Digital Communication 22EC2208

Digital Carrier Modulation

Dr. M. Venu Gopala Rao

A.M.I.E.T.E, M.Tech, Ph.D(Engg)

Cert. in R.S.T (City & Guild's London Institute, London)

F.I.E.T.E, L.M.I.S.T.E, I.S.O.I., S.S.I., M.I.A.E.

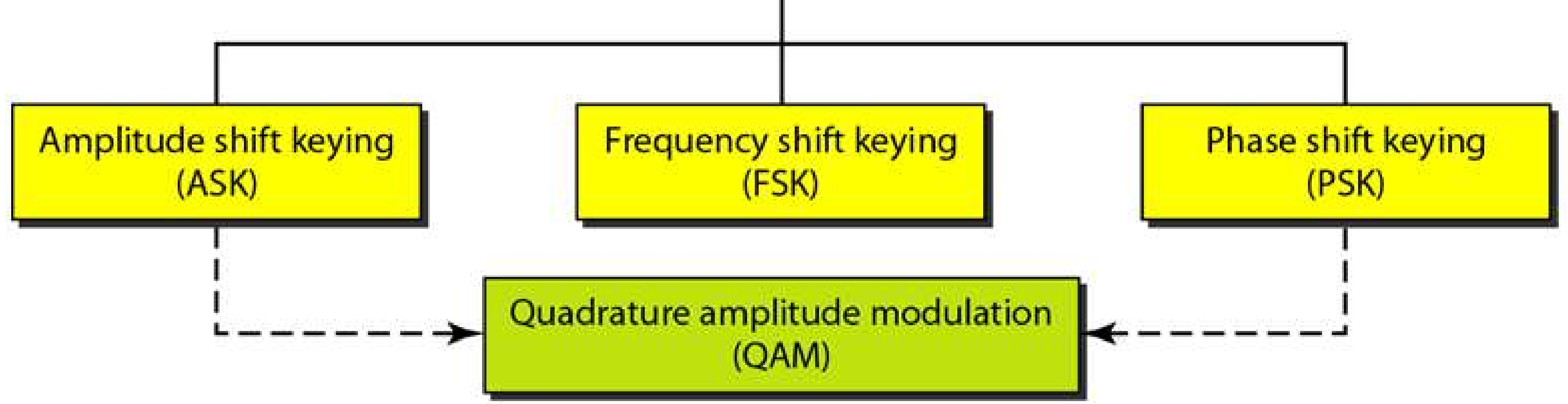
Professor, Dept. of ECE, K L University

mvgr03@kluniversity.in

- **Quadrature Amplitude Modulation (QAM)**
- **Carrier Recovery**
- **Clock Recovery**

QUADRATURE-AMPLITUDE MODULATION (QAM)

