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J. M. WEST

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AMPLIFYING APPARATUS

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FIG. 1

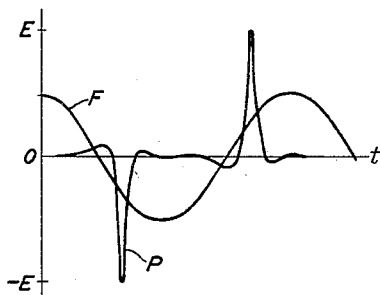


FIG. 2

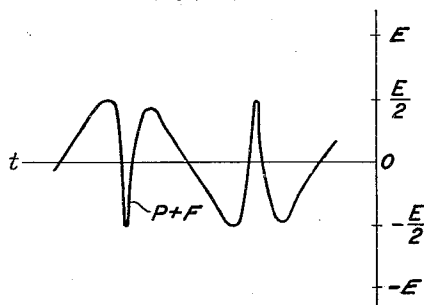
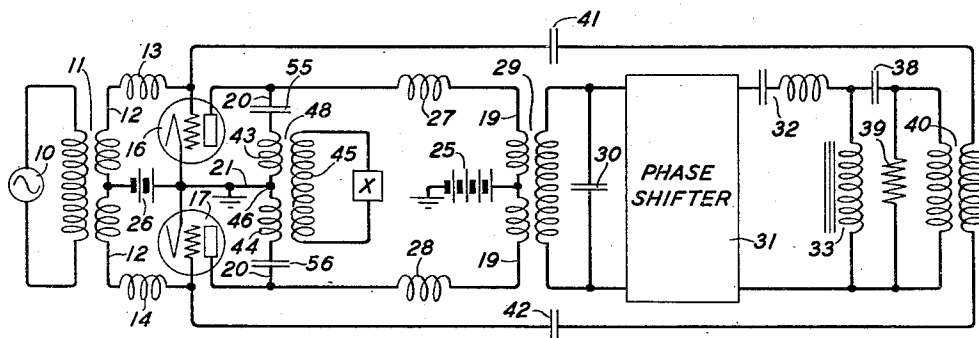


FIG. 3



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AMPLIFYING APPARATUS

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9 Claims. (Cl. 250—27)

This invention relates to amplifying apparatus, and more particularly to a method of and apparatus for amplifying sharply peaked waves.

It is well known that fundamental alternating current waves can be distorted in suitable apparatus of magnetic or thermionic type to produce peaked waves. One such apparatus disclosed in the copending application of L. R. Wrathall Serial No. 77,989 filed May 5, 1936, now Patent No. 2,117,752 granted May 17, 1938, serves to produce from fundamental waves sharply peaked waves. To amplify such peaked waves would require an amplifier that is substantially linear up to the peaks of the peaked waves, otherwise chopping of the peaks would occur. Also, as the peaks of the peaked waves are relatively large, the load carrying capacity of such amplifier would be considerably limited.

It is an object of the invention to provide an arrangement for amplifying sharply peaked waves.

It is another object of the invention to provide for sharply peaked waves an amplifying arrangement that need be linear only up to substantially one-half of the peaks of such waves.

It is a further object of the invention to increase the load carrying capacity of an amplifying device used to amplify sharply peaked waves.

One arrangement for producing sharply peaked waves comprises a source of fundamental waves coupled to a thermionic amplifier whose output includes a pair of circuits in parallel. One of these two parallel circuits is coupled to a non-linear device for applying amplified fundamental waves thereto. The output of the non-linear device including a condenser and a resistance serves to produce a series of sharply peaked waves, one sharp peak occurring for each half-cycle of the fundamental waves. The other of the two parallel circuits serves to supply amplified peaked waves, or amplified odd harmonics of the fundamental waves, to a work circuit adapted to select desired odd harmonics.

In accordance with the invention the sharply peaked waves are fed from the output of the non-linear device to the amplifier for amplification together with the fundamental waves. A phase shifting network is included in the input of the non-linear device to so control the phase of the sharply peaked waves that a wave pattern applied to the amplifier includes the peaked and fundamental waves in substantially equal magnitude and opposite phase relation.

The invention will be more readily understood

from the following description taken together with the accompanying drawing in which:

Fig. 1 is a wave pattern showing sharply peaked waves that are to be amplified;

Fig. 2 is a wave pattern showing the fundamental and peaked waves and produced in accordance with the invention;

Fig. 3 is a diagrammatic circuit illustrating one embodiment of the invention for producing the wave pattern shown in Fig. 2.

