E. H. ARMSTRONG.
SIGNALING SYSTEM.
APPLICATION FILED JUNE 27, 1921.

1,424,065. Patented July 25, 1922.

5 SHEETS—SHEET 1.

Fig.1,

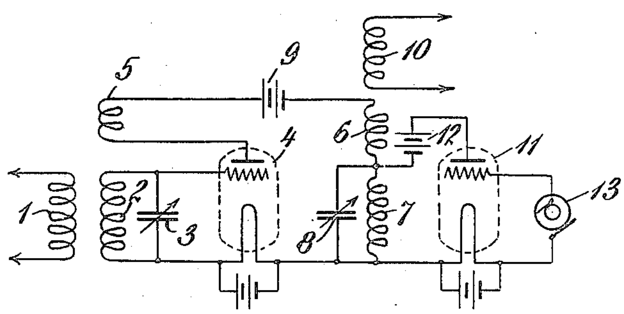


Fig.2,

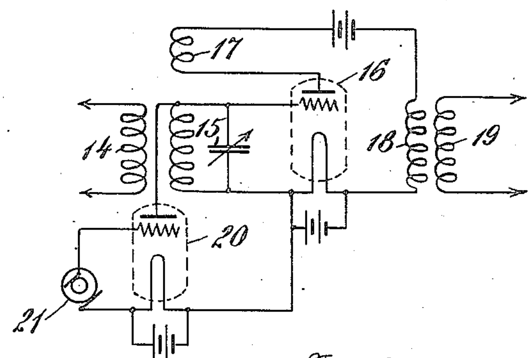
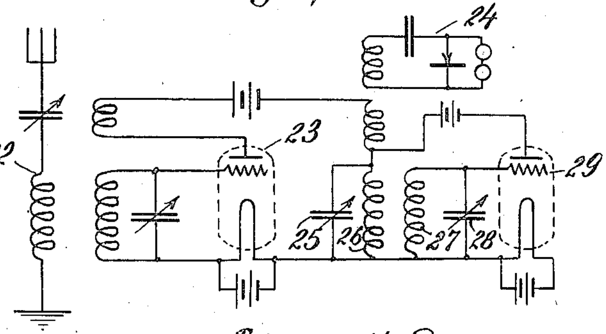


Fig.3,



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5 SHEETS—SHEET 2.

Fig. 4,

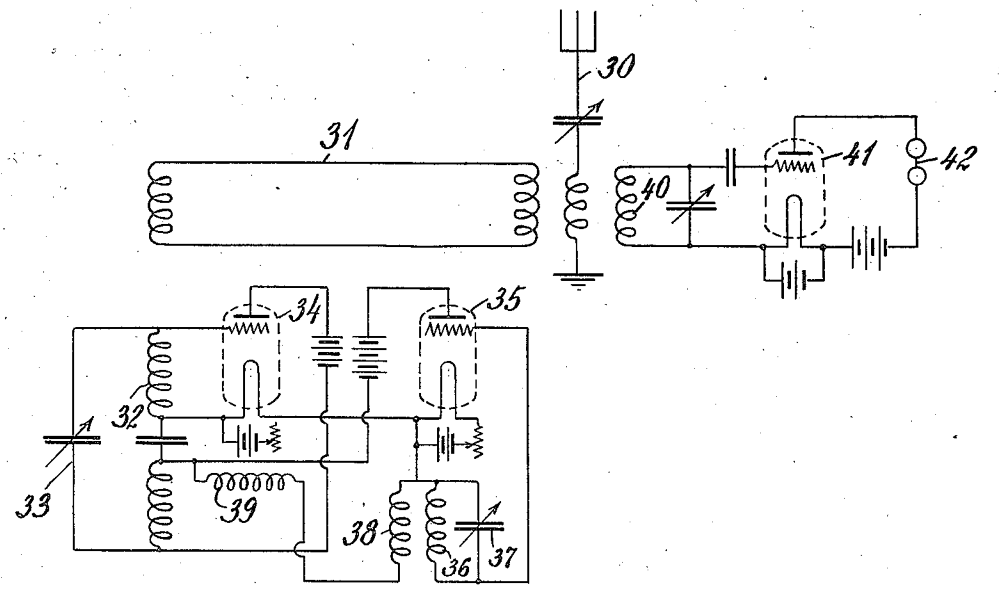
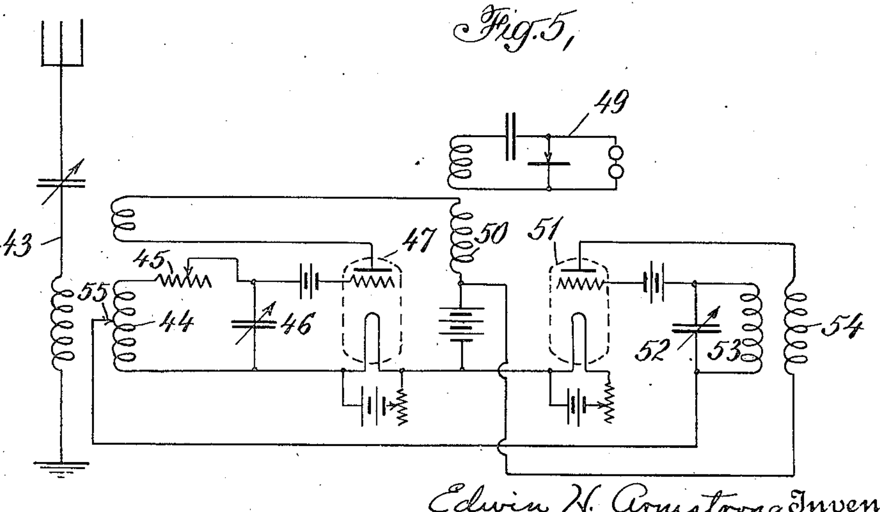


Fig. 5,



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5 SHEETS—SHEET 3.

