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Digital Hearing Aid System With Noise Reduction And Frequency Shaper

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ABSTRACT

A great proportion of the human population suffers from hearing loss. Traditional analog hearing aid is same as simple radio. They can be calibrated and adjusted for volume, bass and treble. Hearing loss is not just a technical loss of volume. Hearing deficiency increases sensitivity and reduces tolerance to certain sounds. Hearing loss is a measure of shift in the auditory system compared to that of a normal ear for detection of a pure tone, But with the availability of modern-day technologies and the recent developments, artificial hearing aid systems can be designed that relax the job of damaged auditory systems to a great extent and make much of the sound available to the hearing impaired.

In this project, the simulation of the simple digital hearing aid is developed using MATLAB programming language. The implementation of this configurable digital hearing aid (DHA) system includes noise reduction filter, frequency- dependent amplification and amplitude compression. Through this project there is- reduction of white Gaussian noise, increase in the gain for frequencies which were difficult to hear, and shape the amplitude to prevent any of the frequencies from becoming too loud.

INTRODUCTION

Hearing Aids systems are one of the most important issues for human being. They are a small electronic instrument which makes sound louder and makes speech easier to hear and understand. The hearing aid is designed to pick up sound waves with a tiny microphone, change weaker sounds into louder sounds and send them to the ear through a tiny speaker. With the microchips available today, hearing aids have gotten smaller and smaller and have significantly improved quality. Roughly 10% of the world population bears from some hearing loss. However, only a portion uses hearing aid. This is due several factors which include the stigma associated with wearing a hearing aid, customer dissatisfaction with the devices not meeting their expectations, and the cost associated with the new digital versions of hearing aids. Hearing loss is typically measured as the shift in auditory threshold relative to that of a normal ear for detection of a pure tone. This is why there are many types of hearing aids with a wide range of functions and features to address individual needs.

A hearing aid is an electronic device that makes sounds louder and can help to offset hearing loss. The aim of the hearing aid is to amplify sound signals in such a way that they become audible for the hearing-impaired person. Basically, all hearing aids were using the analogue technology for the treatment of sound. Improvements have been made by using the development of digital sound treatment for the efficiency of hearing aids. Nowadays, the digital hearing aids are small, which can be hidden inside the ear and have an almost perfect sound reproduction. The research of Digital hearing aids has been growth and now a small programmable computer that are capable in amplifying millions of different sound signals had been constructed in the devices, thus improving the hearing ability of hearing-impaired people.

LITERATURE SURVEY

McCormack et al, 2013 and Chisolm et al, 2007 Suggest that 80% of adults aged 5574 years who would benefit from wearing a hearing aid do not acquire them, and that many who do acquire them do not wear them. Recent research in Australia indicates growth in hearing aid sales, but a decrease in usage. 15% of over 55 year olds in Australia own a hearing aid, but only 1 in 3 actually uses them. Hogan, 2016 suggest that aural rehabilitation that addresses the psychosocial impact of hearing impairment (e.g. through hearing therapy), as well as the functional impact (through fitting and use of a hearing aid /or other assistive technology), can reduce the perception of hearing problems and increase the use of communication strategies and use of the hearing aid.

Abrams et al, 2002 suggest that Participation in an aural rehabilitation programme, plus use of a hearing aid, provides more benefit and is more cost effective than a hearing aid alone. Kelly et al,2012 suggest that 154 older people already fitted with hearing aids, only 52% of hearing aid users reported receiving enough practical help post fitting, and only 41% reported receiving enough support. Approximately 40% reported not feeling confident in the use of their aids or their controls. Older people wanted more information than they received both before and after hearing aid fitting. Information provision and attention to the psychosocial aspects of care are key to enabling older people to adjust and optimise hearing aid benefit."

Wolfe et al,2011 suggest that a typical audiological consultation often does not extend beyond hearing aid fitting and orientation often overlooking other useful and critical components of aural rehabilitation including adjustment to amplification; listening/communication strategies; self-management of hearing loss; environmental issues; issues related to work/educational settings; speechreading; emotional factors concerning hearing loss; impact on significant others; hearing protection – all topics which should be included in counselling of hearing aid candidates. Approximately 10% of the world's population suffer from some type of hearing loss, yet only a small percentage of this statistic use a hearing aid The stigma associated with wearing a hearing aid, customer dissatisfaction with hearing aid performance, and the cost associated with a high performance solution are all causes of low market penetration.

