

Jan. 4, 1944.

E. H. B. BARTELINK

2,338,395

SIGNAL TRANSMISSION SYSTEM

Filed June 25, 1940

4 Sheets-Sheet 1

Fig. 1.

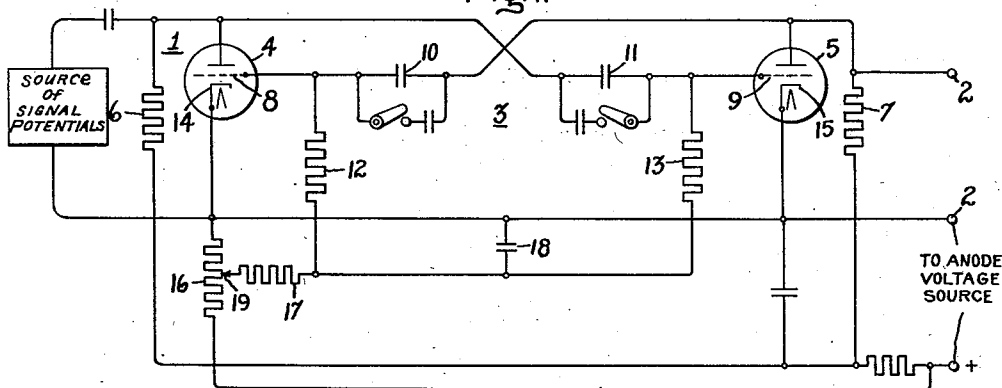


Fig. 2.

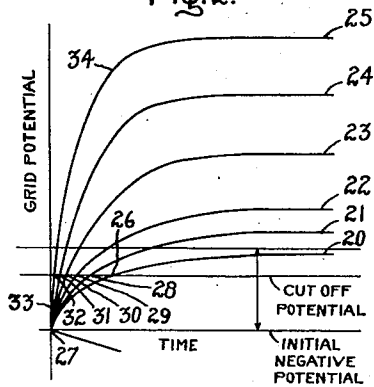


Fig. 3.

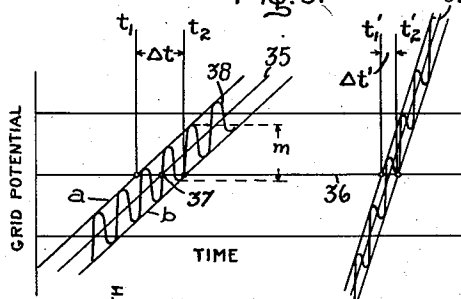


Fig. 5.

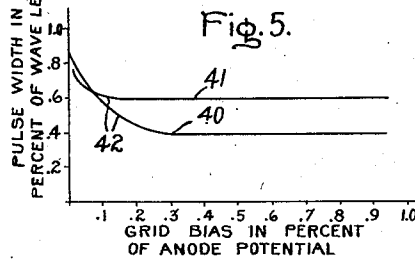


Fig. 4.

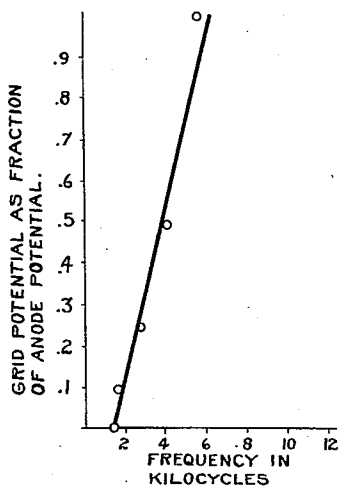
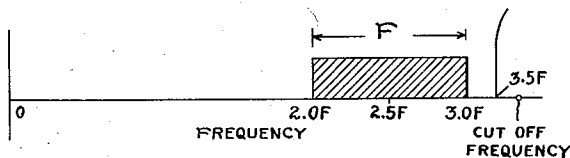


Fig. 7.



Inventor:
Everhard H. B. Bartelink,
by *Harry C. Dunham*
His Attorney.

Jan. 4, 1944.

E. H. B. BARTELINK

2,338,395

SIGNAL TRANSMISSION SYSTEM

Filed June 25, 1940

4 Sheets-Sheet 2

Fig. 6.

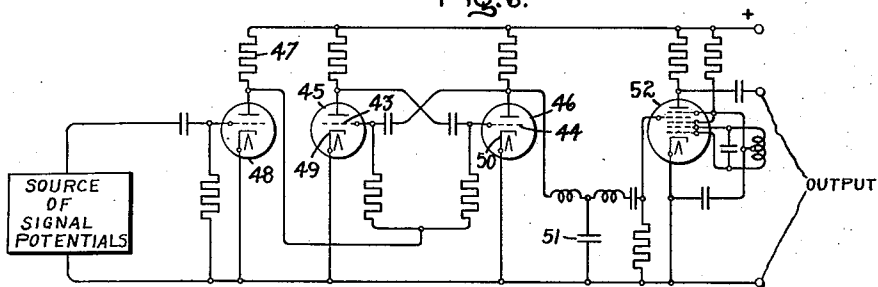


Fig. 8.

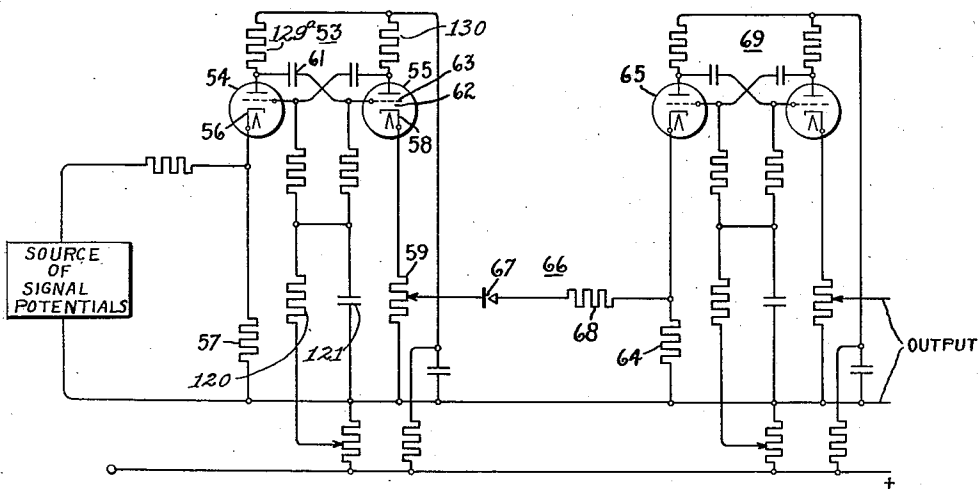
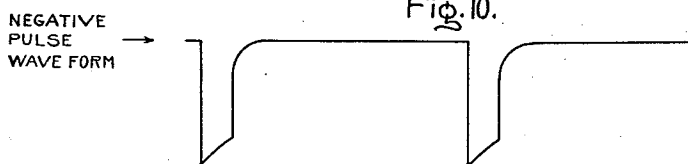


Fig. 9.



