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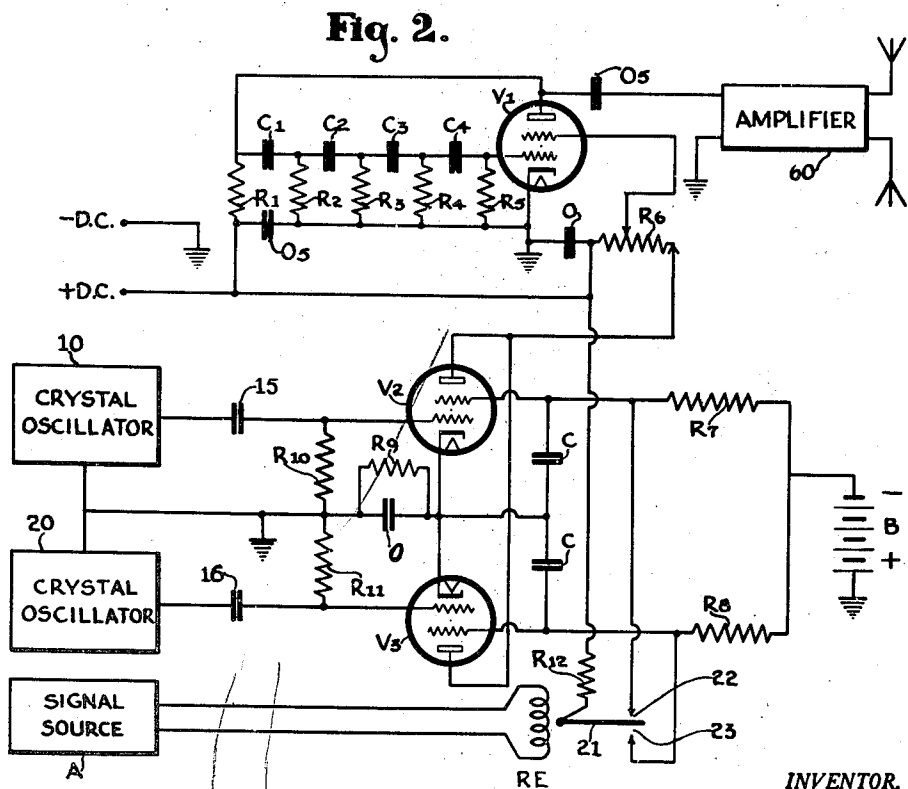
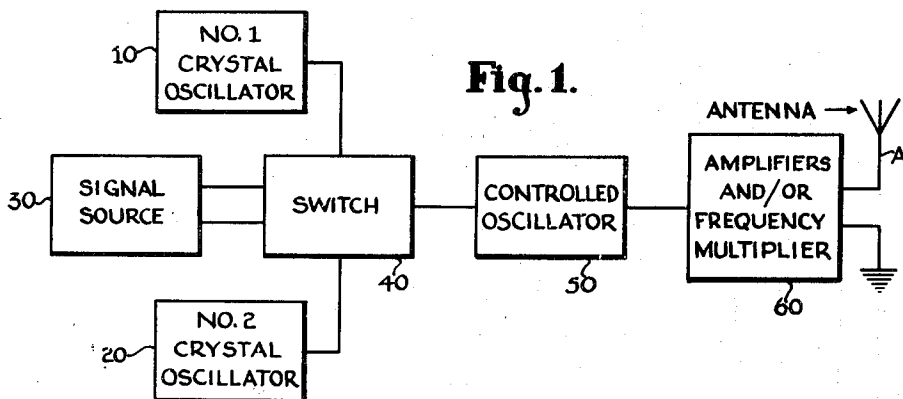
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2,461,456

FREQUENCY SHIFT KEYING

Filed Feb. 11, 1944.

3 Sheets-Sheet 1



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Fig. 3.

