Sometimes a piece of wire is more than a piece of wire, especially in the hands of W1DBM. Under the tutelage of W1DBM a piece of wire becomes an antenna and that can open up the whole world.

LONG WIRE ANTENNAS

BY PHILIP S. RAND*, W1DBM

Phil Rand is one of those people who are legends in their own time. He pioneered work in t.v.i. and his Television Interference *book is still a classic and very worthwhile reading. His writings in CQ date back to the late 1940s, and it is indeed an honor to once again present his work on these pages.* —*K2EEK*

The development of antennas for high-frequency use during the 1920s centered around those using "standing" waves and those using "traveling" waves.[1] A standing-wave antenna is a resonant wire such as a half-wave dipole or a longer wire tuned to resonance so that it supports maximums and minimums of current and voltage along its length. A traveling-wave antenna, on the other hand, is a wire that has a constant value of current and voltage along its length like a transmission line. It must therefore be terminated at its far end with a non-inductive resistor equal to its characteristic impedance.[2] Some examples of this type of antenna are Beverage, rhombic, fishbone, and terminated "V" beam. Most antennas used by amateurs are of the standing-wave type. These can be divided into two types: center-fed and end-fed. Most dipoles and all rotary beams are center-fed, while most long wires are end-fed. Center-feeding an antenna produces a symmetrical radiation pattern which is desirable for a rotary beam. End-feeding an antenna produces a distorted radiation pattern which is useful in constructing long-wire beams.[3]

Back in 1931, when I was first licensed, it was common practice to end-feed an antenna by bringing the end of the long wire right into the shack and connecting it directly to the final tank coil. This, of course, is not practical today because of the requirement for attenuating harmonics and other spurious emissions that can cause t.v.i. Today we feed the r.f. from the transmitter through coaxial cable to a low-pass filter, to an s.w.r. meter, to an antenna tuner, and then to the end of the long-wire antenna.

Long Wires

With inflation and the high cost of rotary beams, tilt-over towers, rotators, and coax cable, probably the simplest and cheapest high-gain antennas from a constructional point of view are those using electrically long wires. The wire length is usually from one to eight wavelengths, and long wires may be excited so as to support either standing or traveling waves as desired. They usually have some of both types of waves. Since, by definition, a long-wire antenna is one which is long in terms of wavelengths, a wire 135 feet long would qualify as a long-wire antenna on 10 meters where it is 4 wavelengths long, but on 80 meters it is only a half-wave dipole.

Advantages and Disadvantages

The big advantage of a long-wire antenna is its low cost and ease of erection. Another advantage is that it can be used on all amateur bands including the new WARC bands and even 6 meters with a special tuner. As a beam antenna, its gain and directivity increase with its length in wavelengths, and expensive crank-up tilt-over towers are not required.

On the disadvantage side, a long-wire antenna cannot be rotated. To cover all directions you must put up at least four of them. The horizontal and vertical angles of radiation change from band to band. An end-fed long-wire antenna cannot be fed with coax cable. Also, during heavy rain or snow storms, a long wire is often subject to precipitation static. The biggest disadvantage is that it requires a large amount of real estate.

Length

The actual length of your long-wire antenna will be determined, of course, by the size of your property. An optimum-

Length of Antenna in Wavelengths	Angle of Main Lobes from Wire in Degrees	Power Gain Over Dipole in dB	Bands for a 560-foot Long-Wire Antenna
½	90	0	B.C.
1	54	.8	160 m
2	36	1.8	80 m
4	26	3.4	40 m
5½	21	4.5	30 m
8	17½	6.5	20 m
10½	17	7.5	16 m
12	16	8.5	15 m
14	15	9.2	12 m
16	14	10	10 m

Table I– This table shows the relationship of the length of the long-wire antenna in wavelengths to the horizontal angle of the main lobes, the gain, and the amateur bands for a wire 560 feet long. A gain of 6 dB is equal to increasing the transmitter's power four times; 10 dB equals a transmitter power increase of ten times.

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size antenna would be one which is from 4 to 16 wavelengths long on the highest frequency that you use. This could be from 280 to 560 feet or longer if you have the room. An ideal setup would be to combine four or more of these long wires like the spokes of a wheel to make a series of "V" beams. The wires are used singly or in pairs. Thirty-six degrees makes a good angle between the wires. It divides evenly into 360 and is also twice the angle in Table I, Column 2, for an 8-wavelength antenna for 20 meters.

Directivity

Most amateurs think of an antenna as radiating its maximum signal at right angles to the wire as shown in fig. 1(A). This is only true of an antenna that is ½ wavelength long. As the length of the wire increases in wavelengths, the radiation pattern changes into a figure "X" pattern as shown in fig. 1(B). The shape of the figure "X" also changes with increased length, getting flatter as the length gets longer as in fig. 1(C). In the case of an antenna 560 feet long, the directivity from either side of the wire would be as shown in Table I, Column 2. These are the horizontal angles of the four main, or strongest, lobes with respect to the wire for each of the amateur bands given in Column 4. Note in Column 1 that a 560-foot wire would be 8 wavelengths long on 20 meters.

Vertical Angle of Radiation

The vertical angle of radiation from a half-wave antenna varies with its height above a perfect ground as shown in Table II. An antenna used on several bands will have a different electrical height on each band. Table II compares two antennas, one at a physical height of 35 feet and one at 70 feet, giving both the electrical height and the angles of radiation for each amateur band. At electrical heights of ¼ wave and less, the ground acts as a reflector on a beam and reflects the signal straight up in the air. Fortunately, the vertical lobe is a big fat one, so there is plenty of radiated signal at useful angles for 160, 80, and 40 meters where high angle radiation is needed for out to say 500 to 1000 miles. Note that the 70-foot height provides a lower angle of radiation needed for DX.

A long-wire antenna, several wavelengths long, is primarily a low angle radiator when installed horizontally over a good ground.[4] Its angle of radiation, however, will be lowered even more by choosing a height above ground, as shown in Table II, that favors a lower angle of radiation for the band in question, or by making the long wire longer. From the above you can see that both the directivity and the angle of vertical radiation will change from band to band as electrical length and height change. This does not cause any problems as long as you understand what is happening.

