

A Technical Overview of MFC

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Summary

Overviews the technical details of multi-resolution frame compatible (MFC) coding solution

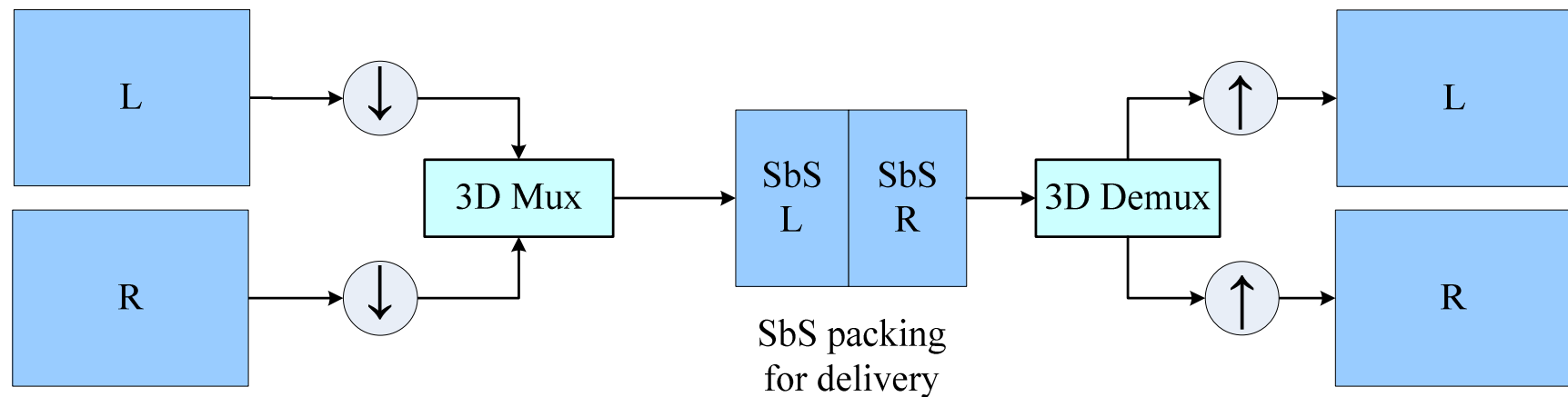
- Reconstructs full resolution stereo 3D video while maintaining backwards compatibility with FC
- Achieves significant picture quality improvement over the FC anchors even with a low overhead (e.g., ~25% of FC bitrate)
- Built upon MVC Stereo High Profile of AVC
- Requires very simple syntax changes at high level
- Marginal increase of complexity c.f MVC decoding
- Easy-to-maintain software
- PDAM5 of MVC

Outline

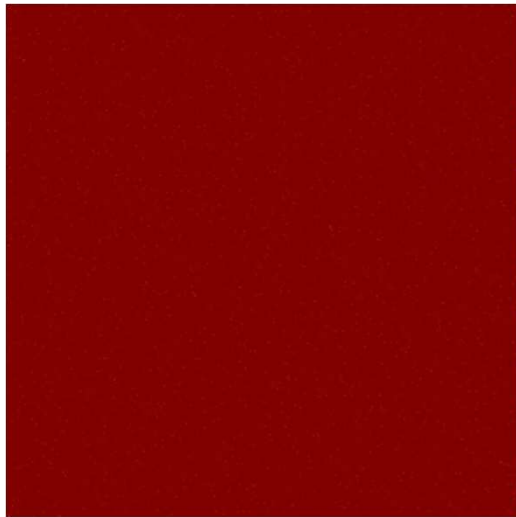
- Introduction
- Algorithm Description
- Compression Performance
- Complexity Analysis
- Software Implementation

Introduction: Multi-resolution Frame Compatible (MFC)

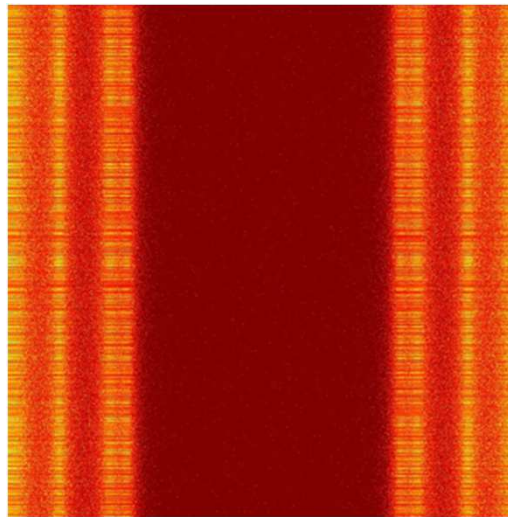
- MFC Goal: scalable extension of FC to full resolution
- Frame Compatible (FC) Delivery
 - Repackage stereo pair into a single frame: Side by Side (SbS), Top and Bottom (TaB), etc.
 - Sacrifice spatial resolution for 3D functionality



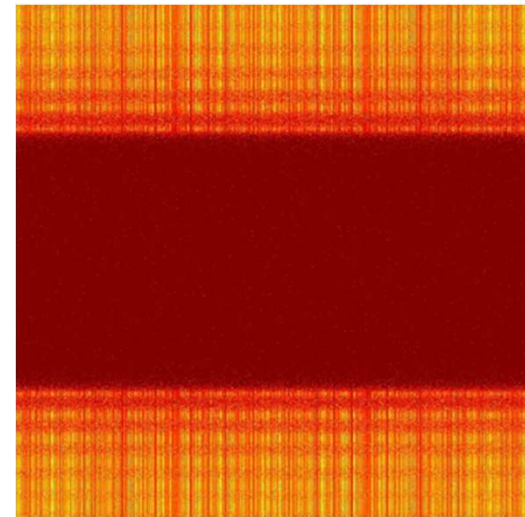
Visualization of FC 3D-muxing in Frequency Domain



original frequency spectrum
(a “flat” spectrum) of white noise



frequency spectrum after
demuxing from SbS-packing



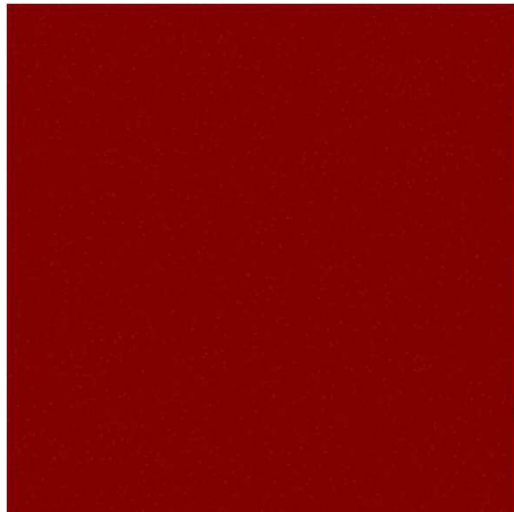
frequency spectrum after
demuxing from TaB-packing

