March 28, 1967 M. L. LEPPERT 3,311,831

COAXIAL COMBINER-SEPARATOR FOR COMBINING OR SEPARATING DIFFERENT ELECTRICAL SIGNALS

Filed July 30, 1964 2 Sheets-Sheet 1

FIG. 1

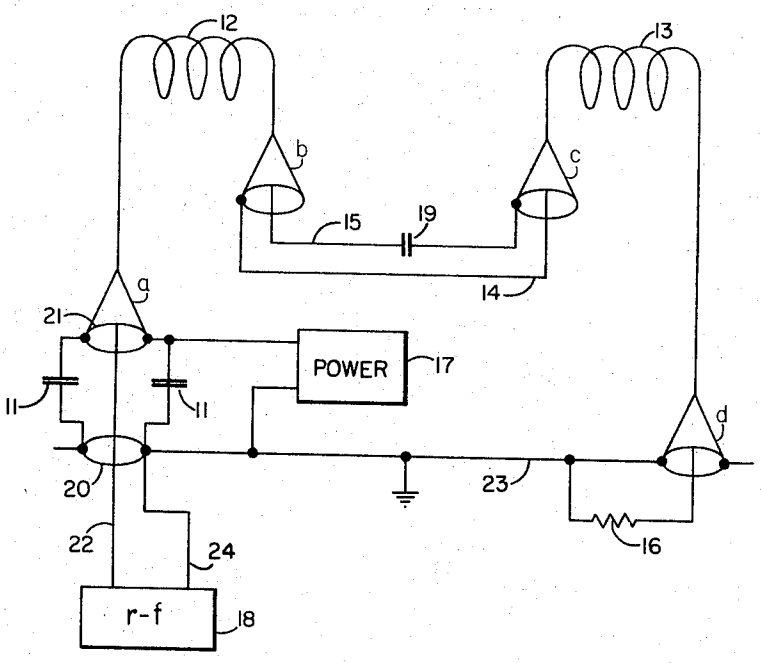


FIG. 3

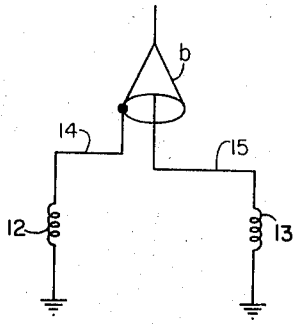
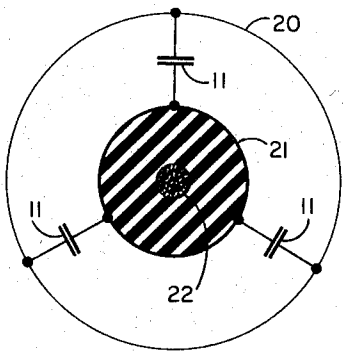


FIG. 2



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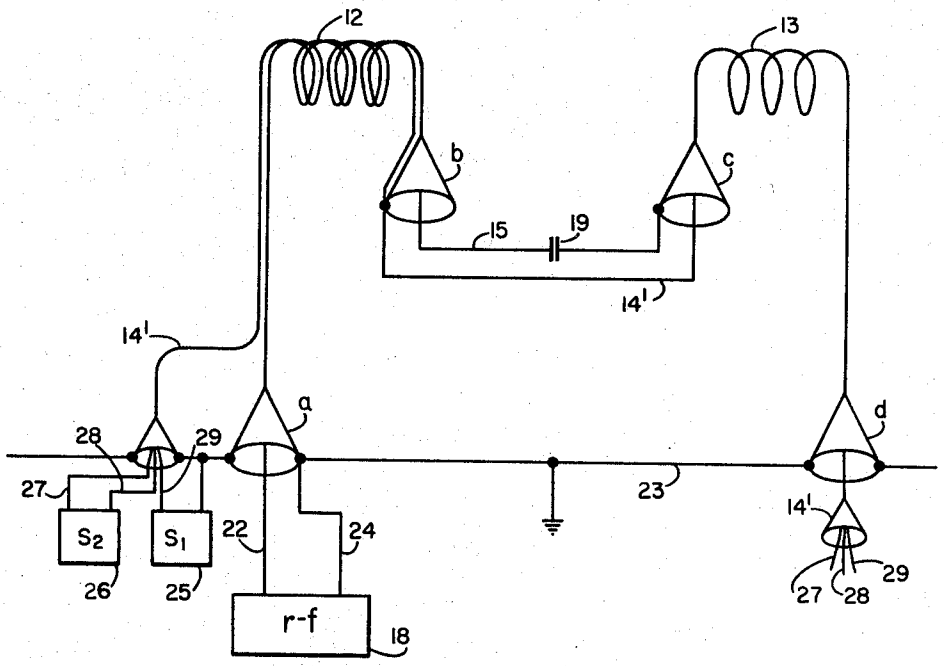
ATTORNEY

