Keysight Technologies
Characterizing High-Speed Coherent Optical Transmission Systems

Part 1: Generating clean modulated signals using the M8195A 65 GSa/s AWG

Application Note
Overview

Latest developments in 100 G+ Coherent Optical Transmission Systems and Sub-Systems require more and more flexibility to generate clean modulated signals as well as distorted test signals. The M8195A Arbitrary Waveform Generator gives you the versatility to create the signals you need for dual polarization digital coherent transmission (BPSK, QPSK, PAM4, QAM16, ... QAM256, ...), Orthogonal Frequency Division Multiplexing (OFDM), Time Domain Pulse Shaping and more with data rates of 32 GBaud and beyond.

Furthermore you can add linear and non-linear impairments to your signal or compensate for distortions between the AWG and the system under test or even components inside your system.

The Keysight M8195A offers sample rates of up to 65GSa/s with 20 GHz bandwidth and up to 4 channels - simultaneously in one single AXIe module.

This is the first application note in a series of application notes to demonstrate Keysight’s latest AWG technology in the M8195A as digital modulation source for electrical and electro-optical components.
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A Generalized Setup for Coherent Optical Transmissions

Figure 1 shows a generalized setup for coherent optical transmissions.

### Signal generation

An Arbitrary Waveform Generator (AWG) is used to generate the complex modulated signal. For each of the two polarization planes one I/Q pair is needed. That means, DAC1 and DAC2 drive the modulators for the X (or H) polarization, DAC3 and DAC4 are used to stimulate the modulators for the Y (or V) polarization.

### Linear driver amplifier

Depending on the Mach-Zehnder Modulators (MZM) used for the setup, additional linear driver amplifiers may be necessary to boost the output level of the AWG. It may also be necessary to provide a bias controller for the MZM, which is not shown here. It is assumed, that the modulators are optimized for the modulation formats analyzed.

### Erbium doped fiber amplifier

An Erbium Doped Fiber Amplifier (EDFA) is used to boost the signal before it is sent into a longer fiber. It may be used to simulate fiber effects. For back-to-back measurements the long fiber may be replaced by a short direct connection to the coherent receiver. Depending on the length of the fiber an additional fiber amplifier may be used at the end of the fiber to boost the signal and compensate for the fiber attenuation. For our measurements we will use the short direct connection.

### Integrated dual polarization intradyne coherent receiver

A coherent receiver is used to receive the signal. The second tunable laser source is used as a local oscillator for the coherent receiver.

### Signal reception and digital signal processing

Four ADCs digitize the detected signal. The DSP corrects the frequency offset and arbitrary polarization and compensates link impairments, like chromatic dispersion, polarization mode dispersion and other distortions.

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Figure 1. General Block Diagram for Coherent Optical Transmitters
The Keysight Measurement Setup

The next figure (Figure 2) shows the measurement setup with Keysight high-performance T&M-grade instrumentation.

A multi-channel modulation source - precisely synchronized

To substitute the AWG in the previous Figure 1, the Keysight M8195A 65 GSa/s Arbitrary Waveform Generator is used as a modulation source. The Keysight M8195A is chosen as it is able to drive dual-polarization systems. It provides four independent, precisely synchronized output channels in a single module. Since all four signals are generated by the same instrument without any external circuitry, precise synchronization down to the femtosecond-range can be achieved and maintained. The synchronization of multiple modules allows for optical super-channel experiments, The M8195A uses digital pre-distortion techniques to achieve a clean signal out-of-the-box and at the device under test.

An optical modulation generator tool - generate the signals

To control the Keysight M8195A and mathematically generate the signals a MATLAB® based software called the “Optical Modulation Generator Tool” or in short “OMG Tool” is used. This tool allows complex modulated signals to be generated as well as sinusoidal signals for calibration and verification purposes.

A tunable laser source - make it flexible

Laser 1 is replaced by a Tunable Laser Source (81940A or 81950A or N7711A). This allows additional experiments at different wavelengths.

