Vintage Radio

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The incredible 1925 RCA 26 portable superhet receiver

The RCA 26 portable superhet receiver with its front open, ready for use.

Prior to the 1930s, virtually all domestic broadcast receivers used TRF circuits. One exception was the 1925 RCA 26 portable which was one of the very first domestic superhets. It used some truly innovative technology for the era.

UNTIL RECENTLY, I'd always thought that "portable" radios (if you could call them that) were an innovation of the mid to late 1930s. However, at the HRSA's 25th Anniversary celebrations last year, I was amazed when I saw Mike Osborne's 1925 RCA 26 portable. Not only is it a fully-working concern but it also uses a superheterodyne circuit.

Why was this so remarkable? Well, superheterodyne receivers didn't become common in Australia until the mid-1930s. This means that, at the time, this set was a truly innovative design that was at the leading edge of technology.

The RCA 26 was also one of the earliest, commercially-made portable radios, although manufacturing portables was not particularly difficult at the time. By contrast, designing a workable superheterodyne receiver wasn't particularly easy in 1925, as the valves that were then available were not very suitable for the task of frequency conversion. In fact, the design could be quite critical if the set was to operate at all.

That situation improved in the early 1930s with the development of the 2A7 and similar converter type valves. These new valves proved to be quite tolerant of circuit design inadequacies, making the design and manufacture of superhet receivers much easier.

Superhet principles

Before the 1930s, most sets employed TRF (tuned radio frequency) circuits. However, these had their shortcomings and superhet designs quickly took over when suitable valves became available.

The superhet (or superheterodyne) principle was developed during World War 1 by Major Edwin Armstrong of the US Army. Armstrong was a prolific radio inventor who also developed other radio techniques, including regeneration, super regeneration and frequency modulation (FM).

Basically, the superhet was developed because during WW1, the allies needed direction finding (DF) receivers that could receive the extremely weak spark transmissions used by the Germans in Europe. Apparently, tuned radio frequency (TRF) receivers could not be made sensitive enough or stable enough for this task, so an alternative technique had to be found.

In operation, a TRF receiver tunes

and amplifies the incoming RF (radio frequency) signal at the frequency of interest and then presents the amplified signal to the detector. This then feeds an audio amplifier stage which boosts the audio signal to headphone or speaker levels.

Although this had the benefit of simplicity, there were a few problems with TRF sets which limited their usefulness. The first was that they had to be capable of accurately tuning the incoming RF signal across a wide range of frequencies. In the early days, this was achieved by adjusting several tuning capacitors or variometers to obtain the best reception, as ganged capacitors were not available. In some sets, this could involve up to four or even five adjustments.

In addition, some detectors require a certain minimum level of signal for them to work effectively. This meant that, in some cases, additional RF gain was needed. Unfortunately, this is difficult to achieve with a TRF set due to problems with feedback between the various stages.

During the early 1920s, triodes were almost exclusively used to amplify both RF and audio signals. However, at RF, triodes must be "neutralised" in order to achieve reasonable gain and stability. This "neutralisation" involves adding an extra capacitor to cancel out the grid-to-plate capacitance inherent in each triode RF stage, to prevent it from oscillating.

In addition, triodes were not good at amplifying frequencies above 500kHz, again due to inter-electrode capacitance and also due to lead inductance. Even in those very early days of radio, the TRF failed to meet the "state of the art" needs of the military during WW1.

By contrast, in a superheterodyne receiver, the RF stage (or stages) provides only moderate amplification, which allows easier tuning and greater stability. This also means that there is less need for significant shielding between stages.

The amplified RF signal is then applied to a converter (or mixer) stage where is mixed with a signal from a local oscillator stage. In an AM broadcast receiver, this local oscillator stage typically operates at a frequency that's 455kHz (or thereabouts) higher than the tuned RF signal.

Another view of the 26 receiver, this time with the access covers removed for the valves (top) and the reflexed horn speaker. The loop antenna was housed in the hinged section attached to the front cover.

