6.14 Quadrature Amplitude Shift Keying (QASK) or QAM :

➤➤➤ [Asked in Exam : May 08 !!!]

- In all the PSK methods discussed till now, one symbol is distinguished from the other in phase, but all the symbols transmitted using BPSK, QPSK or M-ary PSK are of "same amplitude".
- The ability of a receiver to distinguish between one signal vector from another in presence of noise, depends on the distance between the vector end points.
- This suggests that the noise immunity will improve if the signal vectors differ not only in phase, but also in amplitude.
- Such a system is called as amplitude and phase shift keying system.
- In this system the direct modulation of carriers in quadrature (i.e. $\cos \omega_c t$ and $\sin \omega_c t$) is involved, therefore this system is called as the quadrature amplitude phase shift keying i.e. QAPSK or simply QASK.
- It is also known as quadrature amplitude modulation (QAM).

6.14.1 Geometrical Representation of QASK :

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- The geometrical representation is also called as signal space representation.
- Let us assume that using QASK we want to transmit a symbol consisting of 4 bits. That means N = 4 and there are $2^4 = 16$ different possible symbols. Hence the QASK system should be able to generate 16 different distinguishable signals.
- A possible geometric representation of 16 signals is shown in Fig. 6.14.1.
- In the geometric representation of Fig. 6.14.1, each signal point is equally distant from its nearest neighbours. This distance is $d = 2a$.
- Now let us assume that all the 16 signals are equally spaced. As these signal are placed symmetrically, we can determine the energy associated with a signal, by considering the four signals in the first quadrant.
- The average normalized energy of each signal is given by the average of the energy associated with signals in the first quadrant.

