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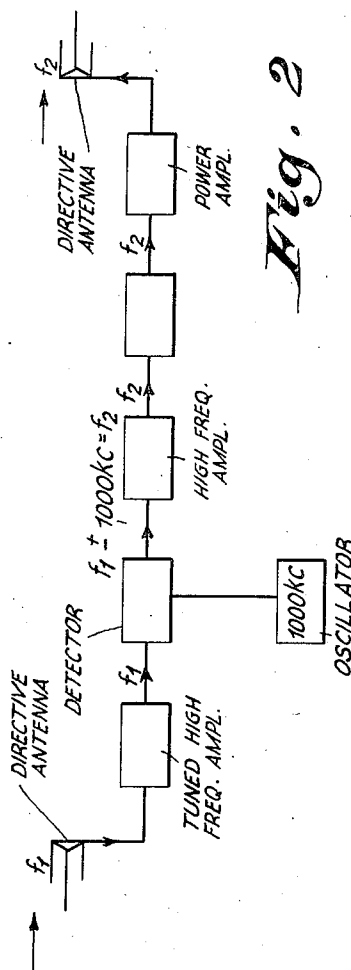
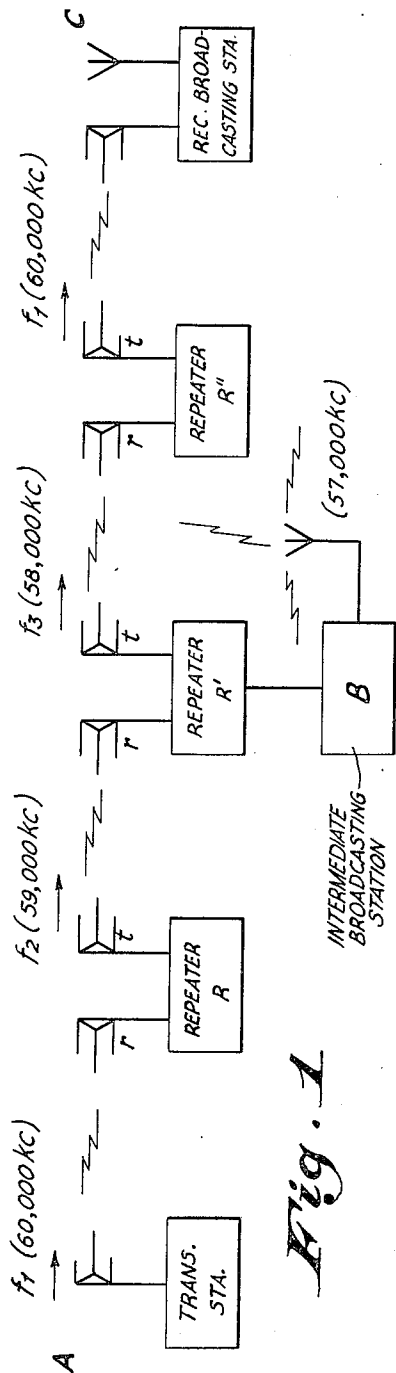
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ULTRA-SHORT WAVE TRANSMITTING SYSTEM

