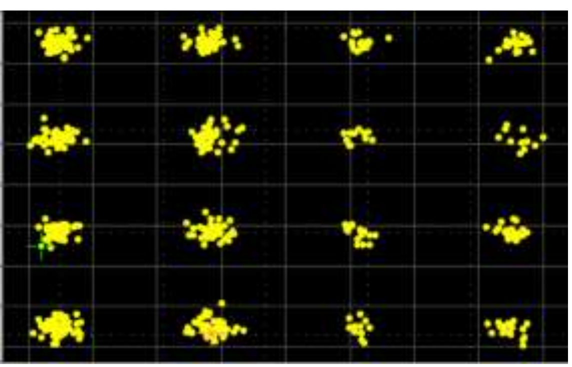
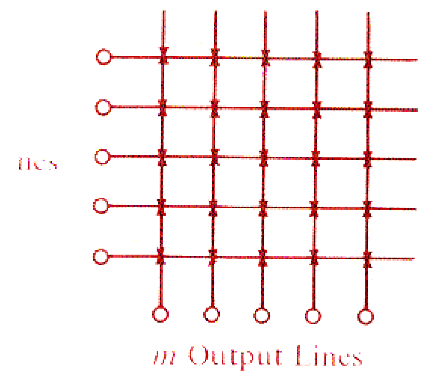
Infokommunikációs rendszerek – Infocommunication Systems Lecture 4. előadás

Kódolás, nyalábolás, kapcsolás
Coding, multiplexing, switching

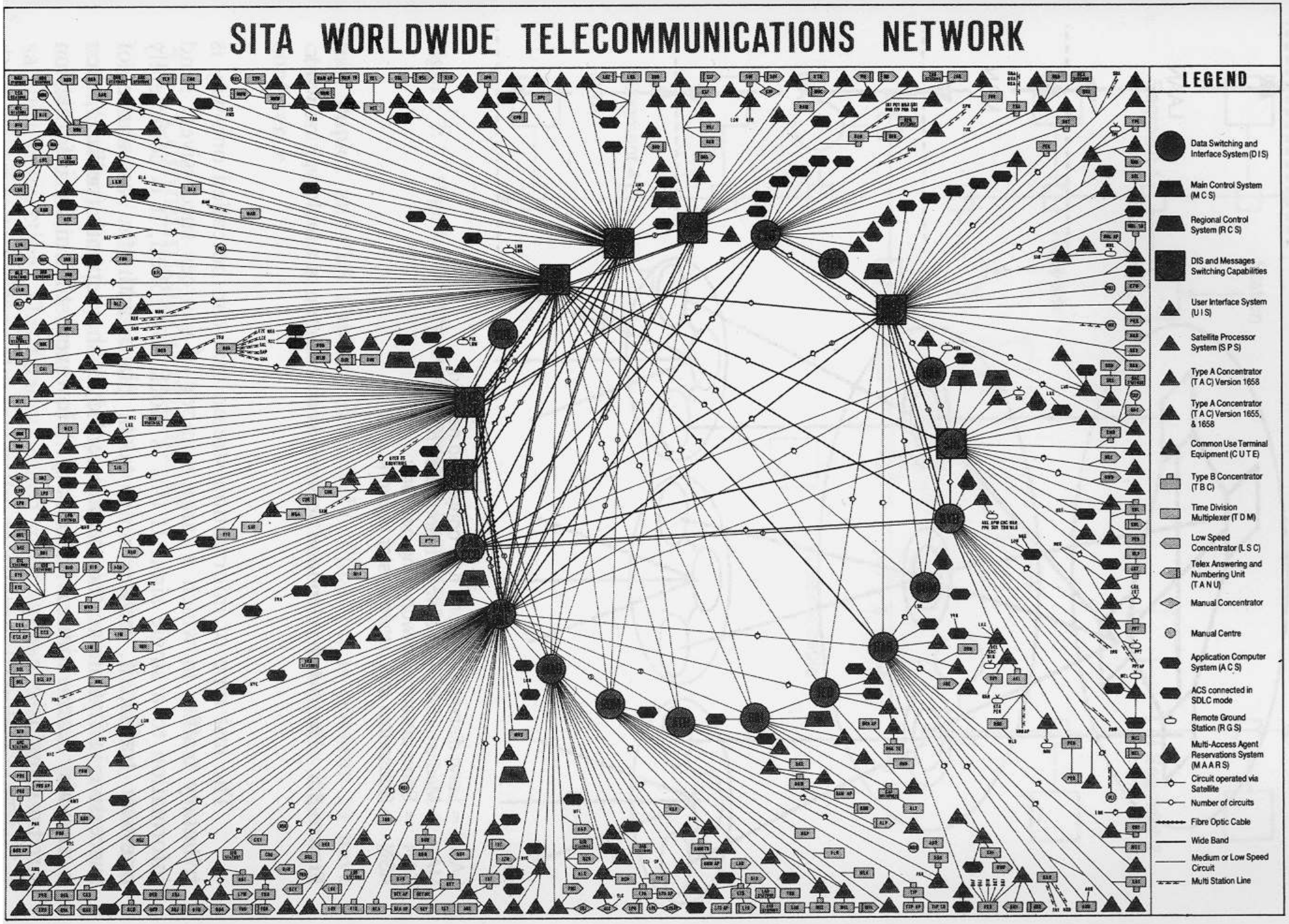
Takács György

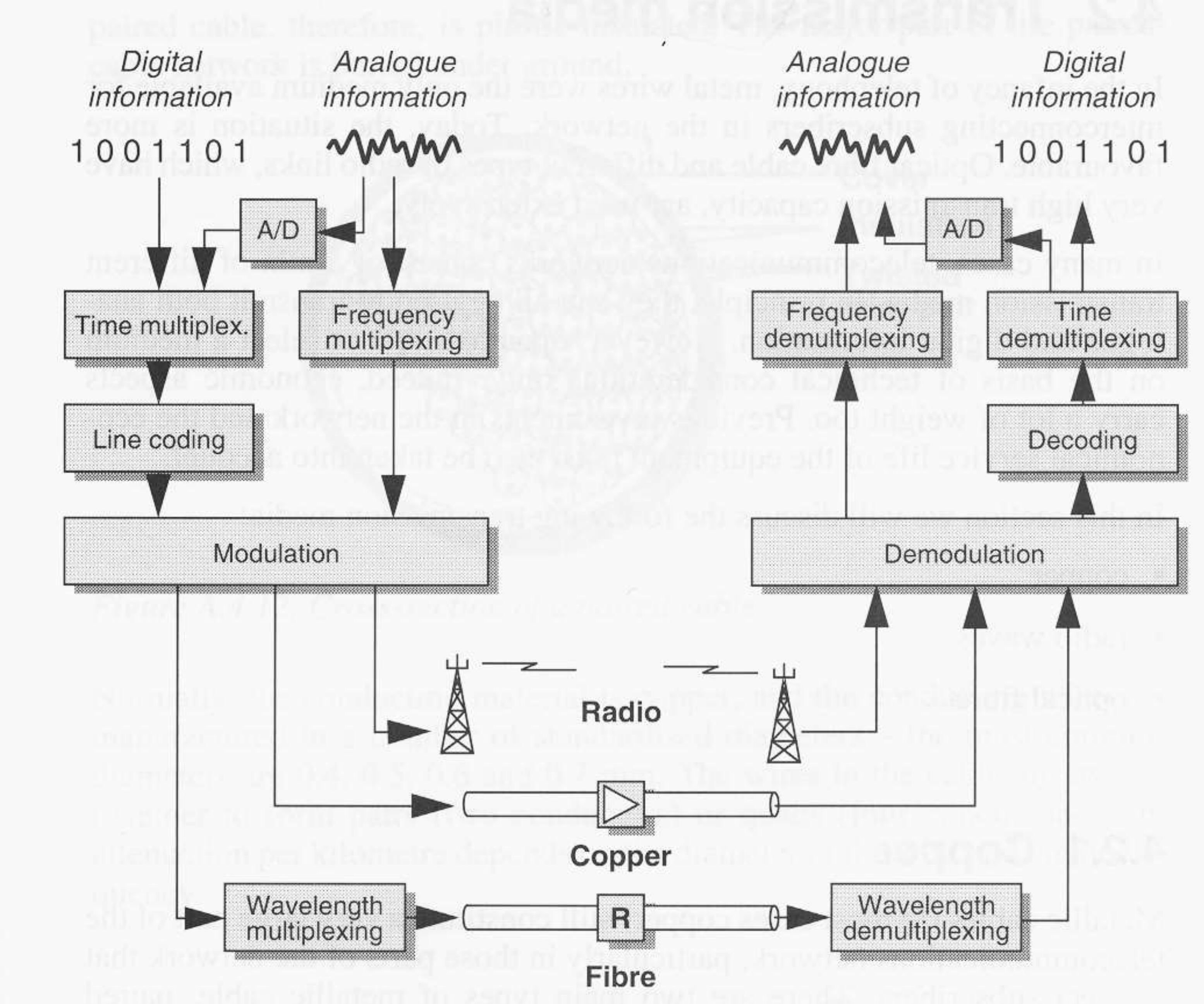




Where we are now in study (tele-, info-) communications systems?

- Infocom systems are: content provision, transport the content (networks), services and applications for users
- Networks are working systems of nodes, links and terminals
- The basic technologies in links (wireline and wireless) have been discussed
- Node functions (modulation, multiplexing, switching, signalling, demultiplexing) will be discussed today


SITA WORLDWIDE TELECOMMUNICATIONS NETWORK
LEGEND
Data Switching and Interface System (D I S)
Main Control System (M C S)
Regional Control System (R C S)
DIS and Messages Switching Capabilities
User Interface System (U I S)
Satellite Processor System (S P S)
Type A Concentrator (T A C) Version 1658
Type A Concentrator (T A C) Version 1655, & 1658
Common Use Terminal Equipment (C U T E)
Type B Concentrator (T B C)
Time Division Multiplexer (T D M)
Low Speed Concentrator (L S C)
Telex Answering and Numbering Unit (T A N U)
Manual Concentrator
Manual Centre
Application Computer System (A C S)
ACS connected in SDLC mode
Remote Ground Station (R G S)
Multi-Access Agent Reservations System (M A A R S)
Circuit operated via Satellite
Number of circuits
Fibre Optic Cable
Wide Band
Medium or Low Speed Circuit
Multi Station Line

