

Dec. 30, 1947.

M. M. LEVY ET AL

2,433,379

GENERATION OF ELECTRICAL IMPULSES

Filed Sept. 11, 1942

3 Sheets-Sheet 1.

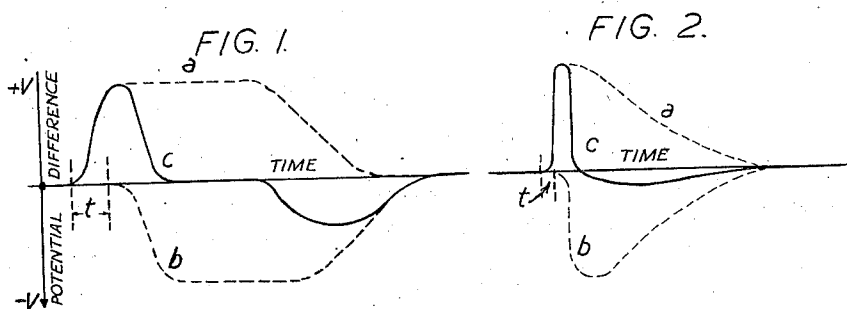
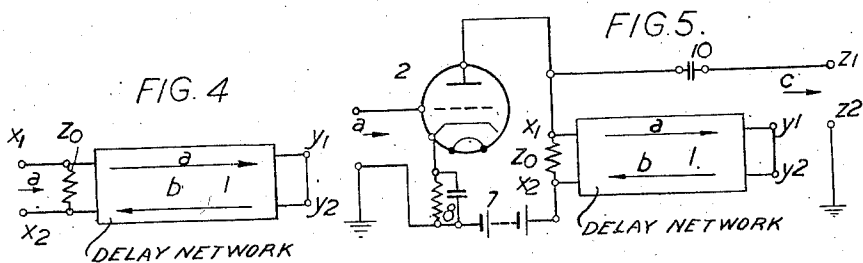
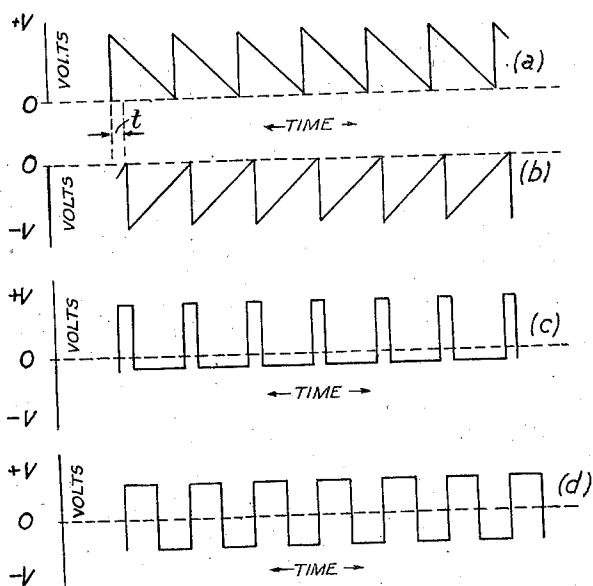


FIG. 3.



INVENTORS
M. M. Levy
L. E. Weaver
BY Lloyd Hall Sutton
ATTORNEY

Dec. 30, 1947.

M. M. LEVY ET AL

2,433,379

GENERATION OF ELECTRICAL IMPULSES

Filed Sept. 11, 1942

3 Sheets-Sheet 2

FIG. 6.

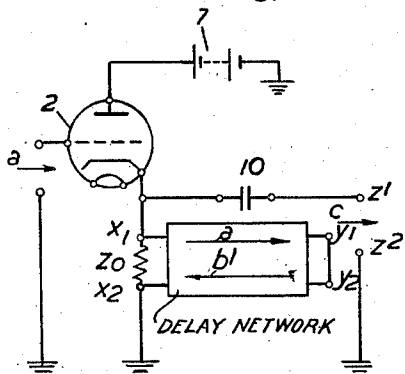


FIG. 7.

