When I Think Back...

by Neville Williams

Vintage radio receiver design 3
Mains supplies usher in a new order

The late 1920's and early 1930's saw the establishment of a vigorous Australian radio industry and the emergence of a large factory-trained workforce, giving rise to a whole new generation of dedicated hobbyists. On the technical front, an initial wave of locally produced mains powered TRF receivers were superseded, in short order, by simplified but efficient superheterodynes.

In the early 1920's, many home handymen had become involved in 'wireless', primarily because it offered access to information, news and entertainment at a time when all three were in short supply — particularly in the country.

With no relevant background and limited back-up in the way of technical literature, such newcomers to the new and unfamiliar technology largely had to learn by trial and error. Fortunately, it was a relatively safe hobby in terms of life and limb.

Operating purely from batteries, receivers of the day posed no threat to unskilled experimenters. The real risk was to the equipment, with beginners all too prone to confuse the battery connections, invoking the ultimate disaster for an impecunious experimenter — 'blown' valves!

However, when the focus later shifted from battery to mains-powered receivers, the supply voltages lurking in the wiring jumped from 135 at most to more then double that figure, plus a decidedly lethal 240V AC direct from the power mains. Rather than the components being at risk, the greater concern was that a chance high-voltage encounter might 'blow' the unwary experimenter!

But while many enthusiasts have experienced salutary 'bites' from mains powered equipment, I'm not aware of any local reader/hobbyist who has paid the ultimate price for their interest in radio.

It may well be that the infusion of academically and/or industry-trained people into the ranks of radio hobbyists fostered an appropriate awareness of the need to be careful with anything connected to the power mains — m point that needs to be borne in mind by the present generation of vintage radio receiver enthusiasts.

Small AC receivers

As happened in the battery set era, designs for a whole range of elementary mains powered receivers appeared in the technical press, *circa* 1930, intended primarily for home construction. They were welcomed by the rising generation of industry-based enthusiasts who, while handling commercial receivers by day, were frequently too poor, in the shadow of the great depression, to afford anything quite as pretentious.

By courtesy of Mr H.D. Burraston of Murrarundi, NSW, I have to hand a copy of a booklet 'Modern Radio Circuits for AC Operation', issued as a supplement to *EA's* predecessor *Wireless Weekly* for August 14, 1931. It offers very helpful glimpses of contemporary receiver design.

Fig.1 shows the circuit of the *WW* 'Direct Coupled 2', using a 224 screened-grid **tetrode** as a regenerative detector feeding a type 245 power triode output valve. The 280 rectifier is not included in the valve count.

(Perhaps I should also mention here that the initial digit, indicating the manufacturer was later dropped from American valve type numbers, so that they became known simply as 24, 45, 80, etc).

Guide notes in the booklet warned that the sensitivity and selectivity of such simple two-stage circuits were limited, and it was recommended only for urban use (I quote): 'within 20 miles or so of the broadcast stations'. Even so, interference between adjacent stations could still be a problem in difficult locations; e.g., close to one or more transmitters.

Compared with an equivalent two-stage battery set, husky valves and a high tension supply voltage in the range 425-450V DC could provide loud reproduction of such signals as the set could successfully tune. In an optimum situation, with an efficient dynamic (moving coil) loudspeaker, the constructor was promised reproduction to rival that available from a much more pretentious design.

Dynamic loudspeakers

Elsewhere in the booklet, readers were reminded that many existing dynamic loudspeakers were of the 'AC powered' electrodynamic type. Introduced about 1926, a step-down mains transformer and copper-oxide rectifier attached to the housing provided low voltage DC to energise the field coil.

Looking back, I recall that discarded examples of the breed were often picked over by hobbyists, in the forlorn hope that the transformer and rectifier would be in good enough shape to double as a modest home battery charger.

The next generation of electrodynamic loudspeakers (Fig.2) were less cumbersome and generally more efficient. Fitted with field coils of much higher resistance, they were capable of being supplied with current from the receiver's own HT power supply, requiring from 7 to 10 watts for adequate field energisation.

