Signal Processing Strategy for Cochlear Implant based on Feature Extraction

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Introduction

*Present the principles of Oticon Medical next generation coding strategy **Spectrum Feature Extraction (SFE)***

We are highlighting 3 technical improvements present on our next generation strategy:

1. *A flexible frequency allocation that allows getting closer to the actual "anatomic" inspired allocation [Landsberger et al., 2015]. Furthermore, on the future can address the needs of electrode arrays with higher number of contacts that would need precise and narrow low frequency allocation [Clopton & Spelman, 2003], [Biesheuvel et al., 2019]*
2. *Precise extraction of temporal and frequency information of the signal features.*
    - *The precise frequency allocation allow us to reduce the "analysis frequency smearing". Goehring et al. 2020 showed how frequency smearing may be detrimental to speech in noise performance.*
    - *Precise temporal information will allow us to convey the missing Temporal Fine Structure to our users.*
3. *The computation of the feature "frequency spread" could allow us to better code the feature into the electrode stimulation and mimic this spread into the actual electrical spread.*

Background: Crystalis Strategy

- *Crystalis is the current strategy used in Oticon Medical CI devices [Bergeron & Hotton, 2016], [Lagner et al, 2020].*
- *FFT based approach (windowed by Hamming window).*
- *Spectral Enhancements intended to reduces frequency smearing artefacts for FFT analysis.*
- *Channel Regrouping selects the energy mapped to each electrode (as a function of the FFT energy spectrum).*

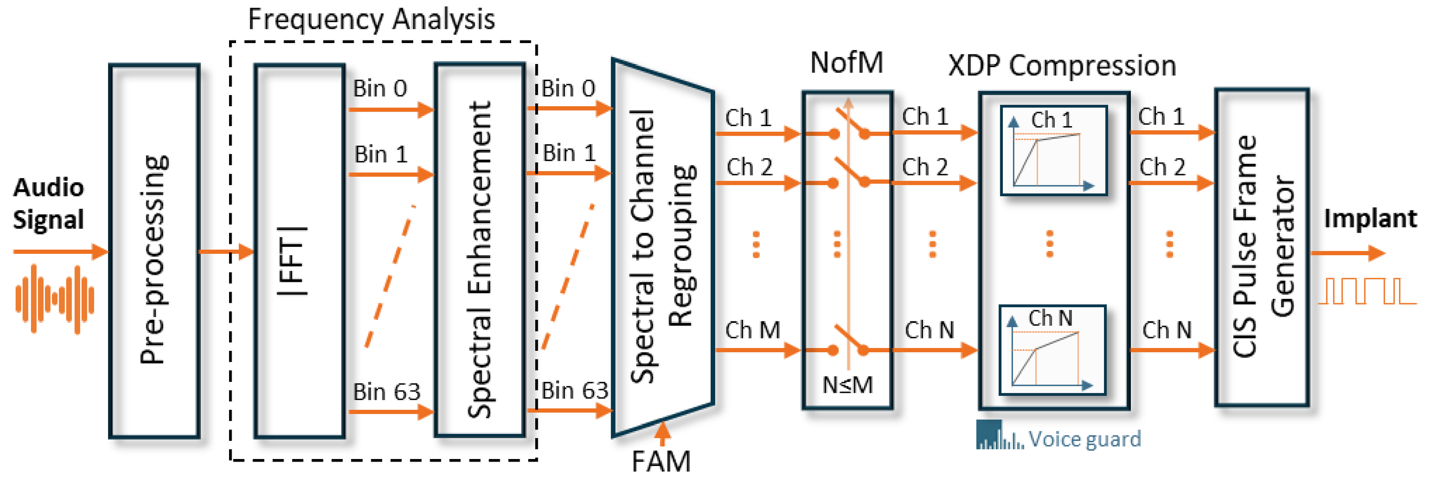


Figure 1. Signal processing chain for the Crystalis coding strategy

Methodology: SFE new coding strategy

- *Briefly present our clinical coding strategy Crystalis (Background)*
- *Explain our next generation coding strategy Spectrum Feature Extraction (SFE)*
    - *Detail some of the main technological components*
    - *Present the improvements compared to previous strategy*
- *Compare electrodogram simulations using equivalent configuration for Crystalis and SFE*
- *Briefly present some of the results of Acute Evaluation (Refer to Poster M50: [1634])*

