April 2, 1946. H. A. RHODES 2,397,885

FREQUENCY DIVERSITY TELEGRAPH SYSTEM

Filed June 30, 1943 2 Sheets-Sheet 1

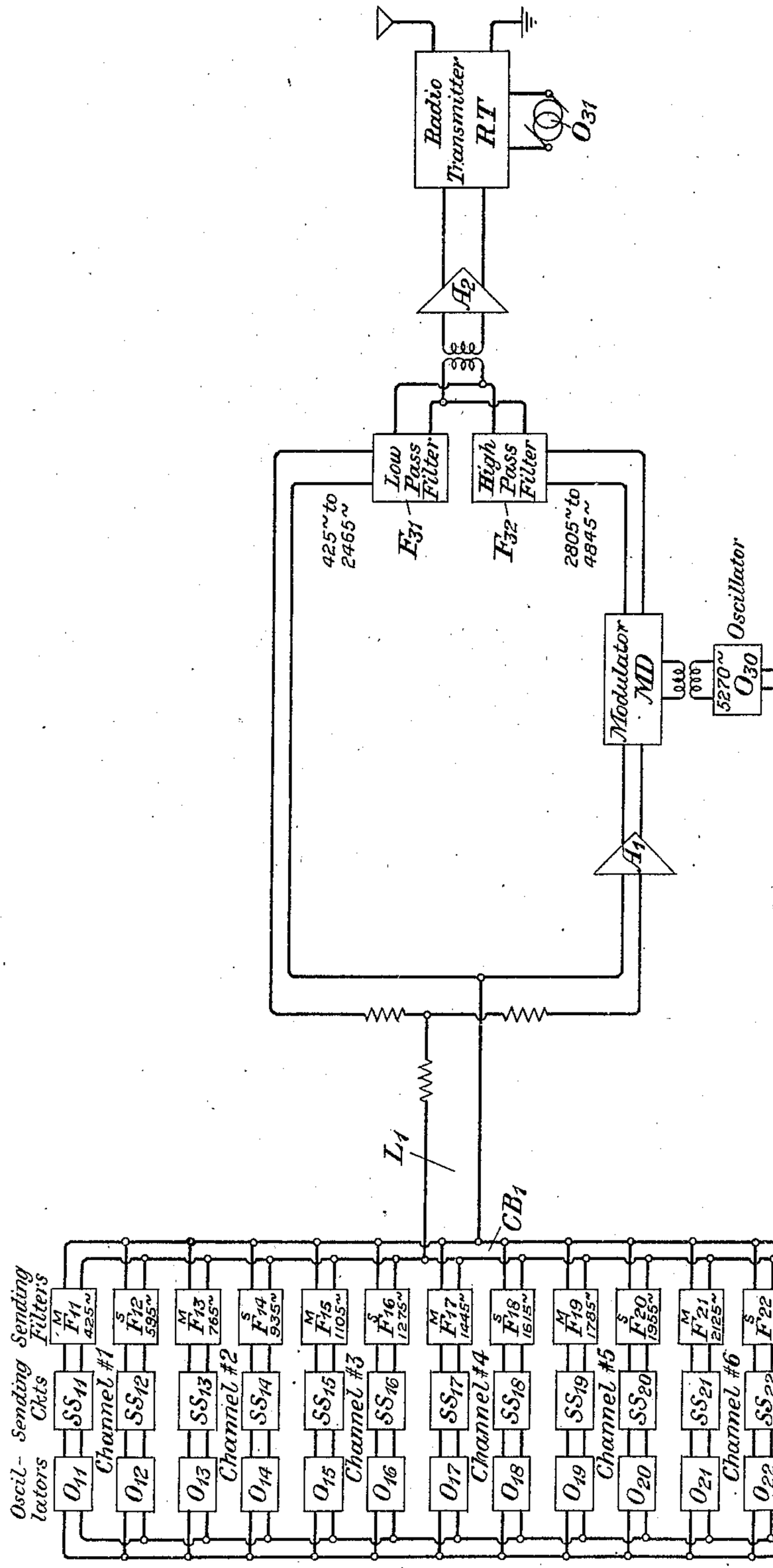