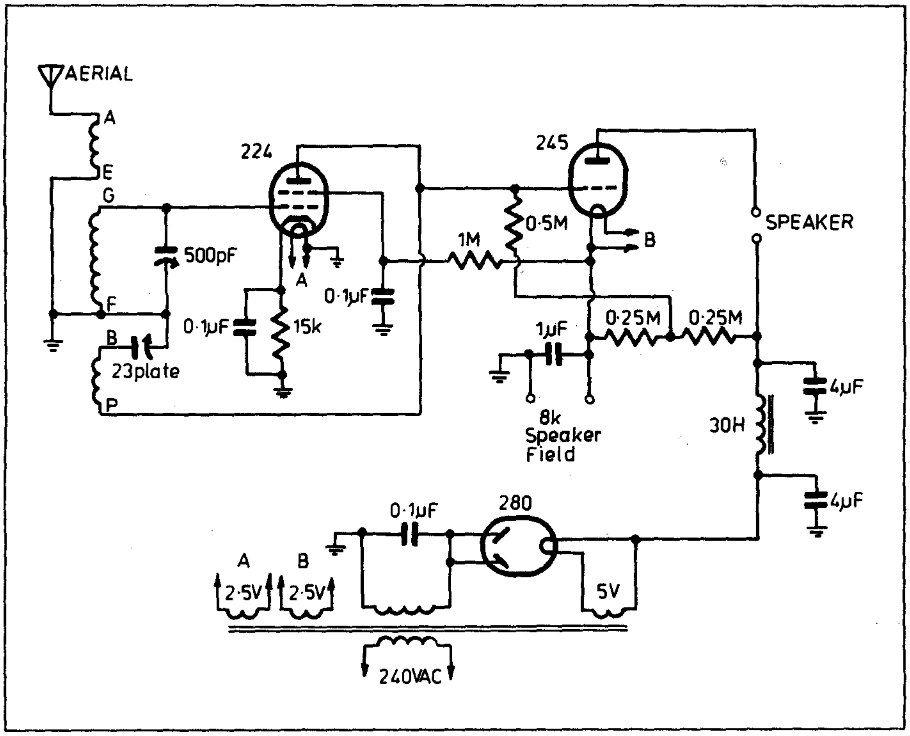

Fig.1: ***Redrawn from a Wireless Weekly booklet issued in August 1931, here is the circuit diagram of the 'Direct Coupled 2", an early and modest mains operated receiver Intended for home construction.***

Subsequent generations of Australian-made Amplion, AWA, Rob and Magnavox loudspeakers looked very much like the Jensen pictured. After World War II, field coils gave way to permanent magnets.

With hindsight, various aspects of the 'Direct Coupled 2' circuit reflect the sometimes immature technical reasoning in the transitional period between the technology of the 1920's and 1930's.

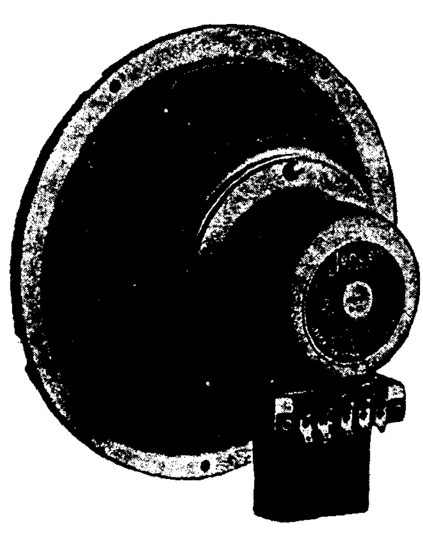

Fig.2: ***A then-current American Jensen dynamic loudspeaker, Imported by the International Radio Company Ltd of Sydney. The field magnet is bolted to the rear of the cone, with the cable tagstrip and voice call matching transformer suspended underneath.***

Thus, while the configuration of the detector is reminiscent of the traditional Reinartz reaction circuit, there is no grid capacitor or 'grid leak' resistor. Instead, the 224 is shown as an over-biased 'anode-bend' detector — an innovation more appropriate to larger receivers, subject to possible detector overload. For a simple receiver, the traditional and reputedly more sensitive 'leaky grid' circuit would normally be a more logical choice.

The output stage

Again, the output valve is a directly heated type 245, normally requiring the hum to be balanced out by returning the negative feed from the HT supply to a filament circuit centre-tap — apparently overlooked in the circuit diagram. In fairness to the designer, use of the 45 probably has more to do with the valve manufacturers, who clung tenaciously to directly heated output valves long after all other functional mains types had been developed around sleeved cathodes.

