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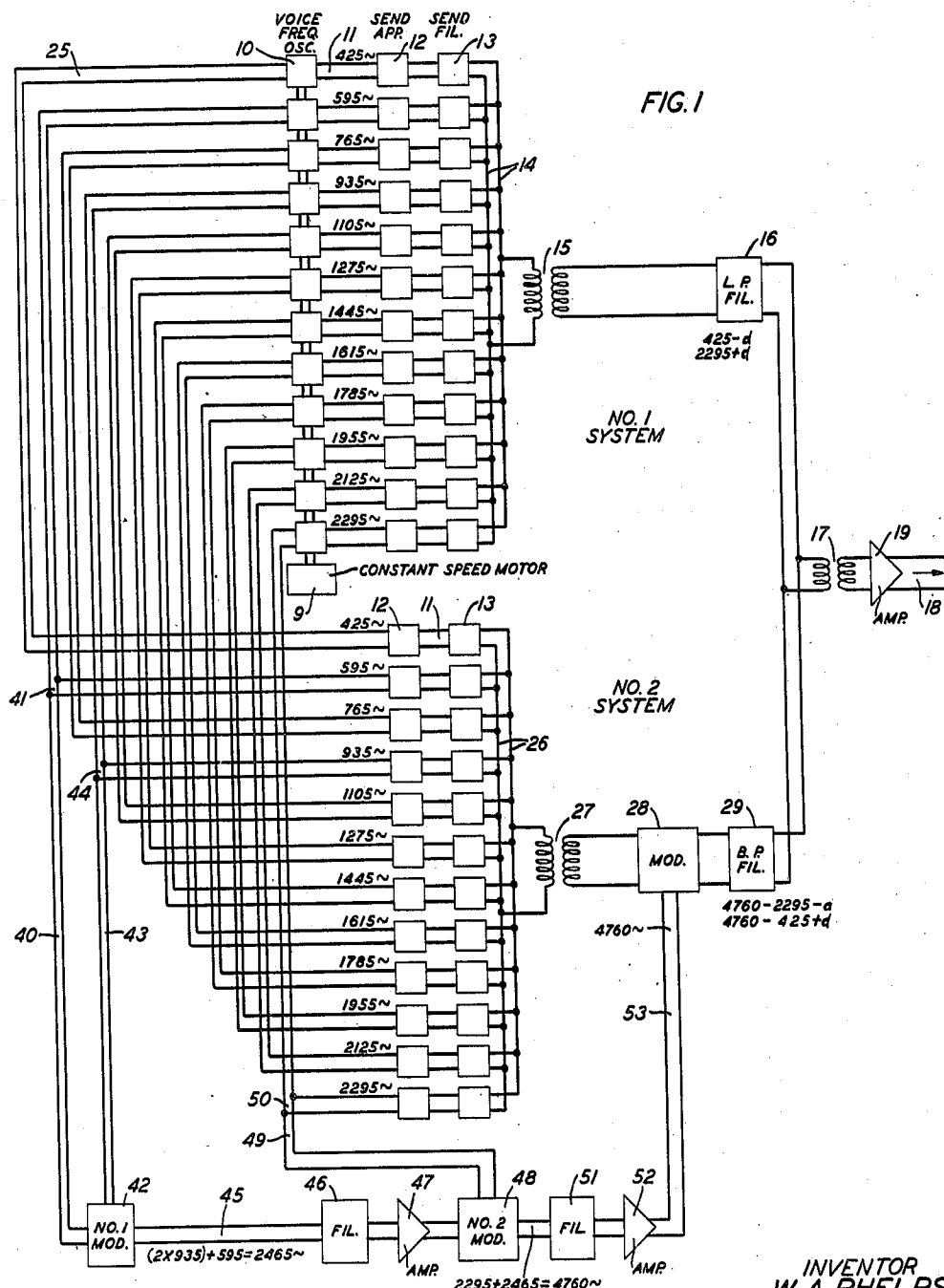
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2,347,332

