

March 4, 1941.

J. T. DIXON

2,233,473

REDUCTION OF MODULATION

Filed March 22, 1939

2 Sheets-Sheet 1

FIG. 1

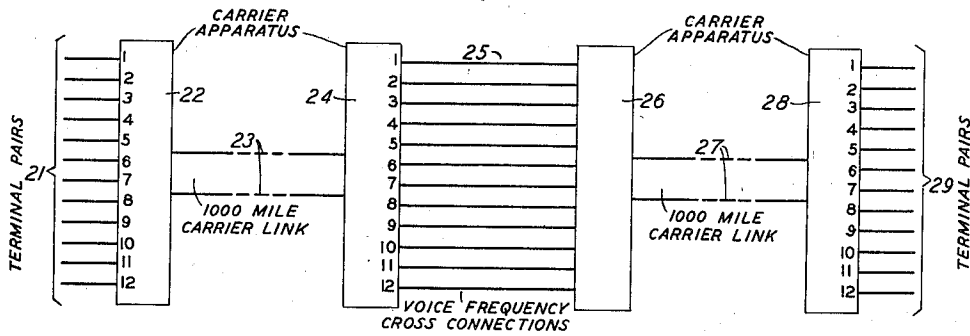
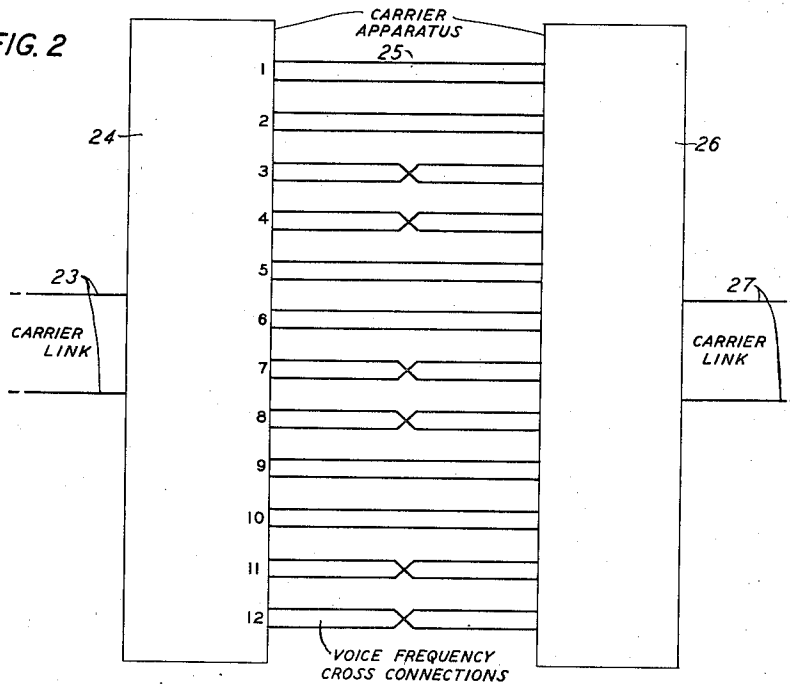


