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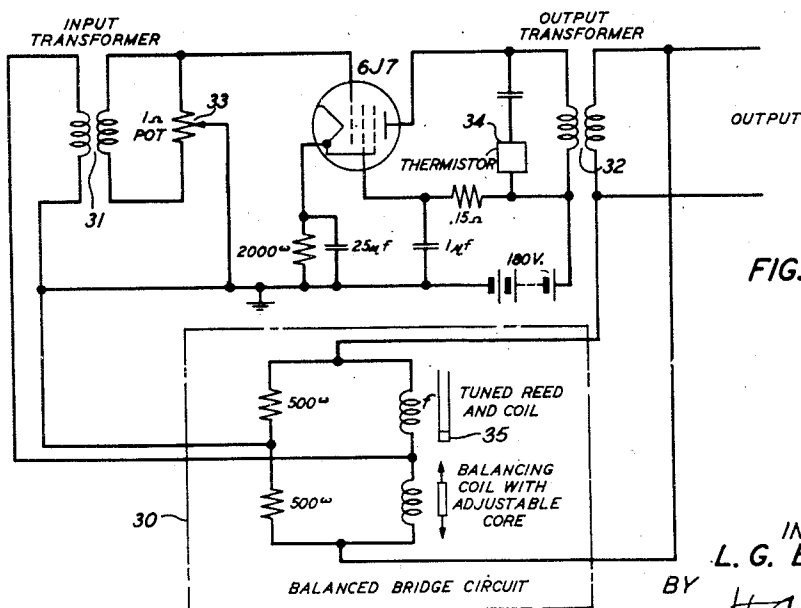
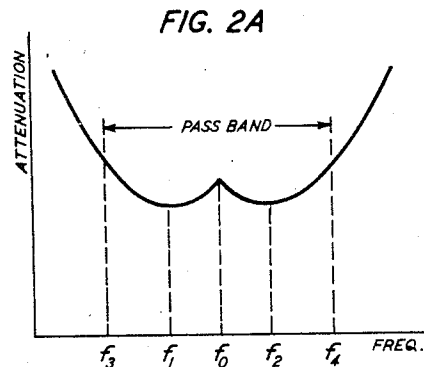
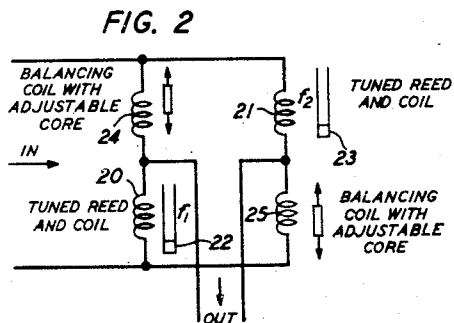
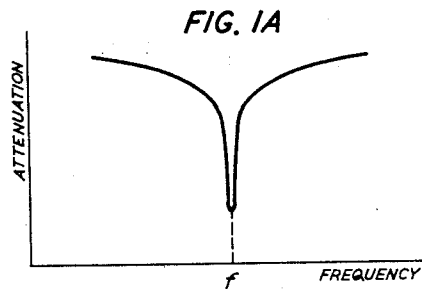
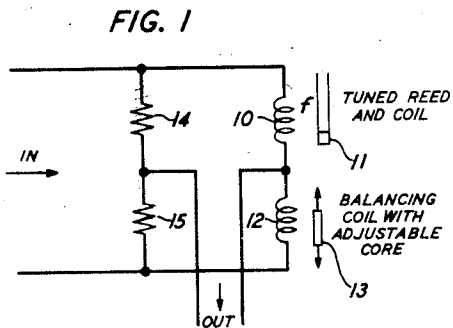
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2,630,482

