

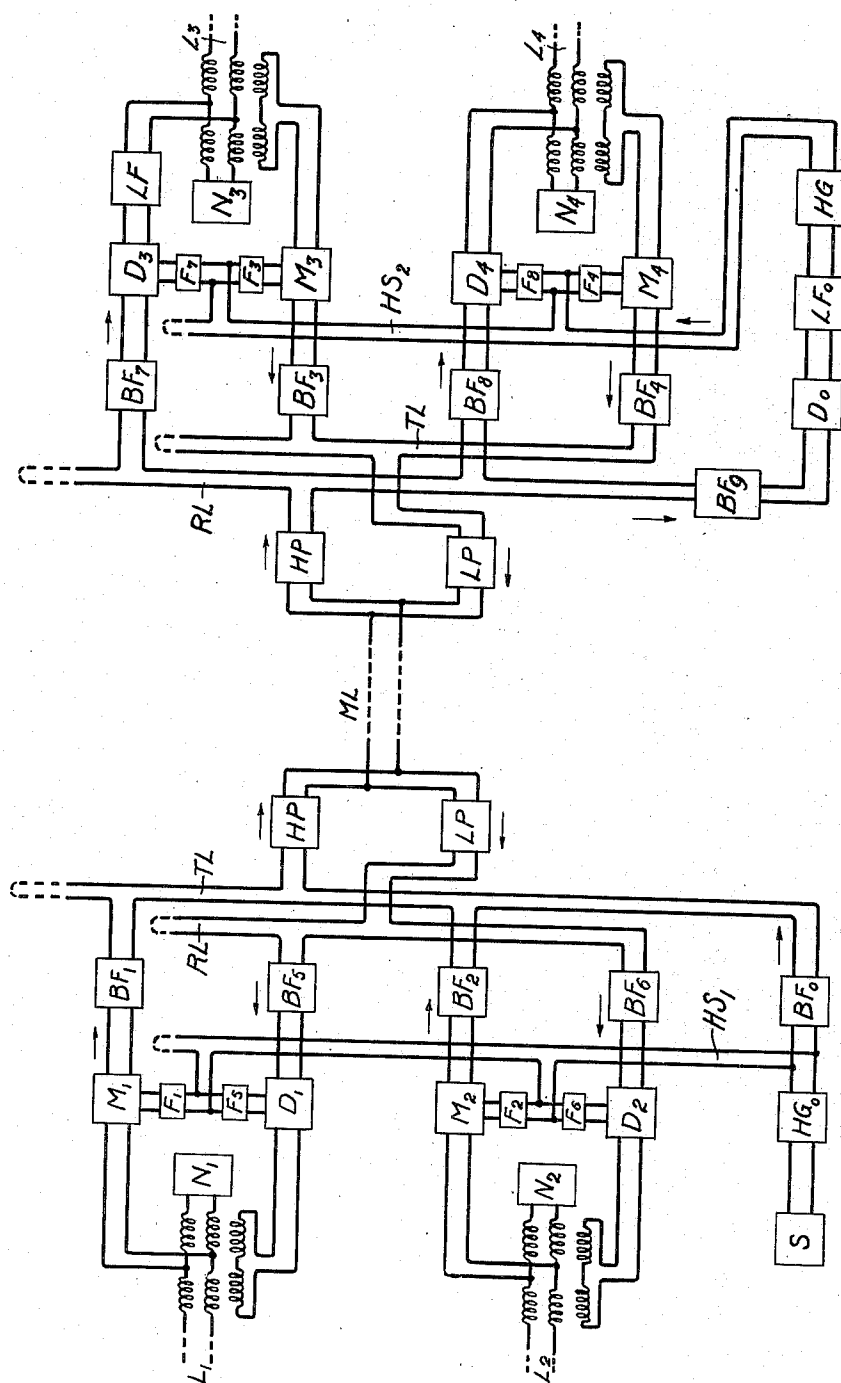
Nov. 24, 1925.

1,562,964

J. W. HORTON

MULTIPLEX CARRIER WAVE TRANSMISSION

Filed Feb. 28, 1923



Inventor:
Joseph W. Horton
by E. W. Briggs Atty

Patented Nov. 24, 1925.

