

Nov. 9, 1943.

R. A. FOX

2,333,992

SIGNALING SYSTEM

Filed Oct. 17, 1940

4 Sheets-Sheet 1

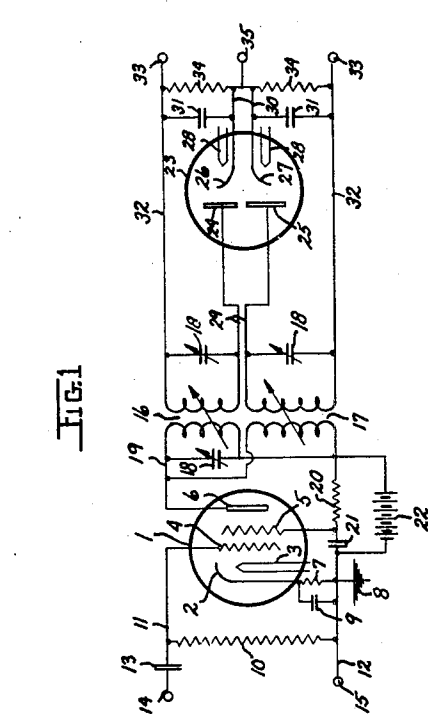


FIG. 1

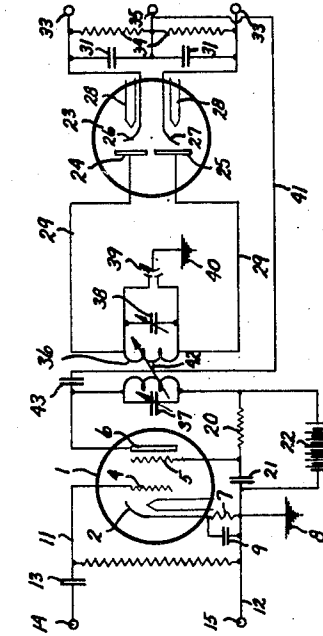


FIG. 2

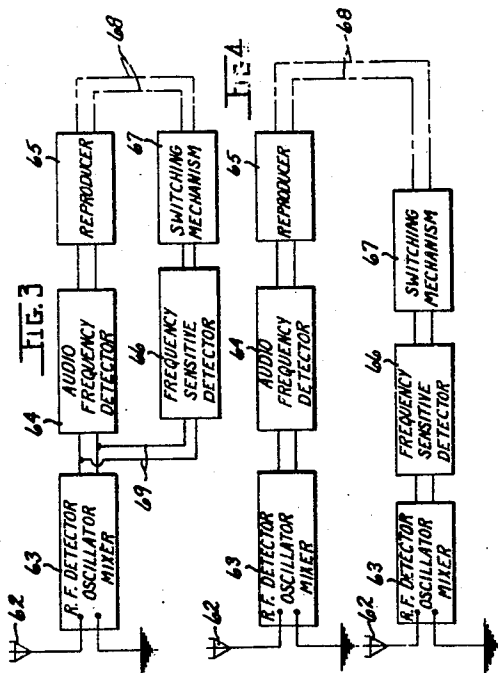


FIG. 3

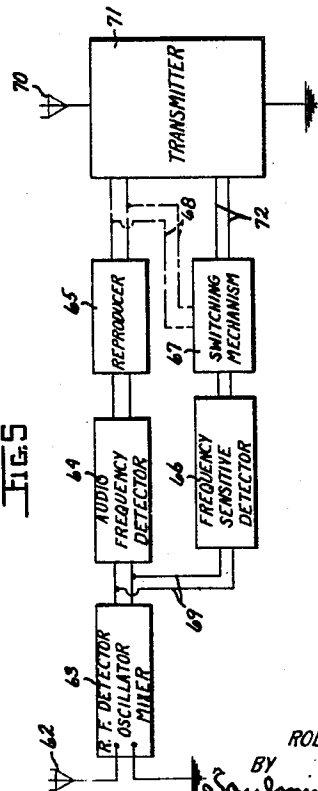


FIG. 4

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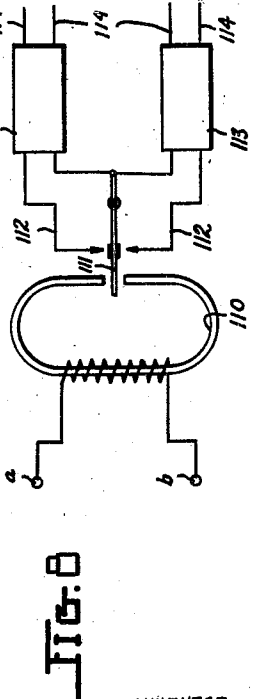
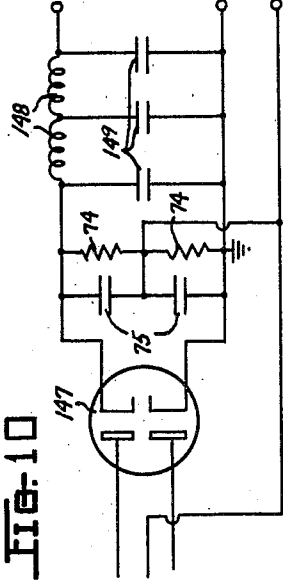
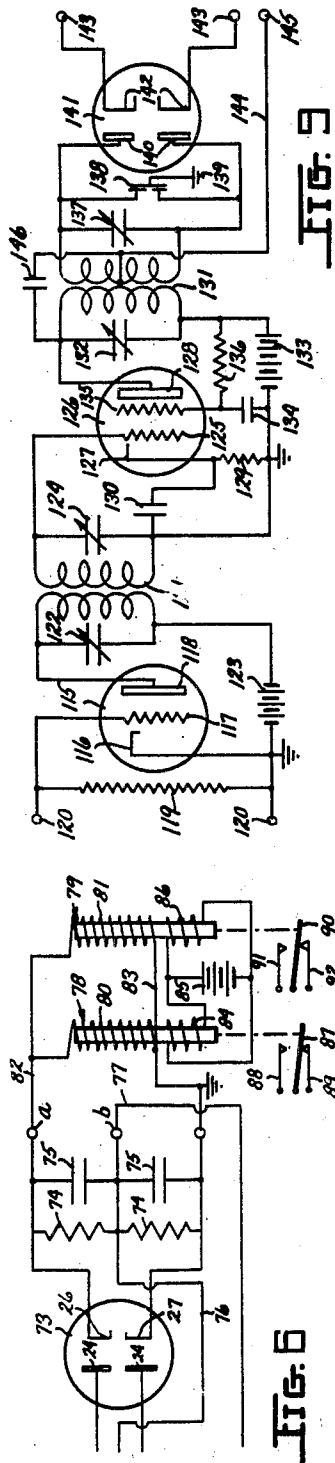


