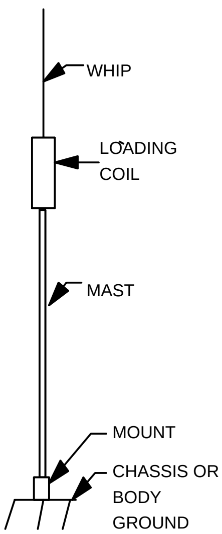
<u>THE HF MOBILE ANTENNA - PART I</u>

Andy Griffith, W4ULD

I had forgotten how much fun HF mobiling can be until I took some trips a few years ago with the home-brew screwdriver antenna. I had become disgusted with 2 meters while traveling because local hams don't welcome travelers like they did in the early days of repeaters. So the HF rig was a lot of company and made the trips shorter. The 40 meter band is still a gentleman's band where one can always find a friendly QSO during the day. Of course, at night the band is flooded with foreign broadcast stations. The 17 meter band is great for mobiling because it is still not crowded. DX is is easy to work. One can even squeeze in on 20 meters occasionally among the 1500 watt stations. If they hear you, both domestic and DX stations will often give priority to a mobile station. Ten meters when it is open has always been a good mobiling band because the 10 meter mobile antenna on the open road is about as efficient as any low vertical antenna at a base station.

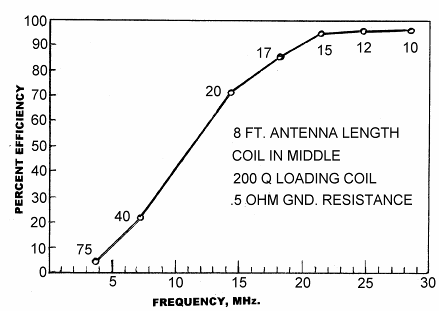
The modern HF mobile antenna is shown in the sketch at the left. It consists of some form of mounting which is well grounded to the chassis or body of the vehicle, a relatively stiff mast which may be tubing or a heavy wire in a fiberglass sheath, a loading inductance to resonate the system at the operating frequency, and a flexible whip. The length of the whip is usually adjustable to fine tune the antenna to resonance. The total length from the mount to the top of the whip is usually 8 ft. to 9-1/2 ft. The efficiency of a vertical, less than 1/4 wavelength long, increases with length (all other factors being equal) so some homebrew systems are designed to just clear 13-1/2 ft. underpasses.



The efficiency of an 8 ft. loaded antenna is quite low, especially on the 75 and 40 meter bands, as can be seen in the graph below. The data were calculated for a fairly high efficiency antenna. Most mobile installations I have seen perform at about half the efficiency shown in the graph for 75, 40, and 20 meters. The only power radiated from the antenna is that absorbed in the radiation resistance (RR). An 8 ft. 75 meter antenna has a radiation resistance of only .97 ohm while rf ground resistance (RG) and coil resistance (RC) may total 15 to 40 ohms. The power consumed in the latter resistances goes into heat. The efficiency of the antenna in percent or power radiated per 100 watts input is shown by the following expression.

$$Efficiency,\% = \frac{RR}{RR + RG + RC} x100$$

The secrets of an efficient mobile antenna for 75, 40, and 20 meters are (1) make the antenna as long as possible to raise the radiation resistance, (2) insure that the direct connection to the vehicle body or chassis is short and low loss for rf, (3) use a loading coil with the highest possible Q factor, and (4) position the coil at or just above the center of the antenna. Unfortunately, many commercial antennas are not designed for best efficiency. If an installation for 75, 40, or 20 meters shows an unmatched SWR of less than 2:1, it is a low efficiency system. I will talk more about this next month.



In the next five newsletters I will try to discuss each of the above parameters and also methods of matching the mobile antenna to 50 ohm coax. Meanwhile there is some very good information on mobile antennas in the latest edition of *The ARRL Antenna Book.* Don Johnson, W6AAQ, is probably the best authority on ham mobiling. His popular book, *40 Years of HF Mobileering,* is a classic.

73 and hope to see you next month. Andy.