Fig. 10.



Inventor:
Everhard H.B. Bartelink,
by *Harry E. Dunham*
His Attorney.

Jan. 4, 1944.

E. H. B. BARTELINK

2,338,395

SIGNAL TRANSMISSION SYSTEM

Filed June 25, 1940

4 Sheets-Sheet 3

Fig. 11.

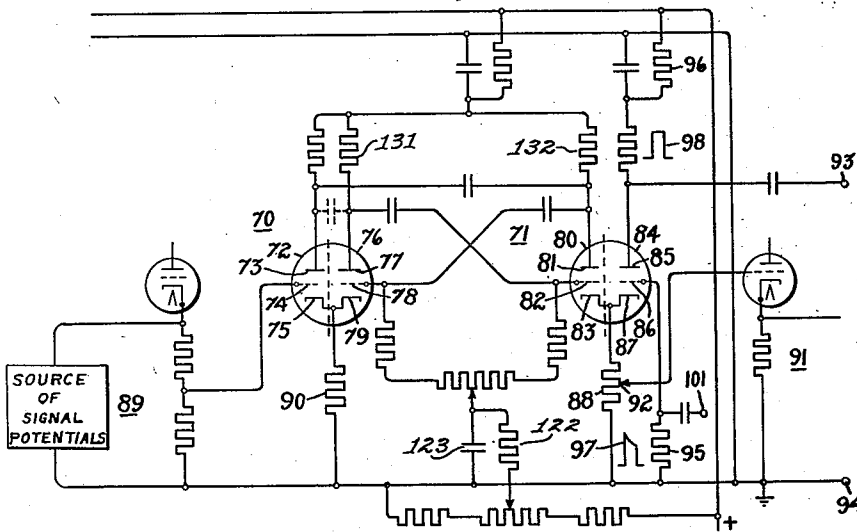


Fig. 12.

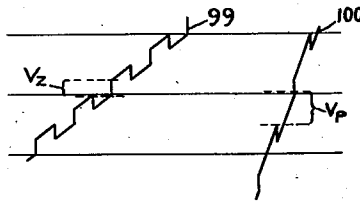
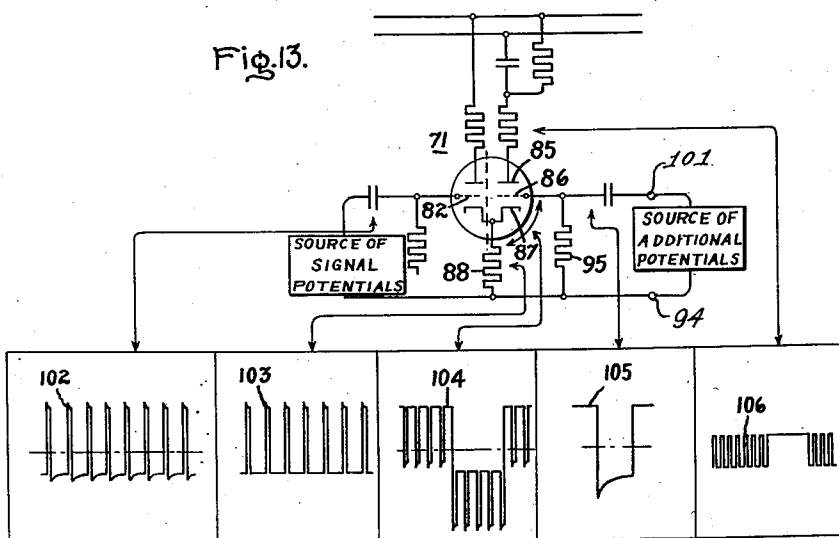


Fig. 13.



Inventor:
Everhard H. Bartelink,
by *Hany E. Dunkan*
His Attorney.

Jan. 4, 1944.

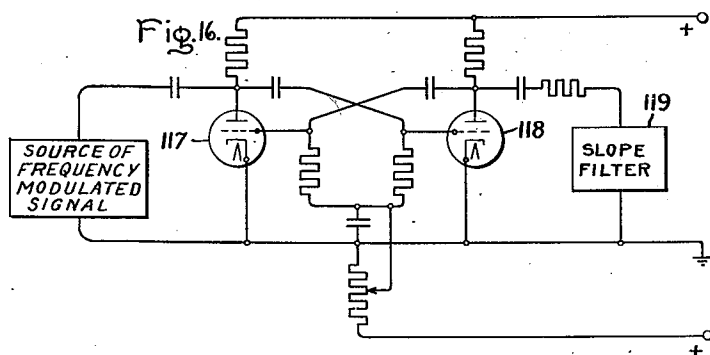
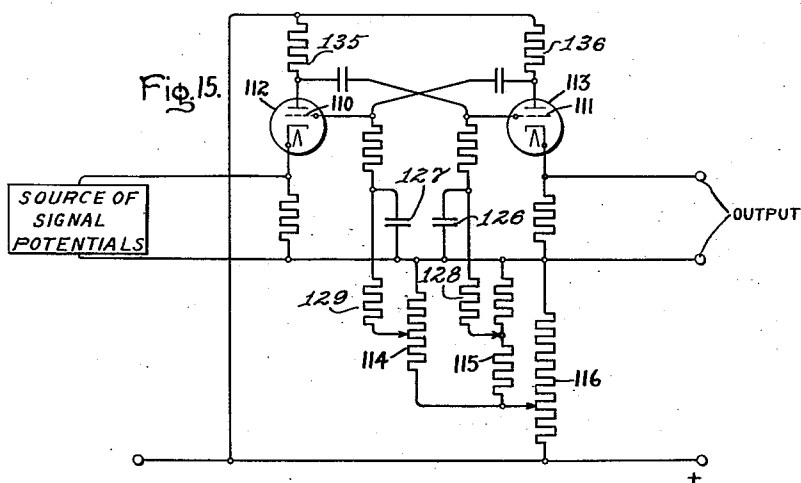
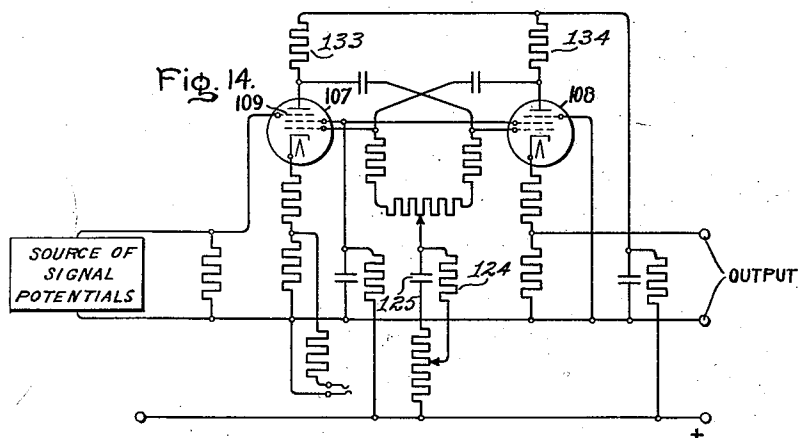
E. H. B. BARTELINK

