qammod

Quadrature amplitude modulation (QAM)

Syntax

```
y = qammod(x,M)
y = qammod(x,M,symOrder)
y = qammod( ___ ,Name,Value)
```

Description

`y = qammod(x,M)` modulates input signal `x` by using QAM with the specified modulation order `M`. Output `y` is the modulated signal. example

`y = qammod(x,M,symOrder)` specifies the symbol order. example

`y = qammod( ___ ,Name,Value)` specifies options using name-value pair arguments in addition to any of the input argument combinations from previous syntaxes. example

Examples

collapse all

Modulate Data Using QAM

Modulate data using QAM and display the result in a scatter plot.

Set the modulation order to 16 and create a data vector containing each of the possible symbols.

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Copy Command

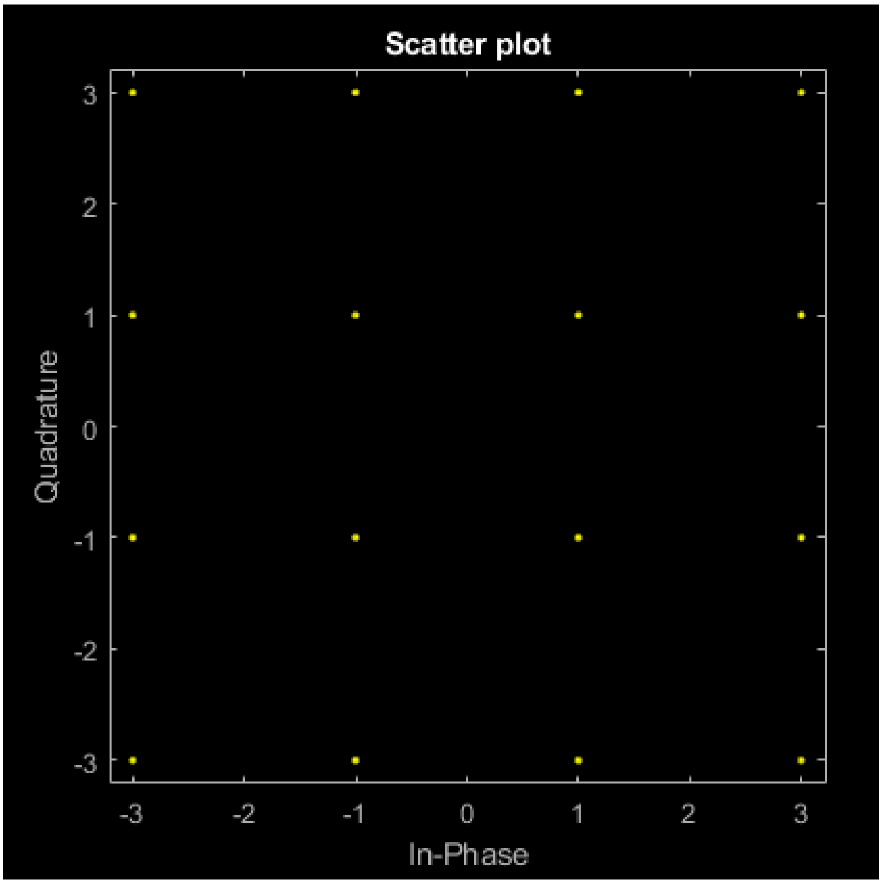
```
M = 16;
x = (0:M-1)';
```

Modulate the data using the `qammod` function.

```
y = qammod(x,M);
```

