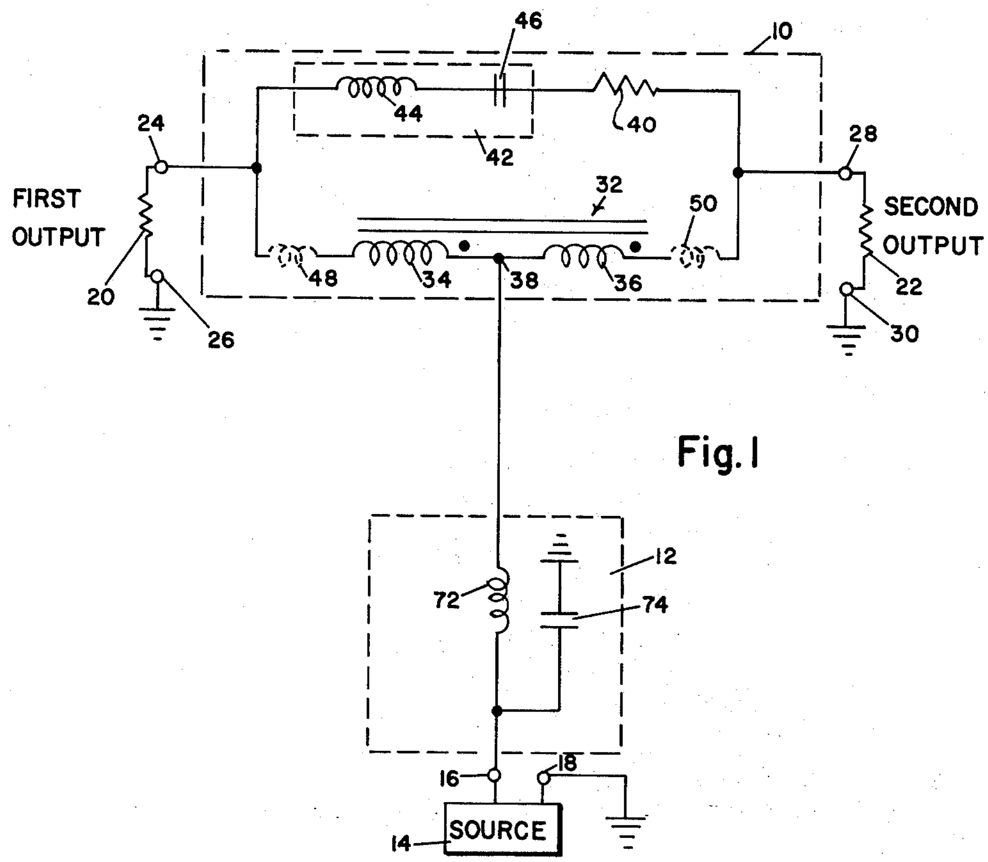


Fig. 1

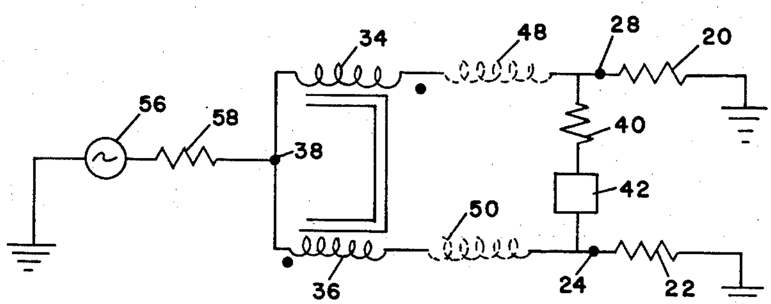


Fig. 2

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MULTIPLE COUPLER EMPLOYING RESONANT EFFECTS TO ISOLATE THE LOAD CIRCUITS FROM EACH OTHER

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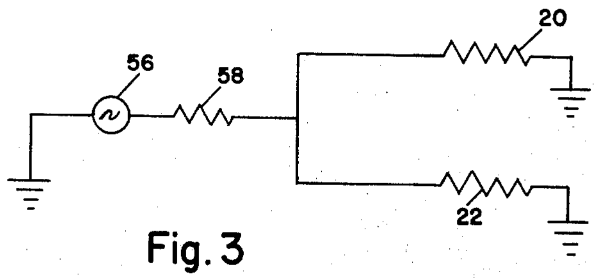


