Sound Coding Strategies and Fitting for Cochlear Implants

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Slides and Materials available under: http://auditoryprostheticgroup.weebly.com/blog

Many Slides from Prof. Andreas Büchner and Tobias Rottmann

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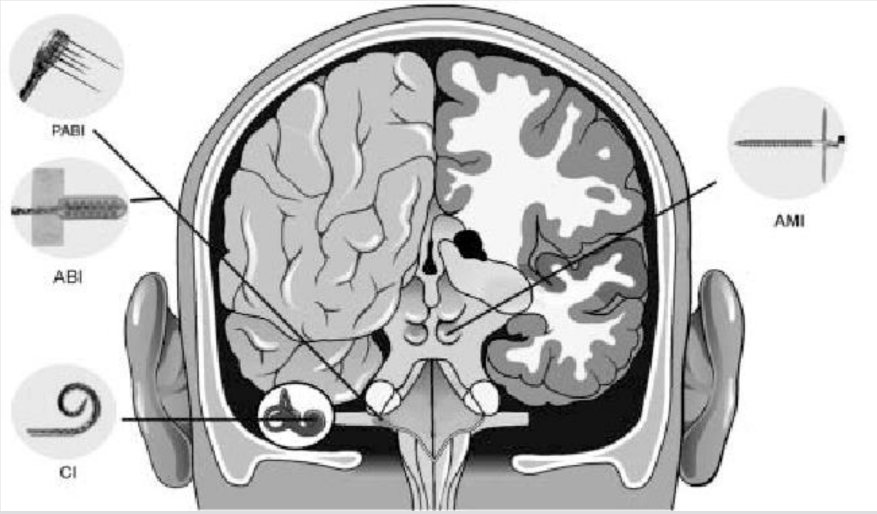
Goals

- 1) Introduction to DHZ-MHH
- 2) To present sound coding strategies in a technical way in a historical context.
- 3) Relating cochlear implant adaptation to coding strategies.
- 4) Example of a study on MHH in this context based on the FS4 strategy.

DHZ-MHH

- Department of Otolaryngology/
- German Hearing Center
  - 30 years of cochlear implant experience
  - World's largest cochlear implant program (10,000 Impl. 2019)
  - ~600 patients are implanted per year
  - Wide spectrum of hearing systems
    - Cochlear Implant, Middle Ear Implant, Hearing Aids
    - ABI (auditory brainstem implant), AMI (auditory midbrain implant)



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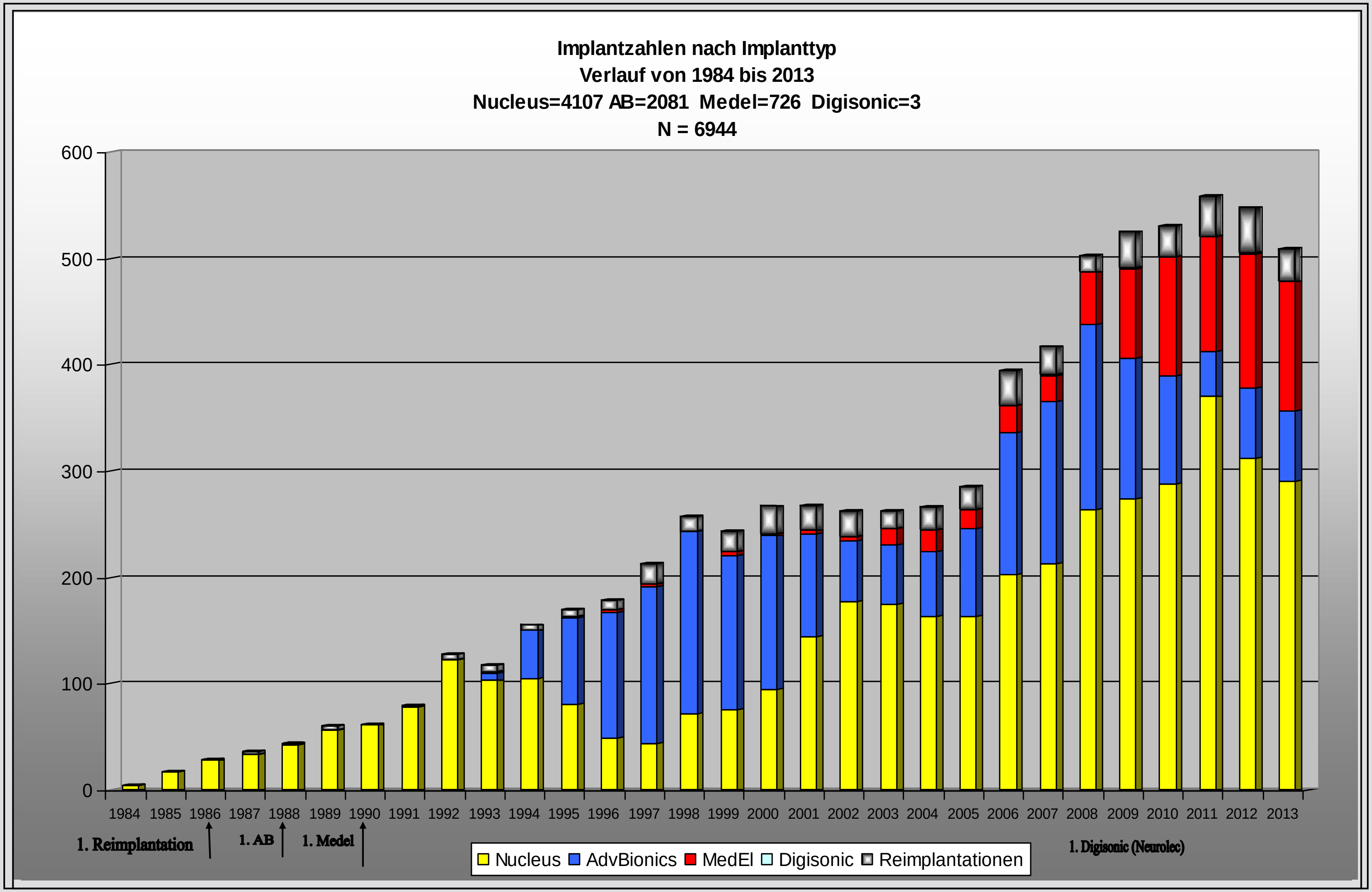
Number of CI implantations at MHH



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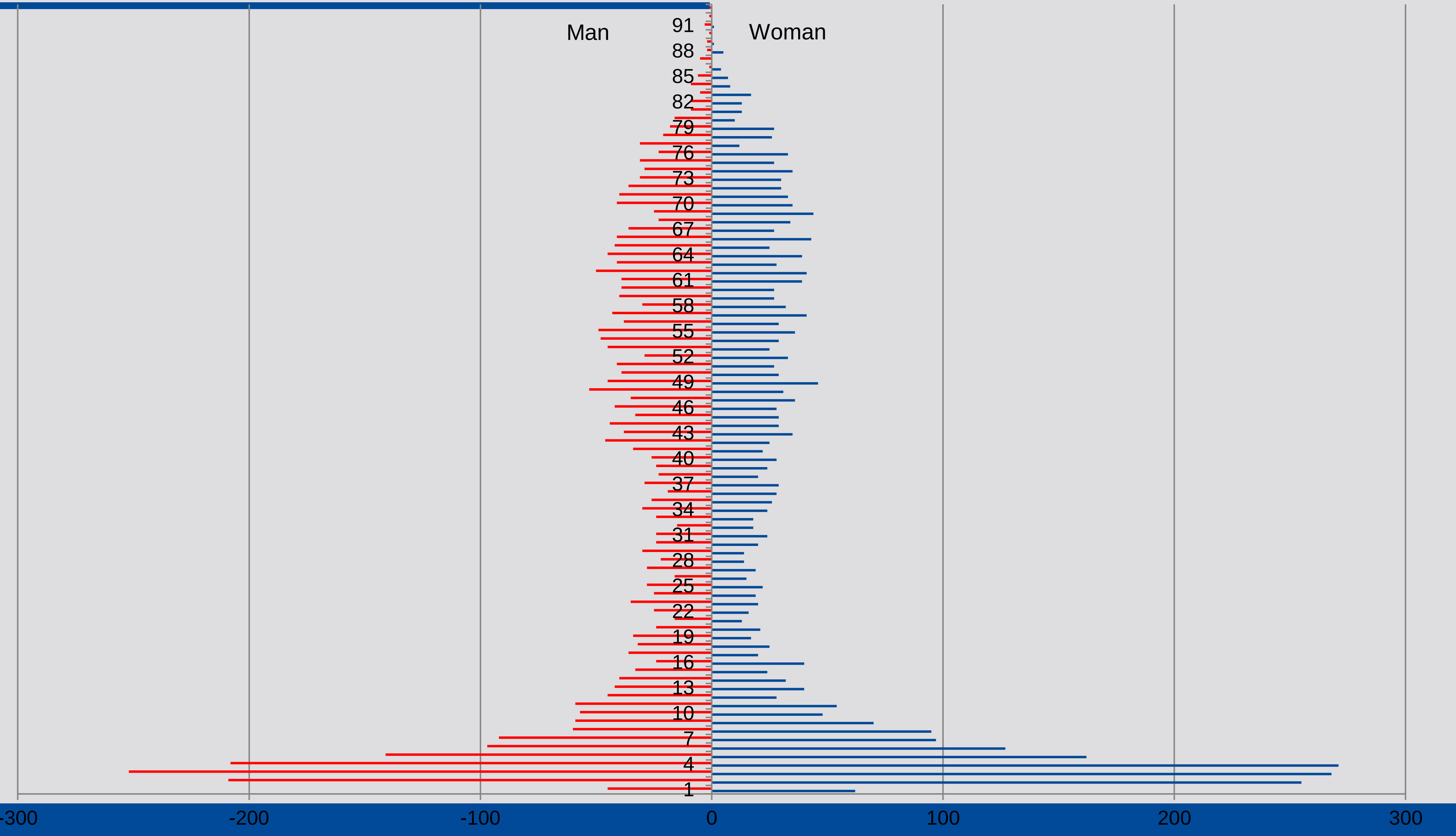
Age distribution at implantation



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DHZ: German Hearing Center

Clinic
Medical
Diagnostic

Engineers
Fitting of
Cochlear
Implants

Research

Audiological
Rehabilitation

Companies:
MED-EL
AB
Cochlear
Oticon
(Research and Service)

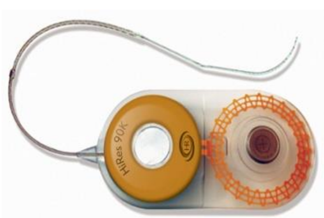
Contents

1. Introduction
2. Fundamentals of electrical stimulation
3. Historical overview of coding strategies
4. Current coding strategies
5. Summary

CI manufacturers and models at MHH

Cochlear
Australia


MEDEL
Austria




Advanced
Bionics
USA


Neurelec/Oticon
France

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Other CI Manufacturers

Cochlear-Implant-System: IES (= „I Enjoy Sound“)

Coclear Implant company from China: Nurotron

Speech tests

- Recognition of numbers test
- Freiburg: Monosyllabic test

1	2	3	4	5	6	7	8	9	10
lak	čir	jež	lan	bon	noj	tat	car	gož	niz
mah	paž	gad	kip	seč	sin	čer	rob	cev	del
vir	grm	piš	set	kad	mah	mož	kih	mir	laž
dlan	sla	beg	brc	srh	gon	ceh	sneg	voh	prag
prod	vid	svat	past	moč	dar	soj	vrat	trst	snov
tast	dom	park	zvon	dir	grah	film	žolč	disk	gumb
kljun	štor	molk	breg	cvet	most	kost	plen	vamp	tisk
sok	pest	stolp	dolg	bron	brat	svet	grom	trup	šport
grušč	noht	tun	smeh	gams	dvom	vrač	strah	vdih	vat
stvar	bran	hrast	trušč	vrag	plašč	strop	pad	zglob	blesk
lift	stran	stric	sad	pisk	kup	dan	zvrst	lord	strok
stih	log	post	vrisk	smrad	drozg	zdrob	blišč	pust	stan
gost	ključ	grič	slast	kal	strel	kramp	test	noč	dren
bog	vzrok	klop	punč	gnjat	glad	glas	vran	gnoj	urh
polh	rast	sod	vlak	tresk	vest	brst	drob	prah	dvor
bas	hrib	last	rep	vzor	slak	trg	mast	mag	kap
trn	svak	čoln	čast	slap	hči	nos	polk	krt	vrč
som	med	drn	nart	polž	polt	uk	nart	peč	os
zid	dvig	zob	maj	vrt	prst	svet	ud	bor	*ptič
reč	tank	dih	srd	list	čar	*sklad	*jed	sad	*cent
ep	pas	vas	pih	drog	ton	*čin	*kri	*član	*shod
*cmok	les	meh	vod	fant	ris	*dol	*laks	*rast	*čaj
*ranč	srp	ar	tla	čut	led	*ring	*las	*dres	*spis
*prt	*čas	*črv	rep	duh	bar	*dah	*hrt	*takt	*gram
*grad	*gol	*rang	*krom	pot	up	*greh	*čip	*sen	*rov
*dež	*hec	*dur	*hod	as	*cvek	*par	*gos	*sir	*gred
*prav	*top	*smer	*rog	*lev	*stik	*šal	*sum	*šal	*hlad
*vic	*trud	*tlak	*rod	*miš	*srž	*plus	*god	*kvas	*tram
*pes			*žig	*vrh		*tip			

7 There was one replacement differing only by two letters, *pirh* "Easter egg" and *fleš* "flash."

- In Germany, the criteria to perform cochlear implantation is based on hearing loss greater than 65 dB HL around 500 Hz and a monosyllables test score below 60%.

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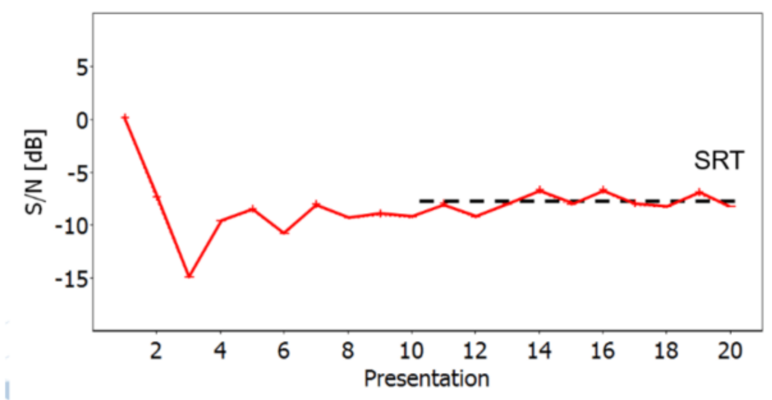
Speech Tests

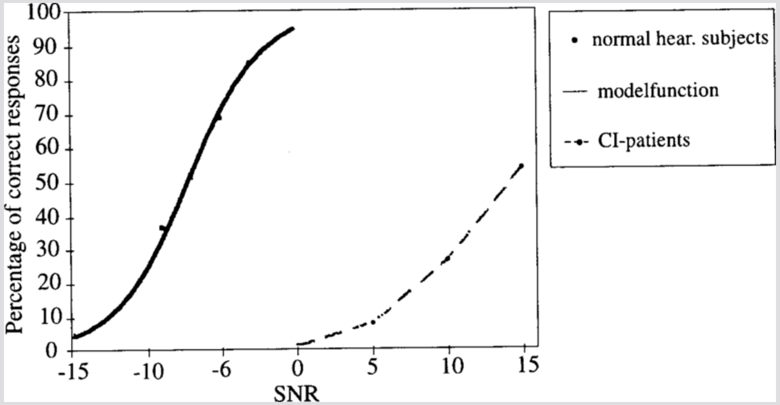
- Sentence test/Open set test: HSM
- 30 balanced lists of 20 words
- Administered without background noise at
- SNR = 0, 5, 10 dB
- A sentence is presented and the subject repeats it.
- The result is given in % of correct words.

Speech Tests

- OLSA: Adaptive Matrix Test
- Speech Reception Threshold (SRT)

Soggetto	Verbo	Aggettivo Numerale	Complemento Oggetto	Aggettivo Qualificativo
Andrea	Cerca	due	bottiglie	azzurre
Anna	Compra	quattro	macchine	belle
Chiara	Dipinge	cinque	matite	bianche
Luca	Manda	sette	palle	grandi
Marco	Possiede	otto	pietre	nere
Maria	Prende	nove	porte	normali
Matteo	Regala	dieci	scatole	nuove
Sara	Trascina	venti	sedie	piccole
Simone	Vede	poche	tavole	rosse
Sofia	Vuole	molte	tazze	utili





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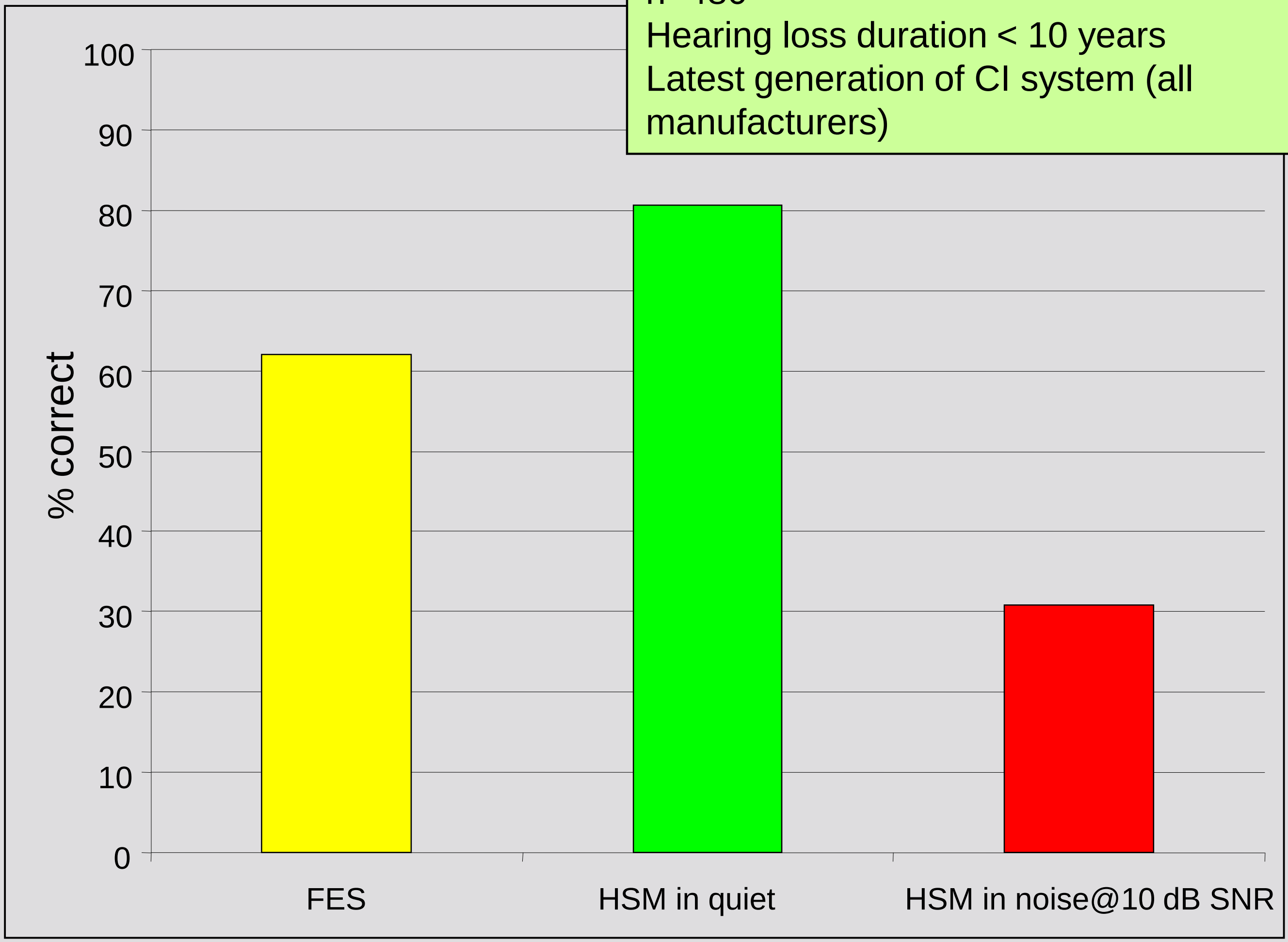
Hearing performance with cochlear implantation

FES: Monosyllables
HSM: Open sentences
‚Ist das Flufzeug gestartet‘

n=480
Hearing loss duration < 10 years
Latest generation of CI system (all manufacturers)



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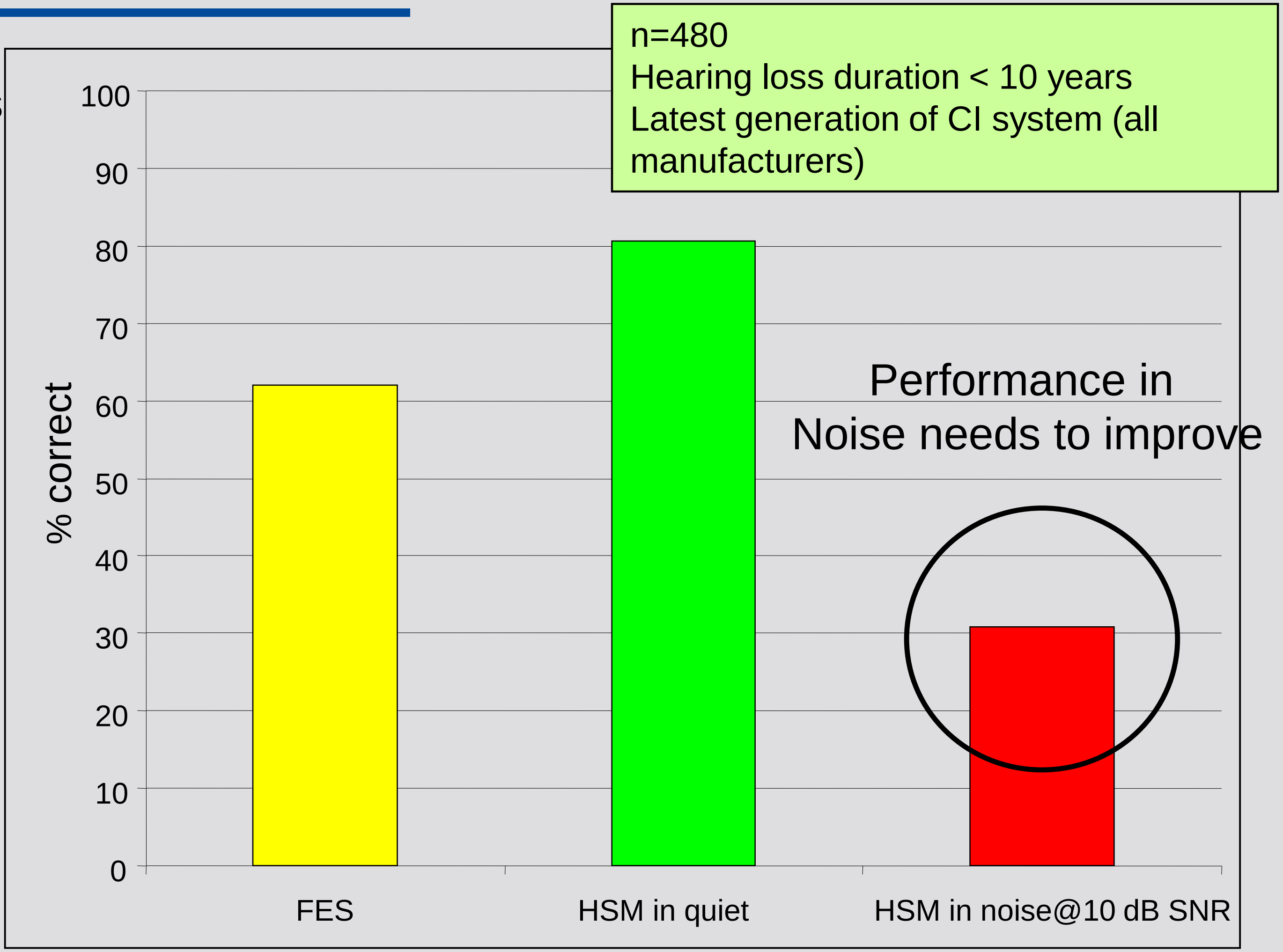

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Alessandro Volta (1745 – 1824)

- Inventor of the voltaic pile, the first battery

- Volta was the first to stimulate the auditory system electrically, by connecting a battery of 30 or 40 ‘couples’ (approximately 50V) to two metal rods that were inserted into his ears. When the circuits were completed, he received the sensation of “a boom within the head”, followed by a sound similar to that of boiling of thick soup.

Alessandro Volta

Voltaic Pile (ca. 1800)

Wever und Bray 1930

Proof of cochlear microphonics

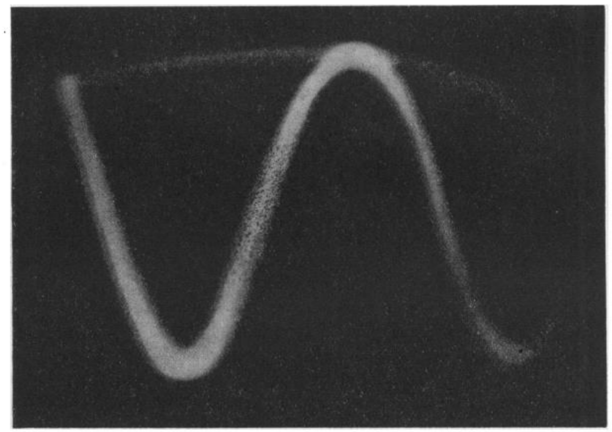
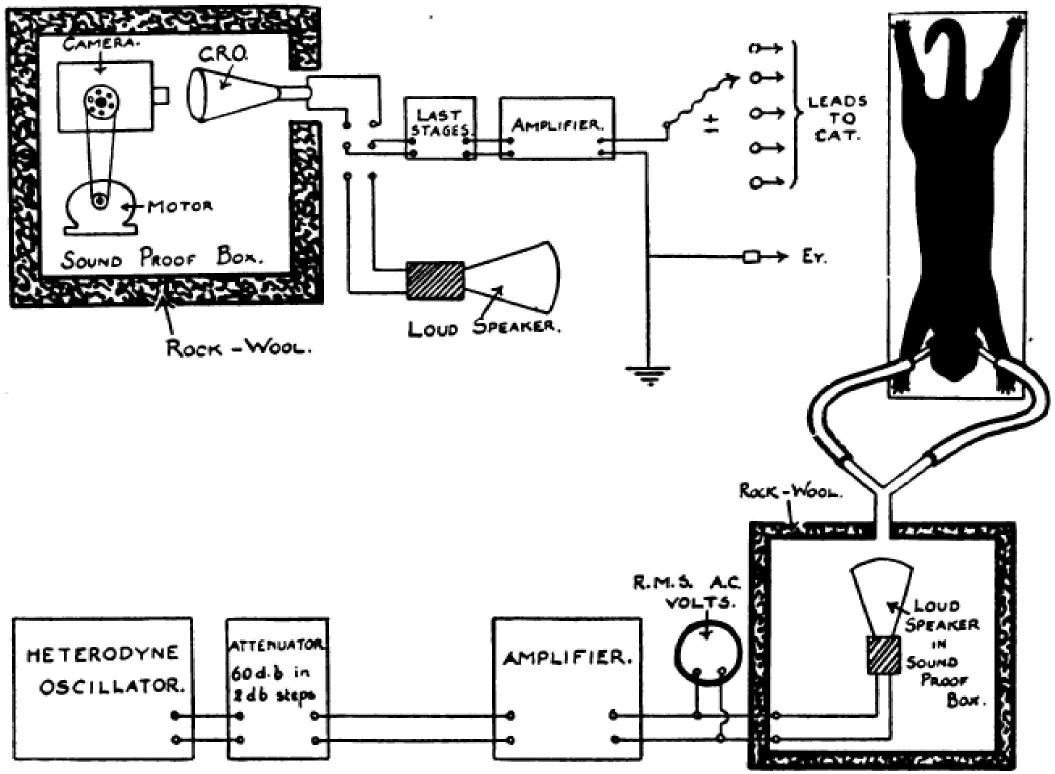


Fig. 2. Wave-form of the cochlear effect. Synchronized linear sweep used, plate exposed for one-fifth second, giving 200 superimposed waves. Frequency of stimulus, 1000 cycles. (Untouched photograph.)



Article in Popular Science, May 1936

Discovering Cochlear Microphonics

POPULAR SCIENCE Monthly
MAY 1936 VOL. 128 No. 5
RAYMOND J. BROWN, Editor

How highly sensitive instruments are used to measure infinitesimal currents in the brain, tracing records of dreams and other mental activity upon the film in a camera

Amazing Electrical Tests show What Happens When You Think

By Edwin Teale

PIONEERS in an amazing new field of research recently traveled to the Loomis Laboratories, Tuxedo Park, N. Y., for the first meeting of its kind in America. The sixty scientists who compared notes are "brain-wave" experts, students of minute, telltale pulsations of electric current that come from the billions of cells in the human brain.

With supersensitive electricity-recording instruments, able to register less than a millionth of a volt of current, they are discovering curious facts about our brains and how they work. Already, these scientists have achieved such exciting feats as "photographing a dream," watching the electrical pattern made by brain cells in solving a mathematical problem, and witnessing an "electrical storm," piling up in the brain of an epileptic. By discovering rhythms in the varying strengths of these tiny currents, they are working toward a radically new technique in detecting and diagnosing various ailments of the brain.

The first man to tap this feeble flow of power was the German scientist, Fleischle von Marxow. In 1890, with crude and relatively insensitive apparatus, he detected faint electrical impulses passing through the skulls of animals.

For generations before, physiologists had known that tiny currents of electricity accompany the functioning of many parts of the body. If you wink your eye, clench your jaws, take a deep breath—each

Popular Science, May 1936

"…words spoken into the animal`s ear could be heared over the phone, proving that ears litterally are microphones, turning sound oscillations into electrical impulses …"

Single Channel Cochlear-Implants

The William House Implant, early 1970’s (later: 3M Implant)

William House

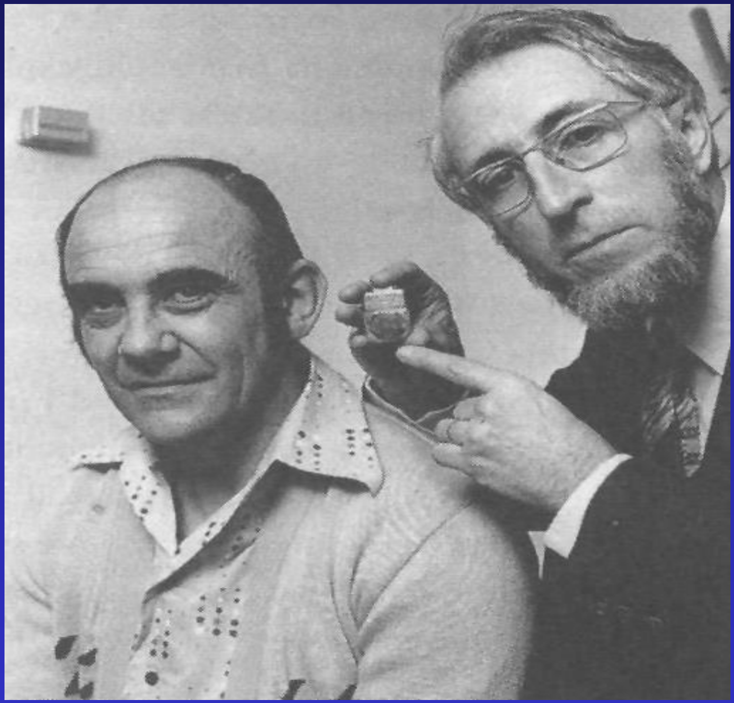
Jack Urban (right)

3M single channel implant

The single channel House-Implant, which was used in hundreds of deaf patients in the 70‘s, gave benefit in terms of lip-reading support and allowed perception of environmental sounds.
It was the first commercially available system with a body-worn signal processor and transcutaneous signal transmission.
However, open speech understanding was hardly ever possible with this device.

