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The National Radio Corp. HRO Senior Receiver/ Army R106 Mk1 & 1/1

Philip Moss describes the once-popular HRO Senior receiver.

This is another receiver that was donated to the British Vintage Wireless & Television Museum, Dulwich. It was donated specifically for my 'Comms Corner' display, by a similar sounding organisation, The British Vintage Wireless Society, publisher of *The Bulletin*, magazine about vintage radio TV and electronics, and holder and organiser of many vintage electronic sales around the country. There have always been close relations between the two organisations, who are both charities. I was offered a choice between the original version, with UX-based valves, or the later Octal types. I said for my own preference I would take the latter, but for a museum, I thought the former, and that is what I got, with almost two complete sets of coil-packs, and the original wooden box for the coils not in use.

History

Apart from the valves and bases the circuit did not change at all between the two series of valves, with one exception, so their characteristics must be very similar. This is a bit surprising as the Octal series have internal screens, and I would have expected if nothing else the capacitor values in the tuned circuits would change with a change in stray capacitance, but clearly it was within the adjustment range of the tuned circuits. The exception was that the 6B7 was a double-diode-pentode, and was replaced by a DD triode in the 6Q7. The Octals used would be the original metal types. They didn't need external screening cans.

This set, like the also famous RCA AR88, was not designed for the Military, but for the radio amateur. It is suggested that HRO stood for Ham Operator's Radio, though Hell-of-a-Rush has also been suggested. In both cases the letters are in the wrong order: for obvious reasons... **Fred Osterman** (see footnote) suggest *"Helluva Rush Order"*. Take your choice. As this was made long before the war, however, I cannot see why it would need to be rushed.

Apparently designed about 1935, it used the rather old-fashioned idea of band change by changing coils. In fairness, there was a very large frequency range covered, and if it was a switched-waveband set, it would have a great many coils in, and not all users wanted the full coverage. For those amateurs, therefore, with a couple of favourite bands, it was OK, and alternatively if you couldn't afford to buy the lot in one go, you could buy them later, perhaps one at a time. Each pack contains four sets of circuits, each in its own aluminium can.

The set was not well regarded by the British Services, as deemed not easy to use, according to **Louis Meulstee**, in *Wireless for the Warrior, Vol 3, Reception Sets* (see footnote), where a very full description is to be found of the sets and how they were used. He dates the set to 1939, but that is when we got them, not the original introduction date. Many were bought by amateurs after the war, and some people loved them.

The late **Pat Hawker G3VA** was one, and went on (and on...) about them in *Technical Topics* in *RadCom*. The fact is a set where you have to plug different coil packs in and then read off the graph to find the frequency is not the height of ergonomics. The bandwidth control isn't the easiest to use, either. It was deemed to require operators to gain too much skill to use effectively, and hence too much time for training. I didn't find the layout of controls to be conducive to easy use but I suppose if this was my own set I would have learned. I far prefer my CR100/B28.

In contrast to Pat, I did like the reminiscence of a user in the war in the Far East who said when they got AR88s, they put their HROs in a rowing boat, went out to sea and threw them over! A bit extreme? They wanted to ensure that the Japanese couldn't get hold of them. The set was replaced with the British R206: a much more complex receiver with no plug-ins! However, many of them were used, mainly for interception. Meulstee has pictures of vehicles with several operator positions, using them.

Photo 1: The set in situ.
Photo 2: Top view.
Photo 3: Bottom view.
Photo 4: The coil packs.

