Nov. 5, 1963 HORST-EDGAR MARTIN 3,109,879

COMMUNICATION CABLE

Filed Sept. 26, 1962

4 Sheets-Sheet 1

Fig. 1

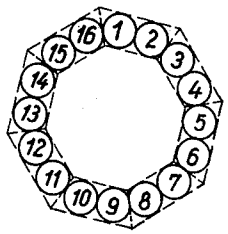


Fig. 2

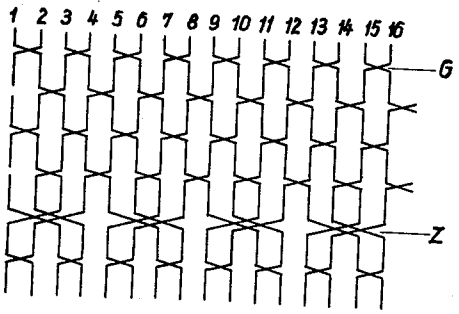
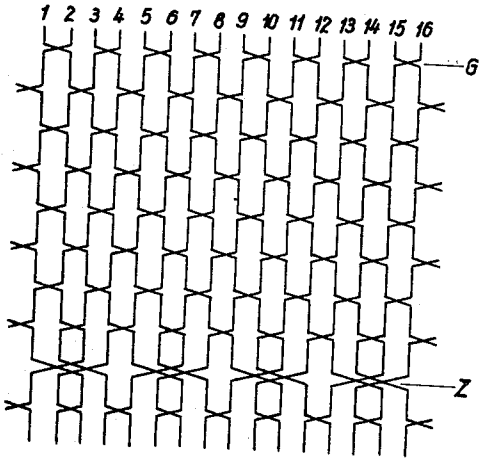


Fig. 3



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Fig. 4

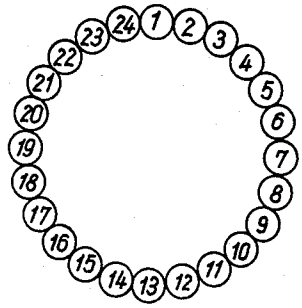
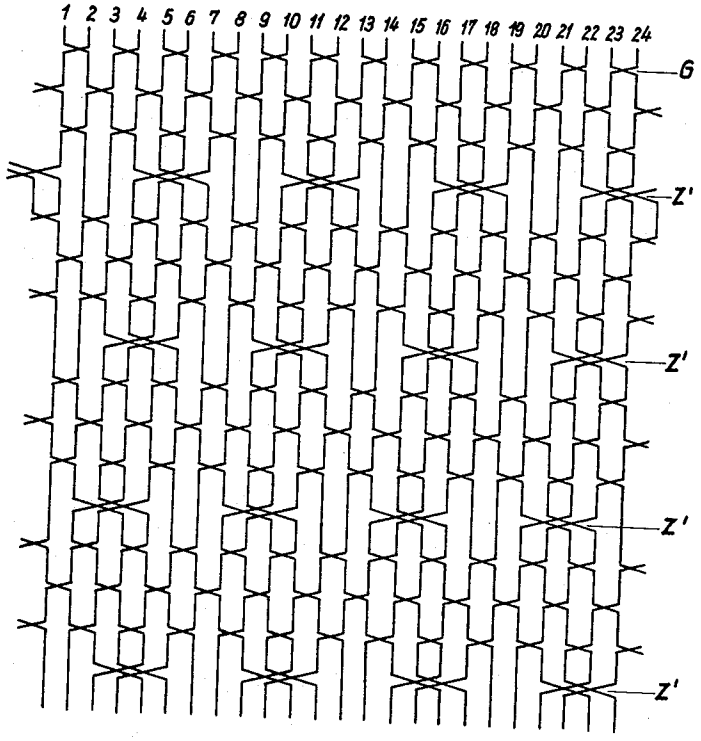


