United States Patent [19]

Kumagai et al.

[11] 3,865,971

[45] Feb. 11, 1975

[54] SUBMARINE COAXIAL CABLES

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[22] Filed: **Aug. 7, 1973**

[21] Appl. No.: **386,284**

[30] **Foreign Application Priority Data**

Aug. 8, 1972	Japan	47-79241
Sept. 1, 1972	Japan	47-87624
Sept. 1, 1972	Japan	47-87625
Sept. 1, 1972	Japan	47-87626
Sept. 1, 1972	Japan	47-87627

[52] **U.S. Cl.** .... **174/102 R,** 174/107, 174/126 R, 174/128

[51] **Int. Cl.** **H01b 7/18**

[58] **Field of Search** .... 174/102 R, 102 A, 107, 174/126 R, 126 CP, 128; 333/96, 81 A, 97 S; 178/45

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Primary Examiner—Arthur T. Grimley

[57] **ABSTRACT**

There is provided a submarine coaxial cable in which both of the inner and outer conductors or at least the inner conductor, is made of a conductive material having a lower temperature-coefficient of resistivity than that of annealed pure copper. The change of attenuation with respect to the temperature of the submarine coaxial cable may be considerably decreased.

12 Claims, 9 Drawing Figures

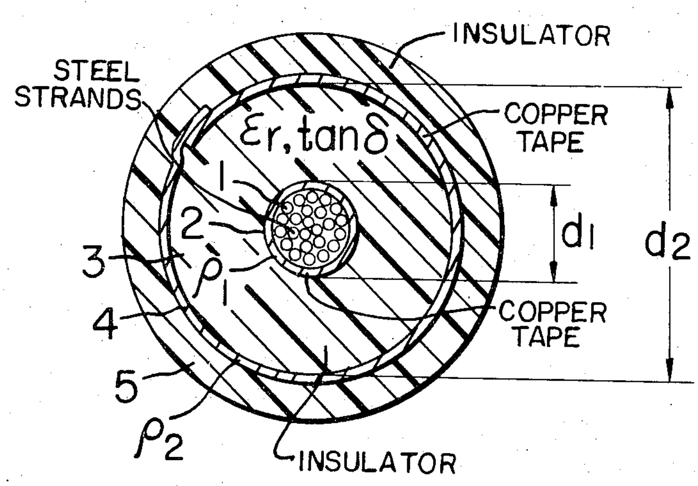


FIG. 1

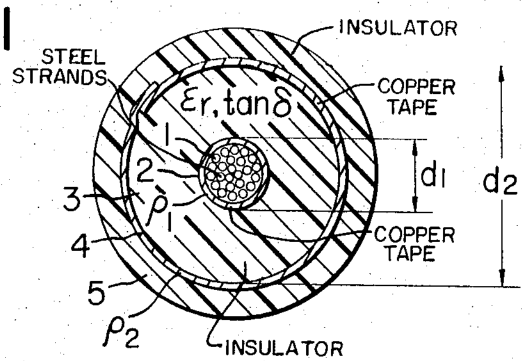
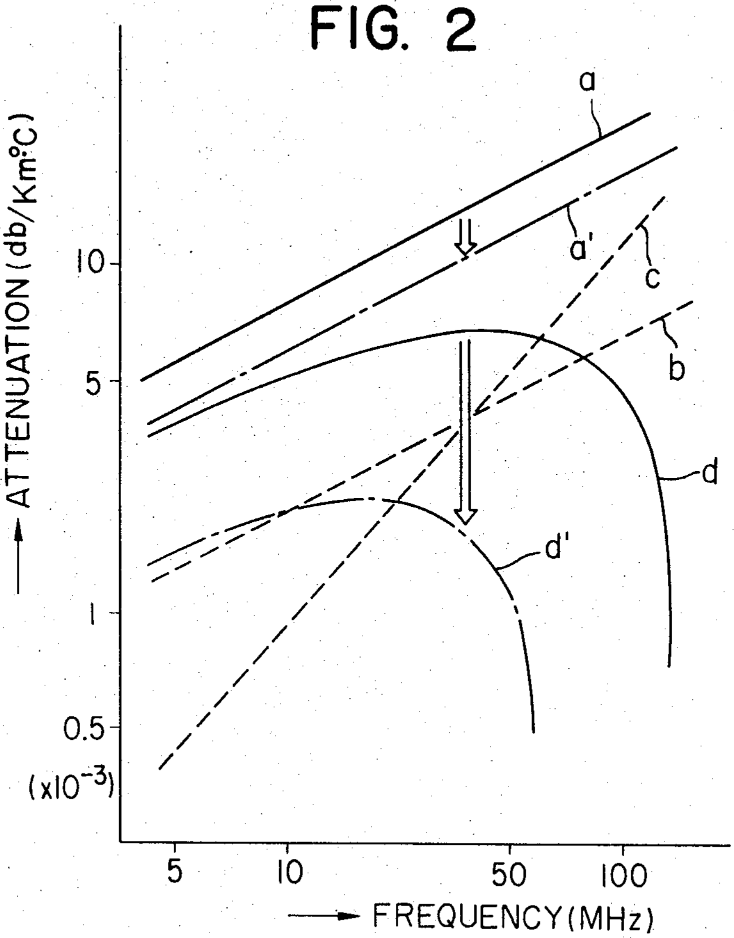
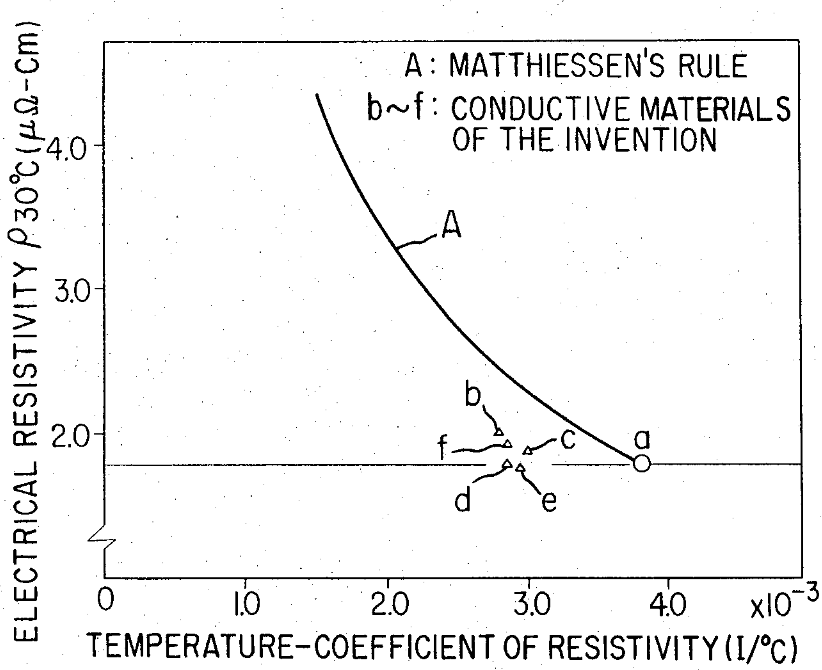


