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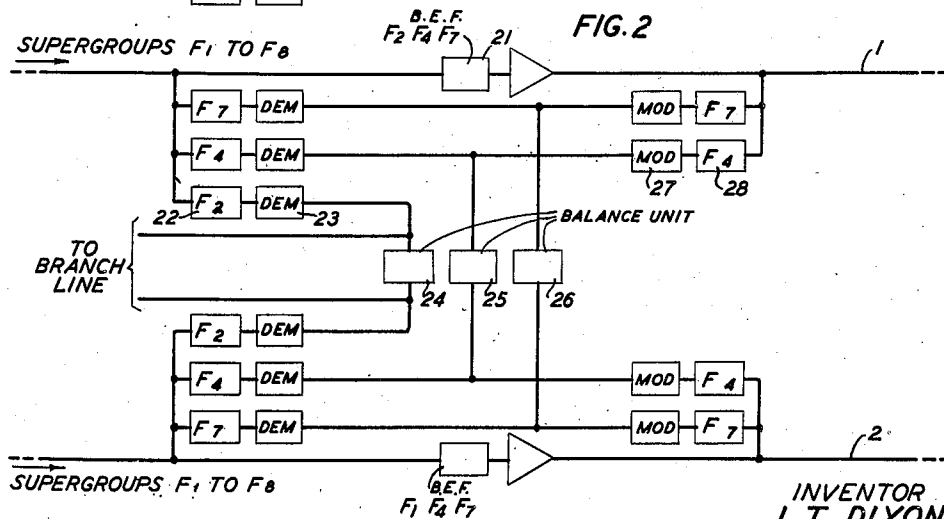
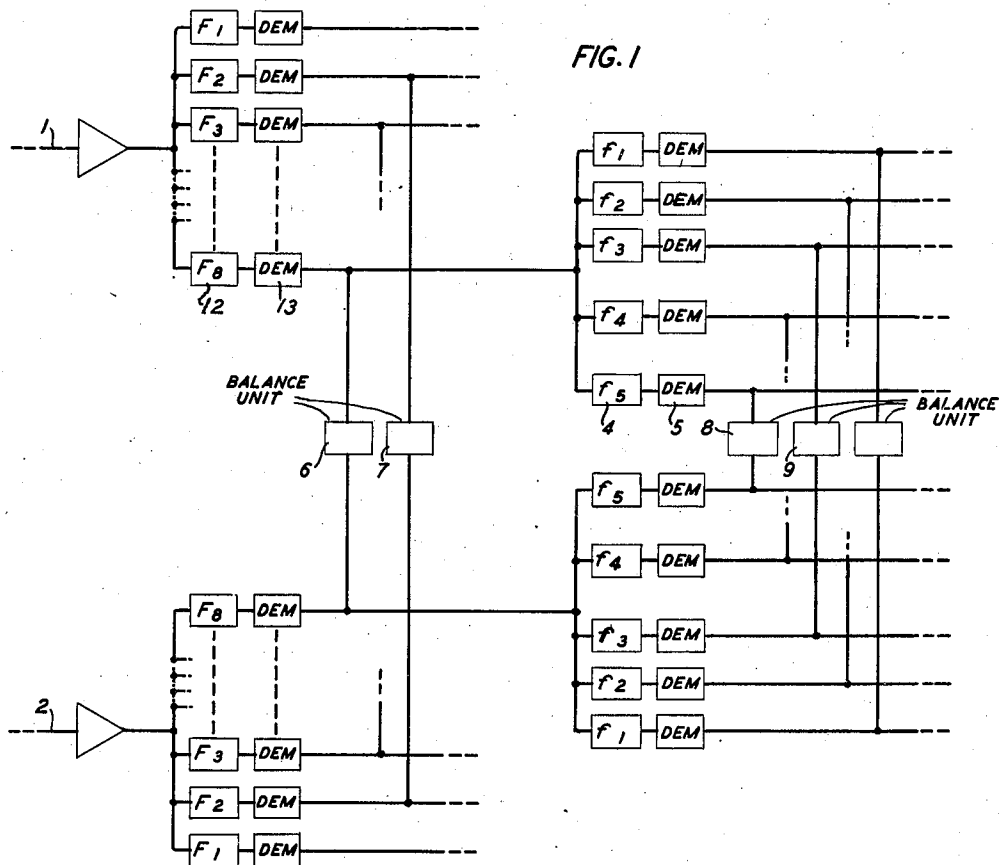
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REDUCTION OF CROSS-TALK

