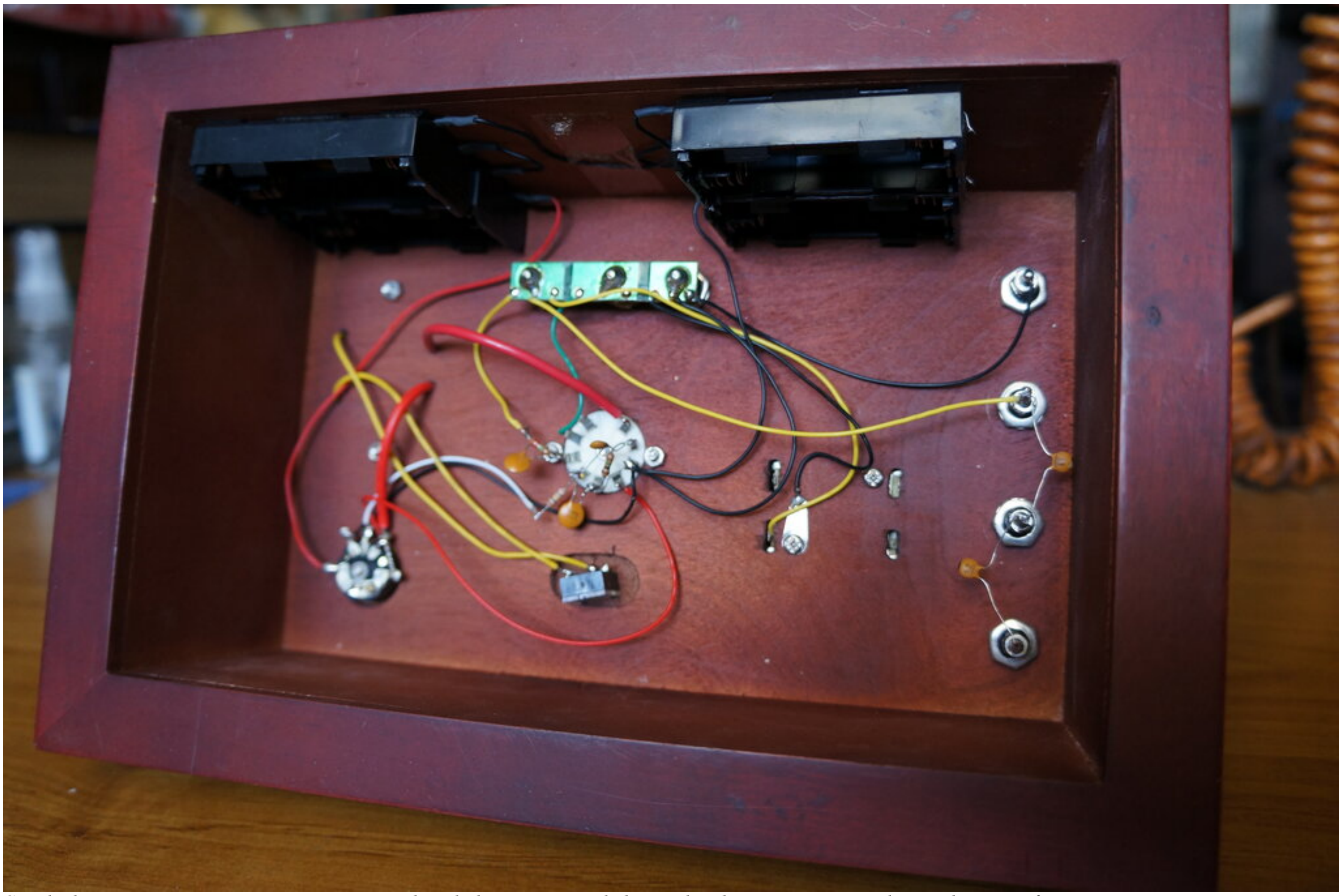
Thames & Kosmos Radio Ace / Radiomann One Valve Receiver.

Coils for MW and SW are supplied.

Despite finding at least 1000 online retailers selling this 'kit' during the mid 2000's, there was very little technical information about this one valve regenerative receiver. It's based on an early kit produced by the German electronic kit company, Kosmos, called the "Radiomann". Outside Europe it's given a more Anglo sounding name, "Radio Ace".
I bought one off eBay from Online Science Mall, back in February 2008. This was one of the cheapest retailers at US$79.95. Postage to Australia was unbelievably fast too; I had the radio in about a week.
Then, in 2022, two more appeared, kindly provided by an enthusiast keen on low voltage valve operation. Some interesting tests were done to see if the design could be improved upon, and also its behaviour with different valves and other modifications. These will be described later.

Construction.
Although promoted as a kit, it is anything but. The radio is already assembled, and all that has to be done to put it into operation is to insert 8xAA cells, screw the aerial coil under the three terminals, plug in the headphones, and connect aerial and earth.
The chassis of the set I bought new is made of veneered MDF and stained in a walnut colour. The two subsequent Radio Ace sets are of a more attractive stained wood, which the manual claims to be cherry wood.
All parts are new. Despite the modernity of the construction, it is very attractive and really does look the part.
Under the chassis, the wiring is point to point. No PCB or tagstrips are used. Wires are soldered to the ends of components with no other support.
Four sets of double AA cell holder are bolted to the back of the chassis.
Plastic binding posts are used to make aerial and earth connections, and also to connect the aerial coil. Two pre wound coils are supplied with the kit; one spiderweb type wound with Litz wire on a blank PCB former for medium wave reception, and the other a conventional air cored enamel copper wire solenoid for short waves wound on a plastic tube.
Modern low impedance headphones with a 3.5mm stereo plug are supplied, and are fed via what is obviously a mains transformer to match the phones to the 12AU7.
The tuning capacitor is an air spaced metal unit, obviously meant for a superhet receiver. The lower capacitance oscillator section is not used.
Quarter watt resistors and ceramic capacitors are used for the circuit.
A miniature 50k switch pot of the type used on transistor equipment is used to switch the 12V supply, and to adjust regeneration.
The valve is a new Chinese 12AU7, and the socket is porcelain.



Simple design using point to point wiring. Even though there is no metal chassis, hand capacitance turned out to be insignificant.

The Design.
The Radio Ace is a very conventional regenerative receiver using a 12AU7/ECC82 twin triode. One triode functions as a regenerative grid leak detector, resistance coupled to the second triode, which is an audio stage feeding low impedance headphones via a transformer. This transformer has, according to the circuit diagram, a ratio of 20:1. This is an error, and it's actually a 220V to 6.3V power transformer, which has a turns ratio of 34.1:1. This was confirmed by testing it. How did I get a ratio of 34.1 when 220 / 6.3 is 34.9? That's because the secondary is actually wound to give out around 7V off load, with the voltage dropping to 6.3V when fully loaded.
Provided there is sufficient turns per volt and the DC flowing through the primary isn't too high, this scheme works well. A 100V audio line transformer would be the other preferred option, in keeping with using standard modern parts.

The unique aspect of design is that the B+ is only 12V, which is the same supply as used by the valve heater. Supply is from eight AA cells. With the heater drawing 150mA, it is wise to use alkaline cells for anything but short periods of use. At 12V the B+ current draw is insignificant. For use of NiCd or NiMh cells, an extra double AA battery holder should be put in circuit, since these cells provide 1.2V, instead of the usual 1.5V from carbon and alkaline cells. A DC input socket would have been a worthwhile feature to allow extended operation from a mains supply (or in my case, the 12V home lighting plant). The manual claims the set works even when the battery has dropped to 9V, which was confirmed.

The aerial is coupled to either the entire coil, or to the tapping, by various values of capacitor. The choice of connection depends mainly on aerial length. In areas with strong signals, spiderweb coils will pick up sufficient signal not to require an an external aerial.
This set uses plate voltage control for adjusting the regeneration.
Feedback is from the detector cathode to a tapping on the aerial coil. This eliminates the requirement for a separate feedback winding.
No volume control is provided, and is not really needed since the volume is seldom loud enough to require it. The regeneration control will however, function as a defacto volume control, although using it this way also reduces the selectivity.

Book Review.
It is obvious that the writings in the manual are a translation from German. Some of the terminology would be strange to those not familiar with German radio. The receiver is never referred to as "regenerative" or "Reinartz", or even "TRF". Instead, it is called an "Audion", which in English, is the name of Lee De Forest's triode.
Nevertheless, it's a nicely set out manual and an interesting read. The 30 "experiments" are fairly limited, and most of them would be applicable to any other radio. They involve things as trying different aerials etc., touching the coil to damp it, and observing how the regeneration control works. Only towards the end do the experiments become slightly more technical, with such things as creating positive feedback through the audio stages, using the resistance of one's fingers to couple to output to the input. There is also some mention of winding your own coils and adding bandspread, although not much practical detail is gone into.

Kit Contents

What You Need to Be a Radio Ace

No.	Item	Quantity	Article No.
1	Pre-wired wooden base	1	771 047
2	12AU7 (ECC82) tube	1	702 891
3	MW coil (Medium Wave Coil)	1	702 886
4	SW coil (Shortwave Coil)	1	702 887
5	Antenna wire (yellow)	1	702 892
6	Ground wire (green)	1	702 893
7	Headphones	1	702 897
8	Radio dial sheets	5	702 894
9	Attachment screws for dial	2	702 895
10	Washers	2	702 896

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Information for the Future Pro

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List of parts which comprise the Radio Ace, and the experiments that can be performed with it.

Would be buyers of the Radio Ace should know that is more of a built up radio to be used as is. It is not, as one might think from the advertising, a kit you install the parts and solder together, or even a kit where the same components are connected in different ways to create different circuits.

Trying it out.
The radio was unfortunately an immediate disappointment. I've had many years of experience with regenerative receivers, and this one was among the worst. Although regeneration was very smooth and operated as it should, the gain and volume were very poor. In fact, the volume was no better than that from a crystal set. Despite their obvious cheapness, the headphones are of reasonable quality, and I verified this by using them with another receiver. However, they are not the most sensitive of this type of headphone I've tried.
The aerial connections seemed to be limited; "Ant. 1" and "Ant. 2" were next to useless, and "Ant. 3" was the only connection that was usable. This was with long and short aerials; the long being my outdoor wire aerial of about 50m length, and the short aerial being the few metres of wire supplied.

I have operated vacuum tubes at low voltage before and knew that this wasn't the cause of poor performance. There should be much more volume into headphones from a 12AU7 operating with 12V on the plates.
The poor performance with the aerial connections was actually expected; since direct or capacitive coupling into an aerial coil is poor practice unless carefully designed. Not only does the aerial load down the coil, but sensitivity at the low end of the band is reduced compared to the top end. A better way is to use a separate primary winding.

The regeneration operated very smoothly, which was expected. I am pleased this set uses plate voltage control for adjusting the regeneration. This, or adjusting the screen grid voltage, where tetrodes or pentodes are used, is the smoothest method. Controlling regeneration by means of a variable capacitor not only makes for critical adjustment, but has bad backlash, and worse, detunes the receiver as the control is adjusted. The other popular means of adjusting regeneration by shunting the feedback winding with a variable resistor can be even worse. While the receiver isn't detuned by this method, the backlash can be considerable, and adjustment extremely critical.
Clearly, some modifications would have to be done to make it a practical receiver with good performance, and not be relegated to being an attractive static display.