Current analog hearing aids yield significant limitations due to their inadequate spectral shaping, narrow operating bandwidth, and only partial noise-reduction capability. This leads to sub-optimal clarity and audibility restoration, as well as sub-optimal speech perception in noisy environments. Analog hearing aids are hardware-driven and thus are difficult to customize to specific hearing problems Digital hearing aids can solve these problems. They provide full bandwidth, fine grain spectral shaping, and enhanced noise reduction. As software- driven devices, they are very flexible and easily customizable to a user's needs.

SOFTWARE REQUIREMENTS

In this chapter we will discuss and software requirements for Digital Hearing Aid System.

What is MATLAB? Programming assignments in this course will almost exclusively be performed in MATLAB, a widely used environment for technical computing with a focus on matrix operations. The name MATLAB stands for "Matrix Laboratory" and was originally designed as a tool for doing numerical computations with matrices and vectors. It has since grown into a high-performance language for technical computing. MATLAB integrates computation, visualization, and programming in an easy-to-use environment, and allows easy matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. Typical areas of use include:

- Math and Computation
- Modeling and Simulation
- Data Analysis and Visualization
- Application Development

DIGITAL HEARING AID

In this chapter we will discuss about Existing/Proposed System, block diagram and methodology for Digital Hearing Aid System.

Existing System

Digital vs analog hearing aids

Hearing aid technologies have changed over the years. Before digital hearing aids came on the scene, hearing aids were based on analog technology alone. Analog hearing aids' sound signals are continuous and uniform in flow, so the sophisticated nuances or layers of sound that digital hearing aids have are missing. Adapting to different sound environments with analog hearing aids means simply turning up the volume, which is very uncomfortable. Also, with analog hearing aids, you don't have the option to reduce background noises – they would also be amplified.

Proposed System

The Digital Hearing Aid System is designed to provide an efficient and effective solution for individuals with hearing impairments. By leveraging advanced digital signal processing algorithms and user-centric design, this system improves speech intelligibility, reduces background noise, and enhances overall sound quality. Digital hearing aid systems employ various algorithms to enhance sound quality and speech intelligibility. Additive White Gaussian Noise (AWGN) simulates real-world noise corruption, allowing developers to test algorithms' robustness in noisy conditions. Low-Pass Filter (LPF) removes high-frequency noise, preserving speech frequencies and improving signal-to- noise ratio (SNR).

Block Diagram

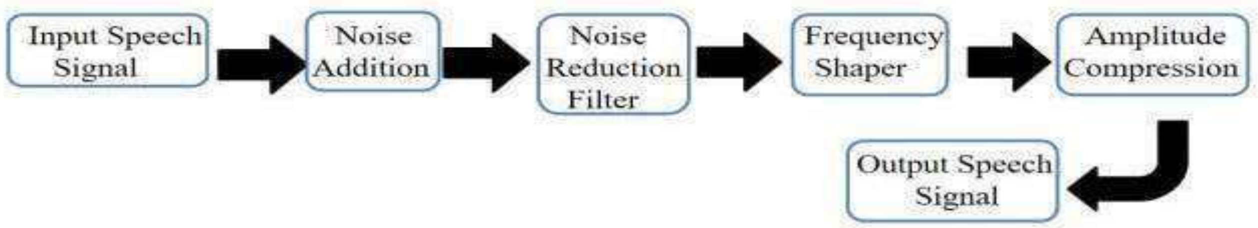

Figure 3.3: Block Diagram of Hearing Aid System

Block Diagram Steps:

- The input speech signal takes the form of human voice.
- The input speech signal will pass through several functions i.e. noise addition, noise reduction filter, frequency shaper and amplitude compression before producing an adjusted output speech signal which is audible to the hearing- impaired person.