Filed April 26, 1941

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 3

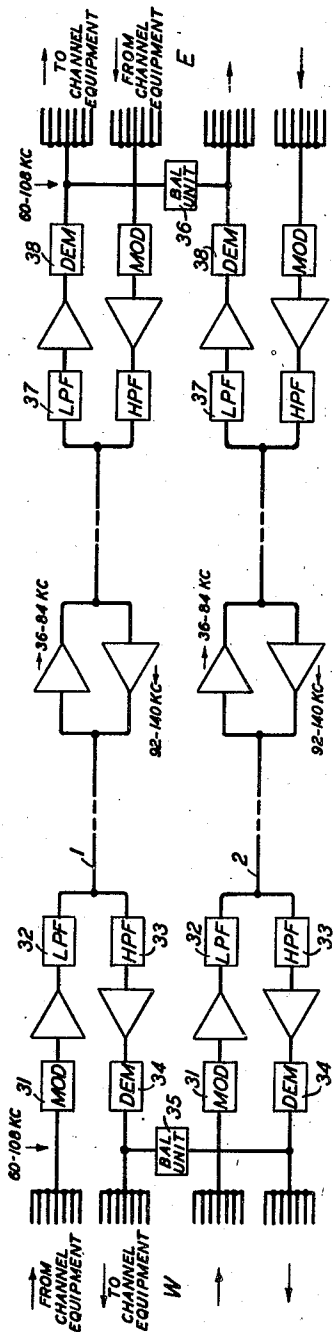
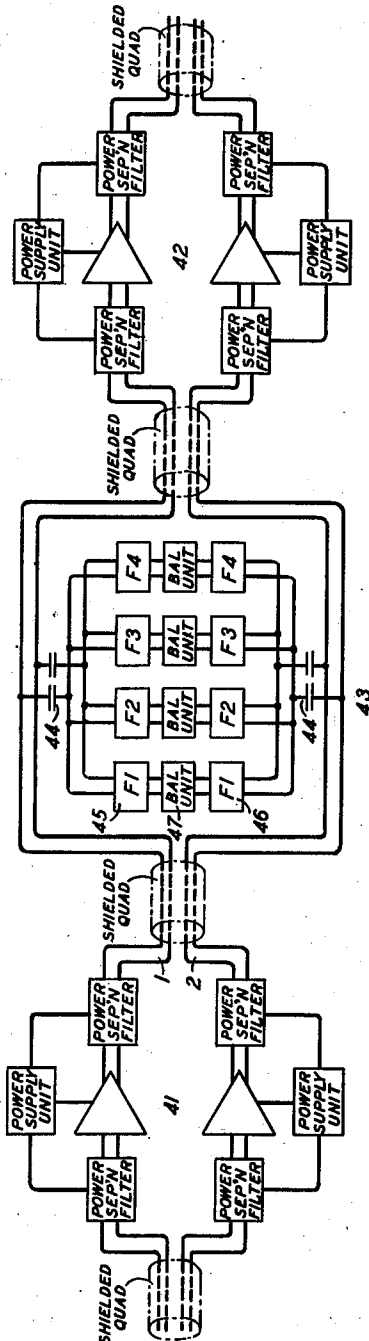


FIG. 4



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REDUCTION OF CROSS TALK

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This invention relates to systems for the transmission of signals occupying a wide frequency range and more particularly to the reduction or neutralization of inter-circuit cross-talk in such systems.

