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Hearing Aid Technology

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Introduction

Increasing signal-to-noise ratio is proven to improve speech discrimination in the presence of background noise [1]. This statement describes one of the most important research and development fields for the hearing aid manufacturers. It includes two crucial elements which also can be described as two major goals for a hearing aid audiologist. The first goal is the invigoration of speech intelligibility and the second goal is the limitation of the background noise. The connection between these two goals is that by achieving the second one, the attainment of the first goal is being facilitated.

From the linear amplification (with analogue hearing aids) era until today there has been outstanding progress in signal-to-noise ratio improvement. Nowadays hearing aid technology has introduced a wide range of features in order hearing aids to provide better speech discrimination especially in the presence of background noise. We are going to present and analyze the main technological features of modern hearing aids which are responsible for this result.

One of the basic limitations of hearing aids, in general, is the ability to provide better hearing especially in noisy environments. Speech discrimination is the cornerstone of this issue. It is a fact that the modern hearing aid technology has contributed to improve the results of hearing aid fittings. In other words the everyday practice for a hearing aid audiologist has become much easier. This has happened because clients nowadays are more satisfied and that has also changed the way the clients think about hearing aids and aural rehabilitation in general. Customers' satisfaction is finally the ultimate goal for both hearing aid manufacturers and audiologists. New technology achievements give the ability to the professional to propose new products to customers having the confidence for a better result.

The previous years, the mission of both manufacturers and dispensers was much more difficult, especially, when the hearing impairment was sensorineural. In other words, analogue technology was not efficient enough to cope with this type of hearing loss. The main reason of course was the basic characteristics of sensorineural hearing loss such as loudness recruitment and high frequency hearing loss. With analogue technology the amplification was linear so there was not the ability for compression adjustments and also for fine tuning [2]. Consequently, as it was mentioned in the beginning the results of dispensing linear amplification were not satisfactory enough.

Consider that we are counseling a customer with bilateral sensorineural hearing loss that currently has a monaural analog fitting. The client is at working age, fit and able, socially active with a family. Our target is to propose to the client to switch from the monaural analog fitting to binaural digital fitting. We are going to analyze the technological features and evaluate the benefits of the new fitting, regarding the increase of signal to noise ratio. For this reason, our product suggestion to the client is a high-end model from the latest product family of "Thrive" from Microtech Hearing Technologies. The product is a pair of receiver-in-canal hearing aids called "Thrive w50", featuring the latest technological updates from the manufacturer's portfolio.

Analogue and Digital Technology

It is high unlikely nowadays to expect someone to wear a hearing aid with analogue technology. Since 1996 when Widex successfully commercialize the first fully digital hearing aid [3], there has been a tremendous evolution on digital signal processing with great benefits for the hearing aid user. This fact has led most of the users, driven by their practitioners, to switch from analogue to digital technology.

At this point it is purposive to give a definition of a hearing aid. "A hearing aid system is a device, which should enable a hearing impaired person to make the maximum use of his/her residual hearing. It should provide optimum speech intelligibility and the maximum amount of useful information from all other sounds, with a minimum of distortion and interference from unwanted background noise [4]." From this definition we may distinguish two concepts: "speech intelligibility" and "background noise".

Hearing aid technology is based on the relation between these two conflicting evidence. In order to optimize the first and

minimize the second, hearing aid manufacturers have finally introduced digital signal processing. In other words, after years of research, analogue technology was replaced first by digitally programmable hearing aids and finally by fully digital devices. This transition was not smooth from the very beginning. There are some reasons to explain this situation. First of all, it was the habituation of users to analogue sound. Some hearing aid dispensers did not have the patience or the knowledge to inform the client effectively. Transition always takes time. Some studies refer that at least a three-month time is required for the user to habituate to the new sound. Another reason was the dispensers' lack of experience to control features as compression and fitting formulas.

There have been clinical studies that dealt with the comparison between analogue and digital hearing aids [5]. These studies were focused especially on the final result which was nothing but the clients' satisfaction level. The characteristics of analogue technology are inferior to digital technology. First of all an analogue hearing device is not efficient to cope with sensorineural hearing loss especially because of the absence of compression features. Directionality, noise reduction strategies and wireless connectivity are features that are not included in the portfolio of an analogue device. As a consequence, for all the features mentioned above, the client is proposed to replace their analogue monaural fitting with contemporary digital technology. Our target is also to convince the client to wear two hearing aids instead of one. We are going to present the benefits of this proposal by analyzing the applied technology for each aspect of the new fitting.

