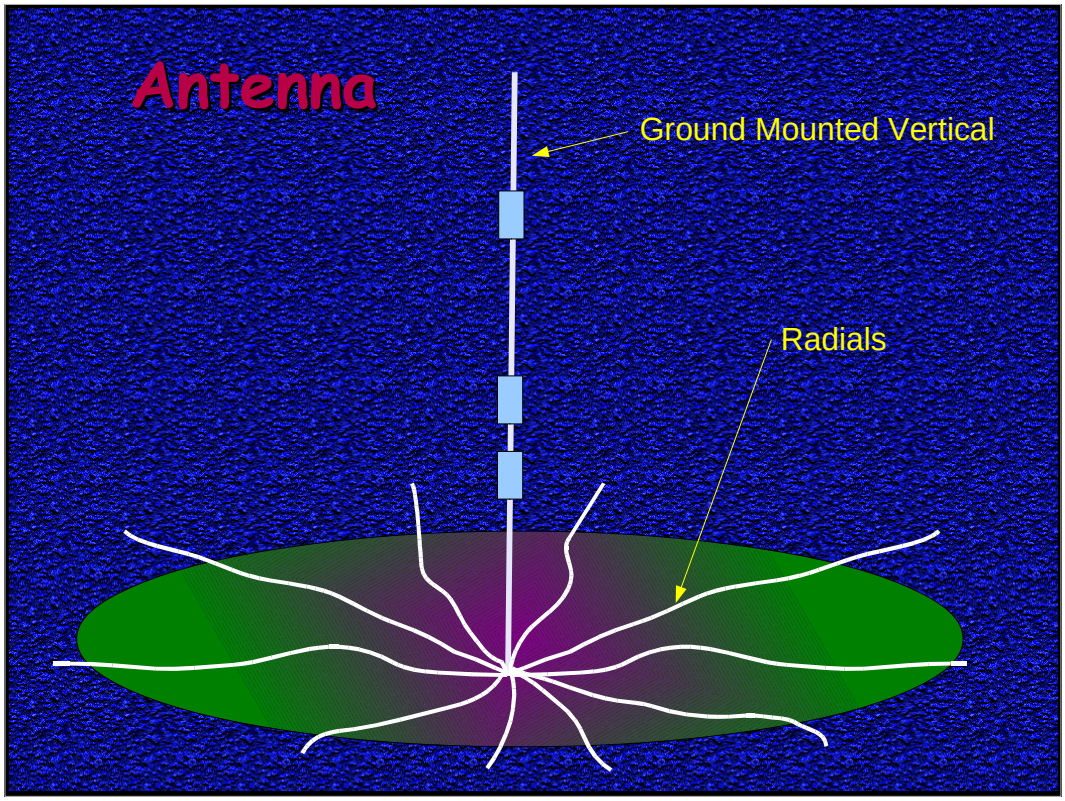
Any antenna should be attached in such a way to maximize the capacitive coupling to ground. The key phrase here is: ***it is the metal mass directly under the antenna, not along side, that counts!***

Antenna

A mobile vertical antenna is ½ of a dipole. The missing half is normally made up using radials – not possible in a mobile HF installation, so we rely on the mass of the vehicle and the capacitive coupling of the vehicle to the surface under it.



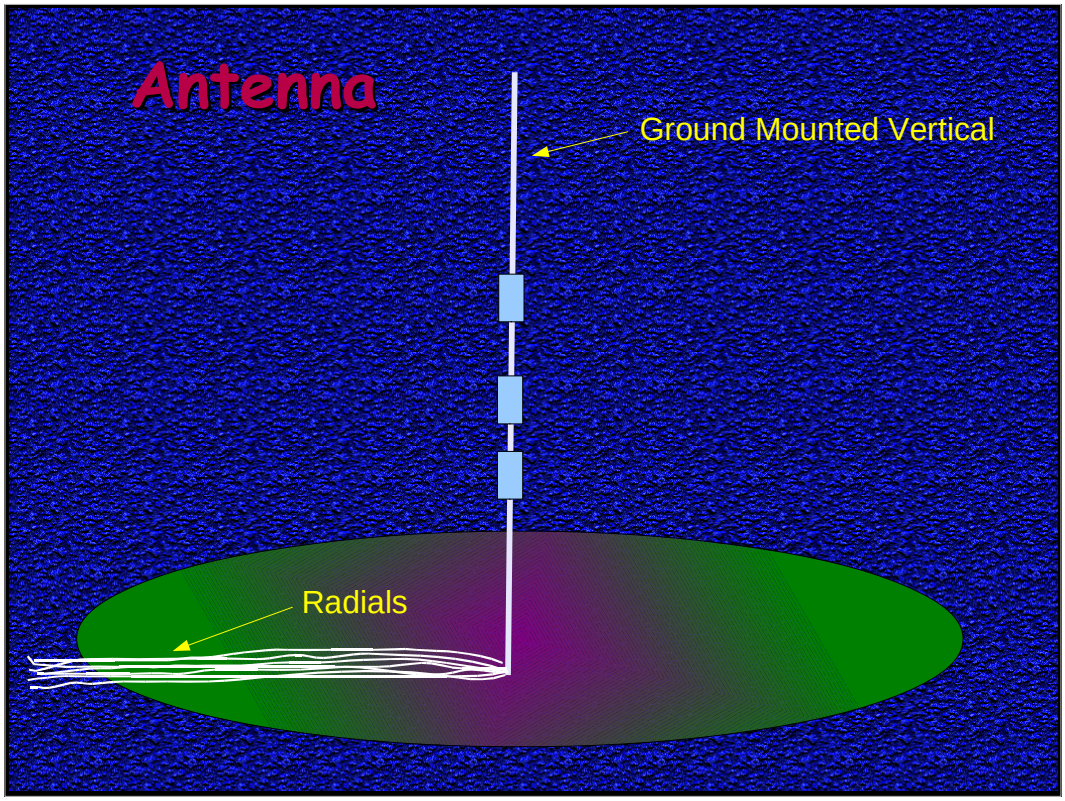
Of course, the left graphic shows two fully meshed plates which yields the highest capacitance or, in other words, the BEST coupling between the two wires on the ends.



Radials need to be arranged on or under the ground in order to couple the shield side of the feed line to ground. A perfect ground plane will result in a feed point impedance of 36 ohms.

Depending on the ground the vertical is mounted on, you may need few or many radials to approach this figure. Contrary to popular opinion, radials on the ground or under the ground DO NOT need to be cut for the desired frequency or frequencies of operation. They merely need to be of adequate number and length in an attempt to reach the 36 ohm feed point impedance.

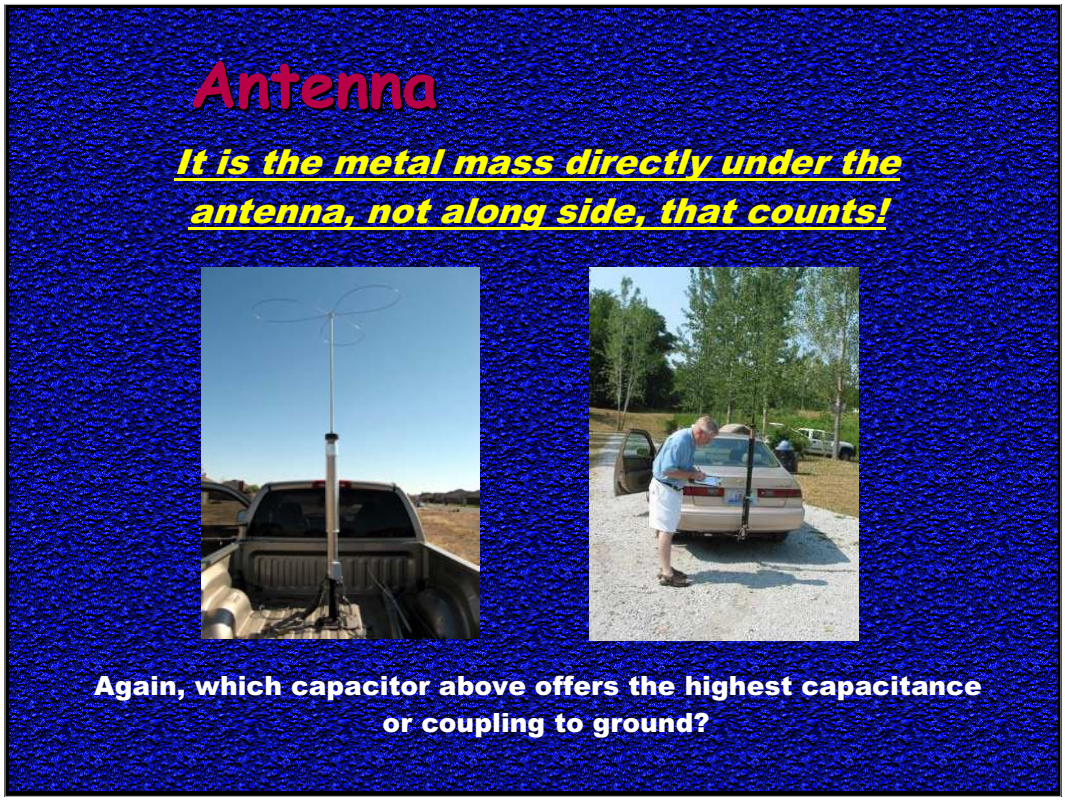
Elevated radials are a completely different story. Each radial needs to be cut for the specific frequencies of operation. The good news is that you can get by with as few as two radials per band.



