(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 190 939 B1**

(12) # EUROPEAN PATENT SPECIFICATION

(45) Date of publication of patent specification: **26.06.91**

(51) Int. Cl.5: **H01B 11/14**

(21) Application number: **86300836.3**

(22) Date of filing: **06.02.86**

(54) **High frequency attenuation cable and harness.**

(30) Priority: **06.02.85 US 698645**

(43) Date of publication of application:
13.08.86 Bulletin 86/33

(45) Publication of the grant of the patent:
26.06.91 Bulletin 91/26

(84) Designated Contracting States:
AT BE CH DE FR GB IT LI NL SE

(56) References cited:
EP-A- 0 081 373
GB-A- 1 134 636

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EP 0 190 939 B1

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Description

This invention relates to a high frequency attenuation cable and to a high frequency attenuation cable harness.

High frequency attenuation cables are well known. In general, such cables include an absorption medium which filters out high frequency energy which could otherwise interfere with the operation of the cable. The effectiveness with which the high frequency energy is filtered out is referred to as the high frequency attenuation. The greater the attenuation, the higher the effectiveness.

Various attempts have been made to improve the high frequency attenuation of these cables. In this regard, see for example, Mayer, USP 4,301,428; Martin, USP 4,347,487; Cornelius et al., USP 4,486,721; and Cornelius et al., USP 4,499,438, all of which are incorporated herein by reference.

These references generally disclose a cable construction in which a conductor is surrounded, in order, by a high frequency energy attenuation medium, a dielectric, and an electrically conductive shielding means. In the Cornelius et al. application, the relative positions of the high frequency energy attenuation medium and the dielectric are reversed.

While the high frequency attenuation cables described in the above references have improved high frequency attenuation above 100 megahertz (MHz), the attenuation in the range of 10 to 100 MHz is somewhat less than that desired for certain applications. This invention provides a high frequency attenuation cable having improved high frequency attenuation in the 10-100 MHz range.

One aspect of this invention comprises a high frequency attenuation cable comprising a core comprising at least one conductor, each said conductor being surrounded by a layer of high dielectric constant material having a dielectric constant greater than about 4 when measured at 10 MHz and a volume resistivity of at least about 10^{13} ohm-cm; and a layer of high frequency absorption medium. The high dielectric constant material preferably also has a tensile strength of at least about 4,000 pounds per square inch (psi) (285 Kg/cm^2). Additional layers of the absorption medium and/or the high dielectric material and/or a second dielectric material may also be present.

It should be understood that the core is that portion of the cable which is surrounded by the electrically conductive shield and any outer or protective jacketing.

I have discovered that the use of a high dielectric constant material surprisingly and unexpectedly improves the high frequency attenuation in the frequency range of 10 to 100 MHz.

Figure 1 is a cut-away side view of one embodiment of a cable construction according to the invention.

Figure 2 is a cut-away side view of another embodiment of a cable construction according to the invention.

Figure 3 is a cross-sectional view of one embodiment of a cable harness according to the invention.

Figure 4 is a cross-sectional view of another embodiment of a cable harness according to the invention.

Figures 5 and 6 are graphs of attenuation versus frequency for cable constructions according to the invention compared to cable constructions according to the prior art.

Referring to the figures in more detail, and particularly referring to Figure 1, there is disclosed a high frequency attenuation cable 2. The cable comprises a core which, in turn, comprises conductor 4, a layer of high frequency absorption medium 6 surrounding the conductor, and a layer of high dielectric constant material 8 surrounding the high frequency absorption medium.

It is to be understood that the cable may further comprise additional layers of absorption medium, high dielectric constant material, a second dielectric material and the like. Further the cable generally also is provided with an electrically conductive shield and a protective outer jacket.

As will become more apparent hereafter, the use of a layer of high dielectric constant material according to the invention markedly increases the high frequency attenuation of the cable in the frequency range of 10 to 100 MHz.

The term "high dielectric constant material" is used herein to mean a material has a dielectric constant (ϵ) greater than about 4 when measured at 10 MHz. Further, the material has a volume resistivity of at least about 10^{13} ohm-cm. The high dielectric constant material preferably also has a tensile strength greater than about 4,000 psi (285 kg/cm^2). A preferred high dielectric constant material is polyvinylidene fluoride. The term polyvinylidene fluoride is used herein to mean polymers of vinylidene fluoride. The homopolymer is preferred. Polyvinylidene fluoride is commercially available under the trademark Kynar from Pennwalt Corporation, Philadelphia, PA.

In typical prior art high frequency attenuation cable construction there generally is a conductor surrounded by a high frequency absorption medium which is in turn surrounded by a dielectric material such as polyethylene or TEFZEL® (TEFZEL is a copolymer of ethylene and tetrafluoroethylene and is a product of E.I. duPont de Nemours, Wilmington, DE). Both polyethylene and TEFZEL are materials having low dielectric constants (ϵ of about 2-3). As mentioned above prior art cables exhibit lower high frequency attenuation in the frequency range of 10-100 MHz than is desirable for certain uses.

