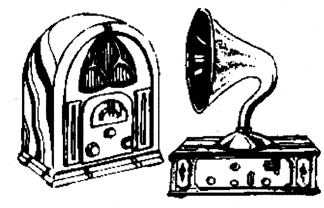
Vintage Radio

by ROGER JOHNSON



'Super-regenerative' receivers

No discussion of vintage radio would be complete without a reference to super-regeneration. An invention of the redoubtable Major Edwin Armstrong in 1922, the popularity of this circuit was initially both limited and short lived. But it surfaced again briefly after WW2, as we shall see.

In the very early 1920s, when valves were hideously expensive, various means were devised to get the absolute maximum performance from a given valve. One such technique was reflexing (refer Vintage Radio, in the February/March 1997 issues of *EA*) and the other was 'super-regeneration'.

Armstrong's first invention, in 1912, involved taking a small portion of amplified radio frequency signal from the plate circuit of the detector valve, and 'feeding it back', (hence *feedback*) to the tuning circuit. The energy so imparted is in phase with that in the grid (tuning) circuit, and enhances or 're-generates' the signal, such that a larger signal is available to the valve to be amplified. This is the concept of *regeneration*.

By carefully controlling the amount of energy being fed back to the grid circuit, a point can be reached whereby the valve and its associated tuning circuit are operating at maximum efficiency, and hence maximum gain and selectivity. A tad too much feedback, and the valve oscillates. Expressed another way, the optimum condition is when the circuit is on the verge of oscillation.

Those enthusiasts who have operated a simple one or two valve regenerative detector are no doubt well aware of the even greater sensitivity (and therefore gain) that can occur when the detector stage is allowed to self-oscillate. Weak signals are received, but not demodulated. Rather, they present themselves merely as the all too familiar 'squeal'. What if there was some method of maintaining the sensitivity and the gain, but eliminating the self oscillation, and receiving intelligible signals?

Armstrong's invention of 'super-regeneration' in 1922 provided the answer.

If the valve's gain was allowed to build up to its maximum state, and then momentarily suppressed, then allowed to build up to maximum gain before being again momentarily suppressed, and so on, to the point where it always on the verge of oscillation, then the desired results might be achieved. When the valve is at its momentarily low gain state, it takes a finite time to build to its maximum gain state, depending upon the instantaneous input voltage at the grid at the moment of switch on.

What *is* super-regeneration?

Super-regeneration is like an ordinary regenerative detector which is being modulated by a signal at supersonic frequencies — i.e., above the audible hearing range. Hence the name 'super-regenerative'. This modulation is not the speech modulation normally associated with a transmitted intelligible signal. It is a method of gating the valve (although the term was unheard of in 1922!) from its low-gain state to its high-gain state, at a supersonic rate referred to above. At the high-gain state it is on the verge of self oscillation, but is not allowed to remain in that state because at a given point of the gating period, it is switched back to its low-gain state.

In the short time available, dictated by the gating period, the valve cannot reach a sufficiently high enough gain to maintain self-oscillation.

A synopsis of Hikosaburo Ataka's explanation and graphic illustration of super-regeneration taken from *Proceedings of the IRE* (USA) for August 1935 was provided by Neville Williams in 'When I Think Back', in the May 1991 issue of *EA*. A graph and caption from that article is produced in Fig.1.

Mr Williams' article, again referring to Ataka's work, gives a good explanation of a very difficult and complex phenomenon, and also explains the generation of the excessive amounts of noise that characterises super-regenerative detectors. If we refer to the waveform designated 'oscillatory voltage' in Fig.1 as a 'packet', then, quoting Mr Williams, 'In the presence of a weak amplitude modulated input signal, the oscillatory packets are triggered partly by the signal, and partly by the noise, so that the recovered audio is a mix of the two'.

