DSP for Signal Fidelity on ONFI-4 Bus

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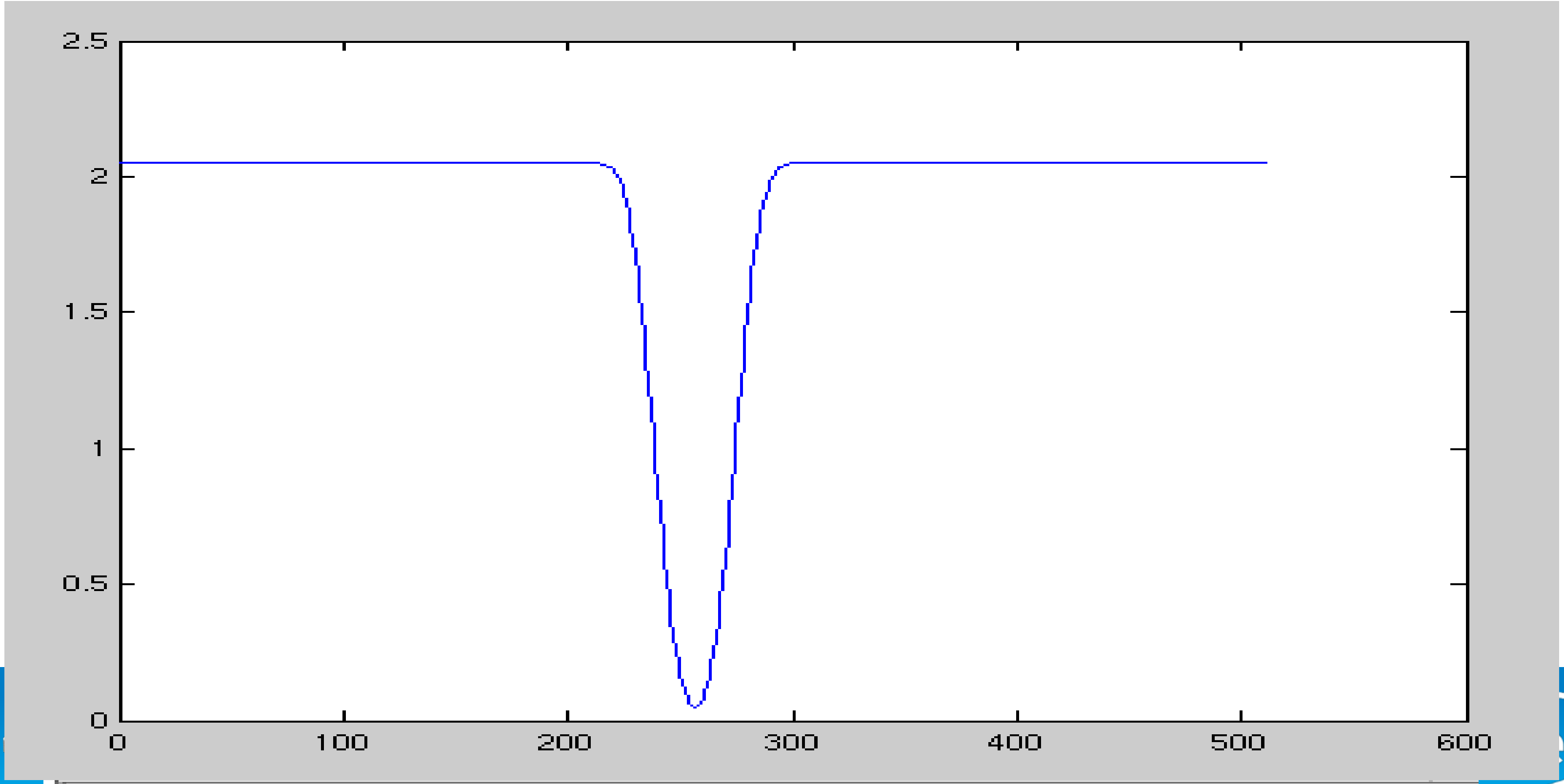
ONFI-4 channel