Multi-channel Cochlear-Implants

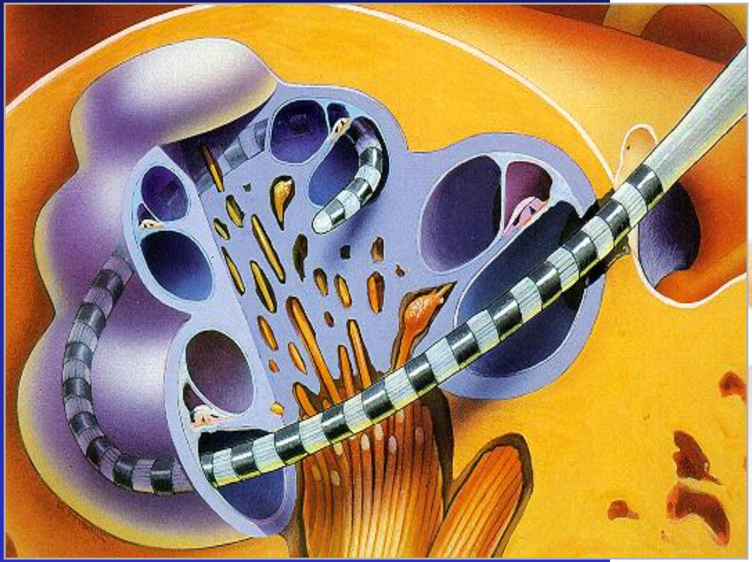
The Graham Clark Implant, 1978

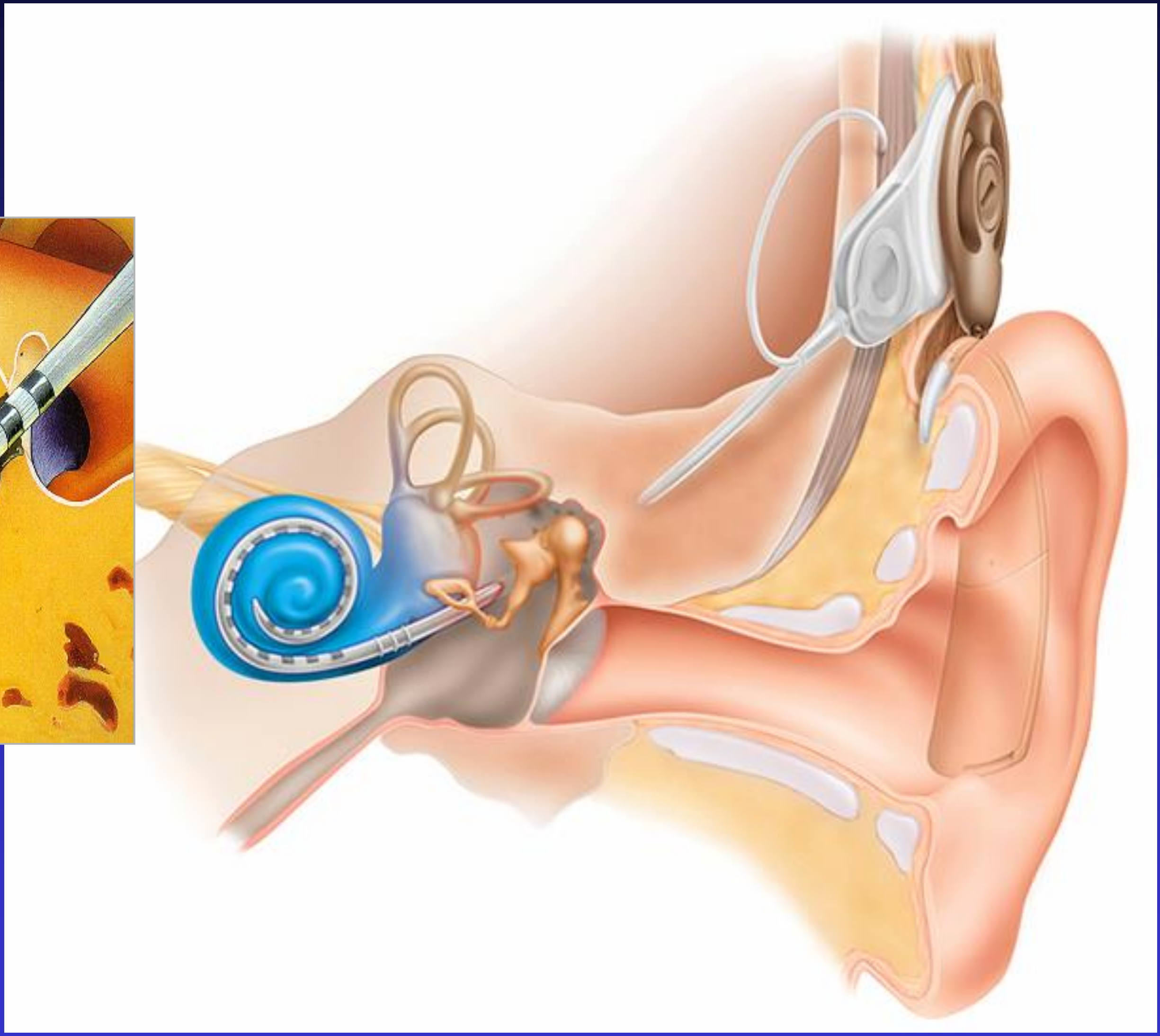


Prof. Graham Clark (right)

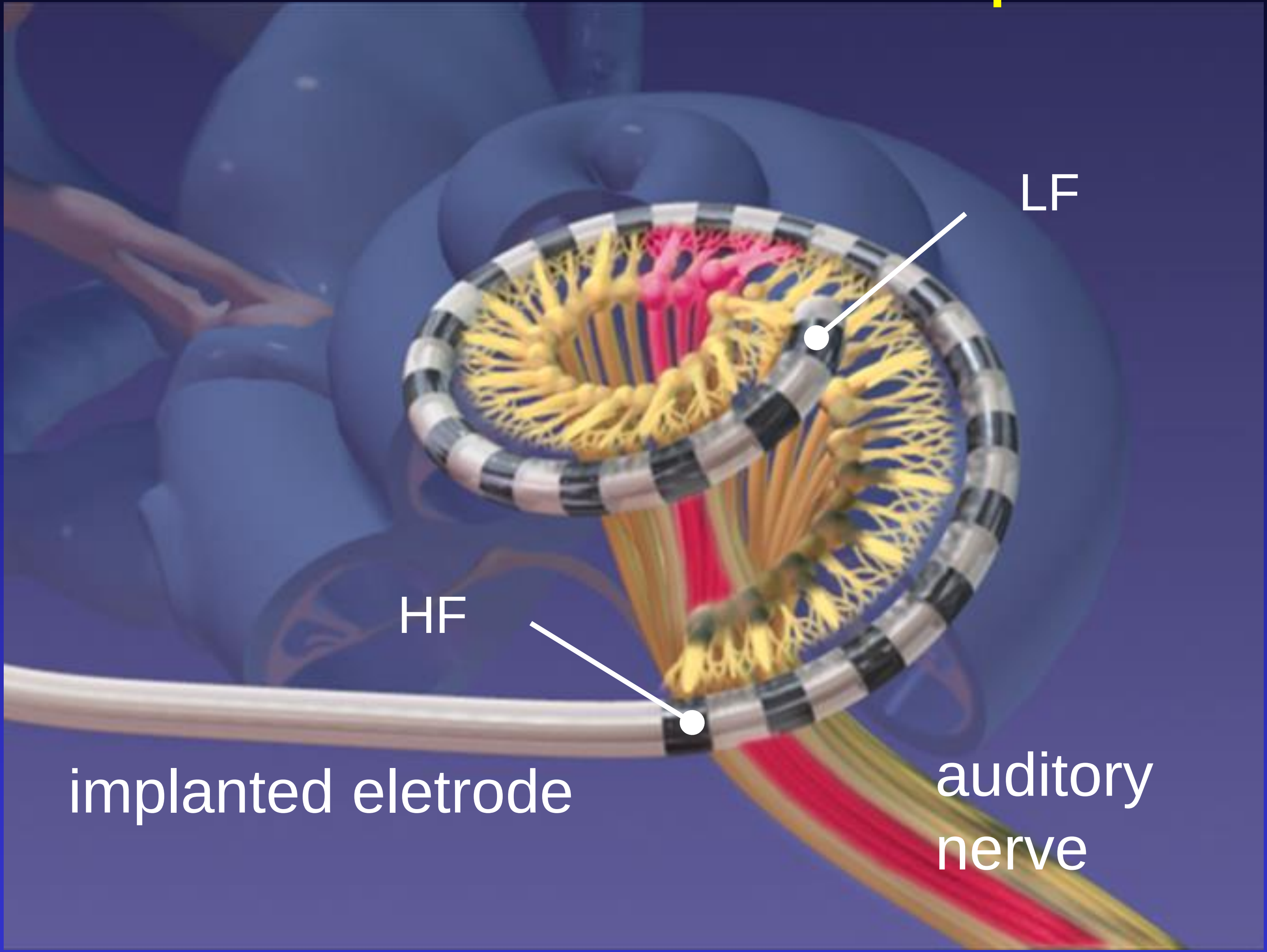
World's first multi channel implant

Multi-channel Cochlear Implant



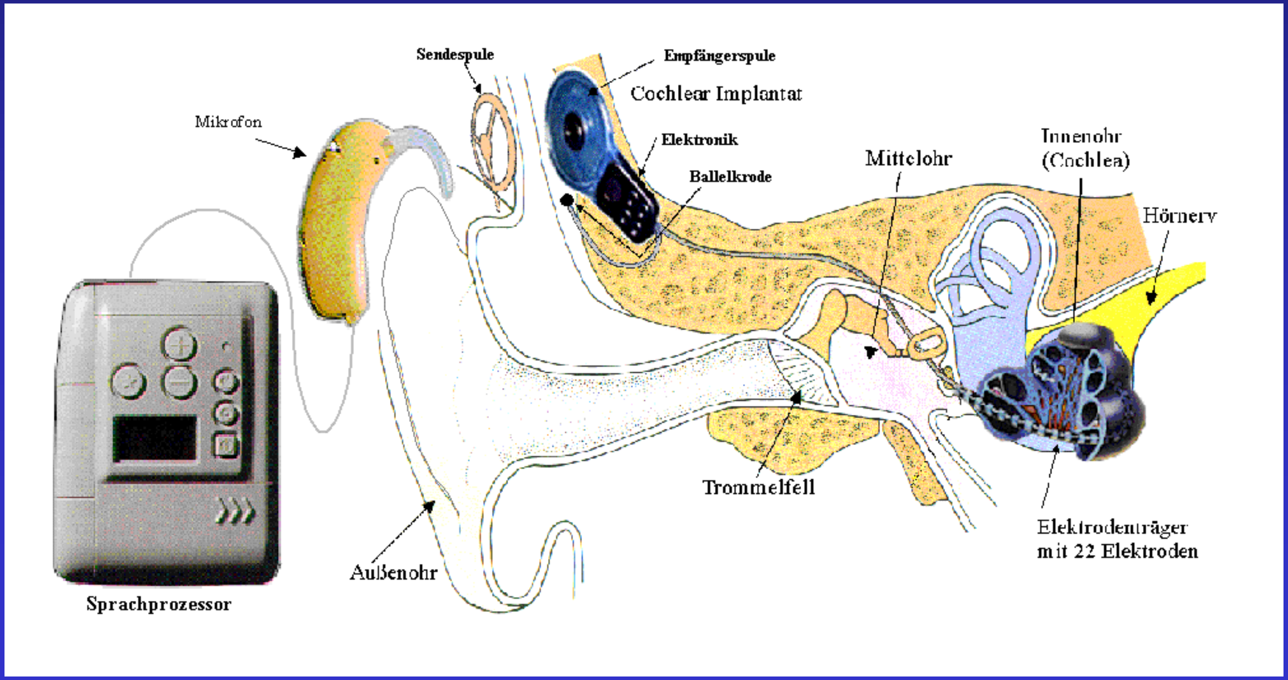


Multi-channel Cochlear-Implants



Why do we need speechcoding?

- Speech coding strategies control the digital processing of environmental and speech sounds.
- Different strategies emphasize different pitch, loudness and timing cues.



Contents

Cochlear implant with a single electrode

William House (1923 – 2012), in 1970 (3M Implant)

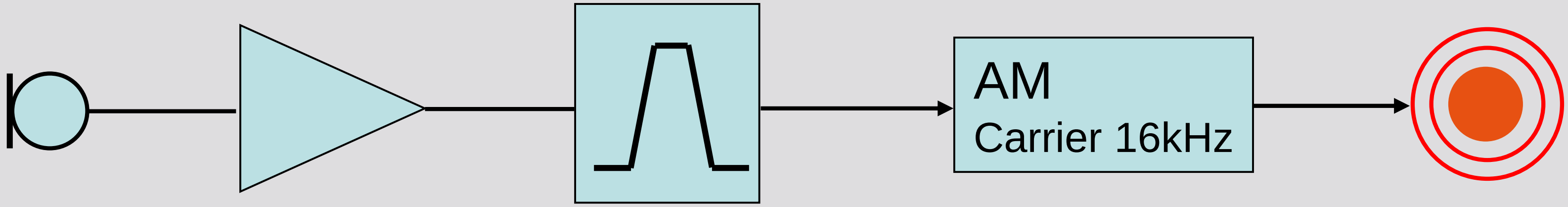
William House

Jack Urban (right)

3M Single-
Electrode Implant

Cochlear implant with a single electrode

Microphone Amplifier Band-pass filter Modulation Electrode

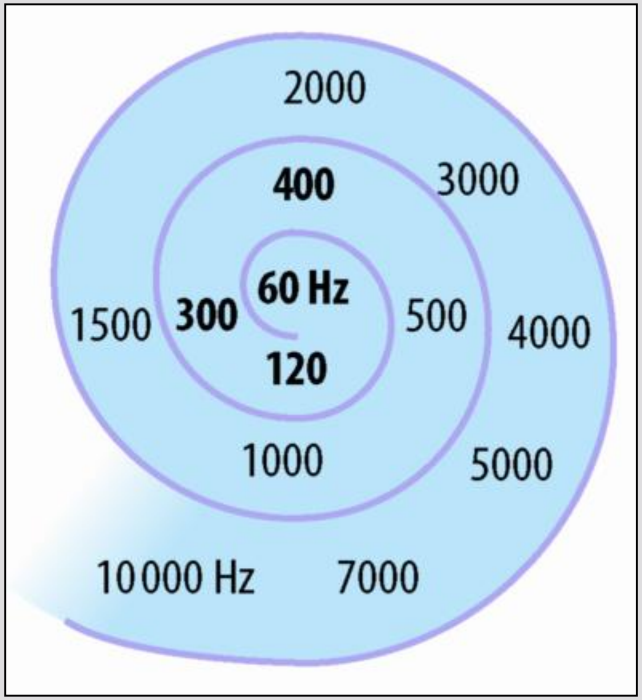


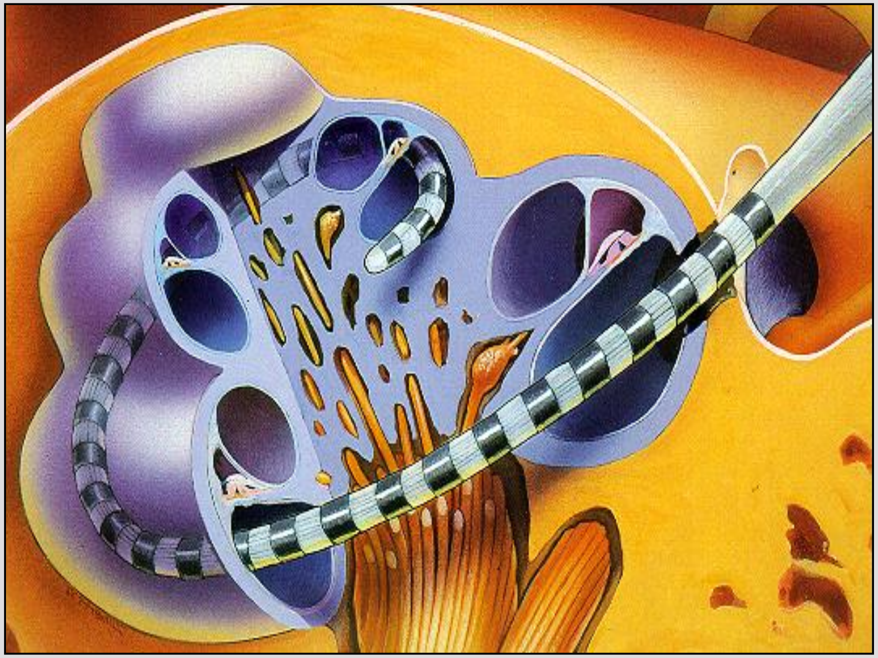
340 until 2700 Hz

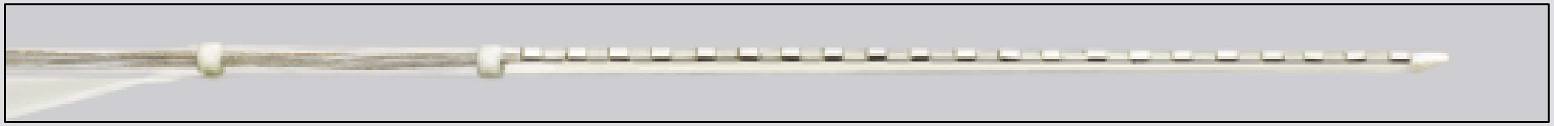
Speech Intelligibility

Zeng 2004

Multichannel Cochlear Implant

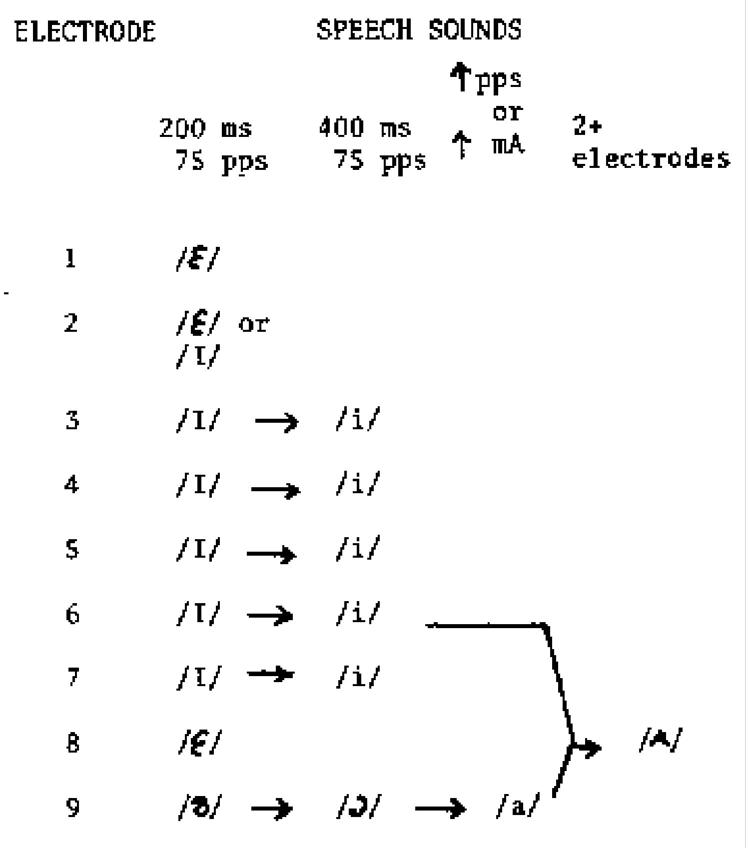






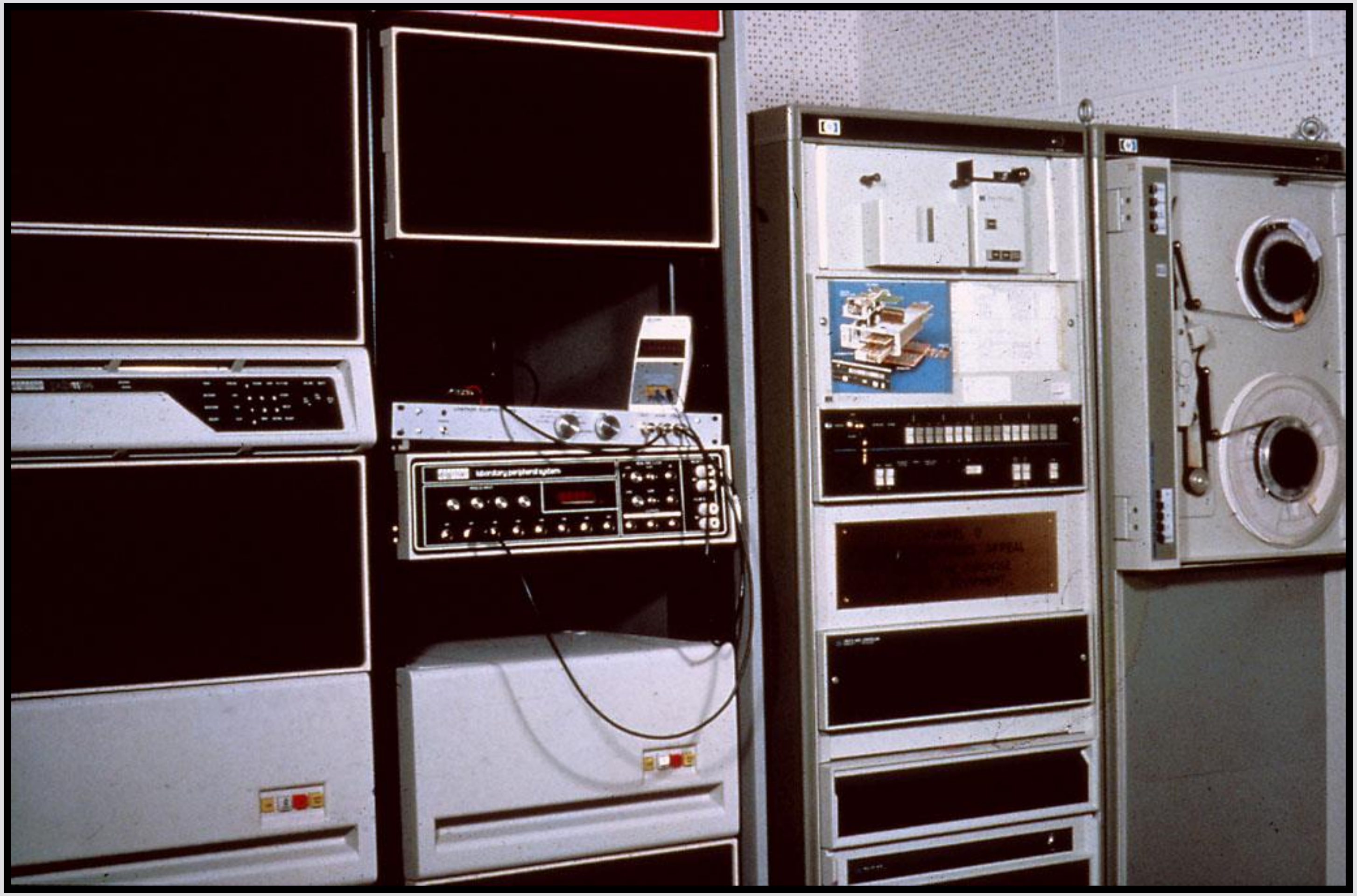
Multichannel Cochlear Implant

Clark Feature Extraction 1978



Multichannel Cochlear Implant

First speech processor for multichannel cochlear implant



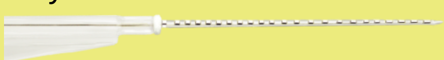
Electrode Arrays

Cochlear (22 Contacts)

Contour Advance

Slim Straight

Hybrid L24



Straight

MEDEL (12 Contacts)

Standard (31 mm)

FLEX^{SOFT} (31 mm)

Medium (24 mm)

FLEX^{28} (28 mm)

Compressed (15 mm)

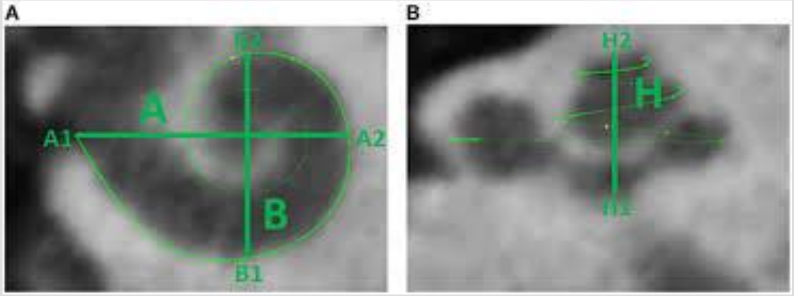
FLEX^{24} (24 mm)

FLEX^{20} (20 mm)

Advanced Bionics (16 Contacts)

Cochlear length vs electrode array

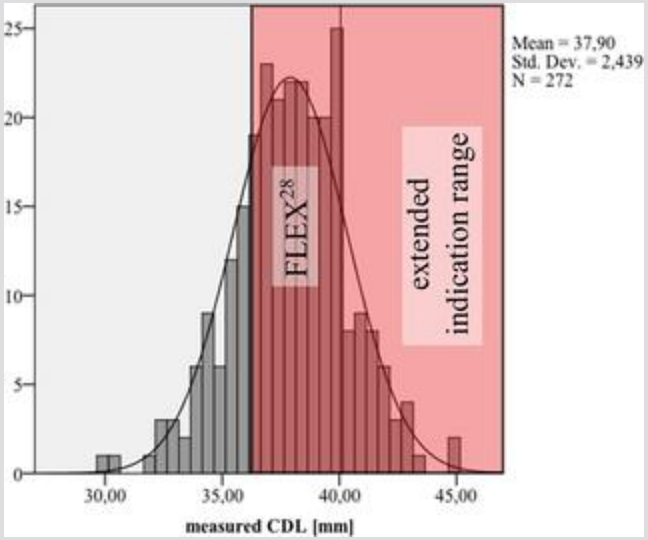
MEDEL (12 Contacts)



Nogueira (2016), Frontiers

Medical Image (CT) for each patient

At MHH (Pre- y Post- operation)



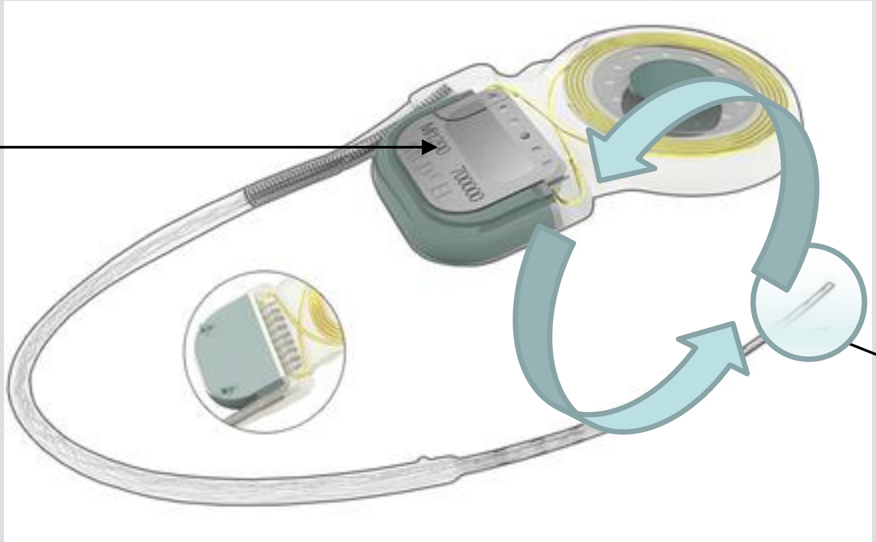
MED-EL & Würfel 2014

Stimulation Mode

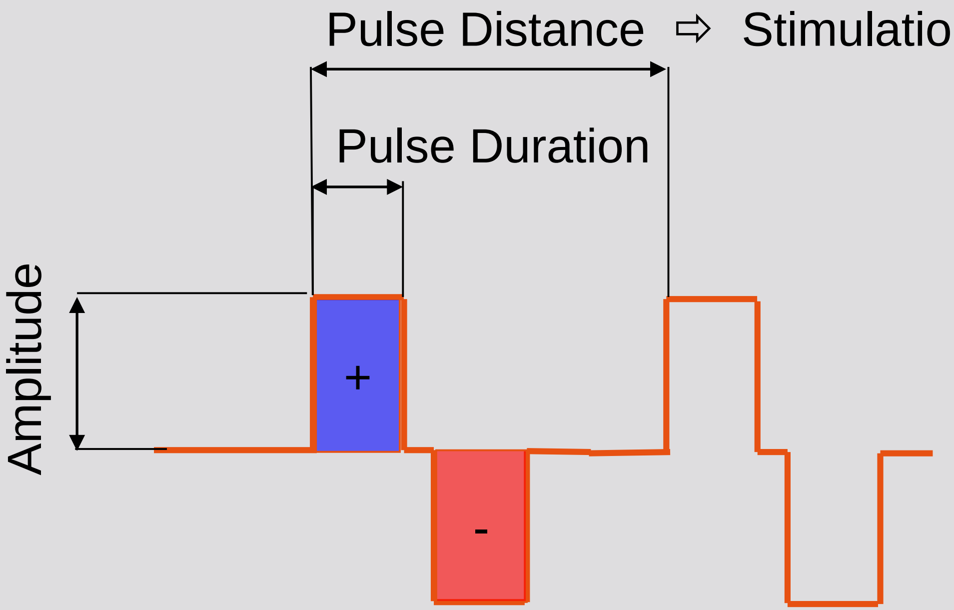
Monopolar Stimulation

- An intracochlear electrode is connected to an extracochlear reference electrode such that current flows between the two electrodes.

- Simultaneous stimulation of multiple electrodes is undesirable because it causes interaction between the channels.



Stimulation with Biphasic Pulses



- The amount of load defines the loudness (pulse duration and amplitude).

