

Dec. 7, 1948.

R. H. VARIAN

2,455,393

MODULATED WAVE MODIFYING APPARATUS

Filed June 9, 1943

3 Sheets-Sheet 1

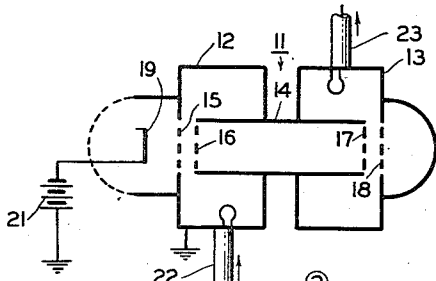


FIG. 1.

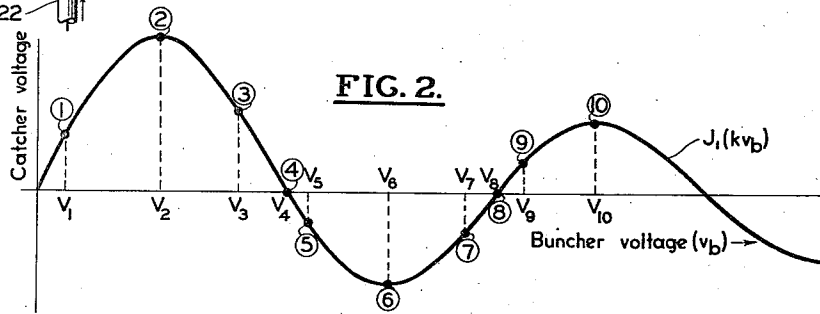


FIG. 2.

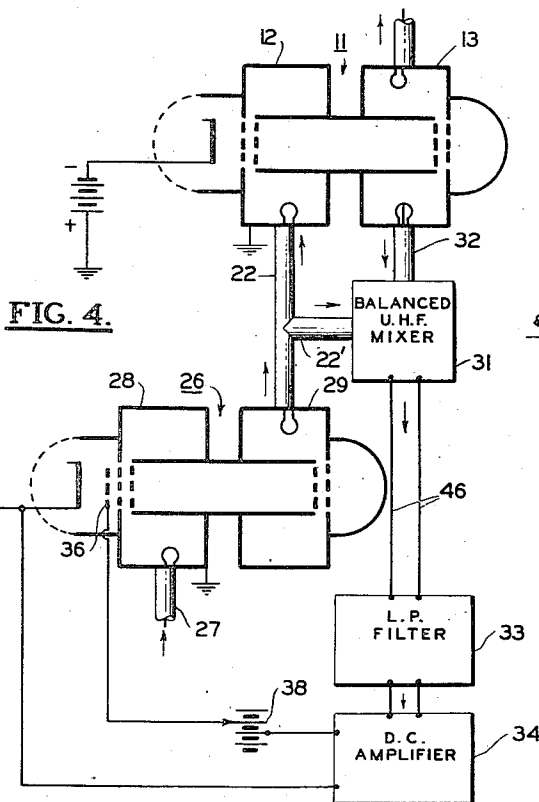


FIG. 4.

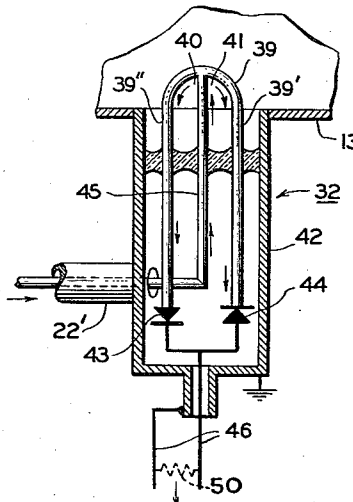


FIG. 5.

INVENTOR
RUSSELL H. VARIAN
BY *Paul B. Hunter*
ATTORNEY

Dec. 7, 1948.