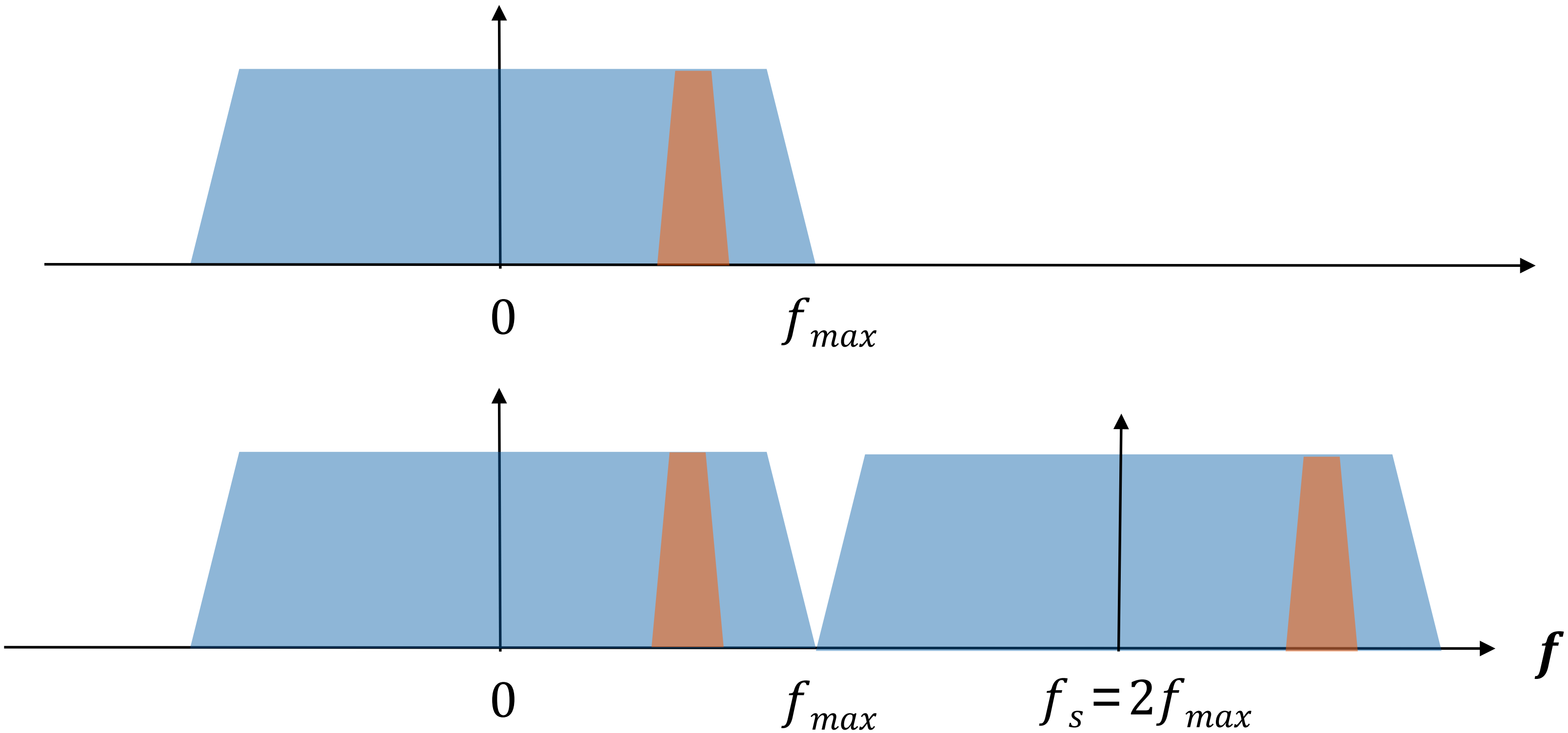
- Data Rates higher than 1.6GHz
- ONFI-4 channel exhibits a notch
- Frequency in the notch region is lost
  - Irrecoverable inter-symbol interference (ISI)



