Dec. 1, 1942. H. S. BLACK 2,303,907

MULTICHANNEL SIGNAL TRANSMISSION

Filed June 14, 1941

FIG. 1

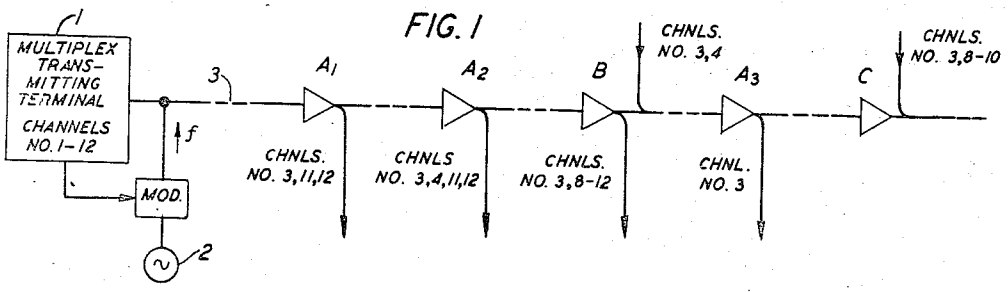


FIG. 2

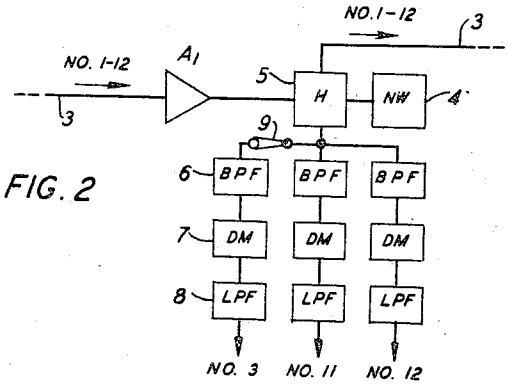


FIG. 3

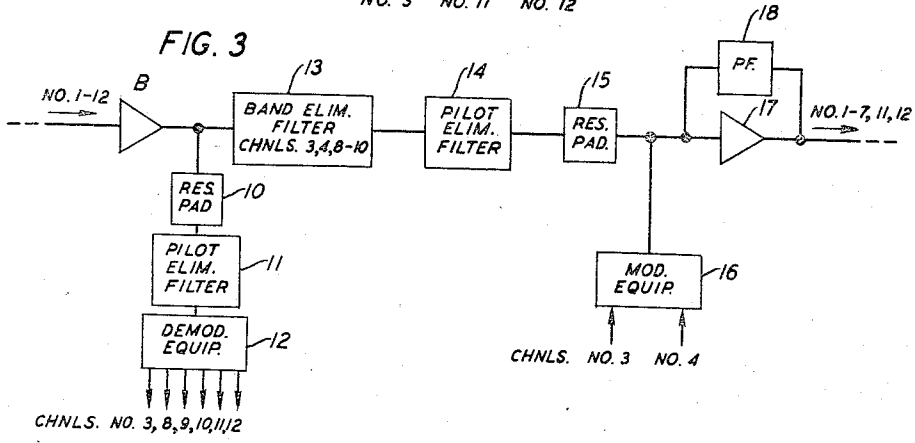
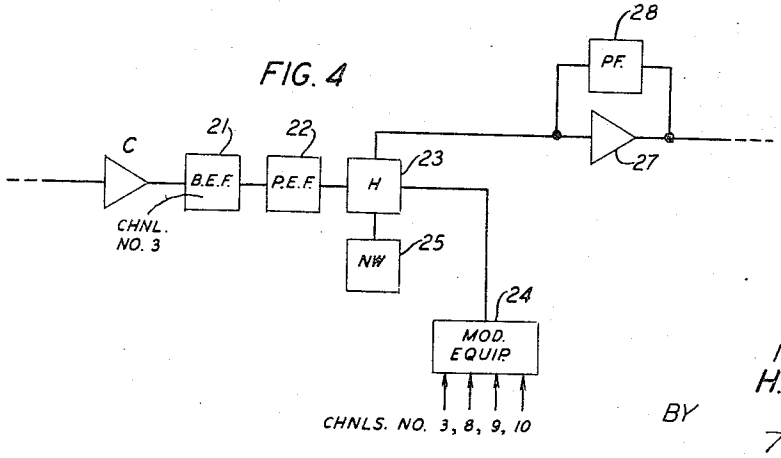


