Installing a Navcom

We put a KX 125 navcom where it belongs—in an aircraft —and find that it works well.

BY T.E. GILLAND

Last month, we described in some detail Bendix/King's KX 125 navcom. We installed it in an airplane and evaluated the results. In short, it performed better than advertised. This month we conclude with some details of the testing and installation tips that apply to avionics in general.

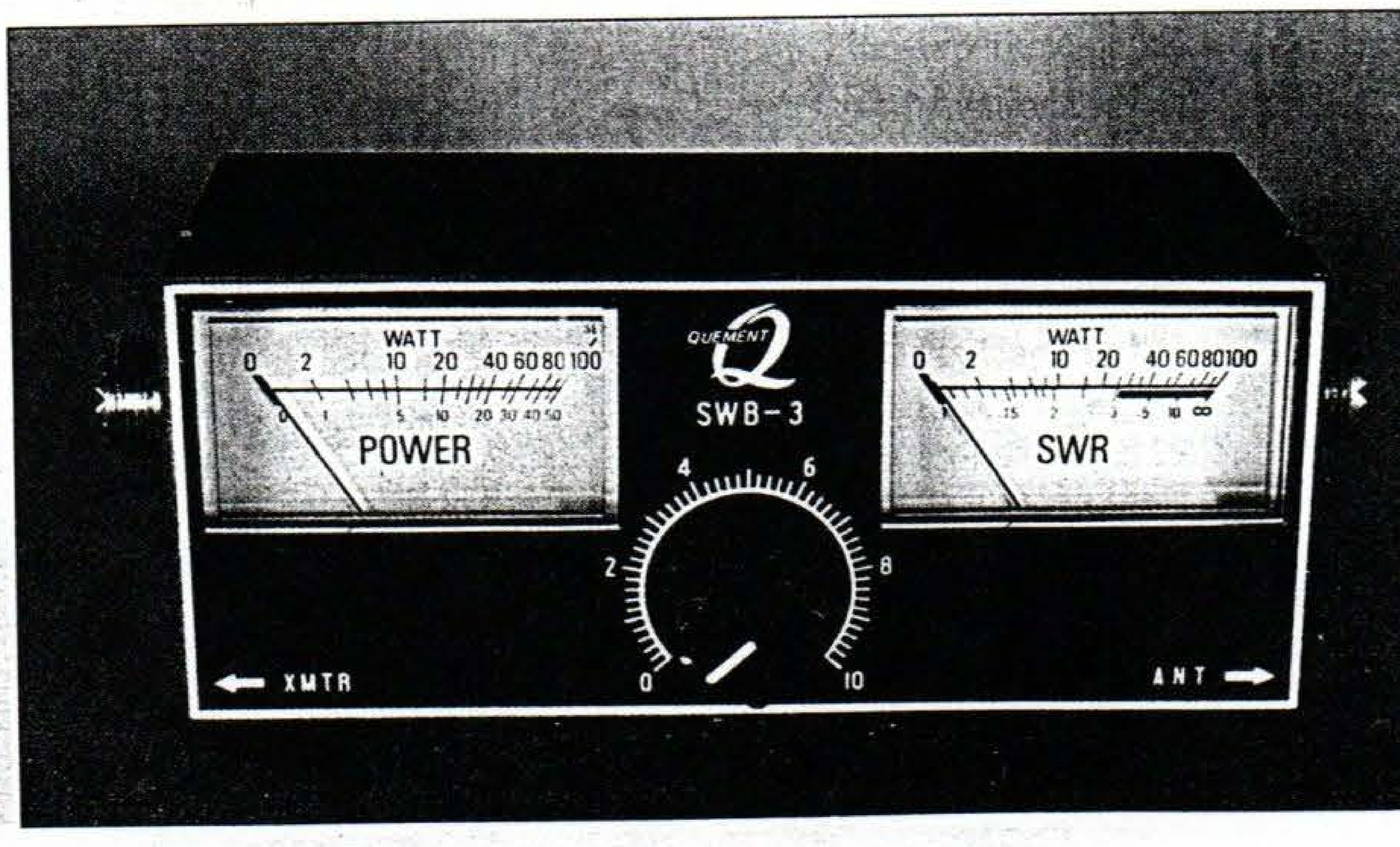
Because my home is under an air traffic corridor between San Francisco and several eastern ports of call, it's an ideal site for monitoring IFR frequencies. Using an old magnetic mount, I improvised a listening antenna for the Bendix/King KX 125 navcom described last month and used the roof of my car for a ground plane. Clear and crisp reception of the heavies flying overhead made every syllable distinct.