THE HF MOBILE ANTENNA - PART II

Andy Griffith, W4ULD

In Part I of this series I said that a 75 meter mobile installation has low efficiency unless the unmatched SWR is at least 2:1. This statement usually raises eyebrows because we normally think that low SWR is desirable. Low SWR at the transceiver terminals is desirable and is obtained by some form of matching device either at the antenna or at the transceiver. However, at the antenna terminal low SWR of a short loaded antenna is undesirable as we can see from the table below for an 8 ft. 75 meter antenna with the loading coil in the center.

Q of Coil	Coil Resistance ohms	Input Impedance ohms	SWR	Efficiency percent
100	36.3	45	1.11	2.1
200	18.1	23	2.17	4.1
300	12.1	15.7	3.19	5.8

Ground resistance is 1 ohm and radiation resistance is .974 ohm in each case.

The resistances of the loading coil and ground system far exceed the radiation resistance of less than 1 ohm. The radiation resistance is the only resistance contributing to radiation from the antenna. Power consumed in the remainder of the input impedance goes into heat. Since the total resistance is less than 50 ohms, the SWR will go up as the losses are reduced. This situation applies to all HF mobile antennas as long as the radiation resistance plus losses total less than 50 ohms. I have seen (and built) some super loss antennas with total resistance exceeding 50 ohms. On 75 meters a coil Q of greater than 200 and a ground resistance of 2 ohms or less are readily obtainable. Thus an SWR at the antenna of 2:1 to 3:1 is obtainable. However most installations I have measured on 75 and 40 meters run only 1.1 to 1.6 SWR.

We will begin our discussion of important parameters with the ground system. We are talking about RF resistance to ground which may not be the same as DC resistance as measured with an ohmmeter. A good RF ground requires a very short, heavy duty connection between the antenna mount and the chassis or body of the vehicle, and in the case of body mounting the body panels must be bonded to each other and to the chassis to create the maximum ground plane. I have found that it is difficult to get a good body ground for HF mobile. I prefer chassis mounting but we will discuss both.

I think the chassis mount at the bumper level is usually best because it is easier to get a heavy duty, low resistance ground and because a longer antenna can be used without striking overhead objects. Just by increasing the antenna length from 8 ft. to 11 ft. the efficiency on 75M more than doubles mainly because the radiation resistance doubles. I am aware that *The ARRL Antenna Book* says that ground losses increase as the base of the antenna is lowered. They mention 6 ohms ground resistance for a bumper mount versus 2.5 ohms for a roof mount. I question their method of measurement but that is another subject. I know that my “screwdriver” antenna has a ground resistance of about 2 ohms on 75 meters. Its SWR is 3.0:1. The mount is a heavy aluminum bar connected directly to the chassis of the sedan using the bolts that attach the bumper to the chassis.

. Direct connection to the chassis is preferred. Trailer hitches and bumpers that are bolted to the chassis are also good provided a clean, paint-free connection is made to the chasis. After installation, the attachment point should be sealed by repainting or spraying with a good electrical sealer. If there is any question about the installation, the antenna mount, bumper and/or hitch should be bonded to the chassis by a short copper strap about 1 in. wide using at least 1/4 in. diameter bolts and lock washers. Tinned braid is not good for this purpose as will be discussed later.

Next month we will cover mounting the mobile antenna on the body of the vehicle. *73, Andy.*

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<u>THE HF MOBILE ANTENNA - PART III</u>

Andy Griffith, W4ULD

In Part II we began our discussion of ground systems with the antenna base at bumper level and connected to the chassis with a short, heavy mount. The other alternative is to mount the antenna on the sheet metal body of the vehicle usually on the trunk lid or the top. While the azimuth radiation pattern is more uniform with body mounting, I do not like it for two primary reasons: (1) it is difficult to get a good RF ground and (2) the antenna will be less efficient than bumper level mounting because its length must be reduced for a given height above ground. However for equal length and equal ground resistance body mounting is more efficient. The maximum allowable height is about 13 ft. to insure that the antenna will pass under wires and overpasses which may be as low as 13.5 ft. Thus an antenna mounted at bumper level can be at least 11 ft long while a top mounted system must be held to about 8 ft. for a modern sedan which is about 58 inches high. As pointed out in Part II, an 11 ft. antenna is twice as efficient as an 8 ft. one on 75M because the radiation resistance is about twice as high. Many Hams use body mounting and are satisfied with the performance although their installations are less than ideal. My comments below are aimed at getting the most out of a system that is basically inefficient. I have employed most of the techniques to be discussed (both good and bad) and know that they can affect a mobile signal.

