July 10, 1923. 1,461,064

DE LOSS K. MARTIN

MULTIPLEX TRANSMISSION CIRCUITS

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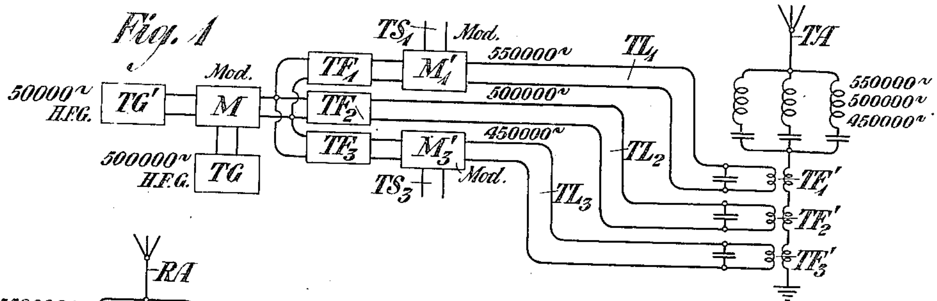
Fig. 1



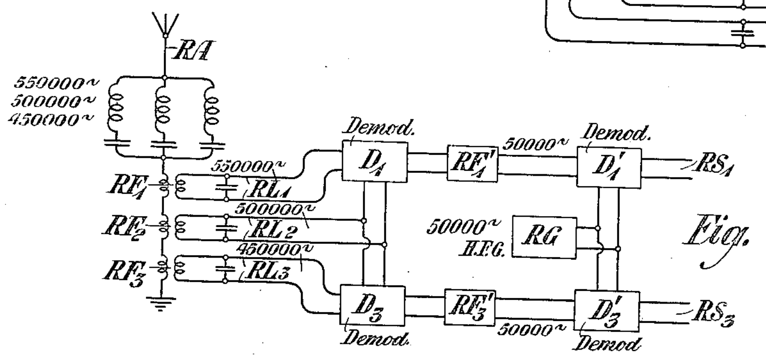
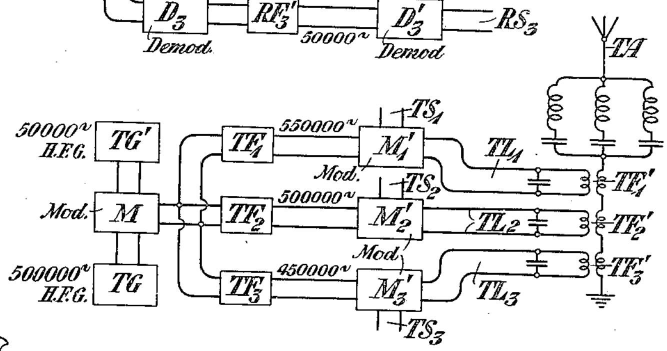


