Picture Coding Symposium 2004

Inter-Resolution Transform for Spatially Scalable Video Coding

Markus Flierl and Pierre Vandergheynst
Signal Processing Institute
Swiss Federal Institute of Technology, Lausanne

Motivation

- Spatially Scalable Representations
  - *Critically sampled spatial wavelet schemes*
  - *Overcomplete spatial representations*

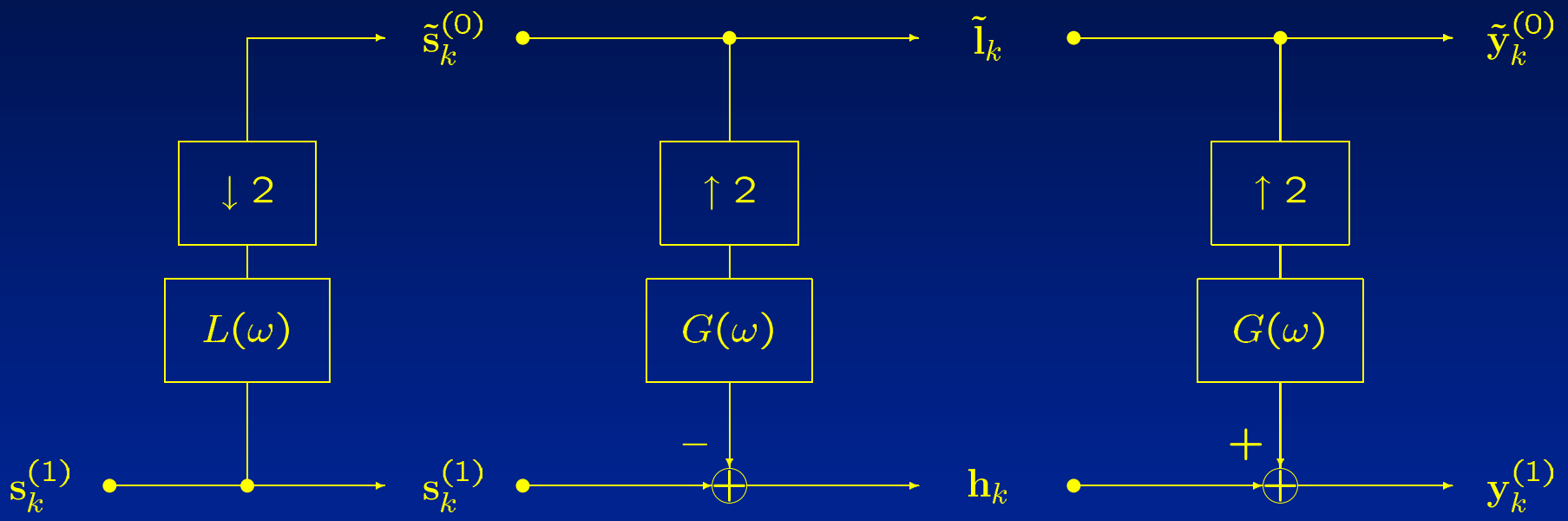
- Critically sampled spatial wavelet schemes
  - *Critically sampled high-bands are shift-variant*
  - *Efficient motion compensation is challenging*

- Overcomplete spatial representations
  - *Can be shift-invariant for all subbands*
  - *Efficient motion compensation*
  - *Problem: Compression efficiency*

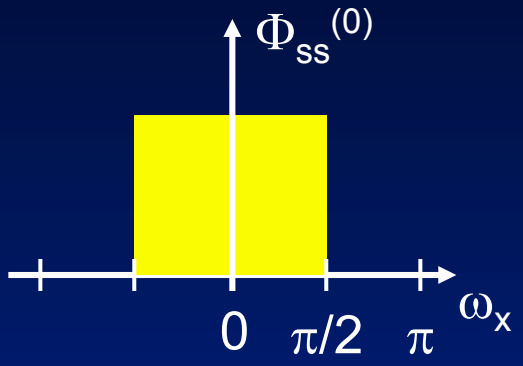
Outline

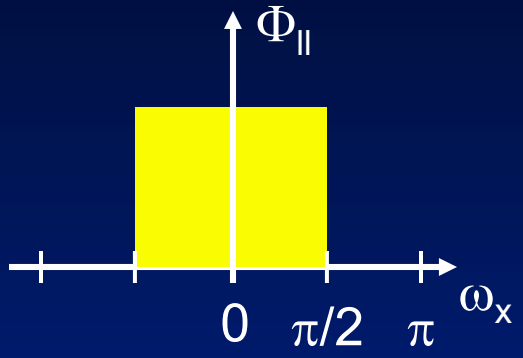
- The Laplacian pyramid
- What is the problem with this overcomplete representation?
- Additional spatial lifting steps
- Related work
- Experiments
- Experimental results