Benefits of using two hearing aids instead of one and wireless connectivity

Almost every person who dispenses hearing aids has met a potential client who has insisted on wearing one hearing device even if his/her hearing loss was bilateral. When a hearing impaired person asks for assistance, there are some factors that affect the way of how the client behaves. Stigma is a social factor that impedes the customer from accepting the optimum solution for the rehabilitation [6]. Most of the customers ask for an invisible solution regardless the level of hearing loss. Of course most of them feel more comfortable by wearing one hearing aid. Another reason for that is also the financial issue. A hearing aid audiologist must be able to explain the benefits of wearing two hearing aids to a person with bilateral hearing loss.

Taking as granted that we refer to a person with bilateral sensorineural hearing loss (BSNHL), the choice of wearing two hearing aids over a single hearing aid has multiple benefits. Previously we have presented a definition of a hearing aid. The definition describes a hearing aid as a device that enables the user to achieve the maximum use of the residual hearing. Therefore, it is obvious that two hearing aids maximize the likelihood for better hearing. In other words, bilateral fitting doubles the opportunity for the auditory system to receive the signal from a sound source [7].

Before presenting the benefits of using two hearing aids for a BSNHL it is useful to define the terms binaural and bilateral in order to avoid confusion from the following analysis. We consider bilateral fitting simply as the fitting of hearing aids in both ears, whilst binaural hearing is the summation of signals end up at two ears independently [8]. According to Mencher and Davis [9-12] bilateral amplification may positive affect:

a) Speech intelligibility in noise

b) Localization

c) Sound quality

d) Tinnitus suppression

e) Directionality (Analysis in a special section)

Speech intelligibility, as a reflection of communication, is undoubtedly the main reason for someone to use a bilateral fitting. It is also the major target for both hearing aid audiologists and manufacturers. There are studies that search the results from bilateral fitting in both noisy and quiet environments. Initially the results from these original studies were conflicting. Some studies proved that bilateral amplification was better and some other ended up to the conclusion that there was no significant difference between bilateral & unilateral fittings. A number of early studies were criticized especially because the test environment was not representative of real situations. This situation led to the devaluation of the benefits of bilateral fittings [13]. Much clearer conclusions has been reached with recent studies that aimed to create a representative to the real world test environment. Researchers has Kobler & Rosenhall [14-16] proved the superiority of bilateral fitting over the usage of one hearing aid and unaided conditions.

Localization is an element truly improved by bilateral amplification. Suppose that someone with BSNHL chooses a unilateral amplification. We may consider that the hearing loss is balanced. The sound signal form a source, under specific circumstances, will arrive almost at the same time in both ears but it will be significantly more audible from the aided ear. Even if the sound source is located from the side or closer to the unaided ear, the signal will arrive stronger in the aided ear. It is often observed the fact someone with unilateral fitting to response to a signal by turning the head from the side of the aided ear, even if the signal is coming from the opposite side. This lack of localization most of the times is embarrassing but sometimes could be proved extremely dangerous. A useful example is when someone with one hearing aid crosses the road and pays attention by hearing a car passing from the side of the hearing aid, but the car is approaching from the unaided side. Localization is truly a very useful matter for everyday life and every potential client should be counseled about the benefits of using bilateral amplification.

Sound quality is a sum of characteristics such as clarity, fullness, loudness and naturalness [15]. There are studies that prove bilateral amplification to improve these elements. Balfour

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& Hawkins [17-20] tested eight sound quality elements for subjects with mild to moderate hearing loss, having bilateral and unilateral fittings. They tried to create a real-life simulation, such as speech in quiet and noise or music in different environments (test booth, living room and concert hall). The results were a clear precedence for bilateral fittings. The subjects underlined especially the importance of clarity which was been enhanced with bilateral amplification. These findings were in accordance with other researchers [21-25] providing once more a clear view about the advantages of bilateral fitting especially with the presence of background noise.

