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Wheeler

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[54] COUPLING APPARATUS

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[52] **U.S. Cl.**.....**324/57 R,** 324/58 A, 324/58 B

[51] **Int. Cl.**.....**G01r 27/00**

[58] **Field of Search**.....324/57 R, 58 B, 58 A

[56] **References Cited**

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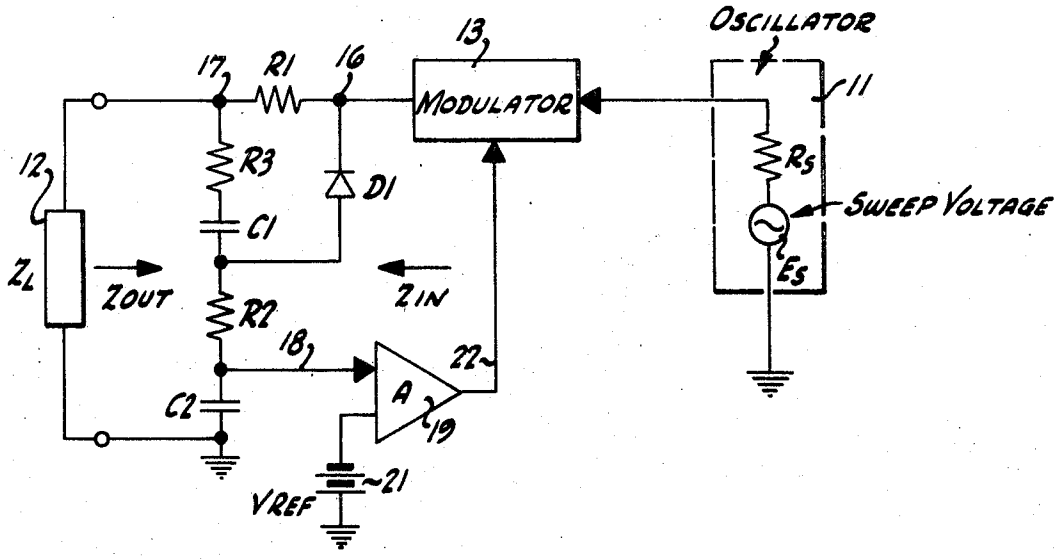
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[57] **ABSTRACT**

Coupling apparatus for coupling an a.c. signal generator to a load and detecting the output level of the generator without appreciable power loss and without the use of a directional coupler or balun. The detected load voltage is coupled to a reference comparator to regulate the generator output in a leveling mode. Reflection coefficients may also be determined by interchanging the location of the load and the generator.

