Dec. 7, 1948. W. SOLLER 2,455,389

METHOD AND APPARATUS FOR SEPARATING AUDIO FREQUENCIES

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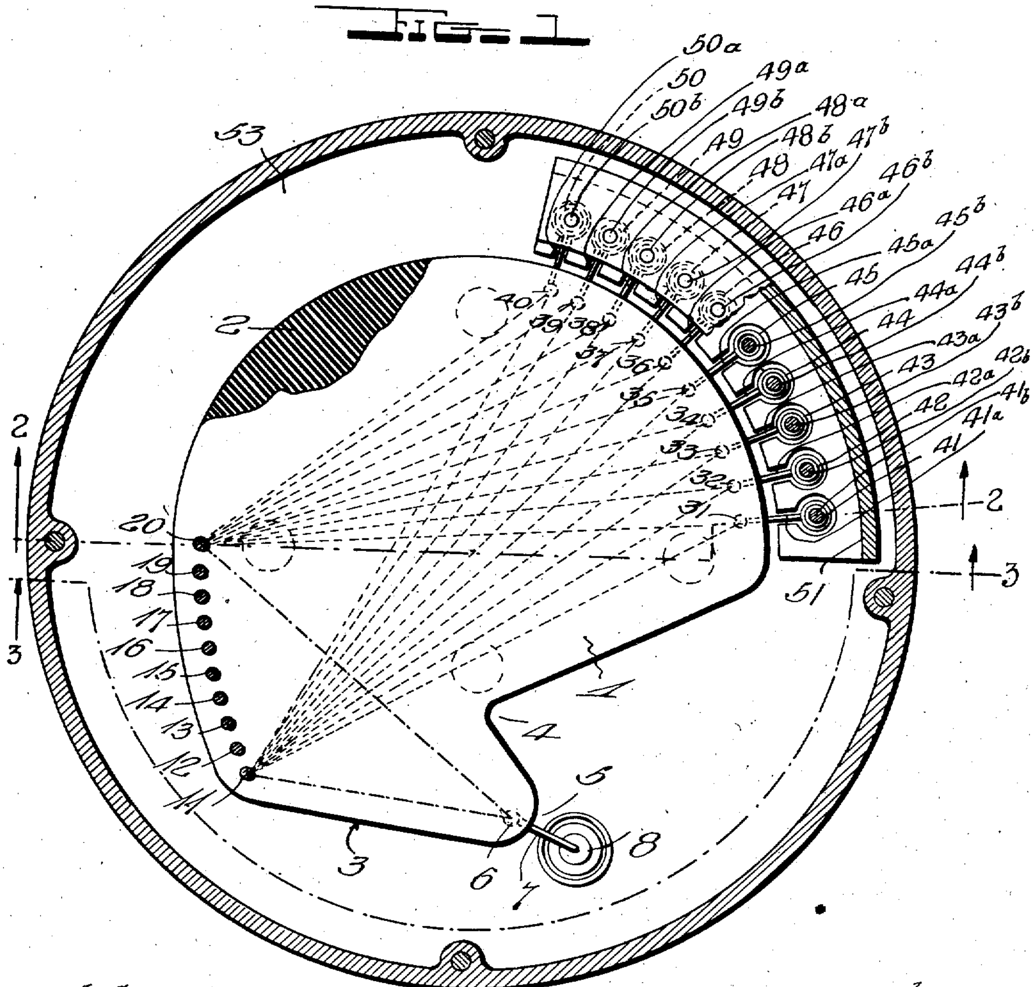
FIG. 1



