

Jan. 26, 1971

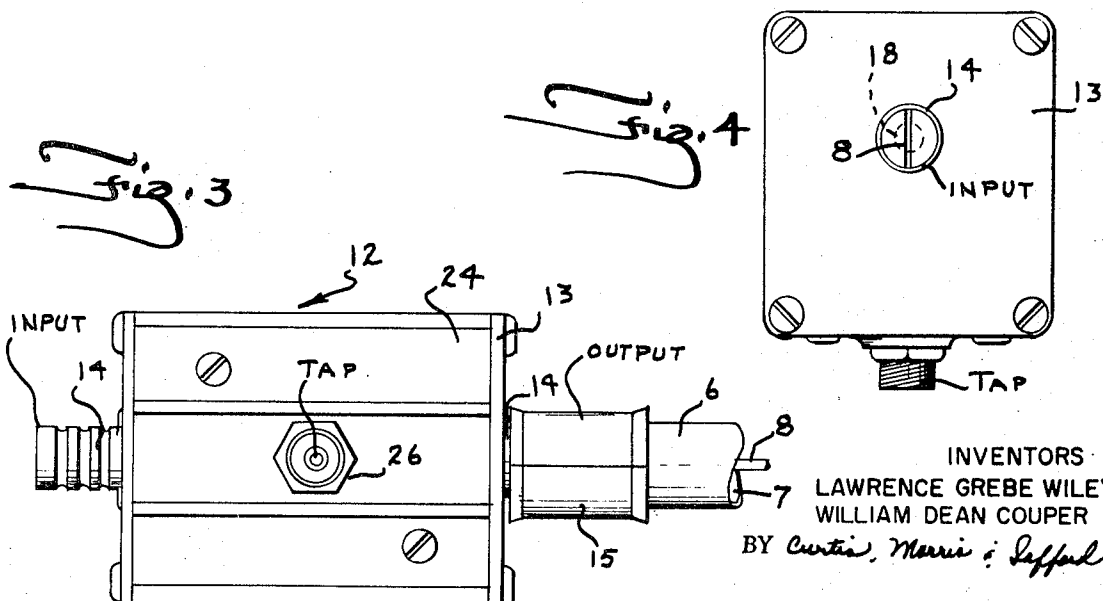
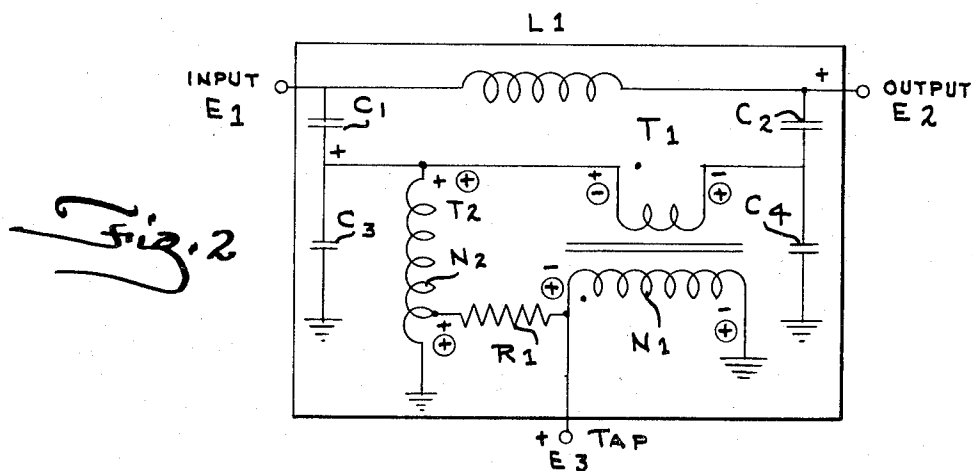
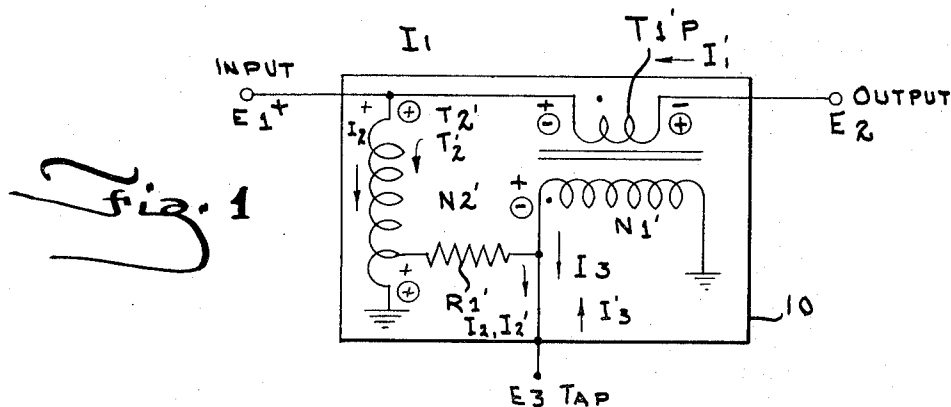
L. G. WILEY ET AL