10 Claims, 3 Drawing Figures



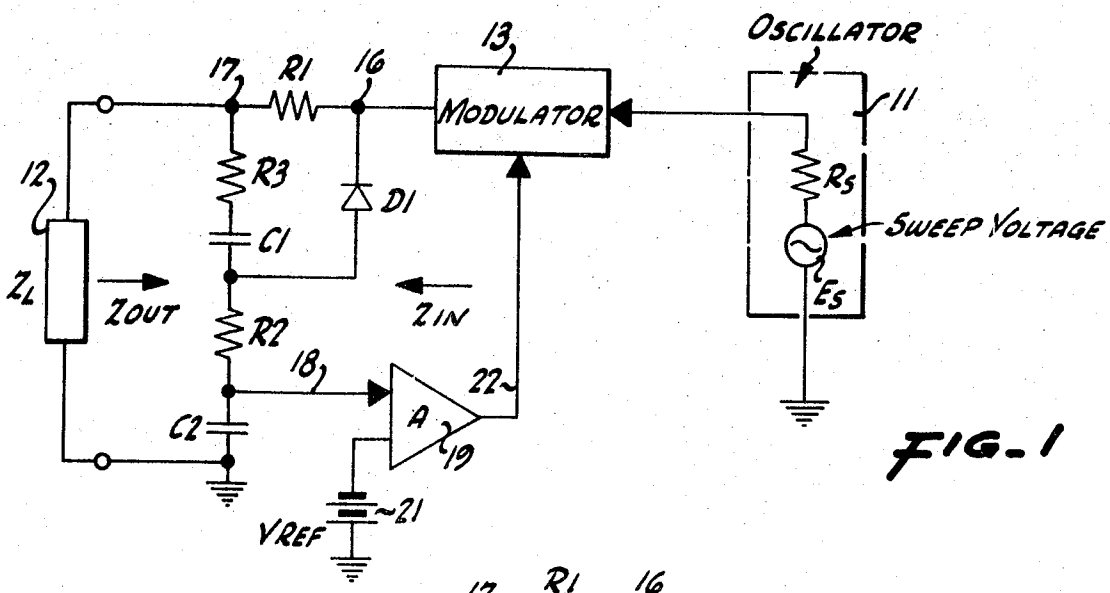


FIG-1

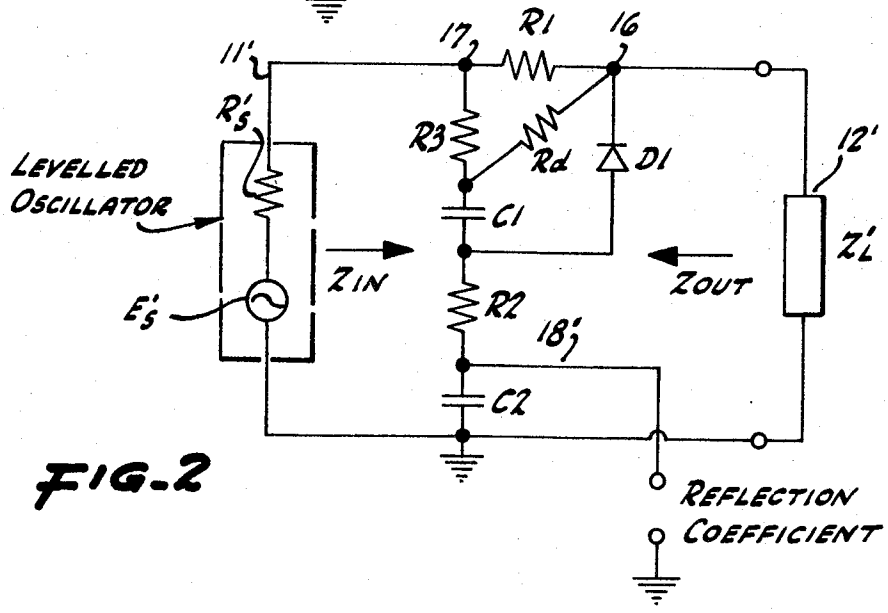


FIG-2

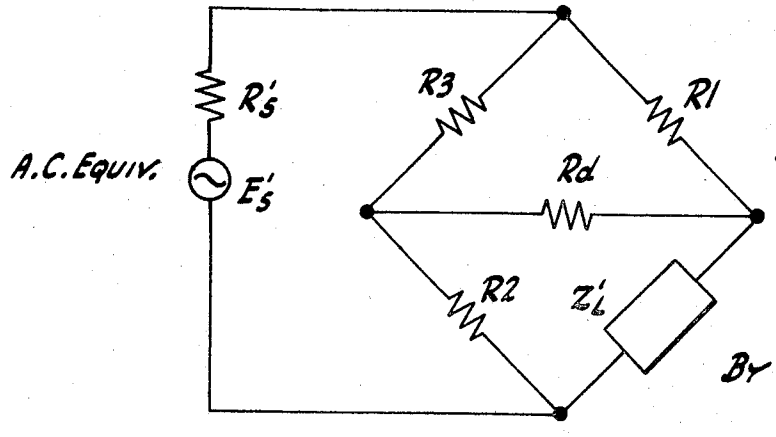


FIG-3

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COUPLING APPARATUS

BACKGROUND OF THE INVENTION

The present invention is directed to coupling apparatus for coupling an a.c. signal generator to a load and more specifically to apparatus where the output level of the generator is detected without appreciable circuit complexity or loss.

Where it is desired, for example, to couple a swept oscillator to a load and at the same time level the output of the oscillator so it remains relatively constant, it is difficult to accomplish the above without excessive losses or without undue expense and the use of limited band couplers. Another concomitant desired characteristic is that the coupler still establishes the effective characteristic impedance of the generator, which for example might nominally be 50 ohms, in order to provide proper matching with the load. It is apparent that if the output signal of a generator is maintained at a constant voltage despite any change in load current that the output impedance of the generator will appear to be zero. This is, or course, undesirable from a matching standpoint. Thus, the coupler must exhibit the proper characteristic impedance and in addition cause the effective generator voltage to be properly leveled. However, this must be done without excessive losses and without sacrificing broad band capability; this is especially necessary, of course, in the case of a swept oscillator.

