Aug. 6, 1946. L. M. LEEDS 2,405,437

IMPEDANCE MATCHING TRANSFORMER

Filed Sept. 1, 1942

Fig. 1.

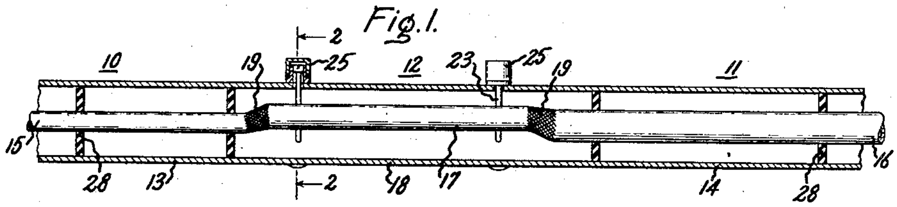


Fig. 2.

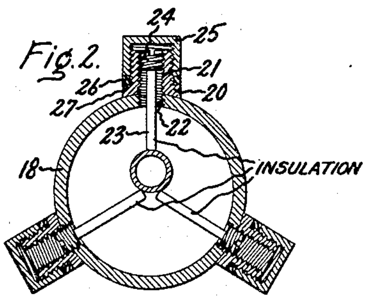


Fig. 3.

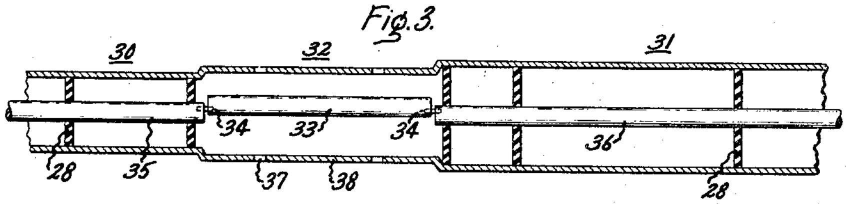
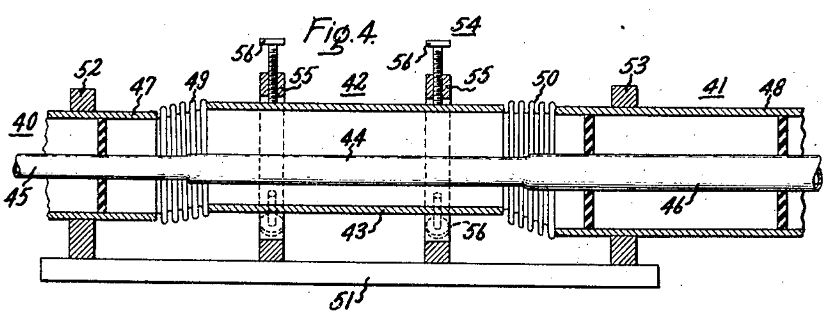


Fig. 4.



Inventor:
Laurance M. Leeds,
by Harry E. Dunham
His Attorney.

Patented Aug. 6, 1946

2,405,437

UNITED STATES PATENT OFFICE

2,405,437

IMPEDANCE MATCHING TRANSFORMER

Laurance M. Leeds, Rotterdam Junction, N. Y., assignor to General Electric Company, a corporation of New York

Application September 1, 1942, Serial No. 456,941

2 Claims. (Cl. 178—44)

My invention relates to impedance matching transformers for a concentric transmission line and it has for its object to provide an improved impedance matching means for two dissimilar sections of such a line.

The use of a transmission line having a length equal to a quarter of a wave length, or any odd multiple thereof, of the wave to be transmitted, to match two unequal impedances is well known. In the past various types of balanced and unbalanced lines, such as a two-wire balanced open line, two bar or strip balanced open lines, coaxial unbalanced lines, and similar composite lines have been employed for this purpose. In general, in most practical applications, it is necessary to vary the surge impedance of the quarter wave line in order to obtain precise impedance matching. This has been accomplished, in the case of the two-wire line, by varying the spacing of the conductor elements. For the concentric line, variation of the surge impedance has been accomplished by varying the ratio of the diameters of the conductors. This method of varying the surge impedance of a coaxial line is cumbersome, requires disassembly of the line, and the variation of surge impedance is not continuous. To obtain a continuous variation of the surge impedance of an impedance matching section and one which does not require disassembly of the line, my invention employs a shielded line in which the inner conductor may or may not be coaxial.

It is an object of my invention, therefore, to provide in a transmission line an eccentric section for matching the impedance of one section of the line with the impedance of an adjacent section, the impedance of the eccentric section being the geometric mean of the impedances of the two sections.

