Radio FUNdamentals

BY BILL ORR, W6SAI

THINGS TO LEARN, PROJECTS TO BUILD, AND GEAR TO USE

More on the ATU

Last month I discussed the antenna tuner (ATU) and the pros and cons of shelling out hard-earned cash to buy one. The bottom line is that it is a good idea to have this handy accessory in the shack, especially if you are the proud owner of a so-called "multiband antenna." I also stated that I liked the inductor-capacitor-inductor (LCL) design better than the capacitor-inductor-capacitor (CLC) design, as the former provided a degree of harmonic attenuation that the latter did not possess (fig. 1).

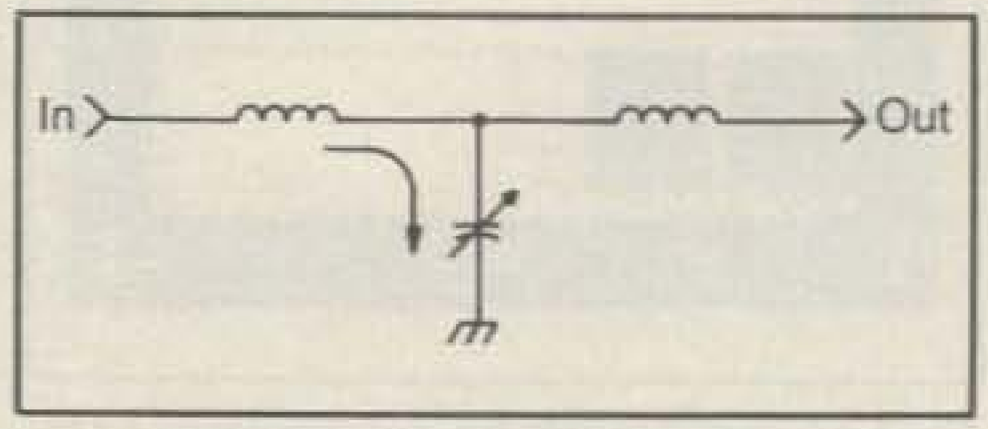

Fig. 1– LCL tuner provides degree of harmonic rejection. Arrow shows harmonic current flowing to ground.

The reason the LCL design provides better harmonic attenuation is that the capacitor provides a low-impedance path to ground for harmonics. The CLC design, on the other hand, impedes the harmonic path to ground because the inductor acts as an RF choke at the harmonic frequencies.

The harmonic attenuation of the LCL circuit is a function of the SWR the ATU is trying to match, and the circuit Q, which is fixed by the design. The SWR is a factor of your particular antenna.

Theoretically, the attenuation of a perfect LCL circuit runs better than 25 dB for the second harmonic, 35 dB for the third, and 45 dB for the fourth. A practical LCL tuner, however, is not designed for harmonic rejection but for ease in matching and for a good-looking front panel. Leads are relatively long at the harmonic frequencies and attention is not paid to small details that make a good harmonic filter. After all, that's not what the designer had in mind. In addition, maximum harmonic attenuation does not occur at the same control settings at which the impedance match occurs.

A representative LCL tuner, under test and properly adjusted for a 50 ohm load, provides about 25 dB attenuation to the second harmonic when operated on 80 meters. Third harmonic attenuation is 24 dB, and fourth harmonic attenuation is 23 dB. In the low TV channels harmonic rejection runs about 15 dB.

On 10 meters second harmonic rejection runs about 19 dB. That would afford some protection to TV channel 2, depending upon the frequency of your transmitter and the precise adjustment of the tuner.

So there you are. A well-designed LCL tuner does provide a degree of harmonic attenuation, but it should not be considered a substitute for a low-pass antenna filter, particularly in rural areas where the TV signals are weak. The LCL tuner will back up a good low-pass filter in any event. If a TVI filter is used, it should be placed between the transmitter and the ATU.