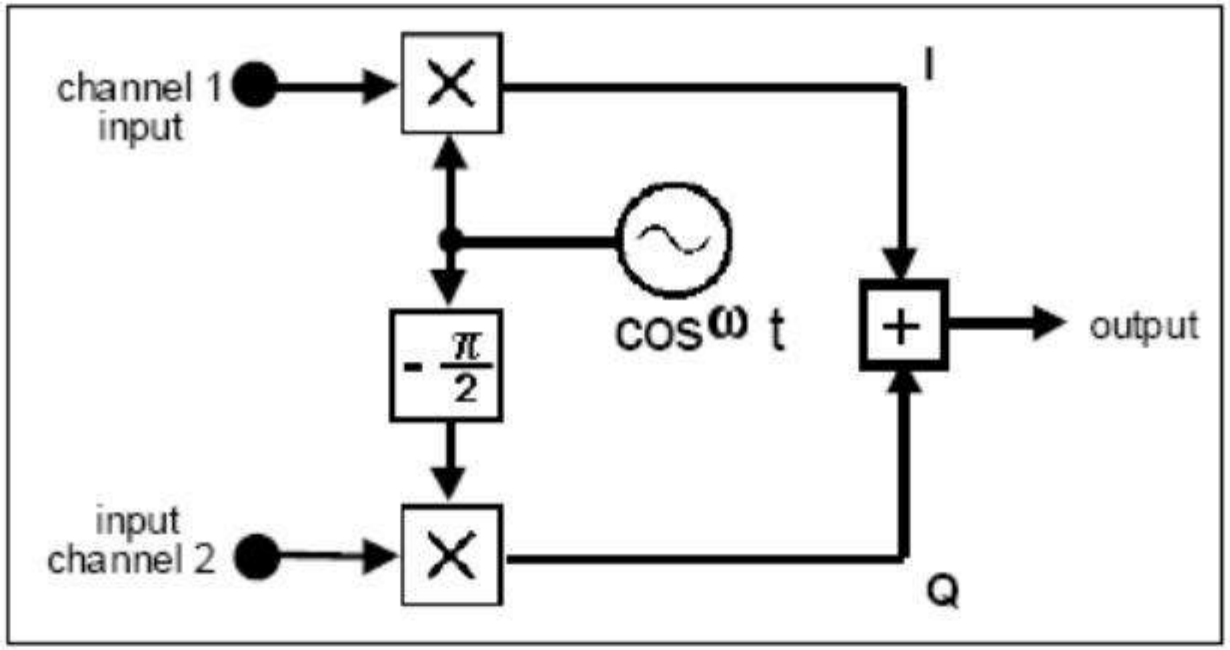
QAM



- Quadrature amplitude modulation (QAM) is a technique that combime both amplitude and phase variations in a carrier at the same time.
- With QAM, amplitude and phase-shift keying are combined in such a way that the positions of the signaling elements on the constellation diagrams are optimized.