FIG. 10

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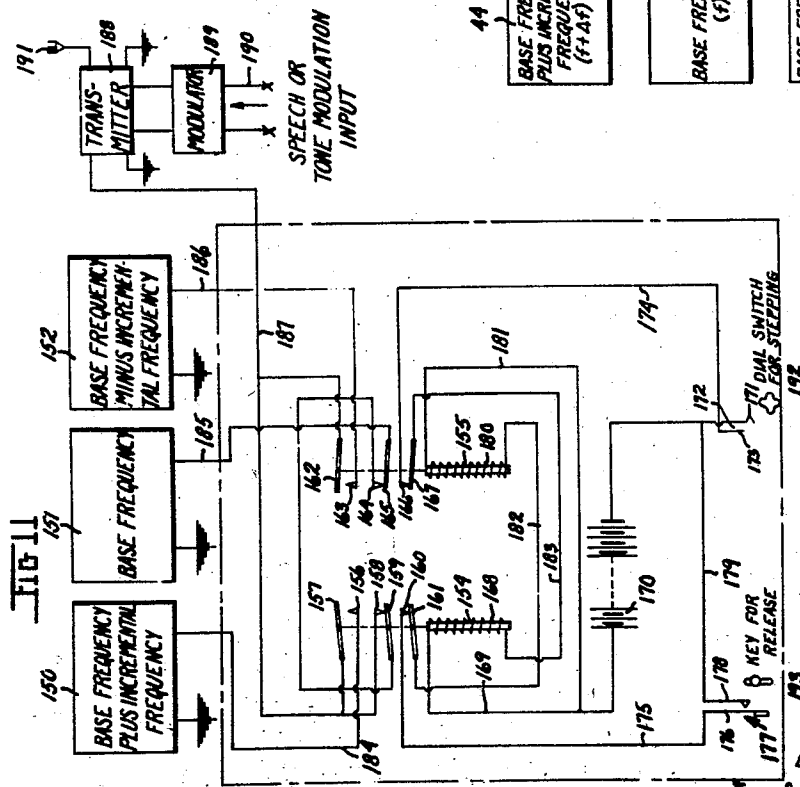
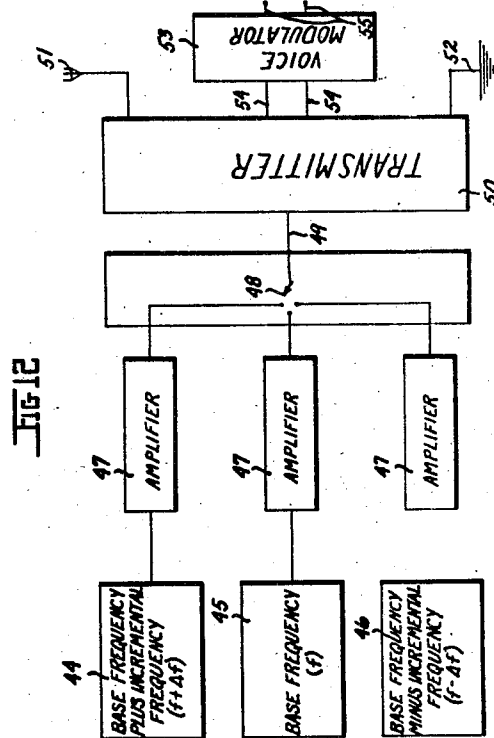
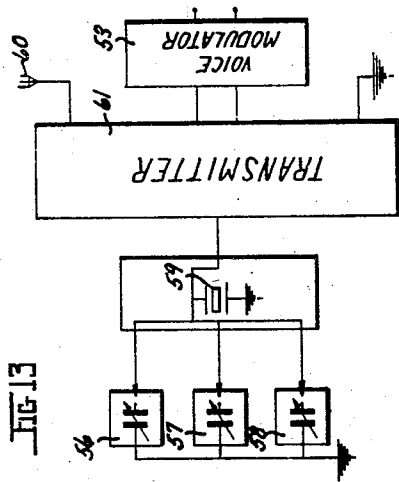
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SIGNALING SYSTEM

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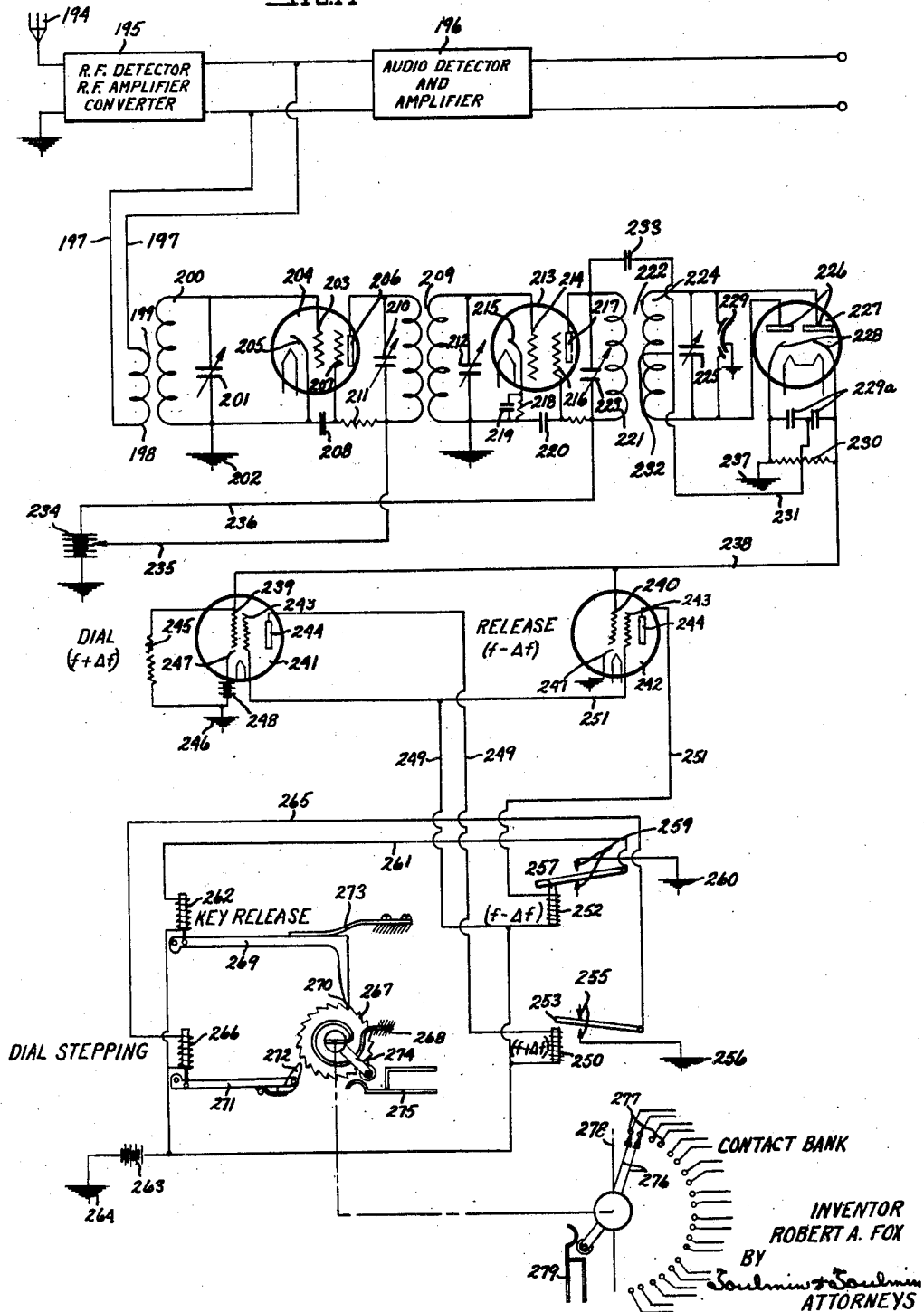
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SIGNALING SYSTEM

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FIG. 14



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UNITED STATES PATENT OFFICE

2,333,992

SIGNALING SYSTEM

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Application October 17, 1940, Serial No. 361,601

5 Claims. (Cl. 250—6)

In the art of signaling, particularly in remote control systems, there has arisen a desirability or necessity for transmitting and receiving impulses over telephonic carrier channels. When these impulses are superposed on carrier frequencies interference may be caused between the telephonic and impulse carriers, or their modulations, to such an extent as to distort voice communication or cause a false operation of the remotely positioned relays or switches. Whereas in the prior art discrimination or selectivity between the carriers is obtained on the basis of differences of amplitude of the transmitted or received currents or voltages, in accordance with the present invention an entirely different method and apparatus are employed to effect the necessary selectivity between the carriers and their side bands.

In brief, my invention contemplates the use of frequency discrimination as contrasted with selectivity obtained solely by differences of current or voltage amplitudes. In carrying out my invention I provide a source of frequencies which consists of a base frequency and an incremental frequency either added to or subtracted from the base frequency, which when acted upon by a frequency sensitive detector will be converted into direct currents of opposite polarities to which the final receiving devices respond selectively.

