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H. S. OSBORNE

EQUALIZATION OF CARRIER TRANSMISSIONS

Filed July 9. 1920

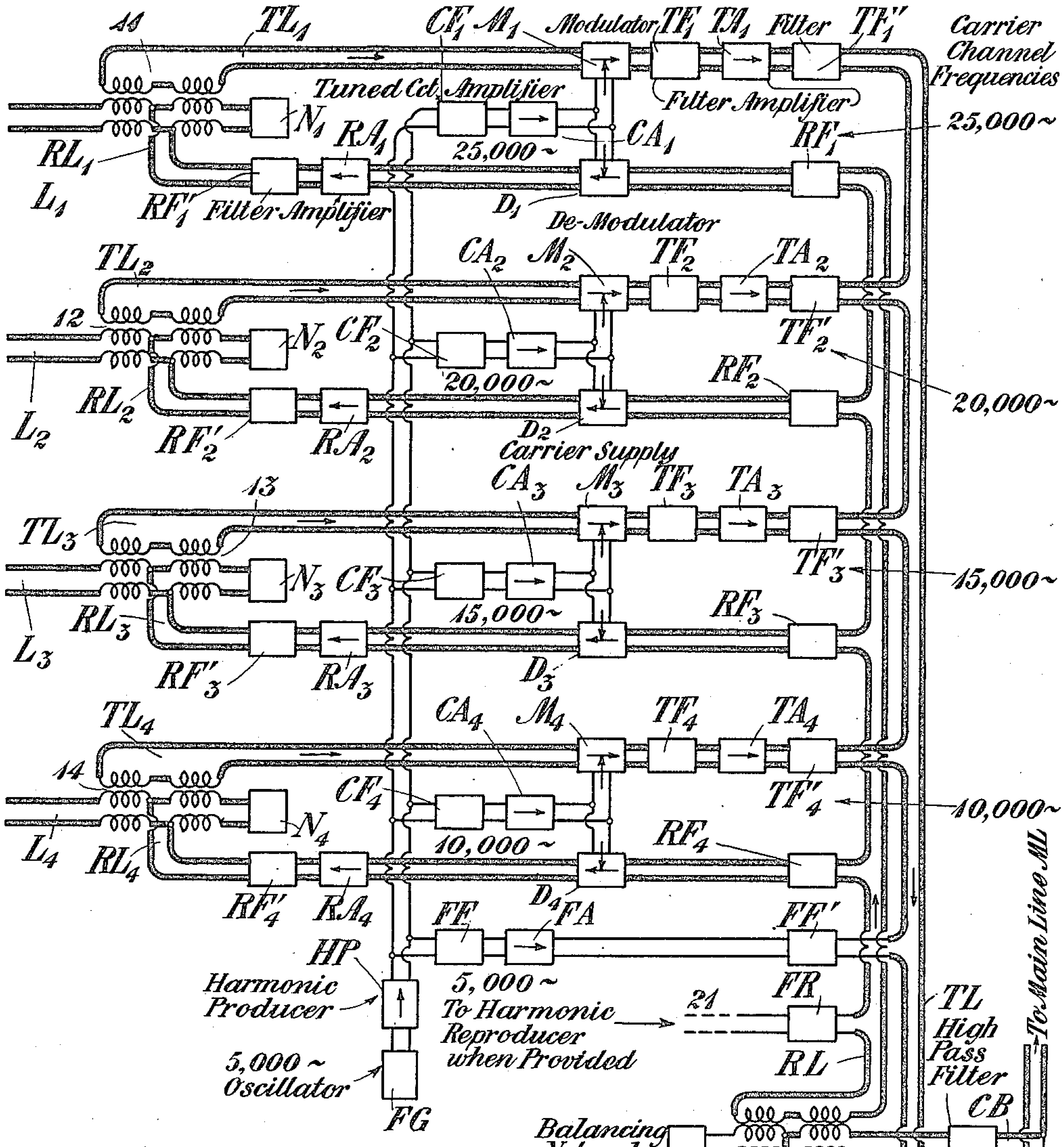


Fig. 1

