United States Patent [19]

Covill

[11] **3,784,931**

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[54] **FOUR PORT COMBINER UTILIZING SINGLE TRANSFORMER**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 194,985, Nov. 2, 1971, Pat. No. 3,747,026.

[52] **U.S. Cl.** **333/6,** 333/11, 336/181
[51] **Int. Cl.** **H03h 7/48**
[58] **Field of Search** 333/6, 8, 11; 336/180, 181

[56] **References Cited**

UNITED STATES PATENTS

3,037,173 5/1962 Ruthroff 333/11

FOREIGN PATENTS OR APPLICATIONS

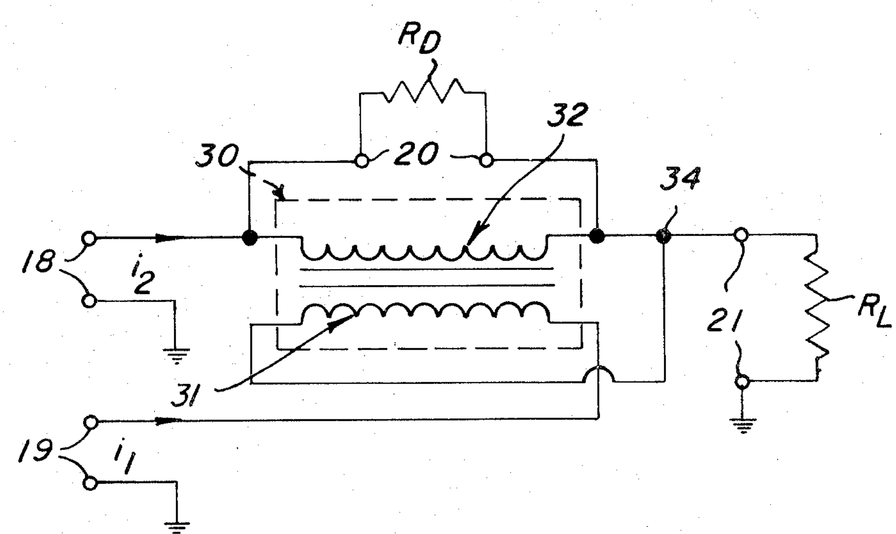
829,905 1/1952 Germany 333/11
1,476,235 2/1967 France 336/180

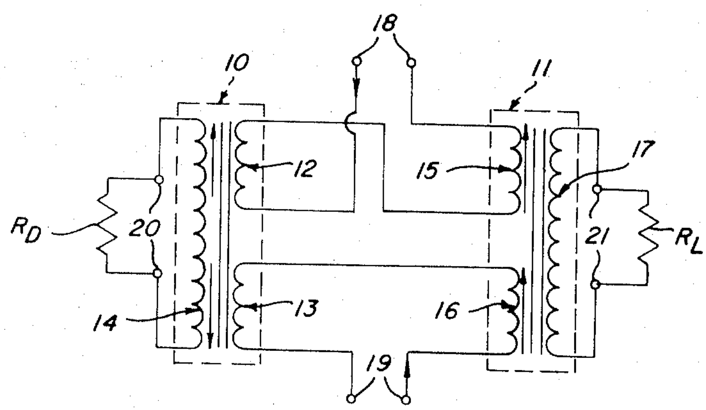
Primary Examiner—Paul L. Gensler
Attorney—Christopher Robinson et al.

[57] **ABSTRACT**

A combiner network for combining two synchronous, coherent AC signals each having differing power levels to form a single relatively high power output. The combiner network is comprised of an output port for supplying a load, a first and a second input port and a single transformer having a first and a second winding. One end of each winding is mutually connected to a terminal of the output port. The other end of the first winding is connected to one terminal of the first input port and the other end of the second winding is connected to one terminal of the second input port. The windings are connected and the windings have a turns ratio so that under rated operating conditions net flux attributable to current flow through the windings is substantially zero and the output currents from the first and second windings additively combine at the output port. The combiner network further comprises dissipative means connected across the windings, the dissipative means having an impedance selected to balance rated load impedance and responsive to non-zero net flux in the transformer to dissipate a portion of the energy supplied by the input ports so as to maintain an impedance balance between the input ports.