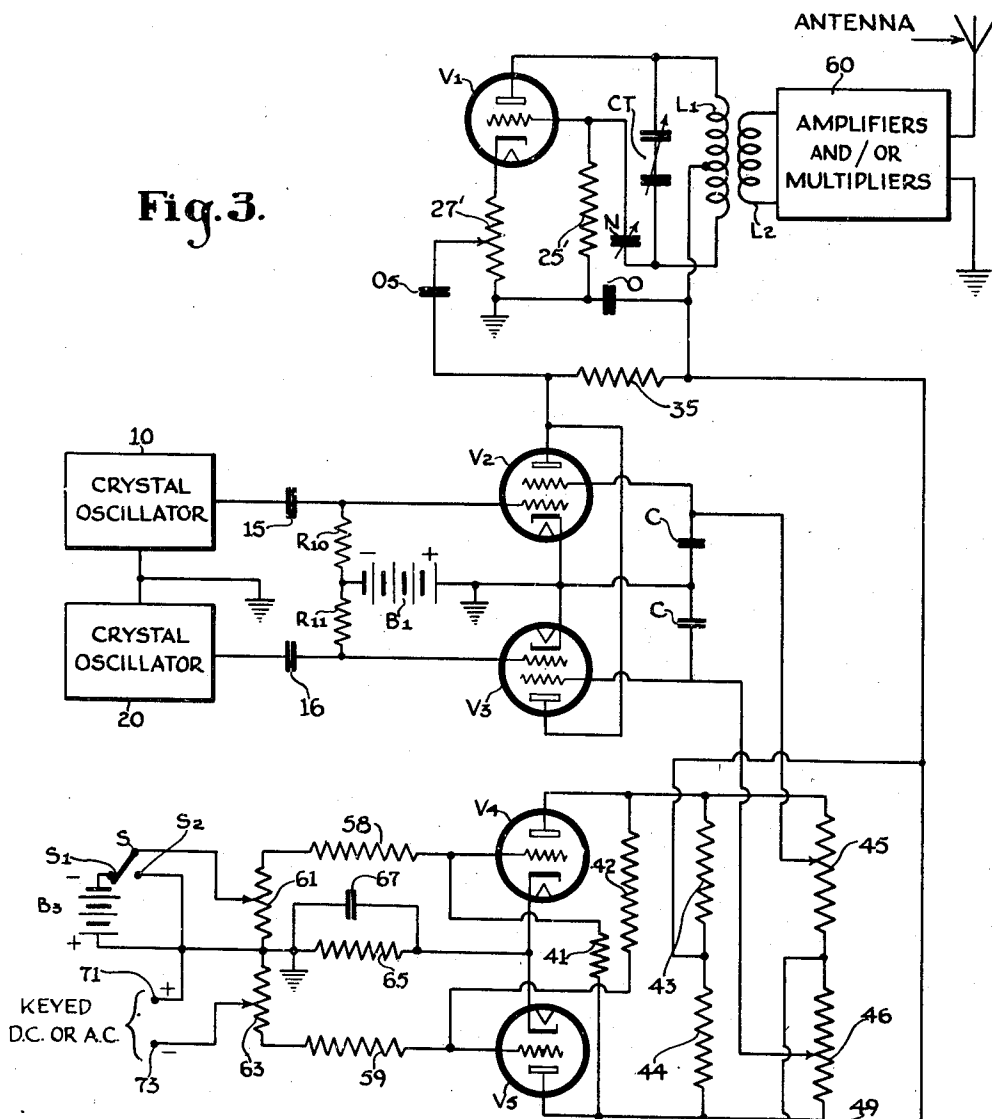
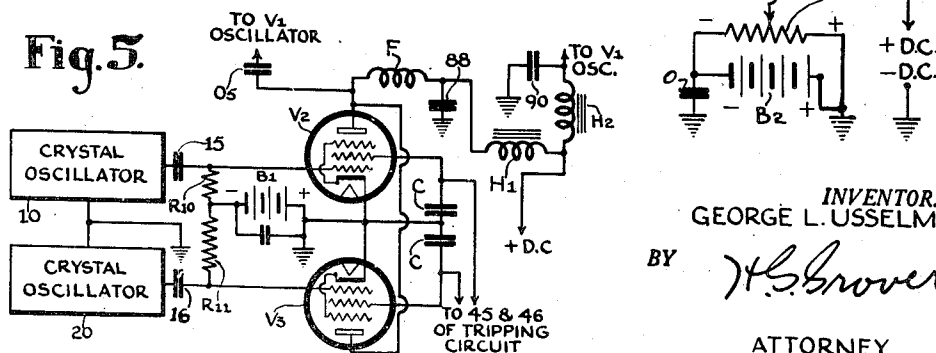


Fig. 5.



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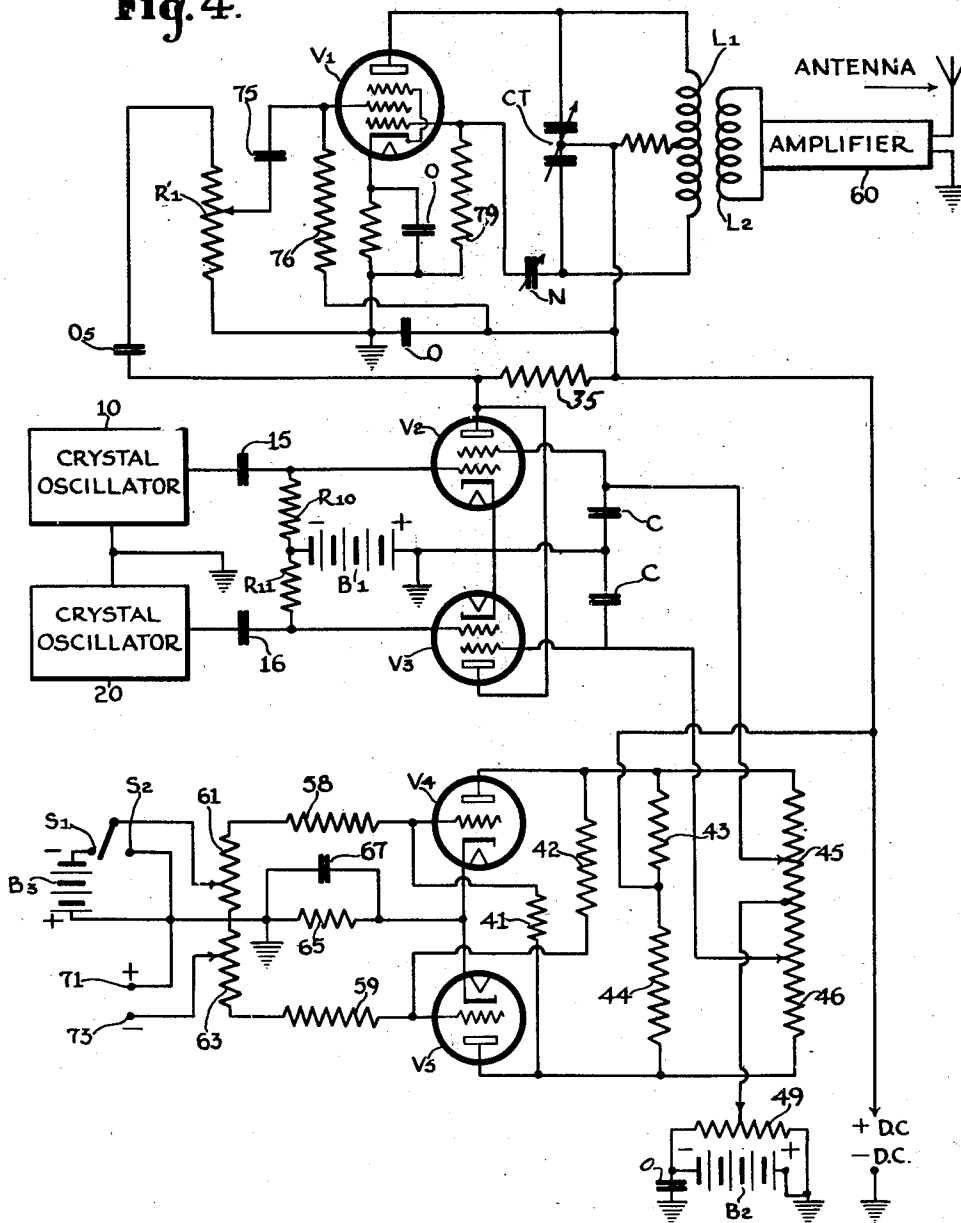
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3 Sheets-Sheet 3

Fig. 4.



