

April 18, 1939.

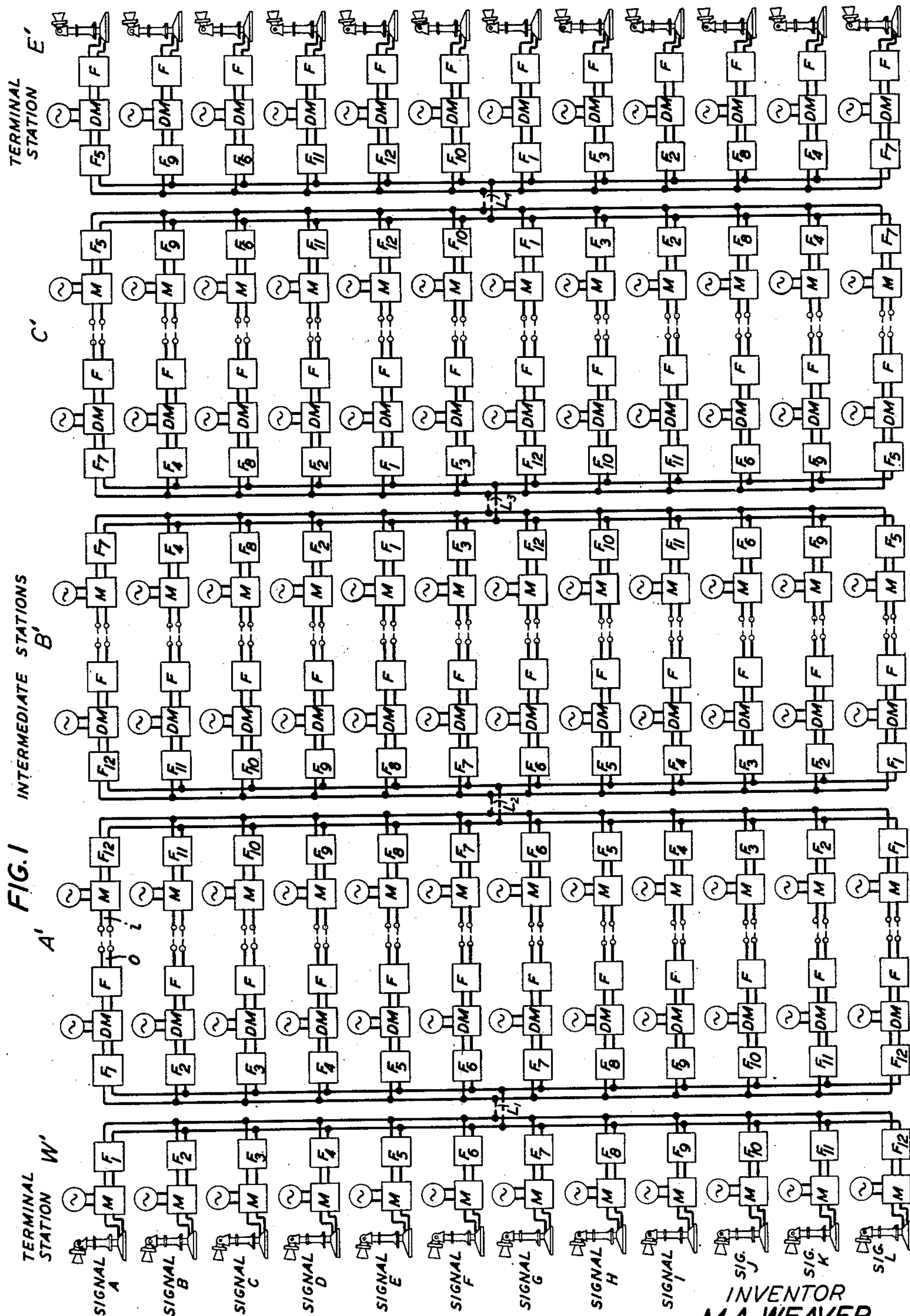
M. A. WEAVER

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MULTIPLEX CARRIER WAVE TRANSMISSION