R. H. VARIAN

2,455,393

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3 Sheets-Sheet 2

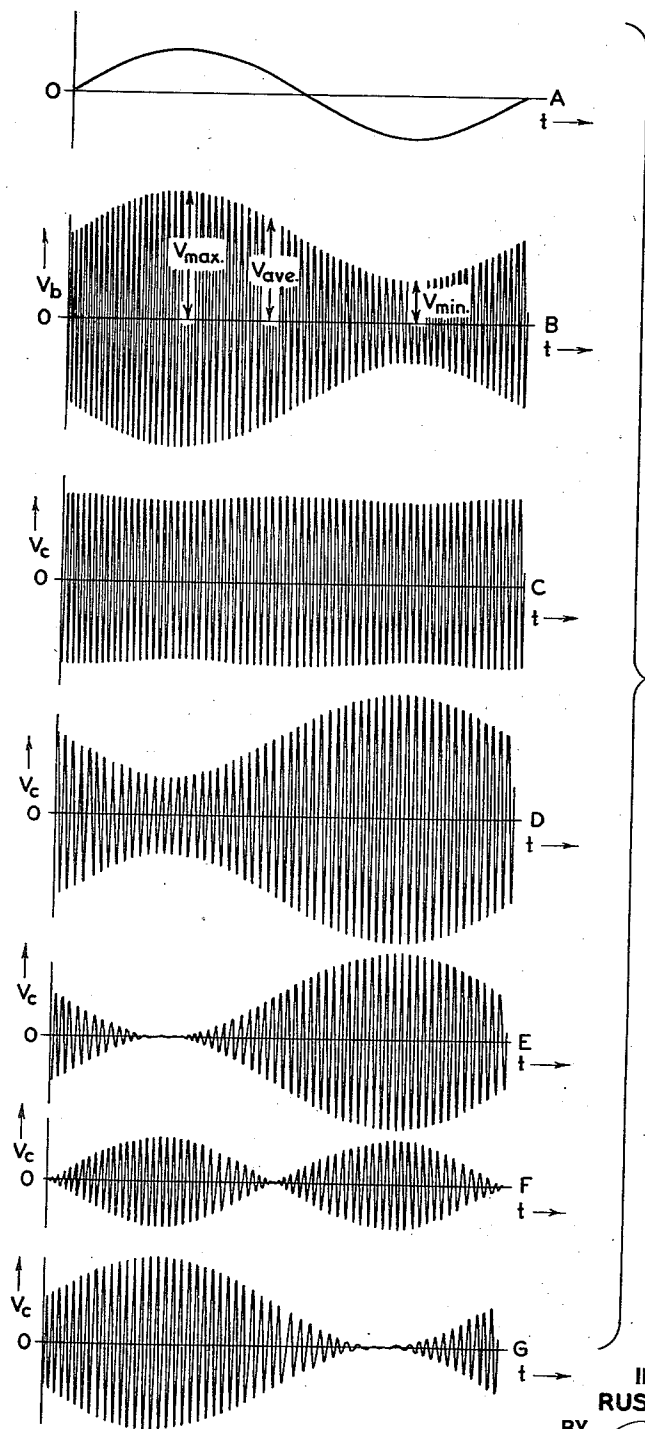


FIG. 3.

INVENTOR
RUSSELL H. VARIAN
BY *Paul B. Hunter*
ATTORNEY

Dec. 7, 1948.

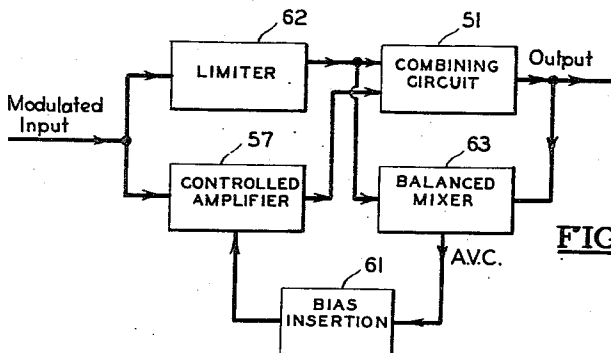
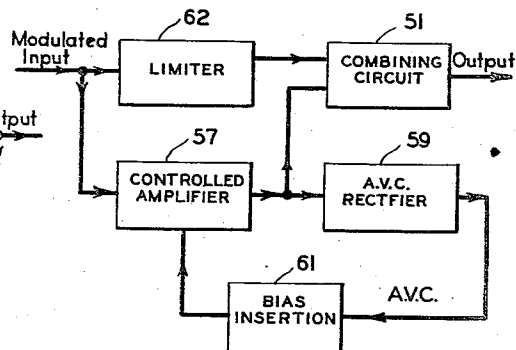
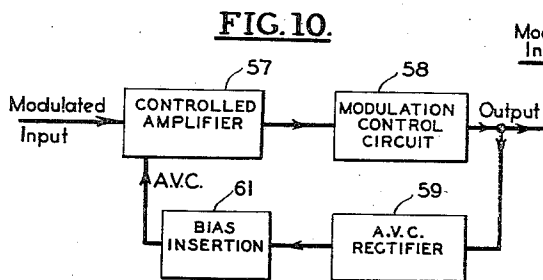
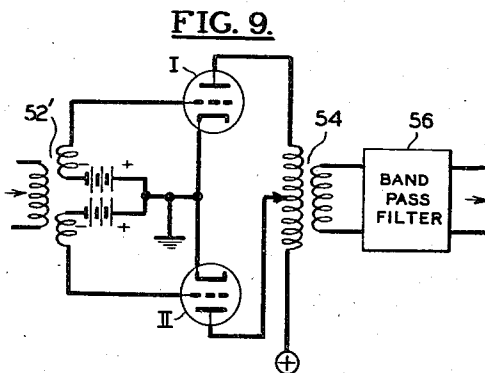
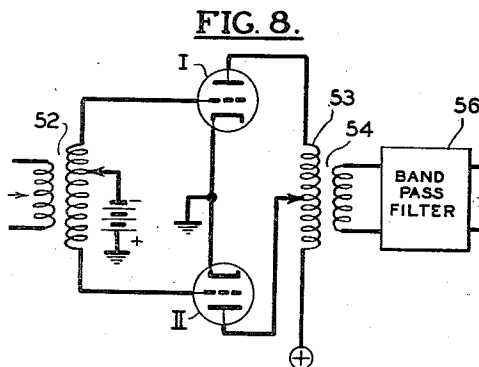
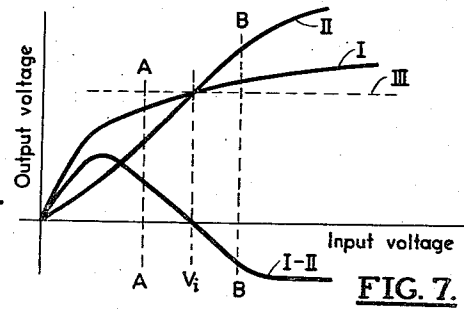
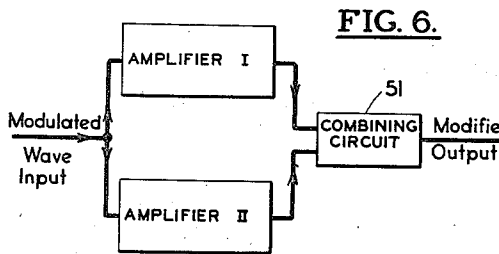
R. H. VARIAN