Filed May 17, 1932

3 Sheets-Sheet 1



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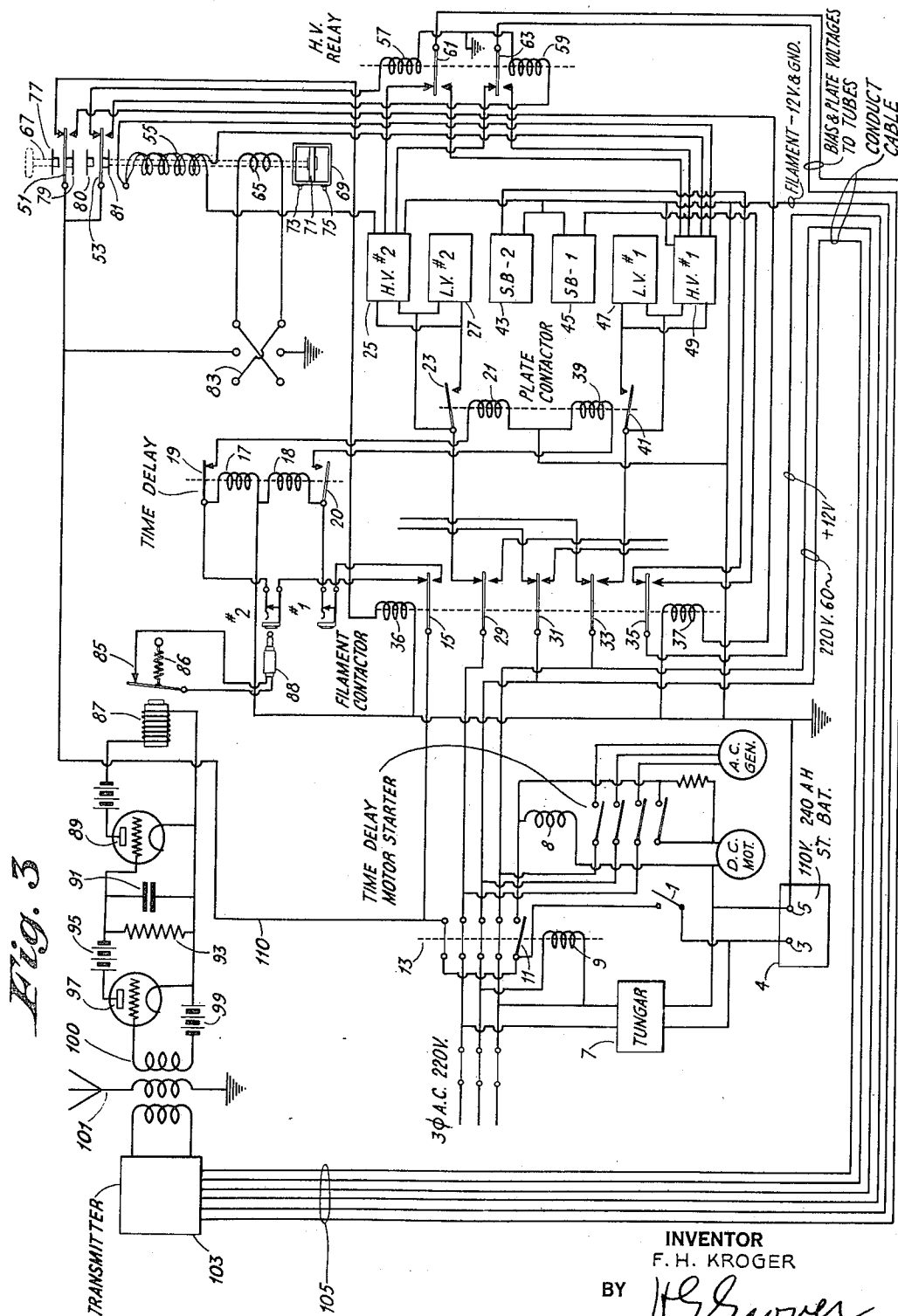
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ULTRA-SHORT WAVE TRANSMITTING SYSTEM

