March 31, 1970 G. H. KAM 3,504,306

TRIAXIAL BALUN FOR BROADBAND PUSH-PULL POWER AMPLIFIER

Filed June 2, 1969

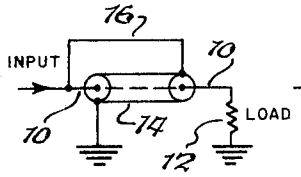


Fig. 1.

PRIOR ART

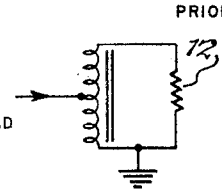


Fig. 2.

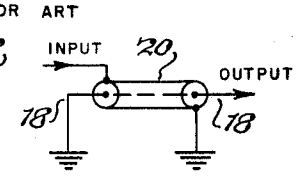


Fig. 3.

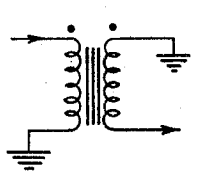


Fig. 4.

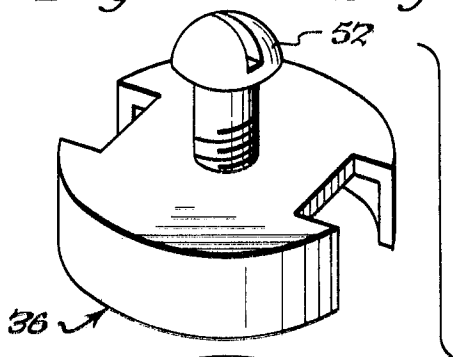


Fig. 8.

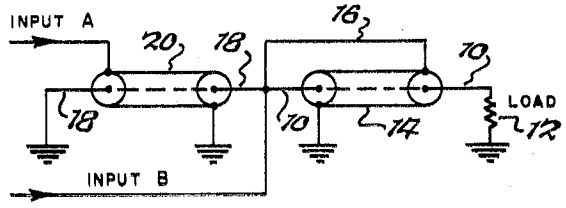
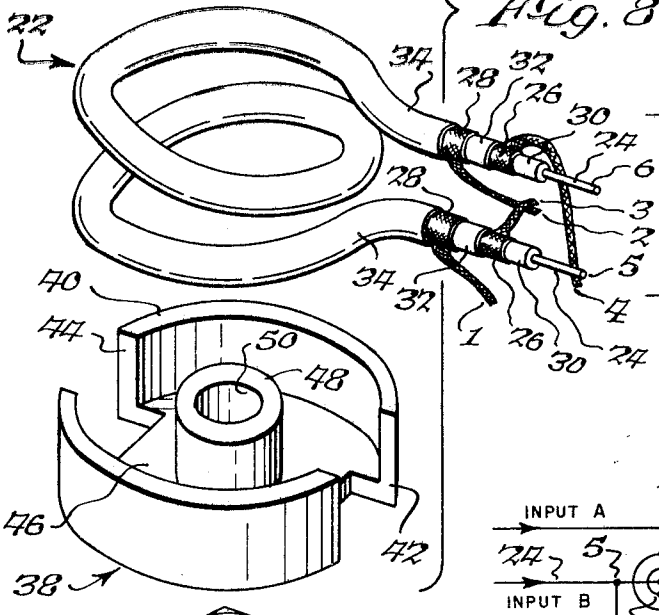


Fig. 5.



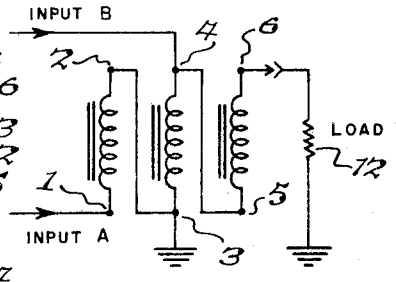
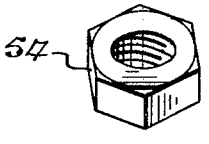


Fig. 7.