7 Claims, 4 Drawing Figures





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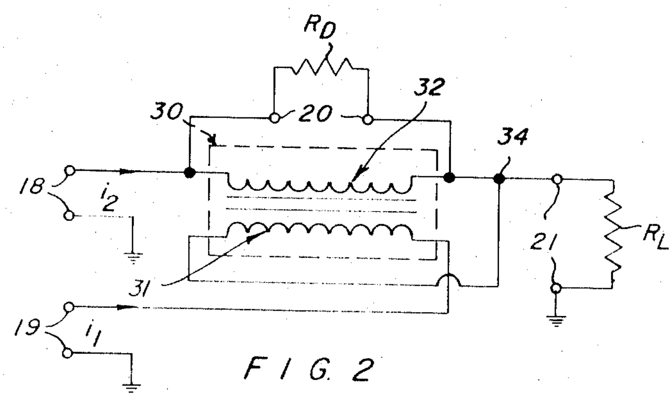

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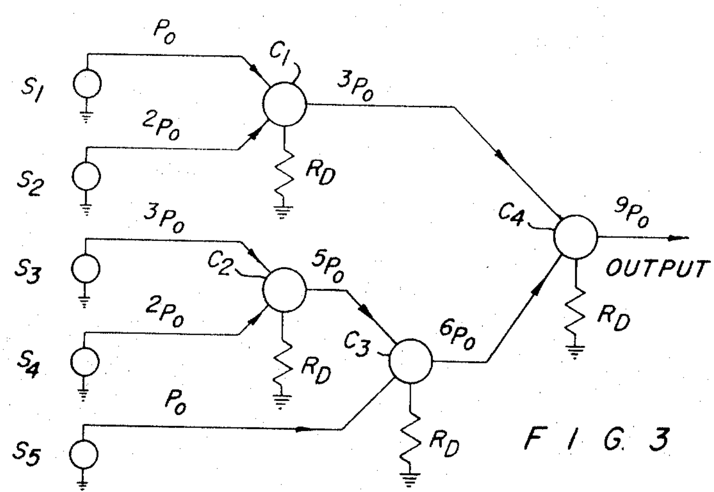

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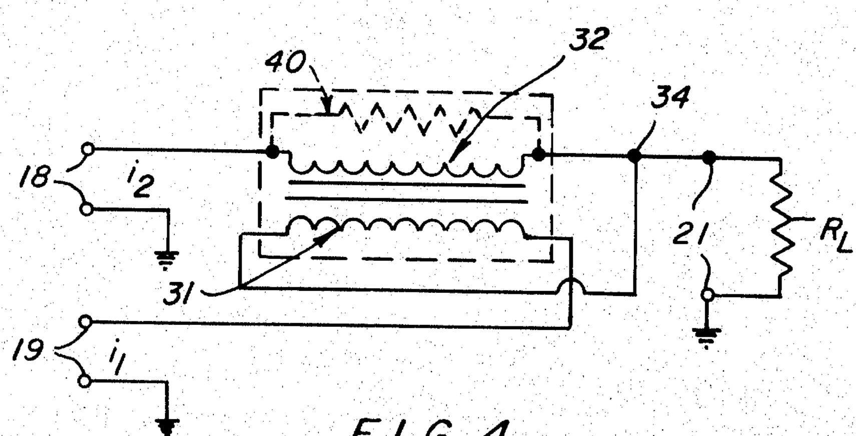

FIG. 4

FOUR PORT COMBINER UTILIZING SINGLE TRANSFORMER

CROSS-REFERENCE

This application is a continuation-in-part application of U.S. application Ser. No. 194,985 which was filed on 2 November 1971, now U.S. Pat. No. 3,747,026.

FIELD OF THE INVENTION

This invention relates to an improved Four-Port Combiner used to combine two synchronous, coherent AC signals of differing signal strength to form a single AC signal.

Known combining networks can be broken down into two categories. The first category contains combiners used to combine narrow band signals and comprises quarter wave transmission line sections arranged generally in the form of a bridge circuit. The second category of combining network and the category in which the present invention is contained, includes the Four-Port Transformer-Wound, Broad-Band Combiner. As in the first category, the transformers are generally arranged in a bridge circuit. An example of a combiner of the second category is described in U.S. Pat. No. 3,503,016, which issued to A.F. Podell on 24 March 1970.