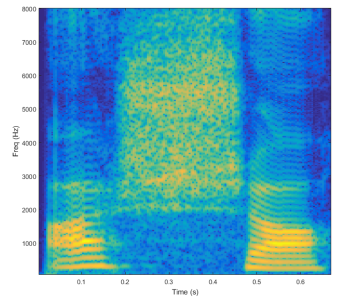
SFE strategy

- *Method aims to identify with precision the main "acoustic" **features***
- *For each feature a time series of events can be defined around the zero crossings.*
- *Next obtain an estimation of energy, frequency, and time for each event*
- *Electrode Channels can have "arbitrary" frequency allocation masks (FAM) (figure 5)*
- *Events are then assigned to the relevant Electrode Channels*

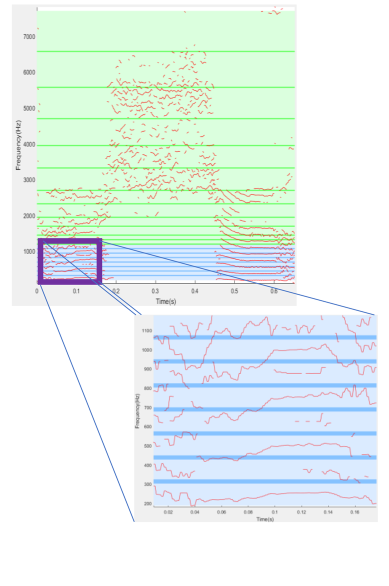
SFX: Synthetic Feature eXtraction

SFE Analysis block

- *SFX assumes Spectral Peaks convey the most important information to be transferred to the user*
- *Reduces analysis frequency smearing compared to FFT based strategies*
- *Improves the resolution of the estimated frequency terms*
- *SFX provides then a periodic vector of events with precise Energy, Phase, Frequency and Level of spread parameters*



a) Spectrum for utterance "a-ch-a"



b) Alternative represesntation of utterance "a-ch-a"