CARRIER CURRENT TELEGRAPH SYSTEM

Filed Aug. 28, 1942

4 Sheets-Sheet 1



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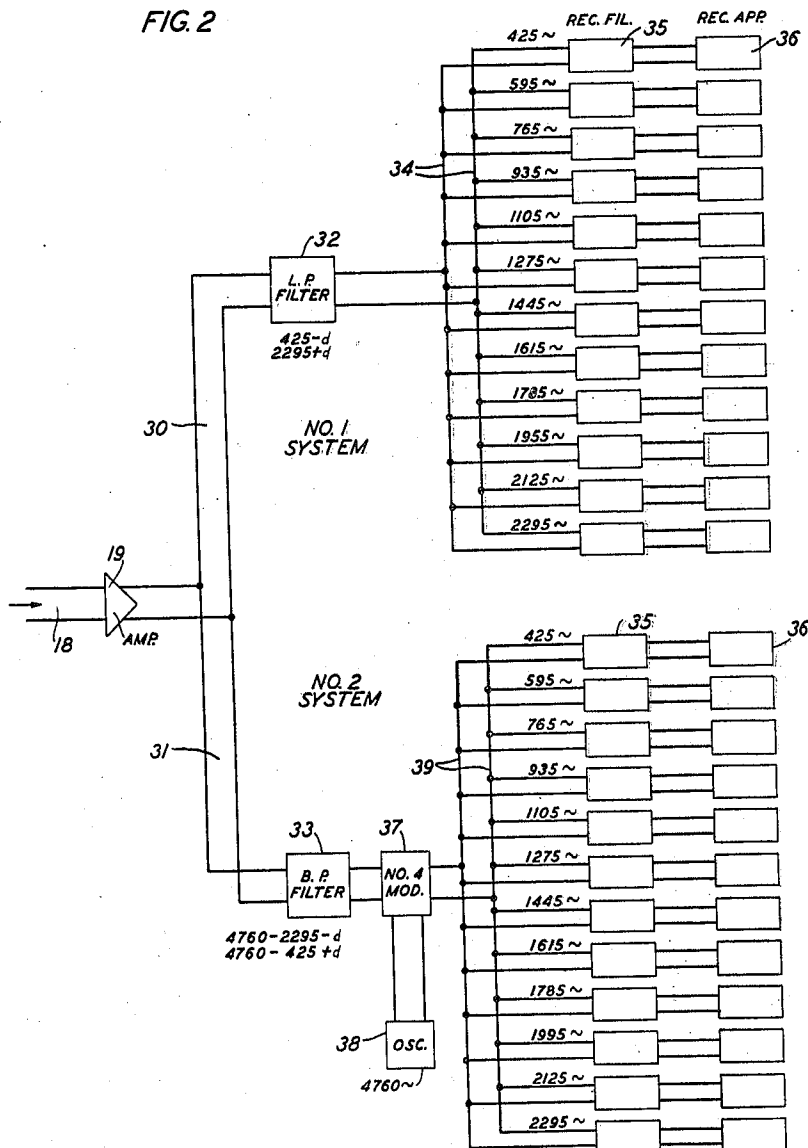
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FIG. 2



