Sept. 20, 1949. E. R. SHENK 2,482,561

VOLTAGE TWO-TONE SOURCE

Filed March 19, 1946 2 Sheets-Sheet 1

Fig. 1

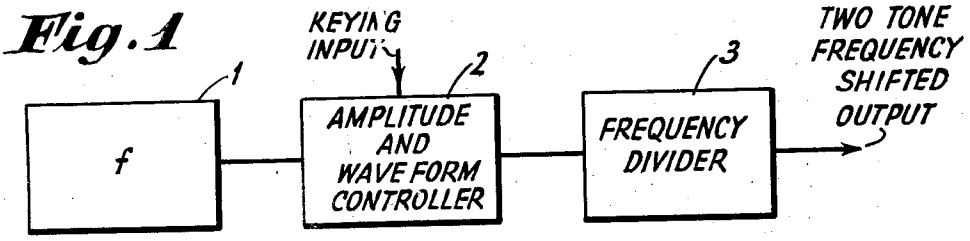


Fig. 2

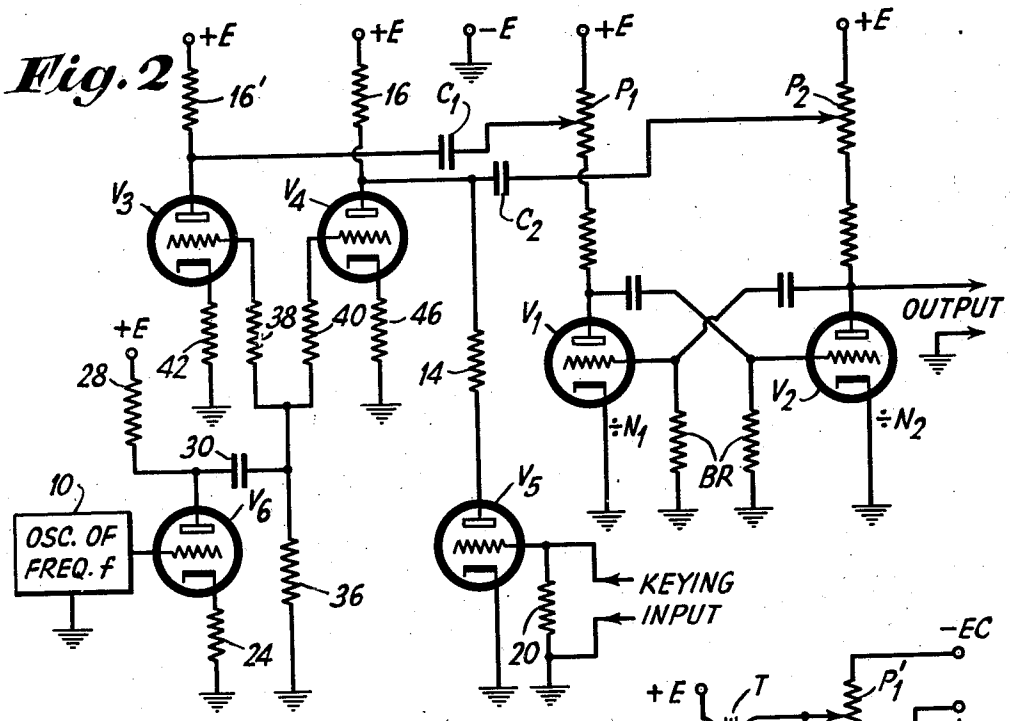
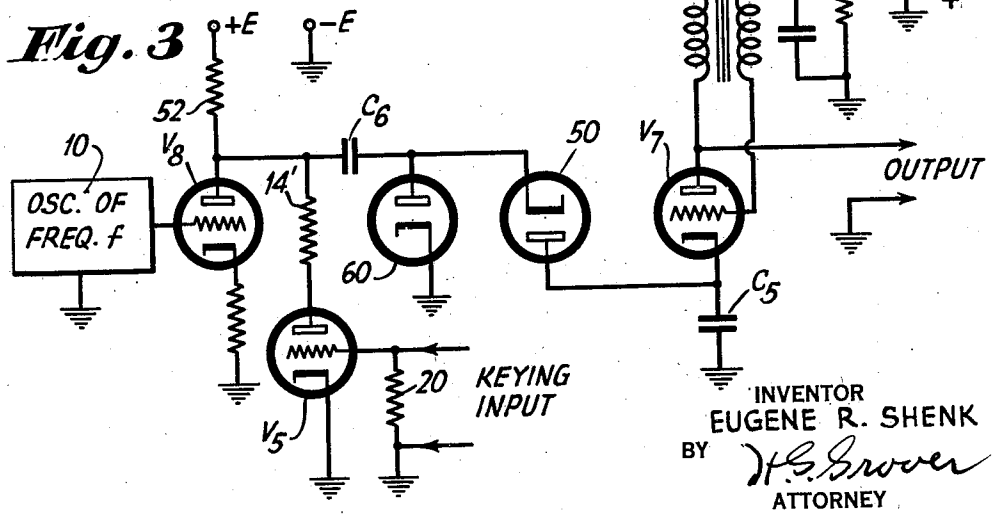


