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```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

Communications-2 Project

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- Hazem Montasser - 2200003

```
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
clc
clear
close all

import ModulationTypes.*;
import Modulator.*;
import DigitalMapper.*;
import demapBits.*;
import Channel.*;
import scatterplot_title.*;
%bits = [1 0 1 0 0 1 0 0 1 1 1 1];
% bits = randi([0 1], 1, 48 * 1000);
rng(1023456381, 'twister');
bits = randi([0 1], 1, 12000);

SNR = 1:1:10;
E = 5;
```

Add modulators

```
mapper = DigitalMapper();
mapper.addModulator(ModulationTypes.BPSK);
mapper.addModulator(ModulationTypes.QPSK);
mapper.addModulator(ModulationTypes.PSK8);
mapper.addModulator(ModulationTypes.QAM16);
```

Modulate all signals

```
modulated_signals = mapper.modulate(E, bits);
bpsk_mod = modulated_signals(char(ModulationTypes.BPSK));
qpsk_mod = modulated_signals(char(ModulationTypes.QPSK));
psk8_mod = modulated_signals(char(ModulationTypes.PSK8));
qam16_mod = modulated_signals(char(ModulationTypes.QAM16));

theoretical_bpsk_ber = [];
theoretical_qpsk_ber = [];
theoretical_psk8_ber = [];
theoretical_qam16_ber = [];

simulated_bpsk_ber = [];
simulated_qpsk_ber = [];
simulated_psk8_ber = [];
simulated_qam16_ber = [];
```

Simulate for all SNRs

```
for i = 1:length(SNR)
```

Pass through channel

```
   channel = Channel(SNR(i));
   [temp_noisy_bpsk, temp_bpsk_ber] = channel.addNoise(bpsk_mod, E,
ModulationTypes.BPSK);
   [temp_noisy_qpsk, temp_qpsk_ber] = channel.addNoise(qpsk_mod, E,
ModulationTypes.QPSK);
   [temp_noisy_psk8, temp_psk8_ber] = channel.addNoise(psk8_mod, E,
ModulationTypes.PSK8);
   [temp_noisy_qam16, temp_qam16_ber] = channel.addNoise(qam16_mod,
E, ModulationTypes.QAM16);
```

Demodulate

```
   psk8_demod = demapBits(temp_noisy_psk8, E, ModulationTypes.PSK8);
   qam16_demod = demapBits(temp_noisy_qam16, E,
ModulationTypes.QAM16);
   bpsk_demod = demapBits(temp_noisy_bpsk, E, ModulationTypes.BPSK);
   qpsk_demod = demapBits(temp_noisy_qpsk, E, ModulationTypes.QPSK);
```

Calculate theoritical bit loss

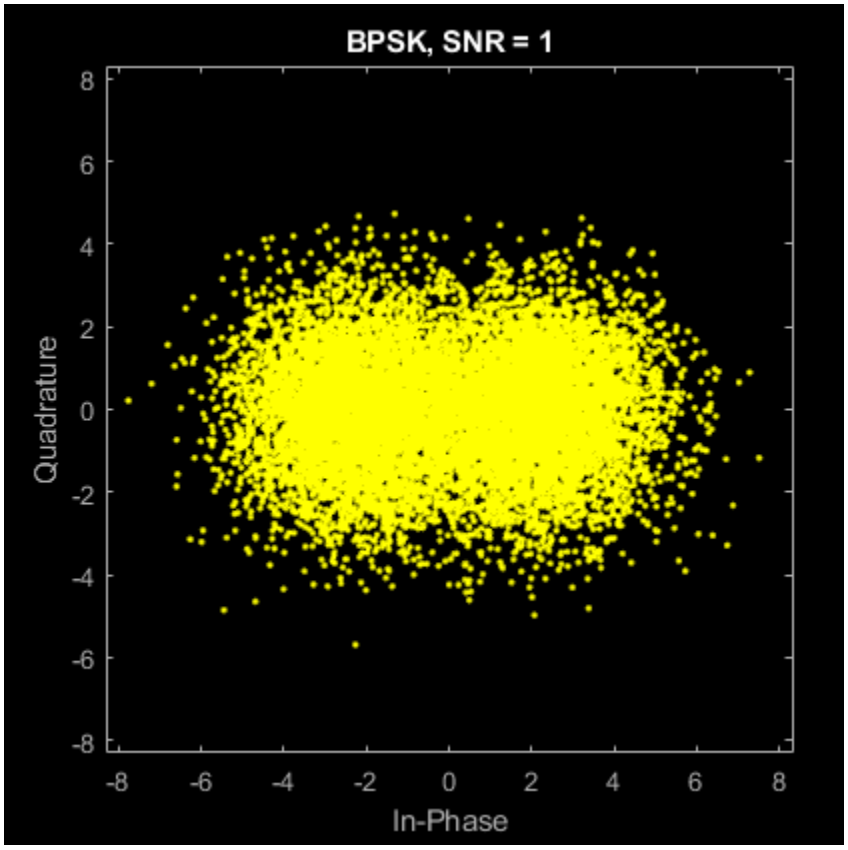
```
theoretical_bpsk_ber(end + 1) = temp_bpsk_ber;
theoretical_qpsk_ber(end + 1) = temp_qpsk_ber;
theoretical_psk8_ber(end + 1) = temp_psk8_ber;
theoretical_qam16_ber(end + 1) = temp_qam16_ber;
```

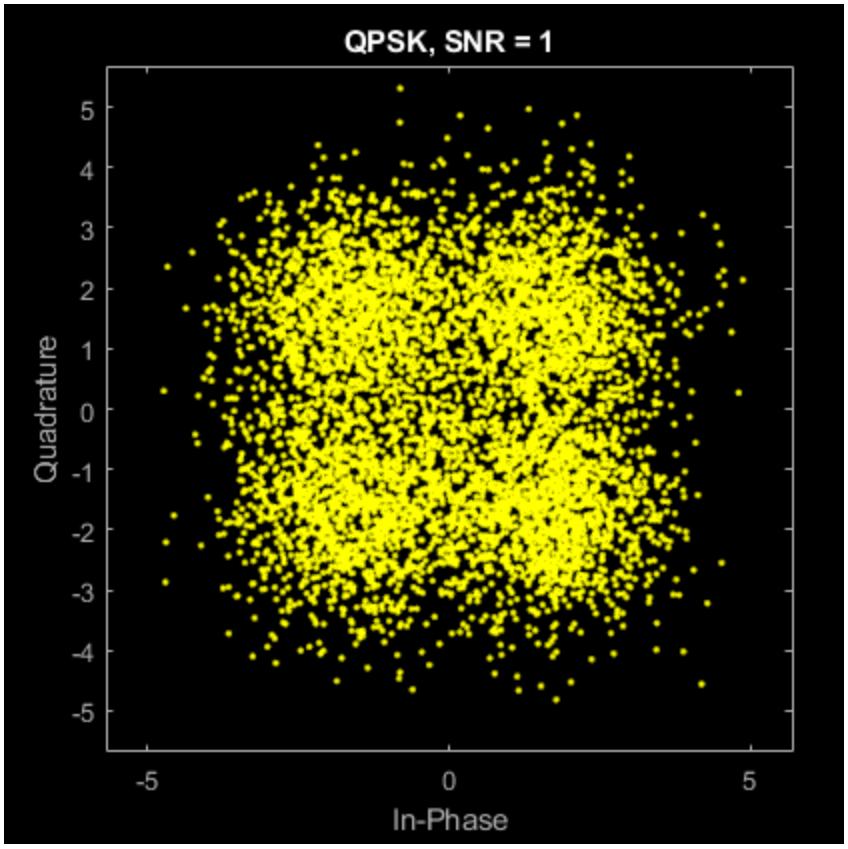
Calculate simulated bit loss

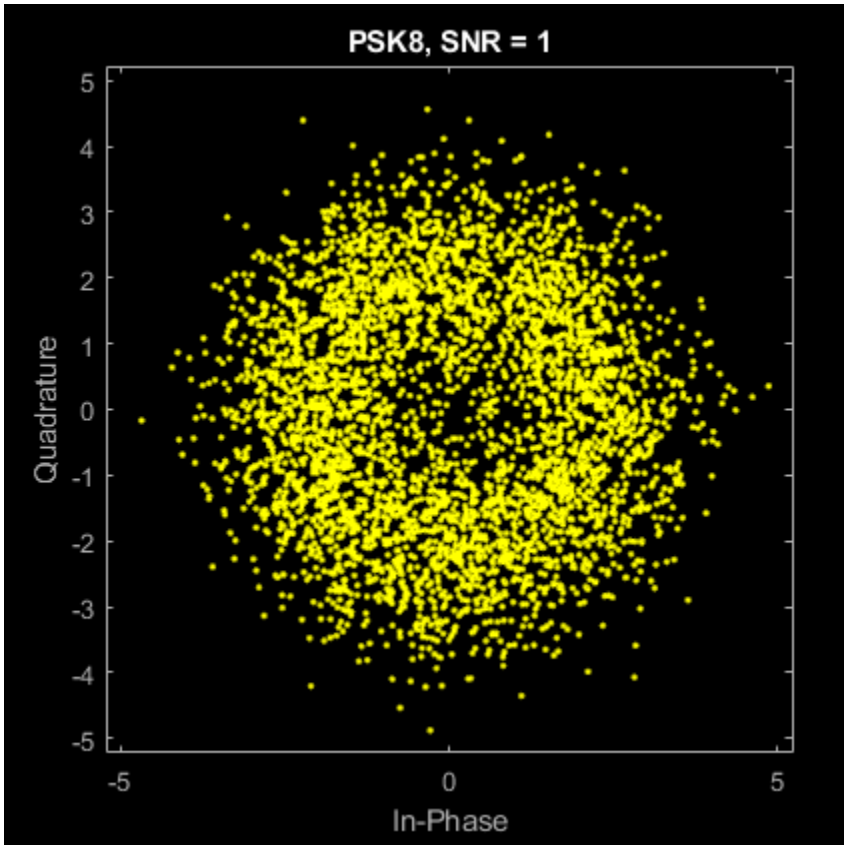
```
[a, simulated_bpsk_ber(end + 1)] = biterr(bits, bpsk_demod);
[a, simulated_qpsk_ber(end + 1)] = biterr(bits, qpsk_demod);
[a, simulated_psk8_ber(end + 1)] = biterr(bits, psk8_demod);
[a, simulated_qam16_ber(end + 1)] = biterr(bits, qam16_demod);
```

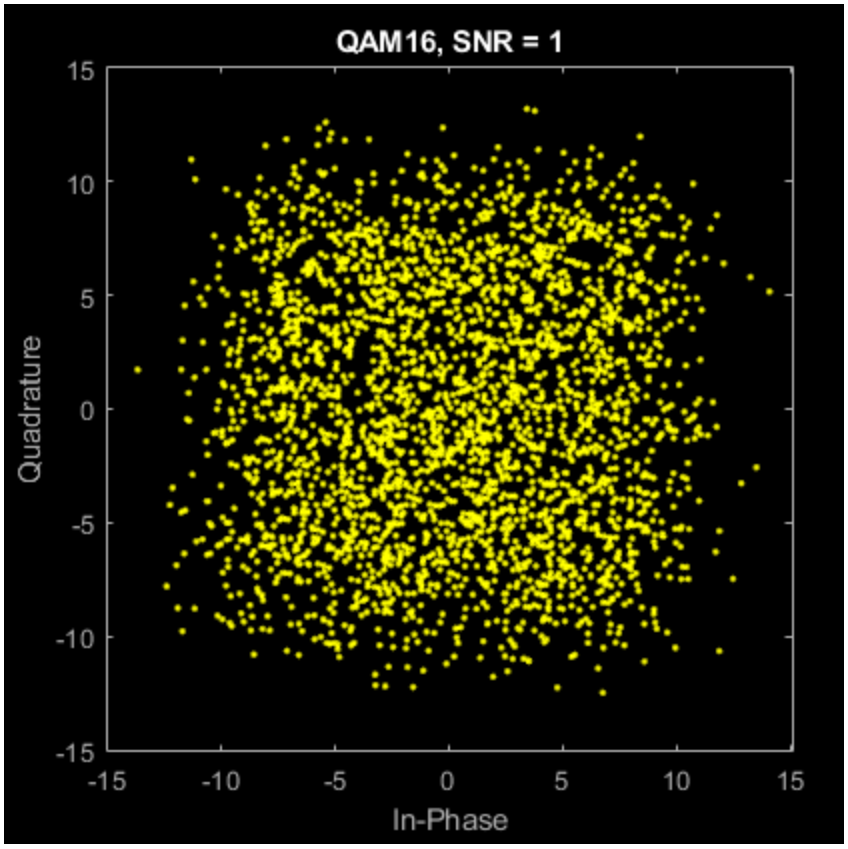
Plot results

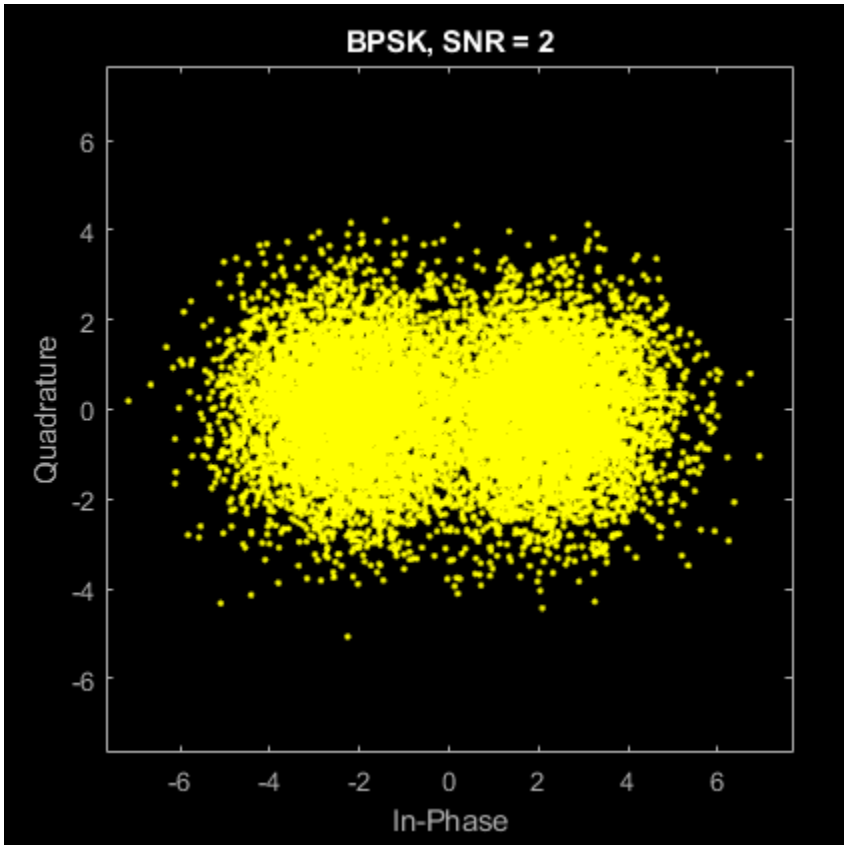
```
   scatterplot_title(temp_noisy_bpsk, 'BPSK, SNR = ' +
string(SNR(i)));
   scatterplot_title(temp_noisy_qpsk, 'QPSK, SNR = ' +
string(SNR(i)));
   scatterplot_title(temp_noisy_psk8, 'PSK8, SNR = ' +
string(SNR(i)));
   scatterplot_title(temp_noisy_qam16, 'QAM16, SNR = ' +
string(SNR(i)));
```

