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Author: John Kraus, W8JK

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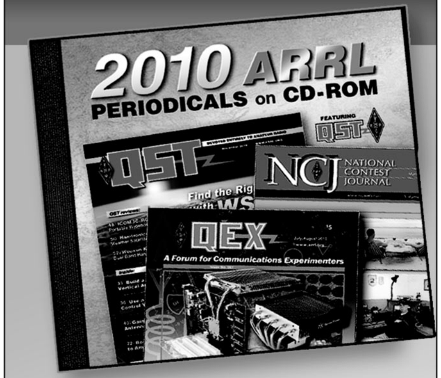

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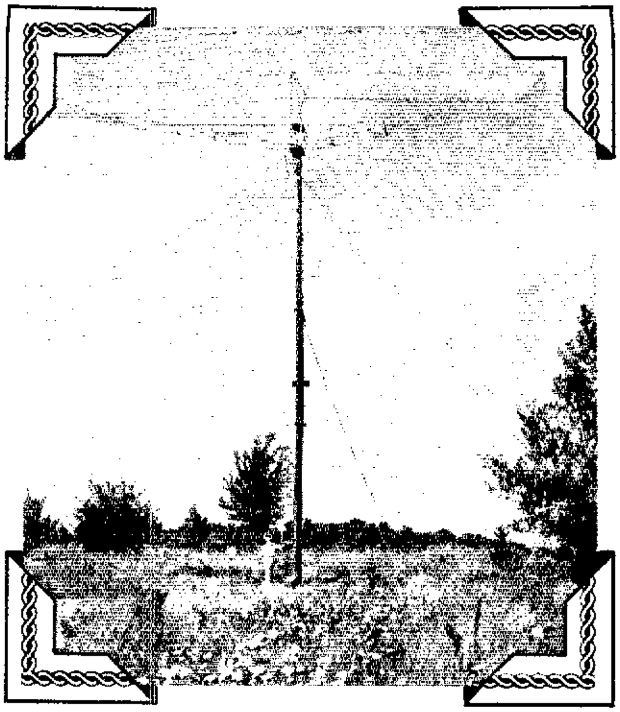
The W8JK Antenna: Recap and Update



John Kraus with the first rotary W8JK antenna in August 1937. The barely visible horizontal wires spanning 60 feet are supported by a gondola-like structure of bamboo.

The famous and effective "8JK" DX antenna remains a favorite with many amateurs. For those who haven't tried it, here's the design rundown.

By John Kraus,* W8JK

Less than 100 years ago, in 1888, Heinrich Hertz built the first radio transmitter and receiver. His transmitting antenna was a half-wavelength dipole and his receiving antenna a one-turn loop. Operating at 5 meters, he was able to demonstrate radio transmission over a distance of a few paces.

Hertz's experiments remained a laboratory curiosity until Guglielmo Marconi repeated and extended them. He added tuning, large antenna and ground systems and, at longer wavelengths, was able to communicate across the Atlantic in 1901. He also demonstrated radio communication with ships. Prior to radio, or "wireless" as it was then called, complete isolation enshrouded a ship at sea. Disaster could strike without anyone on the shore or aboard nearby ships being aware that anything had happened. Marconi changed all that.

Commercial radio focused on wavelengths of 1000s of meters, especially for long-distance communication. Following World War I, with continuous-wave tube transmitters replacing "King Spark," amateurs pioneered in demonstrating that wavelengths of less than 100 meters were useful for long distances. At these shorter wavelengths, dipoles could be conveniently arrayed to produce directional antennas. A simple directional antenna then consisted of a half-wavelength dipole, with a similar dipole placed parallel to and one-quarter wavelength from it as a reflector. One-quarter wavelength spacing was regarded appropriate until George H. Brown of RCA showed in his classic January 1937 paper in the *Proceedings of the Institute of Radio Engineers* that smaller spacings might be better. The key to Brown's discovery was that instead of considering antenna current to be constant, he calculated the antenna gain for a *constant power input.*

When Brown's paper appeared I was intrigued with some of the possibilities it suggested and, in spite of freezing temperatures, lost no time in designing and erecting the first W8JK beam antenna with two parallel dipoles driven in opposite phase and separated by the unprecedentedly small spacing of one-eighth wavelength. It was the first practical, popular antenna to use such closely spaced elements.

