Aug. 26, 1930.

B. W. KENDALL

1,773,901

HIGH FREQUENCY SIGNALING

Filed Nov. 9, 1916

5 Sheets-Sheet 1

Fig. 1.

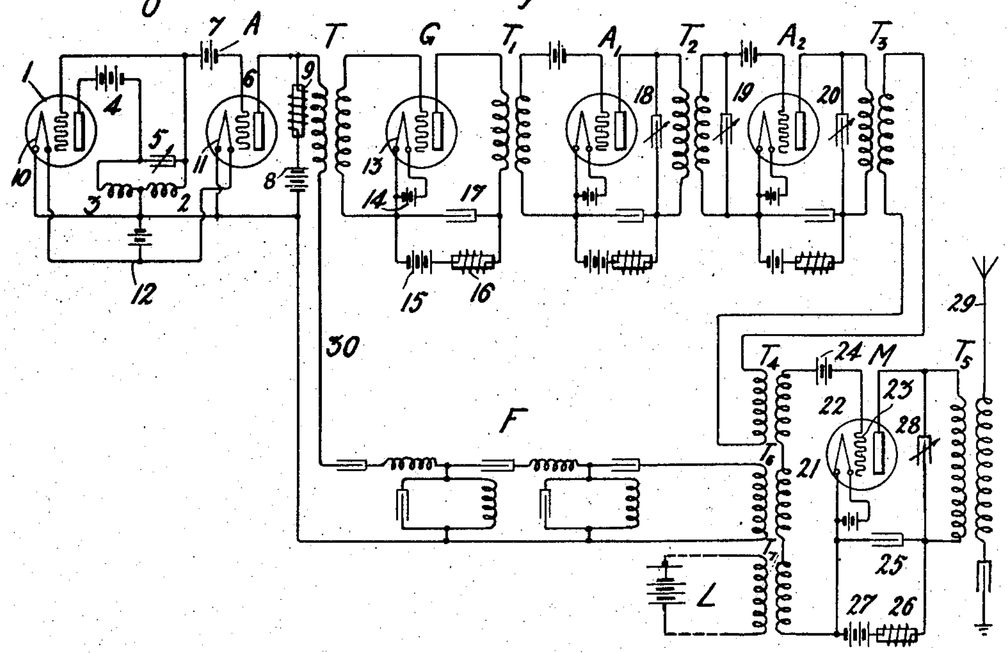
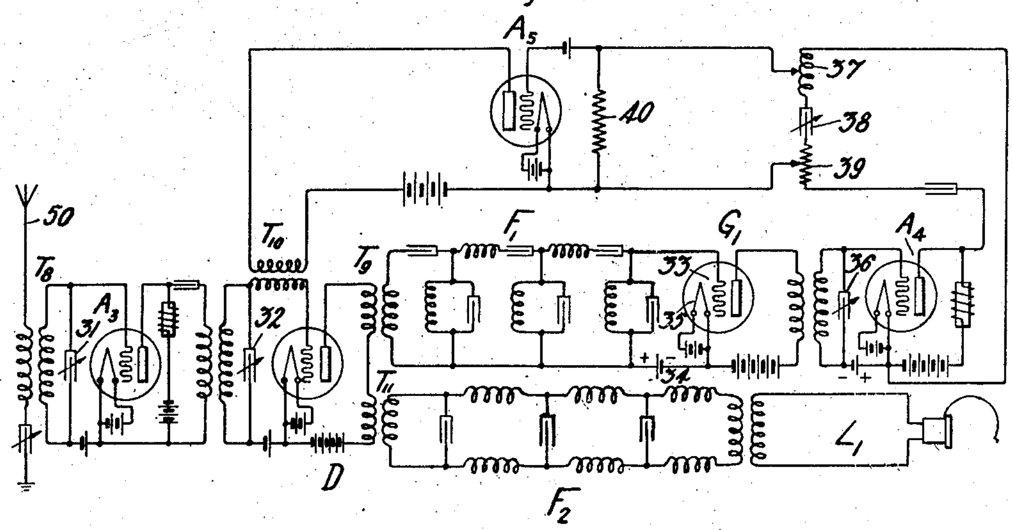


Fig. 2.



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HIGH FREQUENCY SIGNALING

Filed Nov. 9, 1916 5 Sheets-Sheet 2

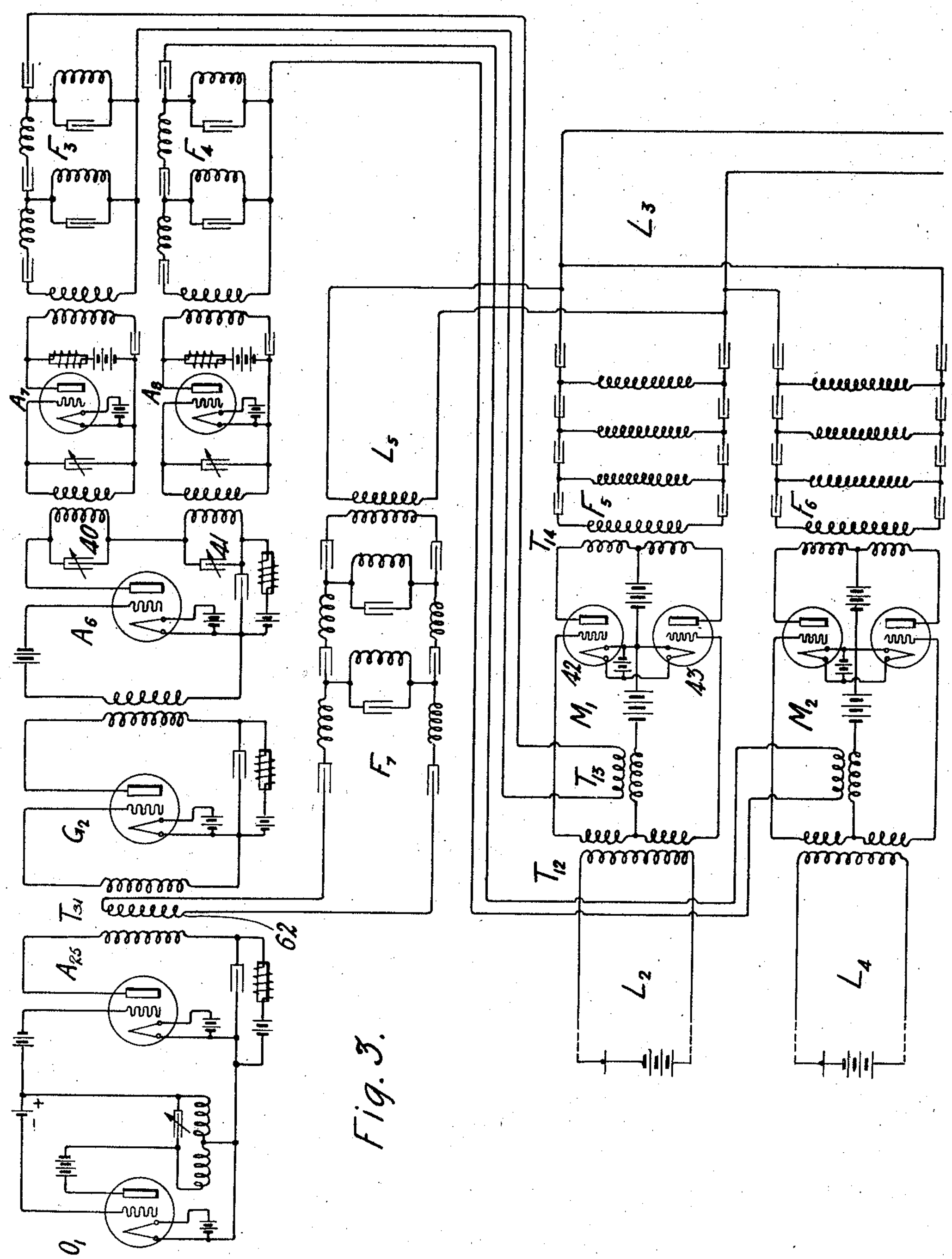

Fig. 3.