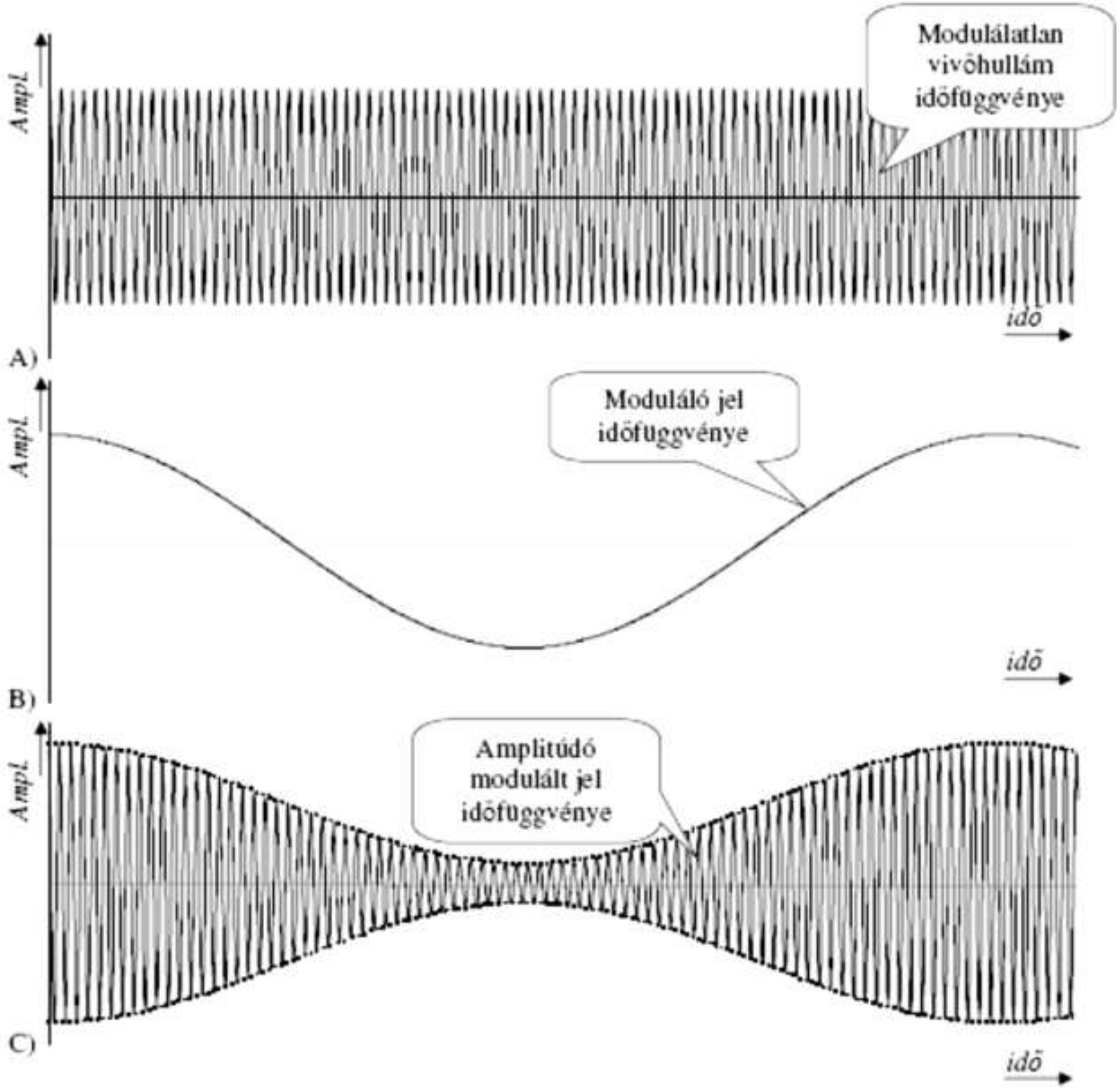

Digital information
Analogue information
1001101
A/D
Time multiplex.
Frequency multiplexing
Line coding
Modulation
Analogue information
Digital information
1001101
A/D
Frequency demultiplexing
Time demultiplexing
Decoding
Demodulation
Radio
Copper
Wavelength multiplexing
R
Wavelength demultiplexing
Fibre

Analog modulation systems- (AM)

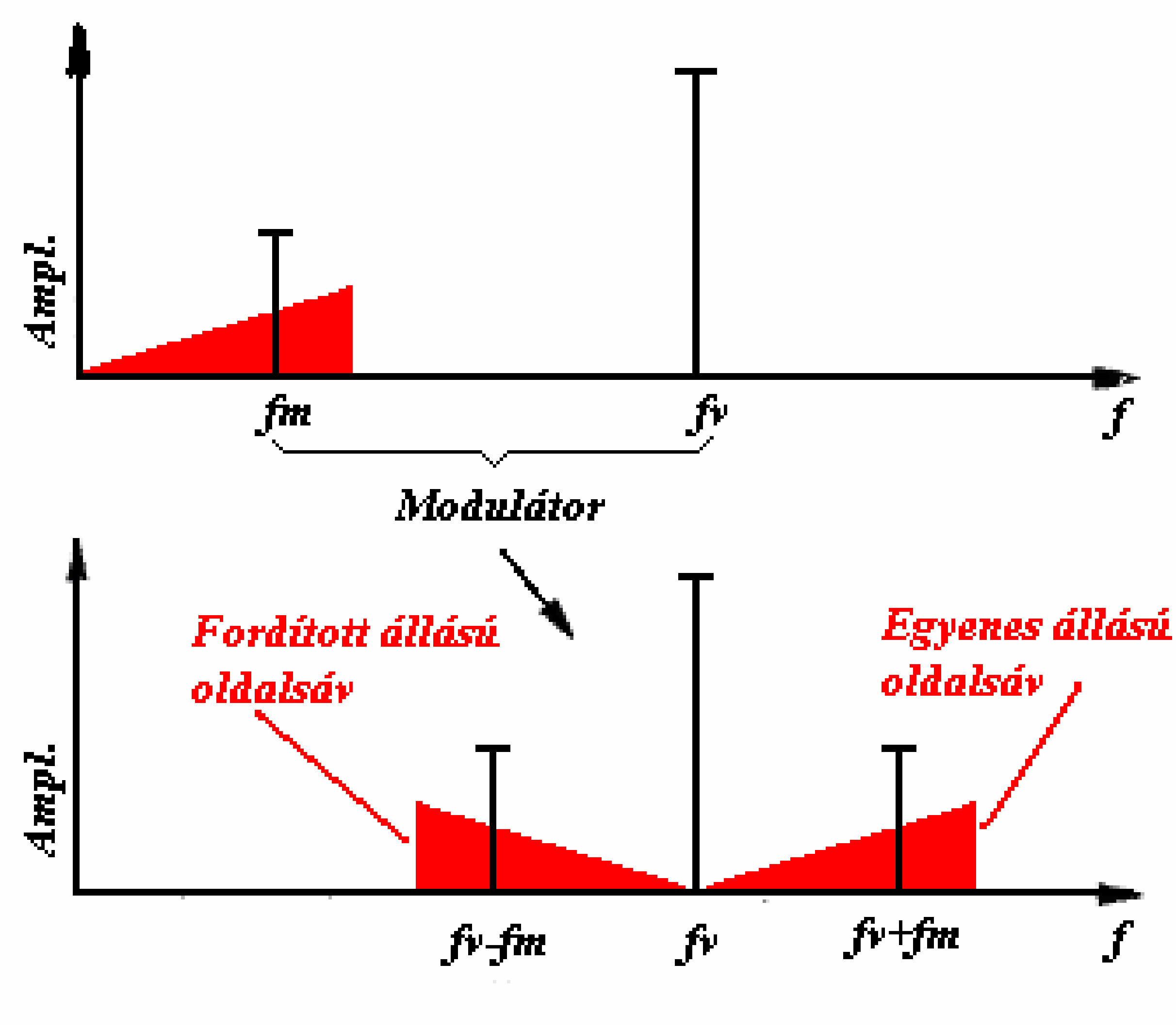
- Amplitude modulation
- The momentary amplitude of the carrier is proportional to the momentary amplitude of the modulating signal

$$u = [U_v + U_m \cos(\omega_m t)] \cos(\omega_v t)$$

Analog modulation systems- (AM)



The spectrum of the AM in the case of discrete f_m modulation frequency

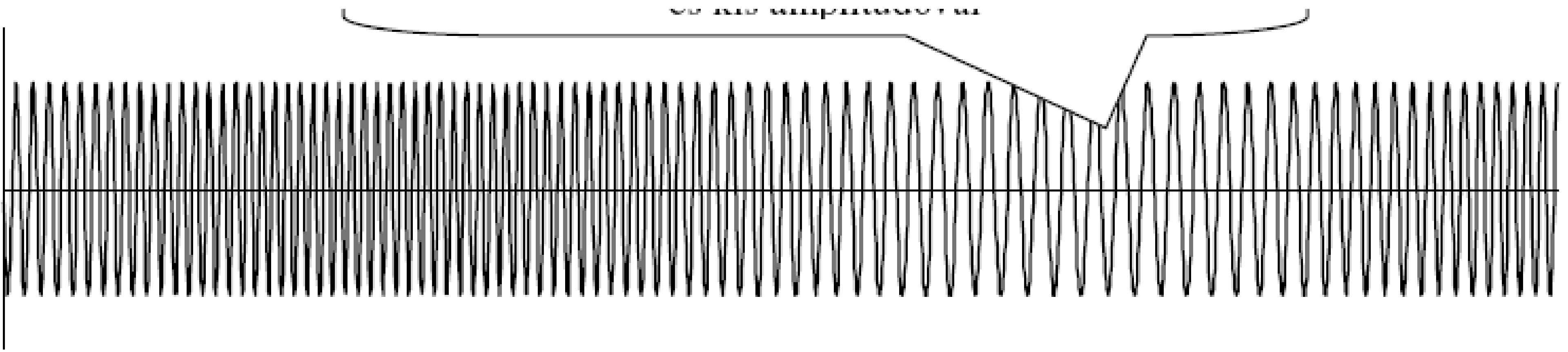


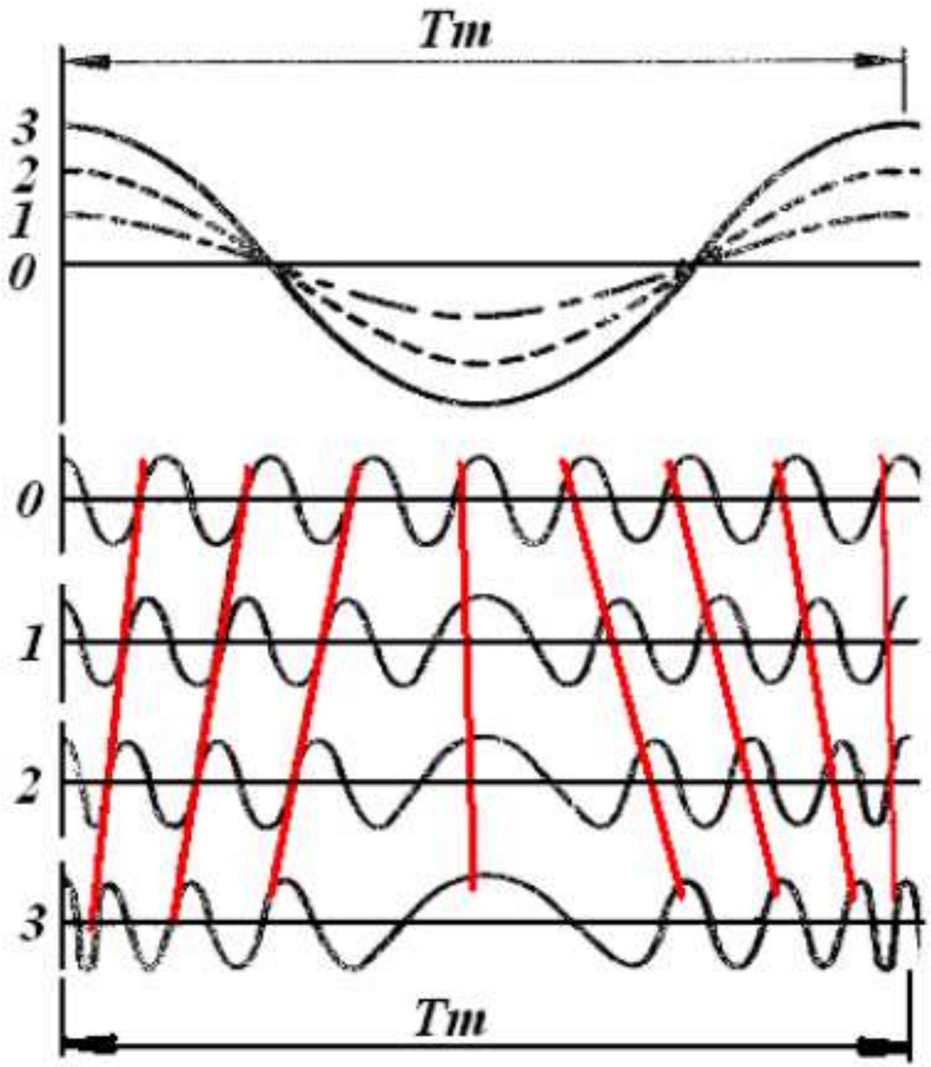
Frequency modulation systems- (FM)

