

June 23, 1942.

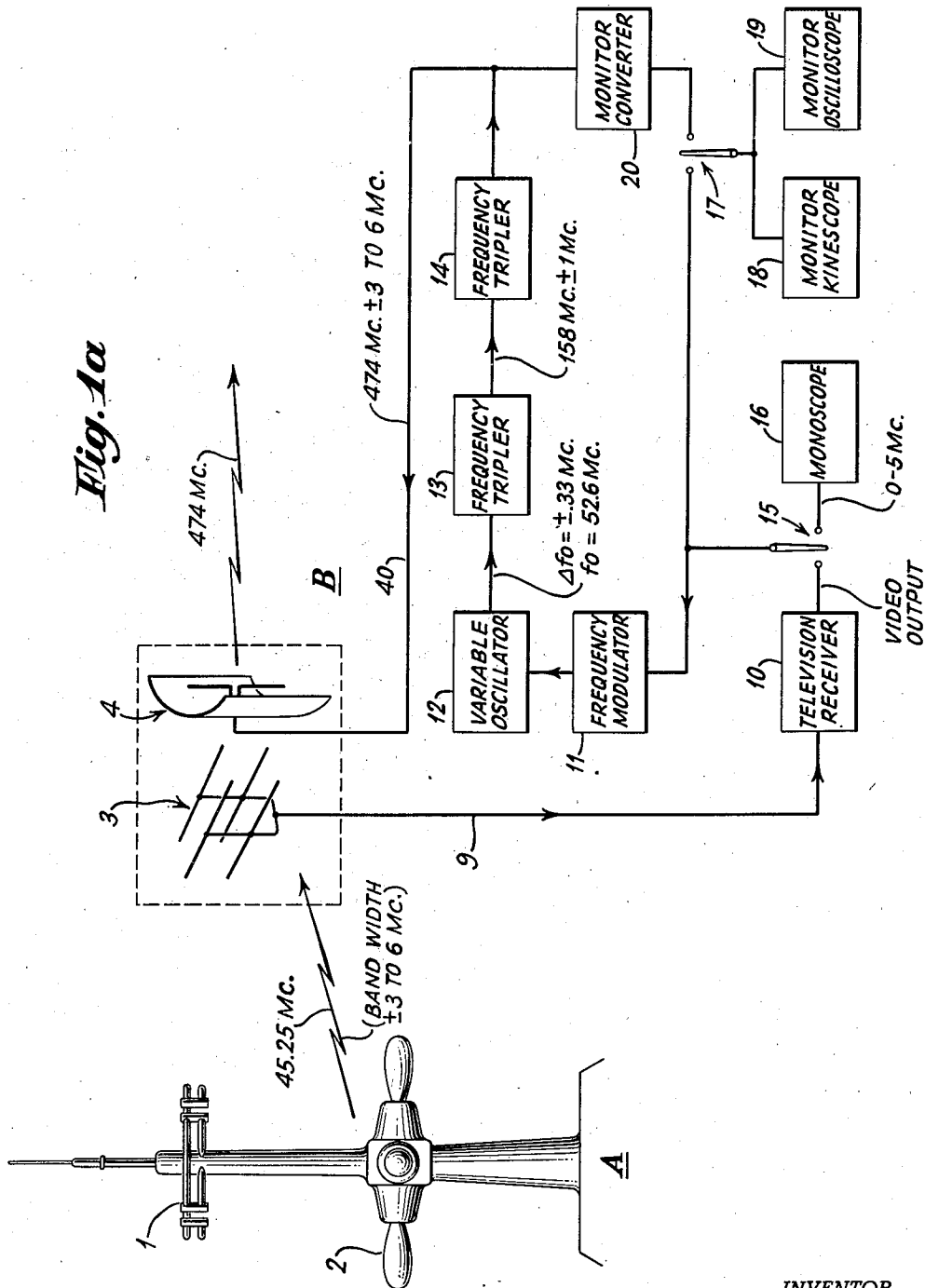
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2,287,044

RADIO RELAYING SYSTEM

Filed May 15, 1940

5 Sheets-Sheet 1



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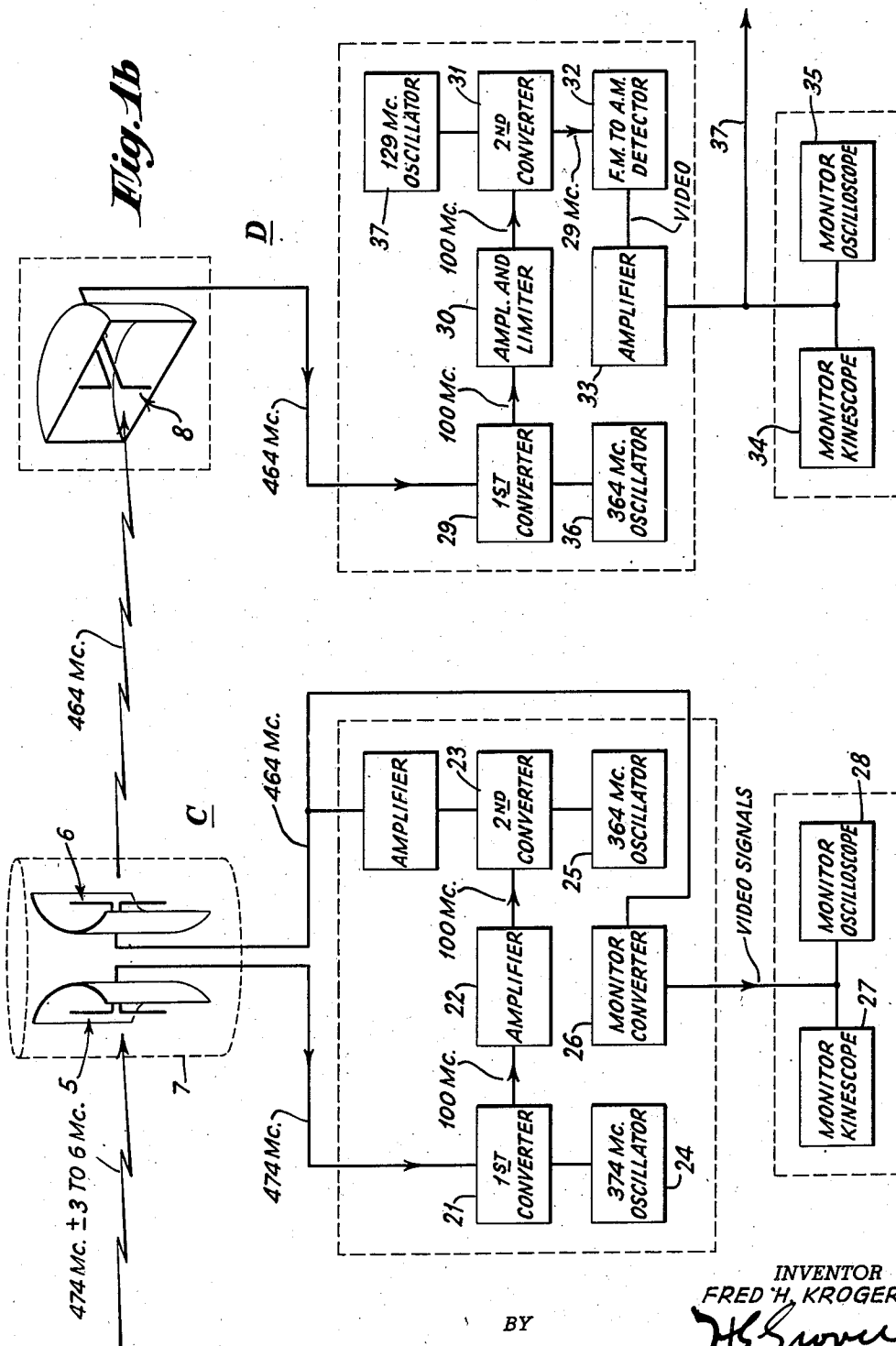
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RADIO RELAYING SYSTEM