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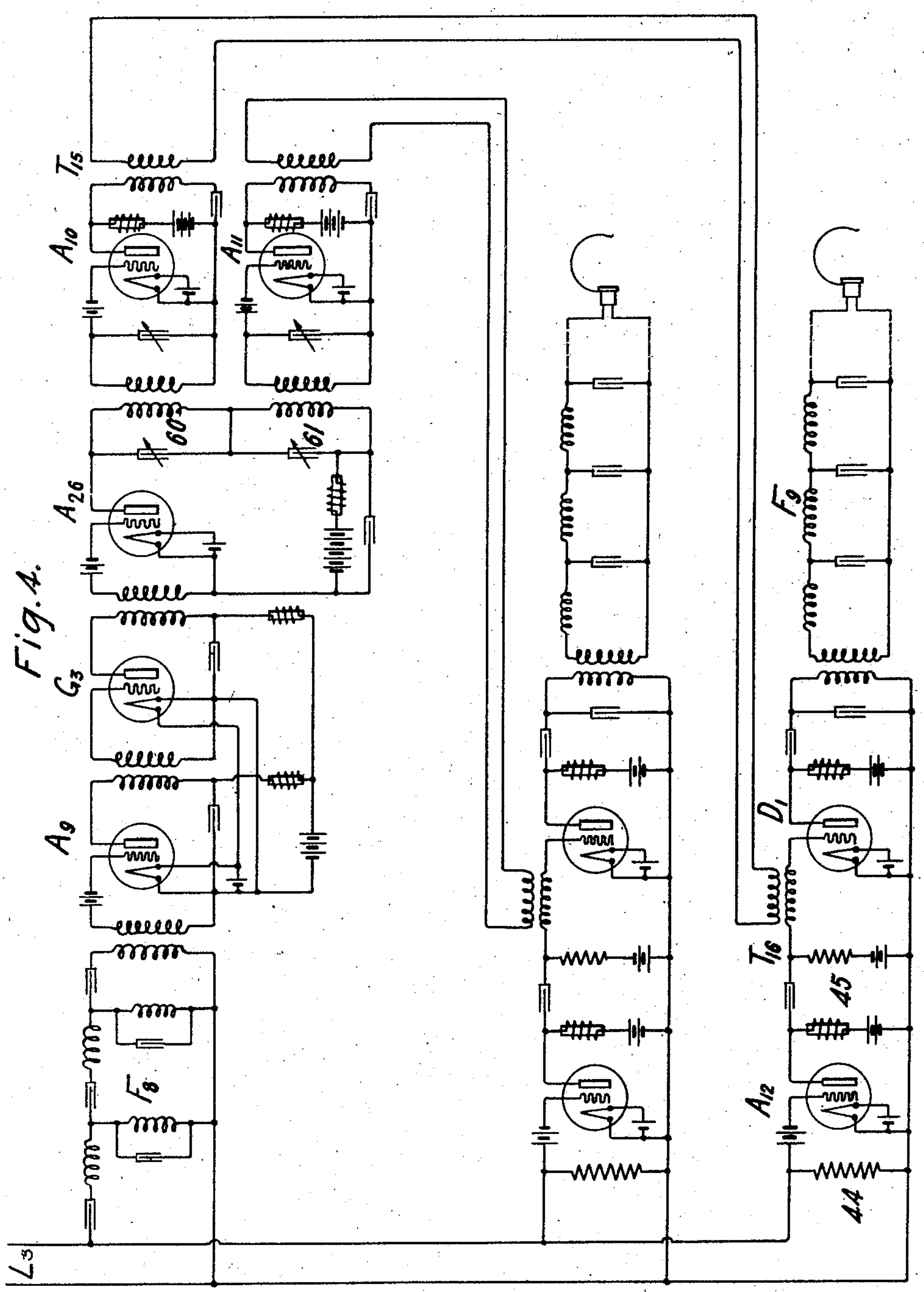
Aug. 26, 1930. B. W. KENDALL 1,773,901

HIGH FREQUENCY SIGNALING

Filed Nov. 9, 1916 5 Sheets-Sheet 3



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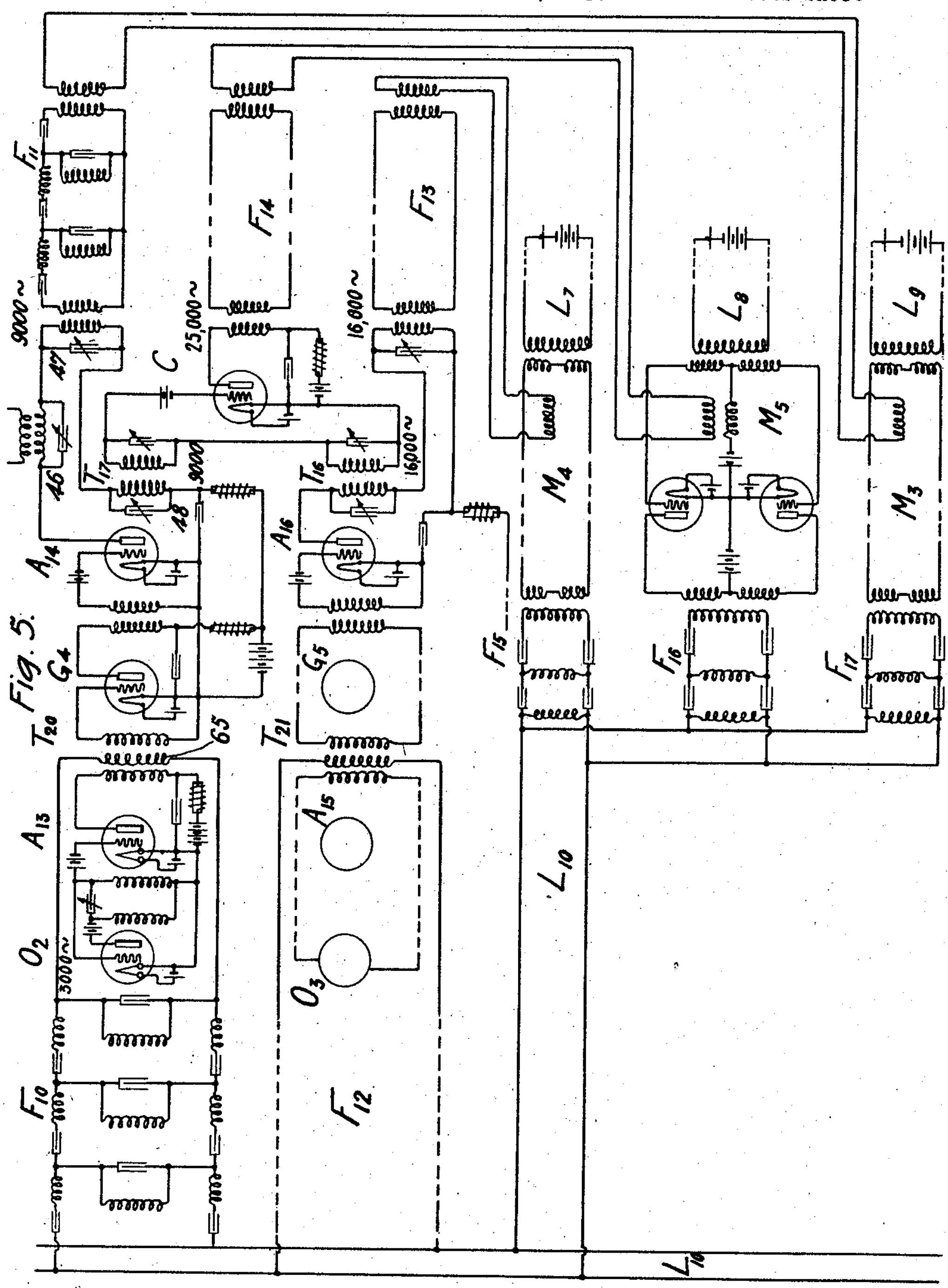
HIGH FREQUENCY SIGNALING

