Nov. 18, 1947. W. E. BRADLEY ET AL 2,431,103

TUNING DEVICE

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FIG. 2.

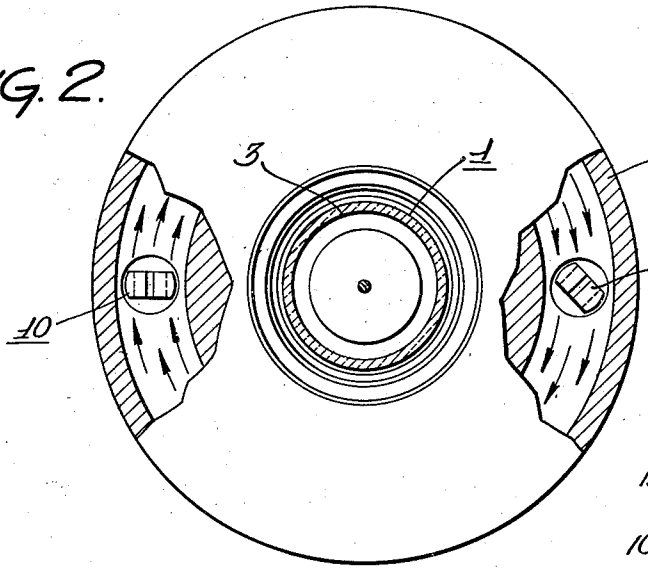


FIG. 3.

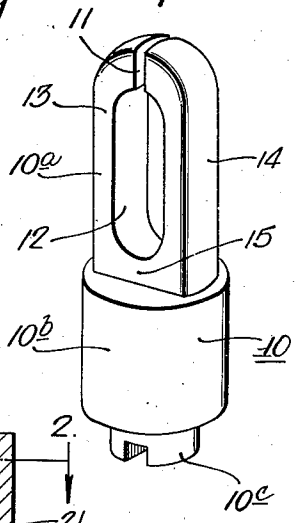
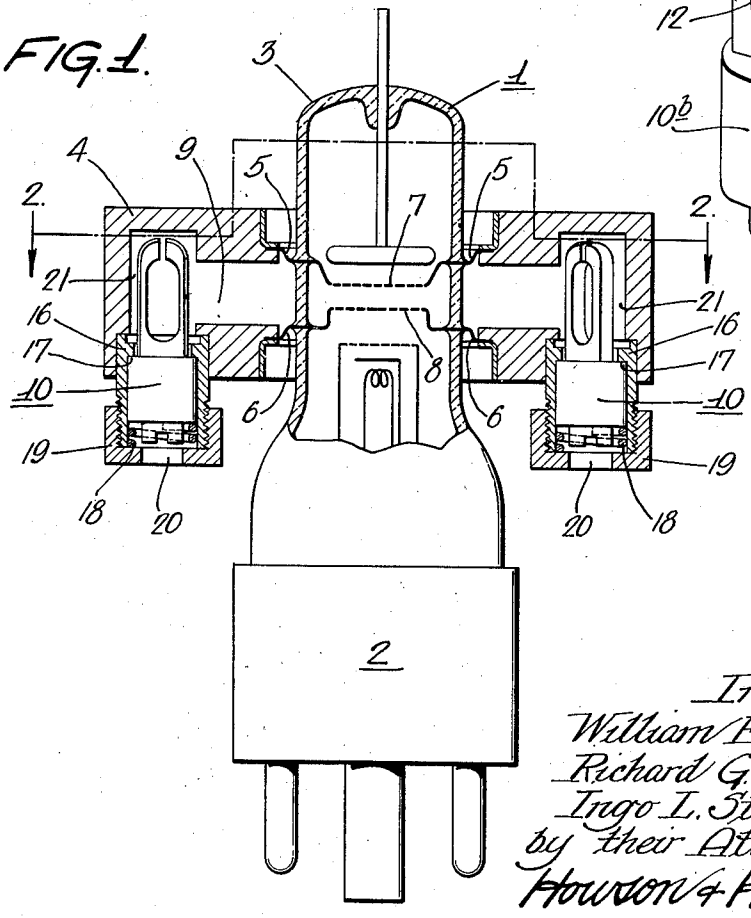


FIG. 1.