Accordingly, the primary object of the present invention is to provide an improved signaling and remote control system for use either in radio or wired circuits.

Another object is to provide a circuit of the character referred to, which is sensitive to changes in the frequency but not in the amplitude of the transmitted or received impulses.

Other objects are to provide an improved system for dialing or operating teletype machines over a radio carrier wave without interference with the voice modulation or other tone modulation being transmitted simultaneously; to provide a composite telephone and telegraph or other impulse system of the carrier wave type, in which static is prevented from affecting the telegraphic impulses being transmitted through the system. Other objects and features will be apparent as the specification is perused in connection with the accompanying drawings.

In the drawings:

Figure 1 is a circuit illustrating a frequency-detecting device which is used to advantage in effecting complete discrimination between the

carrier waves of a composite transmitting or receiving system.

Figure 2 shows a modified form of the circuit shown in Figure 1.

Figure 3 illustrates a superheterodyne radio receiver which employs a frequency sensitive detector to provide frequency discrimination.

Figure 4 is a circuit somewhat similar to Figure 3, but employing two antennae and interconnections between the two receiving circuits.

Figure 5 shows the application of the invention to a wired link, including a superheterodyne receiver, and connected between a receiving antenna and a transmitting antenna.

Figures 6, 7 and 8 illustrate the manner in which the improved frequency discriminating circuit, and including the frequency sensitive detector, may be employed to energize and actuate relays; selectors or other mechanism.

Figure 9 shows a circuit employing the frequency sensitive detector and so arranged as to prevent fading or to prevent changes in signal amplitude from having any effect on the output voltage.

Figure 10 is similar to Figure 6 except that an additional filter is added to the frequency sensitive detector.

Figure 11 shows a transmitting circuit including a dial switch for transmitting selective impulses over a radio link to a receiving station, which has a contact bank and responds to the impulses transmitted by the dial. The receiving circuit is provided with the improved frequency detector and is shown in Figure 14.

Figure 12 shows a switching mechanism at a transmitter station for controlling the rotation of incremental and decremental frequencies which affect the receiving circuit as impulses of different polarities.

Figure 13 illustrates the use of a crystal for controlling the frequencies radiated by the system shown in Figure 12.

Figure 14 shows a superheterodyne receiving circuit provided with the improved frequency detector for actuating receiving dial mechanism, or a contact bank in response to transmitted impulses originating at a circuit similar to that shown in Figure 11.

In telephone practice over wired conductors, and in other electrical fields, relays, switches, selectors and similar apparatus are operated by electric currents. Direct current or alternating current of high and low frequency, also direct current of a polarity reversing character may be employed for this purpose. However, in apply-

ing these methods to a radio carrier wave, direct current cannot be used but instead only alternating currents can be superposed on the carrier wave. The carrier wave itself may be transmitted in impulses, and these rectified at the receiver into direct current impulses, but the polarity cannot be reversed, and under such conditions the carrier wave cannot be used for transmitting voice modulations at the same time.

Alternating current may be applied as modulations superimposed on a radio carrier wave, and several such alternating currents of different frequencies may be transmitted simultaneously and separated at the receiver and rectified into direct currents which may have different polarities. However, this interferes with voice transmission which it may be desirable to transmit at the same time, unless very elaborate wave bands or elimination filters are employed. The device which will be described presently makes it possible to transmit the equivalent of direct current impulses or currents of a continuous nature without the use of alternating current modulation. Furthermore, the polarity of the direct current may be changed, and this may also be accomplished at the same time that voice transmission is taking place, without any interference with the voice transmission or other modulation. The efficacy of the improved system to be described presently depends on the use of a frequency sensitive detector, such for example, as is shown in Figures 1 and 2.

In Figure 1 the numeral 1 designates the envelope of an ordinary tetrode amplifying tube containing an indirectly heated cathode 2, a heater 3, a control grid 4, a screen grid 5 and a plate 6. The cathode 2 is connected through a resistor 7 to ground 8, the resistor being shunted by a condenser 9. There is a resistor 10 shunted between the control grid conductor 11 and the cathode conductor 12. A condenser 13 is connected between the upper end of the resistor 10 and the input terminal 14. The other input terminal is indicated at 15.

The output circuit of the tube 1 contains a pair of transformers 16, 17 which are tuned to different frequencies by the condensers 18, the upper ends of the primaries of these transformers being connected to the plate 6 by a conductor 19, and the lower ends of the primaries being connected to the cathode 2 through a resistor 20 and a condenser 21. The plate potential is derived from a battery 22, poled as indicated, and connected between the lower ends of the primaries of the transformers 16, 17 at a point between the condenser 21 and the resistor 7. In addition to the amplifier tube 1, the circuit employs a double unit rectifier indicated at 23, of any suitable and well known type, and containing a pair of plates 24, 25 respectively, which cooperate with a pair of indirectly heated cathodes 26, 27. Heaters 28 may be provided for the cathodes.

The inner ends of the secondaries of the transformers 16, 17 are connected through conductors 29 to plates 24, 25 respectively. Separate conductors 30 are taken from the cathodes, and a condenser 31 is connected between each conductor and the wires 32 which pass to the extreme outer terminals of the secondaries of the transformers 16, 17. The wires 32 terminate at their ends opposite the transformers in a pair of terminals 33 for connection to succeeding apparatus, examples of which will be described hereinafter. Resistors 34 are connected in shunt

to the condensers 31, these resistors being connected at the middle to form a terminal 35. A circuit, such as described, has the ability to receive changes in frequency and obtain from such changes direct current voltages of different polarities. Any alternating current of either high or low frequency may be connected to the input terminals 14, 15 and the voltage is impressed on the grid circuit of the amplifier tube 1, this grid being biased by the condenser 9 and the cathode resistor 7.

The pulsating current which appears in the plate circuit 6 is fed into the two tuned parallel windings of the transformers 16, 17. These windings are adjustably coupled, as indicated by the arrows, and each of them is tuned by its respective condenser 18 to a frequency which is different from the original frequency. For example, the secondary of the transformer 16 may be tuned by its condenser 18 to a frequency 1000 cycles higher than the frequency to which the primary winding is tuned by its condenser 18, and the secondary of the transformer 17 may be tuned by its condenser 18 to a frequency 1000 cycles lower than that to which its primary winding is tuned. The tube 23 is employed as a rectifier, the condensers 31 serving as alternating current by-passes, while the resistors 34 serve, in effect, as potentiometers for equally dividing the potential applied to the plates 24.

The voltages across the secondaries of the transformers 16, 17 will be the same for the frequency to which the primary windings are tuned, so that when rectified by the tube 23 and fed in opposite directions through the resistors 34, they will oppose each other and cancel out. Under this situation no voltage will appear across the terminals 33, 35. If the frequency across one primary is now changed to 1000 cycles higher, it comes into tune with its secondary, which is tuned to this frequency, and out of tune with the other secondary, resulting in two currents through the resistors 34 of unequal magnitude, causing a voltage to appear across the terminals 33 since cancellation does not take place at the resistors 34. If the frequency across the primary were then changed to a value lower by 1000 cycles than the original base value, then the secondary of the transformer 16 is out of tune and the secondary winding of the transformer 17 is in tune, so that currents are again unequal and a voltage appears across the terminals 33, but of opposite polarity than before. Thus by shifting the frequency from a certain center or base frequency to one higher, and then to one lower, impulses of direct current voltage will appear across the terminals 33, and these impulses can be used to operate other equipment for remote control or signaling purposes.

Figure 2 is a system which operates similarly to Figure 1, except that it employs only a single transformer instead of a pair of transformers. This transformer is indicated at 36, the primary of which is tuned by a variable condenser 37, and the secondary by a condenser 38. The remaining parts, which are similar to parts of Figure 1, have been given corresponding reference numerals. These elements need no further explanation.

