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BUILD PROFESSIONAL QUALITY CONNECTORS

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Make your own high-performance connectors—inexpensively! See page 4 for details.

THE AMERICAN RADIO RELAY LEAGUE, INC

The American Radio Relay League, Inc, is a noncommercial association of radio amateurs, organized for the promotion of interest in Amateur Radio communication and experimentation, for the establishment of networks to provide communications in the event of disasters or other emergencies, for the advancement of the radio art and of the public welfare, for the representation of the radio amateur in legislative matters, and for the maintenance of fraternalism and a high standard of conduct.

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Purposes of *QEX:*

1) provide a medium for the exchange of ideas and information between Amateur Radio experimenters
2) document advanced technical work in the Amateur Radio Field
3) support efforts to advance the state of the Amateur Radio art.

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Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and double spaced. Please use the standard ARRL abbreviations found in the 1985 and 1986 ARRL Handbooks and in the January 1984 issue of *QST*. Photos should be glossy, black-and-white positive prints of good definition and contrast, and should be the same size or larger than the size that is to appear in *QEX*.

Any opinions expressed in *QEX* are those of the authors, not necessarily those of the editor or the League. While we attempt to ensure that all articles are technically valid, authors are expected to defend their own material. Products mentioned in the text are included for your information; no endorsement is implied. The information is believed to be correct, but readers are cautioned to verify availability of the product before sending money to the vendor.

Empirically Speaking. . .

Just the FAX, Ma'am

Facsimile (FAX) has been part of Amateur Radio ever since photo and weather FAX machines have been available on the surplus market. Compared to CW, SSB, RTTY and more recently packet, FAX has not (yet) started a revolution in the world of ham radio. FAX hasn't been as well liked as its sibling, slow-scan television (SSTV), although even their mother has a hard time telling them apart sometimes.

But there's evidence all that may be changing, largely because of computers. The Keith Sueker, W3VF, article on "Real-Time HF WEFAX Maps on a Dot-Matrix Printer," using an Apple II computer, (*QST*, Mar 1986) piqued quite a bit of interest. An adaptation by Elmer Schwittek, K2LAF, for the IBM® PC appeared in Technical Correspondence, *QST*, Dec 1986. Recently, Advanced Electronic Applications, Inc (AEA) added a capability to their PK-232 to print weather FAX maps on a dot-matrix printer having the Epson graphics mode. Although one could argue that WEFAX is simply high-tech SWLing, not Amateur Radio, some hams seem to have a fascination for it.

But there's another kind of FAX: document facsimile. Almost any office building of any size has one or more. You may have used it to send or receive drawings or typewritten material over the telephone but didn't give it any thought as a terminal device for Amateur Radio applications. Basically, if the document FAX machine can communicate over a phone line, it can also do it via ham radio. Some interfacing is required, however, because ham radio circuits are usually half-rather than full-duplex, and signal levels need to be matched. Other than just experimenting, what good is document FAX in the Amateur Radio Service? Plenty. As an emergency-communications mode, it has the potential for sending documents on official letter head and with signatures. It allows originators to type or handwrite messages on any piece of paper and addressees to receive hard copies of incoming messages. Besides text, other black-and-white graphics can be transmitted. These may include maps (such as with satellite tracks and footprints), sketches, schematics, and other line drawings. Add a little telecommand to the recipe and you could ask a FAX bulletin board to transmit a certain page you would like to see. What makes document FAX feasible now for the amateur experimenter is the availability of used machines and the emergence of computer emulation of document FAX. Recently, several Japanese Amateur Radio magazines have been bulging with information on interfacing document FAX machines. Of particular note are the March 1987 issue of *CQ Ham Radio* and the '87 Spring issue of *Ham Journal.* Unfortunately for those who read only English, these articles are in Japanese. We'll try to get on the good side of the authors of these articles and see if we can get some material in English for *QEX*.

The Japanese experimenters are using CCITT Group 2 facsimile machines. Standards for use over the public telephone network are published in CCITT Recommendations:

$ T.2 (Group 1)-a low-definition double-sideband modulation system with no bandwidth compression, 6 minutes/page.

$ T.3 (Group 2)-uses bandwidth compression (encoding and vestigial-sideband modulation), 3 minutes/page.

$ T.4 (Group 3)-reduces redundant information in the document signal prior to transmission, 1 minute/page.

For use over public data networks, CCITT publishes Recommendation T.5 (Group 4).

Personal computers can originate and receive document FAX with appropriate adapters. In fact, documents originated on a PC generally look better. *PC Magazine* listed commercially available FAX modems in their June 23, 1987 edition. Experimenters, here's your assignment: Let's have some manuscripts on document FAX protocols, hardware, interfacing, and computer emulation. Correspondence on the availability of reasonably priced new and used document FAX gear would be welcome in *QEX*.—W4RI

Correspondence

Microwave Bomb Complicates Communications Shielding

Time Magazine for May 25 features an article on the development of special nuclear warheads for the generation of microwaves.[1] These nuclear warheads are specially designed as anti-electronic weapons that would destroy distant electronic circuits with EMP.

The microwave bombs would operate in a higher frequency range (60 GHz) than "conventional" EMP (LF to 150 MHz). This complicates the shielding of communications from electromagnetic attack.

Another book on EMP protection is the *EMP Testing Handbook*, R & B Enterprises, 20 Clipper Rd, West Conshohocken, PA 19428-9990. Price: $150.—*Nick Leggett, N3NL, 1500 Massachusetts Ave, NW, Apt 610, Washington, DC 20005*

Project OSCAR Update

The Project OSCAR Community Access Station (CAS) development team recently met at the West Coast VHF/UHF Convention to firm up plans for step one of the CAS development effort. Attendees were Andy, N6JLJ, Walt, AJ6T, Jeff, WA6KBL, Ron, WA6HBI, Brian, WA6QDP, Joel, N6AMG, and Jim, WB6JNN.

N6JLJ gave a report on the OSCAR station at the Palo Alto Red Cross. The station consists of an ICOM 271 and 471 transceiver, a Mirage D-1010, a 2-m, 200-W amplifier, a KLM 22C (2 m) antenna, a pair of KLM 18Cs, a KR-400 and KR-500 antenna rotator, and a Shackmaster computer interface/controller. One problem is that the N6IIU digipeater is co-sited with this station, making it necessary to have filtering between its 145.070 output and the 145.900-950 OSCAR downlink receiver.

The Palo Alto Red Cross may fund some of the necessary costs to automate this station for Phase IIIB and C once it is established that some usefulness will be achieved using OSCAR 10, and in expectation of a 1988 launch date for Phase IIIC. Alternatively, Project OSCAR will pick up some costs that consist mainly of a controller for the KR-400 and KR-500 antenna rotator units and the linking system that may be required to interface with the system from a repeater(s).

Another meeting to further discuss these topics is to be held once OSCAR 10 is again available. Project OSCAR is also looking for stations that can perform repeater-to-repeater links on a regular basis to the end of August. Please send information about any candidate systems to James Eagleson, WB6JNN, 15 Valdez Lane, Watsonville, CA 95076.—*Tnx WB6JNN*

[1]Micheal D. Lemonick, "A Third Generation of Nukes," *Time*, vol 129, no. 21, May 25, 1987, p 36.

Space Interest Groups Merge

Two of the nation's leading pro-space development groups joined forces in March 1987. The L5 Society merged its membership with the National Space Institute, resulting in a new organization called the National Space Society. The Society's goals are to develop and promote public interest in space exploration and development, and in opening the space frontier for exploration, industrialization, and settlement.

Earlier this year, the L5 Society was approached by Dr John Champa, K8OCL, Executive Vice President of AMSAT, for assistance in preparing Amateur Radio satellites. One area of cooperation was the final stages of development of the Phase IIIC satellite being constructed in Colorado. The L5 Society prepared a special mailing in an effort to locate technical volunteers in the Colorado area. Several members came forth to contribute to the Phase IIIC project, scheduled for launch by Arianespace from the Kourou, French Guiana, facility on the first Ariane IV vehicle.

For more information on the L5 Society and the National Space Society, write to L5 Society, 1060 East Elm St, Tucson, AZ 85719-4109, or call 602-622-6351.—*Tnx L5 Society*

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Build your own computer generated space station for $59.95! Space M + A + X combines project management with business strategy to test your ability to launch, assemble, and operate a space station within a limited time schedule and budget. This simulated program is one of many offered by Selective Software, 903 Pacific Ave, Suite 301, Santa Cruz, CA 95060, tel 1-800-872-6656, or in CA call 408-423-3556.

Getting A Practical Test Signal

A two-tone test signal (from a tape or oscillators) fed into a SSB transmitter produces the RF PEP output at a 41% power output level. That is, the two-tone power output times 2.45 equals PEP. This is a better test level, especially at high power. This method also gives good indication of proper amplifier bias and overloading on a linearity tracer (which I use), or, the usual envelope patterns to be analyzed on an oscilloscope. Peak power output will also be indicated on a peak reading wattmeter.—*Wayne W. Cooper, AG4R, 9302 NW 2nd Place, Miami Shores, FL 33150*

Text and Viewgraphs From OET Tutorial Available

The telecommunications needs of individuals vary from those of industry. To achieve a high-quality dependable service for both sets of customers, five technological advances in communications networks are required. Communications systems have to have broadband capabilities. The networks must be reconfigured so that network and customer-provided services can be easily controlled by software. New portable digital radio terminals are necessary. User-friendly software is needed to guide users through signaling and control maneuvers. And last, high levels of hardware and software reliability are a must.

These concerns were the topic of a discussion given by Dr Alan G. Chynoweth of Bell Communications Research, Inc. His tutorial, "Telecommunications—A Researcher's Perspective," was delivered on April 21, 1987, and the text and copies of the viewgraphs are now available from the Office of Engineering and Technology. Interested parties may obtain a copy of this material by sending a self-addressed label to the Technical Information Officer, Room 7317, Office of Engineering and Technology, Federal Communications Commission, Washington, DC 20554. —*Maureen Thompson, KA1DYZ*

Feedback

Author Newland points out that the two Tables in his article, "Cable Counting," (June 1987 *QEX*) have been mislabeled. In both Tables 1 and 2 on p 10, headings Ring and Tip should be reversed. Additionally in Table 2, pair 10 should be Slate/Red, and pair 15 should be Slate/Black.—*Paul Newland, AD7I, PO Box 205, Holmdel, NJ 07733*

Improved UHF-Type Connectors For Half Inch Heliax

By George Chaney, W5JTL
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The fittings described in this article are an outgrowth of those recently published in *QST*.[1] These connectors are electrically identical to the earlier ones, but are vastly superior mechanically and aesthetically.