As I relate in my book, *Big Ear,* I was elated to find that the antenna provided the gain Brown had predicted mathematically. I wrote a series of articles on the antenna for *RADIO,* starting in the March 1937 issue and, subsequently, articles for *QST, Short-Wave World,* the *Proceedings of the IRE,* and a section for my book, *Antennas* (McGraw-Hill, 1950). Then, in July 1970, I published another article on the antenna in *QST.*

Now, in this article, I wish to introduce some new thoughts, while describing in some detail a rotary beam (W8JK) of the simplest, most versatile type. Some of its characteristics are that:

1) It can operate at any wavelength over a continuous frequency range of more than 3 to 1,

2) It needs no traps or loading coils in the antenna,

3) No antenna dimensions are critical, since the antenna and feed system is resonated,

4) It can be operated horizontally or vertically to obtain optimum elevation angle of radiation (or reception),

5) It is ideal for finding open round-the-world communication paths,

6) It has theoretically zero radiation off the ends of the elements and perpendicular to the plane of the elements,

7) It can be fed with low-loss, inexpensive twin-line,

8) It is compact, a 6-band (20, 17, 15, 12, 10 and 6-meter) design being only 7.3 m[1] long.

The Basic Arrangement

In simplest terms, the W8JK consists of two parallel linear conductors or elements with equal oppositely phased currents, as

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*The Ohio State University Radio Observatory, 1854 Home Rd., Delaware, OH 43015

[1] Notes appear on page 14.

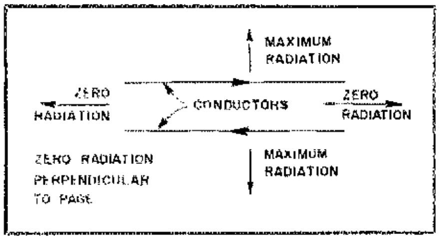

Fig. 1 — Basic W8JK antenna. The conductors carry equal out-of-phase currents.

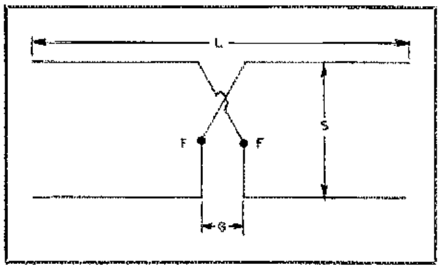

Fig. 2 — Center-fed W8JK antenna. Two-wire feed line connects at FF.

suggested in Fig. 1. The elements may be center fed or end fed. The center-fed arrangement is shown in Fig. 2. Typically, the spacing (S) is about one-eighth wavelength on the lowest frequency used. The length (L) can range from less than one half wavelength to more than three half wavelengths.

If L is somewhat less than one-half wavelength for the 20-meter band, the same antenna can be used also on 6 meters and on all wavelengths in between, including the amateur 17, 15, 12 and 10-meter bands. The center cross-over gap (G) can be any convenient value, such as 250 mm.

Feeding and Matching

The antenna elements can be fed with a resonant twin-line connected to points FF, with tuning done at the station end by means of a balance-to-unbalance, inductor-capacitor tuner. This has the disadvantage that high-voltage points on the twin-line are brought into the station.

An alternative is to short the twin-line at a current maximum and couple a coaxial line at that point. To do this, I have used a section of open twin-line made of aluminum tubing, with a sliding section, or "trombone," as illustrated in Fig. 3. For a given tap distance (T), the trombone is moved up or down to resonate the antenna transmission-line combination and to give a minimum VSWR on the coaxial line to the transmitter. The tap distance can then be adjusted to reduce the VSWR further if necessary. Since the twin-lines above the shorting strap constitute a resonant system with the antenna, it is not necessary that all twin-line sections be of the same impedance. Thus, I have used an aluminum-tubing section with about 300 ohms impedance, while the flexible twin-line between it and the antenna was anywhere between 200 and 400 ohms impedance.