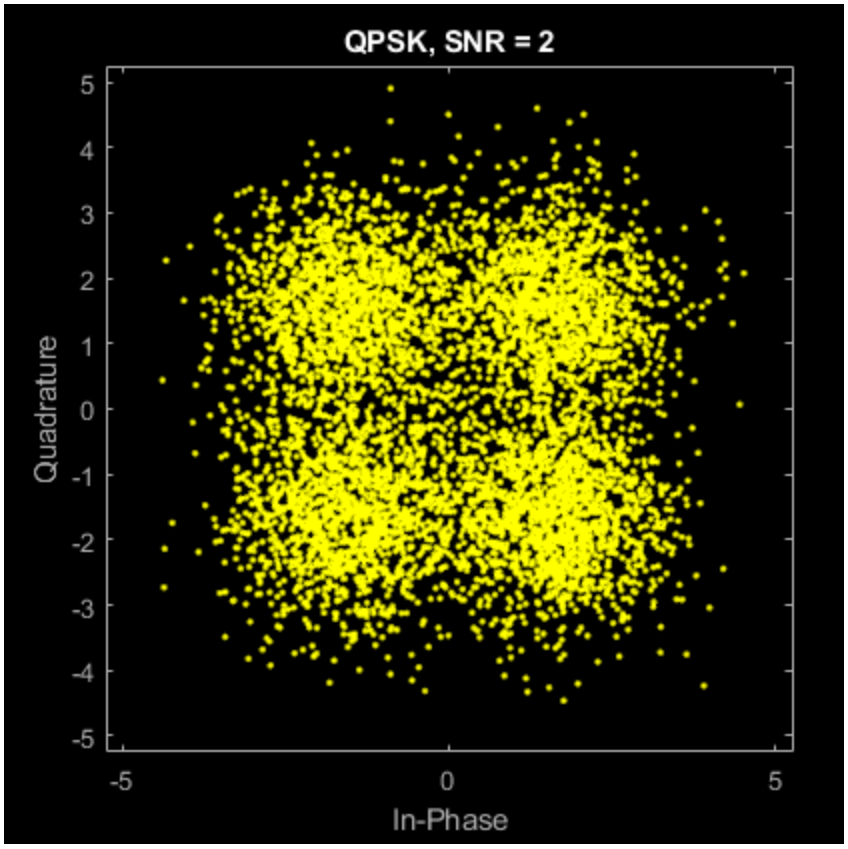


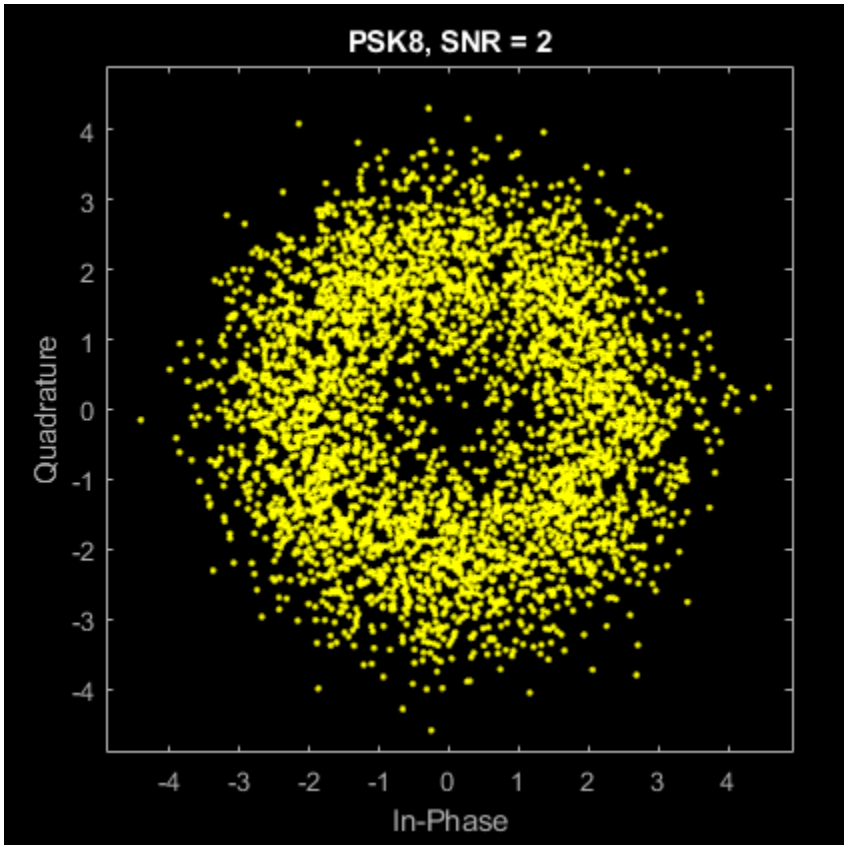

QPSK, SNR = 1
Quadrature
In-Phase
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
0
5

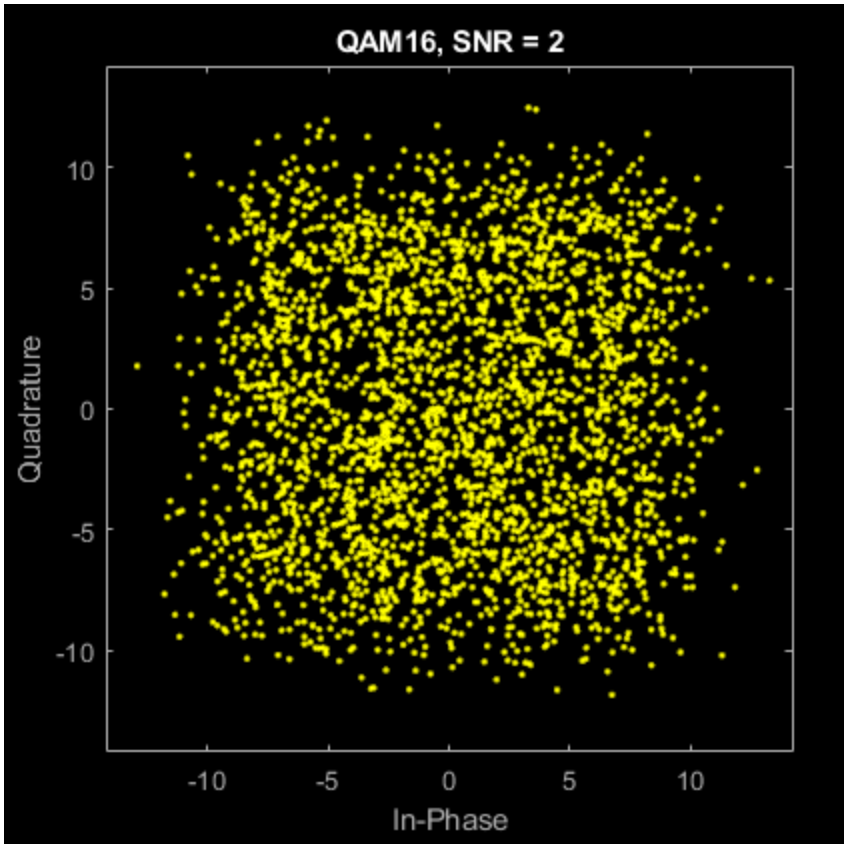

PSK8, SNR = 1
Quadrature
In-Phase
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
0
5

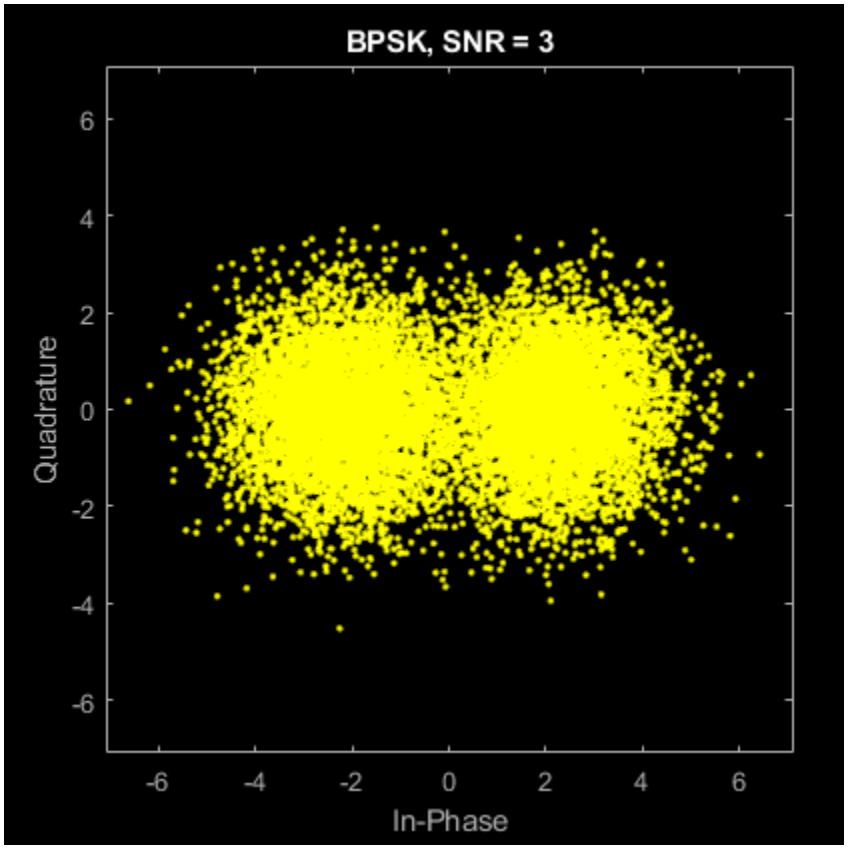

QAM16, SNR = 1
15
10
5
0
-5
-10
-15
Quadrature
-15
-10
-5
0
5
10
15
In-Phase

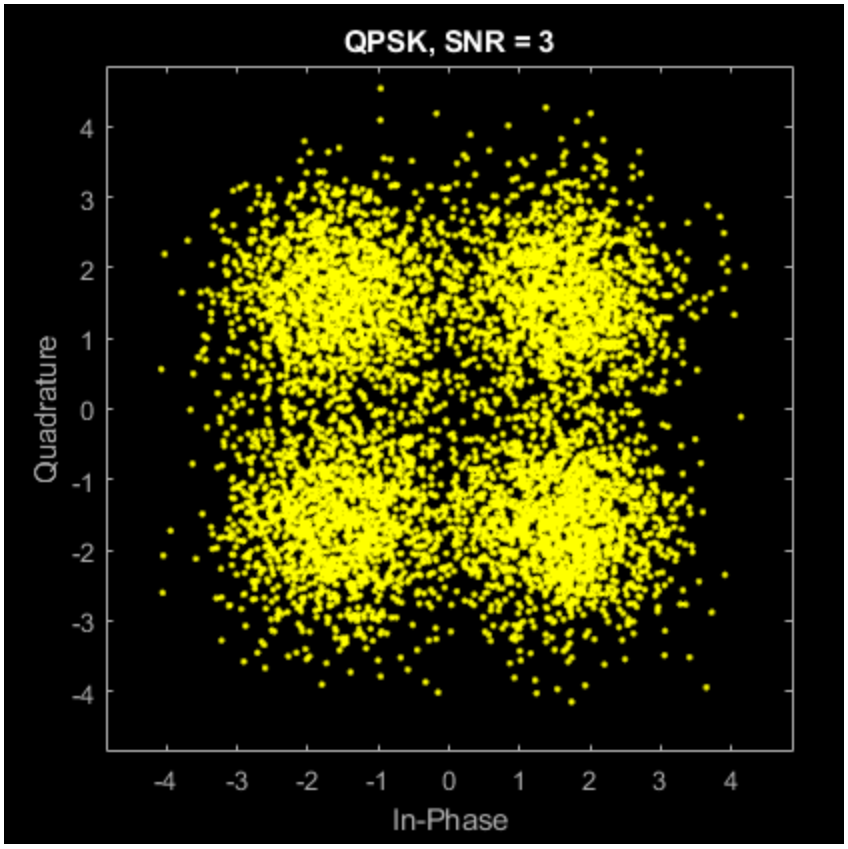

BPSK, SNR = 2
6
4
2
0
-2
-4
-6
Quadrature
-6
-4
-2
0
2
4
6
In-Phase

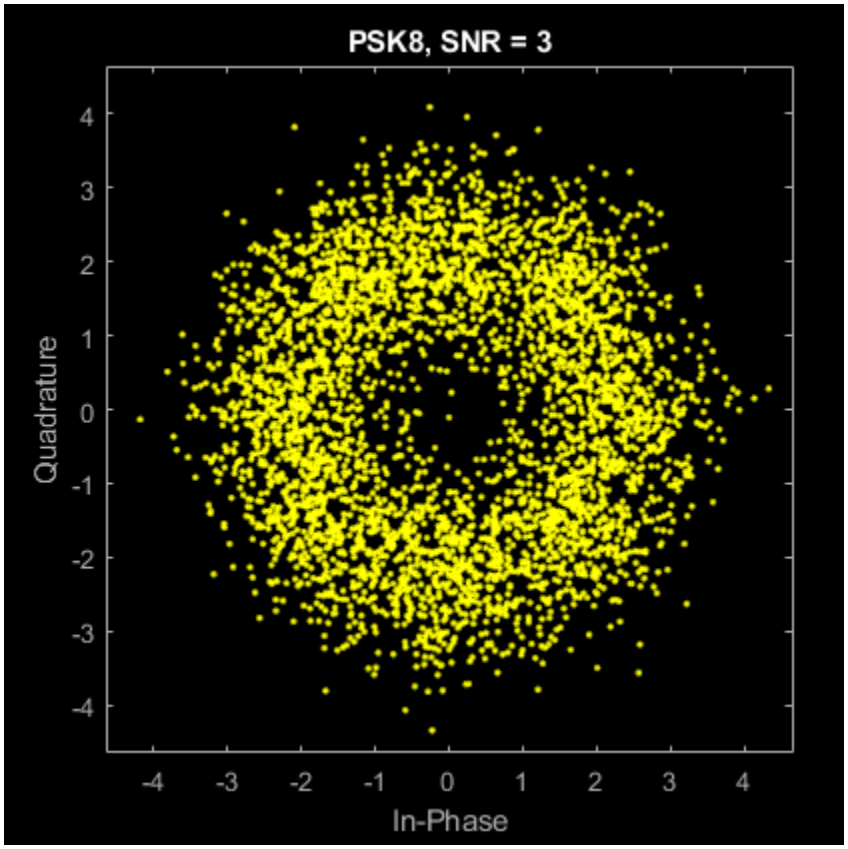

QPSK, SNR = 2
Quadrature
In-Phase
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
0
5