Figure 3. Spectrogram representing only Dominant Spectrum Peaks

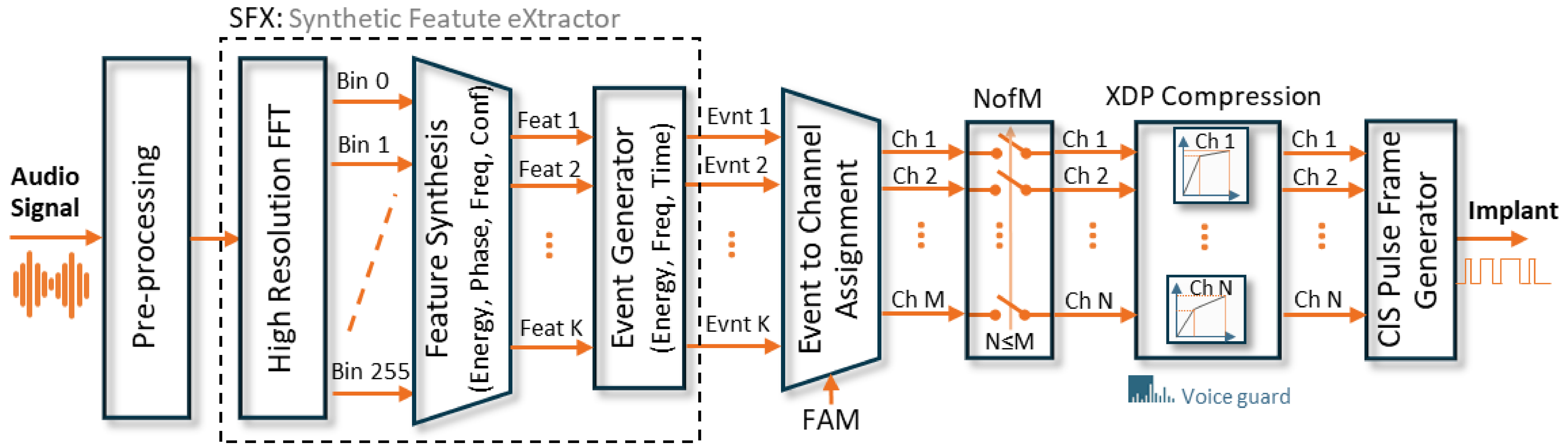


Figure 2. Signal processing chain for the SFE coding strategy

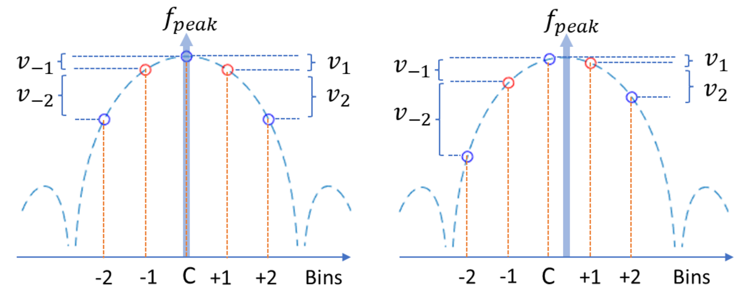


Figure 4. Syntheses of high-resolution features (i.e., frequency, energy, and phase parameters) using smearing characteristics of the Kaiser window

Event to channel Assignment

The trapezoid defines the electrodes Frequency Allocation Mask (FAM). Events with frequencies that fall in the scope of a trapezoid masking function compete to be selected. Energies of the events are scaled by the masking function. The Event with the maximum scaled Energy will be the winner.

In figure 5, event 1 competes with event 2 to be selected for channel 1. After scaling, it is the event 2 that is selected even though its initial energy is lower. Event 4 is participated in two competitions for channels 2 and 3. Channel 4 does not receive any event so a zero energy event is assigned to it.

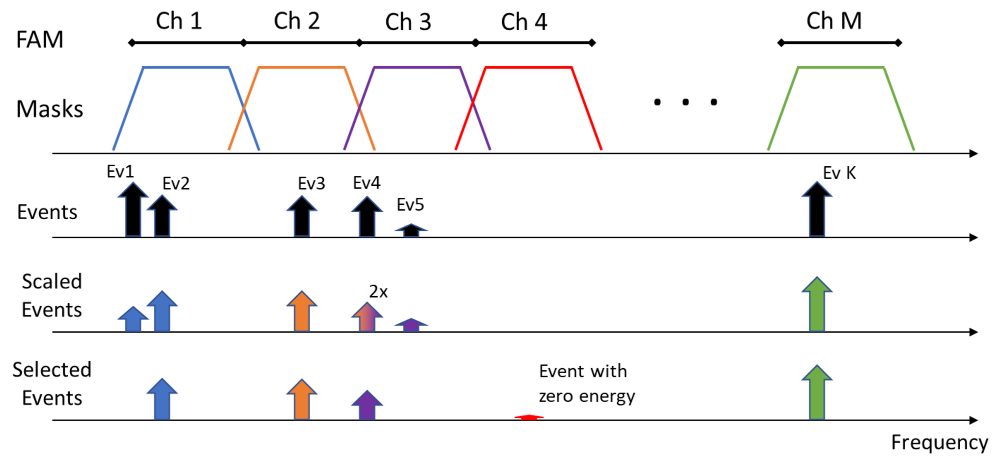


Figure 5. Event-to-Channel assignment process.

Electrode #	Crystalis f_{low}	Crystalis f_{high}	Crystalis F_{center}	SFE f_{low}	SFE f_{high}	SFE f_{center}
e0	187.5	312.5	250	203.125	296.875	250
e1	312.5	437.5	375	328.125	421.875	375
e2	437.5	562.5	500	453.125	546.875	500
e3	562.5	687.5	625	578.125	671.875	625
e4	687.5	812.5	750	703.125	796.875	750
e5	812.5	937.5	875	828.125	921.875	875
e6	937.5	1062.5	1000	953.125	1046.875	1000
e7	1062.5	1187.5	1125	1078.125	1171.875	1125
e8	1187.5	1312.5	1250	1203.125	1296.875	1250
e9	1312.5	1437.5	1375	1328.125	1421.875	1375
e10	1437.5	1687.5	1562.5	1468.75	1656.25	1562.5
e11	1687.5	1937.5	1812.5	1718.75	1906.25	1812.5
e12	1937.5	2312.5	2125	1984.375	2265.625	2125
e13	2312.5	2687.5	2500	2359.375	2640.625	2500
e14	2687.5	3312.5	3000	2765.625	3234.375	3000
e15	3312.5	3937.5	3625	3390.625	3859.375	3625
e16	3937.5	4687.5	4312.5	4031.25	4593.75	4312.5
e17	4687.5	5562.5	5125	4796.875	5453.125	5125
e18	5562.5	6687.5	6125	5703.125	6546.875	6125
e19	6687.5	7937.5	7312.5	6843.75	7781.25	7312.5

Table 1. Crystalis and SFE frequency allocation (FAM) proposed for this study.