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TUNING DEVICE

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6 Claims. (Cl. 178—44)

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This invention relates to devices for tuning ultra high frequency resonant circuits and has to do more especially with variable tuning of resonant cavities—particularly those intended to operate in the microwave range, which takes in frequencies of the order of several thousand megacycles.

The resonant cavities employed as component parts of certain velocity-modulated oscillators designed to function at high microwave frequencies are so limited in available space as to render impracticable the use in them of previously known variable tuners—particularly where it is necessary to make provision for a frequency range of considerable breadth. Oftentimes, in using such prior art tuners, it has been necessary to install a considerable number of them in a single cavity in order to secure, through their combined effect, the frequency range demanded; and that, of course, hindered tuning operations besides adding to the mechanical complexity of the cavity structure as well as its cost.

To meet the above-indicated situation there was devised, before the present invention, the cavity tuner described in various forms and claimed in the co-pending application of Howard E. Tompkins, Serial No. 524,472, filed February 29, 1944, and assigned to the same assignee as the present application. The Tompkins tuner is very satisfactory except that in certain cases involving mass production where it has been necessary to meet narrow tolerances as to uniformity of tuning range it was found quite difficult to maintain a sufficiently high order of manufacturing precision.

The primary object of the present invention is to provide a cavity tuner which is capable of effecting a relatively large frequency variation, comparable to the aforementioned Tompkins tuner, and which does not require maintenance of excessively close manufacturing tolerances in order to achieve substantial uniformity as respects the tuning range.

Another object is to provide a tuner which does not involve introduction of dielectric material into the resonant cavity, and which, therefore, avoids possible dielectric loss and incidental reduction of Q value.

Still another object is to provide a tuner of the kind referred to which is inexpensive to manufacture and which is easy to install and to withdraw from the cavity.

A further object is to provide a tuner which is well adapted for use in cavities where only a small space can be allotted to the tuning means.

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Referring to the accompanying drawing:

Fig. 1 is a view, partly in elevation and partly in longitudinal section, of a reflex-klystron oscillator including a velocity-modulated vacuum tube and resonant cavity together with two tuners, each of which is constructed in accordance with the present invention;

Fig. 2 is an irregular cross-sectional view taken along the line 2—2 of Fig. 1; and

Fig. 3 is an enlarged perspective view of a tuner.

Although we have illustrated the invention as an adjunct to a particular kind of oscillator, it is to be understood that the same is applicable to any cavity resonator—especially where the frequency is extremely high—and, in fact, can be employed for the tuning of resonant circuits other than cavities.

Vacuum tube 1 is a reflex-klystron of the McNally type. It comprises a base 2 and a glass envelope 3 in which are enclosed several tube elements which do not need to be described in order to effect a complete disclosure of the present invention.

A resonant cavity structure 4 encircles envelope 3 and is firmly connected to a pair of thin metal flanges or fins 5 and 6 which encircle the tube and pass through the glass envelope—being continuations of buncher grids 7 and 8.

The cavity structure contains an annular enclosed cavity 9 which encircles the vacuum tube and is electromagnetically a continuation of the cavity space between grids 7 and 8, inside the tube.

For electrical reasons which are applicable in the case of the specific structure shown, cavity 9 is shown expanded widthwise at the periphery to form a generally L-shaped cross-sectional configuration, as shown in Fig. 1; and the two tuners 10, are so positioned as to restrict to a minimum the over-all diametral dimension of the structure; but neither the L-shaped cross-sectional configuration of the cavity nor the illustrated orientation of the tuners are to be regarded as limitations upon the invention.