- The instantaneous (momentary) frequency of the carrier is proportional to the momentary amplitude of the modulating signal

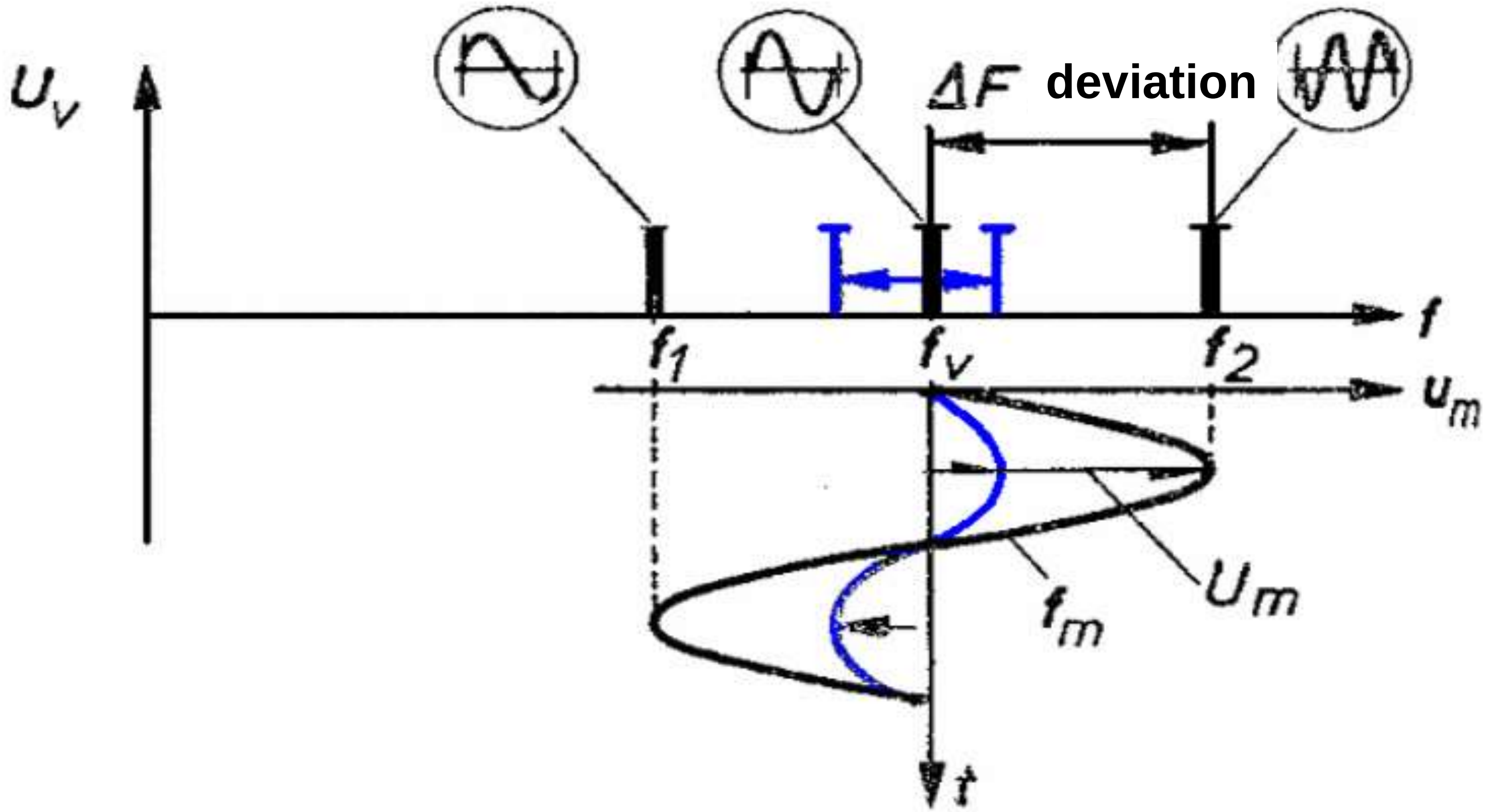
$$u = U_v \cdot \cos\left[\omega_v t + \frac{\Delta\omega}{\omega_m} \cdot \sin(\omega_m t)\right]$$

Frequency modulation systems- (FM)

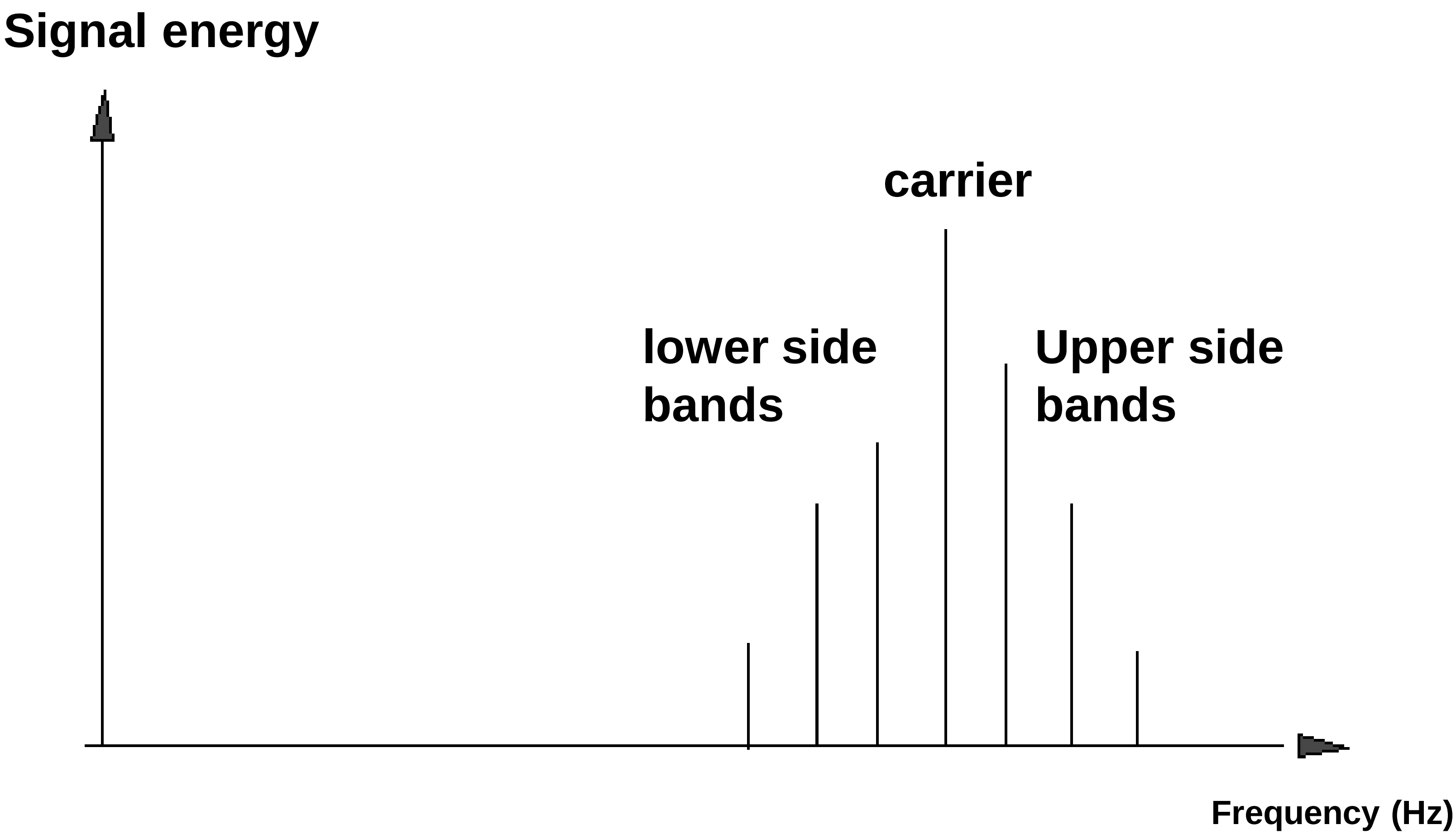



Tm
3
2
1
0
0
1
2
3
Tm

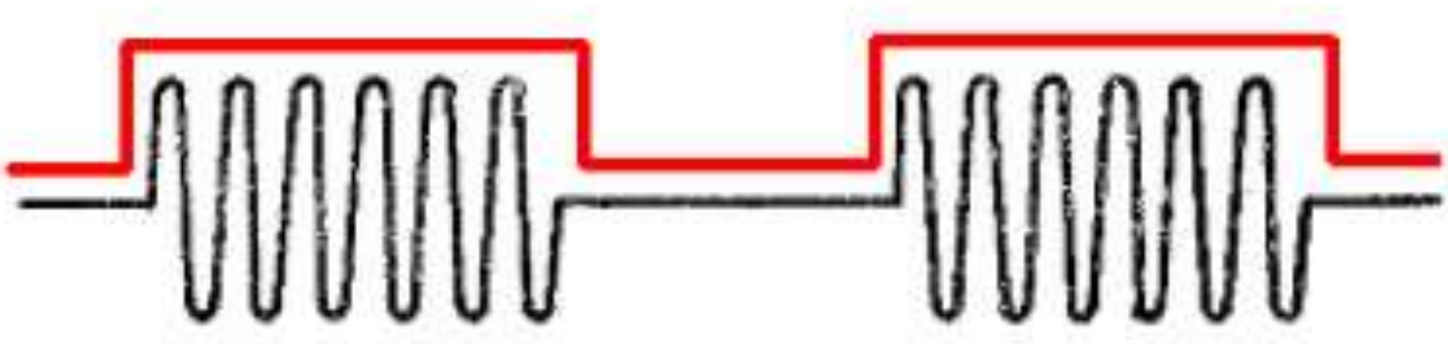
Frequency deviation (ΔF) describe the maximum difference between an FM modulated frequency and the nominal carrier frequency.



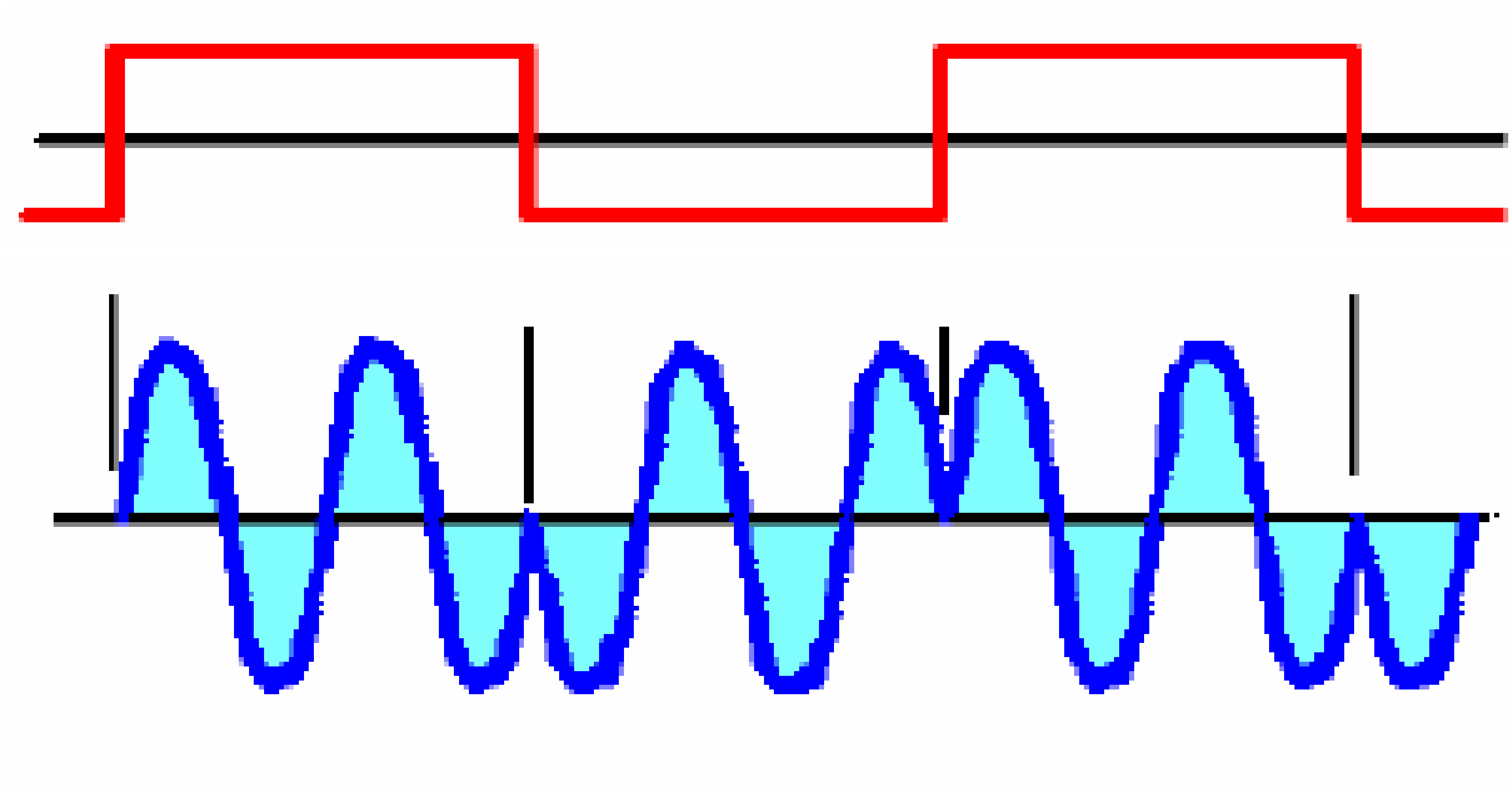
The spectrum of FM modulated signal in the case of discrete f_m modulation frequency