There are many studies clearly prove that bilateral hearing aid use provides more efficient tinnitus suppression comparing to unilateral fittings. Brooks & Bulmer [26,27] created a questionnaire in order to examine the possible difference of tinnitus reduction between unilateral and bilateral fittings. The results from this study have shown a clear preference for bilateral hearing aid usage. Being more specific, 66,52% of the bilaterally aided subjects reported tinnitus suppression. On the contrary, only 12,7% of unilateral aided user reported the same result. Other studies followed [15,28] enhanced the conclusion that hearing aids, especially bilateral fittings, may reduce tinnitus effect.

Latest technology in hearing aid industry has introduced innovations which have improved the performance of hearing devices in general. Such a feature is wireless connectivity between hearing aids and also with extra assistive devices. Wireless connectivity is based on an ear-to ear communication protocol. Starkey laboratories have developed "Binaural Spatial Mapping" [29-31]. This protocol has been designed to perpetually analyze the acoustic environment so as to adjust the signal processing strategy of the hearing aids. Directional microphones play an important role for this procedure. We are going to analyze their benefits later on. For wireless connectivity the signal processing strategy is very important because it improves speech intelligibility and moreover it provides comfort in noisy environments.

A real-life problem for hearing aid users is the quality of hearing in reverberant situations. Reverberation is the result from the reflection of sound on objects, walls or windows. When reverberation is combined with presence of speech in special situations, usually referred as "cocktail party problem" [25-30], the difficulty for the user is enhanced. The customer's hearing aids have the ability to detect such situations, through "Binaural Speech Mapping" and reduce the effect of the incoming delayed copies of the original input. This feature is added to general noise reduction strategy in order to provide the best possible speech intelligibility. There are also similar solutions on the market to solve the problem of reverberation. EchoBlock by Phonak is a technology that promises to offer comfort and clear speech perception in reverberant situations [20].

Another interesting feature for the hearing aid wearer is the connectivity of wireless hearing aids with extra assistive devices. These devices stream the sound from a source directly to the hearing aids. The most integrated device within Microtech model range is the "SurfLink mobile 2". This device is connectable with any sound source such as television, mobile phone, music player and streams the sound signal directly to the hearing aids' receivers. The user can also select to have the hearing aids' microphones on or off depending to his/her needs. So they are able to select the optimum combination for streaming sound from the target source and environmental sound. "SurfLink mobile 2" has also the ability to be used as a remote microphone. This characteristic is very important for lectures where for example a student can place the device in front of the lecturer so that the speech will be streamed directly to the hearing aids [26] In conclusion, under special circumstances the direct sound streaming is an ideal way to increase signal to noise ratio and improve target source discrimination especially in the presence of background noise.

Multichannel technology

The evolution of multichannel technology has accelerated while digital hearing aids develop. Before the benefits of this technology will be explained, it is useful to define the difference between channels and bands. The frequency range is divided in bands where we are able to control the gain on each band separately. From the other hand a channel is a frequency region where we are able to control the process of the input. In other words factors like compression and noise reduction can be adjusted within the channel region [10]. A hearing aid with more channels can be fine tuned more precisely. An important contribution of multiple channels is on the management of multichannel compression a feature which will be analyzed in a special chapter. Usually the entry level models have two to four channels, while the hi-end models are usually equipped with more than 12 channels.

Hearing aid manufacturers often use the number of channels as a marketing tool: The higher the number, the better the performance. From the other hand companies like Bernafon have introduced the channel-free technology which is a completely different approach and contrary to the general competition between the companies. Channel-free technology does not divide the frequency range into channels but the system is focused on phonemes and provides amplification depending on the intensity of the signal. Being more accurate vowels need less amplification while consonants need more [15]. The reason of presenting this technology is to make clear that there have been different approaches in the market opposed to the "number of channels" competition. It is also interesting to refer to the fact that the hi-end model range of Siemens is equipped a 48-channel signal processing element [27], while the top of the range models of Microtech are using a 16-channel system [29]. In conclusion, the intension is to prove that any manufacturer has a different philosophy for the optimum number of channels. Of course this does not weaken the importance of multichannel technology but to underline the importance of the other technological features within a hearing aid.

