Aug. 31, 1954 W. W. SALISBURY 2,688,107

ELECTRON BEAM DEVICE

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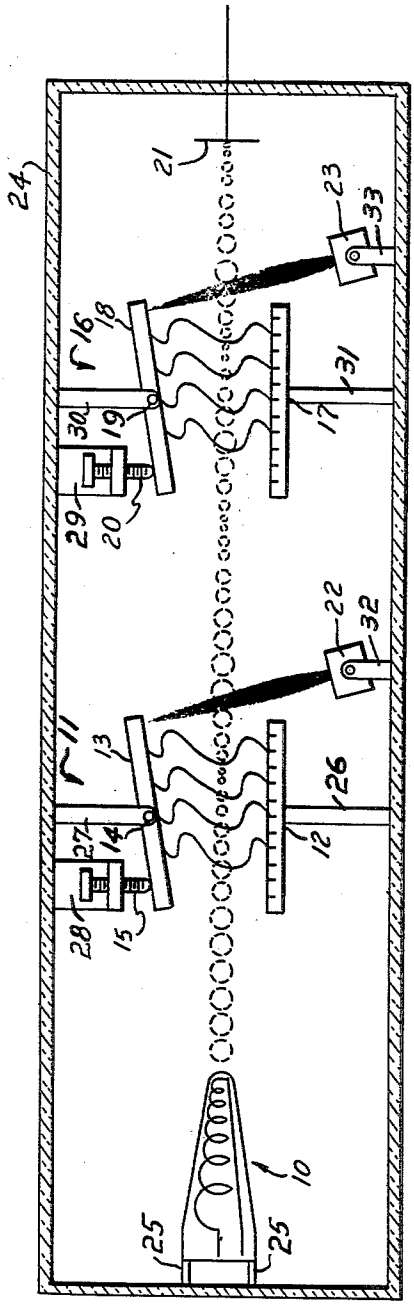


FIG 1

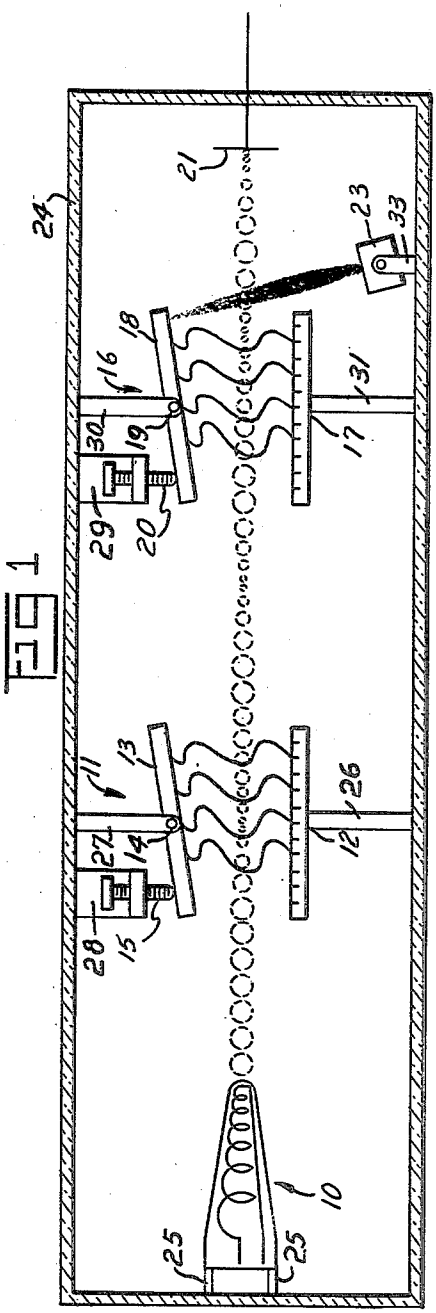


FIG 2

INVENTOR.
WINFIELD W. SALISBURY
BY Morris Moody
ATTORNEY

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ELECTRON BEAM DEVICE

Winfield W. Salisbury, Cedar Rapids, Iowa, assignor to Collins Radio Company, Cedar Rapids, Iowa, a corporation of Iowa

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2 Claims. (Cl. 315—4)

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This invention relates in general to electronic devices and in particular to extremely high frequency electronic apparatus.