Soldered-On Connectors

The original soldered-on connectors are made of 1/2-inch copper water tube, but I found brass to be much better to work with. The machining qualities of brass are good and it is less susceptible to thread damage. Although the cost of brass is high, it amounts to about 50 cents per connector.

The first work piece I will describe is a brass tube that measures 5/8-inch OD x 1/2-inch ID, and is threaded 24 tpi (NEF) to mate with the PL-259 sleeve. Mark off a 1/8-inch section on the end of the tube that is to be soldered to the Heliax LDF 4-50 cable's outer conductor. Thin the metal in this area to about a 0.010 inch thickness. Cut fingers in the thinned section with a Dremel® (or other hobby motor tool) and silicon carbide disc. Then, bend the fingers at a 45° angle and lightly tin them on the underside for soldering to the Heliax.

Be sure to install the center connector before fitting the outer threaded sleeve. The procedure for fitting the center connector is detailed in a latter section of this article and in the *QST* article.

Solder the connector to the outer conductor of the Heliax, and leave a 1/8-to1/4-inch gap between the trimmed end of the vinyl jacket and the connector body. With a flat file, remove any excess solder that may extend past the 5/8-inch diameter of the connector.

Next, get a 1/2-inch copper sleeve coupling that has a 5/8-inch ID. Ream out an internal ring in the center of the coupling to allow the copper sleeve to slide over the connector and the vinyl jacket of the coax. A sharp pocket knife does an excellent job. Push the sleeve about 1/2 inch past the gap between the jacket and connector. Completely fill the gap with Coax Seal, and press down tightly to get good adhesion. Now, push the copper sleeve toward, and overlapping, the connector. As you do so, the sealer may pull with it. Press the sealer back in place as the sleeve is moved. After the sleeve overlaps the connector about 3/8 inch, press additional sealer down around each end and cover it with heat-shrink tubing. The connector is now waterproof and has a professional appearance.

Compression-Fit Connectors

A compression fit means that a connector can be put together without soldering a thing! One of my better-developed talents is browsing in hardware and plumbing stores to see what can be readily converted to something useful (other than its intended purpose). I discovered three brass fittings which, when machined and combined, produce a high-quality UHF connector for 1/2-inch Heliax. From coax to outer end, they are: Part 1 is a male 1/2-inch pipe thread on the outer side, with a 3/8-inch female pipe thread inside. A hex nut is made onto the outer side with a male-threaded extension used for a flange fitting. The flange fitting part is removed in machining; part 2 is a male 3/8-inch pipe thread, hex nut and flange thread. Again, the flange part is removed, as well as part of the hex nut; and part 3 is a half-inch female pipe to 1/2-inch flange adaptor. The flange end, when the threads are cut off and cleaned, has a 5/8-inch diameter—just the right size for UHF connector male threads. Mechanical details for piecing together parts 1 through 3 are shown in Fig 1.

To make a compression-fit connector, screw together tightly parts 1 and 2. On a lathe, drill or bore the center hole to 35/64-inch ID. While doing this, remove the two flange-threaded portions. Next, reduce the diameter of part 2's hex nut section until the remaining wall thickness is about 1/16 inch or slightly thicker. Trim the length of this protrusion so that it extends 1/4 inch outward from where the threads of part 1 start, and round off the outer edges. This results in the formation of one side of the clamp for the Heliax outer conductor. Now, turn the piece around in the lathe and enlarge the hole at the hex end of part 1 to 5/8 inch, to a depth of 1/4 inch to 1/2 inch. These fittings are made of the most free-machining brass I have encountered. Lathe time is minimal.

Place part 3 in the lathe chuck and drill it to 1/2-inch ID. Remove the male thread (flange end) and reduce the diameter to 0.625 inch. Remove the short remaining part of the tapered end. Threads are made with a die that is held in a regular die stock with the lathe in its lowest gear. Apply constant pressure to the back side of the die with the nose of the tail stock chuck to assure that the threads are started and kept straight. Except for plating (optional), this part of the connector is ready to be installed.

To fit the finished piece to the coax, remove a sufficient length of jacket from the Heliax LDF 4-50 cable so that it will go through the 35/64-inch diameter hole. Remove an additional 1/4 inch of jacket at this time. Put a ring of Coax Seal

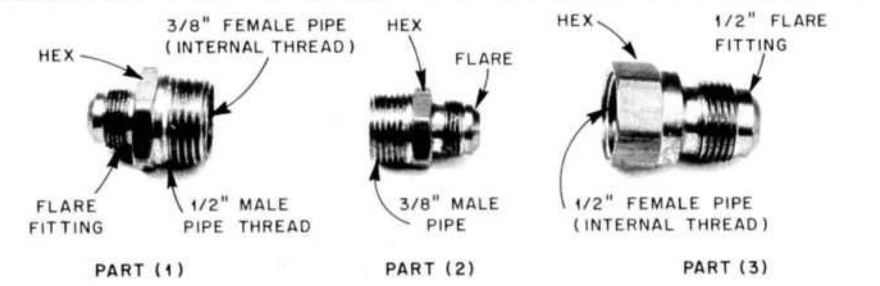

Fig 1—Cross section drawings of the three brass fittings for compression-type connectors. The male and female 3/8-inch pipe threads of parts 1 and 2 are screwed tightly together before machining. Part 2 serves as a filler and provides the clamping lip for the outer conductor. The flare connection ends of both pieces are removed in machining.

The flare fitting threads of part 3 and the tapered end are removed. The diameter is reduced to 5/8 inch and is threaded 5/8 inch x 24 tpi. Clamping of the outer conductor is done between the internal shoulder of part 3 and the lip machined from hex of part 2.

[1]Notes appear on page 14.

around the outer conductor at the end of the jacket. Place the bared outer conductor into the 5/8-inch end of the hole and force it in, compressing the sealer. With a sharp knife, cut the protruding portion of the outer conductor into fingers about 1/8-inch wide and fold them down over the lip that forms the clamping surface. Remove any excess material that might interfere with threading the two parts together. Remove the exposed foam insulation and trim the center conductor to a length that accommodates your center connector. Screw the female 1/2-inch pipe threads of part 3 onto the male 1/2-inch pipe threads of part 1 as tight as possible to clamp the outer conductor of the coax to the body of the connector.

Fig 2—A threaded center pin adaptor, an expendable split sleeve, a female connector and one adaptor. The female connector is threaded at 80 tpi. These are expandable and no taper point is present at the male pin's point of entry. The male pin should be slightly tapered at the point to facilitate entry.

Center Connectors

On occasion, I experience problems with center conductor migration when soldering heat is applied to the center conductor of Heliax LDF 4-50 cable. There are two methods of installing center connectors that I believe are better than soldering. They are: (1) swaging (stretching) the metal to provide a tight fit; and (2) a threading-type connection that will not cut through the copper covering of the aluminum center conductor.

Our next connector is produced on a lathe and made of machine grade brass (this alloy has good temper). Drill a mating hole for the center conductor 0.185 inch in size with a no. 13 drill. The diameter of the center conductor is 0.189 inch (a 0.004-inch expansion). Drive the connector on, after slight chamfering, with a 5/32-inch brass rod about 2 inches in length. Insert the brass rod into the center conductor and use it as a striking surface or anvil. The fit on my connector was tight and straight, and I could not dislodge it with anything short of destructive force.

Special thread taps and dies are available from large industrial tool supply houses. My supplier lists a no. 10 x 80 tpi tap for less than $7.[2] Maximum tap diameter is 0.191 inch, 0.002 inch larger than the center conductor of a Heliax LDF 4-50 cable. When threads are cut with the tap in a 0.185-inch ID hole in the center connector, it self-threads onto the center conductor of a Heliax LDF 4-50 cable without breaking through the copper coating. A split sleeve, made from 5/16-inch OD brass and drilled with a 7/32-inch drill bit, eliminates stretching problems. Cut the split sleeve to a length of about 5/16 inch and split it on one side using a hobby motor tool and silicon-carbide disc. Place the sleeve over the threaded part of the connector and put it in the chuck of a 3/8-inch variable speed reversible electric drill. Tighten the chuck to prevent slippage and expansion. Carefully file the center conductor straight and slightly chamfer it. Hold the drill in alignment with the center conductor, with firm but not excessive forward pressure. Apply power to the drill for a slow speed of perhaps 30 rpm. Clear and distinct threads should be present on the piece when the drill is backed off, and alignment should be excellent. To test the quality of the threads, gently screw the finished pieces together several times. There should be no tendency to cross thread. I also made and threaded several center pin adaptors, similar to the ones manufactured by Andrew for their N-type center pins. They work equally well, but the split sleeve is a necessity in putting them together.

Center connectors removed from SO-239s can also be used with an adaptor. Insert a short piece of 5/32-inch hobby brass in the opening and drill it in the lathe through the open end with a 3/32-inch drill bit. Turn the piece around, cut off the excess material and solder it to the adaptor.

The body dimensions of these connectors do not permit a center connector length of more than 3/4 inch, too short to permit using adaptors, so they are made from 1/4-inch diameter machine grade brass. Turn the brass piece to a 0.217-inch OD. Drill a 0.157-inch hole (no. 22 drill) 1/2-inch deep and cut the brass to the required length. With the brass piece held in the drill press chuck, and a motor tool and a silicon carbide disc held in the drill press vise, cut contact fingers. Gently feed the brass piece into the disc. Place a 12-inch length of brass tubing in one of the chuck key holes to aid in visual alignment of the slits to keep them at a 90-degree angle to each other. Next, drill a hole 3/16-inch deep and tap it to permit slightly more than 1/8 inch of threading to be formed on the center conductor. The entire piece may be tin plated, but this is optional. Plating is undesirable in the threaded hole.

Plating was done with Tinnit®, a warm water solution requiring only immersion and no electricity. According to the label, the solution has low toxicity. I was surprised to find that a 15-minute immersion increased the OD of my connectors slightly more than 0.002 inch! Fig 2 shows a center pin adaptor, a split sleeve, a female center connector and an adaptor.

The female UHF connector is difficult to work with. However, these improved connectors raise the cable's impedance from about 25 ohms to a true 50 ohms with almost no discontinuity. Having solved the female UHF connector problems, what can we do to the other end of the connector?