Fig. 6,

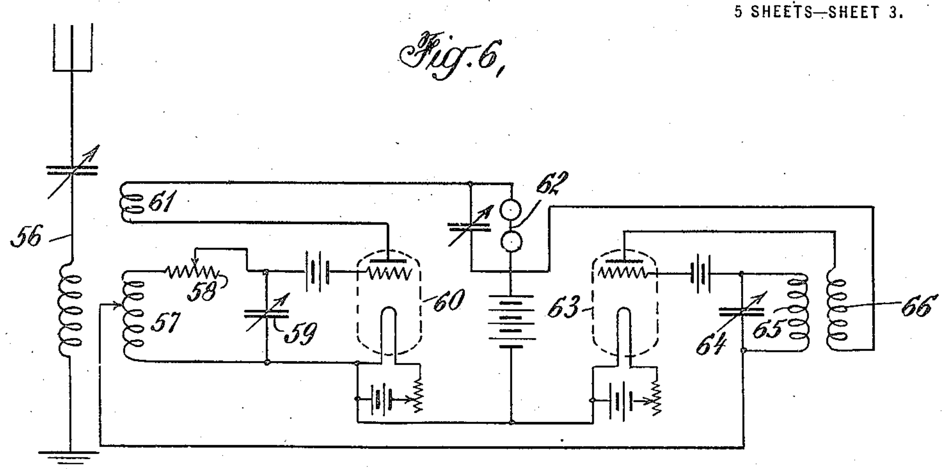


Fig. 7,

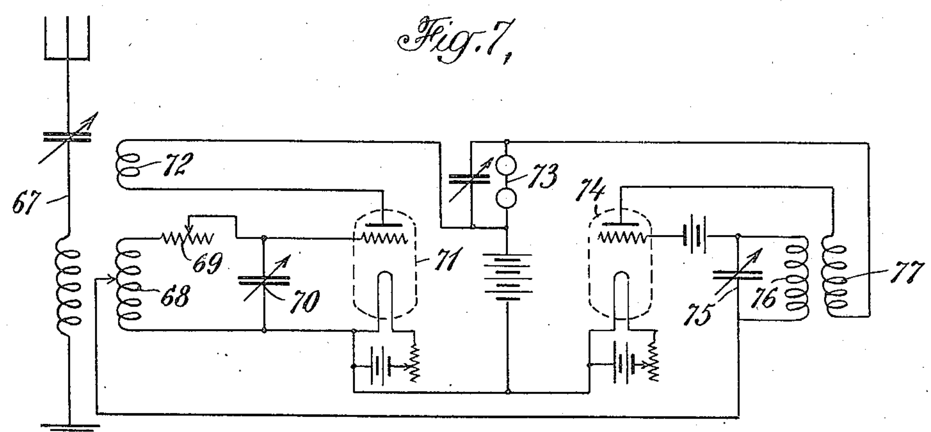
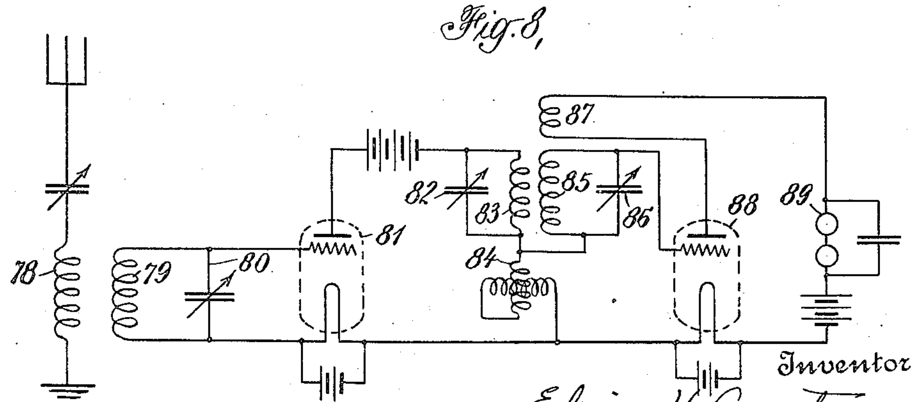


Fig. 8,



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5 SHEETS—SHEET 4.

