APPARATUS AND METHOD FOR RADIO TRANSMISSION AND RECEPTION

Filed May 6, 1930 2 Sheets-Sheet 1

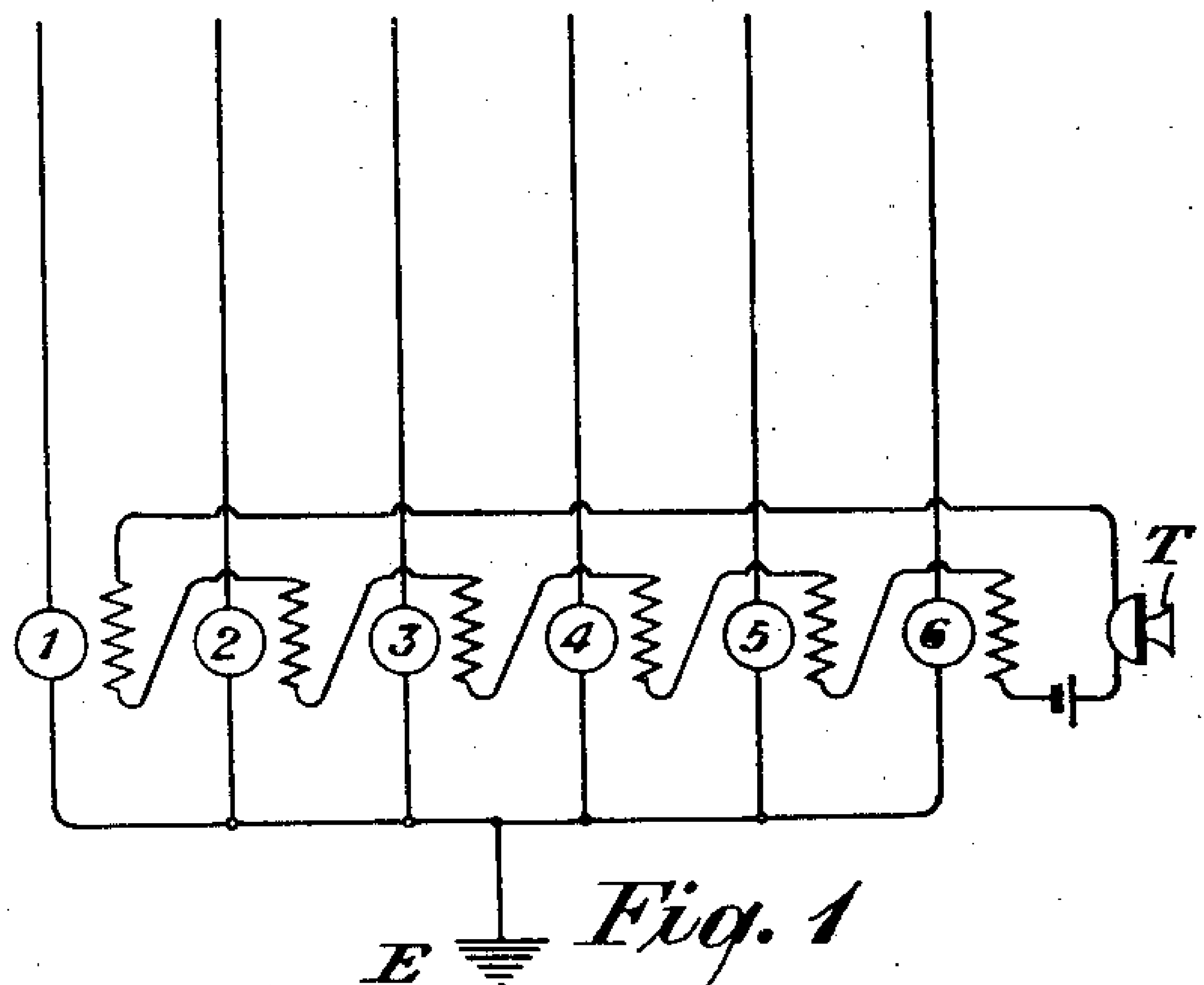

Fig. 1