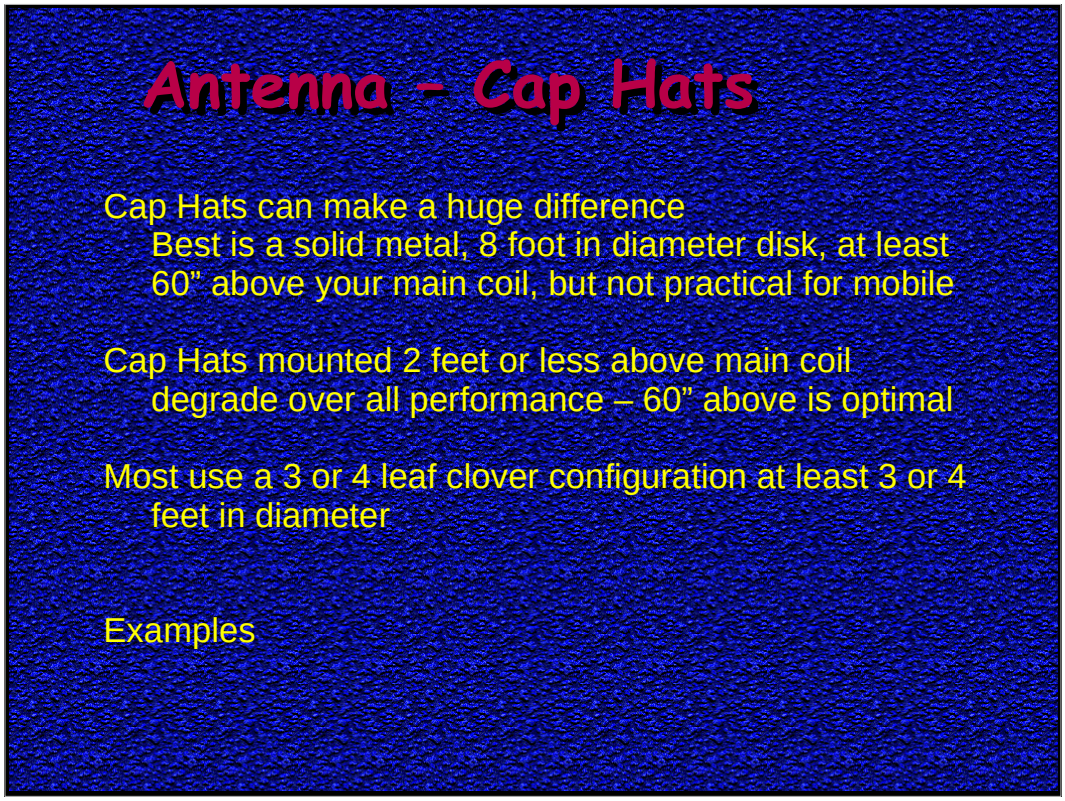
Have you ever seen a vertical antenna installed like this one?

Why not?

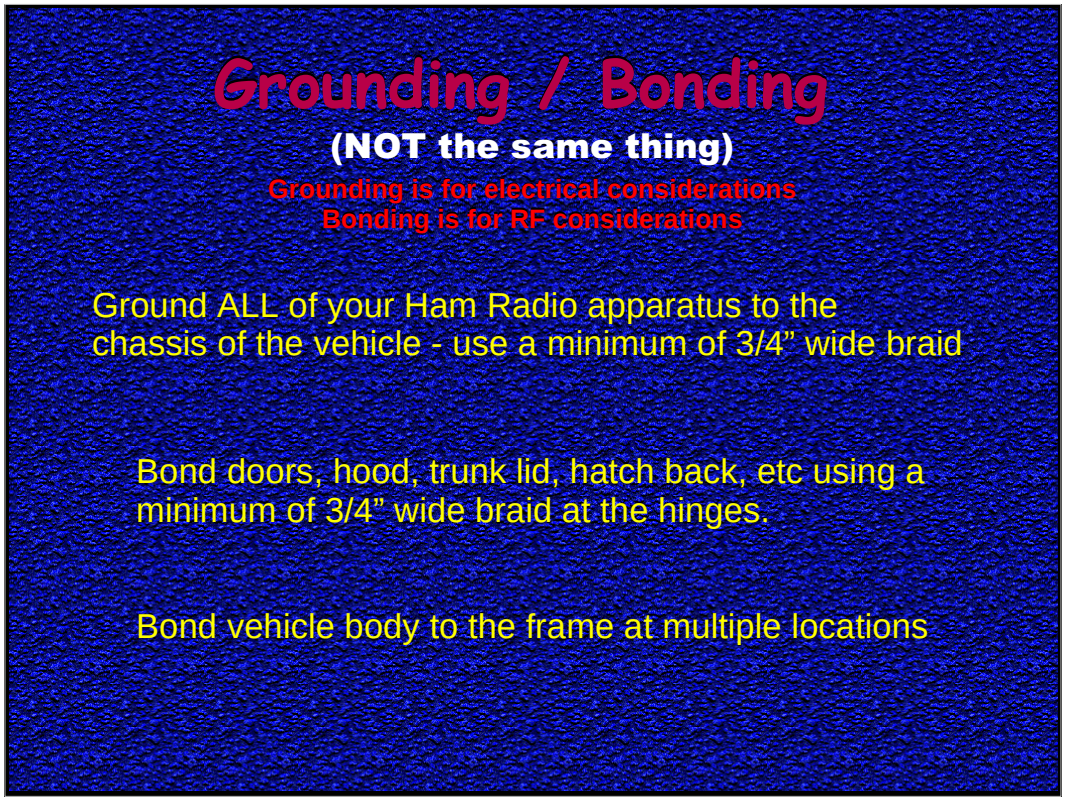
Of course, the answer is that the radials provide virtually no coupling to ground for the shield side of the feed line and, as a result, it won't work worth a hoot.



Again, with the vehicle representing the capacitor, it's not hard to see that the picture on the left provides the most capacitance. Maximizing this capacitance is the goal here. The picture on the right does not allow the antenna to take advantage of virtually any of the vehicle's capacitance to ground, hence you will have high ground losses and an inefficient installation when compared to the vehicle on the left. To be sure, the installation on the right will still be able to make contacts, but at an “S” Meter reading of one to three S-Units lower than the vehicle on the left. With noisy band conditions, one or two S-Units may mean the difference between completing a QSO or not.

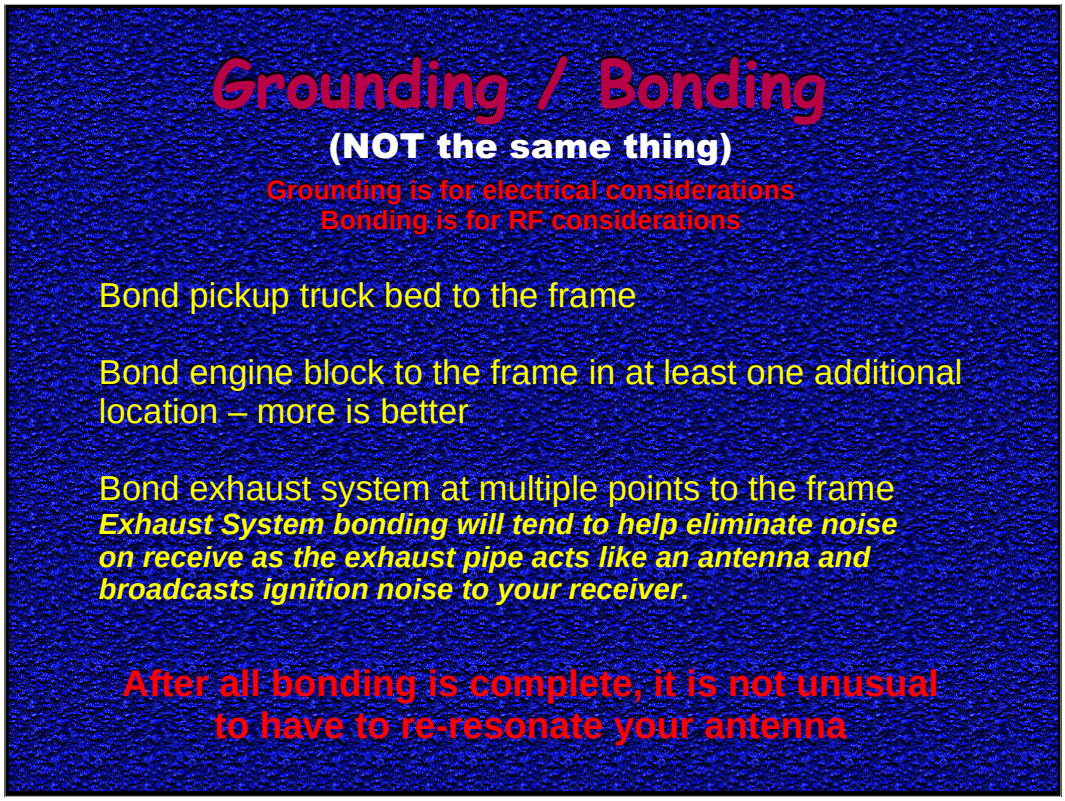


For Century Club Shootout purposes, we have established a maximum diameter of 8 feet for Cap Hats and generally, bigger is better. I'm sure there is a point of diminishing returns, but my testing hasn't gone that far...YET. Another rule we have is that it must be road-worthy. That's a difficult proposition at a diameter of 8 feet. I'm sure someone will design one some day. My 43 inch in diameter, three-leaf-clover Cap Hat is the best I've found so far. I used it all the way from Kansas to the first low bridge in Massachusetts this year, 2011, (I took it off before the bridge did) and had no problems with it. It seems to have a fairly low wind resistance, although a low tolerance for trees and bridges. By the way, if you see a ¾ inch Corona ball rolling down I-90, it's mine.



What you should have in the back of your mind is this: If your antenna is mounted on the trunk lid of your car or the bed of your pickup truck or the roof of your SUV, etc.,etc., without doing ANY bonding, the capacitive coupling of your vehicle to ground is much less than it could be. Just because the individual pieces of your vehicle are bolted together does NOT mean they will act as one big capacitor. Bonding does that. Use ¾" to 1" braid or larger. The bolts that hold your vehicle together cannot provide low impedance connections for RF at HF frequencies, but wide braid can and does.

Bond EVERY separate part and body panel.