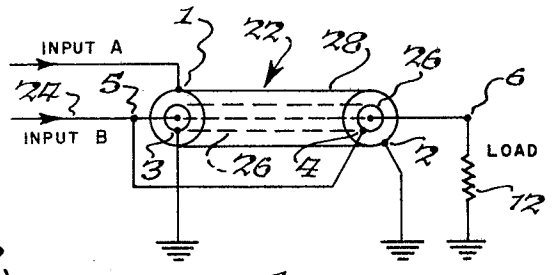


Fig. 6.

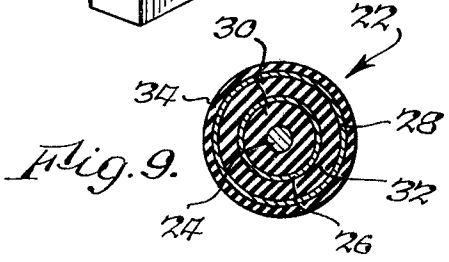


Fig. 9.

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TRIAXIAL BALUN FOR BROADBAND PUSH-PULL POWER AMPLIFIER

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U.S. Cl. 333—26 6 Claims

ABSTRACT OF THE DISCLOSURE

A transformer packaging arrangement comprising the combination of a reversing transformer and a step-up transformer, both of which are coaxial line sections, into a single triaxial section cup core assembly.

BACKGROUND OF THE INVENTION

This invention relates generally to transformers and, more particularly, to an improved transformer packaging arrangement for providing proper phasing and impedance matching at the input or output of a broadband push-pull power amplifier.

The use of transmission line and balun techniques for matching has been found to provide significant advantages in broadband VHF-UHF amplifier applications. Such an approach obviates the need for high frequency peaking or tuning, thereby substantially reducing the phase shift problems of push-pull operation. Further, with conventional matching networks, impedance is optimized at the high frequency end of the band, thereby resulting in a definite roll-off at lower frequencies due to mismatch, especially if the bandwidth is in excess of one octave. The use of transmission line transformers or baluns on the other hand provides a much more optimum match across the band.

Some typical transmission line applications and conventional packaging arrangements are shown in FIGS. 1–4. The pictorial schematic of FIG. 1 shows a half-balun coaxial line device that may be used as an impedance transformer at the output of a single stage power amplifier to obtain a 2:1 step-up in voltage and a 4:1 step-up in impedance. The corresponding transformer schematic is shown in FIG. 2. The coaxial line of FIG. 1 includes a center conductor **10** having an input end connected to the output of an amplifier stage (not shown), an output connected to a load, represented by resistor **12**, and an outer conductor **14** connected to ground at the input end of the coaxial line. A short jumper lead **16** connects the input end of center conductor **10** to the output end of outer conductor **14**. The requisite isolation between the input and output ends of outer conductor **14** is provided by looping the coaxial line within a ferrite cup core (not shown in the schematic). The use of a jumper lead **16**, instead of a second coaxial line, is permitted by using a coaxial line which is significantly shorter than a quarter wavelength so as to make the propagation delay insignificant.

To provide the desired 4:1 impedance transformation, a coaxial cable is selected which has the appropriate characteristic impedance, as determined by the spacing between the center conductor **10** and outer conductor **14** and the dielectric constant of the insulation therebetween. For example, if the input impedance is 12.5 ohms and the output impedance of load **12** is 50 ohms, a coaxial cable having a 25 ohm characteristic impedance would be selected. A step-up impedance transformer of this type is particularly useful and practical at frequencies below 100 mHz.

A conventional transmission line reversing transformer

is illustrated by the pictorial schematic of FIG. 3, with the corresponding transformer schematic being shown in FIG. 4. In this instance, the center conductor of the coaxial line is designated by the numeral **18**, and the outer conductor is identified by the numeral **20**. In order to provide a 180° polarity reversal between the input and output terminations of this coaxial section, the input signal is connected to outer conductor **20** at one end of the coaxial line while the output signal is obtained from the center conductor **18** at the opposite end of the line, center conductor **18** being grounded at the input end of the line and outer conductor **20** being grounded at the output end. In like manner to the impedance transformer of FIG. 1, the opposite ends of the reversing transformer outer conductor **20** may be isolated from each other by looping the coaxial line within a cup core device. To ensure an inherently broadband device, the characteristic impedance of the coaxial line is selected to be equal to the terminating impedances.

