Sept. 3, 1940. E. PETERSON 2,213,941

MULTIPLEX SIGNALING BY PHASE DISCRIMINATION

Filed July 26, 1938 3 Sheets-Sheet 1

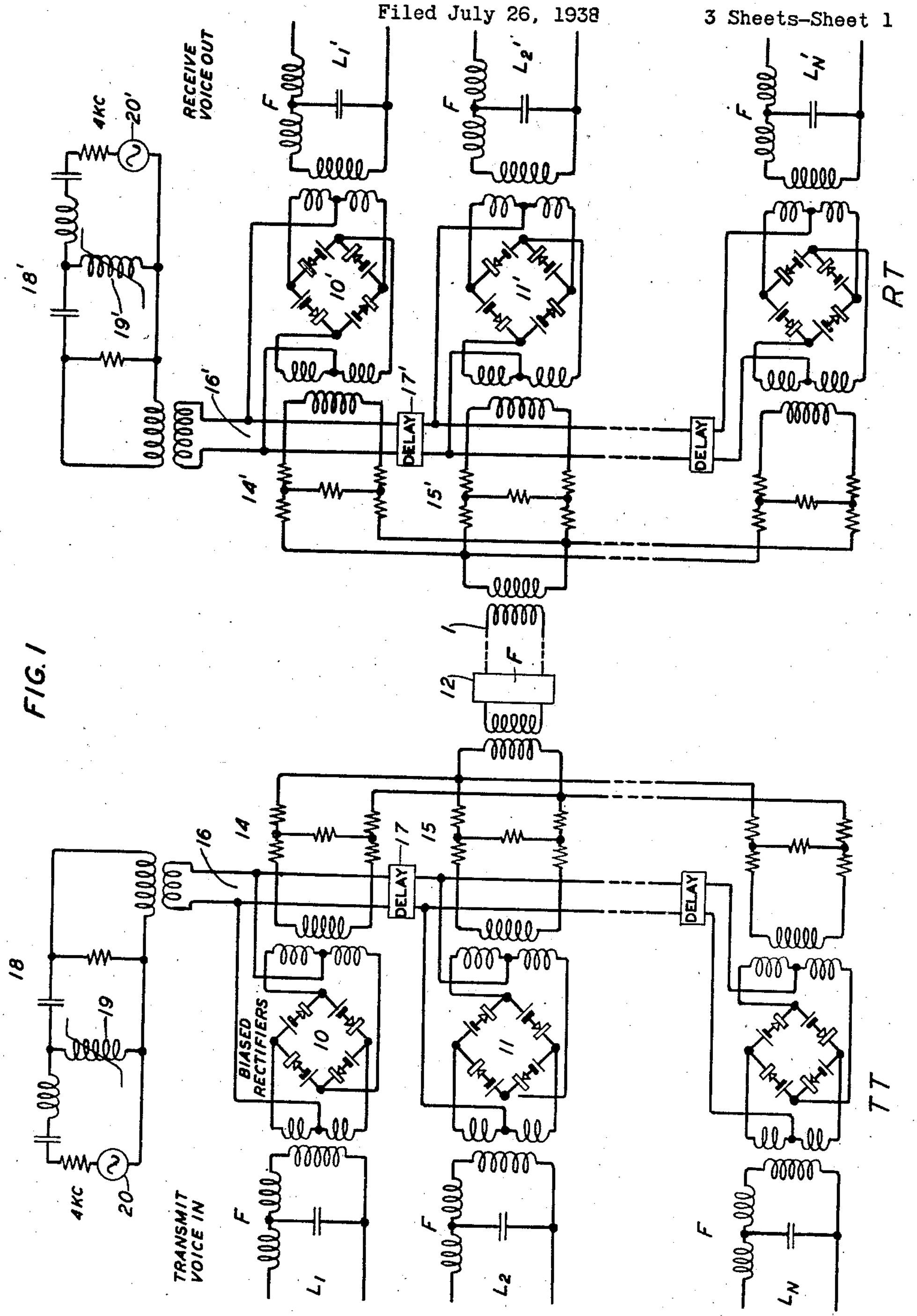

FIG. 1

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FIG. 2

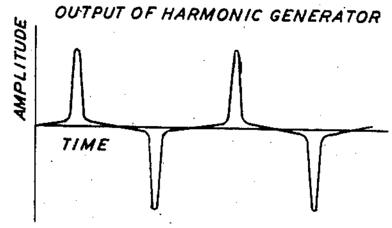


FIG. 6