One type of coupler which has been used is a directional coupler which is a four port device, one port being for the generator, the second for the load, the third for detecting the output level of the generator for leveling purposes and the fourth is terminated in the transmission line characteristic impedance. This is satisfactory in performance but is expensive and of limited bandwidth. Another simple type of coupler may merely include a series coupling resistor which has a characteristic impedance value for use in both matching and detecting the output level of the generator. However, this causes a relatively large power loss. Another type of coupler which has been used includes a resistive network with, however, the output level detector of the generator being coupled to the network by a balun (balancing unit) which is necessary in order to provide a practical feedback loop when the coupling device was also used for leveling. In addition, a balun was required to maintain reasonable sensitivity in measurement of the output level. Again a balun is bandwidth limiting.

OBJECTS AND SUMMARY OF THE INVENTION

It is, therefore, a general object of the present invention to provide improved coupling apparatus for coupling an a.c. signal generator to a load.

It is another object of the invention to provide coupling apparatus as above which is simple and inexpensive but yet has a relatively broad bandwidth.

It is another object of the invention to provide coupling apparatus as above where the output level of a coupled generator may be detected without increasing losses in the system or reducing sensitivity of measurement.

It is another object of the invention to provide a coupling apparatus which is suitable for measurement of reflection coefficients.

In accordance with the above objects, there is provided coupling apparatus for coupling an a.c. signal generator to a load impedance and detecting the level of the output signal of the generator. The apparatus includes first impedance means having two terminals series coupled between the load and generator for sensing load current. Second impedance means are coupled from one terminal of the first impedance means coupled to the load to common for sensing load voltage. Rectifying means are coupled from the other terminal of the first impedance means to an intermediate junction of the second impedance means. D.C. isolation means is series connected in the second impedance means. Output means are coupled across the d.c. isolation means for sensing the rectified a.c. voltage across the rectifying means.

Alternatively, for measuring reflection coefficients the placement of load and generator are reversed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic circuit diagram of coupling apparatus embodying the present invention being used in a leveling mode;

FIG. 2 is a schematic diagram of coupling apparatus embodying the present invention being used to measure reflection coefficients; and

FIG. 3 is an a.c. equivalent circuit of FIG. 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiment of FIG. 1 shows the coupling apparatus of the present invention coupling an a.c. generator or oscillator **11** to a load **12** designated Z_L with the coupler providing in combination with a modulator **13** at the output of oscillator **11**, a leveling type of operation. Oscillator **11** includes the high frequency generator E_s which is driven by a swept frequency voltage generator and which has an internal impedance, R_s.

Resistor **R1**, therefore, by means of the voltage across it senses or samples the load current through load **12**. In shunt across both the load and oscillator **11** are second resistor means which sense or sample the voltage across the load and which includes a first resistive portion **R3** and a second resistive portion **R2**. In series with both of these portions are d.c. isolation capacitors **C1** and **C2**. A rectifying diode **D1** is coupled between terminal **16** of resistor **R1** and between the two resistive portions **R2** and **R3**. The capacitor **C2** serves as d.c. isolation means to complete the shunt coupling of resistors **R2** and **R3** across both the load and the oscillator since capacitor **C2** is terminated at ground or common.

Output means include the output line **18** which is coupled between **R2** and **C2** and also the comparator amplifier **19** which has a second input a d.c. reference voltage source **21** also coupled to common ground. Thus, the d.c. voltage appearing across capacitor **C2** is compared by amplifier **19** which operating in a differential mode provides an error signal on its output line **22** indicating the magnitude of any lack of comparison to correspondingly regulate modulator **13** to change the output level at terminal **16**.

Assuming R_o is the desired characteristic impedance of the system then in accordance with the invention the

ratio $R1/R_o$ is made equal to the ratio R3/R2. Typical values for a characteristic impedance or value of R_o of 50 ohms where the coupling apparatus is rated at 20 decibels (in other words, the signal output appearing across rectifier D1 is 20 decibels down from the leveled output at terminal 16 when Z_L equals R_o) are a ratio equal to 0.052 thus making R1 equal to 2.6 ohms, R3 equal to 50 ohms and R2 equal to 960 ohms.

In operation, the current and voltage samples across resistors R1 and R3 respectively are summed by D1 and the resultant rectified sum appears on output 18.

