Assistive Hearing for Motorcycle Riders Through Spectral Subtraction noise extraction and amplification

Anthony Ibarra,
University of Illinois at Chicago: ECE,
aibarr23@uic.edu

Abstract

It is a widely recognized fact that putting on a helmet significantly diminishes one's perception of sounds within the surrounding environment of the user. This reduction in sound clarity affects sounds the rider would like to be aware of, these sounds get affected even more by the masking or overpowering of other sounds. Among these, the sounds that are most relevant include the wind noise generated by weather conditions, speed of user's bike, and the engine sounds emanating from the motorcycle itself. The objective here is to reduce these distracting noises through spectral subtraction layering, thereby opening the potential for enhancment of the unaffected sounds. These sounds extend to sirens from emergency vehicles, the presence of other vehicles in traffic, as well as the movements of cyclists and pedestrians, particularly in densely populated areas. While it is important to acknowledge that this approach will not eliminate the inherent noise within the helmet, also through its naive implementation it can enhance unwanted sounds aswell unless further optimized. It has the potential to significantly improve the rider's ability to detect sounds that are typically suppressed by the helmet structure and the noise present. This enhancement can be percieved as an addon to other applications when improved, as it allows us to isolate certain sounds and adjust them.

Index Terms

Temporary Hearing Threshold Shifts (THTSs), Noise Induced Hearing Loss (NIHL), Permanent Hearing Threshold Shifts (PHTSs), Normalized Least Mean Square (NLMS), Recursive Least Squares (RLS)

I. Introduction

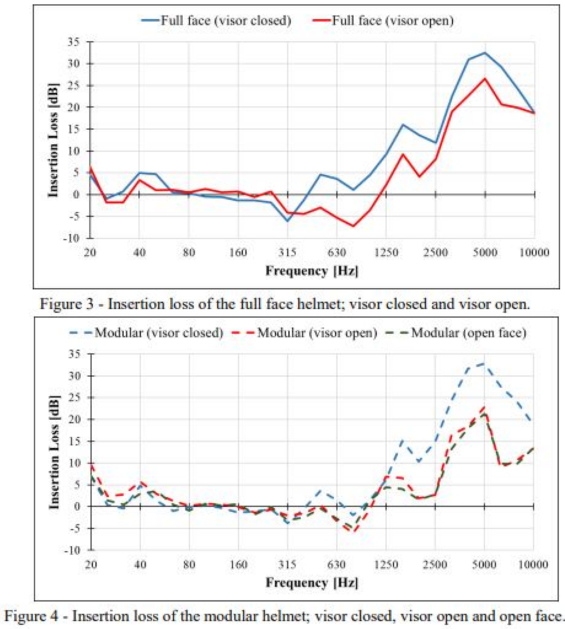
The process of riding a motorcycle is a method of transportation that many people enjoy. Although there are many added risks when riding a motorcycle than compared to riding a larger vehicle like a car. Because of this there are many saftey mechanisms to keep the rider safe and protected, from saftey straps to protective armor and of course the most known is the helmet. It is known that the helmets used for motorcycle riding will attenuate the sound when worn. This in turn will make it more difficult for the user to hear important sounds or alerts from other vehicles; it'll be vastly difficult if the rider has some level of hearing impairment aswell.

The major problem is that there are people with hearing impairment that are unable to hear sounds that are crucial for ones awarness like the sirens from an emergency vehicle or the car horns from traffic are just some examples. This paper will go over the problem at hand and its potential cause and effects related to it, which is affecting the riders and those around the riders. Next we will go over the proposed solution with any improvments that can be made for it. With results showing the advantages and disadvantages that will come with the solution; after the results possible use cases will be described for potential future implementations or future research.

