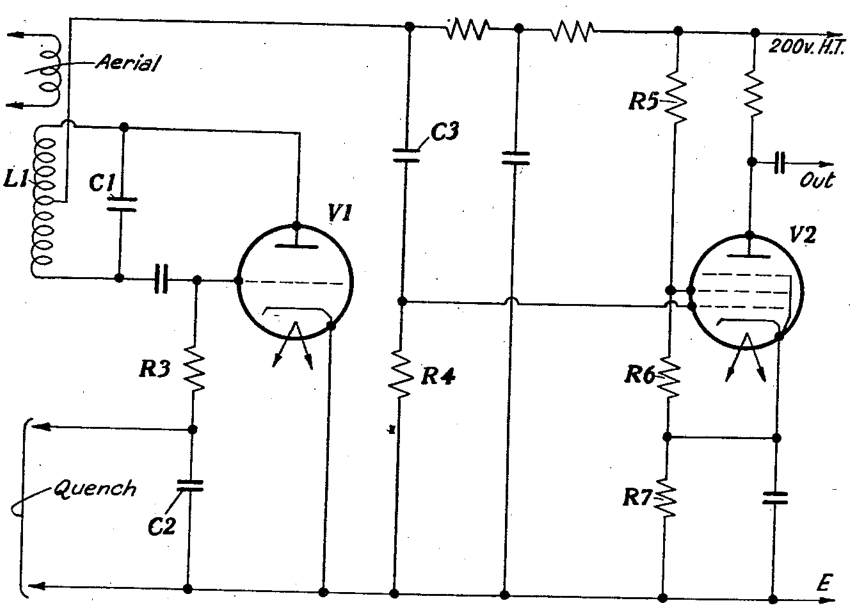
April 27, 1943. W. A. MONTGOMERY 2,317,474

SUPER-REGENERATIVE RECEIVER

Filed June 6, 1941



INVENTOR
W. A. Montgomery
BY Paul R. Adams
ATTORNEY

Patented Apr. 27, 1943

2,317,474

UNITED STATES PATENT OFFICE

2,317,474

SUPERREGENERATIVE RECEIVER

William Alan Montgomery, London, England, assignor to International Standard Electric Corporation, New York, N. Y.

Application June 6, 1941, Serial No. 396,814
In Great Britain June 25, 1940

2 Claims. (Cl. 250—20)

This invention relates to super-regenerative receivers for modulated carrier waves.

It is known that when a super-regenerative detector is working in its most sensitive mode the detector current is given by:

(1) $$Id = A - B \log_e Vi$$

where

Id is the anode current
Vi is the input voltage

and

A and B are constants

This is known as the logarithmic mode of operation. In the linear mode of operation the detector is less sensitive but the output is directly proportional to the input instead of the logarithm of the input.

The chief distinction between the logarithmic and linear modes of operation is in the quench frequency. If the quench frequency is sufficiently low to allow the oscillation to build up to saturation value before being quenched the detector behaves logarithmically. If, however, the frequency is increased until the oscillations are always quenched before reaching saturation value then the detector behaves linearly.

This invention is concerned with the super-regenerative detector in its logarithmic mode of operation.

It will be shown in the following analysis that the audio frequency component of the output of such a detector is logarithmic, that is, that the output signal frequency amplitude is proportional to the logarithm of the modulating voltage of the incoming carrier wave. The magnitude of the harmonic distortion resulting from this particular kind of non-linearity is considered; it is shown that the distortion due to the logarithmic characteristic can be compensated by the use of a succeeding low-frequency amplifier having an exponential characteristic and that for complete correction a critical value of detector load impedance is necessary.

Now assuming that the quench frequency is much higher than the modulation frequency, and expressing Vi as a modulated carrier wave, thus

(2) $$Vi = V(1 + m \cos \omega t)$$

where m is the percentage modulation we obtain by substituting for Vi in Equation 1:

(3) $$Id = A - B \log_e V - B \log_e (1 + m \cos \omega t)$$

The audio output is represented by the alternating components in the second part of this equation. It can be shown that this can be written in the form of an harmonic series as

(4) $$\text{Log}\ (1 + m \cos \omega t) = \log_e \frac{1 + \sqrt{1 - m^2}}{2} - 2 \sum_{n=1}^{n=\infty} \frac{1}{n} \left(\frac{-m}{1 + \sqrt{1 - m^2}} \right)^n \cos n\omega t$$

The only alternating current components of interest in the output are given by:

(5) $$Io = -2B \sum_{n=1}^{n=\infty} \frac{1}{n} \left(\frac{-m}{1 + \sqrt{1 - m^2}} \right)^n \cos n\omega t$$

The fundamental component is given by:

$$Ai = \frac{2Bm}{1 + \sqrt{1 - m^2}}$$

The second harmonic is given by:

$$A^2 = \frac{-m^2 B}{2 + 2\sqrt{1 - m^2} - m^2}$$

etc. from which it can be seen that the distortion in audio output is considerable particularly at high degrees of modulation. In order to eliminate this harmonic distortion the output is now passed through an amplifier having an exponential characteristic such that:

(6) $$Ia = Ke^{kVg}$$

where

Ia is the anode current
Vg is the grid voltage

If the resistance in the anode circuit of the super-regenerative detector is Ri, the voltage output is given by $V_2 = RiIo$.