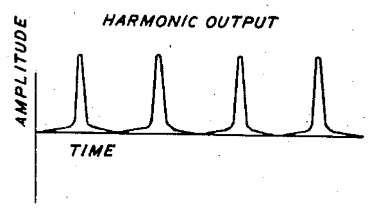


FIG. 3

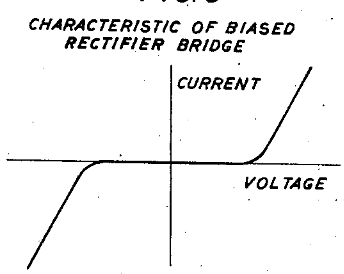


FIG. 7

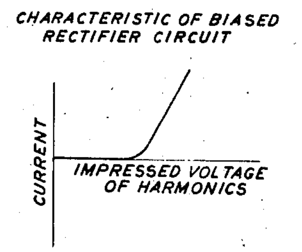


FIG. 4

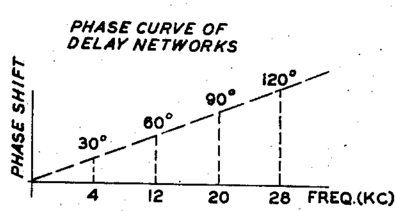


FIG. 5

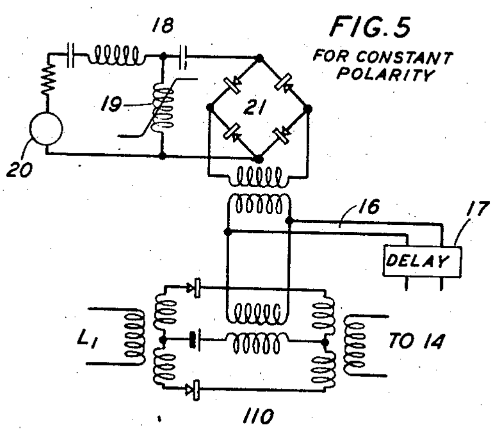
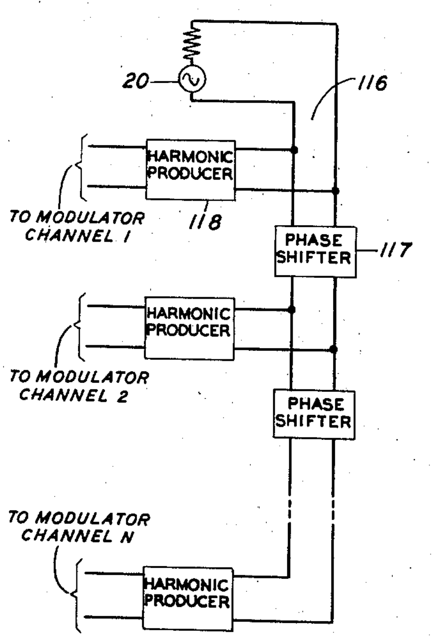