Fig. 9,

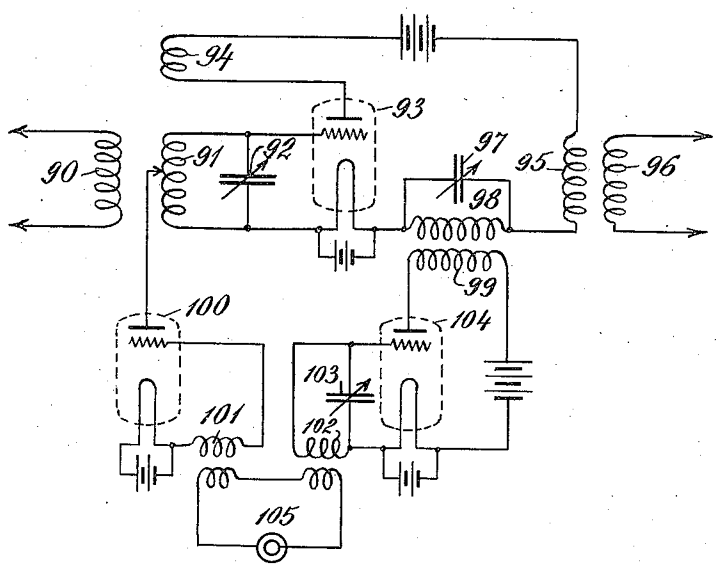
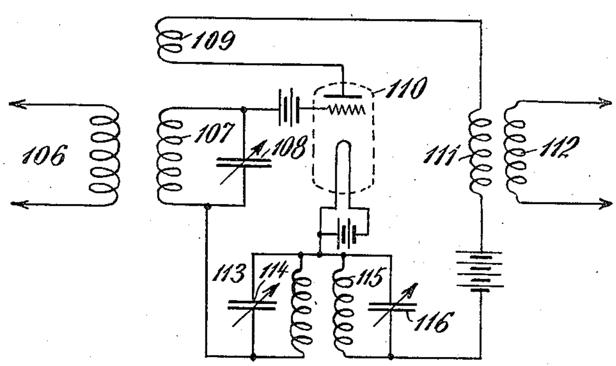


Fig. 10,



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SIGNALING SYSTEM.

APPLICATION FILED JUNE 27, 1921.

1,424,065.

Patented July 25, 1922.

5 SHEETS—SHEET 5.

Fig. 11,

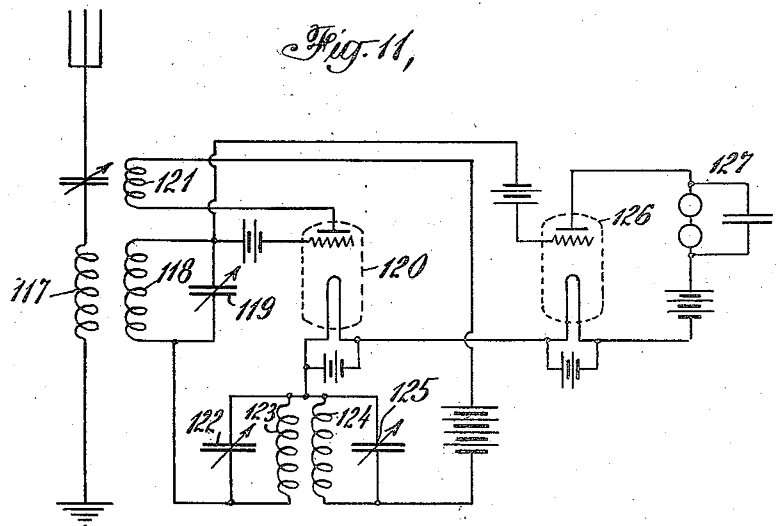
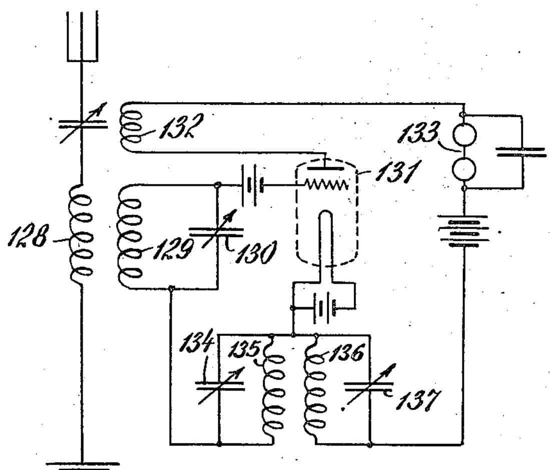


Fig. 12,



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By his Attorneys

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UNITED STATES PATENT OFFICE.

EDWIN H. ARMSTRONG, OF YONKERS, NEW YORK.

SIGNALING SYSTEM.

1,424,065. Specification of Letters Patent. Patented July 25, 1922.

Application filed June 27, 1921. Serial No. 480,563.

To all whom it may concern:

Be it known that I, EDWIN H. ARMSTRONG, a citizen of the United States, residing at Yonkers, in the county of Westchester, State of New York, have invented certain new and useful Improvements in Signaling Systems; and I do hereby declare the following to be a full, clear, and exact description of the invention, such as will enable others skilled in the art to which it appertains to make and use the same.

This invention has for its object the provision of a method of operating an electric regenerative system and of apparatus for obtaining enormous amplification of varying electric currents by means of certain modifications and applications of the wellknown feedback or regenerative principle. The results obtainable are of striking character and are the result of a new principle which will be termed super-regeneration.

Briefly, the invention comprises impressing the feeble varying potential of the current to be amplified upon a feedback or regenerative circuit or system critically adjusted, as will be explained hereinafter; and simultaneously and preferably periodically altering or varying the relation between the amount of feedback, that is, the regenerative energy supplied to the circuit (the so-called negative resistance) and the damping, that is, the rate of dissipation of energy of the circuit by varying either the amount of regeneration or the degree of damping of the regenerative circuit, or both together, at some frequency which may be relatively low as compared to the frequency of the current to be amplified.