Fig. 5



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Fig. 6

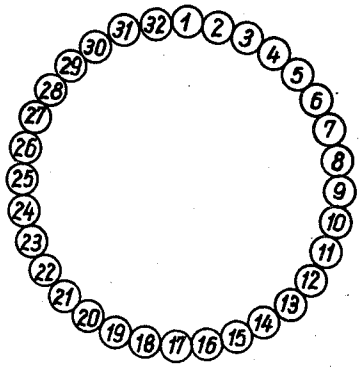
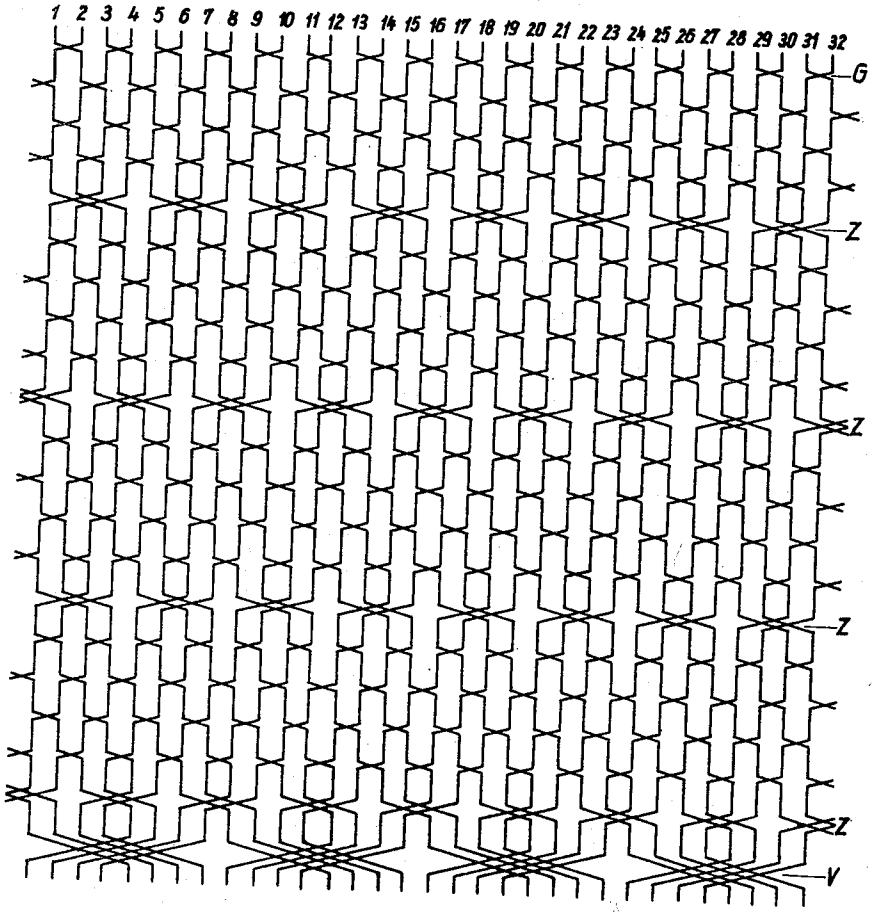