The high frequency absorption medium such as the well-known lossy materials disclosed in the Cornelius et al. references serves to allow the passage of low frequency energy but absorbs the high frequency energy. Lossy materials are also disclosed in Mayer, USP 3,309,633 and USP 3,191,132 which are incorporated herein by reference. A preferred lossy material for the present invention is ferrite-loaded polymer, for example, ferrite-loaded VITON® A (VITON A is a copolymer of vinylidene fluoride and hexafluoropropylene and is a product of E. I. Du Pont de Nemours, Wilmington, DE).

In Figure 2 there is disclosed a second embodiment of the invention. As shown in the figure, there is a high frequency attenuation cable 2'. The cable comprises a conductor 4, a layer of high dielectric constant material 9 surrounding the conductor, a layer of high frequency absorption medium 6 surrounding the layer 9 of high dielectric constant material, and an additional layer of dielectric material 8 surrounding the layer of high frequency absorption medium. The dielectric material of the additional layer can be a high dielectric constant material, as defined herein, or a second dielectric material, e.g. one having a lower dielectric constant, e.g. below about 3.

It has been found that when high dielectric constant material is located both inside and outside of the high frequency absorption medium that similar results are obtained as when a layer of high dielectric constant material having a thickness equal to the total thickness of the two layers is located only outside of the absorption medium.

Another embodiment of the high frequency attenuation cable (not shown) comprises a conductor, a layer of high dielectric constant material surrounding the conductor, and a high frequency absorption medium surrounding the layer of high dielectric material. It is believed that this cable construction will also lead to improved high frequency attenuation in the 10 to 100 megahertz range, as was the case with the previous embodiments.

Thus, it is now apparent that the high dielectric material, preferably polyvinylidene fluoride, can be located either inside of the high frequency absorption medium or outside of the high frequency absorption medium or both inside and outside of the high frequency absorption medium. Further, a layer of dielectric material having a dielectric constant less than about 3 can be included in the construction, preferably as an outermost layer.

The additional layer of dielectric material can be selected to provide desired electrical and/or mechanical properties. For example, for maximum attenuation, it is believed that the additional layer should be of a high dielectric constant material, e.g. polyvinylidene fluoride. In certain situations it may be desirable to optimize the overall capacitance of the cable making it as low as possible while still maintaining good attenuation. In such a situation a material having a lower dielectric constant, e.g. polyethylene or TEFZEL, can be used. In other instances the selection of the additional layer of dielectric material is made to provide good mechanical properties. For example good solvent resistance, toughness, abrasion resistance, cut through resistance and the like may lead to the selection of a particular dielectric material even if optimum electrical performance is not achieved. Suitable dielectric materials under these criteria include polyethylene, polyvinyl chloride, TEFZEL, polyesters, polyamides, polyamide-imides, polyether-esters, and the like also polymeric blends. The high dielectric constant material and the second dielectric material, if present, can include various additives such as stabilizers, pigments, flame retardants, processing aids and the like.

The cable constructions may further comprise an electrically conductive shielding means surrounding the core and an outer jacket surrounding the shielding means.

It has been found that the use of a high dielectric constant material, as defined above, leads to significantly improved performance. It has also been found that reducing the wall thickness of the high dielectric constant material will also lead to enhanced performance. Thus, in a preferred embodiment of this invention, a relatively thin layer of high dielectric constant material is used. While the reason for the improved performance is not fully understood, it is believed to be due to the increased capacitance between the absorptive material and the conductor when the high dielectric constant material is positioned therebetween or between the absorptive medium and the electrically conductive shield when the high dielectric material is positioned outside of the absorptive medium. The capacitance is further increased if the layer of the high dielectric constant material is relatively thin.

Further disclosed according to the invention, as illustrated in Figures 3 and 4, are high frequency attenuation cable harnesses. Each of the cable harnesses comprises a plurality of cables with each cable having a core as described above. Thus, in general the core will comprise a conductor, a high frequency absorption medium surrounding the conductor and at least one layer of high dielectric constant material, preferably polyvinylidene fluoride. The only difference between the various cores will be the location of the high dielectric constant material which may be inside or outside, or both inside and outside of the high frequency absorption medium.

Figure 3 illustrates one embodiment of a cable harness 20 having a plurality of cables 22 in which, in each core there is a conductor 24 surrounded by a high frequency absorption medium 26 which in turn is surrounded by a layer of high dielectric constant material 28.

Similarly, in Figure 4, each cable 42 of cable harness 40 has a core having at least one conductor 44 surrounded by a high frequency absorption medium 46 which is in turn surrounded by a layer of high dielectric constant material 48.