Bonding in the engine compartment has some additional benefits – NOISE ABATEMENT. In addition, the exhaust pipe of most vehicles acts like an antenna on the higher frequencies (20 through 10 Meters) and will serve to broadcast all of your vehicle's noises to your mobile antenna which is connected to your radio and its speaker. This can be very annoying.

Bond the exhaust pipe in at least two places to your vehicle's frame to help eliminate or greatly reduce noise.

Grounding / Bonding

(NOT the same thing)

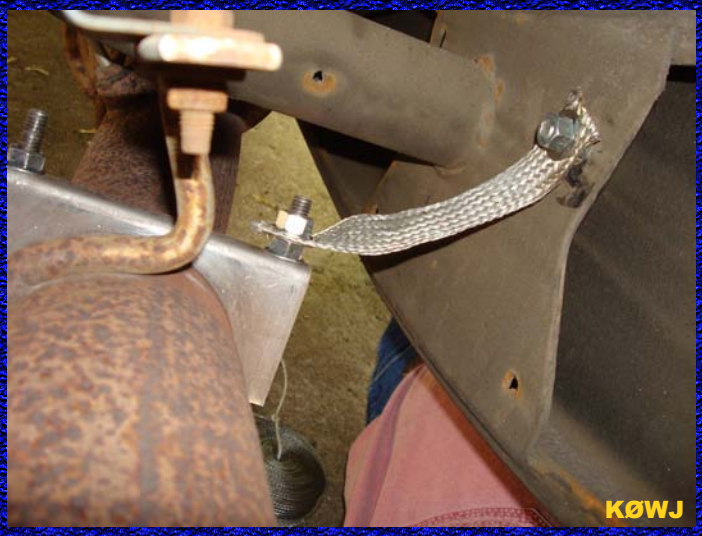
Grounding is for electrical considerations
Bonding is for RF considerations

This shows how Fred, WB1I, bonded his engine hood. There is another braid on the other side as well.

Grounding / Bonding

(NOT the same thing)

Grounding is for electrical considerations
Bonding is for RF considerations



Exhaust Pipe Bonding

This is one of my exhaust bonds. These virtually eliminated my 20 Meter noise and made QSOs while rolling down the highway a pleasure.

Grounding / Bonding

From an RF standpoint, the resulting ground plane is wholly inadequate, and as a result the ground plane losses are high.

It should be clearly evident then, that minimizing ground losses are important, both from an efficiency standpoint, and in curbing both ingress and egress RFI. **Bonding** is one way to do this.

Improper antenna mounting is the number one cause of unwanted Common Mode Current!

Common Mode Choking

What are Common Mode Currents?

"Almost without exception, all RFI ingress problems are caused by one of two scenarios. First, is common mode current flowing on the outside of the coaxial feed line. The second cause is inadequately choked motor control leads. Both scenarios are exacerbated by poor antenna mounting and/or location resulting in excessive ground plane losses."
- ***Alan Applegate, KØBG***

For some real insight into Common Mode Currents, what they are and what the causes are, please visit:
http://www.w8ji.com/verticals_and_baluns.htm

Common Mode Choking

Question: How many independent conductors at RF frequencies do we have in a coaxial cable?

A. One
B. Two
C. Three
D. Four

Common Mode Choking

Question: How many independent conductors at RF frequencies do we have in a coaxial cable?

A. One
B. Two
C. Three
D. Four

Answer: C. Three
- The Center Conductor
- The Inner Surface of the Shield
- The Outer Surface of the Shield

Common Mode Choking

Note: The RF current that flows on the outer surface of the shield is independent of the inner shield current.

This is so, because at RF frequencies, the current penetrates very little inside the conductors. This is called SKIN EFFECT.

Note also that the SWR only applies to the inner shield currents and center conductor. The SWR is independent of the outer shield currents.

Common Mode Choking

Note: The RF current that flows on the outer surface of the shield is independent of the inner shield current.

This is so, because at RF frequencies, the current penetrates very little inside the conductors. This is called SKIN EFFECT.

Note also that the SWR only applies to the inner shield currents and center conductor. The SWR is independent of the outer shield currents.

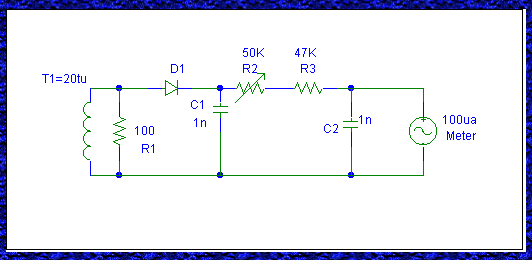
Question: What should be the maximum amount of current allowed on the outer surface of your coax feed line?

Of course, the answer to the question at the bottom is, “NONE.” Coax, when used as a feedline should have NO current flowing on the outer surface of the shield.

There *are* times when you DO want current flowing on the outer surface of coax as in an End-Fed Dipole for instance, but these applications are limited.

Current Probe

http://www.w8ji.com/building_a_current_meter.htm



T1 T157-2 Core wound w/20 turns
C1, C2 .001µf disc capacitor
D1 1N34
R1 100 Ω
R2 50k Ω Potentiometer
R3 47k Ω
Meter 100µA

Tom, W8JI explains:

T1 is a current transformer. I used a powdered iron T157-2 core. When the single turn primary (a whip or mast) has 1 ampere, the secondary will have .05 amperes (inverse of the turns ratio). R1 flattens the response and limits the voltage.

It turned out that 100 ohms gave the flattest response from 1.8 to 30 MHz, which is the frequency range I intend to use the meter on. With 100 ohms we have .05*100=5 volts RMS. The peak dc voltage is 1.414 times 5= ~7 volts. C1 is a filter capacitor for the RF pulses, R2 and R3 set the FS range. With 100uA meter the resistance is 10,000 ohms/volt. 7 volts requires 70K ohms, which will be approximately midway on R2.

Note the choice of a low current meter and >50k multiplier resistance. The low current and high voltage improves detector linearity.

Dissipation in R1 is .25 watts from .05 amperes (T1 current) times 5-Vrms (secondary voltage of 5v with .05a flowing through 100 ohms).

Current Probe – Feb. 1999

by:
Steve Sparks, N5SV
(now WK5S)

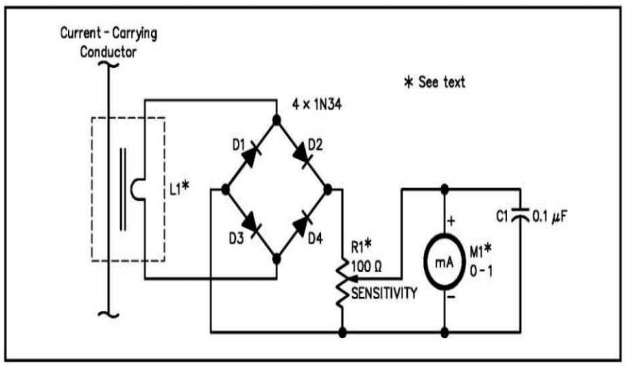


Figure 1—Schematic of the RF current probe. Unless otherwise specified, resistors are ¼ W, 5% tolerance carbon-composition or film units. Part numbers in parentheses are RadioShack. Equivalent parts can be substituted.

C1—0.1 µF disc ceramic (RS 272-135).
D1-D4, incl—1N34 germanium diode (RS 276-1123); do *not* use silicon diodes.
L1—Single turn of #14 wire through a snap-on ferrite choke (RS 273-105); see text.
M1—0-1 mA or greater sensitivity; (an RS 22-410 can be used without the series multiplying resistor supplied as it's a 0-1 mA movement meter.)
R1—Panel-mount pot, 100 to 500 Ω; 10-turn pot used here.
Misc: Enclosure, knob, hardware, adhesive.

QST

In the February, 1999 issue of QST, a good friend of mine wrote this article describing an easy to build and operate Current Probe. With it you can actually determine where the unwanted Common Mode currents are flowing by clamping the bead atop the meter case to the segment of coax in question. Remember, there should be NO current flowing on the outer surface of coax when used as a standard feedline.

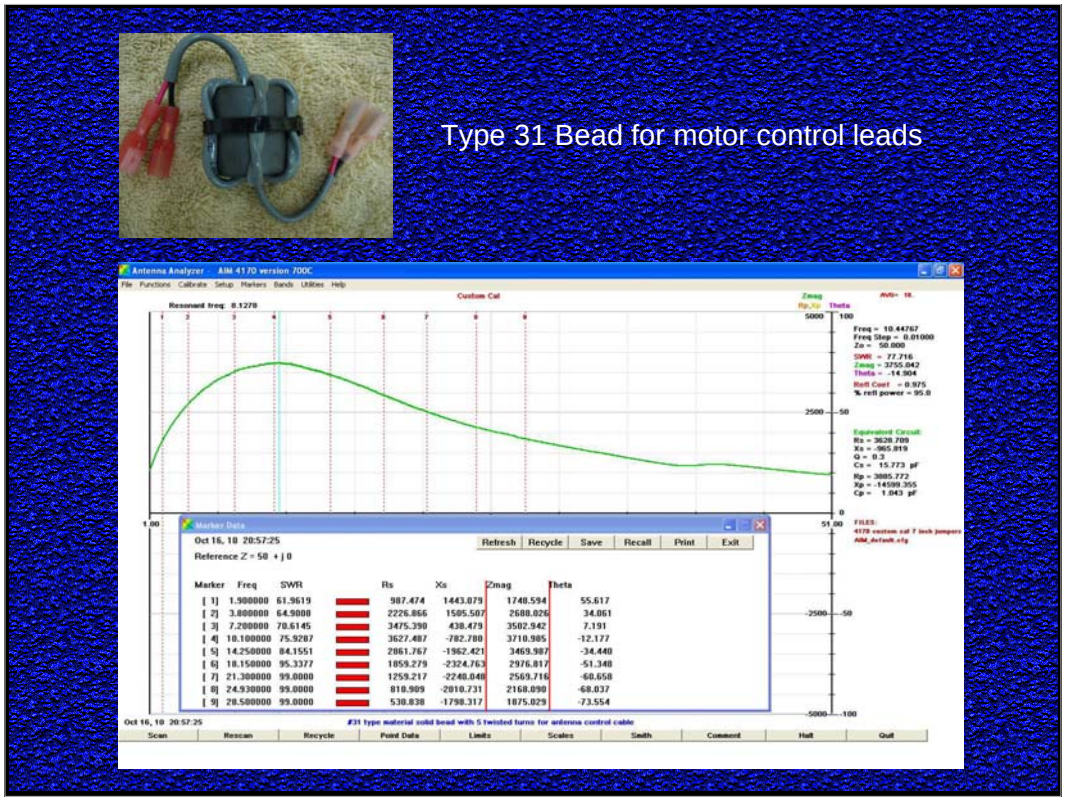
Some people have neither the inclination nor the time to build their own equipment and searching out all of the parts needed on the Internet or in local stores can be a challenge. If that is the case, you may simply wish to purchase a Current Probe.