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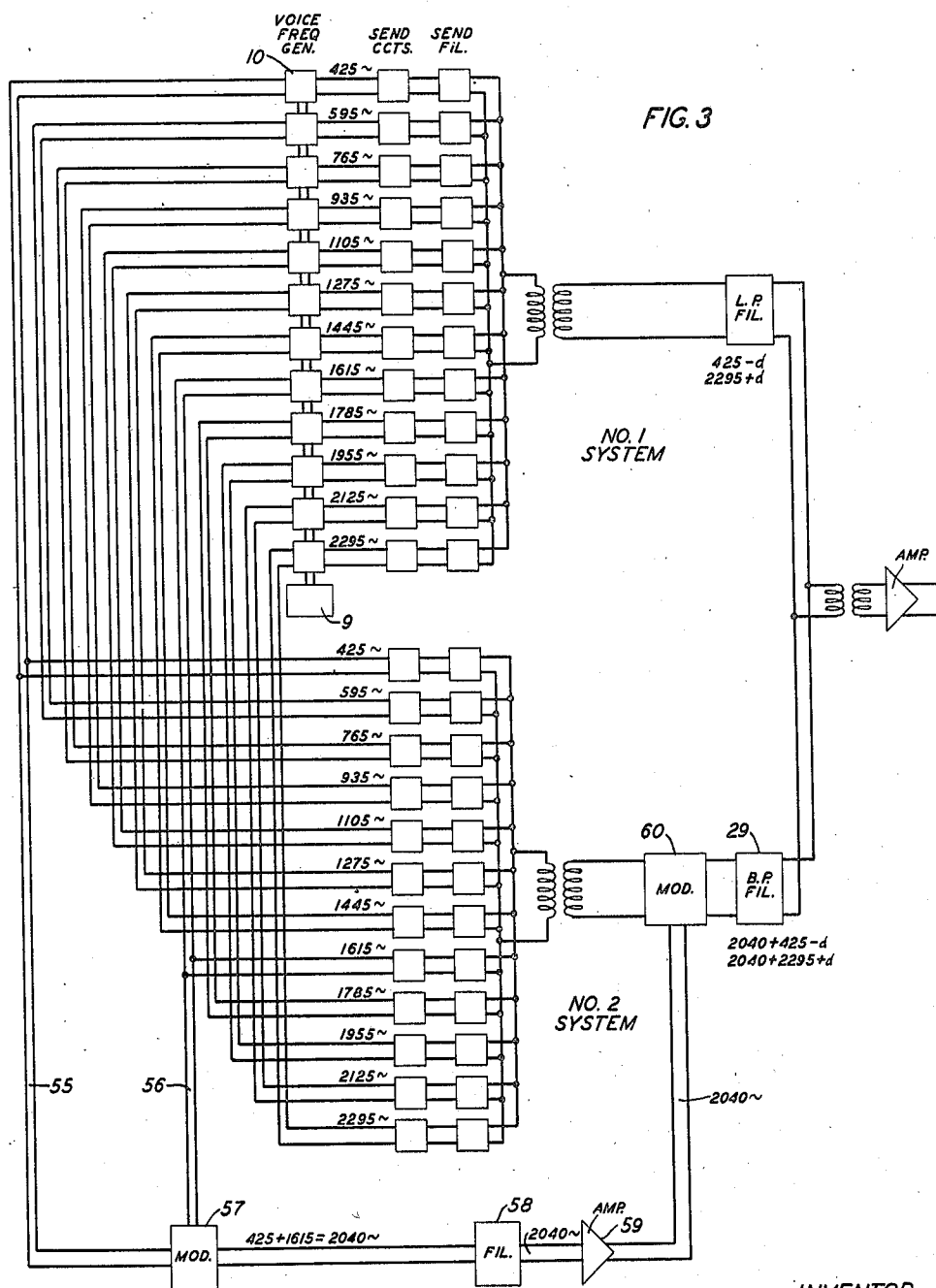
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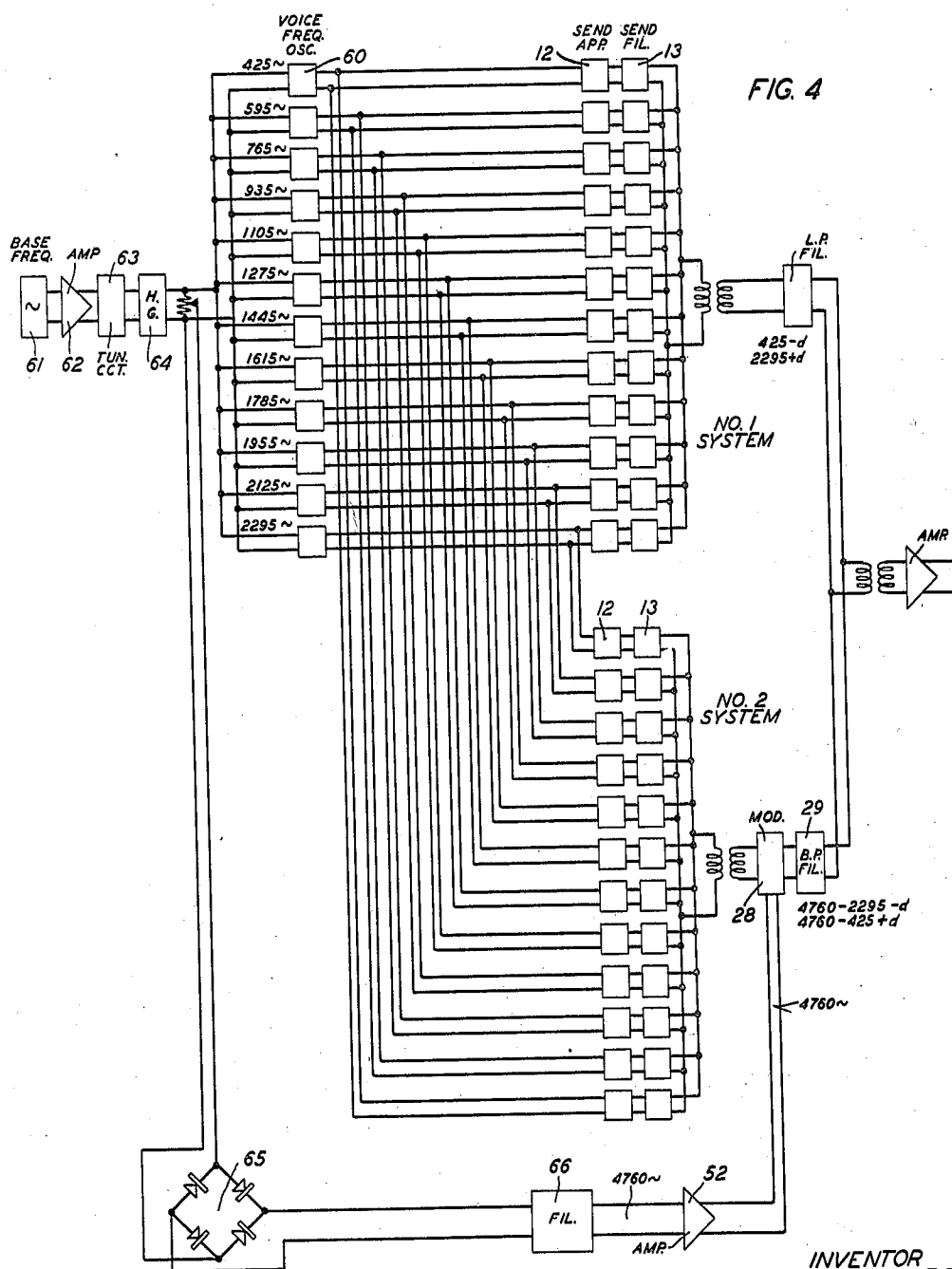
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2,347,332