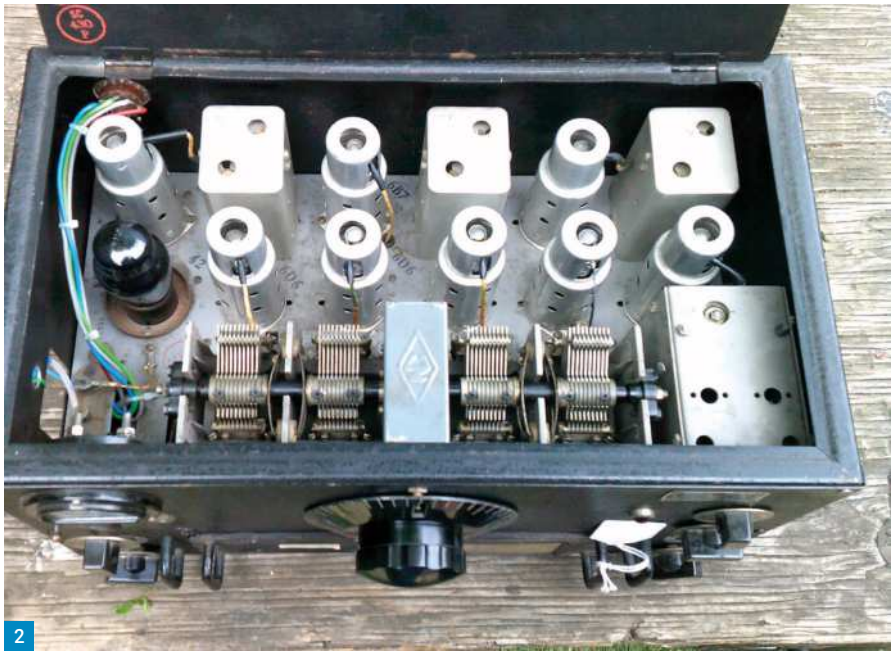
Description

The set is in two parts, apart from the coils. The main set, and a separate PSU. It does not ordinarily contain an output transformer. Why set makers, professional or domestic, liked running HT and anode around, and not putting the output transformer with the valve, I don't know. The original PSU is known as a 'dog kennel' because of its shape with a 'roof' sloping up to a flat section, instead of a simple rectangular box. This set came with no PSU, and I had to build one for it, which I built as two separate supplies in one box to run an R1155 (see *PW* August 2021). Sets supplied to the UK didn't come with a PSU. They were made here in a straightforward rectangular box.

The set follows (almost) conventional lines apart from the plug-ins. For a station main receiver, it has two RF amplifier pentodes, a pentode mixer, a separate local oscillator, two IF amplifiers, double-diode-triode or pentode for audio detection, AF signal amplification, and AGC detection, followed by a power pentode output valve. There is a beat frequency oscillator (BFO) for CW operation, and the PSU contains a full-wave rectifier and transformer for AC mains only, the other PSUs are vibrator types. Why did I say almost conventional? Because they have done what I frequently comment on other sets not doing where a separate local oscillator (LO) is used: they have used a pentode mixer, not a polygrid. Cheaper, simpler, lower noise and higher gain. It also means the spares kit needed one less valve type. The two pentodes are 6C6 (6J7), the straight ones or 6D6 (6K7) the variable mu types. I have given the Octal equivalents in the brackets. The straight ones are the two oscillators: LO and BFO. The DDP/DDT is a 6B7 (6Q7), and the output valve is a 42 (6V6).

The power supplies were model 697 for 115/230V AC, 50/60Hz giving 240V DC at 70mA and consuming 70W. The 686 PSU was for 6V DC and the 1286 for 12V. They only consumed 38W but things are not quite the same, as the HT was only 165V at 45mA. The rectifier in the mains pack was a 6X5, but sometimes a 0Z4, requiring no heater power.

