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ADJUSTABLE VOLTAGE DIVIDER CIRCUIT

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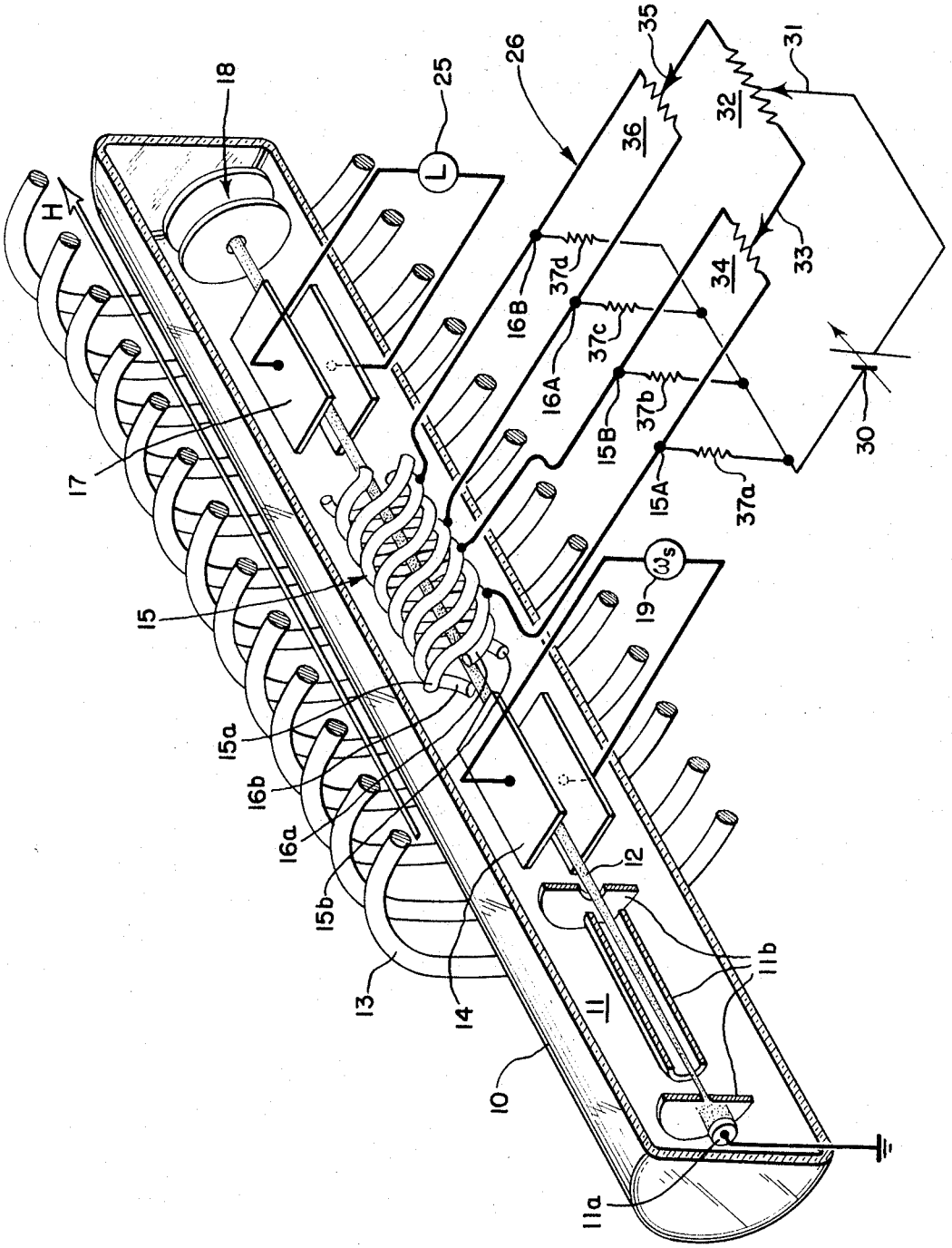

INVENTOR.
John P. Lindley
BY
Hugh H. Drake
Atty.

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ADJUSTABLE VOLTAGE DIVIDER CIRCUIT

John P. Lindley, Redwood City, Calif., assignor to Zenith Radio Corporation, Chicago, Ill., a corporation of Delaware

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The invention is directed to an adjustable divider circuit and is particularly concerned with a circuit for achieving independent voltage or current adjustment between the terminals of a multiple-terminal device, such as between the four electrodes of a quadrupole-type electron beam parametric amplifier.