The distance (D) from the antenna feed points (FF) to the shorting strap on the trombone will vary, depending on the frequency band being used. As an example, for operation on 20 and 6 meters and all bands in between, the overall element length (L), including the center gap (G), can be 7.3 m, with the spacing S equal to 2.6 m, as shown in Fig. 4. For these dimensions, the distance (D) to the shorting strap on the trombone unit will be approximately as indicated in Table 1.[2] Note that, in addition to the closest short

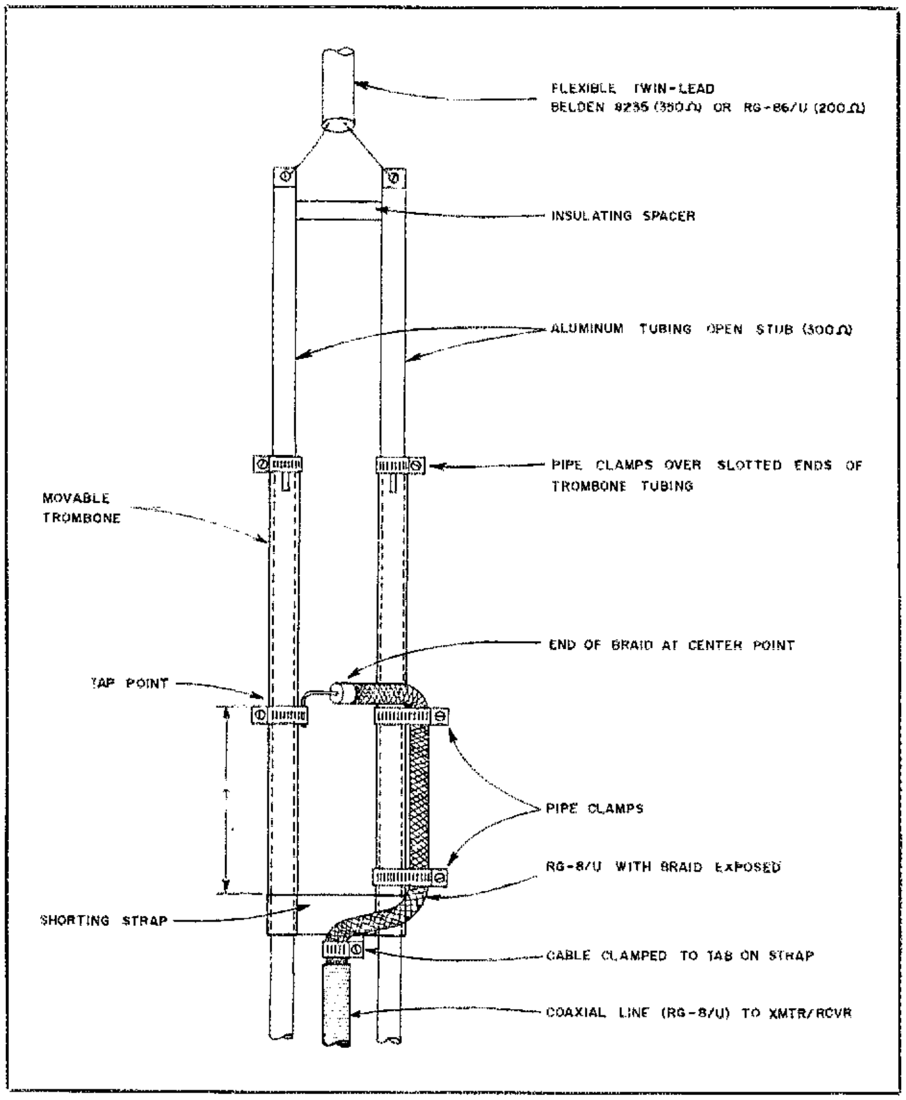

Fig. 3 — Balance-to-unbalance matching unit.

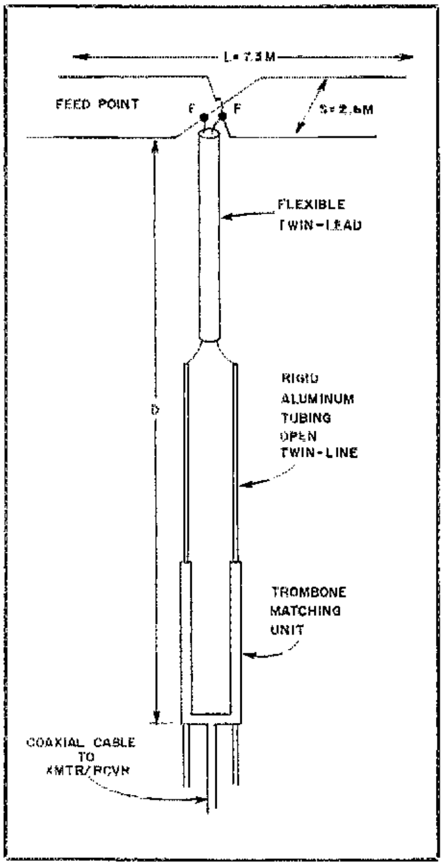

Fig. 4 — Feed-line arrangement for W8JK antenna.

position indicated in the second column, the short can also be a half wavelength farther, as indicated in the third column. In fact, the short can be at any multiple of one-half wavelength.