FIG. 2



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FIG. 3

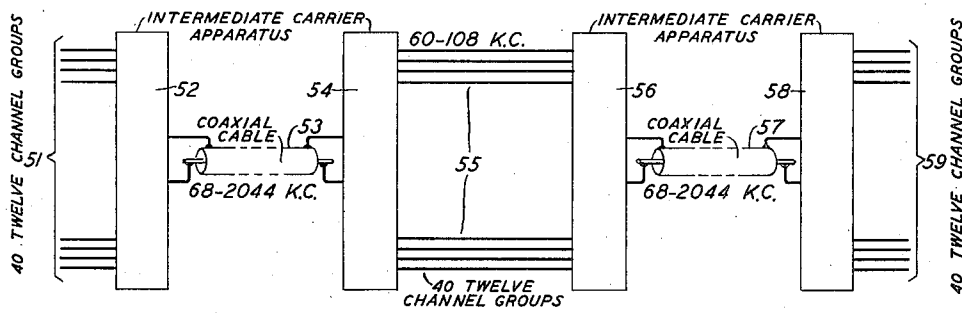
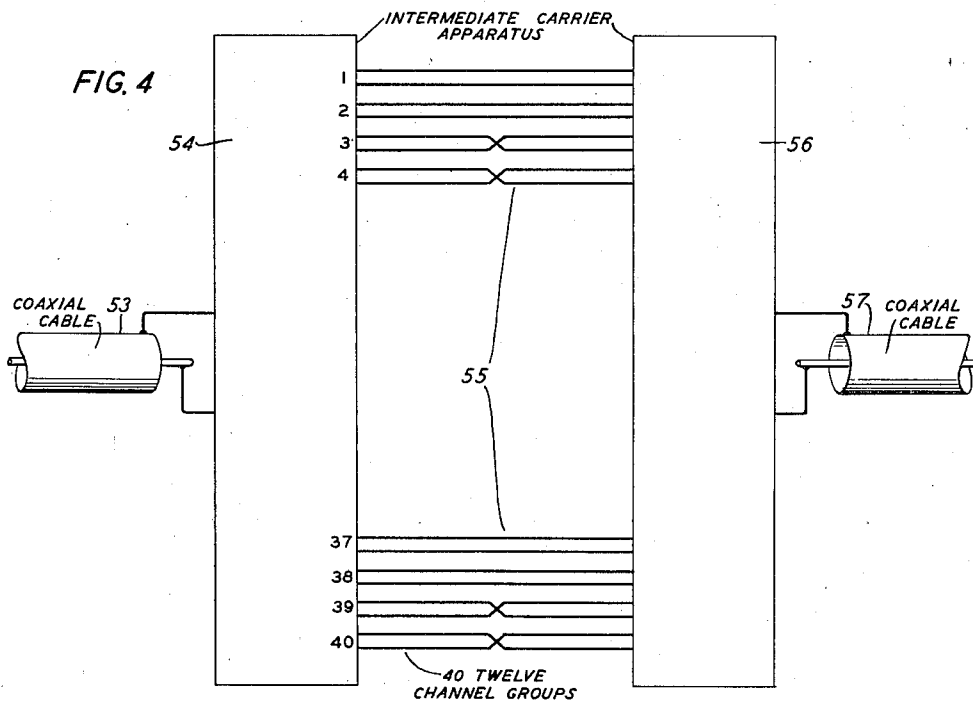


FIG. 4



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2,233,473

REDUCTION OF MODULATION

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5 Claims. (Cl. 179-78)

This invention relates to carrier current transmission systems and more particularly to a method for the restriction of interchannel cross-talk in long haul multichannel carrier systems.

It is well known in the art of telephone and telegraph communication by means of carrier currents that a plurality of messages allocated in a plurality of channels may be simultaneously superposed upon the same transmission line so that the instantaneous current at a given point on the line may be a composite of currents representing said plurality of messages. A preferred method of resolving the said composite current received from such a transmission line consists in the employment of band filters or other selective transducers so proportioned that the several frequencies composing any one message may be segregated from all frequencies composing other messages. The said segregated frequencies may then be so translated as, for example, by demodulation, as to be resolved into the composition of voice frequency currents with which the message originated. Thus, provided that the segregating transducers are sufficiently selective or that the channels are sufficiently spaced apart as to frequency, the several messages might be assumed to be free from interference one with the other.

In practice, however, certain elements of the usual carrier transmission system as, for example, electronic amplifying devices are subject to the generation of modulation products whereby new frequency combinations result which may take the form of harmonics of the original frequencies or sum and difference combinations thereof. Thus, there may arise by intermodulation of frequencies within a channel or of frequencies in one channel with frequencies in another, new frequency combinations such that a derivative of channel A may be accepted by the selective transducer associated with channel B or a derivative of the intermodulation of channels A and B may be accepted by the selective transducer of channel C, whereby interchannel cross-talk results.

