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R. A. HEISING
OSCILLATION DAMPING DEVICE

2,504,329

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FIG. 1

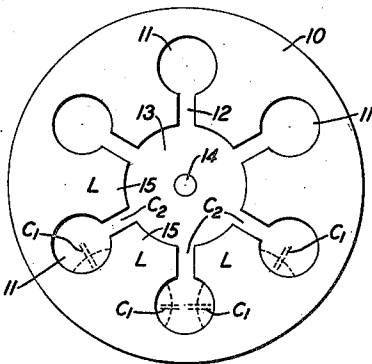


FIG. 5

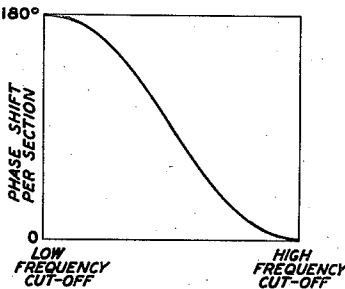


FIG. 2

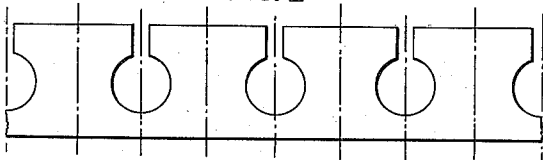


FIG. 3

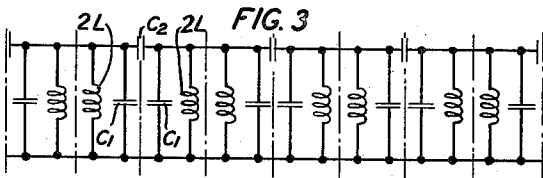


FIG. 4

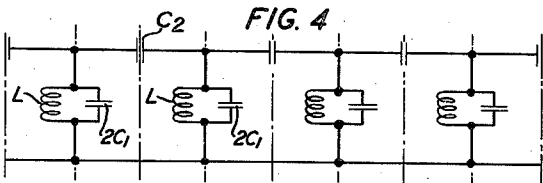


FIG. 6

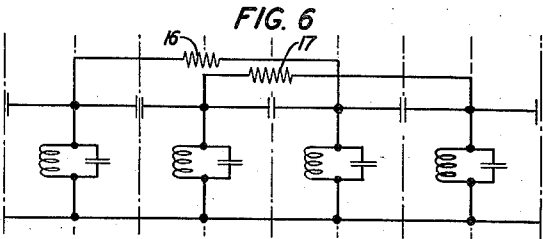


FIG. 7

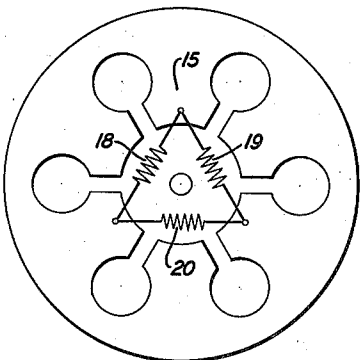
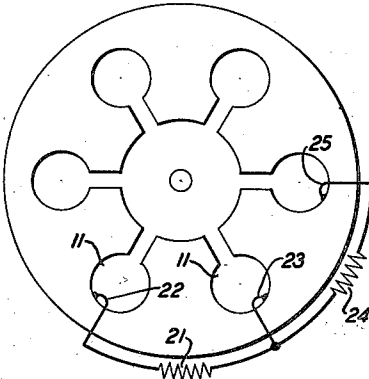


FIG. 8



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OSCILLATION DAMPING DEVICE

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9 Claims. (Cl. 315-40)

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This invention relates to multiply-resonant electro-magnetic systems and to arrangements for operating a plurality of resonant elements in unison.

In microwave oscillation generating systems it has been customary, particularly where magnetron oscillators are concerned, to employ a resonant system comprising a plurality of coupled resonant conductors, conductive structures, or resonating cavities excited in unison by an excitation system, usually electronic, which is common to all the resonators. Resonators of this type have come into use at increasingly high frequencies, reaching at the present time to 3,000 to 10,000 megacycles per second or higher. Difficulty has sometimes arisen due to the tendency of a system to generate different frequencies from time to time and, upon occasion, to shift erratically and unpredictably from one frequency to another.

This difficulty has its origin in a well-known property of coupled oscillatory systems, namely, that a plurality of elements, even if all are resonant at one and the same frequency, form, when coupled together, a multiply-resonant system having a plurality of resonant frequencies, which are generally as numerous as the individual resonators comprising the system. The multiple resonant frequencies are distributed over a band of frequencies in the neighborhood of the resonant frequency of the individual resonators when the latter are tuned alike or nearly so. Under suitable conditions of excitation, the system may oscillate at any one or more of the resonant frequencies and as conditions of excitation change, the operating frequency may also change. To provide a reliable source of a desired single frequency, oscillations at the undesired resonant frequencies should be suppressed under all operating conditions.

