Jan. 17, 1967 HUA-TUNG LEE 3,299,384

WIDE-BAND TRANSFORMER HAVING NEUTRALIZING WINDING

Filed July 1, 1964

FIG. 1

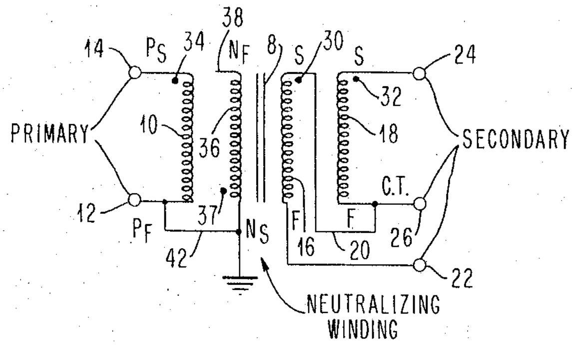


FIG. 2

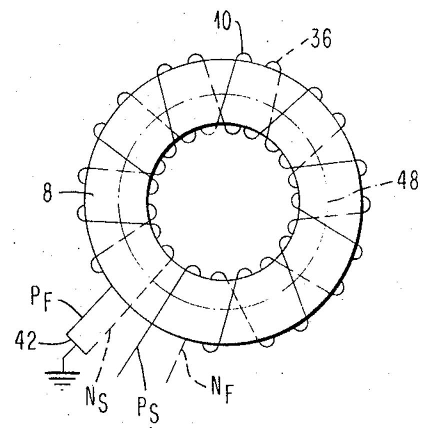


FIG. 3

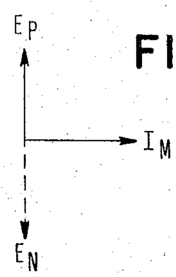


FIG. 4A

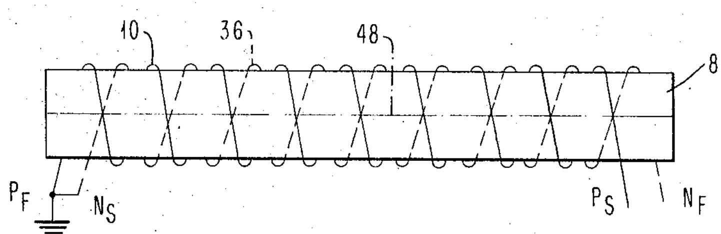
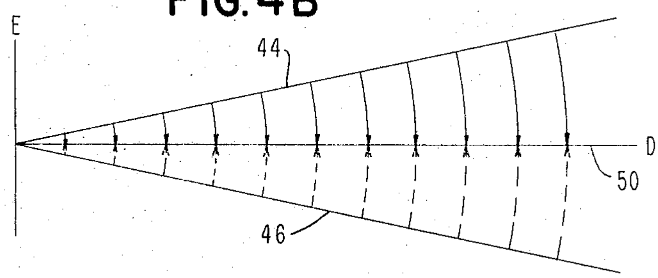


FIG. 4B



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WIDE-BAND TRANSFORMER HAVING NEUTRALIZING WINDING

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This invention relates to signal translating devices and more particularly to wide band coupling arrangements.

Wide-band transformers (up to 200 mc. bandwidth) are often made with interlaced primary and secondary windings in order to reduce the leakage flux between them. The close proximity of the windings increases the distributed capacitive coupling between the primary and a secondary windings. For an unbalanced-to-balanced transformer, this capacitive coupled voltage adds vectorially to the inductively coupled secondary voltages, and the resultant secondary voltages, are in general, not balanced.

Electrostatic shields between primary and secondary windings have been used in the design of narrower band transformers to reduce capacitive effects. This technique is impractical for the high frequency wide-band transformer design because of the mechanical features and the undesirable increased winding to ground capacitance introduced by such a shield.

The present invention provides a wide-band transformer with a neutralizing winding which cancels the distributed capacitive coupling between primary and secondary windings.

In preferred embodiments of the invention, the neutralizing winding has essentially the same number of turns as the primary winding and is wound retrogressively with respect to it along the core. One end of the neutralizing winding is connected to one end of the primary and to ground, and the other end is floating. This enables a simple construction while providing for a constant net electric field with respect to ground.

Accordingly, it is an object of the invention to provide an improved wide band network device.

