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A study on the Frequency Analysis Function of the Auricle Using A Notch Filter

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Abstract

The human auricle is the first part to receive sound from the outside. In this part, the frequency range of human recognizable form is divided and organized. In this study, we propose modeling by applying a single sound source to the surface of the human auricle. This means that when the sound pressure of a low frequency (low frequency) sound enters the pinna, the impedance felt at the tip of a part of the non-linear surface of the pinna is mainly due to the tensile force at the end of the part of the non-linear surface of the pinna. By expressing the situation of moving at a very small speed, the characteristic impedance of the pinna was confirmed to be negative infinity, and it was also confirmed that the speed at the tip of a part of the non-linear surface of the pinna was 0 in the anti-resonance state. It was found that the wave propagation phenomenon that determines the characteristics of the filter is determined by how large the wavelength, kL, is compared to the length of the tip of a part of the non-straight surface of the pinna. Humans first receive sounds from outside through their ears. The auricle is non-linear and has a curved shape, and it is known that it analyzes frequencies while receiving external sounds. The human ear has an audible frequency range of 20Hz - 20,000Hz. Through the study, we applied the characteristics of the notch filter to hypothesize that the human audible frequency range is separated from the auricle, and applied filter theory to analyze it, and as a result, meaningful results were obtained. The curved part and the inner part of the auricle function as a trumpet, collecting sounds, and at the same time amplifying the weak sound of a specific band. The point was found and the shape of the envelope detected in the auricle was found. Selectivity for selecting sounds coming from the outside is the formula of the pinna that implements the function of Q. The function of distinguishing human-recognizable sound from the pinna from low to high through frequency analysis is performed in the pinna, and the 2-3kHz area, where human hearing threshold is the most sensitive, is also the acoustic impedance of the most recessed area of the pinna. It can be seen that starting from.

Keywords: *Auricle, Notch Filter, Collecting Sounds , Envelope*

1. Introduction

When you open the template, select “Print Layout” from the “View” menu in the menu bar (View > Print Layout). The sensory organs on either side of an animal's head that have the function of hearing. Being able to

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hear is just as important as seeing. In addition to hearing, it also controls the sense of balance. It is as important as the eyes and is also the vital point of most animals. Note that only mammals have ears.

When a person is about to faint, or awakens after being stunned, there is no sound until a slight return to consciousness. And it is said that the ear is the organ that lasts until the end of a person's death and loses its function. It may sound like a myth, but it's actually what doctors say to the prospective bereaved families of their patients right before their death.[1] Even if the patient is unconscious or sleeping due to strong painkillers, it is better to keep talking to the patient because hearing is still alive until just before death. There is even a case where a patient who was diagnosed with a vegetative state miraculously woke up after two months, and he remembered exactly the conversations he had heard when he was in a vegetative state. If you continue to say positive things even in a coma, positive changes can occur in the patient's condition.

On the one hand, it is also the organ that is most easily damaged among the five senses, but to some extent, eyesight is not damaged just because the TV screen is bright, or taste is not immediately damaged by eating buldak fried noodles. do. It is also sensitive to aging, so eyesight starts to deteriorate after the age of 40, and presbyopia begins to come gradually, but hearing begins to degenerate from the age of 30, and the audible frequency band gradually narrows. So, even if you buy a high-end speaker, it is said that children can hear it properly. With the global aging population, wireless earphones have become popular since the late 2010s, and there are concerns that the number of patients with hearing loss will increase in the long term

2. PINNA LENGTH AND WIDTH

Even the previous post, referring to ear anatomy, is used in different fields in different fields (surgeons, dysmorphologists, anatomists, artists, forensic agents, hearing aid sellers, listening product engineers, patent writers, etc.), which identifies when describing the ear. We expect consistency in features and terminology. In part, these series reviewed hundreds of patents for products tailored to the human ear, and were stimulated by the frustration of finding the consistency of reference locations left much to be considered. This post, instead of focusing on linear and angular measurements, cannot comment on asymmetry or position relative to facial features.

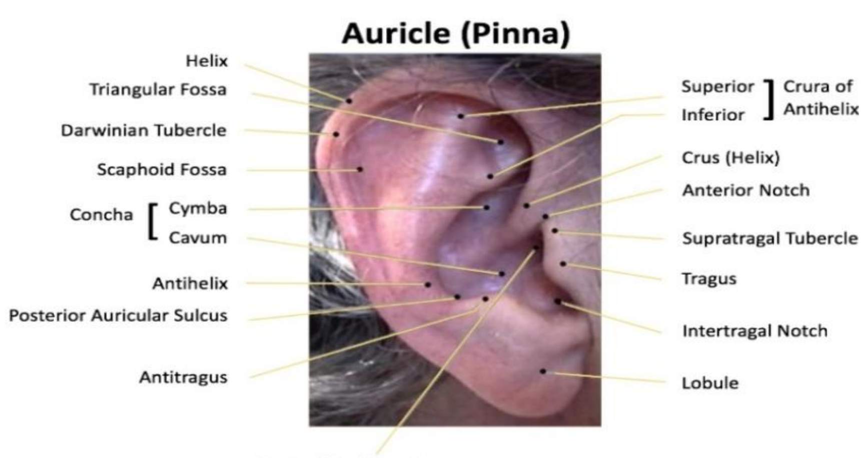

Figure 1. Surface anatomical features of the human auricle [1]

We started by mentioning that we can focus on two very basic measurements of the human pinna - the length of the pinna and the width of the pinna.

