Getting the Shot:
Advanced MPEG-4 AVC Encoding
and
Robust COFDM Modulation
Deliver HD-ENG

John L. Pittas
Fujitsu Computer Products of America, Inc.
Migration of news gathering feeds from SD to HD introduce capacity and performance challenges for RF channels using existing picture coding and modulation technologies

**MPEG-2 picture coding**
- 4.5Mbps – 8Mbps provides acceptable SD contribution picture quality
- 14Mbps – 18Mbps provides acceptable HD contribution picture quality

**DVB modulation**
- DVB-S provides robust transmission using QPSK, FEC=3/4
  - ~6.0Mbps data rate for a 5.5MHz satellite channel
- DVB-T provides robust transmission using QPSK, FEC=1/2, GI=1/8
  - ~5.5Mbps data rate for a 8MHz terrestrial channel
- Both are sufficient for MPEG-2 SD but not for MPEG-2 HD!

Furthermore, in the USA, BAS channel relocation has reduced bandwidth available for terrestrial news gathering

- 17MHz channel bandwidth reduced to 12MHz
  - Dual 8MHz channels (pedestals) are no longer possible
Solution Overview

HD news gathering requires new solutions

- Satellite News Gathering (HD-SNG)
  - DVB-S2 provides ~30% bandwidth improvement over DVB-S
    - Robust transmission using higher order constellations and stronger FEC
    - 8PSK, FEC=3/4 provides 11.14Mbps data rate for a 6MHz satellite channel
  - MPEG-4 AVC provides excellent HD picture quality for news at half the bit-rate or less of MPEG-2
    - 6Mbps – 10Mbps can easily be accommodated in 4.0MHz – 6.0MHz channels
    - Allows HD-SNG in the same bandwidth as SD-SNG

- terrestrial Electronic News Gathering (HD-ENG)
  - DVB-T2 spec is ready but not yet commercialized
    - DVB-S2 type of FEC (LDPC & BCH) will increase payload by 30% over DVB-T
  - Two challenges for HD-ENG using current DVB-T technology
    - Provide good picture quality using robust modulation parameters
    - Provide acceptable picture quality to support 6MHz pedestal
    - Only MPEG-4 AVC can provide acceptable HD picture quality under these conditions!
  - Achieving the above goals will allow news to recover its pre-BAS, pre-HD field production capabilities
    - High confidence in “getting the shot”
    - Ability to transmit multiple HD feeds in a single channel
<table>
<thead>
<tr>
<th>Modulation</th>
<th>Constellation</th>
<th>FEC</th>
<th>CNR (dB) required for BER $= 2 \times 10^{-4}$ after FEC</th>
<th>Data Rates (Mbps) for an 8MHz Channel</th>
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<tbody>
<tr>
<td>Gaussian</td>
<td>Ricean</td>
<td>Rayleigh</td>
<td>Guard Interval</td>
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<td>21.3</td>
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</tr>
</tbody>
</table>

- Gaussian Channel: Line-of-Sight (LoS) signal w/no signal echoes (AWGN-only)
- Ricean Channel: High-power LoS signal plus low-power signal echoes of varying level and phase
- Rayleigh Channel: High-power signal echoes w/low-power or no LoS signal

Data from ETSI Standard: EN 300 744 V1.6.1 (2008-09), DVB Framing Structure, Channel Coding and Modulation for DTT
Rayleigh Channel CNR and Data Rate Graph for 8MHz

- QPSK: 1/2, 2/3, 3/4, 5/6, 7/8
- 16QAM: 1/2, 2/3, 3/4, 5/6, 7/8
- 64QAM: 1/2, 2/3, 3/4, 5/6, 7/8

CNR and data rates are shown for different modulation schemes and guard intervals (GI).
Solution Criteria