It is another object of the invention to provide an improved network device as aforedescribed which functions as an unbalanced-to-balanced transformer in an improved manner.

It is yet another object of the invention to provide a transformer as aforesaid of compact design.

It is still another object of the invention to provide a transformer as aforedescribed in which close coupling can be achieved without the disadvantage of capacitative coupling effects.

It is still another object of the invention to provide an improved wide band transformer as aforesaid employing dynamic shielding which is operative with a minimal energy loss.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention as illustrated in the accompanying drawing.

FIG. 1 is a schematic diagram of a transformer in accordance with the invention;

FIG. 2 is a diagrammatic showing of a preferred physical arrangement of the core and two of the windings of the transformer of FIG. 1;

FIG. 3 is a vector diagram applicable to operation of a transformer constructed in accordance with FIGS. 1 and 2;

FIG. 4A is a diagram similar to that of FIG. 2, wherein the structure has been developed into a straight-line axis of purposes of explanation of the operation of the invention; and

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FIG. 4B is potential versus axial location diagram pertinent to operation of the invention in accordance with the preceding figures.

Referring more particularly to the drawing, FIG. 1 shows the winding connection arrangement of an unbalanced-to-balanced transformer in accordance with a preferred embodiment of the invention. In that arrangement, the transformer core **8** has a primary winding **10** which has grounded and ungrounded input terminals **12**, **14** respectively. The ends of this winding are also identified in the diagram by the indicia P_S and P_F signifying start and finish ends of the winding as described hereinafter. The illustrated transformer also has two secondary windings **16**, **18** which are connected in series as indicated at **20** to constitute a balanced secondary arrangement having terminals **22**, **24** and a center tap terminal **26**. The winding direction of the secondary windings **16**, **18** are the same, as indicated by the dots **30**, **32**. The winding direction of the primary winding can be the same or opposite from that of the secondary windings; in the present instance it is shown as being in the same direction as shown by the dot **34**.

The winding arrangement as thus far described is conventional. In accordance with the prior art various schemes have been employed to overcome the difficulty presented by such an arrangement in a high frequency transformer in that there is considerable capacitative coupling between the primary and the secondary windings whereby each of the halves of the secondary receives an electric field signal from the primary and these signals tend to make the secondary output unbalanced. One prior art arrangement for overcoming this difficulty is to interpose a grounded foil shield between the primary winding **10** and the secondary windings **16**, **18**, but this arrangement introduces a very large amount of capacity to ground.

In accordance with the present invention a neutralizing winding **36** is provided which generates, in effect, a dynamic shield which prevents substantial electric field coupling from the primary to the secondary windings. The neutralizing winding **36** is wound retrogessively (oppositely) with respect to the primary winding **10** as indicated by the polarity dot **37**, and is substantially an open circuit element, that is, has at least one end **38** which is not connected in the transformer network. In the preferred embodiment illustrated, that end is not connected at all, so that no current flows in the winding **36**.

Accordingly, the neutralizing winding **36** has no substantial effect on the magnetic field in the transformer and absorbs no substantial energy. Nonetheless, it has induced in it a potential gradiant which is equal and opposite to that of the primary, by operation of the magnetic field of the primary in the core **8**.

Moreover, in accordance with a preferred embodiment of the invention the other end **40** of the neutralizing winding **36** is connected as indicated at **42** to the adjacent grounded end of the primary **10**. Accordingly, the potential status of the neutralizing winding, turn for turn is equal in amplitude and opposite in sign to that of the primary, with respect to ground.

The winding arrangement of the primary and neutralizing windings with respect to the core **8** is illustrated in FIG. 2. As shown in that figure, the core **8** preferably has a toroidal form, and the primary winding **10** may be placed thereon by starting at the end market P_S and winding in a counterclockwise direction around the core, progressing in a counterclockwise direction along the length of the core to the end P_F. Similarly the neutralizing winding **36** may be wound by starting adjacent the end P_F of the primary and winding in a clockwise direction around the core, progressing in a clockwise direction along the core to the end N_F adjacent the end P_S. For clarity, the secondary windings **16**, **18** may have been omitted from the showing of FIG. 2. However, they may be provided by a single bifilar winding wound in the same direction and with the same progression as the primary winding **10**. The neutralizing **36** may occupy a geometric position between the primary and secondary windings, but it is preferred in practice to apply the neutralizing winding last since this permits a more compact winding structure and facilitates turns adjustment as hereinafter described.