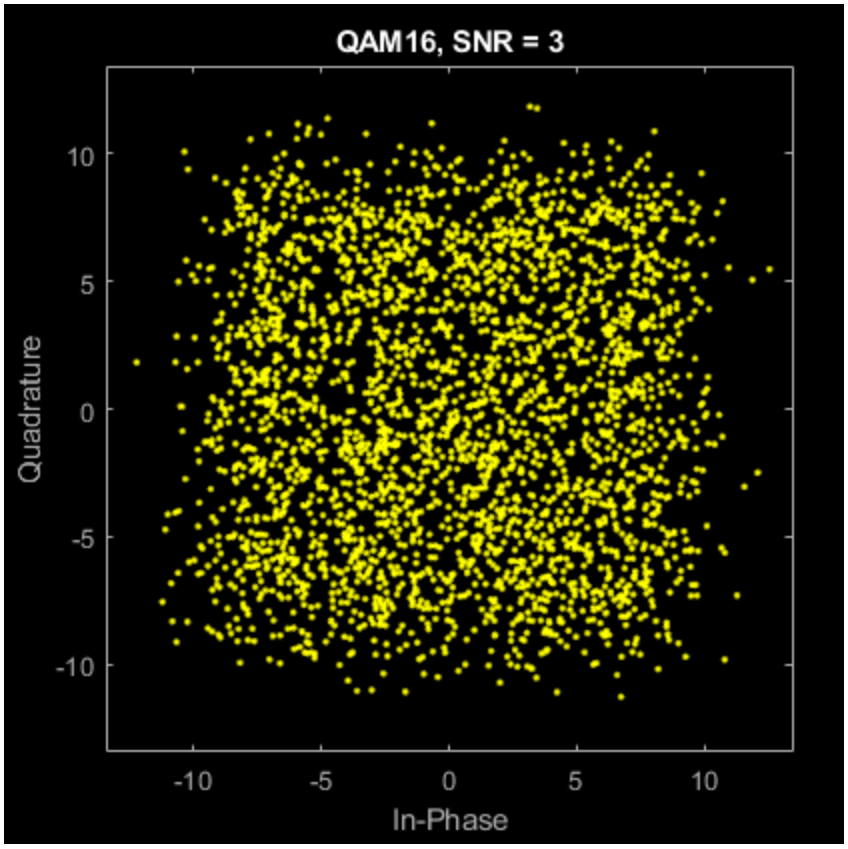

PSK8, SNR = 2
Quadrature
In-Phase
4
3
2
1
0
-1
-2
-3
-4
-4
-3
-2
-1
0
1
2
3
4

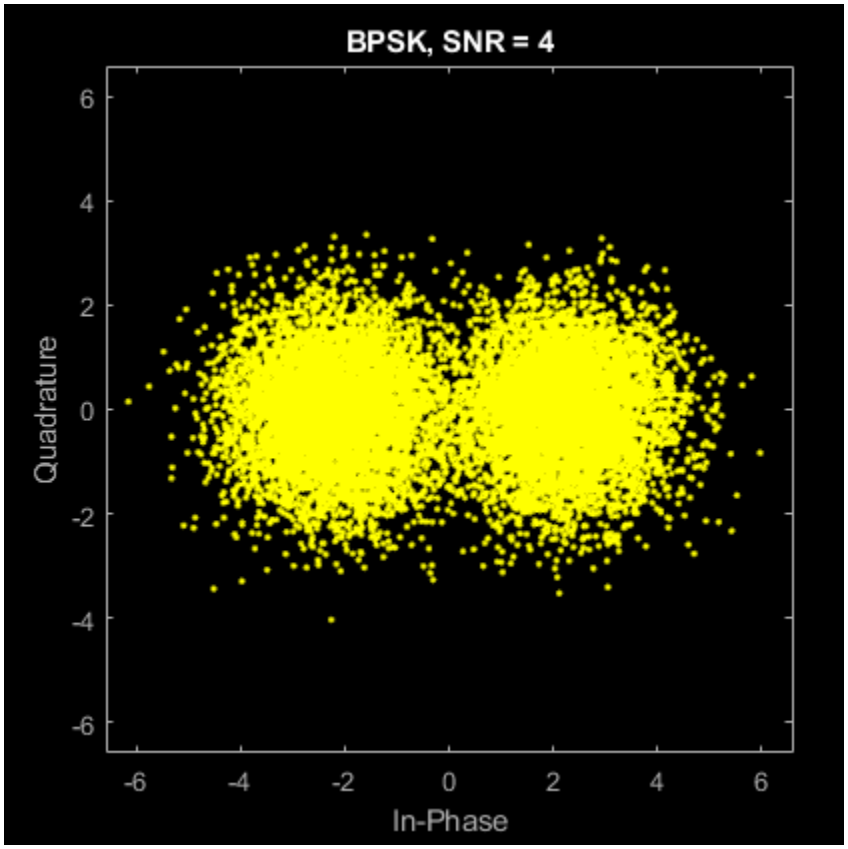

QAM16, SNR = 2
Quadrature
In-Phase
10
5
0
-5
-10
-10
-5
0
5
10

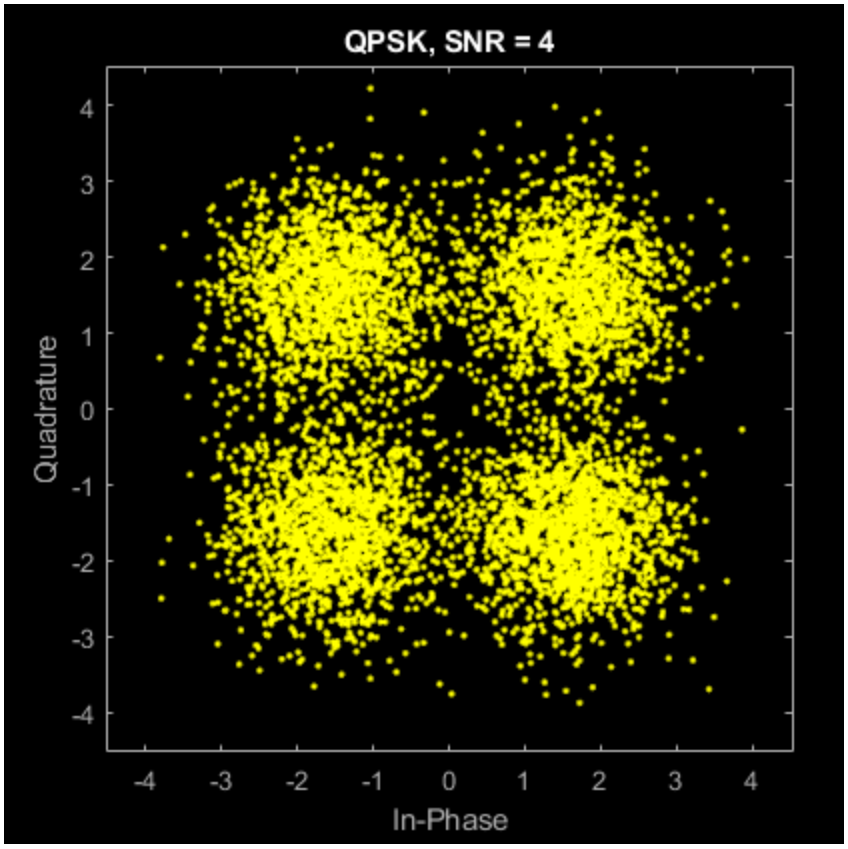

BPSK, SNR = 3
Quadrature
In-Phase
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6