The best way to get a good ground for a body mount is to bolt the mount to the body of the vehicle with clean metal-to-metal contact. Very few people are willing to take this step. It used to be popular because body repair was relatively cheap. Other forms of mounting will most likely compromise the efficiency of the system. Two systems that have provided reasonable efficiency for me are (1) mounting the antenna on a well grounded luggage rack and (2) capacitively coupling the antenna to the body with aluminum foil. The luggage rack on a station wagon is not too bad as long as the rack is metal and attached to the body with several sheet metal screws. Many modern racks are metal but use molded plastic mounting brackets which insulate the rack from the body. Such racks are unsuitable for HF but will work on 2 meters. The magnetic mount has become popular in recent years. Available magnetic mounts do not provide adequate capacitive coupling to the body of the vehicle to form a good RF ground for HF. They must be connected to ground with a short, heavy ground strap as discussed later or connected through additional capacitance. My capacitive ground for 75 meters consisted of 220 square inches of aluminum foil held down with magnetic sign material. I arrived at 220 square inches by experiment. The sign material fit between the magnets so the connection between the foil and the mag mount was very short and consisted of a three inch wide strap of .01 inch thick hobby brass. I used the system for several years. I tested my screwdriver antenna with this system and got an SWR of 2.6:1 vs 3.0:1 for the chassis mount. So it is less efficient than the chassis mount but still above the threshold of 2:1 that I talked about last month. I will provide more details for anyone interested. The heavy ladder to the top of an RV is apparently a good mounting point if the ladder is well grounded to the chassis or metal body at the base. I have never had the opportunity to make measurements on this system but I have heard some good signals from such installations. Apparently the ladder has low reactance. The metal top of an RV is a great ground plane. Some Hams have had good luck with gluing aluminum foil over the top of their fiberglass RV and grounding the mount to the foil.

Unfortunately a common practice is to mount the antenna on a magnetic or other insulated mount and run a lengthy wire to a ground point. The trouble with the long ground wire is that the wire becomes the high current part of the antenna; that is, the feed point is now above ground. The ground wire usually lies close to the body where it does not radiate very well. The shield of the coax will be “hot” and will conduct RF into the cab of the vehicle. RF in the cab will cause a “hot” mike and may cause erratic operation of the cruise control. These same symptoms occur with a high resistance ground. The ground connection must be short and large, such as a 2 inch wide copper strap, to reduce the inductance of the connection. Tinned braid is not suitable. RF flows only on the outer few thousands of an inch of a conductor and tin is not a good conductor. A single sheet metal screw is not adequate to ground the strap. I do not know the limits but a ¼ inch bolt holding the strap in clean metal-to-metal contact has always worked.

A rule of thumb for vertical antennas less than ¼ wavelength high is that the radius of the conductive plane beneath the antenna should be equal to the height (length) of the antenna. Of course, this rule cannot be followed for most mobile installations but one needs to provide as much ground plane as possible. Therefore, for body mounting the body components need to be bonded together and bonded to the chassis using copper straps. This can be difficult unless the components are already welded together. If the antenna is mounted on the lid of the trunk, the lid should be bonded to the rest of the body. Bare copper braid is best for this since the connection must be flexible.

In Part IV we will talk about the loading coil or “resonator”. *73 and hope to see you next month, Andy.*

<u>**THE HF MOBILE ANTENNA - PART IV**</u>
<u>**THE LOADING COIL**</u>

Andy Griffith, W4ULD

The loading coil or "resonator" is usually located at the bottom of the antenna mast or at the top of the mast near the center of the antenna (See Figure 1). The purpose of the loading coil is to bring the antenna to resonance at the operating frequency by canceling the capacitive reactance of the short antenna. The loading coil is the most important part of the antenna because it contributes the greatest losses to the system especially on 75 and 40 meters.

