Interactive discussion on Image and Sound Signals

Coordinator: Prof. Rafael F. S. Caldeirinha
Signal representation

\[ f = \frac{1}{T} \]

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Channel in digital transmission

\[ R_b = R_s \cdot \text{lb}(M) \]

\[ T_m = \frac{1}{R_s} \]

\[ t_m \uparrow \Rightarrow T_m \uparrow \Rightarrow B \downarrow \]

(rising edge)

\[ t_m \cdot B \approx 0.35 \ldots 0.45 \]
A generic communication system
A challenging communication scenario
Real-Time Super High Resolution Image-Intensive Tele-Diagnosis

Surgical or Diagnosis Room
- Surgical table antenna
- UHD Video Camera
- X-Y Positioning system
- Patient under observation

Surgical Table
- Ceiling Antenna
- RF Video Signal
- 60GHz RF Transceiver
- Ethernet

Local monitoring room
- UHD Signal
- ROF to UHD Converter
- UHD Screen

Remote monitoring/control room
- HD Video Projector
- X-Y control station
- Ethernet or WiFi

Radio over Fiber Converter
- Optical Fiber
- Optical Splitter
- RF Video Signal

Radio over Fiber Converter
- X-Y control signal

Optical Fiber
- HD Video Projector
- UHD/Ethernet Demodulator

High Power 60GHz Transceiver
- Long Distance 60GHz Bidirectional RF link

60GHz RF Transceiver
- Radio over Fiber Converter
- X-Y control station

UHD Screen
- UHD Signal

60GHz RF Signal
- Remote monitoring/control room

IARIA SIGNAL 2016
30.06.2016 Lisbon
(Quasi) Real-Time Super High Resolution Image-Intensive Tele-Diagnosis

Channel 1: 57.24 59.40 GHz;
Channel 2: 59.40 61.56 GHz;
Channel 3: 61.56 63.72 GHz;
Channel 4: 63.72 65.88 GHz.


8k UHD (7680 x 4320p), <91 Mbps (H.264) or <50 Mbps (HEVC)
4k UHD (3840 x 216p), <35 Mbps (HEVC)
A challenging communication scenario
Real-Time Super High Resolution Image-Intensive Tele-Diagnosis

- Uncompressed video/image, zero latency (degradation in low SNR regimes):
A challenging communication scenario
Real-Time Super High Resolution Image-Intensive Tele-Diagnosis

A single **Whole Slide Image** (WSI):
- 20mm x 15mm region of a glass slide samples at 0.25 microns/pixel
- 24 bits/pixel (8bpp/colour channel)

...can easily occupy in excess of 15GB in size.

[Source: https://digitalpathologyassociation.org]
Medical images processing

Middle slice of each of the used medical images:

(a) CT_Aperts  (b) CT_carotid  (c) CT_skull  (d) CT_wrist

(a) MR_liver_t1  (b) MR_liver_t2e1  (c) MR_ped_chest  (d) MR_sag_head

[Source: Caldeirinha et al, Project report “Ultra High Definition Image Communication for Medical Imaging”, 2015]
Medical images processing

Coding performance evaluation for lossless encoders applied to medical images (results in bpp):