Fig. 2

Fig. 3



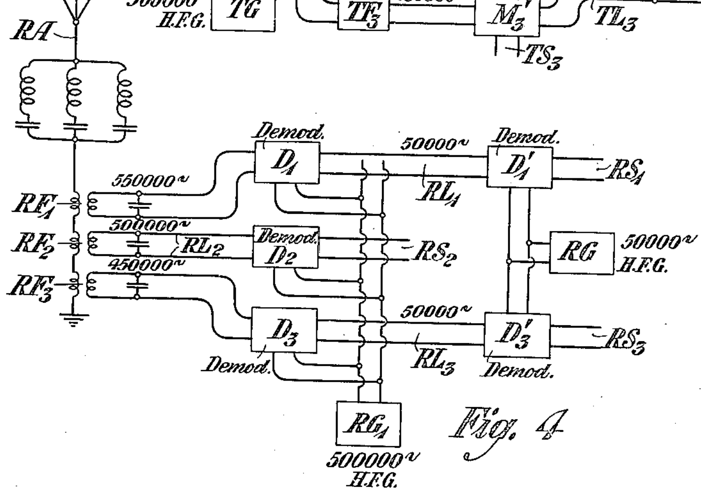


Fig. 4

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Fig. 5

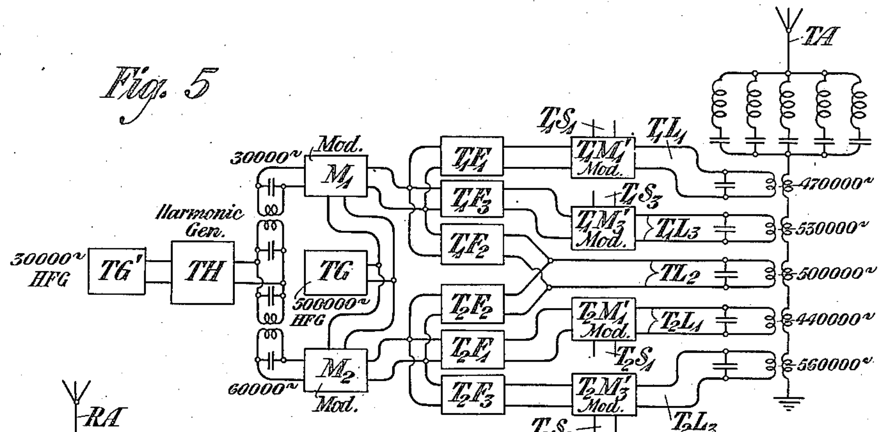


Fig. 6

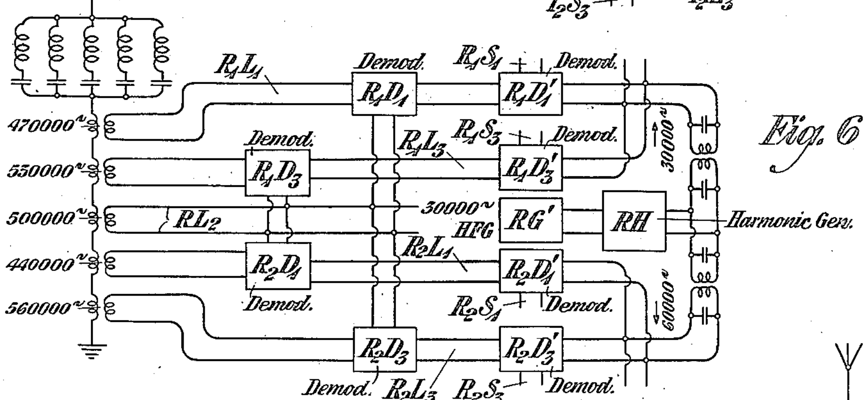
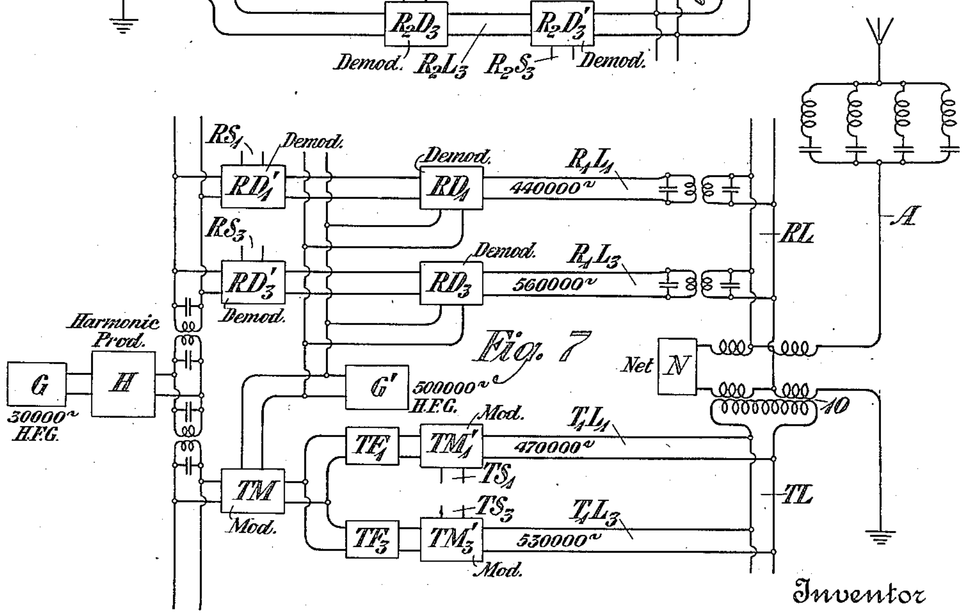


Fig. 7



Inventor

De L. K. Martin

By his Attorney

G. E. Folk

Patented July 10, 1923. 1,461,064

UNITED STATES PATENT OFFICE.

