June 24, 1969 J. P. BRANCH ET AL 3,451,502

TONE FREQUENCY NOISE FILTER

Filed April 3, 1968

FIG. 1

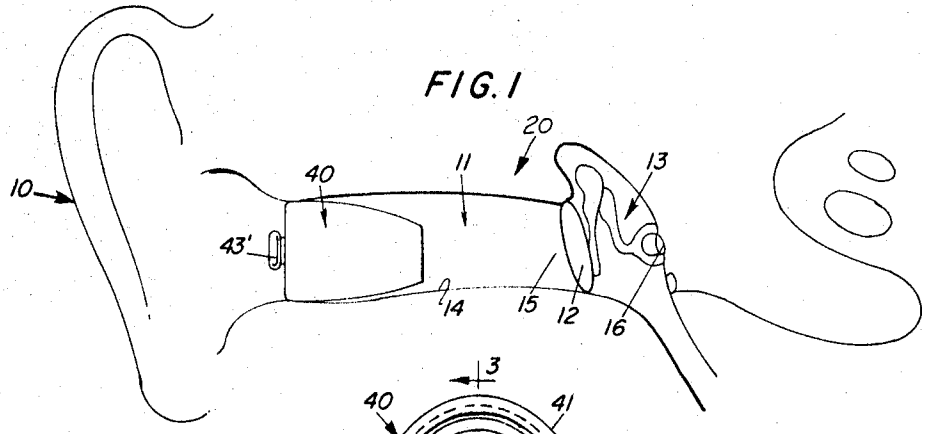


FIG. 2

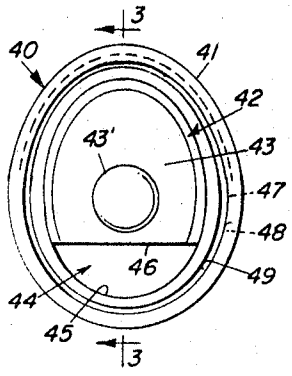
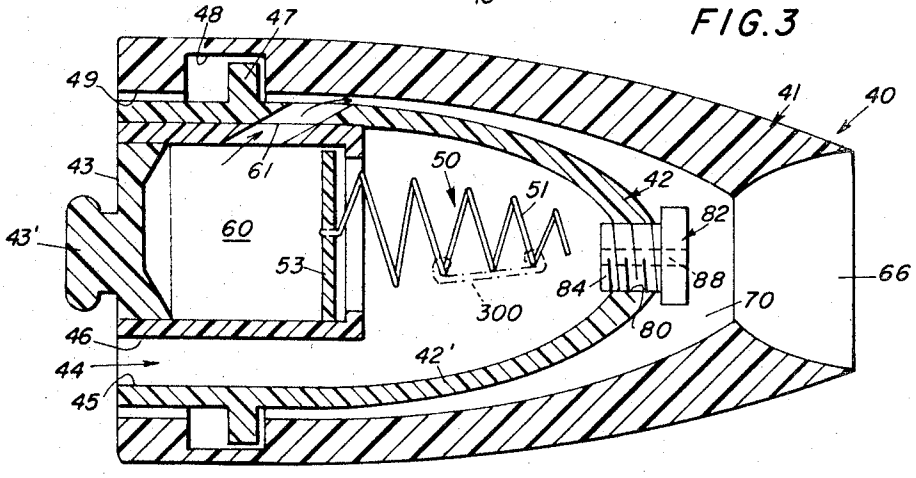


FIG. 3



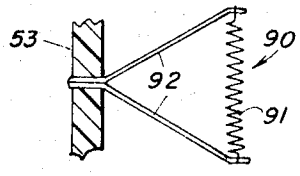


FIG. 4

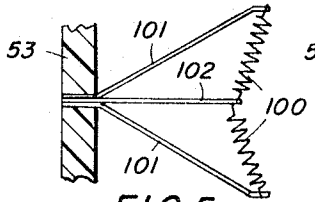


FIG. 5

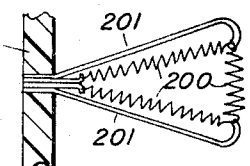


FIG. 6

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TONE FREQUENCY NOISE FILTER

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U.S. Cl. 181—23 20 Claims

ABSTRACT OF THE DISCLOSURE

There is disclosed a process and means for improvement of speech understanding for an individual whose physical surroundings cause a lack of ability to facilely discriminate between auditory speech pulsations and background noises. The present invention discloses means, including a resonant capsule member which capsule encases a vibratory member and a diaphragm, this capsule being adaptable for insertion within the outer portion of the auditory canal. The capsule and the members associated therewith, including inner and outer casings, filter extraneous background noise and transmit, on a preferential basis, those frequencies and vibrations which are essential to perceptive discrimination of human speech. The capsule has incorporated therein a vibratory element or elements having a pre-selected peak frequency response or frequency discriminatory properties, and further includes means to shift the peak of this response, and to broaden this response as to its frequency width.

