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W. W. HANSEN ET AL
HIGH-FREQUENCY RELAY APPARATUS
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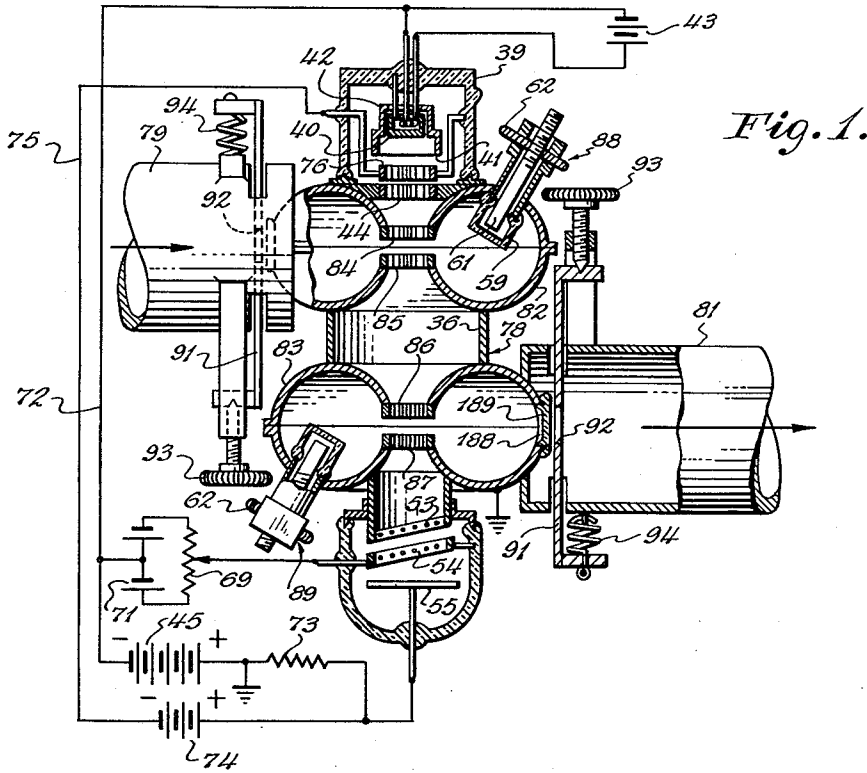


Fig. 2.

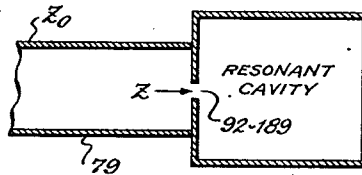
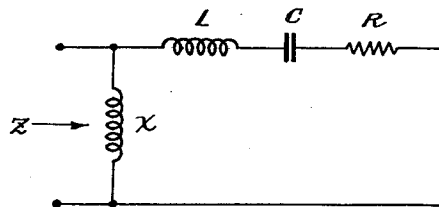


Fig. 2A.



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HIGH-FREQUENCY RELAY APPARATUS

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Original application August 24, 1939, Serial No. 291,652. Divided and application December 6, 1943, Serial No. 513,002. Divided and application October 3, 1947, Serial No. 777,801. Again divided and this application November 2, 1949, Serial No. 125,127

6 Claims. (Cl. 179—171)

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This invention relates to hollow resonator apparatus and is particularly concerned with structural and circuit improvements in such apparatus.

This is a division of our application Serial No. 777,801 for Resonator Apparatus filed October 3, 1947, now Patent No. 2,578,699 as a division of our application Serial No. 513,002 for Resonator Apparatus, filed December 6, 1943, now Patent No. 2,460,288 as a division of application Serial No. 291,652 filed August 24, 1939 for Dielectric Guide Signaling, now Patent No. 2,375,223.

It is a major object of the invention to provide hollow resonator apparatus with a wave guide output connection having adjustable energy coupling arrangements.

A further object of the invention is to provide novel arrangements for matching the impedance of a hollow resonator device with a dielectric or hollow-pipe wave guide.

Fig. 1 of the drawing is a side elevation partly diagrammatic and partly in section of hollow resonator apparatus embodying the invention and wherein wave guide sections 79 and 81 are directly coupled to the resonators 82 and 83 of an amplifier, i. e., each of the wave guide sections terminates in a resonator.

Figs. 2 and 2A show diagrams for illustrating certain features of the operation of the structure of Figure 1.

The term "hollow" as used herein in describing resonators and dielectric or hollow-pipe wave guides is of course intended to embrace all such resonators and dielectric or hollow-pipe wave guides regardless of whether the dielectric therein is air or some other medium. Fig. 1 of the drawing illustrates relaying apparatus including the hollow resonator device 78 which is directly connected by the wave guide sections 79 and 81 to relay and simultaneously amplify a signal passing from left to right along the wave guide.