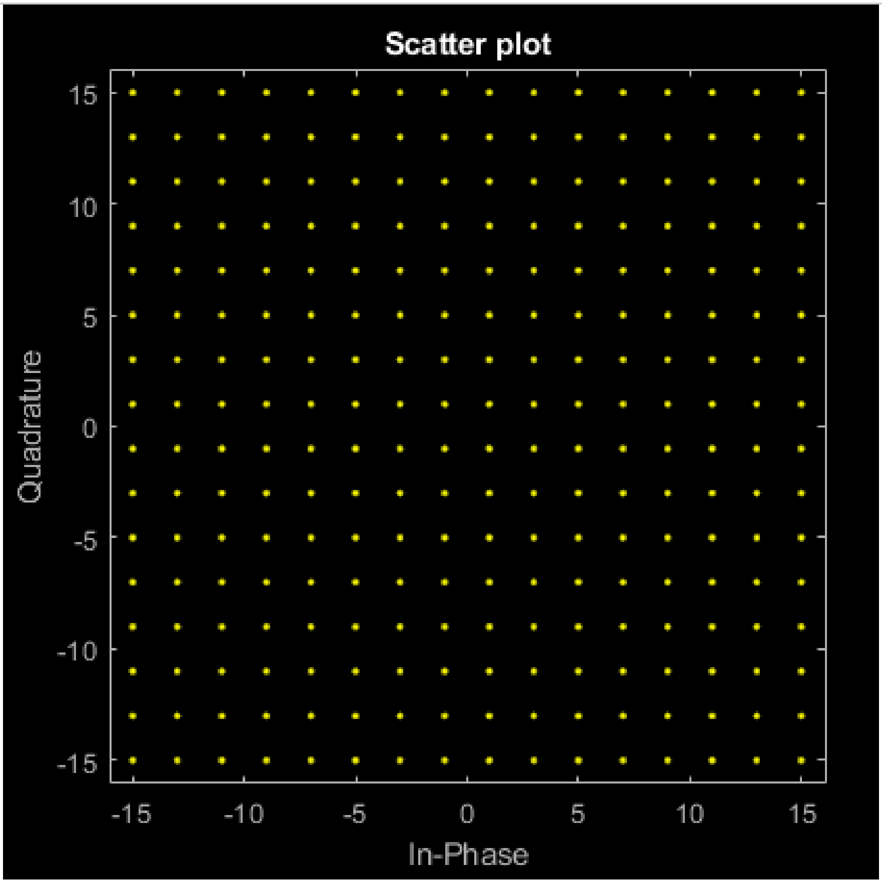
Display the modulated signal constellation using the `scatterplot` function.

```
scatterplot(y)
```



Set the modulation order to 256, and display the scatter plot of the modulated signal.

```
M = 256;
x = (0:M-1)';
y = qammod(x,M);
scatterplot(y)
```



Normalize QAM Signal by Average Power

Modulate random data symbols using QAM. Normalize the modulator output so that it has an average signal power of 1 W.

Set the modulation order and generate random data.

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Copy Command

```
M = 64;
x = randi([0 M-1],1000,1);
```

Modulate the data. Use the `'UnitAveragePower'` name-value pair to set the output signal to have an average power of 1 W.

```
y = qammod(x,M,'UnitAveragePower',true);
```

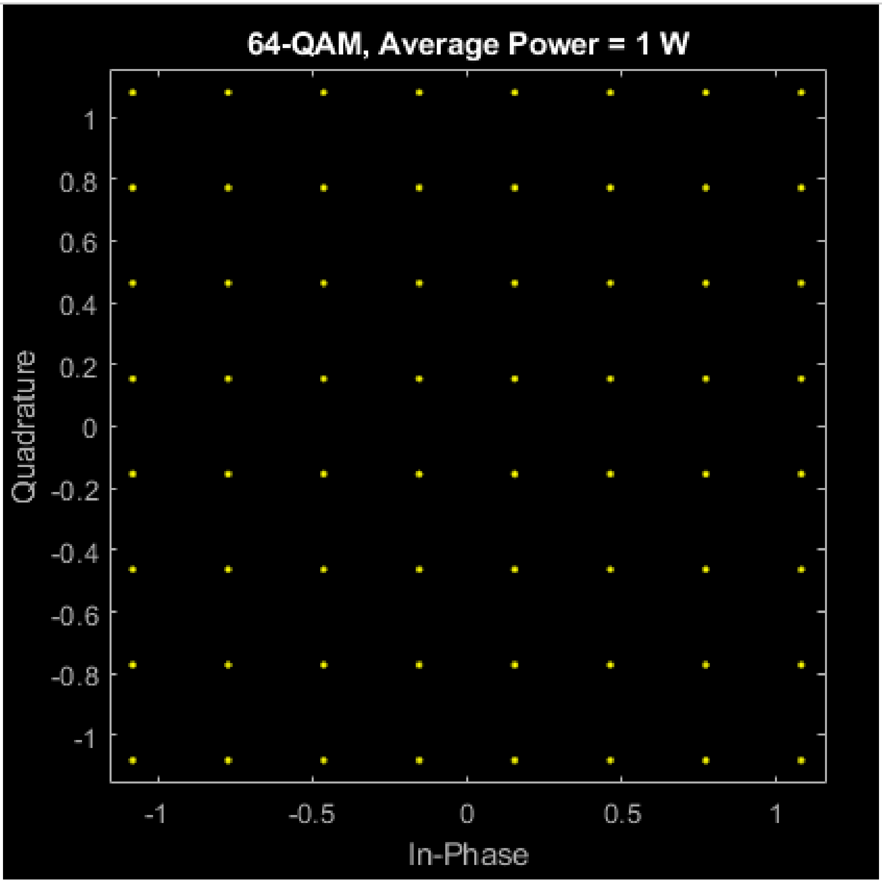
Confirm that the signal has unit average power.

```
avgPower = mean(abs(y).^2)
```

```
avgPower = 1.0070
```

