Potential Health Impacts of Gamma-Frequency Sound in Server Room

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Abstract: - Hearing degradation caused by an exposure to excessive noise is irreversible. Many of the other relative hazards that can be developed from noise-induced hearing loss are impaired communication with family and coworkers, social isolation, irritability, decreasing of self-esteem, anxiety, and loss of productivity. Hearing impairment is a significant health hazard that is naturally occurs with aging. Tinnitus is a disorder in hearing ability and can cause a ringing in the ear without a source for physical sound. More than 40 million people in the United States are suffering from tinnitus disorder. Fourteen percent of adults are suffering from chronic tinnitus, and 50% of normal adults with no clinically confirmed disorders in hearing ability experience subtle tinnitus in a silent environment. An exposure to excessive noise and the process of natural aging of people may increase the occurrence of Tinnitus. Tinnitus is a spontaneous auditory perception that is associated with the continued activity of the gamma frequency band (30 Hz - 80Hz). Server Room can be considered as a continuous source of gamma frequency. Server room running devices are generating a continuous noise that most of its power is allocated in the band of gamma frequency.

Key-Words: - Noise, Server Room, OSHA, Gamma Frequency, Tinnitus.

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1 Introduction

Large server rooms are considered as a new workplace phenomenon and verify merit as an emerging technology. Excessive noise exposure to employees working with servers may be present in data storage sites [1]. Corporate server rooms provide a single location for residential computers to support business goals, which are usually a small temperature-controlled, secure room with a minimum number of passengers. Maintaining a small area allows greater access control (for example, a high degree of security), and also puts the servers in a more intense format.

The server is designed to deliver data to other computers (clients) and process requests over the Internet, or a local network [2]. Those rooms contain multiple devices responsible for transmitting data to and from these data center. These rooms have different densities and dimensions depending on the room's architecture, brand of the server, the server's age, and racks height in addition to the proximity of the units to each other. Strategic placement of units can amplify sound in every server room, as the sound pressure depends on the number of servers and how well they are positioned from each other. Proximity and density of servers have the ability to produce excessive harmful noise. Some operators may find the volume and frequency uncomfortable, and excessive noise may be dangerous to their well-being.

Sound parameters are pressure and frequency that are measured in Newton/Square Meter (N/m^2) or Pascal (Pa) and (Hertz) respectively. Pressure and frequency have health hazard on the users, but the pressure of the sound is the only factor that is regulated by OSHA (Occupational Safety and Health Administration) [3]. Sound in server rooms has a frequency resonant that may be offensive to some people and can somehow cause health issue, but unfortunately is not regulated by any of governmental agency. OSHA mandated that sound pressure levels should not exceed a certain level so that they do not cause an occupational health issue to employees. In this study, we evaluated and investigated sound frequency as it may adversely impact the users. For example, gamma frequency (40 Hertz–100 Hertz) of the sound band has been discovered to be uncomfortable or distracting for some individuals [4]. The average hearing range of the person is maintained from 20 to 20,000 Hertz. The range of the frequency investigated in this study can be reviewed in the Result section of this paper. The objective of this research was to investigate if the sound generated by the servers caused discomfort for the users that maintain and use those data center and also to analyze the characteristics of noise.

The purpose of this study was to find out how much did the servers generate of sound (power and frequency) in a specific area, and then evaluate whether the sound levels at gamma frequency need to be reduced to avoid health hazard or issues related to the productivity for the users. The preferred way to address occupational exposure is through engineering methods, preferably in the design process. If the room or equipment can be configured in a manner that eliminates or reduces occupational exposures to the workers in the workplace, then this could be the first approach by ergonomic engineer supposing that it is economically feasible. Engineering solutions (i.e., workplace design to reduce or avoid workers exposure to risk condition) do not necessitate administrative controls such as reduction of the work hours of employees exposed to a certain contaminant (in this case, sound), rotation of employees in a specific job position, or mandate annual medical test for hearing and compliance by wearing equipment for safety purposes. The preferred approach for reduction of noise impact should always involve engineering solution first, then administrative controls and finally resort protective personal equipment.

