Loading problems and cures with regard to solid-state transmitters

ham radio TECHNIQUES

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My column "A Survey of Antenna Tuners" in July, 1981, *ham radio* brought some feedback in the form of interesting mail. The subject under discussion was the problem of loading a solid-state, high-frequency transceiver into some of today's modern antennas. Many proud users of the latest in ham gear experienced loading problems, feedback, TVI, erratic operation, a "hot" microphone and other melancholy exceptions to normal operation.

What is the problem? What causes this unusual plague of difficulties?

It seems to reduce down to this: The modern, state-of-the-art, high-frequency transceivers with transistor output stages all have one thing in common — they provide their full power into an antenna load *only* under conditions of a *low* SWR on the transmission line. Many solid-state transceivers, when presented with a high-SWR antenna load, simply start to turn themselves off. As an example, one popular transceiver, when working into an SWR of about 2 to 1, will reduce its output by 25 percent (100 watts to 75 watts). And when the SWR reaches about 3 to 1, the transceiver output drops by 50 percent (100 watts to 50 watts).

Someone may say "small potatoes," but a 50-percent power drop is a signal loss of 3 dB, and when the user is paying for the power, I don't see why he can't use it! **Fig. 1** sums up the problem.

what to do about loading problems

Perhaps the loss in power output is not important, but the attending problems mentioned previously are often coupled with the SWR problem. It is all of one piece, so to speak. The answer, then, is to tailor the *antenna system* to provide a better and more compatible load for the solid-state equipment.

From the mail I get on the subject, the antenna that seems to provide the greatest loading problems is the popular tri-band Yagi beam for 10, 15, and 20 meters. Sometimes this antenna is a "bearcat" to tame, especially on 10 meters. So let's take this antenna as an example, remembering that the discussion applies to other antennas as well.

The problem breaks down into two separate parts. First, getting the rf power where it belongs — into the antenna — and not where it is liable to end up — in the telephone wires, utility wires or Grandpa's new stereo system. Second, making the antenna system compatible with the transceiver so the latter "looks into" a reasonably low value of SWR. Neither problem is insurmountable.

getting the rf power where it belongs

It is easy to allow the output power from your transmitter to get into outlandish places. A favorite 40-meter dipole of mine had to be taken down because when I ran a few hundred watts into it, the dining room light fixtures illuminated by themselves, even with the light switch in the off position. And a friend of mine had a talking garbage disposal whenever he went on 15-meter SSB. Many operators have been bitten from a "hot" microphone on 10 meters. Sometimes speech processors break into oscillation, or loading changes when the microphone is grasped.

All of this means that the transmitter rf is getting where it is not supposed to be — into the power mains and back into the transmitter's exciter stages. There are several ways to combat this problem.

First, it is bad medicine to have the station in the near-field of the antenna. Getting the antenna up in the air, away from the station equipment, helps a lot. When the antenna is on a short tower right above the radio room, the station equipment is exposed to the strong radiation field from the antenna. Moving the antenna away from the station is the answer. Or, moving the station away from the antenna accomplishes the same result. My antenna, for example, is on a tower near my garage. Moving the station from the garage workshop to a spare bedroom certainly helped a lot. (My wife had other ideas about that move, but that's another story.)

antenna currents

One aspect of the problem is caused by antenna currents that flow on the *outside* of the coax to the antenna. Antenna currents can be caused by current induced into the outer shield of the line because it is in the field of the antenna. The worst case is when the line length is resonant; that is, a multiple of a half wavelength at the operating frequency. Under this circumstance, you have a resonant conductor (the transmission line) in the near-field of the antenna. Maximum line pickup comes about when the transmission line runs *parallel to the antenna.*

Antenna currents can be reduced by detuning the line and moving it so that it doesn't run parallel to the antenna. In the case of a rotary beam, it is a good idea to bring the coaxial line *and* rotor control cable down to ground level and run them along the ground, or bury them inside a garden hose sunk below ground level. A bad idea is to string the coax and cable above the ground from tower to radio room. My coax and cables came off my tower at about the 10-foot (3-meter) level, then ran across the rooftop to the window of the operating room. This caused no end of problems, especially on 10 meters.

I finally dropped the wires down to ground level and brought them into the radio room through a hole drilled into the corner of a closet floor (when no one was looking). Relocating the cables improved transmitter operation and stability immensely.

