

June 2, 1970

F. RALPH
METHOD OF MAKING ARTIFICIAL TELEPHONE LINES
IMPEDANCE MATCHING NETWORKS

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2 Sheets-Sheet 1

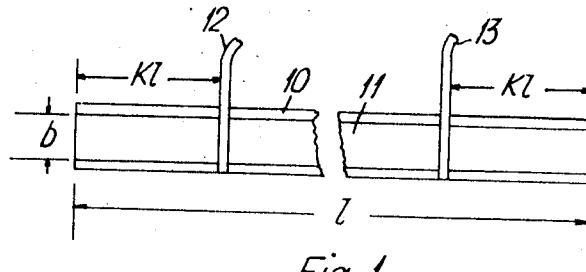


Fig. 1.

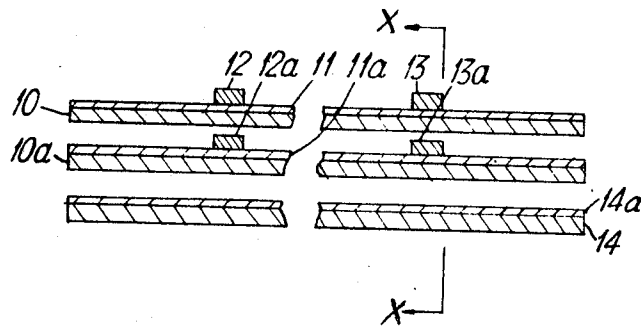


Fig. 2.

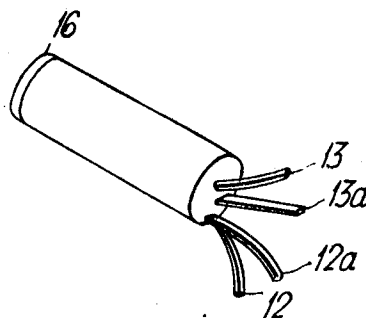


Fig. 3.

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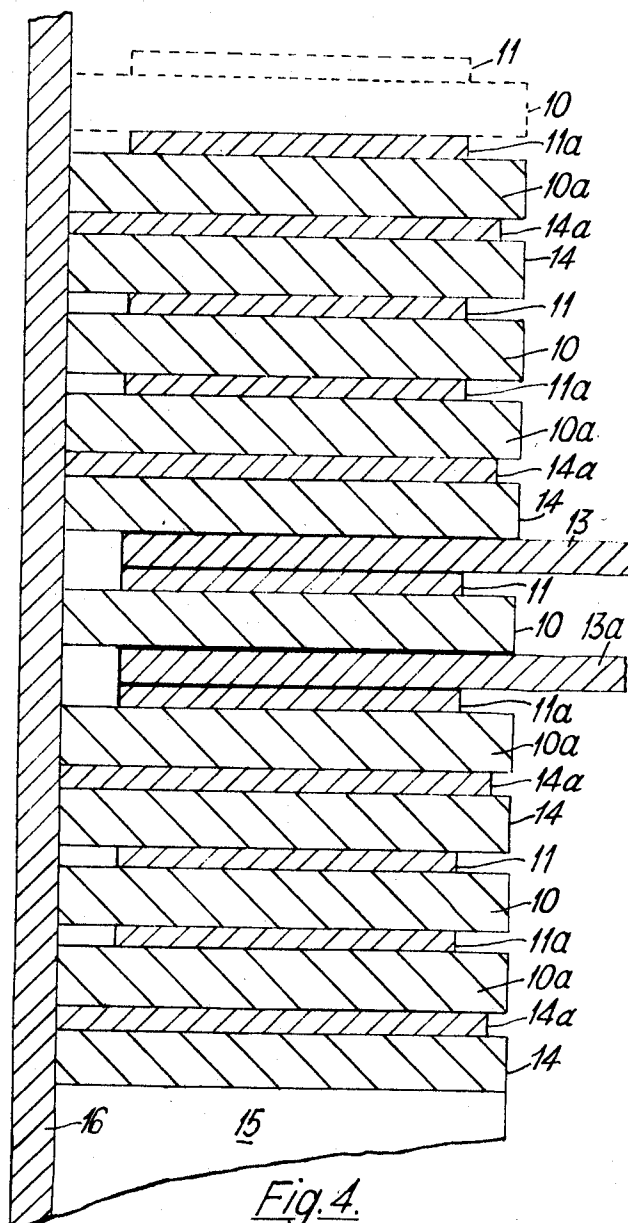
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**METHOD OF MAKING ARTIFICIAL TELEPHONE
LINES IMPEDANCE MATCHING NETWORKS**
Frank Ralph, Bishop's Stortford, England, assignor to
International Standard Electric Corporation
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50,566/66
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U.S. Cl. 29—621