2,455,393

MODULATED WAVE MODIFYING APPARATUS

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3 Sheets-Sheet 3



INVENTOR
RUSSELL H. VARIAN
BY *Paul R. Hunter*
ATTORNEY

UNITED STATES PATENT OFFICE

2,455,393

MODULATED WAVE MODIFYING
APPARATUSRussell H. Varian, Garden City, N. Y., assignor to
The Sperry Corporation, a corporation of Dela-
ware

Application June 9, 1943, Serial No. 490,132

21 Claims. (Cl. 250--27)

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The present invention is related to the art including velocity variation electron discharge tube devices and especially to such devices of the type shown in Varian Patent No. 2,242,275, issued May 20, 1941. The present invention is more particularly directed to apparatus and methods for utilizing such devices for the control of modulation upon an ultra high frequency carrier wave, such as in the centimeter wavelength region.

It has been discovered that velocity variation devices of the above type may be effectively utilized as amplitude limiters or percentage modulation control devices in addition to their ordinary uses as amplifiers and oscillators. Accordingly, it is an object of the present invention to provide improved apparatus and methods for limiting the amplitude of an ultra high frequency carrier wave, whereby random or other variations in amplitude such as due to noise or other causes may be substantially eliminated.

It is another object of the present invention to provide improved apparatus and methods for changing or controlling the percentage modulation of a modulated ultra high frequency carrier wave.

It is still another object of the invention to provide improved apparatus for modifying the modulation of a modulated wave and to automatically maintain the modified condition of the wave at a desired value.

It is a further object of the present invention to provide improved ultra high frequency mixer means useful in the above-described invention, and also generally useful.

It is a still further object of the present invention to provide improved apparatus and methods for eliminating the carrier component of an ultra high frequency modulated wave to form a carrier suppressed wave.

It is still another object of the present invention to provide improved apparatus and methods for increasing the percentage modulation of an ultra high frequency modulated wave.

It is yet another object of the present invention to provide improved apparatus and methods for reversing the phase of the modulation upon a modulated ultra high frequency wave.

It is a further object of the invention to provide improved frequency-independent apparatus for carrier suppression or percentage modulation control of high frequency modulated waves.

Other objects and advantages of the present invention will become apparent from consideration of the following specification and drawings, wherein:

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Fig. 1 shows a schematic diagram of the velocity variation electron discharge tube of the present invention.

Fig. 2 shows a graph useful in explaining the theory of operation according to the present invention.

Fig. 3 shows various voltage versus time curves useful in explaining the various types of operation according to the present invention.

Fig. 4 shows an automatic circuit for producing the improved results according to the present invention.

Fig. 5 shows a detailed view of the balanced mixer of Fig. 4.

Fig. 6 is a block diagram of an electronic circuit adapted to produce the same results as the device of Figs. 1 or 4.

Fig. 7 is a graph useful in explaining the operation of the device of Fig. 6.

Figs. 8-12 are schematic block diagrams of modifications of Fig. 6.

Referring to the drawings, Fig. 1 schematically shows a velocity variation electron discharge device 11, commercially known as the "Klystron," which is described in the above-mentioned Varian Patent No. 2,242,275. As is well known, such devices include a pair of cavity resonators 12 and 13 having respective pairs of electron permeable grids 15, 16 and 17, 18 separated by a field-free drift-space-defining tube 14. An electron stream is projected from a cathode 19 by means of an accelerating battery 21 and successively passes through the gaps between grids 15, 16 and 17, 18. The input or buncher resonator 12 may be excited with ultra high frequency energy by means of an input connection, such as an input concentric line 22, and corresponding high frequency energy may be abstracted from the output or catcher resonator 13 by way of a similar coupling line or terminal 23. The high frequency electromagnetic field existing between grids 15 and 16 serves to periodically vary the velocity of the electrons passing therethrough. These velocity-varied electrons become grouped or bunched during their travel through drift tube 14 and deliver corresponding amplified ultra high frequency energy to the resonator 13 upon passing through grids 17 and 18. As is discussed in the above-mentioned Patent No. 2,242,275, the present apparatus may serve as an ultra high frequency amplifier or an ultra high frequency regenerative oscillator or a regenerative amplifier. The operation of resonators 12 and 13 upon the electron beam is the same as though an alternating voltage were impressed between their corresponding grids 15,

16 or 17, 18. This effective voltage between grids 15, 16 will be hereinafter termed the "buncher voltage," and the corresponding effective voltage between grids 17 and 18 will be termed the "catcher voltage."

It has been found that, as the amplitude of the ultra high frequency buncher voltage is varied, as by changing the energy supplied to line 22 or by changing the coupling between line 22 and buncher resonator 12, the catcher voltage produced will vary in accordance with the curve shown in Fig. 2, which has the form of the well-known Bessel function of first order having its argument proportional to the buncher voltage. This curve shows that the catcher or output voltage is an oscillating function of the input or buncher voltage. In operating the device as an amplifier or regenerative oscillator, in the manner described in my above-mentioned Patent No. 2,242,275, the buncher voltage is adjusted to a value such as V_1 , so that the tube operates approximately at the point 1 of the characteristic of Fig. 2. At this point it will be seen that an increase in buncher voltage will produce a substantially proportional increase in catcher voltage, and accordingly the device may act conveniently as a linear amplifier for a modulated wave input.