FIG. 8



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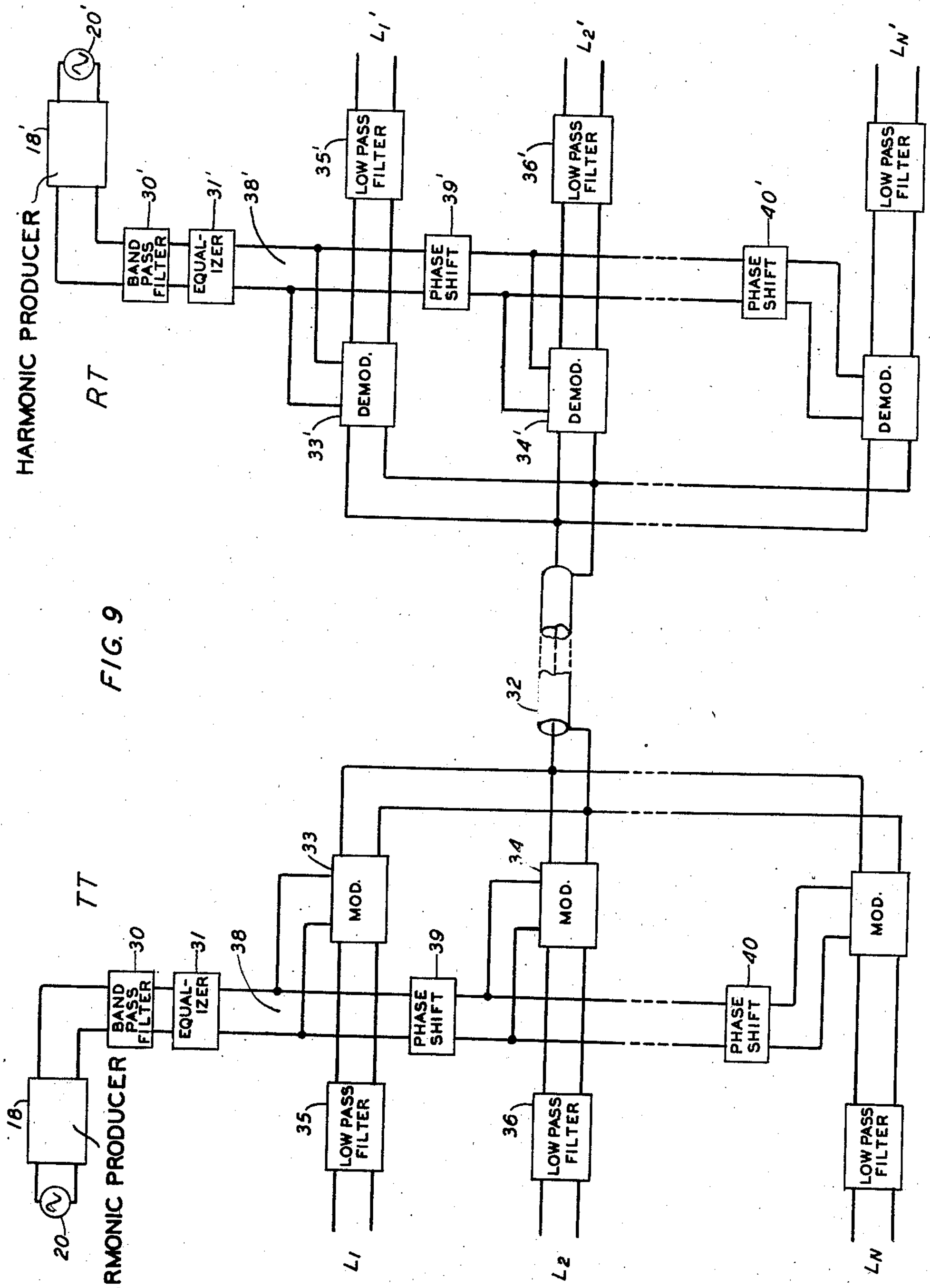

FIG. 9

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MULTIPLEX SIGNALING BY PHASE DISCRIMINATION

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Application July 26, 1938, Serial No. 221,297

5 Claims. (Cl. 179—15)

The present invention relates to multiplex transmission of speech, television or other types of signals on the basis of time division or phase relation.

One type of such system is disclosed in a copending application of W. R. Bennett Serial No. 221,298, filed July 26, 1938, in which the means specifically disclosed comprises a switching or distributing mechanism for, in effect, sampling the different signal currents in rapid succession. It is there pointed out that this action results in the production of side-bands representing all of the N signals being transmitted, based on a number of waves harmonically related in frequency and of equal amplitude. These waves harmonically related in frequency are, in effect, in such a system modulated in different phase by the successive signals from the fact that the sampling of the different signals occurs in succession with finite time intervals between. This results in a progressive shift of phase between the carriers with side-bands representing the successive messages and this shift of phase is relied on at the receiver for separation of the messages into the respective receivers.

In accordance with the present invention, the harmonically related waves are generated as such and are, as a group, controlled in one phase in their transmission in accordance with one signal; the same set of waves is controlled in altered phase by the second signal and so on. Reception is accomplished in analogous manner, by the supply of sets of waves of proper frequency and phase to the respective receiver control devices so that maximum amplitude of a given signal and theoretically zero amplitude of all other signals are produced in respective receiver circuits.

By this general method, as pointed out in the Bennett disclosure, no wider frequency range is needed than in the case of the usual multiplex carrier system and the channel filters used in the latter for separating the different message waves are dispensed with.

The nature and the various objects of the invention will appear more fully from the following detailed description of preferred embodiments as illustrated by way of example in the accompanying drawings.

In the drawings, Fig. 1 is a schematic circuit diagram of a multiplex system in accordance with the invention.