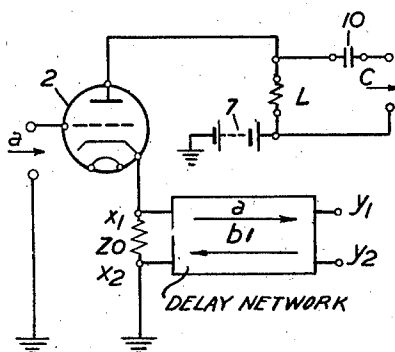


FIG. 8.

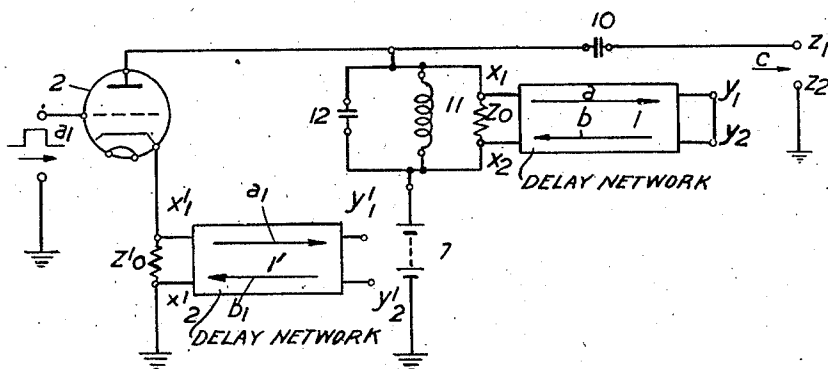
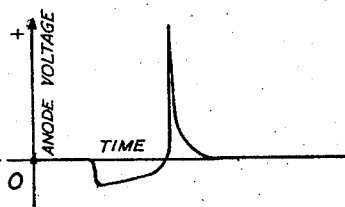


FIG. 9.



INVENTORS
M. M. Levy
L. S. Warner
BY
Lloyd Hall Sutton
ATTORNEY

Dec. 30, 1947.

M. M. LEVY ET AL

2,433,379

GENERATION OF ELECTRICAL IMPULSES

Filed Sept. 11, 1942

3 Sheets-Sheet 3

FIG. 10.

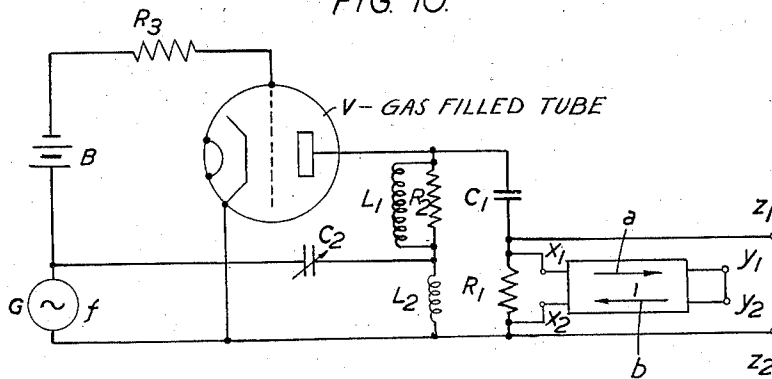


FIG. 11.