A number of different methods have been used to measure the surface features of the human pinna. Because of this, it is often difficult to make measurement comparisons. However, most of all measurements tend to be measured in the same way as measuring the length of the ear. The pinna length is measured from the uppermost to the lowermost protrusion. Both are based on using a horizontal line as the basis for measurements. Width (width) pinna measurements show the greatest variation in procedures as shown in Figure 2.

Figure 2. Pinna length is measured from the top to the bottom of the process.[1]

Both are based on using the horizontal line as the basis for the measurement.

This is due to the reference location of the width measurement and results in the impossibility of directly comparing measurements from specific studies. A notch filter is a filter that has rapid attenuation at a specific frequency. It is used for the purpose of removing unnecessary frequency components using the high-frequency signal output from the television transmitter by branching from the transmission line and reflecting the tuning frequency component by the tuning reflective element. A notch filter is a filter that has rapid attenuation at a specific frequency. It is used for the purpose of removing unnecessary frequency components using the high-frequency signal output from the television transmitter by branching from the transmission line and reflecting the tuning frequency component by the tuning reflective element.

NOTCH FILTER is called BRF (Band Rejection) or BSF (Band Stop) filter. That is, they do the opposite. It was said that it was a sudden damping characteristic, but there is a numerical expression for this. For LPF or HPF, the attenuation rate is expressed as xxdB/oct. Octave means when the frequency is doubled. Usually, in the case of a first-order filter, -6dB/oct, that is, when the frequency is doubled, it is reduced to about 1/2. And in the case of BPF or Notch filter, the Q value expresses the attenuation rate.

3. NOTCH FILTER

A filter designed to remove only the components of a very narrow frequency band around a specific frequency. Usually used to cancel 60 Hz noise induced by power lines.

3.1 Band-Pass Filter

A circuit in a sound receiver that passes signals present in a specific range of frequencies and rejects signals outside this range. There are the following two

3.2 BPF1

Among the amplified signals, the desired frequency was selected and configured using an inductor and a capacitor, but most receiver vendors currently use a surface acoustic wave (SAW) filter. The SAW filter includes an ultra-narrowband filter and a wideband filter, which are selected and used according to the characteristics of the radio pager or the region used.

3.3 BPF2

An unnecessary signal is removed from the frequency components output from the intermediate frequency amplifier and a desired frequency (first intermediate frequency) is passed.

3.4 Notch Filter Effect

The q coefficient of the notch filter is equal to the q of the notch. The Q or quality factor of a notch filter is given by the center frequency/bandwidth equation. Q is a measure of the selectivity of the filter. It also gives an idea of the clarity of depth. The center frequency is the notch frequency, which is the center frequency of the passband.

3.5 Notch Filter q Effect

Use an attenuation of 30 dB or less for precision settings, 60 dB for very fine, and 90 dB for super precision. With higher attenuation, adjacent frequencies can be broadly rejected. Very little noise and artifacts are removed, but requires more processing. This option is only audible through advanced headphones and monitoring systems.

3.6 Notch filter frequency

Use an attenuation of 30 dB or less for precision settings, 60 dB for very fine, and 90 dB for super precision. With higher attenuation, adjacent frequencies can be broadly rejected. Very little noise and artifacts are removed, but requires more processing. This option is only audible through advanced headphones and monitoring systems

3.7 Notch filter frequency

The frequency of the notch filter is called the frequency of the stopband. This is because the narrowband frequencies are what the notch filter rejects. So the frequency is also the identity of the notch filter.

4. POINT IMPEDANCE WITH EXCITATION MOTION OF THE TIP OF A FRACTION OF THE NON-STRAIGHT SURFACE OF THE PINNA.

All printed material, including text, illustrations, and charts, must be kept within the parameters of the 21cm x 28cm. Please do not write or print outside of the column parameters. Margins are 2cm on the sides, 3cm on the top, and 2cm on the bottom. The most used filters today are programmable filters. Impedance is a very useful physical quantity for representing vibration characteristics through a one-degree-of-freedom vibrometer.

Here, the auricle is modeled with respect to the wave phenomenon of a physical quantity called impedance.