The main distinguishing feature between the constructions in Figures 3 and 4 is how the individual cables are shielded. Thus, in Figure 3 each cable comprises electrically conductive shielding means 30 surrounding each of the cores and an outer jacket 32 surrounding each of the electrically conductive shielding means. The construction in Figure 3 may further comprise protective outer jacketing 34 surrounding the plurality of cables.

Returning to Figure 4, the cable harness 40 comprises gross electrically conductive shielding means 50 surrounding the plurality of cables and protective outer jacketing 52 surrounding the shielding means.

As stated above, the high frequency absorption medium may be any of the well-known lossy materials. However the preferred lossy material is ferrite-loaded polymer and more preferably ferrite-loaded VITON.

The advantages of the invention will become more apparent after reference to the following examples.

Example I

Two samples were prepared each by extruding a first layer (about 14 mils thick) of high frequency absorption medium (about 5 mils thick) onto a stranded conductor 40 mils in diameter and then a second layer (about 5 mils thick) of dielectric material. Each core was surrounded by metallic braid for shielding and then surrounded by outer jacketing. The only difference between the samples was that in one sample the dielectric material was TEFZEL (low dielectric constant material) and in the other sample the insulation layer was KYNAR, polyvinylidene fluoride (high dielectric constant material). Each sample was surrounded by a metallic braid and the insertion loss was measured. The results are illustrated in Figure 5.

As can be seen, the cable construction having the KYNAR insulation layer (Sample 2) is far superior over the entire frequency range to the cable construction having the TEFZEL insulation layer (Sample 1). Most importantly, in the critical range of 10 to 100 MHz the attenuation has been dramatically improved.

Example II

Two other samples were similarly prepared. Both of the samples in general had a conductor surrounded by a layer of lossy material which in these samples consisted of 30 volume percent of ferrite in VITON. The cable constructions further comprised a layer of insulative dielectric material surrounded by electrically conductive shielding means and finally surrounded by outer jacketing. The results are illustrated in Figure 6.

The only difference between the samples was that Sample 1 had KYNAR (high dielectric constant material) insulation and the other sample (Sample 2) had polyethylene (low dielectric constant material) insulation. As can be seen in Figure 6 the sample having the KYNAR is far superior over the entire frequency range to the sample having the polyethylene insulation. And again most importantly, in the critical range of 10 to 100 MHz, the attenuation of the sample having KYNAR insulation is markedly improved over the sample having the polyethylene insulation.

In view of the above results it can be appreciated that by using an insulation layer of high dielectric constant material, preferably polyvinylidene fluoride (commercially available as KYNAR) that the attenuation of the cable construction in the frequency range of 10 to 100 MHz is surprisingly and unexpectedly improved over the prior art cable constructions using polyethylene, TEFZEL, or other similar insulation materials.

Example III

A sample was prepared by extruding a first layer of polyvinylidene fluoride having a wall thickness of 3 mils onto a stranded, tin plated 20 AWG copper conductor. Onto this was extruded a 4 mil layer of ferrite filled VITON A as described in Examples I and II. A third layer consisting of an ethylene tetrafluoroethylene copolymer (ETFE) with a wall thickness of 4 mils was then extruded on top of the first two layers. The sample was then surrounded with a metallic braid, and the insertion loss was measured. The results were as follows:

Frequency	Insertion Loss
10 MHz	0.2 dB/ft
100 MHz	2.8 dB/ft
500 MHz	18.0 dB/ft
1000 MHz	41.7 dB/ft

Claims

1. A high frequency attenuation cable (2) comprising a core comprising at least one conductor (4), each conductor being surrounded by:
   (a) a layer of high dielectric constant material (8,9) having a dielectric constant greater than about 4 when measured at 10 MHz and a volume resistivity of at least about 10^{13} ohm-cm; and
   (b) a layer of high frequency absorption medium (6).

2. A cable in accordance with Claim 1, wherein said high dielectric constant material (8,9) has a tensile strength greater than about 4,000 psi (285 Kg/cm^2).

3. A cable in accordance with Claim 1, wherein said layer of high dielectric constant materials (8,9) is positioned between said conductor (4) and said layer of absorption medium (6).

4. A cable in accordance with Claim 1, wherein said layer of absorption medium,(6) is positioned between the conductor (4)and the high dielectric constant material (8,9).

5. A cable-in accordance with Claim 1, which further comprises an additional layer of dielectric material (8).

6. A cable, in accordance with Claim 5, wherein the additional layer of dielectric material (8) comprises a high dielectric constant material having a dielectric constant greater than about 4 when measured at 10 MHz and a volume resistivity of at least about 10^{13} ohm-cm.

7. A cable in accordance with Claim 5, wherein said additional layer of dielectric material (8) surrounds said other layers.

8. A cable in accordance with Claim 5, wherein said additional layer of dielectric material (8) comprises a material having a dielectric constant less than about 3.

9. A cable in accordance with Claim 1, wherein said high dielectric constant (8,9) material is polyvinylidene fluoride.

10. A cable in accordance with Claim 1, wherein said high frequency absorption medium (6) comprises a ferrite loaded polymeric material.