Filed Nov. 9, 1916 5 Sheets-Sheet 4



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HIGH FREQUENCY SIGNALING

Filed Nov. 9, 1916 5 Sheets-Sheet 5

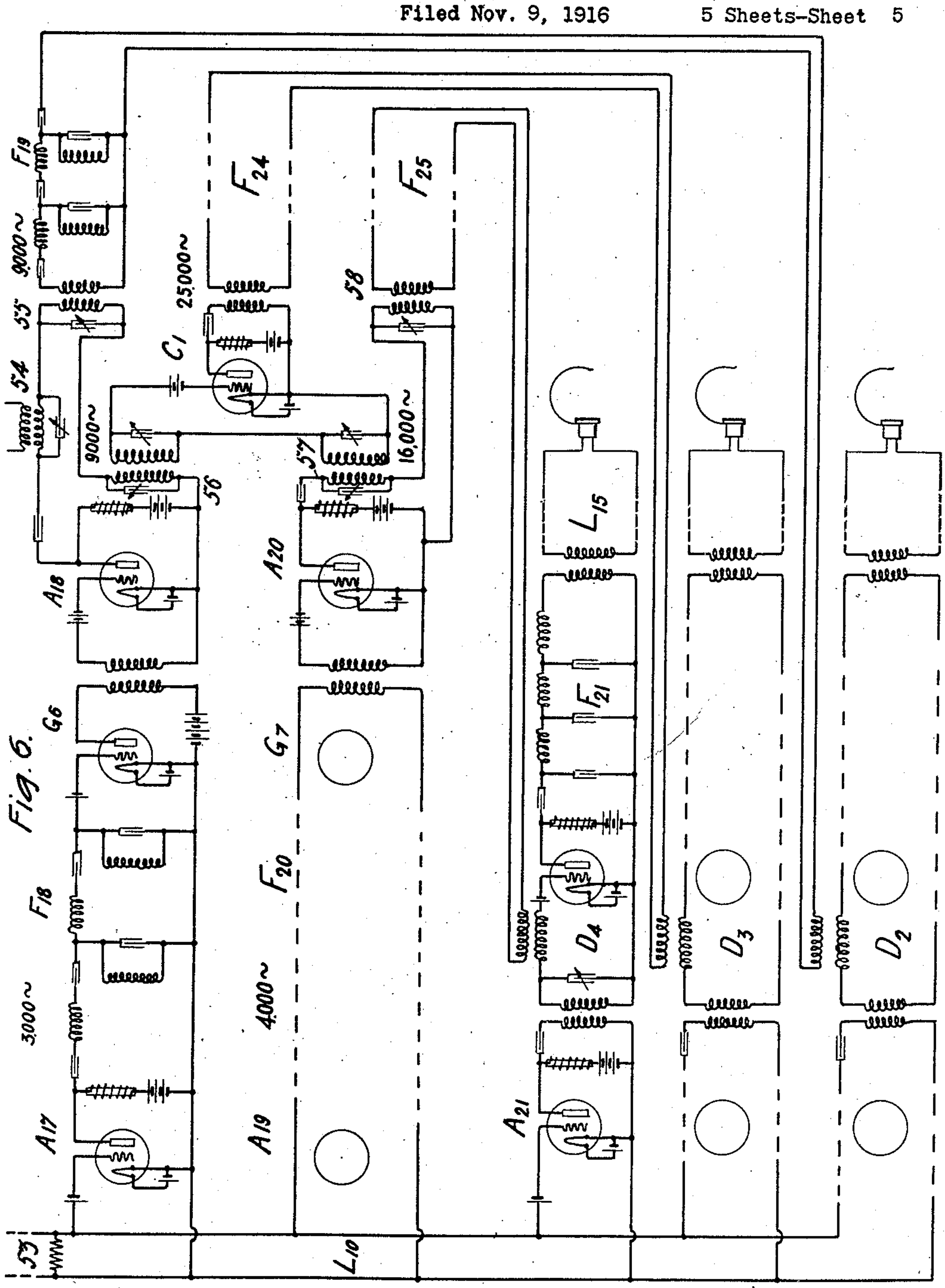

Fig. 6.

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Patented Aug. 26, 1930 **1,773,901**

UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY SIGNALING

Application filed November 9, 1916. Serial No. 130,350.

This invention relates to high frequency signaling, in which signals are transmitted as modulations of a high frequency wave.

In United States Patent 1,330,471 to B. W. Kendall, patented February 10, 1920, for high frequency signaling it is shown how the homodyne method of reception is adapted to telephonic signaling. According to this method, the detected signal is intensified by combining the received modulated oscillations with locally generated oscillations of a frequency the same as the carrier frequency. The oscillations generated at the receiving station will hereafter be termed reinforcing oscillations for brevity and to differentiate them from the carrier oscillations generated at the sending station. If the carrier oscillations have a frequency which is not equal in value to the reinforcing frequency, beats are produced having a frequency equal to the difference in the frequencies of the carrier and the reinforcing oscillations. These beats may be manifested as a sound or noise which is superimposed upon the signal being received, and this interferes with a clear and distinct reception of the signal.

To prevent a masking of the signal by such a sound or noise, the present invention has for an object to provide method and means for insuring that the carrier and reinforcing frequencies shall have identical values.

This is accomplished by generating control oscillations, and by changing the frequency thereof to provide a source of carrier oscillations which are modulated in accordance with a signal to be transmitted. The control oscillations and the modulated oscillations are sent to the receiving station where the frequency of the control oscillations is changed, in the same manner as it was at the sending station, to provide a source of reinforcing oscillations which are combined with the received modulated oscillations to reproduce the signal. Since there is a single source of control oscillations from which both the carrier and reinforcing oscillations are derived, the carrier and reinforcing oscillations will always have the same frequency which may, however, assume different values, due to variations in the control frequency.

It is shown how this scheme of frequency control may be embodied in a multiplex system in which the frequency changing means at the sending station generates a plurality of frequencies which may be multiples of each other, and corresponding reinforcing frequencies are generated at the receiving station.

The frequency changer used in the systems above described is a harmonic generator which gives only a relatively small number of frequencies within a given frequency range, since there are generated only those frequencies which are multiples of the frequency supplied to the harmonic generator.

Other objects of the invention are to make a larger number of frequencies available within a given frequency range than would be possible if only a single control frequency were used, and to provide frequencies which are not multiples of each other.

This is accomplished by generating two frequencies, for instance, oscillations of 3000 and 4000 cycles, which are individually supplied to harmonic generators, each of which gives any desired multiple of the frequency supplied to it. The third multiple, 9000, for example, from the 3000 cycle harmonic generator may be combined in a thermionic device with the fourth multiple, 16000, supplied by the 4000 cycle harmonic generator to produce a frequency equal to their sum, 9000 plus 16000, or 25000, which is a frequency different from that of any multiple supplied by either of the harmonic generators.