FIG. 2



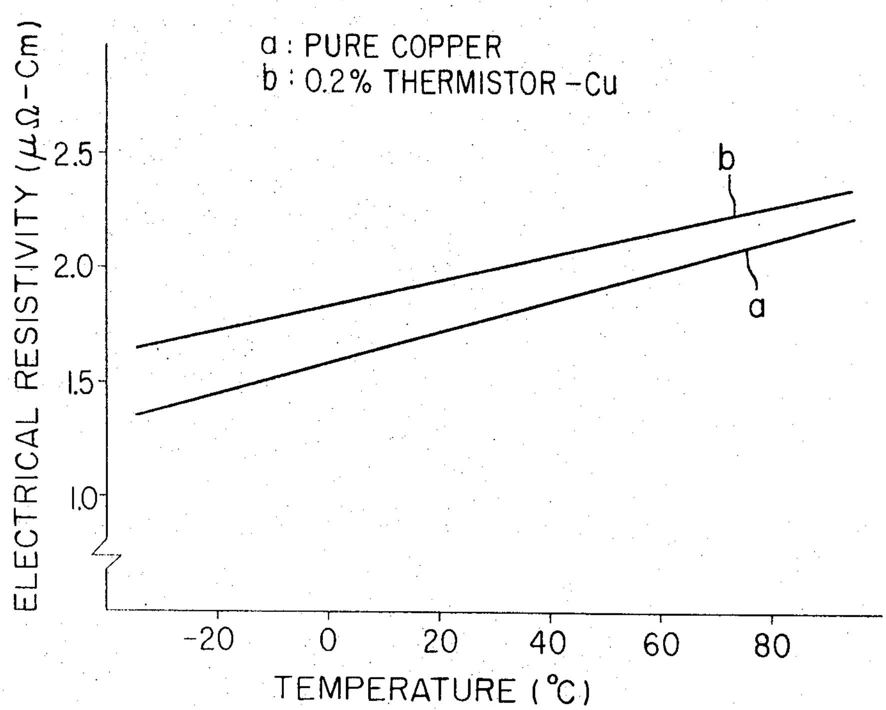
THE GRAPH ILLUSTRATING THE RELATION BETWEEN THE FREQUENCY AND THE ATTENUATION OF THE SUBMARINE CABLE.

FIG. 3



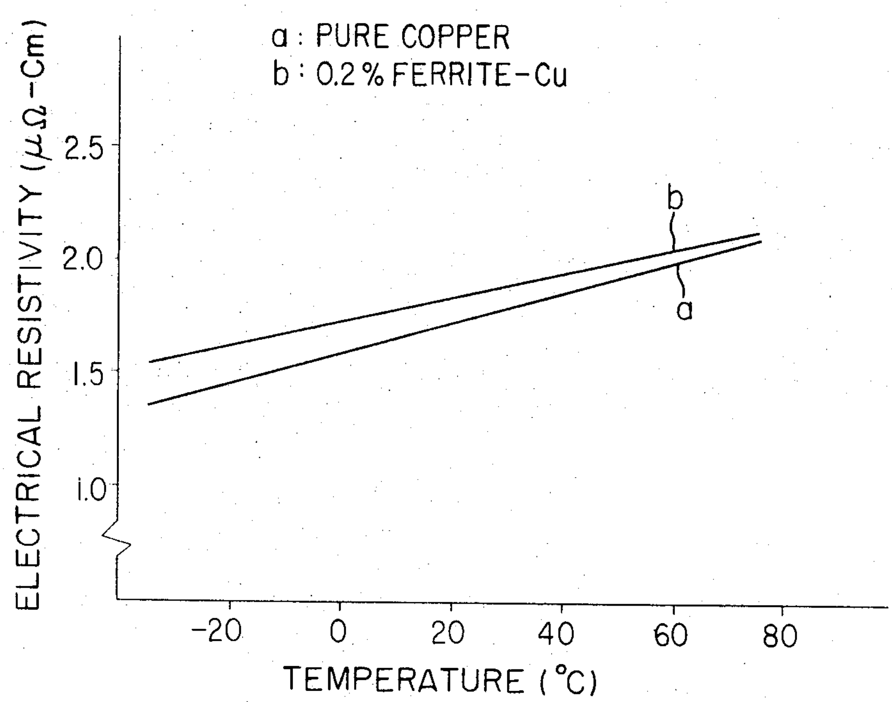
THE GRAPH ILLUSTRATING THE RELATION BETWEEN MATHIESSEN'S RULE AND THE ELECTRICAL PROPERTIES OF THE CONDUCTIVE MATERISLS