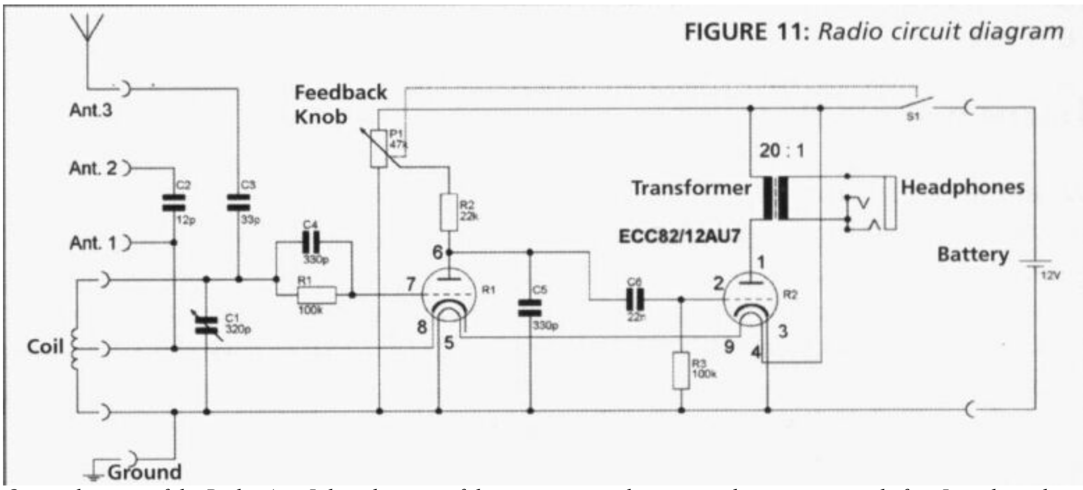


FIGURE 11: *Radio circuit diagram*

Original circuit of the Radio Ace. I thought some of the component values were a bit strange even before I tried out the set. My suspicions were correct. Transformer ratio is 31.4:1

Redesigning the Ace.

The choice of component values had me curious, and it seemed the designer must have had some knowledge of valve regenerative receivers, but some of the values chosen are more suited to a transistor circuit than a valve one.

First thing to deal with was the grid leak. 100k is a rather low value, and there was no way as much detected audio can appear across it, compared to a much higher value. Normal values of grid leak are from around 500k to 2M. I tried 1M which improved things markedly; but 2.2M was even better. The value of grid capacitor is a bit high; something like 100 or 250pF is usual. I left the 330pF in situ as the difference doesn't make it worth changing.

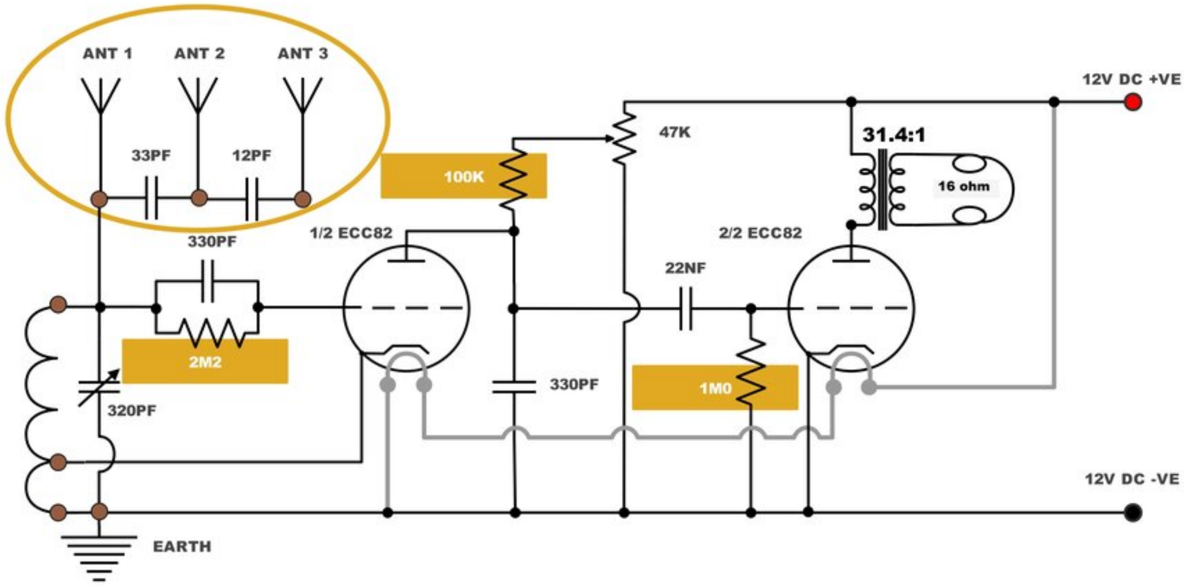
Next was the grid leak for the audio stage. Again, 100k is too low for this application, except for certain high gain output valves which are prone to grid emission, which the 12AU7 is not going to experience running at 12V! Increasing this resistor to a more appropriate value of 1M gave further improvement to volume.

In case you are wondering about the apparent lack of negative bias for the output stage, the 12AU7 triode cannot draw significant current at 12V, and anything more than a small amount of bias would impair the operation of this stage. As it is, a slight negative bias is created by the grid collecting some of the electrons emitted by the cathode, with the negative voltage developed across the grid resistor (R3). The value of grid resistor has some bearing on this, since too low of a value will prevent sufficient bias being generated, and conversely, too high of a resistor could allow too much bias, possibly enough to cut off the cathode current.

Next improvement was for the detector. 22k as a plate resistor is more appropriate to solid state circuitry. Low values mean low gain. It was necessary to increase this resistor at least to around 47k; up to 220k if possible. Doing so with only 12V B+ might reduce the detector plate current to the point where the detector won't oscillate. I had thought of schemes involving 9V batteries to jack up the voltage, but as it turned out this wasn't necessary. With a 100k plate load the detector oscillated just as well as before, even with the aerial coil heavily loaded. The difference now was much more volume and gain. It was what this type of receiver should have.

Final mod was the aerial coupling. While I would prefer a separate primary winding for the aerial coil, to add one would be impractical. An extra terminal would also be needed on the aerial coil. So, I was left with trying to make the best of the capacitive coupling. First thing was to remove the connection to the coil tapping, as connecting aerials here was useless. Worse, connecting through the 12pF capacitor was even more ineffective. This is an absurdly low value to use here, and is more suited to VHF receivers. The coil tapping is at a very low impedance, and a 12pF capacitor has a very high reactance at 1000 kilocycles, meaning virtually no signal gets through.

I settled on a direct connection to "Ant. 1" to allow for very short aerials, via the 33pF to "Ant. 2" for medium length, and via the 12pF in series with the the 33pF to the "Ant. 3" connection, when long aerials are used. The problem with capacitive coupling to aerial coils is that tuning, selectivity, and regeneration are very dependent on aerial characteristics. It's very tight coupling and certain aerials can actually stop the detector being able to oscillate, and this may be evident at only certain parts of the band. Further, even when regeneration can be optimally set, selectivity can still suffer because of excessive signal input due to the tight coupling. The other problem is aerial capacitance is effectively in parallel with the aerial coil, and thus affects tuning range. A long aerial can prevent stations at the top end of the band being tuned to. Also, gain across the band varies; high at the high end where the coupling capacitor reactance is low, becoming less towards the low end when the reactance is higher and less signal is coupled.
This method of aerial coupling is not good design, but if one insists on this method, it's best to use a variable capacitor between the aerial and tuned circuit.



Redesigned circuit, artwork kindly provided by Lance Neame. Modifications were: - R3 to 1M, R2 to 100K, R1 to 2.2M, Ant.1 direct to C1/R1/C4 junction, Ant.2 to Ant.1 via 33pF, and Ant.3 to Ant.2 via 12pF.

The New Improved Ace.
The receiver is now a pleasure to use. Volume is more than adequate now and the DX performance is what it should be; for example receiving 2XL from Cooma in Sydney (about 400km distance) at good volume.
The lack of a volume control is not really important as volume is not overpoweringly loud. Within a few km of the transmitters, it is only necessary to earth the receiver to hear the stations at good volume. An external aerial is not needed. However, 2m of wire connected to "Ant. 1" will give even greater volume. At my location, about 45 to 57km from the transmitters, the full 50m of outdoor aerial connected to "Ant. 3" gives good results. Unfortunately, the limitation of not being able to receive stations at the top end of the band becomes evident when doing this. It would be necessary to reduce the number of turns on the aerial coil to compensate. However, some coverage at the low end of the band would be lost. The seriousness of the problem is not sufficient to warrant modifying the aerial coil.

To the listener it certainly isn't obvious the receiver is running off 12V. It performs much like any other one valve set.
One convenient aspect of this receiver is the binding post aerial coil connections. It becomes a very handy test bed for trying out other coils without having to desolder anything. Another feature is that provided one completes the grid circuit in the DC sense, when the aerial coil is removed, the set can be used as a low power headphone amplifier. Connect the audio input between "Ground" and "Ant. 1" (in the modified receiver, or to the aerial coil terminal that connects to the tuning capacitor in the unmodified set). If the audio source does not have a DC path to earth, simply connect a resistor across it. The value isn't critical; something around 1M will do. Using the set like this isn't anything new; it was often done to add gramophone pickups to early radios. Of course, the cathode must be connected to earth.

Other Valves.
Given there's quite a few other twin triodes with the same pin connections, I decided to try some other types to see how well they worked in this regenerative circuit at low voltage. First off, the other well known 12.6V heater types; 12AT7 and 12AX7. Some faint sound was heard with a 12AX7, but no regeneration was possible. The 12AT7 was better in that regeneration was possible, but distortion was evident.
Then to a couple of 6.3V types, with the heater temporarily powered from an external supply. 6ES8 is a frame grid VHF amplifier used in TV tuners. As I suspected, due to its low plate voltage (90V) and very high gain (12.5ma/V) it worked well; certainly just as well as the 12AU7. 6CG7 was the other valve I tried. It's actually the 9 pin replacement for 6SN7. It was intended to be used in TV line oscillator circuits, but like other valves found widespread applications elsewhere. Despite its similarity with 12AU7, not only did it work very well, I suspect even slightly better than the 12AU7. I think the 6CG7 works so well with 12V plate voltage simply because of its hotter cathode (6.3V@600ma) which is twice the power of the 12AU7's heaters. I do wonder also if the larger cathode and plate area also helps. No doubt 6SN7 or 12SN7 should work the same, being the equivalent. Presumably 12BH7 would be another suitable candidate. However, if operating off a limited battery supply, the obvious choice is to stick with the 12AU7, as all the other types draw more heater current.

12V High Tension for Valves.
Operating valve plates and screens off 12, 9 and even 6V is not new. Not only was this done with one valve sets just like this, to avoid a separate, expensive, and large B battery, but from the late 1950's to the mid 1960's the technique was used in hybrid car radios. Valves were used for the RF, Converter, IF, detection, and audio amplifier in the normal way, but running off 12V B+. Because valves cannot provide high power output at 12V, a transistorised stage was used to drive the speaker.
There is sometimes the assumption that the valves used in hybrid car radios were ***all*** of the space charge type. Space charge mode is used with so called "dual grid" valves like the type 49 and later 12K5. Here, positive voltage is put on the first grid (equivalent to the control grid) to force an increased electron flow. The second grid (equivalent to the screen grid) is used as the control grid. Some pentodes, in particular the

6C6, have been connected to work in space charge mode in simple one or two valve sets running off 6V B+. Apparently, when so used, the heater voltage becomes rather critical and needs to be less than 6V.

Apart from the valve driving the output transistor in some car radios (e.g. 12K5,12AL8,12DL8, 12DS7,12DU7,12DV8), the other valves are in fact ***not*** space charge valves. Not only does the circuit diagram prove the point by showing them connected as per normal 250V valves, so does the internal construction. Generally, the space charge valves provide an audio power of 20-40mW which is sufficient to drive a power transistor operating in single ended class A. However, conventionally constructed valves are also used as drivers; 12J8 and 6ET6 are examples. A few Astor circuits even show a 6BA6. Where a conventionally constructed (i.e. non space charge) valve is used and cannot drive the output transistor on its own, a second transistor is used for driving purposes.
One car radio using valves at 12V has been described here.

The plate current is minimal when conventionally constructed valves are used on 12V. What needs to pointed out here is there's a big difference in voltage gain and power gain.
Plate voltage is not so important with voltage gain in the front end of a radio receiver, and in fact reducing the B+ does not cause it to drop off as much as might be thought. On the other hand, power gain is drastically reduced, and conventional output valves with 12V plate and screen supply can only provide milliwatts of output. Good for headphone use, or even a speaker in a quiet room, but totally useless for a car radio.

