When I Think Back...

by Neville Williams

Vintage Radio Receiver Design — 2: Batteries give way to mains operation

If the twenties saw the birth of radio broadcasting, no less importantly the end of the decade marked a quantum leap in receiver technology. From being the province of technicians, wireless sets became a piece of family furniture and, for urban listeners at least, the tedium and expense of batteries became a thing of the past.

As indicated in the last chapter, battery powered superheterodyne receivers made a noteworthy appearance on the market around 1925, setting new performance standards in terms of gain and selectivity — and to a degree, signal-to-noise ratio.

Their radically different circuit configuration and behaviour, however, prompted some buyer resistance in the marketplace, creating a demand for high performance receivers of less radical design.

For would-be purchasers, put off by the 'peculiarities' of 1926-vintage superheterodyne receivers, the obvious high-performance alternative was a conventional configuration, with at least two tuned radio frequency stages ahead of the detector and audio system — commonly described as a 'TRF' circuit.

Already a familiar term, 'TRF' acquired a somewhat broader connotation than in the days of the old regenerative 4-valvers (see previous chapter). In effect, it signified the alternative design approach to the superheterdyne principle. New receivers were either TRFs or superhets — a distinction that, as we shall see, carried over into the early 1930's.

In traditional form, with polished maple box and black bakelite panel, a typical TRF receiver with two RF stages called for three sets of coils, three separate variable capacitors and three separate tuning dials — one of each for the respective RF stages and the detector. To simplify tuning, the capacitors and coils would hopefully have been double-checked during manufacture, so that all three dials would end up at about the same reading for each individual station.

Some manufacturers went one better, by matching the tuned circuits well enough to allow the capacitors to be physically 'ganged' together and operated from a single tuning dial — a feature that became progressively more popular during the late 1920's (see **Fig.1**).

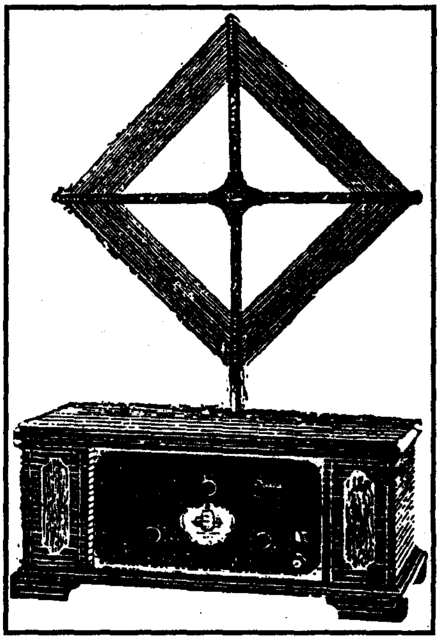

Fig.1: Announced In 'Wireless Weekly' for September 27, 1927, this 8-valve 'Priess De Luxe' receiver from Manufacturers Products boasted a frame aerial, single dial tuning and five RF stages, some untuned. The two-tone etched 'malloy' panel is said to give a 'refined appearance' and to combat possible hand capacitance effects.

Single dial tuning

In some cases the capacitors were lined up behind the dial, sharing a common shaft. In others, they were mechanically coupled by radial links, or by flexible concentric couplers (Fig.2). Yet another approach was to use a 'drum' dial mechanism, with two capacitors on either side, arranged with their axes parallel with the panel. With four capacitors, so driven, it was possible to accommodate three tuned RF amplifiers ahead of the detector.

In due course, component manufacturers progressed to the production of single-unit 2-gang, 3-gang and 4-gang tuning capacitors — even if these were not particularly rigid assemblies in the early stages.

But that was not the limit, with some receivers boasting five RF stages, some untuned (see Fig.1). Viewed from this remote point in time, one might be pardoned for wondering whether the untuned stages were always justified, or whether an important consideration was simply to add to the valve count to compete with 8-valve superheterodynes such as **AWA's** console model `Super-8'.

As also indicated by Fig.1, some large TRF receivers were equipped with a panel-tuned frame aerial, offering the same directional properties as when used with a superhet.