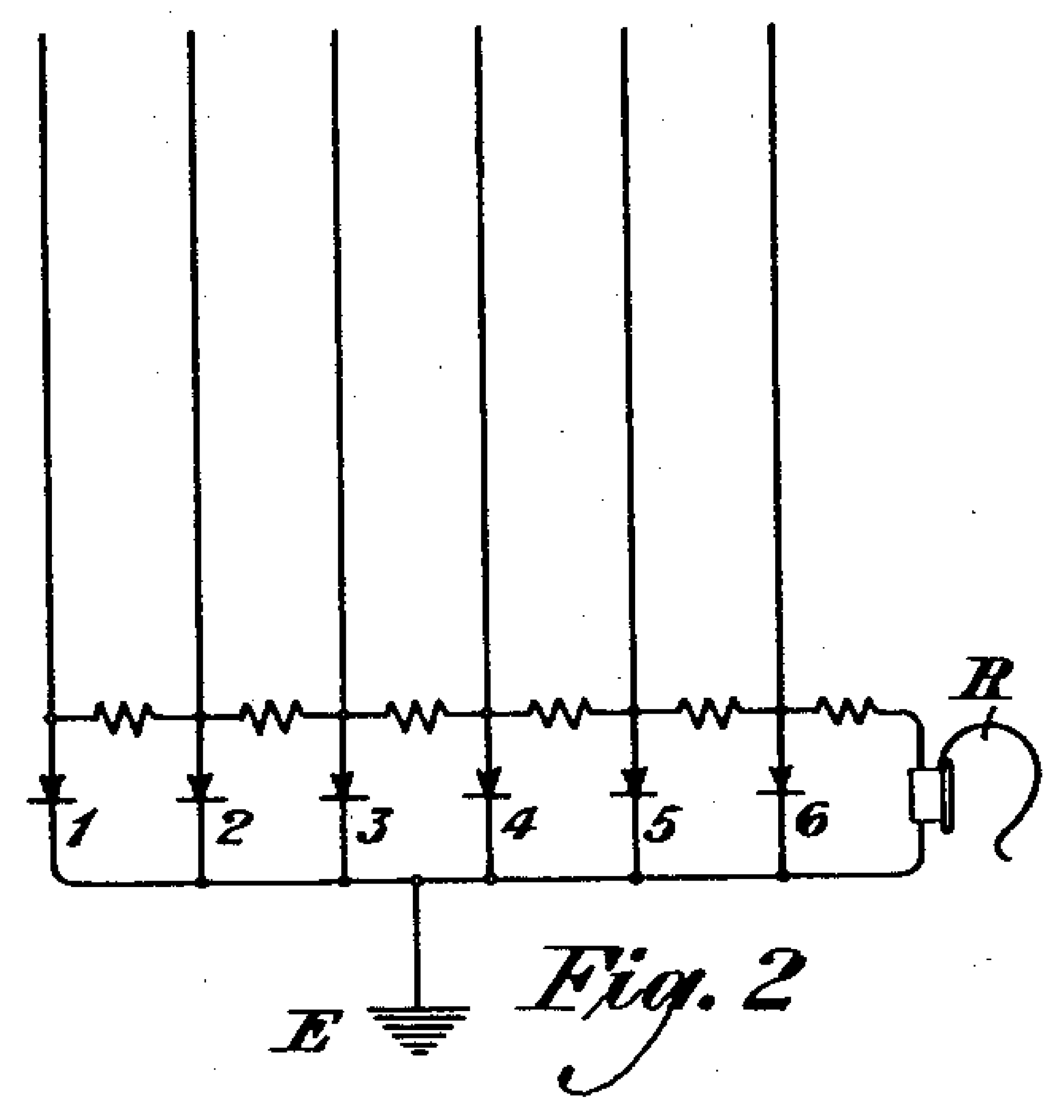

Fig. 2

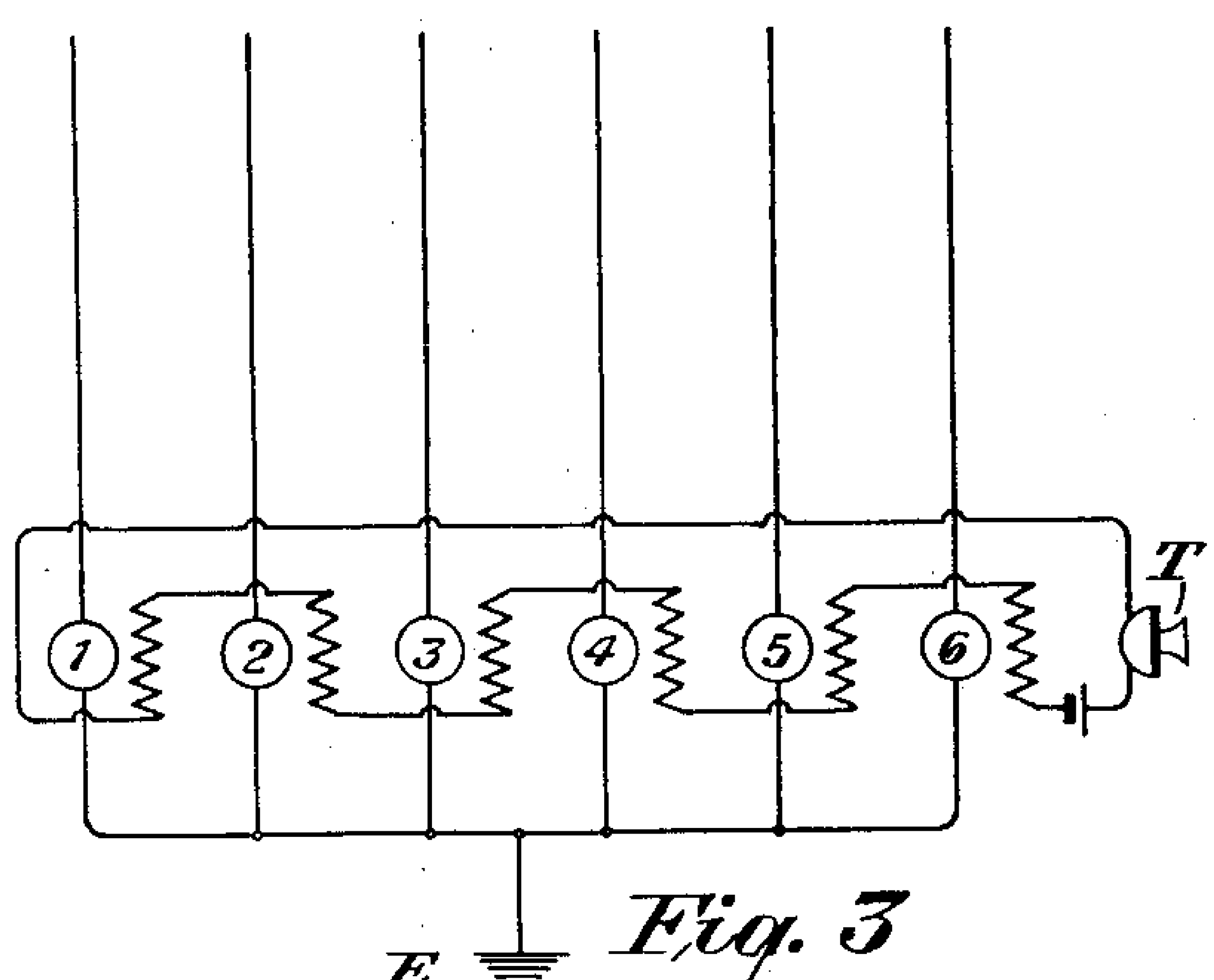

Fig. 3

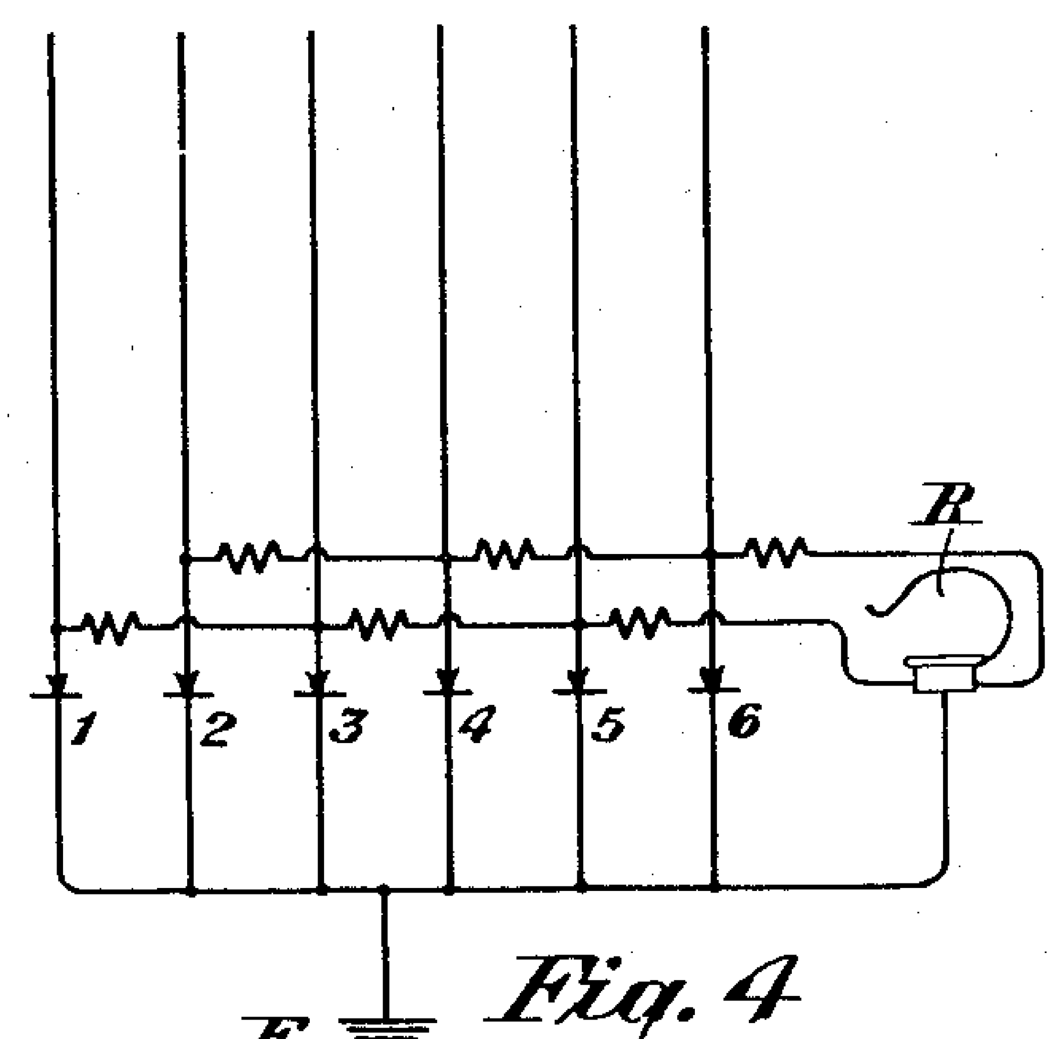

Fig. 4