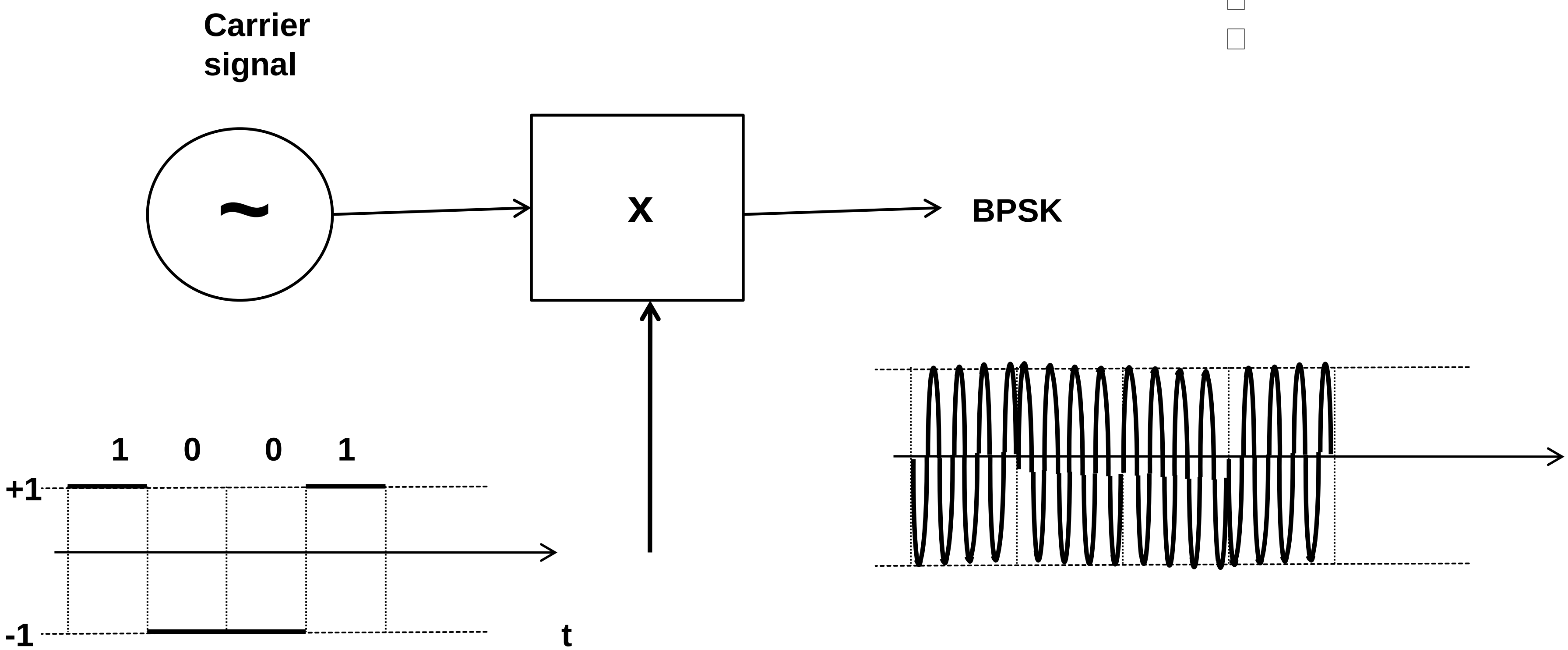
Digital modulation methods – Amplitude Shift Keying (ASK)



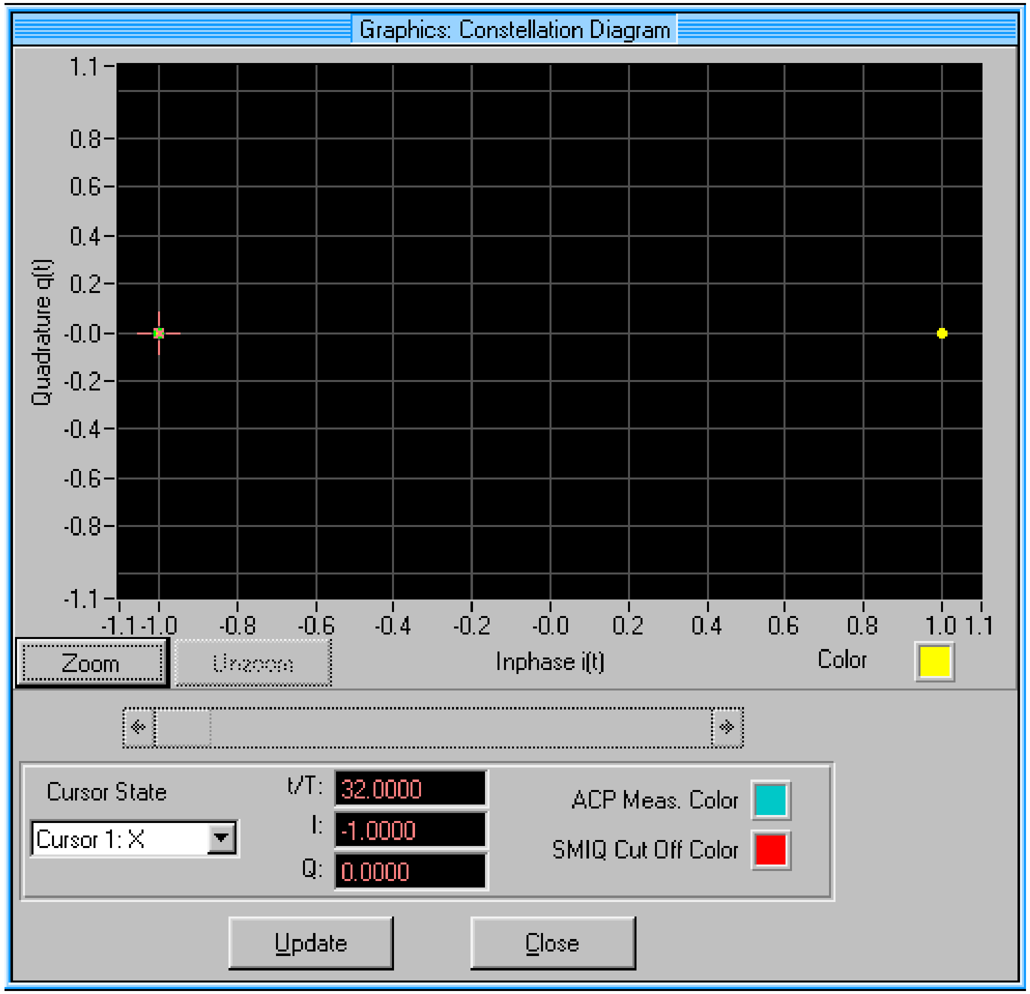
Digital modulation methods – Binary Phase Shift Keying (BPSK)