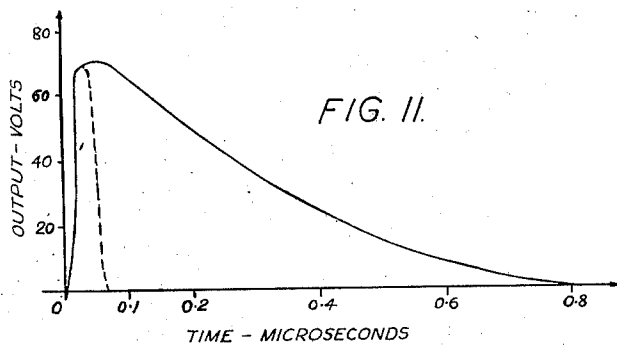
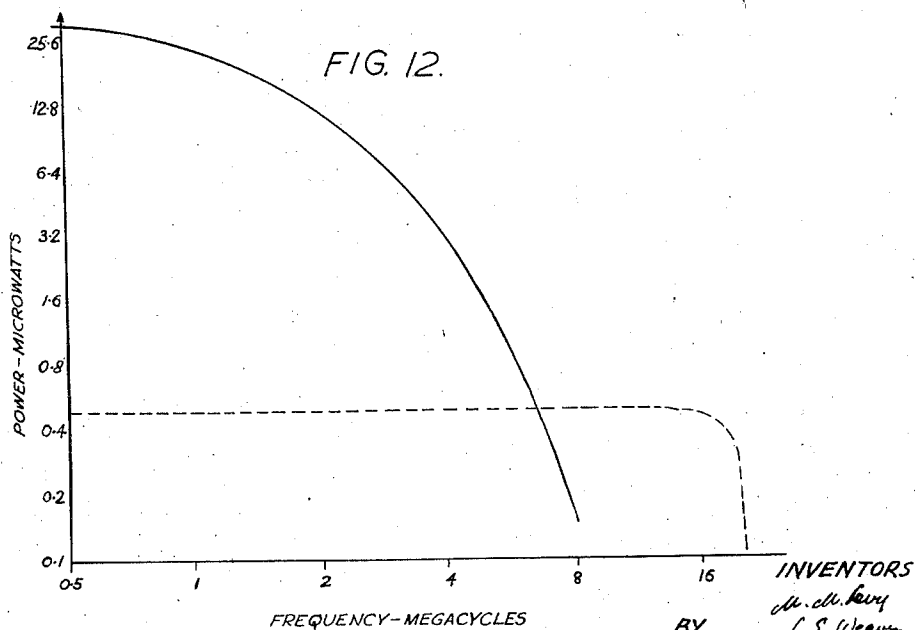


FIG. 12.



INVENTORS
M. M. Levy
L. S. Weaver
 BY *Lloyd Hall Sutton*
 ATTORNEY

UNITED STATES PATENT OFFICE

2,433,379

GENERATION OF ELECTRICAL IMPULSES

Maurice Moise Lévy and Leslie Ernest Weaver,
London W. C. 2, England, assignors to Standard
Telephones and Cables Limited, London, Eng-
land, a British company

Application September 11, 1942, Serial No. 458,058
In Great Britain April 4, 1941

Section 22, Public Law 690, August 8, 1946
Patent expires April 4, 1961

1 Claim. (Cl. 250—27)

1

This invention relates to methods of and arrangements for obtaining from a given electrical pulse another electrical pulse of modified form; and in particular, to suitable application of the methods described for producing pulses having a very steep initial rise; or of very short duration, or both.

In connection with the testing of television systems and in obstacle detection, pulses are required containing relatively large amounts of energy but of exceedingly short duration, perhaps of the order of 1 microsecond or less. This requires that the initial rise must be exceedingly steep. The generation of such pulses presents some difficulty and the present invention discloses some methods by which this may conveniently be done.

While the chief application of this invention is to the generation of these short pulses, the same principles may be used in the solution of other allied problems in which pulses of one type are required to be changed into pulses of some other type.

The principal object of this invention, therefore, is to disclose a method for producing electrical pulses of very short duration.

Another object is to apply the method to pulse generating systems whereby the pulses produced may be considerably shortened.

According to the main feature of the invention, an electrical pulse of short duration is produced from a longer electrical pulse (which may be generated in any of a number of known ways). This original pulse is modified by producing from it a secondary pulse of similar form, which is then delayed in turn and subsequently combined with the original pulse (or a copy of it) in a common circuit. The time delay is produced by the use of a delay network of a type well known in the art. The original and secondary pulses may be arranged to have the same or opposite signs before combination, and two different kinds of modified pulses may therefore be obtained. Further, the delayed secondary pulse may be produced at the input terminals of the delay network by applying the original pulse to the input terminals, and reflecting it at the output terminals.

According to another feature, the delay network may be connected either in the anode circuit or the cathode circuit of a thermionic valve, to the control grid of which is applied the original pulse. The delayed pulse is in these cases obtained by reflection at the output terminals of the network and the modified pulse may be taken

2

from the anode circuit or the cathode circuit of the valve.

In an embodiment of the invention, arrangements similar to those just described are applied to a pulse generator which may be of a type already known, whereby the pulses so generated are made steeper or narrower or both.