As with simpler receivers having only a single RF stage, 'front-end' instability posed a considerable problem for the more ambitious TRFs. While due basically to the grid/plate capacitance within the triode RF amplifier valves, it was aggravated by the stray coupling be-

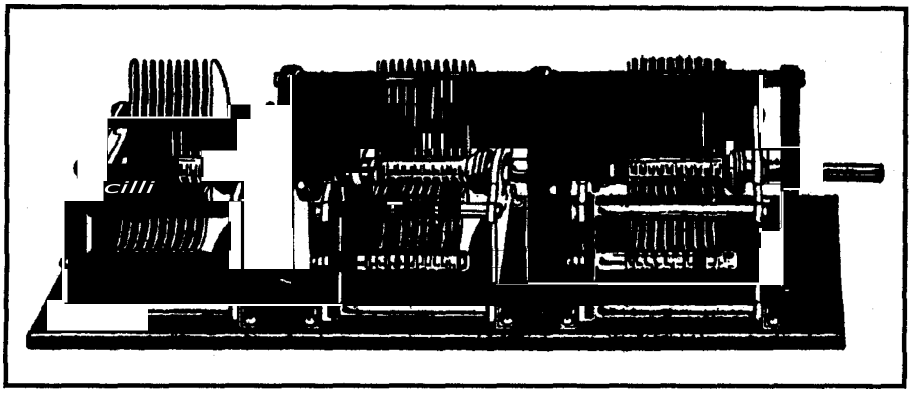

***Fig.2:** Typical ganged tuning condensers, as advertised by Murdochs, the one-time specialist mens store opposite the Sydney Town Hall: Prices for such assemblies varied with brand from about £3 to £6 — a week's wages, or more!*

tween the multiple RF stages and particularly between the large, normally unshielded coils.

Attempts to combat the problem by using lower gain valves or deliberately reducing the 'Q' or goodness of the tuned circuits tended to limit the peak performance of the receiver. Alternatively, relying on filament rheostats to control the gain could prove confusing. In most cases, fitting a 'stabiliser' potentiometer, as explained in the last article, provided a more manageable method of control to meet particular situations.

The neutrodyne

Pending a fundamental cure for instability in the way of screen-grid valves (See *EA* June 1990, page 43), many designers resorted to the use of *neutralisation* — a technique that had been worked out in the early 1920's, but adopted only sparingly. (As reported in *The Australasian Wireless Review* dated August 1923, the Neutrodyne' principle was introduced 'recently' by Professor L.A. Hazeltine M.E., of the Stevens Institute of Technology, New York, to the Radio Club of America.)

In practice, the neutralising circuit took many forms, the most common being to tap and extend the winding supplying the anode of an RF amplifier such that the signal voltage at the lower end would be in opposite phase and, ideally, of equal amplitude to that at the anode. By connecting a small, adjustable capacitor between the lower end of the extended coil and the grid (Fig.3), it became possible to cancel the effect of the direct anode/grid capacitance.

Variations of the scheme included tapping and extending the grid winding instead, and returning the free end to anode via a neutralising capacitor.

Yet another approach involved phasing the interstage coupling transformers in such a way that the necessary neutralising voltage could be picked up from a convenient point in an adjacent stage.

Whatever the configuration, the purpose of a neutralising circuit was to introduce capacitive *negative* feedback around each RF stage, sufficient to exactly balance out the *positive* feedback resulting from the inherent anode-grid capacitance.

(At a time when positive and negative feedback, as such, were not part of the jargon, the failure of early experimenters to comprehend the idea is perhaps understandable!)

That aside, as applied to a generation of otherwise normal TRF receivers, Hazeltine's term **'neutrodyne'** provided a measure of technical mystique which enabled them to compete to better advantage in the marketplace with **'superheterodynes'.**

Over the years, the principle was applied to elaborate (e.g., 8-valve) receivers right down to simple — even reflex — designs with a single RF stage. In some cases, **'neutrodyne'** was used purely as a descriptive term to indicate use of the technique; in others, it was featured on the front panel in the manner of a brandname. **Neutrodynes,** like **superheterodynes,** came in all shapes and sizes — some good, some very ordinary.

Adjustment procedure

Whether the average neutrodyne receiver operated to best advantage throughout its lifetime is another matter. Setting them up called for a critical adjustment procedure, which could all too easily be negated by well-intentioned but ill-informed experimenters.

Setting up typically involved tuning the receiver to a strong signal near the centre of the dial scale. Then, one by one, the RF amplifier stages would be disabled by disconnecting one filament supply lead or interrupting the connection within the socket with a scrap of cambric tubing. The valve itself would be left in position.

