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RADIO RECEIVING SYSTEM

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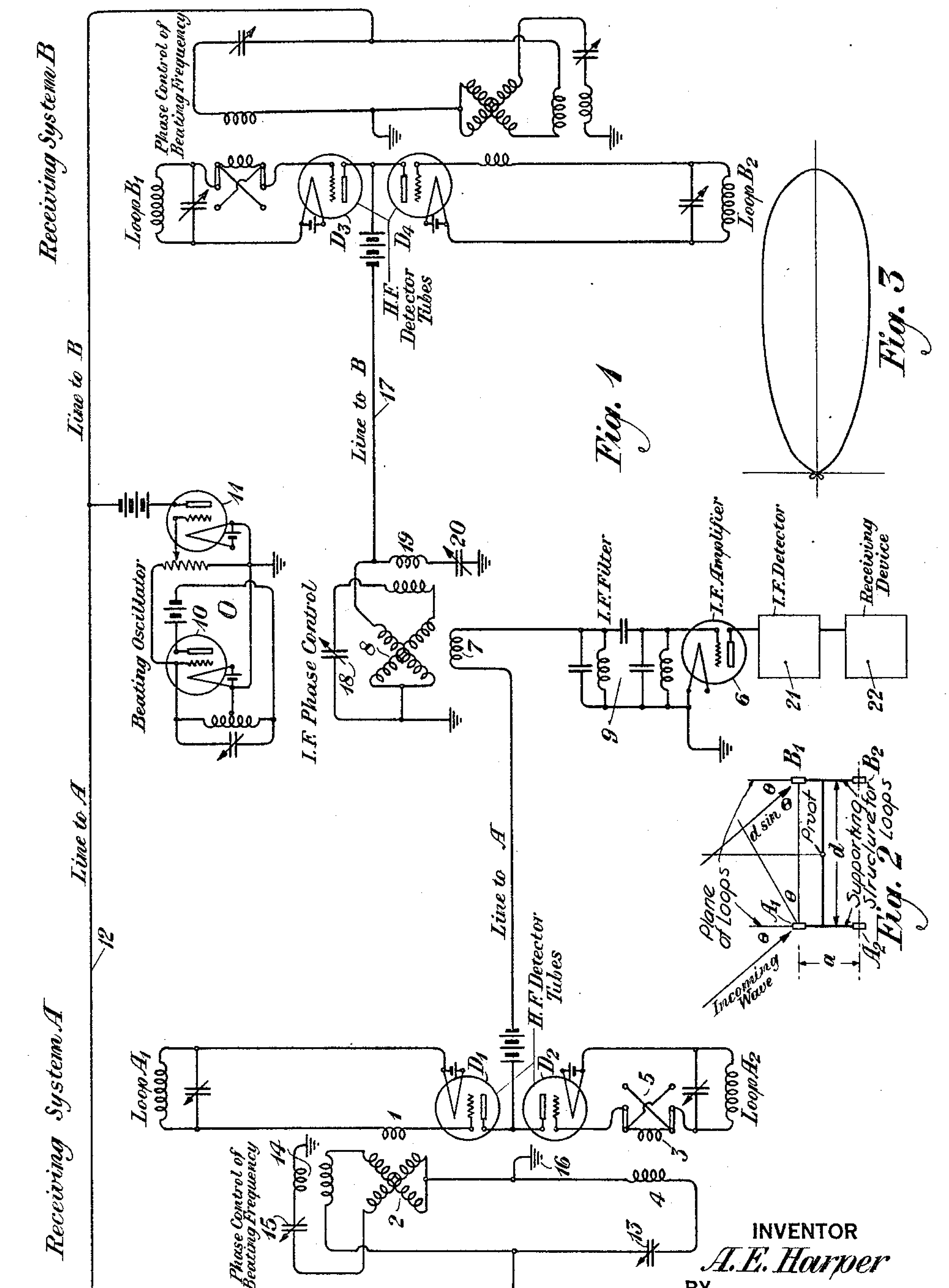

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RADIO RECEIVING SYSTEM.

Application filed August 26, 1925. Serial No. 52,642.

This invention relates to radio receiving systems and particularly to means for improving the directional selectivity of such systems.

Various ways for improving the directional selectivity of radio signaling systems have been proposed and used heretofore. Certain of these employ a plurality of vertical antennæ spaced apart a definite fraction of a wave length so that the voltages resulting from received signaling waves will have such phase relationship as to combine if the signal is from the desired direction or to be opposed and neutralized if the signaling wave setting up the voltage is from an undesired direction. Other forms of directional selecting systems employ a wave antenna or a plurality of such antennæ arranged parallel geographically which have a receiving characteristic highly receptive in a certain direction and diminishing in receptivity in other directions.

