Introduction

DOCSIS 3.1 provides a way for cable operators to increase capacity and speed, with up to 50 percent more data throughput over the same spectrum than DOCSIS 3.0, and the ability to deliver 2.5 Gbps in the upstream and 10 Gbps in the downstream on an existing hybrid fiber-coaxial (HFC) network. DOCSIS 3.1 achieves its capacity increase – as much as 50 percent in the upstream and downstream signal directions—through the use of orthogonal frequency-division multiplexing (OFDM) and low-density parity-check (LDPC) forward error correction (FEC) technology. The standard mandates the use of up to 4096 QAM modulation with a 24- to 192 MHz channel bandwidth in the downstream, and up to 4096 QAM modulation with up to a 96 MHz bandwidth in the upstream. It also supports pure Intellectual Property (IP) payload data, can co-exist with legacy channels on the existing HFC infrastructure and is backward-compatible with the large installed base of earlier DOCSIS gear.

The Keysight Technologies, Inc. DOCSIS 3.1 Baseband Verification Library is an optional add-on library for SystemVue, providing reference designs for DOCSIS 3.1 fully coded sources and receivers for both Downstream and Upstream. It enables end-to-end simulation modeling for DOCSIS 3.1 systems.
Who should use the DOCSIS library?

System-level architects, baseband algorithm designers and RF component designers can use the DOCSIS 3.1 library to perform early system validation, with or without working baseband or RF hardware. SystemVue is also scriptable, linkable to other platforms and connects to high-performance test equipment, providing both flexibility and consistency across the full product lifecycle.

The DOCSIS 3.1 library is intended for use in early research and development, and in academic research systems to enable the exploration of algorithm and system robustness in deep margin and interference situations.

What can you do with the SystemVue DOCSIS 3.1 library?

With the SystemVue DOCSIS 3.1 library, users can simulate DOCSIS 3.1 system performance (including baseband Transmitter (Tx)/Receiver (Rx) algorithms and RF impairments); with or without DOCSIS 3.0 SC-QAM system interference.

- **Baseband modeling**: Replace algorithms in the DOCSIS 3.1 reference design with your own custom algorithms in C++, MATLAB, or HDL model formats, or use graphically-defined schematics. SystemVue also conveniently integrates with MATLAB for IP compatibility and portability.

- **System modeling**: Evaluate algorithms under user-defined fading, noise and interference (e.g., analog TV, DOCSIS 3.0 SC-QAM and LTE). RF impairments can also be included.

- **Research and emerging standards**: Investigate advanced channel coding techniques such as LDPC and OFDM in video systems. Provide a platform to investigate DOCSIS 3.1 system performance with, for example, different windowing functions, time interleaving depths and the number of continuous pilots.

- **RF component evaluation**: Fill gaps for RFIC/RF module designers who want to assess system-level performance based on simulated or tested analog designs. SystemVue can interact with the Keysight ADS and GoldenGate RF EDA simulators, with X-parameters \(^1\), and more.

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1. X-parameters is a trademark and registered trademark of Keysight Technologies in the United States, European Union, Japan and elsewhere. The X-parameters format and underlying equations are open and documented. For more information, visit [www.keysight.com/find/eesof-x-parameters-info](http://www.keysight.com/find/eesof-x-parameters-info).
Figure 1. The DOCSIS Library supports both downstream and upstream sources and receivers, allowing communication designers to quickly analyze BER and MER performance of DOCSIS radio links. Shown here is a DOCSIS 3.1 Downstream BER test.

Figure 2. DOCSIS 3.1 Upstream bit-error rate simulation.
What is included in DOCSIS 3.1?

### DOCSIS 3.1 downstream reference transmitter

- **Channel bandwidth**
  - 24 MHz to 192 MHz

- **IDFT size**
  - 4096
  - 8192

- **Cyclic prefix**
  - 0.9375 μs (192 * Tsd)
  - 1.25 μs (256 * Tsd)
  - 2.5 μs (512 * Tsd)
  - 3.75 μs (768 * Tsd)
  - 5 μs (1024 * Tsd)

- **Tukey raised cosine windowing**
  - 0 μs (0 * Tsd)
  - 0.3125 μs (64 * Tsd)
  - 0.625 μs (128 * Tsd)
  - 0.9375 μs (192 * Tsd)
  - 1.25 μs (256 * Tsd)

- **Flexible exclusion band insertion**
  - Yes
  - No

- **Modulation**
  - 16-QAM
  - 64-QAM
  - 128-QAM
  - 256-QAM
  - 512-QAM
  - 1024-QAM
  - 2048-QAM
  - 4096-QAM

- **FEC coding for payload**
  - BCH
  - LDPC
  - Interleaver
  - Randomizer

### DOCSIS 3.1 downstream reference receiver

- **Frame synchronization**
- **Carrier frequency synchronization**

- **Corrections applied**:
  - Carrier frequency offset
  - IQ phase rotation
  - IQ imbalance
  - AGC re-normalization

- **Channel estimator**

- **Equalization**

- **Log-likelihood ratio (LLR) soft demapper**
  - 16-QAM
  - 64-QAM
  - 128-QAM
  - 256-QAM
  - 512-QAM
  - 1024-QAM
  - 2048-QAM
  - 4096-QAM

- **FEC decoding**
  - BCH decoder
  - LDPC decoder
  - De-interleaver
  - De-randomizer

- **Waveform and data I/O**
  - Input complex modulated waveform from simulation, file I/O or test equipment
  - Output data bits, constellation

- **Measurements and pre-configured templates**
  - BER/FER vs. Eb/N0 or SNR sweeps
  - EVM
  - System-level verification
### DOCSIS 3.1 downstream reference transmitter

