News From Oticon

The Digital Age

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Digital Makes Sense

In many areas digital technology has already become an integral part of our lives. Now it is also available for the hard of hearing. With size and battery consumption diminished, the DigiFocus hearing instrument has computing power equalling today's standard PCs. In this article you will get a description of the basic concepts of digital audio processing.

Man has been subject to digital sound for ages. If you were able to take a close look at the ear and the brain, what you would actually see is how nature, on its own, turns analogue sound waves into digital streams in the nerve cells.

Until now, however, the hard of hearing have had to rely on help from analogue technology only.

Digital is everywhere

In many areas, digital technology has already become an integral part of our lives. Digital cellular phones are becoming common worldwide. Televisions with digital sound and picture processing are available. Compact discs and other digitally based audio equipment have enhanced our listening pleasure for more than a decade.

Size is the simple reason that digital technology, until now, has not been generally available to the hard of hearing. The few "all digital" instruments that were marketed in the 80's were bulky and required a belt-worn electronic supplement. This was not what users wanted.

PC computing power at the ear

Manufacturers of hearing instruments have worked hard to overcome the troubles of size and battery consumption. With the thickness of digital microchips at only 1/100 of a human hair, this has now been accomplished in the world's first fully digital, at the ear hearing instrument - DigiFocus. Inside DigiFocus there is computing power available which equals that of a PC.

The difference between analogue and digital

Analogue basically means that the movements in the air that constitute sound are translated into one unified, but complex, electrical current. You may think of analogue sound as making a photocopy: the sound is depicted and you get an overall picture. Processing or recopying can be done only to a certain extent because it causes a deterioration of the original imprint.

Digital means that sound is described mathematically. This makes it much more precise to actually process the sound, bit by bit. Descriptions of certain details can be changed without affecting the general picture. Descriptions can be repeated accurately and endlessly without deterioration of the quality.

The analogue signal is turned into a series of ones and zeros by an analogue-to-digital converter (A/D-converter). When depicted graphically, an analogue speech waveform is comprised of smoothly changing amplitude variations (Figure A).

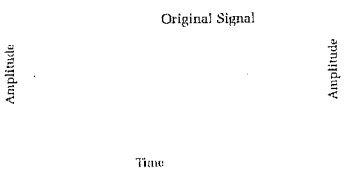


Figure A: Analog

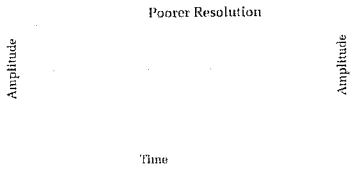


Figure B: Rough digital

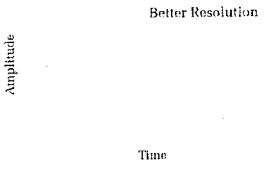


Figure C: Fine digital

In order to be digitized, the changes in amplitude and time need to be converted into discreet points, i.e. continuous sets of x/y coordinates (at time x1 the amplitude equals y1, etc.).

Sampling and quantization

Digital technology includes two basic concepts: Sampling and quantization. Sampling simply means how often the x/y-coordinates are measured. Quantization refers to how finely the amplitude variations are measured and is reported as the number of bits used in the conversion process.

In general, the higher the sampling rate and quantization, the better the quality of the digital sound. This is illustrated in figure B, which shows what the original analogue signal will look like if it is sampled at a low rate with a large amplitude step size. The result is an imprecise digital representation of the original sound. In figure C the original sound is sampled with a higher sampling rate and finer amplitude step size, leading to better fidelity.

In general, the sampling frequency should be at least twice as high as the highest frequency of interest (the Nyquist frequency). Because a hearing instrument focuses on the informative parts of speech, the highest frequency of interest is around 7 KHz. Accordingly, the sampling rate of DigiFocus has been set to 16 KHz. Had this rule not been followed, a phenomenon called aliasing would occur, which would result in audible distortion. DigiFocus incorporates a so-called anti-aliasing filter that drastically attenuates frequencies above 7 KHz, which could otherwise cause distortion.

