Heathkit of the Month #49:
by Bob Eckweiler, AF6C

Heathkit SB-220 (and SB-221) 2KW HF RF Linear Amplifier

Introduction:

Back in September of 2011 (Heathkit of the Month #33) the SB-200 (1,200 watt linear amplifier) was discussed. This month we will take a look at its bigger brother the SB-220. Like the SB-200, the SB-220 required updating when the FCC outlawed commercial linear RF amplifiers from covering the 10-meter band due to their widespread illegal use on the nearby 11-meter CB band. These later amplifiers were given new model numbers: SB-201 and SB-221 replaced the SB-200 and SB-220, respectively.

The SB-220 RF Amplifier:

The SB-220 (Figure 1) was released in late 1969, about six years after the SB-200. Both remained on the market until 1978 when 10-meter capability was eliminated. They both continued in production in their modified state until 1983. The SB-220 originally sold for a factory catalog price of $349.95. (Figure 2 is an ad from the inside rear cover of the December 1969 QST). The retail store price was slightly higher at $369.95. By the 1982 spring/summer catalog the SB-221 price had increased to $649.95.

On January 23, 1970 I visited the Heathkit retail store on Ball Road in Anaheim; adding the *then* 5% sales tax, I happily lumbered out $388.45 poorer, but carrying two heavy boxes.

Table I shows the specifications of the SB-220. It is a heavy duty amplifier, especially if you run it off of 240 VAC. The final tubes are a pair of Eimac 3-500Z glass triodes specifically designed for improved grounded-grid linear operation. With 500 watts of plate dissipation per tube and a large cooling fan, the amplifier is

Fig. 1 SB-220 2KW Amplifier. The SB-221 looks identical except for the 10 meter band switch markings.

conservatively rated. The power supply is built into the amplifier which fits easily on a desktop. Figure 3 shows an inside view of the amplifier tube section.

The SB-220 covers 80 through 10 meters. Using the SB-220 on the newer 12 and 17 meter WARC bands is spotty without modifications. A lot can be found on the subject by Googling *Heath SB-220 WARC.*

The SB-220 front panel meters and controls are uncluttered and laid-out in three rows. The front panel layout and nomenclature are listed in Table II. The mode switch sets the nominal plate voltage. In the **CW/TUNE** position it is 2.5 KV DC and in the **SSB** position it is 3.0 KV DC. The CW/TUNE position can be used for lower power SSB operation.

Like the front panel, the rear panel is simple and uncluttered with just eight items. They are listed in Table III. Instead of fuses, the amplifier uses two circuit breakers in the AC line, resettable by pressing the button on the tripped breaker. They are accessible on the rear panel. Also on the rear panel is the inlet to the fan which forces air over the 3-500Z final tubes and out the cabinet. The tubes are not in airflow directing chimneys. The large fan is located so it also forces air over the tube sockets, cooling the critical filament pins that dissipate a significant amount of heat by themselves.

The SB-220 I bought was one of the early models. The plate transformer shipped in a separate box, and Heathkit warned in their documentation that shipping of an assembled SB-220 could result in damage to the unit due to the heavy transformers. If you were returning the SB-220 to the factory for repair, Heath recommended you order the SB-220 Service Packing kit, (Order # 171-3167 - $5 deposit) and pack the kit using the instructions included with the kit. The deposit was refundable or creditable towards any repair bill.

My SB-220 came with an early release manual (11/29/69) and included a four page errata sheet that has three pages of changes and a new Pictorial 4-6. Heathkit spent a lot of time perfecting their manuals and it was interesting to see how they stayed on-top of keeping their highly praised documentation up to date along with their electronic technology.

Assembling the SB-220:

Assembly began in the usual way for a kit. This is an important step that some people gloss over. It involves inventorying and familiarizing yourself with the individual parts. Rarely have I ever received a new Heathkit with any parts missing, though I occasionally find extra pieces of common small hardware.

