Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

(Special Issue for ITECE 2016)

Review on High Frequency hearing loss reduction methods in Digital hearing Aid.

Prashant G. Patil* — *Research Scholar*

Dr. A.K.Mittra * — *Professor & Head*

Dr.Vijay.S.Chourasia* — *Assistant Professor*

**Department Of Electronics Engineering*

**Manoharbhai Patel Institute of Technology, Gondia (M.S) India*

Abstract -A high frequency hearing loss will affect a person's ability to understand speech. People with high frequency hearing loss can hear vowels just fine, but what they can't hear are the consonant sounds of F, S, T, and Z. Additionally, they are unable to hear higher octaves, like a woman's or a child's voice, or a bird chirping. Losing hearing in those frequencies means that those sounds are harder to discern. For individuals with severe or profound hearing loss at high frequencies, it is simply not possible to restore audibility to normal levels using only amplification. As conventional hearing aids (HAs) have largely failed to provide such individuals with high-frequency cues, alternative methods of signal processing have been considered that present information from high-frequency regions of speech to lower frequency regions. The method to be discussed in this article is commonly referred to as frequency lowering (also known as frequency shifting, frequency compression, or transposition).

Keywords- Hearing Aid, frequency Transposition, High frequency, Hearing Loss.

I. Introduction

The need to communicate has yielded a vast array of inventions. The need to compute has similarly stimulated our inventiveness. According to World Health Organisation (WHO) 1 to 1.5 million Deaf peoples are found in India. The estimates vary according to how "deaf" is defined. Traditional view of hearing impaired market (Worldwide) says that 6 million peoples are wearing hearing aid & 24 millions with no hearing Aid .The reason behind not to wear Hearing aid is patient are not satisfying with hearing aid, they also demands for improvement in performance. Today 83% of all hearing aids sold which are based on digital signal processing. Many researchers have suggested we've reached the limit of what Digital Signal Processing can do; Digital Signal processors are as powerful as they can be and No more digital features left to design. Redesign, Modification of Processor will affect performance of hearing aid to overcome this drawback we need to make Hearing Aid Smart & Intelligent in certain environment. Now a day's many hearing aids available in market are working on concept of Multiband compression, Feedback cancellation, Noise reduction & Directionality. Still many of hearing aid users need improvements in following factors.

- Poor benefit from hearing aids in Background noise/noisy situations.
- Sound quality is poor.
- Volume control adjustment.
- Whistling and feedback.
- High-frequency loss not helped.
- Profound hearing loss not helped.
- Too loud & Does not work on phone.

II. Types of Hearing loss.

In general terms, there are two types of hearing loss, conductive and sensor neural. A combination of both is also seen as a mixed hearing loss. Each is discussed below

A. Conductive Hearing Loss

Conductive hearing loss is caused by any condition or disease that impedes the conveyance of sound in its mechanical form through the middle ear cavity to the inner ear. A conductive hearing loss can be the result of a blockage in the external ear canal or can be caused by any disorder that unfavourably effects the middle ear's ability to transmit the mechanical energy to the stapes footplate. This result in reduction of one of the physical attributes of sound called intensity (loudness), so the energy reaching the inner ear is lower or less intense than that in the original stimulus. Therefore, more energy is needed for the individual with a conductive hearing loss to hear sound, but once it's loud enough and the mechanical impediment is overcome, that ear works in a normal way. Generally, the cause of conductive hearing loss can be identified and treated resulting in a complete or partial improvement in hearing. Following the completion of medical treatment for cause of the conductive hearing loss, hearing aids are effective in correcting the remaining hearing loss. The audiometric profile that indicates a conductive hearing loss is the presence of air-bone gaps (better hearing by bone conduction than by air conduction), excellent word recognition at a comfortable listening level, and evidence of a middle ear dysfunction on hearing. For situations where a blockage is noted in the external ear canal, hearing testing is deferred until the canal is cleared.