2,338,395

SIGNAL TRANSMISSION SYSTEM

Filed June 25, 1940

4 Sheets-Sheet 4



Inventor:
Everhard H.B. Bartelink,
by *Harry E. Dunham*
His Attorney.

UNITED STATES PATENT OFFICE

2,338,395

SIGNAL TRANSMISSION SYSTEM

Everhard H. B. Bartelink, Niskayuna, N. Y., assignor to General Electric Company, a corporation of New York

Application June 25, 1940, Serial No. 342,321

7 Claims. (Cl. 179—171.5)

My invention relates to the application of improved circuits, especially of circuits employing multivibrators, for use as part of a transmission system or of a system used for the transmission of controlling signals in power and other applications.

An object of my invention is to effect certain improvements in multivibrators whereby their operation is less affected by interfering voltages; whereby their utility with respect to the production of current impulses in definitely timed relation to other impulses, as, for example, in television synchronizing systems, is improved; whereby their control with respect to frequency and pulse width of the impulses produced is improved and facilitated; and whereby various other advantages, as hereinafter explained, may be secured.

In recent years multivibrators have come into common use particularly in television systems, where they have great utility. As so employed, however, they comprise electron discharge devices the grids of which are normally without bias voltage or are biased negatively with respect to their cathodes. I have found, however, in accordance with my invention, that very important improvements in the operation of such multivibrators may be secured by biasing the grids positively with respect to their cathodes. In fact marked improvements in all of the respects above pointed out may be secured by such biasing of the multivibrator grids. The degree of such improvement is dependent upon the magnitude of the positive bias potential. In most cases I have found a relatively high positive bias potential to be desirable.

Further improvement is obtained by applying negative feedback to the multivibrator discharge devices.

It has been found in accordance with my invention that if a bias be supplied to the grids of the discharge devices employed in a multivibrator which bias is positive with respect to the cathodes thereof, the frequency of oscillations produced thereby is then substantially linearly dependent upon the magnitude of such bias over a very wide range of frequency variation. An object of my invention is to utilize this property of such multivibrators for frequency modulation.

It is another object of my invention to utilize the properties described above for demodulation of a carrier wave, for the conversion of one type of frequency modulation into another, and for the timing of frequency modulation signals, in general, for the interconversion of two differently characterized waves.

The novel features which are considered to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings wherein Fig. 1 is a diagrammatic representation of a transmission system, employing a multivibrator in accordance with my present invention; Figs. 2 to 5 show curves illustrating the operation of the system illustrated in Fig. 1; Fig. 6 illustrates another multivibrator system in accordance with my invention; Fig. 7 shows curves illustrative of the embodiment of Fig. 6; Fig. 8 illustrates another multivibrator system in accordance with my invention; Figs. 9 and 10 show curves illustrating the operation of the system of Fig. 8; Fig. 11 illustrates another multivibrator system in accordance with my invention; Fig. 12 illustrates advantages obtained in the use of my improved circuits; Fig. 13 shows curves illustrative of the system of Fig. 11; and Figs. 14, 15 and 16 illustrate further multivibrator systems in accordance with my invention.

Referring to Fig. 1 of the drawings, I have shown therein a transmission system comprising an input circuit 1, an output circuit 2, and a multivibrator 3 linking these circuits. A signal of a desired wave form is supplied to the input circuit 1 from a suitable source of signal potentials as represented conventionally in the figure. This signal is transmitted through the multivibrator 3 and synchronizes the pulses in output circuit 2 in a definitely timed relation with the impressed signal in input circuit 1. The multivibrator comprises a pair of electron discharge devices 4 and 5 having the anodes connected to a voltage source (not shown) through anode resistors 6 and 7. The control electrodes or grids 8 and 9 are respectively connected, through condensers 10 and 11 to the anodes of the opposite tubes, and the grid leaks 12 and 13 are respectively connected to the corresponding control electrodes or grids which through these grid leaks are connected with a source of bias potential which preferably is positive with respect to the cathodes 14 and 15. For this purpose a potentiometer 16 is provided connected across the anode voltage source, and the grid leaks 12 and 13 are adjustably connected to the potentiometer through a decoupling resistor 17 and a decoupling condenser 18. A positive bias voltage is therefore impressed upon the control electrodes 8 and

9 which is variable by adjustment of the movable contact 19 along the potentiometer 16.

In the operation of a multivibrator to produce spaced pulses the voltages impressed upon the two control electrodes become periodically of such values that the anode current is interrupted, or blocked, the blocking occurring in the two tubes alternately. The negative charge accumulated on the condenser connected between a given control electrode and the anode of the opposite discharge device at a given period in the cycle of operation and which is sufficiently great to block the corresponding tube, then leaks off in accordance with an exponential law until anode current begins again to flow, or until the cutoff point of the control electrode voltage-anode current curve of the discharge device is reached. The blocking condition is then removed and the corresponding tube again becomes conductive.

In Fig. 2 for example, are shown a series of exponential curves expressing the relation between control electrode potential and time under different control electrode bias potential conditions, from zero bias potential, for which curve 20 illustrates the change in grid potential with time, through successively greater positive bias produced by adjustment of the contact 19 of Fig. 1.

Exponential curves 21 to 25 illustrate the change in the control electrode potential for the latter positive bias conditions. The portions of the curves above zero control electrode voltage can, of course, only be realized while the cathode of the tube is not emitting electrons as otherwise the control electrode conduction would appreciably alter their shape. As shown in Fig. 2, in curve 20 corresponding to the zero bias condition, the slope at the cut-off point 26, is considerably less than at the initial point 27. Throughout the series of curves 21 to 25, however, the slope at the cut-off points, 28 to 32, becomes progressively more nearly equal to the slope at the initial point 27.