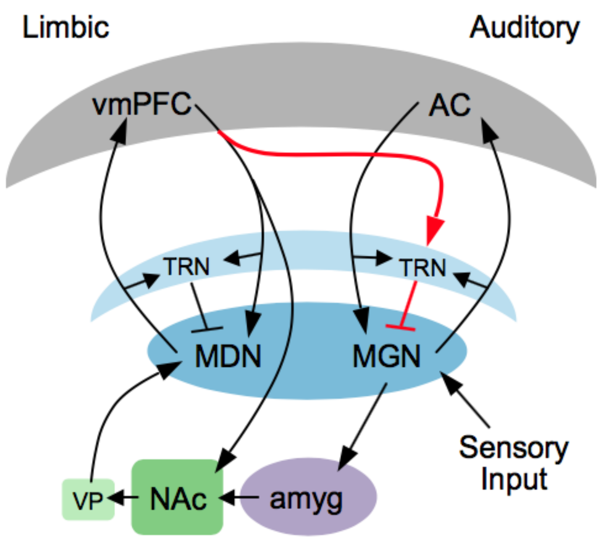
The personal usage of protective equipment may require the documentation for hearing capabilities of each employee, and an investigation of the sound reduction required amount that is defined by OSHA 29CFR1910.95 Hearing Conservation to ensure compliance with regulation [3]. Annually, the cost of conducting tests in order to determine employees' hearing capabilities to choose convenient personal equipment for hearing protectively can be expensive in the long run.

Acoustics can be achieved or reduced in several different ways depending on room configurations, equipment placed in rooms, floor/wall construction restrictions, and sound reduction materials. As an engineering solution, noise encapsulation potentially reduces the sound by isolating the device that emit the sound from the user by enclosing it, completely. Sound reduction methods may still allow the equipment to be accessed by the user easily and keep the sound below harmful levels. Sound reduction involves the usage of appropriate personal protective equipment (ear muffs, ear plugs, etc.) if the pressure levels of the sound exceed the values defined by OSHA. From engineering perspective, noise cancellation is considered as another method of sound reduction and it is more effective in work environment. Noise cancellation method is consisting of devices that use a technology of signal processing to reduce the noise by capturing the noise signal and then emitting an inverting version of the sound wave, it is thereby canceling some of the noise waves. Other forms of sound reduction are accomplished by utilizing acoustic materials on floor, ceilings, or walls, and that reduce the pressure of the noise that emitted by the devices [5]. Personal Protective Equipment (PPE) is typically employed by organizations when engineering and administrative solutions do not minimize sound to an acceptable level to comply with federal regulations [1]. Administrative solutions to protect the hearing of employees include rotating employees reducing employee exposure to noise. These solutions create challenges in the scheduling for organizations and are therefore not as desirable as reducing or eliminating the sound exposure. Lastly, the use of earmuffs, earplugs or any other similar PPE may adversely impact the workers ability to communicate while they are in a server room and cause errors during the work due to poor communication [5].

2 Tinnitus

Tinnitus is hearing impairment that is typically associated with damage that occurs due to noise trauma or chronically noise exposure [4]. Such damage can hurt the central auditory system, specifically the neural synchrony within the central auditory system. These changes have been reported in various studies conducted for animals and humans and could be the cause of various pathologies [4]. These damages have been reported to be specifically tied to the gamma range (30 Hz – 80 Hz) of sound frequency [4]. Tinnitus has been characterized as one of the common auditory disorders in the population. The anatomical substrates and disease associations still continue to be defined. However, Semantic Dementia (SemD) patients are frequently reporting Tinnitus as one of the symptoms [6]. Therefore, it may be possible to report significantly the potential onslaught or prevalence of Tinnitus as a serious issue in SemD. SemD evidence can support previous work implicating of limbic network and a distributed cortico-subcortical auditory in the pathogenesis of these abnormal auditory percepts [6].

In general, Tinnitus is caused by peripheral and central mechanisms such as peripheral injury, a reorganization of central auditory pathways, or anomalies in the limbic system, which produce a sensory emotional content experience [7]. There are many different hypotheses to explain the reason of Tinnitus. Some evidence suggests that Tinnitus can be a pathophysiology that involves damage either central or peripheral pathway or can be both [8]. Another Hypothesis proposed that Tonotopic maps could be the cause of tinnitus. Tonotopic maps are recognized in the auditory cortex and leads to a sensation of Tinnitus frequencies [7]. Previously, it was a suggested that the source of chronic Tinnitus are coming by a compromised limbic corticostriatal circuit that leads to a disordered in evaluation of Tinnitus sensation's perceptual and causing disturbance in the control of cognition in the tinnitus. [8]. On the other hand, anomalies related to Tinnitus are inter-correlated between primary and limbic auditory and/or two limbic area and indicates necessity of auditory-limbic interactions in Tinnitus as shown in figure 1. Although, the role of limbic contributions nature to Tinnitus is not yet verified [8]. Auditory-Limbic, shown in figure 1, clarifies the interaction in Tinnitus, where the sensory input is originated subcortically then enters both auditory and limbic circuits via Medial Geniculate Nucleus (MGN).



