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MECHANICAL HIGH FREQUENCY FILTERS

Filed March 13, 1958

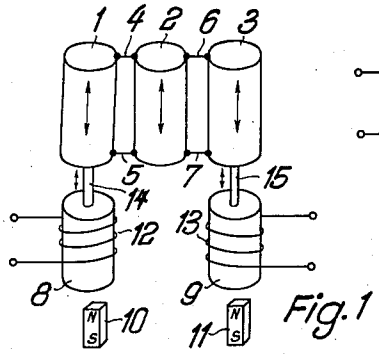

Fig. 1

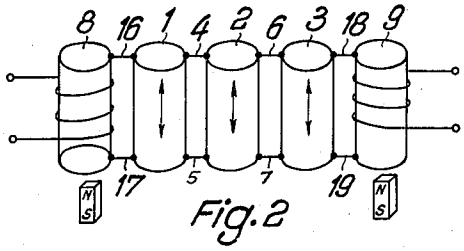

Fig. 2

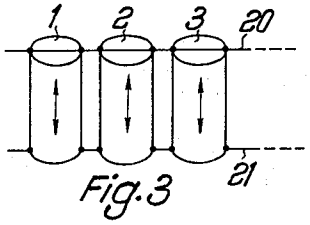

Fig. 3

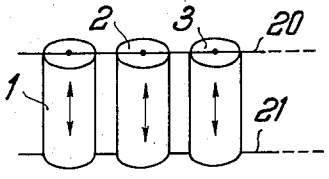

Fig. 4

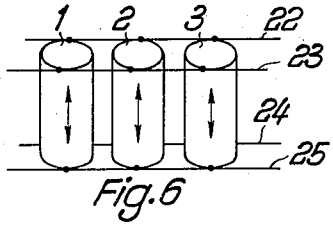

Fig. 6

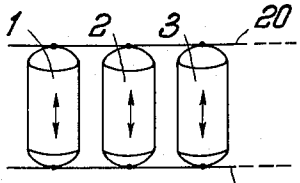

Fig. 5

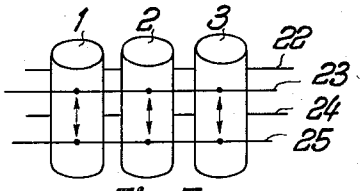

Fig. 7

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MECHANICAL HIGH FREQUENCY FILTERS

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This invention relates to mechanical high-frequency filters preferably comprising cylindrical resonant bodies or resonators excited in longitudinal or torsional modes of oscillation, said resonators being coupled with one another and excited in the same oscillatory mode by means of cylindrical and co-axially disposed coupling elements or couplers (see: RCA Review of September 1949, pp. 348–365). Such filters are mostly made in a single unit, whereby the resonators and the couplers are considered as mechanically resonant lines. Generally, the resonant lines have a length of $\lambda/2$ at the mean frequency of the pass band, for torsional or longitudinal modes of vibration.

In most instances, quarter-wave length line elements are used as couplers. In known filters of this kind, the resonators and couplers are designed as co-axial conductors $\lambda/2$ or $\lambda/4$ in length arranged in a row in such a way that, in case of longitudinally oscillating resonators, the couplers are also excited in longitudinal modes of oscillation. When using band pass filters with a greater number of resonators comparatively long structures are obtained which can be manufactured only with difficulty and are rather bulky.

It has also been found that the known filters, in addition to the desired band pass frequency, oscillate at a number of spurious frequencies which are very close to the band pass frequency. Such spurious frequencies are presumably the result of excitation in modes other than the desired oscillation mode, and their propagation through the filter is facilitated by excitation of the resonators and the couplers in the same oscillation mode.

It is an object of the present invention to provide a mechanical high-frequency filter of simpler structure occupying less space.

It is another object of the invention to provide couplers for such filters such that the spurious frequencies adjacent the pass band of the filter are avoided.

It is a still further object of the invention to provide simple means for connecting the resonators with the couplers in such filters, particularly in filters with a large number of resonators.

It is a further object of the invention to provide in a mechanical high-frequency filter, comprising a plurality of resonators tuned to the mean band pass frequency and excited at a natural frequency in a longitudinal oscillation mode, said resonators being coupled with one another by means of filar mechanical couplers which for purpose of this disclosure include wires, rod-like elements, band-like elements, etc. The paths of oscillation of the resonators are adjacent one another and parallel and the couplers comprise wires or strips excited to oscillate in flexural modes in directions which are transverse with respect to the oscillating directions of the resonators. Aside from a greater protection against spurious oscillations, such filters can be more easily manufactured and tuned, since the resonators can first be individually finished and tuned and thereafter attached to

the couplers, preferably by welding. In addition, filters comprising longitudinally oscillating resonators are shorter in length, because not all of the rod-shaped resonators and the couplers are assembled in series on the same axis, i.e. the resonators are disposed parallel to each other, while the couplers are arranged transversely with respect to the direction of oscillation.

In longitudinally oscillating resonators, it is sufficient to use only one thin wire in order to couple two oscillatory bodies, said thin wire being subjected to bending stresses during the oscillation and being attached either at the points of higher oscillation amplitude of the two resonators or at points of smaller amplitudes than the maximum oscillation amplitude to reduce the coupling. For the sake of stability of the filter and protection against spurious frequencies, there will generally be used more than one coupler wire between each two resonators. Continuous wires may suitably be used as couplers, whereby all of the resonators are secured to these wires, preferably by welding, so that the entire filter represents a relatively stable structure which can be readily mounted in a housing by means of the coupler wires.

