

March 8, 1949.

C. S. BULL
APPARATUS FOR AMPLITUDE MODULATING
HIGH-FREQUENCY OSCILLATIONS
Filed Sept. 30, 1947

2,464,115

Fig. 1

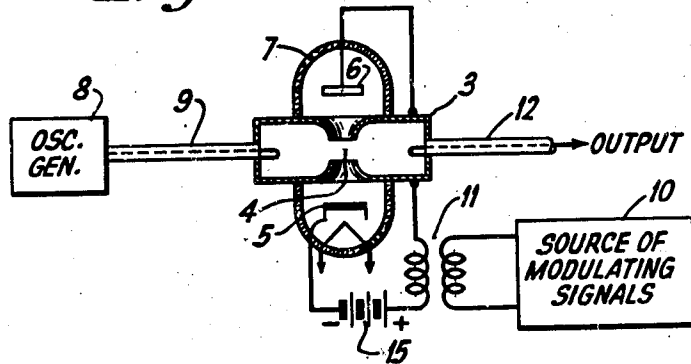
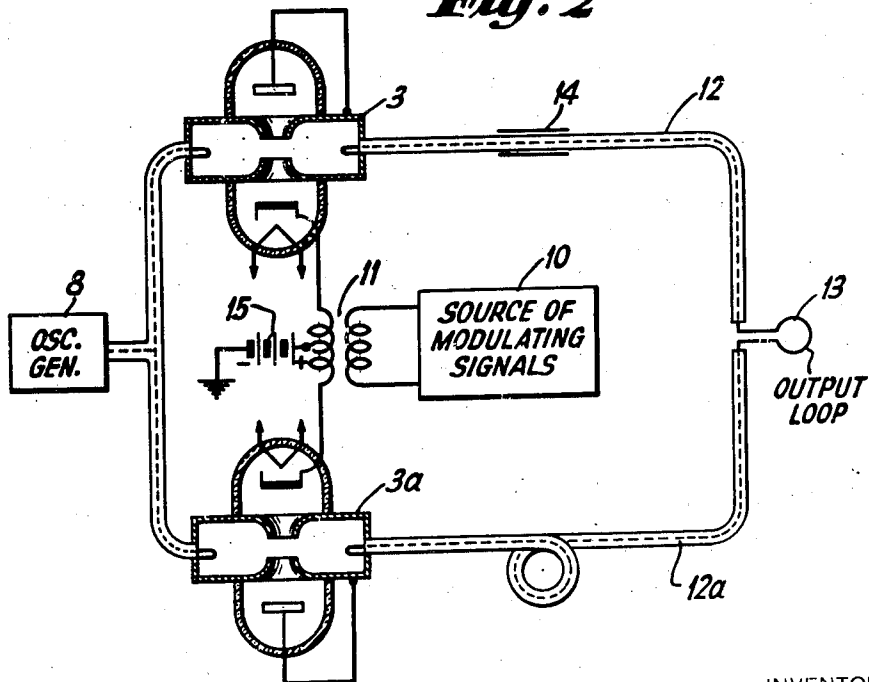


Fig. 2



INVENTOR.
CABOT SEATON BULL

BY

Darry Tunick

ATTORNEY

UNITED STATES PATENT OFFICE

2,464,115

APPARATUS FOR AMPLITUDE MODULATING
HIGH-FREQUENCY OSCILLATIONS

Cabot Seaton Bull, Hillingdon, England, assignor
to Electric & Musical Industries Limited, Hayes,
England, a company of Great Britain

Application September 30, 1947, Serial No. 778,958
In Great Britain December 8, 1944

Section 1, Public Law 690, August 8, 1946
Patent expires December 8, 1964

5 Claims. (Cl. 332—43)

1

This invention relates to apparatus for amplitude-modulating high-frequency oscillations and in particular oscillations having a wavelength of the order of centimeters or lower. In order to amplitude-modulate such high-frequency oscillations it has been proposed to apply the oscillations and the modulating signals to the electrodes of a crystal or diode but owing to the low conversion conductance of such crystals or diodes at ultra-high frequencies the efficiency of these devices when used as modulators is very poor the depth of modulation between one per cent and five per cent in the case of a diode and up to about twenty per cent in the case of a crystal.

The object of the present invention is to provide an improved apparatus for effecting amplitude-modulation of high-frequency oscillations with a view to providing an apparatus in which the depth of modulation can be increased.

According to the invention apparatus for effecting amplitude-modulation of high-frequency oscillations is provided comprising a resonator, means for setting up high-frequency oscillations in said resonator which are generated externally of said resonator, means for generating a beam of electrons, means for causing said beam to pass through said resonator, means for applying modulating signals to said electron beam so as to vary the beam current in accordance with said signals and thus to vary the damping of said resonator and means for abstracting amplitude-modulated high-frequency oscillations from said resonator.