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5 Sheets-Sheet 2



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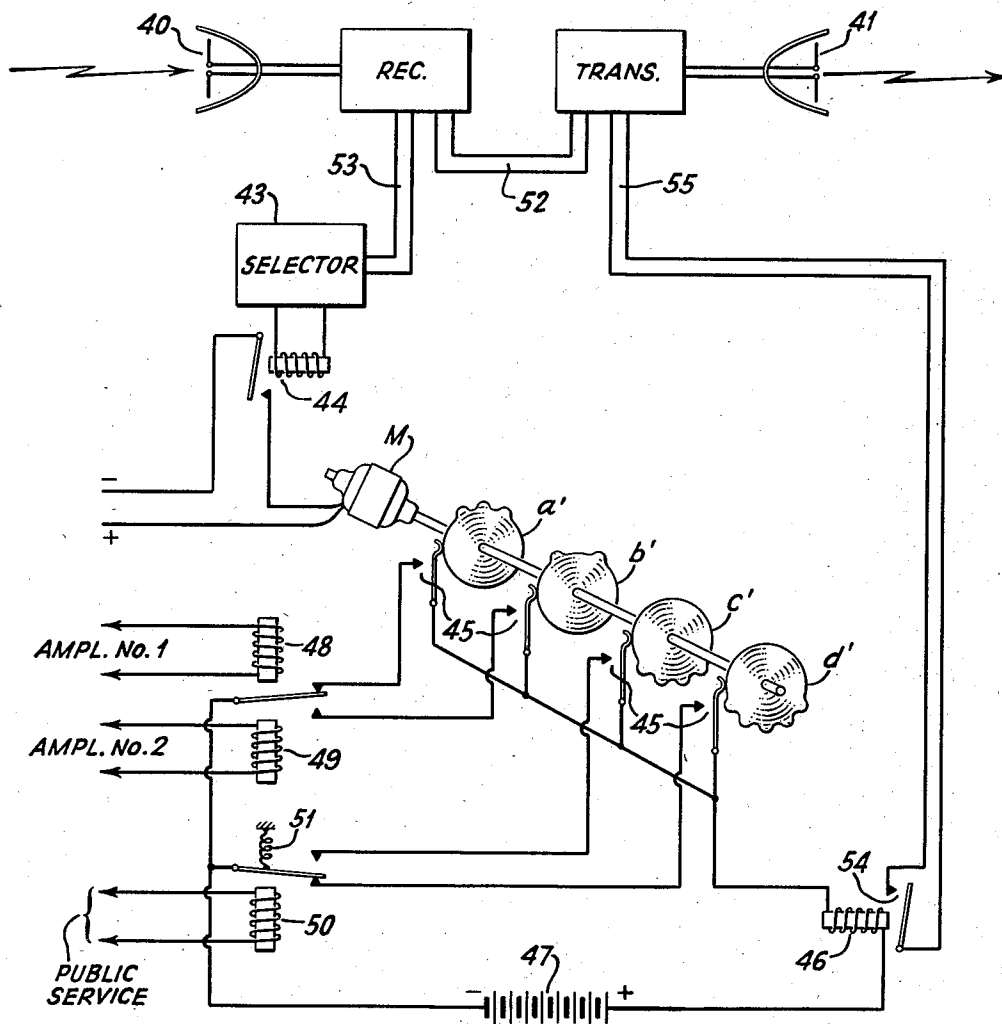
2,287,044

RADIO RELAYING SYSTEM

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5 Sheets-Sheet 3

Fig. 2



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RADIO RELAYING SYSTEM

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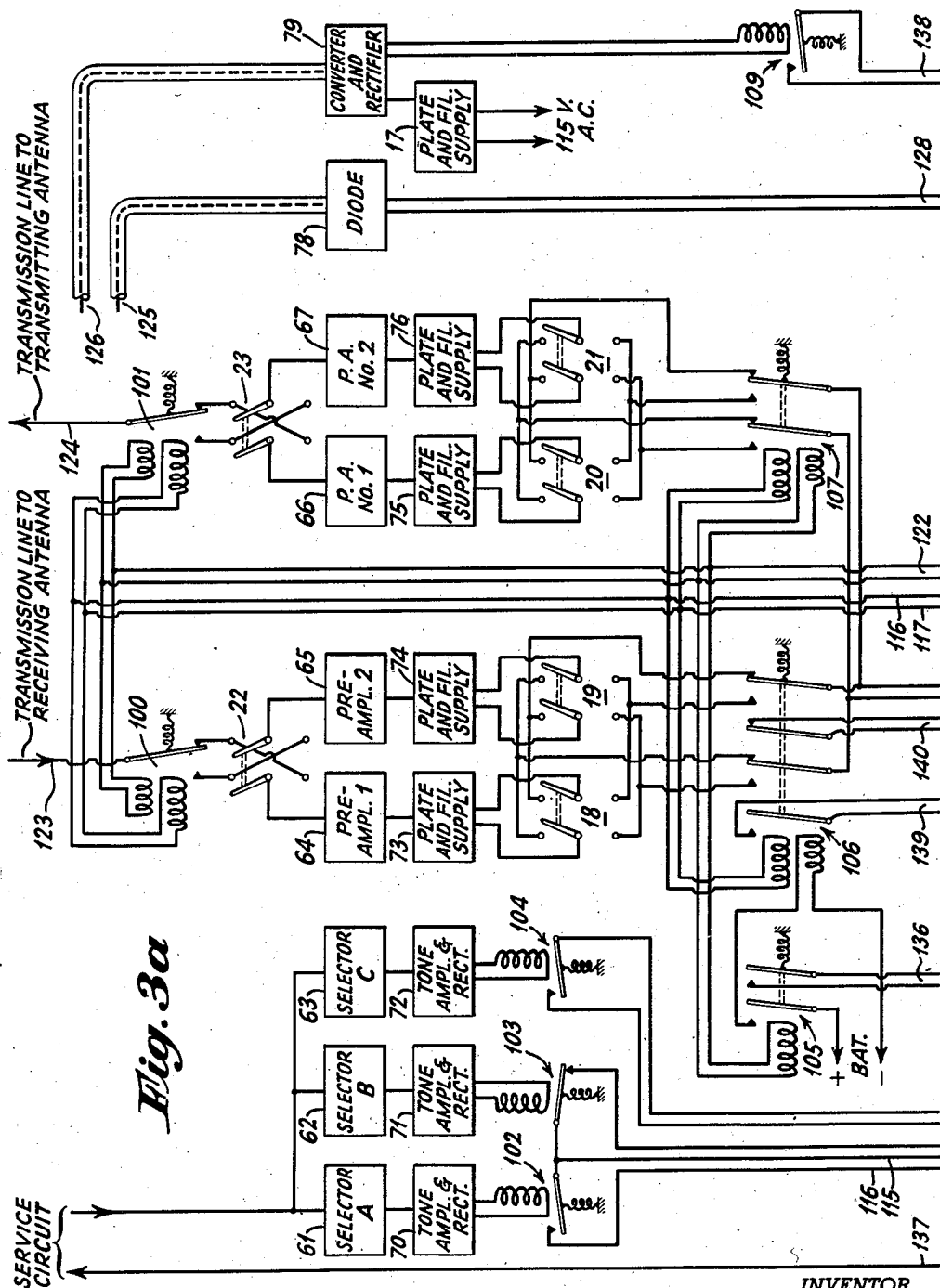


