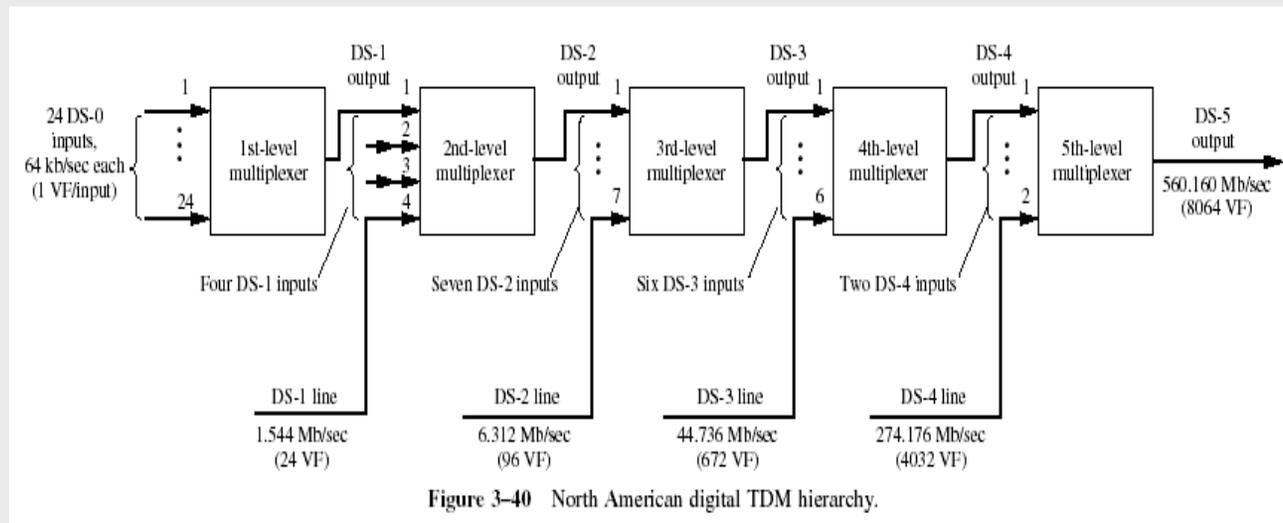


# Signaux numériques :

## Multiplexage temporel : TDM



Pour la hiérarchie TDM, il y a deux catégories :

- Le multiplexage dans les systèmes informatiques :

La transmission TDM dans des lignes haute vitesse à partir d'un ordinateur, suit une série de multiplexeurs dont le débit doit respecter les vitesses standards : 1.2, 2.4, 3.6, 4.8, 7.2, 9.6, 14.4, 19.2, 28.8 kbits/s, 10, 100 Mbits/s.

- Le multiplexage dans les systèmes de lignes partagées (téléphoniques, télégraphes, ...)

# Signaux numériques :

## Multiplexage temporel : TDM

**TABLE 3-8 TDM STANDARDS FOR NORTH AMERICA**

Digital Signal Number	Bit Rate, (Mbits/sec)	No. of 64 kbits/sec NBRE-PCM-VF Channels	Transmission Media Used
DS-0	0.064	1	Wire pairs
DS-1	1.544	24	Wire pairs
DS-1C	3.152	48	Wire pairs
DS-2	6.312	96	Wire pairs, fiber
DS-3	44.736	672	Coax., radio, fiber
DS-3C	90.254	1344	Radio, fiber
DS-4E	139.264	2016	Radio, fiber, coax.
DS-4	274.176	4032	Coax., fiber
DS-432	432.00	6048	Fiber
DS-5	560.160	8064	Coax., fiber