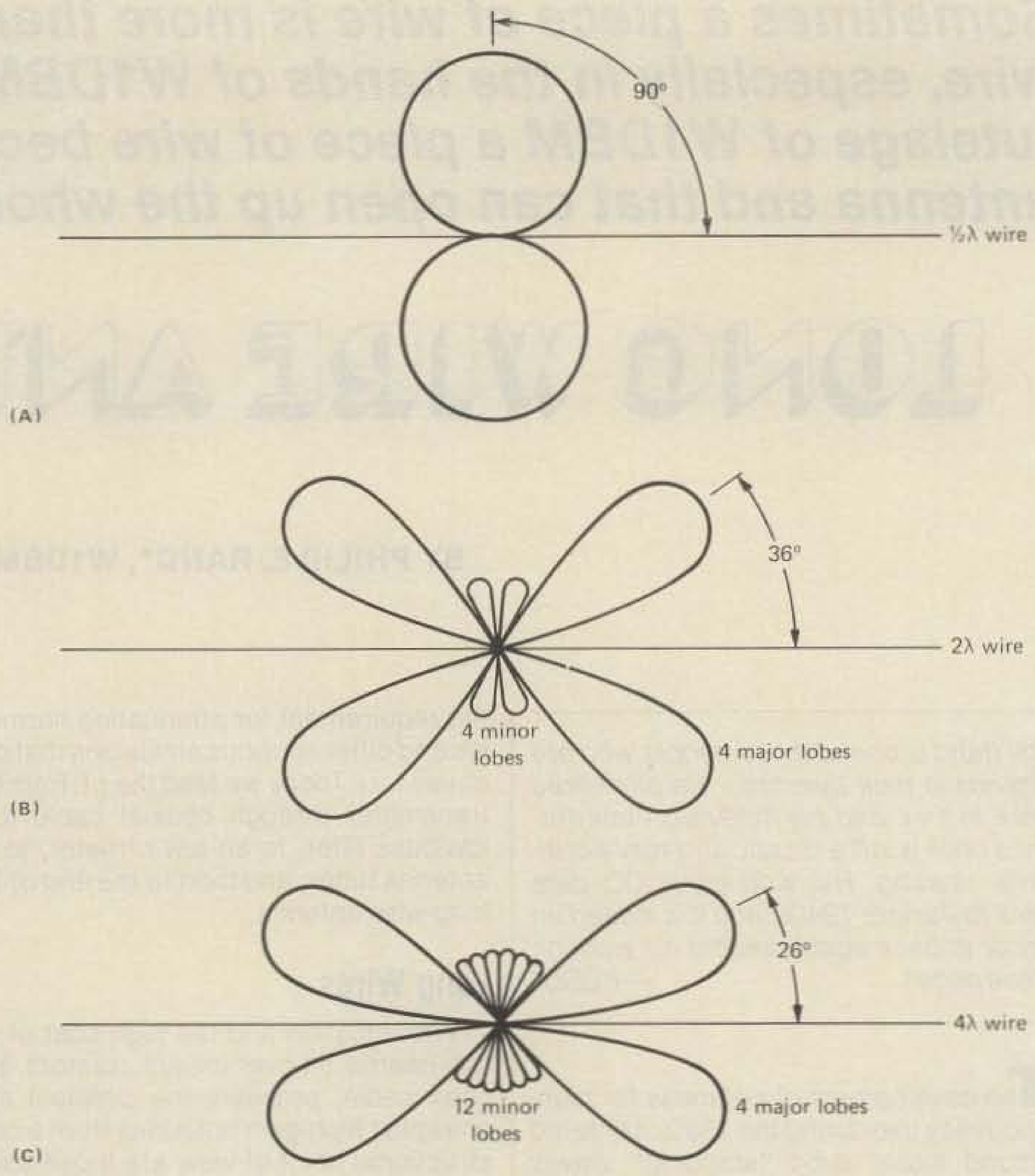

Fig. 1– These are radiation patterns for antennas in free space. (A) A ½-wave dipole, (B) a 2-wavelength long wire, and (C) a 4-wavelength long wire. These patterns were calculated mathematically as explained in the ARRL Antenna Handbook, *page 36, and in footnote #2. What is shown is a slice through the center of the three-dimensional radiation model in a plane containing the wire axis. For example, (A) represents a slice through the center of a doughnut with the antenna wire going through the hole. These diagrams are for center-fed standing-wave antennas.*

Horizontal ½-wave Antenna Above a Perfect Ground

Amateur Band Frequency in MHz	35 feet high		70 feet high	
	Height in Wavelengths	Vertical Angle of Radiation in Degrees	Height in Wavelengths	Vertical Angle of Radiation in Degrees
1.8	1/16	90	⅛	90
3.5	⅛	90	¼	90
7.0	¼	90	½	30
10	⅓	45	⅔	25
14	½	30	1	15
18	⅝	25	1¼	14
21	¾	20	1½	10
24	⅞	17	1¾	9
28	1	15	2	8

Table II– The vertical angle of radiation for a half-wave dipole antenna above a perfect ground is shown here for the amateur bands from 1.8 to 28 MHz for physical heights of 35 and 70 feet above ground. The electrical height in wavelengths is also shown.

