Aug. 22, 1961 A. VAN DER ZIEL 2,997,583

SYSTEM FOR HETERODYNE MIXING

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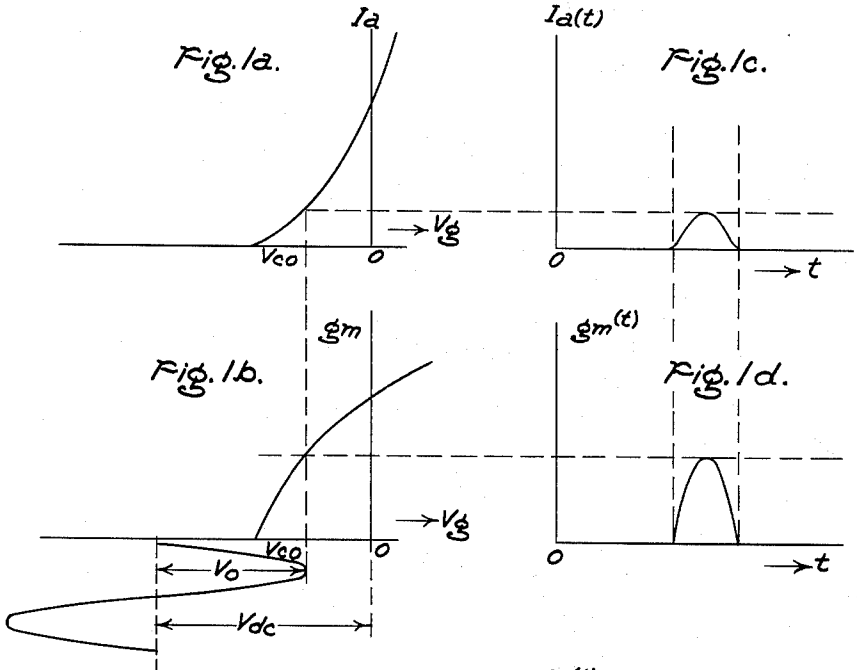


Fig. 1a. Fig. 1c. Fig. 1b. Fig. 1d.

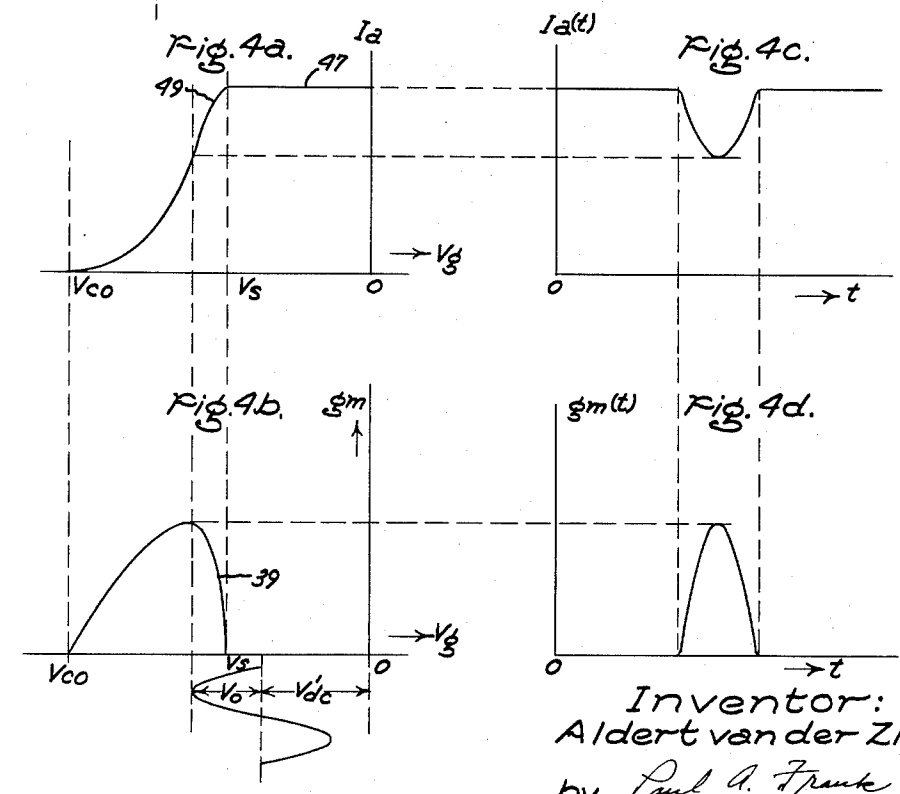


Fig. 4a. Fig. 4c. Fig. 4b. Fig. 4d.