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2,461,456

FREQUENCY SHIFT KEYING

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Application February 11, 1944, Serial No. 521,907

15 Claims. (Cl. 250—8)

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This invention concerns frequency modulation and in particular an improved method and means of communication by frequency shift or spaced wave keying. By this method of communication carrier wave energy keyed from a first to a second frequency and vice versa is produced. The first frequency may represent marking condition while the second frequency may represent spacing condition. The carrier wave energy so keyed may be considered as originating from a single source the frequency of which is alternately keyed or may be considered as separate carriers alternately translated, the alternation being in accordance with signals such as, for example, telegraphy, facsimile, code or television. Various embodiments of my invention are disclosed herein and in my U. S. application Serial #646,069, filed February 7, 1947, now Patent No. 2,457,288, granted December 28, 1948, which is a division of this application.

At the receiver both frequencies, that is, the mark and space or first and second frequencies are used in reproducing the signal thus giving the benefits of positive action on mark and space, the benefit of frequency diversity, etc.

The use of two frequency sources for frequency shift keying as described above, has been disclosed in the art, as has been the use of the mark and space frequencies at the receiver. However, method and means known heretofore for accomplishing the keying of the two carrier waves resulted in amplitude keying thereof with all its attendant disadvantages. In the prior systems, even if amplitude keying were not present or did not accompany the frequency shift keying the change from the first to the second frequencies is so abrupt that there results a wide dispersion of the side frequencies. This extends the channel, causes overlapping of side bands and produces keying clicks, etc., in the circuits.

An object of the present invention is improved frequency shift keying. An additional object of the invention is improved frequency shift keying without amplitude modulation of the keyed wave, so that in effect the keying from the first frequency to the second frequency is smoothly carried out, thereby reducing the side band frequency spectrum, reducing keying shocks, etc.

In attaining the above objects I use two constant frequency sources, but a method and means is included for the frequency shift keying that holds the amplitude keying modulation to a minimum and also prevents sudden frequency changes. My method and means thereby prevents unnecessary widening of the frequency band. Thus the

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present frequency shift system retains the advantage of accurate fixed frequencies for the mark and space characters of the prior art, but none of the disadvantages.

In describing my invention in detail, reference will be made to the attached drawings wherein Fig. 1 is a block diagram illustrating schematically the general arrangement of a spaced wave keying system arranged in accordance with my invention.

Fig. 2 illustrates diagrammatically the essential elements of a practical spaced wave keying system such as illustrated schematically in Fig. 1. In Fig. 2, two crystal oscillators are arranged to be continuously operable at the substantially fixed first and second frequencies and to in turn alternately operate through an electronic and mechanical switching arrangement to synchronize a third oscillator producing the controlled space and mark frequencies. The third oscillator is of the condenser resistance type.

Fig. 3 is a wiring diagram of the essential features of a third embodiment of my improved system. In Fig. 3 a modified controlled or synchronized oscillator is used and the switching system for switching the control of the said oscillator alternately to the two fixed frequency oscillators is of an improved type operating entirely electronically.

Fig. 4 is a modification of the arrangement of Fig. 3; and

Fig. 5 illustrates a modified control circuit to be used in the embodiments illustrated in Figs. 3 and 4.

Referring now to Fig. 1, two crystal oscillators 10 and 20 are provided, one for the mark frequency and the other for the space frequency. The energies from these two crystal oscillators are delivered to the switching circuit and mechanism in 40. The switch in 40 may, as will be seen hereinafter, provide some amplifying effect. The switch in 40 is controlled by the signal from source 30 and as is known, this signal comprises electrical energy representing mark and electrical energy representing space, so utilized that first one crystal oscillator output then the other is switched on or through to deliver crystal controlled excitation to a controlled or synchronized oscillator in 50. The oscillator in 50 may, when uncontrolled, operate at a frequency intermediate mark and space, but is of a nature such that it is smoothly pulled into synchronism by whichever source 10 or 20 is switched through at 40 under the control of signals at 30. The mark and space frequency energy is then amplified and/or fre-

quency multiplied in 60 and utilized say, for example, radiated.

The oscillator 50 is of a type that while it oscillates continuously it is easily controlled and synchronized by either of the crystal controlled oscillations switched on by unit 40. Oscillator 50 is adjusted so that during the intervals of switching it continues to oscillate on a mean frequency with substantially no change in amplitude. The output of controlled oscillator unit 50 is next amplified and/or multiplied in frequency in unit 60 and then radiated by the antenna A. The oscillator in 50 is arranged so that it maintains a substantially constant frequency output by self excitation but readily changes its frequency to synchronize with that of the crystal excitation switched on by the signal from 30 through unit 40.

It can be seen that the oscillator 50 provides a buffer or in effect a fly-wheel between the two crystal oscillators 10 and 20, and the transmitter amplifiers and/or frequency multipliers in 60. The action is two-fold. The oscillations continue at the mean frequency and at substantially constant amplitude during the time when neither crystal is in control. Thus, the receiver has a carrier to operate on continuously. The second action is that several cycles of oscillation in unit 50 occur during the time of frequency change from mark to space and vice versa. Thus the keying is smooth since the time frequency change is not too sudden and side frequencies are not spread so far. Note that actually in my system three frequencies are involved, these frequencies being mark, space and no signal.

In Fig. 2, I have shown a more detailed embodiment of the invention. Here the tube V1 operates in a well known condenser-resistance oscillator circuit and the condenser-resistance oscillator circuit shown may be included in the unit 50 of Fig. 1. The oscillator tube V1 has its anode and controlling electrode coupled by a condenser-resistance network including between the plate and control grid series condensers C1, C2, C3 and C4, and between terminals of said condensers and the cathode, resistors R1, R2, R3, R4 and R5 with a coupling and direct current blocking condenser O5 between R1 and R2 to isolate the cathode of the tube V1 with respect to the direct current potential supplied to the anode of V1 through R1. Bypassing condenser O serves a somewhat similar purpose with respect to the direct current supplied to the screen grid through potentiometer resistance R6. Oscillations are generated by virtue of the fact that the anode of V1 is coupled to the control grid by a network such that the voltages on the control grid and anode are opposed. Moreover, the oscillator, while stabilized as to a particular frequency, is readily swung under control of the synchronizing oscillations about this particular frequency, to which it is tuned, by the signals operating on the switch.

