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Degen

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[54] **TWISTED CONDUCTOR FABRICATION**

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[52] **U.S. Cl.** **140/149;** 57/93; 174/34

[51] **Int. Cl.** **B21f 7/00**

[58] **Field of Search** 140/149; 57/93, 94, 97; 174/34

[56] **References Cited**

UNITED STATES PATENTS

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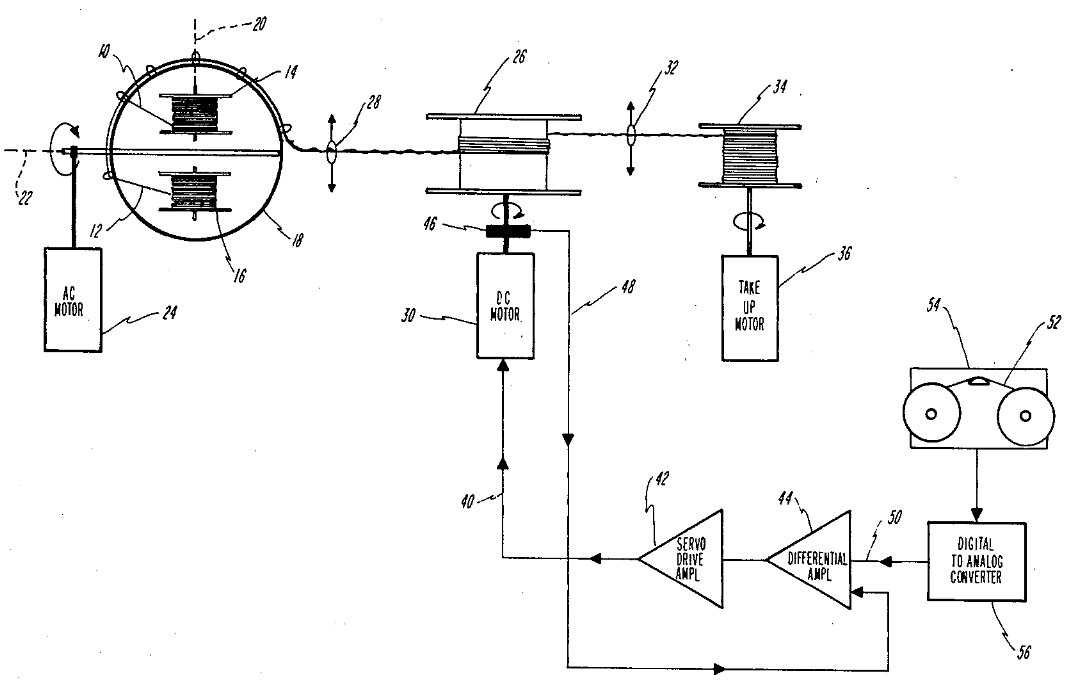
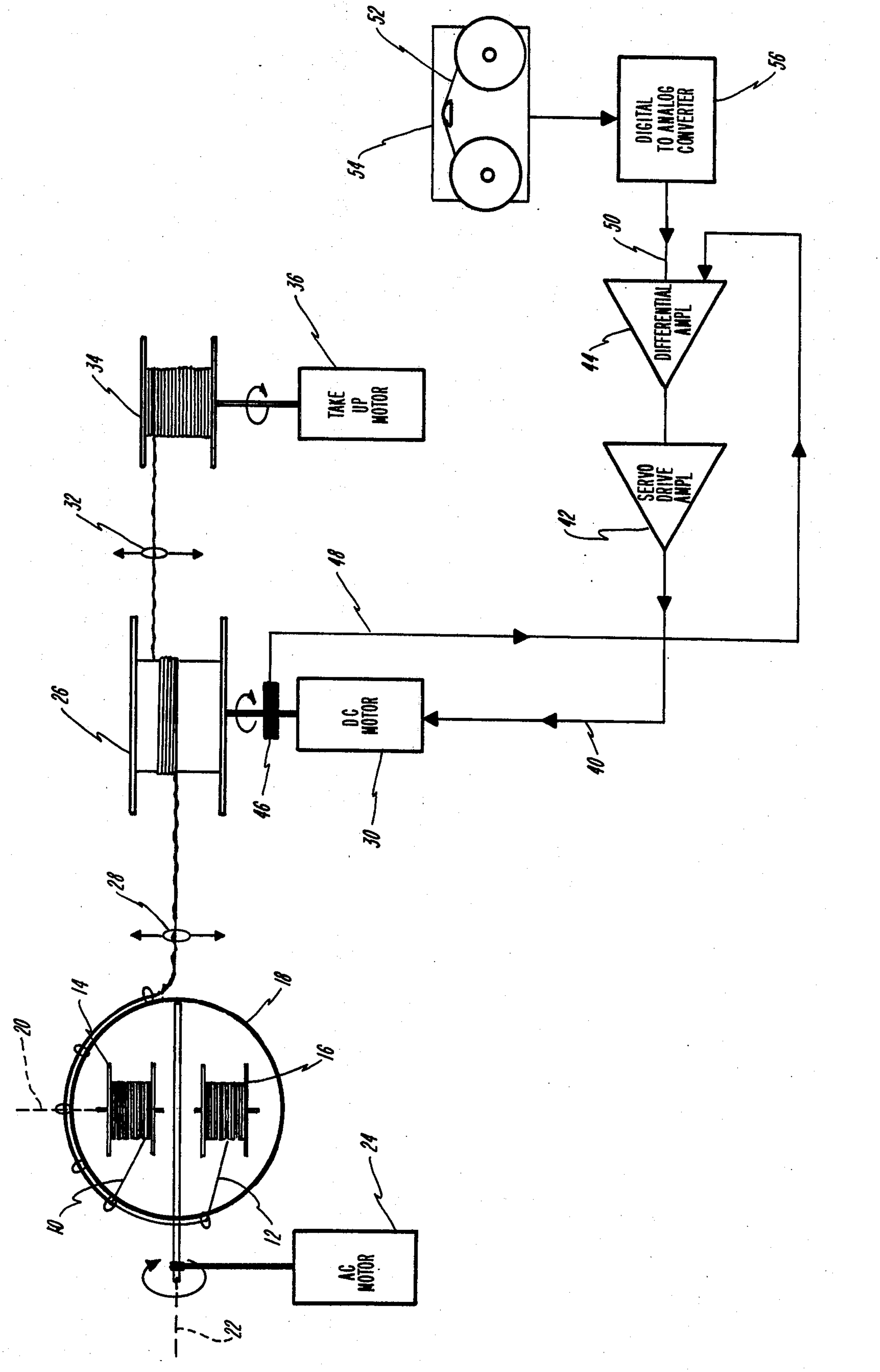
[57] **ABSTRACT**