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3 Sheets-Sheet 2



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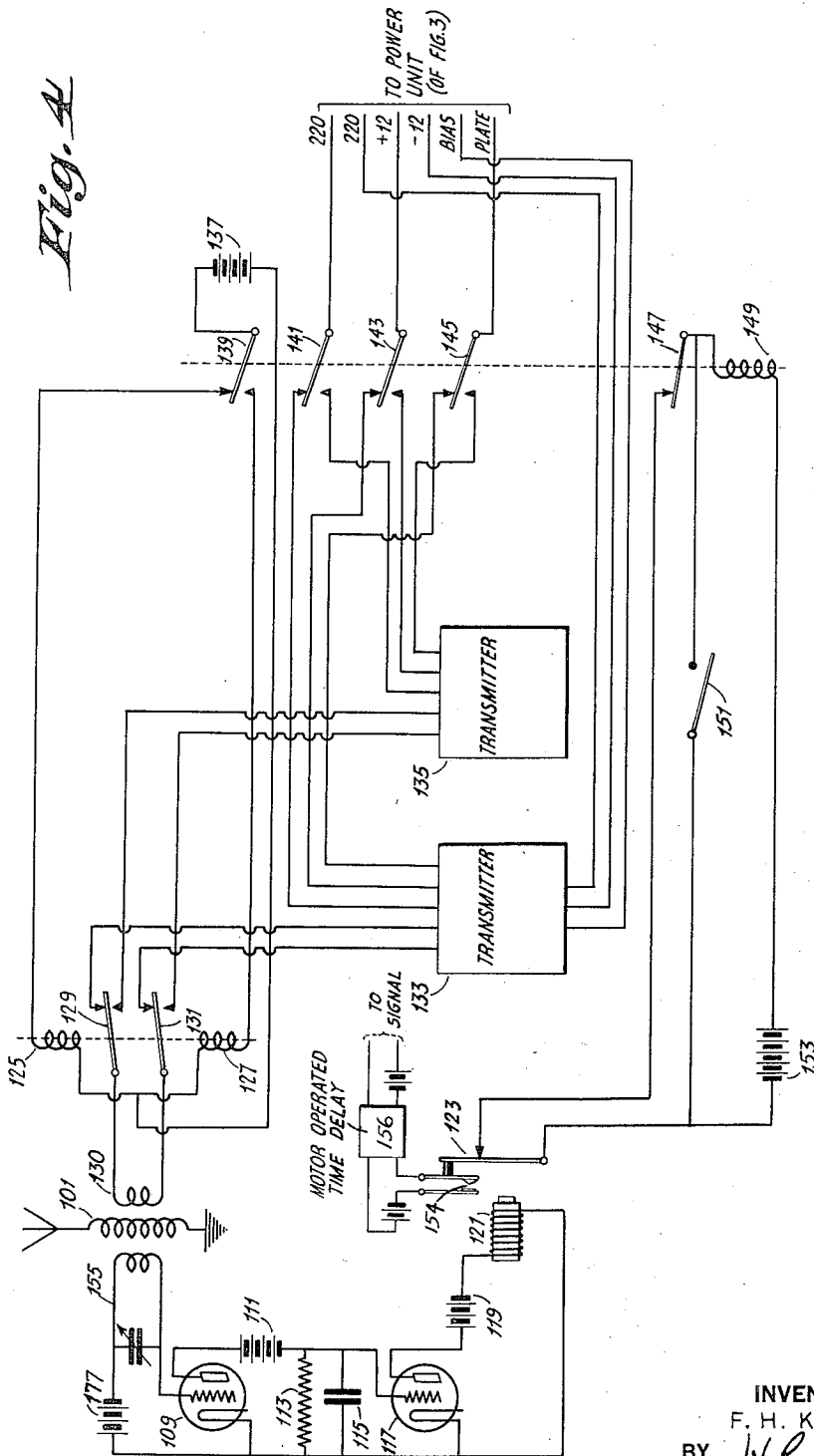
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ULTRA-SHORT WAVE TRANSMITTING SYSTEM

Filed May 17, 1932

3 Sheets-Sheet 3



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ULTRA-SHORT WAVE TRANSMITTING
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Application May 17, 1932, Serial No. 611,769

5 Claims. (Cl. 250—17)

This invention relates to a method of and apparatus for relaying radio signals.

It is well known that electromagnetic waves at the lower wave lengths below ten meters 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 or visible distance. It has been found that the inter-position of objects in the path of transmission of such wave affects, to an extent at least, the ability of a station to receive the radiated energy, and that the condition of the local topography is an important element of consideration in ultra-short wave communication.

One arrangement heretofore suggested for transmitting ultra-short wave signals between points separated by a distance greater than the optical range has been to locate relay or repeater stations at frequent intervals along the line of transmission for amplifying and reradiating the signals. It has been proposed heretofore to provide these relay stations with two directive antennae, one for receiving the signal from the station nearest the transmitting end and the other for reradiating the signal to the next adjacent station nearest the receiving terminal.

In all prior art arrangements, however, the stations have been designed to operate on a single frequency, a mode of operation which introduces great difficulty in maintaining stability of the system. In order to maintain stability and prevent self-oscillation in such relay stations, the receiving and transmitting antennae of each repeater must be so located and must have such sharp directive characteristics that the energy reradiated from the transmitting antenna does not feed back into the receiving antenna. Since the ratio between the input and output levels of these two antennae may be of the order of several million to one, it is extremely difficult if not impossible to make such a system operate in a practical manner.

This difficulty, due to instability or self-oscillation of the amplifiers at the repeater stations, is obviated in the present invention by utilizing different frequencies on the two antennae. According to the present invention it is proposed to receive the signals at a repeater station on one frequency, change its frequency to another frequency which differs from the first frequency by a desired amount and then amplify and reradiate the new frequency.