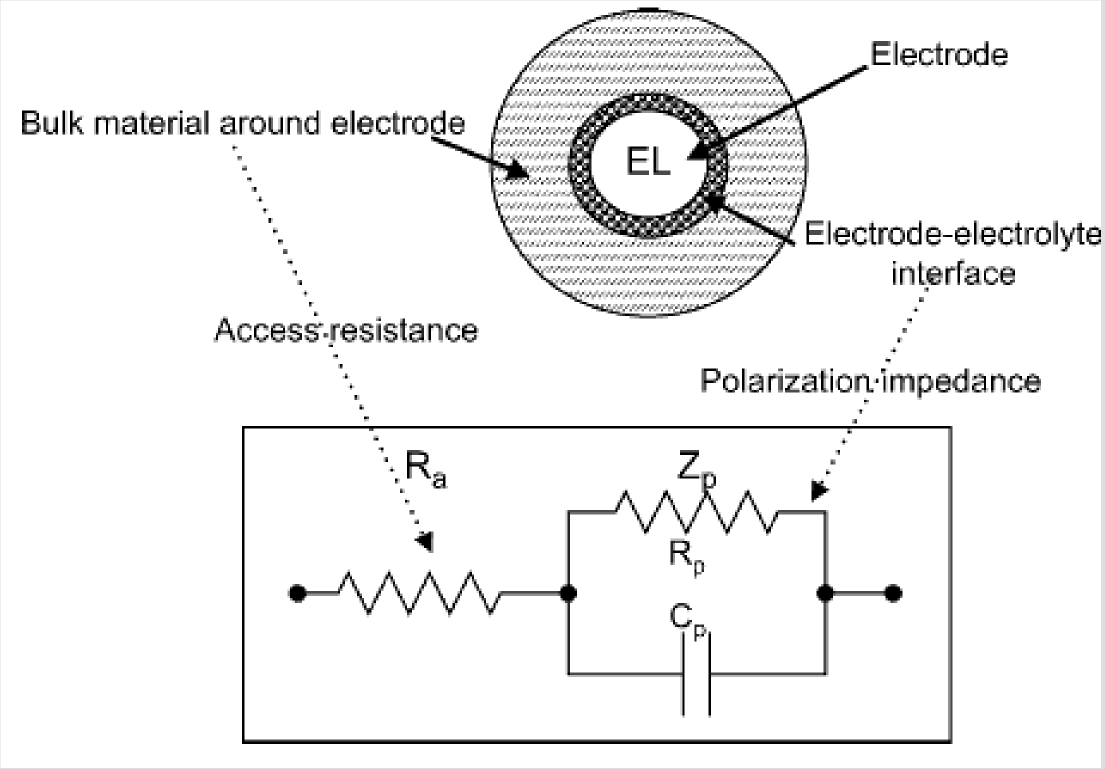
- Stimulation rate (Pulse rate)

- Charge balanced pulses

- The charge density must be limited (depends on the injected charge and the size of the electrodes).

This can cause an irreversible reaction around the electrodes, including changes in the pH level, detachment of parts of the electrode material and formation of protein-metal complexes.

Electrode-Impedance Interface



$$R = \rho \cdot \frac{l}{A}$$

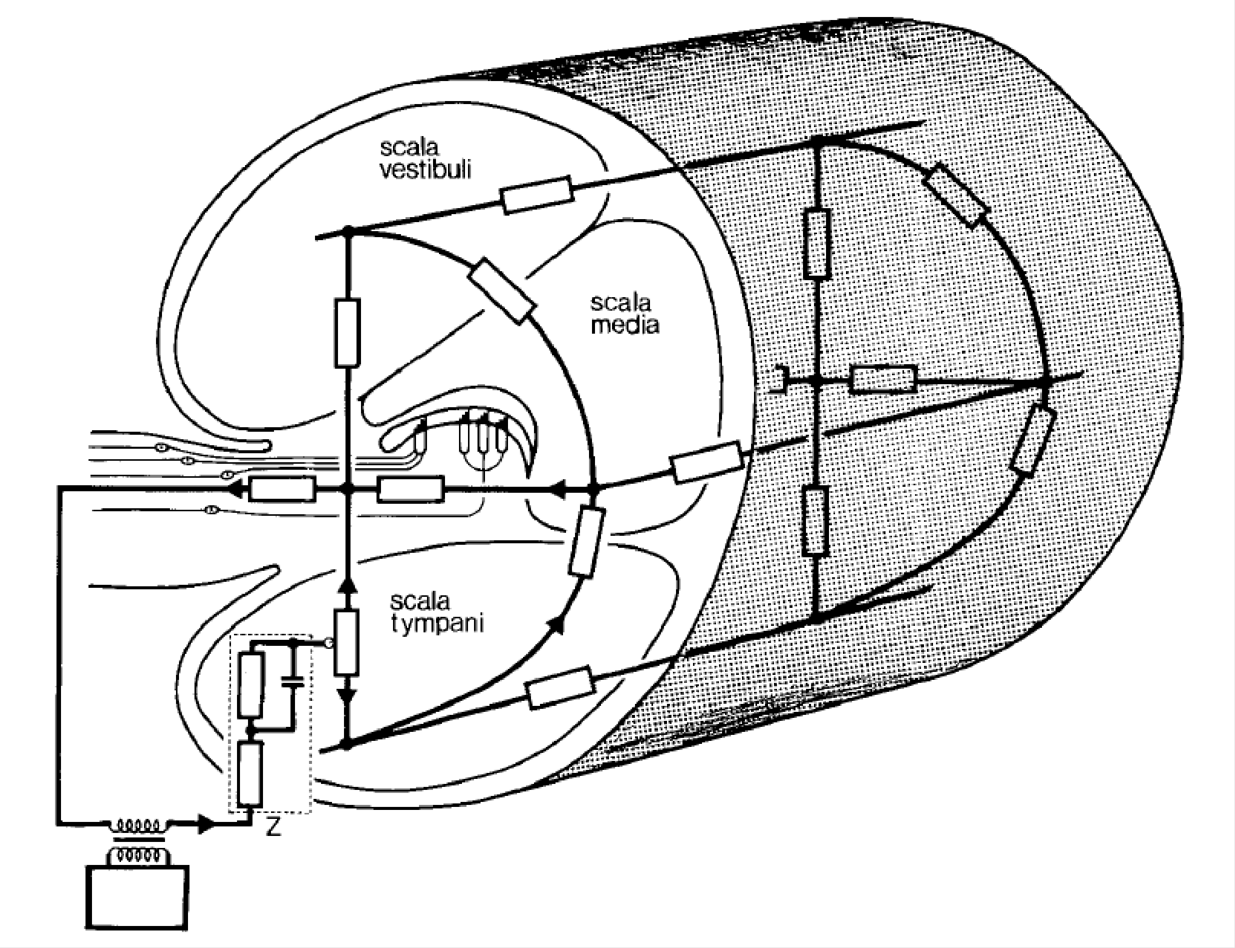
ρ : resistivity

$$C = \varepsilon_0 \varepsilon_r \cdot \frac{A}{d}$$

ε_r : Dielectric constant

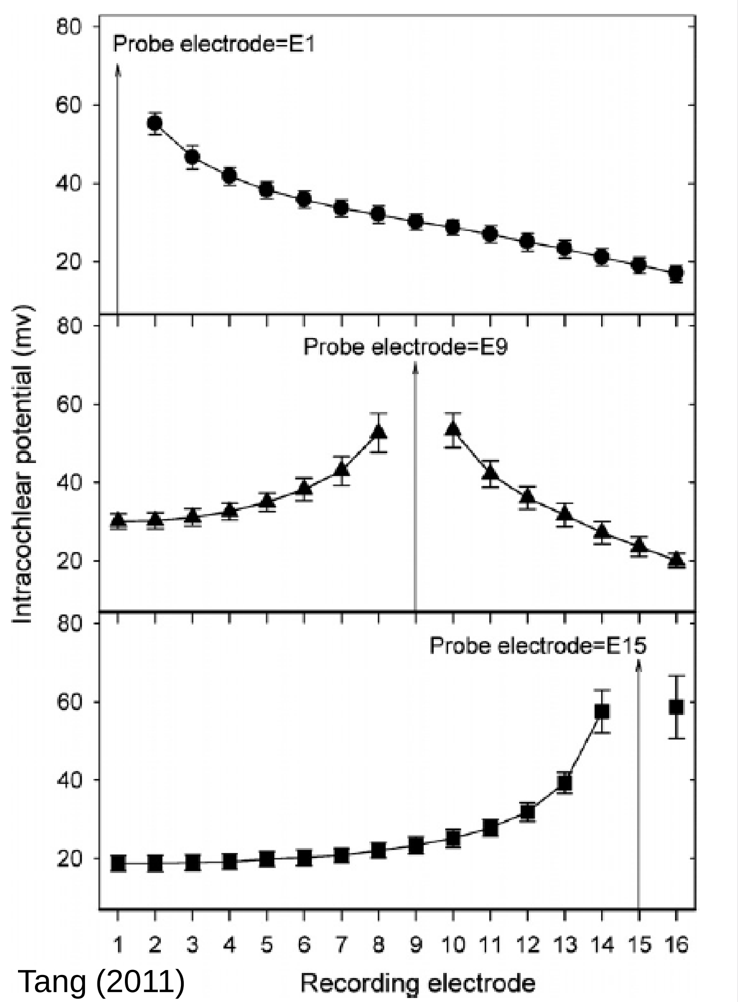
ε_0 : Electric field constant

Current flow within the cochlea



Klinke & Hartmann (1979)

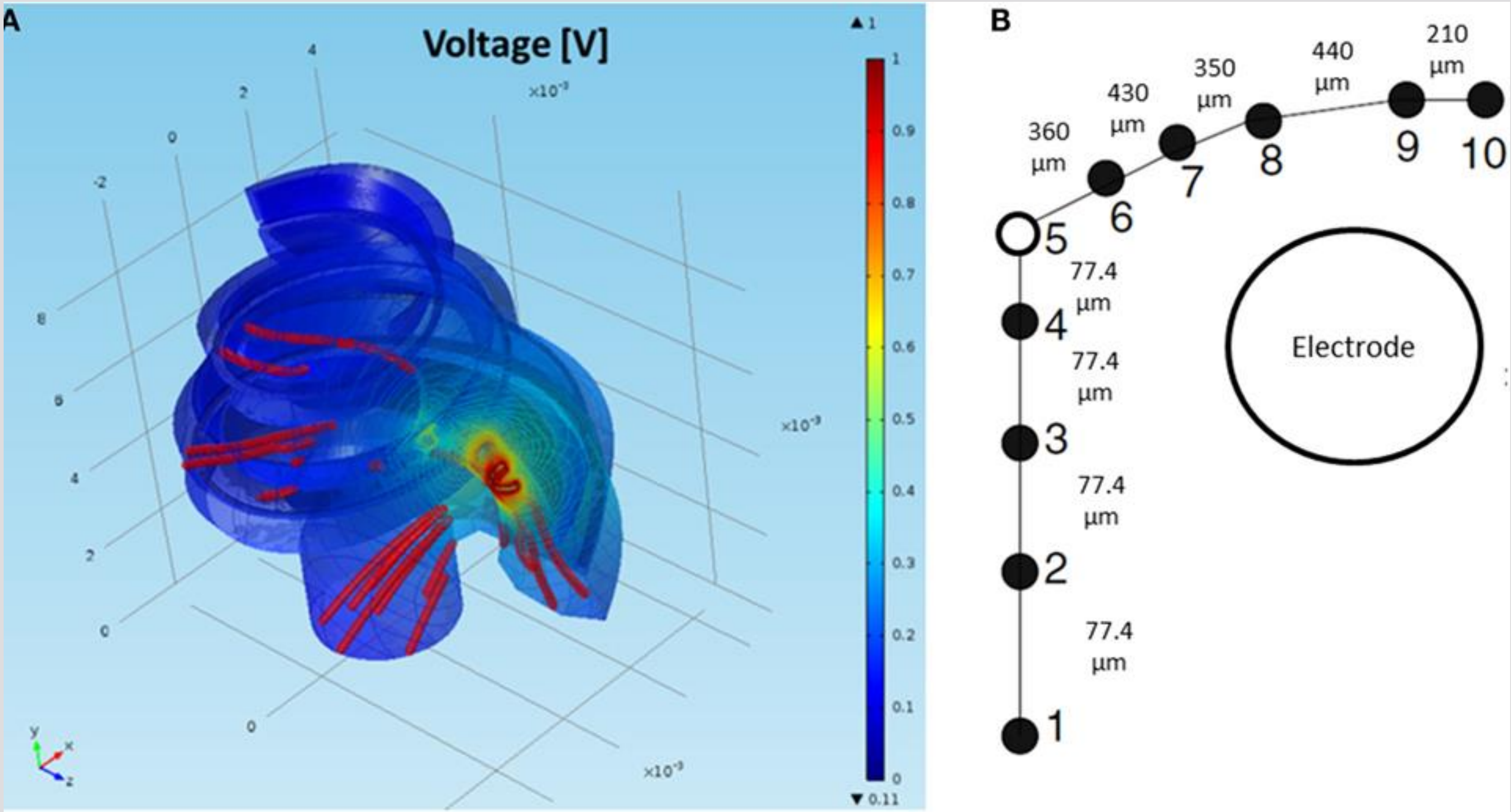
Current flow within the cochlea



Tang (2011)

Simulation of voltage distribution within the cochlea

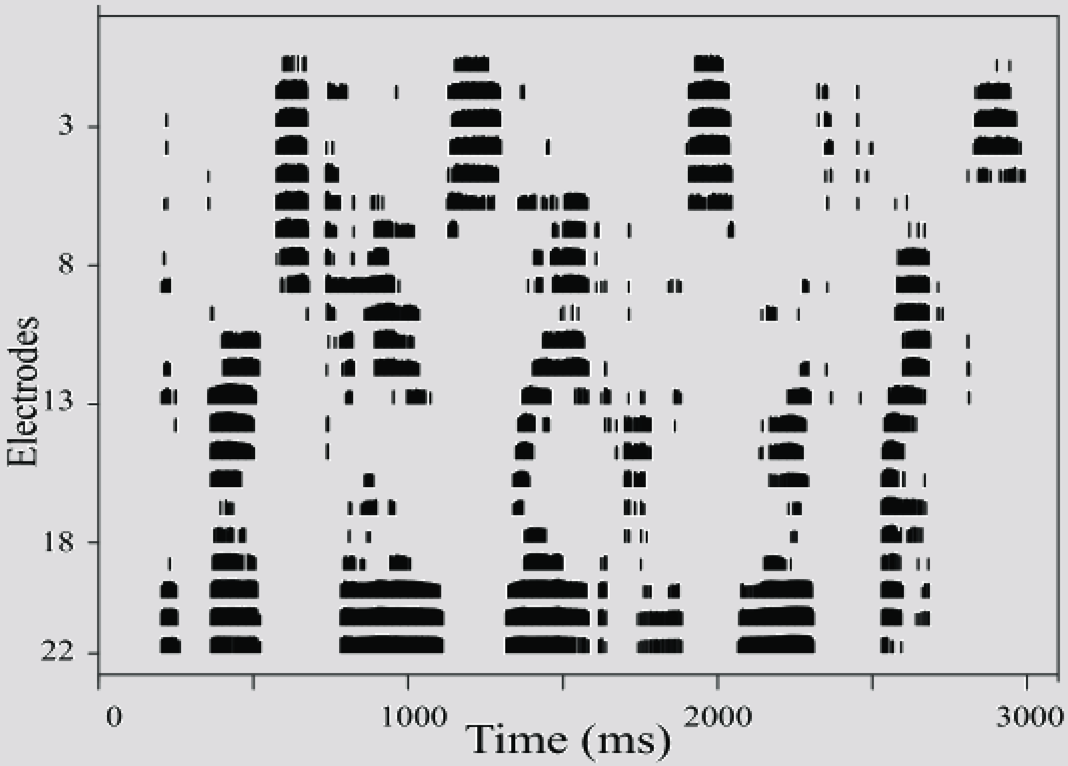
Monopolar Stimulation:



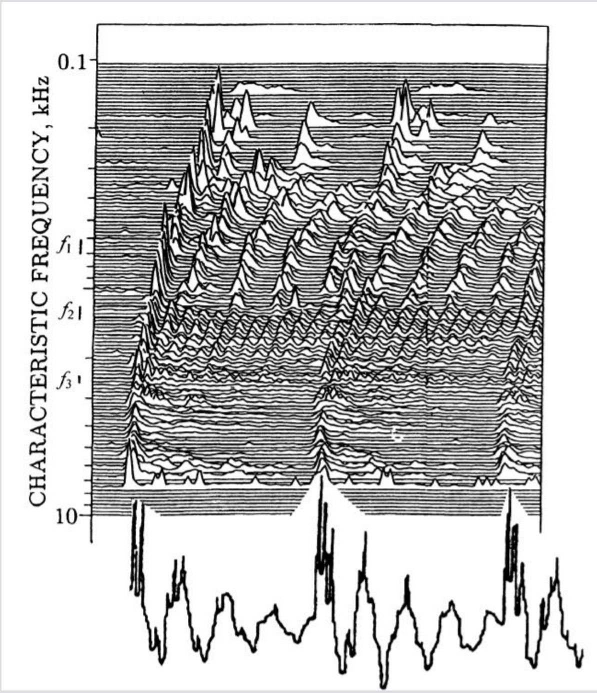
Nogueira (2016), Frontiers

Electrodogram vs Neurogram

Electrodogram Cochlear Implant



Neurogram Normal Hearing



Acustic Stimulation vs. Electric Stimulation

	Normal Hearing	CI Hearing
Spontaneus activity	high	Non-existing
Synchronicity	reduced	high
Dynamic Range	120 dB	12 dB
Spatial Stimulation	narrow	wide
Frequency Resolution	3500 IHC	~10 channels
Temporal stimulation pattern	simultaneous	coded

→ A new CI sound coding is needed

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Hilbert 1912: Signal decomposition

In fast+slow oscilatory components

Fine Structure

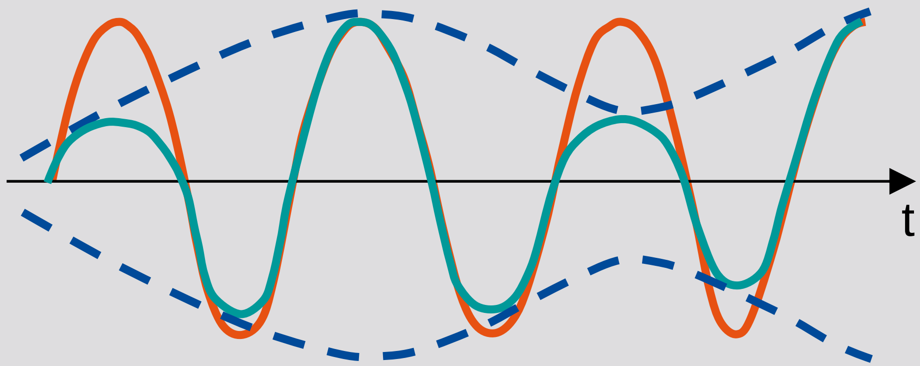
↓

Pitch & Localization

Envelope

↓

Speech



Phonetic Acoustics – Formants Vowels

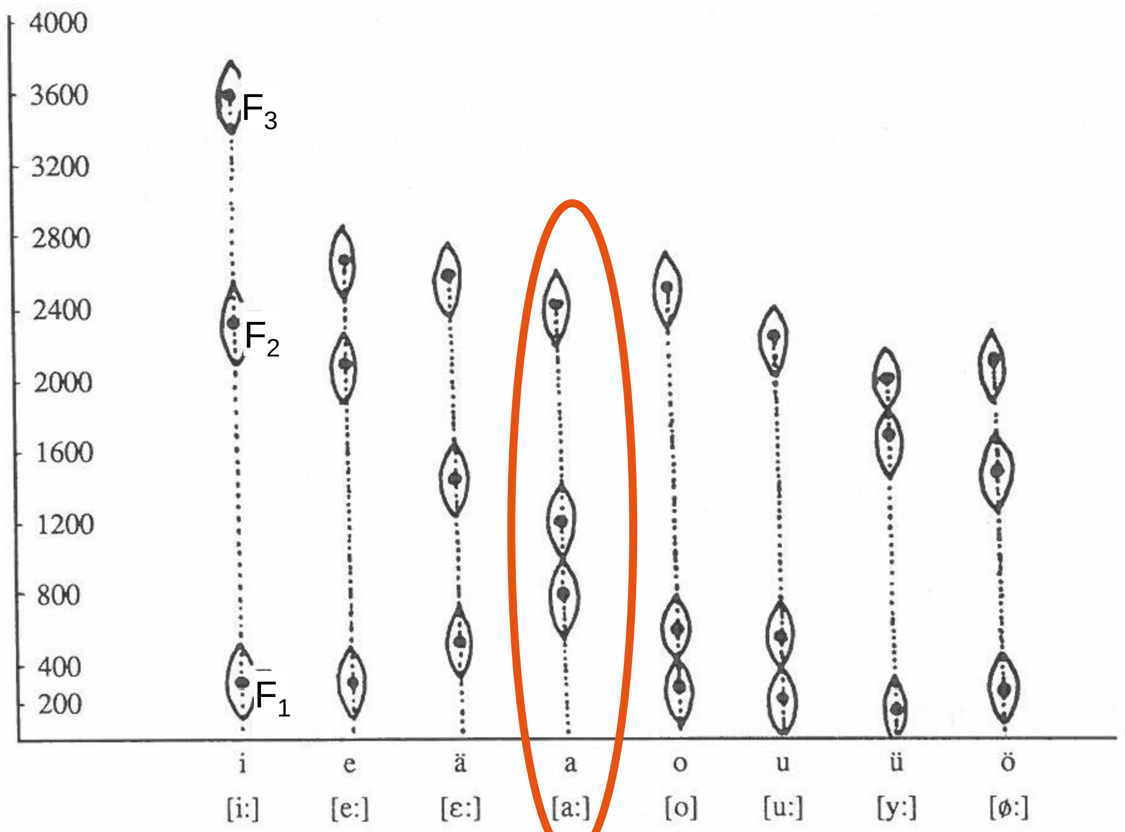
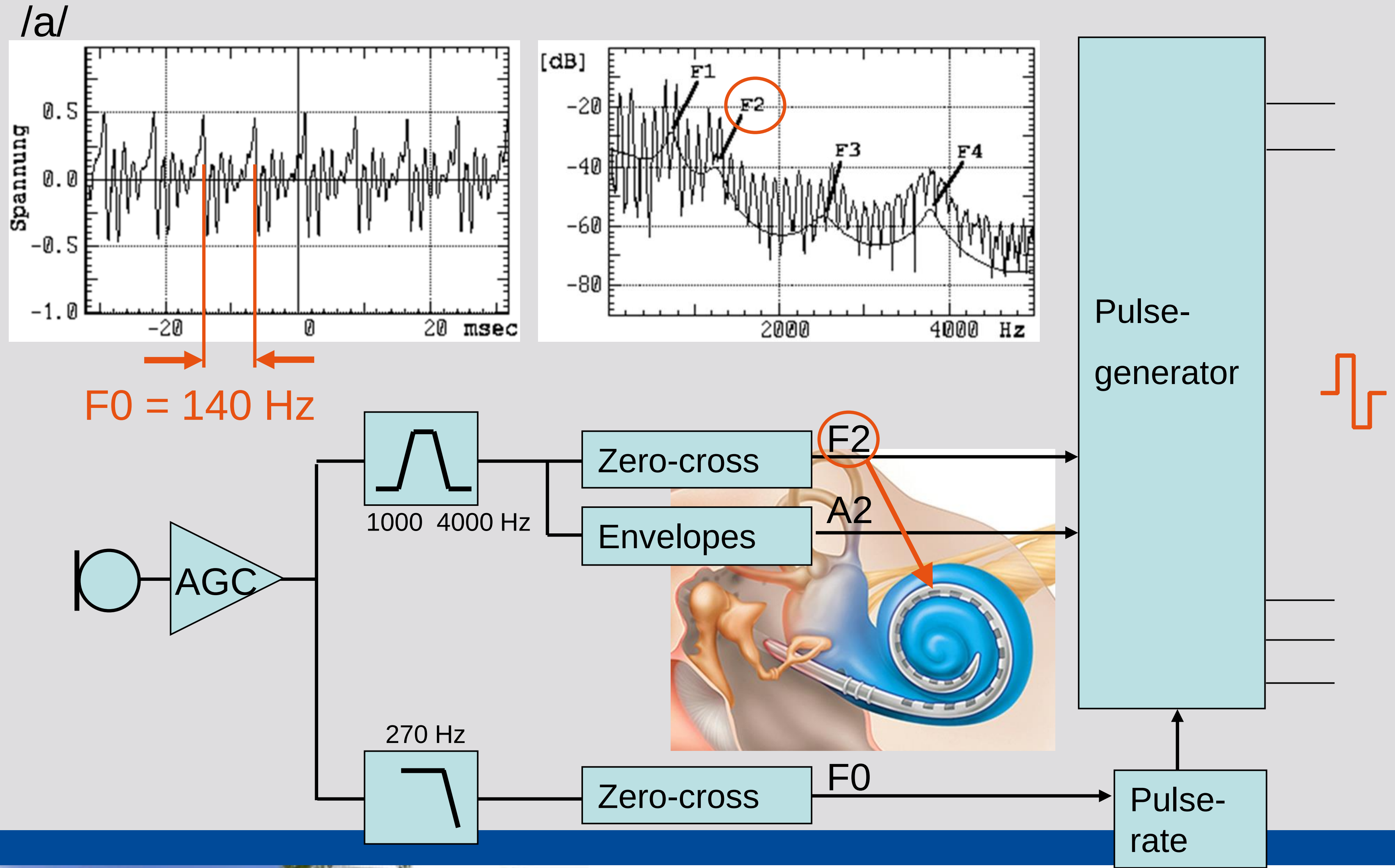


Abb. 13: Schematische Darstellung der Formantbereiche für lange deutsche Vokallaute. (Ermittelt von Dr. D. *Stock*, IPK, Universität Bonn).

Jussen et al., 1994

F0F2 (Beginning of 1980‘s)



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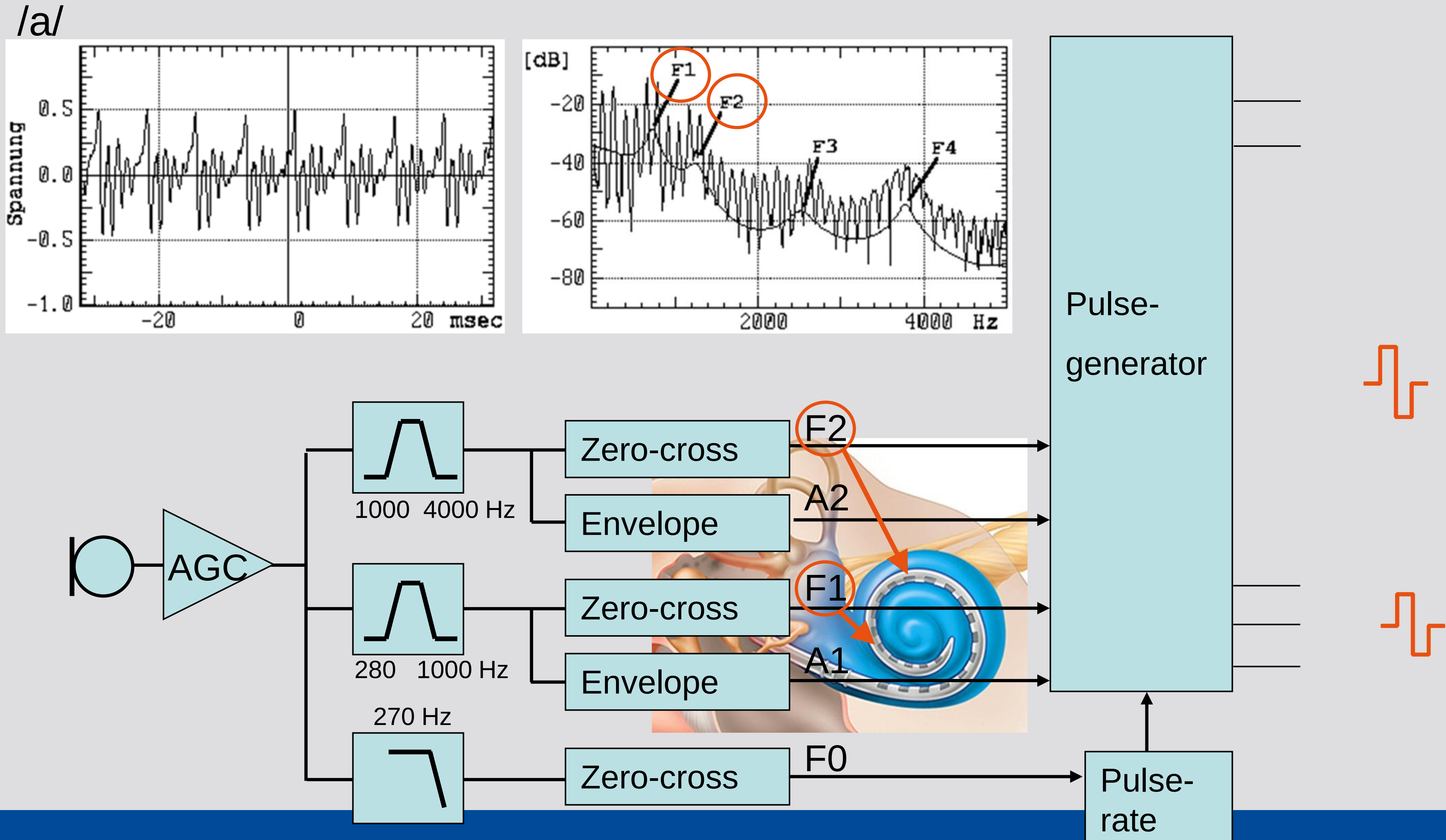
F0F2 (Beginning of the 1980‘s)

Characteristics of the F0F2 strategy:

- The fundamental frequency of the speaker (F0 < 280 Hz) is used as the stimulation rate.
- The second formant (between 800 and 4000 Hz) determines which electrode is stimulated.
- The stimulation current is proportional to the estimated amplitude for the second formant.
- Only one electrode is stimulated in each stimulation cycle.
- Clearly, this strategy was designed to encode speech signals.

