qamdemod

Quadrature amplitude demodulation

Syntax

```
z = qamdemod(y,M)
z = qamdemod(y,M,symOrder)
z = qamdemod( ___ ,Name,Value)
```

Description

`z = qamdemod(y,M)` returns a demodulated signal, `z`, given quadrature amplitude modulation (QAM) signal `y` of modulation order `M`. example

`z = qamdemod(y,M,symOrder)` returns a demodulated signal, `z`, and specifies the symbol order for the demodulation. example

`z = qamdemod( ___ ,Name,Value)` specifies options using one or more name-value pair arguments. For example, `'OutputType','bit'` sets the type of output signal to bits. example

Examples

collapse all

Demodulate 8-QAM Signal

Demodulate an 8-QAM signal and plot the points corresponding to symbols 0 and 3.

Generate random 8-ary data symbols.

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```
data = randi([0 7],1000,1);
```

Modulate `data` by applying 8-QAM.

```
txSig = qammod(data,8);
```

Pass the modulated signal through an AWGN channel.

```
rxSig = awgn(txSig,18,'measured');
```

Demodulate the received signal using an initial phase of $\pi/8$.

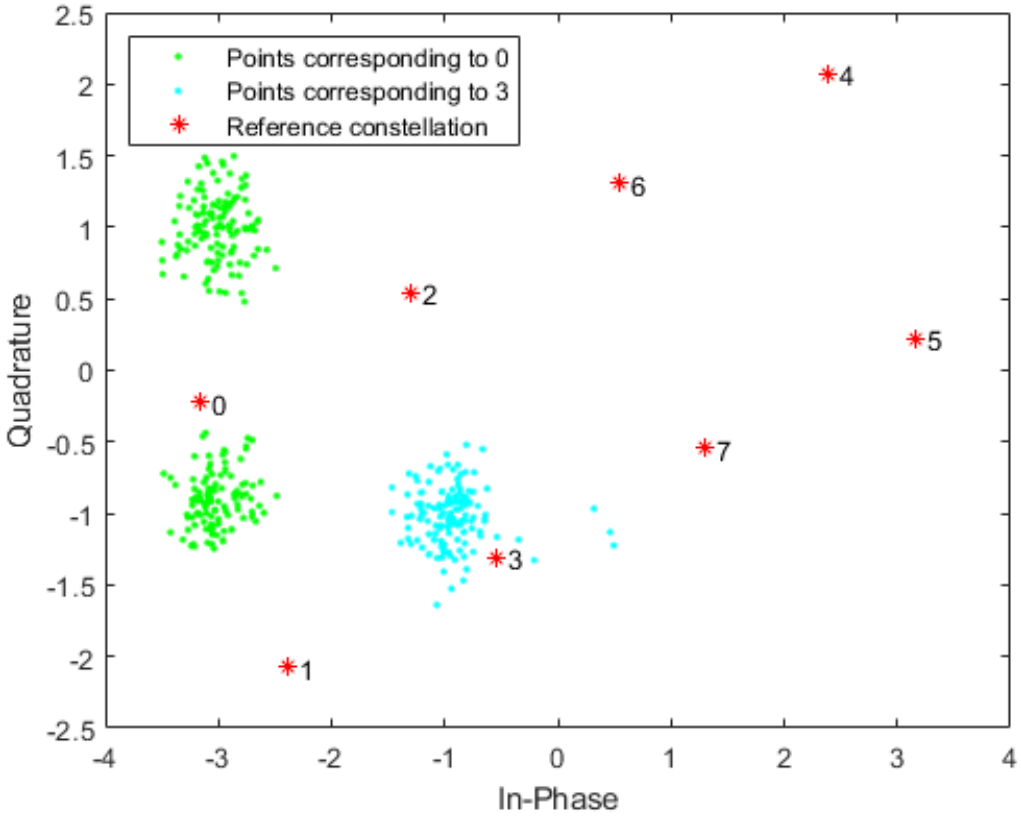
```
rxData = qamdemod(rxSig.*exp(-1i*pi/8),8);
```

Generate the reference constellation points.

```
refpts = qammod((0:7)',8) .* exp(1i*pi/8);
```

Plot the received signal points corresponding to symbols 0 and 3 and overlay the reference constellation. The received data corresponding to those symbols is displayed.

