Aug. 20, 1929.

R. A. HEISING

1,724,922

MULTIPLEX RADIO SYSTEM

Filed Dec. 31, 1923

Fig. 1.

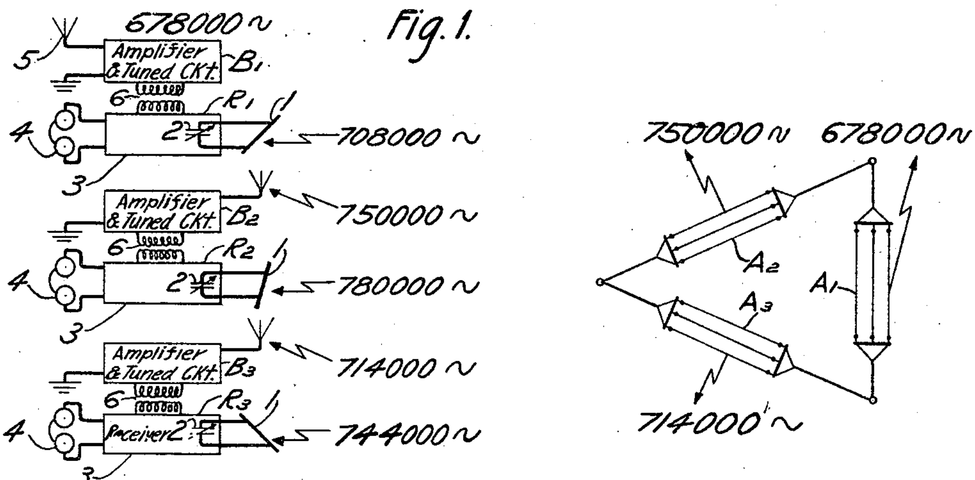


Fig. 2.

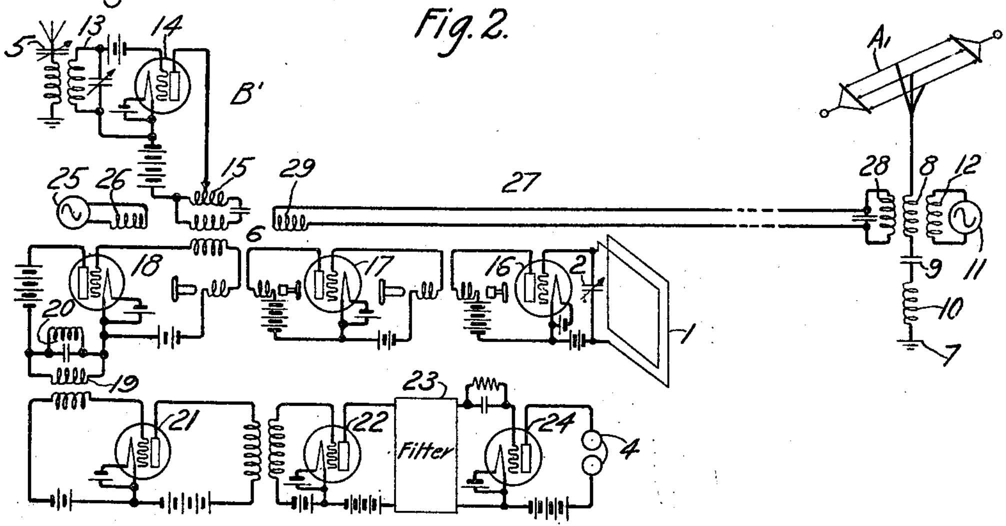
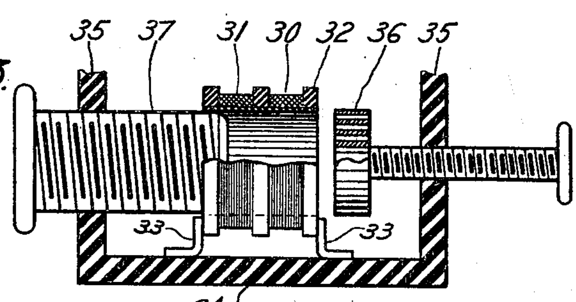


Fig. 3.