Medial Dorsal Nucleus (MDN),
Ventral Pallidum (VP),
amygdala (amyg),
Auditory Cortex (AC),
Medial Geniculate Nucleus (MGN).

Fig 1. Auditory-limbic interaction in Tinnitus [8].

Normally, sensory signal is defined by the limbic system as perceptually irrelevant such as transient Tinnitus followed by noise exposure. Then block unwanted signal to MGN by projections from the ventromedial Prefrontal Cortex (vmPFC) to the auditory thalamic reticular nucleus (TRN, red pathway). Therefore, an unwanted signal can be reduced in either circuit. In the case of tinnitus, inactive vmPFC output can prevent tinnitus signal hosting and cortical thalamic activity. The structures of thalamus in blue, and amygdala is noted in lavender, basal ganglia noted in green, and cortical are noted in gray. Mapping the hubs of the cortical in Tinnitus it has been reported that having major group differences across global networks, especially in the gamma frequency band [4].

Typically, Tinnitus is usually associated with damage to the hearing system such as chronic exposure to noise or noise trauma [4]. This damage can lead to drastic changes at different levels of the central auditory system. As a result, it boosted the rate of automatic fire and nervous synchronization within the central auditory system. These changes have been reported in both animal and human studies and may be caused by various diseases [4].

Another suggestion about the cause of chronic Tinnitus mentioned that it may be caused by plastic reorganization in the auditory cortex followed by peripheral deafferentation. Based on this hypothesis, the reorganization process usually causes hair cells to be lost in the inner ear; Sensorineural Hear Losing (SNHL) may in some cases result in cochlear injury due to sound trauma (i.e. exposure to noise with a certain level of frequency band or associated atrophy Age for the hair cell).

Moreover, the corresponding frequency range can cause the lesion thresholds to rise. Furthermore, the adjacent frequencies became more amplified due to the expansion of the central representation in a vacant frequency band [9]. Indeed, some of the basic findings of Positron Emission Tomography (PET) studies show that the frequencies corresponding to the perceived Tinnitus frequencies lead to frequency expansion in the auditory cortex [9]. While tinnitus is usually considered a heterogeneous condition, most patients who have suffered from tinnitus have reported a complaint of a sense of auditory weakness. With regard to the brain mechanism of tinnitus sufferers, most current data show a very important gray matter that shrinks in the subcallosal region as shown in figure 2 [7].

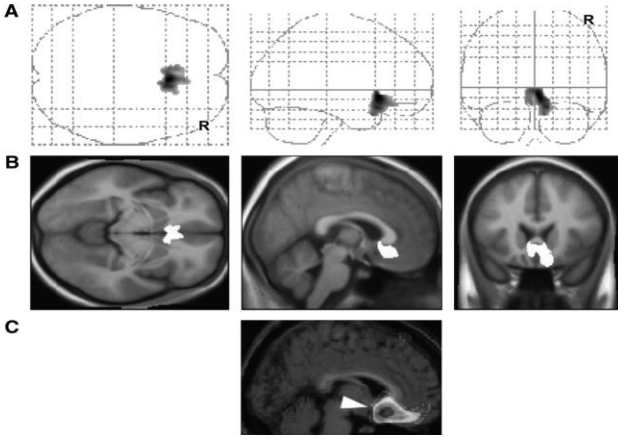


Fig 2. Gray-matter volume decreases in addition to the changes throughout the whole brain [7].

Furthermore, it was found that there was an expansion in the concentration of gray-matter in the auditory thalamus of the Tinnitus group as shown in figure 3 [7]. It is important to find that the structural changes that associate with the region without leaving the Tinnitus for different reasons like activity in the artificial sub-region associated with the unwanted auditory sensation that comes from different amounts of disharmony symmetry, especially in the area where the gray color is shrinking the issue [7].