According to the present invention, the device of Fig. 1 is caused to operate as an amplitude limiter or modulation suppressor, as a modulated wave inverter, as a carrier suppressor, as a percentage modulation increasing circuit, or as a percentage modulating decreasing circuit, depending on the operating point chosen.

For example, if the buncher voltage is adjusted to the value V_2 corresponding to point 2 of the characteristic, at which the characteristic has a maximum value, it will be seen that variations in the amplitude of buncher voltage over a considerable range will have negligible effect upon the catcher voltage. Therefore, if a modulated input wave of relatively small percentage modulation and producing an average buncher voltage V_2 is fed to the buncher resonator 12, the variations in amplitude of this wave caused by its modulated character will be virtually eliminated by the device, and a substantially pure unmodulated wave will be produced in the output line 23. In this way the device will act as a voltage regulator (maintaining constant output amplitude), as a modulation suppressor, or as an amplitude limiter.

In this instance, the output amplitude remains substantially constant despite variations of the input amplitude. This condition is illustrated in Fig. 3, in which curve A illustrates a modulation signal taken for illustrative purposes only as being approximately a sine wave. Curve B illustrates a carrier wave amplitude modulated in accordance with the signal of curve A. If such a wave is fed to the buncher resonator 12 when the device is operating with the average buncher voltage at point 2 of the oscillating characteristic of Fig. 2, the result will be an output wave derived from output line 23 of substantially the form shown in curve C, in which the variations in amplitude of the wave are substantially suppressed. Accordingly, as suggested above, the device with this condition of operation will operate to yield a substantially constant output amplitude despite the variations of input amplitude. It will thus operate to eliminate any modulation, whether intentional or involuntarily caused, such as by noise impulses.

If the device of Fig. 1 operates at point 3 of Fig. 2, as by supplying an average buncher voltage V_3 , it will be seen that an increase in the buncher voltage from the value V_3 will produce a decrease in the catcher voltage, and correspondingly, a decrease in the buncher voltage produces an increase in the catcher voltage. If the wave of Fig. 3B is again supplied to the device of Fig. 1 with an average amplitude V_3 , the output derived from the catcher resonator 13 will be as shown in Fig. 3D; namely, the modulation envelope has been reversed in phase, and the device therefore operates as a modulation phase inverter. It is to be noted that it is only the modulation envelope which is reversed in phase. The actual ultra high frequency alternations are not affected.

The present circuit may also be utilized to increase the percentage modulation of the wave supplied to its input. Thus, if the input wave shown in Fig. 3B is so adjusted that the maximum amplitude V_{max} of its envelope is equal to V_4 , which is the value of the buncher voltage producing operation at point 4 of the characteristic of Fig. 2, it will be seen that, at this value of the buncher voltage, zero voltage will be received at the catcher. For voltages differing from this maximum, the output of the catcher will increase in substantially linear relation to the decrease in the buncher voltage. Accordingly the output wave will be of the form shown in Fig. 3E; namely, it will have its percentage modulation increased to substantially 100 per cent, with a phase inversion of the modulation envelope. It will be clear that for average amplitudes of the buncher voltage between the value producing curve E and that producing curve D, the percentage modulation of the input wave may be changed from its original value to any value to 100 per cent by a suitable choice of operating point.

A further type of operation may be obtained by operating at point 4, at which point the buncher voltage V_4 yields zero catcher voltage. In view of the substantially linear character of the characteristic on either side of point 4, the apparatus may then operate to entirely suppress the carrier component of the modulated wave supplied to the buncher resonator 13. Thus, if the wave of Fig. 3B, having an average amplitude V_4 , is supplied to the input of the device of Fig. 1, the resultant output voltage derived from catcher resonator 13 will have the wave shape shown at Fig. 3F, which will be recognized as a carrier-suppressed wave. In this way a simple modulated wave, such as in Fig. 3B, may be converted to a carrier-suppressed wave, as in Fig. 3F.

As another illustration of the use of the present device, it may be operated at point 5 of Fig. 2, that is, with the average amplitude V_{ave} of the wave of Fig. 3B having the value V_5 , which is so selected that the minimum amplitude V_{min} of the wave of Fig. 3B produces a buncher voltage V_4 . When this is done, the result obtained from the catcher resonator 13 will be the wave of Fig. 3G, in which it will be seen that the percentage modulation has been increased to 100 per cent without the phase inversion produced in Fig. 3E.

Operation at point 6 of the characteristic of Fig. 2 will produce the same constant voltage output as is derived under the condition illustrated in Fig. 3C when the average input amplitude V_{ave} is adjusted to have the value V_6 .

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However, in this case the ultra high frequency wave will be phase-inverted with respect to that obtained by operating at point 2.

If the maximum amplitude V_{max} of the input wave of Fig. 3B is adjusted to have the value V_1 corresponding to the second zero of the curve of Fig. 2, in which case the average input amplitude V_{ave} will produce a buncher voltage V_b , the wave of Fig. 3E will again be produced, having the modulation reversed in phase. The phase of the high frequency oscillations is also reversed with respect to operation with maximum input at 4. By operating with the voltage input amplitude V_{ave} at point 3, at an average buncher voltage V_b , a further carrier-suppressed wave similar to Fig. 3F will be produced in the output. Again by operating with the minimum amplitude V_{min} of the input wave to produce a buncher voltage V_b , in which case the operating point will be at a buncher voltage V_b , the output wave of Fig. 3G will be obtained. Again, when operating at point 10, the characteristic of Fig. 3C will be produced.