Most modern antennas locate the loading coil near or just above the center of the antenna. Near center mounting is approximately 30% more efficient than base mounting as described by some excellent graphs on page 16-9 of *The ARRL Antenna Book, 17th Edition.* Actually higher efficiency could be achieved by loading closer to the top of the antenna if the ohmic resistance of the coil could be reduced. However, the required coil inductance increases as its position is raised and the coil loss increases faster than the benefit.

The inductance required in the loading coil depends upon the mast diameter and length, the whip diameter and length, the position of the coil, and the physical size and shape of the coil. Pages 16-5 through 16-8 of the above publication describe how to approximate the inductance. More accurate calculations can be made by the method described in my article "Capacity Hats for HF Mobile Antennas", *QEX magazine, August 1996.* This reference covers design with and without capacitance hats which I will discuss shortly.

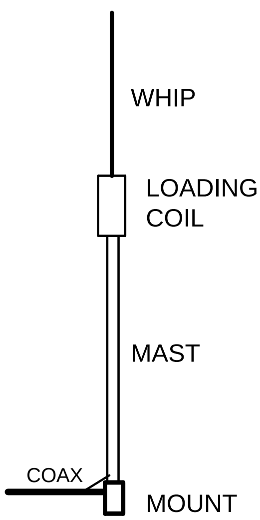


Figure 1

The most important coil parameter is Q or quality factor which is related to the resistance of the coil. As the Q goes down the resistance goes up and vice versa. The power consumed in the coil resistance goes only into heat as discussed in Part I. I have measured the Q of coils for 75 meters as low as 50 and as high as about 350. The effect of Q is shown in Table I. Thus, a high Q loading coil is a must, but many commercial coils do not get a passing grade. Only the large open coils such as that of the Texas Bugcatcher exceed a Q of 300. The coil for my home brew screwdriver antenna is wound with #14 wire on 1-1/4" PVC pipe and is about 18" long. Its Q is fair at about 225. A commercial coil whose fiberglass case is 1-5/8" diameter by 8-1/2" long has a Q of 108. A 1" D by 5" long coil wound with #22 wire has a Q of 98. This latter coil is larger and probably of higher Q than some of the commercial "slim-line" coils designed to keep the wind resistance down.

A popular "stick" antenna wraps the coil over the entire length of the fiberglass mast. I have no actual measurements on such an antenna but did make an on-the-air evaluation of one for 75 meters on a bumper mount. The signal reports were not as good as with my commercial antenna using the 108 Q coil. At 20 through 10 meters I feel sure the "stick" will perform fairly well.

Table I

Coil Q vs. Antenna Efficiency on 75 Meters

Q of Coil	Input Impedance Ohms	SWR	Antenna Efficiency %
100	45.0	1.11	2.1
200	23.0	2.17	4.1
300	15.7	3.19	5.8

8 Ft. antenna with coil in center
Radiation resistance = .97 ohm
Ground resistance = 1 ohm
Calculated using *ELNEC* from Roy Lewallen, W7EL

The efficiency of the 75 meter mobile antenna can be improved significantly by placing a capacity hat above the coil. This is known as capacitive loading and reduces the inductance required in the loading coil. Thus the resistance of the loading coil will be reduced. To reduce wind resistance hats are usually constructed from aluminum sheet as a four or six spoke wheel. For example, the efficiency of the second antenna in Table 1 can be raised to about 5.3% with a 10" diameter wheel on top of the loading coil. It is common practice when operating 75 meter mobile while stationary to use a 40 meter resonator with a large hat and an extended whip for a total antenna height of 15 to 20 feet. A 15 ft. antenna with an 18" diameter hat will have a respectable 33% efficiency assuming 1 ohm ground resistance

Next month we will talk about matching the transceiver to the mobile antenna. *73 and see you next month, Andy*

THE HF MOBILE ANTENNA - PART V
MATCHING SYSTEMS

Andy Griffith, W4ULD

We said that the SWR of a 75 meter mobile antenna should be 3:1 for good efficiency. Thus the input impedance of about 17 ohms must be matched to the 50 ohm output of the transceiver. This must be done by some form of matching network such as those shown in the attached figure. The first four networks must be installed close to the base of the antenna.

