

Aug. 15, 1933.

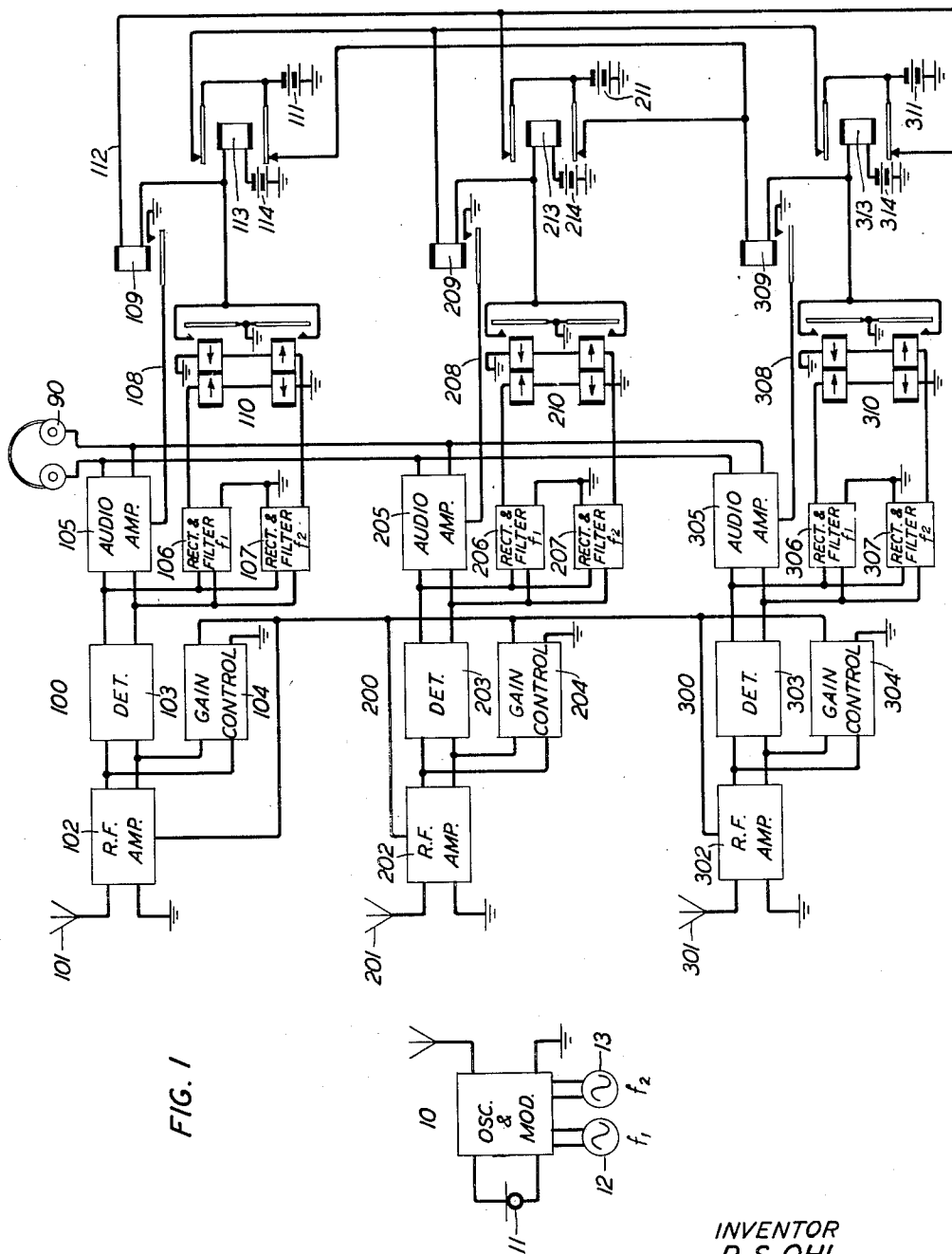
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1,922,059