Proposed Solution

- Uses sampling rate converters
- Digital filters

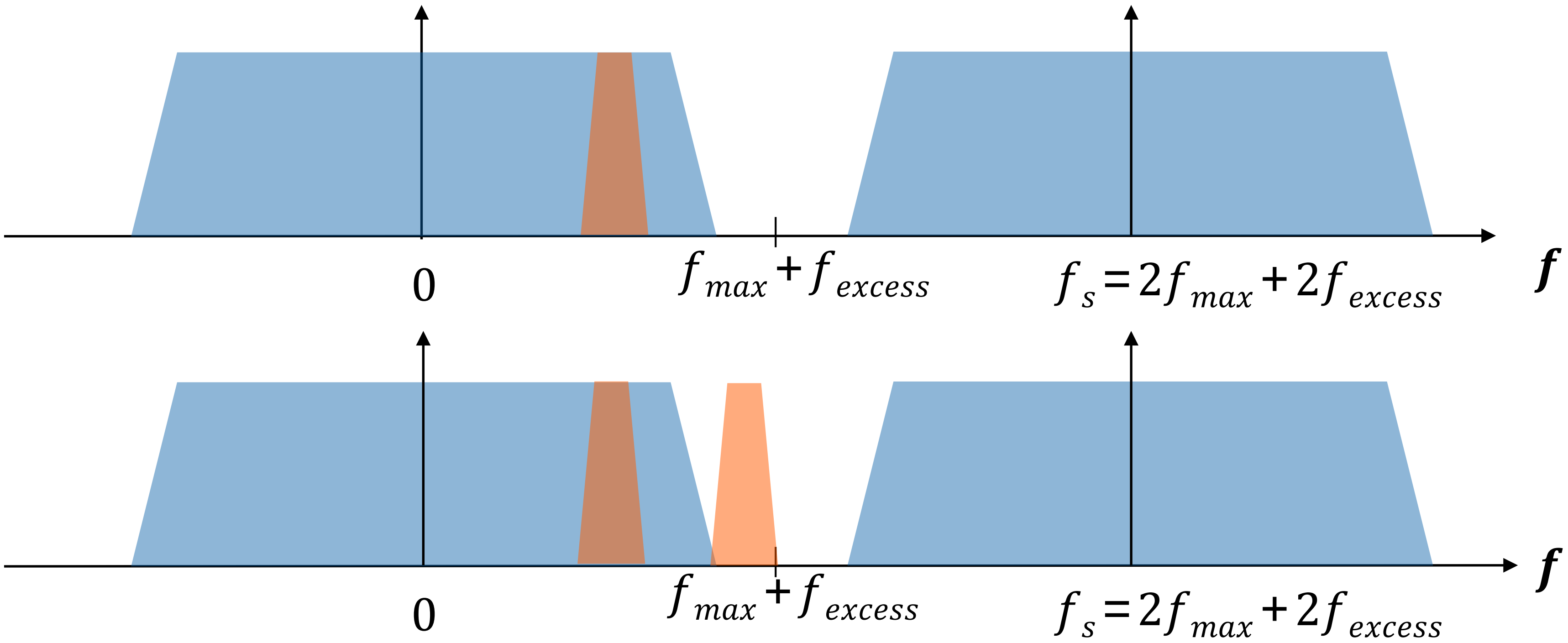
Critically Sampled Signal



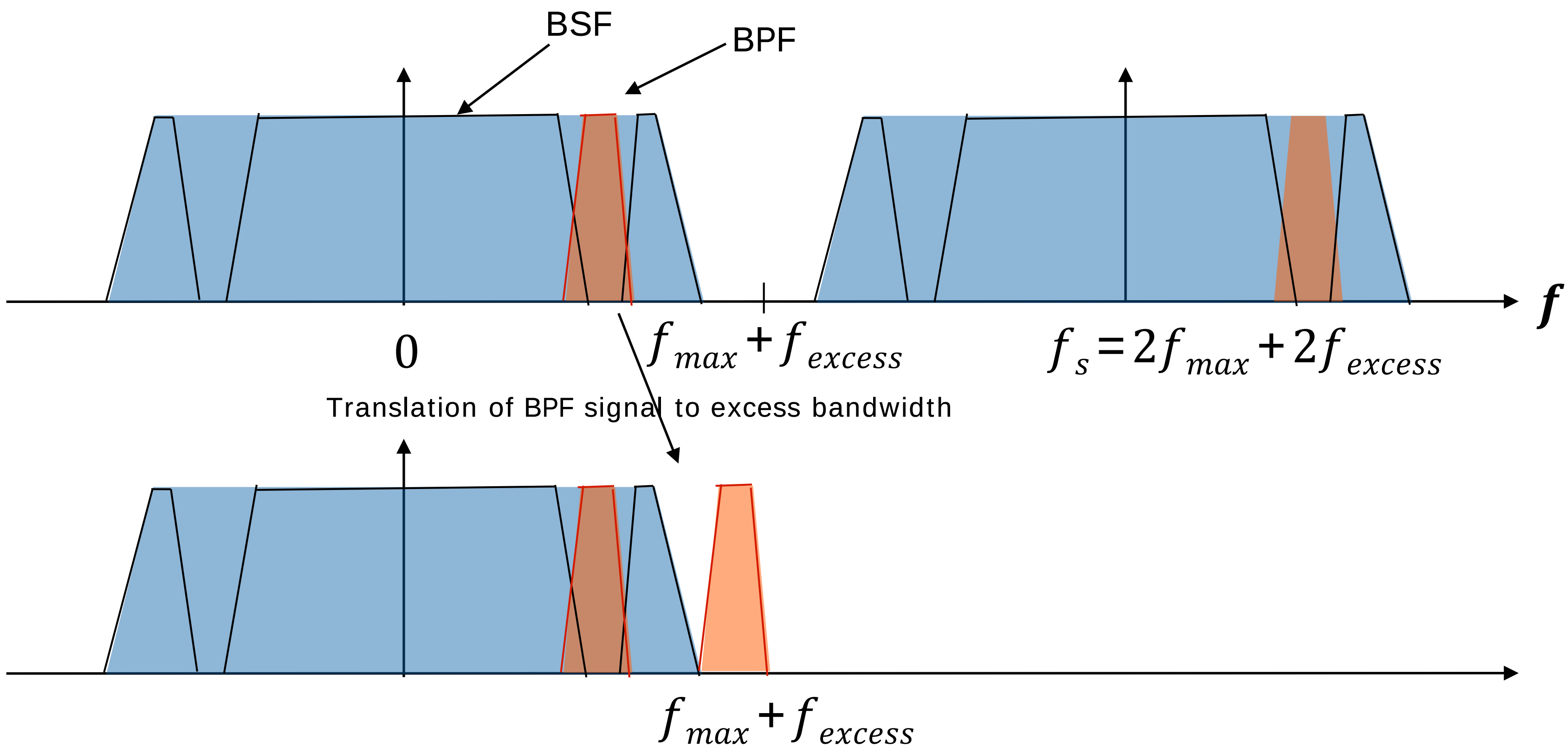
- Signal content in channel notch is lost