```
plot(rxSig(rxData==0),'g.');
hold on
plot(rxSig(rxData==3),'c.');
plot(refpts,'r*')
text(real(refpts)+0.1,imag(refpts),num2str((0:7)'))
xlabel('In-Phase')
ylabel('Quadrature')
legend('Points corresponding to 0','Points corresponding to 3', ...
    'Reference constellation','location','nw');
```



QAM Demodulation with WLAN Symbol Mapping

Modulate and demodulate random data by using 16-QAM with WLAN symbol mapping. Verify that the input data symbols match the demodulated symbols.

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Generate a 3-D array of random symbols.

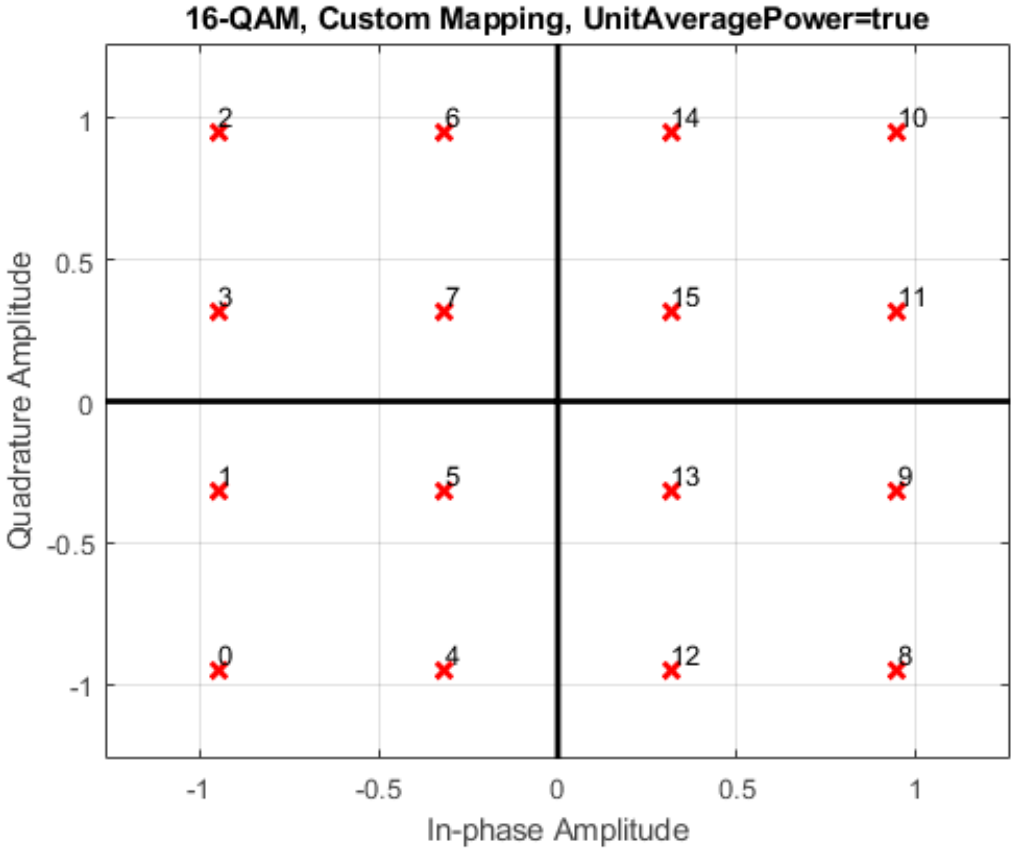
```
x = randi([0,15],20,4,2);
```

Create a custom symbol mapping for the 16-QAM constellation based on WLAN standards.

```
wlanSymMap = [2 3 1 0 6 7 5 4 14 15 13 12 10 11 9 8];
```

Modulate the data, and set the constellation to have unit average signal power. Plot the constellation.

```
y = qammod(x,16,wlanSymMap, ...
    UnitAveragePower=true, ...
    PlotConstellation=true);
```



Demodulate the received signal.

```
z = qamdemod(y,16,wlanSymMap, ...
    UnitAveragePower=true);
```

Verify that the demodulated signal is equal to the original data.

```
isequal(x,z)
```

```
ans = logical
   1
```

Demodulate QAM Fixed-Point Signal

Demodulate a fixed-point QAM signal and verify that the data is recovered correctly.

Set the modulation order as 64, and determine the number of bits per symbol.

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```
M = 64;
bitsPerSym = log2(M);
```

Generate random bits. When operating in bit mode, the length of the input data must be an integer multiple of the number of bits per symbol.

```
x = randi([0 1],10*bitsPerSym,1);
```

Modulate the input data using a binary symbol mapping. Set the modulator to output fixed-point data. The numeric data type is signed with a 16-bit word length and a 10-bit fraction length.

```
y = qammod(x,M,'bin','InputType','bit','OutputDataType', ...
    numerictype(1,16,10));
```

Demodulate the 64-QAM signal. Verify that the demodulated data matches the input data.

```
z = qamdemod(y,M,'bin','OutputType','bit');
s = isequal(x,double(z))
```

```
s = logical
   1
```

Estimate BER for Hard and Soft Decision Viterbi Decoding

Estimate bit error rate (BER) performance for hard-decision and soft-decision Viterbi decoders in AWGN. Compare the performance to that of an uncoded 64-QAM link.