The Improved PL-259

A Teflon® insulated PL-259 has an acceptable impedance and dielectric quality. I always felt that the center pin should be soldered where the center conductor enters it, and not at the other end. The problem lies in the outer conductor connection. A lot of heat is required in soldering. More often than not, the plating is reluctant to accept tinning with solder. A relatively simple lathe operation can handle the soldering problems and slightly raise the impedance.

Remove the section of the connector that contains the dielectric material and center pin. Leave the section to which solder is normally applied and eliminate any sharp edges. From a brass rod, cut a disc 1/2-inch long with a 9/16-inch OD. Drill a 9/32-inch hole through the center. At one end of the brass disc, bore a 1/2-inch diameter hole to a depth of 1/4 inch. Bore the other end of the disc to provide a snug fit for the coax braid, after it is folded over the cut off end of the connector body. Fit the 1/2-inch hole with a Teflon disc, and drill a hole with an ID of 0.157 inch in it. The resulting connector impedance should be 48.5 ohms; it could be raised to 50 ohms if an annular groove

Continued on page 14.

Optimum Wire Size for RF Coils

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There are applications for inductors in electronic circuitry where the inductor Q is of little or no importance. In many other applications, the Q is secondary only to the value of the inductance. Among these are tank circuit coils, impedance matching circuit coils, and virtually all coils involved in loading or tuning antennas.

The Q of an inductor is the ratio of its reactance (X_L) to its ac resistance (R_{ac}) at the operating frequency.

$$X_L = 2\pi FL \qquad \text{(Eq 1)}$$

and

$$Q = \frac{X_L}{R_{ac}} \qquad \text{(Eq 2)}$$

then

$$Q = \frac{2\pi FL}{R_{ac}} \qquad \text{(Eq 3)}$$

where
π = 3.1416
Q = quality factor
F = frequency in Hz
L = inductance in henrys
R_{ac} = ac resistance of coil

The Q of an inductor is proportional to frequency. Less obvious is that the resistance to alternating current is also a function of frequency and of several other factors we will discuss.

RF In A Conductive Sheet

A sheet of conductive material has a resistance at high frequencies that is higher than the resistance measured with direct current. The difference is caused by *skin effect*. That is, the current is carried not by the entire cross section of the material, as in direct current, but by a thin layer of conductor lying at the surface. For example, in a sheet of copper at 1.8 MHz, the current density at a depth of about 0.001 inch is only 0.37 of that at the surface. The current density continues to decrease exponentially with depth. At 30 MHz, the depth is 0.0005 inch.

The depth at which the current density is down to 0.37 of the surface density is called the *skin depth*. It is a mathematical concept in that the sheet's resistance at RF is equal to the dc resistance of a layer of the skin thickness (0.37 is 1/e, where e is the base of the natural logarithms, 2.718).

The skin depth, and consequently the ac resistance, can be calculated by

$$D_s = \frac{0.3937}{\sqrt{\pi \mu F \sigma}} \qquad \text{(Eq 4)}$$

where
D_s = skin depth in inches
F = frequency in Hz
μ = magnetic permeability ($4\pi \times 10^{-9}$ for non-ferrous materials)
σ = conductivity in mhos per centimeter cube (5.8×10^5 for copper)

Since F, μ and σ appear under the square root sign in the denominator of Eq 4, the skin depth varies inversely as the square root of their values.

The higher the frequency, and the higher the permeability, the thinner the skin. Therefore, ferromagnetic metals such as iron, steel, and nickel make poor RF conductors. Non-ferrous metals such as copper, silver, aluminum, and gold have a permeability essentially that of free space. These materials make better, but not equally good, RF conductors.

The higher the conductivity, the thinner the skin. The advantage of using silver over copper is not as great as the ratio of their dc conductivities might conclude. The conductivity of silver is 6% better than that of copper, but is only about 3% better at RF.

Q In A Straight Round Wire

If the conductor is not flat, but has a surface curvature (round wire), then all of the direct inverse square root relationships become more complex. In wire of small diameter, the skin depth is greater. And because a larger portion of the wire conducts, the skin effect is not as severe. The *ratio* of ac resistance to dc resistance is smaller. A large straight wire has a smaller ac resistance than a small wire, but again the advantages are less than might first be thought.

For the reasons stated earlier, large copper, silver (or silver plated), and aluminum wires are used as high-frequency conductors. Silver's surface corrosion products are conductive, and it provides for a good contact. It has a slight advantage over copper's less conductive corrosion products. Aluminum is light and sometimes larger-dimensioned materials can compensate for its somewhat poorer conductivity.

Q In A Coil

When a piece of wire is wound into a coil, three additional factors come into play. First, the wires of adjacent turns are in close proximity, and the current is not distributed uniformly over the surface. Therefore, some parts of the skin carry a higher-current density than other parts, and since the power loss is proportional to the square of the current, the effective resistance is increased. This is called the *proximity effect*.

Second, the coil's magnetic field induces eddy currents in the wire material. The loss incurred by these currents are reflected as more loss resistance in the coil. Smaller wires have less material for eddy current induction and (for the same turns per inch) less proximity effect. The combination of these two effects can combine to overcome the lower ac resistance of the larger wire in its straight form.

The third factor occurs when a coil is wound on a form. Loss in the coil form material may occur. This factor is usually of less concern in the HF range unless poor form material is used, particularly if it is subject to water absorption.

Each factor interacts in an extremely complex manner to yield a multiplying factor that is the ratio of the ac resistance of a coil to its dc resistance. If a coil is wound with a specific diameter, length, and number of turns, we have a sort of dilemma. If the wire is too small, the ac resistance is unnecessarily high in spite of a low multiplying factor because of its high dc resistance. If the wire is too large, the ac resistance is unnecessarily high in spite of its low dc resistance because of a high multiplying factor.

As it turns out, for any coil of a given diameter, length, and number of turns, there is an optimum wire size. That wire size is not the largest that can be accommodated. When a coil specification says *closewound* enameled wire, be assured that the coil will have more loss than it could have. Formulas that minimize dc resistance do not apply at radio frequencies.

Butterworth researched this problem.[1] A fairly simple equation yields the optimum wire diameter for a simple single-layer solinoidal coil wound of round wire. All the complexities described went into the calculation of factor A in Table 1.

$$d_o = \frac{LA}{N} \qquad \text{(Eq 5)}$$

where
d_o = optimum wire diameter
L = length of coil
D = diameter of coil
N = number of turns
A = from Table 1

(These terms are expressed in the same units.)

[1]Notes appear on page 7.

Table 1
Machine-Wound Coil Specifications

$\frac{L}{D}$	A
0.4	0.702
0.6	0.666
0.8	0.637
1.0	0.615
2.0	0.551
4.0	0.508
8.0	0.478
10.0	0.474
∞	0.450

Let's Try An Example

For a 160-m antenna construction project, we want a coil two inches in diameter and four inches long.[2] It should be closewound with no. 14 enameled wire, with an inductance of 80 μH, and a measured Q of 110. (That dictates a loss resistance of 8.7 Ω at 1.9 MHz.) Now, 60 closewound turns of no. 14 enameled wire should fit in four inches and yield an inductance of approximately 80 μH. But is that the optimum wire size for maximum Q and minimum loss and heat? No! Applying Eq 5, we calculate L/D = 4/2 = 2. From Table 1, A = 0.551 and

$$d_o = \frac{LA}{N} = \frac{4 \times 0.55}{60} = 0.0367 \text{ inch} \qquad \text{(Eq 6)}$$

Consulting a wire table, we find that 0.0367 inch in diameter lies between values listed for no. 18 and no. 19 wire. Number 18 wire is used because no. 19 is not commonly available. We space 60 turns of no. 18 wire to occupy the four inches of winding length. Expect the Q to be about 200 or better. This cuts the 1.9 MHz loss resistance from 8.7 Ω to 4.8 Ω or less. You can get less loss with less copper.

Improving Q

It is generally accepted that coils having a length similar to their diameter optimize Q with little difference over the range of lengths of from one half to two times the diameter. With longer lengths the increased coil form loss (if any) also adds to the loss.

If we consider a coil with a specific length-to-diameter ratio, loss can further be reduced by increasing the coil size. If we maintain the same ratio of length to diameter, the Q increases as the square root of the ratio of the diameters, providing that for each coil size we use the optimum wire size for that coil. Larger coils have larger optimum wire sizes. Thus, if the coil in our example were increased to four inches in diameter and eight inches in length, with 44 turns (for the same 80-μH inductance), the optimum wire size would be no. 10 and we'd expect the Q to be 280 or better ($4/2 = 2$, $\sqrt{2} = 1.414$, $200 \times 1.414 = 280$). The 1.9 MHz loss resistance would be reduced to 3.4 Ω or less.

For those interested in the low-frequency experimental band at 160-190 kHz, Litz wire can be used to increase Q. For most amateurs, however, Litz wire is of no advantage; its effect disappears at frequencies above about 0.8 MHz. Hard drawn copper wire should not be used for high-Q coils—its conductivity is only about 59% of that of soft drawn copper wire.

Some commercial loaded antennas use closewound coils. I can only conjecture that the higher loss is tolerated to provide a tradeoff for wider SWR bandwidth. In fact, the manufacturer of one popular antenna states in his packaged instructions, "Do not be concerned if resonators appear to warm up. Efficiency will not be affected." Wow! Perhaps they meant "efficiency will not be effected"!

Notes

[1] S. Butterworth, Effective Resistance of Inductance Coils at Radio Frequencies, *Exp Wireless and Wireless Eng,* vol 3, Apr 1926, May 1926, Jul 1926, Aug 1926. Eq 5 is adapted from Terman, *Radio Engineers Handbook*, 1943, p 77-83, incorporating his Table 22 data into his Eq 100, all based on S. Butterworth, loc. cit.

[2] D. DeMaw, "How to Build A 160-Meter Shortie," *QST,* Nov 1986, p 26.

Bits

Catch Up On Your Reading

Forrest Mims' Circuit Scrapbook II by Forrest Mims is a compilation of 70 projects for the electronics enthusiast from the pages of *Modern Electronics*. Each topic explores a specific area of electronics, but assumes no prior knowledge. Mims has authored 57 books and over 500 articles related to the electronics field. This 272-page book can be enjoyed by both technicians and hobbyists. Price is $19.95.