Table 1

Characteristics for W8JK Antenna

	Distance D (approx.)		*Gain*	*Half-power beamwidth*	
Band	*1st short*	*2nd short*	*dBi*	*Horiz.*	*Vert.*
20m	10.8m	21.2m	5.7	62°	90°
15	5.5	12.6	6.7	60	93
10	2.8	8.1	7.7	56	96
6	9.0	12.0	8.2	30	105

L = 7.3 m and S = 2.6 m, as in Fig. 4.
Values for the new 12- and 17-meter bands can be interpolated.

The distances in Table 1 assume all open conductor twin-line between the antenna and the short, with wave velocity equal to or nearly that in free space. Since the velocity on flexible twin-line is less than this (typically 80%), D will be less by an amount depending on the length of flexible twin-line. For example, at this velocity value (80%), a 4-m section of flexible twin-line will be equivalent to a 5-m length of open line.

Gain and Beamwidths

The gain in dBi of the antenna over an isotropic radiator, and the half-power beamwidths, are given in Table 1. Although the antenna could be operated at wavelengths longer than 20 meters, the gain tends to decrease and the matching adjustments tend to become more critical. At wavelengths shorter than 6 meters, the gain drops sharply and the side-lobes become larger.

The Antenna Environment

Any antenna performance is highly dependent on its environment; that is, its siting and surroundings. What I wish to say in this section about environment applies to all antennas, including the W8JK.

There are two extreme cases. One is with the antenna all alone in free space, a never-realized ideal, even on a satellite. The other is with the antenna situated above a flat, perfectly conducting ground. The latter case is of particular interest because it permits a ground reflection, which at best can double the field strength, giving the equivalent of a fourfold increase in power (6dB gain). At the worst, it can result in a complete cancellation of the signal. Ordinarily, the ground is not flat or perfectly conducting, and there may be trees and buildings, which absorb or scatter the radiation. Nevertheless, let us consider some of the implications of the ideal ground reflection case.

Vertical Angle Control

Consider an antenna at a height (H) above a perfectly conducting flat ground, as in Fig. 5. If the distance (R-D) is an odd number of half wavelengths (1, 3, 5 . . .), then the direct and reflected waves will reinforce for a horizontally polarized antenna, but will cancel for a vertically polarized antenna. However, if (R-D) is an even number of half wavelengths (0, 2, 4 . . .), the reverse is true.

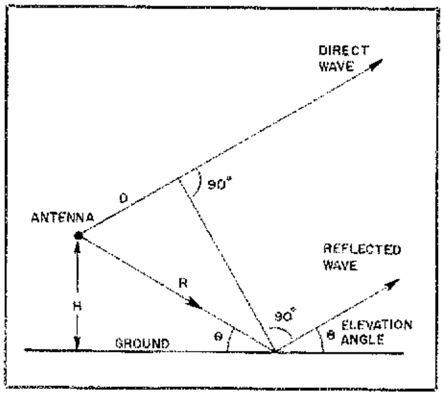

Fig. 5 — Effect of ground reflection.

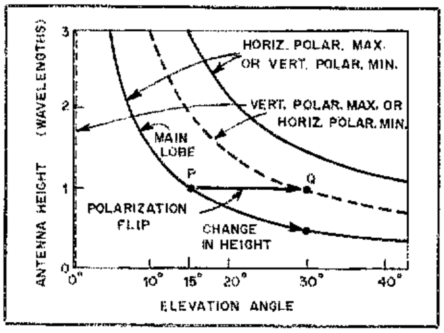

Fig. 6 — Elevation angles of maximum and minimum radiation from horizontally and vertically polarized antennas over a perfectly conducting flat gound.