1,562,964

UNITED STATES PATENT OFFICE.

JOSEPH W. HORTON, OF BLOOMFIELD, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK. N. Y., A CORPORATION OF NEW YORK.

MULTIPLEX CARRIER-WAVE TRANSMISSION.

Application filed February 28, 1923. Serial No. 621,736.

To all whom it may concern:

Be it known that I, JOSEPH W. HORTON, a citizen of the United States of America, residing at Bloomfield, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Multiplex Carrier-Wave Transmissions, of which the following is a full, clear, concise, and exact description.

10 The present invention relates to signaling by means of sustained waves commonly known in the art as carrier waves, which may be either radiated through space or transmitted over a transmission line.

15 The invention relates more particularly to a type of carrier wave transmission in which auxiliary or reinforcing waves, definitely related in frequency to the received waves, are used at a receiving point, for the purpose of assisting in the reception of the signals.

20 A system of the type to which the invention is applicable is described in a paper by Colpitts and Blackwell entitled "Carrier current telephony and telegraphy," appearing in a series of instalments in the Journal of the American Institute of Electrical Engineers beginning April 1921, the particular type of system referred to being illustrated in Fig. 49 of that paper.

30 In the system disclosed in the figure to which reference has been made, the auxiliary or reinforcing waves employed at the receiving point are derived as harmonics of a wave of base frequency which may be transmitted from the sending station along with the carrier waves. In the particular system there disclosed the auxiliary or reinforcing waves have frequencies identical with those of the respective carrier waves.

40 The carrier waves sent from the transmitting station are derived from a wave of the same base frequency as that transmitted to the receiving station, and it is therefore only necessary to select the corresponding harmonics of this base frequency wave at the respective stations to provide waves of respectively the same frequency.

Under some conditions of operation it becomes inconvenient or undesirable to transmit a wave of relatively low base frequency through the system in order to provide the auxiliary or reinforcing waves at the receiving point. In a system employing carrier waves which are derived as harmonics of

55 a base frequency, the frequency of the

base or fundamental wave is determined by the frequency spacing which the carrier waves are to have. For example, if only a single side band is transmitted through each carrier channel, as is now common practice, considerations of economy in total frequency range make it desirable to space the carrier waves the order of 3000 to 5000 cycles apart. This necessitates the use of a base or fundamental frequency of the order of 3000 to 5000 cycles although the lowest carrier frequency of the system may be of the order of 10,000 or 15,000 cycles. If the frequency range below the lowermost carrier channel is to be employed for other purposes such as ordinary speech transmission, wave telegraphy, or the like, it frequently encumbers the system to have to reserve in this lower frequency range a channel for the base frequency wave to be used for deriving the telephone carriers. Also as respects the terminations for the various kinds of signaling carried on over the line, the use of mid-line repeaters, the interconnection of different lines, etc., it often proves very inconvenient to tie up the carrier telephone channels with the circuits or channels which employ the lower frequency range and which are used for other purposes.

The invention provides for the production of auxiliary or reinforcing waves at a receiving point, bearing a definite relation to the frequency of the received waves, without the necessity of transmitting through the system any wave having a frequency lower than the frequencies actually employed by the carrier channels themselves.

The specific manner of producing and controlling the auxiliary or reinforcing waves at a receiving point according to the invention comprises the transmission of two waves differing in frequency by the same interval as two neighboring carrier channels. These two waves are caused to interact at the receiving point to produce a wave of a frequency equal to the difference between the frequencies of the two waves, and this wave of the difference frequency is used as a fundamental or base from which a series of harmonic waves are generated. At the transmitting point the carrier waves and also the two waves used for frequency control are derived as harmonics of a base or fundamental wave which likewise has a frequency equal to the frequency interval between the

carriers, and hence the waves used for the carriers may be made identical in frequency with the waves produced at the receiver. Since any two adjacent harmonics may be used for the frequency control, these control waves may have any convenient frequencies, and these may be as high as or higher than the carrier waves.