When as above described the applied positive voltage is made progressively higher, the exponential curves take the forms illustrated in Fig. 2 due to the different final unidirectional voltages to which the control electrode condensers would become charged. The occurrence of control electrode current, however, affects that part of a given curve which lies above the zero control electrode voltage line, whereas it is the region of the intersection of the curve with the cut-off line, or the region of negative control electrode voltages, which is of interest. If the applied positive bias voltage is relatively high, as in the case of curve 25 of Fig. 2, the intersecting of the exponential curve with the cut-off line occurs in the initial portion 33, instead of in the curved portion 34. Throughout this initial portion 33 the exponential curve is substantially a straight line and its slope practically equals the initial slope at initial point 27.

Referring to Fig. 3 in connection with Figs. 1 and 2 it will be seen how the obtaining of increased stability against interference is obtained in a multivibrator system of the positive control electrode bias type as compared with the system of the zero control electrode bias type. Let it be assumed that numeral 35 designates a portion of a characteristic curve of multivibrator control electrode voltage including the portion of the curve where the characteristic intersects the cut-off line. Numeral 36 designates the latter line. In the absence of interfering voltages impressed

on the control electrode circuit the tripping of the multivibrator will be performed at regular time intervals. The intersection 37 of control electrode voltage characteristic 35 and cut-off line 36 indicates the instant when, in the absence of interference, the tripping occurs. Let it now be assumed that interference is introduced such as a voltage affecting the normal control electrode voltage, and that the peak-to-peak swing of this voltage is a certain fraction, m , of the total driving peak-to-peak swing of the control electrode voltage. This interference may have any arbitrary wave form, such for example as indicated by the curve 38.

Thus, under the influence of the interference, the effective driving voltage may be any single valued function which is included within the region, m , around the normal or undisturbed characteristic 35, for any one tripping of the multivibrator. For consecutive trippings, unless the frequency of the multivibrator and of the interference are direct multiples, the phase of the interference may vary from one tripping of the multivibrator to another. The highest and lowest values of combined or effective control electrode voltages are given by the lines a and b , and their intersection with the line 36 determines the earliest and latest times at which the multivibrator can trip.

Under these interference conditions the tripping operation may start not only at the normal tripping moment indicated by the point designated by the numeral 37 but because of the superimposed voltage represented by 38 may start at any other instant either earlier or later, between the instants t_1 and t_2 on the cut-off line 36. Designating this region as Δt , the uncertainty region along the cut-off line, or that region at any point of which the tripping moment may occur, is expressed as

$$\Delta t = t_2 - t_1$$

The slope s of the normal characteristic is expressed by

$$s = \frac{dy}{dt}$$

wherein y is the instantaneous voltage expressed as a fraction of the peak-to-peak voltage swing. In the cut-off region

$$\frac{dy}{dt} = \frac{m}{\Delta t}$$

approximately, and therefore

$$s = \frac{m}{\Delta t} \text{ or } \Delta t = \frac{m}{s}$$

Therefore for a given interference the uncertainty region varies in extent inversely as the slope s of the control electrode voltage characteristic. For example, if the control electrode voltage characteristic is, as indicated by the curve 39 of Fig. 3, of greater slope than as indicated by curve 35, other conditions being substantially unchanged, the uncertainty region $\Delta t'$ for the voltage having characteristic 39, extending between t_1' and t_2' , is correspondingly less than the uncertainty region Δt extending between t_1 and t_2 .

Thus when the slope of the control electrode voltage characteristic is increased by impressing a positive bias voltage on the control electrode the uncertainty range is decreased. Therefore the stability against interference of a multivibrator of the positive control electrode bias type is correspondingly greater than that of a multivibrator of the zero bias type. The amount of

stability against external interference can be controlled by the amount of control electrode bias used. This improved stability is a major advantage which is obtained by using the improved multivibrator type in the transmission systems.

With regard to the simpler and more effective frequency control obtainable in the positive control electrode bias type of multivibrator as compared with the zero control electrode bias type, Fig. 2 shows that, by varying the positive bias applied to the control electrodes 8 and 9 thereby changing the slope of the control electrode characteristic, the time elapsing, as the negative charge leaks off, from the initial point 27 of negative control electrode potential up to the cut-off point is also varied causing a corresponding change in the frequency of the oscillations produced by the multivibrator. Referring to Fig. 4, the latter figure shows the oscillation frequency as a function of the positive control electrode bias expressed as a fraction of the anode voltage. As shown in Fig. 4, a practically linear relation exists between these quantities over a very considerable range of oscillation frequency. Thus the multivibrator of the positive control electrode bias type makes possible, as compared to the zero bias type, the provision of a positive and simple control means for varying the frequency, and since the frequency variation is controlled solely by variation of direct current bias, it may readily be effected by remote control means.

I have found that a lessened effect on the pulse width is produced when the frequency in the positive control electrode bias type of multivibrator is varied, as compared with the zero control electrode bias type. Referring particularly to Fig. 5, this figure shows the pulse width as a function of the frequency. Curves 40 and 41 illustrate respectively the pulse width and frequency characteristics of two positive bias type multivibrators operating in different frequency ranges. As shown in the curves 40 and 41, nearly all the change in pulse width is confined to the region 42 of low bias voltages.

Referring now to Fig. 6, a frequency modulation generator in accordance with my invention is illustrated therein. The modulation generator includes a multivibrator in which a positive bias voltage is impressed on the control electrodes 43 and 44 of the multivibrator tubes 45 and 46 from a suitable source (not shown) through a resistor 47 which also forms part of the anode circuit of a tube 48. Means for modulating the frequency includes the above mentioned space discharge device or tube 48 the anode-cathode space of which is connected between resistor 47 and ground or the cathodes 49 and 50 of tubes 45 and 46, and the control electrode cathode circuit of which is connected to a suitable source of signal potentials as represented conventionally in the figure.

The current in resistance 47, and therefore the voltage between the anode and cathode of discharge device 48, varies in accordance with the signal, thereby varying the positive bias between control electrode and cathode. In this manner the frequency of oscillations produced by the multivibrator is caused to vary linearly with the signal applied to the control electrode of discharge device 48, as may be seen by reference to Fig. 4.