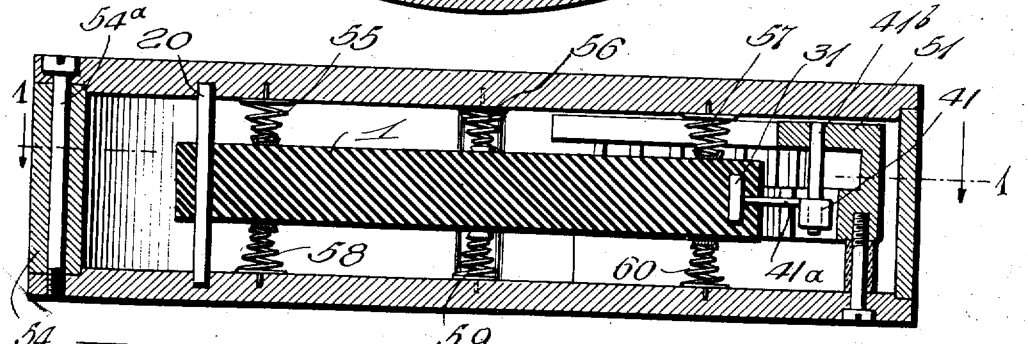


FIG. 2

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FIG. 3

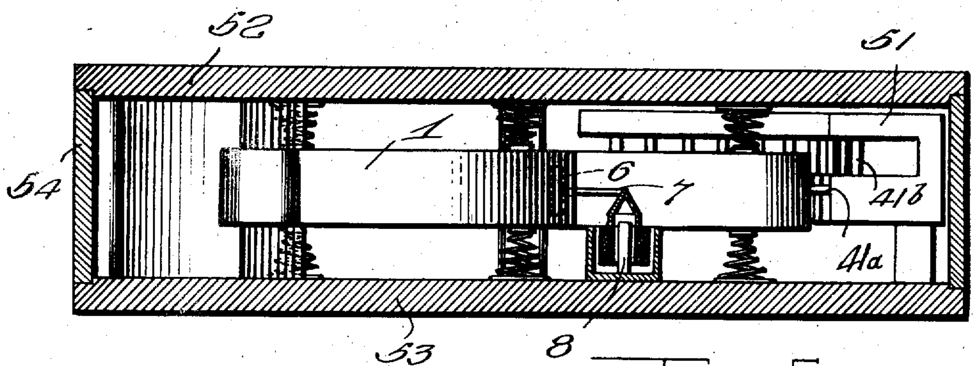


FIG. 4

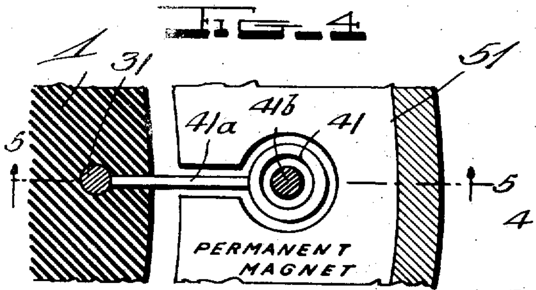


FIG. 5

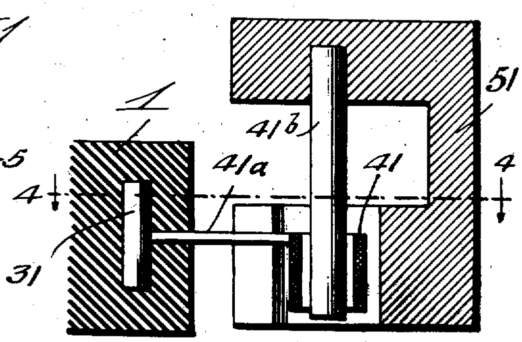


FIG. 6

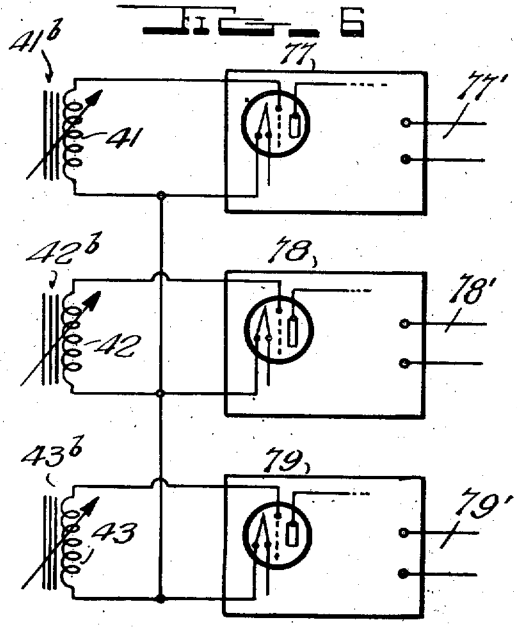
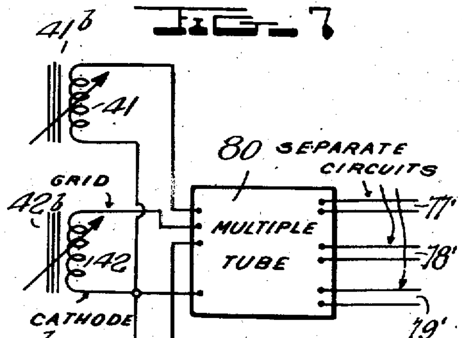


