

Heathkit of the Month #36:
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Heathkit SB-301
HF Ham Band Receiver

Introduction:

Shortly after graduating from college and starting a career in aerospace, I felt it was time to get back on the air. College had limited my ham operations significantly. Most of my equipment prior to college did not make the move from the East Coast with me. I still had my Heathkit Apache transmitter (see HOM # 17, July 2009). I knew I needed a receiver. Thus, finding myself planning to get back on the air, and having some discretionary income from my new job, my first priority was to buy a good receiver.

After some thought, I anticipated buying and building a Heathkit SB-301 ham-band only receiver kit. This kit had replaced the SB-300 in 1966 and included a few refinements. On September 5th, 1968 I ordered the Heathkit SB-301 receiver (\$260) and the optional SBA-301-1 AM and SBA-301-2 CW filters (\$20.95 each) from the Benton Harbor, MI factory. Shipping to Orange, CA cost \$4.90.

A little over a week later the kit arrived, and construction began. The SB-301 (Figure 1) was built on the same folding 6' aluminum table that I've used to built many other Heathkits; the same table has been used at just about every W6ZE Field Day from 1970 to present.

The Earlier Heathkit SB-300 Ham Band Receiver: Heathkit introduced the SB-300 (Figure 2) in mid 1964 - their first new high performance HF ham receiver since the RX-1 Mohawk. The SB-300 was introduced at \$265.00 and came with a crystal filter for SSB. Two optional filters, the SBA-300-1 for AM and the SBA-300-2 for CW (\$19.95 each) were also available. A matching



Figure 1: Heathkit SB-301 HF Ham Receiver

speaker, the SB-600, was not released until 1966.

Along with the Heathkit SB-300, Heathkit introduced a matching SSB-CW transmitter, the SB-400, which I plan to cover in a future article along with the later SB-401. These transmitters can operate independently or in transceiver mode with the SB-300 or SB-301. For split operation a switch on the transmitter allows selecting the receiver or transmitter LMO (Linear Master Oscillator).

Since the SB-300 and the later SB-301 receivers are so similar in design, this article will focus on the SB-301 and point out differences in the earlier SB-300 where they occur.

The Heathkit SB-301 Ham Band Receiver:

The SB-301 is a dual conversion superheterodyne receiver. All oscillators are crystal controlled for stability except for the LMO, which comes prebuilt from TRW and linearly tunes from 5.5 MHz down to 5.0 MHz in five full turns of the shaft. The SB-301 receives the five (non-WARC) amateur bands from 80 through



Figure 2: Earlier SB-300 HF Ham Receiver

10 meters in eight bands. Each band is 500 KHz in width so the 10 meter band is divided into four separate 500 KHz segments on the band switch. The SB-301 also has another position on the band switch that covers 15.0 to 15.5 MHz allowing reception of WWV at 15.0 MHz. This band is not available on the SB-300. Table one shows the SB300/301 frequency bands.

Tuning the SB-301 with its 4:1 vernier drive is a pleasure assuming the kit has been assembled well. Proper alignment of the tuning components is critical to smooth tuning. Each 500 KHz band is covered in five turns of the large circular dial, each covering 100 KHz. A linear slide scale marked 0 - 5 above the window for the circular dial shows the current 100 KHz segment. A small knob allows adjustment of the circular dial cursor to correct for any dial inaccuracy and is used in conjunction with the 100 KHz crystal calibrator built into both receivers. The readout is accurate to within a hundred cycles or so. While not as fancy as today's digital readouts, the frequency can be set accurately enough to still be viable today.

The front panel of the SB-300 and SB-301 are very similar in appearance. A few differences, however, do stand out; most noticeably the SB-301 **FUNCTION** switch and **AF GAIN** controls

Band	From	To	Heterodyne Crystal Freq.
80M	3.5	4.0	12.395
40M	7.0	7.5	15.895
20M	14.0	14.5	22.895
[WWV*]	15.0	15.5	23.895]
15M	21.0	21.5	29.895
10M	28.0	28.5	36.895
10M	28.5	29.0	37.395
10M	29.0	29.5	37.895
10M	29.5	30.0	38.395

All frequencies are in MHz
 * WWV not included on the SB-300

Table 1: SB-300/SB301 Bands.