An optical modulation analyzer - the reference receiver

The coherent receiver is replaced by a N4391A or N4392A Optical Modulation Analyzer. The Optical Modulation Analyzer (OMA) contains a coherent receiver, a tunable laser source as local oscillator for the receiver as well as four high-speed photo diodes connected to high-speed Analog Digital Converters (ADC).

Depending on the signal speed and application two Optical Modulation Analyzers are available:

The N4392A Integrated Optical Modulation Analyzer is the direct match to the M8195A with 63 GSa/s sampling rate and 23 GHz bandwidth.

The N4391A Optical Modulation Analyzer is for more advanced applications. Here the ADCs of a Digital High-End Infiniium Series Oscilloscope DSO-X 93304Q & DSO-Z 563A are used. They provide sample rates up to 80 GSa/s simultaneously on all four channels allowing the analysis of optical signals with up to 62.5 GHz. Higher sample rates of 160 GSa/s with analysis bandwidths of 125 GHz are available optionally e.g. for simultaneous analysis of super-channel signals.

Signal distortions generated by cables, amplifiers etc. can be compensated by embedding / de-embedding the S-parameters of the respective circuits or by performing an in-situ calibration using the Keysight Optical Modulation Analyzer Software based on the 89600 Series Vector Signal Analysis Software.

The Keysight M8195A 65 GSa/s AWG is well suited to address the challenging requirements of clean and distorted signal generation in the high-speed domain.
How to Get the Best Possible Signal Quality Out of the AWG?

Gain offset de-embedding

The gain offset de-embedding accounts for gain imbalances between the received data channels (i.e. frequency independent or static loss occurring during transmission) only. To compensate the imbalance the entered values (amplitude offsets in dB) amplify (>0 dB) or attenuate (<0 dB) the respective data channel.

Cable loss de-embedding

The cable loss de-embedding accounts for the frequency dependent attenuation occurring in every RF cable. The cable attenuation can be calculated using the equations for the conductor and dielectric loss, however this requires the knowledge of the exact properties and dimensions of the used cable. For simplification the cable loss can be approximated here using two parameters $k_1$ and $k_2$ which parameterize the conductor and dielectric loss part respectively according to the following formula.

$$\text{Loss} = k_1 \cdot \sqrt{F} = k_2 \cdot F$$

$F$ denotes the frequency in GHz and factors $k_1$ and $k_2$ parameterize the conductor and dielectric loss part respectively.

When activating the checkbox "Cable loss de-embedding" a plot will show the current loss vs. frequency approximation using parameters $k_1$ and $k_2$. Enter parameters which fit the best to the characteristics of the cables used.

When the checkbox "Cable loss de-embedding" is active the plot figure loss vs. frequency will change accordingly.

Here's an example for a cable loss plot.

![Cable loss example plot for $k_1 = 0.32$ and $k_2 = 0.01$](image)

Let’s look at the AWG side first - how do you get the best possible signal out of the AWG?

The AWG frequency response and resulting de-emphasis is measured and calculated at the instruments output connectors. So connecting external components like cables, DUTs, etc. will add additional signal distortions since these components typically do not have a flat frequency response or add different delays or skews between the channels.

To account for these distortions the OMG Tool User Interface offers three basic elements for compensation besides the de-embedding of S-parameters:

Skew de-embedding

Every external component connected to the AWG will most likely introduce a skew between I/Q and H/V channel pairs since the signal path length for each data channel will be slightly different. Even matched cable pairs tend to have slightly different lengths resulting into skew, often a few picoseconds only. At lower data rates, let’s say 8 or 16 GBaud the impact might be less significant.

At higher data rates like 32 GBaud and beyond these skews can degrade the performance of the transmitted waveform significantly and can be observed by an increased EVM (Error Vector Magnitude) value of the received complex modulation waveform.