This will be further considered in connection with the drawings, in which Figs. 1 and 2 show a wireless sending and receiving station respectively, in which control oscillations supplied at the sending station are employed to maintain a constant phase and frequency relation between the carrier oscillations and the reinforcing oscillations. Figs. 3 and 4 show diagrammatically a sending and receiving station respectively of a multiplex system, in which the carrier and reinforcing frequencies used are multiples of the control frequency. Figs. 5 and 6 show a sending and receiving station respectively of a multiplex system, in which the number of carrier frequencies is increased by combining the multiple frequencies from two harmonic generators, and frequencies are obtained which are not multiples of each other.

Referring to Fig. 1, the oscillation generator O, of the general type disclosed and claimed in the patent to Hartley, oscillation generators, 1,356,763, patented October 26, 1920, supplies control oscillations and comprises a three-element vacuum tube of the audion type, in which the input circuit is inductively connected to the output circuit by means of the coils 2 and 3. The space current in this tube is supplied by the battery 4. By means of the variable condenser 5, shunted across the coils 2 and 3, the frequency supplied by the generator may be given any desired value. This oscillation generator which supplies control oscillations is connected to the input circuit of the amplifier A of the audion type. The grid 6 of this amplifier is supplied with negative potential by means of battery 7. The space current in the output circuit of the amplifier is supplied by the battery 8 through the impedance 9. The filaments 10 and 11 of the oscillation generator and amplifier are heated by the common battery 12. Amplified oscillations in the output circuit of the amplifier A are supplied by means of the transformer T to the input circuit of the harmonic generator G, which is a three-element vacuum tube of the audion type.

The harmonic generator G is described and claimed in the United States Patent to Kendall No. 1,446,752, February 27, 1923, and as noted therein the harmonic generator is overloaded so as to produce a maximum distortion of the wave form supplied by the harmonic generator. Since a distorted wave may be considered as composed of a pure sine wave of the same fundamental frequency as the distorted wave, and a plurality of harmonics having higher frequencies, it remains to select the particular higher frequency which it is desired to transmit.

The filament 13 of the harmonic generator is heated by the battery 14 and the space current in the output circuit is supplied by the battery 15 through the impedance 16. The condenser 17, in shunt to the impedance 16 and battery 15, provides a path for the high frequency currents. The harmonic generator is coupled by means of the transformer T_1 to an amplifier A_1 which is similar to amplifier A above described. The output circuit of amplifier A_1 is tuned by means of the condenser 18 to the particular harmonic frequency oscillations to be selected from the complex wave in the output circuit of the harmonic generator and supplied as a carrier wave. Amplifier A_1 is coupled by means of transformer T_2 to another amplifier A_2, both input and output circuits of which are tuned by means of the condensers 19 and 20 respectively to the harmonic frequency selected from the harmonic generator. The selected carrier oscillations are transferred by means of the transformers T_3 and T_4 to the input circuit 21 of the modulator M.

This modulator M is described and claimed in the patent to Hendrik J. Van der Bijl, 1,350,752, patented August 24, 1920. This modulator comprises a three-element vacuum tube 22 of the audion type, the grid 23 of which is maintained at a negative potential by means of the battery 24. The output circuit of tube 22 comprises condenser 25, which shunts the impedance 26 and the source 27. This output circuit is tuned to the frequency to be transmitted by means of the condenser 28. The modulator M is coupled to antenna 29 by means of the transformer T_5.

By means of the line 30, amplified control oscillations of the frequency generated by the oscillator O are supplied to the filter F, which selectively transmits oscillations of the control frequency to the transformer T_6, coupled to the input circuit of the modulator M. The signal to be transmitted is transferred from the line L to the input circuit of the modulator M by means of the transformer T_7.

The carrier oscillations supplied by the transformer T_4 are then modulated in accordance with both the control oscillations supplied by the transformer T_6 and the signal currents in line L. The carrier oscillations, as modulated, are then transmitted from the antenna 29 and received by the antenna 50, shown in Fig. 2. The antenna 50 is coupled by means of transformer T_8 to the amplifier A_3, the input circuit of which is tuned to the frequency of the oscillations to be received by means of the condenser 31. The amplifier A_3 is similar to the amplifiers above described and is essentially unilaterally conducting for a purpose that will be later described. The output circuit of amplifier A_3 is coupled to the detector D, the input circuit of which is suitably tuned by means of the condenser 32. This detector is a vacuum tube of the well-known audion type. The output circuit of the detector D is coupled by means of the transformer T_9 to the filter F_1, which selectively transmits detected control oscillations of the frequency generated by the oscillator O. By means of the transformer T_{11}, the output circuit of detector D is also coupled to the filter F_2, which suppresses all frequencies above 2500 cycles and which transmits exclusively the detected audible signaling currents.

The filter F_1 selectively transmits the control oscillations to the power limiting tube and harmonic generator G_1, which comprises a three-element vacuum tube of the audion type. The potential of the grid 33 of the device G_1 is maintained positive by means of the battery 34. The positive grid attracts the electrons emitted by the filament 35, and when the potential supplied to the device G_1 reaches a sufficiently high positive value, the electrons will be attracted to the grid to such an extent that no further increase in the current in the plate circuit occurs. The minimum value of the space current in G_1 being zero, it is evident that the power delivered by this tube is limited; and such limitation is necessary in order to prevent singing in the circuit comprising the elements T_9, F_1, G_1, A_4, A_5 and T_{10}, which serve to couple the output circuit of detector D to its input circuit. Any other form of power limiting device may however be used.

The device G_1 operates as a harmonic generator by reason of the fact that it is overloaded as noted above. Carrier frequency reinforcing oscillations from the harmonic generator G_1 are supplied to the amplifier A_4, the input circuit of which is tuned by the variable condenser 36. The phase of the amplified reinforcing oscillations is properly adjusted by means of the variable inductance 37, variable capacity 38 and variable resistance 39. Amplified reinforcing oscillations of the proper phase are supplied to the resistance 40, which serves as a source of potential for the input circuit of the amplifier A_5, the output circuit of which is coupled to the input circuit of detector D by means of the transformer T_{10}. Oscillations from transformer T_{10} cannot, however, be transmitted through amplifier A_3 to antenna 50, since amplifier A_3 is a symmetrically conducting and only permits the passage of currents in the direction from the antenna to the detector D.

It will be apparent than that control oscillations supplied by the oscillator O and the signal currents sent over the line L will serve to modulate the carrier oscillations supplied by the transformer T_4 from the harmonic generator G. The modulated oscillations are transmitted from antenna 29 and are received by the antenna 50. The detector D supplies detected control oscillations which are selectively transmitted by means of the filter F_1 to the harmonic generator and power limiting tube G_1. The device G_1, operating as a harmonic generator, supplies reinforcing oscillations of the carrier frequency and these oscillations are amplified by the amplifier A_4. The phase of the reinforcing oscillations is properly adjusted by means of the variable inductance 37, variable capacity 38 and variable resistance 39. Reinforcing oscillations having a proper phase with relation to the carrier oscillations are then amplified by the amplifier A_5 and transferred to the input circuit of the detector D, where the reinforcing oscillations combine with the received modulated oscillations, thereby intensifying both the received control oscillations and the low frequency signal up to an amount which is limited by the capacity of the power limiting device G_1 to pass control oscillations from filter F_1 to amplifier A_4. The object of this intensification is to reproduce in line L_1 the signal which originated in the line L. The signal currents are then supplied by means of the transformer T_{11} to the line L_1, the filter F_2 serving to suppress all the frequencies above the audible range.

Since the carrier oscillations and the reinforcing oscillations are derived from a common source, and since both are provided by changing the frequency of the oscillations supplied by that source, it follows that the carrier frequency and the reinforcing frequency will always be identical; which is essential for the proper reception of the telephonic signal. It is to be noted here that the selecting devices, i. e., tuned circuits and filters employed, will properly differentiate between the various frequencies involved, even though the control frequency and its multiple are subject to small variations.