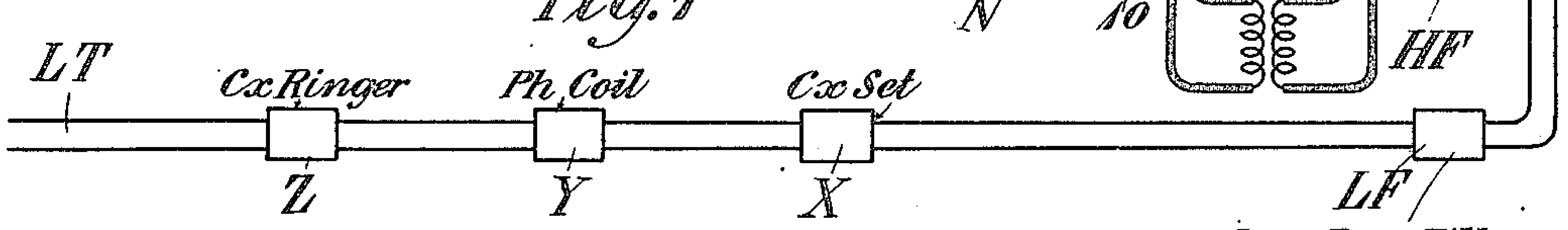
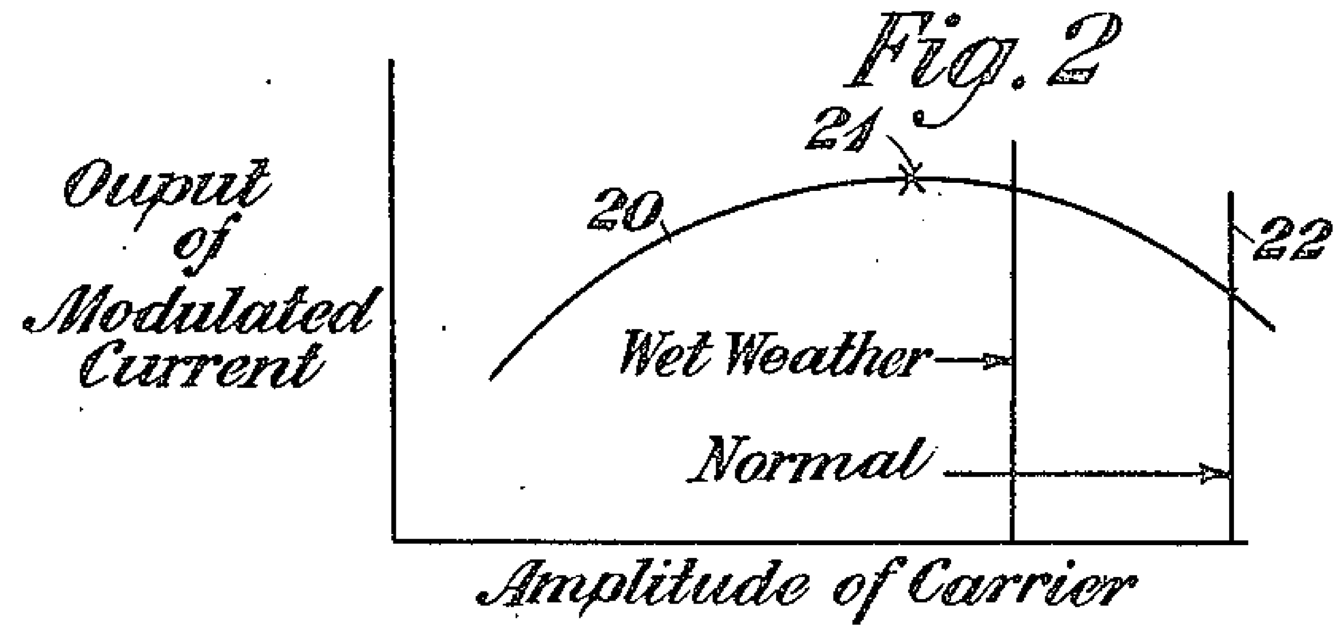


Fig. 2



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UNITED STATES PATENT OFFICE.

