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3,099,703

COMMUNICATION CABLE HAVING TRANSPOSED CONDUCTORS

Filed June 25, 1962

3 Sheets-Sheet 1

Fig. 1

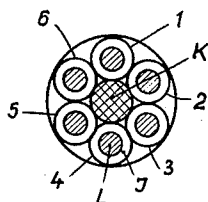


Fig. 2

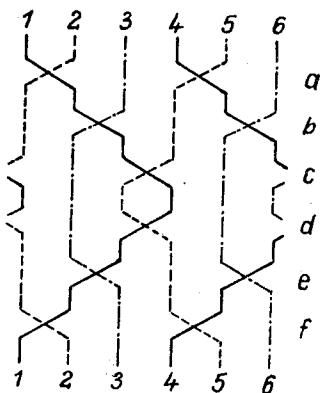


Fig. 3

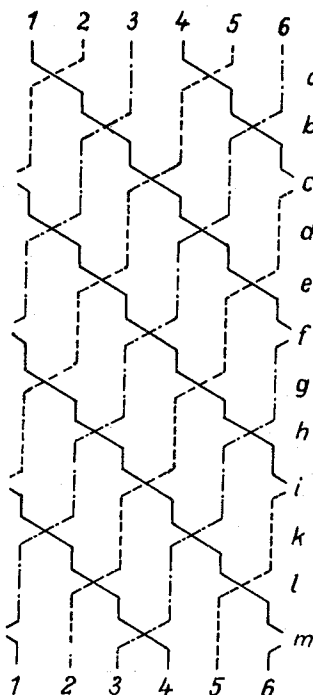


Fig. 4

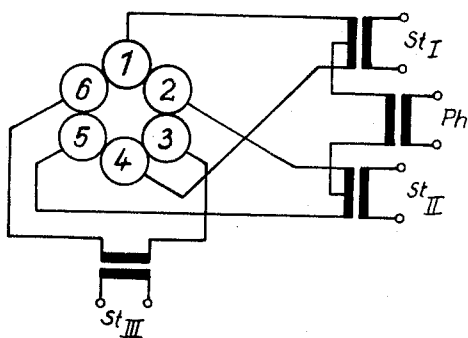
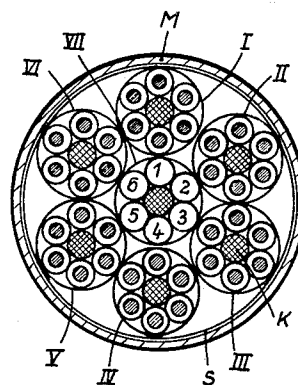