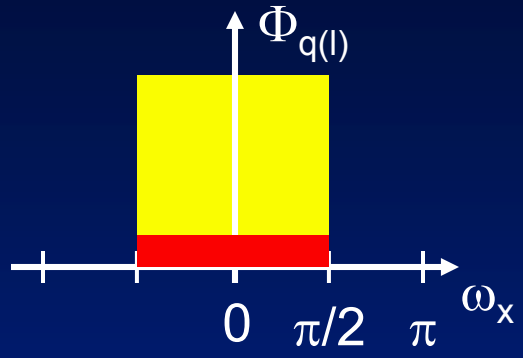
Laplacian Pyramid I

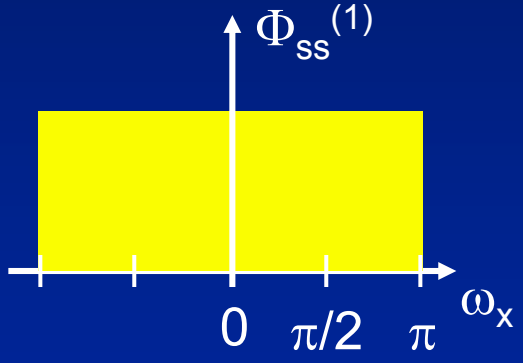


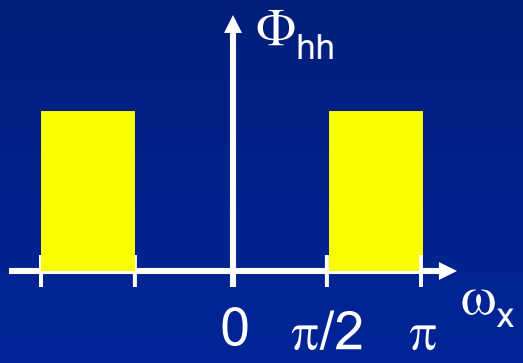
Laplacian Pyramid II



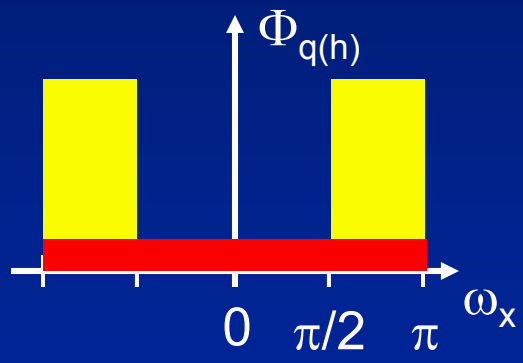






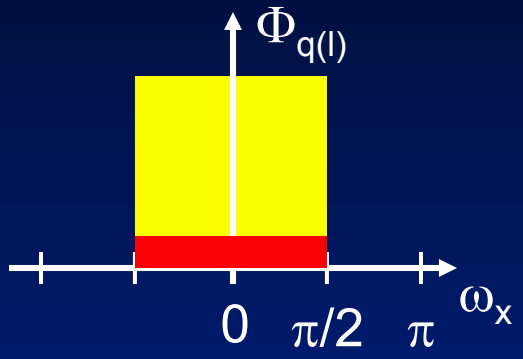


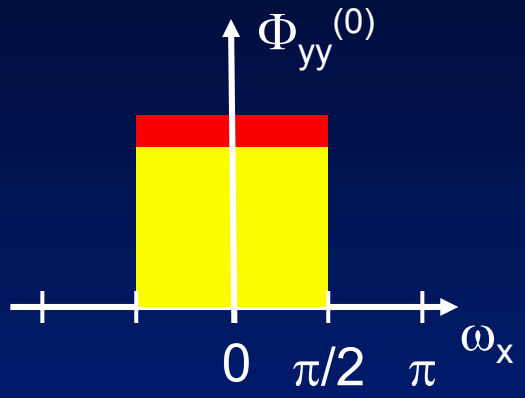
Quantization noise

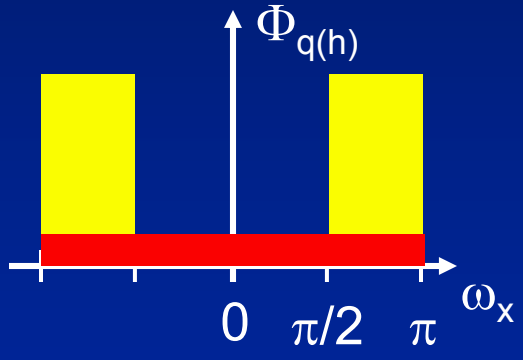


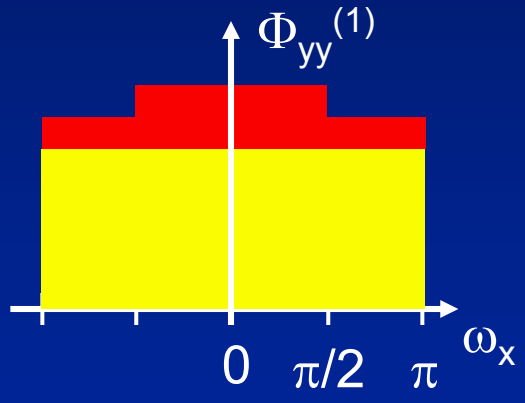
G(ω) is an ideal low-pass

Laplacian Pyramid III









Low-frequent quantization noise in high-band degrades reconstruction

How to Fix this Problem?

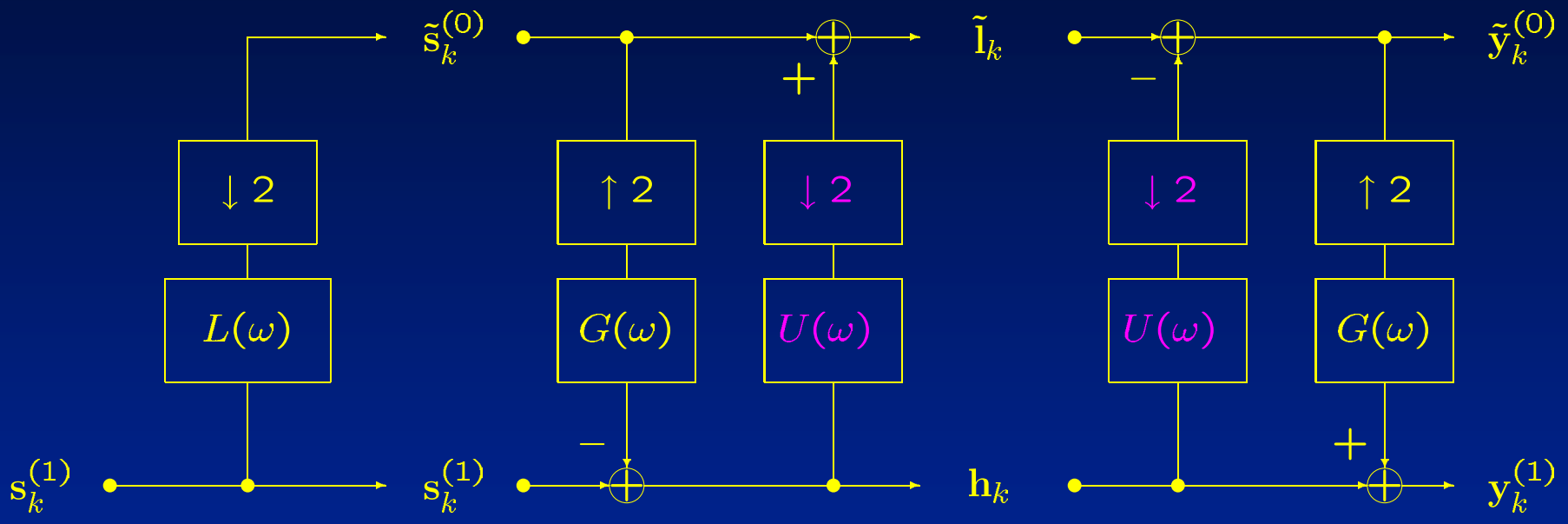
- Goal:

  Minimize the impact of the low- and high-band quantization noise on the reconstructed images

- Improve the decoder by an additional “lifting” step

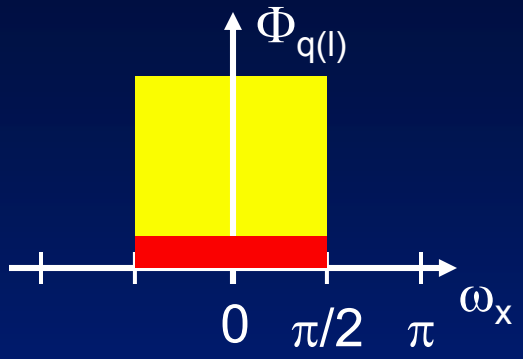
- Complement the encoder to permit perfect reconstruction in the noiseless case

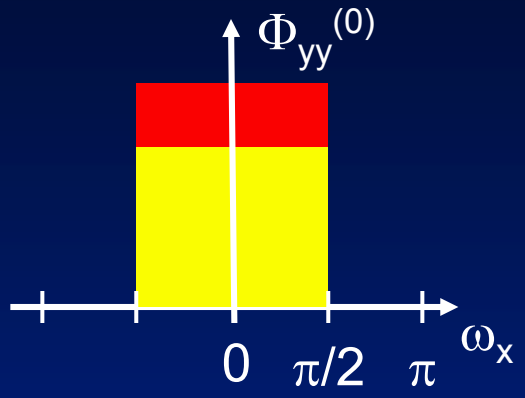
Additional Spatial Lifting Step I

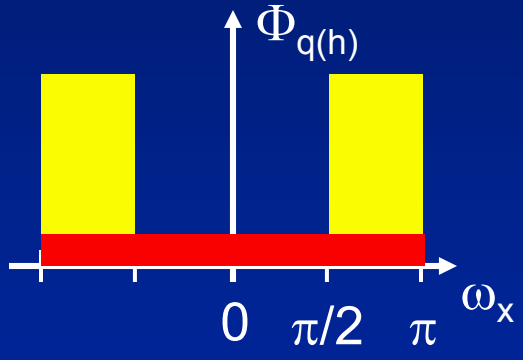


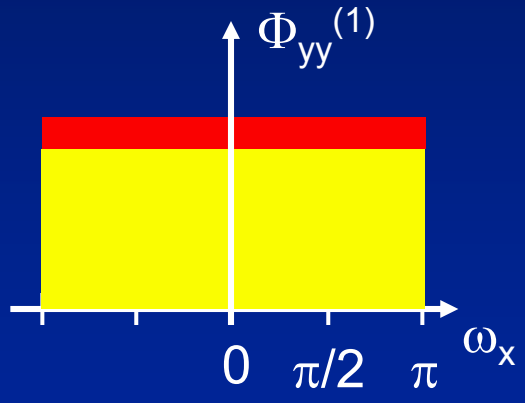
- Perfect reconstruction achievable for any pair of low-pass filters G(ω) and U(ω)