DE LOSS K. MARTIN, OF ORANGE, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MULTIPLEX TRANSMISSION CIRCUIT.

Application filed February 10, 1921. Serial No. 443,930.

To all whom it may concern:

Be it known that I, DE LOSS K. MARTIN, residing at Orange, in the county of Essex and State of New Jersey, have invented certain Improvements in Multiplex Transmission Circuits, of which the following is a specification.

This invention relates to multiplex transmission, and more particularly to a multiplex system employing carrier currents.

In accordance with the present invention it is proposed to generate a carrier frequency for each of three channels by modulating one frequency in accordance with another frequency, thereby producing a fundamental frequency and two side frequencies. Each of the side frequencies and, if desired, the fundamental frequency may be modulated in accordance with a signal, and in the case of radio transmission the antenna may be arranged to have a plurality of degrees of freedom, one corresponding to each side frequency, and one corresponding to the fundamental.

At the receiving station the antenna (in the case of radio transmission) will likewise be arranged to resonate at each of a plurality of frequencies, and the frequencies which are modulated in accordance with signals may be separated into channels and reduced in frequency by beating with one of the original frequencies transmitted (in case such frequency is not used as a carrier) or the frequency reduction may be effected by beating with a locally generated frequency. The signals may be detected from the frequencies thus stepped down, either by a further beating operation in accordance with the homodyne method of receiving or by detection in the usual manner.

The invention may be more fully understood from the following detailed description when read in connection with the accompanying drawing, Figures 1, 3 and 5 of which illustrate different forms of transmitting apparatus operating in accordance with the principles of the invention, Figures 2, 4 and 6 of which illustrate corresponding receiving arrangements, and Fig. 7 of which illustrates the invention as applied to a duplex system in which the operations for transmitting and receiving may be carried on by the same apparatus.

Referring to Fig. 1, M indicates schematically a modulator which may be of any well-known type, for example, as a vacuum tube modulator. Currents of two frequencies may be supplied by generators TG and TG′. In the case illustrated the generator TG may, for example, generate a frequency of 50,000 cycles, and the generator TG′ the frequency of 500,000 cycles. These frequencies may be simultaneously impressed upon the modulator M to produce in the output circuit three frequencies, one of 500,000 cycles corresponding to the carrier frequency of the generator TG, one at 550,000 cycles corresponding to the sum of the frequencies of the generators TG and TG′, and one of 450,000 cycles corresponding to the difference between the two frequencies. These three frequencies may be separated into three branch circuits, TL_1, TL_2, and TL_3 through the filters TF_1, TF_2, and TF_3. The filters may be of any well-known form, as, for example, filters of the band type disclosed in U. S. Patent to G. A. Campbell No. 1,227,113 issued May 22nd, 1917.

Modulators M_1', and M_3', may be included in the branches TL_1 and TL_3 respectively. These modulators may be of any well-known type, such as, for example, vacuum tube modulators, and are supplied with the carrier frequencies transmitted through the filters TF_1 and TF_3 respectively. Signaling currents, such as voice frequency currents, may be supplied to the modulators over circuits TS_1 and TS_3 respectively for the purpose of modulating the carrier frequencies. The antenna TA is provided with three branch circuits, each including inductance and capacity, whereby the antenna may resonate at three different frequencies, one corresponding to each of the frequencies passing through the filters TF_1, TF_2 and TF_3. In the case illustrated, these frequencies will be 550,000 cycles, 500,000, and 450,000 cycles. The modulated carrier frequencies of 550,000 cycles and 450,000 cycles respectively will be impressed upon the antenna TA over the channels TL_1 and TL_3 through tuned circuits or filters TF_1' and TF_3', while the unmodulated carrier frequency of 500,000 cycles will pass from the channel TL_2 through the tuned circuit TF_2' to the antenna TA.