F0F1F2 (1985)



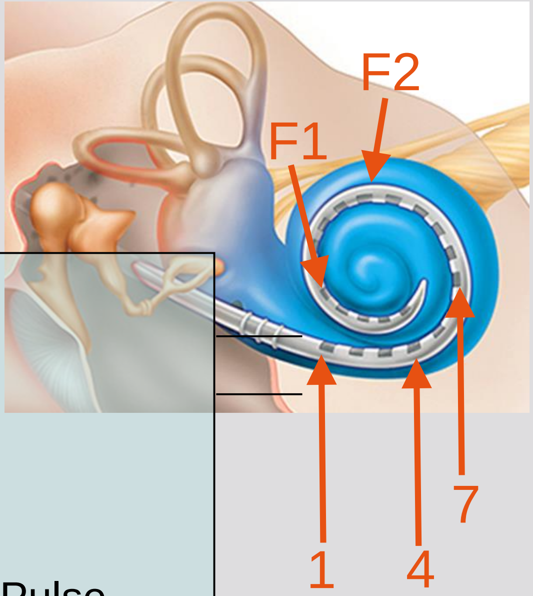
/a/
Spannung
0.5
0.0
-0.5
-1.0
-20
0
20 msec
[dB]
-20
-40
-60
-80
F1
F2
F3
F4
2000
4000 Hz
Pulse-
generator
AGC
1000 4000 Hz
280 1000 Hz
270 Hz
Zero-cross
Envelope
Zero-cross
Envelope
Zero-cross
F2
A2
F1
A1
F0
Pulse-
rate

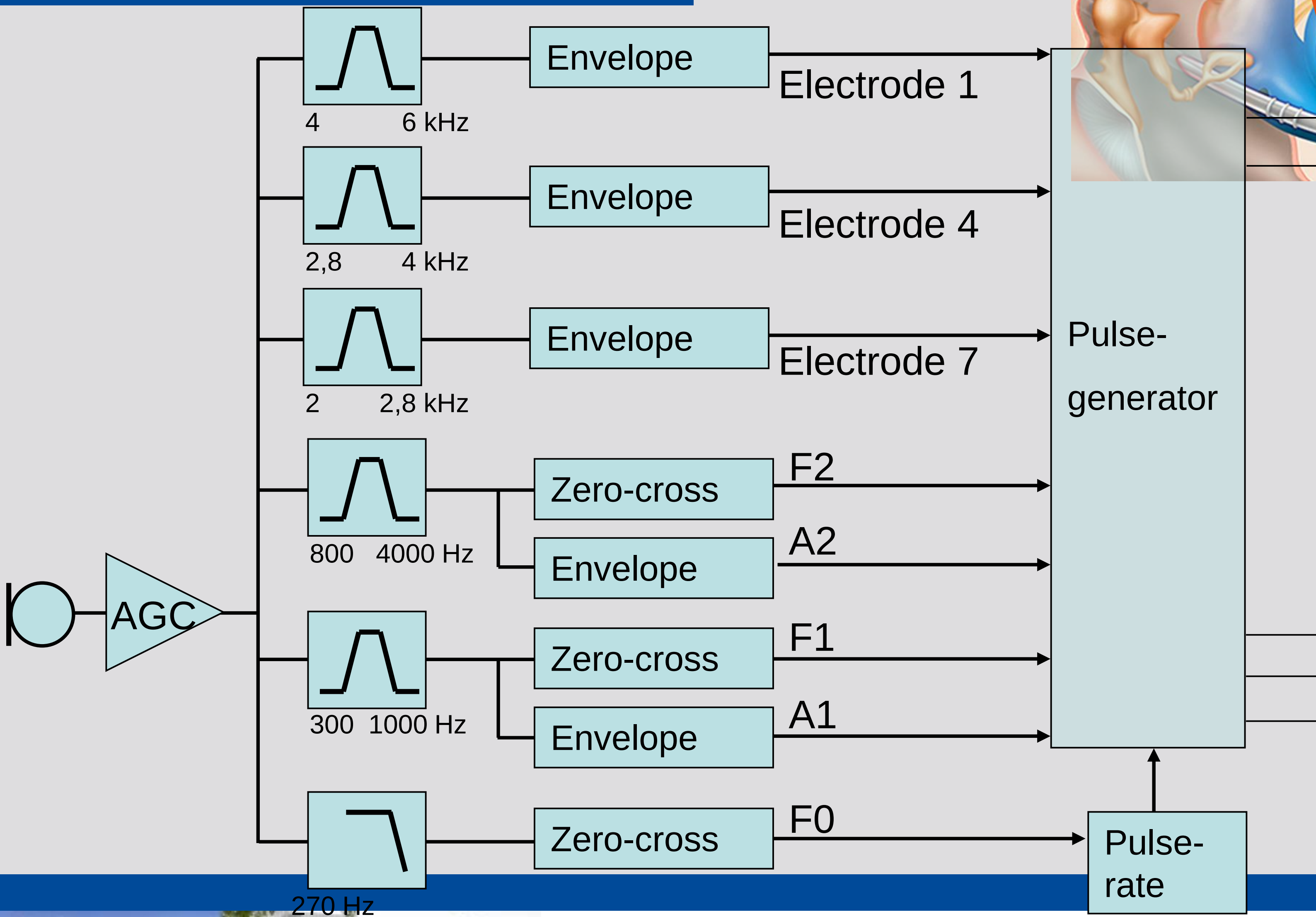
F0F1F2 (1985)

<u>Characteristics of the F0F1F2 strategy:</u>

- The fundamental frequency of the speaker (F0 < 280 Hz) is used as the stimulation rate.
- Electrodes 1 to 5 are used to transmit the 1st formant (between 280 and 1000 Hz).
- Electrodes 6 to 20 are used to transmit the 2nd formant (between 1000 and 4000 Hz).
- Two electrodes are stimulated in each stimulation cycle.
- The stimulation current is proportional to the 1st and 2nd formants.
- Clearly, this strategy was designed to encode speech signals.

MPEAK (End of 1980's)





MPEAK (End of the 1980‘s)

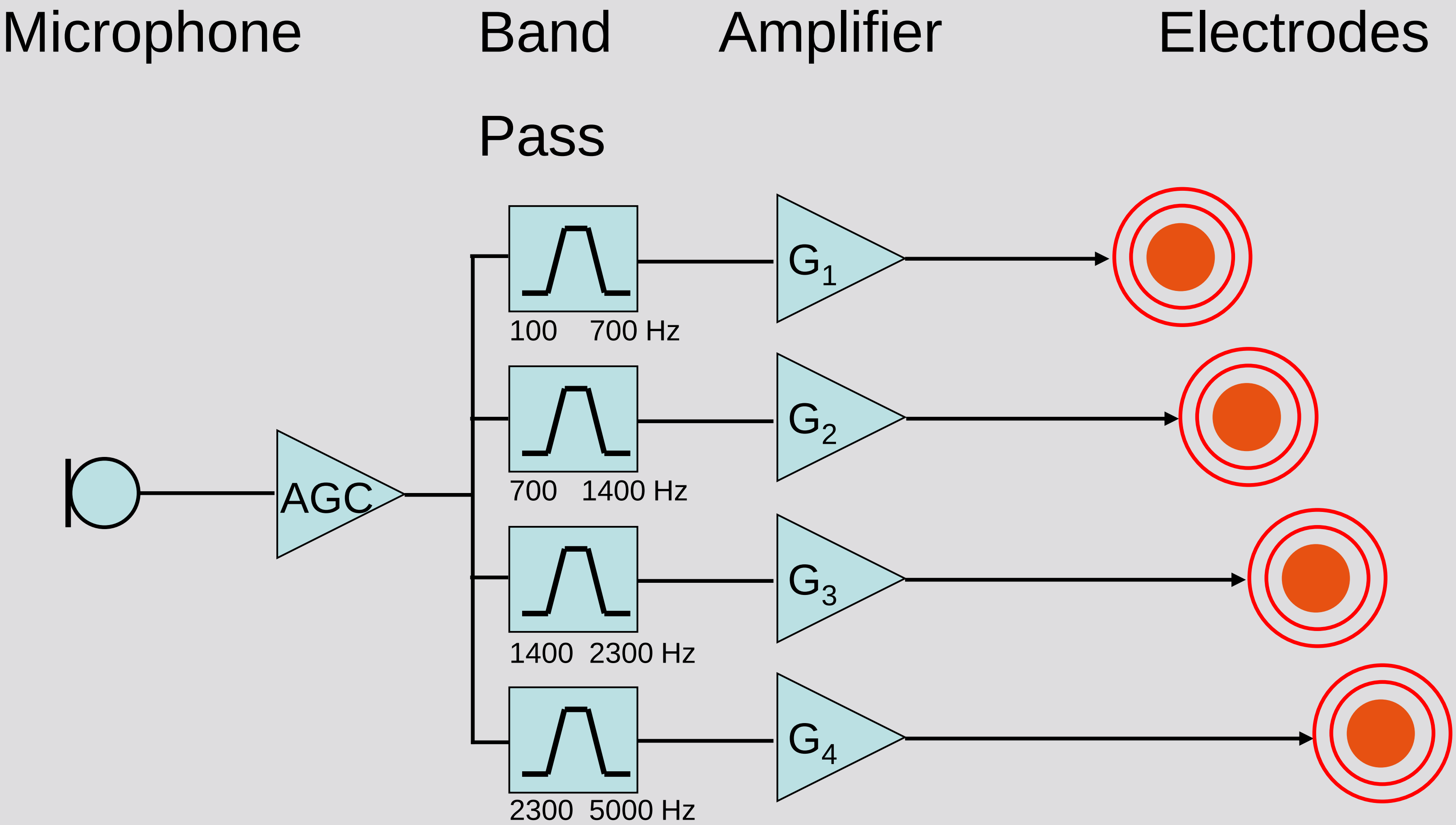
Characteristics of the MPEAK (Multipeak-Strategy) sound coding strategiy:

- The strategy is based on the F0F1F2 strategy (Allows vowel recognition).
- It introduces three high frequency filters:

Electrode stimulation	Frequency Region
7	2-2,8 kHz
4	2,8-4 kHz
1	4-4,7 kHz

- The problem of erroneous feature selection persists.

Compressed Analog (CA)

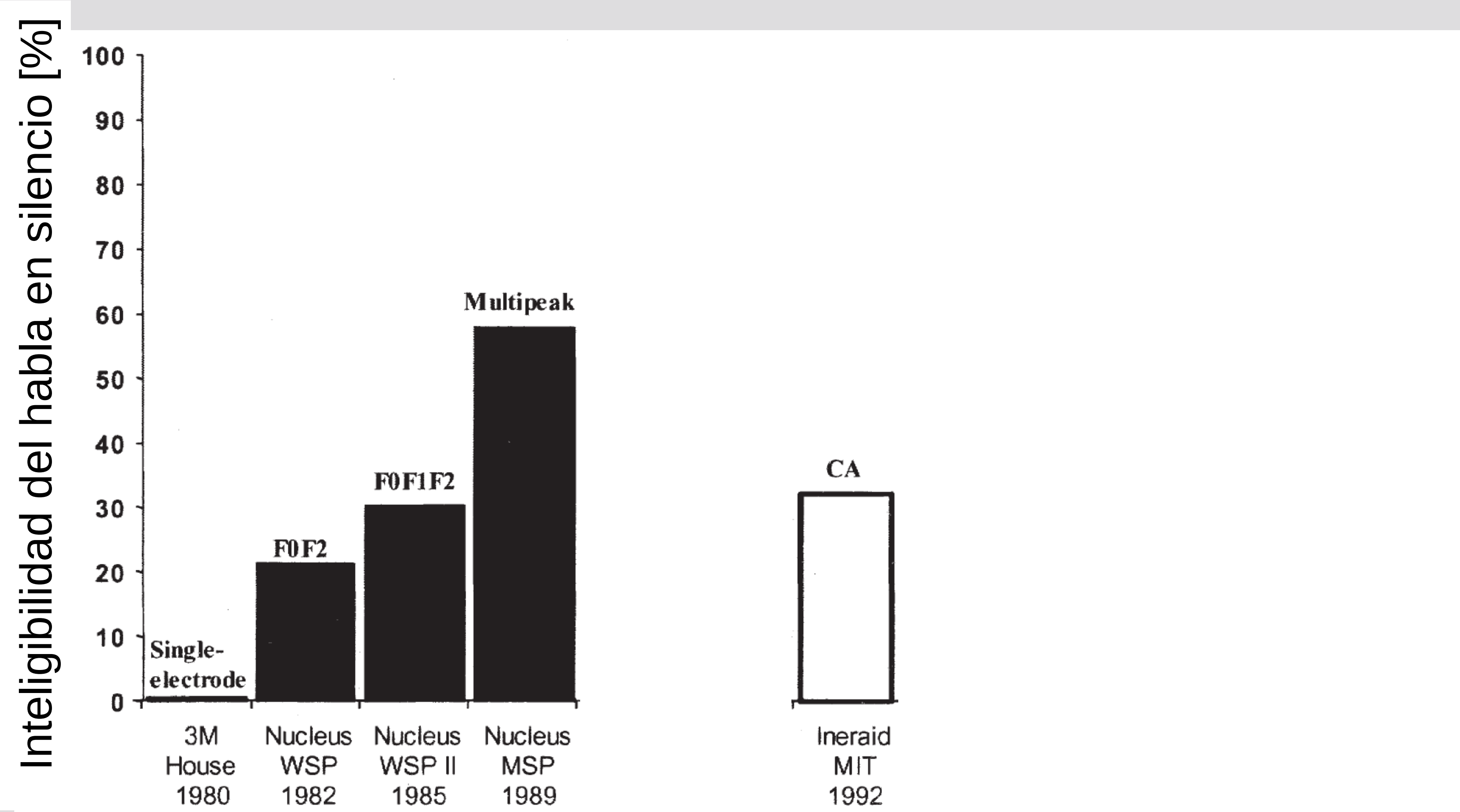


Compressed Analog (CA)

<u>Characteristics of the CA-Strategy:</u>

- Four bandpass filters between 300 and 5000 Hz
- Simultaneous stimulation of 4 intracochlear electrodes
- Monopolar stimulation (later upgraded to bipolar stimulation)
- Better performance than a single electrode system
- Better performance than F0F2 strategy
- Problem: Strong interaction between channels

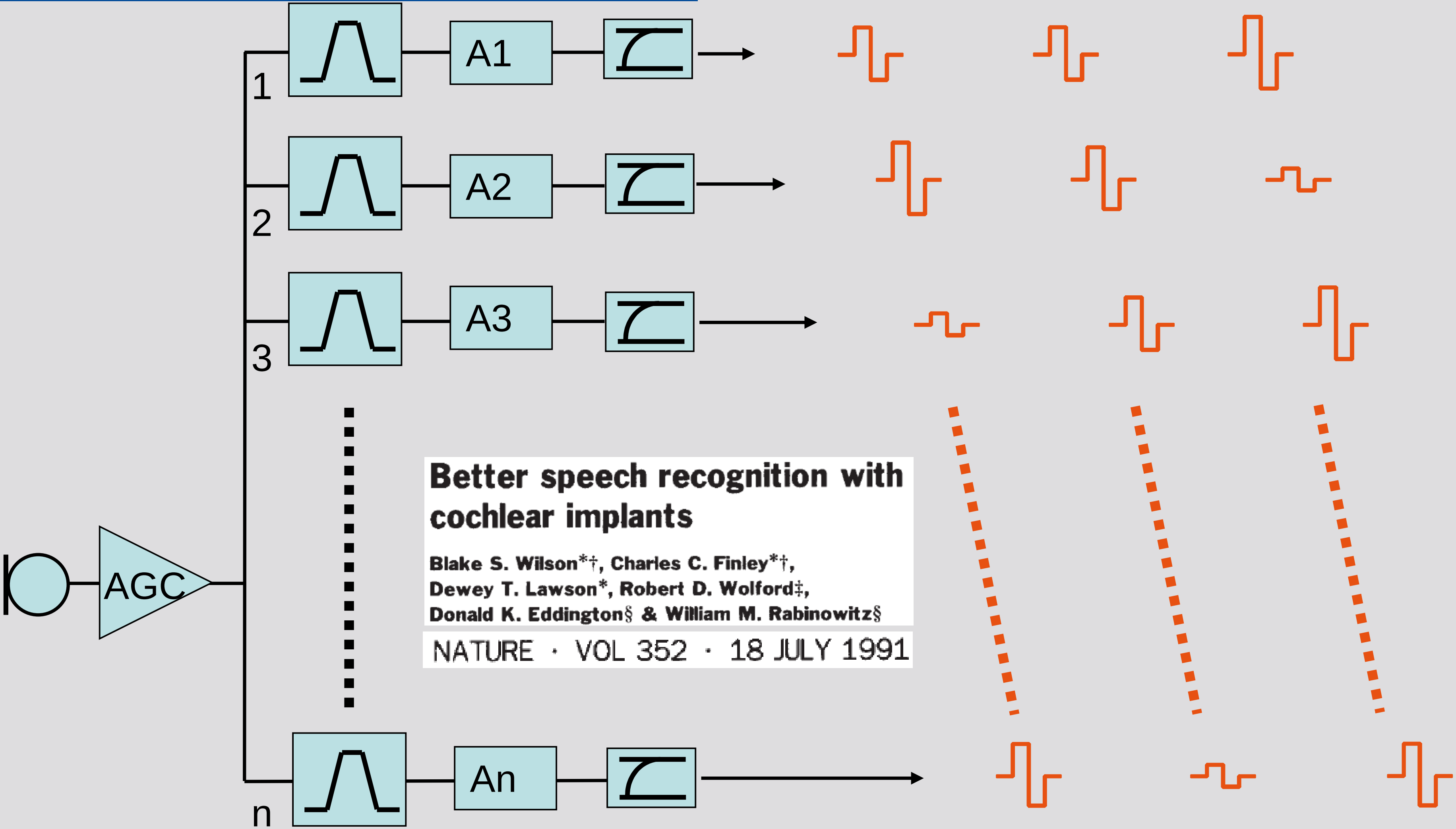
Speech Intelligibility



Zeng 2004

Continuous Interleaved Sampling

CIS (Beginning of 1990's)



Better speech recognition with cochlear implants

Blake S. Wilson*†, Charles C. Finley*†, Dewey T. Lawson*, Robert D. Wolford‡, Donald K. Eddington§ & William M. Rabinowitz§

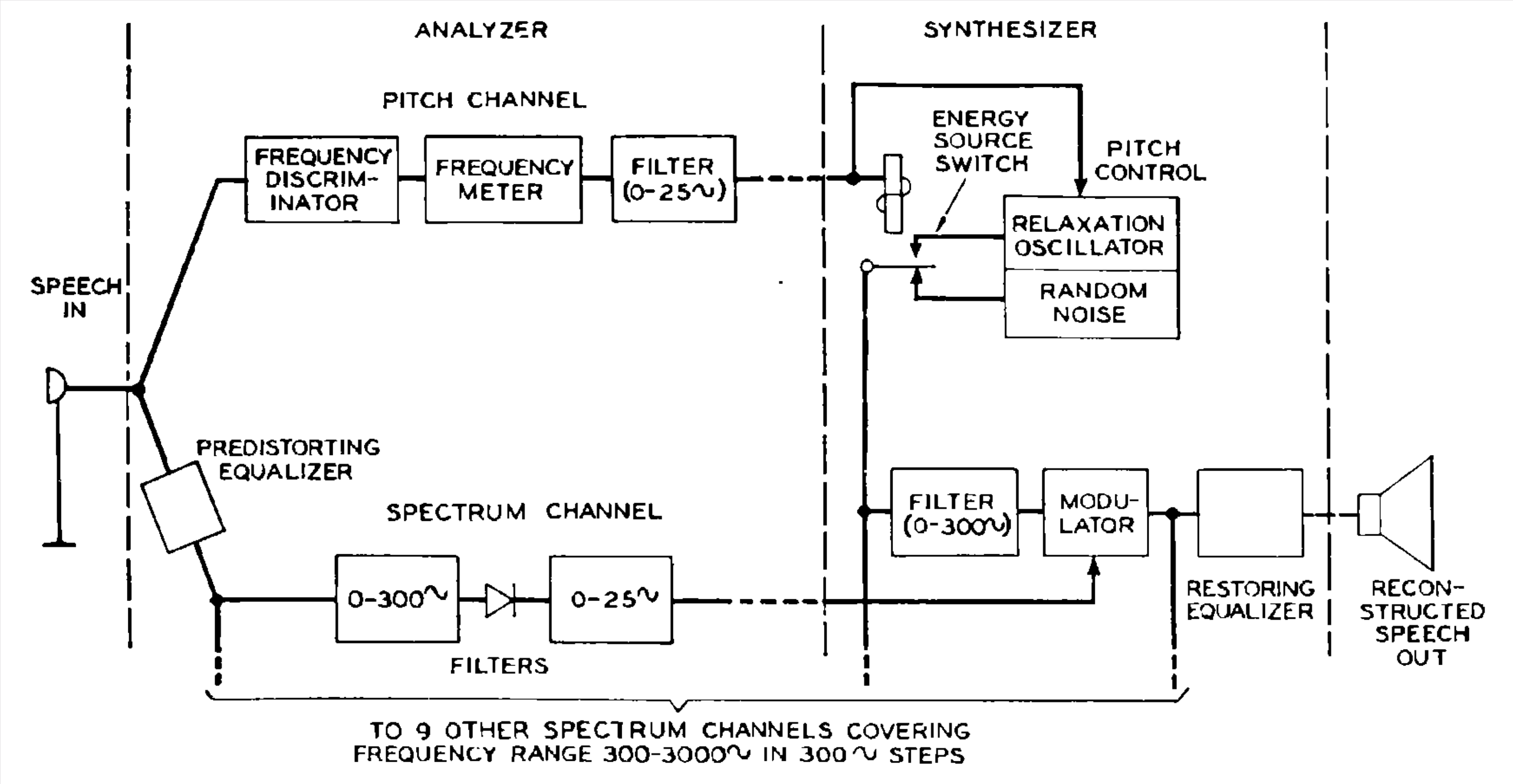
NATURE · VOL 352 · 18 JULY 1991

CIS (Begining of 1990's)

<u>Characteristics of the CIS sound coding strategy:</u>

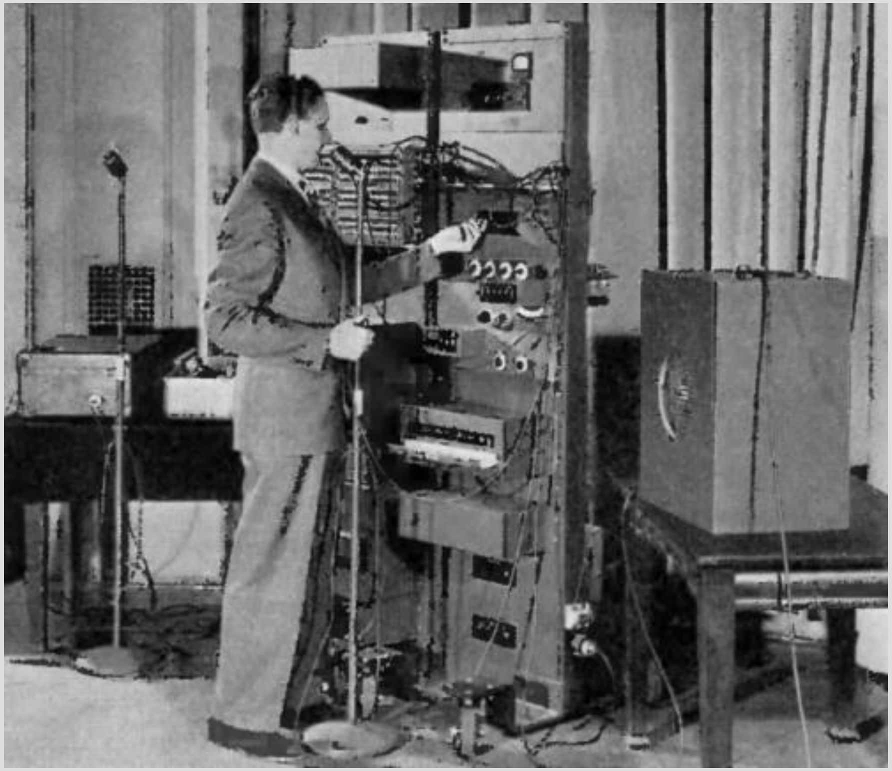
- 8 bandpass filters from 250 to 5500 Hz
- 60 dB dynamic range => Compressed/mapped to patient-specific dynamic range
- Stimulation with square biphasic pulses with a 75 µs/phase duration
- Stimulation rate for each electrode is around 833 Hz
- It is based on a principle similar to the Dudley Vocoder (see next slide).

The Vocoder from Bell Labs (H. Dudley, 1939)



Bell Labs Records, Dec. 1939

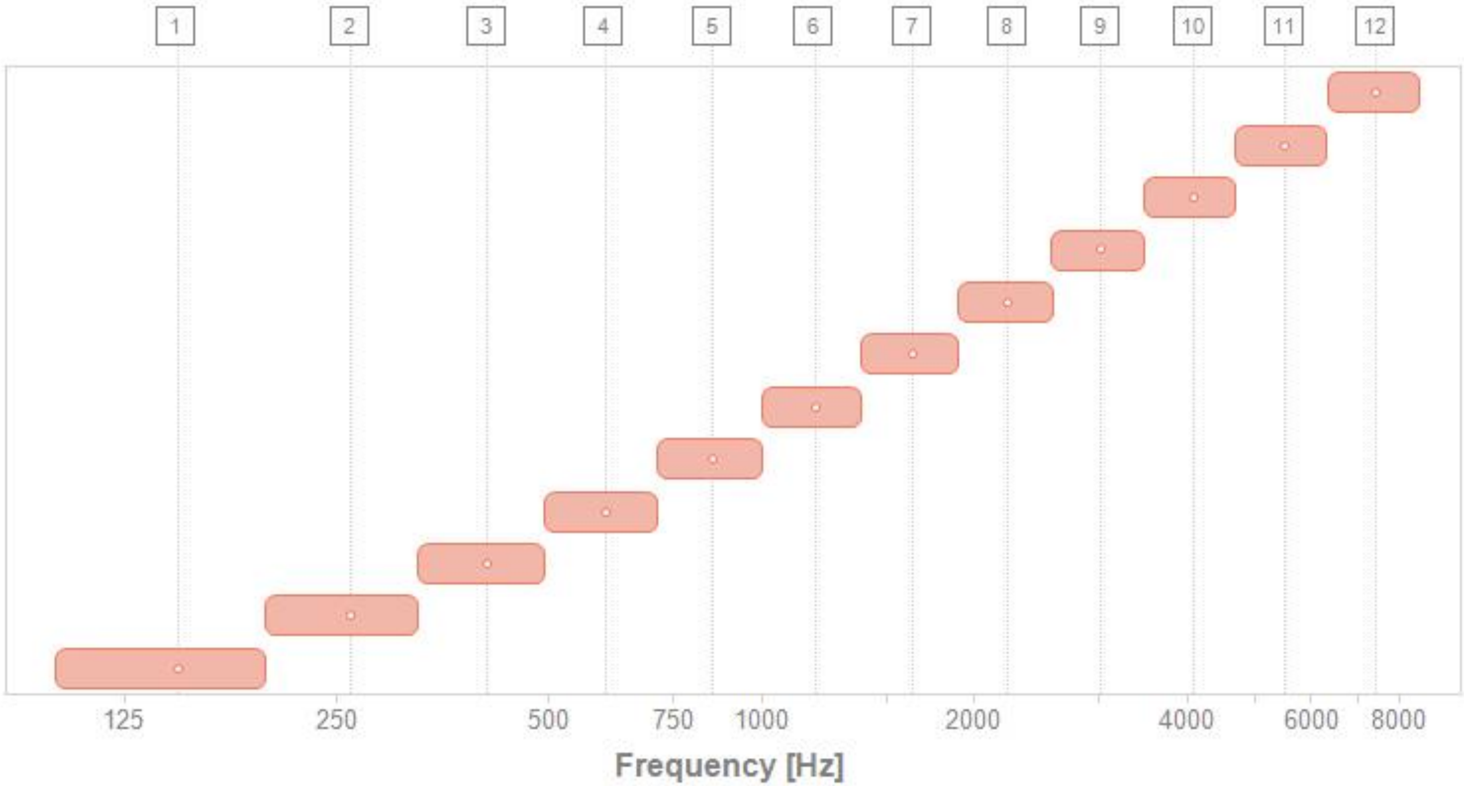
Vocoder with 10 chanels (H. Dudley 1939)