- SbS preserves vertical frequencies
- TaB preserves horizontal frequencies

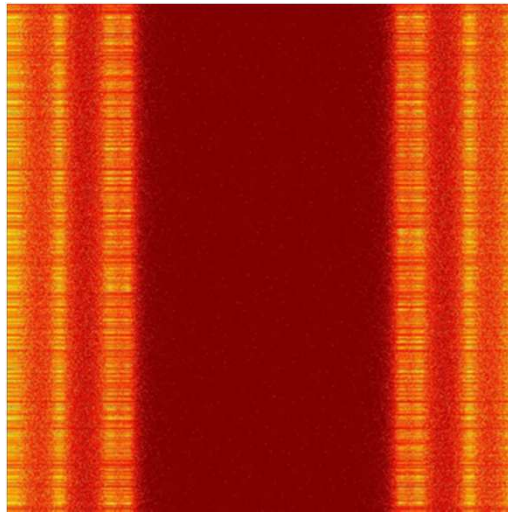
Solution

- Methodology: based on MVC framework
 - Bring back the original spatial resolution by sending the missing information of a picture through an enhancement layer with a relatively low overhead
 - Use only 2 layers: FC 3D base layer + one enhancement layer
 - Base layer (BL) \Rightarrow FC signal, backward compatible with legacy AVC decoder
 - Enhancement layer (EL) \Rightarrow missing high frequencies in the FC signal
 - BL and EL use orthogonal FC formats:
 - BL: SbS (preserve vertical frequencies) \Rightarrow EL: TaB (bring back horizontal high frequencies)
 - BL: TaB (preserve horizontal frequencies) \Rightarrow EL: SbS (bring back vertical high frequencies)
 - Inter-layer reference processed by **Reference Processing Unit (RPU)**
 - Converts BL reference pictures in SbS (/TaB) format to the EL prediction in TaB (/SbS) format
 - Full resolution picture reconstruction
 - Add orthogonal high frequencies in upsampled BL

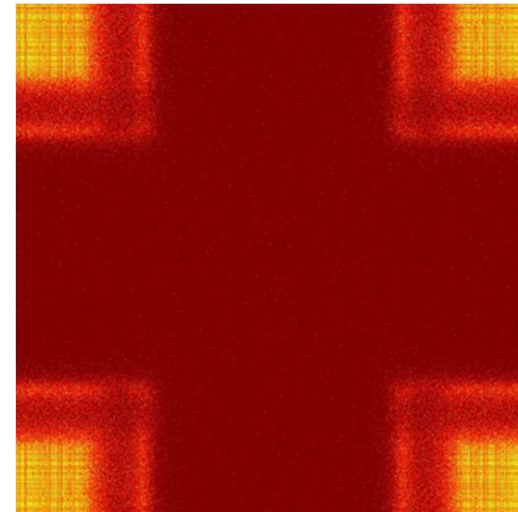
Spectrum Visualization: FC (SbS) vs. MFC in frequency domain