Impedance is expressed as the ratio of velocity to force or to pressure. Therefore, for the applied input, the output for the pressure of the sound entering the pinna causes the surface of the pinna to vibrate. This is expressed as impedance. It is a wave propagation phenomenon formed when the surface of the auricle harmoniously excites one end of a semi-infinite string with a non-straight curved shape. From this point of view, when any external force is applied to the string, the impedance as a measurement value for the degree of the response of the string (the minute portion of the non-linear curved surface of the pinna is simply approximated as a straight line) can be very usefully used. In the case of harmonic excitation with the tip of an infinitely long string, the vibration of the surface of the pinna under the pressure of sound from the pinna can be expressed as impedance. If the vibration of the surface of the pinna is generalized to the form of a complex function, there cannot be a wave traveling to the left.

$$y(x,t) = g(x - c_s t) \quad (1)$$

can be expressed as If the displacement created by in is R for convenience, then the boundary condition at is

$$y(x,t) = g(-c_s t) = Ye^{-j\omega t} \quad (2)$$

is expressed as Considering that the second term of $c_s t$Equation (1) is a function of , Equation (2) can be written as follows.

$$g(-c_s t) = Ye^{jk(-c_s t)} \quad (3)$$

Here, $k = \frac{w}{c_s}$ that is, the relationship between wavenumber, frequency and propagation speed (dispersion relationship, dispersion equation) is used.

It expresses the physical meaning of this dispersion relationship well.

If Equation (3) is rewritten by introducing an arbitrary independent α variable,

$$g(\alpha) = Ye^{+jk\alpha} \quad (4)$$

can be written as Here, since it is an αindependent variable, it can be substituted with anything α. If you put in instead

$$x - c_s t \quad g(x - c_s t) = Ye^{+jk(x - c_s t)} = Ye^{-j(\omega t - kx)} \quad (5)$$

It has a propagating wave with wavenumber $k$and frequency $w$to the right as shown.

The impedance at the tip $x = 0$of a string on the surface of the pinna is the ratio of the force $Fe^{-j\omega t}$acting on the tip $u_y(0,t)$to the speed of the tip of the string, i.e. Here, the speed at the end of the line is obtained by using Equation (2)

$$u_y(0,t) = \frac{\partial y}{\partial t}\Big|_{x=0} = -j\omega Ye^{-j\omega t} \quad (6)$$

could be easily obtained as

In addition, the force acting on a part of the surface of the pinna that receives the input sound pressure in the form of a line sound source is expressed as a single line approximating the non-linear surface of the pinna.

from the equilibrium of forces

$$f_y(0,t) = Fe^{-j\omega t} = -T_L \frac{\partial y}{\partial x}\Big|_{x=0}$$
$$= -T_L jkYe^{-j\omega t}$$
$$= -T_L j\frac{w}{c} Ye^{-j\omega t}$$
$$= -\rho_L c_s jw Ye^{-j\omega t} \qquad (7)$$

From equations (6) and (7), the impedance (Z_{m0}) of the end of one line of the non-straight surface of the pinna

$$Z_{m0} = \frac{f_y(0,t)}{u_y(0,t)} = \rho_L c_s \qquad (8)$$

It can be seen that this where m is the mechanical impedance and 0 denotes the tip of a portion of the non-straight surface of the pinna(x=0).

Equation (8) shows that if a harmonic excitation force is applied to the tip of the string, if a harmonic excitation force is applied to a partial end of the non-linear surface of the pinna, the velocity of the tip of a part of the non-linear surface of the pinna is always in phase with the force, i.e., in the direction in which the force is applied. (It means that the pressure of sound moves the pinna.) Under this impedance condition of the pinna, the wave at the tip of a part of the non-straight surface of the pinna must travel in the right direction. Consequently, the impedance at the tip of a portion of the non-straight surface of the pinna is real and $\rho_L c_s$If equal to the value, there can be only waves propagating to the right (inside the pinna (or into another non-straight part of the pinna)) at the end of some non-straight surface of the pinna. That is, the reflected wave (wave propagating to the left = there is no wave opposite to the wave propagating inside the pinna). The component at the end of a portion of the non-linear surface of the pinna is a real component (regardless of the change in pressure of the input sound, the size of which is Since there is only a certain thing), only the emission of energy to another space in the auricle exists and no absorption exists, so the function of capturing sound pressure from the outside of the auricle can be mathematically modeled. Acoustic impedance can be converted into electrical impedance, and electrical equivalent impedance is

$$\frac{Voltage}{electric\ current} = \frac{Pressure\ of\ sound\ entering\ the\ auricle}{Surface\ movment\ of\ the\ pinna(vibration)}$$

can be viewed as equivalent.

$\rho_L c_s$is determined only by the properties of the tip of the part of the non-straight surface of the pinna itself. The acoustic impedance of this pinna is governed by the properties of the medium through which the wave propagates (at the tip of a portion of the non-straight surface of the pinna). This is called the characteristic impedance of the tip of a portion of the non-straight surface of the pinna.