Example without fundamental frequency

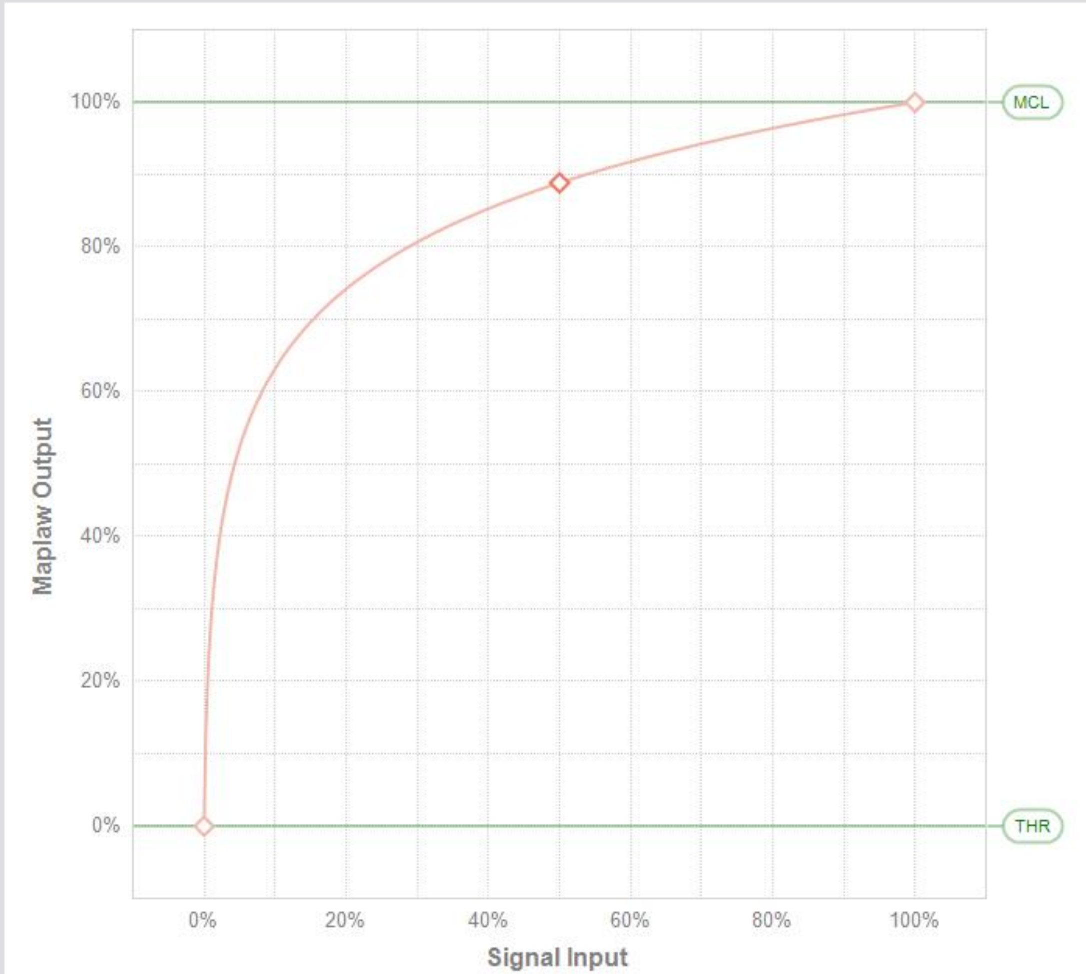
Example with fundamental frequency

Frequency Bands used by the MED-EL devices

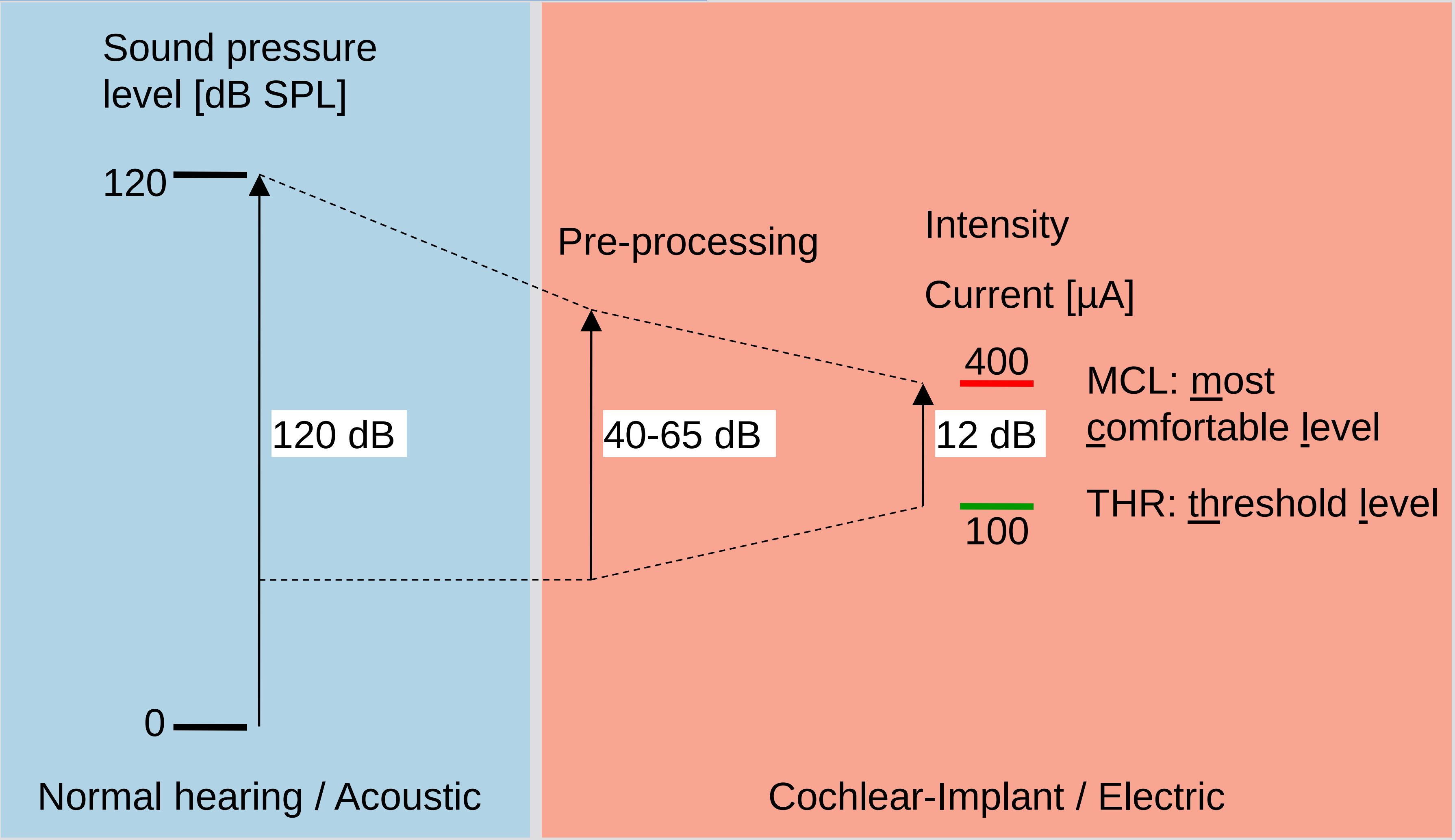


	1	2	3	4	5	6	7	8	9	10	11	12
Desired Lower Frequency [Hz]	100	198	325	491	710	999	1383	1893	2574	3483	4698	6323
Desired Center Frequency [Hz]	149	261	408	601	854	1191	1638	2233	3028	4090	5510	7412
Desired Upper Frequency [Hz]	198	325	491	710	999	1383	1893	2574	3483	4698	6323	8500
Desired Bandwidth [Hz]	98	127	166	219	289	384	510	681	909	1215	1626	2177
Current Frequency Band	100 198	198 325	326 492	493 712	707 995	992 1373	1378 1886	1888 2567	2600 3528	3466 4703	4799 6512	6239 8466

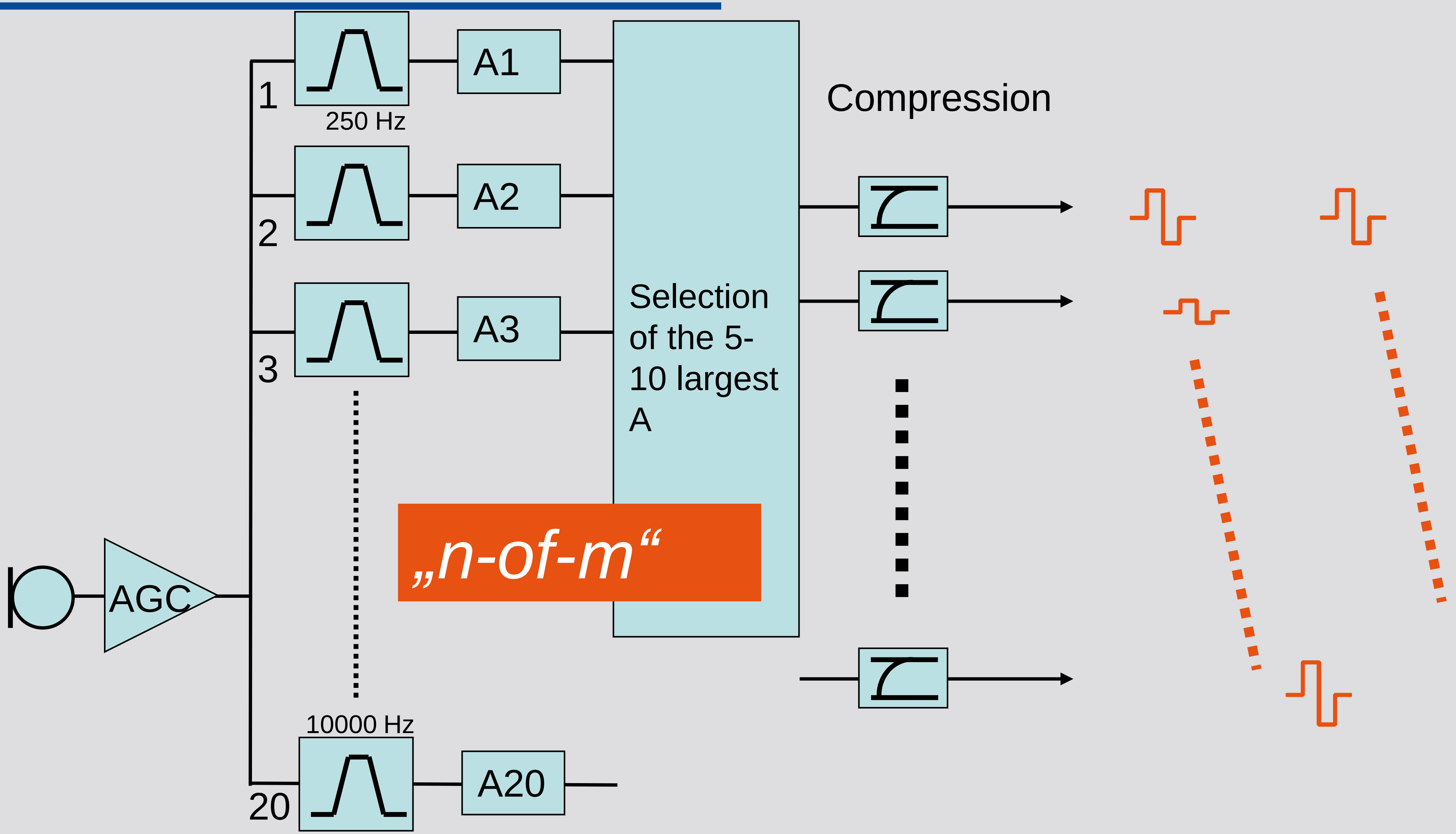
Example of compression used in the MED-EL devices



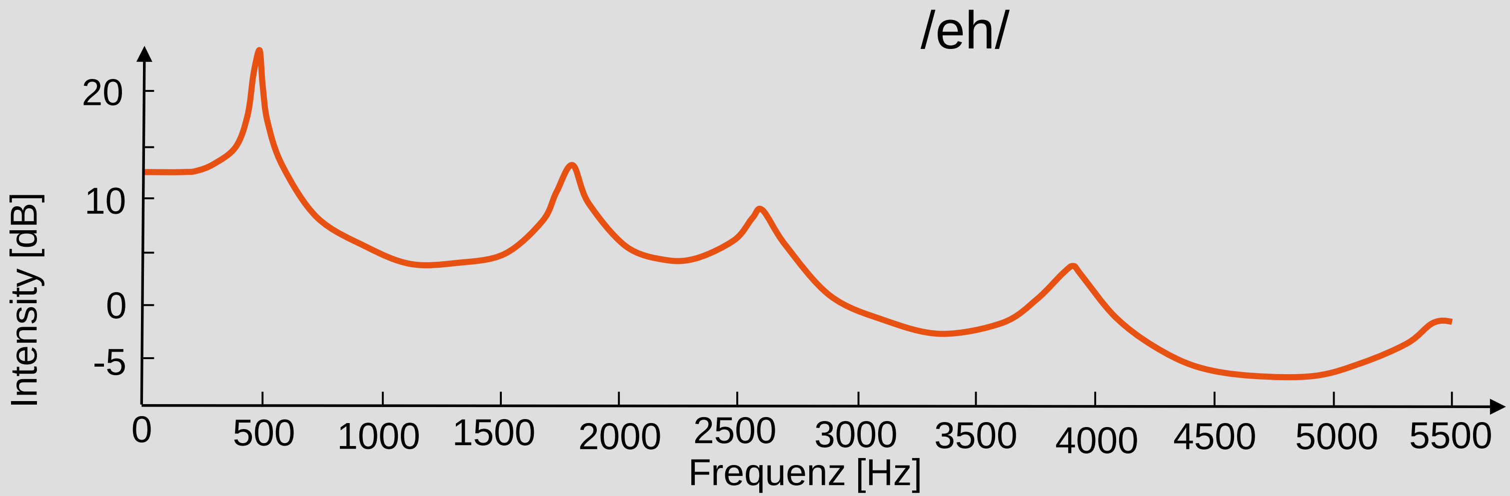
Input Signal Pre-Processing

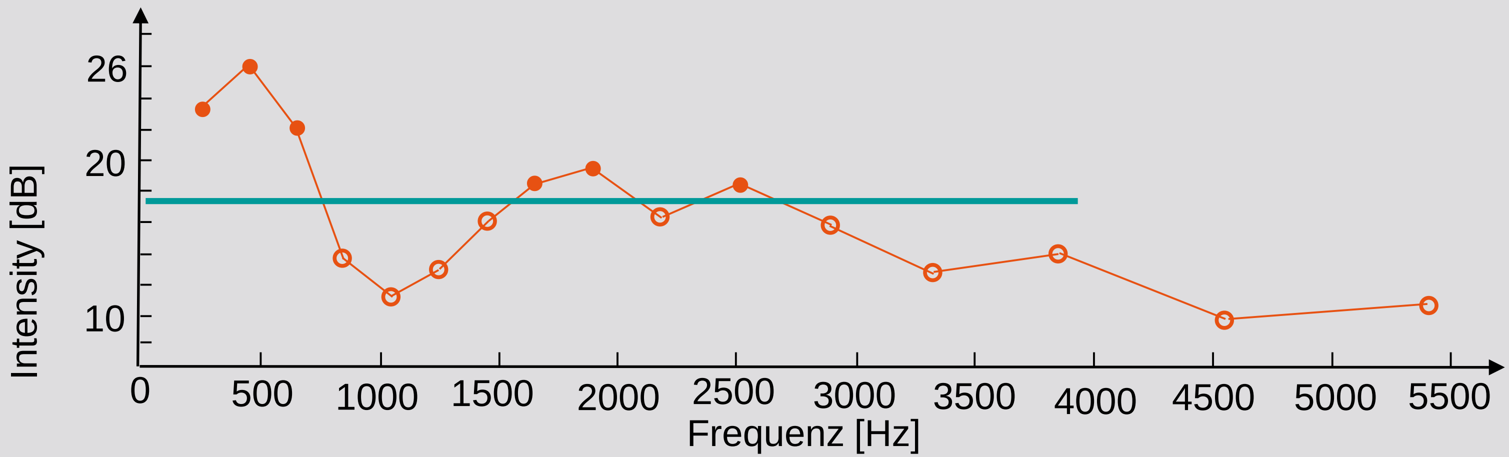


SPEAK (Begining of 1990‘s)



Maxima Selection





SPEAK (Begining of the 1990‘s)

<u>Characteristics of the Speak sound coding strategy:</u>

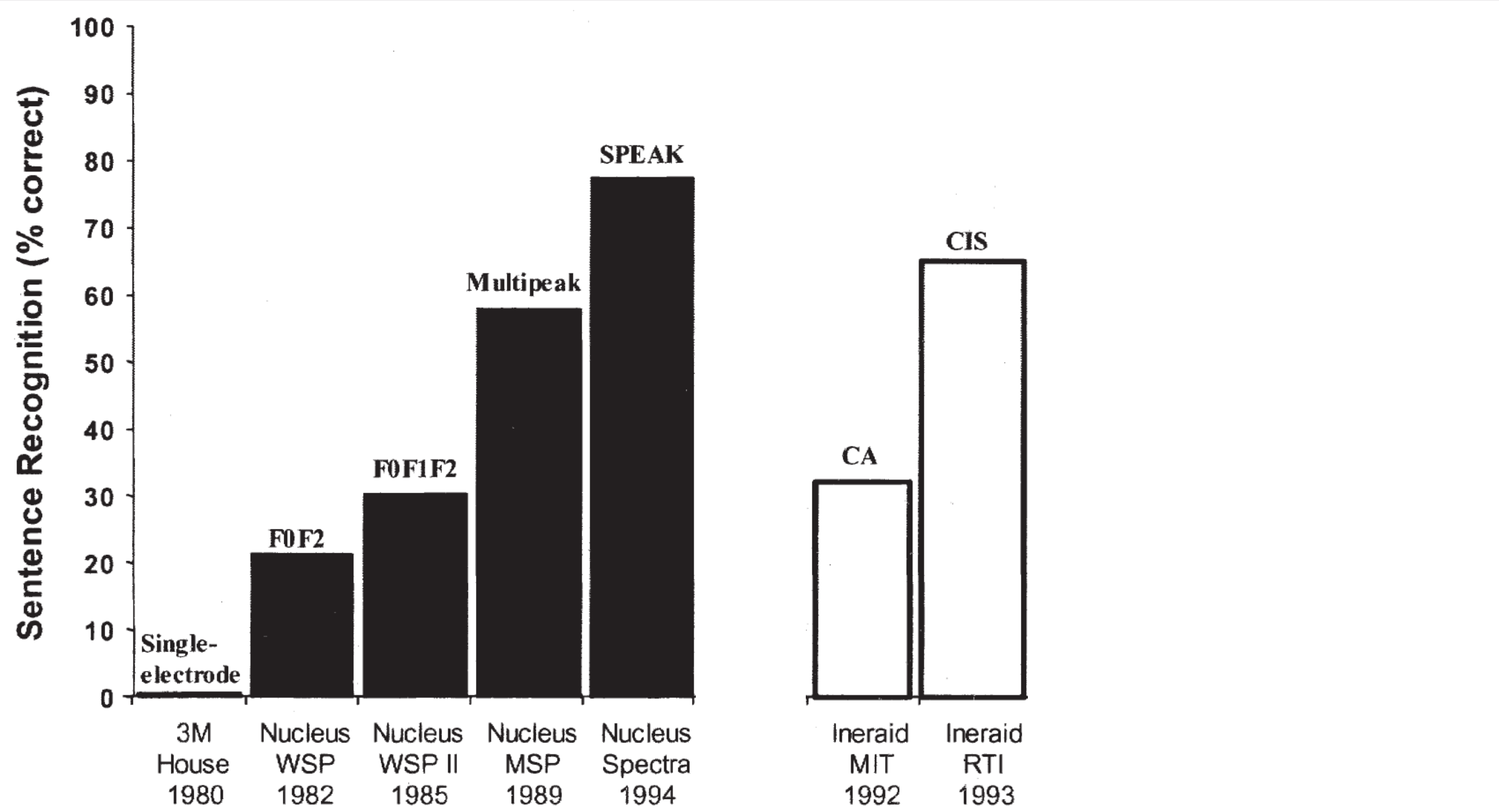
- Larger range of frequencies (250 until 10000 Hz)

- 20 channels

- Only 5-10 channels with largest energy (maxima) are selected for stimulation.
    - The amount of information requires time which causes a reduction in the stimulation rate.

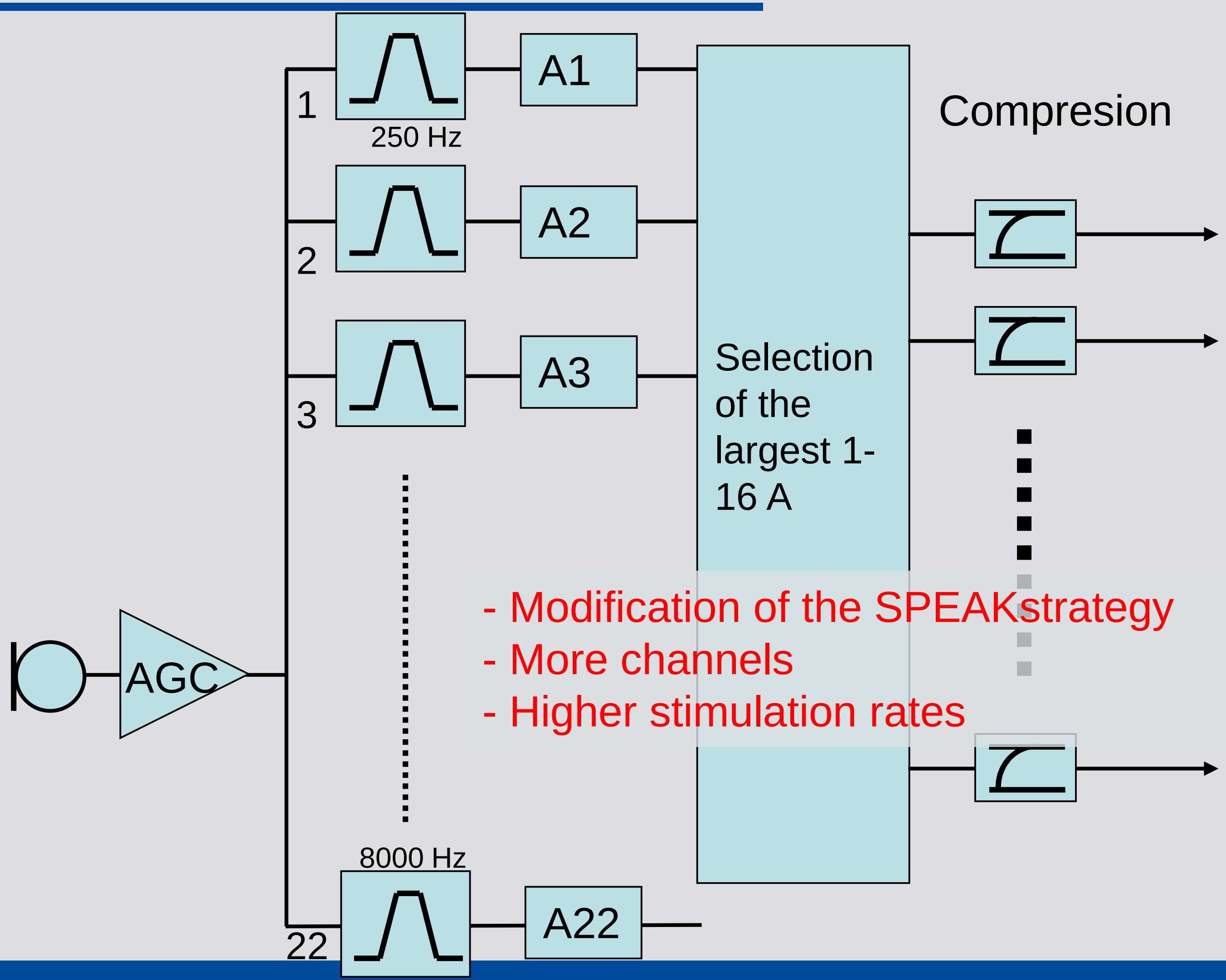
- Stimulation rates up to 250 Hz (limited by Mini-22 implant technology)

Speech Intelligibility



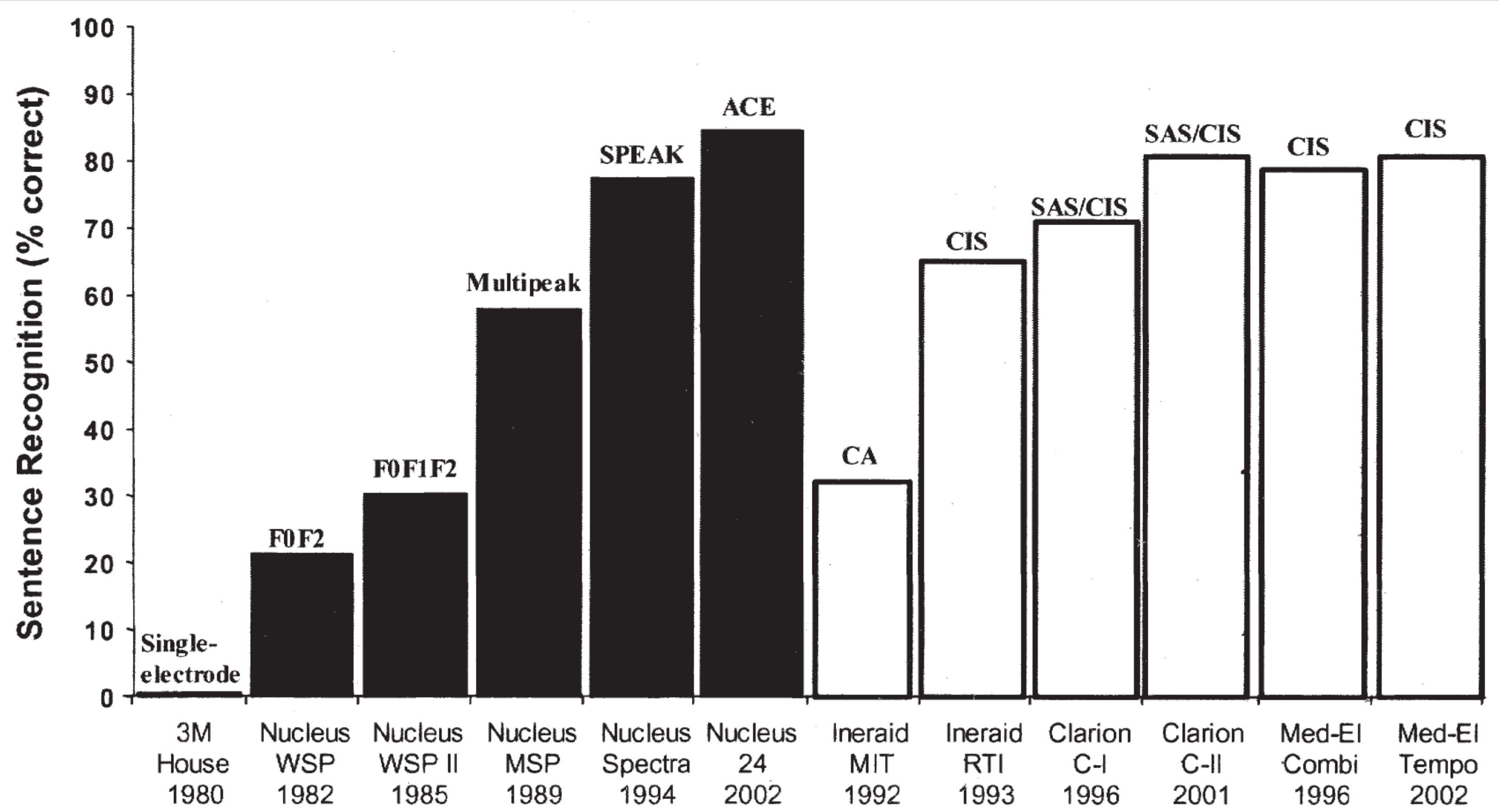
Zeng 2004

ACE (Middle of the 1990's)



- Modification of the SPEAKstrategy
- More channels
- Higher stimulation rates

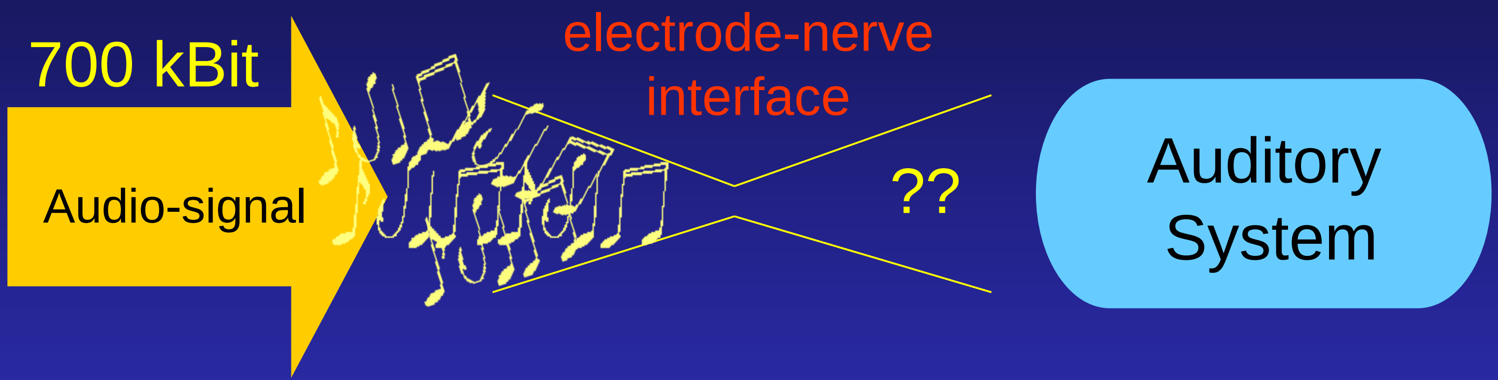
Speech Intelligibility



Zeng, Trends In Amplification 2004:8:1-34

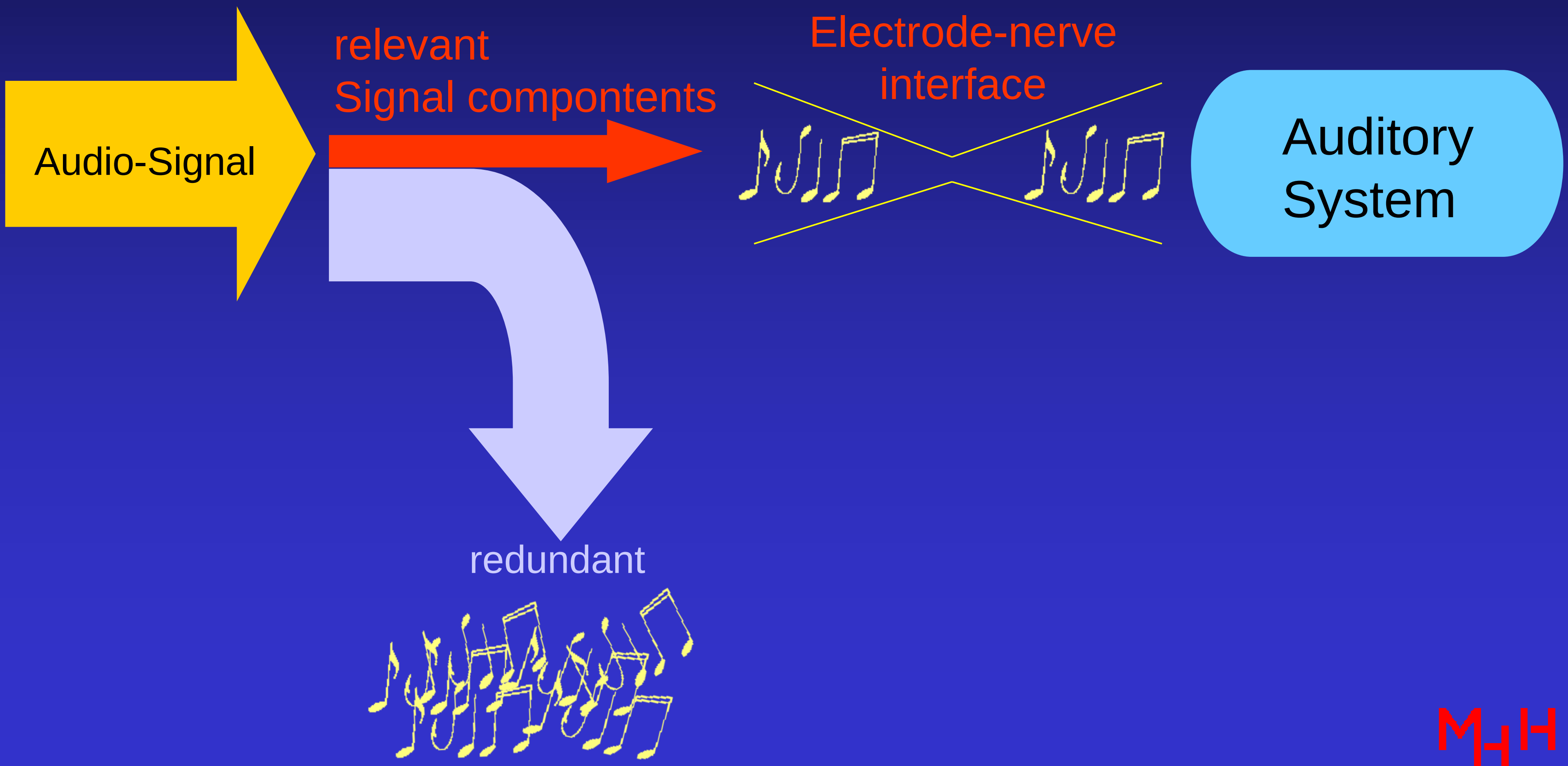
Contents

The problem of low bandwidth in cochlear implants



Cochlear Implant System : 10 - 60 kbit/s

One possible solution: hearing related data reduction



Motivation for designing a psychoacoustic model-based speechcoding strategy

Psychoacoustic models have been successfully used in the HiFi domain without compromising sound quality.

→ Reducing the data of audio-files to 1/10th !