The oscillation generators, amplifiers and harmonic generators shown in the remaining figures are similar to those described above. Referring to Fig. 3, there is shown a multiplex sending system in which the harmonic generators supplies a plurality of carrier frequencies, each of which may be modulated with a signal to be transmitted. The control oscillations supplied by the oscillation generator O_1 are amplified by means of the amplifier A_{25}, and amplified control oscillations are supplied by means of the transformer T_3 to the input circuit of the harmonic generator G_2. The several carrier oscillations supplied by the generator G_2 are amplified by means of amplifier A_6, the output circuit of which comprises the two tuned circuits 40 and 41, each of which is tuned to a different harmonic supplied by the harmonic generator G_2. Carrier oscillations supplied by the tuned circuit 40 are amplified by means of the amplifier A_7 from which amplified carrier oscillations are selectively transmitted by means of the filter F_3 to the modulator M_1. Similarly, the tuned circuit 41 supplies amplified carried oscillations of a frequency different from that supplied by the tuned circuit 40, to the amplifier A_8, which is coupled to the filter F_4, which selectively transmits carrier oscillations to the modulator M_2.

The modulator M_1 comprises two three-element vacuum tubes of the audion type, 42 and 43, which have their input circuits connected in opposition. The signaling currents are supplied to the modulator M_1 by means of the line L_2. The transformer T_{12} has two coils serially connected in its secondary circuit, and the transformer T_{13} supplies carrier oscillations between the points of division of the divided input circuits of the tubes 42 and

43. This modulator is described and claimed in patent to Carson, 1,343,306, Patented June 15, 1920, "duplex translating circuits." The output circuit of the modulator M_1 is coupled by means of the transformer T_{14} to the filter F_5, which suppresses any low frequency signals that might otherwise be transmitted to the high frequency line L_3. The modulator M_2 is provided with the low frequency line L_4, and this modulator is coupled through the filter F_6 to the high frequency line L_3.

By means of the coil 62 of the transformer T_{31}, some of the control oscillations are supplied to the filter F_7, which selectively transmits only oscillations of the control frequency to the line L^5 in circuit with the high frequency line L_3. The modulators M_1 and M_2 serve to suppress the unmodulated component of the carrier wave and each transmits a pure modulated wave to the line L_3, which is also supplied with control oscillations from the line L_5.

The oscillations transmitted to the high frequency line L_3 are received by the receiving station shown in Fig. 4. The filter F_8, connected to the line L_3, supplies control oscillations to the amplifier A_9, coupled to the harmonic generator G_3, which supplies reinforcing oscillations of the various carrier frequencies to the amplifier A_{26} similar to the amplifier A_6, shown at the sending station in Fig. 3.

In Fig. 4, the tuned circuits 60 and 61 supply amplified reinforcing oscillations of the carrier frequencies to the amplifiers A_{10} and A_{11} respectively. Amplified reinforcing oscillations are supplied by means of the transformers T_{15} and T_{16} to the input circuit of detector D_1. The resistance 44, connected across the line L_3, serves as a source of modulated oscillations for the unilateral amplifier A_{12}, which prevents the oscillations supplied by transformer T_{16} from being transmitted to the line L_3. The amplifier A_{12} supplies amplified modulated oscillations to the resistance 45, which serves as a source of potential for the detector D_1. The reinforcing oscillations supplied by transformer T_{16} are combined with the received modulated oscillations to reproduce in the output circuit of the detector D_1 the low frequency signal, which originally effected the modulation of the carrier oscillations at the sending station shown in Fig. 3. The output circuit of the detector D_1 is coupled to the filter F_9, which suppresses all frequencies above the audible range.

The circuits associated with the output circuit of amplifier A_{11} are similar to those just described in connection with amplifier A_{10}.

The filter F_8 will separate out the control oscillations from the other transmissions and the tuned circuits will also oscillate the proper multiples of the control frequency even though this frequency varies by small amounts. As both the carrier oscillations at the sending end and the reinforcing oscillations are here derived as multiples of the same control oscillations, it is evident that they will have identical frequencies.

In the system shown in Figs. 1 and 2, the control oscillations were transmitted as modulated oscillations of the carrier wave, while in Figs. 3 and 4, the control oscillations are directly transmitted over the high frequency line L_3.

The system shown in Fig. 5 is similar to that in Fig. 3, with the addition of means whereby carrier frequencies are provided which are not multiples of the control frequencies used and this serves to increase the number of carrier frequencies within a given range. The oscillation generator O_2, shown in Fig. 5, will be considered as supplying control oscillations of a frequency equal to 3000 cycles, which are amplified by means of amplifier A_{13}, and transmitted by transformer T_{20} to the harmonic generator G_4. Amplified carrier frequencies are supplied from the harmonic generator G_4 to the amplifier A_{14}, the output circuit of which contains the tuned circuits 46, 47 and 48. The circuits 47 and 48, by way of example, may be tuned to a frequency of 9000 cycles while the circuit 46 may be tuned to some other frequency, such as 12000. It is, of course, obvious that any number of other tuned circuits may be provided in the output circuit of the amplifier A_{14} to provide sources of as many different carrier oscillations as desired. By means of the tuned circuit 47, carrier oscillations of frequency 9000 are supplied to the filter F_{11}, which selectively transmits the carrier frequency 9000 to a modulator M_3 similar to the modulators M_1 and M_2 already described. By means of the tuned circuit 48, amplified oscillations of frequency 9000 are transferred to the input circuit of the combiner C.

It is shown in the application of Kendall, Serial No. 121,571, filed September 22, 1916, Patent No. 1,734,132, November 5, 1929, that if oscillations of two different frequencies are supplied to the input circuit of a device having a curved voltage-input current-output characteristic that there will appear in the output circuit frequencies equal to the sum and difference of frequencies supplied to this device. As noted in the said application, No. 121,571, of Kendall, a vacuum tube of the audion type has a curved characteristic, and the combiner C is such a tube.

The oscillator O_3 may be considered as generating control oscillations of frequency 4000 cycles which are amplified by the amplifier A_{15} and transmitted by the transformed T_{21} to the harmonic generator G_5. The details of the last named elements have not been shown in the drawings as they are similar to the sending circuit associated with the oscillator O_2. The harmonic generator G_5 may supply carrier oscillations of frequency 16000 to the amplifier A_{16}. Amplified carrier oscillations of frequency 16000 are supplied from the amplifier A_{16} through the filter F_{13} to the modulator M_4. Amplified oscillations of frequency 16000 are transferred by means of the transformer T_{16} to the input circuit of the combiner C, and amplified oscillations of frequency 9000 are transferred by means of the transformer T_{17} to the input circuit of this combiner. The output circuit of the combiner C then becomes a source of carrier oscillations of a frequency 25000, which are selectively transmitted through the filter F_{14} to the modulator M_5. Low frequencies sent over the lines L_7, L_8 and L_9, associated with the modulators M_4, M_5 and M_3 respectively, effect a modulation of the carrier oscillations supplied to these modulators. The output circuits of the modulators M_4, M_5 and M_3 supply modulated carrier oscillations through the filters F_{15}, F_{16} and F_{17} respectively to the high frequency line L_{10}. By means of the third winding 65 on the transformer T_{20}, control oscillations generated by oscillator O_2 are transferred to filter F_{10} which selectively transmits oscillations of 3000 cycles to the line L_{10}. Similarly, transformer T_{21} transmits control oscillations generated by oscillator O_3 to filter F_{12} and thence to line L_{10}. Each of these filters prevents the control oscillations transmitted to the line L_{10} from the other filters from interfering with the carrier oscillations supplied by its associated generator. Line L_{10} is then adapted to transmit control oscillations of frequency 3000 and 4000, and also modulated oscillations having the carrier frequencies 9000, 16000 and 25000.