It is a further object of my invention to provide an unbalanced impedance matching transformer which may be manufactured at low cost, which may be inserted in a transmission line without difficulty, and which may be adjusted with ease to provide precise impedance matching.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawing, in which Fig. 1 is a section of a transmission line employing the impedance matching transformer of my invention; Fig. 2 is a sectional view of the transformer of Fig. 1 on the line 2—2, and Figs. 3 and 4 are modifications of my impedance matching transformer.

In the transmission line of Fig. 1, adjacent sec-

tions 10 and 11, having different values of surge impedance, are connected together by means of the impedance matching transformer 12. As shown, the sections 10 and 11 comprise coaxial tubular outer conductors 13 and 14 having the same diameter and coaxial inner conductors 15 and 16 of different diameters. The inner conductors are held in spaced relation with respect to the outer conductors by means of suitable insulators 28. Section 10 of the transmission line may be connected to some source of voltage, such as a radio transmitter, and section 11 to some utilization means, for example an antenna. It will be realized of course that instead of connecting the transformer 12 to the section 11, it may be desired to connect this section directly to a load impedance.

In the above described transmission line, if the impedance of section 11, that is the load impedance, is Z_r and the impedance of section 10, that is the sending end impedance, is Z_s, the surge impedance Z_0 of the connecting line or quarter wave transformer, in accordance with well known transmission line theory, is related to the other impedances by the relation $Z_0^2=Z_sZ_r$. In practical application it is difficult to obtain the desired value of surge impedance for the matching line. Considerable experimentation and consequent disassembly of the transmission line are required before a satisfactory arrangement is obtained.

In accordance with my invention, a precise value of Z_0 for the impedance transformer 12 is obtained by making the electrical length of the section 12 equal to a quarter wave length at the angular velocity of the desired operating frequency and by providing in the section 12 an inner conductor 17 which is eccentrically disposed with respect to the tubular outer conductor 18 and means for adjusting the amount of this eccentricity, conductor 17 being connected to conductors 15 and 16 by means of the flexible cable 19.

Adjustment of the position of conductor 17 with respect to the tubular conductor 18 is secured by means of the triadic insulator support shown in Fig. 2. The members 20 suitably secured to the outer conductor 18, as by brazing or welding, have internally threaded bores 21 in alignment with the three equally spaced coplanar threaded openings 22 in the outer conductor 18. Rodlike members 23 of suitable insulating material, having enlarged head portions 24 externally threaded for engagement with the threads 21, hold conductor 17 in spaced relation with outer conductor 18. By adjustment of the threaded heads 24 in members 20, the position of conductor 17 with respect to conductor 18 may be adjusted as desired. Member 20 is likewise threaded over a portion of its outer surface for engagement with cooperating threads on the interior of cap member 25. For installations in which a gas-filled transmission line is used, sealing gasket 26 is provided between cap member 25 and a shoulder portion 27 on member 20.

The ratio of the outside diameter of conductor 17 to the inside diameter of conductor 18 may or may not be different from the ratio of corresponding diameters in sections 10 and 11 of the transmission line. In general, the impedance transformer 12 is used to match two lines or two sections of a line of different characteristic impedance and the above-mentioned diameter ratio for the section 12 is chosen to give substantially the correct surge, or characteristic, impedance for this matching section when the position of conductor 17 with respect to conductor 18 is at approximately the midpoint of eccentric movement. In this way the surge impedance of the matching section 12 may be varied above or below a calculated and expected value in order to obtain precise matching with sections 10 and 11. Movement of the inner conductor 17 from the midpoint of its eccentric path toward the axis of the transmission line is effective to increase the surge impedance of the matching section 12, while movement further from the axis is effective to decrease the surge impedance of this section.

The expression for the surge impedance Z_0 of the matching section 12 for any eccentricity may be derived in the following manner. It can be shown mathematically that the capacitance C of such a line is

$$C=\frac{.08941}{\cosh^{-1}\left[\frac{\left(\frac{b}{2}\right)^2+\left(\frac{a}{2}\right)^2-c^2}{\frac{ab}{2}}\right]}\text{ mfd per mile}$$

where

a=the outside diameter of the inner conductor 17,
b=the inside diameter of the outer conductor 18, and
c=the eccentricity of the conductor 17, that is, the distance between the axis of conductor 17 and the axis of conductor 18.

