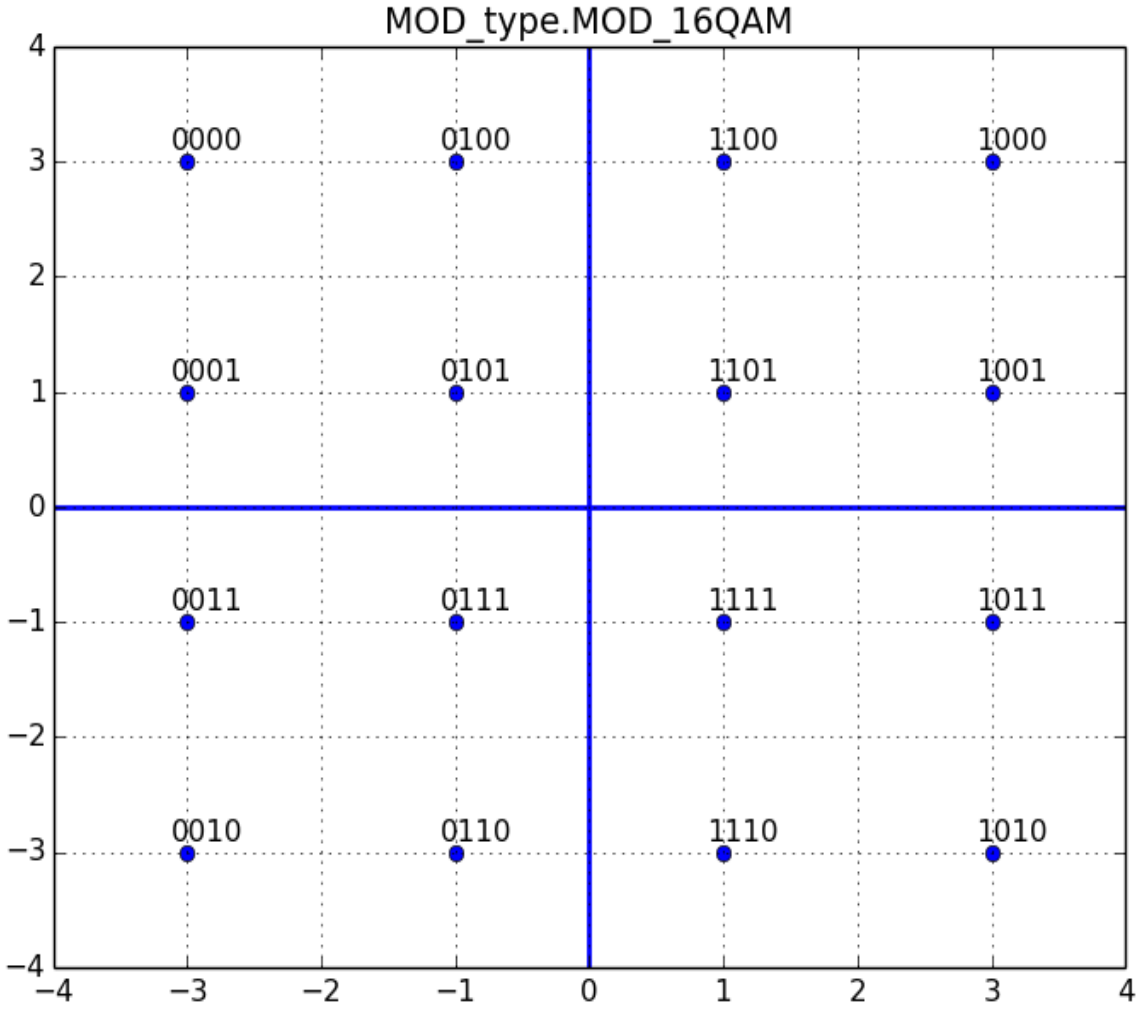
