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[54] **SIGNAL DIRECTIONAL TAP**

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[51] **Int. Cl.** **H03h 7/48**

[58] **Field of Search** 333/6, 8, 10; 325/308

[56] **References Cited**

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[57] **ABSTRACT**

A directional tap for tapping electronic signals from a distribution line is shown herein. The tap includes a directional coupler having a current sensing transformer and a voltage sensing transformer. The current sensing transformer has a primary winding connected in series with the distribution line, and the voltage sensing transformer has a primary winding connected in shunt to the distribution line. The secondary windings of the two sensing transformers are connected in parallel with each other. The current sensing transformer has a turns ratio of

$$\frac{\text{primary winding (current)}}{\text{secondary winding (current)}} = \frac{1}{N \cdot r}$$

and the voltage transformer has a turns ratio of

$$\frac{\text{primary winding (voltage)}}{\text{secondary winding (voltage)}} = \frac{N}{1}$$

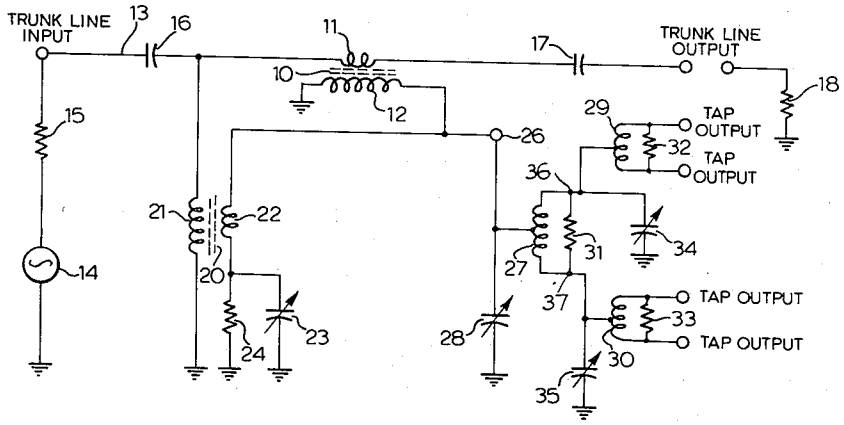
in which N is a variable representing the number of selected windings and r is the ratio Z/z in which

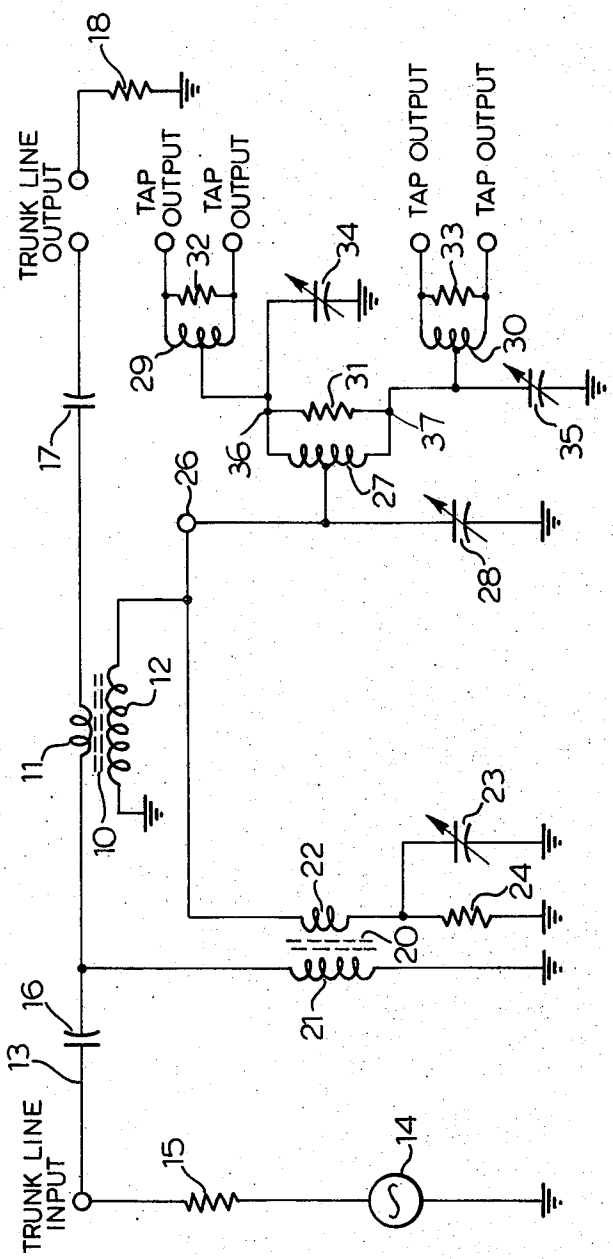
z is the characteristic impedance of the distribution line,

Z is the selected output impedance of the coupler, and

Z is not equal to z.