In the normal way, the signal would still be faintly audible, being fed **through** the disabled stage by the grid-plate capacitance of the inert valve and/or the neutralising circuit. The signal would normally increase as the neutralising capacitor was adjusted to either its maximum or minimum value, diminishing at some median setting.

The aim was to select the setting corresponding to minimum signal level, indicating that the grid-plate and neutralising capacitance were substantially cancelling each other in terms of signal transfer.

The routine would normally be followed for each separate RF stage. Other procedures may well have been specified for other circuit configurations, but it needs little effort to imagine how far astray the adjustments could have ended up at the hands of an owner/experimenter, curious to discover the effect of simply twiddling 'those curious little screw things'! (Fig.4)

Or, yet again, the effect of swapping valves around, or of substituting other

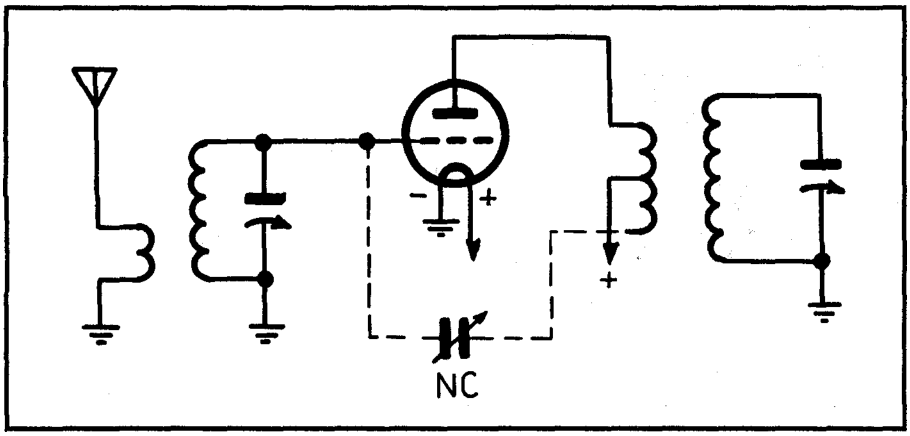

***Fig.3:** Perhaps the most common form of neutralising circuit, calling for an extended and centre-tapped anode feed coil.*

types — without any thought to the fact that their grid-plate capacitance could be quite different from that of the valve for which the particular stage had been optimised.

Vintage receiver enthusiasts who may have occasion to restore a receiver using one or more neutralised RF stages should be aware of these considerations.

Why not mains power?

With its relatively uncomplicated controls, a receiver as illustrated in Fig.1 posed a standing invitation for any member of the family to switch on and listen through any program that happened to be on air. The one obvious deterrent was the knowledge that to do so would flatten the batteries that much sooner.

If only such receivers could be run from the AC power mains, like other domestic appliances. Unfortunately, it was easier said than done!

Of necessity, virtually all receivers produced up to about 1927 were designed around existing battery type valves which required the provision of pure DC voltages as under for the filament, the anode (or plate) and the grid:

- The 'A' or filament supply — 2, 3, 4, or 6 volts at up to 1.0 amp, or thereabouts.
- The 'B' or anode supply — nominally 22.5, 45, 67.5, 90 or 135 volts at up to about 20 milliamps.
- The 'C' or grid bias supply — typically in 1.5 volt steps up to minus 9 volts, with negligible actual current drain.

To obtain supply voltages of that order from the AC (alternating current) power mains required the use of a suitable step-down transformer, a rectifier to produce a unidirectional current, and a filter to smooth out the inherent ripple and ensure pure, hum-free DC (direct current).

Because of the relatively low anode current required by battery type valves, there was no particular problem in providing a suitable 'B' or high tension supply, such as the one pictured in Fig.5.

Of comparable dimensions to a couple of medium size B-batteries, a so called 'B-battery eliminator' could deliver a maximum supply voltage of around 130-150 volts, plus a selection of lower voltages corresponding nominally to those available from the intermediate tappings on ordinary B-batteries.

Perhaps it should be mentioned in passing that, while these intermediate voltages served the purpose, old-time experimenters were often puzzled because they appeared to be much lower than anticipated when measured on a voltmeter. The confusion was due to the fact that the low-resistance voltmeters of the day placed a heavy current load on the source being measured, reducing it to well below what it would have been when supplying the very modest drain of, say, a regenerative detector.