The principle of this invention may be understood from the following general analysis. In the usual form of circuit employing the regenerative or feedback principle, the regenerative amplification continuously increases as the feedback coupling is increased, or broadly, as the amplified oscillation is utilized more and more to reinforce the original oscillation, until the point of oscillation is reached, that is, the point where the regenerative effect is strong enough to automatically build up an oscillation and maintain it indefinitely by the energy derived from the local battery. The regenerative amplification is a maximum either at this point or at a point slightly above or below it, depending on the initial strength of the signal, the characteristics of the vacuum tube or tubes and the circuits associated therewith. In general, there is in practice, no great difference in the amount of regenerative amplification obtained at any of these three points of adjustment and the amplification so obtained may be considered as the limiting value of simple regenerative amplification.

It has been discovered that if a regenerative circuit is adjusted to its maximum sensitiveness and the relation between the amount of feedback action and the damping is periodically varied over a certain minimum range as will be hereinafter explained, a new state of equilibrium will be produced, and enormous amplification will be obtained. This new state of equilibrium will be called the super-regenerative state and it produces amplifications of energy thousands of times greater than those obtained with the simple regenerative circuit.

The periodic variation in the relation between the amount of feedback and the damping of the system may be produced by varying the feedback with respect to the damping, by varying the damping with respect to the feedback, or by varying both simultaneously.

The rate of variation of the amount of feedback or damping, or both, of the regenerative circuit may be either at sub-audible, audible, or super-audible frequencies. Applied to radio receiving systems, for the reception of spark signals, modulated continuous wave signals and radio telephone signals, the rate of variation should preferably be above audibility although in special cases an audible frequency variation may be employed to advantage. In radio telegraphy where it is desired to operate a recording instrument, the sub-audible frequency may be preferable. In the reception of undamped wave telegraph signals where it is desired to produce a tone to receive by ear, an audible frequency variation should be employed.

Referring now to the drawings and the following description, from which a more complete understanding of the invention may be had:

Fig. 1 shows a simple feedback circuit with the necessary apparatus for producing a periodic variation in the plate voltage and hence in the amount of feed-back.

Fig. 2 shows a system similar to that of Fig. 1 with the periodic variation applied to the damping of the tuned grid circuit of the system.

Fig. 3 illustrates a practical form of the device applied to a wireless signaling system, in which the periodic variation illustrated in principle by Fig. 1 is applied by means of an oscillating vacuum tube. In this case the variation is applied to the plate voltage of the amplifying tube of the wave frequency system and hence varies the amount of feedback.

Fig. 4 illustrates another form of the type of variation shown in Fig. 3.

Fig. 5 illustrates a practical form of apparatus for producing the variation in the damping of the grid circuit of the amplifier of the wave frequency system by means of an oscillating vacuum tube.

Fig. 6 illustrates the same circuit arrangement as that of Fig. 5 except that instead of a separate detector as shown in Fig. 5, the regenerative tube of the wave frequency system is also used as the detector.

Fig. 7 illustrates the same circuit arrangement as that of Fig. 6, but in this case the auxiliary frequency oscillating tube producing the variation is used as the detector, thereby introducing additional amplification.

Fig. 8 illustrates an arrangement in which the variation is effected by varying the damping of the tuned plate circuit of a regenerative system and hence the amount of the feedback.

Fig. 9 illustrates an arrangement for carrying out the simultaneous variation of the amount of feedback or regeneration and the degree of damping.

Fig. 10 illustrates a simplified form of the system of Fig. 9 in which the double variation is automatically produced by the amplifying tube.

Fig. 11 illustrates the system of Fig. 10 applied to a radio signaling system.

Fig. 12 illustrates a simplified form of the system of Fig. 11, in which the functions of amplification, variation and detection are all accomplished by the use of a single tube.

Referring now specifically to Fig. 1, a simple regenerative circuit with a magnetically coupled feedback is shown. 1 represents the source of electromotive force to be amplified, 2—3 is a tuned circuit connected to the input of a vacuum tube 4, 5 is the feedback coil, 9 represents the usual plate battery, 6 is a coil for supplying the amplified energy to a circuit 10 wherein it is to be utilized and 7, 8, 11 and 13, are an inductance, capacity, vacuum tube, and source of electromotive force, respectively, for introducing the auxiliary frequency into the plate circuit to produce the variation already referred to.

In order to produce the super-regenerative state, by means of which the increase in amplification over the simple regenerative circuit is brought about, the circuit constants must be properly proportioned and carefully adjusted with respect to each other, otherwise the critical state will not be produced and only the ordinary amplification of the feedback circuit will be obtained. In order to fully complete the disclosure of this invention the constants and method of adjustment of the system of Fig. 1 are given herewith.

For 600 meters wave length, coil 2 is an inductance of 0.1 millihenrys, 3 is a capacity of .001 microfarads, 4 is a Western Electric type J tube, 5 is an inductance of 0.1 millihenrys (which is considerably larger than necessary for the ordinary regenerative circuit as after the variation is introduced it is necessary to increase the feedback coupling beyond normal values) 6 is an inductance of 0.05 millihenrys, 9 is a 40 volt battery, 7 is an inductance of 10 henrys, 8 is a large variable capacity of .01 mfds. maximum, 11 is a second type J tube, 12 is a 40 volt battery and 13 a source of electromotive force which may be varied up to 50 volts. It will, of course, be understood that a considerable variation may be made in these constants provided they are properly co-related with respect to each other, but these specific figures are given so that anyone skilled in the art can immediately set up the apparatus and practice the invention.