Fig. 7



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Fig. 8

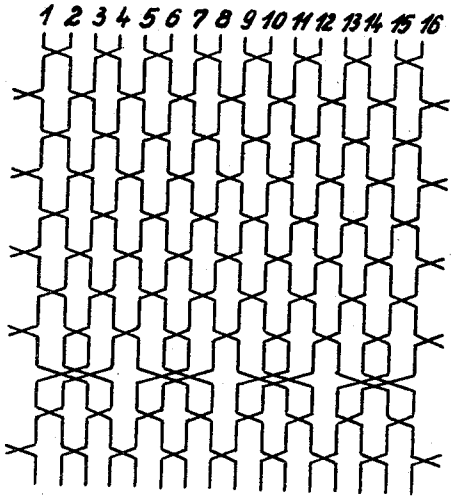


Fig. 9

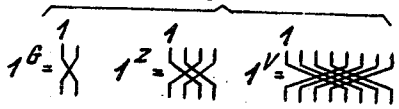


Fig. 11

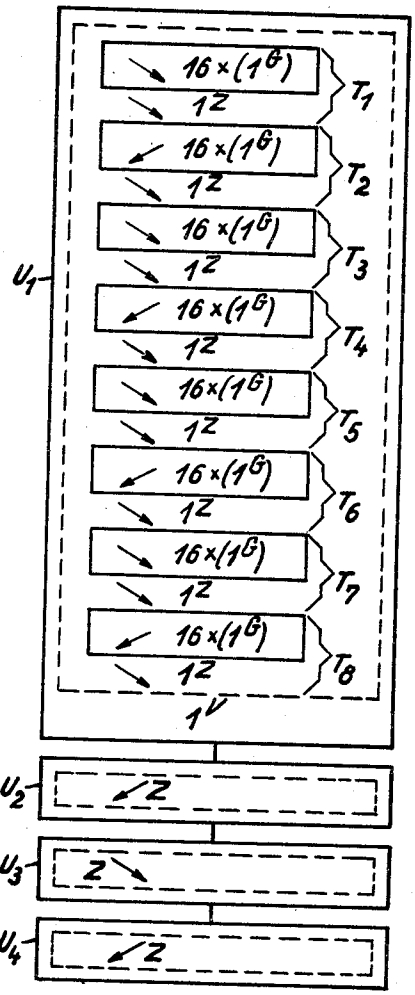
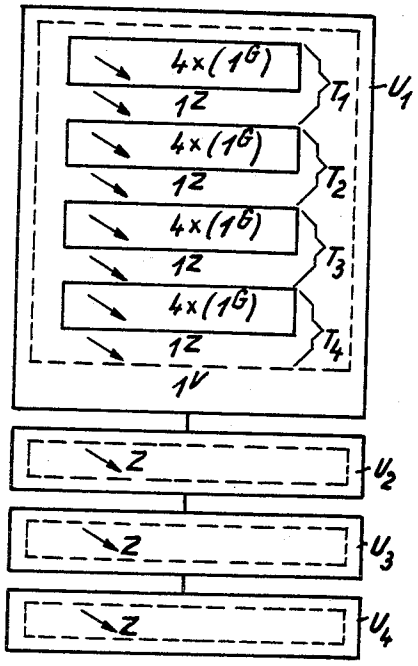


Fig. 10



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United States Patent Office 3,109,879 Patented Nov. 5, 1963

3,109,879

COMMUNICATION CABLE

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Filed Sept. 26, 1962, Ser. No. 226,306
Claims priority, application Germany Sept. 29, 1961
12 Claims. (Cl. 174—34)

The invention disclosed herein is concerned with a communication cable having layers of individual conductors from which are formed two-conductor lines by systematic crossing thereof.

It has already been proposed to carry out, within crossing sections which are short as compared with fabrication lengths of a cable, systematic crossings, in given spacings, always between conductors of a layer which lie adjacent one another, in such a manner, that the same count sequence of conductors appears at the beginning and at the end of each crossing section. The two-conductor lines thus obtained are to a large extent free of trouble.

It has also been proposed to provide between the individual crossing sections or between a plurality of successive crossing sections or within the individual crossing sections, additional conductor transposition points at which respective even numbered or odd numbered conductors are crossed or transposed. These additional conductor transpositions in the form of individual conductor crossings are appropriately effected within a place-change section which is very short as compared with the length of a crossing section. These measures make it possible to compensate within the crossing sections all systematic capacitive and magnetic couplings between all two-conductor lines. However, there appear within the place-change sections in which the additional conductor transpositions or conductor crossings are effected, slight residual couplings, particularly purely inductive couplings.

In accordance with the invention, there are, in twist layers, the conductor number of which is a multiple of eight, at the additional crossing points, as seen in peripheral direction, always 2^p successive conductors exchange with the next successive 2^p conductors, whereby p signifies a whole positive number, especially 1 or 2. In the simplest embodiment, there are always two successive conductors crossed with the next successive two conductors. Mutual crossings respectively of two conductors are herein briefly referred to as dual crossings.