Since, at high frequencies the surge impedance

$$Z_0=\sqrt{\frac{L}{C}}$$

and the velocity of propagation,

$$V=\sqrt{LC}$$

the surge impedance can be determined. Taking suitable regard for the units, it is found that

$$Z_0=60\cosh^{-1}\frac{\left(\frac{a}{2}\right)^2+\left(\frac{b}{2}\right)^2-c^2}{\left(\frac{ab}{2}\right)}$$

By mathematical transformation this can be expressed as follows:

$$Z_0=138\log_{10}\frac{b}{a}+276\log_{10}\left[\sqrt{\frac{\left(\frac{b}{a}+1\right)^2-\left(\frac{2c}{a}\right)^2}{\left(\frac{2b}{a}\right)^2}}+\sqrt{\frac{\left(\frac{b}{a}-1\right)^2-\left(\frac{2c}{a}\right)^2}{\left(\frac{2b}{a}\right)^2}}\right]$$

In the transmission line of Fig. 3, the sections 30 and 31 of different impedance value and the matching section 32 have inner conductors of equal diameter and outer conductors of unequal diameter. In this figure, too, there is shown another method of supporting the inner conductor 33 of the section 32 in a non-coaxial position. Conductor 33 is eccentrically mounted on bearing rods 34 non-coaxially supported in inner conductors 35 and 36. This particular construction is especially suitable for use in a cable which is not gas-filled. In such a case, the eccentricity of conductor 33 may be adjusted by inserting a suitable tool through opening 37 in the outer conductor 38 and rotating the conductor 33 on the bearings 34. The triadic insulator support shown in Fig. 2, of course, may be used in conjunction with matching section 32 as a means for more precisely determining and maintaining the proper eccentricity of conductor 33.

In the modification shown in Fig. 4, the inner conductors of the sections 40 and 41 and the matching section 42 are rigidly connected together and precise impedance matching of section 42 with sections 40 and 41 is obtained by moving the position of the tubular outer conductor 43 with respect to the solid inner conductor 44. This construction is particularly desirable where the conductors of the respective sections are of different diameter. In such a case, the inner conductors 44, 45, and 46 are rigidly connected together, as by brazing or welding. The tubular outer conductor 43 is joined to outer conductors 47 and 48 by means of the Sylphons or corrugated sections 49 and 50. Movement of the outer conductor of one section relative to the outer conductors of the other sections is prevented by means of the supporting arrangement comprising the plate member 51, the clamping rings 52 and 53 and the triadic supporting means 54. The rings 52 and 53 may be welded to the plate 51 and may be either brazed or welded to the outer conductors 47 and 48 or clamped thereto in any well known manner. The triadic supporting means comprises the ring member 55 suitably secured to plate 51 and the thumb-screw members 56 threadedly engaging ring 55. By adjustment of the screws 56 in a well known manner, the position of the outer conductor 43 with respect to the inner conductor 44 may be varied to obtain precise impedance matching.

It is readily apparent that the equation for Z_0 given above for the arrangement of Fig. 1 applies equally well to the arrangement of Figs. 3 and 4.

It is thus seen that my invention provides an unbalanced impedance matching transformer in which the surge impedance of the transformer can be varied for matching purposes, the variation being accomplished by moving one of the conductors of the matching transformer to a non-coaxial position. In the transformers described above, continuous variation of the surge impedance of the matching section is provided without disassembly of the transmission line. Moreover, the value of the required matching impedance may be obtained with speed, with ease, and with precision.

While I have shown particular embodiments of my invention, it will of course be understood that I do not wish to be limited thereto since various modifications may be made, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A transmission line section adapted for connection between adjacent ends of two concentric transmission lines of unequal surge impedance to match the impedance of one of said lines to that of the other, said transmission line section comprising an outer conductor adapted for connection between the outer conductors of said concentric lines and an inner conductor adapted for connection between the inner conductors of said concentric lines, means to move one of said conductors of said section in a direction transverse to the other conductor while maintaining said one conductor substantially parallel therewith to vary the eccentricity of said section to match said impedances, and yielding electrical connections between said one conductor and the conductors of said concentric lines to which it is connected to allow said movement by said means in said transverse direction.

2. In a concentric transmission line system, the combination of a continuous and substantially rigid inner conductor, a pair of tubular outer conductors coaxial with said inner conductor and forming therewith two sections of concentric transmission line having different characteristic impedances, said outer conductors having their adjacent ends spaced apart by a distance equal to a quarter wave length at the operating frequency of said system, a third tubular outer conductor flexibly connected between said ends, said third conductor having a length equal to a quarter wave length at said frequency and forming with said inner conductor an impedance matching section of transmission line connected between said two sections, and means for moving said third conductor in a direction transverse to said inner conductor to vary the eccentricity of said impedance matching section to match said impedances, said pair of outer conductors and said third conductor having substantially uniform thickness throughout their lengths.

LAURANCE M. LEEDS.