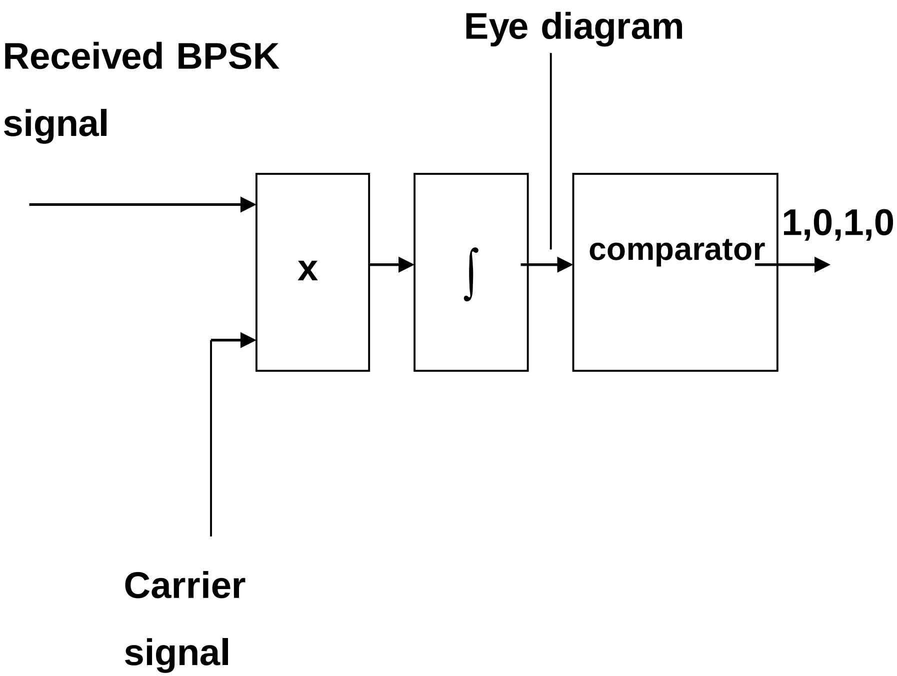
Generation of BPSK

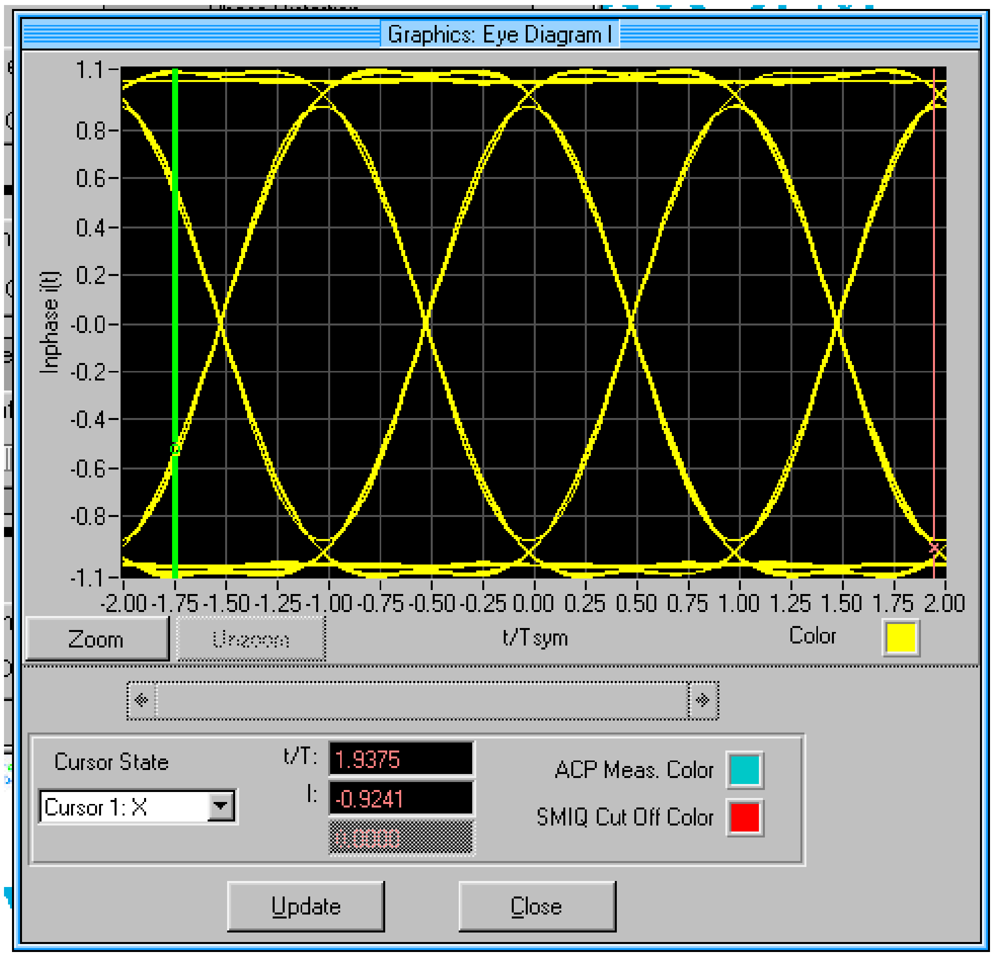


Digital modulation methods – Constellation Diagram / BPSK



Eye diagram as a basis for demodulation of BPSK signal

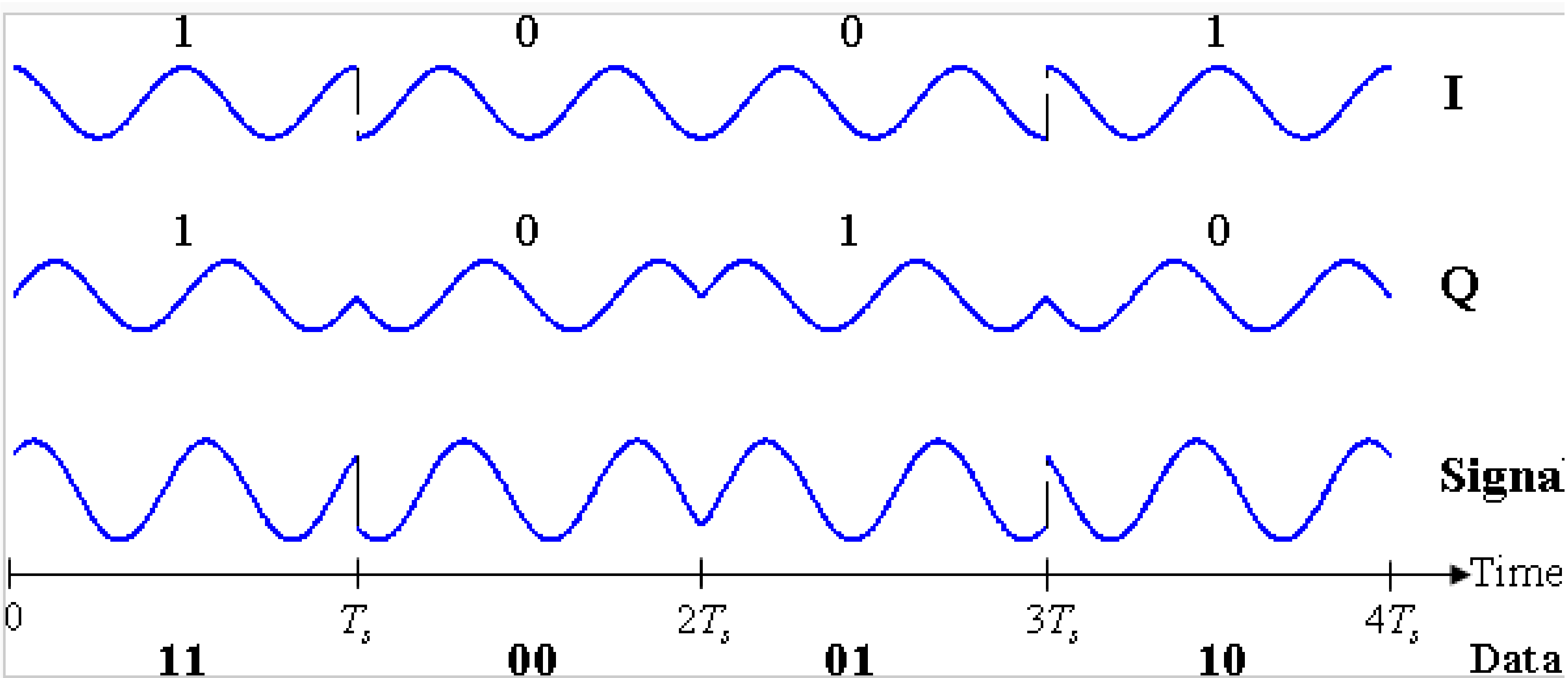




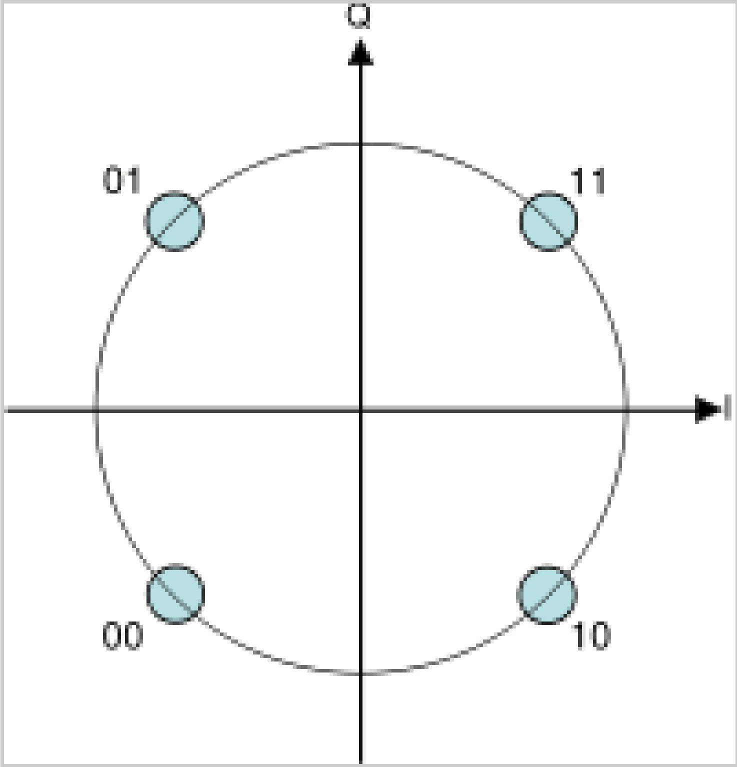
Digital modulation methods –Qadrature Phase Shift Keying (QPSK)

- Two carriers: sine wave (Q) and cosine wave (I)
- The modulated signal is the sum of the two components
- One symbol is two bits

Digital modulation methods –Qadrature Phase Shift Keying (QPSK)

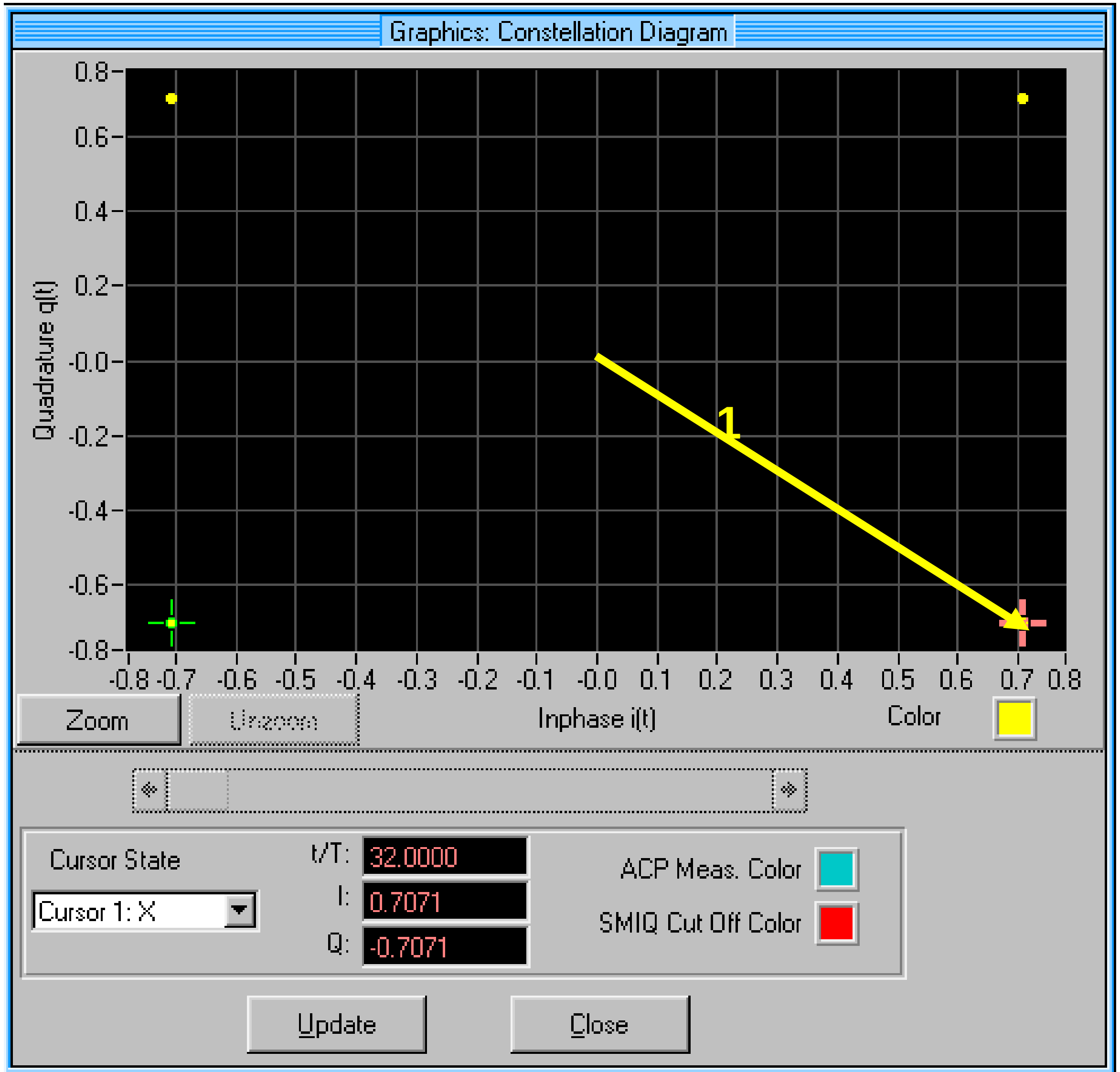


Digital modulation methods –Qadrature Phase Shift Keying (QPSK)



Constellation diagram for QPSK with Gray coding. Each adjacent symbol only differs by one bit.