It is well known that where signaling lines parallel each other for any considerable distance, the signaling current in each line tends to induce disturbing cross-talk currents in the others. To reduce the disturbing effect it is the practice to couple each pair of lines with a cross-talk balancing unit which is designed and adjusted to introduce cross-talk currents of such phase and magnitude as to neutralize or at least substantially reduce the cross-talk that is due to undesired couplings between the lines. Inasmuch as the amplitude and phase of the coupling between the lines vary with frequency, the balancing unit must have a coupling characteristic that is likewise non-uniform with respect to frequency and this characteristic must be maintained over the entire range of coupling values provided by the unit. It will be appreciated that the wider the frequency range to be accommodated by the balancing unit the greater the difficulty and complexity involved in fulfilling these requirements.

The principal object of the present invention is to reduce the stringency of the requirements on the individual balancing units or to improve the accuracy of cross-talk balancing or both.

In accordance with a feature of the present invention, the line frequency range occupied by the signals in a wide band signaling system is broken up into narrower bands for the application of cross-talk balancing. More particularly in accordance with one feature, cross-talk balancing is applied to bands of signals derived by one or more stages of modulation or demodulation at points in the system where such modulation or demodulation is required for signal routing purposes.

In accordance with another feature the line frequency range is successively subdivided into component bands by demodulation, and cross-talk balancing is applied to a plurality of the successive subdivisions.

The nature of the present invention and its various features, objects and advantages will appear more fully from a consideration of the several embodiments illustrated in the accompanying drawings and now to be described.

In the drawings:

Figs. 1, 2 and 3 illustrate embodiments of the invention in which cross-talk balancing is ap-

plied to demodulated signal components; and Fig. 4 illustrates an embodiment of the invention in which cross-talk balancing is applied to subdivisions of the line frequency range without frequency translation.

Fig. 1 is a block diagram showing schematically a receiving terminal in a multiplex carrier telephone system adapted to receive and separate the various message channels incoming over transmission lines 1 and 2. It may be assumed that the two lines comprise separate circuits in a multipair cable or that they are otherwise in cross-talk producing relation.

It will be assumed for specific example that each of the lines 1 and 2 carries a multiplex of carrier telephone channels ranging in frequency from 64 to 2064 kilocycles per second. In the receiving process the message currents taken from each line are first separated by filters 12 into a multiplicity of sub-bands and these are applied to respective demodulating equipments 13 by means of which all of the sub-bands are translated to the same frequency range. Thus the two-million cycle band of line frequencies may be divided into eight sub-bands or supergroups of about 250 kilocycles each, each supergroup then being translated to the frequency range 312 to 552 kilocycles, due allowance being made for space between channels. Each demodulated supergroup is then divided into its component groups by filters 4 and these are translated by individual demodulating equipments 5 to a common group frequency range. Thus there may be five groups each having a width of about 48 kilocycles, and the common frequency range may lie between 60 and 108 kilocycles. By a further stage of demodulation (not illustrated) the groups may, in turn, be separated into their component channels and the latter reduced to voice frequency.

Whatever the particular manner of subdivision in the successive stages of the demodulation may be, it is the same for both of the lines 1 and 2. With this identity of treatment, it follows that any pair of supergroups that occupied the same frequency position on the two lines and which therefore were in cross-talk relation, will be brought out from the respective demodulating equipments 13 with unchanged total band width and occupying identical positions in the frequency spectrum. Similarly any pair of cross-talking groups on the respective transmission lines 1 and 2 are eventually isolated from all other groups and brought out from demodulators 5 at the same frequency level. Likewise,

of course, the individual channels are eventually isolated and brought out at voice frequencies.

To effect the cross-talk balancing between one supergroup and another, a balancing unit, such as 6 or 7, is coupled between the outputs of the respectively corresponding demodulators 13. Each of the balancing units 6, 7, etc. is required to be effective only over the common supergroup frequency range of 312 to 552 kilocycles. The frequency characteristics of these balancing units, however, are not quite alike for it should be appreciated that whereas the balancing is effected at the same supergroup frequency level, the cross-talk to be neutralized arises at different line frequencies involving different cross-talk frequency characteristics. That is, for example, balancing unit 6 may introduce a coupling which increases sharply with frequency if at line frequencies the supergroups it connects are subject to a sharply increasing cross-talk frequency intercoupling. On the other hand at the line frequencies occupied by another pair of supergroups, the cross-talk frequency characteristic may be comparatively flat with respect to frequency, in which case the corresponding cross-talk balancing unit 7 is designed to have a correspondingly flat transmission-frequency characteristic for all settings.