Amplifier 78 is shown as a two-resonator device embodying a hollow input resonator 82 and an output resonator 83 which are evacuated within a vitreous insulating cup 39. At one end of the amplifier is provided a cathode 40 surrounded by a focussing shield 41, said cathode being heated by a heater coil 42 that is applied from the battery 43. The electrons released by the cathode 40 are directed in a columnar stream by a

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strongly positive grid 44 which grid is held positive with respect to the cathode by a battery 45. Note that the positive side of the battery 45 is grounded which is also true of the casing of amplifier 78 to which casing grid 44 is connected.

The electron stream drawn through grid 44 passes through a subsequent pair of spaced grids 84, 85, provided in resonator 82 through the drift space provided within a tubular casing 36 interconnecting the two resonators and through the spaced grids 86, 87 of the second resonator 83. After leaving grid 87 the electron beam passes through additional inclined parallel grids 53, 54 to a collector and detector plate 55. Tuning devices 88, 89 of the adjustable type are provided for resonators 82, 83. This two-resonator amplifier operates in a manner similar to that described in United States Patent 2,242,275.

Output resonator 83 is formed with an energy output aperture 188 sealed by a glass or like wall 189. The adjacent end of wave guide section 81 is slotted to permit passage of an apertured gate plate 91 having aperture 92 adapted to register with aperture 188. Thumb screw 93 opposing a spring 94 is adapted to adjust plate 91 vertically to thereby vary the portion of the area of aperture 92 that registers with aperture 88. Thus, by rotation of screw 93, the impedance of guide 81 may be matched with the internal impedance of amplifier 78. This will be evident from the following analysis referring to Fig. 2, wherein Z_0 represents the characteristic impedance of the wave guide 79, for example, 82' shows a resonant cavity corresponding to 82 in Fig. 1. Z represents the impedance looking into the aperture 92 and window 189 of resonator 82. X represents the coupling reactance of the opening 92 and window 189. Fig. 2A shows the equivalent circuit of Fig. 2. Under these conditions, the following is true.

$$Z = \frac{jXZ_0}{Z_0 + jX}$$

where

$$Z_0 = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

$$\therefore Z = \frac{jX(Z_0 + jX) + X^2}{Z_0 + jX} = jX + \frac{X^2}{Z_0 + jX}$$

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now X is generally much smaller than Z_0 , and therefore the first term may be omitted.

$$Z = \frac{X^2}{Z_c + jX}$$

at resonance, $Z_c + jX = R$

$$\therefore Z \approx \frac{X^2}{R}$$

It can be seen from this that Z may be made equal to Z_0 by adjustment of X , and therefore a perfect match obtained.

A similar adjustable gate structure is provided between input wave guide section 79 and resonator 82 as indicated by the corresponding reference numerals, for matching the impedance of guide section 79 to the input impedance of resonator 82.

In operation, energy from wave guide section 79 is delivered directly through aperture 92 provided in adjustable plate 91 to excite resonator 82. This received energy excites resonator 82 in such mode that an alternating current electric field is established within this resonator and between grids 84, 85, the said electric field serving to alternately impart positive and negative accelerations to successive electrons of the stream passing therebetween; thereby causing the electrons of the stream to traverse the space between resonator 82 and the next resonator 83 with cyclically varying velocities. The faster electrons which pass through the electric field later than the preceding electrons will tend to overtake the latter in the interspace or drift space between resonator 82 and resonator 83 so that by the time the electron stream has arrived at grid 86, the stream will have a periodic variation in electron density at the frequency of the field between grids 84, 85.

The entrance of the stream of variable density into resonator 83 establishes a strong alternating electric field between grids 86, 87 which acts to retard electrons so that they do work upon this field and thereby maintain the alternating electromagnetic field within the resonator 83 and energy from the field is delivered through the window 92 directly to wave guide section 81. Proper impedance match for best operating conditions is attained by adjusting the gate structure 91 thereby resulting in high efficiency performance. Hence, signal energy travelling from left to right in the section is relayed and amplified by the tube or valve 78 with a minimum of losses.

Grid 53, being at the potential of the positive side of battery 45, aids in maintaining the stream in columnar form, whereas inclined grid 54 is preferably maintained at a potential near that of the cathode. This is accomplished by use of potentiometer 59 and battery 71 connected to cathode lead 72. With grid 54 at this potential, most of the electrons are reflected back and to one side, and only the speeded-up electrons will pass through this grid. Thus, as the change in electron velocity increases, more and more of the faster electrons will reach plate 55 beyond grid 54, while fewer of the slower electrons will reach this plate. The current therefore reaching plate 55 increases as the amplitude of oscillations in the hollow resonator device increases, so that said device as a whole serves as a cascade amplifier and detector.