Fig. 3

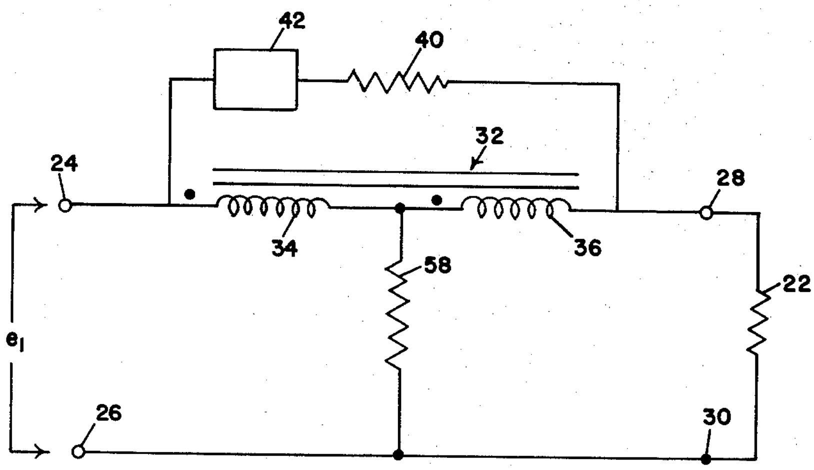


Fig. 4

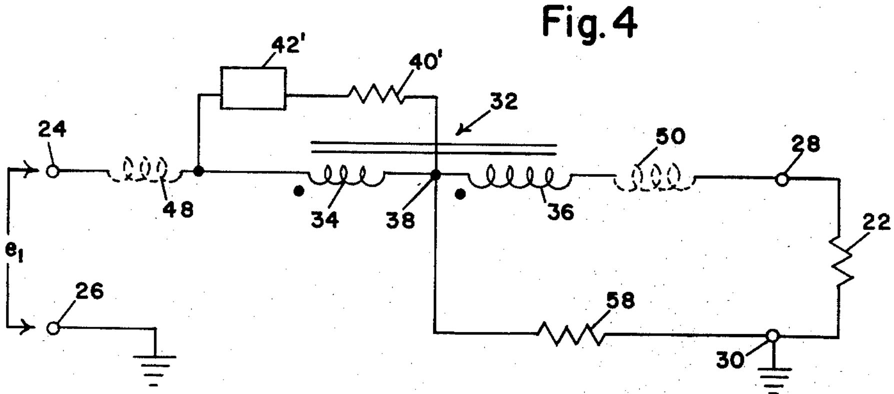


Fig. 5

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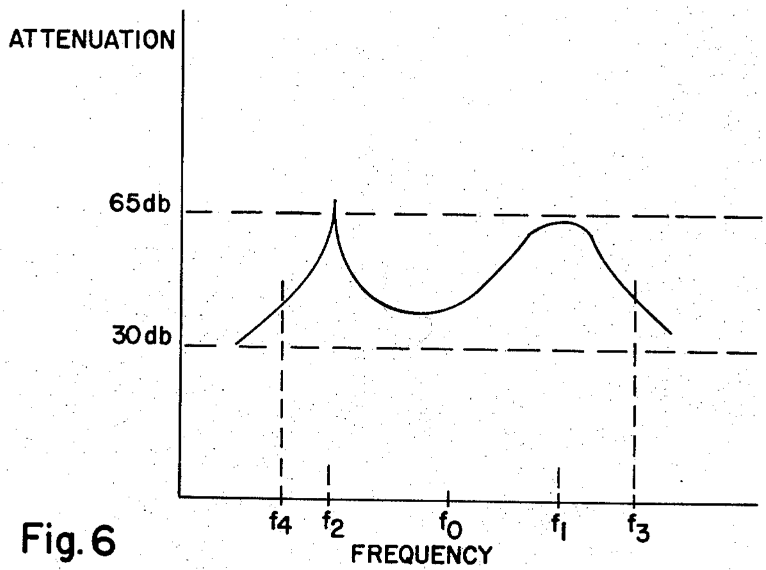