But, to me, the most debatable aspect of the design — a carry-over from the much publicised 1920's-style Loftin-White amplifier — is the use of 'direct coupling' to the grid of the output valve from the anode of the preceding stage.

Clearly the designer of the 'Direct-Coupled 2' assumed that omission of the coupling capacitor would effect a noticeable improvement in the overall quality of reproduction.

I subsequently contested this simplistic — but not infrequent — assumption in the very first instalment of 'Let's Buy an Argument' (now 'Forum% maintaining that the omission of a lone coupling capacitor in a simple non-feedback amplifier merely complicated the rest of the circuitry to no good purpose.

In the circuit of Fig.1, the grid of the output valve is tied to the positive potential at the anode of the 224 detector — a fact that may have influenced the choice of the anode-bend configuration.

For normal class-A operating conditions to apply, the filament of the 245 would need to be about 50V positive with respect to the grid, with the anode supply 250 volts above that again. According to the descriptive text, the design calls for a total supply in the range 425-450V — an incongruous figure for such a small set.

To obtain this voltage, the power transformer/rectifier system has to operate in half-wave mode, as shown. With a ripple frequency of 50Hz and the filtering relying on a nominal 30 henry choke and two 4uF paper capacitors (Fig.3), I do wonder about the residual hum level. (Electrolytic capacitors had yet to emerge as a routine choice for HT filtering.)

I also wonder about the presence of the loudspeaker field coil in the filament/earth return circuit of the output valve. Superficially it might appear to be a neat way of energising the field, but a complex and potentially resonant impedance in a path common to both input and output must introduce random negative current feedback around the output stage, affecting its output impedance. As well it could divert audio power from the voice coil into the field coil.

To invoke an old saying, the complications involved in eliminating one lone coupling capacitor strike me as the technological equivalent of 'straining at a gnat and swallowing a camel'.

Different approach

Interestingly enough, the same supplement offered readers a quite different 2/3-valve receiver called the 'The Hi-Power Two'. Two separate coils and two ganged capacitors provide band-pass tuning (see Fig.4) ahead of a Mullard 354V *indirectly* heated triode, operating as a conventional regenerative leaky-grid detector.

As a result and as distinct from the Direct Coupled 2, this alternative design was credited with 'astounding selectivity' (for a small set) and said to be 'at its best when located right in the midst of the powerful local transmitters'.

The detector was transformer coupled to a British-based Mullard PM24A power output pentode — as distinct from the American 24/24A RF tetrode. The specified loudspeaker was again a Jensen dynamic with 8000-ohm field coil but, in this case, wired directly across the DC HT supply.

Requiring only a routine 250-odd volts, the power supply system involved a 280 type rectifier fed from a normal centre-tapped power transformer, plus a couple of filter chokes and the then routine 'Chanex' or 'Hydra' 4uF paper dielectric capacitors.

Also worthy of mention in this otherwise poor man's 2/3 valver is the inclusion of an audio volume control ahead of the output stage, and a top-cut tone control across the anode circuit. Both warrant explanation at this point; first the volume control:

In urban areas, as already indicated, a small mains powered regenerative set could provide quite high output from strong local stations, necessitating some means of reducing the sound to an acceptable level. The seemingly obvious course was simply to back off the regeneration (or 'reaction') control, but this could adversely affect the selectivity, leading to possible interference problems.

By providing a supplementary volume control, the regeneration could be set for maximum detector gain and selectivity, the volume control being adjusted separately to produce the desired sound level. While a routine procedure for a technically inclined, listener, the critical manipulation of two knobs, both affecting volume, would have been potentially confusing for other members of the household.

The tone control

Most receivers up to this point in time had used triode output valves having a characteristically low output (or anode/plate) resistance; e.g., around 1600 ohms for a type 245.

