CONSTRUCTING EFFICIENT HELICAL ANTENNAS

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A simplified design method is presented for anyone who would like to construct a reduced length antenna in a restricted space and take advantage of the proven superiority of helical loading techniques.

IT HAS been proven by the tests of many antenna designs that helical inductive loading is superior to lumped impedance loading—such as the usual center or base loading coil scheme. Helical loading provides both a form of inductive loading and capacitive loading and the bandwidth and impedance restrictions are far less than with lumped constant loading.

Which form of loading can be used, however, often depends upon the physical conditions under which an antenna is used. In a mobile situation, for instance, the bandwidth restraint imposed by lumped inductive loading of a whip is often accepted because of the ease of constructing such an antenna. Some mobile antennas are available using helical loading but they are not easily constructed by an amateur in his workshop and the small diameter rod used only minimally allows the advantages of the helical construction to be realized.

The home station situation, however, where some additional space (although not enough for full size antennas on all bands) is available presents an ideal opportunity to utilize helical construction. For instance, such a form of antenna, even for the low-frequency bands (80 and 40 meters), can be constructed using a diameter of a few inches and roof or attic mounted. The efficiency will not be that of a full-size dipole but certainly it will be superior to any form of lumped constant loaded antenna. If the diameter of the form used to support the antenna can be made large enough, the helical may also have some unique advantages when a horizontally polarized antenna is desired but where space constraints do not allow the antenna to be aimed "broadside" to the desired direction.

The advantage comes about, as shown in fig. 1, due to the changing radiation pattern of a helical antenna. Figure 1(A) shows a conventional helical loaded ½ λ dipole. As with a regular dipole, the usual figure eight radiation pattern results with the maximum radiation "broadside" to the antenna. However, as the diameter of the dipole helical winding is made larger, some axial mode radiation develops as shown in fig. 1(B). There is no exact study data available to confirm the extent of the axial radiation for dipole antennas. It seems probable, however, that when the diameter approaches the lineal length of one half of the helical dipole that the axial radiation will be about as strong as the broadside radiation. In its extreme form axial mode radiation is used as a basis for a u.h.f. helical antenna with very high gain and directivity having essentially no broadside radiation.

This brief article presents a simple design method to build a helical antenna when one knows a bout what space is available and wishes to fit an antenna into that space for operation on a particular band. The design method allows for options regarding the diameter of the helical antenna in case it is desired to try to take advantage of the axial radiation possibilities of the helical design.

Design Method

Figure 2 presents the basic design chart for a helical as a function of its various dimensions. The chart is not based upon a certain frequency and so can be used to design an antenna for any one of the amateur bands. The

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See page 126 for New Reader Service