Fig. 3



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Fig. 2a

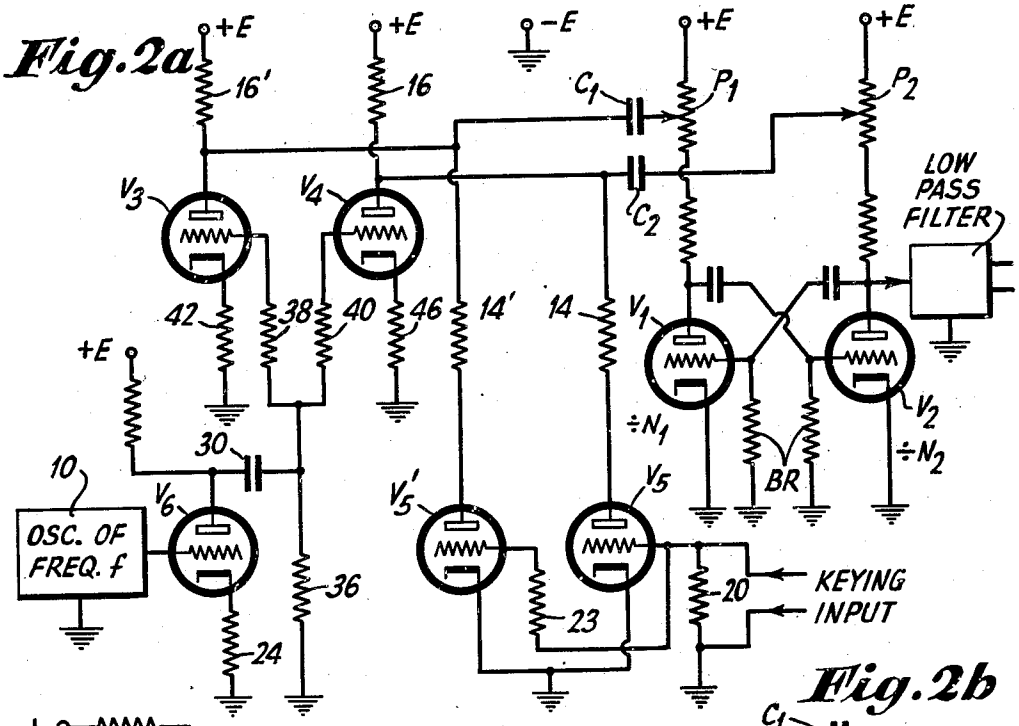
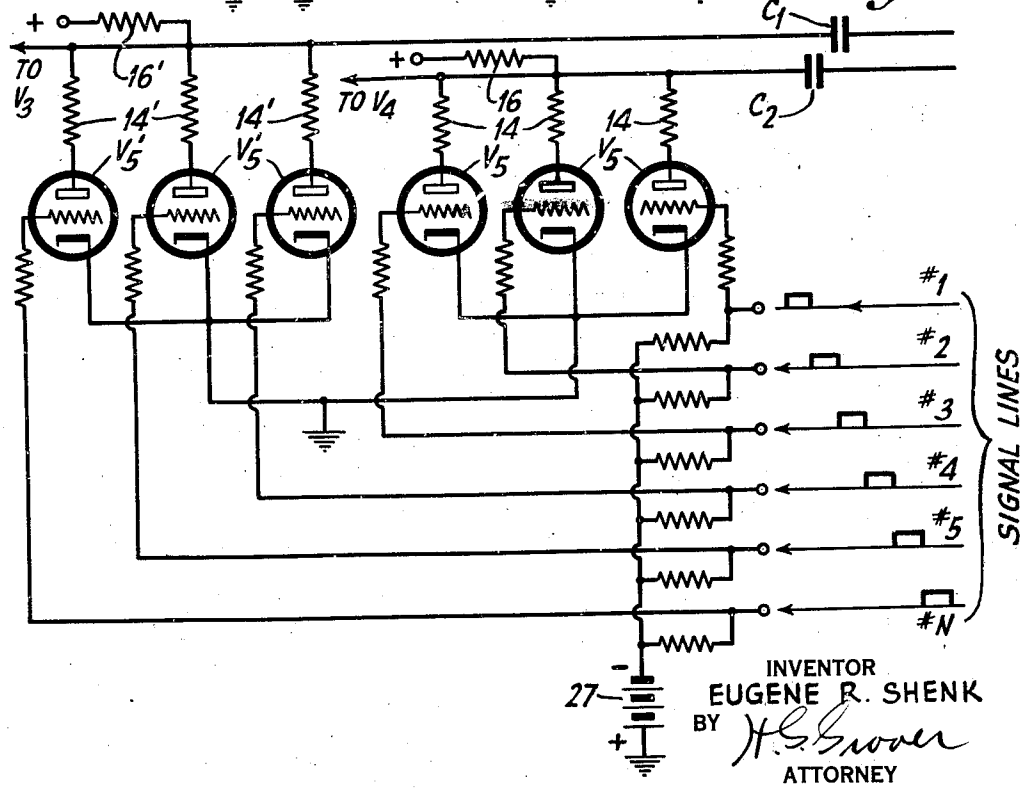