A receiving apparatus corresponding to the transmitting arrangement of Fig. 1 is illustrated in Fig. 2. In this figure, RA represents the receiving antenna, said antenna, like the transmitting antenna TA, having three branches including inductance and capacity, so that the antenna may resonate at the three frequencies 450,000, 500,000 and 550,000 cycles. Tuned circuits or filters RF_1, RF_2, and RF_3 are provided for the purpose of selecting these three frequencies into the receiving channels RL_1, RL_2, and RL_3. Demodulators D_1 and D_3 are included in the channels RL_1 and RL_3 and the channel RL_2 is arranged so that the frequency of 500,000 cycles may be supplied to each of these demodulators to beat with the modulated frequencies of 550,000 cycles and 450,000 cycles respectively, which are impressed upon the demodulators through the channels RL_1 and RL_3. The demodulators D_1 and D_3 may be of any well-known type, such, for example, as vacuum tube detectors, commonly employed for radio receiving. Additional demodulators D_1' and D_3' of similar construction may be included in the channels RL_1 and RL_3. Both the demodulators D_1 and D_3 and band filters RF_1' and RF_3' may be included between each pair of demodulators. These filters RF_1' and RF_3' will each select the side band of frequencies in the neighborhood of 50,000 cycles from the output circuits of the demodulators D_1 and D_3, these bands representing the side bands corresponding to the difference frequencies resulting from the operation of demodulation. The bands thus stepped down in frequency are impressed upon the demodulators D_1' and D_3', said demodulators being at the same time supplied with a beating frequency from the generator RG, so that the low frequency signaling currents in accordance with which the carrier frequencies were originally modulated at the transmitting station will be impressed upon the receiving circuits RS_1 and RS_3.

Fig. 3 illustrates an arrangement similar to that shown in Fig. 1, but differing therefrom in that the fundamental carrier frequency of 500,000 cycles selected by the filter TF_2 and transmitted through the channel TL_2 is used as the carrier frequency for a third transmitting channel. For this purpose a modulator M_2' is included in the channel TL_2, this modulator being supplied with signaling currents from the circuit TS_2. Consequently each of the frequencies 550,000, 500,000 and 450,000 cycles radiated by the antenna TA will be separately modulated in accordance with signals.

The corresponding receiving apparatus is illustrated in Fig. 4. Since the frequency of 500,000 cycles is now modulated in accordance with the signal, it may not be used when selected into the channel RL_2 for the purpose of beating with the modulated frequencies impressed upon detectors D_1 and D_3 but the corresponding frequency of 500,000 cycles is separately generated by a source RG_1 and impressed upon each of the detectors D_1, D_2, and D_3 included in the channels RL_1, RL_2, and RL_3. This frequency, when impressed upon the detector D_2, together with the modulated carrier frequency of 500,000 cycles received from the antenna, results in the production in the output circuit RS_2 of signaling currents corresponding to the signaling currents in accordance with which the carrier frequency of 500,000 cycles is modulated at the transmitting station of Fig. 3. In the case of this channel, no second step of demodulation is necessary. The frequency of 500,000 cycles generated by the generator RG_1, when impressed upon the detectors D_1 and D_3, results in stepping down the modulated carrier frequencies of 550,000 cycles and 450,000 cycles respectively to separate modulated bands of frequencies in the neighborhood of 50,000 cycles. The demodulators D_1' and D_3' are included in the channels RL_1 and RL_3 for detecting the signaling currents from the stepped down frequencies, a source of hymodyne current RG being provided for this purpose, as in the case of Fig. 2. As a resullt of the action of the second stage demodulators D_1' and D_3', low frequency signaling currents are supplied to the circuits RS_1 and RS_3.