Filed Sept. 9, 1937

2 Sheets-Sheet 1



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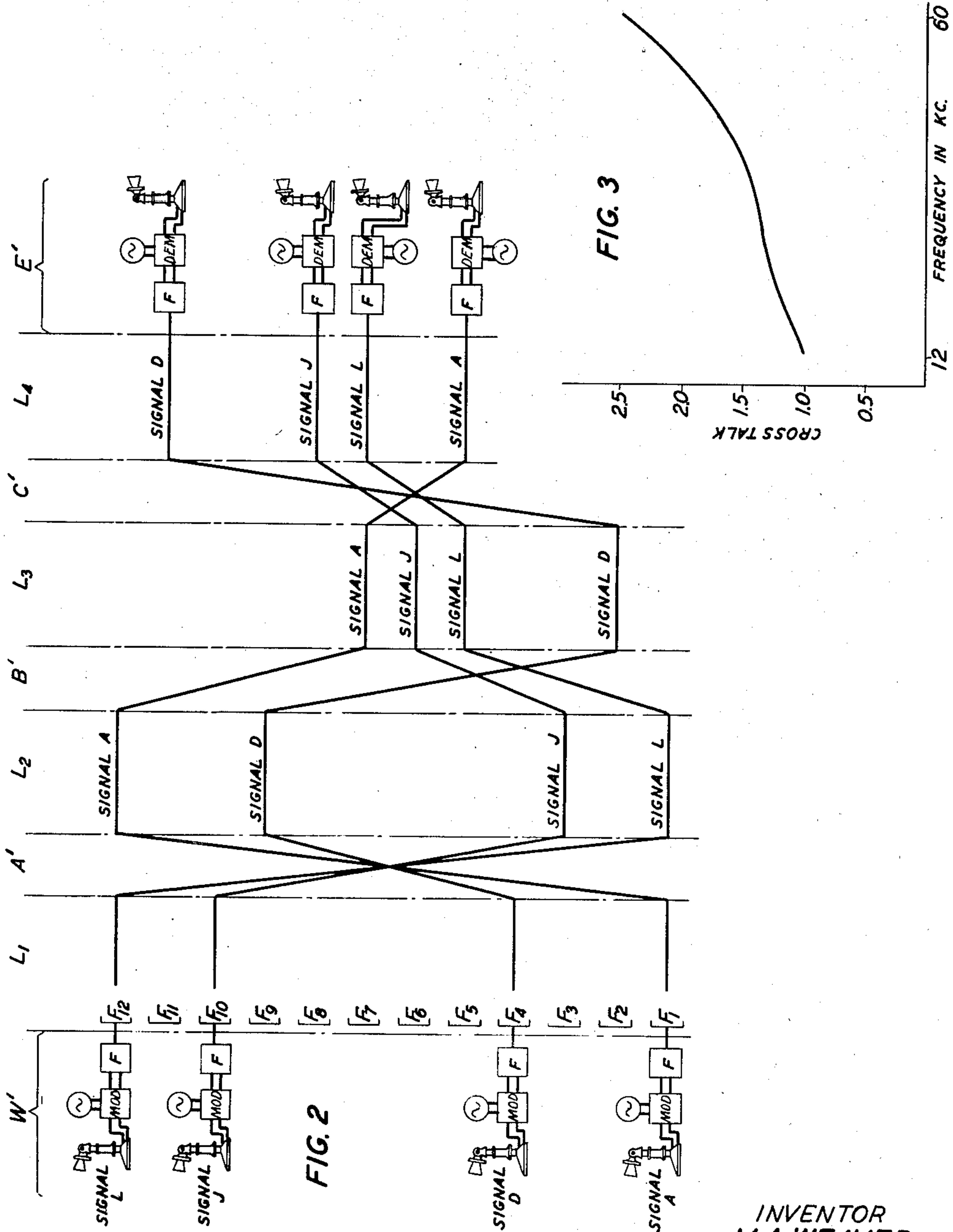
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MULTIPLEX CARRIER WAVE TRANSMISSION