To compensate this skew the data channels HI, HQ, VI and VQ can be time-shifted with respect to each other by means of fractional delay filters. The Optical Modulation Generator Tool User Interface allows the desired time-shift to be entered between each IQ pair (HI/HQ and VI/VQ) and polarization channel (H/V). They are entered in picoseconds into the respective controls.

Here is an example:

Let $gd_{HI}$, $gd_{HQ}$, $gd_{VI}$ and $gd_{VQ}$ be the measured group delays of four cables attached to the outputs of the AWG:

$gd_{HI} = 2.5235$ ns
$gd_{HQ} = 2.5241$ ns
$gd_{VI} = 2.5253$ ns
$gd_{VQ} = 2.5243$ ns

The cable skew is calculated according to:

Skew H-IQ = $gd_{HQ} - gd_{HI} = 0.6$ ps
Skew V-IQ = $gd_{VQ} - gd_{VI} = -1.0$ ps
Skew H-Q = $(gd_{VI}+gd_{VQ}) / 2 - (gd_{HI}+gd_{HQ}) / 2 = 1.0$ ps

The compensation values should then have the opposite signs to reverse the cable skews.
Setup and Check for Best Possible Signal Quality

Manual approach

If S-parameters are not available, we can measure the cable skews with the scope from the OMA and compensate them in the OMG tool.

Setup for skew measurement

To perform the skew measurement, connect the M8195A directly to the electrical inputs of the Oscilloscope with exactly the same cables that are going to be used to connect to the modulator later. Make sure that a termination is connected to the remaining output connector (in our case the negative output) of the AWG to avoid signal degradation due to mismatches.

Of course, the four semi-rigid cables between the OMA testset and the oscilloscope need to be removed prior to this.

As an alternative, the N4392A Optical Modulation Analyzer (OMA) with Option 310 (23 GHz Electrical Receiver, 4 Channel Differential Inputs) can be used to measure and adjust the skews. The electrical inputs are then used to measure the skews.

The proceedings hereafter will use the Oscilloscope to perform the measurements.

Generate single frequency sinusoidal signals

As a next step use the “Waveform Generator” from the “Waveform input” tab of the OMG Tool to generate a single frequency sinusoidal signal on all 4 channels of the M8195A. Select “Single-tone waveforms” for the Waveform Pattern and “Single-tone Sine” for all four channels HI, HQ, VI, VQ. The format looks like this: “Frequency (in GHz); Amplitude (0-1); Phase (in degree),” in our case we will use a 10 GHz sine with 100% Amplitude and a phase offset of 0 degree to check the cable skews.

Verify settings

When finished, navigate to the “Setup & calibration” tab of the Optical Modulation Generator Tool and verify the settings here.

Channel 1 thru 4 should be activated since we are going to compensate all four channels for a dual polarization signal. We will also keep the default channel mapping where Ch1 corresponds to HI, Ch2 to HQ, Ch3 and Ch4 to VI and VQ respectively. In the AWG de-emphasis section make sure that the checkbox “Use AWG de-emphasis” is checked. A system bandwidth setting of 20 to 21 GHz is a reasonable value for the 32 GBaud QAM 16 signal later on. A symbol rate of 32 GHz with a roll-off of 0.35 means an electrical bandwidth of (32 GHz*(1 + 0.35))/2 = 21.6 GHz in the contributing I and Q-channel. It makes sure, that we generate signals with a flat frequency response within the set system bandwidth (refer to the User Guide of the M8195A OMG tool for further details on generating signal with de-emphasis).
(Re-) Initialize AWG

Press "(Re-) Initialize AWG" and wait for the process to finish. Upon successful completion the status window in the lower right corner will change from "Initializing DAC" to "finished successfully." Also the serial number of the AWG connected to the OMG tool will be shown in Figure 6.

Download waveform to AWG

Press "Send waveform to AWG" to download and play your signal. The Status Window will show the following Messages "Calculating Waveforms" "Uploading Waveform ..." and when finished "Waveform uploaded".