Fig. 1

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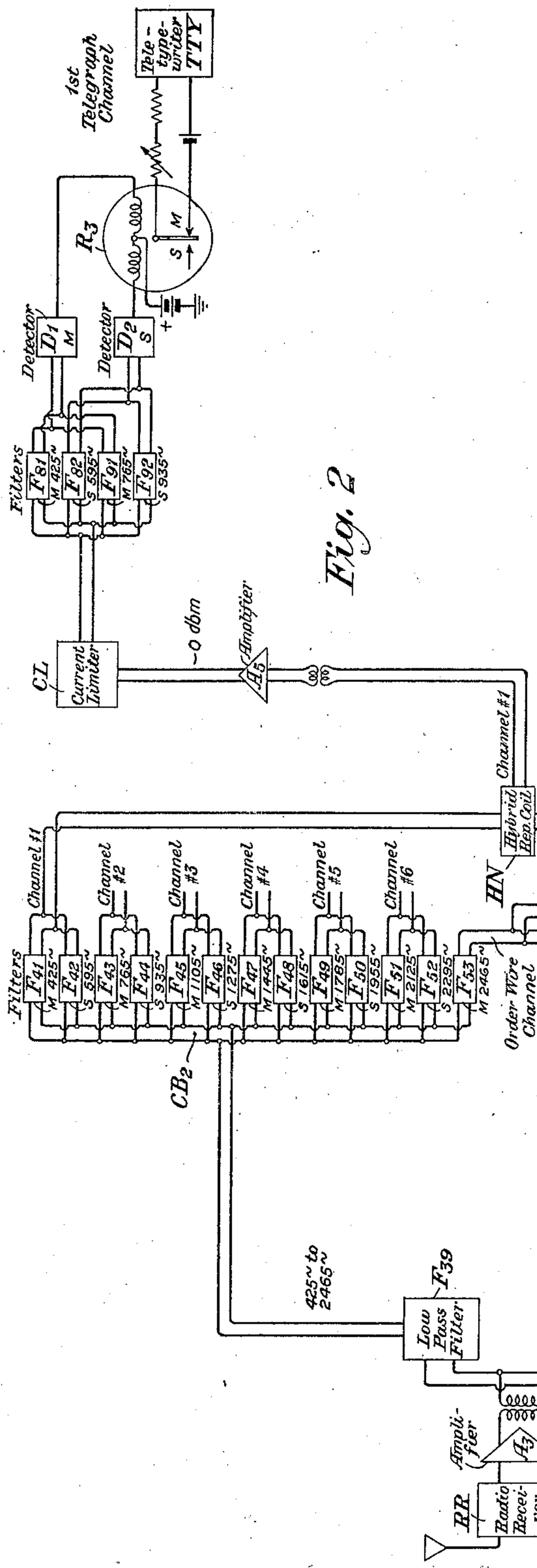
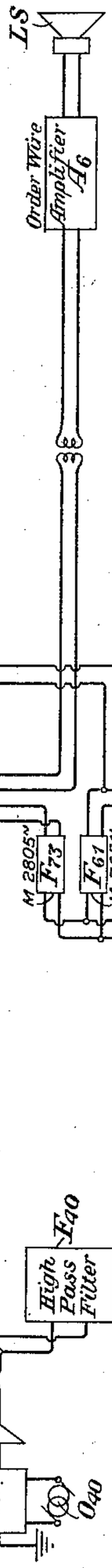


