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H. BENDEL

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MODULATOR

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**Fig. 1**

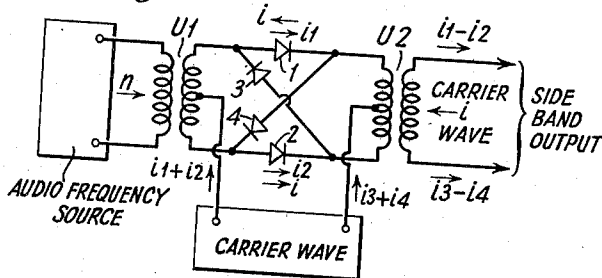


**Fig. 2**

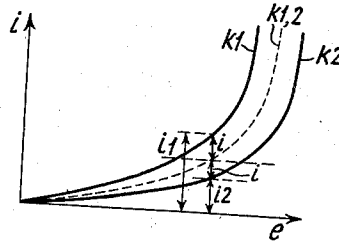


**Fig. 3**

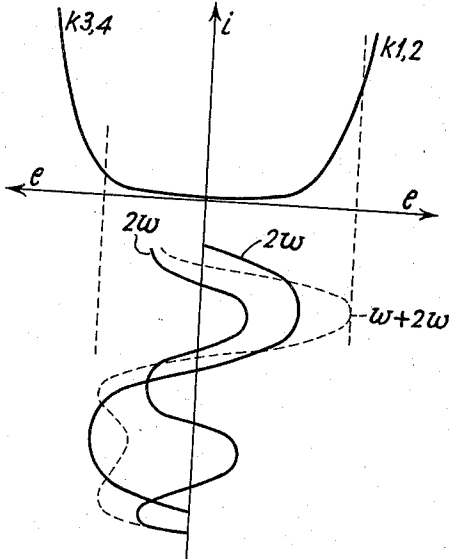


**Fig. 4**

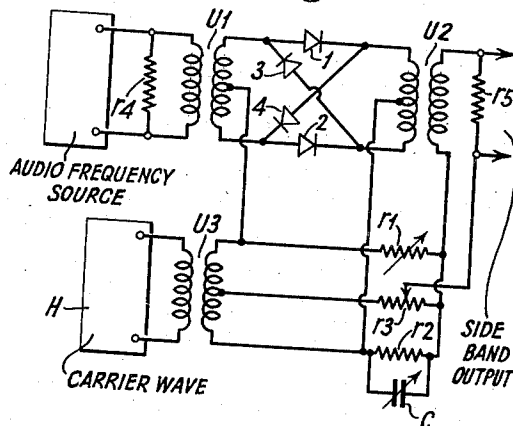
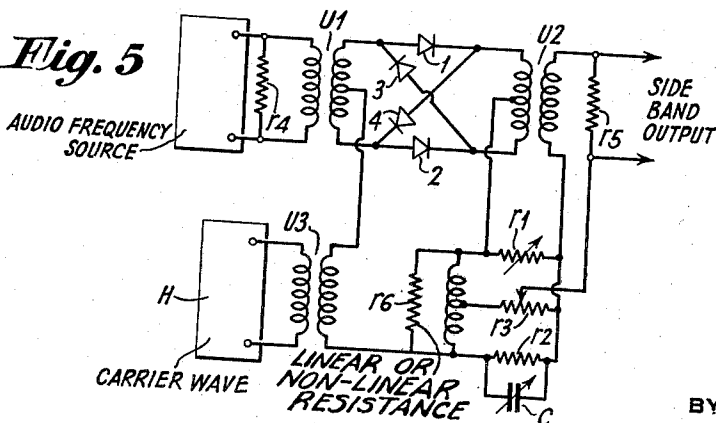


**Fig. 5**



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## UNITED STATES PATENT OFFICE

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## MODULATOR

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This invention concerns a new method of and means for suppressing undesirable frequencies in the output circuit of push-pull modulators.

Push-pull modulators offer the advantage over other modulators that the carrier current can be readily suppressed in the output circuit without having recourse to any special accessory means. However, complete suppression of the carrier current is possible only if the constituents of the modulator present a perfectly equal characteristic. However, for manufacturing reasons it is generally impossible to make the characteristics of the rectifiers perfectly alike. To be sure, it has been suggested in the prior art to match or balance the characteristics of several rectifiers by parallel or series connection of additional resistances to the rectifiers but this method is rather tedious, and where the outside temperature is subject to great variations it mostly does not lead to the desired end.

Hence, according to this invention another method is suggested which insures complete suppression of the carrier current in the output circuit of the push-pull modulator without the rectifiers having necessarily to possess perfectly equal characteristics. The method according to this invention consists in adding an unmodulated carrier current in the output circuit of the modulator which carrier is of the same frequency as the carrier current to be modulated. The said additional carrier current causes a shift of the working points of the rectifiers. Inasmuch as this shift in the several rectifiers will not act in the same sense in each case, indeed, since in some rectifiers it will add to the load, while in others it will subtract therefrom, the working point of the rectifiers in reference (with respect) to the carrier current to be modulated may be varied inside certain limits.