The manual tells us that to attain essentially flat sensitivity across the frequency range of each band,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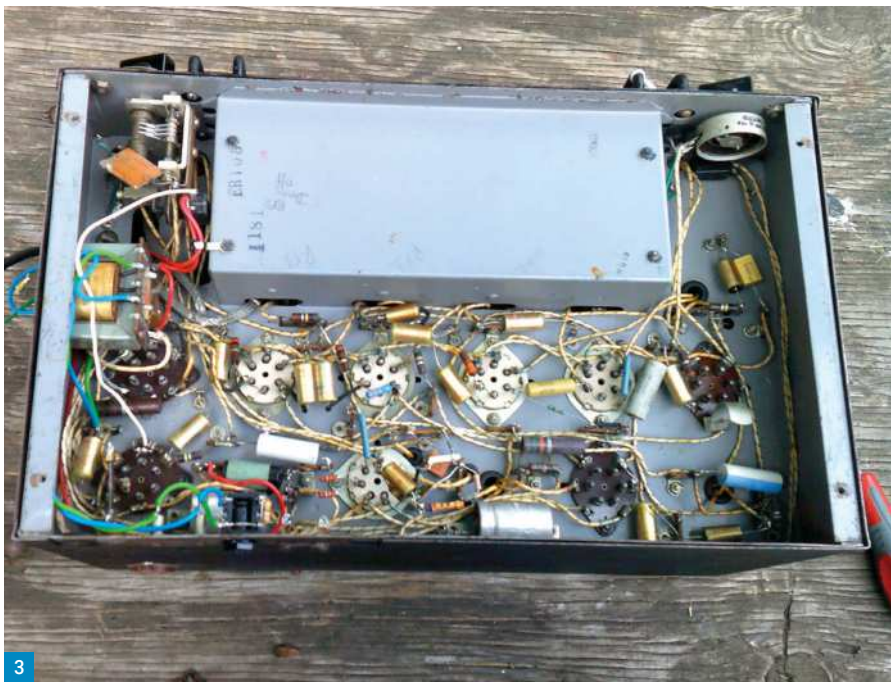
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which intrinsically changes as the L/C (inductance/capacitance) ratio changes, a high-inductance primary is used in the inter-valve RF transformers, leading to the opposite, which is then compensated for by having a small top-coupling capacitor between primary and secondary. This however is not shown on the circuit diagrams.

To get the tuning knob in the centre of the front-panel, and also to have the coil-pack central, an unusual tuning capacitor was needed with a gearbox in the middle between the two pairs of variable capacitors where the shaft from the knob entered. The mixer anode circuit contains the crystal filter circuit. This is quite a complex arrangement. The crystal has a variable phasing control on the front panel. This capacitor has a short in one end of its travel to switch the crystal out, thus leaving the bandwidth to be determined by the selectivity of the IF transformers alone. When used, however, the circuit is balanced against a pre-set capacitor in a push-pull circuit, formed of an untapped secondary winding on the first IF transformer, but balanced to earth by two capacitors. Adjusting the phasing control gives variable bandwidth to the IF

response and the ability to peak it either side of the nominal IF, which is 465kc/s. The combined output from the two joined phases then goes to an autotransformer, which is tuned and steps up the voltage and impedance into the grid of the first IF amplifier.

The slope of the filter is poor, stated by Meulstee as only 5dB/kc/s. The attainable bandwidth is between 2500 and 200c/s. The second and third IF transformers are conventional with no switched coupling. All the bandwidth variability is in that first transformer. The coupling to the detector diodes is only on the secondary of the transformer, not the more typical approach of taking the AVC feed from the anode via a small capacitor, thus reducing loading on the tuned circuits. The audio then goes to a pentode in the UX- series valve, or triode in the Octal valve, then to a conventional output stage. For headphone operation, the output valve isn't used, drive being taken from the preamplifier. Not stated in the manual is that if running on battery power, the output valve can therefore just be unplugged.

Both the LO and BFO circuits use a Hartley oscillator running between cathode and control grid, the output taken from the cathode in the case of the LO. Thus, there is little load on the tuned circuit. The BFO uses the same configuration except that the output is taken from an untuned anode connection. The BFO on/off switch is coupled to the BFO pitch tuning capacitor. Another switch allows the meter to be switched off. Why is unclear. I suspect that with the BFO on and manual control of HF gain, the meter was overloaded. It is stated in the manual that AVC must be off when the BFO is on, or the set is deaf. This is typical though. The BFO signal adds to the received signal and is therefore detected by the AVC diode.

The Coils

Not so simple! Some coils were designed with the radio amateur particularly in mind, and could be adjusted to bandspread (BS) the amateur bands, by simply moving screws within the coil-pack - no adjustment was needed. There are two windows on the front with graphs of frequency versus dial read-out, one for standard and one for the BS setting. There is a B+ switch (HT), and that must be off when changing coils. The antenna terminals float for balanced input, but there is a link installed for earthing one side for unbalanced input. Coverage is as shown in **Table 1**.