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EQUALIZATION OF CARRIER TRANSMISSIONS.

Application filed July 9, 1920. Serial No. 395,111.

To all whom it may concern:

Be it known that I, Harold S. Osborne, residing at New York, in the county of New York and State of New York, have invented certain Improvements in Equalization of Carrier Transmissions, of which the following is a specification.

This invention relates to transmission systems in which carrier currents are employed for the transmission of signals and more particularly to methods and means whereby the transmission over systems of this character may be maintained substantially constant with changes in the condition of the circuits.

In a carrier transmission system the efficiency of the circuit for transmission purposes will vary from time to time due to a number of different causes. Since the carrier currents employed for transmission are of fairly high frequency, changes in the attenuation are due mainly to variations in the leakage conditions of the open wire lines upon which the carrier channels are superposed. Consequently during wet weather when the leakage increases the circuit will be much less efficient than during dry weather. This is one of the principal causes of variation in the transmission efficiency of carrier circuits and is quite distinct from the cause of transmission variations in long cable circuits used for the transmission of ordinary telephone frequencies where the resistance variation with temperature is the controlling factor.

One of the objects of the present invention is to provide means and methods whereby the transmission efficiency of a carrier circuit may be maintained substantially constant under different conditions particularly under different weather conditions. Another object of the invention is to provide methods and means whereby the above results may be accomplished automatically and preferably without the adjustment of mechanical devices.

These objects together with other objects of the invention more fully appearing hereinafter are realized by taking advantage of a peculiar property of certain types of modulating and demodulating devices such as vacuum tubes. It has been discovered that if a vacuum tube is used as a modulator, or as a demodulator operating upon the homodyne principle, the efficiency of the tube varies with the quantity or amplitude of the carrier frequency supplied. As the amplitude of the carrier current is increased the modulated output current increases up to a certain point after which the output current decreases as the amplitude of the carrier current is further increased. If then the carrier current which is to be supplied to the modulating or demodulating tube is transmitted over the carrier circuits and if under normal conditions of the circuit the amplitude of the carrier current be made of such value that the tube is operating at a point beyond the peak of its output efficiency, the efficiency of the transmission circuit will tend to remain constant. This follows from the fact that if, due to wet weather or other abnormal conditions along the line, the transmission efficiency of the line circuit itself is decreased the amplitude of the carrier current transmitted over the line to the modulating or demodulating tube at the opposite end will be decreased with a corresponding increase in the modulated output current. This increase in the volume of the modulated output tends to compensate for the decrease in the modulated carrier current transmitted over the line and thus an automatic regulation is provided which is purely electrical.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing, Figure 1 of which is a schematic circuit diagram of the terminal apparatus of a carrier transmission system and Fig. 2 of which is a curve illustrating the variations in modulated output current of a modulating or a demodulating tube with the amplitude of the supplied carrier current.

Referring to Fig. 1, ML represents an ordinary transmission line, such as a telephone line, said line terminating in a terminal line LT, including the usual composite set whereby the telephone circuit may be composited for Morse operation, and the usual phantom coil Y and composite ringer Z. Since the elements X, Y and Z are well known in the art they are simply indicated schematically upon the drawing and no further description is deemed necessary.

