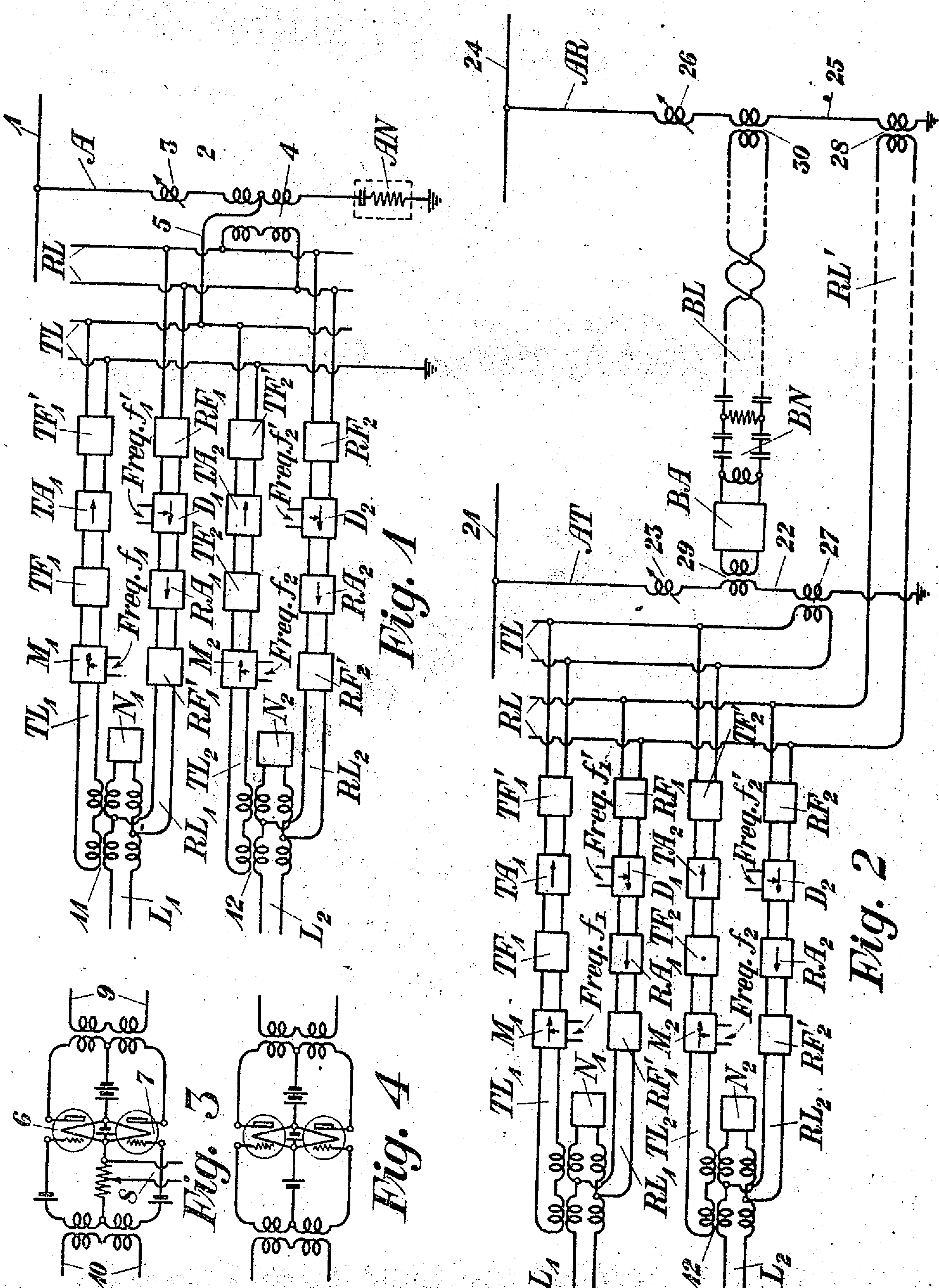
July 15, 1924. 1,501,104

L. ESPENSCHIED

MULTIPLEX RADIOSYSTEM

Filed Sept. 26, 1919



INVENTOR
L. Espenschied
BY
ATTORNEY

Patented July 15, 1924. **1,501,104**

UNITED STATES PATENT OFFICE.