MFJ makes these two. I cannot find any reviews, but if you can believe the MFJ documentation, these will do the job for you.

Common Mode Choking

The best way to control common mode currents is with a choke. You can use the same type of choke that you use for the motor control leads. That is, mix 31 split beads, and preferably the 3/4 ID units. They can be purchased from DX Engineering and others. These will allow 6 to 7 turns of RG58, and 5 to 6 turns of RG8X (as shown in photo). Note that the coax is not tightly wound around the choke. In this case, the diameter is about 3 inches. Any tighter, and the core could migrate and cause a short.

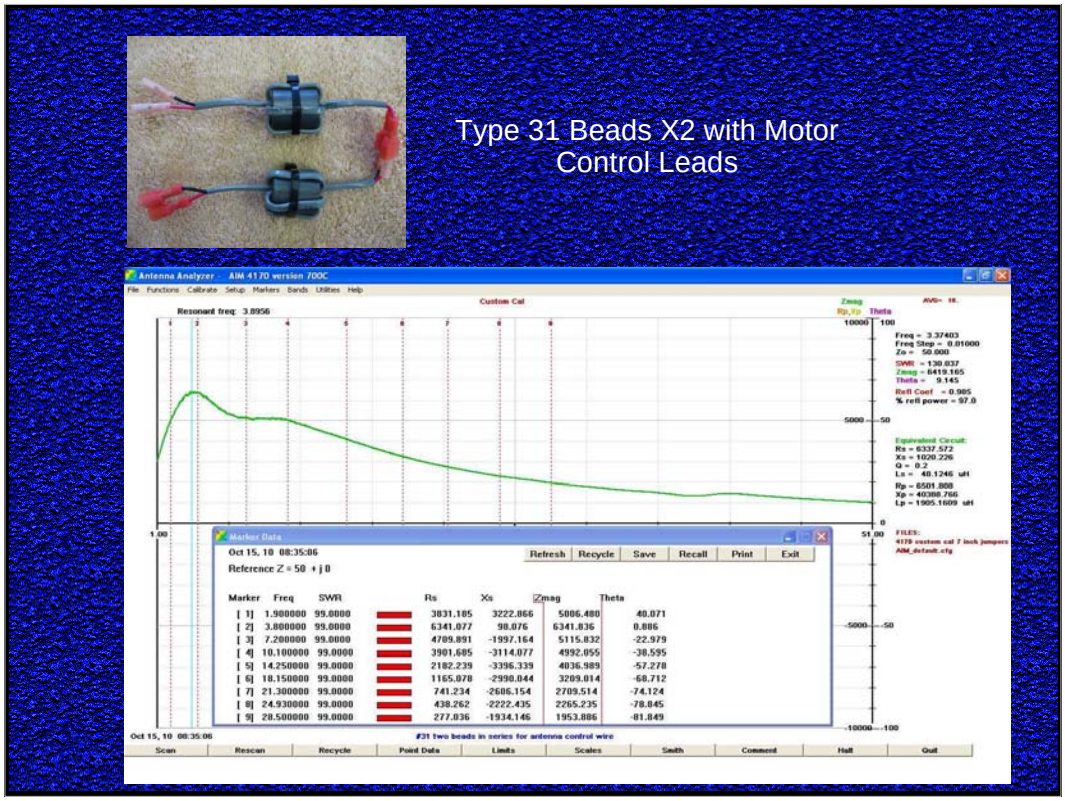
Now, let's look at some real world testing



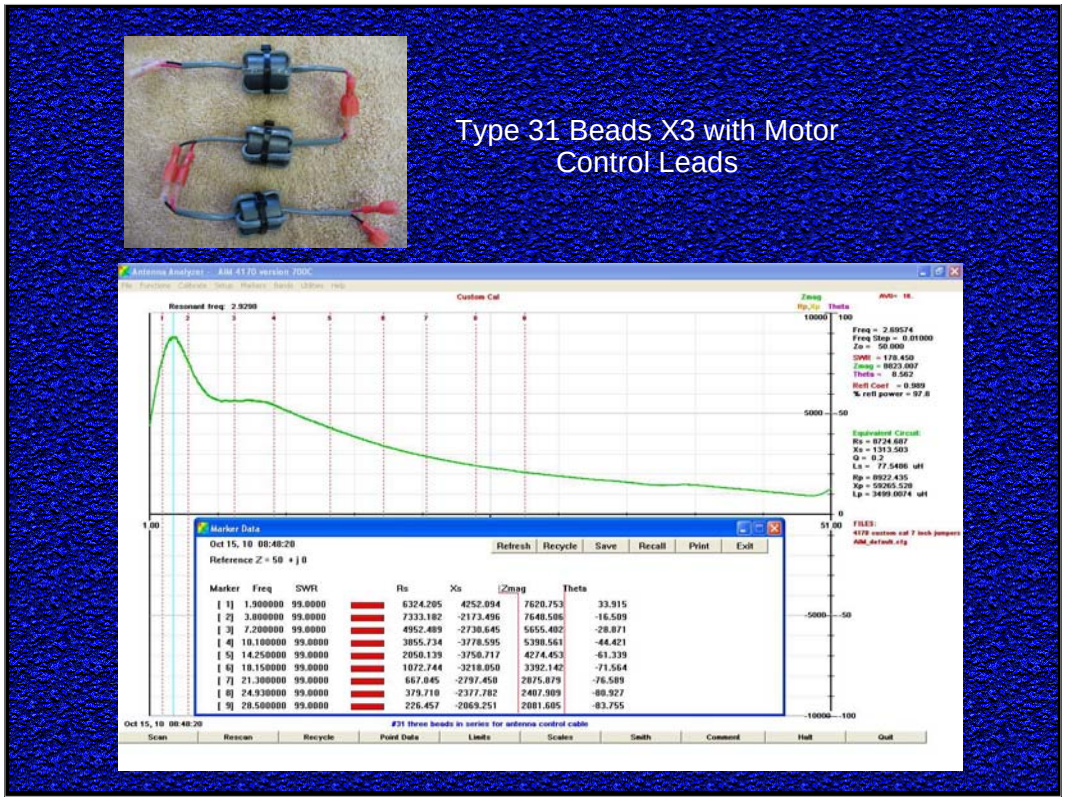
What these next few slides depict are tests that were run with an AIM 4170C from Array Solutions. It's like an MFJ Antenna Analyzer on steroids.

What is being measured is the amount of Impedance Magnitude (or Zmag) for a given scenario.

The above scenario shows a Mix 31 bead with 4 turns of a motor control pair of wires. The peak value indicated is 3,755 ohms at 10.44 MHz. If better performance is needed on 160 – 40 Meters, we can do better – next slide.

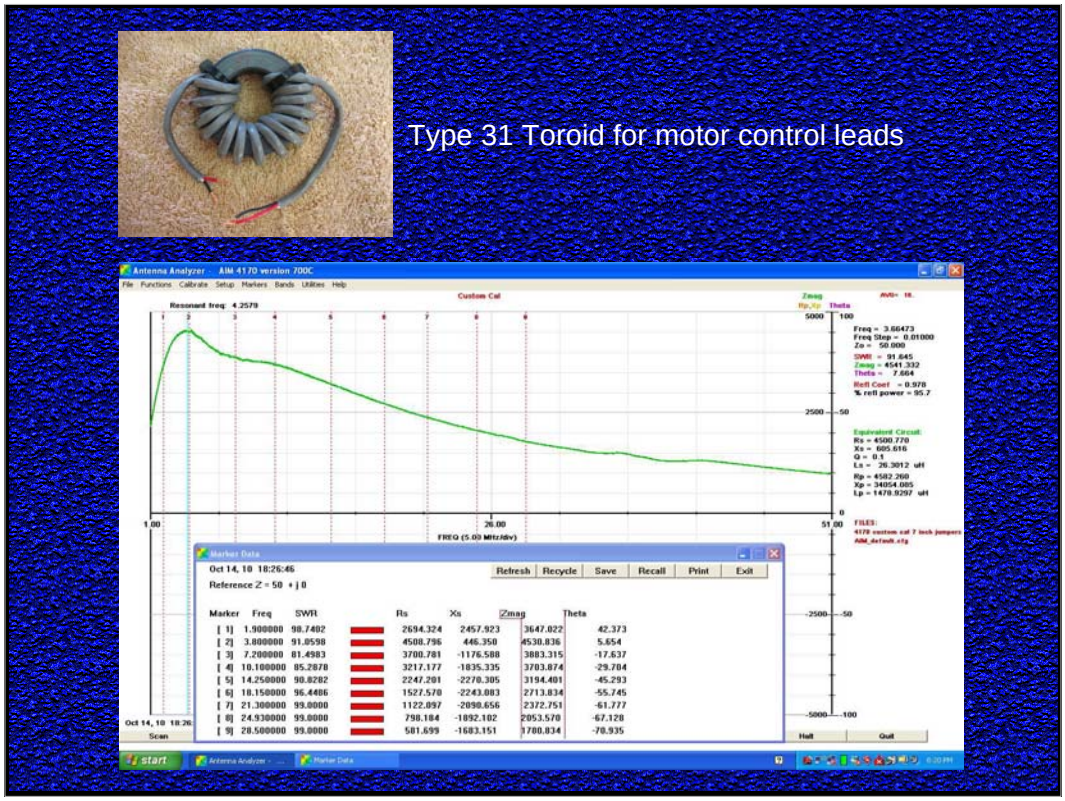


Here we see that 160 – 40 Meters is better taken care of. The peak value of 6,419 ohms occurs at 3.3 MHz, so we've improved our choking performance on 160 – 40 Meters. We can still do better – next slide.

