Tools for Digital and Analog Modulation/Demodulation Communications Analysis

NI Modulation Toolkit for LabVIEW

Bit Generation
- PRBS (orders 5-31)
- User-defined

Digital Modulation/Demodulation
- 2, 4, 8, … ASK and PAM
- 4, 8, 16, 32, 64, 128, 256-QAM
- 2, 4, 8, 16-FSK
- MSK and GMSK
- 8, 16, 64-PSK
- BPSK, QPSK, OQPSK, DQPSK, p/4 DQPSK
- Adaptive (LMS) feedforward equalization for ASK, PAM, QAM, PSK
- Continuous phase modulation (CPM)

Analog Modulation/Demodulation
- AM/DSB, AM/SSB, AM/VSB
- FM
- PM

Modulation Analysis Functions
- r (rho)
- DC offset
- Phase error
- Quadrature skew
- IQ gain imbalance
- Bit error rate (BER)
- Frequency deviation
- Burst timing measurements
- Modulation error ratio (MER)
- Error vector magnitude (EVM)

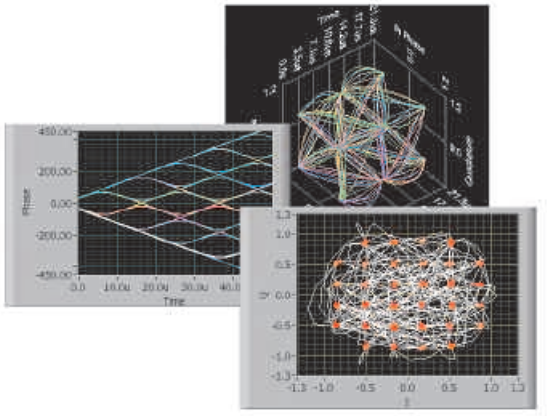
Visualization and Analysis
- Trellis diagrams
- Constellation plot
- 2D and 3D eye diagrams

Channel Coding
- Reed-Solomon
- Golay
- Hamming
- Convolutional
- BCH
- Low-density parity check (LDPC)

Noise/Impairments
- Multitone
- DC offset
- Fading profiles
- Frequency offset
- Quadrature skew
- IQ gain imbalance
- Additive white Gaussian noise (AWGN)
- Phase noise

System Requirements
- Windows XP/2000/NT
- LabVIEW 7.0 or later (Full or Pro)

More than 100 Source Code Examples
- Simulation
- Signal generation and acquisition



Overview

The National Instruments Modulation Toolkit for LabVIEW extends the built-in analysis capability of the LabVIEW graphical development environment with functions and tools for signal generation, analysis, visualization, and the processing of standard and custom modulation formats. With this toolkit, you can rapidly develop custom applications for research, design, characterization, validation, and test of communications systems and components. The numerous applications for the NI Modulation Toolkit include the following modulation formats: AM, FM, PM, ASK, FSK, MSK, GMSK, PSK, QPSK, PAM, QAM, CPM. These modulation schemes are the foundation of many emerging wireless technologies such as those found in 802.11 a/b/g, ZigBee (802.15.4), WiMax (802.16a), RFID, tire pressure monitoring systems (TPMSs), satellite communications, and commercial broadcast among others.

Flexible to Meet Your Needs

A key feature of the Modulation Toolkit for LabVIEW is flexibility, which is important given the rapidly changing nature of communications research, applications, and standards. Flexibility results from the integration of the Modulation Toolkit with the LabVIEW development environment – you can easily combine the modulation-specific analysis of this toolkit with the general-purpose analysis, signal processing, visualization, and instrument control tools of LabVIEW. Using the Modulation Toolkit, you can wire together a complete "software radio" built around analog or digital modulation. This capability not only enables rapid implementation of simulations but also streamlines the development of test and measurement applications that you use to determine the quality of transmitter modulation or receiver demodulation.