FIG. 4



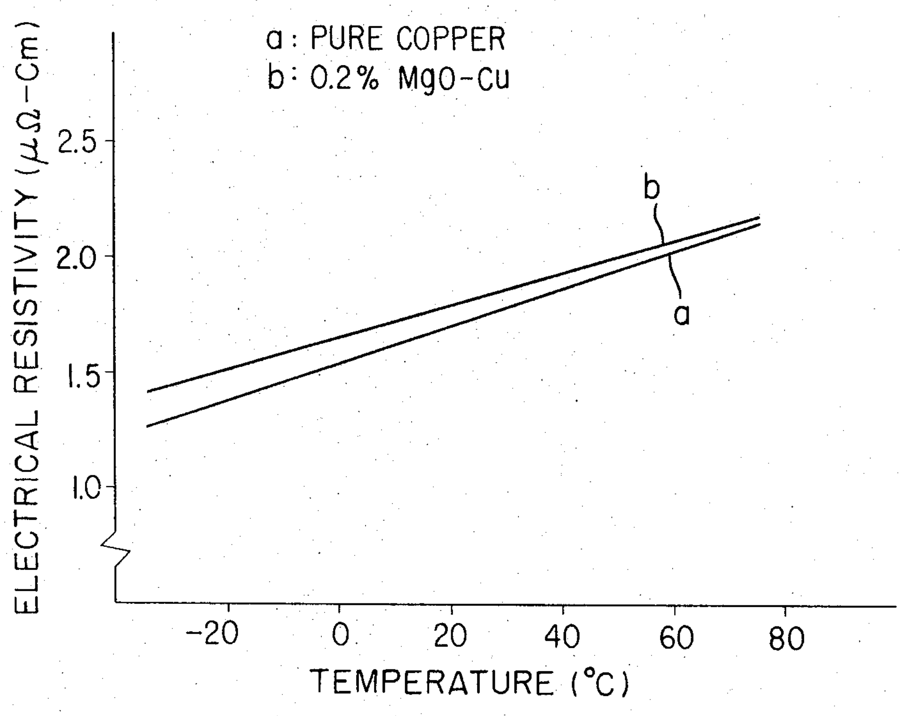
THE GRAPH ILLUSTRATING THE CHANGE OF RESISTIVITY WITH TEMPERATURE OF THE CONDUCTIVE MATERIAL (0.2% THERMISTOR-Cu)

FIG. 5



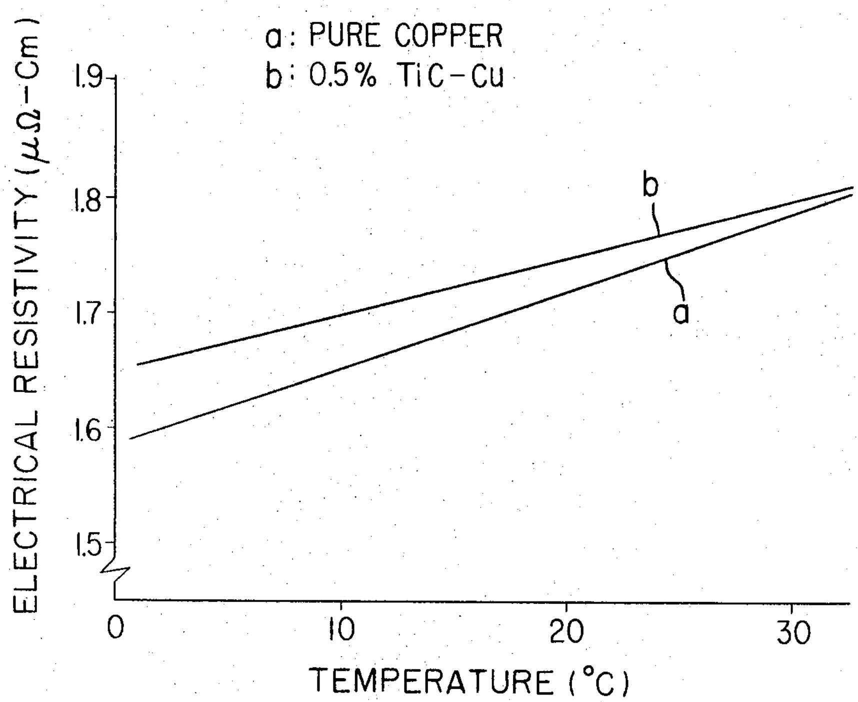
THE GRAPH ILLUSTRATING THE CHANGE OF RESISTIVITY WITH TEMPERATURE OF THE CONDUCTIVE MATERIAL (0.2 % FERRITE-Cu)

FIG. 6



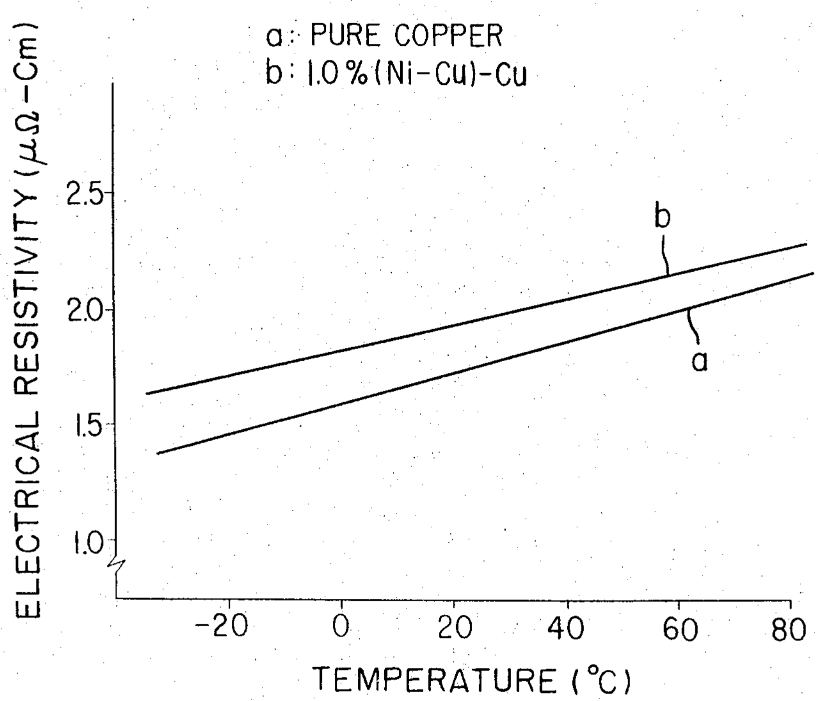
THE GRAPH ILLUSTRATING THE CHANGE OF RESISTIVITY WITH TEMPERATURE OF THE CONDUCTIVE MATERIAL (0.2 % MgO-Cu)