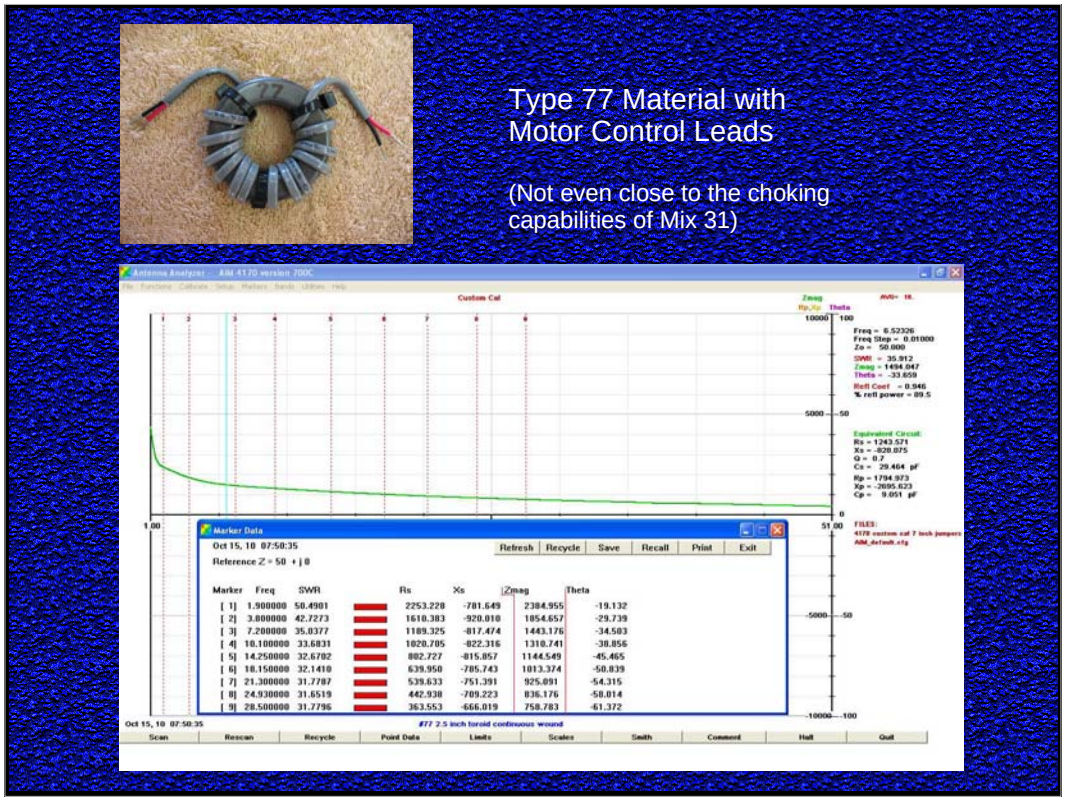


Here we see that no where from 160 – 40 Meters do we have less than 5,600 ohms of choking impedance.

You may be wondering about the values for 20 – 10 Meters and why we're not putting any emphasis on those bands. It is mainly due to the fact that those frequencies are not as plagued with the common mode currents that are more prevalent when operating in the 160 – 40 meter bands. As a general statement, common mode happens more and with more severity the shorter an antenna is as a percentage of the wavelength. In other words, a 102” whip is about a true quarter wavelength on 10 Meters, but only 7% of a quarter wavelength on 160 Meters.

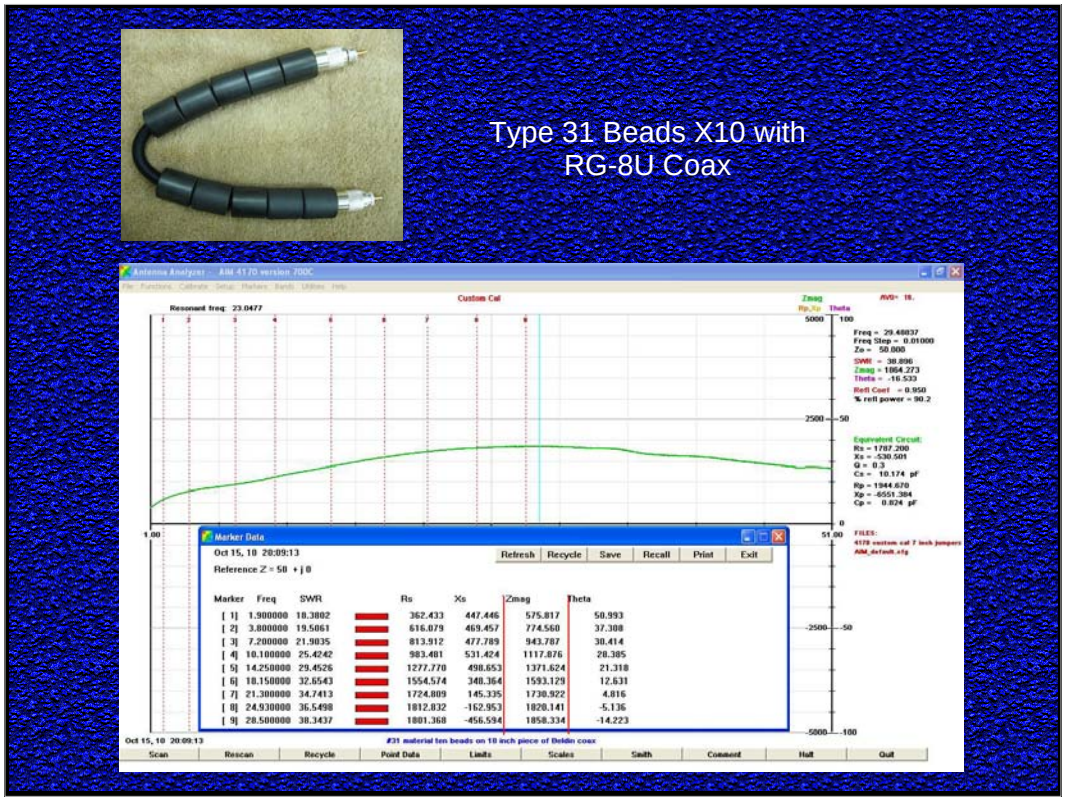


A Mix 31 Toroid can provide some good value too. Here we see that from 160 – 40 Meters there is no value less than 3,600 ohms. The value here is that a Mix 31 Toroid sells for about $7.00 while three Mix 31 Split beads go for about $5.00 each and it takes two of them to match (or a little bit better) the choking value of one toroid.

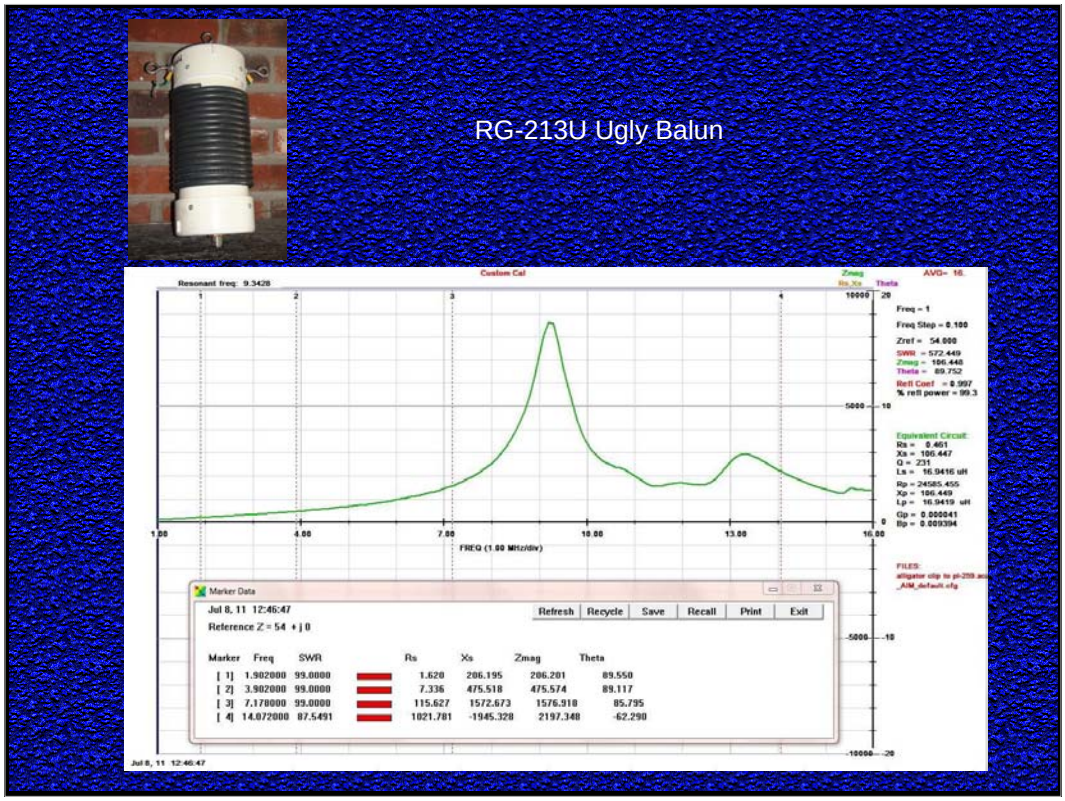


For those of you that grew up with Mix 77 – which used to be the standard before Mix 31, you can see that Mix 77 does not come very close to the values of Mix 31 toroids.