Fig. 5 illustrates a circuit organization in accordance with which the principles of the invention are applied to a transmitting system having four signaling channels. In order to accomplish this result, the modulating frequency generated by the transmitting generator TG′ is supplied to a harmonic generator TH, which may be a vacuum tube so adjusted as to produce a maximum degree of distortion in the wave form of the frequency applied thereto. As is well known, the result of distorting a pure sine wave is to produce harmonics as well as the fundamental in the output of the distorting apparatus. Consequently the fundamental frequency of 30,000 cycles (in the case illustrated) and the first harmonic of 60,000 cycles may be selected from the output circuit of the generator TH and separately impressed upon modulator M_1 and M_2 which are supplied with a carrier frequency of 500,000 cycles from a separate source TG. The resultant carrier frequency and the two side frequencies appearing in the modulator M_1 are selected into branches through filters T_1F_1, T_1F_2, and T_1F_3. The frequencies selected by the filters T_1F_1 and T_1F_3 are impressed upon modulators T_1M_1' and T_1M_3' included in the channels T_1L_1 and T_1L_3, and are modulated in accordance with signaling currents with the circuits T_1S_1 and T_1S_3. The third frequency corresponding to the unmodulated wave of 500,000 cycles is transmitted directly through the channel TL_2 to the antenna TA. In a similar manner the frequency of 500,000 cycles is modulated by a frequency of 60,000 cycles through the action of the modulator M_2 and the three resultant frequencies are selected by the filters T_2F_1, T_2F_2, and T_2F_3. The frequencies selected by the filters T_2F_1 and T_2F_3 are impressed upon modulators T_2M_1 and T_2M_3 to be modulated separately in accordance with signals and then impressed upon the antenna. The unmodulated carrier frequency of 500,000 cycles is at the same time impressed upon the branch TL_2. Consequently the transmitting antenna radiates an unmodulated frequency of 500,000 cycles and modulated frequencies of 470,000 cycles, 530,000 cycles, 440,000 cycles, and 560,000 cycles.

The corresponding receiving arrangement is illustrated in Fig. 6. In this figure RA designates the receiving antenna which is provided with five branches, each including inductance and capacity, so that it will resonate at any of the five principal frequencies radiated by the antenna of Fig. 5. The unmodulated 500,000 cycle frequency is selected by means of a tuned circuit into a receiving channel RL_2 and is utilized as a beating frequency to step down the modulated frequencies. The receiving channels R_1L_1, R_1L_3, R_2L_1, and R_2L_3 are also associated with the receiving antenna through suitable tuned circuits, so that the modulated frequencies of 470,000 cycles, 530,000 cycles, 440,000 cycles, and 560,000 cycles will be supplied thereto. Demodulating devices R_1D_1, R_1D_3, R_2D_1, and R_2D_3 are included in the channels R_1L_1, R_1L_3, R_2L_1, and R_2L_3 respectively. The beating frequency of 500,000 cycles impressed on the channel RL_2 is supplied to each of these modulators and by beating with the modulated frequencies appearing in the channels modulated frequencies of 30,000 cycles will appear in the channels R_1L_1 and R_1L_3 beyond the first demodulator in each channel, and modulated frequencies of 60,000 cycles will likewise appear in the channels R_2L_1 and R_2L_3 at similar points. The signals in accordance with which the currents in the four channels will be modulated will be different, although the carrier frequency may be the same in each channel of a pair. Second stage demodulators R_1D_1', R_1D_3', R_2D_1' and R_2D_3' are included in the four channels carrying the stepped-down modulated frequencies for the purpose of detecting the signals imposed upon the carriers. The vacuum tube oscillator or other form of oscillating device RG′ may be provided for the purpose of supplying a frequency of 30,000 cycles (in the case assumed) and by impressing this frequency on a harmonic generator RH, which may be of the same type as the generator TH at the transmitting station, frequencies will appear in the output circuit of the generator corresponding to the fundamental frequency of 30,000 cycles and various harmonics thereof. The fundamental frequency of 30,000 cycles may be selected by means of suitable tuned circuits and transmitted to the demodulators R_1D_1' and R_1D_3', while the first harmonic of 60,000 cycles may be similarly selected and transmitted to the demodulators R_2D_1' and R_2D_3'. These frequencies, by beating with the modulated frequencies supplied to the demodulators will result in the transmission of the signals in accordance with which the frequencies were modulated to the circuits R_1S_1, R_1S_3, R_2S_1, and R_2S_3 respectively.