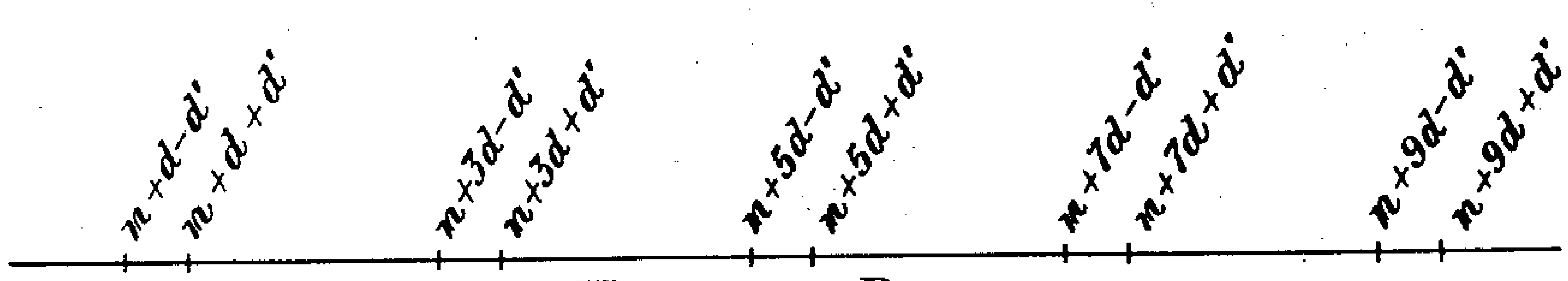

Fig. 5

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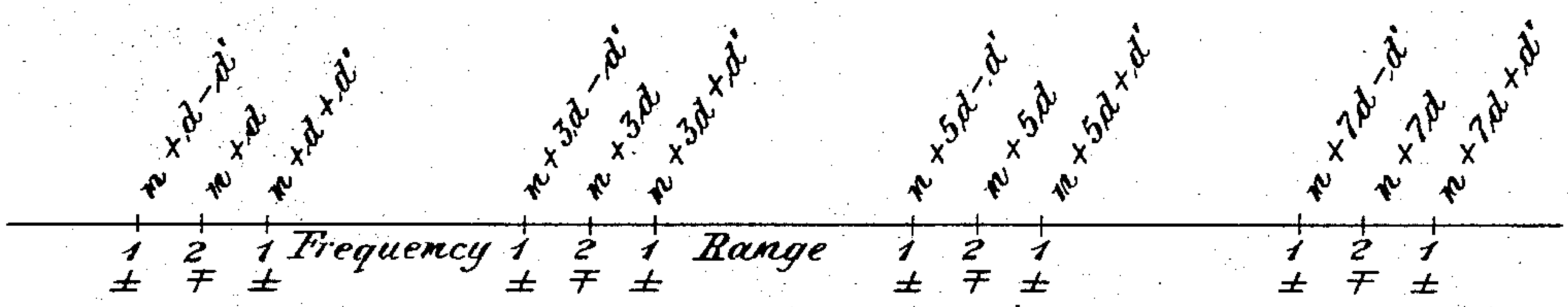