7 Claims

ABSTRACT OF THE DISCLOSURE

There is described herein an artificial line structure consisting of a number of metalized plastic films wound into a cylindrical form. The characteristic impedance z_0 of the structure is related to the width and the effective specific resistance of the films and effective capacitance between them. Thus, once the capacitance has been fixed by the choice of the dielectric and its thickness, z_0 is determined by the relationship between the effective specific resistance and the width of the metalized film. The present invention provides for a standardized construction of metalized films for providing a wide range of z_0 . The standardized construction is made with an impedance $z_m > z_0$ and the required z_0 is achieved by placing the contact strips a specified distance from the ends of the films. Thus, the effective capacitance remains virtually the same for a wide range of values of effective resistance.

This invention relates to a method of making networks for simulating a non-loaded paired telephone cable, or artificial telephone lines as they are sometimes called.

In British patent application No. 43,821/66 (F. Ralph-J. L. Parmee-D. Boswell-F. R. Huntley 9-4-2-2) there is described a method of making an artificial line consisting of a number of metalized plastic films wound into cylindrical form, with contact strips inserted at the ends of the metalized layers to make contact with the principal metalized forms, and with one or more shielding metalized films arranged to prevent mutual capacity between adjacent layers when the films are wound to form the cylindrical structure. For a given width b of the principal metalized layers the characteristic impedance z_0 of the network at angular frequency ω is given by

$$z_0 = \frac{1}{b} \sqrt{\frac{2R_s}{j\omega C_s}}$$

where R_s and C_s are respectively the effective "square" resistance (specific resistivity) of the metalized layers and the effective specific capacitance between them.

Thus, in designing such a network, once C_s has been fixed by choosing the dielectric and its thickness, a particular characteristic impedance can be achieved by preparing a metalized film having the correct relationship between the square resistance R_s and the width b of the metalized strip. Since in practice the deposition of the metalized film is a continuous process, both R_s and b are fixed simultaneously during deposition, the former by the rate of deposition and the latter by the width of the mask aperture through which deposition is effected. Neither parameter can be economically modified after deposition and, however uniform the process may be, if either R_s or b is in error the characteristic impedance will, in general, also be wrong.

It is also evident from the foregoing that if networks of different characteristic impedances are required a special metalized strip is required for each different impedance level required.

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According to this invention there is provided a method of making a network for simulating a nonloaded paired telephone cable having a characteristic impedance z_0 , the method including placing together a pair of resistive metallic film strips, each having a width b and length l , and a dielectric layer, the films being placed one on either side of the dielectric layer, the whole having an impedance z_m greater than z_0 , at an angular frequency ω , between the ends of the strips according to the formula

$$z_m = \frac{1}{b} \sqrt{\frac{2R_s}{j\omega C_s}}$$

where R_s and C_s are respectively the effective "square" (specific) resistance of the strips and the effective specific capacitance between them, and placing in contact with each strip a pair of electrical contacts, the contacts on each strip being placed in from the ends of the strip a distance Kl where K is determined according to the formula

$$K = \frac{1}{2} \left(1 - \frac{z_0^2}{z_m^2} \right)$$

Thus, according to the invention, to produce any network with characteristic impedance z_0 , standardized metalized strips are manufactured, with fixed values of R_s , C_s , b and l and the desired z_0 is then realized by spacing the electrical contacts in a specified distance from the ends of the strips. For example, the characteristic impedance z_m of the basic structure may be equivalent to the characteristics of a telephone line of 2½ lb./mile wire. By removing the contacts in from the ends the same strips can be used to make impedances equivalent to lines of 4, 6½, 10 or 20 lb./mile wire.