In such a case, the natural frequency response of the system is not greatly affected by the wide variations in impedance which loudspeakers typically exhibit over the audio range. Hence, with a clean signal and a loudspeaker of

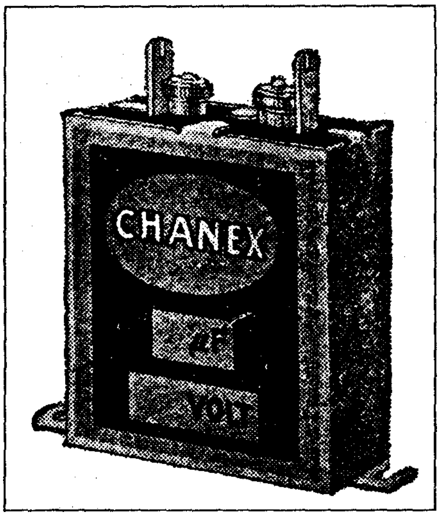

Fig.3: A typical paper dielectric capacitor, used for HT filtering before the general adoption of the electrolytic can type. Many discarded block' capacitors found their way into early home-built amateur station transmitters.

reasonable quality, the overall sound can be relatively smooth.

By contrast, power output tetrodes and pentodes have a much higher output resistance — typically 60,000 ohms in the case of a 247. In consquence, the frequency response tends to vary with the loudspeaker impedance, resulting in a rather 'boomy' quality at the loudspeaker's bass resonance and a pronounced accentuation of the upper treble. The difference between the two was quite noticeable but, while listeners tended to tolerate the extra bass as a novelty, they disliked the strident treble. Designers countered by installing a suitable bypass capacitor across the anode circuit of output pentodes, to attenuate the upper treble response. Indeed, translating a vice into a virtue, they commonly provided a potentiometer in series with the capacitor so that the tone could be varied at will between 'bright' and 'mellow'.

In fact, such 'top-cut' tone controls became a routine fitment on domestic receivers from the early 1930's onward, being commonly left in the 'mellow' setting. As a result generations of listeners became conditioned to 'woolly' music and muffled voices. But back to the original theme.

Extra stages

As had happened in the early 1920's, small regenerative receivers like the foregoing remained largely the province of hobbyists — of financial necessity and/or because they derived a certain satisfaction from achieving impressive results with a minimum of circuitry.

On the other hand, commercial receivers, intended for family use, were invariably of more ambitious design, less reliant on operator skill and able to cope routinely with a greater range of reception conditions. From the viewpoint of both supplier and customer, the ideal receiver was an affordable model that could be delivered to any ordinary address, connected to an aerial and power point and tuned, forthwith, to the full gamut of stations available in the area.

Fortuitously, the abovementioned *Wireless Weekly* booklet features a range of receiver designs using three, four and five valves plus rectifier — all TRFs, with one, two or three tuned RF stages ahead of the tuned detector. All feature direct coupling to the output stage, which complicates the audio circuitry. But more importantly for our present purpose, the notes document how well the respective front ends coped with the less crowded broadcast scene in 1930/31.

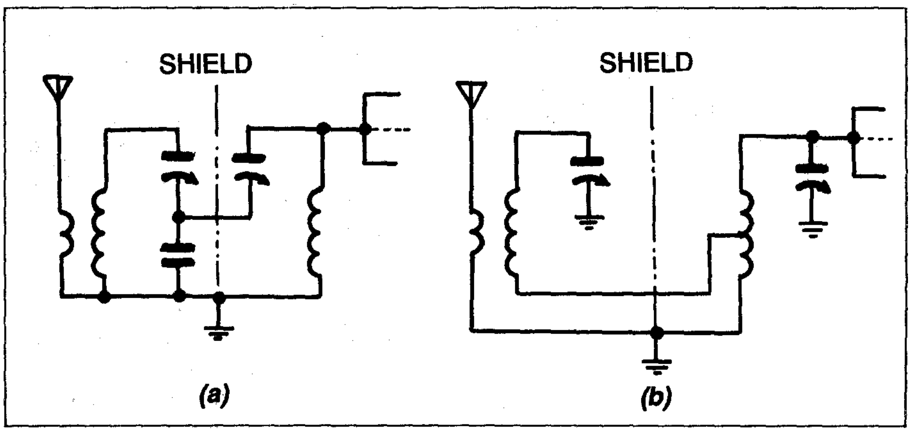

Fig.4: Double-tuned band-pass' circuits were often employed to Improve front-end selectivity. Arrangement (b) is the logical choice when the tuning capacitors share a common, earthed frame.