The 12V "hybrid" or "car radio valves" (especially those in the front end) are essentially the same as their mains counterparts, but are either selected versions, or versions made to much higher specifications. Radio & Hobbies for April 1959 discusses the design of hybrid car radios, and gives examples by saying 12BL6 is constructed similar to 12BA6, and 12AD6 is similar to 12BE6. Essentially, the grid characteristics are made uniform for low voltage operation. It's possible to use selected 'mains' valves as replacements, or alternatively adjust the bias to suit if necessary.
To prove this theory, I got out a mains operated radio with the very typical 6AN7(ECH80) and 6N8(EBF80) converter and IF/detector valves. The audio was a 6DX8(ECL84) triode pentode. I took the 6X4 rectifier out, connected a 12V DC supply into the set's HT line, bridged all the screen and decoupling resistors, and reduced the 6AN7 oscillator feed resistor to half. The heaters were powered off the transformer as per usual. I wasn't really surprised at the very comfortable headphone volume level, and the good sensitivity of the set. Sensitivity appeared to be much like any other valve superhet. The set really started to liven up at 15V B+. The limiting factor was the local oscillator being shunt fed by a resistor. Had I changed the local oscillator circuit, the set would have functioned with less than 12V.

Just for fun, when servicing hybrid car radios, I have sometimes tried the mains equivalent type of valve to compare performance, and in all cases the set did work.
To further prove the point, I have constructed a perfectly normal superhet receiver using '250V' type valves, but operating on 12V. See link below.

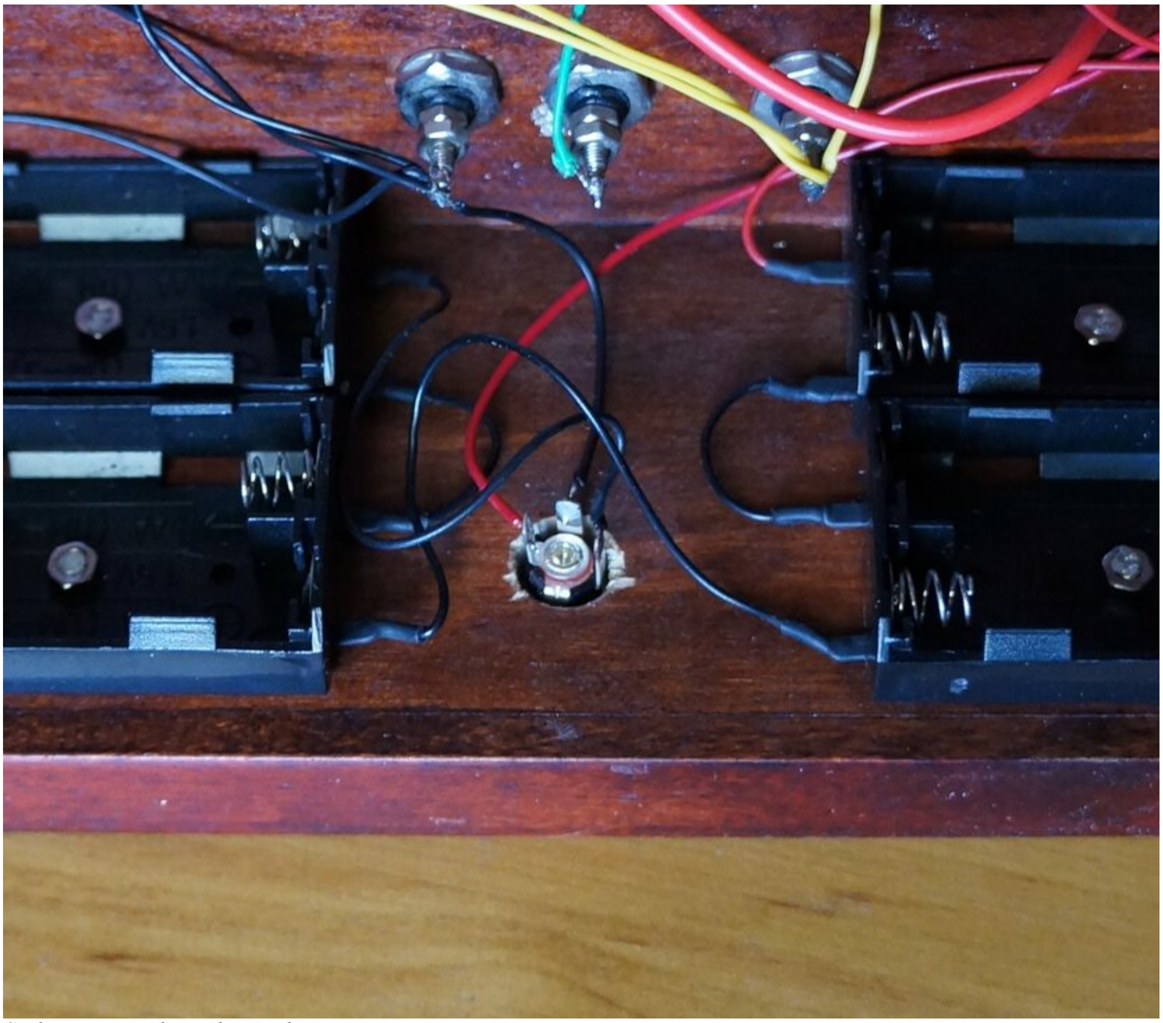
- MW Superhet using normal valves with 12V B+
- VHF Super-Regenerative Receiver with 12V B+
- 12V B+ for valve amplifiers.
- One Valve receiver with 9V B+.

More Information on the Radio Ace:
There is some interesting and useful info here.
Use the Google translator to read in English here. The site examines using other valves and aspects of the design. Its author is the designer of this and other Kosmos kits.

DC Input Socket for the Radio Ace.
With a current draw of 150mA, operating the set off AA cells is impractical and expensive for serious use. For alkaline cells, you could expect about 10 hours operation. Carbon Zinc cells would be considerably less; maybe an hour if used continuously. NiCd or NiMh cells would obviously be more economical, but would still require charging at least every at least 10 hours. Two extra cells would be required due to the 1.2V terminal voltage.

DC socket makes the Radio Ace much more practical to use.

Since the receiver is most likely to be used where a mains supply is available, the obvious thing to do is provide an external 12.6V input socket. Because of the thickness of the wooden chassis, some thought had to be given how to mount the socket, and what type of socket to use. I used a 2.1mm panel mount DC socket. This required an 8mm hole to be drilled from the outside of the chassis, but because the socket is designed for a panel of only a few mm thick, a 12mm hole had to be drilled from the inside to accommodate the socket body. Some care needs to be taken drilling from the inside, since you don't want to go all the way through.



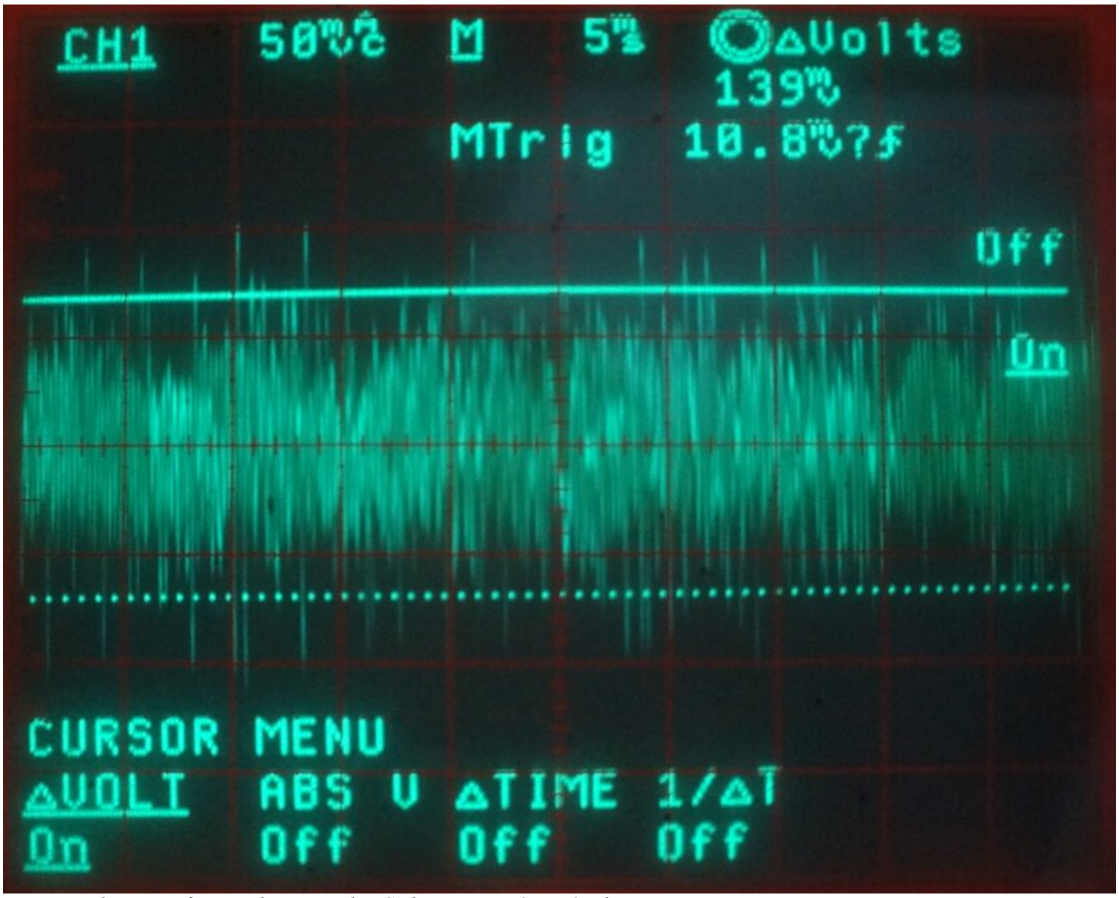
Socket is recessed into the wood.

The result is very professional looking, and eliminates the clip leads I was previously using. Although I don't ever anticipate using AA cells, their holders were left in situ, and the negative wired through the switch in the socket.
An important point is that the DC source needs to be regulated and/or filtered, since it is the B+ for the receiver. Any hum will be audible. This rules out ordinary plugpacks, although a simple RC filter for the B+ should fix that. The heater supply does not need filtering, since the 12AU7 is indirectly heated. I use a regulated bench supply.

Experiments with the Radio Ace.
A lot of the ideas and inspiration for the following experiments came from Lance Neame, who is just across the ditch in NZ. You can see some of his Radio Ace videos here:

- https://www.youtube.com/watch?v=stODIuHCbrE&t=3s
- https://www.youtube.com/watch?v=JTkiT8PFTq0&t=24s
- https://www.youtube.com/watch?v=x5rmA4OXk7Y

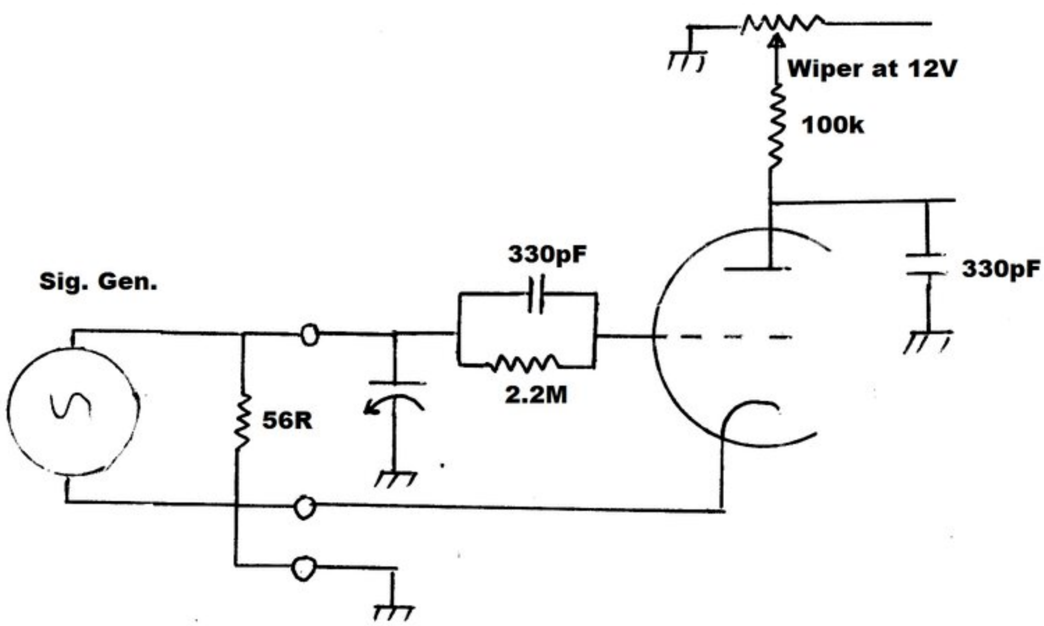
Setting a Reference.
Off air signals are not an accurate way to test the receiver. Apart from being variable with signal strength, the varying program content makes it difficult to provide anything but subjective results.
A set of fixed and calibrated operating conditions needed to be established first. What should these be?
Setting up the Radio Ace for normal reception from one of the 5kW transmitters about 57km away, the detector plate voltage with average program material was about 100mVp-p.