Background of the invention

Increasingly, modern industrial plants and modern so-called "street noises" cause inabilities, on the part of the normal auditory mechanism of an average human being, to discriminate adequately between those sound pulsations which represent intelligible human speech and those background noises which are produced by extraneous, non-desirable sound generators, such as industrial machines, propelled vehicles, ventilating systems, etc.

As is explained in more detail hereinafter, to compensate for this lack of discrimination and decibel rise of overall sound, the auditory nerves of a normal human being involuntarily attempt to raise the threshold of audibility to a level directly correlated with the level of the increase of the overall sound intensity to which the ear is subjected. Thus, for example, as the background noise increases in intensity, there is generally a logarithmic increase in the threshold which the auditory nerve attempts to perceive. This natural phenomenon is self-defeating, in the sense that, as the auditory system raises its threshold, it simultaneously loses, in substantially direct proportion to the raising of the threshold, the ability to distinguish between desirable sounds, such as those contained in human speech, and those undesirable background noises whose intensity have caused the initial rise of the threshold.

It thus becomes more and more difficult to communicate intelligibly, as the background noise level is increased, whether measured in decibels or in dyne force. While a rise in the intensity of the human voice will better enable the person hearing the voice to maintain communication, this process is not satisfactory, since there is a reasonable level to which the human voice can be raised and still be intelligible.

The tone frequency noise filter of the present invention is intended to, and does, suppress these undesirable background noises, which noises are applied, along with speech intelligence, against the ear structure in the form of auditory, oscillatory air signals. At the same time the

filter reinforces those frequencies which are necessary for articulate intelligible communication. The present invention thus lowers the threshold of knowledge audibility, decreasing the voice intensity needed to supply intelligible audible signals to a hearer.

The prior art has described systems designed to decrease the amount of sensations received by the normal auditory system. These prior art devices are generally of one of two forms. In the first form, a simple stopper is utilized to lower the input to the auditory system. Obviously such systems do not transmit intelligble sounds to the human brain. The second form of these systems has generically included means to transmit via simple amplification, some selected portion or portions of those frequencies which most commonly occur in human speech. Such prior art systems have not solved the problem herein described, because they do not provide sufficient amplification and/or selectability as to that portion of the auditory spectrum whose transmission is desirable. Furthermore, such prior art systems do not selectively and effectively suppress the undesirable background noises.

In order to more adequately understand the problem involved, a brief description will herein be given of the functioning of the human voice and its relation by atmospheric or air coupling to the human ear.

The main function of human speech is, obviously, to act as a source of speech energy, which is modified or modulated by the articulatory human system. This speech source provides human articulatory vibration of a complex nature, both as to intensity and frequency, which in turn vibrates the atmosphere or air into which the speech is emitted. The intensity and harmonics are modulated by this human system, as the situation dictates to the speaker.

Essentially, intelligible reception of human speech must include the ability to distinguish between sounds which are generically designated as consonants. These consonants are emited by the normal human being at a low frequency rate, generally centering in the vicinity of 325 cycles per second and, in most instances, having their major energy content included in a spectrum from 300 to 400 cycles.

It is to be understood, however, that due to possible changes in the articulatory system, consonant sounds may be emitted in human speech in extreme ranges of from about 40 to about 3900 cycles.

In addition, and in order to provide intelligible communication, the human voice emits a series of vowels which are inter-connected in spaced time relation to the consonant sounds and are relied upon by the human brain to provide intelligent perception. These vowel sounds, while melliferous as to sensory perception, in actuality constitute only a series of high intensity pulses of spaced energy. The energy pulses which are provided by the vowels, while adding to and augmenting the pleasurable sense of hearing, are not essential, except insofar as they provide a gap means between the spaced consonants.