- Selecting optimal modulator operating point
  - Higher constellations increase data rate and CNR
    - For similar FEC (see DVB-T Table)
      - Data rates: 16QAM = 2xQPSK, 64QAM = 3xQPSK
      - Rayleigh CNR increases by ~6dB from QPSK to 16QAM and by another ~6dB from 16QAM to 64QAM
  - Lower FEC increases data rate and CNR
    - For similar constellation (See DVB-T Table)
      - Data rate increases as $\frac{FEC_L}{FEC_H}$ e.g. $(7/8)/(1/2) = 7/4$
      - But Rayleigh Channel CNR increases by ~12dB from FEC=1/2 to FEC=7/8!
  - Solution! More FEC at higher constellation provides lower CNR and higher payload compared to less FEC at lower constellation in Rayleigh Channel (multi-path) environments
    - Examples
      - 16QAM, FEC=1/2 has CNR=11.8dB, payload of 11.06Mbps @ GI=1/8 versus QPSK, FEC=7/8, has CNR=17.5dB, payload of 9.68Mbps @ GI=1/8
      - 64QAM, FEC=2/3 has CNR of 20.3dB, payload of 23.42Mbps @ GI=1/16 versus 16QAM, FEC=7/8 has CNR of 23.6dB, payload of 20.49 @ GI=1/16
Rayleigh Channel Operating Solutions for 8MHz
# Rayleigh Channel Operating Points for 8MHz

<table>
<thead>
<tr>
<th>Constellation</th>
<th>FEC</th>
<th>Channel Type</th>
<th>CNR (dB) required for BER = 2x10^-4 after FEC</th>
<th>Data Rates (Mbps) for an 8MHz Channel</th>
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<td>21.3</td>
<td>28.6</td>
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</tbody>
</table>
HD-ENG Solution Specifics for 8MHz Channel

**DVB-T Transmission Characteristics for 8MHz Channel**

- **16QAM, FEC=1/2, GI=1/8 operating point**
  - Provides *optimal* balance between channel and payload performance
  - Rayleigh Channel CNR of 11.8dB is sufficiently robust for most multi-path environments
  - 11.06Mbps data rate provides very good picture quality @ 10.0Mbps
  - Provides “good-fit” to 11.14Mbps data rate of a 6MHz SNG channel using DVB-S2 operating point of 8PSK, FEC=3/4

- **QPSK, FEC=2/3, GI=1/8 operating point**
  - Provides improved multi-path performance
  - Rayleigh Channel CNR of 9.6dB for severe multi-path in urban environments
  - 7.37Mbps data rate provides good picture quality @ 6.3Mbps
  - Provides “good-fit” to 7.42Mbps data rate of a 4MHz SNG channel using DVB-S2 operating point of 8PSK, FEC=3/4

- **64QAM, FEC=2/3, GI=1/16 operating point**
  - Provides much higher payload
  - 23.42Mbps data rate provides ~23.1Mbps payload
  - Allows multiplexing of two or more video feeds in a single pedestal or
  - Multiplexing of high IP (file) data traffic w/a single video feed
  - Rayleigh Channel CNR of 20.3dB for moderate multi-path environments
# Recommended Operating Points for 8MHz Channel

## DVB-T Data Rate Tables (in Mbps)

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<thead>
<tr>
<th>FEC</th>
<th>QPSK</th>
<th>1/4 Guard Interval</th>
<th>1/8 Guard Interval</th>
<th>1/16 Guard Interval</th>
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<td>16QAM</td>
<td>64QAM</td>
<td>QPSK</td>
<td>16QAM</td>
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</table>
Recommended Operating Presets for 8MHz Channel using Fujitsu IP-9500 MPEG-4 AVC Encoder

<table>
<thead>
<tr>
<th>Preset</th>
<th>Mod</th>
<th>FEC</th>
<th>GI</th>
<th>Mod Data Rate</th>
<th>TS Bit Rate*</th>
<th>Video Bit Rate</th>
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<tbody>
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<td>1/8</td>
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<td>6.3Mbps</td>
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<tr>
<td>7</td>
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<td>1/2</td>
<td>1/8</td>
<td>11.06Mbps</td>
<td>10.7Mbps</td>
<td>10.0Mbps</td>
<td>64Kbps</td>
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<td>8</td>
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<td>1/8</td>
<td>14.75Mbps</td>
<td>14.4Mbps</td>
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<td>64Kbps</td>
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<tr>
<td>9</td>
<td>64QAM</td>
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<td>17.56Mbps</td>
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<td>512Kbps</td>
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<tr>
<td>10</td>
<td>64QAM</td>
<td>2/3</td>
<td>1/16</td>
<td>23.42Mbps</td>
<td>20.7Mbps</td>
<td>20.0Mbps</td>
<td>512Kbps</td>
</tr>
</tbody>
</table>