9 Claims, 1 Drawing Figure




TRUNK LINE INPUT
TRUNK LINE OUTPUT
TAP OUTPUT
TAP OUTPUT
TAP OUTPUT
TAP OUTPUT
10
11
12
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SIGNAL DIRECTIONAL TAP

BACKGROUND OF THE INVENTION

This invention relates to directional taps and particularly relates to directional couplers and splitters in such taps for retrieving electronic signals from a transmission trunk line or distribution line and supplying the tapped signals to a plurality of subscribers.

In a community antenna television system (CATV system) the electronic signals including the video and audio signals are transmitted by coaxial trunk lines over long distances. Amplifiers are located at periodic intervals to maintain the level of the transmitted signals. The signals in the trunk lines are fed to distribution lines to selected areas and a plurality of directional taps are located in the distribution lines to tap a portion of the signals transmitted therein. The tapped signals are fed through feed lines to the subscribers. The directional taps also provide the required impedance matching between the distribution line and its feed lines.

A directional tap conventionally comprises a directional coupler circuit connected to the distribution line for routing a portion of the signals therefrom. The retrieved signals are then divided into a plurality of equal portions by a splitter circuit for feeding to the subscribers. The splitter circuit also provides a buffer for isolating the feed lines from one another.

The directional coupler circuit comprises mainly a current sensing transformer and a voltage sensing transformer which are identical in construction and have the same turns ratio but the current sensing transformer has a relatively small primary winding and a large secondary winding. On the other hand, the voltage sensing transformer has a large primary winding and a relatively small secondary winding. The primary winding of the current sensing transformer is connected in the distribution line such that the current of the distribution line flows through this winding. The primary winding of the voltage sensing transformer is connected in shunt across the distribution line such that the voltage of the line appears across this winding. The secondary windings of the two transformers are connected in parallel aiding such that the signals retrieved from the distribution line input are in phase and additive at the coupler output; whereas, voltages induced in these secondary windings due to any reflected signals on the distribution line are 180° out of phase at the coupler output and cancel each other. In this manner, the directional coupler prevents any reflected signals to reach the tap output and permits only signals coming from one direction to be routed therethrough.

The signals at the output of the coupler circuit are fed to a splitter circuit which comprises an input shunt step-down transformer for stepping the output impedance of the directional coupler to a desirable lower value to match with the impedance of the output transformers of the splitter which divide the signals into equal portions to be supplied to the subscribers.

The main drawback in the conventional directional taps is the high insertion loss in the retrieved signals due to losses in the stray impedances in the various transformers and particularly in the shunt stepdown transformer in the splitter circuit. This drawback may be somewhat alleviated by incorporating more amplifiers in the distribution line to compensate for the losses. However, amplifiers cause noise and distortion to be injected into the signals. Such amplifiers are very expensive to make and maintain and they contribute to the major sources of unreliability in the CATV system.

Furthermore, the frequency response of such conventional taps is poorer in the low frequency bands than in the mid-frequency and high frequency bands. This is mainly due to the difficulty involved in obtaining enough shunt inductance in the transformers. Also, the stepdown transformer in the splitter circuit contributes to the bulkiness of the tap and the design of such stepdown transformer is very unwieldy.

PURPOSE OF THE INVENTION

The principal object of this invention is to provide a directional coupler which is easily adaptable to distribution lines of elected impedances to tap the signals therefrom.

It is an object of the present invention to provide a directional tap in which no stepdown input transformer is required in the splitter circuit.

It is another object of the present invention to provide a directional tap which has an even frequency response for all bands of the signals.

It is another object of the present invention to provide a directional tap having a low insertion loss.

It is yet another object of the present invention to provide a directional tap which is simple and flexible in structure.