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Analyze Simulated, Previously Acquired, or Live Data

By installing the Modulation Toolkit, you enhance LabVIEW with new palette VIs and more than 100 source code examples. You can apply these new components for hardware-independent simulation where you work with previously acquired data from a file or generated by a simulation model. You can also integrate the functions with high-frequency design tools to address the complexity of accurate source and component design verification by linking a behavioral model for simulation directly to automated test system results. By working within the LabVIEW development environment, you can also easily wire toolkit VIs together with other VIs that control acquisition or signal generation hardware. Custom applications built with the Modulation Toolkit can control PC-based modular instruments from National Instruments as well as send commands and acquire data from a traditional instrument connected to a PC through GPIB, Ethernet, or any other communication protocol supported by LabVIEW.

The Modulation Toolkit for LabVIEW complements the NI PXI-5660 and PXI-5661 RF vector signal analyzers and the NI PXI-5670, PXI-5671, and PXIe-5672 RF vector signal generators. By combining the functionality of the RF vector signal analyzer, RF vector signal generator, and the Modulation Toolkit, you have a virtual instrumentation platform with custom vector signal and modulation analysis and generation capabilities. For lower-frequency operation (baseband or IF signals), the Modulation Toolkit works with 100 MHz mixed-signal test platform digitizers, arbitrary waveform generators, and high-speed digital I/O products from NI.

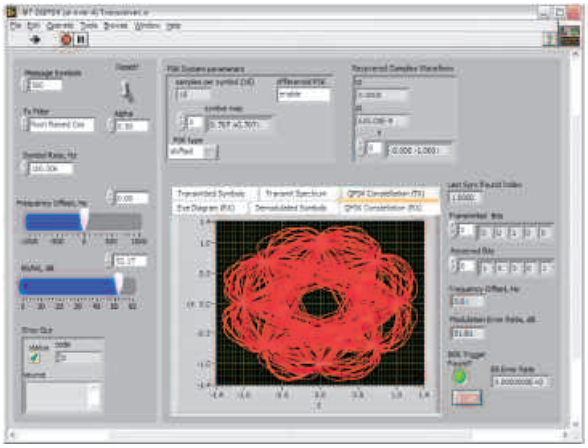

Figure 1. This front panel for π/4 DQPSK is one of more than 100 source code examples that are shipped with the Modulation Toolkit for LabVIEW. You can use these working examples or customize them to meet your needs.

Modeling Impairments

	MT Add AWGN	Generates zero-mean complex additive white Gaussian noise (AWGN) and adds it to the complex-valued baseband modulated waveform, returning a signal-plus-noise waveform having a user-specified Eb/N0.
	MT Add Phase Noise	Models and applies common sources of phase noise present in communications systems components.
	MT Add MultiTone	Generates a multitone and adds it to the complex-valued baseband modulated waveform, returning a signal-plus-tones waveform.
	MT Apply Fading Profile	Applies a Rician or Rayleigh profile to fade the complex-valued baseband modulated waveform.
	MT Apply I-Q Impairments	Applies various I-Q impairments to the complex-valued baseband modulated waveform including DC offset, IQ gain imbalance, quadrature skew, and frequency offset.