In order that a carrier system may be superposed upon the transmission line ML, a carrier branch CB is connected to the main line ML at the junction point of said main line with the terminal line TL, said carrier branch leading to terminal carrier apparatus. In order to prevent the transmission of the carrier frequencies to the terminal line LT and the low frequency apparatus associated therewith, a broad band filter LF is inserted in the terminal line LT said filter being so designed as to transmit frequencies below the upper limit of telephonic transmission and to substantially suppress frequencies above such limit. In order to prevent the transmission of low frequency currents, such as ordinary telephone or Morse currents, to the carrier branch CB, a broad band filter HF is inserted in said branch, said filter being so designed as to transmit frequencies lying above the upper limit of ordinary telephonic transmission while suppressing frequencies lying below said limit.

These filters may be of the general type disclosed in United States patents to George A. Campbell, Nos. 1,227,113 and 1,227,114 dated May 22, 1917. The filters, however, may be of any other type, the only requirement being that they transmit a band of frequencies having the limits above referred to.

The carrier branch CB is associated with a carrier transmitting circuit TL and a carrier receiving circuit RL to which the various carrier channels are connected. The circuits TL and RL are associated with the carrier branch CB in such a manner as to be conjugate with respect to each other, that is, carrier oscillations transmitted from TL to CB will be without effect upon RL and vice versa. This result is secured by providing a balanced transformer arrangement 10, of well known type, and a balancing circuit N.

The carrier transmitting and receiving circuits TL and RL are associated with a plurality of carrier channels, which will now be described. L_1, L_2, L_3 and L_4 represent low frequency telephone or telegraph lines over which telephonic or other signals are transmitted, which signals are to be impressed upon carrier currents and simultaneously transmitted over the main line ML. The line L_1 is associated with a carrier transmitting circuit TL_1 and a carrier receiving circuit RL_1 through a balancing transformer arrangement 11 and a balancing network N_1, the connection being such that the circuits TL_1 and RL_1 will be conjugate with respect to each other. In a similar manner, line L_2 is associated with circuits TL_2 and RL_2 through transformer 12 and network N_2; line L_3 is associated with circuits TL_3 and RL_3 through transformer 13 and network N_3; and line L_4 is associated with circuits TL_4 and RL_4 through transformer 14 and network N_4. Each of the transmitting channels TL_1, TL_2, TL_3 and TL_4 is connected to the common transmitting circuit TL while each of the receiving channels RL_1, RL_2, RL_3 and RL_4 is associated with the carrier receiving circuit RL.

In order to supply the carrier currents having different frequencies for each channel, a frequency control system of the general type disclosed in the application of B. W. Kendall, Serial Number 130,350, filed November 9, 1916, is provided. The frequency control system comprises an oscillator FG, which may be of any well known type, such as, for instance, the well known vacuum tube oscillator, said oscillator serving to generate a basic carrier frequency illustrated, by way of example, in the drawing as being 5,000 cycles. In order to translate the basic frequency into harmonics for the different channels, an harmonic producer schematically indicated at HP is provided. This harmonic producer may be a vacuum tube arrangement for distorting the waves generated by the oscillator FG so as to produce harmonics in the output circuits of the distorting tube. Harmonic producers of this character are shown and described in the above mentioned application of B. W. Kendall as well as in an application of B. W. Kendall, Serial Number 139,530 filed December 29, 1916. The harmonics produced by the harmonic producer HP, which may be for example of 10,000, 15,000, 20,000 and 25,000 cycles, are filtered out and separately transmitted to the several carrier channels through filtering devices CF_1, CF_2, CF_3 and CF_4. These filtering devices may be broad band filters of the type disclosed in the above mentioned applications of George A. Campbell or may be simple tuned circuits of any well known type. The fundamental frequency here illustrated as 5,000 cycles may be transmitted through a similar filtering arrangement FF to an amplifier FA. The amplifier FA may be of any known type, such as, for instance, a vacuum tube amplifier. The amplified fundamental frequency may be then passed through another filter FF′ and impressed upon the transmitting carrier circuit TL. The harmonics used as carrier frequencies after being filtered by means of the filters CF_1, CF_2, etc., may be impressed upon carrier amplifiers CA_1, CA_2, CA_3 and CA_4. These amplifiers may be similar to the amplifier FA already referred to.