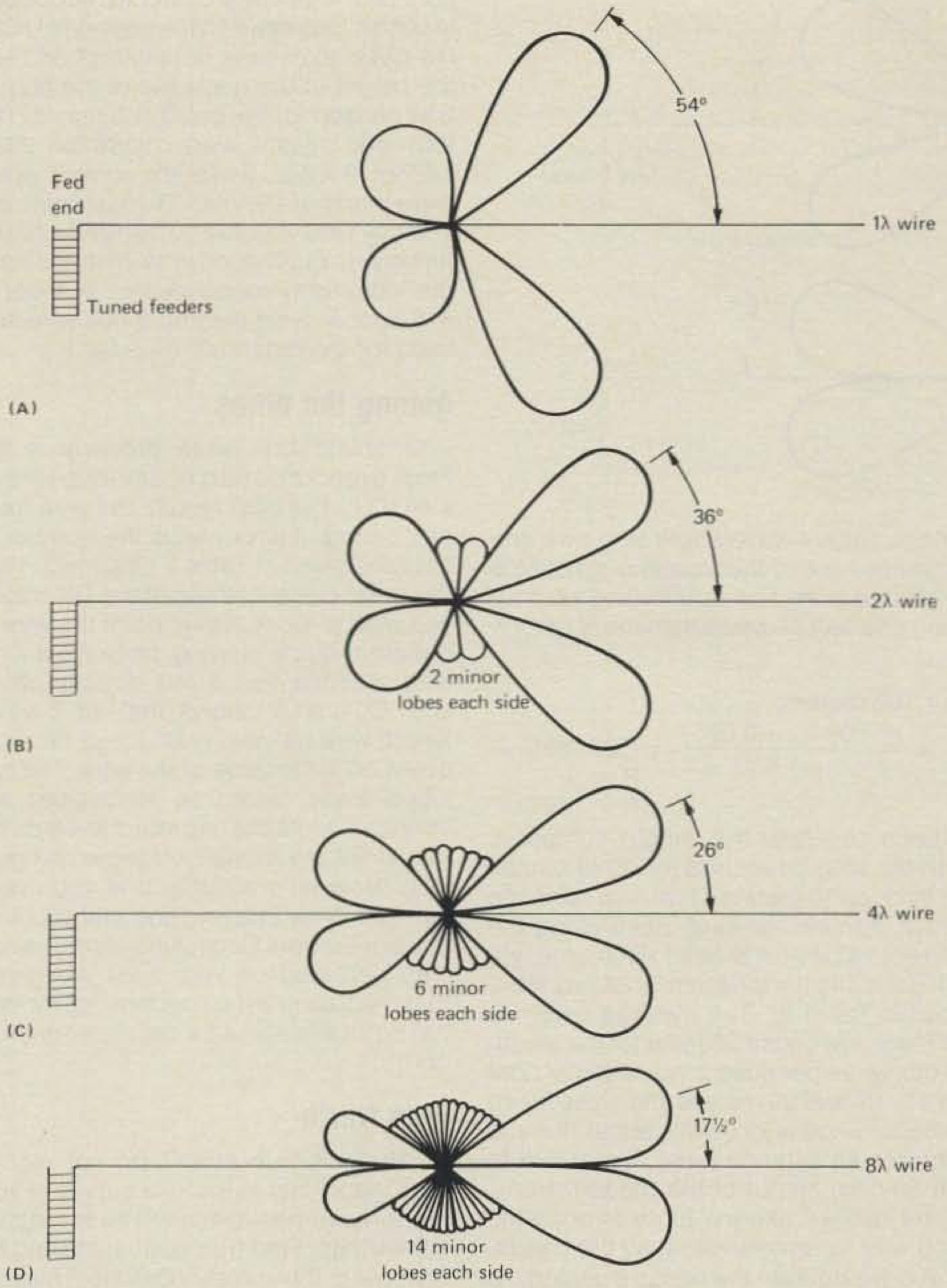

Fig. 2– When a long wire is end-fed, as is usually the case, the radiation losses along the wire cause a substantial traveling wave to exist on the wire, and this causes the directional pattern to become intermediate between that of a pure standing-wave antenna and that of a pure traveling-wave antenna as shown above. This effect makes an end-fed wire semi-bidirectional.

The directional patterns shown in fig. 1 were developed mathematically for a horizontal straight wire in free space with an integral number of half-waves of pure standing wave current distribution on it—for example, a center-fed dipole or other center-fed antenna. When you feed the end of an antenna, this idealized pattern becomes distorted as shown in fig. 2. This is caused by radiation losses as the signal travels from the fed end along the wire to the open end. The signal that is reflected back is less, due to radiation, and therefore produces smaller lobes as shown. If the wire were infinitely long, then there would be no reflected signal and therefore no lobes off the back. An unterminated standing-wave antenna gradually changes into a traveling-wave antenna as the length is increased. An end-fed long wire is not truly bidirectional as many handbooks indicate. The gain is always greatest in the direction away from the feed point.

Major and Minor Lobes

Antenna engineering handbooks tell us that a wire antenna in free space has one lobe for each half wave in its length.[5] A half-wave antenna would have one lobe. Why then does fig. 1(A) show two lobes? To show the radiation pattern in two dimensions on paper, we must take a slice through the three-dimensional model in a plane containing the wire. It's like cutting a doughnut in half and then looking at the cut end. In other words, a three-dimensional model in free space, when reduced to two dimensions on paper, will have two lobes for each half wave in its length. The 8-wavelength antenna, shown in fig. 2(D), will have a total of 32 lobes.

The No. 1 lobe, the one closest to the wire, is always the largest and is called the **major lobe.** The longer the wire in wavelengths, the larger the major lobe, and the smaller the minor lobes. Also the angle between the No. 1 lobe and the wire gets smaller and smaller, approaching but never reaching zero degrees.

The patterns shown in fig. 3 are for traveling-wave antennas. Note that there are no major lobes radiating toward the feed point. Theoretically, all the power reaching the termination resistor has been absorbed, and therefore there should be no pattern to the rear. In practice there is always some radiation in that direction.

Gain

Referring to Table I, Column 3, you will see that the gain of a long-wire antenna varies with its length in wavelengths. The gain approaches 10 dB with a length of 16 wavelengths.[6] This is true whether or not the wire is terminated. The gain of a long wire can be increased by lengthening it or by adding other wires in certain phase relationship. The apparent gain at a distant point can be increased by raising the height of the wire to obtain a lower angle of radiation, more favorable for working DX. Fig. 4(A) shows two 8-wavelength wires connected together with an apex angle of 36 degrees and fed 180 degrees out of phase with a tuned open-wire line. *(For a discussion of open-wire feed line, see Lew McCoy's article elsewhere in this issue—ed.)* This antenna is called a **"V" beam** and will have about 3 dB more gain than a single wire. Another 3 dB of gain can be obtained by arranging two "V" beams back-to-back as shown in fig. 4(B). This antenna is called a **rhombic** or **diamond.** We have chosen not to terminate the rhombic so that it will be semi-bidirectional.[7]

Termination

Converting a standing-wave antenna to a traveling-wave antenna by terminating it in its characteristic impedance only reduces its radiation off the rear without helping the signal off the front. It is a big help, however, in reducing QRM coming in off the back when receiving. The exact value of the terminating resistor for your particular antenna will have to be determined by experiment due to varying height, ground conditions, and nearby surrounding objects. Terman shows a graph giving the radiation resistance of a ½-wave dipole versus an 8-wave horizontal wire for various heights above ground.[8] It looks as though a non-induc-