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UNITED STATES PATENT OFFICE.

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MULTIPLEX RADIO SYSTEM.

Application filed December 31, 1923. Serial No. 683,629.

This invention relates to a multiplex radio system and more particularly to a method of and means for operating a terminal station therefor which permits simultaneous two-way communications over the several channels without interference.

The present invention provides a terminal station for multiplex operation in which the frequencies of the carrier waves used for two-way communication over the different channels are so chosen that by utilizing at the receiving sets frequency discrimination alone in certain channels and the directive properties of loop antennæ in combination with frequency selectivity in the other channels, all of the channels may be simultaneously operated without interference under certain conditions, or a number of two-way communications may be simultaneously maintained under all conditions.

In accordance with this invention each receiving set comprises a loop antenna sharply tuned to the frequency to be received, associated with a successive detection system using a predetermined intermediate frequency.

In one receiving set the loop antenna is adapted to be rotated through a complete revolution to receive in all directions, its high frequency and intermediate frequency selective circuits being relied upon to prevent interference due to the outgoing and incoming signal waves of the other channels.

The loop antennæ of the other receiving sets are used so that they are each nonreceptive for the transmitted signal wave which most nearly approaches the frequency of the signal wave to be received by it, while the high and intermediate frequency selective circuits of the set are relied upon to prevent interference due to the other outgoing and incoming waves. In this manner the directive properties of loop antennæ and frequency discrimination are jointly used to prevent interference.

For operation between the terminal station described above, and a plurality of remote fixed stations, it would be a fairly simple matter to locate the distant stations relatively to the receivers and transmitters of the terminal station so that two-way communications could be simultaneously maintained over all channels at all times.

In a system including mobile distant stations, such as aeroplane or ship stations, it would be impossible to locate the transmitters and receivers so that communication could be maintained over all of the channels; because of the movement of the distant stations and the fact that only one channel can be operated in all directions. However, by locating the receiving sets for the other channels so that the receptive angles or segments of their antennæ overlap and using them to receive successive portions of the incoming message it is possible to maintain one or more additional two-way communications.

One object of this invention is to provide a terminal station for multiplex radio systems in which frequency discrimination alone and the directive properties of loop antennæ combined with frequency selectivity may be used to prevent interference between channels.

Another object is the provision of a radio terminal station which permits a number of two-way communicating channels to be simultaneously operated in any direction without interference.

Still another object is to provide receiving sets for a terminal station in which frequency selection and the directive properties of loop antenna are jointly used to discriminate between several communicating channels.

A feature of this invention is the provision of an adjustable high frequency transformer.

For a complete disclosure of the invention and the operation of the various parts, reference should be made to the following description read in conjunction with the attached drawing.

Fig. 1 shows diagrammatically a terminal station embodying the invention;

Fig. 2 shows the complete circuit arrangement for one channel including alternatives of certain features thereof; and

Fig. 3 illustrates an adjustable high frequency transformer which is used in the receiving circuits.

Throughout this specification A and R will be used to identify respectively, a transmitting antenna, and a main receiving set, and B will be used to indicate an auxiliary radio receiving apparatus.

Referring now to Fig. 1, there is shown a terminal station for a multiplex radio system having three channels.

The transmitters are herein represented by the three antennæ A_1, A_2, A_3. Obviously, a transmitting apparatus is associated with each antenna to supply a carrier signal wave which is radiated to a distant station.

The receiving equipment comprises three receivers, R_1, R_2, and R_3, each comprising a loop antenna 1, including an adjustable tuning condenser 2, a radio receiving apparatus 3, provided with a signal indicating device 4, shown by way of example as a telephone receiver, and an auxiliary radio receiver B_1, B_2 or B_3.

The terminal equipment for the first channel comprises the antenna A_1, and the cooperative main and auxiliary receivers R_1 and B_1, that for the second channel, the antenna A_2 and the cooperative main and auxiliary receivers R_2 and B_2 and that for the third channel, the antenna A_3 and the main and auxiliary receivers R_3 and B_3.