RADIO RECEIVING SYSTEM

Filed Nov. 1, 1930

2 Sheets-Sheet 1



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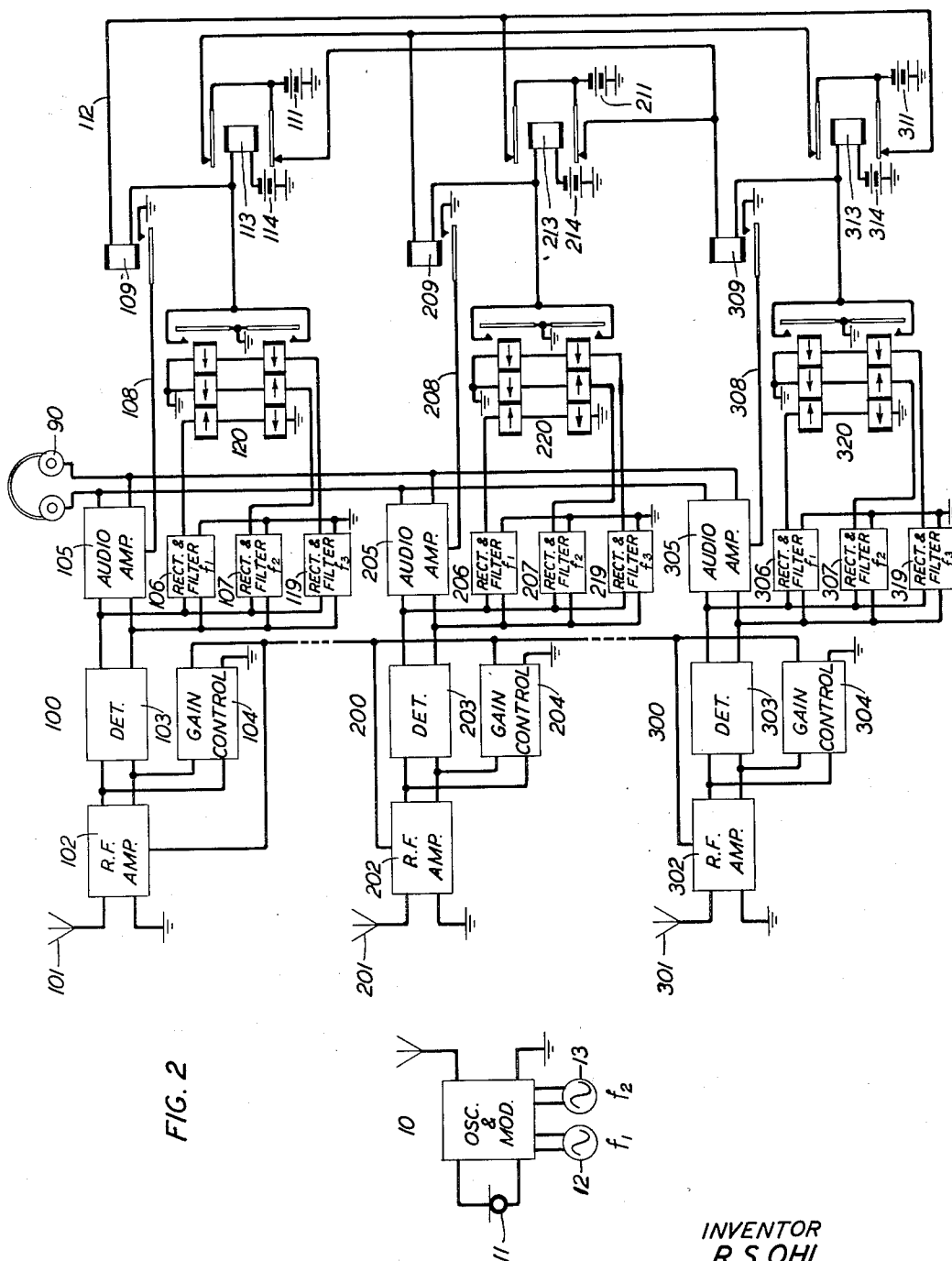


FIG. 2

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1,922,059

RADIO RECEIVING SYSTEM

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Application November 1, 1930. Serial No. 492,635

11 Claims. (Cl. 250—2)

This invention relates to radio signaling systems, and particularly to radio telephone systems.

Fading is one of the outstanding difficulties encountered in radio signaling, particularly when short waves are employed. It manifests itself primarily in general variations in the strength of received signals. However, in radio telephony or other signaling systems in which a wide band of waves is transmitted an effect known as selective fading is found to produce quality distortion.