original frequency spectrum
(a “flat” spectrum) of white noise

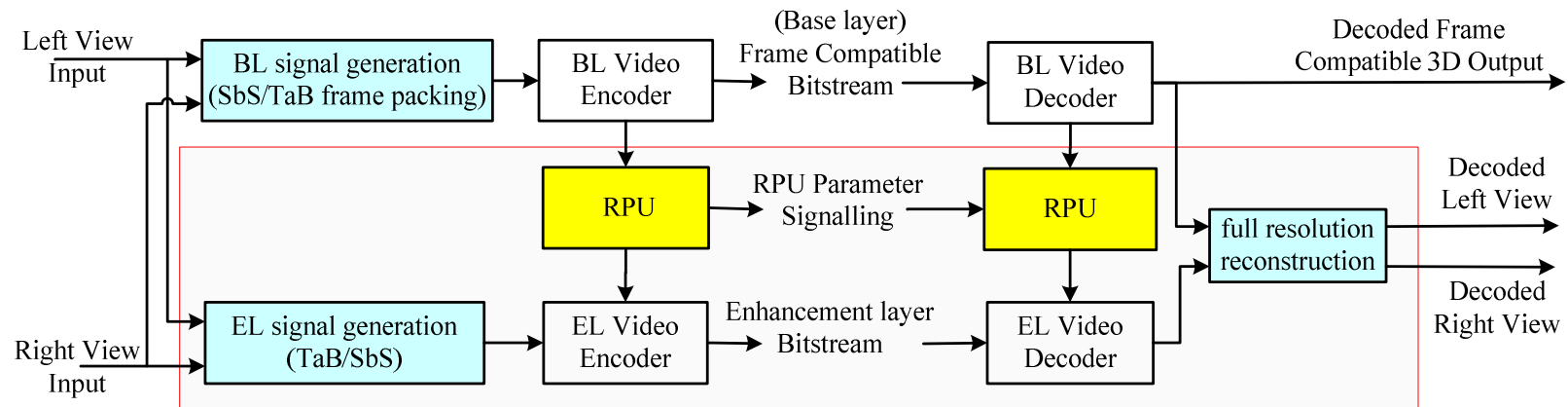


frequency spectrum after
demuxing from SbS-packing

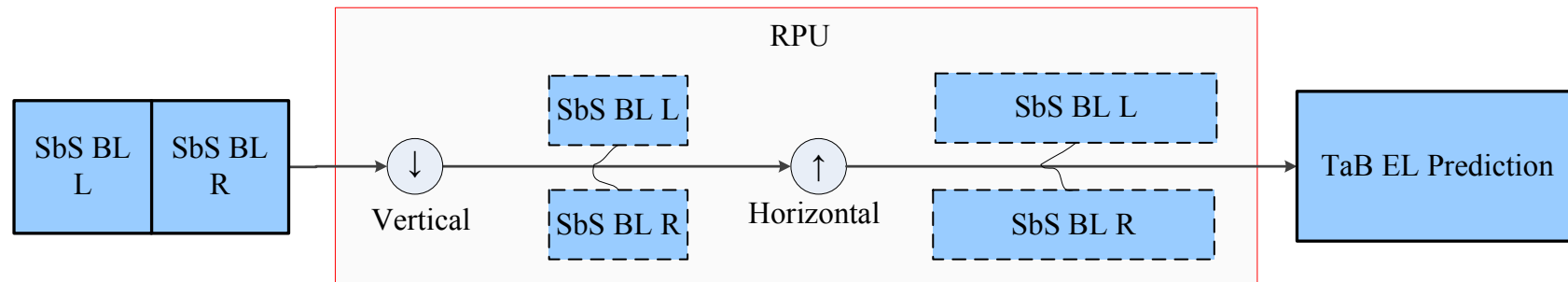


frequency spectrum after
MFC reconstruction

MFC Coding Diagram

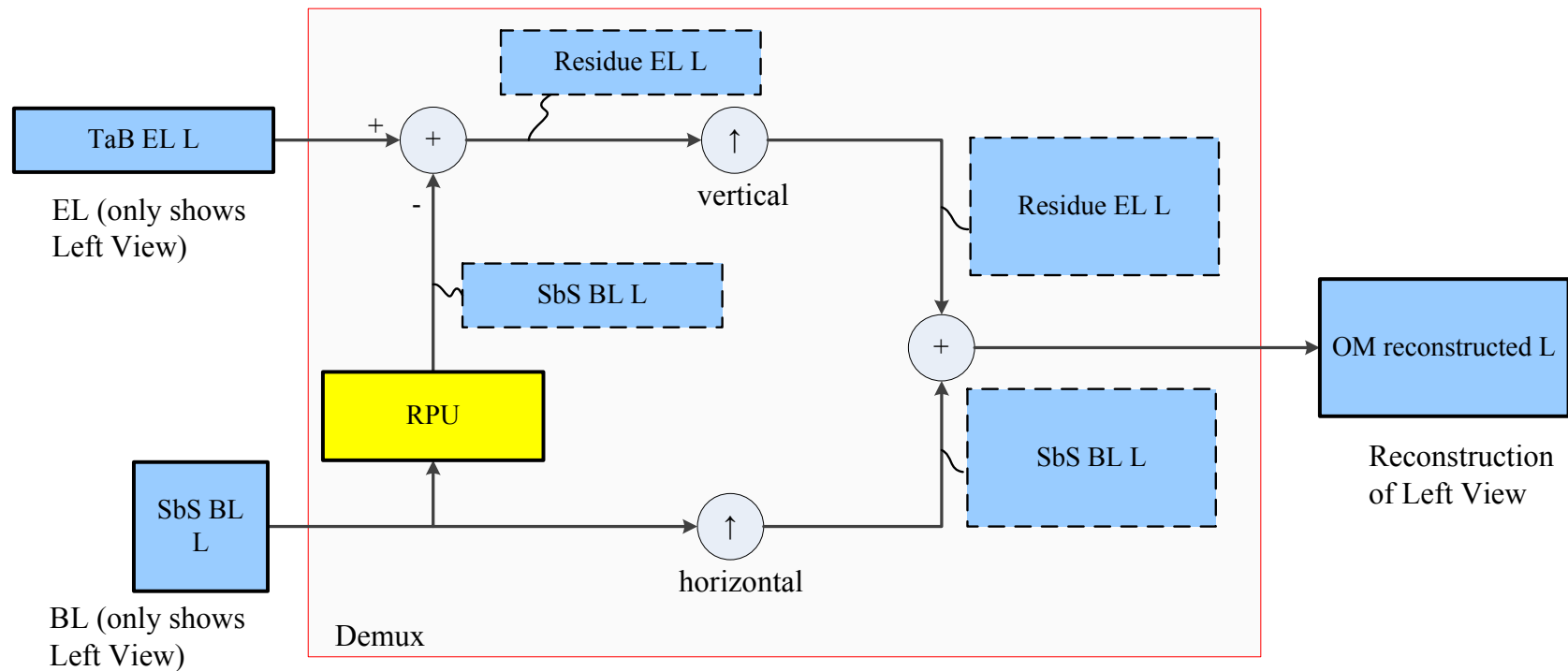


RPU



- Converts BL reference pictures in SbS (/TaB) format to the EL prediction in TaB (/SbS) format
- RPU processing is performed for each view independently