The J packs were therefore for non-amateur use, generally, and were simpler and therefore cheaper. The set covers an unusually wide HF range if the user had all the coils. As is often the case, the MW broadcast band is not ideally covered as in an all-in-one coil-pack, and neither is LW, but then the Americans didn't use it. The dial has 500 divisions. There is a marker at the top, and a window through which a number can be seen, plus the marks around the edge give a very fine read-out of the setting. The re-setting accuracy is good.


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The set has a lidded top, and unusually the heaters are not earthed one side, but balanced to chassis by resistors. While this is good practice at audio for hum reduction, it is rare in RF practice. It has the disadvantage of increasing the likelihood of instability due to RF being transmitted along the heater wiring and indeed the heaters at the first IF amplifier and the BFO have RF bypass capacitors to chassis from one side.

Variants

As with many sets there was more than one version. The set here is a table-top set, the HRO-5A1, but a rack version was also made being sold as the plain HRO. The -C was the HRO, 697 PSU (AC mains) and SPC coil storage rack all in one table-top unit. There was also the cheaper HRO Junior, which omitted the meter and crystal filter, nor were bandspread coils available.

The company loved their unique tuning dial and made other latter models using it too. Examples include HRO-7 of 1947/49, HRO-50 of 49/50, HRO-60 of 52/54, by now using miniature glass valves in the front-end but still using, I assume, cheaper Octals for the IF amplifiers onwards. Even the very much more modern looking HRO-500 used a similar dial: but now in brushed aluminium. The last two sets were dual-conversion.

The company, which became defunct from about 1971, started in 1914 as the National Toy Company. It made toys and 'parts' the nature of which was not specified, but we may assume mechanical and electrical, which would easily lead into radio at that time. In 1916 they changed name to reflect the change in business to The National Company Inc. Their heyday was in the War, as with so many companies, producing all the radios they could for the Allied war effort.

An extremely memorable post-war set was the FRR-24. It was in four 19in racks, each about 300lb in weight, and was for triple diversity point-to-point communications. It is extremely scarce, as are those with the space to accommodate it!

Work

The set had already been re-capped, but the soldering was awful in places and leads left long.

The original 4-pin UX plug that the

Coil set	Coverage	Band spread
A	14-30Mc/s	28-29.7Mc/s
B	7-14.4Mc/s	14-14.4Mc/s
C	3.5-7.3Mc/s	7-7.3Mc/s
D	1.7-4Mc/s	3.5-4Mc/s
E	900kc/s-2.050Mc/s	
F	480-960kc/s	
G	180-430kc/s	
H	100-200kc/s	
J	50-100kc/s	
JA	14-30Mc/s	
JB	7-14.4Mc/s	
JC	3.5-7.3Mc/s	
JD	1.7-4Mc/s	

Table 1: Coverage by Coil Set.

set came with to plug into its PSU was replaced with two 2-pin plugs that were interchangeable and unpolarised. Useful! It came with a PSU, which was beyond a joke, quite incapable of supplying the current due to its tiny transformer and high resistance choke. It was scrapped, and a new one as mentioned would be built. An Octal socket was fitted to the rear, and a cable and plug made up to go with it. Some new wiring also done badly, so it was necessary to rewire the output transformer (which sensibly had been fitted internally) and the connection of HT to BFO. Add a jack socket for the speaker output. The set however was dead, although we did get signal by touching antenna to mixer grid. Another coil-pack was much better and it turned out that all those nice easily accessible adjustments had been adjusted! We went through the packs, roughly assessed their condition, and noted, then went through and re-aligned them all. That was the biggest job. Why people have to fiddle with things, even when it is obvious they are not making them better, I don't know.

The design is poor: the moving vanes are live so using a screwdriver adds stray capacitance. I tried the insulated tool from a Redifon R50M set but the vanes are very stiff and would have broken the tool. I had to strip part of the cabinet down to get access to the trimmers and eventually managed to align it by using a screwdriver, then removing, seeing the effect and trying to allow for it when readjusting, until it was peaked with the tool withdrawn. What a fuss! A very slim 4BA tube spanner was needed, which would have allowed me to do the alignment without the stripping-down.