Again, helpfully, a *Wireless Weekly* 'Call Sign' booklet issued a few months earlier (July 1930) lists the 33 AM broadcast band stations across the Australian continent — compared with a present tally of around 250, crowded into channels only 9kHz apart.

The *Wireless Weekly* 'Midget 3' was so called because it was fitted on to a chassis compact enough to be housed in a table-top cabinet. It used a 224 as a tuned RF amplifier followed by another 224 as a tuned anode-bend detector feeding a 245 power output triode. A 280 rectifier in half-wave mode produced the requisite HT voltage for the direct coupled ouput stage, the 8000-ohm field coil being connected across the HT in series with a 5000-ohm heavy duty resistor.

Using a 224 tetrode in the RF stage ensured much greater amplification of the incoming signal than was normally available with a triode. No less to the point, the presence of a screening electrode between grid and plate, and access to the grid via a top cap connection reduced the grid/plate capacitance by around 100:1.

This obviated the need for neutralising circuitry, the only precaution in the interest of stability being the use of metal shield cans over the 224 valves and the respective coils (Fig.5).

Significantly, the compilers of the booklet classified the 'Midget 3' as the smallest class of receiver which could offer reasonable gain and selectivity without having to rely on the use of regeneration (quote) 'which is considered objectionable by many enthusiasts'.

'Most popular' set

The sequence of small receivers leads up to what the booklet presented as the then-current ideal receiver: 'The 1930 Four', whose circuit is shown in Fig.6. It was described as: 'the most outstanding design ever known to the Sydney radio trade', for which 'more kits of parts have been sold ... than any set previously described in Australia'.

Why? Because it had unmatched tone, 'enough volume to fill a small hall' and sufficient range to give excellent interstate reception.

Another TRF design, it used two 224 tetrodes as tuned RF amplifiers, a third as a tuned anode-bend detector, followed by a Philips P443 — a directly-heated high-power output pentode. The rectifier was a high-voltage half-wave 281, fed from a 575V transformer.

The covering article indicates that there had been problems with the design, when first published, with the lower rated output pentode originally specified and with unreliable resistors. Again, with hindsight, I am not surprised when the article goes on to mention that the HT supply voltage provided for the direct-coupled circuitry ended up at around 625-650VI

Notwithstanding this, the fact remains that the two-RF stage configuration, with single-dial triple-gang tuning (C1/C2/C3), won wide acceptance as the best compromise for the reception conditions that obtained in 1930.

Not surprisingly, many contemporary commercial receivers adopted this general approach, with a 3-gang tuning capacitor and two RF stages, followed by a detector, an ordinary capacitance coupled output stage and a conventional 250-odd volt power supply.

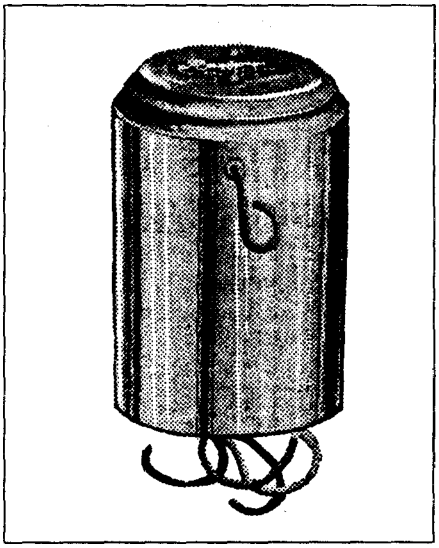

Fig.5: Manufactured by the Metropolitan Electric Co, Sydney, shielded, matched aerial and RF coils like this were available for TRF receivers, priced at 9/11d (990) each.

Gain or volume control

One other point about the '1930 Four' warrants special comment, namely the matter of a gain (or 'volume') control.

Because of their high intrinsic gain and consequently low grid bias, RF tetrodes like the 224 could readily exhibit signal overload effects close to one or more broadcast stations, therefore in many urban areas.

A powerful local signal could conceivably penetrate the first tuned circuit and be cross-modulated onto other carriers by the first RF stage. Even though the interfering carrier itself may be rejected by subsequent tuned circuits, its audio component could still break through as spurious modulation on other carriers. Or, again, in a larger receiver, the excessive signal level may be evident as distortion caused by overload of the final RF *stage* or the detector itself. Either way, a gain control in the audio system is of no help, since the overload has already occurred ahead of where the control can have any effect.