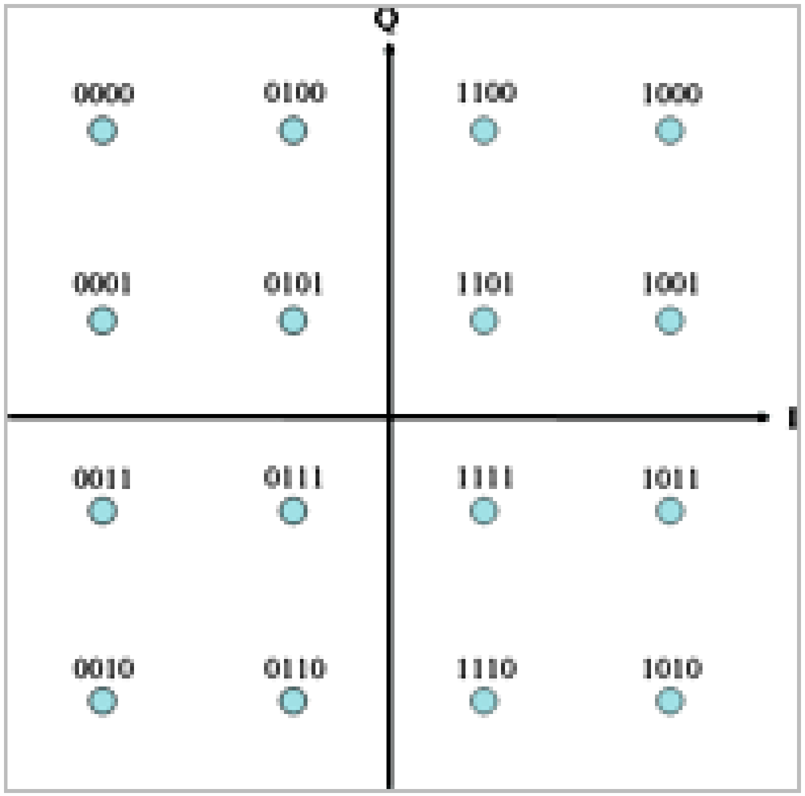
Digital modulation methods –Qadrature Phase Shift Keying (QPSK)



Digital modulation methods –Qadrature Amplitude Modulation (QAM)

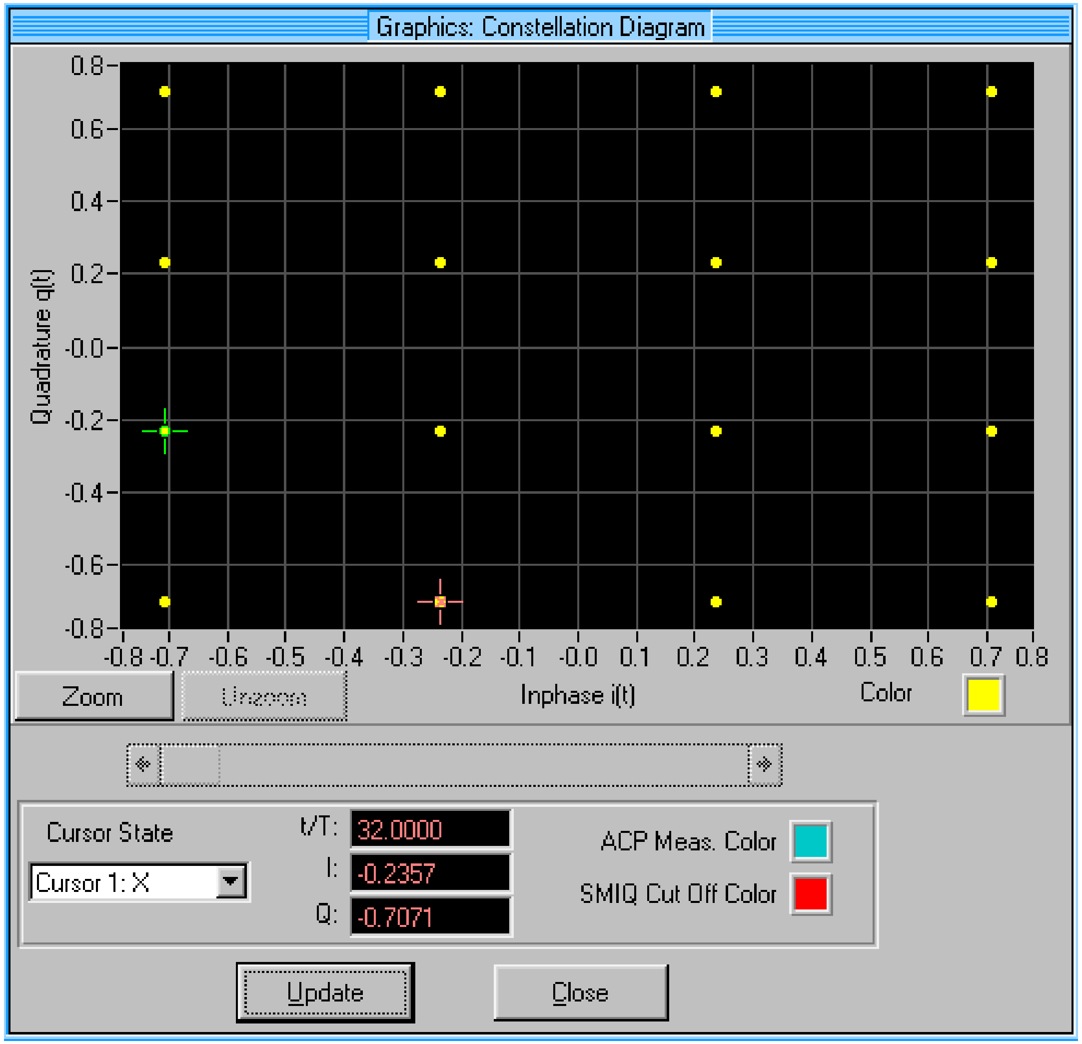
- Two carriers: sine wave (Q) and cosine wave (I)
- The modulated signal is the sum of the two components
- Different amplitude and differnt phase values for one symbol
- 16QAM means: one symbol is four bits

Digital modulation methods –Qadrature Amplitude Modulation (16QAM)

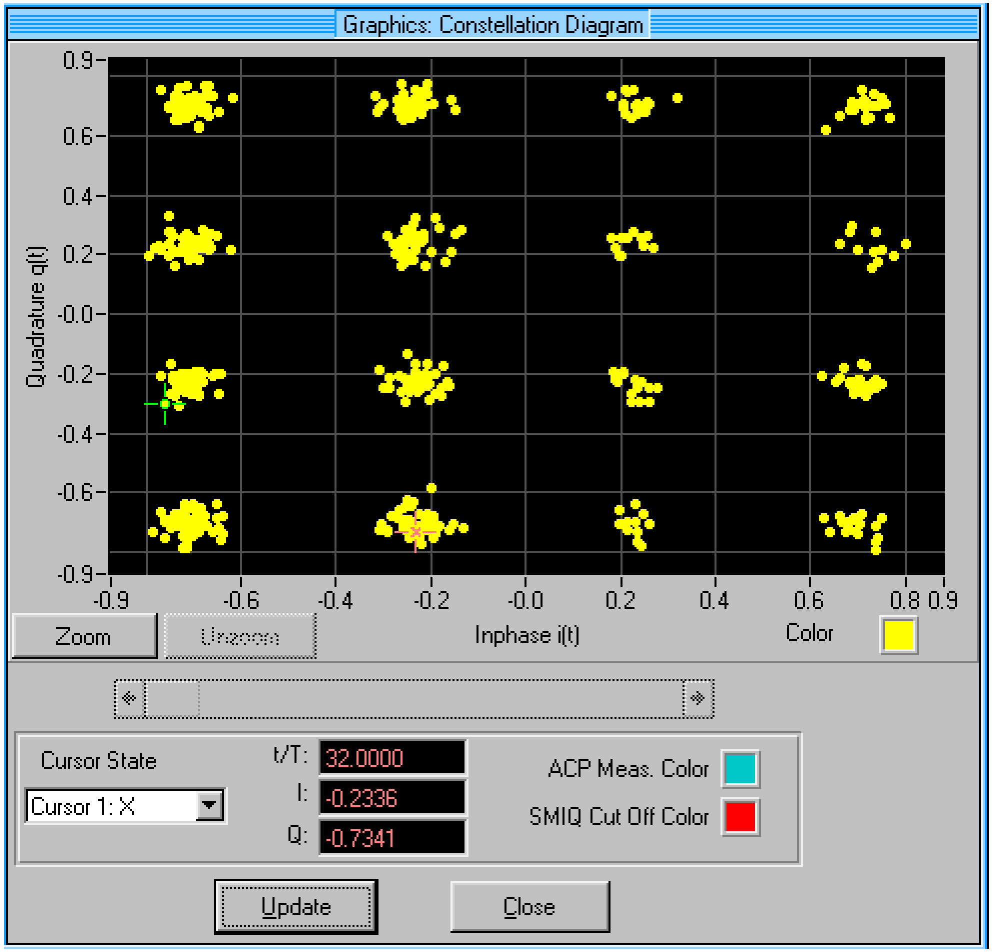


Constellation diagram for rectangular 16-QAM.

Digital modulation methods –Qadrature Amplitude Modulation (16QAM)



Digital modulation methods –Qadrature Amplitude Modulation with channel noise

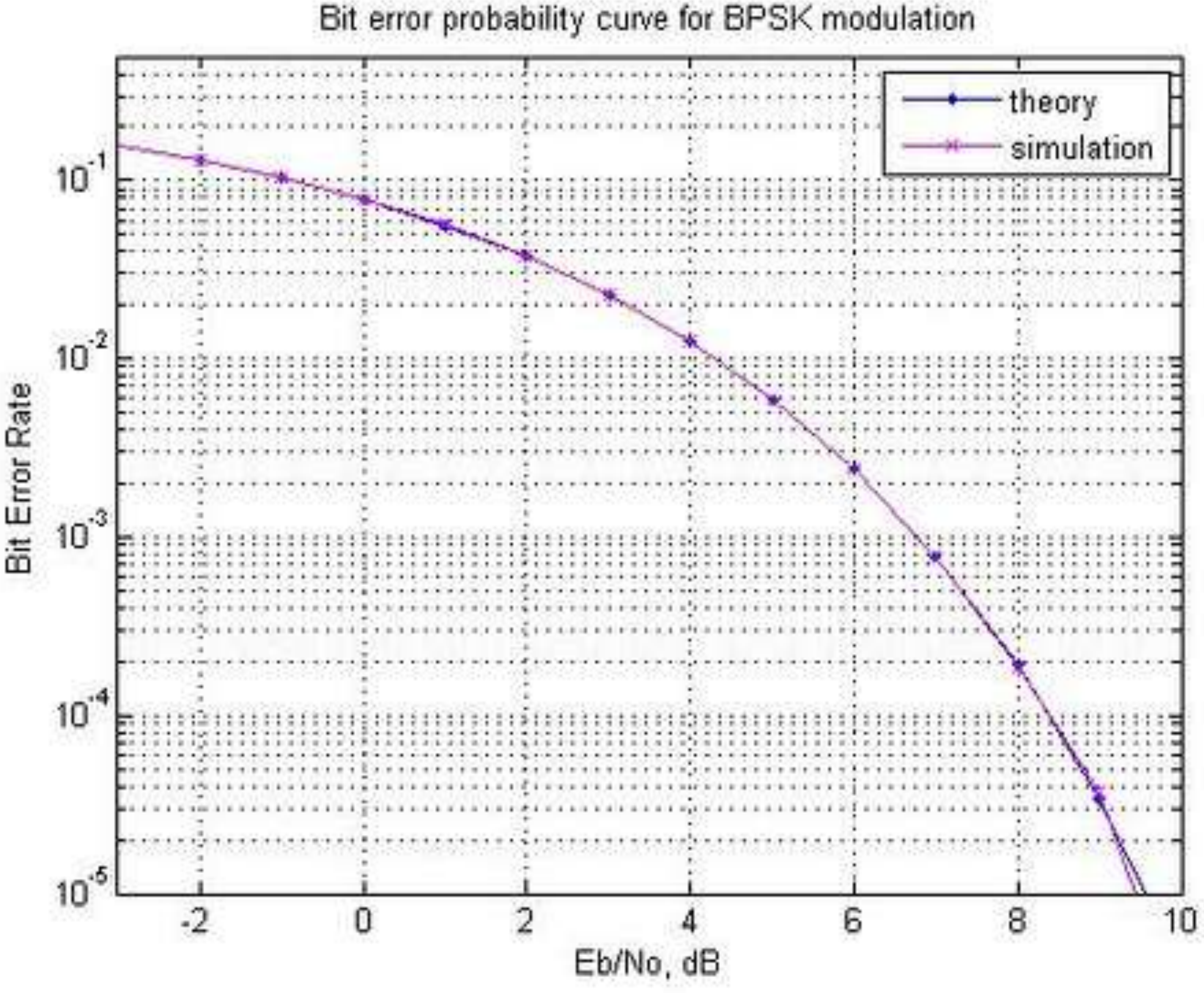


Why to use sophisticated modulations -- like QAM?