For safety's sake, commercial B-battery eliminators were designed to isolate the DC output circuitry completely from the mains potentials — although the isolation may not always have met the very strict specifications that currently apply to present-day mains-sourced supplies like battery chargers and plug-packs.

Curiously, an article on page 52 of *EA's* 1927 *Wireless Weekly* reprint describes a home-made B-battery eliminator with no mains isolation transformer at all. While included, I understand, for its historical interest, readers should be warned NOT to attempt duplicating it, even for historical reasons. It could be positively dangerous to have lying around, because of the direct connection between B-minus and one side of the mains!

Some B-battery eliminators also provided a range of negative bias voltages, to obviate the need for a C-battery.

While this was technically easy enough to arrange, it was equally no big deal; C batteries were relatively inexpensive and, with virtually zero current drain, could be expected to last for their shelf life.

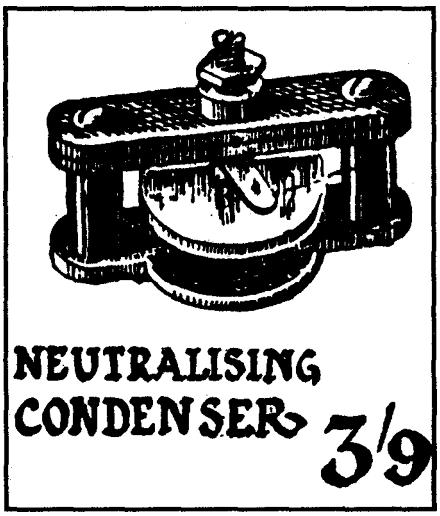

***Fig.4:** Pictured here about actual size, neutralising condensers (capacitors) offered an open Invitation for experimenters to 'fiddle, often to no good purpose.*

Filament supply

The real problem for all-mains operation was to supply the valve filaments. While it would have been no problem at all to step the mains voltage down to 2, 3, 4 or 6 volts, the filaments could not be supplied with raw AC for two main reasons:

Firstly, with the respective ends of the filament swinging plus and minus by the peak value of the AC waveform, the end effect would be rather like having a substantial 50Hz AC signal superimposed on the wanted program signal, causing a prominent 50Hz hum. This problem can be alleviated, but not eliminated, by earthing the filament circuit at an exact centre-tap rather than either end.

The second problem was that, by design, the filaments in battery valves were relatively small in diameter, to minimise the amount of current required to heat them to incandescence.

When fed with AC, the filament temperature tended to vary over each successive half-cycle and, with it, the electron emission. Therefore, quite apart from the spurious signal problem, as above, the emission — and basic efficiency — of the filament would be modulated at the half-cycle rate: 100Hz.

These days, with solid-state rectifiers and other technology, and with very high value electrolytic capacitors readily available, an adequately rect ed and filtered A-supply would doubtless be practical — but back in the 1920's, rectifiers were clumsy and inefficient and capacitors larger than 4uF were hard to come by. The most practical answer was to rely on a conventional lead/acid battery or 'accumulator' to supply the filaments — kept 'topped up' by a small or `trickle' charger connected permanently in circuit.

While this arrangement could be provided by the set owner using separate components, the battery service department of the Clyde Engineering Company, Sydney, made it a little less cumbersome with the self-contained unit illustrated in Fig.6.

Containing an isolating transformer, an electrolytic rectifier and either a 4-or 6-volt accumulator, it was self-regulating and could be left connected permanently to the power mains and the receiver. The only maintenance required was the occasional addition of distilled water to the cells and rectifier.

Because of the buffering effect of the storage battery, the DC output voltage varied little from the expected value and, according to the advertisement, mains hum was 'at all times negligible'.