Referring to Fig. 3, a generator 10 of alternating current of fundamental frequency is connected to the primary of a transformer 11 whose secondary at the opposite ends is applied through divided input 12, 12 including inductances 13 and 14 to the grids of an amplifier comprising a pair of three-element thermionic tubes 16 and 17 having an output comprising divided circuits 19, 19 and 20, 20 in parallel. The filaments are preferably heated from suitable batteries while the anodes are energized by a battery 25.

The potential of biasing battery 26 applied to the grids of the amplifier at the mid-point of the secondary winding of the transformer 11 is of such magnitude that the flow of output current is reduced to a relatively low amount during intervals of no-grid excitation voltage. With the arrangement of the secondary winding of transformer 11 described above, fundamental waves supplied by the generator 10 are impressed simultaneously on each of the grids but in opposite phase.

The divided output circuit 19, 19 includes inductances 27 and 28 together with the primary winding of a transformer 29 whose secondary winding, shunted by a condenser 30, is applied through a tuned circuit 32 to the input of non-linear inductance 33. The output of the latter comprising a condenser 38 and a resistance 39 connected in series is coupled by transformer 40 and condensers 41 and 42 to the grids of the amplifier. The non-linear inductance together with associated input and output circuits is disclosed in the copending application of L. R. Wrathall, supra.

The divided output circuit 20, 20 comprises primary windings 43 and 44 of a broad band transformer 48 whose secondary winding 45 is applied across a work circuit X. Associated with the primary windings 43 and 44 are the respective blocking condensers 55 and 56 for isolating the amplified fundamental waves from the output circuit 20, 20. The mid-point 46 of the primary windings 43 and 44 is connected to the filaments by means of a grounded circuit 21, 55

It is understood that the work circuit X includes suitable filters for selecting desired odd harmonics of the fundamental waves produced in a manner that will be subsequently explained.

In the operation of the above-described circuit shown in Fig. 3, fundamental waves produced in the generator 16 are amplified in the amplifier and then applied through the transformer 29 to the non-linear inductance. As pointed out in the copending application of L. R. Wrathall, supra, the output of the non-linear inductance is proportioned to cause therein the production of a series of sharply peaked waves.

In accordance with the invention, the sharply peaked waves, rich in odd harmonics of the fundamental current, are fed back through transformer 40 and condensers 41 and 42 to the grids of the amplifier for amplification and consequently are superposed on the fundamental waves which are also being applied to the grids of the amplifier to be amplified at the same time. The inductances 13 and 14 preclude the harmonics, due to the sharply peaked waves, from passing into the input circuit 12, 12 while the condensers 41 and 42 prevent the fundamental waves and biasing voltages from passing into the secondary winding of the transformer 40. Due to the above-described arrangement of the amplifier, the output 23, 29 serves to differentially combine the harmonics so that odd harmonics of the fundamental waves are made available to the work circuit X.

A phase shifting network 31 is connected in the input of the non-linear inductance, that is, between the secondary winding of the transformer 29 and the tuned circuit 32. The constants of this phase shifting network are so proportioned that the phase of the amplified fundamental waves impressed on the non-linear inductance is shifted substantially 180 degrees. This causes a corresponding phase shift of the sharply peaked waves superposed on the fundamental waves as both thereof are simultaneously applied to the grids of the amplifier. Consequently, the sharply peaked and the fundamental waves are substantially 180 degrees out of phase when both are simultaneously applied to the grids of the amplifier for amplification. Fig. 2 is a wave pattern showing the sum of the peaked and fundamental waves in such relationship.

Fig. 1 is a wave pattern illustrating one possible phase relationship between the fundamental waves and the sharply peaked waves in the case where no attempt is made to control the phase relation therebetween. In this figure curves F and P represent the fundamental and sharply peaked waves, respectively. To amplify such wave pattern without chopping the peaks of the sharply peaked waves would not only require an amplifier that is substantially linear up to the voltage E, but would also substantially limit the load carrying capacity of such amplifier.

However, to amplify a wave pattern produced in accordance with this invention and illustrated in Fig. 2, the amplifier would have to be substantially linear only up to the voltage

$$\frac{E}{2}$$

As a result the load carrying capacity of the amplifier would be increased six decibels. An additional feature of the circuit shown in Fig. 3 is that the odd harmonics available to the work circuit X appear thereat in amplified form. Referring to Fig. 2 it is seen that the peaks of the fundamental and sharply peaked waves are substantially equal, and occur at the same time although substantially 180 degrees out of phase. Inductances 27 and 28 connected in the output 19, 19 serve to prevent the odd harmonics from passing into the primary of the coupling transformer 29.

