Product Review Column from *QST* Magazine

March 1980

Heath SB-221 Linear Amplifier Kit

Yaesu FT-7B Mobile/Base HF Transceiver And YC-7 Frequency Display

Conducted By Paul K. Pagel,* N1FB

Yaesu FT-7B Mobile/Base HF Transceiver and YC-7 Frequency Display

Are you thinking about doing some mobile or portable operating? If so, you should take a look at the FT-7B, Yaesu's new hf transceiver. If not, you should look at it anyway, because it's also suitable for fixed service. An improved version of the FT-7, intended for the market generated by the Japanese no-code license, the B model features 100-W PEP input on ssb, a-m and cw. The transceiver covers 80 through 10 meters. The bandswitch has four 10-meter positions, each covering a 500-kHz segment. A crystal for 28.5-29.0 MHz is standard equipment; the others are optional. Other features of the FT-7B include a noise blanker, an rf attenuator, a crystal calibrator, concentric rf and af gain controls, a clarifier (RIT) and one fixed channel per band (crystals not supplied).

Circuitry and Performance

The unit is completely solid-state. It contains 54 transistors, 78 diodes and 8 ICs. The usual premixing arrangement is employed to produce an i-f centered on 9 MHz. A 6-pole crystal filter having a shape factor of 1.67 (6 dB/60 dB) establishes the selectivity under all conditions except a-m transmitting. In the receive mode, a monolithic filter precedes the noise blanking gate to provide "roofing" against strong signals outside the crystal filter passband.

The VFO operates at 5 MHz and uses a bipolar transistor. The transceiver performs within its stability specification, but I would expect better performance from an FET. At room temperature the unit stabilized after one hour of operation, during which time it drifted 1 kilohertz. This performance is acceptable for home station environments, but the mobile operator trying to have a QSO during his half-hour drive to work may have trouble on a cold morning. The tuning mechanism operates smoothly and features anti-backlash gears.

The noise blanker is worth looking into because it appears to lack the ills characteristic of other units. This circuit contains seven transistors, six of which are FETs. One of these is used in an 8545-kHz crystal oscillator that establishes a 455-kHz i-f for the blanker. The significant feature of the FT-7B noise blanker is that it doesn't appear to degrade the receiver's dynamic range. Yaesu achieved this improvement at the expense of a slightly higher blanking threshold. Noise pulses must be somewhat more offensive than usual before they are blanked.

In the cw mode, a two-pole RC active audio filter follows the product detector. This filter has a 6-dB bandwidth of 80 Hz, but as would be expected from the simple design, the skirts

The FT-7B transceiver with optional YC-7 remote frequency display. The microphone and mobile mounting bracket are supplied with the transceiver.

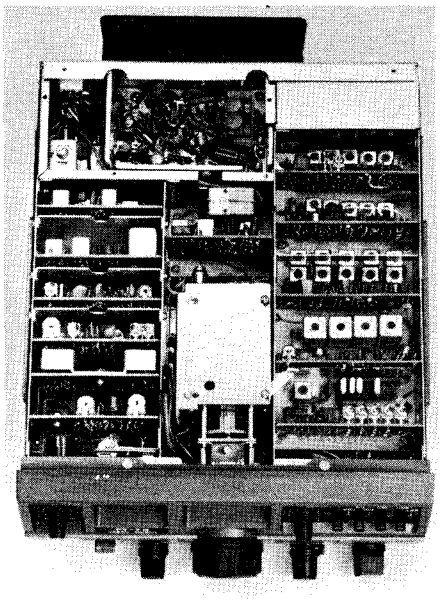
Table 1

FT-7B Mobile/Base HF Transceiver

Frequency Coverage: 500 kHz of 80-15 meters, four 500-kHz segments of 10 meters (crystal for 28.5-29.0 MHz supplied).
Operating modes: lsb, usb, a-m, cw
Power requirements: 13.5 V dc ± 10 percent at 10 A transmit, 0.6 A receive.
Dimensions (HWD): 9- × 3-1/8- × 12-9/16-inches (230- × 80- × 320-mm) including heat sink.
Weight: 12 lbs (5.5 kg)