FIG. 7



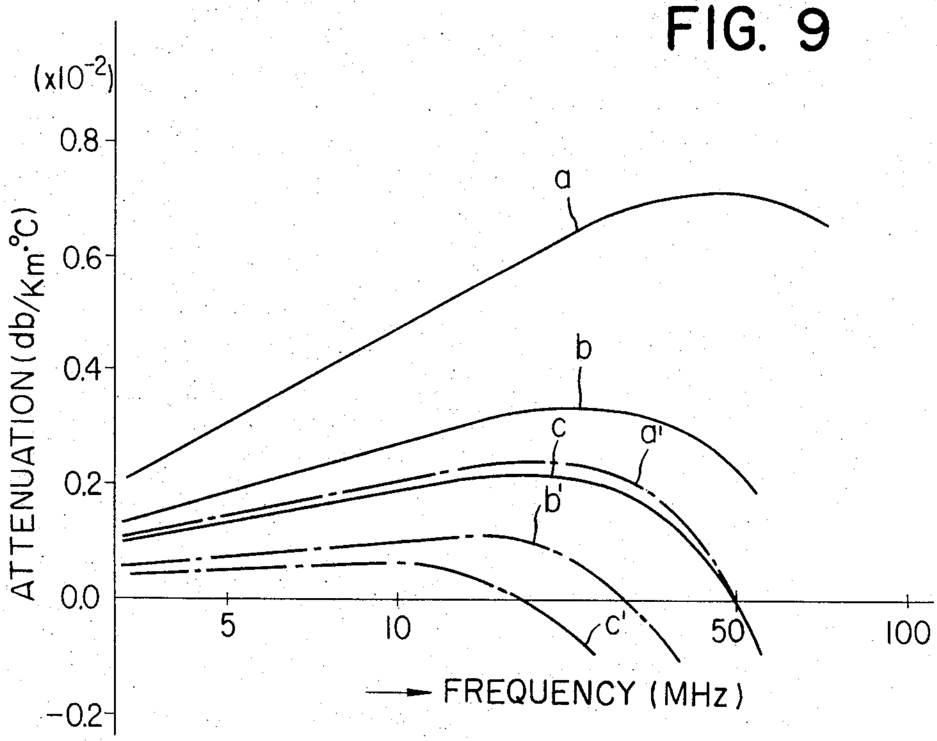
THE GRAPH ILLUSTRATING THE CHANGE OF RESISTIVITY WITH TEMPERATURE OF THE CONDUCTIVE MATERIAL (0.5% TiC-Cu)

FIG. 8



THE GRAPH ILLUSTRATING THE CHANGE OF RESISTIVITY WITH TEMPERATURE OF THE CONDUCTIVE MATERIAL (1.0% (Ni-Cu)-Cu)

FIG. 9



THE GRAPH ILLUSTRATING THE RELATION BETWEEN THE FREQUENCY AND THE ATTENUATION OF THE CABLE IN ACCORDANCE WITH THE INVENTION

SUBMARINE COAXIAL CABLES

BACKGROUND OF THE INVENTION

The present invention relates to a submarine coaxial cable in which an inner conductor or both inner and outer conductors are made of a conductive material having a low temperature-coefficient of resistivity.

Shallow sea cable transmission systems have been recently watched with much interest because the cable laying speed is faster, the cable manufacturing cost is less expensive and the operation is more reliable than land cable system. However the problem is that the repeaters are more expensive than those used in the land cable system. Especially when the transmission band is higher than 10 MHz, the repeaters must be inserted every 10 odd kilometers, so that the cost of the repeaters becomes the major cost of the shallow-sea cable system. Therefore, the problem is the research and development of repeaters which are inexpensive to manufacture yet reliable in operation. However, at the continental shelf up to 200 meters in depth, the temperature of sea water changes from one place to another and according to the season. The conductors of the communication cables are generally made of pure copper whose temperature coefficient of electrical resistivity ($d\rho/dT$) is for very high and is example, 6.77×10^{-3} $\mu\Omega$-cm/°C at 30°C so that the rate of change of electrical resistivity ρ with temperature is very high. Therefore, the change of attenuation with temperature must be taken into consideration in a shallow sea cable system. That is, the change of attenuation with temperature must be equalized by some means and some margin of error must be taken into consideration in the design of the repeaters in order to prevent an overload and the noise decay. As a result, the cost of repeaters is increased.

In order to overcome this problem, there has been proposed and used a method for inserting an automatic gain control (AGC) circuit into a repeater for a submarine coaxial cable system. In a typical automatic gain control circuit, the temperature of the sea water is detected by a direct-heating type thermistor so that the response of an equalizing circuit may be controlled in response to the change in resistance of the thermistor. This method has an advantage in that the circuit is simple in construction, but also has a disadvantage in that the response error is very high. In order to reduce the residual error there has been proposed a method for utilizing an automatic gain control circuit with a pilot control; but the system is complicated and the repeaters become expensive to manufacture and are unreliable in operation.

In view of the above, one of the objects of the present invention is to provide a submarine coaxial cable whose change of attenuation with temperature is extremely small.

Another object of the present invention is to provide a submarine coaxial cable which itself functions as a circuit equivalent to an automatic gain control circuit so that the submarine coaxial cable may become inexpensive to manufacture but is highly reliable in operation.

Another object of the present invention is to provide a submarine coaxial cable using conductors made of a novel dispersion-type conductive material with a low temperature-coefficient of resistivity so that the temperature coefficient of loss of inner dielectrics may be compensated, with the resulting considerable reduction

in the change of attenuation with temperature of the submarine cable.

The present invention will become more apparent from the following description of some preferred embodiments thereof taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a cross sectional view of a typical submarine coaxial cable;

FIG. **2** is a graph illustrating the relation between the frequency and the attenuation of a submarine cable, the graph being used for an explanation of the underlying principle of the present invention;

FIG. **3** is a graph used for the explanation of the relation between Matthiessen's rule and the electrical properties of the conductive materials in accordance with the present invention;

FIGS. **4–8** are graphs illustrating the changes of resistivity with temperature of the conductive materials prepared in accordance with the present invention in comparison with that of pure copper (curve *a*);

FIG. **9** is a graph illustrating the changes of attenuation with temperature of the cables in accordance with the present invention using the conductors made of a conductive material consisting of 0.15% Al_2O_3—Cu prepared in accordance with the present invention in comparison with those of the conventional cables using the conductors made of copper wires; and

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1** a submarine coaxial cable is generally composed of a steel strand **1** covered with a first copper tape **2** which serves as an inner conductor, a second copper tape **4** which is coaxially spaced apart from the first copper tape **2** and serves as an outer conductor, an insulator such as polyethylene **3** filling the space between the inner and outer copper tapes **2** and **4** and a sheath or jacket **5** made of an insulating material such as polyethylene.