CARRIER CURRENT TELEGRAPH SYSTEM

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9 Claims. (Cl. 178—51)

This invention relates to a carrier current telegraph signal system transmitting a plurality of groups of different carrier waves on a line at the same time, and more particularly to an arrangement for synchronizing the groups of carrier waves on the line so that fixed phase relationships are established between corresponding individual carrier waves.

In prior carrier wave telegraph systems embodying two or more identical groups of different carrier waves transmitted at the same time on a single transmission line, it was found that beat notes of relatively large amplitudes occurred in certain of the receiving channels with a consequent diminution of the signal-to-interference ratio. This was due to the fact that, although the individual carrier waves of each group were synchronized with each other, the carrier waves of each group were not synchronized with the carrier waves of the other groups. Consequently, at a given point on the transmission line, no fixed phase relation existed between corresponding individual carrier waves of the several groups of carrier waves. This further caused some of the carrier waves to peak up relatively sharply at one or more different points on the line thereby overloading both the line amplifiers and loading coils at such points. Such beat notes and peaking introduced distortion into the system to an extent depending on the number of carrier waves utilized therein and thereby impaired the signal-to-interference ratio of the overall system.

The present invention contemplates an arrangement for synchronizing a plurality of groups of carrier waves of different frequencies transmitted simultaneously on the same line.

The main object of the invention is to provide fixed phase relations between corresponding individual carrier waves of a plurality of groups of carrier waves of different frequencies.

Another object is to maintain optimum phase relationships between corresponding individual carrier waves of a plurality of groups of carrier waves of different frequencies.

A further object is to minimize the occurrence of momentary voltage and current peaks on a line transmitting a plurality of groups of different carrier waves.

Still another object is to maintain substantially constant a tolerable signal-to-interference ratio in a carrier telegraph system transmitting a plurality of groups of different carrier waves at the same time.

A still further object is to prevent momentary overloading of line amplifiers in a carrier tele-

graph system utilizing a plurality of groups of different carrier waves at the same time.

In prior carrier telegraph systems of the type to which the present invention is especially applicable, a plurality of synchronized carrier waves of different frequencies were generated and supplied to a plurality of groups of channels. The carrier waves of one group of channels were modulated in accordance with code messages and applied through suitable sending filters to the transmission line. The carrier waves of the other group of channels were also modulated in accordance with code messages, and then the message modulated waves were supplied to a modulator together with a wave of an independent source of oscillation of a preselected frequency. By means of such modulation the frequency range of the other group of carrier waves was increased, and thereafter the waves of the increased frequencies were selectively supplied to the transmission line.

In accordance with a specific embodiment of the present invention, means are provided to derive the frequency-shifting wave of the preselected frequency by combinations of wave frequencies of the original group of channels. This preselected wave is then modulated together with the message modulated waves of one group of carrier waves so as to increase the frequencies of this group. Corresponding individual waves of both groups being transmitted at the same time on the line are now provided with fixed phase relationships. In one aspect, three channel currents of different frequencies are utilized to derive the preselected wave, and the lower side-band components of modulation are selected for transmission on the line. In another aspect, two channel currents of different frequencies are employed to obtain the preselected wave, and the upper side-band components of modulation are selected for transmission on the line. In a further aspect, a certain even order harmonic derived from a wave having a fundamental frequency and whose odd order harmonics serve to synchronize the channel oscillators is the preselected wave, and the lower side-band components of modulation are selected for transmission on the line.

The invention will be readily understood from the following description taken together with the accompanying drawings in which:

Fig. 1 is a schematic circuit diagram showing a specific embodiment of the invention located at a sending terminal of a carrier telegraph system;

Fig. 2 is a schematic circuit diagram showing the receiving terminal to be used with Fig. 1;

Fig. 3 is a schematic circuit diagram showing another embodiment of the invention located at the sending terminal of a telegraph system; and

Fig. 4 is a schematic circuit diagram showing another embodiment of the invention located at the sending terminal of a telegraph system.

