A-VSB MCAST Tutorial

NAB 2008
Samsung and
Rohde & Schwarz
Contents

- A-VSB Overview
- Core Technologies
- NAB 2008 Demo
A-VSB Overview
Origin of ATSC Mobile

- 2003: First invention of basic technology
- Nov. 2005: Technology submitted to ATSC
- NAB2006: Showed the feasibility for the first time
- Oct. 2006: Submitted the A-VSB disclosure documents S9
- CES2007: Revealed the first handheld mobile TV on the road
- NAB2007: Demonstrated LIVE Mobile TV with SFN
- CES2008: Demonstrated various CE devices (HHP, MP3P, UMPC, PMP, Laptop PC)
Motivation of ATSC Mobile

No mobility in current broadcasting system
E-VSB falls short of providing mobility
No interactive service

Samsung/ R&S invented The A-VSB Tech

- Improved reception
- Backward compatibility

Digital Terrestrial Versatile Service

- Scalable
- Flexible
- Interactive
- Simulcasting

- Coast to Coast Footprint
- Wide Stream Bandwidth
- Mobility
- Cost effective
- Robustness
Overview

A-VSB MCAST Features

Physical & Link Layers (A-VSB)
- **Power Savings** for Handheld Devices by Burst Transmission
- **Multiple Turbo Streams** for Enhanced Services
- **Flexible Data Rates and Stream Protection Level**
- **Immunity** to drop-outs and burst noise
- **Recently Developed Performance**
  - TU Channel: Doppler **240Hz@20dB**, D-SRS=48 Bytes, 1/ 4 Turbo
  - HT Channel: Doppler **220Hz@20dB**, D-SRS=48 Bytes, 1/ 4 Turbo

Transport Layer (MCAST TS)
- **Quick AV Stream Service by “Primary Service”**
- **Parsimony** 'less is better' on Processing & Data Overhead
  - 7~9% data efficiency gain over conventional TS layer
- **Support for real time, Object, and IP services**
M/H Propagation Challenges

- Mostly Line of Sight
  - 30 ft Receive Ant
  - 10 dBi Ant Gain
  - Line Loss 4 dB

- Lower Ant Ht/Gain
  - constantly changing reception path
  - Nearby objects scattered waves
  - ✓ “Fading”

- Fixed Terrestrial Service
  - “Today”

- Mobile / Handheld Terrestrial Service
  - ✓ “Future M/H Challenges”

- ✓ Shadowing
  - Handheld Reception
Mitigating Mobile Fading

Physical Layer 8-VSB Enhancements
“Mitigate Fading”
Must be Introduced
Backward Compatible Manner
Ways to Mitigate Mobile Fading

✓ Obtain System **Diversity** Gain

Diversity techniques are based on the notion that errors occur in reception when the channel is in a deep fade. If the receiver can use several pieces of the same information signal transmitted over independently fading channels, the error probability will be reduced considerably.

✓ Possible ATSC Diversity Techniques
  - Frequency not option
  - Time
  - Transmitter
    - Antenna

✓ A-VSB Introduces Diversity with **Backward Compatibility**
Core Technologies
A-VSB Cross Layer Design

Core Layer Enables

Tools

UMPC

Phone

Current Standard

Deterministic Frame (DF)
Deterministic Trellis Reset (DTR)

Proposed M/H Standard

* A-VSB Proposed Physical Layer Toolkit

High Definition Quality

A-VSB 8-VSB

DF

DTR

D-SRS

Turbo Codes

SFN

Mobile Hand Held
A-VSB Basis Core Concept

ATSC A/53 VSB Frame

- Fixed Physical Layer Structure
- Fixed Symbol Rate
- Exciter Master (Start of VSB)
- (2) Two Data Field Sync
- 624 Data + FEC Segments
- All Data is Carried Asynchronous with respect to this Structure
- Data is De-Mux PID TS Layer

A-VSB Frame

- Robust Data is Carried Synchronously with respect to VSB Frame Structure
- A-VSB Emission Mux (Master)
- Robust Data De-Mux Physical Layer via the position in Frame (NO PID)
- Enables Cross Layer Design
- Backward Compatible legacy
Deterministic Frame + DTR

- Normal ATSC Multiplexer
  - No knowledge of a frame start packet or ATSC Channel Coding
- Normal ATSC Exciter
  - VSB frame structure in A/53.
  - Independent and arbitrary determination of a start packet in the frame of segments.