Detector plate waveform with set tuned to Sydney station 2UE, 954kHz.

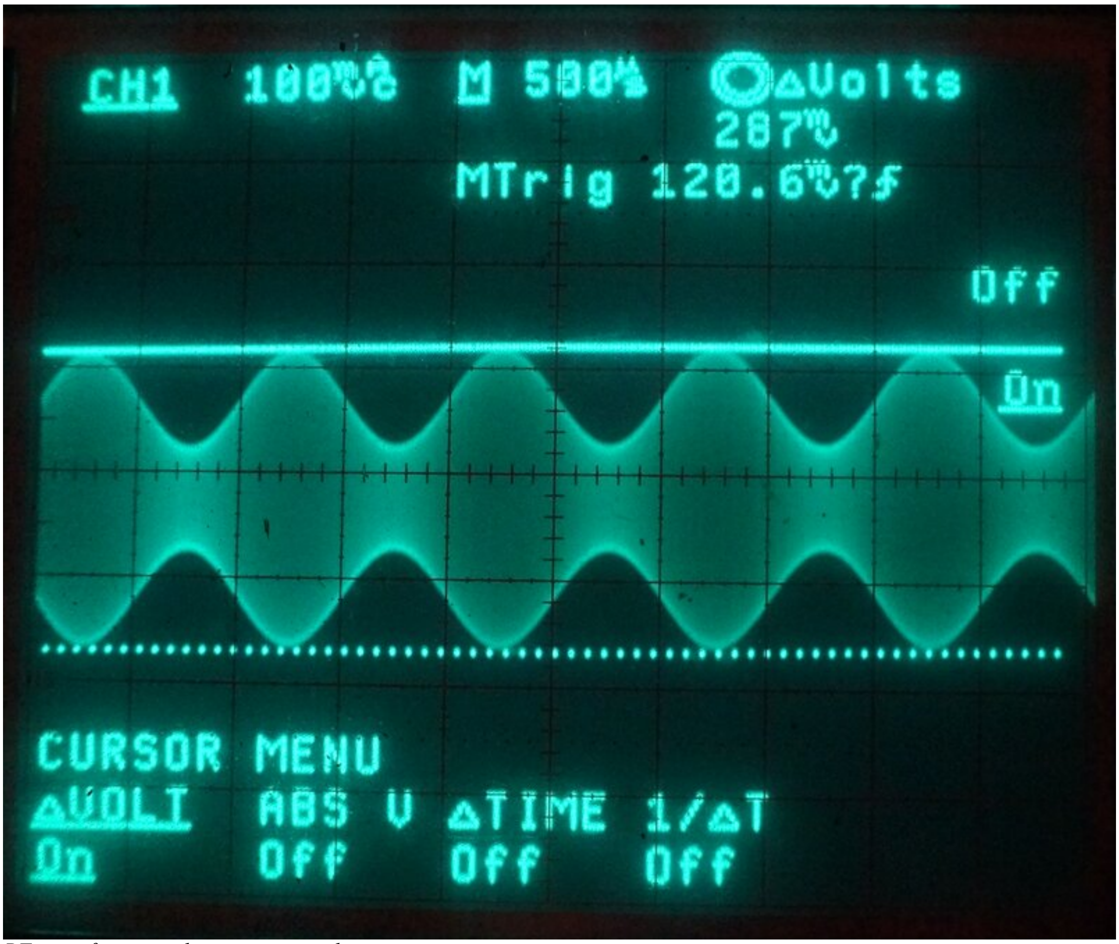
The obvious conditions for the RF signal generator would therefore be to provide an input signal which provided 100mVp-p at the detector plate.

Since the first lot of experiments were to test loading and biassing of the detector and audio stages, the tuned circuit and regeneration was not used. In fact, the regeneration was deliberately omitted since it would have to be varied depending on the experiments, which would make the measurements meaningless. The adjustment of the regeneration is also subjective. It's best to simply use the detector valve as is, with a fixed gain. The detector plate voltage was set to maximum.



Test circuit used for the following measurements. Eliminating the tuned circuit and regeneration provides a known input voltage.

The signal generator was loaded with a 56R resistor, and the RF fed straight into the 2.2M and 330pF grid leak components. Thus, AM detection still occurs as normal. The coil was removed, and the detector cathode earthed. The tuning condenser was left in circuit, as it has no effect without the coil.

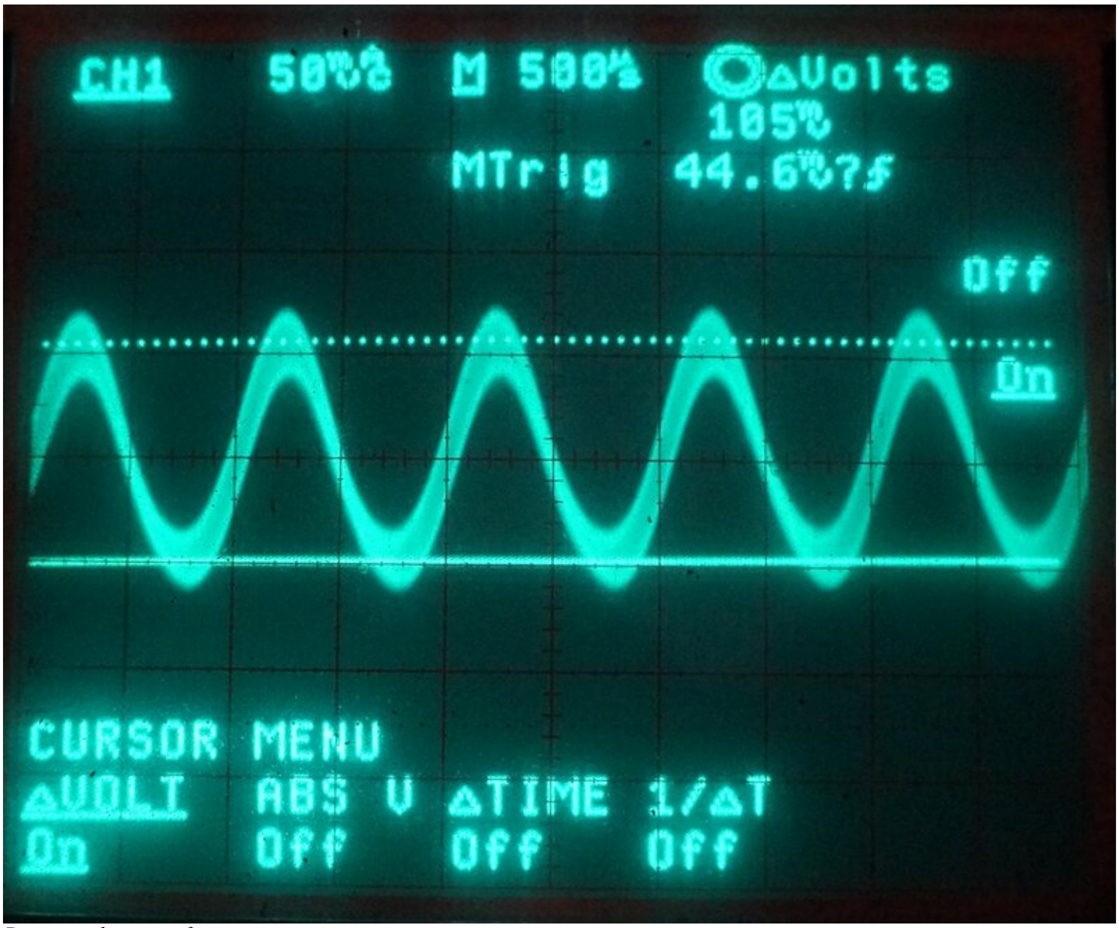


RF input from signal generator into detector.

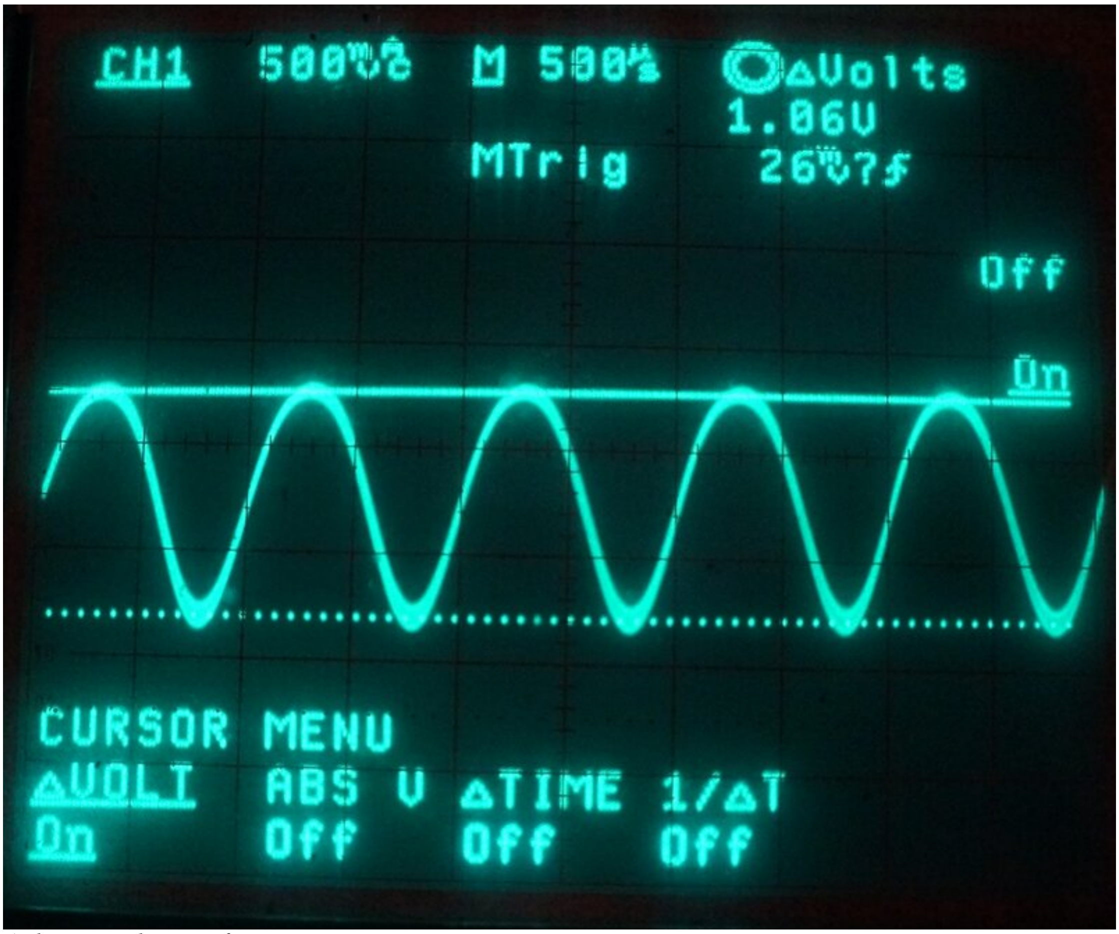
A typical average modulation level might be 50%, so this was chosen, modulated at 1kHz. The middle of the band is as good as any carrier frequency, and 900kHz was chosen. To get the required 100mVp-p detector plate voltage, the RF input signal needed to be 65.3mV.

