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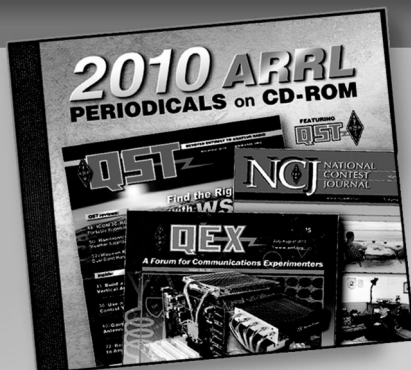
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Putting the Heath SB-200 on 160 Meters

Thinking about modifying your linear amplifier? Here are some tips to help you get started.

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I decided to get on 160 meters last year. Using just my transceiver and a makeshift antenna, I found 160 m to be a nice friendly band, but if I didn't want to be the "weak signal" in a round table, I needed a better antenna and a linear amplifier. My dilemma was whether to buy a new amplifier that would cover 160 or try to convert my SB-200. I took a hard look at the SB-200 to assess the difficulty in modifying it to work on 160 m. It looked like a fun project that would give me a feeling of personal accomplishment.

I was not particularly apprehensive about the technical aspects of the task. My only real concern was the availability of necessary parts. I didn't want to hack up a nice piece of equipment that had performed to my satisfaction on 80 through 10 meters. Before I changed anything, I took the rig out of its enclosure and examined it carefully, particularly looking for space for new tank coils I knew I would need. I had bought the amplifier, complete with instruction manual and schematic, at a local hamfest. It looked like a perfectly straightforward grounded-grid amplifier, well-designed and laid out. Someone unknown to me had done a good job in putting it together.

In talking to several people on 160 m, I learned that many had amplifiers that they considered were candidates for conversion, but few had done so. Most of them hesitated for the same reasons that bothered me. Several articles have been written describing how to convert amplifiers for 160 m, but I had not read them.^{1,2} Anyway, I was not interested in what someone else had done—I wanted the fun and satisfaction of doing it myself!

I knew that if the project was successful, I would be tempted to share my adventure with others. I would probably use components from my vast supply of ugly junk in the cellar, so my particular choice of components would not be of much value to others. Therefore, please don't expect an exact description of the conversion, but

rather follow me through my problems, decision points, and some of the traps I fell into.

I made the conversion successfully, for my own use in my own shack. The end result may not be the answer for you! I took some shortcuts and made some compromises that cause minor performance degradations, but these are acceptable to me. The end product is not a "stand-alone" modified amplifier that anyone can build and use in any radio station. I'll point out the areas where I took liberties and mention some alternatives. I hope that this narrative will interest you technically and that you will enjoy walking with me through my adventure.

Ground Rules and Objectives

Early in the project, I made some ground rules for myself and tried to follow them. First and foremost, I wanted the amplifier to work on 160 m, but I also wanted to retain operation on 80, 40, 20, 15 and 10 meters. I also hoped to find a way to add 12-m operation, if possible. I would perform the conversion one step at a time, so that if I encountered insurmountable problems, I could retrace my steps and put the thing back as it originally was. I preferred not to add anything to the front panel, such as another switch, knob or dial. Lastly, being lazy, I wanted to do everything inexpensively and with minimum reasonable effort.

Looking for Solutions

Some of the required changes were obvious from the start. It would be necessary to change the output coil combination to tune 160 m with a reasonable LC ratio. I also assumed that a new bifilar filament choke—one with higher inductance—would be required to permit adequate drive on 160 m. In addition, I suspected that I would run into some RF choke and capacitor changes.

My first dilemma was a band-switching problem. The band switch on the SB-200 selects coil sections for the output tank circuits and individual coils for the pi-input matching sections. The switch has only five positions—80, 40, 20, 15 and 10 m. Adding 160 and 12 m would require seven positions. My first thought was to change

the entire switch and all the wafers to get the seven bands. I soon backed away from this approach because of the difficulty of removing the switch. The switch assembly extends from the front to the back of the unit and would have to be completely replaced. It would be very difficult to get a set of 7-position switches because most wafer switches have five or six terminals on each half of each wafer. To get seven positions would require one more complete wafer because both sides and both halves of the input wafer were already being used. The coils and switch wafers for the input circuitry are mounted in the crowded rear deck area and would be difficult to modify. I needed to find a compromise.

