May 27, 1947. S. G. TOMLIN 2,421,043

DETECTOR OF MODULATED CARRIER FREQUENCIES

Filed Sept. 9, 1942

FIG. 1

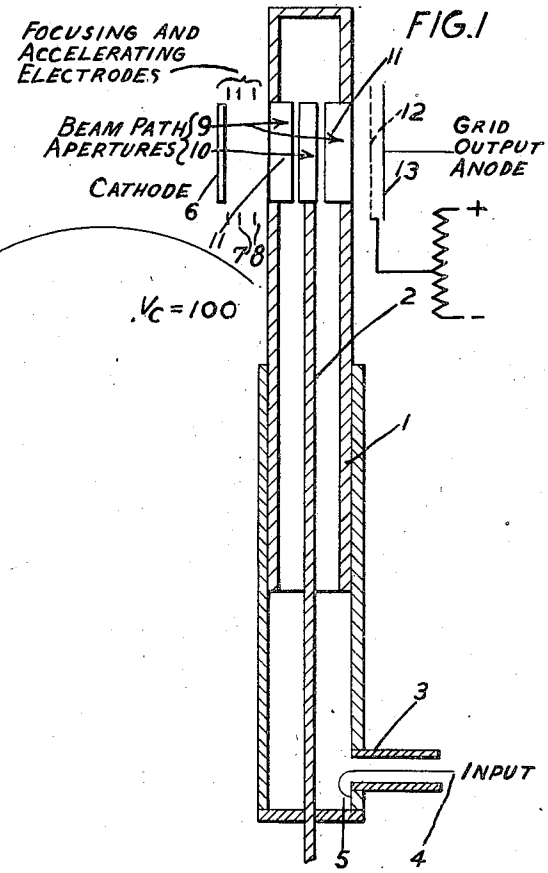


FIG. 3

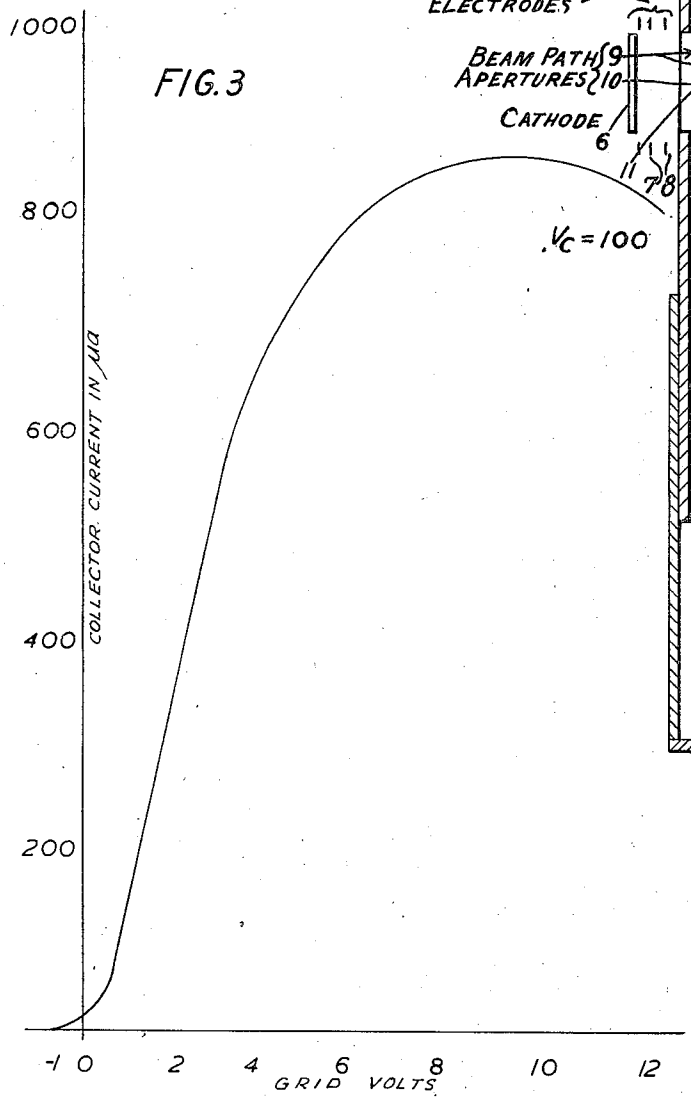
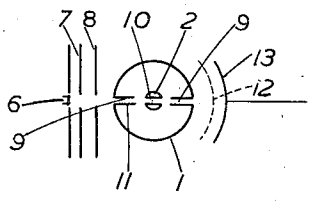


FIG. 2



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DETECTOR OF MODULATED CARRIER FREQUENCIES

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9 Claims. (Cl. 250—27)

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This invention relates to electron discharge apparatus utilising the principles of electron velocity modulation and to receivers for modulated carrier waves comprising such apparatus.