Another advantage of this invention is that to nullify variations in manufacturing tolerances for the metalized strips which would lead to variations in z_0 for a constant size of strip, the strips can be made with z_m deliberately larger than z_0 and then it is merely a question of measuring the actual z_m and determining where the contacts must be placed to achieve accurately the required value of z_0 .

In order that the above and other features of the invention may be more readily understood and carried into effect, embodiments thereof will be described with reference to the accompanying drawings in which:

FIG. 1 is a diagrammatic plan view of a metalized strip with the contacts spaced from the ends thereof;

FIG. 2 is a diagrammatic sectional view of the components of an artificial line before winding;

FIG. 3 is a perspective view of a wound artificial line; and

FIG. 4 is a part sectional view through the wound components in a position indicated by the line XX in FIG. 2.

The metalized strip shown in FIG. 1 consists of a length of plastic or other dielectric material 10 with a metalized film 11 deposited on one face thereof. The metalized film 11 is slightly narrower than the plastic base, and its dimensions are length l and width b . Two of the metalized strips are required to make one artificial line, and each strip is provided with two electrical contacts 12, 13, the positioning of which will be discussed below. Suffice it to say that each contact is spaced in from the end of the strip by a distance Kl . The two strips 10, 10a are then placed one above the other as shown in FIG. 2, together with a third screening strip 14, and the whole is wound up to make a cylindrical component with leads emerging from one end as shown in FIG. 3. The completed, wound artificial line if sectioned so that the sectioned view passes through the line XX of FIG. 2, appears as in FIG. 4. Starting from the bottom, which

can be considered as the innermost portion of the wound structure, adjoining the core or mandrel 15, there is at least one turn of the screening layer 14, perhaps more than one turn. Then the two strips 10, 10a are introduced into the winding process, and probably there is at least one turn of each of these before the first electrical contacts 13, 13a become incorporated in the winding. Winding is then carried on until the strips 10, 10a are completely wound into the structure, a finishing turn or two of the screening strip 14 is made, and the winding is completed. Next the end of the wound structure, remote from that at which the electrical contacts protrude, is sprayed or otherwise treated with an electrically conducting coating 16, i.e. metal, to short together all the turns of the screening strip 14. To achieve this the metalized film of the screening strip 14a is carried right to one edge of the supporting plastic strip. The complete device may then be encapsulated.

Consider now the design of the artificial line to achieve a desired characteristic impedance. The first step is to calculate the impedance z_m of the basic metalized strips 10, 10a, according to the formula

$$z_m = \frac{1}{b} \sqrt{\frac{2R_s}{j\omega C_s}}$$

The actual values of R_s and b are determined by measuring a suitable length of metalized strip and C_s is assumed to be known so that z_m may be readily determined. The metalized strips must be made so that z_m is greater than the desired z_0 .

It is now required to construct the network of impedance z_0 , equivalent to L miles of non-loaded paired cable of that impedance. The length l inches of metalized film required to simulate the L miles of cable of impedance z_m (greater than z_0) is determined according to the formula given above. The position of each electrical contact at a distance Kl from each end is then determined, K being given by the formula