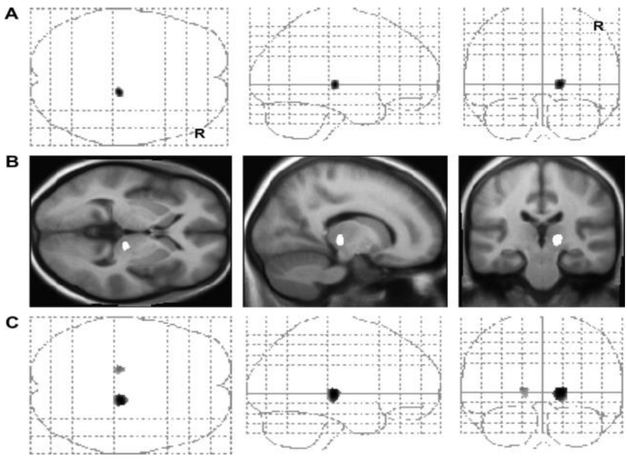


Fig 3. Gray-matter concentration increases [7].

Mainly, the role of the posterior thalamus and subcallosal region in causing Tinnitus is combined changes in both regions. In other words, these changes seem to result in a tinnitus sensation. Mulaw et al. (2005) A model suggested this:

1. Neural tinnitus activity is mainly in MGN and results from reorganization after peripheral hearing loss.
2. Inhibitory feedback from the subcallosal area may help control nervous activity due to Tinnitus.
3. Shrinkage of gray matter in the subcallosal region may reduce these inhibitory reactions. Because of this, people with peripheral hearing loss may be at a health risk for tinnitus.

3 Results

A sound record was conducted in a workstation, which located in an area where the operators could perform paperwork or work on their computers with tasks that were assigned to them. The recorded signal time domain, frequency spectrum, and spectrogram analysis are exhibited in figure 4-6 respectively. According to the time domain of the sound (figure 4), sound pressure is bouncing around ± 0.05 Pa. However, acoustic (i.e., sound) pressure level was plotted to show the noise pressure over time. Refereeing to [1], the sound pressure level (SPL) for the source of sound with pressure (p), is defined as:

$$SPL = 20log_{10}\frac{p}{p_{ref}} .. (1)$$

where pref= 20×10^{-6} Pa.

Therefore, the pressure of the sound at that location could be exceeding the level of 60 dBA. Therefore, it is not close to the maximum level of the sound that is established by OSHA. Although the noise level of the signal is not legally harmful, due to the distance between the workstation and the servers that causes a reduction in the SPL, it was still representing a continuous distraction to the workers in that server room.

A frequency spectrum analysis (figure 5) reveals that the highest power of the signal is located in the lower frequency band (i.e., 20–80 Hertz). At this band, the power of the signal is ranging from -35 dB to -60 dB. In figure 6, the signal power distribution over the frequency is displayed in the time domain. A frequency range of 0–120 Hz for the spectrogram (figure 6) is evident in Figure 7. It shows that the frequency band from 40–80 Hz has a level of power that fluctuated between -50 dB to -60 dB. This range is representing a gamma frequency range, which is considered as the most harmful range in terms of hearing impairment.

As a result, employees were exposed to a high-power level of continuous gamma frequency sound while spending the majority of their work shift in the server room to perform daily tasks and monitor the network. As mentioned earlier, long-term exposure in this frequency range may cause significant damage to the hearing system such as chronic noise trauma [4].

