July 21, 1959 W. C. BROWN 2,896,180

SATURABLE TRANSFORMER

Filed May 25, 1955 2 Sheets-Sheet 1

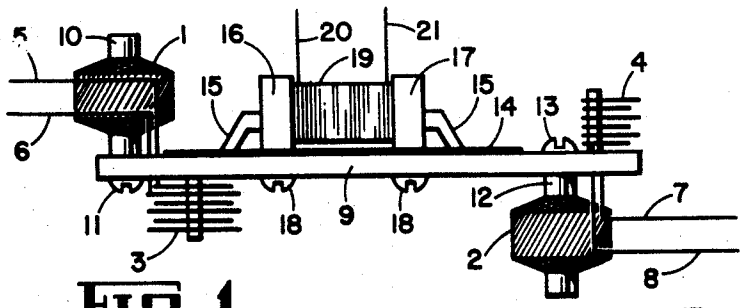

FIG. 1

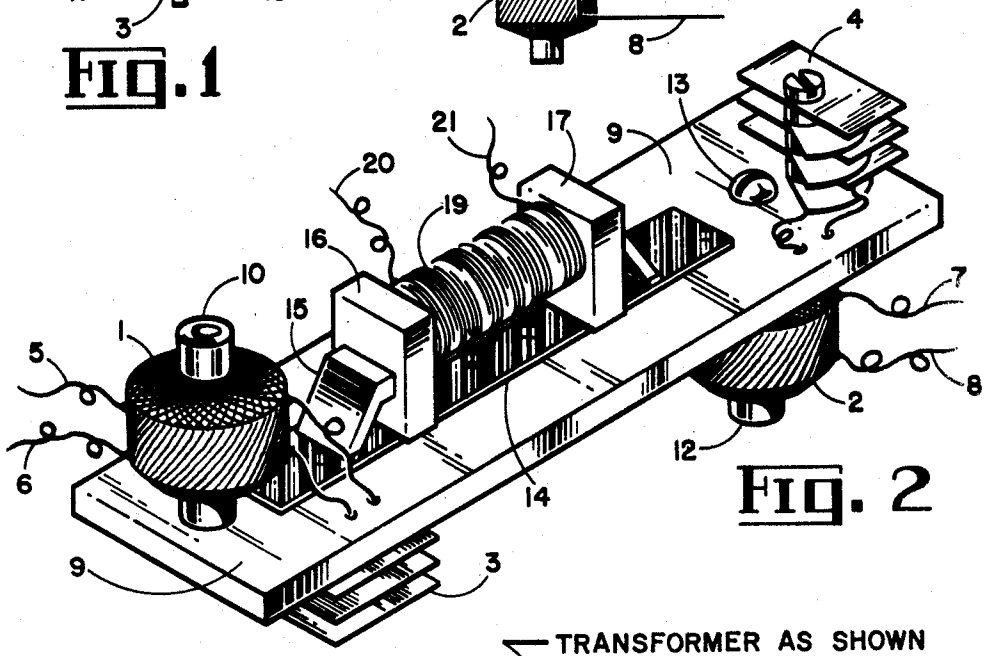

FIG. 2

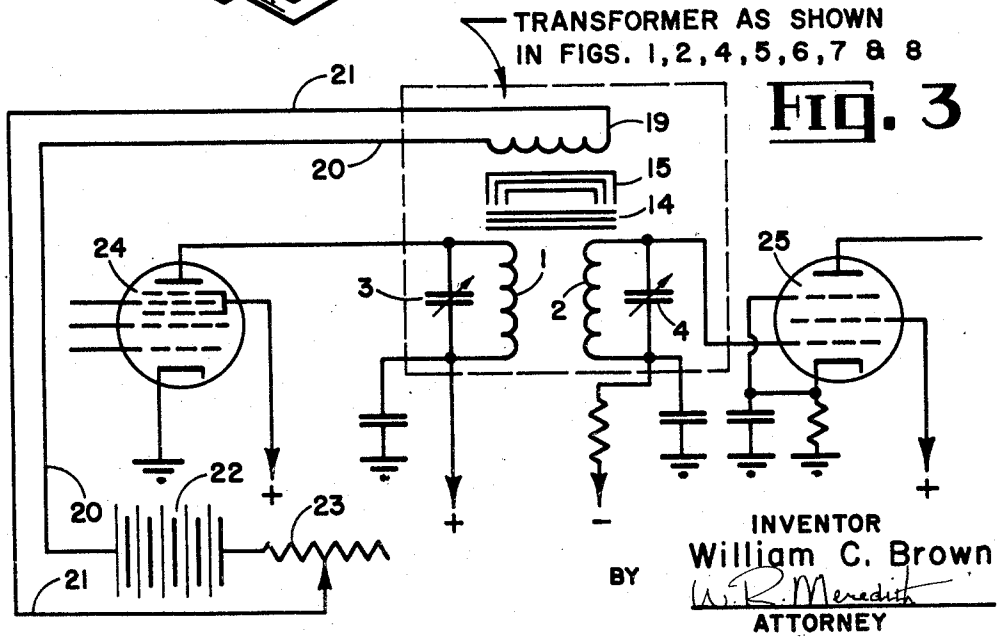

FIG. 3

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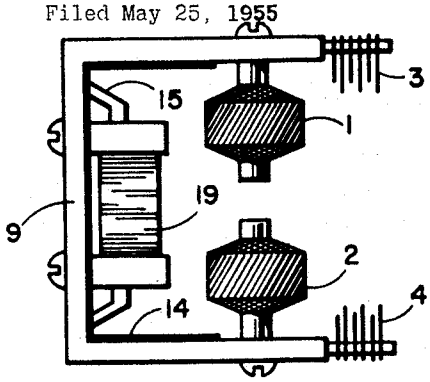

FIG. 4

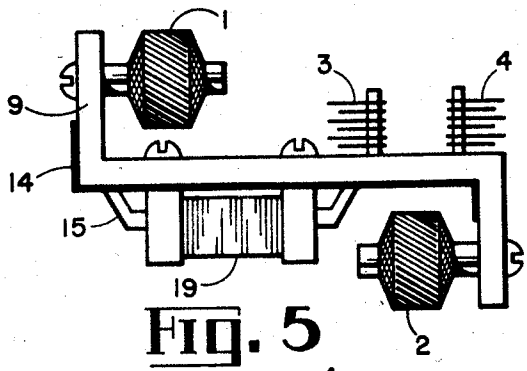

FIG. 5

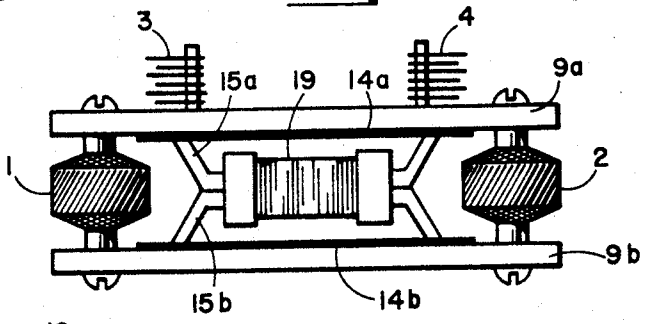

FIG. 6

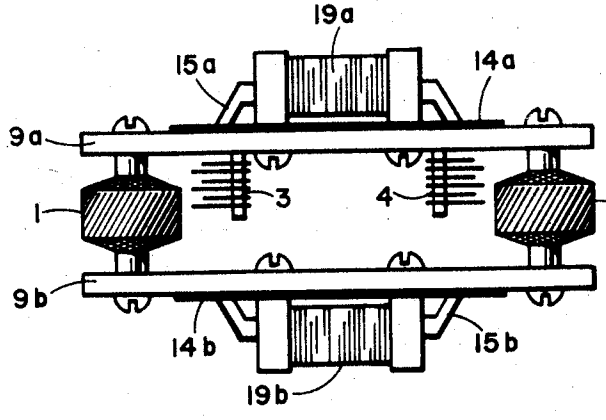

FIG. 7

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SATURABLE TRANSFORMER

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Application May 25, 1955, Serial No. 510,976

6 Claims. (Cl. 336—155)

This invention relates to a transformer having variable coupling, and while of general application, is particularly suitable for use as a radio-frequency transformer.