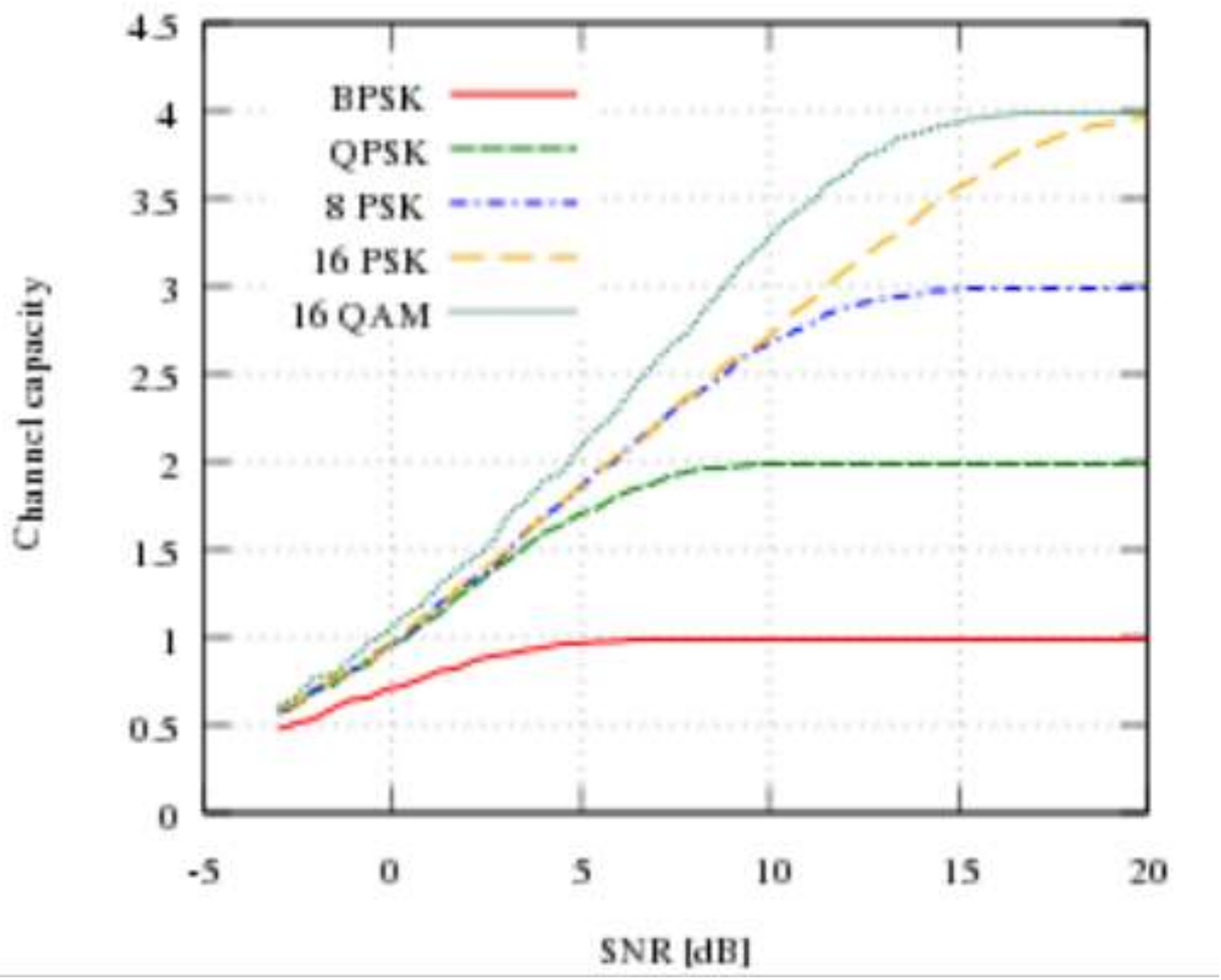
- To put more bits into the standard medium
  - twisted pair cable –ADSL, Gigabit Ethernet,
  - coaxial cable – digital TV, HDTV, INTERNET,
  - Radio – GSM, satellite and terrestrial TV and radio program broadcasting

- Efficient use of spectum (the radio spectrum is a limited resource)

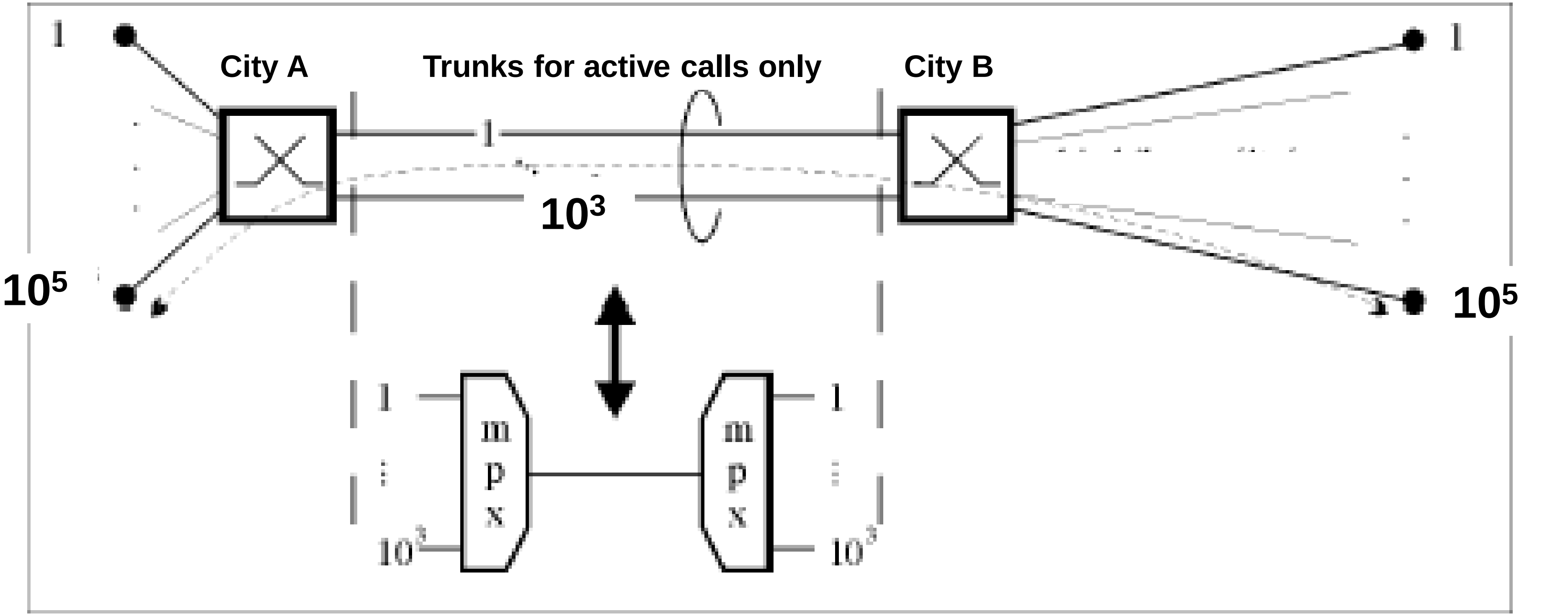
Bit error rate as a function of signal to noise ratio using BPSK modulation



Channel capacity as a function of signal to ratio at different modulation system. The reference is the BPSK