Claimed Specifications	*Measured in ARRL Lab*
Input power: 100 W PEP ssb, a-m 100 watts dc cw	50-55 watts rf output over frequency range
Carrier suppression: >50 dB below rated PEP output	>50 dB
Unwanted sideband suppression: >50 dB at 1000 Hz	>50 dB
Spurious emission: >40 dB below fundamental	>50 dB below fundamental
Distortion products: 31 dB below PEP output	31 dB below PEP
Frequency stability: <100 Hz per half-hour after warm-up	90 Hz per half-hour after one hour
Microphone input impedance: 500 ohms, nominal	
Antenna output impedance: 50 ohms, nominal	
Sensitivity: 0.5 μV for 10 dB S+N/N	0.25-0.5μV over frequency range
Image rejection: 50 dB	50-60 dB over frequency range
I-f rejection: 50 dB	50 dB over frequency range
Selectivity: 2.4 kHz (−6 dB), 4.0 kHz (−60 dB) cw audio	
Peak filter: 80 Hz (−6 dB)	
Audio output power: 3 watts at 10 percent THD	
Audio output impedance: 4 ohms	
Price class: $675	
Manufacturer: Yaesu Musen Co., Ltd., Tokyo, Japan	

*Assistant Technical Editor, ARRL



Inside view of the FT-7B. The top cover of the PA module has been removed. A fan bracket could be made from the plate attached to the heat sink. The loudspeaker is on the underside.

aren't very steep. The receiver agc bandwidth is 2.4 kHz in all modes, so the audio filter isn't the lifesaver it could be.

It would be nice to have cw selectivity at the i-f, but I don't know of a simple way to get it. On 80 meters, the sense (usb/lsb) of the signal is inverted, causing it to be located in a different part of the i-f passband than on the other bands. The cw offset frequency is 800 Hz on 40 through 10 meters and 1200 Hz on 80. If you peak the received signal on the nose of the audio filter, you can't transceive on frequency in the 80-meter band unless you shift the clarifier 400 Hz. The clarifier has plus or minus 3 kHz of range, which was enough to allow me to contact a DX station who was operating on split frequencies.

On ssb, the receiver audio sounds clean and the agc action is smooth. A diode envelope detector is used in the a-m mode. The 2.4-kHz filter is used in both voice modes, so only one sideband reaches the a-m detector, resulting in a poorer signal-to-noise ratio in the detector. Additional i-f and af amplification is used with the a-m detector in an apparent attempt to equalize the a-m and ssb sensitivities, but the result is a somewhat noisier receiver on a-m.

The manual states that the transceiver is spurious-free. With the antenna input terminated by a 50-ohm resistor, I found internally generated responses at 14.001, 21.201 and 28.801 MHz. All of these spurs were weak (below 1 μV equivalent antenna input), but I found the one at 14.001 MHz to be offensive, the futility of competing on that frequency with 50 watts into a vertical antenna notwithstanding.

The overall performance of the receiver is good. We didn't perform the Hayward dynamic-range measurements because the cw-selectivity characteristics aren't the same as those of other transceivers. The numbers derived from the tests wouldn't be directly comparable to previously published results. However, the real test for receivers in Newington is how closely you can tune to W1AW while copying weak signals. My house is one mile from W1AW. So long as I tuned W1AW out of the i-f passband, I couldn't tell it was on the air. This was *without the attenuator activated.*

The transmitter works well on ssb. Using the hand-held microphone supplied with the transceiver, I received a good audio-quality report from N1FB during a 10-meter groundwave contact. He reported high voice recognizability, even though my signal was too weak to move his S-meter (our stations are 10 miles apart and our antennas are cross-polarized). When I switched to a-m, he couldn't hear me at all. Suspecting a malfunction, I made some a-m measurements, and found the FT-7B to be working perfectly well. Why couldn't N1FB hear me? A-m simply isn't as efficient as ssb for weak-signal work. The FT-7B has considerable circuitry devoted exclusively to the a-m function. Rather than merely unbalancing the modulator and transmitting an "a-m compatible" signal through the filter, Yaesu chose to modulate the control gate of a dual-gate MOSFET amplifier following the cw carrier oscillator. The crystal filter is bypassed, resulting in a genuine dsb a-m emission. As can be seen in the a-m envelope photograph, Fig. 3, the modulation linearity is adequate for voice work. The waveform is similar to that obtained with screen modulation (remember screen modulation?). When I applied nearly 100 percent sinusoidal modulation, the average power increased from 12 watts to about 16 watts. A separate a-m alc circuit prevents the final amplifier from being overdriven on positive modulation peaks, but it's still possible to generate plenty of splatter from the negative excursions. If the mic gain and drive controls are adjusted as prescribed by the manual, the unit modulates cleanly.