How about a *Crash Course in Artificial Intelligence and Expert Systems?* Written by Louis E. Frenzel, Jr, this book covers important concepts and techniques that are practical and useful in the real world. Short programming samples using LISP and Prolog are included. The book has 368 pages and sells for $19.95.

A task-oriented program guide for Amateur Radio and electronics enthusiasts, the programmer, engineer or technician is the *Commodore 64® and 128® Programs For Amateur Radio & Electronics* by Joseph J. Carr. It contains 23 programs in the area of Amateur Radio technology and 19 for general electronics. Save time and simplify programming tasks. A diskette is also available from the author for readers who wish to avoid keying the programs themselves.

Solid-State Projects You Can Build by Rudolf F. Graf and George J. Whalen details challenging and stimulating do-it-yourself projects that use simple tools and a VOM. Complete step-by-step construction procedures are illustrated with drawings and photographs. Background theory is presented, as well as tips on where to buy those hard-to-find parts. This book has 176 pages and retails for $10.95.

A must for every ham shack is the *Radio Handbook* by William I. Orr. The 23rd edition contains new material reflecting the latest technology on everything from HF/VHF amplifier design to interference reduction for VCRs and video disc players. This 640 page edition sells for $29.95.

For more information on these books, write or call the Howard W. Sams & Company, 4300 W 62nd St, Indianapolis, IN 46268, tel 317-298-5400.—*KA1DYZ*

Analog Introduces An Ultra-High Speed Monolithic Op Amp

The AD5539 is a high-speed monolithic op amp with one of industry's fastest settling times (12 ns to ± 1%). This device offers a typical gain-bandwidth product of 1.4 GHz, a slew rate of 600 V/μs and a full-power response of 82 MHz. These specs represent a 20-70% improvement over the pin-compatible NE/SE5539 amplifier and excell against GaAs amplifiers.

The AD5539's performance makes it well-suited for buffering low resolution, high-speed flash A/D converters. For use with video displays, the AD5539 is optimized for 75- and 150-ohm input and output termination impedance. For further information on this new monolithic op amp, write Analog Devices' Literature Center, 70 Shawmut Rd, Canton, MA 02021. For applications engineering assistance, contact Applications Engineering, Analog Devices Semiconductor, 804 Woburn St, Wilmington, MA 01887, tel 617-935-5565.

A Transverter Band Switching Display and Universal Power Supply

By Dave Mascaro, WA3JUF
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A transverter is a linear RF unit that converts received and transmitted signals from one frequency range to another. The most popular transverters are the VHF/UHF units that cover 50 to 1296 MHz. All-mode self-contained transceivers are available for use with the converters on VHF/UHF bands, but many don't have the selectivity and the features of an HF radio. Until recently, complete transceivers were available only commercially for bands up to 432 MHz. Now, 1296-MHz all-mode transceivers are commonplace. Transceivers for 2304-and 3456-MHz are not yet available, however, transverters for these bands, and 10 GHz, are available to Amateur Radio operators.

Operation of a transverter is as follows. If a 2-m transverter is primarily used with an HF transceiver in the 28-MHz position, the transmit portion of the transverter up-converts the 28-MHz IF transmit signal to 144 MHz. The receive section down-converts the 144-MHz receive signals to the 28-MHz IF. Therefore, 28.100 on an HF radio is equivalent to 144.100 in the 2-m band.

The Use of Multiple Transverters

Connecting a transverter to an HF transceiver is easy, but the job becomes complicated when multiple transverters are to be connected to a single HF transceiver. Several years ago, I placed the 432- and 1296-MHz transverters in the attic. The IF radio was an ICOM 2-m portable, the IC-202S. Then, I purchased the Kenwood TS-180S and added the 2-m transverter in place of the IC-202S. As I added transverters and linear amplifiers, my switching problem grew worse. I had to design an easy way to remotely switch the transverters and indicate the band in use. Some amateurs change bands by switching the transverter cables. Others use a system of switches and relays. If there are five or six transverters connected to your HF transceiver, you don't want to be switching cables around to change bands.

My 144- to 2304-MHz equipment now resides in my house attic. The HF transceiver and the antenna rotator control box share a desk with the computer in a room upstairs. The operating position is neat and free of the racks of homemade equipment and interconnecting "spaghetti." The nest of wires is hidden in the attic, and the feed lines are short.

A TS-180S is my 28-MHz HF radio. It is the main rig and is also connected to the attic transverters. A means of switching from HF to transverter operation was needed, in addition to the switching of the transverters themselves. In my installation, the HF radio is connected to a 2-m transverter. The other transverters, (220, 432, 903, 1296 and 2304 MHz), are connected to the 2-m transverter. A 144-MHz IF is more suited to driving the UHF and microwave transverters than 28 MHz because the local oscillator and image frequencies are easier to filter out. In addition to the transverters, the solid-state linear amplifiers, preamplifiers, power supplies and control circuits associated with each transverter are also mounted in the attic.

Transverter Band Switching And Displays

To make transverter band switching as easy as possible, I designed and built the transverters with their own power supplies and complete internal switching circuits. (A transverter power supply is described later in this article.) The use of common power supplies and common switching in multiple transverter set-ups can be a nightmare as more transverters are added to the system. Loss of the common power supply means the loss of more than one transverter. Separating each transverter is one way to eliminate this problem.

S1 in Fig 1 is a single 4-pole wafer-type switch. It permits changing bands quickly and effortlessly. A miniature toggle switch (S2) switches the TS-180S between HF operation and transverter operation. I chose to have an LED readout display the letters H and F when the station is used on those bands. With S2 in the HF position, DS2 and DS3 display HF. When S2 is in the transverter position, the LEDs display the band in use.

Only one control line from the IF radio is needed to connect from receive to transmit. S1B switches the control line to each transverter. The only other device that needs to be switched for a band change is the 2-m IF. Using miniature Dow Key BNC relays, the low-level transmit output of the 2-m transverter is wired in a transceive configuration with the 2-m receive signals. A six-port BNC type coax relay allows the 2-m IF to be switched to one of five transverters in use. S1A selects the different ports of the coax relay.

Display Design

One "signal" from the wafer switch changes the LED band display. A diode matrix off each pole of S1D selects the digit matrix for DS1, DS2, DS3, and DS4. Diode matrices, on the input of each of the four BCD-to-seven segment LED decoder/drivers (U1, U2, U3, and U4), select which numeral will be lit. Blanking of the various decoder/drivers turns off the LED display of those not being used. For example, the first digit is blanked on 144, 220, 432 and 903 MHz. In addition, all four of the LED displays are blanked in the HF mode. A third diode matrix, on the output of decoder/drivers U2 and U3, sets up the "alpha" display H F by turning on the equivalent LED segments of the DS2 and DS3 displays.

PC Board Layouts

I designed my switching system on two PC boards so they could be stacked to fit in a box that I had. Also, it was easier to design the boards individually, one for the band-matrix board, the other for a digit matrix and display board (Figs 2 through 5). Each board is a single sided piece of 1/16-inch G-10 fiberglass. Sockets are used for the ICs, the LED display current-limiting resistor assemblies, and LED displays. For ease of interconnecting, ribbon cables fitted with 16-pin IC header plugs are used between the boards.

PC board drafting supplies and a clear sheet of plastic were used to make the artwork. Photo-sensitive methods were used to make the boards.

Power Supply

A 5 V dc source was chosen to keep the power dissipation of the current-limiting resistors low, so that ¼-W resistors on plug-in IC type headers could be used. U1 through U4 are CMOS BCD-to-7 segment latch/decoder/drivers. Their function is to help keep power consumption low.

The 5-V dc power supply uses a three-terminal IC regulator (LM7805). The regulator board is installed inside the TS-180S' 12.5-V dc supply, and supplies the regulator input voltage. By connecting the regulator board in this fashion, the transverter switching display comes on

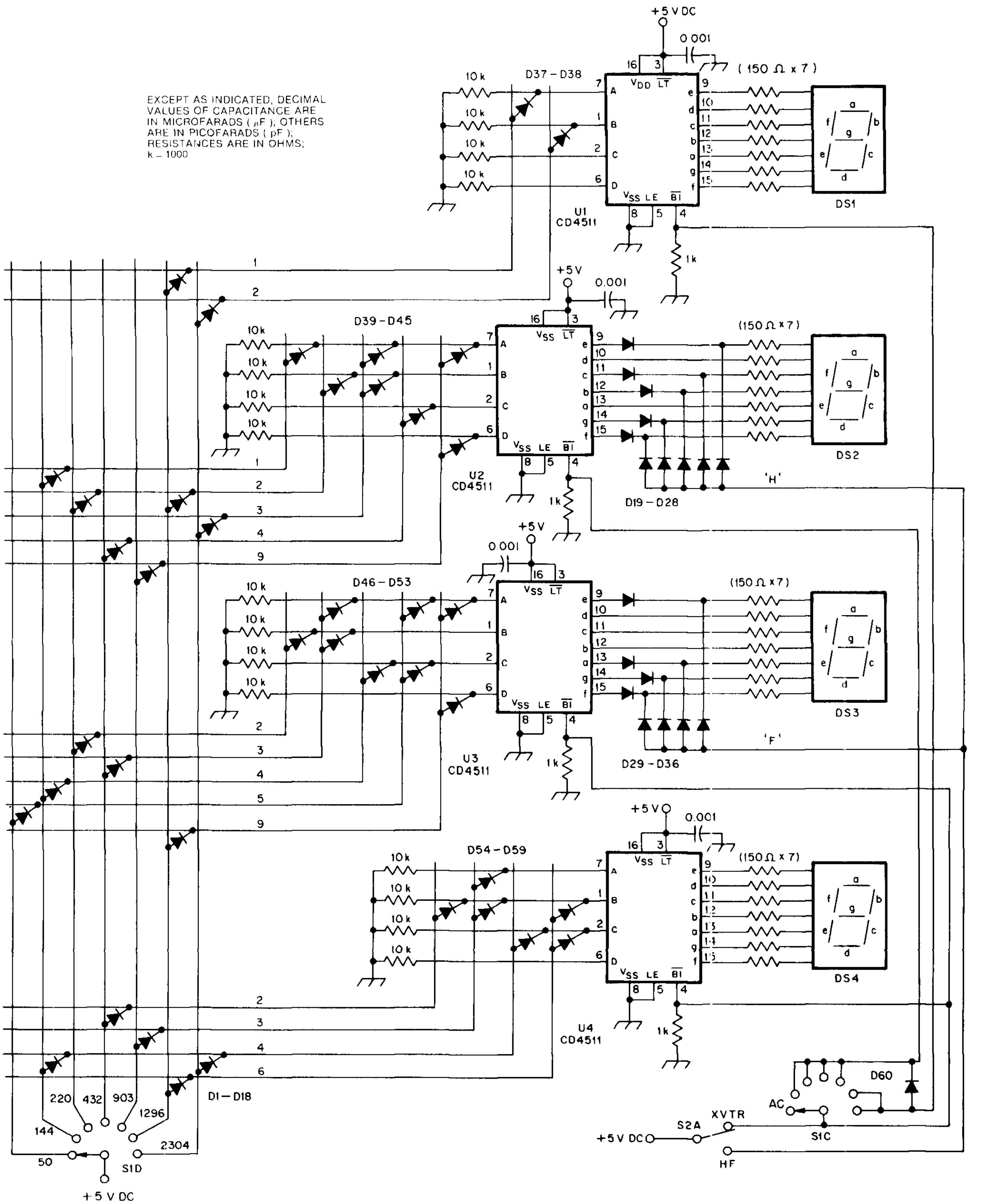


Fig 1—Transverter band-switching display. All IC pinouts are the same.