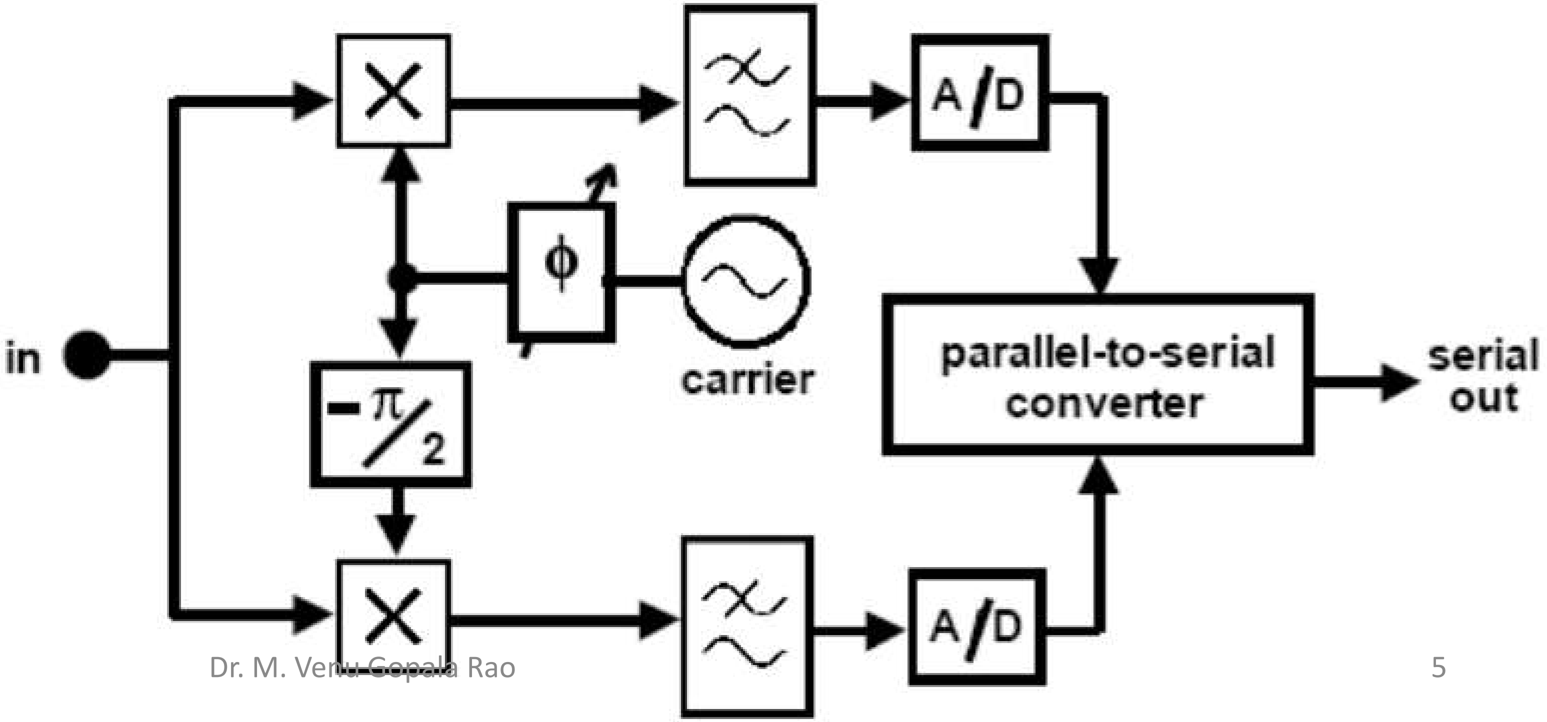
8-QAM

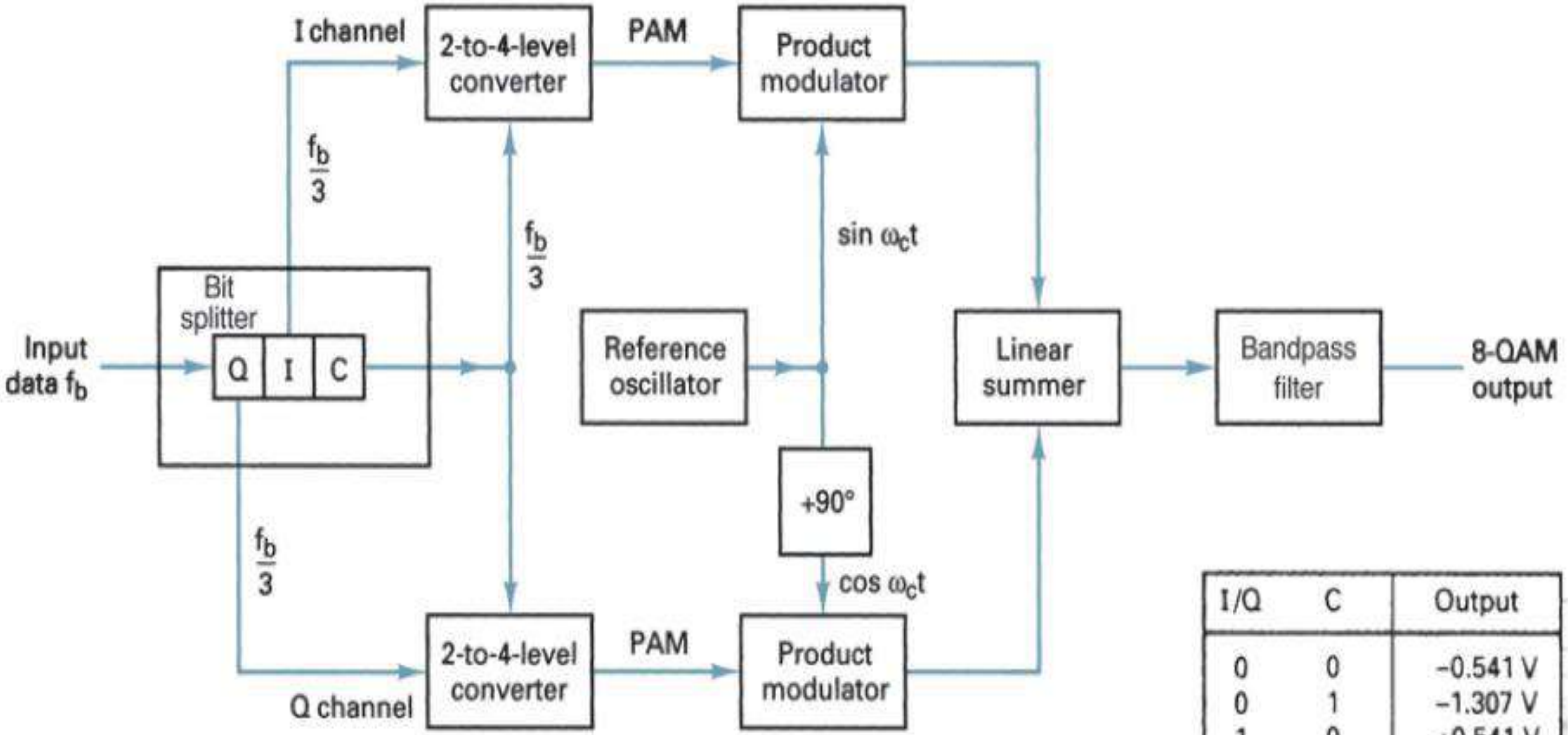
- 8-QAM is an M-ary encoding technique where M=8. Unlike 8-PSK, the output signal from an 8-QAM modulator is not a constant-amplitude signal.