The method of adjustment of the system is as follows. The electromotive force 13 is cut out, condenser 8 set at some large value and the circuit 2, 3 and the coupling 5 are tuned and adjusted as in the ordinary regenerative circuit until the system is at the point of oscillation. The electromotive force at 13 is then gradually increased and condenser 8 is adjusted. Simultaneously the feedback coupling 5 is increased and condenser 3 is readjusted. As these three adjustments proceed, a point will be reached where the signal strength as observed in circuit 10, will be greatly increased. When this increase occurs the system has entered the new state and by suitable readjustments of condenser 3, feed back coupling 5, condenser 8 and voltage and frequency of 13 extremely large amplifications can be built up.

This type of circuit can be applied equally well to the amplification of all types of waves. While there is no hard and fast rule concerning the frequency of the variation of the feedback and the damping, the rules already indicated may be applied in the manner described, depending on whether spark, buzzer modulated, voice modulated, or pure continuous waves are to be amplified.

In order to complete the disclosure, a general outline of the theory of the operation is given herewith in so far as it has been able to be ascertained, but it must be understood that this theory may be subject to modification and that on account of the complexity of the method of operation only fundamental phenomena will be considered.

It is well known that in any regenerative circuit adjusted below the point of oscillation i. e., adjusted so as to feed back less energy than is dissipated in the system, any electromotive force impressed on the system starts a free oscillation which gradually dies away to zero after the impressed electromotive force is removed. In general the initial amplitude of this free vibration may be considered as equal to the maximum amplitude of the forced oscillation set up by the impressed electromotive force. The rate at which the free oscillation will die out depends on the damping of the circuit, as modified by the energy fed back. This state is well known in the practical art.

It is also well known that in the ideal case of a regenerative circuit adjusted at the point of oscillation, i. e., when the amount of energy fed back just equals or compensates for the loss in or the damping of the system, an electromotive force impressed on the system sets up a forced and free oscillation and that the free oscillation starts with the maximum value attained by the forced oscillation and continues at that amplitude forever. In practice on account of imperfections in the tube, it is probably impossible to produce this state exactly but it may be so closely approached that laboratory demonstrations of it can be made and it can be maintained for a short time. It has not been used in practice and has no great advantage over the preceding state, i. e., just below oscillation. It should be here noted that while the circuit has zero damping and an oscillation once set up continues indefinitely, until some electromotive force is in some way impressed on the circuit there will be no current.

It is probably also known that in a regenerative circuit adjusted so that the amount of energy fed back exceeds the dissipation of energy in the system, any electromotive force impressed on the system for however short a time sets up a free vibration which theoretically, builds up to infinity. Practically, of course, the limitation of the amount of energy which can be handled by the tube places some finite limit on the value of the current but during the first part of the oscillation following the impressing of the external electromotive force, the system starts to build up at a rate which very closely approximates the theoretical value. In this state the free oscillation set up by an impressed E. M. F. rises according to the law of free oscillations at a rate determined by the constants of the circuit and the initial amplitude of the impressed E. M. F. The amplitude of the free oscillation is therefore proportional to the strength of the incoming signal and the response of the system is quantitative.

Before the external electromotive force is impressed the system is in a state of the utmost sensitiveness since theoretically, any electromotive force however small, will produce a current which will rapidly rise to infinity. The sensitiveness is, however, transient, since once the local oscillation is started it soon reaches a value where tube limitations come into action and the system becomes insensitive to any impressed electromotive force. Of course, in actual practice, such a system could never be used, since local disturbances and irregularities in the filament would prevent the maintenance of the sensitive state. In accordance with the present invention, by varying the relation between the natural damping of the system and the amount of feedback or regeneration to the proper degree, this transient ordinarily unstable state can be made absolutely constant and dependable so that the system may be maintained at all times in the super-regenerative state.

As already explained a variation may be produced simultaneously of both the damping of the tuned circuit and the amount of feed-back or regeneration. By properly proportioning the relative value and phase of these two variations much greater amplification than that obtainable with a single variation may be secured. By a further extension of this idea of a double variation the amplifying tube may be arranged to oscillate at the frequency required to produce the variation and by a critical adjustment of the relation between the feedback couplings of the high and low frequency circuits an interaction between these two systems may be set up which produces still greater amplification.

The general arrangement for practicing the first method is illustrated by the system of Fig. 1, which has been already described.

The general arrangement for practicing the second method is illustrated in Fig. 2. Here 14 is the source of electromotive force to be amplified, 15 a tuned circuit upon which this electromotive force is impressed, 16 a vacuum tube connected to feed back through the coil 17, and 18—19 a transformer for utilizing the amplified energy, 20 is a vacuum tube connected to vary the damping of circuit 15, and 21 a source of alternating electromotive force to operate the tube 20. The theory of operation of this system is practically the same as for Fig. 1, except as already explained, the variation in the relation between feed back and damping is produced by the variation of the damping with respect to the amount of feedback. This method is especially valuable when, for reasons which will be hereinafter explained, it is desired to use a very high rate of variation as compared to the frequency of the incoming signals.