Oversampling causing excess bandwidth

- Excess Band-width required

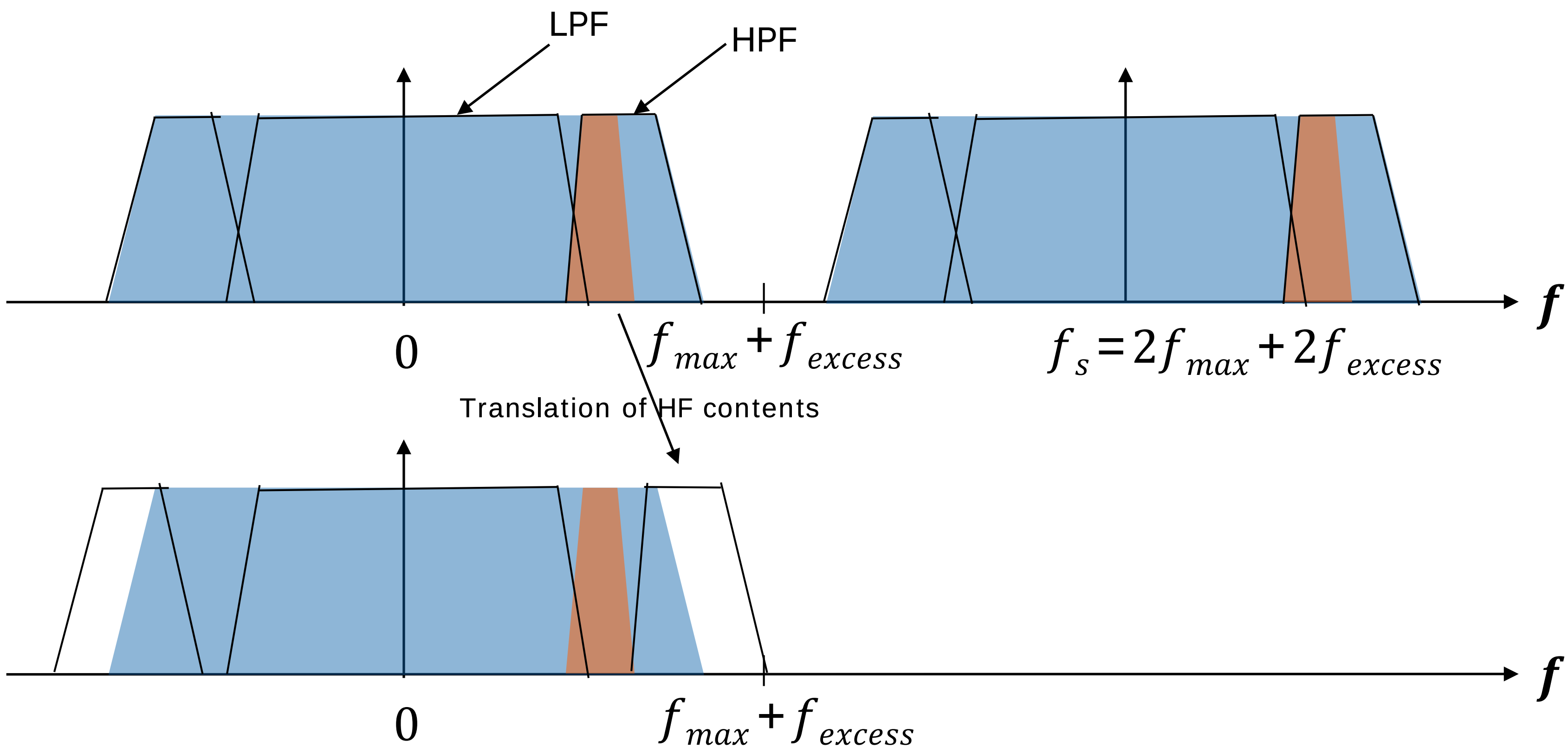


HF content translation-I



- **Scheme requires using Band-pass and Band-stop filters**

HF content translation-II



- **Excess bandwidth created using oversampling**
- **HF content translated to avoid the notch**
- **Scheme uses only Low-pass and High-pass filters**

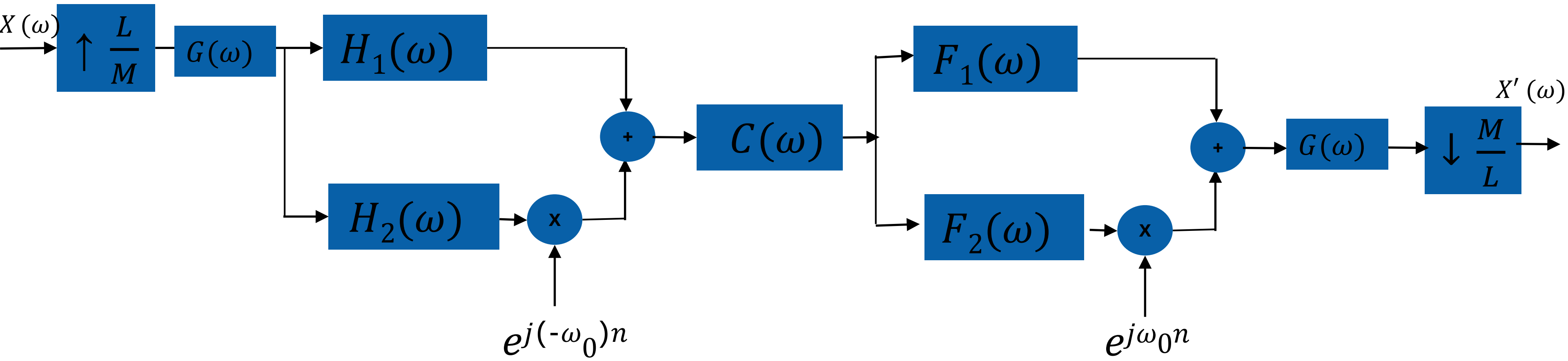
Notch Mitigation proposed scheme

- Ideally $X'(\omega) = X(\omega)$
- Perfect reconstruction condition-

$$H_1(\omega)C(\omega)F_2(\omega)\,(e^{j\omega_0 n}) + H_2(\omega)C(\omega)\big(F_1(\omega)(e^{j(-\omega_0)n})\big) = 0$$

$$H_1(\omega)C(\omega)F_1(\omega) + H_2(\omega)(e^{j\omega_0 n})C(\omega)\big(F_2(\omega)(e^{j(-\omega_0)n})\big) = e^{j\omega n}$$

$$H_1(\omega)C(\omega)F_1(\omega) + H_2(\omega)[C(\omega)(e^{j\omega_0 n})]\big(F_2(\omega)(e^{j(-\omega_0)n})\big) = e^{j\omega n}$$