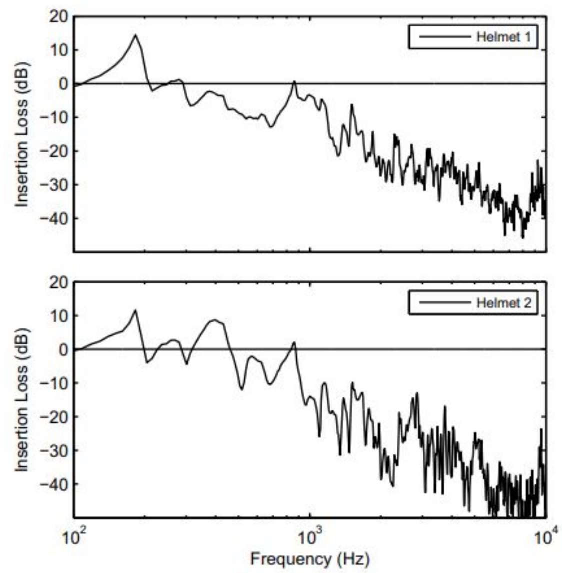
Motivation Overview

It is more dangerous to ride a motorcycle than it is to ride a four wheel vehicle, while the vehicle itself is not the only reason that will increase the risk factor of a rider. Another part of it can be one's hearing or one's capacity to hear certain sounds. Riders with and without hearing impairment will have the sounds around them attenuated by the helmets' noise reduction characteristics. Through other research it has been shown that the helmet of a motorcyclist has a filter characteristic of a spectral filtering.[12]

As it is clearly shown the 1a from the [11] and 1b from the [12], there is little to no attenuation, and actually amplifies within lower frequencies for different helmets.



(a) Case I



(b) Case II

Fig. 1: Noise reduction characteristics for different helmets

There is clearly amplification at under 1kHz for both cases, reaching upto 10dB at the highest. Overall the helmets will have the same properties, but with small differences as they have persumably used different helmets.

Noise

Noise is clearly a huge factor in riding a motorcyle since it makes us more perceptable to get noise induced hearing loss (NIHL). As we know the cochlea will recieve metabolic damage due to continuous exposure of noise around 85dB to 140 dB [9]. While riders highest noise exposure can be as high as 94.84 dBA[9], from continuous exposure the riders will become affected by Temporary Hearing Threshold Shifts (THTSs), which will then become Permanent Hearing Threshold Shifts (PHTSs) a characteristic of NIHL.[6] With all this noise that is causing our riders to get or potentialy get NIHL. This shows that the riders are susceptible to hearing loss or hearing impairment, clearly it offers an increase in risk depending on ones' level of hearing loss whether permanent or temporary. For higher degrees of hearing loss have been associated with an increase odds of falling down, with around 1.4x increase of odds for every 10 dB increase of hearing loss.[2]

As seen noise is a large part of hearing loss for motorcyclist or at least potential hearing loss, currently there is no fool proof preventive measure to remove all the noise. There are many ways rider will attempt to remove or ignore the noise, one way would be to increase the volume of the music playing within the audio device or ear buds although this might actually increase the chances of getting THTSs. Another option would be earplugs but these will attenuate across all frequncies and most likely removing important sounds a rider would require to be aware of. Now active noise control (ANC) is probably the first one that came to your mind, seeing as it removes noise fairly well and it keeps any important sounds or prompts intacted. But it's also not perfect although for a constant 40 mpH, it can hold an average cancellation of 40dB at 200Hz and 15 dB from 200Hz to 600Hz [7]; you can also see this in the image bellow 2 from [8, 7].