The level control loop consists of the rectifier D1 producing a d.c. voltage at terminal 18 that is compared with reference voltage 21. Any difference between 18 and 21 is amplified at 19 and used to control the oscillator source attenuation by modulator 13 and maintain a nearly constant voltage across rectifier D1. As the amplification of amplifier 19 approaches infinity, the voltage across D1 become a prescribed constant and the d.c. voltage at 18 equals V_{REF}. The action of this level control loop creates at all a.c. frequencies a new effective leveled oscillator source at terminal 17 with a constant voltage generator E's with an internal impedance R'_s that is equal to R_o. Designating the rectifier voltage as E_d and as equal to nV_{REF} and the ratio of $R1/R_o$ as k, the effective generator voltage becomes: $E'_s=(nV_{REF})/k$.

The diode D1 in FIG. 1 must have a direct current return to ground at point 16 or 17. If this is not provided by the modulator 13 or the load impedance 12, then an inductance to ground from point 16 must be added.

The embodiment of FIG. 2 provides for measurement of reflection coefficients. The location of the load impedance and oscillator are interchanged. In addition, a leveled oscillator is used. The coupling apparatus is similar to that of FIG. 1 except for the resistor R_d connected between terminal 16 and the junction between capacitor C1 and resistor R3. The reflection coefficient of the load 12' designated Z'_L is measured with respect to a transmission line impedance R_o. The reflection coefficient Rho is equal to $(Z'_L-R_o)/(Z'_L+R_o)$. The leveled oscillator maintains E'_s constant with respect to time and frequency. In addition R'_s is equal to R_o, R_d equal to R_o, R3 equal to R_o and the ratio $(R1/R_o)$ is equal to (R3/R2) or $(R_o/R2)$.

With these conditions in effect Z_{in}, when Z'_L equals R_o, is also R_o. The a.c. equivalent circuit is shown in FIG. 3 which is a familiar Wheatstone bridge proportioned to make a.c. measurements of the magnitude of the reflection coefficient of Z'_L with respect to a resistive transmission line characteristic impedance R_o. If the characteristic impedance has reactance, then R2 should have a similar proportion of reactance. Capacitors C1 and C2 should have very low reactance at all frequencies of use compared to R2.

An a.c. voltage proportional to the reflected wave amplitude from Z'_L appears across R_d. This is rectified by either linear or square law conversion and conducted out through resistor R2 to the output terminal 18'.

The voltage across R_d is the subtractive combination of the current and voltage samples of R1 and R3. This is proportional to the reflection coefficient $[(Z'_L-R_o)/(Z'_L+R_o)]$. The coupling factor, the multiplier for the reflection coefficient is: $(R1/R_o)/[1+(R1/R_o)]$bh2.

For reflection coefficient measurement, an alternative arrangement is to use a constant voltage oscillator source with zero or very low internal impedance and omit R_d while insuring the effective a.c. load impedance presented by D1 is high compared with (R1+R3). With these conditions met, again E_d is proportional to $(Z'_L-R_o)/(Z'_L+R_o)$.

The unique connection of the output lines 18 and 18' to the coupler of the present invention which requires no balun is accomplished by coupling this line to the diode rectifying means or diode D1 through resistor R2. This resistor serves a dual purpose of shunting the a.c. signals through C2 which amounts to a short circuit from an a.c. standpoint to the common, and at the same time, R2 also serves the purpose of coupling the d.c. voltage appearing across D1 to the output line 18 and with the coupling of R2 by capacitor C2 to common or ground the entire d.c. voltage can appear on this line 18. Thus, the detector D1 is in actuality floating but by means of the foregoing circuit connection the d.c. voltage across the detector may still be referenced to ground by the use of the common resistor R2 both for the a.c. or radio frequencies and for the d.c. signal.

The capacitor C1 prevents resistors R1 and R3 from being loaded by the rectified current produced by D1.

The a.c. equivalent circuit of FIG. 3 although specifically illustrating the reflection coefficient circuit of FIG. 2 may be modified to reflect the circuit of FIG. 1 merely by eliminating R_d and interchanging the Z'_L and R'_s legs. In addition, although as discussed above the ratio of resistances for example $R1/R_o$ was 0.052, this ratio may be varied keeping in mind the two conflicting requirements of reducing the amount of power dissipated in the coupling apparatus but on the other hand providing enough power dissipation so that there is enough voltage to be detected by the detector D1.