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It is certain that within the model range of a hearing aid manufacturer, the entry level models have the lower number of channels while the hi-end models have the maximum number. So it is obvious that, within the model range of any manufacturer, the performance of a hearing aid is associated with the number of channels. With multichannel technology the hearing aid specialist is able to provide the best possible fine tuning to the client. The substantial benefits from this technology are strongly associated both with the dimension of the bandwidth and the other technological features within the hearing aid processor. A bigger bandwidth provides more natural sound while features like noise reduction and speed intelligibility strategies act additionally and can be fine tuned more precisely with multichannel technology.

There are some studies trying to define the optimal number of channels that maximize the benefits for the wearer. Rickert et al. [21] had come to the conclusion that the optimal number of channels is four. It is obvious that the reader should be highly cautious about the results of this study. Nowadays, the existence of multichannel hearing aids (up to 48 channels) proves the different opinion from the market. Referring to our customer's, the suggested hearing aids are equipped with a 16-channel processor which is the maximum number of channels on the model range of the specific manufacturer. This feature provides the dispenser a greater ability for fine tuning, so the customer is able to customize their hearing according to their needs.

In conclusion we must underline once more that the number of channels is not the factor that will judge the general performance of the hearing aid. If we compare the performance of two hearing aids, from each different manufacturer, with the same number of channels, we do not expect the same results and benefits for the customer. So it is obvious that indeed multichannel technology is valuable for the best hearing result but with conjunction with the other technological features that have been developed on the market through years of research.

Directional microphones and adaptive directionality

Directional microphone technology was introduced in the late 60's. More specifically, in 1969 Willco -a German company owned by Maico electronics – presented the first hearing aid with a directional microphone [15]. Originally this technology had been considered too sophisticated, so it was equipped only in special (& expensive) models. Nowadays directional microphones are considered as a standard feature at the most of the latest hearing aid models [22].

In antithesis with omni-directional microphones which receive sound signal from every direction, directional microphones have the ability to suppress sounds originating from specific directions. In other words, they can focus on specific sources thus exclude some others. The philosophy behind the development of directional technology is imitation of human pinna which is designed to focus forward. Apart from improvement of sound localization and discrimination, the basic advantage of directional microphones is better speech intelligibility in noise and so the improvement of signal-to-noise ratio [19]. This advantage depends on every real-world environment. For example when the noise comes from the back of the hearing aid user, the reduction could be about twenty decibels but if the noise comes from all around the difference is three to five decibels. Of course all these measurements vary according to the design of the microphone. Another interesting point is that, with omni-directional microphones, subjects who are able to understand 20-30% of words in cues, could reach a score about 50-85% with directional microphones [10].

The way a directional microphone manipulates the environmental sound is based on its construction. This kind of microphone has two entry ports; one on the front side and on the rear side. When a sound (background noise) reaches the rear port, it is delayed in order to reach the microphone at the same time with the background noise coming from the front port. The result from that is the cancellation of both inputs which increases the signal to noise ratio [19].

The evolution of hearing aid technology has brought improvements and innovations. Nowadays most of modern hearing aids are equipped with two microphones in order to improve directionality. Dual microphone devices have the ability to switch from omni-directional to directional and provide the best possible result. Initially this feature was controlled manually by the wearer. Nowadays, it is fully automatic in almost every contemporary hearing aid model. Another more interesting feature though in microphone technology is adaptive directionality. This feature is the ability of the hearing aid to control the polar sensitivity of a directional microphone. The polar sensitivity, in other words, is the capability of the microphone to have minimum sensitivity towards the direction where there is a presence of background noise. There are some elements that affect the polar sensitivity of a directional microphone such as: The distance between the ports, the angle of the ports, the style and shape of the hearing device, the time delay strategy. A more clear view can be obtained by presenting the polar diagram. It is the image which describes the different types of polar sensitivity in comparison with the omni-directional status [19] (Figure 1).

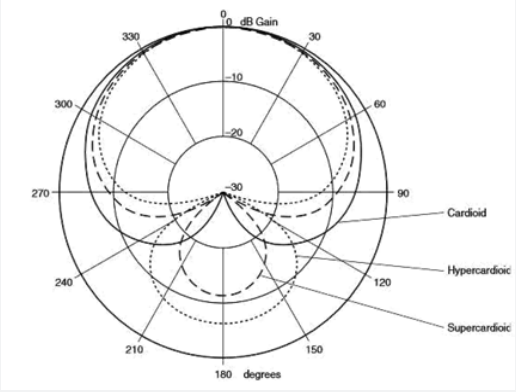

Figure 1: Polar diagram [2].