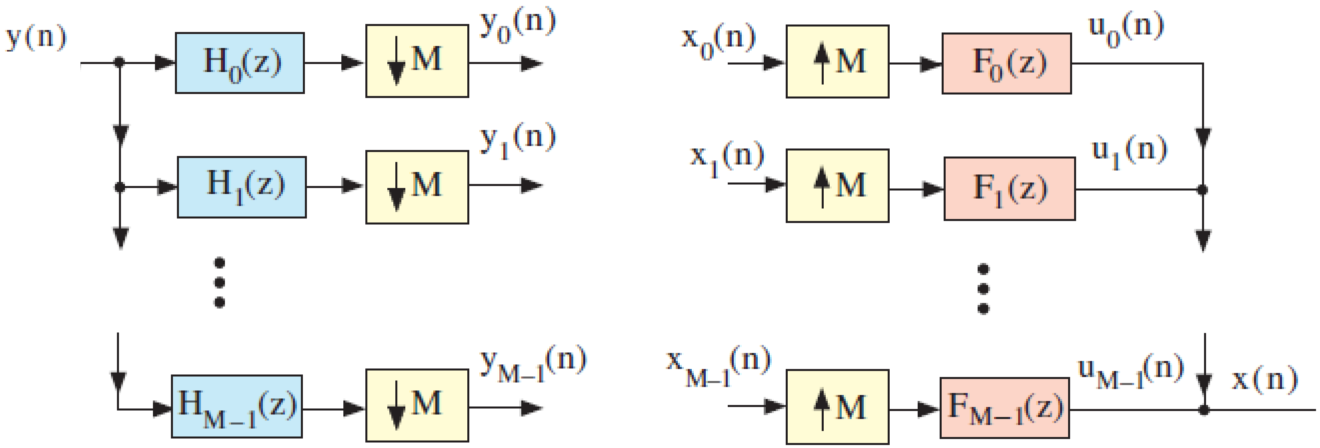
- $H_1(\omega)$ is a band-stop/LP filter and $H_2(\omega)$ is a band-pass/HP filter

Tradeoffs

- Steeper the filter responses, lesser is the oversampling ratio $\frac{L}{M}$
- Effective data rate increases are then lower
- Steep responses means filters impulse response is larger
  - More computations at GHz frequency range
- Problem is that the filters have a complex impulse response