Referring to Fig. 1, a plurality of sources 10 of alternating current waves whose frequencies are 170 cycles apart are driven by a constant speed motor 9 and arranged to provide different frequencies such that the uppermost source supplies a wave whose frequency is 425 cycles per second; the next lower source provides a wave having a frequency of $425+170=595$ cycles per second; the third lower source provides a wave having a frequency of $425+(2 \times 170)=765$ cycles per second; and so on until the lowermost source 10 provides a wave whose frequency is

$$425+(11 \times 170)=2295$$

cycles per second. A pair of conductors 11 connects each of the sources 10 through a sending apparatus 12 and sending filter 13 to a pair of bus-bars 14. The uppermost twelve wave sources 10, sending apparatus 12, and sending filters 13 constitute the sending terminal of a No. 1 system. The bus-bars 14 are also coupled through a sending transformer 15 and low-pass 16 to the input of a transformer 17 embodied in a transmission line 18 which also includes a number of suitable amplifiers 19. The low-pass filter 16 is provided with a frequency range which will be subsequently identified.

A pair of conductors 25 extending from each of the wave sources 10 joins the latter to a second group of twelve individual sending apparatus 12 and sending filters 13, each of the latter associated sending apparatus and filters being connected by the pair of conductors 11 to a pair of bus-bars 26. The lowermost group of twelve sending apparatus 12 and sending filters 13 comprise the sending terminal of a No. 2 system. The pair of bus-bars 26 is also coupled through a sending transformer 27, a modulator 28, and a band-pass filter 29 in sequence to the input of the line transformer 17. From the foregoing it is evident that the individual sources 10 are connected over two parallel branches to the transmission line 18.

Referring to Fig. 2, the receiving end of the transmission line 18 terminates in two parallel branches 30 and 31 arranged to include a low-pass filter 32 and a band-pass filter 33, respectively, both of which correspond in frequency characteristic to the low-pass filter 16 and band-pass filter 29 embodied in the sending terminals of the No. 1 and No. 2 systems. The output of the low-pass filter 32 is supplied to a pair of bus-bars 34 to which are connected in multiple the branches individual to the different frequencies of the waves supplied by the sending sources 10. Each of these branches embodies in sequence a receiving filter 35 and a receiving apparatus 36. The uppermost twelve receiving apparatus 35 and receiving filters 36 constitute the receiving terminal of the No. 1 system. To the output of the band-pass filter 33 is connected the input of a modulator 37 to which is also applied an oscillator 38 which generates an independent wave of certain frequency to be identified hereinafter. The output of the modulator 37 is supplied to a pair of bus-bars 39 to which are connected in parallel the branches individual to the different

frequencies of the waves supplied by the sending sources 10, each of the latter branches embodying in sequence the receiving filter 35 and receiving apparatus 36. The lowermost twelve receiving filters 35 and receiving apparatus 36 comprise the receiving terminal of the No. 2 system. The foregoing arrangement embodying the No. 1 and No. 2 systems is essentially disclosed in the patent of H. Nyquist, No. 1,619,085, issued March 1, 1927.

In Figs. 1 and 2, the wave sources 10, sending apparatus 12, sending modulator 28, receiving apparatus 36, receiving modulator 37 and oscillator 38 may comprise any one of several well-known types of which one is illustrated in the Nyquist patent, supra. In this connection it is understood that the modulators may comprise copper-oxide or thyrite elements, or similar non-linear elements.

In the operation of Figs. 1 and 2, each sending apparatus 12 embodied in both the No. 1 and No. 2 systems may be operated to modulate the waves of individual frequencies in four different respects so as to transmit four messages in the manner described in the Nyquist patent, supra. Thus, each wave of individual frequency may be utilized to transmit eight messages, or a total of ninety-six simultaneous messages for both the No. 1 and No. 2 systems. It is understood that the sending apparatus 12 may be of such design as to modulate the individual carrier waves in any desired manner; and further that modulation of each carrier wave in four different respects as above-mentioned is selected merely for the purpose of this illustration. The message modulated carrier waves of the No. 1 system are applied through the sending transformer 15 and sending filter 16 to the transmission line 18. The sending filter 16 passes waves whose frequencies extend over a range from $425-d$ to $2295+d$, where d is one-half the band width of each of the filters 13 of the No. 1 system and has a value less than one-half of the 170 cycles separating the individual waves produced by the sources 10. The message modulated carrier waves of the No. 2 system are applied to the modulator 28 to which, at the same time, is applied a modulation component whose frequency is derived in a pre-selected manner which will be hereinafter explained. Certain of the modulation components of the increased frequencies are selectively supplied to the transmission line 18 through the sending filter 29 which passes waves whose frequencies extend over a certain frequency range which will be subsequently specified.

