United States Patent

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[73] Assignee **The United States of America as represented by the Secretary of the Army**

[54] **LOW LOSS TRANSMISSION-LINE TRANSFORMER**
5 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** ..... **336/83,** 333/84 M, 336/180, 336/223, 336/229
[51] **Int. Cl.** **H01f 15/02,** H01f 27/28
[50] **Field of Search** ..... 336/83, 223, 69, 70, 148, 180, 222, 229; 333/84 M

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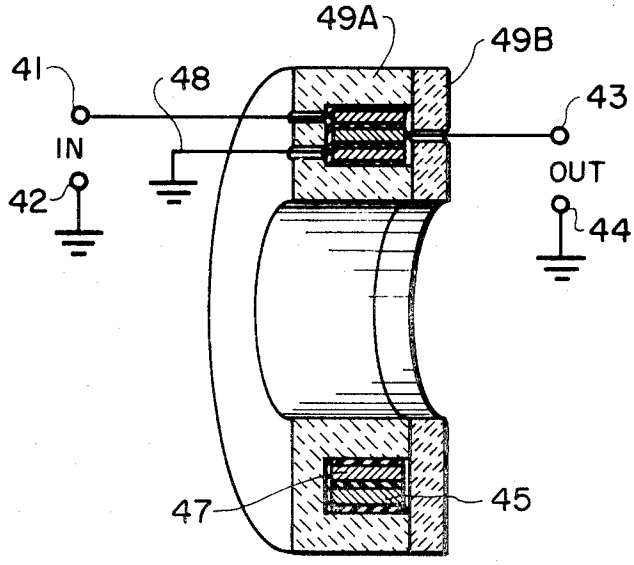
Primary Examiner—Thomas J. Kozma

ABSTRACT: This disclosure relates to transmission-line transformers and particularly to transmission-line transformers formed of parallel-pair conductors. More particularly, this disclosure relates to parallel-stripline or ribbon-type conductors wound about the periphery of a toroidal core to form a pair of inductively coupled, series-connected loops to serve as the halves of a 4 to 1 ratio, transmission-line transformer.



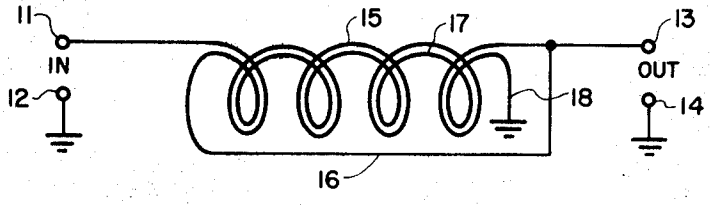


FIG. 1 (Prior Art)

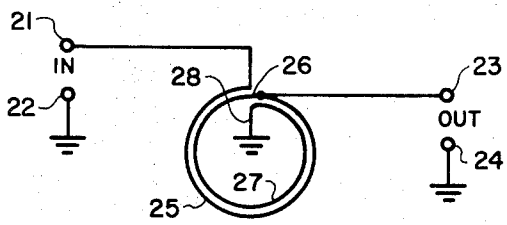
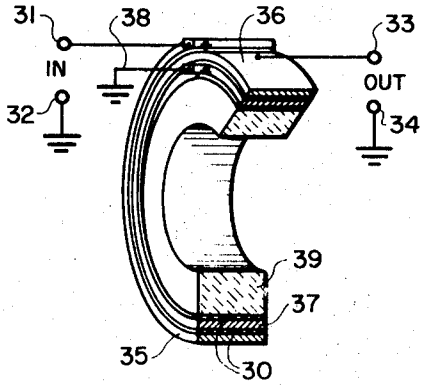