TUNED VIBRATING REED SELECTIVE CIRCUIT

Filed July 10, 1948

2 SHEETS—SHEET 1



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2 SHEETS—SHEET 2

FIG. 4

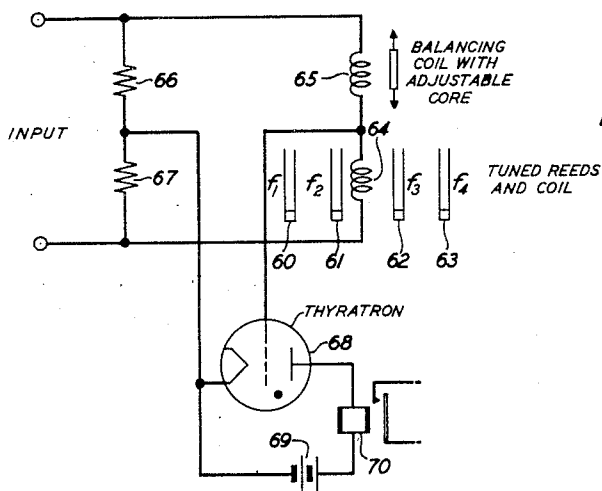
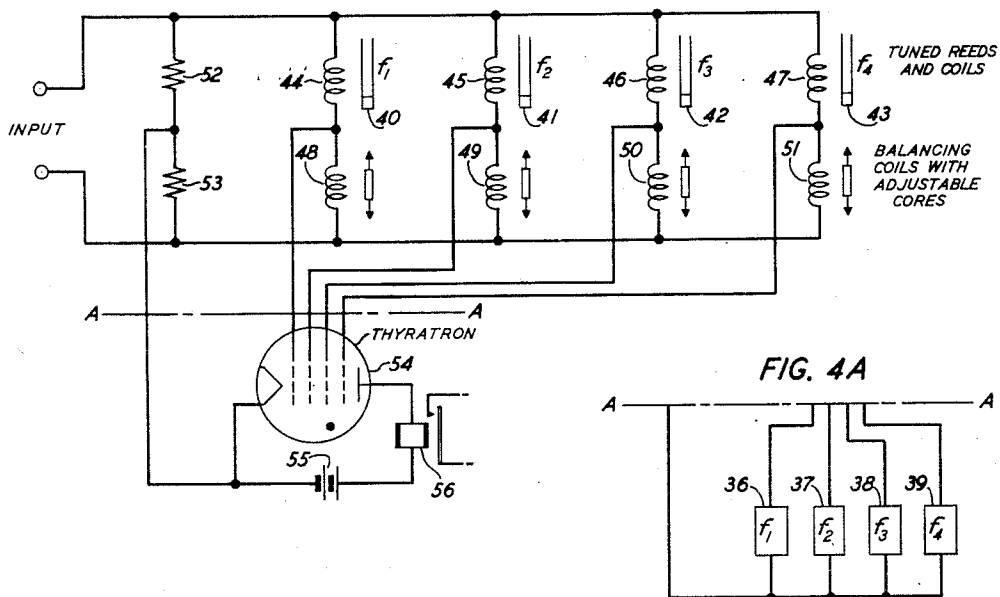


FIG. 5

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TUNED VIBRATING REED SELECTIVE
CIRCUIT

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Application July 10, 1948, Serial No. 38,130

15 Claims. (Cl. 177—353)

1

This invention relates to frequency selective circuits and more particularly to those using a tuned vibratile reed or fork for the selective element.

Although in no wise limited thereto, the invention will be disclosed in a form suitable for use, by way of example in a mobile radio communication system, as a simple, compact and reliable frequency selective means suitable for selective signaling purposes. Such signaling is generally accomplished at audio frequencies and in order to supply a sufficient number of tones to provide a large number of selective signaling tone combinations, the tones must be spaced close to each other in the frequency spectrum. This requires that the selective means used to differentiate and separate one tone from another must possess a relatively high Q value. Such high values of Q are not readily obtained at the lower audio frequencies using conventional coil and condenser resonant circuits. However, mechanically resonant systems are known to have very high values of Q . Accordingly a selective relay has been developed which utilizes an electrically driven tuning fork which is provided with contacts located on the tines for making or breaking a circuit when the electric current drive frequency is equal to the resonant frequency of the tuning fork and is described in copending United States patent application now abandoned, Serial No. 776,252, H. C. Harrison. This arrangement, however, involves the use of contacts and therefore presents a maintenance problem which, if possible, should be avoided.

