Integrating the latest test data with hi-Q components for maximum mobile antenna efficiency

Mobile Antenna Perfection

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A recent article by Elbert Robberson, W2FRQ,* covered the theory and design of mobile antennas. This article was excellent, and timely, and should be carefully studied by those genuinely interested in improving mobile antenna performance.

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The following material is being prepared with the objective in mind of supplementing the data furnished by Mr. Robberson. Theoretical aspects of this subject are being cast aside to make more room for practical and immediately useful information, a few do's and don'ts, and some specific "feet and inches" data. From Mr. Robberson's article you can secure an excellent understanding of what goes on. From the following you can, at once, build an antenna capable of doubling your effective radiated power without halving your pocketbook. It is being done every day. You need not be Albert Einstein to do it. From the data set forth in these two articles you can get something for nothing which "you can't hardly find no more."

Right here we sneak in the only theory you will find. Theoretically the mobile antenna is a ¼-wavelength vertical, a "Marconi," working against ground. At the lower frequencies, due to restricted height, inductance must be added somewhere, in some form, to cancel capacitive reactance and to make the system resonant. A 60′ vertical on a car will perform well at 4 megacyles, but this is not a happy solution. Bridges, trolley wires, tree limbs, and policemen take a dim view of your driving around with such an antenna. Obviously, then, the major limitation becomes mechanical at the outset.

A really good mobile antenna incorporates many design features which are not readily apparent—most of which have been learned the hard way. The mobile antenna is a complex machine. Visually it is sometimes difficult to tell a good one from a bad one. The little things you do not see count the most. There is unquestionably greater room for improvement in the mobile antenna than in any other branch of the antenna art.

In order to clearly understand why we want the mobile antenna improved it should be pointed out that the *average* mobile installation is limited to an input power of about fifty watts. It is neither simple nor inexpensive to attempt to exceed this input level due to limitations imposed by storage battery operation. The *doubling* of this fifty watt input level is practically out of the question unless you happen to own a bank. Many hundreds of dollars can be spent increasing input power in order to pick up the necessary 3 db. All of us, however, have experienced a time when the 3 db. would have pulled us out of the noise level and provided the difference needed for communication. This 3 db. you can get, without difficulty or expense, by improving your antenna.

Unfortunately, most amateurs lack the equipment necessary to follow through from formula to field strength measurement, from theory to perfection. Unlike most fixed station antennas, mobile system efficiency is controlled by a great many interlocking factors, both mechanical and electrical. These tend to separate the men from the boys. Even the best possible mobile antenna is hardly better than a poor compromise and is about equivalent to an extended tank circuit hanging outside the car. Losses can be overwhelming. Reduce or eliminate these losses and you win the daily double.

Optimum Height

Drawing on past experience, we come up with a fact and a starting point. Never put the corona ball more than 12′6″ above the ground. If this height is exceeded it will be but a short time until some low bridge or tree limb will conspire to make you very unhappy. Trolley lines, and there are still trolley lines, often are nearly this low and they carry 600 volts d.c. with copious amperes available. If ever you wheel into a town that has parallel trolley wires, and rubber tired cars, put the high mobile antenna in the trunk or head for the pasture. You've had it.

Impact Strength

Impact strength of the system is important. This is particularly so if you are inclined to go around crashing into trees and the like. This calls for intelligent compromise. When the system is strengthened the weight goes up. When the weight and mass goes up, so does the wind resistance and inertia. You can meet yourself coming back in this program. There are those who have attempted "beefing up" an antenna to a point where crashing into bridges and trees at any speed would leave the antenna intact. Doubling vehicle speed squares the force of impact. The "beefing up" process can be carried to a point where, under impact, the antenna will remain on the fender to which it is attached, but the fender will come off the car. This, too, is the wrong approach.

Rigidity

Electrical considerations demand that the vertical be just that. It must be vertical. It must remain perpendicular to the ground, and the vehicle, at all times, and at all speeds. When it fails to do so, many undesirable things happen. The most noticeable of these is the changing of power input. Detuning, sometimes rapid in form, introduces reactance, shifting terminal impedance, increased transmission line SWR, fading of the signal, and the losses begin to mount. Absolutely no swing and sway, lean, wobble, or floundering around can be tolerated if you want to get the most for the least from your mobile antenna.

