Aug. 21, 1956 G. M. CLARKE 2,760,112

ELECTRICAL AMPLIFYING DEVICES

Filed July 24, 1951 2 Sheets-Sheet 1

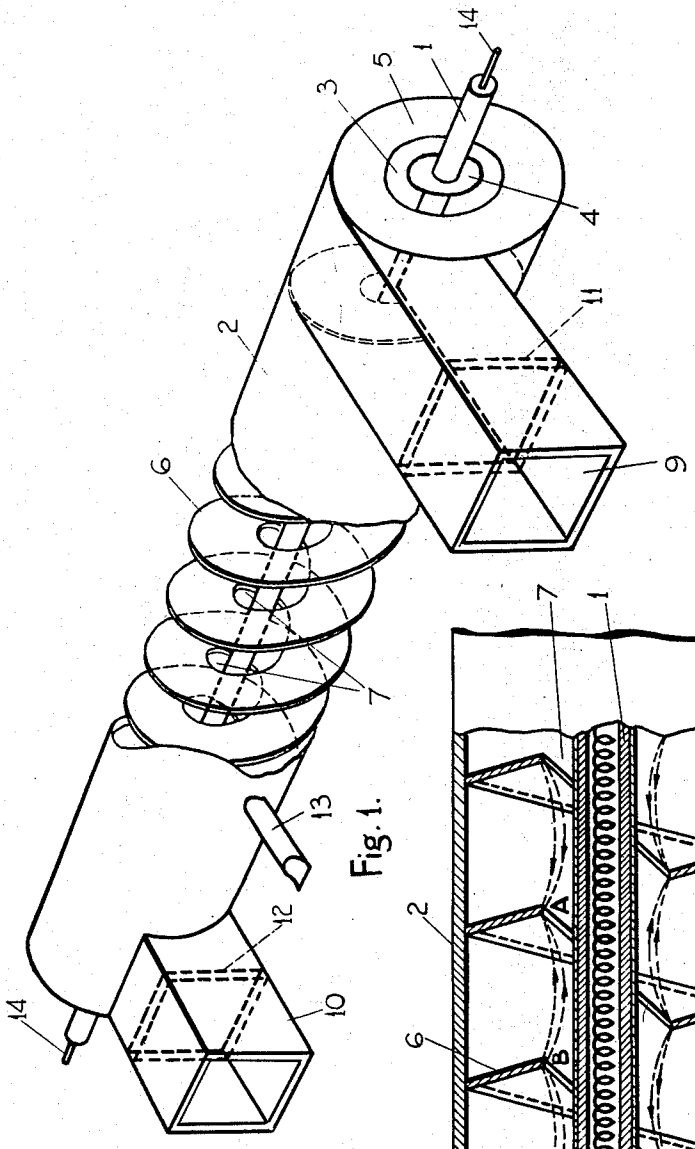


Fig. 1.

Fig. 2.

