Filterbank Design for Low-power Audio Applications

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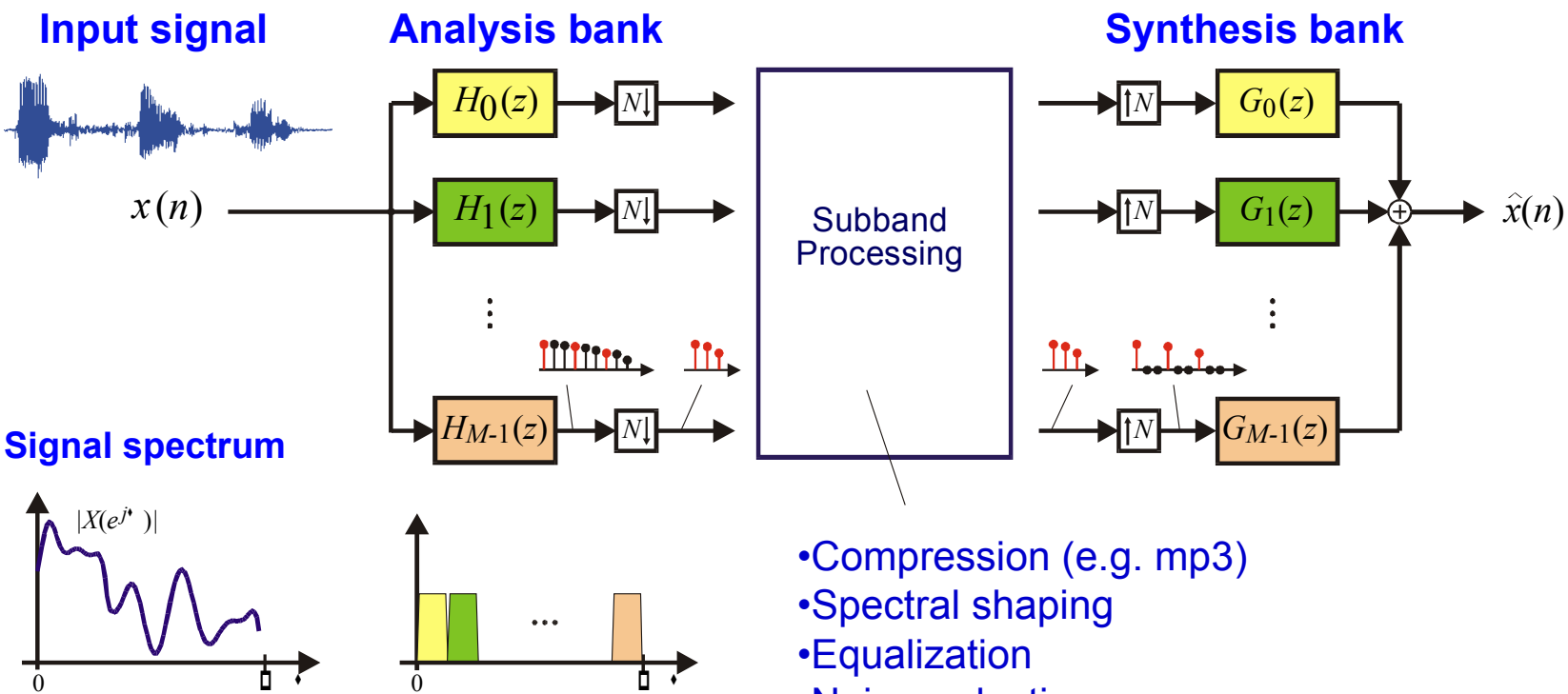
Outline

1. Introduction to filterbanks
2. Efficient filterbank realizations
3. Frame analysis
4. Summary and Conclusions

1. Introduction to Filterbanks

Typical structure for subband processing:



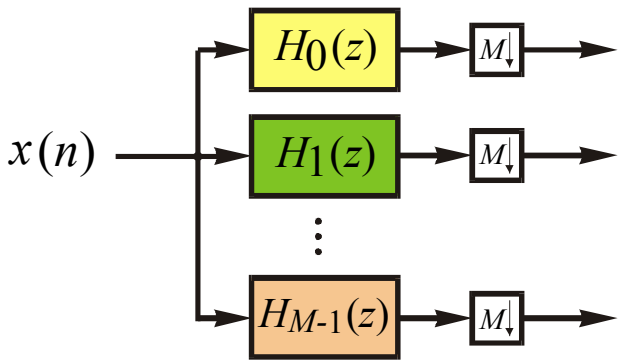
- Compression (e.g. mp3)
- Spectral shaping
- Equalization
- Noise reduction
- Echo compensation

Modulated filterbanks

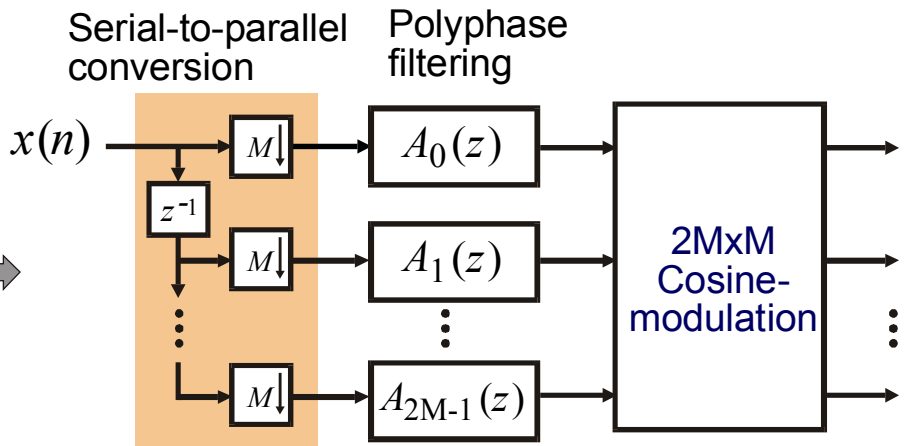
- Only one prototype is needed
- All analysis and synthesis filters are generated through modulation of the prototype (real or complex)
- Efficient implementation in polyphase structure

2. Efficient Filterbank Realizations

Direct structure

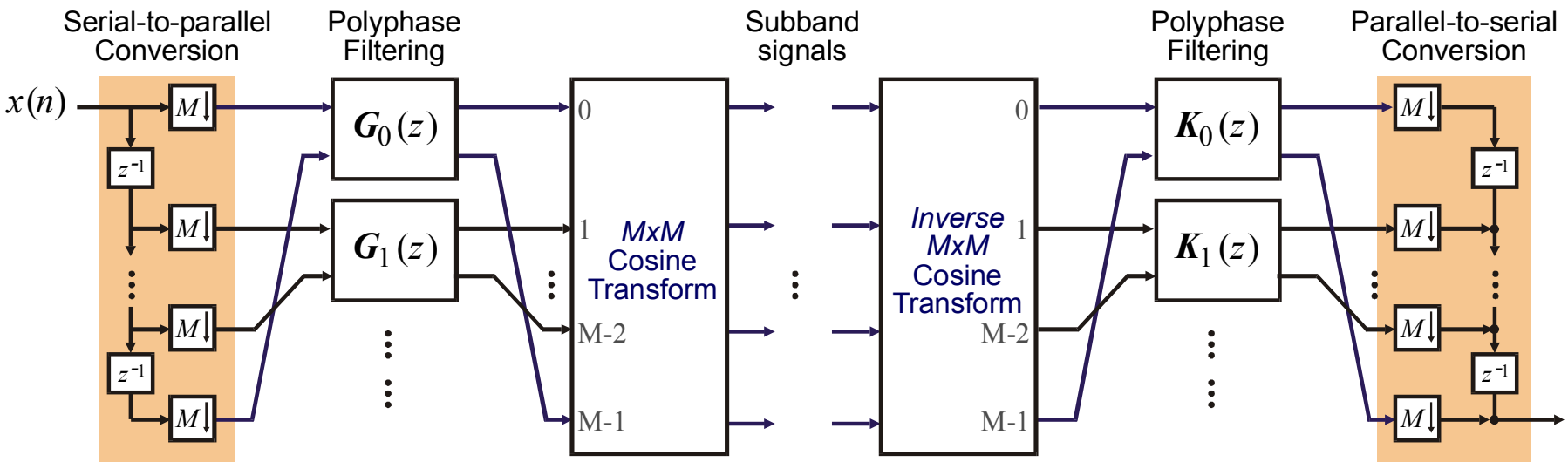


Polyphase structure



More Efficient Polyphase Structure

(Result from a DFG Project)