This represents the physical properties of the wave at the tip of a portion of the non-straight surface of the pinna.

That is, the observed or measured physical quantity at the tip of a part of the non-linear surface of one pinna can be predicted to occur in the entire space of the pinna. This is the concept of impedance to which sound pressure is applied, and is a factor that determines the characteristics of the pinna. In this paper, these characteristics are intended to serve as a cornerstone for future research through the notch filter. .

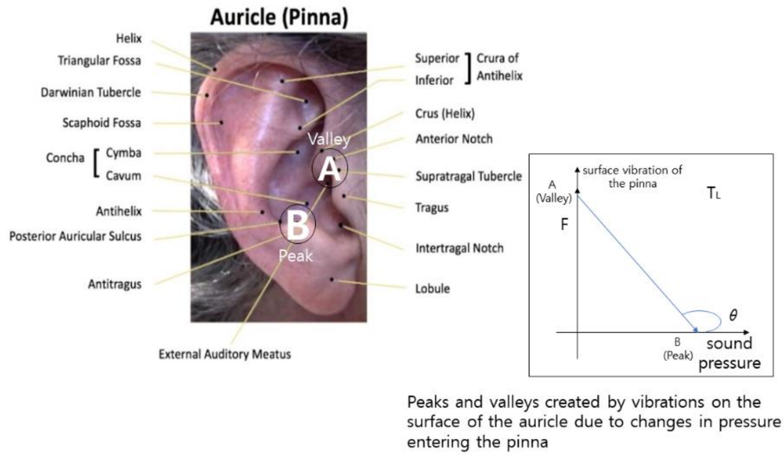

Figure 3. Expression of the relationship between the resonance point of the pinna and the notch filter.[15]

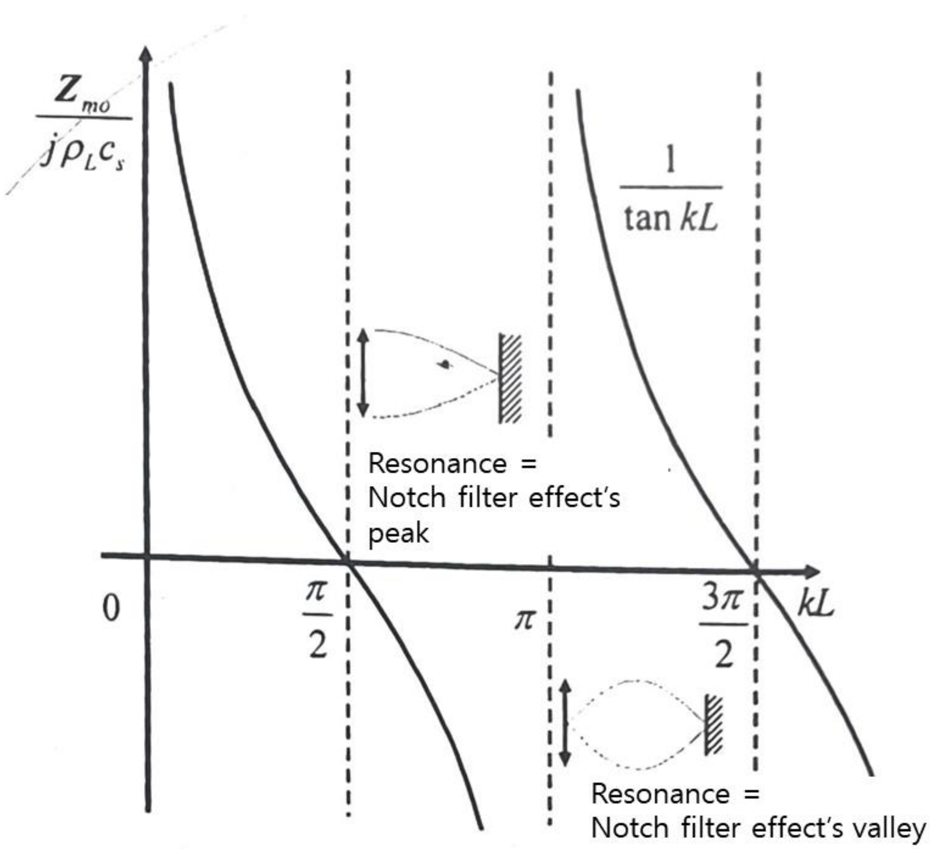

Figure 4. Position of the action point of the notch filter using resonance and anti-resonance according to the change in frequency of sound pressure coming into the pinna[15]

Instead of having an infinite space, consider the case of harmonic excitation at the end of a finite length having a finite space, the pinna space. This phenomenon is observed in terms of acoustic impedance.

First, the boundary condition $x = L$ that determines the physical condition of the pinna is $v(x,t)$

The harmonic function that satisfies this condition and satisfies the wave governing equation is expressed as follows.