Fig. 6

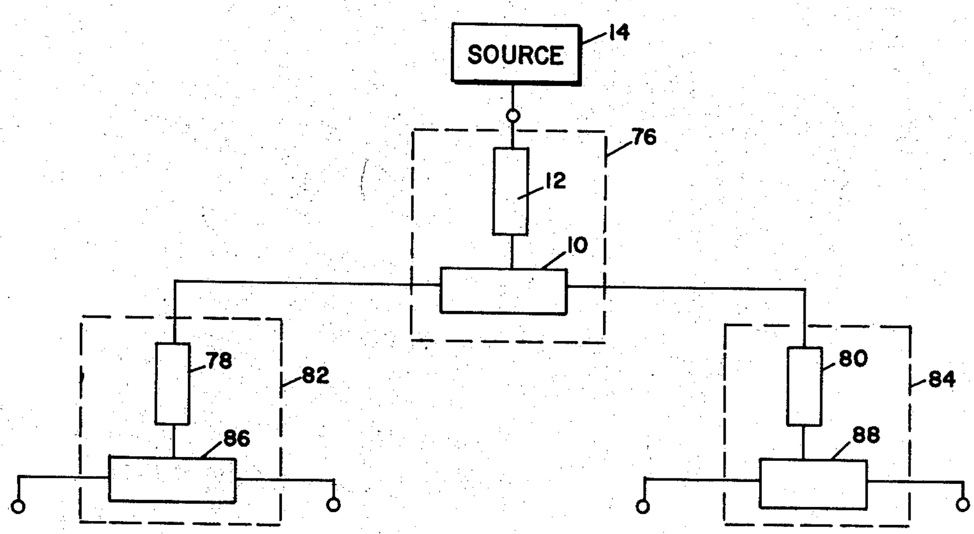


Fig. 7

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MULTIPLE COUPLER EMPLOYING RESONANT EFFECTS TO ISOLATE THE LOAD CIRCUITS FROM EACH OTHER

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3 Claims. (Cl. 333—8)

This invention relates to a multiple coupler. More particularly, it relates to a circuit using only passive elements to couple an alternating current source to a plurality of isolated loads. The coupler is particularly useful in connecting an antenna to a number of receivers which are isolated from each other, thereby preventing spurious signals generated in a receiver from reaching other receivers and degrading the signal-to-noise ratios therein.

A principal object of my invention is to provide an improved multiple coupler having the above characteristics, i.e., isolation of the various loads from each other while using only passive elements.

Another object of the invention is to provide a multiple coupler of the above type having a low insertion loss.

A further object is to provide a multiple coupler having the above characteristics over a broad band of frequencies.

Yet another object of the invention is to provide a multiple coupler of the above type which is reliable in operation, small in size and weight and yet relatively low in cost.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of a coupler, embodying the principles of my invention, adapted to couple a source to two loads isolated from each other,

FIGURE 2 is a somewhat simplified version of the circuit of FIGURE 1, with the elements rearranged to illustrate one of the modes of operation,

FIGURE 3 is a simplified equivalent of the circuit of FIGURE 2,

FIGURE 4 is an equivalent of the circuit of FIGURE 1,

FIGURE 5 is an equivalent of the circuit of FIGURE 4, arranged to illustrate the "transformer mode" of isolation,

FIGURE 6 is a response curve showing isolation between the two outputs of the coupler of FIGURE 1, and

FIGURE 7 is a diagram showing how the coupler of FIGURE 1 may be cascaded to increase the number of loads coupled to a single source.

In the following discussion, the various circuit parameters are identified by standard symbols with subscripts indicating the components associated with them. Thus $R_{58}$ is the resistance of the component identified by the reference numeral 58.

Referring first to FIGURE 1, a multiple coupler embodying the principles of my invention includes an isolator 10 and generally also an input transformer 12. The coupler couples a source 14 connected to input terminals 16 and 18 to output loads indicated as resistors



20 and 22 across output terminals 24 and 26 and 28 and 30, respectively. The source 14 may, by way of example, be a receiving antenna and the resistors 20 and 22 the input impedances of receivers obtaining their input signals from the antenna.

The isolator 10 isolates the two outputs from each other, i.e., it substantially prevents interchange of energy between the terminals 24 and 26 on the one hand and the terminals 28 and 30 on the other. It includes an autotransformer 32, with identical windings 34 and 36 having an equal number of turns. A center tap 38 of the transformer 32 is connected to the transformer 12, and thus it serves as an input terminal for the isolator. A resistor 40 and a reactance unit 42 comprising an inductor 44 and capacitor 46 are connected in series across the transformer 32. The transformer 32 includes leakage inductances indicated by the inductors 48 and 50.

