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COAXIAL IMPEDANCE ELEMENT

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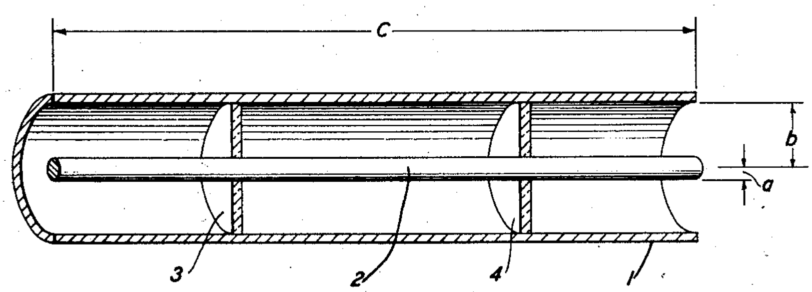

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COAXIAL IMPEDANCE ELEMENT

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5 Claims. (Cl. 178—45)

This invention relates to reactive impedance elements and more particularly to those comprising short sections of coaxial transmission line.

The principal objects of the invention are to reduce the space requirements and the cost of reactive impedance elements of the coaxial type. Ancillary objects are to minimize the volume, the cross-section or the length of such elements.

Due to their low dissipation, short sections of coaxial transmission line, made up of an outer cylindrical conductor and an inner conductor of circular cross-section with suitable insulation therebetween, make very satisfactory reactive impedance elements, especially for use at high frequencies. However, for a large value of inductance the size of the element may become so large that an excessive amount of mounting space is required.

In accordance with the present invention the space required for such a coaxial impedance element is materially reduced by minimizing either the volume, the longitudinal cross-section or the length of the element, depending upon the particular space requirements encountered. Assuming the element is to have a given inductance, its volume will be a minimum when the ratio of the inner radius of the outer conductor to the radius of the inner conductor is 5.8, and its longitudinal cross-section will be a minimum when this ratio is 9.2. Also, there is presented a formula involving the inductance, the operating frequency and the dissipation factor, for the required value of this ratio to give the minimum length of element for a given ratio of length to diameter for the outer conductor.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing, the single figure of which shows in perspective a longitudinal cross-section of a coaxial impedance element to which the invention is applicable.

The element comprises an outer cylindrical conductor 1 of inner radius b and coaxial therewith an inner conductor 2 of circular cross-section and radius a, separated by the spaced insulating rings 3 and 4. The inner conductor 2 may either be solid, as shown, or hollow. The element may be used as a two-terminal impedance by making connections to the outer conductor 1 and to one end of the inner conductor 2, with the other end either left open-circuited, as shown, or short-circuited, depending upon the type of reactance characteristic desired. The element may also be used as a four-terminal network by making connections to the outer conductor 1 and to both ends of the inner conductor 2. Such impedances or networks may be used, for example, to furnish reactances for wave filters and transformers. For disclosures of such uses reference is hereby made to United States Patents 2,149,356, 2,183,123 and 2,284,529 to W. P. Mason, issued, respectively, March 7, 1939, December 12, 1939, and May 26, 1942, and to the article by Mason and Sykes entitled "The use of coaxial and balanced transmission lines in filters and wide-band transformers for high radio frequencies," in the Bell System Technical Journal, July, 1937, pages 275 to 302.

The length c of the coaxial element is preferably so limited that its reactance, as measured between the outer conductor 1 and one end of the inner conductor 2 with the conductors 1 and 2 short-circuited at the other end, does not depart greatly from linearity with frequency. In practice it is found that this condition obtains for all lengths c which do not materially exceed an eighth wave-length at the operating frequency f.

The required length c in inches of a coaxial element to furnish an inductance of L microhenries is given by the formula

$$c=\frac{L}{0.01170\log_{10}k} \quad (1)$$

where k is the ratio of b to a. The inside radius b of the outer conductor 1 in inches is given by the formula

$$b=\frac{Q(1+k)}{1.766\sqrt{f}\log_{10}k} \quad (2)$$

where f is the operating frequency in cycles per second and Q is the dissipation factor, that is, the ratio of the inductive reactance to the resistance at the frequency f.

From Equations (1) and (2) the volume V enclosed by the outer conductor is

$$V=\pi b^2c=\frac{\pi LQ^2(1+k)^2}{1.766^2\times0.01170f\log_{10}^3 k} \quad (3)$$

For any particular element the values of f, L and Q will be fixed. The only undetermined factor affecting the volume V is, therefore, the ratio k. In accordance with the invention, to save mounting space, k may be so chosen that the volume V will be a minimum. This is done by taking the first derivative of the right-hand side of Equation (3) with respect to k, setting this equal to zero and solving for k, which is found to be equal to 5.8. Making k either larger or smaller than 5.8 will increase the volume V. The required length c and radius b are found by substituting this value of k in Equations 1 and 2, and the radius a is found from the expression

$$a=\frac{b}{k} \qquad (4)$$

In some cases space may be more effectively conserved by making the longitudinal cross-section S, instead of the volume V, a minimum. From Equations 1 and 2 the area S is

$$S=2bc=\frac{2LQ(1+k)}{1.766\times 0.01170\sqrt{f}\log_{10}^2 k} \qquad (5)$$

By following the same procedure as outlined above, it is found that the area S will be a minimum when k is equal to 9.2. Again, the dimensions c, b and a are found from Equations 1, 2 and 4. Although for an absolute minimum area k should be 9.2, departures to either side of this optimum value, if not too great, will not unduly increase the area S. For example, for values of k falling anywhere within the range of 5.5 to 19 the area S will not increase over its minimum value by more than 10 per cent. For values of k falling on the lower side of 9.2 down to 5.8, it will be noted, the volume V is also decreasing, and this range of values is, therefore, of particular importance.

Sometimes it is desired to provide a coaxial element of minimum length c consistent with satisfactory performance. As Equation 1 shows, c may be decreased by increasing k. But it is seen from Equation 2 that the radius b becomes larger as k is made larger. One criterion of satisfactory performance is the ratio R of the length c to the radius b. Experience shows that, in general, R should not be permitted to become much less than about 6. However, for any chosen value of R there may be found a value of k which will result in an element of minimum length c. From Equations 1 and 2

$$R=\frac{c}{b}=\frac{1.766\,L\sqrt{f}}{0.01170\,Q\,(1+k)} \qquad (6)$$

from which

$$k=\frac{151\,L\sqrt{f}}{Q\,R}-1 \qquad (7)$$

In accordance with the invention, therefore, the procedure for designing a coaxial element of minimum allowable length c is to choose the permissible value of R, find k from Equation 7, substitute this value of k in Equation 1 to find c, find b from the relation

$$b=\frac{c}{R} \qquad (8)$$

and find a from Equation 4.

What is claimed is:

1. A reactive impedance element comprising a section of coaxial transmission line which comprises an outer cylindrical conductor and coaxial therewith an inner conductor of circular cross-section, the length of said section of line not materially exceeding an eighth wave-length at the operating frequency and the ratio of the inner radius of said outer conductor to the radius of said inner conductor being approximately 5.8.

2. A reactive impedance element in accordance with claim 1 in which said ratio is equal to 5.8.

3. An inductive reactance element for providing a given inductance comprising an outer cylindrical conductor and coaxial therewith an inner conductor of circular cross-section, the ratio of the inner radius of said outer conductor to the radius of said inner conductor being chosen to minimize the volume of said element.

4. An inductive reactance element in accordance with claim 3 in which said ratio is approximately 5.8.

5. An inductive reactance element in accordance with claim 3 in which said ratio is equal to 5.8.

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