Front panel controls are located in three rows.

Left to right on the top row:

S - Meter (lighted): meter (0-1 ma)
0, 3, 6, 9 S-UNITS, 20, 40, 60 DECIBELS
FUNCTION: 4 pos. rotary sw.
OFF, STandBY, OPERate, CALibrate
A. F. GAIN: Potentiometer
 (unnumbered gain scale)
 [ANL Pull on sw on pot]
 (No ANL nomenclature on front panel)

Left to right on the middle row:

AGC: 3 pos. rotary sw.
OFF, FAST, SLOW
MAIN TUNING LMO var. capacitor
 0 - 5 turns scale, 0 - 100 frequency scale
 (both lighted)
PRESELECTOR 4-sec. var. capacitor
 (unnumbered scale)

Left to right on the bottom row:

PHONES: 1/4" phone jack
MODE 4 [5] pos. rotary sw.
[RTTY], LSB, USB, CW, AM
BAND 8 [9] pos. rotary sw.
3.5, 7.0, 14.0, [15.0 RCV ONLY], 21.0, 28.0, 28.5, 29.0, 29.5
 SB-300 only:
R. F. GAIN: potentiometer
 (unnumbered gain scale)
 [SB-301 only - Concentric controls:
CONVERTER 3 pos. rotary sw.
VHF-1 VHF-2, HF - inner control
R. F. GAIN potentiometer
 (no gain scale) - outer control]
 [SB-301 differences are shown in brackets]

Table 2: SB300/301 Front Panel Controls

are mounted higher on the front panel. Also several of the SB-301 controls have added features. Table 2 lists the front panel controls and nomenclature, including differences between the SB-300 and SB-301.



Figure 3: Heathkit SB-301 interior view.
Photo complements of Jim - WB2FCN¹

A feature of both the SB-300 and SB-301 is the provision to mount two VHF converters externally on the back of the cabinet. Heathkit made the SBA-300-3 for 6-meters and the SBA-300-4 for 2-meters. These converters cover the first two MHz of the band and can be modified to cover the last two MHz by changing the crystal and retuning the converter. Both receivers have power and antenna connections for the converters. A switch allows selecting normal HF operation or either of the VHF converters. DC and filament power is only delivered to a converter when it is selected. On the SB-300 the switch is less conveniently located on the right rear of the chassis top, making it necessary to raise the top cover to change the switch. This changed on the SB-301 and the switch is relocated to the front panel concentric with the **R.F. GAIN** control.

Heathkit SB-301 Circuit:

The SB-301 uses ten tubes, two of which are multi-section, and nine solid-state diodes. One tube and diode are part of the pre-built LMO assembly. Table 5 shows the list of tubes.

Power Supply:

The power supply is transformer operated. The two primary windings may be wired in parallel or series for operation on 120 or 240 VAC. The secondary has two windings. A 6.3 VAC winding supplies filament power to the ten tubes,

with enough reserve for a converter and three pilot lamps; a high voltage center-tapped winding is used in a full-wave rectifier circuit to produce 150 VDC, and a separate half-wave circuit produces a negative 60 volts for biasing. Silicon diode rectifiers are used in both supplies. Numerous lower voltages are tapped off the 150 VDC supply.

RF Amplifier:

The RF amplifier uses a 6BZ6 pentode tube in a tuned-grid, tuned-plate, amplifier. The band switch selects the proper antenna and plate coils for each band as well as the required sections of the **PRESELECTOR** variable capacitor. A pair of coils covers both 14.0 and 15.0 MHz, and a separate pair of coils covers all four of the 10-meter band segments.

Heterodyne Oscillator:

The heterodyne signal is generated by a crystal oscillator and uses a 6AB4 triode. The band switch selects one of eight or nine crystals for the heterodyne oscillator. Their values are shown in Table 1. The crystal is always 8.895 MHz above the desired band's lower frequency limit. A section of the band switch selects the proper crystal and plate coil for each band.

1st Mixer:

The signals from the RF amplifier and heterodyne oscillator are mixed in a 6AU6 pentode. Only the difference frequency is allowed to pass through a bandpass coupler. The coupler passes 8.395 to 8.895 MHz and comes factory aligned.