A system designed in accordance with this invention is not limited in scope to the transmission of any one type of radio signal, but may be

utilized to transmit telegraph signals, television, telephony or other suitable forms of modulation. When used for the transmission of television or telephone broadcasting for the syndication of programs between points which are widely separated, the repeater stations of the present system are useful not only as relay stations, but may also be used as local broadcasting stations in rural districts where the economics of the situation do not otherwise warrant the erection of television or telephone broadcasting stations. For example, a radio transmission line might be used to send programs (television, telephone or both) from New York to Chicago. Such line would pass through rural areas. Due to the fact that the repeater stations are provided with highly directional antennae, for reasons of efficiency in operation, these areas would otherwise be beyond the range of the ultra-short wave broadcasting stations at the terminals of the line due to the quasi-optical nature of the electromagnetic waves used. If desired, it may be advisable to provide at one or more repeater stations on the transmission line a non-directional (broadcasting) transmitter in addition to the directional type. Accordingly, whatever programs are passed over the line would be spread out at right angles to the transmission line as well as in the direct line of transmission and would thus give service to a particular area.

One of the features of the present invention is the automatic change-over equipment for substituting one transmitter for another in the event of failure of radiation. Likewise, two rectifiers with automatic change-over apparatus are provided at each station.

A better understanding of the invention may be had by referring to the following description, accompanied by drawings wherein

Figure 1 shows, diagrammatically, a radio communication system embodying the principles of the present invention, and

Figure 2 illustrates, diagrammatically, one form of repeater station circuit which may be utilized in the present system.

Figures 3 and 4 are line or schematic diagrams of the change-over equipment.

Referring in more detail to Figure 1, there are shown a transmitting station A and a receiving station C between which it is desired to transmit signals. As indicated in the drawings by the direction of the arrows, station A is arranged to transmit signals and station C to receive signals. Intermediate A and C are a plurality of repeater stations R, R' and R''. These repeaters are each provided with two di-

rectional antennæ, one of which is adapted to receive signals and is operative in the direction of the next adjacent transmitting station and the other of which is adapted to transmit signals in the direction of the next adjacent receiving station. Since the transmission range of the ultra-short waves 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 directional antennæ may be of any suitable type and may or may not use reflectors. If, for example, the transmitter is designed to operate on frequencies above 300,000 kilocycles (below one meter), highly directive antennæ of compact construction may be used. A transmitting antenna such as developed at present for frequencies above 300,000 kilocycles consists of a copper sheet about 6 feet wide by 6 feet long, on which are mounted insulators for supporting a system of half wave elements parallel to and one-quarter a wave length away from, the copper sheet. The sheet acts as a reflector. On a two way circuit, i. e. where transmission may be effected in two directions, these antennæ should be mounted back to back at the top of the repeater station tower and the receiving antennæ should be mounted alongside the transmitting antennæ.

For lower frequencies, of the order of 60,000 kilocycles (5 meters), other more extensive forms of directive antennæ would be used, as for example, a type such as is disclosed by P. S. Carter in United States Patent No. 1,974,387, granted September 18, 1934.

In Figure 1, frequencies of the order of 60,000 kilocycles are referred to for the purpose of illustration, but it is to be understood, of course, that the same principles apply to the use of higher or lower frequencies.

In Figure 1, transmitting station A is designed to function on a frequency of 60,000 kilocycles. This signal is received at repeater R on the directive antenna *r*, amplified, converted to a new frequency of 59,000 kilocycles by beating with a local oscillator of 1,000 kilocycles and is then reradiated on directive antenna *t* at 59,000 kilocycles. At repeater R' the 59,000 kilocycle signal is received on antenna *r* and is converted to a new frequency of 58,000 kilocycles, amplified and reradiated at 58,000 kilocycles on transmitting antenna *t*.

Likewise, at relay point R'' the 58,000 kilocycle signal is received, converted to 60,000 kilocycles, amplified and reradiated. The 60,000 kilocycle signal has the same frequency as that originally transmitted at transmitter A. These same three frequencies may now be used over again in the same sequence as many times as may be desired.

Since the range of these ultra-short frequencies is limited to points slightly beyond the distance between the relay points it is impossible for the radiation of the 60,000 kilocycle signal from station C to reach back to repeater R which is capable of receiving 60,000 kilocycle energy. Thus, by the use of these three frequencies, all possibility of instability is entirely eliminated. Although the use of three frequencies is preferable in this arrangement and is thought to be the most practical from an operating standpoint, it is to be understood that, if desired, a simi-

lar system utilizing only two frequencies with suitable directive antennæ may be employed.