Figs. 2 to 4, 6 and 7 are diagrams to be referred to in the description of the circuit figures.

Figs. 5 and 8 show detail modifications to be referred to; and

Fig. 9 is a block schematic of a multiplex system containing alternative features to certain features of the system of Fig. 1.

Referring first to Fig. 1, the multiplex line, or medium 1, is shown provided with a transmitting terminal TT and a receiving terminal RT. Lines L_1, L_2—L_N are ordinary telephone line branches or circuits carrying any other type of signals that are to be sent over the system for simultaneous independent communication with the similar lines L'_1, L'_2—L'_N at the receiving terminal. The number of such lines may vary widely but for illustrative purposes herein will be taken as 12. Each line has a low-pass filter F having the pass range usual to speech transmission, such as 0 to 3000 cycles by way of example.

Included between each input line L_1, L_2, etc. and the multiplex line is a corresponding rectifier circuit 10, 11, etc. in series with a respective separating pad 14, 15, etc. The rectifier circuit is in the form of a bridge with suitable rectifier elements in each arm such as copper-oxide rectifiers or diode tubes, suitably biased as will be described. The carrier input diagonal of each bridge is connected to the harmonic supply circuit 16 in which delay circuits 17, etc. are inserted such that the harmonic waves are applied to the rectifiers in successively retarded phase. These harmonics may come from any suitable type of source but are preferably produced in a harmonic generator 18 including a saturable core inductance 19 supplied with fundamental waves from a generator of constant frequency, an appropriate frequency being 4 kilocycles in the case of a telephone system. A harmonic generator of this type is disclosed in L. R. Wrathall Patent No. 2,117,752, issued May 17, 1938.

The circuit elements at the receiving terminal are analogous to those at the transmitting terminal, and are indicated by corresponding numerals primed.

Fig. 2 shows roughly the character of the output wave of the harmonic generator 18. It is seen to consist of sharp short impulses alternating in sign. Fig. 3 shows the characteristic of the biased rectifiers 10, 11, etc. No current is passed except during the peak portion of the impressed impulses. The characteristic is symmetrical so that current is passed on positive and negative peaks.

The operation may be more readily understood from comparing the action at the transmitting and receiving terminals TT and RT to that of rotating commutators. In the case of a commutator with its rotating arm connected to the line 1 and its segments connected in succession to lines L_1, L_2, etc. transmission would occur from lines L_1, L_2, etc. to line 1 in successive time intervals. Similar action but in the direction from line 1 to lines L'_1, L'_2, etc. would take place at station RT.

Considering the system as shown in the drawings, an impulse from the harmonic generator 18 renders the rectifier 10 conductive for a brief instant so that a fragment of the speech or other signal on line L_1 is sent to the main line 1 through separating pad 14. This same impulse would also render each of the other rectifiers 11, etc. conductive at the same instant except that the delay networks 17, etc. cause the action to be retarded so that the rectifiers come into action successively and transmit fragments of the message currents on the input lines in succession to the main line. Similar commutating action occurs at the receiving terminal.

This method of sampling the messages on the various sending lines and distributing to the various receiving lines has the advantage of no mechanically moving parts. Synchronism is necessary between terminals and may be secured by deriving the base frequency 4 kilocycle wave at each station from a common source over a distributing system (not shown) or by sending a wave of this frequency over the line as in Kendall Patent 1,773,901, issued August 26, 1930.

As explained in the Bennett application, supra, in the method of multiplex transmission by sampling the different messages at the transmitter and distributing them at the receiver in accordance with a switching function such that the harmonics are of equal amplitude throughout the utilized range, the requisite degree of discrimination between messages is obtainable. In a twelve-channel system six harmonics of the fundamental 4 kilocycle wave (of which the first may be 4 kilocycles) would be required to have equal amplitude. The line filter 12 will remove all higher harmonics than those used. The six harmonics need not be the first six in the frequency scale but may be selected as desired so long as they are six consecutive harmonics. Each harmonic may be thought of as in a sense a carrier wave accompanied by six lower side-bands superposed within the same frequency limits and six upper side-bands superposed within the same frequency limits. The phase shift characteristic required of the delay networks 17, etc. and 17', etc. is linear and is of the slope shown in Fig. 4.