FIG. 7



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METHOD AND APPARATUS FOR SEPARATING AUDIO FREQUENCIES

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FIG. 8

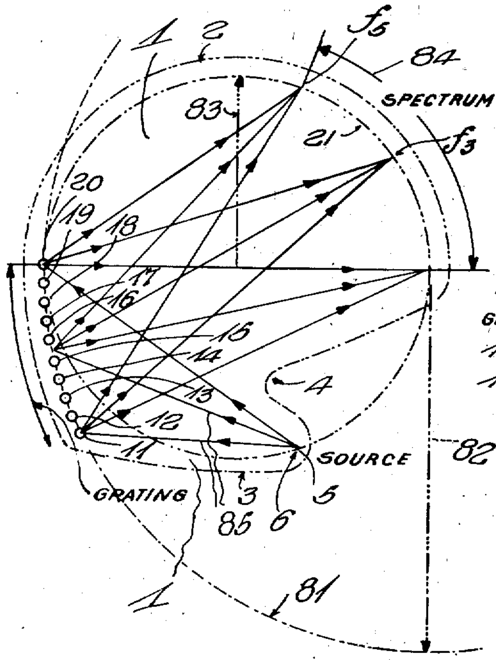
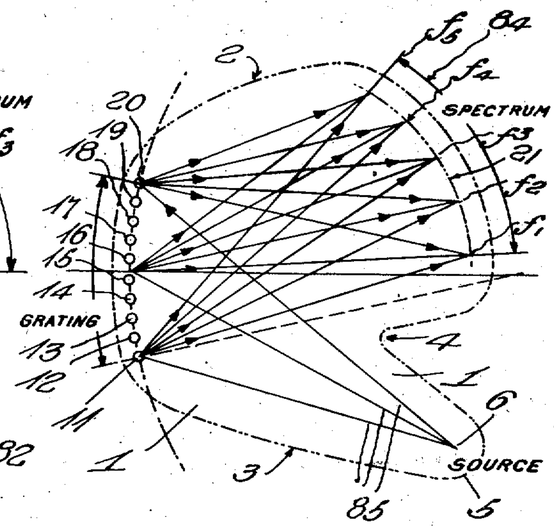


FIG. 9



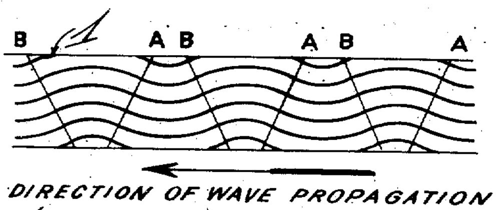
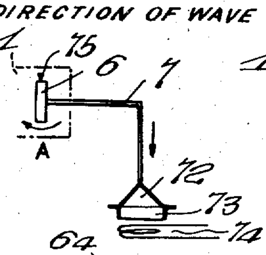


FIG. 10

FIG. 11



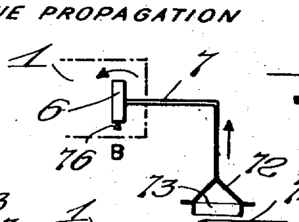
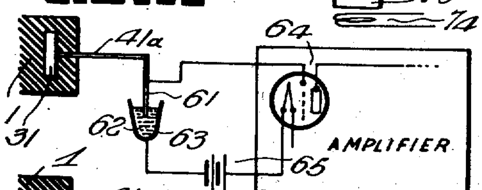


FIG. 12

FIG. 13



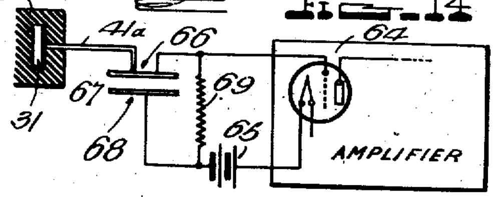


FIG. 14

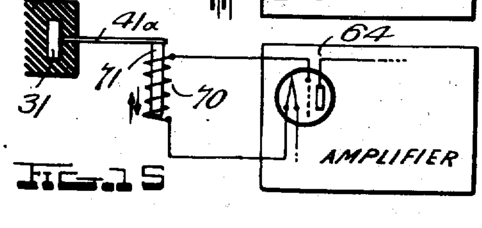


FIG. 15

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Patented Dec. 7, 1948

2,455,389

UNITED STATES PATENT OFFICE

2,455,389

METHOD AND APPARATUS FOR SEPARATING AUDIO FREQUENCIES

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Application February 14, 1944, Serial No. 522,344

11 Claims. (Cl. 178—44)

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My invention relates broadly to frequency selection, and more particularly to a system of wave analysis based on the production of spectra by diffraction through wave interference.

One of the objects of my invention is to provide a method and apparatus for separating and selecting audio frequency vibrations from a complex multi-frequency audio frequency vibration.