So now we know that we must make the thing stand straight up in the air. The only question is how to accomplish this. They do this sort of thing daily in the aviation industry not by "beefing up" and increasing weight and wind resistance, but by slimming down, using lighter materials, and by reinforcing only at strategic points. The place to start is at the base mount. This should be substantial and should be rigidly attached. It should also be adequately reinforced. Any motion at this point is multiplied many times at the corona ball. If you have a late model car, do not lean too hard against the fender while installing the base mount. The sheet metal now being used by car manufacturers is so thin you may fall through. Back up the base mount, behind the fender, with sufficiently substantial reinforcing to positively eliminate excessive flexing and sway.

Springs

The use of a spring in a mobile antenna is highly detrimental. Nothing will cause more loss, or electrical difficulty, than a spring, any spring, any kind, anywhere in the antenna, any time. The easiest way to reduce the effectiveness of your 50 watts to the level of a fair 15-watter is to use a spring. It is obviously not possible to keep the antenna perpendicular when one is used. A little wind resistance will cause the antenna to "lean." When you accelerate, decelerate, apply the brakes, or take a curve, the antenna will flounder around. Springs also "age," sometimes introduce varying amounts of inductance, and add to the loss resistance. They offer no protection against impact unless you happen to be moving slowly. They can destroy all you can otherwise gain by improvement. Take your choice. Either have a spring or an antenna. You cannot have both.

Position on Car

Before going on up the antenna, we should at this point establish the best location on the car to install the base. We have some latitude in this decision but it will be controlled somewhat by the type and design of the car, the type of equipment installed in the car, distance from the equipment to the antenna, your personal desire, and last but by no means least, the XYL's commands. If you really want that additional 3 db. you had better sell her first. That is, sell her on the idea. The rest is easy. It has been well established that, at least for 10-meter operation, the best location is on the left front fender a foot or so ahead of the car windshield. It has also been fairly well established that this same location is best for operation in the lower frequency bands. It has other advantages. It allows the use of a short transmission line, proper base elevation above ground, and the possibility of keeping the antenna clear of car structure and body contours. The next best location is on the rear deck, above the trunk lid, and on the left side of the car. This also provides proper base elevation. The first location is the only good location if you have a station wagon.

Height of Elements

In any case the base mount should be installed at an elevation of about 36″ from the ground. Unless you have mighty high bumpers this eliminates bumper mounts. The elimination of bumper mounting also eliminates much undesirable antenna directivity and pattern distortion. By mounting the base at the 36″ level, using a 36″ standard base support rod, a loading coil, and a standard 60″ top whiprod the coil is about halfway up the antenna from ground and is where it should be electrically. As mentioned earlier we are looking for the best possible compromise and this is it. If you have read the article by W2FRQ, you know that if radiation resistance and loss resistance are equal you are throwing away half the antenna power. All we are attempting to do is to reduce the loss resistance to the lowest possible value and increase the radiation resistance to a high value. This you do not do by correcting any single error in design but rather by doing the right and proven thing at each point. The basic antenna design is that described in this paragraph but don't let that fool you. The details of design control the payoff.

Re-inforcement

It has been stated earlier that the base mount should be adequately backed up with substantial reinforcing. Not only is this essential from a structural standpoint, but it is also necessary in order that a good low resistance ground termination may be had. The sheet metal sections of a car are rarely bonded together electrically in a manner providing good low resistance continuity. This backing plate therefore, serves two purposes. It supports the base mount so that sway of the antenna is eliminated and it also aids in fixing an adequate ground of low resistance. It should be bonded directly to the car frame with heavy braid or flexible cable. The necessity for doing this cannot be emphasized too strongly.