The *ARRL Antenna Book* has a good dissertation on antenna currents and how to decouple the line to avoid line resonance. The solution proposed is to cut the line to a length that avoids resonance. Recommended lengths for the high-frequency bands that avoid the problem are: 27, 39, 57, 76, 95, 110, and 145 feet (8.2, 11.9, 17.4, 23.2, 29, 33.6, and 44.2 meters).

the line choke

Another approach is to wrap a few turns of the transmission line into a coil, forming an rf choke, that will suppress antenna currents that might flow on the outside of the outer shield of the coax. I have used five turns of RG-8A/U, about a foot (30.5 cm) in diameter. In one instance, where I didn't use a balun, but fed a balanced beam with a coaxial line, I noticed that my front-to-back ratio was very poor. The beam seemed to have a bidirectional pattern. The five-turn choke coil was placed in the coaxial line, atop the tower, and about 3 feet (0.9 meter) from the feedpoint of the beam. (Placement was determined by the fact that I am a coward atop the tower, hanging on with both arms and a safety belt.) Once the line was wrapped and taped into a roughly shaped coil, the front-to-back ratio of the beam improved dramatically.

Another stunt is to wrap two turns of the transmission line around a large ferrite core. I've used the Amidon T-200 (6-mix, yellow, with a $u = 8$) with two turns of RG-8A/U through it in a 12-inch (30.5-cm) diameter coil with good results, too.

summing up

So there you have it. *Don't* run your coax line parallel to the antenna elements or, if you must, run it along the ground. *Do* make sure your coax line is not resonant at your operating frequencies. Either detune the line by trimming it to the previously sug-

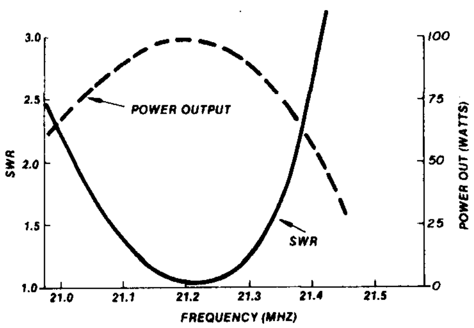

fig. 1. Representative SWR *vs* power output for solid-state transmitter. As SWR of antenna increases, power output of transmitter drops rapidly. At 21.45 MHz, for example, 100 watt nominal output is reduced to less than 30 watts because of high SWR on antenna system. A line flattener will reduce input SWR and boost power output of the transmitter.

gested lengths, or wrap a portion of the line into an rf choke. Bring the line *down* the tower — *don't* run it off at an angle below the antenna.

if all else fails

Sometimes attention to antenna currents on the transmission line doesn't completely solve the problem of rf feedback, a "hot" microphone, or RFI (Radio Frequency Interference). *I* know. Some years ago I lived in an area remarkably free of TVI. I had no TVI problems, including TVI in my own home. One fine day a neighbor decided to add an extra room to his garage — sort of a combined rumpus room and workshop. No sooner was the room added when the neighbor complained to me of severe TVI from his new set installed in the garage room. Sure enough, I wiped it out! And a highpass filter in the TV lead in didn't seem to do any good.

Well, after a lot of fruitless investigation, on-the-air checks, and so on, we discovered that the TVI on this particular receiver could be completely eliminated by merely moving the set from the garage room back into the house!

It seems that my neighbor's house, my house, and the surrounding houses had been wired with solid electrical conduit. That is, all electric wiring was encased in metal conduit which, in turn, was grounded at several points in the homes.

To save building costs, my neighbor decided that conduit was too expensive, so his new garage room was wired with exposed, knob-and-tube wiring! The result was that the electrical wiring acted as a giant antenna, picking up my signal and pumping it directly into the power line of the TV set. Moving the set back into the house, which was wired with solid shielded conduit, completely protected the vulnerable input circuits of the receiver.

What to do? Investigating around the attic area of the new room revealed that the 120-volt wiring was as "hot as a baker's apron" when I was on 20 meters, less so on 15 meters, and again sensitive to 10-meter operation.

It was impossible to retroactively shield the wiring, so an attempt was made to cool things off. At every wall outlet each side of the power line was bypassed to the neutral wire (a three-wire circuit: 120 volts, 120 volts, and ground) with 0.01-μF 1.4-kV disc ceramic capacitors, rated for 125 volts ac and 1400 volts dc. (The capacitors are tested at 2800 volts.)