Another object of my invention is to provide a compact construction of frequency selector apparatus upon which complex audio frequencies may be impressed and selected audio frequencies within the range of the impressed frequencies selected for transmission to separate channels.

Still another object of my invention is to provide an arrangement of audio frequency selector apparatus in which a multiplicity of complex audio frequencies may be impressed upon the input side of the equipment and selected audio frequencies within the range of the impressed frequencies delivered at the output side of the apparatus.

Another object of my invention is to provide an arrangement of massive body into which complex vibrations within the audio frequency range may be introduced and selected audio frequencies derived through mechanical connections with the massive body for selecting, through transverse wave vibrations, particular frequencies within the range of the audio frequencies.

A still further object of my invention is to provide a compact construction of frequency selection apparatus for operation within the audio frequency range in which a physical body is mounted to receive complex vibrations which establish transverse waves through the physical body which may be utilized for the selection of individual audio frequencies within the complex frequency range.

Still another object of my invention is to provide a construction of apparatus in which vibrations are established in a material body and transverse waves utilized in the body for exciting individual audio frequency responsive members for the selection of frequencies within the range of the impressed frequencies.

Other and further objects of my invention reside in the construction of frequency selector apparatus having means for separating individual audio frequencies from complex audio frequencies as set forth more fully in the specification hereinafter following by reference to the accompanying drawings in which:

Figure 1 is a horizontal sectional view of the frequency selector apparatus of my invention

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taken on line 1—1 of Fig. 2 and with certain of the parts shown in top plan view; Fig. 2 is a transverse sectional view taken on line 2—2 of Fig. 1; Fig. 3 is a view taken on line 3—3 of Fig. 1 illustrating parts of the apparatus in side elevation and showing the casing in transverse section; Fig. 4 is a fragmentary view on an enlarged scale of one of the connecting means established with the physical body for utilizing a particular frequency within the complex frequency range of the physical body, the view being taken on line 4—4 of Fig. 5; Fig. 5 is a transverse sectional view taken on line 5—5 of Fig. 4; Fig. 6 is a schematic circuit diagram illustrating the manner of establishing connections to separate audio frequency channels from the frequency selector apparatus of my invention; Fig. 7 is a schematic view illustrating the connection of the output circuits of the frequency selector apparatus through a multiple tube circuit, of the type covered by my Patent 2,210,010, dated August 6, 1940, for Multiple vacuum tube, for transmitting selected audio frequencies to different line circuits; Figs. 8 and 9 are theoretical diagrams explaining the transverse wave theory on which my invention is based; Fig. 10 is a further theoretical diagram showing the method of propagation of the transverse waves through the physical body employed in the system of my invention; Fig. 11 illustrates one method of establishing a connection between the main vibratory source of complex frequencies and the physical body showing movement derived by a reproduced vibration in one direction; Fig. 12 shows diagrammatically the movement produced by a reproduced vibration in the opposite direction; Fig. 13 illustrates one method of deriving a selected frequency from the physical body by change in resistance in the input circuit of an amplification channel; Fig. 14 illustrates a manner of changing capacity across the input circuit of an amplification channel under control of a selected frequency derived from the physical body and Fig. 15 illustrates an arrangement for controlling the inductance of the input circuit of an amplification channel in accordance with a selected audio frequency derived from the frequency selecting apparatus of my invention.

By the method of my invention transverse wave motion is produced in a physical mass and analysis of a complex wave is effected within the sonic or super-sonic range in frequency of vibration which, in the apparatus of my invention, vibrate transversely. Where waves of such frequency have originated as sound waves or similar compressional waves, it is necessary therefore to convert the same to transversely vibrating waves when involved in the analyzing system of my invention. Spectra of the sonic or super-sonic waves are formed, and the wave analysis is completed by introducing means throughout the spectrum for detecting the various component waves which may be present. Again, such components will be in the form of transversely vibrating waves, but may be transformed into sound or other form of energy wave readily observable or employable, as desired.

My invention has numerous applications such as multiplex telegraph and telephone systems for separating carrier channels, television systems, synchroscope systems, systems of measurement using audio frequencies and in other audio frequency systems generally.