As a result, the output from the mixer stage consists of four separate frequencies: (1) the original tuned signal frequency; (2) the signal frequency plus the local oscillator frequency; (3) the local oscillator minus the signal frequency; and (4) the local oscillator frequency. Lets's take a look at an example to illustrate this;

If the tuned frequency is (say) 1000kHz (1MHz), then the local oscillator will run at 1455kHz (ie, 455kHz higher). As a result, the mixing frequencies will be 1000kHz + 1455kHz = 2455kHz and 1455kHz - 1000kHz = 455kHz.

This means that the following frequencies will appear at the plate of the converter valve: 455kHz, 1000kHz, 1455kHz & 2455kHz. These signals are all fed to the following intermediate frequency (IF) stage but since this stage is tuned to 455kHz, only this frequency is passed on for amplification. It does, however, contain all the audio information that was included with the original signal frequency.

Because the IF amplifiers and the RF amplifiers are on different frequencies, they do not inter-react with one another. Because of this, significant gain can be achieved in the IF amplifier and so the overall gain can be quite high. In addition, the IF stages amplify only a narrow band of frequencies and because these are usually lower than the signal frequencies, amplification is easier to achieve.

Initially, in the 1920s, an IF of 100kHz was used, then a very low IF centring on 25kHz was used followed a little later by 55kHz. In fact, this latter IF is used in the RCA 26 portable. At such low frequencies, most triodes didn't need any neutralisation. In addition, the gain of the UV99 RF valve used in the RCA receiver is only 6.6 under optimum conditions, so the IF stages in the 26 were not neutralised.

Following the IF stages, the signal was fed to the detector and the IF component removed. The resulting audio signal was then fed to the audio amplifier.

Audio amplifier stages are generally easier to design than RF amplifiers. Most of the triodes of the 1910s and early 1920s were quite stable at audio frequencies but the gain of individual UV99 triodes was quite low (6.6).

As a result, to achieve a higher gain per stage, inter-stage audio transformers were used. These generally had step-up turns ratios somewhere between 3:1 and 5:1, which could boost the gain of a UV99 stage up to a maximum of 30 times. However, these audio transformers had a very limited frequency response, as well as having peaks and troughs in the response.

On the other hand, a 6AV6 with sim-

The view shows the chassis after it has been removed from the cabinet. The valves are easily accessible so that they can be replaced while most the rest of the circuitry is sealed in the "catacomb box" (or sealed container) at the right, to prevent users fiddling with the adjustments.

ple resistance/capacitance coupling will easily exceed this figure, with amplification of up to 70 times per stage. It will also have a much improved bandwidth and no nasty peaks and troughs across the frequency band.

Early superhet problems

Unfortunately, despite their clear advantages, early superhets also had their problems. However, these were quickly overcome by Edwin Armstrong and other designers of the era.

One early problem involved the large 60-100cm tuned-loop antennas that were commonly fitted to receivers from the 1920s to the early 1930s. Initially, the superhets had a converter stage connected to the loop antenna and a separate local oscillator was coupled into the loop. The following IF section then had up to five stages of amplification.

However, with this arrangement, it was found that the local oscillator radiated signals via the loop antenna and this was picked up as interference (in the form of whistles) by nearby receivers. In addition, the action of tuning the loop (or even someone walking near it) caused the oscillator to change frequency, so much so sometimes that the wanted signal was shifted out of the pass-band of the IF amplifier.

This effect was particularly evident as the loop and the oscillator were tuned to frequencies quite close to one another.

Another problem with early superhets was that one tuned circuit could lock onto the frequency of another stage with a higher "Q" factor. "Q" refers to a tuned circuit's "quality factor" and is a measure of the "sharpness" or selectivity of the tuning response. A circuit with a Q of 100 is much more selective than one with a Q of 10.

As an example, let's assume a circuit with a resonant frequency of 1000kHz and a Q of 10. In this case, the response at 950kHz and 1050kHz will be half that at 1000kHz, ie, the response will be 3dB down at the +50kHz and -50kHz points. Or to put it another way, the circuit has a -3dB bandwidth of 100kHz.