Tubes V2 and V3 work in the amplifier and switching circuit which may be included in the switching unit 40 in Fig. 1. The tubes V2 and V3 have their anodes tied together and coupled to the direct current source through resistance R6. The screen grid electrodes of tube V2 and V3 are connected by resistances R7 and R8 respectively, to the negative terminal of a source B, the positive terminal of which is grounded. The screen grids of tubes V2 and V3 are also connected by radio frequency bypassing condensers C to the cathodes.

The crystal controlled oscillators in units 10 and 20 are coupled by coupling condensers 15 and 16 to the control grids of the tubes V2 and V3 while low radio frequency potential points on both of the crystal oscillators in units 10 and 20 are connected to ground and to the cathodes of tubes V2 and V3 by a resistance R9 shunted by a coupling and bypassing condenser O. Direct current grid circuits for V2 and V3 are completed through the resistances R10 and R11.

The output signals of the signal source at which may be uni-directional current or potentials of opposite or reversible polarity representing mark and space respectively, are supplied to the winding of a relay RE having an armature 21 cooperating with two contacts 22 and 23 to connect the positive terminal of the direct current source to the screen grid of tube V2 or to the screen grid of tube V3 by way of resistance R12 and one or the other of contacts 22 or 23, depending upon whether mark or space signal is being supplied from source A.

The frequencies of the oscillations developed in 10 and 20 are usually made to have the desired prescribed frequency difference of about 100 or more cycles, depending upon the needs of the particular system at hand. The relay RE is operated from the signal source A. The relay contacts 21, 22 and 23 alternately change the screen grid bias potentials of the switching and amplifying tubes V2 and V3 from a negative to a positive value. When contact 22 or 23 is closed the screen grid of tube V2 or V3, depending upon which contacts is closed, is connected to the positive terminal of the source. This alternately switches excitation from crystal units 10 and 20 onto the oscillator stage tube V1 because the oscillations are amplified or repeated through one of the tubes V2 and V3 and supplied to the screen grid circuit of tube V1. In the mid position of the relay RE the contacts 22 and 23 are open, and negative bias is applied to both switching tubes V2 and V3 from source B through the resistors R7 and R8. In this condition no excitation from either crystal oscillator is allowed to pass through the amplifying and keying stage. During this time oscillator V1 is operating on its frequency determining circuit, that is, the condenser resistance network which is set for the mean frequency and this frequency is transmitted.

Now assume that the signal from A closes the relay contacts 21 and 22. Positive bias is applied to the screen grid of amplifying and switching tube V2, which repeats and possibly amplifies the excitation from crystal oscillator 10, impressing it on the screen grid of oscillator tube V1 through potentiometer R6. Since the oscillator V1 is as described above, somewhat flexible in operation, it has its frequency "pulled" so that it synchronizes with the frequency of crystal oscillator 10. This new frequency is now transmitted and may represent space or mark. When the signal from source A reverses the relay RE changes and closes contacts 21 and 23. During the changeover period there is a short interval of time when negative bias is applied to both tubes V2 and V3, and the excitation from both crystal oscillators 10 and 20 is cut off. Then the oscillator V1 swings smoothly back towards its own frequency of operation, that is, mid-frequency. When the relay contacts 21 and 23 are closed positive bias is applied to the switching tube V3 which repeats and possibly amplifies the excita-

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tion from the crystal oscillator in 20, impressing it on the screen grid of oscillator tube V1 to thereby pull its oscillations into synchronism with the oscillations of the crystal oscillator in 20.

A feature of my present invention is that the oscillator V1 and the oscillations generated thereby are not synchronized instantly with the oscillations produced by units 10 and 20. It may take several cycles of oscillation from 10 and 20 before the oscillations developed in tube V1 are locked in synchronism. By adjusting the potentiometer R6 the amount of control excitation potential from the crystal oscillators in 10 and 20 to the controlled oscillator V1 may be set to give the desired "pull-in" or synchronizing time. The effect is a rounding off and slope in the signal characters. Reducing the excitation voltage will increase the rounding and slope of the signal characters. Too much reduction will cause loss of signal or erratic operation. If a large amount of excitation is impressed on oscillator tube V1 from the keying tubes, the signal characters will be more square shaped at the corners and more side frequencies will be generated. During the shifts in frequency the output of oscillator V1 remains substantially constant in amplitude.

Although, as pointed out above, the shift between mark and space frequencies is smoothly carried out, it must be understood that the action is positive under all circumstances provided, of course, sufficient control is applied at R6 to synchronize the oscillator V1 with one or the other of the sources in 10 and 20. The action is positive because when tube V3 is keyed on, that is, has its screen grid connected to the positive source of direct current by contacts 21 and 23, tube V2 is shut off due to the fact that its screen grid is connected by resistance R7 to the negative terminal of source B.

On the other hand, when the tube V2 has its screen grid supplied with positive potential by contacts 21 and 22, tube V3 is blocked due to the fact that its screen grid is connected by resistance R8 to the negative terminal of source B.

The arrangement of Fig. 3 is quite similar to the arrangement of Fig. 2. The main difference between the arrangements of Figs. 2 and 3 results from the fact that a different type of synchronized or entrained oscillator including tube V1 is used with additional control means therefor.

In Fig. 3, V1 is an oscillator of the Hartley type having its anode coupled to its control grid by a tuned LC circuit including condenser CT and inductance L1 with a point on the inductance L1 connected to the cathode by coupling condenser O. Oscillations are generated in the tube V1 and circuit CT, L1 by virtue of the fact that enough electrons are drawn past the control grid at all times to support oscillations. The condenser N is a feedback or regeneration control condenser and 25' is a resistance by means of which operating bias is supplied to the control grid of tube V1.