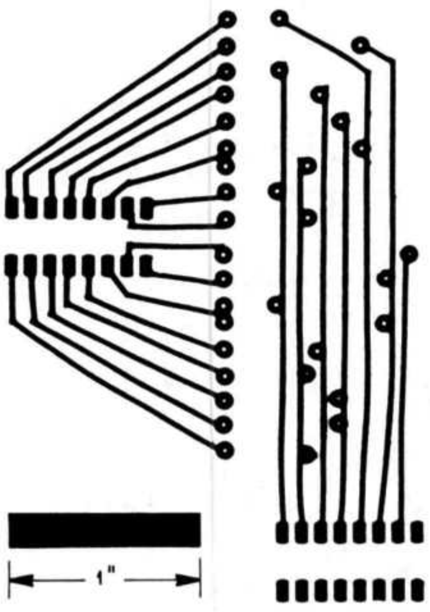


Fig 2—Etching pattern for the band-matrix board. The pattern is shown from the foil side of the board. Black areas represent unetched copper foil.

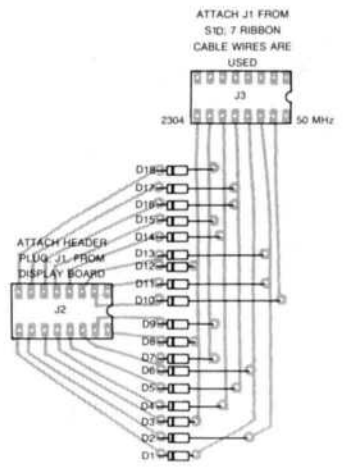


Fig 3—Parts-placement diagram for the band-matrix PC board. Parts are placed on the nonfoil side of the board; gray areas represent unetched copper.
D1-D18, D37-D60—1N914 or 1N4148 diode.

when the HF rig is turned on. The same 12 V also runs the keyer and a 220-MHz hand-held transceiver.

Two additional voltages are taken from the TS-180S power supply. The six-port BNC IF relay operates from 24 V dc, and 12 V dc operates the miniature Dow Key BNC relays (model DK-77) in the 28-MHz HF/transverter switching circuitry. Low power output is available at the transverter accessory jack on the rear of the Kenwood transceiver. The miniature Dow Key relays switch the transceiver's 100-W output to the HF dipole and the low power transverter output to the 2-m transverter in the attic. This switching is controlled by the front panel toggle switch (S2). The diode matrix circuitry is not explained because of the differences in the transverter hook ups of different HF transceivers.

A Homemade Enclosure

Double-sided G-10 PC boards make great enclosures for a homemade project. This type of board is inexpensive, and soldering to the copper is easy. A coat of gray primer and a coat of clear varnish, finishes off the enclosure nicely.

As shown in Fig 6, other circuits were added to my PC boards, and extra switches were mounted in the enclosure.

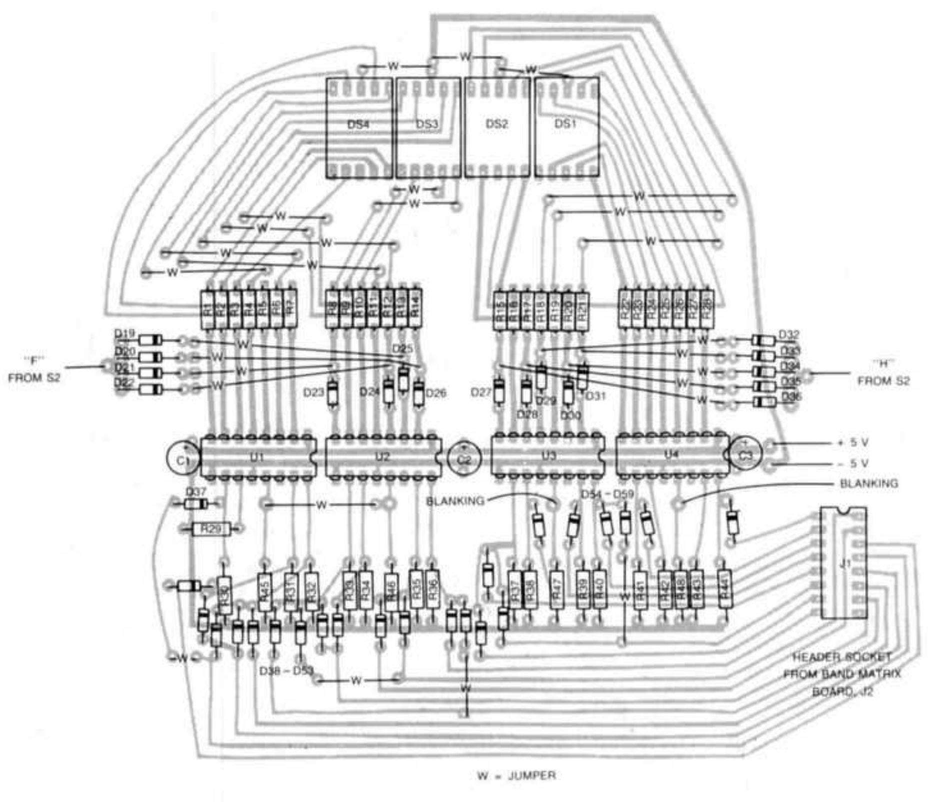


Fig 4—Parts-placement guide for the digit-matrix and display board. The pattern is shown from the foil side of the board. Black areas represent unetched copper foil. Resistors R1-R28 are mounted on 14-pin headers and plugged into sockets. Jumpers are wired on the reverse side of the board. A jumper is connected from pin 3 of U1-U4 to V_{DD} on the etched side.
C1-C3—0.001-µF capacitor.
D1-D18, D37-D60—1N914 or 1N4148 diode.
D19-D36—1N4001 diode.
DS1-DS4—Common-cathode LED display (0.6-inch row-to-row spacing).
U1-U4—CMOS CD4511 BCD-to-7 segment latch/decoder/driver.
R1-R28—150 Ω, ¼ W.
R29-R44—10 kΩ, ¼ W.
R45-R48—1 kΩ, ¼ W.
Misc
S1—4 pole, 7 position, non-shorting wafer switch.
S2—Miniature toggle switch, DPDT.
4-14 pin DIP headers.
4-14 pin IC sockets.
7-16 pin IC sockets.
1-40 pin IC sockets (0.6-inch row-to-row spacing).
2-16 pin header/ribbon cable assemblies.

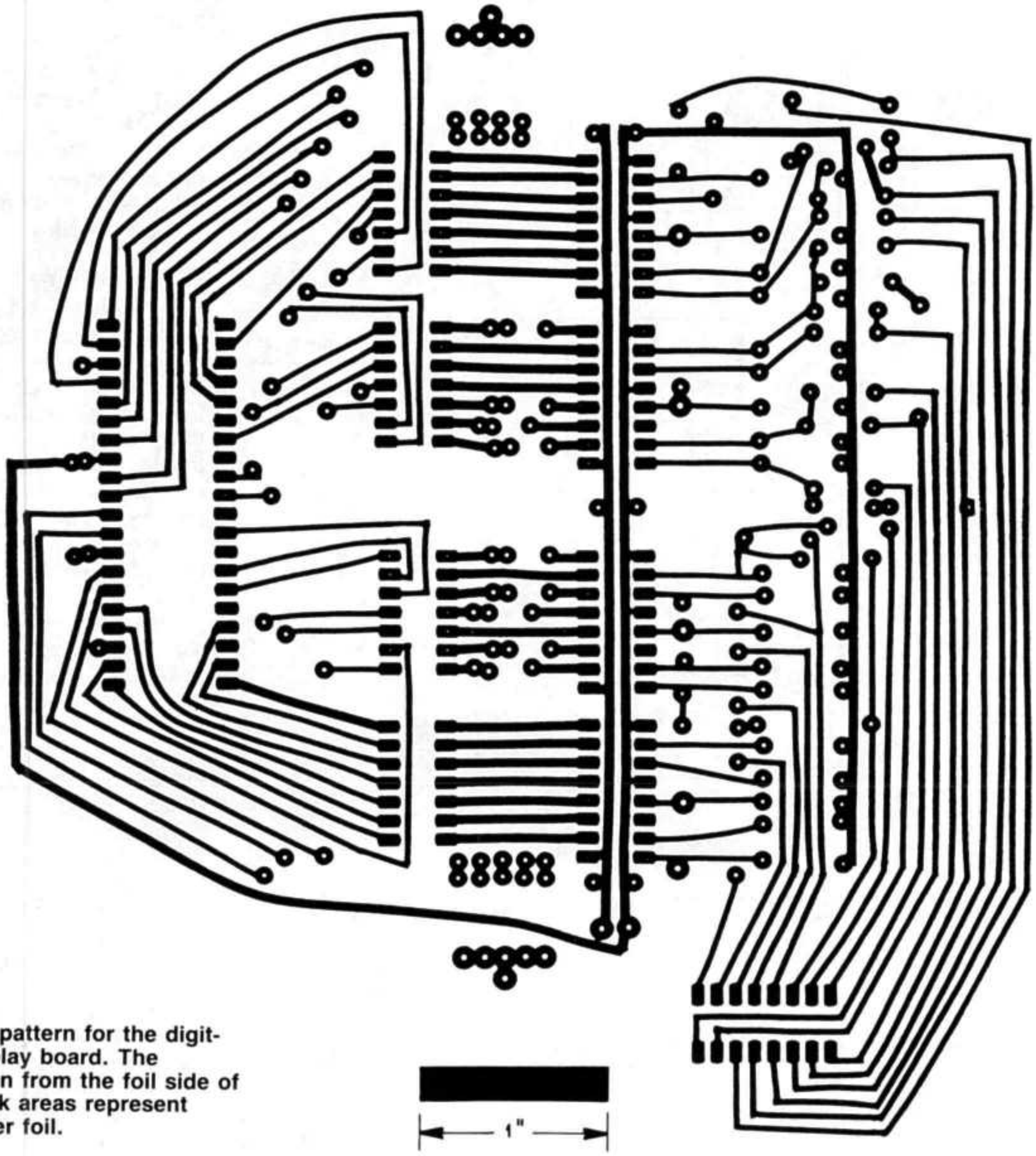


Fig 5—Etching pattern for the digit-matrix and display board. The pattern is shown from the foil side of the board. Black areas represent unetched copper foil.