Additional Spatial Lifting Step II





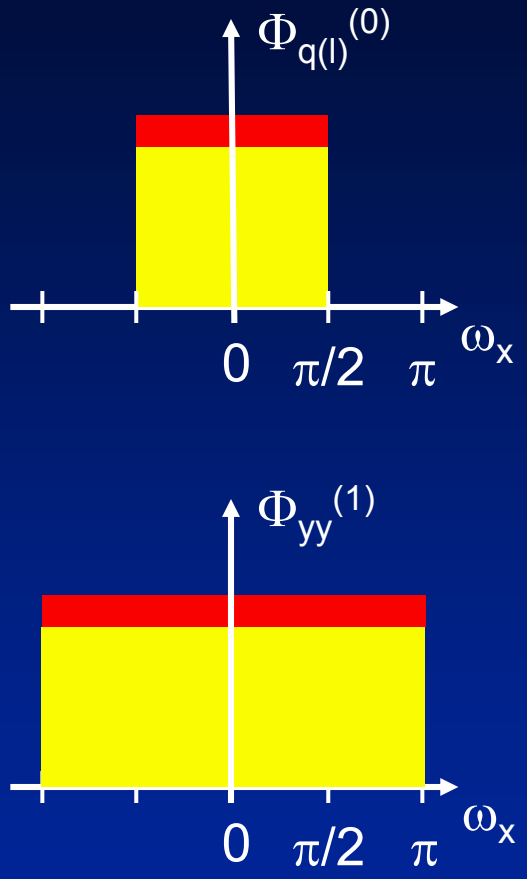




U(ω) and G(ω) are orthogonal for low frequencies

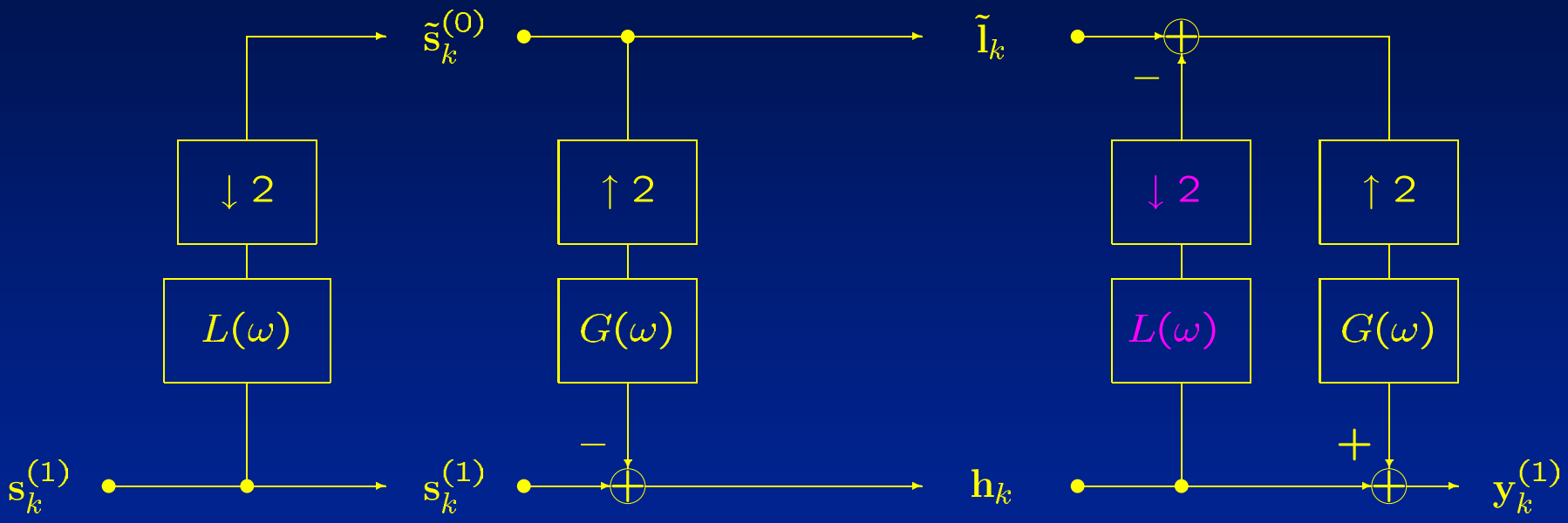
Additional Spatial Lifting Step III

- We select the low-band to represent the signal of lower resolution
- This avoids additional quantization noise
- For the signal of higher resolution, perfect reconstruction is possible in the noiseless case



Related Work

- "Framing Pyramids" [Do & Vetterli, 2003] propose only a reconstruction scheme for the Laplacian pyramid.

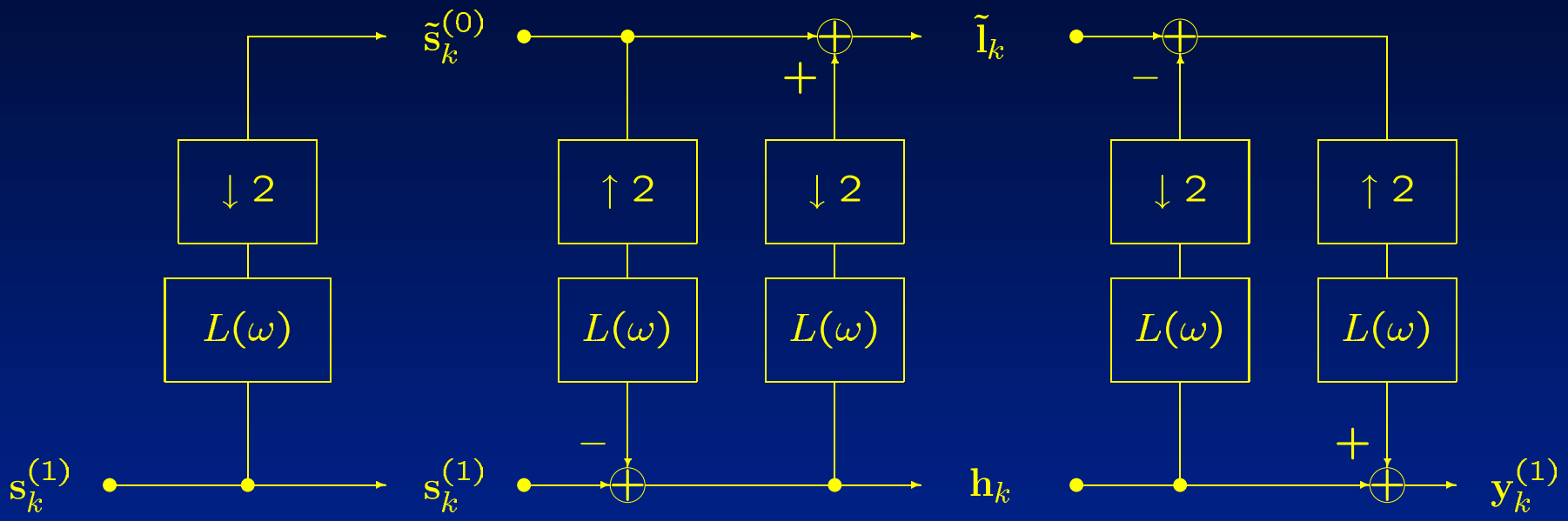


- Reconstruction is the pseudo inverse if L(ω) and G(ω) are orthogonal with respect to the sampling factor 2.