One means of avoiding the use of contacts is to employ the tuning fork or reed as a coupling element between two coils; one a drive coil and the other a pick-up coil. Such an arrangement is shown in United States Patent 1,906,985 to W. A. Marrison dated May 2, 1933, wherein a tuning fork is used as the frequency determining element and is provided with both a drive coil and a pick-up coil. The present invention differs from previously used tuning fork frequency selective means known to applicant in that but one coil is used in association with the tuning fork or reed and that coil serves the dual functions of driving the fork and acting as a variable impedance element.

An object of this invention is to provide an electrical circuit, or filter, having sharply selective frequency characteristics by making use of the electrical motional impedance characteristic of an electromagnetically driven tuning fork.

One feature of this invention is that very high

2

values of Q may be obtained from mechanically vibrating reeds or tuning forks. Another feature is that the filter circuit used is of the bridge type which is simple and inexpensive. A very useful feature is that the frequency at which the filter is selective may be readily changed by simply changing the tuning fork or reed to one which resonates at a different frequency. Another feature is that no contacts are required to be associated with the reeds, imposing a maintenance and replacement burden. A further feature of the invention lies in the ability to provide band-pass filters utilizing two reeds each tuned to a different frequency. Still another feature of the invention is the ability to utilize any number of these simple filters in a multiple arrangement whereby the simultaneous presence of a plurality of frequencies may be recognized.

In accordance with the invention the driving coil of a tuning fork is placed in one arm of an impedance bridge, which is unbalanced near the resonance frequency of the fork by the increase in the coil's impedance due to the motional impedance effect. Because of this unbalance the bridge will pass the frequency to which the tuning fork is tuned. A high degree of selectivity is obtained because of the high mechanical Q of a tuning fork.

In accordance with the invention in one application a plurality of driving coils for a plurality of tuning forks, each of which is tuned to a different frequency, are placed in a multiple arrangement which in effect comprises a multiplicity of impedance bridges in tandem in which two of the arms are common to all the bridges. This arrangement therefore functions as a multi-frequency selective circuit with high degrees of selectivity at each of the tuning fork frequencies.

A more complete understanding of this invention, its objects, features and mode of operation, will be derived from the detailed description that follows, read with reference to the appended drawings wherein:

Fig. 1 shows the basic circuit of the impedance bridge selective filter utilizing the electrical motional impedance characteristic of an electromagnetically driven tuning fork;

Fig. 1A is the selectivity curve for the circuit of Fig. 1;

Fig. 2 shows a modification of the basic circuit of Fig. 1 using two tuning forks to provide a band-pass selective characteristic;

Fig. 2A illustrates the pass band frequency characteristic obtained with the circuit of Fig. 2;

Fig. 3 shows the circuit of an oscillator in which

the frequency of oscillation is controlled by a frequency selective bridge of the type shown in Fig. 1;

Fig. 4 illustrates a multifrequency tandem multiple bridge arrangement wherein the presence of several frequencies is required to operate a multi-grid gas discharge device;

Fig. 4A shows a modification of Fig. 4 where the several frequencies selected are applied to individual load circuits; and

Fig. 5 illustrates another multifrequency selective circuit using a single bridge arrangement in which several forks are electromagnetically coupled to one driving coil.

The invention herein disclosed involves the application of the electrical motional impedance characteristic of an electromagnetically driven tuning fork to provide an electrical circuit, or filter, having sharply selective frequency characteristics. A tuning fork like that described in copending patent application, now abandoned, Serial No. 776,252, H. C. Harrison, except with the contacting elements omitted, may be used or any similar form of electrically driven mechanical system having suitable motional impedance characteristics.

When a tuning fork like that referred to above is placed in a driving coil through which is passed a sinusoidal current, the electrical impedance of the coil must be considered as composed of two parts; namely a damped impedance and a motional impedance. The damped impedance is the impedance of the coil when the fork is either blocked or does not vibrate due to the frequency of the current in the driving coil being different from that of the resonance frequency of the fork. The motional impedance z_m is a change in the impedance coil caused by vibration of the fork. Its magnitude is proportional to the square of the force factor or coupling constant M of the electromechanical system and inversely proportional to the mechanical impedance Z_m , of the vibrating system at the point of application of the driving force. This relation is expressed by the following equation:

$$z_m = \frac{M^2}{Z_m \times 10^9} \quad (1)$$

Where M is expressed in dynes per abampere, Z_m in mechanical ohms and z_m in electrical ohms.