I'm a cw operator, so I looked forward to using the FT-7B on the mode where its 50 watts of output would be most effective. I made several contacts using the hand key, and all of the receiving operators said the rig sounded good. Then I called a station who was sending faster (about 25 wpm), and he asked me to reduce the weighting on my keyer. This puzzled me, because I was sending with a bug! The next day I arranged tests with W1VD and N1FB, who recorded my signal. When he played the tape for me, I couldn't copy it! The dual-trace oscilloscope photo of the keying signal and the resultant rf envelope, Fig. 4, documents the problem. After the keying pulse has ended, the rf output continues for at least 20 milliseconds before it even begins to decay. I tore into the circuit and didn't stop until the unit produced the waveform shown in Fig. 5. My modification is radical, but it allows independent control of the attack and decay slopes. The details of the modification appear in the "Hints and Kinks" section of this issue. Realizing that my approach was somewhat of an overkill, I asked Yaesu for a simpler solution. The engineers reported that R1015 and C1012 have been changed to 47 kΩ and 0.33 μF in current production models. I restored the circuit to its original configuration and changed the two components. The third keying photo, Fig. 6, shows the results of Yaesu's fix. The performance is superior to that of the original circuit, but is somewhat sensitive to temperature variations and component tolerances. Yaesu also suggested changing C1012 to 0.047 μF and placing it between collector and base of the keying transistor in a Miller integrator fashion. If you plan to operate cw with the FT-7B, listen to it critically on a local ham's receiver.

A phase-shift oscillator generates the cw sidetone. The nearly pure sine wave is a pleasant departure from the raucous notes produced by the multivibrators in some other rigs. The sidetone output is rectified and used to activate the T-R relay for "semi-break-in" cw. The relay hang time is adjustable.

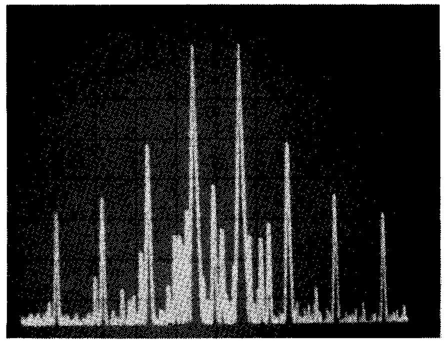


Fig. 1 — IMD spectrum of the FT-7B. Each tone is 6 dB below the rated PEP output. The test tones were 700 Hz and 1900 Hz. Vertical scale: 10 dB per division. Horizontal scale: 1 kHz per division. Test frequency is 14 MHz.

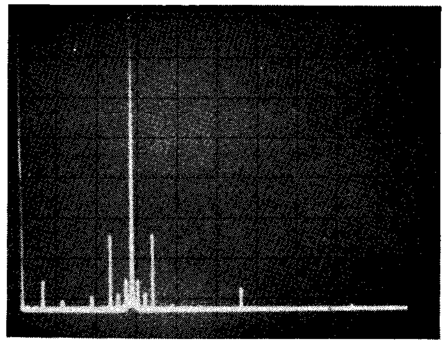


Fig. 2 — Worst-case harmonic and spurious spectrum (28 MHz). At full power input, all spurious outputs are more than 50 dB down. Vertical scale: 10 dB per division. Horizontal scale: 10 MHz per division. The tall pip at the extreme left of the photo is generated within the spectrum analyzer. The FT-7B complies with current FCC spectral purity requirements.