While the invention is described with particular regard to a harmonic producing circuit utilizing a non-linear inductance for producing sharply peaked waves and a single amplifier for amplifying both fundamental and peaked waves, it is understood that the invention is not necessarily limited thereto as it is also readily applicable for use in any circuit employing a suitable non-linear distorting means for producing sharply peaked waves, such, for example, as thermionic or gaseous discharge devices, thyrists and copper-oxide rectifiers, and including amplifiers individual to the fundamental and sharply peaked waves. Thus, in certain circuits, it may be desirable to effect amplification of sharply peaked waves by utilizing therefor separate amplifiers and sources of fundamental current waves.

It is therefore understood that the invention is capable of modifications other than those disclosed herein, and the scope thereof together with such modifications is defined in the appended claims.

What is claimed is:

1. In a circuit having sharply peaked waves, the method of amplifying the sharply peaked waves which comprises applying fundamental waves to an amplifier, applying at the same time the sharply peaked waves to the amplifier, and controlling the phase of the sharply peaked waves until the peaks thereof are substantially equal to those of the fundamental waves and the peaks of both occur substantially in opposite phase relation.
2. In a circuit having sharply peaked waves, the method of amplifying the sharply peaked waves which comprises applying fundamental waves to an amplifier, applying at the same time the sharply peaked waves to the amplifier, and controlling the phase of the sharply peaked waves so that the peaks of the fundamental and sharply peaked waves occur at the same time and are substantially 180 degrees out of phase.
3. In a harmonic generator including means for producing a series of sharply peaked pulses, the method of amplifying the sharply peaked pulses which comprises amplifying a fundamental current, distorting the amplified fundamental current to produce a series of sharply peaked pulses, superposing the sharply peaked pulses on the fundamental current for simultaneous amplification therewith, and controlling the phase of the sharply peaked pulses until the peaks thereof are substantially equal to those of the fundamental current and the peaks of both occur in substantially opposite phase relation.
4. An apparatus for amplifying sharply peaked waves comprising means for producing sharply peaked waves, amplifying means, a source of fundamental waves, means for applying the fundamental waves to the amplifying means, means for connecting the peaked-wave producing means to the amplifying means, and means for so controlling the phase of the sharply peaked waves that the sharply peaked waves and the fundamental waves are applied to the amplifying means substantially 180 degrees out of phase.
5. An apparatus having means for producing

sharply peaked waves comprising means for increasing the output of the sharply peaked waves including amplifying means, a source of fundamental waves, means for applying the fundamental waves to the amplifying means, means for applying the sharply peaked waves to the amplifying means, and means for so controlling the phase of the sharply peaked waves that the fundamental and sharply peaked waves are applied to the amplifying means in opposite phase relation.

6. An apparatus having means for producing sharply peaked waves comprising means for amplifying the sharply peaked waves including amplifying means, a source of fundamental waves, means for applying the fundamental waves to the amplifying means, means for applying the sharply peaked waves to the amplifying means, and means for so controlling the phase of the sharply peaked waves that a wave pattern impressed on the amplifying means includes the fundamental and sharply peaked waves in such relation that the peaks of both waves are substantially equal and of different signs.

7. A harmonic producing system including a source of fundamental waves, an amplifying device having an input and an output, means for coupling the fundamental source to the input of the amplifying device, a non-linear device, means for coupling the output of the amplifying device to the non-linear device for applying amplified fundamental current thereto, an output circuit for the non-linear device including a condenser

and a resistance in series both of which are proportioned to produce a series of sharply peaked waves, and means for amplifying the sharply peaked waves comprising means for coupling the output of the non-linear device to the amplifying device for superposing the sharply peaked waves on the fundamental waves, and a phase shifting network for so controlling the phase of the sharply peaked waves that a wave pattern applied to the amplifying device includes the sharply peaked and fundamental waves in such relation that the peaks of both waves are substantially of the same magnitude and occur at substantially the same time.

8. The harmonic producing apparatus according to claim 7 in which the phase shifting network so controls the phase of the sharply peaked pulses that the wave pattern applied to the amplifying device includes the sharply peaked and fundamental waves in such relation that the peaks of both waves are substantially of the same magnitude and occur in substantially opposite phase relation.

9. The harmonic producing apparatus according to claim 7 in which the phase shifting network so controls the phase of the sharply peaked pulses that the wave pattern applied to the amplifying device includes the sharply peaked and fundamental waves in such relation that the peaks of both waves are substantially of the same magnitude and occur at substantially the same time in opposite phase relation.

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