# Remarkable Pitch Perception Phenomena

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In order to show the tremendous importance of our conclusion – which is in accordance to the experimental results of Wever and Lawrence[1] in 1950, confirmed by Voss et al.[2] in 1996 – that our hearing sense is transferring the incoming sound pressure stimulus *inside the cochlea* into the sound energy stimulus, and is then evoking tonotopically located vibrations on the basilar membrane in all places where the local resonance frequency is equal to that of one of the offered components in the *sound energy stimulus,* we have created a number of sound fragments which have remarkable pitch perception phenomena.

Let us first explain that Wever and Lawrence in the above mentioned paper described experiments with a cat's ear. They had removed the eardrum and ossicular chain and had placed a tube over the round window in order to activate both oval and round window separately and they measured simultaneously the cochlear microphonics in relation to pure tone stimuli in several cases.

They found the following:

1. Stimulating each window with the same sound stimulus gave identical changes in cochlear microphonics.
2. Stimulating both windows with equal stimuli in the same direction – i.e. inwards the cochlea – gave no changes in cochlear microphonics.
3. Stimulating both windows with stimuli having equal amplitudes, but opposite phase – i.e. the one window inwards and the other outwards – gave maximal changes in cochlear microphonics .
4. That maximum was 6 dB higher than can be achieved with only one of both windows stimulated with the same signal.

The experiments of Voss et al. confirmed these findings, and they added the result that both the AC and the DC cochlear microphonics showed that behavior.

Wever and Lawrence concluded that there was no different result by the way the stimulus was offered to the cochlea.
Voss et al. also concluded that the pressure difference between the two windows was the cause of the evoked signal in the cochlea.

Our conclusions are much stronger and directly based on fundamental physics.

The combination of findings 1. and 2. result in the conclusion that only *in case of perilymph movement* and not in the case of pressure changes inside the perilymph duct there is a *change in cochlear microphonics*.

This means that in order to evoke cochlear microphonics the sound pressure stimulus must be transferred via oval window and perilymph displacements into perilymph velocity.
According to physics and mathematics this means that the sound pressure signal is *differentiated*.

Hence every sinusoidal pressure contribution will be transferred into a 90° phase shifted sinusoidal perilymph velocity contribution with a proportional to the frequency enlarged amplitude.

The other strong conclusion is the fact that finding 4. means that the cochlear microphonics – responsible for the electrical signal from the hearing sense via the VIII cranial nerve to the brain – are proportional to the square of that perilymph velocity. And that this squared signal has both a AC and DC component, what was already known by the findings of Voss et al.

**And these two conclusions imply that the mammalian hearing sense is differentiating and squaring the incoming sound pressure stimulus *before* the signal is transferred via the organ of Corti.**

This statement is the basis for the creation of ***Remarkable Pitch Perception Phenomena***

So for that creation it results in a simple scheme of mathematical calculations:

At first we don't use equal amplitudes in the sound pressure stimuli of our sound fragments. Instead of that we use sound pressure contributions with amplitudes reciprocal to the frequency, so a **1/*f* condition** , which will lead after differentiating to equal amplitudes in perilymph velocities.

We will also use as much as possible in our sound fragments contributions having prime number frequency values. [Non prime numbers will be indicated by Italic characters.]
This in order to show that pitch determination doesn't rely on the condition of harmonics and their fundamentals.

Under the 1/*f* condition and completely different from what is known in the existing cochlear models and theories of hearing we can calculate that:

**Sound fragment 01**:
With frequencies: 367 – *567* – 767, having a successive difference in frequency of 200 Hz, but without any harmonic relationship – i.e. the 367 and 767 Hz contributions both being prime numbers have no other fundamental in common than 1 Hz – create a beat phenomenon with a beat frequency of 2 Hz in combination with a frequency of 101 Hz, having an amplitude in perilymph velocity of 2 relative to the velocities of the other contributions.

This clearly heard beat phenomenon, which doesn't exist in the sound pressure stimulus, can only be explained by the fact that the [out of the 101 Hz contribution doubled] frequency of 202 Hz with squared relative amplitude 4 combines with the two difference frequencies *567* – 367 and 767 – *567*, both being 200 Hz with each having a calculable relative amplitude 2, which combines to 4.

This throws a new light on the history of pitch theories given by de Cheveigné[3] in his contribution to the book of Plack *et.al.*

The same basic calculations predict the following behavior:

**Sound fragment 02:**

An identical result is obtained, while the 101 Hz in SF01is changed into 99 Hz and the amplitude is changed according to the $1/f$ rule.

**Sound fragment 03:**
Also created under the $1/f$ condition having frequencies: 809 – 1009 – *1209* – 1409 – 1609 sounds monotonous and without a beat.

**Sound fragment 04:**
Which exist of frequencies 809 – 1009 – *1210* – 1409 – 1609 sounds the same except for the beat of 1 Hz.

**Sound fragment 05:**
Where only the frequencies 809 and 1609 are canceled and exists of: 1009 – *1210* – 1409 Hz can be calculated as having a beat of 2 Hz instead of 1 Hz. Which actually is heard in the fragment without any doubt.

**Sound fragment 06:**
Having frequencies 809 – 1008 – *1209* – 1410 – 1609 sounds the same as Sound fragment 4, except for the fact that it has also a beat of 2 Hz instead of 1 Hz.

Taking into account that according to existing theories pitch phenomena cannot be distinguished for high frequency combinations the following series of sound fragments is even more remarkable:

**Sound fragment 07:**
Having frequencies 7823 – *8023* – 8221 – 8423 – 8623 has a high frequency sound, but also a beat of 2 Hz.

**Sound fragment 08:**
Having frequencies 7823 – *8021* – *8223* – *8425* – 8623 sounds as SF 07, but has a beat of 4 Hz instead of 2 Hz.

**Sound fragment 09:**
Having frequencies *7821* – *8023* – *8223* – 8423 – *8625* sounds as SF 07, and has also a beat of 2 Hz.

In these last three sound fragments the beat that is heard can only exist in the difference frequency of 200 Hz, which is also the pitch frequency of this sound fragment, although not heard as such.

Similar kind of sound fragments and even more peculiar sound fragments out of combinations of pure tones can be created for the entire audible sound spectrum with similar results.

**Completely different from what is known from present hearing theories.**

Every expert familiar with pitch and beat phenomena will agree that this is at least extraordinary remarkable.

And just these evidential data as just one of the eye catching resulting consequences of that new theory in hearing makes it worthwhile to publish our proposed paper under the title:

## Consistent application of physics in hearing theory yields remarkable acoustical experiments as evidence for another auditory paradigm.

### References


1. Wever E.G., Lawrence, M.: *The acoustic pathways to the cochlea* , JASA 1950; 22: 460-7

2. S.E. Voss, J.J. Rosowski, W.T Peake: *Is the pressure difference between the oval and round windows the stimulus for cochlear responses?* JASA(1996) Sep.,**100**(3): 1602-16.

3. De Cheveigné A. 'Pitch perception models' In: Plack CJ, Oxenham AJ, Fay RR, Popper AN. , editors. 'Pitch: Neural coding and perception'. New York: Springer-Verlag; 2005. pp. 169–233.