If the amplitude and the phase of the carrier current to be added have been properly chosen, and if the unequal rectifier elements have been properly arranged in the various arms of the modulator, the ideal state can be closely approached by a use of the method here disclosed, that is to say, a state in which all of the rectifiers will have practically the same working point and the same characteristic. Once this condition has been satisfied, not only the carrier current, but also the audio frequency current with which the carrier wave is modulated will be completely suppressed in the output circuit of the modulator. The reason is that the additional or the added carrier current does not merely compensate as a simple compensating current, the rest of the car-

rier existing in the output circuit but that, as stated, it also so influences the working point of the various rectifiers that by artificial means practically equivalent rectifiers, from an electrical viewpoint, are obtained.

The invention shall be explained in more detail by reference to exemplified embodiments illustrated in the drawing:

Figure 1 shows a balanced modulator with means for impressing carrier energy on the modulator output to improve the operation,

Figures 2 and 3 are graphs illustrating how the improved operation is obtained; while

Figures 4 and 5 are modulators of the type shown in Figure 1 with circuits for impressing carrier energy on the modulated output.

Figure 1 shows a double push-pull modulator or a so-called ring modulator.  $U_1$  is the input transformer through which the audio frequency energy  $\omega$  is fed in.  $U_2$  is the output transformer through which are delivered, on the one hand, the two sidebands of the modulated carrier current to the consumer or load, while, on the other hand, another carrier current  $i$  is introduced, thereby in the modulator circuit. The secondary winding of the input transformer and the primary winding of the output transformer have center taps, and it is at these points that the carrier current to be modulated is introduced. The oxide-type rectifiers 1, 2, 3, 4, connected in ring-fashion carry the partial carrier currents  $i_1, i_2, i_3, i_4$ . The amount of the carrier current for one alternation is  $i_1 + i_2$ , and for the second alternation  $i_3 + i_4$ . Presupposing that the two rectifiers 1 and 2 have like characteristics, the current  $i_1$  and  $i_2$  are equal. If this assumption is not fulfilled, then, for one alternation, a carrier current  $i_1 - i_2$  will arise in the output circuit. The same thing holds good for the case where the characteristics of the rectifiers 3 and 4 are not perfectly alike, for then for the second alternation or half-cycle there arises in the output circuit an equalizing current  $i_3 - i_4$ .

In Figure 2 the characteristic of the rectifier 1 shall be indicated by  $K_1$  and the characteristic of the rectifier 2 by  $K_2$ .  $K_{1,2}$  shall be assumed to be the shape of a characteristic situated between the two rectifiers. If, then, according to Figure 1, another carrier current  $i$  is fed to the transformer  $U_2$ , the current  $i$  for one of the rectifiers, say, rectifier 1 will occasion a reduction of the carrier current by an amount  $i$ , while in the case of rectifier 2 it will occasion a growth of the carrier current by a like amount  $i$ . For the carrier current to be modulated,  $i_1$  and  $i_2$ , the said superposition

of  $i$  has the same effect as if both rectifiers had the same characteristic  $K_{1,2}$ . The same situation holds good for the rectifiers 3 and 4, although care must be taken so that for these rectifiers, by the added current  $i$ , there will also be caused a new characteristic  $K_{3,4}$  located approximately midway between the two characteristics. Under certain circumstances, it may be necessary to the said end to interchange or transpose the rectifiers 3 and 4.

10 If the audio frequency current in the output circuit is to be suppressed completely, then the characteristics  $K_{1,2}$  and  $K_{3,4}$  will have to register or coincide. However, in the majority of instances, this will not be feasible. Thus, a balance or residue of audio frequency current will still be present in the output circuit of the modulator, and while this current has been essentially reduced, it is still discernible, even if the carrier current could be completely suppressed. By regulation of the size and phase of the added carrier current  $i$  it is readily possible to adjust to optimum or most favorable values according to whether it is felt to be more desirable or necessary to accomplish complete suppression of the carrier current or of the audio frequency current in the output circuit.

Now, the method hereinbefore described offers this further advantage that also the harmful effect of harmonics frequently present in the carrier wave generator may be eliminated inside wide limits by the addition of the carrier current  $i$  as hereinbefore suggested. Figure 3 shows the shape of the carrier frequency  $w$ , of the harmonic  $2w$  and the resultant potential  $w+2w$ . It can be readily seen from the figure that the maximum currents of  $w+2w$  may be very different for the two alternations seeing that the absolute value of the harmonic becomes added to the fundamental wave during one alternation, while for the other alternation is subtracted. Also in this instance the method according to this invention can be used to provide a ready remedy inasmuch as the added carrier current  $i$  for corresponding rectifiers will become added in one of them and be subtracted for the other rectifier. If the signs are properly chosen, the influence of the harmonics by the added carrier current  $i$  can be equalized or at least be diminished.