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FIG. 4



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3,311,831

COAXIAL COMBINER-SEPARATOR FOR COMBINING OR SEPARATING DIFFERENT ELECTRICAL SIGNALS

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13 Claims. (Cl. 325—178)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to electrical signal combiners and more particularly to a coaxial signal combiner or separator.

Where antennas are installed at distances from the transmitter or receiver, as is often true when receivers and transmitters are separately housed, the cable loss can be sufficiently high to require amplifiers at the antennas. It is also commonly found that electrical power is needed at the antenna site. When these problems are encountered, it is the present practice to install a power line to the antenna. While laying a power cable is often the most practical solution at the time of original antenna site construction, where the site is already established and additional power cables are needed, the added installation can be time consuming and expensive.

The general purpose of the present invention is to avoid the aforedescribed practice and its attendant disadvantages by providing a novel and relatively inexpensive arrangement whereby both operating power and intelligence signals may be simultaneously supplied to a remotely located antenna over a common conductive path.

It is accordingly, an object of the present invention to provide a means for supplying power to distant antennas over existing signal cables.

Another object of the present invention is to provide a combiner for combining radio frequency and low frequency power signals to be transmitted together over the same coaxial cable.

Another object is to provide a separator for separating combined radio frequency and low frequency power signals transmitted over a single coaxial cable.

It is another object to provide a combiner for combining a radio frequency signal and a plurality of other signals for single coaxial line transmission.

A further object of the present invention is to provide a coaxial combiner for combining high and low frequency signals for coaxial transmission.

Another object of the present invention is to provide a coaxial separator for separating combined high and low frequency signals transmitted over a coaxial line.

It is another object to provide a separator for separating a plurality of combined signals received from a single coaxial transmission line.

In a preferred embodiment of the invention, a balun, consisting of two lengths of coaxial cable wound to form inductors, interconnected shield to inner conductor and terminated at one end shield to ground by capacitive coupling and at the other end by a resistor from the center conductor to ground, provides the signal combining or separating function. The center conductor at the free end of the first coaxial length is connected to a high frequency source, with a low frequency signal being applied to the outer conductor. The terminal resistor provides a realization of these two combined signals as well as providing an impedance match for the circuit to result in a voltage standing wave ratio of 1.2 to 1. This necessary near distortion free characteristic is obtained by balanced

impedance at the point of inter-connection of the two coaxial lengths.

In a second embodiment, the need for capacitive input coupling is obviated by the use of a coaxial length having a hollow inner conductor which houses a plurality of auxiliary signal conductors. The auxiliary signals, one of which may be low frequency power, are combined with the radio frequency signal for single coaxial cable transmission.

The advantages and manner of operation of the invention will become more fully apparent and better understood from the following detailed description of the invention, as illustrated in the accompanying drawings, in which:

FIG. 1 illustrates, partly in block diagram and partly in schematic, a preferred embodiment of the present invention;

FIG. 2 is an end-view of coaxial length **12** as seen through a hole in the ground plane;

FIG. 3 is a simplified radio frequency representation of the coaxial cable interconnection; and

FIG. 4 illustrates, partly in block diagram and partly in schematic, another embodiment of the present invention.