Setup scope to measure Delta Time

Now setup the scope to measure the Delta Time between channel 1 and 2 which is considered to be the skew between I and Q in the H Polarization and the Delta Time between channel 3 and 4 which is considered to be the skew between I and Q in the V Polarization.

See below a screenshot of the scope settings for measuring the Delta Time between channel 1 and channel 2. The function can be found in the Scope User Interface under Measure → Time → Delta Time. Make sure to select the same "Direction" (see Figure 7). Setup the other channels in the same way.

As a third measurement set up a delta time measurement between channel 1 and 3. This represents the skew between the H- and V-Polarization under the assumption that the skews between I and Q in their corresponding polarizations have been minimized.

To get the correct delays, start with the delay measurement between channel 1 and 2 and channel 3 and 4.

Figure 6. OMG Tool Setup & Calibration screen no skew values entered

Figure 7. Setup Delta Time measurement at oscilloscope
The next figure (Figure 8) shows the skew caused by the cables used to connect the M8195A to the Oscilloscope without any compensation.

**Fixture de-embedding**

Enter the skew measurement results from Figure 8 in the “Fixture de-embedding” section under the “Setup & Calibration” tab in the OMG Tool. The skew de-embedding activates or deactivates skew de-embedding. Activate it to improve signal performance and account for channel delays in the IQ cable pairs between the AWG outputs and the modulator or the device under test (DUT).

- Skew \( H \leftrightarrow Q \) represents the skew between HI and HQ channels.
- A positive value denotes that HQ is delayed with respect to HI.
- Skew \( V \leftrightarrow Q \) means skew between VI and VQ channels.
- A positive value denotes that VQ is delayed with respect to VI.
- Skew \( H \leftrightarrow Q \) means skew between H and V components.

The skew between H and V is defined here as the difference between the mean delay of HI/HQ and VI/VQ. A positive value denotes that V components are delayed with respect to the H components.

Since these are compensation values, you need to enter them with the opposite sign in the Fixture de-embedding dialog.

Example: If you measure 7 ps with the scope you need to enter \(-7\) ps in the corresponding data field of the Fixture de-embedding dialog.

Take the two delays for ch1 & 2 and ch 3 & 4 and enter them with the opposite sign in the skew compensation of the OMG Tool. Leave the H-V delay at 0 for the moment and download the waveform with the checkbox checked (Figure 9).

Once the waveform has been downloaded, measure the remaining delay between channel 1 and 3 (Figure 10).
Enter this delay value with an opposite sign in the H-V delay data field for the fixture de-embedding user interface of the OMG Tool and press download again.

Now the delay should be minimized down to a double digit femtosecond region.

It may be necessary to perform minor adjustments on the skew values measured with the scope to further minimize the delay. The measured skew accuracy depends on the horizontal time resolution chosen on the oscilloscope.

**Final settings & overview**

Here’s an overview list of the measurement results and the final settings:

<table>
<thead>
<tr>
<th>Scope Measurement</th>
<th>Correlates to</th>
<th>Meas. Result</th>
<th>Final setting</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta Time Ch1 vs Ch2</td>
<td>I-Q Skew in H Polarization</td>
<td>6.3 ps</td>
<td>-6.09 ps</td>
<td>Measure → Time → Delta Time</td>
</tr>
<tr>
<td>Delta Time Ch3 vs Ch4</td>
<td>I-Q Skew in V Polarization</td>
<td>-2.03 ps</td>
<td>1.63 ps</td>
<td>Measure → Time → Delta Time</td>
</tr>
<tr>
<td>Delta Time Ch1 vs Ch3</td>
<td>H-V Skew</td>
<td>12.53 ps</td>
<td>-12.73 ps</td>
<td>True, in case I-Q skews in H &amp; V have been minimized</td>
</tr>
</tbody>
</table>

Table 1.2. Overview: Skew measurements on oscilloscope and results.