Still, if you have some of these laying around, try stacking a couple of them and that should provide you with a good choke.

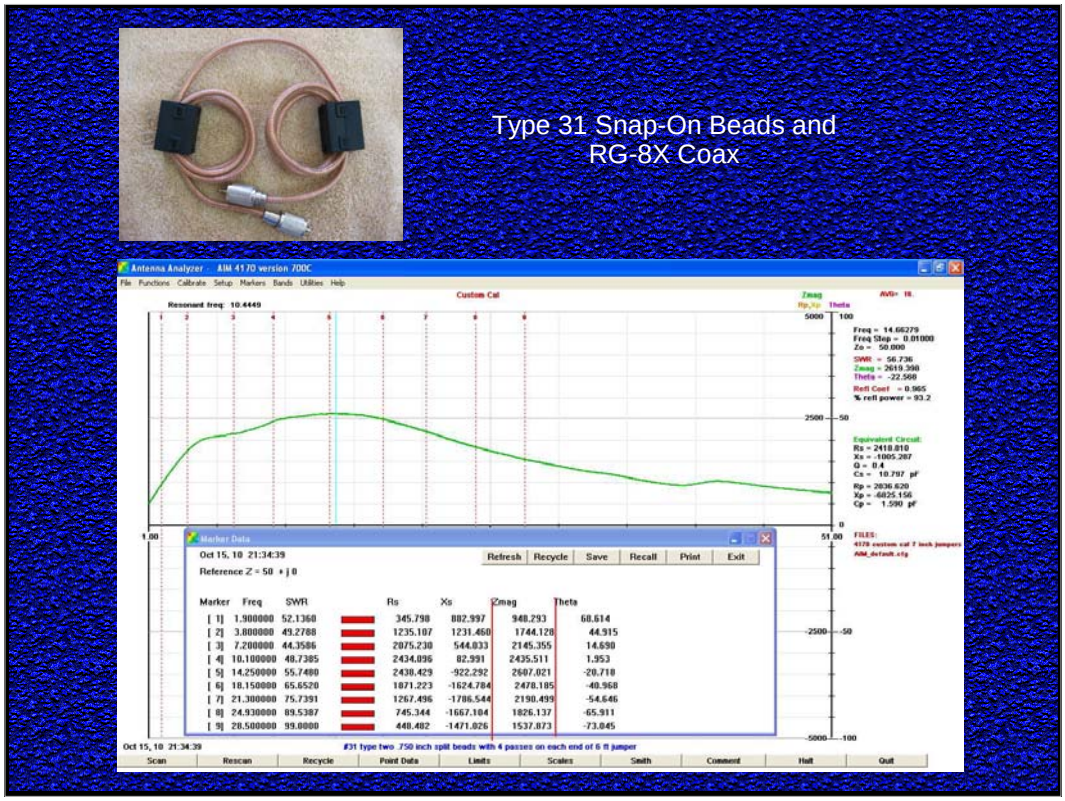


This is what I used to use in my mobile setup, but when I started to get active on 160 Meters, I again experienced Common Mode problems. No wonder – on 160 Meters, this provided only 575 ohms of choking. Palomar Engineers sells a kit of these ten beads for $35 (2 x BA-8 Kit) – not the best use of $35

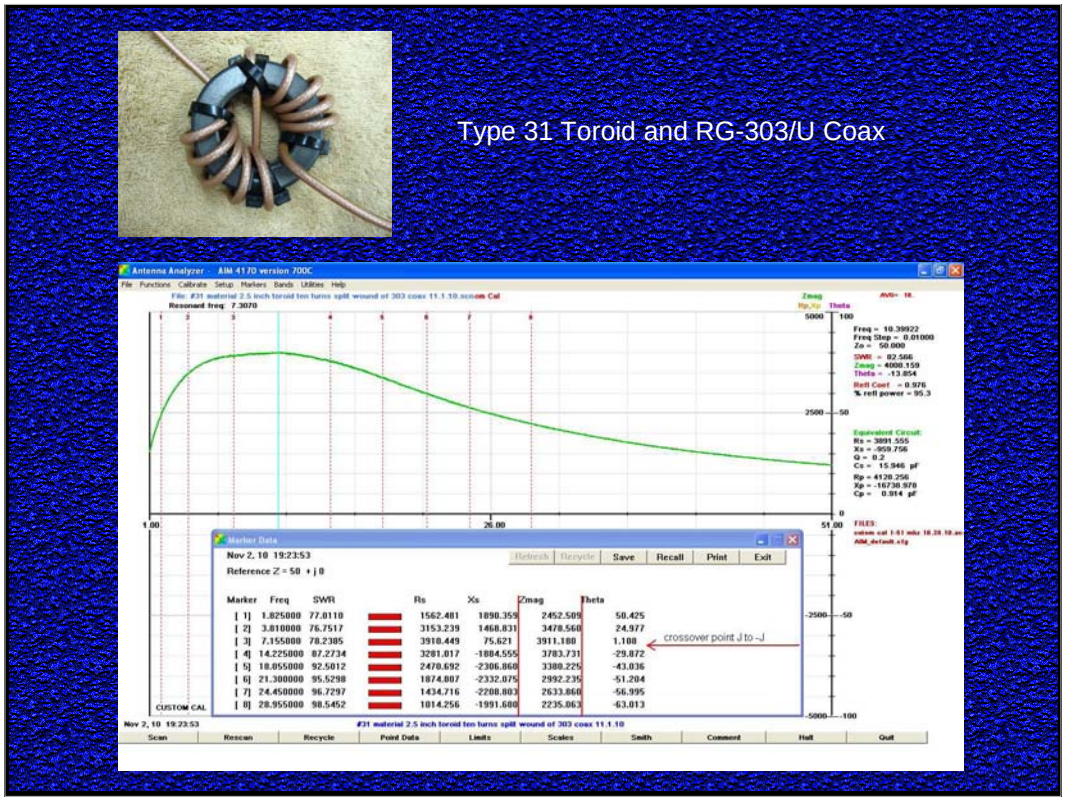


There are plenty of articles on the web and in QST over the years regarding the “Ugly Balun.” This is not a bad way to go if you restrict your home station to 30 Meters, but anywhere else, this is one wasted effort. I had this up on my inverted “V” for a couple of years, but never really saw any value. When I tested it, I found out why. But everything has value. The value this choke has is that I use it as a bad example in my presentations. HA!

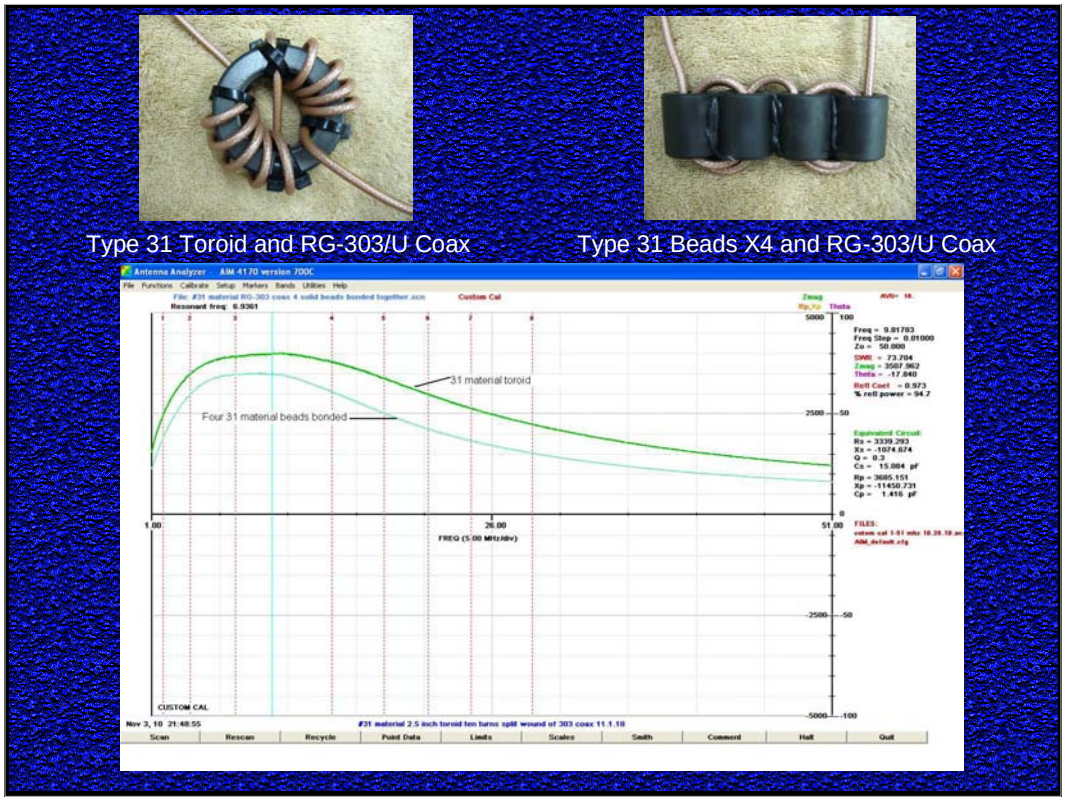
The Ugly Balun has no value in a mobile installation – I just thought I'd throw this test in while I had the AIM 4170C on the bench in its testing configuration.