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As we can observe, there are some different types of polar sensitivity. This is the results of changing the elements we have mentioned before. These types (cardioid, supercardioid and hypercardioid) are the different approaches for noise management, especially when this noise comes from behind. Adaptive directionality is mixing these different polar patterns in order to achieve a better signal to noise ratio. It is also important to mention that the benefits of adaptive directionality are enhanced especially at multi-channel hearing aids where the devices have the capability to generate different directional patterns at any frequency range [10].

Regarding the client, the hearing aids that we recommend are equipped with new directional technology features. The first element is called "Acuity Directionality". This feature is designed in order to minimize the "drift effect". More particularly, this effect is the performance reduction of the hearing aid over time. In other words, factors like dust, humidity and environmental contamination affect the operation of the ports, time delay management and the polar pattern. So through time, a directional microphone tends to operate more like an omni directional one, affecting negatively of course the signal to noise ratio. Starkey hearing technologies have created a new dual microphone directional system which is fully adaptive and automatically switching. The key element of this system, in order to confront with the drift effect, is the special type of the microphones; micro-electronic-mechanical-systems (MEMS) technology is the base of these microphones which are made of a special silicon crystal. This material has better resistant to all environmental factors mentioned before. In terms of performance over time, MEMS microphones are more stable, in comparison with the standard electret option. In conclusion, as the good-performance period is expanded, the client is able to enjoy the benefits of adaptive directionality for a longer period of time [10].

The other new directional feature of the recommended hearing aids is called "Speech ID". This system is able to exclude meaningful sounds coming from the back or the side of the wearer. In other words when the directional microphones detect speech behind the user they function like an omni directional for the speech frequency range and render this signal more audible. Another interesting part is that, by using this feature, the microphones are able to "follow" the speaker when he/she moves by changing the directionality and provide audible speech at any speaker's position [10].

Methods / Approaches to noise reduction

Noise reduction is a field for research and also for competition to all hearing aid manufacturers. Apart from the important role of binaural speech mapping and directionality, as they mentioned before, there are additional approaches regarding noise reduction. These methods are generally referred to the sound processing element of a hearing aid. First of all it should be mentioned that the original way to manipulate noise is the volume control. Volume control is probably the first method for noise reduction which is adjustable by the user. Of course its function is simply the gain control of the device. The original behind-the-ear hearing aids have the classic "wheel type" rocker switch. Nowadays there are more contemporary types of volume controls and for the most sophisticated devices, the volume control can be managed through remote controls or mobile phones. The main disadvantage of volume control is that by turning down the volume to reduce noise, there is also a reduction for speech intelligibility.

Another method for noise reduction is the usage of memories. Memories are basically prefixed gain adjustments for special environments, where the presence of background noise is more intense. For example, there are memories for restaurants, clubs, crowd and so forth. So when a person enters such an environment they have the ability, usually by pressing a button, to switch to the proper memory. Again, for the majority of modern devices, this change can be done either by a remote control or by a mobile phone. This noise reduction approach is also not efficient enough because, as it mentioned before, memories are prefixed adjustments and not an adaptive factor.

Telecoil is a different approach for noise reduction. It is a special system that enables the communication among a hearing aid and an induction loop. The whole system is called "audio frequency induction loop system" or "AFILS" [14]. Originally it was created to assist hearing aid users for telephone conversations. Nowadays public areas such as transport stations, churches, theatres, school buildings and banks are also equipped with AFILS. The induction loop is placed around the walls in the building and in conjunction with an amplifier and microphone(s), creates a magnetic field. By switching the hearing aids -either manually or automatically- to Telecoil option, the devices function in a completely different way. Basically, the microphones are switched off and thus the sound is inducted as an electric voltage to a small coil of wire that is built-in inside the hearing aid. The information towards the hearing aids is sent by the magnetic field that is created within the area that the loop surrounds [8-11]. The basic advantage of this system is that the strength of sound signal does not alter within loop area. As long as a hearing aid wearer remains within the loop area the perception shall be the same at any point [14]. This advantage is highly important especially in environments like churches where the listener is often far from the speaker and there is also a presence of reverberation. Another advantage is that the microphones do not receive background noise. Only the signal that is transmitted from AFILS's microphone(s) is delivered to the user. On the contrary, a disadvantage of a Telecoil system is poor sound quality which results from electromagnetic interference, a fact which is often uncomfortable for the user [14].