Fig. 2



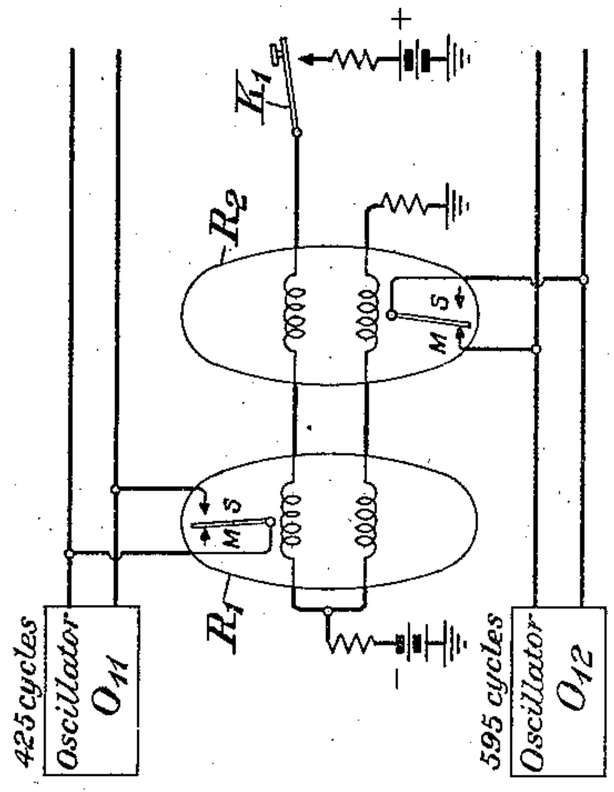


Fig. 3

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FREQUENCY DIVERSITY TELEGRAPH SYSTEM

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5 Claims. (Cl. 178—66)

This invention relates generally to signaling systems, and more particularly to telegraph systems. Still more particularly, this invention relates to two-tone telegraph systems, as well as to frequency diversity telegraph systems employing either wire line, radio or other transmission media.

Telegraph signals are often transmitted either by interrupting the current of a battery or other source of direct current in accordance with signals or by reversing the polarity of the current of the source. In both of these types of transmission the transmitting medium may be such that the signals become greatly attenuated and sometimes lost. It has been proposed to overcome the effect of the attenuation characteristic of the transmitting medium by employing a two-tone method for conveying the signals. In the two-tone method current of one frequency is produced for a marking signal and current of a different frequency for a spacing signal. It has also been proposed to employ a limiter at the receiver to substantially reduce the effect of the attenuation characteristic of the transmitting medium. However, when one of the currents, such as the marking current, becomes attenuated or faded, the limiter will introduce noise and extraneous currents and transmit these undesired currents to the telegraph receiving relay. Hence the signals may become distorted and perhaps rendered unintelligible.

In accordance with this invention it is proposed to transmit telegraph signals by a modified frequency diversity two-tone method. By this method currents of two discrete frequencies will be produced for each marking signal and currents of two still other discrete frequencies for each spacing signal. One of the currents of each pair will be produced by modulation with current of a common oscillator and will thereby be positioned in a somewhat higher position in the frequency spectrum. Hence each marking signal will be conveyed by a low frequency current and by a high frequency current resulting from modulation and each spacing signal will likewise be conveyed by a low frequency current and by a high frequency current resulting from modulation. Thus the marking and spacing signals of any one telegraph channel will be transmitted by means of currents of four different frequencies. At the receiving station the two higher frequencies resulting from modulation at the transmitter will be reduced in the frequency spectrum by demodulation with current of a common oscillator. The two currents of different frequencies corresponding to each marking signal and the two currents of different frequencies corresponding to each spacing signal—which comprise one telegraph channel—will then be amplified and transmitted through a common limiter. The limiter will act to substantially reduce, if not completely eliminate, the effect of noise and extraneous currents of different frequencies arising from the transmission medium and accompanying the signals when the noise and extraneous currents are weaker than the signals. The two currents corresponding to each marking signal will then be combined and detected to actuate a common telegraph receiving relay and likewise the two currents corresponding to each spacing signal will be thereafter combined and detected to actuate the same telegraph receiving relay. Thus the telegraph receiving relay will reproduce the marking and spacing signals originating at the transmitting station.