Fig. 7 illustrates an arrangement in which the same antenna may be used for multiplex transmitting and receiving simultaneously. For this purpose the antenna A is balanced by means of a suitable network N, and is provided with a balanced transformer arrangement 10 to the midpoints of which a common receiving circuit RL is connected, while a common transmitting circuit TL is inductively connected thereto, the arrangement being such that the circuits TL and RL will be substantially conjugate. As it is not generally possible in radio work to obtain a sufficiently accurate balance for good duplex transmission, the separation between the oppositely directed transmissions obtained by balance will be supplemented as described later by employing different frequencies for transmitting and receiving. The transmitting channels T_1L_1 and T_1L_3 are connected with common transmitting circuit TL, and receiving channels R_1L_1 and R_1L_3 are connected with the common receiving circuit RL. A generator G, which may be an oscillator of the vacuum tube type, is provided for generating a modulating frequency which may be, for example, 30,000 cycles, and the second generator G′ of similar type may be provided for supplying a radio frequency of 500,000 cycles. The frequency supplied by the generator G is impressed upon a harmonic producer H, similar to the harmonic producer previously described. The fundamental frequency of 30,000 cycles appearing in the output circuit of this harmonic producer may be supplied to a modulator TM, together with the carrier frequency of 500,000 cycles. The modulator TM functions to modulate the carrier frequency in accordance with the lower frequency, so that side frequencies of 470,000 cycles and 530,000 cycles appear in its output circuit, which circuit is connected to the transmitting channels through filters TF_1 and TF_3. Second stage modulators TM_1 and TM_3' are included in the transmitting channels, so that the two side frequencies may be modulated in accordance with signaling currents incoming from the circuits

TS_1 and TS_3. The modulated frequencies of 470,000 cycles and 530,000 cycles appearing in the output circuits of the modulator are combined in the common transmitting circuit TL and transmitted through the transformer 10 to the radio antenna A.

Receiving channels R_1L_1 and R_1L_3 associated with the common receiving circuit RL are adapted to receive from the antenna A modulated carrier frequencies, which, in the case assumed, may be of 440,000 cycles and 560,000 cycles respectively. First stage demodulators RD_1 and RD_3 are provided in the receiving channels R_1L_1 and R_1L_3, and these demodulators are supplied with a frequency of 500,000 cycles from the oscillator G′. This frequency, by beating with the modulated carrier frequencies, reduces these frequencies to modulated frequencies of 60,000 cycles, the signal imposed upon the modulated frequencies being different in the two channels, however. Second stage demodulators RD_1' and RD_3' are included in the channels R_1L_1 and R_1L_3 beyond the first stage demodulators, and these demodulators are supplied with the first harmonic of 60,000 cycles appearing in the output circuit of the harmonic producer H. Consequently the signals in accordance with which the two frequencies of 60,000 cycles each were modulated will appear in the receiving circuits RS_1 and RS_3 respectively.

It will be understood that in all the figures herein illustrated and described suitable filtering or other arrangements well known in the art may be provided in connection with the various modulating and demodulating apparatus for eliminating undesired frequencies, such, for example, as the unmodulated carrier resulting from the modulation of a frequency in accordance with a signaling current, and if desired the elimination of one of the resultant side bands. These features, being well known in the art and constituting no part of the present invention, have not been illustrated.

It will 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. The method of multiplex signaling which consists in generating a plurality of carrier frequencies by modulating one frequency in accordance with another frequency, selecting certain of the resultant frequencies and modulating certain of the selected frequencies in accordance with signaling frequencies.

2. The method of multiplex signaling which consists in producing carrier frequencies for different channels by modulating one frequency in accordance with another frequency, selecting the resultant frequencies into separate circuits, and separately modulating certain of the selected frequencies in accordance with signals.

3. The method of multiplex signaling which consists in generating a plurality of frequencies, producing harmonics of certain of the frequencies, modulating combinations of the frequencies and harmonics to produce carrier frequencies for separate channels, and modulating certain of the carrier frequencies of the separate channels in accordance with different signaling currents.

4. The method of multiplex signaling which consists in generating a plurality of frequencies, producing harmonics of certain of the frequencies, modulating combinations of the frequencies and harmonics to produce a plurality of carrier frequencies, selecting the resultant carrier frequencies into individual channels, and modulating certain of the individual carrier frequencies in accordance with the separate signals.

5. The method of multiplex signaling which consists in impressing upon a receiving circuit a plurality of carrier frequencies, each modulated in accordance with a signal, beating the carrier frequencies with an unmodulated frequency so chosen that the resultant stepped-down frequencies will be the same in each case so far as the fundamental carrier is concerned but the modulations will be different, and detecting from the stepped-down frequencies the individual signals in accordance with which they are modulated.