Nowadays one of the most contemporary and sophisticated approaches to noise reduction, within the processing element, is the conjunction of general noise and inter-syllable noise

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reduction. General noise management is based on the separation between noise and speech. Being more specific, the system analyzes the signal in each channel in order to judge whether the input is mostly speech or noise. In case the signal is principally noise, the system automatically reduces the gain on the specific channel. When noise is presented at the same channel as speech, it is time for the inter-syllable noise reduction to act. This system is designed to reduce noise in the gaps between the syllables, thus every sentence to be more intelligible. Referring to the client's case, the hearing aids that have been proposed are equipped with a special noise reduction algorithm which is based on the single microphone noise reduction (SMNR) technology. SMNR is a term that is usually used so as not to be confused with the directional microphone technology. This manufacturer's proprietary SMNR implementation is almost similar to a noise reduction strategy that is called spectral subtraction. The mission of this technology is to continuously analyze the inputs of noise and speech and to provide gain reduction not on the overall input but particularly on noise, while using prescribed gain levels for speech [18].

Taking everything into account, these features have been designed to contribute to the improvement of signal-to-noise ratio. The client is provided with additional technology in order to have improved speech intelligibility especially in noisy environments. Each element acts additionally to the overall features of the devices by increasing the maximum level of noise reduction that is able to be applied.

Compression

Before starting to analyze the meaning of compression and its application on hearing amplification, it is important to refer to our potential client. The subject experiences bilateral sensorineural hearing loss. The main characteristic of this type of loss is the phenomenon of loudness recruitment or abnormal loudness growth. This is best described with the following diagram (Figure 2).

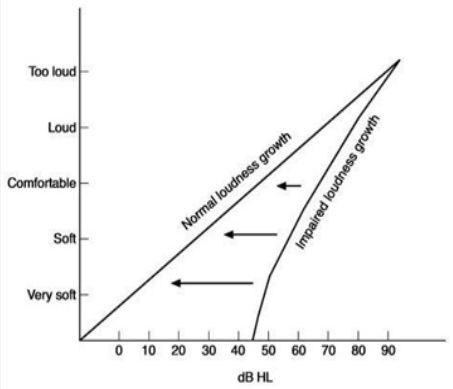

Figure 2: Loudness growth [1].

As we may observe, for soft inputs there is a significant difference between normal and impaired hearing. As the input becomes more intense the difference in perception tends to minimize and finally at louder inputs the perception is similar. In everyday life, this reflects the case that an aided hearing impaired person finds difficulties to hear soft sounds and on the contrary loud sounds may be uncomfortably loud. This means that a client with sensorineural hearing loss needs more amplification for lower inputs, while less or sometimes no amplification is needed for louder inputs.

Compression or automatic gain control is the ability of the hearing device to manipulate the incoming signal and to apply the appropriate gain according to the intensity of the input and thus to determine also the output. We may indicate the absence of compression in hearing aids with analogue (linear) amplification. In analogue hearing devices, the same level of gain is applied at any input so we may consider the difficulties for a person with sensorineural hearing loss to tolerate louder inputs. Digital hearing aids are designed to enable compression after a prefixed input level. This point is called threshold kneepoint (TK). Below that point, where the lower inputs are, the hearing aid provides linear amplification. Above that point the amplification is non-linear, consequently the gain is compressed in order the hearing device to provide comfort in louder inputs. An indication to understand the correlation between input and output is the compression ratio. This value is described better with the following formula provided by Shilpi Banerjee, Ph.D. (2011):

CR = ΔInput / ΔOutput

Below the TK, if the input is increased from 30 to 50dBSPL (Input=20dB), the output is increased for example from 60 to 80dBSPL (Output= 20dB).In that case the CR value is 1:1. On the other hand, above the TK where the inputs are more intense, an increase to the input will not affect the output linear. In other words, increasing the input from 70 to 90dbspl (Input= 20dB) the output will be increased from 90 to 100dbspl (Input= 10Db). In that case the CR value is 2:1, which indicates that the output is compressed (Figure 3).