INVENTOR
GRAHAM MORLEY CLARKE
BY Clifford Bamberger
ATTORNEY

Aug. 21, 1956 G. M. CLARKE 2,760,112

ELECTRICAL AMPLIFYING DEVICES

Filed July 24, 1951 2 Sheets-Sheet 2

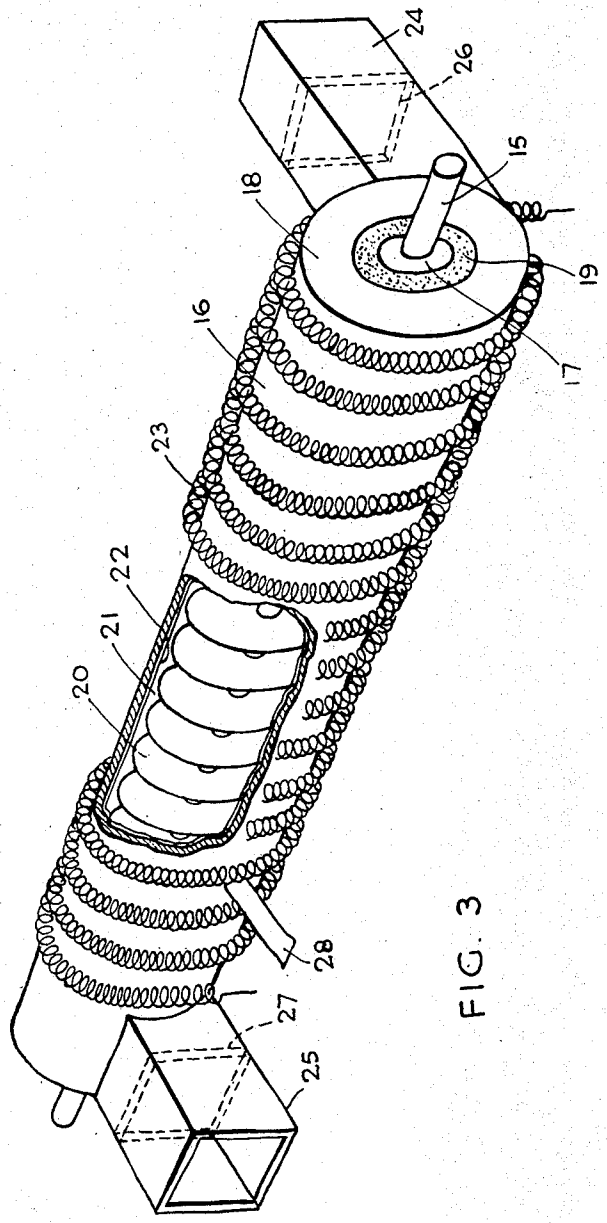


FIG. 3

INVENTOR
GRAHAM MORLEY CLARKE

BY Elson & Sinclair
ATTORNEY

United States Patent Office 2,760,112
Patented Aug. 21, 1956

2,760,112

ELECTRICAL AMPLIFYING DEVICES

Graham Morley Clarke, Hounslow, England, assignor to The M-O Valve Company Limited, London, England

Application July 24, 1951, Serial No. 238,270

Claims priority, application Great Britain July 27, 1950

8 Claims. (Cl. 315—39.3)

This invention relates to electric amplifying devices of the kind in which an electromagnetic wave to be amplified is caused to interact with, so as to extract energy from, electrons moving between two conductors under the influence of an electrostatic field applied between the conductors.

In such devices the electrons are caused to flow as a stream along the space between the two conductors under the influence of a magnetic field transverse to the electrostatic field, and the electromagnetic wave is arranged to flow between the conductors, which act as a guide therefor, at effectively the same velocity as the stream, so that by interaction with the electrons energy is progressively gained by the wave; the interaction results initially in a transfer of energy both to and from the field, but electrons which gain energy from the field are quickly returned to one of the conductors and take no further part in the interaction, whilst the electrons which lose energy become focussed in bunches which move with the electromagnetic wave so as to transfer energy progressively thereto until these electrons are collected by the other of the two conductors.

The stream of electrons may be provided by a single electron emissive cathode within the space between the two conductors, either localised to a small region of the space or extending along the whole of it along the surface of one of the conductors, or a plurality of separately spaced thermionic cathodes may be used.

In order to reduce the velocity of propagation of the electromagnetic wave to that of the electron stream, it is necessary to introduce wave-retarding means in the space between the conductors, and this means has hitherto usually consisted of separate fins extending from one or both of the conductors partly across the said space.

Such fins, however, introduce difficulties in the way of multiple resonances and, moreover, with the known arrangements, it is not easy to provide a satisfactory matching between the arrangement comprising the two conductors and either the input arrangement from which the electromagnetic wave to be amplified is fed to the conductors, or the output arrangement by means of which the amplified wave is extracted from the conductors.

The object of this invention is to provide a novel form of device of the kind referred to in which these difficulties are reduced.

According to the invention an amplifying device of the kind referred to comprises two coaxial conductors at least one of which supports one or more helical partitions which each extend towards the other conductor across part of the space between the conductors so as in effect to form a slotted waveguide wound in a helix round the inner conductor, the partition or partitions providing opposite side walls of this waveguide and slots effectively being formed in each of these side walls by the gaps either between opposing partitions extending from different conductors or between one conductor and a partition or partitions extending from the other conductor, means are

provided for producing a circular magnetic field in the space between and concentric with said conductors, one or more electron emissive cathodes is or are provided adjacent to the space traversing the aligned slots in successive turns of the wave guide, and the said waveguide is continued away from the conductors at each end by a length of waveguide of which the length at one end constitutes or forms part of the input arrangement for feeding the electromagnetic wave to be amplified into the device and the length at the other end constitutes or forms part of the output arrangement for extracting the amplified wave from the device after transmission through said helical slotted waveguide.

The partitions may either provide a spaced turn waveguide, that is to say of the kind formed by coiling a waveguide into a helix with adjacent turns spaced apart, or a contiguous turn waveguide, that is to say one in which a single wall separates adjacent turns, as in a screw-thread.