In the specific embodiment to be described each marked signal will cause the production of current of one frequency and each spacing signal will cause the production of current of a different frequency. These two currents will be transmitted over one path, while over another path these same currents will be modulated upon current of a different frequency to produce the two higher frequencies corresponding to the same signals, as already noted. Thus the transmitter of the system will produce current of one frequency and a modulation product of a higher frequency in accordance with each marking signal, and current of a different frequency and a modulation product of a higher frequency in accordance with each spacing signal, as mentioned above. All four of these currents will be transmitted to the receiving station where the two lower frequencies (which correspond to the marking and spacing signals respectively) will traverse one path and the two higher frequencies (which also correspond to the same marking and spacing signals respectively) will traverse another path which includes demodulating apparatus for reducing the higher frequencies to lower positions in the frequency spectrum. The currents corresponding to the marking signals traversing both paths will be combined, amplified, then limited in amplitude and detected. The remaining currents corresponding to the spacing signals will also be combined, amplified and limited in amplitude and thereafter detected.

This invention will be better understood from the more detailed description hereinafter follow-

ing when read in connection with the accompanying drawings in which Figure 1 represents equipment at the transmitting station of the system employing the invention, Fig. 2 illustrates the equipment at the receiving station of the system of the invention and Fig. 3 illustrates generally the apparatus required for producing currents of two different frequencies in accordance with marking and spacing signals at the transmitting station.

Referring to Fig. 1 of the drawings, the reference character O_0 represents a low frequency oscillation generator which supplies current to a plurality of devices O_{11}—O_{23}, all of which may produce different harmonics of the current of the oscillator O_0. If the oscillator O_0 generates current of, for example, 85 cycles per second, the devices O_{11} and O_{12}, may produce the two harmonics or tones of, for example, 425 and 595 cycles per second respectively, for transmitting the marking and spacing signals of one of the telegraph channels. The other devices O_{13}—O_{22} may similarly produce still higher harmonics of the same base frequency of oscillator O_0 for transmitting the marking and spacing signals of other telegraph channels. To simplify the description, all of these devices O_{11}—O_{23} will be referred to hereafter as oscillators.

The apparatus for controlling the oscillators O_{11} and O_{12} for one of the channels is shown in Fig. 3. The key K_1 may be closed to operate the relays R_1 and R_2. When the key K_1 is closed in accordance with a marking signal, the armatures of both relays R_1 and R_2 will move to their marking contacts M so that the oscillator O_{11} will freely transmit its current, while the current of oscillator O_{12} will be suppressed by the shunt circuit established by the armature and contact M of relay R_2 around this oscillator. When key K_1 is opened in accordance with a spacing signal, the relay armatures will close their spacing contacts S, in which case the oscillator O_{12} will freely transmit current while the current of oscillator O_{11} will be suppressed. Similarly the oscillators O_{13} and O_{14} will be controlled by the marking or spacing signals of another telegraph channel, oscillators O_{15} and O_{16} will be similarly controlled by the marking or spacing signals of a third telegraph channel, and so on. The oscillator O_{23} may be used for supplying current for an order circuit, but in this case the current of oscillator O_{23} may be interrupted in accordance with marking and spacing signals.