# Signaux numériques :

## Multiplexage temporel : TDM

TABLE 3-9 SPECIFICATIONS FOR T-CARRIER BASEBAND DIGITAL TRANSMISSION SYSTEMS

System	Rate (Mbits/s)	System Capacity		Medium	Line Code	Repeater Spacing (miles)	Maximum System Length (miles)	System Error Rate
		Digital Signal No.	Voice Channels					
T1	1.544	DS-1	24	Wire pair	Bipolar RZ	1	50	$10^{-6}$
T1C	3.152	DS-1C	48	Wire pair	Bipolar RZ	1	—	$10^{-6}$
T1D	3.152	DS-1C	48	Wire pair	Duobinary NRZ	1	—	$10^{-6}$
T1G	6.443	DS-2	96	Wire pair	4-level NRZ	1	200	$10^{-6}$
T2	6.312	DS-2	96	Wire pair <sup>a</sup>	B6ZS <sup>b</sup> RZ	2.3	500	$10^{-7}$
T3	44.736	DS-3	672	Coax.	B3ZS <sup>b</sup> RZ	<sup>c</sup>	<sup>c</sup>	<sup>c</sup>
T4	274.176	DS-4	4032	Coax.	Polar NRZ	1	500	$10^{-6}$
T5	560.160	DS-5	8064	Coax.	Polar NRZ	1	500	$4 \times 10^{-7}$

<sup>a</sup> Special two-wire cable is required for 12,000-ft repeater spacing. Because T2 cannot use standard exchange cables, it is not as popular as T1.

<sup>b</sup> BnZS denotes *binary n-zero substitution*, where a string of  $n$  zeros in the bipolar line code is replaced with a special three-level code word so that synchronization can be maintained [Fike and Friend, 1984; Bic, Duponteil, and Imbeaux, 1991].

<sup>c</sup> Used in central telephone office for building multiplex levels; not used for transmission from office to office.

# Signaux numériques :

## Multiplexage temporel : TDM

TABLE 3-10 SONET SIGNAL HIERARCHY

OC Level	Line Rate (M Bits/s)	Equivalent Number of		
		DS-3s	DS-1s	DS-0s
OC-1	51.84	1	28	672
OC-3	155.52	3	84	2,016
OC-9	466.56	9	252	6,048
OC-12	622.08	12	336	8,064
OC-18	933.12	18	504	12,096
OC-24	1,244.16	24	672	16,128
OC-36	1,866.24	36	1,008	24,192
OC-48	2,488.32	48	1,344	32,256
OC-192	9,953.28	192	5,376	129,024

# Modulations numériques

Modulation à déplacement d'amplitude ASK,

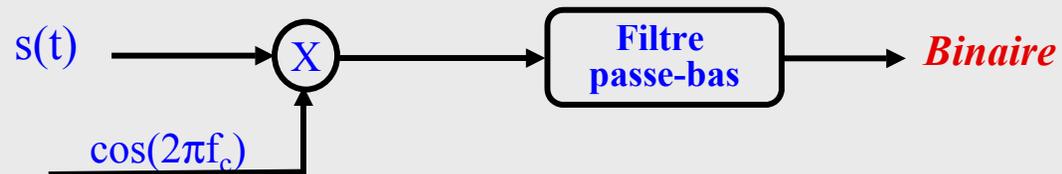
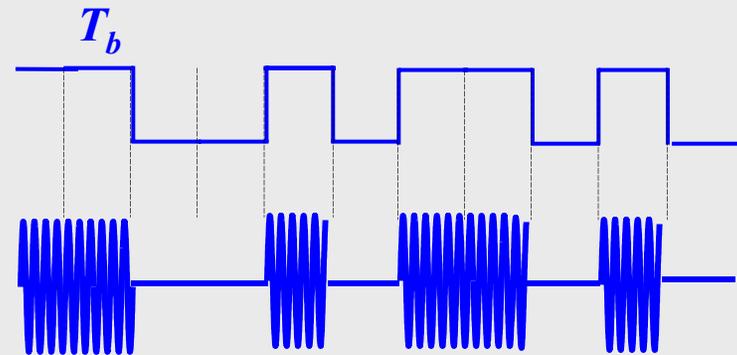
Amplitude shift keying (On-Off keying : OOK)

