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(54) XDSL cable

(57) xDSL cable comprising a plurality of stranded groups (4) of individually insulated copper conductors (2) inserted in a sheath (5), where conductors (2) have a copper diameter of 0.4 +/- 0.05 mm and the PSACR of the cable (1) is more than or equal 30dB at 1MHz for a length of 1km, or conductors (2) have a copper diameter of 0.5 +/- 0.05 mm and the PSACR of the cable (1) is more than or equal 34dB at 1MHz for a length of 1km; stranded groups (4) have a constant twist lay length of more than or equal 20 mm.

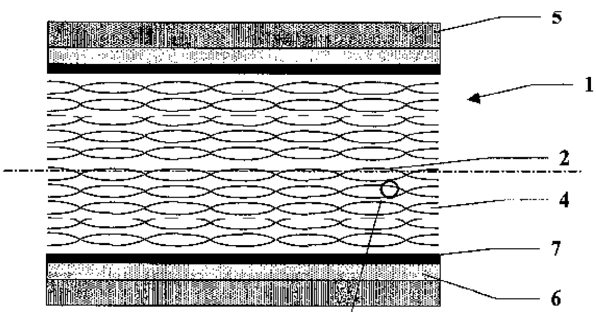

FIG. 1

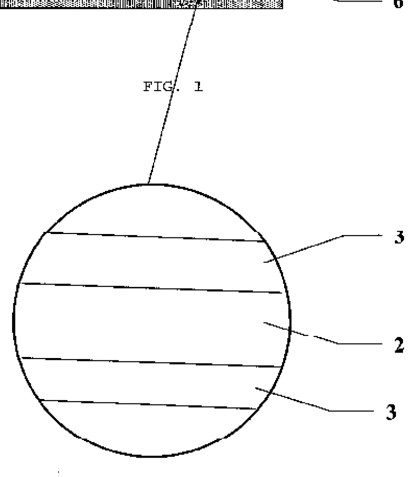

FIG. 2

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Description

[0001] The technical domain of the invention is the domain of telephone cables.

[0002] More particularly, the invention concerns a cable dedicated to numerical transmissions and optimized for xDSL systems.

[0003] A major event in telecoms today is the introduction of sophisticated digital transmission systems (in short called xDSL). XDSL is a new technology using existing telephone networks and cables to transmit data between interconnected users with high bit rate. All traditional telephone operators have long established telephone cable specifications, which define nominal and minimal requirements for cables to be installed in their networks. These specifications have been initially built up to offer a satisfactory telephone service, the frequency range of which is limited to 3400 Hz or sometimes up to 4000 Hz on some networks.

[0004] All cable makers who want to sell to these operators, have optimized their production to meet these minimal requirements at the lowest possible costs, that is, by tightening manufacturing tolerances to just meet the minimal requirements without too much scrap or cable rejected by the operators' inspectors.

[0005] The problem of xDSL is to sustain a highest possible data bit rate to cope with today more and more demanding applications. xDSL systems allow the transmission of several Mbit/s of data. For that purpose they are using frequency bands up to several MHz. The most advanced xDSL systems are expected to operate at frequencies up to 30 MHz, albeit on short distances. Higher frequencies could also be considered. The context of use differs heavily from the one of the telephone application.

[0006] Although the xDSL systems vendors claim that their systems are designed to operate over nearly any cable, two factors have made this claim dubious:

- xDSL systems have encountered a success which brings the "fill rate" (number of xDSL systems operated over the same pair bundle in a cable) much higher than initially thought. Indeed, cables used in the equipment building to connect to the xDSL operator modem (DSLAM) normally contain 100% xDSL fill,
- competition between operators has forced them to offer "unlimited xDSL", that is, xDSL operated at the maximum possible bit rate, while their initial offers were software limited to much smaller values. Offering a higher bit rate is therefore quite a competitive advantage for an operator, even more so that is now offered TV over IP which requires high bit rates, in particular in the case of high definition Television.

[0007] The major drawback of prior art telephone cables derives from the fact they have been optimized for the relatively low frequencies. So a need arises for replacement cables dedicated to xDSL, able to sustain an increased bit rate. When addressing this problem, it is known so far to use techniques derived from the data transmission world (local area networks) .