Fig. 3a

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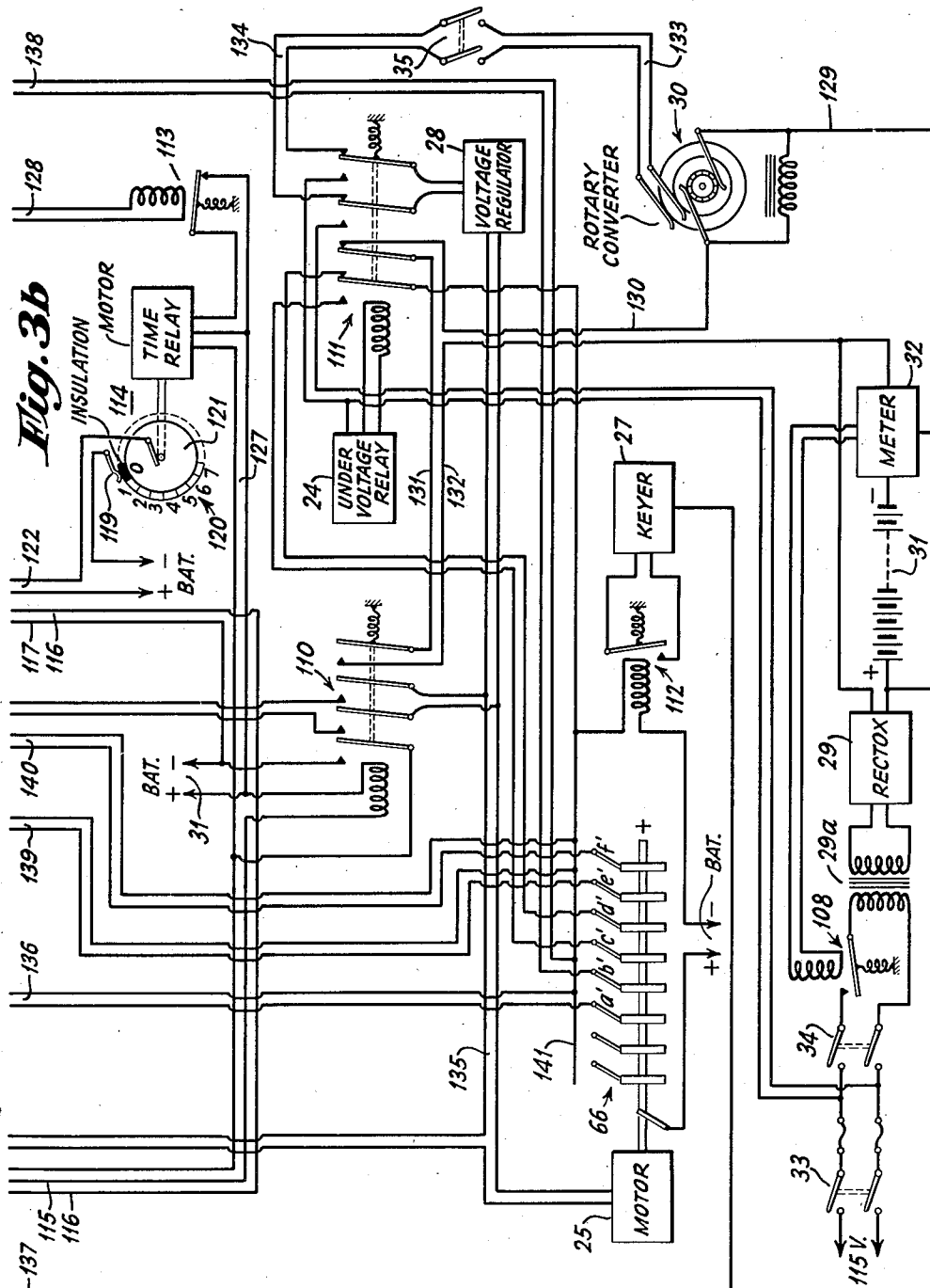
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2,287,044

RADIO RELAYING SYSTEM

Filed May 15, 1940

5 Sheets-Sheet 5



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UNITED STATES PATENT OFFICE

2,287,044

RADIO RELAYING SYSTEM

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Application May 15, 1940, Serial No. 335,217

20 Claims. (Cl. 250—15)

The present invention relates generally to a radio relaying system employing a plurality of repeater or relaying stations, and relates specifically to methods of and means for efficiently relaying signals at ultra short wavelengths, and also to circuit arrangements for indicating at a central or division office the operating conditions existing at any one or more stations of the relaying system.

The invention finds particular application to a radio relaying system wherein there is employed at each repeater station an emergency power supply system with means for automatically switching the station apparatus from the public power supply to the emergency power supply in the event of failure in the public power supply system. Correspondingly, the restoration of normal voltage to the public service power supply causes the station apparatus to be switched back from the emergency power to the public service power. In such a relaying system it has also been suggested that two sets of amplifier equipment be provided with means for automatically switching both the receiving and transmitting antennae from one set to the other in case of a drop in or failure of output for the transmitting antenna. For a more detailed description of a relaying system employing automatic switching or change-over apparatus of the type described above, reference is herein made to my United States Patent No. 2,017,126, granted October 15, 1935.

An object of the present invention is to provide a circuit arrangement for use with a relaying system of the type described above for indicating to a central office or division center which power supply system and/or which amplifier equipment is in use at a particular relay station. The terms "division center" or "central office" herein designate a maintenance center to which is assigned the responsibility of maintaining in working order a certain number of repeater stations in the relay system, these stations constituting a zone. Where numerous repeater or relay stations are employed, there may be several such zones.

A further object is to conveniently and effectively control signal transmitting apparatus at a radio repeater station from a remote point with a predetermined signal to which only the controlled station is responsive.

Another object is to provide a radio repeater station in a relaying system with means which is selectively responsive to a predetermined signal transmitted from the central office or division

center for sending to the central office a signal characteristic of a particular circuit condition at said repeater station. For achieving this purpose, there is provided at the repeater station a circuit which automatically transmits a plurality of code signals indicative of particular circuit conditions then existing at that station.

A further object is to provide a radio relaying system especially adapted for the transmission of frequency modulated signals.

The present invention provides a system whereby the status of the individual relay stations can be communicated to the division center at the will of that center, in a way that requires only one communication channel which can also be used for other communication purposes.

A feature of the invention is a special circuit arrangement at each repeater station including a plurality of code discs and contacts individual thereto with relay means for rendering momentarily effective only those contacts and associated discs which are associated with the amplifier and power supply equipment then operative at the repeater station.

Other features relate to the novel mechanical constructional details which go to make up the new radio relaying system of the invention.

In general, the system at the repeater station includes a receiving antenna and an associated receiver for receiving the signals to be passed on to the next repeater station, a transmitter and associated transmitting antenna, two sets of amplifier apparatus (one automatically effective in case the other fails), an emergency power supply automatically effective in case the public service power supply fails, a selector or filter associated with the receiver and responsive to a characteristic signal for driving a motor, a plurality of rotatable code discs driven by the motor, a pair of contacts associated with each code disc, a relay connected in common to all contacts and responsive to the movements of said contacts for causing signals characteristic of the code discs to be sent out by said transmitter, and relay means associated with the amplifier and power supply equipment for rendering effective only those contacts and code wheels which correspond to the code designation of the particular equipment being used.

In the accompanying drawings, Figs. 1a and 1b taken together illustrate diagrammatically a complete radio relaying system many of whose features have been designed by me and successfully tried out in practice and to which the prin-

ciples of the present invention may be applied; Fig. 2 illustrates schematically apparatus at one repeater station of the relaying system for achieving status indication in accordance with one embodiment of the invention; and Figs. 3 and 3a taken together show apparatus embodying the principles of Fig. 2 as applied to a repeater station, and also apparatus for performing additional functions.