Measurements

	MT Calculate BER After Trigger	Calculates the average bit error rate (BER) using a PN sequence or a user-specified reference pattern. This is a polymorphic function.
	MT Measure Burst Timing	Locates a burst within the input complex waveform with peaks correlating to the input ideal power curve.
	MT Measure ASK Quadrature Impairments	Calculates the DC offset, magnitude error, phase error, error vector magnitude (EVM), and modulation error ratio (MER) for a demodulated signal. Finds DC offset measurements that include I, Q, and origin. Returns the peak, rms, and per-symbol impairment value.
	MT Measure CPM Quadrature Impairments	Calculates the DC offset, magnitude error, phase error, error vector magnitude (EVM), modulation error ratio (MER), IQ gain imbalance, and quadrature skew for a demodulated signal. Finds DC offset measurements that include I, Q, and origin. Returns the peak, RMS, and per-symbol impairment value.
	MT Measure MSK Quadrature Impairments	Calculates the DC offset, magnitude error, phase error, error vector magnitude (EVM), modulation error ratio (MER), IQ gain imbalance, and quadrature skew for a demodulated signal. Finds DC offset measurements that include I, Q, and origin. Returns the peak, RMS, and per-symbol impairment value.
	MT Measure PAM Quadrature Impairments	Calculates the DC offset, magnitude error, phase error, error vector magnitude (EVM), and modulation error ratio (MER) for a demodulated signal. Finds DC offset measurements that include I, Q, and origin. Returns the peak, RMS, and per-symbol impairment value.
	MT Measure PSK Quadrature Impairments	Calculates the DC offset, magnitude error, phase error, error vector magnitude (EVM), modulation error ratio (MER), IQ gain imbalance, and quadrature skew for a demodulated signal. Finds DC offset measurements that include I, Q, and origin. Returns the peak, RMS, and per-symbol impairment value.
	MT Measure QAM Quadrature Impairments	Calculates the DC offset, magnitude error, phase error, error vector magnitude (EVM), modulation error ratio (MER), IQ gain imbalance, and quadrature skew for a demodulated signal. Finds DC offset measurements that include I, Q, and origin. Returns the peak, RMS, and per-symbol impairment value.
	MT Measure Rho	Calculates r (rho) given an acquired and ideal waveform. r (rho) is a measure of correlation between the measured complex-valued waveform and the ideal complex-valued waveform.

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Visualization

	MT Display 3D Eye	Divides an input complex-valued waveform into segments and displays those segments as overlapping plots on a 3D graph. It determines the segment length based on the symbol rate and eye length input parameters.
	MT Format Constellation	Prepares a signal for presentation on a graph showing the detected symbol locations and the transitions between those symbols. The VI inputs a complex-valued waveform and displays a constellation plot of the waveform contents.
	MT Format Eye Diagram	Inputs a complex- or real-valued waveform, divides it into segments, and plots those segments on a waveform graph. It determines the segment length based on the symbol rate and eye length input parameters.
	MT Format Trellis Diagram	Inputs a complex-valued waveform, divides it into segments of (trellis length/symbol rate), and displays those segments as a trellis diagram on a standard LabVIEW waveform graph referenced by the trellis reference input.
	MT IQ to XY Graph	Formats IQ data for plotting on a LabVIEW XY graph.

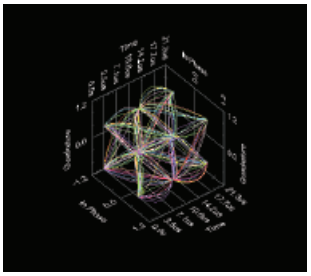

Figure 2. A 3D plot visually separates the I and Q components of a PSK modulated signal.

Design Utilities

	MT Get Complex IQ Component	Extracts the desired component from the IQ data wire. I, Q, magnitude, and phase data are available for extraction. This VI returns a complex envelope (CE) component output containing the t0, dt, and Y values for the chosen component.
	MT Fractional Resample	Inputs a complex-valued waveform and resamples and/or realigns it based on the input parameters that you specify.
	MT Generate Filter Coefficients	Calculates filter coefficients for pulse shaping and matched filters applied by the digital modulation and demodulation VIs.
	MT Generate Fading Profile	Generates a user-specified Rayleigh or Rician fading profile to the complex baseband waveform using a Jakes or Gans model.
	MT Generate CPM System Parameters (M)	Calculates parameters for use with either the MT Modulate CPM VI or the MT Demodulate CPM VI. It accepts an M-ary value that specifies a predefined symbol map with the number of distinct symbol map values to use as symbols.
	MT Generate ASK System Parameters	This polymorphic function calculates parameters for use with either the MT Modulate ASK VI or the MT Demodulate ASK VI. It inputs an M-ary value that specifies a predefined symbol map with the number of distinct levels to use as symbols or an array of symbol values that explicitly specify the symbol positions of a symbol map, with symbols that are evenly distributed between 0 and 1.
	MT Generate FSK System Parameters	This polymorphic function calculates parameters for use with either the MT Modulate FSK VI or the MT Demodulate FSK VI. It inputs an M-ary value that specifies a predefined symbol map with the number of distinct symbol map values to use as symbols or an array of symbol values that explicitly define the positions of the symbol map.
	MT Generate MSK System Parameters	Calculates parameters for use with either the MT Modulate MSK VI or the MT Demodulate MSK VI.
	MT Generate PAM System Parameters	This polymorphic function calculates parameters for use with either the MT Modulate PAM VI or the MT Demodulate PAM VI. It inputs an M-ary value that specify a predefined symbol map with the number of distinct levels to use as symbols or an array of symbol values that explicitly specifies the positions of the symbol map with symbols that are evenly distributed between -1 and 1.
	MT Generate PSK System Parameters	This polymorphic function calculates parameters for use with either the MT Modulate PSK VI or the MT Demodulate PSK VI. It inputs an M-ary value that specifies a predefined symbol map with the number of distinct symbol map values to use as symbols or an array of symbol values that explicitly define the positions of the symbol map.
	MT Generate QAM System Parameters	This polymorphic function calculates parameters for use with either the MT Modulate QAM VI or the MT Demodulate QAM VI. It inputs an M-ary value that specifies a predefined symbol map with the number of distinct symbol map values to use as symbols or an array of symbol values that explicitly define the positions of the symbol map.

