WDM Video Overlays on EFM Access Networks

David Piehler
Harmonic, Inc.
Broadband Access Networks

IEEE 802.3ah January 2002 meeting
Raleigh, North Carolina

david.piehler@harmonicinc.com
Main points of presentation

• Respond to reflector discussions on this subject.
  – Review HFC technology and its application to all-fiber access networks
  – Address technical concern areas
  – Set the stage to provide details
• WDM video overlays have been widely deployed in P2P and P2MP topologies
• A WDM video overlay provides significant advantages for service providers
Analog video modulation

Analog video information is encoded on discrete RF sub-carriers (channels):

For NTSC-80: channels range from 50 to 550 MHz
For NTSC-110: channels range from 50 to 750 MHz
For PAL-80: channels range from 50 to 870 MHz
(with 8 MHz separation)
The other QoS: Quality of Signal

- Transmission quality criteria: noise and distortion
- Carrier to noise ratio, CNR
  - > 55 dB for supertrunking
  - > 47 dB @ Home for no “snow”
- Intermodulation distortion: Composite second order, CSO, and composite triple beat, CTB
  - < -65 dBc for supertrunking,
  - < -54 dBc @Home for no “lines”
  - also referred to as “linearity”
CTB, CSO

Figure 76. Composite triple beam that often appears as horizontal streaks covering one or more lines of video.

Figure 77. Composite second-order distortion that usually appears as swirled diagonal stripes in the TV picture.
Classic HFC system:

- HEADEND to HUB connection uses 1550 nm or 1310 nm fiber with EDFAs.
- HUB to NODE connection uses 65 dBc CSO, 62 dBc CTB.
- NODE to HOME link contributes 48.7 dB CNR, 55 dBc CSO.
- RF amplifiers produce most of the noise and distortion.

**Node to Home Link Contributions**
- CNR: 54 dB
- CSO, CTB: 65 dBc

**Fiber and Amplifiers**
- Fiber, EDFAs
- Coax + RF amps

**Harmonic**
Digital Video (and data)

A typical modern CATV spectrum (cira 2002)

Digital Channels:
• Contain downstream cable modem traffic and digital video
• Are 64- or 256-QAM modulated
• Are spectrally efficient
  • A 6-MHz 64-QAM subcarrier carries 28 Mb/s of data
• Are much more robust than an analog channel
  • Require much lower CNR, CSO, CTB
  • MPEG compression + statistical multiplexing allows > 10 video channels to be delivered on a single 6 MHz RF subcarrier
64-QAM data

**Bit-Error-Rate**

- **CNR (dB)**: 20, 24, 28, 32
- **BER**: $1.00 \times 10^{-9}, 1.00 \times 10^{-7}, 1.00 \times 10^{-5}, 1.00 \times 10^{-3}

**Bit-Error-Rate vs Distortion**

- **Distortion**: 19, 23, 27, 31
- **BER (RS)**
- **BER (CNR 37)**
- **BER (CNR 33)**

**64-QAM**

With FEC, $10^{-9}$ BER can be achieved with CNR, distortion at 30 dB(c)
SCM Video in FTTx

- Typical HFC deployments require (CNR/CSO/CTB) 55/65/65 optics
- Analog video in FTTH architecture requires 47/54/54 optics
- Digital (subcarrier multiplexed) video in FTTH architecture requires 30/30/30 to 40/40/40 optics
  - (depends on modulation order, FEC and design margin)

The all-fiber network and use of digital video make the optical requirements significantly less demanding compared to traditional HFC
Subcarrier multiplexing is the most efficient use of bandwidth.

OC48 Baseband digital: 2.5 Gb/s

SCM: 2.5 Gb/s

80 6 MHz 64-QAM subcarriers

And the demodulation electronics (set top boxes, cable modems) are produced and used in commercial volume.
The video overlay - how?

• A broadcast video network can exist in the same physical plant as an existing P2P or P2MP EFM network

by the use of WDM
Video PON w/ P2P EFM network

A US ILEC has widely deployed this in a FTTC architecture (replace EFM with ATM)
Video PON with P2MP EFM network

Headend/CO

Edge Router PON OLT 1490 / 1310

1550 nm “analog” Tx

EDFA

EDFA

1xN split

1550/1490/1310 WDM

1550/1310/1490 WDM

NIU

PON Tx/Rx PON MAC

Video Rx

Harmonic
Technical issues

- Review issues
  - Solutions exist
  - Technical details can be discussed off-line or in future presentation
- Issues are
  - Optical power for video receiver
  - Optical isolation requirements for WDM at NIU
  - Raman Crosstalk
  - Double Rayleigh Scattering
“Analog” receivers require more power than digital receivers

$$\frac{\text{Carrier}}{\text{Noise}} = \frac{(\text{modulation index})^2 I_{\text{photo}}^2}{B_e (i_{\text{thermal}} + 2eI_{\text{photo}} + (\text{RIN}) I_{\text{photo}}^2)}$$
Isolation requirements

• High power analog signal cannot leak into low power digital signal.
• Low power digital signal cannot leak into analog receiver and raise noise floor.
Raman Crosstalk
Double Rayleigh scattering

• Multipath interference creates noise floor which effect predominately the low frequency channels.
• MSOs *always* use angled connectors to reduce back reflections
• Telcos seem allergic to angled connectors
• Flat connectors work fine *as long as proper craftsmanship is followed.*
• Video overlays widely deployed with flat connectors.
Why does a video overlay make sense for service providers?

• The “analog” TV is the most common residential gateway in the world.
• Digital set top box volume driven by CATV applications - digital tiers and video on demand
• Digital SCM technology is amenable to HDTV
• Broadcast video is a proven market with proven revenue.
• But, it’s a new / unfamiliar business for some
  – Telcos
Video is the bandwidth hog

<table>
<thead>
<tr>
<th>Applications</th>
<th>Example worst case scenario</th>
<th>Generated traffic, DL (Mbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV &amp; VoD</td>
<td>2 * HDTV (20Mbps/ch) + 2 TV (5Mbps/ch)</td>
<td>50</td>
</tr>
<tr>
<td>Video Conferencing</td>
<td>~2Mbps</td>
<td>2</td>
</tr>
<tr>
<td>Web browsing</td>
<td>&lt;10Mbps</td>
<td>10</td>
</tr>
<tr>
<td>Streaming sound</td>
<td>CD quality (200kbps)</td>
<td>0,2</td>
</tr>
<tr>
<td>Telephony</td>
<td>~100kbps</td>
<td>0,1</td>
</tr>
<tr>
<td><strong>Approximate total</strong></td>
<td></td>
<td><strong>62,3</strong></td>
</tr>
</tbody>
</table>

Source: Ericsson P2P
The big payoff

- Broadcast video (“analog” or “digital”) is very bandwidth efficient
- “Switched” video is a bandwidth hog.
- If video is the dominant bandwidth application, use of an overlay can relax bandwidth requirements on an EFM network, enabling
  - lower cost
  - more splits
  - more distance
Wavelength Allocation

• 1550 - 1560 nm (G.983.3) for video overlay is fine.
• *However*, realize that a video overlay may use more than one video wavelength to
  – Enable optical narrowcasting
    • for targeted video services
    • segment the video broadcast
  – Increase the CNR
• The 1550 - 1560 nm band will accommodate multiple wavelengths
Optical Narrowcasting

“Two PONS in One”

8 dB Link at 1550 nm