[0008] Specifications for cables, be it indoor or outdoor cables, put more stringent requirements on both traditional parameters: crosstalk and return loss requirements. In both cases the minimal requirements are set higher and higher test frequencies are specified. But such an approach has not proven to be efficient and is not economic in that the light improvements hardly gained appear to be at a too high cost.

[0009] US 2005/173144 discloses a cable having twisted conductors for use in digital systems. The cable uses simultaneously a series of pitches having a maximum and minimum value between 10 and 80 mm and a conductor insulation with a thickness from 2.0 to 2.2 times the conductor diameter for a dielectric constant of 1.87. The special sequence of pitches provides a decrease in attenuation and an improvement concerning the problem of cross talk in digital transmission.

[0010] That document addresses the same problem of enhancing electrical characteristics of communication cables for digital data transmission. A totally different approach is used in that the pitch is varying according to a geometrical progression.

[0011] Since it is a costly manufacturing process to obtain such geometrically progression of the pitch, it is not economically acceptable. The invention instead uses a constant pitch as usual in the art of cables.

[0012] The present invention addresses and solves this problem.

[0013] The object of the invention is a xDSL cable comprising a plurality of stranded groups of individually insulated copper conductors inserted in a sheath, either conductors having a copper diameter of 0.4 +/- 0.05 mm and the PSACR of the cable being more than or equal 30dB measured at a frequency of 1 MHz and for a length of 1 km, or conductors having a copper diameter of 0.5 +/- 0.05 mm and the PSACR of the cable being more than or equal 34dB measured at a frequency of 1 MHz and for a length of 1 km and stranded groups having a constant twist lay length of more than or equal 20 mm.

[0014] The proposed solution advantageously offers the possibility to produce cables with a significant increase of xDSL performance at a much lower cost than the cables (data type) envisaged and used by most applications.

[0015] Moreover, it offers the possibility of significantly improving the xDSL bit rates. Such cables advantageously allow xDSL traffics with bits rates up to 100% higher than the prior art cables, especially at long distances.

[0016] Furthermore these improved performance cables also meet the existing telephone operator specifications. This is a great advantage, considering the time necessary for an operator to change his specifications.

[0017] The conductors of these cables may be stranded by pairs or by quads.

[0018] According to another feature of the invention the ratio of the diameter of insulation to the diameter of a copper conductor is more than or equal 1.8 for quad grouped conductors.

[0019] According to another feature of the invention the ratio of the diameter of insulation to the diameter of a copper conductor is more than or equal 1.9 for pair grouped conductors.

[0020] According to another feature of the invention, the cable further comprises a screen between said sheath and said groups of conductors.

[0021] According to another feature of the invention, the cable further comprises a water blocking filler between said sheath and said groups of conductors.

[0022] According to another feature of the invention the copper conductors are insulated with material amongst: foam, foam-skin or skin-foam-skin polyolefin (e.g. polyethylene or polypropylene).

[0023] According to another feature of the invention the sheath is made of material amongst: PVC, PE, Low Smoke Zero Halogen compound.

[0024] According to another feature of the invention the screen is made of material amongst: Al, Al + PET.

[0025] According to another feature of the invention each group is individually screened.

[0026] Another object of the invention is a method for specifying an xDSL cable comprising the steps of:

- **a)** defining a minimum necessary bit rate and a minimum PSACR for the cable,
- **b)** selecting a maximum value for copper diameter of conductors,
- **c)** selecting a minimum value for constant twist lay length,

[0027] According to another feature of the invention, the method further comprises a step of selecting a minimum value for the ratio of the diameter of insulation to the diameter of a copper conductor.

[0028] Others features, details and advantages of the invention will become more apparent from the detailed illustrating description given hereafter with respect to the drawings on which:

- figure 1 is a longitudinal cross section of a cable according to the invention,
- figure 2 is a zoomed detail of a conductor,
- figure 3 is an electric wiring used to define the operational attenuation,
- figure 4 is a comparative table of prior art vs. invention cables of a first type,
- figure 5 is a comparative table of prior art vs. invention cables of a second type,
- figure 6 shows a comparative bit rate vs. length performance of a prior art cable vs. a cable according to the invention
- figures 7, 8 show two different arrangements of high pair count cables and their bundles in cross section view.