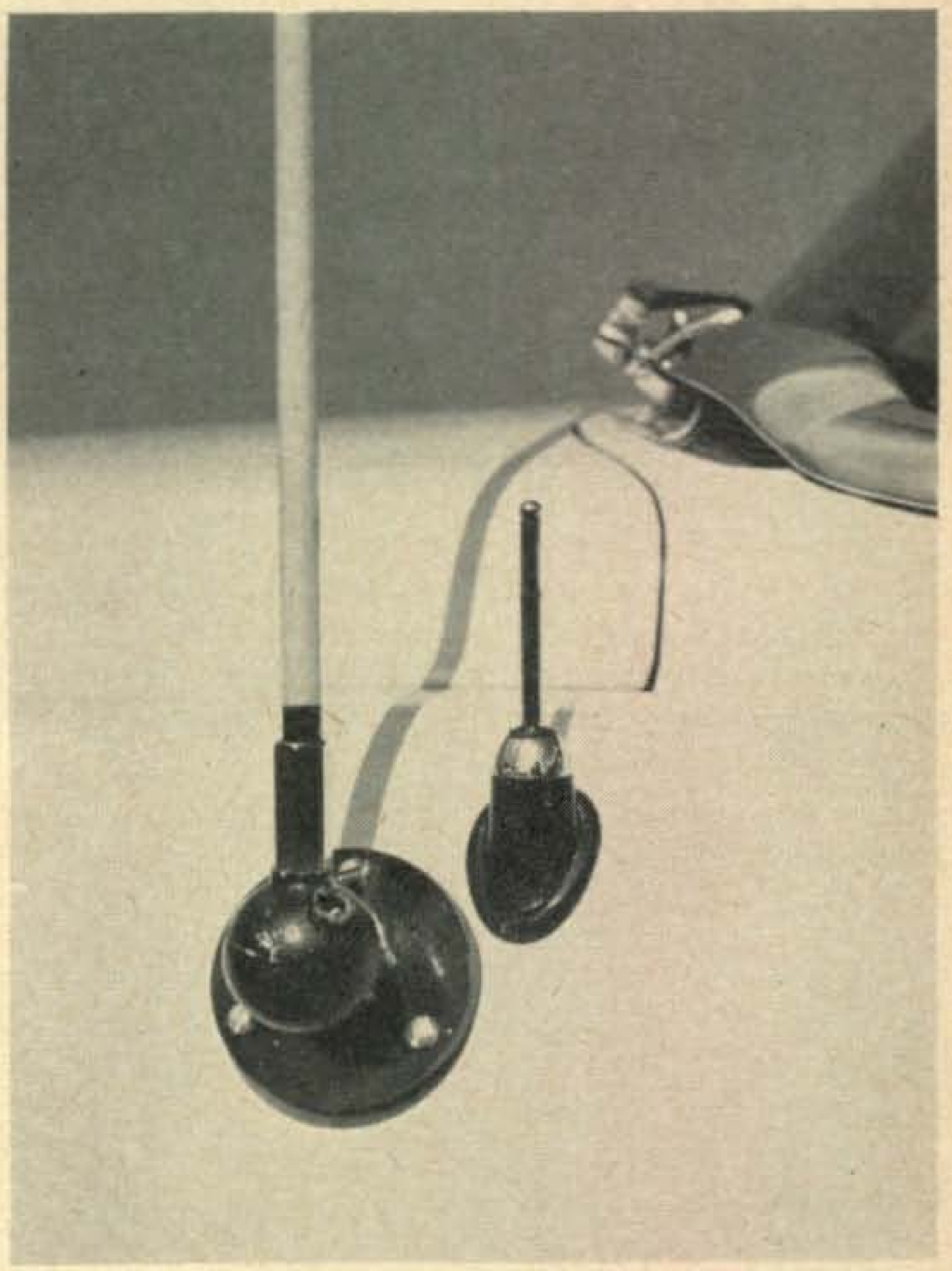
Base mounts with coax terminations built in are attractive, but should be avoided. They are a source of great trouble in that through constant motion and vibration, they eventually work loose and cause intermittent operation. When this occurs, they begin to build up high resistance through contact corrosion, and losses skyrocket. If, for some reason, they must be used, it is suggested that they be modified to include a machined insulating tube around the female connector capable of furnishing constant pressure thus prolonging the period of usefulness before the two parts loosen and corrode. There is no substitute for a well-soldered connection.

Loading Coil

This brings us to the meat in the nut in mobile antenna design which is the loading coil. All of the before-mentioned factors can be perfected to a high degree, but if very great care and attention is not paid to the loading coil, nothing will have been accomplished. It has been truthfully said that right here the success or mediocrity of the mobile antenna is determined. In coil design and construction there is considerably more than meets the eye. It is, in fact, quite impossible to visually inspect a coil and guess correctly what its efficiency is. One little design defect at this point can turn the 50-watt transmitter into a poor 25-watt one. A single, seemingly unimportant correction can readily double its effective power.