FIG. 4



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MULTICHANNEL SIGNAL TRANSMISSION

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6 Claims. (Cl. 178—44)

This invention relates to repeatered multichannel signaling systems in which auxiliary currents of modulated amplitude are transmitted concurrently with the signals and jointly with the signals control the transmission characteristics of the repeaters.

Signaling systems of this general character and components thereof are disclosed for example in United States patents to J. G. Kreer, No. 2,231,538; J. H. Bollman, No. 2,231,558; and C. O. Mallinckrodt, No. 2,231,542, all dated February 11, 1941. In a typical wire line system of this kind the different signals to be transmitted are assigned and translated to respective positions or channels in the frequency range accommodated by the transmission line and applied to the line concurrently with a pilot wave of non-signal frequency. The pilot wave is automatically varied in amplitude in synchronism with the fluctuations in the average intensity of the aggregate of signals and in such manner that the total power applied to the line, signal power plus pilot power, is maintained substantially constant at a predetermined value. If none of the channels are in use at a given time, the pilot alone provides the required constant power. If telephone signals appear in only one channel, the power contribution required of the pilot is reduced and the pilot varies oppositely in amplitude with the variations in signal amplitude that appear from one syllable to another. If several channels are in use, the time variation of pilot amplitude assumes a more complex form, but in all circumstances the fluctuations in initial pilot intensity are critically and quantitatively related to the fluctuations in the intensity of the aggregate of signals which are concurrently delivered to the line.

The repeaters in the transmission line of this typical system are of a self-regulating type in which the repeater gain is automatically controlled by the total power appearing at the repeater output, that is, by the sum of signal power and pilot power, and they are so arranged that the total power output is maintained substantially constant at a predetermined value despite the changes in total input power that variations in line attenuation produce. It has been shown heretofore that if the variations in line attenuation do not disturb the relative intensities of the signals on the one hand and the pilot on the other, accurate gain regulation of the repeaters may be obtained without incidental distortion of the telephone signals delivered to the receiving terminal station.

In any long distance multichannel system there may not be sufficient telephone traffic between its terminal stations to keep all channels busy most of the time, hence efficient utilization of the facilities requires that only some of the channels be reserved for interterminal transmission and that the other channels be made available for transmission between various other stations along the line. This involves diverting or dropping signals from one or more channels at some points, introducing or adding signals at other points and both dropping and adding signals at still other points. Whereas means have been devised for performing these operations in various types of systems known heretofore, as illustrated for example by United States patent to C. L. Weis, No. 2,038,202, the type of system under consideration presents a unique problem in view of the intimate quantitative relation between pilot and signal. Thus if signals be simply diverted from or introduced into a given channel or channels at a repeater station or other intermediate point, there would be a change in the average power content of the aggregate of signals and a change in the power-time characteristic, neither of which is compensated by corresponding changes in the pilot. In other words, while the fluctuations in pilot intensity are properly related to the aggregate of signals applied at the terminal station, they would bear no significant relation to the new aggregate of signals.

A principal object of the present invention is to permit more efficient utilization of the transmission facilities provided by a system of the kind described, to enhance the adaptability of the system to changing telephone traffic conditions, and more particularly to provide for the diversion and introduction of signals at intermediate points in a simple and economical manner consistent with the requirements for proper gain regulation.

The nature of the present invention and its various features, objects and advantages will appear from a consideration of the embodiments illustrated in the accompanying drawing and hereinafter to be described. In the drawing, Fig. 1 illustrates schematically a multichannel signaling system in accordance with the present invention with components thereof shown in detail in Figs. 2, 3 and 4.