The rest of the receiver is basically a single band receiver designed to receive the 8.395 to 8.895 MHz frequencies.

LMO (Linear Master Oscillator):

The only variable oscillator in the SB-301 is the LMO. Manufactured by TRW, it comes factory wired and calibrated. The LMO was modified slightly between the SB-300 and SB-301 receivers changing the tube from a 6AU6 to a 6CB6 and then to a 6BZ6. A few components

were changed as well. These were probably done to further improve very good stability. The LMO tunes *nominally* from 5,500 KHz at the low end of a band down to 5,000 KHz at the high end of the band. It tunes at an accurate and linear rate of 100 KHz per 360° turn of the LMO shaft. The tuning knob has a 4:1 vernier that drives the LMO shaft.

The actual frequency range that the LMO tunes varies by mode. In LSB and RTTY the LMO is 1.4 KHz higher - tuning 5,501.4 to 5,001.4 KHz. In USB, CW and AM it is shifted down by 2.8 KHz - tuning 5,498.6 to 4,998.6 KHz. This shift is controlled by a diode switch inside the LMO. The diode is biased at negative 60 volts in LSB and RTTY and at positive 50 volts in USB and CW. More about the reason for this frequency shift will be discussed in a future section.

2nd Mixer:

The signal from the bandpass coupler and the LMO output mix in the 6AU6 second mixer tube. The output of the mixer is fed into one of three crystal filters, each with a center frequency around 3.395 MHz. which only lets the difference frequency pass.

Crystal Filter(s):

The SB-300 and SB-301 both come with only a SSB crystal filter. AM and CW crystal filters are optional. The supplied and optional crystal filters for the two radios are different. Most noticeably, the SB-300 filters are physically larger, though they both mount in the same hole pattern. Electrically they both have the same center frequency but the later optional filters for the SB-301 have narrower skirts. The AM and SSB filters have a center frequency of 3,395.0 KHz, and the CW filters have a center frequency of 3,395.4 KHz. Wider AM and SSB filters associated with the SB-310 SWL receiver can also be used with the SB-300/301. The optional SB-301 filters can be used in the SB-300 but the optional SB-300 filters cannot be used in the SB-301 without mechanical modifications due to their larger size. Table 3 lists the filters:

Part #(s)	BW @ 6dB/60dB Receiver model	Center Freq.
404-200	SSB 2.1/5.0 KHz SB-300 (Supplied)	3,395.0 KHz
SBA-300-1 (404-201)	AM 3.5/14 KHz SB-300 (Optional)	3,395.0 KHz
SBA-300-2 (404-202)	CW 0.4/2.5 KHz SB-300 (Optional)	3,395.4 KHz
404-283	SSB 2.1/5.0 KHz SB-301 (Supplied)	3,395.0 KHz
SBA-301-1 (404-285)	AM 3.75/10 KHz SB-301 (Optional)	3,395.0 KHz
SBA-301-2 (404-284)	CW 0.4/2.0 KHz SB-301 (Optional)	3,395.4 KHz

Table 3: SB-300 & SB-301 Crystal Filters

IF Amplifier:

The IF amplifier consists of two high-gain stages, both incorporating 6AB6 tubes. Voltage from the automatic gain control circuit (AGC) adjusts bias on both tubes reducing the IF gain on strong signals. This reduction in gain is measured by the S-meter to indicate signal strength. The two stages are coupled with an L-C network mounted in an IF transformer can and a coupling capacitor. A second identical network couples the output of the second IF tube to the AM detector, the product detector and the AGC circuit.

Noise Limiter:

An automatic noise limiter (ANL) is included on the SB-301, but not the SB-300. It is activated by pulling out the knob on the **AF Gain** control. The ANL is not a noise blanker like the ones found on today's equipment; instead it is a self-biased diode clipper that is across the second IF LC network. I've found the noise filter to be effective in certain circumstances. It is much less effective than a noise blanker.

AM Diode Detector:

The AM detector is a simple but very effective diode detector using a 1N191 germanium diode. Heathkit has a recommended modification to improve AM audio on the SB-301. It is simple;

just place a 470K 1/2w resistor across the detector diode (D3). This modification appeared in *Heath News and Views*. It does improve the AM audio. The reason this modification is not well known is because most of the SB-301 receivers do not have the AM filter installed.