Superficially, the gain of RF tetrode amplifiers can be be reduced by simply increasing the negative grid bias — either directly or by using a wire-wound potentiometer as a variable cathode *bias* resistor. The problem is that this simultaneously reduces the plate current and further limits the ability of the valve to handle high level signals. Thus, only partial control is possible, with cross-modulation and/or distortion remaining a potential problem.

In the '1930 Four', the designers have opted instead for an 0.2 megohm potentiometer varying the screen voltage of the first two valves. While this was often used at the time, the idea would appear to suffer the same limitations as variable *bias.*

That it did so is evidenced by the fact that the design specified a 'Local-distant' switch which introduced a low value resistor (typically 10-25 ohms) across the primary winding of the aerial coil. Intended to reduce the level of all incoming signals, the resistor could be switched in or out of circuit, depending on whether or not it provided a cleaner result.

Gain control posed a problem for many medium to large receivers about this time, both TRF and superhets and, while a local-distant switch was a potential source of confusion for non- technical users, it was commonly fitted to both commercial and home-built designs as a matter of necessity.

One other point worthy of mention is the provision of a 'jack' socket (J) in series with the earthy end of the detector grid coil. For the most part ignored, its purpose was to allow a phonograph pickup to be plugged into the grid circuit of the detector so that the phono signal would be fed through the amplifier and loudspeaker.

It could be argued that a detector would not be optimally biased to operate as an straight amplifier, and that there was no provision anyway for an audio control to vary the sound level from discs.

Both observations are legitimate but, at the time, the majority of pickups were relatively crude magnetic types, and fitted with their own loudness potentiometer anyway. Most listeners were aware that electrical phono amplification was possible, but the current emphasis was on broadcast programs. Family radiograms did not really become 'trendy' until around 1935.

A 'deluxe' TRF

The most ambitious receiver presented in the *Wireless Weekly* booklet is The `De Luxe Five' — or 'Six', counting the rectifier. An elaboration of the foregoing 4/5 valve receiver, it used *three* tuned RF tetrodes ahead of the 224 anode-bend detector which, in turn, drove a Philips F443 high power output pentode. The rectifier *was* a half-wave 281, fed with a 600V transformer. As distinct from the smaller receivers, the circuit called for an 'AC Jensen' loudspeaker, providing its own field energisation with an in-built mains transformer and copper-oxide rectifier.

Summing up the receiver, the booklet claimed that, irrespective of valve count, there was nothing that could outperform the De-Luxe Five 'except for some forms of superheterodyne'. It was particularly recommended for use in 'up-country towns' involving a range of several hundred miles, but was not recommended for major cities because `it picks up all kinds of interference noises and amplifies them to an extent which will make reception unpleasant'.

This is an off-putting statement, to say the least, but probably confirms the fact that, at the relevant time, it was one thing to provide high RF gain but quite another to control it smoothly and effectively.

Relying on screen voltage control for the three 224 RF amplifiers and a drastic local-distant switch, the set may indeed have been unduly vulnerable to front-end overload and mains-borne RF interference in urban areas.

Front-end gain control remained an urgent problem until the introduction of `super-control' or 'variable-mu' screen grid valves, in mid 1931. The International Radio Company of Sydney announced local release of the National Union variable-mu 235 in *Wireless Weekly* for April 13,1932.

The variable-mu characteristic was achieved by fitting a special tapered-pitch grid, or by simply snipping selected half-turns from a fixed pitch grid.

The effect was to change the grid control characteristic such that while it appeared quite normal with low values of bias, it required a very high value of bias to cut off the plate current altogether. The abrupt plate current cut-off `corner' in the characteristic was competely eliminated.

Virtually identical in appearance to the 224, the variable-mu 235 offered essentially the same transconductance — and stage gain — as the 224 at -3V. But whereas the 224 plate current curve cut off sharply at around -6V, the 235 plate current curve trailed out to an ultimate cut-off at around -50V.

In announcing their equivalent valve, the 335 in *QST* for July 1931, Cunningham listed the transconductance as 1.050mA/V at -3V, reducing to 0.015mA/V at -40V — implying a huge potential reduction in stage gain. With that degree of control available and a plate current curve free of abrupt corners, it became much easier for designers to forestall front-end overload with its consequent cross-modulation and distortion.