The number of control current generators shown in the drawing is only two, but it is obvious that any number of these may be used, and it is also obvious that other combiners may be used in order to produce various other frequencies which are not multiples of the frequencies supplied to this combiner.

The line L_{10} in Fig. 5 is terminated in the resistance 53, shown in Fig. 6, which serves as a source of oscillations for the various circuits in shunt to this resistance. In shunt to resistance 53 is the amplifier A_{17}, the output circuit of which is connected to the filter F_{18} which transmits control oscillations of a frequency of 3000 cycles. Control oscillations of this frequency are supplied from the filter F_{18} to the harmonic generator G_6, coupled to the amplifier A_{18}, the output circuit of which contains the tuned circuits 54, 55 and 56. The circuit 54 is tuned to the same frequency as the circuit 46 in Fig. 5. The circuit 55 is tuned to the frequency 9000 and is coupled to the filter F_{19}, which serves to selectively transmit reinforcing oscillations of the carrier frequency 9000 to the input circuit of the detector D_2. The circuit 56 is tuned to a frequency of 9000, and currents of this frequency are supplied to the input circuit of the combiner C_1.

The amplifier A_{19}, filter F_{20} and harmonic generator G_7 are similar to the corresponding elements A_{17}, F_{18}, G_6 described above, the difference being in the adjustment of these elements whereby filter F_{20} selectively transmits control oscillations of a frequency of 4000 cycles to the harmonic generator G_7 which supplies reinforcing oscillations of frequency 16000 to the amplifier A_{20}. The output circuit of amplifier A_{20} comprises the circuits 57 and 58 which are tuned to the reinforcing frequency 16000, which is the same as one of the carrier frequencies. Oscillations of frequency 9000, supplied to the combiner C_1 by means of the tuned circuit 56, and oscillations of frequency 16000, supplied to this combiner by means of the tuned circuit 57, produce in the output circuit of this combiner oscillations of the reinforcing frequency 25000, which are selectively transmitted through the filter F_{24} to the detector D_3. Also oscillations of frequency 16000 are supplied from the tuned circuit 58 through filter F_{25} to the input circuit of the detector D_4.

Amplifier A_{21} is connected in shunt to the resistance 53, and amplified modulated oscillations are supplied by this amplifier to detector D_4. The amplifier A_{21} is essentially unilaterally conducting in order that the reinforcing oscillations, supplied to the input circuit of detector D_4, may not be transmitted through the amplifier A_{21} to the high frequency line L_{10}. The modulated oscillations supplied to the detector D_4 by the amplifier A_{21} and the reinforcing oscillations supplied by the tuned circuit 58 combine to reproduce in the output circuit of the detector D_4 the signal which originally effected the modulation of the carrier oscillations of frequency 16000. The filter F_{21} suppresses all frequencies above 2500 and transmits audible frequencies to the line L_{15}.

The connections of the detectors D_2 and D_3 to the high frequency line L_{10} are similar to the circuits associated with D_4 which have been described.

The transmission of the base or control wave as a modulation of the carrier wave, or as one of the components of a complex wave, is claimed in a divisional application Serial No. 315,121, filed October 26, 1928.

The low frequency signaling lines at the transmitting and receiving stations are shown supplied with telephone transmitting and receiving apparatus. Obviously, this system is not limited to telephonic signaling, but may be equally well applied to telegraph or other signaling or, in fact, to selective transmission of any kind.

What is claimed is:

1. The method of telephony in which telephone signals transmitted as modulated carrier oscillations are identified at a receiving station by means of reinforcing oscillations comprising transmitting control energy to said station simultaneously with said modulated carrier oscillations, and maintaining a constant frequency relation between the unmodulated carrier and said reinforcing oscillations.

2. In signaling in which telephone signals transmitted as modulated carrier oscillations are identified at a receiving station by means of reinforcing oscillations, the method of insuring that the carrier frequency at the sending station bears a definite relation to the reinforcing frequency at the receiving station which consists in supplying control oscillations at both the transmitting and receiving stations from a common source, and deriving said carrier oscillations and said reinforcing oscillations as harmonics of said control oscillations.

3. In signaling in which telephone signals transmitted as modulated carrier oscillations are identified at a receiving station by means of reinforcing oscillations, the method of providing carrier and reinforcing oscillations having a constant phase relation which comprises deriving said carrier and said reinforcing oscillations as harmonics of control oscillations.

4. In a signaling system in which telephone signals transmitted as modulated oscillations are identified at a receiving station by means of reinforcing oscillations, the method of providing carrier and reinforcing oscillations having substantially the same frequency values which consists in deriving said oscillations from a common source.

5. The method of signaling which consists in supplying control oscillations and in changing the frequency thereof in a plurality of similar manners to provide a source of carrier oscillations and a source of reinforcing oscillations, modulating said carrier oscillations in accordance with telephone currents, transmitting the modulated oscillations and receiving the same at a distant station, and identifying the signal at said station by combining said reinforcing oscillations with the received modulated oscillations.

6. The method of insuring that the reinforcing oscillations at a receiving station have the same frequency as that of the carrier oscillations at a sending station which consists in generating control oscillations, changing the frequency thereof to provide a source of carrier oscillations, transmitting said control oscillations and receiving the same at a receiving station, and in changing the frequency of the received control oscillations in the same manner as said frequency is changed at said sending station.

7. The method of signaling which consists in modulating carrier oscillations in accordance with signal oscillations, transmitting said modulated oscillations and control oscillations and receiving the same at a receiving station, combining reinforcing oscillations with said received modulated oscillations, in regulating the carrier frequency and the reinforcing frequency in accordance with the frequency of said control oscillations, detecting the combined oscillations, and in translating the desired signal.

8. The method of signaling which consists in modulating carrier oscillations in accordance with signal oscillations, suppressing the unmodulated component, transmitting a pure modulated wave, restoring the unmodulated component at a receiving station, and in deriving said carrier oscillations and said restored component from a common source.

9. The method of signaling which consists in modulating carrier oscillations in accordance with a signal, suppressing the unmodulated component, transmitting a pure modulated wave together with control oscillations, restoring the unmodulated component at a receiving station, and in regulating the frequency of the carrier oscillations and of the restored component in accordance with the frequency of said control oscillations.

10. The method of signaling which consists in modulating carrier oscillations in accordance with a signal, suppressing the unmodulated component, transmitting a pure modulated wave, receiving said transmitted wave, restoring said suppressed component, and maintaining by means of transmitted energy the desired frequency relation between said carrier oscillations and said restored component.

11. The method of telephone signaling which consists in generating control oscillations, changing the frequency thereof to provide a plurality of carrier waves, modulating said carrier waves in accordance with signals, transmitting said control oscillations and said modulated waves and receiving the same at a distant station, changing the frequency of the received control oscillations thereby providing a plurality of sources of reinforcing oscillations, combining the reinforcing oscillations from each of said sources with one of said modulated waves and in detecting the combined oscillations and waves, and in translating the signal resulting from said detection.

12. The method of signaling which consists in generating control oscillations, changing the frequency thereof to provide a plurality of carrier waves, modulating said carrier waves in accordance with signals, transmitting said control oscillations and said modulated waves and receiving the same at a distant station, changing the frequency of the received control oscillations thereby providing a plurality of sources of reinforcing oscil-

lations each having the same frequency as that of one of said carrier waves, combining the reinforcing oscillations from each of said sources with one of said modulated waves, in detecting the combined oscillations and waves, and in translating the signal resulting from said detection.