A more detailed description of the invention as applied to a system of the general type disclosed in the above mentioned Fig. 49 of the Colpitts and Blackwell publication, both as to its construction and manner of operation, will now be given, with particular reference to the accompanying drawing which shows in schematic form the preferred arrangement of a system according to the invention.

The drawing shows a two-way carrier telephone system comprising terminal stations connected by the main line ML. Incoming to the west station of the system are the ordinary telephone lines L_1 and L_2 which cooperate in the two-way transmission of signals with the respective telephone lines L_3 and L_4 terminating in the east station. Each of the lines is provided with a balancing network N_1 etc. and a differential repeating coil in accordance with standard telephone repeater practice for enabling currents to be applied to the respective line and derived therefrom without mutual interference. Each of the lines at each station is connected through a carrier wave transmitting branch to a common transmitting loop TL and similarly through a carrier receiving branch to a common receiving loop RL. The carrier waves that are used for transmission from west to east through the system are assumed to have respective frequencies which, as a group, are higher than the frequencies employed for transmission in the opposite direction. The west to east transmissions may therefore be separated as a group from the oppositely directed transmissions by means of the high pass filters HP, which transmit only the high group, and the low pass filters LP, which transmit only the lower group. The transmitting loop TL of the west station is connected to the line ML through the filter HP of the station, and the receiving loop RL of the east station is connected to the line ML through the filter HP of that station. Similarly the filter LP of the west station connects the receiving loop RL of that station with the line ML, and the filter LP of the east station connects the transmitting loop TL of that station with the line ML.

The filters HP and LP, and each of the other filters of the system to be referred to, may be constructed and designed in accordance with the disclosure in the above mentioned Colpitts and Blackwell publication and also in accordance with the disclosure

of the patent to G. A. Campbell, No. 1,227,113, May 22, 1917. As described in the above mentioned article, the term high pass filter is used to denote a filter having substantially uniform negligible attenuation for currents of all frequencies higher than a predetermined cut-off frequency and substantially infinite attenuation for currents of frequencies lower than this cut-off frequency. Conversely a low pass filter is one which freely transmits currents of all frequencies below a limiting frequency and effectively suppresses transmission of all currents of higher frequency.

The currents of the various carrier waves employed by the west station in transmitting and receiving are derived as harmonics from a wave of base frequency supplied from the source S, these waves being applied to a harmonic generator HG_0 which produces a series of harmonic frequency waves under control of the applied wave. These harmonics pass into the harmonic supply path HS, from which they are selected for the individual use of the channels by the selective circuits F_1 , F_2 and F_3 , F_4 . These selective circuits may be simple tuned circuits or filters of the type shown in the Campbell patent, and have preferably a relatively narrow transmission band. Each carrier transmission branch contains a modulator such as M_1 and a band filter BF_1 and each carrier receiving branch contains a band filter such as BF_5 and a detector or demodulator D_1 . The modulators are preferably of the balanced type for suppressing transmission of the unmodulated carrier wave component. The carrier wave to be used by the uppermost channel of the west station is selected from the harmonic supply circuit HS, by a selective circuit F_1 and is applied to the modulator M_1 in the manner disclosed in Fig. 49 of the Colpitts and Blackwell article cited. The modulated carrier wave resulting from the interaction of this carrier with speech received over the line L_1 is applied to the channel band filter BF_1 which preferably suppresses transmission of one of the two side bands and permits transmission of the other. The selective circuit F_2 , modulator M_2 , and the band filter BF_2 similarly cooperate with the line L_2 to apply to the transmitting loop TL a speech side band of the carrier wave of the frequency employed by that channel. Any desired number of modulated carrier waves of respectively different frequency may similarly be applied to the transmitting loop TL from which they pass selectively through the filter HP to the line ML.

The filter BF_5 is designed to select from the frequencies in the receiving loop RL received over the line ML from the distant station, the particular speech side band which is to be used in repeating speech into

the line L_1 . This side band after selection is applied to the detector or demodulator D_1 in the manner indicated in Fig. 49 of the Colpitts and Blackwell publication. There is simultaneously applied to this detector from the branch HS_1 , by means of the selective circuit F_1 , a reinforcing wave of the same frequency as the carrier wave used by this channel at its transmitting terminal at the East station. The demodulated speech is transmitted from the output of the detector D_1 to the line L_1 . In similar manner the band filter BF_1 , the detector D_2 , and the tuned circuit F_2 cooperate to repeat into the line L_2 the speech transmitted over a second carrier channel, and other similar receiving channels may be provided as desired.