The wave form of the multivibrator contains many harmonics which it is desirable to filter out before the signal is transmitted, and for this purpose a low pass filter 51 is provided in the out-

put circuit of tube 46. Referring more particularly to Fig. 7 in connection with Fig. 6, assuming that it is desired to design the system for frequency modulation over a band of a width F , the low pass filter may be arranged to have a cut-off frequency F_0 of approximately $3.5 F$. The multivibrator may be adjusted to operate at a frequency of $2.5 F$ when no modulation is present. In this particular case, therefore, the frequency is swung, by the varying modulation voltage impressed on the multivibrator control electrodes, between the limits of approximately $2.0 F$ and $3.0 F$ which corresponds to .57 and .86 of the filter cut-off frequency F_0 . This is a range of approximately .30 F_0 or .40 F . If the multivibrator wave is perfectly symmetrical, as it can be made to be by symmetrical construction, the wave will not contain any even harmonics, and it is sufficient if the low pass filter eliminates the third harmonic of the lower multivibrator frequency. Thus in this case the multivibrator can be swung from approximately .40 F_0 to .90 F_0 . This corresponds to a range of .50 F_0 , or approximately seventy-five percent of the average frequency of the carrier.

The resulting signal from the multivibrator of Fig. 6 is impressed upon a space discharge device 52, which changes the frequency, by harmonic amplification, or by heterodyning with a second wave impressed thereon, to that of the desired frequency band. It is to be noted that since the multivibrator system described in connection with Figs. 6 and 7 is capable of transmitting a very wide range of frequencies, the system is especially useful for wide-band frequency modulation and as such is applicable even to wide-band frequency modulation for television purposes.

The multivibrator utilized for frequency modulation in accordance with my invention and as shown in Figs. 6 and 7 possesses the important advantage that the range over which the frequency of the carrier wave may be varied without objectionable distortion may be a very large part of the carrier frequency itself. This means that the modulation may be effected at a low carrier frequency thereby to reduce the extent to which the undesired variations in the carrier frequency itself affects the frequency of the finally transmitted carrier. This low frequency carrier may then, after having its frequency modulated in accordance with the signal, be heterodyned to a desired high frequency. Of course the final frequency is then affected by undesired variations in frequency of the carrier source used to produce the heterodyning action but this source may be crystal controlled, or otherwise accurately regulated, to minimize such variations. Thus undesired variations of the final carrier may be very small.

This is in distinct contrast to more conventional systems in which the initial frequency modulation without distortion occurs only over a very small percentage of the carrier frequency. This necessitates the use of a high carrier frequency for the initial modulation whose frequency cannot be stabilized by crystal control and the undesired variations of which may, therefore, be a substantial part of the desired variation.

Referring to Fig. 8, the arrangement shown therein is one which, among others suitable for the same purposes, is particularly suitable for use in electronic gear, or frequency changing, systems, square wave generators, timing units, and similar applications. In this arrangement,

In one multivibrator stage 53 thereof each tube of the pair of multivibrator tubes 54 and 55, which are of the positive control electrode bias type, is provided with a cathode resistor of relatively low resistance. Each cathode resistor is common to the anode circuit and control electrode circuit of the corresponding tube. The circuit of cathode 56 of tube 54 includes resistor 57 and the circuit of cathode 58 of tube 55 includes resistor 59. These cathode resistors serve the purpose of impedance matching. They serve further for the injection of synchronizing pulses and buffering, while they also introduce negative feedback and thus stabilize the multivibrator operation.

As is well known, it is of advantage to use low impedance transfer circuits, such as provided by the use of the cathode resistors 57 and 59, between the successive stages of an electronic gear because low impedance transfer circuits reduce the difficulties due to crosstalk and make it possible to monitor the wave forms in the system without disturbing the operation thereof. A further considerable advantage lies in the fact that the use of low impedance output circuits eliminates the necessity of employing a voltage divider in the multivibrator output circuit. A further important advantage lies in the fact that the negative feedback provided by a cathode resistor stabilizes the multivibrator frequency against variations in the supply voltages and also assists in limiting the peak cathode currents. Multivibrators have commonly been subject to two types of instabilities, i. e., the tripping time of the pulse has varied erratically causing uneven spacing of the pulses, and a slow drift of the pulse frequency has occurred. I have found that the erratic variation of the tripping time is made negligibly small by impressing in the control electrodes a bias potential which is positive with respect to the cathodes, and that the frequency drift is obviated by the negative feedback provided by the cathode resistors 57 and 59. Using both of these means, the timing of the pulses is caused to be substantially exactly uniform during the entire period of operation of the multivibrator.

These advantages, above pointed out in connection with the use of the cathode resistors 57 and 59 in Fig. 8, hold as well for all other multivibrator circuits described hereinafter in which cathode resistors may be used, as for the multivibrator system of Fig. 8.

As low impedances, constituted by resistors 57 and 59, are used in the cathode circuits of multivibrator tubes 54 and 55, it is obvious that only small voltages can be generated across these impedances. However, since the synchronization of multivibrators requires only small amounts of voltage, therefore the impressing of a voltage across the cathode resistor offers a solution well adapted to the problem of synchronization.

In regard to the buffering action of the cathode resistors 57 and 59, since these cathode impedances are of low value, any load thereacross does not materially affect the frequency of operation of the multivibrator 53. It is thus possible in general to utilize the voltages from the cathode impedance for the synchronizing of any multivibrator stage or for the driving of other circuits.

Still further advantages are obtainable by the use of the cathode resistors in multivibrator circuits, as may be more readily seen from a consideration of the curves shown in Figs. 9 and 10. In those applications of multivibrator cir-

cuits in which synchronization is required, it is as a rule advantageous that the synchronizing pulses have a very steep leading edge in their wave forms. In previous types of multivibrators it has been necessary to derive these pulses from the anode circuits. The positive wave forms in the anode circuits, as represented in Fig. 9 for one of a pair of multivibrator tubes, show a rounding off, at 60, of the leading edge of the wave form. The negative voltages, represented by Fig. 10, obtained on the anode of the other multivibrator would, of course, require inversion before being applicable for synchronizing purposes. The rounding off of the wave form as shown in Fig. 9 is caused by the sudden discharge of the coupling condenser 61, shown in Fig. 8 which is connected to the anode of one multivibrator tube 54 of a pair, through the control electrode to cathode discharge path 62 of the other multivibrator tube 55, when the control electrode 63, of this other tube suddenly becomes positive. Now since a cathode resistor, 59, is inserted in the cathode circuit of the second tube 55, the condenser discharge current occurs as an additional current in this cathode circuit. The additional current therefore causes an extra peak of current on the cathode wave form. The presence of this extra peak generally constitutes an advantage in the use of these pulses for synchronizing, or for the generation of square waves, and similar purposes. The special advantages which are obtained in the use in particular of the square wave generator will be explained hereinafter.