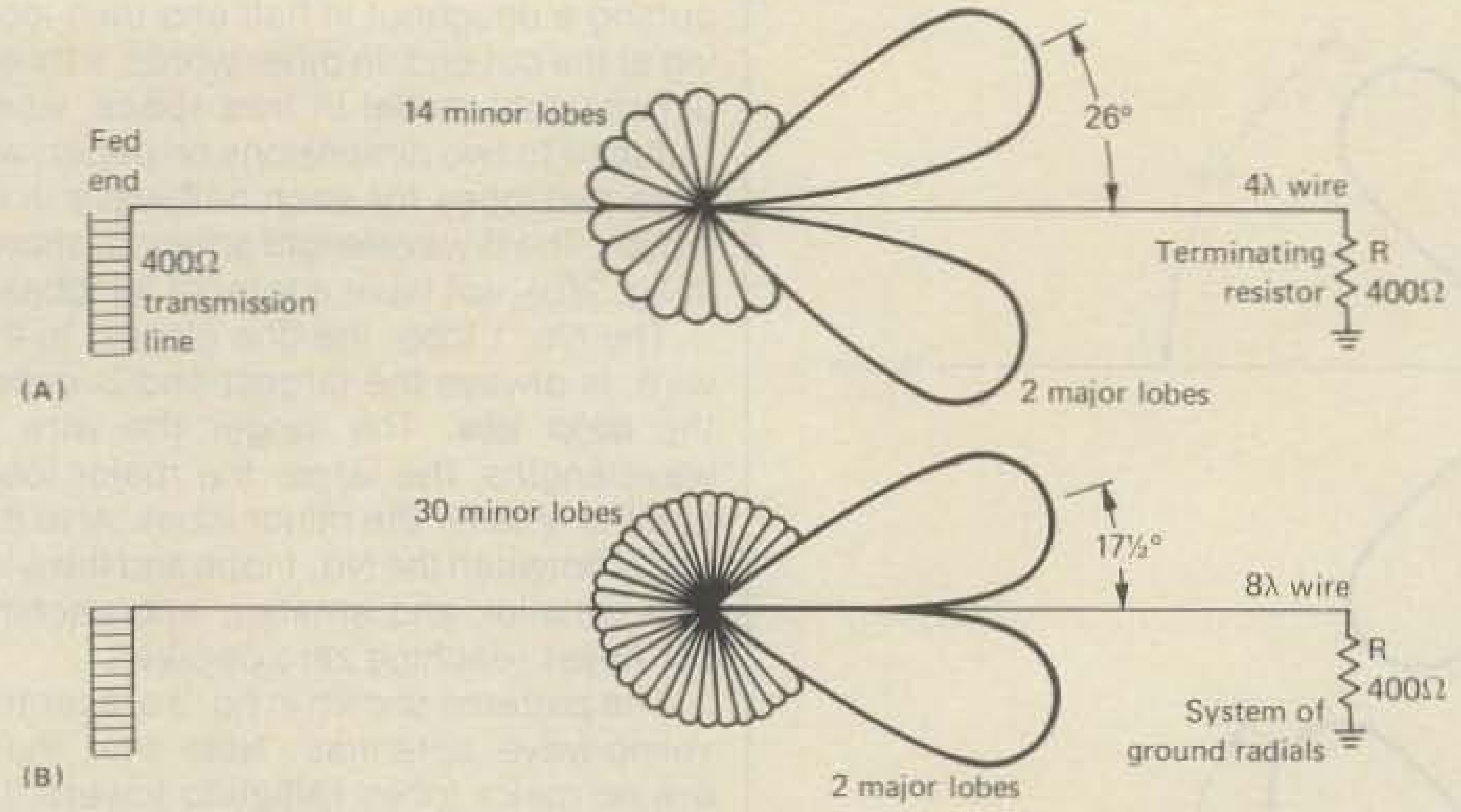

Fig. 3– Radiation patterns for terminated antennas. (A) A 4-wavelength long wire and (B) an 8-wavelength long wire. Both of these antennas are of the traveling-wave type and are essentially unidirectional off the terminated end. The terminating resistor must be non-inductive and capable of dissipating one half of the transmitter's output.

tive resistor of between 150 and 400 ohms might do the job.

A.E. Harper says that the terminating resistor for a 3-wire rhombic varies between 650 and 850 ohms.[9] The reason more amateurs do not use terminated antennas is probably because the resistors are hard to find and expensive. Price a 250-watt 800-ohm non-inductive resistor the next time you go shopping.

To determine experimentally the correct termination for your particular long wire, install a 500-ohm carbon-type variable resistor between the far end of your antenna and the radial ground system that you have put in place out there. Have a friend equipped with a 2-meter handie-talkie turn this pot while you listen to a DX station coming in off the back of the wire. When your "S" meter shows a null, have your friend bring the pot back to the shack and measure it. This will be the value for your terminating resistor.[10] In lieu of an elaborate ground system, you can make an effective ground, for one band only, by connecting your terminating resistor to a ¼ wavelength of wire up in the air. You would cut the antenna ¼ wave from the far end and insert the resistor. The terminated "V" beam in fig. 4(A) uses this idea. The terminating resistor for a single wire is usually about half that of a rhombic.

Designing the Antenna

With the foregoing in mind, let's design one or more long-wire antennas. The formula for calculating the length of a long-wire antenna is as follows:[11]

$$L = \frac{984\,(N - 0.025)}{f}$$

L = wire length in feet.
N = number of wavelengths on the wire.
f = the frequency in MHz.
(N – 0.025) = correction factor for the lack of end effect on all but one ½ wave.

For 160 meters:

$$L = \frac{984(1 - 0.025)}{1.800} = 533 \text{ feet} \qquad N = 1 \qquad f = 1.800$$

Let's see how this length compares with the length required for other bands, 80 through 10 meters. If we now solve the above formula for each band using the correct values for **N** and **f** each time, we will get a slightly different length as tabulated in Table III. The average length is 557 feet. We chose 560 feet for the length of our wires because it was exactly right for 10, 15, and 20 meters and close for 40 meters. Since a long wire fed at the end requires an antenna tuner to match it to the 50-ohm output of the modern transmitter, we will use the tuner to bring the long wire to resonance on all the bands.

A drive through the pasture behind the barn in our Jeep indicated that we could put up at least four long wires pointing from northeast through east to south with one end of each supported at the ridgepole of our house. It was decided to support each wire in the center to reduce sag in such a long span. In the interest of holding down expenses, a height of 36 feet, the height of the ridgepole of the house, was chosen for the poles and masts. The four end masts were made of three 12-foot 2 × 4's, while the center poles were made of 1¼-inch TV mast sections. The guy wire was #14 galvanized electric fence wire purchased in ¼-mile spools at the local farm supply dealer. A spool of #18 copper-weld electric fence wire was used for the antennas. (See fig. 5.)

Aiming the Wires

Orienting the wires properly is the most overlooked part of any long-wire installation. For best results the wire must be pointed plus or minus the number of degrees given in Table I, Column 2, from the great-circle bearing of the DX station you wish to work. Never point the wire at the great-circle bearing, because a long-wire antenna has a null directly off its end. Column 2 shows that an 8-wavelength wire has two main lobes 17½ degrees off either side of the wire. The two lobes away from the feed point are stronger, while the two lobes towards the feed point are weaker, as shown in figure 2(D). Now let's assume that you live in northern New England and that you wish to work Europe. Consulting a great-circle map centered on your area will reveal that the true great-circle bearing for central Europe is about 54 degrees from true north.

True North

Where is true north? Do not rely on road maps, city maps, or a survey of your property. At best these will be in magnetic bearings. Find true north by taking the shadow of the sun at noontime. This is all explained in the *ARRL Antenna Handbook*.[12] Simply drive a stake into the ground at the end of the shadow from a vertical pole at exactly noontime. That night, line up the north star, *Polaris*, over

Frequency of Amateur Band	Number of Wavelengths per Band	Length of Wire in Feet	Resonant Frequency for a Wire Length of 560 feet
1.8	1	533	1.713
3.5	2	555	3.470
7.0	4	558	6.985
10*	5½	538	9.620
14	8	560	14.000
18*	10.5	572	18.406
21	12	561	21.042
24*	14	573	24.556
28	16	561	28.070

**New WARC bands.*

Table III– Table III shows the calculated length of a long-wire antenna for each of the amateur bands, 1.8 through 28 MHz, the average length being 557 feet. Column #4 gives the resonant frequency of a wire 560 feet long. This is the length chosen, since our antenna tuner will resonate this wire on each of the bands.