Fig. 3 illustrates an arrangement in which the first method may be applied to a radio receiving system with a tube arranged to produce, by means of a feedback circuit, the necessary oscillating current to cause it to produce the variation in the amplifying system. In this figure, 22 represents the receiving antenna, 23 the feedback amplifier, 24 a detecting system and 25—26 and 27—28 a pair of tuned circuits connected to the vacuum tube 29 and so adjusted as to produce locally an oscillating current of substantially the frequency of the tuned circuits. In this system oscillations received by the antenna 22 are impressed on the amplifying system 23, amplified therein and detected by the detecting system 24. By reason of the local oscillation of the tube 29 an alternating electromotive force is impressed on the plate circuit of the amplifying tube and hence the amount of feedback is varied in accordance therewith. By adjustment of the coupling 26—27 or in any other suitable manner, the amplitude of this electromotive force can be adjusted by trial to that value which produces the maximum value of super-regeneration.

Fig. 4 illustrates an arrangement of the first method applied to a wireless receiving system in which the amplifying system is indirectly associated with the antenna, which method has certain advantages for special purposes as will appear hereinafter. In this figure 30 represents the antenna; 40, 41, 42 an audion detecting system coupled thereto, and 31 a link circuit connecting the antenna 30 with a regenerative circuit amplifier 32, 33 and 34. The tube 35 is arranged to oscillate by reason of the feedback circuit 36, 37, 38 at any desired frequency. By reason of this oscillation the electromotive force applied to the plate of the amplifying tube 34 is varied in accordance therewith and hence the amount of feedback is varied. The operation of this system is substantially the same as in the preceding cases of the first method except that by coupling the amplifying system to the antenna through a non-tuned loop circuit certain troubles and reactions are avoided and the adjustment of the system becomes more simple.

Fig. 5 illustrates a system of the second method, i. e., one in which the variation is introduced in the damping of the tuned circuit. This arrangement is similar to that of Fig. 3 in that the input end of the amplifying system is coupled to the antenna 43 and the output coupled to a detector system 49. The essential difference is in the system producing the periodic variation. Here 51 is a vacuum tube connected to a feedback oscillating system 52, 53, 54. The grid circuit is completed through the inductance 44 by the lead connected to some point such as 55 on it. In this way the grid-filament circuit of the tube producing the periodic variation is connected across the tuned circuit 44, 45, 46 and introduces into that circuit a variable damping, depending on the instantaneous value of the potential of the grid of the tube 51. For the purpose of varying the relation between the damping already in the circuit 44, 45, 46 and the damping introduced in it by the tube 51 a variable resistance 45 and a variable tap 55 are provided. These are adjusted to produce the loudest signals in a manner best determined by experiment.

Fig. 6 illustrates a system of the same type as Fig. 5, in which the separate detector system is eliminated and the amplifying tube is utilized as the detector by placing the telephone 62 in the plate circuit. This system is almost as effective as that of the preceding figure and of a more practical form.

Fig. 7 is a system of the same type as Fig. 6 except in this case the tube producing the variation is used simultaneously as the detector by placing the telephones 73 in the plate circuit of the tube 74. This arrangement, in general, gives better amplification than either of the preceding figures of the same type for the reason that there is a double amplification of the received signals. First by the amplification of the tubes 71, which converts the amplified energy into current having a frequency corresponding exactly to the frequency of the periodic variation. This current is then amplified by the feedback system of the tube 74 and since it is in exact synchronism with the local frequency already existing there it is detected by the tube 74 according to the zero beat method and hence with great efficiency. This method is of course not very effective where the variation is in the audible range, since the telephones are directly in the plate circuit of the oscillating tube but where inaudible frequencies are employed, particularly where a super-audible frequency of variation is employed for the reception of telephone signals, it is most effective.

Under certain circumstances it may be advisable to combine the arrangements of Figs. 6 and 7 by making the telephone receivers common to the plate circuits of both tubes, so that it responds to the combined detecting effects of both. The arrangement is valuable in improving the articulation of telephone speech and the clarity of tone of spark signals.

Fig. 8 discloses an arrangement in which the variation is introduced into the damping of a tuned plate circuit so that its reaction with respect to the grid circuit is periodically varied. In this figure 78 represents the antenna 79, 80, 81, 84 the usual tuned plate circuit type of regenerative receiver, 88 an oscillating tube arranged to vary the reactance of inductance 84. 85, 86, 87 is a feedback circuit arranged to cause tube 88 to oscillate. 82, 83 is a tuned circuit adjusted to the same frequency as 85, 86. In general, on account of the specific arrangement here shown, where the telephones are directly in the plate circuit of the oscillator, an inaudible frequency of oscillation is preferable. The operation of the system is somewhat complex but the following general description will outline it. By reason of the variation of the potential of the grid of tube 88 the effective reactance of inductance 84 is periodically changed, producing a variation in the amount of feedback and hence super-regeneration in the system 78, 79, 80, 81, 84. The amplified currents of the signal set up in circuit 79, 80, have a variation in amplitude corresponding to the frequency of oscillation of circuit 85, 86. On account of the rectifying property of tube 81 these variations in amplitude are converted into a current in the circuit 82, 83 of that frequency and transferred over into circuit 85, 86. Since these currents are of the same phase and frequency as the oscillation already existing in circuit 85, 86 they are rectified by the tube 88 and indicated by the telephones 89 with great efficiency. This method is of particular value in certain special cases where it is desired to obtain sharp tuning with a minimum supply of power to the system.