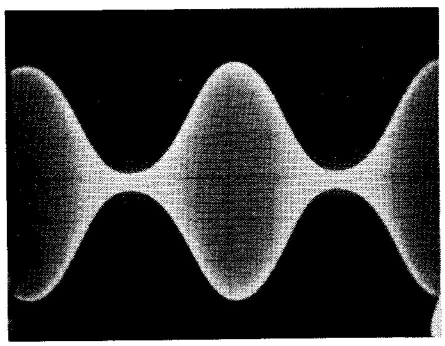


Fig. 3 — When was the last time you saw an a-m envelope? The FT-7B is capable of reasonably good linearity at high modulation percentages. For this test, the carrier frequency was 28.5 MHz and the modulation frequency was 1000 Hz.

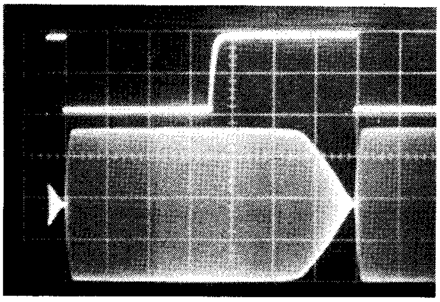


Fig. 4 — Rf envelope vs. keying waveform of the unit as received. The upper trace is the switching waveform at the FT-7B key jack and the lower trace is the output envelope. The horizontal scale is 10 msec per division.

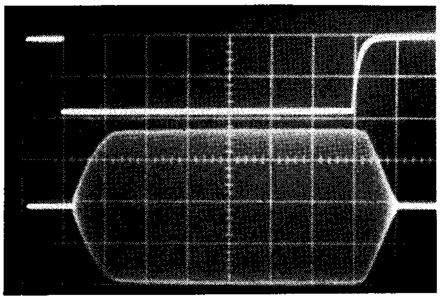


Fig. 5 — After radical surgery, the keying looked like this. In this photo, the horizontal scale is 5 msec per division. The modification information is printed in "Hints and Kinks."

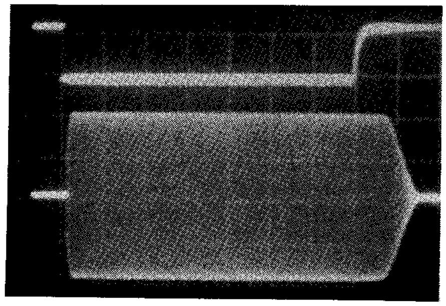


Fig. 6 — Here's the keying resulting from Yaesu's suggested modification (see text). Horizontal scale is 5 ms per division.

The YC-7B Frequency Display

Mobile operators must be able to determine their frequency quickly, with no more than a glance away from the road. The YC-7B remote digital display fills this need. The unit is an optional accessory that plugs into a rear-panel socket of the FT-7B. Stick-on Velcro strips allow the display to be mounted anywhere within reach of the umbilical cable.

The YC-7B counts the final mixer injection frequency. Preset commands from the FT-7B ensure proper carrier frequency readout on all modes. On 80 meters, an 18-MHz crystal oscillator heterodynes the LO signal to the proper range for the counter. The time-base frequency is 655.36 kHz. No special temperature compensation is used, but the overall stability should be at least an order of magnitude better than that of the FT-7B VFO. The readout resolution is 100 Hz, but the instrument counts down to 10 Hz, with a 0.1-second gate time. This unit does not add any spurious responses to the receiver.

Construction

Most of the FT-7B circuitry is assembled on a dozen phenolic pc cards which plug into three mother boards. The card sockets are individual gold-plated spring pins soldered into the mother boards. The mobile operator needn't worry about the reliability of the sockets — the cards are held firmly in place by the top cover. Two wired-in pc boards and the VFO and PA modules complete the electronics. The VFO and PA are shielded, of course. Most of the tuned circuits are on the mother boards, so you can repeatedly remove and reinstall the plug-in cards without upsetting the alignment. The PA heat sink protrudes from the rear panel. The sink is adequate for voice and cw duty cycles. The a-m rating applies to RTTY and SSTV service. Two screws secure a flat plate to the heat sink fins. A small fan could be mounted to this plate very conveniently.