This selective fading is a result of the fact that fading is a function of the frequency of the radio waves. Consequently, when it is realized that the modulated carrier wave may be considered as comprising a number of radio waves of different frequencies, it is apparent that those component waves may fade differently. This causes certain of the frequencies or bands of frequencies to entirely or partially disappear, resulting in distortion of the received speech or signal.

An object of this invention is to reduce the effects of selective fading.

It has been found that fading varies in quite a different manner at receiving stations separated by only a relatively few wave lengths. Consequently, by employing several such stations and automatically selecting that station in which the reception is the best or exceeds a predetermined minimum as compared with the others, the possibility of fading seriously interfering with satisfactory reception is greatly reduced.

In order that such a system may be used to overcome the effects of selective fading, the signal band at each receiver may be divided into sub-bands and the selecting circuit so operated that between corresponding sub-bands, the sub-band from that receiver which has the desired signal output for the particular frequencies is selected. The selected sub-bands are combined in the signal circuit to give the complete signal band.

While such a system will largely overcome the effects of selective fading, it has certain practical disadvantages for some types of installations.

In a specific preferred embodiment of the present invention the radio carrier wave is modulated at the transmitter by two steady tones or pilot frequencies in addition to the signal band. These pilot frequencies are preferably located near the limits of the signal band. At the receiving station there are employed several antennae so arranged geographically that fading varies differently at each. Associated with each of the antennae is a radio receiver including a selecting network for separating the pilot frequencies from the signal. A relay circuit is controlled by the

pilot frequencies from the receiver in use at any instant, so that when their ratio varies beyond a predetermined margin, that receiver will be automatically cut out of the system and one of the other receivers will be connected to the signal circuit.

In this way the signal circuit will always be supplied with a signal band in which the ratio of the pilot frequencies bears a predetermined relation to their ratio at the transmitter.

This invention can be more readily understood by reference to the following detailed description in connection with the drawing:

Fig. 1 shows diagrammatically one embodiment of the invention; and

Fig. 2 shows diagrammatically a second embodiment of the invention in which the selecting circuit takes care of disturbances due to fading of the carrier as well as selective fading of the side band.

In the system of Fig. 1 there is shown a radio transmitter 10 which is shown by way of example as a radio telephone transmitter in which the carrier wave is modulated by speech frequency waves from the telephone transmitter 11. In addition to being modulated by the speech waves the carrier is also modulated by two pilot frequency waves of frequency f_1 and f_2 from the generators 12 and 13 respectively. The frequency of the pilot waves are so chosen that they lie at or near the limits of the signal band. Thus if the system is being used for commercial telephone transmission in which a band extending from 200 to 3,000 cycles is transmitted, f_1 may be 100 cycles and f_2 3,100 cycles.

At the receiving station there are provided a plurality of radio receivers 100, 200 and 300. These receivers are of any type well known in the art and are similar. Each is arranged to receive the same wave length. Receiver 100, for example, comprises an antenna 101 connected to a radio frequency amplifier 102, the output of which is connected in parallel to a detector 103 and a gain control circuit 104. The output of the detector 103 is in turn coupled to an audio frequency amplifier 105. Two rectifier-filter circuits 106 and 107 are connected in parallel with the audio frequency amplifier to the output of the detector 103. The rectifier-filter 106 is designed to select the pilot tones f_1 to the exclusion of the pilot tone f_2 and the frequencies of the signal band. Similarly the rectifier-filter 107 is designed to select the pilot tones f_2 to the exclusion of the pilot tone f_1 and the signal frequencies. The filters employed in the circuits 106 and 107 may be of the

well known Campbell type, or since each is designed merely for selecting a single frequency, tuned circuits may be employed.

The output of the gain control amplifiers 104, 204 and 304 are connected in parallel to the radio frequency amplifiers 102, 202 and 302. This circuit connection is of the general type, described and claimed, in the copending application of Bruce, Serial No. 346,857 filed March 14, 1929 and provides a control over the effects of fading, tending to reduce the general amplitude of the received side band and carrier.