The combination of a plurality or train of coupled resonant circuits or cavity resonators forms the equivalent of a band-pass filter having a number of sections equal to the number of component resonators. From filter theory, it is known that a network of this type has a certain phase shift per section which varies over the transmission band.

With this view of the operation of the resonating system, if it is desired to restrict the operation to a single predetermined frequency or to a preferred mode of oscillation, this may be done by connecting ohmic resistances between pairs of points or circuit portions for which no phase difference arises during oscillations of the pre-

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ferred mode. If operation then tends to occur in a non-preferred mode or at such a frequency that phase differences arise between the portions so connected by resistances, currents will arise in the resistances and the resulting power loss or damping will tend to prevent operation. However, for the preferred mode of oscillation no such loss is introduced. Connectors introduced for the purpose of preventing operation in non-preferred modes are known in the art as mode-locking straps.

In accordance with the invention, resistive connections are made between certain points or poles in the individual circuits of a multiply-resonant system to introduce power loss should currents arise in such resistive connections due to phase difference between the points or poles so connected, with the object of suppressing or preventing oscillations except at a desired one of the resonant frequencies of the system.

In the drawing, Fig. 1 is a schematic representation of a typical multiply-resonant system as used in certain types of magnetron;

Fig. 2 is a representation of a portion of the resonator of Fig. 1 as if unrolled;

Fig. 3 is a schematic representation of the equivalent electric circuit of the resonator of Figs. 1 and 2;

Fig. 4 is a simplified equivalent circuit derived from the circuit of Fig. 3;

Fig. 5 is a graphical representation of the phase shift-frequency relation in the type of circuit shown in Fig. 4;

Fig. 6 is a schematic circuit diagram showing the addition of intercircuit resistances in the network shown in Fig. 4;

Figs. 7 and 8 are schematic representations showing respectively two ways of connecting intercircuit resistances in a resonating system such as shown in Fig. 1.

Fig. 1 is the conventional schematic representation of a resonating system of the general type employed in a magnetron oscillator such as is disclosed in U. S. Patent 2,063,342, issued December 8, 1936 to A. L. Samuel. The resonator comprises a solid anode portion 10 such as a block of conductive material pierced or perforated to define a plurality of resonating cavities 11 connected by channels 12 to a reaction space 13 containing a cathode 14. It is well known that a system of the type shown in Fig. 1, when properly excited, will oscillate electromagnetically as a multiply-resonant system. The conductor shown in Fig. 1 is represented as being unrolled in Fig. 2 for con-

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venient comparison with the equivalent circuit representation in Figs. 3, 4, and 6.

At the high frequencies of microwave operation, it is well known that the cavity 11 is capable of internal resonance wherein capacitances formed between various portions of the walls of the cavity resonate with the inductance of the walls. In Fig. 1, equivalent capacitances C_1 are indicated in dotted lines. At high frequencies the currents will reside principally in a thin conductive layer close to the cavity 11 and to the coupling channel 12, although at lower frequencies entire segments, such as indicated at 15 separating adjacent cavities may conduct currents. The effective inductance of each anode segment 15 is represented by L . The inner surfaces of the channel 12 provide a somewhat concentrated capacitance C_2 which serves to couple reactively between adjacent segments 15. The above considerations lead to the equivalent circuit for the system of Fig. 2 as represented schematically in Fig. 3. The adjacent parallel elements in Fig. 3 may be combined as indicated in Fig. 4 to form the network of a well-known type of band-pass filter. The cut-off frequency at the high frequency edge of the filter band is known from filter theory to be the resonant frequency of the parallel combination of the inductance L with twice the capacitance C_1 . The other cut-off frequency is determined by the capacitance C_2 resonating in series with four times the shunt combination of the inductance L and twice the capacitance C_1 . In the example shown, with six resonant elements joined in a series or in a closed ring with the output and the input connected together, there will be at least six resonant frequencies.

The phase shift per section through a device of this type is indicated in Fig. 5. The phase shift is 180 degrees per section at the low frequency cut-off and zero at the high frequency cut-off. A circuit of this type, resonating at the lowest frequency in its band will have maximum potential difference across all the C_2 capacitances and every second circuit will be substantially in phase. At the other frequencies, higher within the band, somewhat less than 180 degrees phase shift will occur between neighboring circuits until at the high frequency end of the band all the circuits will oscillate substantially in phase. From this figure it will be evident that the modes of oscillation will generally differ in respect to the phase distribution along the series of elements.