The radio relaying system shown in Figs. 1 and 1a is designed for use particularly with television signals, although it will be understood that it may also be used to transmit telegraph signals or any type of radio signal. The system includes a transmitting station A, a plurality of intermediate repeater stations B and C, and a receiving station D suitably spaced apart along the line of transmission. Repeater stations B and C are designed to repeat the signals from station A to station D. The arrows indicate the directions of the signals between the respective stations. Although only two repeater stations have been shown, it should be understood that this number is illustrative of any number of repeater stations which may be located at frequent intervals along the line of transmission for amplifying and reradiating the signals.

The antenna system indicated at the transmitting station A is shown to be of the omnidirectional broadcasting type, having constant characteristics over a frequency band sufficiently wide to accommodate the full band spectrum of high definition television. This antenna consists of two separate, independent radiator systems 1 and 2, the former for sound and the latter for vision transmission, both radiators being supported on a common column located at an appreciable distance above ground, usually on the top of a tall building. The antenna system of the transmitting station A is of the type installed on top of the Empire State building in New York city, New York, and is described quite adequately in the copending application of Nils E. Lindblad, Serial No. 208,573, filed May 18, 1938.

The antenna on stations B, C and D are of the unidirectional type, there being used a pair of antennas at the intermediate stations B and C, one for receiving the signals from the nearest transmitting antenna, and the other for repeating and reradiating the signals to the next repeater or receiving station along the line of transmission. Since the transmission range of the ultra short waves at which this system is designed to function depends upon the air line or visual distance, a factor proportional to the height above the earth's surface, it is proposed to locate all stations at points having as great height as possible, such as mountains, tall buildings, radio masts, etc. The receiving antenna 3 at repeater station B consists of a pair of dipole arrays placed one behind the other and suitably phased relative to each other for providing a unidirectional effect. This antenna is designed to receive the signals transmitted from station A. Reference is hereby made to Carter United States Patent No. 2,183,784, granted December 19, 1939, for a suitable description of antenna 3. The reradiating or transmitting antenna 4 of station B is of the metal parabolic type which has as its focus a plurality of folded dipole antennas arranged in the same straight line. The folded dipole antenna has been found to be much more effective than the single dipole and is of a general form described in copending application Serial No. 155,385, filed July 24, 1937, by Philip

S. Carter. At repeater station C there are shown a receiving antenna 5 and a reradiating or transmitting antenna 6, both of the parabolic type employing folded dipole antennas, as described in connection with antenna 4 of station B. Antennas 5 and 6 are, of course, effective in different directions, the receiving antenna 5 being positioned to receive the signals from station B while the transmitting antenna 6 is positioned to transmit the signals in the direction of the next adjacent station D. Antennas 5 and 6, as well as all the equipment at station C, are enclosed within a thin wooden cylindrical container 7 mounted on a steel tower. Aside from the metal bolts and screws employed in the construction of the wooden cylinder, there is no extra electrically conductive material employed, mainly because I have found that the presence of metallic strips or bands for the wooden cylinder causes a distortion in the directivity pattern of the antennas and undesirable feed-back therebetween, and also causes a loss in signal strength. The wooden enclosure functions not only to mount the equipment and the antennas, but also prevents disturbances caused by wind pressures, sleet, ice and dirt from interfering with the normal characteristics of the antenna system and the associated apparatus. The commodious interior of the wooden container also simplifies the maintenance of the equipment and enables suitable heating apparatus or other desired equipment to be provided within the enclosures.

The antenna 8 at receiving station D comprises a parabolic reflector having at its focus a plurality of folded up dipoles, this antenna being of course directed to receiving the signals from antenna 6 of the adjacent repeater station. The antennas of stations A to D, inclusive, have been described as being of a particular type, mainly by way of example, since it is apparent that other types of antennas can be used to achieve the desired results.

In the operation of the system of Figs. 1a and 1b, television signals emanating from broadcasting station A are amplitude modulated and radiated at a frequency of 45.25 megacycles and received on antenna 3 at station B from which the signals pass to a 72 ohm coaxial cable 9 to a television receiver 10 to provide a video component the band width of which is 4 to 6 megacycles. This video output is used to control a transmitter with multi stages of frequency tripling. In order to convert the signal into centimeter waves, the video component, through the intermediary of frequency modulator 11, modulates a variable oscillator 12, the output of which is at the mean frequency of 52.6 megacycles with a variation of plus or minus .33 megacycle. This output is passed on to a frequency tripler stage 13 which provides an output of 158 megacycles with a variation of plus and minus 1 megacycle or higher, this last output of 158 megacycles being passed on to a final tripler stage 14 from which there is obtained an output of 474 megacycles with a band frequency deviation of plus and minus 3 to 6 megacycles, and higher, if desired, which last output is passed on by a 72 ohm coaxial cable 40 to the transmitting antenna 4. It will thus be seen that the amplitude modulated waves of 45.25 megacycles received from transmitting station A have been converted into frequency modulated waves of a much higher frequency, of an order near 500 megacycles. The vacuum tubes employed in the tripler process, as well as in the final stage in a straight amplifier

(not shown) which connects with the cable 40 and transmitting antenna 4, are preferably of the "inductor" type in which energy is derived from a stream of electrons without their coming into actual contact with the active parts of the circuit and which gives the device the ability to handle with unprecedented efficiency very wide band widths at extremely high frequencies. Reference is here made to my copending application Serial No. 296,045, filed September 22, 1939, for a more detailed description of this type of inductor radio tube. At station B there is also provided a switch 15 which when connected to a monoscope 16 permits the attendant at station B to send out test signals comprising a single picture having a band width of from zero to 5 megacycles. There is also provided a switch 17 which, depending upon the position in which it is thrown, enables the attendant at the repeater station B to observe on a kinescope 18 and an oscilloscope 19 the output radiated over antenna 4 or the input received for the television receiver 10. For this purpose there is provided a monitor converter 20 which converts the frequency modulation from the final stage of the tripler 14 to suitable video signal waves which can be observed. The kinescope 18 provides the picture signal while the oscilloscope 19 shows the wave form of the signal.

At repeater station C the receiving antenna 5 receives the 474 megacycle frequency modulated signal radiated by antenna 4 of station B and converts the signal by means of a converter 21 to a 100 megacycle signal for more efficient amplification. This 100 megacycle signal is amplified by a three stage amplifier 22 and then converted in 23 to an output frequency modulated signal having a mean frequency of 464 megacycles, which is then transmitted by antenna 6 toward the next adjacent station, in this case receiver station D. Oscillators 24 and 25, associated respectively with converters 21 and 23, function at 374 and 364 megacycles respectively to change the incoming frequency down from 474 megacycles to 100 megacycles and then to increase the frequency of the 100 megacycle component to 464 megacycles. Here again an amplifier is provided between the converter 23 and the transmitting antenna 6, and a monitor converter 26 is utilized to provide video signals to the local kinescope 27 and oscilloscope 28. It should be observed at this time that intermediate station C converts the frequency modulated waves received on one frequency into frequency modulated waves of another frequency which are then re-radiated.

At the final receiving station D in the relay link, the frequency modulated signal is received on antenna 3 at 464 megacycles and converted by apparatus 29 to a 100 megacycle signal which is then passed on to an amplifier and limiter 30 to a second converter 31 which reduces the signal to 29 megacycles before it is passed on to a detector 32 which transforms the frequency modulated signals to amplitude modulated signals. The output of detector 32 comprises video signals which are amplified by amplifier 33 so that they can be suitably observed by the local kinescope 34 and the local oscilloscope 35. Oscillators 36 and 37, associated respectively with the converters 29 and 31, generate 364 megacycles and 129 megacycles respectively to reduce the signals to the frequency values mentioned above. If desired, the output from amplifier 33 having a four megacycle band width and higher can be

passed by means of cable 37 to a suitable studio for rebroadcasting over a second broadcasting transmitter (not shown).

