

[54] RF BROADBAND TRANSMISSION LINE
IMPEDANCE MATCHING TRANSFORMER
PAIR FOR LESS THAN 4 TO 1 IMPEDANCE
TRANSFORMATIONS

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336/229**

[51] Int. Cl. **H03h 7/38**

[58] Field of Search..... **333/24 R, 32; 336/173,
336/180, 182, 229; 323/44, 48**

[56]

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[57]

ABSTRACT

An impedance transforming device is disclosed which includes four conductors coil-wound and connected to form a transmission line having two coils connected in series in each side and a circuit network connecting the two sides of the transmission line to achieve a desired transformation ratio.

7 Claims, 7 Drawing Figures

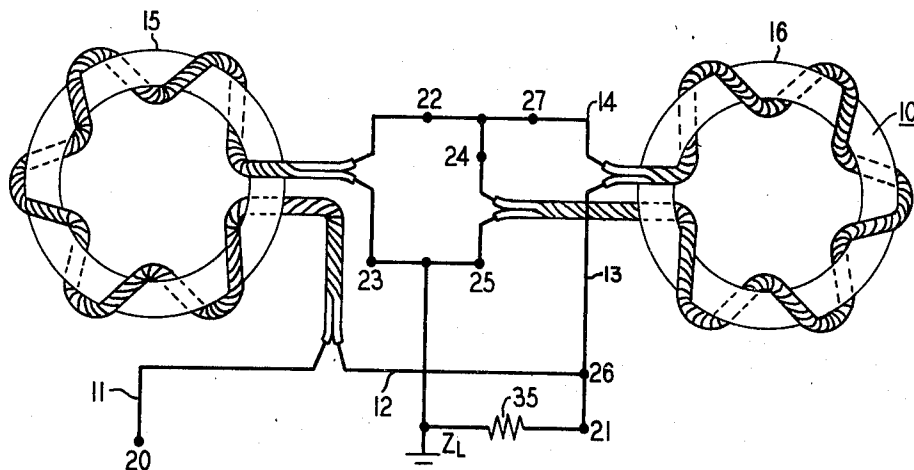
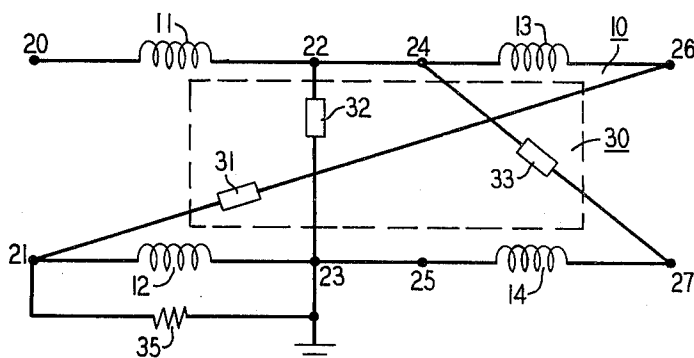