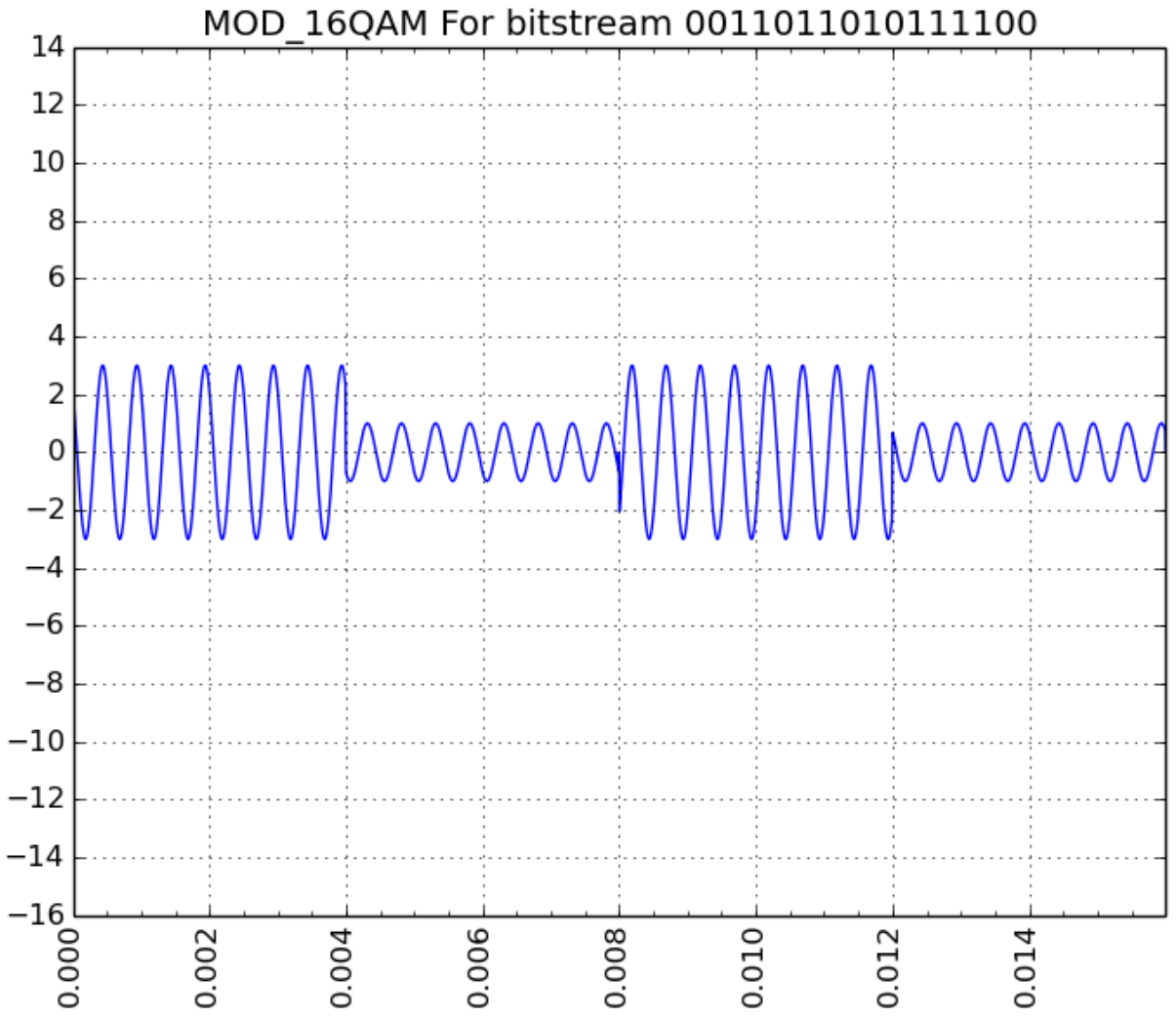
New Modulation Scheme