Making sense out of sound

After the A/D-conversion, the resulting digital code can be mathematically manipulated, or processed (as it is normally expressed when talking about sound). This is where the real benefits of digital technology come in. The amount and types of processing that are possible with digital technology far surpass the capabilities of analogue processing. Once the processing is complete, the digital signal is converted back to analogue form by the D/A-converter. It is now ready for transmission to the small receiver inside the hearing instrument, which makes the sound audible. □

How DigiFocus works

DigiFocus is a fully digital hearing instrument built around the digital audio processor, DAP. This processor is designed to have a specific functionality and to comply with a series of physical, acoustical and audiological demands.
DigiFocus is an automatic hearing instrument without a volume control and programmed in accordance with the 'Adaptive Speech Alignment' fitting rationale. This rationale is implemented by the OtiSet programming software

The input signal

The input signal from the microphone or the telecoil is digitized and fed to a filterbank, which divides the signal into seven band-pass filters with centre frequencies at: 250, 700, 1200, 2000, 3000, 4000 and 5000 Hz. The filterbank covers the frequency range from 125 to about 6000 Hz. The output from each band-pass filter is equipped with an attenuator by which each filtered signal can be weighted. This allows for a very precise fitting in accordance with the audiometric profile of the hearing impaired.

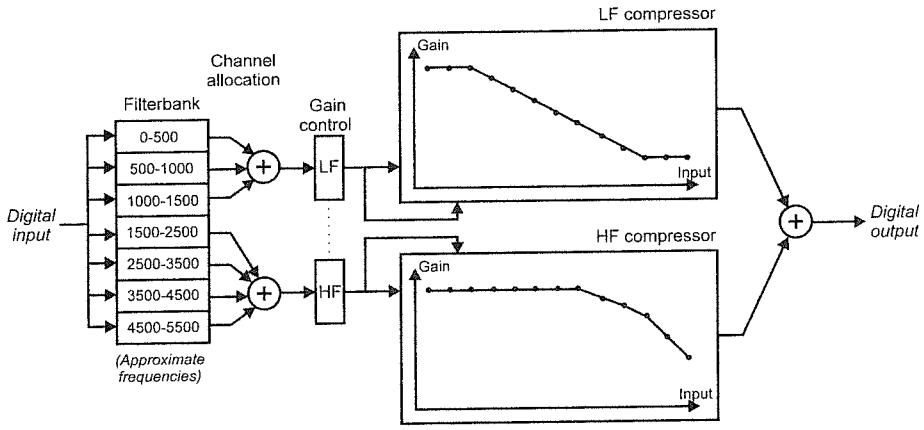


Fig.1. DigiFocus - block diagram of the digital audio processor, DAP.

The weighted band-pass signals are summed with two summators which create the low-pass and the high-pass channel of the hearing aid. The cut off frequency between the two channels corresponds to 1500 Hz, i.e. the three lower bands constitute the low-frequency channel and the four higher bands the high-frequency channel.
The signals from the two channels are processed individually in two compressors operating independently of each other.
Finally the two modified signals are summed into the output signal and sent to the receiver.

The fitting rationale and the software

A. The Low-Frequency channel, LF (see fig.2).

The low-frequency channel is set by means of the fitting rationale in such a way that the balance of loudness between the three pass bands corresponds to that of normal-hearing subjects when the input signal is normalized speech.

The input/output curve consists of three segments corresponding to

1) constant gain below the kneepoint
2) fixed compression between the kneepoint and the completion point
3) 'unity' gain above the completion point

The low-frequency compressor is a 'full dynamic compressor' i.e. with a low kneepoint (50 dB SPL) which means that it is active for most communication signals (speech, music and background noise). The fitting rationale calculates the compression ratio in accordance with the average low-frequency hearing loss and a unique loudness model based on loudness scaling data from a series of subjects with sensorineural hearing loss.

The low-frequency compressor provides *syllabic compression* i.e. it operates with relative short attack and release times. This aims to reduce 'upward-spread- of masking' from loud low-frequency sounds (like e.g. vowels and most back- ground sounds) on soft high-frequency sounds (like e.g. consonants) and to automatically control the perception of loudness, which is necessary in a hearing aid without a volume control.

There are two controls and a trimmer panel for the fitting of the low-frequency channel:

Controls

- **Gain** - gain at input levels below 50 dB SPL
- **Comp Ratio** - the compression ratio in accordance with the slope of the input/output curve between the compression kneepoint and the completion point

Trimmer panel

- **LF response** - three trimmers for the fine tuning of the LF frequency response

