Jan. 13, 1942. H. CHIREIX ET AL 2,269,518

AMPLIFICATION

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Fig. 1.

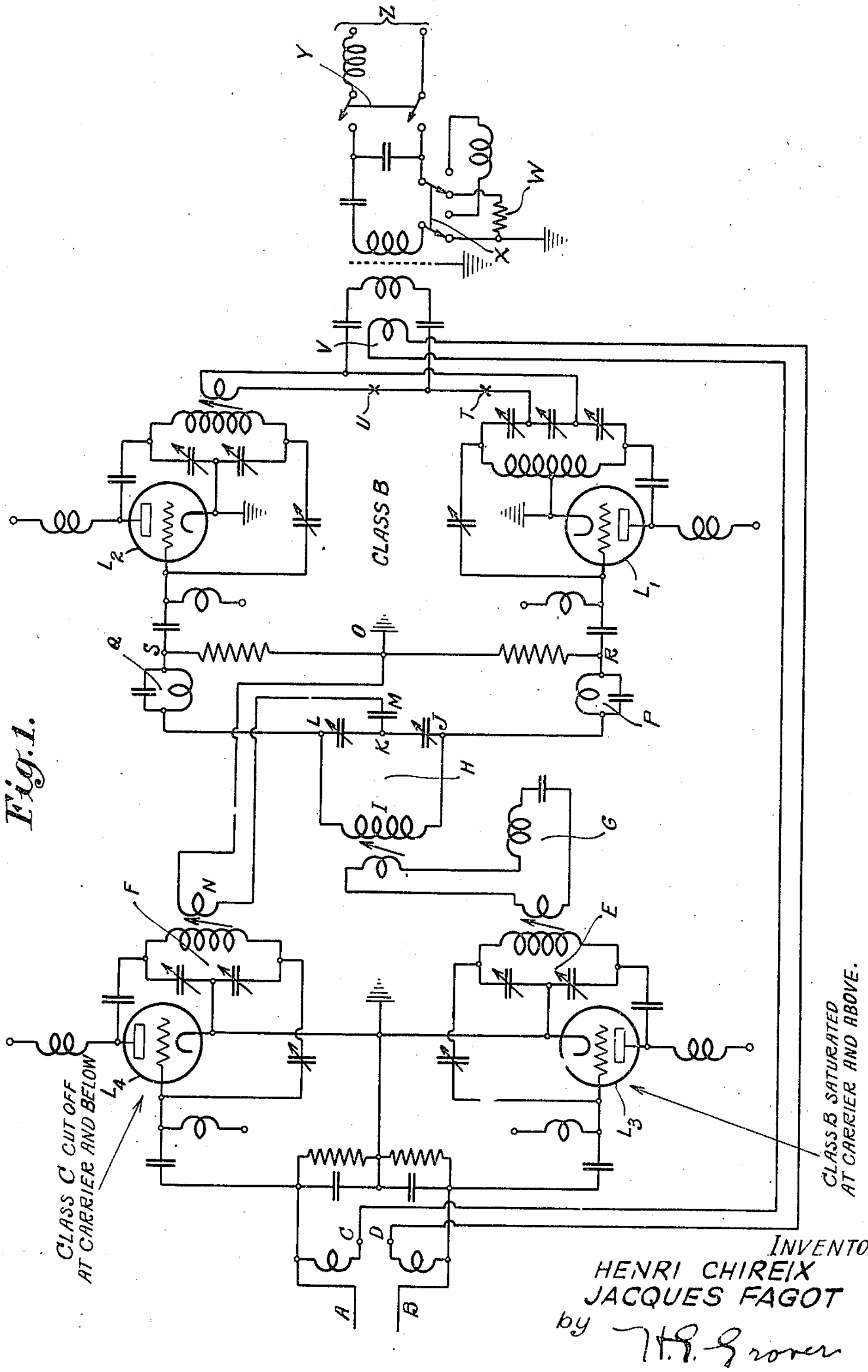

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Fig. 2.

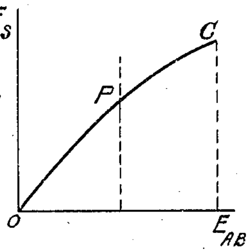


Fig. 4.