13. The method of providing a plurality of sources of carrier oscillations which consists in supplying carrier oscillations of frequency f_1, supplying other carrier oscillations of frequency f_2, in modulating both of said carrier oscillations in accordance with a signal, and in combining both said carrier oscillations to provide an additional source of carrier oscillations of frequency differing from f_1 by the value f_2.

14. The method of signaling which consists in generating control oscillations of frequencies c_1 and c_2, changing the frequencies thereof to provide carrier oscillations of frequencies f_1 and f_2 respectively, combining the frequencies f_1 and f_2 to provide an additional source of carrier oscillations of frequency differing from f_1 by the value of f_2, modulating carrier oscillations of each of said frequencies in accordance with signals to be transmitted, transmitting said modulated and said control oscillations, changing the frequencies of the received control oscillations to provide reinforcing oscillations of the values f_1 and f_2, combining said reinforcing oscillations to provide an additional source of reinforcing oscillations of a frequency differing from f_1 by the value of f_2, and in combining the received modulated oscillations separately with each of said reinforcing oscillations to reproduce the signals transmitted.

15. The method of multiplex signaling which consist in modulating each of a plurality of different frequency carrier oscillations in accordance with a signal, eliminating the unmodulated components, transmitting pure modulated waves to distant stations, and selecting said signals at the proper receiving stations by restoring at each receiving station an unmodulated component having an automatically maintained substantially constant frequency relation to that suppressed at the corresponding sending station.

16. In a signaling system, the combination of a sending station and a receiving station; said sending station comprising a source of carrier oscillations and means for modulating said carrier oscillations in accordance with a signal; said receiving system comprising a source of reinforcing oscillations and means for combining said reinforcing oscillations with the received modulated oscillations to reproduce the signal; and a source of control oscillations from which said carrier and said reinforcing oscillations are derived.

17. In a high frequency signaling system, the combination of a source of control oscillations, means for changing the frequency thereof to provide a source of carrier oscillations, means for modulating said carrier oscillations in accordance with a signal, means for transmitting the modulated oscillations to a distant station, and a system at said station for receiving the transmitted oscillations; said receiving system comprising a frequency changer responsive to said control oscillations, means for combining reinforcing oscillations from said last mentioned frequency changer with the received modulated oscillations, means for detecting the combined oscillations, and a signaling device associated with said detecting means.

18. In a signal system, the combination of a transmitter circuit and a receiver circuit therefor; said transmitter circuit comprising a source of carrier oscillations, means for modulating said carrier oscillations, and means for suppressing the unmodulated component of said modulated oscillations; said receiver circuit comprising a source of reinforcing oscillations, a detector associated with said reinforcing source, and a signaling device for receiving the detected signal, and a source of oscillations from which said carrier and said reinforcing oscillations are derived.

19. A signaling system comprising a source of control oscillations, means for changing the frequency thereof to provide a source of carrier oscillations, a source of signal currents, means for modulating said carrier oscillations in accordance with said signal currents, means for transmitting said modulated oscillations and said control oscillations; a system for receiving said transmitted oscillations comprising a frequency changer, means for selectively transmitting said control oscillations to said frequency changer, means for combining reinforcing oscillations supplied by said frequency changer with the received modulated oscillations, a detector adapted to be supplied with said combined oscillations and a signaling instrument associated with said detector.

20. A system for supplying carrier oscillations comprising a source of oscillations of frequency f_1, a source of oscillations of frequency f_2, and means for combining the oscillations of frequencies f_1 and f_2 to provide a source of unmodulated carrier oscillations of a frequency differing from f_1 by the value f_2.

21. In a signaling system, a source of oscillations of frequency f_1, a second source of oscillations of frequency f_2, a thermionic device having an input and an output circuit, means for supplying oscillations of both said frequencies to said input circuit, said output circuit comprising a source of unmodulated oscillations of frequency differing from f_1 by the value f_2.

22. A system comprising a source of oscillations of frequency c_1, means for changing

the frequency c_1 to the frequency f_1, a source of oscillations of frequency c_2, means for changing the frequency c_2 to the frequency f_2, and means for combining the oscillations of frequencies f_1 and f_2 to provide an additional source of oscillations of a frequency differing from f_1 by the value of f_2.

23. An electrical system comprising a source of oscillations of frequency c_1, means for changing the frequency c_1 to the frequency f_1, a source of oscillations of frequency c_2, means for changing the frequency c_2 to the frequency f_2, and means for combining the oscillations of frequencies f_1 and f_2 to provide an additional source of oscillations of a frequency different from f_1 by the value f_2.

24. In a signaling system, the combination of means for supplying oscillations of frequency f_1, means for supplying oscillations of frequency f_2, f_1 not being a multiple of f_2, and means for combining oscillations of frequency f_1 with frequency f_2 whereby oscillations of frequency differing from f_1 by f_2 are produced, said last mentioned oscillations not being a multiple of either f_1 or f_2.

25. A multiple transmission system comprising a line wire, sources of control oscillations of frequencies c_1 and c_2, means for changing said frequencies to provide sources of carrier oscillations of the frequencies f_1 and f_2 respectively, means for combining oscillations of frequencies f_1 and f_2 to provide an additional source of carrier oscillations, means for modulating oscillations from each of said carrier sources in accordance with a signal, means for eliminating the unmodulated component of each of said modulated carrier frequencies, means for transmitting each of the pure modulated carrier frequencies to said line wire, and a receiving system comprising a plurality of sources of reinforcing oscillations each having a frequency equal to that of one of said carrier frequencies.

26. A multiple transmission system comprising a line wire, sources of control oscillations of frequencies c_1 and c_2, means for changing said frequencies to provide sources of carrier oscillations of the frequencies f_1 and f_2 respectively, means for combining oscillations of frequencies f_1 and f_2 to provide an additional source of carrier oscillations, means for modulating oscillations from each of said carrier sources in accordance with a signal, and means for supplying oscillations from each of said control sources and from each of said modulating means to said line wire; and a receiving system comprising means for changing the control frequency c_1 to the reinforcing frequency f_1, means for selectively transmitting control oscillations of frequency c_1 to said frequency changing means, means for changing the control frequency c_2 to the reinforcing frequency f_2, means for selectively transmitting control oscillations of frequency c_2 from said line wire to said last mentioned frequency changing means, means for combining oscillations of the reinforcing frequencies f_1 and f_2 to provide an additional source of reinforcing oscillations of frequency differing from f_1 by the value f_2, and means for combining oscillations of each reinforcing frequency with the received modulated oscillations to reproduce the signals transmitted.

27. A signaling system comprising the combination of a sending station and a receiving station; said sending station comprising a source of carrier oscillations and means for modulating said carrier oscillations in accordance with a telephone signal; said receiving system comprising a source of reinforcing oscillations and means for combining said reinforcing oscillations with the received oscillations to reproduce the signal; and means for automatically maintaining the desired frequency relations between said carrier and said reinforcing oscillations.

28. A signaling system comprising the combination of a sending station and a receiving station; said sending station comprising a source of carrier oscillations and of control oscillations and means for modulating said carrier oscillations in accordance with a signal; said receiving system comprising a source of reinforcing oscillations responsive to the control frequency and automatically maintained at the proper frequency with respect to the carrier frequency, and means for combining the received signal with said reinforcing oscillations to reproduce the signal.

29. A source of carrier waves, a source of signal waves, means for modulating said carrier waves in accordance with said signal waves and for preventing transmission of an unmodulated component of said carrier frequency, a filter, and means for impressing said modulated waves thereupon, said filter transmitting with practically negligible attenuation waves of the range of frequencies included in said modulated carrier wave while attenuating and approximately extinguishing waves of the order of frequency of said signal waves.