Such modulation results from the use of elements whose voltage versus current characteristics are non-linear. Numerous means have been devised for improving the linearity of such elements as, for example, in patent to H. S. Black 2,102,671, December 21, 1937. Means for the reduction of modulation are disclosed in copending patent application of E. Peterson, Serial No. 257,047, filed Feb. 18, 1939. However, the various

means employed serve in general to limit rather than totally prevent modulation and the effects thereof, and, furthermore, in many cases the corrective means, while effective against certain modulation products, are of little avail against others. Moreover, their employment often adds considerably to system cost.

One of the more troublesome products is that product of third order modulation which is of the form $2a-b$ where a and b are message frequencies and $2a$ is greater than b .

It is an object of this invention to restrict cross-talk resulting from modulation products of the form $2a-b$. A further object is to effect the restriction of such cross-talk in long haul multichannel carrier systems without appreciable addition to system costs.

In certain multiplex carrier systems, such as those designed for use on open-wire and cable systems, it is proposed on long haul circuits that the several carrier current transmitted messages will be brought back to voice frequencies about every 1000 miles. Thus, a 2000-mile circuit might comprise two 1000-mile carrier sections or "links" over which all messages might be superposed upon a single conductor path, said links being joined together by a plurality of conductors in which messages would be carried as voice frequency bands of identical width, each by an individual conductor pair. Thus, assuming a twelve-channel system carrying twelve messages, the interlink between the two carrier links would include twelve conductor pairs.

It is assumed in such proposal that the channel order will remain the same in successive links so that in the carrier frequency band the band of channel 4, for example, remains between channels 3 and 5, and channel 11 between channels 10 and 12, although if desired the numbering in the direction of increasing frequency may be reversed so that channel 1 in one link is in the frequency position of channel 12 in the succeeding link.

Considering now the modulation term $2a-b=c$, if b or c is shifted in phase 180 degrees in one link from its phase in the adjoining link the summation of these modulation terms will be substantially zero for the two links. However, if a is shifted 180 degrees, $2a$ will have been shifted 360 degrees, which is equivalent to zero degrees phase shift. Assume that a is a representative frequency of channel 5, and b of channel 6, then $2a-b=10-6=4$ which is in channel 4. Suppose this modulation product 4 is formed in link 1, 55

whereas, in passing from link 1 to link 2, channel 4 is shifted 180 degrees and that channel 6 is not so shifted. Then since the product of $2a-b=4$ formed in link 2 will be in phase with the product of $2a-b=4$ formed in link 1, but channel 4 has been shifted 180 degrees, the two products will be 180 degrees out of phase and will cancel.

This result may be more clearly demonstrated by the use of specific frequencies. Assume a carrier current system comprising twelve channels each nominally 4000 cycles wide, and employing the lower side-band of carriers 64 kilocycles, 68 kilocycles, 72 kilocycles, etc., to 108 kilocycles, and numbered in the same order from 1 to 12. Thus, channel 4 comprises a band from 72 to 76 kilocycles, channel 5 from 76 to 80 kilocycles, channel 6 from 80 to 84 kilocycles.

If now, a represents 1000 cycles in the message wave carried by channel 5, its frequency in the band will be 79 kilocycles. Similarly, b representing 1000 cycles in the message wave of channel 6 will appear as 83 kilocycles. Thus, $2a-b=158-83=75$ kilocycles, which is the frequency of the 1000-cycle component of the message wave in channel 4 and thus this modulation product appears as cross-talk in channel 4 as do products of other frequencies in channels 5 and 6, respectively. However, if channel 4 is shifted 180 degrees in the interlink between two links and channel 6 is not so shifted these modulation products will cancel or tend to cancel each other in the two links. In fact, in the specific illustration any phase shift in channel 4 in the interlink, assuming no phase shift in channel 6 and zero degrees or 180 degrees phase shift in channel 5, will tend to reduce this interchannel cross-talk.