QAM Transmitter

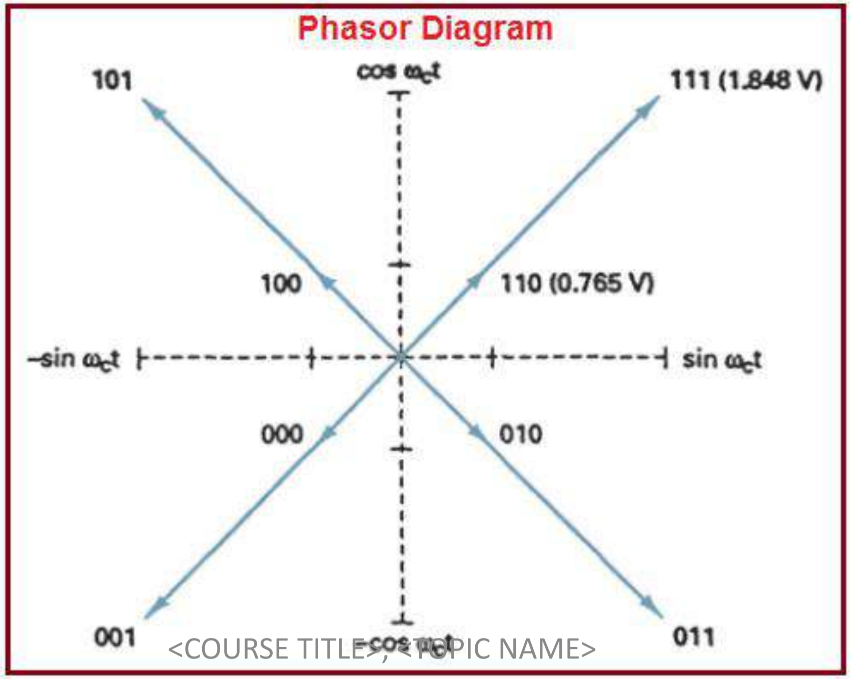
QAM Receiver

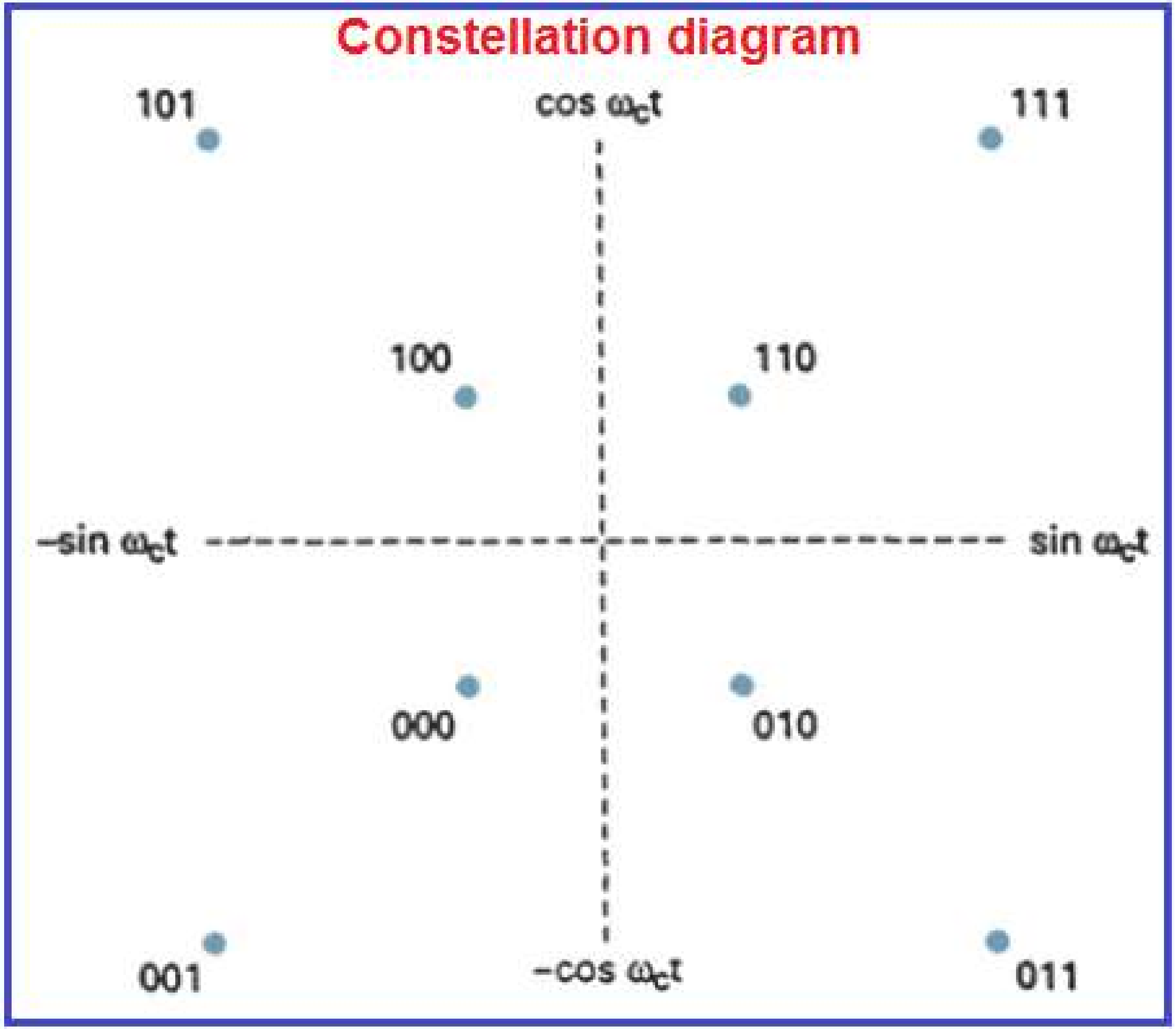




I/Q	C	Output
0	0	−0.541 V
0	1	−1.307 V
1	0	+0.541 V
1	1	+1.307 V

Binary input			8-QAM output	
Q	I	C	Amplitude	Phase
0	0	0	0.765 V	−135°
0	0	1	1.848 V	−135°
0	1	0	0.765 V	−45°
0	1	1	1.848 V	−45°
1	0	0	0.765 V	+135°
1	0	1	1.848 V	+135°
1	1	0	0.765 V	+45°
1	1	1	1.848 V	+45°





Bandwidth Efficiency

- Bandwidth efficiency (sometimes called information density or spectral efficiency) is often used to compare the performance of one digital modulation technique to another.
- In essence, bandwidth efficiency is the ratio of the transmission bit rate to the minimum bandwidth required for a particular modulation scheme.
- Bandwidth efficiency is generally normalized to a 1-Hz bandwidth and, thus, indicates the number of bits that can be propagated through a transmission medium for each hertz of bandwidth.

Mathematically, bandwidth efficiency is