The effect of the transmitting terminal circuits as described is to send to line 1 a total frequency range limited by filter 12 to a width equal substantially to twelve times the signal band width. These are made up of side-bands based upon six harmonic carriers so phased that the lowest carrier is modulated by the signal on line L_1 in, say, zero phase and by the signal on line L_2 after a phase shift of 30 degrees and so on. The next higher carrier is modulated by the signal on line L_1 in zero phase and by the signal on line L_2 in a phase of 60 degrees and so on.

Upon arrival at the receiving terminal the received waves of all of these frequencies are impressed on each biased rectifier 10', 11', etc. together with the harmonics from 18'. The side-bands resulting from modulation of each of the carriers in zero phase, assumed to be the case for the signal on line L_1, upon passing through rectifier 10' together with the harmonic carriers in zero phase from 18' all yield signal components in phase so that they add arithmetically in the output line L_1. The side-bands resulting from modulation of the carriers in other than zero phase, however, upon meeting carriers in zero phase in rectifier 10' produce low frequency components out of phase such that they neutralize one another in line L'_1.

In similar manner the side-bands resulting from signals in line L_2 produce in-phase components in line L'_2 while other side-bands produce components which phase out due to the phase relations between these side-bands and the locally supplied harmonics. In this way the signals are separately received in the lines L'_1, L'_2, etc. by phase discrimination.

Fig. 5 shows a modified form of channel terminal in which impulses of the same polarity, as shown in Fig. 6, may be used. These are generated by the circuit 18, 19 in combination with full wave rectifier 21. In this case the biased rectifier 110 includes only two rectifier elements with divided input and output transformers as shown. Its transmission characteristic is in effect one-half of that of Fig. 3 and is shown in Fig. 7. Rectifier 110 may be considered as substituted for rectifier 10 of Fig. 1 and the distributing circuit 16 extends through delay devices 17, etc. to similar rectifiers in the other channels. The same arrangement would be used at the receiver. Since this circuit produces only even harmonics, the harmonics will have frequencies of 8, 16, 24, etc. kilocycles instead of those indicated in Fig. 4.

It is not necessary to shift the phase of all of the harmonic carriers by the delay devices 17, etc. An alternative, requiring a plurality of harmonic producers, is shown in Fig. 8. The source 20 is connected to a distributing branch 116 in which phase shifters 117, etc. are used to shift the phase of the fundamental 4 kilocycle wave. Harmonic producers 118, etc. individual to the channels are then used. In this case, if the phase of the fundamental is shifted 30 degrees, for example, the phase of the nth multiple is shifted $n \times 30°$.

In the system of Fig. 9 modulators and demodulators of the "pure product" type, for example square law type, are used at the points in the circuit where biased rectifiers are shown in Fig. 1. These may be copper-oxide modulators such as are commonly used in the carrier art or may be triodes or diodes, etc. Referring to Fig. 9, the low frequency lines L_1, L_2, etc. lead through low-pass filters 35, 36, etc. to the modulators 33, 34, etc., the outputs of which are connected to the main line 32, in this case illustrated as a coaxial conductor line.

The fundamental frequency generator 20 connects to a harmonic producer 18 as in the case of Fig. 1. In the present case, however, the harmonics from 18 are limited to a definite number and range by the band-pass filter 30. For example, in a twelve-channel system six consecutive harmonics would be selected by the filter 30 and the other harmonics would be suppressed. An equalizer 31 is used where necessary to bring all of the harmonics to the same amplitude. Those harmonics are distributed by circuit 38 to the different modulators, a phase shift being introduced between the branches leading to successive modulators as shown at 39, 40, etc.

A similar arrangement of apparatus is used at the receiving terminal RT and similar reference characters with primes are used to indicate the apparatus at that terminal.

Let it be supposed that the band used by the twelve channels extends from 60 to 108 kilocycles. The filter 30 must then pass the six carrier frequencies 64, 72, 80, 88, 96 and 104 kilocycles. The low-pass filters 35, 36, etc. have cut-offs lower than 4 kilocycles to prevent overlapping of the side-bands. The amount of phase shift introduced in each phase shifting circuit 39, 40, etc. is 15 degrees at 64 kilocycles and 45 degrees, 75 degrees, 105 degrees, 135 degrees and 165 degrees at the succeeding harmonic frequencies. As in the case of Fig. 1 the line 32 should be equalized for flat gain and linear phase shift over the frequency band used.