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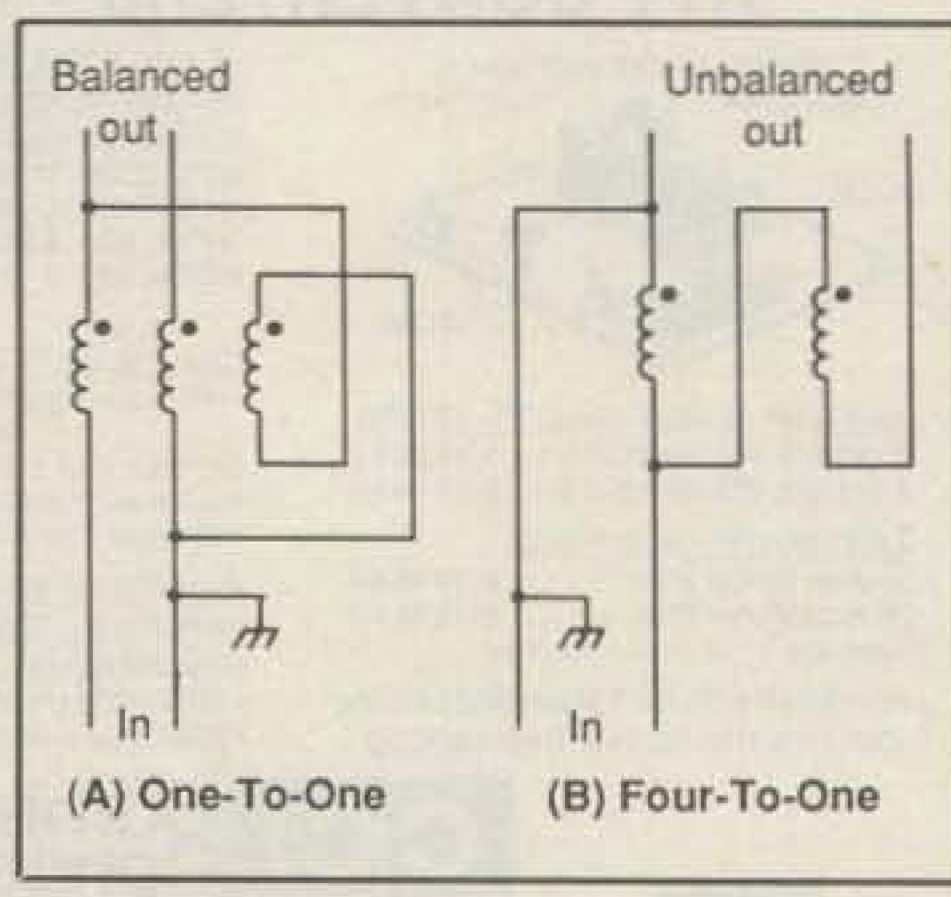

Fig. 2– Voltage-type valuns. May be air or ferrite core. (A) One-to-one (50 to 50 ohms) balanced out. (B) Four-to-one (50 to 200 ohms) unbalanced out.

A New Breed of Balun

A new form of 1-to-1 balun has appeared recently, and it offers improved performance over the popular trifilar ferrite core design. An extensive review of baluns by Roy Lewallen, W7EL, emphasized the fact that there are two classes of baluns for general amateur use.[1] He defines these devices as voltage baluns and current baluns. The voltage balun (fig. 2) is the common trifilar type. It performs a balanced to unbalanced voltage conversion. The current balun, on the other hand, performs a balanced to unbalanced current conversion (fig. 3). Since most conventional antennas are current-fed (the dipole, for example) and the antenna field is proportional to the current, it would seem reasonable that balanced current, as opposed to balanced voltage, is required at the feedpoint. Balanced current in a coax line is achieved only if the antenna is balanced and no current flows on the outer shield of the line. The current balun reinforces this situation, as it acts as an RF choke, impeding unwanted shield current and providing balanced current to the antenna.

The current balun can consist of a number of turns of coax wrapped into an air coil, or wrapped around a ferrite core. The air coil is bulky (about six turns of coax, 8 inches in diameter for RG-8/U or RG-58/U serves in the 14–30 MHz range). This is an inexpensive choke coil, as it can be a portion of the feedline, held together with cable ties. For best results it should be placed at the antenna terminals.

Wrapping coax around a ferrite core is difficult, as anyone who has tried this scheme can affirm. The bulky air coil is better.

Taking an idea from the VHF solid-state world, Doug DeMaw, W1FB, proposed in 1980 that ferrite "sleeves" passed over a coax line could serve as an RF choke, or current balun, to decouple the line.[2] Shortly thereafter, Walt Maxwell, W2DU, built and measured such a decoupling sleeve made up of a number of ferrite beads on a length of the coax.[3] The W2DU HF balun consisted of 50 type 73 beads on a foot-long length of 50 ohm Teflon dielectric cable. The only fly in the ointment with this design is that specified RG-303/U cable isn't obtainable at Radio Shack, nor at most amateur radio distributors. The suggested alternative cable, RG-141/U, also is not a household word!

