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1,457,447

J. MILLS

RADIO RECEIVING CIRCUITS

Filed Dec. 22, 1921

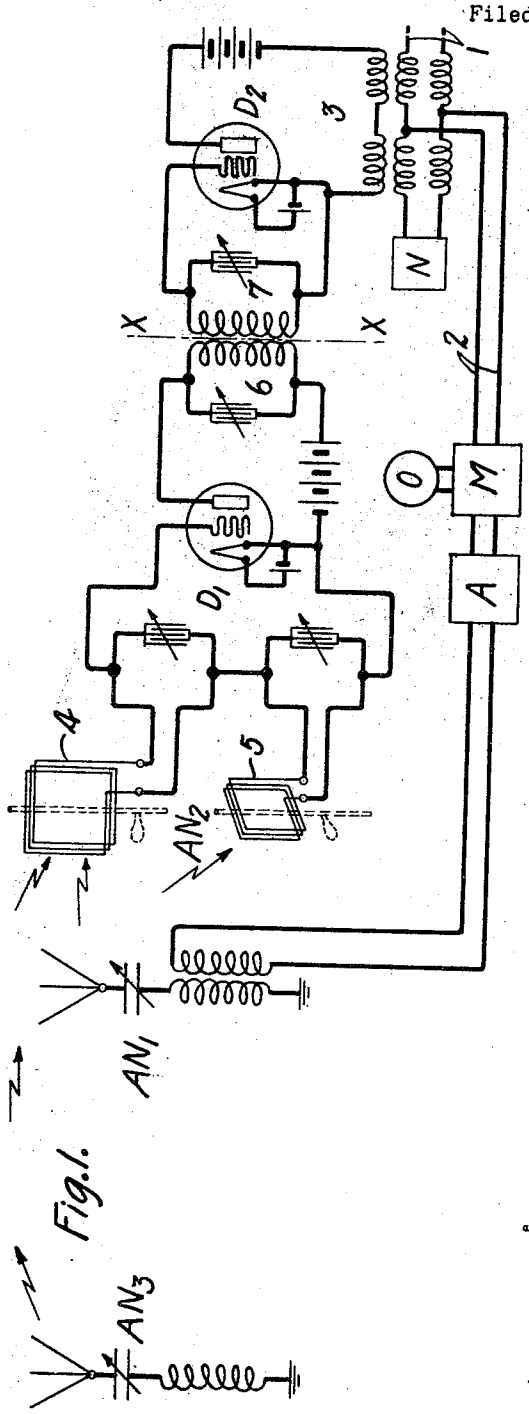


Fig. 1.

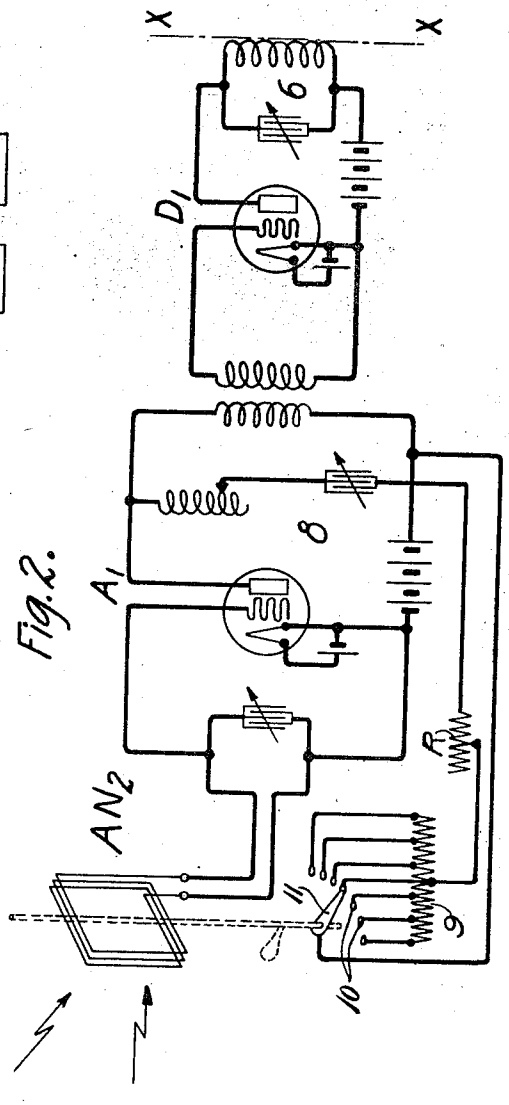


Fig. 2.