- A-VSB Multiplexer (Master)
  - Designation of a start packet in the frame of segments
  - Knowledge ATSC Channel Coding
  - Capability of the trellis encoder state reset
  - Issue of VFIP (VSB Frame Initialization Packet)
- A-VSB Exciter
  - VSB frame structure in A/53
  - Slave to A-VSB Multiplexer

Normal VSB Frame

A-VSB MCAST Deterministic Frame
Deterministic Trellis Reset

- Mux issues the DTR
- Exciter resets the TCM encoder
- Reset at known time and position in VSB Frame

Application of DTR
- Distributed SRS
  - SRS-symbols generation known tracking signal to receivers
- SFN
  - All TCM encoder states synchronized at All transmitters at same instant time
Core Technologies of A-VSB

- Improved Reception in Dynamic Multi-Path Fading Channels
- Operates in a Lower Threshold of Visibility (Mobility)
- Enables Single Frequency Network Implementation

Supplementary Reference Sequence
Scalable Turbo Stream
Single Frequency Network

SRS
STS
SFN

ATSC Enhancement

Operates in a Lower Threshold of Visibility (Mobility) enables Single Frequency Network Implementation, improving reception in dynamic multi-path fading channels and enhancing ATSC performance.
Turbo Stream
Turbo Codes

- Turbo Encoder of **SCCC** (Serial Concatenated Convolutional Codes)
  - Use **Existing TCM encoder** of VSB as Inner Encoder
  - This enables ATSC Turbo Code performance at Physical Layer
  - Coding rate is controlled by Outer Encoder
  - **Iterative decoding receiver gives Diversity Gain**

![Diagram of Turbo Encoder](image)

- Rate = \{1/4, 1/3, 1/2\)
Leverage Time Diversity

Fact Turbo Codes properly implemented offer a good coding gain in Raleigh Fading Channels.

Answer: Propose a Turbo Encoder ATSC M/H Standard that shares the existing inner TCM via **Time Division Multiplexing** in a **backward compatible** manner.
Effective A-VSB Turbo Block Diagram

Turbo Encoder

Robust Data

Outer Encoder

Interleaver

NEW

TCM 1

TCM 2

TCM 12

Existing 8-VSB Inner Code

8 VSB Symbols

Channel

Turbo Decoder

Iterative Decoding Process

TCM 1

TCM 2

TCM 12

8 VSB Symbols

Outer Decoder

DeInterleaver

Robust Data

Soft decision

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By Deterministic Time Division Multiplexing

**Normal** and **Robust** Symbols a “Known Pattern”
Robust Symbols appears in VSB Frame

The Legacy ATSC Receiver treats all Symbols as Normal

**Robust Data** is placed in **AF or Null Packet**
Assures Backward Compatibility

**Conceptual Block**
A-VSB Emission Mux / Exciter Block

A-VSB Mux

A-VSB Exciter
A-VSB Transmission Adapter reserves M/H Data Space Normal TS

-**Turbo Pre-processor**
  - RS Encoder
  - Long time interleaver (1.1s)

-**Outer Encoder**
  - Turbo coding rate: 1/2, 1/3, 1/4
  - SIC coding rate: 1/6

-**Outer Turbo Interleaver**: 24.2 ms Block Interleaver
Overview of MAC

- **Protocol entity for establishing the A-VSB “Core” DF**
  - Under the control of ATSC System Time
  - Create tools such as SRS and enable the efficiency of the A-VSB turbo encoder scheme
  - **Rules for sharing of the physical layer medium** between normal data, turbo data, and SRS
  - Defines an addressing scheme for locating robust data into the DF

- **SIC**
  - Transmit **deterministic frame structure** and Robust Data assignment *(address)*
  - **Robust Coding** *(1/6 turbo coding)* and Known position in every VSB frame
Definition of MAC Unit

- **Track**
  - 4 MPEG data packets
  - Base unit for data mapping structure

- **Sector**
  - Smallest addressable unit of robust turbo data
  - 8 bytes space

- **Cluster**
  - A group of any number of sectors, where a Turbo fragment is placed
### Medium Access Control

- **Inserting VFIP Packet**
  - Communication channel between MUX and Exciter

- **Reserving M/H Data Space**
  - **Highly Flexible Structure for M/H Data**
    - Track: Base unit for data mapping structure. 4 MPEG TS.
    - Sector: Smallest addressable unit. 8 bytes.
    - Cluster: a group of any number of sectors.
  - More opportunity for placing Normal Stream
  - Supporting Burst Transmission