Whether or not any corresponding pair of supergroups are connected in cross-talk balancing relation, one or more of the pairs of group components thereof may be coupled by balancing units 8, 9, etc. at the outputs of the respectively corresponding demodulator equipments 5. Balancing units 8, 9, etc. are all alike with respect to the frequency range for which they are adapted, viz., 60 to 108 kilocycles, and they differ from each other in that their respective transmission-frequency characteristics are designed to match the cross-talk coupling-frequency characteristics obtaining at the line frequencies of the respectively corresponding groups.

The arrangement described with reference to Fig. 1 is a flexible and economical one well adapted to cope with any intercircuit cross-talk characteristic that may be encountered. With some types of lines, for example, the cross-talk in a particular supergroup frequency range may be comparatively small or it may be a simple function of frequency, and in either of these cases it may suffice to provide for terminal cross-talk balancing only between the supergroup pairs and not between the pairs of component subgroups. In another line frequency range on the other hand, the cross-talk may be comparatively great and therefore require accurate cross-talk balancing, or it may be so non-uniform with respect to frequency that it is difficult to obtain accurate balancing over the frequency range of a supergroup with a single balancing unit. In either of these latter cases the balancing units 6, 7, etc. may be of simple construction and adapted to provide an approximate cross-talk balance, and the residual or uncompensated cross-talk may be counteracted with the necessary degree of accuracy by means of the intergroup balancing units 8, 9, etc. Obviously these same principles may be extended, if desired, to individual balancing of the voice frequency channels.

Whereas Fig. 1 illustrates the invention as embodied in a receiving terminal station, the invention has application also to the reduction of cross-talk at intermediate points of the system, as for example at repeater stations.

Fig. 2 illustrates schematically a repeater sta-

tion adapted for a system of the kind described with reference to Fig. 1 and provided with cross-talk balancing equipment in accordance with the invention. At the repeater station shown it may be supposed that the cross-talk on the line in certain supergroups has become undesirably large and that reduction of the cross-talk in these frequency ranges is desired.

As illustrated, it is further supposed that one supergroup is to be diverted from each of the two lines for transfer to a branch line. Assuming for specific example that supergroup No. 2 is the one that is to be transferred to a branch line and that supergroups No. 4 and No. 7 are the ones with excessive cross-talk, these three supergroups are barred from the repeater amplifier in each line by a band elimination filter 21 and they are separately diverted from the line by appropriate band-passing supergroup filters 22. All three are then passed through demodulating equipments 23 which may be the same as the demodulators 13 of Fig. 1. The demodulated supergroup No. 2 is then brought out for application to modulating equipment associated with the branch line, and a supergroup cross-talk balancing unit 24 is connected between the outputs of the corresponding pair of demodulating equipments 23. The other two demodulated supergroups are restored to their line frequencies by means of respective modulators 27 and applied to the outgoing lines through filters 23.

Balancing unit 25 interconnects the pair of demodulated supergroups No. 4 and balancing unit 26 is similarly provided for the pair of No. 7 supergroups. As in the case of Fig. 1, the supergroup balancing units are each designed for a limited frequency range and each has a transmission-frequency characteristic appropriate to the line frequency of its associated supergroups.

In the embodiment of the invention illustrated in Fig. 3, two terminal stations E and W are connected by a pair of transmission lines 1 and 2, each of which is arranged for the transmission of a plurality of carrier telephone channels in the W—E direction in one frequency range and for the transmission of a multiplicity of channels in the opposite direction in another frequency range. A far-end cross-talk problem is presented inasmuch as each set of signals in the one line cross-talks into the like-directed set of signals in the other line. Difficulty is encountered in applying prior art cross-talk balancing methods in a case of this kind, because balancing units applied to the line conductors tend to introduce a near-end cross-talk coupling which may degrade other circuits on the line. For example, if a voice frequency circuit with a two-wire repeater were operated in the frequency range below the carrier system on each of the pairs 1 and 2 of Fig. 3, a balancing unit connected between the pairs to reduce far-end cross-talk between the carrier systems would permit a transfer of voice frequency energy from the output of the W—E voice repeater on pair 1 to the input of the E—W voice repeater on pair 2 or vice versa, thus producing near-end cross-talk between the voice frequency systems. This cross-talk is, of course, made more serious by the differences in level between the voice repeater outputs and inputs. These difficulties are largely avoided and other advantages secured by the arrangement illustrated and discussed below.

