TRANSMITTING ANTENNAS
and
GROUND SYSTEMS
for
1750 METERS

Edited by Michael Mideke

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INTRODUCTION

This collection of articles on 1750 meter transmitting antennas, grounds and related topics includes most of what has appeared on the subject in THE LOWDOWN since 1980. Other material has been drawn from the 1750 METER WESTERN UPDATE. I have added a section on ground systems to fill some minor gaps in the existing material. Additional notes and illustrations are being added on a space-available basis as the cutting and pasting proceeds.

In assembling this collection I've indulged my own inclination to browse and compare, and the result is somewhat redundant. Anyone wishing to put up an effective antenna can refer to any of the three basic articles (Phillips, Pinto or Lee) and learn what he needs to know. Although emphasis varies, the authors all start from the same general premises and arrive at the same general conclusions.

But if you are looking for ideas or seeking the most practical solution to some particular problem, it will be well worthwhile to study all of the authors. Even if none of them address your immediate concern, it may be that their combined ideas will suggest an answer.

For the most part these articles deal with one basic antenna type: the vertical radiator with inductive base loading and capacitive top loading. While there are those who grumble about inefficiency and maintain that this is not much of an answer to the problems of radiating a signal at LF, these antennas have at least two important things going for them - they work and, if constructed to the appropriate dimensions, they are acceptable to the FCC.

It may well be that there are more efficient transmitting antennas for the purpose and it may be that such antennas can be constructed within the dimensional constraints of Part 15. Thus far I've not seen what I consider to be a proven design. Keith Olson (7FS) has been doing interesting work with 1/10 scale helical antennas on 160 meters.

The scaled down approach has a lot of merit. One can find out whether the design works before confronting the difficulties of actually implementing it on longwave. These difficulties are far from insignificant; 15 meters is very small in terms of our wavelengths but it is a big hunk of space in the backyard. Mechanical, electrical and adjustment difficulties abound! I hope the following pages will help to smooth the way.

Michael Mideke- November 1987

TRANSMITTING ANTENNAS FOR 1750 METERS

BY ED PHILLIPS W6IZJ

As mentioned in the introduction (Vol. 7 #1 p 8), successful transmission requires that the transmitting antenna be of maximum possible height, and losses in the antenna and ground system be as low as possible. I shall now describe some general properties of small VLF antennas and their ground systems, and give examples of what you may want to build. The antenna system will first be considered from a constructional point of view, and the electrical properties will be discussed in their relation to the coupling system design and construction. The parameters of the antenna as a circuit element will be given next, followed by the design and construction of the circuits for coupling the antenna to the transmitter, together with methods for their adjustment.

In practice the design of your antenna system may be dictated by the space you have available, as is true in my own case. If your space is limited don't give up, but put up the tallest thing you can, as far away from trees and buildings as you can, and then give it a try. You may be pleasantly surprised!

There are no mysteries to working at 175 KHz, since use of this frequency goes back to the very earliest days of "wireless". In fact, any good old wireless book has a wealth of useful information on antennas and grounds. The advice is excellent but hard to follow. A. P. Morgan's "Wireless Telegraph Construction For Amateurs" (1911) devotes chapter 3 to "aerials and earth connections". A few quotes are of interest:

"In fitting up a wireless station the location and erection of an aerial are of prime importance, and the successful reception and transmission of wireless messages will depend largely upon its condition."

"The higher an aerial is placed above the surface of the earth, the wider will be its electrostatic field, and consequently more powerful electric waves will be developed. But after a height of 180-200 feet is attained, the engineering difficulties and the expenses increase so rapidly that few stations exceed it. Other things being equal, the increased range in transmitting varies as the square of the height of the radiating wires. For example, a 25-foot aerial capable of transmitting one mile theoretically will send waves 16 miles if made 100 feet high.".

"After the limit in a vertical direction has been reached, the only remaining possibilities are to increase the surface and spread out horizontally."

"Ground connections--the importance of a good earth or ground connection can hardly be overestimated. Whenever possible commercial stations are located on moist ground or near a body of water so that a good ground may be secured by imbedding zinc or copper plates in the earth or water."

These quotations are still pertinent today, although note that the quantity which varies as the square of the antenna height is the radiation resistance, not the electric field produced by the antenna, as Morgan implies when he says that increasing the height by four times increases the range by 16 times. However, because of the increase in antenna system efficiency which goes with the increase in height, his remarks about increasing the range of the station are almost correct. A few things I did not quote are also pertinent, especially his remarks on making the antenna installation strong enough to withstand any possible weather, and providing the antenna with a grounding switch for use when lightning is possible. He also emphasizes arranging the antenna so it cannot fall down across power lines, thereby leading to all sorts of unhappy events.