Each of the transmitting channels TL_1, TL_2, etc., is provided with a modulating arrangement schematically illustrated at M_1, M_2, M_3 and M_4. This modulating arrangement may be of any desired character but is preferably a vacuum tube arrangement, such as is illustrated in the U. S. patent to John R. Carson Number 1,343,307, issued June 15, 1920.

Each of the receiving channels is provided with a demodulator or detector, such as D_1,

D_2, D_3 and D_4. These demodulating or detecting arrangements may be of any well known type, but are preferably of the type illustrated and described in the U. S. patent to J. R. Carson, Number 1,343,308, issued June 15, 1920. The detecting or demodulating arrangement of the said patent to J. R. Carson employs the so-called homodyne method of detecting, thereby necessitating that the carrier frequency of that particular channel be supplied to the demodulating arrangement. Accordingly, the carrier frequency of each channel after being amplified by the carrier amplifiers CA_1, CA_2, etc., is supplied in parallel to the modulating arrangement of the transmitting channel and the demodulating arrangement of the corresponding receiving channel.

The carrier oscillations impressed upon the modulator, as for instance M_1, are modulated by means of the low frequency signal waves transmitted from the low frequency line, such as line L_1, to the carrier channel TL_1, and are then filtered and amplified. For this purpose broad band filters TF_1, TF_2, TF_3 and TF_4 are provided in the output circuits of the modulators M_1, M_2, M_3 and M_4. These filters may be of the type disclosed in the patents to Campbell above referred to and each filter should be capable of transmitting a band of frequencies whose width is equal to the range of frequencies employed in low frequency signaling. In the case of telephone transmission, the filter should be so designed as to transmit a band equal to the telephonic range to the exclusion of frequencies lying without this range. The actual frequencies transmitted by the filter of each channel will be different for each channel. The filter of the channel TL_1 transmitting a band of frequencies in the neighborhood of 25,000 cycles, the filter in the next channel transmitting a band in the vicinity of 20,000 cycles, etc. The modulated carrier oscillations transmitted through the filters may be amplified by amplifiers TA_1, TA_2, TA_3 and TA_4 arranged in the several transmitting channels. These amplifiers may be of any well known type but are preferably vacuum tube amplifiers. In order to further increase the selectivity, filters TF_1', TF_2', TF_3' and TF_4' may be provided in the output circuits of the amplifiers.

The several carrier frequencies are modulated in accordance with the low frequency signals transmitted over the lines L_1, L_2, L_3 and L_4 and after being filtered and amplified are simultaneously impressed upon the common carrier transmitting circuit TL, the fundamental frequency here illustrated as being of 5,000 cycles, being at the same time impressed upon the common circuit. These multiple frequencies are then transmitted to the transformer 10 and over the carrier branch CB to the main line ML. Owing to the balancing arrangement of the transformer 10 and the network N, the reaction of these frequencies on the common receiving circuit RL is reduced to small proportions and if a sufficient degree of balance is provided may be rendered negligible. The low frequency filter LF prevents the high frequency carrier oscillations from being transmitted to the terminal line TL.

In each of the receiving channels RL_1, RL_2, etc., a broad band filter is inserted on the input side of the demodulating arrangement. These filters are schematically indicated at RF_1, RF_2, RF_3 and RF_4 and may be of the same type as the corresponding filters TF_1 or TF_1', etc., of the associated transmitting channels. The modulated carrier oscillations transmitted over the main line ML from a distant station pass through the filter HF, being excluded from the terminal line by filter LF, and are then impressed through the transformer 10 upon the common receiving circuit RL. Modulated currents corresponding in frequency to the different channels are filtered out by means of the filters RF_1, RF_2, etc., and impressed upon the demodulators D_1, D_2, etc. Unmodulated carrier frequencies are at the same time impressed upon the demodulators from the control circuit already described so that the low frequency signal waves, in accordance with which the high frequency carrier waves were modulated, appear in the output circuits of the demodulators.