Once the inventory is completed, a small circuit board is stuffed; it holds the (14) high voltage silicon rectifier diodes, the meter scaling resistors and a 5.1V zener diode (ZD1) which sets the tube bias. The diode was originally mounted using two silver-plated strips that acted as heat sinks. More on this diode later. Finally, connecting wires are soldered to the

Bands:	80, 40, 20, 15, 10 Meters
Driving Power:	100 Watts
Power Input -	
SSB:	2,000 Watts PEP
CW / RTTY	1000 Watts
Duty Cycle -	
SSB:	Continuous
CW:	Continuous (Max. key-down 10 min.)
RTTY:	50% (Max. xmit time 10 min.)
3rd. Order Distortion:	better than -30 dB
Input Impedance:	52 Ω nominal, unbalanced
Output Impedance:	50 to 75 Ω unbalanced
SWR:	2.0 : 1 or less
Power Requirements -	
120 VAC:	20 A maximum, 50/60 Hz
240 VAC:	10 A maximum, 50/60 Hz
Cabinet Size:	14-7/8” W x 8-1/4” H x 14-1/2” D
Net Weight:	48 lbs (22 kg)

Table I: SB-220 Specifications

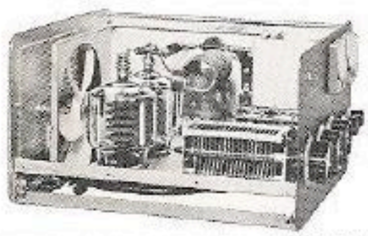
Front Panel Top Row (L to R)	
Model Emblem:	**HEATHKIT SB-220**
(nomenclature):	**2KW LINEAR AMPLIFIER**
Meter (lighted):	**PLATE AMPERES** – 0 to 1 A FS (0.1 A/ major div., 0.02 A/ minor div.)
Meter (lighted):	Multipurpose **PLATE VOLTAGE – KV** – 0 to 3.5 FS (500 V/ major div., 100 V/ minor div.) **GRID MA** – 0 to 350 mA FS (50 mA/ major div., 10 mA/ minor div.) **REL. RWR** - 0 to 350 arbitrary units (50 units/ major div., 10 units/ minor div.)
Middle Row (L to R)	
Capacitor:	Plate **TUNE** - white range areas (Approx. settings for: **80, 40, 20, 15, 10**)
Capacitor:	Plate **LOAD** 0 to 10 units (18°/ major div. – 180° total)
Switch - 5 pos. Rotary:	**BAND** **80, 40, 20, 15, 10** meters
Potentiometer:	Relative Power meter adjustment **SENSITIVITY**
Switch - 3 pos. Rotary:	Multimeter function **GRID, REL. PWR., HV**
Bottom Row (L to R)	
Switch - Rocker	Power **OFF, ON**
Switch - Rocker	Mode **CW/TUNE, SSB**

Table II: SB-220 Front Panel Controls, etc.

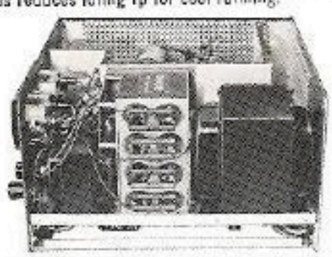
The New Heathkit® 2-KW Linear Is Here

(at last)

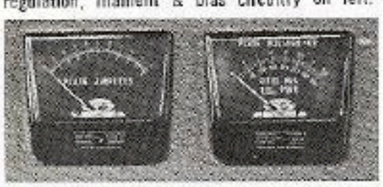
New SB-220 . . . $349.95*



Two rugged, dependable Eimac 3-500Z finals for top performance. Zener regulated operating bias reduces idling Ip for cool running.



Reliable power supply . . . plate transformer on right, capacitor bank in center for excellent regulation, filament & bias circuitry on left.



Continuous monitoring of Ip plus switch selected monitoring of Rel Pwr., Ep & Ig.

It's not just a rumor anymore . . . the SB-220 is here, with a price and performance worth the wait.

The New Heathkit SB-220 uses a pair of conservatively rated Eimac 3-500Z's to provide up to 2000 watts PEP input on SSB, and 1000 watts on CW *and RTTY*. Requires only 100 watts PEP drive. Pretuned broad band pi input coils are used for maximum efficiency and low distortion on the 80-10 meter amateur bands.

Built-In Solid State Power Supply can be wired for operation from 120 or 240 VAC. Circuit breakers provide added protection and eliminate having to keep a supply of fuses on hand. Operating bias is Zener diode regulated to reduce idling plate current for cooler operation and longer life.

