ATSC & ISDB-T TRANSMISSION SYSTEMS

GUY BOUCHARD, CBC / RADIO-CANADA NEW BROADCAST TECHNOLOGIES

Dec 3rd 2013
OUTLINE

• Emission Mask Measurement
• Digital Transmission Fundamental
• Transport stream management
• Mobile television
• Video Compression
# Standards Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>ATSC</th>
<th>DVB-T</th>
<th>DVB-T2</th>
<th>ISBD-T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupied Bandwidth</td>
<td>6</td>
<td>6,7,8</td>
<td>1,7 to 10</td>
<td>6, 7 MHz</td>
</tr>
<tr>
<td>Number of carriers</td>
<td>1</td>
<td>1705 or 6817</td>
<td>1k to 32k</td>
<td>1405, 2809 or 5617</td>
</tr>
<tr>
<td>Guard Interval</td>
<td>1/32 to 1/4</td>
<td>¼ to 1/128</td>
<td>1/32 to ¼</td>
<td></td>
</tr>
<tr>
<td>Equalizer window</td>
<td>Resource dependant</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Data range</td>
<td>19.38</td>
<td>31.7</td>
<td>40</td>
<td>23 Mb/s</td>
</tr>
<tr>
<td>C/ N threshold for 24 Mb/s</td>
<td>16.7</td>
<td>10.8</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Mobility</td>
<td>Clumsy</td>
<td>Good</td>
<td>Excellent</td>
<td>Excellent</td>
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</table>
EMISSION MASK MEASUREMENTS
INTRODUCTION

➢ The measurement of the emission mask of any systems with intrinsic energy dispersal is challenging because of:
  ▪ The difficulty of establishing a reference
  ▪ The test equipment can’t provide you with a plug and play answer
  ▪ The dynamic range required far exceed the spec of all spectrum analyzer on the market
  ▪ The tests cannot be taken at any level
SCOPE

- **Background:**
  - The ubiquitous spectrum analyzer
  - Energy dispersal issues
  - Dynamic Range issues

- **The emission mask**
  - In-Channel measurement
  - Adjacent channel measurements

- **The measurements**
  - Establishing a Reference
  - Shoulder measurements
  - Distant measurements
    - Band stop method
    - Emission mask filter method

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SPECTRUM ANALYZER ARCHITECTURE
ENERGY DISPERSAL ISSUE

- The SA sees only one resolution at the time
- Look at the pilot to signal ratio
- Double the resolution
- Look at it again, it is 3 dB lower, why?
- The real channel power has to be corrected by a factor of 10

\[
\log(\text{edbw}) - 10 \log(\text{rbw})
\]

* Normally a EDBW/RBW ratio of at least 20 is required to ensure a usable spectrum display, 50 is ideal

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THE DYNAMIC RANGE ISSUE

The required dynamic range required is in excess of 120 dB

This creates 2 issues:

- The input level must be optimized to get the most dynamic range of the SA
- The in-channels can be taken, however the adjacent channels are meaningless
DYNAMIC RANGE

Specifications
Dynamic Range

Signal-to-Noise Ratio Can Be Graphed

Displayed Noise in a 1 kHz RBW

Displayed Noise in a 100 Hz RBW

Power at Mixer = Input - Attenuator Setting dBm

Agilent Technologies

Spectrum Analyzer Basics
The Net Result

- The sole fact that the Spectrum analyzer display a result doesn't mean it is a credible one.
TYPICAL SPECTRUM DYNAMIC RANGE

-70 dBc (nominal)
-55 dBc (nominal)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Description</th>
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<tbody>
<tr>
<td>Average noise level</td>
<td>-113dBm + 2 f (GHz) dB</td>
</tr>
<tr>
<td></td>
<td>(RBW 1kHz, VBW 10Hz, ATT 0dB, f ≥ 1MHz)</td>
</tr>
<tr>
<td>1dB gain compression</td>
<td>&gt;-5dBm (Mixer input level, f ≥ 20MHz)</td>
</tr>
<tr>
<td>Secondary harmonic distortion</td>
<td>≤-70dB (f ≥ 10MHz, Mixer input level -30dBm)</td>
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<tr>
<td>Two-signal third order</td>
<td>intermodulation distortion ≤-70dB (f ≥ 10MHz, Mixer input level -30dBm)</td>
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<tr>
<td></td>
<td>Frequency difference between 2 signals</td>
</tr>
<tr>
<td>Other spurious factors related to the</td>
<td>≤-60dB (Offset ≥ 20kHz, Mixer input level -30 dBm)</td>
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<tr>
<td>input</td>
<td></td>
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<tr>
<td>Residual responses</td>
<td>≤-100dB (f ≥ 10MHz, ATT -0dBm, Input termination with 50Ω)</td>
</tr>
</tbody>
</table>

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DYNAMIC RANGE VARIES WITH LEVEL

How can you know we are attacking the Spectrum analyzer at the correct level:

- If it is driven to high, the intermod your are trying to measure will be originated by the front end of the SA.
- If it is driven to low, the intrinsic noise of the unit will mask most of what you are trying to measure.

Procedure to find the optimum level:
OPTIMAL DRIVE LEVEL

• You can use your ISDB-T signal to assess intermods
  • Measure the level of intermod produced by your TX
  • Try to attack the spectrum analyzer at a low level (-30 to -40 dBm)
  • Raise level until the intermod has risen by about 5 dB
  • Back off 6 dB, you should be close to the optimum

• Can the sniffer you need to use deliver the optimum level?
THE ATSC EMISSION MASK

(Based on a 500 kHz RBW)
ATSC emission mask (based on 100 kHz RBW)

Freq from channel center (MHz)

Relative level (Db DTV)
**BRAZILIAN EMISSION MASK**

<table>
<thead>
<tr>
<th>Difference from carrier frequency</th>
<th>Minimum attenuation in relation to average power measured at carrier central frequency</th>
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<tbody>
<tr>
<td></td>
<td>Non-critical mask</td>
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<tr>
<td>±2.86 MHz</td>
<td>20.0 dB/10kHz</td>
</tr>
<tr>
<td>±3.00 MHz</td>
<td>27.0 dB/10kHz</td>
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<tr>
<td>±3.15 MHz</td>
<td>36.0 dB/10kHz</td>
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<tr>
<td>±4.5 MHz</td>
<td>53.0 dB/10kHz</td>
</tr>
<tr>
<td>±9.0 MHz</td>
<td>83.0 dB/10kHz</td>
</tr>
<tr>
<td>±15.0 MHz</td>
<td>83.0 dB/10kHz</td>
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</tbody>
</table>
ISDB-T EMISSION MASK

Fig. 4-1  Transmission-spectrum limit mask for digital terrestrial television broadcasting

Table 4-1  Breakpoints for transmission-spectrum mask

<table>
<thead>
<tr>
<th>Difference from the center frequency (MHz)</th>
<th>Attenuation relative to average power P (dB/10 kHz)</th>
<th>Type of stipulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>±2.79</td>
<td>-27.4</td>
<td>Upper limit</td>
</tr>
<tr>
<td>±2.86</td>
<td>-47.4</td>
<td>Upper limit</td>
</tr>
<tr>
<td>±3.00</td>
<td>-54.4</td>
<td>Upper limit</td>
</tr>
<tr>
<td>±4.36</td>
<td>-77.4*</td>
<td>Upper limit</td>
</tr>
</tbody>
</table>
HIGHLIGHTS:

Rather high noise floor -77 dB DTV
Shoulder at -30 dB DTV (similar to ATSC)
Reference point -27 dB down
Normalized bandwidth at 10 kHz (a practical value)
MEASUREMENTS

- In-Channel measurement
- Optimize input level
  - Start at –20 dBm raise R level until intermod level diminished more than the attenuation provided
  - Establish 0 dB DTV reference (Bar level + 10 log(edbw/rbw))
- Verify the shoulder level

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There is an issue with the dynamic range of the spectrum analyzer, the best spectrum analyzer on the market have about 70 to 80 dB of usable dynamic range. The adjacent channel measurements requires about 100 to 120 dB of dynamic range