In order to provide proper phasing and impedance matching at the output of a broadband push-pull amplifier, the reversing section of FIG. 3 can be serially connected with the impedance transformer of FIG. 1 as illustrated in FIG. 5. The output of one of the two transistors, or vacuum tubes, comprising the push-pull amplifier is connected to one terminal of the reversing transformer outer conductor **20**, as represented by input line A. The output of the other transistor, represented by input line B, is connected to the input terminal of the impedance transformer, represented by the junction of center conductors **10** and **18** and jumper leads **16**. In this manner, a voltage signal applied at input A is phase reversed 180° for in-phase summing with the signal applied at input B, and the resulting combined signal is matched with the impedance of load **12** by the step-up transformer section. The serial combination of FIG. 5 is adaptable to provide input matching and phasing for a push-pull amplifier by using the load-connected terminal of center conductor **10** as the input and obtaining the outputs from the terminal to which inputs A and B are connected. Conventionally, the resulting physical packaging arrangement for this transformer combination comprises two serially connected coaxial line cup core assemblies.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide an improved packaging arrangement for transmission line transformer combinations.

It is another object of the invention to provide a more compact and efficient transmission line transformer packaging arrangement for providing proper phasing and impedance matching at the input or output of a broadband push-pull power amplifier.

Briefly, these objects are attained by a transmission line transformer packaging arrangement comprising a cable having center, inner and outer conductors. The inner conductor is separated from the center conductor by insulation, and the outer conductor is separated from the inner conductor by insulation. One end of the cable is adapted to receive an input signal, and the other end of the cable is adapted to provide an output signal. The terminal of the center conductor at one end of the cable is connected to the terminal of the inner conductor at the other end of the cable, whereby the inner conductor provides the dual function of a coaxial line outer conductor with respect to said center conductor and a coaxial line center conductor with respect to said outer conductor.

BRIEF DESCRIPTION OF THE DRAWINGS

This invention will be more fully described hereinafter in conjunction with the accompanying drawings, in which:

FIG. 1 is a pictorial schematic of a coaxial line imped-

ance transformer to which previous reference has been made;

FIG. 2 is a transformer schematic of the device shown in FIG. 1, also referred to earlier;

FIG. 3 is a pictorial schematic of a coaxial line reversing transformer to which previous reference has been made;

FIG. 4 is a transformer schematic of the device shown in FIG. 3, also referred to earlier;

FIG. 5 is a pictorial schematic of a serial combination of the coaxial line sections shown in FIGS. 1 and 3 adapted for connection at the output of a push-pull amplifier, this figure also having been referred to earlier;

FIG. 6 is a pictorial schematic of a triaxial cable section embodying the reversing and impedance transformer functions of FIG. 5 in accordance with the invention;

FIG. 7 is a transformer schematic corresponding to the device shown in FIG. 6;

FIG. 8 is an exploded perspective view of a cup core assembly including the triaxial cable section of FIG. 6 in the form of a coil; and

FIG. 9 is an enlarged cross section of the triaxial cable.

DESCRIPTION OF PREFERRED EMBODIMENT

For a better understanding of the present invention, together with other and further objects, advantages and capabilities thereof, reference is made to the following disclosure and appended claims in connection with the above-described drawings.

The present invention comprises the use of a triaxial cable to provide the functions of two coaxial line sections. More particularly, the reversing and impedance transformer functions of FIG. 5 are embodied in a single triaxial cable cup core assembly, thereby providing a much more compact packaging arrangement and significantly reducing power losses.