Crossings effected in this manner avoid the disadvantages attending the previously proposed additional place-change sections with a plurality of individual conductor crossings. Particular advantages will be obtained upon forming, in the layers which contain a multiple of eight conductors, phantom lines, always of two-conductor lines (basic lines) the conductors of which are diagonally oppositely positioned and of two-conductor lines the conductors of which are positioned mutually perpendicularly.

It was found that the application of the indicated dual crossings results at least within a 16-conductor layer, in a decoupling of all lines. It is advisable, in the case of layers having a greater number of conductors, for example, 32 conductors, to provide, in addition to the dual crossings, further additional crossings whereby always four successively placed conductors are crossed with the four next successive conductors, so as to mutually decouple all basic lines and therewith also all phantom lines that can be formed, such as four-conductor, eight-conductor and sixteen-conductor phantom lines. These additional crossings are referred to as fourfold crossings so as to distinguish from the dual crossings.

The additional crossings in connection with the basic crossings are particularly advantageously carried out without reversal of the crossing direction, so that the conductors of adjacently positioned two-conductor lines and of four-conductor phantom lines, respectively, are displaced in opposite direction and also by twist angles of different magnitude. The consequence of the additional crossings is, that the conductor displacements selected in the basic crossings, increase at the crossing points for a part of the conductors while decreasing for another part of the conductors. Another possibility resides in providing crossings in such a manner that conductor displacement selected in the basic crossings is at the additional crossing points reversed for all conductors.

In the event that the number of conductors of the layer amounts to $2^n (n>3)$, that is, 16, 32, etc., there will be provided, by the combination of 2^p-conductors, a number of additional crossings, so that $n-3$ different kinds of additional crossings are applied, the lowest of which is $p=1$ and the highest of which is at the most $p=n-3$ conductors per crossing group.

The additional crossings result within the entire decoupled crossing section in partial crossing sections of different kind, namely, basic crossing sections consisting respectively of a basic crossing and a following uncrossed or smooth section, as well as additional crossing sections consisting respectively of an additional crossing and a following smooth section. Fourfold crossings are advantageously carried out midway of a smooth dual crossing section.

The invention will now be explained more in detail with reference to the accompanying drawings.

FIG. 1 shows in simplified cross-sectional view a twist layer comprising 16 individual conductors;

FIG. 2 represents an example of an embodiment employing in a 16-conductor layer additional crossing points;

FIG. 3 illustrates a further embodiment of a crossing section for a 16-conductor layer;

FIG. 4 is a simplified sectional view of a twist layer with 24 conductors;

FIG. 5 indicates the use of additional dual crossings of particular kind;

FIG. 6 represents a twist layer comprising 32 conductors;

FIG. 7 shows systematic crossings of the conductors of a 32-conductor twist layer;

FIG. 8 indicates a crossing plan which deviates from FIG. 2 in that the number of successively directly following basic crossing sections is doubled;

FIG. 9 represents the importance of the abbreviated designations for the basic crossings;

FIG. 10 illustrates in schematic representation the crossing plan according to FIG. 7; and

FIG. 11 shows in schematic representation a decoupled crossing section.

In FIG. 1, which shows in cross-sectional view a twist layer comprising 16 individual conductors 1 to 16, of which always two diagonally oppositely positioned conductors form a two-conductor line. Within this twist layer, there may be arranged eight individual conductors twisted about a core, whereby both twist layers may be separated preferably by a layer forming a hollow space. The dash line framing appearing in the figure is intended to indicate that the arrangement of 16 conductors may be conceived as an arrangement constructed of 2 x 8 conductors. Upon continuously crossing each group of two conductors, similarly as in an 8-conductor layer, with adjacent groups of two conductors, the originally coupled circuits 1/9 and 3/11, for example, will be like-

wise decoupled. From the 16 conductors may be formed the following basic and phantom lines:

Conductors 1/9 = St_1 } Ph_1
Conductors 5/13 = St_2 } $Ph_{1/2}$
Conductors 3/11 = St_3 } Ph_2
Conductors 7/15 = St_4 }
Conductors 2/10 = St_5 } Ph_3
Conductors 6/14 = St_6 } $Ph_{3/4}$
Conductors 4/12 = St_7 } Ph_4
Conductors 8/16 = St_8 }

St_1–St_8 are eight basic lines; Ph_1 to Ph_4 are four four-conductor phantom lines; and $Ph_{1/2}$ and $Ph_{3/4}$ are two eight-conductor phantom lines. Accordingly, there are obtained fourteen decoupled lines.