All of the oscillators O_{11} to O_{23} are connected to telegraph sending circuits designated SS_{11} to SS_{23} and to filters F_{11} and F_{23}, respectively, each pair of telegraph sending circuits SS_{11} to SS_{22} being of the type shown in Fig. 3, and designed to freely transmit only the currents of the associated oscillators O_{11} to O_{22}, respectively, as already mentioned with regard to Fig. 3. The sending circuit SS_{23} may be of a simple type employing a key K_2 for interrupting the current of oscillator O_{23}. The outputs of all of the filters F_{11} to F_{23} are connected to a common bus CB_1, which receives all of the currents of both marking and spacing signals of all of the telegraph channels. The common bus CB_1 is connected through a line L_1 to two paths, the upper of which extends to a low pass filter F_{31} and the other includes an amplifier A_1 and a modulator MD and extends to a high pass filter F_{32}. The modulator MD is supplied with current from another oscillator O_{30}, which is also connected to the base frequency oscillator O_0, the oscillator O_{30} producing a still higher harmonic of the current of oscillator O_0 of, for example, 5,270 cycles. The filter F_{31} is of the low pass type and is employed to transmit the currents of oscillators O_{11} to O_{23}, extending over a range of from 425 to 2,465 cycles, for example, while the filter F_{32} is of the high pass type and will transmit these same currents raised in the frequency spectrum as a result of modulation by the modulator MD. The currents transmitted by filter F_{32} may extend from, for example, 2,805 to 4,845 cycles. The currents transmitted by both filters F_{31} and F_{32} will be amplified by amplifier A_2 and then radiated through space by a radio transmitter RT, which is supplied with a high or radio frequency current generated by an oscillator O_{31}.

Thus the marking and spacing signals corresponding to the first of the telegraph channels will be transmitted by oscillators O_{11} and O_{12} in accordance with the two-tone method, and these currents will be transmitted by the low pass filter F_{31}, while these same currents will be raised in the frequency spectrum by modulator MD for transmission through the high pass filter F_{32}. If the oscillators O_{11} and O_{12} produce currents of 425 and 595 cycles, as already stated, the modulation currents corresponding to the same signals produced by modulator MD and transmitted by filter F_{32} will have frequencies of 4,845 and 4,675 cycles. These four currents are employed for frequency diversity to convey the marking and spacing signals of but one telegraph channel, the currents of 425 and 4,845 cycles corresponding to a marking signal and the currents of 595 and 4,675 cycles corresponding to a spacing signal.

The signals received by the radio receiver RR of Fig. 2 are demodulated by a locally produced current emanating from oscillator O_{40}. The demodulated currents are then amplified by amplifier A_3 and then divided into two bands, one of which is selected and transmitted by the low pass filter F_{39} and the other selected and transmitted by the high pass filter F_{40}. These filters F_{39} and F_{40} may be similar to the filters F_{31} and F_{32} at the transmitting station of Fig. 1, and have the same pass bands. The filter F_{39} is connected to a common bus CB_2 which is bridged by a plurality of filters designated F_{41} to F_{53}. Filters F_{41} to F_{53} correspond, for example, to the filters F_{11} to F_{23} at the transmitting station of Fig. 1, these filters selectively transmitting currents having the frequencies of oscillators O_{11} to O_{23}, respectively.

The output circuit of filter F_{40} is connected to a demodulator DM which is supplied with the current of an oscillator O_{41} for demodulating the received currents in the higher portion of the range so as to reduce these currents to lower frequencies. The lower frequencies resulting from demodulation extend from 765 to 2805 cycles. These currents are amplified by amplifier A_4 and are then impressed upon a common bus CB_3. The common bus CB_3 is bridged by filters F_{61} to F_{73}, which correspond to filters F_{11} to F_{23} and their respective oscillators O_{11} to O_{23} at the transmitting station. The output circuits of filters F_{41} and F_{42} are connected to each other and supply the low frequency marking and spacing currents alternately to a hybrid network HN for telegraph channel 1. The filters F_{61} and F_{62} are also connected to each other and supply the higher frequency marking and spacing currents to the same hybrid network HN of telegraph channel 1. The currents transmitted by filters F_{41} and F_{42} have

frequencies of 425 and 595 cycles while filters F_{61} and F_{62} may transmit, for example, currents of 765 and 925 cycles. The hybrid coil network HN combines these currents as received, the combined currents are then amplified by a common amplifier A_5, and the amplified currents are transmitted through a common current limiter CL.