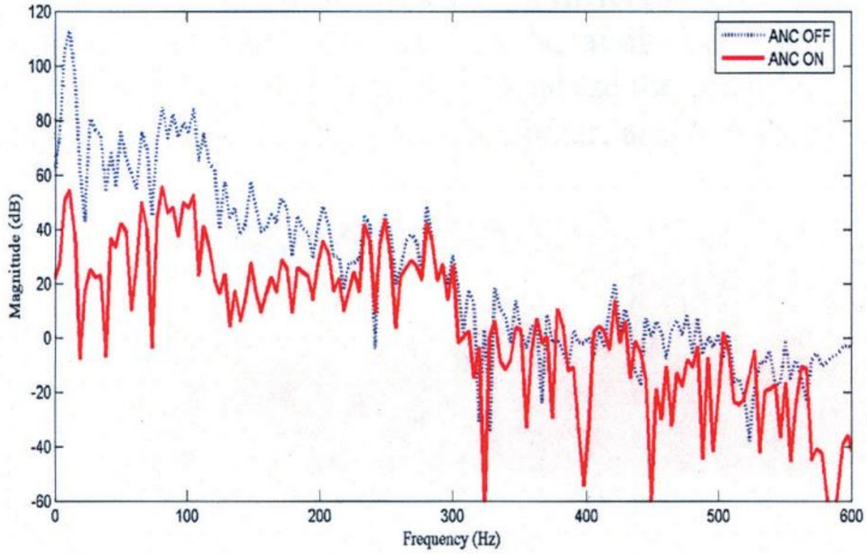


Fig. 2: ANC on a motorcycle at the speed of 40mph

II. Problem

It is also unlikely that all riders will have ANC available with their helmet, just like how unlikely that everyone with some level of hearing impairment will have hearing aids at their disposal. For the most part I will focuse on improveing the audability of the sounds that has been attenuated by the helmets. As we know people with very high level of hearing impairment have more than 90 dB of loss. So if the user has trouble hearing from frequencies around 100Hz to 1000Hz, where there is less attenuation and actually amplification from the helmet we can amplify accordingly allowing the rider to hear vital sounds.

The overall noise heard by a rider is quite spread among different sources, as outlined by Ailin and Roslida "There was wind noise or turbulence around the helmet (19%), the vibroacoustic effect that comes from a motorcycle engine, exhaust and tires/ground interaction (17%), the speed of motorcycle (17%), the road and weather condition (8%), vehicular noises (12%), honking noises from other vehicles (8%), and types of helmets whether open face or full face (19%)."[9] There are also studies about the link between hearing loss and ballance, current there is no final verdict whether if hearing loss has an implication to ones balance.[2] If hearing loss does in fact have an affect on the ballance then THTS could also have some effects increasing the risks of riders if true.

The main focus of the application discussed later will be for riders who are affected by either the helmet, the noise, or their own hearing impairment. We will need to amplify the sounds that the rider cannot or has trouble hearing.

III. Method

There are many better ways one can go about this approach, the method shown in this paper will very simple but will show results completing the desired results to some degree. First parameters that will be needed is the source and the noise to be removed from the recorded source. The source will be obtained from a microphone either located inside or outside the helmet, depending on the location the amplification and attenuation should be adjusted accordingly. Now for the noise extraction Spectral subtraction will be used seperatly to collect the weights or average of the individual noise source. Each noise weight will be scaled accordingly with respect to its respective noise from the source, and then removed with similar manner as in spectral subtraction. The scaling factors for attenuation and for the amplification case are adjusted manually, ideally these factors are to be adjusted through a more robust approach for examples an adaptive filter or some optimal algorithms would be prefered.

$$|Y[n,i]| = |S[n,i]| - \sum_{t=1}^{m} \alpha_{i,t} \left|\hat{W}[t,i]\right| \tag{1}$$

$$Z[n,i] = \frac{|Y[n,i]|}{|S[n,i]|} S[n,i] \tag{2}$$

$$S, Z \in \mathbb{C}^{k \times N} \tag{3}$$

$$Y \in \mathbb{R}^{k \times N} \tag{4}$$

$$\hat{W}, \alpha \in \mathbb{R}^{k \times m} \tag{5}$$

The equations above show the way of removing the noise from the source clearly very similar to spectral subraction other than the addition of mulitple weights and scaling factors. Where k is the total frequency index available from the STFT of the source S, m is the amount of noises extracted or available, with N being the total samples.

As stated before α was adjusted manually, ideally it would adapt based on the current noise power for its respective noise more on this later.