FIG. 2

FIG. 3



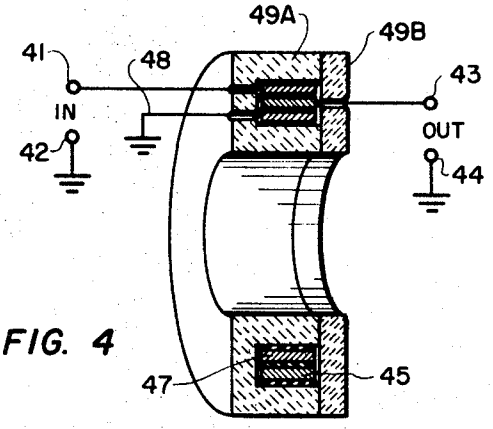


FIG. 4

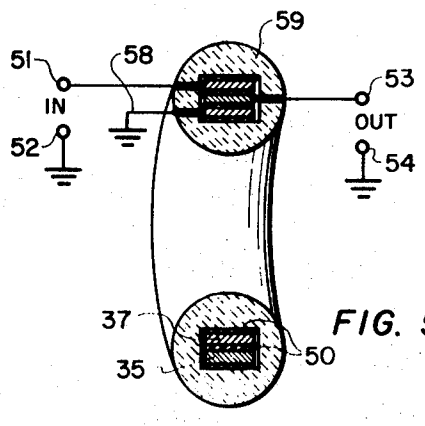


FIG. 5

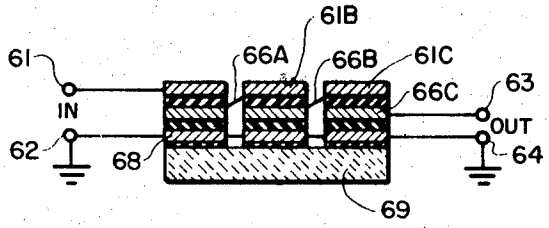


FIG. 6

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LOW LOSS TRANSMISSION-LINE TRANSFORMER

BACKGROUND OF THE INVENTION

Transmission lines are very well known, and there are many types of transmission lines, of very many sizes and shapes. All have at least two conductors, extending in parallel, of a size, shape, and spacing to provide a uniform characteristic impedance along the line. The impedance of a line is chosen to correctly match both the output impedance and the input impedance of the units that it connects.

However, not all outputs and inputs are at the same impedance, and at some point between the output of one unit and of the input of another, the characteristic impedance may have to be transformed for effective and efficient transfer of energy.

In order to change this impedance, at either end of a given transmission line, the line may be connected to a conventional transformer of the correct impedance ratio for raising or lowering the effective impedance of the line. Alternatively, portions of a transmission line can be wound into an inductive configuration with the ends of the line suitably connected to have the conductors of the transmission line function as the separate windings of a transformer.

One of the types of transmission lines that evolve in designing for relatively low impedances has ribbon-type conductors in a parallel-stripline configuration. These lines have flat, relatively wide conductors, extending parallel to each other, and held at an optimum spacing by a suitable dielectric. The width of the ribbon-type conductor and the normally narrow spacing between the conductors make this a relatively low impedance type of transmission line. The wider the conductors, and the closer the spacing, the lower the characteristic impedance of the line that can be achieved.

These flat, parallel-stripline conductors can also be wound into a transformer configuration, but the width of the conductors and mechanical considerations limit the flexibility of the line to one direction and make complex turns and curves extremely difficult without a change in the precise spacing between the two conductors. This is undesirable since any change in the spacing or relationship between the two conductors will cause discontinuities in the uniform characteristic impedance of the line.

In the prior art of transmission-line transformers, where the line is wound in an inductive configuration, there must, at some point, be a break in the continuity of the line where the end of one conductor, forming one winding, must be connected to the beginning of the other conductor, forming the other winding. Sometimes the transmission lines can be wound, mechanically, to bring the ends of the conductors to be connected together relatively close, but even when the connecting wire is short there are some discontinuities.