The frequencies of the incoming and outgoing carrier waves for all the channels are different, and the frequencies of the carrier waves respectively radiated from the antennæ A_1, A_2 and A_3 differ from the frequencies of the incoming carrier waves for the corresponding channels by readily selectable frequencies above audibility.

The antenna of each receiver is sharply tuned to the incoming frequency which it is adapted to receive and the antenna of each auxiliary receiver is sharply tuned to the frequency of the corresponding outgoing carrier wave of the channel.

The auxiliary receiver for each channel is associated with the main receiver by a coupling coil or transformer 6. The purpose of this arrangement will be described hereinafter.

Fig. 2 illustrates the arrangement of the apparatus for one channel comprising a transmitter consisting of an antenna A_1 connected to ground 7 by a lead including a coupling coil 8, a condenser 9 and an inductance 10. A source of signal waves 11 is connected to the antenna by a coil 12 inductively associated with the coil 8, the source 11 diagrammatically represents any well known apparatus for supplying current to the antenna A_1, whereby radio telegraph or radio telephone signals may be transmitted. For example, the system shown in Patent No. 1,442,147, Jan. 16, 1923 to R. A. Heising may be used for radio telephone transmission while a system similar to that described in Patent 1,349,729, August 17, 1920 to E. L. Nelson may be used for radio telegraph transmission.

Condenser 9 and inductance 10 are included in the antenna circuit to render it highly selective or "stiff" for the signal frequency radiated, whereby intermodulation between the different channels is prevented and a minimum of "crosstalk" results.

The auxiliary receiver B′ comprises an antenna 5 coupled by a tuned circuit 13 to the input of an amplifier 14. The coupling circuit 13 is sharply tuned to the frequency of the carrier wave radiated from the antenna A_1.

The output circuit of the amplifier 14 includes a circuit 15 also sharply tuned to the carrier frequency radiated from the antenna A_1.

The main radio receiver is adapted to operate on the basis of the well known successive detection system, in which the incoming signal wave is combined with other oscillations to produce an auxiliary intermediate frequency signal modulated wave which is then detected to yield the signal current.

As described above, the receiver R includes a rotatable loop antenna 1 adapted to be sharply tuned to the incoming signal wave by an adjustable condenser 2. The received high frequency waves are amplified by the amplifiers 16 and 17 and impressed upon the input circuit of the detector 18.

However, since the principles of this invention are independent of radio frequency amplification, the question as to whether radio frequency amplifiers are to be used and the number of stages to be employed in any case is a matter to be determined for each installation. The devices 16, 17 and 18 are intercoupled by transformers especially adapted for use with high frequency currents. The design of this transformer will be described below with reference to Fig. 3.

The input circuit of the detector 18 includes one coil of the coupler or transformer 6 the other coil of which is included in the tuned circuit 15.

The output circuit of the device 18 includes a coupling inductance 19 shunted by an anti-resonant circuit 20 which is of high impedance for the auxiliary intermediate frequency, but provides a low impedance path for other frequencies.

The resultant intermediate frequency wave is amplified by the amplifiers 21 and 22, transmitted through the selective means 23, and detected by the device 24.

The selective means 23 may be either a tuned circuit, resonant to the intermediate frequency, or a filter adapted to freely pass a frequency band including the intermediate frequency wave while suppressing frequencies outside this band.

The low frequency currents resulting

from the second stage of detection are supplied to the indicating device 4 which may be of any well known design, but is herein shown as a telephone receiver.

In a radio receiving circuit employing high frequency amplification as described above, it is desirable to intercouple the amplifying devices by means of circuits tuned to the incoming signal waves. Thus, the coupling circuits between the amplifiers 16 and 17 and between the amplifier 17 and detector 18 should be selective of the frequency of the signal waves received by the antenna 1. Since the input and output circuits of the amplifiers are both tuned to the same frequency, considerable difficulty has been encountered due to the production of undesired oscillations or "singing" in the amplifier circuits. This "singing" is largely due to a coupling effect between the input and output circuits of the amplifier.

The usual method for preventing "singing" in amplifier circuits is to include a resistance at some point in the coupled circuits or else to construct the primary winding of the transformers of resistance wire. As shown in this figure a transformer provided with adjustable means for controlling the electrical characteristics of its primary and secondary circuits is used to intercouple the amplifiers 16 and 17 and to couple the latter to the detector 18.