Fig. 6

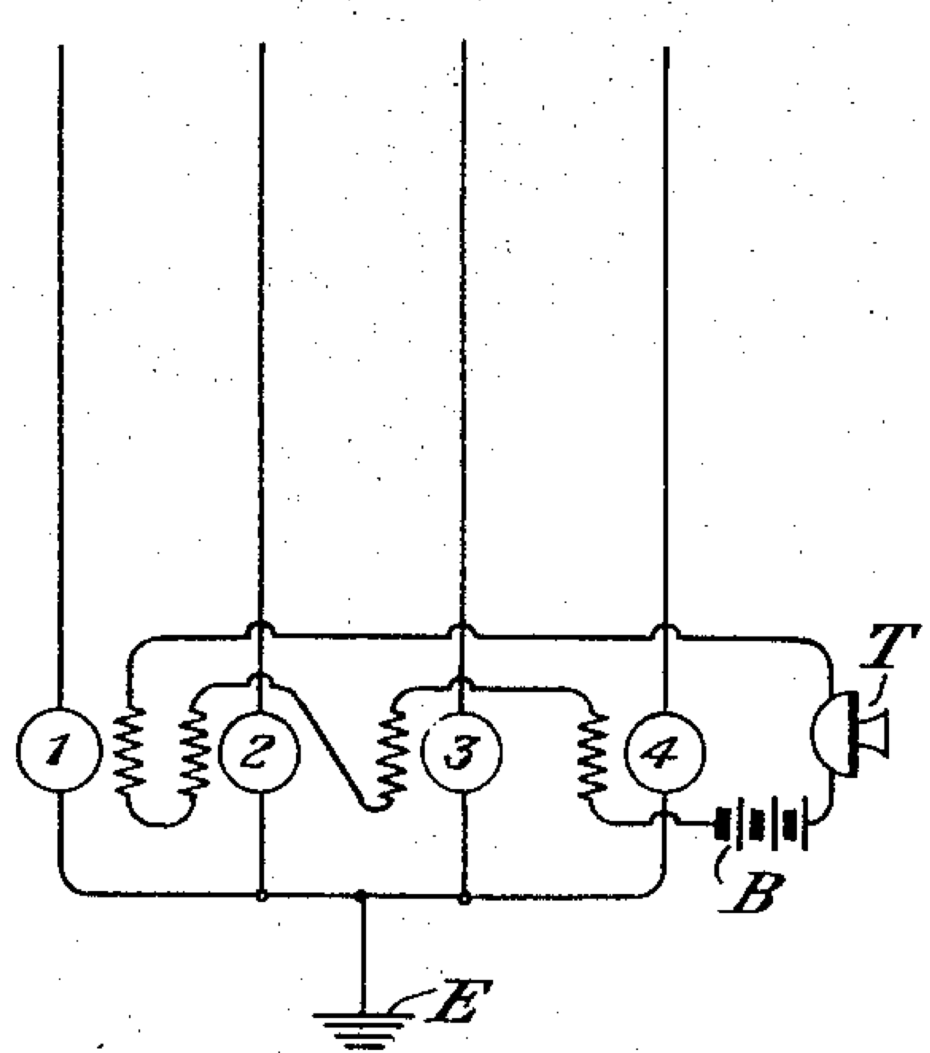

Fig. 7

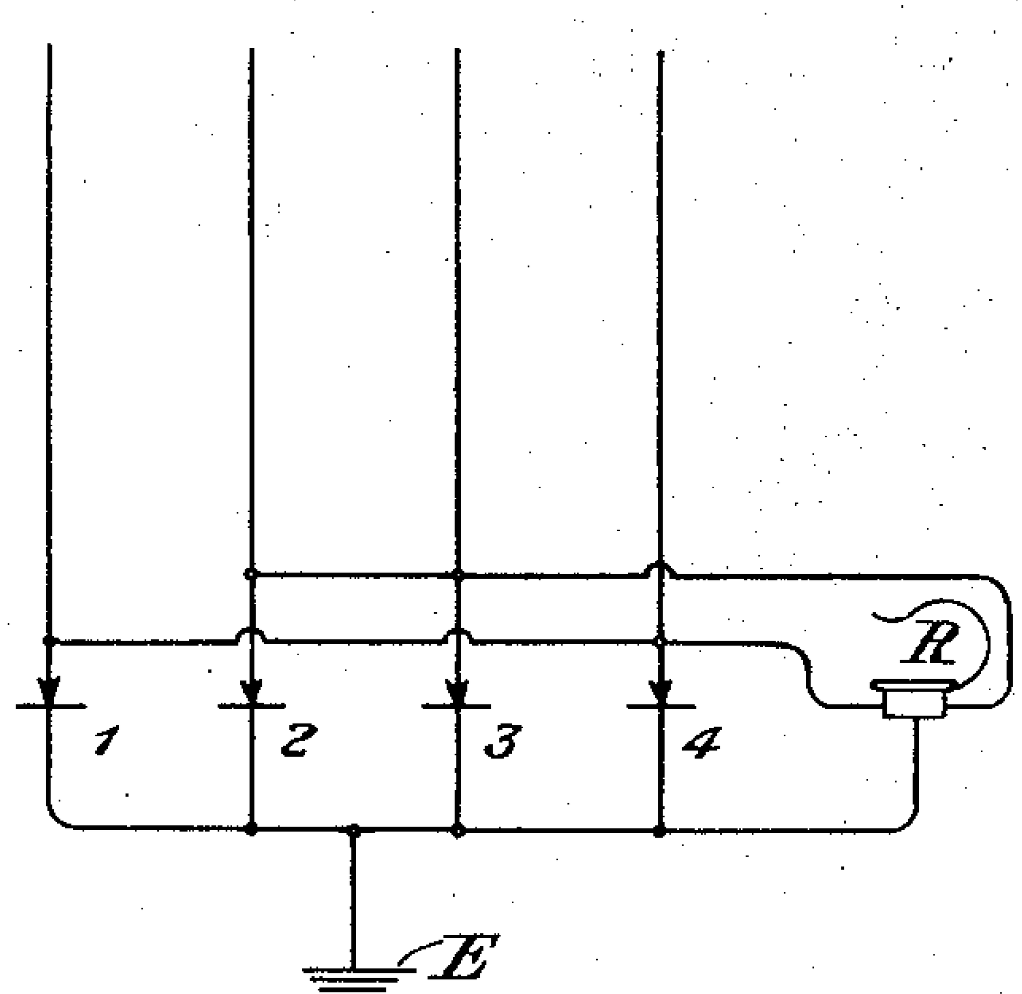

Fig. 8

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UNITED STATES PATENT OFFICE

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APPARATUS AND METHOD FOR RADIO TRANSMISSION AND RECEPTION

Application filed May 6, 1930. Serial No. 450,242.

The principal object of my invention is to provide new and improved apparatus and a corresponding method for the propagation and reception of radio signals without impairment by fading or similar effects. Another object of my invention is to provide for transmitting and receiving radio signals on several different frequencies with a minimum of interference to other receiving stations than the one for which the signals are intended. Still another object of my invention is to send radio signals on several different frequencies so related in phase and in frequency interval that interference with non-intended receiving stations is a minimum. These and other objects of my invention will be readily perceived on consideration of a limited number of examples of practice according to the invention, which I have chosen to present in the following specification. It will be understood that this disclosure has reference to these particular examples of the invention and that its scope will be indicated in the appended claims.

Referring to the drawings, Fig. 1 is a diagrammatic elevation of a multiple antenna transmitting system. Fig. 2 is a diagrammatic elevation of a corresponding receiving system. Fig. 3 is a diagrammatic elevation of a multiple antenna transmitting system with sequential opposite modulation in the series of antennas. Fig. 4 is a diagrammatic elevation of a receiving system adapted for cooperation with the transmitting system of Fig. 3, Fig. 5 is a diagram indicating the frequencies that may be employed in connection with the system of Figs. 3 and 4, Fig. 6 is a similar diagram with a somewhat different set of frequencies, Fig. 7 is a transmitting station for operation according to the frequency plan indicated in Fig. 6, and Fig. 8 is a corresponding receiving station.