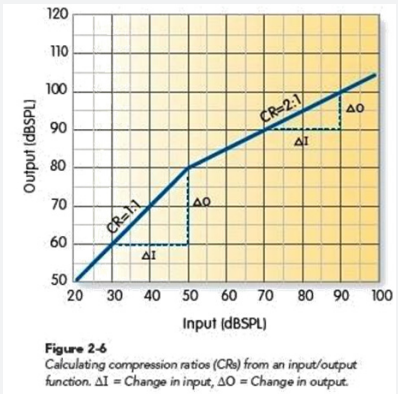

Figure 3: Indicates that the output is compressed [5].

The concept of compression is associated with the residual dynamic range of impaired hearing. A residual dynamic range is described as a loss of audibility for soft sounds and similar sensitivity for louder sounds in comparison with a normal

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dynamic range of hearing. With the contribution of compression, the hearing aid tries to fit the whole range of environmental sounds to the residual dynamic range of the wearer. In other words, the goal is the soft sounds to be audible, the moderate sounds to be comfortable and the loud sounds to remain loud but not in an uncomfortable way. This concept is commonly called wide dynamic range compression (WDRC). Modern hearing aids use adaptive WDRC in order to continuously analyze the hearing environment, adapt the amplification strategy and improve signal-to-noise ratio [5].

An important element that affects the WDRC strategy is the range of the prescribed fitting formulas. These formulas have been developed in order to provide standard characteristics in compression and amplification strategy. The most popular formulas in hearing aid market are the NAL-NL1 and NAL-NL2. They are property of National Acoustic Laboratories of Australia. By providing different values for compression and amplification, these non-linear formulas are very useful tools for the hearing aid audiologist in order to find the proper fitting for any client. In other words the target for any formula is to maximize speech intelligibility and comfort in noisy environments. Referring to our customer, the fitting formula that will be used initially is the E-stat (Evidence-Based Statistic) formula created by Starkey Hearing Technologies. Depending on the customer's review on the follow up fit, it is possible to switch to NAL-NL2 formula which provides higher compression ratios and minimizes the loudness recruitment effect [10]. Of course it is important to mention that higher compression levels do not always affect positively the hearing result. Sound distortion may be presented which will worsen the sound quality. Last but not least, another element which will maximize the final result for our customer is the ability to adjust the compression characteristics at any channel individually. This technology is called multichannel compression. By offering a 16-channel model we are able to fine tune the compression and to enhance the positive result.

Evaluation

The superiority of digital technology against analogue approaches can be evaluated through a variety of methods .Being more accurate, a very effective tool so as to evaluate the customer's progress is the customer's feedback. The every-day life of the customer is the basic field to evaluate the effectiveness of the fitting. By providing the proper instructions to the user, the dispenser is able to receive valuable information, evaluate the general progress or solve possible problems. Apart from that, a more scientific approach for the evaluation is the "Hearing In Noise Test (HINT)".This method is a way to evaluate speech intelligibility in the presence of background noise. The test is divided in twenty five lists and each list contains ten sentences. The main goal is to evaluate the speech discrimination by adapting the presentation level and thus adjusting the signal to noise ratio. Last but not least, another valuable outcome from the HINT is the ability to measure, by following specific test standards, the benefits from the directional microphones [17].

Conclusion

Digital technology has created a new perspective for the improvement of speech intelligibility in the presence of background noise. Hearing aid audiologists nowadays have the ability to provide contemporary solutions in order to achieve this goal. Comparing the present situation with the past, we are able to realize the massive evolution. The special demands of sensorineural hearing loss were not able to meet with analogue technology. Terms like adaptive directionality, wide dynamic range compression and multichannel technology had no application on the analogue era. Some years ago and despite the given will of any specialist to provide the best result for the customers, this was not possible. Within the general context of aural rehabilitation, new hearing aid technology plays an important role. The subject is not any more considered as a "handicapped" person. Hearing impairment is no more a reason for isolation. The new technology gives the ability to the user to remain an active and capable individual of the modern society.