B. Sensorineural Hearing Loss

The second type of hearing loss is called sensor neural hearing loss. This word can be divided into its two components - sensory and neural - to allow us more clarity in specifying the type of hearing loss. The comprehensive audiometric assessment and supplemental tests can yield the information needed to differentiate between a sensory and a neural hearing loss, although they can co-exist in the same ear. Neural hearing loss is another name for retro cochlear hearing loss. Sensor neural hearing loss results from inner ear or auditory nerve dysfunction. The sensory component may be from damage to the organ of Corti or an inability of the hair cells to stimulate the nerves of hearing or a metabolic problem in the fluids of the inner ear. The neural or retro cochlear component can be the result of severe damage to the organ of Corti that causes the nerves of hearing to degenerate or it can be an inability of the hearing nerves themselves to convey neurochemical information through the central auditory pathways.

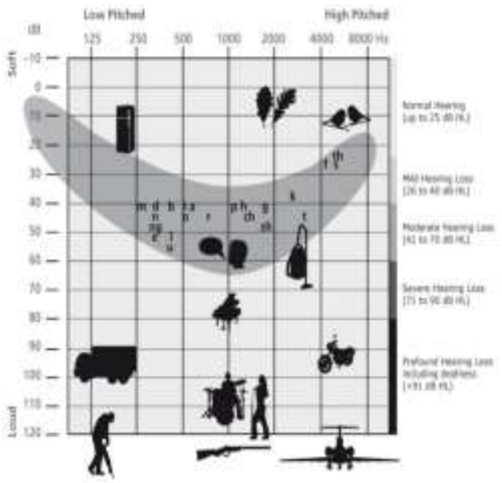
The reason for sensorineural hearing loss sometimes cannot be determined, it does not typically respond favourably to medical treatment, and it is typically described as an irreversible, permanent condition. Like conductive hearing loss, sensorineural hearing loss reduces the intensity of sound, but it might also introduce an element of distortion into what is heard resulting in sounds being unclear even when they are loud enough. Once any medically treatable conditions have been ruled out, the treatment for sensorineural hearing loss is amplification through hearing aids.

C. Mixed Hearing Loss

A mixed hearing loss can be thought of as a sensorineural hearing loss with a conductive component overlaying all or part of the audiometric range tested. So, in addition to some irreversible hearing loss caused by an inner ear or auditory nerve disorder, there is also a dysfunction of the middle ear mechanism that makes the hearing worse than the sensorineural loss alone. Hearing aids can be beneficial for persons with a mixed hearing loss, but caution must be exercised by the hearing care professional and patient if the conductive component is due to an active ear infection.

III. Causes of high frequency hearing loss:

People with high frequency hearing loss can hear vowels just fine, but what they can't hear are the consonant sounds of F, S, T, and Z. Additionally, they are unable to hear higher octaves, like a woman's or a child's voice, or a bird chirping



"*Figure 1- Loudness & Pitch map with Hearing Loss in dB***"**

- Extended exposure to loud sounds
- Diabetes due to neuropathy
- Genetics – family history
- Age – hair cells in the cochlea die off as we get older
- Acoustic neuroma.
- Infections – colds, flu, meningitis
- Otitis Media (inflammation of the middle ear)

A. Symptoms:

- Unable to hear consonants
- Inability to hear higher pitched sounds
- Tinnitus (ringing or buzzing in your ears)
- Difficulty talking in groups & Unable to hear when background noise is present

B. Prevention & Treatment of High Frequency Hearing Loss

There are many ways to prevent high-frequency hearing loss. People concerned about risks can consider various methods of hearing protection, such as ear plugs. High-frequency hearing loss can be managed by using hearing aids. Open-fit hearing aids, which leave your ear canal at least partially open, have become popular for high-frequency hearing loss. Open-fit hearing aids allow low- and mid-frequency sounds into the ear normally, so that only high-frequency sounds are amplified. People with hearing loss may experience some or all of the following problems;

- Difficulty hearing conversations, especially where there is background noise
- Hissing, roaring, or ringing in the ears (tinnitus)
- Difficulty hearing the television or radio at a normal volume
- Fatigue and irritation caused by the effort to hear
- Dizziness or problems with balance

IV. Hearing Loss Range :

When we speak of hearing loss, we mean threshold hearing points that are higher than normal. If, for example, a person has a 45 dB loss in the 4000 Hz range, it means that for him to be able to hear a sound at that frequency or pitch, the sound must be at least 45 dB in loudness. He/she cannot hear sounds below that volume at that frequency.