LLOYD ESPENSCHIED, OF HOLLIS, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MULTIPLEX RADIO SYSTEM.

Application filed September 26, 1919. Serial No. 326,522.

To all whom it may concern:

Be it known that I, LLOYD ESPENSCHIED, residing at Hollis, in the county of Queens and State of New York, have invented certain Improvements in Multiplex Radio Systems, of which the following is a specification.

This invention relates to radio systems and more particularly to arrangements for multiplex signaling by means of radio systems.

One of the principal features of the invention resides in the provision of oppositely directed channels for associating different low frequency signaling circuits with a common antenna system.

Another feature of the invention resides in the provision of multiple balancing arrangements combined with selective devices, for separating the channels of different circuits and for separating the east and west bound channels of the same circuit in a system such as just described.

A still further feature of the invention resides in the association of each of a plurality of low frequency signaling circuits with a common antenna arrangement by means of a circuit organization similar to that of the so-called 22 type of repeater circuit, so that automatic repeating is effected between each low frequency signaling circuit of the multiplex system and the radio system proper.

A still further feature of the invention resides in the use of separate sending and receiving antenna for a multiplex radio system, together with means for balancing the effect of the sending antenna upon the receiving antenna, said means being operative for a plurality of signaling channels.

The embodiment of these features, together with other features of the invention more fully hereinafter appearing, may be understood from the following description when read in connection with the accompanying drawings, Figures 1 and 2 of which constitute simplified circuit diagrams illustrating two forms of the invention, while Figures 3 and 4 illustrate details of the apparatus.

Referring to Figure 1, A designates an antenna comprising an aerial 1 and vertical 2, including the usual tuning inductance 3. L_1 and L_2 designate low frequency signaling circuits which may be ordinary telephone transmission lines. The lines L_1 and L_2 are connected with the common high frequency transmitting bus bars TL, through transmitting channels TL_1 and TL_2 and are similarly associated with the high frequency receiving bus bars RL through receiving chanels RL_1 and RL_2. In order to render the corresponding transmitting and receiving channels associated with each low frequency circuit substantially conjugate with respect to each other, the low frequency lines L_1 and L_2 are balanced by artificial lines or networks N_1 and N_2.

The antenna A is balanced by means of a network AN, for the purpose of rendering the bus circuits TL and RL substantially conjugate with respect to each other at radio frequencies. The bus circuit RL is associated with the antenna by means of a balanced transformer arrangement 4, while a connection 5 extends from the midpoint of the antenna winding of the transformer 4 to one of the bus bars, TL, the other bus bar being connected to ground, as shown. It will thus be seen that each of the lines such as L_1, L_2, is associated with the common antenna through an organization somewhat similar to that of the so-called 22 repeater circuit.

In order to translate the low frequency signals from the line L_1 into high frequency radio frequencies, a modulator M_1 is included in the transmitting channel TL_1. This modulator may be of any well-known type, but is preferably a duplex balanced vacuum tube modulator of the kind illustrated and described in the U. S. patent to John R. Carson, No. 1,343,307, of June 15, 1920. The circuit organization of a modulator of this type is illustrated in simplified form in Figure 3 and comprises a pair of three-element vacuum tubes 6 and 7, connected in a balanced circuit in such a manner that carrier frequencies applied to the tubes over the circuit 8 will produce no effect upon the outgoing circuit 9, unless signaling frequencies are applied to the incoming circuit 10. When low frequency signaling currents are applied to the incoming circuit 10, however, modulated carrier currents are impressed upon the circuit 9, having an amplitude directly proportional to that of the low frequency signaling currents.

The transmitting channel TL_1 is also provided with an amplifier TA_1, which may be of any well-known type, but is preferably an amplifier of the vacuum tube type. If desired, this amplifier may be constructed to operate as a push and pull amplifier, such as illustrated in Figure 4, an amplifier of this type having the advantage that it produces a minimum amount of distortion of high frequencies. As amplifiers of this character are well-known no detailed description thereof is necessary.