A Practical Sleeve Balun

A practical and inexpensive balun can be made either of readily available RG-58/U or RG-8/U. Luckily, toroid beads (sleeves) having inner diameters of 0.5 inch and 0.25 inch that will pass the coax lines are available in either 43 or 77 ferrite material (Table I). The original W2DU design used 73

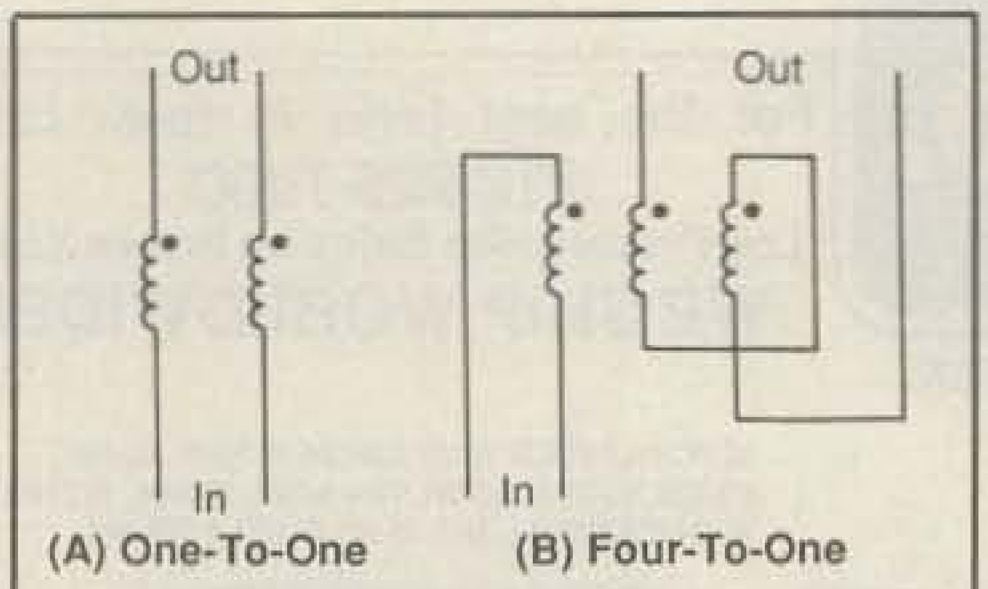

Fig. 3– Current-type baluns. May be air or ferrite core. (A) One-to-one, balanced or unbalanced. (B) Four-to-one, balanced or unbalanced.

Amidon Part No.	Outer Diameter (in.)	Inner Diameter (in.)	Length (in.)	Cable
FB-77-1024	1.000	.500	.825	RG-8/U
FB-43-1020	1.000	.500	1.120	RG-8/U
FB-77-5621	.562	.250	1.125	RG-58/U
FB-43-5621	.562	.250	1.125	RG-58/U

Nomenclature	Permeability	Material
#77	2000	Manganese-Zinc
#43	850	Nickel-Zinc
#73	2500	Manganese-Zinc

Table I– Specifications of toroid beeds (sleeves). (See text for details.)

material which is similar to the 77 stuff, but large cores that slip over coax lines are presently available only in 43 and 77 material, not the 73 material W2DU used. No matter. The 77 material is very similar to the 73 stuff.

Test baluns were constructed using the two available types of ferrite and the baluns were tested using a General Radio RF impedance bridge. Each balun was made up of a short length of RG-58/U cable. The test setup recommended by W2DU was duplicated (fig. 4).

It was arbitrarily decided that the impedance presented by the choke balun should be about ten times the coax line impedance over the operating range of the balun. That's an impedance of 500 ohms for a 50 ohm coax line.

My conclusion was that the balun using 77 material performed best below 10 MHz and the one using 43 material was better above 10 MHz. In both cases excellent current balance was obtained in the load, even when the load itself was purposely unbalanced.