The switches place the 1296- and 2304-MHz high-power amplifiers in and out of my station. Multi-pin connectors and cables connect the transverter-switching display to the interface control box in the attic, and are used as connections to the TS-180S and power supply. A rectangular hole, for the four-digit display, is cut in the front cover of the enclosure. A piece of Rubylith is glued over the hole to provide a lens for the LED display. A panel meter acts as the indicator for the remote power sensors installed in the transmit line of each transverter.

The Universal Transverter Power Supply

Once the main unit is completed, a power supply and control circuits are needed. Building power supplies is easier for solid-state equipment. In an effort to make the building and packaging of solid-state power supplies more enjoyable, I designed the universal transverter power supply.

Amateurs who are familiar with building state-of-the-art UHF and microwave transverters soon find that multiple dc voltages are needed to power the various solid-state devices and coax relays. The universal transverter power supply

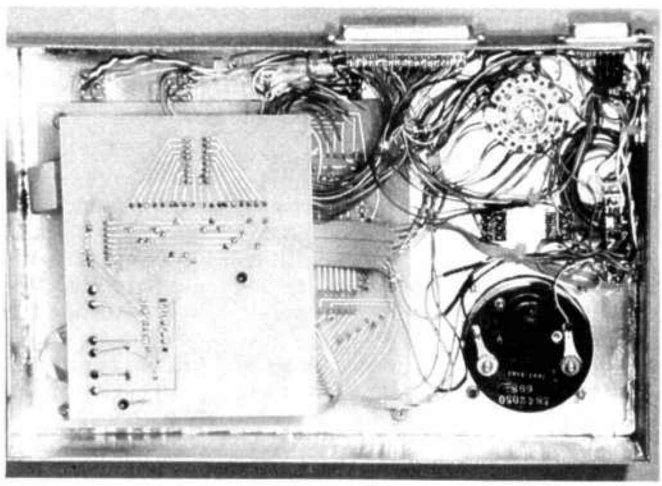


Fig 6—Stacked PC boards. The power supply connector is shown at the upper right, and the interface cable connector is to the left.

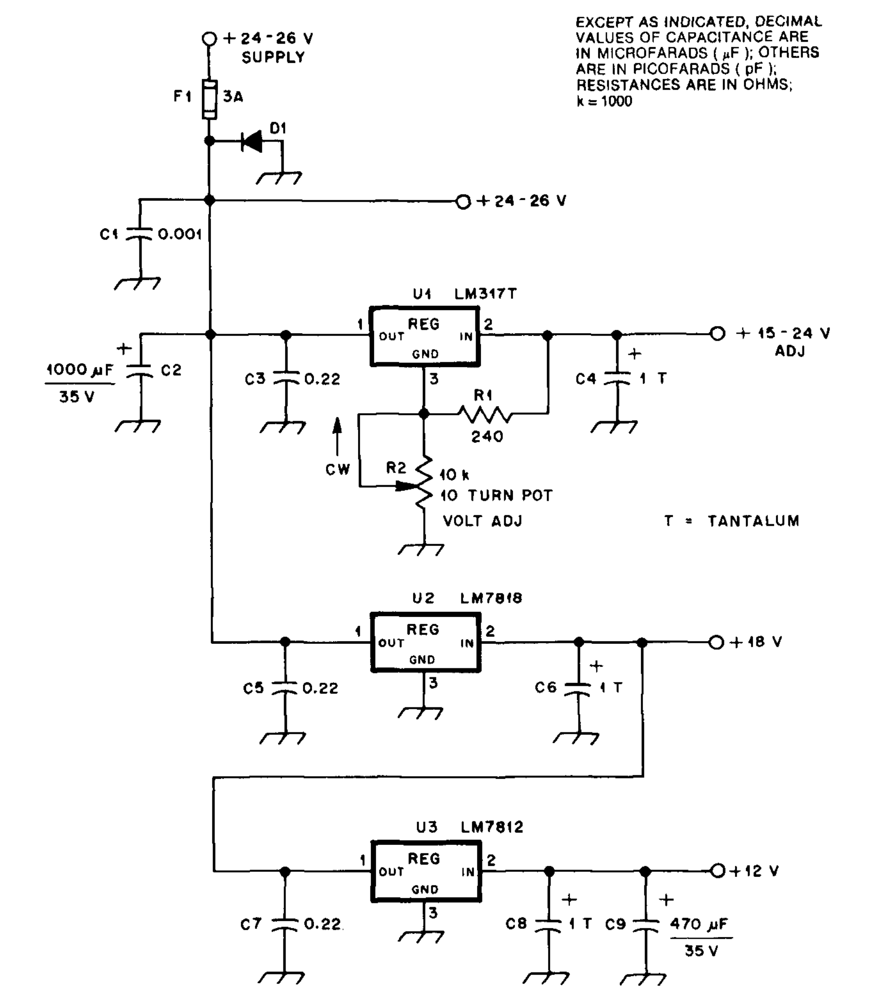


Fig 7—The universal transverter power supply voltage regulator section.

provides the necessary voltages on both transmit and receive.

Power Supply Requirements

In building my 2304-MHz transverter, it was necessary to build a power supply with five different dc regulated outputs. As with all previously built transverters, control of these voltages on receive and transmit was also required. Current requirements are under 1 A, so three-terminal IC regulators were chosen. This power supply operates similar to those in my other transverters, but is built on one PC board, along with all the control circuits. The voltages supplied by this power supply module in the receive and transmit modes are: 24-28 V dc (the source voltage), 18 V dc, 15-24 V dc (adjustable), and 12 V dc. An extra set of relay contacts is also provided. I use the extra contacts to switch in −5 V dc to supply bias to my common-base linear amplifiers.

Amateurs who use VHF/UHF transverters or high-power solid-state amplifiers usually have a high current 12.5-V dc supply in their shack. I have several, in addition to high current 24-28-V dc supplies. In the past, I've built high-power UHF and microwave amplifiers that run on 28 V dc. A solid-state amplifier designed for 28-V dc collector supply draws about half as much collector current as compared to a 12.5-V dc amplifier of similar power output. The physical size of the 28-V dc supply is also smaller.

These high-current 24-28 V dc supplies can be found inexpensively at flea markets. *The 1987 ARRL Handbook* describes the construction of a 28-V, high-current power supply project.[1] Many inexpensive power supplies are being sold because hams won't buy transverters and amplifiers that run on anything but 12.5 V dc. High-power solid-state amplifiers on VHF/UHF and microwave bands require 24-28 V dc power supplies. As technology progresses, more solid-state amplifiers using collector supplies of 28, 32 and even 50 V dc will be commonplace.

The higher power stages used after my 2304-MHz transverter require a high current 24-28 V dc supply, so I use this supply as the source for the universal transverter power supply. Thus, there's no need to build anything but the low-current supplies.

Power Supply Design

Fig 7 is the schematic of the power supply's voltage regulator section. Many articles have been published about the three-terminal voltage regulator designs, so I won't describe these further. One thing that must be stressed, however, is that three-terminal voltage regulators *can oscillate* if the input and output leads are not properly bypassed; the regulator goes out of regulation, and some audio modulation of the dc voltage occurs. A 0.22-µF capacitor placed on the input, and a 1-µF Tantalum capacitor on the output lead, stabilize the regulators. Regulators built by different manufacturers behave differently. Some are stable without the bypasses. Be sure to put the bypass capacitors close to the device being bypassed, especially when working with RF.

The power supply module uses three different three-terminal regulators. Two are used for fixed voltage outputs and one for an adjustable output of 15-24 V dc (this depends on the source voltage). Low-current 12 V dc is switched in the receive and transmit modes using type 2N3906 PNP transistors. The source voltage and the regulator voltages are switched by a 4PDT PC-mounted relay. In addition, the source voltage is switched in the transmit mode with a type TIP30 PNP transistor (Fig 8).

The switched voltage of the TIP30 transistor is used to operate the 28-V dc antenna changeover relay in my system. When the coil field of the relay collapses, spikes are produced on the dc line. These spikes can get back into the power supply and destroy GaAsFETs, transistors and ICs. To prevent component damage, use 1N4001 diodes (or equivalent) across all relay coils in your shack. The extra trouble to wire diodes across the coils is well worth the effort.

Construction

Fig 9 is the etching pattern for the power supply PC board. Fig 10 is the parts-placement diagram. The power supply module is built on 1/16-inch G-10 double-sided PC board. The double-sided board makes it easier to connect the components to ground, and such a board can be designed in a quarter of the time it takes to design one with ground traces on the same side. To properly construct a double-sided board, all non-ground

[1]M. Wilson, ed., *The 1987 ARRL Handbook* (Newington: ARRL, 1986), pp 27-9 to 27-11.

holes must be "cleared" on the unetched side to prevent component shorting. This is done as follows: All non-ground holes are drilled first. Then, the copper is removed by counterboring the holes with an oversized drill bit. The depth of the hole is set to about half the thickness of the PC board. The ground holes are drilled last to prevent confusion of which holes get cleared.

The board can be reproduced easily. Artwork for the board was made with PC-board drafting tape on a clear plastic sheet. Or, PC-board drafting tape can be placed on the PC-board copper directly to act as the resist.

All regulators and the TIP30 switching transistor are heatsinked to the case of the box in which the PC board is mounted. I use BUD aluminum boxes to house my power supplies. A mica washer and heatsink grease are used on the LM317T adjustable regulator and on the TIP30 switch because the center lead of each device is connected to the tab of the package.