FIG. 1

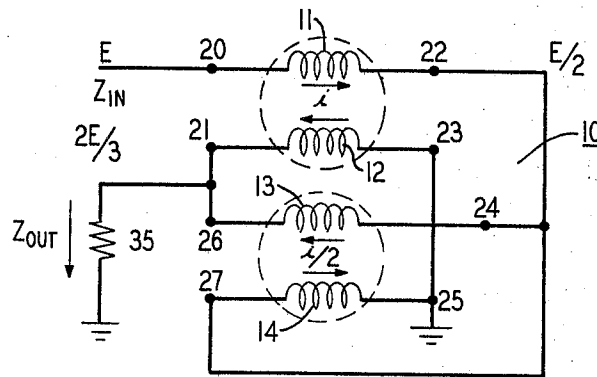


FIG. 2

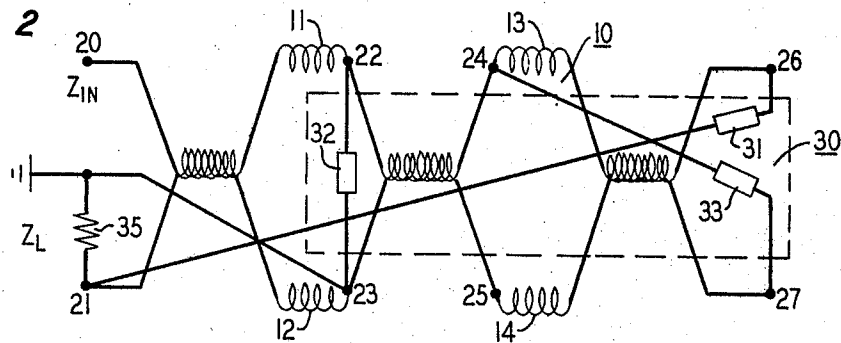


FIG. 3

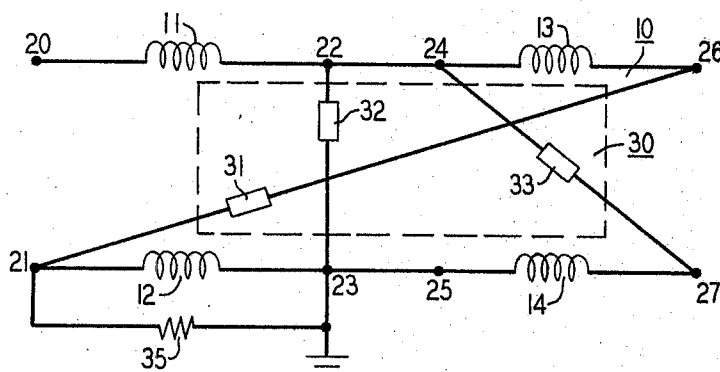


FIG. 5

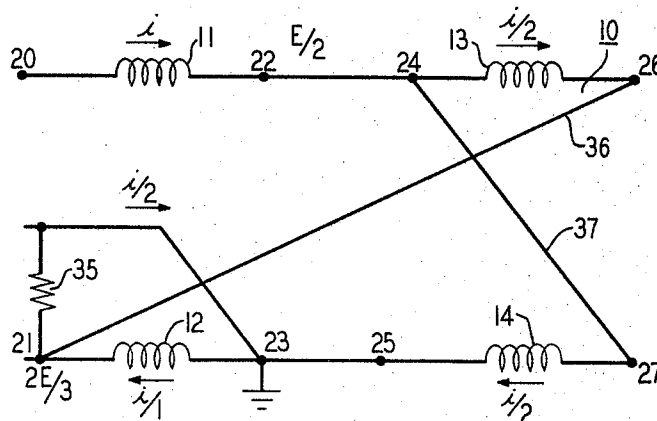


FIG. 4

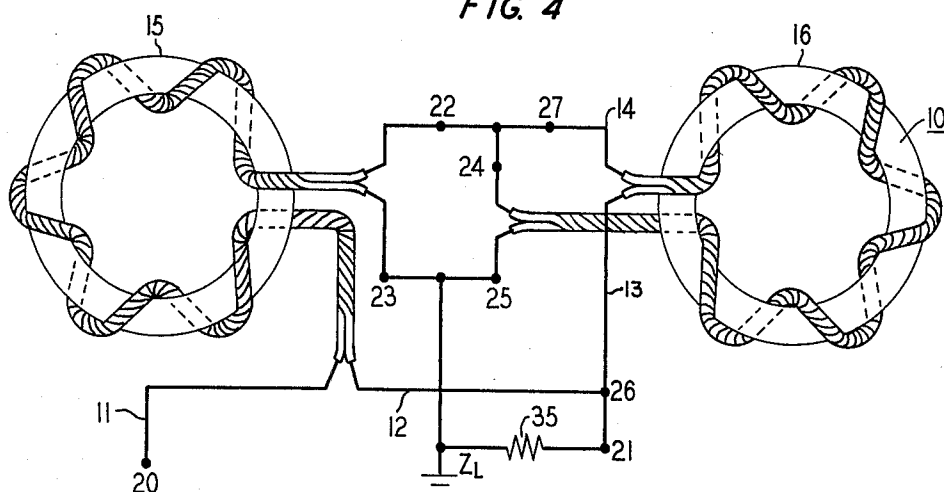


FIG. 6

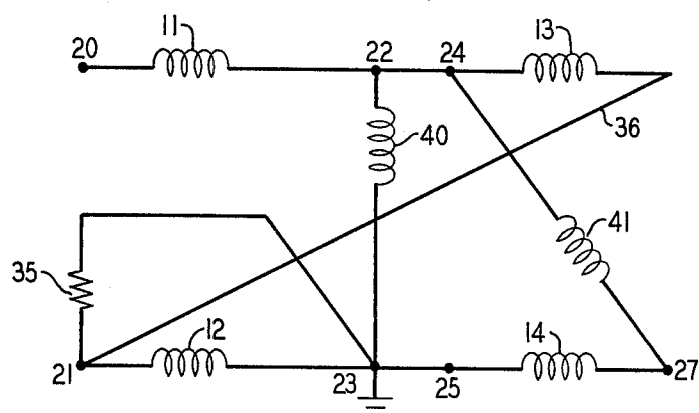
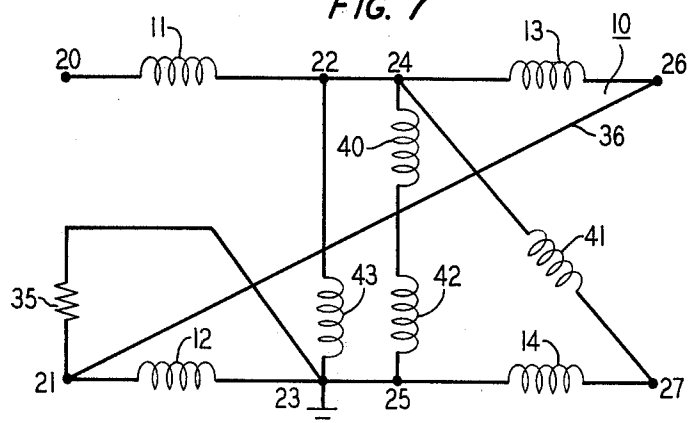


FIG. 7



RF BROADBAND TRANSMISSION LINE IMPEDANCE MATCHING TRANSFORMER PAIR FOR LESS THAN 4 TO 1 IMPEDANCE TRANSFORMATIONS

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefore.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to broadband impedance matching transformers and pertains in particular to those in which the transformer exhibits low insertion loss when placed in a circuit application.

2. Description of the Prior Art

Impedance matching transformers having low insertion loss are generally well known. Most generally, they comprise two or more coils wound and twisted together to form a transmission line. The impedance ratios available from such devices, however, are subject to design restraints which prohibit good matching in many applications. Specifically, the typical transformer arrangement produces impedance ratios following the series: $1/n^2$ or $n^2/1$. Consequently, the lowest ratio which can be achieved is 4:1. Thus, in applications calling for smaller ratios, the match will be inexact and efficiency will suffer.

Accordingly, one object of this invention is to achieve transformation ratios smaller than 4:1 in a simple easily constructed circuit device.

Also, another object of this invention is to achieve ratios less than 4:1 in a transformation device exhibiting low insertion loss when placed in a circuit application.

SUMMARY OF THE INVENTION

In accordance with the preferred embodiment of this invention, four conductors are coil-wound and twisted together in series pairs to form a transmission line, the two sides of the transmission line are connected by a network and one side is grounded to achieve a transformer device having low insertion loss.

In accordance with a feature of this invention, each side of the transmission line has input and output coils connected in series, each coil has input and output terminals, the ground connection is located between an input and output coil and a load impedance is connected to ground across the input coil in the grounded side of the transmission line to obtain a simple and efficient transformer device capable of transformation ratios of less than 4:1.

In accordance with another feature of this invention, a transformation ratio of 9:4 is achieved when the network includes an open circuit across the transmission line at the junction point between the input and output coils in each side thereof, a first shorting segment links the input terminal of the input coil in the grounded side of the line and the output terminal of the output coil in the ungrounded side of the line and a second shorting segment links the junction point between the input and output coils in the ungrounded side of the line and the output terminal of the output coil in the grounded side of the line.

In accordance with another feature of this invention, a transformation ratio of 16:9 is achieved when the open circuit and the second shorting segment are re-

placed by a pair of coils which may advantageously be wound together to form another transmission line transformer.

