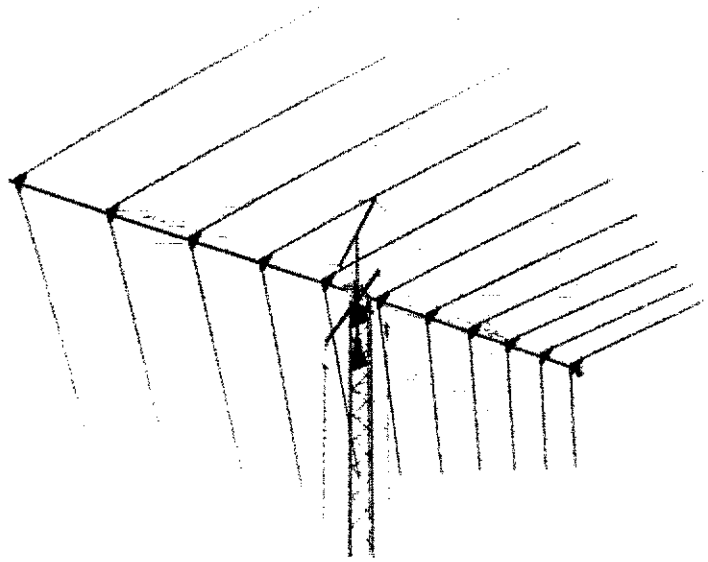
Log-Periodic Dipole Arrays for the Upper HF Bands



Tribanders are fine—for three bands. Here's how to build an LPDA "continuous bander" capable of good beam-antenna performance over an *unbroken* frequency range.

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The acquisition of the 18- and 24-MHz amateur bands[1] has made the LPDA an attractive antenna for use on the upper end of the HF spectrum. The frequency-independent nature of an LPDA (2:1 frequency coverage ratio) gives coverage of *all* of the amateur bands from 14 through 28 MHz—with a single antenna!

The LPDA has no traps, is easy to construct and does not require tuning adjustments after assembly. Reasonable care in measuring the element lengths and spacings is all that's required to build an efficient antenna system. I have received many requests for information on the antennas described in this article, so I thought that a description of the system, along with dimensions for several frequency ranges, would be of interest to *QST* readers.

I calculated dimensions for 7, 9 and 11-element LPDA antennas (see Tables 1, 2 and 3) using a BASIC program I wrote based on equations in *The ARRL Antenna Book*.[2] The tables also give the design constants I used for the antennas. The 7-element LPDA covers 20 to 30 MHz, the 9-element system covers 17.5 to 30 MHz, and the 11-element antenna covers 13.5 to 30 MHz. The antenna design is based upon standard lengths of aluminum tubing to make construction easier. I verified the antenna dimensions using the MiniNEC antenna analysis program.

The LPDA elements are insulated in the center, and each element (all are driven) is fed 180° out of phase with the adjacent elements. Fig 1 shows a simplified schematic of an LPDA. In the 11-element design shown in the title photo, the ele-

[1]Notes appear on p 28.

Table 1

Seven-Element LPDA Dimensions for 20 to 30 MHz

Element number	*Element length (feet)*	*Spacing (feet)*
1	24.53	2.45
2	22.08	2.21
3	19.87	1.99
4	17.89	1.79
5	16.10	1.61
6	14.49	1.45
7	13.04	N/A

Boom length: 12 feet
Shorting strap length: 7¾ in.
Average impedance: 93.6 Ω

Design Information

Design constant: 0.9
Spacing constant: 0.05
B_{AR}: 1.41 (bandwidth of the active region)
R_O: 64 Ω (input resistance)
Z_A: 390 Ω (average characteristic impedance)

Table 2

Nine-Element LPDA Dimensions for 17.5 to 30 MHz

Element number	*Element length (feet)*	*Spacing (feet)*
1	28.94	2.78
2	26.05	2.50
3	23.44	2.25
4	21.10	2.03
5	19.00	1.82
6	17.09	1.64
7	15.38	1.48
8	13.84	1.33
9	12.46	N/A

Boom length: 16 feet
Shorting strap length: 8⅓ in.
Average impedance: 96 Ω

Design Information

Design constant: 0.9
Spacing constant: 0.049
B_{AR}: 1.41 (bandwidth of the active region)
R_O: 64 Ω (input resistance)
Z_A: 380 Ω (average characteristic impedance)