The arrangement of the east station as respects the lines L_3 and L_4 and the carrier transmitting and receiving branches may be entirely similar to those described of the west station, and the various notations used on the figure will make clear the identity of the various elements and their manner of cooperation. It will be understood that the channel band filters serving respectively for transmitting and receiving the same wave at the two stations will have the same transmission frequency band. For example filters BF_1 and BF_7 have the same transmission range; also filters BF_2 and BF_8 have identical ranges; and so with each pair in the same channel.

Between each detector and the low frequency line into which it repeats there may be inserted, if desired, a filter LF such as is shown in connection with the line L_3 for selectively transmitting currents of speech range but suppressing transmission of currents of higher frequency.

The construction and operation of each of the elements such as the source S , the harmonic generator HG_0 and the band filters, are disclosed in the Colpitts and Blackwell publication. For further reference as to the preferred construction of these elements the patent to Hartley 1,356,763, October 26, 1920 may be consulted as to the source S ; the British Patent 142,571 may be consulted as to the harmonic generator; the patent to Carson 1,343,306, June 15, 1920, may be consulted as to the modulators and demodulators, and the patent to Campbell above referred to may be consulted on the band filters.

In addition to the waves employed by the several channels for transmitting speech between the terminal stations in the manner that has been described, the invention provides for transmitting from one of the stations, say the west station, two waves which are used for frequency control. These waves may have any desired frequency, but according to the invention they differ in frequency by the same amount as two adjacent

carrier waves used by the system. The frequency control waves are derived from the harmonic generator HG_0 by the band filter BF_0 which is designed to have a transmission range of the proper breadth to include the two frequency control waves. For example, the filter BF_0 may selectively pass the two successive harmonics next higher than the carrier wave of highest frequency used by the signaling channels of the system. However, the frequency control waves may have any other desired absolute frequency values so long as they differ from each other by the proper frequency interval. Since the frequency control waves lie in the frequency range transmitted from the west station, they will pass through the filter HP of this station over the line ML and through the filter HP of the east station into the receiving loop RL , from which they are selected by the band filter BF_9 having a transmission range equivalent to that of the filter BF_0 . The two waves thus selected are applied to the detector D_0 , which may be a simple detector of the audion type having a non-linear relation between applied voltage and output current. Such a detector has the property of producing in its output circuit a wave having a frequency equal to the difference in frequency of the impressed waves, and in the present case this wave will therefore have a frequency equal to the frequency interval between respective carriers. This base or fundamental wave is selectively transmitted through the low pass filter LF_0 , which is designed to suppress transmission of components of higher frequency, and is applied to the circuit of the harmonic generator HG , which may be similar or identical to the harmonic generator HG_0 . The circuit from this point on may be identical in construction and operation with the output circuit of the harmonic generator HG_0 , the harmonics developed at HG being applied to the harmonic supply circuit HS_2 . As in the case of the west station, the harmonic selected to each modulator is of the frequency to be used as the carrier for that particular channel, and the harmonic which is selected as the reinforcing wave to be applied to each detector is of the same frequency as the carrier wave of that receiving channel.

The circuits and system that have been illustrated and described in detail should be considered as merely typifying what is at present deemed the preferred form of practicing the invention, but are not to be construed as limiting the invention, its scope being defined in the claims.

What is claimed is:

1. In a carrier wave transmission system, a sending station and a receiving station, a source of base frequency waves at the sending station, a harmonic generator associated with said source to produce a plurality

of harmonic frequency waves, circuits for selecting and controlling certain of said harmonic frequency waves in accordance with signals to be transmitted, a circuit associated with said harmonic generator for transmitting a plurality of other harmonic frequency waves, circuits at the receiving station to receive the signal controlled waves, a circuit to receive the other harmonic frequency waves, means to derive from the last mentioned waves a wave of the base frequency, and means for utilizing the wave so derived in reproducing the transmitted signals.