METHODOLOGY

NOISE ADDITION

Since the input speech signal for this system is a clean signal, some noise is added in order to simulate areal situation. In this system, the Additive White Gaussian Noise (AWGN) and random noise are added to the input speech signal by using MATLAB function. The noise (AWGN) has a continuous and uniform frequency spectrum over a specified frequency band and has equal power per Hertz of this band. It consists of all frequencies at equal intensity and has a normal (Gaussian) probability density function.White Gaussian noise (WGN) has a continuous and uniform frequency spectrum over a specified frequency band and has equal power per Hertz of this band. It consists of all frequencies at equal intensity and has a normal (Gaussian) probability density function. For example, a hiss or the sound of many people talking can be modeled as WGN. Because white Gaussian noise is random, we can generate it in MATLAB using the random number generator function, random.

NOISE REDUCTION

In everyday situations, there are always external signals that may interfere with the sounds that the hearing aid user actually wants to hear. This ability to distinguish a single sound in a noisy environment is a major concern for the hearing impaired. For people with hearing loss, background noise degrades speech intelligibility more than for people with normal hearing, because there is less redundancy that allows them to recognize the speech signal. Often the problem lies not only in being able to hear the speech, but in understanding speech signals due to the effects of masking. To adjust for this loss, we developed a noise reduction filter in MATLAB for our hearing aid.

ADVANTAGES OF USING WAVELETS

Wavelets are nonlinear functions and do not remove noise by low-pass filtering like many traditional methods. Low-pass filtering approaches, which are linear time invariant, can blur the sharp features in a signal and sometimes it is difficult to separate noise from the signal where their Fourier spectra overlap. For wavelets the amplitude, instead of the location of the Fourier spectra, differ from that of the noise.

ADVANTAGES, DISADVANTAGES AND APPLICATIONS

Advantages

1. **Improved Speech Intelligibility:**

- Enhances clarity of speech, making conversations easier to understand
- Advanced algorithms analyze sound patterns, emphasizing speech frequencies
- Improves understanding in noisy environments (e.g., restaurants, meetings)
- Beneficial for individuals with speech recognition difficulties

2. **Adaptive Noise Reduction:**

- Automatically adjusts to reduce background noise
- Advanced algorithms analyze sound patterns, distinguishing speech from noise
- Improves hearing in noisy environments (e.g., traffic, construction)
- Reduces listener fatigue and stress

Disadvantages

1. **Software Updates**: Need for regular software updates to maintain performance.

2. **Complexity:** Digital hearing aids require sophisticated algorithms and processing power, making them prone to technical issues.

Applications

1. **Improve communication in everyday situations**: Help individuals hear conversations more clearly in various environments, such as at home, work, social gatherings, and restaurants.

- ➢ Enhancing speech clarity and recognition
- ➢ Reducing background noise and distractions
- ➢ Providing seamless connectivity with various devices
- ➢ Offering personalized audio experiences
- ➢ Facilitating clear communication in noisy environments

2. **Enhance participation in social activities**: Allow people to engage more actively in social settings by facilitating better listening comprehension. These systems provide improved communication, increased confidence, and enhanced social engagement, thereby reducing feelings of isolation and loneliness. With advanced features such as speech enhancement, noise reduction, directional microphones, and audio

3. streaming, digital hearing aids enable users to fully participate in various social activities.

RESULTS

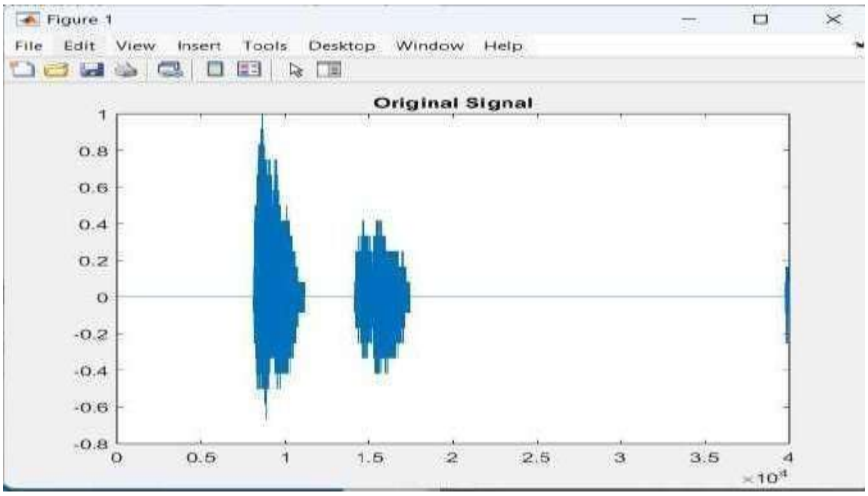

Figure 5.1: Input Signal

"Input," displays the original input sound wave, showing the amplitude of the sound signal over time. This graph provides a visual representation of the sound's characteristics, allowing for analysis and understanding of its properties