$$\boxed{B\eta = \frac{\text{transmission bit rate (bps)}}{\text{minimum bandwidth (Hz)}}}$$

$$\boxed{= \frac{\text{bits/s}}{\text{hertz}} = \frac{\text{bits/s}}{\text{cycles/s}} = \frac{\text{bits}}{\text{cycle}}}$$

where $B\eta$ = bandwidth efficiency

Bandwidth efficiency can also be given as a percentage by simply multiplying $B\eta$ by 100.

Write the mathematical expression for bandwidth efficiency of M-ary signals. Find the bandwidth efficiency of M-ary FSK signals $M = 8$, 16 and 32.

$$BW = (M+3)\frac{f_b}{2N}$$

$$B_\eta = \frac{\text{Transmission bit rate (bps)}}{\text{Minimum bandwidth (Hz)}}$$

$$\text{Then } B_\eta = \frac{2N}{(M+3)}$$

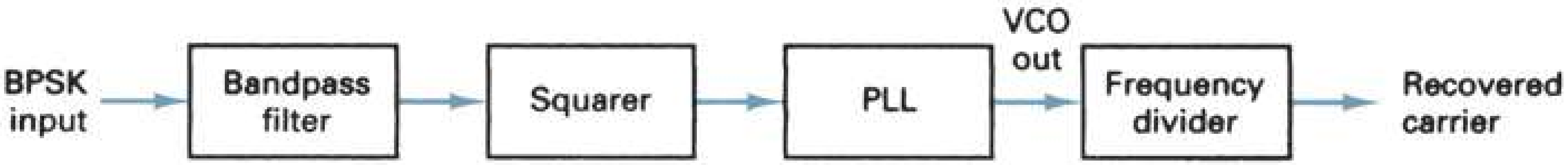
$$\text{For } M = 8 \quad \Rightarrow \quad N = 3 \text{ and } B_\eta = \frac{2N}{(M+3)} = \frac{6}{11} = 54.54\%$$

$$\text{For } M = 16 \quad \Rightarrow \quad N = 4 \text{ and } B_\eta = \frac{2N}{(M+3)} = \frac{8}{19} = 42.1\%$$

$$\text{For } M = 32 \quad \Rightarrow \quad N = 5 \text{ and } B_\eta = \frac{2N}{(M+3)} = \frac{10}{35} = 28.57\%$$