Q

Fundamentally, we must have a loading coil of the highest possible Q with the smallest possible physical dimensions. This is a big order, but we obviously cannot stand a large coil because of weight and wind resistance again building up the sway and lean. We must have very high Q in order to insure lowest possible loss resistance. Careful design consideration and intelligent selection of the best compromise is in order. Other considerations also are present. A mobile antenna, for example, that is a "fair weather" device only, is not too desirable. The only answer to this problem is sealing the entire loading coil in some manner so that in the rain there is no change in dielectric or conductor diameter, which in turn would cause detuning. This means, of course, complete sealing of the hermetic variety and not simply surrounding the coil with shields that breathe, leak, sweat, or just look good. What self-respecting amateur would subject his final amplifier tank circuit to rain, dust, and varying humidity in saturated salt spray and expect it to remain efficiently in tune while swinging across the countryside over varying earth conditions? In a measure this antenna loading coil is also a delicately balanced tank circuit, must be well protected, and should be treated with respect. You can pick up 3 db. or more by doing so.



For maximum Q: Base 36" high, no spring. Shown is best location for omnidirectional field.

Form Factor

Time and effort spent in designing a really efficient loading coil will pay off handsomely. Form factor must be taken into consideration along with proper mechanical support and many other things. An "air-wound" coil is always preferable to one supported by a solid dielectric. The largest possible wire diameter should be employed consistent with practicability of the finished product, the power level involved, and the frequency of operation. It is, for example, useless to end up with a coil having definitely superior electrical qualities if this coil is so huge as to cause excessive wind resistance and have such weight that the antenna supports will not carry it.

Good compromise calls for the lower frequency band coils to be wound with number 18 wire, the medium frequency band coils to be wound with number 14 wire, and the higher frequency band coils to be made of number 12 wire. In each case good form factor demands that the coils be about twice as long as their diameter. These "air-wound" coils can then be supported within sealed insulating tubes having sufficiently high strength to withstand the rigorous treatment to which they will be subjected. They should not be sealed within metal housings nor should they be encapsulated within a solid dielectric material.

Sealed Coils

A newly developed series of coils of this type is sealed within chemically-welded acryllic housings from which the air has been removed by vacuum pump and then replaced with pure helium. This makes them impervious to moisture change, dirt, salt spray, and the like, and assures constantly high operating efficiency. Coils of this type have a measured Q of better than 400.

Optimum Dimensions

For those fortunate enough to have access to good test equipment, including a high quality Q-meter, the following tabulation of inductance and dimensions is sufficient to enable them to build their own coils for each band:

Band	Microhenries	Number Turns	Wire Size	Diameter
75	107	55	#18	2½"
40	32	30	#14	2½"
20	7.5	11	#12	2½"
15	1.85	4	#12	2½"

These coils should be of the air-wound type, rib supported, with the turns spaced about the diameter of the wire. In all cases they are based on using a 36" lower support rod and a 60" top whiprod. Some final adjustment will be required after installation due to differences in winding technique, distributed capacity, and other factors. When a mobile antenna is installed the coils should be left alone if they have been properly designed in the first place. It is never advisable to upset their form factor or in in any way chance destroying the Q of the coil. Adjustment of the antenna to frequency can be made quickly and easily by top rod adjustment. If coils are made in accordance with the charted data, very little frequency adjustment will be required.

Multi-band Operation

At this point it will be apparent to the reader that we have been discussing individual loading coils only. One for each band employed. This article is concerned only with designing the best possible mobile antenna from which the greatest possible radiation can be obtained. All multiband loading devices must sacrifice efficiency in favor of convenience. There has never been built a multiband loading device that can begin to approach the efficiency of the antenna system herein described. The shorting of a single turn in the loading coil can chop the Q in half. Anything inserted in, or near, the coil field will put you right back where you started, or worse. Sliders, rods, switches, variable condensers, slugs, taps, clips, or even a piece of wire, if inserted within the field, will start the process of Q destruction, loss resistance increase, and field strength reduction. By using individual coils we are shooting at maximum possible efficiency. Convenience must therefore be sacrificed. Take your choice. You can either have a very good "one coil per band" antenna or a relatively poor "all band" model. You cannot have both.