Airborne Checks

Later, with the help of several friends, we conducted an evaluation of this neat package in its element: along the airways. To give proper credit to all concerned requires listing many members of two local organizations: EAA Chapter 376 in Fresno and the Madera Amateur Radio Club. I would like to acknowledge by name all who contributed, but a space problem precludes it.

Three generous owners offered their airplanes for in-flight tests and, after resolving minor problems with schedules, the one I used is a Cessna 150. As the owner is a ham radio enthusiast, his airplane has a 2-meter amateur radio aboard, making his airplane an ideal platform. Another participating ham has a sophisticated communications receiver with an accurate signal strength meter in his shack, which is near the Madera airport where we conducted this review.

Despite my temporary wiring harness and somewhat primitive chassis mounting, the KX 125 performed like a champ. My friend on the ground



PHOTOS: T.E. GILLAND

Photo 1. A simple SWR meter checks the efficiency of an antenna installation.

monitored our transmissions while we made medium banked 360° turns about 30 miles away, and using ham vernacular, he reported a 59 signal on all headings (no blind spots detected). The first digit reports readability on a scale from 1 to 5 and the second one translates signal strength on a scale from 1 to 9. A strong, perfectly readable signal prompted a flattering comment from the ground station on 2 meters, "Hi-Q (for quality), communications-grade copy." During the same transmissions, I noted a reading of slightly more than 7 watts on the power meter installed for the occasion. Bendix/King factory specifications may be a bit conservative.

We flew a triangular course of about 150 miles checking navigational features with three VORTAC stations and known landmarks for references. After the flight I used my notes, a sectional chart and a Weems plotter to check accuracy of OBS numbers. I found no discrepancy, suggesting that the VOR course accuracy limit listed for the KX 125 is another conservative specification.

Tweaking the knobs and punching the buttons allowed me to try the various features. Everything worked as the book says it should and as I outlined last month. With the transmitter tuned to an unused frequency, I tried the Stuck Microphone Alert feature. Any pilot who misses that distinctive warning needs refresher training—or something.

Localizer operation is the only feature we did not try. Monitoring traffic at the nearest airport with ILS, we noted several arriving and departing air carriers, plus Air National Guard jets. Prospects of maneuvering a C-150 in that congestion, and a possibility of turbulence on the runway, seemed like a frivolous adventure at the time, so we changed our minds about landing there.

Installation Tips

Electronic and communications technologies invariably produce a cloud of mysticism that, in the eyes of many, associates avionics with the occult. Homebuilders face many limitations concerning the goodies inside a black box, but they have considerable latitude when connecting that box into an integrated system. Perhaps the most predominant enigma is antennas and transmission lines, which are generally coaxial cable (called coax). Several good books clarify these alien subjects, and I have included a few recommendations for your technical library at the end of this article.

Installing radios and tuning stringed musical instruments have much in common. Unfortunately we cannot tune to each operating frequency in radio work like a musician tunes each of several strings on a guitar. Doing so requires a separate antenna for each frequency and, because the com radio alone operates on 760 frequencies, an antenna for each one seems ominous. Clearly, an airplane bristling with that many antennas would be an aerodynamicist's nightmare. Fortunately, aircraft antennas and feed systems are broadbanded enough to perform within limits throughout the range of operation when tuned to the center frequency. For the KX 125, those frequencies are: com = 127.4875 MHz, and nav = 112.975 MHz.

Musicians have the advantage of working with audio frequencies: something they can hear. Radio frequencies, on the other hand, are beyond audio range, so we must rely on dimensions and electronic instruments to harmonize.

One dimension that frequently comes up in antenna work is *wavelength*. A simple definition states, "One wavelength is the distance a radio signal travels in free space during one cycle of operation."

Visualizing an alternating current sine wave contributes to an understanding; the horizontal measurement of one cycle is one wavelength. Radio waves travel at lower velocities in an earth environment, making wavelengths shorter—through a conductor, for example. Standard practice in the industry uses a correction factor of 5% for approximations, producing results accurate enough for practical radio work; practitioners call this a *fudge factor*.