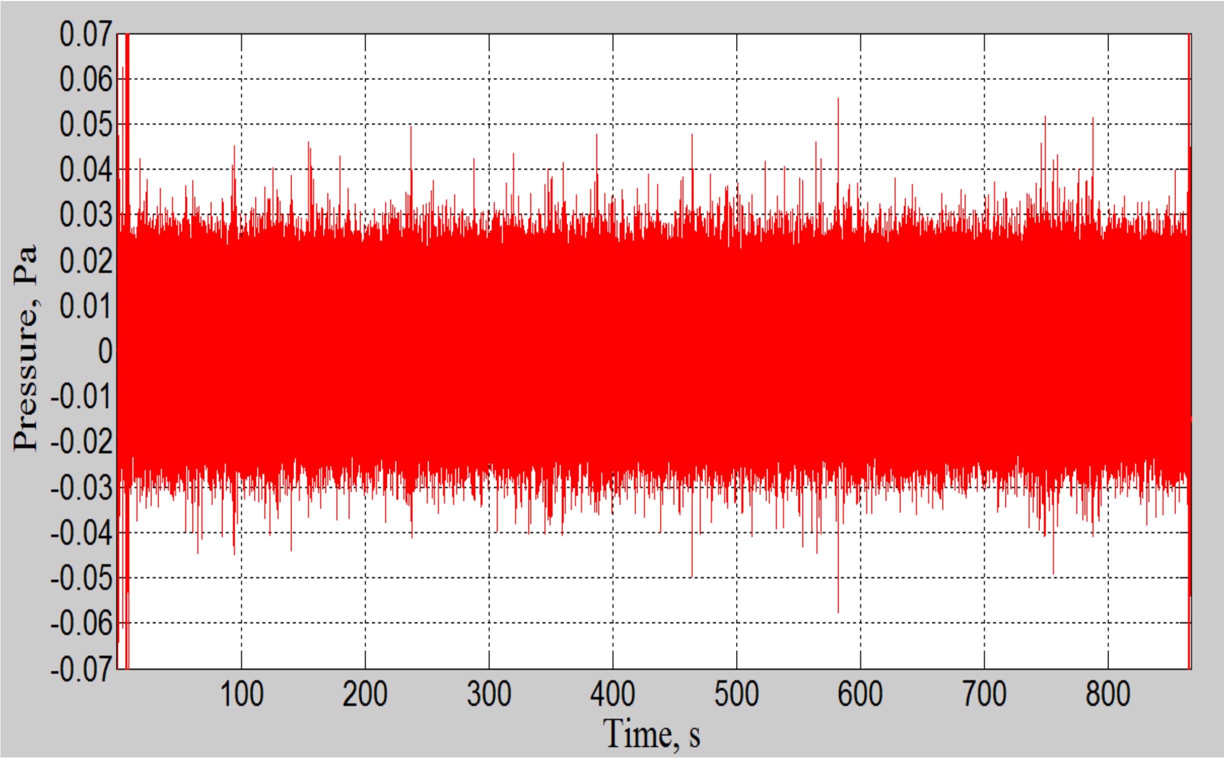


Fig 4. Time domain for the sound pressure.