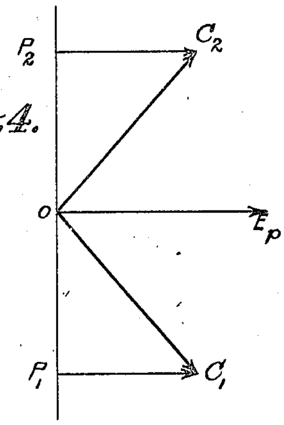


Fig. 3.

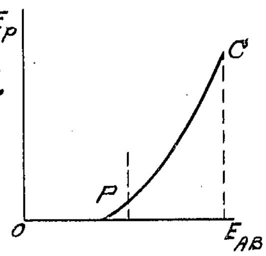


Fig. 5.

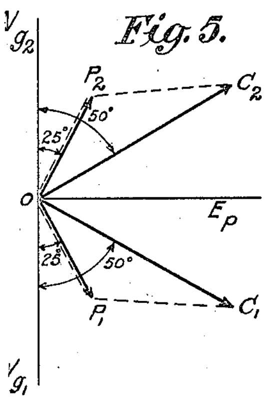


Fig. 6.

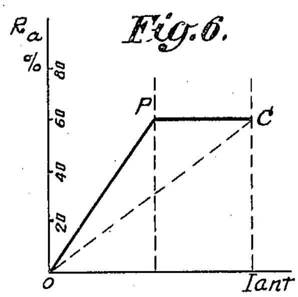


Fig. 7.

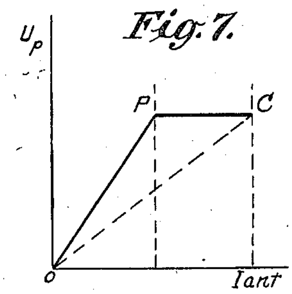


Fig. 8.

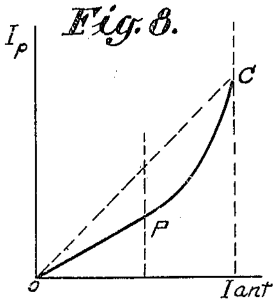


Fig. 9.

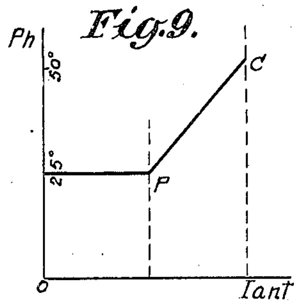
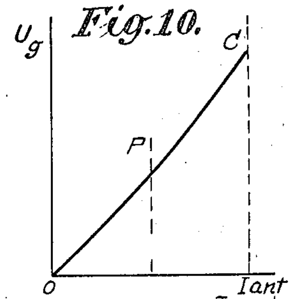


Fig. 10.



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Patented Jan. 13, 1942

2,269,518

UNITED STATES PATENT OFFICE

2,269,518

AMPLIFICATION

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Application February 24, 1940, Serial No. 320,532
In France February 25, 1939

5 Claims. (Cl. 179—171)

This application concerns an improved modulated wave amplifying means and method for radio transmitters. In an earlier United States patent application filed by Fagot on December 1, 1939, Serial No. 307,022, and in an additional United States patent application by Chireix and Fagot on November 22, 1939, bearing Serial No. 305,580, a high-efficiency modulation method has been disclosed which is particularly adapted to radio broadcast stations. In the said systems, the tubes comprised in the power stages are modulated, respectively, in amplitude or under phrase-shift conditions, according to whether the instantaneous power of the signals falls below, or exceeds, the normal value of the carrier wave.

The embodiments described in the said parent patent and improvement patent applications were predicated, to secure the synchronous potentials of the desired phase and intensity impressed upon the grids of the power tubes of the transmitter, upon the combination of a certain number of elementary potentials furnished, on the one hand, from the elements of a chain or cascade of input amplifiers suitably designed for the purpose, and, on the other hand, by inverse reaction also of convenient amplitude from the output circuit of the transmitter, say, the antenna circuit.