In the copending application of H. T. Friis, Serial No. 746,753 filed October 30, 1924, is described a radio receiving system employing two loops spaced apart a definite fraction of a wave length and so connected with circuits adapted to control the phase of the resulting potentials as to have a reception characteristic similar to that of a wave antenna. An arrangement, such as disclosed in the Friis application, has decided advantages over the system employing a wave antenna or a system employing an antenna array in view of the fact that the physical dimensions of the antennæ employed are so much smaller in the Friis system than in any other known system. The Friis receiving system is also fully described in a paper published in the Proceedings of the Institute of Radio Engineers, vol. 13, page 685, et seq. This paper was presented to the institute on May 6, 1925.

The object of this invention is to obtain greater selectivity than that produced by the arrangement shown in the said Friis application, the improvement being effected by an arrangement capable of increasing the intensity of the voltage set up in the system by waves from the desired stations and diminishing in intensity waves from undesired sources or stations.

The invention will be clearly understood from the following description when read in connection with the attached drawing in which Figure 1 shows schematically one form of the invention; and Figs. 2 and 3 illustrate the principle upon which the invention rests.

In Fig. 1 are shown two complete receiving systems designated A and B, each of which is substantially like the other and both of which are connected to a common receiving circuit for the reception of signals. The receiving system A comprises two loops A_1 and A_2, each represented by an inductance and a variable capacity by means of which the loops may be tuned to the frequency desired to be received. The loops are arranged so that they will lie in substantially the same plane which is perpendicular both to the ground and to the wave front of the desired wave. The loops of both receiving systems, as indicated in Fig. 2, are oriented about a common axis. The loop A_1 is connected with the input side of the signal frequency detector tube D_1 and similarly the loop A_2 is connected with the tube D_2. The input circuit of the tube D_1 includes a winding 1, which is coupled with the windings of the variometer 2 by means of which oscillations of the beating frequency are supplied by a source O common to receiving systems A and B for the purpose of beating the incoming frequency to an intermediate frequency, the purpose of which will be clear from subsequent description. In similar manner, the input circuit of the tube D_2 includes a winding 3 which is coupled with the winding 4 of a circuit connected with the said source of beating oscillations. The winding 3 is adapted to be connected in one direction with the input circuit when the arms of the switch 5 are thrown upwardly and in the opposite direction when the said arms are thrown downwardly. The object of the reversing switch is to control the phase of the voltage from the beating oscillator applied to the tube D_2 in order to effect the proper combination of this voltage with the voltage resulting from the loop A_1. The output circuits of the tubes D_1 and D_2 are joined and connected with the input side of an intermediate frequency amplifier 6, the output side of which is connected to an intermediate frequency detector 21 which, in turn, is connected with the signal receiving apparatus 22. The common circuit from the tubes D_1 and D_2 includes a winding 7 which is coupled with the coils of the variometer 8 connected with the detectors D_3 and D_4 of system B, for the purpose of controlling the phase of the intermediate frequency currents applied to the said amplifier by the several groups of detectors. This common circuit also includes an intermediate frequency filter 9 which is adapted to control the range of the frequencies applied to the intermediate frequency amplifier and detector. The beating oscillator O, which includes the oscillating tube 10 and the usual feed-back circuit, is connected with the input side of the amplifier 11, the output circuit of which is connected with a phase control circuit associated with and connected with each of the receiving systems A and B. Thus, the output circuit of the amplifier 11 is connected by the conductor 12 with a phase control circuit forming part of the receiving system A, comprising the inductance 4 and variable capacity 13 and also the variometer 2, the inductances 14 and capacity 15. The high frequency beating oscillations as amplified by 11 will flow over conductor 12 to ground at 16, part of the current flowing through the circuit including the condenser 13 and the inductance 4, and the remainder of the current flowing through the windings of the variometer 2 and through the condenser 15 and one of the inductances 14 to ground. By virtue of the coupling between the inductance 4 and the inductance 3 on one hand and the windings of the variometer 2 and the inductance 1 on the other hand, a potential will be applied to the input circuits of the tubes D_2 and D_1 respectively which will beat the oscillations of the frequency received by the loops A_2 and A_1 respectively to the same intermediate frequency and the phase relationship of these intermediate frequency currents resulting from the beating operation will be controlled by the phase control circuit. In like manner the oscillations received by the loops B_1 and B_2 of the receiving system B will be beaten to an intermediate frequency by the potential from the source O supplied to the receiving circuit at the station B through a signal frequency phase control circuit similar to that described in connection with station A. Since the source of beating oscillations is the same for both stations, the resultant intermediate frequency of the detector tubes D_3 and D_4 will be the same. This intermediate frequency current from station B will be transmitted over conductor 17 to a phase control circuit including the variometer 8, the variable condenser 18, the inductances 19 and the variable condenser 20. The intermediate frequency current from the station B will be controlled as to phase by the intermediate frequency phase control circuit which has just been traced and as thus controlled will be impressed upon the winding 7 of the circuit connected with the intermediate frequency amplifier 6 and the intermediate frequency detector. It will accordingly be seen, therefore, that after the high frequency currents received by each receiving system A and B have been reduced to currents of intermediate frequencies, these intermdiate frequency currents are combined under a definite phase condition and are amplified and detected. The distance between the two receiving systems A and B is approximately one wave length or a fraction thereof in a direction perpendicular to the direction of propagation of waves from a desired station.