Fig. 2b



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Patented Sept. 20, 1949 2,482,561

UNITED STATES PATENT OFFICE

2,482,561

VOLTAGE TWO-TONE SOURCE

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Application March 19, 1946, Serial No. 655,440

16 Claims. (Cl. 250—36)

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This application relates to tone generators and in particular to means for producing oscillations of two frequencies. The means of the present invention is of wide application in the radio and allied arts. In the embodiment used to illustrate my invention a telegraphy system is shown. The system shown may also be used for generation of tones representing black and white in a subcarrier frequency modulation facsimile transmission. In telegraphy one tone frequency is used to indicate marking intervals and a different tone frequency is used to indicate spacing intervals. In many other applications, for example, subcarrier frequency modulation black and white facsimile, it is necessary to key between two tone frequencies at signalling rate, and then one tone represents black and the other white in the picture.

Various methods and means for producing two tones (may be superaudible) frequencies for the purpose described above are known in the prior art. In these known systems, however, usually a large amount of transient energy is generated at the frequency shift points, i. e., when changing from one frequency to the other.

Heretofore the keying from one tone frequency to another has been accomplished by making both tones continuously available and then selectively choosing between the tones by means of an elaborate electronic switching means. Even the best of such arrangements have been beset with switching transients to some degree. This adds to the useful tones many unnecessary side tones and frequencies which then have to be eliminated.

The primary object of this invention is to provide a very simple and straightforward method of and means for producing two-tone keying with no transient at the frequency shift points. These general objects are attained in accordance with the present invention by use of a multivibrator or any other kind of a frequency divider driven or controlled by a source of oscillations of a frequency f to be divided. Preferably the frequency f is a multiple of the two desired tone frequencies for use at the two-tone output. The order of division of the divider is changed to change from one tone frequency to another tone frequency. This order of division is related as desired to the signalling potentials.

In some applications, for example in multiplex telegraph systems or to designate several picture shades, oscillations the frequencies of which are related in steps are desirable. A further object of my invention is to provide any selected one of

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a plurality of oscillating voltages of discrete frequencies related as desired each to the other and free of transients at the frequency shift points. This object is attained by use of a frequency divider controlled by oscillating voltage the magnitude of which is varied in steps by appropriate control potentials. Then the output of the divider will change in frequency in steps as the control voltage magnitude changes in steps.

In describing my invention in detail reference will be made to the attached drawings wherein Fig. 1 illustrates schematically and by block diagram a tone keyer arranged in accordance with my invention.