In the radio relay embodiment shown in Figs. 1a and 1b, and successfully tried out in practice, the transmitting antenna A was located on top of the Empire State building in New York, New York; the repeater station B was located at Hauppauge, Long Island, New York, about 45 miles away from the Empire State Building; the repeater station C was located at Rocky Point, Long Island, New York, which is about fifteen miles from Hauppauge; and the receiving station D was located at Riverhead, Long Island, New York, a distance of fifteen miles from station C. These distances between the stations are not to be considered as being limitative in character, since the stations may be separated from one another any desired distance, so long as any two adjacent stations are within the optical range of visible distance. This is because the electromagnetic waves at the lower wavelengths below ten meters, let us say, with which the relay system of Figs. 1a and 1b are particularly concerned, have characteristics which are quasi-optical in nature; that is, they have a very definite limited range of transmission which is comparable with the optical range.

Fig. 2 illustrates diagrammatically a repeater station equipped with apparatus in accordance with the invention for automatically sending to a division center or central office a plurality of signals for indicating the operating conditions existing at the repeater. In this figure the receiver and transmitter are diagrammatically indicated in box form and appropriately labeled as such, and their respective associated antennas 40 and 41 are also diagrammatically indicated, although it will be understood that the antennas as well as the receiving and transmitting apparatus can be of any suitable kind such as, for example, those shown in repeater stations B and C of Figs. 1a and 1b.

At each repeater station, as shown in Fig. 2, there is provided a selector mechanism 43 responsive to a characteristic signal for operating a relay 44 whose contacts control a motor M. On the shaft of the motor M there are provided four code discs *a'*, *b'*, *c'* and *d'* which are provided with segments according to a prearranged code. The segments of each code disc or wheel occupies less than 180°. The segments on disc *a'* are on the opposite 180° side from code disc *c'*, and correspondingly the segments for code discs *b'* and *d'* are opposite to each other although respectively on the same 180° as *a'* and *c'*, as shown. This arrangement permits two code signals to be transmitted when the motor operates, the possible combinations of which are *a'* and *c'*, *a'* and *d'*, *b'* and *c'*, and *b'* and *d'*. Associated with each code disc or wheel are a pair of contacts 45 which normally are open but are arranged to close when contacted by a raised segment on the disc. One contact of each disc or wheel is connected to the correspondingly positioned contact of each of the other pairs, and these correspondingly located contacts in turn connected to one terminal of the winding or a relay 46, the other terminal of which is connected to the positive side of a battery or suitable source of unidirectional energy 47. The other contact of each pair of contacts 45, 45 is connected to a contact of one of the relays 48, 49 or 50. Thus, the opposed contacts of relays 48 and 49 are connected to dif-

ferent contacts of code discs a' and b' , while opposed contacts of relay 50 are connected to different contacts of code discs c' and d' , as shown. The armatures of relays 48, 49 and 50 are connected together and to the negative terminal of battery 47. A spring 51 associated with the armature of relay 50 normally pulls the armature 50 to the upper or break contact in the absence of energizing current through relay 50. The winding of coil 50 is connected to the public service power supply or some apparatus associated therewith, so that when the apparatus at the repeater station is being energized from the public service power supply the relay 50 will be operated and the armature will be pulled down to engage the make contact. Relay 48 is connected with one set of amplifiers, while relay 49 is connected to the other set of amplifiers, so that depending upon which set of amplifiers is operated the relay 48 or 49 will be energized, thus pulling the armature either up or down, or if the relays are positioned horizontally, to the left or to the right. The armature of each of the relays 48 and 49 will remain in the position in which it is pulled until such time as it is pulled in the opposite direction by energy in one of the relay windings. It will be obvious, of course, that relays 48 and 49 may comprise a single relay of the polarized type having a pair of windings. It is assumed, of course, as mentioned above, that the relay station is provided both with an emergency or spare power supply so that when the public power supply fails the emergency or spare power supply immediately takes over the burden of supplying excitation energy to the receiving and transmitting apparatus at the repeater station, and correspondingly, that when public power service is restored the translating apparatus at the repeater station will automatically be switched or changed back from the emergency to the public service power supply. It is also assumed that one set of amplifiers automatically replaces the other in the event of failure of one of these sets. The failure of one set of amplifiers may manifest itself when the radio output of the relay station is reduced to a value which causes the system to cease to function. This value need not be absolute radiation failure. When this occurs, there will be a shift from one amplifier set to the other. Operation of the relay station may be started and stopped by radio signals sent over the relay system. Obviously, the code disc wheels a' , b' , c' and d' can be replaced by commutator wheels, and the contacts 45 by brushes or suitable contacts engaging the commutator wheels. Thus, each commutator will have a predetermined number of contact segments separated by insulating centers for sending out desired code signals, it being understood that when the motor is at rest the contacts or brushes will engage an insulating sector.

The operation of the system of Fig. 2 will now be described. Assuming that periodically, let us say, every hour or so the attendant at the division center desires information as to which pieces of apparatus are functioning at the different relay stations. To obtain this information the attendant at the maintenance center sends out a signal which is characteristic of a particular relay station from which information is desired, it being understood that each station has a characteristic signal different from the signals of the other stations. This signal may be a code signal or,

preferably, a tone of constant frequency and amplitude. This transmitted tone sent out by the maintenance center is received over antenna 40 and the associated receiver and passed on through line 52 to the transmitter and associated antenna 41 which transmits the signal on to the next station of the chain. A branch circuit 53 at each repeater station passes this tone to the selector 43 and if this selector is responsive to the tone sent out by the maintenance center it will cause the operation of relay 44 which, in turn, will close its contacts over an obvious circuit to operate motor M and cause the rotation of four code wheels a' , b' , c' and d' . The motor is so arranged that it will rotate the code wheels only once and the code wheels will again come to rest in the position indicated in the drawings with the contacts open circuited, unless the tone signal from the division center is being continuously transmitted, in which case the motor will rotate for an integral number of revolutions during which the characteristic signal is being received and passed by the selector 43. As the motor and the wheels rotate, the contacts 45 close in accordance with the code characteristics on the discs to operate relay 46 which in turn closes its contacts 54 to affect the transmitter over leads 55 to cause this transmitter to send code signals to a division center. If desired, these code signals can be sent out continuously until stopped by the maintenance or division center. The code signals transmitted by the repeater station of Fig. 2 over antenna 41 may or may not be radiated in the direction from which signals are received over antenna 40, depending upon whether or not the transmitted code signals from the repeater station are received directly by the division center or through the intermediary of another division center. If the public service power supply is being used, the relay 50 will be operated and will pull its armature down against the restraining influence of the spring 51, thus closing an obvious circuit through the winding of operating relay 46 and the segments of code wheel d' when the motor is operated. However, if the public service power has failed and the emergency power supply is being used, the armature of relay 50 will be in its normal position and will be contacting the upper contact, thus closing an obvious circuit for code disc c' to send out a different code signal. In the same way, the two sets of amplifiers operate on the relays 48 and 49 to condition either code wheel a' or code wheel b' to send out code signals via relay 46, it being understood, of course, that the codes are different for the various code wheels. Thus, during the operation of the motor M the code wheels will send out two consecutive signals, one indicating whether the public service power supply or the emergency power supply is functioning and the other indicating which of the two sets of amplifiers is being used. As soon as the attendant at the division center obtains this desired information, he will cease sending the characteristic tone signal, thus stopping the motor and restoring the shaft and code wheels to their normal rest position. This cycle of operations will be repeated for all the repeater stations within the zone of the division center.

