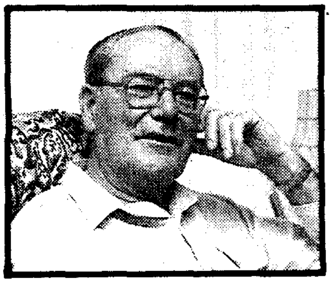


When I Think Back...

by Neville Williams

Major Edwin Howard Armstrong MIEE: a genius who lost the will to live - 1

Enthusiast, amateur, US Army officer and graduate engineer, Edwin Howard Armstrong could well qualify as one of the most inventive of all the pioneers in the history of electronics. But sadly, he is also one of its most tragic figures who, in a mood of despair, ended his own life a few years back at age 64.

The outlook must surely have been much more promising when an obviously young Major Edwin Armstrong was pictured on the cover of *The Australian Wireless Review* in March 1923. It was one of a series of picture/stories featuring scientists and innovators such as Senatore Guglielmo Marconi, Professor Michael I. Pupin, John Henry, Dr Alexander Graham Bell, Sir Oliver Lodge and Sir Joseph J. Thompson.

Explaining his decision to include the 32-year old Armstrong in such auspicious company, the *AWR* editor offered this opinion: 'Major Edward H.Armstrong is a comparatively young man, but there is probably no other single individual who has accomplished so much in the radio field'.

At this early point in his career, he had been a keen radio amateur, prominent in the historic trans-Atlantic tests of 1921, was associated with the Institute of Radio Engineers, President of the Radio Club of America and held a position as a professor at Columbia University.

According to the accompanying one-page biography, he had been born on December 18, 1890, the son of an American representative of a British book publisher. His favourite reading as a lad was *The Boy's Book of Inventions*.

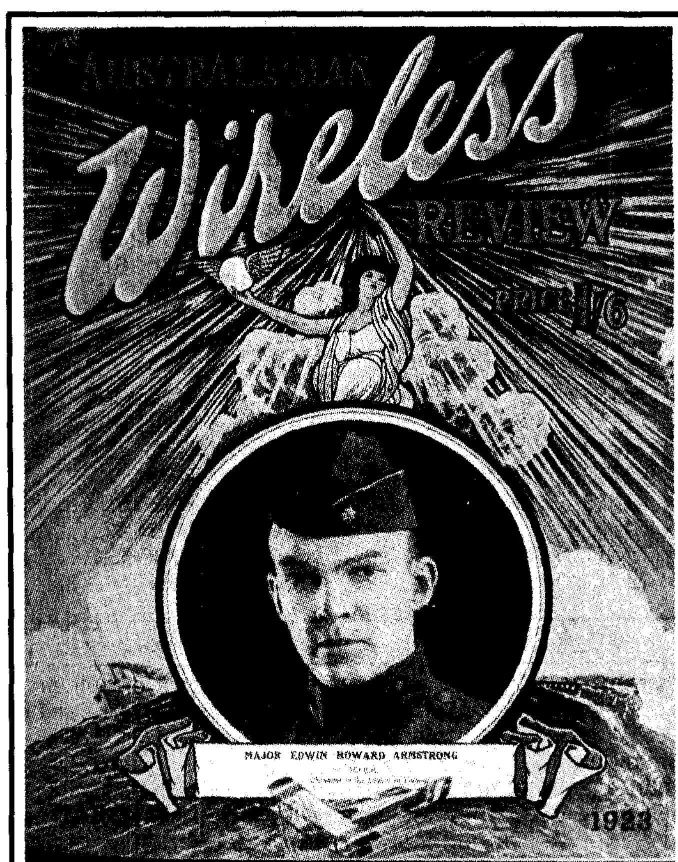
At age 15, while still at high school, Armstrong developed a keen interest in radio, which continued to claim his attention at Columbia University, from which he graduated in 1913 as an Electrical Engineer. He had set up receiving – later, transmitting – equipment in his bedroom, where he pursued his youthful experiments employing the primitive techniques of the period. Armstrong later described it as "The age of darkness; the 'hit or miss' years of radio".

High technology in those days was exemplified by the Fleming diode; but in 1911, Armstrong went one better when he acquired an 'audion' three-element valve made by Dr Lee De Forest. Not content to experiment blindly, he sought out every text he could find on the basics of radio, especially anything that might have a bearing on the operation of the audion triode.