In order to amplify these low frequency waves, low frequency amplifiers RA_1, RA_2, RA_3 and RA_4 are provided in the several receiving channels. These amplifiers may be of any well known type but are preferably vacuum tube amplifiers. In order to purify the low frequency currents from any residual high frequency components, low frequency filters, such as RF_1', RF_2', RF_3' and RF_4' are provided in the output circuits of the amplifiers. These filters may be of the same character as the low frequency filter LF in the terminal line LT and are of the general type disclosed in the patents to Campbell above referred to. The amplified low frequency signal waves from the several receiving channels are then impressed through the transformers 11, 12, 13 and 14 upon the respective low frequency lines L_1, L_2, L_3 and L_4.

It will be remembered that in connection with the production of the various carrier frequencies, a fundamental frequency of some desired value, such as 5,000 cycles, for example, was generated and transmitted through the filters FF and FF′ and the amplifier FA to the common transmitting circuit TL. This fundamental frequency was then transmitted together with various modulated carrier frequencies through the transformer arrangement 10 and the high frequency filter HF to the main line ML. At a distant point in the main line the various carrier frequencies may be separated from the low frequency signaling currents, such as telephone currents, by means of a high frequency composite set similar to that already described and comprising high frequency and low frequency filters similar to the filters HF and LF. The carrier frequencies may then be impressed upon terminal carrier apparatus similar to that shown in Fig. 1. The terminal carrier apparatus may differ, however, from that shown in Fig. 1 with respect to the production of the carrier frequencies. In order to illustrate the manner in which the system will be modified at the distant station in this respect, the apparatus of Fig. 1 has been shown with a circuit 21 leading from the common receiving circuit RL to an harmonic producer (not shown). The filtering arrangement, such as a tuned circuit FR, is included in the circuit 21 to filter out the fundamental frequency of 5,000 cycles transmitted over the line. This frequency is then impressed by means of the circuit 21 upon an harmonic reproducer which will be in general similar to the harmonic producer HP and the general principle of this arrangement is described in the application of B. W. Kendall, Serial Number 139,530, filed December 29, 1916, already referred to. The general arrangement whereby the harmonic reproducer is associated with the receiving circuit is shown and described in the application of B. W. Kendall, Serial Number 130,350, filed November 9, 1916, to which reference has already been made. It is sufficient for the purposes of this application to state that the harmonic reproducer functions to produce harmonics of the basic frequency in a manner similar to the harmonic producer HP already described, the several harmonics being filtered out, amplified to a desired value and then impressed upon the modulating and demodulating apparatus of the terminal system.

It will be seen from the apparatus above described that the fundamental frequency of 5,000 cycles is transmitted over the main line from one terminal station to the terminal station at the other end of the line and that at the latter station the unmodulated carrier frequency which is supplied to the modulating and demodulating tubes is derived from this fundamental frequency. Consequently, the amplitude of the carrier frequencies supplied to these tubes at the distant terminal station will vary as the amplitude of the fundamental frequency varies, which fundamental frequency in turn varies with changes in the transmission efficiency of the main line due to different weather conditions and the like.

As previously stated the output of modulated current from the modulating or demodulating tubes varies in a peculiar manner with increase in the amplitude of the carrier current supplied to the tube. This variation is illustrated by the curve 20 in Fig. 2. It is apparent from an inspection of the curve that as the amplitude of the carrier current is increased the modulated output current also increases until the point 21 is reached after which the output of modulated current decreases with an increase in amplitude of current. If then with the line operating under normal conditions the amplitude of the fundamental frequency supplied at the generating station be made such that the carrier currents derived therefrom at the distant station will be of the amplitude indicated at 22. the modulated output current of the modulators and demodulators at the distant station will be less than the maximum. Should the transmission efficiency of the main line decrease due to wet weather, for instance, the amplitude of the fundamental frequency arriving at the distant station will decrease, with a corresponding decrease in the amplitudes in the carrier currents supplied to the various modulating and demodulating tubes. For a given modulating current, whether high frequency or low frequency, supplied to the tube, the modulated output current would be decreased.