<table>
<thead>
<tr>
<th>Track: 4 MPEG TS</th>
<th>Sector: 8 Byte</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

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Packet Segmentation

- **Data Delivered with**
  - Private data field in AF
  - A/90 data, or other newly defined PID if MPEG data packet is entirely dedicated for data

- **Packet segmentation with Adaptation Field**
  - 22 sectors
  - Sector number 1 reserved for SIC

- **Packet segmentation without Adaptation Field**
  - 23 sectors
  - Sector number 1 reserved for SIC
  - Sector number 2 divided 2 regions (5 and 3 bytes) for Fixed SIC positioning
Physical Layer Signaling

- **DFS + SIC Signaling**
  - DFS (Data Field Sync): Using Primary Service before decoding SIC
  - SIC (System Information Channel): Support Multi Turbo Stream
- **SIC Signaling**

  **SIC**
  - frame group information
  - version indicator information
  - additional service information
  - Padding
  - CRC

  **turbo channel information**

  - number of turbo channel
  - mode of each turbo channel
    - coding rate
    - data rate
    - position
    - burst transmission
    - AL-FEC
    - time interleaver
    - training
### Data Mapping (1/2)

#### Data Mapping Representation Format

<table>
<thead>
<tr>
<th>1 bit</th>
<th>7 bit</th>
<th>6 bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode</td>
<td>Start Point</td>
<td>Amount of Sector</td>
</tr>
</tbody>
</table>

- Adaptation(0) or Full(1)
- Sector, Y (5bit, 2bit)

#### Mapping Example 1

<table>
<thead>
<tr>
<th>A-VSB MCAST data</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>1 bit</th>
<th>7 bit</th>
<th>6 bit</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0)</td>
<td>Start Sector (2, 0)</td>
<td>Amount of Sector (12)</td>
</tr>
</tbody>
</table>

- Adaptation(0) or Full(1)
- Sector, Y (5bit, 2bit)

#### SIC

- frame group information
- version indicator information
- additional service information
- Padding
- CRC
- turbo channel information
Data Mapping with SRS (2/2)

- Sectors used to map the SRS placeholders 0, 6, 7, 10, 14 sectors (Sector = 8 Bytes)

- Distributed SRS Mapping Example

<table>
<thead>
<tr>
<th>M</th>
<th>AF</th>
<th>SIC</th>
<th>SRS</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>H</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>H</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>

AF Header: 5 bytes

3 byte

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Medium Access Control

- **Track Mapping Example**

<table>
<thead>
<tr>
<th>Header</th>
<th>SIC</th>
<th>SRS(0/1/10/14 sector)</th>
<th>Turbo</th>
<th>Normal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Normal</td>
</tr>
</tbody>
</table>

- **Transmission Scheduling**
  - Burst Period: Up to 256 VSB frame (12.3s)
  - Burst Period = Burst Duration => Continuous mode
  - Continuous SIC: Fast Channel Acquisition
A-VSB Multiplexer

PSI/PSIP for Normal Stream → Service Mux → Normal TS → A-VSB Transmission Adapter → randomize → Turbo Data Stuffer → De-randomize → To A-VSB exciter

A/V MPEG Codec

Turbo Post Processor

MCAST stream_1 → Turbo Pre-processor → Outer Encoder → Outer Interleaver

MCAST Service Mux

SIC data → RS encoder → Outer Encoder → Outer Interleaver

SIC

Advanced A/V Codec

IPs

Objects

Advanced A/V Codec

IPs

Objects

Signaling Info

Signaling Info

Objects

Multi-stream Data De-Interleaver
- **MCAST stream**
  - Used for Turbo stream
- **Randomizer**
  - Randomizer of VSB
- **RS encoder**
  - (208,188) RS encoder
- **Time interleaver**
  - Long time interleaver

Deep Inter-leaver
~ 1.1 Second

Time Diversity
“Mitigate Fading”
Turbo Post Processor

- **Outer Encoder**
  - RSC (Recursive systematic convolutional) Encoder
- **Outer Block Interleaver**
  - Bit Interleaver
- **Multi-stream Data De-interleaver**
  - Data De-interleaver
  - Compensates A/53 Data Interleaver which exists between Outer Encoder and TCM encoder for SCCC

![Diagram of Turbo Post Processor](image)
Coding rate is controlled by outer encoder