The invention, while applicable to various multiple-terminal dividers, was developed and will be described in conjunction with an electron beam parametric amplifier having a twisted quadrupole pump section. In such devices, opposite pairs of the four electrodes are maintained at different voltages. The four electrodes are also maintained at an average voltage positive with respect to the cathode in the device. Because of manufacturing difficulties and tolerances, the quadrupole electrodes often are slightly displaced from their theoretically desired positions. To correct for this slight misplacement, the D.C. bias an the particular electrodes can be varied so as to alter the apparent positions as seen by the electron beam. For ease in adjustment and set up, it is desirable that the individual bias adjustments can be achieved independently.

It is a general object of the invention to provide a new and improved multiple-terminal divider circuit.

It is one specific object of the invention to provide a circuit permitting independent adjustment of the average D.C. potential on the quadrupole electrodes in an electron beam parametric amplifier while also allowing independent adjustment of the intrapair electrode potentials and also allowing independent adjustment of the potential between individual ones of the quadrupole electrodes.

It is another specific object of the invention to permit independent adjustment in the apportionment of average current among four terminals, while also allowing independent adjustment of inter-terminal pair-apportioned current and independent adjustment of the apportioned current as between individual ones of the terminals.

It is another object of the invention to provide a circuit capable of achieving the foregoing but which is of simplified and economical construction.

In one aspect, an adjustable divider circuit includes first, second, third, and fourth terminals. A first voltage divider is coupled between the first and third terminals and a second voltage divider is coupled between the second and fourth terminals. A third voltage divider is coupled between respective adjustable points on the first and second voltage divider. Four impedances are coupled individually at their one ends to respective ones of the four terminals and their other ends are coupled in common. A source of adjustable potential is coupled betwen an adjustable point on the third voltage divider and the common ends of the four impedances.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. The organization and manner of operation of the invention, together with further objects and advantages thereof, may best be understood by references to the following description taken in connection with the accompanying drawing, in which the single figure is a partially schematic perspective view, partially broken away, of an electron beam parametric amplifier tube and associated circuitry constructed in accordance with the present invention.

Shown in the figure for the purpose of illustrating the present invention is a D.C.-pumped electron beam parametric amplifier tube. It includes an envelope **10** within which is an electron gun **11** for projecting a stream or beam of electrons along a path or axis **12** which terminates in an electron beam collector **18**. Electron gun **11** may be entirely conventional, including a cathode **11***a* at ground potential and focusing and accelerating electrodes **11***b* for defining the electron beam. Encircling envelope **10** at least over a portion of its length is a solenoid **13** which develops a homogeneous magnetic field H through which the electron beam is projected parallel to the flux lines. Solenoid **13** establishes a condition of cyclotron resonance for the electrons.

An input-signal Cuccia coupler **14** is disposed first along the beam path following the electron gun. The application of input signal energy from a signal source **19**, coupled across the electrodes of coupler **14**, causes the electrons to follow helical orbits along axis **12** with a periodicity determined by the strength of field H and with a radius proportional to the input signal amplitude.

Downstream from coupler **14** is a twisted-quadrupole D.C.-pumped type of electron motion expander **15**. It is composed of a quadrifilar helix wound around axis **12** with a pitch substantially equal to that of the electron orbits.

The quadrifilar helix has four electrodes **15***a*, **15***b*, **16***a* and **16***b* which are twisted about beam path **12**. In any cross section taken perpendicularly to path **12**, the four quadrupole electrodes are at the end points of two diameters, disposed at a right angle to each other, of a circle with its center on axis **12**. Electrodes **15***a* and **15***b* are on opposite ends of one diameter while electrodes **16***a* and **16***b* are at the opposite ends of the other diameter. The electrode pairs **15***a*, **15***b* or **16***a*, **16***b* are so situated that the individual electrodes are sequentially spaced along the beam in the order: **15***a*, **16***b*, **15***b*, **16***a*.

Expander **15** subjects the electrons to a periodic inhomogeneous field. In this instance, the field itself is static as seen by an external observer, but as viewed by the moving electron its polarity reverses four times for every cyclotron orbit. That is, it defines a spatial periodicity equal to twice the cyclotron resonance period.