Referring more particularly now to Fig. 1, there is shown schematically an extended portion of a one-way line system for the transmission of multiplex carrier telephone signals from a transmitting terminal station at the left to a distant

receiving terminal station (not shown). At various intermediate stations along the line provision is made for diverting signals from certain channels and for introducing signals into other channels in accordance with the invention. Although the system shown is adapted for transmission in only one direction between any two stations, it will be understood that the system may be paralleled with a similar system for transmission of signals in the opposite direction.

It will be assumed that the transmitting terminal 1 at the left provides for twelve carrier telephone channels lying adjacent each other in a frequency range extending from 12 kilocycles at the bottom edge of channel No. 1 to 60 kilocycles at the top edge of channel No. 12. The twelve channels are connected to the sending end of the toll transmission line 3. Pilot currents from source 2, having a frequency f of 61 kilocycles, for example, are modulated in accordance with the envelope of the total signal delivered by terminal 1 and applied concurrently with the signals to the line 3. The pilot modulation equipment may be so arranged as now known in the art that the total power applied to the line 3 is maintained substantially constant.

By way of further example it will be assumed that certain channels, No. 11 and No. 12, provide program circuits for the distribution of studio material to various radio transmitters which are connected into the line system at intermediate stations A1, A2, B and other distant stations not shown. These two channels may be used as a single channel of double width if desired. Another channel, No. 3, is utilized to establish a conference connection or the like between the transmitting terminal station and subscribers connected to the line at intermediate stations A1, A2 and B. This connection may be disestablished at will as will presently appear. This same channel No. 3 is utilized between station B and station A3 for a short haul connection, and while it is idle between station A3 and the following station C, it is again put into use at station C for transmission beyond that point. Still another channel, No. 4, is reserved for transmission from the transmitting station to station A2 and again for transmission from station B to a distant station not shown. Similarly channels 8 and 9 provide service between the transmitting terminal station and intermediate station B where they are dropped and not reintroduced until station C is reached. It will be understood that the intermediate stations shown may be many miles apart with a plurality of automatic gain regulating repeaters in each intervening section of the transmission line.

Fig. 2 shows schematically the channel diverting equipment associated with the A1 repeater. This is illustrative also of all of the repeater stations of the A type, that is, of the stations that need be adapted only to permit tapping off of one or more of the carrier channels.

As shown in Fig. 2, the total output of the repeater amplifier A1 is applied to the line terminals of a hybrid coil 5 to the net terminals of which is connected a balancing network 4. The hybrid coil 5 has two sets of output terminals and to one set is connected the end of the next section of transmission line 3. To the other set of output terminals is connected a group of parallel band-pass filters 6 each adapted to selectively transmit one of the channels 3, 11, 12, to be tapped at this repeater station. With each of the filters 6 there is associated an individual demodulator 7 and low-pass filter 8 which are adapted to reduce the carrier frequency signals to audio frequencies for application to a local telephone exchange, for example. Hybrid coil 5 can be and is so designed that the outgoing section of line 3 and the group of filters 6 are in conjugate relation to each other. With this arrangement, part of the power applied to the hybrid coil is absorbed in the diverting equipment and the remainder is transmitted over the outgoing line 3, the loss in power due to absorption being uniformly distributed over the frequency range. If the hybrid coil is of the inequality ratio type, any fraction of the total power, seven-eighths for example, can be delivered to the line and the remainder, one-eighth, diverted.

The loss in power experienced at hybrid coil 5, assuming equal diversion of power, is three decibels and the same at all frequencies transmitted. It is such therefore as not to disturb the relative power content of the signals on the one hand and the modulated pilot current on the other. Hence no distortion appears at the next regulated repeater and the latter simply operates automatically to compensate for the three decibel transmission loss. All twelve channels therefore continue through the intermediate station A1.

Although all twelve channels and the modulated pilot appear at the input terminals of the band-pass filters 6, only the three desired channels are transmitted therethrough; the rest of the power is dissipated. Any of the channel diverting circuits may be disconnected at will without affecting the operation of the system and No. 3 is provided with a switch 9 for this purpose. Likewise, other channels may be diverted by provision of suitable filtering and demodulating equipment. In accordance with a feature of the invention, each of the band-pass filters 6 is designed to present an input impedance that is uniform over the entire frequency range occupied by the twelve channels and modulated pilot so that if the input impedance of the group of filters is reflected in any degree into the through transmission path the effect will be the same at all frequencies and not disturb the relative power content of the various transmitted currents. This feature relaxes somewhat the requirements to be met by hybrid coil 5 and its balancing network 4.