MFC Reconstruction Diagram



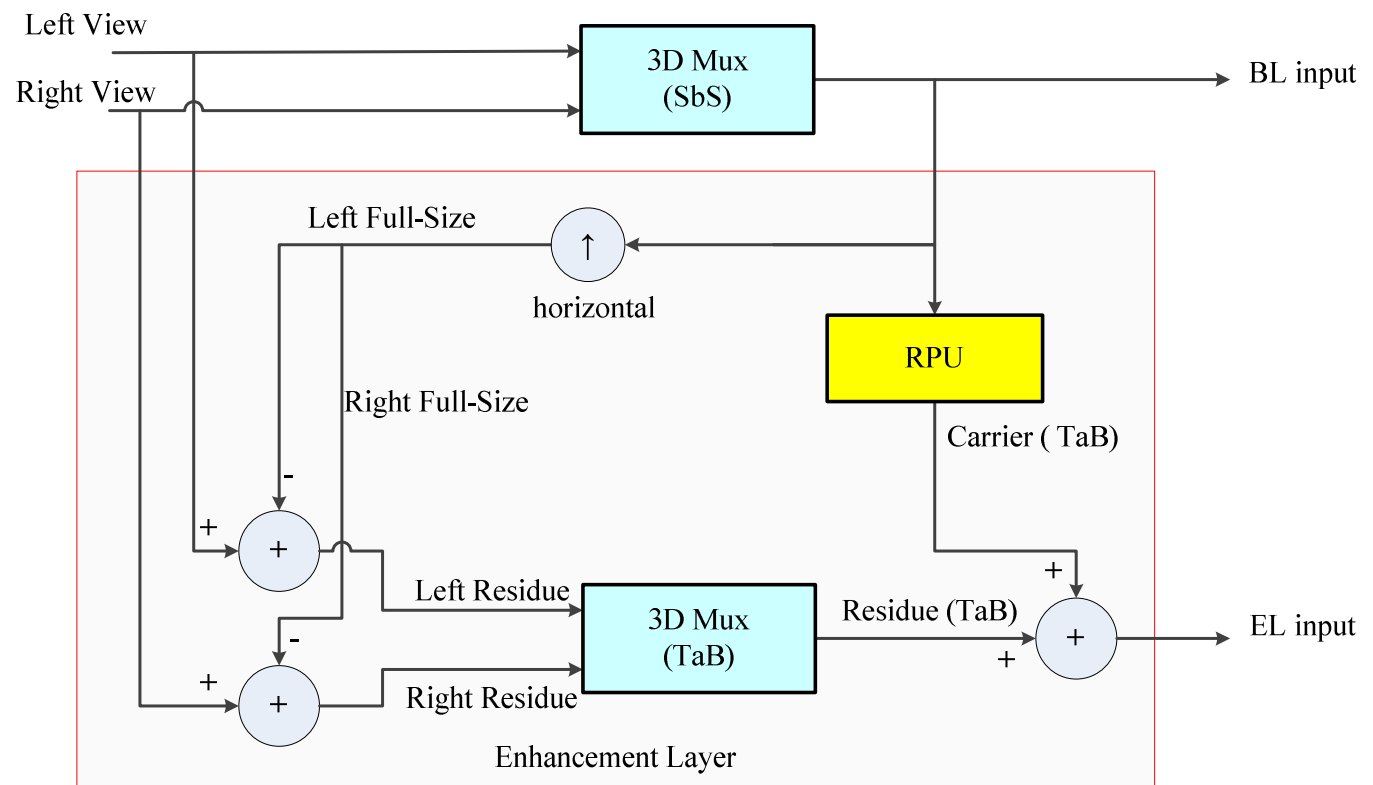
Enhancement Layer Signal Generation

- EL signal contains missing high frequencies lost in BL
- Our approach:
 - EL picture is the differential residue from original FR image and original upsampled BL FC picture.
 - For coding purpose, a carrier image is added to the residue image to generate an EL image.
 - A carrier signal is generated from BL signal using RPU to create an EL input.

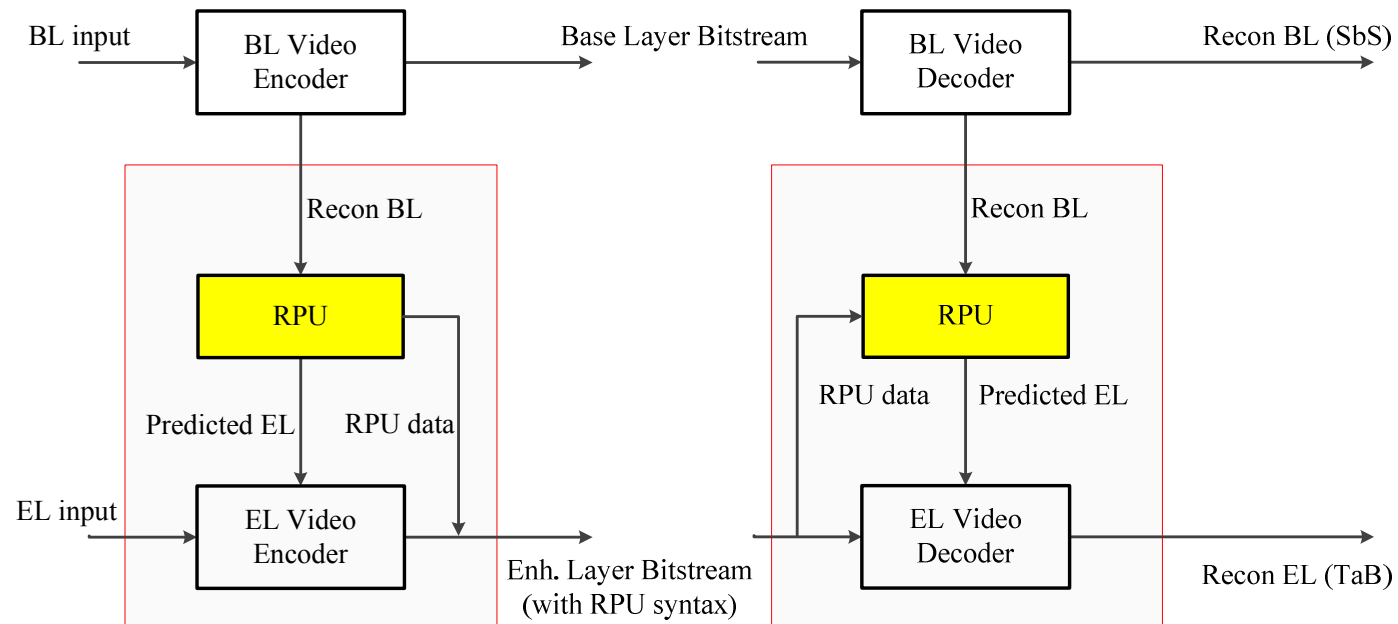
Implementation Details: EL signal generation