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UNITED STATES PATENT OFFICE.

JOHN MILLS, OF WYOMING, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

RADIO RECEIVING CIRCUITS.

Application filed December 22, 1921. Serial No. 524,070.

To all whom it may concern:

Be it known that I, JOHN MILLS, a citizen of the United States, residing at Wyoming, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Radio Receiving Circuits, of which the following is a full, clear, concise, and exact description.

This invention relates to radio receiving circuits and particularly to that type employing the principle of successive detection.

The term "successive detection" as here used is given its usual signification as involving the function of stepping down the frequency of the received radio frequency waves to an intermediate high frequency by one detecting operation and employing a subsequent detecting operation to obtain the low frequency modulating component. According to the present invention the wave to be received and an auxiliary radio wave are received and impressed together upon the input circuit of the first detector by which the first frequency reduction is accomplished. The auxiliary wave is given such a frequency that, by combination with the normally received wave, there will result in the output circuit of said detector an intermediate frequency wave having a desired periodicity. The auxiliary wave source may have its sole function as above indicated or it may combine this function with that of a source for transmitting waves to the distant station, the circuits associated with said source and the receiving circuits constituting the terminal circuits of a complete two-way channel. A system characterized generally by the production of intermediate frequency waves at the receiver will be designated an "intermediate frequency system," the specific type in which the auxiliary wave source has a double function, as described, being correspondingly designated a "modified intermediate frequency system". A receiving circuit having means for stepping down the frequency of its normally received wave by combination with an auxiliary frequency wave, whether said auxiliary wave has the additional function mentioned or not, will be designated an "intermediate frequency receiving circuit". The auxiliary frequency source will be designated as a "local" source and its circuit as the "local transmitting circuit."

It is characteristic of intermediate frequency systems that most efficient operation requires a critical amount of transmission from the auxiliary wave source, this amount being limited, in part, by the inability of the high frequency detector to handle more than a critical value of this current without impairment of its function. In a modified intermediate frequency system of the form in which the transmitting and receiving circuits terminate in a common low frequency circuit, there is the additional limitation imposed by the tendency of the circuits at a station to sing if a critical value of auxiliary current is exceeded.

The principal object of the present invention is to provide a means whereby, in an intermediate frequency receiving circuit a regulable amount of auxiliary radio carrier wave may be impressed on the input circuit of the first detector without detriment to reception from the distant station.

A specific object is to provide means whereby the function described in the statement of the principal object may be accomplished without regard to the relative directions of the distant and local transmitting circuits with respect to the receiving circuit.

An additional object is to provide means for the accomplishment of this function involving the use of a single directive antenna selective to only one of the two frequencies involved, namely, that of the signal modulated wave to be received. A still further object is to provide in a system of this kind means whereby an initial adjustment of the amount of auxiliary carrier wave is caused to persist even though said antenna is adjusted so as to be, by reason of its directive characteristics, more or less favorably related to the local transmitting station than at the time of said initial adjustment.

The means of the invention comprises, in one modification, a receiving antenna comprising a series arrangement of directive loops independently rotatable and respectively tuned to the frequencies of the distant and local transmitting circuits The two frequencies are sufficiently spaced so as to provide the desired intermediate frequency and so that each loop has relatively low impedance to the current of the frequency to which the other loop is tuned. The arrangement, accordingly, provides a means where-

by waves of two different frequencies, each of which is adjustable in amplitude, may be superposed on the input circuit of a detector coupled with said antenna.