Still further objects and the entire scope of applicability of the present invention will become apparent from the detailed description given hereinafter; it should be understood, however, that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

In the drawings:

Fig. 1 shows schematically a three-stage mechanical band pass filter with electro-mechanical ferrite transducers at the input and output.

Fig. 2 illustrates schematically a similar filter to that shown in Fig. 1, in which the ferrite transducers are coupled in a modified way.

Figs. 3 and 4 show schematically a very simple embodiment of the filter according to the invention with the couplers comprising two continuous wires.

Fig. 5 illustrates schematically a part of a filter according to the invention, in which the resonators are modified.

Figs. 6 and 7 show schematically further embodiments of the invention in which four continuous wires are provided as couplers.

In the filter according to Fig. 1, three resonators **1**, **2** and **3** are provided which are excited in longitudinal modes of oscillation as indicated by arrows, and the ends of the resonators are interconnected by means of wires **4**, **5**, **6** and **7** welded to these ends, or secured by any other suitable means such as soldering, brazing, etc. The oscillations of the resonator **1** have the greatest amplitudes at the ends thereof, at which points the wires **4** and **5** are subjected to the greatest bending stresses. As a result of this, the oscillations are transmitted to the resonator **2**, and from there to the resonator **3** via the wires **6** and **7**. Depending upon the desired filter characteristic, the filter comprises a greater or lesser number of these resonators. Coupling of the electric oscillations to the resonators can be obtained in a manner known per se by means of magneto-strictive or other electro-mechanical transducers, comprising for instance ferrite oscillators **8** and **9**, biased by the magnets **10** and **11**, respectively, and being coupled with the electric input or output waves by means of coils **12** and **13**, respectively. The coupling of the electro-mechanical transducer to the resonators **1**, **2** and **3** is obtained by means of coupler members **14** and **15**, which are also excited in longitudinal oscillations in a known manner.

Fig. 2 shows a modified coupling arrangement for the magneto-strictive transducers. In this embodiment the ferrite oscillators **8** and **9** are coupled to the resonators **1** and **3** by means of wires **16**, **17**, **18** and **19**, respectively, in the same way as the resonators **1**, **2** and **3** are interconnected, said wires being subjected to bending stresses.

In place of the individual coupler wires **4**, **5**, **6** and **7** between the resonators or between the resonators and the magneto-strictive transducers, there may be used continuous wires, as shown in Fig. 3. In this case, the edges of the cylindrical oscillating resonators **1**, **2** and **3** are welded to continuous wires **20** and **21** at two places on each end of each resonator.

Fig. 4 shows an embodiment, in which the centers of the resonators at their ends are welded to the continuous wires **20** or **21**.

In the modification of this embodiment, shown in Fig. 5, the ends of each resonator are rounded to form semispherical caps or calottes, whereby the propagation of spurious frequencies can be safely avoided.

To obtain a greater stability of the entire filter structure, more than two continuous coupler wires may suitably be used, as illustrated in Fig. 6. In this embodiment the coupler wires **22**, **23**, **24** and **25** coincide with the edges of a rectangular prism and the resonators **1**, **2** and **3** are secured between these wires by welding them to the two ends or side edges of these bodies at opposite points.

A modification of the latter arrangement is shown in Fig. 7, in which the coupler wires are welded to intermediate points on the cylindrical surfaces of the resonators, at which points the oscillating amplitudes are lower, resulting in a weaker coupling effect between the individual resonators.

The invention is not limited to the embodiments illustrated and described, i.e. various other modifications are possible. For example, any number of resonators other than that shown in Figs. 1 to 7 can be selected according to the requirements of filter characteristics and cut-off slope. Coupling of electrical vibrations may be obtained by other suitable mechanical transducers than those shown in Figs. 1 and 2. An illustration of such elements is unnecessary, since the present invention is not directed to the exciting means as such. The shape of the resonators need not be cylindrical as illustrated in the drawings, i.e. it may be prismatic, having rectangular or a square cross-section.

I claim:

1. A mechanical filter comprising at least two elongated resonators each tuned to vibrate in a longitudinal mode at a common selected frequency, said resonators being disposed side-by-side in spaced mutually parallel orientation with vibrational antinodes substantially in transverse alignment; non-resonant couplers for coupling adjacent resonators with one another, said couplers comprising spring-like filar elements disposed transversely across said resonators and fixed thereto in the vicinity of aligned antinodes, whereby the couplers transmit vibrations between the resonators by flexural oscillation; and motion transducer means coupled with at least one of said resonators, and each transducer means having its direction of motion disposed longitudinally of the resonator to which it is coupled.

2. A filter according to claim 1, characterized in that separate couplers are secured to the respective end surfaces of the resonators.

3. A filter according to claim 1, characterized in that said couplers comprise continuous wires secured to more than two resonators.

4. A filter according to claim 1 characterized in that said couplers are secured to the center points of the end surfaces of said resonators.

5. A filter according to claim 4, characterized in that the end surfaces of said resonators are rounded.

6. A filter according to claim 1, characterized in that said couplers are secured to said resonators at points which each lies intermediate the longitudinal ends thereof and spaced therefrom.

7. A filter according to claim 1, characterized in that said resonators comprise $\lambda/2$ resonators having longitudinal outer surfaces intersecting resonator end surfaces, and said couplers comprising four wires disposed across the resonators with two wires adjacent each end surface and connected to the intersections of end and longitudinal surfaces at transversely spaced points.

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