Several of the references include equations for determining wavelength, so I'll just give dimensions applicable to the KX 125. Computed for center frequencies, and taking the fudge factor into consideration, the physical (not electrical) wavelength dimensions are: com = 87.93 inches, and nav = 99.23 inches. Standard practice rounds these numbers off at two decimal places. An average installation requires physical dimensions only; finding electrical dimensions requires instruments.

Installations of antennas on (or in) airplanes present unique problems, making these vehicles the most difficult for mobile communications systems. Resulting from much research, development and experimentation, two general types of antennas evolved in avionics because they are the best compromise, with convenience and efficiency the prime considerations.

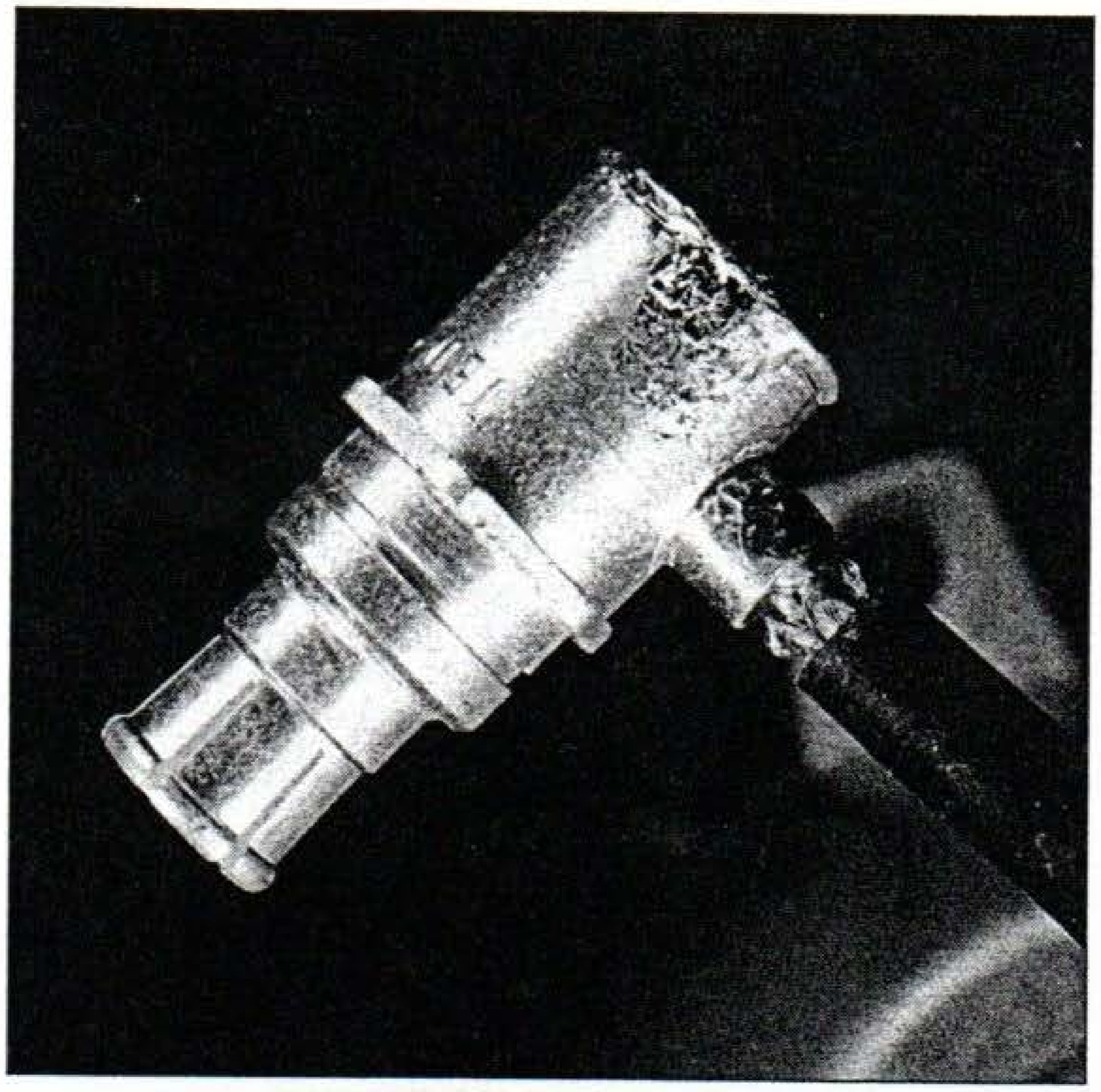


Photo 2. A coax elbow fitting eliminates the need to bend coax severely behind the panel.