Fig. 5



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Fig. 6

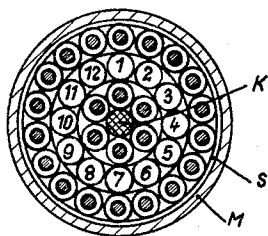


Fig. 7

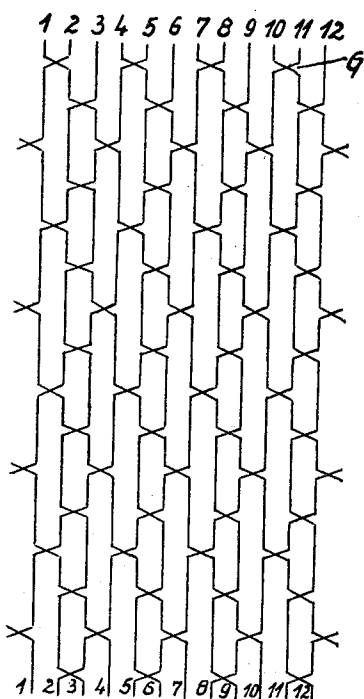
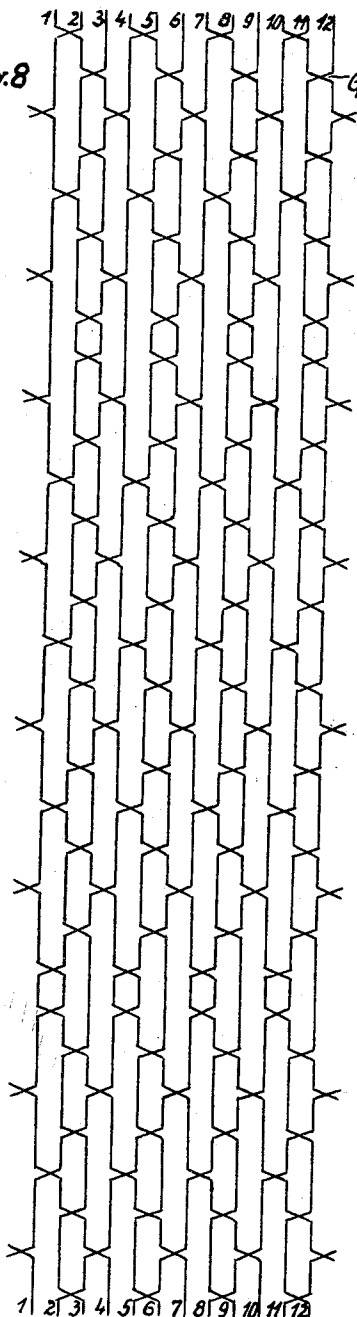


Fig. 8



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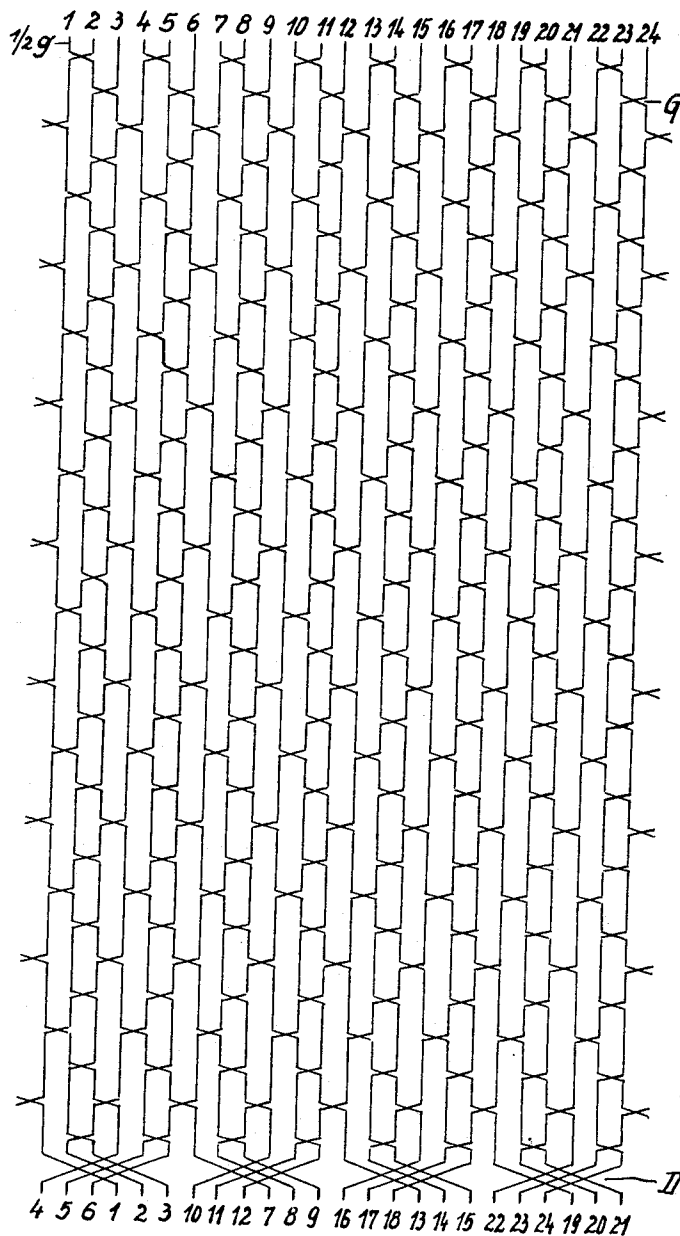
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Fig. 9