SUMMARY OF THE INVENTION

In the directional tap of the present invention, the coupler circuit comprises a current sensing transformer and a voltage sensing transformer. The primary winding of the current sensing transformer is connected in series with the distribution line such that the current of the distribution line flows through this winding. The primary winding of the voltage sensing transformer is connected across the distribution line such that the voltage in the distribution line appears across this winding. The secondary windings of the two transformers are connected in parallel aiding and a resistor is connected in series with the secondary winding of the voltage sensing transformer. The turns ratio of the current transformer is equal to

$$\frac{\text{primary winding (current)}}{\text{secondary winding (current)}} = \frac{1}{N \cdot r}$$

wherein N is the number of windings and $r = Z/z$ in which

z is the characteristic impedance of the distribution line, and

Z is the selected output impedance of the coupler circuit and $Z \neq z$.

The turns ratio of the voltage transformer is equal to

$$\frac{\text{primary winding (voltage)}}{\text{secondary winding (voltage)}} = \frac{N}{1}$$

The variable N determines the amount of the voltage attenuation between the coupler input and the tap output.

BRIEF DESCRIPTION OF DRAWING

The foregoing and other objects and features of this invention will be more fully understood from the following description of an illustrative embodiment thereof taken in conjunction with the accompanying

drawing, the single FIGURE of which shows in schematic form, the details of a directional tap in accordance with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

Referring now to the drawing, the directional tap has a coupler circuit which includes a current sensing transformer **10** which has a primary winding **11** and a secondary winding **12.** The primary winding **11** is connected in series in a distribution line **13** to form part of the line such that the current in the line flows through this winding. The signal in the input end of this distribution line is schematically represented by a variable voltage source **14** having a voltage Vs and the impedance of the line is represented by resistor **15** which has a value z. The output end of the distribution line may be connected to a load **18** which normally also has an impedance equal to z.

The directional coupler circuit also includes a voltage sensing transformer **20** which has a primary winding **21** and a secondary winding **22.** The primary winding **21** is connected across the distribution line such that the voltage of the distribution line appears across this winding.

The secondary windings **12** and **22** are connected in parallel aiding and a resistor **24** is connected in series with the secondary winding **22** of the voltage sensing transformer. A compensation capacitor **23** is connected in parallel with the resistor **24.** The node **26** is the output node of the coupler circuit.

The turns ratio of the voltage sensing transformer is

$$\frac{\text{primary winding (voltage)}}{\text{secondary winding (voltage)}} = \frac{N}{1}$$

in which N is the number of windings in the primary winding in relation to each winding of the secondary.

The turns ratio of the current sensing transformer is

$$\frac{\text{primary winding (current)}}{\text{secondary winding (current)}} = \frac{1}{N \cdot r}$$

in which N is equal to the value N derived from the voltage sensing transformer, and $r = Z/z$ in which z is the characteristic impedance of the distribution line and Z is the selected output impedance appearing at the output node **26** of the coupler circuit and Z is not equal to z.

The voltage induced in the secondary winding **22** of the voltage sensing transformer is

$$Vs/N$$

and the current produced in the secondary winding **12** of the current sensing transformer is

$$I/N \cdot r$$

in which I is the current in the distribution line.

The current in the secondary winding **12** due to a signal coming from the input end of the distribution line is in phase with the voltage Vs/N induced in the secondary winding **22** of the voltage sensing transformer. Therefore, the signal having a voltage Vs/N will appear at the output node **26** of the coupler circuit, and the impedance seen looking into node **26** is $z \cdot r$.

If a reflected signal exists in the distribution line such that this reflected signal is flowing in the opposite direction from the output end of the line to the input end, the current produced by this reflected signal in the secondary winding **12** of the current sensing transformer will produce a voltage across resistor **24** (and capacitor **23**) which is equal and opposite to the voltage in the secondary winding of the voltage sensing transformer. Thus, the reflected signal in the distribution line will not produce any voltage at the output node **26** of the coupler circuit.

In this manner, only the signals flowing from the input end to the output end of the distribution line are routed to the output node of the coupler circuit. The total output impedance Z of the coupler circuit as appearing at the output node **26** is

$$Z = R + (z/N^2)$$

in which R is the resistance of the resistor **24.** Normally, Z is approximately equal to R since the value of z/N^2 is relatively much smaller than the value of R.