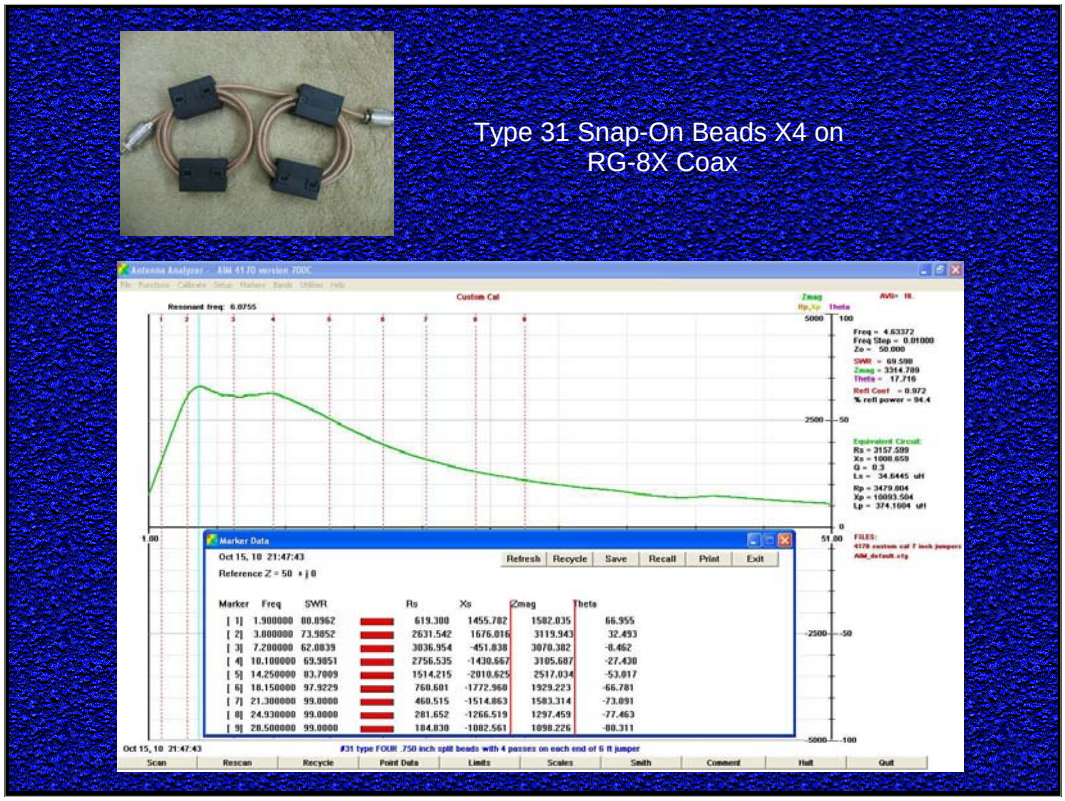
As a common mode choke on 40 Meters, this scenario yields about 2,100 ohms, but on 160 Meters, only 948 ohms. I need more.



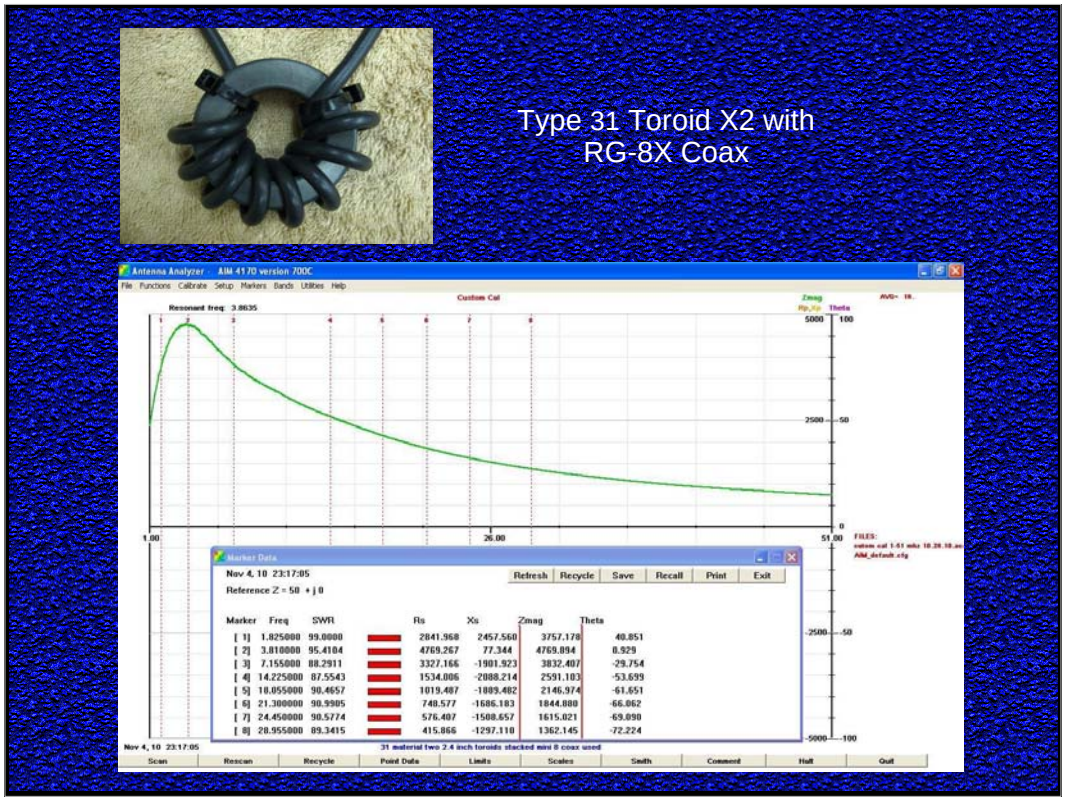
On 160 Meters, this choke provides 2,452 ohms of choking. Pretty good, but RG-303 coax is very difficult to work with and costs around $4.00 per foot. This stuff is not commonly found in my shack; how about yours?



Just as a comparison, the previous slide's RG-303, split-wound toroid is shown against a popular choke from DX Engineering. The toroid wins (and costs much less).



This choke provides 1,582 ohms on 160 Meters and even more on 80 and 40 Meters.



Here is my preferred choke for the mobile. It provides 3,757 ohms on 160 Meters, 4,769 ohms on 80 Meters and 3,832 on 40 Meters. This is a stack of two Mix 31 Toroids using RG-8X coax. Cost is $14 for the two toroids plus a couple feet of coax.

A Comparison

Blue Line – Type 31 Toroid X2 Stacked with RG-303/U Coax

Green Line – Type 31 Toroid X2 Stacked with RG-8X Coax

Here is a comparison between two identical Mix 31 Toroids X 2 (stacked) using RG-303 and RG-8X. Some difference, but sort of overkill in a mobile environment. The big advantage here for the RG-303 setup is in its ability to handle the full legal limit. I only run 500 watts in the mobile, so RG-8X is fine there. At home, however, 1,500 watts is too much for a 100 foot run of RG-8X, so I use the setup depicted on the next slide and run 9913 to the choke.

Just a word here about Toroid mounting. When I started using Toroids and split beads, I just let them lay on the bed of my truck. It only took a few weeks and the split beads began cracking and falling apart. I would advise you to wrap your beads and toroids in foam of some kind to cushion them from all the jarring and knocking around that mobile installations can inflict on them.

As you can see above, NI7J has mounted this choke in a NEMA electrical box and the choke actually sits on a bed of foam.

What Have We Learned?

Some Examples

The yellow numbers in the upper left corner of the next few slides indicates the finishing place and number of entrants a particular shootout. In other words, the photo on the left shows that out of 19 entrants, the red car finished 10th.

I don't know if there was any common mode choking going on with either of these two entrants, but I can tell you that the reason for the last place finish of the entrant on the right was the mounting position which was close to the ground and the main radiating element being right next to the rear of the truck, so ground losses were high along with a drastic reduction in efficiency due to the mast's proximity to the metal truck body. In addition, the mast diameter, coil diameter and wire gauge used in the coil are all too small.

Again, low mounting position, high ground loss and not much of the vehicle's mass is contributing to capacitively couple this antenna's ground plane to the surface below it.

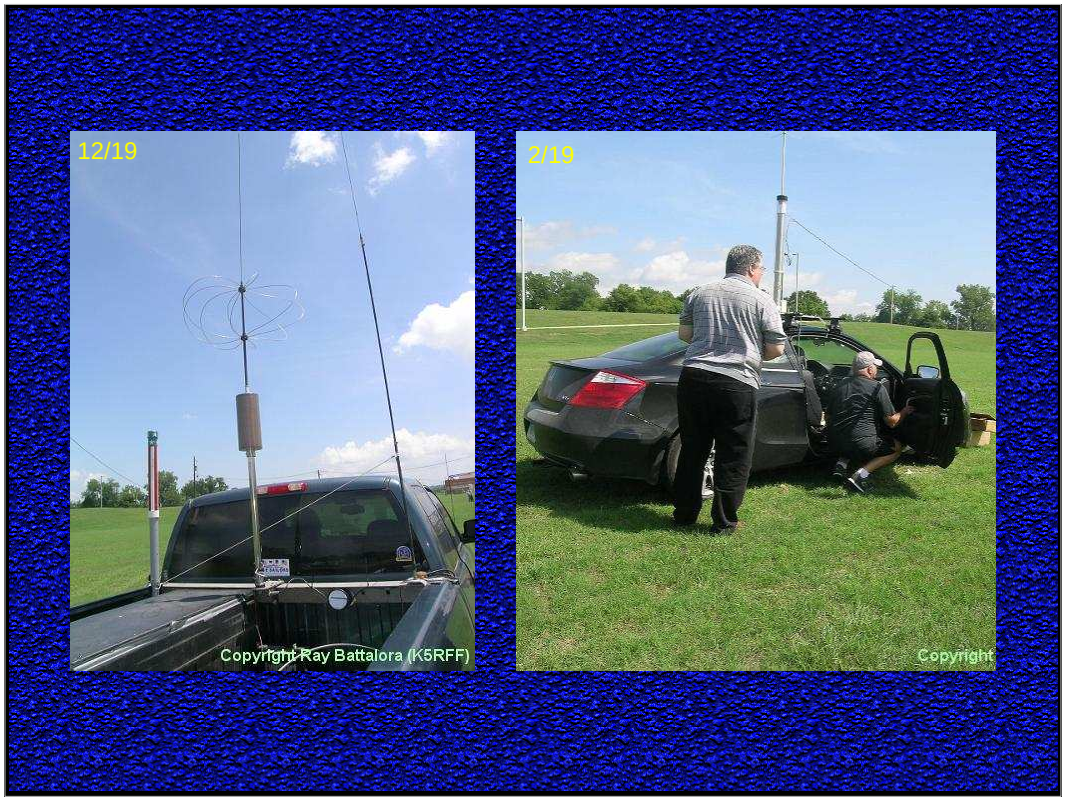
In addition, studies have shown that there exists an optimum wire size and coil diameter for center loaded, electrically short antennas. This is why Texas Bug Catchers usually fare well in shootouts and on the air in general. Also take a look at the QST article on page 39 of the July 2011 issue. It is a monoband mobile antenna optimized for 75 Meters. The diameter of that monobander is much larger than what you see in the photo above. It all equates to efficiency, and efficiency translates into more enjoyable QSOs .