Fig. 2 illustrates by circuit element and circuit element connections a system for generating two tones alternately produced in the presence of signalling and representing different signalling conditions;

Figs. 2a and 2b are modifications of the arrangement of Fig. 2; while

Fig. 3 is a further embodiment of my improved two-tone keyer.

In Fig. 1 the box 1 represents a source of oscillations of say sinusoidal wave form and of frequency f. The rectangle 2 includes a wave current amplitude and wave form controlling network and is shown as being connected to a keying input whereat the signals are applied. This showing is diagrammatic as will be seen from the detailed discussion of the following figures. The amplitude limited and formed voltages of frequency f are supplied to the rectangle 3 wherein is included a frequency divider having as an output two tone frequencies alternately present in accordance with the effectiveness of the keying input to shift the frequency of operation of the divider between the said two tones. The keying input wave may consist of a direct current voltage which varies in amplitude and/or polarity in accordance with signal voltage. The whole arrangement is such that the amplitude of the voltage of frequency f which is supplied to the frequency divider in 3 is under control of the keying input voltage. The frequency divider is so constituted as to be sensitive to the amplitude of the controlling voltage supplied thereto, i. e., the order of count of the frequency divider depends upon the amplitude of the controlling voltage supplied from unit 2 to unit 3.

Now turning to Fig. 2, wherein the essential elements of a practical embodiment are shown, tubes V1 and V2 are in the frequency divider circuit of rectangle 3 of Fig. 1. This frequency divider is shown as being of the multivibrator type and

comprises the tubes V1 and V2 with their anodes and control grids cross-coupled as shown. The cathodes are connected to ground and the control grids are supplied by operating biases through resistors BR. The anode of tube V1 is connected through resistance including potentiometer P1 resistor to the positive terminal of a source E of direct current potential the negative terminal of which is grounded. The anode of tube V2 is similarly connected by resistance including potentiometer P2 resistor to this source. The arrangement and operation of such a multivibrator is well known in the art as is the fact that the frequency of operation of the multivibrator as a whole and of the tubes of the multivibrator per se depends in part at least on the magnitude of the potential supplied to the tube anodes. The potential supplied includes, riding on the direct current component, the energy of pulse wave form and of the frequency of the oscillatory energy from source 10 in variable magnitude. It is assumed that tube V1 divides the frequency f of source 10 by a factor N1 and that the tube V2 divides the frequency of the source 10 by a factor N2 when the tube V5 is non-conductive.

The tube V5 has its cathode grounded and its anode connected to the anode of tube V4 by resistor 14 so that it shares anode potential, as supplied by resistor 16, with tube V4. The input electrodes of tube V5 are shunted by a grid resistor 20 and connected to a source of keying input here assumed to be a direct current potential as used in telegraphy, which varies from zero potential at mark to a high negative value in space condition.

The source 10 supplies oscillatory energy of say sinusoidal wave form to the control grid of a tube V6 which has its cathode connected to ground by a biasing resistor 24 and its anode connected to the positive terminal of source E through a resistor 28. The tube V6 is operated as a limiter, i. e., it is biased beyond cutoff by the negative half cycles of the input oscillation from 10 and runs to saturation on the positive half cycles. The output of the tube V6 is fed by coupling condenser 30 to impedance 36 and thereby impressed in like phase on the control grids of tube V3 and V4. The control grids of tubes V3 and V4 are separated by isolating and biasing resistors 38 and 40. The cathodes of the tubes V3 and V4 are grounded by resistors 42 and 46 and the anode of tube V3 is coupled to the positive terminal of the source E by a resistor 16'. These tubes are likewise arranged to amplify and limit the oscillatory energy supplied from 10 before it is applied to the potentiometers P1 and P2 and in so limiting operate in a manner similar to that in which tube V6 operates as described hereinbefore.

In operation voltage of the frequency f is supplied to the current amplitude limiter V6 wherein it is amplified, squared off and supplied to the tubes V3 and V4. These tubes further amplify and limit the amplitude of the oscillatory energy and supply these voltages as synchronizing voltages over coupling condensers C1 and C2 to points on the potentiometers P1 and P2 in the anode circuits of tubes V1 and V2 respectively. The potentiometer P1 is adjusted so that tube V1 divides by the factor N1. The potentiometer P2 is adjusted so that the tube V2 divides by the factor N2 when the tube V5 is conducting and this is when the signal on the input thereof is of about zero potential. The overall order of division of the multivibrator including tubes V1 and V2 is $N1+N2$.