Hence the signal at the anode is a greatly amplified series of packets or bursts of the input signal, corresponding to the gating frequency and amplitude. This gating signal is smoothed by filtering, despite it being at supersonic frequencies, so that intelligible signals

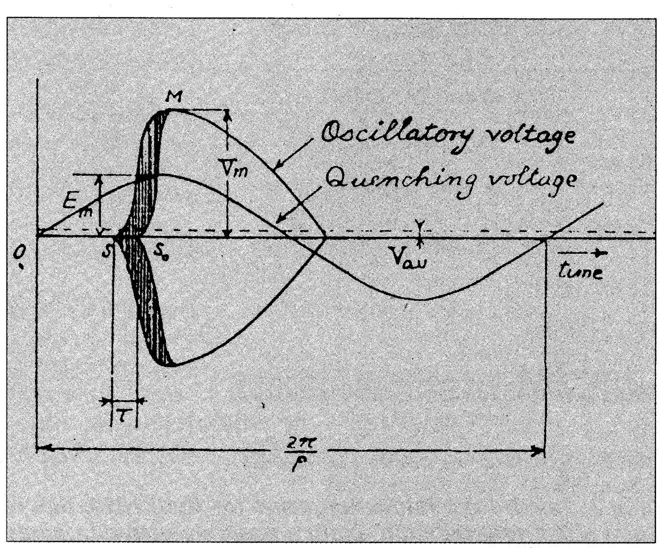


Fig.1: Ataka's diagram showing the essential clue to the operation of a super-regenerative detector. The quench signal initiates and quenches packets of RF oscillation. Extraneous noise and/or signal advances the trigger point (shading), affecting the duration of the burst and superimposing a resulting audio component on the anode current and voltage (dotted line, Vav).

are available either in the headphones or for further amplification.

It may be prudent to add that an alternative name for the gating frequency is the 'quenching' frequency, a term often used in American texts.

How is it achieved?

The gating/quenching may be achieved either by the valve self-oscillating at the supersonic quench frequency, in addition to acting as a normal regenerative stage, or by feeding a supersonic signal to the circuit by separate means involving another valve. The circuits are quite tricky, and understanding them was heavy going for the experimenter of the 1920s!

In the early 1920s there were spark, CW and telegraphy signals, and different circuits were said to favour the reception of the different modes of transmission.

The circuit shown in Fig.2 appeared in *Radio News* for March 1923, and was said to be suitable for spark, telephony or 'ICW' (interrupted continuous wave?) signals — but not suitable for straight CW telegraphy. The text of the article shies away from how it works, instead proclaiming that, 'the manner in which these variations of the regenerative system produce the enormous amplification of the super regenerator are rather complicated and will not be entered into at this time'!

One possible explanation might be as follows. Notice that the negative return of battery B2 is connected in series with a tuned circuit L4/C3, and in the un-earthed grid return circuit is the tuned circuit L3/C2. These coils are of the large honeycomb variety comprising 1500 and 1250 turns respectively, and are magnetically coupled.

By virtue of the cathode current, as opposed to the filament current, flowing through L4/C3, oscillations are established, in the tuned circuit L3/C2. The inductive reactance of the main tuning coil L1 will have little or no effect on L3/C2 as a quenching oscillator. When this circuit swings sufficiently positive to overcome the standing bias, a small amount of grid current will flow for a portion of the gating period, and this dampens entirely the normal regenerative circuit L1/L2/C1 for the corresponding portion of the quenching period. That is, the valve is gated to a low-gain state.

Not shown in the circuit, but explained in the text, is that L1 and L2 are the two coils of a variometer, and L3/L4 are also variably coupled. This is done to enable optimum coupling so that the detector stage is neither shut down completely, because of too much grid current flowing for too greater part of the cycle, nor allowed to oscillate freely because of no grid current flowing at any part of the cycle.

The L1/L2 variometer is one of the normal means of controlling regeneration for maximum effect. For super-regeneration, coupling must be tight. Explained in the text is the fact that the grid bias may have to be adjusted to 'get it going', then re-adjusted for optimum results. The text gives quite detailed operating procedures, suggesting that there is quite an interplay between the variometer, the quenching circuit and adjusting of the grid bias, in additional to the tuning of a signal.