The output circuit of limiter CL is bridged by four filters designated F_{81}, F_{82}, F_{91} and F_{92}. The filters F_{81} and F_{91} may be the same as the filters F_{41} and F_{61}, respectively, and filters F_{82} and F_{92} may be the same as filters F_{42} and F_{62}. The filters F_{81} and F_{91} will transmit currents of two different frequencies corresponding to a single marking signal, and filters F_{82} and F_{92} will transmit currents of two different frequencies corresponding to a single spacing signal. The filters F_{81} and F_{91} are connected to each other and to a detector D_1 which detects the currents corresponding to a marking signal. The filters F_{82} and F_{92} are connected to each other and to a detector D_2 which detects the currents corresponding to a spacing signal. The relay R_3 connected to both detectors D_1 and D_2 will be operated to close its marking contact M in response to marking currents supplied by detector D_1, and the relay will close its spacing contact S in response to spacing currents obtained from detector D_2. Relay R_3 will, therefore, respond to the received marking and spacing signals of one of the telegraph channels and may transmit the signals to a teletypewriter TTY, a recorder or any other signal indicating apparatus.

Although the amplifier A_5, the current limiter CL, filters F_{81}, F_{82} and F_{91} and F_{92}, detectors D_1 and D_2 and relay R_3 are shown common to but one of the telegraph channels, it will be understood that similar apparatus (not shown) is common to each of the other telegraph channels and operates in the same manner. The order circuit marking and spacing signals—which are of the interrupted type—are selected by filters F_{53} and F_{73}, the output circuits of which are combined and connected to an amplifier A_6. These signals are therefore amplified and are then caused to operate a loud speaker LS.

It will be observed that but one current limiter such as CL is used in each telegraph channel to act on all of the currents corresponding to the marking and spacing signals in any one channel. As is well understood, the marking currents will be interspersed with the spacing signals so that in general either the marking currents or the spacing currents always will be present and acted on by limiter CL. When one of the two marking currents, for example, is reduced in amplitude or becomes otherwise faded due to the attenuation characteristic of the transmitting medium, the other marking current will be effectively selected by the limiter CL to transmit a strong marking signal. The appropriate filter connected to the output circuit of the limiter will pass a strong marking signal to the detecor D_1 to actuate the relay R_3. The limiter CL will perform in the same manner when one of the spacing currents of the channel becomes faded, the limiter acting to produce a strong spacing signal. Thus when any of the various marking or spacing currents are appreciably reduced in amplitude due to the attenuation characteristic of the transmitting medium, the limiter of the channel will effectively overcome this condition and the signals will nevertheless be reproduced accurately. The effect of noise and extraneous currents will be overcome in each telegraph channel by a single limiter.

The arrangement of the invention embodies a frequency diversity system in which two currents of different frequencies, such as 425 cycles and 765 cycles per second, transmitted in accordance with each marking signal, and two currents of still other frequencies, such as 595 cycles and 935 cycles per second, transmitted in accordance with each spacing signal, are impressed upon the common limiter CL. The limiter CL accentuates the stronger of the two marking currents while effectively suppressing the weaker marking current and, moreover, the limiter CL accentuates the stronger of the two spacing currents while effectively suppressing the weaker spacing current. Thus, if the amplitude of the 765 cycle marking current exceeds the amplitude of the 425 cycle marking current, the stronger 765 cycle marking current will be effectively selected by the limiter CL while the weaker 425 cycle marking current will be effectively suppressed along with any extraneous noise present. Similarly, the stronger spacing current will be effectively selected by the limiter CL and the weaker spacing current and extraneous noise will be effectively suppressed. The filters F_{81}, F_{82}, F_{91} and F_{92}, connected in parallel to the limiter CL, act to transmit the stronger marking and spacing currents, whichever they may be, to detectors D_1 and D_2. If the 765 cycle marking current is the stronger, it will be transmitted by filter F_{91} and detected by detector D_1. Likewise, if the 595 cycle spacing current is the stronger, it will be transmitted by filter F_{82} and detected by detector D_2.