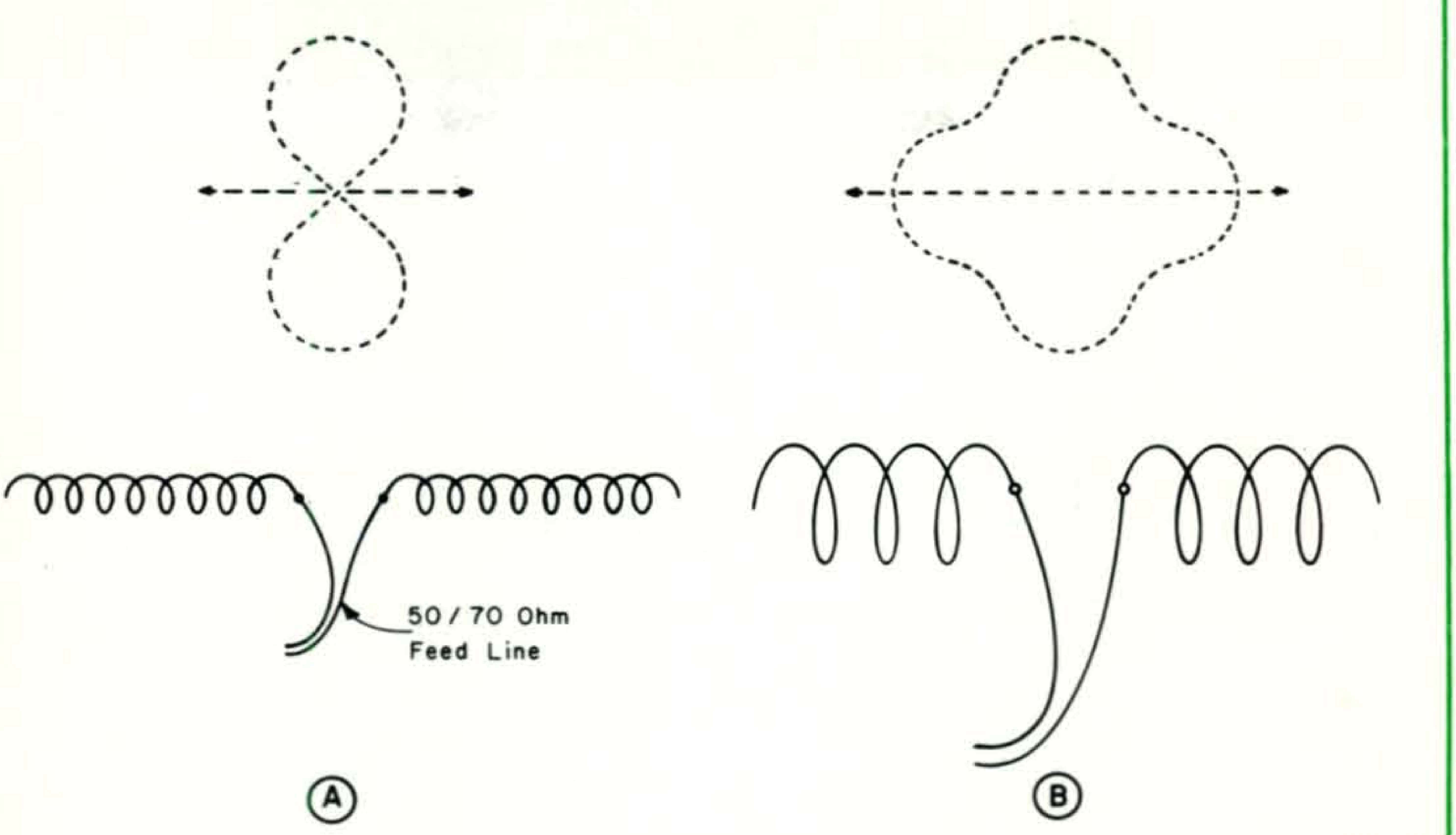


Fig. 1—Small diameter helical dipole has radiation pattern similar to normal dipole (A). As diameter is increased, however, some axial radiation occurs to make pattern more omnidirectional (B).