I could immediately see two alternatives: either tune two bands on each of two switch positions or tune three bands on one switch position. I felt that the lower frequencies would suffer too much degradation from such a scheme, and that left 20, 15, 12 and 10 m as candidates. I definitely wanted uncompromised performance on 20 m, but was somewhat less interested in 15, 12 and 10 m, at least until the sunspot cycle catches up with us. I explored putting 15, 12 and 10 m on one switch position, using only the SB-200's plate tuning capacitor to tune all three bands. I thought that if I was successful in putting all three on one switch position, I could optimize toward the one band I wanted most of the three—15 m.

Putting three bands on one switch position means that the output tuning circuitry can use only one coil section, and the input selection and tuning circuitry can use only one of the pi-tuned input coils. Except for a rough calculation, I had no way of knowing how well the output circuit would work except by building it and trying it. By checking resonance with a dipper, I determined that I could cover 10, 12 and 15 m with the plate tuning capacitor, but that was about as far as I could go in predicting what these changes would do to the output circuit. The less-than-optimum LC ratio would probably cause some efficiency loss; I would just have to wait and see.

I made a series of tests that gave me hope for the input circuit. The input impedance of a grounded-grid amplifier is sufficiently low (about 300 ohms) to permit a comparatively low Q in the pi-input networks. In

¹Notes appear on page 35.

other words, the tuning is quite broad, allowing fixed tuning.

I customarily use a low-power "homebrew" matching network between my TS-830S exciter and the amplifier. This makes my exciter happy on the band edges, somewhat off resonance of the amplifier input circuit. I rationalized that with the matching network I might be able to get the single input circuit in the amplifier to accept drive on all three bands. However, I had to find out if this was possible before committing myself to the scheme. I would have to read the RF drive level at the filaments of the amplifier tubes in the amplifier. I chose to do this with an old oscilloscope, and its vertical amplifier would not respond well at 21 to 30 MHz. I fed the vertical plates directly—a hundred or so volts of RF will indeed provide a vertical deflection. I adjusted the input coil in the amplifier to maximize the signal at 21 MHz and was able to get respectable drive on 12 and 10 m. The SWR/wattmeter between the exciter and the matching network showed that the exciter was looking at a satisfactory load.

I knew these readings were only a first-order approximation. Had the amplifier tubes been fired up, the impedance seen by the input signal would be considerably lower. I figured that I had a good chance at making this scheme work, however, and at this point I felt I had an acceptable course of action.

Amplifier Changes

Input and Output Networks

Up to this point I had made no changes to the SB-200—just some simple measurements. I did, however, have a series of schemes I hoped would work. The first thing needed was a new output tank coil, or coils, that would tune 160 m, and

physically fit the space that would be available after removal of the existing coil. Fig 1 shows the top view of the unmodified amplifier, and, as can be seen, considerable space can be made available. Making coils is not that tough—most of us old-timers have made lots of coils using plastic tubing or plastic strips for spacing to obtain the proper number of turns. I was lucky and found two ceramic forms of the same diameter, and only slightly smaller in diameter than the original coil. The two coils, placed end-to-end, would fit in the available space. I glued the two forms together with some "magic glue" from the drugstore. The forms already had coils wound on them, and, when the forms were put together, there was about two inches of unused coil form space left between them. I wound a bunch of turns of no. 14 enameled magnet wire to fill this unused space. Temporarily, I hung the coil in the circuit with clip leads and, with the tubes in place (to use their internal capacitance), I checked for resonance with the dipper. Luckily, I was low in frequency, so I removed turns from the center winding until it resonated at 1.8 MHz with the tuning capacitor nearly fully meshed. I had my coil (or so I thought), so I made taps for 80, 40 and 20 m using the dipper.