BFO and Product Detector:

CW and SSB signals are detected by heterodyning the IF signal with a BFO signal in a product detector. These circuits use a 12-pin 6AS11 Compactron tube containing three sections. A triode section is the product detector, a second triode is the BFO oscillator and a pentode section is a BFO amplifier.

The BFO oscillator in the SB-301 has three crystals, one each for RTTY and LSB, and a third for USB, CW and AM. Their frequencies are: 3,392.110, 3,393.6 and 3,396.4 KHz respectively. The SB-300 does not have RTTY capability and uses only two crystals.

Output from the BFO is coupled to the cathode of the product detector triode section. It is also coupled to the grid of the pentode BFO amplifier section. This amplifier drives the external

BFO output connector on the rear of the receiver, and is used by the transmitter in transmitter mode on SSB .

The signal from the IF is fed to the grid of the product detector section where it heterodynes with the BFO signal producing audio.

Audio Output Stages:

Audio is selected from either the AM diode detector or the product detector by the mode switch and fed through the **A.F. GAIN** control to a two-stage audio amplifier. The first stage uses the triode section of a 6HF8; the output stage uses the pentode section. The audio output transformer has two taps. 500Ω for the headphones and external **ANTI VOX** output and 8Ω for the speaker. Negative feedback from the 500Ω tap is coupled to the cathode of the 1st stage to reduce distortion. Audio output is specified as 1 watt at less than 8% distortion.

Automatic Gain Control (AGC):

The signal from the output of the IF amplifier is also coupled to the AGC circuit where it is rectified to produce a negative voltage. Bias voltage to the RF stage and both IF stages de-

	Rcv'd Freq	1st MIXER	LMO LSB	LMO USB/CW	BFO LSB	BFO USB/CW
Rcvr Tuned Freq:			28,375.000	28,375.000		
Osc Freq:		36,895.000	5,126.400	5,123.600	3,393.600	3,396.400
USB				2nd MIXER		
Carrier (suppressed)	28,375.000	8,520.000		3,396.400		0.000
Low Tone - 500 Hz	28,375.500	8,519.500		3,395.900		0.500
Hi Tone - 2300 Hz	28,377.300	8,517.700		3,394.100		2.300
LSB				2nd MIXER		
Carrier (suppressed)	28,375.000	8,520.000	3,393.600		0.000	
Low Tone - 500 Hz	28,374.500	8,520.500	3,394.100		0.500	
Hi Tone - 2300 Hz	28,372.700	8,522.300	3,395.900		2.300	
CW						
Carrier (Zero beat)	28,375.000	8,520.000		3,396.400		0.000
Carrier (1,000Hz Tone)	28,376.000	8,519.000		3,395.400		1.000

Table 4: USB & LSB frequencies in KHz for a two-tone (500 Hz & 2,300 Hz) signal, and for a CW signal, as they appear within a properly tuned SB-301 (See Text).

termines the receiver's overall gain. This bias is set by the **RF GAIN** control. Should the AGC voltage exceed the threshold set by this bias the gain is further reduced. The gain reduction is very fast but the operator can select **FAST** or **SLOW** release depending on the type of signal being listened to. This selection is done by the **AGC** switch on the front panel that selects different time constants; it also has a third position - **OFF** - that disconnects the AGC circuit so RF gain is only controlled by the **RF GAIN** control.

Muting:

Muting is controlled by a normally grounded circuit at the **MUTE** connector on the rear panel. When transmitting, this connection is opened by the transmitter. When open a large negative bias is placed on the audio output stage, the 1st mixer stage and the AGC line, effectively biasing those circuits to cutoff and muting the receiver. The receiver **FUNCTION** switch must be in **STANDBY**. In the **RECEIVE** and **CALIBRATE** positions of the **FUNCTION** switch the mute line is grounded internally in the receiver.

100 KHz Crystal Calibrator:

A 100 KHz crystal oscillator with strong harmonics through the HF band is built into the receiver. It is used for calibration of the tuning dial and can be used in place of a signal generator to align the receiver. The oscillator uses a 6AU6 tube.