Preferably each of the said one or more partitons extends approximately perpendicular to the common axis of the conductors so that the partitons and conductors together form a slotted waveguide of substantially rectangular cross-section, and preferably the partitions extend from only one of the conductors, the other conductor carrying on its surface one or more electron emissive cathodes; in some cases a single cathode may extend over substantially the whole of the surface of said conductor.

Preferably the means for producing the circular magnetic field between the concentric conductors consists of means for passing an electric current along the inner conductor, which current may in some cases serve at the same time as a heating current for an electron emissive cathode or cathodes provided at the surface of the inner conductor. A circular magnetic field is, of course, required with concentric conductors to produce axial flow of the electrons under the influence of the magnetic field and the radial electrostatic field applied between the conductors. In some cases the electrostatic field may be applied in pulses, and the current establishing the magnetic field may then also be pulsed in synchronism therewith; when the current serves also for heating a cathode, the effective heating of the cathode may be controlled by varying the duration of the current pulses.

In the operation of an amplifying device in accordance with the invention, the electromagnetic wave is transmitted round the helical slotted waveguide, formed by the one or more partitions and the conductors, in a mode having a component of electric intensity directed along the axis of the conductors, and the magnetic and electrostatic fields are arranged to produce in the space traversing, the aligned slots of the waveguide, which will hereinafter be referred to as the reaction space, a flow of electrons along said axis at a velocity which is substantially equal to the effective velocity of phase propagation of the electric field axially along said reaction space.

The effective retardation of the electromagnetic wave is thus effected by virtue of the longer path, for a given axial length of the conductors, which the wave is caused to travel round the helical waveguide formed by the one or more partitions and the conductors; the electrons react with the fringing electric fields formed across the aligned slots in successive turns of the waveguide.

Preferably the helical wave-guide is of substantially rectangular cross-section and the electromagnetic wave is arranged to be fed to it along the input waveguide in the H_{10} mode with electric field directed along the axis of said conductors.

By continuing the helical waveguide at each end to form input and output waveguides, the difficulties of matching are largely overome.

The amplifying device in accordance with the invention

is, of course, intended to operate with an evacuated reaction space, and the outer conductor and input and output waveguides, suitably sealed, may conveniently form part of the evacuated envelope.

The invention will be further explained with reference to the accompanying schematic drawings in which Figure 1 shows a perspective view of one embodiment of the invention with partly cut-away outer wall, Figure 2 represents a fragmentary section along the axis of the embodiment of Figure 1, and Figure 3 shows in perspective a second embodiment of the invention with partly cut-away outer wall.

Referring now to Figures 1 and 2, the amplifying device shown comprises an inner conductor in the form of cylindrical metal tube **1** which is insulatingly supported along the axis of a cylindrical outer metal tube **2** at each end by a glass annulus **3** sealed on one side to a flange **4** projecting radially outwards from the inner conductor and on the other side to a flange **5** projecting radially inwards from the outer conductor.

The outer conductor **2** supports a single helical partition **6** which extends towards the inner conductor **1** but does not touch it, leaving gaps **7** which define by their alignment an approximately cylindrical reaction space surrounding the inner conductor. The inner conductor is coated on its outer surface, that is to say the surface facing the partition **6**, for most of its length with electron emissive material **8**, for example alkaline earth oxide (see Figure 2), and an electric resistance heating element **14** is contained within the inner conductor **1**.

At each end the rectangular-section waveguide constituted by the adjacent turns of the partition **6** and by the conductors **1**, **2** is continued by short lengths **9**, **10** of similar section waveguide each soldered into an aperture in the outer conductor and each hermetically closed by a glass window **11**, **12** respectively, sealed therein.

The device is provided with a glass or metal side stem **13** by which it is evacuated and sealed off during manufacture, a metal stem closed by a cold-weld cut-off being shown.

In operation of the device the input wave to be amplified is fed into the waveguide **9**, say, in the H_{10} mode with the electric field directed parallel to the axis of the conductors. The outer conductor **2** is maintained at a suitable positive potential relative to the conductor **1**, and a unidirectional current is passed along the inner conductor **1**, the potential at **9** being negative relative to the potential at **10**, so that the electrostatic and magnetic fields thereby produced together give rise to a progression of electrons emitted from the coating **8** on the surface of the inner conductor **1** in the direction from **9** to **10**. The inner conductor **1** is raised to the temperature required for the emission of electrons from the coating **8** both by the unidirectional current passed through the conductor and by the passage of a suitable heating current through the heater **14**.