References

1. Anglia Distance Learning Ltd, (2013) Loudness growth.
2. Anglia Distance Learning Ltd, (2013) Polar diagram.
3. Balfour PB, Hawkins DB (1992) A comparison of sound quality judgments for monaural and binaural hearing aid processed stimuli. Ear Hear 13(5): 331-339.
4. Banerjee S (2011) Binaural Spatial Mapping optimizes real-world hearing aid behavior. (1st edn). [ebook] Starkey Laboratories.
5. Banerjee S (2011) The Compression Handbook. (3rd edn). [ebook] Starkey Laboratories.
6. Beckerexhibits.wustl.edu (2015) Hearing Device Timeline.
7. Bernafon.com (2015) ChannelFree™ DSP - Bernafon International.
8. Beutelmann R (2009) Modelling binaural speech intelligibility in spatial noise and reverberation for normal-hearing and hearing-impaired subjects. (1st edn). [ebook] Oldenburg, USA, p.3.
9. Blay A (2010) Critical Review: Do Elderly Hearing Aid Users Perform Better on Speech Recognition in Noise Tests when Fitted Monaurally or Binaurally? (1st edn).
10. Blog.starkeypro.com (2012) Summarizing the Benefits of Bilateral Hearing Aids.
11. Brooks DN, Bulmer D (1981) Survey of Binaural Hearing Aid Users. Ear and Hearing 2(5): 220-224.
12. Chalupper, J., Wu, Y. and Weber, J. (2010). SpeechFocus - A new automatic directional microphone system for special listenining situations. 1st ed. [ebook] Siemens, p.2. Available at: https://media.sivantos.com/siemens-website/media/2014/07/2011_01_SpeechFocus_v2.pdf [Accessed 19 Apr. 2015].
13. Clark L (2006) What is the Optimum Number of Hearing Aid Channels?. [online] Audiology Online.
14. Cui T (2013) What are the Advantages and Disadvantages of Using Induction Loops Tao Cui. [online] Audiology Online.
15. Dillon H, Keidser G, Ching T, Flax M, Brewer S (2015). Development of NAL-NL2. (1st edn). [ebook] The hearing CRC & the National Acoustic Laboratories.
16. Features & Technology (2015) In: Introduction to Hearing Aid Technology, (1st edn). Anglia Distance Learning, p.59.

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17. Gabriel B (2005) Echo Block: Proven to be highly effective in reverberant situations. (1st edn). [ebook] Phonak.

18. Galster J (2014) Voice iQ - Multivariate Benefits. (1st edn). [ebook] Starkey Hearing Technologies.

19. Galster J, Galster E (2015) The Value of Increasing the Number of Channels and Bands in a Hearing Aid Jason Galster Elizabeth A Galster [online] Audiology Online.

20. Killion M (1999) Digital, Analogue and Directional: Will the real winner please step forward. BSHAA NEWS.

21. Köbler S, Rosenhall U (2002) Horizontal localization and speech intelligibility with bilateral and unilateral hearing aid amplification. Int J Audiol 41(7): 392-400.

22. Maltby M (2009) Adult Aural Rehabilitation. Distance Learning Ltd, Guernsey, p. 2-3.

23. Mencher GT, Davis A (2006) Bilateral of unilateral amplification: is there a difference? A brief tutorial. Int J Audiol 45(S1): S3-11.

24. Nal.gov.au (2015) National Acoustic Laboratories.

25. Phonak, (2013) Listening with two ears instead of one. (1st edn). [ebook] Phonak Insight.

26. Rodemerk K, Galster J (2014) Evaluation of SurfLink Mobile Remote Microphone Technology. (1st edn). [ebook] Starkey Hearing Technologies.

27. Siemens Hearing Instruments. Product Portfolio - Spring/Summer 2015. (2015). (1st edn). [ebook] Siemens, p 8.

28. Sound Processing Systems (2013) In: Introduction to Hearing Aid Technology, 1st ed. [online] Anglia Distance Learning, p.1.

29. Starkey Product Portfolio. (2015) (1st edn). [ebook] Starkey Hearing Technologies, p.2.

30. Starkeypro.com, (n.d.) The Hearing In Noise Test. [online]

31. Widex (2014) What is a telecoil? [Blog] Widex blog.

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