$$c(t) = A_c \cos(2\pi f_c t)$$

**m(t) : OOK**

$$s(t) = m(t) \cdot c(t)$$

$$s(t) = A_c m(t) \cdot \cos(2\pi f_c t)$$



# Modulations numériques

## Modulation binaire à déplacement de phase

### BPSK Binary Phase-shift keying

$$c(t) = A_c \cos(2\pi f_c t)$$

**m(t) : OOK**

$$s(t) = A_c \cos(2\pi f_c t + D_p m(t))$$

**m(t) = +/-1**

$$s(t) = A_c \cos(D_p) \cos(2\pi f_c t) - A_c m(t) \sin(D_p) \sin(2\pi f_c t)$$

La porteuse

Les données

L'indice de modulation digital est définie par :  $h = 2 \Delta\theta / \pi$

La déviation d'angle est pilotée par :  $\Delta\theta = D_p$

Pour avoir un coefficient d'amplitude maximum pour les données,  $D_p = \pi/2$  (h=1)

$$s(t) = - A_c m(t) \sin(2\pi f_c t)$$

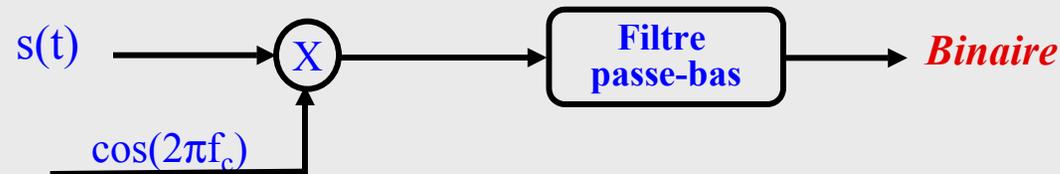
**DSB-SC**

# Modulations numériques

## Modulation binaire à déplacement de phase

### BPSK *Binary Phase-shift keying*

$$s_{\text{BPSK}}(t) = -A_c m(t) \sin(2\pi f_c t)$$

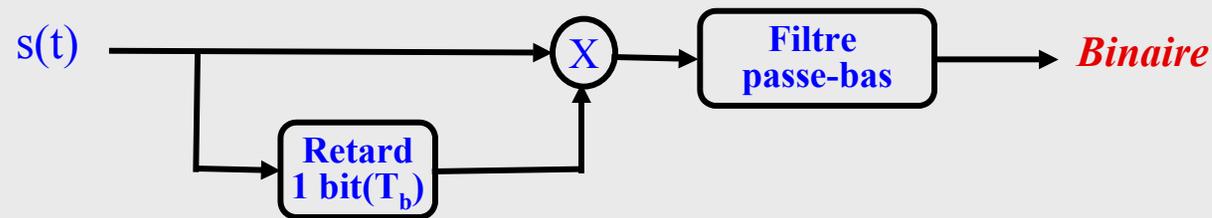


# Modulations numériques

## Modulation différentielle à déplacement de phase

### DPSK Differential Phase-shift keying

$$s_{\text{DPSK}}(t) = -A_c m(t) \sin(2\pi f_c t)$$



$$s_{\text{BPSK}}(t) = -A_c m^k(t) \sin(2\pi f_c t)$$

$$\text{OUT} = \frac{1}{2} A_c^2 m^{k+1}(t) m^k(t)$$

# Modulations numériques

## Modulation à déplacement de fréquence

### FSK Frequency shift keying

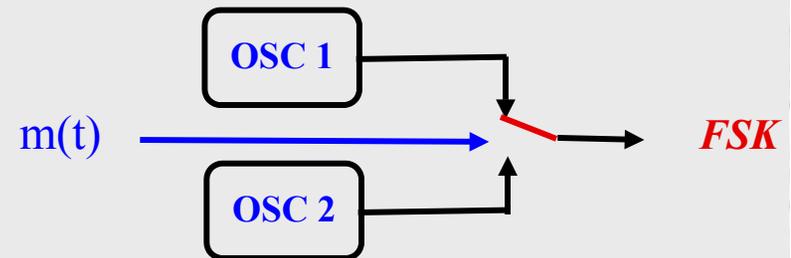
**FM:**

$$f_i = f_c + D_f m(t)$$

$$\begin{aligned} s(t) &= A_c \cos [ 2\pi f_1 t ] & m(t) &= 0 \\ &= A_c \cos [ 2\pi f_2 t ] & m(t) &= 1 \end{aligned}$$