Referring further to Fig. 8, in this figure is illustrated also the interconnection of two multivibrator stages in the system. The low impedance transfer circuit for connecting the stages includes the cathode resistor 59 of first stage tube 55, cathode resistor 64 of the second stage tube 65, and a connection means or network 66 interconnecting the resistors 59 and 64 at suitable points thereon to produce the desired transfer voltages. It may be of advantage to employ a network including a copper oxide rectifier 67 or other suitable rectifier in this transfer circuit or to insert a resistor 68 in this connection. The network may be arranged to reduce any feedback of voltages, generated in the second multivibrator stage 65, into the first stage 53. It can be shown that it is of advantage if the product of the rectifier capacitance and its resistance in the reverse current direction is smaller than $1/2 f_0$, where f_0 is the higher of the two frequencies employed in the electronic gear unit comprising multivibrator units 53 and 65.

Referring to Fig. 11, another multivibrator circuit is illustrated therein adaptable for use in electronic gear systems, time bases, square wave generators, and similar circuits. While for reasons of stability against interference and protection against locking in of incorrect frequency division ratios it is preferable to use positive bias in the multivibrator, the circuit will also operate when the applied bias is reduced to zero or even if it is made slightly negative. The circuit of Fig. 11 may comprise a multivibrator stage including four space discharge devices or tubes which may be of the multiple grid, screen grid, pentode or triode type. Instead of the single multivibrator tubes, two twin tubes of the multiple grid, screen grid, pentode or triode type may be employed. In one of the preferred forms, as illustrated in Fig. 11, two twin tubes 70 and 71 of the triode type are employed, each including

two space discharge devices. In tube 70 one discharge device 72 comprises anode 73, control electrode 74 and cathode 75 and the other discharge device 76 comprises anode 77, control electrode 78, and cathode 79. In tube 71, one discharge device 80 comprises anode 81, control electrode 82 and cathode 83, and the other discharge device 84 comprises anode 85, control electrode 86, and cathode 87.

The above described arrangement, employing for the fourth discharge device either a pentode or a triode, having the cathode 83, of the multivibrator discharge device 81 and the cathode 87 of the fourth discharge device 84 connected to ground through a common cathode resistor 88 and having the control electrode 86 of the fourth discharge device connected to ground, is my preferred arrangement used for the generation of square topped waves.

In the circuit shown in Fig. 11 the injection of the synchronizing pulse is accomplished from a low impedance network 89 connected to a suitable source of signal potentials. Elimination of feedback from the multivibrator stage into preceding stages is obtained by injecting the synchronizing pulses into the control electrode of one of the space discharge devices, as control electrode 74 of the first discharge device 72 of twin tube 70. The cathode 75 of this first discharge device of twin tube 70 is directly connected to the cathode 79 of the second discharge device 76 of twin tube 70. The two cathodes 75 and 79 of the twin tube 70 have a common resistor 90, which may connect these cathodes to ground. Thus the synchronizing pulses, injected into the control electrode-cathode circuit including the common cathode resistor 90, are transferred to or impressed upon this cathode resistor 90 which forms part of the cathode circuit of the second discharge device 76.

Likewise the cathode 83 of space discharge device 80 of twin tube 71 is connected to the cathode 87 of discharge device 84 of the latter twin tube, and the two cathodes 83 and 87 have the common resistor 88, which may connect them to ground. The multivibrator stage comprising space discharge devices 76 and 80 of tubes 70 and 71 respectively then operates in essentially the same manner as the multivibrator stage 53 described above in connection with Fig. 8. As in the case of stage 53 of Fig. 8, output voltages from the multivibrator stage of Fig. 11 may be obtained from the cathode resistance 88, of a second multivibrator tube 71.

In order to synchronize a second stage 91, partially shown in the circuit illustrated in Fig. 11, the synchronizing pulse may be derived directly from the cathode resistor 88 or from a tap 92 on the resistor. Monitoring of the synchronizing pulses may be accomplished in the cathode circuit including resistor 88 without disturbing the operation of the system provided the impedance of the monitoring circuit (not shown) is large relatively to the impedance of the cathode resistor 88. Safe monitoring without interruption of operation may be obtained by inserting a series resistor (not shown) between the cathodes 83 and 87 and the connection point of the monitor.

The anode 85 of the space discharge device 71 which is the final discharge device of the unit constituted by twin tubes 70 and 71 may be employed to obtain a buffered output from the unit, the output voltages being obtained between terminals 93 and 94. By suitable arrangement

of the circuit constants this buffered output may be made to have either the same wave form as the cathode circuit wave, or a square wave form, or a sawtooth wave form. It will be sufficient to explain herein the case of the square wave output, as the sawtooth output may be obtained by providing a condenser between the anode 85 of tube 71 and ground.

In regard to the square wave output, the arrangement in the circuit of Fig. 11 is such that a short positive pulse appears on the common cathode resistor 88 of the third and fourth space discharge devices 80 and 84. A positive voltage of the cathode 87 with respect to ground means a negative voltage of the control electrode 86 with respect to the cathode 87, if this control electrode be connected to ground. In Fig. 11 this connection of control electrode 86 to ground is effected through a resistance 95 which may be very small. By suitable choice of the operating characteristics of the fourth space discharge device 84, the negative pulse may be caused to drive the fourth discharge device 84 beyond cutoff. This may be accomplished in the case of a triode, such as discharge device 84, by the provision of a large decoupling resistor 96 in its anode circuit. As the discharge device 84 is thus driven beyond cut-off, the upper or peaked portion of the pulse wave form, designated by the numeral 97, is therefore clipped off and a square wave positive output, of wave form designated by the numeral 98, is obtained in the anode circuit of the fourth space discharge device 84.

In both of the multivibrator arrangements of the positive bias type above described in connection with Figs. 8 and 11, the same general advantages of increased stability, easier adjustment of frequency, and reduction of the change of pulse width with frequency as were previously described herein, are obtained. These forms of my invention are disclosed in all essential particulars and are claimed in my application Serial No. 473,360, which is assigned to the assignee of my present application.

A specific advantage which is obtained in the use of multivibrators of the positive bias type in electronic gear or frequency changing systems may be easily understood by reference to Fig. 12. The numeral 99 designates a curve of multivibrator control electrode voltage having synchronizing impulses impressed thereon and having the low degree of slope characterizing the control electrode voltage in multivibrators of the zero bias type. Numeral 100 designates a corresponding curve carrying this synchronizing frequency but having the steep slope characterizing the control electrode voltage in the positive bias type of multivibrator. In this figure it is shown how the increase in steepness of the multivibrator control electrode wave form characterizing the positive bias type produces a greater voltage range for discrimination against synchronization of the multivibrator over incorrect frequency ratios. V_p in the illustrated case is the relatively large voltage range available in the positive bias type for discrimination against incorrect synchronizing ratios, and V_z is the relatively small voltage range available in the zero bias type.