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Set the simulation parameters.

```
rng default
M = 64;                % Modulation order
k = log2(M);           % Bits per symbol
EbNoVec = (4:10)';     % Eb/No values (dB)
numSymPerFrame = 1000; % Number of QAM symbols per frame
```

Initialize the BER results vectors.

```
berEstSoft = zeros(size(EbNoVec));
berEstHard = zeros(size(EbNoVec));
```

Set the trellis structure and traceback depth for a rate `1/2`, constraint length `7`, convolutional code.

```
trellis = poly2trellis(7,[171 133]);
tbl = 32;
rate = 1/2;
```

The main processing loops perform these steps:

- Generate binary data
- Convolutionally encode the data

- Apply QAM modulation to the data symbols. Specify unit average power for the transmitted signal
- Pass the modulated signal through an AWGN channel
- Demodulate the received signal using hard decision and approximate LLR methods. Specify unit average power for the received signal
- Viterbi decode the signals using hard and unquantized methods
- Calculate the number of bit errors

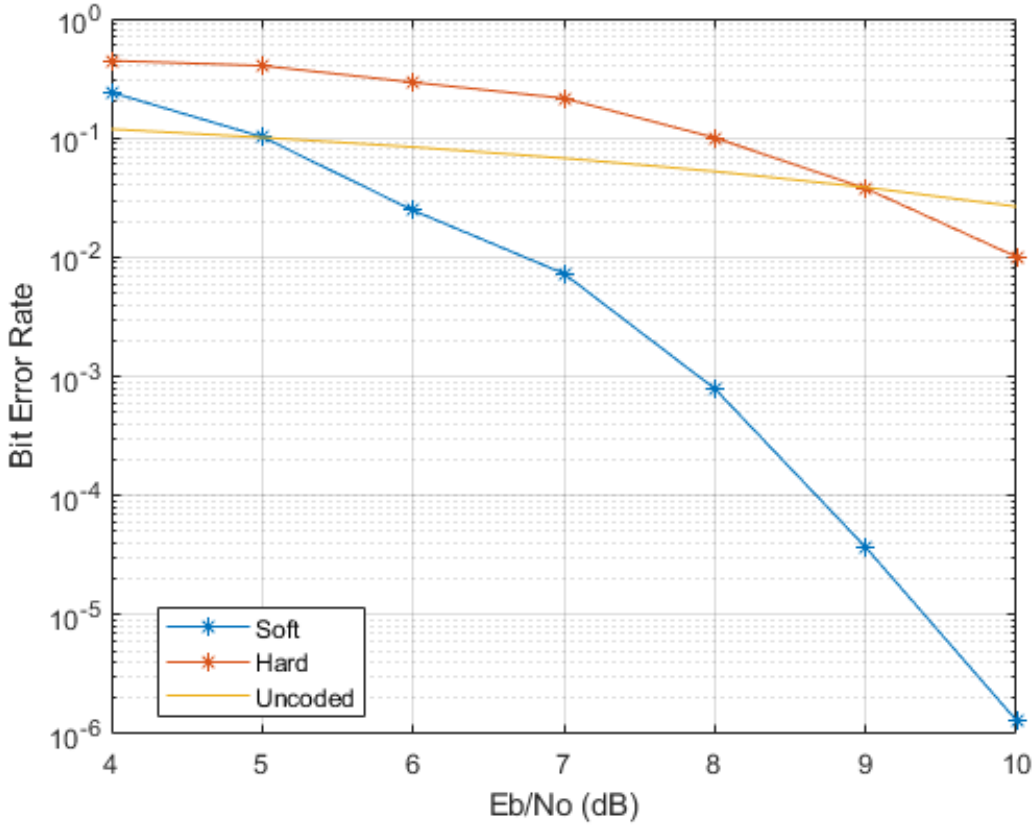
The `while` loop continues to process data until either 100 errors are encountered or 10^7 bits are transmitted.

```
for n = 1:length(EbNoVec)
    % Convert Eb/No to SNR
    snrdB = EbNoVec(n) + 10*log10(k*rate);
    % Noise variance calculation for unity average signal power
    noiseVar = 10.^(-snrdB/10);
    % Reset the error and bit counters
    [numErrsSoft,numErrsHard,numBits] = deal(0);

    while numErrsSoft < 100 && numBits < 1e7
        % Generate binary data and convert to symbols
        dataIn = randi([0 1],numSymPerFrame*k,1);

        % Convolutionally encode the data
        dataEnc = convenc(dataIn,trellis);

        % QAM modulate
        txSig = qammod(dataEnc,M, ...
            InputType='bit', ...
            UnitAveragePower=true);

        % Pass through AWGN channel
        rxSig = awgn(txSig,snrdB,'measured');

        % Demodulate the noisy signal using hard decision (bit) and
        % soft decision (approximate LLR) approaches.
        rxDataHard = qamdemod(rxSig,M, ...
            OutputType='bit', ...
            UnitAveragePower=true);
        rxDataSoft = qamdemod(rxSig,M, ...
            OutputType='approxllr', ...
            UnitAveragePower=true, ...
            NoiseVariance=noiseVar);

        % Viterbi decode the demodulated data
        dataHard = vitdec(rxDataHard,trellis,tbl,'cont','hard');
        dataSoft = vitdec(rxDataSoft,trellis,tbl,'cont','unquant');

        % Calculate the number of bit errors in the frame.
        % Adjust for the decoding delay, which is equal to
        % the traceback depth.
        numErrsInFrameHard = ...
```

```
            biterr(dataIn(1:end-tbl),dataHard(tbl+1:end));
        numErrsInFrameSoft = ...
            biterr(dataIn(1:end-tbl),dataSoft(tbl+1:end));

        % Increment the error and bit counters
        numErrsHard = numErrsHard + numErrsInFrameHard;
        numErrsSoft = numErrsSoft + numErrsInFrameSoft;
        numBits = numBits + numSymPerFrame*k;

    end

    % Estimate the BER for both methods
    berEstSoft(n) = numErrsSoft/numBits;
    berEstHard(n) = numErrsHard/numBits;
end
```