11. A cable in accordance with Claim 1, wherein said core is surrounded by an electrically conductive shielding means (10).

12. A high frequency attenuation cable harness (20) comprising a plurality of cables (22) each cable comprising a core comprising at least one conductor (24), each conductor being surrounded by:
    (a) a layer of high dielectric constant material (28) having a dielectric constant greater than about 4 when measured at 10 MHz and a volume resistivity of at least about 10^{13} ohm-cm; and
    (b) a layer of high frequency absorption medium (26).

13. The high frequency attenuation cable harness of Claim 11 wherein the high dielectric constant material (28) is polyvinylidene fluoride.

14. The high frequency attenuation cable harness of Claim 12, wherein the high frequency absorption medium (26) is ferrite loaded polymer.

15. The high frequency attenuation cable harness of Claim 12, further comprising an electrically conductive shielding means (50) surrounding each of said cables (20) and an outer jacket (52) surrounding each of said shielding means (50).

16. The high frequency attenuation cable harness of Claim 15, further comprising protective outer jacketing (52) surrounding the plurality of cables.

17. The high frequency attenuation cable harness of Claim 12, further comprising gross electrically conductive shielding means surrounding the plurality of cables and protective outer jacketing (52) surrounding the gross shielding means.

Revendications

1. Câble d'atténuation de haute fréquence (2) comprenant une âme renfermant au moins un conducteur (4), chaque conducteur étant entouré par :
   (a) une couche d'un matériau de haute constante diélectrique (8, 9) ayant une constante diélectrique supérieure à environ 4 lors d'une mesure à 10 MHz et une résistivité volumique d'au moins environ 10^{13} ohms-cm ; et
   (b) une couche d'un milieu d'absorption de haute fréquence (6).

2. Câble suivant la revendication 1, dans lequel le matériau de haute constante diélectrique (8, 9) possède une résistance à la traction supérieure à environ 4000 lb/in^2 (285 kg/cm^2).

3. Câble suivant la revendication 1, dans lequel la couche de matériau de haute constante diélectrique (8, 9) est positionnée entre le conducteur (4) et la couche de milieu absorbant (6).

4. Câble suivant la revendication 1, dans lequel la couche de milieu absorbant (6) est positionnée entre le conducteur (4) et le matériau de haute constante diélectrique (8, 9).

5. Câble suivant la revendication 1, qui comprend en outre une couche supplémentaire de matériau diélectrique (8).

6. Câble suivant la revendication 5, dans lequel la couche supplémentaire de matériau diélectrique (8) comprend un matériau de haute constante diélectrique ayant une constante diélectrique supérieure à environ 4 lors d'une mesure a 10 MHz et une résistivité volumique d'au moins environ 10^{13} ohms-cm.

7. Câble suivant la revendication 5, dans lequel la couche supplémentaire de matériau diélectrique (8) entoure les autres couches.

8. Câble suivant la revendication 5, dans lequel la couche supplémentaire de matériau diélectrique (8) comprend un matériau ayant une constante diélectrique inférieure à environ 3.

9. Câble suivant la revendication 1, dans lequel le matériau de haute constante diélectrique (8, 9) est le polyfluorure de vinylidène.

10. Câble suivant la revendication 1, dans lequel le milieu d'absorption de haute fréquence (6) consiste en un matériau polymérique renfermant une charge de ferrite.

11. Câble suivant la revendication 1, dans lequel l'âme est entourée par un moyen de blindage électriquement conducteur (10).

12. Harnais de câbles d'atténuation de haute fréquence (20) comprenant plusieurs câbles (22), chaque

câble comprenant une âme renfermant au moins un conducteur (24), chaque conducteur étant entouré par :

(a) une couche d'un matériau de haute constante diélectrique (28) ayant une constante diélectrique supérieure à environ 4 lors d'une mesure à 10 MHz et une résistivité volumique d'au moins environ 10^{13} ohms-cm ; et

(b) une couche d'un milieu d'absorption de haute fréquence (26).

13. Harnais de câbles d'atténuation de haute fréquence suivant la revendication 11, dans lequel le matériau de haute constante diélectrique (28) est le polyfluorure de vinylidène.

14. Harnais de câbles d'atténuation de haute fréquence suivant la revendication 12, dans lequel le milieu d'absorption de haute fréquence (26) est un polymère renfermant une charge de ferrite.

15. Harnais de câbles d'atténuation de haute fréquence suivant la revendication 12, comprenant en outre un moyen de blindage électriquement conducteur (50) entourant chacun des câbles (26) et une gaine extérieure (52) entourant chacun des moyens de blindage (50).

16. Harnais de câbles d'atténuation de haute fréquence suivant la revendication 15, comprenant en outre une gaine extérieure protectrice (52) entourant l'ensemble des câbles.