It is also noted that currents of two different frequencies are derived from one of the oscillators, such as O_{11}, for transmitting a marking signal through one of the channels. Two similar currents corresponding to the same marking signal are passed by filters F_{81} and F_{91} at the receiver and are combined and detected by the marking detector D_1. Two corresponding currents derived from oscillator O_{12} are employed for transmitting a spacing signal. Two similar currents are selected by filters F_{82} and F_{92} at the receiver and are similarly combined and detected by the spacing detector D_2. This arrangement provides the frequency diversity so essential to the faithful transmission of signals under varying conditions.

Although Fig. 3 shows a key K_1 for controlling the transmission of currents from oscillators O_{11} and O_{12}, for example, this is merely a symbolic representation and any form of current controlling device, including a teletypewriter, may be used for this purpose.

Although this invention has been shown and described in certain particular embodiments merely for illustrative purposes it will be understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. In a telegraph signaling system, the combination of means for producing currents of two frequencies in accordance with each marking signal and currents of two other frequencies in accordance with each spacing signal, an amplifier for amplifying all of said currents, a limiter connected to said amplifier, the limiter acting to effectively suppress the weaker of the two currents corresponding to each marking signal as well as the weaker of the two currents corresponding to

each spacing signal, means connected to said limiter for separating the different currents from each other, two detectors one for detecting the stronger of the two currents corresponding to each marking signal and the other for detecting the stronger of the two currents corresponding to each spacing signal, and means for reproducing the marking and spacing signals from said detected currents.

2. In a telegraph system, the combination of means for producing currents of first and second frequencies in accordance with marking and spacing signals respectively, means for producing two currents which are modulation products of the currents of said first and second frequencies respectively and transmitting said modulation products along with the currents of said first and second frequencies, receiving means including means for obtaining currents corresponding to said first frequency and its modulation product for each marking signal and currents corresponding to said second frequency and its modulation product for each spacing signal, a limiter for effectively suppressing the weaker of the currents corresponding to said marking and spacing signals, and means for detecting the stronger currents corresponding to each marking signal separate from the stronger currents corresponding to each spacing signal.

3. Telegraph apparatus for receiving a plurality of currents of different frequencies corresponding to a marking signal and a plurality of other currents of different frequencies corresponding to a spacing signal, comprising a limiter effectively accentuating the strongest of the currents corresponding to each marking signal and the strongest of the currents corresponding to each spacing signal while substantially suppressing all of the other currents corresponding to said marking and spacing signals, two detectors coupled to said limiter for detecting the accentuated currents corresponding to a marking signal separately from the accentuated currents corresponding to a spacing signal, and an indicator coupled to both detectors for indicating said marking and spacing signals.

4. In a telegraph system in which a plurality of currents of different frequencies are produced for each marking signal and a plurality of other currents of different frequencies are produced for each spacing signal, the combination of an amplifier-limiter, said amplifier-limiter amplifying all of the various currents corresponding to each marking signal and each spacing signal and then effectively suppressing all currents except the strongest current corresponding to each marking signal as well as all currents except the strongest current corresponding to each spacing signal, a first detector for detecting the strongest of the currents corresponding to a marking signal, a second detector for detecting the strongest of the currents corresponding to a spacing signal, means interposed between said amplifier-limiter and said first and second detectors for selectively transmitting the currents corresponding to said marking and spacing signals, and a relay connected to both detectors for reproducing said detected marking and spacing signals.

5. In a telegraph system, the combination of means for producing marking and spacing signals alternately, each marking signal and each spacing signal consisting of currents of a plurality of different frequencies, a limiter through which all of said currents are transmitted, a plurality of filters for separating each current from all other currents, two detectors, one detector being connected to all of the filters passing currents corresponding to a marking signal and the other detector being connected to all of the filters passing currents corresponding to a spacing signal, said limiter acting to accentuate the strongest of the currents corresponding to each marking signal as well as the strongest of the currents corresponding to each spacing signal while effectively suppressing all of the weaker currents, and means controlled by both detectors for reproducing the marking and spacing signals.

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