Downstream from pump section **15** is an output Cuccia coupler **17** which in use is coupled to a load **25**. Coupler **17** operates inversely to input coupler **14** and extracts the amplified signal energy from the electron beam.

The general operation of the electron beam parametric amplifier herein disclosed and a more detailed description of its structure is contained in the co-pending application of Robert Adler, Ser. No. 326,737, filed Nov. 29, 1963, and assigned to the same assignee as the present application. As there fully discussed, the device preferably further includes means for producing a more intense magnetic field at the cathode in order to improve the signal-to-noise ratio. It will here suffice to note that the orbiting electrons which leave input coupler **14** are subjected, in twisted quadrupole **15**, to field forces having the proper direction to cause additional energy to be imparted to the moving electrons. In the particular case of the D.C. pump illustrated, the D.C. energy which effects translation of the electrons along beam path **12** is converted by the inhomogeneous quadrupole field to rotational kinetic energy of the electrons. The higher-energy motion of the electrons is converted to an output signal by coupler **17** and fed to load **25**.

Each of the quadrupole electrodes is connected individually to one terminal of an adjustable-divider network or circuit **26**. In accordance with the invention, circuit **26** is arranged to permit independent adjustment of the potential average on all terminals and on individual pairs

of terminals as well as of the potentials on individual terminals. To this end, circuit 26 includes a source of adjustable voltage 30 one side of which is connected to the center tap 31 of a voltage divider or potentiometer 32. One end of potentiometer 32 is connected to the center tap 33 of a second potentiometer 34. The other end of potentiometer 32 is connected to the center tap 35 of a third potentiometer 36. One end of potentiometer 34 is connected to terminal 15A, which in this embodiment is connected to electrode 15*a*, while the other end of potentiometer 34 is connected to terminal 15B which in turn is connected to electrode 15*b*. Similarly, one end of potentiometer 36 is connected to terminal 16A which in turn is connected to electrode 16*a* and the other end of potentiometer 36 is connected to terminal 16B which in turn is connected to electrode 16*b*. Also connected respectively to each one of the terminals 15A, 15B, 16A, and 16B, and therefore coupled to each of electrodes 15*a*, 15*b*, 16*a* and 16*b*, is one end of equal-value resistors 37*a*, 37*b*, 37*c* and 37*d*. The other ends of resistors 37*a*, 37*b*, 37*c* and 37*d* are coupled in common to the other side of adjnstable voltage supply 30.

In operation, adjustment of voltage supply 30 determines the average positive voltage on the four quadrupole electrodes 15*a*, 15*b*, 16*a* and 16*b* relative to cathode 11*a*. Potentiometer 32 permits adjustment of the overall gain of the amplifier by setting the intraquadrupole pair voltage. Potentiometers 34 and 36 enable adjustment of the interelectrode potential as necessary to compensate for any irregularities in electrode positioning, thereby permitting the beam to be centered.

While circuit 26 has been depicted and described in conjunction with a D.C. bias adjustment function, the invention contemplates applying the same approach to any apparatus requiring independent potential or current division among a plurality of terminals with a like number of degrees of freedom, whether the division is one of signals or of biases. For example, in a different embodiment potentiometers 32, 34 and 36 and resistors 37*a*, 37*b*, 37*c* and 37*d* may be replaced by reactive elements, such as capacitors or inductors, and voltage source 30 may be an alternating-current signal source, without departing from the spirit of the invention.

The circuit described provides a flexible scheme of independent multi-function potential or current adjustment. Yet, the circuit is simple and economical of construction. The concept is fully expandable to embrace a large number of terminals; this entails only the addition of further individual dividers according to the same pattern, analogous to enlarging the brackets for a single-elimination sporting meet.

While a particular embodiment of the invention has been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. An adjustable-divider circuit comprising: first, second, third and fourth terminals;
- a first voltage divider coupled between said first and third terminals;
- a second voltage divider coupled between said second and fourth terminals;
- a third voltage divider coupled between respective adjustable points on said first and second voltage dividers;
- four impedances each of which is coupled individually to a respective one of said four terminals and the other ends of which are coupled in common;
- a source of adjustable potential coupled between an adjustable point on said third voltage divider and the common ends of said four impedances; and utilization means coupled to and responsive to changes in potentials on said terminals.