- Generation steps :**

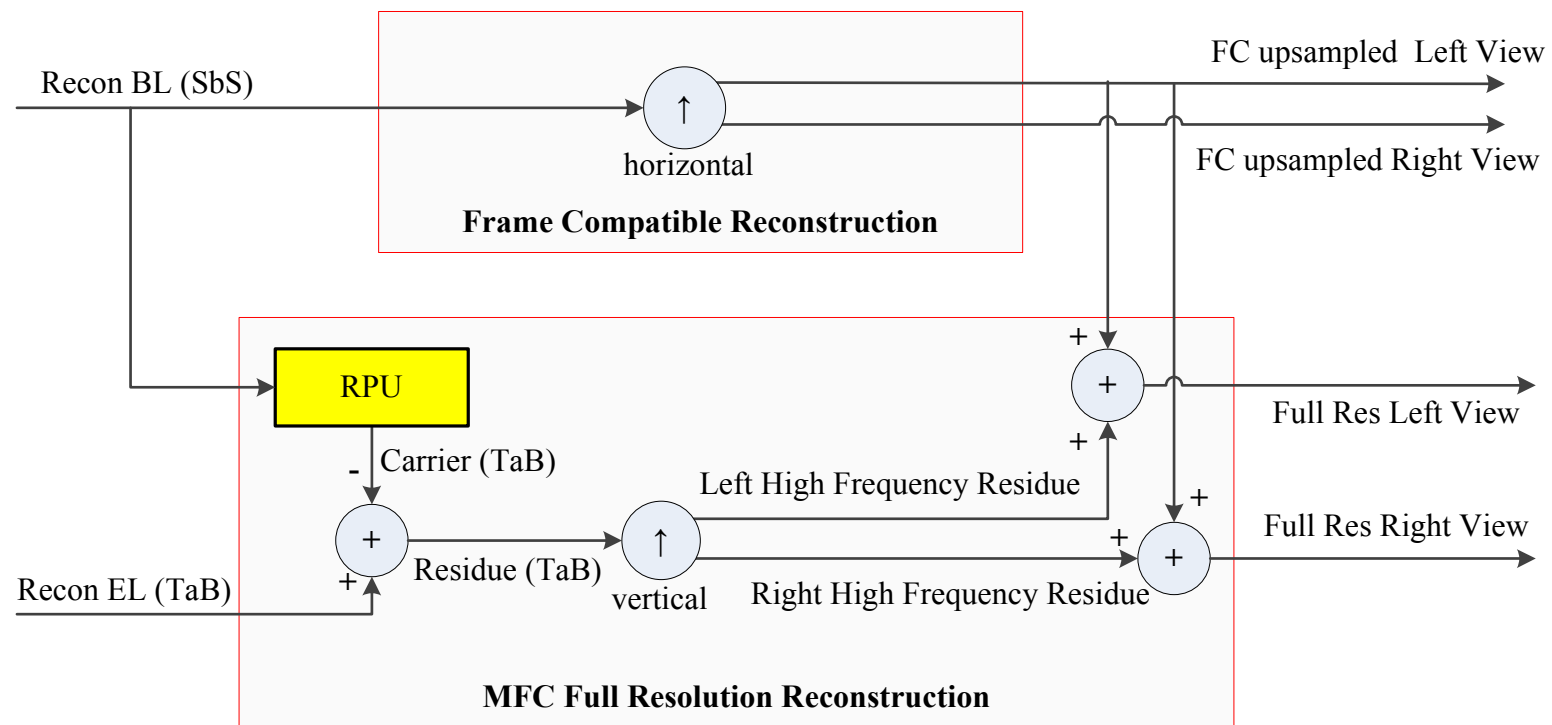
1. Horizontally upsample BL signal to full size;
2. Create full size residue signal by subtracting the original upsampled BL signal from the FR original source
3. Mux full size residue signal into TaB format after vertical downsampling;
4. Generate a TaB carrier signal through RPU by converting original BL SbS signal to TaB;
5. Add the TaB residue signal and the TaB carrier signal to form an EL signal.



Implementation Details: Encoder and Decoder



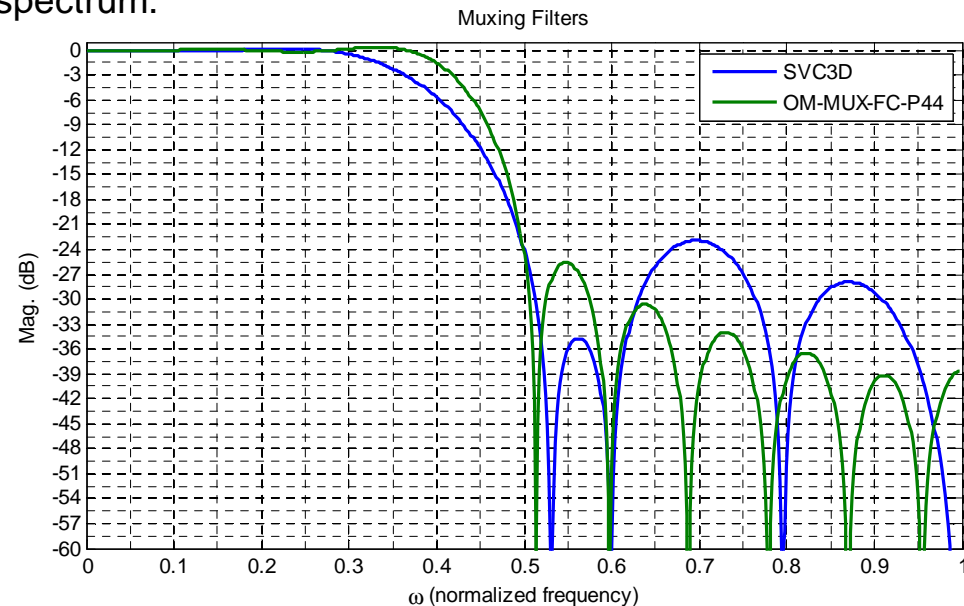
Implementation Details: FR Reconstruction



Filter Design: Muxing Filter (non-normative)

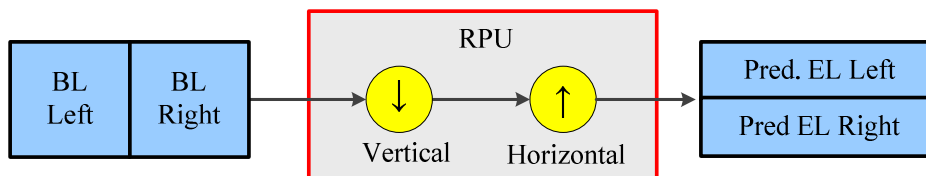
- Filter in muxing (non-normative)
 - Keep as much high frequencies as possible without causing aliasing.
 - For downsampling, a muxing filter is designed to have very flat pass band response and strong attenuation at midpoint of the spectrum.