The mechanical impedance at the end of a tine of a tuning fork varies like that of a simple series resonant circuit consisting of inductance, capacitance and resistance. At resonance the impedance goes through a minimum and increases as the frequency departs from resonance. The shape of the impedance frequency curve, or the rapidity with which the impedance changes as the frequency departs from resonance, depends upon the phase constant Q of the circuit. With a mechanical vibrating system like a tuning fork the Q can be made large and therefore the impedance made to change rapidly with frequency. If the fork is electromagnetically driven, this rapidly changing mechanical impedance is reflected into the electrical system as indicated by Equation 1, to give an electrical motional impedance that varies in a reciprocal manner, but at the same rate or with effectively the same Q .

This electrical motional impedance characteristic is used to obtain a sharply selective network as shown in Fig. 1. This network is in the form of an electrical bridge with the drive coil 10 of the tuning fork or reed 11 serving as one arm and

a similar coil 12 with an adjustable core 13 serving as another arm. This latter balancing coil 12 preferably (although not necessarily) should have the same resistance and the same number of turns as the driving coil 10 and the core 13 should be capable of giving about the same effective magnetic reluctance as the fork 11. The other two arms of the bridge are shown as resistances 14 and 15, although these could as well be capacitors, inductors or a tapped coil or transformer. In operation the core 13 of the balancing coil 12 is adjusted so that its impedance is equal to the damped impedance of the coil 10 with the fork 11. Consequently for voltages at frequencies that cause negligible vibration of the fork 11 there is a large transmission loss, or attenuation between the "in" and "out" terminals in accordance with the usual properties of a balanced bridge. However, if the input voltage to the bridge has a frequency that is near the resonance frequency of the fork 11, vibration of the fork 11 will result in a motional impedance that will unbalance the bridge and the transmission loss will be reduced by an amount depending upon the degree of unbalance. Since the motional impedance is appreciable compared to the damped impedance only near the resonance frequency of the fork and has the same phase constant Q as the fork, the result is a sharply selective frequency attenuation characteristic like that shown in Fig. 1A.

Several coil driven forks of different frequencies may be used in a bridge at the same time to give a multiplicity of pass-bands corresponding to the resonance frequencies of the forks. For example, several forks with individual coils connected in series or several forks in a common coil may serve as one arm of a bridge and be balanced by another coil having an impedance equal to the combined damped impedance of the coil or coils with all the forks. Then for frequencies that are not near the resonance frequencies of the forks the bridge will be balanced but for frequencies near the resonance frequencies the bridge will be unbalanced and these latter frequencies will be relatively less attenuated.

Coil driven forks may also be placed in the different arms of the bridge where they balance each other at frequencies away from resonance, but individually unbalance the bridge at their resonance frequencies. If these resonance frequencies are close together the unbalance of one fork may be made to complement that of another, to pass a wider band of frequencies than that obtained with either fork alone. Such a band-pass arrangement is shown in Fig. 2. This bridge consists of two coils 20, 21 with tuned reeds 22, 23 of frequencies f_1 and f_2 and two balancing coils 24, 25. The two reed coils 20, 21 are placed in opposite branches of the bridge so that their motional impedances unbalance the bridge in the same or aiding direction. If f_1 and f_2 are the same frequency the effect of the unbalance due to one reed is increased by that due to the other reed and the transmission loss or attenuation is less than that when using a single reed as in Fig. 1. If f_1 and f_2 are slightly different, it is evident that the maximum unbalance of one reed will occur at a different frequency from that of the other. The degree of unbalance will be less than when both frequencies are alike, but the unbalance will occur over a wider frequency range.