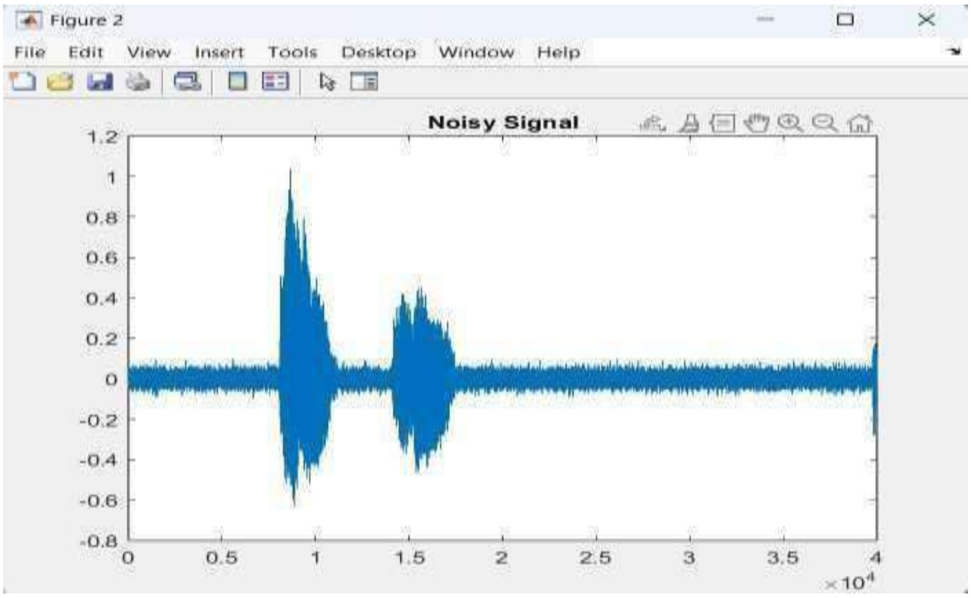

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Figure 5.2: Adding Noise Using Additive White Gaussian Noise (AWGN)

"AWGN (Additive White Gaussian Noise)," displays the input sound wave with added white Gaussian noise, simulating real-world noise corruption. This graph demonstrates the impact of noise on the original signal, highlighting the need for denoising techniques.