As the current through the circuit of plate 55 increases, the drop across a resistor 73 in the plate circuit increases, thereby lowering the potential at the plate, which is shown connected through a biasing battery 74 and lead 75 to a

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grid 76 positioned in front of emitter 40. Thus the potential of grid 76 is correspondingly lowered, effecting a decrease in the current passing through the device due to the repellent action of the grid 76 on the electron stream. Thus, since plate 55 becomes more negative as the signal intensity increases, grid 76 acts as an automatic volume control serving to cut down the current in the device and thereby the gain when the amplitude of oscillation increases.

It will be understood that although the wave guide described herein is illustrated as being of the hollow-pipe single conductor type, other types of guide such as dielectric guides or other enclosed-field energy conducting systems may be used.

Since 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. High frequency apparatus comprising an evacuated hollow conductive body adapted to contain standing electromagnetic waves and having an opening sealed off by a wall which is permeable to high frequency energy, a wave guide connected in energy transferring relation to said body, and means for adjusting the effective area of said opening which is presented to said guide, said adjusting means comprising an apertured shutter within said guide mounted for adjustable registration with said opening.
2. High frequency apparatus comprising a hollow evacuated resonator having a sealed off opening therein, a wave guide having one end adjacent to said opening and adapted to thereby be coupled to said resonator, means in said wave guide for matching the impedances of said resonator and said wave guide comprising a movable apertured shutter in parallel face-to-face relation with said opening, and means projecting externally of said wave guide for adjusting the registration of said shutter aperture transversely with respect to said resonator opening.
3. High frequency apparatus comprising a hollow evacuated resonator having a sealed energy transferring window in a wall thereof, a wave guide, an impedance matching connection between said resonator window and said wave guide comprising an apertured gate plate situated within said wave guide adjacent said window for effecting energy transfer between said resonator and said wave guide, and means for moving said gate plate transversely of said wave guide relative to said window for adjusting the effective cross-sectional area of said passage between said resonator and said wave guide.
4. High frequency apparatus comprising first and second evacuated hollow resonators each having a sealed energy transferring window, a drift space between said resonators, means for passing an electron beam successively through said first resonator, said drift space, and said second resonator, a first wave guide section, a first impedance matching connection between the window of said first resonator and said first wave guide section, a second wave guide section, a second impedance matching connection between the window of said second resonator and said second wave guide section, said first and second impedance matching connections each compris-

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ing a movable apertured plate overlying the energy transferring window.

5. Ultra-high-frequency electron tube apparatus comprising means for forming and projecting a beam of electrons along a predetermined path, conducting walls defining a hollow cavity resonator surrounding the path of said beam, said hollow resonator having an opening through a wall portion, a section of wave guide having an open end joined to said hollow resonator surrounding said opening for energy transfer between said resonator and said wave guide through said opening, a gaseous-tight seal permeable to ultra-high-frequency energy sealing off said opening, an apertured plate situated within said wave guide adjacent said opening, and means for moving said apertured plate relative to said opening for adjusting the effective cross-sectional area of the passage between said resonator and said wave guide.

6. Ultra - high - frequency electron discharge tube apparatus comprising a toroidal cavity resonator having hollow axial reentrant portions defining an electron permeable gap, said cavity resonator having an aperture through the side wall thereof, means covering said aperture and joined to the wall of said resonator for forming a gaseous-tight seal over said aperture, said means

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being permeable to ultra-high-frequency energy, a section of wave guide having an open end surrounding said aperture for energy transfer between said resonator and said wave guide through said aperture, movable means situated within said wave guide adjacent said aperture, and means extending through the wall of said wave guide for moving said movable means transversely with respect to said aperture for reducing the effective area of the passage between said resonator and said wave guide through said aperture.

References Cited in the file of this patent

UNITED STATES PATENTS

	Number	Name	Date
15	Re. 22,724	Varian et al.	Feb. 19, 1946
	2,106,769	Southworth	Feb. 1, 1938
	2,106,771	Southworth	Feb. 1, 1938
	2,122,538	Potter	July 5, 1938
20	2,129,711	Southworth	Sept. 13, 1938
	2,200,023	Dallenbach	May 7, 1940
	2,206,923	Southworth	July 9, 1940
	2,253,589	Southworth	Aug. 26, 1941
	2,517,731	Sproull	Aug. 8, 1950
25	2,560,353	Kerwien	July 10, 1951
	2,568,727	Freeman	Sept. 25, 1951
	2,579,327	Lund	Dec. 18, 1951
	2,593,463	Kinzer	Apr. 22, 1952