In one aspect the invention resides in a receiver for electromagnetic waves of very high frequency comprising a valve including an electrode system for setting up an electron beam, a collector electrode and a grid electrode in the path of the beam, means for maintaining the electrodes at such potentials that the operating condition of the valve is at a curved part of the grid-voltage collector-current characteristic, and means for velocity modulating electrons approaching the grid electrode in accordance with the incoming modulated high frequency wave.

In another aspect the invention resides in a receiver for electromagnetic waves of very high frequency comprising a valve including an electrode system for setting up an electron beam, a collector electrode, means for maintaining the electrodes at such potentials that the operating condition of the valve is at a curved part of the collector-current collector-voltage characteristic, and means for velocity-modulating electrons approaching the collector electrode in accordance with the incoming modulated high-frequency waves.

The invention also resides in the method of detecting modulated waves of very high frequency comprising the velocity modulation in accordance with said waves of electrons in the cathode-grid space of a valve set to operate at a curved part of the mutual characteristic.

The invention further resides in the method of detecting modulated waves of very high frequency comprising the velocity modulation in accordance with said waves of electrons in the cathode-collector electrode space of a valve set to operate at a curved part of the collector-current collector-voltage characteristic.

In another aspect the invention resides in electron discharge apparatus comprising a length of co-axial line constituting a high-frequency resonator, an electrode system for directing an electron beam through diametric apertures in the conductors of the co-axial line at a field antinode, a collecting electrode in the beam path beyond the conductors of the co-axial line and a grid electrode interposed between the co-axial line and the collecting electrode.

In accordance with the invention such apparatus, arranged for the detection of modulated high-frequency waves, includes means for applying the modulated waves to the resonator, the resonator having a natural frequency approximately equal to the carrier frequency, a low frequency output circuit connected to the collector electrode and means for applying to the grid electrode and the collector electrode such direct potentials that an operating point on a curved part of the grid-voltage, collector-current characteristic is reached.

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The preferred method of reception is based upon the velocity modulation of a beam of electrons passing transversely through suitable apertures in a co-axial line resonator which is tuned to the frequency of the radiation to be received.

The invention is illustrated in the accompanying drawings in which:

Fig. 1 is a substantially central, longitudinal, sectional view, partly diagrammatic, of one form of electron discharge apparatus which may be used with the invention;

Fig. 2 is a diagrammatic cross sectional view through the upper end of the apparatus at substantially the center of the electron beam; and

Fig. 3 is a collector-current, grid-voltage curve of the apparatus of Figs. 1 and 2 which is to be used to explain the invention.

In one form, the apparatus consists of some type of electron gun producing a parallel beam of electrons, a resonator which allows the beam to be velocity modulated, a control grid, and a final collecting electrode. This is shown schematically in Figs. 1 and 2 of the accompanying drawings.

Referring to these figures, co-axial conductors 1 and 2 form a resonator of adjustable length. A co-axial line 3, 4 terminating in a loop 5 serves to feed incoming waves to the resonator. Electrons from a cathode 6 are projected in a beam by focussing and accelerating electrodes 7, 8 through apertures 9, 10 in the conductors 1 and 2. Fins 11 are provided to reduce the gaps between the conductors at the apertures. The electrons are modulated in velocity in passing the gaps between the conductors and then pass into the field of a grid 12 beyond which is a collecting electrode 13.

The resonator may have an open end at the point where the beam passes through it, or it may be closed at both ends, and in that case the beam must pass through it at one-quarter of a wavelength from the end. The gap between the inner and outer conductors at the apertures must be small so that the transit time across the gap is small compared with a period of the oscillation applied to the resonator. The diameter of the inner rod is such that the transit time of electrons passing through this rod is an odd number

of half periods of the frequency to be detected. Then electrons accelerated in the first gap are again accelerated in the second gap and electrons retarded in the first gap are retarded in the second gap.

On investigating the collector current dependence upon the grid potential when no modulation is applied to the resonator, a curve 14 of the type shown in Fig. 3 of the accompanying drawings, which was obtained in a particular case, is obtained.

Now suppose that the grid potential is adjusted to the point of maximum curvature of the above characteristic curve, and that the beam is velocity modulated by a signal applied to the resonator, then electrons arriving at the grid have potentials varying sinusoidally about the grid potential and it is clear that a rectified current will flow to the collector, the action of the system being analogous to that of an anode bend detector.

The design of the grid and collector system is such as to make either the lower or upper bend of the characteristic as sharp as possible. The addition of other grids for screening or suppressing secondary emission may be desirable.