Apparatus for twisting a pair of wires together in such a manner that a plurality of continuous randomly disposed non-repetitive and non-duplicating twists are distributed over the entire length of the twisted pair and each twist length is other than an odd multiple of the adjacent twist lengths.

3 Claims, 1 Drawing Figure





DIGITAL TO ANALOG CONVERTER
DIFFERENTIAL AMPL
SERVO DRIVE AMPL
TAKE UP MOTOR
D.C MOTOR
AC MOTOR
10
12
14
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18
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22
24
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28
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TWISTED CONDUCTOR FABRICATION

BACKGROUND OF THE INVENTION

This invention relates generally to electrical wires or conductors and cables made therefrom and to a method and apparatus for making the same. More particularly, the present invention relates to an improved twisted conductor pair circuit for use as an individual two-wire cable or assembled into multi-wire cables for the transmission of electrical signals.

Heretofore, cables have been produced from a plurality of individual twisted pairs of wires or conductors wherein either all of each twisted pair had the same twist length uniformly distributed through its length and produced a "parallel lay" cable or each twisted pair had the same twist length uniformly distributed throughout its length, but each twisted pair in a cable had a different twist length from the other twisted pair in the cable and produced a "staggered lay" cable. The "staggered lay" cable is preferred for use in telephony since the different predetermined twist lengths of the plurality of twisted pairs of conductors cause the conductors of one twisted pair to be offset with respect to those of another pair and thereby reduce inductive disturbances, such as, for example, crosstalk. However, conventional "staggered lay" cable currently in use requires an extensive stock of twisted pairs of conductors, each twisted pair having a predetermined twist length and a close inventory control as to the identity of each pair must be maintained. Additionally, each twisted pair has a prescribed location within a cable and it must be maintained in that prescribed location throughout the entire length of the cable. Therefore, the production of such "staggered lay" cable is costly and requires utilization of storage space which would be better employed for production.