The manner in which the system shown in Fig. 1 operates will perhaps be more clearly understood if the mode of operation of a single receiving system is first described. As set forth in the said copending application of Friis, hereinbefore referred to, the voltage set up in the loop A_1 by a wave advancing in the direction represented by the arrow is

$$e_1 = E \cos\theta \cos\omega t \quad (1)$$

and the voltage set up in the loop A_2, which is separated from A_1 by the distance "a" meters, is

$$e_2 = E \cos\theta \cos\left(\omega t - \frac{a \cos\theta}{\lambda} 2\pi\right)$$

Θ is the angle between the direction of the signal wave and a line connecting the two loops, ω is 2π times the frequency and λ is the wave length of the signal.

The phase of the voltage e_2 is shifted a certain angle ϕ before the two voltages e_1 and e_2 are combined. The combined voltage is therefore

$$e_1 + e_2 = E \cos\theta\, \omega t + E \cos\theta \cos\left(\omega t - \frac{a \cos\theta}{\lambda} 2\pi - \phi\right)$$

the maximum value of this voltage is

$$R = 2E \cos\theta \cos\left(\frac{a \cos\theta}{\lambda}\pi + \frac{\phi}{2}\right)$$

That is to say, the loops A_1 and A_2 are oriented so that the angle Θ is equal to zero when the resultant intermediate frequency currents balance and the zero effect is produced. When this result obtains the switch 5 is thrown downwardly so that the winding 3 is connected into the circuit in the opposite direction. The resultant intermediate frequency currents will be added instead of subtracted from each other so that we get maximum receptivity from the desired station instead of zero receptivity.

I have found that by employing a plurality of receiving stations based upon the

Friis principle, having their intermediate frequency circuits connected and the phase relationship of those currents adjusted the resultant current will be much greater in the reception of signals from a desired station than in the Friis system. This will be evident from the following description when read in connection with Fig. 2 of the drawing. The voltage in each Friis receiving circuit will be

$$R=2E\frac{a}{\lambda}\pi\cos\theta\ (1-\cos\theta)$$

In Fig. 2 the loop antennæ of system A, designated A_1 and A_2 are separated by the distance a and the antennæ of system B, designated B_1 and B_2 are likewise separated by the same distance. The two stations are separated by the distance d, and the angle between the direction of travel of the incoming wave and the plane of the antennæ of each receiving system is designated Θ. The sum of the maximum potentials of these two systems then will be

$$V=4E\frac{a}{\lambda}\pi\cos\theta\ (1-\cos\theta)\ \cos\left(\frac{d}{\lambda}\pi\sin\theta-\psi\right)$$

where d is the distance between the systems and ψ is a phase angle which may be adjusted to obtain certain desired results.

An example of an application of this system is given below.

Assume

$$\frac{a}{\lambda}=1/12$$

$$\frac{d}{\lambda}=1/2 \therefore \frac{\pi}{2}=90°$$

$$\psi=0$$

Then

$$E=1$$

θ	$\cos\theta$	$1-\cos\theta$	$\frac{4\pi}{12}\cos\theta$ $(1-\cos\theta)$	$\sin\theta$	(90°) $\sin\theta$	cos (90° $\sin\theta$)	V
0	1.00	0	0	0	0	−1	0
30	.86	.14	.012	.5	45	.71	.008
60	.5	.5	.245	.86	77	.2	.048
90	0	1	0	1	90	0	0
120	−.5	1.5	−.78	.86	77	.2	.15
150	−.86	1.86	−1.05	.5	45	.71	.75
180	−1.0	2	−2.08	0	0	1.0	2.08
210	−.86	1.86	−1.05	−.5	315	−.71	.75
240	−.5	1.5	−.78	−.86	283	−.2	.15
270	0	1	0	−1	270	0	0
300	.5	.5	.24	−86	283	−.2	.048
330	.86	.14	.0121	−.5	315	−.71	.008
360	1.0	0	0	0	0	−1.0	0

Fig. 3 shows graphically these results when plotted to polar coordinates. It will be seen that the directional selectivity in the above mentioned case, or ratio of front to rear receptivity is

$$\frac{V_{180}}{V_{60}}=\frac{2.08}{.048}=43.4$$

It will be apparent, therefore, that by means of my invention the selectivity of a receiving system employing a plurality of spaced loop antennæ is greatly increased along the lines of desired reception and greatly diminished in other directions.

