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ELECTRON BEAM MODULATOR

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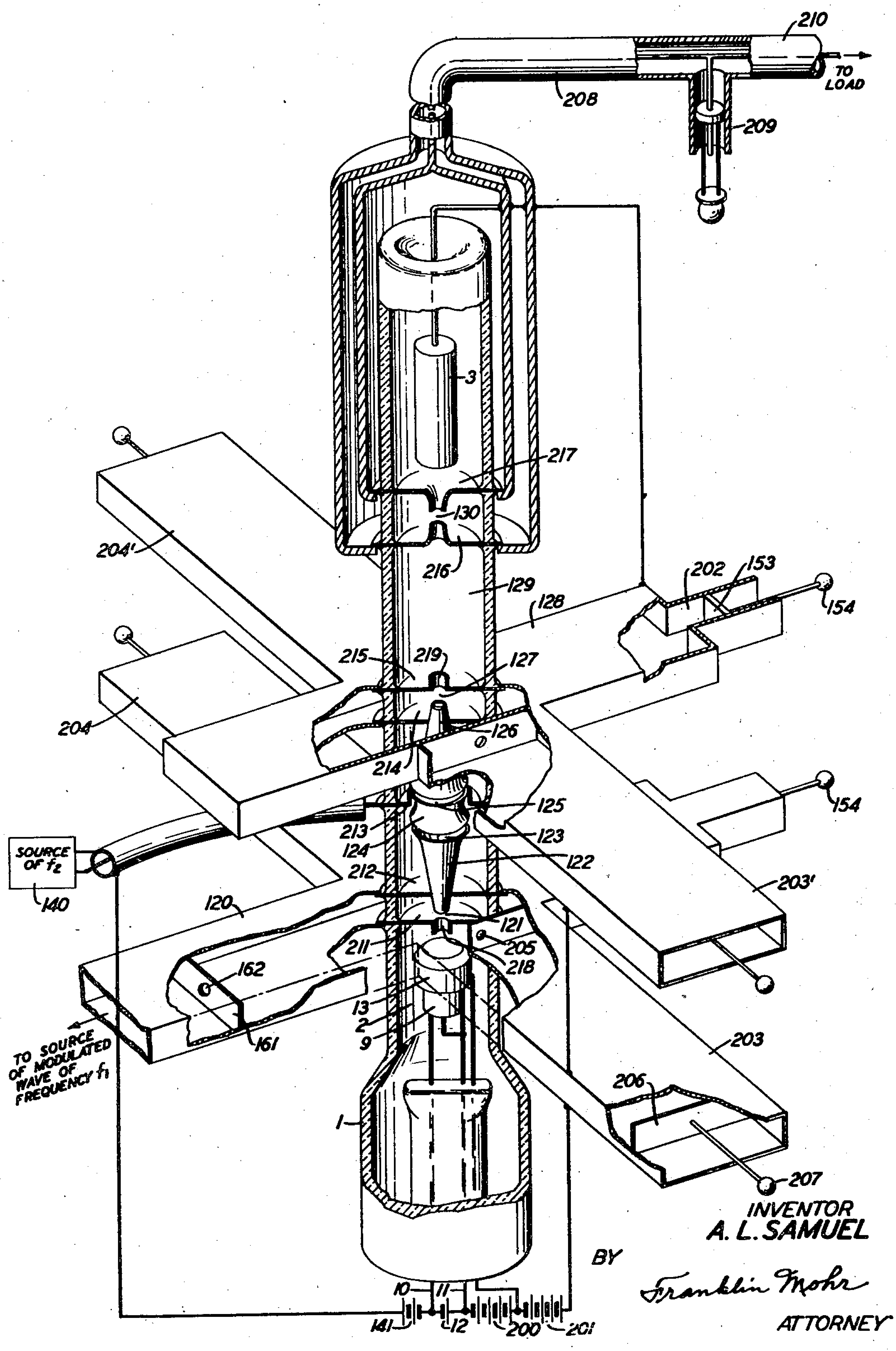

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ELECTRON BEAM MODULATOR

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5 Claims. (Cl. 250—20)

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This invention relates to electronic devices, particularly for operation at ultra-high frequencies.

