A Comparison of HF Mobile Antenna Designs

Picking an HF mobile antenna is often the biggest challenge of getting on the air from your vehicle.

Rich Roznoy, K1OF

Mobile operation on the HF bands has become more and more popular as compact, efficient radios make it easy to put a 100 W signal on the air from your vehicle.[1] Unfortunately, the laws of physics haven't gotten any more lenient and a quarter wave (λ/4) whip antenna that would be 19 inches long for 2 meters, or a barely manageable 100 inches for 10 meters, is an unwieldy 65 feet long for 75 meters.

So What's the Solution?

While 10 meters is great fun during the peak of the sunspot cycle, offering great worldwide DX contacts, most HF operation now is on much lower HF bands. The traditional solution to the problem is to electrically shorten the mobile antenna so that it is about the 8 foot length of a 10 meter whip. There is no magic here. This can easily be accomplished by inserting a series inductance somewhere in the length of the antenna, resulting in an antenna that is resonant on the desired amateur band.

The three most frequently encountered methods of electrically shortening a mobile antenna are:

- Helically wire wound, vinyl covered, single band types.
- Center-loaded swappable resonator types.
- Base-loaded motor-tuned coils with a whip above.

In addition there are those with various kinds of bottom mounted tuning units. There are also some that combine one of the above whips with a "capacitive top hat." We decided to limit our evaluation to locally available samples representative of the most frequently encountered types.

Which to Choose?

I often hear stories on the bands comparing HF mobile antennas and wondering which is best. Most of these discussions are based on anecdotal evidence at best with measured performance data rarely if ever presented. Unfortunately brand loyalty and personal belief systems (either right or wrong) provide the basis for most of these discussions. The purpose of this article is to attempt to quantify the differences in HF mobile antenna performance by measuring the actual differences between samples of the three types.

Keep in mind that performance is just one of a number of possible selection criteria, others being perceived aesthetics (by us as well as family members), price, ease of changing bands or frequencies, as well as individual mounting and height constraints. Any of these could trump performance as the primary decision maker. For this study we focused on measuring performance. The other criteria can be determined from manufacturers' literature.

Where's the Beef?

The impetus for this investigation came from a conversation with a friend about a shared incident. Recently, one of my HF center-loaded resonators needed some repair and I was able to fix it myself. When I told my story to George, K1EHW (see photo), he said: "By golly I have the same problem." He was also able to repair his and this got us thinking about ways to test mobile antenna to see how well they are working. We soon realized that in our ham careers neither one of us has seen much in the way of performance measurements for mobile HF antennas. We realized we had the necessary equipment and a suitable location to do a side-by-side

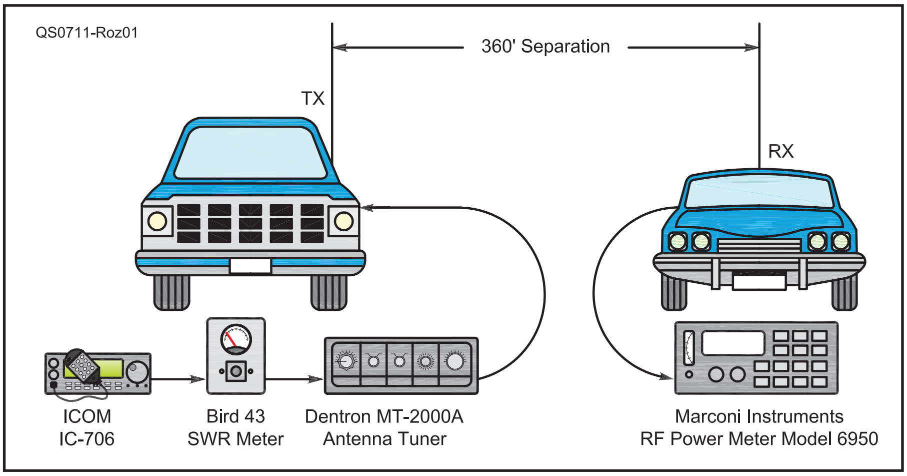

Figure 1 — The Dentron tuner was adjusted to an SWR of 1:1 for each sample.

---

[1] Notes appear on page 33.

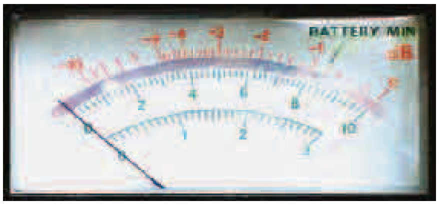

Figure 2 — Marconi 6950 Power Meter.