High frequency attenuation of the submarine cable of the type described consists of a term of conductor loss and a term of dielectric loss of insulator, and is given by

$$\alpha = \alpha_{r1} + \alpha_{r2} + \alpha\delta \qquad 1$$

where

$$\alpha_{r1} = K_1 \sqrt{\epsilon_r f}\,[(\sqrt{\rho_1/d_1})/\ln(d_2/d_1)] \quad \text{Nep}/m \qquad 2$$

$$\alpha_{r2} = K_1 \sqrt{\epsilon_r f}\,[(\sqrt{\rho_2/d_2})/\ln(d_2/d_1)] \quad \text{Nep}/m \qquad 3$$

$$\alpha\delta = K_2 \sqrt{\epsilon_r}\, f \tan\delta \quad \text{Nep}/m \qquad 4$$

d_1,d_2 = outer diameters of inner conductor and insulation in meters,

ρ_1,ρ_2 = resistivities in ohm-meter of inner and outer conductors,

ϵ_r = relative dielectric constant of insulator **3** filled into the space between the inner and outer conductors,

$\tan\delta$ = dielectric power factor of the insulator **3**,

f = frequency in Hz,

K_1 = coefficient equals 5.27×10^{-6}, and

K_2 = coefficient equals 1.05×10^{-8}.

When the temperature of the coaxial cable changes from T°C to (T + ΔT)°C, the above parameters change as follows:

$$d_1 \approx \text{constant} \qquad 5$$

$$d_2(T + \Delta T) = d_2(T)\,\{1 + K_d \cdot \Delta T\} \qquad 6$$

$$\rho_1(T + \Delta T) = \rho_1(T)\,\{1 + K_{\rho 1} \cdot \Delta T\} \qquad 7$$

$$\rho_2(T+\Delta T)=\rho_2(T)\,\{1+K_{\rho 2}\cdot\Delta T\} \tag{8}$$
$$\epsilon_r(T+\Delta T)=\epsilon_r(T)\,\{1+K_{\epsilon}\cdot\Delta T\} \tag{9}$$
$$\tan\delta\,(T+\Delta T)=\tan\delta(T)\,\{1+K_{\delta}\cdot\Delta T\} \tag{10}$$

Since the linear thermal expansion coefficent of the inner conductor is negligibly small, d_1 is constant as shown in Eq. 5, and temperature coefficients K_d, K_{ϵ}, and K_{δ} are negative whereas $K_{\rho 1}$ and $K_{\rho 2}$ are positive.

Due to the temperature variations of these parameters, there are attenuation changes with temperature as shown in Table 1.

Next, the underlying principle of the present invention will be described with reference to FIG. 2. The curve d' indicates the change in attenuation when a conductive material with a low temperature coefficient is used so that the change in attenuation due to change in resistivity is decreased from the curve a to the curve a'. It can be seen that this method is very effective to decrease the overall change in attenuation of the cable. In the instant embodiment, the temperature coefficients of the conductors were reduced by about 30 percent with the result of the reduction in change in attenuation to about one third. FIG. 2 shows that when the temperature coefficient of the conductors are decreased from the curve a to the curve a' the change in attenuation is considerably reduced as shown by the arrow d to d'. Ordinarily the change in resistivity of the conductor with temperature, which is the main cause of the change in attenuation, is compensated to some extent by the change with temperature of the insulator, so that the change in attenuation with temperature may be considerably reduced when the temperature coefficient of resistivity of the conductor is slightly reduced. The curve d' in FIG. 2 indicates the case where both the inner and outer conductors 2 and 4 of the coaxial cable shown in FIG. 1 were made of a material with a low temperature coefficient of resistivity. However, in practice, the change in attenuation with temperature may be satisfactorily reduced only by making the inner conductor 2 of a material with a low temperature coefficient of resistivity.

Table 1

alternation variation in response to temperature rise	frequency characteristics of attenuation	attenuation in Nep or dB	causes	symbol
increase	in proportion to $f^{1/2}$	$\frac{1}{2}K_{\rho 1}\alpha_{r1}\Delta T$	change of resistivity of inner conductor	a
	do. $f^{1/2}$	$\frac{1}{2}K_{\rho 2}\alpha_{r2}\Delta T$	change of resistivity of outer conductor	
decrease	do. $f^{1/2}$	$\frac{1}{2}K_{\epsilon}(\alpha_{r1}+\alpha_{r2})\Delta T$	change of dielectric constant	b
	do. $f^{1/2}$	$K_d\{\alpha_{r2}+(\alpha_{r1}+\alpha_{r2}/\ln(d_2/d_1)\}$	change of diameter of outer conductor	
decrease	do. $f^{1.17}$	$\frac{1}{2}K_{\epsilon}\alpha_{\delta}\Delta T$	change of dielectric constant	c
	do. $f^{1.17}$	$K_{\delta}\alpha_{\delta}\Delta T$	change of $\tan\delta$	

The terms in proportion to $f^{1.17}$ are introduced because the frequency characteristic of dielectric power factor of the insulator, which is generally polyethylene, is in proportion to $f^{0.17}$ at a low frequency less than 500 MHz. Changes in diameter of the outer conductor are caused by the volume expansion of the insulator.

When the conductors are made of annealed pure copper and the insulators are made of polyethylene, the temperature coefficients are as follows:

$K_{\rho 1}, K_{\rho 2}=3.9\times10^{-3}/°C$
$K_{\epsilon}=-4.9\times10^{-4}/°C$
$K_d=-2.9\times10^{-4}/°C$
$K_{\delta}=-5.7\times10^{-2}/°C$

The relation of the above variation factors with the overall variation is shown in FIG. 2 when the outer conductor is 25.4 mm in inner diameter and the inner conductor is 8.38 mm in diameter. The frequency change per 1°C of the submarine coaxial cable of 1 kilometer is shown, and a, b and c in FIG. 2 show the parameters shown in Table 1.