3,559,110

DIRECTIONAL COUPLER

Filed Nov. 12, 1965

2 Sheets-Sheet 1



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DIRECTIONAL COUPLER

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2 Sheets-Sheet 2

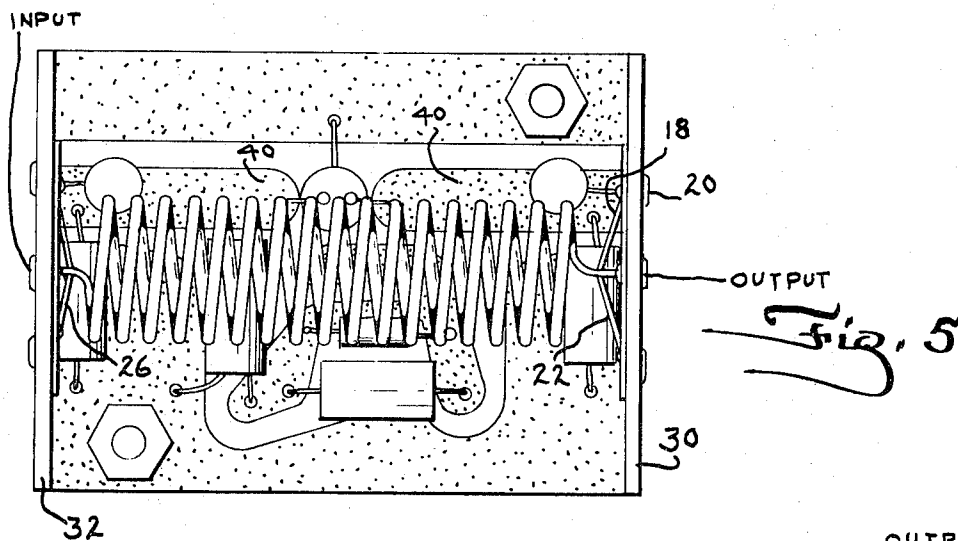


Fig. 6

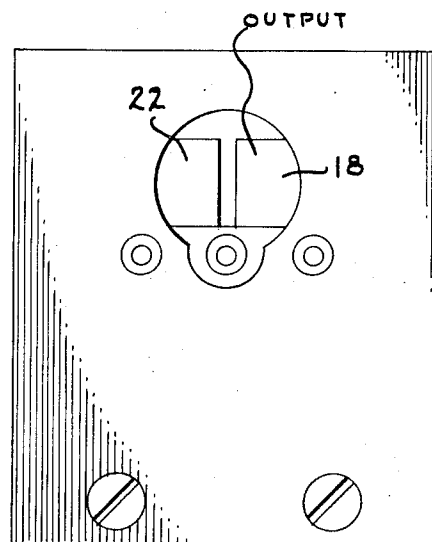
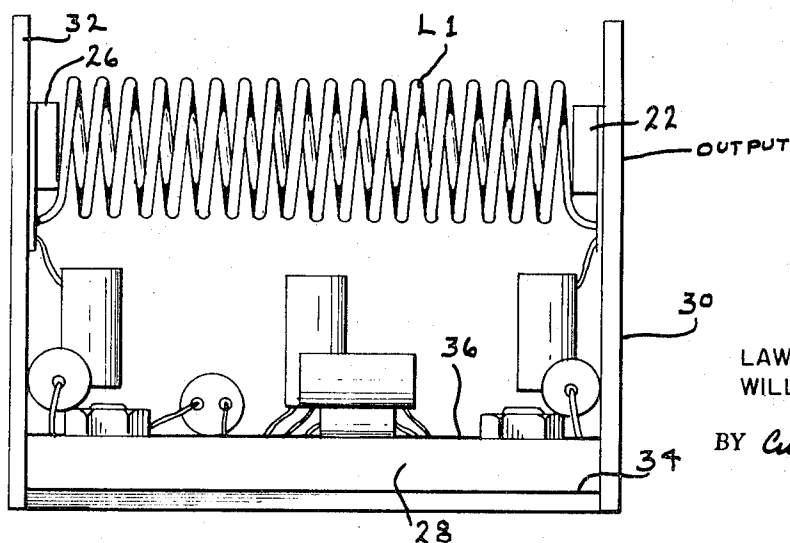