This problem is aggravated in the case of parallel-stripline conductors that have a more limited degree of flexibility, and the wider the line the more difficult it becomes to vary the mechanical configuration in order to minimize the degree of discontinuity in the line at the connecting wire. Along the connecting wire, the discontinuity appears as a series inductance which is not balanced by the capacitance of the line. This produces leakage or parasitic reactance losses.

It is therefore an object of this invention to provide an improved, wideband, four to one ratio impedance, parallel-strip transmission-line transformer having a minimum of discontinuities, and in an extremely simple and easy-to-construct configuration.

SUMMARY OF THE INVENTION

A single conductor of a parallel-strip transmission line is wound in a flat spiral of two turns with contacts at each end and at a center tap to form two, series-connected, inductively coupled loops in a four to one impedance ratio, transmission-line transformer. The coupling has almost no discontinuities to cause leakage or parasitic reactance. The reduction in discontinuities increase the bandwidth and the efficiency and

reduces the losses in the transformer. The flat spiral can be wound around a ferrite core of cylindrical, or toroidal configuration, or it may be fit into a preformed, slotted, toroidal core. It can also be molded into a solid ferrite core that completely surrounds the spiral windings for minimum leakage losses and maximum inductance.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 shows the configuration of a typical example of the prior art of transmission-line transformers;

FIG. 2 shows the configuration of applicant's transmission-line transformer;

FIGS. 3, 4 and 5 are pictorial views showing typical core structures; and

FIG. 6 shows the combination of two or more of these transformers.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The typical, prior art in transmission-line transformers is shown in FIG. 1. Here a segment of transmission line is wound in an inductive configuration which may be around a ferrite core, not shown. The input **11** with respect to ground **12** is connected to one end of the winding **15** at the input end of the transmission-line transformer. The other end of this winding **15** is connected to the output **13** with respect to ground **14**. This other, output end of the winding **15** is also connected back through the connecting wire **16** to the input end of the winding **17**. The other end of the winding **17** is grounded.

No matter how this transmission line may be wound, physically, there will, almost invariably be an appreciable distance between the output end of the one winding and the input end of the other winding. This inevitably causes a discontinuity in the line, and the connecting wire **16** appears as a series inductance that unbalances the transmission-line transformer and introduces losses that reduce the efficiency. This connecting wire inductance will have higher reactance, and higher losses, at the higher frequencies which makes this limitation reduce the effective bandwidth of transmission-line transformers.

With the ribbon-type conductors of parallel-striplines, which have even less flexibility of mechanical configuration than most parallel-pair, transmission lines, the discontinuities will be even more abrupt and the losses will be greater.

Applicants reduce the length of this connecting wire to a virtually negligible quantity, in a four-to-one-impedance-ratio transformer, by the configuration of FIG. 2. Here a single, flat conductor is wound in a tight spiral of two turns. The input **21** with respect to ground **22** is connected to input end of the winding **25** whose output end at **26** becomes the input to the inductively coupled winding **27** whose other end is grounded. The center tap **26** on this continuous spiral where one winding ends and the other begins is the equivalent of the connecting wire **16** of FIG. 1 but obviously has an almost irreducible minimum of length and mechanical distortion.

A typical embodiment of this parallel-stripline transformer is seen in FIG. 3 where the conductor is wound around a flat, toroidal core **39**. The input **31** with respect to ground **32** is connected to the input end of the outer winding **35** which continues around to its output end at the center tap point **36** which is also the input end of the inner winding **37** whose other end is grounded. The center tap **36** is connected to the output **33** with respect to ground **34**.

Another version of this transformer is seen in FIG. 4. This has a substantially larger toroidal core **49A** which is concentrically slotted to accommodate the spiral windings of the transformer. The additional ferrite core material around the spiral windings will increase the inductance of the transformer core and the effectiveness of the transformer at lower frequencies. The effective core area can be further improved by covering the slot with a cap **49B** to complete the inductive core path around the windings of the transformer. This will obviously have a higher inductance than the single core species of FIG. 3.