Table 3

Eleven-Element LPDA Dimensions for 13.5 to 30 MHz

Element number	*Element length (feet)*	*Spacing (feet)*
1	36.44	3.64
2	32.80	3.28
3	29.52	2.95
4	26.57	2.71
5	23.91	2.66
6	21.52	2.39
7	19.37	2.15
8	17.43	1.94
9	15.69	1.74
10	14.12	1.57
11	12.71	N/A

Boom length: 25 feet
Shorting strap length: 10 ½ in.
Average impedance: 93.6 Ω

Design Information

Design constant: 0.9
Spacing constant: 0.05
B_{AR}: 1.41 (bandwidth of the active region)
R_O: 64 Ω (input resistance)
Z_A: 390 Ω (average characteristic impedance)

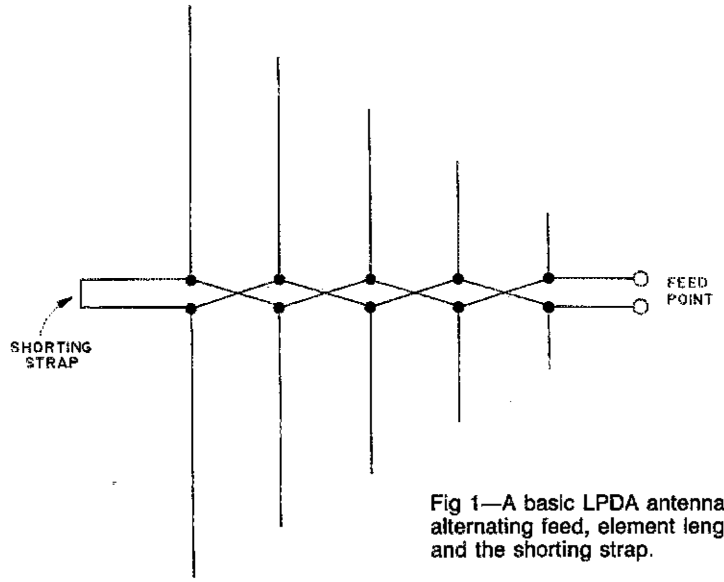
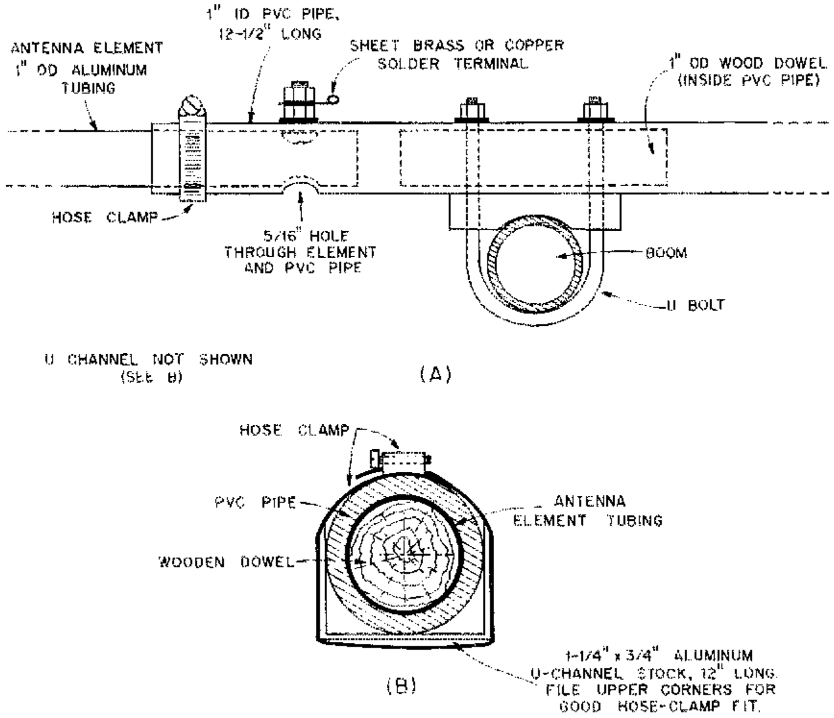


Fig 1—A basic LPDA antenna, showing alternating feed, element length tapering and the shorting strap.



ments are angled 30° forward (the element ends are more forward than their respective element-to-boom attachment points). This technique gives some additional gain, and provides more uniform gain distribution over the antenna's frequency range. The antennas described here can be built with the elements perpendicular to the boom or swept forward. The assembly of the swept-element versions is somewhat more complicated than the straight-element versions, however.