- Ac = -3L for 00, -L for 01, L for 11 and 3L for 10
- As = 3L for 00, L for 01, -L for 11 and -3L for 10
- For symbol 0000, (Ac, As) = (-3L, 3L), 0001 : (-3L, L), 0010 : (-3L, -L) …
- The geometric shape of the signal-space diagram would be different than 16-PSK. The symbol points are not on a circle as 16-PSK, instead they are organized as a grid structure.
- This modulation scheme is called 16-ary Quadrature Amplitude Modulation (16-QAM).

Signal Space diagram



Modulated signal



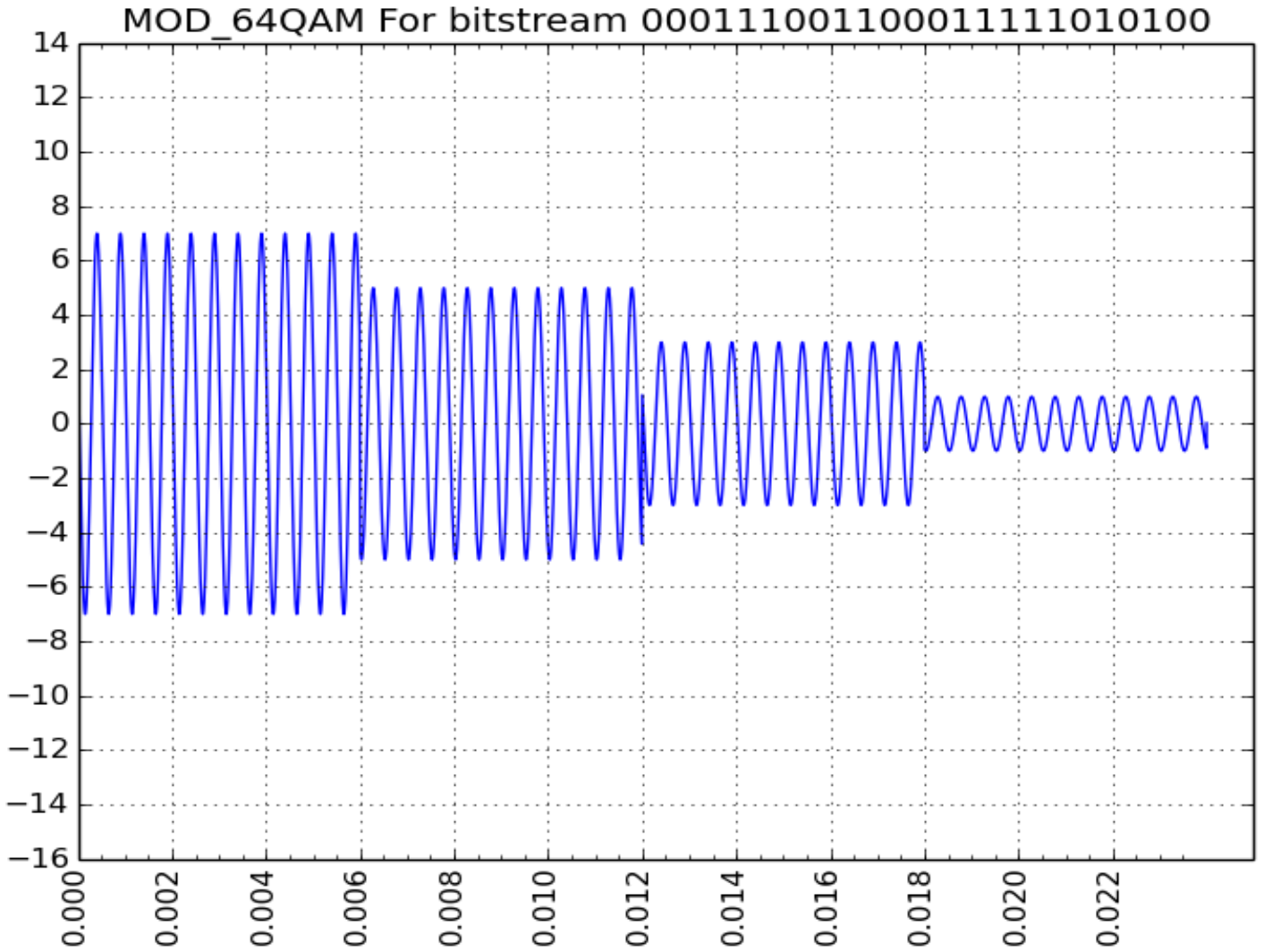
Modulated signal

- s(t) = A cos (2 pi f t + phi), where
- A for 0000 = $\sqrt{9\,L^2+9\,L^2}=3\,L\sqrt{2}$
- A for 0001 = $\sqrt{9\,L^2+L^2}=L\sqrt{10}$
- Phi for 0000 = $\arctan\left(\frac{-3\,L}{-3\,L}\right)=\frac{pi}{4}$
- Phi for 0001 = $\arctan\left(\frac{-L}{-3\,L}\right)=\arctan\left(\frac{1}{3}\right)$
- Similarly, A and phi values for other symbols can be computed.