An object of the invention is to intermodulate waves of different frequencies by virtue of non-linear actions in a system comprising an electron stream associated with a plurality of electrodes, particularly in frequency shifting arrangements for radio repeaters, first and second detectors in superheterodyne receiving systems, and the like.

Another object of the invention is to facilitate the operation and tuning of amplifiers, oscillators and the like, especially those employing resonating chambers or cavity resonators.

A feature of the invention is a system to effect frequency conversion employing an electron beam and one or more resonating chambers, in which the output is obtained at the frequency of a local energy source.

Other features include fine adjustment and broad-band tuning arrangements for a resonating chamber.

This application includes subject matter originally disclosed in my copending application, Serial No. 412,067, filed September 24, 1941.

Further objects and features of the invention will be apparent from the following detailed description and the accompanying drawing, while the scope of the invention is defined in the appended claims.

The single figure of the drawing represents a preferred embodiment of the invention.

Referring to the drawing, an evacuated, insulating envelope 1 is represented as enclosing a plurality of elements including a suitable source of an electron stream such as an electron gun or beam projector shown generally at 2, and an electron intercepting electrode or collector 3. The electron gun 2 is provided with an electron emitting cathode 9 which may be associated with any suitable heating means energized, in the embodiment illustrated, through leads 10 and 11 by a source 12 of electromotive force. Associated with the cathode 9 there may be an electrode 13 for use in regulating and varying the current of the electron beam and commonly known as an accelerating electrode. It may be adjacent to and coaxial with the cathode.

A plurality of conductive discs 211 to 217 inclusive are hermetically sealed into and through the envelope 1 in any known manner. The discs are spaced at suitable intervals along the path of the electron stream as hereinafter described, and each is provided with a central aperture in alignment with the axis of the electron gun 2 in order to accommodate the passage of the electron stream

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from said gun to the collector 3. A pair of adjacent discs 211 and 212 respectively form parts of opposing walls of an input resonator 120. The disc 211 may have attached thereto a short tube 218 aligned with the aperture and extending outwardly with respect to the walls of the resonator 120. The disc 212 has fastened to the edge of the aperture therein a relatively long, flaring tube 122. Longitudinally of the path of the electron stream a gap 121 is defined between the central portion of the inner surface of the disc 211 and the small end of the tube 122. The disc 213 has fastened to the edge of the aperture therein a ring-shaped electrode 124 positioned adjacent to the large end of the tube 122. An annular gap 123 is defined between the adjacent ends of the tube 122 and the electrode 124. A pair of adjacent discs 214 and 215 respectively form parts of opposing walls of an intermediate resonator 128. The disc 214 supports a flaring tube 126 similar to but inverted with respect to the tube 122 with the large end of the tube 126 defining together with the upper edge of the electrode 124 an annular gap 125. The disc 215 may have, attached to its outer side and surrounding the aperture, a short tube 219. A gap 127 is defined between the central portion of the inner surface of the disc 215 and the small end of the tube 126.

The walls of the resonator 120 should be conductive, or should at least have conductive inner surfaces. The tubes 122, 126, 218 and 219 and the ring 124 should be conductive and should be conductively fastened to their respective supporting discs.

The portion of the arrangement so far described is similar to one disclosed and claimed in my copending application Serial No. 388,031, filed April 11, 1941, and assigned to the assignee of the present application. The resonator 120 may be connected with a suitable wave guide for supplying incoming waves to the resonant system, the guide being separated from the resonant chamber by a conductive partition 161. Coupling between the guide and the resonant chamber may be effected by means of a suitable aperture 162 in the partition 161. The wave guide may be formed as an extension of the walls of the resonator 120 as shown.

Separated from the gap 127 by a suitable drift space 129 is a gap 130 which is defined by opposed truncated conical portions of the discs 216 and 217. These discs form portions of the walls of a resonator, e. g., a quarter wave-length coaxial conductor system 208, which may have a tuning branch 209. A source 140 of alternating potentials is connected with the electrode 124, the direct potential of electrode 124 being maintained at a relatively low potential with respect to the cathode by a source 141, whereas the conductive portions of the resonators 120, 128 and 208 and the collector 3 are maintained at a relatively high positive potential with respect to the cathode by means of batteries 200 and 201. The electrode 13 may be connected, as shown, to the positive terminal of the battery 200. To effect the relative potential values hereinbefore specified the potential of the battery 141 may be relatively low with respect to the combined potential of batteries 200 and 201. The tuning branch 209 may serve to define the short-circuited end or voltage node of the quarter wave-length line 208, another branch 210 being provided for connection to any suitable load.