The *average* mobile installation is not of the calibre where quick band-change, including the antenna, can be accomplished while the vehicle is still in motion with any degree of safety or convenience anyway. This type of mobile operation is coming, but it just is not here yet. The *average* mobile installation is a single band affair, or, at least, is primarily used as such. For the time being the only answer to antenna efficiency lies in having a set of good loading coils, one for each band employed, and, if you want to live to a ripe old age, stop your car and change both at the same time, equipment and antenna coil, when shifting from band to band.

Preliminary adjustment of the antenna can be made with a grid dip meter. Final adjustment should never be attempted with this instrument. If you have made your coils in accordance with the chart, you will probably find that using the grid dip meter at all is simply a waste of time. You will probably be able to insert them, one after the other, and discover that your antenna "loads" with all of them. We are, however, shooting at considerably more than just "loading" which is not an expression of radiation efficiency. It is, however, a step along the way. What we want is a set of coils to cover all amateur bands when used with the same top rod length. The chart is designed to give you such a set of coils. It is more difficult to secure resonance within the 75-meter band than in any other band. This is the place to start checking.

75 Meters

The 75-meter coil shown on the chart is designed to center, with the rod lengths stated, at 3900 kc when operating, and not by grid dip measurement.

You should fire up your transmitter and determine that it will center there. It will cover approximately 50 kilocycles either side of this center with fair efficiency although it should be used on center for maximum efficiency. This may be all of the 75-meter band you will ever care to cover. If it is not, and you wish to cover the entire band, you must resort to capacitive tuning.

It is not possible to design one coil, or one antenna, with sufficient bandwidth to provide anything resembling efficient operation over such a wide frequency range as the entire 75-meter band or even between 3800 kc and 4000 kc. You cannot tap the coil and move inductively. You cannot place a variable condenser in, or near, the coil field. You cannot place an adjustable slug within the coil. There is only one answer. The distributed capacity of the entire antenna system must be changed or the inductance must be changed. In either case, this means that the top tuning element, above the coil, must be modified. There is nothing you can do to the coil and there is nothing you can do below the coil that will not louse up the antenna efficiency. This includes inserting variable inductors, motor driven or otherwise, at the base of the antenna.

Top Loading

The addition of a very small capacitive device, "hat," strip of aluminum, wire, or rod firmly attached to the top whiprod is the only good method. When this is attached it then becomes necessary to adjust the top rod length in a manner so that with this device located some distance up the top rod, you can achieve resonance at the 4-megacycle end of the band. The device can then be moved down the top rod, closer to the coil, to predetermined locations, for satisfying resonance at lower frequencies in the band. This hat will cause some swing and sway and is to be recommended only for those who must cover the entire band quickly and are willing to sacrifice some efficiency to this end. A better method is to carry along more than one top rod and change to a different length if necessary. You will experience no difficulty at all in covering the other bands higher than 75 meters with but a single rod and without tuning devices. This complication is applicable only to the 75-meter band.

Top Rods

On the subject of top rods, here too the best compromise must be selected. The top rod is essentially a tuning element and not a radiating one. Most effective radiation takes place below the loading coil.

Whipping around of the top rod can cause more detuning, mismatch, changing plate loading, and SWR, than motion of any other antenna section. If the top rod "leans" this can usually be compensated for by equipment adjustment. If it wobbles all over the sky while you are driving you are licked. A heavy metal top rod is definitely not the answer. A slim, stiff, lightweight metal rod is better. The newer, very lightweight fiberglas top rods are better yet. Standard fiberglas rods of the proper length are now being made that will stand up practically straight at any car speed and will not flounder around when the brakes are applied. If you select one, make certain that it is equipped with a metal corona ball and not one of plastic. With a really high-Q coil at 4 megacycles you can actually burn the plastic ball right off the top of the rod.

Final Adjustment

Now for final frequency adjustment of the antenna. Again let us say that if your coils have been properly made in the first place, it is a serious mistake to prune them. Set up the antenna and fire up the transmitter. With antenna resonance somewhat on the low side, which is where it will be, you are ready to go. If you use a pi-net output circuit in your transmitter it is a relatively simple job at this stage to trim the antenna to exact frequency. With the antenna somewhat on the low frequency side it will exhibit inductive reactance and the transmitter will "load" only with a minimum of pi-net loading condenser. By trimming the top rod, fractions of an inch at a time, the pi-net loading condenser will start coming in and more capacity will be required each time the rod is trimmed. When you arrive at a point where from 300 $\mu\mu$fd to 500 $\mu\mu$fd is being used to properly load your final, you are there. Go no further, it is tuned.