Double Shielding For Maximum TVI Protection. The new "220" is the only final on the market that's double shielded to reduce stray radiation. The heavy gauge chassis is partitioned for extra strength and isolation of components. When you put this kind of power on the air, you'd better be sure. With the SB-220, you are.

Really Cool Running. The layout of the SB-220 is designed for fast, high volume air flow, and a quiet fan in the PA compartment does the job. The "220" actually runs cooler than most exciters.

Other Features include ALC output for prevention of overdriving . . . safety interlock on the cover . . . easy 15 hour assembly and sharp Heathkit SB-Series styling.

Tired Of Stumbling Barefoot Through The QRM? Put on big shoes . . . the new Heathkit SB-220. Another hot one from the Hams At Heath.

Kit SB-220, 55 lbs. **$349.95***

HEATHKIT®
a Schlumberger company

HEATH COMPANY, Dept. 9-69
Benton Harbor, Michigan 49022

☐ Enclosed is $__________ plus shipping.
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☐ Please send FREE Catalog.

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City__________ State__________ Zip__________

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AM-228

board; their other ends will be connected when the board is later installed.

Next, the RF input coil assembly is built. The five input coils, one for each band, are installed on a small sub-chassis along with a wafer section of the band switch. The fixed capacitors that broadly tune these coils are then soldered in place, and the coils are wired to the band switch wafer. The remainder of the band switch is assembled along with its shaft on the outside of the sub-chassis, which acts as a shield. Shielded wires are added to carry the RF. Their other ends will be connected when the sub-chassis is installed.

The front panel is assembled next. The meters, nameplate, meter switch and sensitivity pot are added, as is the meter lighting circuitry.

Assembly then moves to the basic chassis. Tube sockets, rocker switches, relays, terminals, rear connectors and other hardware are installed. The ALC circuit components are added next on a terminal strip mounted to the chassis.

Top chassis assembly is then conducted. Part of the top RF shield is installed as is the HV interlock and some of the minor pi-network components. At this time the input sub-chassis, built earlier, is installed, followed by the major parts of the pi-network. The two large transformers and the previously wired front panel are attached to the chassis, as is the fan and numerous other chassis shielding components. At this stage you will find the assembly has become quite heavy!

The previously wired circuit board is then attached to the outside of a large capacitor bracket, into which eight well insulated 200 µF 450V capacitors are installed, forming the power supply filter system. A series of high wattage bleeder resistors are wired to the capacitors.

Finally, the top and bottom wiring are completed; the amplifier is set for the correct line voltage, the tubes are installed and the amplifier is ready for test.

Rear Panel Items (L to R)

Power Cord:	Heavy Duty 3-wire
Circuit Breakers (pair):	(10 Ampere)
Phono Jack (input):	**ANT RELAY** (Ground to switch amplifier to transmit)
Phono Jack (output):	**ALC** (Automatic Level Control)
RF Connector (input):	**RF – INPUT** SO-239 UHF Connector
Stud:	Ground Post #10-24 screw with washers and wing nut
RF Connector (output):	**RF – OUTPUT** SO-239 UHF Connector

Table III: SB-220 Rear Panel Connections, etc.

Plugging in a 2 KW amplifier for the first time can be intimidating. However, to Heathkit's credit, it came on without smoke, arcing or any other problems. Testing went smoothly with one minor exception, the fan motor was quite noisy. Heath quickly shipped a replacement fan under their warranty.

The SB-220 Circuit:

Grounded-grid linear amplifier models using a pair of 3-500Z tubes are generally quite similar in their basic design. The design Heath used for the SB-220 follows it, with a few exceptions.