In another embodiment of the invention a delay network is applied to a harmonic generator of a known type in which harmonics are obtained from a train of repeated pulses of short duration. The application of the delay network enables the pulses obtained to be very considerably shortened, thereby enabling a very much greater number of harmonics of approximately equal power to be obtained.

The objects and features of the invention will be more fully understood from the following detailed description, and from the attached drawings in which:

Fig. 1 shows the variation of voltage with time of an original pulse, a secondary delayed pulse and the resultant combined pulse.

Fig. 2 is similar to Fig. 1 except that the secondary pulse is steeper and is delayed by a shorter time.

Fig. 3 shows a particular example of the combination of a series of original pulses and a series of delayed pulses.

Fig. 4 shows schematically a network arranged for delaying a pulse by reflection.

Fig. 5 shows a circuit arrangement for producing a modified pulse in which the delay network is connected in the anode circuit of a valve.

Figs. 6 and 7 show other circuits in which the delay network is connected in the cathode circuit of a valve.

Fig. 8 shows a circuit arrangement for producing extremely steep and/or narrow pulses in which two delay networks are associated with an impulse generator.

Fig. 9 shows the form of the pulse produced by the generator shown in Fig. 8.

Fig. 10 shows another circuit arrangement for producing extremely narrow pulses in which a delay network is associated with a harmonic generator.

Fig. 11 shows the forms of pulses produced by the harmonic generator shown in Fig. 10.

Fig. 12 shows the relation between the frequency and the power of the harmonics produced by the generator of Fig. 10.

In Fig. 1 the dotted curve *a* shows the outline of a pulse which might be applied to the terminals of a circuit. The curve gives the relation

3

between the difference of potential of the circuit terminals and the time. The dotted curve *b* shows likewise the outline of a pulse having the same shape as *a* but of opposite sign and displaced horizontally by a time *t* seconds which is small compared with the duration of the pulse. If now pulse *b* be applied to the circuit *t* seconds after *a* the resultant effect will be the full-line pulse *c* which is obtained by adding algebraically the ordinates of *a* and *b*.

In Fig. 2 is shown another example in which the original impulse has a very steep initial rise and in which the time *t* separating the pulses *a* and *b* is much shorter. This enables a substantially rectangular pulse of duration very short compared with the original pulse, to be obtained.

Another type of modified pulse can be obtained similarly by combining with the original pulse *a* a delayed pulse *b* of the same shape as *a* and having the same instead of a reversed sign.

While these methods may be applied to pulses of any form, particular importance is attached to pulses having a steep initial rise. Thus Fig. 1 indicates how a relatively narrow pulse *c* may be obtained from a pulse *a* having a moderately steep initial rise. Fig. 2 shows how a much narrower pulse *c* may be obtained from a pulse *a* having a much steeper initial rise by making the time interval *t* smaller. Generally, as the resultant pulse *c* is required to be narrower, so the initial rise of the original pulse *a* must be steeper.

There are several well-known means of producing pulses having a steep initial rise, so that this requirement does not constitute a practical limitation to the application of the process just described.

According to the principle of the invention, the pulse *a* is generated by some such convenient means and the pulse *b* is obtained from it by applying a proportion of the voltage to a delay network from which the pulse *b* emerges a short time *t* later. Pulse *b* with the same or reversed sign is then combined with pulse *a* and applied to the circuit terminals, and as explained above, the resultant pulse *c* will be obtained. By suitably adjusting the delay in the network, the time *t* can be varied, and the resulting pulse can accordingly be made to have any desired width. Details of various methods of utilising the delay network will be explained below.

An example is shown in Fig. 3. The series of saw-tooth pulses *a* is displaced by a time *t* and reversed in sign, as shown in *b*. When these two series of pulses are combined at the input of a circuit, the resultant will be the series of square topped pulses shown in *c*. In the special case when *t* is equal to half the interval separating the successive peaks of series *a*, the symmetrical series of square pulses *d* will be obtained.