Carrier Recovery

- Carrier recovery is the process of extracting a phase-coherent reference carrier from a receiver signal. This is sometimes called phase referencing.
- Squaring loop carrier recovery circuit for a BPSK receiver:



With BPSK, only two output phases are possible: $+\sin\omega_c t$ and $-\sin\omega_c t$. Mathematically, the operation of the squaring circuit can be described as follows. For a receive signal of $+\sin\omega_c t$, the output of the squaring circuit is

$$\text{output} = (+\sin\omega_c t)(+\sin\omega_c t) = +\sin^2\omega_c t$$

$$= \frac{1}{2}(1 - \cos 2\omega_c t) = \overset{\text{Filtered}}{\frac{1}{2}} - \overset{\text{Output}}{\frac{1}{2}\cos 2\omega_c t}$$

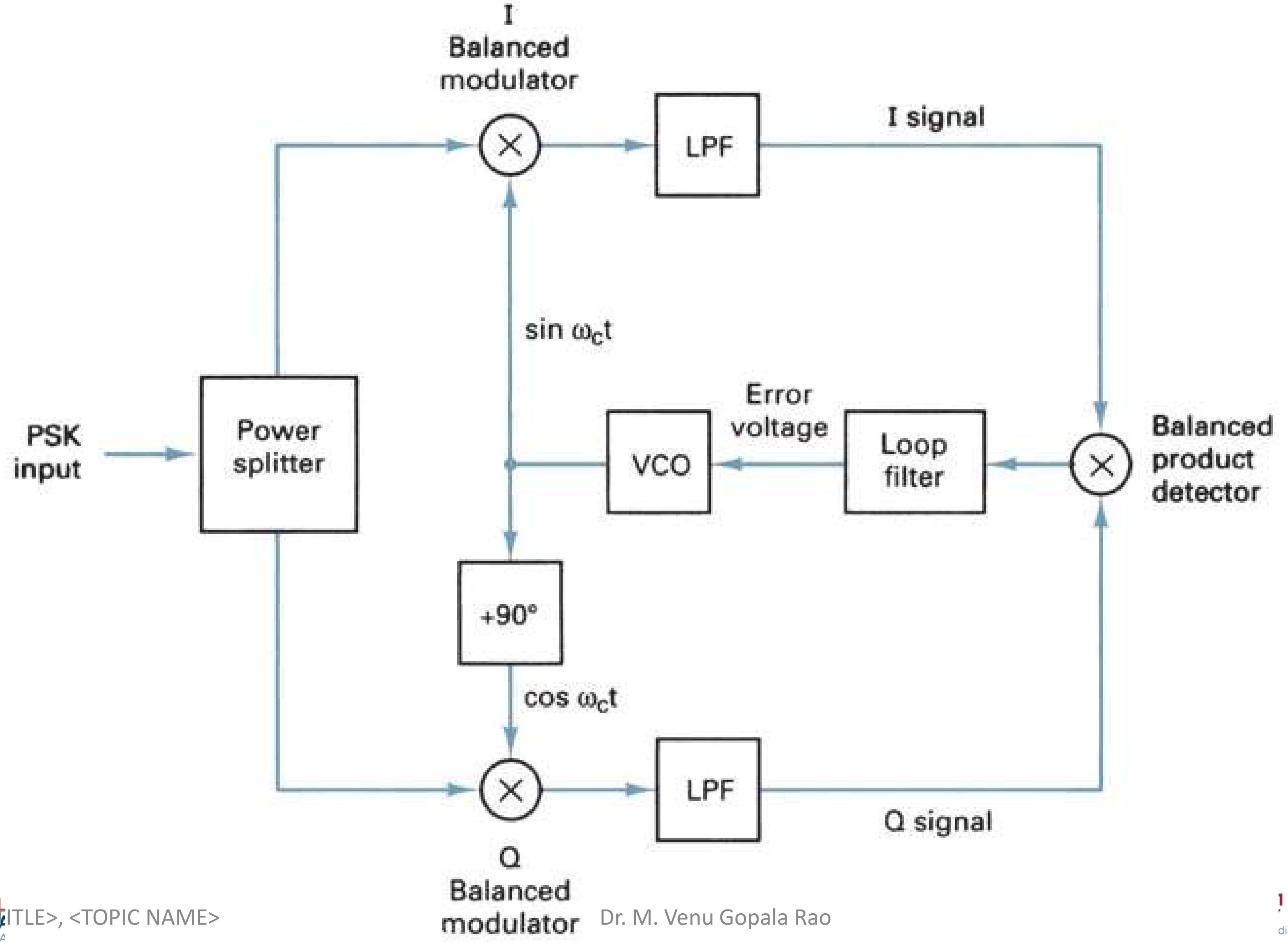
For a received signal of $-\sin\omega_c t$, the output of the squaring circuit is