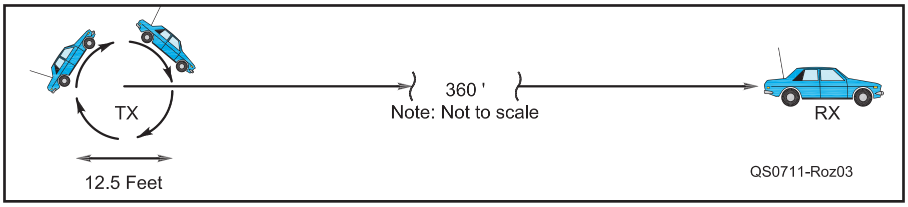

Figure 3 — Each vehicle was turned in a tight circle to determine the orientation for maximum signal.

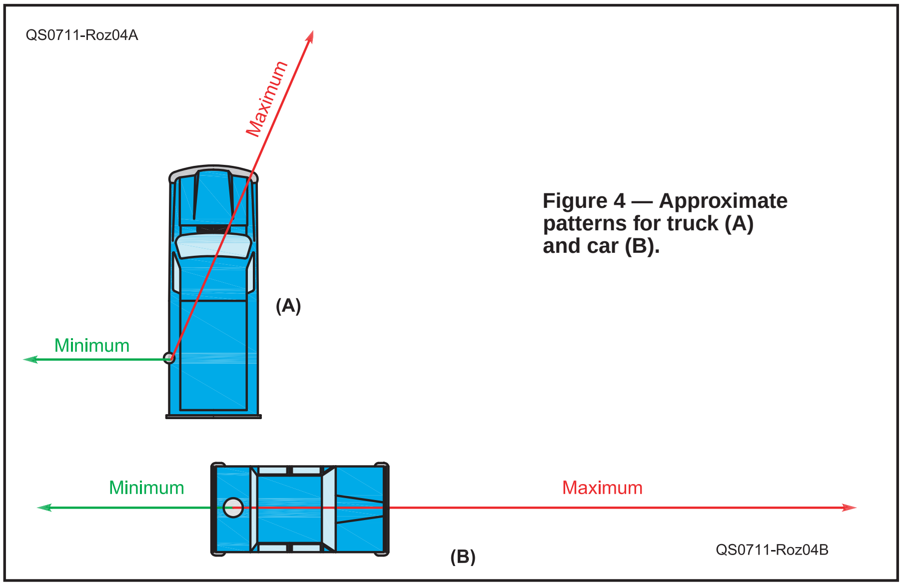

Figure 4 — Approximate patterns for truck (A) and car (B).

comparison of our two different types of 60 meter antennas. Now, for the first time I knew how much better or worse my helically wound antenna performed compared to my center-load coil type. Based on these results we were encouraged to test additional antenna types resulting in a comparison of 25 antennas for 80 through 10 meters.

The ARRL Antenna Book devotes an entire chapter to mobile antenna theory but no field measurements are included.[2] If you are inclined to homebrew an antenna, this is an excellent source of theory and will serve you well. Understanding the basic theory behind mobile antenna performance will also go a long way in determining which parameters to look for. If on the other hand, you are like most of us and purchase an off-the-shelf antenna, it is impossible to *see* the parameters that determine performance.

How can you make an informed choice? One way is to compare measured performance between actual antennas and that is what we present here. The data provided in this article will enable the reader to make choices by taking into account the relative field strength measurements and associated trade-offs associated with each of three types of antennas described above. The types chosen are representative samples of the more popular mobile antennas, all of comparable size to a 10 meter whip.

What is Performance?

The most complete picture of mobile antenna performance is one where theory and practice come together. Luckily, a few generalizations can be made that will help make this picture clear. For starters, a definition of performance is needed. For this analysis antenna performance is determined solely by the efficiency of the radiating element. In this context the antenna that radiates or produces the highest field strength for a given input power is the one with the highest performance. This may present a caveat for some because they may think of performance in terms of lowest SWR, widest bandwidth or even the highest price tag. While these are important parameters and vary from antenna to antenna, they do not constitute a single measurable quantity, whereas field intensity or signal strength does. SWR, bandwidth, size, cost, and even aesthetic appeal should be considered as trade-offs and not a measure of performance.

Where is the Boundary?