In the operation of the system shown in the drawing, the input wave, the carrier frequency of which will be designated f_1 and which wave may bear signals in the form of modulations, e. g., amplitude modulations, is resonated in the chamber 120 and produces an electron velocity variation in the electron stream as the latter traverses the associated gap 121. The frequency of the wave supplied by the local source 140 will be designated f_2. Electron velocity sorting takes place within the tube 122 due to the influence of the relatively low potential of the electrode 124. With proper selection or adjustment of the battery potentials, a condition is readily secured in which the faster electrons pass through the space within the electrodes 124 and 126 whereas the slower electrons are deflected and intercepted by the electrodes 122, 124 and 126, the result being a charge density variation both in the stream of electrons which pass beyond the tube 126 and in the current intercepted by the electrodes. The degree of velocity sorting and resultant grouping produced is, however, in the present system, under the control of the local source 140 by virtue of the variable potential superimposed upon the direct current biasing potential of the electrode 124 which causes the resultant bias to fluctuate. Upon passing the gap 127, the density-varied electron stream serves to excite electromagnetic oscillations in the resonator 128, which resonator may be tuned to respond to one or both of the frequencies (f_1+f_2) and (f_1-f_2), to reinforce these frequencies which, it will be noted, are modulation products separated from the frequency of resonator 120 by an amount equal to the value of the frequency of the source 140. Oscillations thus produced in resonator 128 impress a corresponding velocity variation upon the electron stream as the latter traverses the gap 127. The velocity variation of the electron stream entering the drift space 129 will contain a component of the local frequency f_2 of source 140 bearing the signal modulations of the original incoming wave of frequency f_1. The velocity variation is converted in the draft space 129 into density variations at the gap 130 by the grouping effect of faster electrons overtaking slower electrons.

The resonant line 208 may be tuned by means of the adjustable branch 209 to the frequency f_2 of the source 140 and will be excited into forced oscillations by means of the density variations at the gap 130. The output of the line 208 may be led through the branch 210 to a suitable load such as an intermediate frequency amplifier or other utilization means.

In connection with the resonator 128 there is

shown a precise or fine tuning arrangement, comprising a branch cavity 202 of relatively small dimensions, shown broken open, in which is slidably mounted a piston 153 which may be moved by means of a suitably connected knob 154. A similar arrangement may be employed in connection with the resonator 120. The branch cavity 202 is preferably of such restricted dimensions compared with the main cavity that the resonant frequency of the main cavity is close to and somewhat below the range of free transmission of the branch cavity so that the latter will not fully support a wave of the frequency to be resonated. Then a relatively large motion of the piston 153 will produce only a relatively small change in the resonant frequency of the combination. The currents flowing in the branch cavity will be less than in the main cavity with the result that any losses associated with the sliding contacts between the piston 153 and the walls of the cavity 202 will be minimized.

The resonator 120 is provided with adjustable side cavities 203 and 204 for the purpose of enabling the resonator to respond to a relatively wide frequency band. The side cavity 203 is coupled to the main cavity by means of an aperture 205 and is adjustable by means of a piston 206 connected to a knob 207. The side cavity 204 is connected to the main cavity and adjustable in a similar manner. The resonator 128 may be similarly equipped. The aperture 205 is preferably of a suitable size to provide a loose coupling between the adjacent chambers. The side cavities may be independently adjusted to resonate at the same frequency as the associated main cavity or at slightly different frequencies, producing in either case a broad frequency band or relatively flat transmission characteristic in the well-known manner of coupled resonant circuits of whatever form.

In the operation of the system as above described the resonator 120 is assumed broadly tuned to the frequency f_1 of the incoming wave and responsive to the sidebands due to the modulation which the incoming wave may bear. The resonator 128 may be tuned broadly to (f_1+f_2) or (f_1-f_2) as desired, while the line 208 is tuned to f_2. It is also feasible to operate by tuning the resonator 128 sharply to one of the above-mentioned frequencies. In that case, the side chambers 203′ and 204′ are not needed and the apertures for coupling the side chambers to the main cavity should be closed. It is also feasible to operate with the resonator 128 tuned so broadly as to include both (f_1+f_2) and (f_1-f_2), in which case the line 208 may be energized at twice the frequency f_2 and the length of the line 208 up to the position of the tuning stub should be increased accordingly.