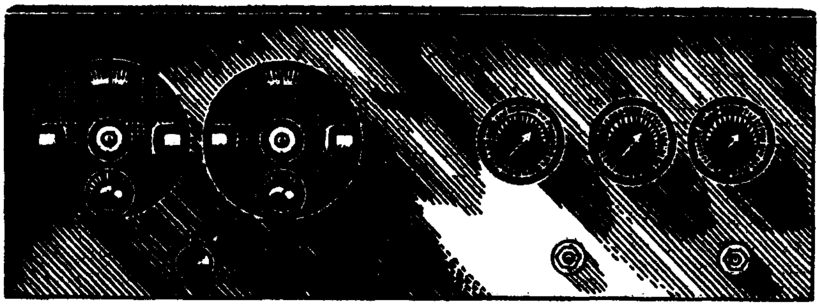
Armstrong was fortunate that, during his student years, the Professor of Electro-mechanics at Columbia was the celebrated Michael Idvorsky Pupin PhD (Hon) DSc, DLl. A world authority on matters electrical, Pupin had himself devoted considerable attention to wireless communication.

Regeneration

In 1912, it occurred to Armstrong to try tuning the plate circuit of the audion



Armstrong as pictured on the front cover of the 'Australasian Wireless Review' for March 1923. Still a young man, he had already earned a high reputation for his contribution to wireless/radio.



The front panel of an 8-valve build-it-yourself superhet described in 'Wireless Weekly' for July 29, 1927. The main controls are (L to R) oscillator tuning, loop aerial tuning, IF amplifier filament current and bias, and detector filament current.

triode, as well as the customary grid circuit. He was rewarded by a substantial increase in the loudness of the incoming signals, although any attempt to increase the gain of the detector beyond a certain point resulted in a 'raspy' degradation of the audio content, with the signal ultimately becoming almost 'indistinguishable'.

With hindsight, Armstrong had stumbled upon the configuration of what later became known as the TPTG (tuned plate, tuned grid) oscillator, in which a valve may sustain oscillation by reason of its internal grid/plate capacitance, when the plate circuit is brought to near-resonance with the grid circuit.

In the case of a triode valve being used as a detector, Armstrong's experiment set up a situation whereby bringing the plate and grid circuits towards a common resonance resulted in positive feedback – later to become known as *regeneration* or *reaction* – thereby substantially increasing detector gain or sensitivity.

On the verge of instability, the audio content of the incoming signal tended to become distorted, being ultimately swamped by the detector's own self-generated signal when oscillating strongly. In the years that followed, countless experimenters with small regenerative receivers had to contend with these very same effects.

At first, Armstrong did not understand why the circuit should behave in this manner but, in early 1913, he felt that he had worked out a logical explanation. His technical friends were not convinced that he had uncovered an important circuit principle but, following the advice of a canny uncle, he took the precaution of having a copy of his circuit witnessed by a notary public.

Patent litigation

By way of interest, *ARW's* picture/story on Professor Pupin, in their April 1923 issue, mentions that on the patent application for the so-called 'Armstrong Regenerative Circuit', Pupin's name is coupled with that of Armstrong as joint applicant. To quote from the article:

It is hard to say what part was actually played in the invention of the regenerative circuit by Professor Pupin, but it is certain that Major Armstrong had the benefit of the Professor's mature experience in wireless research matters to aid and guide him.

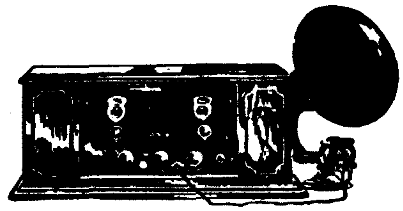
In due course, the original notarised circuit proved to be a key document when the concept of feedback and the audion oscillator became the subject of litigation involving Armstrong, De Forest and others. Indeed, the patent litigation between Armstrong and De Forest is said to have been the most protracted ever in wireless history.

Armstrong won the first round in 1917, after which De Forest assigned his patent interests – past, present and future – to AT&T. In that same year, Armstrong was awarded the IRE Medal in recognition of his discovery. The court verdict was effectively reversed some time later but, in the eyes of contemporary engineers, Armstrong was thereby unjustly denied his rights.