It is well known that when radio waves are subject to fading the effects are entirely different at different receivers in the same area even though the receivers are separated only by the distance of a wave length or so. Also a phenomenon known as selective fading has been observed, as a result of which certain parts of the detected signal bands will be subject to fading effects, other parts of the signal bands will either not be subject thereto or will not fade to the same extent. In order to take advantage of the first described phenomenon to eliminate undesirable effects due to the second, the antennae 101, 201 and 301 are so arranged geographically that normally the fading effects are quite different at each. The relative amplitudes of the pilot frequency output at each receiver will therefore give at any instant an indication of the condition of selective fading for the respective antenna. In order that the control may be automatic selective circuits responsive to the relative amplitudes of the pilot frequencies at the respective receivers, are provided for selecting at any instant the desired receiver.

These selective circuits are arranged so that the signal circuit will be responsive to one of the receivers at which the conditions of selective fading are such as to give a satisfactory signal output and to operate in response to a change in the fading conditions at that receiver which make the signal output unsatisfactory to switch the signal circuit to another receiver which gives a satisfactory signal output. Provision is also made to prevent the disabling of the particular receiver in operation at any instant if none of the other receivers are giving a satisfactory output. In other words if at any particular time a receiver in operation begins to give an unsatisfactory signal output the signal circuit will not be shifted until the conditions at one of the other receivers are such that its signal output is satisfactory. This prevents the occurrence of a condition in which the signal circuit is not operatively connected to any receiver.

This automatic selection is accomplished by means of the following circuit arrangement. The signal circuit represented by the telephone receivers 90 is connected in parallel to the output of the audio frequency amplifiers 105, 205 and 305. Exactly similar relay circuits are associated with each of the receivers. For convenience only the circuit associated with the receiver 100 will be described in detail. There is provided a relay 109 which when operated grounds the connection 108 from the audio frequency amplifier 105 thus disabling that amplifier. The relay 109 is controlled by a relay circuit responsive to the pilot frequency received in the radio receiver 100. The control is effected by means of a differential relay 110. The windings of this relay are connected as indicated to the output of the rectifier circuits 106 and 107 so that if the amplitude of either of the pilot frequencies f_1 or f_2 becomes

less than that of the other by a predetermined amount, indicating that the selected fading conditions at the receiver 100 are unsatisfactory, one of the armatures of the relay 110 will be operated. When such a condition occurs and the fading conditions are such that the output of one of the other receivers 200 or 300 is satisfactory, the relay 109 will be operated through a circuit from ground through one of the armatures of relay 110, winding of relay 109, connection 112 to either battery 211 or 311. The operation of relay 109 disables the audio frequency amplifier 105 as above described and the receiver 90 will then be responsive only to current in some one of the other receivers which gives, at the moment, a satisfactory output. The relays 113, 213 and 313 are provided so that if at the instant in which the output of the receiver then supplying current to the signal circuit becomes unsatisfactory, the output of the other two receivers is also unsatisfactory, no change in the connections of the signal circuit will occur, but instead the circuit will remain in its previous condition until conditions become such that the output of one of the other receivers is satisfactory.

It will be observed that the relay 109 receives operating current from either battery 211 or the battery 311 through the armature and contact of the relays 213 and 313 respectively. Similarly the relays 209 and 309 receive operating current from either of the batteries associated with the corresponding other receivers through the armatures and contacts of the corresponding 13 relays. Thus the operation of any two of the 13 relays will open the battery circuit of the 09 relays associated with the third radio receiver and prevents the operation of that relay to block the audio frequency amplifier of the particular receiver. The 13 relays are connected so that they are operated by the operation of the respective differential relay 10, thus if the relay 110 is operated by a difference in amplitude of the pilot frequency received in the receiver 100, a circuit is established from ground through one of the armatures of the relay 110, winding of relay 113 and battery 114 to ground, operating the relay 113.

Assuming, for example, that the system is operating with current from the receiver 100 supplied to the signal receivers 90 and the condition at the antennae 201 and 301 is such that there is such a difference in the amplitudes of the two pilot frequencies received in each that both the relays 210 and 310 are operated, then the relays 213 and 313 will be operated and the operating circuit from the relay 109 to both the batteries 211 and 311 will be opened. Then, if the fading conditions so change that there is such a difference in the two pilot frequencies received in the antenna 101 that the relay 110 operates, the relay 109 will not operate to block the amplifier 105 until there is such a change in the receiving conditions that the output of one of the receivers 200 or 300 becomes such that one of the relays 210 or 310 is released. When such a change does occur the corresponding relay 213 or 313 will be operated closing the battery circuit for the relay 109 through the corresponding battery 211 or 311.