The change of attenuation is given by $a-(b+c)=d$. It is seen that the change in attenuation is suddenly decreased at a high frequency mainly because of the effect of tan δ (the curve d), but is considerably high at a low frequency because of the lesser effect of $\tan\delta$.

In view of the above, the primary object of the present invention is to considerably decrease the change in attenuation with temperature of a submarine coaxial cable by using a conductive material with a low temperature coefficient of electrical resistivity.

Next, the conductive materials for the inner and outer conductors of the coaxial cable of the present invention will be described. In FIG. 3 the curve A indicates the Matthiessen's rule. It is seen that the product of the resistivity (ρ) of a conductor (including copper alloy) and the temperature coefficient $[(1/\rho)\cdot(d\rho/dt)]$ is a constant so that the resistivity is increased as the temperature coefficient of resistivity is decreased. Therefore, in the conventional coaxial cables using the inner and outer conductors made of copper alloys, it is difficult to reduce the temperature coefficient of resistivity without increasing the attenuation even when a conductive material with a low temperature coefficient of resistivity is used. However, in case of the conductive materials in which a small percentage of one of the metal oxides, ferrite, finely divided thermistor, carbides, or finely divided nickel-copper alloy powder is dispersed into copper, Matthiessen's rule is not valid so that the temperature coefficient of resistivity may be reduced by about 30 percent without increasing resistivity. In FIG. 3, a white dot *a* indicates the measured value of a standard annealed copper wire; a white triangle *b*, a copper wire into which is dispersed 0.2 percent of thermistor fine powder; *c*, a copper wire into which is dispersed 0.2 percent of MgO; *d*, a copper wire into which is dispersed 0.15 percent of Al_2O_3; *e*, a copper wire into which is dispersed 0.5 percent of finely divided TiC; and *f*, a copper wire into which is dispersed 1.0 percent of nickel-copper alloy powder. Electrical properties of these conductive materials are shown in Table 2.

Table 2

Materials	ρ30°C (μΩ-cm)	(dρ/dT) 30°C (μΩ-cm/°C)	α30°C (/°C)
copper	1.79	6.77×10^{-3}	3.78×10^{-3}
0.2% thermistor-Cu	2.00	5.55×10^{-3}	2.77×10^{-3}
0.2% MgO-Cu	1.87	5.60×10^{-3}	2.99×10^{-3}
0.15% Al_2O_3-Cu	1.80	5.10×10^{-3}	2.83×10^{-3}
0.5% TiC-Cu	1.79	5.13×10^{-3}	2.86×10^{-3}
1.0% (Ni-Cu)-Cu	1.98	5.58×10^{-3}	2.82×10^{-3}

In addition to the above conductive materials, there may be used ferrite such as $MnCoFe_2O_4$, $BaFe_{12}O_{19}$, $NiZnFe_2O_4$, $NiCuFe_2O_4$, $Li_{0.5}Fe_{2.5}O_4$, and the like; thermistor powder consisting of, as a major component, oxides of transition metal elements, that is the oxides of Mn, Ni, Co and Cu, and, as a minor component, the oxides of Mo, Fe, Cr, and V; oxides such as MgO, Al_2O_3, MnO_2, CrO_2, VO_2, V_2O_3, ThO_2, and the like; and carbides such as MoC, SiC, TaC, WC, Fe_3C and the like. In general, 0.01 – 5.00 percent by weight of these compounds are added to copper to obtain a desired temperature coefficient of resistivity. In addition to the above compounds, 0.01 – 5.00 percent by weight of, Ni-Cu alloy may be added to copper. However, when the weight of a compound to be added is less than 0.01 percent, a desired low temperature coefficient is not obtained, and when the weight is in excess of 5.0 percent, a conductive material becomes too brittle to be drawn or rolled even though a satisfactory low temperature coefficient of resistivity is obtained. Next, some examples of the present invention will be described.

EXAMPLE 1

FIG. 4 shows the change of resistivity with temperature (curve *b*) of a copper wire into which is dispersed 0.2 percent by weight of thermistor powder in comparison with the curve *a* indicating that of a pure copper wire. The composition of thermistor powder consists of 40 percent by weight of MnO_2, 35 percent by weight of CoO, 20 percent by weight of NiO and 4 percent by weight of CuO 50 grams of pure copper powder of about 100 microns in particle size and 50 grams of thermistor fine powder about 40 microns in particle size were uniformly mixed in ethyl alcohol, and thereafter the alcohol was evaporated at 50°C. The mixed powder was molded into a cylinder under a pressure of 1,000 kg/cm², and the molded cylinder was sintered for 1 hour to provide a copper-thermistor mother alloy. 1.6 grams of the mother alloy was added to 200 grams of molten copper at 1,250°C, mixed for about 10 minutes, and then cast into a metal mold. The cast ingot was forged at 850°C and drawn into a wire 0.7 mm in diameter. The wire was annealed for about 1 hour at 600°C in vacuum, and then cooled in the furnace. The content of thermistor powder in the wire was 0.2 percent. The thermistor oxide was uniformly dispersed in copper matrix. The resistivity was measured by an automatic electrical resistance measuring equipment at 1×10^{-4} torr at a speed of 0.625°C/minute.

EXAMPLE 2

FIG. 5 shows the change of resistivity with temperature (curve *b*) of a copper wire having 0.2 percent of ferrite dispersed therein in comparison with that of a pure copper wire. 99.8 grams of pure copper powder 10 microns in particle size and 0.2 grams of $MnCoFe_2O_4$ 500A in particle size was uniformly mixed in ethyl alcohol, and thereafter the alcohol was evaporated at 50°C. The mixture was pressed by a rubber press machine under a hydrostatic pressure of 3,000 kg/cm², and then sintered in vacuum for 2 hours at 950°C. The pressed material was forged at 850°C and drawn into a wire 0.7 mm in diameter. The wire was annealed for about 1 hour at 600°C in vacuum and then cooled in the furnace. Ferrite was uniformly dispersed in copper matrix which was confirmed by an image analyzer in a quantitative metallurgical system.

Co-precipitation of $MnCoFe_2O_4$ was effected by reaction in aqueous solution and then synthesized by hydrothermal synthesis. The particle size of $MnCoFe_2O_4$ was confirmed by an electron microscope. In like manner, other ferrites such as $BaFe_{12}O_{12}$, $NiZnFe_2O_4$, $NiCuFe_2O_4$ and $Li_{0.5}Fe_{2.5}O_4$ were used, and the electrical properties of copper wires thus provided are shown in Table 3.