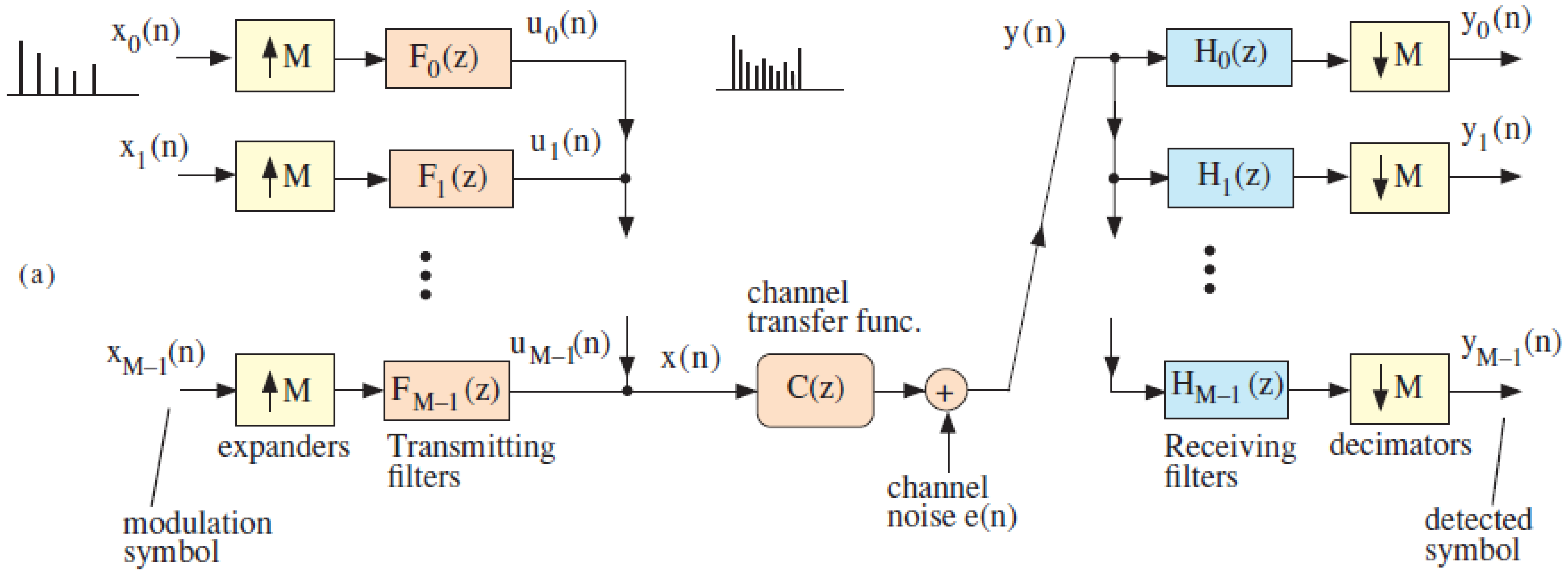
Perfect Reconstruction Filter Banks

- M-Channel Uniform Filter Bank
- Used in Sub-band coding



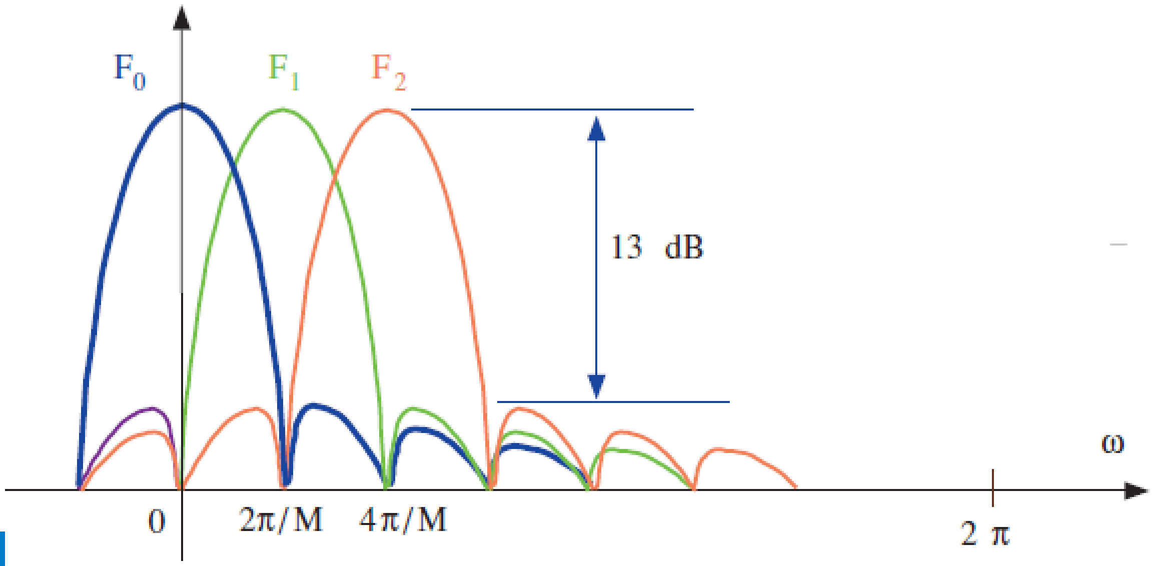
DMT System- ADSL

- Biorthogonal Filter Bank



Filter Impulse Response

- Frequency Response of the filters
- Filters in the notch region
- Do not transmit in those channels



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2M Channel Filters

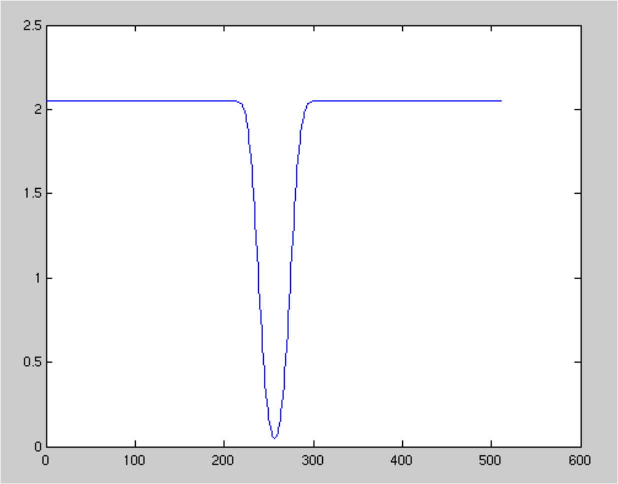
- Start with a prototype filter $p_0(n)$

- Analysis filters $h_k(n)$, $h'_k(n)$ and synthesis filters $f_k(n)$, $f'_k(n)$

$$
\begin{aligned}
h_k(n) &= \sqrt{2}p_0(n)\cos\left(\frac{\pi}{M}kn\right), \quad k = 0 \text{ or } M, \\
h_k(n) &= 2p_0(n)\cos\left(\frac{\pi}{M}kn\right), \quad k = 1, \ldots, M-1, \\
h'_k(n) &= 2p_0(n-M)\sin\left(\frac{\pi}{M}k(n-M)\right), \\
& \qquad k = 1, \ldots, M-1, \\
f_k(n) &= h_k(N+M-n), \quad k = 0, \ldots, M, \\
f'_k(n) &= h'_k(N+M-n), \quad k = 1, \ldots, M-1.
\end{aligned}
$$

Choice of parameters

- M chosen so that suppression of one channel leads to a channel which matches the ONFI-4 notch