Fig. 7



INVENTORS
LAWRENCE GREBE WILEY
WILLIAM DEAN COUPER

BY *Curtis, Morris & Lafford*

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DIRECTIONAL COUPLER

Lawrence Grebe Wiley, Camp Hill, and William Dean Couper, Palmyra, Pa., assignors to AMP Incorporated, Harrisburg, Pa.

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6 Claims

ABSTRACT OF THE DISCLOSURE

A directional coupler is disclosed which includes a first transformer having its primary in series with a transmission line and its secondary of N_1 turns connected directly between ground and a tap to provide a sample signal output. An auto-transformer is connected between the input of the coupler and ground and has N_2 turns. An output is provided from the auto-transformer through a resistance to the tap and the transformer turns N_1 and N_2 have a relationship so that current components of transmitted signals are effectively added to provide an output sample signal and current components resulting from reflected signals cancel each other.

BACKGROUND OF THE INVENTION

A directional coupler is a device which is inserted into a transmission line to develop a sample of the line signal. The device is made directional so as to extract the signal being transmitted by the line and not extract reflected signals which may be present in the line due to conditions occurring in portions thereof in the receiver side of the line. As an important consideration the coupler should be capable of handling the full frequency range of the transmitted signal without causing degradation to the signal being transmitted or degradation to the signal being sampled.

The present state of the art in directional couplers finds a number of different circuits being employed. Most of these are satisfactory only over a very limited frequency range, and many of them are less than satisfactory with respect to factors of VSWR, line-to-tap attenuation, through loss, or directivity. Many of the prior art couplers are not capable of passing power as well as communication signals. In certain of the prior art couplers the circuits employed are relatively complex and inherently difficult to package for convenient use on pole or line installations.

SUMMARY OF THE INVENTION

This invention relates to a directional coupler of the type utilized with communication transmission lines. This invention is particularly related to the sampling or tapping of coaxial cables carrying television signals.

It is one object of the present invention to provide a directional coupler capable of handling a relatively broad signal frequency range. It is another object of the invention to provide a directional coupler operable over a broad frequency range with minimum transmitted signal degradation and minimum sample signal degradation. It is a further object of the invention to provide a directional coupler having relatively few components. Another object is to provide a coupler circuit capable of broad frequency response which employs only passive components. Still another object of the invention is to provide a directional coupler circuit and package which is of simple and inexpensive construction and which is capable of an easy and convenient installation and use.

The foregoing problems are overcome and the foregoing objectives are attained in the present invention through a directional coupler design which achieves di-

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rectivity by combining separately developed voltage and current sample components of the signal passing through the coupler. These signal components are, in accordance with the invention, made to be in phase in the forward direction of signal transmission and 180° out of phase in the reverse sense of transmission and the amplitudes of these components are adjusted so that the two components algebraically add to zero in the reverse sense of transmission; i.e., from the direction of the receiver. The invention circuit is packaged in a manner minimizing impedance mismatch through the use of strip-line techniques and a provision is made for passing sixty cycle power at a current level adequate to operate devices in the transmission line downstream of the installation of the coupler.

In the description to follow the embodiments of the invention will be specifically related to an application for coupling into television signal transmission lines. This sort of application is now being widely employed in commercial antenna television (CATV) installations, wherein there is a central antenna positioned in an optimum location for signal reception and connected to feeder lines comprised of coaxial cables leading out to various receivers of subscribers to the system. At each subscriber location there is provided a directional coupler which effectively taps a small portion of the transmitted signal and supplies such to the subscriber receiver. As a general requirement the coupler is made directional so as to receive the transmitted signals from the central antenna but block reflected signals and block transients caused by receivers further down the line. As a specific requirement the coupler must develop its sample with fidelity over a broad frequency range without itself causing modulation of the transmitted signals.

While the description of the embodiments chosen to represent the present invention is related to CATV applications, it is understood that other and general uses of the invention are also contemplated.