The distinction between an *antenna*, the object you purchase off the shelf, and the *antenna system*, which may be thought of as the combination of the antenna, car body, rig, matching network (if used), interconnecting cables, ground connections and antenna mounting location must be made. In order to measure the performance of just the antenna using a single metric, all of these other factors must be held constant throughout the tests. As a result, only the differences in measured signal strength due to the individual antenna is reported. To further clarify the demarcation, the standard ⅜ × 24 mount has been chosen as a point of demarcation between the *antenna* and the *antenna system*.

What are the parameters that determine performance? In this case it comes down to efficiency. This is where the theory and practice come together. A generalization may be made that the more efficient HF mobile antenna is one with:

- The highest Q, which means it has the lowest RF resistance. All things being equal, this means the conductors have the largest surface area (based on skin effect).
- The one with optimum current distribution.
- All other things being equal, the one with the longer length.

An excellent summary of efficiency factors may be found in *The ARRL Antenna Book*.[3]

Test Setup

Test Site

Two important considerations were made in choosing the test site. First, the site had to be clear of any wires or metallic objects that might reflect or conduct RF and second, it had to free of any movable objects that could alter the signal path during the tests. An open field at a nearby beach was perfect. The test vehicles were located 360 feet apart with their exact locations recorded by GPS. This was done to ensure that the same test conditions could be met if the tests were repeated in the future.

Antenna Setup and Adjustments

The transmitting test antenna was mounted on a pickup truck. A car located 360 feet away was used for receiving. See Figure 1. The receiving antenna is not critical in this case, as long as the same one is used for all tests and it couples enough power into the Marconi power meter to allow a proper reading. The use of this meter was critical to the success of these tests because it could accurately measure changes as small as 0.1 dB. S-meters could never measure signals with this resolution or accuracy. The meter scale is shown in Figure 2.

A two-step process was used to tune the antennas before taking field strength measurements. First, each antenna was tuned for lowest SWR without the Dentron MT-2000A tuner in line by either adjusting the whip length or by the use of the motor driven "screwdriver" mechanism. Then the Dentron MT-2000A was placed in line and tuned to achieve a 1:1 match. This was done to ensure that the input power was the same for each antenna. This was necessary because the base impedance of each antenna was sufficiently different from model to model, resulting in the ICOM IC-706's SWR protection circuitry reducing power for some samples. On average the tuner provided about a 0.5 dB improvement. To be fair, each antenna tested needed to have the same power applied to it. What we measured is how efficiently each converted that power into RF radiation. The antenna tuner was adjusted for a 1:1 match for each antenna using a Bird reflected power meter to ensure each antenna received the same power. The matching was so good that the reflected power was not perceptible in the Bird meter. This is as close to a 1:1 match as we could get.

Always Something!

During our initial set of tests we noticed that the signal varied as people walked around the vehicle with the receiving equipment. The problem was traced to the extension cord used to supply 120 V ac to the Marconi power meter. The extension cord was acting as a ground radial! The solution was to remove the extension cord and power the meter from an inverter inside the car, thus eliminating all extraneous RF paths to the car. A benefit of putting all the equipment and operators inside the vehicles was that the vehicles acted as Faraday shields that prevented operator movement from affecting the radiation pattern.

Measure in the Peak of the Pattern

The radiation pattern of the transmitted signal has no bearing on the efficiency of the antenna. As we wanted to provide as much signal to the power meter as possible we optimized the orientation of the vehicles for maximum field strength. This increased the signal to noise ratio and is a good practice to follow when taking measurements. To accomplish this, each vehicle was driven in a tight circle and the change in the received signal was noted as shown in Figure 3. Since the distance to receiver was much larger than the turning radius of vehicle, the effects of the change in signal strength due to path length change was very small.

In a perfectly symmetrical situation the signal should not vary as the vehicles are turned. The difference between the maximum and minimum reading was 2.5 dB for the truck and 2.0 dB for the car. Our goal was to determine the orientation for maximum signal and not to plot the actual radiation pattern. Figure 4 shows that the maximum radiation occurs in the direction from the antenna through the largest dimension of the vehicle body. For the truck, with its side