The operation of the circuit of Fig. 9 is analogous to that described in the case of Fig. 1 but in the system of Fig. 9 it is not necessary that the transmission of the waves be substantially instantaneous. The only requirement is that a sufficient number of harmonics of equal amplitude be employed. Moreover, in Fig. 9 it is not necessary to include a line filter in line 32 to limit the band since this effect is produced by the use of the filter 30 together with the type of modulators employed.

Side-bands based on the differently phased carriers are transmitted over the line as in the case of Fig. 1. Detection is accomplished by pure product demodulation of the received waves by carriers synchronized with the transmitting carriers.

The invention is not to be construed as limited to the specific means or dimensions disclosed, but its scope is defined by the claims.

What is claimed is:

1. In multiplex signaling, means to generate waves of a succession of frequencies harmonically related and substantially equal in amplitude, a plurality of signal input circuits coupled to different signals to be transmitted, a control device for each signal input circuit and biased against transmission in the absence of applied waves, means to apply said succession of waves to the first of said control devices and, after equally increasing delay, to each of the other control devices in succession, means causing the waves so applied to unbias the respective control devices, means including said control devices for causing side-bands to be transmitted representing modulations of each of said harmonic frequency waves by the signal in the respective signal input circuit, and means limiting the transmitted frequencies to a band of sufficient width to embrace a plurality of non-overlapping side-bands corresponding in number to the number of said signal input circuits.

2. In multiplex signaling, a main transmission path, individual signal branches at opposite terminals of said path, individual control devices between each such branch and said path, means to apply to respective control devices at each terminal a succession of waves of harmonically related frequency, means at each terminal to introduce equally increasing delay in the application of said waves to the successive control devices at the respective terminal, said control devices serving to impress signals on said harmonically related waves for transmission and respectively to recover signals from the incoming signal-controlled harmonically related waves and means to restrict the transmitted frequencies to a band whose width is substantially equal to the product of the band width of one side-band by the number of said individual signal branches at a terminal

3. In multiplex signaling, a plurality of lines at each of two multiplex stations, a multiplex medium for effecting transmission between said stations, a plurality of wave modulators at each multiplex station coupled to the respective lines thereat and coupled in common to said multiplex medium, means to apply to each of said modulators a succession of harmonically related waves of equal amplitude for combining with the signals received from the individual lines for multiplex transmission and for combining with the waves received from the mutiplex medium for multiplex reception, means to restrict the transmitted frequencies to a band whose width is substantially equal to the product of the number of lines at a multiplex station by the band width of a single side-band resulting from so combining said signals with said harmonically related waves and means at each station to shift the phase of the harmonically related waves by the same amount from modulator to modulator.

4. In multiplex signaling by phase discrimination, a sending and a receiving station, a multiplex transmission medium for effecting transmission between said stations, means at each station for generating waves harmonically related in frequency and of uniform amplitude, one or more phase shifting networks at each station for shifting the phase of said waves such that sets of waves of the same succession of harmonically related frequencies but progressing in phase from set to set are produced at each station, means causing said sets to be in respective phase coincidence at the respective stations, a plurality of signal input circuits at said sending station, a plurality of modulating means at said sending station coupled individually to said input circuits and coupled in common to said multiplex transmission medium, said modulating means serving to modulate the waves of said sets by signals from said respective signal input circuits for transmission over said medium, means restricting the band width of the transmitted waves to a band whose width is substantially equal to the product of the number of signals being simultaneously sent and the band width of a single one of the side-bands resulting from such modulation, a plurality of signal receiving circuits at said receiving station, individual demodulating means inserted between said multiplex medium and the respective receiving circuits and connections for applying said sets of waves at said receiving station to said demodulating means to demodulate the received waves.

5. In multiplex signaling, a plurality of signal wave input circuits, means to produce carrier waves harmonically related in frequency and of uniform amplitude, a modulator for each signal input circuit, means to apply all of said carrier waves to each of said modulators, means to shift the phase of all of said carrier waves by a successively greater amount before applying them to the successive modulators after the first, whereby all of said carrier waves are modulated in the successive modulators by signals in each of said input circuits, resulting in a progressive phase shift between side-bands of like frequency, the side-bands produced in any one modulator occupying mutually exclusive frequency ranges, means to limit the number of transmitted side-bands of mutually exclusive frequency range to the number of said signal input circuits, means to transmit the resulting modulated waves, and means at a receiving point to produce waves similar in frequency and phase to the said carrier waves and to demodulate the received modulated waves in successive circuits respectively by said similar waves.

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