The antennas which Morgan describes are all tall structures with some form of "flat top" or capacitive top loading. Figures 1 and 2 are copied from E. E. Bucher's "The Wireless Experimenters Manual" (1920), and illustrate two methods of constructing an antenna with top loading. In each case the loading consists of a group of horizontal wires spread out as much as possible to increase the capacitance to ground. The purpose of this top loading is to increase the current at the top of the antenna, thereby increasing its radiation resistance. The radiation resistance of an antenna is a fictitious resistance which, when multiplied by the square of the current flowing in the base of the antenna, gives the radiated power; increasing the radiation resistance increases the power radiated for a given antenna current. For a very short antenna the radiation resistance is proportional to the squares of the effective height and of the frequency. For an unloaded antenna 50 feet high the theoretical radiation resistance at 175 KHz is only 0.0312 ohms! This is only a very tiny fraction of the minimum total resistance with which the antenna system can be built, and shows the importance of keeping the losses as low as possible. As an example of what this means, if the antenna current is 0.2 amperes, a typical value for a one watt transmitter and fairly low loss antenna system (sum of ground and loading coil resistance equal to 25 ohms), the radiated power will be only about 1/800 watt, and the efficiency will be only 1/8 percent!

For a straight vertical radiator whose length is a small fraction of a wavelength (the wavelength of a 175 KHz signal is 5620.4 feet) the antenna current decreases linearly to zero at the top. If capacitance is added at the top, the current there is increased. If the current at the top is equal to the current at the base the radiation resistance will be four times that of an unloaded antenna. For the example given above this would mean an increase in radiation resistance to 1/8 ohm, of radiated power to 1/200 watt (5 whole milliwatts!), and the efficiency would be 1/2 percent. The effective range of the station would be doubled. Now that I have discussed the merits of top loading I must point out that in all probability you will not be able to use very much of it. I have no idea how the FCC would feel about antenna installations like those in the examples above, particularly if the height of the vertical section is the magic 15 meters, but it is doubtful that they would be very happy. If we fudge the 15 meters to 50 feet, which was in the old regulations before the FCC "went metric", a literal interpretation would say that a single vertical conductor 50 feet long is all that is legal, and if the matter ever came to an argument I am sure that is what the ruling would be. (The best way to win such an argument is to avoid it: keep your signals clean and your out of band radiation to a minimum and you will not bring attention to yourself.)

Two points regarding top loading may be in order. First, if we accept the total length of the antenna to be 50 feet, then there is no advantage to reducing the height of the antenna and running part of it horizontally to produce top loading. If you can get 50 feet use it. If not, then make the vertical section as tall as you can and add top loading to bring the total length to 50 feet. An "L" shaped antenna will be slightly better than a "T" shaped one in this case. Second, in principle the top loading can be made more effective if the antenna loading coil (or part of it) is placed at the top of the antenna. Examples of such tuned top loading circuits for use on 160 meters are given in "The ARRL Antenna Book", which is recommended reading, particularly in the older editions which may be available in libraries or from long time hams. I believe that the problems in adjusting such loading coils, together with the fact that their losses will probably be excessive, makes such techniques of little or no value for 1750 meters, and I recommend their use only to the advanced experimenter. In the discussion to follow only base tuning will be considered.

Let us now consider some specific antennas. Figure 3 shows an antenna similar to the previous examples; it is "best but clearly illegal". A 50 foot vertical wire is top loaded by a flat top of horizontal wires, supported by wooden poles. The whole setup is placed over a salt water ground plane, which serves two important purposes. First, a connection to the salt water provides an effective, low resistance ground system. Second, the effect of the salt water is to make the resistance of the ground plane under the antenna very low. This minimizes the losses due to the currents which flow in the ground under the antenna due to capacitive coupling; they are a very important component of the total antenna (as contrasted to the loading coil) loss. More of this later. The only purpose of this example is to show what could be done if the FCC restrictions are ever lifted.

Before discussing "how to build an antenna" let's consider "where to build it?" The environment in which the antenna system is installed is the hardest part of the system to control, but it is of great importance in determining the antenna's overall performance. Because of capacitive coupling from the radiator, RF currents will flow in every object near the antenna, and the presence of electrically lossy material will increase the losses in the antenna circuit. (For all practical purposes only things within a radius equal to the height of the antenna are important loss contributors.) Any buildings or vegetation will have significant electrical loss, and detract from the antenna performance, so the first rule to try to follow is to keep the antenna at least 50 feet from any trees or buildings. This means, of course, that you have to run power and control leads out to the base of the antenna, and they may be inconveniently long.