Building the Sleeve Balun

A ferrite sleeve balun can be built by sliding six beads of the proper size over the coax at the antenna end of the transmission line. The beads can be held in position against each other by application of heat-shrink tubing. Use the 77 beads below 10 MHz and the 43 beads above 10 MHz. If you don't mind a slightly poorer balance at the low frequency end, the 43 beads can be used down to 3.5 MHz.

That's all there is to it. Six beads plus some heat-shrink tubing does the job. You'll have a current balun that is hard to beat!

MINIPROP™ Plus

Now that the sunspot cycle is on the downswing, DXers need all the help they can get! Good DX openings are growing shorter; 10 and 12 meters are showing signs of pooping out. From now until 1997 conditions will become steadily poorer, according to the predictions of George Jacobs, W3ASK, in the August 1992 issue of *CQ*. It will then take a year or so for the MUF to permit good DX conditions to bounce back. That means until the year 2000 or so the glory days of super-DX on the higher bands will be conspicuous by their absence.

One DX aid that will be of comfort in the bleak years ahead of us is the popular MINIPROP™ computer-aided propagation program released in 1985 by Sheldon Shallon, W6EL. The good news is that it has been upgraded to MINIPROP™ Plus, a follow-on program which, in addition to the excellent propagation predictions of MINIPROP 3.0, features a world map display showing the "gray line" terminator and the great-circle path between two DX stations. Gray-line propagation will be increasingly important in the bleak days ahead!

In addition to the nifty MUF data, signal-level prediction, beam headings, radiation angles, and other good stuff, an on-disk atlas provides latitudes and longitudes of more than 360 locations and a DXCC list that can be edited by the user. Also in the program is a customized table of beam headings from the user's QTH to all of the locations in the atlas.

MINIPROP™ Plus is for IBM and compatible machines with at least 512K RAM, DOS 2.11 or higher, and CGA/EGA/VGA or Hercules graphics.

Noteworthy is the 62-page manual accompanying MINIPROP™ Plus. It has a comprehensive tutorial on propagation, plus clear directions on running the program. It's sort of like having W3ASK in your shack giving you constant information on propagation!

I can't cover all the impressive details of this program. You can find these out by contacting W6EL Software, 11058 Queensland St., Los Angeles, CA 90034-3029. Current price of MINIPROP™ Plus is $60, postpaid in the U.S. and Canada, US $65 elsewhere.

Low-Pass TVI Filters and SWR

Most stations operating in the HF bands employ a 50 ohm low-pass harmonic filter in the feedline to the antenna. Plenty of filter stopband curves are available[4,5] which provide an insight as to the degree of harmonic attenuation available in these little boxes. One unanswered question is: To what degree is filter attenuation affected by SWR on the transmission line? As the SWR rises, does filter performance deteriorate? Does high SWR mean more TVI? One way to determine this is to examine the filter stopband under SWR conditions. With the assistance of Tiff, W6GNX, and his Hewlett-Packard 141T Spectrum Analyzer and HP 606B signal generator combination a quick check of the problem was made.

A Drake TV-3300LP filter was tested.