Had 235 type valves been available in time for the '1930 Four' and the 'De-Luxe Five', the designers could simply have specified them for the RF stages, arranged for variable cathode bias and ended up with much smoother control — minus the local-distant switch.

Selectivity vs quality

That aside, while receivers such as those above offered predictable gain and selectivity for the listening situation circa 1930, the industry was well aware that, as far as domestic receivers were concerned, such designs epitomised the practical limits of TRF technology. Two and three-gang tuning capacitors were acceptable, four-gangs were manageable but anything beyond that would be too clumsy and too expensive.

In any case, the selectivity curve exhibited by a TRF tuner varied unduly across the broadcast band. According to one set of figures to hand, when tuned to 600kHz, a typical receiver using a three-gang capacitor exhibited a total bandwidth of 100kHz at 60dB down. However, when tuned towards the high frequency end, its bandwidth, as a simple proportion of the resonant frequency, widened to around 250kHz.

Unfortunately selectivity was worst at the very end of the band where it really needed to be at its best — thereby comparing very unfavourably with a superheterodyne, which could provide a narrower passband which was substantially uniform over the whole tuning range. Arguing with as much spirit as characterised their later forays, audio buffs of the period stoutly maintained

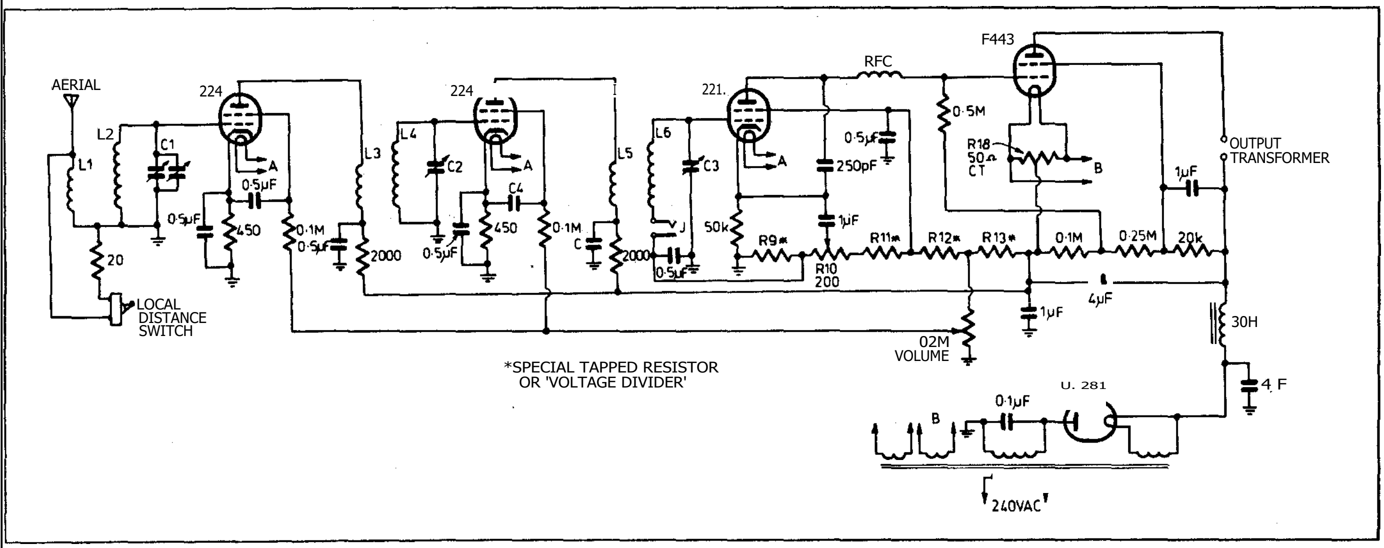

***Fig.6:** The '1930 Four', said by Wireless Weekly at the time to be their most popular project to date and considered to be the best current compromise between performance and cost for the average listener.*