There is a double pole rotary condenser 39 connected across the variable condenser 38 and grounded as indicated at 40. A wire 41 is connected between the middle terminal 35 and a conductor 42 which is connected to the mid tap on the secondary of the transformer 36 for the pur-

pose of supplying a direct current path for the rectified current back to the plates. A condenser 43 is connected between the conductor 42 and the plate 6 of the tube 1 in order to isolate the last-mentioned plate potential from the secondary of the transformer 36.

It is apparent that by rotating the movable element of the condenser 38, the secondary of the transformer 36 can be first tuned to a frequency greater than a given or base frequency and then to a frequency less than the base frequency with exactly the same effect as in Figure 1, in which impulses of direct current voltage will appear across the terminals 34 and having opposite polarities. A suitable transmitting circuit for generating the various frequencies necessary for the operation of the circuits shown in Figures 1 and 2 will be described in connection with Figure 12. Condenser 39 serves to balance the circuit to ground so as to have only inductive coupling between the primary and secondary of transformer 36.

The rectangles 44, 45 and 46 indicate in a general way three crystal controlled, or other type of master frequency controlled oscillators of any suitable and well known type, in which the rectangle 45 indicates the oscillator of the base frequency, the rectangle 44 the oscillator of the plus incremental frequency and the rectangle 46 of the minus incremental frequency. The output of each of the oscillators is connected through any suitable form of amplifier 47 to the contacts 48, or any standard form of multiple switch. The output conductor of the switch is indicated at 49, and passes into a multiple-stage power amplifier indicated at 50. The output of the amplifier is connected in any suitable and well known manner to an antenna 51 and a ground indicated at 52. The rectangle 53 designates a modulating tube, the output of which is fed through the conductors 54 into the power amplifier 50. Wires 55 pass to any suitable circuit on which the electrical impulses corresponding to voice undulations can be impressed.

Assume that the difference frequency between the oscillators 44 and 45 is 1000 and the difference frequency between the oscillators 46, 45 is 1000—, the oscillator 45 in both cases being considered the base frequency from which these differences are measured, the three frequencies are amplified by their respective amplifiers 47 and applied to the contacts of the switch 48. Thus by moving the switch in any suitable manner, the 1000 cycle plus frequency is first passed through the power amplifier 50, radiated at 51, and then the 1000 cycle minus frequency is given the same treatment. Now let us assume that the circuit shown in Figure 1 is connected to a receiving antenna and hence is adapted to receive the two frequencies generated at the rectangles 44 and 46, for example, through a demodulating oscillator and a radio frequency detector. Certain forms of a suitable receiving circuit will be explained presently in connection with Figures 3 and 4.

The switch 48 (Figure 12) may be moved in any suitable manner, for example, by a continuously operating contact making and breaking device, or by a relay operated from a telephone dial or tape, or by manual operation. A systematic code may then be transmitted, consisting of three different frequencies, namely $f+\Delta f$, f and $f-\Delta f$, transmitted in various combinations. If the frequency $f+\Delta f$ is alternated with the frequency $f-\Delta f$, there will appear across the terminals 33, in Figures 1 and 2, direct current poten-

tials which reverse in polarity at the same rate as the reversals which take place at the switch 48. The secondary of 36 is always tuned to the base frequency and changing to $f+\Delta f$ and $f-\Delta f$ causes the secondary to be out of tune for the $f+\Delta f$ and $f-\Delta f$ conditions. This detuning causes the + and - voltages to appear when $f+\Delta f$ and $f-\Delta f$ are transmitted. It is apparent that the reversals of the direct current potentials at the terminals 33 give satisfactory selection methods of operating two relays, one of which responds to potentials of one polarity and the other responding to potentials of the other polarity. Such a system will be explained in connection with Figures 8 to 10, inclusive, and Figure 14. While the usual method of operating the transmitter would be to alternate the incremental frequency as applied to the antenna with the decremental frequency, it will be understood that if desired the incremental frequency may be transmitted as succeeding impulses.

If desired, crystal controlled oscillators may be employed at the rectangles 44, 45 and 46, the crystals of each oscillator being shunted by an adjustable condenser the variations of which control the frequencies generated by the respective oscillators. Such a system is shown in Figure 13, in which the variable condensers are indicated at 56, 57 and 58. A master oscillator is controlled as to frequency by the crystal 59, and changes in the transmitted frequency may be brought about by the variable condensers 56, 57 and 58 which are shunted to ground in any suitable manner across the oscillator and controlled by switches, as is well known in the art. It will be understood that there is provided at a suitable point a switch similar to the element 48 in Figure 12, which serves to connect the output of the master oscillator to the antenna 60 through a suitable power amplifier apparatus 61, and simultaneously controlling the frequency at the condensers 56, 57, 58 which is delivered to the power amplifier oscillator apparatus. The latter may also receive voice current modulations from the devices contained in the rectangle 53.

In Figures 3 and 4 typical forms of receiving circuits are illustrated, including the frequency sensitive detector shown in Figures 1 and 2 to obtain selective operation of direct current relays at a remote position, and controlled by one of two frequencies originating at a transmitter station. In Figure 3 the receiving antenna is indicated at 62, and is connected to a superheterodyne receiving circuit including a radio frequency detector and demodulator, contained in a rectangle 63. The output of the detector feeds an audio frequency detector indicated by the rectangle 64, and is connected to a reproducer indicated by the rectangle 65 of any suitable type. From a position between the rectangles 63 and 64 there is taken a pair of conductors which feed the input circuit of a radio frequency detector indicated by the rectangle 66, such for example, as is illustrated in Figure 1. The output of the frequency sensitive detector may be connected to a switching mechanism indicated by the rectangle 67 of a type which will be described presently, this switching mechanism being so arranged as to perform a desired function on the reproducer, as indicated by the dot-dash lines 68.

Assume that the antenna 62 receives in succession the three frequencies generated in the rectangles 44, 45 and 46 (Figure 12). The voice modulated carrier which is the frequency modulated carrier passes through the radio frequency

detector and the demodulator, where the carrier frequencies are reduced in accordance with superheterodyne practice. The voice modulated intermediate frequency is then passed through the audio frequency detector 64, into the reproducer 65. However, the impulse modulated intermediate frequency is taken from the main receiving circuit at the conductors 69 and fed through the frequency sensitive detector 66, and finally to a switching mechanism 67.

It is apparent that the detector and demodulator 63 serves merely to lower the frequency spectrum of the frequencies $f+\Delta f$, f or $f-\Delta f$, but all of the original modulation side bands are retained and any frequency changes of a small amount, such as Δf , are changed into corresponding changes at the new frequency, the only difference being the percentage difference between the frequency change and the new carrier frequency produced by heterodyning. For example, if the frequency of the impulse transmitter was originally 100 cycles from a center or base frequency of 3,000,000 cycles, and this 3,000,000-cycle wave is converted to an intermediate frequency of 450,000 cycles at the receiver, then the frequency change will still be 1000 cycles above and below the new carrier frequency of 450,000 cycles. The frequency shift of 1000 cycles is not divided in the same manner as the original carrier frequency is divided, but remains the same.

It was pointed out in connection with Figure 1 that when $f-\Delta f$ frequency is applied to the frequency sensitive detector, a direct current potential will appear at the upper terminal 31 of the outgoing line. On the other hand, when a frequency $f+\Delta f$ is applied to the detector a direct current potential of negative polarity will appear at the upper terminal 31. The base frequency f , upon reaching the frequency sensitive detector, will be balanced out at the resistors 34 and therefore no voltage will reach any switching mechanism which is connected to the frequency sensitive detector. The switching mechanism 67 may include a pair of relays, one of which responds to direct current potentials of one polarity and the other responding to potentials of the opposite polarity. It is apparent that these relays may be so connected with the reproducer, which in the case of Figure 3 might be a loud speaker, as to effect any kind of control over the loud speaker. Such a control might be the closing of the circuit of the loud speaker or a change in volume delivered by the loud speaker, over which absolute control is exercised by the frequencies $f+\Delta f$ and $f-\Delta f$ generated at the transmitting station and transmitted in any desired sequence.