FIG. 6 is a pictorial schematic showing a section of triaxial cable **22** connected in accordance with the invention to provide the reversing and impedance transformer functions of FIG. 5. Triaxial cable **22** comprises a center conductor **24**, an inner conductor **26** surrounding the center conductor, and an outer conductor **28** surrounding the inner conductor. Insulation is disposed between the center and inner conductors and between the inner and outer conductors.

As will become clear from the following description, the terminations of the three conductors comprising triaxial cable **22** are connected in a manner whereby outer conductor **28** corresponds to outer conductor **20** of the coaxial line reversing transformer, center conductor **24** corresponds to center conductor **10** of the coaxial line impedance transformer, and inner conductor **26** provides a dual function by corresponding to both center conductor **18** of the reversing transformer and outer conductor **14** of the impedance transformer. Accordingly, one end of outer conductor **28** is adapted as a signal terminal **1** to which input line A is connected, and a terminal **2** at the opposite end of outer conductor **28** is connected to ground. The terminal of inner conductor **26** at the input end of the triaxial cable, designated by the numeral **3**, is also connected to ground. Terminal **4** at the opposite end of the inner conductor is connected back to terminal **5** of center conductor **24** at the input end of the cable. Center conductor terminal **5** is also adapted as a signal terminal to which input line B is attached, and the connection between terminals **4** and **5** corresponds to jumper lead **16** of the coaxial line impedance transformer. At the opposite end of the triaxial cable from that adapted to receive input signals, center conductor **24** has a terminal **6** adapted to provide an output signal to the load, represented by the resistor **12** connected between terminal **6** and ground. The transformer schematic corresponding to the FIG. 6 arrangement is shown in FIG. 7.

In order to provide a triaxial line with insignificant propagation delay, the length of cable **22** should be shorter than a quarter wavelength of the intended operating frequency. The requisite isolation between the opposite terminals **1** and **2** of outer conductor **28** and between the opposite terminals **3** and **4** of inner conductor **26** is provided by looping the triaxial cable to form a coil and enclosing the coil in a cup core, as shown in FIG. 8.

A suitable flexible cable construction for this application is illustrated by the enlarged cross section of triaxial cable **22** shown in FIG. 9. A layer of insulating material **30** is wrapped or molded about a wire comprising center conductor **24**, and a conductive braid enclosing the insulation **30** comprises the inner conductor **26**. Outer conductor **28** comprises a second conductive braid, which is separated from the inner conducting braid **26** by a layer of insulating material **32**, the outer braid **28** is then enclosed by a covering layer of insulation **34**. As the transmission line comprising the inner and outer conductors is connected to provide the function of the reversing transformer of FIG. 3, the spacing between conductive braids **26** and **28** and the dielectric constant of insulation **32** are selected to provide a characteristic impedance for that transmission line which is approximately equal to the impedance of input A. The spacing between center conductor **24** and braid **26** and the dielectric constant of insulation **30**, therefore, are selected to provide a characteristic impedance for the transmission line comprising conductors **24** and **26** which is approximately twice the characteristic impedance of the transmission line formed by inner conductor **26** and outer conductor **28**. In this manner, the transmission line formed by the center and inner conductors will provide the step-up transformer function (FIG. 1) for which it is connected.

As illustrated in FIG. 8, the coil formed by cable **22** requires only about two turns within the cup core to provide the requisite isolation. The cup core is composed of a ferrite material and has two identical halves **36** and **38**. Each of the half cup cores has an outside wall **40** having a pair of diametrically opposite slots **42** and **44**, a base portion **46**, and a cylindrical projection **48** having an axial hole **50** therethrough. The coil of triaxial cable **22** is fitted within cup core half **38** so that the bottom of the coil rests on a ferrite base **46**, the sides of the coil are partially enclosed by ferrite wall **40**, the ferrite cylindrical projection **48** passes through the center of the coil, and the cable ends are passed through slot **42** so that the stripped portions are accessible outside the cup core. The top half **36** of the cup core is then assembled to the bottom half **38** to fully enclose the coil of triaxial cable, except for slots **42** and **44**, by means of a screw **52** passing through the axial holes **50** and secured by a nut **54**.