[0029] According to figure 1, a telephone cable 1 typically comprises a plurality of conductors 2, generally made of copper. Each conductor 2 is individually insulated by a surrounding insulation 3 shown in zoomed detail on figure 2. Insulated conductors 2 are assembled in groups 4. Each group 4 is individually stranded. A plurality of groups 4 is gathered in bundles or concentric layers to form a cable 1. Individual bundles may be screened or unscreened. A cable 1 may comprise an important number of conductors 2, up to 64 individual conductors or even more. That plurality is inserted in a sheath 5 which protects said conductors 2.

[0030] An increasing copper diameter of conductors 2 is known to provide better transmitting characteristics. But copper is an expensive metal and economics considerations have to be taken into account in order to not manufacture a cable with conductors 2 having too big diameters. Furthermore the cables 1 according to the invention are intended to progressively replace existing telephone network cables. Such existing cables together with all the surrounding network or maintenance equipments are designed with copper diameters of 0.4 or 0.5 mm. For these both reasons, economics and habits, the cable 1 of the invention must preferably stay in the same range.

[0031] The main idea of the invention is that the crosstalk is both a costly feature to implement (very slow manufacturing speeds) and an inefficient way to increase performance. Much higher gains in bit rate have been demonstrated (theoretically and experimentally) by reducing the cable's attenuation. This is achieved by increasing the cable's impedance, which is a counterintuitive solution for data cables, since return loss is increased, echo generated, and impedance mismatch loss encountered.

[0032] xDSL systems are extremely tolerant to return loss and echo, since they do not in general use the same band to transmit in both directions. Besides, high losses effectively mask the echoes and return losses generated deep in the network (i.e. far from the modems).

[0033] Impedance mismatch loss is not a problem for xDSL systems because of the long cable lengths: in other words, the reduction in transmission loss does much more than compensate the mismatch loss. In data cables, typically limited to 100 meters in length, this is not the case. With reference to figure 3, the operational attenuation a_b including the reflection losses can be expressed vs. the attenuation of the cable a by the following relations:

$$a_B = a + 20\log|q_1| + 20\log|q_2| + 20\log|w|$$

$$q_1 = \frac{Z_1 + Z_0}{2\sqrt{Z_1 Z_0}} \qquad q_2 = \frac{Z_0 + Z_2}{2\sqrt{Z_0 Z_2}} \qquad w = 1 - \frac{Z_1 - Z_0}{Z_1 + Z_0} \cdot \frac{Z_2 - Z_0}{Z_2 + Z_0} \cdot e^{-2\gamma \cdot l}$$

where:

a is the attenuation of the cable without reflection losses,
a_b is the operational attenuation of the cable,
q_1 and q_2 are the mismatch losses caused by the step from the system impedance to the cable impedance,
w is the interaction loss caused by multiple reflections,
γ is the complex attenuation constant of the cable,
l is the length of the cable,
Z_0 is the characteristic impedance of the cable,
Z_1 is the impedance of the generator, and
Z_2 is the impedance of the receiver.

[0034] For typical values of 100 Ohms for the system impedance and 130 Ohms for the cable impedance Z_0 the mismatch loss q is only 0.1 dB, which is neglectable compared to the improvement of the cable attenuation.

[0035] For long cable length or high attenuation, which is the case in xDSL installations, the interaction loss w tends to 1, i.e. 0dB.

[0036] When trying to optimize a cable able to sustain a higher bit rate, with the previous idea, the Applicant discovers that a minimum measure of a PSACR value could advantageously be correlated with the bit rate performance of the cable 1.

[0037] PSACR is defined as a ratio of attenuation to crosstalk (ACR). This ACR is measured using power sum (PS) to obtain PSACR. The PSACR measurement is described in normative document IEC 61156-1 Ed. 1.2 and in Ed. 3.0 in the committee draft 46C/757/CD at section 3.11. For the purpose of the claimed invention, the PSACR of each pair in the cable is measured [in dB] at a frequency of 1 MHz and for a cable length of 1 km. For the purpose of this measurement, a quad is considered as comprising two pairs. Although the PSACR is only specified at 1MHz it is measured over a frequency range of 100KHz to 10MHz. This is done to be able to draw an envelope over the measured curve and to take the value from this envelope. This is necessary because the PSACR, respectively the PSNEXT measure, is length and frequency dependent showing minimum and maximum values which will change when changing the measurement length.