Now, I have found that considering two substantially equal sections or links of a multichannel carrier current transmission system interconnected by a voice frequency interlink as described, if alternate pairs of channels are shifted substantially 180 degrees in phase, as by interchanging tip and ring in the voice frequency interlink, there will result for those two links substantial cancellation of $2a-b$ cross-talk producing modulation products, as between adjacent channels and that there will also be substantial cancellation as between a considerable number of more remotely related channels. Measurements have shown that such interference between adjacent channels is ordinarily 6 decibels or more greater than that between more remote channels. It is thus apparent that by the use of my invention substantial reduction of interchannel cross-talk in a long haul multiple channel carrier current system may be effected and that furthermore such reduction may be achieved without appreciable addition to system costs.

The invention is also applicable to coaxial cable systems such as the proposed 480-channel broad band system. This system may comprise forty basic groups of twelve channels, each group covering a frequency range from 60 to 108 kilocycles but each allocated for transmission over the coaxial cable to an exclusive position in a band from 68 to 2044 kilocycles. It is proposed to reduce this band at intervals to the forty basic groups each in the band 60 to 108 kilocycles and thereupon intergroup modulation may be restricted after the manner described by transposing alternate pairs of groups.

The invention may be more fully understood

from the following description read in connection with the accompanying drawings, in which:

Fig. 1 shows in schematic diagram a portion of a carrier current transmission system;

Fig. 2 shows in greater detail a portion of the diagram of Fig. 1;

Fig. 3 shows in schematic diagram a portion of a broad band transmission system for coaxial cable; and

Fig. 4 shows in greater detail a portion of the diagram of Fig. 3.

Referring to Fig. 1, twelve incoming message circuits 21, each represented by a single line in the figure, terminate in a carrier apparatus 22 which is assumed to comprise conventional modulators, amplifiers, band filters, etc., whereby twelve messages incoming on message circuits 21 may be modulated by twelve different carrier waves respectively and superposed upon carrier link 23 as twelve carrier channels. Carrier apparatus 24 connected to the other terminal of carrier link 23 comprises band filters, amplifiers, demodulators, etc., whereby the twelve carrier channels transmitted as a carrier band over carrier link 23 are reduced to voice frequency messages again and are then conducted on individual pairs 25 to carrier apparatus 26 which may function by modulation and band filter segregation to similarly prepare them for transmission over carrier link 27 to carrier apparatus 28 wherein they may be demodulated and sent out over individual message pairs 29 to their respective destinations.

Fig. 1 thus shows a carrier system whereby twelve messages may be transmitted, wherein for purposes of illustration it may be assumed that all transmission is from left to right in the diagram, comprising twelve incoming voice frequency message circuits, transmitting carrier apparatus, a carrier link, an interlink comprising incoming and outgoing carrier apparatus cross-connected by twelve voice frequency message pairs, a second carrier link, carrier receiving apparatus and twelve voice frequency receiving circuits. The terminal apparatus at 22, 24, etc., may be of the type shown in U. S. patent to Huber, 2,142,316, patented January 3, 1939.

In Fig. 2 the interlink of Fig. 1 is shown to illustrate the method by which restriction of modulation products is accomplished according to the invention. Carrier apparatus 24 is cross-connected to carrier apparatus 26 by twelve individual two-wire circuits numbered 1 to 12 and carrying respectively the twelve messages transmitted by the twelve like-numbered carrier channels. Alternate pairs of these circuits are shown transposed. Thus, carrier channels 1, 2, 5, 6, 9, 10 are carried through the voice frequency portion of the interlink straight, whereas channels 3, 4, 7, 8, 11, 12 are transposed, thus shifting the phase of the transmitted current by 180 degrees.