Figs. 3a and 3b considered together illustrate a preferred and practical circuit embodiment which can be installed at each of the repeater stations of the relaying system for indicating to the division center not only the status of the amplifier and power supply equipment, but also for

indicating the noise level and carrier level, as well as any other desired condition of operation. The system of Figs. 3a and 3b also includes a start and stop arrangement for conditioning the repeater station to operate or to shut down. In these last figures there are shown a public service power supply outlet indicated diagrammatically as 33; an emergency or spare power supply system indicated by the rotary converter 30 and battery 31; a pair of amplifier systems each including a preamplifier 64 or 65 and a power amplifier 66 or 67; switch-over devices 22 and 23 for associating the receiving and transmitting antennae with the particular preamplifier and power amplifier required for operation; time delay apparatus 114 for isolating necessary automatic change-over at a rotary station without interfering with the individual functioning of the other repeater stations; selector apparatus 61, 62 and 63 for selecting and passing to the proper relay the tone signals received over the service channel; code discs 66 for sending code signals indicative of the status of the various pieces of equipment at the repeater stations; and various relays and switches associated with the foregoing pieces of equipment.

In the operation of the system of Figs. 3a and 3b, assuming that it is desired to start up the repeater station at which this apparatus is located, the remote central office or division center (not shown) will send out a tone A over the service circuit, which may be either a wire line or a radio channel. If a radio channel is used for the service circuit, then it is preferred that a narrow band of frequencies be used thereover which is outside the range of the message waves, and that separate amplifiers and repeating equipment (antennas, etc.) be used therefor at the repeating stations than for the message waves. This start tone A will start up all the relay stations in the system simultaneously and will be sent out for at least thirty seconds. The start tone will be received at each repeater station and passed on to the selector equipment where only selector 61 will pass tone A through to a tone amplifier and rectifier 70, the latter producing a rectified current for operating relay 102. The operation of relay 102 will close its contacts and cause the operation of relays 110, 100, 101, 106 and 107. The path for operating these relays will be traced over a circuit from the positive terminal of battery 31 through the operating coil of relay 110, lead 115, contact of relay 102, lead 116, to one terminal of the coils 106, 107, 100 and 101 in parallel, through these coils to lead 117, then to the negative terminal of battery 31. When relay 110 operates, the closing of the left hand contact serves to hold it closed through an obvious circuit involving the normally closed contacts of relay 103. The two intermediate pairs of contacts of relay 110 now having been closed, a circuit is provided for the passage of power from public service terminal outlet 33 over right-hand operated contacts of relay 111 and through voltage regulator 28, through the two central operated contacts of relay 110, through the operated or made contacts of relays 106 and 107 to the plate and filament supply leads 73, 74 and 75 and 76 for the preamplifiers and power amplifiers, respectively. It should be noted at this time that relay 111 operates when the public service voltage is above a minimum value determined by under-voltage relay 24, and it has been assumed that this relay was operated before

the operation of relay 110. Manually operated switches 22, 23, 18, 19 and 20 and 21 determine which set of amplifier equipment and their respective power supply outlet is to be used in the normal operation of the repeater system and which is to function as a spare. Assuming that switches 22 and 23 are thrown upward, and that relays 100 and 101, now operated, pull their respective armatures to the left, it will be obvious that the transmission line 123 from the directive receiving antenna and the transmission line 124 from the directive transmitting antenna will be connected through the left hand terminals of the reversing switches and the left hand blades of switches 22 and 23 to one set of power amplifier equipment comprising preamplifier 64 and its associated power amplifier 66. This state of facts requires that switches 18 and 20 be thrown down and switches 19 and 21 thrown up, in order to supply power to the plates and filaments 73 and 75 of the preamplifier 64 and power amplifier 66, respectively, through the operated contacts of relays 106 and 107. The radiation of carrier current over transmission line 124 will occur in some thirty seconds after the operation of relay 110. By exposure to this radiation through proper coupling of transmission lines 125 and 126, radio frequency currents will be passed on to diode 78 and converter and rectifier 79. The output of diode 78 will pass current over leads 128 and through the winding of relay 113 for enabling current to be supplied to the holding winding of relays 100, 101, 107 and 106, the last holding winding, namely 106, being operated by the intermediate or accessory relay 105, in the manner now to be described. The output of this diode 78 passing current over leads 128 will operate relay 113; thus breaking the normally made contacts leading from the motor of the time delay relay 114 to its power supply. At this time it should be observed that the time delay relay 114 had its operating circuit closed upon the operation of relay 110, through a path extending over leads 127 and the normal make contacts of relay 113, as a consequence of which the time delay relay 114 (comprising some suitable motor arrangement such as a telechron motor, here given by way of example only) will rotate the commutator 121 clockwise through the shaft shown, and cause the segmented cam 120 to commence its travel. The commutator 121 will continue to rotate until the operating circuit for the time delay circuit 114 is opened at the contacts of relay 113. The operation of relay 113, which will occur approximately thirty seconds after the initiation of the start signal, will stop the rotation of the time delay motor maintaining contact 119 in about the mid position on one of the electrically conducting segments of cam 120, thus closing a circuit over contact 119 and leads 122 and the terminals of the battery 31 to pass current through the holding windings of relays 100, 101, 107 and 106. This repeater station has thus been started and the relays are set for normal operation, after which the starting tone A is removed from the circuit by the attendant at the central office or division center. It will be noted that it is only necessary to keep the starting tone on the service circuit until cam 120 reaches the beginning of segment position #1, say for thirty seconds.

In the event that all repeater stations in the system which start up simultaneously function in intended manner with no failures in equipment, then all of the repeater cams 120 at the various stations will stop at the midposition of

#1 segment. The electrical circuit for the first relay station in the system will be constructed to open at the end of the #1 segment position on the cam. The circuit for the second or next relay station will be constructed to open at the end of the #3 segment position on its particular cam. The circuit for the third repeater station will be constructed to open at the end of the #5 segment position on its particular cam, while the circuit for the fourth repeater station will open at the end of #9 segment position, etc.

In the event that the amplifier selected by operation of relays 100 and 101 fails after having started to function, there will then be insufficient radiation over output transmission line 124, and insufficient output from diode 78 to maintain relay 113 operated. The restoration of relay 113 to normal, caused by the failure of carrier current radiation and the consequent failure of energy in leads 128, recloses the operating circuit for the motor of the time delay relay 114 through a path extending over the normal make contacts of relay 113. Relay 114 will now cause the commutator 121 to continue its rotation until such time as contact 119 leaves the particular operating segment on cam 120 associated with this station and breaks electrical contact with the commutator, at which time the motor will come to an automatic stop and will maintain this condition until the entire system is shut down, at which time it will return to normal and contact 119 and cam 120 will be restored to the position shown in the drawings. As a consequence of the opening of the electrical circuit between contact 119 and the particular operating segment on cam 120, current will be removed from leads 122 and the holding windings of relays 100, 101, 106 and 107 and these relays will return to normal. The return to normal of relays 100 and 101 will cause the respective armatures thereof to be drawn to their right-hand positions by their restoring springs, and will connect the transmission lines 123 and 124, respectively, to the right-hand blades of switches 22 and 23, respectively, and to the amplifier equipment comprising preamplifier 65 and power amplifier 67 with their respective plate and filament supply circuits 74 and 76. The restoration of relays 106 and 107 to normal will close their normal break contacts to provide a path for the power supply through the central contacts of relay 110 and through the normally made normal break contacts of relays 106 and 107 and through switches 19 and 21, respectively, in their prescribed position, to the plate and filaments of the electron discharge devices associated with the spare amplifier.

In the event that the second relay station in the relay system does not begin to supply radiation because the normally selected amplifier does not function properly, the cam 120 at this station will continue to rotate until the end of #3 segment is reached when the electrical circuit between contact 119 and commutator 121 will be opened, and the spare amplifier at this station will be thrown into service. The cam 120 at the first relay station, however, will be stopped in the midposition of #1 segment. As soon as radiation occurs from the second relay station, the signal coming through the second relay station will stop all subsequent stations at the #3 segment position on their respective cams.