All of the antenna elements are made of 6061-T6 aluminum tubing. Each element uses tubing of three outer diameters: Center sections, 1 inch; middle sections, 7/8 inch; outer sections, ¾ inch. The insulating material used between the element halves is 1-inch ID Schedule 40 PVC pipe.

I used 1-inch OD wooden dowels inside the PVC pipe sections at the points where the U bolts attach the elements to the boom. The wooden plugs keep the pipe from collapsing under the pressure exerted on it by the hardware. The 7- and 9-element antennas (with straight elements) use 1-inch ID PVC pipe as element-center insulators (see Fig 2). The element supports for the 11-element LPDA are constructed of 1/8-inch aluminum sheet, with 1-inch ID PVC pipe used as insulators (see Fig 3).

Construction

The elements are assembled first, beginning with the element-to-boom attachment points. The 1-inch OD 6061-T6 aluminum element-center tubing sections and the PVC insulators for each element are assembled as shown in Figs 2 and 3 (depending on the element-mounting technique you choose). Install the U bolts to hold the wooden plugs in place. Leave the U bolts loose enough to allow the elements to be slid onto the

← Fig 2—The method of mounting straight LPDA elements is shown at A. At B, a cross-sectional view of this mounting technique is shown. A piece of aluminum U-channel stock is used to reinforce the assembly, but is omitted at A for clarity. Be sure to use all-stainless-steel hose clamps when assembling the LPDAs.

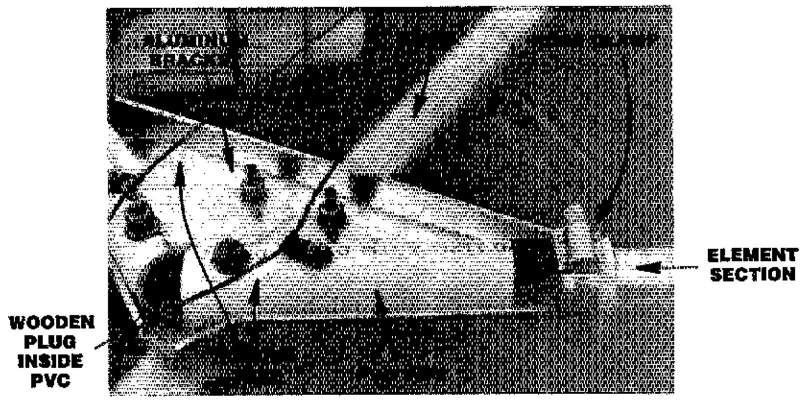


Fig 3—Element-to-boom attachment scheme for swept-forward element mounting. The aluminum bracket is made of 1/8-inch sheet aluminum that is bent to support the element.