It is an object of this invention to modulate an electron beam at very high frequencies as, for example, between 25,000 to 500,000,000 megacycles, and this frequency range will be referred to as the "extremely-high" range in this specification.

To produce standing waves by optical means and thus transfer energy between electro-magnetic waves and an electron beam is an object of this invention.

Another object of this invention is to provide an electronic device which will amplify signals in the extremely-high frequency range. Yet another object of this invention is to provide a mixer which will mix together two signals which are in the extremely-high frequency range.

A feature of this invention is found in the provision of an electron gun which passes a beam of electrons through a pair of tunable modulating members. When used as an amplifier, the first modulating member is placed closely adjacent to an external modulating signal source. A signal from the source impinges upon the first modulating member to set up a standing wave pattern therein. The electron beam passing through the first modulating member is modulated in response to the modulating signal before passing out into a drift space. A second modulating member is tuned to substantially the same frequency as the modulating signal, and as the bunched electron beam passes there-through, the modulation is amplified and energy is removed from the beam. The output has substantially the same frequency as the modulating signal but is greatly amplified.

Another feature of this invention is the provision for mixing extremely-high frequencies between 25,000 megacycles to 500,000,000 megacycles. An electron beam once more passes a beam of electrons through two modulating members which are tuned respectively by means of a standing wave pattern to the frequencies that it is desired to mix. A drift space is provided between the modulating members and the output from the second modulator contains the mixed signal.

Further objects, features, and advantages will become apparent from the following description and claims, when read in the light of the drawings, in which:

Figure 1 is a schematic view of this invention when operating as an amplifier, and

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Figure 2 is a schematic view of the apparatus of this invention when operating as a mixer.

Referring to Figure 1, an electron gun produces a steady beam of electrons, in a well-known manner. The velocity of the electrons from the electron gun varies as the accelerating voltage. Thus for a particular accelerating voltage there will be an associated velocity. This average velocity of the electrons will be referred to herein as the electron velocity.

The phase velocity of waves in an electron beam is defined by the equation:

$$V_{pe}=\frac{c}{\sqrt{1-\frac{ne^2}{\omega^2 m E_0}}} \quad (1)$$

where ω is equal to the angular frequency, n is equal to the number of electrons per cubic centimeter, e is equal to the voltage of the electrons, E_0 is equal to the dielectric constant of the medium through which the beam is passing, m is equal to the mass of the electron, and c is the speed of light.

Adjacent the electron gun is a first modulating means, designated generally as 11. The modulating member 11 comprises a pair of reflecting members 12 and 13. The members 12 and 13 may be moved relative to each other to vary the angle between them. This may be accomplished by pivoting the member 13 with the shaft 14 and connecting the threaded screw 15 to the member 13. The member 12 may be a diffraction grating. As is well known to those skilled in the art, a diffraction grating may be constructed by placing a multiplicity of spaced lines on a glass sheet. The number of lines per unit length and the width of each line should be chosen in accordance with the desired range of the output radiation frequency. For example, 10,000 lines per centimeter may be used to give an interlined spacing of .001 millimeter. The member 13 should have a highly reflecting surface and may be a mirror. As the reflector 13 is rotated about the axis 14, a standing wave pattern will be set up between the grating and reflector and the frequency depends upon the angle between them. The reflector picks up one wave-length from the diffraction grating and reinforces it to obtain a standing wave pattern between the grating and reflector. This is true even through there be no auxiliary exciting source 22, in that all bodies above a temperature of absolute zero radiate energy. This radiant energy will be sufficient to set up standing waves. An excitation source 22, which might be, for ex-

ample, a tungsten filament heated to a light emission temperature, is placed so as to throw energy upon the reflecting surface 13. If any of the energy given off by the source 22 is at the resonant frequency of the members 12 and 13, then the standing wave pattern between these members will be reinforced and as the intensity of the energy at the resonant frequency from the member 22 is varied, the amplitude of the standing wave pattern between the members 12 and 13 will be varied.