The ratio of the turns ratios of the two sensing transformers may be selected such that the output of the coupler circuit may be connected to a distribution line of any selected impedance. Also, the ratio of the turns ratios of the two sensing transformers may be selected such that the output impedance matches that of the splitter circuit or the impedance of the feed lines directly so that a stepdown transformer is not required to match the impedances of the coupler circuit and the splitter circuit as in known directional taps.

The output impedance Z of the coupler is predetermined by $z \cdot r$, where r is the preselected or desired ratio between the output impedance of the coupler and the characteristic impedance z of the distribution line. The resistor R may then be chosen equal to

$$R = Z - (z/N^2)$$

Then, the turns ratio of the current sensing transformer is made equal to 1:N.r to obtain the directional characteristics of the tap.

In the above manner, it is able to select any desired impedance at the output of the coupler, thus alleviating the necessity for any impedance changing transformer at the input of the splitter circuit as in known directional taps.

The turns ratio of the voltage sensing transformer N:1 is selected to provide the desired attenuation between the input of the coupler and the tap output. This attenuation expressed as a ratio is equal to 1/N.

It will be appreciated that the capacitor **23** and resistor **24** may be connected to the node **26** instead and the output of the coupler taken from the secondary winding of the voltage sensing transformer to achieve the same effective result. In this case, the total output impedance of the coupler is

$$Z = [R \cdot z(N \cdot r)^2]/[R + z(N \cdot r)^2]$$

$$\text{or } R = [Z \cdot z(N \cdot r)^2]/[z(N \cdot r)^2 - Z]$$

The tapped signals at the output node **26** of the coupler circuit may be divided into two equal portions by a splitter comprising an autotransformer **27** having output terminals **36** and **37.** Each output terminal **36** or **37** may be connected to a feed line to supply the feed signals to two subscribers. A compensation capacitor **28** is connected to the input of the autotransformer **27** to compensate for the leakage inductances in the autotransformer. An output resistor **31** may be connected across the terminals **36** and **37** to provide the imped-

ance match with the impedance of the feed lines and to provide electrical isolation between the feed lines. Additional autotransformers **29** and **30** may be connected to the output terminals **36** and **37** to divide the feed signals into further equal portions to supply the further feed signals to four subscribers as shown in the drawing. A compensation capacitor **34** connected to the input of the autotransformer **29** to compensate for the leakage inductances in the autotransformer, and an output resistor **32** is connected across the output terminals to provide the required impedance matching with and electrical isolation between the feed lines. Similarly, a compensation capacitor **35** is connected to the input of autotransformer **30** to compensate for the leakage inductances in this autotransformer and an output resistor **33** is connected across the output terminals to provide the proper impedance matching with and electrical isolation between the feed lines. In this manner, a selected number of autotransformers may be incorporated to make up the splitter circuit to provide signals to two, four or even eight subscribers if required. It will be appreciated that the output impedance of the coupler, and therefore the ratio *r*, changes with the number of tap outputs provided for the subscribers.

In known directional taps, the splitter circuit must necessarily and basically include the stepdown transformer as well as at least three autotransformers to provide four tap outputs, or at least one autotransformer when only two subscribers are serviced by the tap. On the other hand, the coupler circuit of the present invention may be directly connected to a selected number of subscribers by incorporating a splitter circuit comprising of a suitable number of autotransformers without any stepdown transformer. Hence, the design of the directional tap of the present invention is extremely flexible such that it can match any requirements without the presence of any unused component parts. The number of component parts is therefore greatly reduced. This reduces the manufacturing time and costs. And, due to the elimination of the stepdown transformer, the insertion loss of the directional tap is greatly reduced.

In a typical example, if a directional tap is required to be connected to a 75 ohms distribution line to provide a 20 dB signal output and the output impedance of the coupler is desirable to be 18.75 ohms as is the case when four tap outputs are required, the ratio *r* of the coupler of the present invention is

$$r = Z/z = 18.75/75 = 1/4$$

The turns ratio N/1 = 10.

The insertion loss from the input to the output ports of the directional tap is

$$\text{insertion loss (dB)} = 20 \log (1-4/N^2)$$
$$= 20 \log (1-4/100)$$
$$= -0.36 \text{ dB}$$

or equal to −0.4 dB maximum on the average, taking into consideration other imperfect component leakages and losses.