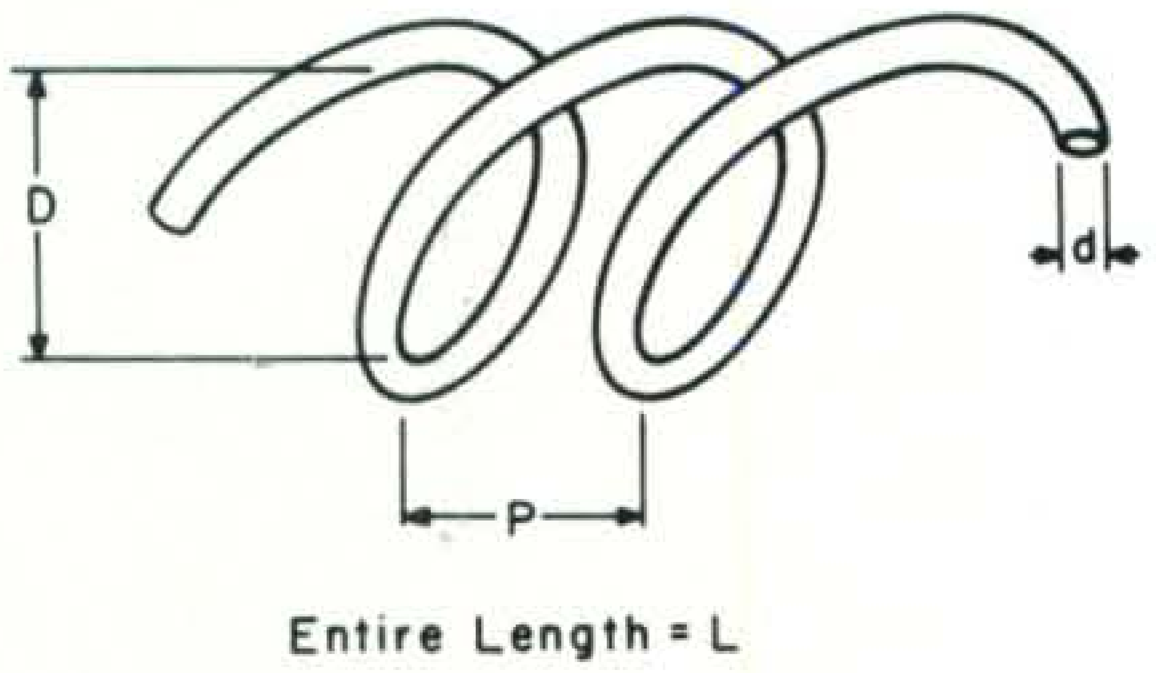
meaning of the various letter symbols is shown in the illustration of the two turn helix in fig. 2 and should be clearly understood (both *d* and *D* are diameters). Being in absolute terms, the chart can be used either with inch or centimeter dimensions, whichever is most suitable for the reader.

The basis of the chart is linked to fitting an antenna into the space available as seen from the vertical axis of the graph. From the space available one determines by what factor a full-size antenna must be reduced and then, from the graph, find the helical antenna dimensions which will suit this antenna size reduction. The one dimension ratio which is not covered on the graph is d/D. The chart is based on a nominal d/D ratio of 1/10 but actually will remain fairly accurate as this ratio goes from 0.01 to 0.3, a range which covers most of the practical construction needs for a fixed station situation. In general, however, the largest wire diameter (d) is desirable from the viewpoint of reduced losses and maximum antenna bandwidth.

Tubing, of course, is excellent material to use if one can bend it propertly. Coaxial cable (using the shield as a form of flexible tubing) is also excellent for use where one can make some support (such as in an attic) upon which to wind the cable. The cable need not be in new condition and in fact can have suffered internal dielectric damage as long as its shield is intact so surplus cable at bargain prices, which one may have to be very wary of for use as a coaxial transmission line, is perfectly suitable. The chart is based upon circular windings and the closer the windings are to this form the more accurate the chart dimensions will be. Discontinuities and sharp bends in the windings will distort the radiation pattern. However, if the pattern is not too important and one just wishes to construct a general coverage antenna for 80 or 40 meters in a given space there is no reason why the windings cannot be diamond-shaped so that construction is greatly simplified using a simple wooden support frame.

Design Example

The use of the design chart is best illustrated by a simple example. For instance, suppose the space available will only allow construction of an antenna 16½ feet long and it is desired to construct a 20 meter dipole (having a normal full scale ½ λ length of 33 feet). In this case, the length reduction factor is 0.5 and one enters the vertical axis of the chart in fig. 2 at this value. The D/L ratio is chosen as 0.01 (0.02 or 0.04 could also be used depending upon other factors as ex-