The potentiometer 27' has a tap thereon and provides a means for applying the synchronizing or controlling voltage to the generator of tube V1. Any excitation applied to the control grid or any tube element of the oscillator tube V1 will have a tendency to control the frequency of oscillations generated in tube V1, thereby synchronizing the same with the controlling potentials, provided the natural oscillating frequency of the tube V1 is not too far different from the excitation or control frequency. A controlled oscil-

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lator of this general type has been shown and described in detail in Fig. 3 of my U. S. Appl. Serial #487,095, filed May 15, 1943, now Patent No. 2,425,165, granted August 5, 1947.

In my improved system a tap on the potentiometer resistor 27' in the cathode return circuit of tube V1 is coupled to the anodes of the tubes V2 and V3, by way of direct current blocking and alternating current coupling condenser O5.

Control in Fig. 3 is accomplished in an improved manner by applying the output of one or the other of the amplifying and keying tubes V2, V3 to a potentiometer 27' in the cathode to ground circuit of the oscillator so that this oscillator V1 is synchronized through control of the potential on the cathode thereof. The grid direct current circuit is completed by grid leak resistance 25'. The anodes of tubes V2 and V3 are coupled to 27' through coupling and direct current blocking condenser O5 over resistance 35.

The switching circuit now takes the form of a tripping type keying circuit thereby also eliminating the use of the mechanical relay RE. In this tripping circuit tubes V4 and V5 are arranged and operate substantially as disclosed in U. S. Patent #2,326,314, dated August 10, 1943. The anodes of the tubes are cross-connected to the control grids by resistances 41 and 42 in such a way that the potential drops in anode resistances 43 and 44 are applied respectively to the grids of the tubes V5 and V4. When one of these tubes draws current the grid of the other thereof is made more negative by applying the potential drop at the anode of the said one tube to the grid of the other tube.

The anodes are also coupled together by resistances 45, 44, and 45 and 46. A point intermediate the resistances 43 and 44 is connected to the positive terminal of the direct current source while a point intermediate the terminals of resistances 45 and 46 is connected to a point on a potentiometer 49 in shunt to the source B2. The source B2 has its positive terminal grounded like source B of Fig. 2, and this source B2 is shunted by a bypass condenser O. The resistances 45 and 46 which are potentiometers have points thereon coupled to the screen grids in tubes V2 and V3, and are means for supplying alternately positive and negative bias to the screen grids of keying tubes V2 and V3 for keying the same on and off as described hereinbefore. The outer ends of resistances 45 and 46 are connected to an alternately varying positive voltage, that is, to the anodes of tubes V4 and V5. The anodes are made alternately more positive and less positive as the bias on the grids of the tubes V4 and V5 is keyed. The central ends of these resistors are connected to a negative source of supply by resistance 49.

The tripping tubes V4 and V5 have their control grids coupled respectively by resistances 50 and 51, and 59 and 63 to ground and by resistance 65 to the cathodes of the tubes. Resistance 65 is shunted by a condenser 67 of low impedance to potentials of the keying frequency.

61 and 63 are potentiometer resistances with a point on resistance 61 connected by switch S either to the negative terminal of a source B3, or to ground. A point on potentiometer resistance 63 is connected to one terminal of the keying source, the other terminal of which is connected to ground. The potentiometers 61' and 63 couple in the control or keying potentials. The source B3 is sometimes necessary to apply a

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fixed negative bias to the grid of tube V4 in order to get positive tripping action. More specifically, the setup is such that the tube V4 is biased to cutoff in the absence of marking and spacing signals either by the drop in resistances 58 and 61 or if necessary by negative potential from B3 with S on S1 instead of on S2. The current then is switched through tube V5 and the resistances 45 and 46, the tap on source 49, etc., is such that the screen grid of tube V3 is negative to block this tube at the same time the anode of tube V4 is at a positive potential (main D. C. source) such that the screen grid of tube V2 is positive, and oscillations from source 10 are amplified through V2 to take control of the generator tube V1. This frequency of operation of source 10 and V1 as now controlled could be designated the space frequency.

Now when signals are applied to connections 71 and 73 and are sufficiently negative tube V5 will be blocked, the grid of tube V4 being tied to the anode of tube V5 will become more positive and the current will be switched through tube V4. This applies a negative potential to the screen grid of tube V2 to block this tube. A positive potential is applied from the anode of tube V5 and from the end of resistance 44 through the tap on resistance 46 to the screen grid of tube V3 and the control of tube V1 shifts from source 10 to source 20 which may then be said to operate at the marking frequency, and the generator V1 now is entrained by source 20. The keying potentials applied at 71 and 73 may be alternating current or direct current pulses. Alternating potentials may be applied to the input 73 of the tripping circuit for keying.

When alternating current and voltage is applied across terminals 71 and 73 of Fig. 3 it is usually done through a transformer. During one part of the cycle the grid of tube V5 will be biased positive and during the other part of the cycle the grid of tube V5 will be biased by a negative potential. This is evident when it is remembered that alternating currents are caused by alternate surges of positive and negative potential. The resistances 41 and 42 are of higher value than resistances 58 and 59 so that the positive bias from the tube anodes is overcome when negative bias is applied. During operation when contact S2 is closed by switch S the grid of tube V4 is more negative than the grid of tube V5 when no signal or when positive signal is applied to V5. When a sufficiently large negative signal pulse is applied to terminal 73, the grid of tube V5 is made sufficiently more negative than the grid of tube V4 to cause the circuit to trip so that tube V5 is cut off and tube V4 carries large current. When terminal 73 goes to zero or a positive potential the circuit will trip back to the original condition of large current in tube V5 and no current in tube V4. Switch contact S1 or S2 is closed when only negative pulses of potential are applied to terminal 73. If alternating positive and negative potential pulses are applied to terminal 73 then switch S1—S2 may be left open and satisfactory operation will be obtained. The tripping circuit performs the additional function of squaring up the keying wave form. The arrangement of Fig. 3 performed very well in operation.

Irrespective of whether the potentials at 71 and 73 are alternating current or direct current the basic operation is as follows.