It is to be understood, of course, that the members 12 and 13 are resonant at only one frequency, depending upon the angle between them and the interlined spacing on the diffraction grating. The source 22 might provide a monochromatic radiation which has a frequency equal to the resonant frequency of the members 12 and 13. However, radiation over a relatively broad band will not prevent operation of the device in that only the resonant frequency from the excitation source 22 will cause amplification of the standing waves between 12 and 13. Thus, there is provided means for varying the amplitude of the standing wave pattern between the members 12 and 13. The electron beam from the gun 10 passing between the members 12 and 13 interacts with the electromagnetic waves produced by the grating and, as a result, the beam of electrons tend to group or "bunch." If the angle between the members 12 and 13 is designated as α the phase velocity of the standing wave between them will be defined as:

$$v\,(\text{phase})=\frac{c}{\cos\alpha} \tag{2}$$

and the group velocity will be defined as:

$$v\,(\text{group})=c\cos\alpha \tag{3}$$

where c is equal to the velocity of light and ω is defined above. It is to be noted that the phase velocity multiplied by the group velocity is equal to the speed of light squared.

$$v\,(\text{phase})\times v\,(\text{group})=\frac{c}{\cos\alpha}\times c\cos\alpha=c^2 \tag{4}$$

When the electron velocity is slightly greater than the group velocity of the electronic medium, and the phase velocity of the medium and the phase velocity of the modulating member match, amplification will occur. Stated otherwise, if the voltage of the electron beam is such that the electron velocity is greater than the group velocity, and the modulating member is tuned to a frequency having a phase velocity in the modulating member equal to the phase velocity of the electron beam, amplification will occur.

Referring once again to Figure 1, a second modulating member, designated generally as 16, is placed longitudinally from the first modulator and the electron gun 10. A drift space is provided between the modulating means 11 and 16. The second modulating member comprises the members 17 and 18 which are angularly movable relative to each other to allow tuning. The member 17 comprises a diffraction grating with the same physical characteristics as the diffraction grating 12, and the member 18 comprises a reflecting surface. Thus, a standing wave pattern will be set up between the members 17 and 18 whose frequency depends upon the angle a between them. The member 18 is pivotally supported by shaft 19 and screw 20 adjusts its position. A collector plate 21 is placed adjacent the end of the modulator 16 and collects the electrons after they have passed through the second modulating means. If an input signal is furnished to the first modulating means 11 from a modulation source 22 in such a manner that a standing wave pattern will be set up in the first modulating means, the electron beam passing through the first modulating member will be bunched in the drift space in response to the input signal. It is to be understood, of course, that this first modulating member is tuned to substantially the same frequency as the incoming modulating signal. The modulating signal may be a monochromatic light source. Message modulations of variable intensity or a frequency or phase variation may be used.

It is to be realized, of course, that the apparatus of this invention is enclosed in a suitable envelope 24 which might be made of glass, for example. Support members 25 extend from the envelope and support the electron gun 10. Stand-offs 26 and 31, respectively, support the members 12 and 17, and stand-offs 27 and 30, respectively, rotatably support the members 13 and 18. Stand-offs 28 and 29 support the screws 15 and 20. The modulation source 22 and the resonator 23 are pivotally supported by stand-offs 32 and 33, respectively.