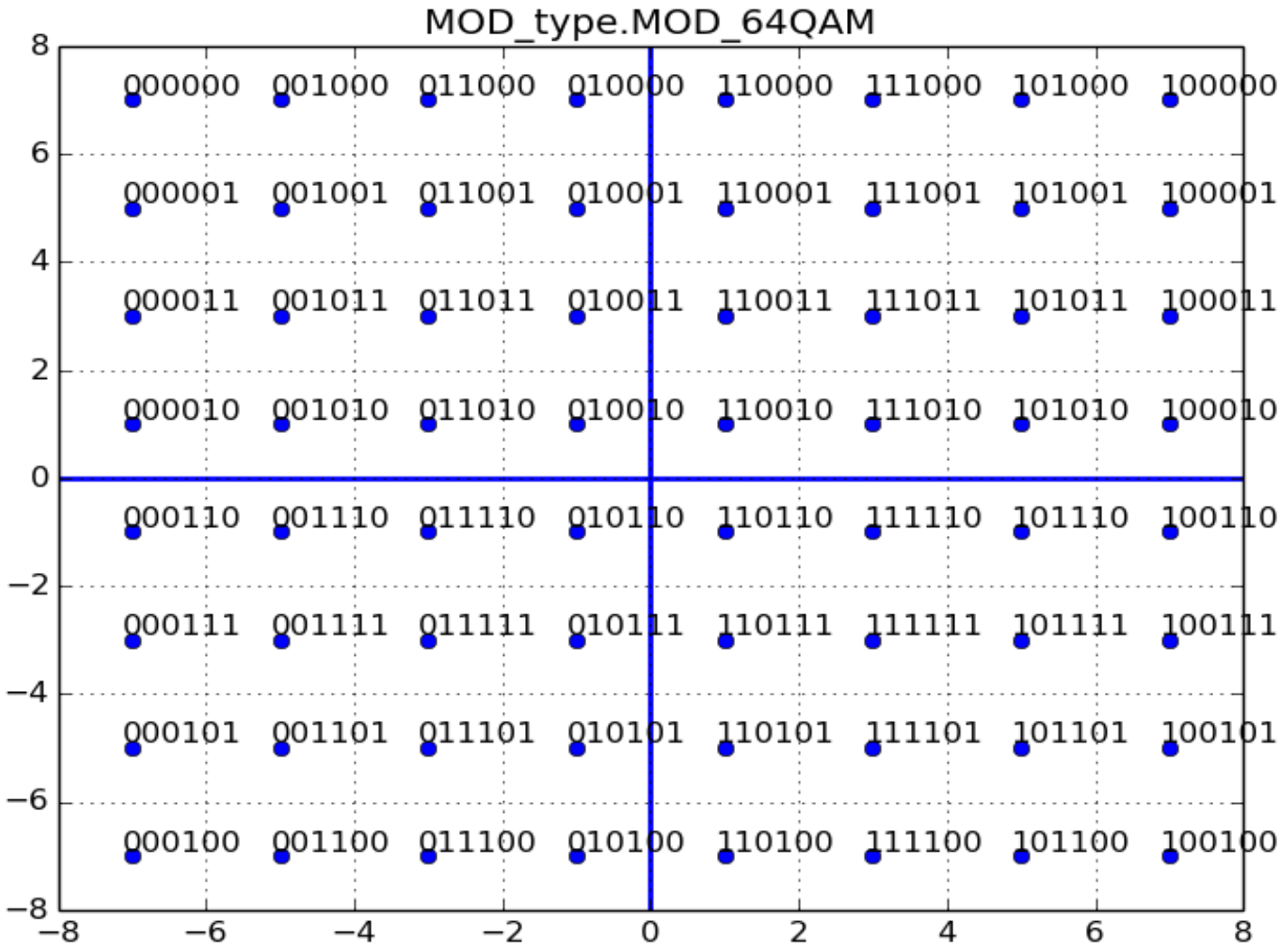
Other M values for QAM

- Other possible M values for QAM are 64 and 256.
- 64-QAM: 6 bits/symbol. Most significant 3-bits are for Ac values, and least significant 3-bits are for As values.
  - Ac = -7L for 000, -5L for 001, -3L for 011, -L for 010, +L for 110, +3L for 111, +5L for 101, +7L for 100.
  - As = 7L for 000 … -7L for 100.
- 256-QAM : 8-bits per symbol. 4 bits for Ac (-15L for 0000, … +15L for 1010), 4 bits for As (15L … -15L).

Modulated waveform for 64-QAM



Signal-Space diagram for 64-QAM



Usage of QAM

- 16-QAM, 64-QAM and 256-QAM are used for 4G mobile systems at present.
- 64-QAM and 256-QAM are also used in certain DTH channels.
- Achieved bit rate of 256-QAM = 4 times the bit rate achieved by QPSK over a channel with same symbol rate (baud rate).

Tasks in lab

- Write a C-code to generate successive symbols for 2-bits, 3-bits and 4-bits.
- Simulate QPSK, 8-PSK, 16-PSK, 16-QAM, 64-QAM and 256-QAM modulator and demodulator. Use same number of samples/symbol for each modulation/demodulation scheme, and have at least 4 samples per sine-wave cycle, and at least 2 sine-wave cycles/bit.
- Compare the demodulation error performances.