A. Hearing Loss and Speech Intelligibility

In the audiogram below, we can see where our basic speech sounds lies when engaging in normal conversation. Two things are important to recognize. For the most part:

1. Consonants are higher pitched than vowels (they lie more to the right on the chart).
2. Consonants are spoken more softly than vowels (they lie higher on the chart, in the lower decibel ranges).

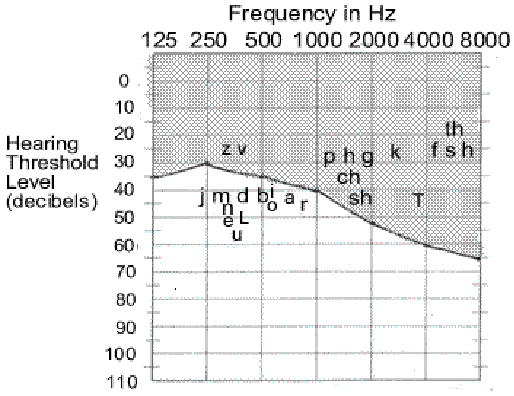
Most vowels and consonants lies in the following regions: So a person with hearing loss will have trouble hearing the consonants in the first place. He may be hanging on by a thread.

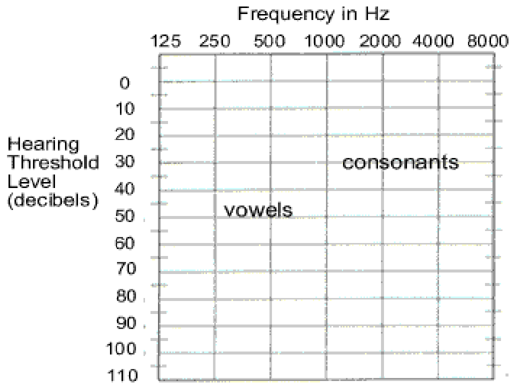
3. Consonants convey most of the word information; they are much more important to putting it together:

- Consonants are more important than vowels in understanding speech.
- Consonants are spoken more softly than vowels, and they tend to get drowned out in noisy environments.
- Consonants are higher-pitched than vowels and most hearing loss occurs in the higher frequencies.

"Table 1- Types of Hearing Loss & Symptoms".

Category	Hearing Loss Range in dB	Symptoms
Normal hearing Loss	0 - 19 dB	Normal People also having this kind of loss
Mild hearing loss	20 - 39 dB.	Unable to hear soft sounds. Cannot hear a whispered conversation in a quiet room. Can hear a normal conversation in a quiet room but has difficulty in a noisy environment
Moderate hearing loss	40-59 dB.	Has considerable difficulty hearing a normal conversation in a quiet room.If there is background noise, he/she will not be able to understand many of the words, unless he lip reads.
Severe hearing loss	60 - 89dB.	Cannot hear a conversation unless the speaker speaks loudly
Profound hearing loss.	90+ dB.	Cannot understand speech even if the person speaks very loudly. Can only hear very loud sounds such as a chainsaw.





"Figure 2- Alphabets mapping with pitch frequency & HTL in db"

V. Signal processing for removing high frequency hearing loss :

For individuals with severe or profound hearing loss at high frequencies, it is simply not possible to restore audibility to normal levels using only amplification. As conventional hearing aids (HAs) have largely failed to provide such individuals with high frequency cues, alternative methods of signal processing have been considered that present information from high-frequency regions of speech to lower frequency regions. The method to be discussed in this article is commonly referred to as frequency lowering (also known as frequency shifting, frequency compression, or transposition. These terms are often used interchangeably when describing frequency lowering techniques). For convenience, the second section of this review describes these processing techniques under the headings of channel vocoder, slow playback, transposition, and frequency compression.