In Figure 4 there is shown a receiving circuit in which the signaling and audio receiving channels are separated, and each passes through its individual radio frequency detector and demodulator apparatus in order to perform functions which might not be accomplished by the system shown in Figure 3. It is apparent that the same considerations of reducing the carrier frequency by the heterodyning effect apply to the circuit shown in Figure 4 as in the case of the circuit shown in Figure 3. The dot-dash lines 68 indicate the same function as in Figure 3, namely, that connections may be taken from the switching mechanism 67 to perform any desired function with respect to the reproducer 65.

The heterodyning principle has been carried one step farther in Figure 5, in that the use of the frequency sensitive detector 66 has been shown in connection with a wire link between the

receiving antenna 62 and a transmitting antenna 70. As in the case of Figure 3, the frequency sensitive detector 66 and the audio frequency detector 64 are connected to the common heterodyning apparatus 63, and the output of the reproducer 65 is taken to a suitable and well known form of radio transmitter 71 including an oscillator. The switching mechanism 67 is connected to the output circuit of the frequency sensitive detector, and may be arranged to control certain functions in the transmitter 71 through the wires 72. The dot-dash lines 68 indicate that the switching mechanism 67 may also serve some useful control function with respect to the reproducer 65 and also the transmitter 71. It is apparent that in the system shown in Figure 5 complete control of the transmitter 71 may be exercised from the transmitting end of a radio link, of which the antenna 62 is the receiver.

In Figures 6, 7 and 8 I have shown various forms of switching mechanism which lend themselves to operation when energized by positive and negative polarity impulses appearing at the upper terminals of the frequency sensitive detectors shown in Figures 1 and 2. The detector is indicated at 73, and it will be understood that the detector is preceded by suitable heterodyning apparatus in case the $f+\Delta f$ and $f-\Delta f$ frequencies are transmitted as carrier frequencies. Across the cathodes 26, 27 there is connected a pair of resistors 74 which are shunted by condensers 75. A wire 76 is taken to the mid tap of the secondary of a transformer 36 (Figure 2) or to any suitable mid-point in the plate circuit of the frequency sensitive detector of Figure 1. The wire 76 is extended into a wire 77 from which the voice modulation may be obtained. The output of the frequency sensitive detector in Figure 6 is fed into a pair of electromagnets 78, 79 provided with coils 80 and 81, respectively. A conductor 82 is connected between the upper ends of the coils 80, 81 and the cathode 26 of the detector, while the conductor 83 is connected between the lower ends of said coils and the other cathode 26 of the detector. The armature of the electromagnet 78 is extended to receive a coil 84 which is wound in the same direction as the coil 80, and forms part of a circuit including a battery 85. The latter is so poled as to make the upper portion of the coil 84 negative. The core of the electromagnet 79 is similarly extended to receive a coil 86 wound in the same direction as the coil 81, the coil 86 being connected to the battery 85 in such a way as to make the upper portion of the coil positive with respect to the lower portion thereof. There is a spring armature 87 directly below the electromagnet 78 and responsive to the electromagnetic field, this armature being adapted to swing between a pair of stationary contacts 88 and 89 making alternate contact therewith. There is a corresponding spring armature 90 positioned directly below the electromagnet 79, and this armature is adapted to swing between a pair of stationary contacts 91, 92. It will be understood that the armatures 87, 90, also the contacts 88, 89, 91 and 92 are connected to external circuits which may include relays. Assuming that there is an amplifier preceding the frequency sensitive detector 73, as in the case of Figure 1, this output current is rectified in the detector 73 and passed through the resistors 74 and filtered by the condensers 75.

Thus there will appear at the point *a* an output voltage which is positive for one frequency change and negative for the other frequency

change, and zero for the center frequency (assuming that the three frequencies $f+\Delta f$, f and $f-\Delta f$ have been received by the amplifier, using a heterodyning effect in case these frequencies are superposed on a carrier. At the point b there will appear a direct current voltage and an audio frequency voltage if the carrier were originally modulated. Only the voltage at a is employed for the operation of the electromagnets 78 and 79. The voltage from the battery 85 is applied to the electromagnets in such a way as to polarize them in different directions so that they will differentiate between positive and negative potentials. It is apparent that the current from the battery passes through the coils 84, 86 in opposite directions with respect to their electromagnets. Consequently, in order to operate the electromagnet 78 it is necessary that the current passing through the coil 80 shall be in the same direction as the current passing through the coil 84, and this current must be in the opposite direction to the current which passes through the coil 81 for energizing the electromagnet 79. The electromagnet 78 will therefore pull up the armature 87 when the potential at the point a is such as to make the upper portion of the coil 80 negative. The electromagnet 79 will pull up the armature 90 when the potential at the point a is such as to make the upper portion of the coil 81 positive. The make and break operation which takes place at the armatures 87, 90 may be used to perform many operations under the control of a distant transmitter.

Still another way in which the frequency sensitive detector 73 (Figure 6) can be arranged selectively to operate two relays is shown in Figure 7. The output of the detector 73 is caused to be fed into a pair of thermionic tubes or relays 93, 94 provided with cathodes 95, 96, control grids 97, 98 and plates 99, 100. A resistor 101 and a battery 102 are connected in series across the grid-cathode circuit of the tube 93, and a resistor 103 is connected directly across the grid-cathode circuit of the tube 94. The battery 102 is so poled as to make the grid 97 negative with respect to its cathode, and a connection is made from the negative side of the battery through a conductor 104 to one of the cathodes of the detector 73. The grids 97, 98 are connected together, and also connected through a conductor 105 to the point a which leads to the other cathode of the detector. The output circuits of the tubes 93, 94 include a plate battery 106 and an electromagnet 107. Directly below these electromagnets there is a pair of spring armatures 108 adapted to swing between a pair of fixed contacts 109.

As in the case of Figure 6, assume that the point a becomes first positive and then negative, due to the rectification within the detector 73 of the $f+\Delta f$ and $f-\Delta f$ frequencies, if the potential applied by the battery 102 to the grid 97 is such as to normally cut off the plate current flowing through the tube, only a positive charge on the grid will cause current to flow through its electromagnet 107. When the positive potential is removed at the point a the electromagnet will release. The resistor 103 connected across the input circuit of the tube 94 cooperates with the tube in such a way that when a negative charge is applied to the grid 98 its electromagnet 107 will become deenergized. Consequently, in the case of the tube 93, current through its electromagnet 107 will cause its armature 108 to pull up and make contact with its upper terminal

109, whereas in the case of tube 94 a negative charge on the grid will cause its electromagnet 107 to release, permitting its armature 108 to make contact with the lower terminal 109. The armatures 108 and the contacts 109 obviously may be connected to external circuits for control purposes. Thus the distant transmitter which generates and radiates the frequencies $f+\Delta f$, f and $f-\Delta f$ can readily control the electromagnets 107 in any particular sequence, depending on the sequence in which the different frequencies are transmitted.

In Figure 8 there is shown another method and apparatus which might be used to operate a relay from the frequency sensitive detector. The elements corresponding to those described in connection with Figures 6 and 7 are identified in Figure 8 by the same reference characters. The output of the detector is taken to a polarized relay indicated at 110. A reed 111 is adapted to oscillate between the poles of the relay 110, this reed making and breaking the contact between the terminals 112. The rectangles 113 represent electrical devices, including the necessary energizing voltages which are under the control of the make and break contacts at the polarized relay. The wires 114 connect these devices with other relays and switches, depending on the type of circuit being controlled. Thus when potential at the point a is positive, as a result of the detector 73 receiving the $f+\Delta f$ frequency, the reed 111 may be moved upwardly to make contact. On the other hand, when the point a is at a negative potential, due to the reception by the detector 73 of the $f-\Delta f$ frequency, the reed 111 is pulled downwardly to make contact. When the frequency f is received by the detector 73 the reed 111 is in its neutral position because, as explained above, the impulses of the base frequency are balanced out in the resistors 74.