First, the dipole, or two-element antenna, which is sometimes called a *Hertz antenna* in honor of the inventor. VOR receiving antennas exemplify this type. Second is the vertical—or whip antenna—that requires a ground plane (or radiating surface at the base), explaining another frequent expression: *ground plane antennas*. Another name, *Marconi Antenna,* also honors the inventor, and this type prevails in aircraft com systems. Development of both types took place around the turn of the century, and fundamental principles remain valid despite advances in communications technologies.

In aircraft systems, most dipole types became known as *half-wave antennas* because of the total length; two elements of one quarter wavelength each totals one half wavelength.

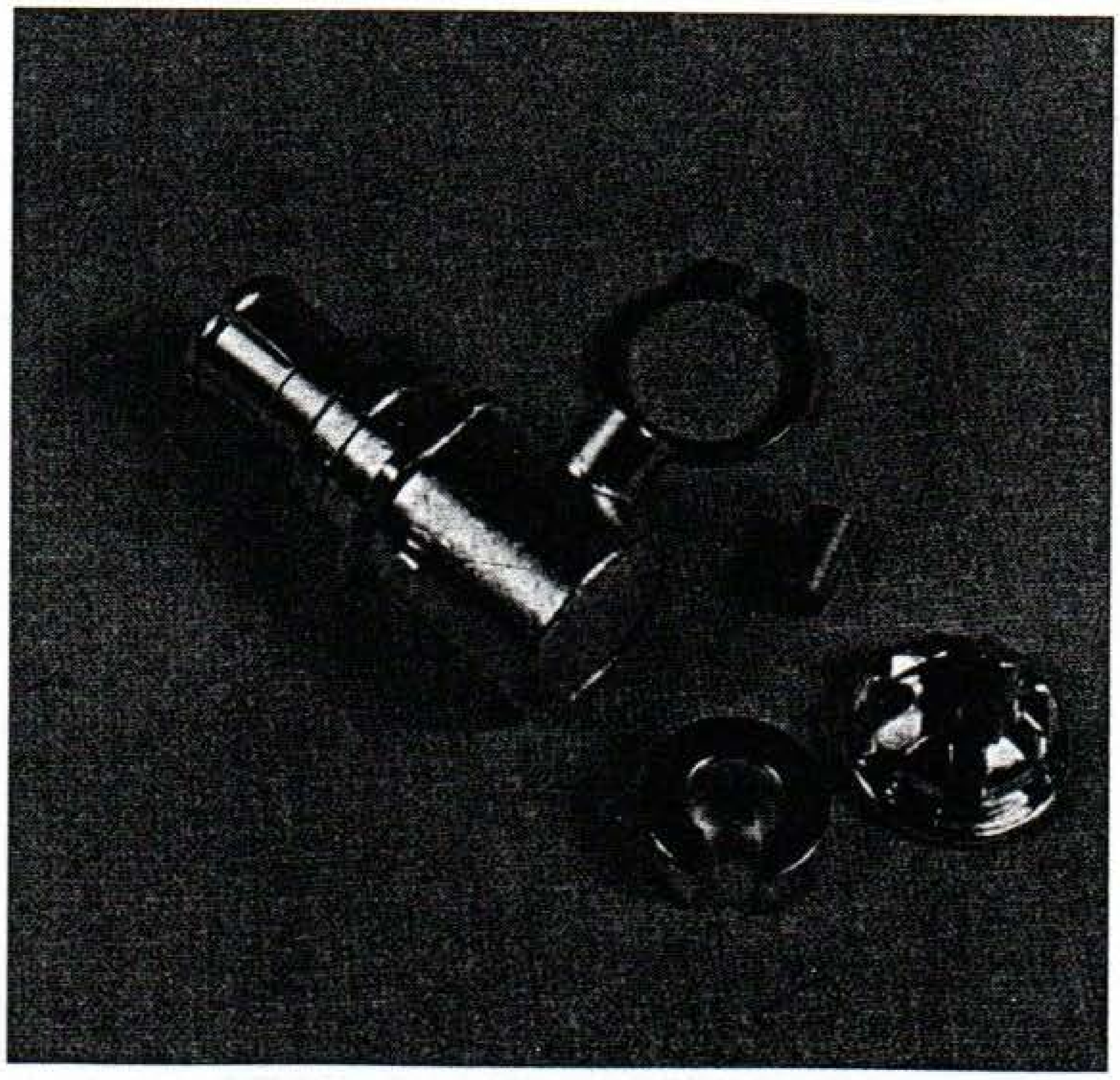


Photo 3. A coax elbow kit includes these parts.