The SB-200 output tank uses a separate, small coil for 10 and 15 m (visible in Fig 1). My modification uses only the tapped portion of the coil for 10, 12 and 15 m.

In view of all the tests I had made, here is where I stood regarding the input circuits. The original 5-position band switch would be used to select 160, 80, 40 and 20 m, with one position for 10, 12 and 15 m. Right now, however, the input select switch did not select the same frequency ranges as the modified output band switch. In the new 160-m position, the input switch selected

the 80-m coil, and so on. I left the 80, 40 and 20-m coils in their original physical location, but rewired them to the next higher band-switch position, to correspond with the output band-switch selection positions. This left two unused input coils. I rewound the 10-m coil for 160 m using lots of turns of enameled wire that was smaller than the original, and wired it over to the correct switch position. The remaining 15-m coil I peaked up as best I could to be able to drive 10, 12 and 15-m signals into the amplifier with the matching network. This whole coil-juggling operation is a lot easier than it sounds. I had originally thought that I would have to remove and rewind all the SB-200 input coils. Instead, I just cross-connected them to new switch positions, and had to make only one new coil—the 160-m one.

Ham that I am, I was anxious to find out how things would work, so far. At this point, however, I had not touched the filament choke, so I assumed that the rig could not yet work on 160 m, because sufficient drive would not be obtained on the low band. I gingerly cranked the amplifier up, and was delighted to find that it apparently worked quite well on all the original bands. I did not try operating it on 160 m.

Filament and Plate Choke Problems

Next, I tackled the bifilar filament choke problem. I found a core of ferrite or polyiron about 1/2 inch in diameter and about 4 inches long. I had picked it up at a hamfest, and the seller said he had used it for a filament choke. I wound as many bifilar turns of no. 14 enameled magnet wire on the core as I could and with the new choke in series with the original choke, checked them for resonance with the dipper. They resonated at a frequency lower than 1.8 MHz, so I figured I now had my filament

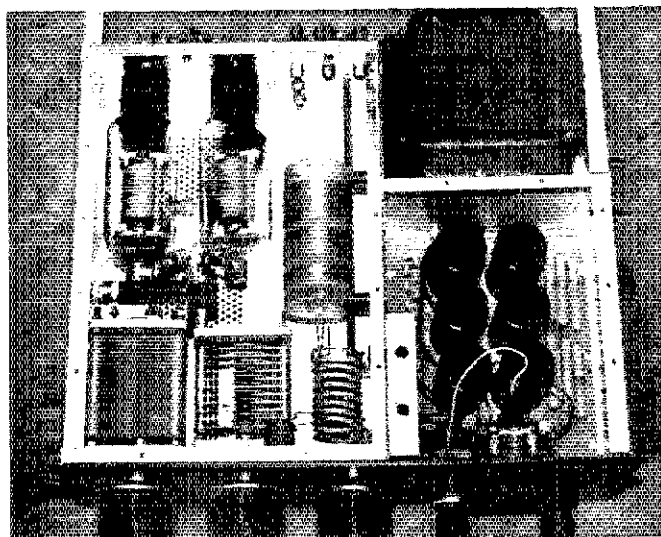


Fig 1—The original, unmodified Heath SB-200 linear amplifier. Note the relatively uncramped arrangement of components, allowing space for additional parts. At the bottom center, the output tank coil has three sections, and the smaller 10- and 15-m coil is tapped at about two turns.

