FineHearing™
Technology
A STEP CLOSER TO NATURAL HEARING
A New Dimension of Hearing ...........................................3

An Invisible Wave: A Short Explanation of Sound .................4
  :: The Sense of Hearing .............................................5
  :: The Elements of Sound and their Significance for Normal Hearing ..................................6

Sound Coding in Normal Hearing .....................................9

Sound Coding as a Central Function of a Hearing Implant ........10

What Traditional CI Sound Coding Can Effect .................11

FineHearing™ Technology:
A New Dimension of Sound Coding ........................................13
  :: The Experience of Hearing with FineHearing™ ....................14
  :: Scientific Data .....................................................14

Med-EL’s Technological Innovations Supporting FineHearing™ ....16
  :: 100 Cochlear Implant Electronics ..............................16
  :: Latest Speech Processor Technology ............................16
  :: Complete Cochlear Coverage ....................................17

Users’ Voices ..............................................................18
A New Dimension of Hearing

The enjoyment of listening to complex sounds such as music, or discussions in noisy environments, requires the ability to process and differentiate an enormous amount of sound information in a highly precise way. The normal sense of hearing is unsurpassed in its capacity to perform this task.

Hearing implants represent the first realization of a technological replacement of a human sense and attempt to mimic normal hearing for the benefit of individuals with hearing loss.

As a pioneer in developing technologies for hearing implants and following more than 30 years of research and development, MED-EL has succeeded in developing a completely new sound coding technology that provides a richer and more detailed hearing experience than ever before possible.

MED-EL’s FineHearing™ technology opens a new dimension of hearing by providing the fine details of sound for a hearing experience with unprecedented depth and complexity.

* FSP is not indicated for use by pre-lingual children.
FineHearing™ uses the latest technological innovations developed to enhance the entire hearing experience.
An Invisible Wave
A Short Explanation of Sound

Sound consists of a pressure wave, varying above and below the ambient pressure. Properties such as frequency, wavelength, amplitude, speed and direction are used to characterize these waves.

The **amplitude**, or sound level, corresponds to the loudness of sound, and is measured in decibels (dB) whereas the **frequency**, which corresponds to pitch, is measured in cycles per second – also called hertz (Hz).

The quietest sounds that humans are able to hear correspond to a hearing level of approximately 0 dB, the average hearing threshold.
The Sense of Hearing

Our sense of hearing allows us to perceive the loudness, pitch and timbre of a sound, as well as to localize where a sound is coming from.

The outer ear helps to ‘gather’ sound which passes down the ear canal until it reaches the eardrum. The eardrum and middle ear systems convert the pressure wave into a pattern of vibration. This vibration is transferred to the inner ear, or cochlea, where it causes a pressure wave in the cochlear fluid. This pressure wave sets a membrane in the cochlea in motion. Hair cells located on the membrane detect the motion, and in turn, cause activity in the fibers of the auditory (hearing) nerve. The brain interprets this nerve activity as sound.

Normal hearing covers a frequency range of sounds between 20 Hz and 20,000 Hz (20 kHz). However, this range varies significantly with age. Usually, the sensitivity for high frequencies diminishes with advancing age. The majority of speech sounds are within a frequency range of between 100 and 8000 Hz. The human ear is most sensitive to frequencies around 1000–3500 Hz. Sound frequencies above the hearing range are known as ultrasound.

The brain also exploits the fact that we have two ears. Having two independent listening points on either side of our head allows nerve pathways in the brain to compare and contrast the signal from both sides. This can help us to hear more easily in noisy situations, and helps us to determine which direction a sound is coming from.
The Elements of Sound and their Significance for Normal Hearing

A sound signal comprises two components, the envelope and the fine structure.

Elements of Sound

**Envelope**
The envelope is the “loudness contour” of the sound signal and is essential for speech understanding.

**Fine structure**
The fine structure contains the subtle details of a sound signal and enhances pitch and sound quality.

The envelope represents the “outline,” or “broad brush strokes” of the sound signal. It mainly carries information about the relatively slow changes in sound level over time, and contributes to our perception of loudness. The envelope of a signal alone is sufficient for speech understanding in quiet conditions (for western, non-tonal languages). However for more challenging situations, such as listening to music, or speech in noisy background conditions, research has demonstrated that normal hearing subjects are using an additional component of sound: **fine structure**.