<table>
<thead>
<tr>
<th>Sequence</th>
<th>H.264</th>
<th>HEVC Intra</th>
<th>HEVC RA</th>
<th>HEVC RExt</th>
<th>MMP</th>
<th>MMP 3D</th>
<th>JPEG 2000</th>
<th>JPEG-LS</th>
<th>CALIC</th>
<th>MRP</th>
<th>JP3D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperts</td>
<td>1.193</td>
<td>1.289</td>
<td>0.825</td>
<td>0.728</td>
<td>1.178</td>
<td>0.938</td>
<td>1.261</td>
<td>1.058</td>
<td>0.998</td>
<td>0.775</td>
<td>0.941</td>
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<tr>
<td>carotid</td>
<td>2.062</td>
<td>2.198</td>
<td>1.586</td>
<td>1.424</td>
<td>1.977</td>
<td>2.019</td>
<td>2.019</td>
<td>1.778</td>
<td>1.684</td>
<td>1.374</td>
<td>1.547</td>
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<tr>
<td>skull</td>
<td>3.183</td>
<td>3.083</td>
<td>1.905</td>
<td>1.766</td>
<td>2.959</td>
<td>2.991</td>
<td>2.761</td>
<td>2.628</td>
<td>2.329</td>
<td>2.088</td>
<td></td>
</tr>
<tr>
<td>liver_t1</td>
<td>3.489</td>
<td>3.742</td>
<td>2.391</td>
<td>2.052</td>
<td>3.393</td>
<td>3.256</td>
<td>3.160</td>
<td>3.022</td>
<td>2.582</td>
<td>1.745</td>
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<tr>
<td>liver_t2e1</td>
<td>2.806</td>
<td>2.811</td>
<td>1.725</td>
<td>1.509</td>
<td>2.460</td>
<td>2.572</td>
<td>2.418</td>
<td>2.269</td>
<td>1.722</td>
<td>2.356</td>
<td></td>
</tr>
<tr>
<td>ped_chest</td>
<td>3.080</td>
<td>3.352</td>
<td>1.700</td>
<td>1.536</td>
<td>3.074</td>
<td>3.021</td>
<td>2.937</td>
<td>2.789</td>
<td>2.337</td>
<td>2.071</td>
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<tr>
<td>sag_head</td>
<td>2.635</td>
<td>2.732</td>
<td>1.873</td>
<td>1.748</td>
<td>2.808</td>
<td>2.905</td>
<td>2.582</td>
<td>2.519</td>
<td>2.279</td>
<td>2.160</td>
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<tr>
<td>Average</td>
<td>2.545</td>
<td>2.675</td>
<td>1.645</td>
<td>1.471</td>
<td>2.446</td>
<td>2.473</td>
<td>2.290</td>
<td>2.183</td>
<td>1.821</td>
<td>1.768</td>
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</tr>
</tbody>
</table>

[Source: Caldeirinha et al, Project report “Ultra High Definition Image Communication for Medical Imaging”, 2015]
Medical images processing

Results of the encoding of the pixel-wise difference residue (results in bpp).

<table>
<thead>
<tr>
<th>Sequence</th>
<th>H.264</th>
<th>HEVC Intra</th>
<th>HEVC RA</th>
<th>HEVC RExt</th>
<th>MMP</th>
<th>MMP 3D</th>
<th>JPEG 2000</th>
<th>JP3D</th>
<th>JPEG-LS</th>
<th>CALIC</th>
<th>MRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperts</td>
<td>0.798</td>
<td>0.857</td>
<td>0.722</td>
<td>0.673</td>
<td>0.890</td>
<td>0.869</td>
<td>0.938</td>
<td>0.942</td>
<td>0.794</td>
<td>0.774</td>
<td>0.632</td>
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<tr>
<td>carotid</td>
<td>1.511</td>
<td>1.633</td>
<td>1.366</td>
<td>1.272</td>
<td>1.544</td>
<td>1.592</td>
<td>1.472</td>
<td>1.396</td>
<td>1.355</td>
<td>1.147</td>
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<tr>
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<td>2.101</td>
<td>1.510</td>
<td>1.444</td>
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<td>1.984</td>
<td>1.974</td>
<td>1.899</td>
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<tr>
<td>wrist</td>
<td>1.112</td>
<td>1.254</td>
<td>0.905</td>
<td>0.860</td>
<td>1.133</td>
<td>1.212</td>
<td>1.218</td>
<td>1.043</td>
<td>1.054</td>
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<tr>
<td>liver_t1</td>
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<td>1.852</td>
<td>2.229</td>
<td>2.255</td>
<td>1.693</td>
<td>2.070</td>
<td>2.020</td>
<td>1.765</td>
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<tr>
<td>liver_t2el</td>
<td>1.789</td>
<td>1.971</td>
<td>1.329</td>
<td>1.228</td>
<td>1.721</td>
<td>1.818</td>
<td>2.283</td>
<td>1.685</td>
<td>1.604</td>
<td>1.310</td>
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<tr>
<td>ped_chest</td>
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<td>1.738</td>
<td>1.346</td>
<td>1.301</td>
<td>1.749</td>
<td>1.815</td>
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<td>1.586</td>
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<tr>
<td>sag_head</td>
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<td>1.580</td>
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<td>2.218</td>
<td>2.185</td>
<td>2.113</td>
<td>2.001</td>
<td>1.979</td>
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<tr>
<td><strong>Average</strong></td>
<td>1.632</td>
<td>1.751</td>
<td>1.343</td>
<td>1.268</td>
<td>1.697</td>
<td>1.744</td>
<td>1.703</td>
<td>1.574</td>
<td>1.534</td>
<td>1.317</td>
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</tr>
</tbody>
</table>