Mitigation technique have to be used
OPTION A – USE A BAND-STOP FILTER

- A single piece of test Equipment is required SA
  - The filter cannot be used 500 kHz from the channel edge
  - Requires Judgment and expertise
  - Preclude the measurement of the harmonic response
OPTION A – USING A STOP BAND FILTER (WIDE NOTCH)
AMPLITUDE RESPONSE REQUIRED FROM

Zero Loss

0dB + AdB

-10dB + A_{dB}

-20dB + A_{dB}

-30dB + A_{dB}

-40dB + A_{dB}

-46dB + A_{dB}

A_{dB} < 3dB

±5.0 MHz

±2.5 MHz

±3.0 MHz

Fo = Center of the Channel to be Measured

Note: The Attenuation at the edge of the pass band can be any value, A dB up to 3dB at Fo ±9 MHz. However, the required stop-band attenuation is increased by A dB to compensate for the required signal power increase caused by the filter's loss.
TYPICAL RESPONSE

Analyzer's Noise Floor
Analyzer's Spurious Intermodulation Products
FCC Full Service Mask
Transmitter's Actual Response (Without Filter)
Measured Response After the Filter
Band Stop Filter's Amplitude Response

Analyzer's
Spurious
Intermodulation
Products

Lower
Band Edge

Upper
Band Edge

Band Stop Filter's
Amplitude Response
MEASUREMENT FILTER =/- 1 K

NEW PRODUCT RELEASE
DTV Mask Emission Test (Bandstop) Filters

Choose from one of two new model filters offered by MFC - specifically designed for use as the bandstop test filter described in the IEEE Broadcast Technology Society’s preferred test method (#2) from their document “Practice for Measurement of 8-VSB Digital (US) Television Mask Compliance”.

<table>
<thead>
<tr>
<th>Model</th>
<th>Test Channel (Fc)</th>
<th>Center Frequency Option</th>
<th>Stopband</th>
<th>Filter Performance</th>
<th>Stopband</th>
<th>Passband</th>
<th>DTV Mask Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>16150-(ch)</td>
<td>(54–806) MHz</td>
<td>Fc ± 2.5 MHz</td>
<td>49 dB [Min.]</td>
<td>Fc ± 3 MHz</td>
<td>43 dB [Min.]</td>
<td>Fc ± 5 MHz</td>
<td>3 dB [Max.]</td>
</tr>
<tr>
<td>16560-(ch)</td>
<td>(54–806) MHz</td>
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The information pertaining to these bandstop test filters is as follows:
OPTION B - TAKE PRE EMISSION MASK FILTER MEASUREMENTS AND CORRECT FOR IT -
OPTION B - TAKE PRE EMISSION MASK FILTER MEASUREMENTS AND CORRECT FOR IT

- 2 Instruments are required: a network analyzer and a Spectrum Analyzer
  - The measurement has to be taken on a hot filter to preclude drift error
  - Requires Judgment and expertise
  - Preclude the measurement of the harmonic response, beware of overmoded coupler
IN PRACTICE

Channel Filter Response

Transmitter Before Channel Filter

Transmitter After Channel Filter (limited by instrument's noise floor)

Computed Response After Channel Filter

Frequency, MHz

dB\textsubscript{DTV}
MATHEMATICAL PROCESSING

Filter response

Emission Mask Measurement (method B)

Attenuation (dB DTV)

Relative freq (MHz)

Attenuation (dB)

Relative freq (MHz)
2ND HARMONIC MEASUREMENTS

- Coupler are a wavelength sensitive device
- At the second harmonic all classic sniffers will be overmoded and will no longer offer a reliable coupling ratio.
CONCLUSION

- Emission mask measurements are tricky
- Test equipment dynamic range is quite an issue
- Results cannot be taken directly from spectrum analyzer
- 0 DB DTV reference has to be established first
- Use filter wisely
- 2\textsuperscript{nd} harmonic measurements cannot be taken from a sniffer
DIGITAL TRANSMISSION
Why convert in digital?

- Better
  - Qualité
  - Spectral efficiency
  - More rugged coverage
  - System integration
Typical Digital Transmission System

Signal Conditioning → A/D → Compression → Coding → Multiplex → Modulation

Clock recovery → DeMux → Decode → De-Compres → D/A

Medium

Clock
To be successful in digital transmission you have to be smarter than the average bear.
**What is coding:**
Using a code to transfer a message

**Example:**
The catcher and Pitcher are exchanging
- Coded messages so the catcher knows
- what type of Ball to expect
Why Coding?

- Lower the binary rate
- Avoid conflicts
- Alleviate the weight of errors
- Ensure message privacy
Coding Binaire

- Ex: gray Code

- Characteristics:
  - All adjacent symbols vary from Only one bits

- Advantages:
  - Alleviate the impact of errors
  - Ex:
    - Binary: 7 is (0111) and 8 is (1000) [4 bits changed]
    - Gray: 7 is (0100) and 8 is (1100) [1 bit changed]
Imagine that your employer pay system has underwent a burst of error that suddenly changed your paycheck from XXXX $ a 9999$

Sadly a temporal mixing technique called interleaving will distribute the errors on time, so four happy employee will have one of the digit of their paycheck canged to 9
The Bursty Nature of Errors

Amplitude vs Time

- Bursty nature of errors indicated by spikes in amplitude over time.
- Time ranges from 5 to 61, with specific spikes at 21 and 25.
Interleaving

The cards are distributed in orderly stacks: 1, 2, 3, 4, 5

2,000,000 cards

PRBS
999
3
445
227
784

The stacks are then serialized by being picked-up using a pseudo-random sequence

2000 stacks of 1000 cards
Inter-décalage

The cards were distributed in orderly stacks: 1, 2, 3, 4, 5

2,000,000 cartes

Serialized and de-serialized using a common pseudo random Sequence

2000 stacks of 1000 cards
The burst of error is then spread on the length of the interleaver.

So 4 employees will have one of the digit of their paycheck changed to 9.

Another technique called FEC will finalize the process and eliminate the errors caused by the burst of errors.
Interleaving

Write in Rows

Shift register

RF Media

Shift register

Transmis en colonnes

Reads in rows
Forward Error Correction

- But: Transmitt startegic codes aimed to reconstruct the signal at the other end

- Types:
  - Viterbi
  - Reed Solomon
  - TCM

- Best results tends to be
- achieved with 2 concatenated layers of coding
Convolutional Interleaving

From Trellis Decoder

(B-1)M

To Reed-Solomon Decoder

M=4, B=52, N=208, R-S Block =207, BXM=N
Error corrector

Input variable BER

Error Corrector

Corrected output constant low BER
Typical performance of FEC

Error Corrector System Performance

BER at the input of the error Corrector

BER at the output of the Error Corrector
How does FEC gets inserted?

- By adding the overhead bistream before the interleaver.
- The FEC ratio actually represent the share of the payload in an FEC augmented bitstream
  - 1/2 50% means that 50% of the data is payload 50% F
  - 3/4 75% of the data is payload 25% is FEC
  - 7/8 87.5% of the stream is data 12.5% FEC
  - ¼ means that 25% of the stream is payload and 75% FEC
A maximum likelihood decoder, applies a mathematical process that permits to detect and correct errors at the bit level, based on the highest probability of error.