Filter realization with finite word length

- **Integer prototypes and modulation sequences**
  (Mertins and Karp, IEEE Trans. Signal Process., June 2002)

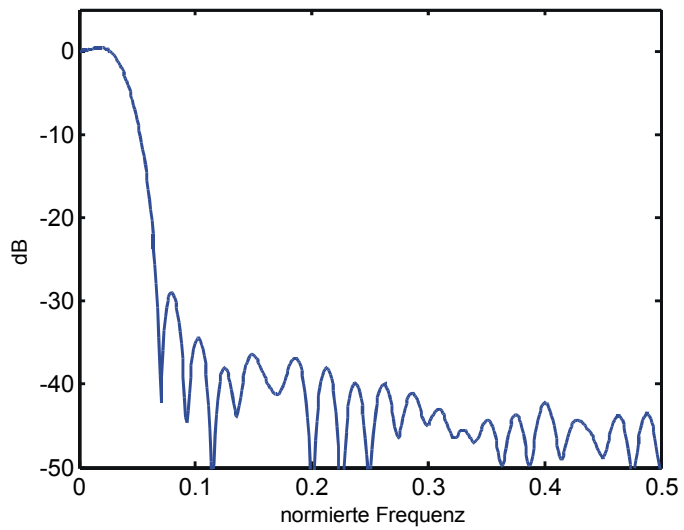
- **Prototypes that do not expand the word length**
  (Karp und Mertins, Proc. ISCAS 2001)

  - **Applications in integrated lossy and lossless audio compression**

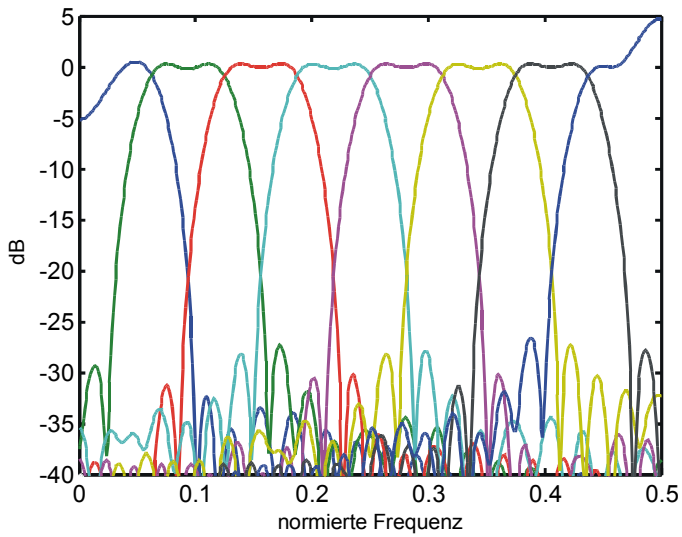
3. Frame Analysis

A Problem that often occurs with low-delay filterbanks:

Example of a prototype frequency response: (M=8, D=15, L=32)



Frequency responses of modulated filters:



Frame Bounds *A* and *B*

$$A\,\|\boldsymbol{x}\|^2 \le \sum_{k=0}^{M-1} \sum_{m=-\infty}^{\infty} |\langle \boldsymbol{x}, \boldsymbol{h}_{k,m} \rangle|^2 \le B\,\|\boldsymbol{x}\|^2 \qquad \forall\, \boldsymbol{x} \in \ell^2(\mathbb{Z})$$

