

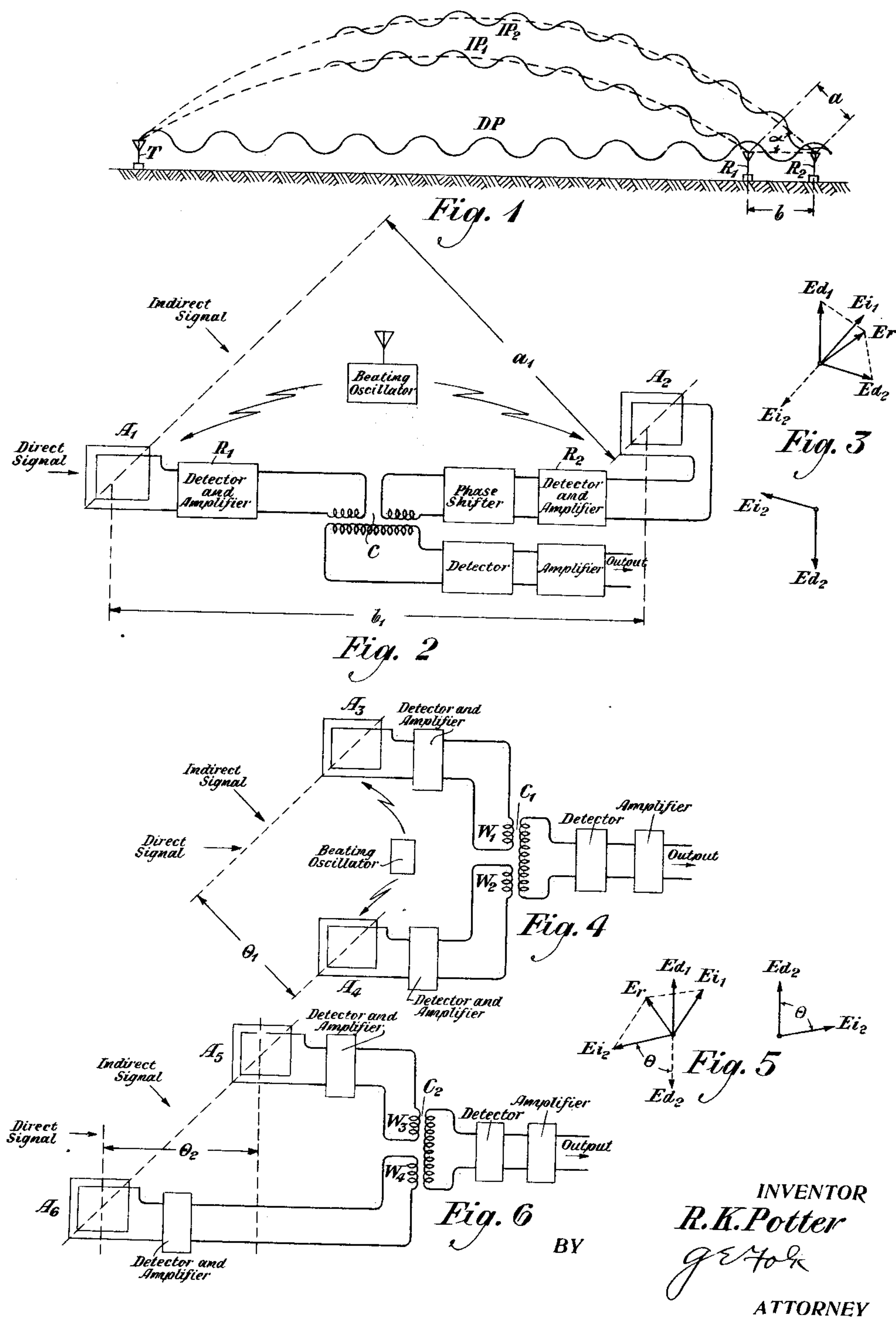
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RADIORECEIVING CIRCUITS

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RADIORECEIVING CIRCUITS

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This invention relates to radio receiving circuits, and more particularly to methods of and means for overcoming fading effects in radio reception.

5 It has been discovered that in night-time transmission of radio signals, at least at the wave lengths used in broadcasting, the signals sent from a point of transmission to any point of reception follow at least two
10 major paths. One of these paths is a direct path between the transmitter and the receiver, while the other path is devious and apparently of considerably greater length than the direct path. It appears further that
15 these two major paths are in a common vertical plane between the transmitter and the receiver, and that the direct and indirect signal energy components received at the distant point combine at a space angle in this
20 plane.

It is the object of my invention to overcome the fading effects due to the existence of these two major transmission paths, and thus to provide for satisfactory reception
25 during the periods when such fading is observed with the ordinary receiving system.