The pass-band characteristic obtained is shown in Fig. 2A and depends upon the Q values of the

two electromechanical resonant reeds. The term pass-band is restricted to mean the frequency band in which the transmission loss is constant within certain definite limits. For example, suppose the transmission is to be kept constant within 3 decibels throughout the pass-band. Assuming a given value of Q for both reeds, f_1 and f_2 are spaced so that at f_0 , mid-way between them, the response is down 3 decibels; and f_3 and f_4 represent the 3-decibel points at the lower and upper ends of the pass-band. Then suppose that the value of Q is increased so that the selectivity curves are sharper. This requires that f_1 and f_2 be spaced closer together so that the loss at f_0 will not exceed 3 decibels and also means that f_3 and f_4 will be closer to f_1 and f_2 , respectively. This means that to maintain response within 3 decibels, the pass-band and the spacing between f_1 and f_2 must be reduced when the Q is increased. Only a narrow range of frequencies near the pass-band is depicted in Fig. 2A.

Figs. 3, 4 and 5 show circuit schematics in which use is made of the principle above-described to obtain sharply discriminating frequency control. Fig. 3 shows the balanced bridge circuit 30 of Fig. 1 used as the frequency control of regenerative feedback oscillator. This oscillator consists of an amplifier with input and output transformers 31, 32, a gain control potentiometer 33 on the secondary of the input transformer, and a thermistor 34 in the plate circuit to limit the amplitude as oscillation is built up. Thermistor 34 is of the general type of thermally sensitive element in which current flow through the device causes internal heating, which in turn causes a sharp reduction in the resistance of the device. The transformers and circuit elements are chosen so that the phase shift or transmission time through the amplifier is small over a substantial frequency range encompassing the resonance frequency of the tuned reed or fork 35. The tuned reed selective circuit 30 is connected between the output and input terminals of the amplifier so that transmission through the bridge circuit 30 near the resonance frequency of the fork 35 causes regenerative feedback or singing in a well-known manner. The gain of the amplifier is adjusted to be slightly larger than the loss through the bridge near the resonance frequency where the loss is minimum and the phase shift is proper to permit singing. The loss and phase shift through the bridge varies rapidly with frequency near resonance of the fork and consequently the conditions necessary to permit sustained feedback oscillations are sharply defined by the fork 35.

Figs. 4 and 5 show two arrangements of four reeds in multifrequency selective circuits that may be used in a system for selectively signaling substations from a central station by sending out from the central station signaling currents of a plurality of different predetermined frequencies. The central station may be provided with a plurality of tuned reed controlled oscillators like those shown in Fig. 3 and each substation may be provided with a multifrequency receiving circuit with several reeds such as shown in Fig. 4. This latter circuit consists of four forks 40, 41, 42, 43 of frequencies f_1, f_2, f_3 and f_4 , each in a driving coil 44, 45, 46, 47 in series with a balancing coil 48, 49, 50, 51 and these in turn bridged across the line from the central office. Likewise bridged across the line are resistors 52 and 53 which, with each driving coil 44, 45, 46, 47 and its associated balancing coil 48, 49, 50, 51,

form a bridge like that in Fig. 1. The output of each bridge thus formed is individually connected to the cathode and one grid of a multi-grid gas discharge device 54 which is designed to break down and cause plate current to flow when a suitable positive potential appears simultaneously between all four grids and the cathode. When four oscillators having frequencies f_1, f_2, f_3 and f_4 are connected to the line at the central office the corresponding four reeds 40, 41, 42, 43 in the receiving circuit at the substation vibrate and their motional impedances unbalance the normally balanced bridges. Voltages at each of these four frequencies are then transmitted through the corresponding bridges and appear at the grids of the gas discharge device 54 which breaks down and allows current to flow in the plate circuit from battery 55 through relay winding 56 to operate a signal bell or other device. All four frequencies must be present at the same time because, otherwise, the gas discharge device will not break down. If one or more of the four frequencies applied at the central office differs from that of the resonance frequencies of the forks, the frequencies will be attenuated by the bridge circuits sufficiently to be ineffective at the gas discharge device grids. Other substations connected to the same line may have similar receiving circuits, except with forks tuned to different frequencies in order to permit each substation to be signaled individually.