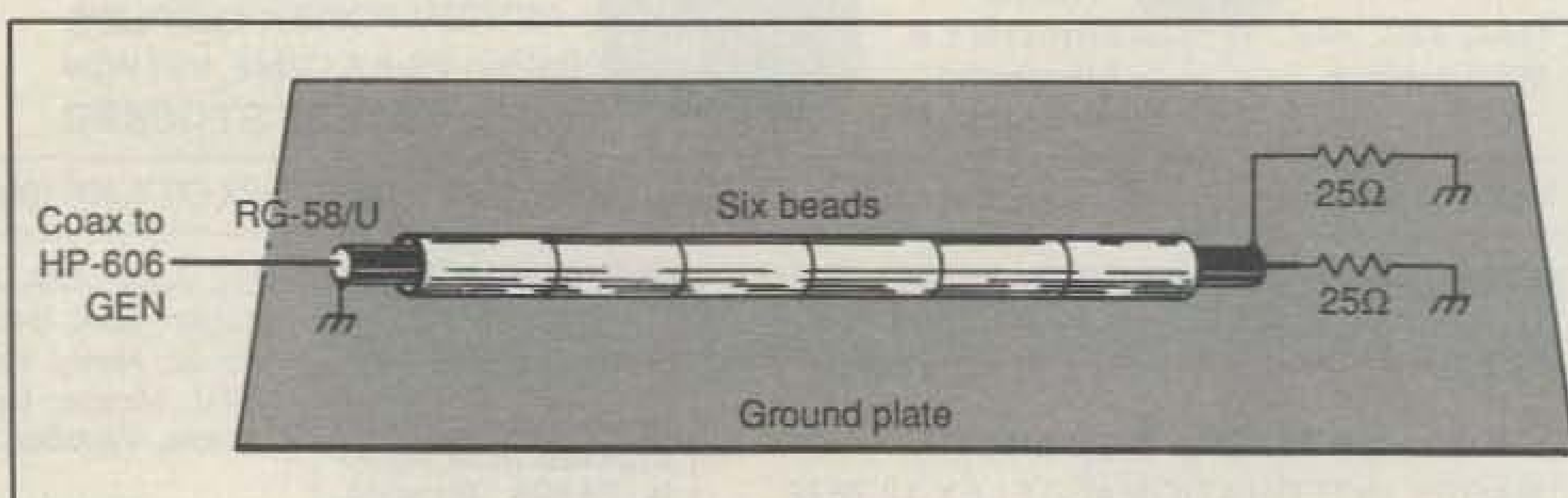

Fig. 4– Duplicate of W2DU test bed for current balun. RF voltmeter compares voltage across load resistors. Voltage across resistors is proportional to their resistance. RF bridge determines impedance of balun from one end to the other.

(Filter connoisseurs acknowledge the superiority of this model over lesser designs.) When terminated with a 50 ohm load the filter exhibited better than 70 dB attenuation above 41 MHz. Terminating the filter in various load combinations (providing up to 3-to-1 SWR) indicated that SWR has little effect when it comes to filter attenuation. The W6GNX curves are almost identical to those run by W6FR at an earlier date using 50 ohm filter termination. That is comforting to know, as most antennas do not maintain a flat SWR response across an amateur band.

Commentary for The Month: Technology In Reverse

"Let me introduce you to retarded technology. It's the opposite of advanced technology. Advanced technology allows us to do useful new things or to do old things more efficiently. By contrast, retarded technology creates new and expensive ways of doing things that were once done simply and inexpensively. Worse, it encourages us to do things that don't need doing at all.

"The survival of stupid technology is ordained by ego and money. New technologies often require a hefty investment. Once investments are made, they can't be easily unmade. To do so would be embarrassing. Old and inexpensive ways of doing things are eliminated to help pay for new and expensive methods. Retarded technology becomes institutionalized and is permanent."

So says Robert J. Samuelson in an essay in the July 20, 1992 issue of *Newsweek* magazine.

His remarks bring to mind my first VCR. It was a dandy. Four buttons on it, plus an on-off switch. Even *I* could work it. Today my new technology-perfect VCR has a confusing remote control with a plethora of commands that would take a rocket scientist months to figure out. I've struggled with it for over a year and have finally mastered most of the tricky functions. What a waste of time!

If the AC power goes off for an instant, a painful re-entering of data is required. Time? AM or PM? Date? Year? SAP? Mono? Stereo? Yes? No? Maybe? I long for my old 4-button VCR. It demanded so little of me.

Is amateur radio gear going the same way? My zippy up-to-date transceiver has 16 knobs (some of them dual controls) plus the tuning dial, and 62 push-switches. Most of them I ignore. I just can't be bothered with all this fol-de-rol. Is amateur radio entering the dark ages of retarded technology? What do you think?

New Yagi Optimizer Program

The new Yagi Optimizer 5.0 antenna program was introduced to hamdom at the ARRL National Convention in August by Brian Beezley, K6STI. It is a great improvement over the older program, which I have used many times to determine the worthiness of a Yagi design. The Yagi Optimizer does what the name implies: If you input Yagi dimensions specifying element spacing, diameters, taper, and other attributes of the design, the Optimizer will crunch away at your command. You can specify parameters for the Optimizer to emphasize. Best front-to-back ratio? The Optimizer will search for that. Highest gain? No problem. Best combination of gain and front-to-back ratio, using your definition of "best"? Easy. Many, many choices are at your disposal. You can determine the effects of mounting brackets, or find out how much gain you'll lose if an element comes off during a hurricane.

Broadband a design? Yes, and the Optimizer will tell you if you lose or achieve gain and front-to-back ratio in this exercise.