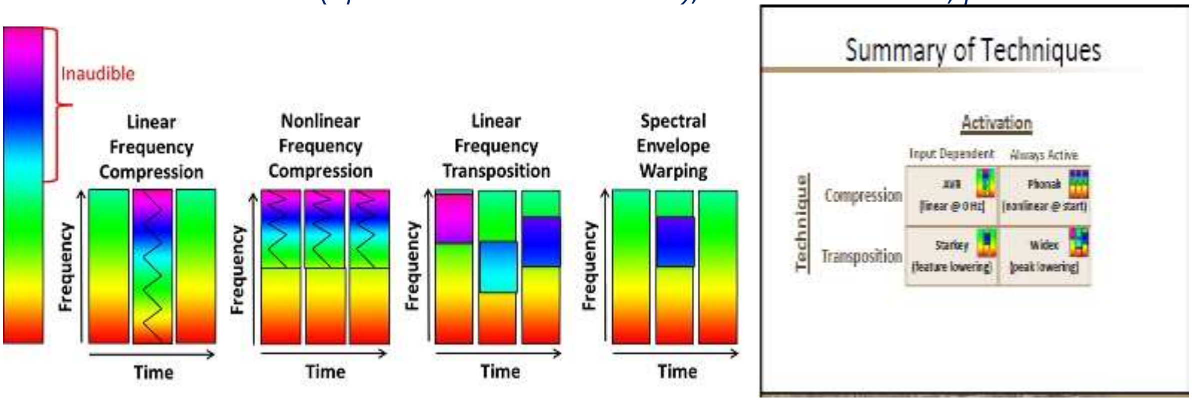
Currently five techniques are implemented in commercially available hearing aids:

- Linear frequency compression by AVR Sonovation of Israel (Introduced 1991)
- Linear frequency transposition (LFT) by Widex of Lynge, Denmark (Introduced 2006)
- Nonlinear frequency compression (NFC) by Phonak of Stafa, Switzerland (introduced 2008).
- NFC also used by Unitron of Kitchener, Ontario, Canada (starting 2012)
- Spectral envelope warping by Starkey Hearing Technologies of Minnesota ,USA (introduced 2011)

The need for compression

- The problem with linear hearing aids – the same gain is applied to all levels of input signal.
- We need high gain for low input levels, and low gain for high input levels compression.
- We need some way of automatically turning down the gain of the hearing aid as the input intensity increases.

Following figure & table will illustrate operating concept & principle of all techniques. There are certain advantages & Disadvantages of each technique.



"Figure 3- A visual representation of how different frequency lowering methods affect the signal."

"Table 2- Comparison of all techniques"

Method	Way of Processing	Advantages	Disadvantages
Transposition	Transposition Shifts high-frequency sounds to lower frequencies and adds transposed signal to unprocessed lower frequency signal	More natural sound quality, preserves harmonic relationship between frequency components	If continuously active, overlap of high and low frequencies can mask useful low-frequency information, can transpose unwanted high-frequency background noise
Nonlinear frequency compression	Lower frequencies unprocessed, higher frequencies compressed in greater amounts	More natural sound quality, preservation of vowel intelligibility, no overlap in frequency information	Does not preserve harmonic relationship between frequency components
Frequency shifting	Lowers all frequency components downward by a constant factor	Preserves harmonic relationship between frequency components	Lowers pitch of speaker, unnatural sound quality
Slow playback	Records segments of the speech signal and then plays these segments back at a slower speed than that used in the original recording	Preserves harmonic relationship between frequency components	Segment deletion can cause distortion or discard useful speech information, signal stretched in time

"Table 3- Literature review on high frequency loss reduction in Digital Hearing Aid"

Sr No	Author/s (Year Published)	Signal Processing method in hearing Aid	No. of HA User	Outcome Measures	Training Details	Results
1	Ling (1968)	Channel vocoder	8	Vowel and consonant discrimination, word recognition	No training	
2	Ling and	Channel	18	Nonsense syllables	No training	