Let us consider the effect of this as applied to transmission from the station at which the fundamental frequency is generated to the distant station. The modulated current supplied at the generating station to the line as a result of the modulation of a carrier current by a signal will have the same amplitude when applied to the line regardless of conditions on the main line since the fundamental frequency generated at that station together with the carrier currents derived therefrom will be the same. If the attenuation of the main line is greater than normal, however, the modulated carrier currents will be decreased in amplitude to a greater degree than normal upon arriving at the distant station. The fundamental frequency transmitted over the main line will, however, arrive at the distant station correspondingly diminished thereby tending to increase the output of the modulating and demodulating tubes. The output of the demodulating tubes, however, will not actually be increased because the modulated carrier currents supplied to the tube after transmission over the line have been decreased by corresponding amounts. Consequently, the actual low frequency output of the demodulating tube will be substantially the same as under normal conditions.

In the case of transmission from the distant station to the terminal station at which the fundamental frequency is generated, if the attenuation of the main line is greater than normal the amplitude of the fundamental frequency will be decreased below its normal value upon arriving at the distant station. This results in a carrier current of increased amplitude being supplied to each of the modulating tubes and assuming that the low frequency signals applied to the modulators are of normal amplitude the modulated high frequency output currents supplied to the line will be of increased amplitude as compared with normal. This increase in the amplitude of the modulated carrier currents supplied to the line from the distant station will be about sufficient to make up for the increase in the attenuation of the line so that the currents will arrive at the generating station with their amplitudes about normal. Since the amplitudes of the carrier frequencies supplied to the demodulating tubes at the generating station do not vary with changes in the condition of the main line the low frequency demodulated output currents supplied to the terminal low frequency lines will have substantially the same values as under normal conditions.

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 maintaining the transmission of a carrier circuit substantially constant for all carrier frequencies transmitted thereover regardless of changes in the line condition, which consists in subjecting a pilot carrier current to the same transmission conditions as those to which the various carrier currents employed for the transmission of signals are subjected, and controlling the amplitudes of the carrier currents employed for signaling transmission in accordance with variations in the amplitude of the pilot carrier current in such a manner that a decrease in the amplitude of the pilot carrier current will produce an increase in the amplitudes of the signaling carrier currents.

2. In a carrier system including a line circuit, and modulating and demodulating devices operating most efficiently at a certain input amplitude and less efficiently for greater or lesser amplitudes, the method of maintaining the transmission of a carrier circuit substantially constant for all carrier frequencies transmitted thereover regardless of changes in the line transmission condition, which consists in generating at one terminal station a fundamental frequency from which all other carrier frequencies for use at said station are derived, transmitting said fundamental frequency over the main line to the distant station, deriving from said fundamental frequency at said distant station carrier frequencies for use at said station, and maintaining the amplitude of the generated fundamental at such values that under normal line transmission conditions the amplitudes of the derived carrier frequencies at the distant station will be greater than the amplitude necessary for maximum output of the modulating and demodulating devices.

3. In a carrier system including a line circuit and modulating and demodulating devices operating most efficiently at a certain input amplitude and less efficiently for greater or lesser amplitudes, the method of maintaining the transmission of a carrier circuit substantially constant for all carrier frequencies transmitted thereover regardless of changes in the line transmission condition, which consists in generating at one terminal station a fundamental frequency from which all other carrier frequencies for use at said station are derived, transmitting said fundamental frequency over the main line to the distant station, deriving from said fundamental frequency at said distant station carrier frequencies for use at said station, and maintaining the amplitude of the generated fundamental at such values under normal line transmission conditions that the amplitudes of the carrier frequencies supplied to the demodulating devices at the distant station will be greater than the amplitudes necessary for maximum output of said demodulating devices by an amount such that the efficiency of the demodulating devices will increase as the attenuation of the line increases to offset the increased attenuation of the modulated carrier currents transmitted over the line to the distant station.