The transformer which is the subject of this invention is of a type which provides for variable saturation of the core. There are many prior art transformers having a saturating winding, but the concept of saturation in such prior art transformers is different than that of the present device, and the present invention provides a considerable improvement and simplification thereover.

The principal object of the present invention is to provide an improved transformer wherein the saturation of the magnetic path linking the primary and secondary cores is easily controlled, whereby the degree of coupling therebetween may be varied.

A further object is to provide such a device which is easy to construct, requires no parts difficult to manufacture and can be easily substituted for existing transformers so as to provide improved operation without disturbing existing circuits.

It is also an object of the present invention to permit remote control of the coupling of transformers in various remote locations, and to do this by direct current which will not interfere with the radio frequency function of the equipment in connection with which it is used.

An additional object is to provide a device which will permit variable gain or variable attenuation control in a manner which is stable and independent of the characteristics of electronic tubes which may be used.

An additional object is to provide a device which permits a plurality of radio frequency channels to be controlled by a single direct current control circuit, this providing an electrical analogy to mechanical "ganging" of a plurality of variable devices.

A further object is to provide a precise attenuator permitting a very wide range of attenuation.

A further object is to provide a transformer, the selectivity of which is not altered by the variation in coupling.

A final object is to provide a device which does not necessitate the insertion of any additional components or material in the radio frequency path, where the transformer is used as a radio frequency transformer.

Embodiments of the invention will now be described with the assistance of the accompanying drawings wherein like parts are denoted by identical reference numerals. Although specific embodiments are shown it will be appreciated that modifications are possible within the scope of the invention.

In the drawings,

Figure 1 shows a side elevation view of one form of the invention;

Figure 2 shows a three-quarters oblique view of the device of Figure 1;

Figure 3 shows schematically a typical circuit employing a device according to the present invention;

Figure 4 shows a slightly different form of the device of Figure 1, wherein the base denoted by 9, is bent into a U-shaped configuration;

Figure 5 shows another alternative form of the device of Figure 1 in which the base 9 is bent into Z-shaped configuration;

Figures 6 and 7 show further alternative forms of the device illustrated in Figure 1 except that in each of the present figures there is duplication of one ore more of the elements shown in Figure 1.

Referring to Figure 1, the transformer has two conventional coils denoted by 1 and 2 and the coils shown are similar to coils normally used in a radio frequency transformer, such as an intermediate frequency transformer, but the invention is not restricted to a transformer operating at such frequency. The invention, with appropriate changes, apparent to one skilled in the art, can be adapted to transformers operating at low frequency where tuning of the two coils would not be necessary, and the transformer coils used may be either of the air-core variety or could be provided with any of the usual types of core materials.

Coil 1 could, for example, be the primary coil and coil 2 the secondary coil, although this is in no way essential. Connected in parallel with coil 1 is a small trimmer capacitor denoted as 3, and a like trimmer capacitor denoted by 4 is similarly connected in relation to coil 2.

Trimmer capacitors such as 3 and 4 would of course only be used where the transformer is to be tuned, and it will be understood that if a low-frequincy transformer were to be constructed, trimmer capacitors 3 and 4 would be omitted.

It is important to note that with the device as constructed herein, as applied to a tuned transformer, varying the degree of coupling between the primary and secondary coils 1 and 2 has no appreciable effect on the center operating frequency.