A number of resistors had gone well beyond their tolerance and were replaced. A 30kΩ was >3MΩ. There was distortion, and no AVC. I found that where a capacitor had been replaced: for the wrong value, it should have been 0.01µF and was actually 0.1µF. This was replaced. An adjacent wire on the tag board had been accidentally cut. Reconnect to restore AVC. Some of the 0.01µF capacitors had been replaced with 0.015µF, but as it didn't seem to unduly effect the AVC operation they were left.

The set was still insensitive. The first IF transformer had been got at. Re-align then much better.

The meter had always read oddly. I found I couldn't zero it, and then noted loose connections. Someone had reversed them despite there being different size studs and solder tags to denote which way round. Rewire correctly then OK. I also glued back the loose glass in the meter, and then polished all the contacts on the coil-packs and in the receiver. The shaft of the zeroing pot is live and positioned to make it easy to short to chassis.

Finally, I got the kind of sensitivity I should have, which varies according to the specification between 1 and 5µV for 20dB SNR. Those are impressive figures.

Conclusions

I would not want this as my main set, but it did very good service for amateurs after the War, and indeed was still used by the Forces into the fifties. For those who love a particular band, and don't need to keep changing coils, it is fine. It would take a long time for radios to be available new at the price that could compete with its specification and facilities. It is also one of the most-needed sets in the Museum 'Comms Corner' collection, on the grounds of fame and being 'Iconic'.

Sources

The following sources were used in writing this article, apart from experience doing the renovation of the Museum's set. Photocopies of the original manual were available and came with the set. Also Fred Osterman's *Shortwave Receivers Past & Present* (subtitled) *Communications Receivers 1942-1997, third edition.* This is a compendium of 1000 receivers, giving short-form descriptions with a picture. Hard to get hold of but very interesting to those who collect such sets. *Wireless for the Warrior, Vol 3, Reception sets,* by Louis Meulstee. There are five volumes covering virtually all the sets used by the British Army in the WWII, and sets running up to and just after it. A hugely comprehensive work of the design, detail and use of these sets. Circuits and service information are also generally included. I can thoroughly recommend both.

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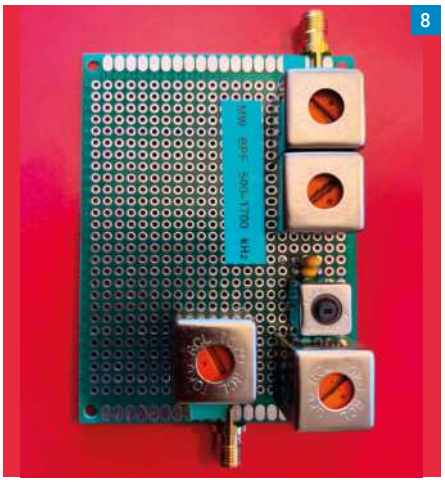

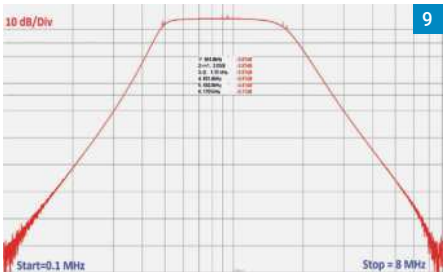

purpose. However, any larger inductance values would need a smaller diameter wire to be used.

The Prototype

The assembled filter is shown in **Fig. 8** and following some work with a vector network analyser the tuned filter's performance is shown in **Fig. 9**. The loss through the filter is slightly less than 1dB and setting the 3dB points and the shape of the filter was fairly simple to achieve.

End Note

Capacitor C3, 5.5nF, is not a standard E12 or E24 value and as can be seen Fig. 8, next to L3 (the smaller can) is made up of two capacitors in parallel – a 3.3nF and a 2.2nF. There is no issue with using a standard value capacitor of 5.6nF as there is more than enough adjustment achievable with L3 – I just did not have that particular value to hand.

You only need a small length of wire to achieve low µH values with these two formers and it is simple enough to remove 100 or more turns of the original wire from the large former and then use that for your own windings. While it is very thin and needs good eyes the enamel coating burns off easily.

If it helps, I have made high resolution copies of all the graphics in this article as well as a few examples of using the one equation, available on my website at:
www.samuelritchie.com