For tutorial purposes we will explore a simple but effective FEC scheme, obviously today's FEC schemes are much more efficient.
Imagine a bit block of 64 bits, augmented by the sum of each rows and columns: $64 + 2 \times (3 \times 8) = 112$ Bits

<table>
<thead>
<tr>
<th>Data</th>
<th>Sum</th>
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<tbody>
<tr>
<td>1 1 0 0 1 1 1 1</td>
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<td>1 1 1 0 1 1 1</td>
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</tbody>
</table>

$s$ 1 1 1 0 1 1 1 1
$u$ 0 0 0 0 0 0 0 0
$m$ 1 0 1 1 0 0 1 1
Oops an error took place in the payload section

<table>
<thead>
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<th>Data</th>
<th>Sum</th>
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<tbody>
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<td>1 1 1 0 1 1 1 1</td>
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</table>

Toujours septique, essayons insérer l’erreur sur l’une des sommes
### FEC

**In the Sum section…**

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*all OK!*
The case of 2 errors

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### FEC

2 errors of the worst kind

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<td></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

s 1 1 1 0 1 1 1
u 0 0 0 0 0 0 0
m 1 0 1 1 0 0 1

%?* ….
In this case we can affirm that our FEC scheme will correct all errors in the block provided they don't exceed one error per block: 1/112 soit un TE de 8 E –3 knowing this we better use an interleaver that is at least 112 bits long.
Families of Modulations

- **DSB Double Sideband**
- **DSB Double Sideband**
  - With supressed Carrier
- **SSB-SC Single Sideband**
  - With Partially Suppressed carrier

For DVB modulations, the bandwidth to transmit one symbol is 1 Hz, in the case of SSB, the required bandwidth falls to $\frac{1}{2}$ Hz.
Phase Modulation (QPSK)

Satellite 101

Code 2 Bit /Hz

C/N requirement: 5 dB approx. at 2/3 rate FEC
requires tandem intermod 25 dBC
Phase Modulation (8PSK)

Constellation

Edge Factor

Modèle Spectral

Code 3 Bit /Hz

C/N requirement: 7 dB approx. at 2/3 rate FEC

requires tandem intermod 25 dBC

Porteuse suprimée
AMPLITUDE MODULATION

8VSB

Code 3 Bit /Hz

C/N requirement: 716dB approx.. at 2/3 rate FEC requires tandem intermod 25 dBC

Porteuse supprimée

1/6th IR

C/N

Modèle Spectral
Linearization

\[ \text{Signal d'entrée} + \text{Réponse du PA} = \text{Résultat} \]

\[ \text{Signal d'entrée pré-distorsioné} + \text{Réponse du PA} = \text{Résultat} \]
Intermods

![Graph showing close-up of satellite signal with 71 dBc annotation.](image-url)
Satellite 101

Amplifier

Gain Linéaire $g_a$

Pré-correction manuelle

Signal d'entrée

Sortie $I = (g_a k_0 \sin(A) + g_a k_0 \sin(B)) +$

Linéaire

$K_1 \sin(A + B) + K_2 \sin(A - B) + K_3 \sin(2A - B) + K_4 \sin(A + 2B)....$

Non-Linéaire

Pré-correction automatique et fine tuning manuel

General specs: $IMD = 2 \times (OPBO) - 16 \text{ dB}$

Signal d'entrée

Mer > 36 dB

Mer > 28 dB

wo pre-cor

avec pre-cor
Linearization

Parfaite

Compression

Sur-correctée
POWER MEASUREMENTS

-20 dBm

RBw 30 kHz

28/12/2013
Guy Bouchard, CBC
ATSC POWER MEASUREMENT

We can read the power of an energy dispersed carrier by adding the following correction factor

- $10 \log (\text{EDBw}) - 10 \log (\text{res bw})$
- $10 \log (5.38 \times 10^6) - 10 \log (\text{res bw})$

- An amplitude marker on top of the waveform shows -20 dBm, the analyzer is running at a resolution bandwidth of 30 kHz

- Puiss: $-20 + 10 \log (5.38 \times 10^6) - 10 \log (3 \times 10^4)$ = 2.53 dBm
- On peut aussi utiliser la fonction power Window de l’analyseur
Parameters for VSB Transmission Modes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Terrestrial mode</th>
<th>High data rate mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel bandwidth</td>
<td>6 MHz</td>
<td>6 MHz</td>
</tr>
<tr>
<td>Excess bandwidth</td>
<td>11.5%</td>
<td>11.5%</td>
</tr>
<tr>
<td>Symbol rate</td>
<td>10.76 Msymbols/s</td>
<td>10.76 Msymbols/s</td>
</tr>
<tr>
<td>Bits per symbol</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Trellis FEC</td>
<td>2/3 rate</td>
<td>None</td>
</tr>
<tr>
<td>Reed-Solomon FEC</td>
<td>T=10 (207,187)</td>
<td>T=10 (207,187)</td>
</tr>
<tr>
<td>Segment length</td>
<td>832 symbols</td>
<td>832 symbols</td>
</tr>
<tr>
<td>Segment sync</td>
<td>4 symbols per segment</td>
<td>4 symbols per segment</td>
</tr>
<tr>
<td>Frame sync</td>
<td>1 per 313 segments</td>
<td>1 per 313 segments</td>
</tr>
<tr>
<td>Payload data rate</td>
<td>19.28 Mbps</td>
<td>38.57 Mbps</td>
</tr>
<tr>
<td>NTSC co-channel rejection</td>
<td>NTSC rejection filter in receiver</td>
<td>N/A</td>
</tr>
<tr>
<td>Pilot power contribution</td>
<td>0.3 dB</td>
<td>0.3 dB</td>
</tr>
<tr>
<td>C/N threshold</td>
<td>14.9 dB</td>
<td>28.3 dB</td>
</tr>
</tbody>
</table>
ATSC FRAME STRUCTURE

- **4** symbols
- **828 Symbols**
- **313 Segments**
- **Field Sync #1**
- **Data + FEC**
- **Field Sync #2**
- **Data + FEC**
- **1 Segment** = 77.3 μs
- **24.2 ms**
ATSC SEGMENT

Levels Before Pilot Addition (Pilot=1.25)

+7
+5
+3
+1
-1
-3
-5
-7

Data Segment SYNC

4 Symbols

828 Symbols
207 Bytes

Data + FEC

Data Segment

832 Symbols
208 Bytes
DATA SEGMENT

ONE DATA SEGMENT (832 SYMBOLS - 208 BYTES)

ONE DATA FIELD (313 SEGMENTS)

FIGURE 3: ATSC BASEBAND DATA FIELD
PEAK TO AVERAGE RATIO
ADAPTIVE TAP EQUALIZER

Aimed at removing unwanted Multipath components
Based on the impulse response of known part of the signal
Synthetize and cancel known undesired multipath components
The length of the equalizer is resources dependent and vary from -20 uS to 120 us
Beware that the speed of light is 3.16 us per km
INTERFERENCE ISSUES

- Static multipath is no longueur an issue for ATSC receivers neither should it be for ISDB-T
- Overload is often the issue, beware the overload may be out of band
  - Active antennas may be saturating as their input circuit is fairly wideband
  - Digital demods are sensitive to:
    - Image frequency
    - Microphonics
  - Multiple Receive antennas are an efficient work-around as the receiver may not see part of the signal due to multipath, Giving the equalizer more meat to deal with is often a good measure.
ADAPTIVE EQUALIZER
TRANSPORT STREAM MANAGEMENT
**SIGNAL LEVEL**

- **Visual layer**
- **Baseband layer**
- **Transport layer**
- **RF layer**

**Layers and Formats**

- Pixels
- SDI
- MPEG
WHAT IS A TRANSPORT STREAM?

A transport stream is a formatted data stream aimed at carrying compressed broadcast signals in a fully addressable format.

A Transport Stream is a logical entity carried on a Physical layer.
TRANSPORT STREAMS

Transport streams are the vehicle over which the necessary information is multiplexed to allow a receiving device (ex: an ATSC receiver) to fully decode a compressed service including:

- Video
- Audio
- Caption
- Navigational Information (ex: program guide)
Transport streams are mostly carried on the following Physical layer:

- **SMPTE-310**
  - relies on a coax transmission system based on a synchronous feed @ 19.39 Mb/s

- **DVB-ASI**
  - DVB-ASI relies on a coax transmission based on a subset of the SDI specification. The signal is always transmitted @ 270 Mb/s. However a clever stuffing protocol permits transmission from 1 to 214 Mb/s.