In the drawings:

FIG. 1 is a schematic diagram of a general embodiment of the directional coupler of the invention;

FIG. 2 is a schematic diagram of another embodiment of the coupler of the invention capable of handling A.C. power for line amplifiers in addition to the communication signal being transmitted by the line;

FIG. 3 is a bottom view of a conductive shell utilized to house the coupler of the invention;

FIG. 4 is an elevational view taken from the right end of the FIG. 3;

FIG. 5 is a plan view from the top of a component package adapted to be fitted within the shell of FIG. 3;

FIG. 6 is an end elevational view taken from the right side of FIG. 5; and

FIG. 7 is a side elevational view resulting from turning the package shown in FIG. 5 into an upright position.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to FIG. 1, 10 represents a directional coupler in accordance with the general embodiment of the invention. The coupler is connected into a transmission line which includes a transmitter displaced by some distance from the input side and some approximately matched load or loads displaced some distance from the output side. If the transmission line is a typical coaxial cable the cable center conductor is connected to the coupler input and output terminals with the cable ground conductor terminated to the ground plane of 10. FIG. 3 shows this type of cable including an outer conductor 6 surrounding a dielectric sheath 7 and a center conductor 8. The tap of 10 is utilized to develop the sample signal supplied to a receiver. The voltage shown as E_1 repre-

sents the input or transmitted signal and the voltage E_2 represents some reflected signal which is desirably blocked by the directional characteristics of the coupler. The voltage E_3 represents the sample signal tapped from the line. The general object of the circuit is then to provide a signal E_3 , which is a small percentage of E_1 . The coupler 10 must operate to substantially block E_2 with respect to reverse transmission and with respect to any effect of E_2 on E_3 . Additionally, the coupler should itself have a relatively low VSWR and relatively low line-to-tap attenuation and through loss. In view of recent changes in the regulations governing the frequency range of television receivers being domestically manufactured, the coupler should operate with the foregoing characteristics throughout a frequency range of from 54 to 216 megacycles. As an example of desirable characteristics the VSWR of the coupler should be equal to or less than 1.20 with a line-to-tap attenuation approximately equal to 12 db. and a through loss equal to or less than 1.0 db. It would be highly desirable to have a coupler directivity equal to or greater than 20 db.

In accordance with the circuit of the invention shown in FIG. 1 there is provided an electro-magnetic coupling comprised of a transformer T_1 , adapted to couple a current sample to the tap and an auto-transformer T_2 adapted to couple a voltage sample to the tap. The primary of T_1 is connected in series to the line between the input and output terminals of 10, and the winding of T_2 is connected in series between the line and ground. This type of coupling is ideally suited to handling a substantial frequency range. The secondary of T_1 is of the polarity shown with respect to current flow from the input to the output of the coupler and is connected between ground and the tap and to the winding of T_2 through a resistor shown as R_1 at a point to provide a proper ratio of the winding turns of T_2 to develop a desired output voltage.

In accordance with the invention the turns N_1 of the secondary of T_1 and the turns N_2 of T_2 are chosen so as to provide the following operation. Considering current flow due to the transmitted signal potential E_1 with a polarity with respect to ground as shown, not circled, a current component I_1 will be developed flowing through the circuit to the output. From the impedance relationship of T_1 and T_2 a current sample I_2 will be developed flowing through the upper part of the turns of T_2 through the resistance R_1 to the tap. This current is made to have the polarity with respect to ground as shown. With the secondary winding of T_1 having the polarity shown, the current I_1 flowing in the primary thereof will induce a voltage in the T_1 secondary causing a current I_3 to flow to the tap. The current components I_2 and I_3 are accordingly in phase and by an appropriate choice of turns ratios and choice of R_1 can be made to be equal in amplitude. The resulting voltage E_3 supplied to the tap then represents a faithful sample of E_1 with respect to phase and is of a quantity dependent upon the impedances of the individual paths encountered by I_2 and I_3 .

Assume now that some reflected and unwanted signal of a voltage E_2 is presented to 10 to develop a drop across the primary T_1 of the polarity shown encircled at each end of the winding. A resulting current I_1' will flow through T_1 . This current will result in a component I_2' flowing through T_2 having the polarity shown encircled which, as will be apparent, is identical to the case just described with respect to the E_1 signal. The voltage induced by reason of I_1' with respect to the secondary of T_1 will develop a current I_3' having a polarity opposite to I_3 described with respect to forward current flow. If I_1 and I_3 are made to be equal the current components will cancel to provide an E_3 tap voltage equal to zero. In this way signals due to E_2 may be blocked from the tap to provide directivity to the circuit.

