16-QAM (16 Point Quadrature Amplitude Modulation).

12.1 Overview.

16-QAM is a complex modulation scheme combining amplitude and phase modulation.

If we consider Bit voltage levels of: 1V, and 3V, the following mapping tables, phasor diagram, and ultimately a QAM constellation can be generated.

12.2 16-QAM Transmitter.

As shown, the input binary data is divided up into four channels, the I, I', Q, Q'. The bit rate in each channel is equal to one-fourth of the input bit rate (f/4).

Four bits are serially clocked into the bit splitter, then they are outputted simultaneously and in parallel with the I, I', Q, and Q' channels.

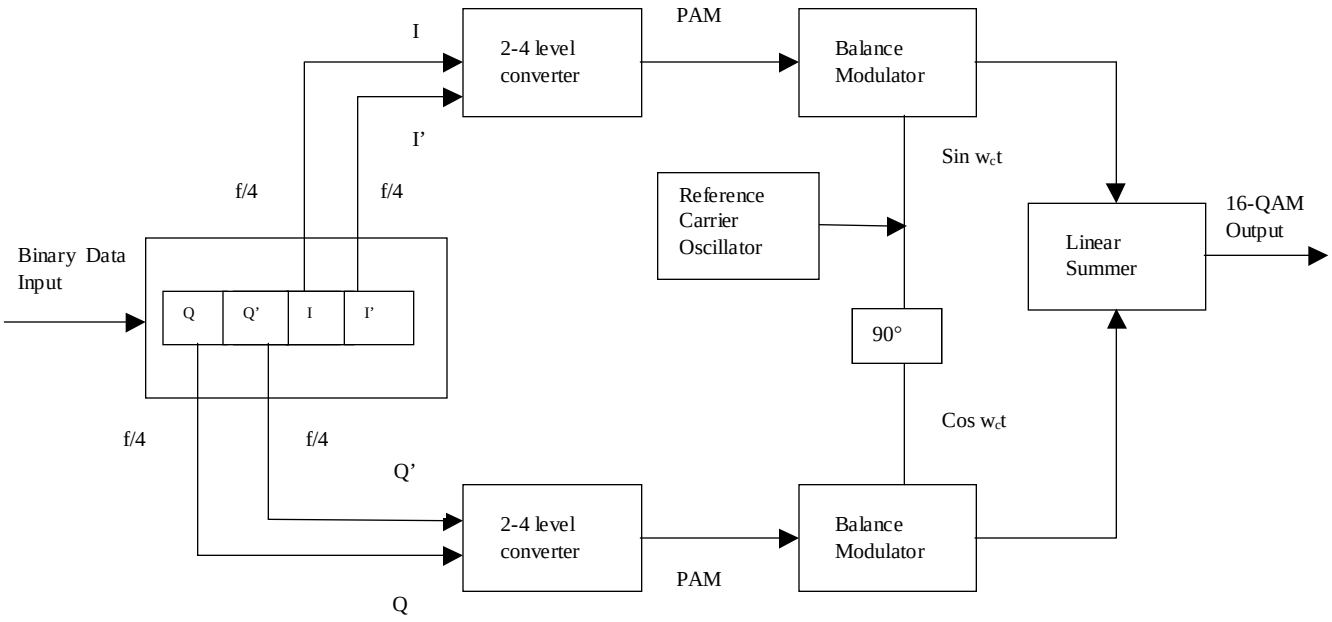
The I and Q bits determine the polarity at the output of the 2-4 level converters (logic 1 = negative and a logic 0 = positive.)

The I' and Q' bits determine the magnitude at the output of the 2-4 level converters (a logic 1 = 3 V and a logic 0 = 1 V). Consequently, the 2-4 level converters generate a 4-level PAM signal.

Two polarities and two magnitudes are possible at the output of each converter. They are ± 1 V and ± 3 V.

The PAM signals modulate the in phase and quadrature carriers in the product modulators. Four outputs are possible for each product modulator.
For the I product Modulator they are + 3 sin $w_c t$, - 3 sin $w_c t$, + 1 sin $w_c t$, and – 1 sin $w_c t$.
For the Q product modulator they are + 3 cos $w_c t$, - 3 cos$w_c t$, + 1 cos $w_c t$, and – 1 cos $w_c t$.

The linear summer combines the outputs from the I and Q channel product modulators and produces the 16 output conditions necessary for 16-QAM.



12.3 Mapping Tables for the I and Q channel 2-4 level convertors.

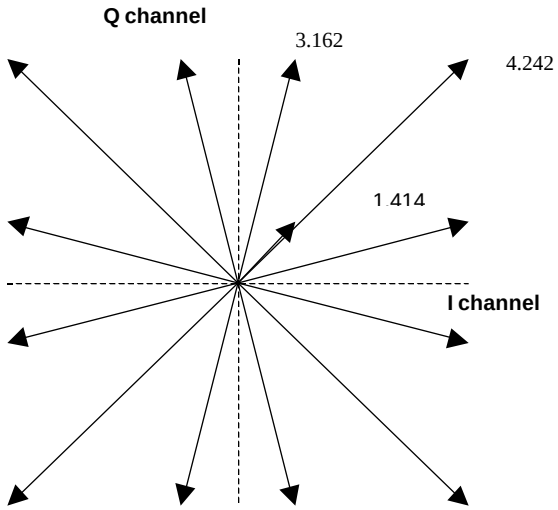
Mapping tables are defined for any particular system, which inevitably provide the final output locations for the 16-QAM modulated signal. See below.

Q	Q'	Output
0	0	+1 V
0	1	+3 V
1	0	-1 V
1	1	-3 V

I	I'	Output
0	0	+1 V
0	1	+3 V
1	0	-1 V
1	1	-3 V

12.4 Mapping Table and Phasor Diagram for 16-QAM Modulated Signal.

Binary Input				16-QAM Output	
Q	Q'	I	I'		
0	0	0	0	1.414	+45°
0	0	0	1	3.162	+18.43°
0	0	1	0	1.414	+135°
0	0	1	1	3.162	+161.57°
0	1	0	0	3.162	+71.56°
0	1	0	1	4.242	+45°
0	1	1	0	3.162	+108.43°
0	1	1	1	4.242	+135°
1	0	0	0	1.414	-45°
1	0	0	1	3.162	-18.43°
1	0	1	0	1.414	-135°
1	0	1	1	3.162	-161.57°
1	1	0	0	3.162	-71.56°
1	1	0	1	4.242	-45°
1	1	1	0	3.162	-108.43°
1	1	1	1	4.242	-135°



Using basic trigonometry, we can therefore determine the various points representing the QAM quad-bit. See below.

12.5 Constellation Diagram for 16-QAM Modulated Signal.