- **Ethernet**
  - The Ethernet physical layer can be used to carry encapsulated MPEG transport stream
SMPTE-310

Coax interface

SDI like signal (800 mV p-p)

Polarity sensitive

Synchronous @ 19.392658 Mb/s
**DVB-ASI**

Coax interface

SDI like signal (800 mV p-p)

Polarity sensitive

Synchronous @ 270 Mb/s

Stuffed for the difference between the payload (1 to 218 mb/s and 270 mb/s)
ETHERNET

Ethernet

- IP mostly relies on Unshielded Twisted Pair (UTP, or cat-5) cable.
  Transport streams are encapsulated in 1388 bytes packets, carried mostly as UDP traffic.
BASIC ENCODING TECHNIQUES

Non Return Zero – NRZ – low voltage=0, high voltage=1
Good for slow speed data links, Very susceptible to interference
Manchester encoding – voltage transitions (low > high=1, high<low=0) - Good for 10BaseT Ethernet
MONITORING THE ENTIRE NETWORK

Local Broadcast centers → Carrier 1 → Technology switch → Diverse control network → Management Console → Regional Broadcast centers
## TS ON IP

Typical TS over IP implementation, we encapsulate 5 or 7 MPEG packets per IP packets

<table>
<thead>
<tr>
<th>IP</th>
<th>UDP</th>
<th>RTP</th>
<th>n * 188 bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 bytes</td>
<td>8 bytes</td>
<td>12 bytes</td>
<td>40 + n * 188 bytes</td>
</tr>
</tbody>
</table>

**UDP header**

- V = Version (RTP = 2)
- P = Padding
- X = Extended Header
- M = Marker bit

<table>
<thead>
<tr>
<th>V</th>
<th>P</th>
<th>X</th>
<th>CSRC count</th>
<th>Payload Type</th>
<th>Sequence Number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CSRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>count</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CSRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>count</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CSRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>count</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Timestamp
- Sync Source (SSRC)
- First Contributing Source (CSRC)
- nth Contributing Source (CSRC)
**UTP CABLE**

**Cable 10BASE-T/100BASE-TX Straight-Through**

<table>
<thead>
<tr>
<th>Pin Label</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>TX+</td>
<td>TX+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TX-</td>
<td>TX-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RX+</td>
<td>RX+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC</td>
<td>NC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC</td>
<td>NC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RX-</td>
<td>RX-</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC</td>
<td>NC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NC</td>
<td>NC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Straight-Through Cable**

Wires on cable ends are in same order.
UNICAST OR MULTICAST

Unicast represent a private conversation, it implies a one for one relationship.
MULTICAST

Presume a non private relationship between one stream and multiple clients.
SERIAL FORMAT

The MPEG data has to be serialized in order to be transmissible over cable or RF. The serialization process is made according to a strict protocol based on Packet based multiplexing.

The encoder has to fit all program elements in the transport stream:

- Audio
- Video
- Data
The MPEG transport stream relies, unlike IP, on fixed length packets. The length of a standard MPEG packet is 188 bytes.

The best human scale model for a data packet is a train wagon. The wagon carries a certain payload. In data terms it can be expressed in the number of bytes it carries. In the specific case of MPEG it is 188 Bytes. Bytes look all the same so a header has to be added to the packet so the de-multiplexer can know what is the content or the destination of the data packet.
MPEG PACKETS TRANSPORT

PID #

Header

Payload

188 Bytes

Table:

<table>
<thead>
<tr>
<th>OSI Model</th>
<th>Data unit</th>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host layers</td>
<td>Data</td>
<td>7. Application</td>
<td>Network process to application</td>
</tr>
<tr>
<td></td>
<td>Segments</td>
<td>6. Presentation</td>
<td>Data representation, encryption and decryption, convert machine dependent data to machine independent data</td>
</tr>
<tr>
<td></td>
<td>Packet/Datagram</td>
<td>5. Session</td>
<td>Interhost communication, managing sessions between applications</td>
</tr>
<tr>
<td>Media layers</td>
<td>Bit/Frame</td>
<td>4. Transport</td>
<td>Reliable delivery of packets between points on a network.</td>
</tr>
<tr>
<td></td>
<td>Bit</td>
<td>3. Network</td>
<td>Addressing, routing and (not necessarily reliable) delivery of datagrams between points on a network.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Data link</td>
<td>A reliable direct point-to-point data connection.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Physical</td>
<td>A (not necessarily reliable) direct point-to-point data connection.</td>
</tr>
</tbody>
</table>
MULTIPLEXING

CLOCK

Audio
Video
Ancillary Data
Data Channel
Traffic related info
Forward Error Correction

MULTIPLEXER

1 OUTPUT DATA STREAM WITH DENSITY STATISTICS SUITABLE FOR CLOCK RECOVERY
MULTIPLEXING

Video

Audio

Audio

Aggregated Stream
MPEG SIGNAL TRANSPORT

The MPEG compression takes place.

Mpeg encapsulates video in a compressed transport stream that is segmented into packets, each packet may be compared to a train wagon.
You may decide to decode the MPEG signal at any time and get the video and audio back:

CC1  CC2  CC3  CC4  CC5
MPEG MULTIPLEXER

An Mpeg Multiplexer Can:

- Select Packets
- Rename packets
- Filter unwanted PID’s
- Carrousel Table information
The PID or Program Identifier is a number (13 bit integer) located in the transport packet header. The latter is used to index MPEG packets. Just like IP routers, the MPEG TS handling equipment doesn’t have to read all the 188 bytes packets it relies solely on the PID number to elect if the packet is required, and where it shall be routed to.
**PID NUMBER**

188 bytes

<table>
<thead>
<tr>
<th>Header 32 bits</th>
<th>Adaptation Field (Variable)</th>
<th>Payload (Variable)</th>
</tr>
</thead>
</table>

32 bits

<table>
<thead>
<tr>
<th>Sync Byte 8 Bits 0x47</th>
<th>Flags (3 bits)</th>
<th>PID (13 bits)</th>
<th>Flags (4 bits)</th>
<th>Continuity Counter (4 bits)</th>
</tr>
</thead>
</table>

32 bits
MPEG TABLES

PAT (Program Association Table): (pid 0)
- List the services in the TS
- Points to the PMT of Each PMT

PMT: (Program Map table) (Pid variable)
- One PMT per service
- Points to the location of each program elements
- Gives service info (Title, TSID etc)

MGT (Master Guide Table) or Si (service information table)
- fixed PID Location (1FFB or 16)
- Points to program guide information
Service 4 Selected

41
Video Buffer
Video Decoder
Video Assembler

48
Audio Buffer
Audio Decoder

44
CC

1FFB +
children

EPG
Engine

All
Other
PID's

Junk Yard

 PTS

All
Other
PID's

CBC Radio-Canada
MPEG FILTERING

Program Association Table (PAT)
Table_id 0x00
Transport_stream_id 0x001234

<table>
<thead>
<tr>
<th>Program number</th>
<th>PMT PID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>30h</td>
</tr>
<tr>
<td>1</td>
<td>40h</td>
</tr>
<tr>
<td>5</td>
<td>50h</td>
</tr>
</tbody>
</table>

MPEG Structure

PAT (0)

PMT(30)
PCR(31)

Service 3
Video(31) Audio (34) VBI (37) Data(38)

Service 4
Video(41) Audio (44) VBI (47) Data(48)

Service 5
Video(51) Audio (54) VBI (57) Data(58)

PMT(50)
PCR(51)

PMT(40)
PCR(41)
MPEG MULTIPLEXING

MPEG Structure

Service 3

Service 4

Service 5

PAT (0)
PMT (30)
Audio (34)
VBI (37)
Data (38)
Video (51)
CC
PCR (31)
PMT (40)
Audio (44)
VBI (47)
Data (48)
Video (41)
CC
PCR (41)
PMT (50)
Audio (54)
VBI (57)
Data (58)
Video (51)
CC
PCR (51)

PAT

PMT (50)
PCR (51)

Service 5

Video (51)
Audio (54)
VBI (57)
Data (58)
Service descriptor:

Now that the audio decoder has the audio packets and the video decoder has the video packets, does the decoder have sufficient information to decode the stream?