<u>The Power Supply</u>:

The SB-220 uses a standard voltage doubler circuit to achieve the high voltage. The HV transformer has a Hypersil core. Hypersil is a material originally patented by Westinghouse. This grain aligned core provides more power per pound of of core material, resulting in a smaller transformer that runs cooler. The transformer in the SB-220 is no wimp as its duty cycle specification shows. The transformer's 120/240V dual winding primary is tapped to provide 2,500 VDC or 3,000 VDC out of the voltage doubler. Each doubler leg uses seven 600V PRV diodes in series and four 200 µF 450 volt electrolytic capacitors also in

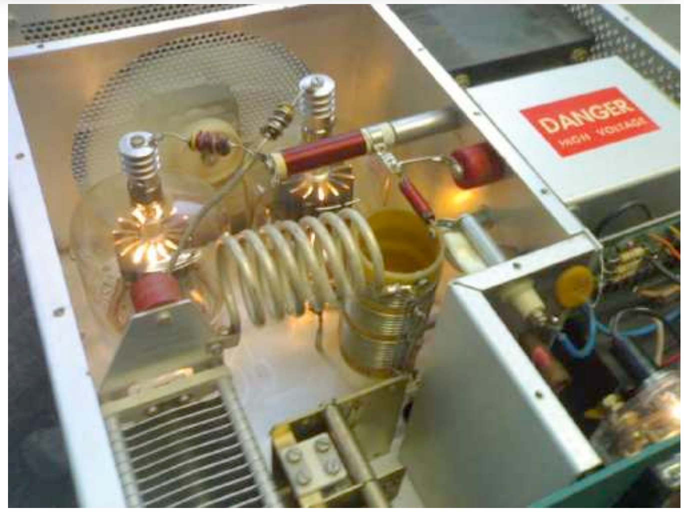

Fig. 3 Inside view of the SB-220 showing the two 3-500Z tubes. Note large cooling fan. Photo courtesy of Kees – PA2X. Visit his site at: http://www.heathkit.nl

series. Each capacitor is shunted by a 30KΩ 7-watt bleeder resistor.

A separate filament transformer provides 5 VAC voltage to the two 3-500Z finals. The transformer is rated at 30 amperes. Each tube's filament draws 14.5 amperes. It is important that the soldering in the filament circuit be checked carefully. If the voltage drops below 4.75 volts the tube life may be negatively affected. The filament transformer also powers the two #47 meter lamps. A separate bias winding produces about 120 VDC after rectification and filtering. This voltage is used to bias the 3-500Z tubes, to operate the transfer relay and is tapped down to provide the ALC threshold voltage. These will be discussed more later.

The Input Circuit:

A separate pi-network input circuit exists for each of the five bands: 80, 40, 20, 15, & 10M. The required network is selected by the band switch. The Q of these circuits is low, a bit more than 1. This affords good bandwidth but poor isolation to the amplifier tubes which swing from a very high impedance to a low impedance of less than 40Ω. This is no problem for tube type exciters like the SB-401 to drive; however, solid-state transmitters may encounter difficulties matching the amplifier input. RF from the tuned network is AC coupled to the filaments (cathodes) of the tubes. A bifilar filament choke isolates the RF from the filament transformer.

Amplifier Circuit:

The two 3-500Z tubes (see Fig. 4) are high mu power triodes, each capable of 1,110 watts PEP input. The tube's grids are effectively at AC ground and the input RF drives the filaments (cathodes). RF power fed to the cathode is effectively fed through to the output, adding to the power efficiency. The tube plates are connected to a pi-network output circuit. The tubes run at a plate voltage of 3 KV in SSB mode, and 2.5 KV in CW/TUNE mode. The pi-network has to handle high voltages and currents, both RF and DC; thus, components and wiring must be conservative. The band switch contacts are probably the weakest part in this circuit.

Switching Circuit:

A single 3PDT relay controls the amplifier. The relay is open when the amplifier is off or in receive. One set of contacts switches the input and one the output. When the amplifier is in receive (or off) these contacts route the input directly to the antenna, bypassing the amplifier; on transmit they connect the exciter to the amplifier input and the amplifier output to the antenna. The third set of contacts controls the bias. With the amplifier on and the relay open, approximately +115 V DC is applied to the center tap of the filament transformer raising the cathode voltage and making the grid of each tube very negative, cutting the tube off. When the relay closes, this voltage is fed to a zener diode lowering the cathode voltage to where the grid voltage is negative by only about 5.1 volts below the cathode. The result is the tubes start conducting plate current at about 45 to 60 ma each – a good bias voltage for class B operation. The relay is powered by the bias supply and is operated by an external circuit connected to the **ANT RELAY** jack on the rear panel.