Aesthetics and Impressions

The unit certainly is compact. That's not surprising, considering the cars it was designed to be installed in. At a time when the styling of Amateur Radio equipment is diverging toward the "military" and "hi-fi/furniture" looks, the FT-7B represents a refreshing alternative to these extremes. The cabinet is painted a businesslike metallic blue that won't look out-of-place in your car or on your kitchen table. The four-color dial and meter are highly visible, yet not at all garish. For fixed service, the analog dial is easy to read, and with its 1-kHz resolution and good linearity, you really don't need the optional digital readout. It's handy, though, for precise clarifier tuning and keeping track of the VFO. All of the controls are conveniently located.

Table 2

YC-7B Remote Digital Frequency Display

Specifications

Resolution: 100 Hz
Clock frequency: 655.36 kHz
Gate time: 0.1 sec.
Operating temperature: 0-40° C
Power connections: from FT-7B
Dimensions (HWD): 1-5/8 × 3-5/8 × 5-3/8 inches (40 × 93 × 135 mm)
Weight: 12-1/2 oz (360 g)
Price class: $110
Manufacturer: Yaesu Musen Co., Ltd., Tokyo, Japan

I experienced a small amount of TVI while operating the rig into a dummy load on the same table with my plastic-encased television set. You may have to scrape some paint off the mating metallic surfaces of the FT-7B enclosure if you live in a weak TV signal area.

A *QST* advertisement for the FT-7B reads: "Enough power to drive those linears!" The manual makes no mention of using the transceiver with an external amplifier, but if you dig into the schematic diagram, you'll find that the alc line and the 13.8-volt transmit line (to control a relay) are brought out to the power connector. There's an unused set of contacts on the T-R relay, but they aren't accessible from outside the transceiver.

The attention Yaesu paid to the a-m mode is perplexing. If the intent was to make the transceiver compatible with converted CB rigs, a better solution is to install BFOs in the CB rigs. If you want to participate in the second genesis of a-m, you'll never compete with those plate-modulated Valiants and DX-100s! I would much prefer to see the a-m mode scrapped in favor of some advanced ssb/cw features, such as sharp i-f selectivity, full break-in, VOX and even (bite my tongue) speech processing.

Tinkerers will love this rig, for one can remove most of the cards without unsoldering any wires. If you like, you can fabricate a completely new set of cards. Serious experimenters will undoubtedly conceive numerous worthwhile modifications. With a little ingenuity, a remote VFO could be plugged into one of the fixed-channel crystal sockets. Another possible improvement would be a VFO drift correction circuit using feedback from the YC-7B. If you apply the correction voltage to the wiper of the dial calibration potentiometer, you won't have to violate the VFO compartment.

The FT-7B offers something for everybody. You can have plenty of fun with it just like it is. And if you're ambitious, you can turn it into a truly deluxe station. The equipment is covered by a three-month limited warranty. — *George Woodward, W1RN*

HEATH SB-221 LINEAR AMPLIFIER KIT

How does the SB-221 differ from the earlier SB-220[1] amplifier? The major difference, electrically, is an unfortunate by-product of FCC action to prevent amateur-equipment manufacturers from including our 10-meter band in linear amplifiers: The SB-221 does not operate on 10 meters! The band-switch panel markings read only "80, 40, 20 and 15" (meters).

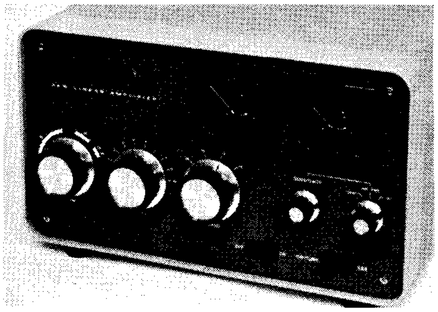
Heath Company and other commercial manufacturers of hf-band amateur amplifiers are required to ensure that all amplifiers require at least 50 watts of driving power and that they must be incapable of operation at 27 MHz. They can't, therefore, operate at 28 MHz without elaborate and highly expensive circuitry which is beyond manufacturing reason. All of this came to pass because of widespread illegal operation by CBers who purchased amateur-band linear amplifiers and employed them at 27 MHz. The FCC's inability to enforce the CB regulations imposed a severe economic and marketing hardship on the amateur-equipment manufacturers as well as the amateurs. These regulations, fortunately, do not apply to vhf and uhf types of amplifiers.