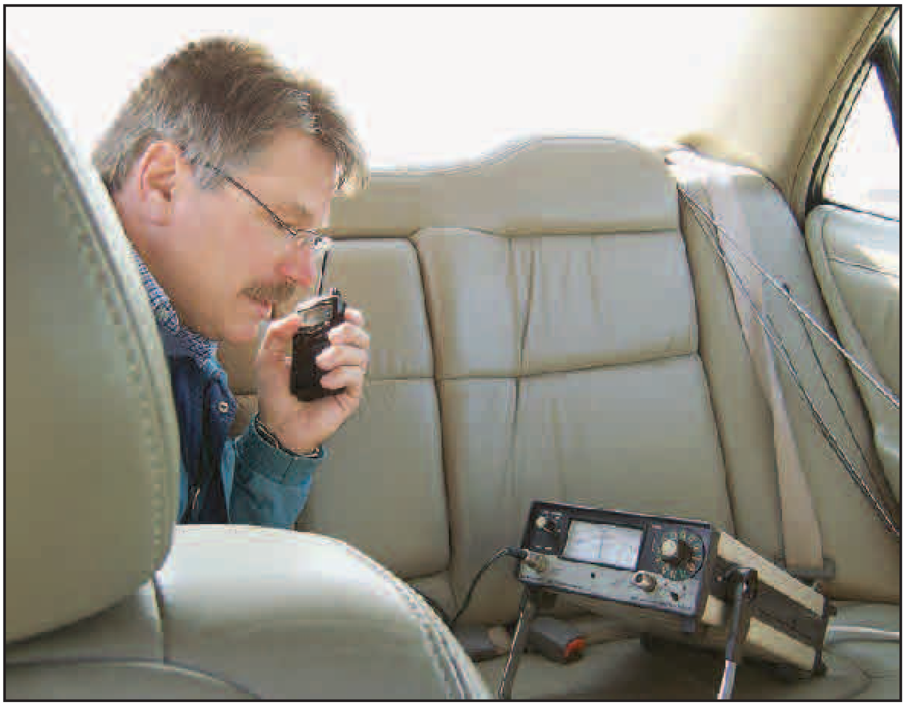

Figure 5 — The author records the received signal strength.

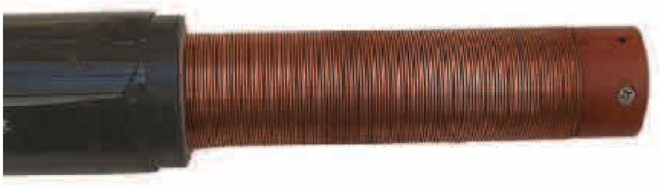

Figure 6 — Exposed coil in the screwdriver antenna.

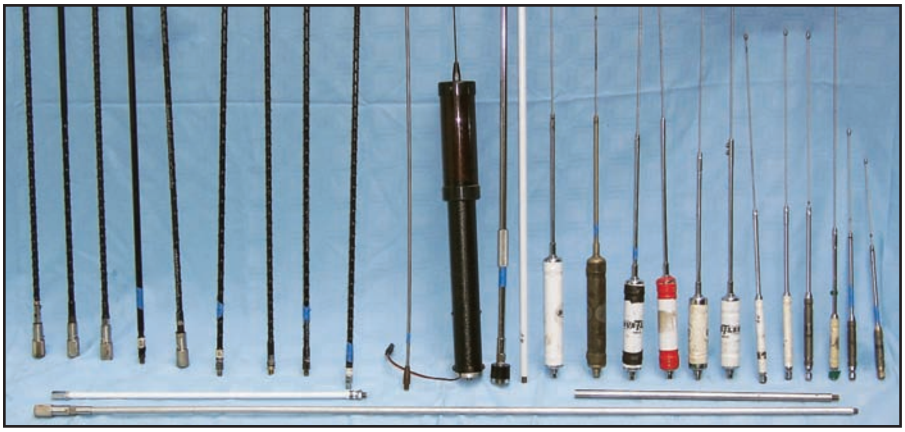

Figure 7 — The parts of all the antennas used in the test.

Table 1
Relative Performance of Three Types of Mobile HF Antennas

	Helical		*Center-Loaded*		*Motor Driven*	
Band	*dB*	*Power*	*dB*	*Power*	*dB*	*Power*
80	–2.2	166	0	100	–4.2	263
60	–2.3	170	0	100	–6.9	490
40	0	100	0	100	–4.2	263
20	0	100	0	100	–3.8	240
15	0	100	–0.6	115	–3.4	219
10	0	100	–0.1	102	–2.4	174

Table 2
Length of Representative Antennas

Band (meters)	*Helical*	*Center-Loaded*	*Motor Driven*
40	95"	87"	83"
20	83"	81"	80"