For a conventional directional tap to meet the same requirements, the turns ratio of both sensing transformers is 4:1. The insertion loss is

$$20 \log (1-1/N^2)$$
$$= 20 \log (15/16) = -0.56 \text{ dB}$$

The maximum insertion loss on the average in a conventional tap, taking into consideration the imperfect component leakages, is about −0.8 dB.

Therefore, by using the directional tap of the present invention a saving of about 0.4 dB can be achieved.

For a distribution line having ten directional taps cascaded between line amplifiers, the present directional tap provides a maximum reduction of about 4 dB in insertion loss. After a five-amplifier cascade, there is a saving of 20 dB. The gain of an amplifier in a distribution line is normally about 20 dB, so that by the use of the present directional tap, one amplifier may be eliminated in a conventional five-amplifier cascaded distribution line to achieve a saving of 20% of the number of amplifiers required. This will result in a substantial improvement in noise, distortion and reliability for the system.

Since no stepdown transformer is required in the present directional tap and a relatively large turns ratio may be incorporated in the sensing transformers, the present directional tap has an even response in all frequency bands of the transmitted signals.

Although a specific embodiment of this invention has been shown and described, it will be understood that various modifications may be made without departing from the spirit of this invention and within the scope of the appended claims.

What I claim as new and desire to protect by Letters Patent of the United States is:

1. In a directional tap for tapping electronic signals from a distribution or transmission line and supplying the tapped signals to at least one subscriber, said directional tap including a directional coupler means having a current sensing transformer and a voltage sensing transformer wherein said current transformer has a primary winding connected in said distribution line and said voltage sensing transformer has a primary winding connected in shunt across said distribution line, the secondary windings of the sensing transformers being connected in parallel, the improvement comprising said current sensing transformer having a turns ratio of

$$\frac{\text{primary winding (current)}}{\text{secondary winding (current)}} = \frac{1}{N \cdot r}$$

and said voltage sensing transformer having a turns ratio of

$$\frac{\text{primary winding (voltage)}}{\text{secondary winding (voltage)}} = \frac{N}{1}$$

wherein *N* is the number of windings and *r* is the ratio *Z*/*z* in which

z is the characteristic impedance of said distribution or transmission line and

Z is a selected output impedance of said coupler means, and $Z \neq z$.

2. A directional tap according to claim **1** including a resistor R connected in parallel with the secondary winding of the current sensing transformer, said resistor having a resistance equal to

$$R = [Z.z(N \cdot r)^2]/[z(N \cdot r)^2 - Z$$

3. A directional tap according to claim **1** including a

resistor R connected in series with the secondary winding of the voltage sensing transformer, said resistor having a resistance equal to

$$R = Z - z/N^2$$

4. A directional tap according to claim **2** including a splitter means connected to said coupler means for receiving the tapped signals from an output port of said coupler means and for dividing said tapped signals into two equal feed signals for servicing two subscribers, said splitter means comprising an auto-transformer having a center tap connected to said output port of said coupler means and two output terminals for supplying said feed signals through feed lines to said subscribers.

5. A directional tap according to claim **3** wherein the resistance of said resistor R is substantially equal to Z.

6. A directional tap according to claim **3** including a splitter means connected to said coupler means for receiving the tapped signals from an output port of said coupler means and for dividing said tapped signals into two equal feed signals for servicing two subscribers, said splitter means comprising an auto-transformer having a center tap connected to said output port of said coupler means and two output terminals for supplying said feed signals through feed lines to said subscribers.

7. A directional tap according to claim **6** including a compensation capacitor connected to said center tap for compensating leakage inductances in said auto-transformer, and an output resistor connected across said output terminals.

8. A directional tap according to claim **7** including two output autotransformers, each of said output auto-transformers having a center tap connected to one of said two output terminals for dividing said feed signals into further equal feed signals, and having four output ports for supplying said further feed signals through feed lines operative for servicing four subscribers.

9. A directional tap according to claim **8** wherein each of said center taps of said output autotransformers has a compensation capacitor connected thereto for compensating leakage inductances in said output auto-transformers, and each output autotransformer having an output resistor connected across its output ports.

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