Another type of prior art twisted conductor pair (disclosed in Lilly, U.S. Pat. No. 2,869,316, issued Jan. 20, 1959) which alleviated some of the difficulties and disadvantages inherent in the production of "staggered lay" cable purported to employ random twist lengths throughout its entire length. This enabled one to dispense with the making and storage of a variety of twisted pair conductors and to utilize a plurality of the same twisted pairs to make a telephony cable supposedly with a minimum chance of occurrence of crosstalk. However, the twist lengths were not entirely random throughout the entire length of the twisted pair but consisted of a plurality of repeated patterns wherein the twist lengths in each pattern only were random. The same twist lengths often were present two or more times in the length of the twisted pair. Although crosstalk was reduced, it was not entirely minimized. Furthermore, some of the twist lengths apparently fell outside of an acceptable range.

Accordingly, it is an object of the present invention to provide a new and improved twisted pair of electrical conductors having improved properties which overcome the deficiencies and disadvantages of the prior art twisted pairs of electrical conductors.

Another object of the present invention is to provide new and improved twisted pairs of electrical conductors each having random twist lengths wherein each twist length is present only once in the entire length of the conductor pair.

Another object of the present invention is to provide new and improved twisted pairs of electrical conductors having random twist lengths wherein each twist length is present only once in the entire length of the conductor pair and adjacent twist lengths are other than odd multiples of each other.

A further object of the present invention is to provide new and improved random lay cable comprising a plurality of twisted pairs of electrical conductors wherein each of the twisted pairs of electrical conductors has random twist lengths throughout, wherein each twist length is present only once in the entire length of the conductor pair and wherein adjacent twist lengths are other than odd multiples of each other.

A still further object of the present invention is to provide a new and improved method and apparatus for manufacturing twisted pairs of electrical conductors wherein each twist length is present only once in the entire length of the twisted pair.

BRIEF DESCRIPTION OF THE INVENTION

A new and improved twisted conductor pair and a method and apparatus for producing the same. The conductor pair has a plurality of continuous randomly disposed non-repetitive and nonduplicating twists distributed over the entire length of the twisted pair and each twist length is other than an odd multiple of the adjacent twist lengths.

In accordance with the method of the invention a pair of wires is drawn through a twister under the control of a drawing mechanism which is arranged to draw the wires at speeds dependent upon the respective magnitudes of electrical signals which are applied to an input to the drawing mechanism. The electrical signals are analog voltages which correspond to a digital representation of uniform probability random numbers which may be generated by any of several suitable known means-for example, by a digital computer under the control of a stored program. The random numbers are selected in such a manner that no number is an odd multiple of the preceding or of the succeeding number and, where desired, the numbers may be suitably rounded to compensate for the effects of inertia and momentum inherent in the apparatus which is utilized to perform the twisting of the conductor pairs. Comparison means are provided for comparing the last specified drawing speed with the next specified drawing speed and for generating to the input of the drawing mechanism a difference signal of the proper magnitude to change the drawing speed to the next specified drawing speed.

BRIEF DESCRIPTION OF THE DRAWING

Other objects, features and advantages of the present invention will become apparent from the following description of a preferred embodiment of the invention, taken together with the attached drawing thereof, which is a diagrammatic view of apparatus for manufacturing twisted conductor pairs in accordance with the method of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, a pair of wires **10** and **12**, preferably insulated electrical conductors, are arranged to be fed from a pair of payoff reels **14** and **16**, respectively, both of which are suitably mounted on a twister **18** and are arranged for rotation about an axis designated **20.** Twister **18,** which may be any of a number of suitable twisting mechanisms, is arranged to be rotated at a constant speed about an axis **22** (which is generally perpendicular to and lies in the same plane as axis **20**) under the control of an AC motor **24.** A capstan wheel **26** is provided and is arranged to draw twisted wire pairs **10, 12** from twister **18** through a reciprocating wire guide **28** under the control of a variable speed DC motor **30.** The twisted wire pairs are then drawn from the capstan wheel **26** through a reciprocating wire guide **32** onto a takeup reel **34** which is rotated by a constant speed takeup motor **36** arranged to provide a substantially constant tension in the twisted wire pairs after they have been fed off the capstan wheel **26.**