At the receiving end of the transmission line 18, Fig. 2, the incoming waves are divided into the two branches by the respective filters 32 and 33, of which the filter 32 possesses a frequency characteristic which is identical with that of the sending filter 16 and the filter 33 is provided with a frequency characteristic which is equivalent to that of the sending filter 29 and which will be later mentioned. From the output of the filter 32, the message modulated waves comprising the frequency range extending from $425-d$ to $2295+d$ cycles per second are supplied to the twelve filters 35 and receiving apparatus 36 so that the latter are actuated to reproduce the messages that served to modulate the sending apparatus 12 located at the sending terminal of the No. 1 system. From the output of the receiving filter 33, the message modulated waves of the increased frequencies are applied to the modulator 37 whereby the frequencies of these waves are decreased to the range

extending from $425-d$ to $2295+d$ and equivalent to the frequency range supplied to the receiving filter 32. The message modulated waves of the range $425-d$ to $2295+d$ are applied to the receiving filters 35 and receiving apparatus 36 comprising the No. 2 system so that the latter are actuated to reproduce the messages that served to modulate the sending apparatus 12 located at the sending terminal of the No. 2 system. The foregoing essentially describes a carrier telegraph system utilizing at least two groups of different carrier waves as disclosed in the Nyquist patent, supra.

In accordance with the present invention, as illustrated in Fig. 1, the modulation component of preselected frequency supplied to the modulator 28 and employed to increase the frequencies of the message modulated waves in the output of the modulator 28 of the sending terminal of the No. 2 system is derived in a manner which will now be explained. A pair of conductors 40 connected to a pair of points 41 embodied in the pair of conductors 25 carrying the 595-cycle wave from the 595-cycle source 10 of the No. 1 system to 595-cycle branch of the No. 2 system supplies the wave of 595 cycles per second to a modulator 42 to which is also supplied the wave of 935 cycles per second over a pair of conductors 43 connected to a pair of points 44 embodied in the pair of conductors 25 carrying the 935-cycle wave from the 935-cycle source 10 of the No. 1 system to the 935-cycle branch of the No. 2 system. The output of the modulator 42, including a component having a frequency of 2465 cycles per second, is supplied over a pair of conductors 45 to a filter 46 which attenuates all modulation components except the 2465-cycle component. The latter is then amplified in amplifier 47 and supplied to a modulator 48 to which at the same time is supplied a 2295-cycle wave over a pair of conductors 49 extending from the modulator 48 to a pair of points 50 embodied in the pair of conductors 25 carrying the 2295-cycle wave from the 2295-cycle source 10 of the No. 1 system to the 2295-cycle branch of the No. 2 system.

The output of the modulator 48, including a component having a frequency of 4760 cycles per second, is supplied to a filter 51 which attenuates all modulation components except the 4760-cycle component. The latter is amplified in the amplifier 52 and supplied over a pair of leads 53 to the modulator 28. As above mentioned, the modulation components in the output of the modulator 28 are supplied to the filter 29 which is provided with a frequency characteristic which attenuates all frequencies except those extending from $4760-2295-d$ to $4760-425+d$. The message modulated waves at the sending terminal of the No. 2 system are, therefore, provided with increased frequencies embracing the latter range and superposed on the transmission line 18 together with the message modulated waves of the No. 1 system appearing in the output of the sending filter 16. At the receiving terminal of the transmission line 18, Fig. 1, the receiving filter 33 is provided with a frequency characteristic which is identical with that of the sending filter 29.

Deriving the 4760-cycle component from portions of certain of the waves produced in the sources 10 and unmodulated with messages serves to provide at any point on the transmission line 18 a fixed phase relation between corresponding individual waves of the groups of waves supplied thereto by both the No. 1 and No. 2 systems. In other words, the utilization of the 4760-cycle component syn-

chronizes all the groups of waves of both the No. 1 and No. 2 systems during their simultaneous transmission on the transmission line 18 whereby fixed phase relationships are established between corresponding individual waves. This tends to obviate the occurrence of undesirable beat notes in individual receiving channels, and the peaking of some waves at the line amplifiers and loading coils. Optimum phase relations between all waves of both groups of waves supplied by the No. 1 and No. 2 systems to the transmission line 18 may be obtained by use of the well-known phase control networks, not shown, in the outputs of certain of the sources 10; approximately optimum phase relations in the foregoing respect may also be provided by reversing the output terminals of certain of the sources 10, which reversal is common to the art. Such optimum phase relationships are preserved because the synchronization of corresponding individual waves of the groups of waves in the line prevents drifts in frequency of one or more of the wave sources 10 which frequency drifts would cause desired phase relationships between individual waves to be lost in a few seconds. As a consequence, distortion in the system is maintained substantially constant at a certain tolerable signal-to-interference ratio.

Another arrangement for establishing a fixed phase relation between the corresponding individual waves of both the No. 1 and No. 2 systems is illustrated in Fig. 3. In the latter arrangement, conductor pairs 55 and 56 supply 425- and 1615-cycles waves to a modulator 57 whose output among other modulation products includes the component having a frequency of 2040 cycles per second. The output of the modulator 57 is supplied to a filter 58 which serves to attenuate all modulation products except the 2040-cycle component which is amplified in amplifier 59 and supplied to the modulator 60. The output of the latter is supplied to the band-pass filter 29 which has a frequency characteristic extending from $2040+425-d$ to $2040+2295+d$, or a frequency characteristic which is essentially the same as that of the sending filter 29 of Fig. 1. In other respects, the operation and advantages of Fig. 3 are identical with those of Fig. 1.