The resonator may be of toroidal form similar to a resonator known as a rhumbatron and provided with a gap at its centre through which an electron beam is caused to pass and to be collected by a target electrode. It is found that on passing a modulated electron beam through such a resonator the latter is damped appreciably with the result that the oscillations set up in said resonator become amplitude-modulated in accordance with the modulation applied to the electron beam. With such a construction it is found possible to obtain a depth of modulation of up to 50 per cent.

It may be mentioned that in British Patent No. 537,491 it has been proposed to employ in a single or double resonator apparatus utilising velocity modulation of electrons, an auxiliary electron beam which if modulated will afford a frequency modulation of the high-frequency output in the case of a single resonator and in the case of a double resonator an amplitude modu-

2

lation (owing to the detuning of one resonator with respect to the other) and probably combined with some degree of frequency modulation. The present invention distinguishes from this prior proposal in that the resonator does not employ velocity modulation and is fed with high-frequency oscillations which are generated independently of the resonator.

It is possible that, during operation of apparatus according to the invention frequency-modulation may occur in addition to the amplitude-modulation and in order to overcome this defect another feature of the invention consists in employing a pair of resonators to the electron beams of which the modulating signals are applied in push-pull. Either of the outputs of amplitude-modulated oscillations from the resonators may be employed and the other dissipated in a resistive load or, according to another feature of the invention, means may be provided for delaying the output from one of the resonators by one half period of the modulation frequency the two outputs being then combined.

In order that the said invention may be clearly understood and readily carried into effect, it will now be more fully described with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic view of apparatus constructed in accordance with one embodiment of the invention, and

Figure 2 is a diagrammatic view of apparatus constructed in accordance with the invention in which two resonators are employed in push-pull.

Referring now to Figure 1 of the drawings, the modulating arrangement according to the invention comprises a hollow toroidal resonator 3 provided at its centre with a gap 4 through which a beam of electrons emanating from a cathode 5 is caused to pass and to be collected by a target electrode 6. The cathode 5, the gap 4 of the resonator 3 and the target or collector electrode 6 are enclosed in an evacuated envelope 7, the general construction of the device being similar to the known forms of high-frequency oscillators employing rhumbatrons. The high-frequency oscillations to be modulated are fed into the resonator from an oscillation generator indicated at 8 which may comprise a klystron oscillator or a high-frequency oscillator of any other form which is coupled to the resonator 3 by a section of waveguide 9 or by a concentric line coupling.

The modulating signals are applied between the cathode 5 and the resonator 3 so as to cause the modulating signals to vary the intensity of the

3

electron beam emanating from the cathode 5. As shown in the drawing, the reference numeral 10 indicates a source of modulating signals, the signals being applied between the cathode 5 and the resonator 3 via a transformer 11 and a D. C. source of supply 15. In operating the device shown in Figure 1, the target or collector electrode 6 is maintained at a positive potential which may be the same potential as that applied to the resonator 3 for which purpose the target electrode 6 can conveniently be connected to the resonator 3, as shown. The passage of an electron beam through the resonator 3 is found to effect considerable damping of the resonator which is of course tuned to the frequency of the oscillations fed thereto from the source 8, the degree of damping depending on the intensity of the electron beam passed therethrough and on the time of flight of the electrons in relation to the period of the oscillations. Thus, by modulating the electron beam with the modulating signals the oscillations fed to the resonator 3 from the source 8 are varied in amplitude in accordance with the modulating signals. An output of amplitude-modulated oscillations can be obtained from the resonator 3 by an output coupling 12 in the form of a waveguide or a concentric line. It is found that in such an arrangement a depth of modulation up to 50 per cent can be obtained which is a considerable improvement compared with the depth of modulation obtained with the previously known arrangements employing crystals or diodes.

The arrangement described in Figure 1 has the disadvantage that the load applied to the source of oscillations 8 varies during modulation so that frequency-modulation may occur as well as amplitude-modulation unless sufficient attenuation is present between the source of oscillations and the modulator. In order to overcome this defect the arrangement shown in Figure 2 may be employed. In this construction, the source of oscillations 8 feeds a pair of resonators 3 and 3a each having cathodes and target (viz, collector) electrodes similar to the construction described in Figure 1, the electron beams passing through the resonators 3 and 3a, however, being modulated in push-pull from the source of modulating signals 10. The outputs from the resonators 3 and 3a in Figure 2 will be similar but in opposite phase and in using such an arrangement the output from one of the resonators may be utilized while the output of the other resonator may be dissipated in a resistive load. If, however, the modulation-frequency is nearly constant it is possible, in accordance with a feature of the invention, to combine the outputs from the resonators 3 and 3a so avoiding waste of power which occurs when it is necessary to dissipate one of the outputs in a resistive load. In order to combine the outputs of the resonators it is necessary to delay the output from one resonator by one half period of the modulation frequency so that the two outputs are then in suitable relation for additive combination. As shown in Figure 2 the outputs from the resonators 3 and 3a are fed into lengths of coaxial line 12 and 12a, the line 12a being of such a length that the output from the resonator 3a is effectively delayed by half a period of the modulation frequency. The extra length of line necessary to impart this delay is shown coiled in Figure 2. Any other suitable delay network may alternatively be used. The inner conductors of the lines 12 and 12a are connected together and terminate in a loop 13 which can be coupled to the load.

