HD Radio Innovation

HD PowerBoost Gen4
HD Multiplex
CAUTION: The ideas presented here may be dangerous and/or contagious. Nautel takes no responsibility for its application ... we just think they are neat.
Your questions please?

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Please enter your questions in the text box of the webinar control panel (remember to press send)
Agenda

• HD Radio Overview
  – HD Radio today
  – IBOC Signal review

• IBOC Broadcast Equipment Evolution
  – 3rd gen architecture

• HD PowerBoost Gen4
  – HD PowerBoost vs PAR2

• HD Multiplex
  – Economic Benefits
  – Application Areas
HD Radio™: Where are we today?

- 28 million receivers
- 2087 IBOC stations on air
- 3708 total HD channels
- 1735 multicast channels
- International interest increasing
HD Radio™: Hybrid IBOC Signal

Mode MP3
up to 5 audio
98.4 kbps R2
24.8 kbps R4

24 kbps
≈ FM quality

10 frequency partitions
- 18 data, 1 reference carrier
- 382 carriers in total
- QPSK modulated
- 2.9 ms symbol time

- 100 kHz lower sideband
- 100 kHz upper sideband

75 kHz deviation

FM

-200 kHz -100 kHz 0 kHz 100 kHz 200 kHz

lower sideband upper sideband
All primary service modes are supported today MP1,3,11,5,6. Secondary modes MS1-4 are not implemented.
Most cannot tell quality improvement above 48 kBps
Stereo mode good performance until 36 kBps
Parametric stereo good performance until 24 kBps
  - FM comparable quality used as base line later
Mono mode good performance until 16 kBps
HD audio processing and pre-conditioning is key
IBOC Broadcast Systems Architecture

automation, processing, service provider

AES: HD-2,3,4

audio clients

importer

synchronizer

HDC encoder

FM delay

exporter

exciter

IBOC

HD Power Boost

PAR1

PAR2

eXgie

GPS

GPS

L2E link (TCP)

AES: FM, HD-1

E2X link (UDP/TCP)

Delayed FM

STL

STL

HD Innovation
HD PowerBoost: Revisited

PAR1 reduction only considers the IBOC signal …

… what if we considered both the analog and digital signals together?
HD PowerBoost: PAR1 Clipping
HD PowerBoost: Smart Clip
HD PowerBoost MER Configuration

HD PowerBoost
30% more TPO at -10 dBc
14.5 dB MER

PAR1
>4 dB peaks
17 dB MER

HD PowerBoost
23 dB MER high quality
PAR1 TPO
HD Spectrum Optimizer

Measures mask clearance and adjusts TX parameters. Takes corrective action.
PAR2: Modulator Spectrum

Configurable mask clearance

Affects peaks by up to 9% - 25%

Competes with transmitter spectral re-growth

Optimal mask clearance at 8 dB
PAR2: FM modulation creates peaks

FM modulation now affects spectral regrowth

100% 1kHz modulation dictates TPO spec

Typical modulation drives efficiency spec

Size your transmission system to the max peaks
PAR2: MP3 mode

20% more carriers

HD Innovation
PAR2: IBOC Quality Slider

Impact of Signal Quality Configuration

- 11.3 dB MER
- 14.1 dB MER
- 23.0 dB MER

Probability Exceeding Power Level

Power Level Above 1 kW FM Carrier (kW)
PAR2 vs HD PowerBoost

HD PowerBoost has
- Best measured TPO performance
- Best measured efficiency
- Best absolute peak control

<table>
<thead>
<tr>
<th></th>
<th>PAR1</th>
<th>PAR2</th>
<th>HD Power Boost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power increase</td>
<td>0%</td>
<td>2%</td>
<td>25%</td>
</tr>
<tr>
<td>(MP3 test tone)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power increase</td>
<td>0%</td>
<td>18%</td>
<td>33%</td>
</tr>
<tr>
<td>(MP3 typical mod)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DC-RF efficiency</td>
<td>56.0%</td>
<td>61.9%</td>
<td>67.2%</td>
</tr>
<tr>
<td>(MP3 typical mod)</td>
<td></td>
<td>(+5.9%)</td>
<td>(+11.2%)</td>
</tr>
</tbody>
</table>
HD PowerBoost: Hybrid IBOC