17. Harnais de câbles d'atténuation de haute fréquence suivant la revendication 12, comprenant en outre un moyen brut de blindage électriquement conducteur entourant l'ensemble des câbles et une gaine extérieure protectrice (52) entourant le moyen brut de blindage.

Ansprüche

1. Hochfrequenzdämpfungskabel (2), umfassend eine Seele, die wenigstens einen Leiter (4) umfaßt, wobei jeder Leiter umgeben ist von:

(a) einer Schicht aus einem Material (8, 9) mit einer hohen Dielektrizitätskonstanten, die, bei 10 MHz gemessen, größer als ca. 4 ist, und mit einem spezifischen Durchgangswiderstand von wenigstens ca. 10^{13} Ohm cm; und

(b) einer Schicht aus einem Hochfrequenzabsorptionsmedium (6).

2. Kabel nach Anspruch 1, wobei das Material (8, 9) mit hoher Dielektrizitätskonstante eine Zugfestigkeit von mehr als ca. 4000 psi (285 kg/cm^2) hat.

3. Kabel nach Anspruch 1, wobei die Schicht aus dem Material (8, 9) mit hoher Dielektrizitätskonstante zwischen dem Leiter (4) und der Schicht aus Absorptionsmedium (6) positioniert ist.

4. Kabel nach Anspruch 1, wobei die Schicht aus Absorptionsmedium (6) zwischen dem Leiter (4) und dem Material (8, 9) mit hoher Dielektrizitätskonstante positioniert ist.

5. Kabel nach Anspruch 1, das ferner eine zusätzliche Schicht aus einem dielektrischen Material (8) umfaßt.

6. Kabel nach Anspruch 5, wobei die zusätzliche Schicht aus dielektrischem Material (8) ein Material mit einer hohen Dielektrizitätskonstanten, die, bei 10 MHz gemessen, größer als ca. 4 ist, und mit einem spezifischen Durchgangswiderstand von wenigstens ca. 10^{13} Ohm cm umfaßt.

7. Kabel nach Anspruch 5, wobei die zusätzliche Schicht aus dielektrischem Material (8) die übrigen Schichten umgibt.

8. Kabel nach Anspruch 5, wobei die zusätzliche Schicht aus dielektrischem Material (8) ein Material mit einer Dielektrizitätskonstanten von weniger als ca. 3 umfaßt.

9. Kabel nach Anspruch 1, wobei das Material (8, 9) mit hoher Dielektrizitätskonstante Polyvinylidenfluorid ist.

10. Kabel nach Anspruch 1, wobei das Hochfrequenzabsorptionsmedium (6) ein ferritbeladenes Polymermaterial umfaßt.

11. Kabel nach Anspruch 1, wobei die Seele von einer elektrisch leitenden Abschirmung (10) umgeben ist.

12. Hochfrequenzdämpfungskabelbaum (20), umfassend eine Vielzahl von Kabeln (22), wobei jedes Kabel eine wenigstens einen Leiter (24) umfassende Seele umfaßt und jeder Leiter umgeben ist von:

(a) einer Schicht aus einem Material (28) mit einer hohen Dielektrizitätskonstanten, die, bei 10 MHz gemessen, größer als ca. 4 ist, und mit einem spezifischen Durchgangswiderstand von wenigstens ca. 10^{13} Ohm cm; und

(b) einer Schicht aus einem Hochfrequenzabsorptionsmedium (26).

13. Hochfrequenzdämpfungskabelbaum nach Anspruch 11, wobei das Material (28) mit hoher Dielektrizitätskonstante Polyvinylidenfluorid ist.

14. Hochfrequenzdämpfungskabelbaum nach Anspruch 12, wobei das Hochfrequenzabsorptionsmedium (26) ferritbeladenes Polymer ist.

15. Hochfrequenzdämpfungskabelbaum nach Anspruch 12, ferner umfassend eine elektrisch leitende Abschirmung (50), die jedes Kabel (20) umgibt, und einen Außenmantel (52), der jede Abschirmung (50) umgibt.

16. Hochfrequenzdämpfungskabelbaum nach Anspruch 15, ferner umfassend einen äußeren Schutzmantel (52), der die Vielzahl von Kabeln umgibt.

17. Hochfrequenzdämpfungskabelbaum nach Anspruch 12, ferner umfassend eine elektrisch leitende Gesamtabschirmung, die die Vielzahl von Kabeln umgibt, und einen äußeren Schutzmantel (52), der die Gesamtabschirmung umgibt.