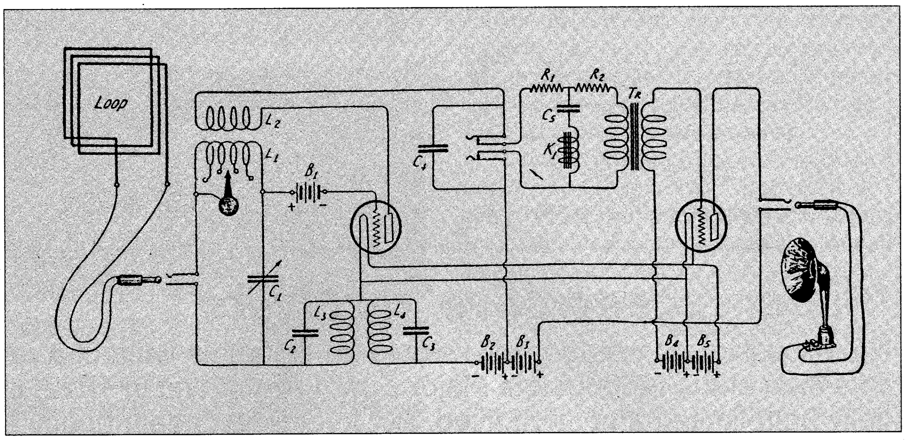


Fig.2: The circuit for the 'Radio Flivver' given in Radio News for March 1923. The RF stage (left valve) is a self-quenching super-regenerative detector.

Quench frequency filter

The second stage of Fig.2 is merely an audio amplifier, with a filter comprising of C5 and inductor K1, which together comprise a series tuned circuit. This presents little or no impedance to the quench frequency.

Quite often the circuit constants were arranged such that a choke of suitable value was used in conjunction with a variable 0.001uF (1nF) capacitor, so that the quench frequency could be literally tuned out.

R1 and R2 are, in all probability, to isolate the inductance of the primary of audio coupling transformer Tr, and hence eliminate any undesirable filtering, loading or detuning effects. The values given are in the order of 10kΩ, large enough to achieve the desired effect whilst minimising any DC resistance of the signal to the primary of the transformer.

Two tube super-regen

For all intents and purposes, the super-regenerative detector in Fig.2 can be regarded as using a single tube (valve). However, in Fig.3, taken from *Radio* for April 1924, a separate tube is used to generate the oscillations, and in this circuit, the output of the quench oscillator is imposed on and added to the anode of the detector tube such that the increased anode voltage increases the stage gain and places it in a super-regenerative state for the desired portion of the quenching cycle.

No mention of valve types appears

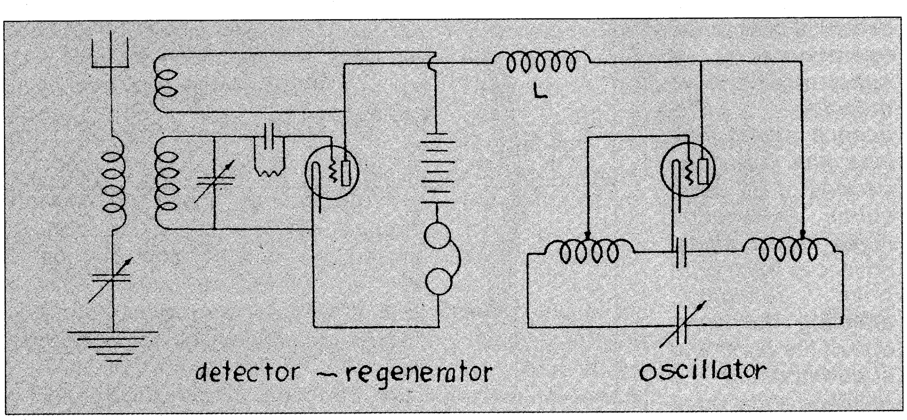


Fig.3: Taken from Radio magazine for April 1924, this circuit shows plate voltage super-regeneration using a separate quenching oscillator.