$$K = \frac{1}{2} \left(1 - \frac{z_0^2}{z_m^2} \right)$$

Once the positions of the electrical contact strips have been calculated they may be inserted in these correct positions by measuring the amount of metalized strips which is being wound. In practice, since the contacts for each strip should be the same distance from the end of the strip, at least the two innermost contact strips would normally be adjacent one another, separated only by the thickness of the intervening dielectric layer. This can lead to difficulties in preventing electrical shorting between the contacts. To avoid this problem it is permissible to displace the two corresponding contact strips to opposite sides of the correct position by an equal amount. Thus in FIG. 2 contact 12, for example, can be moved a short distance x to the right to a position $Kl+x$ from the end while contact 12a is moved a similar distance to the left to a position $Kl-x$. When the metalized layers are wound up into a cylinder, if $x=\pi d/4$ where d is the average diameter of the turns at the position of the contact strips, then the two contacts will be diametrically opposed. A similar adjustment may be made

concerning the outermost pair of contacts to space them one from another, although they may not be moved the same distances as the innermost pair. The important point to note is that provided both contacts of a pair are moved small, equal and opposite distances about the calculated correct position z_0 will not be significantly altered.

The characteristic impedance of the network will then be equal to z_0 and the attenuation-frequency characteristic of the network will closely resemble that of L miles of cable of impedance z_0 .

The invention is intended primarily to apply to networks simulating non-loaded telephone subscriber cable over the normal voice frequency range of 300 to 3400 c./s. and for length of 1 or 2 miles.

As an example in applying the method, and as an illustration of the wide range over which the impedance may be controlled, we may take a unit simulating approximately one mile of No. 28 A.W.G. cable (approximately $2\frac{1}{2}$ lb./mile) having loop resistance of 680 ohms/mile and capacitance of 0.0600 mfd./mile.

By a suitable choice of K such a unit may be made to simulate 1 mile of heavier gauges of cable, even 20 lb. cable, with the characteristic impedance over the frequency range 300 to 3400 c./s. having a return loss, against the ideal value, of not less than 30 decibels.

The approximate values of K required to simulate various gauges of cable are given in Table I.

TABLE I

Cable (A.W.G.)	28	26	24	22	19
Gauge (lb./mile)	$2\frac{1}{2}$	4	$6\frac{1}{2}$	10	20
Impedance z_0	1.00	0.749	0.553	0.426	0.298
Relative to No. 28 A.W.G. K	0	0.2295	0.347	0.409	0.456

An experimental verification of the efficacy of the above method was made using accurately constructed adjustable artificial lines consisting of lumped components arranged in discrete sections which could be switched in or out of circuit by means of keys. By arranging three such units in tandem and measuring across the terminals of the centre unit, keeping the total line constant and the outer sections equal, the effect of moving the effective tapping points could be conveniently studied.

The artificial lines used were for No. 28 A.W.G. ($2\frac{1}{2}$ lb./mile) cable. As the adjustment was in discrete steps it was not possible to achieve exactly the values of K required for other gauges, but the "target" values of z_0 corresponding to the actual values of K used are shown on Table II below together with the actual characteristic impedance obtained at various frequencies in the voice frequency range. For convenience in comparison all measurements have been normalized with respect to frequency and relative to a value of 1000—j 1000 ohms for the No. 28 A.W.G. cable. The total loop resistance used was 700 ohms and not 680 ohms, and when simulating 20 lb. cable a total of 1100 ohms was used, because the particular unit available for the centre section could not be set below 100 ohms loop resistance.

The results given for $K=0$ merely serve as an indication of the accuracy of construction of the adjustable units employed for the test.

TABLE II

Frequency, c./s.									
Approx. gauge, lb./mile	K	Target $R=X$	Measured	300	500	1,000	2,000	3,400	
$2\frac{1}{2}$ -----	0	1,000	R	1,004	1,003	1,004	1,007	1,000	
			X	993	998	988	988	990	
4-----	0.2143	756	R	755	752	748	743	730	
			X	745	745	748	743	757	
$6\frac{1}{2}$ -----	0.3570	534	R	536	538	537	532	528	
			X	527	526	527	524	528	
10-----	0.4280	380	R	391	397	389	390	390	
			X	380	379	377	376	394	
20-----	0.454	303	R	314	311	314	319	322	
			X	304	304	299	294	289	

In the above table the worst impedance error occurs at 3400 c./s. for $K=0.454$ when simulating 20 lb. cable, and is just under 24 ohms. This corresponds to a return loss of 31 db against the target of 303—j 303 ohms.