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COMMUNICATION CABLE HAVING TRANSPOSED CONDUCTORS

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Claims priority, application Germany June 28, 1961
8 Claims. (Cl. 174-34)

The invention disclosed herein is concerned with a communication cable having at least one layer of individual conductors from which are formed two-conductor lines by mutual crossing thereof. The invention may be considered as an improvement on the invention described in the copending application Serial No. 818,083, filed June 4, 1959, which is owned by the assignee also named in the present case.

The prior application proposes to carry out, within cable sections which are short as compared with fabricated cable lengths, systematic crossings, spaced apart by given distances, always involving two conductors of a layer which lie adjacently at the respective crossing points, so that the same count sequence of the conductors obtains at the beginning and at the end of each crossing section. The cable is in a preferred embodiment of the prior application constructed of one or more groups each having eight individual conductors which are twisted about a core. This construction is advantageous since there may be formed from the eight conductors at least four two-conductor lines as well as two phantom circuits and, in given cases, from the two phantom circuits, a symmetrical phantom circuit of higher order (octagon phantom circuit), that is, a total of seven symmetrical transmission circuits, of which the six first named circuits have nearly the same transmission properties. The core of a group consisting of eight conductors has a diameter which amounts to 1.3 times the conductor diameter, referred to as diameter d . The expenditure resulting thereby as to the space for the core, is of course a disadvantage. Moreover, the construction of a cable comprising a plurality of groups each having eight conductors does not in all cases constitute an economically favorable construction.

The present invention proceeds from the recognition of the fact that the indicated crossings can be advantageously applied in the case of communication cables having at least one layer of twisted individual conductors, wherein the number of individual conductors lying in one twist position, is divisible by six. According to a feature of the invention, each third conductor remains uncrossed at the crossing points—as seen in peripheral direction.

In a communication cable having one or more groups of six individual conductors twisted about a core, the core diameter shall be equal to the conductor diameter, thus resulting in a particularly favorable utilization of space. While four conductor crossings must be effected at each crossing point, in the case of a group comprising, as proposed in the prior application, eight conductors twisted about a core, only two conductor crossings will suffice per crossing point in the case of a group comprising, as proposed by the present invention, six conductors twisted about a core. The number of crossings is thus reduced by one third. This results, of course, in reduced thickening of the corresponding cable section at the crossing points thereof.

Details of the invention will appear from the claims taken together with the description of embodiments which is rendered below with reference to the accompanying drawings.

FIGS. 1 to 4 show embodiments for groups comprising six individual conductors; and

FIGS. 5 to 8 show embodiments for twisted layers hav-

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ing a number of conductors which is a multiple of six.

FIG. 1 shows a group of six individual conductors one to six which are twisted about a core K, briefly conveniently referred to as sextuple. Each individual conductor L is provided with an insulation J. As will be seen from the drawing, the core K has in such embodiment the same diameter as the individual insulated conductors. The total diameter D of the sextuple therefore amounts to $D=3d$. According to the invention, two diagonally oppositely disposed conductors, that is, conductors 1 and 4, 2 and 5 and 3 and 6, are always combined to form respectively a two-conductor line.

FIGS. 2 and 3 show two embodiments of the systematic crossings effected in the case of a sextuple within a crossing section of a cable. In the corresponding crossing plans, having respectively the crossing points a to f and a to m , the crossings are effected within a crossing section which is relatively short as compared with a fabrication length of the cable, so that the conductors appear at the beginning and at the end of the crossing section in the same count sequence. A novel feature resides in that two conductors forming parts of one and the same two-conductor line, always remain uncrossed at each crossing point. Accordingly, as seen in peripheral direction, each third conductor remains uncrossed.