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Function Description and Highlights

Digital Modulation

	MT Generate Bitstream	Generates the sequence of data bits to be modulated. This VI generates bit sequences based on a fixed pattern, a user-defined pattern, or a PN sequence.
	MT Modulate ASK	Inputs a sequence of data bits, performs ASK modulation, and returns the modulated complex baseband waveform in the output complex waveform parameter.
	Modulate CPM	Inputs a sequence of data bits, performs continuous phase modulation (CPM), and returns the modulated complex baseband waveform in the output complex waveform parameter.
	MT Modulate FSK	Inputs a sequence of data bits, performs FSK modulation, and returns the modulated complex baseband waveform in the output complex waveform parameter.
	MT Modulate MSK	Inputs a sequence of data bits, performs MSK modulation, and returns the modulated complex baseband waveform in the output complex waveform parameter.
	MT Modulate PAM	Inputs a sequence of data bits, performs PAM modulation, and returns the modulated complex baseband waveform in the output complex waveform parameter.
	MT Modulate PSK	Inputs a sequence of data bits, performs PSK modulation, and returns the modulated complex baseband waveform in the output complex waveform parameter.
	MT Modulate QAM	Inputs a sequence of data bits, performs QAM modulation, and returns the modulated complex baseband waveform in the output complex waveform parameter.

Digital Demodulation

	MT Demodulate ASK	Demodulates an ASK-modulated complex baseband waveform and returns the time-aligned oversampled complex waveform, the demodulated bit stream, and the results of offset and drift measurements.
	Modulate Demodulate CPM	Demodulates a CPM-modulated complex baseband waveform and returns the time-aligned demodulated waveform, the demodulated information bit stream, and measurement results obtained during demodulation. This VI attempts to remove carrier and phase offset by locking to the carrier signal.
	MT Demodulate FSK	Demodulates an FSK-modulated complex baseband waveform and returns the time-aligned demodulated waveform, the demodulated information bit stream, and measurement results obtained during demodulation.
	MT Demodulate MSK	Demodulates an MSK-modulated complex baseband waveform and returns the time-aligned oversampled complex waveform, the ideal oversampled waveform, the demodulated bit stream, and the results of offset and drift measurements.
	MT Demodulate PAM	Demodulates a pulse-amplitude-modulated (PAM) complex baseband waveform and returns the time-aligned oversampled complex waveform, the demodulated bit stream, and the results of offset and drift measurements.
	MT Demodulate PSK	Demodulates a PSK-modulated complex baseband waveform and returns the time-aligned oversampled complex waveform, the demodulated bit stream, and measurement results obtained during demodulation.
	MT Demodulate QAM	Demodulates a QAM-modulated complex baseband waveform and returns the time-aligned oversampled complex waveform, the demodulated bit stream, and the results of offset and drift measurements.