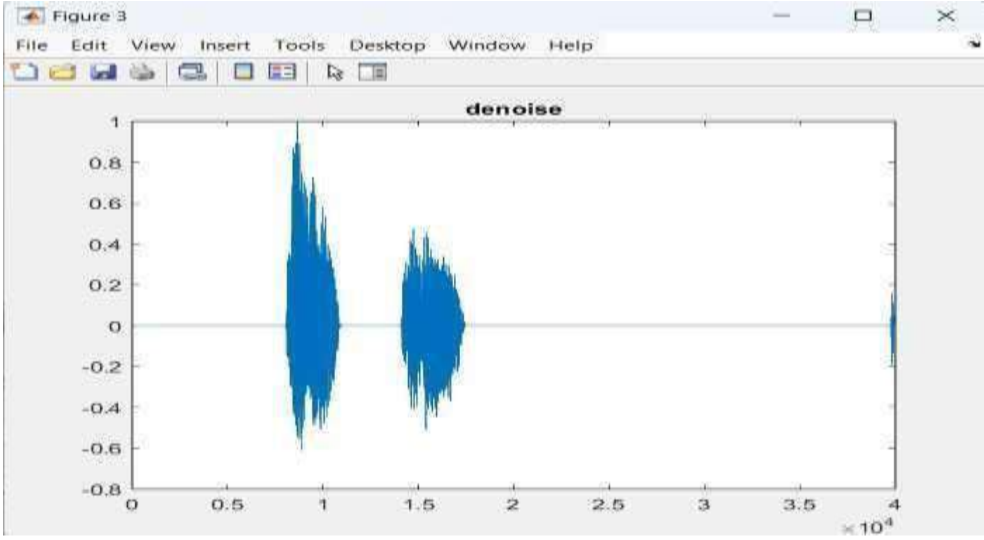

Figure 5.3: Denoised Signal Using Low Pass Filter

Denoise," displays the denoised sound wave after applying a low-pass filter to remove high frequency noise. This graph shows the effectiveness of the denoising technique in reducing noise and preserving the original signal.

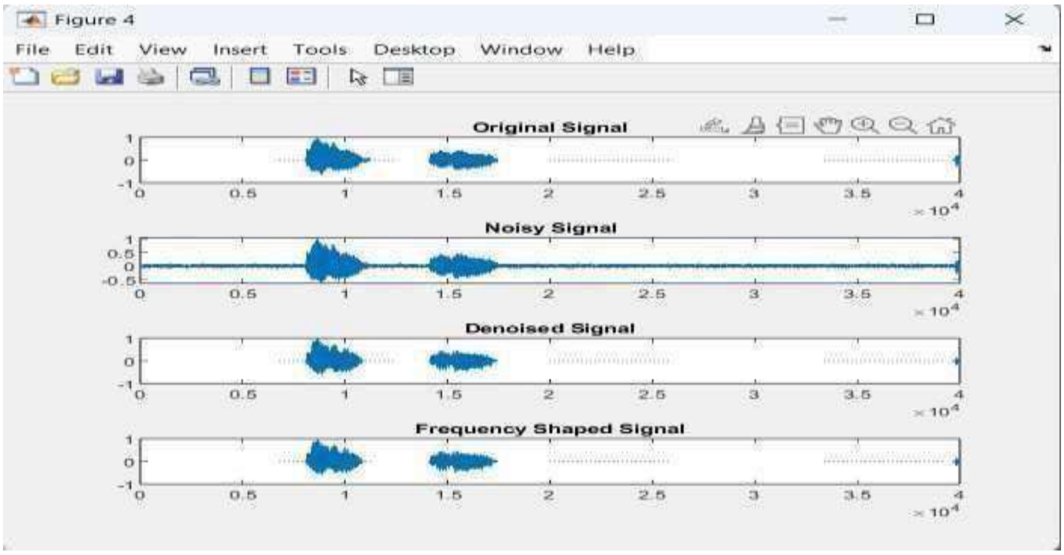

Figure 5.3: Comparison of Signals

"Freqz," displays the frequency response of the band-pass filter used for frequency shaping. This graph illustrates the passband and stopband, demonstrating the filter's ability to selectively allow or block specific frequency ranges.