In general, I accomplish the desired result by establishing two receiving points in a common vertical plane with the point of
30 transmission, providing for a suitable space relation between the two points of reception, and combining the directly received signal and the indirectly received signal in such phase relation that one or the other is cancelled.
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My invention will be clearly understood when the following detailed description is read with reference to the accompanying drawing, in which—

40 Figure 1 illustrates schematically the condition of transmission in which the signals follow both a direct path and an indirect path between the point of transmission and a point of reception and indicates one desirable position of the two receivers;
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Figure 2 shows diagrammatically one arrangement of the receivers and associated circuits;

50 Figure 3 comprises two vector diagrams indicating the phase relations of Figure 2;

Figure 4 shows diagrammatically a second arrangement of the receivers and associated circuits;

Figure 5 shows by means of vector diagrams the phase relations of Figure 4, and
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Figure 6 shows diagrammatically a third arrangement of the receivers and associated circuits.

Figure 1 of the drawing illustrates schematically and approximately the condition of
60 night-time transmission discussed above. If two radio receivers R_1 and R_2 are placed in a common vertical plane with the transmitter T , the two receivers having a considerable horizontal separation, radio signals
65 sent from T will reach the receivers R_1 and R_2 over a direct path DP . Also, the signals will reach the receiver R_1 over some such path as IP_1 and the receiver R_2 over some
70 such path as IP_2 . The horizontal separation of the two receivers may be made such that the signals received at the two points over either the direct or the indirect path will be completely out of phase and may be
75 cancelled in a common output of the two receivers by adjusting the amplification of each to give equal output, while the signals received over the other path may be combined either completely or partly in phase.

The first arrangement which will be considered in detail is one in which the receivers
80 are so separated that the directly received signals will be combined absolutely in phase, while the indirectly received signals will have a phase difference of 180° and may be cancelled. With a given wave length λ the above condition is satisfied if the receiver outputs are equal and if
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$$a + \lambda/2 = b \quad (1)$$

Letting α equal the angle of incidence of the indirect wave, it is apparent that
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$$a = b \cos \alpha \quad (2)$$

Substituting (2) in (1), we find that
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$$b = \frac{\lambda/2}{1 - \cos \alpha} \quad (3)$$

Hence, if the value of the angle α is known, it is possible to determine accurately the nec-
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essary spacing of the two receivers R_1 and R_2 , to suppress either the directly or indirectly transmitted wave.

With a wave length of 492 meters, it has been determined that the difference in length between the direct path and the indirect path is approximately 135 kilometers for a distance of 110 kilometers between transmitter and receiver. It is assumed that the direction of the indirect path is caused either by reflection from an overhead layer or by refraction. Accordingly, with the data stated above, it is found that the value of the angle α is approximately 26° . Substituting in (3), we now find that for the condition under consideration the receivers R_1 and R_2 must be separated by distance of approximately two and one-half kilometers. It is to be noted that the value of b (the distance of separation of the receivers) varies directly with λ . Thus it is readily seen that while the separation in the specific case considered above is very great, for the shorter wave lengths this distance is much smaller and the arrangement discussed becomes a practicable one.

Fig. 2 of the drawing shows diagrammatically a desirable arrangement of two receivers employed in radio reception based upon the principle discussed above. The circuit comprises the antenna A_1 and the detecting and amplifying apparatus R_1 , the antenna A_2 and the detecting and amplifying apparatus R_2 , the coil C and detecting and amplifying means between the secondary winding of the coil C and the output of the system. If the receivers are so separated that the directly received signals, for instance, are in phase, and the indirectly received signals are completely out of phase and of equal amplitude, it is readily understood that given an accurate determination of the desired spacing of the receivers, the directly received signals will combine in the coil C and will be passed to the output, while the indirectly received signals will be cancelled out. In this case, however, dissimilarities in the receivers may call for the placing of a phase shifter in the branch of one of the two receivers in order that slight phase discrepancies may be taken care of. A beating oscillator may be employed to reduce the frequency of both branches of the system to a value which is more easily handled than the received frequency without changing the phase relation. This oscillator will function to impress the beating frequency upon the two antennae A_1 and A_2 with or without an antenna. The antenna shown in the drawing serves to bring out clearly the idea that the beating oscillator radiates its oscillations.

Satisfactory results may be obtained with the arrangement shown in Fig. 2 by providing a smaller separation than that shown in