	Cutoff Freq.
BL: SVC3D (CfP)	0.4
EL: OM_MUX_FC_P44	0.44



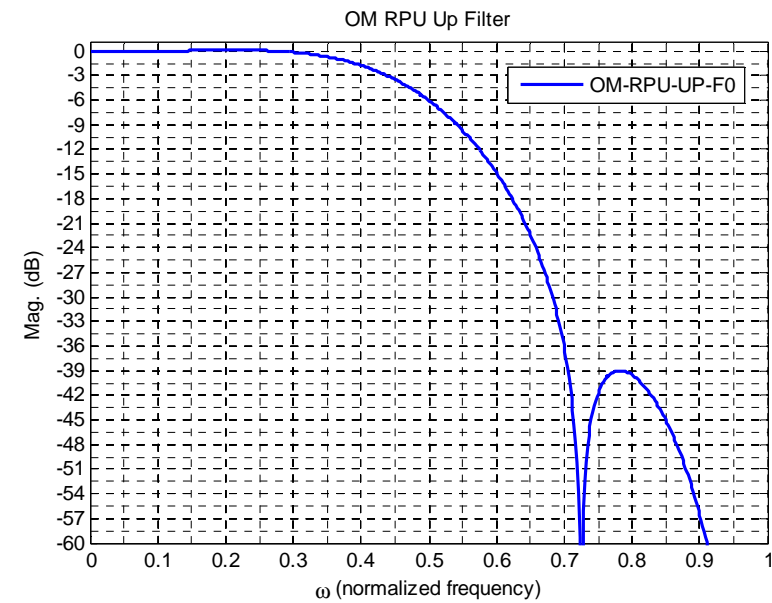
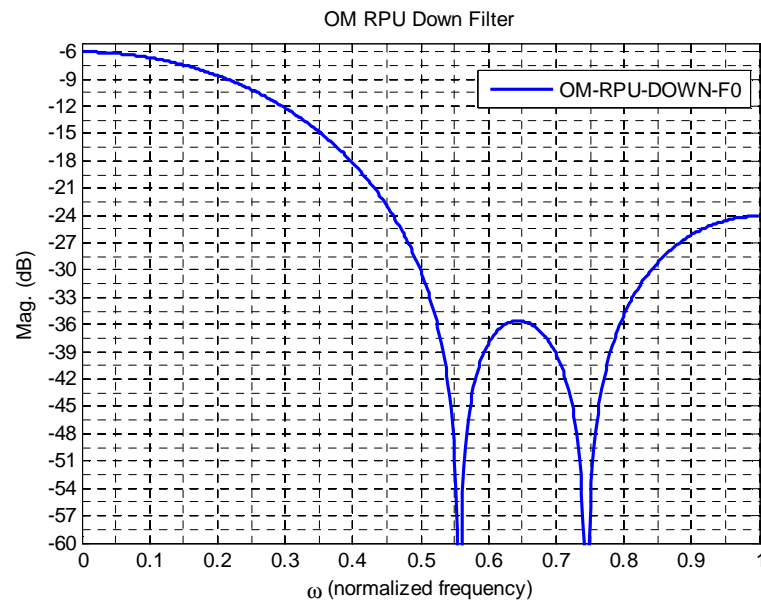
Filter Design: RPU Filters

- RPU filters: 1D downsampling + 1D upsampling
 - (vertical) downsampling: OM_RPU_DOWN_F0
 - (horizontal) upsampling: OM_RPU_UP_F0
 - These filters are normative in the coding loop.



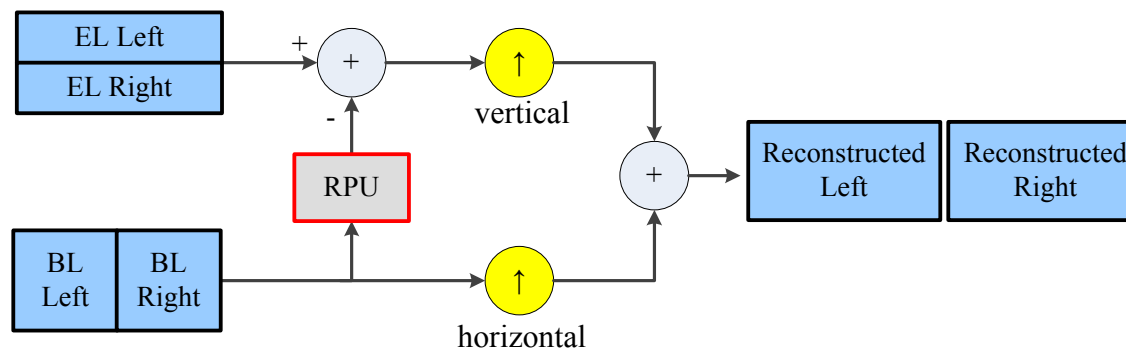
filter_name	filter_1D_tap	dynamic_range	filter_offset	filter_tap_length	cutoff freq (ω)
OM_RPU_DOWN_F0	[4 7 10 7 4]	6	32	5	0.29
OM_RPU_UP_F0	[3 -17 78 78 -17 3]	7	64	6	0.50

RPU Filter Responses



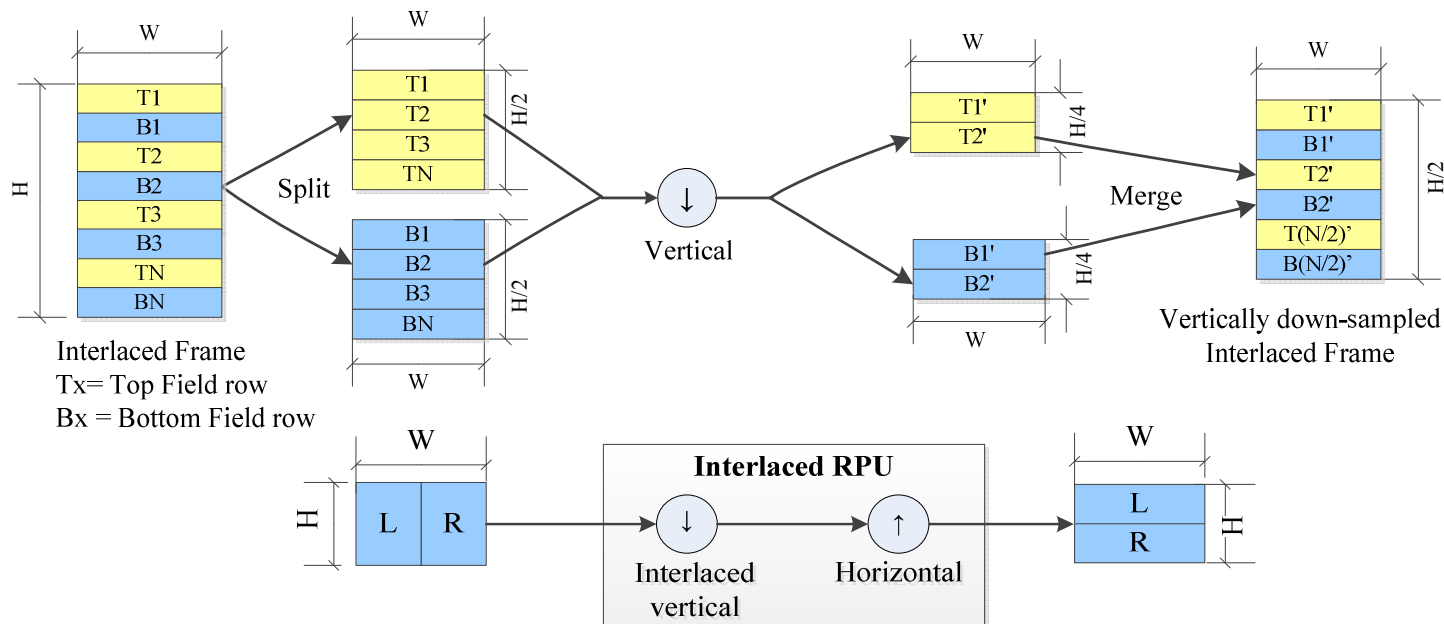
Filter Design: Reconstruction Filters

- Reconstruction filter: 1D upsampling
 - (vertical / horizontal) upsampling: OM_RPU_UP_F0 (same as the RPU upsampling filter)
 - This filter is non-normative but recommended.