RF Input	**Frequency**	**Modulation**	**Detector plate (100k)**	**Audio Plate**	**Headphones**
63.5mV (50R)	900kHz	50%, 1kHz	100mVp-p	1.05Vp-p	22.4mVp-p

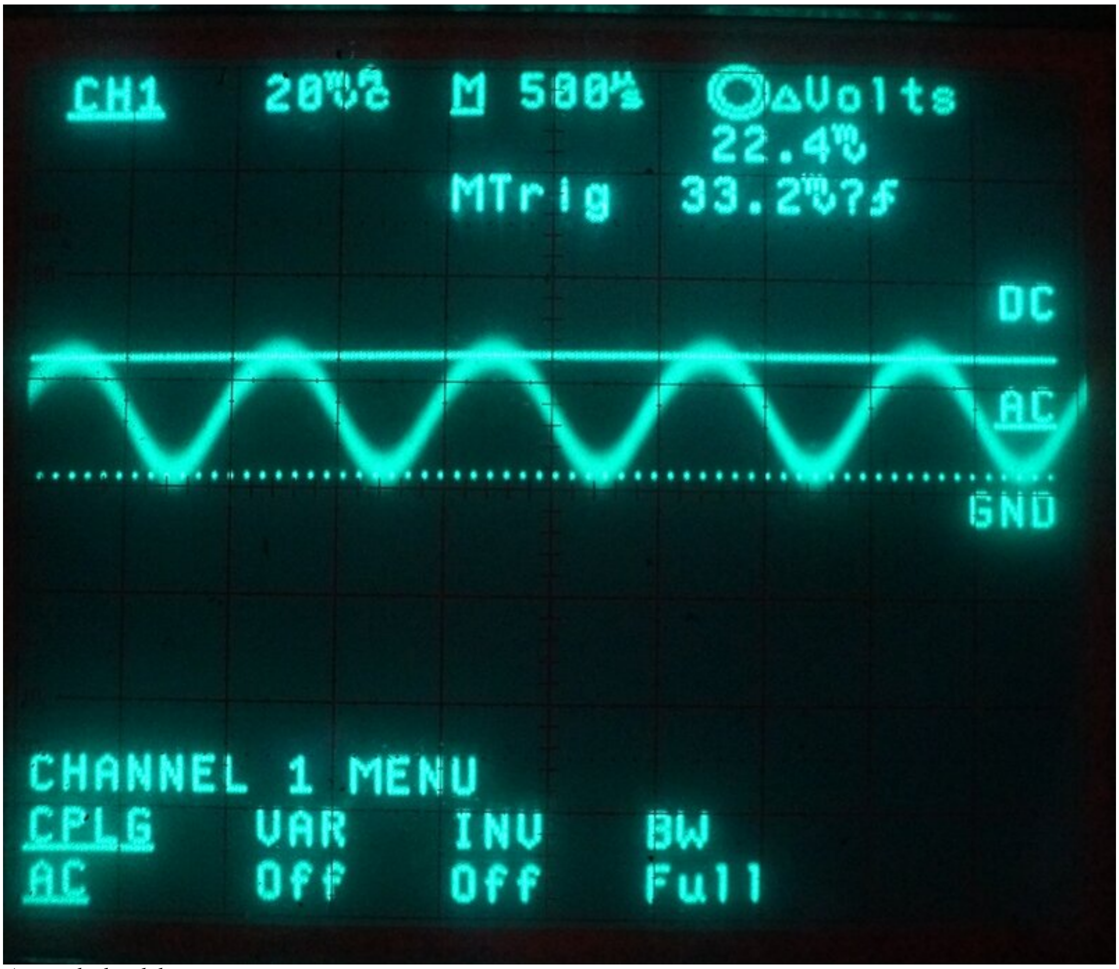
Initial operating conditions for the standard circuit.



Detector plate waveform.



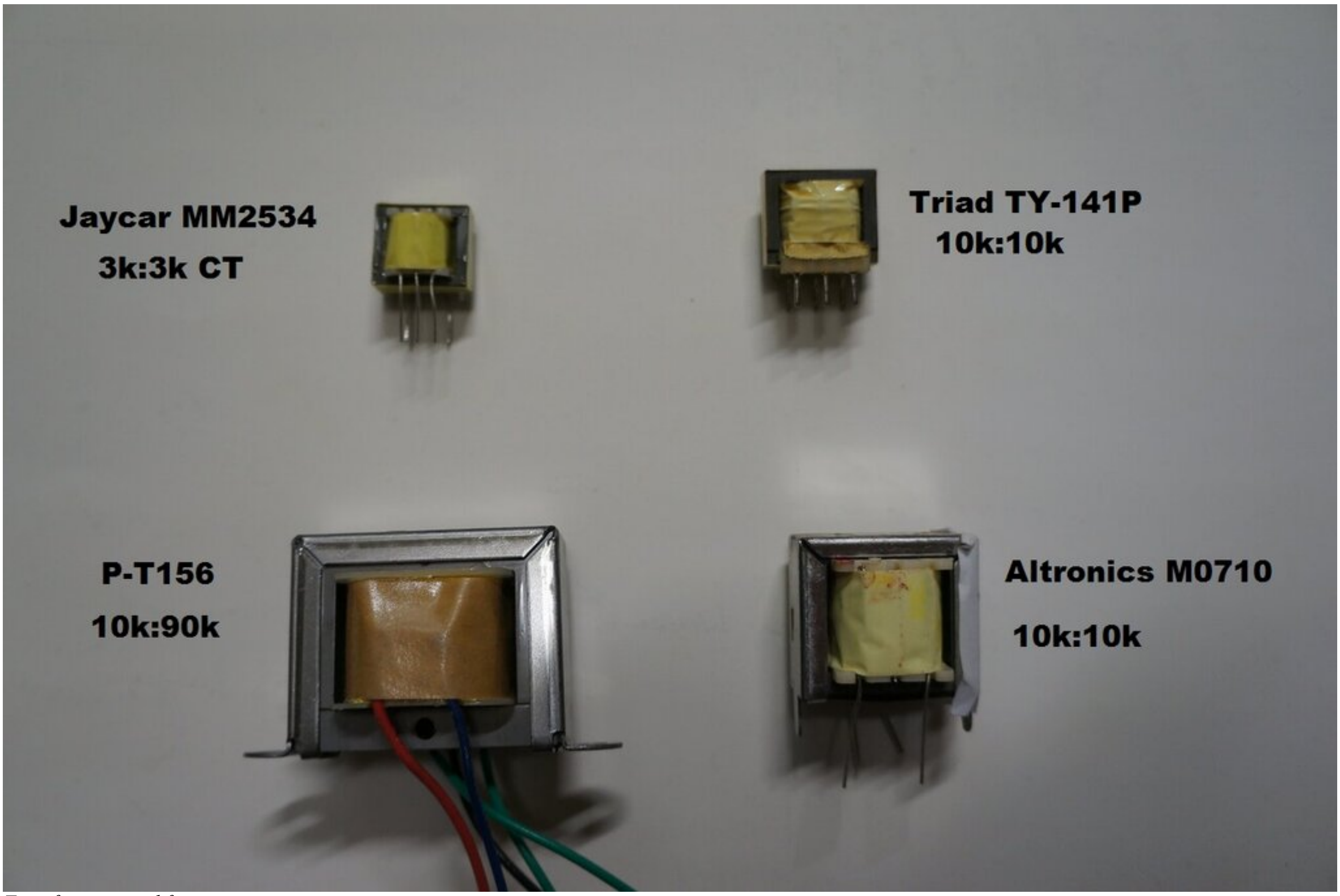
Audio output plate waveform.



Across the headphones.

Detector Loading.

Investigations were made into how choke and transformer coupling compared to the existing resistive coupling. Choke and transformer coupling have the advantage of increasing the DC plate voltage, which in turn provides a higher gain. Transformer coupling can further increase the gain if a step-up ratio is provided.



Transformers used for tests.

A selection of four audio transformers were used for the following tests.

- Jaycar MM2534. This is a transistor coupling transformer designed to drive output transistors in small push-pull amplifiers. Impedance ratio is 3k:3k centre-tap.
- Triad TY-141P. 10k:10k audio transformer.
- P-T156. This appears to originate from Antique Electronics. It is an interstage transformer intended for driving valve grids in push-pull. Impedance is 10k:90k CT.
- Altronics M0710. Described as an 'audio bridging' transformer. Impedance ratio is 10k:10k.

Frequency response was measured at the detector plate with an audio voltmeter. The 0dB frequency was 1kHz. The existing 330pF plate bypass was in circuit.

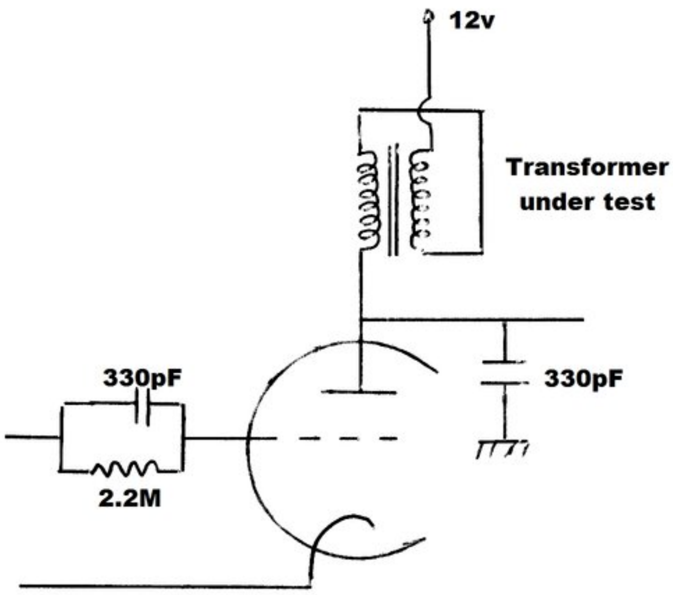
1. Resistor.

- 100k resistor.

Detector Plate	**Audio Plate**	**3dB Frequency Response**
100mVp-p	1.05Vp-p	5Hz - 18kHz

2. Choke.

For the tests, the smaller transformers were used as chokes by connecting the two windings in series. Obviously, phasing is important to obtain the full inductance.



- Altronics 10k:10k.

Detector Plate	Audio Plate	3dB Frequency Response
206mVp-p	2.12Vp-p	130Hz - 8.8kHz

- Jaycar 3k:3k CT.

Detector Plate	Audio Plate	3dB Frequency Response
162mVp-p	1.67p-p	340Hz - 12.4kHz

- P-T156 primary.

Detector Plate	Audio Plate	3dB Frequency Response
180mVp-p	1.96Vp-p	330Hz - 4.3kHz

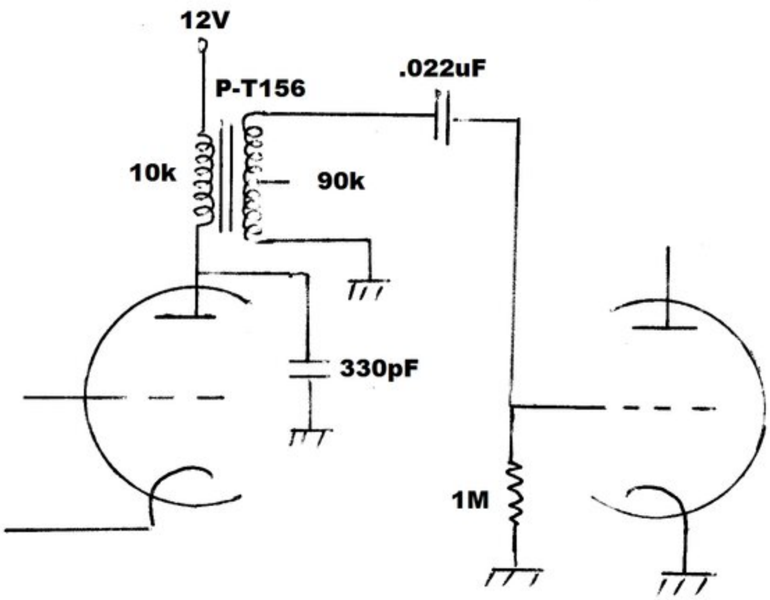
- P-T156 secondary.

Detector Plate	Audio Plate	3dB Frequency Response
213mVp-p	2.12Vp-p	43Hz - 12kHz

- Triad TY-141P 10k CT:10k CT.

Detector Plate	Audio Plate	3dB Frequency Response
184mVp-p	1.98Vp-p	57Hz - 13kHz

3. Transformer.
Only the P-T156 was tested in this configuration, since previous tests here had shown that lower impedance transformers were vastly inferior.



- P-T156 used as transformer with full secondary.