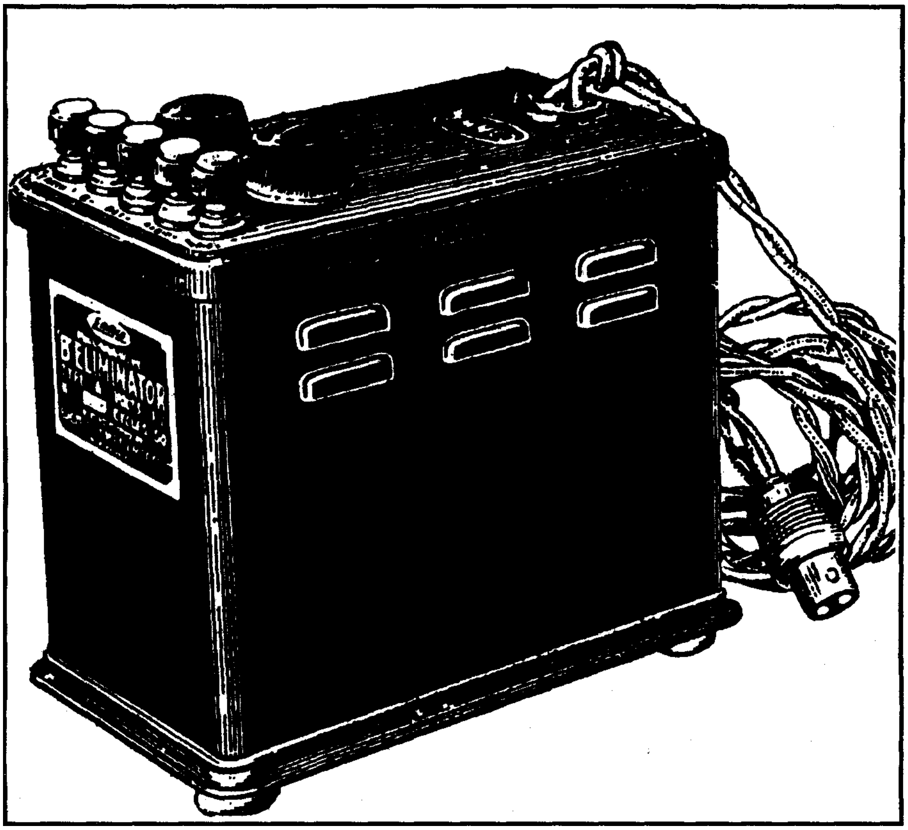

Fig.5: An Emmco B-battery eliminator, which was advertised for 10 guineas ($21) in 1927 — about three times the price of a set of B-batteries. The terminals and knobs on top provided a selection of semi-adjustable high tension voltages.

In an effort to find another solution to the filament supply problem, some designers adopted the idea of selecting valves with a similar, low filament current rating and wiring the filaments in series, thereby calling for a much higher voltage but lower current.

A valve which lent itself to this technique was the American type V99 or X99, with a filament rating of 3.0-3.3V at 60-63mA. While easing the filtering problem, however, the string of frail filaments proved rather vulnerable and the technique found only limited application.

Mains type valves

The salient point that emerged from all this was that battery valves and associated design parameters were not really compatible with mains operation, either technically or in terms of listener expectation in respect to sound output power.

There was an obvious need for valves which could operate with AC on the filament and at more generous anode voltage and current levels — beyond the economic limits of battery supply.

In fact, a solution to the AC filament problem had been identified back in 1921, by Messrs Freeman and Wade of Westinghouse. For the traditional filament, they substituted a narrow tube with an emissive surface, to serve as an electron source or *cathode.* Inside the tube, but insulated from it, they placed a heating element or *heater* which could be fed from a separate supply, most obviously low voltage AC from a step-down transformer winding (Fig.7).

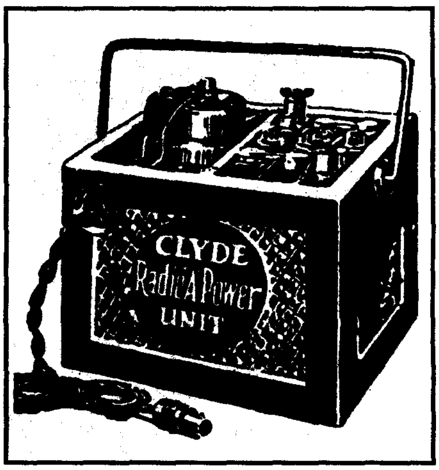

Fig.6: This Australian 'Radio A-power Unit, advertised by Clyde Batteries in 1927 contained an isolating transformer, an electrolytic ('slop') rectifier and either a 4 or 6 volt battery. it was self-contained and self-regulating.

Being independent of the electron stream within the valve, the AC could not interact directly with the signal, while the thermal inertia of the heater/cathode assembly would be such as to obviate hum due to temperature variation at the half-cycle rate.

While it subsequently proved to be the logical answer to the problem, the idea was not exploited to any extent until around 1927. One can only assume that the difficulties of devising, patenting, producing and marketing the early generations of battery-based receivers were sufficient, in themselves, to inhibit any radical departure in valve and receiver design!