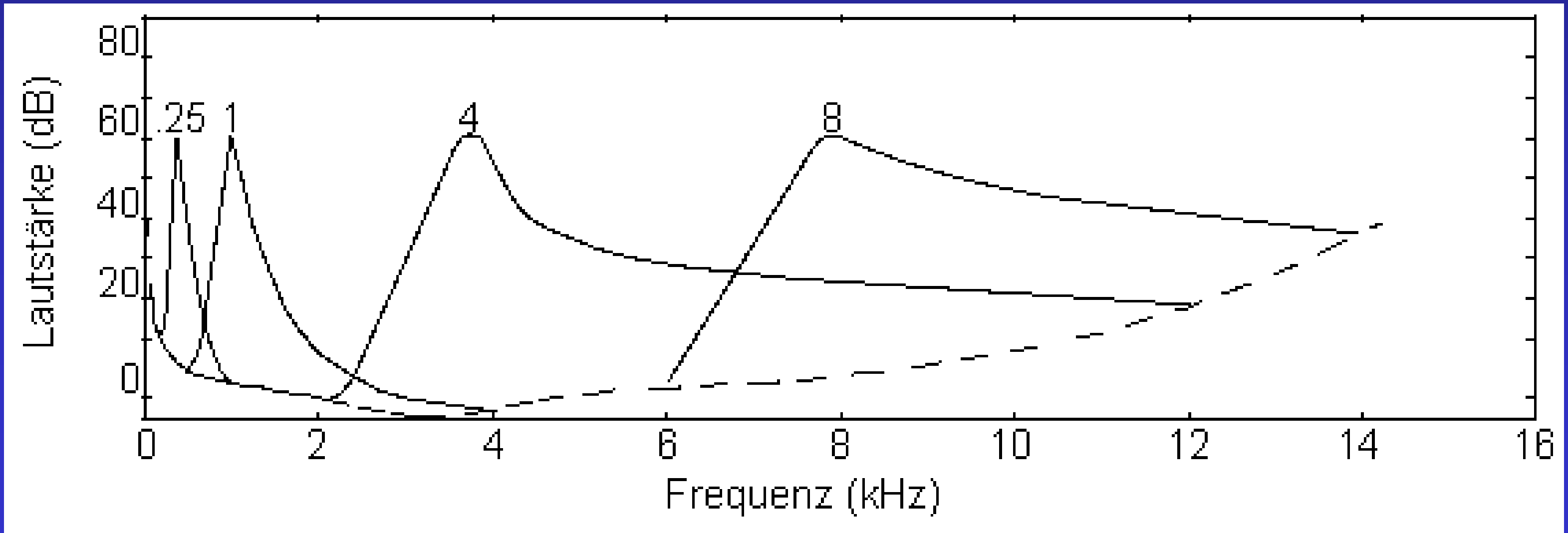
Apple's iPod

Psychoacoustics I

(simultaneous masking effect)

During an acoustic excitation the threshold of perception is lifted depending on the spectrum of the signal. All signal components below this threshold are imperceptible.

The simultaneous masking is the strongest masking effect.



Next step:

Speechcoding based on psychoacoustic model

- achieve higher compression rates compared to ACE
  → further increase of stimulation rate

- more realistic selection of the electrodes due to more intelligent algorithms
  → should lead to better sound quality

- MP3000 was released as a commercial strategy

Nogueira et al. 2005

What else?
Provide more spectral resolution.

- 30.000 haircells vs. 16 electrode contacts

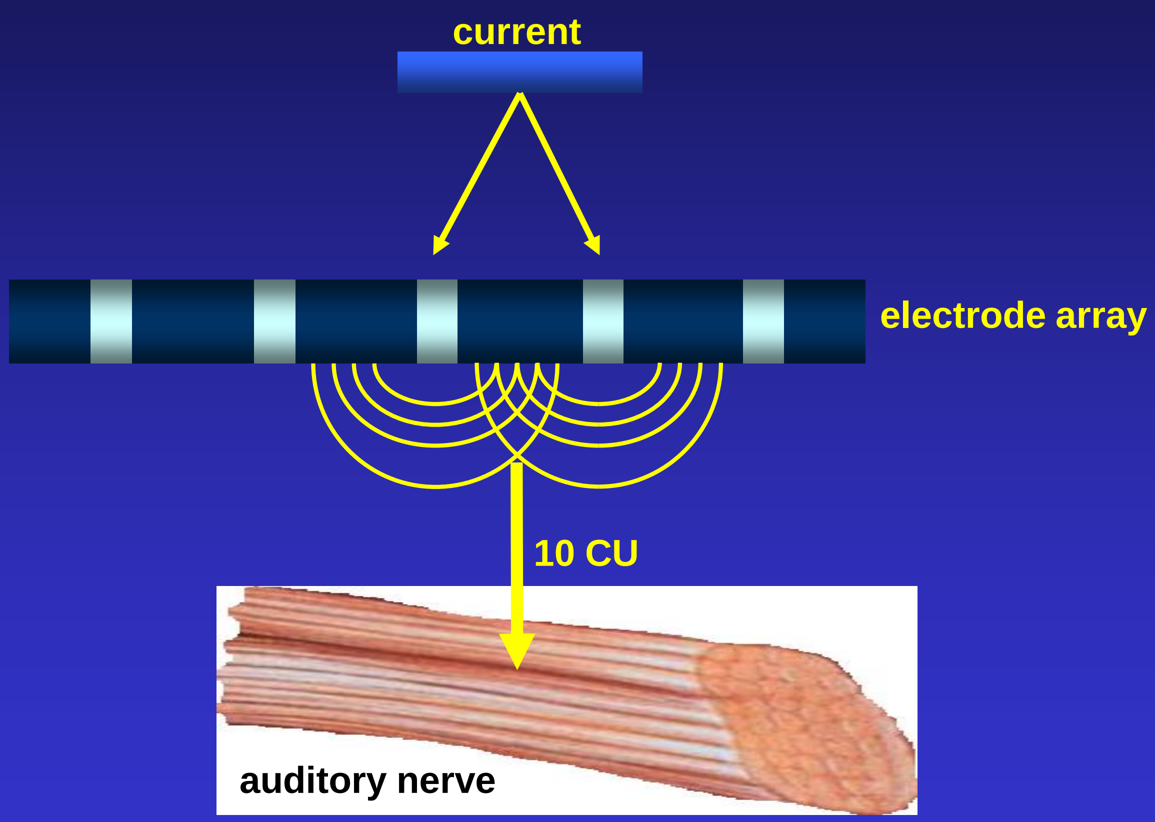
    - improved sound quality

    - better speech in noise discrimination

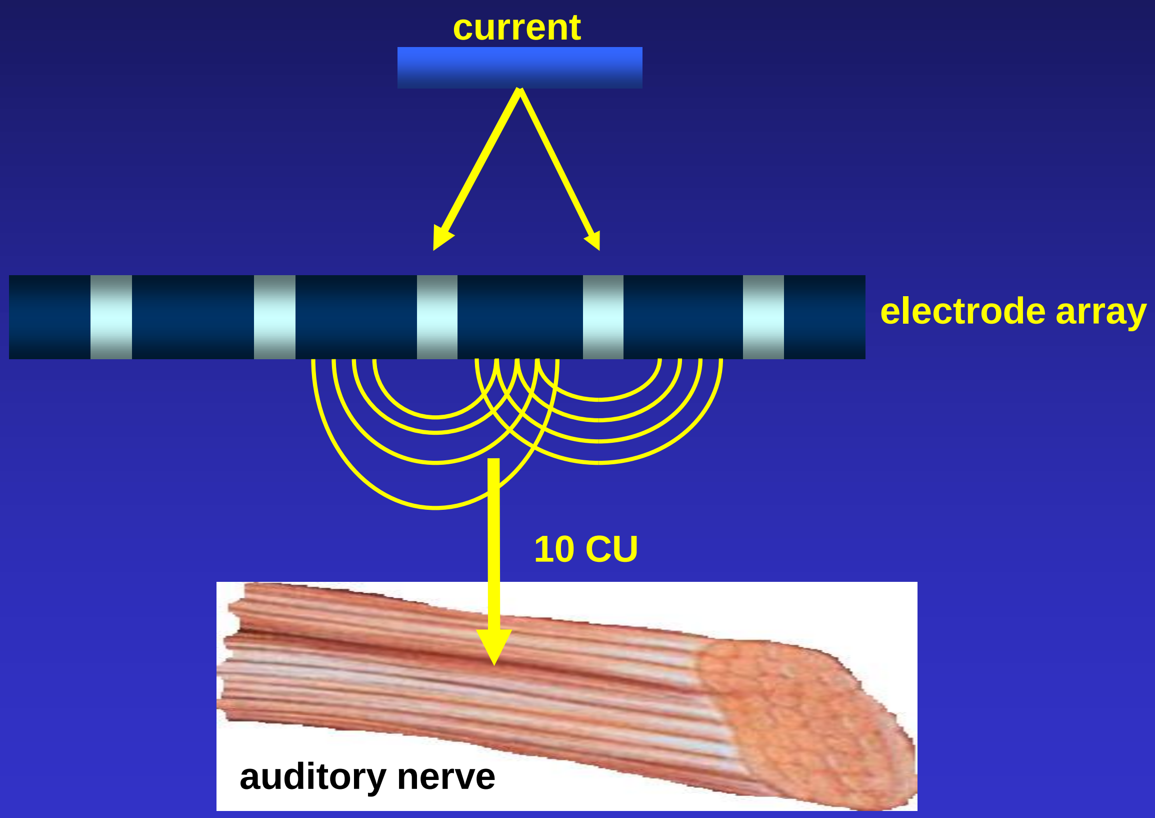
    - better music perception

With the current steering technique it is possible to generate virtual channels between two physical electrode contacts