The coupling transformer, shown in detail in Fig. 3, comprises an air core transformer having a primary and a secondary winding, 30 and 31, respectively, wound on an insulating core 32, secured to a supporting frame 34. The supporting frame as shown, is of insulating material and may be of any such material and of any form. Arms 35 of the frame 34 are adapted to support elements 36 and 37 axially of the core 32.

The windings 30 and 31 when used with discharge devices 16, 17 and 18 are each wound to cooperate with the internal capacity of the associated device to constitute a tuned circuit. When used with other forms of high impedance amplifiers and detectors, such winding should be designed to have the necessary inductance and distributed capacity to determine its tuning.

The element 36 consists of a spirally wound laminated iron strip or ribbon with its convolutions spaced apart. This element is carried by a threaded shank engaging a screw-threaded opening in one of the arms 35 and is associated with the primary winding 30.

A conductive element 37, which may be a copper or brass rod, is provided with a screw thread to engage a screw-threaded opening in the other arm 35. The area of the rod 37 should be as large as possible, and preferably its diameter should be only slightly less than the internal diameter of the secondary winding 31.

The transformer should be mounted so that the only coupling between the windings 30 and 31 is that due to their mutual inductance. In other words the supporting means for the windings should introduce substantially no coupling effect between the primary and secondary circuits of the transformer.

High frequency current flowing through the primary winding 30 will produce a magnetic field in the space surrounding it. With the element 36 lying in this magnetic field, losses will be introduced into the primary circuit due to eddy currents traversing the ribbon winding and to the hysteresis of the iron. These losses appear as an effective resistance load in the primary circuit.

Because of the high frequencies involved, the iron does not function to decrease the reluctance of the magnetic circuit and hence the reactance of the primary circuit and the mutual inductance between the transformer windings remains substantially constant.

By varying the position of the element 36 relatively to the winding 30 the value of the losses in the ribbon winding and hence the amount of the resistance load introduced into the primary circuit may be regulated.

In a similar manner, high frequency current flowing through the secondary winding 31 will generate a magnetic field. The rod 37 being of conductive material functions as a short-circuited winding in which eddy currents will be produced when this element lies within the magnetic field of winding 31.

Because of the transformer action between the winding 31 and element 37, the magnetic field due to the flow of eddy currents in the element 37 will be opposed to the magnetic field resulting from current flow in the winding 31 and consequently the effective inductance of the winding 31 will be decreased.

By adjusting the element 37 relatively to the winding 31, the coupling between 31 and 37 can be varied to control the amplitude of the eddy currents, and hence the value of the inductance thereby introduced into the secondary circuit. In this manner the tuning of the circuit including the winding 31 may be accurately adjusted.

The operation of the system and the function of its various parts will be clear from the following description of the arrangement shown in Fig. 2 which will be considered as illustrating the apparatus of channel No. 1 of a radio telephone system.

It is assumed, for purposes of illustration, that the incoming and outgoing carrier frequencies used in the different channels are as follows: channel No. 1, incoming 708,000 cycles and outgoing 678,000 cycles; channel

No. 2, incoming 780,000 cycles and outgoing 750,000 cycles; and channel No. 3, incoming 744,000 cycles and outgoing 714,000 cycles.

Let it also be assumed that: 1st, the loop antennæ of the first and third channel receivers R_1 and R_3 are so located relatively to each other that their zero reception direction differs by an angle of approximately 25 degrees; 2nd, the loop antennæ are so positioned and orientated with reference to the transmitting antennæ that the latter always lie within the non-receptive range of both of these receiving loop antennæ; and 3rd, that the antenna of the second channel receiver R_2 is rotatable through a complete circuit, whereby it may receive in any direction.

The second condition as stated above may be fulfilled by locating the loop antennæ of the first and third channel receivers at some distance from the transmitting antenna and at such directions therefrom that the lines connecting the loop antennæ with the transmitting antennæ form an angle of 25° which is the same angle as the angular distance between their respective directions of zero reception. The angle 25° is chosen as an illustrative value only and may in practice vary over a large range.