Spacing between the elements is a critical dimension; anything more than half an inch vilifies the antenna's performance. Commercially manufactured antennas have elements cut to electrical dimensions, instead of physical, and present a 50-ohm balanced load. Coax, on the other hand, is an unbalanced load; therefore, a device called a *balun* (meaning balanced to unbalanced) matches the feed line to the antenna. Most commercial antennas with baluns have them sealed into the assembly.

Most vertical antennas used in airplanes have a single quarter-wave element and require a ground plane to complete a half-wave system. Thinking of the ground plane as a reflecting surface, like a mirror, helps to understand the Marconi principle. A radiating element looking into the mirror thinks it sees another quarter-wave element extending straight through the base, like a dipole. Ground plane antennas present a 50-ohm unbalanced load, eliminating the need for baluns.

Obviously, a proper ground plane is critical when installing vertical antennas. Outer skin on sheet metal airplanes makes an ideal surface providing that electrical connections are good; paint, for example, destroys electrical integrity. Tube and fabric airplanes require a ground plane inside the structure at the antenna base, usually a piece of aluminum sheet cut 18 inches square (324 square inches).

Composite airplanes made a profound impact on homebuilding, and antenna installations in these airplanes is a controversial subject. On one side of the issue, critics argue that modern streamlined antennas (mounted outside) offer superior communications efficiency, which compensates for the small aerodynamic trade-off. But another group claims that antennas mounted inside wood and fiberglass (not carbon fiber) airplanes offer the same electrical efficiency, providing the design and installation conform to established conventions.

RADIOS

continued

Jim Weir, a renowned electronic engineer, ham radio buff and homebuilder's pundit, is a staunch supporter of the second group. In 1975, the Bellanca Aircraft Company needed a complete IFR antenna package concealed in the Viking's wood wing; Weir's designs solved the problems. Perhaps his most famous accomplishment is the *Voyager*'s antennas, which contributed to the record-setting flight around the world without refueling. Who can argue with success?

Weir has another talent: He is a prolific author who wrote several magazine articles on the subject of hidden antennas. Now for the best news: Radio Systems Technology, Inc. (RST)—the company that Weir started and later sold—has compiled these articles into a brochure, which RST sells (see Reference 3). Although these articles are of primary interest to those building composite or wood airplanes, sections on antenna basics contain good information for any homebuilder. One section regarding loran receivers is especially informative.