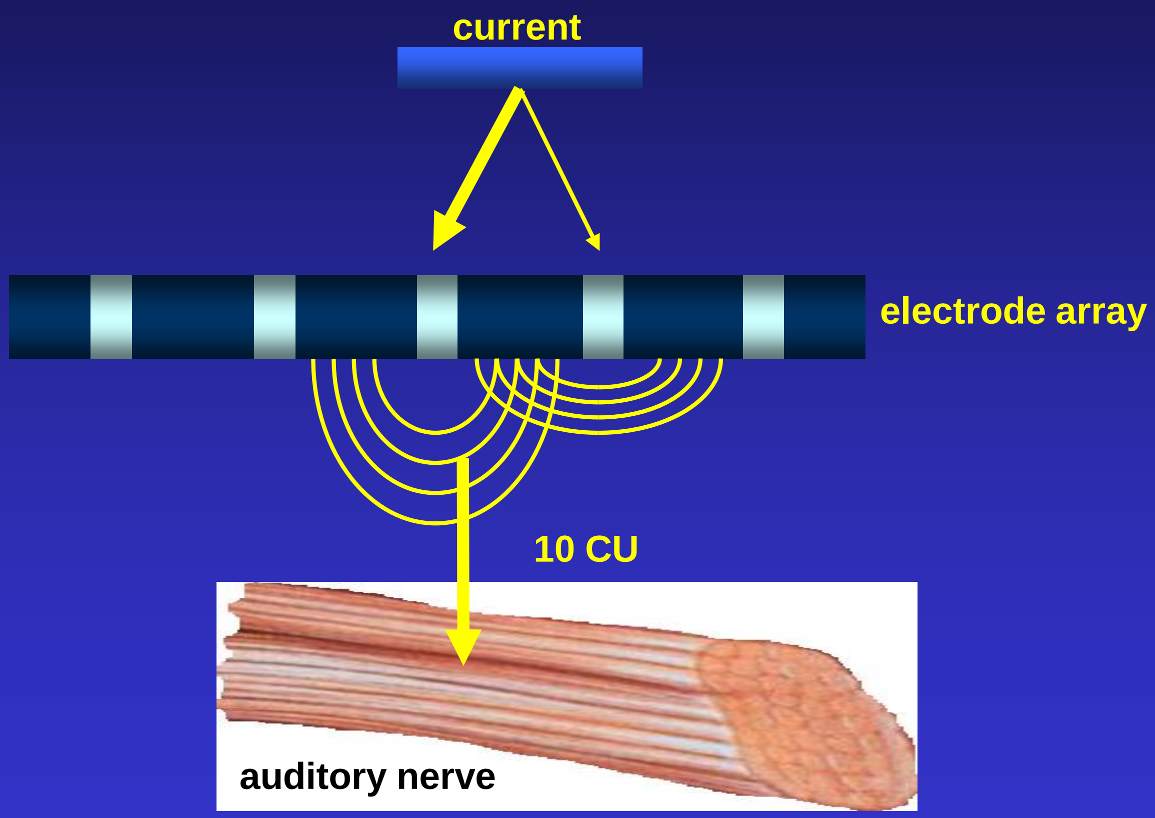
The benefit of current steering



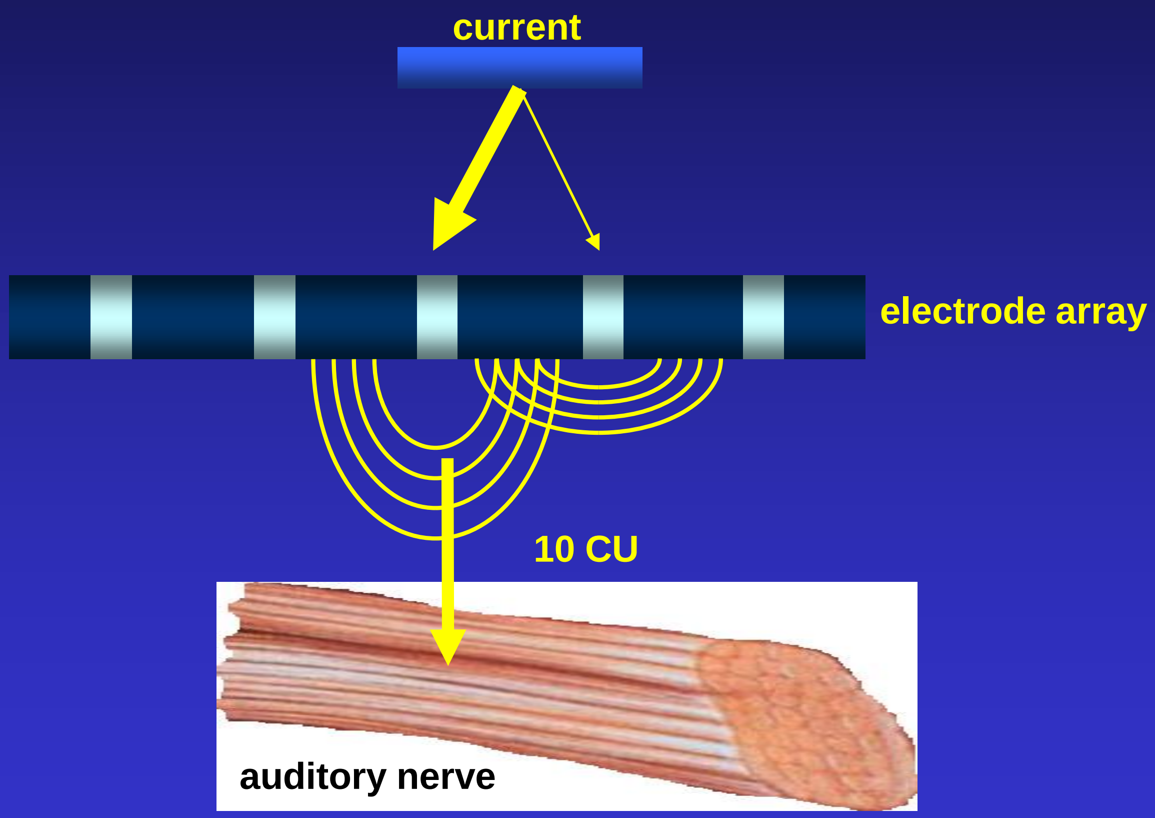
The benefit of current steering



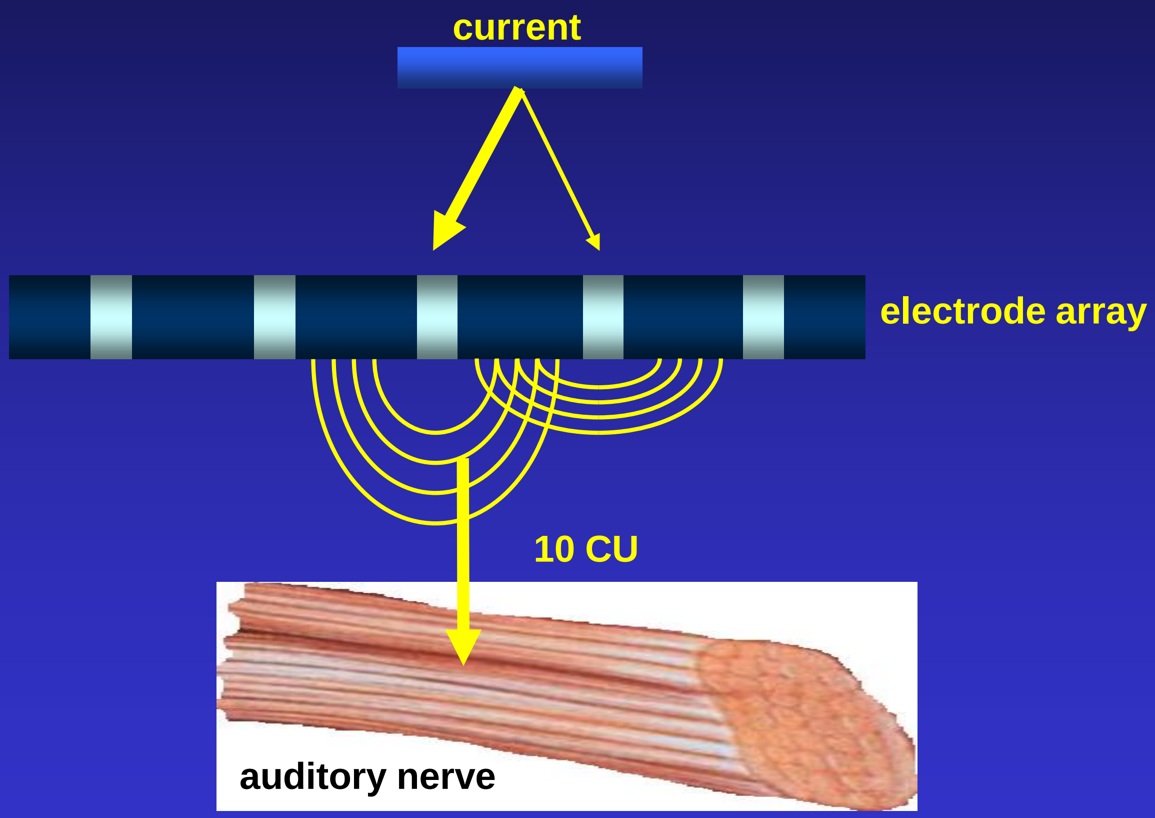
The benefit of current steering



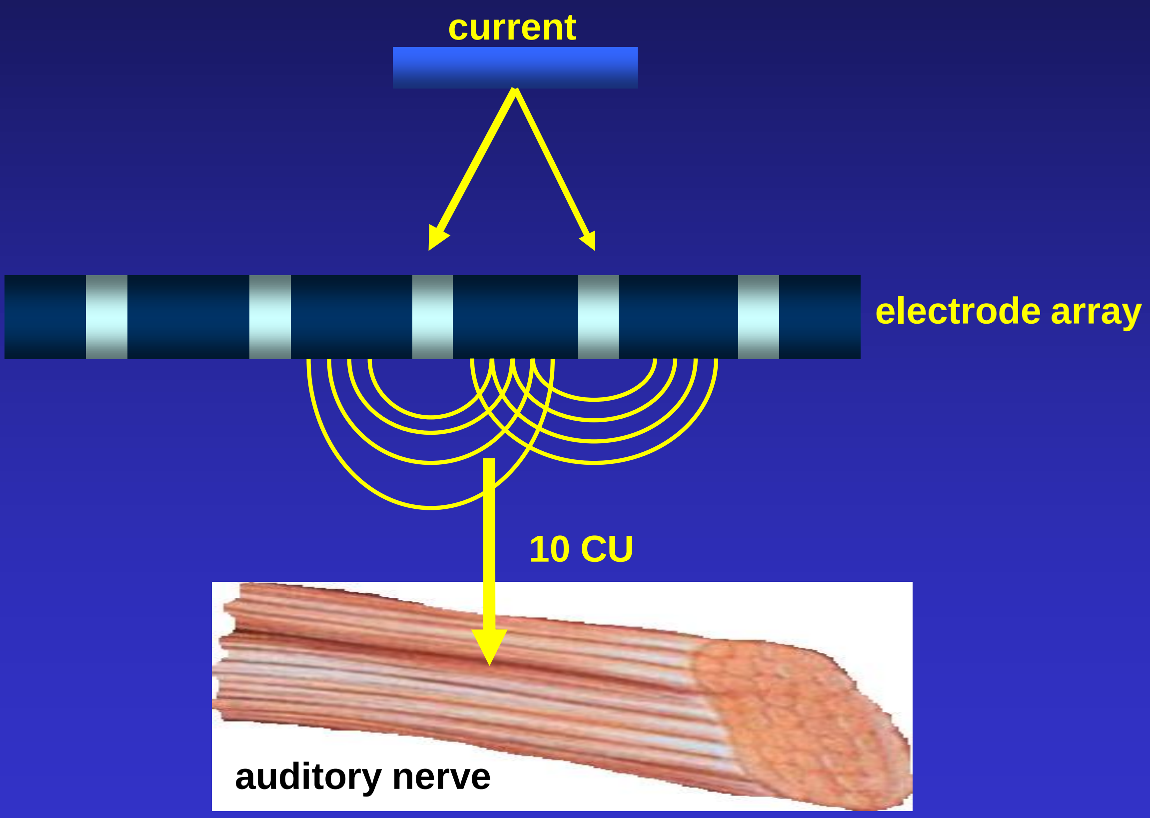
The benefit of current steering



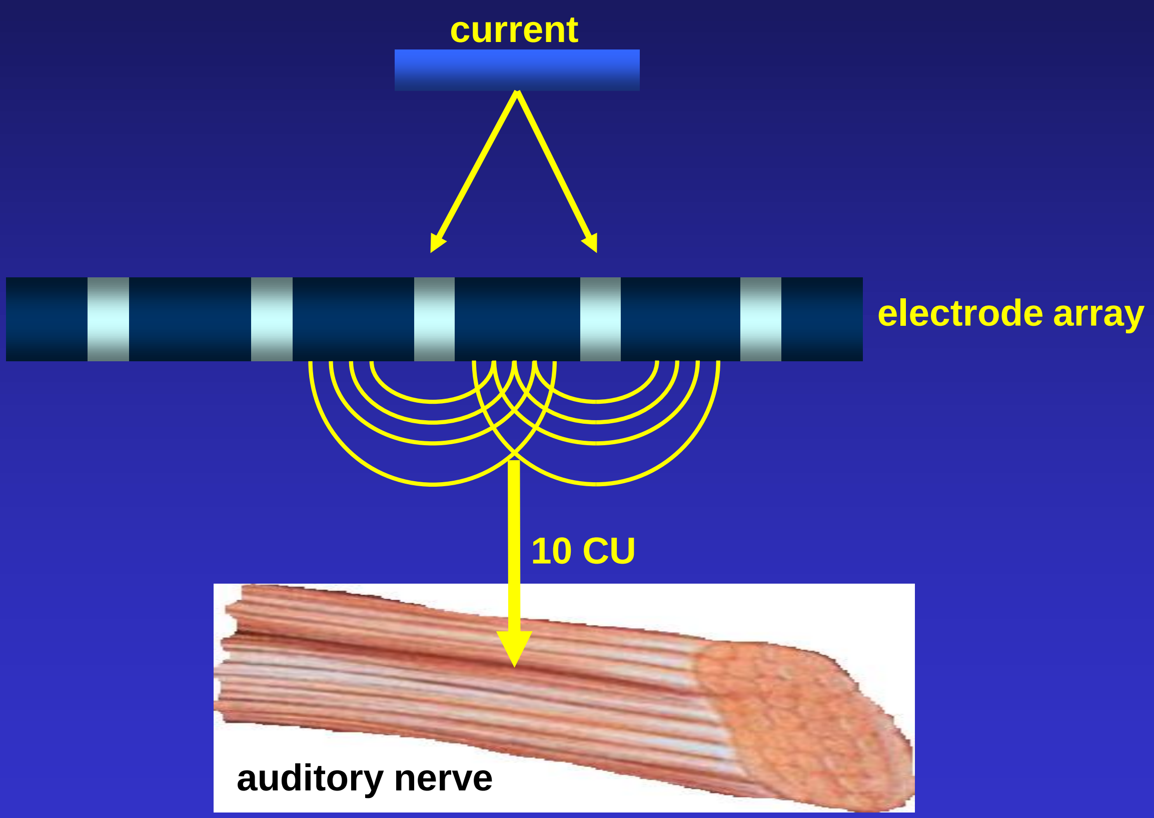
The benefit of current steering



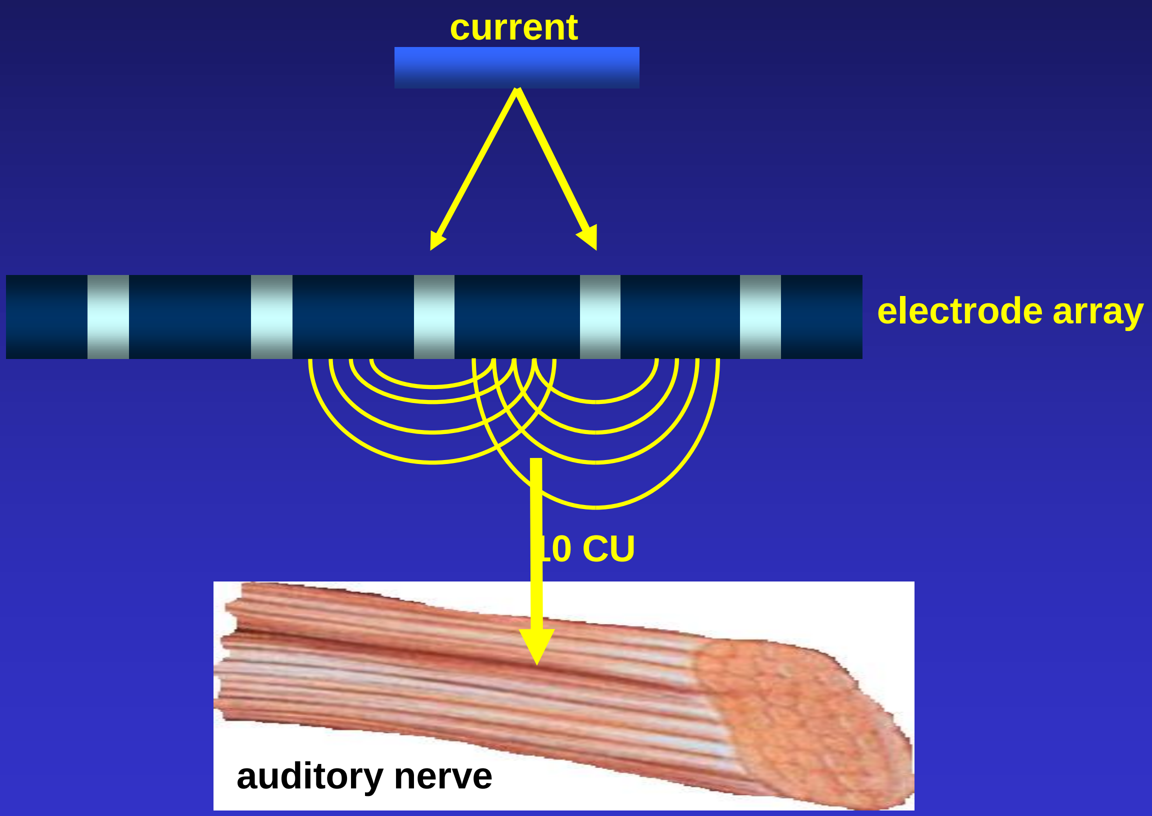
The benefit of current steering



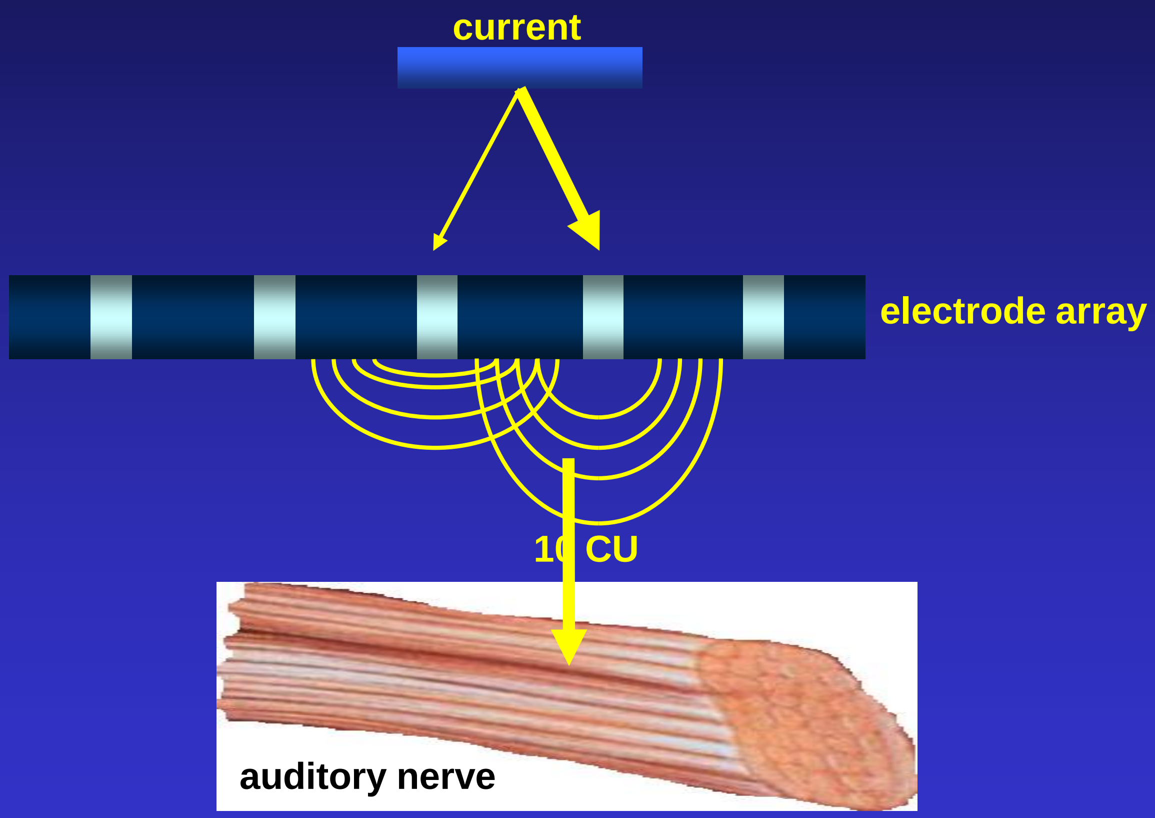
The benefit of current steering



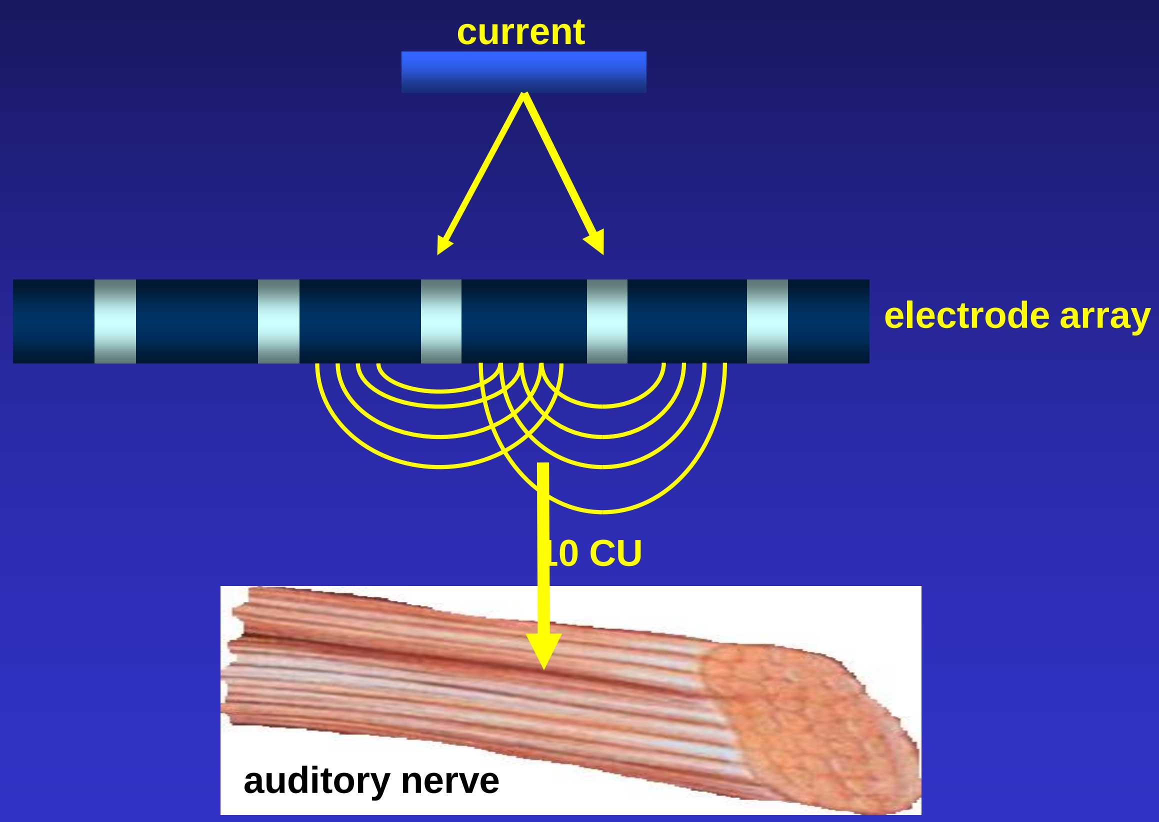
The benefit of current steering



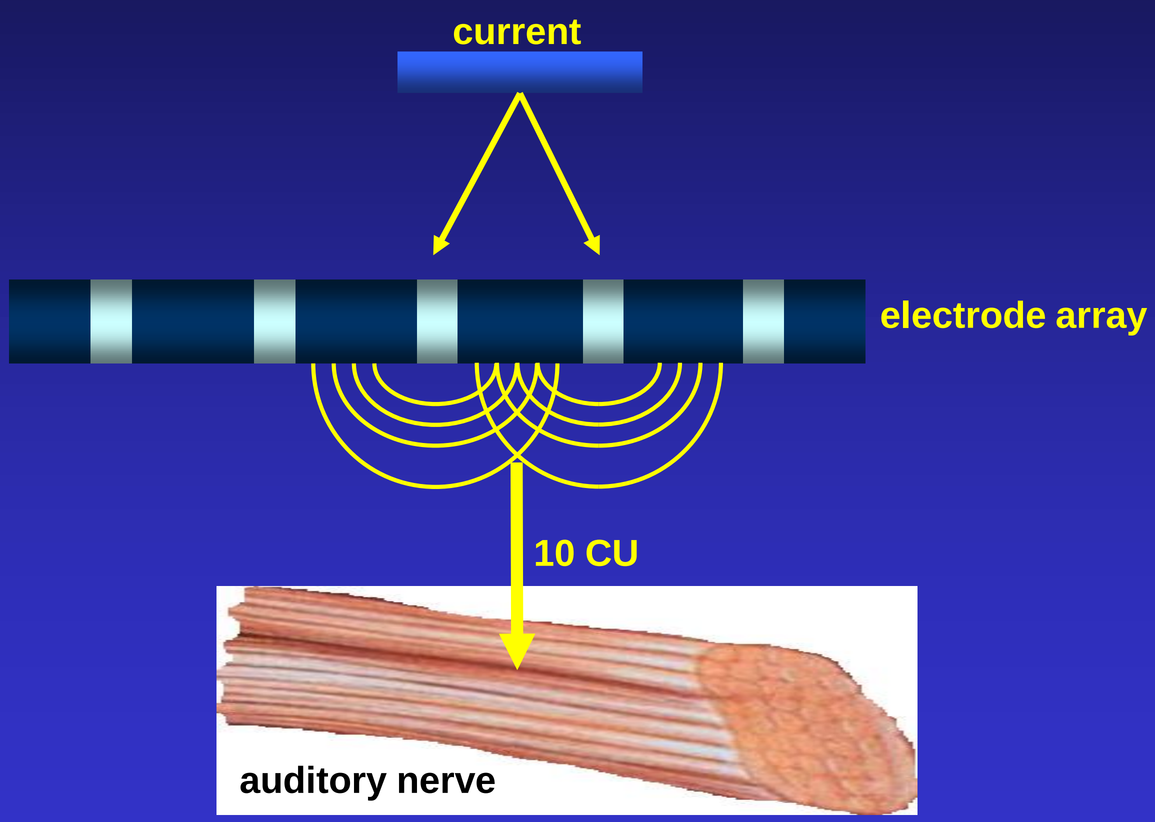
The benefit of current steering



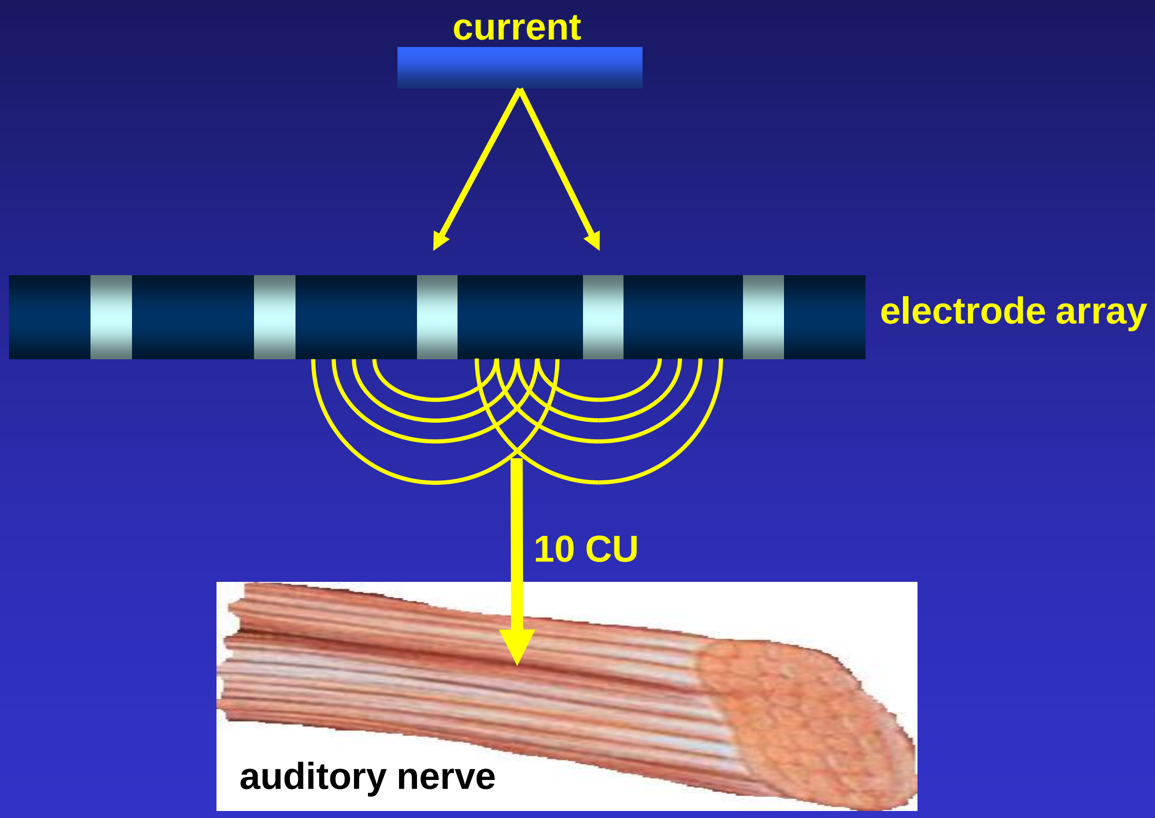
The benefit of current steering



The benefit of current steering



The benefit of current steering

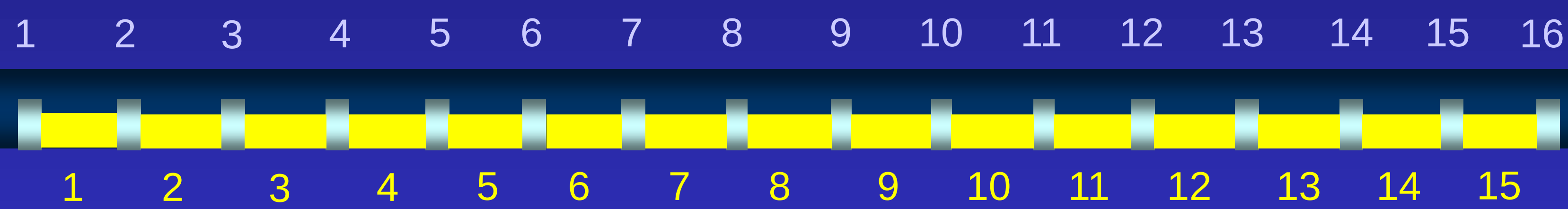


„Current Steering“

16 electrode contacts → 15 current steering areas

discrete number of channels

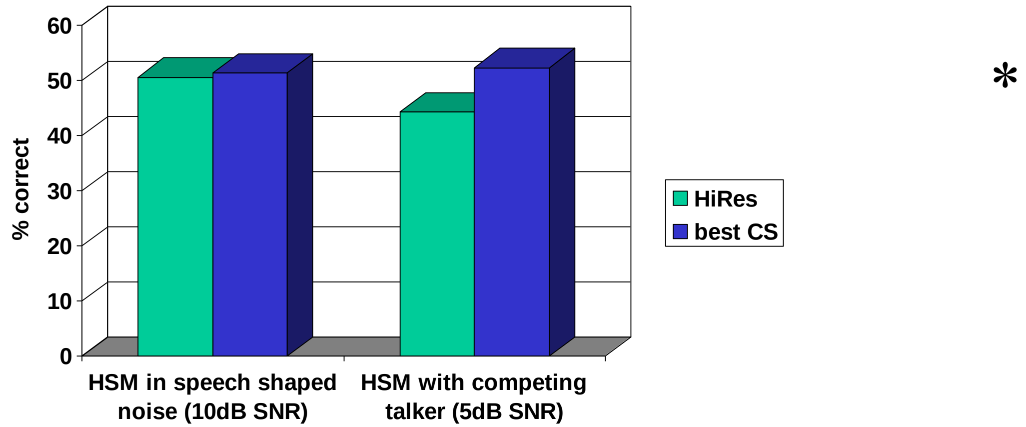
infinite number of channels



Current can be continuously steered between the electrode contacts.

Speech Perception in HiRes vs. Current Steering

(neclecting subjects with ceiling or floor effect)



Intermediate Summary

- The current steering technique seems to have potential to improve speech perception subjectively as well as objectively.

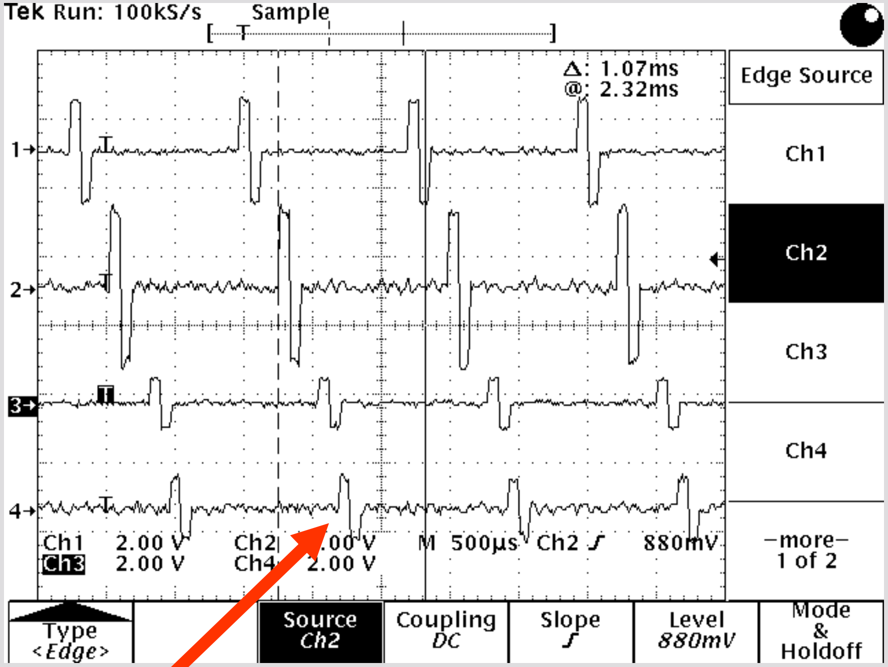
- The majority of all subjects preferred HiRes120 over the HiRes and report:
  - Easier listening
  - More natural environmental sounds
  - Differentiation of voices.

- To evaluate the benefit of the current steering strategies very sensitive test material is required:
  - Demanding with respect to frequency resolution
  - Avoid ceiling and floor effects for all study subjects

Output of the Implant circuit

Detector box of the MEDEL system

Image of an Oscilloscope captured with an 8-channel strategy



833 pps

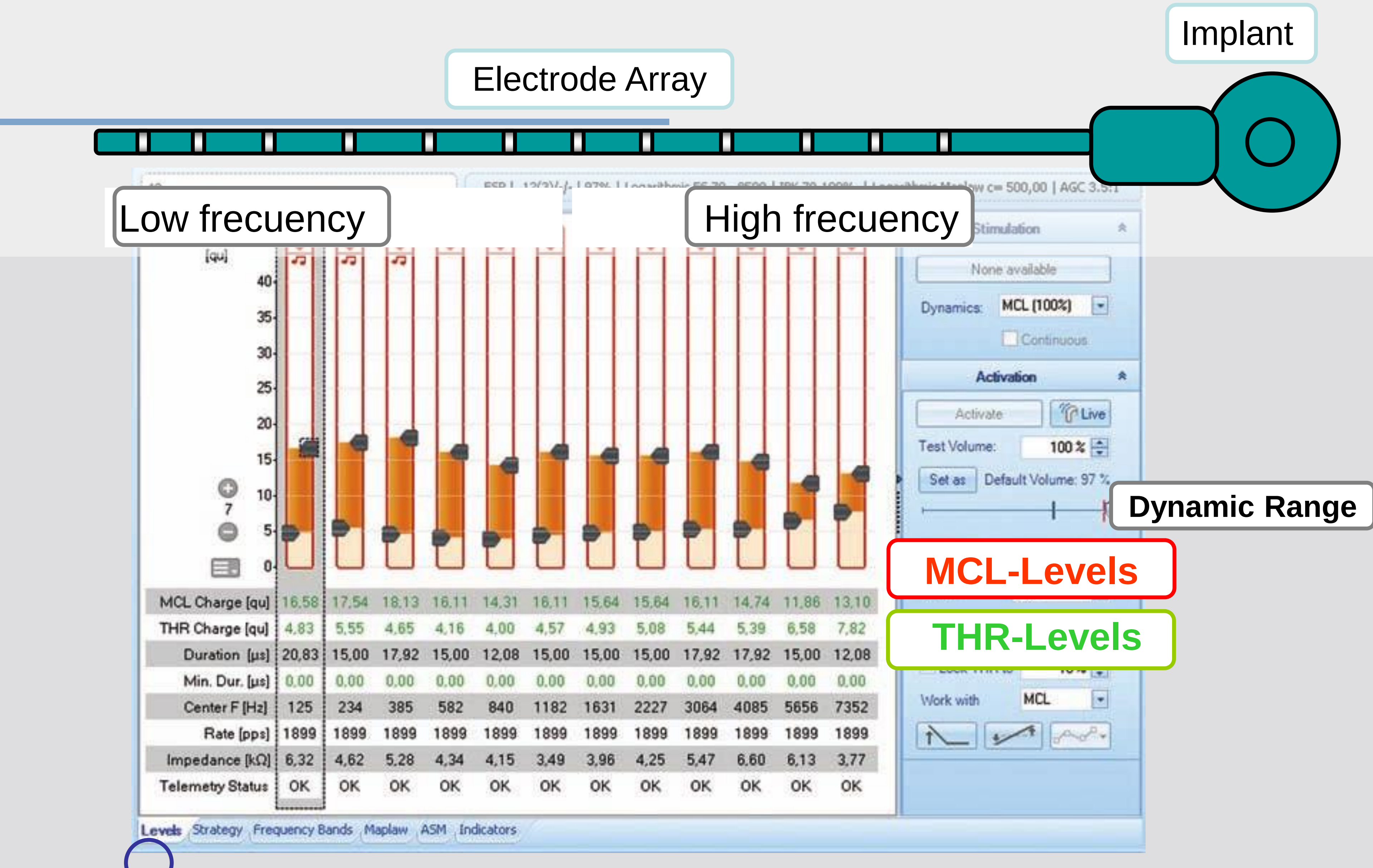
How is the implant configured in the clinical routine?

Basic Parameters:

- **Comfortable (MCL) Level:** Maximum current value that is perceived as comfortable.

- **Threshold (THR) Level:** The minimum current level that can be perceived.

- **Dynamic Range**: Difference between MCL and THL level.



MCL Charge [qu]	16,58	17,54	18,13	16,11	14,31	16,11	15,64	15,64	16,11	14,74	11,86	13,10
THR Charge [qu]	4,83	5,55	4,65	4,16	4,00	4,57	4,93	5,08	5,44	5,39	6,58	7,82
Duration [µs]	20,83	15,00	17,92	15,00	12,08	15,00	15,00	15,00	17,92	17,92	15,00	12,08
Min. Dur. [µs]	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Center F [Hz]	125	234	385	582	840	1182	1631	2227	3064	4085	5656	7352
Rate [pps]	1899	1899	1899	1899	1899	1899	1899	1899	1899	1899	1899	1899
Impedance [kΩ]	6,32	4,62	5,28	4,34	4,15	3,49	3,96	4,25	5,47	6,60	6,13	3,77
Telemetry Status	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK

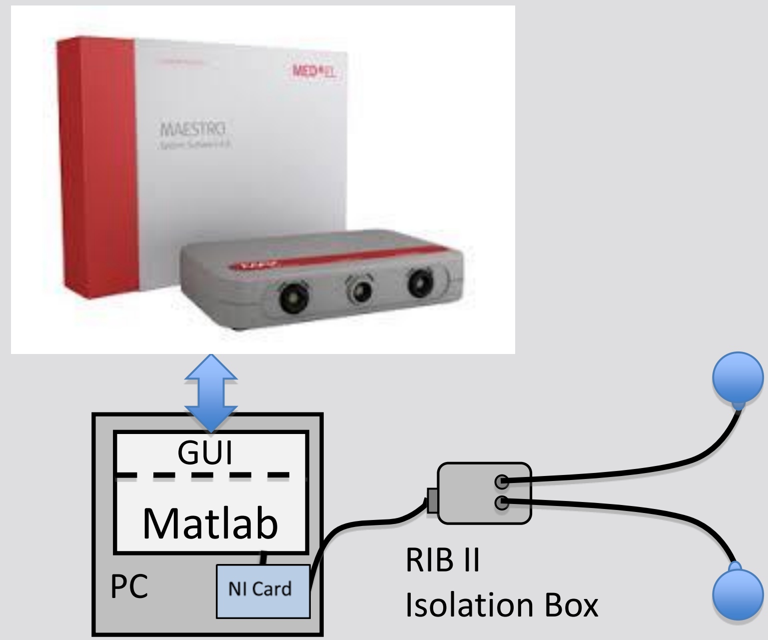
Contents

CI Research Interface

- **MEDEL**

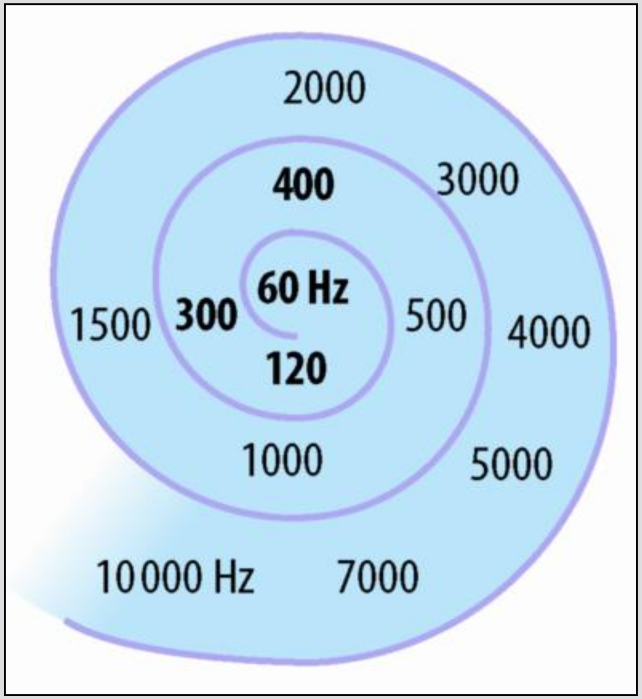
Research Interface Box (RIB)

- Streaming of pre-defined sequences
- Possibility to use trigger
- Possibility to use bilateral stimulation



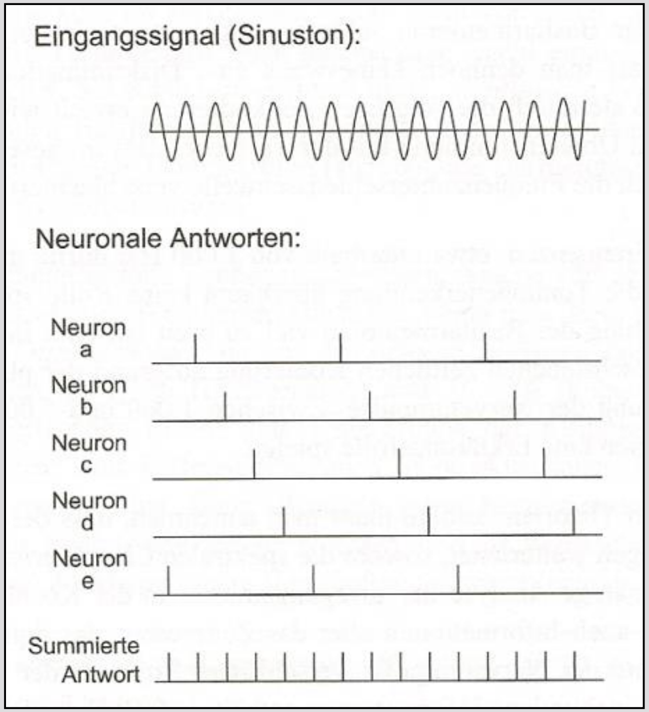
Frequency Analysis in the Cochlea

Basic Principle:



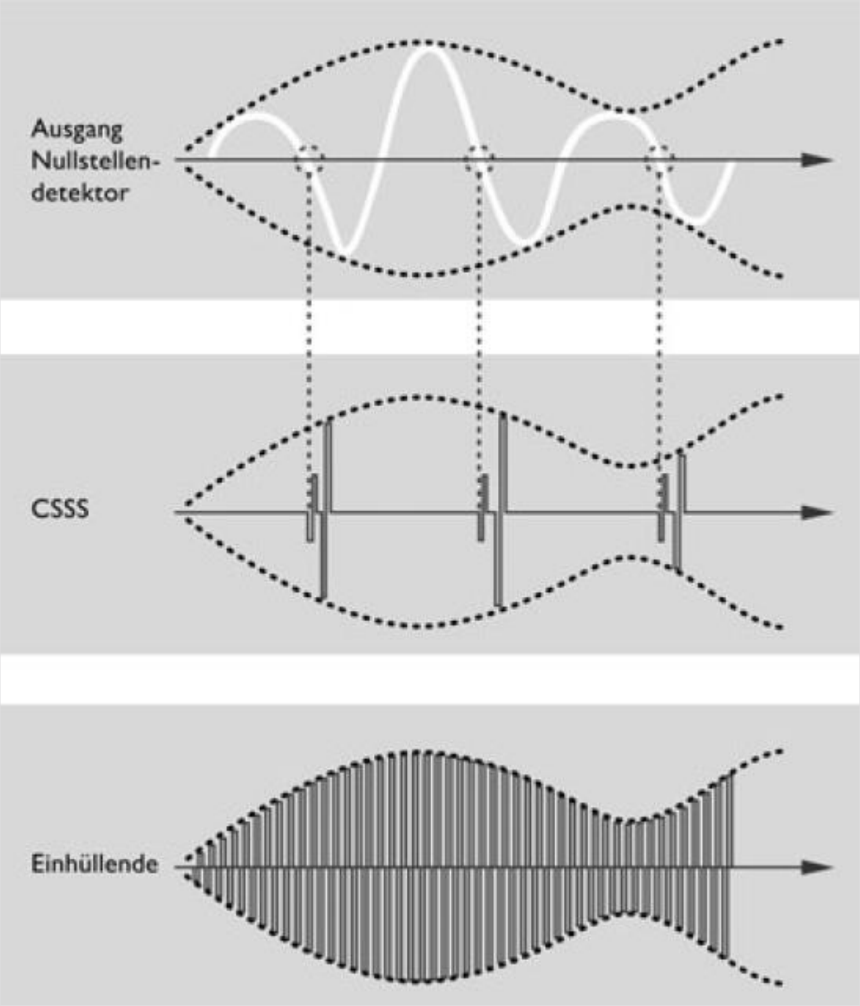
Boenninghaus, Lenarz:
Hals-Nasen-Ohren-Heilkunde (2007)

Periodicity Principle:



Hellbrück, Ellermeier: Hören (2004)

FSP



Channel-Specific Sampling Sequences CSSS

CIS

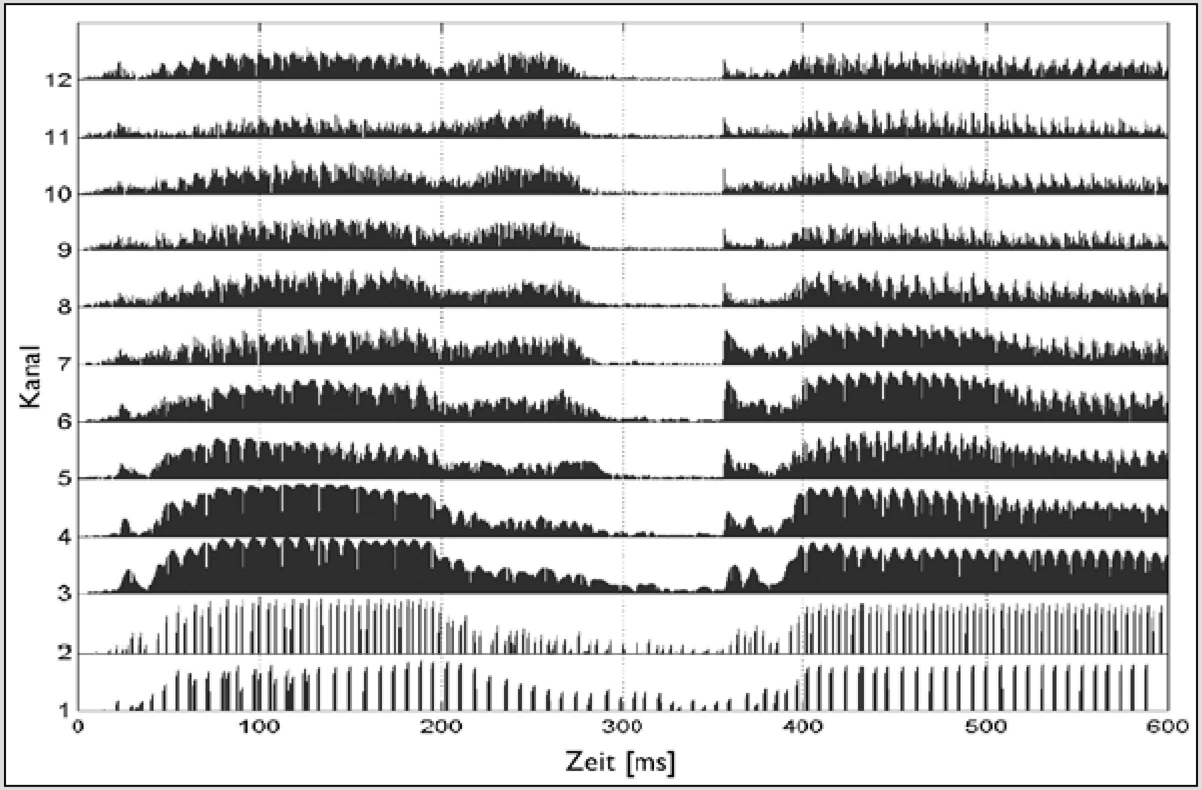
Fa. Medel

MEDEL Estrategia de codificación
Fine structure-Strategy (FSP)

Stimulation Pattern (Electrodogram) :

CIS channels - envelope transmission

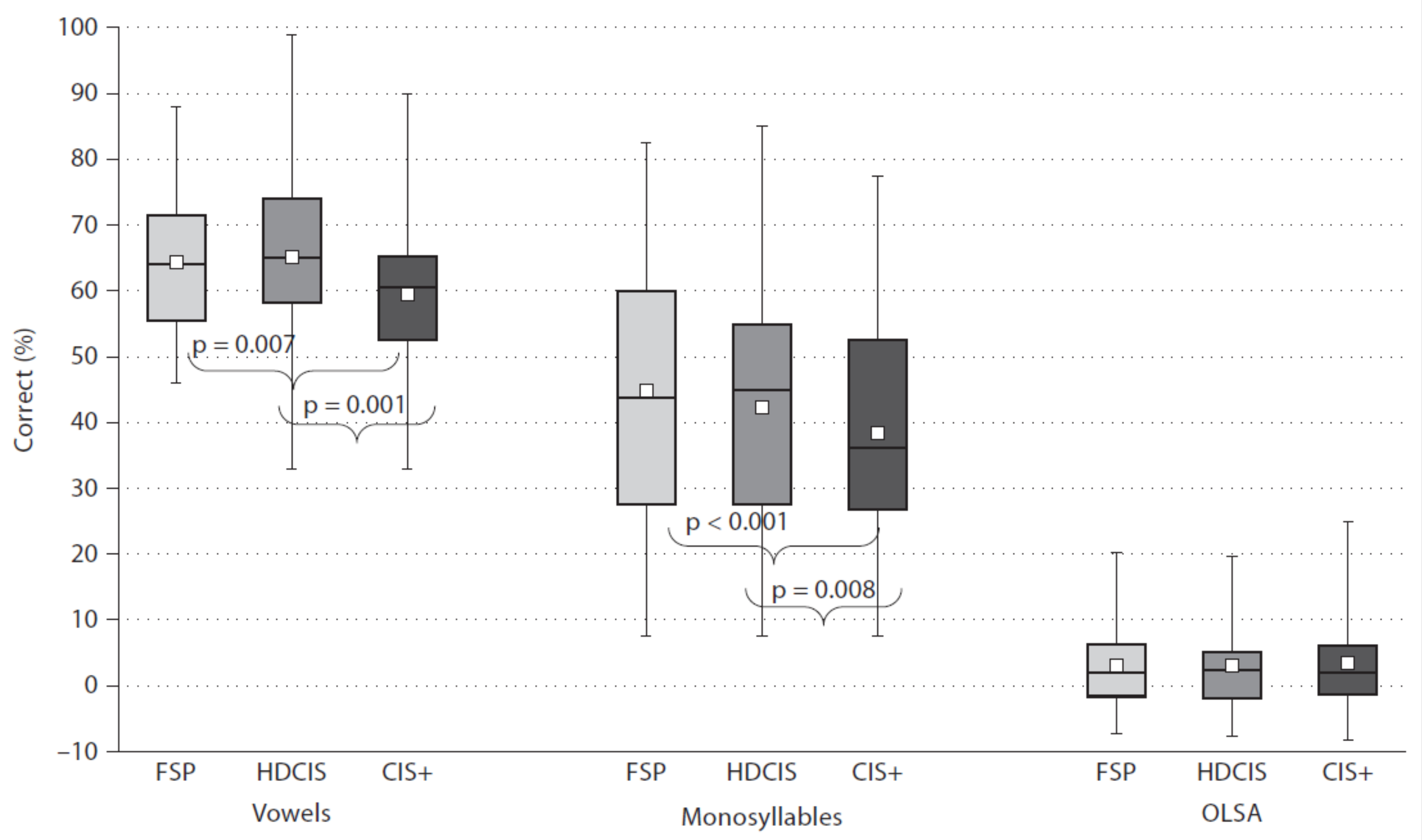
2 to 4 fine structure channels (information up to 1000 Hz) are used.