In considering the transfer of energy from the source 14 to the load resistors 20 and 22, the circuit of FIGURE 1 may be redrawn as in FIGURE 2, with the input to the isolator 10, as seen from the tap 38, represented by a generator 56 in series with a resistor 58. Because of symmetry ($L_{48}=L_{50}$, $R_{20}=R_{22}$,) the generator 56 impresses equal voltages across the idealized windings 34 and 36. However, because of the 1:1 ratio between these two windings, each of them induces in the other a voltage equal to the impressed voltage therein. The induced voltages are opposite in polarity from the impressed voltages, and therefore, there is no net voltage across either of the windings 34 or 36. Accordingly, the voltages across the two series arms comprising the inductor 48 and resistor 20, and the inductor 50 and resistor 22 are equal. It follows that equal power is delivered to the two load resistors. Furthermore, the voltages at the terminals 24 and 28 are equal. In other words, for power received from the source 14, the circuit of FIGURE 2 may be represented as in FIGURE 3, with the isolator 10 having essentially no effect on transmission of power to the resistors 20 and 22.

The manner in which isolation is obtained between the outputs of the isolator 10 will now be described in detail. The circuit of FIGURE 1 may be redrawn as in FIGURE 4, with a voltage $e_1$ impressed across the terminals 24 and 26. Next, if the resistor 40 and reactance unit 42 are referred to the primary of the transformer 32 i.e., the winding 34 and inductor 48 when operating as in FIGURE 4, the circuit of FIGURE 5 results, with a resistor 40′ and reactance unit 42′ in series across the primary. Since the winding 34 in FIGURE 4 is the primary of an ideal transformer whose secondary includes the windings 34 and 36 in series, the turns ratio of this transformer is $n=1/2$. The impedance transformation between the secondary and primary is equal to $n^2$, i.e., 1/4. Therefore, the resistance

$$R_{40'}=\frac{R_{40}}{4}$$

and the reactance

$$X_{42'}=\frac{X_{42}}{4}$$

Preferably, $R_{40}=4R_{58}$ and therefore, $R_{40'}=R_{58}$. Also, at a first frequency $f_1$, the reactance $X_{42}$ and the lead inductance in the bridging arm including the resistor 40 are self resonant, i.e.

$$\omega(L_{44}+L_{\text{lead}})=\frac{1}{\omega C_{46}}$$

Therefore, only the impedance of the resistor 40 is reflected across the primary.

Still referring to FIGURE 5, the voltages across the idealized windings **34** and **36** and the currents through them are equal. Accordingly, the current in the resistor **40'** must be equal to the current in the resistor **58**, and, therefore, the voltage drops across the resistors are equal.

However, the voltage across the resistor **40** is the same as the voltage across the winding **34**, and subsequently the voltage across the resistor **58** equals the voltage across the winding **36**. The voltage across the load resistor **22**, resulting from the input voltage $e_1$, is therefore zero.

It will be apparent that at low frequencies, where the effect of lead inductors associated with the resistor **40** is negligible, the reactance unit **42** may be eliminated, with a wide attenuation band width for operation in the above matter. However, at high frequencies use of the reactance unit is desirable, although of course there is a resulting limitation on attenuation band width. It will also be understood that if the source impedance represented by the resistor **58** has an reactive component, the resistor $R_{40}$ should also be an element having a similar component of reactance.

In view of symmetry in the circuit of FIGURE 4, it will be apparent that the same result is obtained when a voltage is impressed between the terminals **28** and **30**, and the resulting voltage at the terminals **24** and **26** is determined. Thus, there is complete isolation between the two outputs of the isolator **10**.

Isolation achieved in the manner described above may be termed "transformer isolation" as opposed to "parallel resonance isolation," also inherent in my multiple coupler. A detailed discussion of what is termed the parallel resonance isolation is difficult to accomplish as the precise theoretical explanation is not fully understood. It has been observed that the arrangement described above provides a unique capacity to provide isolation between the terminals **24** and **28** over a broad band of frequencies between a predetermined first and second frequency.

Thus, at the frequency $f_2$, there is a parallel resonant circuit between the terminals **24** and **28**, and the high impedance provided by the parallel resonance effectively isolates the loads connected to these terminals.