Not quite, the decoders needs to know a little more about the signals like (the standard the packets were coded), the language, etc :

- Coding standards:
  - Audio (MPEG layer 1, Dolby AC-3, etc)
  - Video: (MPEG-1, MPEG-2, AVC, etc)

This information is carried on a 8 bit number called a service descriptor

<table>
<thead>
<tr>
<th>Service</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mpeg-2 video</td>
<td>01h</td>
</tr>
<tr>
<td>Mpeg layer 2 audio</td>
<td>03h</td>
</tr>
<tr>
<td>Dolby AC-3</td>
<td>81h</td>
</tr>
</tbody>
</table>

Figure 7 MPEG service descriptors
Language Descriptor

The language selection is made using a worldwide standard that defines languages called ISO-639, the latter defines a 2 letter codes for most known languages. The so called “Language Descriptor” permits to encode audio in several languages for the user selection. On most ATSC receivers the MTS key permits to toggle between languages.

Language ISO 639 Descriptor

English en
French Fr
German de
Finnish fi
Polish Pl
Portuguese Pt
Russian ru
Input streams

ASI 1 (ASTRA, 12.168 GHz)
- PAT (10 programs, TS id = 0x440)
  - ASTRA SDT-1 (Pn = 0xA, Pid = 0x2B)
  - Travel (Pn = 0x6D61, Pid = 0x403)
    - Pid = 0x29 (tag = 0x22)
    - Pid = 0x5C (tag = 0x20) (eng)
    - Pid = 0x5D (tag = 0x21) (pol)
    - ECM Pid = 0x600 (Philips)
  - Pid = 0xA3 (tag = 0x1F)
- Cartoon Network (Pn = 0x6E5F, Pid = 0x401)
TRANSPORT STREAMS HAVE A LANGUAGE OF THEIR OWN

The receiving device expect to receive information in a known order, (just like a sentence where a subject, a verb and a complement are expected in order).

The language or Syntax required varies with the application:

- 2 MPEG devices in a lab environment don’t need much of Shakespeare language, in fact a few commands are sufficient.
- The basic MPEG syntax is used
SYNTAXES

A satellite receiver needs a little more information (carrier freq, FEC, number of services etc)

- The DVB syntax is used in this case, please note that all the elements of the basic MPEG syntax are also included in the DVB syntax.

An ATSC receiver also requires more information (program title, program Info, Vchip, caption)

- The ATSC syntax is used in this case, note that all the elements of the basic MPEG syntax are also included in the ATSC syntax.
**PHYSICAL LAYER AND SYNTAX**

Physical Layer and syntax are independent variables: so you can end up with:

<table>
<thead>
<tr>
<th>Physical layer</th>
<th>Syntax</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMPTE-310</td>
<td>ATSC</td>
</tr>
<tr>
<td>DVB-ASI</td>
<td>DVB</td>
</tr>
<tr>
<td>Ethernet</td>
<td>SCTE</td>
</tr>
</tbody>
</table>
Digital Video Broadcasting (DVB) is a worldwide standard defining Digital Video transmission across various media's:

- Satellite DVB-s
- Cable DVB-C
- Terrestrial transmission DVB-T
- SCTE for North American Cable

» ATSC is terrestrial Only
Each syntax defines a number of tables into which the information is stored in an orderly manner:

**Ex: The MPEG syntax defines 2 types of tables:**

- Program Association Table (PAT) (always located at PID 0): defines how many services are multiplexed in the current stream, their name or ID and the location (in Pid no) of each service's index table or PMT.
- Program Map Table (PMT): defines the location of the video, audio and ancillary information for one service, it is located in a PID number defined in the PAT.
Each syntax defines a variety of system tables as follows:

**DVB Syntax**
- Network Information Table (Pid 16, reserved)
  - Time & date Table (TDT)
  - Bouquet Association Table (BAT)
  - Service Description Table (SDT)
  - Event Information Table (EIT)
  - Extended text table (ETT)

**ATSC Syntax**
- Master Guide Table (Pid 1FFB, reserved)
  - System Time Table (STT)
  - Region Rating Table (RRT)
  - Virtual Channel Table (VCT)
  - Directed Channel Change table (DCCT)
  - Event Information Table (EIT)
  - Extended text table (ETT)

**Program Association Table (Pid 0, reserved)**
- Program Map Table (PID appointed by PMT)
- Program Map Table (PID appointed by PMT)
- Program Map Table (PID appointed by PMT)
TS OVER IP

Used as an ASI coax replacement
Not made to resist dropped or delayed packets
Prefers to be routed over simple routes with dum switches
Not the protocol we streamed content over the internet
Every Television station shall have:

- A Video functional
- And audio functional
- A TS functional
- A control functional
- Where is your network diagram?
NOT ALL SWITCHES ARE CREATED EQUAL
**TS ON IP**

Typical TS over IP implementation, we encapsulate 5 or 7 MPEG packets per IP packets

<table>
<thead>
<tr>
<th></th>
<th>IP 20 bytes</th>
<th>UDP 8 bytes</th>
<th>RTP 12 bytes</th>
<th>n * 188 bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>40 + n * 188 bytes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**UDP header**

32 bits

<table>
<thead>
<tr>
<th>V</th>
<th>P</th>
<th>X</th>
<th>CSRC count</th>
<th>M</th>
<th>Payload Type</th>
<th>Sequence Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timestamp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sync Source (SSRC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First Contributing Source (CSRC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>nth Contributing Source (CSRC)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- V = Version (RTP = 2)
- P = Padding
- X = Extended Header
- M = Marker bit
MPEG TS PACKET HEADER

- S - Sync
- TPR - Transport Priority
- PUSI - Payload Start
- EI - Error Indicator
- PID - Packet Identifier (stream ID)
- SCR - Scrambling Control
- AF - Adaptation Field
- CC - Continuity Check Index
BROADCAST TRAFFIC ENEMY

NO 1: JITTER

Jitter originates from a speed differential between parts of a serialized stream

• This train symbolizes a stream of IP packets, imagine for a minute that those wagons are tied together by steel joints with very little expansion contraction, all wagons will travel at precisely the same instantaneous speed

• Imagine now that the wagon are tied with bungee cords
SOURCE OF IP JITTER

Each time the traffic is exposed to route switching

Each time a switch has to take a decision it take some time to do so, not exactly the same time at each occurrence
RESULTS
MINIMIZING JITTER

Minimize multipath
Equalize paths
Uses fastest switch available
Create dum network segments
The PCR is a signal sent from the encoder to the decoder to synchronize the decoder 27 MHz clock.

The PCR is sent over standards 188 bytes MPEG packets just like any other MPEG payload.

PCR packets is sent at a fixed repetition rate.
The PCR signal is carried over either a private PID, or embedded in the video PID.

PCR occupies about 45 kbs.

The PCR packets are sent at a minimum frequency.

If the encoder doesn't send PCR often enough, a PCR repetition error will be generated.

PCR is required to be accurate within 226 Hz.

If the result of PCR synchronization is not within limits a PCR accuracy error will be generated.