In the event that the third relay station in the system does not begin to supply radiation because the normally selected amplifier does not function properly, it will be apparent from what

has gone before that the first two relay stations will have stopped in the midposition of the #1 segment on the cam, while the third station as well as the subsequent stations will advance to the end of the #5 segment position. At the end of the #5 segment position, the spare amplifier at the third relay station will be thrown into service and the radiation of signal therefrom will stop the cams at the subsequent stations.

The table below shows the position of the cams at the several repeater stations under various conditions of transfer from normally selected amplifier to spare amplifier.

	Relay station #1	Relay station #2	Relay station #3	Relay station #4	Relay station #5
Start with tone A—no failure.....	1	1	1	1	1
At start only relay station #5 fails.....	1	1	1	1	17
At start only relay station #4 fails.....	1	1	1	9	9
At start only relay station #3 fails.....	1	1	5	5	5
At start only relay station #2 fails.....	1	3	3	3	3
At start only relay station #1 fails.....	2	2	2	2	2
If all start O. K. and then station #5 fails.....	1	1	1	1	17
If all start O. K., and then stations #5 and #4 fail in succession.....	1	1	1	9	17
If all start O. K., and then stations #5, #4, #3 and #2 fail in succession.....	1	1	5	9	17
If no station starts O. K. If all start O. K., then station #4 fails.....	2	3	5	9	17
If all start O. K., then station #4 and then station #3 fails.....	1	1	1	9	9
If all start O. K., then station #4, then station #3, then station #2 fails.....	1	3	5	9	15
If all start O. K., and then stations #4, #3, #2 and #1 fail in succession.....	2	3	5	9	16
If all start O. K., and stations #4, #3, #2, #1 and #5 fail in succession.....	2	3	5	9	17

From the foregoing, it will be seen that the starting tone A starts all the cams at the various repeaters together, but the signal coming through stops the cams.

One advantage of the present invention lies in the fact that if the diode current in diode 78 fails in any one repeater station, causing a transfer to the spare amplifier, the subsequent repeater stations in the direction of transmission need not transfer to the spare amplifier.

In the event that the public service power supply fails either completely or falls below a minimum prescribed voltage determined by the under-voltage relay 24, the relay 111 will return to its normal position and the emergency or spare power supply comprising rotary converter 30 and battery 31 will be connected to the system through a path including the positive terminal of battery 31, through lead 129, through armature and field in parallel of rotary converter 30, lead 130, intermediate break contacts of relay 111, lead 131, right-hand operated contact of relay 110, lead 132, meter 32 to the negative terminal of battery 31. The emergency or spare power supply equipment will pass power through leads 133 and closed switch 35, leads 134, and normally made or break contacts of relay 111 to

voltage regulator 28 and then over a circuit previously described to relay 110 for supplying power to the plates and filaments of the amplifiers. The change-over from the public power supply to the emergency supply is designed to be so rapid upon failure of the public service power supply that the relays maintain their normal operating positions without any interruption whatever, due to the changeover. As soon as the voltage on the public service supply becomes normal, a change-over is again effected from the spare or emergency power supply to the public service supply by the operation of relay 111 in a manner previously described. While the system is on the public service power supply, the battery 31 is kept charged through Rectox unit 29 and its associated transformer 29a and the enclosed switch 34. This charging is regulated by the ampere-hour meter 32.

If the division center desires to know the status of the apparatus at the repeater station, a tone C will be sent out over the service circuit and passed through selector 63 to be amplified and rectified at 72 in order to operate relay 104, the latter upon operation closing its contacts to operate motor 25 over a path including leads 135 which extend to the alternating current power supply. A plurality of code wheels 66 are secured to the shaft driven by the motor and function in a manner similar to that described in Fig. 2 to send out code signals indicative of various conditions at the repeater station. The code segments selected by the code wheels a', b', c', d', e' and f' cover predetermined non-overlapping sections on the periphery of the code wheels, each code wheel sending out a characteristic signal indicative of the condition of a particular piece of equipment at the repeater station. Considering code wheel a' as an example, this code wheel will indicate whether or not diode 78 is functioning in response to a minimum normal of radiation. If normal radiation is occurring, the output from diode 78 will operate relay 105 in a manner previously described and close a circuit over its contacts and over leads 136 and through the code wheel to operate relay 112, this last relay, in turn, operating keyer 27 to transmit a characteristic signal over lead 137 extending to the service circuit. Code wheel b' functions to indicate whether or not there is a noise level at the repeater station above a desired normal. For this purpose there is provided a relay 109 which is connected in the output of converter and rectifier 79, the latter in turn being connected to a suitable pick-up transmission line 126 coupled to the output transmission line 124. This noise level status can only be determined when the division center removes modulation from the carrier. Converter and rectifier 9 is a balanced detector circuit and therefore only supplies rectified current to relay 109 when there is modulation on the carrier. Obviously, if modulation is removed by the division center, the only modulation which can operate relay 109 will be that produced by noise. The contacts of relay 109 are connected through leads 133 to the disc wheel b' to cause operation of relay 112 when the segments on the disc wheel b' are engaging the spring contact associated therewith. Code wheel c' indicates when relay 111 is operated and consequently that public service power supply is connected to the system, while code wheel d' indicates when relay 111 is normal and consequently that the emergency or spare power supply equipment is functioning. Both of these

contacts are employed in order that the division center may be given a positive indication at all times of whether one or the other of the power supply equipment is being used. Code wheels e' and f' serve to indicate which set of amplifier equipment is being used. For example, if amplifiers 64 and 66 are being used, the switches 18 and 20 will be down (assuming the conditions prescribed above), relay 106 will be operated and leads 139 from code wheel e' will be closed through the contacts of this relay. However, if the spare amplifier set comprising 65 and 67 is being used under the conditions prescribed above, then relay 106 will be restored to normal and a path will be closed over leads 140 and the normally closed contacts of relay 106 to cause code wheel f' to influence relay 112. It will be seen from an inspection of the drawing that the shaft of the motor 25 is maintained at a positive potential and that the code wheels directly mounted thereon are also maintained at this potential, while a bus 141 directly connected to the coil 112 is common to one contact of the various pairs of contacts associated with the respective code wheels. As in the case of Fig. 2, the motor will come to rest at the position where all contacts to the code wheels are open.

When it is desired to shut down the repeating station, the division center will send out a tone B which will be received over the service circuit and passed through selector 62 and amplified and rectified at 71 to operate relay 103. The operation of this relay will break its normally closed contacts to open the return circuit of the magnet coil of relay 110, thus restoring relay 110 to normal. The restoration of this relay to normal removes power supply from the plates and filaments of the amplifiers which passed through the operated contacts of this relay. The right-hand contacts of relay 110 will now be opened, thus opening the circuit of leads 131 and 132 to prevent the operation of relay 111, and insuring that the emergency power supply does not start up when the station is not in operation. The return to normal of relay 110 will also cause all the relays in the circuit to return to normal. It will thus be obvious that the shut down signal provided by tone B will set all relays so as to prevent the necessary functions of the apparatus at this station until the starting tone A is again applied.

By the term "timing" used in the appended claims, I refer to the timing of the occurrence of similar portions of successive waves. If the frequency is changed, the time between successive similar portions is correspondingly changed. Or, if the phase of a wave is shifted, the time of occurrence of any wave portion is made earlier or later than in the absence of such phase shift. Thus, the term "timing modulation" includes both variation of frequency and variation of phase. In contrast to this, in the case of amplitude modulation the timing of the occurrence of similar portions of successive waves is unaffected by the modulation.

What is claimed is:

1. In a radio relaying system, a first station, a remote second station, and an intermediate station for relaying signals between said first and second stations, said intermediate station comprising a radio relaying station having two sets of apparatus for alternatively performing the same function, and circuit means at said station responsive to a predetermined signal arriving over one of said other stations for trans-

mitting a characteristic signal indicating which one of said two sets is performing its intended function.