The loop antenna of receiver R_1 is adjusted to receive an incoming carrier wave of 708,000 cycles modulated in accordance with signals, but at the same time to prevent reception of the outgoing carrier wave of 714,000 cycles.

The outgoing carrier frequency of 678,000 cycles is received by the antenna 5 of the auxiliary receiver B_1, amplified by the device 14 and impressed by the coupling 6 upon the input circuit of the detector 18. Incoming signal waves received by the loop antenna 1 after being amplified are impressed upon the input circuit of the detector 18.

The carrier modulated wave of 708,000 cycles is combined with the unmodulated carrier wave of 678,000 cycles to produce in the output circuit of the detector an intermediate frequency modulated carrier wave having a frequency equal to the difference between the waves incident upon the antennæ 1 and 5, i. e., 30,000 cycles plus and minus side bands of speech width.

The shunt circuit 20 being of high impedance for the intermediate frequency wave causes this wave to traverse the coil 19 which is inductively coupled to a coil included in the input circuit of the amplifier 21. Intermediate frequency waves in amplified form will be supplied to the device 22, again amplified, transmitted through the filter 23 and impressed upon the input of the detector 24. The output circuit of the detector will include speech currents adapted to actuate the receiver 4.

Current components of frequencies outside the intermediate frequency band contained in the output circuit of the detector 18 will be diverted through the low impedance path provided by the shunt circuit 20 and hence will not be supplied to the amplifier 21.

The carrier wave of 750,000 cycles radiated by the antenna A_2 differs by 42,000 cycles from that receivable by the antenna 1 and by 72,000 cycles from that receivable by the antenna 5 and hence they will be substantially suppressed by the selective action of these elements.

However, should any energy of 750,000 cycles flow through the antenna circuits 1 and 5, the resultant current will be considerably attenuated by the successive actions of the selective circuits 13 and 15 and when combined with the transmitted carrier wave for this channel will produce intermediate frequency waves of 42,000 and 72,000 cycles respectively which will be suppressed by joint action of the shunt path 20 and the filter 23. In a similar manner, any waves of the other incoming carrier frequencies, i. e., 744,000 cycles and 780,000 cycles, differ from the wave to be received over the channel under consideration by 46,000 cycles and 72,000 cycles respectively and will be suppressed by the selective means included in the receiver circuit.

The second channel, employs incoming and outgoing frequencies which are both widely spaced in the frequency spectrum from the carrier frequencies radiated from the antennæ A_1 and A_3 and hence the radio frequency selectivity of the antennæ of R_2 and B_2 as well as the selectivity of the different tuned circuits and filter included in the receiving circuit of this channel may be relied upon to effectively suppress the energy received from A_1 and A_3.

The nearest incoming frequency is a weak 744,000 which differs from that received by the antenna 5 of B_2 by 6000 cycles. The 744,000 cycle wave and its intermediate frequency current of 6000 cycles will be effectively suppressed by the cooperative action of the high frequency tuning and the intermediate selective currents included in the receiver R_2.

The operation of the third channel is identical with that of the first channel. The loop antenna of the third channel is always arranged to be non-receptive of the 750,000 cycles wave radiated from antenna A_2. The nearest incoming frequency is 708,000 cycles which differs from the wave to be received by 36,000 cycles. These main and intermediate frequency waves will be suppressed by the selective means included in receivers B_3 and R_3.

In the case of a system including mobile stations two-way communications may be maintained in all directions over the second channel. Two-way communication may be had over channel No. 1 until the movable station is in such position relatively to receiver B_1 that its antenna is blind or non-receptive. However, when this occurs the movable station is within the receptive range of channel No. 3 and, by adjusting the apparatus at the movable station to cooperate with the third channel apparatus of the terminal station, two-way communications may be continued over this channel.

Fig. 2 shows two alternative arrangements for supplying oscillation to the input circuit of the detector 18.

According to one arrangement oscillations of the desired frequency supplied by a local source 25 are impressed upon the input circuit of the detector 18 by the coil 26 inductively associated with the secondary winding of the coupling coil 6.