A method of producing the necessary time delay is indicated in Fig. 4. A delay network *1* of the type well known in the art in which a pulse entering at terminals *x*₁ and *x*₂ emerges from terminals *y*₁ and *y*₂ after a finite interval depending upon the elements of which it is composed, has an impedance *z*₀ preferably equal to its image impedance, connected to its input terminals *x*₁ and *x*₂. The pulse *a* is applied to the input terminals, and the output terminals *y*₁, *y*₂ are short circuited as shown. The pulse travels into the network and is reflected at the short circuited output terminals, and returns as the *b* pulse to the input terminals *x*₁, *x*₂ after a certain delay. The *b* pulse will arrive at terminals *x*₁, *x*₂ with the sign opposite to that of the orig-

4

inal *a* pulse. If however the output terminals *y*₁, *y*₂ are unconnected the *a* pulse will be reflected as before and the *b* pulse will arrive with the same delay at the input terminals *x*₁, *x*₂ but with

the same sign as that of the original impulse *a*. Thus in either case the original impulse *a* and the delayed impulse *b* will add together at the input terminals *x*₁, *x*₂; and the resultant pulse *c* will be of the type shown in Figs. 1 and 2 if the output terminals are short-circuited, and will be of the alternative type if they are left unconnected: While for most practical purposes the output terminals *y*₁, *y*₂ of the network will be either short circuited or left unconnected, the delayed pulse *b* can be varied in amplitude by connecting to *y*₁ and *y*₂ some impedance *Z* different from the image impedance *z*₀, and its sign will depend upon whether *Z* is greater or less than *z*₀.

It should be added that the impedance *z*₀ is preferably chosen to be equal to the image impedance of the network in order to prevent additional reflections at the input terminals. When the input terminals of the network are connected to a circuit the impedance of that circuit will be effectively in parallel with *z*₀. Accordingly in this case the value of *z*₀ should preferably be so chosen that when it is combined with the circuit impedance the resultant impedance will be equal to the image impedance of the network. In the circuits described below it will generally be assumed that the value of *z*₀ has been so chosen.

Some circuits showing various methods by which the principles explained above may be carried out will now be described.

In Fig. 5 is shown a simple circuit employing one valve. The valve 2 is provided with the usual anode battery 7, cathode circuit 8 and blocking condenser 10, and suitable pulses are applied between the grid electrode and earth. The anode load consists of a delay network 1 shunted by a suitable impedance *z*₀. The input pulses will be amplified by the valve 2 and *a* pulses of similar shape will appear at the input terminals *x*₁, *x*₂ of the delay network 1. As already explained delayed *b* pulses will also be produced at the terminals *x*₁, *x*₂ by reflection at the output terminals *y*₁, *y*₂ and *c* pulses will accordingly appear at the output terminals *z*₁, *z*₂. If the output terminals *y*₁, *y*₂ of the network 1 be short circuited as shown in Fig. 5, then the *c* pulses will be of the type shown in Figs. 1 and 2. If *y*₁ and *y*₂ be left unconnected, then the *c* pulses will be of the alternative type.

One arrangement whereby the delay network 1 is connected in the cathode circuit of the valve 2 is shown in Fig. 6. The anode is fed from the battery 7. The output terminals *z*₁ and *z*₂ are connected across the terminating impedance *z*₀, a blocking condenser 10 being introduced in the connection between the terminals *x*₁ and *z*₁. By this arrangement the valve is operated as a cathode follower. The output terminals of the delay network 1 are short circuited, in which case a *c* pulse similar to Figs. 1 or 2 will be obtained, at terminals *z*₁ and *z*₂. The resulting *c* pulse will be slightly different from that produced by the circuit of Fig. 5, because the use of *z*₀ in the cathode circuit introduces negative feedback which changes somewhat the form of the *c* pulse.

A second arrangement whereby the delay network 1 is connected in the cathode circuit of valve 2 is shown in Fig. 7. This differs from Fig. 6 in

that the anode circuit contains a load impedance L across which the output is taken at terminals z_1 and z_2 , and that the delay network output terminals are left unconnected. In this case, when a positive pulse is applied to the grid, a similar positive a pulse appears in the cathode circuit, and the anode current increases. The reflected b pulse will arrive at the input terminals x_1, x_2 of the network with the same sign as the a pulse. This then causes the cathode voltage suddenly to increase, and since the grid voltage remains unchanged, the cathode voltage assumes a large positive value with respect to the grid, so that the plate current is suddenly cut off. The c pulse obtained in the plate circuit will accordingly be of the type shown in Fig. 2.