As the input signal operates the tripping circuit the anodes of tubes V4 and V5 alternately

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trip to high and low positive voltages. If the movable points on potentiometers 45 and 46 are correctly adjusted the screen grids of switching tubes V2 and V3 will have impressed on them alternately positive and negative bias voltages in accordance with the signal potential variations. The adjustments of potentiometers 45, 46, and 49 control these biasing potentials and adjustment can be made to make the switching action as positive as desired.

Advantage of this modification is that there are no mechanical relays as in Fig. 2. The tripping circuit squares up the marking pulses and the same are amplitude limited by the tripping circuit. The tripping circuit also operates so that there is a minimum of transition time between mark and space frequencies. In other words, the time of uncontrolled oscillation in the circuit of V1 is a minimum.

The condensers C connecting the keyed screen grid electrodes of tubes V2 and V3 to the cathodes of the respective tubes in Figs. 2, 3, and 4, are bypass condensers for voltages of radio frequency such as generated in sources 10 and 20, but these condensers are not to be so large as to distort audio frequency characteristics, as otherwise the keying impulses of higher frequency might be greatly reduced in amplitude. However, these condensers may be made as large as .1 MF or .3 MF for the purpose of rounding off the signal characters if very high keying speeds are not used. In the prior figures and in Fig. 4, to be described hereinafter, the letter O is applied to condensers such as between R6 and the cathode in Fig. 2, which serve primarily as bypassing condensers but may also serve as blocking condensers. These may be of relatively large capacity such as .01 to .1 without doing any harm, and depending on the operating frequency.

The embodiment illustrated in Fig. 4 uses a controlled oscillator of the modified Hartley type including tube V1, with switching tubes V2 and V3 coupled thereto and controlled by the tripping circuit including tubes V4 and V5 as illustrated in Fig. 3. The anode of tube V1 is coupled to the control grid by a tuned LC circuit including condenser CT and inductance L1 with a point on the inductance L1 connected to the cathode by a coupling condenser O. Oscillations are generated in a well known manner in this regenerative circuit. The screen grid is connected by coupling condenser 75 to a point on potentiometer resistance R1 coupled by condenser O5 between the anodes of tubes V2 and V3 and the cathode of tube V1. Direct current is supplied for this electrode from the main source by resistor 76. Resistance 79 supplies bias for the control grid of tube V1. In Fig. 4 in so far as possible reference characters corresponding to those used in the prior Figs. 2 and 3 have been used. Moreover, the operation of the tripping circuit and switching tubes is as described in detail hereinbefore in connection with Fig. 3. It does not appear necessary to repeat this operation in connection with Fig. 4. It will be noted, however, that the embodiment of Fig. 4 operated very well when tested and is now believed to be a preferred embodiment.

The operation of the embodiments illustrated in Figs. 3 and 4 is made more positive by modifying the direct current supply circuits for the oscillator including tube V1 and the two switching tubes V2 and V3, as shown in Fig. 5.

The audio frequency choke H1, together with

radio frequency choke F and radio frequency bypass condenser 88, is used for the following purpose. Ordinarily without the choke it is possible for the cut off and on of the keying tubes V2 and V3 to be somewhat ragged or out of step. That is, both might be off at once or on at one time. Although this seldom occurs, I may wish to provide further assurance that it will not occur by installing iron core choke coil H1 as shown in Fig. 5. This choke coil tends to maintain constant current flow so that when one keying tube, say V2, cuts off the difference current is forced to flow in tube V3. Suppose that the total current in choke coil H1 is 10 MA. Then I would have conditions of keying currents like these: V2=10 MA, V3=0 MA; V2=8 MA, V3=2 MA; V2=5 MA, V3=5 MA; V2=0 MA, V3=10 MA, etc. At any tripping speed of the keying tubes these tube currents would be complementary, thus insuring that the keying tubes operate properly at all speeds. The radio frequency choke F and bypass condenser 88 are provided to prevent the choke H1 from absorbing radio frequency power, which it would otherwise do.

Similarly, I may wish to use a choke coil similar to H2 of Fig. 5 in the plate current supply lead to the controlled oscillator circuit and tube V1. The purpose of choke coil H2 is to maintain constant current flow in oscillator tube V1 in order to inhibit any amplitude modulation. For instance, if during the excitation switching operation there is a change of excitation level to tube V1, the same anode current flow is maintained by choke coil H2, which tends to hold constant radio frequency amplitude output.

The tripping circuit of Fig. 3 uses two tubes and has a pushpull output. Its input and output circuits may be either single ended or pushpull as desired.

Pushpull input may be obtained by leaving switch S open and then applying the pushpull signal through switch S to potentiometer 61 and through terminal 73 to potentiometer 63. The pushpull input signal should be balanced positive and negative potentials similar to ordinary alternating currents and voltages. However, single ended input is satisfactory and will usually answer every purpose. It can be applied to either the upper or the lower side of the input circuit providing the other side is biased.

In the tripping circuit of say Fig. 3, I not only want to adjust the amount of keyed output voltage but I want to adjust the amounts of positive and/or negative voltage supplied by the keyed output. This is done by adjusting the negative voltage supplied by potentiometer 49 and by adjusting the output connections on potentiometers 45 and 46 in Fig. 3.

If the ground connection of potentiometer 49 in Fig. 3 is moved part way upon the potentiometer, then this tripping circuit may be adjusted to supply modulated positive or negative potential output.

I claim:

1. In a telegraphy system a source of oscillations of controllable frequency, a source of oscillations of a first and substantially fixed frequency, a source of oscillations of a second and substantially fixed frequency, a circuit including an amplifier between each oscillator of fixed frequency and said oscillator of controllable frequency and apparatus including a switching device controlled in accordance with telegraphy signals for rendering one amplifier operative

and the other amplifier inoperative or vice versa for entraining said source of oscillations of controllable frequency by oscillations from one or the other of said sources of substantially fixed frequency for controlling the frequency of the oscillations generated in said source of controllable frequency in accordance with said telegraphy signals.

2. In a telegraphy system, a source of oscillations of controllable frequency, a source of oscillations of a first and substantially fixed frequency, a source of oscillations of a second and substantially fixed frequency, a circuit including a tube amplifier between each of said last two sources and said first source, and a pair of switching tubes coupled to said tube amplifiers and controlled in accordance with telegraphy signals for alternately rendering said amplifiers operative for coupling one or the other of said sources of substantially fixed frequency to said source of controllable frequency for entraining the same with one or the other of the substantially fixed sources.