In a second arrangement a wire line 27 may be used to transmit carrier oscillations from the source 11. A tuned circuit 28, resonant to the carrier waves supplied by the source 11, is inductively associated with the coil 8 and is included in the line 27 which is provided with a coil 29 adapted to be inductively associated with the secondary winding of the coupling coil 6 included in the input circuit of the detector 18.

A terminal station for a three-channel system has been described. However, it will be apparent that the priniciples of this invention may be applied to a system embodying any number of channels.

From the preceding description, it will be seen that the present invention provides a terminal station for a multi-channel radio system adapted to permit simultaneous two-way signaling over all channels without interference, but which is especially effective where it is desired to maintain a plurality of two-way communications in all directions between a fixed station and a plurality of movable stations.

A system embodying certain apparatus and specific details has been described for the purpose of completely and clearly disclosing the principles of the invention. However, it is to be understood that this invention is not limited to the arrangement or specific features disclosed, but only by the scope of the attached claims.

What is claimed is:

1. In a multiplex radio system, a method of operating a terminal station, including for each two-way channel a radio transmitter and a radio receiver having a directively selective antenna, which comprises employing a wave of different frequency for each transmission, using waves for the several channels the frequencies of certain of which are too closely spaced to permit frequency selection between them, adjusting certain antennæ to each directively receive an incoming wave while directively preventing the reception of the wave of closely spaced frequency, and preventing the reception of all other waves by frequency selection.

2. A terminal station for a radio system having a plurality of two-way channels, a transmitter and a receiver for each two-way channel, the frequencies of all outgoing and incoming waves being different, the frequencies of certain of the waves being too closely spaced to permit frequency selection between them, each receiver including an antenna for directively receiving one incoming wave, for directively preventing the reception of at least one other wave and having associated therewith frequency selective means for preventing the reception of the remainder of the waves used in the system.

3. A terminal station for a radio system having a plurality of two-way channels, a transmitter and a receiver for each two-way channel, the frequencies of certain of the waves used in the system being too closely spaced to permit frequency selection between them, each receiver including a loop antenna and frequency selective means, the frequency selective means of certain channels being adjusted to permit two-way communications thereover, the loop antennæ, respectively, of other channels being adjusted to directively receive one wave and to cooperate with the associated frequency selective means for preventing the reception of the too closely spaced and other waves used in the system.

4. A terminal station for a multi-channel radio system for use with a plurality of mobile stations, comprising a transmitter for each channel, a receiving set for each channel, each receiving set including a loop antenna and frequency selective means, the antenna of one of said receiving sets and the selective means associated therewith being adjustable to receive a desired wave in all directions and to prevent reception of all other waves, the antennæ of the other receiving sets being adjustable to receive desired waves from certain directions, but each to be at all times non-receptive for certain waves radiated from said transmitters and the selective means associated with each being effective to prevent reception of other undesired waves, the antennæ of said other sets being adjustable so that their receptive angular ranges overlap, whereby a plurality of two-way communications may be maintained in all directions between said mobile stations and said terminal station.

5. A terminal station for a multiplex radio system for use with a plurality of mobile stations, comprising a plurality of transmitters, a plurality of receiving sets including a loop antenna and frequency selective means, the antenna of one of said

sets and the selective means associated therewith being adjustable to receive a desired wave in all directions and to prevent reception of all other signal waves, and for the other sets the directive selectivity of each loop antennæ and the associated frequency selective means operating jointly to permit reception of one signal wave while preventing reception of all other waves, the loop antennæ of said other sets being adjustable so that their receptive ranges overlap whereby one and then the other may be used to maintain communications between said mobile stations and said terminal station from all points of the compass.

6. A terminal station for a radio system having a plurality of two-way channels comprising a transmitter and receiver for each channel, the difference in frequency of at least two of the radio waves employed in said system lying within the range of audibility, an antenna for one of said receivers directionally selective to one of said two waves to the substantial exclusion of the other, and frequency selective means for said receiver whereby the reception of other waves is prevented.

In witness whereof, I hereunto subscribe my name this 28 day of December A. D., 1923.

RAYMOND A. HEISING.