Referring now to the drawings wherein like reference characters designate like parts throughout, there is shown in FIG. 1 first and second coaxial lengths **12** and **13** interconnected at ends *b* and *c*, inner conductor to outer conductor, via lines **14** and **15**. These two coaxial lengths are wound to form inductors. The free end *a* of coaxial length **12** has its outer conductor **21** coupled to the electrical common or ground plane **23** by capacitors **11**, while the center conductor **22** passes through a hole **20** in this ground plane to receive radio frequency signals from source **18**. Radio frequency source **18** thus is applied across inner conductor **22** and ground via line **24**. Capacitors **11** serve also as an input impedance across which a low frequency power signal, as from source **17**, is applied. With reference to ground plane **23**, it is preferred to encompass the circuit of FIG. 1, excluding signal sources **17** and **18**, within an electrically conductive box so that hole **20** is actually a hole in the wall of this box. Capacitor **19**, coupling the inner conductor of coaxial length **12** to the outer conductor of coaxial length **13**, serves to improve the low frequency response of the circuit by tuning out the effects of the inductive reactance. Free end *d* of coaxial length **13** has its outer conductor grounded and its inner conductor terminated by resistor **16** to ground. Resistor **16** is an output impedance across which both the radio frequency signal and the power signal appear. The coaxial transmission line to the antenna or other device to receive these signals is connected in place of this resistor, so that when the signals are to be separated at the other end of the transmission line by the inverse circuit of that shown in FIG. 1, the characteristic impedance of each circuit serves as the load for the other and resistor **16** is not needed.

While the drawings show coaxial lengths **12** and **13** separated by a relatively large length compared to the depicted length of these conductors, this is only for the purpose of showing the interconnection and is not to be interpreted as representative of the physical dimensions. The interconnection of these two conductors must be physically small in order for there to be high frequency conduction.

FIG. 2 shows the physical connection of capacitors **11** to the outer conductor **21** of free end *a* of coaxial length **12**, seen through hole **20** in ground plane **23**. This figure shows the preferred embodiment of the capacitor coupling, in that three capacitors **11** equally spaced about conductor **21** cause this connection to appear as if there

were no break at all in the conductor to an R.-F. signal. Also shown in this figure is the center or inner conductor **22** and the dielectric between the two conductors shown cross-hatched.

FIG. 4 illustrates an alternate embodiment of the present invention. Here, coaxial length **13** contains a hollow inner conductor **14'**. The interconnection of this coaxial length with coaxial length **12** is the same as that shown in the embodiment of FIG. 1. Inner conductor **14'**, however, does not terminate at end *b* of coaxial length **12**, but continues along this length winding in parallel while length **12** forms an inductor and terminates at input end *a*. This hollow inner conductor houses a plurality of control conductors **27**, **28** and **29**. Sources **25** and **26**, shown respectively with a ground return and an independent return, provide control signals or various power signals to be used by the antenna or other load means. Source **25** could thus provide the power delivered by source **17**, shown in FIG. 1, while source **26**, connected across control conductors **27** and **28**, can provide servo control information. Conductors **27**, **28** and **29** are shown at the output end *d* of coaxial length **13** where they, along with this coaxial length, connect to a hollow inner conductor coaxial transmission line.

The terminal resistor **16** of the FIG. 1 embodiment is not shown in the circuit of FIG. 4 because of the particular coaxial cable used in this latter circuit. The hollow inner conductor coaxial cable balun is preferably terminated by its inverse circuit, used as a separator, at the other end of the transmission line. The inverse circuit is the same as that shown in the drawings, with the exception of the free end of coaxial length **13** serving as the circuit input instead of the free end of coaxial length **12**.

It should be noted that in addition to the increased signal handling flexibility of the embodiment of FIG. 4, capacitors **11**, necessary for the circuit of FIG. 1, are no longer needed, due to inner conductor **14'** being brought out to the circuit input to directly receive the auxiliary signals from sources S_1 and S_2.