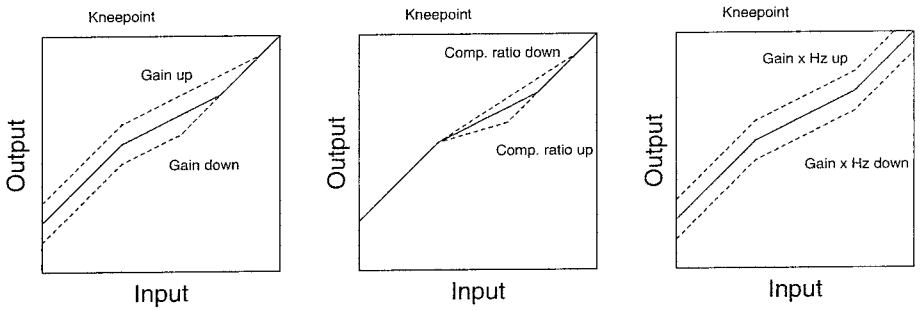


Fig.2. DigiFocus - input/output curves for the low frequency channel

The insertion gain in each of the low-frequency pass bands can be adjusted individually by means of the *'LF response'* trimmer panel. Adjustment of the gain in 250 Hz band is especially useful to avoid excessive 'upward-spread-of-masking' from powerful sounds within this frequency band and to fine tune 'listening comfort' and 'sound quality' of the listener's own voice.

B. The High-Frequency channel, HF (see fig.3).

The high-frequency channel is set by means of the fitting rationale such that the shape of the frequency characteristic is approximately in accordance with the POGO II fitting algorithm.

The input/output curve consists of two segments corresponding to

1) constant gain below the kneepoint
2) fixed compression above the kneepoint.

The high-frequency compressor also has a relatively low kneepoint (50 dB SPL). The fitting rationale calculates the compression ratio from the frequency with lowest hearing loss (best hearing) and the loudness model - however, loudness is not restored!

The high-frequency compressor provides *'adaptive gain'* i.e. it operates with short attack and *long* release times. This aims to provide sufficient audibility and listening comfort for both soft and loud high-frequency sounds in changing environments, without disrupting the high-frequency amplitude contrasts in speech signals. It further seeks to protect against discomfort from sudden loud sounds.
There are two controls and a trimmer panel for the fitting of the high-frequency channel:

Controls

- **Low Level** - gain at input levels below 50 dB SPL
- **High Level** - gain at high input levels corresponding to 80 dB SPL

Trimmer panel

- **HF response** - four trimmers for the fine tuning of the HF frequency response

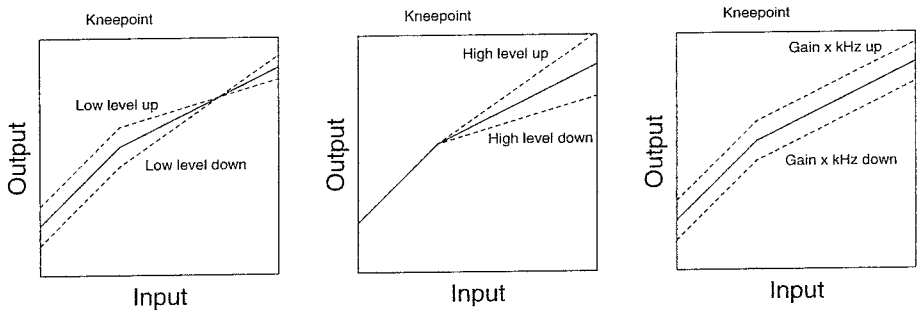


Fig.3. DigiFocus - input/output curves in the high-frequency channel

The insertion gain in each of the high frequency pass bands can be adjusted individually by means of the *'HF response'* trimmer panel. This may be used to obtain 'optimal' high-frequency insertion gain and for 'feedback management'.

DigiFocus Subject to Extensive Pre-market Evaluations

More than 60 hearing care professionals are at present involved in extensive series of pre-market clinical evaluations of DigiFocus. Oticon is aiming at the highest possible level of quality by testing not only the instruments but also the dispensing process itself. Prior to the present pre-market evaluations, DigiFocus was taken through several extensive clinical field tests. Furthermore, a number of the world's leading audiologists have been invited to examine DigiFocus and the possibilities it offers for hearing research.

Aiming at the highest possible level of quality, Oticon has reserved the first series of DigiFocus for extensive pre-market tests. The goal has been to test not only the instruments, but also the complete dispensing process with a limited number of hearing care professionals.
Following this concept, a small but steady stream of final version DigiFocus units have, since February, been tested by hearing care professionals and in turn fitted to hearing impaired worldwide. By April 1996 DigiFocus will have been fitted by approximately 60 dispensers in the US and in several European countries.