Fig. 1. For instance, the receivers may be separated by a distance equal to one-half the wave length received. The result may now be that the directly received signals will be equal in amplitude and have a phase difference in the two paths of 180° , while the indirectly received signals will not add in phase, but will have a vector sum depending upon the relation of the distances a_1 and b_1 . Letting D represent the distance between the receivers, and α the angle of incidence of the indirect wave, the two signals will have a phase separation equal to

$$2\pi D\lambda(1 - \sin \alpha).$$

If the indirect signals are to be cancelled and the direct signals used, no shifting of phase is required. However, the direct signals may be used and the indirect signals cancelled, by the inclusion of the phase shifter in one of the receiving branches. The phase relations will be more clearly understood upon examination of Fig. 3 of the drawing, which shows a pair of vector diagrams. The phase of the directly received signal in the antenna A_1 is represented by the vector Ed_1 , and the indirectly received signal is represented, with respect to phase, by the vector Ei_1 in the upper diagram. The vectors Ed_2 and Ei_2 of the lower diagram represent the signals received in the antenna A_2 directly and indirectly, respectively. If it is desired to cancel out the signals indirectly received and to use the directly received signals, the phase shifter is employed in the branch of receiver R_2 to shift the phase of the signals received in R_2 as shown in the upper diagram. The indirectly received signals are equal in amplitude and are given a phase difference of 180° and may accordingly be cancelled, while the directly received signals having a phase difference less than 180° will have a positive resultant value. The signal impressed upon the output is then represented by the resultant vector Er which is the sum of the vectors Ed_1 and Ed_2 of the upper diagram, that is, the vector sum after the phase has been shifted in the second receiver. Of course, with the use of a phase shifter to change the phase of the signals received in one receiving branch, the two receivers may be separated by any suitable distance. In such a case, the phase is shifted so that when the signals of equal amplitude are combined, either the direct or the indirect signals will have a phase difference of 180° and will be cancelled.

It is to be understood that vertical antennae may be employed in place of the loops shown in the drawing. Such a change does not disturb the phase relations, the determining relation being that of the distances a_1 and b_1 representing the difference in time phase of the signals arriving at the two points of reception.

A modified arrangement of two receivers suitably spaced in a common vertical plane with the transmitter is shown in Fig. 4 of the drawing. The antennæ A_3 and A_4 are spaced vertically in the plane of transmission. With the arrangement shown in Fig. 4, the direct waves will arrive in time phase, while the indirect waves will have a phase difference determined by the distance Θ_1 . In this case, no phase shifter is required, but the outputs of the intermediate frequency amplifiers are reversed by a suitable and obvious arrangement of the windings W_1 and W_2 of the coil C_1 . The result is that the directly received signals are cancelled, and the indirectly received signals are combined with a phase difference, the output being the vector sum of the indirectly received signals. Fig. 5 shows a pair of vector diagrams helping to clarify the phase relations involved in the arrangement of Fig. 4. The vectors Ed_1 and Ei_1 represent the directly and indirectly received signals, respectively, of the first receiver, while the vectors Ed_2 and Ei_2 of the right diagram represent the phase relation of the signals received in the second receiver. The effect of the reversal of the equalized outputs of the intermediate frequency amplifiers of Fig. 4 is shown in the left diagram of Fig. 5, the broken vector Ed_2 cancelling the vector Ei_1 , and the position of the vector Ei_2 separated from Ed_2 by the angle Θ (corresponding to the distance Θ_1 of Fig. 4) determining with Ei_1 the resultant vector (Er). A modification of the arrangement of Fig. 4 is shown in Fig. 6 of the drawing. In this case, the two antennæ A_5 and A_6 are so disposed in the vertical plane that the indirect waves arrive in time phase, while the direct waves have a phase difference. The windings W_3 and W_4 of the coil C_2 are so arranged that the outputs of the intermediate frequency amplifiers are reversed. The result is that the indirectly received signals are cancelled out, and the output of the system is a vector sum of the directly received signals, the angle determining the phase difference of the signals directly received in the two receivers varying with the distance Θ_2 .

It is to be understood that various changes from the disclosure of the drawing may be made within the scope of the appended claims without a departure from the spirit of the invention.

What is claimed is:

1. The method of receiving radio signals which follow both a direct path and an indirect path in a single vertical plane between the point of transmission and any point of reception, which consists in receiving the direct and indirect signals from a single source at two points in a common vertical plane with the point of transmission, said points being so chosen that the signals received at the two points over the one path will be in phase and

the signals received over the other path will have a phase difference, and combining the outputs from said two points so that the signals received over the first of said paths will cancel one another, and the signals received over the other of said paths will have a positive vector sum.

2. A system for receiving radio signals which follow both a direct path and an indirect path in a single vertical plane between the point of transmission and any point of reception, said system comprising two radio receivers substantially in a common vertical plane with the point of transmission and so disposed in said plane that the signals received in the two receivers over the one path will be in phase and the signals received over the other path will have a phase difference, means for combining the outputs of the two receivers, and means for cancelling the signals received over the first path.

3. A system for receiving radio signals which follow both a direct path and an indirect path in a single vertical plane between the point of transmission and any point of reception, said system comprising two radio receivers substantially in a common vertical plane with the point of transmission and so disposed in said plane that the signals received in the two receivers over the one path will be in phase and the signals received over the other path will have a phase difference, means for combining the outputs of the two receivers, means for cancelling the signals received over the first path, a detector, and means for impressing the vector sum of the signals received over the second path on said detector.

In testimony whereof, I have signed my name to this specification this 2nd day of December, 1926.

RALPH K. POTTER.