Instead of connecting the output of each bridge between cathode and one of the grids of a gas discharge device, these individual outputs may be connected to a like number of separate loads. In this manner the circuit of Fig. 4 minus the gas discharge device and associated relay could be used to select particular frequencies from among a large number of frequencies present at the input to the circuit, and to actuate a different load device in response to each frequency. Such an arrangement is shown in Fig. 4A which may be substituted for that part of Fig. 4 shown below section A—A. The different load devices 58, 59, 60 and 61 will respond to the respective frequencies f_1, f_2, f_3 and f_4 . These load devices may be mere resistors or any other types of load impedances across which it is desired to develop voltages of the respective frequencies; or they may be alternating current relays or trigger devices responsive to voltages of reed frequency which may be applied to them.

Fig. 5 shows a similar substation receiving circuit except here all four reeds 60, 61, 62, 63 are located in a common drive coil 64 and the balancing coil 65 is adjusted to balance the combined damped impedance of this common drive coil 64. Two resistors 66, 67 complete the bridge circuit. When the four frequencies f_1, f_2, f_3, f_4 of the forks 60, 61, 62, 63 are received from the central office each of the four frequencies f_1, f_2, f_3, f_4 is passed to the control grid of a gas discharge device 68 which requires a definite value of grid-cathode potential to operate. Since all four frequencies f_1, f_2, f_3, f_4 are different the voltages are continuously changing in relative phase and within a short period of time the resultant voltage at the grid will be momentarily equal to the sum of the individual peak voltages at each frequency. This resultant voltage is chosen to be adequate to operate the device 68 causing current from battery 69 to flow through and operate relay 70. If one or more frequencies are absent then the voltage is below the just operate voltage of the

device 68 which will not break down and under this condition relay 70 will not operate.

It will be apparent to those skilled in the art that there are many variations and modifications of the arrangements described herein. For example, several forks or reeds with individual driving coils connected in series may be placed in one arm of the bridge and be balanced by a coil having an impedance equal to the combined damped impedance of all the driving coils. In addition, the band-pass arrangement may be modified to provide a wider pass-band by the use of more than two forks or reeds in the bridge arms.

Certain of the subject-matter disclosed herein is the basis of a divisional application, Serial No. 104,755, filed July 14, 1949, by L. G. Bostwick, for Vibratory Reed-Controlled Oscillator, and issued January 29, 1952, as Patent No. 2,583,542.

Although the disclosure is in reference to tuning forks or reeds, it is obvious that any similar form of electrically driven mechanical system having suitable motional impedance characteristics may be used.

What is claimed is:

1. Frequency selective means comprising a first coil, a vibratile reed tuned to a given frequency and located in the field of said coil, a second coil having an adjustable magnetic core, a pair of impedance elements, said coils and said elements being connected in a bridge arrangement with said coils in one pair of adjacent arms of the bridge, and an input circuit connected across one diagonal and an output circuit connected across the other diagonal of said bridge arrangement.

2. Frequency selective means comprising a first reactance coil including a tuned vibratile member positioned in the field of said coil so as to react thereon at the frequency to which the member is tuned, to change the effective impedance of said coil, a second reactance coil including an adjustable magnetic core and having an impedance substantially equal to the impedance of said first coil at frequencies removed from that of the tuned member, an input circuit, said coils being connected in series across said circuit, a pair of impedance elements connected in series across said circuit, and an output circuit connected between the midpoints of each of said series connections.

3. Frequency selective means in accordance with claim 2 wherein said pair of impedance elements comprises a third reactance coil including a second vibratile member tuned to substantially the same frequency to which said first vibratile member is tuned, and a fourth reactance coil having an impedance substantially equal to the impedance of said third coil at frequencies removed from that of the tuned members.

4. Frequency selective means in accordance with claim 2 wherein said pair of impedance elements comprises a third reactance coil including a second vibratile member tuned to a frequency other than that to which said first vibratile member is tuned, and a fourth reactance coil having an impedance substantially equal to the impedance of said third coil at frequencies removed from that of the second tuned member.