2. In a carrier wave transmission system, a sending station and a receiving station, a source of base frequency waves at the sending station, a harmonic generator associated with said source to produce a plurality of harmonic frequency waves, circuits for selecting and controlling certain of said harmonic frequency waves in accordance with signals to be transmitted, a circuit associated with said harmonic generator for transmitting two other harmonic frequency waves, circuits at the receiving station to receive the signal controlled waves, a circuit to receive the other two waves, means to derive from the interaction of said two waves a wave of base frequency and to produce harmonic frequency waves therefrom, and means for utilizing the harmonic frequency waves so produced in reproducing the transmitted signals.

3. In a carrier wave transmission system, a transmission line, a source of base frequency waves, a harmonic generator adapted to produce a plurality of harmonic frequency waves and having an input circuit associated with said source and an output circuit associated with said line, circuits associated with said output circuit for selecting and controlling certain of said harmonic frequency waves in accordance with signals to be transmitted, means in said output circuit for selectively transmitting a plurality of other harmonic frequency waves to said line, circuits for selectively receiving the signal controlled waves transmitted over said line, a circuit to receive the other harmonic frequency waves transmitted over said line, means to derive from the last mentioned waves a wave of the base frequency, means to reproduce harmonic frequency waves from said last mentioned base frequency wave, and means for combining the harmonic frequency waves so produced with the signal controlled waves to reproduce the transmitted signals.

4. In a carrier wave transmission system, a transmission line, a plurality of transmitting channels associated with said line, a source of base frequency waves, a harmonic generator associated with said source to produce a plurality of harmonic frequency

waves, circuits for selectively transmitting said harmonic frequency waves to said channels, means associated with said channels to control the harmonic frequency waves in accordance with signals to be transmitted and for selectively transmitting the waves so controlled to said line, a circuit associated with said harmonic frequency generator for selectively transmitting other harmonic frequency waves to said line, circuits for receiving the controlled waves transmitted over said line, a circuit for receiving the other harmonic frequency waves transmitted over said line, means associated with said last mentioned circuit to derive from said last mentioned waves a wave of the base frequency, a harmonic generator for producing harmonic frequency waves from the derived base frequency wave, and means for combining the harmonic frequency waves so produced with the received signal controlled waves to reproduce the transmitted signals.

5. In a carrier wave transmission system, a sending station and a receiving station interconnected by a transmission line, a plurality of two-way channels associated with the line at each of said stations, a source of base frequency waves at said sending station, a harmonic generator associated with said source to produce a plurality of harmonic frequency waves, circuits for selectively transmitting the harmonic frequency waves to said channels, means associated with said channels for modulating the harmonic frequency waves in accordance with signal waves therein, means associated with each of said channels for selectively transmitting certain of said modulated waves to said line, a circuit associated with said harmonic frequency generator for selectively transmitting two other harmonic frequency waves to said line, circuits at said receiving station for selectively receiving the modulated waves transmitted over said line, a circuit for receiving said two harmonic frequency waves transmitted over said line, a detector associated with said last mentioned circuit to derive from said last mentioned waves a wave of the base frequency, a harmonic generator for producing harmonic frequency waves from the derived base frequency wave, modulating circuits associated with the two-way channels at said receiving station, and circuits for selectively impressing the derived harmonic frequency waves and the received modulated waves upon said modulating circuits to reproduce the transmitted signals.

6. In a carrier signaling system, means to produce a plurality of carrier waves having the same fundamental frequency separation, means to modulate each of said carrier waves by speech and to suppress the transmission of the unmodulated carrier component of each carrier, means to produce two other

waves of the same fundamental frequency separation as said carrier waves, said two waves having frequencies at least as high as the lowest frequency of the carrier waves, means to transmit all of said waves to a distance, means to derive from said two waves a wave of said fundamental frequency, means to derive from the fundamental frequency wave so derived a plurality of waves identical in frequency with the respective carrier waves and means to combine the derived waves of carrier frequencies with the respective received waves to reproduce the speech transmitted by each of said carrier waves. 15

In witness whereof, I hereunto subscribe my name this 16 day of February A. D., 1923.

JOSEPH W. HORTON.