As will be readily appreciated the speed of rotation of the DC motor **30** determines the speed at which the capstan wheel **26** draws twisted wire pairs from the twister **18** and, since the speed of rotation of the twister **18** is constant thereby determines the twist length in the conductor pairs. The speed of rotation of the DC motor **30** is controlled by a DC voltage signal transmitted over a line **40** from a servo drive amplifier **42** to the field winding of DC motor **30** (Alternatively, the DC voltage signal from the servo drive amplifier **42** may be applied to the armature winding of the DC motor **30.**).

The output of a differential amplifier **44** having a variable integrator circuit (which compensates for — or smooths — the effects of the inertia or momentum of the capstan wheel **26,** depending upon whether the next specified drawing speed is greater than or less than, respectively, the current drawing speed, during adjustments between successive drawing speeds) drives the servo drive amplifier **42** and is arranged to compare an electrical voltage analog (which is transmitted to the differential amplifier **44** via a line **48** from a tachometer **46** which is connected to the output shaft of the DC motor **30**) with the electrical voltage analog of the next specified drawing speed (which is transmitted over a line **50** to the differential amplifier **44**) and to transmit to the servo drive amplifier **42** an amplified difference signal of the proper magnitude for the output voltage of the servo drive amplifier **42** to adjust the speed of rotation of the DC motor **30** and of the capstan wheel **26** to the next specified drawing speed.

The electrical voltage signals which are analogs of the drawing speeds utilized may be provided in the following manner:

A digital computer (not shown) is provided with any of several suitable conventional programs — for example, a program similar to the RAND program disclosed in IBM Manual C20-8011, *Random Number Generating And Testing* — and is utilized to generate a succession of uniform probability random numbers selected from a set of numbers falling between the practical limits of operation of the twisting mechanism. For example, the set of numbers from which the random values are selected typically comprises a set of numbers which are discrete and substantially continuous, and which correspond to twist lengths which range from between approximately two twists per foot to between approximately six to 10 twists per foot. The output from the computer may, for example, be provided in eight to 10 digit binary form. Advantageously, the numbers are rounded or smoothed by the program to eliminate the effects of machine chatter in the twisting and drawing mechanisms. In addition, (for reasons explained in greater detail below) the random numbers are preferably generated in a manner that no number generated is an odd multiple of either the preceding or the succeeding random number which is generated.

The random numbers generated by the digital computer may be provided in output form on a deck of punched cards, a disc, or, as shown in the FIGURE, on a magnetic tape **52.** A tape reader **54** is provided and is arranged to sequentially read the numbers on the magnetic tape **52** and to generate digital signals representative of the randomly selected numbers. The digital signals are transmitted to a digital-to-analog converter **56** which is arranged to convert the digital numbers to electrical voltage analog signals representative thereof. The voltage analog signals are transmitted via the line **50** to the differential amplifier **44** and define the input thereto which specifies the drawing speeds at which the DC motor **30** rotates.

In operation, the conductors **10** and **12** are fed from payoff reels **14** and **16,** respectively, through the twister **18** which is rotated at a constant speed by the AC motor **24.** The drawing of the wires **10** and **12** is performed under the control of the capstan wheel **26** and the wires are guided onto the capstan wheel **26** by the wire guide **28.** A substantially constant tension is provided in the twisted wires by the take-up reel **34** which is rotated by take-up motor **36** and the wire guide **32** guides the twisted pairs onto the take-up reel **34.**

The speed of rotation of the capstan wheel **26** is controlled by the DC motor **30.** The DC motor **30** is rotated at a speed which is dependent upon the instantaneous differences between the electrical analog voltages of the randomly selected drawing speeds transmitted over line **50** to the differential amplifier **44** and the electrical analog voltages of the actual speeds of rotation of the DC motor **30** (and the capstan wheel **26**) which is transmitted from the tachometer **46** via the line **48** to the differential amplifier **44.** By providing the feedback indication of the actual speed of rotation of the DC motor **30** and generating a difference signal (by means of the differential amplifier **44**) the changes in input voltages, which are transmitted via servo drive amplifier **42** and the line **40** to the DC motor **30,** are minimized, thereby reducing the effects of the inertia or momentum of the DC motor **30** and the capstan wheel **26** during changes in speeds of rotation. The list of numbers sequentially provided on the tape **52** is sufficiently long to control the twisting of conductor pairs over a period of time which is greater than a typical production run (generally of the order of 20,000 to 50,000 feet).