However, at a tuned frequency of 100kHz, the -3dB bandwidth points would be just 10kHz on either side of 100kHz. In fact, it was the low "Q" factor of early tuned circuits and the meagre amplification of signals above 500kHz by the triodes of the era that dictated the use of low intermediate frequencies in early superhets.

Overcoming the problems

Oscillator radiation from the loop antenna was overcome by adding a neutralised triode RF amplifier between the loop and the converter stage. In addition, the RF stage and the converter were coupled using an untuned RF transformer and this overcame much of the pulling of the oscillator by the RF tuned circuits.

It was also found that running the oscillator at half the received signal frequency plus or minus the intermediate frequency, also substantially reduced oscillator pulling. So how did the circuit work if the oscillator ran at half the required frequency. The answer was quite simple – the second harmonic of the oscillator was used to heterodyne with the received signal to give the IF.

Having solved most of the problems of producing a usable superhet receiver, the designers found that no less than eight valves were required to build it. However, an 8-valve set, even one using low-current valves, had a higher current drain than was practical to expect dry batteries to supply.

In fact, the first superhet receivers used 201 valves which draw 1A each at 5V, thus giving a total current consumption of 8A. This meant that the very early designs could not be used as portables.

At that stage, a superhet receiver used a neutralised triode RF stage (V1) which was coupled to a triode mixer/ converter stage (V2). The signal was then mixed with the heterodyning signal from a separate local oscillator (V3).

The output from the converter then fed two IF stages (V4, V5) and these in turn were coupled to a grid leak detector (V6). This then fed two transformer-coupled audio stages (V7, V8), with the amplified audio signal then going to a speaker or to headphones.

In order to produce a portable set, it was necessary to find some way of reducing the current drain. That meant reducing the number of valves while still maintaining good performance.

Two techniques were available to

achieve this: (1) reflexing and (2) using a self-oscillating mixer.

Last month, we looked at how reflexing was achieved in the Astor KM receiver. However, in those early days of superhet receivers, the technique was applied in a slightly different way. The RF amplifier stage amplified the incoming signal, which then went to the mixer. The resulting IF signal was then fed back into the RF stage again which now acted as the first IF stage. Its output was then applied to the second IF amplifier.

Basically, it was possible to use the RF stage to handle both RF and IF signals because the signals were at a low level. In addition, the difference between the IF frequency (25-55kHz) and the signal frequency (520kHz or more) meant that there was minimal interaction between the two.

Initially, the mixer and local oscillator stages required two separate valves. However, this was subsequently reduced to just one valve when the designers came up with the self-oscillating mixer. In other words, one valve functioned as both the mixer and the oscillator and this stage became known as an "autodyne mixer". It was seldom used during the later valve era but was commonly used in transistorised receivers.

Thus, by using a reflexed RF stage and an autodyne mixer stage, the designers were able to reduce the valve count from eight to six. This not only reduced the current drain but saved on expensive valves as well.

RCA's 26 portable receiver

RCA's 26 portable receiver uses this same 6-valve design technique. In fact, this set is one of several variants built by RCA at the time and their circuits are almost identical – see Fig.1. However, some of the features shown on the circuit are not included in the 26, while some of the features of the 26 do not appear on other variants.

For example SW1, SW2 and J1 are not fitted to the 26. The 26 is switched off by turning the battery rheostat (R3) fully anti-clockwise, so SW1 was not needed. In addition, the loudspeaker is wired permanently to V6 so the use of headphones is not an option.