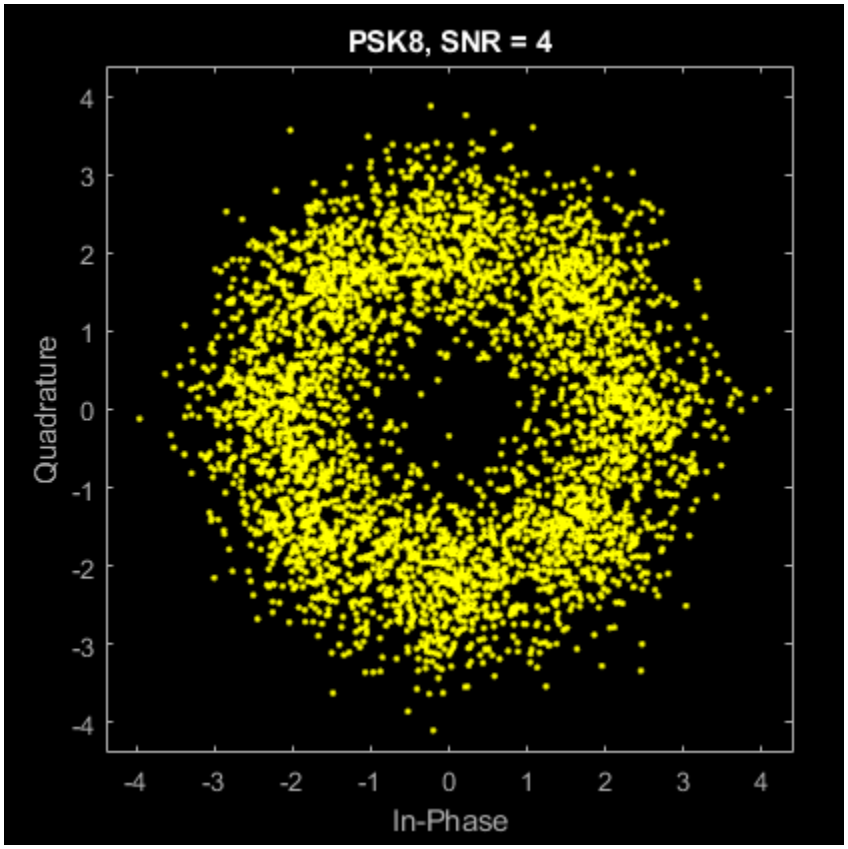

QPSK, SNR = 3
Quadrature
In-Phase
4
3
2
1
0
-1
-2
-3
-4

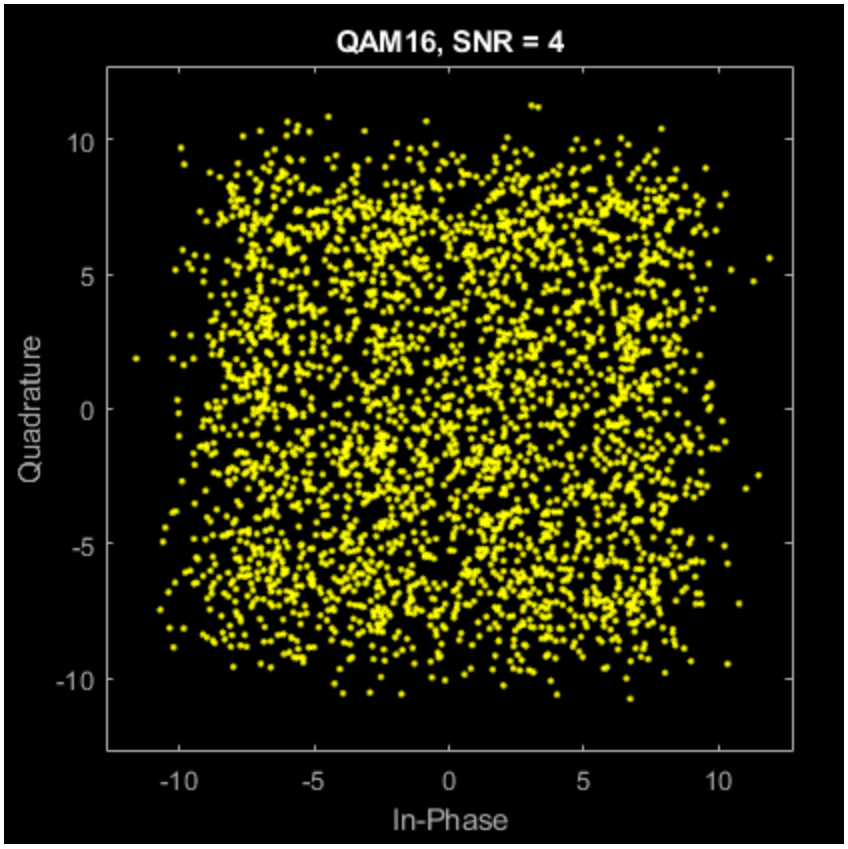

PSK8, SNR = 3
Quadrature
In-Phase
4
3
2
1
0
-1
-2
-3
-4

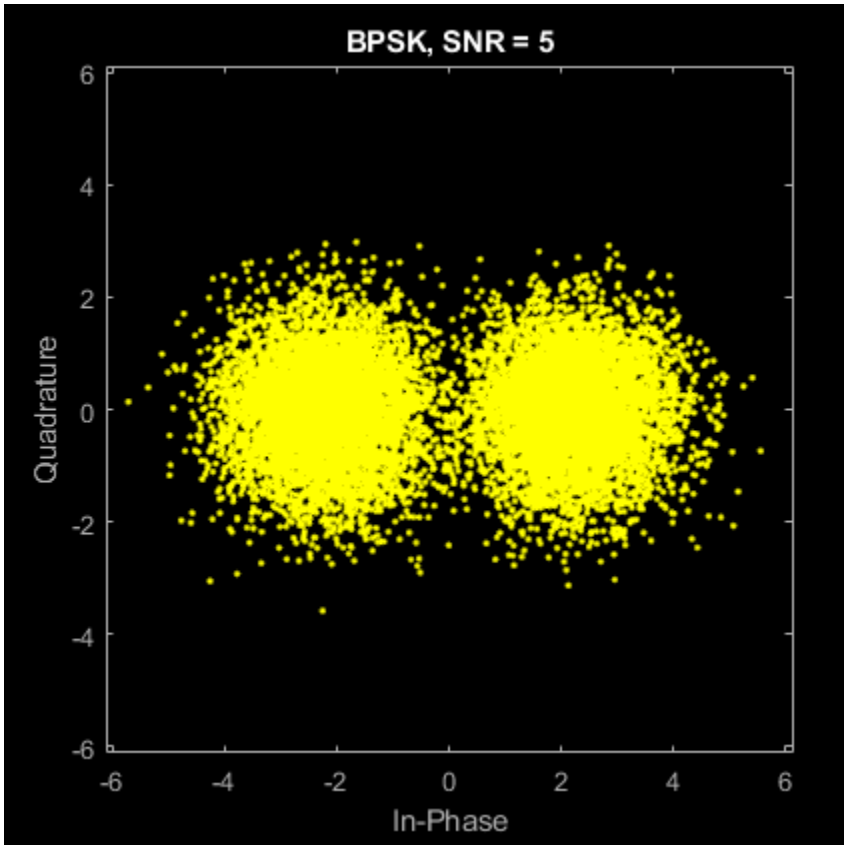

QAM16, SNR = 3
Quadrature
In-Phase
10
5
0
-5
-10
-10
-5
0
5
10

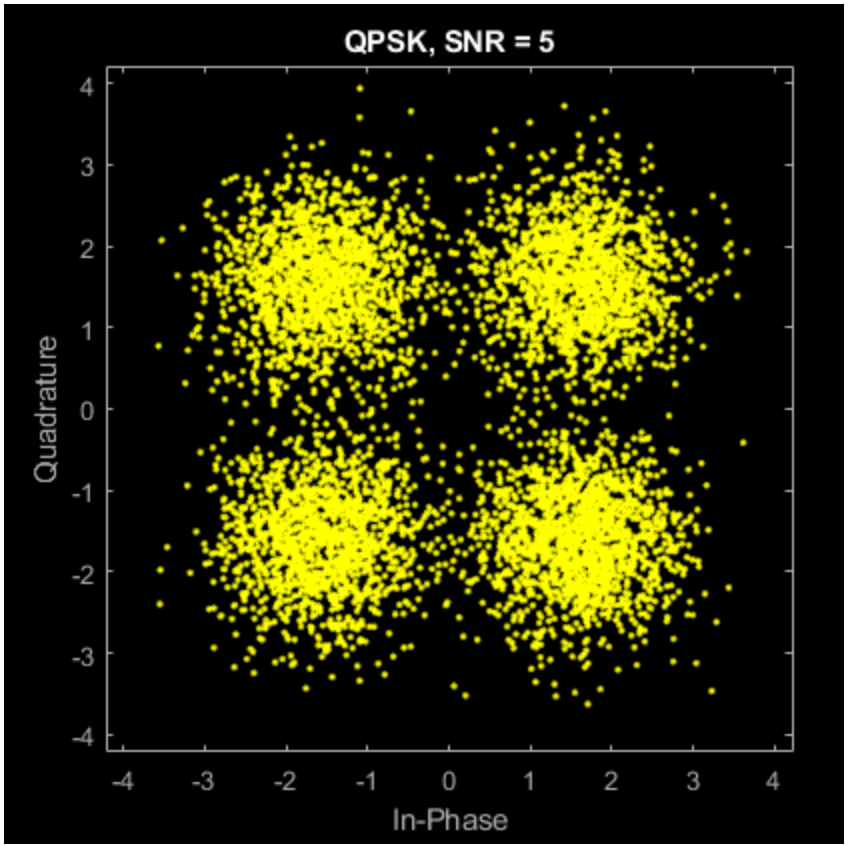

BPSK, SNR = 4
Quadrature
In-Phase
6
4
2
0
-2
-4
-6
-6
-4
-2
0
2
4
6

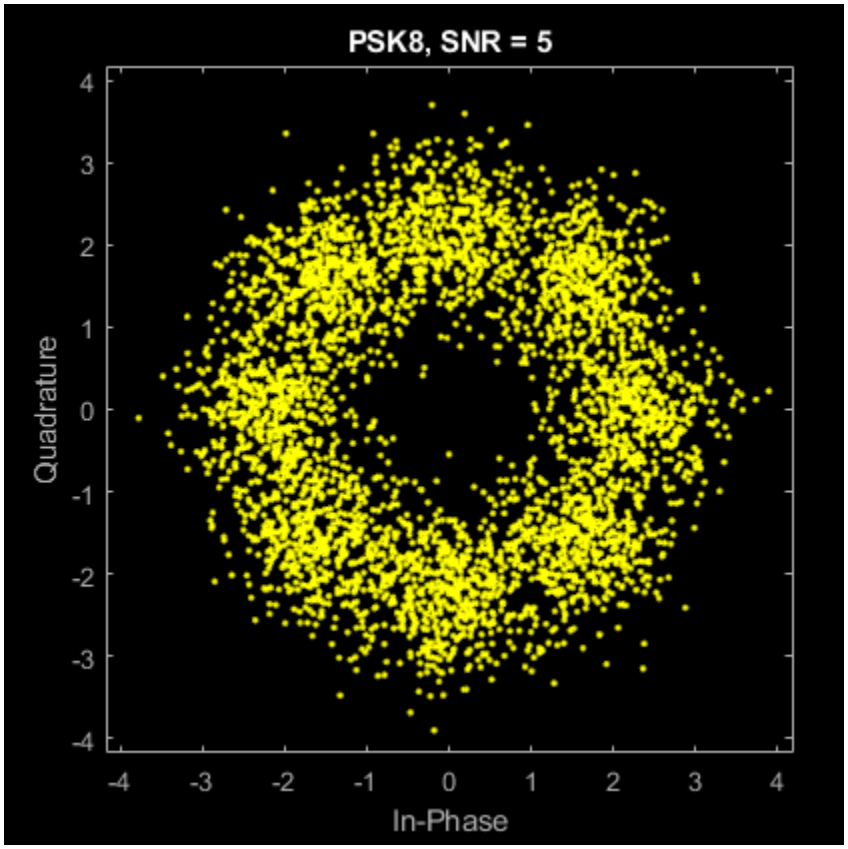

QPSK, SNR = 4
Quadrature
In-Phase
4
3
2
1
0
-1
-2
-3
-4

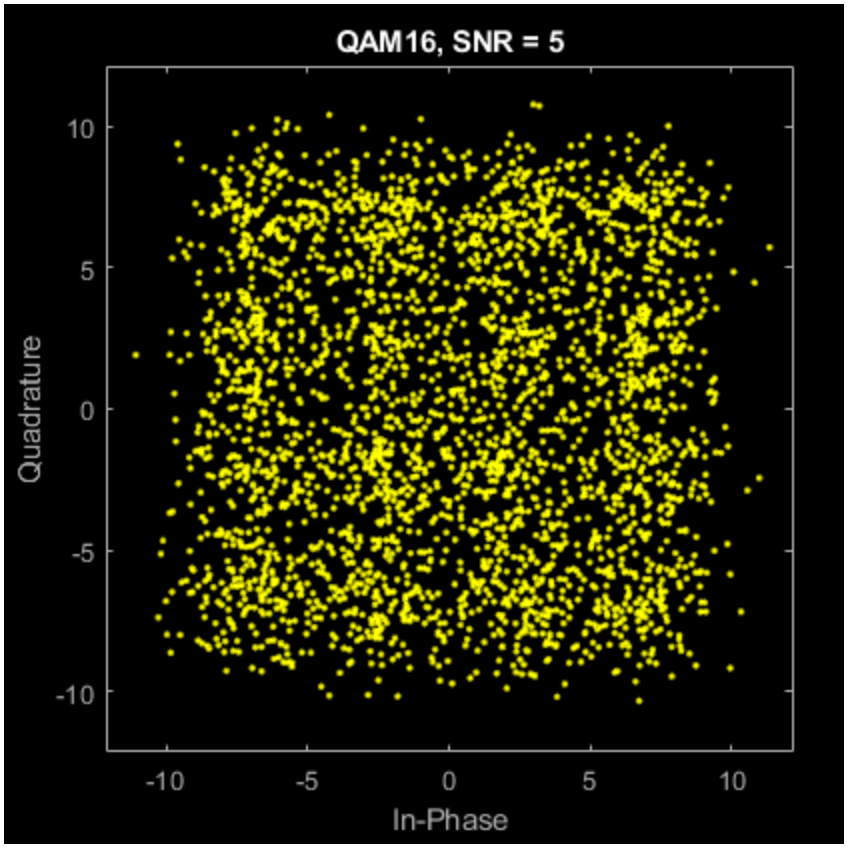

PSK8, SNR = 4
Quadrature
In-Phase
4
3
2
1
0
-1
-2
-3
-4

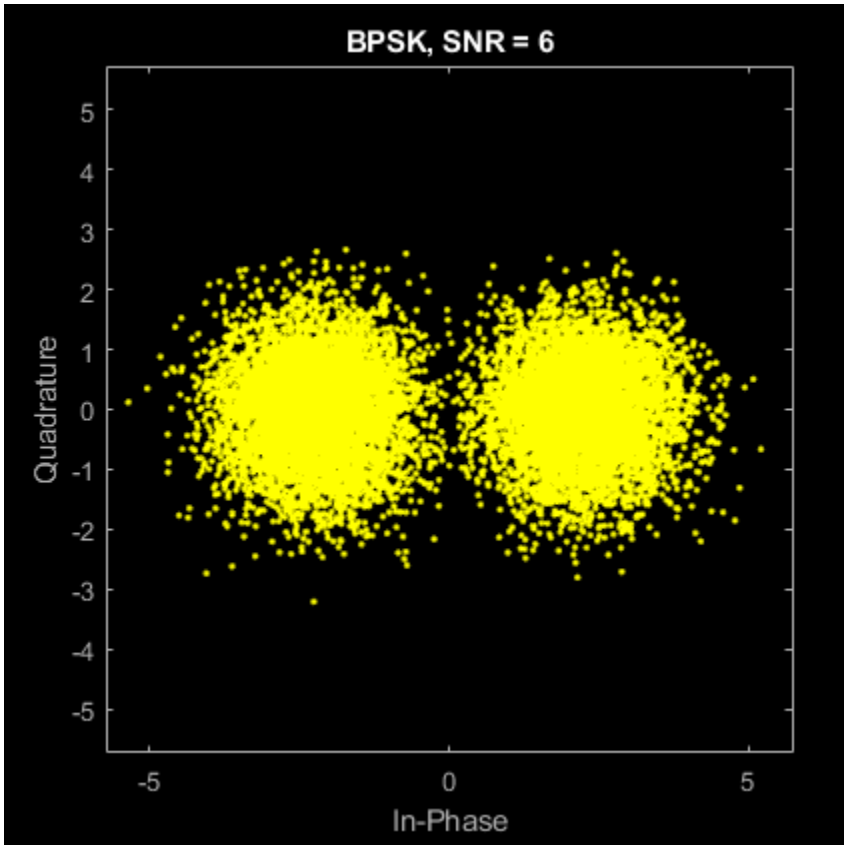