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Fig. 2.

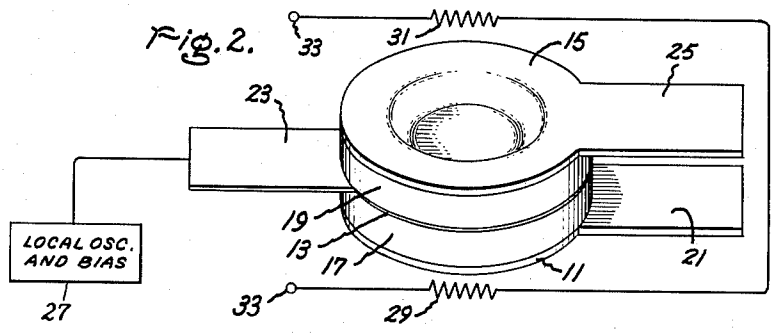
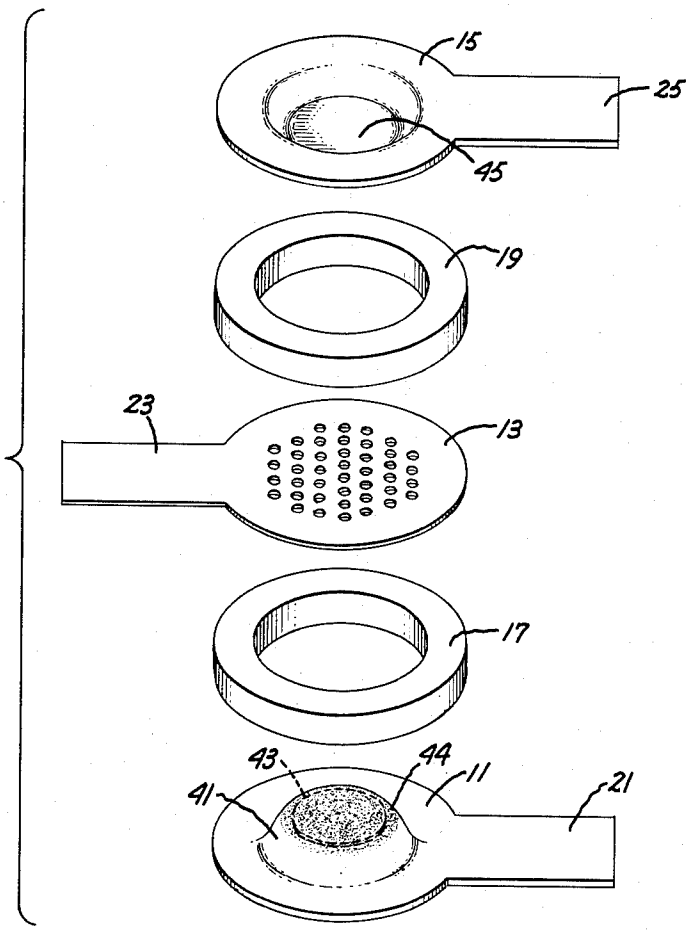


Fig. 3



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SYSTEM FOR HETERODYNE MIXING

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3 Claims. (Cl. 250—20)

The present invention relates to a heterodyne mixing system and to an improved heterodyne mixing system employing an electron tube having a particular type of characteristic.

Most television and radio receivers utilize conventional well known circuits to convert received signals into a signal having another frequency, called the intermediate frequency, which is independent of the frequency of the received signal. This frequency conversion is often produced by an electron tube, called a heterodyne mixer, which mixes the received signal with another signal that is usually derived from an oscillator, called the local oscillator. This mixer tube is switched off and on in the rhythm of a large local oscillator signal so that the tube draws current only during a portion of each cycle of the local oscillator signal. One of the disadvantages of this mixing system and its manner of operation is that a relatively large oscillating voltage is required. Also, the electrons have transit times between the electrodes of the tube that are neither short nor uniform and produce "noisy" operation.