Fig. 9 illustrates a system for simultaneously varying the damping of the tuned circuit and the amount of feedback. In this figure 90 represents the source of electromotive force to be amplified, 91, 92, 93, 94, 95, the usual regenerative circuit for producing the amplification, 96 a circuit for utilizing the amplified energy. 100 is a tube for varying the damping of the circuit 91, 92; 104 is a tube for varying the amount of feedback. 105 is a source of electromotive force for operating these tubes and 101, 102, 103 are circuits for applying the electromotive force of 105 to the actuation of the tubes 100 and 104, and for varying the relative phase and amplitude. The adjustment of this system is carried out in the following way. With the electromotive force 105 cut out the amplifying system is tuned in the ordinary way and the feedback coupling 94 adjusted to bring the system to the point of oscillation. The electromotive force 105 is then cut in and gradually increased in value. Simultaneously couplings 101, 102 and the tuning of circuit 91, 92 and 97, 98 are varied together with the feed-back coupling 94. By a proper adjustment of these various elements enormous amplifications can be built up.

Fig. 10 illustrates a more practical form of apparatus embodying the principle of operation described in connection with Fig. 9. In this Figure 106 represents the source of electromotive force to be amplified, 107, 108, 109, 110, 111 the usual regenerative amplifying apparatus, 112 the circuit for utilizing the amplified energy and 113, 114, 115, 116 a feed back oscillating system for producing the frequency of variation. Without entering into a detailed description of the theory of operation of this system it may be stated that when the feedback couplings 107, 109 and 114, 115 are properly related with respect to each other a reaction between the two systems is produced which still further enhances the amplification. The adjustment of this system to produce extreme amplification is carried out in the following manner. Circuit 107, 108, is tuned and adjusted to the signal to be amplified in the usual way. Circuits 113, 114 and 115, 116 are set for some frequency relatively low in comparison with the frequency to be amplified. This frequency may be either audible or inaudible depending on the type of signal to be amplified. Coupling 114, 115 is next closed up until oscillations start. Once started, the coupling is weakened nearly to the point where oscillations cease. The first feedback coupling 107, 109 is next adjusted until the circuit 107, 108 is just on the edge of the oscillating state. Coupling 114, 115 is next readjusted. In the tuning of circuits 113, 114 and 115, 116 in order to adjust the relative phases of the voltages applied to the grid and plate by the reactions of the circuits it is necessary to adjust either circuit 113, 114 or circuit 115, 116 so that one or the other alone practically determines the period of oscillations. This is done by making one condenser much larger than the other. The period is determined by the circuit having the larger condenser and the other condenser may be made quite small. Any value sufficient to by pass the currents of the signaling wave frequency will suffice. In general it is preferable to have the grid circuit determine the period but this is not in any way essential. By suitable continual adjustment between the relation of couplings 107, 109 and 114, 115 a point will be arrived at in which the normal amplification of the regenerative circuit, as observed in circuit 112, will be enormously increased. This indicates that the new state has been entered. By suitable adjustments of the tuning of 107, 108, coupling 107, 109 and the tuning and coupling of 113, 114 and 115, 116, enormous amplifications can be built up.

In order to complete the disclosure and

enable those skilled in the art to practice the invention the constants of this system for a wave length of 600 meters are hereby given.

Coil 107 is an inductance of 0.1 millihenrys. Condenser 108 has a capacity of .001 mfds. The feed back coil 109 has an inductance of 0.1 millihenrys. Coil 111 has an inductance of 0.05 millihenrys. For the reception of signals in which a superaudible frequency of variation is desired 114 and 115 may have an inductance of from 50 to 100 millihenrys. Condensers 113 and 116 have a maximum capacity of .015 mfds. each. For the reception of signals in which an audible frequency of variation is desired coils 114 and 115 have an inductance of 1.5 henrys each. With apparatus having the above values connected according to the diagram of Fig. 10 and adjusted in the manner already described, amplifications can be produced which are far greater than those which can be obtained with the simpler systems of variation previously shown.

Fig. 11 illustrates the system of Fig. 10 applied to a radio signaling system. In this system 117 represents the antenna, 118, 119 a tube system arranged to simultaneously amplify and produce the necessary variation and 126, 127 a detecting system. The adjustment of this system is carried out in exactly the same way as in the system of the preceding figure.

Fig. 12 illustrates a radio signaling system similar to Fig. 11 except that the separate detector is dispensed with and the single tube performs simultaneously the function of amplification, variation and detection.

In the practical operation of the systems herein described certain rules of adjustment must be observed to obtain the maximum of result. These rules differ somewhat, depending on the type of signal which is to be received and the degree of selectivity desired. For example, in receiving undamped wave telegraph signals and where a maximum of selectivity is desired a system in which the variation is introduced into the amount of regeneration or feed-back rather than into the damping of the system should be used. Where the system which is in use employs a combination of both the feedback and the damping then the tuned circuit should be made up of small inductance and large capacity and as large a negative charge as possible used on the grid. In radio telephony where it is not possible to obtain as high a degree of selectivity as in undamped wave telegraphy, either type of variation can be effectively employed.

In general, the higher the frequency of variation the broader will be the tuning. In fact, by making the ratio of the frequency of variation sufficiently high with respect to the signaling frequency the resonance curve of the system takes on the characteristics of a band filter and such a system can be used to great advantage as a substitute for such filters, as it is capable of accomplishing the same degree of selection with much less loss of energy.