Historically, he is still seen as the father of the two related concepts – regeneration and the valve oscillator – both of which were further developed by other designers during the 1920s.

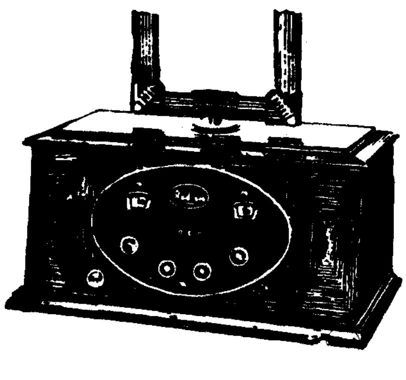
This view is supported by an article in the UK paper *Electronics Weekly* for January 30, 1963. I quote:

It is no disparagement to the parallel work of of De Forest, Langmuir, Meissner and our own Captain H.J. Round to point out that even though the US Supreme Court – in the face of the bulk of engineering opinion – twice refused him the credit for the discovery of regeneration, there can be little doubt that Armstrong was the first to realise its practical importance and to benefit from it in actual receiving practice.



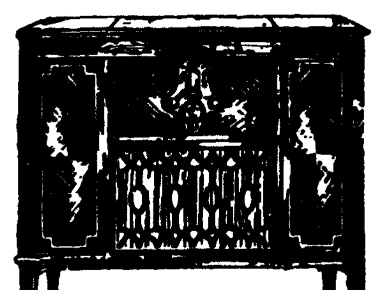
THE RADIOLA STANDARD 6

A 6 Valve Superheterodyne Receiver housed in a handsome Laminated Maple Cabinet. Complete with all accessories, including Amplion Loud Speaker, £45.



THE RADIOLA SENIOR 6

A 6 Valve Superheterodyne Receiver complete with all accessories, including Amplion Loud Speaker, £65.



THE RADIO SUPER 8

A magnificent 8 Valve Superheterodyne Receiver with concealed loop and enclosed Amplion Loud Speaker.

AWA followed RCA's lead by introducing an Australian series of AWA Radiola superheterodynes. The Standard 6, Senior 6 and Super 8 were advertised in 'Wireless Weekly' for November 18, 1927.

WHEN I THINK BACK

The 'superhet'

In 1917, Armstrong was commissioned into the Signal Corps of the AEF (American Expeditionary Force) and sent to Paris – there to investigate the possibility of intercepting messages being exchanged by German low-power trench wireless sets. It was an assignment that called for unusually sensitive receivers, capable of working from directional loop aerials concealed behind the allied front-line trenches.

As a possible answer, Armstrong came up with the idea of a receiver with a built-in oscillator that would beat with or 'heterodyne' the wanted signals, reducing them to a much lower frequency. He reasoned that, at 50-100kHz, they could be isolated and demodulated far more efficiently.

In his book on Guglielmo Marconi (Heron, 1970) David Gunstan mentions, *inter alia*, that Armstrong had his own dream about a further role for such a receiver: that it might be sensitive enough to sense the ignition systems of approaching enemy aircraft before they could be discerned acoustically.

In fact, the proposed supersonic-heterodyne or *superheterodyne* receiver emerged too late to find much practical application in World War I. But Armstrong's research earned him the rank of Major in the American Army, and a citation by the French as Chevalier of the Legion of Honour.

But, as if on-going litigation about his earlier work was not sufficient, his responsibility for the superheterodyne principle was also questioned – as would have been apparent to readers who have followed the 'Letters to the Editor' columns of *Electronics Australia* over the past year or so.

In response to an article by Peter Lankshear in the September 1988 issue, letters in the November '88 and February '89 issues from both the author and retired STC engineer Winston Muscio drew attention to the fact that the first superhet receiver patent was filed in Paris by Lucien Levy on August 4, 1917 – some eighteen months ahead of Armstrong's American patent.

The Levy patent was subsequently assigned to Western Electric of London (June, 1924) and, for Australasia, to STC of Sydney (June, 1926) to whom the relevant licence fees in this country had thus become payable.

Possible explanation

Commenting on this in the October 1989 issue, a former patents examiner (wireless) G.H. Rance BSc, says that the US Patents Office is unlikely to have deliberately ignored Levy's claim; a more logical explanation being that a wartime patent issued in Paris may simply not have been circulated to it. In any case, he says, in terms of novelty, US law at the time allowed a US citizen's patent to date back to the actual time of the invention.