RPU Processing for Interlaced Content

- Vertical filtering is done for each field independently
 - Split top and bottom fields
 - Filter each field independently
 - Merge (line interleave) top and bottom fields back to create frame



Syntax: seq_parameter_set_mvc_extension()

seq_parameter_set_mvc_extension() {	C	Descriptor
...		
if (profile_idc == 134) {		
rpu_type	0	u(6)
rpu_format	0	u(6)
if (rpu_type == 0 && (rpu_format == 0 rpu_format == 1)) {		
default_grid_position_flag	0	u(1)
if(!default_grid_position_flag) {		
view0_grid_position_x	0	u(4)
view0_grid_position_y	0	u(4)
view1_grid_position_x	0	u(4)
view1_grid_position_y	0	u(4)
}		
}		
if (!frame_mbs_only_flag)		
rpu_field_processing_flag	0	u(1)
}		

Encoder Control

- The reference software was implemented using MVC framework in JM18.3.
 - Base layer configuration \Rightarrow FC anchor setting defined in MFC CfP
 - Enhancement layer configuration \Rightarrow MVC setting in JM18.3
- No specific encoder optimization was added.

Spectrum Visualization: NewsRoom



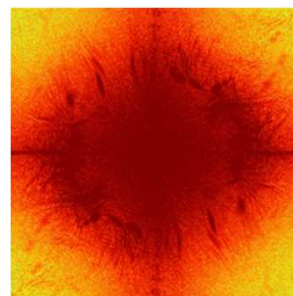
Original full resolution



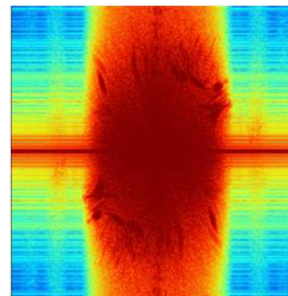
Demuxed from SbS-FC



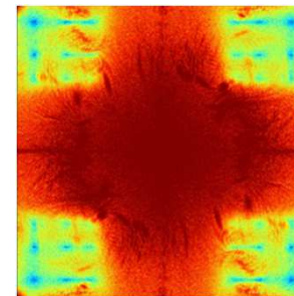
MFC reconstructed



original frequency spectrum

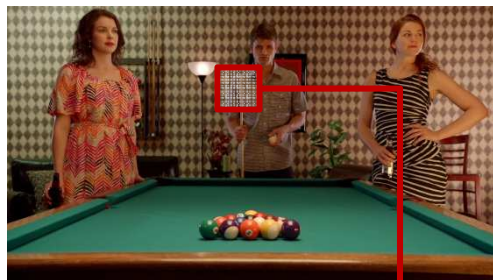


frequency spectrum of demuxed
from SbS-FC



frequency spectrum after
MFC reconstruction

Spectrum Visualization: Billiards



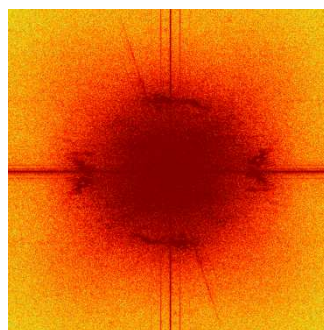
Original full resolution



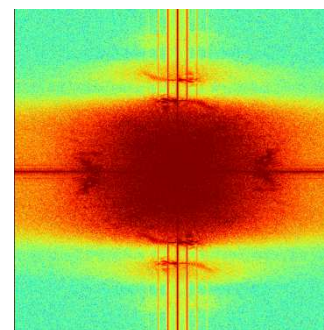
Demuxed from TaB-FC



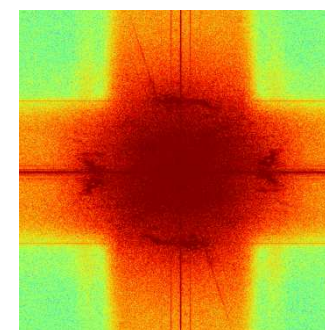
MFC reconstructed



original frequency spectrum



frequency spectrum of demuxed
from TaB-FC

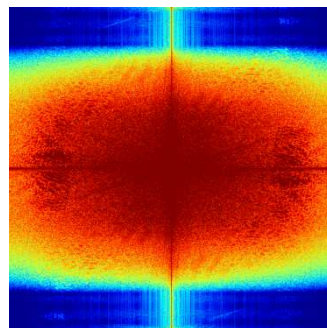


frequency spectrum after
MFC reconstruction

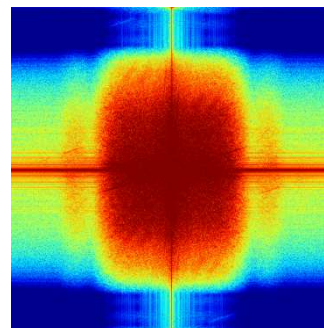
Spectrum Visualization: Amelia



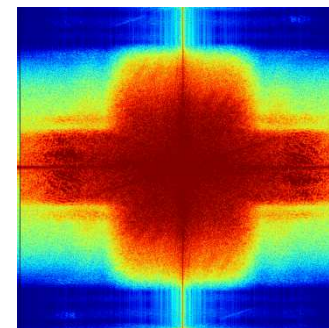
Interlaced:
Frequency spectrum of
upsampled top fields