Therefore, it is apparent, and is known, that human intelligible perception is based predominantly upon the sustained oscillations caused by the production of consonants by the human voice. Accordingly, as is also known, any means which concentrates, in its application to the human auditory system, those frequencies in which the consonants are centered, provides intelligible information to the human brain, so as to enable the brain to readily perceive intelligence contained in the auditory oscillations.

Due, by happenstance, to the selection of 60 c.p.s. for the operation of most electrically powered equipment and further due to the happenstance that most so-called "street noises" occur generally in a range above 4,000 c.p.s.

there is available to the human ear a range of frequencies in which the ear can distinguish intelligible speech, but in which range the background noises have relatively low intensity in comparison to the intensity of the human voice.

It is therefore the principal object of the invention to selectively couple to the human ear only those sounds which fall within this range of desirable human speech, while at the same time suppressing the transmission to the human auditory system of those noises whose frequencies do not fall within this range, so far as their major power components are concerned.

The system of the present invention, therefore, serves to eliminate undesirable background noises, and facilitates auditory reception and brain response to signals derived from the human voice. The intensity of these desirable signals, while low in decibel level relative to the overall decibel strength including the background noises, is stronger in the desired frequency of the speech spectrum.

The figures of the drawings

FIGURE 1 is a schematic view of the human ear, many of the parts thereof being eliminated for simplification, with the generic device of the invention inserted within the auditory canal leading from the outer ear to the interior portions of the auditory system.

FIGURE 2 is a front elevation of the invention.

FIGURE 3 is a view in cross section taken on the line 3—3 of FIGURE 2.

FIGURE 4 is a partial cross-sectional view of a different form of the transmitting member of the invention.

FIGURE 5 is a similar view of another form of the transmitting member of the invention, while;

FIGURE 6 is a view of a third embodiment thereof.

Detailed description of the invention

As shown in FIGURE 1, the human auditory apparatus includes, among its essential components, an outer ear designated as **10**. This portion of the ear operates predominantly as a means for concentrating and funneling sound oscillations to the interior elements of the auditory system **20**. In effect, the outer portion of the ear consists of a horn which concentrates and transmits sound vibrations into nerve responses in the human brain, after these signals have traversed the other members of the auditory system, whose essential components will now be described.

It is to be understood that the shape of this outer portion of the ear serves to direct the vibrating column of air at maximum intensity into the entrance of the auditory canal, this canal being designated in its entirety as **11**. This canal **11** in turn concentrates and feeds these air vibrations to a tympanic membrane **12**, which in turn feeds the vibrations to an ossicle chain **13** and to a fenestra **16**. Thereafter, those vibrations which are received by the fenestra are transformed by other portions of the auditory system **10** into nerve impulses, which are transmitted to the brain, in order to convey thereto information contained in the pulses received by the ear. The inner end of the auditory canal is designated herein as **15**.

The apparatus of the present invention is intended to be placed within the canal member **11** so as to effect speech discrimination relative to noise background. This is accomplished by rejecting undesirable tones and by transforming the voice portion of the received auditory energy in a manner such as to boost, preferably in time delaying fashion, speech energy. For this purpose there is provided a frequency selective vibrating member **50**, contained within a capsule, designated in its entirety as **40**, positioned within the canal **11**. Since the membrane member **12** and the ossicle chain **13** are normally substantially intact and are operatively coupled in the normal human auditory system, it is to be noted that they would, in the absence of the device of the present invention, be responsive to a wide frequency of sounds, including all of the undesirable background sounds.

Reference will now be made to a preferred detailed embodiment of the invention, as shown in more particular detail in FIGURES 2 and 3.

The capsule **40** preferably includes a base member having an inner casing **42** and an outer casing **41**. Positioned exteriorly, i.e., towards the anterior of the canal **11**, when the capsule **40** is inserted within the canal **11**, is a sound transmission passage **44** to direct auditory air oscillations to vibrator **50** of diaphragm **53** which may be of any desired configuration, but which, as herein shown in FIGURE 3, is defined by the arc **45** of the casing **42** and a generally chordlike line designated as **46**. Thus, in effect, auditory signals received by vibration of the atmosphere, and applied to the outer ear **10**, are compressed into and passed through the passage **44**.

In normal usage of the apparatus of the invention it is intended that no further air column signals be transmitted through the ear canal other than those which enter the passage **44**.