If the some PCR packets are delayed from a variable amount of time (typical of switched network) a PCR clock Jitter error will be recorded.
PCR ISSUES

Encoder

Decoder

27m, 0

27m, 0
**PCR**

**Encoder**

27m, 0

Receiver clock too slow

**Decoder**

27m, 0

9880455

10,000000
Satellite 101

PCR

Encoder

Decoder

27m, 0

12,333,226

Receiver clock too fast

10,000000

12987003

12333226
Satellite 101

Encoder

27m, 0

14443556

Decoder

27m, 0

14443342

Almost there

PCR

14443356

Encoder

Decoder
The PCR signal is carried over either a private PID, or embedded in the video PID. PCR occupies about 45 kbs. The PCR packets are sent at a minimum frequency. If the encoder doesn't send PCR often enough, a PCR repetition error will be generated. PCR is required to be accurate within 226 Hz. If the result of PCR synchronization is not within limits, a PCR accuracy error will be generated. If some PCR packets are delayed from a variable amount of time (typical of switched network), a PCR clock Jitter error will be recorded.
**Transport Layer**

**New Ways to Carry TS in IN IN OUTSIDE THE BROADCAST PLANT?**

<table>
<thead>
<tr>
<th>OSI Model</th>
<th>Data unit</th>
<th>Layer</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Host layers</strong></td>
<td>Data</td>
<td>7. Application</td>
<td>Network process to application</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Presentation</td>
<td>Data representation, encryption and decryption, convert machine dependent data to machine independent data</td>
</tr>
<tr>
<td></td>
<td>Segments</td>
<td>5. Session</td>
<td>Interhost communication, managing sessions between applications</td>
</tr>
<tr>
<td><strong>Media layers</strong></td>
<td>Packet/Datagram</td>
<td>4. Transport</td>
<td>Reliable delivery of packets between points on a network.</td>
</tr>
<tr>
<td></td>
<td>Bit/Frame</td>
<td>3. Network</td>
<td>Addressing, routing and (not necessarily reliable) delivery of datagrams between points on a network.</td>
</tr>
<tr>
<td></td>
<td>Bit</td>
<td>2. Data link</td>
<td>A reliable direct point-to-point data connection.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Physical</td>
<td>A (not necessarily reliable) direct point-to-point data connection.</td>
</tr>
</tbody>
</table>
UNICAST OR MULTICAST

Unicast represent a private conversation, it implies a one for one relationship.
MULTICAST

Presume a non private relationship between one stream and multiple clients.
VIRTUAL CHANNEL

Global Variable identified by a number holding all pointers to a group of service selectable at the receiver

Imagine a system having 2 Videos (A,B) and 6 audio's (1 to 6) and 2 VBI signals

The virtual Channel table may look like this

Selecting any of these numbers will provide the associated services
# VIRTUAL CHANNEL

### Service distribution exemple

<table>
<thead>
<tr>
<th>V Chan</th>
<th>Vidéo</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>VBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>101</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>7</td>
<td>8</td>
<td>none</td>
</tr>
<tr>
<td>103</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>201</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>none</td>
<td>none</td>
<td>2</td>
</tr>
<tr>
<td>202</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>3</td>
<td>none</td>
</tr>
</tbody>
</table>
Thème: les grands incompris
Ce soir Pascal recoit:
Le colonel Kadaphi, Bill Gates, Margaret Tacher et le docteur Mailloux

OK
VCHIP

Each Program is V-Chip coded in reference with the rating code applicable in the province (dynamic psip)

The Rating code is downloaded in the Static PSIP section (Regional Rating Tables)

Today’s receiver have the US RRT hard coded (issue pending at CEMA & CRTC)
SYSTEM ISSUES

PSIP is unique to each market

95 % of the PSIP is common to all program stream of the same root.

Static PSIP needs to be tailored to the local market.

Detailed RF information has to be entered in the static PSIP tables
SYSTEM MANAGEMENT ISSUES

If the info in The MGT is incorrect receiver may not lock up, generating a service call at the NAC

The Transmission Services staff have to be aware of each mux configuration at all times, otherwise they can’t locate the faults.
TABLE STRUCTURE

```
base_PID

STT
RRT
MGT

VCT
For channel x:
  source_id
For channel y:
  source_id

PID-K -> EIT-0
source_id

PID-L -> EIT-1
source_id
source_id

PID-M -> EIT-2
source_id
source_id
source_id
```
• Major Channel. The previously assigned, paired NTSC channel is the major channel number. See Section 6.3.1 for more detail and rare exceptions.
• Service Type. The service type selects DTV, NTSC, audio only, data, etc., and must be set as operating modes require. See Section 6.3.1.
• Modulation Mode. A code for the RF modulation of the virtual channel. See Section 6.3.2.
• Source ID. The Source ID is a number that associates virtual channels to events on those channels. It typically is automatically updated by PSIP equipment or updated from an outside vendor. Proper operation of this feature should be confirmed. See Section 6.3.4.
• Service Location Descriptor (SLD). Contains the MPEG references to the contents of each component of the programs plus a language code for audio (ISO 639-2, [9]). See Section 6.9. The PID values for the components identified here and in the PMT must be the same for the elements of an event/program. Some deployed systems require separate manual setup, but PID values assigned to a VC should seldom change.
Figure 5.1 Recommended PSIP table cycle times.
Ethernet

Outline

- Multiple Access and Ethernet Intro
- Ethernet Framing
- CSMA/CD protocol
- Exponential backoff
HOW CAN WE KNOW SOMETHING WENT WRONG?

MONITORING
What happened already happened...

We need to understand what it To avoid re-occurrence
HOW DO YOU KNOW SOMETHING WENT WRONG

A Stream Monitor can show-up a whole stack of transport & set-up errors

One of the most common is the MPEG Continuity Count error:

- Hidden in the of each MPEG packets a 4 bit counter called the continuity counter is present
- If any packets is dropped an ETR 290 layer 1 alarm will show up on your TS analyzer screen
- Mpeg continuity count error, expected 3 found 7
  - This means that you lost (7-3=4) packets or 4 packets plus a multiple of 16 as the counter may have overunned a few times before the ts retrieved synch
A sniffer program will:

- Capture and displays every things that happens in your segment
- Requires L1 visibility
MOBILE TELEVISION
ALL ABOUT ME!

Today`s viewers want to consume contents:

• The content they want to watch
  • When they want to watch it
  • Where they want to watch it

• Linear television is somewhat limited in this aspect. This presentation is all about what we can do about the where component.
A LOOK AT THE MOBILE MEDIA LANDSCAPE

Real time mobile services:

- FM Radio + RBDS (multicast)
- Cell Phone streaming (unicast)
- Wifi streaming (mostly unicast)
UNICAST VEHICLES

Unicast transport vehicles carries a copy of the content for each requestor

Typical from bi-directional environment

- The cost model is linear. The more viewers the most ressources is tied-up.
  - Tends to overflow bandwidth limited pipes
MULTICAST VEHICLES

Ties up the same volume of resources whether they have one client of a million.

- Typical of unidirectional environment
- Quickly becomes bandwidth efficient

The cost of coverage varies with the broadcast model

- Multicast @ $1000 for the transmission
- Unicast @ 10 cents per viewer
ATSC TO ATSC MOBILE

ATSC is the North American Digital Television Standard, it is in use in USA Canada, Mexico, Korea and 19 other countries, it is aimed at:

- Providing a service that is spectrally compatible with NTSC
- Minimizing interference to NTSC
- Be spectrally efficient
- Delivering HDTV to fixed receiver
CHALLENGES OF A MOBILE ENVIRONMENT: DOPPLER
CHALLENGE OF A MOBILE ENVIRONMENT: MULTIPATH
CHALLENGES OF A MOBILE ENVIRONMENT

Multipath

Original signal  in Phase addition  Mixed Phase addition  Out-of-Phase addition
CHALLENGES OF A MOBILE ENVIRONNEMENT

Multipath Fading

[Image of a horse, a camel, and a diagram of a genetic modification process]
ANALOG TELEVISION HAD A BULLET PROOF SYNCHRONIZATION SYSTEM
MULTIPATH CANCELLATION

Does it Rings a Bell to you?

RS-170A WAVEFORMS
COLOR SUPERFRAME

VERITCAL BLANKING INTERVAL

PRE-EQUALIZING PULSE FIELD 4
POST-EQUALIZING PULSE FIELD 4

COMPOSITE BLANKING

VERITCAL SYNC

WHITE 100

BLANKING 10.5 IRE

52.5 IRE

1.5 IRE

VERTICAL SYNC

EVERN ODD EVEN ODD

VERTICAL SYNC

4.7 IJS

BURST FLAG (CLAMP)
ATSC ALSO HAS A SYNCH STRUCTURE
ADAPTIVE TAP EQUALIZER

Received Signal = Waveform in memory

Derived Undesired signal = Timing Difference

Amplitude difference = Reconstructed signal
ADAPTIVE TAP EQUALIZER
DEFEATING INTERFERENCE INTERLEAVING
DEFEATING INTERFERENCE: INTERLEAVING
SIGNAL DE-INTERLEAVING
DEFEATING INTERFERENCE FREE-RUNNING INTERLEAVED FEC

Reed-salomon

TCM

TPC
Maximum likelihood decoding is a process by which errors are corrected by a probability algorithm that makes educated guesses on the nature of the error.