Hands-on experience at seminars

Gradually enrolling more and more hearing care professionals, Oticon gave the first seminars on DigiFocus in February and March. For example, in Orlando, Florida, participants - including hearing care professionals and university researchers from all over the US - tried out DigiFocus and the OtiSet fitting software.

Participants were anxious to hear the explanations of the audiological concept behind DigiFocus. Some were surprised to learn that DigiFocus can be used for typical hearing problems and not only for those with uncommon types of hearing losses. Others remarked that they found the fitting software very easy to use compared to the complexity of DigiFocus.

Hearing care professionals who returned home with their first DigiFocus instruments from the seminars were invited to bring forth all questions and comments they might have. Further they were given the opportunity to provide a written assessment of DigiFocus and the accompanying Human Link support tools.

Extensive clinical field testing

Prior to the current ongoing international pre-market evaluations, DigiFocus was taken through several extensive field tests. These field tests took place in both Denmark and Sweden.

First bodyworn versions were tested. Then when the first BTE prototypes became available they were tested in different clinical settings, both alone and against other hearing instruments. The final test of DigiFocus versus MultiFocus resulted in an 80% overall preference for DigiFocus.

Dialogue with audiological experts

In line with Oticon's philosophy of providing Quality Hearing Care based on knowledge sharing, some of the world's leading audiological researchers have been invited to participate in research projects. This research will focus on developing fitting algorithms for future application of digital technology.

In January 1996, international audiological researchers from around the world were invited to attend a conference at Oticon's Eriksholm Research Center in Denmark. During the workshop, detailed information about a special research version of DigiFocus was given. Participants received a sample of this version and programming software to take home.

All the participants expressed interest in getting involved and they presented ideas for new research projects. When these research proposals have been finalized, Oticon will provide each of the researchers with the number of digital instruments necessary. □

Quality Hearing Care: The Human Link

A number of different tools are provided by Oticon to help make fitting DigiFocus and other instruments easy and efficient. These tools are part of Oticon's Human Link concept. The tools include: user diaries, specially designed forms for interview, fine tuning guides, the OtiSet programming software, and more.

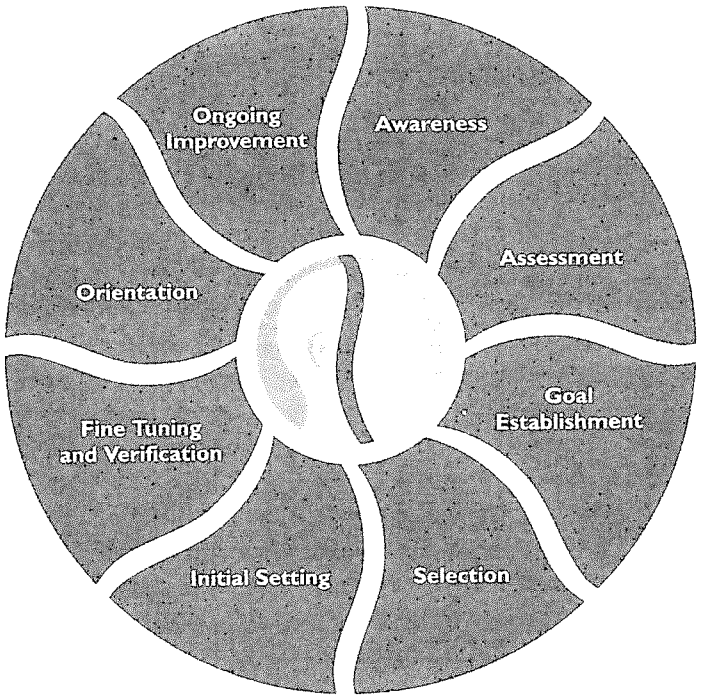
The Human Link is a concept for quality hearing care developed to help you obtain more satisfied patients.

The Human Link concept covers the four cornerstones of hearing care:

- A process for quality hearing care
- A set of tools for auditory rehabilitation
- A breakthrough in hearing instrument technology
- A program for knowledge sharing

A process for quality hearing care

In co-operation with hearing care professionals around the world, Oticon has identified a set of techniques for optimizing success in dispensing hearing instruments. These elements have been gathered to create a dispensing framework, The Dispensing Wheel.



The Dispensing Wheel covers all possible aspects of the dispensing process. It provides you with a holistic view of the process that goes on between you and each individual patient. It helps you identify what should be done next in order to deliver the best possible service. And which tools and instruments to utilize and when.