QAM16, SNR = 4
10
5
0
-5
-10
Quadrature
-10
-5
0
5
10
In-Phase

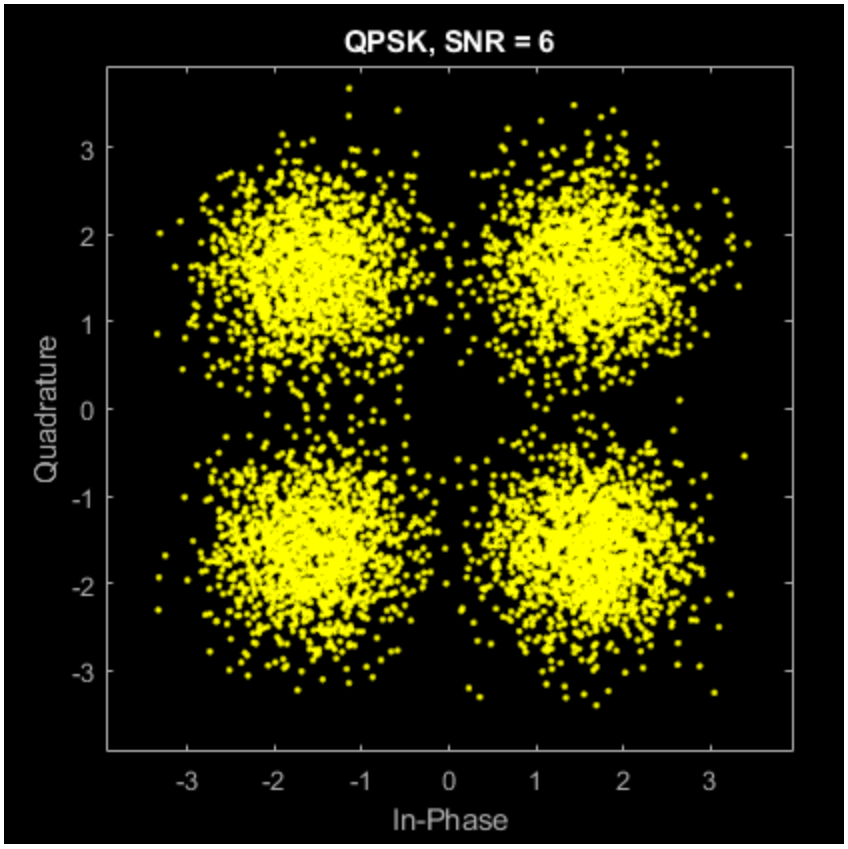

BPSK, SNR = 5
6
4
2
0
-2
-4
-6
Quadrature
-6
-4
-2
0
2
4
6
In-Phase

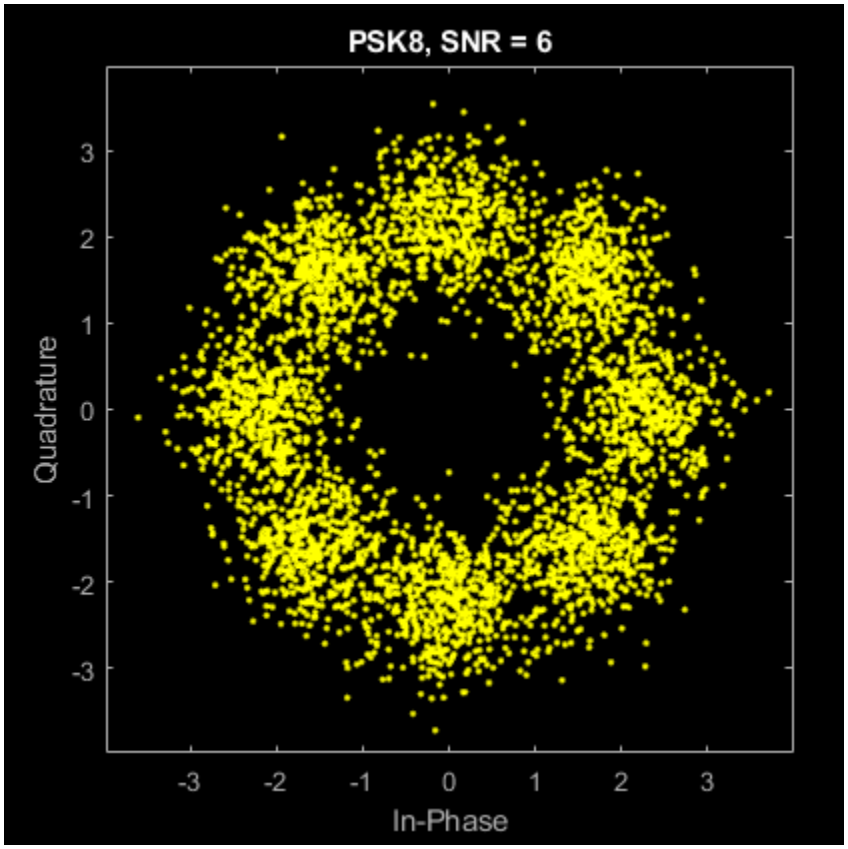

QPSK, SNR = 5
Quadrature
In-Phase
4
3
2
1
0
-1
-2
-3
-4

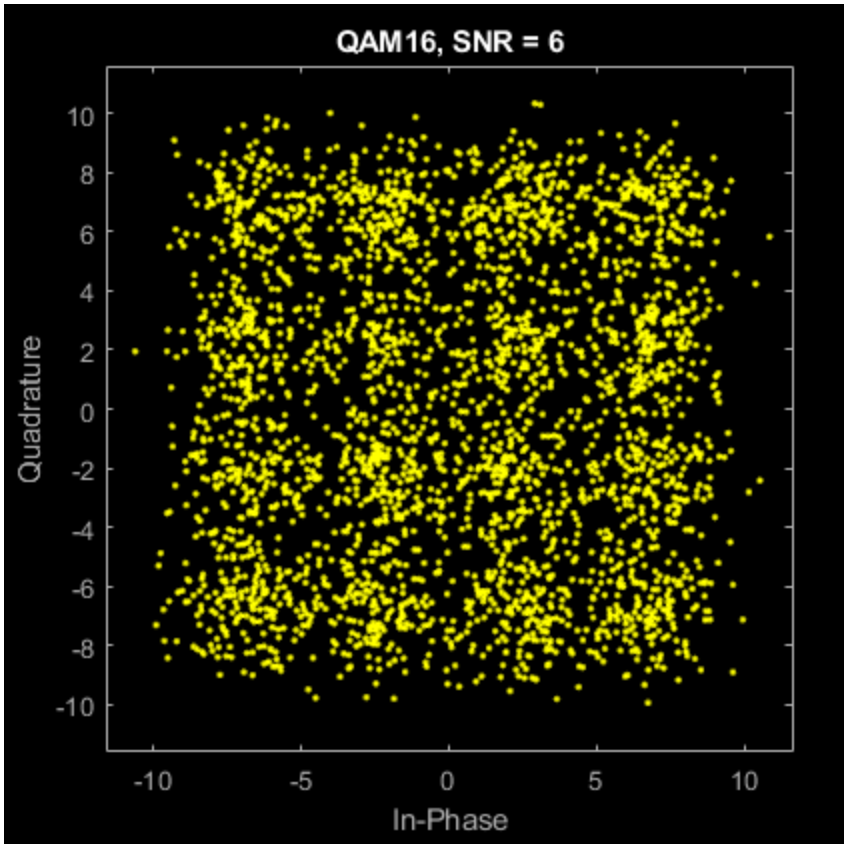

PSK8, SNR = 5
Quadrature
In-Phase
4
3
2
1
0
-1
-2
-3
-4

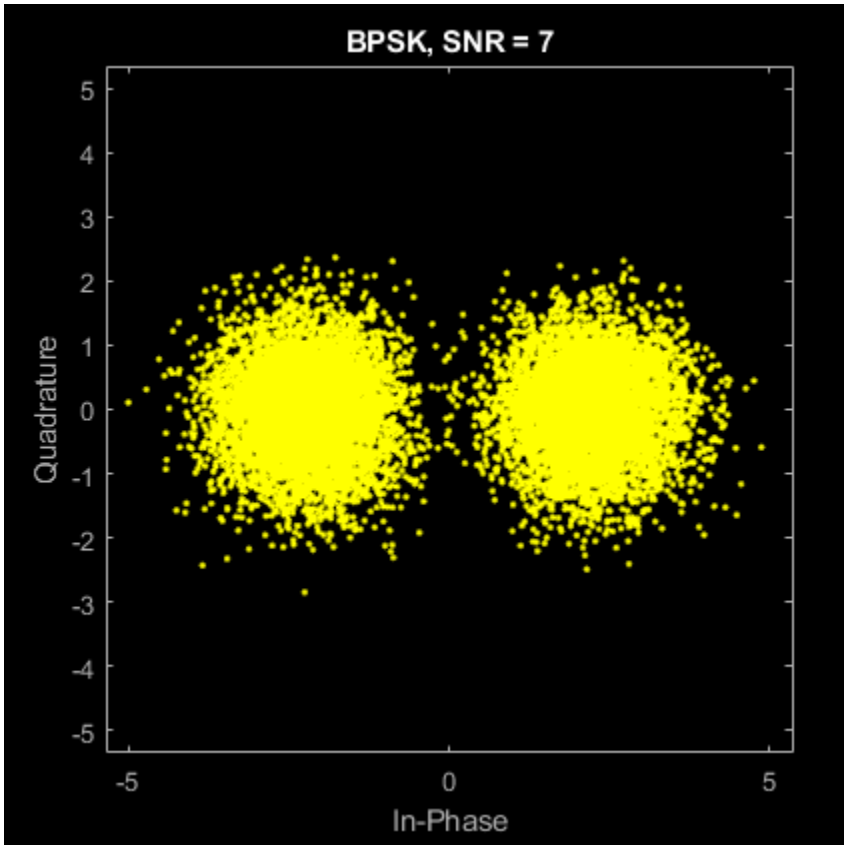

QAM16, SNR = 5
Quadrature
In-Phase
10
5
0
-5
-10
-10
-5
0
5
10

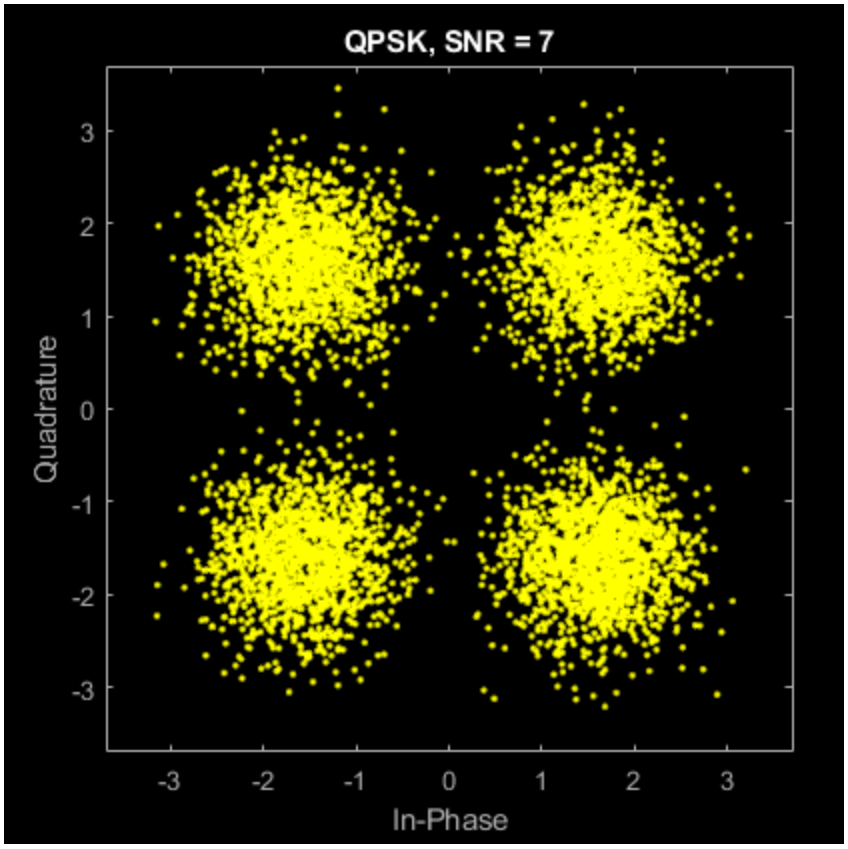

BPSK, SNR = 6
Quadrature
In-Phase
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
0
5