Those compressed sound waves which enter the passage **44** are in turn directed to a vibratory element, or vibrator, **50** and vibrate this member through their contained energy pulses. This vibratory member **50** is operatively associated with and, preferably, supported by a diaphragm member designated as **53**. Positioned between the outer end wall **43** of casing **42** and the vibratory member **50** is an air resonating chamber **60** capable of vibration, this chamber being hereinafter designated as a resonator, the rear wall surface of which is formed by said membrane **53**. Connected to the one end of the resonating chamber **60** is an end wall **43** having, for ease of insertion and removal, a projecting member or handle, designated as **43'** mechanically coupled thereto. This member is, in effect, a manually graspable projection.

From the above described elements it will be understood that, in normal assembly of the device thus far described, the chamber **60** is assembled by inserting therewithin the diaphragm **53** and its coupled vibrator **50** within a generally annular member **46**. Thereafter, end wall **43** is inserted within this member to complete the chamber **60**. It is to be understood that this entire association or elements is incorporated within inner casing **42**.

The vibratory member has a natural resonant frequency which is preselected. This frequency preferably centers about 325 cycles per second. Generally speaking, it is desired that that this resonant frequency is within the range of a spectrum of from about 300 to about 400 cycles per second. In extreme cases the resonant frequency may include the ranges of from about 40 to about 3900 cycles per second.

The entire apparatus as described hereinabove and as described hereinafter, further incorporates, as noted above, an outer shield member or casing **41** which serves to accomplish physical contact between the capsule and the interior surfaces **14** of the ear canal.

To aid in insertion or removal from outer casing **41** and to aid in insuring proper positioning of the inner casing **42**, this latter member preferably has a projecting annular rib surface **47** which axially slidably co-acts with a groove **48** formed in the interior wall **49** of the outer casing element **41**, which rib **47**, upon insertion of the inner casing within the outer casing, is engaged by the groove. This coupling may be achieved by means such as flexure, or bayonet coaction, or any similar means known in the art.

Referring again to the inner casing **42** and the elements contained therein, it will be seen that the resonator **50** has preferably associated therewith a circumferentially positioned release vent **61**.

The vibrating member **50**, adapted to actuate by air auditory oscillations, may be formed in various shapes, as shown in the drawings and as described herein. In the embodiment shown in FIGURE 3, the vibrating element thereof consists of a tapered or conically shaped helical spring member **51**. This spring may be formed of any desired material having the requisite tensile strength

and mass in relation to the mass of the diaphragm **53**, and has its axis substantially perpendicular to the plane of said diaphragm.

Spring member **51** is preferably formed of a flexible, planar, metallic material, but may, of course, be formed of other materials, such as those generically designated as plastics. In this preferred form of the invention the material of the member **51**, and the formatory heat treatment thereof, are so selected that the spring member has an inherent, or natural, basic vibratory frequency which is contained within the above-descibed spectrum of human speech. This predetermined natural resonant frequency of the vibrating member preferably occurs at the peak of normal human speech. Thus, for example, the spring has a preselected resonant frequency in the range of from about 300 to about 400 cycles.

It will be understood that the vibrating member, or spring element **51** and chamber **60** respond to reverberation of the diaphragm to acoustically absorb undesirable sound noises and reradiate the desirable sound passing through the acoustic capsule **40**, thus, in effect, acting as an acoustic wave guide attenuator, since the undesirable noise frequencies are selectively attenuated.

As the coupled reverberation of the chamber **60**, the diaphragm **53** and the spring member **51** intensifies, acoustic scattering takes place within the outer chamber, or air space, of the capsule **40** designated as **70**; the energy received from auditory atmospheric vibrations is thus so transmitted through the spring as to create an acoustic delay line.

The spring **51**, being fundamentally resonant to the basic frequencies of human voice energy will, of course, transmit additional desired second and third harmonics and the like into the sonic vibration of the above-described members, these vibrations being in addition to the desired fundamental frequencies to which the spring is attuned.

Reference is now made in more detail to the diaphragm **53** which acts, in effect, as a tympanum. Since this diaphragm constitutes a flexible wall of the acoustic vibratory chamber, or resonator **60**, contained within the capsule **40**, it will resonantly transmit the fundamental and harmonic portions of speech energy into pneumatic pulsations through a vibratory pumping action.