Even in 1926/7, when RCA released their first manifestly non-battery valve, they still passed over the indirectly heated option. Designated as type 226 (or 26) their first mains type valve was, a clear derivative of their `old faithful' 201-A.

Virtually identical in appearance and with very similar electrical characteristics, its one vital digression was a conventional directly heated filament rated at 1.5V and 1.05A.

The purpose of the stout, heavy-current filament was to provide sufficient thermal inertia to minimise the half-cycle temperature ripple. At the same time, assuming a centre-tap or `balanced' earth return, the reduced filament voltage would hopefully reduce the level of AC hum injected into the grid bias/signal path.

So to mains power

The 226 undoubtedly maintained a degree of continuity between the design philosophy of battery powered receivers of the late '20s and their immediate mains powered derivatives — but with one important qualification. By careful null-balancing of the heater earthing, the 226 could indeed be used in all established roles — except that of detector, where the hum level proved totally unacceptable.

It was a limitation that forced manufacturers, at long last, to come up with mass produced valves having an indirectly heated cathode, the best known of which was the 227 (or 27). With a 5-pin base, it was still electrically similar to the ancient 01A — but it was essentially hum-free.

The 27, and valves like it, broke the intellectual log-jam preventing the development of true all-mains receivers. Designers soon expressed a preference for indirectly heated valves for all roles, giving rise to a demand for companion types with more generous performance

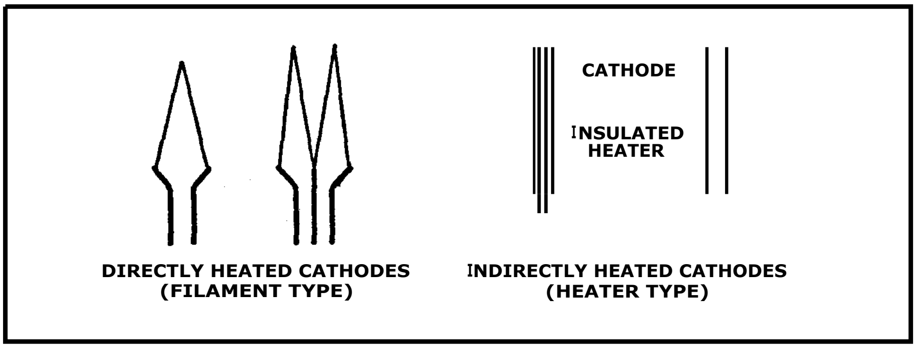

Fig.7: ***The indirectly heated cathode (right) was a virtual pre-requisite for AC mains powered receivers. First suggested In 1921, the idea was not adopted for mass-produced valves for another six odd years.***

parameters than could be contemplated with a battery supply.

For their part, valve manufacturers, once they had come to grips with **heater/cathode** technology, foresaw the emergence of a whole new market area — requiring not just mains powered general-purpose triodes, but power output valves and sundry other types optimised for particular roles in a new generation of receivers.

In fact, the period from about 1928 onwards was marked by a procession of new valve types, as outlined in this `Think Back' series for May and June 1990 under the sub-heading 'The rise and fall of thermionic valves or tubes'.

There were power output valves like the 45 and 47, rated to deliver 2 watts or thereabouts to the loudspeaker — ten times as much as available from even a loud battery set. There were rectifier valves like the 80, meant to be built right into a mains receiver and supply the necessary high tension voltage and current.

There were screened-grid, **tetrode** and pentode valves like the 24, 35, 57 and 58 designed for use as RF or **superhet** IF amplifiers, or for very high gain audio stages.

Thermionic diodes became commonplace, for use as detectors, and so too did complicated valves intended for use as frequency changers in superheterodyne receivers.

In many cases, new valves were introduced to meet urgent demands from the ever-expanding receiver market. In others, they were the result of on-going research in valve laboratories which resulted in new receiver design concepts. Ironically, progress in mains type valve and receiver design generated a demand for parallel technology in battery powered domestic and portable sets and automotive receivers. As a reminder of valves in those categories, readers may care to turn back to the articles mentioned above.

Assembly and wiring

This same period saw a complete revolution in the methodology of assembling and wiring domestic radio receivers.