Filed Sept. 9, 1937

2 Sheets-Sheet 2



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2,154,594

MULTIPLEX CARRIER WAVE
TRANSMISSIONMyron Alexander Weaver, Rye, N. Y., assignor to
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Application September 9, 1937, Serial No. 163,117

5 Claims. (Cl. 179—78)

This invention relates to carrier wave communication systems, and more particularly to multiplex transmission systems and to the reduction of the effects thereon of atmospheric disturbances, cross-talk, noise or the like.

Most, if not all, carrier communication systems are affected in some degree by electrical disturbances that arise in the system and tend to interfere with the intelligence bearing waves to be transmitted. In nearly all cases the disturbing effects are not of the same intensity throughout the operating frequency range but are a function of frequency. Thus, for specific example, in open wire carrier systems static and cross-talk from adjacent carrier systems tend to increase with frequency; in shielded transmission systems, such for example, as a coaxial conductor system, the noise due to atmospheric disturbances decreases with frequency; and in cables where the circuits are separated by an effective shield, cross-talk between circuits tends to decrease with increase in frequency. Where signals are transmitted over any such system in a multiplicity of respective frequency bands, some signals are therefore subjected to greater interference than others. Some carrier circuits, accordingly, may be excessively noisy whereas others may be unnecessarily quiet; but it is the condition of the noisiest circuit that is the limiting factor in the design of the system.

In accordance with the present invention, each signal is not transmitted throughout the length of the multiplex system in a respective frequency band or channel, but it is systematically assigned to successively different channels as it progresses through the system. The system of successive assignments is such that the intensity of disturbing noise, cross-talk or the like is substantially the same for all circuits; and substantially less than it would be in the noisiest circuit if the signals were confined to respective frequency channels.

The nature of the present invention, its advantages and its features will more fully appear in the following description of specific systems embodying the invention, reference being made to the accompanying drawings in which:

Figures 1 and 2 show schematically a multiplex carrier telephone wire transmission system embodying the invention; and

Fig. 3 is a graph showing a typical disturbance-frequency characteristic.

Referring now more particularly to Fig. 1, the specific illustrative embodiment of the invention therein depicted comprises a twelve-channel

multiplex carrier wave telephone system suitable for wire line transmission from a terminal station W' to another terminal station E, perhaps four thousand miles distant. At several points along the system are intermediate stations A', B' and C' which are presumably located in large cities, and connecting the several stations are the transmission lines L₁, L₂, L₃ and L₄ each roughly one thousand miles in length. These lines may be of any form suitable for carrier wave telephone signals, such as an open wire line, a coaxial pair, or an ordinary shielded or non-shielded pair in a multi-pair cable, but the last-mentioned form will be assumed for purposes of further discussion.

At terminal station W', modulating means M and band filters F₁, F₂, F₃, etc., are provided for impressing twelve different signals, speech signals in this case, on respective carrier waves so that the resulting bands of signal-modulated waves occupy respective, adjacent positions in the frequency spectrum ranging for specific example from 12 kilocycles to 60 kilocycles. These waves are then applied to the transmission line L₁ for transmission thereover to the first intermediate station A'.

Each signal is designated by a letter A, B, C, D, etc. and the carrier wave on which it is impressed may be designated by its frequency f_1 , f_2 , f_3 , etc. The latter designations may be understood to apply also to the carrier frequency channels through which the signal-modulated waves are transmitted, f_1 representing the channel of lowest frequency.