Table 3
Effect of Length on 40 Meter Radiated Signal Strength

Antenna Type	*Length*	*Relative Output (dB)*	*Power*
Helical	87"	0 (reference)	100
	105"	+1	79
Motorized	83"	0 (reference)	100
	53"	–5	316

mounted antenna, the maximum radiation was off the right front fender. For the car, with its antenna at the center of the trunk, it was directly off the front of the vehicle.[4]

Metrics

Received signals were measured on a commercial test instrument in units of decibels relative to a milliwatt (dBm) as shown in Figure 5. Since we were not trying to determine absolute levels, but differences between antenna types, we shifted the levels for each band so that the strongest signal is shown as 0 dB, and the weaker ones are shown in dB below that point to allow comparison. For those who don't think in terms of decibels, I have provided a conversion to power in watts.[5] For this case, I've shown the strongest signal as 100 W, and the weaker ones as the amount of power needed to obtain the same signal. This is actually a trade-off that could be made since there are a few 500 W amplifiers designed for mobile service. Because most mobile rigs run 100 W many of us will already have an intuitive sense of the performance obtainable with that much power. The results for our three antennas are shown in Table 1. The raw data is available on the ARRLWeb.[6]

Size Matters

The three antenna types we tested were not exactly the same length, although all were relatively close. To complicate matters, each is a somewhat different size depending on the band, and at what frequency it is tuned to within the band. As an example, if we look at 40 and 20 meters, the approximate total lengths are shown in Table 2.

While the length differences are not great, the total length will have an impact on the results. In order to get a gauge on length dependence, we made some spot checks on 40 meters using antennas that were of the same type but of different length. We added an 18 inch extension to the helical antenna and used a 30 inch shorter whip (36 compared to 66 inches above the coil) in the motorized antenna. Each represents potential real cases, but are particularly interesting to see the effect of length on performance. The results are shown in Table 3.

Conclusions

Using the data in Tables 1 through 3 you can judge how much better or worse the performance of one type of antenna is compared to the others. On all bands the motorized antenna we tested is the least efficient. Other motorized models, especially the larger ones with heavier coils, are likely much better performers. The construction of our sample gives us some clues. The coil has lower efficiency because the windings have high RF resistance due to the many turns of thin wire (see Figure 6), the current distribution is not optimum because it is not center or top-loaded, and it is the shortest of all the antennas. This should not be a surprise in light of the three previous generalizations regarding efficiency.

By comparison the center-loaded antenna is more efficient because its base is a thick ½ inch piece of aluminum rod, the coil is center-loaded for optimum current distribution and finally, the whip is thicker (lower loss) and longer. A view of all the antenna samples is given in Figure 7.

Does this mean you should never use a motorized antenna? Perhaps not, since there are some advantages to using this type of antenna. The question now becomes one of convenience versus performance. This type would certainly rank high on the convenience scale. It can be as short as you want and may be left on the car when it is parked in the garage. It is tunable from inside the car. If, however, maximum performance is your goal, choose the one wound with the thickest coil wire, one that is center or top-loaded, one that has the thickest base and whip dimensions, and the one with the longest practical length.

A special thanks goes out to George, K1EHW; Joel, W1ZR, and Dan, N1ZZ, for the loan of their antennas that made these tests possible.

Notes

[1] J. Hallas, W1ZR, "Getting to Know Your Radio — One for the Road," *QST*, Aug 2007, pp 60-62.

[2] R. D. Straw, Editor, *The ARRL Antenna Book,* 21st Edition. Available from your ARRL dealer or the ARRL Bookstore, ARRL order no. 9876. Telephone 860-594-0355, or toll-free in the US 888-277-5289; **www.arrl.org/shop/**; **pubsales@arrl.org**.

[3] See Note 2, p 16-11.

[4] You might consider this the next time you are operating mobile from a fixed location and want to provide the most signal toward a specific direction. You may only gain a dB or two, but it may be worth the effort.

[5] J. Hallas, W1ZR, "Making Sense of Decibels," *QST*, Apr 2007, p 61.

[6] **www.arrl.org/files/qst-binaries/**.

Rich was first licensed at age 12 as KN1QKQ. Now, more than 40 years, and a few calls later, he has just as much enthusiasm for Amateur Radio as he did as a youngster. Rich earned a degree in electrical engineering and is the founder of RL Design Group. He is primarily a consultant in the field of statistical process control but occasionally has an opportunity to do what he enjoys most — RF design and construction. He was previously on the ARRL staff as an Assistant Technical Editor. He can be reached at 5 Keyser Rd, Westport, CT 06880 or at **rldes@optonline.net**.