In this same manner further operating points may be chosen along the characteristic of Fig. 2, which will produce any of the types of operation discussed above and also many other types intermediate those described. Also, the amount of decrease of percentage modulation may be varied by selecting various points along the characteristic, since the decrease in percentage modulation will depend upon the slope of the characteristic, divided by the height of the curve above zero.

It will be noted that the slopes existing at various points in the curve continuously become less and less as the higher modes of operation are reached. Therefore, for best operation as an amplifier in the manner discussed in my Patent No. 2,242,275, the operating point should remain at point 1 which has the steepest slope anywhere along the curve, and therefore produces the highest gain.

In order to be able to maintain operation at any predetermined point of the characteristic of Fig. 2, to derive any of the types of operation already discussed, use may be had of the system of Fig. 4, which shows a system for controlling the input to resonator 12 of the device 11. For this purpose an ultra high frequency amplifier 26, also preferably of the velocity modulation type, is supplied with the input wave corresponding to the wave of Fig. 3B by means of its input concentric line 27 coupled to its buncher resonator 28. The output derived from the catcher resonator 29 is then fed by line 22' to resonator 12, and also is fed to a balanced ultra high frequency mixer 31 by line 22'. Balanced mixer 31 is also supplied with energy derived from catcher resonator 13 of the controlled device 11, as by way of the coupling line 32 shown more in detail in Fig. 5, and is thereby adapted to produce an output having a wave form corresponding to the product of the instantaneous wave forms of its inputs, in accordance with the well-known theory of balanced mixers.

Fig. 5 shows in more detail the arrangement of the balanced mixer 31. The coupling line 32 comprises a U-shaped conductor 39 located within the electromagnetic field of the catcher 13 and having a central conductor 45 connected to the center of the U-shaped portion to form two coupling loops 40, 41. This central conductor 45 is connected to, or forms an extension of, the central conductor of line 22' connected to line 22

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supplying energy from amplifier 26 to the buncher 12. The outer conductor of line 22' is connected to the outer conductor 42 of the transmission line 32. In this way the current flowing in the inner conductor of the transmission line 22' is connected in series with each of the currents induced in the two loops 40, 41. The currents induced in these two loops 40, 41 will be of opposite phase, and preferably the current produced in the inner conductor 41 is adjusted in phase by means of any suitable phase-shifting mechanism inserted in line 22' (not shown), so as to be in phase opposition to one of the two loop currents and in phase concurrence with the other. These resultant currents in the legs 39, 39' of conductor 39 are then rectified by respective rectifiers 43 and 44 connected in series therewith.

It will be clear that when zero current is picked up by the two loops 40, 41, the outputs of rectifiers 43 and 44, being in opposition with respect to the currents flowing in conductor 41, will produce zero direct current output in the output leads 46, which may be connected to a load resistor 50. When a current of predetermined phase is induced in the two loops, 40, 41, one of the currents supplied to rectifiers 43 and 44 will be increased and the other will be decreased, producing a direct current output of predetermined polarity. When reverse phase currents are induced in the loops 40, 41, the formerly decreased current is now increased and the formerly increased current is now decreased, producing an opposite polarity direct current output.

It will be seen that if the input to buncher 12 is an unmodulated pure carrier, and if the device 11 is operating at point 4 of the characteristic of Fig. 2, the catcher voltage will have zero amplitude, and, accordingly, the mixer 31 will have zero output as discussed above.

For a buncher voltage either less than or greater than the value V_1 required to operate at point 4, a catcher voltage will appear in the catcher 13, whose amplitude will be substantially proportional to the deviation of the actual buncher voltage from the value V_1 for reasonable excursions from V_1 . However, as the buncher voltage increases from a value less than V_1 to a value greater than V_1 , the phase of the ultra high frequency oscillations produced in the catcher resonator 13 will reverse; that is, the phase-sense of this catcher voltage depends on the sense of excursion of the buncher voltage from the value V_1 .

Therefore, if the input to the mixer 31 derived from line 22' is adjusted in phase with respect to the input derived from line 32, to be either in relative phase concurrence or phase opposition, it will be seen that the direct current output from mixer 31 will reverse polarity as the buncher voltage passes through the value V_1 , and that the magnitude of this direct current output will depend upon the deviation of the actual buncher voltage from the value V_1 . This feature is utilized in the present circuit to automatically control the actual buncher voltage fed to buncher 12 to maintain the catcher 13 output at a desired point of the characteristic of Fig. 2.

Thus, the output 46 of mixer 31 is passed through low pass filter 33, which permits only the direct current component of the mixer output to pass therethrough. This direct current output is then amplified, if desired, in a suitable direct current amplifier 34, and is impressed upon the control grid 36 of the amplifier 26.

As is well known, the amplification of a

"Klystron" amplifier, such as 26, depends upon the beam current passing therethrough. By thus controlling the beam current from the output of mixer 31, the output of catcher 29 can be adjusted to give a desired voltage for buncher 12. For example, let it be supposed that it is desired to operate at the point V_4 of the characteristic of Fig. 2. At this point, as has been discussed, the mixer output should be zero. If the buncher voltage departs from the value V_4 , this will be sensed by the appearance of a direct current output from mixer 31, the polarity of this output depending upon the sense of the deviation of the buncher voltage from the value V_4 , and the output magnitude depending upon the amount of buncher voltage deviation.

Let it be assumed that a negative voltage is obtained from direct current amplifier 34 when the buncher voltage is higher than the value V_4 , as can be obtained by properly poling amplifier 34 to grid 35. This negative voltage applied to grid 36 decreases the output of "Klystron" amplifier 26 and thereby decreases the voltage of buncher 12. By making the amplification of direct current amplifier 34 relatively large, the system can be made to operate substantially exactly at the voltage V_4 .