As a reason for the objectionable phenomenon of "fading" in radio reception, it is the common opinion that this is due to the arrival at the receiving station of different wave fronts from the transmitting station that have come over different paths and that arrive at the receiving station in opposite or nearly opposite phase. The difference of the two paths is ascribed to the "Heaviside layer" with the view that one wave train suffers more reflections between this layer and the earth's surface than the other. Such being the case, there will be at and near the receiving station an interference pattern on the ground; in one zone the waves will interfere and produce null reception; in a neighboring zone the waves will be in phase and will produce a substantial effect. Due to changing conditions in the Heaviside layer, and other changes, this interference pattern shifts in time giving the well-known phenomenon of intermittent fading.

Obviously this shifting pattern depends on the frequency and an entirely different pattern will be produced by waves of a different frequency. It is a principle employed in the present connection to transmit on several different frequencies simultaneously so that even though there may interference at the receiving station for one of those frequencies, the chance of interference for all of them will be exceedingly small.

Figure 1 represents a transmitting station according to the principle that has just been stated. The respective radiating antennas are energized at different frequencies but their currents are all modulated from the one transmitter T. The corresponding receiving station is shown in Fig. 2. The received currents in its antennas are of different frequency but are all reduced to audio frequency currents which flow in multiple circuits to the single receiver R.

One objection to the transmitting and receiving stations of Figs. 1 and 2 is that they employ a considerable range of frequencies which may extend so far as to cause interference with the receiving station or stations of systems that are desired to be kept independent.

Referring to Fig. 3, this shows a set of transmitting antennas energized in frequencies which grade from left to right. In this case, unlike Fig. 1, the modulation is opposite going from each antenna to the next of the series; that is, when the power on the first is increasing, it is decreasing on the second, increasing on the third, decreasing on the fourth, and so on.

Adapted for cooperation with the transmitting system is the receiving system shown in Fig. 4, where a differential telephone receiver R is employed connected in one sense with one set of alternate receiving antennas 1, 3 and 5, and in the opposite sense with the remaining alternate set of receiving antennas 2, 4 and 6. This connection compensates for the opposite sense in which modulation of the corresponding two groups of antennas at the transmitter takes place, so that the ultimate receiver in Fig. 4 responds to the arithmetical sum of the audio frequency responses of all the demodulators just as in the case of the system illustrated in Figs. 1 and 2.

The disturbance of nearby stations by the system of band or group frequency transmitters of Fig. 3 is decidedly less than that which would result from the band or group transmitter of Fig. 1, but such disturbance as there would be from Fig. 3 may be further reduced by a modification which will now be described.

Hitherto in connection with Figs. 3 and 4 it has been assumed that the frequencies were graded nearly evenly along the series of antennas at the transmitting station and likewise at the receiving station. That is, suppose the evenly graded frequencies heretofore assumed have been

$$n,\ n+2d,\ n+4d,\ n+6d,\ \text{etc.}$$

It will be seen that this is an arithmetical progression. Now instead let the frequencies be

$$n+d-d',\ n+d+d',\ n+3d-d',\ n+3d+d',$$

etc. where d' is small compared with d. These frequencies will lie along a frequency scale as indicated in Fig. 5. Assume that these frequencies are imposed on the respective antennas of the transmitting array of Fig. 3. Thus two frequencies quite close together are oppositely modulated and the reduction of interference is substantially greater than when the frequencies were evenly graded as assumed at an earlier stage of this discussion.

In one aspect my invention involves radio signaling on two or more channels so as to secure privacy and freedom from interference, and other advantages.

The crosstalk produced in a single channel line of frequency n' by the two-channel line whose frequencies are $n''-d'$ and $n''+d'$ is considerably less than that which would occur between two one-channel lines whose respective frequencies were n' and n''; this is in accordance with the foregoing disclosure. But it can be shown that the cross-talk produced in a single-channel line of frequency n' by what I call a "concentric channel line" whose frequencies are $n''-d'$, n'', and $n''+d'$ is decidedly less than in the case mentioned above. This principle is embodied in a system whose construction will readily be apparent in Fig. 6 as compared with Fig. 5. In this diagram, as in Fig. 5, the frequencies used as channels of the radio transmission are indicated by the letters above the horizontal line which represents the frequency range, but the relative amplitudes or intensities of the radiations transmitted on these channels are indicated by the numerals 1, 2, 1 below the frequency range line, and the relative phases of the modulation of the radiations transmitted on the channels is indicated below the range line by the signs $\mp$ and $\pm$. The three channels of each one of the groups of Fig. 6 are what I call a "concentric channel line" and the types of transmitters and receivers used in transmitting and receiving in such a system are indicated respectively in Figs. 7 and 8.

In Fig. 7 the four antennas shown are energized by the four equal sources 1, 2, 3, and 4. These sources are of frequencies $n+pd-d'$, $n+pd$, $n+pd$, and $n+pd+d'$ respectively. The adjustments are such that the four antennas radiate waves of equal intensity or amplitude. The modulator T is so associated with the four sources 1, 2, 3 and 4, that sources 1 and 4 are modulated in unison and sources 2 and 3 are also modulated in unison, but in opposite phase or sense to that of sources 1 and 4.

In Fig. 8 the four antennas are connected to four equal detectors 1, 2, 3, and 4, the antennas being respectively attuned to frequencies $n+pd-d'$, $n+pd$, $n+pd$ and $n+pd+d'$. The adjustments are such that the four antennas with their associated detectors are equally receptive. The common differential receiver R is so associated with the four detectors 1, 2, 3 and 4 that detectors 1 and 4 act upon it in unison, and detectors 2 and 3 also act upon it in unison, but the detectors 2 and 3 act upon it in the opposite sense from detectors 1 and 4.