For transmission in W—E direction over either line, the several carrier telephone channels from

the respectively corresponding channel transmitting equipment are assembled in a single band ranging for example from 60 to 108 kilocycles. This group is then passed through its respective modulator 31, amplified and applied to line 1 or 2 through a low-pass filter 32. The line frequency range for this group may be 36 to 84 kilocycles. The east terminal is assumed to be arranged similarly to apply to each of the lines a band of carrier telephone channels having a line frequency range of 92 to 140 kilocycles. The receiving equipment at the west terminal comprises for each line a high-pass filter 33 and a demodulator 34 adapted to translate the line frequency band of 92 to 140 kilocycles to the 60 to 108 kilocycle range. The east terminal is similarly provided with low-pass filters 37 and demodulators 38 adapted to translate the incoming pairs of 36 to 84 kilocycle bands to the 60 to 108 kilocycle range for application to the channel equipment.

For the reduction of cross-talk a balancing unit 35 is connected between the outputs of the two receiving demodulators 34 at the west terminal and a balancing unit 36 is similarly connected between the outputs of the receiving demodulators 38 at the east terminal. Whereas the line frequency range involved in the production of cross-talk is 36 to 140 kilocycles, each of the balancing units need be adapted to cover only half of this range and the problem of simultaneously balancing oppositely directed channels for cross-talk is avoided. Each balancing unit is designed to introduce a frequency characteristic corresponding to the interline coupling characteristic in one or the other of the two line frequency ranges.

In any of the systems illustrated in Figs. 1, 2 and 3 it may be necessary or desirable to compensate for any differences in the phase shifts introduced by the modulators or demodulators in the cross-talking circuits. This may be done and greater precision of balancing insured by incorporating compensating phase shift in the modulator or demodulator equipments or in the balancing units.

Fig. 4 shows an embodiment of the present invention in which cross-talk balancing is effected on the line and at line frequencies, the latter being subdivided in the cross-talk balancing equipment into groups, without frequency translation, and separately balanced from cross-talk. The system shown may be a part of that described with reference to Fig. 1, and it will be assumed for purposes of exposition that it is and that the line frequencies involved are therefore the same, viz., 64 to 2064 kilocycles. The two transmission lines 1 and 2 are illustrated as comprising separate pairs which may form a quad under a common shield or sheath, for example. Two successive repeater stations 41 and 42 are shown and each comprises a pair of repeater amplifiers for W—E transmission through the two lines. Associated with each repeater amplifier is a pair of power separation filters so that direct current or low frequency power supplied over the respective pairs may be passed around each repeater amplifier for through transmission and a part diverted for energizing the power supply unit of the amplifier. Similar arrangements are, of course, provided for E—W transmission at the repeater stations.

Midway between the two repeater stations is a cross-talk balancing station 43. At this point the message currents are taken off each line through a respective set of power blocking con-

densers 44 and separated by a respective set of band-pass filters 45, 46 into their respective component frequency bands. Each filter 45 is then connected through a balancing unit 47 to a filter 46 that covers the same line frequency range. An advantage with respect to ease and accuracy of cross-talk balancing may be obtained by correlating the sub-division of the line frequency range at balancing station 43 with the subdivision that is effected at the terminal stations as shown in Fig. 1. Whereas eight pairs of filters 45, 46, each adapted to select one of the supergroups on the line, might therefore be employed to advantage, only four such pairs are indicated. Suitable correlation of the kind contemplated, however, may be obtained by designing each pair of these filters to pass two adjoining supergroups. Alternatively, however, the band widths may be unequal, and specifically, for example, the width of each band may be adjusted so that it is a fixed fraction of the mean band frequency. Alternatively, too, balancing station 43 may coincide with a repeater station, in which case the power separation filters can serve in lieu of power blocking elements 44.