Fine structure conveys the subtle details of a sound’s timing structure. It seems to be very important in the perception of pitch, which has an influence on our ability to appreciate music, and recognize the emotional tone of speech, as well as recognize the gender of the person speaking to us. Having the fine structure of signals available at both ears allows greater precision in sound localization.
Scientific studies have demonstrated that FineHearing™ enables hearing implant recipients to detect small differences in pitch – for example, between two neighboring piano notes.
Sound Coding in Normal Hearing

Normal hearing employs two main mechanisms for coding the frequency of sounds: Coding by place (tonotopicity) and coding by rate (phase locking). In general, both the place and rate code are used by the auditory system to hear lower frequency sounds. As sounds increase in frequency, the ability to use the rate code diminishes, and for very high frequency sounds the auditory system uses just the place code.

Coding by Place
Coding in place corresponds to the tonotopic arrangement of the cochlea. Like the keys of a piano (see pg. 17), the cochlea is arranged in order of frequency – and in normal hearing, each place along the cochlea responds best to a certain frequency. The base of the cochlea responds best to high frequencies, whereas the apex (deepest part) responds best to low frequencies. The pattern of activity in both the auditory nerve and the brain match this arrangement.

Coding by Rate
The second fundamental mechanism of sound coding in normal hearing is coding by rate. In the cochlea the hair cells are responsible for converting the movements of the membrane in the cochlea into electrical impulses. Due to the way the hair cells respond to this movement, the firing pattern of the auditory nerve activity closely corresponds to the timing pattern (fine structure) of the sound signal.

This process works well in normal hearing for frequencies up to ~1 kHz. As frequency increases, the efficiency of phase locking decreases, until about 4–5 kHz, where phase locking no longer operates.

In normal hearing, the pitch caused by sounds where only place coding is available tends to be weak, and doesn’t evoke a perception of ‘musical pitch’. Rate coding seems to be highly important for producing strong pitch, and the sensation of musical pitch. A strong pitch sensation also requires the rate and place cues to match.
Sound Coding as a Central Function of a Hearing Implant

In a cochlear implant, an external sound processor (usually worn behind the ear) picks up sound signals using a microphone and converts them into a pattern of electrical signals. These signals are transmitted to an implanted electronics package under the skin, and transferred by wires to an electrode array implanted in the cochlea. The electrical signals cause activity of the fibers of the auditory nerve, and the brain interprets this as sound.

Different approaches are possible for the conversion of a sound signal into a pattern of electrical signals. A sound coding strategy describes in detail the way this is carried out. Sound coding strategies can vary in how efficiently aspects of the sound signal are transmitted, and in what priority is given to these aspects. These variables of sound coding strategies have a direct effect on the quality of the hearing experience.
All coding strategies that have been used in cochlear implants (CI) for the last 15 to 20 years provide place coding by splitting the sound into frequency bands, and sending this information to an implanted electrode array, mimicking the tonotopic arrangement of the cochlea. At the same time, the envelope of each of these frequency bands is presented. These envelope extraction strategies provide relatively good place coding of frequency, and good transmission of a signal’s envelope, but they largely discard the fine structure.

In accordance with the description for normal hearing above, implantees using envelope extraction strategies tend to understand speech relatively well in quiet situations, but have more difficulty in background noise. They will typically have a poor sensation of pitch, and often struggle to appreciate music, although there can be exceptions. Furthermore, although western, non-tonal languages (such as English) can be well transmitted by envelope information alone, tonal languages (such as Mandarin) where the meaning of a word is also affected by voice pitch, are not well transmitted.

By including the fine structure, the normal hearing process can be represented with greater accuracy than with the envelope alone.
FineHearing™ provides the fine details of sound that can help cochlear implant users recognize individual musical instruments.
With the introduction of FineHearing® technology, MED-EL overcomes the limitations of envelope-based, “traditional” coding strategies. Similar to frequency coding in normal hearing, FineHearing codes a sound signal both in rate and in place. The additional rate coding in low to mid frequencies mimicks natural hearing better than ever before and provides fine structure information important for more complex listening tasks and situations. As mentioned above, the fine structure information of a sound is highly important for good music perception and sound localization.

Thus, MED-EL’s FineHearing better represents both components of a sound, the envelope and the fine structure. By including the fine structure, the normal hearing process can be represented with greater accuracy than with the envelope alone.

MED-EL’s sound coding strategy to apply FineHearing technology is called Fine Structure Processing® (FSP).