$$Z[n, k] = \beta_k Z[n, k] \tag{6}$$

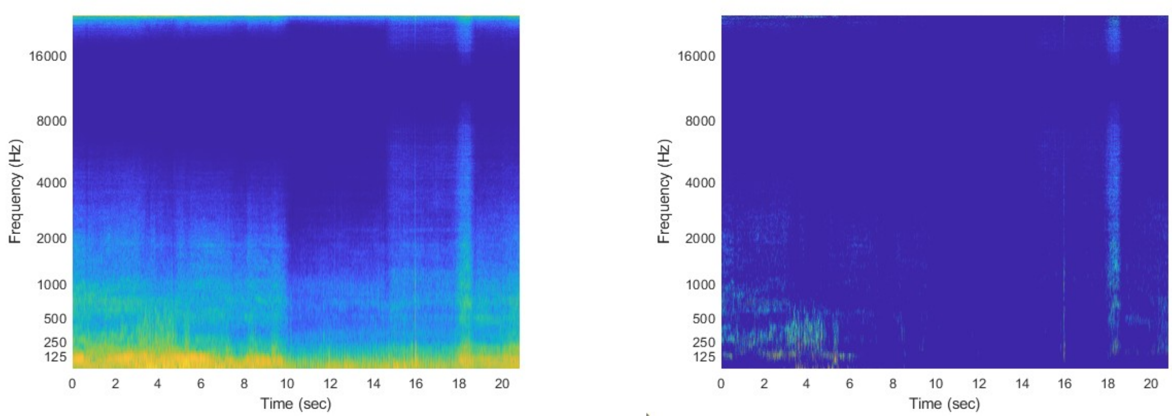
$$\beta \in \mathbb{R}^k \tag{7}$$

β is what is known as the scaling factor before finally outputing to the speakers located within the helmets interior. Again this can also be improved but it is very dependent on the situation and configuration of the whole system as in the mic location the rider current auditory levels and the scene where the rider is currently riding.

IV. TESTING & RESULTS

The helmet used for testing is the AT4.0 carbon jormungandr of size S from Ruroc priced at around $600 as of writing this paper. Also a Shockwave sound by Harman Karman audio system at $230, the microphone from this audio system has a resolution of 8000Hz while its speakers can go upto 44100Hz. This helmet does not have ANC included, and the source used for testing was recorded from and insta360 Ace camera with a microphone that can do upto 48000Hz. The insta360 was used to collect a recording of roughly 20min ridnig with various situations for testing.

During testing there was 2 primary noise source that was obtained the speed of the motorcycle and the motorcycle itself as it is shown in fig 3.

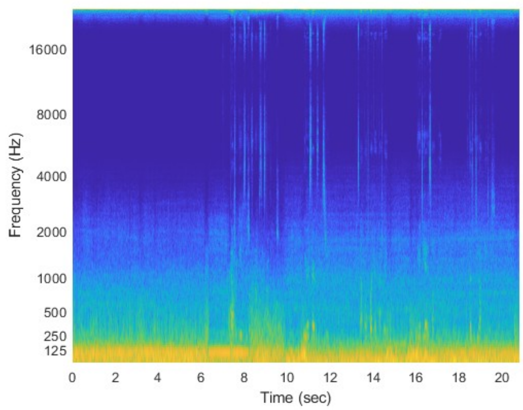


(a) Case I

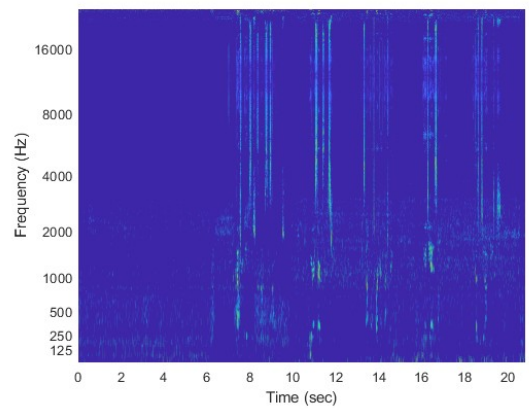
(b) Case II

Fig. 3: Noise reduction characteristics for different helmets

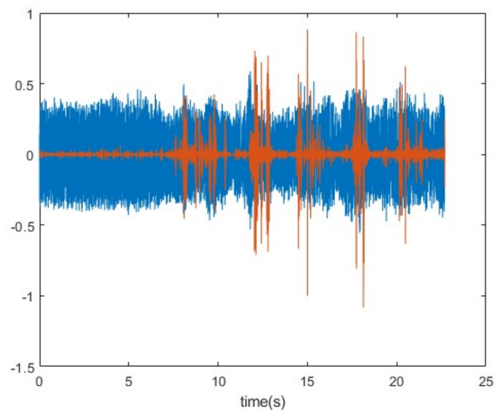
The figure 3 show only noise of the motorcycle and the speed noise during riding. The following will be different situation with speech added simulation a sound the rider might want to hear, a speech with noise and speech with noise and a siren respectivvly.