As noted before, FIG. 2 shows as an example of an embodiment the use of additional crossing points in a 16-conductor layer. As will be seen, the crossing section begins, disregarding half of the smooth initial section, with four basic crossing sections, each with four basic crossings G and four smooth sections. There follows then a dual crossing section formed by the dual crossing Z ($p=1$) and a smooth section. Four such partial sections, each comprising four basic crossing sections and one dual crossing section, form the entire decoupled crossing section. The figure also shows a basic crossing section following the dual crossing Z, so as to indicate the continuation of the crossings in the next successive partial section.

The displacement of an odd numbered and an even numbered conductor is at the dual crossing point straightened to the displacements of these conductors and the displacement of the other two conductors is at the basic crossing points oppositely directed with respect to the cooperating conductor displacements. As a consequence, the conductor displacements selected for the basic crossings will be at the dual crossing points increased for half of the conductors (conductors 1, 4, 5, 8, 9, 12, 13, 16), while it is decreased for the other half of the conductors (conductors 2, 3, 6, 7, 10, 11, 14, 15), so that the conductors of the two neighboring four-conductor phantom lines Ph_3 and Ph_2 and the conductors of the other two neighboring four conductor phantom lines Ph_4 and Ph_1 are in peripheral direction displaced by twist angles of different amounts, such angles being in a ratio of $\pm 1 : \pm 3$.

FIG. 3 shows another embodiment of a crossing section for a 16-conductor layer, wherein the conductor displacement directions selected for the basic crossings are at the additional crossing points for all conductors reversed. The crossing section begins, following half of the smooth initial section, with eight basic crossing sections, each with eight basic crossings G and eight smooth sections, followed by a dual crossing section formed by the dual crossing Z and a smooth section. The displacement direction is reversed for half of the conductors directly ahead of the dual crossing point Z, while being for the other half reversed following the dual crossing point. The entire decoupled crossing section is formed by four sections, each with eight basic crossing points and one dual crossing section. The next following basic crossing and the smooth section associated therewith are shown in the figure so as to indicate the continuation of the crossings.

The use of additional crossings in a layer comprising 24 conductors, will now be explained with reference to FIGS. 4 and 5.

FIG. 4 shows in sectional view the twist layer with the conductors 1 to 24, from which are respectively formed the following basic lines and phantom lines:

Conductors 1/13 = St_1 } Ph_1
Conductors 7/19 = St_2 } $Ph_{1/2}$
Conductors 3/15 = St_3 } Ph_2
Conductors 9/21 = St_4 } $Ph_{1/2-3/4}$
Conductors 2/14 = St_5 } Ph_3
Conductors 8/20 = St_6 } $Ph_{3/4}$
Conductors 4/16 = St_7 } Ph_4
Conductors 10/22 = St_8 }
Conductors 5/17 = St_9 } Ph_5
Conductors 11/23 = St_{10} }
Conductors 6/18 = St_{11} } Ph_6
Conductors 12/24 = St_{12} }

St_1–St_{12} are twelve basic lines; Ph_1–Ph_6 are six four-conductor phantom lines; $Ph_{1/2}$, $Ph_{3/4}$ are two eight-conductor phantom lines; and $Ph_{1/2-3/4}$ is a sixteen-conductor phantom line. Accordingly, there are provided 21 decoupled lines.