Fa. Medel

Results: Speech Intelligibility

With FSP only minimally better than with CIS+/HDCIS

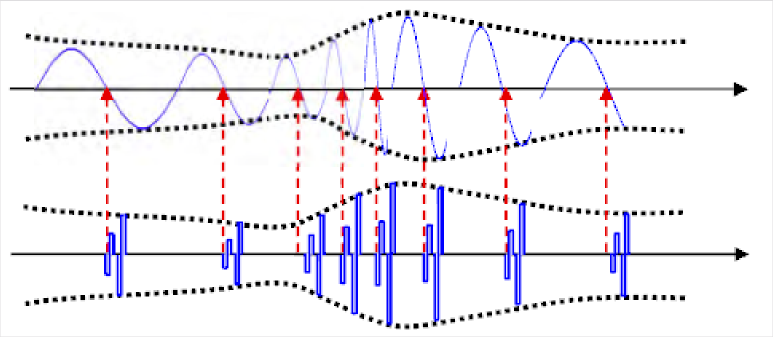


Müller et al., 2012

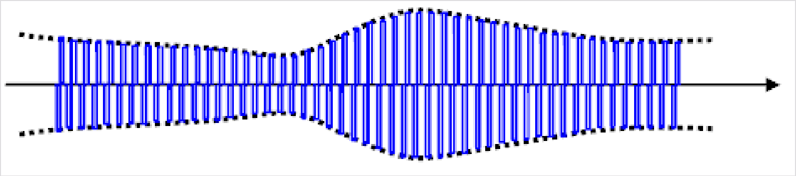
New Generation: FS4

MEDEL principles for coding fine structure:

Fine Structure Information



Envelope Information



FS4

El.	1	2	3	4	5	6	7	8	9	10	11	12
mid freq.	149	262	409	602	851	1183	1632	2228	3064	4085	5656	7352
Rate	6000	6000	6000	6000	750	750	750	750	750	750	750	750

Deutsches HörZentrum Hannover

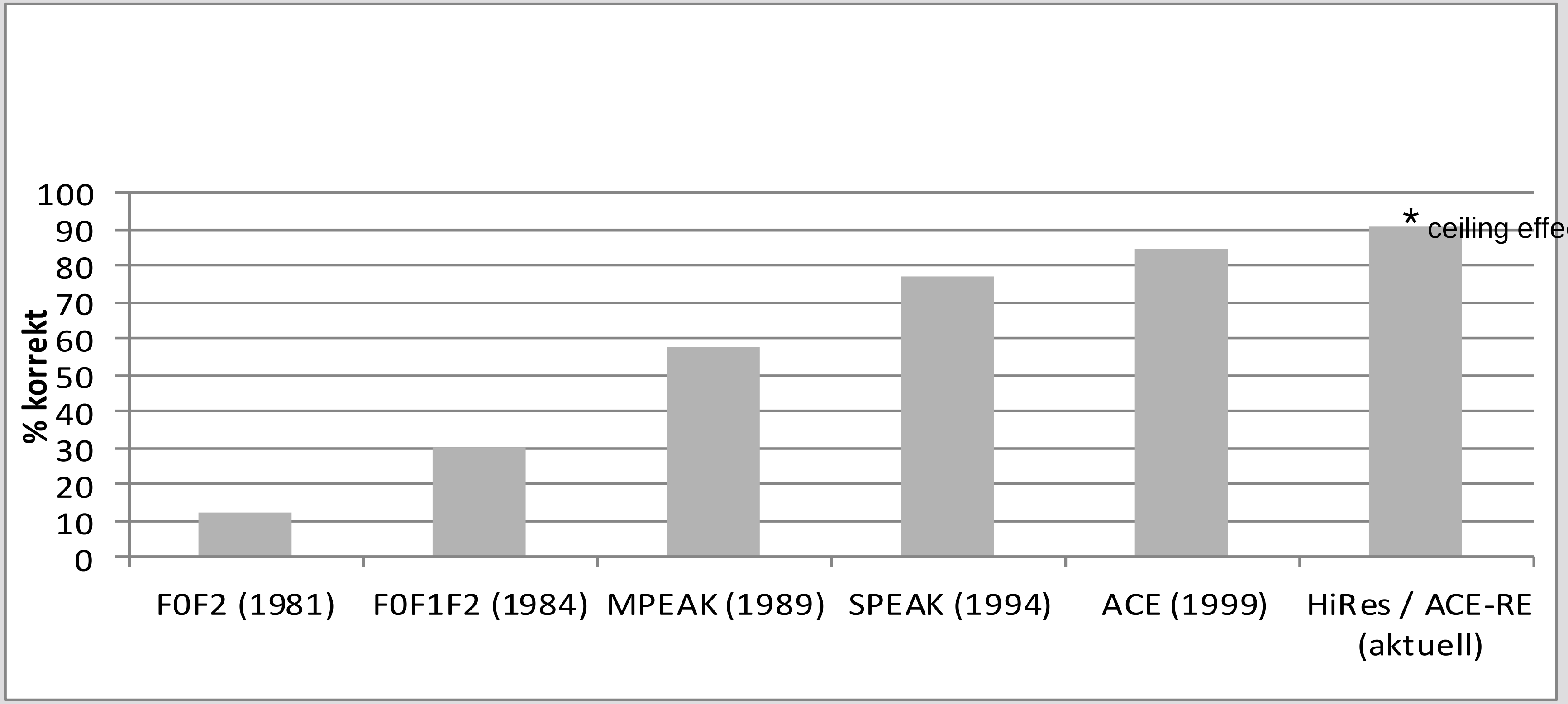
Medizinische Hochschule Hannover

New generation: FS4

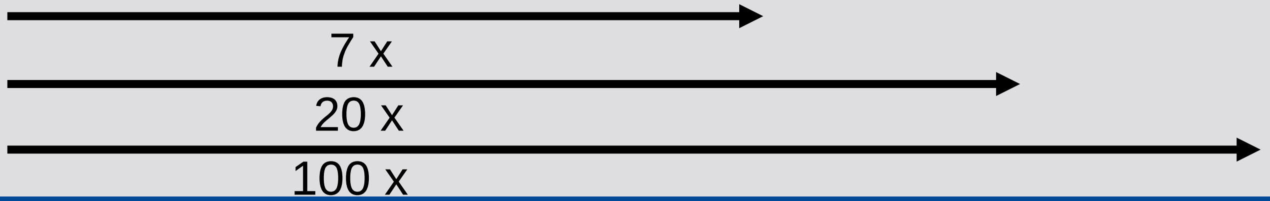
El.	1	2	3	4	5	6	7	8	9	10	11	12	
m. Freq.	149	262	409	602	851	1183	1632	2228	3064	4085	5656	7352	
Rate	1635	1635	1635	1635	1635	1635	1635	1635	1635	1635	1635	1635	FSP
Rate	6000	6000	6000	6000	750	750	750	750	750	750	750	750	FS4 LR
Rate	10042	10042	10042	10042	1255	1255	1255	1255	1255	1255	1255	1255	FS4 HR

➡ MHH study comparing **FS4 LR** (low rate) and **FS4 HR** (high rate).

Effect Stimulation Rate

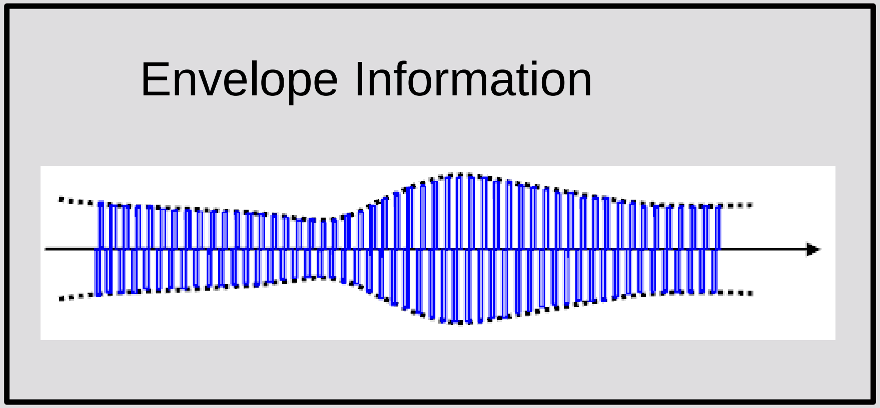


Stimulation-rate



Effect Stimulation Rate

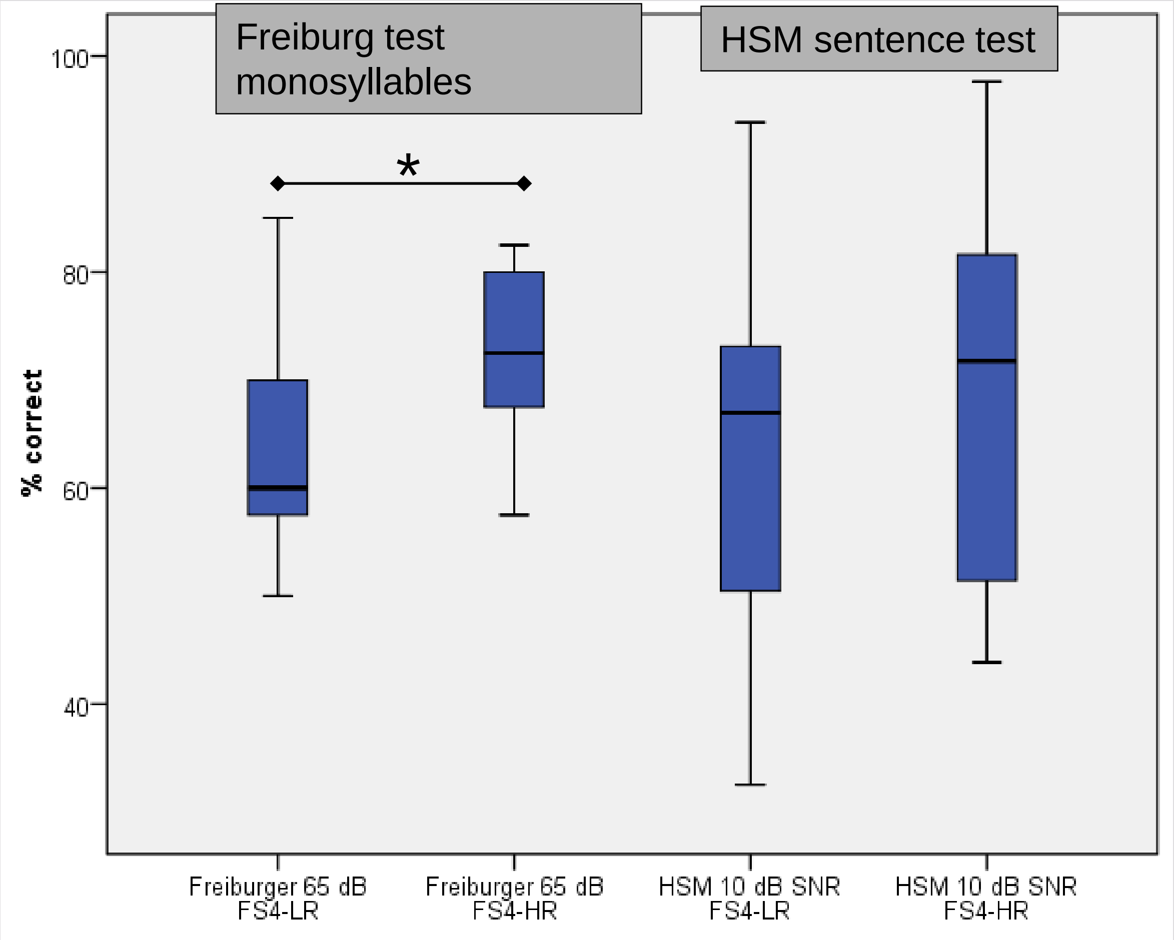
Coding strategies that mostly encode envelope information (e.g. HDCIS):



El.	1	2	3	4	5	6	7	8	9	10	11	12
m. Freq.	149	262	409	602	851	1183	1632	2228	3064	4085	5656	7352
Rate	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019	1019

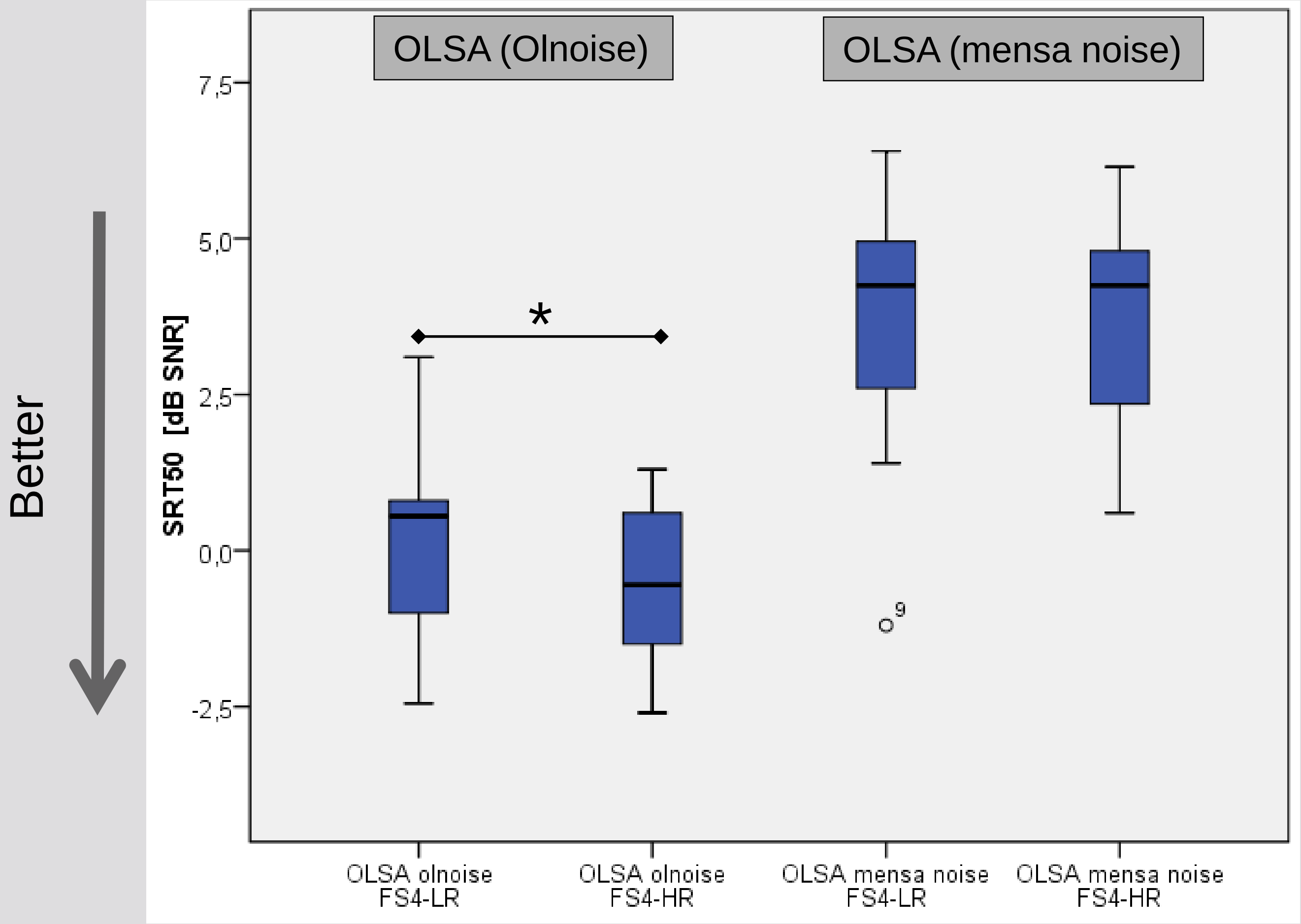
Resultados: Inteligibilidad del habla

Tras 3 meses de uso continuado (n=9):



Results: Speech Intelligibility

After 3 months of continuous use (n=9):



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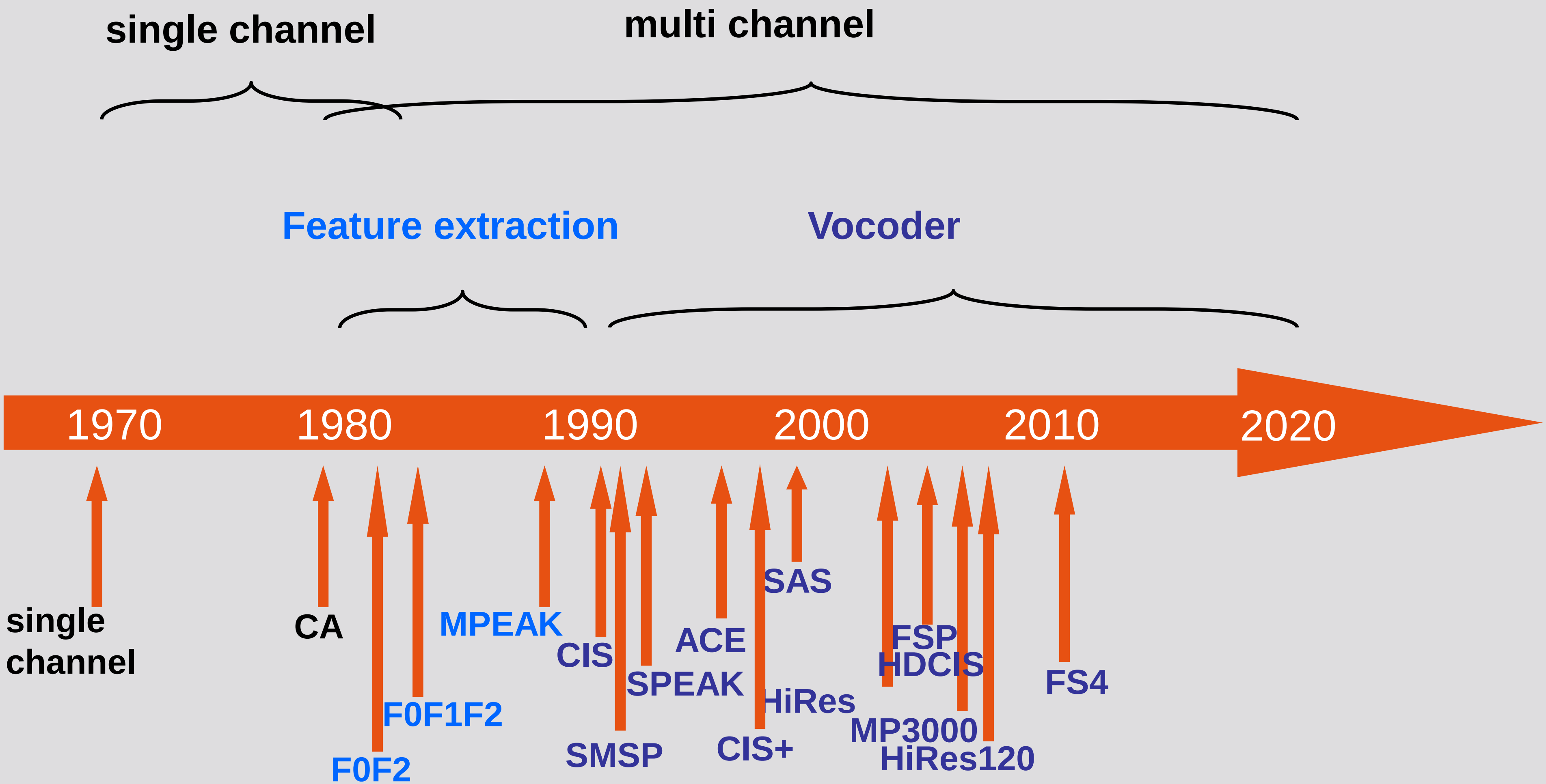
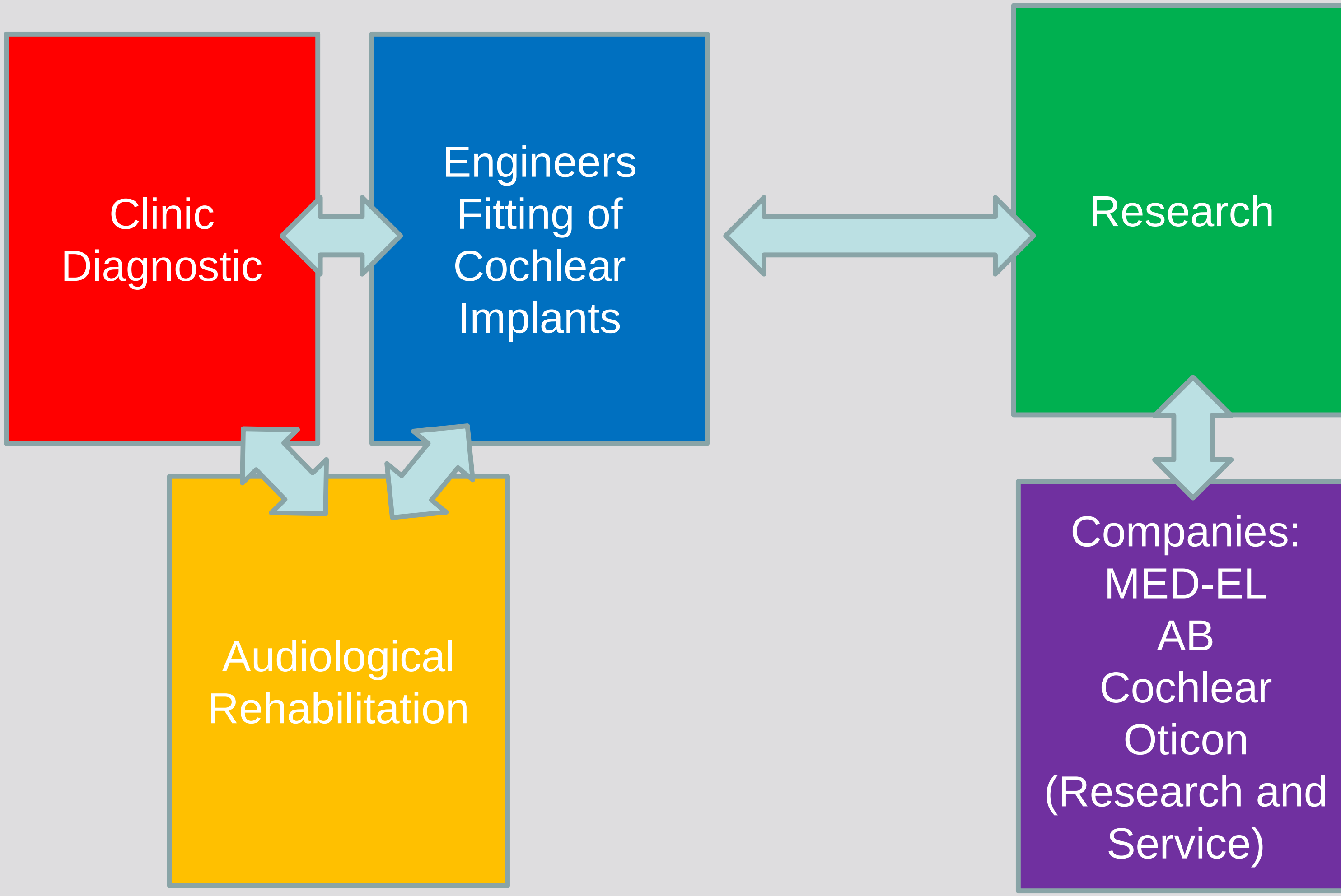
Medizinische Hochschule Hannover

Summary



Medizinische Hochschule Hannover

DHZ: German Hearing Center



hno mhh DHZ Deutsches HörZentrum Hannover VIANNA MHH Medizinische Hochschule Hannover

Molte grazie!

hno mhh

MHH Medizinische Hochschule Hannover

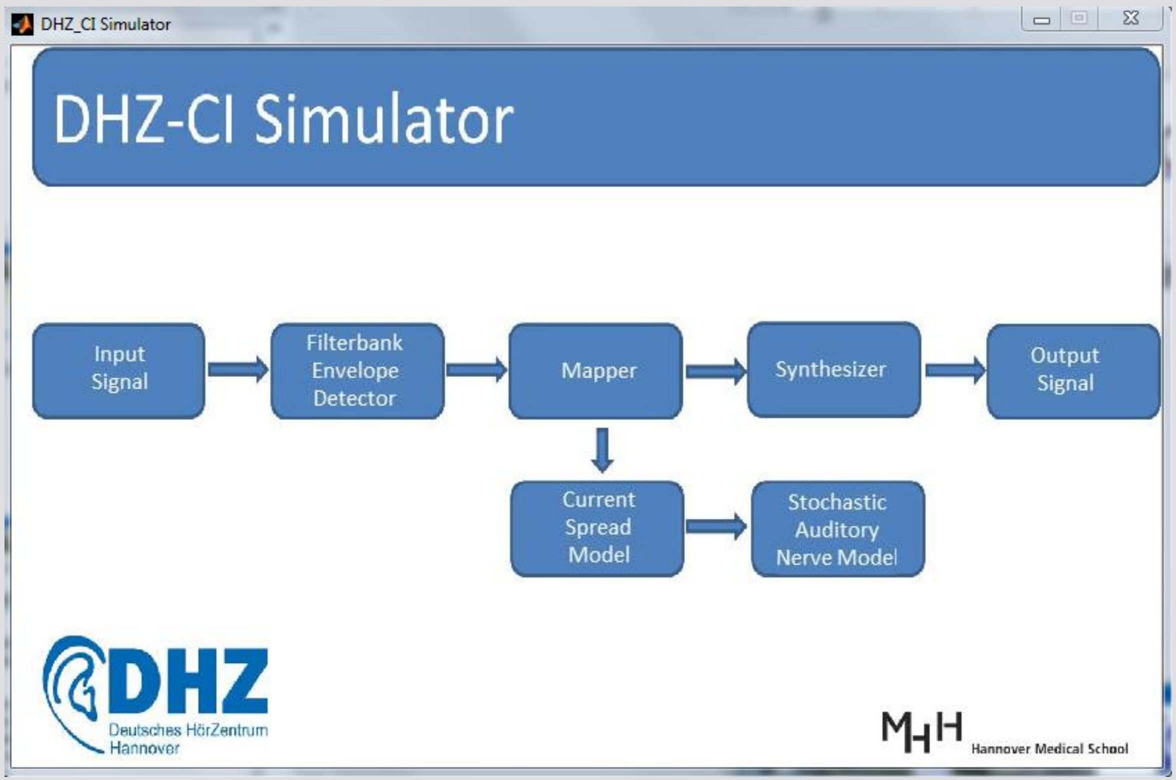
DHZ Deutsches HörZentrum Hannover

VIANNA

Hearing 4all

VoCoder

- DEMO: DeHoCI Simulator



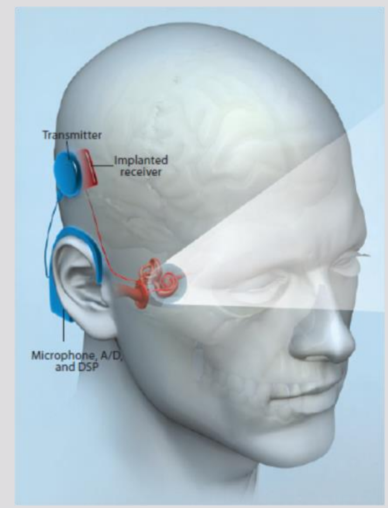
Tecnología: Personalización

Objetivo: Optimizar individualmente la inteligibilidad de la música y el habla para usuarios de IC

Caracterización de la interfaz Eléctrico Acústica

Estado del Arte: Procesado del Sonido (Reducción de Ruido)

Individualización de los parámetros (Reducción de Ruido)



Respuestas Subjetivas Medias Psicoacústicas

Ejemplo: F0/F2 y „ACE“

F0F2 (in noise)	F0/F2	ACE	
			Ist das Flugzeug gestartet?
			Er hat heute einen Arzttermin.

Auditory Prosthetic Group (APG)

- <u>Objetivos del APG</u>
  - Mejorar la inteligibilidad del habla en ruido así como la percepción musical para usuarios de imlante coclear
- <u>Cómo</u>? Dos posibilidades
  - <u>Tecnología</u>: Modificar el Procesador del implante coclear (IC)

  - <u>Art</u>: Crear contenidos específicamente para usuarios de IC