The main body is constructed of elastic material such as soft rubber. The body 1 is shaped in the form of a sounding board or harp and includes a curved peripheral portion 2, a flattened portion 3, an acutely angled recessed portion 4 and a rounded end portion 5. Vibration transmitting member 6 is embedded in the body 1 adjacent the rounded end portion 5 and connected through arm 7 to an electromagnetic sound reproducing mechanism indicated at 8 giving out a complex modulated wave. Rods 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 which extend through body 1 form a concave reflecting diffracting grating which reflects and diffracts modulated complex waves in a body of material, producing a spectrum at some surface indicated at 21. The individual points or surface 21 will then be vibrating at separate frequencies. Small metal rods 31, 32, 33, 34, 35, 36, 37, 38, 39, and 40 are embedded in the rubber body 1 to take up or collect these vibrations. Onto these metal rods 31, 32, 33, 34, 35, 36, 37, 38, 39 and 40, coils 41, 42, 43, 44, 45, 46, 47, 48, 49 and 50 are fastened by means of arms 41*a*, 42*a*, 43*a*, 44*a*, 45*a*, 46*a*, 47*a*, 48*a*, 49*a*, 50*a*, which are allowed to vibrate in a strong magnetic field established by permanent magnet 51 from which extends the magnetic core members 41*b*, 42*b*, 43*b*, 44*b*, 45*b*, 46*b*, 47*b*, 48*b*, 49*b*, 50*b*, passing through the associated windings 41, 42, 43, 44, 45, 46, 47, 48, 49 and 50 respectively as shown, thereby producing a potential of the same frequency as the rods 31, 32, 33, 34, 35, 36, 37, 38, 39 and 40. This voltage then is amplified by vacuum tube systems from which the useful separated individual currents of selected frequencies are taken. The multiple vacuum tube of my Letters Patent 2,210,010, dated August 6, 1940, can be used in place of a plurality of separate tubes.

The frame of the apparatus consists mainly of two metal plates 52 and 53 supported rigidly on their peripheries by side frame 54 and by rods 54*a*. The mass of the rubber or elastic material body 1 is supported by a series of coil springs 55, 56, 57, 58, 59 and 60 disposed between the plates 52 and 53 and the body 1 as shown.

The diffracting grating composed of equally spaced rods 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 is supported rigidly in the frame 52—53 of the apparatus. The rods 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20 enter recesses in the plates 52—53 at each end as shown. Rods 11, 12, 13, 14, 15, 16, 17, 18, 19, and 20 also adhere to the rubber or elastic body 1.

The result is that embedded rod 6 will be vigrating according to a complex frequency while the rods 31, 32, 33, 34, 35, 36, 37, 38, 39, and 40 will be vibrating at separate individual frequencies.

One of the basic features of the filter is that frequencies are separated by means of properties of waves due to their wave lengths in this material rather than by purely frequency characteristics. For this reason difficulties in the methods of separating out frequency by frequency characteristics are overcome.

In particular, the difficulties with respect to side bands do not enter into this method. The rods 31, 32, 33, 34, 35, 36, 37, 38, 39 and 40 will vibrate at varying intensities according to the modulated waves that particular frequency may be subjected to but still will only be vibrating at one separate frequency.

The method of taking off the separate frequencies shown in Figs. 1–5 is only one of many that are possible. Systems in which resistance, capacities, potentials or currents may be varied by a moving member can be used in place of the method shown in Figs. 1–5. For example the member that is embedded in the vibratory body 1, as represented at 31 through 40, which serve as the transmitting means for selected vibrations, may have the arms 41*a*—50*a* extend to various electrical control means. In Fig. 13 I have shown the arm 41*a*, for example, terminating in member 61 that enters a pool of mercury or graphite composition represented at 62, as contained in cup 63 and which serves as a variable resistance device in the input circuit of electron tube amplification system 64. The input circuit to the electron tube amplification system includes suitable source 65 in the series path leading to the grid circuit of the amplifier 64 so that the input circuit path may be varied in conductivity by physical displacement of member 61 in the respective pool 62 for varying the input to the amplifier circuit, in accordance with the audio frequency vibrations imparted to member 61 from the embedded member 31 in the massive body, 1.

In place of the resistance change, I may employ a capacitance change, as represented in Fig. 14, in which arm 41*a* is physically connected with movable capacity area 66 of variable condenser 67 associated with the stationary capacity area 68. The input circuit through the first stage of amplification of the amplifier system, represented at 64, is completed through resistor 69 in shunt with variable condenser 67. Vibrations transferred by arm 41*a* variably displace plate 66 changing the effective capacity across the input circuit to the amplification system for reproduction of selected frequencies by capacitance variations.