The transmission line receiving the combined radio frequency and control signals is in turn terminated by the circuit shown in FIG. 4. At this end the signals are separated, sources **18**, **25** and **26** being replaced for this purpose by the devices to independently utilize these signals.

FIG. 3 is a diagram to aid in the understanding of the low frequency requirements of the present invention and will be used in the explanation of its operation. This figure represents the radio frequency picture at end *b* of coaxial length **12**. If the inductive reactances of the inductors formed by coaxial lengths **12** and **13** are equal and large compared to the characteristic impedance of these interconnected coaxial lengths, if the conductor so formed is terminated by a resistance equal to this characteristic impedance, and if the output impedance of the radio frequency source is matched to this line, the circuit is said to be balanced, and radio frequency signal source **18** and resistor **16** will appear to be across conductors **14** and **15** at the point of interconnection. With source **18** appearing to be across these conductors, inductor **12** appears to couple the outer conductor to ground while inductor **13** appears in the path of the inner conductor from end *b* to ground. Since the resistive load **16** also appears across conductors **14** and **15** at end *b*, it is readily seen that the frequency-dependent reactances of these inductors **12** and **13** determine the low frequency limit of the high frequency signal to be passed by the circuit as these reactances decrease in value with frequency, approaching a short circuit in the limit. At low radio frequencies capacitor **19** will appear in this figure in series with inductor **13**. This capacitor, of a value selected to resonate with inductors **12** and **13** at the lower frequencies, compensates for the low frequency limiting effect of these inductors.

From the foregoing, it is readily seen that it is necessary that the inductive reactance of inductors **12** and **13** be large compared to the characteristic impedance of the coaxial line forming these two inductors. This requirement prevails only for the R.-F. signal and is not a limitation for the low frequency power signal. This signal has therefore, no low frequency restriction and can be a direct current signal.

The requirement that the inductive reactance be much greater than the characteristic impedance also requires that the high frequency signal be at least several orders in magnitude higher than the low frequency signal.

Another requirement in the relationship between inductors **12** and **13** and the other operating parameters of the circuit of the present invention is that the individual effective length of coaxial lengths **12** and **13** be less than one-half wavelength at the highest frequency to be passed. Effective length, for the purposes of the present circuit, is defined to be the electrical length or the length that inductors **12** and **13** appear to be when considering distributed capacitance due to the spacing between the windings of these inductors, the effect of the capacitive reactance thereof with frequency, the actual length of these coaxial conductors, and the number of turns. This effective length must be less than one-half the wavelength of the highest frequency passed, since at a length equal to one-half wavelength the transmission line appears to be a short circuit to the signal at this frequency. While it is possible to choose an effective length greater than one-half wavelength at the highest frequency to be passed, but less than the next multiple half-wavelength, this will not provide continuous frequency band transmission. Thus, radio frequency transmission by the present circuit has a low frequency limit determined by the inductive reactance of inductors **12** and **13** and a high frequency limit at the frequency at which inductors **12** and **13** become half-wave resonant.

Another operating requirement of the circuit of the preferred embodiment of the present invention is that the capacitive reactance of capacitors **11** be very low compared to the characteristic impedance of this transmission line. It is necessary for these capacitors to serve as a high impedance for the low frequency signal supplied by source **17**, and at the same time to maintain electrical continuity between the outer conductor of coaxial length **12** and the ground plane **23** to form a return path for the radio frequency signal. Actual values selected for a characteristic impedance of 50 ohms was an inductive reactance of 200 ohms and a capacitive reactance of approximately 2½ ohms at the low frequency limit.

The present invention, while described as a signal combiner, is equally utilizable as a signal separator. Indeed, when used in the preferred embodiment, to combine power with the radio frequency signal on the coaxial line to an antenna, it will be necessary to separate these two signals at the antenna site for their independent use.

Since various changes and modifications may be made in the practice of the invention herein described without departing from the spirit or scope thereof, it is intended that the foregoing description shall be taken primarily by way of illustration and not in limitation except as may be required by the appended claims.