- Every GV can produce -16 dBC at nameplate power
- 10% headroom: -14 dBC
- 35% headroom: -10 dBC
System Architecture

- HD PowerBoost reduces peaks effectively
- HD PowerBoost off loads exeengine
  - Exeengine core is used with PAR disabled
  - Hybrid and digital IBOC
- Exporter and importer run as software components
Extended HD PowerBoost

• HD PowerBoost handles additional carriers
  – frequency shift and add signals
  – Frequency shift is an integral number of IBOC carriers
HD PowerBoost Multiplex

- 3+ IBOC stations
  - A: 97.9 MHz
  - B: 98.0 MHz
  - C: 98.1 MHz
- 100 kHz tuning
- 600 kHz occupied bandwidth
- 3x123.2 kBps $\Rightarrow$ 369.6 kbps
- up to 15 audio streams
  - 32kbps, 24kbps and 16 kbps
- Adjustable sideband levels
- **Standard exgine** MP3 and MP5 IBOC modes are compatible with existing receivers.
Receivers with 100 KHz Tuning

- Sony XDR-S10HDiP
- Insignia NS-CLHD1
- Sony XAV-712HD
- Sparc SHD-BT1
- Sparc SHD-TX2
- Sangean HDT-1
- JVC KD-HDR40

- Most receivers are capable
- Some receivers require region set
- Many receivers have HD scanning
  - Some require FM carrier
### HD Mux: Transmitter Savings

#### GV FM+IBOC Transmitter
- **RMS**: 0%
- **Peak**: 160%

#### Single HD
- **RMS**: 20%
- **Peak**: 80%

#### MP1 HD Multiplex
- **RMS**: 40%
- **Peak**: 120%

#### MP3 HD Multiplex
- **RMS**: 60%
- **Peak**: 140%

#### MP5 HD Multiplex
- **RMS**: 80%
- **Peak**: 160%

#### GV Capacity

<table>
<thead>
<tr>
<th></th>
<th>MP1</th>
<th>MP3</th>
<th>MP5</th>
<th>MP6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nameplate TPO</td>
<td>75%</td>
<td>85%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Audio streams</td>
<td>12</td>
<td>15</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>RMS Power (compared to FM)</td>
<td>30%</td>
<td>36%</td>
<td>42%</td>
<td>42%</td>
</tr>
<tr>
<td>Amplifier reduction (per stream)</td>
<td>6.3%</td>
<td>5.7%</td>
<td>6.7%</td>
<td>8.3%</td>
</tr>
</tbody>
</table>

*HD Innovation*
HD Mux: GV Conversion

A GV broadcasting hybrid IBOC or FM only today can be converted:

1. Exciter update
2. 3 ExporterPlus
3. 3 EmporterPlus

GV already has the transmitter power output
HD Mux: Transmission Savings

Other savings:
• Single antenna transmission system
  – Reduced tower space / rent
• Reduced cooling
• Footprint
• Content distribution
• Maintenance
• Transmission power …
# HD Mux: Power Savings