The leads connecting coil 1 and capacitor 3 to the external circuit elements are denoted by 5 and 6 and similar leads denoted by 7 and 8 are connected to coil 2 and capacitor 4.

The coils 1 and 2 and the capacitors 3 and 4 just described are mounted on a base denoted by 9, consisting of a strip of dielectric material such as phenol-formaldehyde resin sold under the trade-name "Bakelite," or polystyrene. Coil 1 is mounted on base 9 by means of a spindle denoted by 10 which is attached to base 9 by means of a suitable fastening means such as capscrew 11, and a similar spindle 12 and capscrew 13 are used to mount coil 2. Spindles 10 and 12 would of course be used only in the case of an air-core coil 2, and if a coil 2 were provided having a powdered core, the core itself could be mounted in any suitable manner on base 9.

Capacitors 3 and 4 are attached to base 9 in any convenient manner and are shown on the opposite side of base 9 from the coils to which they are connected, but this is not essential.

Base 9 has been shown as a simple linear prismatic strip, but this is only by way of example, and base 9 instead of having a linear form as seen in Figure 1, could for example have a curved shape, such as in the form of a U or a Z as is shown in Figures 4 and 5, respectively.

A thin strip of easily saturated magnetic material denoted by 14 is attached to base 9, for example adhesively attached, and it is contemplated that the two ends of the strip of magnetic material 14 will lie adjacent to coils 1 and 2 so as to provide coupling therebetween. It is important to note that the strip of magnetic material 14 links the coils 1 and 2 magnetically, but does not link them physically, and for this reason coils 1 and

2 of any ordinary type may be used in an embodiment of the present invention.

The material of which strip **14** is made is a matter of choice and many materials may be used so long as they have such properties that their magnetization curve approaches saturation flux density for relatively small applied magnetizing energy. A material which has been found satisfactory is that denoted by "Telcon 79."

A core denoted by **15** made of material not easily saturated such as soft iron, is mounted so that its ends firmly abut strip **14**, in such a manner that a closed magnetic loop is formed with the ends of strip **14** protruding at either end thereof, and this spatial relationship may be maintained by providing a pair of yokes of dielectric material similar to that of base **9** denoted by **16** and **17** passing over core **15** and attached to base **9** by means of capscrews **18**.

A saturating coil denoted by **19** is wound around core **15**. It will be apparent that with no current flowing through coil **19**, there will be considerable coupling between coils **1** and **2** because of the magnetic properties of strip **14**, but that when a current is passed through coil **19** sufficient to magnetically saturate strip **14**, the coupling may be reduced to any desired value.

The leads from coil **19** denoted by **20** and **21** are attached to any suitable source of direct current, which may be adjusted as by a rheostat so as to saturate strip **14** to any desired degree.

It is possible to have more than one winding instead of coil **19** and this is advantageous where it may be desired to control the linkage between coils **1** and **2** at more than one remote point.

Although no external shield has been shown or described, it will be apparent that a shield could be used with the embodiment described, under the same circumstances where a shield would be used for a transformer having only the coils **1** and **2**, and the capacitors **3** and **4**.

Although apparent from the foregoing, the operation of the device will now be described. It will be assumed that an input signal is being received on lines **5** and **6**. By virtue of the magnetic properties of strip **14**, there is excessive coupling between coils **1** and **2**. A saturating current is then passed through coil **19** and adjusted until the proper coupling between coils **1** and **2** is achieved and the desired output is received at lines **7** and **8**.

Figures 4 and 5 are merely a rearrangement of Figure 1 and need not be further discussed. The exact form of the device shown in any one of Figures 1, 4 and 5 depends on the size and space requirements, but the elements are substantially unchanged.

Figures 6 and 7 illustrate devices also very similar to those of Figures 1, 4 and 5, but in each of Figures 6 and 7 there is a duplication of one of the elements previously referred to.