Cup cores suitable for this application are available from various sources; for example, Ferroxcube Corp. of America, Saugerties, N.Y., and Magnetics Inc., Butler, Pa.

The physical terminations and connections of the transmission line transformer are also illustrated in FIG. 8 by the use of reference numerals corresponding to those employed in FIG. 6. Hence, terminal **1** of conductive braid **28** and terminals **5** and **6** of center conductor **24** are adapted as signal terminals. Terminal **2** of conductive braid **28** and terminal **3** of conductive braid **26** are joined together and adapted to be connected to ground. Terminal **4** of conductive braid **26** is connected to terminal **5** of center conductor **24** to provide the function of impedance transformer jumper wire **16**. If the transformer of FIG. 8 is to be employed as a push-pull output device, as in FIG. 6, conductive braid terminal **1** and the junction of terminals **4** and **5** are connected to the respective push-pull amplifier outputs, while center conductor terminal **6** is connected to the load. On the other hand, if the transformer were to be employed as an input device, terminal **6** would be the transformer input and terminal **1** and the junction of terminals **4** and **5** would provide the transformer outputs. More specifically, as an input device, terminal **1** and the junction of terminals **4** and **5** would be

connected to the respective inputs of the push-pull amplifier, and terminal **6** would be connected to the output of a drive amplifier.

In summary, the present invention embodies the functions of two coaxial line transformers into a single triaxial line section. In part, this feature is accomplished by connecting the triaxial line inner conductor to provide the dual function of a coaxial line outer conductor with respect to the triaxial center conductor and a coaxial line center conductor with respect to the triaxial outer conductor. As a result, the number of cup core assemblies required to provide the dual transformer function is reduced to one, thereby reducing power losses by one-half and minimizing the circuit layout space required. In the case of high power solid-state electronic equipment employing a plurality of push-pull amplifiers, the above noted advantages become increasingly significant.

It is contemplated that the present invention may also be embodied in a packaging arrangement including a toroid in lieu of a cup core enclosure. Further, the three-conductor cable may be embodied in various strip transmission line configurations.

What is claimed is:

1. A transmission line transformer packaging arrangement comprising, in combination, a cable including first, second and third conductors, and insulation disposed between said first and second conductors and between said second and third conductors, one end of said cable being adapted to receive an input signal, the other end of said cable being adapted to provide an output signal, and the terminal of said first conductor at a first end of said cable being connected to the terminal of said second conductor at the second end of said cable whereby said second conductor is a common component of two transmission lines, one of which comprises said first and second conductors and the other of which comprises said second and third conductors.

2. A transformer in accordance with claim **1** wherein said first conductor is a center conductor, said second conductor is an inner conductor surrounding said center conductor, said third conductor is an outer conductor surrounding said inner conductor, and said inner conductor is operative to provide the dual function of a coaxial line

outer conductor with respect to said center conductor and a coaxial line center conductor with respect to said outer conductor.

3. A transformer in accordance with claim **2** wherein the terminals of said center conductor at both ends of said cable are adapted as signal terminals, the terminal of said outer conductor at said first end of said cable is adapted as a signal terminal, and the terminal of said inner conductor at said first end of said cable and the terminal of said outer conductor at said second end of said cable are adapted to be connected to ground.

4. A transformer in accordance with claim **3** wherein the spacing between said inner and outer conductors and the dielectric constant of said insulation therebetween are selected to provide a first characteristic impedance for the transmission line comprising said inner and outer conductors, and the spacing between said center and inner conductors and the dielectric constant of said insulation therebetween are selected to provide a second characteristic impedance for the transmission line comprising said center and inner conductors which is approximately twice said first characteristic impedance.

5. A transformer in accordance with claim **4** wherein said cable is arranged to form a coil, and further including a ferrite cup core enclosing the coil formed by said cable.

6. A transformer in accordance with claim **5** wherein said cable is shorter than a quarter wavelength of the intended operating frequency.

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U.S. Cl. X.R.

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