$$\text{output} = (-\sin\omega_c t)(-\sin\omega_c t) = +\sin^2\omega_c t$$

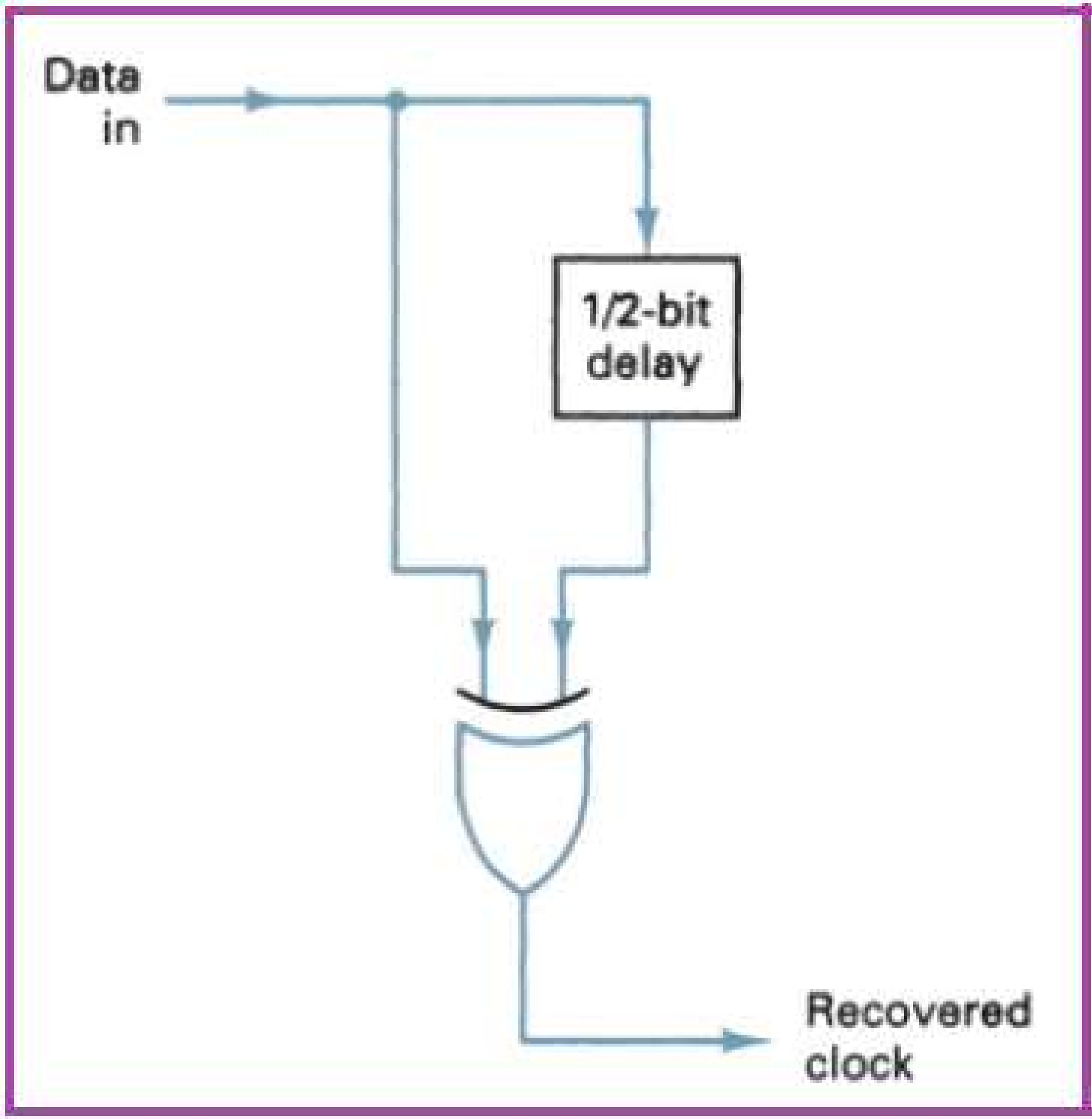
$$= \frac{1}{2}(1 - \cos 2\omega_c t) = \overset{\text{Output}}{\frac{1}{2}} - \overset{\text{Filtered}}{\frac{1}{2}\cos 2\omega_c t}$$