[0038] The twist lay length is another parameter affecting performance. The twist lay length is an average measure of the period of the twist of conductors 2 in groups 4. A more stranded group 4, which means a smaller twist lay length, leads to a better performance. Nonetheless, under a certain value of the lay length the cost of the twisting operation becomes too expensive. The invention allows the resulting performance to be obtained with a constant twist lay length of 20 mm or more.

[0039] A group 4 of stranded conductors 2 may be a quad comprising four conductors 2. It may also be a pair comprising two conductors 2.

[0040] Another parameter related to performance is a ratio of the diameter of insulation 3 to the diameter of a copper conductor 2 so insulated. The performance increases when the relative amount of insulation 3 increases. The performance can not be increased too much in this way, since the whole diameter of the cable and the price will also tend to increase in an unaffordable manner. The invention allows the resulting performance to be obtained with such a minimum copper to insulation ratio of 1.8 for quad grouped conductors and of 1.9 for paired grouped conductors.

[0041] The cable 1 may further comprise a screen 7 between said groups 4 of conductors 2 and said sheath 5.

[0042] In other embodiments dedicated to environment critical applications the cable 1 may also comprise a water blocking filler 6 between said sheath 5 and said stranded groups 4 of conductors 2.

[0043] The material for insulation 3 of conductors can typically be chosen amongst foam, foam-skin or skin-foam-skin polyolefin (e.g. polyethylene and polypropylene). An example of solid polyethylene is the product TR-210 Alcudia® from Repsol. An example of foam-skin polyethylene is the product HE1344 from Borealis.

[0044] The material of the sheath 5 can typically be chosen amongst Poly Vinyl Chloride (PVC), polyethylene (PE), either with or without laminated aluminium glued and Low Smoke Zero Halogen compound (LSZH), like i.e. SCAPA S500 or POLYONE ECCOH 5860).

[0045] The screen 7 is typically made from a tape of metal, e.g. aluminium (Al), for outdoor applications. The typical thickness of the metal tape in this case is about 0.15 to 0.2 mm.

[0046] For indoor applications the screen 7 is typically a sandwich tape made of a combination of metal and plastic, e.g. aluminium (Al) and polyester (PET). The typical thickness of the sandwich tape, in this case is about 0.05 mm.

[0047] In another embodiment, xDSL cable may comprise an important number of groups 4. In such a case, some of theses groups 4 may be assembled together in bundles. These bundles may be screened. For high pair counts (e.g. 128 pairs) several of those pairs or quads are assembled together in bundles (e.g. 4 bundles of 32 pairs). The pairs of those bundles may be assembled in concentric layers (e.g. 5+11+16) or in sub bundles (e.g. 4 bundles of 8 pairs). Each of these bundles or sub bundles may or may not be screened. Figure 7, 8 illustrates such assemblies in bundles respectively for a 32 pairs cable and a 128 pairs cable.

[0048] Another embodiment is also possible with each group 4 being individually screened.

[0049] According to the invention a method of cable specification may be proceeded by the following steps: for a minimum necessary bit rate a minimum PSACR is associated. This minimum PSACR is known from testing of the xDSL performance in a real copper cable infrastructure. For this necessary minimum PSACR a minimum copper diameter of conductors 2 and a minimum twist lay length is chosen. The so obtained PSACR performance will guarantee the associated performance in bit rate.

[0050] Further, a maximum value for the ratio of the diameter of a copper conductor 2 to the diameter of insulation 3 may be given before proceeding to the step of specifying a maximum twist lay length.

[0051] As the impact of copper diameter on the cost is higher than the pair lay length (increased copper diameter results in increased insulation diameter, i.e. same ratio, and finally increased cable diameter) the smallest copper diameter possible is chosen to provide the minimum PSACR.

[0052] The tables of figures 4 and 5 provide illustrative samples of cables according to the invention. They also provide comparative descriptions with respect to cables of prior art.

[0053] Table of figure 4 shows indoor paired unfilled cables. Two prior art cables appear in first to second columns. A cable according to the invention appears on the third and last column.

