Cable Channel and Noise Characteristics - Simulation and Impact on RB Capacity

Haleema Mehmood
Stanford University
PhD Candidate
Department of Electrical Engineering
Summary

• Fixed, non-transient channel and noise characteristics
• Downstream
• Upstream
• RB capacity statistics
Channel and Noise Impairments Affecting Bit-loading

- Coax characteristics
  - Attenuation
  - Tilt
- Network characteristics
  - Echo/ Multipath
  - Taps, splitters, amplifiers
- Interferers and legacy
  - FM
  - Analog video
  - Digital video
- Signal Impairments
  - IM products
  - CSO and CTB
  - CPD
Coaxial Cable Attenuation/Tilt

Assumptions

- Amplifiers in the coax path counter coax loss, tilt
- Taps with decreasing insertion loss along the feeder cable
- Coax from tap to home has tilt, unaccounted loss
- Assume 50m to 150m length from tap to home

2000, Cisco Systems Inc.
Echo/Multipath

- IEEE 802.14 over-estimates echo
- Use Redesign model [5]
- Assume 2 reflections in 200 ns (within home)
- Assume 4 reflections in 200 to 800 ns (multi-tap)
- Allow up to 20 dB lower echo power

<table>
<thead>
<tr>
<th>Power (dB)</th>
<th>Delay (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-11</td>
<td>0-200</td>
</tr>
<tr>
<td>-14</td>
<td>200-400</td>
</tr>
<tr>
<td>-17</td>
<td>400-800</td>
</tr>
<tr>
<td>-23</td>
<td>800-1200</td>
</tr>
<tr>
<td>-32</td>
<td>1200-2500</td>
</tr>
<tr>
<td>-40</td>
<td>2500-15000</td>
</tr>
</tbody>
</table>

Sample Downstream Channels
422 to 614 MHz

<table>
<thead>
<tr>
<th>Freq, MHz</th>
<th>Attenuation, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>-10</td>
</tr>
<tr>
<td>500</td>
<td>-15</td>
</tr>
<tr>
<td>550</td>
<td>-20</td>
</tr>
<tr>
<td>600</td>
<td>-25</td>
</tr>
</tbody>
</table>

Length = 60m, Coax type = 13

<table>
<thead>
<tr>
<th>Freq, MHz</th>
<th>Attenuation, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>-12</td>
</tr>
<tr>
<td>500</td>
<td>-14</td>
</tr>
<tr>
<td>550</td>
<td>-16</td>
</tr>
<tr>
<td>600</td>
<td>-18</td>
</tr>
</tbody>
</table>

Length = 110m, Coax type = 9

<table>
<thead>
<tr>
<th>Freq, MHz</th>
<th>Attenuation, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>-5</td>
</tr>
<tr>
<td>500</td>
<td>-4</td>
</tr>
<tr>
<td>550</td>
<td>-3</td>
</tr>
<tr>
<td>600</td>
<td>-2</td>
</tr>
</tbody>
</table>

Length = 163m, Coax type = 11

<table>
<thead>
<tr>
<th>Freq, MHz</th>
<th>Attenuation, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>-6</td>
</tr>
<tr>
<td>500</td>
<td>-5</td>
</tr>
<tr>
<td>550</td>
<td>-4</td>
</tr>
<tr>
<td>600</td>
<td>-3</td>
</tr>
</tbody>
</table>

Length = 60m, Coax type = 13

<table>
<thead>
<tr>
<th>Freq, MHz</th>
<th>Attenuation, dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>-6</td>
</tr>
<tr>
<td>500</td>
<td>-5</td>
</tr>
<tr>
<td>550</td>
<td>-4</td>
</tr>
<tr>
<td>600</td>
<td>-3</td>
</tr>
</tbody>
</table>

Length = 135m, Coax type = 2
Noise floor

• -160 to -140 dBm/Hz


<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave</td>
<td>-140</td>
</tr>
<tr>
<td>50%</td>
<td>-150</td>
</tr>
<tr>
<td>90%</td>
<td>-140</td>
</tr>
<tr>
<td>95%</td>
<td>-136</td>
</tr>
<tr>
<td>99%</td>
<td>-128</td>
</tr>
</tbody>
</table>

Table gives average, 50 (median), 90,95, and 99 percentile noise (dBm/Hz)

Downstream Sharing

• Analog TV
• Digital TV
• FM
• Assume
  - 15 PAL channels starting at 300MHz
  - 20 Digital channels starting at 650MHz
  - 20 FM stations in 88 to 108 MHz range
IM Products - Nonlinearities

• IM products with one or more digital parents have “broad” spectrum with a low PSD

• IM products from PAL/SECAM signals only have a “narrow’’ spectrum with a high PSD

• Narrowband beats in the frequency domain have [5]: A variable signal level with an average level of 24 dB above the noise level.

• FCC system specification for CSO and CTB: equal to or greater than 51 dB [6]

[6] Operation and Design of the HFC Network, PS # 10348 -TG Rev.1.0 053105
Sample Downstream Noise and Legacy

- 15 PAL channels starting at 300MHz
- 20 Digital channels starting at 650MHz
- 20 FM stations in 88 to 108 MHz range

Figures show intermodulation affects:
- Raised broadband noise floor
- Narrowband peaks

Can use downstream spectrum from 422 to 614 MHz
Upstream

- Up to 300MHz
- Higher noise than downstream
- FM interference
- Common path distortion (CPD), intermodulation products
FM shielding

- FM Radio band - 88 to 108 MHz

Table gives average, 50 (median), 90, 95, and 99 percentile home wiring shielding (dB)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave</td>
<td>67</td>
</tr>
<tr>
<td>50%</td>
<td>58</td>
</tr>
<tr>
<td>90%</td>
<td>42</td>
</tr>
<tr>
<td>95%</td>
<td>36</td>
</tr>
<tr>
<td>99%</td>
<td>27</td>
</tr>
</tbody>
</table>

Common Path Distortion

- Occurs on the part of the network common to the forward and return Path
- Composed of distortion products of the downstream signals
- 2nd or 3rd order or both
- Amplitudes vary with conditions

http://cable.doit.wisc.edu/cpd/cpd2.v2.html#origins
Upstream Simulation

Channel Profile
- Select distance from tap to user (50m to 150m)
- Select cable type (1 to 18)
- Get basic attenuation profile
- Select number of multipath components
- Add multipath

Noise Profile
- Select basic noise level
- Add intermodulation products
- Add FM interference

Do bit-loading
Measure RB capacity (Number of subcarriers = 8, Number of symbols = 1)
Upstream Results

Channel response

Noise spectrum

RB capacity

Freq, MHz

Channel response

Noise spectrum

RB capacity

Freq, MHz

Freq, MHz

Freq, MHz

Freq, MHz

(channel response)

(channel response)

(channel response)

(channel response)
Upstream Results
100 cases
Summary

• Channel model for data rate analysis and bit-loading simulation
• RB capacity variation for upstream

Questions?