For some purpose extremely narrow pulses are required. As already explained, reduction in the width of the c pulse is limited by the steepness of the initial rise of the a pulse. There are several known methods of producing pulses having a steep initial rise and it is convenient to combine in one circuit the means for generating such pulses with the methods of reducing their width which are the subject of the present invention. One way in which this may be done is shown in Fig. 8. The valve 2 has connected in its anode circuit an anti-resonant circuit consisting of an inductance l_1 and a capacity l_2 , which if desired may be represented by the capacity associated with the plate circuit of the valve. Connected in parallel with the inductance is a delay network I having its output terminals y_1, y_2 short circuited, and having the usual impedance Z_0 connected to its input terminals x_1, x_2 . The combined impedance of the network I and Z_0 is of such a value that the antiresonant circuit l_1, l_2 is critically damped. Connected in the cathode circuit of the valve is a second delay network I' having its output terminals y'_1, y'_2 left unconnected, and its input terminals x'_1, x'_2 shunted by the impedance Z'_0 . The output of the valve circuit is taken from terminals z_1, z_2 through a blocking condenser 10.

The circuit of Fig. 8 with the omission of delay networks I and I' is in essentials the same as one already known for producing pulses having a very steep initial rise. Pulses a_1 of square topped form are applied to the grid of the valve 2. After the initial sudden rise of grid potential due to the pulse a_1 the anode current increases very slowly owing to the nature of the anode load and conditions are chosen so that the anode current reaches a maximum before the final fall of the grid potential at the end of pulse a_1 . When the grid potential falls the anode current is suddenly cut off and the inductance l_1 discharges very sharply, producing a single peak of the type shown in Fig. 9, the circuit being critically damped.

When the delay networks I and I' are added, the operation of the circuit will be as follows:

The pulse a_1 applied to the grid of valve 2 will produce across Z_0 a pulse a of form similar to Fig. 9 as already explained. The network I produces the delayed b pulse which combines with the a pulse to produce the c pulse at the output terminals in the manner already explained with reference to Fig. 5. Since the a pulse has a very steep initial rise, the time delay in the network may be made very small, so that the c pulse can have a width small compared with the width of the a pulse shown in Fig. 9. The delay network I' in the cathode circuit operates in the manner described with reference to Fig. 7, and causes

the anode current to be cut off much more suddenly on the final fall of the pulse a_1 . As a result the initial rise of the pulse a (Fig. 9) is made steeper than before. Thus in belief, the network I' steepens the initial rise of the pulse a in the anode circuit, and network I produces the narrow pulse c from a by combining with it the delayed and reversed pulse b . It will be clear that the functions of networks I and I' are independent and either could be used alone without the other.

Another application of particular interest is to a harmonic generator of a known type the circuit of which is shown in Fig. 10. In this circuit a train of pulses is produced from a sinusoidal generator, one pulse being produced for each complete cycle of the generator. Referring to Fig. 10, the generator G is connected to a resonant circuit consisting of an inductance L_2 and a variable capacity C_2 , which is tuned to the frequency of the generator. The potential across the inductance L_2 is applied through a high resistance R_2 to a condenser C_1 and a resistance R_1 connected in series, and the output is taken from terminals z_1 and z_2 connected across R_1 . A small inductance L_1 is connected across R_2 to improve the operation of the circuit. The circuit also includes a gas-filled triode V , the plate cathode impedance of which is connected across the series circuit of R_1 and C_1 , and the grid is connected to the generator through a high resistance R_3 and a polarising battery B . A delay network I is shown connected with its input terminals x_1, x_2 across R_1 with its output terminals y_1 and y_2 short circuited.

Assuming for the moment that the delay network I is not connected to R_1 , the circuit produces at the terminals z_1 and z_2 a pulse of the form shown by the full line curve shown in Fig. 11. As the potential produced by the generator rises so also the potential across the series circuit C_1, R_1 rises and the circuit elements are so chosen that this rise of potential is very sharp. At the same time the potentials of the grid and the plate of the valve V have risen until a point is reached at which the valve suddenly becomes conducting and the plate-cathode impedance becomes low, thus discharging the condenser C_1 , and causing the potential across R_1 to fall in the manner indicated at Fig. 11.