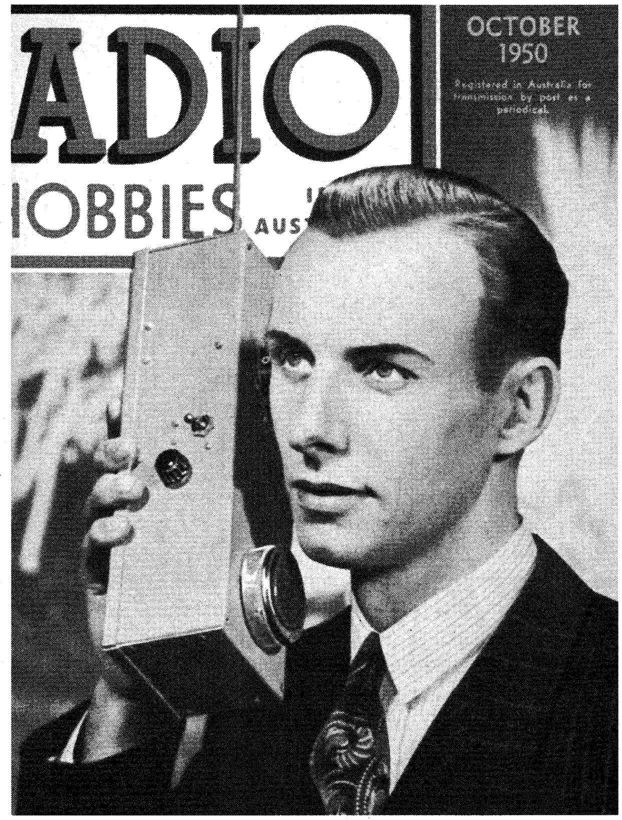


Fig.4: Part of the front cover of Radio and Hobbies for October 1950, showing a 'walkie talkie' transceiver for the 288MHz band using only two tubes. It used a super-regenerative detector in the receiver.

in the text from which the diagram of Fig.2 was taken, except for a cursory mention of 'five-watt tubes'. This refers to five-watt transmitting types, and it is generally accepted that power types, rather than general purpose types, gave better results. Mind you, in 1923 there were not a huge number of valve types on offer, and a five-watt transmitting type would no doubt cost more than a 'general purpose' type. However power triodes, as such, gave good results. In reality, experimenters of 1923 would have most likely used the bright emitter type UV-201.

Limitations & performance

Quite outstanding results have been claimed for the super-regeneration circuit in terms of sensitivity. Unfortunately, the same cannot be said of selectivity. By the very nature of the super-regenerative process, the tuned circuit (i.e. the grid circuit) is sufficiently dampened to make it more like a feather mattress rather than neatly honed razor (I trust you'll pardon the rather gauche similes).

So in terms of tuning selectivity, super-regens had the reputation of being 'as broad as a barn door'.

For best results, the quenching frequency had to be low in comparison to the tuning range, and if used these days on the normal broadcast band with the station separations of 9kHz, all sorts of difficulties could arise — not the least of which would be heterodyning and cross modulation, and any amount of mixing of quench frequencies with adjacent carriers, sidebands, and so on. However in 1923, those problems did not arise.

A loop antenna was often employed for two reasons: firstly, a large outside antenna was unnecessary; secondly, unless the set was properly adjusted, severe radiation could result and a loop antenna reduced considerably the likelihood of interference to adjacent receivers.

With the quenching oscillator causing generous amounts of noise from within the valve, and possibly inadequate filtering, there was always a nice dose of constant background 'w-h-o-o-s-h' — particularly when tuned off-station. It is also said that unless properly adjusted, high pitched squeals (possibly sub-harmonics of the quench frequency) would be heard in the phones, leading to headaches etc. after prolonged operation!

Who used them?

Because of the inherent difficulty in operation and associated unpleasant noises, commercial manufacturers avoided super-regenerative sets like the plague. This type of set was strictly for the enthusiast. There are no known instances of commercial set manufacturers offering a super-regenerative receiver in their range of models. Experimenters on the 'short waves' — i.e., our current broadcast band — claimed admirable results, such as loudspeaker reception on two valves using only a loop antenna. Such results would have been unheard-of using conventional circuitry.

The 'Walkie Talkie'

Super-regenerative receivers had a brief reappearance just after the second world war, when radio amateurs used two- and three-valve handheld transceivers to operate on the two-metre (144MHz) and one-metre (288MHz) bands. In these circuits, high frequency 'acorn' valves such as the 954 and 955 were put to good use as they were available quite cheaply from disposals stores of the day.

For the receiver section, super-regeneration was invariably used as a very cost-effective means of obtaining sensitivity using only a short whip antenna. The number of valves was minimised, but more importantly, so too was battery current.

At that time, 1m and 2m equipment was still in the realms of experiment, and the bands allocated to the hams were fairly generous. Given these conditions, and the comparatively few hams who were using the band, the selectivity limitations of the super-regenerative receivers were of little consequence.

As the band became more popular and the various regulatory authorities reduced the bandwidth (and better and more powerful transmitting tubes became available) the days of the super-regenerative receiver were numbered. ❖