A filter TF_1 may be included in the channel TL_1, between the modulator M_1 and the amplifier TA_1. This filter is preferably of the type disclosed in the U. S. patents issued to George A. Campbell, Nos. 1,227,113 and 1,227,114, dated May 22, 1917. This filter may be of the high pass type and should be so constructed as to freely transmit a band of frequencies extending above the frequencies employed in ordinary signaling, while suppressing low frequencies. A second filter TF'_1 may be included between the amplifier TA_1 and the bus bars TL. This filter is also of the type disclosed in the Campbell patents above referred to and should be designed to transmit a band of frequencies in the neighborhood of the carrier frequency assigned to the channel, the width of the band being sufficient to accommodate the range of frequency variation due to the modulation of the carrier frequency by low frequency signals.

The receiving channel RL_1 is provided with a demodulator or detector D_1 for the purpose of translating the radio frequencies into low frequency signals. This detector may be of any well-known type, but is preferably a duplex balanced vacuum tube detector of the type disclosed in the U. S. patent to John R. Carson, No. 1,343,308, issued June 15, 1920. As described in said application of John R. Carson, this type of detector may be identical in construction with the duplex modulator already referred to and the diagram of Figure 3 applies equally well to both the modulator and demodulator. The demodulator operates upon the so-called homodyne principle and is therefore supplied with carrier currents of the frequency assigned to the receiving channel, over the circuit 8, while the modulated carrier currents to be detected are applied over the circuit 10 and the resultant low frequency currents appear in the outgoing circuit 9.

Owing to the enormous difference in the magnitude of the transmitted energy, as compared with the received energy in a wireless system, it is desirable that the separation due to balance between oppositely directed channels be supplemented by frequency separation; accordingly if a frequency f_1 is assigned to the transmitting channel TL_1, a different frequency f'_1 will be assigned to the receiving channel RL_1 and consequently the frequency f'_1 will be supplied to the modulator D_1 over the circuit corresponding to circuit 8 of Figure 3.

In order to provide for frequency selectivity, the receiving channel RL_1 may be provided with a filter RF_1, which is in general similar to the filter TF'_1, except that it transmits a band of frequencies in the neighborhood of the frequency f'_1, instead of a band in the neighborhood of the frequency f_1. If, however, both the transmitting and receiving channel have the same frequency assigned thereto, filter RF_1 will be identical in construction with filter TF'_1.

In order to amplify the low frequency currents detected by the demodulator D_1, an amplifier RA_1 is provided. This amplifier may be of the push and pull type illustrated in Figure 4, but since the amplifier only amplifies low frequency currents, it is usually sufficient to provide a simple vacuum tube amplifier of ordinary construction. In addition to the amplifier RA_1, the receiving channel RL_1 also includes a filter RF'_1. This filter is also of the general type disclosed in the patents to Campbell, above mentioned, and is designed to transmit the low frequency detected signals, while suppressing higher frequencies.

Similarly the transmitting channel TL_2 is provided with a modulator M_2, a filter TF_2, identical in construction with the filter TF_1, and amplifier TA_2, identical in construction with the amplifier TA_1, and a band filter TF'_2. The latter filter is similar to the filter TF'_1, but transmits a band of frequencies in the neighborhood of the carrier frequency f_2 assigned to this channel, which frequency should be substantially different from either frequency f_1 or f'_1. So also the receiving channel RL_2 is provided with a filter RF'_2, identical in construction with the filter RF'_1, an amplifier RA_2, identical in construction with the amplifier RA_1, a demodulator D_2 and a filter RF_2. The demodulator D_2 is similar to the demodulator D_1 already described, but is supplied with a different carrier frequency f'_2. The filter RF_2 is in general similar to the filter RF_1, but transmits a band of frequencies in the neighborhood of the carrier frequency f'_2, instead of in the neighborhood of the frequency f'_1.