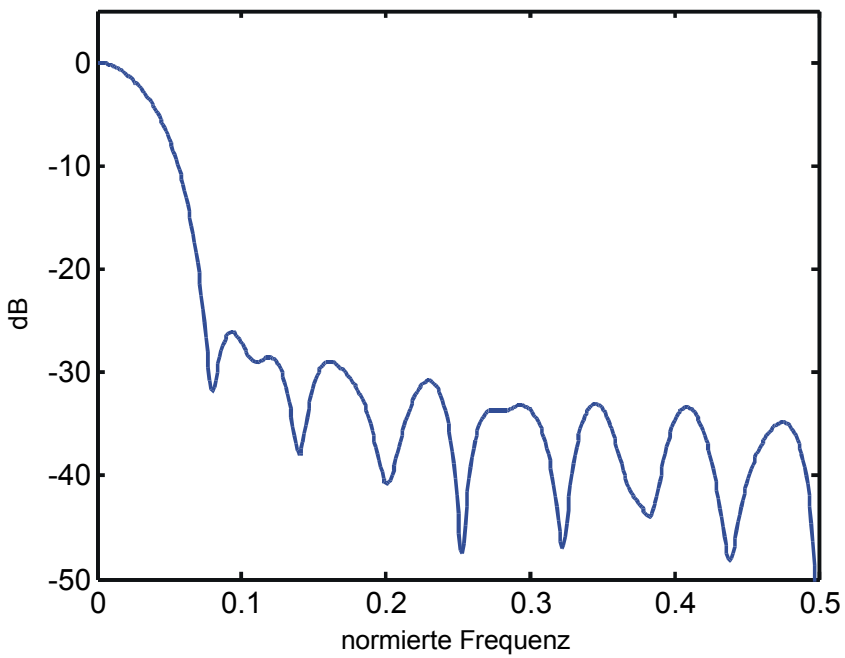
In the previous example we had

A=0.31, B=3.27

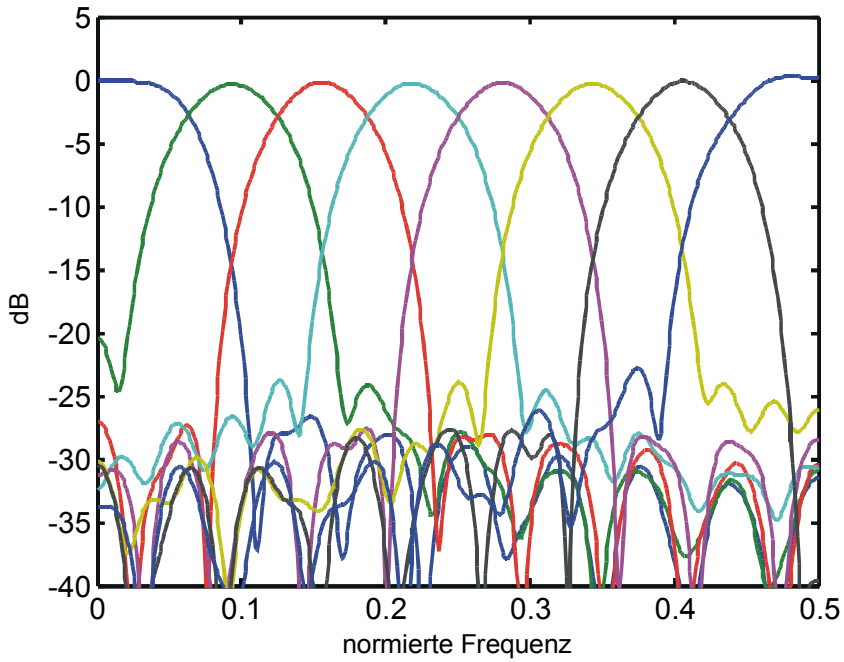
- Incorporate a frame analysis into the prototype design procedure. *(Mertins, IEEE Trans. Signal Process., Jan. 2003).*

Design Example (M=8, D=15, L=32)

Prototype frequency response:



Modulated filters:



Frame Bounds:

$$A=0.91,\quad B=1.1$$

4. Summary and Conclusions

- Efficient polyphase structure
- Perfect reconstruction with finite precision
- Filterbanks can be designed to have low delay, even with many channels and long filter impulse responses.
- Filterbank properties can be controlled via frame analysis
- Applications are in all areas audio signal processing and possibly in hearing aids