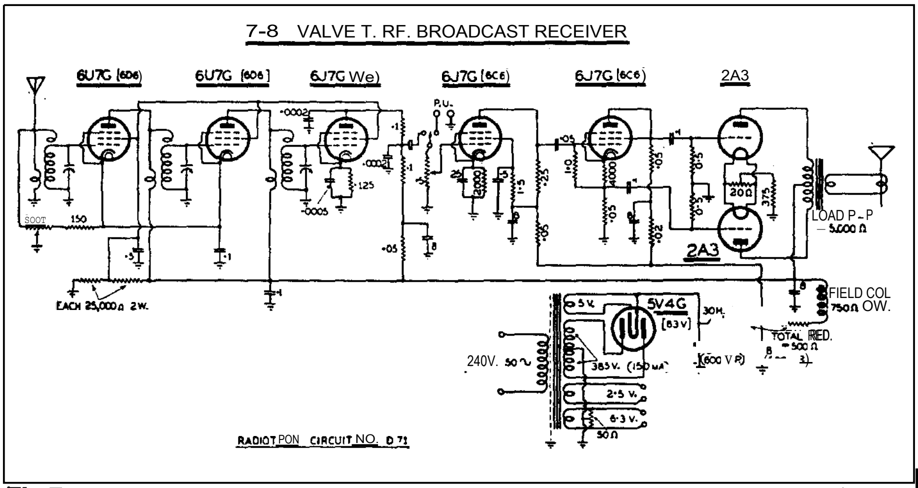

***Fig.7:** Designed especially for audio buffs and featured in 'Radiotronics' No.82 (1937), this receiver combined a three-valve TRF tuner with a classical push-pull 2A3 triode amplifier.*

that emphasis on receiver selectivity was inappropriate; that the vast majority of families listened only to their local stations, and that extra selectivity would diminish rather than augment their listening pleasure.

Receivers with a narrower bandwidth had to be tuned with greater accuracy for minimum distortion, they suggested. What's more, they attenuated the high frequency **sidebands**, diminishing the clarity of voices and robbing music of its natural overtones.

The arguments gave rise to an audio cult which supported TRF receivers on principle, and equated them with **'hifi'** radio reception.

In all fairness, it probably has to be admitted that the best sounding receivers of the era *were* TRF tuners with two variable-mu RF stages, an anode-bend detector and a power triode output stage. The modest front-end provided a reasonably balanced signal and the power **triode(s)** delivered it to the loudspeaker with much less distortion than characterised the louder — and more strident — non-feedback power pentodes.

As we shall see in the next chapter, vital design initiatives enabled the superheterodyne system to capture the mass market from 1930 onwards. But TRF tuners retained lingering support throughout the decade from specialist suppliers and audio buffs.

Fig.7 shows the circuit diagram of a TRF receiver for **hifi** enthusiasts developed in the Applications Laboratory of the **A.W.** Valve Company and published in ***Radiotronics*** **No.82,** dated December 1937. It used two tuned variable-mu RF amplifiers and a 'reflex' detector — essentially an anode bend detector with a large cathode resistor bypassed only for RF. It did not load the input circuit and had notably low distortion by reason of the cathode negative feedback. Because the design did not lend itself to AVC, the user had to manipulate two manual gain controls — one for the front end, the other for the audio system. High impedance primary windings in all coils and a capacitive coupling loop adjacent to the active end of the respective secondaries helped to equalise the gain across the tuning range. Fitted with a push-pull power triode output stage and an appropriately baffled **hifi** loudspeaker system, it was very much a **receiver/amplifier** for **hifi** enthusiasts of the day.

In May 1941, the Editor of this magazine (by then called *Radio & Hobbies) the* late John Moyle, presented a TRF tuner very like that used in the **AWV** receiver, with the idea that it could be used with an existing ***R&H*** amplifier using push-pull 2A3 output triodes. For sound quality, he said, the combination would be 'almost unbeatable'. A year later, in May 1942, I personally described the 'TRF Quality Six' in *Radio & Hobbies.* With parts scarce, due to the war, it was a distinctly different economy design, slanted to take advantage of possible alternative components. Since then, **TRFs** have been remembered mainly 'in absentia', with **hifi-orientated** engineers more intent on dreaming up ways and means of creating wideband or variable-selectivity **superhets.** Only recently, with the arrival of solid-state technology and AM-stereo has such technology come of age.

But that's much too recent to qualify as history. In the next chapter I will be looking at the evolution of 1930's-style **superhets.**

(To be continued) ■