Up to and beyond the mid 1920's, most receivers were constructed on a baseboard and panel, which slid into a table-top cabinet with lift-up lid. The major components were designed to mount on the baseboard or panel, with the incoming lead-ends being bent into an eyelet shape and clamped under flat-headed screw terminals or knurled nuts with a concave undersurface. It was very much the 'handyman' approach.

The done thing was to effect the interconnections with bare tinned copper **busbar**, of *square* cross section and about 1/16" (**1.6mm**) thick.

This was laid painstakingly in place and bent at strict right-angles, as appropriate, so that every run would be either exactly parallel to the panel and baseboard or at right-angles to them. The resulting 'geometric' style of wiring is well illustrated in **Fig.8**. Fairly **ob-**

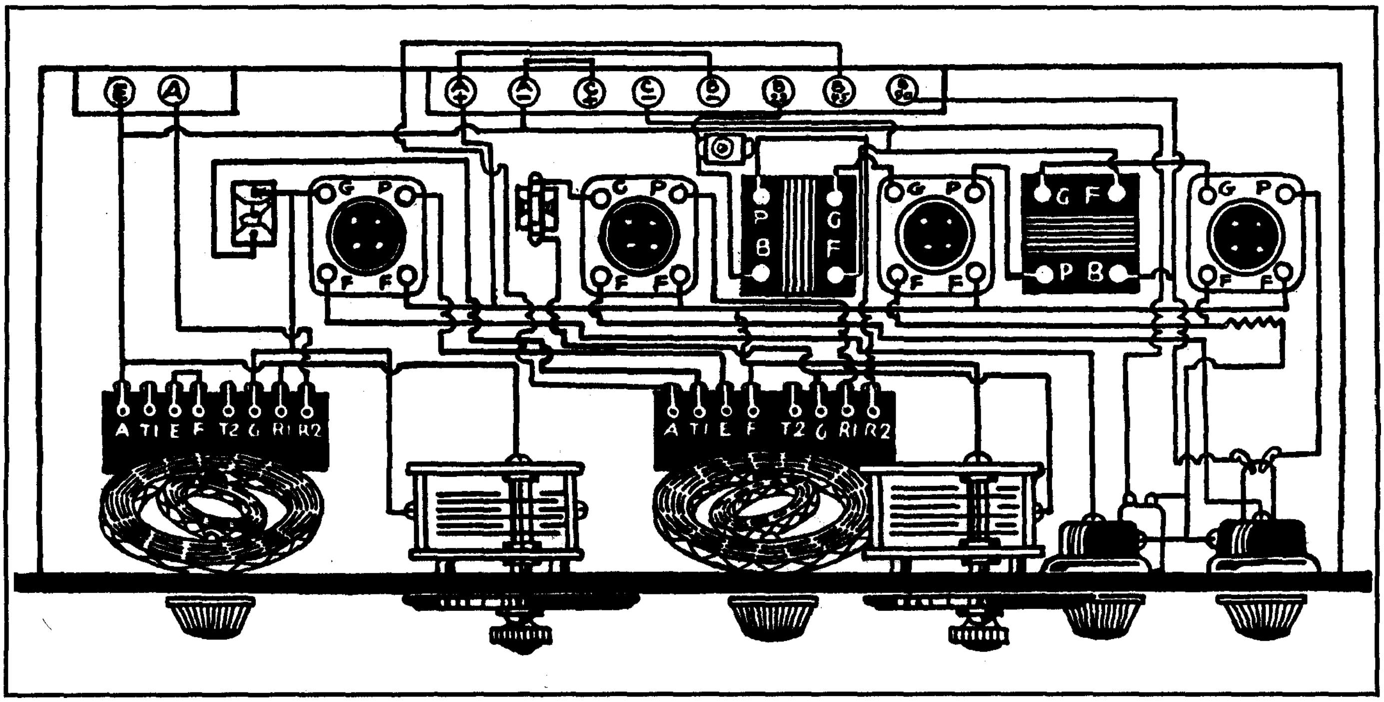

Fig.8: ***Originally from 'Wireless Weekly' for August 19, 1927, this shows the suggested wiring pattern for the 'Everyman's Four' receiver. To a handyman, ability to wire a receiver In the approved manner was as much an art form as his wife's embroidery!***

viously, in the two-dimensional drawing, loops have to be used to indicate that various wires cross without touching. In the actual receiver, the busbars would be elevated one above the other, to provide the necessary clearance.