SB-221 Features

The popular and reasonably priced amplifier can be made to work satisfactorily on 10 meters by converting it back to an SB-220. More on that later. But, let's examine the circuit and features for the benefit of those who are contemplating the purchase of a "pair of shoes" for that presently "barefoot" exciter.

In its present form, the SB-221 operates in the 80, 40, 20 and 15-meter bands. The required driving power is 100 watts maximum. Rf power amplification is accomplished by means of two 3-500Z triode tubes which are forced-air cooled. These well-proven tubes

[1] "Recent Equipment," *QST*, August 1970, p. 45.



The Heath SB-221 linear amplifier. Though it may appear to be "stock," this '221 operates in five bands. Modification information is given in the text.

Table 4

Results of SB-221 Tests Performed in ARRL Laboratory

Band	$P_{IN(watts)}$	$P_{OUT(watts)}$	*Input VSWR*	*Drive Power (watts)*	*Efficiency (%)*
80	1000	560	1.53:1	70	56
80	1900	1150	1.42:1	100 +	60
40	1000	600	1.41:1	70	60
40	1900	1200	—	100 +	63
20	1000	580	1.6:1	75	58
20	1900	1100	—	100 +	58
15	1000	560	1.79:1	75	56
15	1900	1050	—	100 +	55
10	1000	500	1.42:1	67	50
10	1900	1000	—	100 +	53

offer reliable service and good efficiency. They are the instant-heating-filament type. Hence, operation is permissible the moment the amplifier power switch is turned on.

Maximum dc power input is 2-kW PEP on ssb, 1 kW on cw and 1 kW on RTTY. This amplifier is rated, in terms of its duty cycle, for continuous voice modulation on ssb. For cw use the maximum key-down (steady carrier) time is 10 minutes. When operating the RTTY mode the manufacturer specifies a 50 percent duty cycle, or a *maximum* transmit time of 10 minutes.

The metering system enables the operator to monitor the plate current at all times by means of a 0- to 1-ampere dc meter. A second meter and related switch permits the monitoring of grid current, relative output power or dc plate voltage. There is a two-level plate-voltage setup which is programmed from the front panel by means of a rocker switch. One position provides the proper operating voltage for tune-up and cw. The alternate switch position is for ssb operation. In the latter position the plate voltage and current are elevated to provide the 2-kW PEP power input level while keeping the plate impedance the same as it is in the tune position. Therefore, no readjustment is needed when going from tune to the ssb mode.

Driving power is supplied to the grounded-grid 3-500Zs through switched, broadband pi-section matching networks. The amplifier input impedance is approximately 50 ohms. Hash noise is prevented during the standby period by automatic application of beyond-cutoff bias to the tubes. The proper idling current for the tubes during transmit is established with Zener-diode-regulated bias.

Table 3

SB-221 Specifications

Size (HWD): 8-1/4 × 14-7/8 × 14-1/2 inches (210 × 378 × 368 mm).
Weight: 50 pounds (22.7 kg).
Color: Two-tone light and dark green.
Power requirements: 117 V ac at 50/60 Hz (20 A max.), or 240 V ac at 50/60 Hz (10 A max.).
Driving power: 100 W max.
Dc input power: 2-kW PEP for ssb and 1 kW for cw and RTTY.
Key-down maximum at full power: 10 minutes.
Frequency range: 3.5 through 21 MHz.
Price class: $620.
Manufacturer: Heath Company, Benton Harbor, MI 49022.