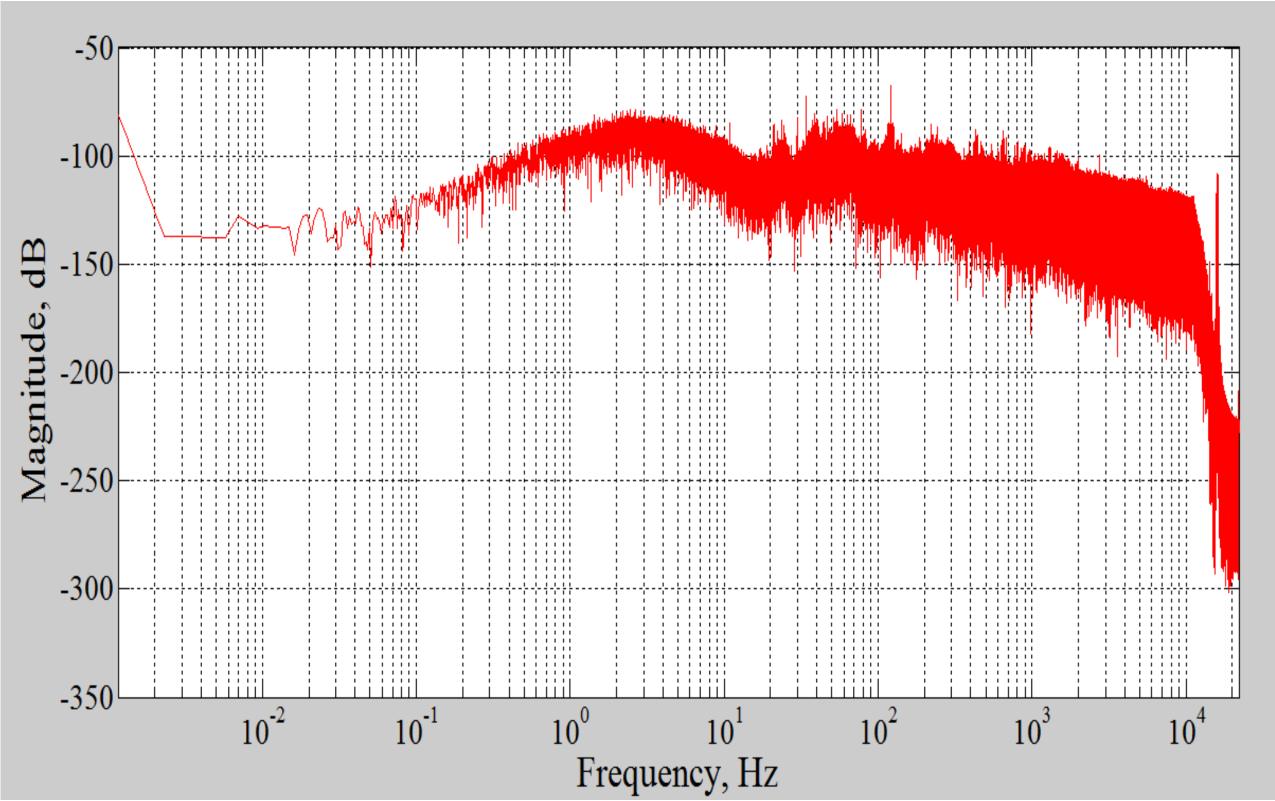


Fig 5. Frequency spectrum for the noise signal.