Plot the resulting constellation.

```
scatterplot(y)
title('64-QAM, Average Power = 1 W')
```



QAM Symbol Ordering

Plot QAM constellations for Gray, binary, and custom symbol mappings.

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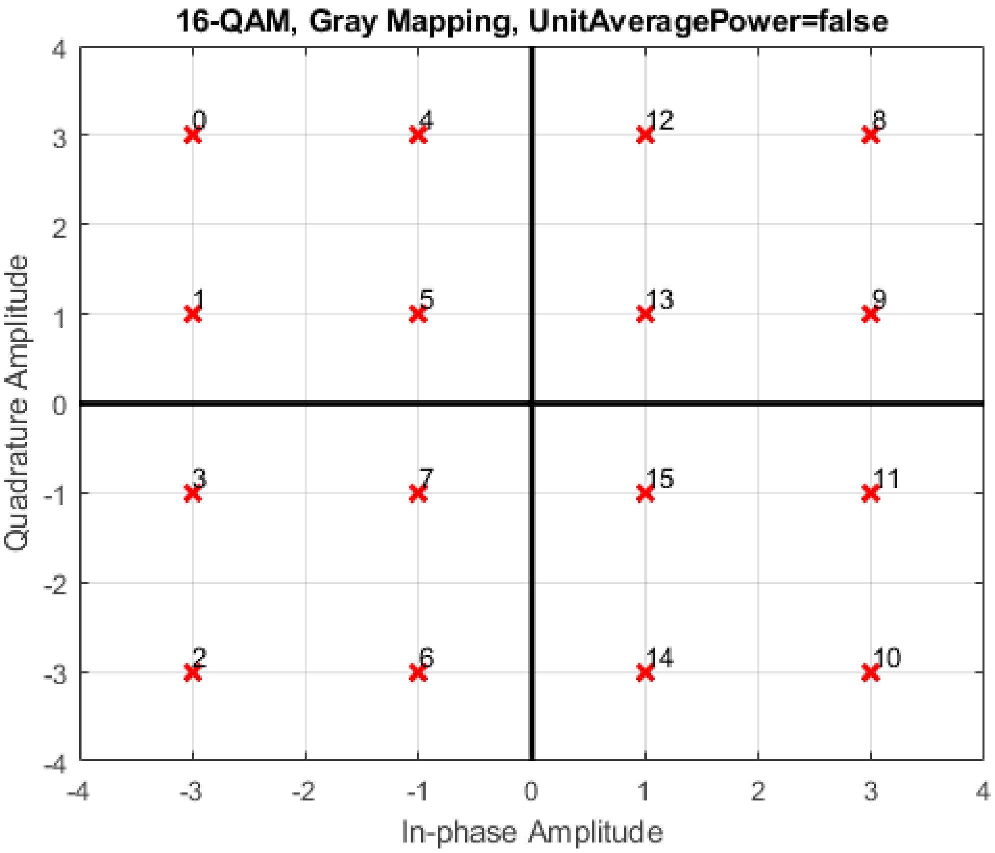
Copy Command

Set the modulation order, and create a data sequence that includes a complete set of symbols for the modulation scheme.

```
M = 16;
d = [0:M-1];
```