The 26 uses UV99 valves in all six valve sockets. This valve is designed for a filament voltage of 3-3.3V and a filament current of 60-63mA. As a result, the receiver draws approxi-

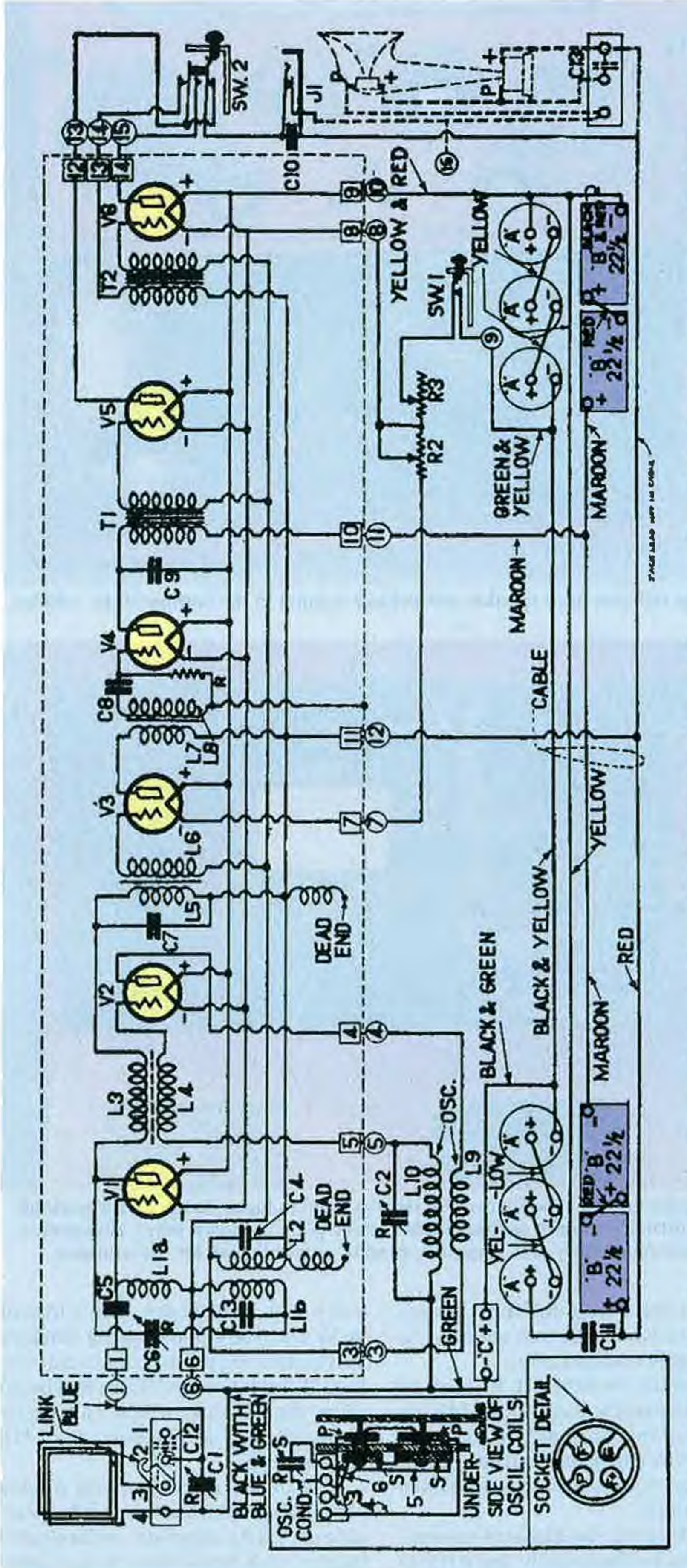
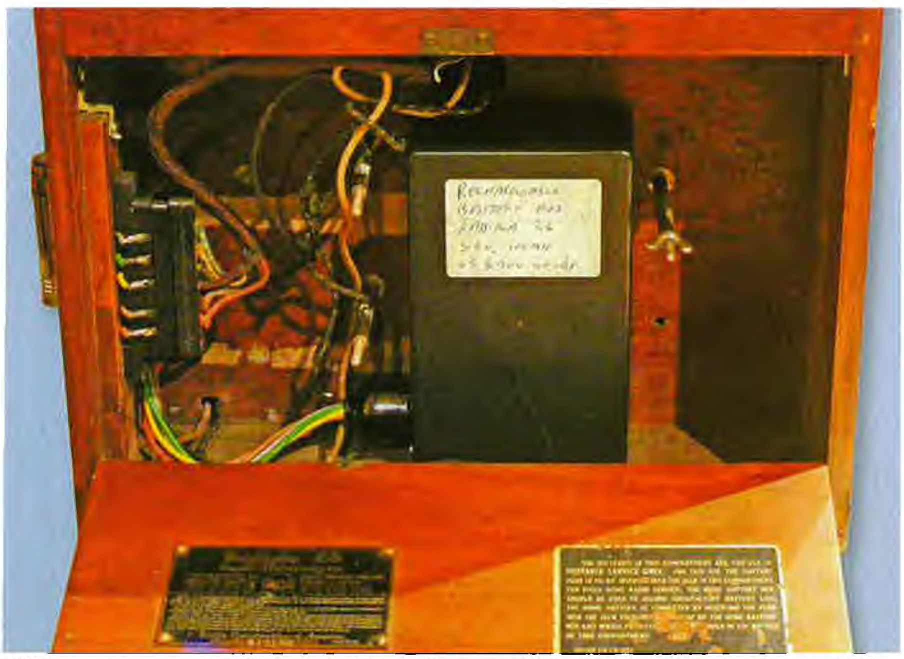