The equipment at intermediate station A2 of Fig. 1 may be the same as that shown in Fig. 2 except for the addition of a filter and demodulator for channel No. 4. Although the signals in channel No. 4 are destined only for a subscriber connected to station A2, it will be noted that the signals are not completely removed from the line at this point but are allowed to continue through the next section of line along with the other eleven channels.

At station B of Fig. 1 equipment of the kind represented schematically in Fig. 3 may be employed to effect the routing of traffic prescribed for this station. At a point immediately following the gain regulated repeater B, channels Nos. 3 and 8 to 12 are tapped off through a resistance pad 10 and a filter system 11 adapted to suppress the modulated pilot, and applied to the demodulating equipment 12 for translation to voice frequency. Inasmuch as the resistance pad 10 has the same shunting effect at all frequencies, the various frequencies passing the tapping off point are equally affected. Following repeater B in circuit is a band elimination filter

13 which is designed to suppress the modulated pilot and the currents in channels 3, 4 and 8 to 10. Any vestige of the modulated pilot that may leak through filter 13 is substantially completely eliminated by pilot elimination filter 14. It is to be noted that the filter 13 clears the line of the signals in channel 4 as well as the signals in channels 3 and 8 to 10, which, as assumed hereinbefore, terminate at station B. The channels so interrupted may be said to be blocked, which is to be distinguished from the mere tapping-off of signals. On the other hand channels 1, 2, 5, 6, 7, 11 and 12 continue through the repeater B and line filters 13 and 14.

The channels that are to be continued through station B are applied through a resistance pad 15 to the input of a modulator-amplifier 17 together with locally supplied signals that are translated by modulating equipment 16 to the frequency range of channels Nos. 3 and 4 respectively. Amplifier 17 is of a type such as disclosed in the Mallinckrodt patent, supra, that is adapted to generate oscillations at a frequency fixed by a pilot filter 18 in a positive feedback path and to modulate the oscillations generated in accordance with the total signal input so that the total power output is substantially constant. The output of amplifier 17 therefore consists of the signals in channels Nos. 1 to 7, 11 and 12 and a variable pilot that is modulated in differential relation to the signal power in these particular channels.

At station A3, the signals in channel No. 3 are diverted by apparatus of the kind described with reference to Fig. 2.

At station C, apparatus of the kind illustrated in Fig. 4 is provided to clear the line of any channels unnecessarily carrying signals, viz. channel No. 3, and to reestablish or introduce channels needed for transmission from point C forward. A band elimination filter 21 following repeater C suppresses channel No. 3 and permits the other channels in use to pass through a filter 22 to hybrid coil 23. Filter 22 is adapted to suppress the modulated pilot generated at station B. The channels, Nos. 3, 8, 9 and 10, which it is assumed are to be reestablished on the line at station C are provided by modulating equipment 24 which is connected by hybrid coil 23 in conjugate relation to the output of repeater C. A balancing network 25 is connected to a third pair of terminals on the hybrid coil and the fourth pair of terminals is connected to the outgoing section of transmission line through an amplifier 27. The latter is like amplifier 17 of Fig. 3 in that it is provided with an oscillation generating loop including filter 28 and arranged to modulate the oscillations generated under the control of the signal supply to maintain the total power output constant. The conjugacy afforded by hybrid coil 23 eliminates interaction between the filters 21 and 22 and the output filters of the modulating equipment 24, thus simplifying the design requirements for all of these filters.

Although in Figs. 3 and 4 the frequency of the substitute pilot generated in amplifiers 17 and 27, respectively, may be entirely different from that of the suppressed pilot, important advantages can be secured in accordance with a feature of the invention now to be explained if the frequency difference is small or zero.