In accordance with another feature of this invention a transformation ratio of 25:16 is achieved when the second shorting segment is replaced with a coil forming the first half of a first transformer and the open circuit is replaced by two parallel circuit elements in which the first element comprises the second half of said first transformer connected in series with the first half of a second transformer and the second element comprises the second half of said second transformer.

BRIEF DESCRIPTION OF THE DRAWING

This specification concludes with claims particularly pointing out and distinctively claiming the subject matter which is regarded as the invention. It is believed, however, that both as to its organization and method of operation, together with further objects and advantages thereof, the invention may be best understood from the description of the preferred embodiments, taken in connection with the accompanying drawings in which:

FIG. 1 is a schematic circuit design of an impedance matching device in accordance with this invention.

FIG. 2 is an alternative form of the schematic shown in FIG. 1.

FIG. 3 is another alternate form of the schematic shown in FIG. 1.

FIG. 4 is a structural embodiment of the schematic shown in FIG. 1.

FIG. 5 is a schematic circuit design of an impedance matching device exhibiting a transformation ratio of 9:4.

FIG. 6 is a schematic circuit design of an impedance matching device exhibiting a transformation ratio of 16:9.

FIG. 7 is a schematic circuit design of an impedance matching device exhibiting a transformation ratio of 25:16.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, an impedance matching transformer 10 is shown which comprises four conductors 11, 12, 13 and 14. All of the conductors are coil-wound and adapted to cooperate with each other to exhibit a transformer function. As best seen in FIG. 4, the conductors 11 and 12 are wound on a common core 15, while the conductors 13 and 14 are wound on a common core 16. Advantageously, the cores are made of a ferrite material having a permeability of 100 or less, the conductors are made of No. 22 enameled wire and each conductor is wound with turns in the range of 2 to 12 depending upon the frequency band desired.

Referring to FIGS. 2 and 3, the conductors are connected so that each has input and output terminals; i.e., conductor 11 has an input terminal 20 and an output terminal 22; conductor 12 has an input terminal 21 and output terminal 23; conductor 13 has an input terminal 24 and an output terminal 26, and conductor 14 has an input terminal 25 and an output terminal 27. As best seen in FIGS. 2 and 3, the conductors are twisted together and connected in series to form a transmission line. More particularly, conductors 11 and 13 are series connected to form one side of the transmission line and conductors 12 and 14 are series connected to form the other side thereof. Moreover, conductors 11 and 12

and conductors 13 and 14 are twisted together, respectively.

As best seen from FIGS. 2 and 3, the two sides of the transmission line are joined by a network 30 (shown blocked in phantom for convenience) and one side is grounded at the common junction between the output terminal 23 and the input terminal 25. As shown in FIGS. 2 and 3, the network 30 comprises circuit elements 31, 32 and 33.

Referring to FIG. 2, a load impedance 35 is shown connected across the coil 12 and by adjusting the circuit elements 31, 32 and 33, the disclosed transformer device 10 will provide transformation ratios of less than 4:1.

Referring to FIG. 5, a transformer device 10 is disclosed which exhibits a transformation ratio of 9:4. As shown therein, that ratio is achieved by connecting the load impedance 35 from input terminal 21 to output terminal 23 which is advantageously grounded. Moreover, the circuit element 31 comprises a short circuiting lead 36 connecting input terminal 21 and output terminal 26, the circuit element 32 comprises an open circuit and the circuit element 33 comprises a short circuit lead 37 connecting input terminal 24 and output terminal 27.

Referring to FIG. 6, a transformer device 10 is disclosed which exhibits a transformation ratio of 16:9. As shown therein, the load impedance 35 is again taken between input terminal 21 and the grounded output terminal 23 and the circuit element 31 comprises the short circuit lead 36 connected as before. The circuit elements 32 and 33, however, have been replaced with coils 40 and 41, respectively, which may advantageously be the two sides of a transformer which, in turn, may be wound as a transmission line.