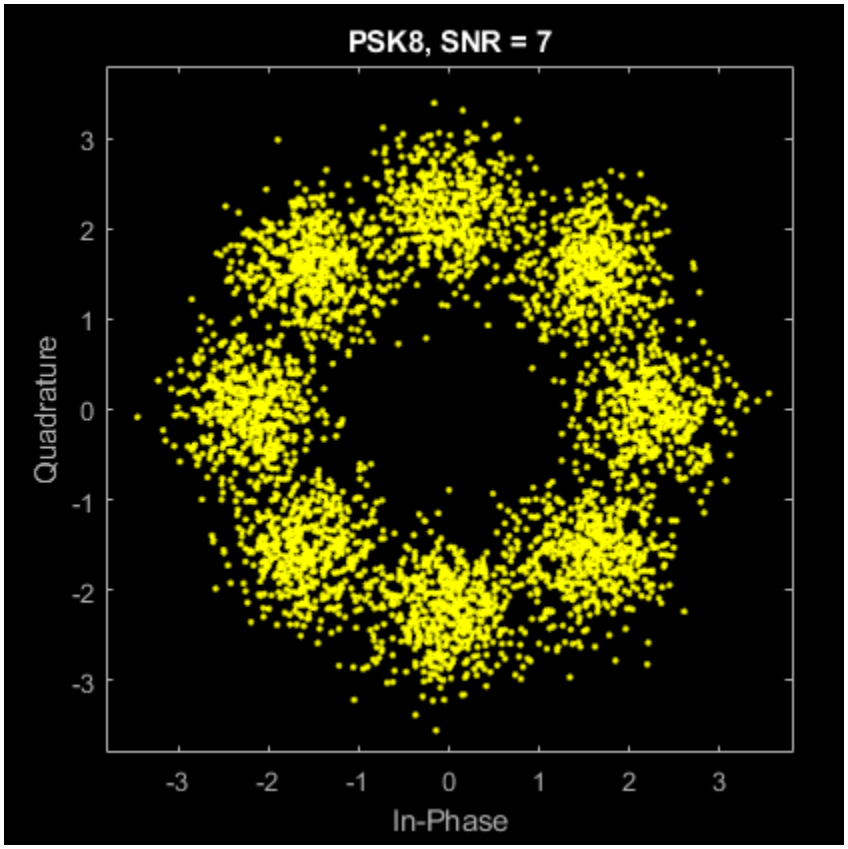

QPSK, SNR = 6
Quadrature
In-Phase
3
2
1
0
-1
-2
-3

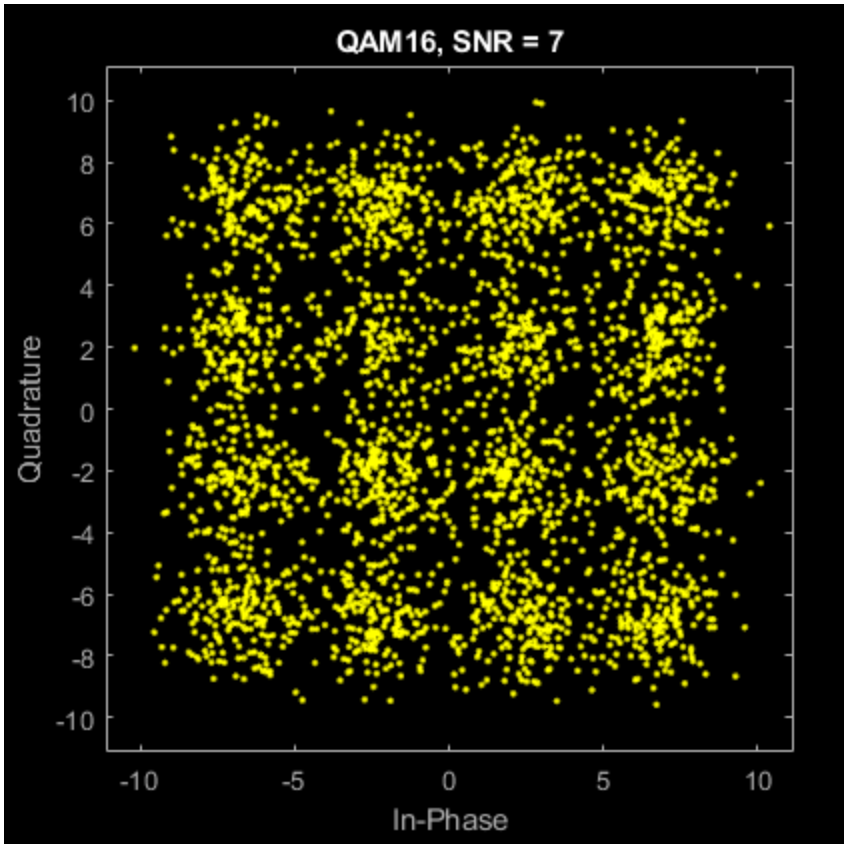

PSK8, SNR = 6
Quadrature
In-Phase
3
2
1
0
-1
-2
-3

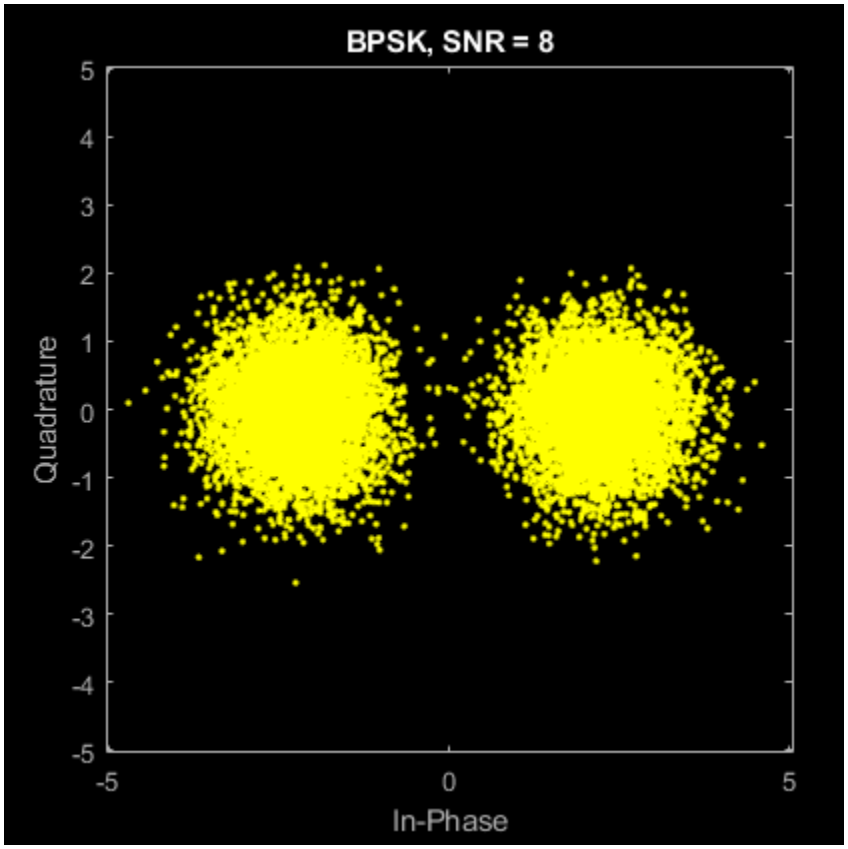

QAM16, SNR = 6
Quadrature
In-Phase
10
8
6
4
2
0
-2
-4
-6
-8
-10
-10
-5
0
5
10

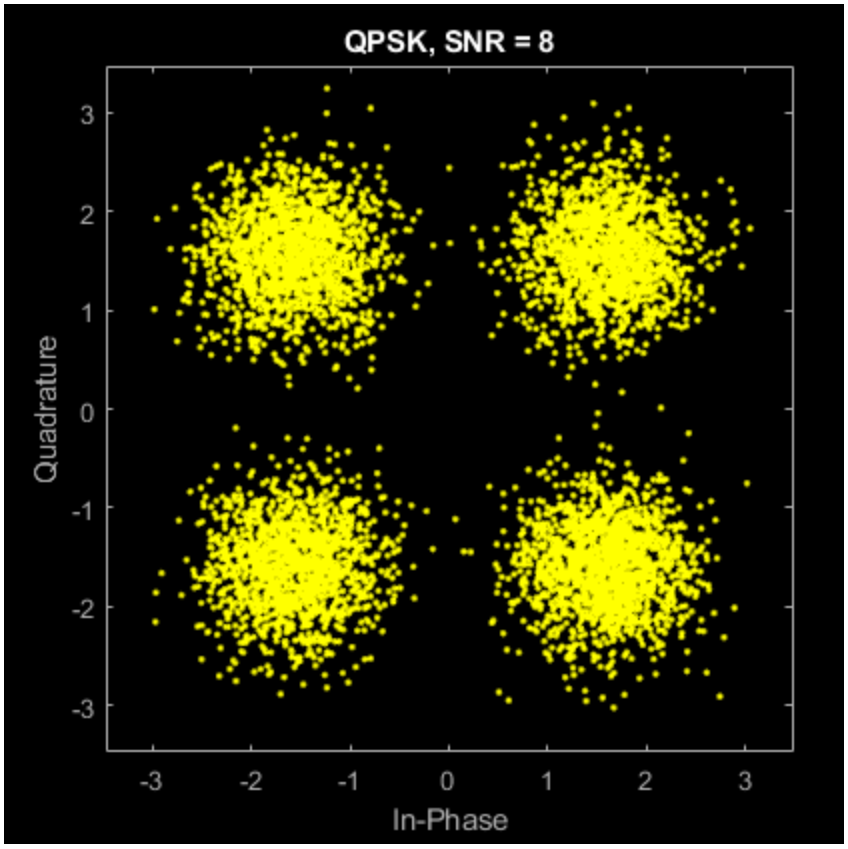

BPSK, SNR = 7
Quadrature
In-Phase
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
0
5

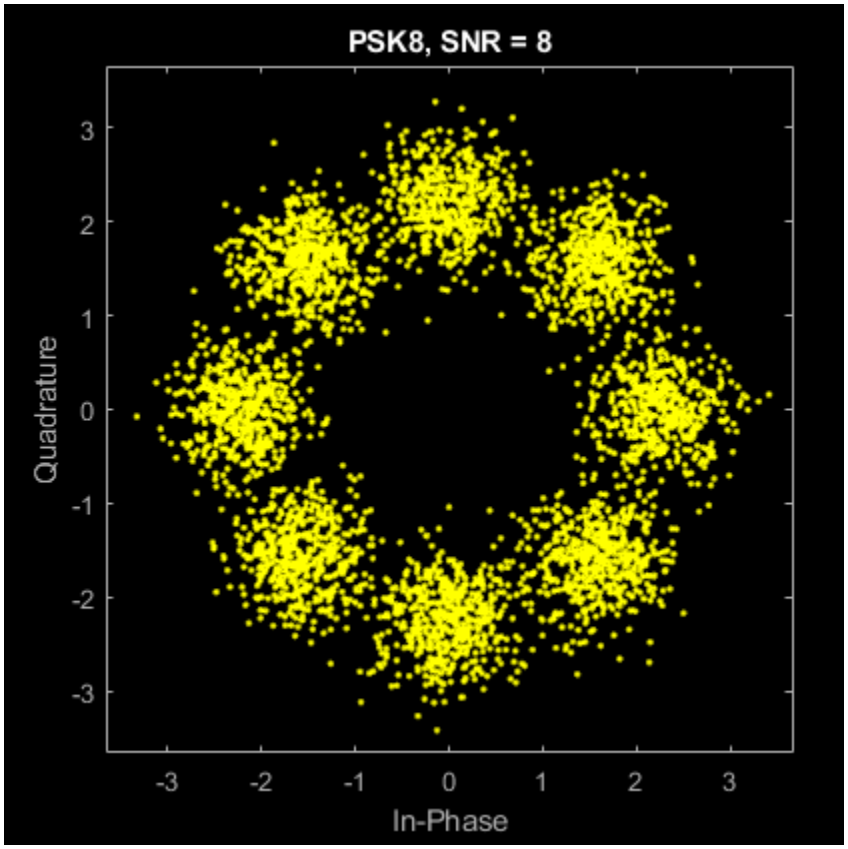

QPSK, SNR = 7
Quadrature
In-Phase
3
2
1
0
-1
-2
-3

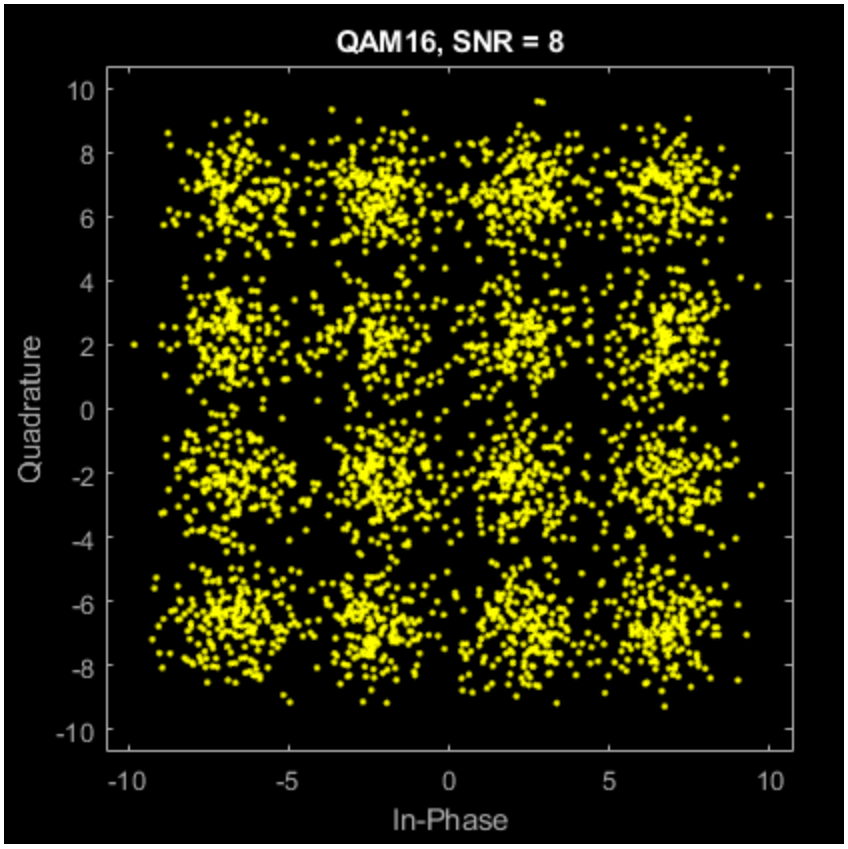

PSK8, SNR = 7
Quadrature
In-Phase
3
2
1
0
-1
-2
-3

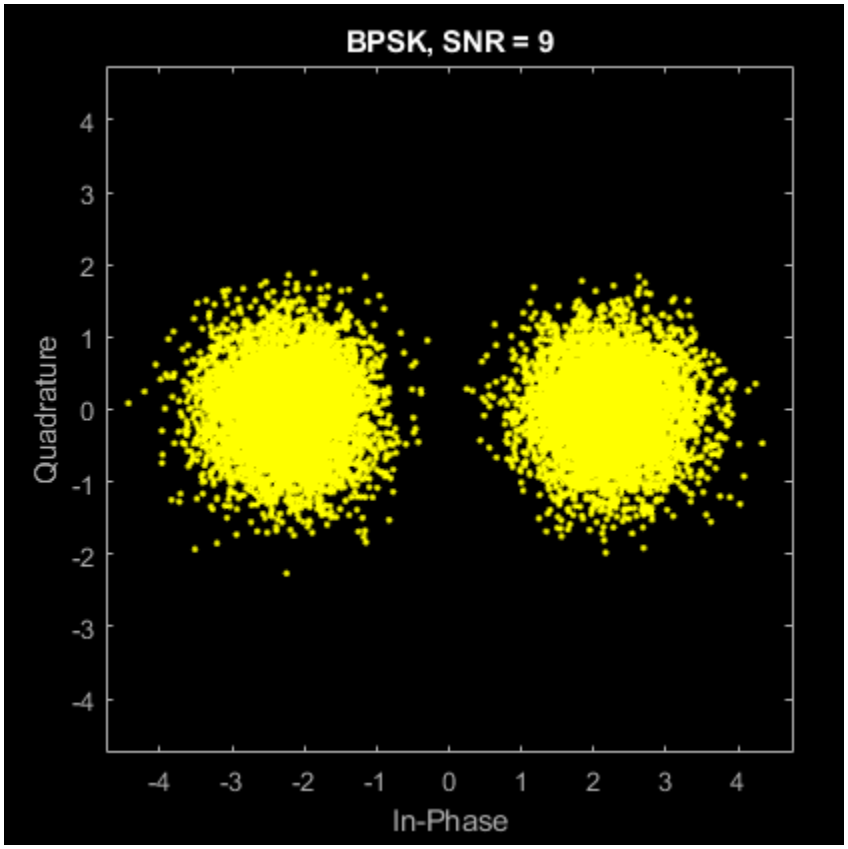

QAM16, SNR = 7
Quadrature
In-Phase
10
8
6
4
2
0
-2
-4
-6
-8
-10
-10
-5
0
5
10

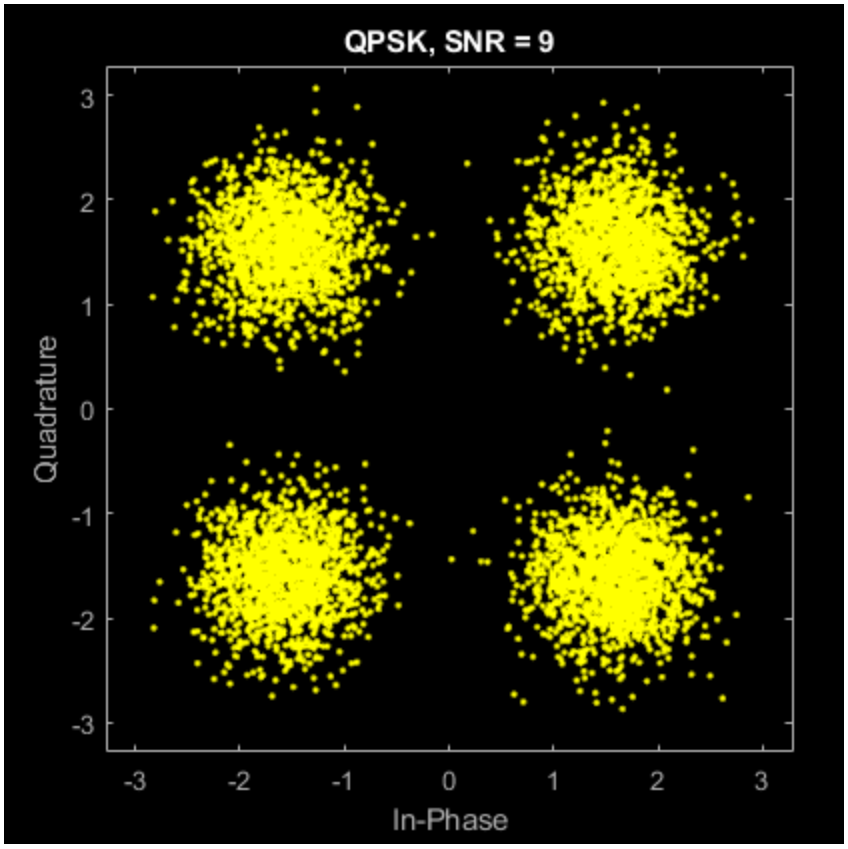

BPSK, SNR = 8
Quadrature
In-Phase
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
0
5