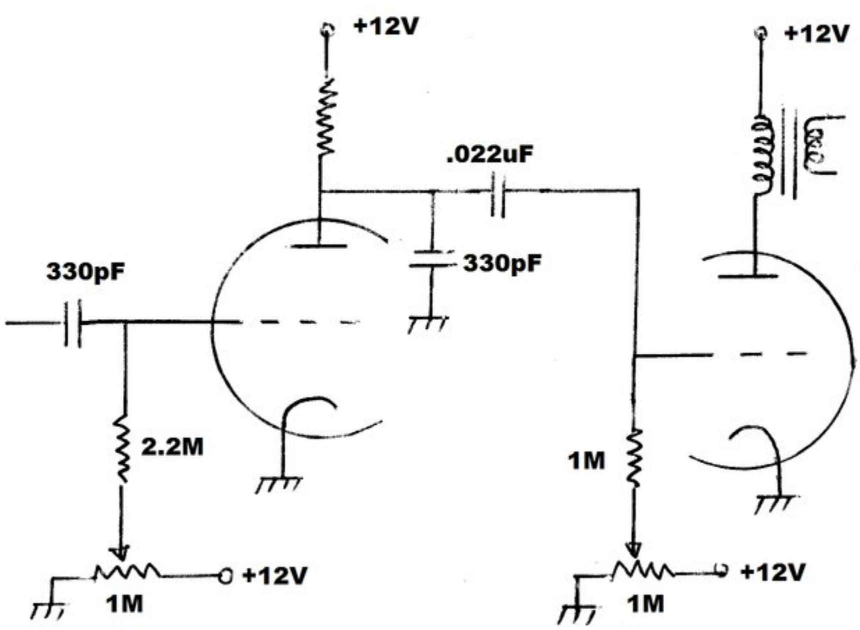
Detector Plate	Audio Grid	Audio Plate	3dB Frequency Response
124mVp-p	375mVp-p	3.69Vp-p	176Hz - 2.9kHz

Note that the detector plate voltage has fallen from 180mV to 124mV when using the P-T156 as a transformer. This is due to the loading of the secondary winding by the output triode grid. Nevertheless, this has been more than compensated for by the step-up ratio.
The .022uF and 1M might seem superfluous, since the secondary of the transformer could provide DC continuity from grid to earth for the audio valve. However, the grid resistance needs to be around 1M for the triode to generate suitable bias.

Conclusion.
In all instances of choke coupling, distortion was clearly visible from around 5kHz to 7kHz depending on the transformer. Although it provides higher gain, choke coupling does not provide distortion as low as, and frequency response as good as, with resistive coupling.
The P-T156 transformer, used in the normal way, provided the best gain but the worst frequency response. However, it is no worse than a commercially made transistor superhet. Distortion was acceptable throughout the audio range.

- For inductive coupling between the detector and the audio stage, best results are from the P-T156 transformer, connected as a transformer.
- Best sound quality is with the 100k resistor.

Biassing the 12AU7.



Circuit for operating the triodes with positive bias. The bias voltages given in the test results are taken at the pot wipers.

- **Audio Stage**

Taking the audio valve grid positive or negative via its 1M resistor did not increase the audio output. The 1M resistor and the grid emission seems to provide the right amount of bias. Importantly, the input signal to the audio triode is not sufficient to cause clipping.

- **Detector**

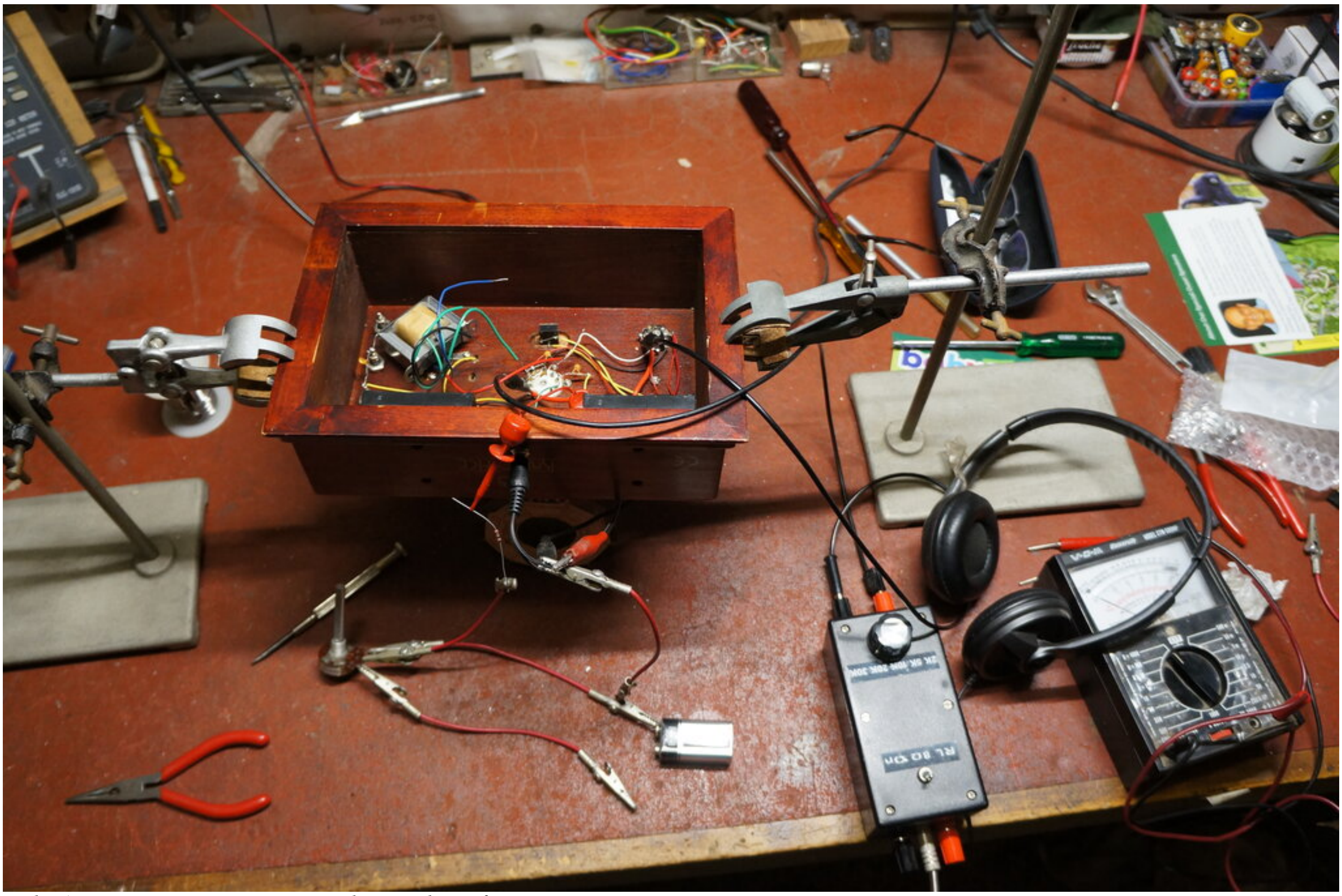
A slight positive bias to a grid leak detector can sometimes improve sensitivity and output. Doing so causes the diode (formed by the grid and cathode) to conduct more at a lower voltage. Thus, the detector is more responsive to a weak signal.
The detector load chosen for this experiment was the P-T156 transformer primary. To more accurately observe the effect, the signal input was reduced to 20mV.
The bias supply was introduced through the earthy end of the 2.2M resistor. Note that the grid leak resistor can be connected across the grid capacitor, or from grid to earth. The DC conditions are the same.

Bias via 2.2M	Detector Plate
0	42mVp-p
+2.9V	59mVp-p

Detector output peaked with a bias of +2.9V.

Optimum Load Impedance.
The Radio Ace uses a 220V to 6.3V output transformer. Because the offload secondary voltage is closer to 7V, the turns ratio is about 31.4:1. Assuming the headphones are 32R each, the secondary load will be 16R since they are connected in parallel. Since the impedance ratio is the square of the turns ratio, 31.4 x 31.4 x 16 gives 15.8k at the primary.
Maximum output was, however, found to be with a primary impedance of 20k. A multi-tapped P.A. line transformer was used for this test, and output was 58mVp-p into an 8.2R load resistor across the 8R secondary. The difference between the two transformers is minimal, and it is hardly worth replacing it. In any case, the impedance of the headphones used determines what the primary impedance will be. Ideally, the headphone drivers should be 32R each, or slightly higher.

Conclusion.
For maximum gain and output, use the P-T156 to transformer couple the detector to the audio grid. Use an output transformer which presents a 20k impedance. Bias the detector to +2.9V (this may vary with individual valves).
With these modifications, the maximum RF input to the detector can be as high as 92.5mV before distortion. Output is then 98mVp-p into 8.2R.

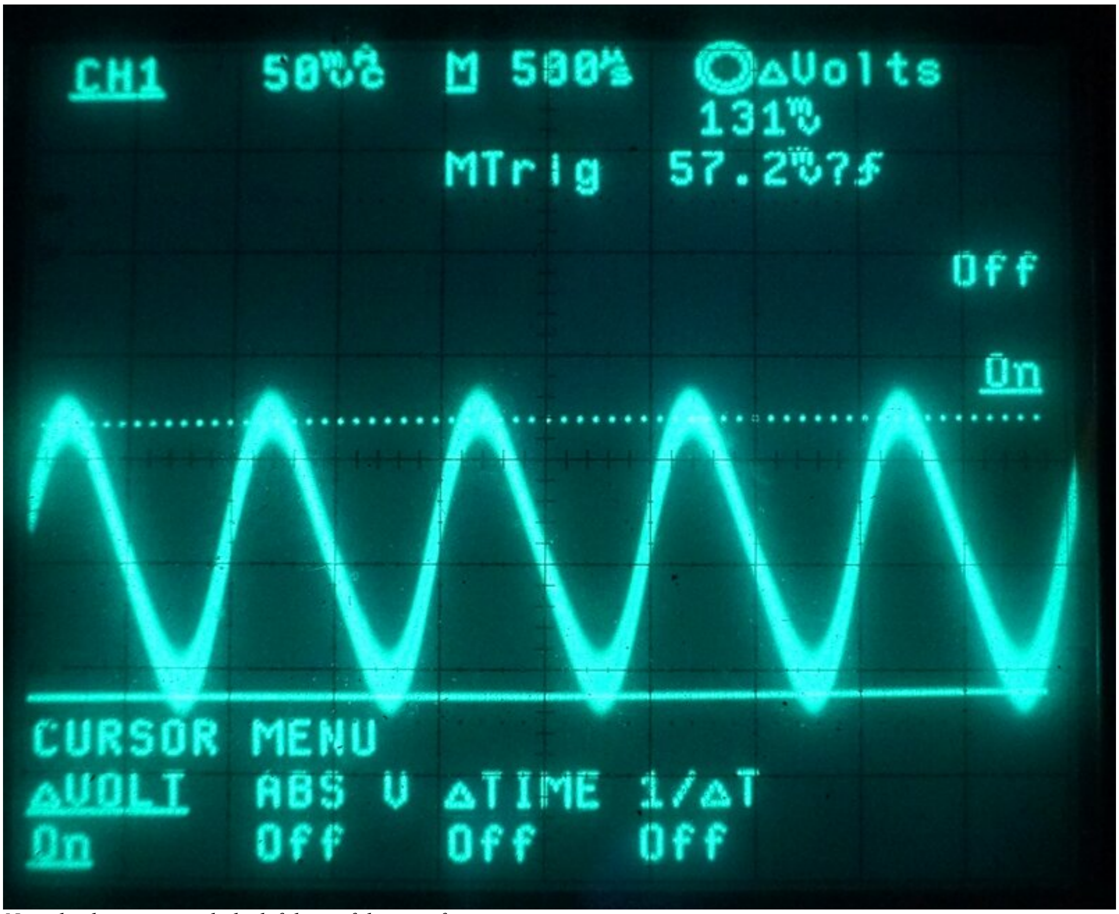


Radio Ace in its testing position. Note multi-tapped transformer.

12AT7 Experiments.
Along with 12AU7, other common 12.6V heater twin triodes include the 12AX7/ECC83 and 12AT7/ECC81. These are of similar construction with the same heater ratings, and pin connections.
Previous experiments with 12AX7 showed it to be a very poor performer with 12V B+, except when used as a class B output stage. The 12AT7 seems to hold a bit more promise, so it was tested.
The biassing circuit was the same as shown for the 12AU7 previously.