Prototype filter design

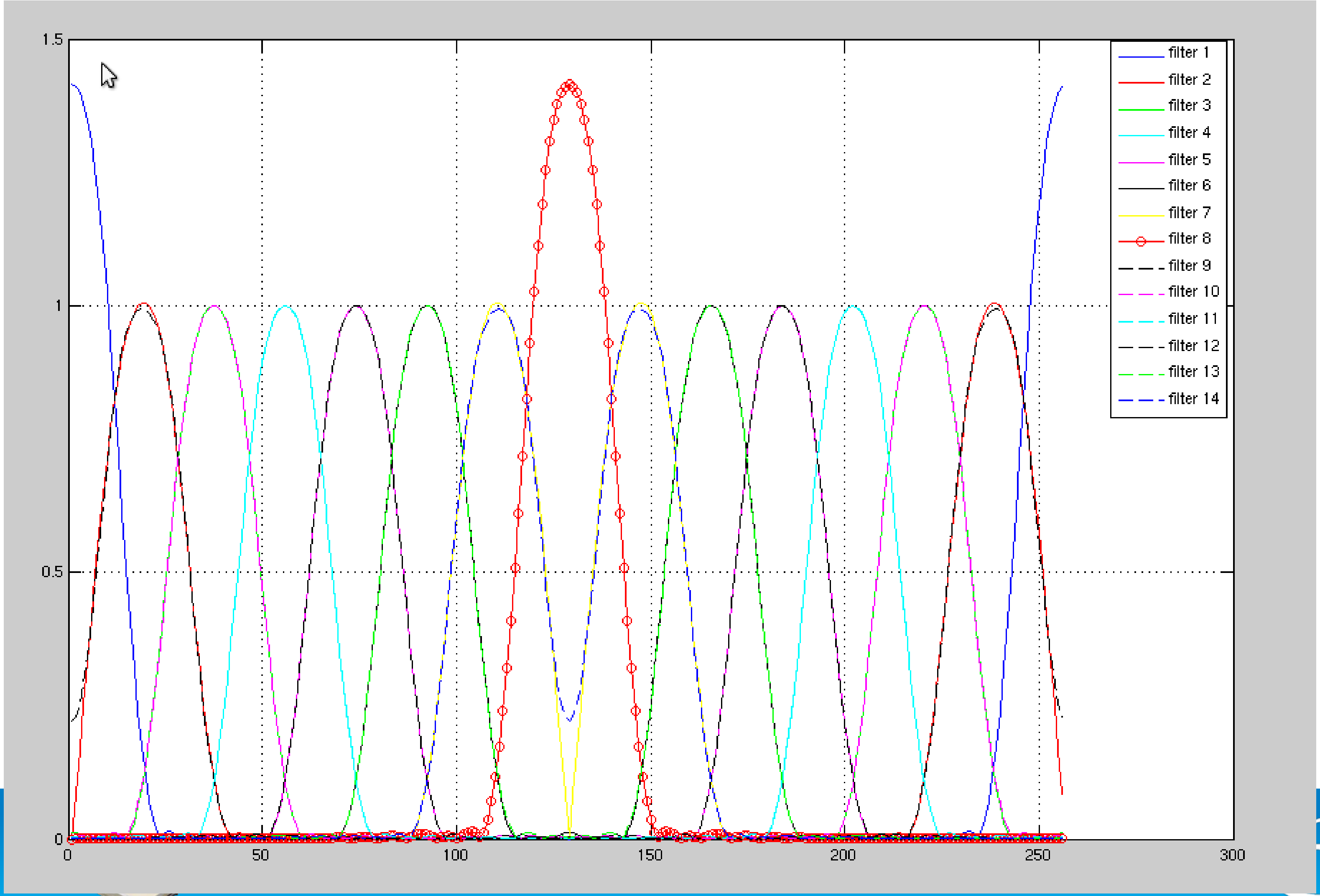
- Linear Phase Cosine Modulated Maximally Decimated Filter Banks with Perfect Reconstruction- Yuan-Pei Lin, P. P. Vaidyanathan