At the first intermediate station A', the various signal bands arriving over the line L₁ are separated by band filters F₁, F₂, F₃, etc. and the signals are reduced to their original voice frequency by demodulating means DM and voice frequency filters F which are now well-known in the art. These various signals are then made to appear at respective output terminals o at the intermediate station. On another panel at the same station are the input terminals i which may be cross-connected to any of the output terminals o. Each input terminal is associated with means similar to those at the terminal station W' for impressing applied voice frequency waves on a respective carrier wave, so that again twelve bands of signal-modulated waves may be obtained and applied to the transmission line L₂.

The voice frequency patching or cross-connecting bay comprising the two aforementioned panels permits the connection of local subscribers' circuits into the transcontinental car-

rier system, but this feature is not so important with respect to the objects of the present invention as the manner in which through calls are passed from one panel to the other. More specifically, in accordance with an embodiment of the present invention, signal A arriving over carrier channel f_1 of lowest frequency is patched to carrier channel f_{12} of highest frequency and the other signals are similarly patched to effect a frequency inversion of the 12-60 kilocycle band.

At the next intermediate station B' it will be found that there is not as great disparity in the relative cross-talk levels in the several channels as there was at station A', for no one signal has occupied a comparatively noisy channel for more than half the distance from the terminal station W'. Repeated frequency inversion at successive intermediate stations along the system might be effective in retaining substantially the same relative cross-talk level as obtained at station B' but in the usual case it would be found that some of the signals were far more affected by cross-talk than others. This follows because the relation between cross-talk and frequency is in practice not a linear one. A typical cross-talk-frequency characteristic is shown in Fig. 3, the data for this characteristic curve being obtained by measurement on a system of the kind herein described in which cross-talk balancing devices were applied at intervals along the cable. A closer approach to the ideal condition of equal cross-talk in all of the carrier channels is realized by following the system of successive channel assignments, following the initial frequency inversion, that is now to be described.

At station B', as will appear from Fig. 1, signal A is assigned to carrier channel f_7 , signal B to channel f_4 , C to f_8 , D to f_2 , E to f_1 , F to f_3 , G to f_{12} , H to f_{10} , I to f_{11} , J to f_6 , K to f_9 and L to f_5 . At the last intermediate station C' the process is repeated with each signal assigned to a carrier channel not previously traversed by that signal. Thus signal A is by frequency translation assigned to carrier channel f_5 , signal B to channel f_9 , signal C to f_6 , signal D to f_{11} , E to f_{12} , F to f_{10} , G to f_1 , H to f_3 , I to f_2 , J to f_8 , K to f_4 , L to f_7 .

After transmission over the last section of line L₄, the signals arrive at the terminal station E' where the signals are translated to their original voice frequencies for distribution through the local telephone exchange.

Fig. 2, which is based on Fig. 1, shows the successive carrier frequency assignments of four representative signals A, D, J and L as they are transmitted from one end of the system to the other.

To obtain a quantitative idea as to the extent to which cross-talk disparity is reduced by employing the scheme illustrated in Fig. 1, assume that Fig. 3 is applicable and that the cross-talk per thousand mile length varies as there indicated from a value of unity to a value of 2.5. Assume further that the phase of the cross-talk is random in the successive intervals of the line. Under these circumstances, the cross-talk in the several through circuits is very nearly the same, the comparable figures being 3.36 for signals A, E, G and L, 3.15 for signals C, F, H and J, and 3.46 for the other four signals. Calculation will show that in this case the cross-talk in the noisiest channels is less than five per cent greater than the average for all twelve circuits.

A more nearly perfect averaging of the cross-talk in the carrier channels can be obtained by increasing the number of links or intermediate

stations in the system and properly applying the principle of successive channel assignments. Thus, if the four thousand mile system shown in Fig. 1 is provided with eleven intermediate stations instead of three, thus dividing the system into twelve transmission links each about 333 miles in length, the following is the preferred scheme of channel assignment. Signal A will be transmitted over the first link of the system in carrier channel f_1 , over the second link in channel f_2 , over the third in f_3 , and so on to the last link where the signal occupies channel f_{12} . Signal B similarly starts in channel f_2 , progresses to channel f_{12} in the eleventh link and to channel f_1 in the last. The following schedule shows the channel assignment for each of the twelve signals in each of the twelve links of the system.