In Figures 9 and 10 there are shown two ways of preventing fading and changes in signal amplitude from having any effect on the output voltage from the frequency sensitive detector. However, the detector will not be greatly affected by such changes and for most purposes no special precautions will be necessary. Figure 9 shows a system for "ironing out" amplitude changes when necessary. A current limiting tube 115 is employed, this tube being provided with an indirectly heated cathode 116, a grid 117 and a plate 118. There is a resistor 119 connected between the grid of the plate, and the input terminals 120 are connected to any circuit which receives the $f+\Delta f$, f and $f-\Delta f$ frequencies, suitable heterodyning effects being provided in the receiver.

The output circuit of the limiter tube includes a transformer 121, the primary of which is shunted by a condenser 122. There is a plate battery 123 connected between the transformer primary and the cathode 116. A variable condenser 124 is shunted across the secondary of the transformer 121 and a connection is taken to the control grid 125 of an amplifier tube 126. The latter includes an indirectly heated cathode 127 and a plate 128. The cathode is grounded through a resistor 129, and a small fixed condenser 130 is connected between the cathode 127 and the condenser 124.

The output or plate circuit of the tube 126 includes a transformer 131, the primary of which is shunted by a variable condenser 132, and the latter is connected to the cathode through a plate battery 133 and through the resistor 129.

A condenser 134 is connected between the negative side of the battery 133 and a grid 135 contained within the tube. There is a resistor 136 connected between the condenser 134 and the positive side of the battery. The secondary of the transformer 131 is shunted by a variable condenser 137, and the latter in turn is shunted by a multi-pole condenser 138 which is grounded as indicated at 139. The plates 140 of the frequency sensitive detector 141 are connected across the secondary of the transformer 131, as indicated. The detector includes a pair of indirectly heated cathodes 142, from which terminals 143 are taken. There is a wire 144 terminating in a terminal 145 and connected to the midpoint of the secondary of the transformer 13, this wire being extended through a small fixed condenser 146 to the plate 128 of the tube 126. As in the case of the circuit shown in Figures 6, 7 and 8, the terminals 143 may be connected to relays which respond selectively to negative and positive direct current potentials produced in the output circuit of the detector 141.

Assuming that the limiting tube 115 has a fairly low plate voltage 123 and no bias due to the direct connection of the resistor 119, the tube will quickly overload and will provide only a limited output. Once this tube has been overloaded, no further output can be obtained from it. The entire circuit, including the limiting tube, is so adjusted that weak signals cause the limiting tube to function, and this limited output is then amplified by the tube 125 to provide sufficient power for operating the frequency sensitive detector 141. The direct current output voltage of the detector thus remains constant for a wide range of input voltage levels. It is apparent that if automatic volume control is also provided in the receiver, a still wider range of input voltage levels may be obtained.

In Figure 10, I have shown still another circuit for limiting the current changes within a system employing the frequency sensitive detector. Instead of inserting a limiter tube before the amplifying stage, as in Figure 9, I provide a filter in the output circuit of the detector which serves to smooth out the variations of output current, thus transmitting to the relays, which respond to the positive and negative polarities of the detector output current, direct currents of substantially constant amplitude. In this figure the frequency sensitive detector is designated 147, and the output of the detector is connected to an alternating current filter comprising series chokes 148 and shunt condensers 149. It is apparent that if desired the filter elements 148, 149 can be employed in addition to the limiter tube 115 shown in Figure 9 in order still further to maintain a constant direct current level at the output terminals of the detector.

In Figure 11 I have shown a transmitting circuit for generating and radiating the $f+\Delta f$, f and $f-\Delta f$ frequencies, these frequencies, with the exception of the base frequency, being transmitted in any suitable succession for the purpose of controlling relays at a distant receiving station. A typical receiving station which cooperates with the system shown in Figure 11 is illustrated in Figure 14. The rectangle 150 contains any suitable and well known apparatus, such as a tube oscillator for generating the $f+\Delta f$ frequency. The rectangle 151 designates similar apparatus for generating the base or center frequency f , while the rectangle 152 designates apparatus for

generating the $f-\Delta f$ frequency.

There is a pair of multi-contact switches in two lines, under the control of electromagnets 154 and 155. One set of switches (the left-hand set) consists of a fixed contact member 156 and a spring contact member 157, these two switch contacts being normally open; a fixed contact member 158 and a spring contact member 159, these contacts being normally closed; and a fixed contact member 160 and a spring contact member 161, these contacts being normally closed. The right-hand side of the multi-switch bank comprises a spring contact member 162 and a fixed contact member 163, these contacts being normally open; a fixed contact member 164 and a spring contact member 165, these contacts being normally closed; and a fixed contact member 166 and a spring contact member 167, these contacts being normally closed. The left-hand group of switches is under the control of the relay 154, and the right-hand group under the control of the relay 155.

The relay 154 has a coil 168, the upper end of which is connected through a conductor 169 through a battery 170 to the spring contact 171 of a dial switch, indicated at 172. The fixed contact member 173 of the dial switch is connected through a conductor 174 to the fixed contact member 166. There is a conductor 175 connected between the spring contact member 160 and the fixed contact 176 of a key switch indicated at 177. The spring member 178 of the key switch is connected through a conductor 179 to the spring member 171 of the dial switch.

The electromagnet 155 is provided with a coil 180, and a conductor 181 is taken from the upper end of the coil to the conductor 189. The conductor 182 is connected between the lower end of the coil 180 and the spring contact 161. The lower end of the coil 188 is connected through a conductor 183 to the spring contact 167. A wire 184 is taken from the generator 150 to the fixed contact 156. A conductor 185 is taken from the generator 151 to the spring contact 165, and a conductor 186 is connected between the generator 152 and the fixed contact 163. A conductor 187 is connected each to the spring contact members 157, 158 and to the spring contact member 162, this conductor passing into a transmitter 188 of any suitable and well known type. A modulator 189 may be connected to the transmitter, the input of the modulator as indicated at 189, being connected to a speech or tone modulation device. An antenna 191 is connected to the transmitter.

In operation, when the key 192 of the dial switch is rotated through ninety degrees, the spring member 171 makes contact with the fixed contact 173. A circuit is then established from the battery 170 through the dial switch, through conductor 174, through the contact members 166, 167, through the dial relay 154 and back to the battery, causing energization of the relay. This relay will then close the circuit between the contact members 157, 156, and will also open the circuit between the contact members 158 and 159 and between contact members 160, 161. The closing of the contacts 156, 157 connects a circuit from the generator 150 to the transmitter 188, causing $f+\Delta f$ frequency from that generator to be radiated at the antenna 191 as a modulated carrier wave. It is assumed that the carrier wave amplified in the transmitter 188 is simultaneously being modulated by speech

or tone impulses transmitted through the wires 190. Consequently, the antenna 191 transmits the carrier $f+\Delta f$ frequency and also the same carrier modulated by the speech or tone impulses.

At the receiving circuit, one example of which will be described in connection with Figure 14, suitable and well known devices are employed to separate the two transmitted waves. The opening of the contacts 158, 159 by the relay 154, in effect, opens the circuit of the conductor 185 and thus prevents the base frequency f from being conducted to the transmitter 188. When the contact members 160, 161 are opened by the relay, the opposite relay 155 is rendered inoperative. It will be noted that the generator 152 cannot transmit impulses to the transmitter 188 because its circuit is opened at the contacts 162, 163. Consequently, as the dial 192 is rotated the frequency $f+\Delta f$, is radiated at the antenna 191 and the circuit connections are such that the base frequency f , also the differential frequency $f-\Delta f$ are prevented from reaching the transmitter. It is apparent that as many impulses as are necessary of the $f+\Delta f$ frequency may be radiated at the antenna 191 by simply rotating the dial switch.