Accordingly, an object of the present invention is to provide a mixing system requiring only a relatively small local oscillator signal.

A further object of the present invention is to provide a heterodyne mixing system having much less "noise" than conventional heterodyne mixing systems.

These and other objects of my invention are achieved in one embodiment in which a tube having a sharp decline in transconductance, which is the ratio of change of output current to the change in input voltage with a constant plate electrode voltage, is biased to current saturation in mixing system,

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, together with further objects and advantages thereof may best be understood by reference to the following description, taken in connection with the accompanying drawings, in which:

FIG. 1*a* is a graph of plate current I*a* versus grid voltage V*g* for a conventional triode that might be used in a mixing system,

FIG. 1*b* is a graph of the transconductance *gm* corresponding to the plate current of FIG. 1*a* versus grid voltage V*g*,

FIG. 1*c* is a graph of plate current on a time scale corresponding to the plate current graph of FIG. 1*a*,

FIG. 1*d* is a graph of transconductance on a time scale corresponding to the transconductance graph of FIG. 1*b*,

FIG. 2 is a perspective view of a ceramic triode electron tube that has a transconductance characteristic with a sharp decline from maximum transconductance to zero transconductance,

FIG. 3 is an exploded perspective view of the tube of FIG. 2,

FIG. 4*a* is a graph of plate current I*a* versus grid voltage V*g* for the triode of FIG. 2,

FIG. 4*b* is a graph of the transconductance *gm* versus grid voltage V*g* for the triode of FIG. 2,

FIG. 4*c* is a graph of the change in plate current corresponding to a specific change in grid voltage for the triode of FIG. 2, and

FIG. 4*d* is a graph of the change in transconductance corresponding to a specific change in grid voltage for the triode of FIG. 2.

In the several figures of the drawings, corresponding elements have been indicated by corresponding reference numerals to facilitate comparison. Referring now to FIG. 1*a* I have illustrated the graph of the plate current characteristic, i.e. of the plate current versus grid voltage, for a conventional triode tube of the type that might be used in a mixer system. The most pertinent feature of this graph is the lack of a well-defined saturation region; that is, a region where the tube current is substantially constant.

Due to the low slope of the graph of FIG. 1*a* near the point of zero plate current, the graph of the transconductance characteristic of FIG. 1*b*, which is the slope of the graph of FIG. 1*a*, does not attain appreciable magnitude near the cut-off voltage V*co*. Thus, a large local oscillator voltage V*o* is required to produce the large change in transconductance usually desired. Since the plate current should flow for only a small portion of the local oscillator voltage cycle, a large negative D.C. (direct current) grid voltage V*dc* is required to bias the grid electrode sufficiently negative so that the large local oscillator voltage V*o* does not produce plate current flow for a longer portion of the local oscillator voltage cycle than that desired.

In FIGS. 1*c* and 1*d* I have illustrated the changes in plate current and transconductance, respectively, that are produced by the local oscillator voltage V*o*.

A tube has been developed, recently, having a transconductance characteristic with a sharp decline from maximum to zero transconductance. This tube, which is illustrated in FIG. 2, comprises a cathode electrode **11**, a grid electrode **13**, and a plate electrode **15**, separated by two ceramic insulators **17** and **19**. The electrodes **11**, **13**, and **15** have tabs **21**, **23**, and **25**, respectively, for connection to external circuits such as to a source **27** of grid voltage bias and of a local oscillator signal. This tube requires substantially uniform heating of the electrodes, which may be provided by means shown to comprise two filaments **29** and **31** having input terminals **33**. In some applications the plate dissipation may provide sufficient heating and thus filament **31** may be dispensed with. Also, the environment in which the tube is used may have a sufficient ambient temperature to heat the electrodes to operating temperatures (300 to 700 C.) and thus both filaments **29** and **31** may be eliminated.