$y(x,t) = Y\sin k(L-x)e^{-jwt}$ (9)

where Y is the magnitude of any displacement of the auricle space. Here, the spatial properties are $(L-x)$ Represented is the tip of a portion of the non-straight surface of the pinna $x = L$. The spatial shape of the wave observed based on Using Equation (9) $x = 0$ Finding the velocity of the tip of a portion of the non-linear surface of the pinna at

$$u_y(0,t) = \frac{\partial y}{\partial t}|_{x=0} = -jwY\sin kLe^{-jwt} \quad (10)$$

$x = 0$: The force at (the tip of a portion of the non-straight surface of the pinna) is

$$f_y(0,t) = -T_L\frac{\partial y}{\partial x}|_{x=0} = T_L kY\cos kLe^{-jwt} \quad (11)$$

At the tip of a portion of the non-straight surface of the pinna($x = 0$)

impedance Z_{m0} is from equations (10) and (11)

$$Z_{m0} = \frac{f_y(0,t)}{u_y(0,t)} = j\frac{T_L}{c_s}\cot kL = j\rho_L c_s \cot kL \quad (12)$$

Looking at Equation (12), it can be seen that, unlike the case of infinite space, it has an imaginary value at the tip of a part of the non-linear surface of the pinna. That is, there is a phase difference of 90 degrees between the force and the velocity, and the characteristic impedance of the tip of a part of the non-linear surface of the pinna is $\rho_L c_s$ not equal to This means that the energy at the tip of a portion of the non-straight surface of the auricle does not dissipate and returns to the auricle. Unlike the case of infinite space, a wave other than a wave propagating to the right, i.e., a boundary (a specific boundary of the non-straight surface of $x = L$ reflected from the left (opposite x), it can be inferred that there is a wave propagating The figure shows the impedance at the tip of a portion of the non-straight surface of the pinna. The expression of the various frequencies included in the sound pressure of the input sound as a wave number is expressed as k. First, when kL is very small, that is, the length obtained by calculating the frequency of the sound as a wavelength λ In the case where the auricle is significantly larger than the tip of a portion of the non-straight surface of the pinna, Equation (12) is. $Z_{m0} \simeq j\rho_L c_s \cdot \frac{1}{kL}$ is approximated

To recap, $Z_{m0} \simeq j \cdot \frac{T_L}{wL}$ is expressed The impedance of the partial tip of the non-straight surface of the pinna is governed by the tensile force of the partial tip of the non-straight surface of the pinna and has a very large value. This means that when the sound pressure of a low frequency (low frequency) sound enters the pinna, the impedance felt at the tip of a part of the non-linear surface of the pinna is mainly due to the tensile force at the end of the part of the non-linear surface of the pinna. It expresses a situation that moves at a very small speed. On the other hand, as the kL value gradually increases, $\frac{\pi}{2}$ When it approaches the value, that is, when the wavelength of the sound pressure is 4 times the length of the partial tip of the non-linear surface of the auricle, the impedance of the partial end of the non-linear surface of the wheel has a value of 0, and resonance occurs. kL value $\frac{\pi}{2}(90^o)$ After passing through, the impedance has a negative imaginary value, that is, the moving speed of the tip of a portion of the non-linear surface of the pinna is equal to the sound pressure coming from the outside. $-\frac{\pi}{2}(-90^o)$ A situation of having a phase difference of The characteristic impedance of the pinna becomes negative infinity. Again, the anti-resonant state, i.e. the velocity at the tip of a portion of the non-straight surface of the pinna is zero. The motion of the tip of a part of the non-linear surface of the auricle, that is, the wave propagation phenomenon, is determined by how large kL, that is, the generated wavelength, is compared to the length of the tip of the part of the non-linear surface of the auricle.

5. FREQUENCY ANALYSIS AT A SPECIFIC POINT ON THE PINNA WITH NOTCH FILTER APPLIED

Just like the antenna receives radio waves, the outermost part of the human body, the pinna, receives longitudinal sound waves first. Depending on the surface area and softness of the auricle, the smoothness of the auricle is a trumpet that generates resonance while accepting the change in sound pressure while the surface of the auricle vibrates slightly as the auricle receives the sound and enters the external auditory canal. do.
Notch Filter Design || RLC Notch filter design || How to design a notch filter

Let's design a notch filter from scratch. First, let's create an RLC type filter (Notch) to remove the 45[kHz] to 50[kHz] band. The inductance is L = 30[mH].