[0054] Table of figure 5 shows outdoor quaded filled cables. Three prior art cables appear in first to third columns. A cable according to the invention appears on the last column.

[0055] Accordingly, figure 6 shows bit rate (vertical axis in Mbit/s) vs. length of cable (horizontal axis in km) comparative performance curves. The lower curve corresponds to a prior art cable and the upper curve corresponds to an improved cable according to the invention.

Claims

1. xDSL cable comprising a plurality of stranded groups (4) of individually insulated copper conductors (2) inserted in a sheath (5), **characterized in that**:

    - conductors (2) have a copper diameter of 0.4 +/- 0.05 mm and the PSACR of the cable (1) is more than or equal 30dB at 1 MHz for a length of 1 km, or
    - conductors (2) have a copper diameter of 0.5 +/- 0.05 mm and the PSACR of the cable (1) is more than or equal 34dB at 1 MHz for a length of 1 km;
    - stranded groups (4) have a constant twist lay length of more than or equal 20 mm.

2. xDSL cable according to claim 1, where said groups (4) are either pairs or quads.

3. xDSL cable according to claim 2, where the ratio of the diameter of insulation (3) to the diameter of a copper conductor (2) is more than or equal 1.8 for quad grouped conductors (2).

4. xDSL cable according to claim 2, where the ratio of the diameter of insulation (3) to the diameter of a copper conductor (2) is more than or equal 1.9 for pair grouped conductors (2).

5. xDSL cable according to any one of claims 1 to 4, further comprising a screen (7) between said sheath (5) and said

groups (4) of conductors (2).

6. xDSL cable according to any one of claims 1 to 5, further comprising a water blocking filler (6) between said sheath (5) and said groups (4) of conductors (2).

7. xDSL cable according to any one of claims 1 to 6, where the copper conductors (2) are insulated with material amongst: foam, foam-skin skin-foam-skin polyolefin.

8. xDSL cable according to any one of claims 1 to 7, where the sheath is made of material amongst: PVC, PE, Low Smoke Zero Halogen compound.

9. xDSL cable according to any one of claims 1 to 8, where the screen (7) comprise a tape made of material amongst: Al, Al + PET.

10. xDSL cable according to any one of claims 1 to 9, where a number of groups (4) are assembled together in bundles and these bundles are screened.

11. xDSL cable according to any one of claims 1 to 10, where each group (4) is individually screened.

12. Method for specifying an xDSL cable (1) **characterized in that** it comprises the steps of:

a) defining a minimum necessary bit rate and the associated minimum PSACR of the cable.
b) selecting a minimum value for copper diameter of conductors (2),
c) selecting a maximum value for constant twist lay length.

13. Method according to claim 12 further comprising a step of selecting a minimum value for the ratio of the diameter of insulation (3) to the diameter of a copper conductor (2).