Instead of the multifrequency source 10 utilized in Figs. 1 and 3, a group of phased and synchronized channel oscillators 60, Fig. 4, may be employed as the individual sources of different frequencies as disclosed in my copending application, No. 356,128, filed September 10, 1940. In this connection a source 61 supplied an alternating current wave having a fundamental frequency of 85 cycles per second to an amplifier 62 whose output is impressed through a tuned circuit 63 onto a harmonic generator which may be of the type disclosed in the patent of L. R. Wrathall, No. 2,117,752, granted May 17, 1938. The output of this harmonic generator comprising certain odd harmonics of the fundamental frequency is impressed on the individual channel oscillators 60. However, for the purpose of the present invention, the 4760-cycles wave employed in the modulator 28, Figs. 1 and 4, to increase the message modulated waves of the No. 2 system is obtained from the output of the harmonic generator 64. As the output of the latter embodies only odd harmonics of the 85-cycle fundamental wave, and further as the 4760-cycle wave is the 56th even harmonic of the 85-cycle fundamental wave, the output of the harmonic generator 64 is also supplied to the vertical diagonal of a rectifier bridge 65 which translates the odd order

harmonics into even order harmonics of the 35-cycle fundamental wave so that the even order harmonics appear across the horizontal diagonal of rectifier bridge 65 as pointed out in the Wrathall patent, supra. The even order harmonics are supplied to a filter 66 which has such frequency characteristic as to pass the frequency of 4760 cycles per second and to attenuate the other harmonics. The 4760-cycle harmonic is supplied through the amplifier 52 to the modulator 28. In other respects, the operation and advantages of Fig. 4 functions are identical with those of Fig. 1.

What is claimed is:

1. In combination in a carrier current signal system, comprising a transmission line, means to generate a plurality of alternating currents having different frequencies and synchronized with respect to each other, circuit means to provide at least two branches extending from said generating means for each current of different frequency, separate means to modulate the currents of each of said branches for each current of different frequency in accordance with code messages, means to apply the group of message modulated currents of one of said branches for each current of different frequency to said line, means to increase the frequencies of the message modulated currents of the other of said branches for each current of different frequency and to apply a selected group of currents of the increased frequencies to said line, means at the receiving end of said line to separate the group of message modulated currents of said one branch for each current of different frequency and the selected group of currents of the increased frequencies into two further branches, and means to utilize the currents of said further two branches to reproduce the code messages; means to provide corresponding individual currents of the groups of currents transmitted on said line with fixed phase relationships, such that the peak magnitudes of the corresponding currents on said line and the production of beat notes in said current utilizing means are substantially minimized, comprising means to obtain a current of certain frequency from preselected current of said generating means, and circuit means to apply said certain current to said frequency increasing means for modulation with the group of message modulated currents of said other branch for each current of different frequency whereby said latter modulated currents are increased in frequencies.

2. A carrier current signal system comprising a transmission line, a plurality of sources to generate alternating current waves having different frequencies and synchronized relative to each other, circuit means to provide at least two branches extending from said generating means for each current of different frequency, circuit means to modulate the different currents of each of said two branches for each current of different frequency in accordance with code messages, means to apply the group of message modulated currents of one of said branches for each current of different frequency to said line, means to increase the frequencies of the message modulated currents of the other of said branches for each current of different frequency and to apply a selected group of currents of the increased frequencies to said line, and means to provide fixed phase relationships between corresponding individual currents of the groups of currents trans-

mitted on said line such that the peak magnitudes of the corresponding individual currents on said line are maintained substantially at minimum values, comprising means to derive a component of predetermined frequency from certain of the generated currents and unmodulated with the code messages, and circuit means to apply said predetermined component to said frequency increasing means for modulation together with the message modulated currents of said other branch for each current of different frequency whereby said latter modulated currents are increased in frequencies.

3. The carrier current signal system according to claim 2 in which said deriving means derives said component of predetermined frequency from three of the generated currents of different frequencies and unmodulated with the code messages.

4. The carrier current signal system according to claim 2 in which said deriving means derives said component of predetermined frequency from two of the generated currents of different frequencies and unmodulated with the code messages.