Experiments

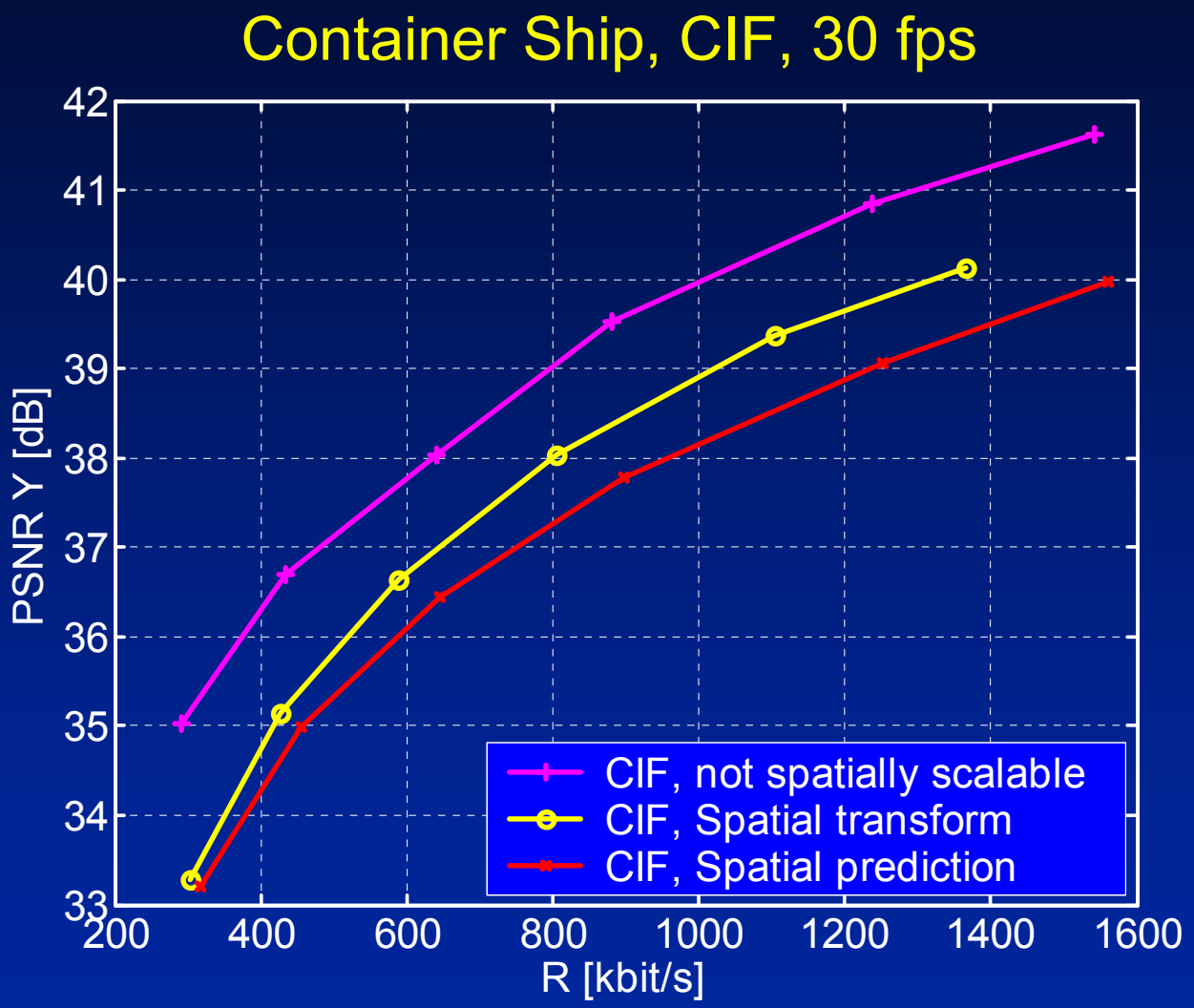
- Coding scheme:
  - *QCIF and CIF pictures are spatially decomposed*
  - *Spatial subbands are coded with motion-compensated temporal wavelet transforms [MCTF extension of H.263++, Flierl & Girod, PCS 2003]*
  - *Decoded low-band represents the spatial base layer in QCIF resolution*
  - *Decoded low- and high-band reconstruct the spatially scalable CIF resolution*
- Experiments:
  - *Motion-compensated Haar and 5/3 kernel*
  - *GOPs of 32 pictures*
  - *Neither temporal nor SNR scalability is used*

Coding Scheme



- Low-band pictures l_k represent the image sequence of lower resolution
- The low-pass filter $L(\omega)$ is symmetric

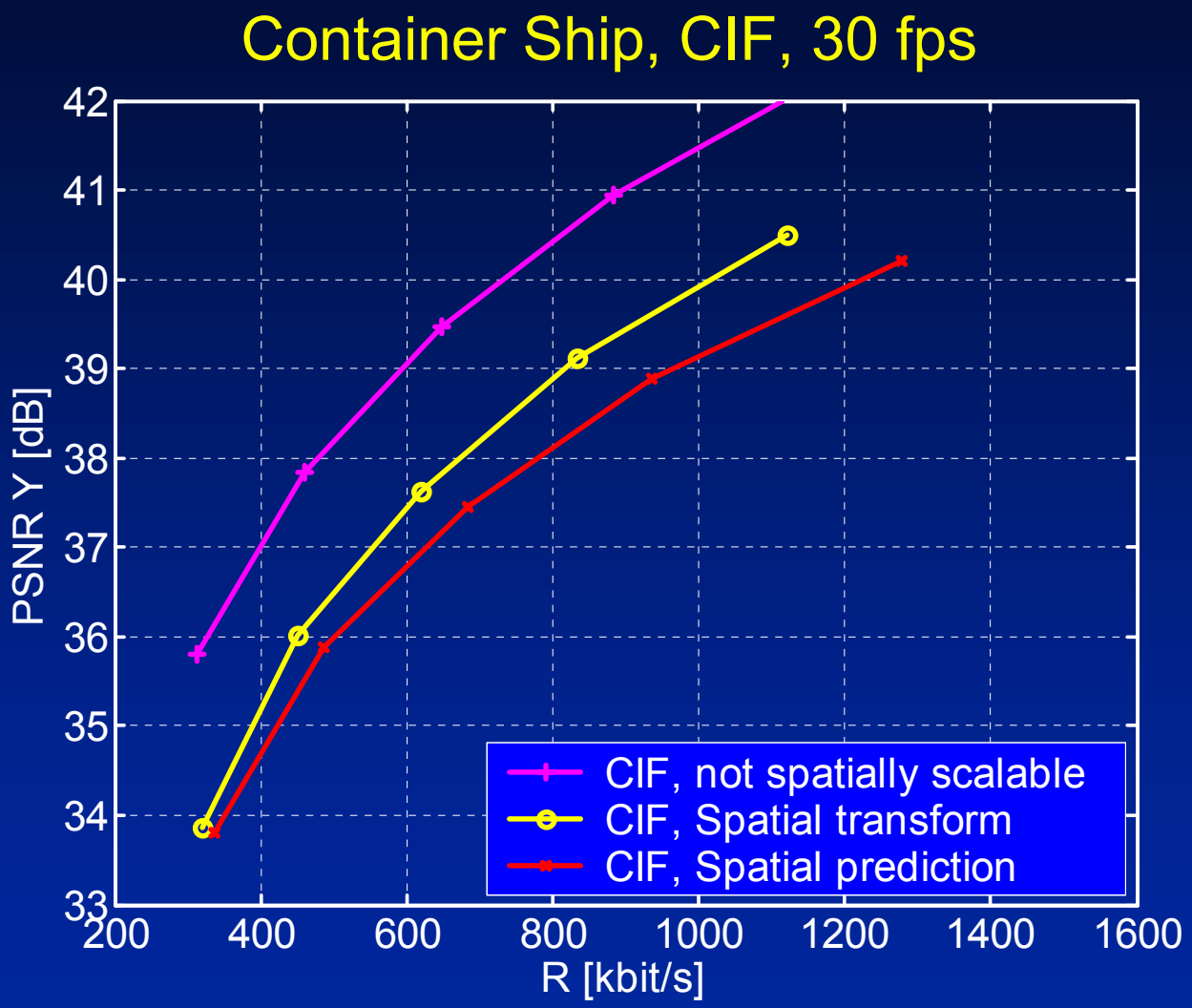
Rate-Distortion Performance for High Resolution