Even if there are no objects above ground in the vicinity of the antenna, the ground itself can and will provide very significant losses. All of the current which flows in the antenna must return in (or on the surface of) the ground, and most soil is very lossy. For this reason it was common practice in the early days of wireless to locate transmitting stations at salt marshes, and build the antennas over them. In addition, hundreds of conducting cables were laid in or on the ground under the antenna to further reduce the loss, with some installations having literally hundreds of miles of them. These practices are still necessary and are still followed, in spite of the immense cost associated with them. In the case of simple vertical towers the ground system usually consists of "radials", or wires radiating from the base of the antenna in all directions to a distance at least equal to the height of the tower. The radials are usually buried beneath the earth with a special plow, in order to get them out of the way.

In principle there is a clear distinction between radial systems and ground systems. The primary purpose of the radials is to eliminate losses due to currents which are induced in the ground by the electric field of the antenna, and even fairly short radials accomplish this. However, there are still currents flowing in the ground beyond the radials, and a conventional ground is often needed in addition to the radials. If the soil conductivity is poor the radials, together with a few ground rods and a connection to the water pipes, will probably be about the best ground that can be hoped for.

E. A. Laport gives an excellent description of ground systems in his "Radio Antenna Engineering", McGraw Hill, 1952. Section 1.12 discusses VLF ground systems, while section 2.5 describes broadcast antenna ground system design. The latter section is of most interest, since in it he gives data on the performance of a simple vertical radiator with various lengths and numbers of radials. The results may be very crudely summarized by saying that radials of length equal to the antenna height are almost as good as those of infinite length, and that a length of half the antenna height (outside diameter of radial system equal to antenna height) is about 2/3 as effective as very great length. Furthermore, 2 radials are about half as good as a very large number, and 16 radials are within a few percent of being as good as 112. Applying this information to our hypothetical tower installation, we can say that it will be near to ideal in performance if the tower is at least 50 feet away from trees and buildings, and if the ground under it is provided with 4 or more radials whose length is at least 25 feet and preferably 50 feet. Improvements will result from more and longer radials but the increase in performance is probably not worth the extra trouble. The size of the wire used for the radials is not particularly important, so long as it is strong enough to withstand whatever mistreatment it may experience in installation, and even galvanized iron clothesline wire will do in a pinch.

Unfortunately, it will be very hard to find room for this "ideal" antenna installation, and you will probably have to fall back on the advice I gave above. Make the antenna as high as you can, as far away from trees and buildings as you can, put down as many radials as you can find room for, and feel that you have done your best. Your antenna system will certainly work, and the results will probably satisfy you. In this discussion I have omitted one thing which may be of interest to those who really have a lot of space and ambition. The laying of the radials in or under the ground is done mainly to keep them out of the way, and results in an increase in loss because the current must "flow" through the ground to reach them. A better practice, but one which is much more awkward, would be to place the radials above the ground by several feet. I doubt if the difference in performance would be noticeable, but it would be a noble experiment. Such installations are called "counterpoises", and were fairly common in the early days of wireless. They might still be of considerable interest to someone who wished to install his antenna on top of a house, where the length of the ground lead would be considerable. The counterpoise would be installed on top of the roof, with as many radiating wires as possible, run out as far as possible. It would probably be OK to run them over the edge of the roof and down to ground level. I have an idea that such an installation might work very well, since it would place the antenna well out of the way of most trees, and would also be convenient for the use of guy wires.

As an example of an installation which violates most of the rules given above, I will use my own antenna system to show "what not to do". The tower is installed in the only spot my wife would permit, between the "radio room" and the driveway. One wall of our house is only two feet away, and extends up to the 30 foot mark. Two large oak trees grow within less than ten feet of the tower, and numerous camellia bushes are planted near the base. The soil in our neighborhood is shallow, with loose gravel and boulders underneath, and the water table is at least 100 feet down. I have a fairly good ground connection in the form of a number 4 wire running to a recently installed copper water connection to the street. The pipe has a total length of about 200 feet, but there are no radials and I have no space to put them. The total resistance of my antenna system at present is about 65 ohms, although when I first installed the VLF gear and had the oak trees pruned way back I measured something like 25 ohms, and could get about 0.22 amperes antenna current with one watt input to the final. I believe that in this installation the loss due to the trees is dominant, although as a second factor all of the surrounding ground is very dry due to being under houses and driveways. Cliff Walker has a much simpler antenna in the middle of his back yard, with a water pipe ground, and puts out about twice as strong a signal as I do. I think the absence of the big trees is one major difference, and the presence of a watered lawn beneath the radiator may be another.