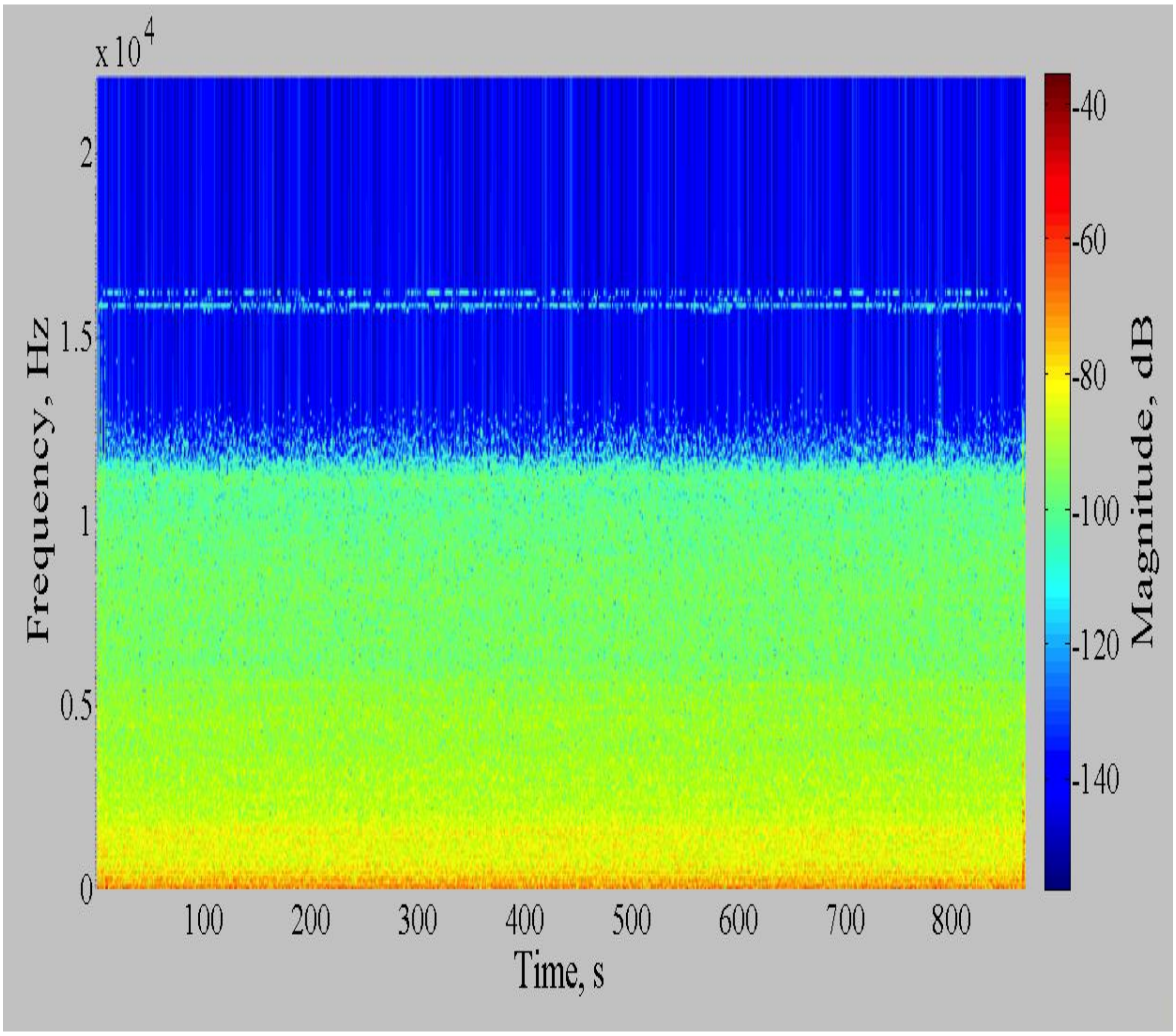


Fig 6. Frequency spectrum in time domain for the noise signal.

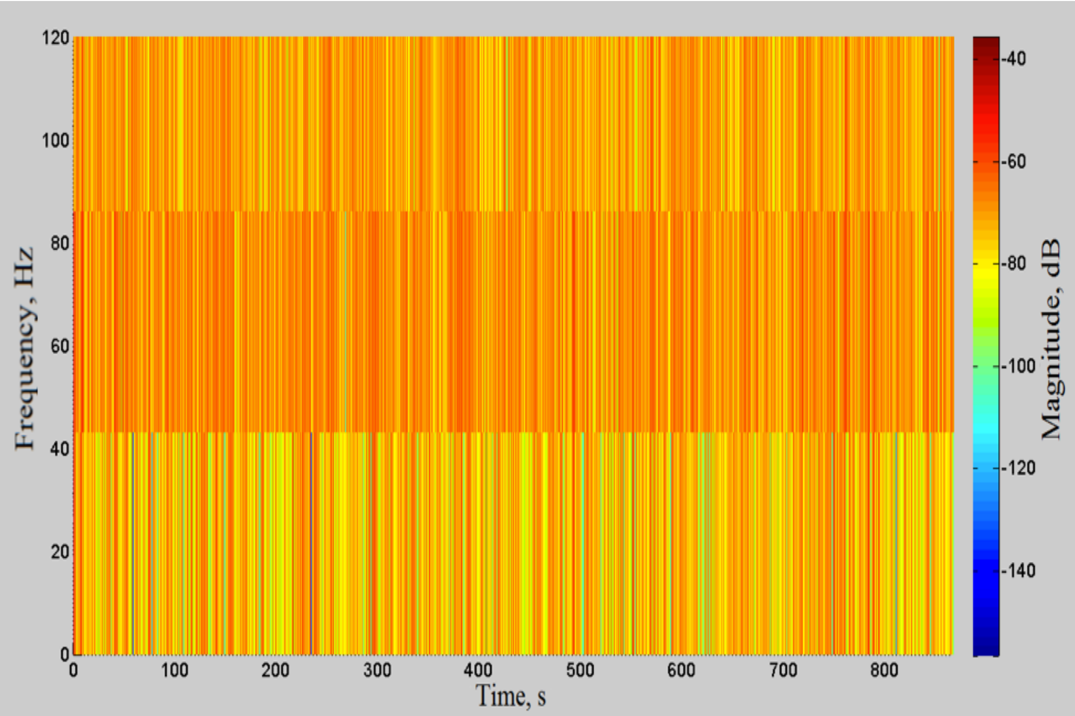


Fig 7. Spectrogram for noise signal.

4 Conclusion

In this paper, it was hypothesized that high sound level at low frequency can cause a deleterious effect on individuals who exposed to it for extended periods. Some evidence supports this theory, and this paper summarizes similar facts. The purpose was to promote more investigative work in this area and facilitate this discussion.

The impact of noise on job performance should not rely on sound level only as parameter. It should look up the frequency range of the noise too, as the frequency can influence a person's hearing ability and even mental functionality. According to this research effort, it is recommended that employees in work environments similar to the server room or data center to wear personal protective equipment until an appropriate engineering solution can be implemented to reduce noise levels.

Finally, it is recommended to collect more data from inside server rooms with different configurations, which help in investigation and validation the impact of this sort of noise on human performance in occupational environments.

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Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

Ahmed N. H. Alnauimy carried out the data collection and statistical analysis.
Michael Johnson assisted in data collection.
Rasha Hashem assisted in the Statistics.