So the given data is: f_L = 45[kHz], f_H = 50[kHz], L = 30[mH] = 0.03[H]
The resonant frequency is $f_r = f_H - (\frac{B_W}{2})$ is the bandwidth and = 50 – 45 = 5[kHz]
or $f_r = 50 \times 10^3 - [\frac{5\times10^3}{2}]$
or = 50000 - 2500
or = 47.5 * 103
So the resonant frequency is 47.5 [kHz]
Now we know that the resonant frequency can be written as

$$f_r = \frac{1}{2\pi\sqrt{LC}} \tag{13}$$

or $47.5 \times 10^3 = \frac{1}{\sqrt{1.088\times C}}$
or C = 374.41[pF]
So the quality factor will be = $\frac{f_r}{B_W} = \frac{47500}{5000} = 9.5$

Again, $$Q = \frac{\omega_r L}{R} \tag{14}$$

or. $$R = \frac{\omega_r L}{Q} = \frac{2\pi f L}{Q} \tag{15}$$

or R = 8.95[kΩ]
So, for a notch filter, R = 8.95[kΩ], L = 30[mH] and C = 374.41[pF]

6. NOTCH FILTER DESIGN APPLICABLE TO PICK AND PICK UP ON THE PINNA

Just like the antenna receives radio waves, the outermost part of the human body, the pinna, receives longitudinal sound waves first. Depending on the surface area and softness of the auricle, the smoothness of the auricle is a trumpet that generates resonance while accepting the change in sound pressure while the surface of the auricle vibrates slightly as the auricle receives the sound and enters the external auditory canal. do.
Notch Filter Design || RLC Notch filter design || How to design a notch filter

Type your main text in 11-point Times New Roman, single-spaced. Italic type may be used to emphasize words in running text. Bold type and underlining should be avoided. Do not use double-spacing. Leave a space between word and parenthesis. Special words of Latin or French origin should be in italic (*e.g., in vitro, et al.*). Be sure your text is fully justified-that is, flush left and flush right. / Just like the antenna receives radio waves, the outermost part of the human body, the pinna, receives longitudinal sound waves first.

The principle of masturbation in the auricle is that the surface of the auricle is a slightly hardened form of cellulose that is intermediate between a solid and a liquid, and has a sufficient function to collect sound. This determines the selectivity. The inductance expresses the mass of the pinna, which is equivalent to 30 mH.

Let's design a notch filter from scratch. First, let's create an RLC-type filter (notch) to remove the 55[kHz] to 60[kHz] band. The inductance is L = 30[mH].

So the given data is: f_L = 55[kHz], fH = 60[kHz], l = 30 mH = 0.03H The resonant frequency is $f_r = f_H - (\frac{B_W}{2})$ BW is the bandwidth and $B_W = 60 - 55 = 5[kHz]$

or $f_r = 60 \times 10^3 - [\frac{5\times10^3}{2}]$

or $f_r = 60000 - 2500$

or $f_r = 57.5 \times 10^3$

So the resonant frequency is 57.5[kHz]

Now we know that the resonant frequency can be written as

$f_r = \frac{1}{2\pi\sqrt{LC}}$

or $57.5 \times 10^3 = \frac{1}{\sqrt{1.088\times C}}$

or $C = 255[pF]$

So the quality factor will be = $\frac{f_r}{B_W} = \frac{57500}{5000} = 11.5$

Again, $Q = \frac{\omega_r L}{R}$

or. $R = \frac{\omega_r L}{Q} = \frac{2\pi f L}{Q}$

or $R = 7.39[k\Omega]$

So for a Notch Filter, $R = 7.39[k\Omega]$, $L = 30[mH]$ and $C = 255.51[pF]$.

7. NOTCH FILTER TO EXPRESS THE APPEARANCE OF THE PINNA AS AN ELECTRICAL EQUIVALENT CIRCUIT

Just like the antenna receives radio waves, the outermost part of the human body, the pinna, receives longitudinal sound waves first The figure below is a concept that implements the concept of expressing the compliance and sound mass of the pinna with inductance, and the outermost contour of the pinna is a parabolic equivalent circuit.

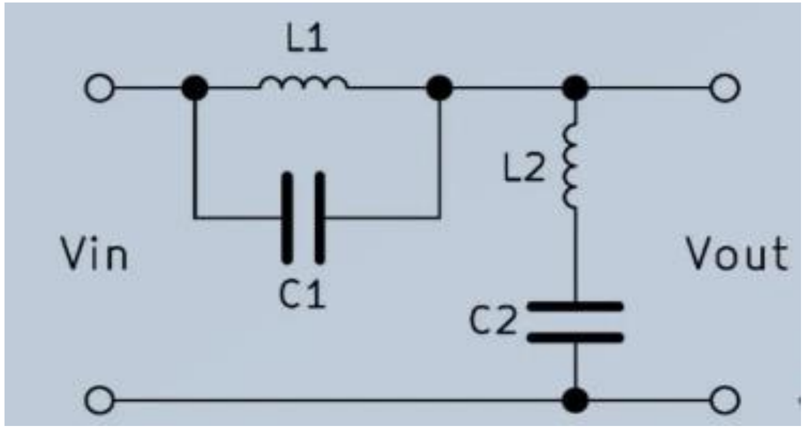

Figure 5. auricle LC circuit for notch filter The output impedance [15]