Referring now to the fragmentary axial section shown in Figure 2, the arrowed dotted lines indicate at one instant the nature and direction of the electric fringing fields formed at the gaps **7** by the input wave. It will be apparent that an electron at A travelling in the direction from **9** to **10** will give up energy to the facing electric field as it progresses from A to B, and the velocity of progression is arranged by control of the magnitude of the direct current flowing along **1** and the voltage between **1** and **2**, to be such that by the time the electron has reached B the facing electric field has oscillated to a retarding phase. In this way a repeated transfer of energy from the electrons to the electromagnetic field is obtained and an amplified output wave is taken from the waveguide **10**.

The amplifying device shown in Figure 3 is in effect the inverse of that shown in Figures 1 and 2. An inner conductor **15** is supported axially within an outer conductor **16**, by flanges **17**, **18** and a glass annulus **19** at each end similar to those described with reference to Figure 1. The inner conductor **15** carries a helical waveguide-forming petition **20** leaving a gap **21** which forms the electron reaction space. The inner surface of the outer conductor is coated with electron emissive material **22** and a heating coil **23** is wound round the outer conductor for raising the material to its electron emissive temperature in operation; the coil **23** is wound in coiled coil form for minimising the magnetic field produced by it within the space between the conductors.

The waveguide formed by the partition **20** is effectively continued at each end by short lengths **24**, **25** of similar section waveguide soldered into apertures in the outer conductor **16** and sealed by means of glass windows **26**, **27** respectively.

The device is evacuated and sealed off during manufacture by means of a side-stem **28** shown as a metal tube closed by a cold-weld cut-off.

The operation of this device is similar to that described with reference to Figure 1 except that in this case the inner conductor **15** is maintained at a positive potential relative to the outer conductor **16** and the direction of the direct current passed through the inner conductor for generating the magnetic field is reversed for operation with **24** as the input end and **25** the output end.

The partition **20** and inner conductor **15** may conveniently be formed in one piece by cutting a deep helical groove, the wall of which forms the partition, in a solid rod.

What we claim is:

1. An amplifying device for amplifying an electromagnetic wave by interaction with a moving stream of electrons, comprising within an evacuated space a pair of mutually insulated coaxial conductors, at least one helical partition supported in the annular space between said conductors and extending part way across this space to form a slotted waveguide wound in a helix round the inner conductor, means for producing a circular magnetic field concentric with said conductors in said annular space between them, at least one electron emissive cathode arranged in said annular space for producing a stream of electrons through the part of the space traversing the aligned slots in successive turns of the helical waveguide under the influence of the circular magnetic field and a radial electrostatic field applied between said coaxial conductors, input means for feeding into one end of said helical waveguide the electromagnetic wave to be amplified and output means for extracting from the other end of said waveguide the wave amplified during its passage through the waveguide by interaction with said stream of electrons.

2. An amplifying device according to claim 1 wherein the input means and output means each consists of a length of waveguide coupled to said coaxial conductors at each end thereof so as to form a continuation of said slotted helical waveguide.

3. An amplifying device according to claim 1 wherein the partition extends perpendicular to the common axis of said coaxial conductors so that the slotted helical waveguide is formed with substantially rectangular cross-section.

4. An amplifying device according to claim 1 wherein an evacuated envelope is provided of which the co-axial conductors form part.

5. An amplifying device according to claim 1 wherein the input means and output means each consists of a length of waveguide branched from the end of said coaxial conductors so as to form a continuation of said slotted helical waveguide, wherein the device includes an evacuated envelope of which the input and output waveguides form part and wherein wave-transmissive windows seal the input and output waveguides.

6. An amplifying device according to claim 1 wherein a single helical partition extends from only one of the coaxial conductors, and the electron emissive cathode is formed on the surface of the other of said conductors.

7. An amplifying device according to claim 6 wherein

the cathode extends over substantially the whole of the surface of the other conductor.

8. An amplifying device according to claim 1 wherein the means for producing a circular magnetic field consists of means for passing an electric current along the inner conductor.

References Cited in the file of this patent

UNITED STATES PATENTS

2,122,538	Potter	July 5, 1938
2,402,184	Samuel	June 18, 1946
2,439,401	Smith	Apr. 13, 1948
2,541,843	Tiley	Feb. 13, 1951
2,566,087	Lerbs	Aug. 28, 1951
2,636,948	Pierce	Apr. 28, 1953
2,651,686	Clavier et al.	Sept. 8, 1953
2,672,572	Tiley	Mar. 16, 1954