The use, for this purpose, of additional dual crossings of particular kind is indicated in FIG. 5. As shown in this figure, the crossing section begins following half of the smooth initial section, with three basic crossing sections each with three basic crossings G and three smooth sections. Thereupon follows an additional crossing section, at the crossing point Z' of which follow alternately, in peripheral direction, respectively a dual crossing and two uncrossed conductors. Four of such partial crossing sections form the entire decoupled crossing section. The advantage resulting from these crossings resides in that the conductors of mutually bordering 2-conductor lines and four-conductor lines are not only displaced in opposite directions, but that they are also displaced by differently great twist angles, that is, by angles which are in a ratio of $\pm 1 : \pm 2 : \pm 3$.

It will also be seen from FIG. 5 that, in twist layers, the number of conductors of which amounts to $3-2^n$, whereby n is a whole positive number which is greater than 2, two conductors remain, as seen in peripheral direction, uncrossed at the dual crossing points Z^1, after a dual crossing point.

FIG. 6 shows a twist layer comprising 32 conductors from which can be formed the following 30 basic lines and phantom lines:

Conductors 1/17 = St_1 } Ph_1
Conductors 9/25 = St_2 } $Ph_{1/2}$
Conductors 5/21 = St_3 } Ph_2
Conductors 13/29 = St_4 } $Ph_{1/2-3/4}$
Conductors 3/19 = St_5 } Ph_3
Conductors 11/27 = St_6 } $Ph_{3/4}$
Conductors 7/23 = St_7 } Ph_4
Conductors 15/31 = St_7 }
Conductors 2/18 = St_9 } Ph_5
Conductors 10/26 = St_{10} } $Ph_{5/6}$
Conductors 6/22 = St_{11} } Ph_6
Conductors 14/30 = St_{12} } $Ph_{5/6-7/8}$
Conductors 4/20 = St_{13} } Ph_7
Conductors 12/28 = St_{14} } $Ph_{7/8}$
Conductors 8/24 = St_{15} } Ph_8
Conductors 16/32 = St_{16} }

Crossings according to FIG. 7 are advantageously applied for the systematic crossing of the conductors of a twist layer having 32 conductors. When ignoring half of the smooth initial section, the crossing section begins with four basic crossing sections, each with four basic crossings and four smooth sections, followed by a dual crossing section formed by the dual crossing Z and by a smooth section. Thereupon follow three more such partial sections each with four basic crossing sections and a dual crossing section. A fourfold crossing V ($p=2$) is carried out centrally of the last dual crossing Z of this partial section, so that one half of a smooth section will lie on each side of the fourfold crossing section. Four such sections with a total of 16 basic crossing sections and four dual crossing sections as well as one fourfold crossing section jointly form the entire decoupled crossing section. There will then again obtain the same count sequence of the conductors as at the beginning of the crossing section. The conductors of mutually bordering two-conductor lines and four-conductor phantom lines are in this embodiment likewise displaced in opposite directions and by different large twist angles, the twist angles being mutually in a ratio of $\pm 1 : \pm 3 : \pm 5 : \pm 7$.

The crossing plans according to FIGS. 2, 5, 7, which do not provide for a reversal of the crossing direction, are respectively matched or constructed so that there is between the additional crossing sections a number of basic crossing sections which is as small as possible. There are thus, in these embodiments, respectively four (FIG. 2), three (FIG. 5) and four (FIG. 7) directly successive basic crossing sections. However, complete decoupling may also be obtained with crossing plans, for example, with plans wherein the number of basic crossing sections between two dual crossing sections is doubled or generally multiplied with the factor 2^m, whereby m is a whole

positive number. As may be seen from FIGS. 2, 3, 5 and 7, in principle, between two embodiments: For communication cables with twist layers with a conductor number 2^n, whereby n is a whole positive number greater than 3 (FIGS. 2, 3, 5 and 7), there will be obtained between two dual crossing sections a number of 2^{n+1} basic crossing sections, while for communication cables with twist layers the conductor number of which amounts to 3.2^n, wherein n is a whole positive number greater than 2 (FIG. 5), there will be obtained between two dual crossing sections a number of basic crossing sections amounting to 3.2^{m-1}.