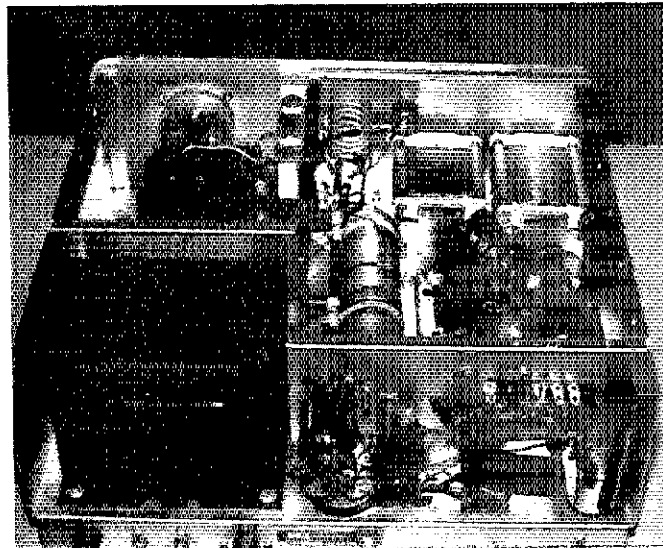


Fig 2—Rear view of the modified amplifier. The larger added tank coil can be seen in the center. The added bifilar filament choke is mounted vertically at the extreme front-right side of the photo.

choke. I wired the new choke in series with the original SB-200 filament choke, and mounted it in a vertical position off to one side (see Fig 2). Now came the moment of truth—I was ready to try it out on 160 m!

The amplifier produced reasonable output on all bands but 160 m; output was puny there. I suspected that the plate choke was the problem. I measured its resonance, and, sure enough, it resonated at a frequency higher than 2.0 MHz. I rewound the choke with many more turns of smaller wire, but still had troubles. The choke had a circular, metal clamp on the end, and I finally realized that this clamp was, in effect, a shorted turn, which raised the resonant frequency and ruined the Q of the choke. I rewound it in layers, or groups, and pared it until it showed no response near any of the bands of interest. Only then was I able to get the choke to be resonant at a frequency lower than 1.8 MHz. The thing really gave me fits!

At about the same time, I found a plate choke from an old military transmitter. That proved to be adequate, so now I had two chokes. Doug DeMaw's excellent article on chokes also arrived in the February issue of *QST* at about this time.³ It helped to reinstate my self-respect regarding all the trouble I had.

The Output Network, Again!

With the new plate and filament chokes installed in the amplifier, and with great expectations, I was ready to fire up the rig again. To be safe, I redipped the output tank for resonance, and got another rude awakening. The output circuit would not tune 160 m at all! Resonance of the new final amplifier coil was now much lower than 1.8 MHz. The reactance of the original plate choke and my new tank coil had been in parallel, and this had thrown me way off in checking out my carefully made new coil. I had to remove the new coil and remove some of the added turns to bring it into resonance. But, at last, I was again ready for a power test on 160 m.

I have a home-brew shielded dummy load in a one-gallon paint can that is a perfect 50- Ω load, but it is limited to a dissipation of about 100 W. To obtain a dummy load with a higher power rating, I employed the old trick of using household light bulbs. I used four 100-W incandescent bulbs in parallel. This arrangement exhibits about 25 Ω when the bulbs are lit. This load gives me an SWR of about 1.5:1—not perfect, but handy for approximating power output. I used the TS-830 in TUNE mode to feed about 40 W to the amplifier. I rejoiced when the amplifier lit up the load to full brilliance on all bands, including 160 m.

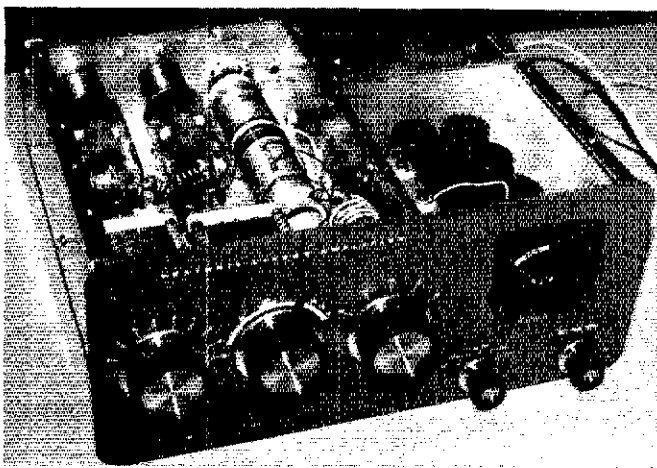


Fig 3—The completed modified SB-200 amplifier. The large, added output tank coil is suspended from two nylon straps attached to standoffs. Additional windings between the two halves of the coil form are evident by their darker color.