The present invention is concerned with a modification of the foregoing method. According to this modified method the identical result is obtained in the last stage of the transmitter, the latter being organized as for the phase modulation system, though here grid potentials are employed which are generated and combined in a slightly different manner.

The invention shall now be described somewhat more fully by reference to Figure 1 of the appended drawings which illustrate schematically a preferred embodiment of the basic idea, while Figures 2 to 10 are designed to illustrate the operation of the scheme by the aid of graphs.

The final or power stage of the transmitter equipment shown in Figure 1 comprises two power valves L_1 and L_2. The plate circuits thereof which are organized in the fashion of a transmitter operating on phase displacement modulation system work by way of a feeder Z upon a sending antenna which is not shown in the figure.

These two power-stage tubes are regulated so as to work as class B amplifiers in the phase shift modulation system. They will thus operate always in an identical manner and they will both be enabled to yield their maximum crest power.

The independent organization of their plate circuits, moreover, allows to regulate them in a ready and independent manner to exact tuning position by introducing for such regulation gaps at T and U so as to suppress the charge.

Breakers or switches X and Y mounted where feeder Z goes out also makes it possible, for regulation, to cause the transmitter to work either upon the antenna or upon a dummy antenna comprising a resistance W.

The coil V, finally, is adapted to return at C D in the first amplifying stages of the transmitter an inverse reaction or feedback to reduce distortion.

The first or input stages of the transmitter of which the end is only indicated at AB, are, on the other hand, identical to those of any conventional type of amplitude-modulated transmitter. For instance, they may comprise the use of one of the conventional plate control or modulation, push-pull, modulated amplification or other schemes.

The stage before the last which comprises the two intermediary power tubes L_3, L_4, together with their circuits presents, on the contrary, a special circuit organization according to the invention which will have to be described in more detail.

The grids of the two tubes L_3, L_4, are first excited symmetrically from one and the same circuit receiving from the preceding stages an amplitude modulated potential; but their operation differs essentially on the ground that their bias is regulated in a different way.

Accordingly, tube L_3 is biased like a class B amplifier. Indeed, it is regulated in such a way that the potential of its oscillatory circuit is saturated for all instantaneous values of the modulated current being close to the value of the carrier or higher than it.

Tube L_4 on the contrary, is polarized like a class C amplifier with the result that it is cut off for instantaneous values less than, or sensibly equal to, the value of the carrier.

The plate circuits of these two tubes L_3, L_4, on the other hand, work upon the grids of the power valves L_1, L_2, in such a way that these grids are excited at one and the same time: (*a*) in parallel by way of the tuned plate circuit F of tube L_4, and then, respectively, by the circuits ORPJKMNO and OSQLKMNO, the assembly of which likewise behaves like a tuned circuit; (*b*) under symmetric conditions, i. e. in opposed phase relation by way of the plate circuit E of tube L_3, of circuit G which is in coupling relation therewith, and of circuit H in coupling relation with the one before mentioned by way of IJ KL LI, all of these circuits being tuned.

The intermediate circuit G connected between the plate circuit of tube L_3 and circuit H has as its object to introduce a quadrature relation between the excitations originating from the symmetric and parallel paths.

The two supplementary circuits P and Q which are inserted, respectively, in the grid circuits of the two end or power tubes L_1, L_2, finally have the object to cause a leading rotation of one of the vectors of the grid potential, and a lagging rotation of the other. These shifts or rotations which could amount to 25 degrees approximately, as shall be shown by the graphs mentioned below, will as a matter of fact govern the normal load conditions of the two tubes L_1, L_2 for points of the working cycles which correspond to instantaneous values which are less than, or equal to, the carrier.

The graphs shown in Fig. 2 to 10 illustrate in more detail the operation resulting from the specific arrangements of the circuits as represented in Figure 1.

The graphs of Figures 2 and 3 first represent, respectively, at E_s and E_p the values of the symmetric and parallel excitations which are fed to the power tubes L_1, L_2 by way of paths JKL and KMNO and preceding stages as a function of the exciting amplitude E_{AB} from the lower stages. These graphs, at OPC indicate the symmetric and parallel exciting values which, respectively, correspond to zero excitation C at AB, to excitation corresponding to the carrier P and the maximum excitation corresponding to the crest value C.