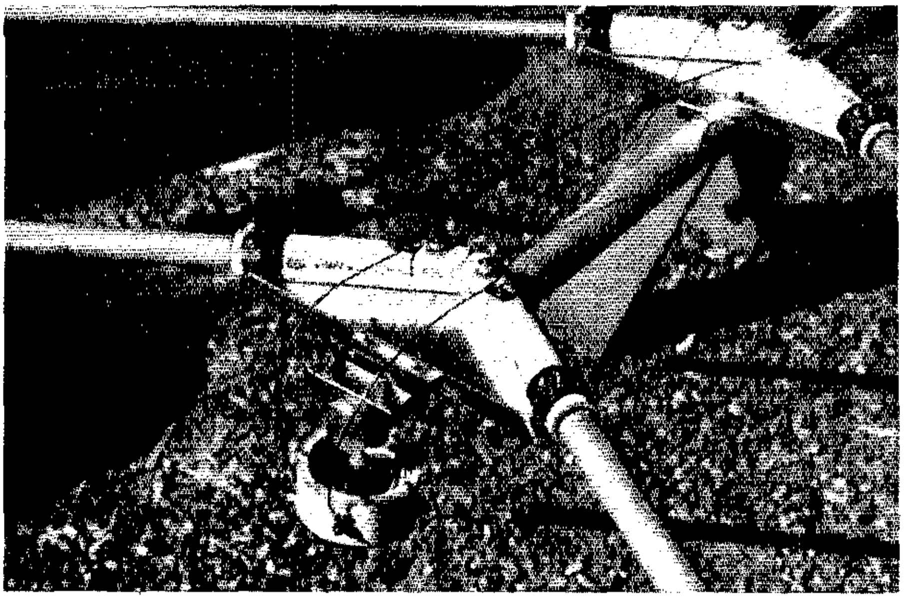


Fig 4—Photograph showing the feed-point end of a swept-forward-element LPDA. The antenna shown is an 11-element version, with the balun mounted just below the boom and in front of the shortest element.

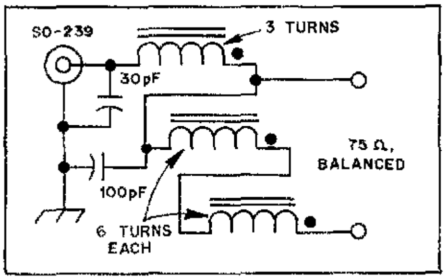


Fig 5—Schematic of the balun used on the 11-element version of the LPDA. The balun inductor is wound on a T-200-2 powdered-iron toroidal core. The entire assembly should be enclosed in a weatherproof enclosure at the feed point, as shown in Fig 4.

boom. Carefully measure and mark the location of each element on the boom, using Table 1, 2 or 3, depending on the antenna version you are building.

I assembled my 7-element antenna on the ground. I used two 12-foot-long 2 × 4s as a jig to help in element alignment. To do this, place the 2 × 4s on level ground, six inches apart and parallel to each other, with the boom between them. Slide all of the elements to their respective locations on the boom. Place the assembly on the 2 × 4s with the element insulators resting on the edges of the jig and the boom hanging between the 2 × 4s. Make the final spacing adjustments and tighten the U bolts. Be sure to double check the element spacings before continuing.

Starting with the longest element, insert the ¾-inch element section into the 1-inch center section. Measure the length, and tighten the hose clamp. Do the same with the shortest array element. Then, without moving the boom, place a chalk line or straightedge from the tip of the longest to the tip of the shortest array element and adjust the tips of the remaining elements so that their ends are on the chalk line, and tighten the element clamps. This procedure eliminates a lot of tedious measuring.

Find the balance point of the array on the boom by lifting the antenna by the boom and holding it loosely until it balances. Attach the boom-to-mast mounting plate at the balance point. The 7, 9 and 11-element antennas all use ¼-inch-thick aluminum mounting plates, 8 inches square.

Attaching the Feed Wires

After element assembly is completed, the element feed wires are attached. I used solid copper insulated no. 12 house wire for the feed wire. A continuous length of wire (twice as long as the boom, plus four feet) makes up the feed wire. The 7-element array, for example, has a 12-foot boom. The feed for this antenna requires (12 × 2) + 4, or 28 feet, of wire. Fig 1 shows the feed-system arrangement for the LPDAs.

Bend the feed wire at the halfway point (the ends are connected last—they are wired to the balun, which is located on the boom underneath the shortest element). The looped end makes up the shorting strap, and is the first wiring connection made—at the center of the longest element. Beginning with the looped end, find the center of the total wire length. Mark the length of the shorting strap (given in the tables—half the length should be on each side of the center of the wire). Remove ½ inch of insulation at the marks and solder the wires to the two feed-point lugs on the longest element.

The feed wires are spaced 4 inches apart for their entire length along the boom. The spreaders that maintain the 4-inch spacing between the feed wires can be made of 3/8-inch OD, 5-inch long pieces of wooden dowel sprayed with several coats of clear Krylon® or other waterproofing material. The spreaders can also be made of plastic, as shown in the upper right of Fig 4. Holes are drilled ½ inch in from each end of the spreaders. The holes should be small enough to provide a tight fit when the feed wire is passed through.

After attaching the feed wires to the longest element, thread a spacer onto the two feed wires to a point halfway between the two longest elements. Pull the wires taut and rotate them so that the spacer is perpendicular to the boom. Rotate the wires another 90° and attach them to the next element by removing ½ inch of insulation from the wire and soldering it to the feed-point lugs of the element. Connect the feed wire to the remaining elements in the same way. After the feed wire is connected to the shortest element, connect the balun as shown in the foreground of Fig 4.