Due to the fact that the cavity is a departure from the cylindrical, the wave pattern therein cannot be precisely identified by any of the wave-pattern designations which have come to be recognized with respect to standing waves in cylindrical cavities; but it is believed that the wave pattern which actually obtains is a derivation of the familiar TM_{010} wave pattern. In any event, it will be postulated that there is a magnetic field, as indicated by arrows in Fig. 2, disposed along the periphery of the cavity, concen-

trically with the axis thereof; and both tuners 10 are interposed in said magnetic field and appropriately oriented with respect thereto.

The two tuners may be identical, but not necessarily so, and one of them is shown in perspective, greatly enlarged, in Fig. 3. It consists, preferably, of one piece of metal comprising an elongate loop portion 10*a*, a bearing portion 10*b*, and a screw-slotted boss 10*c* .Only the loop portion 10*a* is directly effective to tune the cavity, and it constitutes a resonant loop circuit having inductance, capacity, and resistance. Loop portion 10*a* is slotted through at 11 to form a gap defined by two narrowly spaced parallel surfaces disposed face-to-face and constituting the plates of a condenser; and said loop portion is milled out at 12 to form two spaced parallel arms 13 and 14. These arms are connected together at 15 and they form the inductive portion of the loop. The resonant frequency of this loop is determined, as usual, by its inductance and capacity; and the latter is, of course, a function principally of the width of gap 11 and the areas of the surfaces defining said gap. There is also some fringe capacity, as will be self-evident.

The bearing portion 10*b* of each tuner is journaled in a bushing 16; and each tuner is held in place against a shoulder 17 by means of a helical spring 18 and a screw-cap 19. When the latter is removed the tuner will drop out. Each cap 19 is apertured at 20 to permit insertion of a screw driver into the slot in boss 10*c*, by means of which the tuner can be rotated to vary the tuning of the cavity.

The two tuners are shown, in Figs. 1 and 2, in different rotational adjustments. The tuner to the left is turned to the position wherein the maximum of magnetic lines traverse the opening 12 through the loop. This is the position of maximum coupling and is effective to tune the oscillator to its lowest frequency—provided both tuners are so adjusted.

The tuner to the right of Figs. 1 and 2 is shown oriented at an angle of 45° to the magnetic lines. This is an intermediate coupling position and it results in an intermediate frequency value.

If the tuner at the left of Figs. 1 and 2 were turned 90° from the position of maximum coupling in which it is shown, the coupling would be reduced to zero. With both tuners at zero coupling the resonant frequency of the cavity is maximized; and with both tuners at maximum coupling the resonant frequency of the cavity is minimized. It would be more correct to say that the frequency of the dominant and effective resonance peak of the cavity is maximized or minimized, as the case may be, because the resonance curve of the cavity is double-peaked as a consequence of the influence of the tuner. The two tuners together afford approximately double the tuning range obtainable with one tuner; and further increments of the tuning range can generally be realized, if needed, by adding more tuners.

The preferred practice is to proportion each tuner so that its natural frequency, per se, is higher than the natural frequency of the cavity, per se, by an amount approximately equal to the total tuning range, measured by the same frequency unit. If that procedure is followed each tuner wil afford approximately the maximum tuning variation of which it is capable.

In the Tompkins tuner described and claimed in the previously identified co-pending Tompkins application, tuning is accomplished largely as a

result of varying the capactiy between the tuner element and the cavity walls, by rotating the tuner; and in order to obtain substantial tuning capacity with a small tuner it usually is necessary that the separation between the sides of the tuner and the cavity wall be very small. With such close spacing any slight variation in the diameter of the tuner or in its alignment will have a material effect on the value of the tuning capacity, with the result that it is difficult, when employing the Tompkins tuner, to manufacture on a mass production basis tunable cavities having substantially identical tuning ranges. The truth of that assertion may not be as self-evident as experience shows it to be factual.