The application of the invention to a broad band coaxial cable system is indicated in Fig. 3 in which for the purpose of illustration transmission may be assumed to be in one direction as from left to right and wherein forty twelve-channel basic groups 51 are allocated to their assigned positions in the broad band carried by coaxial cable section 53 through the agency of intermediate carrier apparatus 52 and then returned to forty twelve-channel groups of like frequency band 55 by intermediate carrier apparatus 54. The process is then repeated through intermediate carrier apparatus 56, coaxial cable

section 57, intermediate carrier apparatus 58 and the forty groups 59 of twelve channels each. This process may be repeated with successive coaxial cable sections to make up a desired system.

Further disclosure of a broad band system of this general type is given in U. S. patent to Espenschied et al. 1,835,031, patented December 8, 1931.

As instanced above, each group may after primary modulation from voice frequency messages cover a range from 60 to 108 kilocycles comprising twelve 4000-cycle channels and the forty groups each of 48 kilocycles may after intermediate modulation for coaxial cable transmission be allocated to cover a range from 60 to 2044 kilocycles.

In Fig. 4 the interlink between coaxial cable sections is shown to comprise the intermediate carrier equipments 54, 56 and forty two-conductor cross-connections 55, one for each 60 to 108-kilocycle group. By transposition of alternate pairs of these cross-connections as 3, 4, 7, 8, etc., to 35, 36, 39, 40, the corresponding twelve-channel groups are shifted in phase 180 degrees in coaxial cable 57 from their phase relation in coaxial cable 53 relative to the non-transposed groups as 1, 2, 5, 6, etc., to 33, 34, 37, 38.

I have thus disclosed a method for restricting interchannel or intergroup modulation in carrier current systems by so arranging the system that the modulation produced in one section thereof will be out of phase with that produced in another section. Although by way of illustration I have shown a particular and preferred embodiment, it is to be understood that my invention is not so limited but only by the principles involved as defined by the appended claims.

What is claimed is:

1. In a communication system, the method which comprises establishing a plurality of multiplexed carrier channels subject to interchannel cross-talk and extending through successive carrier transmission links, translating said carrier channels from their individual frequency allocations to a common frequency allocation at each interlink junction, and electrically transposing those translated channels that prior to translation occupied positions as alternate pairs in the frequency spectrum, whereby interchannel cross-talk is restricted.

2. In a transmission system comprising a plu-

ality of message channels transmitted respectively by a plurality of carrier waves as a broad frequency band, the method of restricting interchannel cross-talk which consists in subdividing said transmission system into a series of interlinked transmission links, translating said channels to a common frequency allocation at said interlinks and therein introducing phase shift in such channels as with respect to their frequency allocation in said band constitute alternate pairs of channels.

3. In a multichannel carrier transmission system comprising a plurality of carrier frequency links interlinked by voice frequency cross-connections, the method of restricting the in-phase addition of third order modulation products which consists in electrically transposing alternate pairs of channels in said voice frequency cross-connections.

4. In a broad band carrier transmission system comprising a plurality of groups of carrier channels allocated respectively to a plurality of positions in said band, the method of restricting intergroup cross-talk which consists in subdividing said transmission system into a series of interlinked transmission links, translating said groups to the same frequency allocation at said interlinks and providing a separate transducer in said interlinks for each of said channel groups and with respect to the frequency allocation of said channel groups in said broad band transposing alternate pairs of channel groups in said interlinks.

5. In the multiplex transmission of signals in at least three individual frequency ranges through a system comprising two tandem-connected carrier transmission links each with a plurality of repeaters therein tending to give rise to modulation products of the form $2a-b$ where a and b are wave frequencies lying respectively in two of said frequency ranges and $2a-b$ lies in a third, the method which comprises translating the signals in said three ranges to a common frequency allocation in individual circuits at the junction of said two links, and electrically transposing relative to each other the said circuits carrying respectively the translated b and $2a-b$ frequencies, whereby said $2a-b$ modulation products arising in one of said links are reduced by modulation products of the same form arising in the other.

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