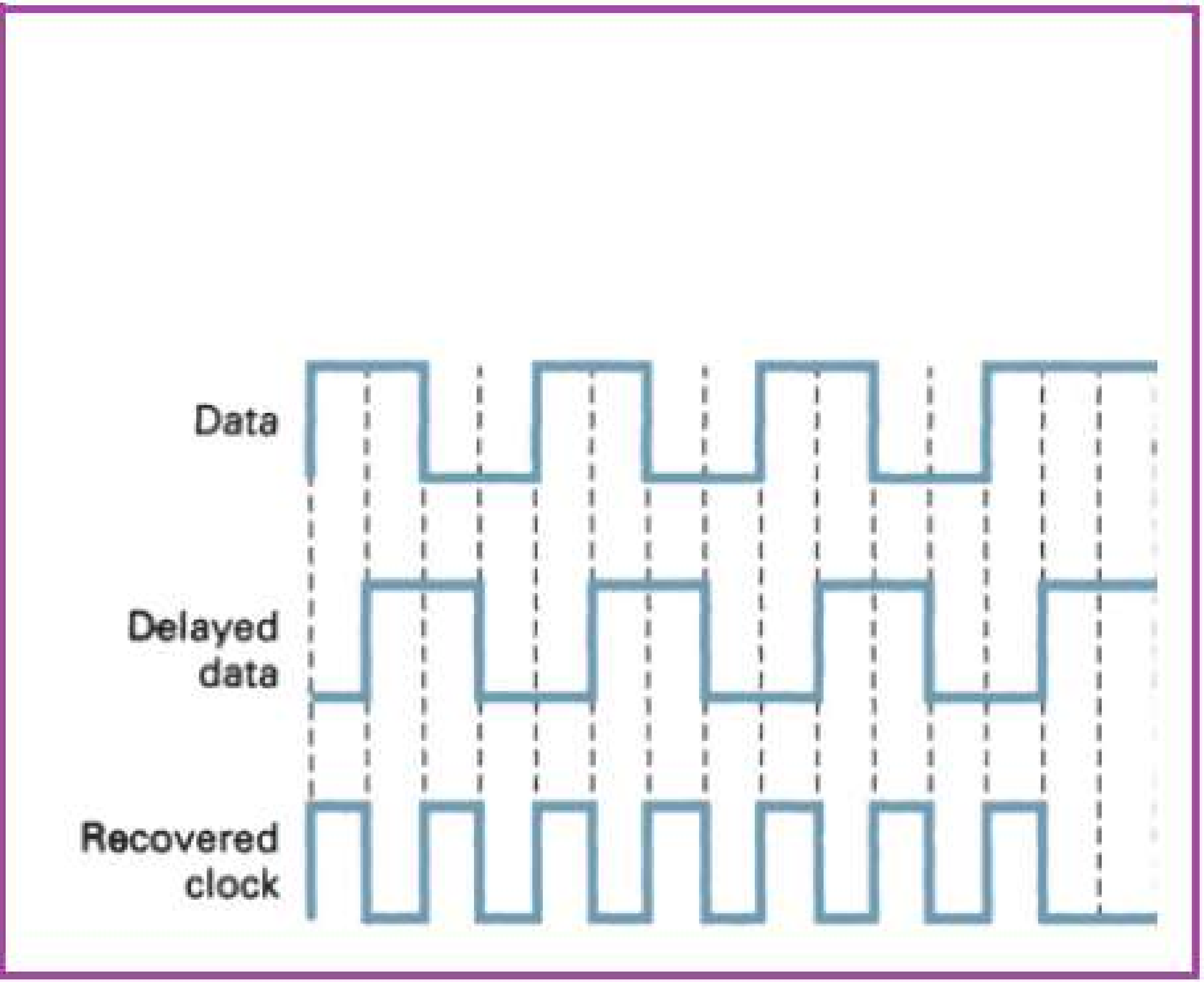
It can be seen that in both cases, the output from the squaring circuit contained a constant voltage (+1/2 V) and a signal at twice the carrier frequency ($\cos 2\omega_c t$). The constant voltage is removed by filtering, leaving only $\cos 2\omega_c t$.

Costas Loop Carrier Recovery Circuit



Clock Recovery





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