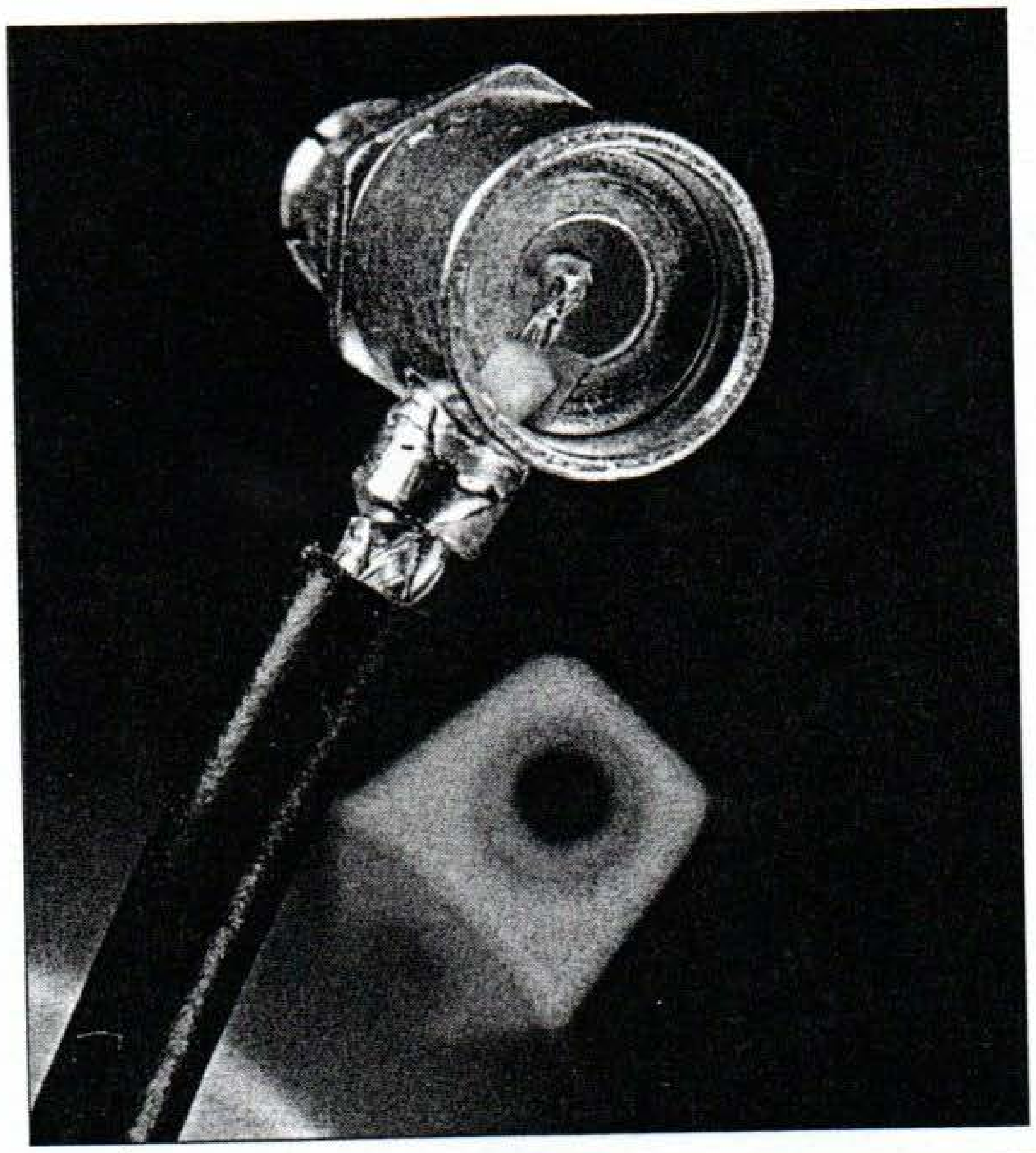


Photo 4. Before its end cap is attached, the assembled 90° coax elbow looks like this.

Novices who install antennas generally use a coax feed line just long enough to reach from the radio to the antenna. This frequently results in a mismatch that introduces line losses and degrades performance. Cutting the feed line one-half wavelength (or a multiple of it) amounts to tuning the circuit. Suppose, for example, the distance between a KX 125 com radio and the antenna is 10 feet (120 inches). Because one wavelength (87.93 inches) is a tad short, 1.5 wavelengths span the distance with some to spare (87.93 x 1.5 = 131.90 inches); 11.90 inches is left over.

Standard aircraft practice takes up that much slack, slightly less than a foot, by routing the transmission line in a serpentine fashion. I do not recommend coiling coax to take up slack; sometimes this detunes circuits. It's the same principle as failing to depress a guitar string firmly against the finger board. Who needs sour notes in an aircraft communications system?

Those who use a dealer-fabricated harness can specify lengths for coaxial cable. Tell the technician that you want circuits tuned to resonate at the center frequencies. Better yet, take your antennas to the shop and have them tune the entire system; good avionics shops have instruments for doing this electronically. An alternative is to solicit the help of an amateur radio operator who owns a grid dip oscillator (called a dip meter). Most hams enjoy "pruning and tuning" parties and take pride in their work. Perhaps the best part of this suggestion is that tuning takes place on the airplane, which compensates for unforeseen anomalies.

Many technicians scoff at the praccontinued

Industry standards dictate that ground stations radiate vertically polarized signals for communications and horizontally polarized signals for navigation. Therefore, aircraft standards install antennas in the same orientation for maximum efficiency.

Antenna location often makes the difference between good installations and bad ones. Bendix/King recommends separation distances of 6 feet from a DME and 4 feet from an ADF sense antenna. They also specify a minimum of 3 feet of separation between the KX 125, with its wiring harness, and an antenna. Besides equipment interference, any things detune antennas. Predominantly, metallic objects or structures disrupt radiation patterns and absorb energy; carbon fibers have the same effect. Any of these materials within one quarter wavelength of antenna tips deteriorates radio communications.