2. A relaying station for radio waves comprising a transmitting antenna, two amplifiers, and means responsive to a predetermined signal received by said station for automatically radiating over said antenna a characteristic signal indicating which amplifier is operatively associated with said antenna, there being different characteristic signals for said two amplifiers.

3. A relaying station for radio waves, electron discharge device equipment at said station, two sets of power supply apparatus, and means responsive to a predetermined signal received by said station for automatically radiating a characteristic signal indicating which set is operatively associated with said electron discharge device equipment, there being different characteristic signals for said two sets of power supply apparatus.

4. A relaying station for radio waves comprising a transmitting antenna, two amplifiers, two sets of power supply apparatus for said amplifiers, and means responsive to a predetermined signal received by said station for automatically radiating over said antenna characteristic signals in sequence and in a predetermined order indicating which amplifier is operatively associated with said antenna and which set of power supply apparatus is operatively associated with the said amplifiers, there being different characteristic signals for said amplifiers and sets of power supply apparatus.

5. A radio relaying system comprising a central office, a remote station in said system, said remote station having two sets of apparatus for alternatively performing the same function, and circuit means at said remote station responsive to a predetermined signal from said central office for transmitting to said central office a characteristic signal indicating which one of said two sets is performing its intended function.

6. A radio transmitting station having two sets of apparatus for alternatively performing the same function, a motor, a selector responsive to a predetermined signal for operating said motor, a shaft for said motor, a pair of code wheels on said shaft, said wheels being equipped with elements around the periphery thereof providing different codes for said sets of apparatus, contacts for each code wheel for engaging said elements, circuit means under control of the contacts on said code wheels for transmitting characteristic signals corresponding to the codes on said wheels, and relay means controlled by at least one of said sets for determining which one of said code wheels will operatively affect said circuit means through its associated contacts, whereby the transmitted code signals indicate which one of said two sets of apparatus is performing its intended function.

7. A radio transmitting station having an amplifier and also a spare amplifier, power supply apparatus and also an emergency power supply apparatus, a motor, a selector responsive to a predetermined signal for operating said motor, a shaft for said motor, four code wheels on said shaft, one for each of said amplifiers and power supply apparatus, said wheels having different codes provided by segments, the segments on the code wheels associated with said amplifiers being located on substantially the same 180° portion but oppositely with respect to the segments on the code wheels associated with said power supply

apparatus, contacts for each code wheel, circuit means under control of the contacts on said code wheels for transmitting characteristic signals corresponding to the codes on said wheels, relay means controlled by at least one of said amplifiers and additional relay means controlled by at least one set of said power supply apparatus for respectively determining which code wheel associated with said amplifiers and which code wheel associated with said power supply apparatus will effectively operate said circuit means to cause the same to send out the desired characteristic signals upon rotation of said shaft.

8. A radio relaying system including a transmitting station radiating amplitude modulated waves, a repeating station for receiving said radiated amplitude modulated waves, there being means at said repeater station for changing said amplitude modulated waves to frequency modulated waves and for radiating said frequency modulated waves, and a receiving station for receiving the frequency modulated waves transmitted by said repeating station.

9. A radio relay system for use at ultra short wavelengths comprising a transmitting station radiating amplitude modulated waves, a repeating station receiving said amplitude modulated waves and converting them to frequency modulated waves having a different wavelength and for radiating said last waves, a second repeater station for receiving the waves sent out by said first repeater station, means at said second repeater station for converting the received frequency modulated waves to frequency modulated waves of a still different wavelength and for transmitting waves of said still different wavelength, and a receiving station for receiving the waves transmitted by said second repeater station.

10. A radio relaying station comprising an electron discharge device amplifier, power supply equipment, means responsive to a predetermined signal for connecting said power supply equipment to certain electrodes of said amplifier for conditioning the same to operate, means responsive to another predetermined signal to disconnect said power supply equipment from said amplifier, and means responsive to a third and different predetermined signal to cause said station to transmit a signal indicative of the status of said amplifier.

11. A radio relay station comprising an electron discharge device amplifier, public service power supply terminals and spare power supply terminals for said station, means at said station responsive to a predetermined signal for connecting said amplifier to one of said power supply terminals, means at said station responsive to another predetermined signal to disconnect said last power supply terminals from said amplifier, and means responsive to a third and different predetermined signal to cause said station to transmit a signal indicating which of said power supply terminals is connected to said amplifier.

12. A radio relay station comprising a receiving element, a transmitting element, amplifier apparatus adapted to be connected between said elements, and means responsive to a predetermined signal for causing said station to transmit a characteristic signal indicating whether the noise at said station is above normal, said means including radio frequency pick-up apparatus coupled to said transmitting element and a converter and rectifier coupled to said pick-up apparatus.

13. A radio relay station comprising a receiving

ing element, a transmitting element, amplifier apparatus adapted to be connected between said elements, and means responsive to a predetermined signal for causing said station to transmit a characteristic signal indicating whether the noise at said station is above normal, said means including the following elements: a radio frequency pick-up apparatus coupled to said transmitting element, a converter and rectifier coupled to said pick-up apparatus, a motor, a selective circuit passing only said predetermined signal for operating said motor, a code wheel driven by said motor, a circuit operatively responsive to modulating energy in said converter and rectifier and linking said converter and rectifier to said code wheel, and keying means responsive to the rotation of said code wheel.

14. A radio relaying station comprising a receiving antenna, a transmitting antenna, a pair of amplifiers adapted to be alternatively connected to said antennae, relays for controlling the operative association of said amplifiers with said antennae, said relays having holding coils, and means responsive to the reduction of radiation from said station below a predetermined minimum for switching said amplifiers, said means including a radio frequency pick-up member, a rectifier coupled to said pick-up member, and connections from the output of said rectifier to the holding coils of said relays, whereby reduction of current in the output of said rectifier below said predetermined minimum reduces current in said holding coils and releases said relays.

15. A relaying station for radio waves comprising a transmitting circuit, two amplifiers, and means responsive to a predetermined signal received by said station for automatically sending over said circuit a characteristic signal indicating which amplifier is operatively associated with said circuit, there being different characteristic signals for said two amplifiers.

16. A relaying station for radio waves, electron discharge device equipment at said station, two sets of power supply apparatus, and means responsive to a predetermined signal received by said station for automatically transmitting a characteristic signal indicating which set is operatively associated with said electron discharge device equipment, there being different characteristic signals for said two sets of power supply apparatus.

17. A radio relaying system including a transmitting station radiating amplitude modulated waves, a repeating station for receiving said radiated amplitude modulated waves, there being means at said repeater station for changing said amplitude modulated waves to waves modulated as to timing and for radiating said last waves, and a receiving station for receiving the waves transmitted by said repeating station.

18. A radio relaying system including a transmitting station radiating amplitude modulated waves, a repeating station for receiving said radiated amplitude modulated waves, there being means at said repeater station for changing said amplitude modulated waves to shorter waves modulated as to timing and for radiating said last waves, and a receiving station for receiving the waves transmitted by said repeating station.

19. A radio relaying system including a transmitting station radiating amplitude modulated waves, a repeating station for receiving said radiated amplitude modulated waves, there being means at said repeater station for changing said amplitude modulated waves to frequency modulated waves of shorter wavelength than the received amplitude modulated waves and for radiating said frequency modulated waves, and a receiving station for receiving the frequency modulated waves transmitted by said repeating station.

20. A radio relay system for use at ultra short wavelengths comprising a transmitting station radiating amplitude modulated waves whose length is of the order of six meters, a repeating station receiving said amplitude modulated waves and converting them to frequency modulated waves having a shorter wavelength below one meter and for radiating said last waves, a second repeater station for receiving the waves sent out by said first repeater station, means at said second repeater station for converting the received frequency modulated waves to frequency modulated waves of a still different wavelength but also below one meter and for transmitting waves of said still different wavelength, and a receiving station for receiving the waves transmitted by said second repeater station.

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