Now if the keying input potential becomes negative, i. e., goes to the space condition, tube V5 is rendered non-conductive and the plate supply potential effective on the limiter tube V4 rises. That is because the resistor 16 is no longer supplying potential to both tubes V4 and V5. As a result, the amplitude of the synchronizing voltage supplied to the potentiometer P2 increases and the factor of division N2 of this tube of the multivibrator decreases so that the frequency of operation of tube V2 thereof goes up. Now the overall order of division of the multivibrator is decreased and is $N1+N2+\Delta N2$ and the output frequency of the system is higher and might represent spacing condition. When the signal voltage returns to the zero potential condition tube V5 becomes conductive, the potential on the anode of tube V4 drops, the amplitude of the synchronizing voltage supplied to the potentiometer P2 goes down and the factor of division of the tube V2 returns to N2, and the output frequency is lower and may represent the marking condition.

If it is desired to effect a greater change in the count of the multivibrator an additional tube V5' may be provided as shown in Fig. 2a with its anode coupled by resistor 14' to the coupling between the anode of tube V3 and the potentiometer P1. The grid of the tube V5' is connected by isolating resistance 23 to the keying input in parallel with the grid of the tube V5 so that these tubes are operated in like manner by the keying potentials. Then when the tube V5' becomes non-conductive it no longer shares with tube V3 the potential supplied by resistor 16' and the amplitude of the synchronizing voltages supplied to tube V1 by tube V3 increases when the amplitude of the synchronizing voltages supplied to tube V2 by tube V4 increases so that the factor of division of both tubes of the multivibrator decreases. As a consequence, the overall factor of division decreases considerably more than in the arrangement of Fig. 1, and the output frequency swings up more than in the arrangement of Fig. 1.

If desired a low pass filter may be used in the output of the multivibrator to remove the harmonics of the tones inherent in the multivibrator. It will be obvious, however, that in the arrangement substantially no transient effects are set up as the frequency of operation of the multivibrator is switched from one tone to the other tone.

In the arrangements of Figs. 2 and 2a the circuit constants may be so chosen that a multiplicity of output frequencies may be obtained. These voltages of different output frequencies would then each correspond to a specific amplitude of voltage or control potential applied to the control grid of the keying input tube V5 of Fig. 2, and V5 and V5' of Fig. 2a. The control potentials then might increase in a series of discrete steps. In the example given they might increase in steps from zero potential in a negative direction. Then the gains of the synchronizing voltage amplifier tubes V4 of Fig. 2, and V4 and V3 of Fig. 2a would increase correspondingly in steps as would the amplitude of the synchronizing voltages supplied to the multivibrator tubes V2 of Fig. 2, or V1 and V2 of Fig. 2a. The circuit of this embodiment then may be substantially (except for circuit element value and adjustment) as in Figs. 2 or 2a.

In a further embodiment I may use a plurality of controlling tubes with their plate cir-

cuits connected in parallel and with separate controlling voltages supplied to their control grids. Such an arrangement is illustrated in Fig. 2b. With such a system the location of the tones in the frequency spectrum may be readily shifted. Several channels may be used and their frequency locations exchanged in accordance with some coded signal. Some degree of secrecy may be obtained in this manner. The embodiment of Fig. 2b is a modification of Figs. 2 and 2a. In this modification the tube V5 is replaced by a plurality of tubes V5, for example 3, with their output circuits in parallel. Each tube V5 has its cathode grounded and has in series with its anode a resistor 14 as in the prior figures, and the resistors 14 have their ends remote from the tube anodes tied together and connected to the positive terminal of the source through resistor 16. These ends of the parallel resistors 14 are also coupled by condenser C2 to potentiometer resistor P2. The grid circuits of the tubes V5 of Fig. 2b are separated and are biased by separate grid biasing resistors connected to bias source 27. The grids of the tubes are individually and separately supplied by control potentials or signals over lines #1, #2 and #3. The control potentials are shown as appearing sequentially (in time), and it will be understood that the sequence of the potentials on lines #1, #2 and #3 may be arranged as desired. The tube V5' of Fig. 2a in the embodiment of Fig. 2b is likewise replaced by three tubes V5', and these tubes have their anodes connected in parallel by resistors 14', and to the direct current source by resistor 16', and to the potentiometer P1 by condenser C1. These tubes also have their grids in separate circuits supplied by potentials over lines #4, #5 and #6, and these potentials may be supplied in any sequence as desired. The sequence followed may be a continuation of the sequence in which potentials are applied over the lines #1, #2 and #3. The potentials may represent signals or control potentials of any desired nature and may be for sending messages or for producing oscillations of tone frequency the frequencies of which may be changed in steps as desired, and which are subharmonically related to the oscillations of frequency *f*.