In accordance with the invention it has been found that the foregoing current relationships and operation may be

developed in a preferred manner when the turns N_1 and N_2 are adjusted in accordance with the following relationship:

$$N_1 = \frac{N_2^2 + 1}{N_2}$$

FIG. 2 relates to an embodiment of the circuit of the invention capable of handling A.C. power applied to the line for the purposes of supplying line amplifiers. This power is typically 110 volts, 5 amperes and 60 cycles in frequency. The principal components of the circuit for providing directivity are as described with respect to FIG. 1 and are similarly identified by numerals. In addition there is provided in series with the line an inductor L_1 which is capable of handling the relatively heavy current involved. The primary of T_1 is placed in parallel with L_1 and separated therefrom by capacitors C_1 and C_2 which together with L_1 form a low pass filter. The winding T_2 is connected on the input side of the line through C_1 . Additionally provided in the circuit of FIG. 2 are capacitors C_3 and C_4 which isolate the input and output paths to T_1 and T_2 with respect to ground.

The inductor L_1 is made to have an impedance which is quite small with respect to the sixty cycle power signal and is relatively large with respect to the communication signal. For example, L_1 in an actual circuit was made to be on the order of one microhenry with sufficient turns to provide an inductive reactance of considerably less than one ohm with respect to a signal at sixty cycles and an inductive reactance approaching 250 ohms at signal frequencies between 54 and 216 megacycles. The inductive reactance of the primary of T_1 was made to be slightly less than two ohms with respect to the high frequency signal range.

Because of this, essentially all of the power signal is transmitted through the path including L_1 and essentially all of the communication signal is transmitted through the path including T_1 . The capacitors C_1 and C_2 have a relatively low impedance in the higher frequency signal range, as for example on the order of one ohm and a relatively high impedance with respect to the power signal at sixty cycles, as for example on the order of a million ohms.

It has been found that C_3 and C_4 can be eliminated if the stray capacitance of the circuit is properly adjusted.

With the circuit of FIG. 2 the following components were used:

L_1 —1.0 μ h.
 C_1, C_2 —500 μ mf.
 C_3, C_4 —3.3 μ mf.
 R_1 —75 Ω .

The transformer T_1 included a primary comprised of 1 turn of #27 AWG Formvar wire wound on a ferrite core with a secondary of 4 turns of #32 AWG Formvar wire. T_2 was comprised of 3½ turns of #32 AWG Formvar wire wound onto a ferrite core.

It has been found to be advantageous to package the foregoing circuit in a way to maintain an impedance match relative to the impedance of the line. FIGS. 3-7 show a package in accordance with the invention with the circuit of FIG. 2 having its elements arranged relative to insulating and conductive parts and relative to each other in a way which permits a desirable packaging density without undesirable interaction between components and with a proper matching of impedance.

This package is comprised of a housing 12 made of conductive material formed into a box-like configuration. The housing may be made of aluminum sheet material suitably fastened together to provide a relatively rigid and moisture-proof structure. In the embodiment shown in FIGS. 3 and 4 the housing includes end plates 13, each of which has a rigid cylindrical sleeve member 14 secured thereto to accommodate line cables. These members serve as the input and output paths to the coupler

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circuit. FIG. 3 shows cable terminated to the output by means of a ferrule 15 crimped downwardly over the cable outer conductor 6 to mechanically and electrically join the cable to the sleeve member 14 and to the coupler. In this embodiment the dielectric 7 of the cable is permitted to extend down inside member 14 to a point approximately even with the surface of the end plate 13. The center conductor 8 is made to extend slightly within the housing beyond the surface of plate 13 to engage a center contact path formed by opposing and flexible contact spring members 18 carried on an insulating structure and riveted thereto as by rivets 20 in a manner shown in FIGS. 5 and 7. The contact members 18 are made to have a configuration to assure contact with the cable center conductor as the cable is worked up on sleeve 14 and to maintain such contact against displacement due to pull out.

The housing 12 includes a bottom plate 24, as shown in FIG. 3, having secured to the center thereof a connector structure 26 which is adapted to receive the tap cable. This connector structure may be any standard receptacle which will provide a mechanical and electrical connection of coaxial cable. As will be apparent, the outer conductors of the input and output cables of the transmission line and the outer conductor of the tap cable are grounded to the metallic housing 12.