How long is this fish? If your answer is wrong, what is the most likely error you may have done?
Turbo is a forward error correction technique which uses the MLD in an iterative manner, over which already corrected signals are getting fed back to the input of the error corrector.
TURBO CODES PERFORMANCE

![Graph showing BER/FER performance vs. Eb/N0 dB for different iterations.]
TYPICAL RECEIVERS
PERFORMANCE:

Receiver Threshold (AWGN)   ATSC:                       16.0 dB

ATSC Mobile ¼ FEC: 3.5 dB

ATSC Mobile ½ FEC: 7.0 dB

Ability to cope with Multipath: ATSC: echoes at – 3dB from -10 to + 15 us

ATSC Mobile: echoes at – 3dB from -10 to + 45 us

Doppler resistance: ATSC: 4 Hz

ATSC Mobile 16 Hz
IMPACT ON LEGACY RECEIVERS

From The RF standpoint: none

From the picture quality standpoint: there is a perceptible loss of quality due to the lower video rate that the use of ATSC Mobile dictates. This quality restriction will be applicable to all receivers tuning to this ATSC channels whether they decode the ATSC mobile signals or not.
MOBILE DTV RECEIVERS
ABOUT THE WHEN COMPONENT

All about ME!

- Today’s viewers want to consume:
  - The contents they want to watch
    - When they want to watch it
    - Where they want to watch it

Storage is becoming a commodity, it now retails around 2.1 /GB

Watch for ATSC Non-Real-time Service in a Mobile device near you
VIDEO COMPRESSION
VIDEO COMPRESSION

Why Compress:

Because the resources required to transmit uncompressed Video is higher than analog and is clearly not cost efficient.

- CCIR 601 704 X 480 4:2:2 takes 243 MB/s
- SMPTE 292 1980 X 1080i30 takes 1.485 Gbps

For satellite SCPC:

- 243MB/s X 2 bit/Hz (QPSK)/1/2 rate FEC 243 MHz (5 Ku band transponders)
- An Analog signal @ 9.2 MHz dev makes 20 MHz (Carson rule)
Spectral content of an Image

Time ->  
F-> LF HF

Time ->  
F-> LF HF
One image, its way too large
Structured Macro-blocks

- MPEG-2
- 8X8

- MPEG-4
- 8X8
- 4X4 or 16X16
DCT

Time to Frequency transform

\[ F(u) = \left( \frac{2}{N} \right)^{\frac{1}{2}} \sum_{i=0}^{N-1} \Lambda(i) \cdot \cos \left[ \frac{\pi \cdot u}{2 \cdot N} (2i + 1) \right] f(i) \]

Ex Bank record vs a Quicken categorised report
Les coefficients are getting classified in frequency order, a picture such as a cartoon will have very few coefficients.
A typewriter scan will deliver 64 coefficients, 38 in a row which are null.

A Zig-zag scan still delivers 64 coefficients, however we have 54 null coefficients in a row.

Série 10, 7.9, 5.5, 5, 4, 2, 3, 0, 0.2, 1, 0.1

As the tail of zeros is not transmitted the compression rate reaches $(64-11)/64 = 83\%$.
DCT

H Frequency

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<td>3</td>
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<td></td>
<td></td>
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<tr>
<td>4</td>
<td></td>
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<td></td>
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<tr>
<td>5</td>
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<tr>
<td>6</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Compression d’image

Temporal compression, Motion Vectors

Previous frame

Current frame

Info to code

Motion vector

Flying Saucer
A frame structure is required to allow some borrowing of information.

The structure defines 3 types of frame:
- I (incident Frame) is a complete frame
- P (predicted or past frame) is based on a prediction of what the previous frame was
- B (Bi Directional) Borrows elements from both past and future frame
Transmission order

<table>
<thead>
<tr>
<th>Frame type</th>
<th>Encoding and transmission order</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100 99 102 101 104 103 106 105 108</td>
</tr>
<tr>
<td>B I B P B P B P B I</td>
<td>99 100 101 102 103 104 105 106 107</td>
</tr>
</tbody>
</table>

Source and display order:

99 100 101 102 103 104 105 106 107 108
A new term is defined the GOP is the distance in frames between 2 I frames.

The longer the GOP, the best coding efficiency

The Longuer the GOP the most ugly each individual frames

The longueur the Gop, the longest latency

- The shortest the GOP, the best individual
- Frames quality.
Image compression takes place in a dynamic manner:

- **Video Input**
- **Spacial Compression**
- **Temporal compressor**
- **Rate allocation**
- **Control**
- **Output buffer**
- **Buffer occupancy**
- **Bit budget allocation**
- **Data**
- **Output**
Have you notice how fast superman moves?
Have you notice if he was in focus while moving?
  Probably not, but you would notice a picture freeze or a steppy motion much before.

When the encoder is faced with an allocation issue between giving bits to definition or motion, it will always favors the motion compensation.
Entropy Coding

- Variable Length Coding VLC
- Based on a probability scale
- The values that repeats themselves often get short codes assigned
- The value that don't repeat very often gets long codes assigned
What you may see:
- Picture freeze
- Macroblocking
- Aliasing
- Washed-out Picture

What you may not see
- Interférence
Profiles and Levels for particular applications

- Profile: a subset of entire bit stream of syntax, different decoder design based on the Profile
  - Four profiles: Baseline, Main, Extended and High

<table>
<thead>
<tr>
<th>Profile</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Video Conferencing, Videophone</td>
</tr>
<tr>
<td>Main</td>
<td>Digital Storage Media, Television Broadcasting</td>
</tr>
<tr>
<td>Extended</td>
<td>Streaming Video</td>
</tr>
<tr>
<td>High</td>
<td>Content contribution, Content distribution, Studio editing, Post processing</td>
</tr>
</tbody>
</table>
### H.264 Profiles

<table>
<thead>
<tr>
<th>Feature</th>
<th>Baseline</th>
<th>Main</th>
<th>Extended</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>I &amp; P Slices</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Deblocking Filter</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>¼ Pel Motion Compensation</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Variable Block Size (16x16 to 4x4)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>CAVLC/UVLC</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Error Resilience Tools – Flexible MB Order, ASO, Red. Slices</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>SP/SI Slices</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>B Slice</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Interlaced Coding</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>CABAC</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data Partitioning</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
H.264 Profiles