![Figure 11. H-V delay entered in OMG Tool](image_url)

![Figure 12. Skews after final H-V delay adjustment](image_url)
S-parameter approach

In case S-parameters are available, open the “Setup & Calibration” tab of the OMG Tool, navigate to the “fixture de-embedding” area and press the “Configure” button at the bottom.

This will open a new dialog that allows you to select the S-Parameter (s2p) files of the cables you are using. Figure 13 shows the file dialog.

In this dialog you can choose between de-embedding just the amplitude response or the amplitude and phase response of your cables or the components between the AWG and the Oscilloscope or Device Under Test (DUT).

When checking the “Remove common delay (linear Phase)” checkbox, only the delta delay between the corresponding channels will be compensated. Use this feature if you experience questionable results with larger delays (e.g. using long cables...) per channels.

When all files are selected, close the window and make sure to check the “S-parameter deemb...” checkbox to activate the de-embedding.

Make sure to un-check the cable loss, gain imbalance and skew de-embedding in the Fixture de-embedding section in case the S-parameters contain these corrections already. If needed, they may be used to correct for additional static losses and skews not covered by the S-parameter files.

Press the Download button and wait for the process to finish.

With the same settings on the oscilloscope as in Figure 8, the skews should be down to a few double digit femtoseconds which should be fine for a 32 GBaud 16QAM signal later on.

Again, depending on the quality of the cables used during S-parameter characterization it may be necessary to do some fine adjustments to the delay values in the OMG Tool user interface.

This can be done in the “skew de-embedding” section of the OMG tool as shown for the manual approach.

Press the Download button and wait for the process to finish.

With the same settings on the oscilloscope as in Figure 8, the skews should be down to a few double digit femtoseconds which should be fine for a 32 GBaud 16QAM signal later on.

Again, depending on the quality of the cables used during S-parameter characterization it may be necessary to do some fine adjustments to the delay values in the OMG Tool user interface.

This can be done in the “skew de-embedding” section of the OMG tool as shown for the manual approach.

![Figure 13. S-Parameter file dialog](image-url)
Setup the AWG to Generate Complex Modulated Signals

Now that we compensated the cable losses and skews, we can switch to complex modulated signals.

In our case we want to generate a 32 GBAud DP-16QAM with 0.35 Root Raised Cosine filtering and a PRBS11.

Switch to complex modulated signals

In the Optical Modulation Generator Tool open the “Waveform Input” tab and change the waveform generator setting from “Single-tone waveforms” to “4ch Complex modulation waveforms” and select a 16QAM with a Symbol rate of 32 GBAud.

Choose the right pulse shaping filtering

In most cases complex modulated signals require appropriate filtering to limit the bandwidth usage. The OMG tool allows to set the filtering in the “Pulse shaping” tab.

It provides controls to activate or bypass and configure the pulse shaping filter. Please note, that pulse shaping filter is only active for complex modulation waveforms.

To activate the Pulse Shaping make sure the checkbox “Bypass pulse shaper” is unchecked. The pulse shaping filter is active by default. Filtering is performed by applying a FIR filter to the complex modulation waveform. Each channel (HI, HQ, VI, VQ) will be filtered with the same FIR coefficients.

The Pulse shaping filter selector allows you to select from five different filter settings:

- **Transparent (no filter):** applies a unit impulse response (no filtering).
- **Hold (rectangular filter):** applies a rectangular impulse response (acting like a sample and hold element). Remark: The length of the rectangular pulse depends on the selected baud rate.
- **Raised Cosine:** applies a raised cosine filter using the entered roll-off factor
- **Root Raised Cosine:** applies a root raised cosine filter using the entered roll-off factor
- **Gaussian:** applies a Gaussian filter using the entered bandwidth-time product (BT) parameter
The Roll-off / BT controls the parameter for the filter selected. For Raised Cosine and Root Raised Cosine filter it defines the Roll-off parameter which must be in the range of 0...1. For the Gaussian filter it sets the Bandwidth-time product. The two graphs show the response of the selected filter in the time and frequency domain.