This may in given circumstances lead to a situation in which the number of successive sections, in which two directly bordering two-conductor lines or phantom lines which exert a mutual influence, is reduced, so that the resultant summation couplings become upon individual not fully compensated partial sections as small as possible.

FIG. 8 shows a crossing plan wherein, deviating from FIG. 2, the number of the directly successive basic crossing sections is doubled, thus amounting to eight, which also applies for the crossing plan according to FIG. 3. The basic crossings in back of the dual crossing section are, however, carried out in the same manner as in FIG. 2, so that the crossing direction is retained. The decoupled crossing section (decoupling section) comprises four partial sections each with eight basic crossing sections and one dual crossing section. Accordingly, there will obtain at the end of the decoupled crossing section the same count sequence as at the beginning thereof.

While the conductors retain their crossing directions, in the embodiment according to FIG. 7, it is in connection with a 32-conductor twist layer also possible to reverse the crossing direction at the dual crossing points. It is in such case advantageous that a dual crossing section follow each sixteen basic crossing sections and that eight such sections are followed by a fourfold crossing section. The decoupled crossing section is then formed by four such sections wherein the crossing direction of the dual crossings is alternately changed.

A corresponding embodiment will be explained with reference to the schematic representation shown in FIGS. 9 to 11.

FIG. 9 illustrates the significance of the abbreviated designations for the basic crossings G, also for the dual crossing Z and for the fourfold crossing V. The arrows indicate the directions of displacement of the conductor 1 at the place of crossing. The numeral 1 indicates also that the continuous crossing of the conductors shall be started in peripheral direction with conductor 1. More in detail, and referring to FIG. 9:

1^G: Starting with conductor 1, there are carried out basic crossings in the peripheral direction, that is, there are always two conductors crossed.

1^Z: The conductor 1 and the conductor neighboring thereon in clockwise direction, are crossed with two mutually neighboring conductors in the sense indicated by the arrow.

1^V: The conductor 1 and three conductors neighboring thereon in clockwise direction, are crossed with four mutually neighboring lines in the sense indicated by the arrow.

FIG. 10 shows, for better understanding, in schematic representation the crossing plan according to FIG. 7, using thereby the abbreviations applied. The decoupled crossing section (decoupling section) embraces four sub-sections U_1, U_2, U_3, U_4. Each of these sub-sections comprises four partial sections T_1, T_2, T_3, T_4 and the fourfold crossing section indicated by the fourfold crossing 1^V, whereby each respective partial section comprises four basic crossing sections indicated by the basic crossing 1^G and a dual crossing section indicated by the dual crossing 1^Z. The arrows show that all crossings are effected without reversal of the crossing direction.

FIG. 11 shows in schematic representation, in a manner similar to FIG. 10, a decoupled crossing section (decoupling section) wherein the crossing direction is reversed at the dual crossing points. The decoupled crossing section embraces four sub-sections U_1–U_4. Deviating from FIG. 10, each sub-section comprises eight partial sections T_1–T_8 and one fourfold crossing section with the fourfold crossing 1^V, whereby each partial section comprises sixteen basic crossing sections with the basic crossing 1^G and one dual crosing section with the dual crossing 1^Z. Another difference resides in that the crossing direction is in the eight successive partial sections T_1–T_8 reversed, so that a reversal of the crossing direction takes place in spacings of $\pm 90°$, while the crossing direction is retained at the successive dual crossing points. Moreover, the dual crossings change their crossing direction in the successive sub-sections U_1–U_4.

The invention is likewise applicable when using other numbers of conductors which are divisible by eight.