Pulses of this type periodically repeated at the frequency of the generator G produces a series of harmonics the relative power of which plotted against the frequency is shown in the full line curve of Fig. 12, and it will be seen that the power falls rather rapidly as the frequency of the harmonic increases. The frequency of the generator may be, for example, 4 kc., and the values shown in Figs. 11 and 12 are those which can be obtained by a suitable choice of the values of the elements shown in Fig. 10.

When, however, the delay network I is connected to the resistance R_1 as shown in Fig. 10 the pulse shown in the full line of Fig. 11 will be reflected at the short-circuited output terminals and will return to the resistance R_1 with a change of sign, and with a suitable delay. Accordingly, a modified pulse will be obtained at the output terminals z_1 and z_2 of the type shown in Fig. 2. This pulse has been indicated in Fig. 11 by the dotted line. Such a pulse as this, when periodically repeated at the frequency of the generator, will produce a series of harmonics whose power is shown plotted against the frequency in the dotted line of Fig. 12, and it will be seen that the

power of the harmonics is practically constant up to about 15 megacycles. In other words, assuming the generator produces a frequency of 4 kc., something like 3000 harmonics of equal power will be produced in this way.

It will be understood that no change whatever has to be made to the values of any of the elements of the circuit excepting that the resistance R_1 should be doubled in value and the delay network should be designed so that its characteristic impedance at the terminals z_1 and z_2 is also $2R_1$. Accordingly, the effective resistance connected across terminals z_1 and z_2 is again R_1 . Thus it follows that the curves shown in Figs. 11 and 12 represent the improvement obtained with a circuit having elements of predetermined values when the delay network 1 is added to it.

With the values shown in Figs. 11 and 12 the delay network should have a delay of approximately 0.015 microsecond, thereby producing a time interval between the a and b pulses of about 0.03 microsecond, and, as seen from Fig. 11, dotted line, the width of the c pulse so produced is perhaps 0.07 microsecond. A delay network of an already known type is suitable for a case like this. Such a network consists of a small solenoidal coil with tapings at equal intervals to which are connected a number of equal condensers having capacities of the order of a few μf . The self inductance of the corresponding sections of the coil will be of the order of 10 microhenrys and such a coil might be perhaps 2 or 3 inches long.

Other similar methods of combining delay networks with generators of pulses for use in obstacle detecting and the like, or for producing harmonics will occur to those skilled in the art. For example, a delay network may be connected in the plate circuit of a relaxation oscillator and very narrow pulses may be obtained from the output terminals.

What is claimed is:

A system for producing electrical impulses of short duration, comprising a source of impulses, an electron discharge device including a cathode, control grid and anode for converting the impulses from said source into impulses of shorter duration, a circuit connected between the anode

and cathode of said discharge device including a first impedance which is also common to the cathode-grid circuit and an anti-resonant circuit comprising a second impedance, a first electrical delay network having its input terminals connected across said first impedance and its output terminals unconnected, a second electrical delay network having input and output terminals and having a delay characteristic such that the total time taken by said converted impulses of shorter duration to travel from said input terminals to said output terminals and after reflection at said output terminals to travel back to said input terminals is less than the duration of said converted shorter impulses, means for connecting said input terminals of said second delay network across said second impedance, means for short-circuiting the output terminals of said second delay network, and an output circuit coupled to said anode-cathode circuit.

MAURICE MOÏSE LÉVY.
LESLIE ERNEST WEAVER.

REFERENCES CITED

- The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,188,970	Wilson	Feb. 6, 1940
2,212,173	Wheeler	Aug. 20, 1940
2,212,420	Harnett	Aug. 20, 1940
2,212,967	White	Aug. 27, 1940
2,221,666	Wilson	Nov. 12, 1940
2,226,459	Bingley	Dec. 24, 1940
2,236,985	Bartelink	Apr. 1, 1941
2,265,996	Blumlein	Dec. 16, 1941
2,246,534	Peterson	June 24, 1941
2,200,009	Nuttall	May 7, 1940
2,266,154	Blumlein	Dec. 16, 1941
2,310,692	Hansell	Feb. 9, 1943

FOREIGN PATENTS

Number	Country	Date
485,939	Great Britain	May 23, 1938
479,935	Great Britain	Feb. 14, 1938