Table 3

	Resistivity (μΩ-cm)	temperature coefficient	coefficient of pure copper wire
pure copper	1.792	6.77	100
0.5% $BaFe_{12}O_{19}$-Cu	2.10	5.42	80.0
0.2% $NiZnFe_2O_4$-Cu	1.87	5.46	80.7
0.1% $NiCuFe_2O_4$-Cu	1.85	5.70	84.2
0.2% $Li_{0.5}Fe_{2.5}O_4$-Cu	2.07	5.57	82.3
0.2% $MnCoFe_2O_4$-Cu	1.88	5.40	79.8

EXAMPLE 3

FIG. 6 shows the change of resistivity with temperature (curve *b*) of a copper wire containing 0.2 percent of MgO in comparison with the curve a of a pure copper wire.

50 grams of pure copper powder about 100 microns in particle size and 50 grams of MgO about 10 microns in particle size were mixed in ethyl alcohol, and then the alcohol was evaporated at 50°C. The mixture was pressed into a cylinder by a mechanical press under a pressure of 1,000 kg/cm². The mold was sintered for about 1 hour at 800°C to provide a Cu-MgO mother alloy. 1.6 grams of the mother alloy was added to 200

grams of molten copper at 1,250°C and mixed for about 10 hours before it was cast in a mold. The yield of MgO in the mother alloy was about 50 percent, and the copper alloy contained 0.2 percent of MgO. The ingot was forged at 850°C, drawn into a wire 0.7 mm in diameter, annealed in vacuum at 600°C for about 1 hour and then cooled in the furnace. The added MgO was uniformly dispersed in a copper matrix, and the change of resistivity with temperature was measured by an automatic electrical resistance measuring equipment at 1×10^{-4} torr and at a speed of 0.625°C/minute.

In like manner, 99.5 grams of pure copper powder 10 microns in particle size and 0.5 grams of ThO_2 powder 0.7 microns in particle size were uniformly mixed in ethyl alcohol, and thereafter the alcohol was evaporated at 50°C. The mixture was pressed by use of a rubber press machine under a pressure of 3,000 kg/cm^2, and sintered for 2 hours at 950°C in vacuum. The sintered material was forged at 850°C, drawn into a wire of 0.7 mm in diameter, annealed for 1 hour at 600°C in vacuum and then cooled in the furnace. It was confirmed by an image analyzer in a quantitative metallurgical system that ThO_2 was uniformly dispersed in copper matrix.

In like manner the copper wires containing other oxides such as MnO_2, CrO_2, VO_2 and V_2O_3 were prepared, and the electrical properties of the copper wires of Example 3 were shown in Table 4.

Table 4

	resistivity (μΩ-cm)	temperature coefficient of resistivity	ratio to the temperature coefficient of pure copper
pure copper	1.792	6.77	100
0.2% MgO-Cu	1.87	5.60	82.7
0.5% ThO_2-Cu	1.98	5.38	79.5
0.3% MnO_2-Cu	1.95	5.62	83.0
0.3% CrO_2-Cu	1.86	5.43	80.2
0.5% VO_2-Cu	2.09	5.72	84.5
0.5% V_2O_3-Cu	2.11	5.69	84.0

EXAMPLE 4

FIG. 7 shows the change of resistivity with temperature (curve *b*) of a copper wire having 0.5 percent of TiC dispersed therein in comparison with that of a pure copper wire (curve *a*).

50 grams of pure copper powder 100 microns in particle size and 50 grams of TiC 40 microns in particle size were uniformly mixed in ethyl alcohol and thereafter the alcohol was evaporated at 50°C. The mixture was pressed into a cylinder by a mechanical press under a pressure of 1,000 kg/cm^2 and the cylinder was sintered for one hour at 800°C to prepare a Cu-TiC mother alloy. 2.0 grams of the mother alloy was charged into 98 grams of molten copper at about 1,250°C and mixed for 10 minutes before it was cast into a metal mould. The yield of TiC in the mother alloy was about 50 percent, and the ingot contained 0.5 percent of TiC. The ingot was forged at 850°C, drawn into a wire of 0.7 mm in diameter, annealed for about 1 hour at 600°C in vacuum, and then cooled in the furnace. The change of resistivity with temperature was measured by an automatic electrical resistivity measuring equipment at 1×10^{-4} torr and at a speed of 0.625°C/minute.

Table 5 shows the electrical properties of copper wires containing carbide powder.

Table 5

	resistivity (μΩ-cm)	α30 ($\times 10^{-3}$/°C)	(dρ/dT) ($\times 10^{-3}$ μΩ-cm/°C	ratio to dρ/dT of pure copper
pure copper	1.79	3.78	6.77	100
0.5% TiC-Cu	1.792	2.86	5.13	75.8
1.5% TiC-Cu	1.870	3.02	5.65	83.5
0.3% WC-Cu	1.904	2.93	5.58	82.4

EXAMPLE 5

FIG. 8 shows the change of resistivity with temperature (curve *b*) of a copper wire containing 1 percent of (50% Ni—Cu) alloy in comparison with that of a pure copper (curve a).

198 grams of pure copper powder about 100 microns in particle size and 2.0 grams of (50% Ni—Cu) alloy about 40 microns in particle size were uniformly mixed in ethyl alcohol. (50% Ni—Cu) alloy was prepared by an atomization method. A ball mill was used for mixing. The ingredients were therefore 99% Cu and 1 percent (50% Ni—Cu).

The mixture was dried at 50°C to completely remove the alcohol and was pressed into a cylinder about 200 mm in length and about 10 mm in diameter by a rubber press machine under the pressure of 2,000 kg/cm^2. The cylinder was sintered in vacuum for 30 minutes at 700°C, and thereafter drawn by a swaging machine into a wire about 4 mm in diameter. The wire was annealed at 600°C for a few times in order to prevent the hardening in a continuous drawing step by which the wire was finally drawn to a wire 0.7 mm in diameter. The wire was annealed for one hour at 600°C. The added NiCu was uniformly dispersed in Cu matrix.