[Source: Caldeirinha et al, Project report “Ultra High Definition Image Communication for Medical Imaging”, 2015]
Medical images processing

Results of the encoding of the HEVC residue (results in bpp):

<table>
<thead>
<tr>
<th>Sequence</th>
<th>H.264</th>
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<th>CALIC</th>
<th>MRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aperts</td>
<td>0.778</td>
<td>0.836</td>
<td>0.819</td>
<td>0.890</td>
<td>0.926</td>
<td>0.814</td>
<td>0.807</td>
<td>0.700</td>
</tr>
<tr>
<td>carotid</td>
<td>1.472</td>
<td>1.581</td>
<td>1.562</td>
<td>1.544</td>
<td>1.576</td>
<td>1.430</td>
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<td>1.259</td>
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<tr>
<td>skull</td>
<td>1.836</td>
<td>1.891</td>
<td>1.834</td>
<td>2.095</td>
<td>1.957</td>
<td>1.818</td>
<td>1.736</td>
<td>1.589</td>
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<tr>
<td>wrist</td>
<td>1.081</td>
<td>1.179</td>
<td>1.152</td>
<td>1.133</td>
<td>1.209</td>
<td>1.087</td>
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<td>liver_t1</td>
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<td>2.300</td>
<td>2.256</td>
<td>2.229</td>
<td>2.275</td>
<td>2.120</td>
<td>2.038</td>
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<td>liver_t2e1</td>
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<td>1.629</td>
<td>1.721</td>
<td>1.659</td>
<td>1.532</td>
<td>1.461</td>
<td>1.316</td>
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<tr>
<td>ped_chest</td>
<td>1.583</td>
<td>1.678</td>
<td>1.652</td>
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<td>1.667</td>
<td>1.553</td>
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<td>sag_head</td>
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<td>2.015</td>
<td>1.843</td>
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<tr>
<td><strong>Average</strong></td>
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<td>1.627</td>
<td>1.590</td>
<td>1.697</td>
<td>1.676</td>
<td>1.539</td>
<td>1.483</td>
<td>1.346</td>
</tr>
</tbody>
</table>

[Source: Caldeirinha et al, Project report “Ultra High Definition Image Communication for Medical Imaging”, 2015]
Communications at 60 GHz - IEEE 802.15.3c

Usage Models:
- (UM1) Uncompressed video streaming
- (UM2) Uncompressed multivídeo streaming
- (UM3) Office desktop
- (UM4) Conference ad hoc
- (UM5) Kiosk file downloading

Comparison of the three modes provided by the standard:

<table>
<thead>
<tr>
<th>Main usage model</th>
<th>SC PHY</th>
<th>AV PHY</th>
<th>HSI PHY</th>
</tr>
</thead>
<tbody>
<tr>
<td>UM3 and UM5</td>
<td>UM1 and UM2</td>
<td>UM3 and UM4</td>
<td></td>
</tr>
<tr>
<td>0.3 Mbps-5 Gbps</td>
<td>0.95-3.8 Gbps</td>
<td>1.54-5.78 Gbps</td>
<td></td>
</tr>
<tr>
<td>SC-FDE</td>
<td>OFDM</td>
<td>OFDM</td>
<td></td>
</tr>
<tr>
<td>Reed Soloman code/LDPC</td>
<td>Reed Soloman code</td>
<td>LDPC</td>
<td></td>
</tr>
<tr>
<td>512</td>
<td>512</td>
<td>512</td>
<td></td>
</tr>
</tbody>
</table>

[Source: Caldeirinha et al, Project report “Ultra High Definition Image Communication for Medical Imaging”, 2015]
Communications at 60 GHz - IEEE 802.15.3c

[Source: Caldeirinha et al, Project report “Ultra High Definition Image Communication for Medical Imaging”, 2015]
Immersive 3D Holoscopic Video Processing

3D imaging and video applications are emerging in the consumer market:
• visual inspection
• multilayer incremental video,
• refocusing photography
• glasses-free 3D television

Source: A. Aggoun et al, 2013
Sound particles

- Sound Particles is a CGI-like software for Sound Design, capable of using particle systems to generate thousands of sounds in a virtual 3D world.
“(...)

new technology that uses optical holographic methods to literally image the signals coming off the massive MIMO antenna array, avoiding a lot of the difficult issues with ADC cost and beam processing. Could this be the missing technology to bring practical MIMO to the field? (...)

[Source: Dennis W. Prathe, IEEE ComSoc Technology News, June 2016]