Another method and means of carrying out the invention is shown schematically in Fig. 3 of the drawings. Here the tube V7 has its anode and control grid regeneratively coupled by windings of a transformer T. The anode winding is connected to the positive terminal of the source E. The grid winding is connected to a point on the resistance of a potentiometer P1' across which is applied a negative biasing source EC. The arrangement is such that the bias on the grid of the tube V7 may be adjusted beyond cutoff, the extent of this bias being used to set the count or order of division to determine the frequency of operation of the regenerative oscillator. The cathode of the tube V7 is coupled to ground through the impedance of diodes 50 and 60 thereby supplying the direct current circuits through the tube V7 between the cathode and the anode and between the cathode and the grid. The condenser C5 is coupled between the cathode of tube V7 and ground. The source of ocsillations 10 is now supplied to a current amplifying and current amplitude limiter tube V8 similar to V6 of Fig. 2, and from the limiter V8 through a coupling condenser C6 to the cathode of diode 50 and to the anode of diode 60. The anode of tube V8 is coupled to the positive terminal of

the source E by a resistor 52, while the anode of the modulator tube V5 is coupled to the positive terminal of this source by resistors 52 and 14', and to the anode of tube V8 by resistor 14'.

The tube V7 with its regenerative circuit T and diodes 50 and 60 and condenser C5 is connected in a counter circuit. The frequency of operation of this circuit depends on the grid bias and on the rate at which condenser C5 can charge up (through resistance 52, condenser C6 and diode 50), to a point at which it energizes oscillator tube V7 and discharges through diodes 60 and 50. The synchronizing voltages fed through coupling condenser C6 are applied to the anode of diode 60 and being negative do not leak off. They are, however, also supplied to the cathode of diode 50 and this diode passes the voltages to charge the condenser C5. The potentiometer P1' is used to adjust the grid bias of tube V7 sufficiently beyond the plate current cutoff value to secure the desired count.

If now tube V5 is caused to change from the conductive condition, at which say zero potential representing mark might be applied to the control grid thereof, to the non-conductive condition at which a high negative potential might be applied to the control grid thereof, the effective plate supply voltage to the tube V8 increases, as does the magnitude of the synchronizing voltages fed to condenser C6. Consequently, the charge supplied to the capacitor C5 on each cycle of the oscillator frequency *f* increases and the number of charges or cycles or steps required to make the cathode of tube V7 sufficiently negative to render tube V7 conductive decreases. Obviously the number of cycles of the frequency *f* required to charge the condenser C5 to a point at which tube V7 conducts is larger when tube V5 is conducting than when tube V5 is non-conducting. Thus the rate of oscillation of tube V7 is of one value when tube V5 is conducting and is of a higher value when the tube V5 is non-conducting.

What is claimed is:

1. In a wave generator, a frequency divider including an electron discharge tube in a controlled oscillation generating circuit, a source of oscillating voltages coupled to said divider to entrain it to operate at a fundamental frequency which is a subharmonic of the frequency of said voltages, the factor of division of the divider depending in part on the tube circuit constants and the magnitude of the applied controlling voltages, an amplifier in said coupling, a source of potentials which varies in magnitude by steps, and means for controlling the gain of said amplifier in accordance with said potentials to correspondingly control the magnitude of the voltages controlling the frequency divider to correspondingly vary the fundamental frequency of the produced oscillatory energy.