In making use of such concentric channel transmitters and receivers in the scheme of Fig. 6, a number of such transmitters are grouped together and a similar number of such receivers are grouped together, a common modulator taking the place of the individual modulators of the concentric channel transmitters, and a single common differential ultimate receiver taking the place of the individual differential receivers of the concentric channel receivers.

I claim:

1. The method of employing a plurality of wave frequencies in radio transmission which consists in grading them according to the numbers, $n+d-d'$, $n+d+d'$, $n+3d-d'$, $n+3d+d'$, $n+5d-d'$, $n+5d+d'$, etc., d' being relatively small, and modulating them oppositely in succession along this sequence.

2. The method of employing at least three

wave frequencies in radio transmission which consists in grading them in systematic progression in frequency and modulating them oppositely in succession along this sequence.

3. The method of employing at least three wave frequencies in radio transmission with reduction of interference therefrom which consists in grading the frequencies and modulating and demodulating them oppositely in succession along the graded sequence.

4. A plurality of antennas to the number of at least three, and means to energize them with respective frequencies at intervals alternately small and great, and to modulate them oppositely in sequence along the frequency scale.

5. A plurality of antennas to the number of at least three, and means to energize them with frequencies differing regularly in sequence along the frequency scale, and to modulate them oppositely in sequence along this scale.

6. The method of signaling which consists in transmitting the signals on at least three different frequency bands with phase reversal of modulation in the bands of one of the two sets of alternate bands taken along the frequency scale, and combining the received wave effects at the receiving station with phase reversal in the same bands in which there was phase reversal at the transmitting station so that these received wave effects cooperate to reproduce the signals at the receiving station but neutralize each other in respect of interference.

7. The method of signaling which consists in transmitting the signals on at least three different equally spaced frequency bands with phase reversal of modulation in the bands of one of the two sets of alternate bands taken along the frequency scale, and combining the received wave effects at the receiving station with phase reversal there in the same bands as at the transmitting station so that the effects in all these bands cooperate at the receiving station to produce signals but neutralize each other in respect to interference.

8. The method of signaling which consists in transmitting the signals on three different equally spaced and juxtaposed frequency bands with phase reversal of modulation in one of the two sets of bands of which one set is the extreme bands and the other set is the intermediate band, and combining the received wave effects at the receiving station with phase reversal there in the same band or bands as at the transmitting station so that the received effects cooperate to produce signals but neutralize each other in respect to interference.

9. The method of signaling which consists in transmitting the signals on three different frequencies, modulating the extreme frequencies in opposite sense to the intermediate frequency and combining the effects of the three frequencies at the receiver oppositely in the same way so that they cooperate to produce signals, but neutralize each other in respect of interference.

10. The method of signaling which consists in transmitting the signals on three different equally spaced frequencies, modulating the extreme frequencies in opposite sense to the intermediate frequency and combining the effects of the three frequencies at the receiver oppositely in the same way so that they cooperate to produce signals, but neutralize each other in respect of interference.

11. The method of signaling which consists in transmitting the signals on three different equally spaced and juxtaposed frequencies, modulating the extreme frequencies in opposite sense to the intermediate frequency and combining the effects of the three frequencies at the receiver oppositely in the same way so that they cooperate to produce signals, but neutralize each other in respect of interference.

12. The method of signaling which consists in transmitting the signals on three different equally spaced frequencies, with the intermediate frequency at twice the intensity of the extreme frequencies, modulating the extreme frequencies in the opposite sense to the intermediate frequency and combining the effects of the three frequencies at the receiver oppositely in the same way so that they cooperate to produce signals, but neutralize each other in respect of interference.

13. The method of signaling which consists in transmitting the signals on three different equally spaced and juxtaposed frequencies, with the intermediate frequency at twice the intensity of the extreme frequencies, modulating the extreme frequencies in the opposite sense to the intermediate frequency and combining the effects of the three frequencies at the receiver oppositely in the same way so that they cooperate to produce signals, but neutralize each other in respect of interference.

14. The method of signaling which consists in transmitting the signals on three different and juxtaposed frequencies, with the intermediate frequency at twice the intensity of the extreme frequencies, modulating the extreme frequencies in the opposite sense to the intermediate frequency and combining the effects of the three frequencies at the receiver oppositely in the same way so that they cooperate to produce signals, but neutralize each other in respect of interference.

15. In a transmitter, three antennas, means for energizing them with respective different frequencies, and means for modulating the extreme frequencies in the same sense and the intermediate frequency in the opposite sense.

16. In a transmitter, three antennas, means for energizing them with respective differ-

ent equally spaced frequencies, and means for modulating the extreme frequencies in the same sense and the intermediate frequency in the opposite sense.

17. In a transmitter, three antennas, means for energizing them with respective different equally spaced and juxtaposed frequencies, and means for modulating the extreme frequencies in the same sense and the intermediate frequency in the opposite sense.

18. In a transmitter, four equal antennas, means for energizing two of them each with one of the extreme frequencies of a group of three frequencies and the other two antennas with the remaining frequency, and means for modulating the intermediate frequency in the opposite sense to that with which the extreme frequencies are modulated.

19. In a transmitter, four equal antennas, means for energizing two of them each with one of the extreme frequencies of a group of three equally spaced frequencies and the other two antennas with the remaining frequency, and means for modulating the intermediate frequency in the opposite sense to that with which the extreme frequencies are modulated.