In an alternative form a single directive loop, tuned to the frequency of the waves transmitted from the distant transmitting station is used. The loop is connected to the first detector through a vacuum tube amplifier, or other unilaterally conducting device across the output circuit of which is placed a variable shunt consisting of a series arrangement of inductive and capacitive elements adjusted to resonance at the frequency of the local transmitting circuit. In series with these elements is an adjustable resistance which constitutes, with the remaining portions of the circuit, an adjustable impedance means. The resistance adjusting means for this circuit is mechanically coupled with the rotating means of the directive loop in such manner that when said loop is oriented so as to receive with maximum intensity from the local transmitting circuit, the shunting effect of the circuit is a maximum, and sufficient to give the proper amount of the auxiliary wave in the output circuit of the first detector. As the loop is oriented from this position in order to receive with maximum intensity from a distant station, the loop becomes relatively less favorably positioned with regard to the related transmitting circuit. The mechanical coupling means by introducing resistance in the shunt circuit correspondingly reduces the shunting effect and accordingly tends to automatically maintain the amount of the auxiliary current constant.

For a further disclosure of the invention, reference is had to the following detailed description taken in connection with the accompanying drawing wherein Fig. 1 illustrates a system using two receiving loops, and Fig. 2 illustrates circuits which may be substituted for those shown at the left of line X—X of Fig. 1 to give the alternative form of the invention using a single receiving loop.

In the figures of the drawing, the circuits most closely related to the means of the invention are shown in detail and the remaining circuits in diagrammatic form only. Throughout the drawing the component elements are identified, so far as possible, by reference letters so chosen as to be suggestive of the function of said elements, subscripts being used to distinguish between different elements of a kind.

Referring to Fig. 1, there is shown a station including the transmitting and receiving antennae AN_1 and AN_2 respectively, said station being designed to communicate with a distant station provided with transmitting antenna AN_3. The remaining circuits at the distant station are not shown, it being understood that they may be of the character more fully disclosed in connection with antennae AN_1 and AN_2 or of any other type capable of transmitting and receiving modulated radio frequency waves. The circuits of the station at the right provide means whereby low frequency signals originating in line 1 may be transmitted as modulations of a radio frequency carrier wave from transmitting antenna AN_1 to the distant station, and whereby signal modulated carrier waves similarly transmitted from the antenna AN_3 may be received by antenna AN_2, detected, and the modulating component thereof transmitted to the circuit 1. In order to unite the functions of the outgoing and incoming low frequency circuits in a single circuit 1, as described, a balanced three-winding transformer or hybrid coil arrangement with a balancing network N is used, according to a principle well understood in the art. Obviously, the principle of the invention is broad enough to include other arrangements than that shown, and may be applied, for example, to an arrangement in which the low frequency transmitting and receiving circuits are distinct.

The transmitting circuit is conventionally represented by the low frequency circuit 2, the oscillator O, the modulator M, the amplifier A, and the transmitting antenna AN_1. This typifies any suitable system for impressing high frequency modulated wave on antenna AN_1.

The receiving circuit is represented by the receiving antenna AN_2, the high frequency detector D_1, the intermediate frequency detector D_2, and the low frequency circuit 3. The antenna AN_2 comprises two directive loops 4 and 5 in series, each including a capacity element as shown, for the purpose of providing adjustment of the frequency at which it is resonant. The loops are independently rotatable and are respectively resonant to the waves from antennae AN_3 and AN_1. The loop 4 is normally oriented so as to receive waves from the distant communicating station with a maximum intensity. By reason of its resonance to a different frequency, it is able to discriminate against the frequency of waves from the local transmitting antenna AN_1. However, loop 5 is resonant to the latter frequency and accordingly permits a potential to be built up between its terminals which has a value depending on the angle of presentation of said loop to the direction of incidence of waves from antenna AN_1. Since loop 4 has low impedance to the waves from antenna AN_1 and correspondingly loop 5 has a low impedance with respect to waves from antenna AN_3, there is provided a means whereby a regulable amount

of each of the two waves may be, substantially independently of the other, impressed on the input of detector D_1. In operation, after adjustment of loop 4, so as to give a maximum intensity of signals, loop 5 is oriented until the desired amplification of the signal, as measured in the low frequency circuit, is secured, or until the limiting amount of the auxiliary wave is impressed on detector D_1, as determined, for example, by a tendency of the circuits to sing if increased above the critical value.