Phono jacks are used for different supply outputs instead of a multi-pin connector for several reasons. Audio connectors are more readily available, and it is easier to troubleshoot the supply from outside the enclosure if one voltage should fail. It is also easier to plug in a temporary power supply if a voltage failure should occur. Banana jacks can be used as an alternative to phono jacks.

Using The Power Supply Module

The supply module can be used for different voltage outputs. It is necessary to mount only those regulators and components for the voltages you need. If you need a voltage that I didn't use in my unit, change the regulator. Other than power dissipation requirements, the most impor-

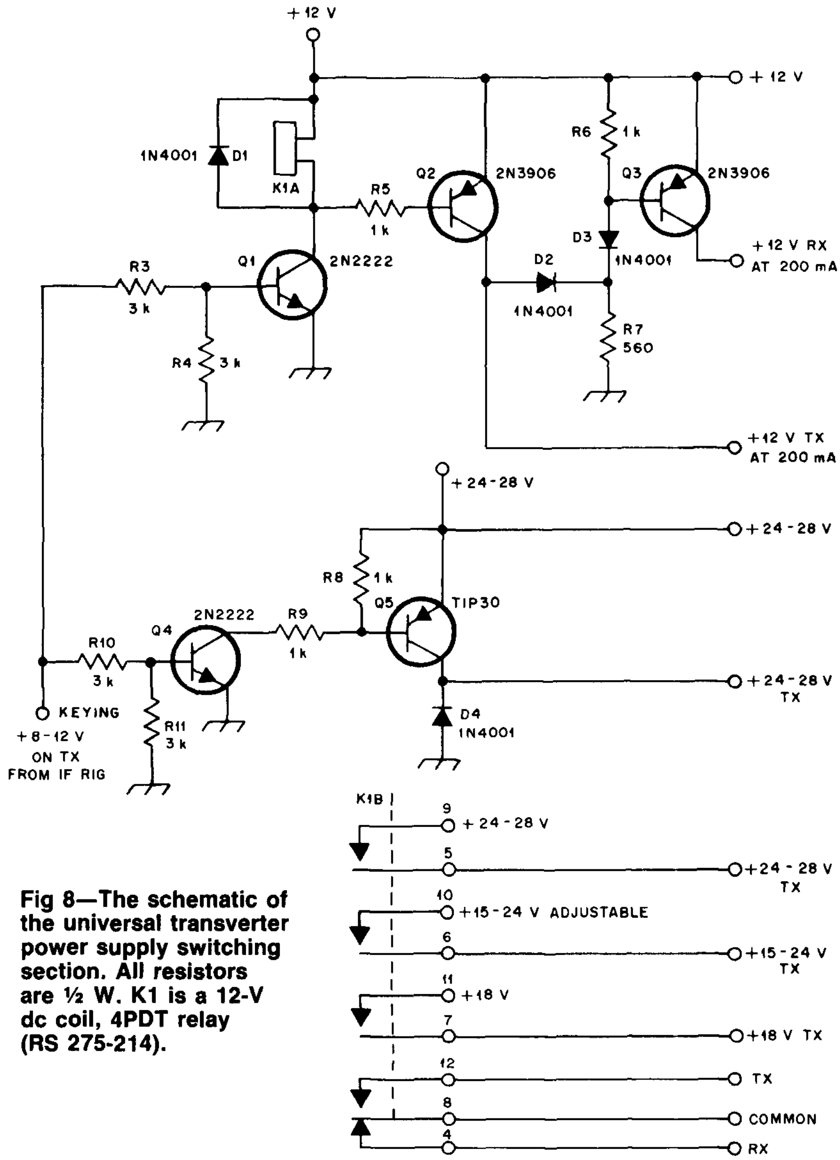
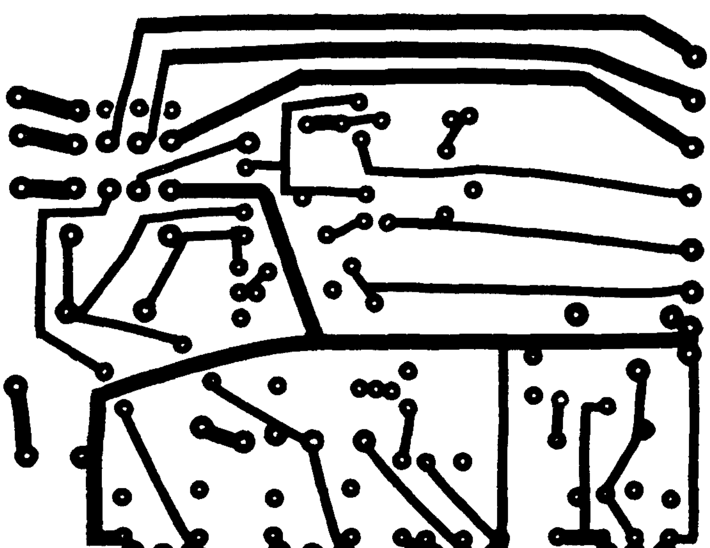


Fig 8—The schematic of the universal transverter power supply switching section. All resistors are ½ W. K1 is a 12-V dc coil, 4PDT relay (RS 275-214).



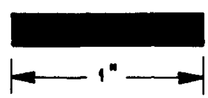


Fig 9—Etching pattern for the universal transverter power supply. The pattern is shown from the foil side of the board. Black areas represent unetched copper foil. All single holes are ground connections, except the three holes of K1 that are not used.

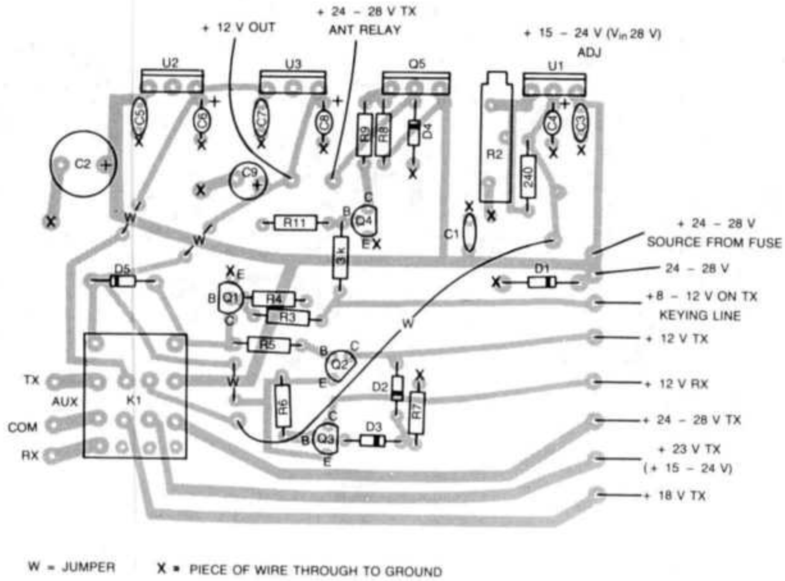


Fig 10—Parts-placement diagram for the universal transverter power supply. Parts are placed on the nonfoil side of the board; gray areas represent unetched copper. Clear all holes on this side of the board, except for ground holes. Solder all grounds on both sides of the PC board.

C1—0.001-μF disc capacitor.
C2—1000-μF/35-V dc electrolytic capacitor.
C3, C5, C7—0.22-μF disc capacitor.
C4, C6, C8—1-μF Tantalum capacitor.
C9—470-μF/35-V dc electrolytic capacitor.
D1—50 PIV, 6-A diode.
D2-D5—1N4001 diode.
K1—12-V dc coil, 4PDT relay (RS 275-214).
Q1, Q4—2N2222 NPN transistor.
Q2, Q3—2N3906 PNP transistor.
Q5—TIP30 PNP transistor.
R1—240 Ω, ¼ W.
R2—10 kΩ, 10-turn potentiometer.
R3, R4, R10, R11—3 kΩ, ¼ W.
R5, R6, R8, R9—1 kΩ, ¼ W.
R7—560 Ω, ½ W.
U1—LM317T adjustable regulator.
U2—7818 voltage regulator.
U3—7812 voltage regulator.

tant requirement to remember about regulators is: The input voltage (under load) must be at least 3 V higher than the output voltage, without exceeding the maximum ratings of the regulator.

The multiple outputs of this module supply all the necessary voltages for a transverter, including the coaxial antenna changeover relay. This is the easiest way to successfully use multiple transverters hooked up to the same IF radio. To change bands, just switch the IF RX/TX lines and the keying line to the transverter power supply module. If "ground to transmit" is used from the IF radio, a type 2N3906 transistor inverter can be used between the IF radio and the keying input of the power supply module.

Protect Your Equipment With Fuses

It is important to use fuses in both the ac and dc circuits. A fuse should be placed between the 12.5-V dc power supply and each amplifier or transverter connected to it. Fuses serve double duty. They protect power supplies when excessive current is drawn, and they can protect the equipment connected to the power supply when the dc power leads are accidentally reversed. If a fuse is used in the transverter's dc lead, the fuse blows instead of pumping the 20 A from your power supply into the transverter. This high current would otherwise damage the reverse polarity diode inside the transverter, as well as many other semiconductor devices.

Be sure to use a fuse between your 24-28 V dc source power supply and the universal transverter power supply. The fuse should be slightly larger than the maximum current drawn by your power supply module and transverter.

Improved UHF-Type Connectors For Half Inch Heliax

Continued from page 5.

is cut in the Teflon so as to reduce precisely the correct amount of dielectric material. I doubt you would ever know the difference. Center pins for this exercise are made with a 5/8-inch length of 5/32-inch OD hobby brass tube, and are soldered to the coax before final assembly.

Conclusion

Attenuation tests at 1296 MHz, a frequency much higher than one would expect to use this type of connector for, were performed on my homemade connectors. My test method, which I won't describe in detail, required preparation of a chart to aid in converting millivolts, as read on a digital voltmeter across a Bird 43 wattmeter, into very small increments of RF power in watts. This necessitated a source of infinitely variable UHF RF power. My IC 1271 was the only such source available to me. Indicated attenuation is much less than I had expected it to be. Unless I get different results on further development of my measuring technique, I would consider these connectors to be usable for anything other than very weak-signal communications at 1296 MHz.