A better view of the individual components of the tube of FIG. 2 can be had in the exploded view of FIG. 3. The cathode electrode **11**, which may be constructed from almost any metal that is suitable for a cathode, has a raised portion **41** on which there is a thin disk **43** of platinum coated with emissive material **44** such as B*ao*, S*r*O that is applied as a carbonate and then during the process of heating the tube in the manufacture thereof is converted to an oxide, and with additional heating is activated. Since platinum is passive to the emissive material **44**, disk **43** does not react with coating **44**, and thus extends the life of the tube for it prevents the reaction of coating **44** with the cathode metal. Grid electrode **13**, which is perforated to permit the passage of electrons, is constructed from a metal such as titanium, tungsten, nickel, or stainless steel that does not become contaminated during the operation of the tube. The anode electrode **15**, which is formed from an active metal such as titanium, zirconium, or hafnium, and preferably titanium, has a raised portion **45** facing the grid electrode **13**. The raised portions **43** and **45** permit a close spacing of the tube electrodes with a minimum of interelectrode capacitance. The ceramic insulators **17** and **19**, separating these electrodes, are formed from a ceramic material such as forsterite. The electrodes and insulators are vacuum sealed by nickel shims (not shown) that are placed be-

tween each metal and ceramic part and heated to solder the parts together.

The over-all diameter of this tube is approximately ¼ inch, and the ceramic parts are approximately 35 mils thick and the metal parts approximately 10 mils thick. The amplification factor is between 20 and 100 depending upon the condition of operation. And the transconductance is approximately 2,000 to 3,000 micromhos at a plate current of 1 milliampere.

In FIG. 4*a*, in which I have illustrated the tube current characteristic for the tube of FIG. 2, one of the most important features is a region 47 which is so well defined, that is so flat, that the transconductance characteristic, which is shown in FIG. 4*b*, is zero for grid voltages corresponding to this region. The grid voltage of least magnitude that produces saturation of the tube current, is indicated as V*s*. Another important part of this graph is a region 49 in which the slope of the tube current characteristic changes from a maximum value to zero in a very short range of grid voltages. The portion of the transconductance characteristic in FIG. 4*b* corresponding to this region has a sharp decline from maximum to zero transconductance.

Instead of conventionally biasing this tube below cutoff with a large negative grid voltage so that there is no tube current during most of the local oscillator signal cycle, I bias it with a small negative voltage V'*dc* that is preferably of only slightly greater magnitude than V*s*, although it could also be slightly less, so that the local oscillator voltage V*o* swings over a larger portion of the region of sharp decline in the transductance characteristic. Then, as is illustrated in FIG. 4*c* the same change in tube current can be obtained in the tube of FIG. 2 with a small local oscillator voltage as is obtained in a conventional triode although the conventional tube is activated by a much larger local oscillator voltage. Thus, with the disclosed method of operation, better results are obtained with a small local oscillator voltage than is obtained in a conventional triode with a large local oscillator voltage.

If a conventional mixer tube were operated in the saturation region, it would be quickly destroyed due to "poisoning" of the emitting surface by gaseous substances that are released from the anode surface by the high energy electrons that are present when a tube is operated in a saturation condition. Since the anode electrode 15 of the tube of FIG. 2 is constructed from an active metal, it does not release gaseous substances. There are probably other additional causes for this lack of "poisoning" that are not understood at present, but whatever the reasons, the tube of FIG. 2 can be operated in the saturation region without significant poisoning of the cathode emitting surface.

Even if a conventional tube could be operated in the saturation region, it would not have the sharp decline in transconductance of the tube of FIG. 2. This sharp decline is partly the result of the flat, well-defined, tube current region 47 of FIG. 4*a*. This flat saturation of the tube current in turn is due in part to the substantially uniform heating of all of the electrodes of the tube and to the uniform heating of all of the electrodes of the tube and to the uniform activation of the emitting surface. Also, with the platinum disk 43 beneath coating 44 there is no contamination of any part of this coating with the result that all parts of the coating produce a saturation current at substantially the same grid electrode voltage. Thus, once saturation is attained, the tube current flow is substantially independent of the grid voltage.