This circuit insures that the audio amplifier of any receiver which is at any instant supplying current to the signal circuit will not be blocked by a change in the receptive condition, unless the receptive conditions at one of the other receivers are such as to make the output of that particular receiver satisfactory.

The system of Fig. 1 has been described as a general type of radio telephone system and may be of any of the well known types, for example, one in which the carrier and both side bands, the carrier and one side band or only one side band is transmitted. It is, however, well suited to a type of system in which either one side band and the carrier or one side band alone is transmitted. In the latter case, of course, the carrier would have to be supplied at the receiving point and this may be done by using a single source of carrier wave connected to all three receivers.

Fig. 2 shows a system which is in general similar to the system of Fig. 1 except that it is provided with additional apparatus for controlling the operation in response to fading of the carrier. In this system both side bands and the carrier are employed.

The additional apparatus consists in the addition to each receiver of a third rectifier filter 19 selective of a frequency f_3 which is twice the frequency of one of the pilot frequencies, for example, $2f_2$, and the use of a six winding differential relay 20 in place of the four winding differential relay 10.

As is well known when the carrier is removed from a modulated wave, there is produced by detection a frequency band the individual frequencies of which are twice the frequency of the individual frequencies of the signal band. Thus if the carrier of the wave received at the antenna 101 fades, the two side bands will combine in the detector 103 to produce a wave having a component of frequency $2f_2$. This double frequency product will be selective in the rectifier-filter 119 and produce a current in the output of the rectifier which will cause the operation of the relay 120, thus operating the selecting circuit in the same manner that a difference in the amplitudes of the pilot frequencies f_1 and f_2 will operate the selective circuits.

In the type of circuit of Fig. 2 it is not essential to its proper operation that the output of the gain controls 104, 204 and 304 be connected in parallel since the relay circuits themselves take care of the conditions of fading of the carrier. It is therefore preferable that this common connection of the gain control circuit be dispensed with, though in some cases it may be desirable to use it. For this reason the connection is shown dotted in the circuit of Fig. 2.

What is claimed is:

1. In a radio receiving system, a plurality of radio receivers so related that the component parts of the received waves vary differently at the several receivers with variations in transmission efficiency, and means selectively responsive to predetermined components of the waves received in each of said receivers for automatically selecting between the entire signal outputs of the respective receivers to select the output of that receiver at which there is a predetermined relation between the energy levels of said components of the received waves.

2. In a radio receiving system, means for generating and modulating a carrier wave by a signal wave of a band of frequencies and a plurality of pilot frequency waves, said pilot frequency waves being so distributed in the frequency spectrum as to give an indication of the transmission conditions in the part of the spectrum occupied by the signal modulated carrier wave, a plurality of radio receivers so related to each other that the received waves and component parts vary differently with varying transmission conditions, and means

responsive to the relative amplitudes of the pilot frequency waves received by each receiver for automatically selecting that one of said receivers in which there is a predetermined relation between the energy levels of the received pilot frequencies.

3. In a radio system, means for generating and modulating a carrier wave by a band of signal frequencies and by a pilot frequency near each limiting frequency of said band, a plurality of receivers so related to each other that the received waves and component parts thereof vary differently with varying transmission conditions, and means responsive to the relative amplitudes of the pilot frequencies received in each receiver for automatically selecting from instant to instant that one of said receivers in which there is a predetermined relation between the received energy levels of said pilot frequencies.

4. In a radio system, a transmitter including means for generating a carrier wave and means for modulating said wave by a signal wave of a band of frequencies and by a plurality of pilot waves of frequencies lying substantially in that portion of the frequency spectrum occupied by the signal modulated carrier wave, and a plurality of radio receivers so related to each other that the received waves and component parts thereof vary differently with varying transmission conditions, each of said receivers comprising means for demodulating the received waves, means for separating the demodulated pilot waves from the essential components of the demodulated signal wave and from each other, a signal wave path and means responsive to the relative amplitudes of the detected pilot waves for rendering said signal wave path inoperative when the relative amplitudes of the pilot waves vary by a predetermined amount from their relative amplitudes at the transmitter.