What is claimed is:

1. An electrical circuit for simultaneously transmitting a plurality of discrete signals of different frequencies, comprising:

a pair of coaxial cables, each having inner and outer conductors,

said cables being wound to form separate inductors, the inner and outer conductors of one of said cables being coupled respectively to the outer and inner conductors of the other of said cables;

first conductive means connected to the free end of said one cable to permit conduction of one of said plurality of signals along the inner conductor thereof,

second conductive means connected to the free end of said one cable for permitting at least one of the others of said plurality of signals to be conducted along the outer conductor thereof;

and an electrical common connecting said first and second conductive means with the outer conductor of said other cable at the free end thereof.

2. An electrical circuit as recited in claim 1, including capacitor means to couple the inner conductor of said one cable to the outer conductor of said other cable.

3. An electrical circuit as recited in claim 1, wherein said second conductive means is a plurality of capacitors connecting the outer conductor of said one cable to said electrical common.

4. An electrical circuit as recited in claim 1, wherein the inner conductor of said other cable is hollow and houses a plurality of auxiliary signal conductors,

said hollow conductor being wound with said one cable to the free end thereof,

whereby said plurality of auxiliary signal conductors form said second conductive means.

5. An electrical circuit suitable for combining or separating signals, comprising:

first and second lengths of coaxial cable wound to form separate inductors,

the outer conductor of said first coaxial length being coupled to the inner conductor of said second coaxial length;

capacitor means coupling the inner conductor of said first coaxial length to the outer conductor of said second coaxial length,

the inner conductor of said second coaxial length being hollow and containing a plurality of conductors,

said hollow inner conductor being wound with said first coaxial length to the free end thereof, where said plurality of conductors provide electrical conduction for some of said signals, the other of said signals being conducted by the inner conductor of said first coaxial length;

and an electrical common connecting said hollow inner conductor and the outer conductor of said first coaxial length at the free end thereof,

whereby signals applied to the free end of said first coaxial length and to the conductors contained within said hollow conductor will be combined, and combined signals appearing at the free end of said second coaxial length will be separated.

6. An electrical circuit as recited in claim 5, wherein said inductors formed by said coaxial length have a combined reactance greater than the characteristic impedance of the coaxial lengths, and the indivdiual effective length of said coaxial lengths is less than one-half wavelength at the highest frequency to be passed by said electrical circuit.

7. An electrical circuit suitable for combining or separating high and low frequency signals, comprising:

first and second lengths of coaxial cable wound to form

inductors and interconnected inner conductor to outer conductor;

capacitor means coupling the outer conductor of said first coaxial length at its free end to an electrical common and forming a high impedance allowing the conduction of said low frequency signal along the outer conductor thereof, the inner conductor of said first coaxial length to conduct said high frequency signal; and

resistance means coupling the inner conductor of said second coaxial length to said electrical common at the free end thereof, the outer conductor being directly connected to said electrical common,

whereby separate signals received at the free end of said first coaxial length will be combined across said resistance means, or combined signals received by said resistance means will be separated, the low frequency signal being conducted by the outer conductor of said first coaxial length and the high frequency signal being conducted by the inner conductor of said first coaxial length.

8. An electrical circuit as recited in claim 7, wherein the value of said capacitor means is selected to present a low impedance to said high frequency signal and a high impedance to said low frequency signal.

9. An electrical circuit as recited in claim 7, wherein said inductors formed by said coaxial length have a combined reactance greater than the characteristic impedance of the coaxial lengths, and the individual effective length of said coaxial lengths is less than one-half wavelength at the highest frequency to be passed by said electrical circuit.

10. An electrical circuit as recited in claim 7, wherein said low frequency signal is a direct current signal.

11. An electrical circuit as recited in claim 7, wherein said low frequency signal is alternating current power and said high frequency signal is in the radio frequency spectrum.

12. An electrical circuit as recited in claim 7, wherein said interconnection between said first and second coaxial lengths contains frequency sensitive means.

13. An electrical circuit as recited in claim 12, wherein said frequency sensitive means is a capacitor, and the voltage standing wave ratio of said electrical circuit is no greater than 1.2 to 1.

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