2. In a telegraphy system, a frequency divider including two tubes in a multivibrator circuit, a source of oscillating voltages coupled by separate paths to the two tubes of the multivibrator to entrain the same to operate at a fundamental frequency which is subharmonically related to the frequency of said voltages, the factor of division of each tube of the divider depending in part on the tube circuit constants and the magnitude of the applied voltage, said divider operating to produce oscillatory energy of a frequency determined by the sum of said factors, a source of potential which varies between two values each of which represents a different sig-

fialling condition, a current amplitude limiter and amplifier tube in at least one coupling between the first mentioned source and the divider tubes, and means for varying the gain of said amplifier tube by potential from said source to correspondingly vary the magnitude of the voltages supplied to one tube of the multivibrator to correspondingly vary the frequency of operation of the multivibrator.

3. In a signalling system, a multivibrator comprising a pair of electron discharge tubes having electrodes interconnected by capacitors and connected to potential sources by resistors whereby the multivibrator oscillates at a frequency depending in part on the value of the circuit elements, a source of oscillating voltages of a frequency which is a multiple of the frequency at which said multivibrator tubes operate, a current amplitude limiter having input electrodes coupled to said source of voltage, an amplifier in a path coupling the output of said current amplitude limiter to a resistor in the circuit of one of said multivibrator tubes, the arrangement being such that the tubes tend to operate at a fundamental frequency which is a fraction of the frequency of said source, and a source of signal potentials connected to electrodes of said amplifier for modulating the gain of said amplifier to correspondingly vary the fundamental frequency of operation of the multivibrator.

4. In a two-tone generator a multivibrator including a pair of electron discharge devices having electrodes interconnected by circuits including resistance and capacity and potential sources, a source of oscillating voltage, a current amplifier and current amplitude limiter tube having input electrodes coupled to said source, a coupling between the output electrodes of the tube and a circuit supplying direct current to at least one of the devices in said multivibrator, a modulating tube having output electrodes associated with the electrodes of said current amplitude limiting tube to control the amplitude of the voltage fed to said one tube of said multivibrator, and means for applying control potentials to said modulating tube.

5. In a signalling system, a multivibrator comprising a pair of electron discharge tubes having electrodes interconnected by capacitors and connected to potential sources by resistors whereby the multivibrator oscillates at a frequency depending in part on the value of the circuit elements, a source of alternating voltages of a frequency which is a multiple of the frequency at which said multivibrator tubes operate, a current amplitude limiter having input electrodes coupled to said source of voltages, a first amplifier in a first path coupling the output of said current amplitude limiter to a resistor in the circuit of one of said multivibrator tubes, a second amplifier in a second path coupling the output of said current limiter tube to a resistor in the circuit of the other multivibrator tube, the arrangement being such that the multivibrator tubes tend to operate at a first fraction of the frequency of said source of voltages, a source of signal potentials, and means for modulating the gain of said amplifiers in said paths in accordance with said signals whereby the tubes operate at a second fraction of the frequency of said source.

6. In a signalling system, an electron discharge device having its electrodes coupled in a regenerative oscillation generating circuit including a control grid with a variable biasing circuit connected with the same, a charging condenser coupled in the biasing circuit of said device, a source of oscillatory voltage of a frequency higher than the frequency of operation of said oscillation generator, a current amplitude limiter tube having input electrodes coupled to said source, a coupling between the output electrodes of said current amplitude limiter tube and the biasing circuit of said device, a uni-directional device in said coupling arranged to pass voltage to said condenser to charge the same an amount depending upon the amplitude of the voltage supplied from said source by said tube to said device, a discharge path for said condenser, a source of keying potentials, and means for modulating the gain of said limiter tube in accordance with said keying potential to thereby control the amplitude of the voltage supplied to said charging condenser and the frequency of operation of said regenerative generator.

7. In a multiple tone generator, a multivibrator including a pair of electron discharge devices having electrodes interconnected by circuits including resistance and capacity and potential sources, a source of oscillating voltages, a current amplifier and current amplitude limiter tube having input electrodes coupled to said source, separate couplings between the output electrodes of said tube and the two circuits supplying direct current to the two discharge devices in said multivibrator, a plurality of modulating tubes for each coupling, the modulating tubes of each group having output electrodes connected to the coupling with which they are associated for controlling the magnitude of the voltages passed by said couplings, and means for applying control potentials sequentially to said modulating tubes.