The species of FIG. 5 has a ferrite core 59 molded around the spiral windings. The molded ferrite core form would obviously have the core and the magnetic flux path even closer to the conductors and would provide the maximum inductive coupling and the minimum losses possible for this type of transformer winding.

The species of FIGS. 4 and 5 have the same mechanical, spiral configuration and the same electrical connections of the conductor windings as the specie of FIG. 3. In all of these figures, similar elements are similarly numbered for clarity. The species of FIGS. 3, 4 and 5 are shown with parts of the spiral windings and the cores in cross section to show the relationship between the spiral windings and the cores.

It is obvious that this geometric configuration has inductively coupled windings of equal length. This will provide a four to one impedance transformer ratio. Other transformer, impedance ratios are not possible with this particular configuration. However, additional units of spiral windings may be placed side-by-side as shown in FIG. 6 with contacts 66A and 66B between the center output taps and the corresponding input taps 61B and 61C of the next units.

The second unit would increase the impedance ratio to 16:1 at the output tap 66B. The third unit would increase the impedance ratio to 64:1 at the output tap 66C. All the windings can be mounted on the same core 69 and the ends of the inner windings, that are all grounded, can be connected together.

Connections to the conductors may be made by any of the well-known techniques, and holes must be provided through the surrounding core material, where necessary, as shown in FIGS. 4 and 5.

While three of the typical core forms that could be used here have been shown, it will be obvious that other sizes and shapes of ferrite cores can be used here. The higher the permeability of the ferrite core material and the lower the reluctance of the magnetic flux path around the conductors, the more efficient the transformer becomes at lower frequencies.

The stripline conductor can be of any desired type, and will normally have a nonconductive coating to provide the electrical insulation and the dielectric separation necessary for the required characteristic impedance of transmission lines. This coating maintains the correct spacing throughout the spiral and will, presumably, the sufficient to insulate the transmission-line transformer from the core material or from any adjacent metallic structures.

In a typical embodiment of this invention as in FIG. 3, a CF–117 type core of Q–1 "Ferramic" material made by Indiana General Co. can be used with a rectangular transformer wire 0.092 inch in width and 0.008 inch in thickness. This has "Formex," enamel insulation 0.0005 inch thick and is made by General Electric Corp. The transformer is effective between about 10 and 70 megahertz and, preferably, for a characteristics impedance of about 12 ohms.

While the invention has been described in connection with an illustrative embodiment, obvious modifications thereof are possible without departing from the spirit of the invention. Accordingly the invention should be limited only by the scope of the appended claims.

What is claimed is:

1. A transmission-line transformer for stripline conductors comprising at least one spiral winding of two turns of a single flat, ribbon-type parallel-stripline conductor, said spiral winding having an outer-end connection, a center tap, and a grounded, inner-end connection; a source of input signals having a grounded side and an ungrounded side; a utilization circuit having a grounded side and an ungrounded side; means for connecting said outer-end connection of said spiral winding to said ungrounded side of said source of input signals, and means for connecting said center tap of said spiral winding to said ungrounded side of said utilization circuit.

2. a transmission-line transformer as in claim 1 having a plurality of said spiral windings of substantially the same size, positioned adjacent to each other, with said center tap at the output of each of said spiral windings being connected to said outer-end connection at the input of the next, adjacent one of said spiral windings; and said center tap at the output of the last one of said spiral windings being connected to said ungrounded side of said utilization circuit.

3. A transmission-line transformer as in claim 1 having a ferrite core positioned in an inductive relationship with said spiral winding.

4. A transmission-line transformer as in claim 3 wherein said ferrite core comprises a toroidal structure having a cylindrical outer surface, and said parallel-stripline conductor is wound around said outer surface of said toroidal structure.

5. A transmission-line transformer as in claim 3 wherein said ferrite core completely surrounds said spiral winding.