A set of tools for auditory rehabilitation

Part of the Human Link is to provide you with a number of audiological tools that help you establish a systematic dialogue with your patients. Additional tools enable you to use this information to create an optimal hearing instrument fitting for each patient.

With DigiFocus you have an extremely flexible hearing instrument. By using the right tools you can define a personal, social and audiological profile for each individual patient. This enables you to utilize the capacity of DigiFocus to the fullest extent. The Human Link tools for DigiFocus include:

- The COSI interview (Client Oriented Scale of Improvement) enables you to set the goals for hearing improvement together with the patient, and later measure how well the goals have been achieved
- The DigiFocus diary enables you to determine quickly when a hearing instrument needs adjustment
- The fine-tuning recommendations help you to adjust the settings
- OtiSet, a PC based software program, and the programming belt enable you to fit and fine tune DigiFocus while the client is wearing the instrument. This takes place without your patient being wired to the PC.

A breakthrough in hearing instrument technology

The same procedure - using diaries, COSI, fine tuning recommendations and OtiSet - works with the other members of Oticon's high performance products in The Focus Family.

Apart from DigiFocus the Focus Family consists of microFocus, MultiFocus and PrimoFocus. All products in the Focus Family were developed with the most important user needs in mind: To provide the optimal balance between speech clarity and listening comfort. This means that there is a product in the Focus Family for almost every patient.

A program for knowledge sharing

Knowledge sharing is an inherent part of The Human Link. Oticon wants to share knowledge with hearing care professionals and audiological researchers that will make fitting of hearing instruments better and easier. Oticon is equally interested in getting feedback on day-to-day experiences and research results. □

OtiSet Makes Fitting Easy

The OtiSet software is the single most important tool for fitting DigiFocus. Underneath its simple and easy to use interface, OtiSet sums up all of the advanced knowledge on which DigiFocus is built. By analyzing all of the available personal data, OtiSet automatically recommends the best suitable settings. In short, OtiSet enables you to draw on all the audiological knowledge available from Oticon.

Click, drag and at a glance you have a graphical representation of how your patient will experience DigiFocus. This is how simple it is to use OtiSet.

OtiSet version 3.5 is a programming and fitting software module that complies with the hearing industry's standard NOAH platform. It runs on any PC in a Windows 3.11 environment. Together with Oticon's other Human Link tools, it provides everything you need to fit DigiFocus. OtiSet has been designed to make fitting easy while giving you relevant and context-sensitive audiological information.

Underneath its simple and easy to use interface, OtiSet considers all the advanced knowledge on which DigiFocus is built. It relies on top audiologi-cal research, summarizing many years of work and field testing performed at Oticon's Eriksholm Research Centre in cooperation with hearing care professionals and audiological researchers worldwide. The new version of OtiSet fully supports DigiFocus, helping you to fit the exact needs of your patients.

Getting the most out of your patients' comments

While using OtiSet, you are able to compare your patient's audiogram with the fitting range of all Oticon's hearing instruments. Based on the choice of instrument and available audiological data, OtiSet automatically recommends the initial control settings. During fitting, OtiSet gives you instant access to graphical representations that show how various speech and sound spectra perform as the controls are adjusted on screen.

OtiSet also includes interactive Fine Tuning Guides which are easy-to-use tools that make practical use of your patient's comments. As with other Human Link tools, OtiSet gives you the framework for an intensive and systematic dialogue with your patient during the finetuning process.

Encouraging patient involvement

OtiSet enables you to demonstrate visually to your patient which hearing instrument compensates best for his or her hearing loss. Involving your patients in the process makes it easier for them to understand and accept your recommendations.

Since it is based on the NOAH standard, OtiSet can make full use of all client data that is stored in NOAH's database. For future reference, OtiSet also documents the fitting procedures - both electronically and on paper - used at each session.

Going cordless

Many people find it uncomfortable to be wired to a computer. This "constricted" feeling can be avoided by using the OtiSet programming belt, which is worn on the shoulder. The programming belt provides cordless infrared communication between the PC and the hearing instrument while in the ear. Alternatively, you may use the HI-PRO interface for a wired solution.

Three different views

OtiSet offers a choice of three different views of the fitting. The Audiological View provides a visual guide to instrument performance in four typical sound environments. The Technical View illustrates traditional technical information such as coupler data and insertion gain at different input levels. With the Binaural View you are able to examine settings for both right and left instruments at the same time.

The upgrade to the latest version of OtiSet 3.52, which is required to fit DigiFocus, is free. □