In the absence of supplementary phase-shift circuits P and Q, the composition of these two symmetric and parallel excitations would be as shown in Figure 4 representing on either side of the parallel excitation axis E_p the potentials OP_1 and P_1, C_1, OP_2 and P_2, C_2 whose resultants OC_1 and OC_2 would, respectively, be impressed upon the grids of tubes L_1 and L_2.

The rotations of phase by an angle of 25 degrees approximately in the two directions such as result from the two supplementary circuits P and Q are, as a matter of fact, causative of rotations in opposite directions of 25 degrees of the potentials OP_1 and OP_2 so that the potentials V_{g1} and V_{g2}, represented by the vectors below and above the line OE_p respectively, which are applied to the grids of the tubes L_1 and L_2 are shown in Figure 5. There are indicated by dash-lines in this figure, the locus of the grid excitation voltages V_{g1} and V_{g2} for different values of the exciting amplitude E_{AB} from the low stages.

Note that for low modulation stage L_4 supplies little or no radio frequency output and the voltage on the grid of, say, L_1, varies in amplitude along the line OP_1 reaching P_1 at carrier output. The voltage on L_2 grows in like manner and the grid excitation voltages are of substantially fixed phase relation. When carrier output is reached tube L_4 supplies output (see vectors P_2C_2 and P_1C_1, Figures 4 and 5) and the resultant grid excitation on L_1 grows in amplitude and varies in phase. The voltage on L_2 grows and varies in phase in like manner. At carrier output V_{g1} and V_{g2} may be represented by vectors OP_1 and OP_2 respectively. For substantially maximum output V_{g1} and V_{g2} may be represented by vectors OC_1 and OC_2 respectively.

As in the mixed modulation method based upon amplitude and phase shift disclosed by Chireix and Fagot in the applications for United States patents mentioned above it will be seen that the phase variation of the grid potentials is used only for the upper portion of the cycles of modulation, in other words, for the region of the characteristics where the instantaneous amplitude of the antenna current is greater than the amplitude of the carrier wave. It is known that for this region a phase shift variation of from 25 to 50 degrees approximately causes the antenna current to vary linearly and that the efficiency is always above a high level at least equal to 60%. Throughout this range the grid excitation will be maintained at a value sufficient to supply the power required by the power tubes, that is to say, the phase variation imposed upon the grids of these tubes will be accompanied by a growth of the amplitude of the excitation, the maximum value of the latter corresponding to the crest value.

On the contrary, for the lower part of the modulation cycles, that is to say, for the region of the characteristics in which the instantaneous amplitude of the antenna current is less than the amplitude of the carrier wave, the excitation of the grids will be reduced exactly as in modulated amplification systems, the phase displacement angle staying then constant and equal to, say, 25 degrees as for the value of the carrier.

The working conditions which result therefrom in respect to the power stage of the transmitter are graphically shown in Figures 6 to 10. These figures show respectively as the function of the instantaneous value of the antenna current I the following variations:

Of the plate efficiency R_a (Fig. 6); of the potential in the plate oscillation circuit U_p (Fig. 7); of the plate D. C. I_p (Fig. 8); of the grid exciting phase P_h (Fig. 9) and of the amplitude of these grid excitations U_g (Fig. 10).

There is further plotted in dash-lines in Figures 6, 7, and 8 the shape these curves would have in the case of a modulation system simply based upon modulated amplification, that is to say, in the absence of concommitant phase modulation or variation above the level of the carrier.

What these figures demonstrate particularly is that by a mixed amplitude and phase modulation the power tubes operate under far improved conditions.

Among the particular merits inherent in the system here disclosed may be mentioned the following: high efficiency of the system, ease of regulation, improvement in the quality of transmission obtained by an easy use of inverse reaction, and reduction of background noise which might make possible, if desired, the heating of the power tubes themselves with alternating current.