Fig. 4: Eimac 3-500Z Triode Transmitting Tube.

Meter Circuits:

The two meters are each µA full-scale with an internal resistance of 1.4KΩ. Each meter will read full scale when 0.28 volts is applied across it.

Plate Current Meter - This meter reads full scale when 1 ampere of plate current is flowing. All the plate current passes through R1, a 1Ω 5W resistor in the negative side of the HV power supply. At 1 ampere this resistor will drop 1 volt. The meter is placed in series with a 3.6K resistor which raises its effective resistance to 5KΩ causing the meter to reach full scale (200 µA when 1 amp flows through R1).

Multimeter - The second meter acts as a multimeter measuring grid current, relative power and high voltage depending on the position of the meter switch.

a. Grid Current - Grid current is returned to ground through the cathode, ZD1 and a 0.82Ω resistor; it is isolated from the plate current because the plate current meter circuit is returned to the negative end of the power supply filter chain. When in the **GRID** position the meter is switched across this resistor which produces 0.28V when 350 mA of grid current is flowing.

b. Relative Power - In the **REL PWR** position RF output voltage is sampled by a voltage divider consisting of R24 and R25, rectified and filtered by D17 and C54, scaled by the front panel **SENSITIVITY** control and fed to the meter, giving indication of relative output power.

c. H. V. - In the **HV** meter position, the meter reads 3.5 KV full scale. A voltage divider consisting of 14.1 MΩ (three 4.7 MΩ resistors in series) and 1.12 KΩ (5.6 KΩ resistor in parallel with the 1.4 KΩ meter resistance) results in 0.28V across the meter with 3.5 KV applied.

ALC Circuit:

Finally the ALC circuit provides a voltage back to the exciter when the amplifier is being overdriven into a non-linear state. The exciter uses the voltage to reduce the RF output driving the amplifier.

A DC voltage of about 60VDC is tapped off the bias supply. This voltage reverse biases D18 which is coupled to the RF driving the amplifier. Should the peak negative driving voltage exceed the 60V threshold, D18 will conduct on the negative peak of each RF cycle. This negative voltage is filtered and fed to the ALC connector on the back of the SB-220/221.

The SB-221 Changes:
The major changes to prevent the SB-221 from operating on 10/11 meters include removal of the 10 meter contacts on the band switch, and the removal of the 10 meter input coil. Also installed in the input circuit is a sealed filter which is riveted to the input shield assembly and acts as a low-pass filter with a cutoff frequency below the 10 meter band.

Heathkit did allow licensed amateurs to purchase the needed parts to restore 10 meter operation on the SB-221. Doug DeMaw W1FB discussed the procedure in the May 1980 issue of ***QST*** on page 44.

Early Modifications:
Numerous modifications have been suggested for the SB-220 over the years. To discuss many of them is beyond the scope of this article. Perhaps a future article may cover some of the more important ones. So at this time we will just touch on a few important ones.

Zener Diode Replacement Modification: (Kit SBM-220-1)
Early SB-220 amplifiers began experiencing a problem where the idling plate current would suddenly increase to 300 mA instead of the expected 90 to 120 mA. This occurred most frequently on amplifiers operating RTTY. The cause was the failure of ZD-1 the 5.1-volt bias zener. Heathkit released a free modification kit to owners designated the SBM-220-1. This kit replaced the 1W zener with its attached heat sinks to a 10W stud-mounted 1N3996A (56-82) zener diode. The kit also included mounting hardware, wire, silicon heat sink grease and a 4-page instruction sheet. The diode mounts in an existing hole on the capacitor mounting bracket. and is wired in place of the circuit board mounted zener. This modification was incorporated into later SB-220 kits.

Insulated Spacer Modification:
A second modification answers a situation where arcing occurs between the diodes on the circuit board and the metal spacers mounting the board. The two lower spacers should be replaced with #6-32 x 3/4” tapped phenolic spacers. The upper spacers must remain metal to provide a ground path for the board. This modification was also incorporated directly into later kits.