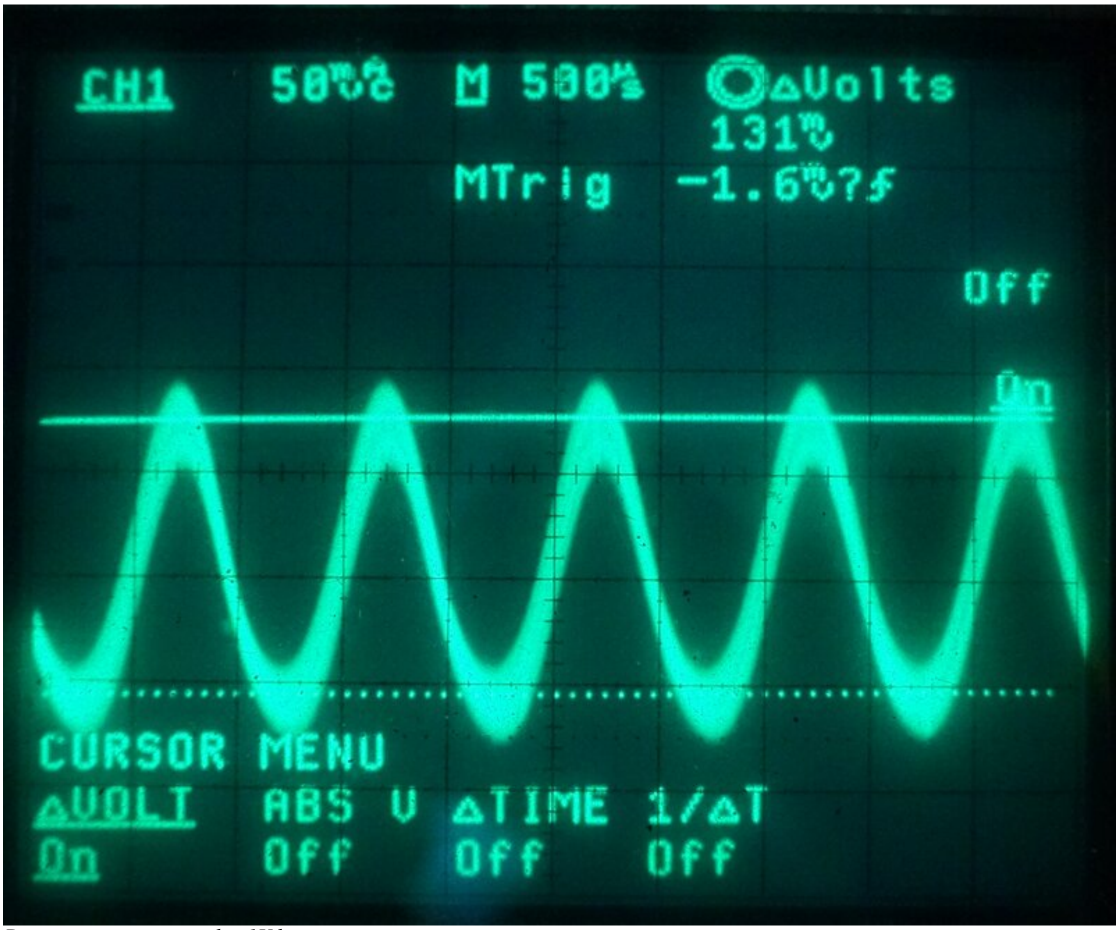
- **Detector.**

When tested in the standard circuit with 100k plate resistor, the plate voltage was 131mVp-p. On that basis, the gain was higher than the 12AU7. However, slew rate distortion was visible.



Note the distortion, with the left lean of the waveform.

Distortion cleared with +1V bias via the 2.2M.



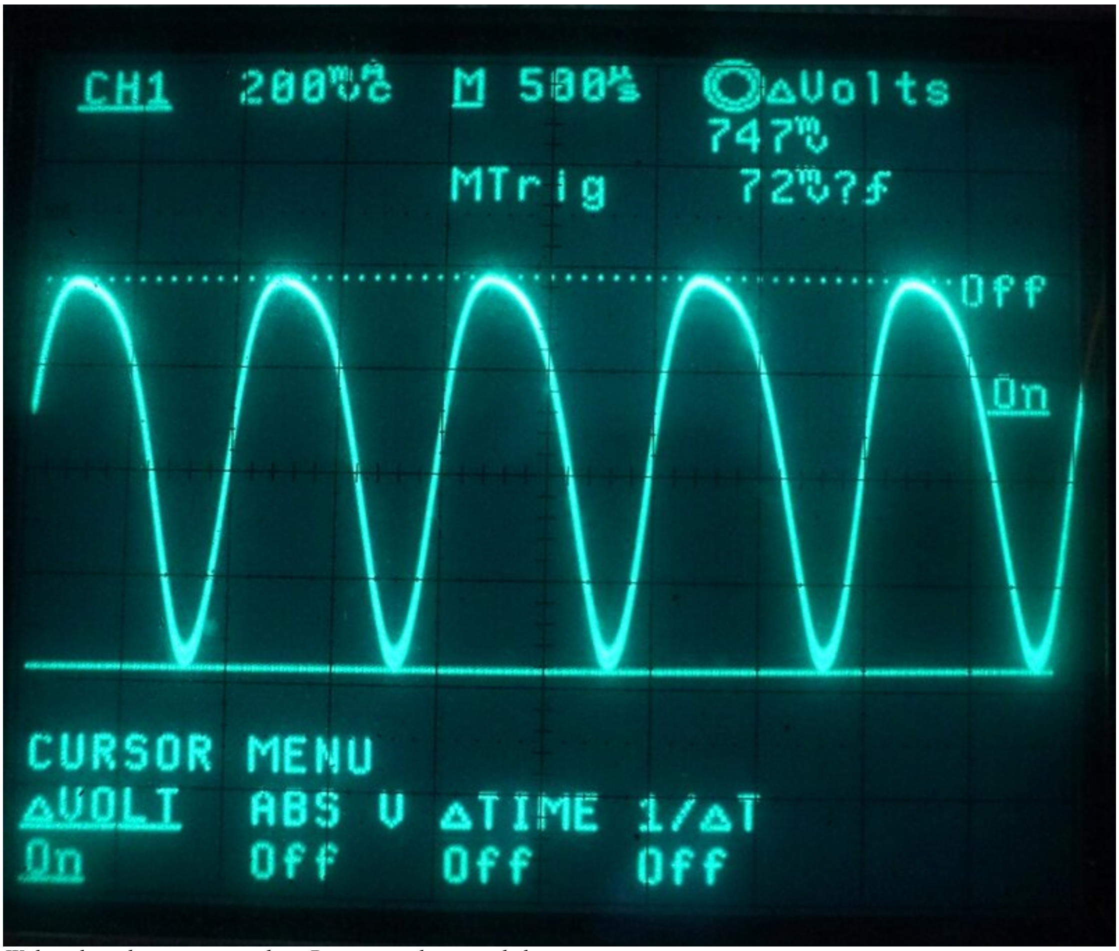
Distortion improves with +1V bias.

If bias was further increased to +12V, plate voltage increased to 185mVp-p.

Detector Bias	**Plate Voltage**	**Output**
0	131mVp-p	Distortion evident.
+1V	131mVp-p	Distortion removed.
+12V	185mVp-p	Max output.

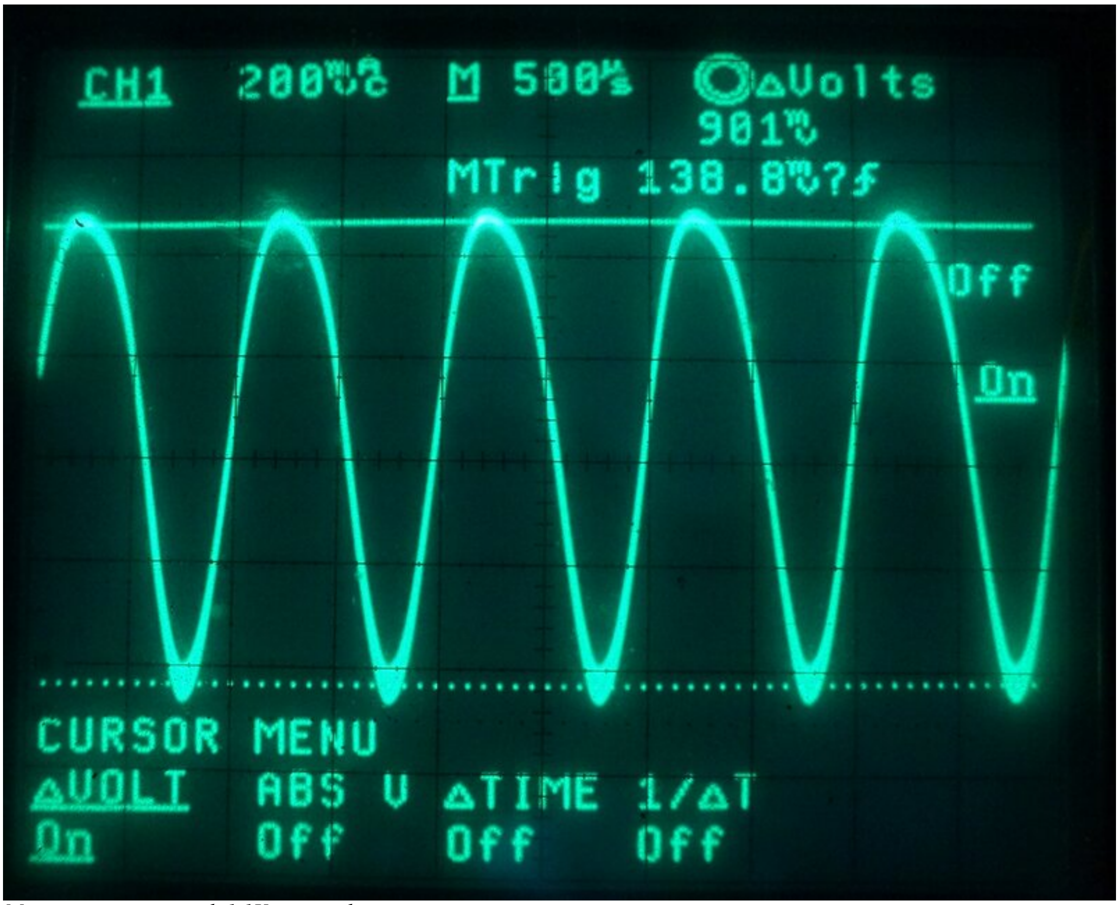
- **Audio Stage.**

Distortion was evident in the audio stage, with a 12AT7 operating in the standard circuit.



With no bias distortion is evident. Positive peak is rounded.

Positive bias had a worthwhile effect on the distortion.



Maximum output is with 1.1V positive bias.

Plate Voltage	**Bias via 1M**	**Distortion**
715mVp-p	+3.6V	Least distortion.
729mVp-p	0	Most distortion.
874mVp-p	+1.1V	Max. output. Some distortion.

The maximum peak to peak output was with +1.1V bias. Increasing the bias beyond this reduces the output, but also reduces distortion. +3.6V was the best compromise with the least distortion. A further increase only reduced output, without any further improvement in distortion.