<table>
<thead>
<tr>
<th>Channel bandwidth</th>
<th>10 MHz to 96 MHz</th>
<th>6.4 MHz to 96 MHz</th>
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</thead>
<tbody>
<tr>
<td>IDFT size</td>
<td>2048</td>
<td>4096</td>
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<tr>
<td>Cyclic prefix</td>
<td>0.9375 μs (96 * Tsu)</td>
<td>1.25 μs (128 * Tsu)</td>
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<tr>
<td></td>
<td>1.5625 μs (160 * Tsu)</td>
<td>1.875 μs (192 * Tsu)</td>
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<tr>
<td></td>
<td>2.1875 μs (224 * Tsu)</td>
<td>2.5 μs (256 * Tsu)</td>
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<tr>
<td></td>
<td>2.8125 μs (288 * Tsu)</td>
<td>3.125 μs (320 * Tsu)</td>
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<tr>
<td></td>
<td>3.75 μs (384 * Tsu)</td>
<td>5.0 μs (512 * Tsu)</td>
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<tr>
<td></td>
<td>6.25 μs (640 * Tsu)</td>
<td></td>
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### DOCSIS 3.1 downstream reference receiver

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</table>
What is included in DOCSIS 3.0?

SystemVue also has DOCSIS 3.0 library which covers both fully coded downstream (ITU J.83B) and upstream sources as well as downstream receiver.

### DOCSIS 3.0 downstream reference transmitter

- MPEG framing
  - MPEG-2 transport framing
- Forward error correction (FEC)
  - Reed-solomon encoder
  - Interleaver
  - Randomizer
  - Trellis encoder
- Modulation
  - 64-QAM
  - 256-QAM

### DOCSIS 3.0 downstream reference receiver

- Carrier frequency synchronization
- Frame synchronization
- Corrections applied:
  - Carrier frequency offset
  - IQ phase rotation
  - IQ imbalance
  - AGC re-normalization
- MPEG de-framing
  - MPEG-2 transport framing
- FEC decoding
  - Reed-solomon decoder
  - De-interleaver
  - De-randomizer
  - Trellis decoder
- Measurements and pre-configured templates
  - EVM
  - Decoded MPEG-2 transport packet

### DOCSIS 3.0 upstream Reference transmitter

- Modulation
  - QPSK
  - 8-QAM
  - 16-QAM
  - 32-QAM
  - 64-QAM
- Forward error correction (FEC)
  - Reed-solomon encoder
  - Scrambler
  - Interleaver

### DOCSIS 3.0 upstream Reference receiver

- Not provided by this library.
Figure 3. In this example, the DOCSIS library is used to analyze a 4096-QAM upstream communication link having AWGN receiver noise, with a 10 kHz carrier frequency offset. (a) The received constellation is shown without carrier frequency synchronization; (b) and again, with synchronization turned on.

Figure 4. The DOCSIS library provides reliable signal processing references that approach the theoretical performance of various modulation formats. Under non-ideal conditions, the reference receiver corrects for carrier offset frequency (a mistuned receiver), synchronization, IQ rotation/mismatch, and other impairments, just as a finished radio would do. Shown here is BER vs Eb/No of the Upstream link.
Figure 5. BER vs Eb/No of the Downstream communications link.

Figure 6. DOCSIS 3.1 works alongside legacy signals from previous standards. Above, SystemVue combines DOCSIS 3.1 OFDM, DOCSIS 3.0 SC-QAM, and Analog TV into a single wideband signal for download to a AWG.
Configuration

The DOCSIS 3.1 library can be added as an option to any W146x-series SystemVue environment or bundle, such as the W1461BP SystemVue Comms Architect.

The SystemVue W1902 Digital Modem Library can complement the DOCSIS library by generating additional wideband waveforms, such as single-carrier QAM channels (SC-QAM).

SystemVue DOCSIS 3.1 library also works with Keysight hardware, such as M8190A AWG, M9703A digitizer, N5182B (MXG) and N9040A (UXA) to measure MER and BER. Figure 7 shows a configuration of DOCSIS 3.1 library with Keysight EDA simulation tools and test instruments.

Complementary Keysight software (such as Keysight I/O libraries, Command Expert, and the 89600 VSA with option 300) is often used to connect SystemVue to families of Keysight test equipment, including AWGs, digitizers, RF sources, RF analyzers, and others. SystemVue offers a convenient modeling and verification platform that can be used in the R&D environment, in the test lab, or shared over a network.
### Ordering Information

<table>
<thead>
<tr>
<th><strong>Required software configuration</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>– W1461BP SystemVue Comms Architect</td>
</tr>
<tr>
<td>– E4729A Consulting Services (requires quotation)</td>
</tr>
<tr>
<td>– Delivers software simulation library for choice of:</td>
</tr>
<tr>
<td>– DOCSIS 3.1 Downstream TX &amp; RX</td>
</tr>
<tr>
<td>– DOCSIS 3.1 Upstream TX &amp; RX</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>T&amp;M instruments commonly used with this configuration</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>– M8190A wideband baseband AWG</td>
</tr>
<tr>
<td>– N9040A UXA signal analyzer</td>
</tr>
<tr>
<td>– 89600 vector signal analysis software</td>
</tr>
</tbody>
</table>

*See also DOCSIS 3.1 Application Brief 5991-4301EN*

### More Information

For more detailed application information, refer to:
- [www.keysight.com/find/eesof-systemvue-info](http://www.keysight.com/find/eesof-systemvue-info)
- [www.keysight.com/find/eesof-systemvue-videos](http://www.keysight.com/find/eesof-systemvue-videos)
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