(a) Case I

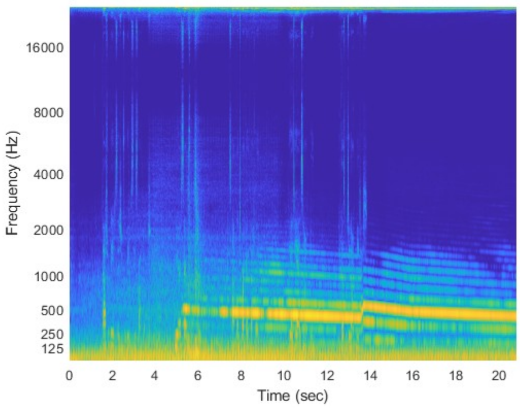


(b) Case II

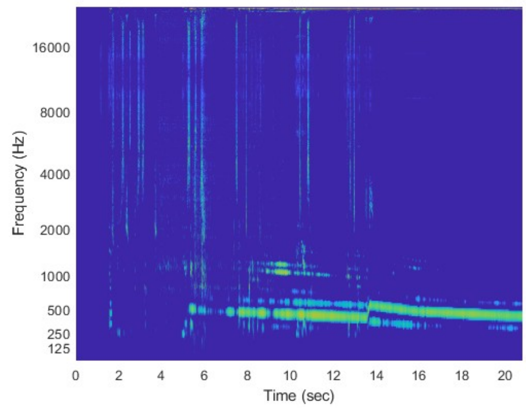


(c) Case III

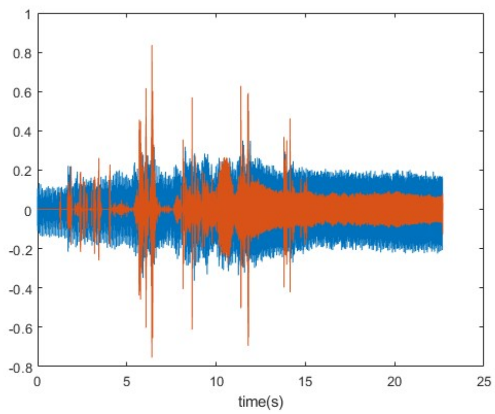
Fig. 4: (a)source of sound, (b)noise removed and amplified 1kHz and above, (c) signal comparisons of (a) and (b)



(a) Case I



(b) Case II



(c) Case III

Fig. 5: (a)source of sound, (b)noise removed and amplified 1kHz and above, (c) signal comparisons of (a) and (b)

V. Result Analysis

From figure 5 there is actually overattenuation since the siren is quieter than the source and it was only amplified from 1kHz and above. This might be desirable if the rider is developing THTS this will also depend on the current noise power within the helmet at the rider's ear. Also if the rider has hearing impairment within a certain frequency amplifying might be prefered if the rider does not use some form of hearing aids. As it can be seen in the figures from testing the noise can be removed pretty well, and this is without any adaptive implementation regarding the scaling and attenuation factors. An adaptive filter would suffice to improve robustness and accuracy like NLMS or RLS if there is enough computing power. There are other situations that one would require to take into account like the location of the mic in testing it was place outside of the helmet. If source from inside of the helmet was used the noise reduction characteristics would be taken into account when amplifying or attenuating.

With improvement in attenuation and amplification the final result will have far less artifacts compared to what has been shown through the results. Another factor that will affect the system would be the change in scenery for example the sound around you would change while you enter a tunnel and exit the tunnel; so a scene classification would be required. Let's not forget the possible development of THTSs for the rider, so the noise power and the riding duration will need to be monitor to adapt any variables.

VI. Conclusion

There is clearly room for improvement regarding making the overall system more robust and actually usable for real application. At it's current state it would actually cause more harm than good if used as is. Nonetheless the results show that there is potential worth looking into atleast in a less broader target. A more higher level of hearing impairment would be more ideal for people without hearing aids. Older riders can also benefit from a more improved and robust version of this application, since older riders with impairments are crash prone; also hearing and balance functions may need to be considered regarding a riders competenct.[3]

There are other attempts of using devices for hearing impairment riders. Like the deliver of vibrations to the antebrachial area and there is also detection system using LED lights. [4] The helmet type is another factor one should be aware of since helmets can affect the rider's vision, hearing, and ventilation. [10] Localization would be the next part to improve this application and making the riders more aware of their sorroundings. Using the entire helmet as an artificial pinna might be worth looking into; since there has already been research on how the helmets influence of sound localisation showing surface pinnas that resemble the pinna from our ears.[1]

There are many similarities to this problem for motorcycle riders with hearing impairment and the problems that the highend hearing aids resolve. From feedback suppresion to noise reduction, also monaural classification separating speech in quite from speech in noise with feature extraction. [5] There are many technics used within a hearing aid that can be of use in the application discussed within this paper, there also can be different situations related to a motorcycle riding compared to your average hearing aid user that could potentially improve further research in this field.

List of Figures

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