Known broad-band combining networks have the disadvantage that they are relatively complicated arrangements of a plurality of individual transformers. The individual windings of these transformers must be capable of handling the power output of one of the inputs. In contrast, the combiner of the present invention utilizes a single transformer having two windings and therefore represents a considerable simplification of known prior art devices. The transformer of the combiner in accordance with the present invention need only be capable of handling a fraction of the power of either input and in fact during normal operating conditions, only a fraction of the power output of an individual source.

U.S. Pat. No. 3,037,173 which issued to C.L. Ruthroff on 29 May 1962, discloses a single bifilar wound transformer hybrid network. Since the device disclosed in the above mentioned patent is a bifilar wound transformer, it can only handle two signals of equal power. As a result, combinations of the Ruthroff device can only combine 2^n signals of equal power, where n is a positive integer. It is very desirable to be able to combine n signals of differing power to yield a single high power output. The device according to the present invention satisfies this requirement.

SUMMARY OF THE INVENTION

The device according to the present invention combines two signals of similar frequency and phase but of differing power levels. The device is comprised of two windings which are connected so that the magnetic flux generated by one winding is cancelled by the flux generated by the other winding. The power from one input signal generates a flux in the magnetic circuit of the transformer in one direction. The power from the other input signal is arranged to generate a flux in the magnetic circuit of the transformer in the opposite direction. By manipulating the turns ratio of the windings in the transformer, the net flux circulating in the transformer is made equal to zero. Under these conditions no power from either input signal is dissipated in the transformer with the exception of usual resistive losses. Since the turns ratio of the combining transformer is arranged, under rated operating conditions, to produce a zero net magnetic flux in the transformer magnetic circuit the combiner according to the present invention is capable of combining two separate signals of different power levels.

In accordance with the present invention there is provided a combiner network for combining two synchronous, coherent AC signals each having differing power levels to form a single relatively high power output, said combiner network comprising an output port for supplying a load, a first and a second input port, a single transformer having a first and a second winding, one end of each of said first and second windings being mutually connected to a terminal of said output port, the other end of said first winding being connected to one terminal of said first input port, the other end of said second winding being connected to one terminal of said second input port, the polarization and turns ratio of said windings being such that under rated operating conditions net flux attributable to current flow through said windings is substantially zero and output currents from said first and second windings additively combine at said output port; said combiner further comprising dissipative means connected across said windings, said dissipative means having an impedance selected to balance rated load impedance and responsive to non-zero net flux in said transformer to dissipate a portion of the energy supplied by said input ports so as to maintain an impedance balance between said input ports. One embodiment of the combiner according to the present invention utilizes a fourth port to externally connect the dissipative means to the transformer.

DESCRIPTION OF THE DRAWINGS

The invention will be described in detail hereinbelow with the aid of the accompanying drawings, in which:

FIG. 1 is a schematic diagram of a known broad-band, wound transformer combiner;

FIG. 2 is a particular embodiment of the broad-band combiner according to the present invention;

FIG. 3 is a schematic diagram of a network for combining five signal sources of differing power level to form a single output using a plurality of combiners described in FIG. 2; and

FIG. 4 is a schematic diagram of a second embodiment of the broad-band combiner according to the present invention.

DETAILED DESCRIPTION

The combiner shown in FIG. 1 is comprised of two individual transformers **10** and **11**. Transformer **10** has two primary windings **12** and **13** and a secondary winding **14**. Similarly, transformer **11** has primary windings **15** and **16** and secondary winding **17**. The combiner network is comprised of two input ports **18** and **19** and two output ports **20** and **21**. In operation, two coherent and synchronous AC signals are applied to input ports **18** and **19**. The amplitudes of the signals need not be the same but it is important that the frequency and phase of the two signals be identical. The current sense of the AC signals is indicated by the arrows leading away from input ports **18** and **19** respectively. The currents circulating in the two primary windings **15** and **16** of transformer **11** are wound in aiding sense and produce a net flux circulating in the magnet core of transformer 11 whose intensity is proportional to the sum of the two currents. As a result, there is induced into the secondary winding 17 of transformer 11 a current which is proportional to the sum of the two individual input currents. This summation current is fed to a load R_L via output port 21. The same input currents which additively combine in transformer 11 exactly oppose one another in transformer 10. The flux created by the current in winding 12 is opposite in sense to the flux created by the current flowing in winding 13. It can be seen that if the frequency and phase of the two input signals are identical, and the flux created by the two output ports are identical, there will be no net flux circulating in the magnetic circuit of transformer 10 and as a result, there will be no current induced into the secondary winding 14.