When the key 177 is operated, contact is made at the contacts 176, 178 through the contact members 160, 161, through conductor 182, through the coil 189 and the battery 170, back to the conductor 179 to the key switch. Thus the relay 155 is energized to close the circuit between the contact members 162, 163, also to open the circuit between the contact members 164, 165 and between the contact members 166, 167. The closing of the contacts 162, 163 closes the circuit from the generator 152 through the conductors 186, 187 to the transmitter, thus applying the $f-\Delta f$ frequency to the transmitter 188. The opening of the contacts 164, 165 opens the circuit through the conductor 185 of the generator 151, thus preventing the base frequency from being applied to the transmitter. The opening of the contacts 166, 167 renders the dial relay 154 inoperative. It will also be noted that the contacts 156 and 157 are open since the dial relay is deenergized, thus preventing the $f+\Delta f$ frequency from being applied to the transmitter 188. Consequently, as the key 193 is actuated the frequency $f-\Delta f$ is radiated from the antenna 191.

In Figure 14 there is illustrated a circuit which is suitable for receiving the impulses radiated from the antenna 191 in Figure 11. The receiving antenna is designated 194, and the carrier wave modulated by speech frequency and the $f+\Delta f$ or $f-\Delta f$ frequencies is passed through a standard superheterodyne receiving circuit, indicated by the rectangle 195. The speech modulated carrier is conducted, after the heterodyning stage, to a standard audio frequency detector and amplifier, indicated by the rectangle 196, and from there to a loud speaker (not shown) or to a modulation stage (not shown) for retransmission. Conductors 197 are taken off the main receiving circuit at a position between the heterodyning stage and audio frequency detector stage, these conductors being connected to the primary 198 of a transformer 199. The secondary 200 of the transformer is shunted by a variable condenser 201, which is grounded as indicated at 202. The secondary 200 is connected to a grid 203 of a current limiting tube 204. The latter also includes an indirectly

heated cathode 205, a plate 206 and a grid 207. The cathode 205 is connected to the lower end of the secondary 200. There is a small fixed condenser 208 connected between the cathode 205 and the grid 207.

The output circuit consists of a transformer 209, across the secondary of which there is a variable condenser 210. A resistor 211 is connected between the condenser 210 and the grid 207. The secondary of the transformer 209 is shunted by a variable condenser 212, and the transformer constitutes the input of an amplifier tube 213. The latter includes a control grid 214, an indirectly heated cathode 215, a screen grid 216 and a plate 217. There is a grid leak 218 shunted by a condenser 219 connected in the input circuit of the tube for properly biasing the control grid. A small fixed condenser 220 is connected between the grid leak 218 and the screen grid 216.

The output circuit of the tube consists of the primary 221 of a transformer 222, the primary being shunted by a variable condenser 223. The secondary winding 224 of the transformer 222 is shunted by a variable condenser 225, and connections are taken from opposite sides of the condenser to the plates or anodes 226 of a frequency sensitive detector 227. The latter also contains indirectly heated cathodes 228 cooperating with the plates 226, as has been explained hereinbefore. There is a multi-plate variable condenser 229 shunted to ground and connected between the two plates 226. The output of the detector 227 is provided with the shunting condensers 229^a and the balancing resistors 230. A wire 231 is taken from a position between the condensers 229^a, and is connected to the mid tap 232 on the secondary 224. A small fixed condenser 233 is connected between the upper end of the winding 221 and the mid tap on the secondary of the winding 224. A battery 234 supplies plate potential to the plate 206 of the limiting tube and the plate 217 of the amplifier tube through the respective conductors 235 and 236.

The output circuit of the frequency sensitive detector 227 is taken at one side through a ground 237 and at the other side through a conductor 238 to the grids 239 and 240 of a pair of electronic relays 241 and 242, respectively. In addition to the control grid 239, the relay 241 contains a grid 243 and a plate 244. There is an indirectly heated cathode 247 within the tube relay, this cathode being maintained at a positive potential with respect to the ground by a battery 248. The potential and the polarity of the battery are such as to require a positive potential to be applied to the control grid 239 in order to operate the relay, i. e. to produce plate current therein. The bias potential necessary for this purpose may be carried through a resistor 245. The tube 242 is constructed similarly to the tube relay 241 except that the cathode 247 is maintained at approximately ground potential so that if a negative charge were applied to the control grid 240 the effect of this charge would be to reduce the plate current flowing between the plate 244 and the cathode 247. The resistor 245 serves also properly to bias the grid 240.

The output circuit of the tube relay 241 is taken through the conductors 249 to an electromagnet 250. The output of the tube relay 242 is taken by the conductors 251 to an electromagnet 252. The movable armature 253 of the electromagnet 250 is adapted alternately to make contact with

each terminal 255. The lower terminal 253 is grounded at 256. Similarly the armature 257 of the electromagnet 252 makes contact with terminals 259, the upper one of which is grounded at 260. There is a conductor 261 connected between the armature 258 and an electromagnet 262 through a battery 263 to ground 264. A conductor 265 is connected between armature 258 and an electromagnet 266, also through the battery 263 to ground 264.

There is shown a spring-biased ratchet wheel 267, the spring being of the spiral type and indicated at 268. The function of the spring is to return the ratchet wheel 267 in a counter-clockwise direction to its initial position after the latter has been moved in a clockwise direction by the action of the electromagnet, 266, as will now be explained. Cooperating with the electromagnet 262 there is a pointer 270, fitting into the teeth of the ratchet wheel. A pivoted lever 271 provided with a spring-pressed pawl 272 cooperates with an electromagnet 266, the arrangement being such that as the electromagnet 266 is energized the pawl 272 is caused to rotate the ratchet wheel 268 in the clockwise direction against the returning force exercised by the spring 268. The pawl 272 and its lever 271 are operated intermittently, i. e. as a step-by-step operation so that it is necessary to hold the ratchet wheel 267 in its last stepped position while the pawl is engaging the next tooth of the ratchet in order to turn the latter still farther. This function is performed by the lever 269, which may be spring-biased in any suitable manner, for example, by the element 273 to hold the ratchet wheel rigidly in position until the lever 269 is withdrawn. The electromagnet 262, upon energization, serves to withdraw the lever 269 and thus permit the spring 268 to restore the ratchet wheel to its initial zero position. The latter is provided with an arm 274 which serves to open and close a switch 275, depending on whether the ratchet wheel is being rotated clockwise by the pawl 272 or allowed to return in the counter-clockwise direction to its initial position.

The pivot of the ratchet wheel 267 may be constituted of a shaft on which is mounted a double-armed lever or switch 276, which is adapted to rotate as the ratchet wheel is rotated and to make contact between a number of circuits indicated at 277. These circuits may be described as telephone lines which it is desired selectively to connect from a distant transmitter station, as will be explained hereinafter. In case there are ten pairs of wires at the contact bank 278, the switch 276 will connect one pair of wires to any of the ten pairs dialed. The shaft on which the switch levers 276 are mounted may be also provided with an arm which opens and closes a switch indicated at 279 as the shaft is rotated. The switch 275, which responds to the operation of the ratchet wheel 268 and the switch 279 which operates as the switch arms 276 are rotated, may be used in any suitable manner for controlling external circuits, this control being exercised in a predetermined manner depending on the transmitted signals which reach the receiving antenna 194. Thus both switches, or either of them, could control the switching on or off of a loud speaker, and in addition the loudness of the loud speaker which may be connected to the audio detector and amplifier 196.