In the embodiment according to FIG. 2, the conductors which are at the successive crossing points a to f not crossed with other conductors, are as follows:

Crossing point:	Conductors
a -----	3 and 6
b -----	2 and 5
c -----	3 and 6
d -----	3 and 6
e -----	2 and 5
f -----	3 and 6

As compared with this scheme, in the embodiment according to FIG. 3, the conductors 3 and 6 and 2 and 5 will remain uncrossed at successive alternate crossing points, throughout all crossing sections.

It will be seen that, as compared with the previously proposed crossing plans according to the prior application, which involves all conductors, only the conductors of a two-conductor line which is at each crossing point crossed with conductors of another two-conductor line, are displaced by a given angle in the peripheral direction, whereby the relative direction of displacement is, according to FIG. 2, reversed upon a displacement amounting on the average to 180° , while the relative direction of displacement is, in the embodiment according to FIG. 3, retained without reversal, until the original conductor sequence is again obtained.

It is understood, of course, that it is possible to depart from the embodiments shown in FIGS. 2 and 3, and to begin the crossings by leaving uncrossed at the first crossing point a , either the conductors 2, 5 or the conductors 1, 4.

The use of the new crossing plans results, in the case of a sextuple, in the advantage that a mutual decoupling of all three two-conductor lines is achieved even with uncrossed arrangement of the conductors of a two-conductor line at the individual crossing points. Moreover, in addition to the three two-conductor lines, there may be formed a phantom circuit of two of the two-conductor lines, that is, a phantom line composed of 1, 2/2, 5; 1, 4/3, 6 or 2, 5/3, 6. The corresponding phantom circuits are decoupled with respect to the three two-conductor lines and have nearly the same transmitting properties as the respective two-conductor lines, which may also be referred to as basic lines.

To give an example, FIG. 4 indicates the manner of

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forming three basic lines StI , $StII$, $StIII$, and a phantom circuit Ph which utilizes the conductors 1, 4 and 2, 5.

There is also the possibility to form a transmission circuit utilizing the three odd numbered conductors 1, 3, 5, for a line in one direction and the three even numbered conductors for a return line.

The invention is not only applicable in the case of communication cables having a single sextuple, or having a plurality of sextuples arranged in layers, but also in the case of communication cables comprising centrally thereof a sextuple about which are twisted one or more layers of individual conductors.

FIG. 5 shows in cross-sectional view a communication cable comprising seven sextuples (six-conductor units) I to VII, whereby the units I-VI are twisted about the centrally disposed unit VII. The cable core formed in this manner is covered by a core web S and the waterproof sheath M. The six individual conductors of each sextuple unit are systematically mutually crossed according to a crossing plan proposed by the invention, for example, one of the plans represented in FIGS. 2 or 3. Each sextuple unit is constructed as explained in connection with FIG. 1.

The invention is particularly advantageously applicable in cases in which the number of conductors of a layer amounts to two-times and four-times six. In case the number of conductors exceeds two-times six, it will be for the decoupling of all lines of advantage to provide mutual crossings respectively between the individual crossing sections or between a plurality of successive crossing sections; it is however preferable in such case, to cross within the respective crossing sections, at further crossing points thereof, three successive conductors and to likewise mutually cross the next successive three conductors.

FIG. 6 shows in cross-sectional view a communication cable comprising an inner core K about which is twisted the first layer of six conductors, the second layer of twelve conductors 1 to 12, and the third layer of eighteen conductors. Each conductor comprises a conductor proper and an insulation carried thereby. See parts L and J in FIG. 1. Letter S indicates again the covering web and M indicates the waterproof sheath. Two diagonally oppositely positioned conductors always form a two-conductor line.