- Supporting coding rate: 1/6, 1/4, 1/3, 1/2
  - 1/6: In (D0) => Out (D0, D0, Z1, Z1, Z2, Z2)
  - 1/4: In (D0) => Out (D0, Z1, Z2, Z3)
  - 1/3: In (D0) => Out (D0, Z1, Z2)
  - 1/2: In (D0) => Out (D0, Z1)
Design Reduces A-VSB Receiver Complexity

Negates Legacy Randomizer For Robust Only

Negates Legacy Byte & Symbol Interleaver Robust Only

A-VSB receiver Ignores Legacy RS
Novelty A-VSB Turbo Streams

Normal ATSC Receiver (Decodes ALL Symbols)

Normal TS 19.4 Mbps

Note: Normal Path shown for reference not part of A-VSB receiver

~4 dB AWGN

A-VSB Receiver (Decodes Only Robust Symbols)

Robust TS

---

Novelty A-VSB Receiver

Turbo Decoder (FEC) Physical Layer

Tuner -> IF -> A/D -> Demod EQ -> Turbo Decoder

Pre-Process Decoder -> De-Random (Robust)
Turbo Transmission Modes

- Each Turbo Stream can occupy multiple sectors according its data rate and coding rate
- Multiple Turbo Streams Possible

<table>
<thead>
<tr>
<th># of MCAST packets in package (NT)</th>
<th>Turbo TS Rate (kbps)</th>
<th>Normal TS Loss (kbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/2 (sector)</td>
<td>1/3 (sector)</td>
</tr>
<tr>
<td>3</td>
<td>186.45</td>
<td>825.12 (4)</td>
</tr>
<tr>
<td>4</td>
<td>248.60</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>372.89</td>
<td>825.12 (4)</td>
</tr>
<tr>
<td>8</td>
<td>497.19</td>
<td>1,650.25 (8)</td>
</tr>
<tr>
<td>9</td>
<td>559.34</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>745.79</td>
<td>1,650.25 (8)</td>
</tr>
<tr>
<td>16</td>
<td>994.38</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1,118.68</td>
<td>2,475.37 (12)</td>
</tr>
<tr>
<td>24</td>
<td>1,491.57</td>
<td>3,300.50 (16)</td>
</tr>
</tbody>
</table>
Supplementary Reference Sequence
A-VSB Distributed SRS

Current Standard

Deterministic Frame (DF)
Deterministic Trellis Reset (DTR)

Core Layer
Enables

Tools

A-53 8-VSB

DF

DTR

D-SRS

Turbo
Codes

SFN

Mobile
Hand
Held

Proposed
M/H Standard

A-VSB Proposed
Physical Layer Toolkit
Supplementary Reference Sequence

- **SRS Featured ATSC Transmitter**
### Distributed SRS

<table>
<thead>
<tr>
<th>SYNCH</th>
<th>Header</th>
<th>Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYNCH</td>
<td>Header</td>
<td>Payload</td>
</tr>
<tr>
<td>SYNCH</td>
<td>Header</td>
<td>Payload</td>
</tr>
<tr>
<td>SYNCH</td>
<td>Header</td>
<td>Payload</td>
</tr>
</tbody>
</table>

1 byte 3 bytes 184 bytes

**Adaptation Field**

- Private data field

<table>
<thead>
<tr>
<th>SYNCH</th>
<th>Header</th>
<th>AF Header</th>
<th>Private Header</th>
<th>SIC</th>
<th>SRS</th>
<th>Payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYNCH</td>
<td>Header</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYNCH</td>
<td>Header</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYNCH</td>
<td>Header</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYNCH</td>
<td>Header</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2 bytes 3 bytes 8 bytes \{48, 80, 112\} bytes 171 - \{48, 80, 112\} bytes

1 byte 3 bytes 184 bytes
- Various Reference Signal Lengths
  - Flexible for applications
  - 0, 6, 7, 10, 14 sector (Sector = 8 Bytes)

- Enhancing Adaptive Equalizer Performance
  - Enhancing Doppler shift
  - Enhancing Normal Stream
Parity Correction for SRS
- Some bits change values after DTR for SRS
  → Need RS Re-Encoding for Backward Compatible with legacy receiver
- Processor
  - Gathering the Packet Data after DTR
    → RS Re-Encoding
    → Exchange the new parity
- Method
  - Distributed SRS: Erasure RS Encoding
A-VSB Frame D-SRS
- 1 SRS symbol per 4 symbols
- SRS exist in all segments