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

I claim:

1. A communication cable comprising at least one layer of an even number of twisted insulated individual conductors which number is a multiple of eight, whereby, in continuous numbering of the conductors of a layer which follow successively in peripheral direction, an even numbered conductor borders always on an odd numbered conductor; said cable being longitudinally subdivided into decoupled crossing sections, referred to as decoupling sections, the length of said sections being short as compared with fabrication lengths of said cable; said decoupling sections being respectively subdivided into a plurality of sections which respectively contain at least one additional crossing point; there being in such section, in addition to at least one additional crossing point, a number of longitudinally identically spaced basic crossing points at which each even numbered conductor of a layer is crossed with an odd numbered conductor neighboring thereon; the even numbered conductors which retain their mutual relative positions being displaced at said basic crossing points in one peripheral direction and the odd numbered conductors which retain their mutual relative positions within a crossing section, being at said basic crossing points displaced in the other peripheral direction; the number of said basic crossing points being within a decoupling section such that the same count sequence of conductors prevails at the beginning and at the end of each decoupling section; 2^p successive conductors being, at said additional crossing points, as seen in peripheral direction, crossed with the 2^p next successive conductors, p being thereby a whole positive number.

2. A communication cable according to claim 1, wherein the crossings at said additional crossing points are, in connection with the basic crossings, at said basic crossing points, carried out without reversal of the crossing direction, and wherein the conductors of mutually neighboring two-conductor lines and four-conductor lines, respectively, are displaced in opposite directions and also by twist angles of different amounts.

3. A communication cable according to claim 2, in connection with twist layers with sixteen conductors, wherein the conductor displacement provided at said basic crossing points increases at said additional crossing points for one half of the conductors while decreasing for the other half of the conductors.

4. A communication cable according to claim 2, in connection with twist layers with a number of conductors corresponding to 2^n, n being a whole positive number greater than 3, wherein the conductors of mutually neighboring two-conductor and four-conductor lines are at said addition crossing points displaced by twist angles in a ratio of $\pm 1 : \pm 3 : \pm 5 : \pm 7 : \pm 9$, etc.

5. A communication cable according to claim 2, in

connection with twist layers with a number of conductors which amounts to $3 \cdot 2^n$, n being a whole positive number greater than 2, wherein the conductors of mutually neighboring two-conductor lines and four-conductor lines are at said additional crossing points displaced by twist angles in a ratio of $\pm 1 : \pm 2 : \pm 3 : \pm 4$, etc.

6. A communication cable according to claim 1, wherein the conductor displacement directions provided at said basic crossing points are at said additional crossing points for all conductors reversed.

7. A communication cable according to claim 1, in connection with twist layers with a number of conductors amounting to 2^n, n being a whole positive number greater than 3, wherein there are carried out, at said additional crossing points, by combining 2^p-conductors, crossings sufficient in number so that $n-3$ different kinds of crossings are realized, the lowest of such crossing kind containing $p=1$ and the highest containing $p=n-3$ conductors per crossing group.

8. A communication cable according to claim 1, wherein a decoupling section embraces four partial sections which respectively comprise a plurality of basic crossing sections and one dual crossing section in which two respective successive conductors are crossed with two respective next following conductors.

9. A communication cable according to claim 1, wherein a decoupling section embraces four sub-crossing sections which comprise respectively a plurality of partial sections and one fourfold crossing section in which four successive conductors are crossed with four next successive conductors, each partial section comprising a plurality of basic crossing sections and one dual crossing section in which two successive conductors are crossed with the two next successive conductors.

10. A communication cable according to claim 8, in connection with twist layers the number of conductors of which amounts to 2^n, n being a whole positive number greater than 3, wherein the number of basic crossing sections between two dual crossing sections amounts to 2^{m+1}, wherein m is a whole positive number.

11. A communication cable according to claim 8, in connection with twist layers the number of conductors of which amounts to $3 \cdot 2^n$, n being a whole positive number greater than 2, wherein the number of basic crossing sections between two dual crossing sections amounts to $3 \cdot 2^{m-1}$, wherein m is a whole positive number.

12. A communication cable according to claim 8, in connection with twist layers the number of conductors of which amounts to $3 \cdot 2^n$, n being a whole positive number greater than 2, wherein two conductors at the dual crossing points remain, as seen in peripheral direction, uncrossed following a dual crossing point.

No references cited.