Seeking to explain the apparent conflict, Winston Muscio suggested a likely course of events in the February 1990 issue of *EA*. It is well known, he said, that Armstrong and Levy worked closely together during World War I on the problem of achieving higher receiver gain using then-available triodes. It is entirely possible that they reached the same conclusion together or simultaneously. At this point, Levy may well have pressed on with the paperwork, with Armstrong putting it off until he had clarified his thinking about another concept that he was pursuing, namely *superregeneration*.

Quite obviously, Armstrong's contribution was recognised by the US military and the French Government and endorsed by the US Patents Office by the issue of patent No. 1,342,885, filed on February 8, 1919 and issued on June 8, 1920.

As it happens, I have on hand an original article on the superheterodyne receiver written by Edwin Armstrong. Entitled 'A New System of Short-Wave Amplification', it was published in the Australian magazine *Sea, Land and Air* for September 1, 1921.

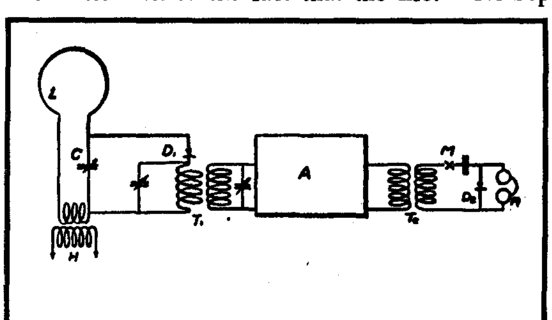


Fig.1: From Armstrong's own paper published in Australia in September 1921, the basic concept of a superhet receiver. Early superhets commonly used loop aerials to minimise objectionable signal radiation from their heterodyne oscillator.

It should be noted that, in those days, the term 'short wave' signified wavelengths below (shorter than) about 600 metres (500kHz), and would therefore include the whole of our present-day AM broadcast band, which we now describe as 'medium wave'.

Armstrong's article

Reviewing the design options for a high sensitivity 'short wave' receiver, Armstrong mentions the following:

1. *Amplification of the audio frequency current after rectification.* The limitations of this approach lie in the diminishing efficiency of available detectors with decreasing wavelength, and the noise problems with high-gain audio amplifiers working from too small a recovered signal.
2. *Amplification of the radio frequency current before detection.* A difficult approach on short waves, because resistance-coupled RF stages yield very limited gain and tuned systems are prone to self-oscillation. In passing, Armstrong acknowledges a notable contribution in this area by Round in England and Latour in France, with special low-capacitance valves and what we would now define as high L/C, low-Q resonant coupling circuits.
3. *Application of the heterodyne principle to increase the efficiency of rectification.* The reference is unclear, but rather suggests the direct conversion or 'homodyne' principle. Armstrong rejects it for use at wavelengths below 600 metres, because of instability of the beat tone – which results in distortion in the case of telephony and the loss of 'clear tone' and 'individuality' with spark signals.

Armstrong then proceeds to introduce and explain an 'expedient' approach "evolved at the Division of Research and Inspection of the Signal Corps, American Expeditionary Force".

As depicted in Fig.1, the incoming signals are intercepted by loop L, which is rendered broadly resonant in conjunction with the secondary winding of transformer H and variable capacitor C.

Transformer H provides a means of introducing to the input circuit a second signal, from an external tuneable oscillator. A signal rectifier D1, in the role of 'first detector', feeds to resonant transformer T1 the original input and the local oscillator signals, plus their sum and difference resultants.

Typical figures

By way of example, Armstrong assumes that circuit LC is tuned to select

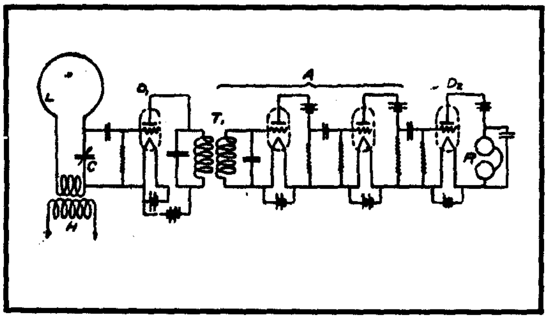


Fig.2: More elaborate than Fig.1, this suggests the use of a resistance coupled IF amplifier (bracketed 'A') which, in practice could involve up to six separate stages. Note the use of triodes as the first and second detectors.

a wanted signal at 3,000,000 cycles (Hz) and that T1 has been pre-tuned to what we would now describe as an 'intermediate' frequency of 100,000 cycles. If the external heterodyne oscillator is now set to either 3,100,000 or 2,900,000 cycles, the heterodyne process will produce a difference resultant of 100,000 cycles, which will be passed on to amplifier A, the original source frequencies being rejected.