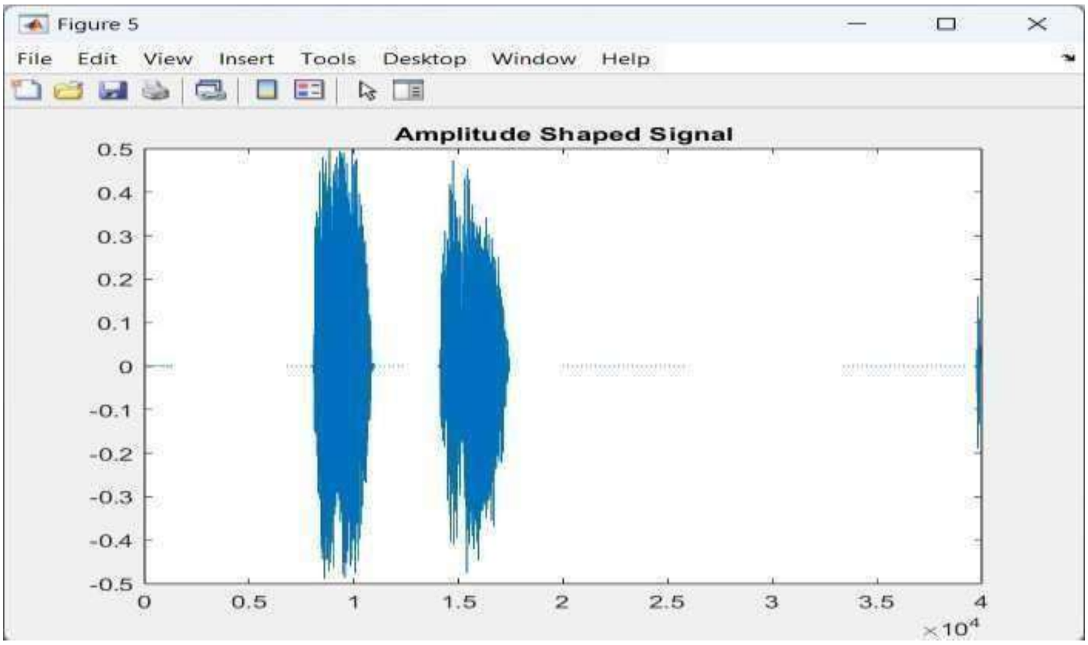

Figure 5.4: Frequency Response of Amplitude Shaping

This step applies amplitude shaping via FFT (Fast Fourier Transform) and thresholding. This process alters the amplitude of specific frequency components to achieve the desired sound characteristics.

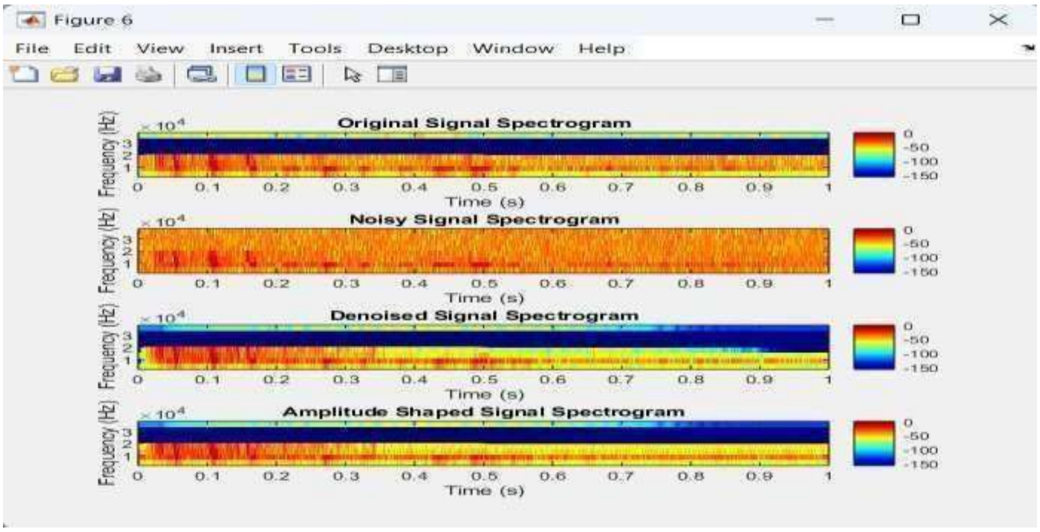

Figure 5.6: Spectrogram Signals

Finally, the spectrogram graphs provide a time-frequency distribution comparison between the original noisy signal and the adjusted signal after denoising and frequency shaping. The spectrogram of the original signal shows the impact of noise on the time frequency distribution, while the spectrogram of the adjusted signal demonstrates the effectiveness of the processing steps in improving sound quality.

CONCLUSION

In conclusion, this chapter explored the implementation, simulation and results of the project.

We proposed a newer digital aid is more capable of fine-tuning the sound without distorting the quality. In this digital hearing aids system implementation using MATLAB, sound processing is digitalized. Thus, it is possible to refine the sound signal, for instance by reducing noise and improving speech signals. Inaddition, by using digital technology, the amplification can be done only at the frequencies that the user needs to amplify. This will eliminate the problems with conventional amplifiers which amplified the whole signal including the noise. In general, digital hearing aid converts the incoming signals to digital signals. This digitalization makes it possible to precisely analyse & filter the signals. The signals can be processed in one or more frequency channels. At the end, the digital signal is again converted to its analog form. The benefits of using digital aids can improve quality of life by improving sound quality.

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