$$\begin{aligned} s(t) &= A_c \cos [ 2\pi f_1 t + \theta_1 ] \\ &= A_c \cos [ 2\pi f_2 t + \theta_1 ] \end{aligned}$$

$$s(t) = A_c \cos [ 2\pi f_c t + 2\pi D_f \int m(t) dt ]$$

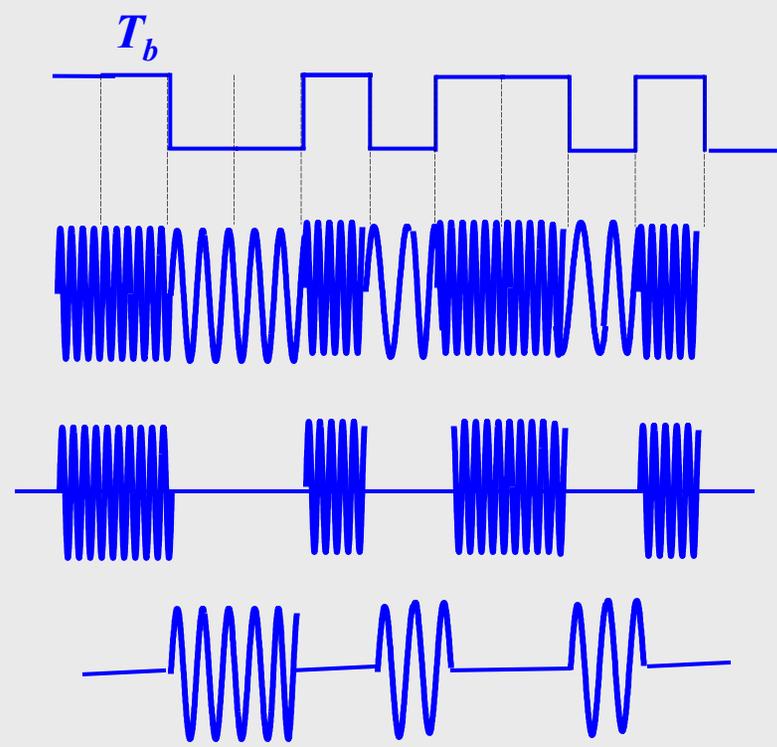
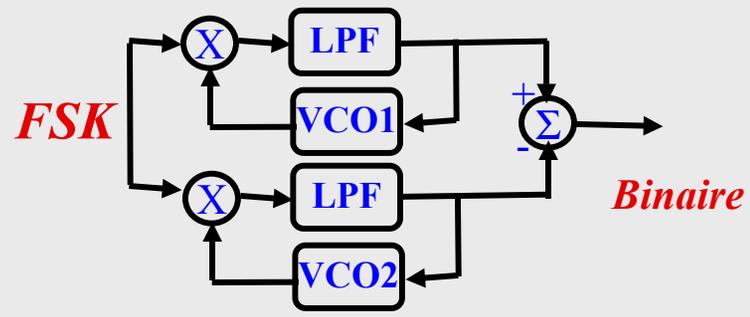
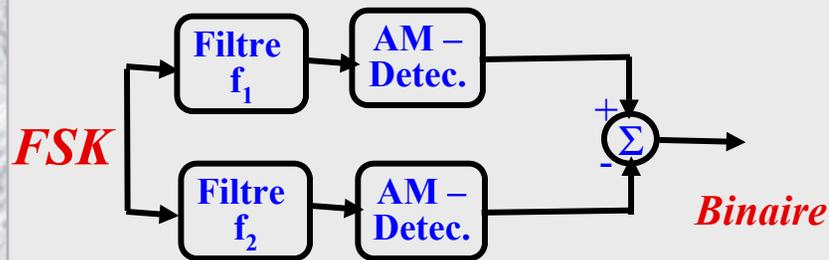


# Modulations numériques

## Modulation à déplacement de fréquence

### FSK Frequency shift keying

Signal FM idéal en deux ASK:



# Modulations multiniveaux

## Modulation en quadrature à déplacement de phase

### QPSK Quadrature phase-shift keying

Pour un signal 4 niveaux modulé en PM:

Pour un signal 4 niveaux modulé en PM:

$$x_i(t) = A_c \cos [\theta_i]$$

$$y_i(t) = A_c \sin [\theta_i]$$

$i=1,2$

L'enveloppe complexe :

$$g(t) = A_c e^{j\theta(t)}$$

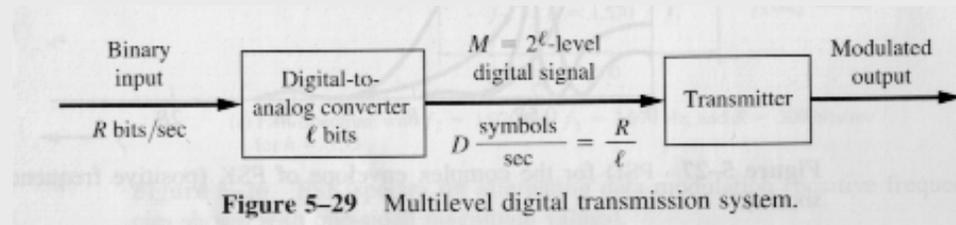


Figure 5-29 Multilevel digital transmission system.

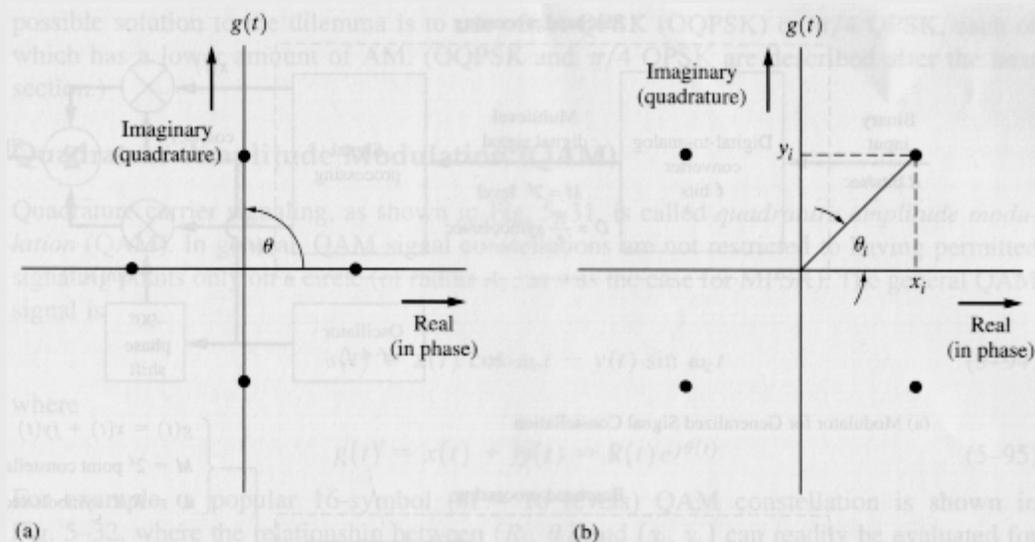


Figure 5-30 QPSK and  $\pi/4$  QPSK signal constellations (permitted values of the complex envelope).