Results

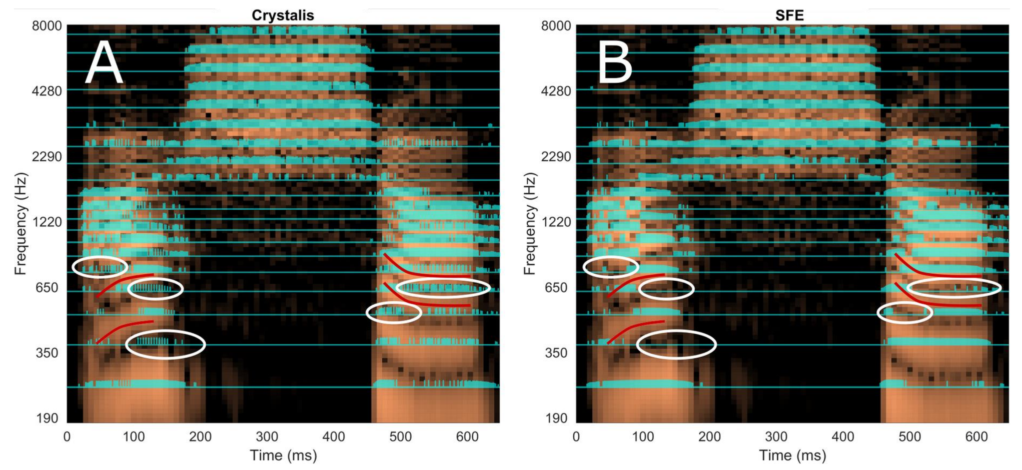


Figure 6. Electrodogram for utterance "a-ch-a"

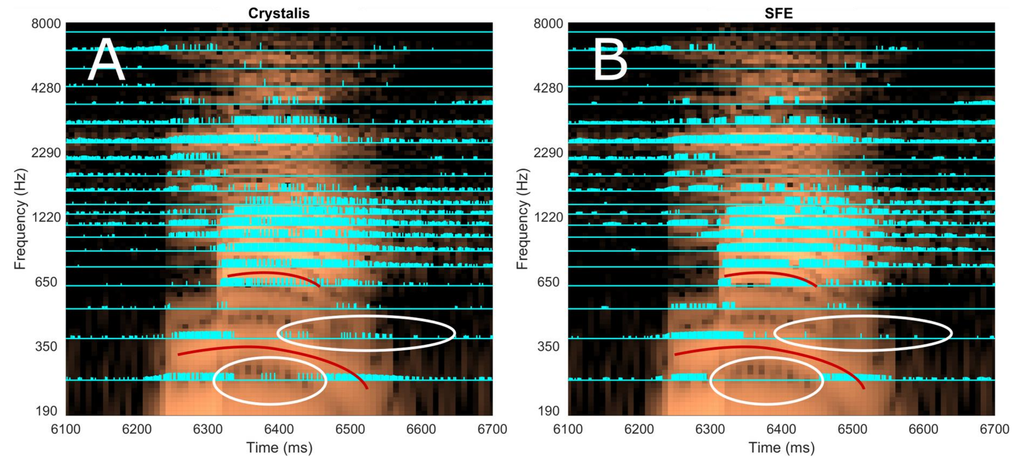


Figure 7. Electrodogram for utterance "mà".

Example electrodograms

- *For the examples shown in this section, the electrodograms were calculated with a N-of-M selection of 8 channels per frame and a stimulation rate of 500pps. The FAMs used in the following simulations for both Crystalis and SFE are described in Table 1 by the center frequency (fcenter), the low cutoff frequency (flow), and the high cutoff frequency (fhigh)of the mask attributed to each electrode.*
- *The electrodograms for the utterance "a-ch-a" are presented in Figure 6, with Crystalis on image A, and of SFE on image B. The main differences can be seen in the representation of the vowels. The red lines point out how the first vowel 'a' has an ascending pitch, whereas the second 'a' has a descending pitch.*
- *A good representation of the dynamics of speech formants is specially interesting for tonal languages. Figure 8 brings the electrodograms relative to an utterance of the Mandarin syllable "mà", distinguished by its descending tone. Here again the SFE electrodogram matches the audio spectrodogram better than the Crystalis one.*