6. The method of multiplex signaling which consists in impressing upon a receiving system a plurality of modulated carrier currents whose basic carrier frequencies bear the relation to each other of side frequencies of the same carrier, reducing said modulated carrier frequencies to modulated carrier frequencies of the same order of frequency by beating them with a current having the frequency of the carrier to which they are related, and detecting from the resultant currents the signals in accordance with which the carriers were individually modulated.

7. The method of multiplex signaling which consists in impressing upon a receiving circuit a plurality of carrier frequencies bearing the relation to each other of a basic carrier frequency and side frequencies thereof, the side frequencies at least being modulated in accordance with signaling currents, beating the modulated frequencies with a frequency corresponding to that of the basic carrier, thereby stepping the modulated side frequencies down to the same point in the frequency spectrum, and detecting from the various modulated frequencies the signals in accordance with which they were individually modulated.

8. The method of multiplex signaling which consists in impressing upon a receiving circuit a plurality of frequencies, each modulated in accordance with a signal and bearing the relation to each other of side frequencies resulting from the modulation of the same carrier by a harmonic of a basic frequency, beating each frequency with a frequency corresponding to that of the carrier to which they are related to step down the modulated frequencies to the same point in the frequency spectrum, producing a harmonic frequency of the basic frequency used in the original modulation, and beating the stepped-down frequencies with the harmonic frequency to detect the signals in accordance with which the frequencies were originally modulated.

9. The method of multiplex signaling which consists in generating a plurality of frequencies, modulating one generated frequency in accordance with another to produce three frequencies bearing the relations of side frequencies and unmodulated carrier frequency, selecting the three frequencies into individual circuits, individually modulating the side frequencies, impressing said modulated frequencies and unmodulated carrier upon a receiving circuit, beating the modulated frequencies with the unmodulated frequency to step the modulated frequencies down to the same point in the frequency spectrum, and detecting from the stepped-down frequencies the signals in accordance with which they were modulated.

10. In a multiplex signaling system means to generate a plurality of frequencies, means to modulate one of the generated frequencies in accordance with another frequency, means to select certain of the resultant frequencies and means to modulate certain of the selected frequencies in accordance with different signaling frequencies.

11. In a multiplex signaling system means to generate a plurality of frequencies, means to modulate one of the generated frequencies in accordance with another frequency, means to modulate certain of the resultant frequencies in accordance with different signaling frequencies, and a radiating antenna for transmitting the several frequencies, said antenna having a plurality of degrees of freedom corresponding to the resultant frequencies of the first step of modulation.

12. In a multiplex signaling system means for generating a plurality of frequencies, means to modulate one of said frequencies in accordance with another of said frequencies to produce side frequencies and an unmodulated component, means for selecting said frequencies into separate circuits, and means in the separate circuits for modulating certain of the selected frequencies in accordance with signals.

13. In a multiplex signaling system means for generating a plurality of frequencies, means to modulate one of said frequencies in accordance with another of said frequencies to produce side frequencies and an unmodulated component, means for selecting said frequencies into separate circuits, means in the separate circuits for modulating certain of the selected frequencies in accordance with signals, and a radiating antenna for radiating said frequencies, said antenna having a plurality of degrees of freedom corresponding to said side frequencies and said unmodulated component.

14. In a multiplex signaling system means for generating a plurality of frequencies, means to produce harmonics of certain of the frequencies, means to modulate combinations of the frequencies and harmonics to produce carrier frequencies for separate channels, and means for impressing separate signals on the carrier frequencies of the separate channels.

15. In a multiplex signaling system means for generating a plurality of frequencies, means to produce harmonics of certain of the frequencies, means to modulate combinations of the frequencies and harmonics to produce carrier frequencies for separate channels, means for impressing separate signals on the carrier frequencies of the separate channels, and a radiating antenna for transmitting said frequencies, said antenna having a plurality of degrees of freedom corresponding to the several carrier frequencies.

16. In a multiplex signaling system means for generating a plurality of frequencies, means for producing harmonics of certain of the frequencies, means for modulating combinations of the frequencies and harmonics to produce a plurality of carrier frequencies, means to select the resultant carrier frequencies into individual channels, and means to modulate certain of the individual carrier frequencies in accordance with the separate signals.