If you have made your coils according to the chart, you can now shift from coil to coil and you will find that your antenna is properly adjusted for all bands. About the same amount of pi-net loading condenser will be used on each band. This is the time to begin finding out what you really have accomplished.

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Hermetically-sealed Helium-filled case permits extremely high Q in this loading coil.

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Measurements

This is not too easy to do. Right here you need a lot of expensive test equipment or, in lieu thereof, a lot of patience. If you do not have access to the high quality test equipment, you may be forced to test your antenna in "on the air" measurements. These can never be wholly relied upon and depend to a great extent on band "conditions" over an extended period of time. At any rate if you cannot secure high quality test equipment, do not get any. Even the best is not yet good enough in many respects.

Impedance/Efficiency

Many comparative measurements have been made with a representative antenna built in accordance with the data contained herein. Using a General Radio Model 916A bridge, this antenna will exhibit a terminal impedance of 25 ohms. The average mobile antenna employing a coil of poor form factor, and half the Q, and wound on some poor dielectric, will hardly achieve half this impedance. Most will measure 10 ohms or less. At a specified power input level the base current of the 10-ohm antenna will be somewhat less than the base current exhibited by the 25-ohm antenna as measured with a radio frequency ammeter. So there you are, and where are you? You have an antenna power better than twice as great and with the same power input. You have just managed to get something for nothing and you should feel pretty good about it.

Feed Line

There are a number of ways of feeding power from the transmitter to such an antenna. They have been adequately discussed elsewhere and often. A very short length of RG-8/U is customarily employed. If longer lengths are used there is always the possibility of running into reactive difficulties. In such cases the best bet is to use a one-half wavelength line of RG-8/U. In any case, the antenna being 25 ohms, there is always the possibility of using two identical lengths of RG-8/U in parallel and coming up with a "perfect" impedance match. Handbooks should, of course, be referred to for methods of feeding. Here we are interested only in having something to feed.

Follow closely the suggestions contained herein and you can come up with a mobile antenna that will enable you to pick 3 db. or more, as compared to "just another mobile antenna" as a reference. You will discover that communication can be maintained where the usual mobile system fails.

Do not be surprised if you cannot successfully compete with a fixed station on the same frequency using a kilowatt and a three element beam. A few kc away from his frequency, however, you will find that you can work nearly everything that he can. An antenna of this design has been instrumental in working WAC mobile over and over again. It has worked Australia the long way around in the middle of the afternoon, and has worked western Ausralia, the furtheset point on the globe from the East Coast, the short way around at midnight, right through the West Coast QRM.

Amateur Utopia can be defined as possessing an antenna system capable of working anything you can hear. With this antenna many calls have been answered by stations that were actually too weak to copy. What more can anyone ask for? Careful study of the material furnished herein, together wtih the data supplied by W2FRQ, will pay off handsomely. If you can double your effective radiated power without increasing your power input you can really get something for nothing the easy way.

Ham Club and the Law

[*from page 15*]

cited where liability could attach to innocent club members to make everyone who is a member of an unincorporated club take a long hard look at the danger.

Here are just a few examples of how liability can attach to you.

A. The club plans a picnic, or a transmitter hunt, or an outing. Someone drives his car recklessly and a stranger gets hurt. If the club is unincorporated, every member could be involved.

B. The club buys a club transmitter. Everyone may become liable for the full purchase price.

C. Someone leaves some equipment in a dangerous condition and an accident occurs. Again everyone may become liable.

The examples could fill a book. It is just not possible to foresee every potential source of danger.

The Remedy

Unlike the partnership or joint venture, a corporation is an entirely new and separate entity and separate and distinct from its members. The general law imposes no liability or responsibility on the individual members for the debts or obligations of a corporation.[4] One member is not liable legally for the acts, negligence or carelessness of another member.[5] This is true even if the corporation is itself liable for the acts of its members. Thus, in one of the examples mentioned above, let us say that on a field day trip, an accident occurs and someone is injured. The person who actually did the act will, of course, be liable. The corporation may be also liable but the other members will not be liable unless they actively participated in the act of negligence themselves.

This aspect of limited individual liability makes the incorporation of amateur clubs highly desirable. More and more clubs are