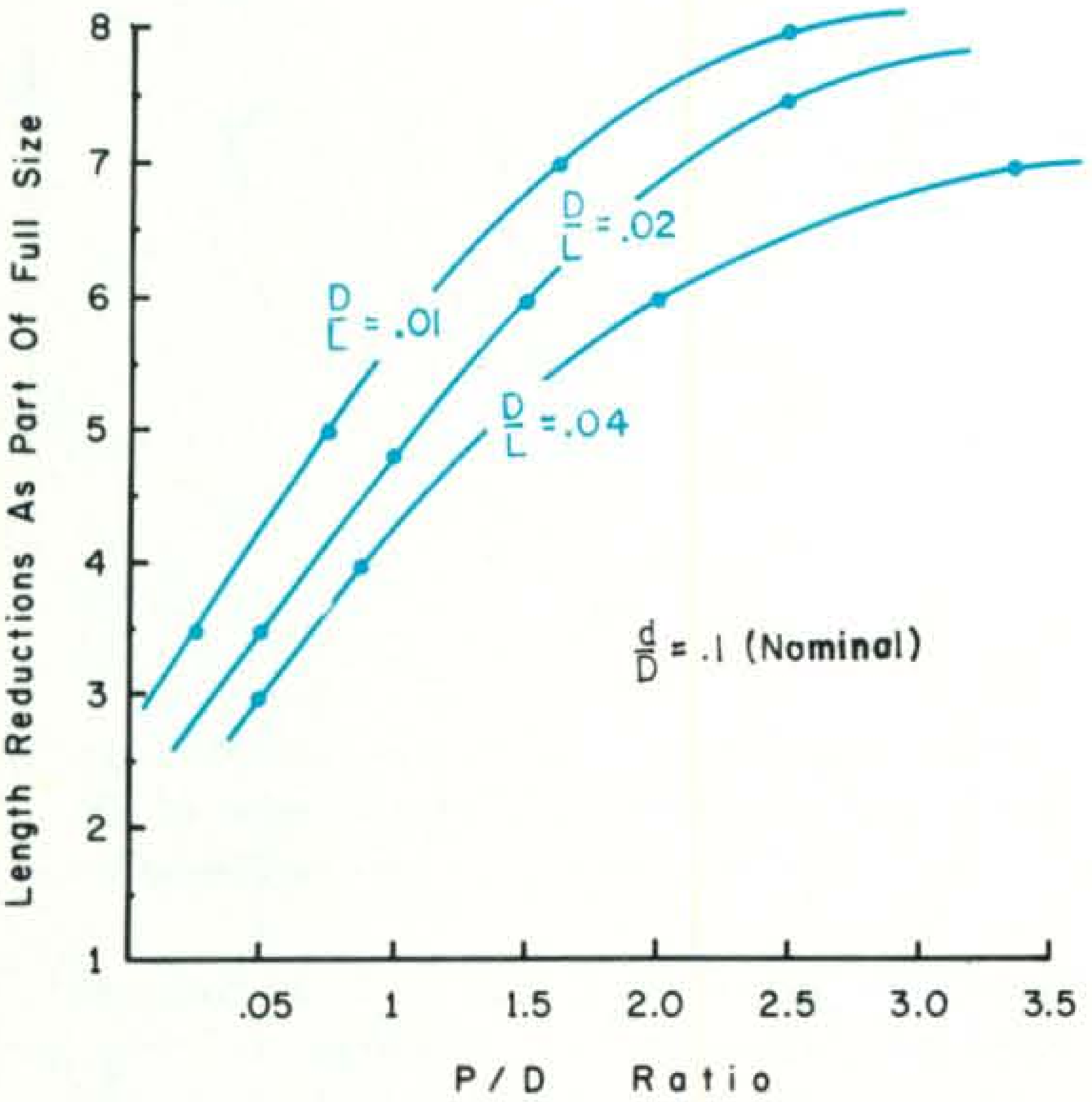


Figure 2—Graph to determine helical antenna dimensions based on size reduction desired.