4. In a carrier system including a line circuit and modulating and demodulating devices operating most efficiently at a certain input amplitude and less efficiently for greater or lesser amplitudes, the method of maintaining the transmission of a carrier circuit substantially constant for all carrier frequencies transmitted thereover regardless of changes in the line transmission condition, which consists in generating at one terminal station a fundamental frequency from which all other carrier frequencies for use at said station are derived, transmitting said fundamental frequency over the main line to the distant station, deriving from said fundamental frequency at said distant station carrier frequencies for use at said station, and maintaining the amplitude of the generated fundamental under normal line transmission conditions at such values that the amplitudes of the carrier frequencies derived therefrom at the distant sta-

tion and applied to the modulating devices thereat will be greater than the amplitudes necessary for the maximum output of said modulating devices, whereby as the attenuation of the line is increased the efficiency of the modulating devices will be correspondingly increased so that the output currents in the modulators when transmitted over the line will arrive at the station at which the fundamental frequencies were generated with substantially the same amplitude as under normal conditions.

5. The method of maintaining the transmission of a carrier circuit substantially constant regardless of changes in the line transmission condition, which consists in transmitting the carrier current over said circuit and in translating the transmitted carrier current into another current so related to the transmitted current that a decrease in the amplitude of the translated carrier current will produce an increase in the amplitude of the signaling current detected from the translated current.

6. A carrier wave transmission system in which signal variations of carrier waves are produced and transmitted to a distant station over a suitable transmitting medium subject to changes in transmission efficiency, modulators associated with said transmitting medium at the terminal station, said modulators being so arranged that for normal transmission conditions of the transmitting medium the unmodulated carrier component supply exceeds the value for which said modulators operate at maximum efficiency, whereby poor transmission conditions of the transmitting medium and a consequent decrease in applied unmodulated carrier component are accompanied by an increased efficiency of the over-all transmission of the circuit including the transmitting medium and modulators.

7. A carrier wave transmission system in which signal variations of carrier waves are produced and transmitted to a distant station over a suitable transmitting medium subject to changes in transmission efficiency, demodulators for said waves associated with said transmitting medium at the receiving station, said demodulators being so arranged that for normal transmission conditions of the transmitting medium the unmodulated carrier component supply exceeds the value for which said demodulators operate at maximum efficiency for reproducing signals, whereby poor transmission conditions of the transmitting medium and a consequent decrease in applied unmodulated carrier component are accompanied by an increased efficiency in the reproduction of the signals.

8. In a carrier wave transmission system in which signal variations of carrier waves are produced and transmitted to a distant station over a suitable transmitting medium subject to changes in transmission efficiency, modulators and demodulators for said waves, said modulators and demodulators being so arranged that for normal transmission conditions of the transmitting medium the unmodulated carrier component supply exceeds the value for which said modulators and demodulators operate at maximum efficiency for reproducing signals, whereby poor transmission conditions of the transmitting medium and a consequent decrease in applied unmodulated carrier component are accompanied by an increased efficiency in the reproduction of signals.

9. A carrier wave transmission system in which signal variations of carrier waves are produced and transmitted to a distant station, a pair of translating arrangements corresponding to each carrier wave, one of said translating arrangements comprising a modulator and the other comprising a detector, one of said translating arrangements being so arranged that for normal transmission conditions of the transmitting medium the unmodulated carrier component supply exceeds the value for which said translating arrangement operates at maximum efficiency, whereby poor transmission conditions of the transmitting medium and the consequent decrease in applied unmodulated carrier component are accompanied by an increased efficiency of the over-all transmission of the circuit, including the transmitting medium and translating arrangements.

In testimony whereof, I have signed my name to this specification this 30th day of June 1920.

HAROLD S. OSBORNE.