<table>
<thead>
<tr>
<th>Mode</th>
<th>Mode</th>
<th>Mode</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>1.37</td>
<td>1.58</td>
<td>2.20</td>
<td>3.03</td>
</tr>
<tr>
<td>Mbps</td>
<td>Mbps</td>
<td>Mbps</td>
<td>Mbps</td>
</tr>
</tbody>
</table>

Mode 0 = Off

Trade BW vs. EQ Dynamic Tracking Performance
SRS Burst Transmission

- For Data Rate Efficiency, SRS Burst Transmission is applied
Single Frequency Network
A-VSB Transmitter Diversity

Current Standard

Deterministic Frame (DF)
Deterministic Trellis Reset (DTR)

Proposed M/H Standard

D-SRS
(1)²

Mobile Hand Held

Turbo Codes
(2)²

SFN
(3)²

Tools

Core Layer Enables

A-53 8-VSB

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A-VSB Single Frequency Network

Transmitter Diversity

Mobile Reception

Handheld Reception
A-VSB SFN

- **Low Complexity** SFN Solution (DF, DTR)
- **Scalability** (1 VFIP No limit # Transmitters)
- **Extensibility**
  - ATSC System Time Support
  - Support Handoff SFN/ SFN/ MFN
  - SFN Translator Network

HDTV
M/H
Content

Emission Mux

Distribution Network

GPS Time 10MHz 1PPS

A-VSB Exciter

PA

TS w/ VFIP

GPS Time 10MHz 1PPS

PA

A-VSB Exciter

TS w/ VFIP
A-VSB Transmitter Diversity

Multiple signal arrival directions
Uncorrelated Fading

Urban Indoor
Building Penetration Loss

Higher Probability Indoor M/H Service

Log Normal (Shadow) Fading
Help Mitigate Fading
Enabling M/H Interoperability

- Global VSB Framing Reference
  - Across all Stations SFN/ MFN
  - VSB frames Aligned Air Interface
  - Select Robust Content Aligned
- Enable Future
  - Enhanced Handoff
  - Positioning
  - Location Based Services
Concept M/H Handover

- **One Tuner Solution**
MCAST
**MCAST (Mobile Casting)**

- Transport & Signaling Layer of Turbo data
- Support IP Datacasting
- Complete integration of IP based broadcasting and Rich media system (SVG)
- Providing application or physical based burst transmission mechanism
MCAST

- **Processing Flow of the A-VSB MCAST**

  - Turbo extraction
  - Initial Fast Access
  - SIC (Signaling Information Channel)
  - Select Turbo Channel
  - MCAST Demux
  - App Processing

- **Fast Access Information** is possible without ESG Ex) service guide information, primary channel

- Signaling information are carried over only two adjacent VSB frames

- Multi turbo stream information are contained

- Providing **Flexibility in time slicing granularity**

- Indicating the exact location of the specified IP within every MCAST parcel (624 TS packets) : LMT (Location Map Table)

- Provides IP tunneling mechanism

- Low overhead and easy to encapsulate various IP based services
IP based services

- Easy to bind with various IP based services.
- Provides low overhead and general mechanism for mapping IP based services
- AVSB-MCAST-OMA-BCAST demo is available on NAB
NAB 2008 Demo
### End to End Solution for ATSC Mobile

#### Rich media service
- Now available in NAB

#### Contents Packaging & Delivery
- **Service Solution**
- **Service / Application Layer**
  - IP based service (Ex. OMA BCAST)
  - Rich Functionality
  - Proven Solution
- **Link & Transport Layer**
  - MCAST (IP Service, MCAST TS Based Natural A/V)
  - IP for Interactive Service
  - MCAST TS for Efficient Conventional Live TV
- **Physical Layer**
  - SRS
  - SFN
  - STS
  - Proven Backward Compatibility
  - Most Efficient & Optimized Technology
- **Equipment**
  - Multiplexer
  - Exciter
  - Already Available

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A-VSB Initiative at NAB 2008

- A-VSB Initiative Booth at Central Hall (C1539)
- A-VSB Initiative Mobile Demonstration (Renaissance Hotel)
Configuration of NAB 2008 Demo

- Location 1 (KVMY): Local Contents, Contents Authoring & Packaging
- Location 2 (KBLR): Local Contents, Contents Authoring & Packaging
- Contents Authoring & Packaging
- MUX
- STL (Microwave)
- SES AMERICOM
- National Contents
- Interactive Solution
- ROHDE & SCHWARZ
- SAMSUNG
- mobitv
Thank you!