plained shortly). Since L is 16½ feet, D is about 2″. The wire size used is approximate and determined from the nominal (d/D) ratio upon which the graph is based of 0.1. Diameter d is, therefore, $0.1 \times 2''$ or about the size of #4 A.W.G. If larger size wire is available it certainly can be used to advantage. The use of smaller size wire (down to a minimum d/D ratio of 0.01) has to be considered in terms of the transmitter power being used. The use of wire based upon the minimum d/D ratio of 0.01 would indicate about #24 A.W.G. Such a size of wire might be useful for flea power but would certainly produce terrible ohmic losses if not simply burn up when used with even a moderate power transmitter. Using the $D/L = 0.01$ curve on the graph, then, the P/D ratio for a 0.5 length reduction is found to be 0.75. The pitch is, therefore, $0.75 \times 2''$ or 1½″. The 20 meter helical antenna dimensions are then, in summary, $L = 16½$ feet, $D = 2''$, $d = \#4$ A.W.G. and $P = 1½''$. This information is sufficient to construct the antenna. The only question one may have is how much #4 AWG wire is needed. This can be calculated easily using the formula:

$$\frac{L}{P}\sqrt{P^2 + (\pi D)^2}$$

which simply represents the number of turns (L/P) times the lineal length of one turn if it were stretched out.

In the case of the example given, the total length of wire required comes out to about 70 feet. This may seem like quite a bit of wire to simulate a 33 foot long regular antenna but it is necessary because of the loading effect of the helical design. As a check of the graph, one could calculate the length of wire necessary if the reduction factor were only 0.8. In this case, the length of wire needed is only 36 feet which very closely approaches the normal 33 foot length.

Similar to the example shown, one can calculate the parameters of a helical antenna for any given band. The graph can also be used in reverse. That is, one can decide upon a certain diameter and then use the graph backwards to find the pitch, length and other parameters. Such a procedure might be employed when one wanted to make the diameter as large as possible to achieve more of an omnidirectional radiation pattern. Not all calculations will yield practical solutions. That is, wire sizes may be indicated which will not handle the transmitter power or lengths may be indicated which fall far out of the nominal $0.1 d/D$ ratio of the graph. This does not mean that such antennas cannot be constructed nor that they may not be efficient but simply that their resonant frequencies cannot be related to full size antennas in the same manner that others can which fall within the design range of the graph.

Construction

Used within its indicated limits, the graph of fig. 2 will yield, to a narrow tolerance, the parameters of a helical antenna. No graph, however, can take into account all the factors which modify an individual installation. Some provision, therefore, should be made for final adjustment of the helical antenna using either an s.w.r. meter or a grid-dip meter. Using either instrument, the helical should be tuned in its mounted position for correct resonance by allowing a few extra turns on the helix and cutting them off as necessary. The tuning becomes more critical

See page 126 for New Reader Service

as the length reduction factor is decreased.

Summary

The purpose of this article was to present a simple design means for relatively high efficiency helical antennas. The graph of ig. 2 goes down to a length reduction factor f about 0.2, which represents an 80 meter dipole in 24 feet of space. Certainly, helical antennas have been made much shorter than his on 80 meters but then one starts to enter he realm of relatively inefficient designs, estricted bandwidth and touchy tuning, a ituation comparable to using an inductively oaded mobile whip.

The bandwidth of a helical antenna with a ength reduction factor of 0.5 will be about he same as a full size antenna. A length reuction factor of 0.3 will usually allow roper operation over the c.w. or phone porion of the low-frequency bands. Lower ength reduction factors produce very rapidly ecreasing bandwidths over which the s.w.r. emains below about 2:1 or 3:1.

The graph of fig. 2 can be used to deternine the parameters for either a helical diole or a ¼ λ helical monopole where the ther ¼ λ part of the antenna is simulated y a ground plane. However, a ground plane f sufficient size and low-loss becomes a very lusive thing on the low-frequency bands and, enerally, if space limitations permit it at all balanced form of antenna such as a dipole ill be found to be a much more efficient type f reduced size radiator. ■

"What's your secret . . . how did you manage to get your antenna up so high by yourself?"