	Maretic (1971)	vocoder				
3	Beasley, Mosher, and Orchik (1976)	Slow playback	9	Picture plates	No training	
4	Rosenhouse (1990)	AVR transonic (slow playback)	1	Aided thresholds, environmental and Ling sounds	No training	
5	Rees and Velmans (1993)	Transposition	8	Monosyllabic words, nonsense syllables	No training	
6	Parent, Chmiel, and Jerger (1997)	AVR transonic (slow playback)	4	Spondees, vowel and consonant recognition, monosyllabic words, sentence	Take-home use of 4 to 6 weeks	2 participants showed average improvement of 22% for sentences with device
7	Turner and Hurtig (1999)	Linear frequency shifting	15	Closed-set testing of consonant–vowel nonsense syllables	Up to 10 training sessions with materials similar to that used for testing	50 % group showed improvements & 7% on average when listening to a female speaker
8	McDermott, Dorkos, Dean, & Ching (1999)	AVR transonic (slow playback)	5	Sentences and consonants in quiet	Take-home use of 12 weeks	2 participants showed statistically significant improvement of 10% to 30%
9	McDermott and Dean (2000)	Linear frequency shifting	6	Monosyllabic words	A total of 10 training sessions of 1 hour duration using vowel stimuli	No statistically significant improvements reported for the group for frequency-shiftedspeech
10	Sakamoto, Goto, Tateno, and Kaga (2000)	Nonlinear frequency compression	5	Sentences recognition	Take-home use of 1 to 2 weeks.	No participant showed statistically significant improvement with device
11	McDermott and Knight (2001)	AVR ImpaCt (slow playback)	3	Monosyllabic words, consonants, and sentences in noise	Take-home use of 6 weeks	No participant showed statistically significant improvement with device
12	MacArdle et al. (2001)	AVR transonic (slow playback)	11	Aided thresholds, speech intelligibility ratings, closed-set speech testing	Live Demonstration	
13	Miller-Hansen,	AVR transonic (slow playback)	19	Aided thresholds, word	Live Demonstration	

	Nelson, Widen, (2003)			recognition testing		
14	Simpson, Hersbach, and McDermott (2005)	Nonlinear frequency compression	17	Monosyllabic words	Take-home use of 4 to 5 weeks	Eight participants showed statistically significant improvement with device with a mean group improvement of 6% for phoneme scores
15	Simpson, Hersbach, and McDermott (2006)	Nonlinear frequency compression	7	Monosyllabic words, sentences in noise	Take-home use of 3 to 4 weeks	No participant showed statistically significant improvement
16	Kuk (2007)	Transposition	13	Nonsense syllables	Take-home use of 2 weeks	Average group improvement of 3-6% for vowels and consonants
17	Robinson, Baer, and Moore (2007)	Transposition	7	Nonsense syllables	Three to four training sessions of 2 hours duration with materials similar to that used for testing	Average statistically significant group improvement of 20% for affricates
18	Gifford, Dorman, Spahr, and McKarns (2007)	AVR Nano Xp (slow playback)	6	Monosyllabic words, sentences in quiet and in noise	Take-home use of 5 weeks	2 participants showed improvement with device, with average improvement of 17%
19	Glista et al. (2009)	Nonlinear frequency compression	13	Ling sound test, consonant and vowel recognition, and plural recognition	Take-home use of 4 weeks	Eight adults showed statistically significant improvement with device
20	Glista, Scollie, Bagatto, Seewald, and Johnson (2009)	Nonlinear frequency compression	11	consonant and vowel recognition, & plural recognition	2-3 Weeks (take Home)	
21	Xianbo xieo Hui zhuang Guangshu Hu Chanhong Hu Jia liu (2009)	By setting parameters for Vowels & consonants and uses overlapping ,squeezed method	6	Vowels Consonants Syllables Mono syllables Words Short Sentences	Comparing with users previous hearing Aid & new algorithm	Significant Improvement In all types
22	Hugh J.	LFT, NLFC	--	Sinusoids, flute	Spectral analyses	Significant

	McDermott (2011)	(According to User Parameter Fitting)		sounds, speech material.	on the output signals produced by the hearing aids in each condition	improvement in both LFT & NLFC
23	Mohammed Alnahwi, Zeinab A AlQudehy (2015)	Comparison Between FT & FL method	376	Vowels Consonants Syllables Mono syllables Words Short Sentences		FC showed benefit (91%) compared with children who benefited from FT (70%).