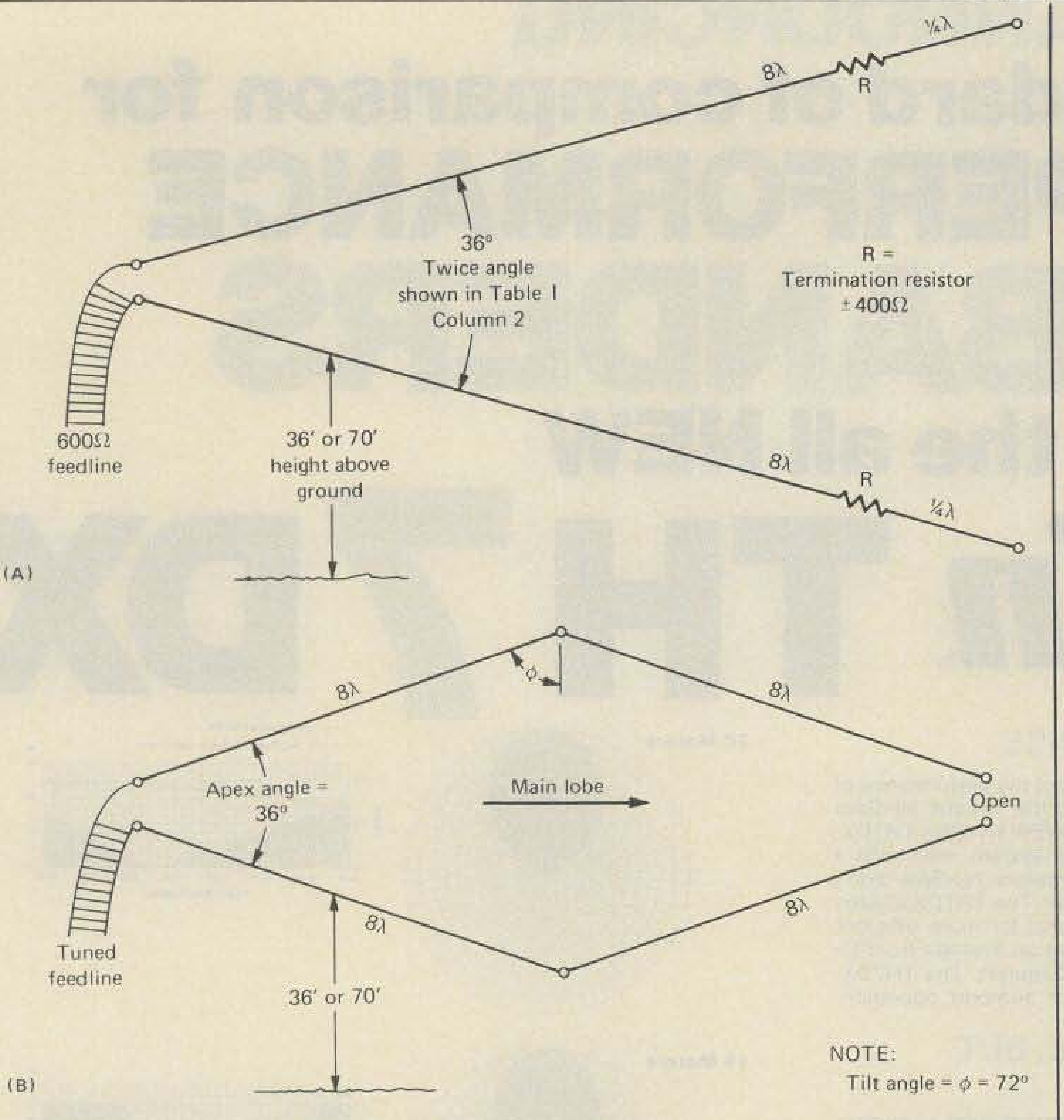

Fig. 4– Illustrated above are two methods of increasing the gain of a long-wire antenna by combining two long wires in a phase relationship. (A) A "V" beam, terminated for one band only by using a ¼-wave piece of wire as an artificial ground. This beam will only be unidirectional on the band for which the wire is ¼ wavelength. (B) An unterminated rhombic antenna is shown. It could be terminated if desired by using a non-inductive resistor of around 800 ohms. The apex angle of 36 degrees is optimum for a leg length of 8 wavelengths. If you try to use it with more than 8 wavelengths per leg, the front lobe will split into two lobes, throwing a null straight ahead. If you want to use more than 8 waves per leg, then the apex angle must be reduced.

the top of the same vertical pole and drop a brick on the ground at your feet. The next day, the brick, pole, and stake should all line up. If so, you now have a true north-south line and may lay out or aim your antennas in the correct directions. With a protractor, measure off the number of degrees you have decided on from your north-south line, put up your poles and masts, and string your antenna wire.

To put a lobe at 54 degrees you may point your 8-wavelength long wire at 36 degrees (54 − 18) or at 72 degrees (54 + 18). The first gives you lobes at 18 and 54 degrees, while the second gives you lobes at 54 and 90 degrees. If you elect not to terminate your wire, you will also have two lobes, maybe an "S" unit or so weaker, 180 degrees in the opposite direction. We chose 72 degrees for our first wire, giving us lobes aimed at Europe and Africa off the front and lobes aimed at New Zealand and Australia off the back. If, in like manner, you put up three more wires spaced radially 36 degrees apart, you will end up with the beam headings shown in Table IV. Note that wires #1 and #2 may be connected up as a "V" beam pointed at Africa off the front and at Australia off the rear. Similarly, wires #2 and #3, and #3 and #4, may also be used as "V" beams. The above is for the higher frequency bands. On the lower bands try every other wire or the two outside wires as "V"s. The combination that works best on receive usually also works best on transmit.

Antenna Tuner

Most any type of antenna-tuning network or "matchbox" will tune up a long wire for the bands it was designed to cover. For example, a Johnson Viking Matchbox will not tune any antenna on 160 meters or the new WARC bands. My preference is one with a rotary inductor similar to the Heathkit Model SA-2060 shown in fig. 6. This circuit allows you to tune any long wire to any frequency from 1.800 to 30 MHz with a 1:1 s.w.r. Matching the antenna to the 50-ohm output of your transmitter this close is only important if you have a solid-state final amplifier. The 4:1 balun shown is used only when feeding a "V" beam or when using 2-wire feeders. (See fig. 7.)

Static Protection

On a windy day with a highly charged atmosphere, a long-wire antenna will pick up a lot of static electricity—enough voltage to jump a good half inch or more. This will give you quite a jolt if you accidently touch one of the ungrounded wires. The best solution is to install an r.f. choke, similar to that in your final amplifier, between your antenna-tuner single-wire output and ground.

Referring to fig. 6, you will note that most antenna tuners leave the unbalanced output floating above ground, and so on windy days you can hear the click, click, click of the static charge jumping the plates of the output capacitor. A ground is automatically provided by the balun center-tap when feeding a balanced line. Some amateurs mount an automobile spark plug in a weatherproof box between the far end of the antenna and a ground rod. The spacing of the electrodes in the spark plug should be adjusted so that there is no arcing when the transmitter is modulated. A combination of the r.f. choke and the plug might be even better. Probably the best solution would be actually to ground the far end of each long wire to a group of ground rods for d.c. and a group radials for r.f. This would conduct the static directly to ground at a point as far away from the receiver as possible. The antenna tuner would retune the system to resonance. It is planned to try this idea this summer.