What is claimed is:

1. In a frequency conversion system employing an electron beam device, a source of modulated waves of carrier frequency f_1, a source of waves of frequency f_2, means for combining waves of frequencies f_1 and f_2 from said respective sources in conjunction with the electron beam to produce charge density variations in said beam with frequency components of f_1 plus and minus f_2 and bearing the said modulations originally carried by the wave of frequency f_1, a resonator selectively responsive to one of the frequencies (f_1+f_2) and (f_1-f_2) in energy exchanging relation with the electron beam to be energized by said electron density variations of the electron beam and in turn to impress electron velocity

variations upon said beam, means for converting the compound variations of the electron beam so produced into a second succession of electron density variations, and resonating means tuned to the frequency f_2 in energy exchanging relation with the electron beam to be energized by components of said second succession of electron density variations which carry substantially the original modulation.

2. In a frequency conversion system employing an electron beam device, a source of modulated waves of carrier frequency f_1, a source of waves of frequency f_2, a resonator selectively responsive to the frequency f_1 in energy exchanging relation with the electron beam to impress electron velocity variations upon said beam under the control of modulated waves from said source of said waves of carrier frequency f_1, means to impress an electron retarding field of variable potential upon said velocity varied beam under the control of waves from said source of frequency f_2 whereby the slower electrons are turned back and electron density variations are thereby developed in the continuing portion of the stream including frequency components of $f_1 \pm f_2$ and bearing the said modulations originally carried by the waves of frequency f_1, a resonator selectively responsive to one of the frequencies (f_1+f_2) and (f_1-f_2) in energy exchanging relation with the electron beam to be energized by said electron density variations of the electron beam and, in turn, to impress further electron velocity variations upon said beam, means defining a drift space for converting the compound variations of the electron beam so produced into a second succession of electron density variations, and a resonator for waves of frequency f_2 in energy exchanging relation with the electron beam to be energized by components of said second succession of electron density variations which carry substantially the original modulation.

3. In a frequency conversion system, means for producing an electron stream, a plurality of resonators coupled to the electron stream in energy exchanging relation and arranged at successive points along the path of the electron stream, the first resonator in order in the direction of flow of said stream being resonant to a given frequency f_1, the third resonator in said order being resonant to a given frequency f_2, and the second resonator in said order being resonant to one of the combination frequencies $(f_1 + f_2)$ and (f_1-f_2), variably controllable means located between said first and second resonators to convert velocity variations of the electron stream into charge density variations, a source of waves of the frequency f_2, means actuated by waves from said source to variably control said conversion means, and means located between said second and third resonators for the further conversion of velocity variations of the electron stream into charge density variations.

4. In a frequency conversion system, means for producing an electron stream, a source of modulated waves of carrier frequency f_1, means to impress upon said electron stream a velocity variation in accordance with waves from said source, variably controllable means located beyond the region of said velocity varying means whereby velocity variations of the stream are converted into density variations, a source of waves of a given frequency f_2 for variably controlling said conversion means, means located beyond the region of said conversion means whereby a component of one of the combination frequencies $(f_1 + f_2)$ and (f_1-f_2) is reinforced to produce in said stream a velocity variation under the control of the said charge density variations, means located beyond the region of said reinforcing means whereby velocity variations are converted into charge density variations, and load means arranged to be excited by modulated charge density variations at a carrier frequency equal to f_2.

5. The method of frequency conversion which comprises operating upon an electron stream according to the following steps in the order given: velocity varying said stream under control of a modulated wave of carrier frequency f_1, developing density variations in variable degree under control of a wave of frequency f_2, reinforcing a component variation of one of the combination frequencies $(f_1 + f_2)$ and (f_1-f_2) by developing at said frequency a velocity variation under the control of said density variations, developing further density variations from the component variations so produced and using said stream to excite a load circuit at a carrier frequency equal to f_2 accompanied by substantially the original modulations of said modulated wave of carrier frequency f_1

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