The balun is attached to the underside of the boom at the shortest element. House it in a small plastic container to protect it from the weather. If a coaxial balun is used, it can be attached to the boom with cable ties. Coat any exposed feed connections with silicone sealant.

The balun used on the 11-element antenna (Fig 5) is housed in a 3-inch-long, 2½-inch ID piece of PVC pipe. The ends of the pipe are covered with ¼-inch-thick clear plastic. This housing holds the two capacitors, the balun coil, connections for the antenna feed, and the SO-239 coax connector.

The Boom Truss

A boom truss is required on the 11-element array to reduce boom stress caused by the element weight. The 7- and 9-element antennas do not require trusses. The truss is made in the form of a T, as shown in Fig 6 and the title photo. The truss is constructed from 1-inch angle iron and welded at the junction of the T. The T is 4½ feet high with a 4-foot-long cross bar. Stainless steel boom-support wires pass through holes in the ends of the cross bar, and are attached to eye bolts mounted through the boom, 6 feet in from each end. Use 3/16-inch or larger guy wire for the boom truss wire.

Feed Line

Coaxial feed line is used on all the LPDAs. The 11-element system uses 52-Ω line with a toroidal balun (see Figs 4 and 5). The 7- and 9-element systems use 75-Ω line and baluns made of 10 turns of 75-Ω coax wound into 6-inch-diameter coils. The turns of cable are fastened with cable ties.

The feed-point and element impedances are complex, and are not constant over the entire frequency range of the antenna. Feed-line impedances of 75 to 100 Ω will provide SWRs under 2:1. An antenna tuner

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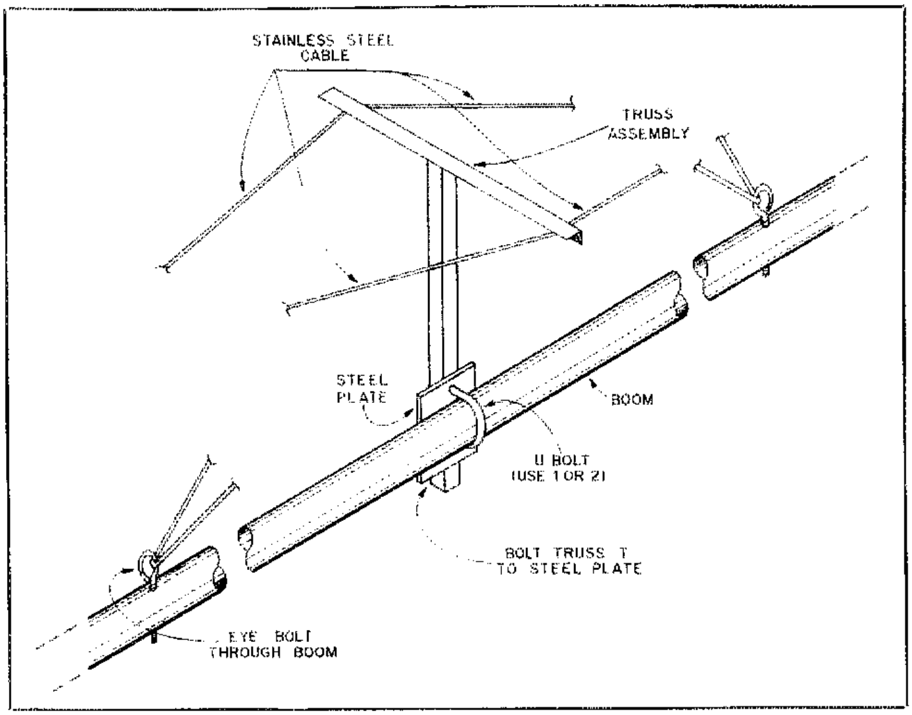

Fig 6—Details of the boom truss needed on the 11-element LPDA. The steel T bracket can be attached to the boom directly (with a U bolt) or via a steel or aluminum plate. The truss must be secured to the boom so that it cannot twist with respect to the boom.