The simplest network is the L-network in Figure A. The shunt component may be a capacitor or inductor. For 75 meters the shunt capacitor should be about .001 μF and should be a 600V transmitting type or two 500 pF 1000V ceramics in parallel. Usually the series coil is not used and the required inductance is obtained by increasing the whip length. The whip is adjusted for minimum SWR at the transceiver. Some designers use a motorized series coil so that the antenna can be both matched and resonated from the cab of the vehicle throughout the band. The actual value of the capacitor and inductor will depend upon the input impedance of the particular antenna. However, the .001 capacitance value will bring most systems to 1.5:1 SWR or less on 75 meters. Different values will be required for each band.

If a shunt inductor is used it should be about 1.5 uH for 75M. The series component would then be a capacitive reactance obtained by tuning the whip shorter than normal or reducing the inductance of the loading coil. This system is used by in the High Sierra screwdriver antenna. The "screwdriver" is a type of mobile antenna that can be adjusted to each band from the cab of the vehicle. I will say more about this next month. The shunt inductance becomes transparent at 20M and below. Thus a single coil is good for all bands.

The tapped unun or toroid transformer of Figure B is used on some of the commercial screwdriver antennas. The W6AAQ unun uses 15 bifilar turns of #18 wire on a T-106-2 powdered iron toroid. Several taps are provided on one of the toroid windings. The tap is selected to provide the lowest SWR. It is reported that a single tap position may be used on all bands. I have not tried this unun so I am quoting the manufacturer's flyer. However, I know several Hams that are using the system successfully.

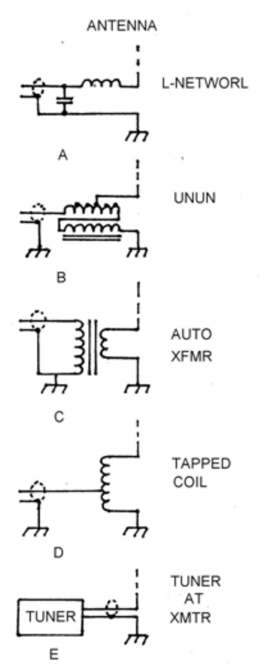
Figure C is a conventional toroid transformer that is best suited for a single band. However, I have made one transformer work on both 75 and 40 meters. With 100 watts on 75 meters the primary (coax side) should be about 10 turns of #14 and the secondary 5 - 8 turns depending on the antenna impedance. A FT-140-61 ferrite toroid is used.

Figure D shows the system which has been used for many years. A portion of the inductance normally in the center loading coil is placed at the base of the antenna and the coax is tapped up from the base of the coil for a match. By providing several taps on a single coil, the coil can be used for all bands. Thus, when the resonator is changed to change bands, the length of the coil and the coax tap position are changed according to predetermined data. The arrangement also allows one to change the resonant frequency within the 75 and 40 meter bands. As in Figure A, some operators motorize the coil so that the antenna can be tuned throughout a band from the cab.

The system that I used for several years with my home brew "screwdriver" antenna is shown in Figure E. The coax is fed directly to the base of the antenna and matching is accomplished with an antenna tuner in the cab at the rig. I used an automatic mobile tuner but still have the manual home brew tuner that I used for years. One must accept the loss in the coax but this is usually small since less than 20 feet of coax is used in most installations. The loss is only .2 dB for 3:1 SWR on 75 meters and 2:1 SWR on 40 meters with RG-8X coax. No additional loss is incurred with this system on 20 through 10 meters because the SWR is fairly low on these bands. Of course one of the remote automatic tuners can be installed close to the antenna feed point and reduce the extra loss on 75 and 40. With the remote tuner and a "screwdriver" antenna one must be able to remotely bypass the tuner so that the antenna can be resonated from the cab when changing bands.

Next month we will discuss some of the limitations of mobile systems.