The output energy from detector D_1 contains a modulated intermediate frequency component having a frequency equal to the difference of the normally received and auxiliary wave frequencies which is selected by circuits 6 and 7 which are resonant to said frequency and impressed on intermediate frequency detector D_2. Tht output current of detector D_2 contains a separable component of the signal frequency, which is utilized in the low frequency circuit 1.

The loops 4 and 5 are preferably of different size on account of the difference in distances of the transmitting stations from which they are designed to receive, loop 4 accordingly being the larger. For a similar reason the two loops may have a different number of turns. Although tuned circuits are shown between detectors D_1 and D_2, other forms of selective circuits such as, for example, filter circuits, may be substituted therefor, as is well known. A selective circuit of any type may be inserted between the detector D_2 and the hybrid connection in order to eliminate from the low frequency circuit undesired currents resulting from detection. Although the minimum number of vacuum tube devices for the accomplishment of the necessary functions has been shown, in many cases the detecting devices may give insufficient amplification, in which case additional tubes arranged to give distortionless amplification may be inserted in the circuit as desired, as in the input circuits of the detecting tubes or in the output circuit of detector D_2.

The system of Fig. 2 differs from that of Fig. 1 in the use of a single directive loop and in the addition of an unidirectional conducting device A_1 between the antenna and the high frequency detector. This device is here shown as an amplifier or repeater although its function as such is incidental to its primary function of separating the shunt circuit 8, shown connected across its output, from the receiving antenna so that the function of the antenna is unaffected by the presence of the shunt circuit or by adjustment thereof.

The antenna is tuned to the frequency of the distant station and is rotatably mounted. During normal operation it is oriented to such position as to receive the waves from the distant communicating station with the maximum intensity. At the same time it will receive, less efficiently, waves from the local transmitting station, the two waves being superposed in the circuit coupled with the antenna in the same manner as in Fig. 1. It is accordingly to be noted that the directive and selective functions of the antenna are here combined in a single loop as distinguished from the system of Fig. 1.

In order that the intensity of the wave received from the local transmitting circuit may be independently adjustable and may maintain such adjustment as the loop is oriented to receive from variously located distant stations, the shunt circuit 8 is provided. This circuit is tuned to the frequency of the local transmitting circuit and contains an impedance varying element 9, the circuit thus constituting a variable shunt for the auxiliary wave. The impedance varying means is shown as a resistance for reasons which will be hereinafter explained.

The impedance is initially adjusted so that, with the loop most favorably positioned with respect to the local transmitting circuit, the proper amount of auxiliary wave energy from said circuit is incident on detector D_1. The orienting loop and impedance varying means are mechanically coupled in such manner that as the loop is rotated from its initial position in either a clockwise or counter-clockwise direction, the shunting effect will be decreased at such a rate as to maintain the intensity of the auxiliary wave incident on the detector D_1 constant. In the particular arrangement shown the centrally-positioned contact 10 is connected to the end of resistance element 9, so that when contact arm 11 is on this contact the shunting effect is a maximum, the contact 11 being associated with the loop in such manner that this position of contact 11 corresponds to the initial position of the loop. For this position, the impedance is adjusted as by varying the magnitude of resistance R to give the proper shunting effect. Pairs of contacts 10 equally spaced from the central contact are connected together and to resistance 9 in such a manner that the shunting effect is decreased in the manner above described as the loop is rotated in either direction from the initial position. The arc formed by contacts 10 need not exceed one hundred and eighty degrees since the arc of an entire cycle is swept when the loop is rotated through this angle. Accordingly, the initial conditions, so far as affecting detector D_1 and the circuits related to its output, are not changed as the receiving antenna is adjusted to receive with maximum intensity from any desired distant station, the ultimate result being therefore the same as accomplished by the system of Fig. 1. Since the circuit 8 is

resonant to a frequency differing by a considerable amount from the frequency of the waves from the distant station, it will at all times constitute an inefficient shunt for current of said frequency. The impedance varying function may be secured by detuning the shunt circuit, instead of by the method shown. The method described is the one preferred since by its use the variable shunting effect is more nearly confined to the auxiliary wave frequency. Further, the variation of impedance effected by the means shown can be caused to more closely obey the law of variation of the energy incident on the detector from the local source as the loop is oriented. Accordingly such variation of energy can be more completely compensated. Filters and amplifiers may be used in the circuits of this figure in the manner described in the description of Fig. 1.