Referring now to FIG. 3, it will be seen that when a sinusoidal signal is applied to the input terminals **12**, **14** of the primary, the electric vector E_P applied to the transformer will set up a magnetizing current I_M. Assuming a low loss design, the vector I_M will trail that electric vector by nearly 90°. The magnetic flux resulting from the magnetizing vector I_M will, in turn, set up an electric vector E_N in the neutralizing winding **36**, virtually diametrically opposed to the primary vector E_P.

This relationship is shown in another way in FIGS. 4A and 4B. In FIG. 4A, the showing of FIG. 2 has been developed, that is, unrolled to a straight line for purposes of explanation. In FIG. 4 directly below, plots **44**, **46** are shown for the peak potentials E in the primary and neutralizing windings, respectively, versus distance D along the axis **48** of the core **8**, at a given instant. One quarter cycle later these two potential curves pass each other on the center line or zero potential value. Another quarter cycle later they will have adopted a value exactly opposite to that which they had in the first place. It will be seen that in every case the average value of the two curves is that if the horizontal zero potential axis **50**.

The introduction of a neutralizing winding reduces the effects of capacitive coupled voltage in the secondary of a wide-band, high frequency transformer.

The neutralizing winding turns can be adjusted to give the best balance. This is a great convenience since any mechanical unbalance between the two halves of the secondary or between the primary and neutralizing winding can be easily compensated.

In one example, a transformer in accordance with the invention has the following characteristics:

Input and output impedance: 75 ohms
Power handling capacity: no less than 10 mw.
Upper operating frequency limit: greater than 140 mc.
Insertion loss: less than 1.0 db
Amount of secondary unbalance: less than 2.5%
Transformer core: Ferrite toroid (¼" O.D.)
Primary winding: 13 turns #30 a. W.G.
Each ½ secondary winding: 13 turns #30 a. W.G.
Neutralizing winding: 11–14 turns #30 a. W.G.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. In a transformer,
a magnetic circuit comprising a toroidal core,
a primary winding on said core having input terminal means,
a neutralizing winding on said core geometrically coextensive with said primary winding,
said neutralizing winding being wound oppositely with respect to said primary winding,
one end of said neutralizing winding being substantially open circuited,
and secondary winding means on said core substantially geometrically coextensive with said primary and neutralizing windings,
whereby said neutralizing winding is operative to offset in its effect on said secondary winding means an electric potential applied to said primary winding by said input means.

2. In an unbalanced-to-balanced transformer,
a magnetic circuit comprising a toroidal core,
a primary winding on said core having grounded and ungrounded input terminals,
a neutralizing winding on said core geometrically coextensive with said primary winding,
said neutralizing winding being wound oppositely with respect to said primary winding and the grounded end of said primary winding being connected to the adjacent end of said neutralizing winding,
the other end of said neutralizing winding being open circuited,
and a center tapped secondary winding on said core comprising winding halves which are each geometrically coextensive with said primary and neutralizing windings.

3. In a transformer,
a magnetic circuit assembly comprising:
a first winding having terminal means,
a neutralizing winding geometrically coextensive with said first winding,
said neutralizing winding being wound oppositely with respect to said first winding,
one end of said neutralizing winding being substantially open circuited,
and second winding means substantially geometrically coextensive with said first and neutralizing windings,
whereby said neutralizing winding is operative to offset in its effect on said second winding means an electric potential applied to said first winding.

4. In a transformer,
a magnetic circuit assembly comprising:
a first winding having grounded and ungrounded terminals,
a neutralizing winding geometrically coextensive with said first winding,
said neutralizing winding being wound oppositely with respect to said first winding and the grounded end of said first winding being connected to the adjacent end of said neutralizing winding,
the other end of said neutralizing winding being open circuited,
and a center tapped second winding comprising winding halves which are each geometrically coextensive with said first and neutralizing windings.

References Cited by the Examiner

UNITED STATES PATENTS

2,412,609	12/1946	Ganz	336—70
2,692,372	10/1954	Goldstine.	
2,700,129	1/1955	Guanella.	
2,860,312	11/1958	Krepps	336—69

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