In the tuner of the present invention the above-indicated difficulty is avoided because the space 21 around the tuner, that is between the tuner and cavity wall, is relatively wide; and that spacing can be wide because the capacity between the tuner and cavity wall is not depended upon, to any major extent, as a tuning factor. This capacity, which we will call the external capacity, to distinguish from the capactiy of gap 11, does in fact play a part in the tuning, since it is in parallel with the capacity formed by gap 11, and it serves to increase the frequency range of the tuner; but its value is small compared to the capacity of the loop gap. Hence, ordinary production variations in the dimensions of the tuner have very little influence on the tuning range. It is, of course, generally essential that the resonant frequency of the tuner, per se, be quite precisely in conformity with a predetermined frequency value, within whatever limits may be specified; but any discrepancy in this respect due to ordinary manufacturing variations can easily and quickly be corrected, where necessary, by slightly increasing or decreasing the width of gap 11. It should be apparent that slight misalignments of the tuner with respect to the cavity will influence the tuning range only to a very trivial degree.

Like the Tompkins tuner, the device of the present invention has greatly increased effectiveness as compared to prior art tuners of equal size. By this we mean that the frequency range which can be achieved with a tuner of given size is substantially greater than can be achieved with equal size prior art tuners of which we have any knowledge—except the Tompkins tuner, the effectiveness of which is of the same order as that of the subject tuner.

This greater effectiveness of the present tuner is due, in part, as is likwise true of the Tompkins tuner, to the fact that it operates simultaneously and additively upon both the magnetic field and the electric field of the cavity, by displacement—which is wholly in addition to the influence of the tuner as a resonant circuit coupled to the cavity. We have heretofore in this specification treated our present tuner wholly on the basis of a resonant circuit variably coupled to a second resonant circuit, which latter is the cavity; and, usually, if not always, the frequency peak shifting phenomenon which results from varying the coupling is by far the major factor in determining the range of the tuner. But that is not the sole tuning factor, as we shall now attempt to point out.

As previously stated, when the coupling is minimum the resonant frequency of the cavity is maximum; and that would be true if the only factor were the effect due to the intercoupling of two resonant circuits. But when the coupling is

minimum the tuner loop (being of substantial width athwart the magnetic field) displaces the magnetic field to a substantial extent and the effect is that of decreasing the cavity inductance. Decreased inductance, without an offsetting increase of capacity, causes increased resonant frequency. Hence the increased magnetic field displacement aids in raising the frequency of the cavity. At the same time, that is to say, with the tuner in the minimum coupling position, the aforementioned external capacity is minimized; and the reduction of capacity produces increased frequency. Now it will be seen that there are three factors which contribute jointly to increasing the frequency. The converse obviously holds true when the tuner is rotated to maximum coupling position; and the three factors are in aiding relation at all intermediate points of adjustment. However, it is important to observe that the resonant frequency of the tuner must always be higher than that of the cavity, if the effects due to displacing the magnetic field and of varying the external capacity are to be in aiding relation to the main tuning factor.

Due to its high Q value the resonance curve of a cavity, per se, is sharp and single-peaked. When there is coupled to such a cavity a tuner according to the present invention having, per se, a different resonant frequency, the resultant resonance curve of the cavity becomes double-peaked. But because of the fact that the Q value of the tuner is inherently much lower than that of the cavity, one of the two peaks of the resultant resonance curve of the cavity is very much lower than the other. Neither of the resonant peaks corresponds to the natural frequency of the cavity, per se. If the tuner is designed to have, per se, a higher natural frequency than that of the cavity, the higher amplitude peak will be at a frequency level below that of the cavity, per se, and the lower amplitude peak will be at a frequency level above that of the cavity, per se. As an oscillator the assemblage of Figs. 1 and 2 will function only at the frequency corresponding to the higher amplitude peak; and the other peak, which is of lower amplitude, will exercise no influence on the frequency of oscillation.