Although the principle of the invention has been embodied, for purposes of illustration, in a system in which the local radio source has a dual function, it should be understood that the invention, in its broad conception, is independent of the particular type of circuit associated with said source. It should further be understood that although an inaudible intermediate frequency has been assumed, the theory and mode of operation apply equally well to the case of an audible intermediate frequency. The low frequency impulses or signals may be speech or telegraph currents, although the claims are not intended to be so limited to any particular signaling wave.

What is claimed is:

1. A receiving antenna comprising a series arrangement of two directive loops, respectively tuned to different frequencies, said loops being independently rotatable.

2. A receiving circuit comprising, in combination, a receiving conductor consisting of two independently rotatable directive loops connected in series and respectively resonant to different frequencies, and two detecting devices connected in tandem to said conductor.

3. A receiving circuit comprising, in combination, two independently rotatable loop antennae connected in series and respectively tuned to different frequencies, a detector electrically connected to said antennae, circuit means for selecting from said detector a modulated difference frequency component, and circuit means for impressing said component on a second detector.

4. A radio system comprising a source of radio carrier waves, a second source of radio carrier waves having a different frequency, a receiving conductor for said waves, and means electrically coupled therewith for combining waves from said sources, said receiving conductor comprising two independently rotatable directive loops connected in series and respectively tuned to the frequencies corresponding to the two sources.

5. A duplex radio station comprising means for producing and radiating a carrier wave, and means for receiving and deriving signals from an incoming modulated carrier wave having a frequency differing by an inaudible amount from that of said first mentioned wave, said last mentioned means comprising a series arrangement of two independently rotatable directive loops, respectively tuned to the two carrier wave frequencies, whereby a portion of the outgoing wave is received with the incoming wave, means for combining said received waves, means for selecting the modulated difference frequency component of the resultant wave, and means for detecting said difference frequency wave.

6. A duplex radio station comprising, in combination, a low frequency transmitting circuit for signals, a source of carrier waves, means for modulating said waves in accordance with said signals, means for radiating said modulated carrier waves, and a receiving circuit for receiving and deriving signals from an incoming modulated carrier wave, said receiving circuit comprising a directive loop tuned to the incoming waves, a directive loop tuned to the frequency of said source in series with said first mentioned loop, means for independently rotating said loops, means for combining the received waves, means for selecting the difference frequency component of said waves to produce an intermediate frequency wave, means for detecting and deriving the signal frequency component from said intermediate frequency wave, and means conjugately relating the output circuit of said last mentioned detector and said low frequency circuit to a common circuit.

7. A receiving circuit comprising, in combination, a directive receiving antenna tuned to the frequency of a desired wave, means for rotating said antenna, a unilaterally conducting device and a detecting device serially related to said antenna, a reactive shunting circuit positioned between said devices, adjustable means for varying the impedance of said shunting circuit, and coupling means between said rotating and adjustable means whereby said coupled means may be simultaneously actuated.

8. A receiving circuit comprising a directive receiving antenna tuned to a desired frequency and having a rotating means, a thermionic repeating device and a detecting device coupled in tandem to said antenna, a series resonant circuit tuned to a frequency differing from that of the antenna connected in shunt to the output of said repeating device, a variable resistance means included in said resonant circuit, and mechanical coupling means between said antenna ro-

tating means and said resistance varying means whereby said coupled elements may be simultaneously actuated.

9. A duplex radio station comprising a source for producing and radiating a carrier wave, a local directive receiving antenna tuned to a desired incoming wave having a different frequency for receiving said incoming wave and a reinforcing wave from said source, a thermionic repeating device and a detecting means connected in tandem to said antenna, a series resonant circuit tuned to the waves from said source connected across the output of said device and including a variable resistance, and means adapted to simultaneously rotate said directive antenna and vary said resistance, said last mentioned means being adjusted so that said circuit has a maximum shunting effect for said reinforcing wave when the antenna is positioned to receive with maximum intensity from said radiating means.

In witness whereof, I hereunto subscribe my name this 20th day of December A. D. 1921.

JOHN MILLS.