During transmit, an automatic limiting control (alc) circuit in the amplifier develops negative voltage which can be routed to the exciter to reduce its gain when the exciter output is sufficient to overdrive the amplifier. A phono jack is provided on the rear apron of the amplifier for alc takeoff. Another jack is located on the rear of the amplifier for a control line from the exciter which actuates the amplifier changeover relay. When this line is shorted, the relay closes. Fig. 7 shows the amplifier third- and fifth-order distortion product levels. Fig. 8 is a spectrum display of the amplifier spurious products. The harmonic levels are well within FCC limits. Additional TVI protection is offered by the double-shielding technique used in the SB-221: The rf deck has a perforated metal enclosure. The amplifier cabinet serves as the second shield. Rf bypassing is employed at the power-supply primary, the alc jack and the relay-control jack.

What About 10-Meter Operation?

This reviewer couldn't make an ounce of sense out of having this fine amplifier on the operating desk without being able to use it on 10 meters. So, a check was made between the schematic diagrams of the earlier SB-220 and the SB-221. Most of the circuit remained the same. The new version contained a sealed filter in the excitation line to prevent 27- or 28-MHz operation. The band switch lacked the necessary contacts for 5-band use. There was no 10/15-meter plate coil and the 10/15-meter input coil was missing. There were other differences (slight), but none that couldn't be resolved easily.

The lineup of required components was obtained from Heath. Here is the list needed for conversion back to the SB-220 format: 63-561 rotary switch, 63-562 wafer switch, 20-99 22-pF mica (2), 20-120 220-pF mica, 20-113 470-pF mica (2), 20-103 150-pF mica, 20-124 115-pF mica (2), 40-966 40-meter input coil, 40-964 10/15 meter input coil (2), 40-968 10/15 meter plate coil, 595-1122 SB-220 manual. The cost of the foregoing parts at the time of this writing is $31.50. Heath has agreed to sell these parts to SB-221 owners if a photocopy of the purchaser's valid amateur license accompanies the order. The filter in the SB-221 must be removed by drilling out the rivets which hold it to the main chassis. There is no 10-meter marking on the front-panel band switch. A white press-on decal can be added if that band position needs to be identified.

Converting an already-built SB-221 to the SB-220 format will require a certain amount of "unbuilding" first. Fortunately, the reviewer started from scratch with the amplifier kit and wired it as an SB-220. Everything went smoothly by working from the SB-220 manual. Now, the 10-meter band is situated in the "nothing" position on the panel, respective to band-switch indexing. Assembly time for an experienced amateur builder should be on the order of 20 hours. Neophytes should plan to spend up to 35 hours for a project of this nature. — *Doug DeMaw, W1FB*

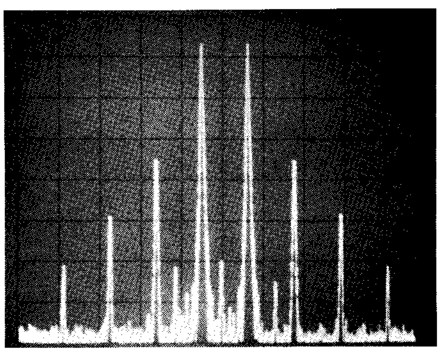


Fig. 7 — Spectral display of the SB-221 IMD characteristics at 3.5 MHz during a two-tone test. Vertical divisions are 10 dB; horizontal divisions are 1 kHz. Third-order distortion products are down approximately 35 dB from the PEP output. The individual tones are 6 dB down from the PEP output. All measurements were taken in the ARRL lab.

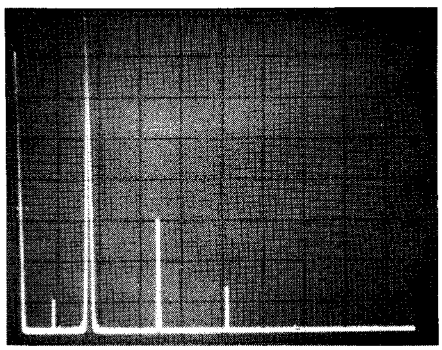


Fig. 8 — Spectral display of the SB-221 amplifier on 3.5 MHz. Vertical divisions are 10 dB; horizontal divisions are 2 MHz. The full-scale pip is the 3.5 MHz carrier with a low-level spur off to its left. The signal immediately to the right of the carrier is the second harmonic at approximately 50 dB below peak power. The third harmonic is 66 dB below peak power.