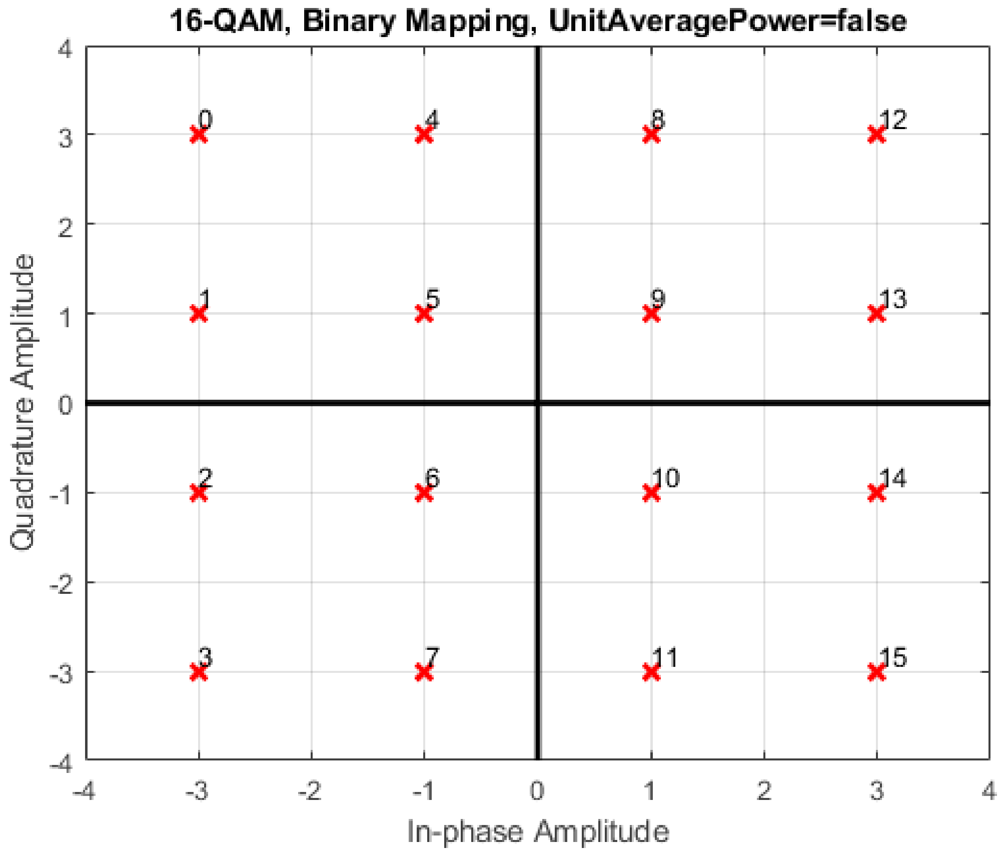
Modulate the data, and plot its constellation. The default symbol mapping uses Gray ordering. The ordering of the points is not sequential.

```
y = qammod(d,M,'PlotConstellation',true);
```



Repeat the modulation process with binary symbol mapping. The symbol mapping follows a natural binary order and is sequential.

```
z = qammod(d,M,'bin','PlotConstellation',true);
```