Likewise, the modulating means 16 is tuned substantially to the modulating signal. The electron beam passing through the first modulating member 11 interacts with the standing wave pattern caused by the modulating source 22. This causes the electron beam to "bunch" in the space between the modulating members 11 and 16. When the beam passes through the member 16, the modulated beam causes a standing wave pattern to be set up. The output is removed by coupling energy therefrom as, for example, by reflecting energy from the member 16 to a resonator 23. The output removed will be at the same frequency as the modulating signal, but will be substantially amplified. Thus it becomes possible to modulate and amplify extremely-high frequency signals. This may prove of great value in detecting extremely-high frequency radiations for astronomical work, for example. Another possible use of such a device is for amplifying infra-red radiations so that they may be easily and accurately detected. Frequencies which have heretofore been unavailable to electronic engineers may thus be made available by the apparatus of this invention.

Figure 2 illustrates the manner in which the modulating means 11 and 16 in combination with a gun 10 may be used as a mixer.

Once again the electron beam is produced by the electron gun and passes through the modulators 11 and 16. The modulators and their standing wave patterns are tuned, respectively, to frequencies which it is desired to mix, as, for example f_1 and f_2. Frequencies f_1 and f_2 are selected by varying the angle α of the respective modulators. The output removed will contain the frequencies f_1 and f_2 and the various side bands. When the electron beam passes through the modulating member 11, the resonant frequency of the member will be excited to set up a standing wave pattern which will interact with the electron beam. The electrons of the beam will be "bunched" in response to this standing wave before passing into the second modulating member 16. Standing waves will be set up in member 16 and the electron beam will emerge with frequencies of f_1, f_2, f_1-f_2 and f_1+f_2 super-

imposed on it. The member **23** will be placed so as to intercept energy from the reflector **18**. If the response of the member **23** is such that it is energized by only one of the mixed signals then its output will contain only the particular mixed component. For example, assume that f_1 in the above example is equal to 100,000,000 megacycles and f_2 is equal to 50,000,000 megacycles. If the member **23** is responsive to 150,000,000 megacycles only, this frequency will appear in the output of member **23**. It is to be understood, of course, that suitable filters may be used to filter out the undesired frequencies. For example, if the apparatus is operating in the visible spectrum, filters of colored glass may be used to remove undesired frequencies.

It is seen, therefore, that this invention provides a device for amplifying and mixing signals in the extremely high frequency range. Many applications of this invention may be imagined and foreseen.

Although this invention has been described with respect to a preferred embodiment thereof, it is not to be so limited since changes and modifications may be made therein which are within the full intended scope of the invention as defined by the appended claims.

I claim:

1. Extremely high frequency energy producing means comprising, an electron gun for producing a beam of electrons, a first modulating means mounted in the path of the electron beam so that it passes therethrough, said first modulating means comprising a first pivotally supported reflecting surface and a diffraction grating, a second modulating means with the electron beam passing therethrough, said second modulating means comprising a diffraction grating and a reflecting surface pivotally supported so as to be angularly adjusted relative to the diffraction grating, a collector plate for intercepting said

electron beam, a modulation source mounted adjacent the first modulating means and furnishing energy to the first modulating means, a resonator mounted adjacent the second modulating means and positioned so as to intercept energy from the reflecting surface of the second modulating means.

2. An extremely high frequency electron modulating means comprising, an envelope, an electron gun supported at one end of said envelope for producing a beam of electrons, a collector plate mounted to the opposite end of said envelope and intercepting said beam of electrons, first and second modulating means supported by said envelope with the electron beam passing therethrough, said modulating means comprising, respectively, a diffraction grating, and a reflection means pivotally supported by the envelope, said diffraction grating and reflecting means mounted on opposite sides of the electron beam and tunable by varying the relative angle therebetween, a modulation source adjacent the first modulating means for supplying energy to the reflecting means so as to excite the first modulation source with a standing wave pattern, and a resonator mounted adjacent the second modulating means and positioned so as to receive energy from the reflecting means of said second modulating means.

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