It is seen therefore that with 1 mile of cable the simulation is very accurate. For larger lengths the accuracy (or the range of impedance reduction possible for a given accuracy) will diminish.

In a test however, made with approximately 5 miles of 2½ lb. cables in which the impedance was reduced to approximately that of 10 lb. cable, the measured impedance still showed a return loss of approximately 24 db against the "target" value.

It can be shown that as the contacts are moved in from the ends of the winding to provide lower values of z_0 , the propagation constant is also modified so as to be equivalent to approximately the same length of (lower impedance) cable as is represented at the initial impedance z_m with the contacts at the ends of the winding. More exactly, if the total capacity (equal to $1/C_s$) is made equal to the total capacity of the length of lower impedance line to be simulated, then the propagation constant at voice frequencies of the unit formed by setting the contacts at the calculated distance of Kl from each end will be close to the correct value.

From the foregoing description it is evident not only that only one type of metalized strip need be stocked to cover a wide range of impedances but also that, provided individual batches of strip are uniform, variation of strip from batch to batch can be taken into account provided the nominal value of z_m is made sufficiently in excess of the highest value of z_0 required, having regard to the manufacturing tolerances of the metalizing process, since an exact relationship between R_s and b is not necessary, that is to say that the values of K required for any particular batch may be determined after appropriate measurements have been made on a sample length of strip to enable the actual value of z_m for that batch to be determined.

It is to be understood that the foregoing description of specific examples of this invention is made by way of example only and is not to be considered as a limitation on its scope.

What I claim is:

1. A method of making a network for simulating a non-loaded paired telephone cable having a characteristic impedance z_0 , the method including placing together a pair of resistance metallic film strips, each having a width b and length l , and a dielectric layer, the films being placed one on each side of the dielectric layer, the whole having an impedance z_m greater than z_0 , at an angular frequency ω , between the ends of the strips according to the formula

$$z_m = \frac{1}{b} \sqrt{\frac{2R_s}{j\omega C_s}}$$

where R_s and C_s are respectively the effective "square" (specific) resistance of the strips and the effective specific capacitance between them, and placing in contact with each strip a pair of electrical contacts, the contacts on each strip being spaced in from the ends of the strip a distance Kl where K is determined according to the formula

$$K = \frac{1}{2} \left(1 - \frac{z_0^2}{z_m^2} \right)$$

2. A method according to claim 1 wherein the resistive metallic film strips are each deposited on a separate dielectric support layer.

3. A method according to claim 2 including the step of winding the two dielectric layers with their associated metallic films into a cylindrical structure with the electrical contacts protruding from the end thereof.

4. A method according to claim 3 including winding a further screening dielectric layer coated on one side with an electrically conducting film together with the two resistive film coated dielectric layers.

5. A method according to claim 4 including the step of making the screening layer extend axially beyond the limit of the resistive films in one direction and coating with metal or otherwise treating the end of the wound structure to short together all the turns of the wound screening layer.

6. A method according to claim 3 including displacing the two contacts at the innermost end of the pair of resistive films by equal and opposite amounts from the calculated position Kl from the end so that when the films are wound into a cylindrical structure the two contacts are angularly disposed from one another.

7. A method according to claim 3 including displacing the two contacts at the outermost end of the pair of resistive films by equal and opposite amounts from the calculated position Kl from the end so that when the films are wound into a cylindrical structure the two contacts are angularly disposed from one another.

References Cited

UNITED STATES PATENTS

3,160,801 12/1964 Haas et al. ----- 29—621 X

FOREIGN PATENTS

544,144 3/1942 Great Britain.

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U.S. Cl. X.R.

317—101; 333—31, 84