At repeater station R' there is shown a local broadcasting station B. The input of the transmitter B may be obtained, in any suitable manner, from the radio transmission line signals, that is, the signals passing along the radio transmission line would be demodulated and used to control the broadcasting transmitter B located at the repeater station R'. The frequency of transmission from this broadcasting transmitter may be any frequency other than the frequency used on the radio transmission line. Transmitter B is arranged to be an automatically operating broadcasting transmitter (as distinguished from a directional) and may be connected at any one or more of the repeater stations to serve rural areas with broadcasting service effectively. Of course, the power of the broadcasting transmitter may be adjusted independently to whatever value it is desired to give adequate service.

In Figure 2 there is shown one manner of receiving a signal on one frequency and heterodyning this received signal with another frequency to obtain a third frequency slightly different from the received frequency for reradiation purposes. The received signal *f*₁ received over the directive antenna will be amplified by the tuned radio frequency amplifier and impressed upon a suitable detector having a separate oscillator connected thereto. The output of this detector will include the desired frequency *f*₂ which, after amplification and filtering, will be impressed upon a power amplifier for reradiation over the other directive antenna. It is to be understood that all the usual precautions which have been developed for short wave receiving equipment will be used, such as complete shielding, filtering of the leads, etc. If desired, the last few power stages may be entirely separate from the radio frequency amplifier and, if necessary, placed in another screened room to reduce all possibility of feed-back in the equipment itself.

The transmission lines to the receiving and transmitting directive antennæ of the circuit in Figure 2 are well separated and so positioned as to reduce the coupling between them to a minimum. The frequency difference between the incoming and outgoing signals is sufficient to make it possible to readily separate the transmitted energy from the incoming energy at the receiver so that the system will tend to be entirely stable. Of course, if a quite large frequency difference between the incoming and outgoing signals is used, the system tends to become inherently more stable and many of the precautions mentioned above may not be necessary.

In Figure 3 there is shown, in a line diagram, suitable apparatus for automatically changing over from one rectifier to another in case of failure of radiation in the transmitter. An emergency power supply is also included in case of failure in the power service. The operation of this circuit will now be described.

Assuming that the outside power source designated in the drawings as a three phase alternating current 220 volt supply is operative, relay 9 will be energized, in turn, closing the four switches interlocked on lever 13. The emergency power supply connecting with switch 11 will be opened. In starting up the equipment, switch 1 will be closed by the attendant causing voltage from the terminal 3 of battery 4 to flow through switch 1, then over lead 10 to contact 51 of the plate relay 55. Current will also flow through

reversing switch 83 to the biasing coil 65. Switch 83 may now be thrown to such a polarity that the pull of coil 65 opposes the pull of the plate coil on the active rectifier. For example, if it is desired to use rectifier 2, which comprises 25 (high voltage rectifier #2), 27 (low voltage rectifier #2), and 43 (storage battery #2), switch 83 will be thrown to such a position that coil 65 opposes the closing of contacts 51 and 53 to the circuits of rectifier 2. The reason for this will be explained later.

Let it be assumed that it is desired to start up the apparatus, using rectifier 2 (elements 25, 27, and 43) and leaving rectifier 1 (elements 45, 47, and 49) as a standby. After switch 83 is thrown to the proper position, handle 67 should be pulled up against the magnetic pull from coil 65 in order to close contacts 51 and 53, the latter being operated by thimbles 79 and 81 mounted on the relay control handle. Current will then flow from contact 51 through filament contactor 36 back to the negative terminal 5 of battery 4. Current will also flow through contact 53 to high voltage relay coil 57, pulling up contacts 61 and 63, and connecting high voltage rectifier 2 to the transmitter. When the filament contactor coil 36 is energized, contacts 15, 29, 31, 33, and 35 are closed in an upward position. Contacts 29, 31, and 33 connect the three phase supply to rectifier 2. Contact 35 connects storage battery 43 to the transmitter. Contact 15 connects the circuit from battery 4 through jack 2 and coil 17 to the negative side of battery 4.

Relay 17 is arranged for time delay in order to give the filaments of the rectifier tubes time to warm up before contact 19 closes. When contact 19 finally closes, battery current is passed through plate contactor coil 21 which, in turn, closes contact 23 applying the plate voltage to the rectifier.