Referring to FIG. 7, a transformer device 10 is disclosed which exhibits a transformation ratio of 25:16. As shown therein, the load impedance 35 is again taken between input terminal 21 and the grounded output terminal 23. Moreover, the circuit element 31 is again a short circuiting lead 36 extending between the input terminal 21 and the output terminal 26 and the circuit element 33 is again the coil 41. The circuit element 32, however, now comprises the coil 40 connected in series with another coil 42 which advantageously is one half of a transformer in which the other half is coil 43 connected electrically in parallel with the series combination of the coils 40 and 42. Coils 42 and 43, as before, may advantageously be wound as a transmission line. Coils 40 and 41 have the same relationship as in FIG. 6.

A careful analysis of the circuits disclosed in FIGS. 5, 6 and 7 will reveal there is a common mathematical relationship which links them all. Specifically, the ratio expressed by each follows the series $(n+1/n)^2$ wherein n is an integer greater than unity. Furthermore, it will be apparent that additional transformation ratios in the series can be achieved merely by expanding the components of the circuit element 32 in the manner indicated.

Operation of the transformer device 10 can be best understood by reference to FIGS. 1 and 5. As illustrated therein, $Z_{in} = E/i$. Furthermore, for the current and voltage arrangement of the branches shown, $Z_{out} = 2E/3 \div 3 i/2$. Combining the two equations reveals: $Z_{out} = 4/9 Z_{in}$.

Referring to FIG. 4, it will be seen that the cores 15 and 16 are advantageously toroids. Accordingly, the

low frequency range of operation of the transformer device 10 will be increased because of the increase in line inductance. The conductors 11 and 12, and the conductor 13 and 14 must be twisted together, respectively, to give the desired characteristic impedance Z_0 . It will be readily apparent that connections between the various components must be kept extremely short to prevent unwarranted parasitic losses.

In summary, a transformer device has been disclosed which is simple and easy to construct, will exhibit low insertion loss over a broad band of frequencies in a circuit application and will exhibit transformation ratios of 9:4 16:9, etc. in accordance with the series $(n+1/n)^2$. While several embodiments have been disclosed, it will be recognized that they are merely representative of the invention and many others falling within the scope of the invention will readily occur to those skilled in the art.

We claim:

1. A broad band impedance matching transformer including a first conductor coil-wound on a first core and having first and second terminals, a second conductor coil-wound on a second core and having third and fourth terminals, said second and third terminals being connected electrically in common, to form the first side of a transmission line, a third conductor coil wound on said first core and having fifth and sixth terminals, said first and third conductors being twisted together, a fourth conductor coil wound on said second core and having seventh and eighth terminals, said seventh and sixth terminals being connected electrically in common to form the second side of a transmission line, said second and fourth conductors being twisted together, and a network interconnecting said first and second sides of said transmission line characterized in that a load impedance is connected in parallel with said third coil-wound conductor, and said network includes first circuit element means for interconnecting said second and sixth terminals, second circuit element means for interconnecting said third and eighth terminals and third circuit element means connecting said fourth and fifth terminals electrically in common.

2. A broad band impedance matching device in accordance with claim 1 wherein said first circuit element means is an open circuit across said second and sixth terminals, and said second circuit element means connects said third and eighth terminals electrically in common.

3. A broad band impedance matching device in accordance with claim 1 wherein said first circuit element means comprises a first coil connected across said second and sixth terminals and said second circuit element means comprises a second coil connected across said third and eighth terminals.

4. A broad band impedance matching device in accordance with claim 3 wherein said first and second coils are the two sides of a transformer wound as a transmission line.

5. A broad band impedance matching device in accordance with claim 1 wherein said second circuit element means comprises one side of a first transformer connected across said third and eighth terminals, said first circuit element means comprises the other side of said first transformer connected across said second and sixth terminals in series with the first side of a second transformer and the other side of said second transformer being connected across said second and sixth

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terminals in parallel with said serially connected other side of said first transformer and first side of said second transformer.

6. A broad band impedance matching device in accordance with claim 5 wherein said first and second transformers are wound as transmission lines.

7. A broad band impedance matching device having four conductors coil-wound and serially connected in pairs to form input and output coils in either side of a transmission line and one side of said transmission line

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being grounded between input and output coils characterized in that a load impedance is connected across said input coil in the grounded side of said transmission line and a network is connected across the two sides of said transmission line, said network having means to produce a ratio of input and output impedance in said device following the series $(n+1/n)^2$ where n is an integer greater than unity.

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