However, if one of the input signals should fail, the power of the remaining input signal will be divided between the two transformers 10 and 11 and the output signal will appear at both output ports 20 and 21. At such time, a "dummy load" dissipative impedance element R_D dissipates a portion of the remaining input signal. In this manner, the two input ports will remain mutually isolated.

FIG. 2 is a schematic diagram of a particular embodiment of the present invention. Input port 19 accepts a signal from a source having a power P_1. This signal generates a current I_1, the sense of which is shown by the arrow directly adjacent input port 19. Input port 18 accepts a signal from a source having a power P_2. This signal generates a current I_2, the sense of which is shown by the arrow directly adjacent input port 19. P_1 is not equal to P_2 and therefore it can be assumed that I_1 is not equal to I_2.

The current I_1 flowing in winding 31 of transformer 30 generates a flux Φ_1 flowing in one sense in the magnetic circuit of the transformer in accordance with the equation $\Phi 1 = I_1 N_{31}$; where N_{31} is the number of turns in winding 31. Similarly, a flux Φ_2 is generated in the same magnetic circuit of transformer 30 by virtue of current I_2 flowing in winding 32, so that Φ_2 equals $I_2 N_{32}$.

Considering the direction of the arrows indicating the direction of current flowing for currents I_1 and I_2 and considering the manner in which the windings are interconnected, it can be seen that Φ_2 circulates in the magnetic circuit of the transformer in the opposite sense to the flux Φ_1. When Φ_2 equals Φ_1 there is no net flux circulating in the transformer. Under this condition there will be no induced power loss in the transformer and the two currents I_1 and I_2 will combine to $I_1 + I_2$ at the terminal 34. Since the frequency and the phase of the currents are identical this addition will be sympathetic.

Since Φ_2 equals Φ_1 it follows that:

$$I_1 N_{31} \text{ equals } I_2 N_{32} \qquad (1)$$

When one of the signals fails, the combiner according to the present invention isolates the remaining operating input port from the input port which has failed. A net flux now circulates in the transformer and a portion of the power of the remaining signal is dissipated across a "dummy load" R_D. By properly choosing the value of R_D the combined effect of the new impedance created by the dummy load and the impedance created by the load R_L can be arranged to present, at the remaining operating input port, an impedance equal to the impedance present when both input signals are supplying current. In this manner, input ports 18 and 19 are mutually isolated.

The input impedance of the circuit shown in FIG. 2 for input port 18 is:

$$Z_{18} = Z_L\ (1 + N_{32}/N_{31}) \qquad (2)$$

and for input port 19, the impedance is:

$$Z_{19} = Z_L\ (1 + N_{31}/N_{32}) \qquad (3)$$

where Z_L is the impedance of the load R_L.

The turns ratio for N_{31} and N_{32} is determined by the power delivered by equation 1 above.

Isolation can be obtained by chosing the correct impedance Z_D of the dummy load R_D by assuming an ideal transformer which has a unity coupling coefficient and negligible magnetizing current.

The voltage transfer coefficient $C_{18\text{-}19}$ from input port 18 to input port 19 is given by:

$$C_{18-19} = N_{32}\ Z_L - N_{31}\ Z_D/N_{32}\ (Z_L + Z_D) \qquad (4)$$

In order to obtain perfect isolation, the transfer coefficient must be zero. Therefore, setting the right hand side of equation 4 equal to zero and solving for Z_L it can be seen that the isolation is total when Z_L equals $Z_D(N_{31}/N_{32})$.

The condition for zero coupling or total isolation from input port 19 to input port 18, (i.e. C_{19-18} equals zero), is identical with the above result.

In the embodiment shown in FIG. 2 the dummy load R_D is shown across winding 32. The dummy load R_D could just as easily be placed across winding 31 or the value of the dummy load R_D could be divided and placed separately across both windings 31 and 32.