Motion-compensated Haar kernel

GOP=32

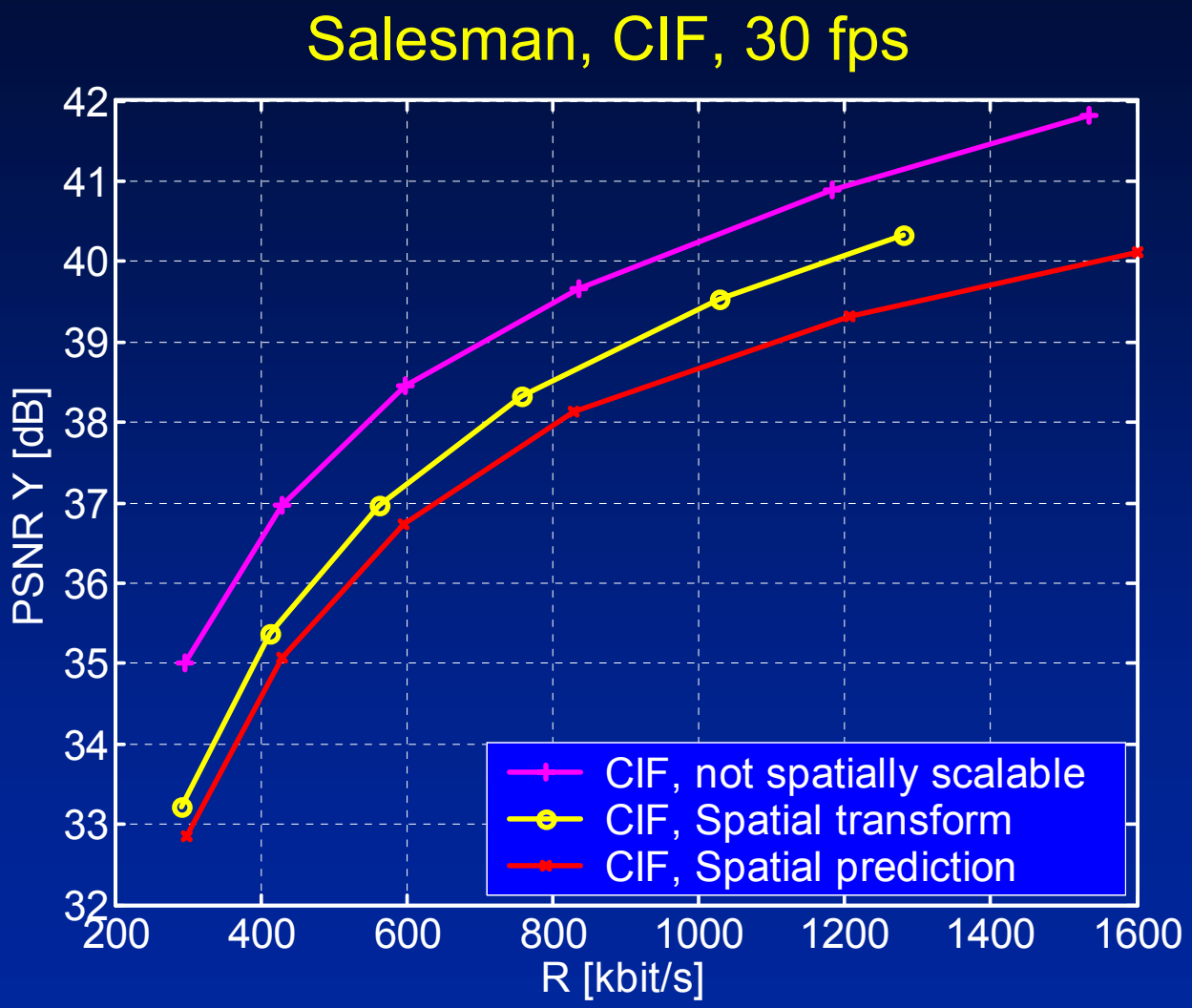
Rate-Distortion Performance for High Resolution