Whatever the particular manner of line frequency subdivision may be at the balancing station 43, each of the balancing units need be adapted to cover only a fraction of the total line frequency range. As in the other embodiments described hereinbefore, each of the balancing units introduces constant frequency weighting according to the line frequencies involved in the balancing circuit.

In a complete transmission system, a balancing arrangement of the kind shown in Fig. 4 may be utilized in each repeater section, or in occasional repeater sections, to effect approximate cross-talk balancing in the several major subdivisions of the line frequency range, and balancing units 47 of exceedingly simple construction may be employed for this purpose. At longer intervals the arrangement shown in Fig. 2 may be employed if certain major groups need special attention, and the balancing units 25, 26, may in this case have fairly precise coupling-frequency characteristics. At the receiving terminal of the system, the arrangement shown in Fig. 1 may be employed to reduce the residual cross-talk to a tolerable value in all supergroups, groups, or channels where such additional balancing is required.

Although the present invention has been described with reference to several illustrative embodiments thereof, these embodiments are not intended to be limitative, for the invention is susceptible of application in various other forms within the spirit and scope of the appended claims.

What is claimed is:

1. In combination, a pair of long distance transmission lines in cross-talking relation both carrying signals in the same wide carrier frequency range, means at a signal receiving point common to said lines for separating the signal frequencies on each line into a multiplicity of groups, means for translating the separated groups to the same frequency position, means for bring a plurality of the translated groups from the one line into cross-talk balancing relation with the respectively corresponding translated groups from the other line, means for further subdividing said last-mentioned translated groups into subgroups, means for translating said subgroups to a common frequency position, and means for bringing at least one of said trans-

lated subgroups into cross-talk balancing relation with the corresponding translated subgroup from the other line.

2. In combination with a pair of long distance transmission lines that carry multiplex carrier telephone signals in the same frequency range and in the same direction of transmission, said lines lying adjacent each other over a substantial portion of their length, frequency selective means adapted to divert signals occupying a fractional part of the total frequency range occupied by signals on one of said lines, frequency selective means adapted to divert from the other of said lines signals occupying the same fractional part of the line frequency range; and a cross-talk balancing coupling between said frequency selective means.

3. A long distance signaling system comprising a pair of transmission lines in cross-talk producing relation, means for transmitting through both of said lines in the same direction of transmission respective sets of multiplex carrier telephone signals occupying the same frequency range in both of said lines, means for transmitting in the opposite direction over both of said lines respective sets of multiplex carrier telephone signals occupying another common frequency range, frequency selective receiving means at a point common to both of said lines for separately receiving like directed sets of signals, means for translating said selected sets of signals to another common frequency range and means for cross-talk balancing the translated sets.

4. In combination, a pair of long distance transmission lines that are in cross-talk producing relation substantially throughout their length, means for transmitting through both of said lines in the same direction of transmission respective sets of multiplex carrier tele-

phone channels, said sets occupying the same line frequency range and comprising a multiplicity of groups of channels, frequency selective means for selectively diverting from each of said lines and separating from each other a plurality of said groups of channels, and means coupling the respective groups of channels selected from the one line into cross-talk balancing relation at line frequencies with the respectively corresponding groups selected from the other line.

5. A combination in accordance with claim 4 comprising in addition terminal circuit means adapted to select and receive said groups of channels, means for demodulating said groups of received channels to an intermediate carrier frequency range, and means for cross-talk balancing the separated, demodulated groups.

6. In a system comprising a pair of multichannel carrier signaling circuits each carrying a multiplicity of signals in individual frequency bands, the method of reducing cross-talk between the circuits which comprises separating the signals of both circuits into groups of signals occupying substantially contiguous frequency bands and cross-talk balancing the separated groups of the one circuit against the respectively corresponding separated groups of the other circuit.

7. In a system comprising a pair of like-directed multiplex carrier telephone transmission circuits, the method of reducing intercircuit cross-talk which comprises selectively receiving constituent groups of carrier telephone signals from each of said circuits, translating said selected groups to the same frequency range and cross-talk balancing the translated groups from the one circuit against the translated groups from the other circuit.

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