Analog Modulation

	MT Modulate AM	Performs amplitude modulation on an RF carrier wave, with optional suppression of the carrier wave, according to a baseband information signal input to the message signal input. Polymorphic instances of this VI support double sideband (DSB), single sideband (SSB), and vestigial sideband (VSB) modulation.
	MT Modulate FM	Performs frequency modulation on an RF carrier wave according to a baseband information signal input to the message signal control.
	MT Modulate PM	Performs phase modulation on an RF carrier wave according to a baseband information signal input to the message signal control.
	MT Upconvert Baseband	Upconverts baseband IQ (complex envelope) signal data to its real passband equivalent.

Analog Demodulation

	MT Demodulate AM	Demodulates an amplitude-modulated baseband (IQ) signal with optional suppressed carrier wave. Polymorphic instances of this VI support double sideband (DSB), single sideband (SSB), and vestigial sideband (VSB) demodulation.
	MT Demodulate FM	Demodulates a frequency modulated baseband (IQ) signal.
	MT Demodulate PM	Demodulates a phase modulated baseband (IQ) signal.
	MT Downconvert Passband	Downconverts real passband signal data of a user-specified bandwidth.

Channel Encoding

	MT BCH Encoder	Generates a Bose-Chaudhari-Hocquenghem (BCH)-encoded bit stream.
	MT LDPC Encoder	Performs LDPC encoding on the input bit stream based on the parity check matrix.
	MT Convolutional Encoder	Generates a convolutional-coded bit stream based on a specified rate or a user-defined generator matrix.
	MT Golay Encoder	Generates a Golay-encoded bit stream. The VI provides the two triple-correcting Golay codes: the Golay (23,12,3) code and the extended Golay (24,12,3) code.
	MT Hamming Encoder	Generates a Hamming-encoded bit stream. The order-m Hamming codes are a special class of Bose-Chaudhari-Hocquenghem (BCH) codes in which the data word length equals 2m-m-1, code word length equals 2m-1, and the error correcting capacity equals 1.
	MT Reed-Solomon Encoder	Generates a Reed-Solomon (RS)-encoded output bit stream from an input binary-valued bit stream. RS codes are generalized Bose-Chaudhari-Hocquenghem (BCH) codes in which the code elements are drawn from the Galois field GF(2m).
	MT Spread Symbols	Performs the direct sequence spread spectrum (DSSS) spreading operation given a user-defined spreading code.

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Channel Decoding

	MT BCH Decoder	Performs decoding on a Bose-Chaudhari-Hocquenghem (BCH)-encoded bit stream using the Berlekamp algorithm for binary BCH codes.
	MT Convolutional Decoder	Decodes the input convolutional-coded bit stream based on a specified rate or a user-defined generator matrix.
	MT Despread Symbols	Performs the direct sequence spread spectrum (DSSS) despreading operation on a spread sequence of data bits.
	MT Golay Decoder	Decodes a Golay-encoded bit stream. The decoder provides the two triple-correcting Golay codes: the Golay (23,12,3) code and the extended Golay (24,12,3) code.
	MT Hamming Decoder	Decodes a Hamming-encoded bit stream. The order-m Hamming codes are a special class of Bose-Chaudhari-Hocquenghem (BCH) codes in which the data word length (k) equals 2m-m-1, code word length (n) equals 2m-1, and the error-correcting capacity (t) equals 1.
	MT Reed-Solomon Decoder	Decodes a Reed-Solomon (RS)-encoded output bit stream from an input binary-valued bit stream.

Equalization

	MT ASK Feedforward Equalizer	Applies adaptive feedforward software equalization using the least-mean-squared (LMS) algorithm to the demodulated input complex waveform.
	MT PAM Feedforward Equalizer	Applies adaptive feedforward software equalization using the least-mean-squared (LMS) algorithm to the demodulated input complex waveform.
	MT PSK Feedforward Equalizer	Applies adaptive feedforward software equalization using the least-mean-squared (LMS) algorithm to the demodulated input complex waveform.
	MT QAM Feedforward Equalizer	Applies adaptive feedforward software equalization using the least-mean-squared (LMS) algorithm to the demodulated input complex waveform.

Ordering Information

NI Modulation Toolkit for LabVIEW 778786-03

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