FIG. 7 shows a crossing section provided for twelve conductors and having sixteen basic crossings including the basic crossing G at the beginning of the section. Thereupon follow, beginning with the conductor 1, as seen in peripheral direction, first, a conductor (conductor 1), which is at the successive crossing points displaced in one peripheral direction, second, a conductor (conductor 2), which is at the successive crossing points displaced in opposite direction, and third, a conductor (conductor 3), which is at the successive crossing points alternately displaced in the one and in the other direction.

Accordingly, the conductors 1, 4, 7, 10 are displaced in one peripheral direction and the conductors 2, 5, 8, 11 in the opposite peripheral direction, while the conductors 3, 6, 9, 12 are at the successive crossing points alternately displaced respectively in the one and the other direction. Each respective pair 3, 9 and 6, 12 of these conductors, which are not alternately crossed at the successive crossing points, forms a two-conductor line.

The crossing plan shown in FIG. 8, which embraces a crossing section having thirty-two basic crossings, departs from the scheme shown in FIG. 7, in that the displacement of the conductors 1, 4, 7, 10 and 2, 5, 8, 11, respectively, is reversed at points angularly spaced apart by 180° , thus resulting in a greater number of crossings per crossing section, so as to obtain the same count sequence of the conductors at the beginning and at the end of the respective crossing section.

The crossings as carried out according to FIGS. 7 and 8, result in mutual decoupling of all two-conductor lines (basic lines) and of all phantom lines formed therefrom.

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From the twelve conductors can be formed decoupled basic lines St and phantom lines Ph , as follows:

Conductors 1 and 7= $St1$ -----	} $Ph1$ -----	} $Ph1/2$.
Conductors 4 and 10= $St2$ -----		
Conductors 2 and 8= $St3$ -----	} $Ph2$ -----	
Conductors 5 and 11= $St4$ -----		
Conductors 3 and 9= $St5$ -----	} $Ph3$.	
Conductors 6 and 12= $St6$ -----		

In the above table, $St1$ - $St6$ are six basic lines, $Ph1$ - $Ph3$ are three quadruple-line phantom lines, and $Ph1/2$ is an octagon-line phantom line formed from $Ph1$ and $Ph2$. Accordingly, there are a total of ten decoupled lines.

In order to obtain, in a twist comprising twenty-four individual conductors, decoupling of all basic or two-conductor lines and all phantom lines, there are provided within a crossing section auxiliary preferably uniformly spaced apart crossing points, at which three successive conductors are crossed with three successively following conductors. These auxiliary crossings are briefly conveniently referred to as triple crossings. An example of such crossing arrangement is shown in FIG. 9.

The basic crossings are effected in FIG. 9 in the same manner as explained with reference to FIG. 7. The crossing section begins with thirty-two basic crossings. The triple crossings D are provided midway of continuous portions following the last basic crossings, so that a continuous portion lies on each side of the triple crossings. At the triple crossing, three successively positioned conductors are always crossed with three immediately following conductors. Three more such triple crossings are provided following the crossings D, so that a crossing section is produced having at its beginning the same conductor count sequence as at the end thereof. A complete decoupling of all basic lines and all phantom lines is achieved by the use of the auxiliary triple crossings in twists having a number of conductors which exceeds more than three-fold six. From the twenty-four conductors can be formed twelve basic lines, six quadruple-line phantom lines, three octagon-line phantom lines, and a phantom line involving sixteen conductors.

The invention is analogously applicable in the case of different numbers of conductors, amounting to a multiple of six. The reversal of the conductor displacement in peripheral direction can be applied, departing from the example shown in FIG. 8, in angular spacing other than $\pm 180^\circ$ (π). It can be said, generally, that the conductor displacement direction can be effected according to displacement angle of π or according to an integral multiple of π , which means, however, that the displacement direction—as may also be recognized from FIGS. 3, 6 and 8—of conductors displaced in one direction and of conductors displaced in the other peripheral direction, can be retained without reversal. The arrangement of the various crossing schemes can always be carried out so that the different displacement angles are obtained which are preferentially applied with respect to different conductors, thereby securing in a complete decoupling section the mutual decoupling of all possible transmission lines.