<table>
<thead>
<tr>
<th></th>
<th>FM</th>
<th>FM+MP3</th>
<th>MP1</th>
<th>MP3</th>
<th>MP5</th>
<th>MP6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RMS Power</strong></td>
<td>10 kW</td>
<td>11.2 kW</td>
<td>3 kW</td>
<td>3.6 kW</td>
<td>4.2 kW</td>
<td>4.2 kW</td>
</tr>
<tr>
<td><strong>AC-RF Efficiency</strong></td>
<td>72%</td>
<td>55%</td>
<td>45%*</td>
<td>45%*</td>
<td>45%*</td>
<td>45%*</td>
</tr>
<tr>
<td><strong>Audio streams</strong></td>
<td>1</td>
<td>5</td>
<td>12</td>
<td>15</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td><strong>Total power</strong></td>
<td>13.9 kW</td>
<td>20.4 kW</td>
<td>6.7 kW</td>
<td>8.0 kW</td>
<td>9.3 kW</td>
<td>9.3 kW</td>
</tr>
<tr>
<td><strong>Per stream power</strong></td>
<td>13.9 kW</td>
<td>4.1 kW</td>
<td>560 W</td>
<td>530 W</td>
<td>620 W</td>
<td>775 W</td>
</tr>
<tr>
<td><strong>Annual cost</strong></td>
<td>$12,541</td>
<td>$3,699</td>
<td>$505</td>
<td>$478</td>
<td>$559</td>
<td>$699</td>
</tr>
<tr>
<td><strong>15 audio streams</strong></td>
<td>$188,115</td>
<td>$55,490</td>
<td>$7,575</td>
<td>$7,170</td>
<td>$8,385</td>
<td>$10,485</td>
</tr>
</tbody>
</table>

* estimated efficiency, **US10.3c/kWh

95% savings in transmission power

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HD Mux: Spectral Efficiency

- Band II: 87.5-108 MHz supports 34 HD Multiplex
  - 255 audio streams with $\frac{1}{2}$ frequency reuse factor
- Tight spectral packing on a single transmitter
- No self-interference concerns
  - Relative signal levels remain fixed on HD Multiplex
- Short spacing is possible
  - D/U ratios as little as 4 dB (20-30 dB for FM)
  - small interference zones
- Regionalization support
  - 3 transmission patterns
- Single frequency network
HD Multiplex 400 kHz mode

- Turn off outer sidebands
  - 2/9 rate code provides enough forward error correction
- Boost inner carriers
  - Compensate for loss of 2nd sideband and frequency diversity
- Outer carriers at -10 dBc
- Switch inner carriers to MP6 for highest robustness
HD Multiplex 400 kHz mode

Switch inner carriers
Tuning is at 200 kHz

Not all receivers are ready to handle single sideband IBOC
HD Multiplex 400 kHz mode

9 audio streams in standard channel allocations

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HD Multiplex 200 kHz mode

4 audio streams in single channel allocations
HD Multiplex Demonstration at NAB2015

• 15 looping audio streams
  • Audio clips processed thanks to Omnia
• Running on VS and GV transmitters
• Service modes MP3,5,6
• More signal combinations
• A variety of receivers
# HD Multiplex Demonstration

## 15 audio clips

<table>
<thead>
<tr>
<th>HD-1</th>
<th>HD-2</th>
<th>HD-2</th>
<th>HD-2</th>
<th>HD-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>32 kbps stereo</td>
<td>24 kbps parametric</td>
<td>24 kbps parametric</td>
<td>24 kbps parametric</td>
<td>15 kbps mono</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency</th>
<th>HD-1 32 kbps stereo</th>
<th>HD-2 24 kbps parametric</th>
<th>HD-2 24 kbps parametric</th>
<th>HD-2 24 kbps parametric</th>
<th>HD-2 15 kbps mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>97.9 MHz</td>
<td>Handel_ Music For The Royal Firew (Classical)</td>
<td>Locked Out Of Heaven (Reggae Rock)</td>
<td>The Dream (Jazz)</td>
<td>When I Was Your Man (Pop)</td>
<td>05 Mozart_ Requiem In D Minor, K 626 (Classical Vocal)</td>
</tr>
<tr>
<td>98.0 MHz</td>
<td>Dancing Queen (Euro Disco)</td>
<td>Funkytown (Disco)</td>
<td>Take It Easy (Country Rock)</td>
<td>Daybreak - Overwerk (Electro House).</td>
<td>Shallow Be Thy Game (Alt Rock)</td>
</tr>
<tr>
<td>98.1 MHz</td>
<td>Bohemian Rhapsody (Progressive Rock)</td>
<td>Train Leaves Here This Morning (Folk Rock)</td>
<td>Celebration (Post Disco)</td>
<td>Metallica Enter Sandman (Hard Rock)</td>
<td>Aeroplane (Funk Rock)</td>
</tr>
</tbody>
</table>