Precipitation static sounds like high-speed automobile spark-plug interference that varies as the wind blows highly charged snow flakes or rain drops against your bare wire antenna.[13] This happens to all antennas, but is worse with long wires because of the greater area. The noise you hear is the individual discharge from each snow flake to the bare wire. About the only cure is to use insulated wire for your antenna, which is not always practical. Precipitation static only occurs occasionally and does not affect your transmission. Therefore, the easiest solution is to provide an indoor antenna for receiving during those periods.

Lightning Protection

When properly installed, a long-wire antenna should not be any more of a lightning hazard than your power or telephone lines. They really are long wires! The greatest lightning hazard is an ungrounded TV antenna strapped to your

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Handles up to 200 watts output; efficient airwound inductor gives more watts out. 5x2x6".

Use any transceiver, solid-state or tube.

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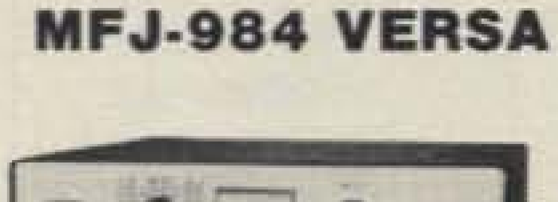

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10 amp RF ammeter assures max. power at min. SWR. SWR/Wattmeter, for./ref., 2000/200W.

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300 watt dummy load. 4:1 ferrite balun.

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6 position antenna switch on front panel, 12 position air-wound inductor; coax connectors, binding posts, black and beige case 10x3x7".

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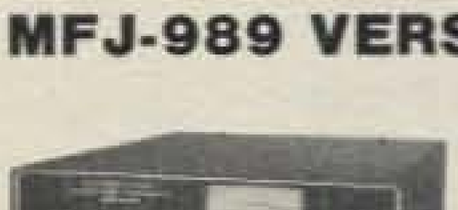

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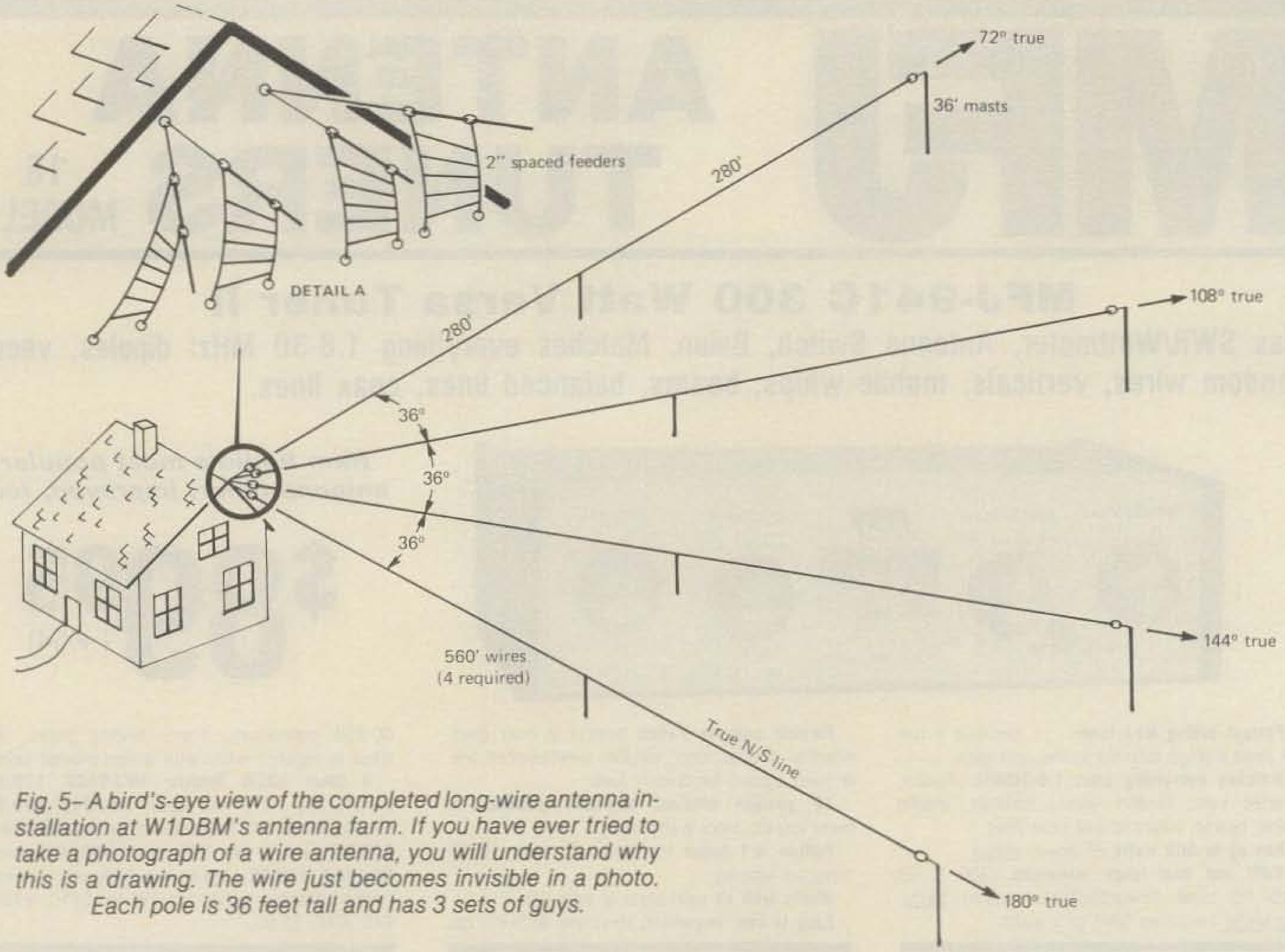

Fig. 5– A bird's-eye view of the completed long-wire antenna installation at W1DBM's antenna farm. If you have ever tried to take a photograph of a wire antenna, you will understand why this is a drawing. The wire just becomes invisible in a photo. Each pole is 36 feet tall and has 3 sets of guys.

chimney. If any antenna system receives a direct lightning hit, a lot of damage can be done to buildings and equipment.[14]

When a highly charged cloud moves over the ground, it attracts an equal and opposite charge in the ground. When the potential difference between the cloud and the ground becomes great enough to jump the air gap, the lightning strikes the nearest object. The amount of damage done is a function of the current squared times the resistance, I^2R. Even though there is not much you can do about a direct hit, you can try to prevent a hit by keeping all your antennas well grounded so that they will leak off the ground charge, thus reducing the potential difference between the cloud and the ground.