Motion-compensated 5/3 kernel

GOP=32

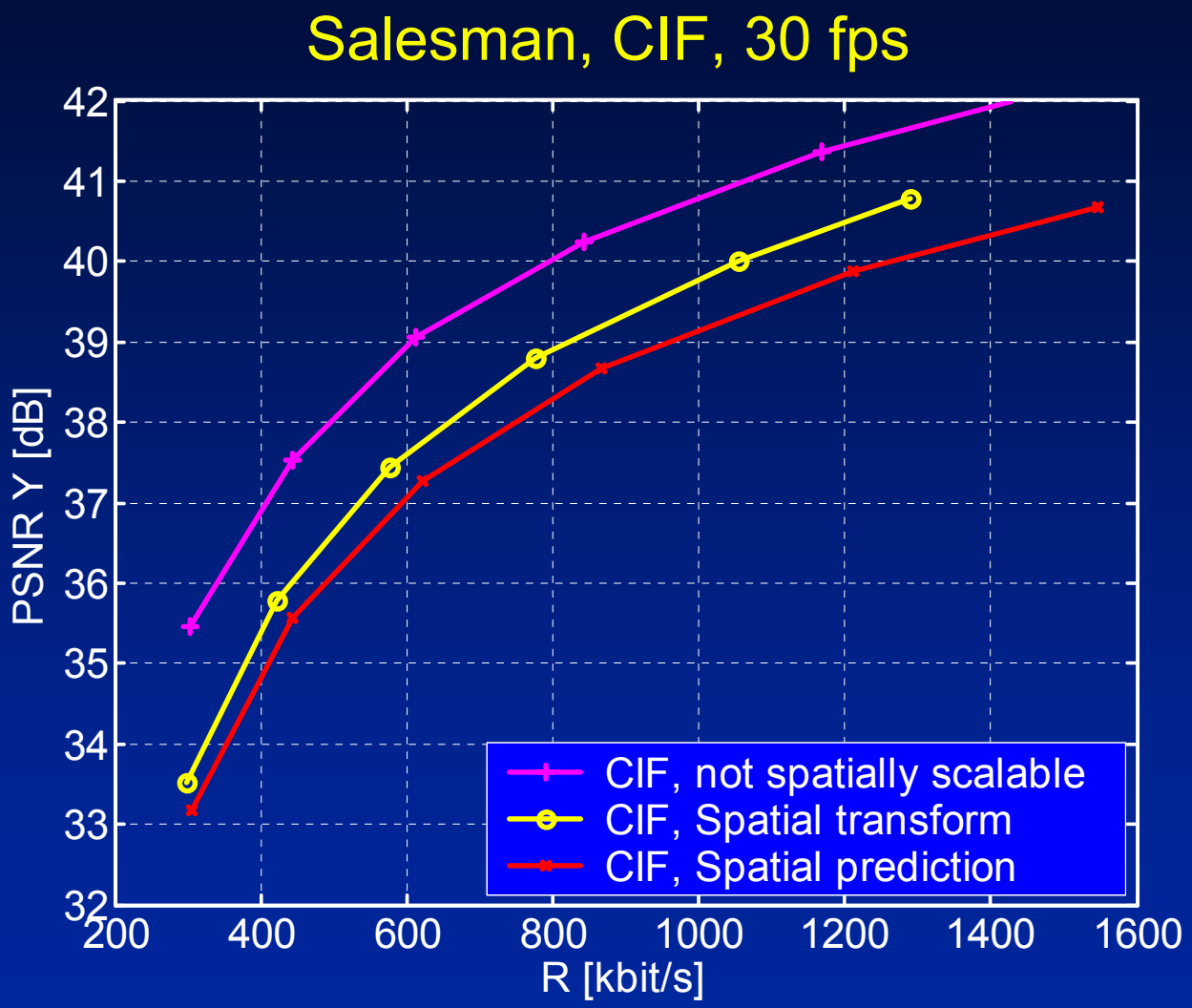
Rate-Distortion Performance for High Resolution



Motion-compensated Haar kernel

GOP=32

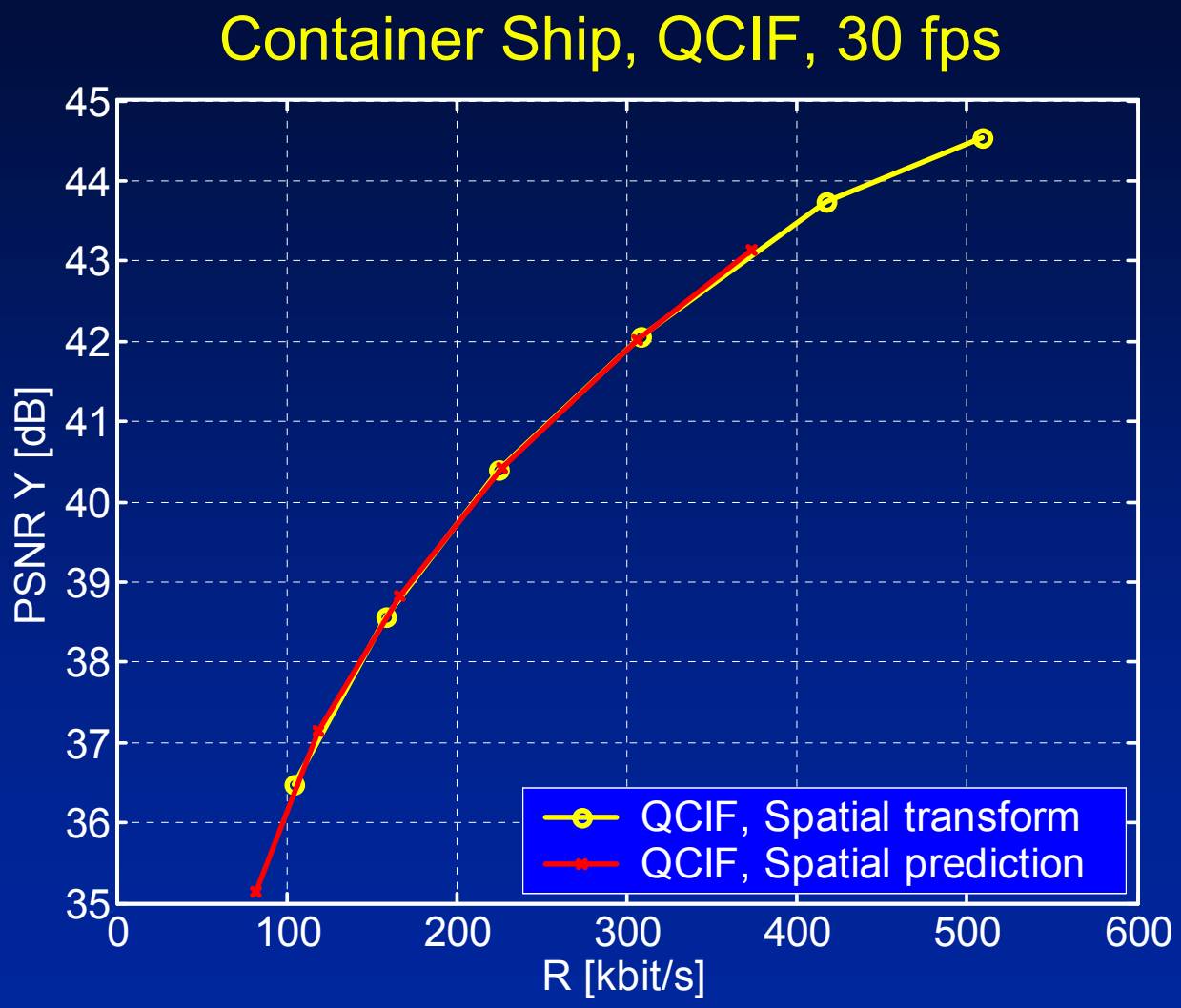
Rate-Distortion Performance for High Resolution