5. Frequency selective means in accordance with claim 2, in which said impedance elements comprise a pair of resistors.

6. In combination, an input circuit, a pair of series-connected impedances connected across said circuit, a plurality of pairs of series-con-

nected reactance coils connected across said circuit, a plurality of tuned vibratile reeds, each of which is tuned to a different frequency and coupled to one of the reactance coils of each pair of reactance coils, and a plurality of output circuits each having a common connection to the junction of the series-connected impedances and each having a separate connection to the junction of each pair of series-connected reactance coils, whereby electrical energy at the frequencies to which the respective reeds are tuned, is filtered from the total energy applied at the input circuit and supplied to the respective output circuits.

7. Frequency sensitive means comprising two reactance coils having substantially the same impedance in adjacent arms of a bridge circuit, balanced by two equal impedances in the remaining adjacent bridge arms, and a multiplicity of tuned vibratile reeds each having a different resonant frequency from the other and all of which are coupled with one of said reactance coils and an adjustable magnetic core coupled to the other of said reactance coils whereby said bridge circuit becomes unbalanced proportionally to the number of resonant reed frequencies included in an input wave applied to the bridge circuit.

8. The combination of claim 6 including a multigrid gas discharge device and utilization device, wherein each grid of said discharge device is connected to a different one of the plurality of output circuits, and the utilization device is connected in the cathode-anode circuit of said discharge device.

9. The combination of claim 6 including a discharge device, having a cathode, an anode and a plurality of control electrodes, each control electrode being connected in a different one of the plurality of output circuits, and utilization means included in the anode-cathode circuit of said discharge device.

10. In a multifrequency circuit, an input circuit, a pair of series-connected impedances connected across said circuit, a pair of series-connected reactance coils connected across said circuit, a plurality of tuned vibratile reeds, each of which is tuned to a different frequency and all of which are coupled to one of the reactance coils, a utilization circuit comprising a gas discharge device having a grid connected to the junction of said reactance coils, a cathode connected to the junction of said impedances, and an anode connected to a current responsive device, whereby said discharge device ionizes and supplies current to said responsive device when all the frequencies to which the reeds are tuned, are present in an input wave applied to said input circuit.

11. Frequency selective means, comprising a plurality of circuit branches each responsive to a selected different frequency, each of said branches including series-connected inductors, one of said inductors including a vibratile member tuned to the frequency to which the respective circuit branch is to be responsive, and another of said inductors being of selected impedance substantially equal to the impedance of the one inductor at frequencies removed from that of the tuned member.

12. A combination as claimed in claim 11 including a further pair of impedances serving in common with each of said branches as the third and fourth arms of a bridge of which the first and second arms are comprised of the series-connected inductors in the respective branch.

13. Frequency selective means for insertion be-

tween input and output terminals comprising inductors normally contributing to a balanced condition in which transmission from input to output terminals is reduced, one of said inductors including a vibratile member of magnetizable material having a resonant frequency and another of said inductors including an adjustable magnetic core and having an impedance value substantially equal to that of the first inductor when said vibratile member is substantially quiescent, as normally, but widely different from said impedance value when said vibratile member is vibrating at its resonant frequency.

14. In combination, an input circuit, a pair of series connected impedance elements connected across said input circuit, a plurality of tuning forks, a plurality of driving coils for said forks, an equal number of balancing coils, each connected in series with a driving coil, said series circuits being connected in multiple across the input circuit to form a multiplicity of impedance bridges in tandem, in which said pair of impedance elements comprise two arms common to all the bridges.

15. Frequency selective means comprising a pair of series-connected inductive impedance elements, one of said elements including a tuned vibratile reed and having an impedance characteristic with frequency such that its impedance at the frequency desired to be selected is sharply different from its impedance at frequencies removed from said desired frequency, and the second of said impedance elements including an adjustable magnetic core and having an im-

pedance characteristic with frequency such that its impedance is substantially equal to the impedance of the first impedance element in the frequency region removed from the frequency desired to be selected, including an input circuit and an output circuit and in which said series-connected impedance elements are connected across said input circuit, a second pair of impedance elements is also connected in series across said input circuit and in which the output circuit is connected across the internal junctions of said pairs of impedance elements.

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