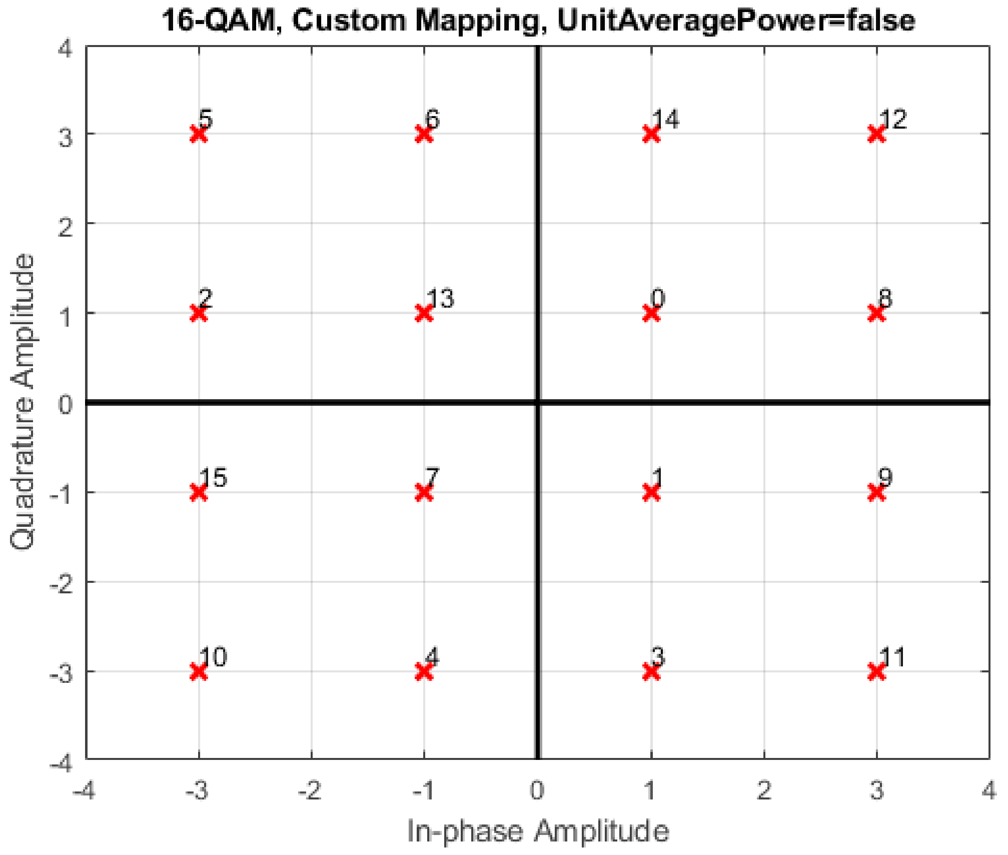


Create a custom symbol mapping.

```
smap = randperm(M)-1;
```

Modulate and plot the constellation.

```
w = qammod(d,M,smap,'PlotConstellation',true);
```



Quadrature Amplitude Modulation with Bit Inputs

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Modulate a sequence of bits using 64-QAM. Pass the signal through a noisy channel. Display the resultant constellation diagram.

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

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

Create a binary data sequence. When using binary inputs, the number of rows in the input must be an integer multiple of the number of bits per symbol.

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

Modulate the signal using bit inputs, and set it to have unit average power.

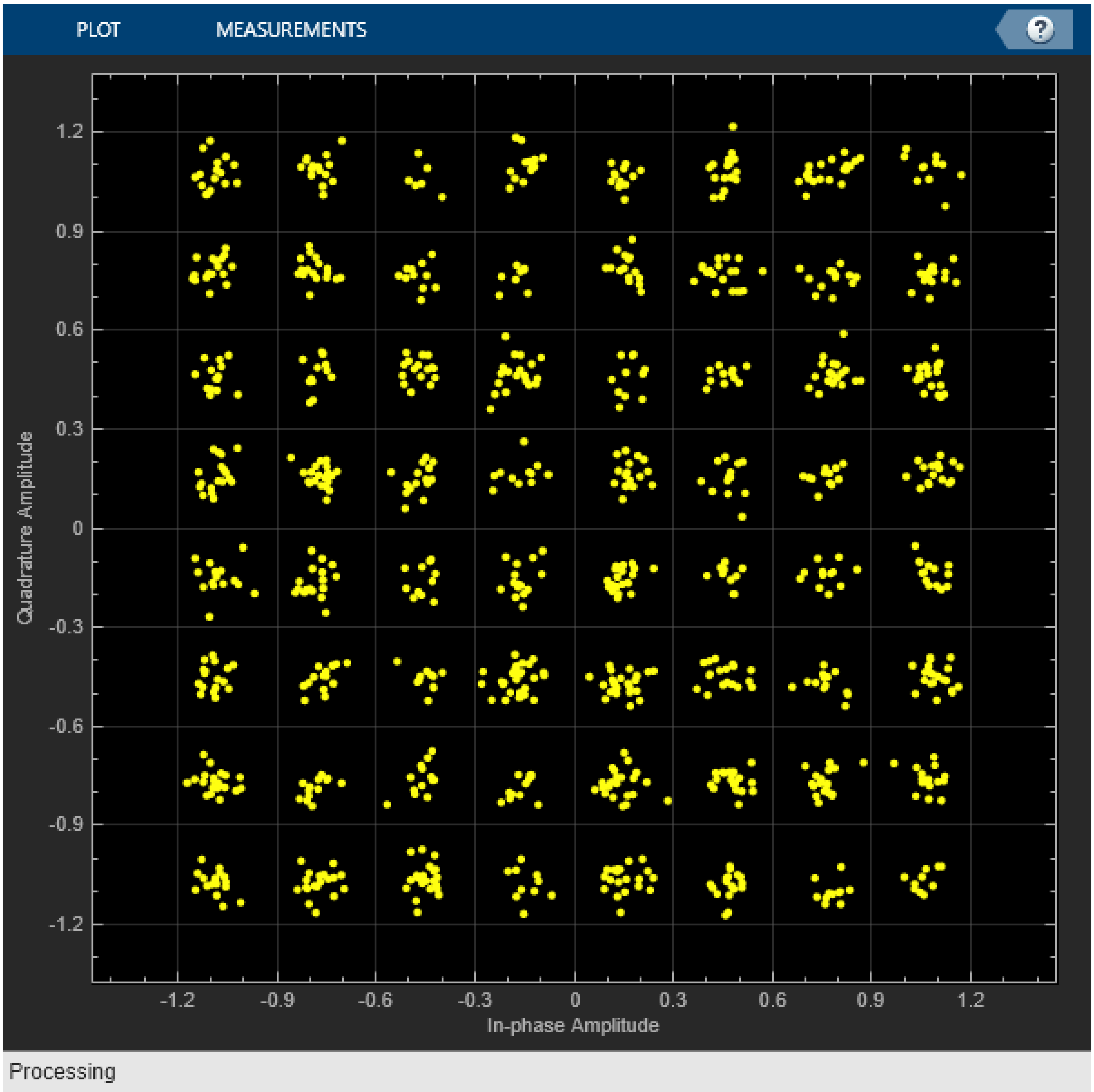
```
txSig = qammod(data,M,'InputType','bit','UnitAveragePower',true);
```