In lieu of the resistance and capacity methods, I may employ an inductive variation method, as represented in Fig. 15, wherein inductance 70 from the input circuit to amplifier channel 64 is variably acted upon by magnetic armature member 71 connected to arm 41*a* so that armature member 71 is vibrated in accordance with the vibrations impressed upon embedded member 31. Currents are generated in winding 70 proportional to the displacement of armature 71 within winding 70. Variations in inductive effect of winding 70 thereby control the operation of the amplification channel 64. Other means for exciting the input circuit of the amplification channel in accordance with vibratory motion imparted from the associated member embedded in the massive body may be employed for controlling different channels at selected frequencies.

The manner of impressing audio frequencies upon the massive body may also be varied and the methods explained herein are to be considered in the illustrative sense rather than in the limiting sense.

For example in Fig. 11 I have shown the vibration transmitting member **6** embedded in body **1** connected through arm **7** to the diaphragm **72** of an electro magnetic sound reproducing mechanism which develops a complex modulated wave. The diaphragm **72** may carry a winding on a suitable coil support represented at **73**, which is operative within either a permanent or an electro-magnetic field. Variations in the circuit of the winding **74** carried by coil support **73** effect displacement of arm **7** which in turn imparts angular movement to vibration transmitting member **6**, which rock within physical body **1** about a theoretical fulcrum **75** imparting vibrations to the massive body **1**. I have designated the form of the reproduced impulse illustrated in Fig. 11 by letter A. I show by letter B in Fig. 12 the movement of vibration transmitting member **6** about a theoretical fulcrum **76** in the reverse direction for impressing complex vibrations upon the member **6** through arm **7** as heretofore explained. Other methods of mounting the vibration transmitting member **6** with respect to the massive body **1** may be provided and the force transmitting diagrams A and B are illustrative of a variety of mounting arrangements.

Figs. 6 and 7 show circuit arrangements for impressing the selected frequencies on different channels for use in various applications. Windings **41**, **42** and **43**, associated with the magnetic system and core member indicated at **41b**, **42b** and **43b**, which are subjected to vibrations from the massive body **1** through the link transfer members **41a**, **42a** and **43a** are illustrated as individually connected in the input circuits of separate channels constituted by electron tube systems **77**, **78** and **79**. The output circuits of these electron tube systems are represented at **77'**, **78'** and **79'** extending to selected channels for utilization in independent circuits.

In lieu of the separate tube systems shown at **77**, **78** and **79**, I may employ a multiple tube system of the type disclosed in my Letters Patent 2,210,010, supra, wherein the vibratory windings **41**, **42** and **43** associated with magnetic systems represented at **41b**, **42b** and **43b** connect to individual control grid elements of the multiple vacuum tube which I have indicated generally by reference character **80** serving to segregate the desired frequencies into separate circuits leading to channels **77'**, **78'** and **79'** as accomplished in the separate tube system of Fig. 6.

Fig. 10 illustrates the manner in which transverse waves are established in the physical body **1** from the complex frequencies impressed by vibratory device **6** on physical body **1**. The wave stresses produced in the physical body **1** result from the displacement of vibratory member **6** alternately about its upper and lower extremities according to positions A and B in Figs. 11 and 12, respectively, where the member **6** is illustrated fulcruming about pivots **75** and **76**. Stresses A and B are produced in the physical mass **1** as represented at A—B in Fig. 10 as the vibratory member **6** pivots about fulcrum **75** and fulcrum **76** in positions A and B in Figs. 11 and 12, respectively. Thus complex waves as developed at member **6** travel through the physical mass of body **1** and strike the grating constituted by the rods **11**, **12**, **13**, **14**, **15**, **16**, **17**, **18**, **19** and **20** shown in Fig. 8. The number of rods in the grating bears no relation to the number of frequencies selected from the spectrum, but is a factor in determining the extent and effectiveness of the spectrum itself. Likewise, the waves from the source **6** are not individually separated by the coaction of an individual rod of the grating; but by the cooperative action of all the rods as a grating, per se, a spectrum is produced in which the waves appear in the order of their frequencies. That is, the absence of any rod does not mean the absence of any frequency from the spectrum—this seems to be a basic advantage of the device of my invention.