In FIGURE 6 I have plotted, as a function of frequency, the attenuation imposed by the isolator **10** (FIGURE 1) on signals passing between the two outputs thereof. The frequency $f_1$, corresponding to "transformer isolation," is characterized by a fairly broad peak, and the frequency $f_2$, corresponding to "parallel resonance isolation," is characterized by a sharp peak resulting from the relatively high Q nature of the reasonance. The response curve was obtained from a unit designed to operate in the VHF region, and, in this particular unit, the 40 db attenuation bandwidth, i.e., $f_3$–$f_4$, was 40 percent of the center frequency $f_0$.

Greater attenuation in the center of the band may be obtained, at the expense of attenuation bandwidth, by moving the frequencies $f_1$ and $f_2$ closer together. With a given leakage inductance in the transformer **32** (FIGURE 1), these frequencies may be varied by changing the values of the inductor and capacitor **46** in the reactance unit **42**. It should be noted that, at both the frequencies $f_1$ and $f_2$, the reactance unit **42** exhibits a net capacitive reactance. Therefore, a single capacitor may, in some cases be used instead of the inductor-capacitor combination. However, with only the capacitor, either the frequency $f_1$ or $f_2$ may be controlled but not both, assuming a given leakage inductance. With the combination, both frequencies may be set at the values desired.

Returning to FIGURE 1, the transformer **12** is required for maximum transfer of power between the source **14** and the load resistors **20** and **22**, unless the internal resistance of the source is equal to one half the resistance of the resistor **20** and **22**, that is, unless there is an impedance match in the circuit of FIGURE 3. Ordinarily, the source and load resistances will be equal and, therefore, a 2:1 impedance match by the transformer **12** is required. This can easily be accomplished by a L-type transformer comprising a series inductor **72** and shunt capacitor **74**.

In FIGURE 7 I have shown multiple couplers of the type described above may be cascaded to provide any desired number of outputs. Thus, the source **14** may be connected to the input of a coupler **76**, including the isolator **10** and transformer **12**, described above. The outputs of the isolator **10** are connected to input transformers **78** and **80** of multiple couplers **82** and **84**, of the type described above, provided with isolators **86** and **88**. Thus, the source **14** may be coupled to four loads connected to the outputs of the couplers **82** and **84**, and the loads will be isolated from each other in the manner described above. Since the resistive elements in the multiple couplers do not absorb power from the source **14**, the loss in each coupler is relatively low, approximately 0.1 db per stage. Therefore, a number of stages may be cascaded without appreciable degradation of signal-to-noise ratio.

Thus, I have described an improved multiple coupler adapted to couple a source between a pair of loads while isolating the loads from each other. The coupler is formed entirely of passive elements and, therefore, is characterized by high reliability together with low operating costs. Isolation is provided, in the first place, by means of a novel autotransformer arrangement, and where isolation over a wide band of frequencies is desired, a parallel resonance mode may also be resorted to. The coupler is also relatively simple in construction and considerably less expensive to fabricate than prior units requiring active elements of various types.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A broad band multiple coupler comprising, in combination, an auto-transformer having first and second windings, the turns ratio of said windings being substantially unity, said transformer having a center tap and first and second end terminals on said first and second windings respectively which may be connected to respectively separate loads, a parallel branch connected between said first and second terminals, a source having an impedance connected between said center tap and a common reference point, said source providing energy over a broad range of frequencies between a predetermined first and second frequency, said branch when referred across said first winding having an effective impedance, at said first frequency, substantially equal to the impedance of said source, said branch having a reactance component sufficient to form a parallel resonance circuit with the impedances of said windings between said first and second end terminals at said second frequency which parallel resonance provides a high impedance which effectively isolates the loads connected to these terminals, said first and second frequencies being spaced sufficiently to provide substantial isolation between said first and second terminals over a broad band of frequencies.

2. The combination defiened in claim 1 in which said branch includes a resistance and a reactance, the values

of said resistance and reactances being selected to permit broad band operation of the coupler

3. A broad band multiple coupler comprising, in combination, an autotransformer having a center tap and two end terminals; a first source connected between said center tap and a common reference point, said source providing energy over a broad range of frequencies between a predetermined first and second frequency; a branch circuit connected between said end terminals, said branch circuit including a reactance in series with a resistance to resonate and thereby cancel lead inductances of said branch circuit at said first frequency; loads connected between said terminals and said reference point,



the total impedance of said branch at said first frequency being four times that of said source; the reactance of said branch being such at said second frequency as to resonate with twice the leakage reactance between said tap and said one of said terminals; and thereby provide parallel resonance which parallel resonance establishes a high impedance which effectively isolates said loads from each other.

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