Figure 4 shows a practical embodiment of the invention. The radio frequency generator H by way of transformer  $U_1$  feeds directly the ring-type modulator. Connected with the secondary winding of the said transformer  $U_1$  is a differential bridge comprising the regulable resistance  $r_1$  and the further resistance  $r_2$  and resistance  $r_3$  inserted in the diagonal of the bridge arrangement. Connected in parallel to the resistance  $r_2$  is moreover a variable condenser  $c$  which has the purpose to regulate the phase of the current  $i$ . The amplitude may be regulated in fine steps by resistance  $r_1$  and coarsely by the tap of  $r_3$ .  $r_4$  and  $r_5$  indicates the resistance of the input and the load circuit.

Figure 5 shows another exemplified embodiment which differs from the one shown in Figure 4 essentially in that the differential bridge is not connected directly with the secondary circuit of the transformer  $U_1$ , but rather in parallel relation to a resistance  $r_6$  which is traversed by the carrier current to be modulated. If  $r_6$  is linear in nature, then the added current  $i$  and the current to be modulated will vary in like proportion. However, in some instances it is convenient to make the resistance of material whose action is a function of temperature and

thus of current. The result is that the carrier current  $i$  is adapted to the temperature variations of the rectifier elements to a large degree.

In both exemplified embodiments the carrier current  $i$  to be added is derived from one and the same generator H as the carrier current to be modulated. This offers the special advantage that in the case of fluctuations of the generator voltage, these will similarly act upon the carrier current to be modulated as well as on the added or supplemental carrier current. The output transformer  $U_2$  is then used not only to deliver the modulated current to the load circuit, but also for the purpose of introducing the additional carrier current  $i$  into the modulator. It would also be feasible to provide besides transformer  $U_2$  another transformer which solely serves the purpose to introduce the additional carrier  $i$  into the modulator. On the other hand, it would also be feasible to equip transformer  $U_2$  with a third winding which would serve only for feeding in the carrier current  $i$ .

The method hereinbefore described may be used in a similar way not only for a double push-pull modulator as here suggested, but also in simple or plain push-pull modulator circuit organizations.

I claim:

1. In a modulation system, a pair of rectifiers, an output circuit connected between corresponding electrodes of said rectifiers, means for impressing wave energy to be modulated in phase on like electrodes of said rectifiers, means for impressing modulating energy in phase opposition on like electrodes of said rectifiers, and additional means for additionally impressing wave energy in phase displaced relation on like electrodes of said rectifiers to control the operating characteristics of said rectifiers in a sense such that their characteristics are made similar.

2. In a modulation system, a source of wave energy to be modulated, a pair of rectifiers, a circuit coupling said source of wave energy to be modulated in phase to like electrodes of said rectifiers, a circuit coupling said modulating wave energy in phase displaced relation to like electrodes of said rectifiers, an output circuit connected between like electrodes of said rectifiers, and a circuit including amplitude regulating and phase adjusting elements coupling said source of wave energy to be modulated to said like electrodes coupled with said output circuit to control the operating characteristics of said rectifiers in a sense such that their characteristics are similar.

3. A modulation system as recited in claim 2 wherein one of said amplitude regulating elements is non-linear in character.

4. An arrangement as recited in claim 2 wherein an additional pair of rectifiers are cross-connected between the electrodes of said first named pair of rectifiers.

5. In a balanced modulation system, a pair of rectifiers having input and output electrodes, two sources of wave energy to be superimposed, an output circuit connected with corresponding electrodes of said rectifiers, means for impressing wave energy from one of said sources in phase on like electrodes of said rectifiers, means for impressing wave energy from the other of said sources in phase opposition on like electrodes of said rectifiers whereby wave energy characteristic of both of said sources appears in said output circuit, and undesired wave energy related in fre-

quency to the energy of at least one of said sources appears in said output circuit due to dissymmetry in the operating characteristics of said rectifiers, and means for opposing and substantially suppressing said undesired wave energy comprising an additional circuit coupling one of said sources to said output circuit to impress additional wave energy on said rectifiers to control the operating characteristics thereof, said additional circuit including ohmic amplitude regulating resistances and reactive phase regulating impedances.

6. In a balanced modulation system, a pair of rectifiers having input and output electrodes, two sources of wave energy to be superimposed, an input circuit coupling the input electrodes of said rectifiers in push-pull relation, an input circuit connecting the input electrodes of said rectifiers in parallel, means for impressing wave energy from one of said sources on one of said input circuits and wave energy from the other of said sources on the other of said input circuits, an output circuit connecting the output electrodes of said rectifiers in push-pull relation, a utiliza-

tion circuit, in which wave energy characteristic of the combined wave energy of said sources and the separate wave energies of said sources flows, coupled with said output circuit, and means for opposing and substantially suppressing wave energies in said utilization circuit characteristic of the wave energy of said source coupled with said second input circuit comprising a bridge circuit connecting said second input circuit to said utilization circuit to impress thereon wave energy to control the operating characteristics of said rectifiers, said bridge circuit comprising series ohmic amplitude regulating resistances and a reactive phase regulating impedance shunting one of said resistances.

7. A system as recited in claim 6 wherein a non-linear resistance is connected in series with second named input circuit and said bridge is connected in shunt to said non-linear resistance, said non-linear resistance serving to compensate for the effects of temperature changes on said rectifiers.

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