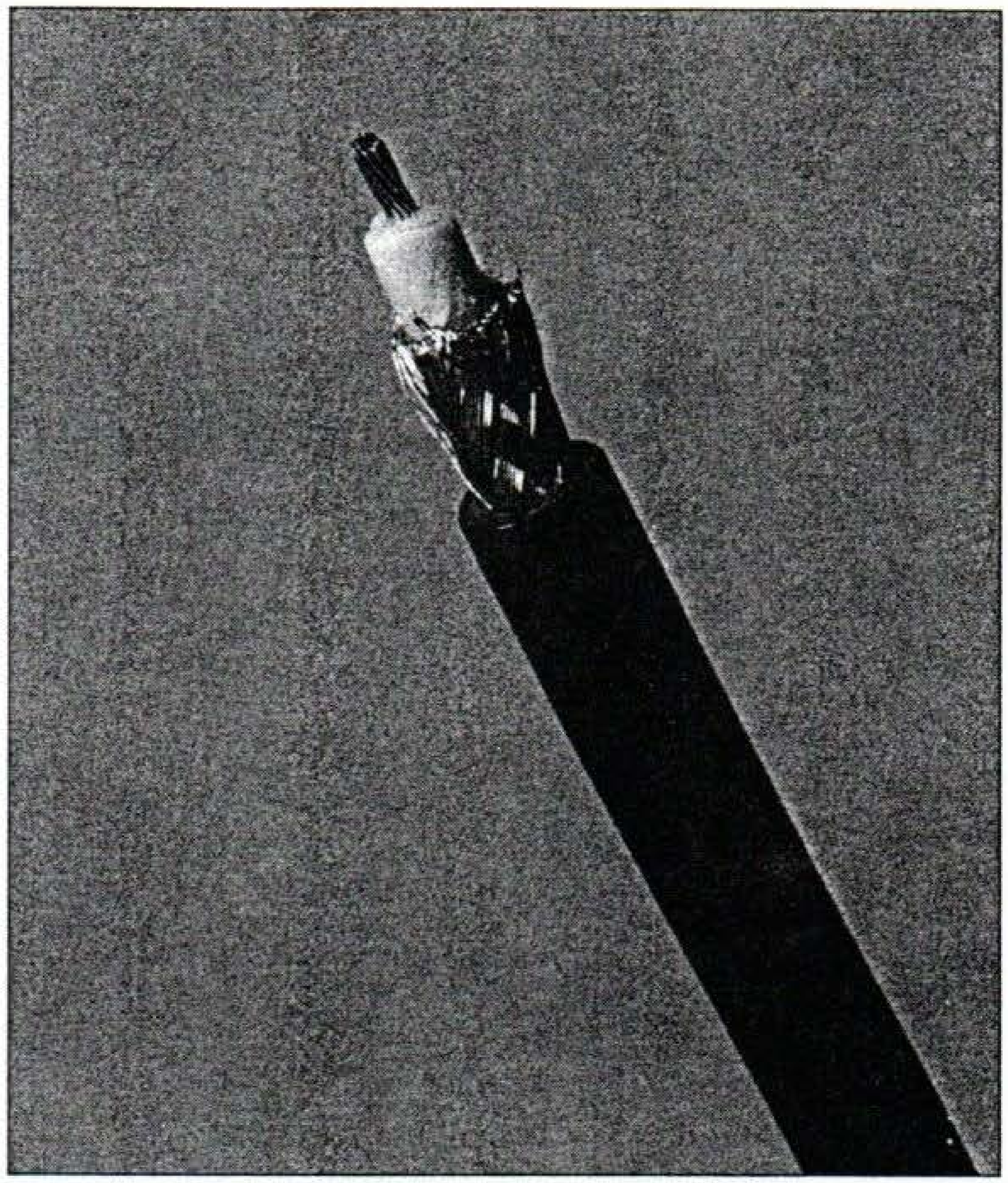


Photo 6. Good coax. Shield coverage is much better.

One of Weir's hidden antennas is a vertically polarized dipole communications type, which is something of a boomer. Yes, I said "boomer," not "bummer," because I have a high regard for dipoles; like many other ham operators, I frequently use this type for globe-circling communications. His design works very well inside vertical fins of some airplanes and winglets of others. They work so well that they captured the attention of other homebuilders.