8. In a frequency shift telegraphy system, a multivibrator comprising a pair of electron discharge devices having electrodes interconnected by capacitors and connected to potential sources by resistors of such a value that one of the two devices of the multivibrator operates at one frequency and the other thereof operates at another frequency, a source of oscillations of a frequency which is a multiple of the frequencies at which said multivibrator devices operate, a current amplitude limiter having input electrodes coupled to said source of oscillations, a first path coupling the output of said current amplitude limiter to a resistor in the circuit of one of said multivibrator devices, signal amplifying means in said path, a second path coupling the output of said current limiter to a resistance in the circuit of the other multivibrator device, a source of signal potentials, and means for modulating the gain of said amplifying means tube in said first-named path in accordance with signals.

9. In apparatus for generating two tones of different frequencies both of which frequencies are sub-harmonically related to the frequency of oscillatory energy, a source of oscillatory energy of substantially constant frequency f, a frequency divider including at least one tube in an oscillation generating circuit the frequency of operation of which depends on the magnitude of a tube electrode potential, a coupling between said source of oscillatory energy of frequency f and an electrode of said one tube to entrain said divider to operate at a frequency sub-harmonically related to the frequency of said source, a source of control potentials which is keyed in magnitude between two values, an electron discharge device having input electrodes coupled to said last

named source and having output electrodes connected to said coupling between said source of oscillatory energy of frequency f and said electrode of said one tube, the arrangement being such that when the control potential is of one value the divider operates at one tone frequency sub-harmonically related to the frequency f and when the control potential is of the other value the frequency divider operates at a second tone frequency sub-harmonically related to the frequency f, and an output circuit coupled to said frequency divider.

10. Apparatus as recited in claim 9 wherein said coupling between said source of oscillatory energy of frequency f and said divider includes a voltage limiting tube having an input coupled to the source and having an output coupled to said electrode of the frequency divider tube.

11. Apparatus as recited in claim 10 wherein said coupling between said limiting tube output and said electrode of the frequency divider tube includes a voltage amplifier tube having input electrodes coupled to the output electrodes of the limiting tube and having output electrodes coupled to said electrode of said divider tube.

12. Apparatus as recited in claim 9 wherein said output circuit includes a filter to select said tone frequencies.

13. In apparatus for generating two tones of different and substantially fixed frequencies which frequencies are sub-harmonically related to the frequency of oscillatory energy of frequency f, a frequency divider including two tubes in an oscillation generating circuit the frequency of operation of which depends on the magnitude of a potential on an electrode of each of said tubes, a source of signals comprising potential keyed between two values, a source of oscillatory energy of frequency f, an amplifier tube having input electrodes coupled to said source of frequency f and having output electrodes coupled to an electrode of one divider tube, a second amplifier tube having input electrodes coupled to said source of frequency f and having output electrodes coupled to an electrode in the other of said divider tubes, whereby said divider is caused to operate at a frequency sub-harmonically related to the frequency f, at least one modulator tube having output electrodes coupled to one of the amplifier tubes, and having input electrodes coupled to said source of signals to change the magnitude of the potential on an electrode of at least one of said divider tubes to entrain said divider to operate at first and second tone frequencies one representing one signal potential value the other the other signal potential value, and an output circuit coupled to said divider.

14. Apparatus as recited in claim 13 including a second modulator tube having input electrodes coupled to said source of signals and having output electrodes coupled to the other amplifier tube.

15. Apparatus as recited in claim 13 wherein said output circuit includes a low pass filter to reject unwanted harmonics and pass said two voltages of said two tone frequencies.

16. In apparatus for generating two tones of different and substantially fixed frequencies which frequencies are sub-harmonically related to oscillatory energy of frequency f, a frequency divider including two tubes in an oscillation generating circuit the frequency of operation of which depends on the magnitude of a potential on an electrode of each tube, a source of oscillatory energy of frequency f, a source of signals which vary between two values of potential, a voltage amplitude limiter having an input coupled to said source of oscillatory energy of frequency f and having an output coupled by separate paths to an electrode of each of said tubes to apply oscillatory energy of substantially square wave form to said electrodes whereby said divider operates at a frequency sub-harmonically related to the frequency f, two modulator tubes each having output electrodes in shunt to a different one of said separate paths between said limiter and the electrodes of said frequency divider tubes and each having input electrodes coupled to said source of signals to apply potentials of different magnitude to said divider tube electrodes to entrain said divider to operate at two tone frequencies one representing one of said signal potential values the other representing the other of said signal potential values.

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