While the invention has been disclosed as embodied in a particular form it is to be understood that this is purely schematic since it is capable of embodiment in different forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a directionally selective radio system, the combination with a receiving circuit comprising two antenna both lying in the same plane and fixedly held at a predetermined distance apart, the said plane being perpendicular to the ground and to the wave front, a detector individual to and connected with each antenna, a source of beating oscillations connected with the input side of each detector to produce an intermediate frequency from the received signaling frequency, the connection including means to change the phase of the said oscillations, a common output circuit for both detectors, of a second receiving circuit substantially similar structurally to said first receiving circuit and connected with the same source of beating oscillations, and an intermediate frequency detector and receiver connected with the output circuits of said first and said second receiving circuits, the connection including means to control the relative phase of the intermediate frequency currents applied to the said intermediate frequency detector.

2. In a directionally selective radio system, the combination with a receiving system comprising two loop antennæ, means to support the said antennæ in the same vertical plane and at a predetermined distance apart, the said plane being perpendicular to the ground, a plurality of demodulators each individual to and having its input circuit connected with an antenna, the output circuits of said demodulators being connected with a common output circuit, a source of beating oscillations connected with the input circuits of said demodulators to beat the incoming signal frequency to an intermediate frequency, one of said connections including a reversing switch to change the phase of the beating oscillations in said input circuit, a second receiving system substantially similar to the said first receiving system having similar antennæ similarly supported, the antennæ of both systems being oriented about a common axis parallel to the plane of the antennæ and connected with the same source of beating oscillations, means connected with the second system to combine the intermediate frequency voltages of the first receiving

system with those of the second receiving system and to control the phase of said voltages, and an intermediate frequency detector and an indicating device to detect the signal from said combined voltages.

3. In a system as set forth in claim 2, the method for effecting the reception of signals which consists in receiving waves of signal frequency in the antennæ of each receiving system, beating the signal frequency with oscillations of a frequency differing from the signal frequency to produce the same intermediate frequency in all of the receiving systems, opposing in each system the intermediate frequency potentials so that they will tend to neutralize and orientating the antennæ of both receiving systems about a common axis until full neutralization is effected, then changing the phase of the beating oscillations so that the said intermediate frequency potentials in each system will be in such phase relation as to produce an additive effect, combining the said intermediate frequency from both systems and detecting the signal from said intermediate frequencies.

4. In a directionally selective radio system, the combination with a receiving circuit comprising two antennæ both lying in the same plane and fixedly held at a predetermined distance apart, the said plane being perpendicular to the ground and to the wave front, a detector individual to and connected with each antenna, a source of beating oscillations connected with the input side of each detector to produce an intermediate frequency from the received signaling frequency, the connection including means to change the phase of the said oscillations, a common output circuit for both detectors, of a second receiving circuit substantially similar structurally to the said first receiving circuit and connected with the same source of beating oscillations, and an intermediate frequency detector having its input side connected with the output circuits of the said first and said second receiving circuits.

5. In a directionally selective radio system, the combination with a receiving circuit comprising two antennæ both lying in the same plane and fixedly held at a predetermined distance apart, the said plane being perpendicular to the ground and to the wave front, a detector individual to and connected with each antenna, a source of beating oscillations connected with the input side of each detector to produce an intermediate frequency from the received signaling frequency, the connection including means to change the phase of the said oscillations, a common output circuit for both detectors, of a second receiving circuit substantially similar structurally to the said first receiving circuit and connected with the same source of beating oscillations, and an intermediate frequency detector having its input side connected with the output circuits of the said first and said second receiving circuits, the input connection including means to control the relative phase of the intermediate frequency currents applied to the input of the said intermediate frequency detector.

6. In a directionally selective radio system, the combination with a receiving circuit comprising two antennæ both lying in the same plane and fixedly held at a predetermined distance apart, the said plane being perpendicular to the ground and to the wave front, a detector individual to and connected with each antenna, a source of beating oscillations connected with the input side of each detector to produce an intermediate frequency from the received signaling frequency, the connection including means to change the phase of the said oscillations, a common output circuit for both detectors, of a second receiving circuit substantially similar structurally to the said first receiving circuit and connected with the same source of beating oscillations, and an intermediate frequency detector having its input side connected with the output circuits of the said first and said second receiving circuits, the said input connections including a frequency selecting device capable of passing the intermediate frequency and a phase controlling device to adjust the phase relation of the intermediate frequency currents applied by said output circuits to the input side of the said intermediate frequency detector.

In testimony whereof, I have signed my name to this specification this 24th day of August 1925.

AUGUSTUS E. HARPER.