For proud owners of new receivers, the routine was to switch on and demonstrate to visitors how they worked, then explain the purpose of the various knobs, finally lifting the lid to display the working parts — the valves and, of course, the orderly wiring.

I remember my father, responding to an article in a magazine, preparing to make changes in the family Colmovox. He could have used any wire to hand, but that wasn't good enough. He had to equip himself with several lengths of square-section busbar and a pair of long, round-nosed pliers to form eyelets at the end of each run. The job done, it was difficult to tell that the original wiring had ever been tampered with.

In fact, as I recall mentioning elsewhere, he was so proud of his handiwork that he set about making a glass front-panel for the receiver so that visitors, listening to the sound, could also contemplate the internal works!

A different approach

In due course, however, the industry began to realise that fancy terminals and fussy wiring methods were tedious and costly, without adding anything to the actual performance of the receiver. If you have a copy of the *Wireless Weekly 1927* reprint, take a look at the layout diagrams on pages 35 and 36 for an 8-valve superheterodyne, and imagine the man-hours that would be involved in translating them into a multi-layered pattern of bare busbar.

So it was that geometrically arranged busbar gave place to insulated 'point-to-point' wiring, with tags and soldered joints taking over from terminals and eyelets.

The move to mains operation also had an important bearing on the transition. It was certainly not prudent to have exposed bare wiring or terminations carrying mains potentials, or even the 250-odd volts DC that was commonly applied to the anodes of mains type valves.

The end result was the almost universal adoption of inverted metal dish 'chassies', with the major components mounted on top and the point-to-point insulated wiring and small components underneath, well away from prying fingers.

Apart from safety, the format lent itself to familiar metal working techniques and to assembly line production. If the chassis needed to be made attractive to the prospective purchaser, the external components could be variously embellished with lacquer, enamel, electroplating and labels, all of which were variously exploited in typical Australian receivers.

That was about the way things were when I ceased to be an onlooker and took my first job in a radio factory. I must confess that, against a traditional battery set background, it came as something of a culture shock to learn that the attributes of a capable production wirer were accuracy, speed and the ability to make good soldered joints. Neatness didn't seem to count for much, apart from keeping leads reasonably short and reasonably firm.

After encountering a few early examples of 'new-age' mass-produced chassies, it became evident that, in the matter of neatness, some production supervisers and bench wirers had taken liberty for licence. On top, the chassis and other metalwork may have been `prettied up' with gold coloured lacquer — but underneath, to compare the wiring with a proverbial `rat's nest' would have been unfair to rodents!

How NOT to do it!

Leads ran hither and yon in all directions, trimmed to 'near enough' length, looped around to reach their destination and spot soldered to the appropriate lug. Overlaying the wiring was an assortment of resistors and capacitors, bridging from here to there and supported for the most part by their own roughly trimmed leads.

If that wasn't bad enough, much of the wiring had been done with stranded tinned copper wire, covered in a rubber which had gone 'gooey', interacting with the wire and solder to coat it with a chemical salt of some kind. For a technician, replacing leads or parts in that kind of environment was nothing short of a horror.

When I started at Reliance Radio, it was in a completely virgin situation: my first job, on the first day of a new factory, assembling and wiring the first batch of a completely new line of receivers.

Another novice wirer and I were given the circuit, the wherewithal and a laboratory prototype to follow, and it was more or less up to us to work out the details of how best to arrange the leads and minor components.

Fortunately, my new mate was also methodically inclined and, under the supervision of the designer, we worked out a common wiring routine: short, direct leads for the high frequency connections and methodically grouped runs for the supply leads, anchored to the chassis by clips or other means. A bare tinned copper busbar linked all the earth lugs under isolated mounting nuts, and provided a convenient anchorage for the various earth bypass capacitors.

Once devised, the wiring style was adopted for all models and, in later years, Reliance took to displaying their chassies in radio shows over a 45° mirror, with under-lighting to emphasise the orderly wiring.

In fact, there was more to *all this than* mere cosmetics. Manufacturers soon realised that underside wiring had to be kept clean and accessable for ease of service, and suitably anchored if it was to survive long delivery journeys by Australian road and rail transportation.

It was a lesson that had to be even more scrupulously applied later in the monochrome television era, with its greatly increased valve and parts count and more complex wiring.

In the next chapter, we will be looking at the evolution of typical mains type TRF and superheterodyne circuits.

(To be continued)