In addition, in Figures 6 and 7 the base **9** is of double construction denoted by **9***a* and **9***b* in each figure, and in addition to permitting a different arrangement of the parts, it is apparent that the mechanical strength of the devices of Figures 6 and 7 is greater. Each of the base elements **9***a* and **9***b* has a strip of easily saturable magnetic material **14***a* and **14***b*, respectively.

In Figure 6 there are two cores **15***a* and **15***b* similar to core **15** of Figure 1, both passing through a single coil **19**.

In Figure 7 two cores **15***a* and **15***b* are again shown, and in this case there are two coils **19***a* and **19***b*, which may be either connected in series, or else may be connected to two different sources of current, permitting remote control from two different positions.

Referring now to Figure 3, a transformer as shown in the other figures is used to couple the converter stage of a superheterodyne circuit to the first intermediate frequency stage thereof. The transformer parts are here shown schematically and identified by the same reference numerals as in Figure 1. Except for the transformer, the elements of the partial circuit shown in Figure 3 are quite conventional, and to identify them, the converter tube is shown at **24** and the first intermediate frequency tube at **25**. The other elements of the partial circuit shown are standard and their functions will be apparent to one skilled in the art.

The transformer of Figure 3, constructed according to this invention, is used as an intermediate frequency transformer, and a battery denoted by **22** produces current for coil **19** and the current may be varied by means of a variable resistance shown at **23**.

Variable resistance **23** may be remote from the transformer.

It will be apparent that one of the advantages of this invention is that it enables the remote adjustment of coupling in a transformer without disturbing the circuit or other devices in which such transformer may be used. It is possible for example to have a number of transformers constructed according to this invention and to provide a like number of remote adjusting means so that all may be adjusted from a remote point.

I claim:

1. A radio frequency transformer comprising a non-magnetic base, a primary coil mounted on said base, a secondary coil also mounted on said base and physically separated from said primary coil so that in the absence of a magnetically permeable path between said coils the coupling therebetween would be negligible, a strip of easily-saturated magnetic material rigidly fixed with respect to said base, each end of said strip being spaced from one of said coils to define a discontinuous magnetic path between said coils, a core of magnetic material difficult to saturate, the said core having two ends in contact with said strip and a saturating coil around said core, whereby passing of a predetermined current through said saturating coil will cause said strip to be saturated to a desired degree thus controlling the degree of coupling between said primary and said secondary coils without altering the selectivity of said transformer.

2. A device according to claim 1 wherein said base and strip are of linear construction.

3. A device according to claim 1 wherein said base and strip are formed in a U-shaped configuration including a pair of parallel legs each of which supports a different one of said coils in a position between both of said legs so that both of the coils are in axial alignment.

4. A device according to claim 1 wherein said base is of Z-shaped construction.

5. A radio frequency transformer comprising two linear non-magnetic base means separated one from the other, a primary coil mounted between said two linear base means, a secondary coil similarly mounted between said linear base means, said coils being physically separated so that in the absence of a magnetically permeable path between said coils the coupling therebetween would be negligible, a pair of strip means made of easily-saturable magnetic material each being rigidly fixed with respect to a different one said base means and spaced from said coils to define a discontinuous magnetic path between said coils, and electromagnetic means including a saturating coil magnetically coupled to said strip means, whereby passing of a predetermined current through said saturating coil means will cause said strip means to be saturated to a desired degree thus controlling the degree of coupling between said primary and said secondary coils without altering the selectivity of said transformer.

6. A radio frequency transformer comprising a non-magnetic base, a primary coil mounted on said base, a secondary coil also mounted on said base and physically separated from said primary coil so that in the absence of a magnetically permeable path between said coils the coupling therebetween would be negligible, a strip of easily-saturated magnetic material rigidly fixed on said base and spaced from each of said coils to define a dis-

continuous magnetic path between said coils, and electromagnetic means including a saturating coil magnetically coupled to said strip, whereby passing of a predetermined current through said saturating coil will cause said strip to be saturated to a desired degree thus controlling the degree of coupling between said primary and said secondary coils without altering the selectivity of said transformer.

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