The operation is as follows:

Low frequency signals incoming from the line L_1 are transmitted through the transformer 11 to the channel TL_1 and impressed upon the modulator M_1, thereby modulating carrier frequency f_1, so that the modulated high frequency currents are passed through the filter TF_1 and amplified by the amplifier TA_1. The amplified currents are then passed through the filter TF'_1 to the bus bars TL. At the same time other modulated high frequency currents from other transmitting channels are also impressed upon the bus bars and all of the modulated currents are then transmitted over conductor 5 to the midpoint of the antenna winding of the transformer 4. Half of the energy is thereby impressed upon the vertical member 2 of the antenna and is radiated by the aerial 1 to a distant receiving station in a well-known manner. The other half of the energy flows through the antenna balancing element AN to ground. Since the energy flows in opposite directions through the two halves of the antenna winding of the transformer 4, but a small fraction of the energy reacts through the other winding of the transformer 4 upon the receiving bus bars RL, the amount of energy thus reacting being only that due to unbalance. The energy thus transmitted to the receiving bus bars RL may be substantially prevented from reacting upon the receiving channels RL_1 and RL_2, by reason of the fact that these receiving channels have assigned to them frequencies differing substantially from the transmitting frequencies and hence the transmitting energy reacting upon the bus bars RL is substantially suppressed by the filters RF_1 and RF_2.

Modulated high frequency currents transmitted from the antenna of a distant station are absorbed by the antenna A and are impressed through the transformer 4 upon the receiving bus bars RL. The frequencies corresponding to the several receiving channels are separated and selected into the proper channels by the filters RF_1 and RF_2 and are then impressed upon the demodulators D_1 and D_2. The demodulators operate to detect the low frequency signaling currents in accordance with which the high frequency currents are modulated and the detected currents, after being amplified by the amplifiers RA_1 and RA_2 the low frequency currents are passed through the low pass filters RF'_1 and RF'_2 to the signaling lines L_1 and L_2.

Instead of using a single antenna both for transmitting and receiving, separate antennæ may be used, as indicated in Figure 2. In this figure AT designates a transmitting antenna having an aerial 21 and a vertical member 22 including the usual tuning inductance 23. AR designates a receiving antenna having an aerial 24 and a vertical 25, including a tuning inductance 26. The transmitting bus bars TL are connected to the transmitting antenna AT through a transformer 27, while the receiving bus bars RL are similarly connected to the receiving antenna AR through a transformer 28. In practice it is desirable to locate the transmitting and receiving antenna some distance apart and where this is done the receiving bus bars RL may be connected to the transformer 28 through a section of transmission line RL′. The association of signaling lines L_1 and L_2 with the transmitting and receiving bus bars will be the same as in Figure 1 and need not be further described.

It will be apparent that a certain amount of transmitting energy radiated by the antenna AT will be received by the antenna AR and transferred over the line RL′ to the receiving bus bars RL. In order to balance out this energy, a balancing line BL is arranged to interconnect the antennæ AT and AR through loose-coupling transformers 29 and 30. This balancing circuit may be of any suitable character, but is illustrated as a full metallic line, including an adjustable network BN for adjusting the transmission efficiency of the line and the phase angle of the current. The balancing line BL may also include an amplifier BA for further determining the amplitude of the currents transmitted over the line. This amplifier may be of any well-known type, but is preferably a vacuum tube amplifier. Where a full metallic circuit is used it should preferably be transposed, as indicated, to prevent unbalances to ground with respect to the exposure of the sending antenna, in order to avoid the production of currents of different phases in the line BL. By a proper adjustment of the various elements of the line BL, energy may be impressed upon the receiving antenna AR over said line, said energy being substantially equal to that absorbed by the antenna AR from the transmitting antenna AT and having an opposite phase relation with respect thereto, so that only the relatively small amount of energy due to unavoidable unbalance will be transferred over the circuit RL′ to the receiving bus bars RL. This relatively small amount of energy may be prevented from reacting upon the receiving channels by the action of the filters RF_1 and RF_2, as described in connection with Figure 1. It will be understood that this is but one specific means for effecting high frequency balance between separate sending and receiving antenna, and that other expedients may be used such as that of a loop receiving antenna disposed to be non-receptive from the home transmitting antenna.