Pass the signal through a noisy channel.

```
rxSig = awgn(txSig,25);
```

Plot the constellation diagram.

```
cd = comm.ConstellationDiagram('ShowReferenceConstellation',false);
cd(rxSig)
```



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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Copy Command

```
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
```

Input Arguments

collapse all

x — Input signal

scalar | vector | matrix | 3-D array

Input signal, specified as a scalar, vector, matrix, or 3-D array. The elements of x must be binary values or integers that range from 0 to (M – 1), where M is the modulation order.

Note

To process input signal as binary elements, set the 'InputType' name-value pair to 'bit'. For binary inputs, the number of rows must be an integer multiple of $\log_2(M)$. Groups of $\log_2(M)$ bits are mapped onto a symbol, with the first bit representing the MSB and the last bit representing the LSB.

Data Types: double | single | fi | int8 | int16 | uint8 | uint16

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.

Example: 16

Data Types: double

symOrder — Symbol order

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

Symbol order, specified as 'gray', 'bin', or a vector.

- `'gray'` — Use Gray Code ordering
- `'bin'` — Use natural binary-coded ordering
- Vector — Use custom symbol ordering

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.

Example: [0 3 1 2]

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: `y = qammod(x,M,symOrder,'InputType','bit')`

`InputType` — Input type

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

Input type, specified as the comma-separated pair consisting of `'InputType'` and either `'integer'` or `'bit'`. If you specify `'integer'`, the input signal must consist of integers from 0 to `M` – 1. If you specify `'bit'`, the input signal must contain binary values, and the number of rows must be an integer multiple of $\log_2(\mathrm{M})$.

Data Types: `char`

`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.

`OutputDataType` — Output data type

`numerictype` object

Output data type, specified as the comma-separated pair consisting of `'OutputDataType'` and a `numerictype` object.

For more information on constructing these objects, see `numerictype` (Fixed-Point Designer). If you do not specify `'OutputDataType'`, data type is `double` if the input is of data type `double` or built-in integer and `single` if the input is of data type `single`.

`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

`y` — Modulated signal

scalar | vector | matrix | 3-D array

Modulated signal, returned as a complex scalar, vector, matrix, or 3-D array of numeric values. For integer inputs, output `y` has the same dimensions as input signal `x`. For bit inputs, the number of rows in `y` is the number of rows in `x` divided by $\log_2(M)$.

Data Types: `double` | `single`

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

Introduced before R2006a

expand all

R2018b: Initial Phase Input Removed

Errors starting in R2018b

See Also

`qamdemod` | `genqammod` | `genqamdemod` | `pammod` | `pamdemod` | `modnorm`

Topics

Digital Modulation