Three well known manufacturers that supply these line capacitors, and their type number are: Aerovox type AC-7, Centralab type CI-103, and Sprague type 125L-S10. These capacitors, or their equivalents, are suitable for the 120-volt, 60-Hz power line. *Do not* use garden-variety 600-volt disc ceramic capacitors, as they are not rated for this service.

Bypassing the line at various points helped to clean up the trouble, and when a highpass filter was placed in the ribbon line to the TV set, it did the job. Result: no more TVI in the new garage room!

the line flattener

Taming the rf floating around the radio room and cleaning up your neighbor's receiver doesn't go all the way in solving the loading problems inherent in some solid-state rigs, but it surely helps. The last trick in the deck is to use a *line flattener* — this is a simplified matching network that is placed between the transmitter and the antenna to reduce the SWR on the line to a value acceptable to the transmitter. Mind you, the SWR at the antenna and on the line doesn't change — the line flattener is merely a matching device that makes the real world more palatable to the station equipment. A good line flattener can drop an SWR of more than 5 to 1 to unity in the wink of an eye!

The schematic of a line flattener for power levels up to 250 watts PEP (or slightly more) is shown in **fig. 2.** A connoisseur will recognize this circuit as a simple pi network with three adjustable components. The line flattener is inserted into the transmission line *after* the SWR meter, and the

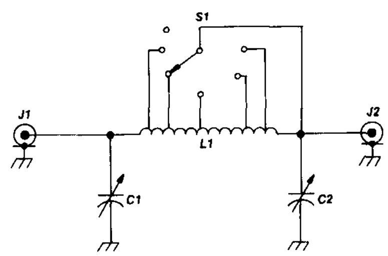

fig. 2. Line flattener for coaxial cable. Many components for the line flattener can be found in the junk box. J1, J2 are coaxial receptacles to match the plugs used in your antenna system (type SO-239 receptacles mate with plug PL-259, for example). Capacitors C1 and C2 are 100 pF (for 10-15-20 meter operation) and 250 pF for 40-80 meter operation. Single-spaced, receiving types will be satisfactory for power levels up to 100 watts PEP output. For higher power levels, the surplus capacitors found in the BC-series "Command" transmitters are ideal. Fair Radio Sales, in Lima, Ohio, has a good selection of transmitting capacitors.

The coil, L1, is ten turns of No. 12 (2.1 mm) 1 inch (2.54 cm) diameter and 1-1/2 inches (3.8 cm) long (10-15-20 meters); 20 turns, 1 inch (2.54 cm) diameter 3 inches (7.6 cm) long (40-80 meters). Five taps, every other turn on every fourth turn. The coil is not critical; the air-wound type is satisfactory, or it may be hand wound on a ceramic form. Use what you have. Switch S1 is a ceramic affair with an insulated shaft extension. Or, it may be mounted on an insulated plate affixed over an oversized panel hole. Remember: the arm of the switch is at rf potential. Again, Fair Radio Sales is a good choice for suitable switches.

controls are adjusted to reduce the SWR to a minimum value. Suitable components for the line flattener are listed in the drawing caption.

To keep everything shipshape and rf tight, the line flattener should be built into an enclosure such as an aluminum utility cabinet. The Bud AU-1040, measuring 9 by 6 by 5 inches (22.8 by 15.2 by 12.7 cm), will do the job as will any equivalent cabinet that is all-metal and does not have plastic end panels. The input and output coaxial fittings can go on either end of the cabinet, or on the rear, depending upon your particular equipment layout.

It is a good idea to use extra screws to hold the box panels in place; the box is pretty leaky when it comes to rf shielding. And don't forget to clean any paint off the mating lips of the box and panels to make a good electrical joint.

tuning the line flattener

Easy! Place the SWR meter between the line flattener and the coax line to the transmitter. You'll need a short, extra length of line to reach from flattener to transmitter. And *be sure* to properly install *all* coax plugs on your antenna line as recommended by the manufacturer. A sure-fire way to get into trouble is to improperly use the connectors. The temptation is great to jam the connectors onto the cable and forget about soldering the shield and inner conductor. *Don't do it!*

When everything is together, fire up the transmitter and adjust the controls of the line flattener for the lowest value of *reverse power* (or SWR) as read on the SWR meter. That's all there is to it. Log the control settings for each band for future use.

Need more information on antennas, feedlines, and beams? Read *The Radio Amateur Antenna Handbook,* by W6SAI and W2LX. It's available from Ham Radio's Bookstore, Greenville, NH 03048. Price, $6.95 plus $1 to cover shipping and handling.

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