This transduced energy, primarily consisting of low intensity components, causes reinforcement of the received human speech syllables which are, in effect, auditorily and by ear pulsation, pumped through the above-described release vent **61** into that interior portion **15** of the ear canal **11** which is interior of the capsule **40**, through circumferential area **66**. These vibrations then in turn serve to stimulate the eardrum and its associated auditory system.

There has been shown and described a simple acoustic delay line, including means for both amplifying, discriminating and time delay reinforcing the desirable components of the sound spectrum which correspond to intelligible human speech.

It is to be further understood that the storage and dissipation efficiency of the device of the invention are determined by both the geometry and mass of the resonator **60** and by the configuration and fundamental resonant frequency of the vibrator **50**, and by the mass and sensitivity of the diaphragm **53**.

Thus, the tone frequency noise filter of the invention is responsive in a major degree to speech energy and is responsive in a substantially lesser degree to background noise energy.

The preferred configuration described above selectively directs, at one or more preselected deflection angles, the received sound energy, so as to direct this energy into contact with the diaphragm and vibrator. While only one configuration of this inlet system has been shown, it will be understood that one or more similar apertures, of any desired shape or direction, may be utilized, so long as they coact to selectively place sound energy on a particular part or parts of the vibrating member for frequency selective attenuation of undesired sound.

In a preferred embodiment of the invention the resonating diaphragm is formed of a simple planar, flexible, metallic material. The choice of this material is determined by factors such as cost, acoustic response characteristics thereof, and the like.

Referring again to FIGURE 3, it is seen that the inner casing **42**, which contains the vibrator **50**, is preferably generally bullet-shaped in form so far as the casing end **42'** is concerned, and has at the other end **46** thereof a generally uniplanar wall surface **43**. There will be further noted that at this apex or end **42'** of the inner casing **42** there is formed an additional aperture **80**, comprising a transmission passage. Fitted within this aperture **80** is a further sound transmitting member **82** having a generally axial, annular projection **84** which is substantially conformed to the aperture **80**, by screw fit or the like. At the end of this member **82** there is positioned an annulus having a larger diameter than that of the said aperture **80**.

Positioned interiorly of, and extending through this member, are one or more bores or passages **88, 88**. Incoming energy of undesirable frequency is, with proper selection of the size of the bore or bores, leaked through the capsule and member **82**. However, the desired speech frequencies are not predominantly within that portion of the spectrum which passes through the bore or bores **88**. Thus, in effect, this portion of the apparatus acts to selectively attenuate undesired frequencies by scattering the energy contained therefrom in a non-vibratory fashion. These undesirable frequencies, having passed by air coupling through the bore or bores **88** are reduced to minimal desired intensity, so that a small portion of the initial undesirable auditory energy is transmitted or acoustically coupled to the inner ear **16**.

This selective coupling to the human auditory system of a small portion of background noises is desirable in order to produce nerve sensed signals which appear to the nerves and brain as natural. In other words, complete filtration of the background noises is not desirable, since the sound which is perceived by the human brain is then unnatural, not corresponding to normal environments, in which at least some level of background noise is generally present.

There has been previously dscribed a single form of vibrating member, designated generally as **51**, whose qualities have been described in detail hereinabove.

In FIGURES 4, 5 and 6 there are also shown alternative embodiments of equivalent structures of the vibrating member **51** per se. It will be understood that in each of these figures there is shown in broken line fashion a cross-sectional portion of the vibrating members **51** which are coupled to the vibrating membrane or diaphragm **53**; in each of these alternative embodiments, it is to be further understood that the remaining elements of the invention are equivalent to those which have previously been described.

Considering now FIGURE 4, the numeral **53** designates the diaphragm to which there is mechanically coupled, in the manner previously described, and for the purposes previously described, one or more spring members **90** having individual coils, generally axially aligned, and designated generally as **91**. These coils **91** have coupled thereto in vibratory relation energy transmitting members **92** which are supported by diaphragm member **53**.

In FIGURE 5 there is shown a somewhat similar embodiment. In this embodiment vibratory spring members **100, 100** have at their junction a middle member **102** and at their ends have members **101** and **101**. Members **101, 101** and **102** are mechanically, vibratorily coupled to diaphragm **53**.

In FIGURE 6 it will be noted that a basic vibrator **200**

has coupled thereto other spring elements **200**, **200**, and similar vibratory transmitting members **201**, **201**.