Take a look at the QST article on page 39 of the July 2011 issue. It is a monoband mobile antenna optimized for 75 Meters. The diameter of this main coil is much larger than what you saw in the previous photo. It all equates to efficiency, and efficiency translates into more enjoyable QSOs .

Here on the left is a great home brewed Cap Hat, but it would be much more effective if moved to the top of the mast. Most whips are not capable of supporting a cap hat like this one and that is the reason most often given for mounting them too close to the main coil, but this serves to greatly degrade the performance of the antenna system. Masts are available from DX Engineering at:
http://www.dxengineering.com/Products.asp?ID=88&SecID=47&DeptID=25

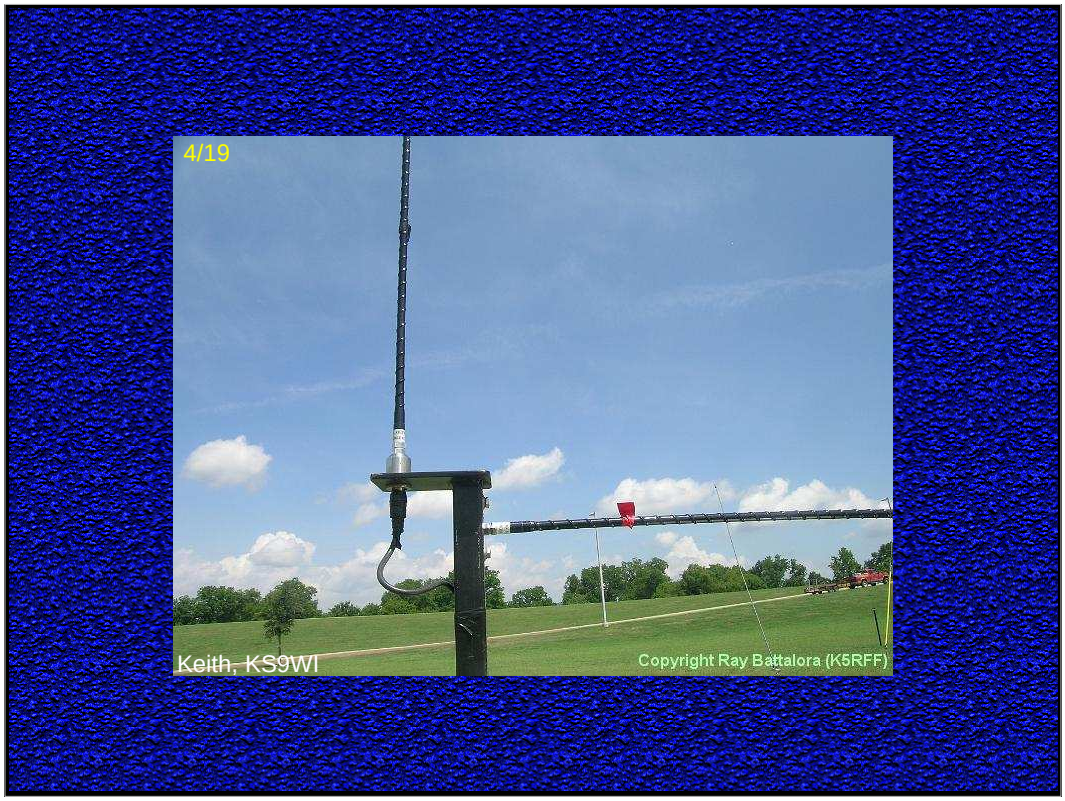
These masts are quite strong and both ends are threaded with the 3/8 x 24 standard and come in lengths of 24”, 36”, 48”, 54”, 60” and 72”. I have several of them.

After some minor improvements, the guy on the right finished #1 at the 2011 3905 CC Shootout. Nice job Steve (KC4YBO).



What I believed happened in the left photo was that the cap hat was too close to the main coil.

Almost everything that could be done wrong was AVOIDED in the right photo. Fred (WB1I) finished #2 in the 2010 3905 CC Shootout with about as comprehensive of an install as was possible. Just a work of art.



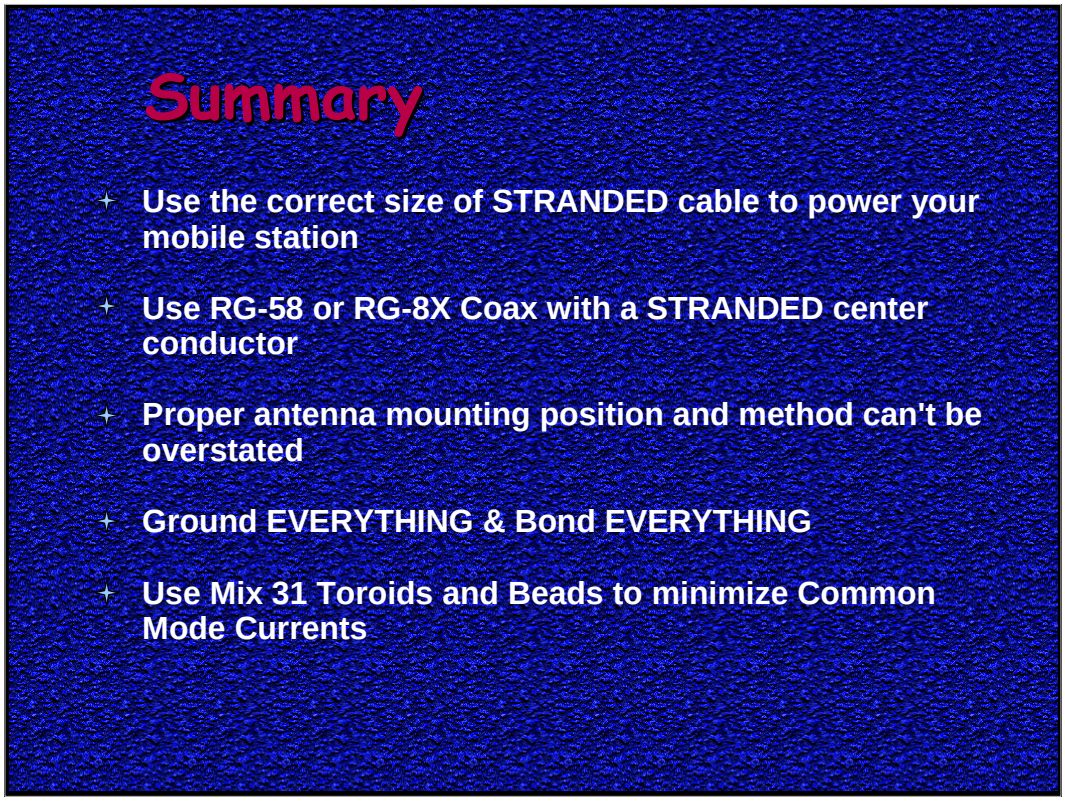
Innovation is the Hallmark (or should be) of any Ham Radio operator. Here was a Hamstick mounted up high with another resonant Hamstick used as a radial. Keith (KS9WI) is da MAN.

When this fellow drove to the line at the Vista Shootout in 2009, many comments from people at the receive site predicted his demise. The antenna was mounted near the ground, the main coil was right next to the body of the car and the cap hat was too low and within 14” of the main coil – a formula for failure and that is exactly what happened. I have no idea if any common mode choking was going on, but I suspect, not. Please use this picture as an example of how NOT to install a mobile antenna.

Bill, N3WD did a great job with this install and it paid of in a #1 finish at the 2005 Shootout in Georgia. My pre-enlightenment days entry is shown at the right. Poor mounting position, no choking, but a large main radiator and large diameter coil and wire gauge still managed a #2 in the same shootout.

Mouser has Mix 31 Toroid Cores available now for $7.00 at
http://www.mouser.com/ProductDetail/Fair-Rite/2631803802/?qs=P8bU7i9nNAWMk1EJQzshLg%3d%3d

The DX-Engineering snap-on beads are the ¾" I.D. ones at:
http://www.dxengineering.com/Parts.asp?ID=290&PLID=182&SecID=152&DeptID=42&PartNo=DXE-CSB-750P



As I answer questions that you may have, I will add the answers to this document. Eventually I will put it on my own web page (with a link from the 3905 CC site) as a living document, so you'll always see the latest info there.

The pictures used as examples were not used to disparage anyone. I merely used them to show the good and the bad of installations that are very typical in the Ham Mobile world.

Keep in mind that ALL of the operators that own these mobile stations, routinely enjoy many satisfying QSOs while mobile. I have only wanted to point out how they (and you) could improve their installations and enjoy mobile operating even more. I point this out, not to bash, but to help.

This presentation was based on my own personal experiences with using, testing, modifying, and then retesting various scenarios over the years. I do not claim to be the expert, but I do know what works for me and it can work for you too. 73, Lon, KØWJ