Mathematical analysis shows that FIG. 1 will provide at terminal 17 a leveled oscillator output voltage, provided the unleveled generator voltage E_s exceeds a prescribed minimum value established by the d.c. reference voltage V_{REF} 21. It will also provide an equivalent generator impedance R_o at terminal 17. The coupling factor is adjusted by the ratio $R1/R_o$ and R3/R2.

Further analysis shows that FIG. 2 measures reflection coefficient of the load Z'_L. Again the coupling depends on the ratio $R1/R_o$ and R3/R2.

Thus, the present invention provides an improved coupling apparatus which may advantageously be used for coupling a swept oscillator with a load in combination with feedback leveling loop or used for reflection coefficient measurements. Since no baluns or directional couplers are utilized, the apparatus has extremely good frequency bandwidth and since a relatively low series resistance R1 can be used the coupling apparatus loss will introduce a low power dissipation.

I claim:

1. Coupling apparatus for coupling an a.c. signal generator to a load impedance and detecting the level of the signal generator, said apparatus comprising: first impedance means conductive to direct current having two terminals such terminals being coupled between said signal generator and said load for sensing load current; second conductive impedance means divided into two portions and having an intermediate junction and connected from one terminal coupled to said load and

to a common ground terminal to sense voltage across said load, rectifying means coupled to said other terminal of first impedance means and said intermediate junction of said second impedance means to rectify the sum of said load current and load voltage samples, d.c. capacitive isolation means series connected in said second conductive impedance means, and d.c. output means coupled across said d.c. isolation means and said common ground terminal to sense the rectified a.c. voltage across said rectifying means.

2. Coupling apparatus as in claim 1 where said first and second impedance means are proportioned so that the ratio of the voltage to current samples is a predetermined ratio for a predetermined characteristic load impedance corresponding to standard two conductor interconnecting transmission lines.

3. Coupling apparatus as in claim 1 where said common ground terminal is common to both said load impedance and signal generator.

4. Coupling apparatus as in claim 1 where said first and second impedance means which sample load current and voltage are resistive elements to provide widest possible r.f. bandwidth of operation.

5. Coupling apparatus as in claim 1 together with a d.c. reference and r.f. level regulating means, said rectified a.c. voltage level being compared with said d.c. reference and the difference error signal being applied to said r.f. level regulating means interposed between said signal generator and said coupling apparatus for minimizing said error signal whereby the combination of signal generator and coupling apparatus operates to provide a constant effective output voltage delivered through an impedance equal to a selected characteristic impedance even when the originating signal generator's voltage level and impedance vary widely.

6. Coupling apparatus for coupling an a.c. signal generator to a load impedance and detecting the quality of the load by determining a reflection coefficient, said apparatus comprising: first impedance means conductive to direct current having two terminals such terminals being series coupled between said signal generator and said load for sensing load current; second conductive impedance means divided into two portions and having an intermediate junction and connected from one terminal coupled to said signal generator to a common ground terminal to sense voltage across said signal generator, rectifying means coupled to said other terminal of first impedance means and said intermediate junction of second impedance means to rectify the difference of said current and voltage samples, d.c. capacitive isolation means series connected in said second conductive impedance means, and d.c. output means coupled across said d.c. isolation means at the ground terminal to sense the rectified a.c. voltage across said rectifying means.

7. Coupling apparatus as in claim 6 where first and second impedance means are proportioned so that the ratio of the voltage to current samples is a predetermined ratio for a predetermined characteristic load impedance corresponding to standard two conductor interconnecting transmission lines.

8. Coupling apparatus as in claim 7 where said current sample and the voltage sample combine subtractively to provide zero d.c. output when said load impedance is equal to said characteristic impedance but is increasingly non-zero as the applied load value is changed away from the characteristic impedance.

9. Coupling apparatus as in claim 7 where said signal generator has a constant voltage and an output impedance equal to said characteristic impedance together with resistive means having said characteristic impedance for shunting said rectifying means and where the portion of said second impedance means generating the voltage sample also has said characteristic impedance whereby said rectified output is a direct measure of the classical transmission line reflection coefficient of any unknown applied complex load impedance.

10. Coupling apparatus as in claim 7 where the signal generator has constant voltage and zero output impedance and said rectifying means presents a high effective a.c. impedance compared with the sum of the impedance elements for said voltage and current samples, whereby said rectified output is a direct measure of the classical transmission line reflection coefficient of any unknown applied complex load impedances.

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