# Modulations multiniveaux

## Modulation à déplacement de phase

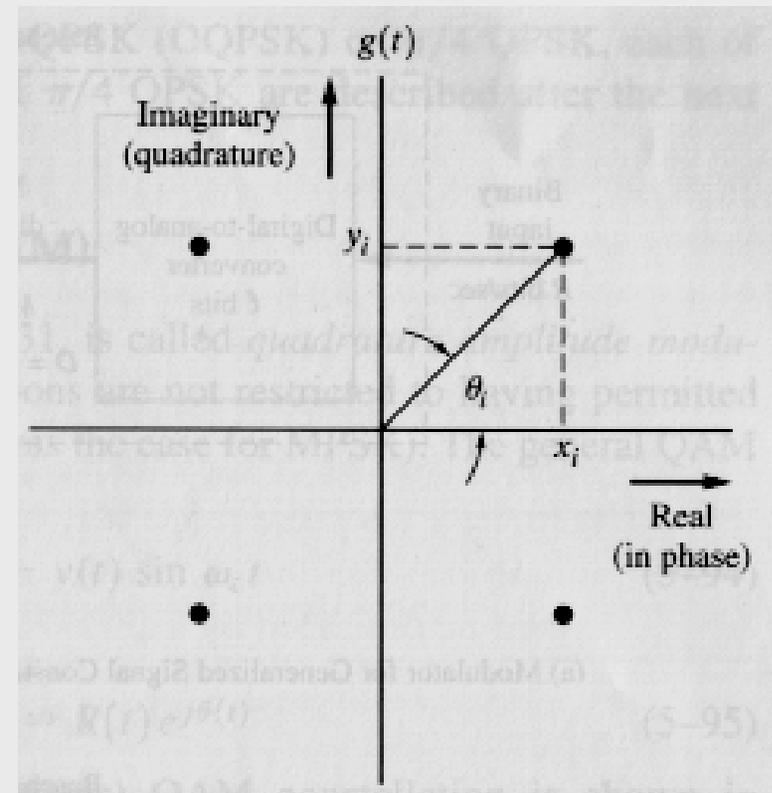
### MPSK M-ary phase-shift keying

Pour un signal M niveaux modulé en PM :

$$x_i(t) = A_c \cos [\theta_i]$$

$$y_i(t) = A_c \sin [\theta_i]$$

$$i=1,2, \dots, M$$

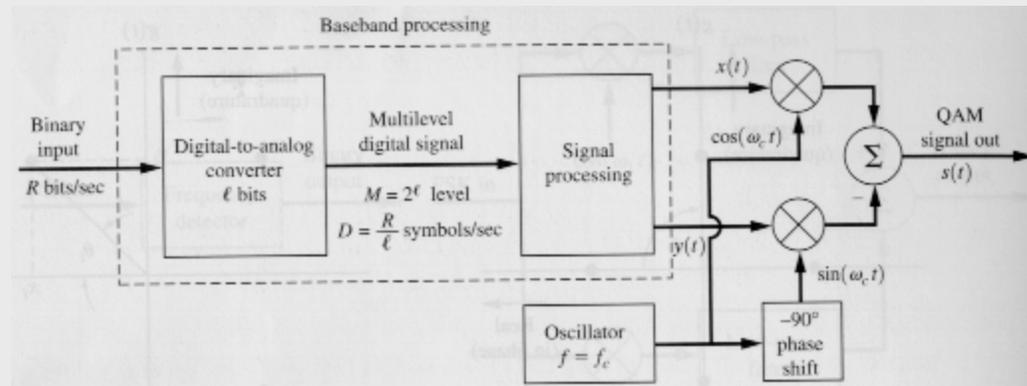


# Modulations multiniveaux

## Modulation AM en quadrature

### QAM Quadrature amplitude Modulation

Pour un signal M niveaux modulé en PM :



$$S(t) = x(t) \cos [2\pi f_c t] - y(t) \sin [2\pi f_c t]$$

$$g(t) = x(t) + j y(t) = R(t) e^{j\theta(t)}$$

Pour 16 niveaux :

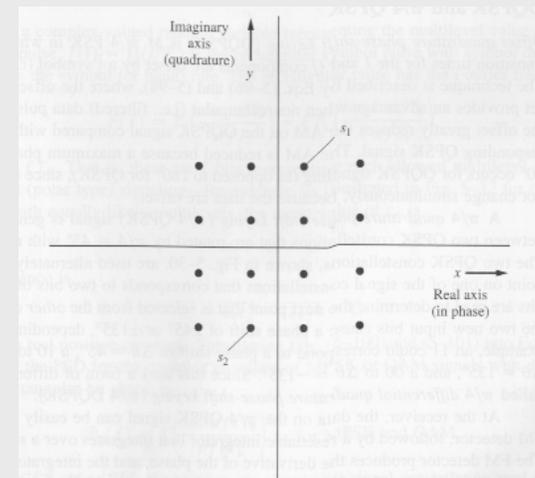


Figure 5-32 16-symbol QAM constellation (four levels per dimension).