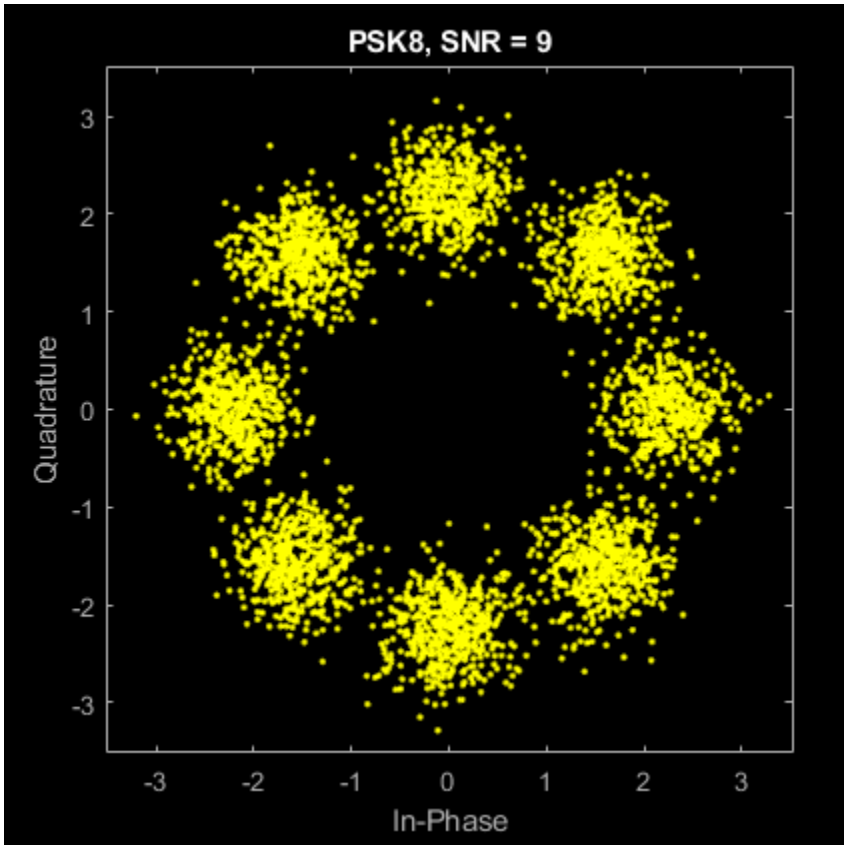

QPSK, SNR = 8
Quadrature
In-Phase
3
2
1
0
-1
-2
-3

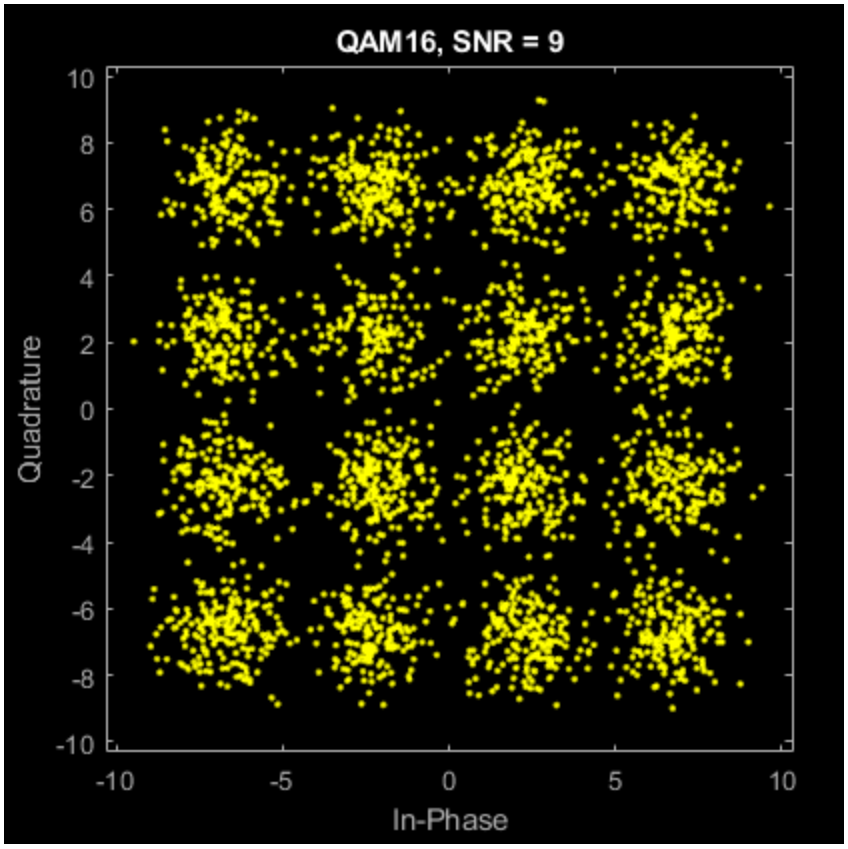

PSK8, SNR = 8
Quadrature
In-Phase
3
2
1
0
-1
-2
-3

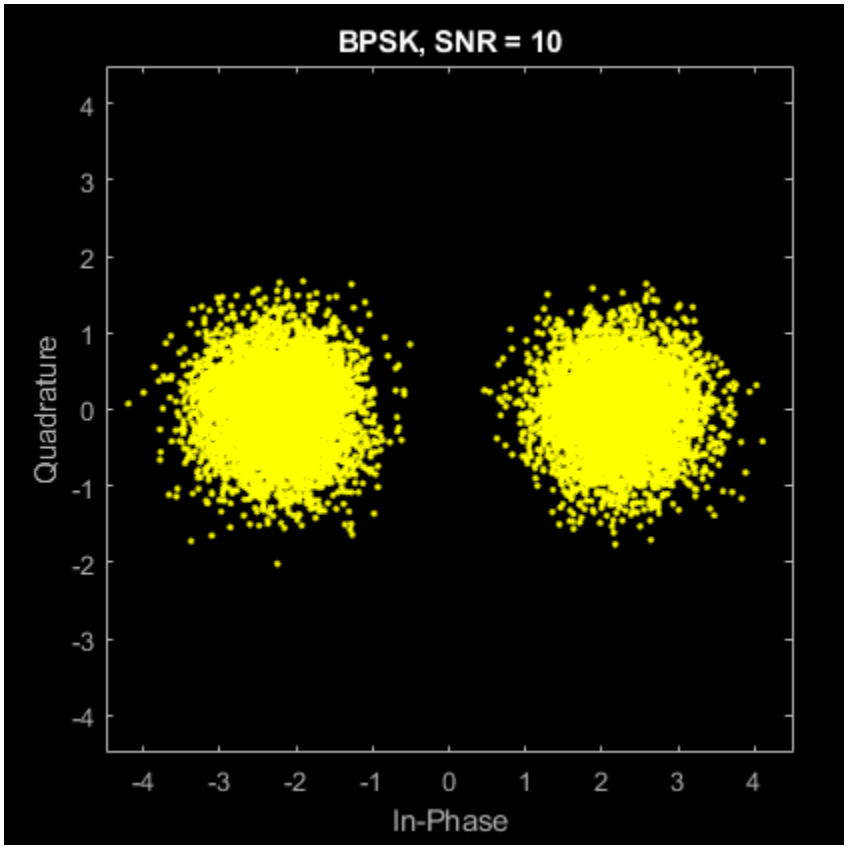

QAM16, SNR = 8
Quadrature
In-Phase
10
8
6
4
2
0
-2
-4
-6
-8
-10
-10
-5
0
5
10

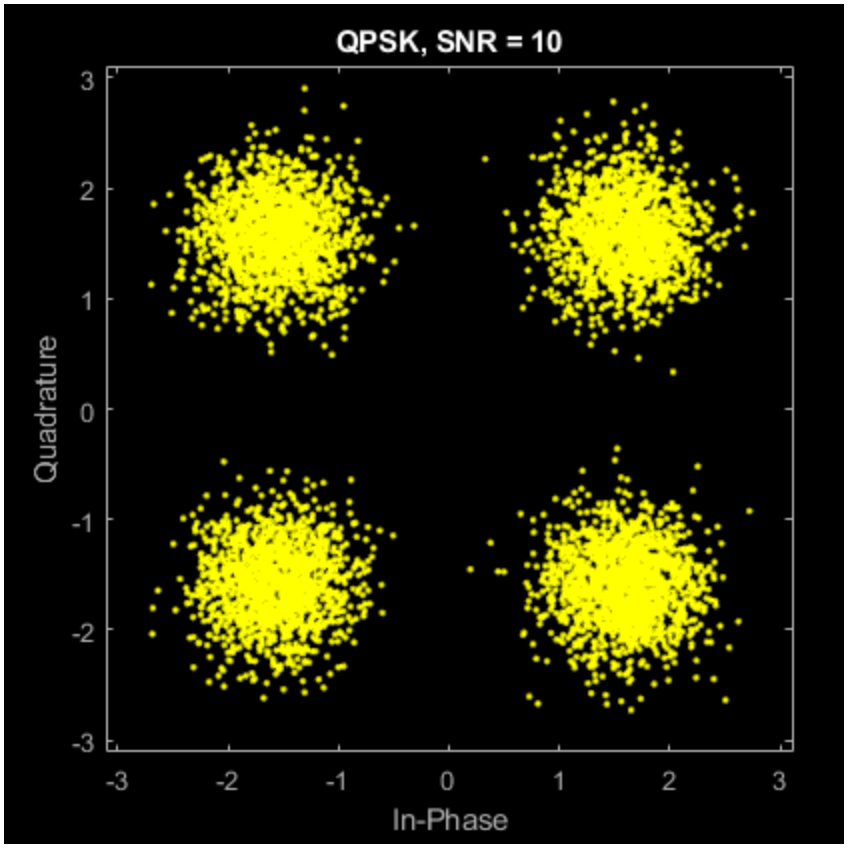

BPSK, SNR = 9
Quadrature
In-Phase
4
3
2
1
0
-1
-2
-3
-4
-4
-3
-2
-1
0
1
2
3
4

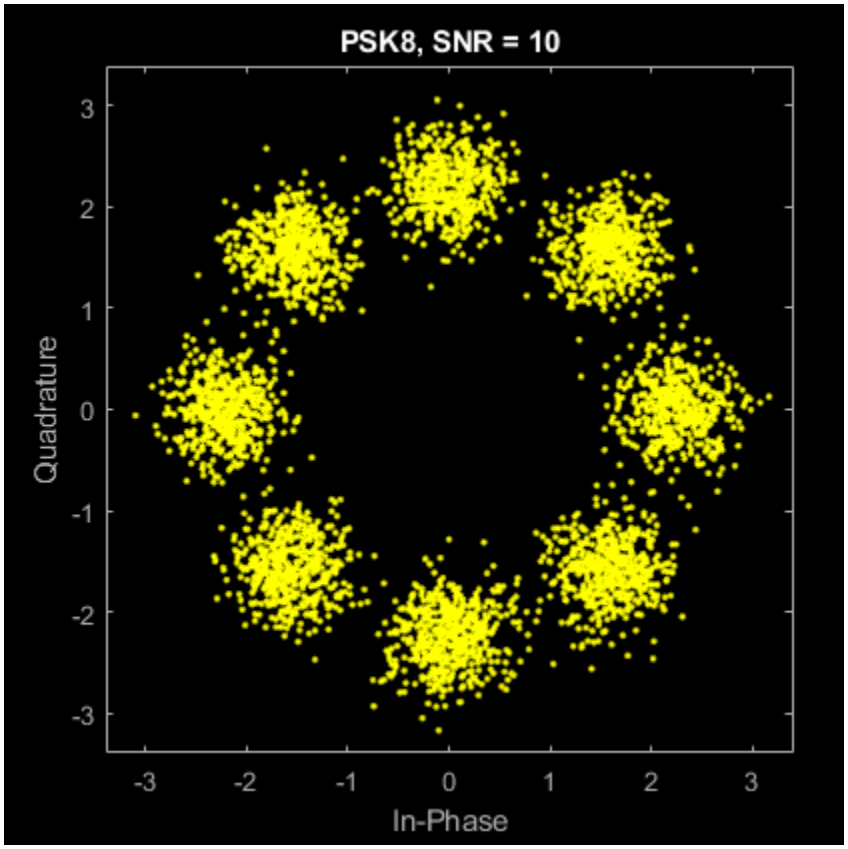

QPSK, SNR = 9
Quadrature
In-Phase
3
2
1
0
-1
-2
-3

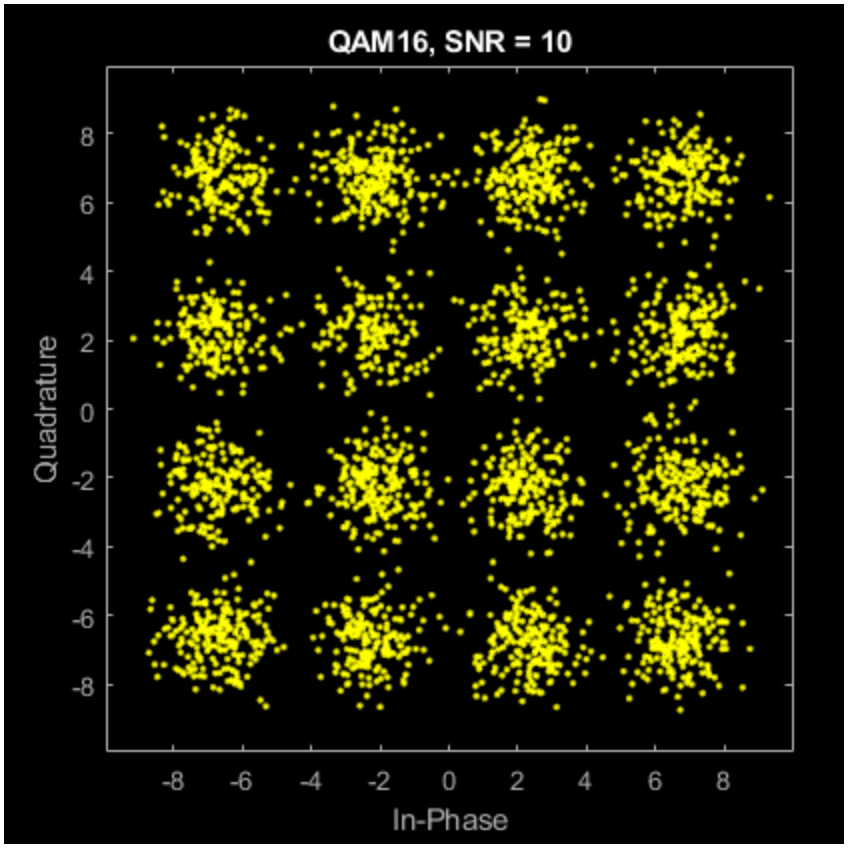

PSK8, SNR = 9
Quadrature
In-Phase
3
2
1
0
-1
-2
-3


QAM16, SNR = 9
Quadrature
In-Phase
10
8
6
4
2
0
-2
-4
-6
-8
-10
-10
-5
0
5
10


BPSK, SNR = 10
Quadrature
In-Phase
4
3
2
1
0
-1
-2
-3
-4
-4
-3
-2
-1
0
1
2
3
4


QPSK, SNR = 10
Quadrature
In-Phase
3
2
1
0
-1
-2
-3


PSK8, SNR = 10
Quadrature
In-Phase
3
2
1
0
-1
-2
-3



Print results

```
    fprintf("-----------------------------------------------------------
\n");
    fprintf("SNR = %d\n", SNR(i));

    fprintf("Theoretical BPSK BER = %f, simulated BPSK BER = %f\n",
 theoretical_bpsk_ber(end), ...
        simulated_bpsk_ber(end))
    fprintf("Theoretical QPSK BER = %f, simulated QPSK BER = %f\n",
 theoretical_qpsk_ber(end), ...
        simulated_qpsk_ber(end))
    fprintf("Theoretical PSK8 BER = %f, simulated PSK8 BER = %f\n",
 theoretical_psk8_ber(end), ...
        simulated_psk8_ber(end))
    fprintf("Theoretical QAM16 BER = %f, simulated QAM16 BER = %f\n",
 theoretical_qam16_ber(end), ...
        simulated_qam16_ber(end))

    fprintf("Actual number of errors:\n")
    fprintf("BPSK: %d bits,\testimated: %.5f bits\n", biterr(bits,
 bpsk_demod), theoretical_bpsk_ber(end) * length(bits))
    fprintf("QPSK: %d bits,\testimated: %.5f bits\n", biterr(bits,
 qpsk_demod), theoretical_qpsk_ber(end) * length(bits))
```

```
    fprintf("PSK8: %d bits,\testimated: %.5f bits\n", biterr(bits,
 psk8_demod), theoretical_psk8_ber(end) * length(bits))
    fprintf("QAM16: %d bits,\testimated: %.5f bits\n", biterr(bits,
 qam16_demod), theoretical_qam16_ber(end) * length(bits))
    fprintf("-------------------------------------------------------
\n");
```

```
-------------------------------------------------------
SNR = 1
Theoretical BPSK BER = 0.056280, simulated BPSK BER = 0.056667
Theoretical QPSK BER = 0.056280, simulated QPSK BER = 0.056167
Theoretical PSK8 BER = 0.097640, simulated PSK8 BER = 0.123583
Theoretical QAM16 BER = 0.118350, simulated QAM16 BER = 0.118667
Actual number of errors:
BPSK: 680 bits, estimated: 675.36000 bits
QPSK: 674 bits, estimated: 675.36000 bits
PSK8: 1483 bits, estimated: 1171.68000 bits
QAM16: 1424 bits, estimated: 1420.20000 bits
-------------------------------------------------------

-------------------------------------------------------
SNR = 2
Theoretical BPSK BER = 0.037510, simulated BPSK BER = 0.037083
Theoretical QPSK BER = 0.037510, simulated QPSK BER = 0.037417
Theoretical PSK8 BER = 0.079320, simulated PSK8 BER = 0.101250
Theoretical QAM16 BER = 0.097560, simulated QAM16 BER = 0.099833
Actual number of errors:
BPSK: 445 bits, estimated: 450.12000 bits
QPSK: 449 bits, estimated: 450.12000 bits
PSK8: 1215 bits, estimated: 951.84000 bits
QAM16: 1198 bits, estimated: 1170.72000 bits
-------------------------------------------------------

-------------------------------------------------------
SNR = 3
Theoretical BPSK BER = 0.022880, simulated BPSK BER = 0.021250
Theoretical QPSK BER = 0.022880, simulated QPSK BER = 0.021667
Theoretical PSK8 BER = 0.061830, simulated PSK8 BER = 0.077000
Theoretical QAM16 BER = 0.077420, simulated QAM16 BER = 0.079500
Actual number of errors:
BPSK: 255 bits, estimated: 274.56000 bits
QPSK: 260 bits, estimated: 274.56000 bits
PSK8: 924 bits, estimated: 741.96000 bits
QAM16: 954 bits, estimated: 929.04000 bits
-------------------------------------------------------

-------------------------------------------------------
SNR = 4
Theoretical BPSK BER = 0.012500, simulated BPSK BER = 0.011417
Theoretical QPSK BER = 0.012500, simulated QPSK BER = 0.011750
Theoretical PSK8 BER = 0.045790, simulated PSK8 BER = 0.057083
Theoretical QAM16 BER = 0.058620, simulated QAM16 BER = 0.060333
Actual number of errors:
BPSK: 137 bits, estimated: 150.00000 bits
```

```