In Fig. 13 are illustrated wave forms as they are applied to the multivibrator circuit of Fig. 11 in order to obtain a combined mixing and square-wave-forming, or clipping, operation. Additional voltages from a suitable source rep-

resented conventionally in the figure are applied at terminals 101 and 94 to the impedance 95 connected between the control electrode 86 of the space discharge device 71 and ground. These additional voltages may be so poled and of such magnitude as to drive the control electrode 86 of this discharge device 71 beyond cut-off for periods other than those prescribed by the voltages appearing on the common cathode resistor 88. In Fig. 13 is illustrated one example in which a complete "pedestal pulse" as used in television, may thus be derived from a multivibrator circuit, assumed to be operating at the horizontal frequency of a television system, by inserting a voltage, corresponding to the vertical pedestal pulse, in a negative polarity into the control electrode 86.

In this case, waves which may be of the form designated by the numeral 102 are impressed upon the grid 82 of discharge device 71. Waves designated by the numeral 103, corresponding to the waves designated by 102, appear in the cathode resistor 88, and pulses designated by the numeral 104 appear across the grid 86 and cathode 87. The additional voltage, applied to the grid 86 across the resistor 95, has the wave form designated by the numeral 105. The mixing of this wave 105 with the pulses 104 appearing across resistor 88 results in the "pedestal" pulse 106 in the anode circuit including anode 85 and cathode 87. It will be understood that if, in obtaining the pulse 106 of square form, a clipping operation is required as in the case of the example illustrated in Fig. 13, this may be accomplished in the manner above explained in connection with Fig. 12.

Other effects may be obtained by suitably changing the operating conditions of the fourth discharge device 85.

In Fig. 14 is illustrated a multivibrator circuit of the positive bias type similar in general to the circuits of Figs. 8 and 11 and adapted to the same uses as the circuits of the latter figures. In the circuit of Fig. 14 pentode multivibrator tubes 107 and 108 are employed, and for the injection of synchronizing pulses a suppressor grid, as grid 109 of tube 107, is utilized, connected to a suitable synchronizing-pulse source.

In Fig. 15 is illustrated a multivibrator circuit of the positive bias type in which the pulse width may be changed by an improved method employing a pure direct current control. In this circuit the rate of change of the voltages on the control electrodes 110 and 111 of the tubes 112 and 113 respectively may be varied independently, for example, by potentiometers 114 and 115, while one combined control means, as the potentiometer 116, varies the rate of change on both control electrodes simultaneously and thus controls the multivibrator frequency. This arrangement obviates the need for making variable any of the signal carrying components of the multivibrator circuit.

The circuit of Fig. 6 has been described herein as a frequency modulation generator. It will be understood that the circuit of Fig. 6 is a special case of the more general case where the multivibrator or relaxation oscillator of which the multivibrator is a special case, is used as a device in a transmission system to correlate a pair of variable voltage functions. One of these voltage functions may be a variation in the operating, or bias, voltage of the multivibrator while the other may be a frequency modulation of a carrier. It is well known that it is possible to change the

timing intervals or frequencies of a multivibrator, or of a relaxation oscillator in general, by changing its direct current operating conditions. Conversely, and in agreement with the reciprocity theorem, upon the occurrence of any change in the timing intervals or the frequency of a multivibrator or of a relaxation oscillator in general, changes are produced in its direct current operating condition. This process is referred to as frequency demodulation. This possibility of frequency demodulation exists because the properties of the multivibrator or relaxation oscillator circuit are such that the circuit tends to follow, or to become synchronized with, any impressed external signal.

The property of a multivibrator, or, in general, of a relaxation oscillator, of synchronizing its oscillations in accordance with an impressed external signal may be utilized to obtain frequency changing also. The frequency changing may be obtained with either an unmodulated wave or a frequency modulated wave. For example, the relaxation oscillator may be synchronized to a frequency one-fourth that of the impressed signal. If the fifth harmonic of this frequency be now filtered out, a frequency is thereby obtained which is at all times 20% higher than the original input signal. This relation will hold for the case wherein the signal is unmodulated and the signals are therefore characterized by their frequencies alone, and the relation also holds for the case wherein the original signal has been frequency modulated.

In this process of frequency changing, the frequency of the impressed input signal and the frequency of the output signal obtained from the oscillator are integral multiples of a predetermined frequency which in the present case is the oscillator synchronizing frequency. The process may, therefore, be referred to as frequency transformation on a common multiple basis.

In the circuit of the special case of a device for correlating a pair of voltage functions, illustrated in Fig. 6, the multivibrator of positive bias type is described as employed to convert an audio frequency into a frequency modulated signal. The possibility of thus obtaining frequency modulation, as in Fig. 6, by using the positive grid type of multivibrator exists because the relation between the positive bias and the frequency of the multivibrator is practically linear.

It will be noted further that since, when the frequency of the multivibrator is varying, its D. C. operating conditions will also vary, therefore any varying in frequency of impressed signal will also cause a varying of the D. C. potential across the resistors 6, 7 and 17 in Fig. 1, resistors 121, 129 and 130 in Fig. 8, resistors 122, 131, and 132 in Fig. 11, resistors 124, 133, 134 in Fig. 14, resistors 128, 129, 135 and 136 in Fig. 15, as well as in all of the cathode resistors shown in these circuits. In other words, frequency demodulation occurs in these circuits in which the multivibrator frequency varies. Across all of these elements in Figs. 1, 8, 11, 14 and 15 the frequency demodulated signal is available in greater or smaller amplitude, and accordingly the frequency demodulated signal may be derived from the oscillation generator employed in the circuits illustrated in any of Figs. 1, 8, 11, 14 and 15.

It will be noted also that the circuits illustrated in Fig. 1, in each of sections 53 and 69 of Fig. 8, in Fig. 11, in Fig. 14, and in Fig. 15 are

all capable of synchronizing in a harmonic or subharmonic ratio with the impressed signal as above explained, for example, in connection with frequency transformation on a common multiple basis. For this reason the circuits of Figs. 1, 8, 11, 14 and 15 are all suitable for changing the frequency of a frequency modulated signal from one range into another range.

In Fig. 16 is illustrated the application of an improved multivibrator circuit of the positive bias type to use as a limiter in a frequency modulation receiving system. In this system a multivibrator of the latter type comprising, for example, two tubes 117 and 118 is connected at its input side to a source of amplitude modulated signals which may comprise tuning circuits (not shown) of the system, and at its output side to the slope filter 119 of the system. The slope filter is a device which will convert a signal having frequency modulation and no amplitude modulation into a signal having both types of modulation, but in which the amplitude modulation is materially in greater proportion than the frequency modulation.