2. A circuit for achieving independent adjustment of the average voltage on four terminals, independent adjustment of the average voltage on the first and second terminals with respect to the average voltage on the third and fourth terminals, independent adjustment of the voltage on said first terminal with respect to said third terminal and independent adjustment of the voltage on said second terminal with respect to said fourth terminal, comprising: means defining said four terminals;
- a first voltage divider coupled between said first and third terminals;
- a second voltage divider coupled between said second and fourth terminals;
- a third voltage divider coupled between respective adjustable points on said first and second voltage dividers;
- four impedances each of which is coupled individually to a respective one of said terminals and the other ends of which are coupled in common;
- a source of adjustable potential coupled between an adjustable point on said third voltage divider and the common ends of said impedances; and utilization means coupled to and responsive to changes in potentials on said terminals.

3. An adjustable divider circuit comprising: first, second, third and fourth terminals;
- a first voltage divider coupled between said first and third terminals;
- a second voltage divider coupled between said second and fourth terminals;
- a third voltage divider coupled between respective adjustable points on said first and second voltage dividers;
- four resistors of equal value each of which is coupled individually to a respective one of said terminals and the other ends of which are coupled in common;
- a source of adjustable potential coupled between an adjustable point on said third voltage divider and the common ends of said resistors; and utilization means coupled to and responsive to changes in potentials on said terminals.

4. An adjustable-divider circuit comprising: first, second, third and fourth terminals;
- an adjustable source of potential;
- means coupled between one side of said source and two circuit points for adjustably apportioning the potential at said one side between said two points;
- means coupled between one of said two points and said first and third terminals for adjustably apportioning the potential at said one point between said first and third terminals;
- means coupled between the other of said two points and said second and fourth terminals for adjustably apportioning the potential at said other point between said second and fourth terminals;
- means for coupling each of said terminals individually to the other side of said source; and utilization means coupled to and responsive to changes in potentials on said terminals.

5. An adjustable-divider circuit comprising: first, second, third and fourth terminals;
- an adjustable source of potential;
- means coupled between one side of said source and two circuit points for adjustably apportioning the potential at said one side between said two points;
- means coupled between one of said two points and said first and third terminals for adjustably apportioning the potential at said one point between said first and third terminals;
- means coupled between the other of said two points and said second and fourth terminals for adjustably apportioning the potential at said other point between said second and fourth terminals;

impedance means for coupling each of said terminals individually through an impedance to the other side of said source; and utilization means coupled to and responsive to changes in potentials on said terminals.

6. An adjustable-divider circuit comprising: first, second, third and fourth terminals;

an adjustable source of current;

means coupled between one side of said source and two circuit points for adjustably apportioning the current at said one side between said two points;

means coupled between one of said two points and said first and third terminals for adjustably apportioning the current at said one point between said first and third terminals;

means coupled between the other of said two points and said second and fourth terminals for adjustably apportioning the current at said other point between said second and fourth terminals;

impedance means for coupling each of said terminals individually through an impedance to the other side of said source; and utilization means coupled to and responsive to changes in potentials on said terminals.

7. An adjustable-divider circuit comprising: first, second, third and fourth terminals;

an adjustable voltage supply for varying the average voltage on said four terminals;

a first adjustable impedance coupled between said voltage supply and said terminals for varying the voltage on said first and second terminals with respect to said third and fourth terminals;

a second adjustable impedance coupled between said first adjustable impedance and said first and third terminals for varying the voltage on said first terminal with respect to said third terminal;

a third adjustable impedance coupled between said first adjustable impedance and said second and fourth terminals for varying the voltage on said second terminal with respect to said fourth terminal;

fixed impedances coupled individually from each one of said four terminals to said voltage supply; and utilization means coupled to and responsive to changes in potentials on said terminals.

8. An intraquadrupole direct-current adjustment circuit comprising: an electron beam tube having four quadrupole electrodes;

an adjustable voltage supply having two output terminals;

a first variable resistor having first, second and third terminals the first of which is connected to one of said voltage supply output terminals;

second and third variable resistors each having first, second and third terminals, the first terminals being respectively connected to the second and third terminals of said first variable resistor and the second and third terminals being respectively connected across different space-opposed pairs of said quadrupole electrodes;

and four fixed resistors individually connecting each one of said quadrupole electrodes to the other output terminal of said voltage supply.

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JOHN F. COUCH, *Primary Examiner.*

A. D. PELLINEN, *Assistant Examiner.*