The apparatus may also be used for the detection of modulated waves of very high frequency if the grid 12 and the collecting electrode 13 are connected together or if the grid 12 is omitted. The apparatus then consists essentially of an electron gun, means for velocity modulating the electron beam and a single collecting electrode. It has been found that the collector-current collector-voltage curve is then similar to the curve of Fig. 3 and by biassing the collecting electrode to work on a point on the bend of the curve detection may be obtained in a manner similar to that already described. This arrangement suffers, however, from the disadvantage that on account of the varying voltage drop across the external load impedance resulting from variation of the output current, the bias voltage on the collecting electrode varies and may give rise to distortion.

The theory of the triode-anode bend or square law detector shows that the amplitude of the audio frequency output can be increased by superposing on the incoming modulated carrier wave, an additional or local carrier frequency voltage in phase with it. This process has been found difficult to apply in practice owing to the difficulty of effecting exact synchronisation. The principle can, however, be applied with the apparatus previously described, since the tube itself can be arranged to produce oscillations of the required frequency, which are necessarily in synchronism with the incoming high frequency waves. A part of the electrons will be reflected by the grid (or in the case where the grid is omitted by the collecting electrode), and if the spacings of the electrodes and the potentials applied to them are such that the transit time of these reflected electrons in travelling from the resonator to the grid (or collecting electrode) and back again to the resonator is $n+\frac{1}{2}$ periods of the received carrier frequency, oscillations will be set up in the resonator at that frequency. For fixed electrode spacings the frequency of oscillation may be varied over a substantial range by adjustment of the potentials.

Thus the voltage variation on the resonator at the point where the electron beam passes through it can be augmented by a voltage of the same frequency and in phase with the incoming carrier voltage. This will result in an increased audio frequency output.

Further modifications within the scope of the appended claims will readily occur to those versed in the art.

What is claimed is:

1. Arrangement for detecting modulated carrier waves of very high frequency comprising an electron discharge tube including an electrode system for setting up an electron beam, a collector electrode and a grid electrode in the path of the beam, means for maintaining the electrodes at such potentials that the operating condition of the tube is at a curved part of the grid-voltage collector-current characteristic, means comprising a device resonant at the frequency of said carrier waves between said first-mentioned electrode system and said grid electrode for velocity modulating electrons approaching the grid electrode in accordance with the incoming modulated high frequency waves, and an output circuit connected to said collector electrode.

2. Arrangement for detecting modulated carrier waves of very high frequency comprising an electron discharge tube including an electrode system for setting up an electron beam, a collector electrode, means for maintaining the electrodes at such potentials that the operating condition of the tube is at a curved part of the collector-current collector-voltage characteristic, means comprising a device resonant at the frequency of said carrier waves between said first-mentioned electrode system and said collector electrode for velocity modulating electrons approaching the collector electrode in accordance with the incoming modulated high-frequency waves, and an output circuit connected to said collector electrode.

3. Electron discharge apparatus comprising a length of co-axial line constituting a high-frequency resonator, an electrode system for directing an electron beam through diametric apertures in the conductors of the co-axial line at a field antinode, a collecting electrode in the beam path beyond the conductors of the co-axial line, a grid electrode interposed between the co-axial line and the collecting electrode, means for maintaining the said electrodes at such potentials that the operating condition of the tube is at a curved part of the grid-voltage collector-current characteristic, and means for applying modulated carrier waves to said resonator.

4. Electron discharge apparatus according to claim 3, wherein the beam path is spaced a distance of one quarter wavelength from a closed end of the co-axial line.

5. Electron discharge apparatus according to claim 3, wherein the beam path is located at an open end of the co-axial line.

6. Electron discharge apparatus according to claim 3, wherein the dimension along the beam path of the aperture in the inner conductor of the said coaxial line is such that for a given beam velocity the transit time of electrons passing through said aperture is an odd number of half periods of a chosen natural frequency of the resonator.

7. Electron discharge apparatus according to claim 3, wherein the gaps between the co-axial conductors of said coaxial line at the beam aperture are such that for a given beam velocity the transit time across the gaps is small compared with the oscillation period of a chosen natural frequency of the resonator, fins or projections being provided in the apertures to limit the length of the gaps.

8. Electron discharge apparatus according to

claim 3, wherein means is provided for adjusting the length of the said co-axial line resonator to tune the resonator to the carrier-wave frequency.

9. Receiver for electromagnetic waves according to claim 3, in which the spacing between said grid or collector electrode and said resonator is such that for a given beam velocity the transit time of electrons reflected from said grid or collector electrode in travelling from resonator to such electrode and back is an odd number of half periods of the frequency of the incoming carrier waves whereby oscillations are produced in said resonator at the frequency of said carrier waves.

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