You can protect your equipment against voltages induced in your antennas and power line by nearby hits[15] by installing transient protection devices[16] and a very low-resistance ground system. Keep all your antennas grounded at all times except when you are actually using them. When you leave the shack, always disconnect both the power line and antenna from your radio equipment. The above applies to any antenna, not just long wires.

Problems

An end-fed antenna often brings a strong r.f. field into the shack, and therefore may cause an r.f. feedback problem with some rigs. This problem gets worse when the shack is located on the second floor. My ground lead is a piece of ⅜-inch copper tubing 17 feet long. This is like using the top of a 20-meter ground-plane antenna as your ground (some ground!). The r.f. feedback not only caused severe distortion on the audio, but even held the send/receive relay in the send position at times. None of this happened when using dipoles or beams fed with RG/8-U coaxial cable. This feedback problem was solved by taking the following four steps:

1) Detuning the ground by attaching several 17 foot radials and running them around the room at the floor level.[17]

2) Installing a variable inductor in the ground lead ahead of the radials and tuning it for least r.f. in the shack.

3) Installing 40 feet of 2-inch spaced feeders from the antenna tuners to the ends of the antennas up at the ridgepole of the house. This reduced the r.f. field enough in the shack so that most of my other rigs worked with no feedback. One still acted up.

4) Removing the rig from its cabinet

560-foot Wire No.	Orientation of Wire in Degrees from True North	The Two Strongest Lobes Point in Degrees from True North	The Two Weaker Main Lobes Point in Degrees from True North
1	72	54 & 90	234 & 270
2	108	90 & 126	270 & 306
3	144	126 & 162	306 & 342
4	180	162 & 198	342 & 18

Table IV– This arrangement of wires will give strong signals in the following directions in degrees from true north: 18, 54, 90, 126, 162, 198, 234, 270, 306, and 342. We will have available "V" beams with added gain pointing 90, 126, 162, 270, 306, and 342 degrees, all selected with a rotary switch. The above main lobes are for the 20 meter band and will vary by only 4 degrees from 10 through 30 meters. On 40 and 80 meters they will differ by as much as ± 18 degrees.

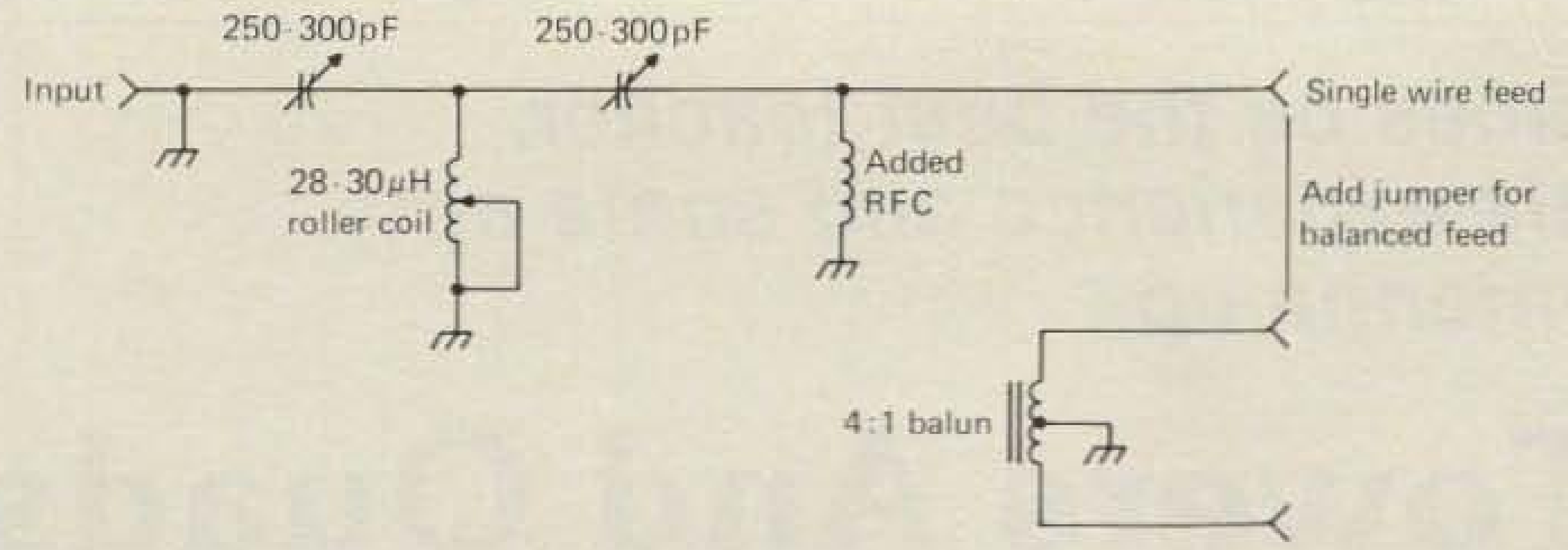

Fig. 6– This is a simplified diagram of the Heathkit model SA-2060 antenna tuner. This unit has a roller-type variable inductor so that you can get an exact 1:1 s.w.r. match between your transmitter and any long wire at any frequency between 1.8 and 30 MHz. This is not possible with some tuners using tapped coils. Note the added rfc to provide a ground for bleeding off static electricity. The jumper between the single-wire feed and the balun is only used with a two-wire feed.