Signal	Transmitted over link No.											
	1	2	3	4	5	6	7	8	9	10	11	12
	In carrier channel f -No.											
A-----	1	2	3	4	5	6	7	8	9	10	11	12
B-----	2	3	4	5	6	7	8	9	10	11	12	1
C-----	3	4	5	6	7	8	9	10	11	12	1	2
D-----	4	5	6	7	8	9	10	11	12	1	2	3
E-----	5	6	7	8	9	10	11	12	1	2	3	4
F-----	6	7	8	9	10	11	12	1	2	3	4	5
G-----	7	8	9	10	11	12	1	2	3	4	5	6
H-----	8	9	10	11	12	1	2	3	4	5	6	7
I-----	9	10	11	12	1	2	3	4	5	6	7	8
J-----	10	11	12	1	2	3	4	5	6	7	8	9
K-----	11	12	1	2	3	4	5	6	7	8	9	10
L-----	12	1	2	3	4	5	6	7	8	9	10	11

In the foregoing examples of the present invention cross-talk has been assumed to be the source of interference, but this is for illustrative purposes only and other types of interference might have been assumed. If several types of interference are present in the system the intensity-frequency characteristic of each may be determined and a composite interference-frequency characteristic used as the basis of the scheme of successive channel assignments. If desirable, the relative interfering effects of the various disturbances can be properly weighted in deriving this composite characteristic.

What is claimed is:

1. A multiplex signaling system comprising two terminal stations, a transmission line interconnecting them and means for establishing a multiplicity of carrier wave channels for the transmission of signals from one station to the other, means at said one station for applying signals each to a respective one of said channels and means at the other of said stations for selectively receiving said signals, said system being subject to interference which has a net disturbing effect on signal transmission that is non-uniform over the frequency range occupied by said channels so that the ratio of signal level to the effective disturbance level tends to vary from channel to channel, and means for substantially equalizing the said ratio for all of the received signals comprising means at each of several points between said terminal stations for shifting each of said signals to a successively different channel, each of said channels successively carrying several different signals.

2. In a signaling system, two terminal stations and means providing a multiplicity of carrier wave channels for the transmission of signals from one of said stations to the other, means at one of said terminal stations for applying signals to respective ones of said channels, means at the

other of said terminal stations for selectively receiving signals transmitted over said channels, and means at each of several intermediate points in the transmission system for transferring each of said signals to a frequency channel other than one previously occupied by said signal.

3. In a system comprising a pair of terminal stations and several intermediate stations all connected by a transmission line, the method of multiplex transmission which comprises applying to said line at one of said terminal stations a multiplicity of bands of high-frequency waves each bearing respective telephone signals, selectively receiving said bands of waves at each of said intermediate stations and at the other of said terminal stations, and at each of said intermediate stations reducing the said telephone signals to their original frequencies and reapplying each of them to said line in a respective frequency band other than one previously occupied by it in its transmission from said one terminal station.

4. The method of multiplex transmission of signals over a system having several sections or links which comprises transmitting a multiplicity

of signals in respective frequency bands over the first link of the system, changing the relative positions of said signals in the frequency spectrum and transmitting them over the second link of the system, and similarly changing the relative frequency positions of said signals for transmission over each succeeding link, the successive relative positions of the said signals being such that each of said signals occupies as many different relative positions as there are links in the system.

5. In a multiplex carrier wave wire line transmission system, where interference from crosstalk, static, noise and the like is a function of frequency and greater in some carrier channels than in others, the method of reducing the effect of such interference which comprises systematically reassigning each signal to a different frequency channel at several successive points along the line, the interference in the successive channels to which each signal is successively assigned being such that the cumulative interference effect is substantially the same for all of said signals.

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