Because of the maximum change of transconductance from maximum to zero magnitude for small changes in grid electrode voltage, only a small local oscillator voltage is required. This is of primary importance for those mixing system applications in which there is only a small magnitude of local oscillator power available. Another advantage of this system is that the magnitude of grid electrode bias voltage V'*dc* is considerably less negative than for mixer tubes under conventional operating conditions. The effective increase (in a positive sense) of this voltage produces more uniform and shorter transit times for the electron flow between the electrodes and thus decreases noise as compared to a conventional mixing system. To understand this, consider that in a conventional mixer tube, the electrons emerging from the cathode electrode in the shadow of the grid structure, that is, those electrons that are directly beneath the grid wires, take a much longer path to the anode electrode than do the electrons emerging from the cathode directly beneath openings in the grid structure. The electrons beneath the openings can travel in approximately straight lines through the grid openings but the other electrons must first move over to approximately the center of the grid openings before passing through the grid electrode due to the large negative grid bias voltage that prevents these electrons from coming close to the grid structure. However, in the present invention the negative bias voltage V'*dc* is much lower in magnitude thereby permitting these electrons to travel much closer to the grid structure and thereby take paths that are much straighter and more uniform and thus shorter. Also, the electrons have more energy and thus can travel closer to the grid electrode. Since the electrons paths are short and substantially uniform the electrons that emerge from the cathode at any one instant tend to arrive at the anode electrode at the same time and thus are not so apt to produce what might be called an excess induced grid "noise" which results from the spread in transit time for individual electrons.

The foregoing discussion although specifically related to a mixer tube of the triode type, is equally applicable to any type tube that is suitable for mixing electrical signals and that has characteristics similar to those illustrated in FIGS. 4*a* through 4*d*. The tube may have many more elements than those shown and the local oscillator signal and bias may be applied to an electrode other than the grid electrode. Thus, in general, it can be said that the local oscillator signal and bias voltage are applied to the input electrode of the tube.

While the invention has been described with respect to certain specific embodiments, it will be appreciated that many modifications and changes may be made by those skilled in the art without departing from the spirit of the invention. I intend, therefore, by the appended claims, to cover all such modifications and changes as fall within the true spirit and scope of the invention.

What I claim is:

1. An electrical circuit for heterodyning electrical signals comprising an electronic tube having an anode electrode formed from an active metal selected from the group consisting of titanium, zirconium and hafnium and a passive cathode electrode that is substantially uniformly activated and a signal input electrode, said electrodes being contained in an enclosure formed of materials free from elements capable of poisoning said cathode electrode, means for heating said electrodes of said tube to substantially the same temperature sufficiently high to produce electron emission from said cathode whereby said tube has an operating condition of current saturation without injury to said cathode at grid bias potentials greater than a predetermined value and a transconductance characteristic having a large change in magnitude for input signal potentials in a range extending from said predetermined value to small decrements therefrom, means for supplying a bias potential to said signal input electrode of a magnitude approximately equal to said predetermined potential, and means for supplying to the signal input electrode a variable potential of a magnitude equal to a substantial portion of said small magnitude for producing a large change in transconductance of said tube.

2. An electrical signal heterodyne mixing circuit comprising an electronic tube having an anode electrode

formed from an active metal and passive cathode electrode that is substantially uniformly activated and a signal input electrode, said electrodes being contained in an enclosure free from poisoning influences on said cathode, means for heating said electrodes of said tube to substantially the same temperature whereby said tube has an operating condition of current saturation without injury to said tube at grid bias potentials greater than a predetermined value and a transconductance characteristic having a large change in magnitude for input signal potentials in a range extending from said predetermined value to small decrements therefrom, means for supplying a bias potential to said signal input electrode of a magnitude approximately equal to said predetermined potential, and means for supplying to the signal input electrode a variable potential of a magnitude equal to a substantial portion of said small magnitude for producing a large change in transconductance.

3. An electrical signal heterodyne mixing circuit comprising an electronic tube having an input signal electrode, an element of active material and a passive cathode electrode contained in an enclosure free from poisoning influences on said cathode, the tube being of the type

in which the tube current readily saturates at grid bias potentials greater than a predetermined value without injury to the tube and which has a large change in transconductance for input signal potentials in a range extending from said predetermined value to small decrements therefrom, means for supplying to the input signal electrode a bias potential approximately equal to said predetermined potential, and means for supplying a varying potential to the input signal electrode of sufficient magnitude for producing a large change in transconductance.

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