In operation, when both input ports 18 and 19 are being fed by the required signal, the vector addition of the two signals will take place at terminal 34, and substantially no loss will occur in the transformer. As a result, under rated operating conditions no signal will appear across dummy load R_D and all of the signal will appear across the load R_L (which is usually an antenna or the like).

The transformer 11 shown in FIG. 1 must be capable of handling the entire power from the input ports 18 and 19. However, transformer 10, will, under the worst conditions, only be required to handle a fraction of the power of the remaining input port which has not failed. Under these conditions, the power of the remaining input will be divided between both transformers 11 and 10. In the combining network according to the present invention, as shown in FIG. 2, there is no one winding which must be capable of handling the complete power input of the two ports 18 and 19. As a result, not only has one transformer been eliminated using the combining network according to the present invention but the remaining transformer may be reduced in size.

A further alternative embodiment shown in FIG. 4 removes the dummy load R_D altogether. In this alternative embodiment, the transformer 30 is made "lossy." The losses shown by the resistor 40 (which is drawn in phantom to indicate that it is in reality a distributed resistance) are arranged to be equal to the loading effect of dummy load R_D (shown in FIG. 2), absorb the power normally handled by dummy load R_D, and thereby further simplify the network. A transformer having the required lossiness may be realised by winding the transformer on a core material having suitably high eddy current losses and/or hysteresis losses. Losses, will not appear under normal operating conditions when zero net flux is circulating in the magnetic circuit of the transformer **30.** Since there is no need to connect a dummy load resistor to the combiner of this embodiment the resulting combiner is a three port device.

FIG. **3** is a schematic diagram of a combining network for combining five signal sources having the same frequency and phase but differing power levels. FIG. **3** clearly illustrates a combining system which would not be possible according to the above mentioned Ruthroff device. As mentioned above, the Ruthroff device can only combine 2^n signal sources each having the same signal strength. Dummy load resistors R_D connect the fourth port of each combiner to ground.

According to FIG. **3,** there are five signal sources, $S_1 - S_5$ having a power output level of P_O, $2P_O$, $3P_O$, $2P_O$ and P_O respectively. Combiner C_1 combines the signal sources S_1 and S_2 yielding an output power of $3P_O$. Combiner C_2 combines the signal sources S_3 and S_4 to yield an output power of $5P_O$. The output of combiner C_2 is in turn combined with signal source S_5 by combiner C_3 to yield an output power of $6P_O$. Finally, combiner C_4 combines the power outputs of combiners C_1 and C_3 to yield a total power output of $9P_O$.

Using combinations of the combining network according to the present invention it is possible to combine N power sources to form a single high power output utilizing N-**1** combiners, where N is a positive integer.

What I claim as my invention is:

1. A combiner network for combining two synchronous, coherent AC signals each having differing power levels to form a single relatively high power output, said combiner network comprising an output port for supplying a load, a first and a second input port, a single transformer having a first and a second winding, one end of each of said first and second windings being mutually connected to a terminal of said output port, the other end of said first winding being connected to one terminal of said first input port, the other end of said second winding being connected to one terminal of said second input port, the polarization and turns ratio of said windings being such that under rated operating conditions net flux attributable to current flow through said windings is substantially zero and output currents from said first and second windings additively combine at said output port; said combiner further comprising dissipative means connected across said windings, said dissipative means having an impedance selected to balance rated load impedance and responsive to non-zero net flux in said transformer to dissipate a portion of the energy supplied by said input ports so as to maintain an impedance balance between said input ports.

2. A combiner network according to claim **1,** wherein the dissipative means is connected in parallel across one of said windings.

3. A combiner network according to claim **1,** wherein said dissipative means is connected in parallel with a combination of said windings.

4. A combiner network as defined in claim **1,** wherein said transformer and windings are selected to operate at R.F. signal frequencies.

5. A system for combining N synchronous coherent AC power sources to form a single relatively high power output utilizing N-**1** combiner networks according to claim **1,** where N is a positive integer.

6. A combiner network according to claim **1,** wherein said transformer is a lossy transformer and said dissipative means comprises the losses internal to the transformer in the presence of non-zero net flux circulating within said transformer, said losses being so dimensioned as to dissipate a portion of the energy supplied by said input ports to maintain an impedance balance between said input ports.

7. A combiner network according to claim **6,** wherein said turns ratio of said first and second windings is substantially 1:1.

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