SB300/301 Rear Connectors:

The rear panel of the SB-300 and SB-301 have a myriad of connectors including nine active RCA jacks, a connector for the AC line and an octal connector for powering accessories. Both receivers come with additional RCA jacks marked **SPARE**; the SB-300 has two and the SB-301 has four. Table 6 lists the connectors and their use.

Frequency Operation:

Table 4 traces three signals through the receiver - USB, LSB and CW. Sideband signals are shown modulated by a two-tone signal with

audio tones of 500 Hz and 2,300 Hz (Column 1). On USB, with the transmitter and receiver tuned to the club's 10-meter net frequency of 28,375.0 KHz, the two tones are actually being received at 28,375.5 and 28,377.3 KHz (Column 2). Since the carrier is suppressed nothing is received at 28,375.0 (This is where the carrier would be.) These signals are mixed in the first mixer with the heterodyne oscillator that is running at 36,895.0 KHz, producing difference frequencies of 8,519.5 and 8,517.7 KHz (Column 3). These frequencies are passed by the bandpass coupler to the second mixer.

The LMO nominally operates from 5,500 down to 5,000 KHz. Actually though on LSB it is shifted down by 1.4 KHz and on USB/CW it is shifted up by 1.4 KHz. Thus on USB, when the receiver is tuned to 28,375.0 the LMO is not at 5,125.0 KHz, but actually at 5,126.4 KHz. This frequency mixes with the frequencies from the bandpass coupler creating difference frequencies of 3,395.9 and 3,394.1 KHz for the two tones (Column 5). These both pass through the SSB crystal filter whose 6 dB points are 3,393.95 and 3,396.05; however the frequency of the suppressed carrier is at 3,396.4 and any remaining carrier will be further suppressed.

Finally the signals are mixed with the BFO oscillator in the product detector. On USB the BFO frequency is 3,396.4. The resulting difference frequencies are the two tones of 500 and 2,300 Hz, which are sent on to the audio amplifier.

LSB operates similarly except the frequencies generated by the tones are below the suppressed carrier frequency, the LMO is 1.4 KHz above its nominal frequency and the BFO frequency is switched to 3,393.6 KHz.

CW uses the same oscillator frequencies as USB. However the center frequency of the CW filter is at 3,395.4 KHz. Table 4 includes rows for CW reception, both at zero beat and when the receiver is tuned up 1.0 KHz producing an audible tone that is right in the center of the optional 400 Hz BW crystal filter. CW reception can also

be received with the mode switch in USB. Here the SSB filter is used and the selectivity is broader. Note that zero beat will be outside the filter passband when using the CW filter.

SB-301 Kit Construction:

The assembly of the receiver is divided into five sections. Small parts for each section are packaged separately to aid parts identification. In the first section the IF printed circuit board is assembled; it contains three tubes, the two IF stages (V6 and V7) and the dual audio stage (V10). A small board containing four parts for the ANL circuit is also assembled and soldered to the IF board (SB-301 only).

The RF circuit board is assembled next; it contains five tubes, the RF stage (V1), the heterodyne oscillator (V4), the 1st and 2nd mixers (V2 and V3) and the crystal calibrator (V8). The 8.395 to 8.895 MHz bandpass filter transformer mounts on this circuit board.

In the third section the chassis assembly is begun. First the 19 coils for the antenna, RF amplifier and heterodyne oscillator are installed on the top of the chassis with their appropriate capacitors. A coil cover shield with partitions is then assembled and mounted over the coils

protecting them during further assembly. Next, most of the parts that mount on the chassis are installed including transformers, terminal lugs and crystal sockets, rear panel connectors, etc. Also mounted are the two circuit boards assembled in sections 1 and 2, along with the SSB crystal filter. If you bought the optional AM and/or CW filters they are mounted at this time too. Hardware for their mounting is supplied with the kit. The socket for the only chassis mounted tube (V9) is also mounted.