original frequency spectrum



frequency spectrum of demuxed
from SbS-FC



frequency spectrum after
MFC reconstruction

Spectrum Visualization: LivingroomQuestion



Original full resolution

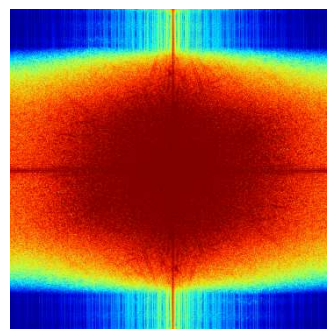


Demuxed from SbS-FC

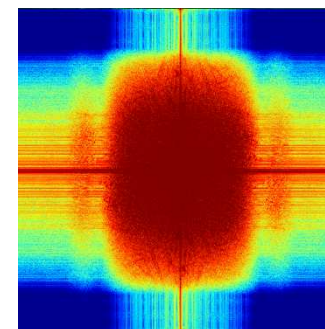


MFC reconstructed

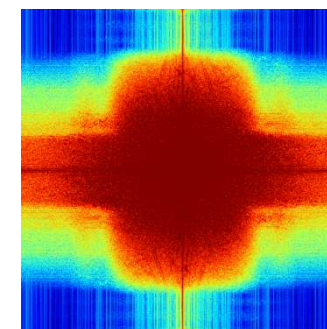
Interlaced:
Frequency spectrum of
upsampled top fields



original frequency spectrum



frequency spectrum of demuxed
from SbS-FC



frequency spectrum after
MFC reconstruction

Test Condition (N12961) in MFC CfP

- Anchor
 - Progressive: FC upsampled and SVC
 - Interlaced: FC upsampled

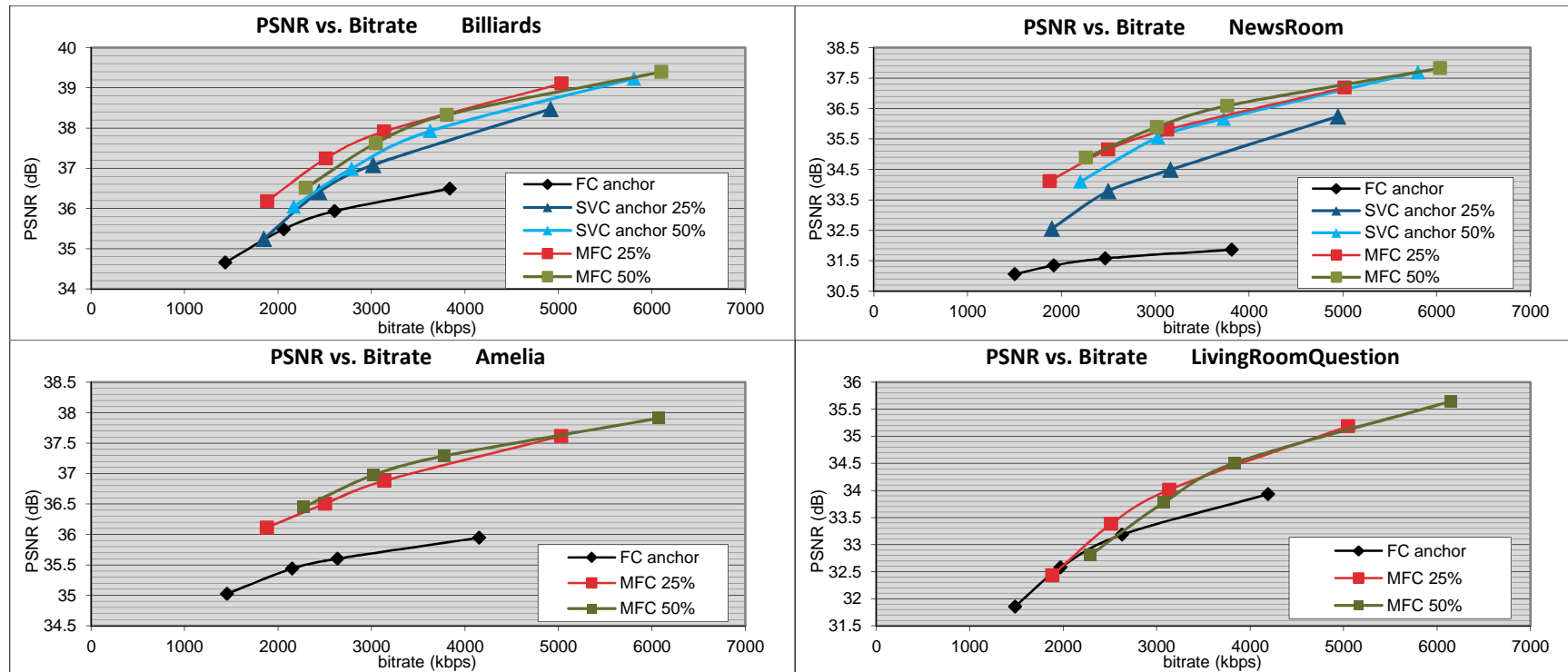
Base Rate	Total Rate 1 (25%)	Total Rate 2 (50%)
1.5Mbps	1.875Mbps	2.25Mbps
2.0Mbps	2.500Mbps	3.00Mbps
2.5Mbps	3.125Mbps	3.75Mbps
4.0Mbps	5.000Mbps	6.00Mbps

Sequence Idx	Sequence Name	Properties	Frame-Compatible Base Layer Format
S01	Billiards	1920x108024p, 240 frames	Top-and-Bottom
S02	NewsRoom	1920x108024p, 240 frames	Side-by-Side
S03	Amelia	1920x108050i, 250 frames	Side-by-Side
S04	LivingRoomQuestion	1920x108060i, 300 frames	Side-by-Side

Compression Performance

- Objective performance:
 - RD curves show a significant gain achieved over the FC upsampled anchor.
 - On average, more than 1.5dB PSNR gain compared to FC upsampled anchor.
 - For progressive sequences, all OM-FCFR RD performance is better than SVC
- Subjective performance:
 - MPEG official subjective evaluation is completed and chair's report is available.
 - Test shows MFC does provide significant subjective quality improvement for lost resolution.

RD Curves



Complexity Analysis: Expected Memory

Memory usage for encoding

Sequence	MFC	
	Peak (MB)	Factor against MVC Like
Progressive	1517	1.014
Interlaced	2292	1.015

Memory usage for decoding and reconstruction

Sequence	MFC	
	Peak (MB)	Factor against MVC Like
Progressive	200	1.142
Interlaced	311	1.091

Reference Software Implementation

- Implemented on top of JM18.3: standard C implementation
- Platform independent
 - Compiles under Windows and Linux (32/64 bit)
- SDK built with a clean interface in JM 18.3 software.
 - Functions related to MFC algorithm implemented as static libraries in a SDK
 - Facilitates integration of MFC to any MVC based encoder or decoder with minimal effort
 - Standalone test routines: easier to track flow of MFC code
 - Optimization for different platforms can be easily added and enabled