Although such an ideal situation is rarely realized in practice, it is noteworthy that a transmitted (or received) signal might be quadrupled in power, or reduced to zero, depending on the height (H) of the antenna, the wavelength and the vertical or elevation angle (θ). If there is imperfect ground reflection, there will be only partial reinforcement and cancellation, resulting in less than a 6-dB reflection gain and significant radiation at the zero radiation angles of the ideal case.

The ideal situation is shown graphically in Fig. 6. With the antenna one wavelength above ground, there is a maximum signal at an elevation angle of 15° if the antenna is horizontally polarized (point P), but zero signal if it is vertically polarized. At this same height, a vertically polarized antenna will have maximum radiation at a 30° elevation angle, while a horizontally polarized antenna has zero radiation at this angle (point Q). To produce maximum radiation at 30°, the horizontally polarized antenna can be lowered in height to one-half wavelength, or the antenna could be flipped to vertical polarization.

Owing to Faraday rotation of the polarization, a horizontally polarized wave transmitted via the ionosphere may arrive at any polarization, and the polarization may fluctuate continuously. Thus, if 15° is the optimum elevation angle for the transmission path in use, it does not mean that a horizontally polarized antenna one wavelength above ground will be effective at all times. But the polarization and height are at least necessary conditions, because a vertically polarized antenna at that height will have a null at 15°.

The curves of Fig. 6 were calculated for an isotropic radiator, so they do not correspond exactly to those for directional antennas. But at the lower elevation angles shown, the differences are small.

To flip a W8JK antenna between horizontal and vertical polarization, the central boom can be constructed as suggested in Fig. 7. The W8JK antenna is small and light enough to make this polarization change practical. Alternatively, a vertical W8JK antenna, identical to the horizontal one, could be mounted on the same boom and a relay used to switch either antenna to the twin-line. Vertical-angle control can be just as important as the horizontal-angle control afforded by an antenna rotator.

Round-the-World Paths

A bi-directional antenna, such as the W8JK, is ideal for finding open round-the-world communication paths. A simple technique I have used is to tap out an occasional dot while slowly rotating the antenna. When I hear an echo, it means that my signal has found an open path around the world. The time delay is about one-seventh of a second, and most receivers recover from a transmitted signal in less time than this. In my experience, 15 meters was the most productive of open round-the-world paths. Once I found one, I listened for a while or sent a "CQ," and was frequently rewarded by DX contacts all along the path. The question of long

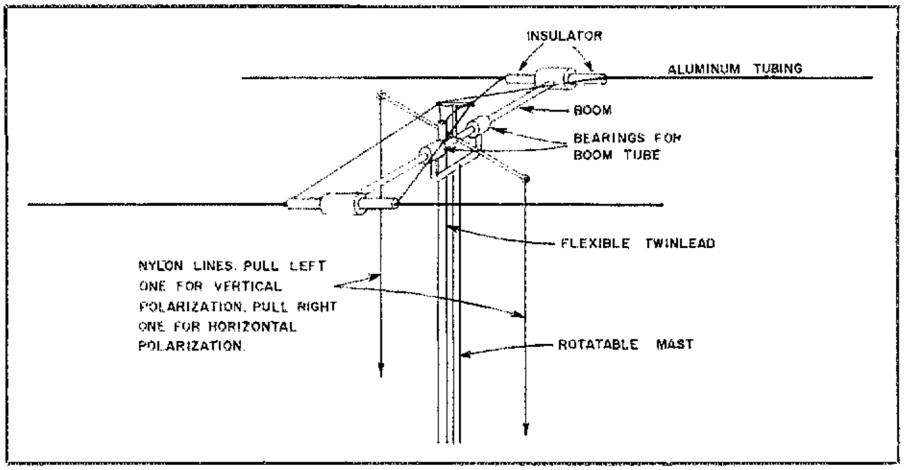

Fig. 7 — Central boom construction for flipping between horizontal and vertical polarizations.

path versus short path does not arise.

Summary

The characteristics of W8JK antennas are reviewed, and a simple 6-band (20, 17, 15, 12, 10, 6-meter) version is described in some detail. Feeding, siting, polarization and vertical-angle control are discussed. I hope the information will make the advantages of the W8JK better understood, and may even encourage some enterprising amateurs to build one.