Fitted within the housing 12 is an insulating structure comprised of insulating members 28, 30 and 32. These members are bound together by means of screws or the like fastened through 30 and 32 which serve as ends to member 28 which serves as a bottom for the structure. The bottom member 28 is comprised of a lamination of thin and relatively thick sheets of insulating material having therebetween a ground plane typically comprised of a sheet of copper 34 extending over the entire surface area between the two sheets comprising 28. The top of sheet 28 also carries a conductive sheet 36 etched to provide a printed circuit for connections to the various elements of the circuit and at the outside a further ground plane.

The components of the circuit can be seen to be disposed within the volume defined by 28, 30 and 32. In this regard it is preferred to maintain the lead length from each component to the printed circuit path as short as possible to minimize and control stray capacitance.

The upper portion of the printed circuit forming the connections of the package of FIG. 5 includes portions 40 which are made of a width relative to the adjacent ground paths to serve as a strip line matched to the impedance of the transmission line. In the center of the strip line is the transformer T_1 , the transformer core being shown as 42. The ends of the strip line are connected to the input and output center conductive paths of the cable through the contact members 18 in the embodiment shown in FIG. 1 and are connected at each end through the capacitors C_1 and C_2 to the input and output portions of the line.

With an actual circuit like that of FIG. 2 packaged as described a signal from 54 to 216 mc. was handled with a VSWR of the coupler approximately equal to 1.20, a line to tap attenuation of approximately 12 db., a through loss of approximately 1.0 db. and a directivity of approximately 20 db.

Having now described my invention in a preferred mode of practice, I define it through the appended claims:

What is claimed is:

1. In a directional coupler adapted to be inserted in a transmission line to provide a sample signal representative of the signal being transmitted by such line a circuit comprising a first transformer having a primary in series with said line and a secondary of N_1 turns connected between ground and an output tap providing a sample signal output of the signal current carried in said primary and said line, a second transformer connected between the input of said coupler and ground having N_2 turns, a voltage dividing connection to said N_2 turns in series through a

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resistance to the said output tap providing a sample signal of the voltage on said line, the said secondary and the said second transformer turns N_1 and N_2 having an approximate relationship relative to said primary, said resistance and said connections such that current components of transmitted signals developed in said turns will be effectively added to provide an output sample signal at said tap and current components resulting from reflected signals back through the output of said coupler will be developed in equal quantity and 180° out of phase to effectively cancel each other and provide an approximate zero output to said tap.

2. The coupler of claim 1 wherein the relationship of said turns is approximately:

$$N_1 = \frac{N_2^2 + 1}{N_2}$$

3. The coupler of claim 1 wherein there is further included a circuit path in parallel with said first transformer and in series with said line, said paths including elements connected thereto to pass low frequency power signals through said line and to block low frequency power signals from said transformers and said tap.

4. The coupler of claim 1 wherein the circuit including said transformers and resistance has a characteristic impedance approximating that of the line when viewed from either the input or output terminals of said coupler.

5. In a directional coupler of the type utilized to provide a signal sample from transmission lines, a circuit having an input and an output connected to a transmission line and a tap to supply an output sample signal of the signal transmitted on said line, the said circuit including first means connected to said tap to couple a sample to said tap which is independent of line frequency and has a polarity dependent upon sense of current flow in said line and second means connected to said line to couple a sample to said tap which is independent of line frequency and has a polarity independent of the sense of current flow in said line, said first means and said second means both being directly connected to the said input of said circuit and being connected in parallel to said tap thereby providing inductive coupling from the line to said tap and each said means having an impedance to develop an approximately equal current component supplied to said tap, the said first means providing a current component in phase with the current component of the second means with respect to forward transmission of signals through said line and providing the said current component 180° out of phase with the current component from the said second means in response to signals reflected back into the output of said circuit.

6. In a directional coupler of the type utilized to provide a signal sample from transmission lines, a circuit having an input and an output connected to a transmission line and a tap to supply an output sample signal of the signal transmitted on said line, the said circuit including first means connected to said tap to couple a sample to said tap which is of a polarity dependent upon sense of current flow in said line and second means connected to said line to couple a sample to said tap which is of a polarity independent of the sense of current flow in said line, said first means and said second means both being directly connected to the said input of said circuit providing inductive coupling from the line to said tap and each said means having an impedance to develop an approximately equal current component supplied to said tap, the said first means being adapted to provide a current component in phase with the current component of the second means with respect to forward transmission of signals through said line and being adapted to provide the said current component 180° out of phase with the current component from the said second means in response to signals reflected back into the output of said circuit, said first means including a transformer having its secondary connected to said tap to supply one current

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component, and said second means including an auto-transformer connected between the line and the tap to supply the other current component.

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