If the fixed bias on the amplifying valve is Vi the grid voltage is given by:

$$Vg = Vi + V_2$$

From Equation 4

(7) $$-2 \sum_{n=1}^{n=\infty} \frac{1}{n} \left(\frac{-m}{1 + \sqrt{1 - m^2}} \right)^n \cos n\omega t = \log_e \frac{2(1 + m \cos \omega t)}{1 + \sqrt{1 - m^2}}$$

whence:

(8) $$V_2=BRi\log_e\left(\frac{2(1+m\cos\omega t)}{1+\sqrt{1-m^2}}\right)$$

(9) $$I_a=Ke^{k(Vi+V_2)}$$
$$=Ke^{KVi}\cdot e^{kV_2}$$

(10) $$\text{Log}_e\frac{Ia}{K_e^{kV_1}}=kV_2$$
$$=kBRi\log_e\frac{2(1+m\cos\omega t)}{1+\sqrt{1-m^2}}$$

(11) $$Ia=Ke^{kVi}\left(\frac{2(1+m\cos\omega t)}{1+\sqrt{1-m^2}}\right)^{kBRi}$$

The load in the anode circuit of the super-regenerative detector is so adjusted that

$$kBRi=1$$

thus

$$Ri=\frac{1}{kB}$$

then

(12) $$Ia=Ke^{kVi}.\frac{2(1+m\cos\omega t)}{1+\sqrt{1-m^2}}$$

If the resistance in the anode circuit of the amplifying valve is R_2 the output voltage is given by:

$$Vo=R_2Ke^{kVi}\frac{2.m\cos\omega t}{1+\sqrt{1-m^2}}$$

It will be seen from this that the output now contains alternating current of the fundamental frequency only, and all the harmonics have been eliminated. There still remains a small amount of amplitude distortion which is in the nature of volume expansion. The degree of expansion is given by:

(13) $$\phi=\frac{2}{1+\sqrt{1-m^2}}$$

For degrees of modulation not greater than 70% this represents an expansion of little over 1 db. which is negligible.

Pentodes with fairly high negative bias form suitable amplifier valves for the present purpose. The Philips valve type E.452T has an exponential characteristic with grid bias voltages between −9 and −3.

The anode current of this valve is represented by $Ia=28.7\ e^{.995Vg}$ ma. when the anode voltage is 200 v. and the screen voltage is 100 v.

The anode current of a typical super-regenerative detector is given by:

(14) $$Id=6.845-.235\log_{10}Vi\text{ ma.}$$

where *Vi* is the peak input voltage in microvolts.

To obtain correction it has been shown that:

$$Ri=\frac{1}{kB}$$

With the numerical values given above

$$B=\frac{.235.10^{-3}}{2.3025}\text{ mhos.}$$

and

$$k=.995$$

whence

$$Ri=9850\text{ ohms.}$$

If the anode load (R_2) of the amplifying valve is 100000 ohms and the standing bias on the valve 4.3 v. the output voltage is given by:

(15) $$Vo=\frac{56.3m}{1+\sqrt{1-m^2}}\ V.\ R.\ M.\ S.$$

and at 30% mod. the audio output is:

8.65 V. R. M. S.

and this output will be obtained for all inputs modulated to 30% irrespective of the signal strength.

A super-regenerative receiver embodying the invention and using the amplifier valve and impedance values given above by way of example is shown in the accompanying drawing.

The receiver comprises a super-regenerative detector stage having a triode valve **V1** with a tuned input circuit **L1**, **C1** connected between grid and anode an intermediate point of this circuit being at ground or cathode potential for high frequencies. A quenching voltage wave is applied across a condenser **C2** which is inserted in series with a grid leak **R3**, whereby a pulse is applied to grid periodically to quench the oscillation after it has built up to saturation point.

The output of the detector valve is applied by resistance-capacity coupling **R1**, **C3**, **R4** to the control-grid of a pentode amplifying valve **V2**. The connections to this valve are of well-known kind but the grid bias voltage is critically determined by suitable choice of resistance values in the potentiometer **R5**, **R6**, **R7** to ensure that the valve operates over an exponential part of its grid characteristic.

What is claimed is:

1. A receiver of modulated carrier waves comprising a super-regenerative wave detector wherein the quench frequency is sufficiently low to allow the oscillation to build up to saturation value before being quenched followed by a low frequency amplifier the anode current of which is an exponent of the grid voltage over the working range of grid voltages.

2. A receiver according to claim 1, wherein if the output current of the amplifier valve is expressed as Ke^{kVg}, Vg being the amplifier input voltage, K and k being constants and if the detector anode current is expressed as $A-B\log_e Vi$ amps, Vi being the signal input voltage to the detector, A and B being constants, the detector anode-circuit load resistance has the approximate value of

$$\frac{1}{Bk}$$

ohms.

WILLIAM ALAN MONTGOMERY.