17. In a multiplex signaling system means for generating a plurality of frequencies, means for producing harmonics of certain of the frequencies, means for modulating combinations of the frequencies and harmonics to produce a plurality of carrier frequencies, means to select the resultant carrier frequencies into individual channels, means to modulate certain of the individual carrier frequencies in accordance with the separate signals, and a radiating antenna for transmitting said frequencies, said antenna having a plurality of degrees of freedom corresponding to the carrier frequencies of the individual channels.

18. In a multiplex signaling system means for producing a plurality of carrier frequencies, each modulated in accordance with a signal, means to impress said frequencies upon a receiving circuit, means to beat said

frequencies with an unmodulated frequency so chosen that the resultant stepped-down frequencies will be the same in each case so far as the fundamental frequency is concerned but the modulations will be different, and means for detecting from the stepped-down frequencies the individual signals in accordance with which they are modulated.

19. In a multiplex signaling system, means for producing a plurality of carrier frequencies, each modulated in accordance with a signal, a receiving antenna having a plurality of degrees of freedom corresponding to each of said carrier frequencies, means associated with said antenna for beating the carrier frequencies with an unmodulated frequency so chosen that the resultant stepped-down frequencies will be the same in each case so far as the fundamental carrier is concerned but the modulations will be different, and means for detecting from the stepped-down frequencies the individual signals in accordance with which they are modulated.

20. In a multiplex signaling system means for producing a plurality of modulated carrier currents whose basic carrier frequencies bear the relation to each other of side frequencies of the same carrier, means for reducing said modulated carrier frequencies to modulated carrier frequencies of the same order of frequency by beating them with a current having the frequency of the carrier to which they are related, and means for detecting from the resultant currents the signals in accordance with which the carriers were individually modulated.

21. In a multiplex signaling system means for generating a plurality of modulated carrier currents whose basic carrier frequencies bear the relation to each other of side frequencies of the same carrier, a receiving antenna having a plurality of degrees of freedom corresponding to the several basic carrier frequencies, means for reducing said modulated carrier frequencies to unmodulated carrier frequencies of the same order of frequency by beating them with a current having the frequency of the carrier to which they are related, and means for detecting from the resultant currents the signals in accordance with which they were originally modulated.

22. In a multiplex signaling system means for producing a plurality of carrier frequencies bearing the relation to each other of a basic carrier frequency and side frequencies thereof, means for modulating at least the side frequencies in accordance with signals, means for beating the modulated frequencies with a frequency corresponding to that of the basic carrier, thereby stepping the modulated side frequencies down to the same point in the frequency spectrum, and means for detecting from the various modulated frequencies the signals in accordance with which they were originally modulated.

23. In a multiplex signaling system means for producing a plurality of carrier frequencies bearing the relation to each other of a basic carrier frequency and side frequencies thereof, means for modulating at least the side frequencies in accordance with signals, a receiving antenna having a plurality of degrees of freedom corresponding to the several carrier frequencies, means for beating the modulated frequencies with a frequency corresponding to that of the basic carrier, thereby stepping the modulated side frequencies down to the same point in the frequency spectrum, and means for detecting from the various modulated frequencies the signals in accordance with which they were originally modulated.

24. In a multiplex signaling system means for generating a plurality of carrier frequencies, each modulated in accordance with a signal and bearing the relation to each other of side frequencies resulting from the modulation of the same carrier by a harmonic of a basic frequency, means for beating each frequency with a frequency corresponding to that of the carrier to which they are related to step down the modulated frequencies to the same point in the frequency spectrum, means for producing a harmonic frequency of the basic frequency used in the original modulation, and means to beat the stepped-down frequencies with the harmonic frequency to detect the signals in accordance with which the frequencies were originally modulated.

25. In a multiplex signaling system means for producing a plurality of frequencies, each modulated in accordance with a signal, bearing the relation to each other of side frequencies resulting from the modulation of the same carrier by a harmonic of the basic frequency, a receiving antenna having a plurality of degrees of freedom corresponding to the several frequencies generated, means for beating each modulated frequency with a frequency corresponding to that of the carriers to which they are related to step down the modulated frequencies to the same point in the frequency spectrum, means to produce a harmonic frequency of the basic frequency used in the original modulation, and means to beat the stepped-down frequencies with the harmonic frequency to detect the signals in accordance with which the frequencies were originally modulated.

In testimony whereof, I have signed my name to this specification this 8th day of February, 1921.

DE LOSS K. MARTIN.