$$\therefore \qquad E_s = \frac{E_{s1} + E_{s2} + E_{s3} + E_{s4}}{4}$$

- Looking at Fig. 6.14.1 we can write that,

$$E_{s1} = (a^2 + a^2), \quad E_{s2} = (9a^2 + a^2)$$

$$E_{s3} = (9a^2 + 9a^2) \text{ and } E_{s4} = (a^2 + 9a^2)$$

- Substituting these values into expression for E_s we get,

$$E_s = \frac{1}{4}[(a^2+a^2)+(9a^2+a^2)+(a^2+9a^2)+(9a^2+9a^2)]$$

$$= 10\,a^2 \qquad ...(6.14.1)$$

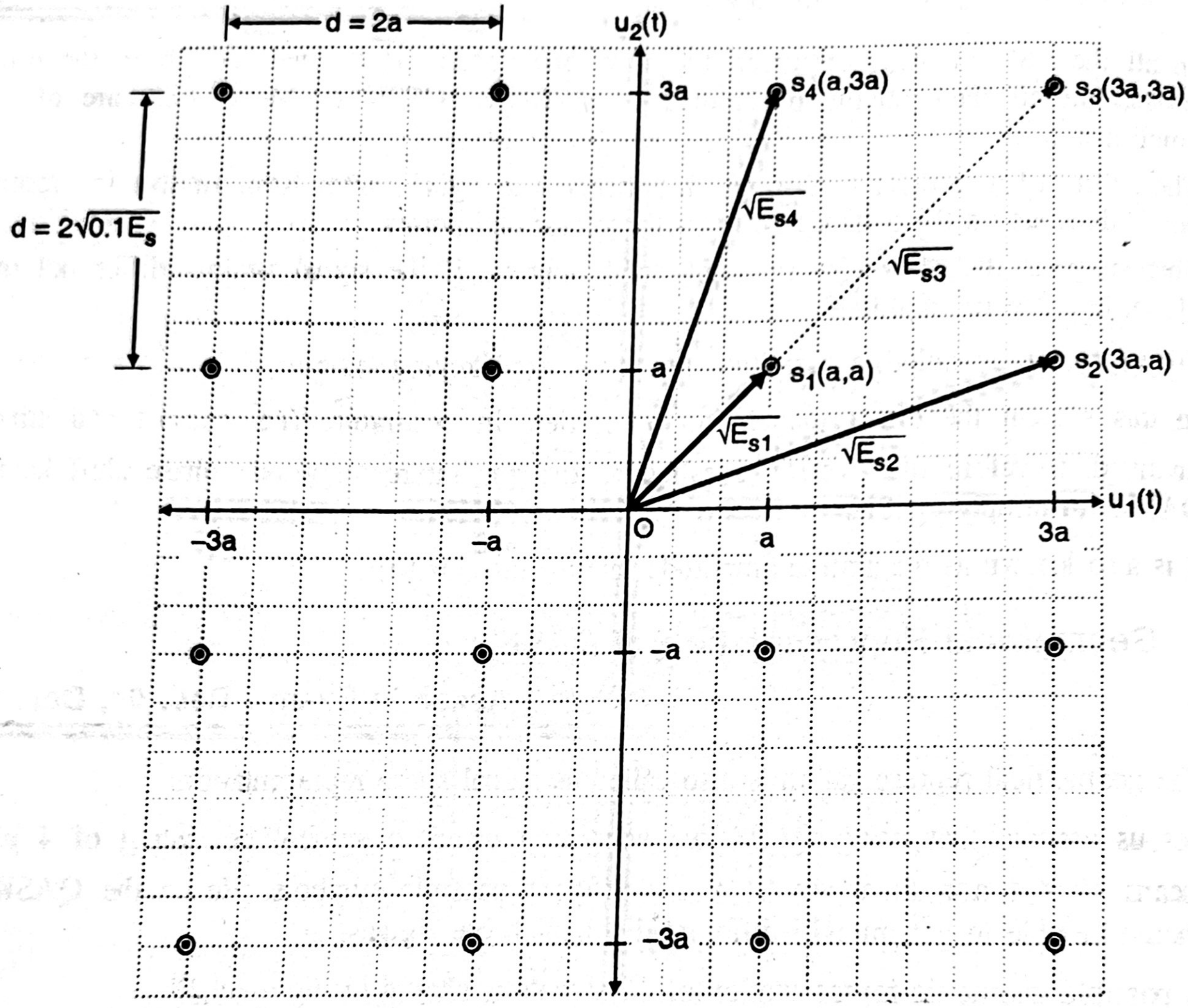


Fig. 6.14.1 : Geometric representation of 16 signals in a QASK system (16 - QAM)

ıerefore, $$a = \sqrt{0.1\,E_s} \qquad ...(6.14.2)$$

and $$d = 2a = 2\sqrt{0.1\,E_s} \qquad ...(6.14.3)$$

where E_s = Normalized symbol energy. In this system, because each symbol consists of 4 bits, the normalized symbol energy is given by,

$$E_s = 4\,E_b \qquad ...(6.14.4)$$

where E_b is the normalized energy per bit.

- Substituting Equation (6.14.4) into Equations (6.14.2) and (6.14.3) we get,

$$a = \sqrt{0.4\,E_b} \text{ and } d = 2\sqrt{0.4\,E_b} \quad ...(6.14.5)$$

Equation (6.14.5) shows that the distance "d" for QASK system is significantly less than the distance between the adjacent QPSK signals where $d = 2\sqrt{E_b}$. But this distance "d" is greater than the 16-ary PSK where,

$$d = \sqrt{16\,E_b \times \sin^2\frac{\pi}{16}} = 2\sqrt{0.15\,E_b} = \sqrt{0.6\,E_b} \quad ...(6.14.6)$$

Thus the 16 QASK system will have a low error rate as compared to 16-ary PSK but a higher error rate as compared to a QPSK system.

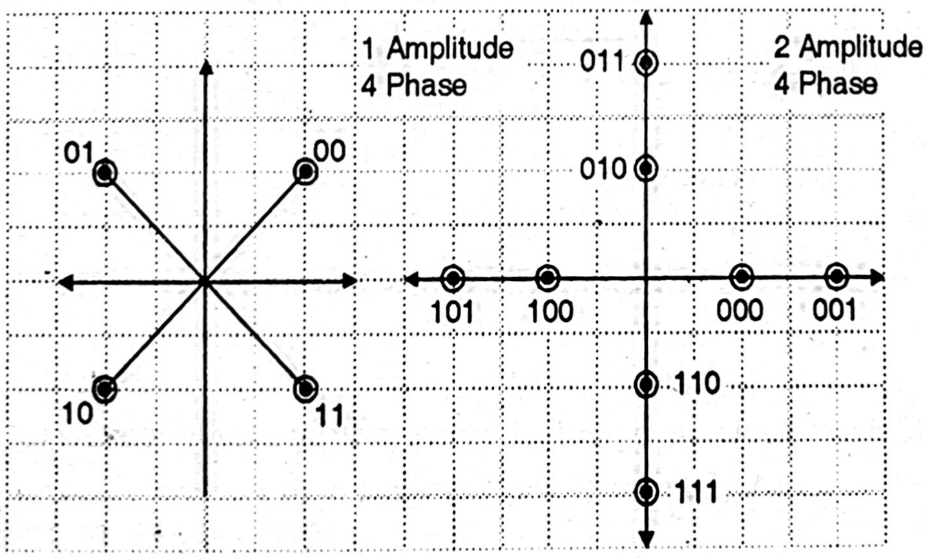
6.14.2 Types of QAM :

Depending on the number of bits per message the QAM signals are classified as follows :

Name	Bits per symbol	Number of symbols
4 QAM	2	$2^2 = 4$
8 QAM	3	$2^3 = 8$
16 QAM	4	$2^4 = 16$
32 QAM	5	$2^5 = 32$
64 QAM	6	$2^6 = 64$

6.14.3 4 QAM and 8 QAM Systems :

- The constellation of 4 QAM system is shown in Fig. 6.14.2(a). All the symbols have same amplitude but different phases.



(a) 4 QAM (b) 8 QAM

Fig. 6.14.2 : Constellation diagrams