For our measurement, we will select a Root Raised Cosine filter with a Roll-off of 0.35.

With the settings done, switch back to the “Setup & Calibration” tab. It should look like Figure 16.

Send the waveform to the AWG
Press the Send waveform to AWG button and wait for the download process to finish. The process may take a couple of seconds to finish depending on the CPU power of your PC.

Setup the scope
Start the OMA/VSA software on the scope and set it up for electrical measurements. Under Input make sure to select a dual I+jQ configuration with a channel map like the one in Figure 17.

Go to Meas Setup and setup the Digital Modulator according to your transmitter/AWG settings.
Setup the OMA software similar to Figure 17 through Figure 19 and observe the EVM readings in the Optical Properties for channel 1 and 2 representing the H and V channel and the Optical Signal Summary which also shows the skew between H and V as well as the symbol rate of the signal.

**In-situ calibration**

Now let’s perform the in-situ calibration to compensate the residuals in our setup. For this measurement we selected the generic manual compensation for skew measured with the scope and a general cable loss compensation which does not consider individual frequency response differences in the cables we used.

**Adaptive equalization filter**

The OMA/VSA Software can measure and compensate these residual frequency and phase responses with the help of the Adaptive Equalization Filter in the OMA/VSA software.

Adaptive equalization removes linear errors from modulated signals by dynamically creating and applying a FIR (feed-forward) compensating filter. Linear errors can come from filters in a transmitter or from the presence of multiple paths in the transmission path, such as reflections in a cable system. These types of problems appear as group-delay distortion, frequency-response errors (tilt, ripple), and reflections or multipath distortion.

Equalization allows measurement of some impaired channels and can be used to isolate linear from non-linear error mechanisms. Equalization does not require symbol lock or prior knowledge of the signal (such as a training sequence) and is compatible with recorded data.

**Signal pre-distortion**

The equalizer response is then used to pre-distort the signal in the AWG and compensate the residual frequency and phase responses of the setup.
### A 10-step procedure to determine the pre-distortion

Here’s a general procedure to determine the pre-distortion for the AWG waveform:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Generate mathematically “correct” signal</td>
</tr>
<tr>
<td>2</td>
<td>Load waveform into AWG</td>
</tr>
<tr>
<td>3</td>
<td>Capture with scope directly and demodulate with VSA</td>
</tr>
<tr>
<td>4</td>
<td>Turn on Equalizer functionality in OMA/VSA</td>
</tr>
<tr>
<td>5</td>
<td>Let the equalizer determine frequency &amp; phase response and read it out</td>
</tr>
<tr>
<td>6</td>
<td>Invert frequency and phase response</td>
</tr>
</tbody>
</table>
| 7    | Multiply with original signal in frequency domain  
    | or  
    | Create FIR filter and apply to original signal |
| 8    | Load pre-distorted signal into AWG |
| 9    | Turn off Equalizer in VSA |
| 10   | Optionally: repeat steps 3 - 9 |
See the whole procedure above, displayed in a flowchart.

Figure 20. Process to determine pre-distortion
The Pre-distortion process can be extended to include external components (like amplifiers) as well.

Figure 21. Setup to compensate amplifiers in the path

The Equalizer can be accessed in the MeasSetup → DigitalDemodProperties → Compensate menu (see Figure 22).

Figure 22. Adaptive Equalizer for in-situ calibration of the measurement setup.

With the equalizer turned on, allow a couple of updates until the EVM values are stabilizing and they are not improving anymore. Depending on the Equalizer Settings you may need to increase the Convergence factor in case the equalizer distorts immediately or decrease the value in case the equalizer does show no effect over time. Figure 23 shows the equalizer frequency responses for channel 1 (upper yellow trace) and channel 2 (lower green trace) on the left hand side, the right hand side shows the phase response for the two channels (Ch1 upper yellow, Ch2 lower green).