Correspondingly, if the actual buncher voltage is too low, a positive output voltage will be derived from direct current amplifier 34 which, when applied to grid 36, will increase the output of "Klystron" amplifier 26 and will therefore increase the voltage of buncher 12. The buncher voltage can thereby be maintained at the desired operating point illustrated as V_4 .

If it is desired to operate the device at any other operating point, it will be seen that for this operating point a particular mixer output, or output from direct current amplifier 34, will be derived. This output may be effectively cancelled out by a bias derived in any suitable manner, as from an adjustable direct current source, such as battery 38, in series with grid 36; so that grid 36 is properly biased to produce a buncher voltage which in turn will produce an output from direct current amplifier 34 just sufficient to maintain this desired buncher voltage. By proper choice of the bias of battery 38, any desired operating point may be automatically maintained.

It will be noted that in each of the types of operation discussed above, and especially in the type of operation wherein the carrier component of the modulated wave is removed, the apparatus is responsive, not to frequency, but solely to the amplitude of the modulated wave. In this respect the present apparatus constitutes a distinct change from prior practice in which a carrier is usually removed by filter means or other frequency sensitive apparatus.

The same principle may be applied to eliminate the carrier component of a modulated lower frequency wave. A block diagram for such a system is shown in Fig. 6. Thus, the modulated wave is fed to a pair of amplifiers I and II whose input versus output characteristics may be as shown by the corresponding curves of Fig. 7. The outputs on this characteristic may be that at a particular harmonic of the input, or at the same frequency as the input. It will be seen that these characteristics are adjusted or selected to that at a predetermined input voltage V_1 the outputs of the two amplifiers will be equal. At other input voltages differing from V_1 , the outputs of the

two amplifiers will be unequal, and, in fact, the difference between these outputs may be as represented by the resultant curve I—II shown in Fig. 7, which is another form of oscillating function, somewhat similar to that of Fig. 2. The difference between the outputs may then be obtained by a suitable combining circuit 51.

If the average amplitude of the modulated input wave is chosen or adjusted to have the value V_1 , then the output from combining circuit 51 will have the carrier component suppressed in the same manner discussed with respect to Figs. 1 to 5. This is produced by the characteristic I—II of Fig. 7, which gives zero output at the average amplitude of the modulated wave and has substantially linearly varying output at the selected harmonic of the carrier with respect to deviations of the amplitude of the input modulated wave from this average value. Furthermore, the phase reversal in the output of the combining circuit assures that the output wave will be a true carrier-suppressed wave. The circuit of Fig. 6 therefore constitutes essentially an amplitude discriminator.

The amplifiers I and II may be provided in several different manners, of which two are illustrated in Figs. 8 and 9. In Fig. 8 the amplifiers I and II are chosen to have differing amplification characteristics. Then the input modulated wave is supplied in opposite sense to the control grids of the amplifiers I and II by way of a coupling transformer 52. Preferably, although not necessarily, the amplitude of the voltage applied to one of these control grids is greater than that applied to the other.

The outputs from the amplifiers I and II are additively combined in the primary 53 of an output transformer 54. One of the amplifiers, shown as amplifier II, is coupled to only a portion of primary 53, the other being coupled to the entire primary 53. By suitable adjustment of the relative couplings of the two amplifiers to the primary 53, and of the relative values of the input voltages to control grids of these tubes, it can be assured that at a particular average input voltage V_1 the output voltage of fundamental frequency derived from the secondary of transformer 54 will be substantially zero. At other voltages than V_1 , however, one or the other of tubes I and II will have a greater output than the other, so that a corresponding output will be derived from transformer 54, producing a carrier-suppressed wave.

Generally speaking, the differing amplification characteristics of tubes I and II can be provided by selecting these tubes to be of different types. Alternatively, it can be provided by operating the tubes of the same type with different excitations, as is shown in Fig. 8.

Fig. 9 shows still another way of providing these different characteristics in which differing biases are applied to control grids of the tubes I and II, so that they will operate at different portions of their plate characteristics, having different curvatures. Other ways of providing these different curvatures may also be used.

In most instances the difference in amplification characteristics of the two tubes will necessitate operating at least one of them upon a curved portion of its plate characteristic. This, as is well known, tends to produce distortion. Such distortion is evidenced by demodulation or by the production of harmonics of the carrier and side band frequencies. By supplying a suitable band pass filter 56, adapted to pass all frequencies in the neighborhood of the desired carrier fre-

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quency to the output of transformer 54, all of the undesired distortion components can be eliminated and the resultant output will be a substantially pure carrier-suppressed modulated wave.

Alternatively, the device may simultaneously frequency multiply, by passing only a harmonic of the input carrier.

It will be noted that the device of Figs. 8 and 9 is completely independent of frequency, except for the band pass filter 56 which effectively is merely a refinement of the circuit. Accordingly, the circuit can operate satisfactorily over a wide range of nominal carrier frequencies. It will be clear that further modifications can be provided similar to Figs. 8 and 9 all operating upon the principle described with respect to Figs. 6 and 7.

While the systems of Figs. 6 to 9 have been described with respect to suppressing the carrier component of modulated waves, it will be seen that they can also be utilized to increase the percentage modulation of such modulated waves. Thus, if the minimum amplitude of the modulated wave input is adjusted to have the voltage value V_1 , the output wave derived from the apparatus of Figs. 6 to 9 will have its percentage modulation increased to substantially 100%. Similarly, if the maximum value of the modulator wave to be expected is adjusted to have the value V_1 , a similar increase in percentage modulation will result. By other adjustments of the voltage of the modulated wave, the percentage modulation may be increased to other values.