Changes may be made within the scope and spirit of the appended claims which define what is believed to be new and desired to have protected by Letters Patent.

I claim:

1. A communication cable comprising at least one layer of twisted insulated individual conductors, each layer having an even number of individual conductors which number is divisible by six, an even-numbered conductor always neighboring, in the numerical succession of the conductors of a layer in peripheral direction, on an odd-numbered conductor, said cable being lengthwise subdivided into crossing sections the length of which is small as compared with the fabrication length of the cable, there being provided within each crossing section, lengthwise thereof, uniformly spaced apart crossing points, an even-numbered conductor of a layer being at such crossing point crossed with an odd-numbered conductor neighboring thereon in the succession in the peripheral direction, the

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next following conductor remaining uncrossed, the number of said crossing points within a crossing section being such that the conductors appear in the same count sequence at the beginning and at the end of each crossing section, each two respectively odd- or even-numbered conductors forming a two-conductor line.

2. A communication cable according to claim 1, comprising a twist having six conductors and longitudinally successive crossing points therefor, wherein only the conductors of a two-conductor line, which is at each crossing point crossed with conductors of another two-conductor line, are displaced in peripheral direction by a given angle, the relative displacement direction of such conductors being after an average displacement angle π (180°) reversed, so as to obtain the same count sequence of the conductors at the beginning and at the end of each crossing section.

3. A communication cable according to claim 1, comprising a twist having six conductors and longitudinally successive crossing points therefor, wherein only the conductors of a two-conductor line, which is at each crossing point crossed with conductors of another two-conductor line, are displaced in peripheral direction by a given angle, the relative displacement direction of the conductors being maintained without reversal, so as to obtain the same count sequence of the conductors at the beginning and at the end of each crossing section.

4. A communication cable constructed of a plurality of units each having at least one layer of twisted insulated individual conductors, each layer of said units having an even number of individual conductors which number is divisible by six, an even-numbered conductor always neighboring, in the numerical succession of the conductors of a layer in peripheral direction, on an odd-numbered conductor, the units of said cable being subdivided into crossing sections the length of which is small as compared with the fabrication length of the cable, there being provided within a crossing section a number of longitudinally substantially uniformly spaced apart crossing points, an even-numbered conductor of a layer being at such crossing point crossed with an odd-numbered conductor

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neighboring thereon in the succession in peripheral direction, the next following conductor remaining uncrossed, the number of said crossing points being within a crossing section such that the conductors appear in the same count sequence at the beginning and at the end of each crossing section, each two respectively even-numbered or odd-numbered conductors of a unit forming a two-conductor line.

5. A communication cable according to claim 1, having at least one twist portion comprising a number of conductors which is a multiple of six, and having longitudinally spaced apart crossing points at which appear conductors in the following sequence, as seen in the peripheral direction, namely, first, a conductor which is at the successive crossing points displaced in one peripheral direction, second, a conductor which is at the successive crossing points displaced in a direction opposite to the direction of displacement of said first conductor and, third, a conductor which is at the successive crossing points alternately displaced in one and then the other direction.

6. A communication cable according to claim 5, wherein the displacement direction respectively of said first and said second conductor is reversed after a displacement amounting to $\pm\pi$ (180°), so as to obtain the same count sequence of the conductors at the beginning and at the end of each crossing section.

7. A communication cable according to claim 5, wherein the peripheral direction of displacement of said first and second conductors is maintained without reversal, so as to obtain the same count sequence of the conductors at the beginning and at the end of each crossing section.

8. A communication cable according to claim 1, having at least one twist portion comprising a number of conductors which amounts to two-times six, there being provided within the individual crossing sections, auxiliary crossings involving, as seen in peripheral direction, three successive conductors crossed with the next successive three conductors.

No references cited.