The operation of Figure 2 is as follows: The low frequency signals incoming from the lines L_1 and L_2 after being translated into high frequency currents by the apparatus associated with the transmitting channels TL_1 and TL_2 in the manner described in connection with Figure 1 are impressed upon the transmitting bus bar TL and transmitted through the transformer 27 to the sending antenna AT. The energy impressed upon this antenna is radiated to the distant station, a certain amount of the energy, however, being absorbed by the receiving antenna AR. At the same time, however, an equal amount of energy is transferred over the balancing line BL and impressed upon the receiving antenna AR through the transformer 30, so that the absorbed energy is substantially neutralized and only a relatively small amount of energy due to unbalance reacts upon the receiving bus bars, RL. High frequency currents radiated from a distant sending station are absorbed by the receiving antenna 24 and impressed through the transformer 28 upon the connecting circuit RL′ leading to the receiving bus bars RL. The filters RF_1, and RF_2 operate to select into the proper receiving channels the several received frequencies which are translated into low frequency signaling currents and impressed upon the signaling lines L_1 and L_2 in the manner already described in connection with Figure 1.

It will be understood that while but two signaling circuits are shown associated with the antenna arrangements of Figures 1 and 2, in practice a larger number of signaling circuits may be associated with the antenna by connecting the transmitting and receiving channels thereof to the transmitting and receiving bus bars.

It will furthermore be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a radio system, an antenna arrangement, a plurality of paths for superposing different transmitting frequencies upon said antenna arrangement, selective devices in each of said paths for maintaining frequency separation therebetween, a plurality of paths upon which different receiving frequencies may be impressed from said antenna arrangement, selective devices in each of said last mentioned paths for selecting to each path its proper frequency, means for balancing said antenna arrangement, whereby all of said transmitting paths may be maintained substantially conjugate with respect to all of said receiving paths, a plurality of signalling circuits, and means for associating each signalling circuit with a transmitting path and corresponding receiving path.

2. In a radio system, an antenna arrangement comprising a transmitting antenna and a receiving antenna, a plurality of paths for transmitting different signaling frequencies to said transmitting antenna, selective devices in said paths for maintaining frequency separation therebetween, a plurality of paths for receiving different frequencies from said receiving antenna, selective devices associated with said last mentioned paths for selecting the proper frequencies to each path, means associated with said antenna arrangement for rendering all of said transmitting paths substantially conjugate at radio frequencies with respect to said receiving paths, a plurality of signalling circuits, and means for associating each signalling circuit with a transmitting path and corresponding receiving path.

3. In a radio system, an antenna arrangement comprising a transmitting antenna and a receiving antenna, a plurality of paths for transmitting different signaling frequencies to said transmitting antenna, selective devices in said paths for maintaining frequency separation therebetween, a plurality of paths for receiving different frequencies from said receiving antenna, selective devices associated with said last mentioned paths for selecting the proper frequencies to each path, means associated with said antenna arrangement for rendering all of said transmitting paths substantially conjugate with respect to said receiving paths, said means comprising a circuit for transmitting energy from said transmitting antenna to said receiving antenna, to balance the energy radiated from said transmitting antenna to said receiving antenna, a plurality of signalling circuits, and means for associating each signalling circuit with a transmitting path and corresponding receiving path.

4. In a radio system, an antenna arrangement, a plurality of low frequency signaling circuits, a transmitting path associated with each circuit for translating low frequency signals incoming from the circuit into radio frequencies for radiation by said antenna arrangement, a receiving path associated with each signaling circuit, for translating radio frequencies received from said antenna arrangement into low frequency signals for transmission over said signaling circuits, means to balance each signaling circuit, thereby rendering the associated transmitting and receiving paths substantially conjugate with respect to each other at low frequencies, and means associated with said antenna arrangement and common to all of said paths for rendering all of the transmitting paths substantially conjugate with respect to the receiving paths at radio frequencies.

In testimony whereof I have signed my name to this specification this 25th day of September, 1919.

LLOYD ESPENSCHIED