5. A carrier current telegraph system comprising a plurality of generators to produce alternating currents of different frequencies and synchronized relative to each other, circuit means to provide two branches extending from each of said generators, separate means to modulate the different currents of one of said branches for each current of different frequency in accordance with code messages and to apply this group of modulated currents to said line, separate means to modulate the different currents of the other of said branches for each current of different frequency in accordance with code messages, means to increase the frequencies of the modulated currents of said other branch for each current of different frequency and to apply a selected group of currents of the increased frequencies to said line, and means to synchronize the groups of currents on said line so that fixed phase relationships are established between corresponding individual currents for controlling the peak magnitudes of said latter currents on said line, comprising means to derive from portions of three of the different generated currents unmodulated with the code messages a component whose frequency is above the frequencies of the generated currents, circuit means to apply said component to said frequency increasing means to be modulated with the message modulated currents of said other branch for each current of different frequency whereby said latter modulated currents are increased in frequencies, and selective means embodied in said frequency increasing means to apply to said line the selected group of currents of increased frequencies comprising the lower side-band components of the modulation components in said frequency increasing means.

6. A carrier current telegraph system comprising a plurality of generators to produce alternating currents of different frequencies synchronized relative to each other, circuit means to provide two branches extending from each of said generators, separate means to modulate the different currents of one of said branches for each current of different frequency in accordance with code messages and to apply this group of modulated currents to said line, separate means to modulate the different currents of

the other of said branches for each current of different frequencies in accordance with code messages, means to increase the frequencies of the modulated currents of said other branch for each current of different frequency and to apply a selected group of currents of increased frequencies to said line, and means to synchronize the groups of currents on said line so that fixed phase relationships are established between corresponding individual currents for controlling the peak magnitudes of said latter currents on said line, comprising means to derive from portions of two of the different currents unmodulated with the code messages a component whose frequency is below the highest frequency of the generated currents, circuit means to apply said component to said frequency increasing means to be modulated with the message modulated currents of said other branch for each current of different frequency whereby said latter modulated currents are increased in frequencies, and selective means embodied in said frequency increasing means to apply to said line the selected group of currents of increased frequencies comprising the upper side-band components of the modulation components in said frequency increasing means.

7. A carrier current telegraph system comprising a plurality of generators to produce alternating currents of different frequencies and synchronized relative to each other, circuit means to provide two branches extending from each of said generators, separate means to modulate the different currents of one of said branches for each current of different frequency in accordance with the code messages and to apply this group of modulated currents to said line, separate means to modulate the different currents of the other of said branches for each current of different frequency in accordance with code messages, means to increase the frequencies of the message modulated currents of said other branch for each current of different frequency and to apply a selected group of currents of increased frequencies to said line, and means to establish fixed phase relationships between corresponding individual currents of the two groups of currents on said line for controlling the peak magnitudes of said latter currents on said line, comprising means to derive from portions of two different currents unmodulated with the code messages a component of certain frequency, means to modulate the certain component with a portion of another different current unmodulated with the code messages to produce a component of further frequency, means to apply the further component to said frequency increasing means for modulation with the message modulated currents of said other branch for each current of different frequency whereby said latter modulated currents are increased in frequencies, and selective means embodied in said frequency increasing means to apply to said line the se-

lected group of currents of increased frequencies which frequencies are above the frequency range of the produced currents.

8. A carrier current telegraph system comprising a plurality of generators to produce alternating currents of different frequencies, means including a harmonic generator to apply certain odd harmonics of a current of base frequency to said generators to synchronize the currents produced thereby, circuit means to provide two branches extending from the output of each of said generators, separate means to modulate the different currents of one of said branches extending from the output of each of said generators in accordance with code messages and to apply this group of modulated currents to said line, separate means to modulate the currents of the other of said branches extending from the output of each of said generators in accordance with code messages, means to increase the frequencies of the message modulated currents of said other branch extending from the output of each of said generators and to apply a selected group of currents of increased frequencies to said line, and means to establish certain phase relationships between corresponding individual currents of the two groups of currents on said line for controlling the peak magnitudes of said latter currents on said line, comprising means to derive a certain even order harmonic of said base frequency from the odd order harmonics in the output of said harmonic generator, circuit means to apply said certain even order harmonic to said frequency increasing means for modulation with the message modulated currents of said other branch extending from the output of each of said generators whereby said latter modulated currents are increased in frequencies, and selective means embodied in said frequency increasing means to apply to said line the selected group of currents of increased frequencies which frequencies are above the frequency range of the produced currents.

9. In a carrier telegraph system, a group of channels having carrier frequencies in a low range, a group of channels having carrier frequencies in a high range above said first range, means to generate the carrier waves in the first-mentioned range with the desired frequency spacing and phase relationships, means to provide similar frequency spacings and phase relationships for the carrier waves of the second-mentioned range comprising means to modulate waves having frequencies in said first range and derived from said first means, with a wave of fixed frequency and predetermined phase to shift the frequencies of said derived waves into said high range, and means to derive said wave of fixed frequency and predetermined phase by intermodulation between certain of the carrier waves in said first range.

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