John Kraus, W8JK, is McDougal Professor Emeritus of Electrical Engineering and Astronomy at the Ohio State University, where he has been on the faculty since 1946. He is also Director of the Ohio State-Ohio Wesleyan Radio Observatory and is visiting Stocker Chair Professor at Ohio University. He received his PhD degree in physics from the University of Michigan in 1933. He is author of hundreds of technical articles and of the books Antennas *(McGraw-Hill, 1950),* Electromagnetics *(McGraw-Hill, 1953),* Radio Astronomy *(McGraw-Hill, 1966),* Electromagnetics *2nd edition with K. R. Carver (1973),* Big Ear *(Cygnus-Quasar, 1976), and* Our Cosmic Universe *(Cygnus-Quasar, 1980). Dr. Kraus is the inventor of the helical beam antenna, the corner reflector antenna, the backward-angle-fire grid antenna, the W8JK and other close-spaced arrays, multi-wire doublets and additional antenna types. Dr. Kraus is a Fellow of the IEEE and a Member of the National Academy of Engineering. He has been a licensed amateur since 1926.*

Notes

[1] inches = mm × 0.03937; feet = meters × 3.281.

[2] When properly adjusted, a given T and D usually provides less than a 2:1 VSWR over all or most of any amateur band. The tap distance (T) is typically 0.5 m.

New Books

☐ *Interference Handbook* by W. R. Nelson, WA6FQG. Published by Radio Publications, Inc., Box 149, Wilton, CT 06897. Soft cover, 5-3/8 × 8-1/8 inches, 241 pages plus index, $8.95.

William Nelson worked 33 years for the Southern California Edison Company. He spent two years as a groundsman and then moved up to lineman. After five years as a lineman he was promoted to estimator. His work included distribution design, power facilities and load management. In 1964 he was appointed Amateur Radio Representative and RFI Investigator for the company. He held that position until his retirement in 1980. As an investigator, Nelson was both RFI sleuth and speaker at club meetings and conventions. He helped change construction practices in the electrical utilities. These changes have reduced the potential for RFI.

Nelson is past chairman of the Los Angeles Council of Radio Clubs TVI Committee. Today he is a consultant to power utilities on RFI problems, including investigation and training.

RFI is a growing problem, the kind of problem that finds the Amateur Radio operator the victim more often than the culprit. Most of us need help in developing the art and understanding the science of RFI identification and elimination. This book should help you toward that end.

Interference Handbook contains 13 chapters and 173 illustrations. Chapter 1 consists of introductory material. In Chapter 2, spark discharge interference and noise suppression are discussed. Other items covered in this interesting and useful chapter include: the means by which RFI can be transmitted, and some helpful hints on tracking down interference. Did you know that RFI carries farther on lower frequencies? By listening to the highest frequency that the interference can be heard on and moving higher as you "zero" in on it, an RFI source can be tracked down. Nelson describes how to use your car radio, hf mobile rig and a vhf receiver to track down troublesome RFI sources.

Electrostatic discharge is the subject of Chapter 3. This is a potential troublemaker that most of us don't think about very often. When you get through reading this one you'll want to go out and check your station grounding, or, perhaps, install a better ground system.

Chapters 4 through 6 cover the RFI investigator and power company practices. We may not be able to climb the power pole to correct a fault, but most of us will find power line construction and how it can generate RFI fascinating. Every power utility employee in the country should be required to read Chapters 5 and 6.

Noise-reducing bridges for your receiver is the subject of Chapter 7. Chapters 8 through 10 cover nonlinear devices, transmitters, TV sets and audio equipment. Chapter 11 is on grounds and grounding; it concludes: "A combination of multiple ground rods and bypass plugs will be a great help in difficult cases of RFI when transmitter and receiver are located in the same building."

Vehicle noise suppression is the topic of Chapter 12. Mobile Amateur Radio operators, and even more so, RFI investigators, dislike those annoying noises that are sometimes generated by vehicular electric systems. Nelson gives some good pointers on locating and reducing noise sources in your car, truck or boat.

The book concludes with an RFI roundup. This includes a variety of miscellaneous items that did not fit handily into any of the earlier chapters. The final item is the *Consumer Products RFI Assistance List* compiled by Harold Richman, W4CIZ, of the ARRL RFI Task Group.

The easy-to-read style and the many anecdotes found throughout make this book fun to read and easy to understand. The perspective and insights into power utility practices are of interest to any ham who has had a noise or power-line interference problem. — *Chuck Hutchinson, K8CH*