*Assumes ~300Kbps buffer between Modulator ASI input and Encoder ASI output

- Presets 9 and 10 illustrate use of single high bit-rate video feed but are better suited to multiplexing of multiple lower bit-rate streams and/or IP data traffic before the DVB-T modulator.
KYW HD-ENG Field Trial System

KYW Liberty Site

KYW Sector Scan Antennas

KYW Antenna Controller

RF Splitters

Link 2 GHz BDC's

UHF Splitters

ASI

10/100BaseT

Fujitsu IP-9500 D Decoder

MTX5000

KyW CR system

Fujitsu IP-9500 Encoder

UMG Link

ASI Back-Haul Link

Fujitsu IP-9500 D Decoder

IF In

ASI

13 GHz Strata TXU

Video + Audio

13 GHz Strata RXU

Produced by Fujitsu Corporation

M. Wheeler 7/16/2008
KYW HD-ENG Field Trial Demo Workflow

Field Production
- Camera Original
  - Recorded on Sony XDCAM HD Pro-Disc @ 35Mbps (HQ mode)
- Receiver Original
  - Encoded by Fujitsu IP-9500 MPEG-4 AVC Encoder
  - Backhauled by MRC MXT5000 XMTR & DRS4000 RCVR
  - Decoded by Fujitsu IP-9500D MPEG-4 AVC Decoder
  - Recorded on Sony XDCAM HD Pro-Disc @ 35Mbps

Post Production
- Server-based edit of Master
  - Originals recorded into GV K2 Server @ 50Mbps I Frame
  - Master edited/rendered on GV K2 Server @ 50Mbps I Frame
  - Master recorded on Sony XDCAM HD Pro-Disc @ 35Mbps

Camera Original processed through 4 codecs
Receiver Original processed through 5 codecs
Roll the demo!
### KYW HD-ENG Field Trial Results for 8MHz Channel

<table>
<thead>
<tr>
<th>XMTR Location</th>
<th>Distance to RCVR</th>
<th>XMTR Antenna</th>
<th>XMTR Site Type</th>
<th>Constellation</th>
<th>FEC</th>
<th>GI</th>
<th>Modulator Data Rate (Mbps)</th>
<th>Encoder TS Bit Rate (Mbps)</th>
<th>Video Bit Rate (Mbps)</th>
<th>Audio Bit Rate (Kbps)</th>
<th>Video Quality</th>
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<tbody>
<tr>
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<td>Omni</td>
<td>No LoS</td>
<td>QPSK</td>
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<td>1/8</td>
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<td>64</td>
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<tr>
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<td>MB, FF</td>
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</table>

Video source is 1080i/59.94Hz format, 1440 horizontal resolution; Video encoding is MPEG-4 AVC HP/L4

Audio source is one AES Stereo Pair; Audio encoding is MPEG-2 AAC

MB: Macro Blocking
FF: Freeze Frame
Rayleigh Channel Mapping of KYW Field Trial Operating Points

- QPSK
- 16QAM
- 64QAM

- GI = 1/4
- GI = 1/8
- GI = 1/16
- GI = 1/32

- Mbps
- dB

- Failed
Acknowledgements

Many thanks to the following for their expertise, effort and assistance in conducting the field trials

- MRC
  - Mike Wheeler
  - Vance D’Arcangelo
  - Bob Morrissette

- KYW
  - George Gammond

- Fujitsu
  - Rich Harvey

Special thanks to Rich Paleski of KYW and Rich Miller of MRC for their many years of ENG expertise which greatly assisted in organizing and guiding the trials

- Final thanks to Russell Booth of KYW who made editing the Master so easy!
Dual Modulation FEC GI Modulation Encoder TS Video Audio Receive D/U Ratio SNR Video Pedestals Data Rate Bit Rate Bit Rate Bit Rate Antenna Reception

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Liberty receive site located on 61st floor of One Liberty Place, 1650 Market Street Philadelphia, PA

Dual pedestal 6MHz transmission from KYW (N. 16th Street between Hamilton & Spring Garden) to Liberty is 0.7 miles