By proper predetermined selection, as explained hereinabove, of the configuration and materials of the resonator, acoustical chamber, vibrator, end bores, the noise filter may be selectively attuned for desired sound transmission. To accomplish this, adjusting means shown schematically at **300** may be utilized to alter the resonant frequency of the vibrator **50** or the sound transmitting member **82**. Means **300** constitute an adjustable short circuiting means coupled to spring **51**. Other means may be used to adjustably bias or to longitudinally position element **82**.

It is to be understood that in all of the above embodiments the vibrator includes elements which have a natural resonant frequency in relation to the input of auditory air stimulation, this frequency being determined by the choice of materials, as described above, and being further determined by, in the case of a plurality of coils or vibratory members, their interrelation.

What is claimed is:

1. A tone frequency noise filter comprising, in combination

a capsule member adapted to be inserted within the human auditory canal,

a diaphragm member positioned within said capsule,

a vibratory member, having frequency discriminatory properties, and adapted to be actuated by air oscillation and operatively coupled to said diaphragm member, and

means to direct auditory air oscillations to said capsule, whereby the output of said tone frequency noise filter is responsive in a major degree to speech energy and is responsive in a lesser degree to background noise energy.

2. The tone frequency noise filter of claim **1** wherein the said vibratory member has a preselected natural resonant frequency.

3. The tone frequency noise filter of claim **2** wherein the said frequency is within the range of from about 300 to about 400 cycles per second.

4. The tone frequency noise filter of claim **2** wherein the said frequency is within the range of from about 40 to about 3900 cycles per second.

5. The tone frequency noise filter of claim **1** wherein the vibratory member consists of a helical spring.

6. The tone frequency noise filter of claim **5** wherein said helical spring is of conical shape, and has an axis which is positioned substantially perpendicular to said diphragm member.

7. The tone frequency noise filter of claim **1** wherein the vibratory member consists of a plurality of springs of substantially helical form and wherein at least one end of each of said plurality of springs is operatively connected to said diaphragm member.

8. The tone frequency noise filter of claim **1** wherein said capsule has an end member and wherein said end member has positioned therein a sound transmitting member having at least one bore having a preselected size and which bore is adapted to be directed towards the interior of a human auditory system.

9. The tone frequency noise filter of claim **1** wherein

said capsule further includes an outer casing, and an inner casing, and wherein said inner casing has formed therein a vibratable acoustical chamber.

10. The tone frequency noise filter of claim **9** wherein said inner casing includes a generally planar surface at one end portion thereof and a generally bullet-shaped other end portion.

11. The tone frequency noise filter of claim **10** wherein the said bullet-shaped end portion has bore means positioned therein, which bore means is capable of transmission of auditory oscillation.

12. The tone frequency noise filter of claim **1** wherein said capsule includes means to selectively direct auditory energy to said diaphragm and to said vibratory member.

13. The tone frequency noise filter of claim **12** wherein said directing means comprises a transmission passage positioned in an end wall of said capsule, said directing means being adapted to provide a source of auditory oscillations derived from said vibratory member and said diaphragm.

14. The tone frequency noise filter of claim **1** wherein said diaphragm member consists of a flexible, metallic planar member.

15. The tone frequency noise filter of claim **1** wherein said capsule has contained therein an acoustical vibratory chamber.

16. The tone frequency noise filter of claim **15** wherein said chamber has a circumferentially positioned vent therein.

17. The tone frequency noise filter of claim **9** wherein an air space is formed between said inner and outer casing.

18. The tone frequency noise filter of claim **1** wherein said capsule has an end surface and wherein said end surface has positioned thereon a manually graspable projection.

19. The tone frequency noise filter of claim **11** wherein there is positioned within said bore means a member having a generally annular and axial portion fitted within said bore, a passage through said axial portion and an end portion whose diameter is greater than that of said bore.

20. The tone frequency noise filter of claim **2** wherein the structure includes means for selecting said preselected natural resonant frequency.

References Cited

UNITED STATES PATENTS

1,824,427	9/1931	Fensky	181—23
1,908,850	5/1933	Kinsley et al.	181—23
3,394,698	7/1968	Calkins	128—1

FOREIGN PATENTS

428,733	5/1935	Great Britain.

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U.S. Cl. X.R.

179—107