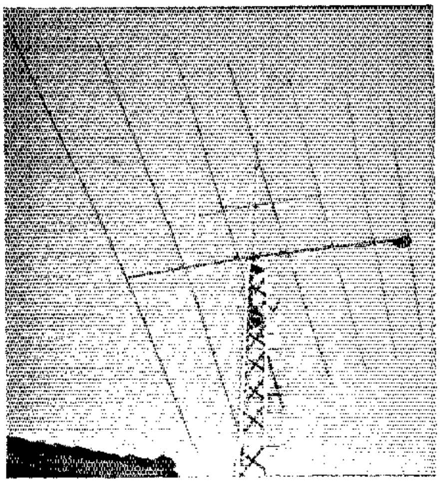

Fig 7—Photo of K6VV's 7-element LPDA antenna mounted below a 2-meter FM Yagi.

should be used at the transmitter to keep any spurious radiation out of the antenna passband.

Results

The antennas shown in the title photo and Fig 7 have been in operation for over two years. My 7-element version performs better than the three-element monoband Yagis that it replaced.

An LPDA is not an inexpensive antenna to build. The time and expense involved in construction have been worthwhile, however, considering that I now have *one* antenna that covers four bands. Working DX on all modes is easy using the LPDA. The improvement in performance is so great, in fact, that I've disassembled the old monoband Yagis and used their aluminum in other projects!

Thanks to Fred Schulz, K6UK, for his assistance with the measurements; Bob Crawford, WO6I, for help with the manuscript; Chet Knoll, NKØO, for building and testing the 11-element LPDA; and Maurice Harp, KF7L, for designing the toroidal balun used with the 11-element array.

Notes

[1]US radio amateurs are to gain access to the 18-MHz band no later than July 1989.
[2]J. Hall, ed, *The ARRL Antenna Book* (Newington: ARRL, 1988), pp 10-1 through 10-7.

References

J. Hall, ed, *The ARRL Antenna Book* (Newington: ARRL, 1988).
W. Orr and S. Cowan, *The Beam Antenna Handbook* (Wilton, CT: Radio Publications Inc, 1976).
E. D. Isbell, "Log Periodic Dipole Arrays," *IRE Transactions on Antennas and Propagation*, Vol. AP-8, no. 3, 1960, Fig 3.

Asa ("Ace") Collins was first licensed in 1938 as W6QVS, and held that call for 36 years. He served in the Navy (in communications) for four years during World War II. After his Navy stint, Ace returned to college, working in broadcast radio to pay tuition. Upon graduation in 1947, he went to work for the telephone company, where he worked until retiring in 1982 as Engineering Manager of a Central Office Design Engineering Group.

Ace returned to college in the 1970s and earned a BBA degree. He's a member of the Antennas and Propagation Society of the IEEE, and is presently an engineering design consultant. Ace has been interested in antenna design for many years, and has written several articles on the subject, including one called "A Multiband Vertical Radiator," QST, *Apr 1977.*

Strays

SAFETY FIRST

□ There are reasons for accidents involving radio gear, but never *good* reasons. Take no chances with electricity. Even a low-voltage shock can be serious—sometimes fatal.

Heed the ARRL safety code: While there's no reason for you to be involved in a ham-related accident, that possibility always exists if you are not thinking safety. Following the ARRL safety code will make your ham experience more enjoyable. Read it and practice it.

1) Kill all power circuits completely before touching anything behind the panel or inside the chassis or the enclosure.

2) Never allow anyone else to switch the power on and off for you while you're working on equipment.

3) Don't troubleshoot gear when you're tired or sleepy.

4) Never adjust internal components by hand. Use special care when checking energized circuits.

5) Avoid bodily contact with grounded metal (racks, radiators) or damp floors when working on the transmitter.

6) Never wear headphones while working on gear.

7) Follow the rule of keeping one hand in your pocket.

8) Instruct members of your household how to turn the power off and how to apply artificial respiration. (Instruction sheets on the latest approved method can be obtained from your local Red Cross office.)

9) If you must climb a tower to adjust an antenna, use a safety harness. Never work alone.

10) Do not install antennas at levels that permit humans or animals to come in contact with them. Not only might the victim sustain a serious RF burn, he or she could run into the antenna and be injured.

11) Do not operate high-power UHF or microwave gear that has inadequate shielding against radiation. Similarly, do not look into or stand near microwave antennas when transmitter power is being fed to them.

12) Do not install antennas near electrical power lines.

13) Don't drink alcoholic beverages when working on equipment or installing antennas.

Take time to be careful. Death is permanent.