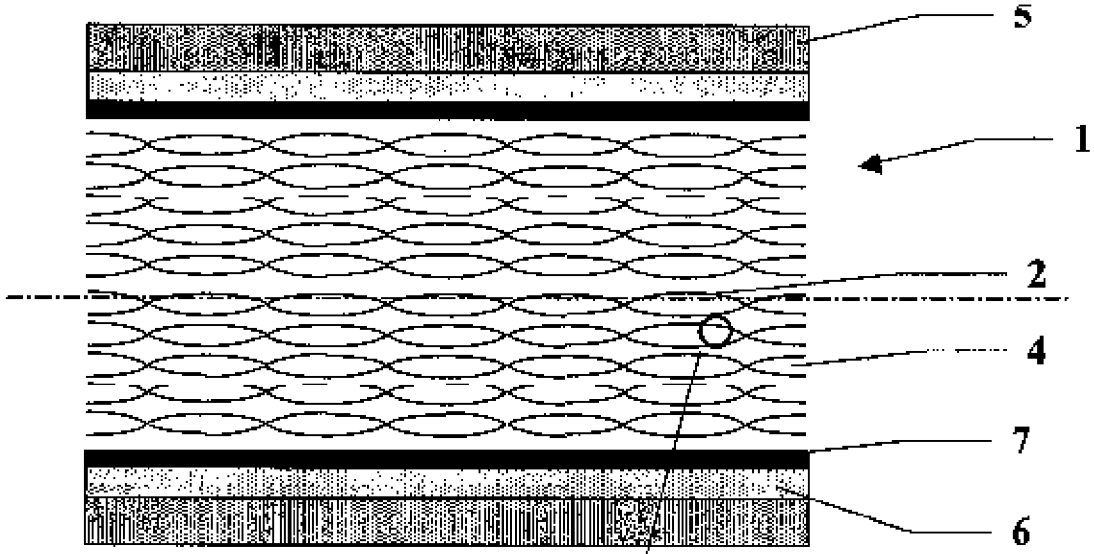

FIG. 1

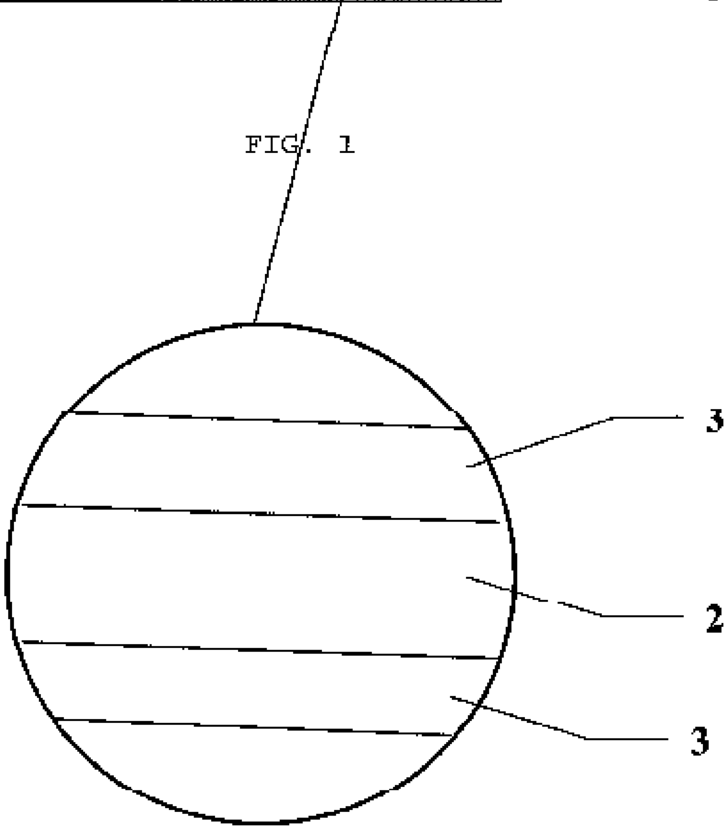

FIG. 2

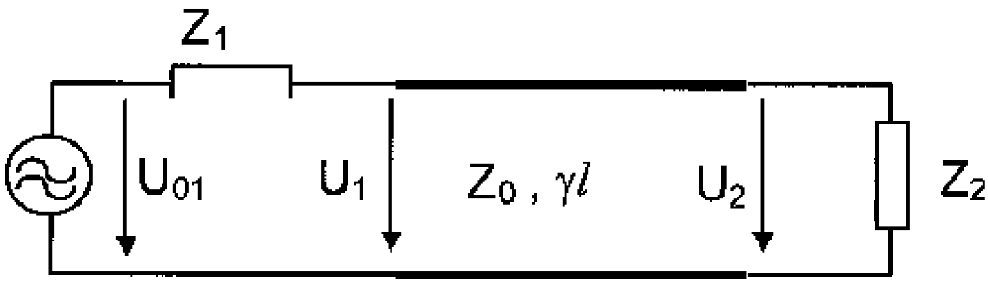

FIG. 3

# of groups	32			32			32		
Pair/Quad	Pair			Pair			Pair		
Filled	No			No			No		
ØCu	0.4			0.4			0.4		
ØInsulation	0.71			0.71			0.85		
Insulation	Solid PE			Solid PE			Foam-skin PE or foam-skin PP		
Assembly	4x(8/2)			4x(8/2)			4x(8/2)		
Screen	Al/PET			Al/PET			Al/PET		
Sheath	PVC			PVC			PVC		
	min	avg	max	min	Avg	max	min	Avg	max
Impedance@1MHz, 1km	100	103	105	95	105	115	120	125	130
Attenuation@1MHz, 1km	24	24	26	23	25	28	19	20	21
PSNEXT@1MHz, 1km	35	38		50	53		62	68	
PSACR@1MHz, 1km	9	14		22	27		41	48	