I measured about 400 W out with 40 W drive. Then I switched to SSB and gingerly watched the bulbs flicker as I talked, with the mic gain turned quite low. This was great, except... on 160 m I got very little output during voice modulation. What now? I was getting good output on 160 (at reduced power) in CW, but low output on SSB. After poring over the schematic, it finally dawned on me that the grid bypass capacitors, with their associated resistors, might have the wrong time constant to bypass the grids properly under SSB conditions. I hung on some additional bypass capacitors, and that did the trick. The SSB output came right up. I now had an all-band amplifier that apparently worked fine into a rather poor dummy load. Fig 3 shows the amplifier after modification. The only obvious change in the photo is the large replacement coil assembly that is suspended in position using two nylon straps mounted to standoffs.

The Output Network—One More Time!

This just about completes the story of my misadventures, except for an output loading problem. Connected to my 160-m antenna, the amplifier would not load up completely—it seemed to need more output (loading) capacitance. I knew the antenna was not at fault. It is a 160-m dipole, center fed with coaxial cable. I have measured its SWR across the band; it is about 1:1 in the middle of the band, and somewhat higher at the edges. So, I needed more than the 850-pF output capacitance provided in the amplifier. By experimentation, I determined that I needed an additional 500 pF. There were no unused band-switch contacts in the SB-200 to add the capacitance on 160 m, and the thought of an external switch didn't appeal to me. I came up with a simple solution, peculiar to my needs and setup. This solution may not appeal to others, however.

I have four coaxial cables coming into my shack, one each for my 160, 80 and 40-m antennas, and one for my triband antenna. I connect these through a 4-position changeover switch to the amplifier output. I installed a 500-pF fixed capacitor across the 160-m position of this switch. This gives the SB-200 the added output capacitance necessary to load the antenna on 160 m, but removes the added capacitance when I switch to another band. This works fine for me, but you might prefer to mount the added capacitor in the amplifier and switch it in and out.

Summary

I have taken two side steps that make my modification depart from a universal approach. My system requires a

low-power matching network to permit sufficient amplifier drive on 10, 12 and 15 m, and I use an added capacitor across the 160-m antenna feed line to avoid mounting the capacitor in the amplifier. Both departures are justified for my application, and neither is difficult for anyone else.

The dc input to the modified amplifier is between 375 and 400 mA at 2100 V (780-840 W) on all bands (about 10 or 15 mA less for 10 and 12 m). I prefer not to postulate as to what the P-P output power is. I get lots of compliments on my signal, and lots of questions on how I did it. It was a rather lengthy job, but I had a lot of fun doing it. The total cost was less than \$10 (for wire), not including the stuff I used from the cellar. The entire operation required only a few days of actual work on the equipment—the planning, head scratching and teeth gnashing took longer.

I have purposely not included diagrams, specific values or coil turn data in this narrative. I intended only to point out areas of engineering interest and importance that I learned from the experience. I hope this account will bolster the confidence of the apprehensive, and forewarn the neophyte of problems. Mostly, I hope that I have provided reinforcement for those who would like to tackle this truly ham activity by offering insight into the planning and decision points they may encounter, as well as some of the mechanics of the changes.

Notes

¹D. DeMaw, "The Low-Bander's Special," *QST*, Sep 1979, pp 17-19.

²M. Wilson, ed., *The 1987 ARRL Handbook* (Newington: ARRL, 1986), pp 30-39 to 30-40.

³D. DeMaw, "Understanding and Constructing RF Chokes," *QST*, Feb 1987, pp 16-19.