No.	Type	Function
V1	6BZ6	RF Amplifier
V2	6AU6	1st Mixer
V3	6AU6	2nd Mixer
V4	6AB4	Heterodyne Oscillator
V5	6AU6	LMO (most SB-300)
V5	6CB6	LMO (some SB-300/301)
V5	6BZ6	LMO (most SB-301)
V6	6BA6	1st IF Amplifier
V7	6BA6	2nd IF Amplifier
V8	6AU6	100 KHz Xtal Oscillator
V9A	1/3-6AS11	Product Detector (triode)
V9B	1/3-6AS11	BFO (triode)
V9C	1/3-6AS11	BFO Amplifier (pentode)
V10A	1/2-6HF8	1st Audio Amp (triode)
V10B	1/2-6HF8	Audio Output (pentode)

Table 5: SB-300/301 Tube Line-up

Connectors are listed from left to right as viewed from the rear.

The first eight RCA jacks are mounted vertically in pairs and are listed top then bottom:

HF ANT:	Antenna connector
SPARE:	Not used
VHF NO 1:	Ant. from converter 1
VHF NO 2:	Ant. from converter 2
MUTE:	Ground to un-mute
SPARE:	Not used
ANTI VOX 500Ω:	Audio to Transmitter
SPKR 8Ω:	Audio output
AC INPUT:	2-pin male AC socket.

The next three RCA jacks are **OUTPUTS:**

HET. OSC.:	To SB-400/401 for xcv
LMO:	To SB-400/401 for xcv
BFO:	To SB-400/401 for xcv

Octal Accessory socket for VHF converters

Pin 1:	6.3 VAC VHF NO 2
Pin 2:	GND
Pin 3:	140 VDC VHF NO 2
Pin 4:	AGC
Pin 5:	NC
Pin 6:	140 VDC VHF NO 1
Pin 7:	GND
Pin 8:	6.3 VAC VHF NO 2

[The next two RCA jacks are SB-301 only:

SPARE:	Not used
SPARE:	Not used]

Table 6: SB-300/301 Rear Connectors

The fourth section involves the under chassis wiring and the installation of the large band and mode switches. A prewired harness simplifies some of the wiring. In this section many of the small leaded components are wired.

Top wiring is done in the fifth section. The LMO (with V5) is installed along with the tuning drive components. Alignment of these parts is critical for a smooth tuning receiver. Next, parts are mounted to the front panel and the panel is attached and wired to the chassis.

After a series of resistance check the moment of truth arrives. Crystals, tubes, pilot lamps and the fuse are installed and the unit is turned on. Two choices of alignment are available. The first uses the built-in 100KHz crystal oscillator, the other requires a signal generator. After alignment the receiver is installed in its cabinet.

Finishing Up:

As I've found with most of the Heathkits I've built, the receiver worked well right off the bat. The parts were all well identified and none were missing. Assembly order was well planned and none of the assembly steps required the skills of a brain surgeon.

Alignment instructions were well written and the procedure appeared solid. I used the alignment procedure that used the built-in calibrator. Since then I've aligned it using a good signal generator with no notice in improvement.

SB-301 Operation:

I used the SB-301 as my primary receiver into the early nineties when I bought a used Kenwood TS-440SAT from W6NGO. The SB-301 receiver has been solid and sensitive over the whole period. Selectivity was very good and far better than I ever experienced with older receivers.

My only maintenance over those twenty plus years was having to clean and re-lubricate the LMO capacitor bearings which developed an

intermittent sliding ground contact that caused erratic tuning.

Since the SB-301 was put on standby behind the TS-440SAT I've used it occasionally to keep it working. In that time two additional problems cropped up. The first problem was a partially failed 6AS11 tube, easily repaired with a new tube - and the only tube I've replaced in the receiver! And the other problem was a sudden increase in hum. My fear was a failing filter capacitor (Four-section can-type that is hard to replace); I traced the problem to a poor ground connection to the RF board. Tightening the hardware mounting the board cleaned up the hum. The board was removed, the contact between the board and chassis cleaned and the board reinstalled and soldered to the chassis ending the hum problem.

Summary:

The SB-301 remains a viable receiver 43 years after it was bought and assembled. What it is missing is coverage of the WARC bands introduced years after the SB-301 and the later SB-303 were discontinued. It is also lacking a noise blanker - though circuits are available on the Internet.

I expect to cover the SB-400/401 as well as the SB-303 in future articles; also possibly, some accessories will also be covered in the future.

Notes:

1. I'd like to thank Jim Walker - WB2FCN for letting me use his photo as figure 3. Visit the ham section of his website at: <http://128.205.126.49/>

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.