5. In a radio system, a transmitter including means for generating a carrier wave and means for modulating said carrier wave by a signal wave of a band of frequencies and by a plurality of pilot waves of frequencies lying substantially in that portion of the frequency spectrum occupied by the signal modulated carrier wave and a plurality of radio receivers so related to each other that the received waves and component parts thereof vary differently with varying transmission conditions, each of said receivers comprising means for demodulating the received waves, means for separating the demodulated pilot waves from the essential components of the demodulated signal wave and from each other, a signal wave path, main control means responsive to the relative amplitudes of the demodulated pilot waves for rendering said signal wave path inoperative when the relative amplitudes of the pilot waves vary by a predetermined amount from their relative amplitudes at the transmitter, and auxiliary control means responsive to the condition in which the relative amplitudes of the pilot wave outputs of all the other receivers simultaneously vary by such predetermined amount to prevent the main control means from rendering the respective signal path inoperative.

6. In a radio system for transmitting signal waves of a band of frequencies, a plurality of receivers so related to each other that the component parts of the received waves vary differently at the receivers with variations in transmission conditions, and means selectively responsive to predetermined components of the waves received in each of said receivers for automatically se-

lecting, to the exclusion of the others, the wave received at that one of said receivers at which said components of the waves bear a definite relation with respect to their relation at the transmitter.

7. In a radio system, a transmitter including means for generating carrier waves and means for modulating said waves by a signal wave of a band of frequencies and by a plurality of pilot waves of frequencies lying substantially in that portion of the frequency spectrum occupied by the signal modulated carrier waves, and a plurality of radio receivers so related to each other that the received waves and component parts thereof vary differently with varying transmission conditions, each of said receivers comprising means for demodulating the received waves, means for separating the demodulated pilot waves from the essential components of the demodulated signal wave and from each other, a signal wave path, differential relay means responsive to a predetermined difference in the amplitudes of the received waves, a control relay controlled by said differential relay, means responsive to the operation of said control relay for rendering inoperative said signal wave path, auxiliary relays controlled by said differential relay, and an operating circuit for said control relay, said circuit including parallel paths to contacts of the corresponding auxiliary relays of the other receivers whereby a control relay of any receiver can be operated to render the respective signal path inoperative only when the differential relay of at least one of the other receivers is not operated.

8. In a radio system, a transmitter including means for generating carrier waves, means for modulating said waves by a signal wave of a band of frequencies and a plurality of pilot waves, a plurality of radio receivers for receiving the modulated waves and so related to one another that the received waves and the component parts thereof vary differently with varying transmission conditions, a signal circuit responsive to the signal output of any of said receivers, means associated with each of said receivers for selecting

each of the received pilot waves to the substantial exclusion of waves of other frequencies, means associated with said receivers for comparing the relative amplitudes of the pilot waves so selected with the relative amplitudes of the pilot waves at the transmitter and responsive to a predetermined difference in said relative amplitudes to render the signal circuit unresponsive to such a receiver.

9. A radio system according to the next preceding claim, in which each of said receivers comprises means selectively responsive to a frequency double the frequency of one of said pilot frequencies to the substantial exclusion of waves of other frequencies to render the signal circuit unresponsive to a receiver in which there appears such a double frequency wave.

10. In a radio signaling system, means for generating and modulating a carrier wave by a pilot frequency wave, a plurality of receivers for receiving the modulated waves and so related to each other that the waves as received at each receiver vary differently with variations in transmission conditions, and means selectively responsive to the received pilot frequency waves for selecting between the signal output of said receivers to discriminate against any receiver in which such pilot frequency waves appear as a wave of frequency double that of said pilot frequency wave.

11. In a radio signaling system, means for generating and modulating a carrier wave by a pilot frequency wave, and a plurality of radio receivers for receiving the modulated wave and so related to each other that the wave as received at each receiver varies differently with variations in transmission conditions, each of said receivers including means selective to a wave of double said pilot frequency to the substantial exclusion of waves of other frequencies, and means responsive to the output of the selective means to cause the signal circuit to be unresponsive to any receiver having at the instant an output containing a component of frequency double that of said pilot frequency wave.

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