20. In a transmitter, four equal antennas, means for energizing two of them each with one of the extreme frequencies of a group of three equally spaced and juxtaposed frequencies and the other two antennas with the remaining frequency, and means for modulating the intermediate frequency in the opposite sense to that with which the extreme frequencies are modulated.

21. In a transmitter, four equal antennas, means for energizing two of them each with one of the extreme frequencies of a group of three frequencies and the other two antennas with the remaining frequency, the energizing means being such as to equally energize the four antennas and means for modulating the intermediate frequency in the opposite sense to that with which the extreme frequencies are modulated.

22. In a transmitter, four equal antennas, means for energizing two of them each with one of the extreme frequencies of a group of three equally spaced frequencies and the other two antennas with the remaining frequency, the energizing means being such as to equally energize the four antennas and means for modulating the intermediate frequency in the opposite sense to that with which the extreme frequencies are modulated.

23. In a transmitter, four equal antennas, means for energizing two of them each with one of the extreme frequencies of a group of three equally spaced and juxtaposed frequencies and the other two antennas with the remaining frequency, the energizing means being such as to equally energize the four antennas and means for modulating the intermediate frequency in the opposite sense to that with which the extreme frequencies are modulated.

24. In a radio receiver, four component receivers, two of which are attuned each to one of the extreme frequency bands of a group of three frequency bands, the other two attuned to the remaining frequency band of the group, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the four component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the several component receivers are caused to cooperate in actuating the telephone receiver in the production of signals, but neutralize each other in respect of interference.

25. In a radio receiver, four component receivers, two of which are attuned each to one of the extreme frequency bands of a group of three equally spaced frequency bands, the other two attuned to the remaining frequency band of the group, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the four component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the several component receivers are caused to cooperate in actuating the telephone receiver in the production of signals, but neutralize each other in respect of interference.

26. In a radio receiver, four component receivers, two of which are attuned each to one of the extreme frequency bands of a group of three equally spaced and juxtaposed frequency bands, the other two attuned to the remaining frequency band of the group, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the four component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the several component receivers are caused to cooperate in actuating the telephone receiver in the production of signals, but neutralize each other in respect of interference.

27. In a radio receiver, four component receivers of equal receptivity, two of which are attuned each to one of the extreme frequency bands of a group of three frequency bands, the other two attuned to the remaining frequency band of the group, said com-

ponent receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the four component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the several component receivers are caused to cooperate in actuating the telephone receiver in the production of signals, but neutralize each other in respect of interference.

28. In a radio receiver, four component receivers of equal receptivity, two of which are attuned each to one of the extreme frequency bands of a group of three equally spaced frequency bands, the other two attuned to the remaining frequency band of the group, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the four component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the several component receivers are caused to cooperate in actuating the telephone receiver in the production of signals, but neutralize each other in respect of interference.

29. In a radio receiver, four component receivers of equal receptivity, two of which are attuned each to one of the extreme frequency bands of a group of three equally spaced and juxtaposed frequency bands, the other two attuned to the remaining frequency band of the group, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the four component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the several component receivers are caused to cooperate in actuating the telephone receiver in the production of signals, but neutralize each other in respect of interference.

30. In a radio receiver, three component receivers, two of which are attuned to the extreme frequency bands of a group of three frequency bands, the other component receiver being attuned to the remaining frequency band of the group, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the three component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the three component receivers are caused to cooperate in actuating the telephone receiver in the production of signals, but neutralize each other in respect of interference.

31. In a radio receiver, three component receivers, two of which are attuned to the extreme frequency bands of a group of three equally spaced frequency bands, the other component receiver being attuned to the remaining frequency band of the group, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the three component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of three component receivers are caused to cooperate in actuating the telephone receiver in the production of signals, but neutralize each other in respect of interference.

32. In a radio receiver, three component receivers, two of which are attuned to the extreme frequency bands of a group of three equally spaced and juxtaposed frequency bands, the other component receiver being attuned to the remaining frequency band of the group, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the three component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of three component receivers are caused to cooperate in actuating the telephone receiver in the production of signals, but neutralize each other in respect of interference.

33. In a radio receiver, three component receivers, two of which are of equal receptivity and are attuned respectively to the extreme frequency bands of a group of three frequency bands, the third component receiver having a receptivity double that of either of the other component receivers and being attuned to the remaining frequency band, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the three component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the several component receivers are caused to cooperate on the telephone receiver in the

production of signals, but neutralize each other in respect of interference.

34. In a radio receiver, three component receivers, two of which are of equal receptivity and are attuned respectively to the extreme frequency bands of a group of three equally spaced frequency bands, the third component receiver having a receptivity double that of either of the other component receivers and being attuned to the remaining frequency band, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the three component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the several component receivers are caused to cooperate on the telephone receiver in the production of signals, but neutralize each other in respect of interference.

35. In a radio receiver, three component receivers, two of which are of equal receptivity and are attuned respectively to the extreme frequency bands of a group of three equally spaced and juxtaposed frequency bands, the third component receiver having a receptivity double that of either of the other component receivers and being attuned to the remaining frequency band, said component receivers being adapted to produce respective audio frequency outputs, a telephone receiver common to the three component receivers, the components of extreme frequency being connected to the telephone receiver oppositely to the components of intermediate frequency, whereby in the reception of correspondingly opposite frequency bands the audio frequency outputs of the several component receivers are caused to cooperate on the telephone receiver in the production of signals, but neutralize each other in respect of interference.

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