QPSK: 141 bits, estimated: 150.00000 bits
PSK8: 685 bits, estimated: 549.48000 bits
QAM16: 724 bits, estimated: 703.44000 bits
---------------------------------------------------

---------------------------------------------------
SNR = 5
Theoretical BPSK BER = 0.005950, simulated BPSK BER = 0.004667
Theoretical QPSK BER = 0.005950, simulated QPSK BER = 0.004667
Theoretical PSK8 BER = 0.031840, simulated PSK8 BER = 0.038833
Theoretical QAM16 BER = 0.041890, simulated QAM16 BER = 0.041917
Actual number of errors:
BPSK: 56 bits, estimated: 71.40000 bits
QPSK: 56 bits, estimated: 71.40000 bits
PSK8: 466 bits, estimated: 382.08000 bits
QAM16: 503 bits, estimated: 502.68000 bits
---------------------------------------------------

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SNR = 6
Theoretical BPSK BER = 0.002390, simulated BPSK BER = 0.002333
Theoretical QPSK BER = 0.002390, simulated QPSK BER = 0.002333
Theoretical PSK8 BER = 0.020480, simulated PSK8 BER = 0.023917
Theoretical QAM16 BER = 0.027870, simulated QAM16 BER = 0.028667
Actual number of errors:
BPSK: 28 bits, estimated: 28.68000 bits
QPSK: 28 bits, estimated: 28.68000 bits
PSK8: 287 bits, estimated: 245.76000 bits
QAM16: 344 bits, estimated: 334.44000 bits
---------------------------------------------------

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SNR = 7
Theoretical BPSK BER = 0.000770, simulated BPSK BER = 0.000667
Theoretical QPSK BER = 0.000770, simulated QPSK BER = 0.000750
Theoretical PSK8 BER = 0.011950, simulated PSK8 BER = 0.014000
Theoretical QAM16 BER = 0.016970, simulated QAM16 BER = 0.015667
Actual number of errors:
BPSK: 8 bits, estimated: 9.24000 bits
QPSK: 9 bits, estimated: 9.24000 bits
PSK8: 168 bits, estimated: 143.40000 bits
QAM16: 188 bits, estimated: 203.64000 bits
---------------------------------------------------

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SNR = 8
Theoretical BPSK BER = 0.000190, simulated BPSK BER = 0.000000
Theoretical QPSK BER = 0.000190, simulated QPSK BER = 0.000167
Theoretical PSK8 BER = 0.006180, simulated PSK8 BER = 0.007750
Theoretical QAM16 BER = 0.009250, simulated QAM16 BER = 0.008500
Actual number of errors:
BPSK: 0 bits, estimated: 2.28000 bits
QPSK: 2 bits, estimated: 2.28000 bits
PSK8: 93 bits, estimated: 74.16000 bits
```
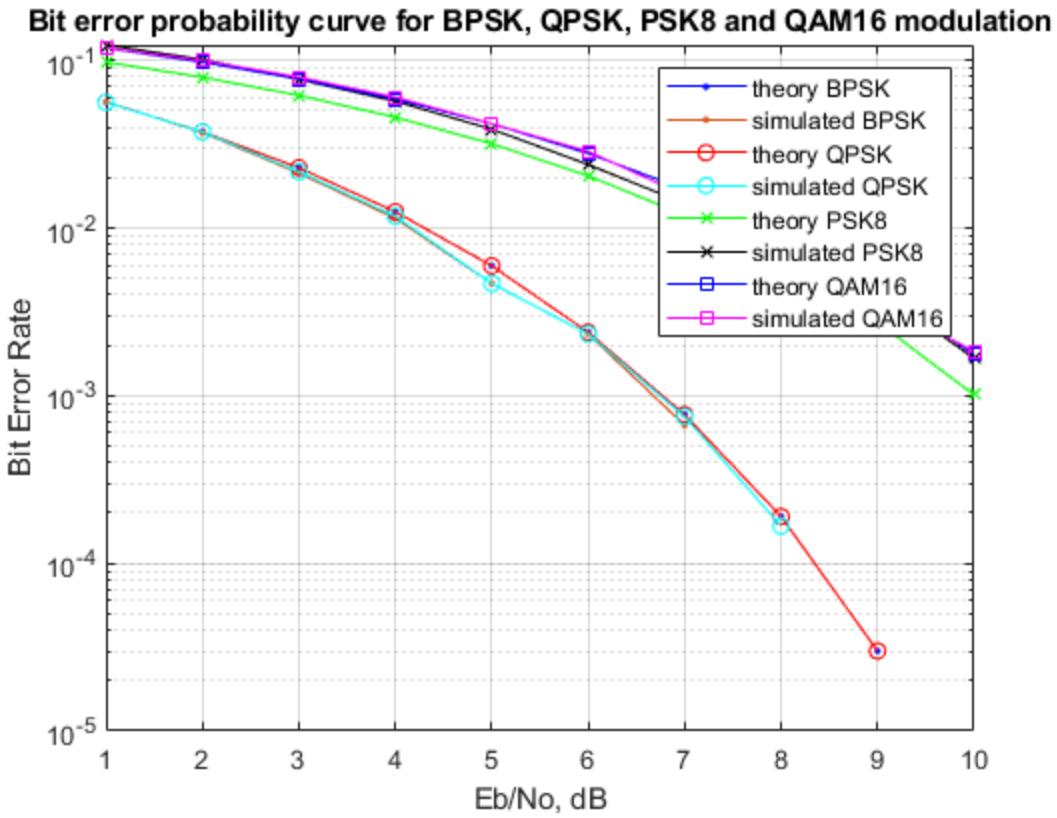

```
QAM16: 102 bits, estimated: 111.00000 bits
-------------------------------------------------------

-------------------------------------------------------
SNR = 9
Theoretical BPSK BER = 0.000030, simulated BPSK BER = 0.000000
Theoretical QPSK BER = 0.000030, simulated QPSK BER = 0.000000
Theoretical PSK8 BER = 0.002750, simulated PSK8 BER = 0.004333
Theoretical QAM16 BER = 0.004390, simulated QAM16 BER = 0.003750
Actual number of errors:
BPSK: 0 bits, estimated: 0.36000 bits
QPSK: 0 bits, estimated: 0.36000 bits
PSK8: 52 bits, estimated: 33.00000 bits
QAM16: 45 bits, estimated: 52.68000 bits
-------------------------------------------------------

-------------------------------------------------------
SNR = 10
Theoretical BPSK BER = 0.000000, simulated BPSK BER = 0.000000
Theoretical QPSK BER = 0.000000, simulated QPSK BER = 0.000000
Theoretical PSK8 BER = 0.001010, simulated PSK8 BER = 0.001667
Theoretical QAM16 BER = 0.001750, simulated QAM16 BER = 0.001833
Actual number of errors:
BPSK: 0 bits, estimated: 0.00000 bits
QPSK: 0 bits, estimated: 0.00000 bits
PSK8: 20 bits, estimated: 12.12000 bits
QAM16: 22 bits, estimated: 21.00000 bits
-------------------------------------------------------

end
```

Plot results

```
figure
semilogy(SNR, theoretical_bpsk_ber, 'b.-', SNR,
 simulated_bpsk_ber, '.-', 'MarkerFaceColor', [0 0.447 0.741]);
hold on
semilogy(SNR, theoretical_qpsk_ber, 'ro-', SNR,
 simulated_qpsk_ber, 'co-');
semilogy(SNR, theoretical_psk8_ber, 'gx-', SNR,
 simulated_psk8_ber, 'kx-');
semilogy(SNR, theoretical_qam16_ber, 'bs-', SNR,
 simulated_qam16_ber, 'ms-');
legend('theory BPSK', 'simulated BPSK', 'theory QPSK', 'simulated
 QPSK', 'theory PSK8', 'simulated PSK8', 'theory QAM16', 'simulated
 QAM16');
grid on
xlabel('Eb/No, dB');
ylabel('Bit Error Rate');
title('Bit error probability curve for BPSK, QPSK, PSK8 and QAM16
 modulation');
```



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