If desired, an automatic modulation control circuit similar to that of Fig. 4 may be provided. Fig. 10 shows one such circuit. Here the modulated input wave is supplied to the modulation control circuit 58 of any of the Figs. 6 to 9 through an amplifier 57 having controllable amplification. The amplification of amplifier 57 may be controlled to maintain the average voltage input to the control circuit 58 at any desired value. For example, the output derived from control circuit 58 may be suitably rectified in a rectifier 59 whose output is then connected in series with an adjustable bias indicated schematically by the bias insertion circuit 61. The combined voltage thus produced serves to control amplifier 57 to maintain the input to control circuit 58 at the desired operating point.

The circuit of Fig. 10 is particularly useful in obtaining carrier-suppressed outputs, since it is for such an output that the average rectified output voltage will be a minimum, which is a condition that may readily be maintained by the circuit of Fig. 10. However, the variable bias provided by circuit 61 permits operation at any desired point of the characteristic I—II of Fig. 7, to control the modulation accordingly.

Fig. 11 shows a modified form of the circuit of Fig. 10, including a modified form of the modulation control circuit of Fig. 6. In Fig. 11 the modulated input wave is supplied to a limiter circuit 62 of any desired type adapted in well known manner to produce an output having a substantially constant amplitude. If desired, in place of the output of limiter 62 the actual carrier wave before modulation may be utilized.

The modulated wave is also fed to a controllable amplifier 57 similar to that in Fig. 10. The outputs of limiter 62 and amplifier 57 are combined in the combining circuit 51 to produce the desired modified output.

The output of the amplifier 57 is rectified by a suitable rectifier 59 whose output is combined

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with the variable bias provided by circuit 61 to control amplifier 57. The limiter 62 provides a characteristic III shown in Fig. 7, which, when combined with the characteristic II of the amplifier 57, provides a characteristic similar to I—II of Fig. 7, and useful in the same manner.

By controlling the amplification characteristics of amplifier 57 in the manner shown in Fig. 11, the circuit may be made to operate at any desired point of the characteristic I—II, under the control of the bias provided by circuit 61.

Fig. 12 provides a circuit similar to that of Fig. 11, but adding a modified form of automatic modulation control. In this instance, instead of using rectifier 59, the output of the combining circuit 51 and of limiter 62 are supplied to a balanced mixer 63. Balanced mixer 63 operates in a manner similar to that of Fig. 4 to provide a reversible polarity direct current output representing a deviation of the output of the apparatus from the carrier-suppressed condition, that is, from the operating point V_1 . By adding to this output a variable direct current bias provided by circuit 61, the amplifier 57 may be controlled to maintain in operation the system at any desired point of the characteristic. In this manner automatic modulation control is provided.

Accordingly I have provided an improved type of modulation control system which is responsive to the amplitude of the input modulated wave and is in no way responsive to or affected by variations in carrier frequency. This device, as indicated above, may be utilized on high frequencies or low frequencies.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for removing the modulation of a modulated high frequency wave, comprising a velocity modulation electron discharge device having means for producing a stream of electrons, means energized by said wave for velocity grouping said electrons, and means for extracting high frequency energy from said velocity grouped stream whereby said device has an oscillating input versus output characteristic; and means for causing said extracted energy to have substantially zero percentage modulation, comprising means for adjusting the average amplitude of said modulated energizing wave to a value corresponding to a maximum or minimum of the input versus output characteristic of said device.

2. Apparatus for suppressing the carrier of a modulated high frequency wave comprising a velocity modulation electron discharge device having means for producing a stream of electrons, means responsive to said wave for varying the velocity of said electrons and means for extracting high frequency energy from said velocity-varied stream; and means for suppressing the carrier of said extracted energy comprising means for adjusting the average amplitude of said modulated wave to a value substantially equal to that producing a zero of the output voltage versus input voltage characteristic of said device.

3. Apparatus for modifying the percentage modulation of a modulated high frequency wave comprising a velocity modulation electron discharge device having means for producing a

stream of electrons, means responsive to said waves for varying the velocity of said electrons, and means for extracting high frequency energy from said velocity-varied stream; and means for causing said extracted energy to have a percentage modulation modified with respect to that of said modulated wave, comprising means for adjusting the average amplitude of said modulated wave to a value corresponding to a point of the input voltage versus output voltage characteristic of said device having a negative slope.

4. Apparatus for controlling the modulation of a modulated high frequency wave, comprising means for producing an electron stream, means for velocity-grouping the electrons of said stream, means for extracting energy from said grouped stream, whereby the relation between the excitation of the grouping means and the energy derived from the extracting means displays an oscillating characteristic having an initial linear portion, and means for exciting said grouping means with said modulated wave at an average amplitude greater than that required to produce operation at said linear portion, whereby said extracted energy will have a percentage modulation different from that of said modulated wave.

5. Apparatus for controlling the modulation of a modulated high frequency wave, comprising a high frequency translating device having means for producing an electron stream, means for velocity-grouping the electrons of said stream, and means for abstracting energy from said grouped stream, whereby said device has an input versus output characteristic having an initial linear portion and subsequent non-linear portions, and means for exciting said grouping means with said modulated wave at an average amplitude greater than that required to produce operation at said portion, whereby said extracted energy will have a percentage modulation different from that of said modulated wave.