It may be readily appreciated that the comparatively intense pilot oscillation in a system of the kind described tend to intermodulate with other currents in the system, such as message currents and signaling and ringing currents in the several channels, and that the products of modulation may appear as substantial distortion components in various channels. The most troublesome of these modulation products is the third order difference product of the form $2a-b$, which is of such nature that the distortion products generated at one point tend to combine in phase with the same products generated at all other points in the system. This in-phase addition of the products generated at different points may be avoided and a neutralizing or opposing phase relation derived by reversing the relative phase of the frequency component b at one or more of the repeaters or other points where the intermodulation occurs. If in Figs. 3 and 4 therefore the substitute pilot oscillations are of exactly the same frequency as the pilot oscillations in the preceding line section but reversed in phase relative to the signals, all of the $2a-b$ products involving the pilot and generated at the several repeaters in the following section of line will combine in phase opposition with the like products generated in the preceding section. Thus the system may be separated by pilot elimination filters into a multiplicity of sections with a separate pilot source for each section, and the relative phase of the pilot delivered to each section so adjusted that the $2a-b$ modulation products generated in half of the sections combine in phase opposition with the like products generated in the other half. This may be done even though no channels are introduced or diverted along the line.

Whereas the arrangement last described would require synchronization of the several pilot sources, substantial reduction of the $2a-b$ products may be realized also if the frequencies of the several pilot sources do not differ by more than a small amount. For example, if the difference is one-tenth or one-hundredth of a cycle per second, then there is established a beat frequency period of ten or one hundred seconds during part of which the $2a-b$ products are additive in phase and during another part of which they are additive in phase opposition. This illustrates that the improvement as compared with in-phase addition at all points is proportional to the square root of the number of sections.

What is claimed is:

1. In a multichannel carrier signaling system in which there is transmitted, concurrently with the signals in the several channels, a pilot wave so modulated that the average intensity of the signals and pilot wave combined is initially substantially constant and in which a transmission characteristic of the system is regulated at repeater points under the control of said signals and pilot wave jointly, the method which comprises partially diverting signals from less than all of said channels at one point along said system, blocking through transmission of the said pilot wave and channels from which signals have been partially diverted, combining channels to be added with the unblocked channels, applying a new pilot wave for transmission concurrently with signals in the combined channels, and modulating said new pilot wave under the control of said last-mentioned signals to maintain the intensity of the said last-mentioned signals and new pilot wave combined substantially constant.

2. In a signaling system of the kind described, the method which comprises establishing multiplex carrier channels for the long distance transmission of signals, transmitting concurrently

with the signals pilot oscillations so modulated that the average intensity of the signals and oscillations combined is initially substantially constant, partially diverting signals from less than all of said channels at an intermediate point along said system, compensating for differences in relative transmission levels, arising from the aforesaid partial diversion, as between the pilot oscillations and the several channels whereby the total transmission loss incident to the diversion is equally distributed over the frequency range, and at a subsequent point regulating a transmission characteristic of the system under the control of the transmitted signals and oscillations combined.

3. The method defined in claim 2 comprising the additional step of blocking the channels from which said signals are diverted at a point in the system following said subsequent point.

4. A repeatered multichannel signaling system of the kind described, in which pilot oscillations, modulated in predetermined relation to the variations in average intensity of the transmitted signals, are transmitted concurrently with the signals and utilized jointly with the signals for automatic regulation of the gain of repeaters in the system, said system including means for partially diverting signals from less than all of the channels at an intermediate point, said means comprising frequency selective equipment for the channels to be diverted, and hybrid connecting means coupling said selective equipment in energy transfer relation with all of the channels incoming at said point and in conjugate relation with all of the outgoing channels, said connecting means having a transmission loss characteristic for through transmission that is substantially flat throughout the range of frequencies transmitted, whereby the aforesaid predetermined relation between the modulated pilot and the average intensity of the transmitted signals is preserved.

5. A combination in accordance with claim 4 in which said frequency selective equipment presents to said connecting means an impedance that is uniform throughout the transmitted frequency range.

6. The method in accordance with claim 1 which comprises maintaining the frequency of said new pilot wave substantially the same as the frequency of the first-mentioned pilot wave.

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