It's as if you have antenna range, complete with instrumentation at hand! All you need is an IBM-style computer, a graphics driver (CGA, EGA, VGA, or HCG), and you are off to the races!

Well, I think it's a neat program with potential that will surprise you. If you didn't attend the National Convention, you can get full information on this and other computer-driven antenna programs from Brian Beezley, K6STI, 507½ Taylor St., Vista, CA

92084. Or you can call (619) 945-9824 (0700–1800 PST).

The Dead Band Quiz

I appreciate the cards and letters concerning these little brain ticklers. I hope you continue to enjoy them. To bring things up to date, here are some more readers who have solved past quizzes:

Danny Kaye (. . . the flagon with the dragon . . .): VE4AHR and K1XA.

RMS, Average and peak voltage: N9HWC, K1SRR, K5RA, AC4DY, KAØZFK, KØALL, N4UZ, W7FSP, NØMCD, and K6JG.

Twilight Zone: N3CTB (He must have been the producer! He knew it all!).

And my warmest thanks to the following who wrote personal letters. I really appreciate your input: Mike, WA8MCQ; Charles, WD4PAH; Charles, W8JI; Wayne, AG4R; Carl, W6OZA; Henry, W6TDP; George, W2CFX; Sam, W5AG.

Shop Talk

I've gotten several letters recently concerning filament-grid shorts in 3-500Z and 4-400A tubes. Interestingly enough, commercial users of these tubes almost never have this annoying problem. Why is it endemic among radio amateurs? Here's the story.

Thoriated-tungsten filaments used in these tubes have a 10:1 ratio of cold to hot resistance. That is, if the filament draws 15 amperes when hot, it will draw about 150 amperes when it is first turned on. Filament current quickly drops to normal value in less than a second as filament resistance increases.

In real life the tube practically never gets the chance to draw 150 amperes, as the filament transformer "sags" under the huge load.

"Inrush" filament current in many cases is limited to about 50 to 70 amperes per tube depending upon design of the transformer. The filament transformer in the old Heath SB-220 was built to limit filament current, as the transformer would saturate under heavy load. Even so, 50 amperes inrush current is still too high.

The effect of high inrush filament current is to place a heavy physical strain on the coiled filament. The filament actually reacts by a violent movement, the coils collapsing toward each other in a haphazard way. If the filament moves far enough, it will touch the grid, causing an electrical short between the two elements. Each time the tube is turned on the filament experiences a quick distortion and then returns (nearly) to its previous shape. Enough inrush shocks can permanently distort the filament, causing it to lean nearer and nearer to the grid. After repeated turn-on cycles—zap—the elements are shorted and the tube is ruined.

Leaving the filaments on 24 hours a day as is done in broadcast stations is not the solution. The solution is to turn the tube on, limiting the filament current as you do so. There are several ways to do this:

1. Use a variable voltage transformer (Variac) to bring the filaments up to proper voltage over a period of a second or so.

2. Use a step-start circuit. A series resistor in the filament circuit is shorted out by a time-delay relay or a manually operated switch.

3. If the filament winding is on the large plate transformer, use a step-start circuit on that.

4. For 3-500Zs or similar tubes, use a 6.3 volt transformer with a series primary resistor to drop the voltage to the correct value under tube operation. The resistor will absorb inrush current.

5. For sideband service, undervolt the filament. Instead of 5.0 volts, run it at 4.85 to 4.9 volts.

6. Use an RMS-responding meter or a solid-state VOM of known accuracy to check your filament voltage.

73. Bill, W6SAI

Footnotes

1. Lewallen, Roy, W7EL, "Baluns: What They Do And How They Do It"; *The ARRL Antenna Compendium, Vol. 1.*

2. DeMaw, Doug, W1FB, *Ferromagnetic-Core Design and Application Handbook*, p. 140; Prentice-Hall, Inc., Englewood Cliffs, NJ 07632.

3. Maxwell, Walter, W2DU, *Reflections*, ARRL, Newington, CT 06111 (chapter 21).

4. Gonsior, Marv, W6FR, "Low-Pass Filter Performance," *Communications Quarterly*, Spring 1992, pp. 75–84; Box 465, Barrington, NH 03825.

5. Grammer, George, W1DF, "Eliminating TVI with Low-Pass filters," Part III, *QST*, April 1950, pp. 23–30.