Plot the estimated hard and soft BER data. Plot the theoretical performance for an uncoded 64-QAM channel.

```
semilogy(EbNoVec,[berEstSoft berEstHard],'-*')
hold on
semilogy(EbNoVec,berawgn(EbNoVec,'qam',M))
legend('Soft','Hard','Uncoded','location','best')
grid
xlabel('Eb/No (dB)')
ylabel('Bit Error Rate')
```



As expected, the soft decision decoding produces the best results.

Soft-Decision OQPSK Modulation-Demodulation

Use the `qamdemod` function to simulate soft decision output for OQPSK-modulated signals.

Generate an OQPSK modulated signal.

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```
sps = 4;
msg = randi([0 1],1000,1);
oqpskMod = comm.OQPSKModulator('SamplesPerSymbol',sps,'BitInput',true);
oqpskSig = oqpskMod(msg);
```

Add noise to the generated signal.

```
impairedSig = awgn(oqpskSig,15);
```

Perform Soft-Decision Demodulation

Create QPSK equivalent signal to align in-phase and quadrature.

```
impairedQPSK = complex( ...
    real(impairedSig(1+sps/2:end-sps/2)), ...
    imag(impairedSig(sps+1:end)));
```

Apply matched filtering to the received OQPSK signal.

```
halfSinePulse = sin(0:pi/sps:(sps)*pi/sps);
matchedFilter = dsp.FIRDecimator(sps,halfSinePulse, ...
    'DecimationOffset',sps/2);
filteredQPSK = matchedFilter(impairedQPSK);
```

To perform soft demodulation of the filtered OQPSK signal use the `qamdemod` function. Align symbol mapping of `qamdemod` with the symbol mapping used by the `comm.OQPSKModulator`, then demodulate the signal.