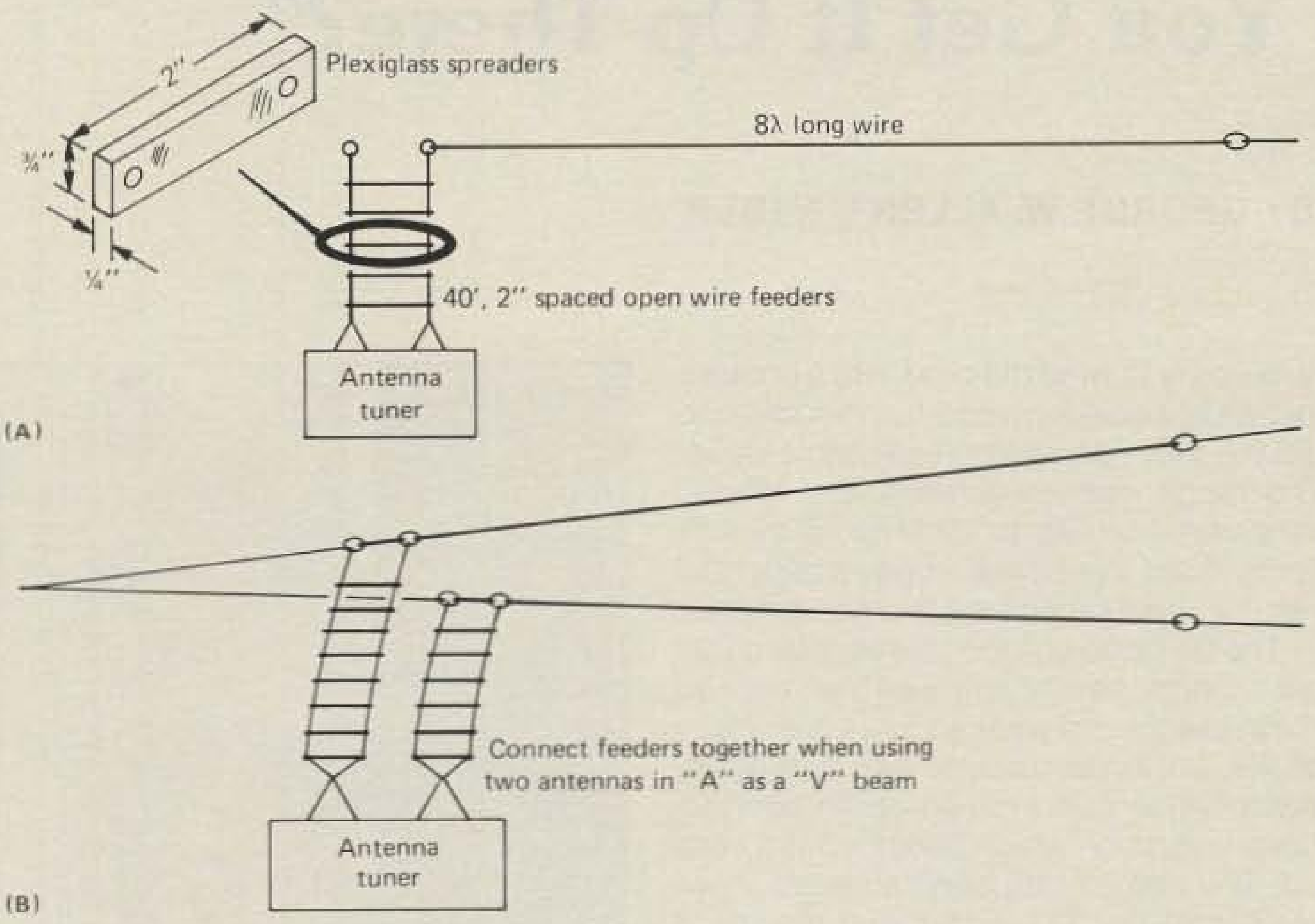

Fig. 7– (A) This illustrates the use of "Zepp" open-wire feeders to reduce the r.f. field in the shack in case of r.f. feedback. To make the spreaders, cut up a piece of ¼-inch thick plexiglass as shown. (B) Each pair of feeders is shorted together at the tuner when feeding a "V" beam as shown.

and installing a 0.01 disc capacitor and a ferrite bead on every lead leaving the chassis. Sounds like t.v.i. in reverse.[18] These included loud speaker, earphones, key, a.c. line, external S/R relay, a.l.c., and any control-voltage lines to an external v.f.o. The shield on the mike cable was floating and had to be grounded to the shell of the mike connector so that it would not conduct r.f. up to the speech amplifier circuit board. The hot mike lead, pin #2 of the connector, required a 200 pF capacitor and a ferrite bead on the end of the 100-ohm resistor. The push-to-talk lead, pin #3, required a 0.01 disc and a ferrite bead.

Results

In general the results are pretty much as you would expect. There are very good signal-strength reports on 160 and 80 meters, although not too much directivity due to the antenna's low height—perhaps an "S" unit or so. On 40 meters the directional characteristics become more noticeable, and the reports on the long wires are always better than on the dipole. The gain on 20 meters and above seems to be higher than Table I, Column 3, would indicate.

For example, K4ETS in Florida reports my signal S9 on my reference antenna and S9 plus 20 dB on the long wire pointing south. When he cuts in the 20 dB attenuation pad, the signal drops to an even S9. This would indicate that the long wire had a gain of 20 dB over the reference antenna on this particular path at this time of day. Table I, Column 3, indicates that an 8-wave long wire should have a gain of only 6.5 dB. On this same north-south longwire, also on 20 meters, KA6JM, in Okinawa, a bearing of 340 degrees, reported S5 on the reference antenna and S9 on the long wire. The same type of reports are received on 10 and 15 meters. On 15 meters ZS6BWF reported L.W. #2 at S6 and the reference antenna at S3. F9OJ reported L.W. #1 at S8 and the reference antenna at S5. On 10 meters ZS6XB reported L.W. #1 at S9 and the reference antenna at S5, while PY5SSA found that L.W. #3 was best by three "S" units.

To make comparisons such as the above, it is necessary to be able to switch antennas quickly. A six-position coaxial switch was installed so that any one of the four long wires or a reference antenna could be switched into circuit between words when transmitting. Each long wire has its own antenna tuner so that all antennas can be tuned up and ready for instant use on any given band. The directivity on the three higher frequency bands seems to be about the same. Table I indicates that there is only a ± 4 degrees from the 30- to the 10-meter bands.

Footnotes

[1] *Radio Antenna Engineering,* A.E. Laport, 1st edition, 1952, p. 197.

[2] *Radio Antenna Engineering,* Laport, p. 304.

[3] *ARRL Antenna Handbook,* 13th edition, p. 58; *Radio Antenna Engineering,* Laport, p. 247.

[4] *ARRL Antenna Handbook,* p. 166.

[5] *Radio Antenna Engineering,* Laport, p. 308.

[6] *Radio Handbook,* W.I. Orr, W6SAI, 19th edition, p. 25.3.

[7] *Radio Engineer's Handbook,* F.E. Terman, 1st edition, p. 804–807.

[8] *Radio Engineers' Handbook,* Terman, p. 791.

[9] *Rhombic Antenna Design,* A.E. Harper, 1941, p. 86.

[10] "The Classic Antenna," H.H. Beverage, ex-W2BML, *QST,* Jan. 1982, p. 11.

[11] *ARRL Antenna Handbook,* p. 167.

[12] *ARRL Antenna Handbook,* p. 323.

[13] *Radio Engineers' Handbook,* Terman, p. 769; *Radio Engineering Handbook,* Keith Henney, 2nd edition, 1935, p. 704.

[14] "A Primer of Lightning Protection," T.E. White, K3WBH, *CQ,* July 1981 p. 42; "Lightning Protection for the Amateur Station," John E. Becker, K9MM, *Ham Radio Magazine,* December 1978, p. 18.

[15] *Antenna Feed Line Lightning Protectors,* E.A. Whitman, K2MFY; "Lightning Protection for the Ham-M," J.E. Mackey, K3FN, *QST,* April 1981, p. 56.

[16] "Protect Your Equipment from Damaging Power-Line Transients," Ken Stuart, W3VVN, *QST,* February 1982, p. 35; "Lightning Protection—A New Era," Don Tyrrell, *CQ,* April 1982, p. 22.

[17] *The Radio Amateur Antenna Handbook,* W.I. Orr, W6SAI, 1st edition, p. 35.

[18] *Television Interference,* Phil Rand, W1DBM, Chapter 5, Filtering, p. 29.

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