Fig.1: the RCA 26 is an early superhet receiver employing a reflexed RF stage (V1) and an autodyne (or self-oscillating) mixer stage based on V2. In operation, the reflexed RF stage functioned as both an RF stage and as the first IF stage. V3 is the second IF stage, V4 is the detector and V5 & V6 are the audio stages.

The large reflexed horn speaker sits behind a panel in the bottom of the cabinet.



This compartment at the rear of the set was used to house batteries for portable use (the owner's modern rechargeable battery pack is shown here). However, a larger external battery was generally used to power the set for use at home.

mately 370mA from the three series-connected No.6 cells that are used in the portable configuration.

Adjustable resistor R3 is used to set the filament voltage applied to the valves and this must not exceed 3.3V. Note that if eight valves had been used, the filament current drain would have been 500mA.

In addition to the filament current, valve data books indicate that a UV99 valve will draw 2.5mA with a bias of -4.5V and a 90V plate supply. With all valves drawing the maximum current, the HT (high-tension) drain will be no more than 15mA, which can easily be handled by a relatively small HT battery pack.

One of the accompanying photos shows where the batteries sit for portable use (Mike's modern, rechargeable battery pack can be seen in the centre of the photo). However, for home use, a larger battery pack was normally used to power the set.

The 26 receiver has the usual frame (loop) antenna but provision was also made to connect a larger loop antenna and to connect long-wire antennas. This tuned circuit feeds valve V1 which functions as a combined RF and first IF amplifier stage. This stage is neutralised using trimmer capacitor C6.

V1's output is coupled via an aperiodic (untuned) RF transformer to V2, the self-oscillating mixer. The oscillator's tuned circuit consists of L9, L10 and C2. The resulting IF signal is fed through L9, L2, L1b & L1a to the grid of V1 where it is amplified and fed via L3 the second IF transformer (L5 & L6).

V3 is the second IF amplifier and its output feeds grid detector stage V4 (via L7, L8 & C8). The audio from this stage is then applied via transformer T1 to audio amplifier stage V5. Note that in some sets (but not the 26), V5's output is either fed via switch SW2 to a set of headphones or fed to audio output stage V6 via transformer T2.

A reflexed horn speaker is fitted into the bottom of the receiver case (see photo) and this is driven by V6. The efficiency of these speakers is quite high, so the very low output from the UV99 is perfectly adequate for normal listening.