Figure 23. Equalizer responses from Channel 1 and 2 in VSA software

When satisfied with the equalizer effects, put it on “Hold” and switch to the OMG Tool. In here navigate to the AWG de-emphasis section. When the OMA/VSA VISA address known to the OMG Tool, it is able to read the response and pre-distort the signal mathematically to compensate the distortions introduced by the setup.

Figure 24. Read VSA Equalizer in OMG Tool

Once the equalizer data has been transferred into the OMG Tool, check the “Use VSA equalization filter” checkbox and press “Send waveform to AWG”.

The equalizer response has been used to pre-distort the signal in the AWG and compensate the residual frequency and phase responses of the setup.
When the process has finished, the VSA should look like Figure 25.

Figure 25 shows now the pre-distorted and compensated signals from the M8195A. It can be considered as the base line for further measurements.

Figure 25. Pre-distortion in the AWG turned on using the EQ responses. EVM down to 3.93%rms for H and 4.16%rms for V.

Summary

- A wide bandwidth AWG is a very versatile instrument for signal generation in coherent optical applications for both clean and distorted signals
- Precise (< 1ps) synchronization of 2 or 4 channels is a requirement to generate dual-polarization I + Q signals
- Built-in pre-distortion techniques can improve signal quality significantly
What’s Next?

The chart below shows a block diagram to describe a typical high-speed transmission line with network components, distortions, and impairments.

- The impact of distortions and impairments in each network element needs to be understood to assure proper high-speed transmission.
- The transmission distance for advanced modulation schemes are limited not only by the available optical signal-noise ratio (OSNR) but also by fiber non-linearities. Increasing signal power generates unwanted non-linearities. How can non-linearity effects be avoided or compensated?
- How does one link impairment or signal distortion interact with others?
- How can high-capacity optical transmission links be developed minimize electrical power consumption?
- How can the distortions and impairments mentioned above be emulated to develop more robust digital signal processing for the receivers?
- How can the tolerance of the transmission link for the above mentioned impairments and distortions be increased?

Follow Keysight’s series of application notes, which describe Keysight’s product offering in depth to answer these questions.

Application Note Part 1: Generating clean modulated signals using the M8195A 65 GSa/s AWG.
Application Note Part 2: Generating distorted test signals and link impairments using M8195A 65 GSa/s AWG.
Application Note Part 3: Keysight analysis tools to support the verification and design of coherent transmission links.
Outlook

The described developments in Coherent Optical Transmission Systems and Sub-Systems require more and more flexibility to generate clean modulated signals as well as distorted test signals. The Keysight M8195A 65 GSa/s Arbitrary Waveform Generator gives you the versatility to create the signals you need for dual polarization digital coherent transmission, Orthogonal Frequency Division Multiplexing (OFDM), Time Domain Pulse Shaping and more.

Furthermore you can add linear and non-linear impairments to your signal or compensate for distortions between the AWG and the system under test or even components inside your system.

The Keysight M8195A offers sample rates of up to 65 GSa/s with 20 GHz bandwidth and up to 4 channels for generating > 32 GBaud complex modulated signals – simultaneously in one single AXIe module.

To characterize and analyze the impact of versatile signal and impairment generation a high-performance analysis tool is needed. The N4391A and N4392A Optical Modulation Analyzers offers comprehensive characterization of amplitude and phase modulated optical signals for 400 Gb/s up to 1 Tb/s transmission systems and advanced research for terabit transmission.

The Optical Modulation Analyzer provides:

- Standalone software to extend your analysis capabilities offline
- Wide-bandwidth polarization-diverse coherent optical receiver technology with real-time detection
- Novel signal processing algorithms combined with Keysight 89600 vector signal analysis software
- Seamless integration of Keysight's high-speed real-time data acquisition unit, the Infiniium 90000-Q Series Oscilloscope

Related Literature

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<thead>
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<th>Title</th>
<th>Pub-Number</th>
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<tr>
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<td>5990-3509EN</td>
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<tr>
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