240 V Failure Modification:
A third modification involves SB-220 amplifiers wired to operate on the 240V line. Should the mode switch partially fail or a primary winding open up in the HV transformer, excessive current is drawn through the filament transformer primary causing it to fail. To prevent this the black-green and black yellow wires from the filament transformer should be removed from the four-screw terminal strip under the chassis and connected together with a wire nut. Do this only for 220V operation and restore to original configuration should the unit be returned to 120 V operation.

This modification is from Heathkit service bulletins SB-220-19, SB-220-27 and SB-221-14.

Operation with Solid State Radios:
The SB-220 was designed to work with the SB line of exciters and transceivers and other tube output transmitters of the late 60s and early 70s. Special considerations must be taken before these radios are used with newer solid-state radios:

a) Many solid-state transmitters have trouble matching to the input of the amplifier. An internal or external antenna tuner may be required.

b) To switch the Heathkit SB-200 and 220 series of amplifiers to transmit requires a switch capable of switching 150 VDC to ground. Many solid-state switching circuits use a transistor that cannot handle this high voltage. Either an external relay is required or a modification kit needs to be installed in the amplifier. Harbach Electronics offers such a kit – the SK-220 Soft Key kit (http://harbachelectronics.com).

c) AVC voltages from the SB-220 may run high for some solid-state exciters. Often a resistor divider or zener diode limiter can be incorporated to solve this problem. Many transceivers are not powerful enough to overdrive the amplifier and the ALC can just be left unconnected. Google your transceiver model and SB-220 to see how others have hooked up their transceiver. Heathkit service bulletin SB-220-26 discusses using ALC with Kenwood transceivers.

Parasitics Problems:
There has been a lot written about parasitic oscillations occurring in the SB-220. This oscillation, usually around 110 MHz results in a large grid current pulse that creates a magnetic field, sometimes resulting in a grid to filament short in the tube. This parasitic oscillation also often results in arcing of the tuning capacitor, or in later units arcing at the delicate band switch contacts, as well as failed RF grid chokes and more.

Richard Measures - AG6K wrote a two part article starting at page 25 of the November 1990 issue of ***QST*** discussing improvements to the SB-220 including ways to reduce the possibility of the damaging VHF parasitic oscillations. Before condemning the Heathkit engineers and this amplifier, this problem is also found in other HF amplifiers, especially ones using newer high µ tubes capable of operating at high gain above 15 MHz (the 3-500Z). Mr. Measures traced a significant contribution of the problem “*to the high VHF Q copper conductors between the tuning capacitor and the anode connections…”* Part of his solution is the use of low Q nichrome wire in place of the copper wire in the anode leads. ARRL members can download Mr. Measures’ articles from the periodical archives at the ARRL website.

Conclusion:
I’ve used my SB-220 amplifier for many years, until I encountered a period of little hamming due to the discovery of computers. The SB-220 sat so long that I wanted to clean it out and give it a good dusting before putting it back in service. Switching from daily use of the SB-401/SB-301 to a Kenwood solid-state transceiver, knowing I’d have to rework the SB-220 to make it compatible with both radios, further delayed the refurbishment. It has recently gotten higher on the priority list thanks to my operating the recent WPX context.

I was one of the SB-220 owners who encountered the parasitic problem early in its use. A loud hum and a puff of smoke told of the problem. Switching off the amplifier immediately I found a grid choke “cooked” and a solid grid to plate short on one of the 3-500Z tubes. Heathkit replaced the tube under warranty but I also bought a spare at, what was then, Henry Radio on Euclid Ave. in Anaheim. ($34 ea. back then!)

Interestingly, I was handling phone patches with Bill Orr - W6SAI (then portable KH6) with his daughter who lived down the coast. Bill sent me a lot of good information on the Eimac 3-500Z in Amateur Service. After replacing the tube, I never encountered the parasitic problem again. Still, I will be ordering a parasitic kit for the SB-220 sold by AG6K to be on the safe side. http://www.somis.org/Price-Info.html

Using the SB-220 in the early 1970s I worked close to 200 countries in a year and was spending less time in pileups than when running barefoot. All while working 60+ hour workweeks.

Yes, the SB-220 is a still an excellent amplifier, if it is restored and some simple modifications added.

73, from AF6C

Remember, if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.

Thanks - AF6C

This article originally appeared in the month year issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.