In Figs. 8 and 9 I have shown the theoretical principles involved in the system of my invention. The massive body **1** may be of soft rubber as heretofore explained or other materials may be used which are sufficiently elastic to transmit transverse waves. The shape of the body, as has been previously explained, simulates the form of a sounding board or harp including the curved peripheral portion **2**, the relatively flattened portion **3**, the acutely angled recessed portion **4** and the rounded end portion **5**. The rounded end portion **5** is substantially isolated from the portion **21** of the massive body so that complex frequencies generated at **6** in the massive body are directed to the grating **11—20** for reflection to the portion **21** of the massive body and direct transmission of transverse waves from the source **6** to the portion **21** is prevented. As will be observed, the rod members **11—20** forming the grating are arranged on a curve represented at **81** drawn on a radius **82**. The transverse waves are established through the massive body **1** by reflection from the grating formed by rods **11—20** and directed to the portion **21** of the massive body. Portion **21** of the massive body is formed on the periphery of a circle and a radius represented at **83**. The distance within which the spectrum is confined in the massive body **1** is represented at **84** and within this distance the metal rods **31—40** are embedded along the portion **21** of the massive body as heretofore explained. In Fig. 8 it may be assumed that the complex frequencies at any instance which are impressed upon the massive body **1** of **6** include, for example, frequencies f_1, f_3, and f_5. These frequencies establish transverse waves along the lines represented at **85** which are reflected by certain of the rod members **11—20**, representing the grating and individual frequencies directed to the portion **21** of massive body **1** which vibrates along the portion **21** at these individual frequencies. At the points which are vibrating the individual selected frequencies, these vibrations are taken off by the rods **31—40** and the transfer links **41a—50a** associated therewith for imparting vibratory movement to the particular vibratory means employed for generating currents corresponding to the selected frequency. Each of the generating means, such as **41—49**, are individually designed for generating definite frequencies and discriminate and differ one from the other for insuring selective generation of the individual frequencies for impression upon the transmitting channels in suitable manner such as represented in Figs. 6 and 7.

In Fig. 9 I have represented the transverse waves established in the massive body **1** wherein the source includes frequencies f_1, f_2, f_3, f_4 and f_5, etc. That is additional frequencies f_2 and f_4 are included in the complex frequencies impressed upon massive body **1** from source **6**. The additional frequencies are reflected from the grating formed by rods 11—20 and cause, through wave interference and the establishment of transverse waves, the weaving of the portion 21 of massive body 1 for setting up nodes along the portion 21 of the massive body 1, at which are located the transfer means for selectively taking off the derived individual frequencies.

I have described my invention in certain of its preferred embodiments but I realize that modifications may be made in the arrangement and form of my invention and I intend no limitations upon my invention other than may be imposed by the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. Apparatus for separating frequencies comprising a massive body of substantially circular contour recessed adjacent one side thereof forming a projecting portion on said massive body, a generator of complex frequencies connected with the projecting portion of said massive body, for setting up compressional waves therein a grating embedded in said massive body in the path of the compressional waves established therein for transmitting compressional waves of selected frequency and establishing individual vibrations at the said frequencies at intervals adjacent the peripheral edge of said massive body substantially opposite said grating, and means connected at spaced intervals with the peripheral edge of said body for reproducing the frequencies isolated from said complex frequencies.

2. Apparatus for separating frequencies comprising a massive body of substantially circular contour recessed adjacent one side thereof forming a projecting portion on said massive body, a generator of complex frequencies connected with the projecting portion of said massive body, for setting up compressional waves in the massive body a grating comprising a plurality of spaced rods embedded in said massive body in the path of the compressional waves transmitted from said generator of complex frequencies, a multiplicity of frequency responsive members embedded in said massive body in substantially diametrically opposite positions with respect to the rods constituting said grating, said frequency responsive members being substantially shielded from direct waves from said generator of complex frequencies, and means connected with the frequency responsive members for reproducing the individual frequencies within the spectrum embraced by said generator of complex frequencies.

3. Apparatus for separating frequencies comprising a massive body of resilient material, means for resiliently suspending said body for the passage therethrough of compresional waves in complex frequency, said body having a projection on one side thereof, a generator of complex frequencies connected with said projection, a grating constituted by a multiplicity of rods embedded in said body along the periphery thereof substantially opposite to the projection thereon, a multiplicity of frequency responsive members embedded adjacent the peripheral edge of said body in positions substantially opposite to the positions occupied by the rods constituting said grating whereby the periphery of said body is vibrated at individual frequencies at spaced intervals by the last mentioned compressional waves, and means for individually reproducing individual frequencies through said frequency responsive members.

4. Apparatus for separating frequencies comprising a massive resilient body, yieldable means engaging opposite sides of said body for suspending said body for vibratory movement in space, means for impressing vibrations on said body adjacent one portion thereof, a grating embedded in said body in a position opposite the position in which the means for impressing vibrations upon said body is connected to said body, a multiplicity of frequency responsive members embedded in said body adjacent the periphery thereof in position substantially opposite the position occupied by said grating, and means connected with said frequency responsive members for reproducing the frequencies individual to said members within the frequency range of said first mentioned means.