During all this time it has been assumed that handle 67 of differential relay 55 was being pulled up by the attendant. However, as soon as the plate voltage is built up on rectifier 2 the rectifier plate voltage applied to coil 55 will oppose the pull of coil 65 and hold contacts 51 and 53 closed over the circuits associated with rectifier 2. The time within which this operation takes place is about two or three seconds, or whatever time may be required to heat up the filaments before contact 19 of the time delay relay closes.

Should it be desired to use rectifier 1 and its storage battery instead of rectifier 2, the starting up operation is exactly the same except that switch 83 will now be reversed and handle 67 pushed down instead of being pulled up. Once rectifier 2 has been put in operation in a manner heretofore described, it will continue to run until shut down by the attendant or, until for some unforeseen reason, rectifier 2 fails. Such a failure may be caused by a number of reasons, such as a filament burnout, a broken down condenser or a burned out resistance. It will be noted, however, that if the plate voltage of rectifier 2 should fail, then coil 55 of the differential relay would be de-energized and coil 65 would function to pull down handle 67.

In order to protect against momentary loss of voltage a dash pot 69 is utilized, having a piston 71 which is arranged to force air out of vent 73 or 75 according to whether the piston is being pulled upward or downward. Under the present assumption of the operation of the apparatus, coil 65 is pulling the handle 67 downward causing the piston 71 to force air through vent 75. If the

plate voltage is not restored within a short interval of time, piston 71 will descend low enough to cause collars 77 and 80 to open contacts 51 and 53 and close them to the lower contacts. As soon as contact 51 is broken the circuit through filament contactor 36 will be opened, thus disconnecting the power supply from rectifier 2. When contact 51 reaches the lower contact, coil 37 is energized and places the power supply on rectifier 1.

Rectifier 2 is arranged to be completely shut down while rectifier 1 is started up with its proper sequence of events, that is, the filament circuits are energized before the plate voltage is put on. During this sequence of events, coil 65 is arranged to hold contacts 51 and 53 closed in the downward position so that the change-over is entirely automatic. When the voltage of rectifier 1 is built up, coil 55 is excited thereby, but the pull of coil 55 is now in the same direction as the pull on coil 65 and consequently nothing happens. It will be evident, therefore, that rectifier 1 is held in operation until the attendant is called to the station. After making repairs on the rectifier, the reversing switch 83 may be thrown to the opposite position so that coil 65 opposes the voltage from rectifier 1 in coil 55. If desired, the system may be left operating on rectifier 1 and, in case of failure, rectifier 2 may be put into service in a manner which is obvious from the foregoing.

In the drawing of Figure 3 there is also shown one manner in which switching may be made to a spare rectifier or, alternatively, to a spare rectifier and transmitter, should radiation fail. Cable 105 is arranged to carry the power supply from the rectifier system to transmitter 103, which is coupled to antenna 101. A coil 100 associated with bias rectifier 97 is also coupled to antenna 101. When no radiation takes place from antenna 101 battery 99 is arranged to bias tube 97 to cut-off so that no plate current flows through resistance 93. For this condition, the grid of tube 89 is at the same potential as the filament of tube 89, which follows from the fact that there is no voltage drop across resistance 93. Consequently, plate current will flow in tube 89 through relay coil 87 holding contact 85 open against the pull of spring 86. On the other hand, if antenna 101 is radiating, energy will be picked up by coil 100 and will cause the grid of tube 97 to swing positive, creating a flow of plate current in tube 97 through resistance 93. The voltage drop across resistance 93 swings the grid of tube 89 to zero and thereby causing the tongue of relay 87 to be drawn back by spring 86, closing contact 85.

From the foregoing, it will be apparent that as long as antenna 101 radiates in a normal manner, relay contact 85 will be closed, but if the radiation fails, then relay contact 85 will be open. To protect against momentary interruption of the antenna current, condenser 91 has been placed in parallel with resistance 93 and the time constant of this resistance-condenser circuit adjusted to a suitable value. If it is assumed, as mentioned above, that the operator has started up rectifier 2 after the system is in operation, the radiation from antenna 101 will close the contact 85 of relay 87 and the operator will then insert plug 88 into jack 2. Should radiation now fail, the control circuit through contact 19 to plate contactor 21 will be opened and the plate voltage removed from rectifier 2, thus causing rectifier 1

to start up in a manner hereinabove described. From the foregoing, it will be obvious that rectifier 1 and rectifier 2 may be associated with spare transmitters entirely independent of each other, in which case, a failure of radiation would cause the apparatus to be switched over to a spare transmitter.