As in the usual case, the antenna of the radio system may be replaced by conducting lines if it is desired to employ the invention in connection with carrier current wire transmission systems, so-called wired wireless systems.

It will be understood that modifications, both in the method and apparatus described as illustrative of the invention, may be made, without departing from the spirit and scope of this invention, particularly if after the adjustment of the modified system or circuit super-regenerative action is obtained.

I claim—

1. The method of amplifying varying electric currents which comprises impressing the varying potential of the current to be amplified upon a feedback system having a certain degree of damping, and periodically altering the relation between the amount of feedback and the degree of damping of the system, whereby super-regenerative action is obtained.

2. The method of amplifying varying electric currents which comprises impressing the varying potential of the current to be amplified upon a feedback circuit having a certain degree of damping, and periodically varying the relation between the amount of feedback and degree of damping of the circuit at some frequency relatively low as compared to the frequency of the current to be amplified, whereby super-regenerative action is obtained.

3. The method of amplifying varying electric currents which comprises impressing the varying potential of the current to be amplified upon a feedback circuit, and periodically varying the amount of feedback, whereby super-regenerative action is obtained.

4. The method of amplifying varying electric currents which comprises impressing the varying potential of the current to be amplified upon a feedback circuit having a certain degree of damping, and periodically varying both the amount of feedback and the degree of damping of said circuit, whereby super-regenerative action is obtained.

5. The method of amplifying varying electric currents which comprises impressing the varying potential of the current to be amplified upon a feedback system having a certain degree of damping, and adjusted near the point of oscillation; and simultaneously periodically varying the amount of feedback with respect to the damping,

whereby super-regenerative action is obtained.

6. The method of amplifying varying electric currents which comprises impressing the varying potential of the current to be amplified upon a feedback circuit having a certain degree of damping, and periodically varying both the amount of the feedback and the degree of damping of said circuit at some frequency relatively low as compared to the frequency of the current to be amplified, whereby super-regenerative action is obtained.

7. Apparatus for amplifying varying electric currents comprising a feedback system having a certain degree of damping, and means for periodically altering the relation between the amount of feedback and the degree of damping of the system, whereby super-regenerative action is obtained.

8. Apparatus for amplifying varying electric currents comprising a feedback system having a certain degree of damping, and means for periodically varying the relation between the amount of feedback and degree of damping of the system at some frequency relatively low as compared to the frequency of the current to be amplified, whereby super-regenerative action is obtained.

9. Apparatus for amplifying varying electric currents comprising a feedback circuit upon which the potential of said currents is adapted to be impressed, and means for periodically varying the amount of feedback in said circuit, whereby super-regenerative action is obtained.

10. Apparatus for amplifying varying electric currents comprising a feedback system having a certain degree of damping, and means for periodically varying both the amount of feedback and the degree of damping of said system, whereby super-regenerative action is obtained.

11. Apparatus for amplifying varying electric currents comprising a feedback system having a certain degree of damping, and adjusted near the point of oscillation; and means for periodically varying the amount of feedback with respect to the damping of said system, whereby super-regenerative action is obtained.

12. Apparatus for amplifying varying electric currents comprising a feedback system having a certain degree of damping, and means for periodically varying both the amount of feedback and the degree of damping of said system at some frequency relatively low as compared to the frequency of the current to be amplified, whereby super-regenerative action is obtained.

13. The method of operating an electric regenerative system having damping, which comprises impressing a varying potential on the system and periodically varying the relation between the amount of regeneration and the damping of the system to produce transient free oscillations proportional to the amplitude of the impressed potential and maintaining the resulting oscillations and the system in the transient ordinarily unstable state, whereby super-regenerative action is obtained.

14. A vacuum tube regenerative system comprising a feed-back circuit having damping and adjusted near the point of oscillation, an oscillating feedback circuit associated therewith and means by which it causes a periodic variation in the relation between the amount of feedback and the damping of said first circuit, whereby super-regenerative action is obtained.

15. An electric regenerative system comprising a feed-back circuit having damping and including a vacuum tube having grid, filament and plate elements, and circuits associated therewith, together with means for adjustably inductively coupling the grid and plate circuits thereof to the point of oscillation, and an oscillating feedback circuit associated therewith including a vacuum tube having grid, filament and plate elements and circuits associated therewith together with means for inductively coupling the grid and plate circuits thereof, and means including said oscillating feedback circuit to produce a periodic variation in the damping of said first circuit with respect to the amount of feedback thereof, whereby super-regenerative action is obtained.

16. A vacuum tube regenerative system comprising a feedback circuit having damping and adjusted near the point of oscillation, an oscillating feedback circuit associated therewith and means by which it causes a periodic variation in both the amount of feedback and the damping of said first circuit, whereby super-regenerative action is obtained.

17. An electric regenerative system comprising a feedback circuit having damping and including a vacuum tube having grid, filament and plate elements, and wave frequency circuits associated therewith together with means for adjustably coupling the grid and plate wave frequency circuits to the point of oscillation, and additional auxiliary frequency circuits associated with said tube elements adapted to couple the grid and plate circuits thereof sufficiently to produce oscillation, said auxiliary frequency circuits in conjunction with the tube forming means for producing a periodic variation in the relation between the amount of feedback and the damping of the wave-frequency circuits, whereby super-regenerative action is obtained.

In testimony whereof I affix my signature.

EDWIN H. ARMSTRONG.