It has been found that twisted conductor pairs produced in accordance with the method of the invention minimize the occurrence of coincidences of twistpoints between adjacent conductor pairs and significantly reduced the inductive and electrostatic coupling between twisted pairs of conductors. Although it has been found that control of twist length by randomly selected values results in levels of crosstalk which are sufficiently low (noise levels which are a minimum of 73 Db down between adjacent conductor pairs) to conform to existing standards for telephone transmission cables, I have found that the crosstalk levels can be further reduced by providing the randomly selected values in the manner that each value is other than an odd multiple of the immediately succeeding and the immediately preceding values of drawing speeds. That the elimination of such adjacent twist lengths will further reduce the crosstalk level and will become apparent from the following example:

If two successive production runs are run under the control of the same set of randomly selected drawing speeds and one of the runs is offset by one unit twist length with respect to the other (assuming for example that a twist length A in each run is one unit long and that the succeeding twist length B is three units long), the portion of the succeeding twist length which is aligned with the preceding twist length A in that adjacent twisted pair will effectively cancel inductively with the twist length A; however, the inductive coupling of the remaining two-thirds of the twist length B will be additive with the first two-thirds of the twist length B in the adjacent wire pair. As can readily be appreciated, the crosstalk levels in adjacent twisted conductor pairs will be reduced in such instances, in which more than one-half of the adjacent twist lengths are additive, are eliminated. This will occur when such successive twist lengths (involving odd multiples) are eliminated in a twisted conductor pair in which the lengths are otherwise generated under the control of randomly selected drawing speeds.

The greater reduction of crosstalk levels becomes increasingly important in those applications in which the speeds of transmission of signals (for example, in data transmission) are increased and in those applications (for example, in some switchboards) in which large numbers of parallel runs of twisted conductor pairs occur.

Finally, production of a twisted conductor pair in accordance with the method of the instant invention not only assures randomness in the distribution of twist lengths (as opposed to the Lilly method, which produces twist lengths according to chance), but also insures that all twist lengths selected fall within the acceptable limits for the particular apparatus being utilized.

While the invention has been described with reference to a particular embodiment thereof it will be apparent to those skilled in the art to which the invention pertains that various modifications in form and detail may be made therein without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a method of forming a pair of twisted conductors comprising the steps of:

drawing the conductors through a twisting mechanism under the control of a drawing mechanism operating at a first speed, which is dependent upon the magnitudes of signals applied to an input of the drawing mechanism and being arranged to draw the wires at the first speed;

operating the twisting mechanism at a second speed, which is substantially constant, to twist the conductors around each other;

successively providing individual values of drawing speed selected at random from a set of unique and permissible drawing speeds;

converting the selected individual values of drawing speed to signals which are representative of the selected individual values, and

applying the signals representative of the successively provided values to the input, the improvement comprising the step of:

providing the individual values of drawing speed so that each value of drawing speed is other than an odd multiple of the immediately preceding and the immediately succeeding values of drawing speed.

2. A method as claimed in claim **1** wherein the drawing mechanism comprises a capstan around which twisted conductor portions are wound and a variable speed motor which is arranged to rotate the capstan and to be energized by electrical signals applied to the input, and

the signals representative of the successively provided values comprise electrical signals.

3. A method as claimed in claim **1** further comprising the steps of:

successively detecting the speeds of rotation of the variable speed motor and generating electrical signals representative thereof;

successively comparing the electrical signals which are representative of the successively provided values with the electrical signals representative of the speeds of rotation;

generating a difference signal representative of the actual difference between the electrical signals which are representative of the successively provided values and the electrical signals representative of the actual speeds of rotation, and

applying the difference signal to the input of the variable speed motor to adjust the speed of rotation of the variable speed motor from one selected value to the next successively selected value.

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