Audio clips for demo were processed by Omnia
HD Multiplex
Use cases
HD Mux: Frequency Availability

for illustrative purposes only – data from radio-locator.com
HD Multiplex: Use case #1 - Small Market

• Worldwide, small market stations are increasingly financially challenged.
• Consider a town of 30,000 people, with maybe 3 or 4 FMs, and 1 or 2 AMs - and all of them are struggling.
• The stations could cooperate to create a single station, which carried all of their signals, plus perhaps some expansion.
• The transmission operating costs of the single station could be less than one of the stations alone.
• The extra sites / real estate could be sold.

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HD Multiplex: Use case #2 - Narrowcasting

- Radio used to be the primary entertainment & information audio provider, and stations provided a broad range of content throughout the week.
- Today, with so many content sources, Radio needs the ability to compete with niche, focused content from satellite and the web.
- What's needed is the ability for broadcasters to offer a wide range of formats, without increasing the number of competitors for advertising revenue.
- An example: Foreign language content is very expensive to offer using traditional methods, but this technology changes everything.
With the digitalization of TV, some space is being freed in Band 1, especially from 76 through 88 MHz.

There are efforts underway in some countries to reallocate this band for re-located AM content.

If Radio was able to utilize this bandwidth, it could be planned intelligently, and be used to offer far more content than is available today.

Single frequency networks could be used to offer content extremely cost effectively, to provide wide geographic coverage for a broad range of high quality content.
HD Multiplex: Use Case #4 - Interactivity

Make radio interactive

– Listeners are spread across HD Multiplex streams
– Individual input now counts and is exciting
  • playlists, bombs, games, dedications …
– Meaningful impact compared to online sharing, broadcast immediately
– Participation on mobile devices

Entire HD Multiplex is branded as one

– Air talent and shows are shared
– Each stream dedicated to specific genre
– Playlists are crowdsourced
– Low operating cost of HD Multiplex makes this possible

Example: Station with 100,000 weekly reach

– 10 streams, 10,000 listeners per stream
– 5% active voting participation => 500 participants
HD Mux App: In-Band DAB Alternative

• Maintain band II for its original purpose: VHF Sound Broadcasting
  – Band III can be re-purposed for DVB-T
  – No universal FM switch off is envisioned

• Cap EX and Op Cost lower than DAB
  – Comparable data capacity
    • DAB
    – 1 IBOC transmitter can cover 4 DAB transmitters

• National broadcasts through HD Multiplex SFN

• Hybrid FM+IBOC for local stations

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Frequency Versatility

Band III: DAB/DVB

Band II: HD Multiplex with FM
SFN Capability

- 75 us
- Working on industry standard SFN solution
- TODO: Insert Nautel SFN research
HD Multiplex: How can I try it?

FCC White Space Data Base
“The Commission has adopted rules to allow unlicensed radio transmitters to operate in the broadcast television spectrum when that spectrum is not used by a licensed service. The unused spectrum is often referred to as white spaces and can represent a significant amount of unused spectrum in some areas. Subject to certain rules the spectrum may be used for new and innovative products and services.”

https://www.fcc.gov/encyclopedia/white-space-database-administration

- If channel 6 is free (82-88 MHz):
  - center HD Multiplex at 87.6 MHz (87.3-87.9 MHz)
  - No FM stations are allocated below 88.1 MHz (1 exception in the US)
  - Station A is at 87.5 MHz, Station B is at 87.6 MHz, Station C is at 87.7 MHz

- Apply for experimental license
- Test both technical feasibility and new business models
- Many receivers with European tuning are available for tests
- Nautel GV & VSHD 87.5 to 108 MHz
Your questions please?

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Web: www.nautel.com
Email: sales@nautel.com