30. A signaling system comprising a source of oscillations of frequency f_1, a source of oscillations of frequency f_2, means for combining the oscillations of frequencies f_1 and f_2 to provide other oscillations, and means for modulating each of said oscillations in accordance with a signal.

31. In a signaling system, a source of oscillations of frequency f_1, a second source of oscillations of frequency f_2, a thermionic device having an input and an output circuit, means for supplying oscillations of both said frequencies to said input circuit, said output comprising a source of unmodulated oscilla-

tions of frequency differing from f_1 by the value f_2, and means for modulating said oscillations of differential frequency in accordance with a signal.

32. The method of signaling comprising producing a plurality of different frequency electrical currents from a common electrical source, varying each of a plurality of said currents in accordance with a signal individual thereto, transmitting said varied currents together with one of said different frequency currents which is unvaried to a distant station, and producing from said unvaried current reinforcing oscillations of the frequency of said varied currents.

33. The method of transmission comprising transmitting oscillations to a distant station, identifying said transmitted oscillations at said station by means of reinforcing oscillations, and maintaining a constant frequency relation between said transmitted oscillations and said reinforcing oscillations by deriving all of said oscillations from a common source.

34. The method of insuring that reinforcing oscillations at a receiving station have the same frequency as that of carried oscillations transmitted from a sending station, comprising producing control oscillations, changing the frequency of a portion thereof to produce carrier oscillations, transmitting another portion of said control oscillations and receiving the same at said receiving station, and changing the frequency of said received control oscillations, in the same manner as said frequency is changed at said sending station, to produce reinforcing oscillations at said receiving station.

35. The method of transmission in which transmitted oscillations are identified at a receiving station by means of reinforcing oscillations comprising transmitting control energy to said station simultaneously with said oscillations, amplifying said received control energy and said transmitted oscillations and employing said amplified control energy to maintain a constant frequency relation between said transmitted oscillations and said reinforcing oscillations.

36. The method of signaling which comprises transmitting carrier oscillations modulated in accordance with signals, receiving said modulated oscillations at a receiving station, identifying said receiving oscillations by means of reinforcing oscillations locally generated at said station and maintaining a constant frequency difference between said carrier oscillations and said reinforcing oscillations by deriving them from control oscillations produced by a common source.

37. A system comprising means for receiving a wave of a given frequency, means for locally generating another wave, means for causing the frequency of the locally generated wave to vary substantially equally and simultaneously with variations in the frequency of said received wave, means for producing currents corresponding to said received and locally generated waves, and means for combining said currents.

38. The method of telephony which consists in transmitting the speech as a modulated carrier wave and maintaining by received energy the received carrier wave and local waves in a coaction continuously effective for resolving the carrier wave modulations into a continuous speech conveying effect.

39. The method of telephony which comprises generating a wave at a transmitting station, producing therefrom a plurality of carrier waves each modulated in accordance with an individual telephone message, transmitting said carrier waves to a distant station, producing thereat a wave, deriving from said produced wave a plurality of reinforcing waves corresponding in number to said transmitted carrier waves, and reproducing a telephone message from each of said transmitted carrier waves by causing a corresponding one of said reinforcing waves to interact therewith.

40. In a multiplex wave telephone system, two stations, means to supply a wave at each station, means at one station to produce from the supplied wave at that station a plurality of speech-modulated carrier waves of different carrier wave characteristic each representing a different speech message, means to transmit the speech-modulated waves, means at the other station to produce from the supplied wave at that station a corresponding plurality of waves of different characteristic, and means to cause interaction between each of the said speech-modulated waves and one of the locally produced waves to reproduce the respective speech message.

41. In a signaling system, a transmitting station and a receiving station, means at each station for changing a characteristic of a wave of the same characteristics to produce at each station a plurality of waves of characteristics respectively different from each other, the corresponding waves of the respective stations being of substantially identical characteristic, means at the transmitting station to control each of the waves so produced in accordance with signals to be sent, and to simultaneously transmit the signal-controlled waves, means at the receiving station for receiving the signal-controlled waves and for causing interaction between each of the received waves and the locally produced wave of corresponding characteristic, and a plurality of means each actuated as a result of the interaction between one of the received waves and the corresponding locally-produced wave for reproducing the respective signal.

42. In multiplex telephony, the method

which comprises simultaneously transmitting a plurality of telephone messages in the form of modulated carrier waves, identifying the individual messages at a receiving station by means of reinforcing waves of substantially the same frequency as the respective carrier frequency, and deriving all of said transmitting carrier and reinforcing waves from a common source.

43. The method of receiving a signaling wave employed to transmit a signal by variations produced therein, which consists in producing another wave and rectifying the signaling wave under the influence thereof while causing the frequency of the said other wave to vary in proportion with frequency variations in the signaling wave, and employing the signaling variations of the rectified signaling wave to convey the signal.

44. The method of signaling which consists in deriving a signaling wave from a controlling source, producing a signaling variation in the signaling wave, transmitting said signaling wave to a receiving point and there deriving another wave from the said controlling source, rectifying the signaling wave under the influence of said other wave to produce a signaling current, and employing the signaling variations in the latter signaling current to convey the signal.

45. A system comprising a plurality of sources of oscillations, one of which is a space discharge generator, and means under the joint control of said sources whereby an increase or decrease in the frequency of one of the said sources causes a corresponding increase or decrease in the frequency of the other.

46. A signal receiving system comprising a vacuum tube oscillation generator, and means operable by received oscillations whereby the said generator is caused to generate oscillations of a frequency having an approximately constant relation to the frequency of the received oscillations.

47. The method of multiplex signaling comprising producing from an electrical wave of a given frequency a plurality of electrical waves of other frequencies, separately and independently varying each of a plurality of said latter waves in accordance with a different signal and simultaneously transmitting to a distant point each of said signal-varied waves and a component from which a wave having the frequency of said electrical wave may be obtained.

48. The method of multiplex transmission which comprises producing from an electrical wave of a given frequency a plurality of electrical waves of other frequencies, simultaneously transmitting said latter waves to a distant station and causing said waves so transmitted to act separately and independently of one another to operate devices individual to each at said station.

49. In a signaling system, a transmitting station having means thereat for producing a plurality of waves of respectively different characteristic and for controlling each of said waves in accordance with a different signal, a receiving station having a source of waves thereat, means for deriving therefrom a plurality of waves corresponding in characteristic respectively to the plurality of waves produced at the transmitting station, means for combining said waves produced at the receiving station with the respective signal controlled waves from said transmitting station, and means to receive separately the resulting signals.

50. The method of multiplex signaling which consists in generating a plurality of carrier frequencies by modulating one frequency in accordance with another frequency and modulating certain of the resulting frequencies in accordance with signaling frequencies.

51. 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, and means to modulate certain of the resultant frequencies in accordance with different signaling frequencies.

52. The method of signaling comprising supplying at each of a plurality of geographically separated locations a wave of the same frequency, deriving therefrom at each location a series of waves of other frequencies, similar at the different locations, utilizing said series of waves at one such location for transmitting messages, and utilizing the corresponding respective waves at another location to receive said messages.

53. In a multiplex signaling system a transmission line, a source of electrical waves of given frequency, means for deriving from said waves a plurality of electrical waves of other frequencies, frequency-selective means for separating each of said latter waves into an individual circuit, means associated with said circuits to vary each of the selected waves in accordance with a different message to be transmitted, and frequency-selective circuits for simultaneously and independently impressing on said line, bands of frequency components comprising the said several message-varied waves.

In witness whereof, I hereunto subscribe my name this 8th day of November A. D., 1916.

BURTON W. KENDALL.