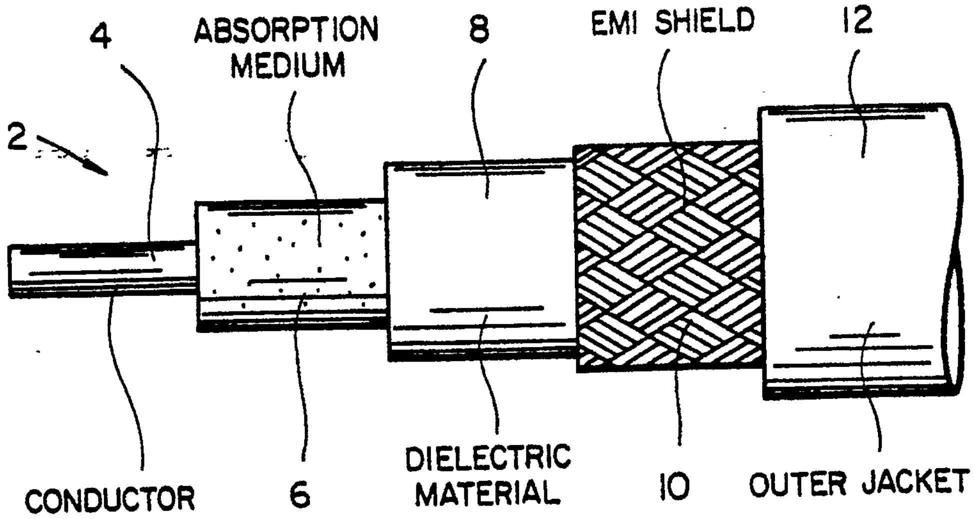

4
ABSORPTION
MEDIUM
8
EMI SHIELD
12
2
CONDUCTOR
6
DIELECTRIC
MATERIAL
10
OUTER JACKET

FIG_1

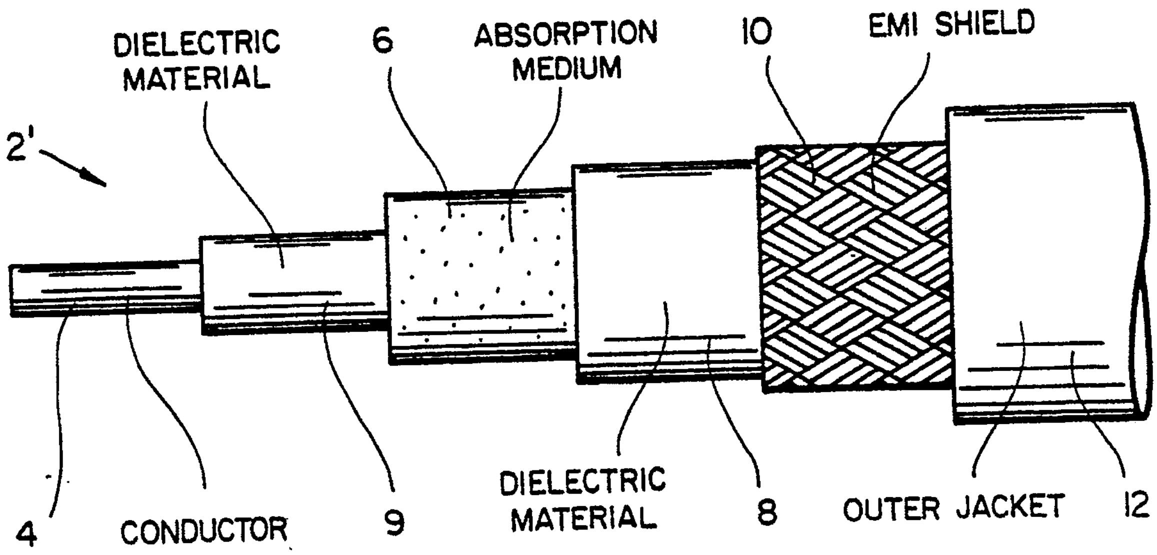

DIELECTRIC
MATERIAL
6
ABSORPTION