In the appended claims we have used the term "employed resonance peak." By this we mean the peak of greater magnitude referred to above.

In practice the cavity would almost certainly have a Q valve much higher than that of the tuner, but in any case where this may not be inherently so the tuner should be deliberately designed to have a lower Q value than that of the cavity, if the latter forms part of an oscillator. Where the use is such that the cavity does not determine the frequency of oscillation, it may not be important to suppress one of the peaks, in which event it may be permissible to make the Q of the tuner as high or higher than that of the cavity. We have previously stated that the optimum difference between the resonant frequency of the cavity, per se, and that of the tuner, per se, is approximately equal to the tuning range. Observance of that relation results in each tuner having maximum effectiveness; but the relation is not highly critical. It is possible to realize a substantial tuning range even though the difference of resonant frequencies is considerably greater than the indicated optimum. On the other hand, as the difference is increased the effectiveness of the tuner becomes progressively less until at last it is almost wholly ineffective. Manifestly, it is impossible for us to lay down any hard and

fast rule as to the maximum difference between the two resonant frequencies beyond which our invention does not extend. All we can say is that if the difference is so chosen as to produce a worth-while tuning band the result is within the contemplation of our inventive concept. Practical concrete values are easily determinable in each case.

We claim:

1. In combination, a resonant cavity which is intended to have an employed resonance peak which is variable through a frequency range, and a tuner within said cavity for shifting said employed resonance peak throughout said range, said tuner comprising a loop having inductance and lumped capacity, said loop being variably coupled to a magnetic field of said cavity, said cavity and said loop each, per se, possessing a resonant frequency which differs, each from the other, by an amount so chosen as to cause the aforesaid frequency range of said employed resonance peak to be of substantial width.

2. In combination, a resonant cavity which is intended to have an employed resonance peak which is variable through a frequency range of substantial width, and a tuner within said cavity for shifting said employed resonance peak throughout said range, said tuner comprising a loop having inductance and lumped capacity, said loop being variably coupled magnetically to a magnetic field of said cavity, said cavity and said loop each, per se, possessing a resonant frequency which differs, each from the other, by an amount which is of the same order as the frequency difference between the two ends of said range.

3. In combination, a resonant circuit which is intended to have an employed resonance peak which is variable through a frequency range, and a tuner for said resonant circuit, said tuner comprising a loop having inductance and lumped capacity, said loop being variably coupled to said resonant circuit, said resonant circuit and said loop each, per se, possessing a resonant frequency which differs, each from the other, by an amount so chosen as to cause the aforesaid frequency range of said employed resonance peak to be of substantial width, the resonant frequency of said loop, per se, being higher than that of said resonant circuit.

4. In combination, a resonant cavity which is intended to have an employed resonance peak which is variable through a frequency range of substantial width, and a tuner within said cavity for shifting said employed resonance peak throughout said range, said tuner comprising a loop having inductance and lumped capacity, said loop being variably coupled magnetically to a magnetic field of said cavity, said cavity and said loop each, per se, possessing a resonant frequency which differs, each from the other, by an amount which is of the same order as the frequency difference between the two ends of said range, the resonant frequency of said loop, per se, being higher than that of said cavity.

5. In combination, a resonant cavity which is intended to have an employed resonance peak which is variable through a microwave frequency range of substantial width, and a rotatable tuner within said cavity for shifting said employed resonance peak throughout said range, said tuner comprising an elongate loop having inductance and lumped capacity, said loop being coupled to a field of said cavity, the coupling being variable by rotating the tuner, said cavity and said loop

each, per se, possessing a resonant frequency which differs, each from the other, by an amount which is of the same order as the frequency difference between the two ends of said range, the resonant frequency of said loop, per se, being higher than that of said cavity, per se.

6. The combination according to claim 5 characterized in that the maximum capacity between tuner and cavity is small compared to said lumped capacity.

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