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The Experience of Hearing with FineHearing™

The fine structure information of sound provided by FineHearing® may enable users to benefit from additional details, and may be particularly advantageous for the fulfilment of difficult listening tasks.

Users focus better on speech while filtering out the background. Better understanding of “tonal” languages such as Mandarin can become possible. Music perception, as well as sound localization, may considerably improve.

By combining rate and place coding, FineHearing technology improves pitch perception with cochlear implants. Moreover, the combination of both coding modalities allows the user to make the best use of both rate and place without adverse interference between the two.

Scientific Data

Scientific studies with FineHearing users show clear benefits for speech understanding in background noise. They also show that listeners are able to detect smaller differences in pitch and perceive a wider range of tones, which is critical for the perception of music and tonal speech elements.

<table>
<thead>
<tr>
<th>Listening Task or Situation</th>
<th>Sound component</th>
<th>Traditional speech coding</th>
<th>FineHearing™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech in quiet</td>
<td>Envelope</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Music and tonal languages</td>
<td>Fine structure</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Speech in noise</td>
<td>Envelope and fine structure</td>
<td>NO</td>
<td>YES</td>
</tr>
</tbody>
</table>

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FineHearing™ provides the most complete and accurate representation of sound — better than previous generation strategies have ever been able to offer.
MED-EL’s Technological Innovations

Supporting FineHearing™

MED-EL is the only hearing implant manufacturer offering FineHearing™ through the use of Fine Structure Processing*. The following technological innovations of MED-EL support FineHearing and make it a unique technology in the world of hearing implants.

I100 Cochlear Implant Electronics
MED-EL’s new generation of cochlear implants, PULSAR C100 and SONATA T100, introduce the powerful and sophisticated I100 electronics platform, ensuring an unprecedented precision in the transfer of sound information to the hearing nerve. Only this new implant platform is able to support Fine Structure Processing as the fastest and most effective sound coding strategy available today.

Latest Speech Processor Technology
The new generation of MED-EL speech processors, OPUS 1 and OPUS 2, are designed to take full advantage of I100 cochlear implant electronics. Using the latest advances in microchip technology, they represent a milestone achievement in speech processor engineering.

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Complete Cochlear Coverage

Like the keys of a piano, the neural structures are arranged in order of pitch (frequency). In normal hearing, one end of the cochlea sends high-pitched information to the brain, while the other sends low-pitched information. High-pitched sounds cause the sensory cells in the bottom (base) of the cochlea to vibrate, low-pitched sounds cause that reaction in the uppermost part of the cochlea (apex).

As mentioned above, in natural hearing, low frequency sounds at the apex of the cochlea are coded in both rate and place. Furthermore, to evoke a strong pitch sensation, the rate and place should match. Therefore, to best mimic natural hearing, it is of utmost importance for a cochlear implant to stimulate the entire length of the cochlea – including the apex. In cochlear implant technology, only a long electrode array will reach deeply enough into the cochlea to provide Complete Cochlear Coverage and to stimulate the apical region.

MED-EL offers the longest electrode array currently available, which is specifically designed with an extraordinarily flexible tip to protect the delicate structures of the cochlea during insertion. The MED-EL standard electrode array extends 31.5 mm in the cochlea, covering its entire range from the base to the apex.

Through additional rate coding in the apical region, Fine Structure Processing allows better pitch perception especially in the low frequencies. Complete Cochlear Coverage, with MED-EL’s especially long electrode array, fully supports FineHearing and allows the best possible simulation of natural hearing using a cochlear implant system.
Listening to music and hearing in noise has become even better. Now I can thoroughly enjoy my favorite music, watching TV and going to the cinema. I even discovered new sounds.

Roswitha G.

I instantly noticed the difference when listening to music. Now, music sounds more melodic. I can hear and differentiate between the individual instruments. Listening to music is enjoyable again!

Eveline S.

Hayley’s singing is so much clearer and in pitch than before. And for anyone that knows her well, she loves music and loves to sing, so this is huge for her. She is so happy.

Jillian H., mother of Hailey
And for anyone that knows her well, she LOVES music and loves to sing...
Founded by industry-leading scientists and engineers, MED-EL provides innovative solutions for those dealing with hearing loss.

By advancing the field of hearing implant technology, MED-EL’s people and products connect individuals around the globe to the rich world of sound.