```
oqpskModSymbolMapping = [1 3 0 2];
demodulated = qamdemod(filteredQPSK,4,oqpskModSymbolMapping, ...
    'OutputType','llr');
```

Input Arguments

collapse all

y — Input signal

scalar | vector | matrix | 3-D array

Input signal that resulted QAM, specified as a scalar, vector, matrix, or 3-D array of complex values. Each column in the matrix and 3-D array is considered as an independent channel.

Data Types: `single` | `double` | `fi`
Complex Number Support: Yes

`M` — Modulation order

scalar integer

Modulation order, specified as a power-of-two scalar integer. The modulation order specifies the number of points in the signal constellation.

Data Types: `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`symOrder` — Symbol order

`'gray'` (default) | `'bin'` | vector

Symbol order, specified as one of these options:

- `'gray'` — Use Gray Code ordering.
- `'bin'` — Use natural binary-coded ordering.
- Vector — Use custom symbol ordering. The vector must be of length `M`. Vectors must use unique elements whose values range from 0 to `M` – 1. The first element corresponds to the upper left point of the constellation, with subsequent elements running down column-wise from left to right.

Data Types: `char` | `double`

Name-Value Arguments

Specify optional pairs of arguments as `Name1=Value1,...,NameN=ValueN`, where `Name` is the argument name and `Value` is the corresponding value. Name-value arguments must appear after other arguments, but the order of the pairs does not matter.

Before R2021a, use commas to separate each name and value, and enclose `Name` *in quotes.*

Example: `z = qamdemod(y,M,symOrder,'OutputType','bit')`

`UnitAveragePower` — Unit average power flag

`false` or `0` (default) | `true` or `1`

Unit average power flag, specified as the comma-separated pair consisting of `'UnitAveragePower'` and a numeric or logical `0` (`false`) or `1` (`true`). When this flag is `1` (`true`), the function scales the constellation to the average power of one watt referenced to 1 ohm. When this flag is `0` (`false`), the function scales the constellation so that the QAM constellation points are separated by a minimum distance of two.

`OutputType` — Type of output

`'integer'` (default) | `'bit'` | `'llr'` | `'approxllr'`

Type of output, specified as the comma-separated pair consisting of `'OutputType'` and `'integer'`, `'bit'`, `'llr'`, or `'approxllr'`.

Data Types: `char`

`NoiseVariance` — Noise variance

`1` (default) | positive scalar | vector of positive values

Noise variance, specified as the comma-separated pair consisting of `'NoiseVariance'` and one of these options:

- Positive scalar — The same noise variance value is used on all input elements.
- Vector of positive values — The vector length must be equal to the number of elements in the last dimension of the input signal. Each element of the vector specifies the noise variance for all the elements of the input along the corresponding last dimension.

> **Tip**
>
> Because the Log-Likelihood algorithm computes exponentials using finite precision arithmetic, the computation of exponentials with large or small numbers can yield positive or negative infinity. The approximate LLR algorithm does not compute exponentials. For more details, see Soft-Decision Demodulation.
>
> When `'OutputType'` is `'llr'`, any `Inf` or `-Inf` values returned by the demodulation computation output are likely due to the specified noise variance values being smaller than the signal-to-noise ratio (SNR).
>
> To avoid returning output values of `Inf` or `-Inf`, set `'OutputType'` to `'approxllr'` instead of `'llr'`.

Dependencies

To enable this name-value pair argument, set `'OutputType'` is `'llr'` or `'approxllr'`.

Data Types: `double`

`PlotConstellation` — Option to plot constellation

`false` or `0` (default) | `true` or `1`

Option to plot constellation, specified as the comma-separated pair consisting of `'PlotConstellation'` and a numeric or logical `0` (`false`) or `1` (`true`) To plot the QAM constellation, set `'PlotConstellation'` to `true`.

Output Arguments

collapse all

`z` — Demodulated output signal

scalar | vector | matrix | 3-D array

Demodulated output signal, returned as a scalar, vector, matrix, or 3-D array. The data type is the same as that of the input signal, `y`. The value and dimension of this output vary depending on the specified `'OutputType'` value, as shown in this table.

`'OutputType'`	Return Value of `qamdemod`	Dimensions of Output
`'integer'`	Demodulated integer values from 0 to (`M` – 1)	`z` has the same dimensions as input `y`.
`'bit'`	Demodulated bits	The number of rows in `z` is $\log_2(M)$ times the number of rows in `y`. Each demodulated symbol is mapped to a group of $\log_2(M)$ bits, where the first bit represents the most significant bit (MSB) and the last bit represents the least significant bit (LSB).
`'llr'`	Log-likelihood ratio value for each bit calculated using the Exact Log Likelihood algorithm. For more details, see Exact LLR Algorithm.	
`'approxllr'`	Approximate log-likelihood ratio value for each bit. The values are calculated using the Approximate Log Likelihood algorithm. For more details, see Approximate LLR Algorithm.	

More About

collapse all

Gray Code

A *Gray code*, also known as a reflected binary code, is a system where the bit patterns in adjacent constellation points differ by only one bit.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

Version History

expand all

Introduced before R2006a

R2018b: Initial Phase Input Removed

Errors starting in R2018b

See Also

Functions

`genqammod` | `genqamdemod` | `modnorm` | `pamdemod` | `qammod`

Topics

Compute Symbol Error Rate