VI. Conclusion

Providing high-frequency information successfully is important for both male & female hearing aid user who uses these cues to learn articulation of sounds as well as many grammatical rules. Despite improved technology, today's conventional hearing devices are still far from providing improved speech recognition for severe high-frequency hearing loss. With this challenge in mind, an alternative to current amplification techniques is to shift high-frequency components of a signal into a lower frequency region. These schemes are beginning to show successful outcomes for individuals with high-frequency hearing loss. Mean while there are lot of improvement required in terms of consonants, vowels recognition. These algorithm needs to work & modification required for different languages .

VII. References

[1] FranciscoJ Fraga,Letica Pimenta C,S prates, Alan M Marotta, "frequency lowering Algorithms for Hearing Impaired, "A Text book of Speech technologies", Book Chapter 18 , pp. 361 -388.
[2] Alexander J.M. (2012). Nonlinear frequency compression: Balancing start frequency and compression ratio. 39th Annual meeting of the American Auditory Society, Scottsdale, AZ.
[3] Alexander J.M. (2013). Individual variability in recognition of frequency-lowered speech. Seminars in Hearing, 34, 86-109.
[4] Danielle Glista, Susan Scollie, Marlene Bagatto, Richard Seewald, Vijay Parsa, Andrew Johnson, "Evaluation of nonlinear frequency compression: Clinical outcomes". International Journal of Audiology 2009; 48: pp 632644
[5] Harry Levitt, "A Historical Perspective on Digital Hearing Aids: How Digital Technology Has Changed Modern Hearing Aids", Trends in Amplification Volume 11 Number 1,March 2007.pp 7-24
[6] Joshua M. Alexander, "Individual Variability in Recognition of Frequency-Lowered Speech", Seminars in Hearing, Volume 34, Number 2 ,2013
[7] Francis Kuk, "Considerations in Verifying Frequency Lowering", Published on January 19, 2013. International Journal of Audiology 2013(online).
[8] Francis Kuk, Denise Keenan, Jane Auriemmo, Petri Korhonen, Heidi Peeters, Chi Lau, and Bryan Crose, "Interpreting the efficacy of frequency-lowering algorithms". The Hearing Journal, April 2010, Vol. 63, No. 4
[9] Xianbo Xiao , Hui Zhang , Guangshu Hu, Chunhong Liu , Jia Liu , "Evaluation of frequency-lowering algorithms for intelligibility of Chinese speech in hearing-aid users", Progress in Natural Science 19 (2009), 741–749, Available online at www.sciencedirect.com.
[10] Hugh J. McDermott, "A Technical Comparison of Digital Frequency-Lowering Algorithms Available in Two Current Hearing Aids,. Published at "PLoS ONE" July 2011 , Volume 6 ,Issue 7 , e22358.
[11] Hartmut Traunmüller and Anders Eriksson, "The frequency range of the voice fundamental in the speech of male and female adults". Acustica 50, pp 118–125.
[12] J Gou, J Smith, J Valero, I Rubio, "The Effect of Frequency Transposition on Speech Perception in Adolescents and Young Adults with Profound Hearing Loss". Deafness & education international, Vol. 13 No. 1, March, 2011, 17–33.
[13] Andrea Simpson, "Frequency-Lowering Devices for Managing High-Frequency Hearing Loss: A Review", Trends in Amplification, Volume 13, Number 2, June 2009, 87-106.
[14] Vijay Parsa, Susan Scollie, Danielle Glista and Andreas Seelisch, "Nonlinear Frequency Compression: Effects on Sound Quality Ratings of Speech and Music", Trends in Amplification 17(1), 54–68.
[15] Silvia Allegro, Olegs Timms, Hersbach, "Method for Frequency Transposition and use of the method in a hearing device & communication device". United States Patent, US007248711B2.

[16] Andreas Tiefenau,Zaandam , “Method for frequency Transposition for Hearing Aid”, United States Patent, US 20110142271Al.
[17] Ying-Yee Kong , Ala Mullangi, “On the development of a frequency-lowering system that enhances place-of-articulation perception”, Speech Communication 54 (2012) 147–160, Available online at www.sciencedirect.com.
[18] http://www.languagesgulper.com/eng/Marathi.html
[19] http://www.audiologyonline.com/articles/highs-and-lows-frequency