FIG. 4

# of groups	10			10			10			10		
Pair/Quad	Quad			Quad			Quad			Quad		
Filled	Yes			Yes			Yes			Yes		
ØCu	0.6			0.6			0.6			0.48		
ØInsulation	1.07			1.02			1.02			0.99		
Insulation	Foam-skin PE			Foam-skin PE			Foam-skin PE			Foam-skin PE		
Assembly	[3+7]/4			[3+7]/4			[3+7]/4			[3+7]/4		
Screen	Al 0.2mm			Al 0.2mm			Al 0.2mm			Al 0.2mm		
Sheath	PE			PE			PE			PE		
	min	avg	max	min	Avg	max	min	avg	max	min	avg	Max
Impedance@1MHz, 1km												
Attenuation@1MHz, 1km		17	17.4		16.9	17.3		16.9	17.2		17.7	18.0
PSNEXT@1MHz, 1km	39.8	60.2		56.2	66.1		54.3	63.6		59.6	67.3	
PSACR@1MHz, 1km	22.5	43.3		38.9	49.2		37.1	46.8		41.6	49.6	

FIG. 5

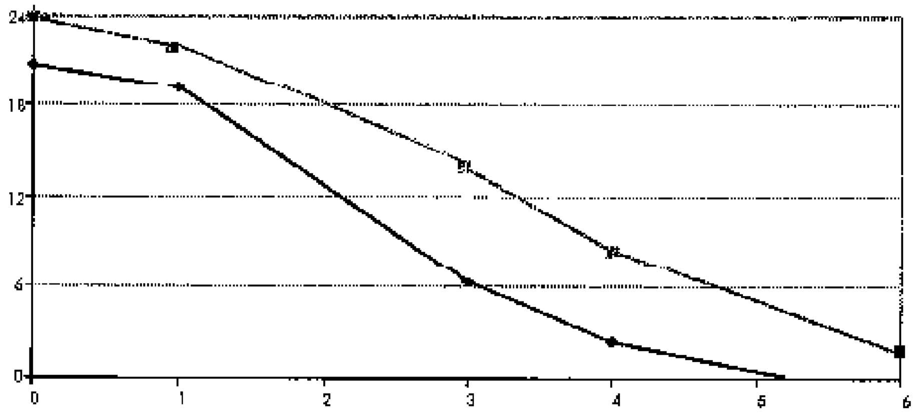

FIG. 6

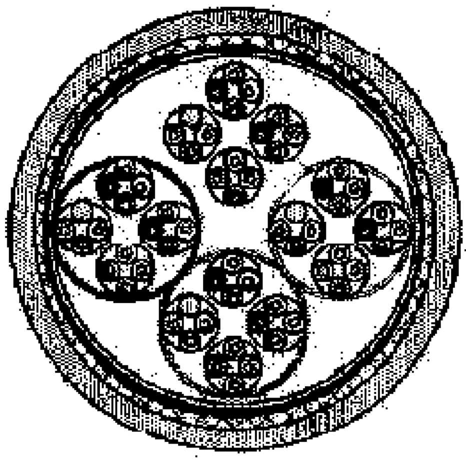

FIG. 7

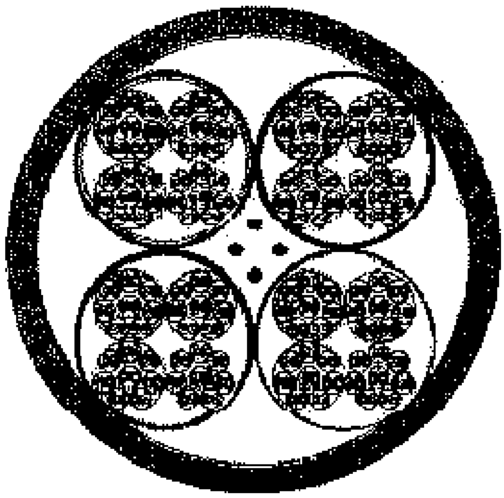

FIG. 8

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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