It is commonly found desirable in the operation of circuits of this type to favor the mode of operation in which neighboring poles operate in opposite phase, corresponding to the condition at the low frequency end of the band. In order to restrict the operation to this particular frequency, provision may be made as shown in Figs. 6, 7 and 8 by connecting together those pairs of circuit portions which it is desired to maintain in continual phase agreement. The connection is preferably made by means of resistances. If operation then tends to occur at such frequencies that phase differences occur between the resistance-connected points, power losses will occur in the resistances and suppress or prevent oscillations. At the frequency at which the resistance-connected points are in phase, no loss is introduced. Resistances are preferable for such connections as they introduce an actual loss when current traverses them and thus definitely tend to stop oscillations. Connecting by wires or conductors which mainly

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comprise inductance or are without material amounts of ohmic resistance will not generally serve to prevent oscillation. In the case of purely inductive connectors, the inductance will generally be so great compared to other reactances in the circuit to which they are effectively in parallel that they will fail to seriously influence the phase relations.

Assuming that it is desired to operate at the lowest frequency in the band, alternate or non-adjacent circuits may be connected by resistors 16 and 17 as in Fig. 6.

Fig. 7 shows another scheme of resistance inter-connections to suppress oscillations at frequencies other than the lowest frequency in the band. In this arrangement alternate segments 15 are connected by resistors 18, 19 and 20, as shown. In case there are eight or more resonant circuits, four or more resistors may be employed in an obvious extension of the arrangement of Fig. 7.

Fig. 8 shows another way in which the resistance connections may be made. In this arrangement, the resistors are inductively coupled to the resonant cavities as shown. A resistor 21 has one terminal connected to an inductive loop 22 extending into one of the resonant cavities and the other terminal connected to the adjacent cavity by means of an inductive loop 23 of reverse polarity with respect to loop 22. Other resistors such as resistor 24 may be connected in a similar manner, the resistor 24 being shown coupled by means of the loop 23 at one end and by means of another loop 25 at the opposite end, the loop 25 being coupled to the next adjacent cavity in opposite polarity to the loop 23. The system of connection in Fig. 8 may be extended to several, or all, of the individual cavities. The connections from the inductive loops may be brought out through the side of the resonator and tuning devices or transmission lines may be incorporated, if desired, into the connecting leads. The connections are such that when the magnetic fields in the resonators 14 are in phase no potential differences will occur across the resistors.

What is claimed is:

1. An anode comprising a block of conductive material perforated to define a train of coupled cavity resonators, forming a system having a plurality of modes of electromagnetic oscillation including a preferred mode in which adjacent cavities oscillate in phase opposition, and a resistor coupled to two adjacent resonant cavities by couplings of opposite polarity whereby damping is introduced into both of said adjacent resonant cavities selectively to suppress non-preferred modes of oscillation.

2. The combination as in claim 1 having a plurality of resistors each coupled to two adjacent cavity resonators by couplings of opposite polarity.

3. An anode block of conductive material perforated to define a plurality of cavity resonators connected by individual channels to a reaction space and having conductive anode segments between adjacent cavity resonators, and a mode-locking strap connected between two anode segments, said mode-locking strap comprising a damping resistor, the resistance of which is comparable in impedance value to the impedance value of the inductance of said strap in the operating frequency range of said anode block.

4. The combination according to claim 3 in which the mode-locking strap is connected between two non-adjacent anode segments.

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5. The combination according to claim 3 in which the mode-locking strap connects a pair of alternate anode segments.

6. An anode block of conductive material perforated to define a plurality of cavity resonators connected by individual channels to a reaction space and having conductive anode segments between adjacent cavity resonators, and a plurality of mode-locking straps connecting a set of alternate anode segments, each said mode-locking strap comprising a damping resistor the resistance of which is at least as great in impedance value as the impedance value of the inductance of said strap in the operating frequency range of said anode block.

7. An anode block of conductive material perforated to define a plurality of cavity resonators connected by individual channels to a reaction space and having conductive anode segments between adjacent cavity resonators, and a set of mode-locking straps connecting a set of alternate anode segments, each said mode-locking strap comprising a damping resistor the resistance of which is at least as great in impedance value as the impedance value of the inductance of said strap in the operating frequency range of said anode block.

8. An anode block of conductive material perforated to define a plurality of cavity resonators connected by individual channels to a reaction space and having conductive anode segments between adjacent cavity resonators, and a closed loop circuit comprised of a plurality of mode-locking straps in serial connection, the junction points between said straps being connected re-

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spectively to alternate anode segments, each said mode-locking strap comprising a damping resistor the resistance of which is of the same order of magnitude in impedance value as the impedance value of the strap in the operating frequency range of said anode block.

9. The combination according to claim 8 in which the number of mode-locking straps is equal to one-half the number of anode segments in the anode block.

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