5. The method of separating frequencies which comprises impressing complex frequency vibrations upon a resilient suspended body for establishing compressional waves therethrough, alternately reflecting and absorbing the compressional waves at spaced positions at one portion of the body for setting said body into vibration adjacent another portion thereof by reflected waves at different frequencies within the range of the complex frequencies, and reproducing the different frequencies at which the body is vibrating adjacent the last mentioned portion thereof.

6. The method of separating frequencies which comprises impressing complex frequencies upon a portion of a yieldable body, establishing compressional waves at the complex frequencies through the body, alternately reflecting and absorbing the compressional waves at spaced intervals adjacent one side of the body, transmitting the compressional waves at acute angles to the opposite side of the body, and establishing vibrations at the last mentioned side of the body at individual frequencies within the range of the impressed complex frequencies and separately reproducing the individual frequencies.

7. Apparatus for separating frequencies comprising a massive body of substantially circular contour recessed adjacent one side thereof forming a projecting portion on said massive body, means for supporting said body for substantially free vibration, a generator of complex frequencies connected with the projecting portion of said massive body for setting up compressional waves therein, a grating embedded in said massive body in the path of the compressional waves established therein for directing transverse waves of selected frequency and establishing individual vibrations at the said frequencies at intervals adjacent the peripheral edge of said massive body substantially opposite said grating, and electromagnetic means connected at spaced intervals with the last mentioned peripheral edge of said body for reproducing the frequencies isolated from said complex frequencies.

8. Apparatus for separating frequencies comprising a massive body of substantially circular contour recessed adjacent one side thereof forming a projecting portion on said massive body, means for supporting said body for substantially free vibration, a generator of complex frequencies connected with the projecting portion of said massive body for setting up compressional waves therein, a grating embedded in said massive body in the path of the compressional waves established therein for directing compressional waves of selected frequency and establishing individual vibrations at the said frequencies at intervals adjacent the peripheral edge of said massive body substantially opposite said grating, electromagnetic coil members supported by the

peripheral edge of said massive body at the spaced intervals thereof vibrating at individual frequencies, magnetic core means spacially related to said electromagnetic coil members, and electronic means connected in circuit with said electromagnetic coil members for reproducing the frequencies isolated from said complex frequencies.

9. Apparatus for separating frequencies comprising a massive body of substantially circular contour recessed adjacent one side thereof forming a projecting portion on said massive body, means for supporting said body for substantially free vibration, a generator of complex frequencies connected with the projecting portion of said massive body for setting up compressional waves therein, a grating embedded in said massive body in the path of the compressional waves established therein for directing transverse waves of selected frequencies and establishing individual vibrations at the said frequencies at intervals adjacent the peripheral edge of said massive body substantially opposite said grating, variable capacity areas supported by the peripheral edge of said massive body at the spaced intervals thereof vibrating at individual frequencies, coacting fixed capacity areas adjacent said variable capacity areas, and electronic means connected across coacting pairs of said capacity areas for reproducing the frequencies isolated from said complex frequencies.

10. Apparatus for separating frequencies comprising a massive body of substantially circular contour recessed adjacent one side thereof forming a projecting portion on said massive body, means for supporting said body for substantially free vibration, a generator of complex frequencies connected with the projecting portion of said massive body for setting up compressional waves therein, a grating embedded in said massive body in the path of the compressional waves established therein for directing compressional waves of selected frequencies and establishing individual vibrations at the said frequencies at intervals adjacent the peripheral edge of said massive body substantially opposite said grating, magnetic core members supported by the peripheral edge of said massive body at the spaced intervals thereof vibrating at individual frequencies, an inductive winding surrounding each magnetic core member, and electronic means connected with said inductive windings for reproducing the frequencies isolated from said complex frequencies according to the vibratory movement of said magnetic core members.

11. Apparatus for separating frequencies comprising a massive body of substantially circular contour recessed adjacent one side thereof forming a projecting portion on said massive body, coil springs on opposite sides of said body for suspending said body for substantially free vibration, a generator of complex frequencies connected with the projecting portion of said massive body for setting up compressional waves therein, a grating comprising a multiplicity of spaced rods embedded in said massive body in the path of the compressional waves transmitted from said generator of complex frequencies, a multiplicity of frequency responsive members embedded in said massive body in substantially diametrically opposite positions with respect to the rods constituting said grating, said frequency responsive members being substantially isolated from direct waves from said generator of complex frequencies by the recessed portion of said body, and means electrically associated with the frequency responsive members for reproducing individual frequencies within the spectrum embraced by said generator of complex frequencies.

WALTER SOLLER.

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