Several who are building metal airplanes, such as RV-6s, frequently ask about installing one of these antennas inside a fiberglass wingtip and I have two objections. First, polarization of that installation is horizontal, or 90° out of phase with the rest of the world. Second, it's near a metal wing where I think it's physically impossible to have an antenna tip clearance of one quarter wavelength.

Admittedly, I have never installed or tested one of these wingtip antennas but reasoning tells me they exhibit eccentric performance and have weird blind spots. I hope somebody can prove me wrong because, after almost a century, we're past due for something new. Do we have any Hertz- or Marconi-type homebuilders out there?

Feedlines

Working with coax is something new for many homebuilders. Coax is a two-conductor transmission line in which one conductor surrounds the other, explaining the nomenclature *coaxial*. In the most common form, a continuous dielectric keeps the two conductors separated and maintains critical spacing, which determines characteristic impedance.

The outside diameter of the center conductor and inside diameter of the outer conductor are factors in a complex mathematical equation for computing impedance. In practical shop work, those computations are not necessary. Just use the type coax specified and handle it carefully. Negligence during shipping, handling and storage probably damages more coax than anything else; kinking makes for a heap of scrap. Careful attention to detail pays dividends when making installations; the minimum radius of a bend is six times the outside diameter of the coax.

Photo 2. Space-saving, 90° elbow coax connectors eliminate the need to make sharp bends in transmission lines behind the panel. This is fairly common hardware in the aircraft industry but is seldom used elsewhere.

Photo 3. Three of the five parts in the installation kit are easily identified. These include the fitting itself, a snap ring and a snap-on cover. A thick horseshoe-shape washer is a 50-ohm load, and a small piece of tubing is an adapter. The adapter is for small coax, which is not used in this installation.

Photo 4. Assembly amounts to slipping the coax into the fitting, with the braided shield inside, and soldering the center conductor. Also, the shield is soldered to the fitting, taking care not to melt the coax's dielectric. Then the 50-ohm load is slipped inside and tamped down; it's a snug fit. All that remains is to install the snap-on cover, solder it in two places and the fitting is ready to fly. See Photo 2.

Photo 5. Coax can be purchased in a variety of grades, and this picture illustrates one extreme. Shown here is a piece of RG-8/U purchased at an electronic supermarket for this article and typifies bargain-basement merchandise. I chose this type because of its size, which is large enough to show photographically what to look for when buying coax.

Skimpy braid used for the outside conductor (appropriately called the shield) identifies this sample for what it is: cheap coax (not discounted bucks but cheap). A careful look at the picture reveals many gaps in the braid; my estimate is only about 60% coverage. (Much greater shield coverage is much better.) Manufacturers who produce this grade coax generally use adulterated, reclaimed material and run their equipment at excessive speeds with little or no regard for quality.

Material used in the center conductor's insulator is another important consideration. Foam predominates the low-grade coax market, and a simple fingernail test identifies its soft and yielding nature. When installed in a hot environment, foam becomes plastic, allowing the conductor to sink toward the shield—playing havoc with characteristic impedance. In extreme cases, like inside aircraft structures on hot days, the foam becomes soft enough for the conductor to slump into the shield, causing an electrical short. This disables receivers and often cooks final stages of transmitters.

Photo 6. From my research of mail order catalogs, I find that most firms catering to homebuilders stock RG-58A/U like the example shown here, which Bendix/King recommends for the KX 125. Full coverage of the shield (96% in this case) is one hallmark of quality; solid polyethylene dielectric is another. Polyvinyl chloride (PVC) is the material used in the jacket of this sample for protection against scuffing. I used the coax pictured here for my review and I can recommend it for an average homebuilt project. This coax is also stocked in many electronic stores; ask for Belden Number 8259.

Despite merits of this coax, there are better grades that some homebuilders may wish to consider. One document in the military sector provides aircraft wiring guidelines that most avionic technicians find useful (see Reference 7). This reference is a road map for the Mil-Spec network, handbooks, technical manuals and technical orders. A customer number, assigned with the first order, makes it easy to use a computerized telephone for ordering additional references.

Summing Up

Evaluating the KX 125 was a fun project and I can recommend this nav-com without reservation. Installed and maintained properly, it should give many years of reliable service. Happy homebuilding! ❑

FOR MORE INFORMATION, contact Bendix/King General Aviation Avionics Division, 400 North Rogers Road, Olathe, Kansas 66062; call 913/782-0400.