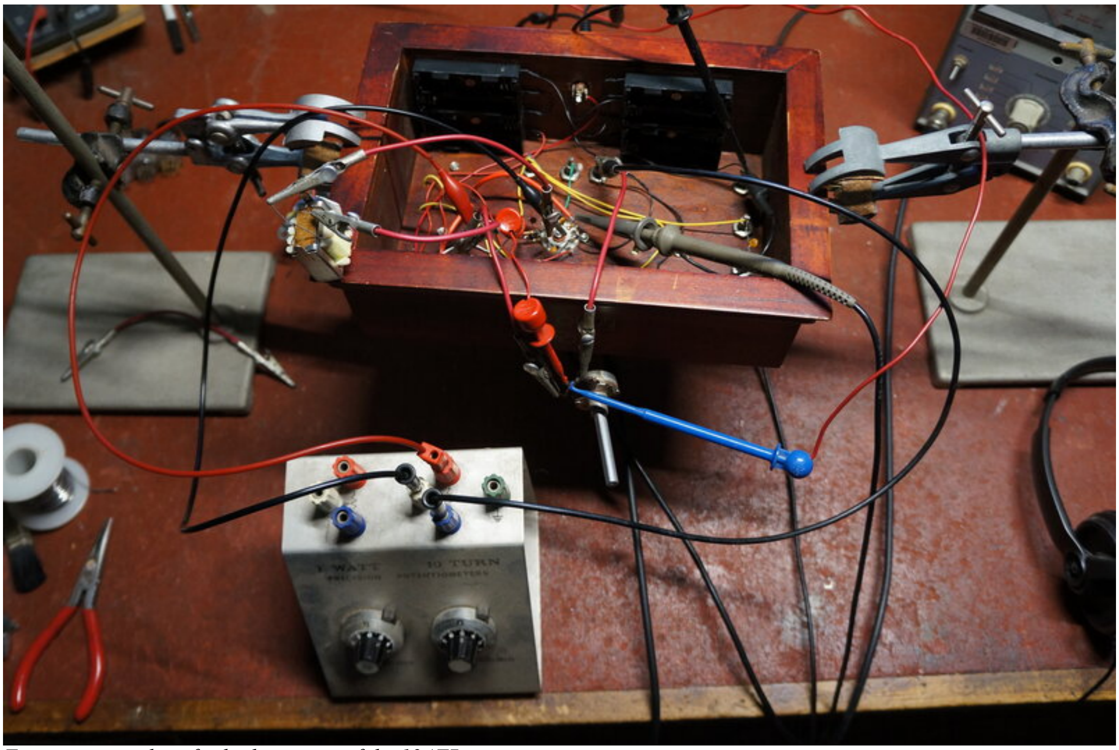
Choke Coupling.
In view of the increase in detector output with a choke plate load, it was thought that more audio output should be available, and experiments were done to see how a positively biassed audio stage would work with a greater input signal.
For this test, the Altronics 10k:10k transformer was connected as a choke.

The detector required +1V bias to clear the distortion. From here, increasing the bias would increase the output.

Detector Bias via 2.2M	**Detector Plate**	**Audio Output**	**Audio Bias via 1M**
+1V	311mVp-p	1.97Vp-p	+1.7V
+12V	590mVp-p	distorted	0
+12V	270mVp-p	3.4Vp-p	+6.5V

The problem here is that as the bias is increased, the 12AT7 grid becomes low impedance, thus loading down the source. You can clearly see that detector output voltage falls as the following audio stage is biassed positively.
Yet, positive bias is required to get maximum power output. Positively biassing control grids to make valves run on low voltage reduces the input impedance. This obviously causes difficulty where the preceding stage is of high impedance, as it usually is with valve circuitry. The best compromise here is to use the lowest amount of bias that gives acceptable results.

There's almost an infinite choice of valves, transformers/chokes, and circuit configurations to try, but the purpose of these experiments is to give an idea of what it possible. Anyone modifying their Radio Ace, or building up the circuit from scratch, would be wise to do further experimentation to optimise the results.



Testing positive bias for both sections of the 12AT7.

Conclusion.
After this testing, what conclusion have I come to?

- Transformer and choke coupling increases gain, but at the expense of distortion and frequency response.
- The 12AT7 can be made to work with positive bias, but is always more distorted than the 12AU7. Although as a detector it provides more output than the 12AU7, it cannot provide quite the same output into the headphones. (A twin triode with dissimilar sections is an interesting possibility).
- Positively biassing valves will make them draw a higher current at 12V B+, but severely reduces the input impedance by so doing.
- For operation at very low B+, the best choice of valves are those that draw sufficient cathode current without positive bias.
- The Radio Ace works best with its original modified circuit using a 12AU7 or similar valves.

Regeneration. How Much Does it Improve Sensitivity?
We all know that regeneration provides a huge increase in sensitivity, but have you ever wondered by just how much? Without regeneration, the receiver with a grid leak detector is no more sensitive than a crystal set. Its only advantage is the higher audio gain.
The next test gives some approximate figures.

The coil was reconnected, and the RF signal generator (loaded by 56R) was connected to the "Ant. 2" connection. The detector cathode was earthed, so that the receiver had no regeneration. Again using 100mVp-p as a detector plate voltage reference, we now find the RF input required is now only 2.37mV. Thus, the gain of the tuned circuit in its passive form is 63.5 / 2.37 = 26.8.

Next, the cathode tapping of the coil was reconnected, and the regeneration optimally adjusted. Now, to obtain 100mVp-p at the detector plate, the RF input was 168uV.
Therefore, the sensitivity improvement is 2.37 / 0.168 = 14 times.
The gain of the detector as a whole is 100mV / 168uV = 595.

Detector Configuration	**Gain from RF input to detector plate**
Detector only	1.6
With tuned circuit	42
With tuned circuit & regeneration	595

In practice, about 16uV was detectable, listening with the headphones. About 40uV was required to follow the program comfortably.

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6 Volts B+.
There are a number of 6.3V heater twin triodes which have the same pin connections as the 12AU7 (except no heater centre-tap). A quick test was done to see if 6V operation would be possible. Valve types chosen were 6ES8/ECC189 and E88CC. Previous experience has shown these types to work well with low B+, and if a 6.3V supply is provided, can be used in the Radio Ace with no modification.

For testing at 6V, the P-T156 transformer was used to couple the detector to the audio stage. It was felt that at 6V, the voltage drop across the 100k would be too much and regeneration would be difficult. The valve tested first was a 6ES8.
It certainly worked. The volume was not noticeably increased compared to the 100k load at 12V. Without actually measuring it, the frequency response seemed to contain much more treble. Regeneration occurred at around 5.7V at the pot wiper.

Next, the E88CC was tested. It provided strong oscillation with 3.16V at the pot wiper.
The 100k resistor was reinstalled, and the E88CC continued to work well, now with 3.6V on the plate, and 4.6V at the pot wiper. However, there

still seemed to be too much treble, and changing the bias did not help.
An increase in loudness was obtained by using a 30k primary transformer for the headphones.

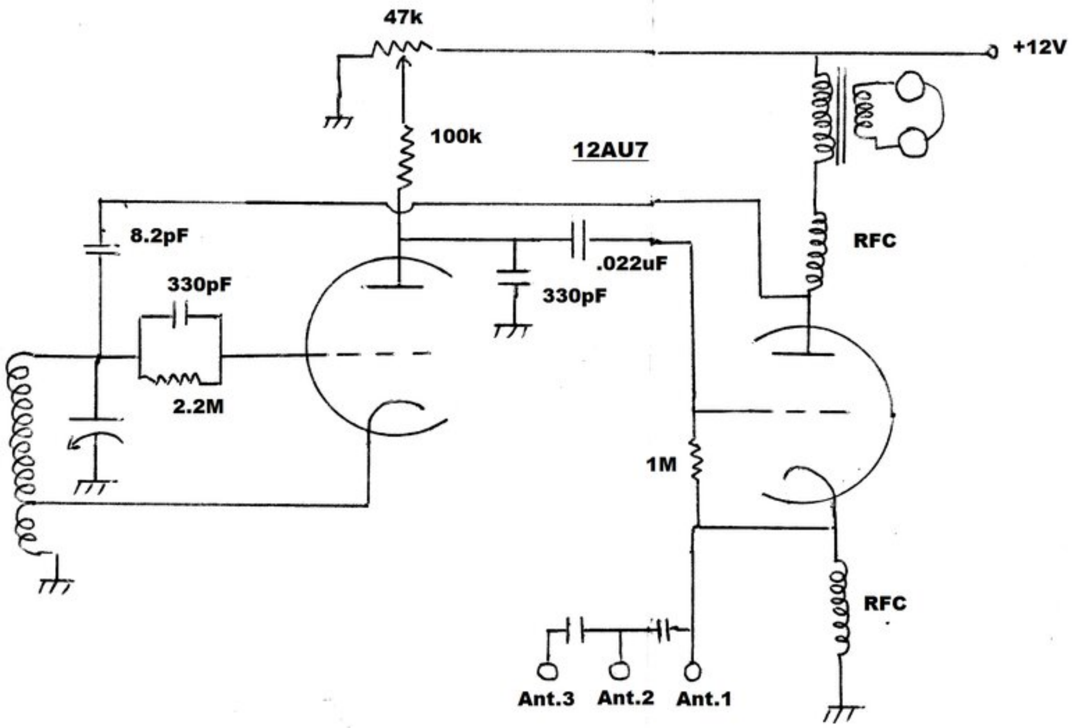
Although the set will work from 6V, the sound quality is not as good. It is hard to imagine an application where 6V operation would be desirable. It must also be remembered that the heater current is at least doubled for 6V.

- If you really want 6V operation, use an E88CC as first choice.

Reflexing.
As previously mentioned, the method of aerial connection is a compromise, with loading effects evident. An RF stage would provide the necessary isolation to overcome this.
Since there are only two triodes in this receiver, how can we conveniently include an RF stage, without adding another valve?
The answer of course is reflexing. That is, making one stage amplify two frequencies which are quite separate from each other; i.e. the RF and audio signals. This has been described with various MW and VHF receiver circuits elsewhere on this site.
Effectively, the audio stage of the receiver is also made to amplify the RF. It's a simple matter of keeping the two circuits separate with filtering.

With the Radio Ace, we only have a triode. Triodes, in the normal way, are problematic as RF amplifiers because of the grid to plate capacitance. Various schemes have been used to make them work as RF amplifiers; neutralising being the most efficient. Alternatively, simply loading down the circuit, or feeding the signal into the grid via series resistors, to restore stability, is another method which has been used (mainly to avoid the Hazeltine neutralising patent). A popular method with VHF is to operate the triode in grounded grid mode. Earthing the grid isolates the plate from the input signal which is fed in from the cathode.

The Radio Ace was tested using the following circuit.



Reflexed Radio Ace.

To understand the operation, pretend the two RFC's are wire links, and ignore the 8.2pF for now. Except for the aerial coupling, it is otherwise the same as the standard circuit. The difference now is that the audio output stage is functioning also as a grounded grid RF amplifier. The aerial signal is injected into the cathode of the triode, which is now at a high impedance at RF above earth. As far as the audio is concerned, the cathode is still earthed, since the RF choke has a low reactance at audio frequencies.
The grid is at RF earth, since the existing .022uF and 330pF capacitors act as an RF bypass.
Another RFC allows the amplified RF to appear at the plate. Again, the RFC has low impedance at audio frequencies, so the audio current is not impeded on its way to the output transformer.
The amplified RF is then coupled to the tuned circuit by the 8.2pF.
For the test circuit, the RF chokes were 2.5mH. The 8.2pF was actually just the existing 12pF in series with the 33pF. Strictly speaking, an RF bypass should be included at the junction of the RFC and output transformer, but I found it made no difference.
Note that the 1M is returned to the cathode and not to earth. This is to prevent any DC resistance of the choke increasing the bias.

Results seemed very promising. The upper frequency limit was higher than when the aerial was connected directly to the tuned circuit via a capacitor. So, in that regard, reflexing had solved that problem. However, in one way the performance was too good. With the long wire aerial, the 50kW station 2BL on 702kHz, 45km distant, could be heard in the background across the band, even with the regeneration optimally adjusted. It was necessary to reduce the aerial coupling, by reducing the capacitor feeding into the RF amplifier cathode.
For those wanting to permanently modify their Radio Ace, the existing Ant. 1-3 terminals could provide a suitable choice of series capacitor, and direct input for short aerials. For the test I used a 300pF variable capacitor. About 43pF seemed to be the best value of coupling capacitor with my aerial and location. A suitable starting point might be 100pF between Ant.1 and Ant.2, and 47pF between Ant.2 and Ant.3.

The choice of choke and coupling capacitor values I've used here are not necessarily the optimum, and could be experimented with further.

Short Wave.
It must be pointed out that my original modification of the Radio Ace was to optimise MW performance. With the 100k detector load resistor, the set will no longer oscillate with the supplied short wave coil.

I have never been concerned about this, since I do not use the Radio Ace for SW listening, and in the modern day, there is scarcely anything of interest to receive. Australia killed off its shortwave broadcasting some years ago.
If SW reception is important, choke or transformer coupling needs to be used, or revert to the original circuit with the 22k load resistor, and live with the low volume. In fact, I suspect that the set's original design may have actually been intended more for SW than MW.

Homepage

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