Acute Protocol

- *A repeated measures protocol was used to compare SFE and Crystalis strategies. Details of protocol on: Poster M50: [1634].*
- *Details of testbench setup for clinical protocol on Th49: [1637].*
- *Speech Reception Thresholds (SRT50) was significantly better on first day for Crystalis. The results improved significantly for SFE during testing. No significant difference observed on last day of testing (figure 8).*
- *MUSHRA shows a subjective preference for the Crystalis strategy.*

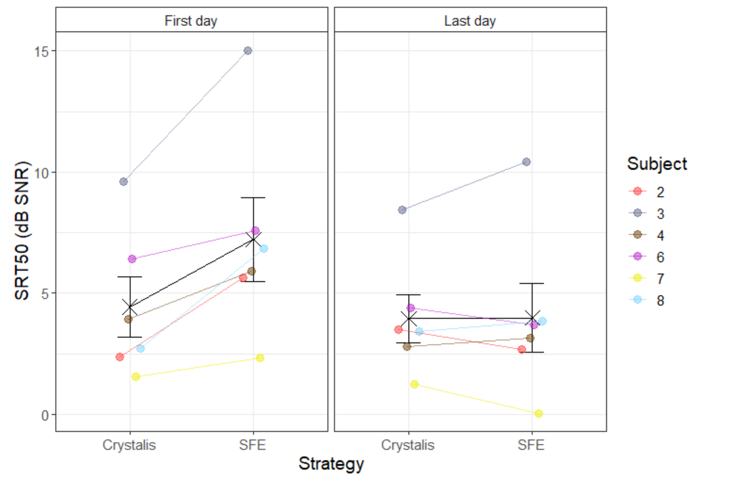


Figure 8. Speech in noise recognition.

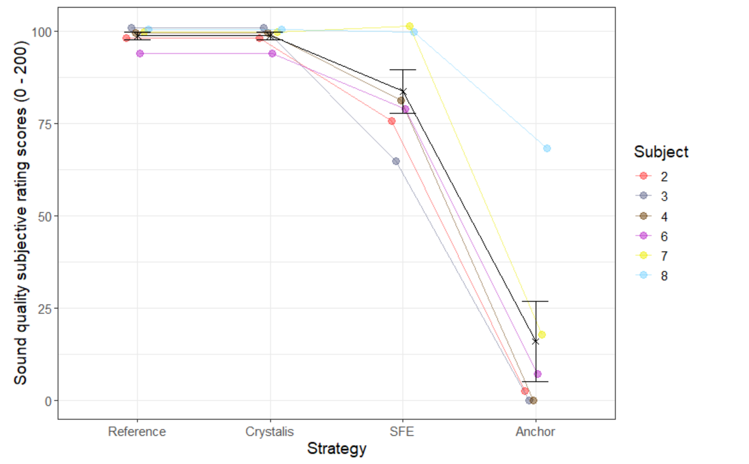


Figure 9. MUSHRA results..

Discussions and Conclusions

- *Next Generation Oticon Medical strategy has been presented.*
- *Results using a first SFE configuration were presented (and details of the acute protocol is presented on Poster M50: [1634]. The frequency allocation is equivalent to the allocation already proposed by the Crystalis strategy.*
- *Acute protocol, SFE does not shown regression speech recognition in noise compared to Crystalis. This opens the introduction of SFE on Oticon Medical next generation sound processor.*
- *MUSHRA is still worse for SFE than Crystalis, probably due to longer time needed to get used to sounds.*
- *A lot is still to be investigated around the technology improvements introduced by SFE.*
- *We expect long term benefits coming from SFE, specially for patients with good spectral temporal coding that should benefit from lower frequency smearing [Goehring et al. 2020]. Then, chronic testing is a must to better understand the benefits for our patients.*
- *Parallel studies are planned to investigate anatomical and precise frequency allocation. Bimofuse (Hanna Dolhopiatenko talk session 6b) and Anemone (Posters M46: [1594] and W46: [1655]) are aimed to define the tools and methods to optimize electrode array frequency allocation.*
- *Further studies around novel methodologies of stimulation are planned (T41: [1750] , T53: [1742]). Can we exploit the precise timing information extracted on SFE to improve perception for CI users?*
- *Investigation on configuration for music appreciation are also planned similar to the approach presented on Tahmasebi et al. 2023.*

References

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