LC circuit for notch filter The output impedance is It's like.

$$Z = R_o = \sqrt{\frac{L_1}{C_2}} = \sqrt{\frac{L_2}{C_1}} \quad (16)$$

The transfer function is as follows.

$$T(s) = \frac{1+\frac{s^2}{w_o{}^2}}{1+s\frac{B}{w_o{}^2}+\frac{s^2}{w_o{}^2}} \quad (17)$$

cutoff frequency is

$$f_L = \frac{1}{2\pi\sqrt{L_1C_1}(-\frac{1}{2}\sqrt{\frac{C_2}{C_1}}+\sqrt{1+\frac{1C_2}{4C_1}})} \quad (18)$$

$$f_H = \frac{1}{2\pi\sqrt{L_1C_1}(+\frac{1}{2}\sqrt{\frac{C_2}{C_1}}+\sqrt{1+\frac{1C_2}{4C_1}})} \quad (19)$$

The above formulas express the high cutoff frequency by expressing the impossibility of masturbation in the pinna, and express the frequency range that can be heard using other methods

7.1 60Hz Notch filter

A 60Hz notch filter can reject a 60Hz signal by keeping the force of movement almost intact. Notch filters are used because they accurately attenuate frequency bands. 60Hz notch filters are in demand in the United States because the frequency of household power supplies is 60Hz. 60 Hz is the lowest frequency band among the frequency bands that the auricle absorbs. It represents the lowest frequency that resonates in the pinna, and after that, the sound pressure is the lowest frequency band that is secured. It is the lowest cutoff frequency of the pinna from the outside only physically.

7.2 60Hz Notch Filter design

Among the amplified signals, the desired frequency was selected and configured using an inductor and a capacitor, but most receiver vendors currently use a surface acoustic wave (SAW) filter. The SAW filter includes an ultra-narrowband filter and a wideband filter, which are selected and used according to the characteristics of the radio pager or the region used. / A 60Hz notch filter can reject a 60Hz signal by keeping the force of movement almost intact. Notch filters are used because they accurately attenuate frequency bands. 60Hz notch filters are in demand in the United States because the frequency of household power supplies is 60Hz. 60 Hz is the lowest frequency band among the frequency bands that the auricle absorbs. It represents

the lowest frequency that resonates in the pinna, and after that, the sound pressure is the lowest frequency band that is secured. It is the lowest cutoff frequency of the pinna from the outside only physically.
All notch filters are designed as high-pass filters and low-pass filters. An additional op amp is required to sum the outputs of the two filters. Typically Q is 60 for a 6Hz filter. The given equation can determine the notch frequency.

$$f_{\Phi CH} = \sqrt{\left(\frac{A_{LP}}{A_{HP}}\right) \bullet \frac{R_{Z2}}{R_{Z1}}\Big)} \bullet f_o \tag{20}$$

ALP is the output of the low-pass filter when the frequency of the filter is equal to the desired output frequency, and AHP is the output of the high-pass filter.
Generally $\frac{A_{LP}}{A_{HP}} \bullet \frac{R_{Z2}}{R_{Z1}}$The value is 60.
So the notch frequency is XNUMXHz It is provided as an output frequency.
The following expression can also determine the output frequency.

$$f_o = \frac{1}{R_F \bullet C \bullet 2\pi} \tag{21}$$

The value is 60. So the notch frequency is given as an output frequency which is 1Hz. As can be observed, the output frequency is RF It depends. So changing this value will change the notch frequency.
The value is 60. So the notch frequency is given as an output frequency which is 1Hz. As can be observed, the output frequency is RF It depends. So changing this value will change the notch frequency.

8. EXPERIMENTS AND RESULTS

It is an equivalent circuit that expresses the level of sound pressure received by the pinna by calculating the gain and cutoff frequency to which the resonance frequency is applied by equivalently converting the acoustic elements of the pinna into electrical inductance and capacitance.

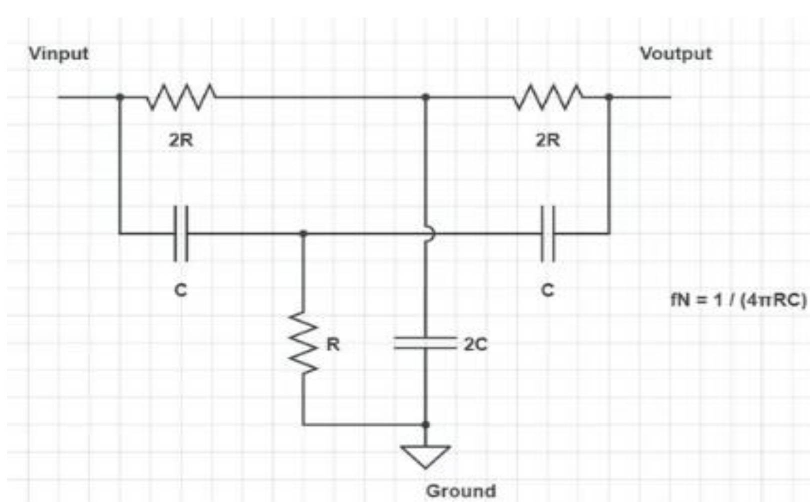

Figure 6. Electrical equivalent circuit of the tested pinna [15]