In effect, the original 3,000,000Hz signal, together with any superimposed modulation will have been 'shifted down' to 100kHz. Further filtering is possible by output transformer T2, which can also be tuned to 100kHz. A signal rectifier D2 serves to isolate the modulation, to drive the headphones or for further amplification by an audio amplifier.

Although expressed without the benefit of present-day jargon, this is pure superheterodyne theory. Armstrong even mentions the option of double frequency changing, with the idea of achieving still higher overall gain with minimal risk of interstage feedback and instability. For example, to receive signals in the vicinity of 5MHz, it may well prove worthwhile to use double frequency shift to 500kHz and then 50kHz before final detection.

He also mentions the possibility of simplifying the overall circuitry by exploiting self-oscillation – presumably a self-oscillating mixer – although he recommends separate heterodyne oscillators by reason of their superior frequency stability, particularly at the higher frequencies.

Fig.2 is another of the six diagrams used to illustrate other points in Armstrong's paper. One is the use of a triode valve as a combined signal amplifier and first detector, ahead of the tuned transformer T1. This not only provides gain, but also opens the way for the introduction of input circuit regeneration.

Next is the use of resistance coupling in the intermediate frequency amplifier, bracketed as 'A'. The point is made that two such stages may be needed, just to compensate for the signal loss in frequency changing, and that as many as six IF stages may be considered desirable in a high performance receiver.

At the time, limited selectivity was scarcely a problem because of the relatively few transmitters on air and the poor frequency stability of those that were. Perhaps significantly, Fig.2 omits the output coupling transformer T2 and features another triode as the second detector, for extra gain.

(Intended mainly to illustrate principles, Fig.2 shows each stage with its own separate filament and plate supply batteries. Normal practice would be to use common A- and B-batteries for all stages).

Superhet development

In view of the earlier debate about the origin of the superhet, the final paragraph in Armstrong's article is interesting, having in mind that it must have been written shortly after the patent documents had been issued:

While the fundamental idea of this method of reception is relatively simple, the production of the present form of the apparatus was a task of the greatest difficulty for reasons known only too well to those familiar with multi-stage amplifiers; and to Lieutenant W.A. MacDonald, Master Signal Electricians J. Pressby and H.W. Lewis and Sergeant H. Houck, all of the Division of Research and Inspection, Signal Corps, A.E.F., I wish to give full credit for its accomplishment.

Hartley Research Laboratory, Columbia University, New York City.

According to the article in the UK journal *Electronics Weekly* (January 30, 1963), that same H. (Harry) Houck assisted Armstrong to adapt the design for domestic broadcast band reception – a project that worked out so well that Armstrong offered it to RCA in February 1923.

At a time when outdoor antennas were mandatory, Armstrong turned up at RCA Chairman David Sarnoff's apartment carrying a radio playing at full blast. Sarnoff was so impressed that the receiver became the basis of the RCA 'Radiola' for 1924, setting new performance standards in a market that was otherwise locked into the TRF-plus-reaction format.

In that same year, at a more personal level, Armstrong 'acquired' one of Sarnoff's secretaries, who became his wife!

It took a while for industry as a whole to face up to the challenge of the superhet circuit, but more or less coincident with the design revolution that accompanied the switch from battery to mains operation in the late 1920s, superhets took over and TRFs virtually disappeared.

Superhets are still with us, even if rendered functionally unrecognisable by solid-state digital technology. Gone are the accoutrements that were once necessary to make it all happen. Whether in a domestic AM/FM radio, a TV receiver or high-tech communications equipment, you simply press a button and built-in logic circuitry does the rest. Yet Armstrong's basic explanation, as above, still applies.

We'll look at Armstrong's other achievements and the unhappy circumstances associated with the end of his life, in the second half of this story.