MEDIUM
10
EMI SHIELD
2'
4
CONDUCTOR
9
DIELECTRIC
MATERIAL
8
OUTER JACKET
12

FIG_2

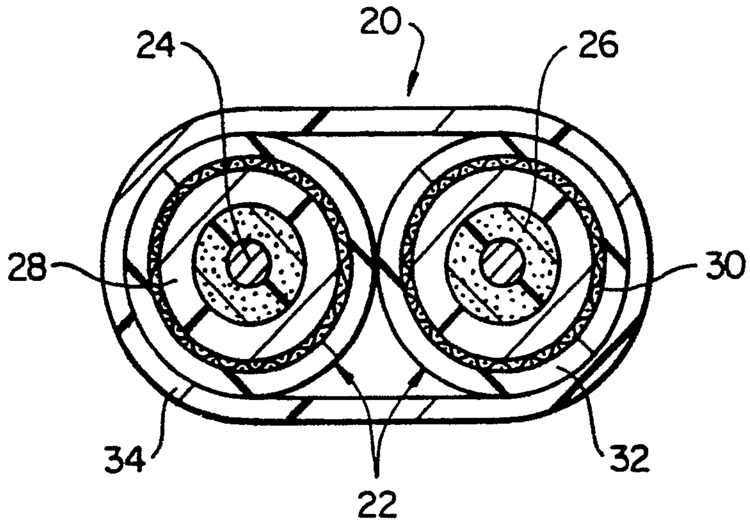


FIG_3

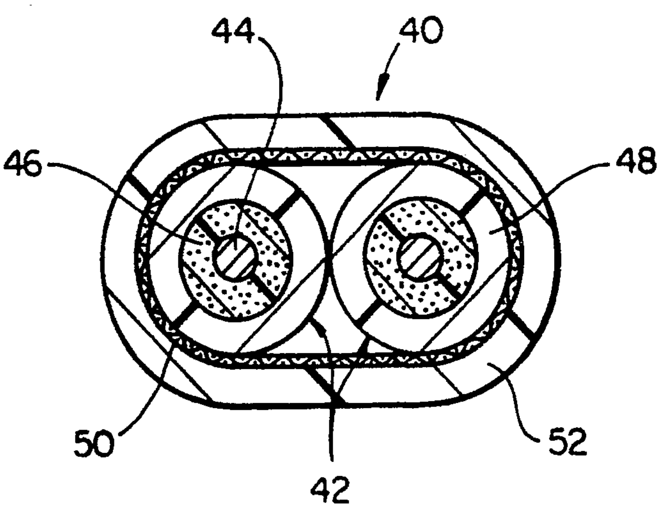
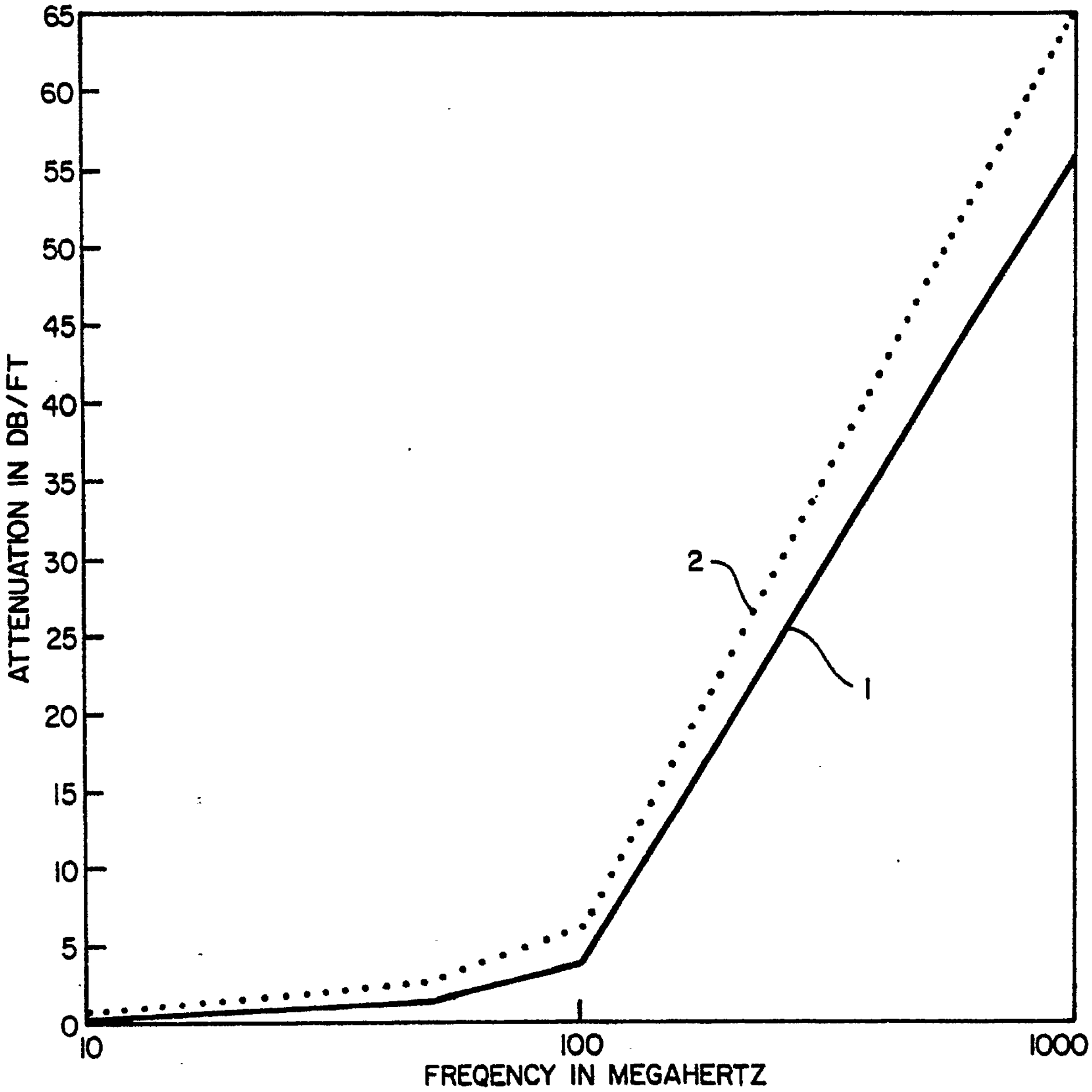