As is well known, the voltage and the wave shape of the multivibrator output vary only very slightly if the operating frequency of the multivibrator is changed over relatively wide ranges under the influence of an external synchronizing force. This output is also widely independent of the amount of input voltage. These properties of the multivibrator exactly meet the requirements to be fulfilled by a limiter circuit. An additional advantage lies in the fact that, in performing the limiting process, the multivibrator permits the obtaining of amplification rather than causing a loss as in the case of certain other types of limiters. The amplification function is inherent in the multivibration circuit, in that this type of circuit is by nature an oscillator in which a small amount of synchronizing voltage is able to control the frequency of oscillation. The employment of the multivibrator of the positive bias type, illustrated in Fig. 16 for example, as the limiter in frequency modulation systems results in greatly improved stability, ease of frequency control and other important advantages thereby making more practicable the employing of the multivibrator type of limiter, with its general advantages hereinbefore described, in place of limiters of the types heretofore used.

In regard to the converting of direct to alternating current, it will be understood that any of the modulated multivibrator systems described hereinabove, in accordance with my present invention, may be used for current conversion, the arrangement being such that the alternating current output is synchronous to a small external alternating controlling voltage.

The multivibrator employed as the limiter for frequency modulated carrier waves is disclosed and claimed in my copending application Serial No. 474,114, which is assigned to the assignee of my present application.

My invention has been described herein in particular embodiments for purposes of illustration. It is to be understood, however, that the invention is susceptible of various changes and modifications and that by the appended claims I intend to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A transmission system for producing a frequency modulated signal, said system compris-

ing a multivibrator having cathodes and control electrodes, a source of amplitude modulated signals, means to impress a bias potential positive with respect to said cathodes upon said control electrodes, and means to vary said potential in accordance with said amplitude modulated signals, said bias potential being of sufficiently high value to cause substantial increase in the rate of change of the control electrode potential at each cycle thereof over what would be the rate of change under zero or negative bias conditions thereby to decrease the varying of the tripping time by interfering voltages and to increase the stability of said system against said interfering voltages.

2. A transmission system for producing a frequency modulated signal, said system including a source of amplitude modulated signals, a multivibrator having cathodes and control electrodes, a source of anode potential for said multivibrator, means to impress a varying potential positive with respect to said cathodes upon said control electrodes, said means including a resistance and an electron discharge device having its anode-cathode circuit in series therewith connected to said potential source, and means including said first-named source to impress said amplitude modulated signals upon the control electrode-cathode circuit of said discharge device to vary the impedance thereof in accordance with said first-named signal, said positive bias potential having a value sufficiently high to increase substantially the rate of change of the multivibrator control electrode potential over the corresponding rate of change which would occur under zero or negative bias conditions thereby to increase substantially the stability of said system against interfering voltages.

3. A transmission system for producing a frequency modulated signal, said system including a source of amplitude modulated signals, a multivibrator having cathodes and control electrodes, a source of anode potential for said multivibrator, and means to impress upon said control electrodes a bias potential positive with respect to said cathodes and varying in accordance with said amplitude modulated signals, said means including in series with said anode potential source a resistance and an impedance connected to said first-named source and adapted to be varied in accordance with the signals therefrom, and means to connect said control electrodes to said resistance, said positive bias potential being of sufficiently high value to cause the rate of change of control electrode potential to be substantially increased compared with the rate of change which would occur under zero or negative bias conditions thereby to increase substantially the stability of the system against interfering voltages.

4. The combination, in a wide band frequency modulation system, of a multivibrator comprising a pair of electron discharge devices, each having a control electrode and a cathode, means to supply a potential to said control electrode positive with respect to said cathodes and varying in continuous increments in accord with desired signals thereby to vary the fundamental frequency of said multivibrator over a wide range in linear relation to said potential, and means to eliminate harmonics of the fundamental frequency of said multivibrator thereby to produce a sinusoidal carrier wave varying in frequency substantially linearly over a wide range in accord with said signals.

5. The combination, in a wide band frequency modulation system, of a multivibrator comprising a pair of electron discharge devices, each having a control electrode and a cathode, means to supply a potential to said control electrodes positive with respect to said cathodes and varying in continuous increments in accord with desired signals thereby to vary the fundamental frequency of said multivibrator linearly over a wide range with said potential, said multivibrator having an output circuit including a filter for eliminating harmonics of the fundamental frequency of said multivibrator, and means to translate the range of frequencies produced at the output of said filter to a range of frequencies higher in the frequency spectrum.

6. The combination, in a wide band frequency modulation system, of a source of potential variable in continuous increments of both frequency and amplitude over a wide range in accord with desired signals to be transmitted, a multivibrator comprising a pair of electron discharge devices, each having a control electrode and a cathode, means to supply potential to said control electrodes positive with respect to said cathodes, and means to vary said positive potential in accord with said continuous variations of said first mentioned source thereby to vary the fundamental frequency of the oscillations produced by said multivibrator, the average fundamental frequency

of said multivibrator being higher than the highest frequency of said source and said fundamental frequency of said multivibrator varying linearly in accord with said positive potential over a wide range of frequencies higher than the highest frequency of said source.

7. The combination, in a wide band frequency modulation system, of a multivibrator comprising a pair of electron discharge devices, each having an anode, a cathode, and a control electrode connected in symmetrical multivibrator circuit arrangement to eliminate even harmonics of the oscillations produced by said multivibrator, means to supply potential to said control electrodes positive with respect to said cathodes and varying continuously over a range in accord with signals to be transmitted thereby to vary the fundamental frequency of oscillations produced by said multivibrator in substantially linear accord with said signals, a low pass filter, means to transmit the oscillations of said multivibrator through said low pass filter, said filter having a cutoff frequency sufficiently high to pass the highest fundamental frequency of said oscillations and sufficiently low to eliminate the third harmonic of the lowest fundamental frequency of said oscillations, and means to transmit the range of frequencies appearing at the output of said low pass filter.

EVERHARD H. B. BARTELINK.

CERTIFICATE OF CORRECTION.

Patent No. 2,338,395.

January 4, 1944.

EVERHARD H. B. BARTELINK.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, first column, line 4, for "wtih" read --with--; page 7, second column, line 31, claim 2, strike out "first-named signal" and insert instead --amplitude modulated signals--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 4th day of April, A. D. 1944.

Leslie Frazer

(Seal)

Acting Commissioner of Patents.