3. In a frequency shift system, a source of oscillations of controllable frequency, a source of oscillations of a first and substantially fixed frequency, a source of oscillations of a second and substantially fixed frequency, two electron coupling tubes each having input electrodes coupled respectively to one of said sources of substantially fixed frequency, and having output electrodes coupled in parallel and to said first source to entrain the frequency of operation thereof, a source of signals comprising energy the character of which changes between two conditions representing respectively mark and space, and connections between said source of signals and electrodes of said pair of tubes for controlling oppositely the conductivity of the tubes as the character of the signal energy changes.

4. In a frequency shift signalling system, a regenerative tube generator of controllable frequency, a source of oscillations of a first and substantially fixed frequency, a source of oscillations of a second and substantially fixed frequency, two electron coupling tubes each having input electrodes coupled respectively to one of said sources of substantially fixed frequency, and having output electrodes coupled in parallel and to said first source to entrain the same and control the frequency of operation thereof, a source of signals comprising energy keyed between two conditions representing respectively mark and space, a second pair of electron discharge tubes each having an output electrode coupled respectively to an electrode of one of said coupling tubes to control the operativeness thereof, connections cross-coupling electrodes of said second named pair of tubes so that when one draws current, current through the other is reduced and vice versa, and connections between said source of signals and electrodes of said second pair of tubes for controlling oppositely the conductivity of the tubes as the character of the signal energy changes.

5. In a frequency shift signalling system, a source of oscillations of controllable frequency, a source of oscillations of a first and substantially fixed frequency, a source of oscillations of a second and substantially fixed frequency, two electron coupling tubes each having input electrodes coupled respectively to one of said sources of substantially fixed frequency, and having output electrodes coupled in parallel and to said first source to entrain the frequency of opera-

tion thereof, a source of signals comprising energy the character of which changes between two conditions representing respectively mark and space, connections between an electrode of each of said tubes and a negative and a positive source of potential, a switch in at least one of said connections to each electrode, and a relay co-operating with said switch and controlled by said signals for applying a negative potential to an electrode in one of said tubes and a positive potential to an electrode in the other of said tubes or vice versa as the character of said signals changes.

6. In a frequency shift telegraphy system, an oscillator of controllable frequency operating to generate oscillations of a first frequency, an oscillator operating at a second and substantially fixed frequency, an electron discharge tube coupling the last mentioned oscillator to the first mentioned oscillator, for entraining the first oscillator by the second oscillator, a source of currents representing two signalling conditions, and connections from said source to said tube to control the coupling through the tube from the second oscillator to the first oscillator in accordance with currents from said source.

7. In a telegraphy system of the type wherein signals are transmitted at a first frequency designated mark and a second frequency designated space, an electron discharge device oscillator having electrodes coupled in alternating current circuits and to a source of direct current potential all arranged to produce oscillatory energy or carrier wave frequency, an oscillation generator of fixed frequency, a second oscillation generator of fixed frequency different than the frequency of said first oscillation generator of fixed frequency, two electron discharge tubes each having input electrodes and output electrodes, a coupling between one oscillator of fixed frequency and the input electrodes of one tube, a coupling between the other oscillator of fixed frequency and the input electrodes of the other tube, a connection tying the output electrodes of said tubes together and to a point on the alternating current circuits of said device oscillator, a source of direct current potential coupled to the output electrodes of said tubes, a source of potential which varies with respect to a base value in accordance with telegraphy signals, and a relay actuated by said last mentioned potentials for controlling the conductivity of said tubes differentially in accordance with said last mentioned potentials for entraining said first mentioned oscillator by energy developed by one or the other of said two fixed frequency oscillators depending on the value of said last mentioned potentials relative to said base value.

8. In a telegraphy system of the type wherein signals are transmitted at a first frequency designated mark and a second frequency designated space, an electron discharge device oscillator having electrodes coupled in alternating current circuits arranged to produce oscillatory energy of carrier wave frequency, an oscillation generator of fixed frequency, a second oscillation generator of fixed frequency different than the frequency of said first oscillation generator of fixed frequency, two electron discharge coupling tubes having input electrodes and output electrodes, a coupling between one oscillator of fixed frequency and the input electrodes of one tube, a coupling between the other oscillator of fixed frequency and the input electrodes of the other tube, a connection tying the output electrodes of said

tubes together and to a point on said alternating current circuits, a control electrode in each of said tubes, a source of potential for said control electrodes such as to bias said tubes to substantially cutoff, a source of potential which varies relative to a base value in accordance with telegraphy signals, a relay having a winding coupled to said last named source and having an armature the position of which depends on the value of said potentials relative to said base value, a source of positive direct current connected to said armature, two contacts associated with said armature, a connection between one contact and one control electrode, and a connection between the other contact and the other control electrode.

9. In a telegraphy system of the type wherein signals are transmitted at a first frequency designated mark and a second frequency designated space, an electron discharge device oscillator having electrodes coupled in alternating current circuits arranged to produce oscillatory energy of carrier wave frequency, an oscillation generator of fixed frequency, a second oscillation generator of fixed frequency different than the frequency of said first oscillation generator of fixed frequency, two electron discharge tubes each having input electrodes and output electrodes, a coupling between one oscillator of fixed frequency and the input electrodes of one tube, a coupling between the other oscillator of fixed frequency and the input electrodes of the other tube, a connection tying the output electrodes of said tubes together and to a point on said first mentioned alternating current circuits, a control electrode in each of said tubes, a source of negative direct current potential connected to said control electrodes, a source of potential which varies with respect to a base value in accordance with telegraphy signals, a second pair of electron discharge tubes each having input and output electrodes cross-coupled so that when current flows in one of said last mentioned pair of tubes current is cutoff in the other of the tubes of said last mentioned pair of tubes and vice versa, means for controlling the conductivity of at least one of the tubes in said last mentioned pair in accordance with said telegraphy signals, impedances coupling the output electrodes of the tubes of said second pair of tubes to said control electrodes of the tubes of said first pair of tubes, and a source of positive direct current potential connected to the output electrodes of the tubes of both pairs of tubes.