Notes

[1]G. Chaney, "Hardline Coaxial Connectors You Can Make," *QST*, Apr 1987, p 32.
[2]Special thread taps and dies are available from J & L Industrial Supply Co, 19339 Glenmore, Detroit, MI 48240. Machine-grade brass bar stock and hobby brass tube is available from Small Parts, Inc, PO Box 381736, Miami, FL 33238-1736.

Bits

Optical Disk Systems—Futuristic Storage Space

Using laser technology, optical disk systems store huge amounts of information with a capacity nearing a thousand times that of floppy disks. Optical disks can store digital data for retrieval in video form, audio (audio CD), text, graphics and other interactive formats being developed. Market forecasts project a growth from under $3 million in 1986 to almost $341 million by 1988, to $661.7 million by 1990.—*Frost & Sullivan, Inc, 106 Fulton St, NY 10038-2786*

By Bill Olson, W3HQT
Box 1655A, RFD 1
Burnham, ME 04922

Coaxial Cable at VHF and UHF

I am often asked for recommendations on what feed line to use for a particular application or how much loss one type of coax has at some frequency. While the subject has been treated extensively elsewhere, I thought I'd devote this month and next to some highlights of this important subject.[1] I will cover (1) some performance parameters of coaxial cable; (2) uses (and recommendations) for various types of cable; and (3) common coax connectors.

Performance Parameters

Loss

Loss, or attenuation, is the most commonly quoted specification associated with RF transmission line. Usually expressed in decibels (dB) per 100 feet, it is certainly an important parameter. Attenuation is a function of conductor losses and dielectric losses. Generally, attenuation can be decreased by (1) increasing the size (diameter) of the cable (thereby decreasing the dielectric loss); (2) using a lower-loss dielectric (such as air, or a dielectric that is mostly air—for example, foamed polyethylene); or (3) increasing the conductivity of the conductors (by going to solid copper outer conductors, silver plating, and so on). Attenuation varies with frequency of operation and cable length.

A rough equation relating attenuation to frequency is

$$\alpha \approx K\sqrt{f} \qquad \text{(Eq 1)}$$

where
- α = attenuation
- K = a constant
- f = frequency

If we know the attenuation at one frequency, the reference frequency (usually 100 or 1000 MHz), we can find the attenuation at another frequency from

$$\alpha_x = \alpha_{ref}\sqrt{\frac{f_x}{f_{ref}}} \qquad \text{(Eq 2)}$$

where
- α_x = unknown attenuation at f_x
- α_{ref} = attenuation at f_{ref}
- f_x = frequency where attenuation is unknown
- f_{ref} = frequency where attenuation is known

[1]J. Reisert, W1JR, "VHF/UHF World: Transmission Lines," *Ham Radio*, Oct 1985, p 83.

This is a rough approximation that ignores a number of factors that show up mostly at higher frequencies, but it gives a general idea of what happens.

Loss varies linearly with the length of the cable. Most manufacturers specify cable loss in dB/100 feet, so it is easy to find the loss of any length. For example, the loss for 200 feet is twice that for 100 feet; the loss for 50 feet is half that for 100 feet.

Impedance

The characteristic impedance of a coaxial line is given by

$$Z_0 = \frac{138}{\sqrt{e}} \log\left(\frac{D}{d}\right) \qquad \text{(Eq 3)}$$

where
- Z_0 = characteristic impedance in ohms
- e = dielectric constant
- D = inside diameter of the outer conductor
- d = outside diameter of the inner conductor

Amateurs most often use 50-ohm cable. Since most transmitters, receivers, power amplifiers, test equipment, antennas and connectors are designed for 50 ohms, that's pretty much become the standard. In recent years, there has been a lot of surplus 75-ohm cable TV Hardline available, so many amateurs are using this for their main feed lines. Amateurs sometimes use cable of other impedances—commonly 75 ohms and sometimes 62 and 93 ohms—for phasing lines in arrays and for matching sections.

Velocity Factor

An RF wave travels more slowly in a dielectric than it does in a vacuum. Consequently, an electrical wavelength in a transmission line that has a dielectric constant greater than 1 will be shorter than a wavelength in a vacuum. The dielectric constant of air approximates that of a vacuum in this case. The shortening factor (velocity factor) expressed, in percent is given by

$$VF(\%) = \frac{100}{\sqrt{e}} \qquad \text{(Eq 4)}$$

where
- VF = velocity factor in percent
- e = dielectric constant

The velocity factor of cable is used when a cable of a specific electrical wavelength (not physical wavelength) is needed. For example, you might need to cut a ½ wavelength balun or ¼ wavelength matching section.

Power Handling Capability

Ever put your hand on a piece of RG-8 with 400 watts of 432-MHz energy flowing through it? Hot! Loss means heat. All coaxial cables have a maximum rated power that, like attenuation, varies with frequency. Once again, if we know the power handling capability at one frequency and some attenuation numbers, we can find the power rating at any other frequency from

$$P_x = P_{ref}\frac{\alpha_x}{\alpha_{ref}} \qquad \text{(Eq 5)}$$

where
- P_x = power rating at the frequency where power rating is unknown
- P_{ref} = power rating at the frequency where power rating is known
- α_x = attenuation at the frequency where power rating is unknown
- α_{ref} = attenuation at the frequency where power rating is known

When coax gets very hot, the dielectric material can melt, allowing the conductors to short together. This often happens at bends in the cable. Teflon® dielectric cables are often termed "high temperature" cables by the manufacturers. While Teflon cables often have the same loss characteristics as similar-sized polyethylene dielectric cables, they have a much higher dielectric melting point. This means that they can handle much higher power for a given cable size. Flexible Teflon-dielectric cables such as RG-141 and semi-rigid types such as UT-141 are useful in baluns, toroidal transformers, and other applications where high power-handling capability and small size are needed.

Longevity

Many factors cause the deterioration in cable performance over time. The most common factor is seen in flexible cables such as RG-8 and Belden 8214 that have a "contaminating" PVC jacket. In these cables, moisture seeps through the PVC into the braided outer shield. Eventually, the shield corrodes, resulting in electrical deterioration. Cables such as RG-8A or RG-213 have noncontaminating plasticizers in the jacket material and do not suffer this problem.

Other deterioration effects are normally caused by moisture seeping into the ends of the cable. In air-dielectric cables, both conductors can corrode. In foam-dielectric cables, the dielectric material can soak up moisture as well. The best way to prevent moisture damage is to use the proper connectors and keep them sealed.

Flexibility

The most flexible cables have a braided outer conductor and a stranded center conductor. Flexible cable is convenient for interconnecting equipment, antenna relays, power measuring equipment and so on, and it is essential for going around a rotator at the top of the tower. Flexible cables often have higher loss than solid-jacketed cables (Hardline) for a given size. A good practice is to use large diameter Hardline as a main feed line and the flexible stuff to connect the Hardline to the antenna and equipment.

Some RG-8 type cables such as Times FM-8 and Belden 9913 have solid center conductors and offer lower loss than cable with a braided shield and stranded center conductor. The construction of 9913 and FM-8 is such that it can fail after continued flexing, so be careful when using this cable around a rotator. A better choice if you must use cable with lower loss than RG-213 is the flexible Hardlines, such as Andrew superflexible Heliax® .

Cutoff Frequency

Coaxial cable propagates electromagnetic energy as a transverse electromagnetic wave, or in the TEM mode. This mode is characterized by the fact that the E wave and the H wave are both perpendicular to the direction of propagation. The important thing to know about all this mumbo jumbo is that a TEM wave *cannot* be propagated in a waveguide. Therefore, as a coaxial cable gets large (physically) in comparison to a wavelength, the wavelength mode (the TM mode in this case) starts to be excited and interferes with the TEM mode. The result is that a coaxial cable starts to cut off when it gets close to a half wavelength in diameter. The equation that governs this cutoff frequency is

$$F_{co} = \frac{7.52}{\sqrt{e}\,(D + d)} \qquad \text{(Eq 6)}$$

where

F_{co} = cutoff frequency in GHz
e = dielectric constant
D = inner diameter of the outer conductor
d = outer diameter of the inner conductor

While the cutoff frequency doesn't affect most of us, it is interesting to note that 7/8-inch Heliax won't work at 5760 MHz and 1-5/8-inch cable won't work at 3456 MHz. Most foam-dielectric 1-5/8-inch cable will work at 2304 MHz, but 1-5/8-inch air line is starting to cut off so much that 7/8-inch cable is nearly as good!

Cost

Cost is a very important parameter for most of us. Usually you have to pay dearly for low loss cable. An important point to remember is that low attenuation Hardline usually has a lifetime of 10 to 20 years, versus two or three years for some flexible types, so it is important to amortize the cost over the lifetime of the cable. Bargains on low-loss cable are often available at flea markets and hamfests. Often this cable is brand new "roll ends" that commercial antenna installers have left over. Don't trust that a piece of cable is good, though. Always test a feed line before you put it up—especially the heavy stuff!

Next month we'll take a look at characteristics and recommended applications of popular cable types.

Bits

VHF PAK Software

VHF PAK is a collection of programs of interest to the active VHF/UHF operator. It is designed to run on the IBM® PC, PCjr, PC-XT, PC-AT, PS/2 and compatibles. A faster version, VHF87 PAK, supports the 8087 math coprocessor. With this software, you can

• calculate a six-digit grid square from latitude and longitude input, or vice-versa
• calculate distance, bearing and reverse bearing to other locations based on grid square or latitude/longitude input
• predict the best time to run a meteor scatter schedule
• locate and track the moon and print out azimuth and elevation pointing information, as well as data on sky noise, path degradation and mutual moon "windows" with stations in other areas of the world
• track the moon and major celestial noise sources in real time
• print EME log sheets showing two-minute sequences
• calculate an EME link budget based on the specifics of your station equipment
• calculate vertical radiation angles for horizontal antennas

Although separate programs exist to perform most of these tasks, VHF PAK integrates everything into one easy-to-use package. Once you customize the program for your call sign and QTH, you only have to boot VHF PAK to do all of your VHF/UHF operating calculations. VHF PAK is menu driven, and the screen prompts are easy to understand. The 19-page manual explains in great detail how to use the program.

VHF PAK requires at least 256 k RAM, one disk drive and DOS version 2.0 or later. VHF87 PAK also requires an 8087 math coprocessor. Price class: VHF PAK, $35; VHF87 PAK, $45. Add $3 shipping and handling. Manufacturer: Bob Mobile, WA1OUB, RFD 2, Box 442, Hillsboro, NH 03244, tel 603-464- 3187.—*Mark Wilson, AA2Z*

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