As stated hereinbefore, the receiving circuit shown in Figure 14 is intended to respond to impulses generated at a transmitter station and

constituted of different frequencies transmitted in any predetermined order. Such a transmitting circuit is illustrated in Figure 11. Assume, for example, that the dial switch 172 (Figure 11) were opened and closed five times. The dial relay 154 will have connected the generator 150 ($f+\Delta f$ frequency) to the transmitter 188, where the impulses will be transmitted as a carrier and received by the antenna 194. The carrier frequency will be heterodyned at 195 (Figure 14) and the detected signal impulses will pass through the current limiting tube 204 and through the amplifier 213, and finally through the frequency sensitive detector 227. These impulses will be impressed on the conductor 238 as a group of positive impulses which will affect only the tube relay 241 and cause plate current to flow in that relay. This current will cause energization of the electromagnet 250 which draws its armature 253 downwardly and connects ground 256 to the conductor 265, completing the circuit through the electromagnet 266, the battery 263 to ground 264. Thus the electromagnet 266 is intermittently energized as many times as there are impulses transmitted through the frequency sensitive detector 227. The ratchet wheel 267 will be caused to rotate in the clockwise direction, due to the intermittent upward movements of the pawl 272.

It will be noted that the electromagnet 262 is deenergized all during this time because its circuit is open at the upper contact 259. Consequently, the arm 269 is forced downwardly by the spring 273 into the successive ratchet teeth as the ratchet wheel is rotated, in order to prevent the ratchet wheel from turning in the counter-clockwise direction due to the urge of the spring 268. As the ratchet wheel rotates five teeth in the clockwise direction, (still assuming that five positive impulses have been transmitted to the electromagnet 266) the switch 275 is opened and the shaft on which the ratchet wheel is mounted is turned through a predetermined angle to cause the switch arm 276 of the contact bank 277 to rotate and contact with a predetermined pair of wires. The rotation of the shaft may also serve to open any switch to which the shaft is mechanically connected. Consequently, the rotation of the dial 172 at the transmitting station (Figure 11) through five steps or positions will move the switch arm 276 of a contact bank through the same number of steps in order to select any pair of wires, as determined by the number selected at the dial 172.

In order to return the ratchet wheel 268 and the switch arms 276 to a zero initial position, it is simply necessary to energize the electromagnet 262, which serves to withdraw the lever 269 from the teeth of the ratchet wheel and against the action of the spring 273. This operation may be accomplished by moving the key 193 (Figure 11) in order to close the switch 177. It has been explained that when the contacts 176 and 178 are closed a frequency $f-\Delta f$ is applied to the transmitter 188 and the frequency $f+\Delta f$ is automatically disconnected from the transmitter. The $f-\Delta f$ frequency may be transmitted as impulses of the same number as were transmitted by the dial 172, or if desired as one relatively long impulse. This frequency, upon being obtained from the carrier at the rectangle 195, is transmitted through the receiving circuit and frequency sensitive detector shown in Figure 14, and appears at the conductor 238 as a direct

current of negative polarity. This current has no effect on the tube relay 241 for obvious reasons, but will affect the relay 242 to reduce the normal plate current flowing through this relay. This decrease in plate current serves to deenergize the electromagnet 252, causing the lever 258 to be moved upwardly against the upper contact 259. The conductor 261 is then grounded, completing a circuit through the electromagnet 262 and the battery 263 to ground. Energization of the electromagnet 262 will withdraw the lever 269 from the ratchet wheel either as a step-by-step operation, depending on the character of the impulses produced at the key 193 (Figure 11), or completely remove lever 269 from the ratchet wheel to permit the latter to return immediately to its zero or initial position ready for the next dialing operation.

As in the case of the figures previously discussed, the frequency sensitive detector 227 serves to rectify either the $f+\Delta f$ or $f-\Delta f$ frequencies and to convert these frequencies into direct current potentials, either of positive or negative polarity depending on the particular frequency. The tube relays 241 and 242 discriminate between these impulses of opposite polarity selectively to operate apparatus, namely, the ratchet wheel 268 and the contact bank 278, either in the clockwise or counter-clockwise direction depending on the frequency received at the detector 227.

It is also apparent that the switching functions performed by the detector 227, as explained above, are not affected by the presence of the voice modulated carrier which passes through the heterodyning stage 195 because the detector is sensitive to changes in frequency only, and not to changes in amplitude. The only effect that changes in amplitude can have will be to cause slight changes in the amplitude of the output voltages from the frequency sensitive detector, but these changes do not change the polarity. Even these slight changes in amplitude of the voltages may be removed, if desired, by small filter condensers placed across the output circuit of the detector, as explained in connection with Figure 10, or a limiter tube for maintaining constant voltage to the input of the frequency sensitive detector may be employed as indicated at 204 (Figure 14).

The devices and systems described hereinbefore are almost entirely free from static interference which normally produces false operation of the remote relays. The detector tube 227 is sensitive to changes in frequency only, whereas static is composed of energy having large proportional changes of amplitude. Any increase in voltage that is produced by static at the output of the detector tube 227 (Figure 14) is of a very transient character and of short duration, and may be still further reduced, if desired, by using filters to delay the operating speed of the switching mechanism.

It will be understood that I desire to comprehend within my invention such modifications as come within the scope of the claims and the invention.

Having thus fully described my invention, what I claim as new and desire to secure by Letters Patent, is:

1. In a composite receiving system, means for receiving a carrier of the frequencies $f+\Delta f$, f and $f-\Delta f$ which is modulated by voice undulations, means for separating the voice undulations from said carrier and for transmitting the voice undulations to a voice-frequency-responsive device, a separate means for transmitting said carrier frequency to a device which responds to difference of frequency, said last-mentioned device comprising a double-unit rectifier which serves to convert the frequencies $f+\Delta f$ and $f-\Delta f$ into direct current impulses of opposite polarities, said rectifier also serving to eliminate the f frequency, and means responsive to said direct current impulses of opposite polarity for controlling the device which responds to said voice undulations.

2. In combination, a transmitting station comprising a source of frequencies f , $f+\Delta f$ and $f-\Delta f$ and an outgoing line, dial means for transmitting over said line a succession of impulses of the $f+\Delta f$ frequency, said means also serving to prevent the transmission of the f frequency, key means for applying to said line an impulse of the $f-\Delta f$ frequency at the conclusion of the $f+\Delta f$ frequency impulses, said key means also serving to prevent the transmission of the f frequency.

3. In combination, means for receiving frequencies $f+\Delta f$ and $f-\Delta f$ from a transmitting circuit, a dial means for transmitting said frequency $f+\Delta f$, and a keying means for transmitting said frequency $f-\Delta f$, said receiving means including a relay which responds cumulatively to the dial-transmitted succession of impulses and becomes deenergized when the key-transmitted impulse is impressed thereon.

4. In combination, means for receiving a plurality of frequencies $f+\Delta f$ and $f-\Delta f$, dial means for transmitting the $f+\Delta f$ frequency to the receiving means in the form of a succession of impulses, keying means for transmitting said $f-\Delta f$ frequency to the receiving means at the conclusion of the $f+\Delta f$ frequency, said receiving means comprising a relay which responds cumulatively to the $f+\Delta f$ impulse and becomes deenergized when the $f-\Delta f$ impulse is impressed thereon.

5. In combination, a receiving circuit adapted to receive a plurality of signaling frequencies f , $f+\Delta f$ and $f-\Delta f$ modulated by a voice frequency responsive device, means for separating the voice undulations from said signaling frequencies, and means for conducting the carrier frequencies through an amplifier to a double-unit rectifier which converts the signal frequencies into direct current impulses of opposite polarity, a relay responsive to the received frequency $f+\Delta f$, a different relay responsive to the received frequency $f-\Delta f$, and a device for receiving said signal frequencies, said device being adapted to be actuated in one direction upon the receipt of the $f+\Delta f$ frequency and to be actuated in the opposite direction upon the receipt of the $f-\Delta f$ frequency, said device serving to control an outgoing circuit in accordance with the direction in which it is actuated, said outgoing circuit being constituted at least in part of mechanism by which the voice-frequency-responsive device is controlled.

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