The electrical properties were measured in vacuum (1×10^{-4} torr.) and at a speed of 0.625°C/minute by an automatic electrical resistivity measuring equipment, and shown in Table 6.

Table 6

	resistivity (μΩ·cm)	α30 ($\times 10^{-3}$/°C)	$(d\rho/dT)_{30}$ ($\times 10^{-3}$ μΩ·cm/°C)	ratio to dρ/dT of pure copper(%)
pure copper	1.79	3.78	6.77	100
0.1% (Ni-Cu) -Cu	1.84	3.0	5.52	81.5

Table 6 – Continued

	resistivity ($\mu\Omega$·cm)	$\alpha 30$ ($\times 10^{-3}$/°C)	$(d\rho/dT)_{30}$ ($\times 10^{-3}$ $\mu\Omega$·cm/°C)	ratio to $d\rho/dT$ of pure copper(%)
0.5% (Ni-Cu) -Cu	1.87	3.06	5.72	84.5
1.0% (Ni-Cu) -Cu	1.98	2.82	5.58	82.4

Remarks: (Ni—Cu) is 50% Ni—Cu alloy.

EXAMPLE 6

The inner and outer conductors of the coaxial cable were made of copper having 0.15 percent of Al_2O_3 dispersed therein, and the insulator was polyethylene with a low density for submarine cables. FIG. **9** shows the changes of attenuation with temperature of 1 kilometer submarine cables of the type described and 1 inch, 1.5 inch and 2 inch in diameter (curves *a'*, *b'* and *c'*, respectively) in comparison with those (curves *a*, *b*, and *c*) of the conventional submarine cables of 1 inch, 1.5 inch and 2 inch in diameter and using the ordinary soft copper wires. It is seen that the change of attenuation of the submarine coaxial cable of the present invention is reduced to about ⅓ as compared with the conventional submarine cables.

What is claimed is:

1. A submarine coaxial cable characterized by comprising

a. an inner conductor,

b. an outer conductor disposed coaxially of said inner conductor and in spaced apart relation therewith to surround the same,

c. an insulating material filling the space between said inner and outer conductors, and

d. said inner conductor being made of a dispersion type conductive material having a temperature coefficient of resistivity lower than that of pure copper and consisting of copper and 0.01–5.00 percent by weight of finely divided powder dispersed in said copper, said finely divided powder being from the group consisting of metal oxides, ferrite, thermistor, carbides, and nickel-copper alloy powder.

2. A submarine coaxial cable as defined in claim **1** wherein said dispersion-type conductive material consists of copper having 0.01 – 5.00 percent by weight of finely divided ferrite powder dispersed therein, said ferrite powder being selected from the group consisting of $MnCoFe_2O_4$, $BaFe_{12}O_{19}$, $NiZnFe_2O_4$, $NiCuFe_2O_4$ and $Li_{0.5}Fe_{2.5}O_4$.

3. A submarine coaxial cable as defined in claim **1** wherein said dispersion-type conductive material consists of pure copper having dispersed therein 0.01–5.00 percent by weight of finely divided thermistor powder, said thermistor powder consisting of, as a major component, oxides of transient elements selected from the group consisting of oxides of Mn, Ni, Co and Cu and, as a minor component, oxides selected from the group consisting of Mo, Fe, Zr, Cr and V.

4. A submarine coaxial cable as defined in claim **1** wherein said dispersion-type conductive material consists of pure copper having dispersed 0.01 – 5.00 percent by weight of at least one compound selected from the oxide group consisting of MgO, MnO_2, CrO_2, V_2O_3 and Al_2O_3.

5. A submarine coaxial cable as defined in claim **1** wherein said dispersion-type conductive material consists of pure copper having dispersed therein 0.01 – 5.00 percent by weight of at least one compound selected from the carbide group consisting of TiC, MoC, SiC, TaC, WC and Fe_3C.

6. A submarine coaxial cable as defined in claim **1** wherein said dispersion-type conductive material consists of pure copper having dispersed therein 0.01 – 5.00 percent by weight of 30 – 70 percent Ni—Cu alloy (by weight percent).

7. A submarine coaxial cable characterized by comprising

a. an inner conductor

b. an outer conductor disposed coaxially of said inner conductor and in spaced apart relation therewith to surround the same,

c. an insulating material filling the space between said inner and outer conductors, and

d. said inner and outer conductors being made of a dispersion type conductive material having a temperature coefficient of resistivity lower than that of pure copper and consisting of copper and 0.01 – 5.00 percent by weight of a finely divided powder dispersed in said copper, said finely divided powder being from the group consisting of metal oxides, ferrite, thermistor, carbides, and nickel-copper alloy powder.

8. A submarine coaxial cable as defined in claim **7**, wherein said dispersion-type conductive material consists of copper having 0.01–5.00 percent by weight of finely divided ferrite powder disposed therein, said ferrite powder being selected from the group consisting of $MnCoFe_2O_4$, $BaFe_{12}O_{19}$, $NiZnFe_2O_4$, $NiCuFe_2O_4$ and $Li_{0.5}Fe_{2.5}O_4$.

9. A submarine coaxial cable as defined in claim **7** wherein said dispersion-type conductive material consists of pure copper having dispersed therein 0.01–5.00 percent by weight of finely divided thermistor powder, said thermistor powder consisting of, as a major component, oxides of transient elements selected from the group consisting of oxides of Mn, Ni, Co and Cu, and, as a minor component, oxides selected from the group consisting of Mo, Fe, Zr, Cr and V.

10. A submarine coaxial cable as defined in claim **7** wherein said dispersion-type conductive material consists of pure copper having dispersed 0.01–5.00 percent by weight of at least one compound selected from the oxide group consisting of MgO, MnO_2, CrO_2, V_2O_3 and Al_2O_3.

11. A submarine coaxial cable as defined in claim **7** wherein said dispersion-type conductive material consists of pure copper having dispersed therein 0.01–5.00 percent by weight of at least one compound selected from the carbide group consisting of TiC, MoC, SiC, TaC, WC and Fe_3C.

12. A submarine coaxial cable as defined in claim **7** wherein said dispersion-type conductive material consists of pure copper having dispersed therein 0.01–5.00 percent by weight of 30 – 70 percent Ni—Cu alloy (by weight percent).

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