4

It is also necessary to ensure that the phases of the high-frequency oscillations at the point where the two lines 12 and 12a are connected are in the proper phase and to achieve this condition the length of line 12 may be made adjustable in length, exemplified in Figure 2 by a telescopic section 14, to enable the length of line 12 to be adjusted for this purpose.

It may be found desirable in designing resonators for use in the invention for the gap, through which the electron beam passes, to have a width approximately twice that of the gap-size used in a rhumbatron oscillator, generating oscillations of a frequency corresponding to those of the source 8.

Although the invention as described above is shown as applied to an electron discharge device, similar to a rhumbatron oscillator, it will be understood that the invention is not to be limited to such a discharge device since it can be applied to other discharge devices in which an electron beam can be caused to damp a resonator.

I claim:

1. Apparatus for effecting amplitude-modulation of high-frequency oscillations comprising a pair of cavity resonators, means for setting up high-frequency oscillations in said resonators which are generated externally of said resonator, means for generating beams of electrons, means for causing a beam of electrons to pass through the interior of each resonator, means for applying modulating signals in push-pull to the electron beams of said resonators so as to vary a characteristic of the beams in accordance with said signals and thus to vary the damping of said resonators, and means for abstracting amplitude-modulated high-frequency oscillations from one or both of said resonators.

2. Apparatus according to claim 1 wherein means are provided for delaying the amplitude-modulated output from one of said resonators by one half a period of the modulation frequency and means for combining the delayed output and the amplitude-modulated output from the other resonator.

3. A modulation system comprising a cavity resonator having a pair of oppositely disposed walls separated by a gap, a high frequency oscillation generator coupled to the interior of said resonator for setting up high frequency oscillations in said resonator, a cathode located externally of said resonator on one side of said gap, and in the same straight line with said gap, an electron collector electrode located externally of said resonator on the other side of said gap and also on the same straight line with said gap, whereby electrons emanating from said cathode and passing through the interior of said resonator are collected by said collector electrode, a direct connection between said resonator and said collector electrode, whereby said resonator and collector are maintained at the same potential, an inductance coil in circuit with said cathode, means for applying modulation potentials to said coil, and an output circuit coupled to said resonator in the interior thereof.

4. A modulation system comprising a cavity resonator having a pair of oppositely disposed walls separated by a gap, a high frequency oscillation generator coupled to the interior of said resonator for setting up high frequency oscillations in said resonator, a cathode located externally of said resonator on one side of said gap and in the same straight line with said gap, an electron collector electrode located externally of said resonator on the other side of said gap and also

5

on the same straight line with said gap, whereby electrons emanating from said cathode and passing through the interior of said resonator are collected by said collector electrode, a direct connection between said resonator and said collector electrode, whereby said resonator and collector are maintained at the same potential, an inductance coil in series with a source of unidirectional potential in circuit with said cathode, the positive terminal of said source being connected to said resonator while the negative terminal of said source is connected to said cathode, means for applying modulation potentials to said coil, and an output circuit coupled to said resonator in the interior thereof.

5. A modulation system comprising a cavity resonator having a pair of oppositely disposed walls separated by a gap, a high frequency oscillation generator coupled to the interior of said resonator for setting up high frequency oscillations in said resonator, a cathode located externally of said resonator on one side of said gap, an electron collector electrode located externally of

6

said resonator on the other side of said gap, a connection between said resonator and said collector electrode, the series circuit of a source of unidirectional potential and an inductance coil connected to said cathode, means for applying modulating signals to said coil and means for deriving energy from the interior of said resonator.

CABOT SEATON BULL.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

15	Number	Name	Date
	2,275,065	Nelson -----	Mar. 3, 1942
	2,280,026	Brown -----	Apr. 14, 1942
	2,512,919	Litton -----	Mar. 2, 1942
	2,409,227	Shockley -----	Oct. 15, 1946
20	2,419,984	Boothroyd -----	May 6, 1947
	2,424,959	Alford -----	Aug. 5, 1947