- Prototype filter-
- $h(n) =$

  1e-2 $[0\ \ 0\ \ 0\ \ 0\ 1.87\ \ 3.57\ \ 5.69\ \ 7.85\ 9.54\ \ 10.52\ \ 10.95]$

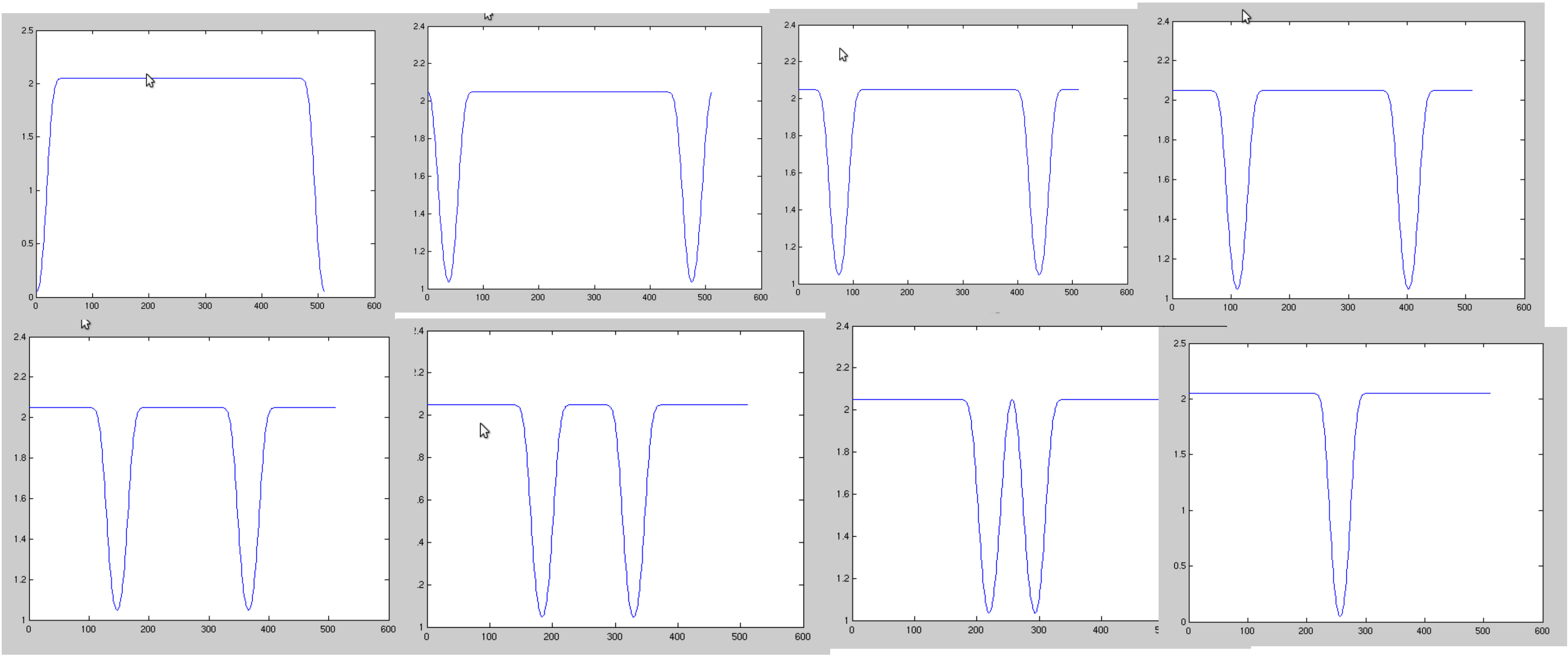
2M Channel Filter Bank

- M=7, Cosine Modulated Filter Bank responses



Zero-out one channel

- If input to one channel is suppressed-



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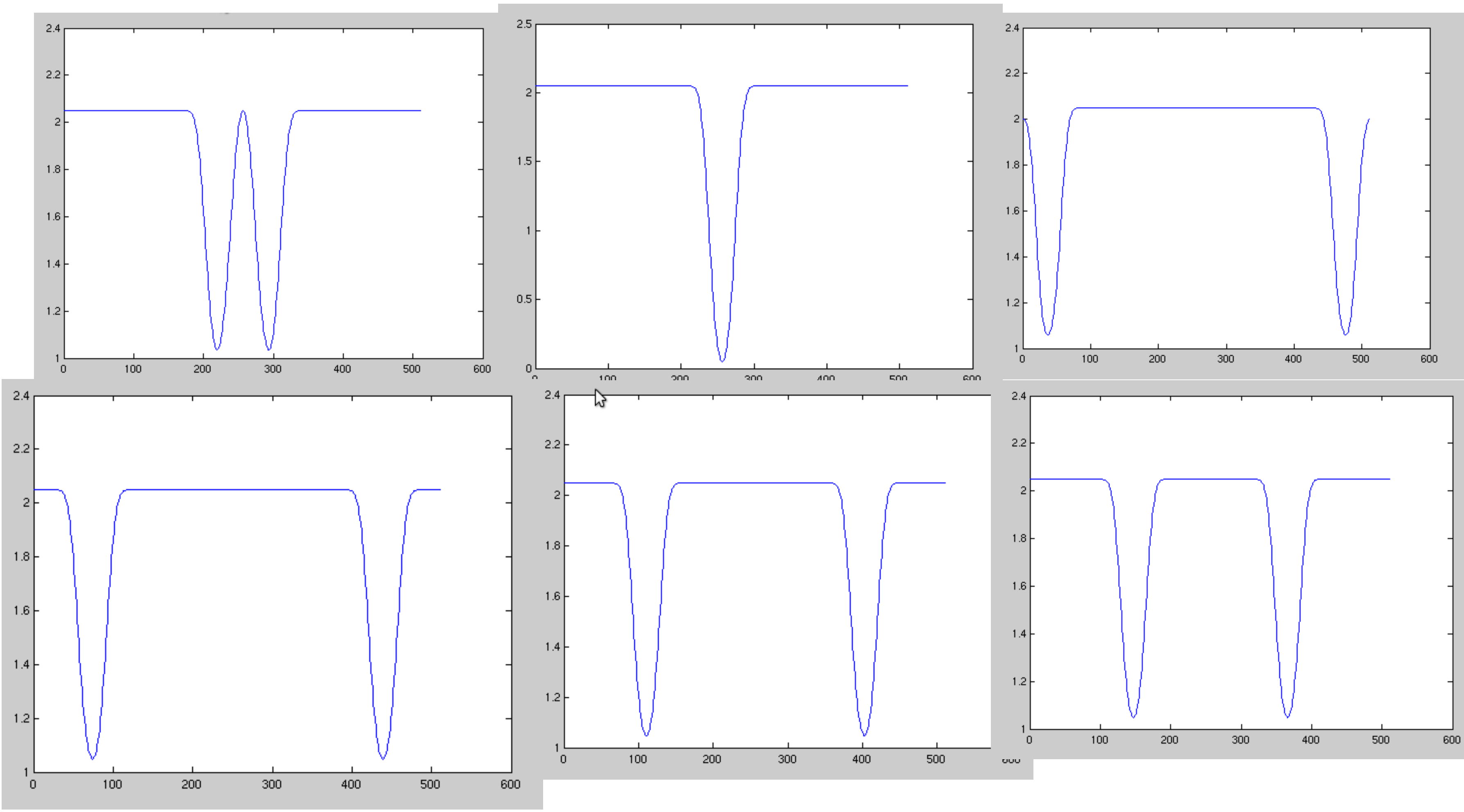
Conclusion

- Choose M such that suppression of one or more channels leads a channel which resembles the notch

- Transmit the signal over the filter bank suppressing the input to the singled out input

- Transmission over the ONFI-4 channel does not lead to loss of information

Suppression of one input



Suppression of one input