73, Andy - W4ULD



MATCHING SYSTEMS

The HF Mobile Antenna - Part VI
Limitations and Parting Words

Andy Griffith, W4ULD

In this last article on HF mobile antennas we will discuss some of the limitations of mobile operation. The major limitations are bandwidth, effective radiated power, and inconvenience of tuning.

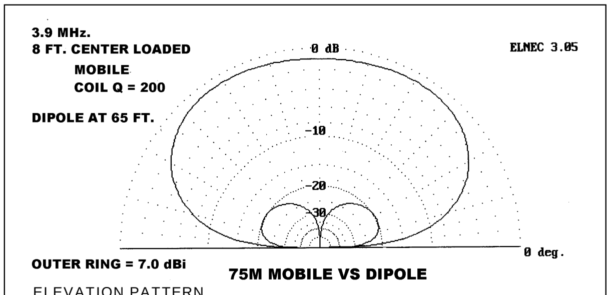


Figure 1

Short antennas are notoriously narrow in bandwidth. As can be seen from Table 1 only a very small portion of the 75 and 40 meter bands can be covered by a single setting of a mobile antenna without exceeding 2:1 SWR. The data in the table assumes that the antenna has been matched to 50 ohms at the resonant frequency. On 20 meters most of the phone band can be covered. On 17, 15, 12, and 10 meters all of the popular portions of the phone segments can be covered since the antenna is not very short on these bands.

Table 1

Bandwidth of 8 Ft. Center Loaded Mobile Antenna for 2:1 SWR

Frequency MHz.	Bandwidth KHz.
3.9	14+
7.2	32
14.3	158

Thus when using an antenna with a fixed coil and adjustable whip, one must stop the vehicle and readjust the whip length to the desired portion of the band. Most operators paint marks on the whip to indicate the length of the whip for different band segments. Of course to change bands the loading coil must be replaced or, in the case of a bug catcher type, the jumper must be moved to a new tap position. Finally, when changing bands, the matching network will probably have to be readjusted.

The above inconveniences can be eliminated by using a “screwdriver” antenna with a manual or automatic antenna tuner in the cab of the vehicle. In the “screwdriver” the length of the whip is fixed and the amount of loading coil in the circuit is adjusted from the cab. The “screwdriver” has a large (about 2” diameter) base section. The coil rides in and out of the base section with spring fingers maintaining electrical contact between the turns of the coil and the base section. The coil is moved up and down on a threaded rod which is turned by an electric screwdriver mounted in the base section. Thus bands can be changed and a segment within a band selected while the vehicle is in motion. A SWR meter in the cab indicates when the antenna is tuned to the desired frequency.

The “screwdriver” is now available commercially from at least two sources for $250 to $300. I am not sure what these prices include. During my trip in early September I was surprised to find that about half of the mobile stations I worked or heard are now using “screwdrivers”. It is the modern way to go!

As we discussed in Part I of this series, The efficiency of a good 75 meter mobile antenna is only about 5% and that of a 40 meter antenna is about 22%. The efficiency increases rapidly below 40 meters. Thus one should not expect to get an answer to a CQ on 75 meters. It is best to check into nets or into QSO’s in progress. However, the antenna is helped on 75 meters by its typical vertical pattern as shown in Figure 1. Most of the radiation is concentrated at about 30 degrees. The overhead radiation common to a dipole is not present. This is why a 75 meter mobile station often comes in better at about 150 miles away than when close in.

On 40 meters 22 watts radiated out of 100 watts can be surprisingly effective. Here again the radiation is concentrated at about 29 degrees. I commonly receive S9 reports when the fixed stations are 5 to 10 dB over S9. As the sun spot cycle progresses, the higher frequency bands, especially 17, 12, and 10, will offer some excellent mobiling. As stated previously, the mobile antenna on these bands is just about as good as any vertical as long as one is on the open road.

This completes our series on HF mobile antennas. I have tried to talk about some things that are not in the handbooks. Thus for further general information I encourage you to study the *ARRL Antenna Book.* This is an excellent publication

I haven’t decided on a subject for next month but expect to be here.

CUL on HF mobile! Andy - W4ULD