10. In a telegraphy system of the type wherein signals are transmitted at a first frequency designated mark and a second frequency designated space, an electron discharge device oscillator having electrodes coupled in alternating current circuits arranged to produce oscillatory energy of carrier wave frequency, an oscillation generator of fixed frequency, a second oscillation generator of fixed frequency different than the frequency of said first oscillation generator of fixed frequency, two electron discharge coupling tubes each having input electrodes and output electrodes, a coupling between one oscillator of fixed frequency and the input electrodes of one tube, a coupling between the other oscillator of fixed frequency and the input electrodes of the other tube, a connection tying the output electrodes of said tubes together and to a point on said alternating current circuits, a control electrode in each tube of said pair of tubes, a source of negative direct current potential connected to

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the control electrodes of the tubes of said pair of tubes, a source of potential which varies with respect to a base value in accordance with telegraphy signals, a second pair of electron discharge tubes each having input and output electrodes, impedances cross-coupling the input and output electrodes of the tubes of said second pair of tubes so that when current flows in one of said tubes current is cutoff in the other of said tubes and vice versa, a coupling between said variable source of potential and the input electrodes of the tubes of said last named pair of tubes for controlling the conductivity of at least one of said tubes of said last named pair in accordance with said telegraphy signals, and impedances coupling the output electrodes of the tubes of said second pair of tubes to the control electrodes of the tubes of said first pair of tubes and to a source of positive direct current potential.

11. In a frequency shift telegraphy system, a source of oscillations of controllable frequency, a source of oscillations of a first and substantially fixed frequency, a source of oscillations of a second and substantially fixed frequency, two electron discharge devices having output electrodes and having input electrodes, a coupling between the input electrodes of one device and one of said sources of oscillations of substantially fixed frequency, a coupling between the input electrodes of the other device and the other of said sources of oscillations of substantially fixed frequency, couplings between the output electrodes of said devices and said source of oscillations of controllable frequency to entrain the frequency of operation thereof, a source of signals comprising pulse energy which varies between a first value representing mark and a second value representing space, and connections between said source of signals and electrodes of said pair of devices for differentially controlling the conductivities of the devices as the pulses vary in magnitude between said two values.

12. In a frequency shift telegraphy system, a regenerative tube generator of controllable frequency, a source of oscillations of a first and substantially fixed frequency, a source of oscillations of a second and substantially fixed frequency, two electron coupling tubes each having output electrodes and each having input electrodes, a coupling between the input electrodes of one of said coupling tubes and one of said sources of oscillations of substantially fixed frequency, a coupling between the input electrodes of the other coupling tube and the other of said sources of oscillations of substantially fixed frequency, couplings between the output electrodes of said coupling tubes and said regenerative generator to entrain the frequency of operation thereof, a source of signals comprising energy keyed between two conditions representing respectively mark and space, a second pair of electron discharge tubes each having an output electrode coupled respectively to an electrode of one of said coupling tubes to control the operativeness thereof, circuits interconnecting the electrodes of said second pair of tubes in such a manner that when one thereof draws current, current through the other thereof is reduced and vice versa, and connections between said source of signals and electrodes of at least one pair of said second pair of tubes for keying the same to be conductive or non-conductive as said signal energy condition changes.

13. In a frequency shift telegraphy system, a source of oscillations of controllable frequency, a

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source of oscillations of a first and substantially fixed frequency, a source of oscillations of a second and substantially fixed frequency, two electron coupling tubes each having output electrodes and each having input electrodes, a coupling between the input electrodes of one coupling tube and one of said sources of oscillations of substantially fixed frequency, a coupling between the input electrodes of the other of the coupling tubes and the other of said sources of substantially fixed frequency, couplings between the output electrodes of said coupling tubes and said first source of oscillations to entrain the frequency of operation thereof, a source of signals comprising pulse energy the magnitude of which changes between two values representing respectively mark and space, connections between an electrode of each of said tubes and a negative and a positive source of potential, a switch in at least one of said connections to each electrode, and a relay cooperating with said switch and controlled by said signals for applying a negative potential to an electrode in one of said tubes and a positive potential to an electrode in the other of said tubes and vice versa as the characteristic of said signals changes.

14. In a frequency shift telegraphy system, a regenerative generator of controllable frequency, said generator comprising an electron discharge device having an anode-like electrode and a control grid electrode regeneratively coupled for the production of oscillations, biasing circuits for the electrodes of said device including a resistance connecting the cathode thereof to ground, two sources of oscillations of substantially fixed but different frequencies, two electron discharge coupling tubes each having input electrodes coupled respectively to one of said sources of oscillations of substantially fixed frequency and having output electrodes coupled to said regenerative generator to entrain the same at the frequency of one or the other of said sources of substantially fixed frequency, a source of signals comprising pulse energy the magnitude of which changes between two values representing respectively mark and space, and connections between said source of signals and electrodes of said pair of tubes for differentially controlling the conductivity of the tubes as the magnitude of said signals varies between said two values.

15. In a frequency shift telegraphy system, a regenerative generator comprising an electron discharge device having an anode and a control grid and a cathode regeneratively coupled for the production of oscillations, said device having an additional control electrode coupled by a potentiometer resistance to its cathode, two sources of oscillations of substantially fixed and of different frequencies, two electron coupling tubes each having input electrodes coupled respectively to one of said sources of fixed frequency, and having output electrodes coupled to said regenerative generator to entrain the same at the frequency of one or the other of said sources of substantially fixed frequency, a source of signals comprising pulse energy which varies in magnitude between two values representing respectively mark and space, a second pair of electron discharge tubes each having an output electrode coupled respectively to an electrode of one of said coupling tubes to control the operativeness thereof, connections cross-coupling electrodes of said second pair of tubes so that when one draws current, current through the other is reduced and vice versa, and connections between said

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source of signals and the electrodes of at least one of the tubes of said second pair of tubes for controlling the conductivity thereof to thereby differentially control the conductivities of the tubes of the second pair of tubes.

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