- **Baseline Profile (BP)**: Primarily for lower-cost applications with limited computing resources, this profile is used widely in videoconferencing and mobile applications.
- **Main Profile (MP)**: Originally intended as the mainstream consumer profile for broadcast and storage applications, the importance of this profile faded when the High profile was developed for those applications.
- **Extended Profile (XP)**: Intended as the streaming video profile, this profile has relatively high compression capability and some extra tricks for robustness to data losses and server stream switching.
- **High Profile (HiP)**: The primary profile for broadcast and disc storage applications, particularly for high-definition television applications (this is the profile adopted into HD DVD and Blu-ray Disc, for example).
- **High 10 Profile (Hi10P)**: Going beyond today’s mainstream consumer product capabilities, this profile builds on top of the High Profile—adding support for up to 10 bits per sample of decoded picture precision.
- **High 4:2:2 Profile (Hi422P)**: Primarily targeting professional applications that use interlaced video, this profile builds on top of the High 10 Profile—adding support for the 4:2:2 chroma sub sampling format while using up to 10 bits per sample of decoded picture precision.
- **High 4:4:4 Predictive Profile (Hi444PP)**: This profile builds on top of the High 4:2:2 Profile—supporting up to 4:4:4 chroma sampling, up to 14 bits per sample, and additionally supporting efficient lossless region coding and the coding of each picture as three separate color planes.
- **High 10 Intra Profile**: The High 10 Profile constrained to all-Intra use.
- **High 4:2:2 Intra Profile**: The High 4:2:2 Profile constrained to all-Intra use.
- **High 4:4:4 Intra Profile**: The High 4:4:4 Profile constrained to all-Intra use.
- **CAVLC 4:4:4 Intra Profile**: The High 4:4:4 Profile constrained to all-Intra use and to CAVLC entropy coding (i.e., not supporting CABAC).
<table>
<thead>
<tr>
<th>Level number</th>
<th>Max macroblocks per second</th>
<th>Max frame size (macroblocks)</th>
<th>Max video bit rate (VCL) for Baseline, Extended and Main Profiles</th>
<th>Max video bit rate (VCL) for High Profile</th>
<th>Max video bit rate (VCL) for High 4:2:2 and High 4:4:4 Predictive Profiles</th>
<th>Examples for high resolution @ frame rate (max stored frames) in Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1485</td>
<td>99</td>
<td>64 kbit/s</td>
<td>80 kbit/s</td>
<td>192 kbit/s</td>
<td>128x96@30.9 (8) 176x144@15.0 (4)</td>
</tr>
<tr>
<td>2</td>
<td>11880</td>
<td>396</td>
<td>2 Mbit/s</td>
<td>2.5 Mbit/s</td>
<td>6 Mbit/s</td>
<td>320x240@36.0 (7) 352x288@30.0 (6)</td>
</tr>
<tr>
<td>2.1</td>
<td>19800</td>
<td>792</td>
<td>4 Mbit/s</td>
<td>5 Mbit/s</td>
<td>12 Mbit/s</td>
<td>352x480@30.0 (7) 352x576@25.0 (6)</td>
</tr>
<tr>
<td>2.2</td>
<td>20250</td>
<td>1620</td>
<td>4 Mbit/s</td>
<td>5 Mbit/s</td>
<td>12 Mbit/s</td>
<td>352x480@30.7 (10)</td>
</tr>
<tr>
<td>3</td>
<td>40500</td>
<td>1620</td>
<td>10 Mbit/s</td>
<td>12.5 Mbit/s</td>
<td>30 Mbit/s</td>
<td>352x576@25.6 (7) 720x480@15.0 (6) 720x576@12.5 (5)</td>
</tr>
<tr>
<td>3.1</td>
<td>108000</td>
<td>3600</td>
<td>14 Mbit/s</td>
<td>17.5 Mbit/s</td>
<td>42 Mbit/s</td>
<td>352x576@51.1 (10) 720x480@30.0 (6) 720x576@25.0 (5)</td>
</tr>
<tr>
<td>3.2</td>
<td>216000</td>
<td>5120</td>
<td>20 Mbit/s</td>
<td>25 Mbit/s</td>
<td>60 Mbit/s</td>
<td>720x480@80.0 (13) 720x576@66.7 (11) 1280x720@30.0 (5)</td>
</tr>
<tr>
<td>4</td>
<td>245760</td>
<td>8192</td>
<td>20 Mbit/s</td>
<td>25 Mbit/s</td>
<td>60 Mbit/s</td>
<td>1280x720@60.0 (5) 1280x1024@42.2 (4)</td>
</tr>
<tr>
<td>4.1</td>
<td>245760</td>
<td>8192</td>
<td>50 Mbit/s</td>
<td>62.5 Mbit/s</td>
<td>150 Mbit/s</td>
<td>1280x720@68.3 (9) 1920x1088@30.1 (4) 2048x1024@30.0 (4)</td>
</tr>
</tbody>
</table>
HD coding efficiency

- Possible future performance of FERExt
- FERExt of H.264 (July 04)
- Performance of FERExt on HD 720p vs MPEG2
MPEG-2 MP HL (Main Profile High Level)

La compression video est basée sur une analyse perceptuelle qui identifie des éléments redondants que le codeur retirera pour les ré-insérer au niveau du décodeur.

**Diagram: 1.485 Gb/s Input signal ➔ Codeur ➔ 17 mbps Output ➔ Information dé-corellée**
2012 VIDEO COMPRESSION STATUS

10 years after the finalization of H.264/AVC, encoders are still improving

New generation of encoders launched this year achieves:

- An excellent HD1080i quality, close to source quality, at 15Mb/s in 4:2:2 10 bits for contribution,
- 15% bitrate gain for broadcast and an additional 15% gain is targeted by end 2013
  - 7 Full HD1080i programs in DVB-S (34Mb/s) or 9 programs in DVB-S2 (46Mb/s) by end 2013

1st version of HEVC standard nearly finalized.

Now is coming the “encoder makers know-how” time!
One goal: to make the best use of the toolbox
HEVC PERFORMANCE ANALYSIS

Initial goal achieved:

- Same subjective quality with half the bitrate for HEVC model (Main profile) vs H.264/AVC model
- Best gains on higher resolutions and on low activity contents (sometimes more than 50%)

<table>
<thead>
<tr>
<th>Source type</th>
<th>Resolution</th>
<th>Frame rate</th>
<th>Bitrate saving average *</th>
<th>Bitrate saving min *</th>
<th>Bitrate saving max *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Progressive</td>
<td>3840x2160 (4K)</td>
<td>25</td>
<td>30.6%</td>
<td>22.0% (Ducks)</td>
<td>42.3% (Old town)</td>
</tr>
<tr>
<td>Progressive</td>
<td>1920x1080</td>
<td>50</td>
<td>29.2%</td>
<td>17% (Parkjoy)</td>
<td>46.3% (Old town)</td>
</tr>
<tr>
<td>Progressive</td>
<td>1280x720</td>
<td>50</td>
<td>24.7%</td>
<td>14.6% (Parkjoy)</td>
<td>36.6% (Old town)</td>
</tr>
</tbody>
</table>

* PSNR Bjøntegaard metric
  HM7.0 MP / JM18.3
HEVC PERFORMANCE ANALYSIS

Why HEVC is better?

• Large blocks up to 64x64 pixels

• Better adaptation to the image content, no over-partitioning inherent to a regular MB structure

• Advanced motion coding: able to capture more redundancy with less signaling data

• Accurate and efficient Intra coding
HEVC PERFORMANCE ANALYSIS

HEVC model computation time

• Far from real-time on a Xeon processor core (range of x1000-3000)

Why HEVC real-time implementation timeline should be faster than in H.264/MPEG4-AVC?

• Entropy encoder well mastered
• Same High-level encoder architecture (hierarchical GOP structure)
• Parallelism tools included in the standard (Wavefront for entropy coding, Tiles)
• Same packetization layer (NAL)
H.264/AVC – HEVC bitrates evolution plan for DTH

![Graph showing the evolution of bitrates for H.264/AVC and HEVC from Q4 2012 to Q4 2016.](image-url)
HEVC CURRENT LIMITATIONS

• The “Main profile” only supports 4:2:0 8-bits contents for the time being.
  • Proposal to add a 4:2:0 10 bits profile in the first DIS (useful for 4K content)
  • Professional profiles (4:2:2 / 4:4:4) will be released in 2013
• The « Main profile » brings a limited support to interlaced formats:
  • PAFF (Picture Adaptive Frame Field) is limited at the sequence level with Closed-GOP constraints
  • Field coding is therefore not possible for I pictures when Frame coding is used in the sequence
  • no MBAFF for internal Frame-Field adaptation inside the pictures
OUR VISION OF HEVC DEPLOYMENT

OTT applications: certainly the first user of HEVC in 2013

- Fast renewal of decoding devices
- Real-time SW implementations already demonstrated
- 50% bandwidth savings enables HD on mobile networks

4:2:0 8-bits DSNG & 4:2:2 10-bits Contribution applications

- Will immediately take benefit of lower bandwidth
- No constraint of existing decoder park

IPTV

- Extended HD eligibility
- Need of cheap STBs

DTT

- Legacy issues and display replacement may delay the introduction of HEVC

DTH

- Replacement of existing decoder park, migration scenario TBD

Nov-12
THATS ALL FOLKS

Questions?

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