In order to provide as great flexibility as possible in the operation of the circuit it may be preferable to utilize the arrangement shown in Figure 3 for insuring proper operation in the event only of a rectifier failure, and to use an arrangement that is only capable of switching the transmitters in case of radiation failure. In Figure 4 there is shown in line diagram an arrangement for effecting this purpose wherein there are shown two transmitters 133 and 135 having suitable contactors 141, 143, and 145 for switching the power supply from one transmitter to the other. Interlocked with these contactors is a fourth contactor 139 which is arranged to energize coils 125 or 127, in turn, operating contacts 129 and 131. These latter contacts switch the coupling coil 130 from one transmitter to the other. Since the operation of the circuit shown in this figure is well known to anyone skilled in the art it will only be briefly described herein.

In starting up the arrangement, switch 151 is closed, thus energizing coil 149 from battery 153. Coil 149 connects all contactors in the upper position, as indicated in the drawing, thereby operatively conditioning transmitter 133 for operation. The radiation in antenna 101 is coupled through coil 155 to tube 109, producing an IR drop through resistance 113 which biases the grid of tube 117 negative, causing the tongue of relay 121 to be pulled back by spring 124 and make contact at 123. Switch 151 may now be opened since coil 149 is energized through contacts 123 and 147. In the event of failure of transmitter 133, radiation from antenna 101 will cease and, should it fail long enough for the time constant circuit 113 and 115 to operate, the relay contact 123 will break the energizing coil 149 and throw all contacts 139, 141, 143, and 145 to transmitter 135. In such case, contact 147 will also be opened so that, when antenna 1 is again radiating normally, the closing of contact 123 will have no effect on coil 149 and transmitter 135 will continue in operation until there is a manual switch-over to the other transmitter. It should be noted that the operation of relay 121 closed an alarm circuit over contact 154 which functions in an obvious manner to indicate an alarm at any desired location of the failure of the transmitter. A time delay unit 156 may be utilized, if desired, to prevent slight momentary failure from being indicated.

It is to be distinctly understood that this invention is not limited in application to the precise arrangements shown since it is apparent that they are susceptible of being modified to meet different conditions encountered in their use and it is, therefore, aimed to cover by claims all modi-

fications within the spirit and scope of the present invention.

I claim:

1. An ultrashort wave radio relaying communication system comprising a first station, a second station and a third station, each of said stations having a directive antenna pointed at its next adjacent station, apparatus for energizing said antennae to radiate two sets of power supply equipment at each station for said apparatus, only one set of said equipment being adapted to be operatively connected to said apparatus at a time, and means at each station responsive to a failure of radiation in its associated antenna for automatically changing-over from said operatively connected set to the spare set.

2. An ultrashort wave radio relaying communication system comprising a first station, a second station and a third station, each of said stations having a directive antenna pointed at its next adjacent station, two sets of power supply equipment at each station for enabling energization of said antennae, only one set of said equipment being adapted to be operatively connected to the antenna at a time, and means at each station responsive to failure of energization of its associated antenna for automatically changing-over from said operatively connected set to the spare set.

3. A relaying station for radio signal waves comprising a receiving antenna and a transmitting antenna, means for amplifying the signals received over said receiving antenna and for applying them to said transmitting antenna for reradiation purposes, power supply equipment operatively in circuit with said last means, additional power supply equipment, and automatic change-over apparatus responsive to a failure of radiation from said transmitting antenna for connecting said last power supply equipment to said means.

4. A relaying station for radio signal waves comprising a receiving antenna, a transmitting antenna, means for amplifying the signals received over the receiving antenna and for applying them to the transmitting antenna including two sets of transmitting apparatus for energizing said transmitting antenna, said transmitting antenna being adapted to be connected to only one of said sets at a time, and automatic change-over equipment responsive to a failure of radiation from said transmitting antenna for connecting said transmitting antenna to the spare transmitting apparatus.

5. In combination at a station in a communication system, a transmitting antenna, two sets of transmitting apparatus for energizing said antenna, said antenna being adapted to be connected to only one of said sets at a time, and automatic change-over equipment responsive to a failure of radiation from said transmitting antenna for connecting said antenna to the spare transmitting apparatus.

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