6. Apparatus for controlling the modulation of a modulated high frequency wave, comprising means for producing a stream of electrons, means energized from said wave for velocity grouping said electron stream, means for abstracting energy from said velocity-grouped stream, and means for causing said extracted energy to have a percentage modulation different from that of said modulated wave, comprising means for adjusting the average amplitude of said modulated wave to a value greater than that required to produce a linear relation between the amplitudes of said input wave and said abstracted energy.

7. Apparatus as in claim 6, further including means for automatically controlling said amplitude-adjusting means in response to said extracted energy to maintain said different percentage modulation.

8. Apparatus for controlling the modulation of a modulated high frequency wave, comprising a translating device having means for producing a stream of electrons, means for velocity-grouping said stream, and means for abstracting energy from said grouped streams, whereby said device has an oscillating input versus output characteristic having a linear first portion; means for energizing said grouping means from said modulated wave, and means for causing said extracted energy to have a percentage modulation different from that of said modulated wave, comprising means for adjusting the amplitude of said energizing wave to a value greater than that required

to produce operation of said device on said linear first portion.

9. Apparatus for controlling the percentage modulation of a high frequency modulated signal comprising a high frequency repeater of the velocity-grouped electron discharge type having an input versus output amplitude characteristic with an initial linear portion and subsequent non-linear portions, means for supplying said signal to said repeater at an amplitude producing operation beyond said linear portion of said characteristic, whereby the percentage modulation of the output of said repeater is different from that of the input, and means for controlling said supplying means to control said percentage modulation.

10. Apparatus as in claim 9, further including means for actuating said controlling means in response to the output of said repeater to maintain said output signal at a predetermined percentage modulation.

11. Apparatus as in claim 9, wherein said controlling means comprises means for comparing the output of said repeater with said signal to obtain a comparison signal, and means for actuating said supplying means by said comparison signal.

12. Apparatus for modifying the modulation of a modulated wave comprising a pair of electron discharge devices having equal outputs for a predetermined input amplitude and having differing input versus output characteristics, means for connecting the outputs of said devices in opposition, and means for supplying said wave to the inputs of said devices, whereby for input amplitudes of said wave in the neighborhood of said predetermined amplitude the opposed outputs of said devices have a modulation differing from that of said input.

13. Apparatus for controlling the modulation of a modulated high frequency wave, comprising translating means adapted to produce an output signal whose amplitude is an oscillating function of the amplitude of an input signal thereto, said oscillating function having a linear portion at relatively low input signal amplitudes, and means for exciting said translating means with said modulated wave at an average amplitude greater than that required to produce operation on said linear portion.

14. Apparatus for automatically controlling the modulation of a modulated high frequency wave comprising repeater means for said wave adapted to modify the percentage modulation of an input wave for predetermined values of input amplitude, said repeater means having an input circuit and an output circuit, and means connected to said input and output circuits for maintaining said input wave at an amplitude value yielding a desired output percentage modulation.

15. Ultra high frequency mixer apparatus comprising a pair of coupling loops having a common conductor, means for exciting said loops by one of said waves to be mixed, means for exciting said common conductor by a second wave to be mixed, and a respective rectifier connected to each of the remaining conductors of said loops, said rectifiers having a common terminal, whereby the unidirectional component of the potential of said common terminal will represent a mixed version of said two waves.

16. Ultra high frequency mixer apparatus for mixing two input waves, comprising a pair of coupling loops having a common conductor, means for exciting said loops in opposite phase by one

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of said waves, means for exciting said common conductor by the second of said waves, and asymmetrical conducting means connected to each of the remaining conductors of said loops and having a common terminal, whereby the unidirectional component of the potential of said common terminal will represent a mixed version of said waves.

17. Ultra high frequency mixer means comprising a hollow cavity resonator adapted to be energized by a first wave, two coupling loops having a common central conductor, said coupling loops being inserted within said resonator to be excited by the field thereof, a transmission line adapted to be energized by a second wave and having the inner conductor thereof connected to said central conductor, and a rectifier connected to each of the remaining conductors of said loops and having a common terminal, whereby the unidirectional voltage between said common terminal and ground will represent a mixed version of said two waves.

18. Apparatus for modifying the percentage modulation of a modulated high frequency wave comprising electron discharge means adapted to produce a zero output for a predetermined non-zero value of input, said means comprising a pair of channels having their outputs connected in opposition, one of said channels having a different input versus output characteristic from the other of said channels and said channels being adapted to provide equal outputs at said predetermined input value, means for supplying said modulated wave to the input of said electron discharge means, and means for adjusting the average amplitude of said modulated wave to a value in the neighborhood of said predetermined value.

19. Ultra high frequency apparatus comprising a cavity resonator, a pair of coupling loops having a common conductor and inserted within said resonator to be excited by the field thereof, a transmission line having the inner conductor

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thereof connected to said common conductor and the outer conductor connected to the exterior of said resonator, and a pair of series-connected detectors connected between the other conductors of said loops.

20. High frequency mixer apparatus for mixing a pair of input voltage waves comprising a pair of rectifiers connected in series arrangement and having a common terminal, a load resistor connected to said common terminal, means for connecting said two voltage waves in series across one of said rectifiers and said load resistor in series, means for obtaining a phase-reversed version of one of said input voltage waves, and means for connecting said phase-reversed version in series with the other of said voltage waves across the other of said rectifiers in series with said load resistor, whereby the unidirectional voltage across said load resistor will represent a mixed version of said two voltage waves.

21. High frequency apparatus comprising electron discharge translating apparatus having an input and an output, means for exciting said input by an input high frequency wave, means for mixing a version of said input wave and a wave derived from said output, and means coupled to the output of said mixing means for controlling the amplitude of said input wave.

RUSSELL H. VARIAN.

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