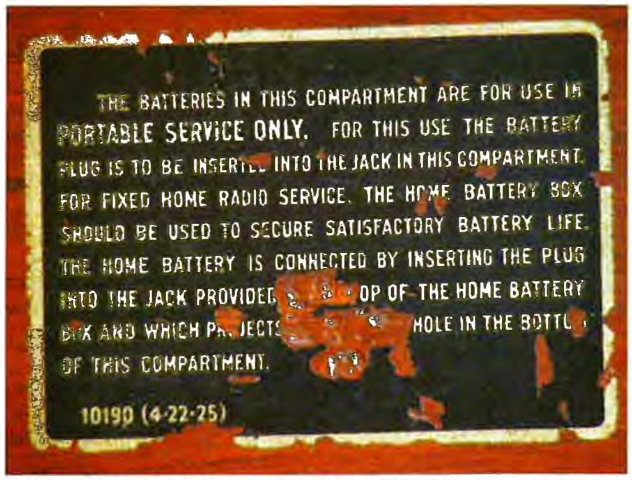
Tuning

The receiver is tuned using separate local oscillator and RF controls on the front panel. We rarely experience "double-spotting" or image reception in modern broadcast receivers but radios like the 26 allow the same station to be heard on at least two other spots on the broadcast band, this in addition to the intended position. This is due to the very low IF used (approximately 55kHz) and also due to the use of the oscillator's second harmonic to produce this IF.

As previously indicated, R3 is used to adjust the filament voltage. It could be adjusted so that the valves still received around 3V even with almost flat batteries.

R2 is the volume control and operates by varying the filament voltage applied to valve V3. This rather crude method of volume control was used on many early radios. No form of AVC (or AGC) is employed on this receiver

This plaque attached to the back of the set shows the patent information relating to RCA's Radiola 26.



This adjacent label gave advice on battery use. A lead fitted with a jack plug selected the battery pack.

and in fact, this feature didn't become common on radio receivers until the 1930s.

Access to the valves is obtained by removing a metal cover near the top of the set. The loop antenna is mounted on the front lid of the receiver and once the lid is opened, the loop can be swivelled for best performance. The antenna loop is terminated on a 4-terminal strip – see Fig.1.

Fig.1 also shows two sets of "A" batteries, as used for the larger home battery pack. In addition, the receiver used four 22.5V B batteries to supply 90V of HT to all valves except the grid-leak detector (V4).

The main workings of the receiver are enclosed in a sealed box section called the "catacomb". This section of the receiver is shown within the dotted lines of Fig.1. The valve sockets are mounted on the front face of the catacomb and the valves are the only components shown within the dotted-line enclosure that are actually outside the shielded box.

Apparently, early superhet receivers were difficult to service and the sealed container was designed to stop people from fiddling with the adjustments of this rather critical circuit. Prior to the introduction of superhets, experimenters and serviceman were only used to TRF receivers and so might have been tempted to experiment with the adjustments in the absence of a cover.

As shown in Fig.1, there are a couple of coils with the comment "dead end" on them in the circuit. The purpose of these coils is unclear, although they may have been some form of neutralisation system for the IF stages.

No external antenna

Early superhet sets were popular with people who did not want to take out a radio listener's licence, as no external antenna was necessary (which meant they could avoid detection). However, they were not used in Australia for many years, mainly because they were so advanced for their time that fault-finding proved difficult for service people, who generally only understood TRF technology. In addition, there were problems for non-technical users such as double-spotting and extraneous whistles.

AWA did make superhets from 1925-1927 but then stopped and made nothing but TRF receivers until 1933. It would appear that they found the early superhets just too advanced for the average serviceman to effectively maintain.

The early AWA designs were very similar to the RCA "catacomb" designs. However, there were a few variations such as the use of anode-bend detectors and regeneration on the RF stage (called an "intensifier"). Their 1927 models used L410 or P410 valves in the audio output stage.

Summary

The RCA 26 was a remarkable receiver for its time. Even today, it performs remarkably well, with quite good sensitivity, although double-spotting and other extraneous whistles and noises are quite obvious. This is a set well worthwhile having in a vintage radio collection. **SC**