Motion-compensated 5/3 kernel

GOP=32

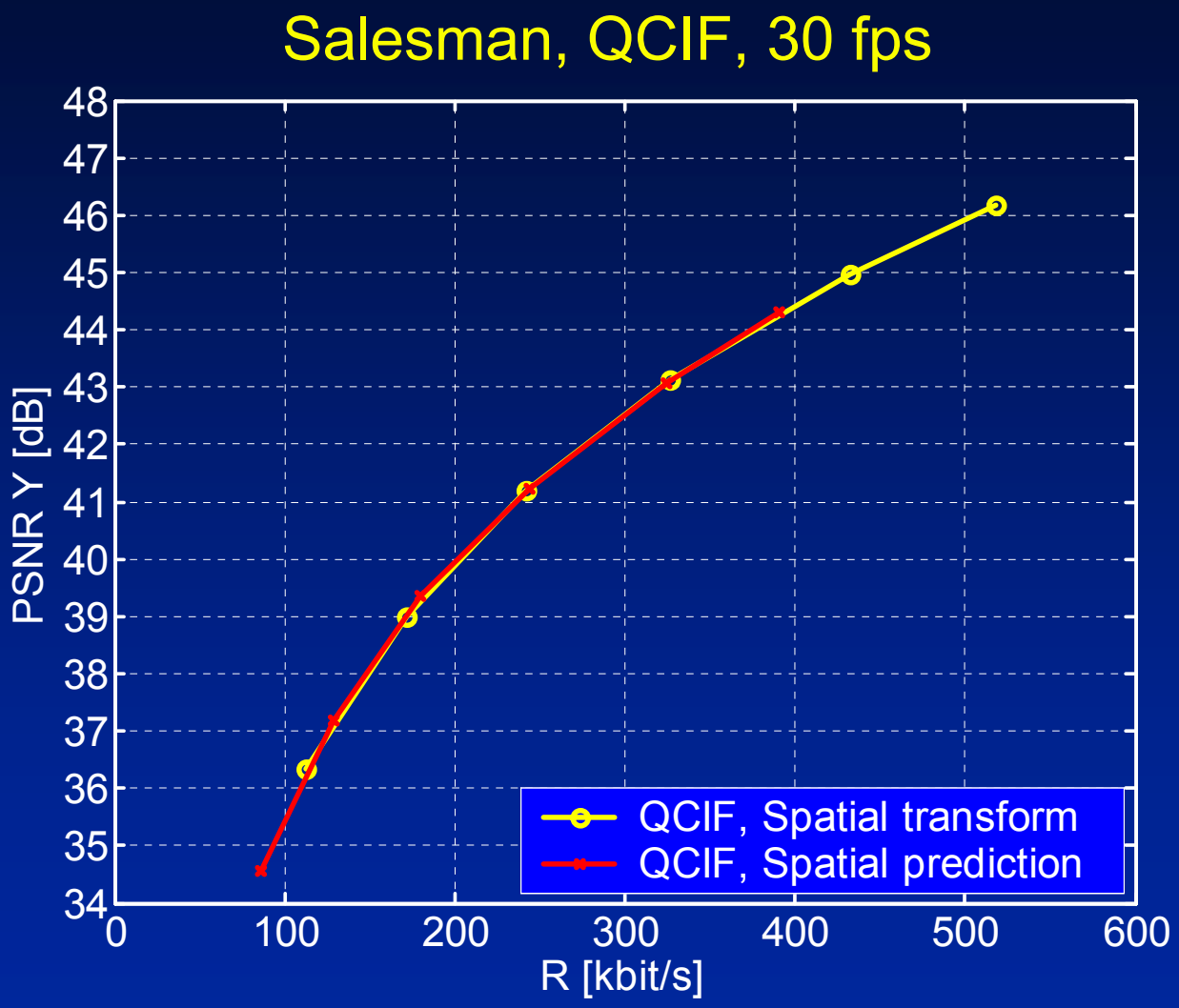
Rate-Distortion Performance for Low Resolution



Motion-compensated Haar kernel

GOP=32

Rate-Distortion Performance for Low Resolution



Motion-compensated Haar kernel

GOP=32

Conclusions

- Discussed a problem of the Laplacian pyramid
- Impact of the low- and high-band quantization noise on the reconstructed images
- Proposed an inter-resolution decomposition and composition with the following advantages:
  - *Quantization noise is handled efficiently at the decoder*
  - *"Lifting" scheme permits perfect reconstruction in the noiseless case*
  - *Perfect reconstruction even without orthogonal filters*
  - *Improved coding gain over Laplacian pyramid*