FIG_4

INSERTION LOSS OF KYNAR AND TEFZEL INSULATED FILTERLINE



1) TEFZEL INSULATED FILTERLINE, 79 MIL OD
2) KYNAR INSULATED FILTERLINE, 78 MIL OD

FIG_5

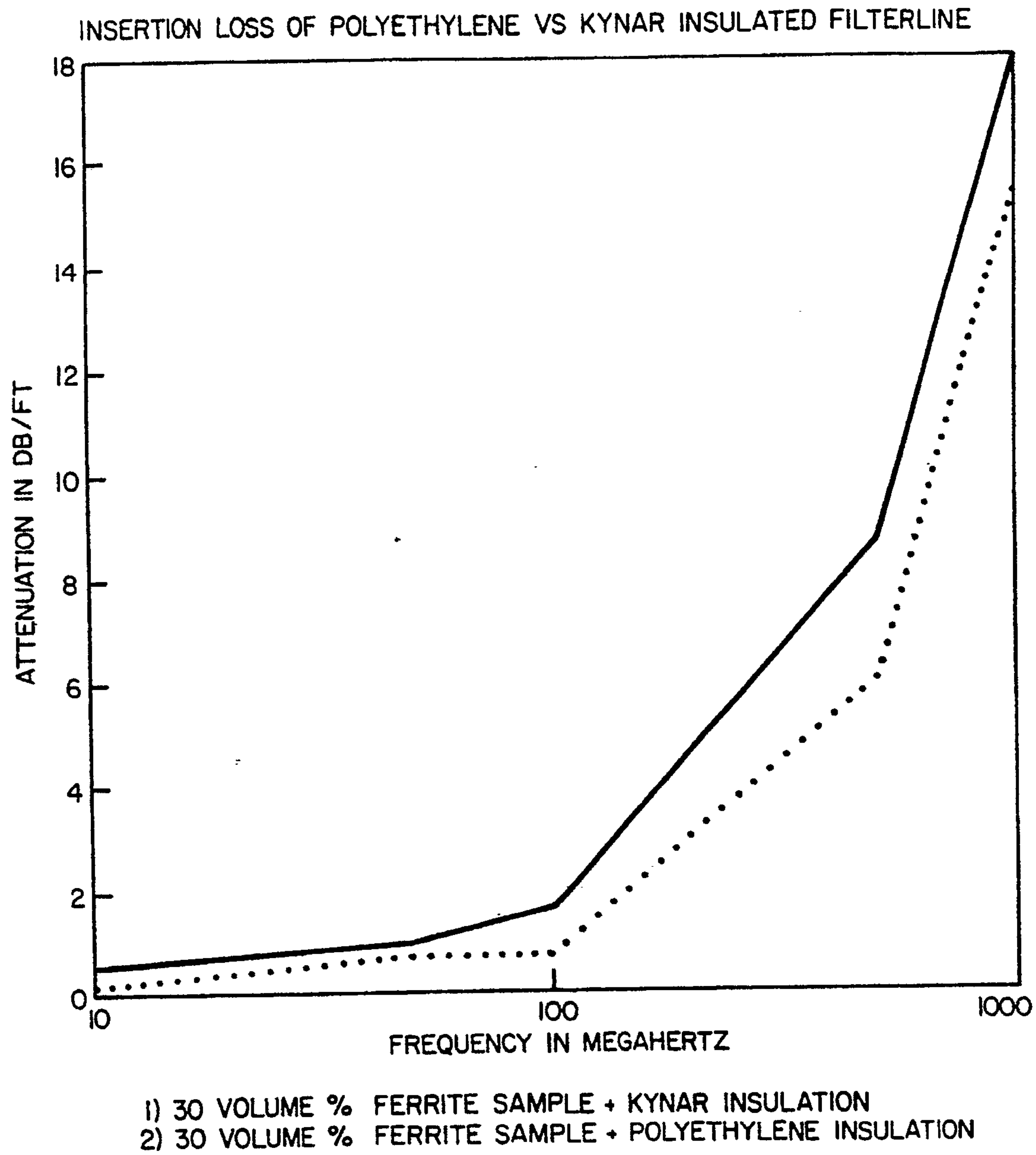

INSERTION LOSS OF POLYETHYLENE VS KYNAR INSULATED FILTERLINE
ATTENUATION IN DB/FT
18
16
14
12
10
8
6
4
2
0
10
100
1000
FREQUENCY IN MEGAHERTZ
1) 30 VOLUME % FERRITE SAMPLE + KYNAR INSULATION
2) 30 VOLUME % FERRITE SAMPLE + POLYETHYLENE INSULATION

FIG_6