It will finally be understood that the invention is not limited to the particular embodiment hereinbefore discussed by reference to the drawings; more particularly, that the circuit organization illustrated in Figure 1 could be modified in any suitable way to secure the same operation. For instance, tube L_4 could be regulated so as to be biased to the point of incipient current (class B), while tube L_3 would be biased very negatively (class C).

To this end, all that would be necessary is to inverse the sense of the coupling between the tuned output circuit of tube L_2 and the antenna circuit, for in the presence of symmetric excitation it would then be made to play the part of parallel excitation and vice versa.

The phase shifting circuit Q could, moreover, be inserted in the grid circuit of tube L_3 or else in that of the grid or the plate of tube L_4.

What we claim is:

1. In a modulated wave amplifying system, a pair of amplifier tubes having input electrodes coupled in phase displaced relation and in parallel by compound input circuits, said tubes having an output circuit coupled with utilization means, a first tube stage having an input and having an output coupled to the input circuit coupling the input electrodes of said amplifier tubes in phase displaced relation, a second tube stage having an input and having an output coupled to the input circuit coupling the input electrodes of said amplifier tubes in parallel, means for impressing amplitude modulated waves on the inputs of said two tube stages, means for imparting a phase shift to the voltage fed to one of said amplifier tubes' input circuits from one of said tube stages relative to the voltage fed from the other of said tube stages to the other of the input circuits of said amplifier tubes, and means for operating one of said tube stages to cut-off at a carrier amplitude and below and the other of said tube stages to saturation at carrier amplitude and above whereby the inputs of said amplifier tubes is excited by a voltage which is of substantially fixed phase for carrier wave amplitude and below but shifts in phase for carrier wave amplitude and above.

2. A system as recited in claim 1 with a degenerative feedback circuit coupling said pair of amplifier tubes to said first means.

3. In combination with a source of amplitude modulated carrier voltage, an amplifier comprising two tubes having input electrodes and having output electrodes associated with utilization means, a class B stage having an input excited by voltages from said source of amplitude modulated carrier voltage and having an output, a coupling for applying voltages amplified by said class B stage from its output in phase displaced relation to the input electrodes of said two tubes, a class C stage having an input excited by voltages from said source of amplitude modulated carrier voltage and having an output, a coupling for applying voltages amplified by said class C stage from its output substantially cophasally to the input electrodes of said two tubes, and phase shifting means in one of said couplings.

4. In a modulated carrier wave amplifier, a source of modulated carrier waves, two pairs of electron discharge devices each having input and output electrodes, a load circuit, means for applying voltages from said source on the input electrodes of each of the tubes of said first pair of tubes, means for applying voltages from the output electrodes of one of the tubes of said first pair in substantially parallel relation on the input electrodes of the tubes of the second pair of said tubes, means for applying voltages from the output electrodes of the other tube of said first pair of tubes substantially in phase opposition one to the other and in quadrature with the last mentioned voltages on the input electrodes of the tubes of said second pair of tubes, means to shift in opposite senses the phases of the voltages on the last said input electrodes, a coupling between the output electrodes of said second pair of tubes and said load circuit, means for retroactively coupling in phase opposition the said load circuit with the input electrodes of said first pair of tubes, and means for biasing the input electrodes of all of said tubes.

5. In a modulated carrier wave amplifier, a source of modulated carrier voltage, two pairs of electron discharge devices each having input and output electrodes, a load circuit, means for applying voltages from said source on the input electrodes of each of the tubes of said first pair of tubes, means for applying voltages from the output electrodes of one of the tubes of said first pair in substantially parallel relation on the input electrodes of the tubes of the second pair of said tubes, means for applying voltages from the output electrodes of the other tube of said first pair of tubes substantially in phase opposition one to the other and in quadrature with the last mentioned voltages on the input electrodes of the tubes of said second pair of tubes, means to shift in opposite senses the phases of the voltages on the last said input electrodes, a coupling between the output electrodes of said second pair of tubes and said load circuit, means for retroactively coupling in phase opposition the said load circuit with the input electrodes of said first pair of tubes, and means for polarizing the input electrodes of the tubes of said first pair of tubes, one tube being biased to operate class C with cutoff at about carrier level and below and the other tube being biased to operate class B, with voltage saturation at about carrier level and above.

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