The leftmost part is the part that receives the sound input from the outside, and it is modeled as a place that distinguishes human auditory frequencies by matching the impedance of free space and the auricle like a parabolic antenna with a curved outermost part of the ear. A bi-quad filter is a digital filter. More specifically, it is an IIR filter with two poles and two poles. 'Biquad' is an acronym for the term Bi-quadratic. Notch filters can also be designed using a topology.

The transfer function of the filter is:

$$H(z) = \frac{b_o+b_1z^{-1}+b_2z^{-2}}{1+a_1z^{-1}+a_2z^{-2}} \quad (22)$$

Harmonic components analyzed in the pinna : A harmonic notch filter is a special type of notch filter that has many applications. The filter follows the transfer function:

$$H(z)=12(1+A(z)) \quad (23)$$

Selectivity considering the shape of sound pressure analyzed in the pinna : The formula modeling the electrical equivalent circuit of the tested pinna was implemented as the following formula. Deriving the notch filter transfer function

$$H(s) = \frac{(s^2+\omega_z{}^2)}{s^2+\frac{\omega_p}{Q}s+\omega_p{}^2} \quad (24)$$

where wz is the zero-circle frequency and wp is the pole-circle frequency. Finally, q stands for the quality factor of the notch filter.

Q is $-\frac{f_r}{\text{B and width}}$. If $\omega_p = \omega_z$, this is the standard notch type.

If $\omega_p > \omega_z$, high pass notch type. If $\omega_z < \omega_p$, it is a low-pass notch type.
Selectivity for selecting sounds coming from the outside is the formula of the pinna that implements the function of Q. The function of distinguishing human-recognizable sound from the pinna from low to high through frequency analysis is performed in the pinna, and the 2-3kHz area, where human hearing threshold is the most sensitive, is also the acoustic impedance of the most recessed area of the pinna. It can be seen that starting from

8. CONCLUSION

The human auricle is the first part to receive sound from the outside. In this part, the frequency range of human recognizable form is divided and organized. In this study, we propose modeling by applying a single sound source to the surface of the human auricle. This means that when the sound pressure of a low frequency (low frequency) sound enters the pinna, the impedance felt at the tip of a part of the non-linear surface of the pinna is mainly due to the tensile force at the end of the part of the non-linear surface of the pinna. By expressing the situation of moving at a very small speed, the characteristic impedance of the pinna was confirmed to be negative infinity, and it was also confirmed that the speed at the tip of a part of the non-linear surface of the pinna was 0 in the anti-resonance state. It was found that the wave propagation phenomenon that determines the characteristics of the filter is determined by how large the wavelength, kL, is compared to the length of the tip of a part of the non-straight surface of the pinna. In conclusion, it is concluded that the impedance of the partial end of the non-linear surface of the peak and the valley, which functions as a notch filter in a specific part of the pinna, is dominated by the tensile force of the partial end of the non-linear surface of the pinna and has a very large value. can also be obtained Modeling was implemented to realize the change in the sound pressure level received by the auricle by converting the area and volume length of the human auricle into the equivalent of compliance and inductance, which are acoustic elements. The function of frequency analysis was identified in the curved part, which is the part that first receives the frequency of sound coming from free space. The convex part of the pinna corresponds to the peak part of the sound pressure, and the concave part of the pinna corresponds to the belly part of the sound pressure level. confirmed to be.

A 60Hz notch filter can reject a 60Hz signal by keeping the force of movement almost intact. Notch filters are used because they accurately attenuate frequency bands. 60Hz notch filters are in demand in the United States because the frequency of household power supplies is 60Hz. 60 Hz is the lowest frequency band among the frequency bands that the auricle absorbs. It represents the lowest frequency that resonates in the pinna, and after that, the sound pressure is the lowest frequency band that is secured. It is the lowest cutoff frequency of the pinna from the outside only physically. Humans first receive sounds from outside through their ears. The auricle is non-linear and has a curved shape, and it is known that it analyzes frequencies while receiving external sounds. The human ear has an audible frequency range of 20Hz - 20,000Hz. Through the study, we applied the characteristics of the notch filter to hypothesize that the human audible frequency range is separated from the auricle, and applied filter theory to analyze it, and as a result, meaningful results were obtained. The curved part and the inner part of the auricle function as a trumpet, collecting sounds, and at the same time amplifying the weak sound of a specific band. The point was found and the shape of the envelope detected in the auricle was found.

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