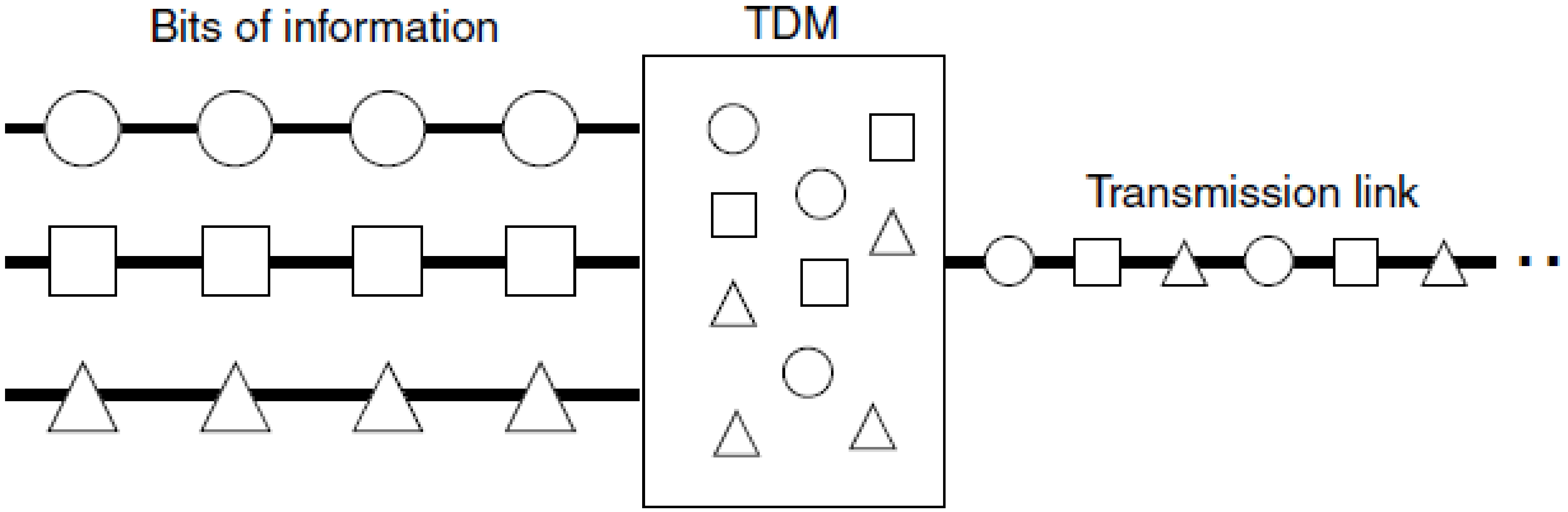
Multiplexing vs. switching



Multiplexing principles

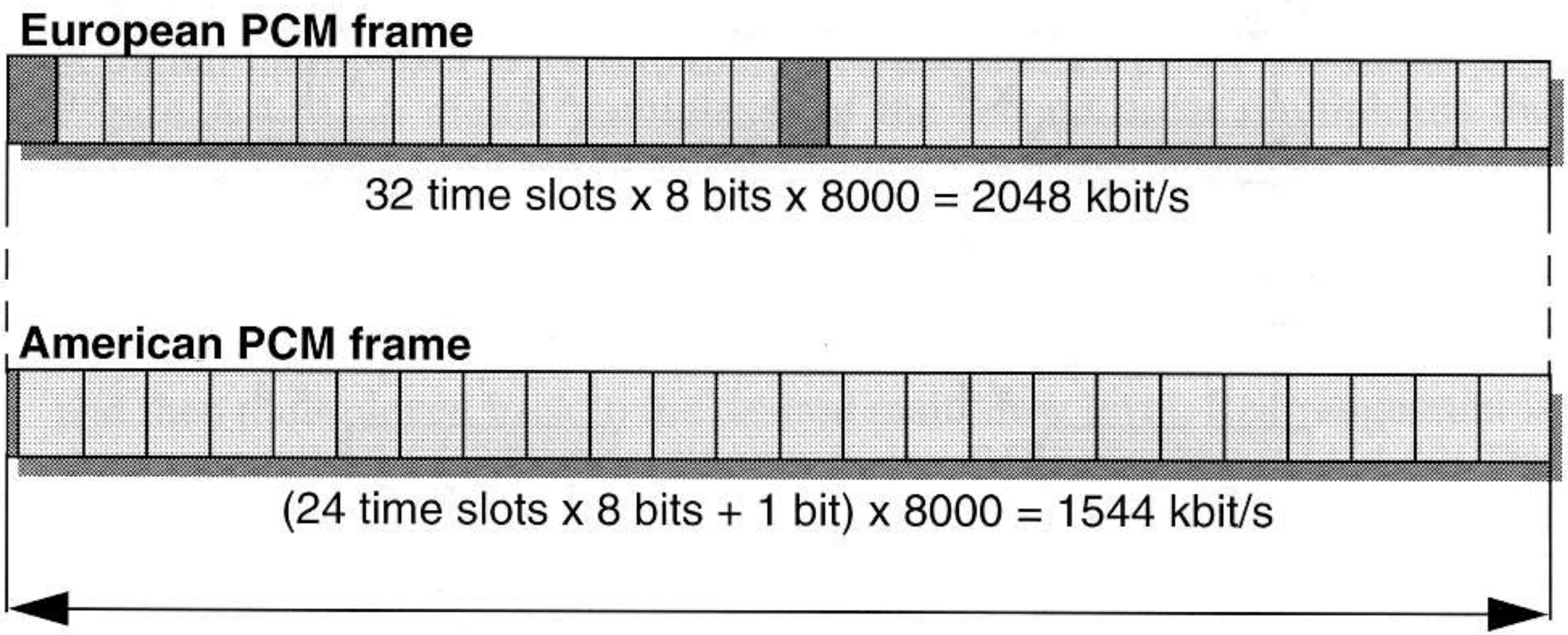
- To reduce transmission costs
- To utilize higher bandwidth
- „Framing” and „packing” of information
- TDM -- Time Division Multiplexing
- FDM -- Frequency Division Multiplexing
- CDMA -- Code Division Multiple Access
- WDM -- Wavelength Division Multiplexing
- Mixed

The **T**ime **D**ivision **M**ultiplexing concept



TDM principles I. PCM frame

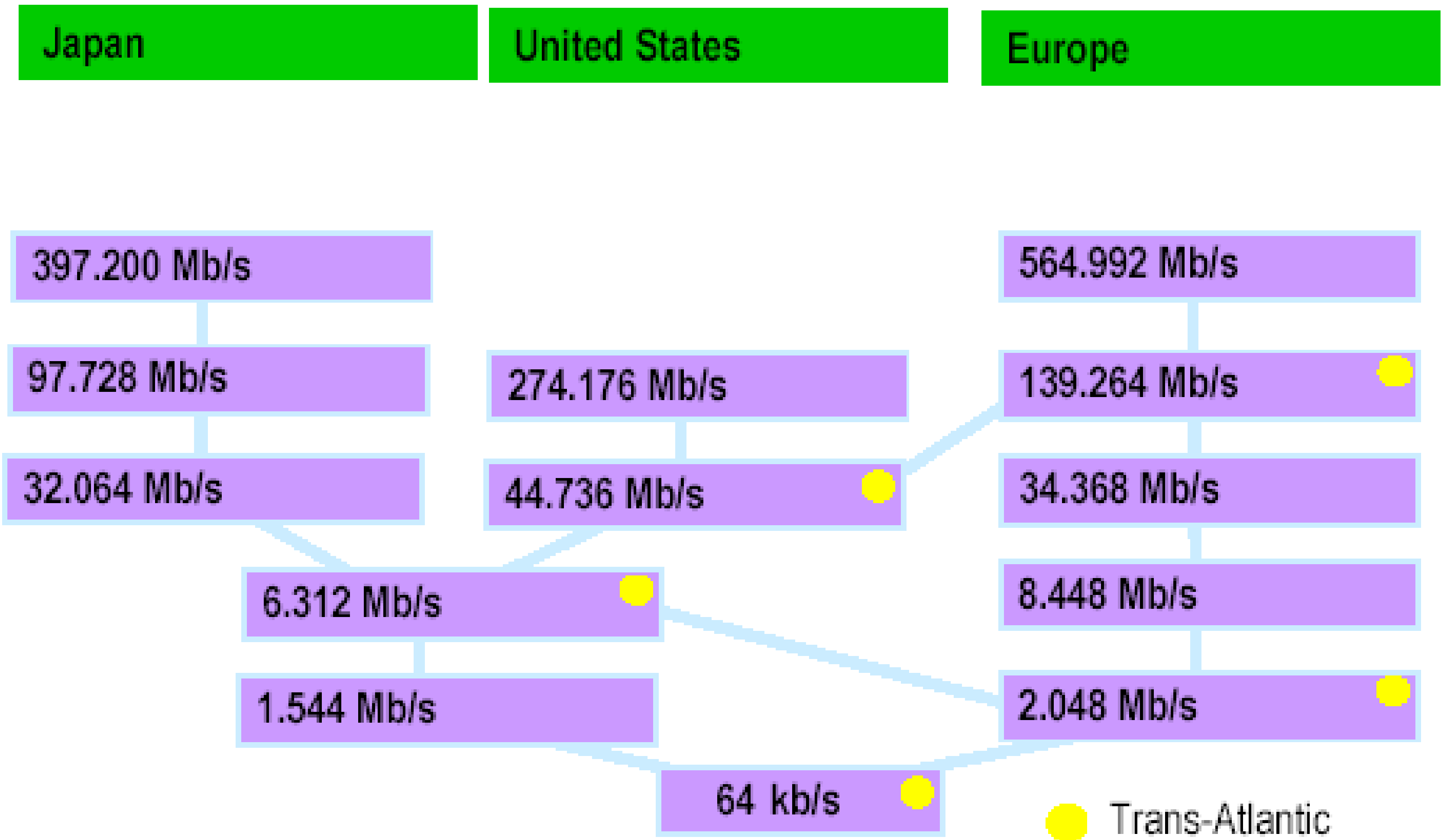
(Pulse Code Modulation)



125 μs

TDM principles II. PDH hierarchy

Plesiochronous Digital Hierarchy



TDM principles III. PDH hierarchy

Európai hierarchia:

<table>
<tr><td>hierarchia szint</td><td>0</td><td>E1</td><td>E2</td><td>E3</td><td>E4</td><td>E5</td></tr>
<tr><td>névleges sebesség [Mb/s]</td><td>0,064 (PCM)</td><td>2</td><td>8</td><td>34 (34>8x4!!!)</td><td>140</td><td>565</td></tr>
<tr><td>beszédcsatornák száma</td><td>1</td><td>30</td><td>4×30 = 120</td><td>4×120=480</td><td>4×480=1920</td><td>4×1920 = 7680</td></tr>
<tr><td rowspan="4">átviteli közeg</td><td colspan="2">szimmetrikus kábel csavart érpár</td><td colspan="4"></td></tr>
<tr><td></td><td colspan="4">koaxiális kábel</td><td></td></tr>
<tr><td colspan="6">földfelszíni és műholdas rádió</td></tr>
<tr><td colspan="3"></td><td colspan="3">fénykábel</td></tr>
</table>

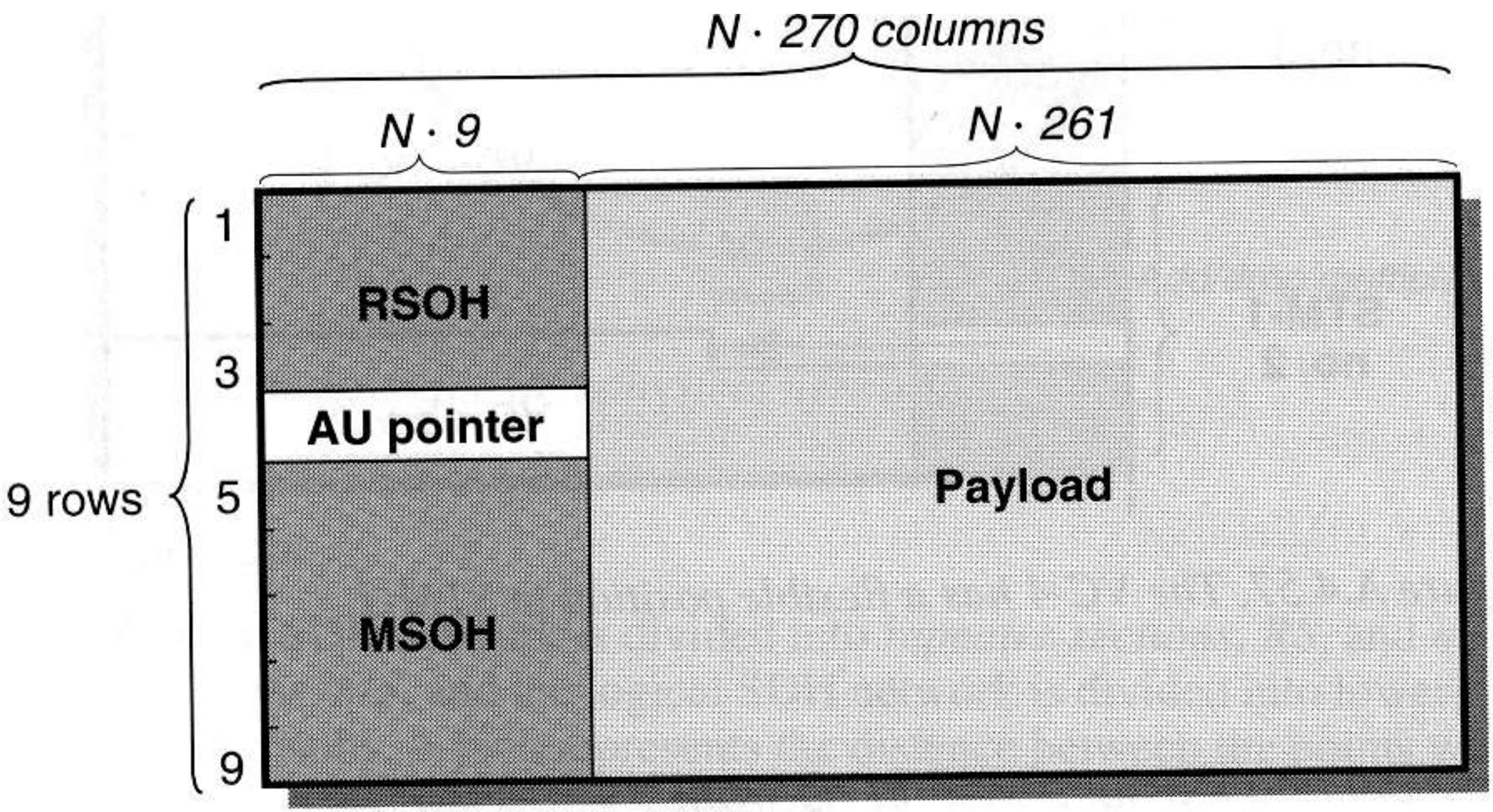
SDH hierarchy

- SDH – Synchronous Digital Hierarchy
- VC – Virtual Container (multiplexing level)
- STM-N Synchronous Transport Modules (line signal level)
- POH – path overhead (control and supervisory information)
- POH+Payload=VC
- A number of VCs can packaged into a larger VC

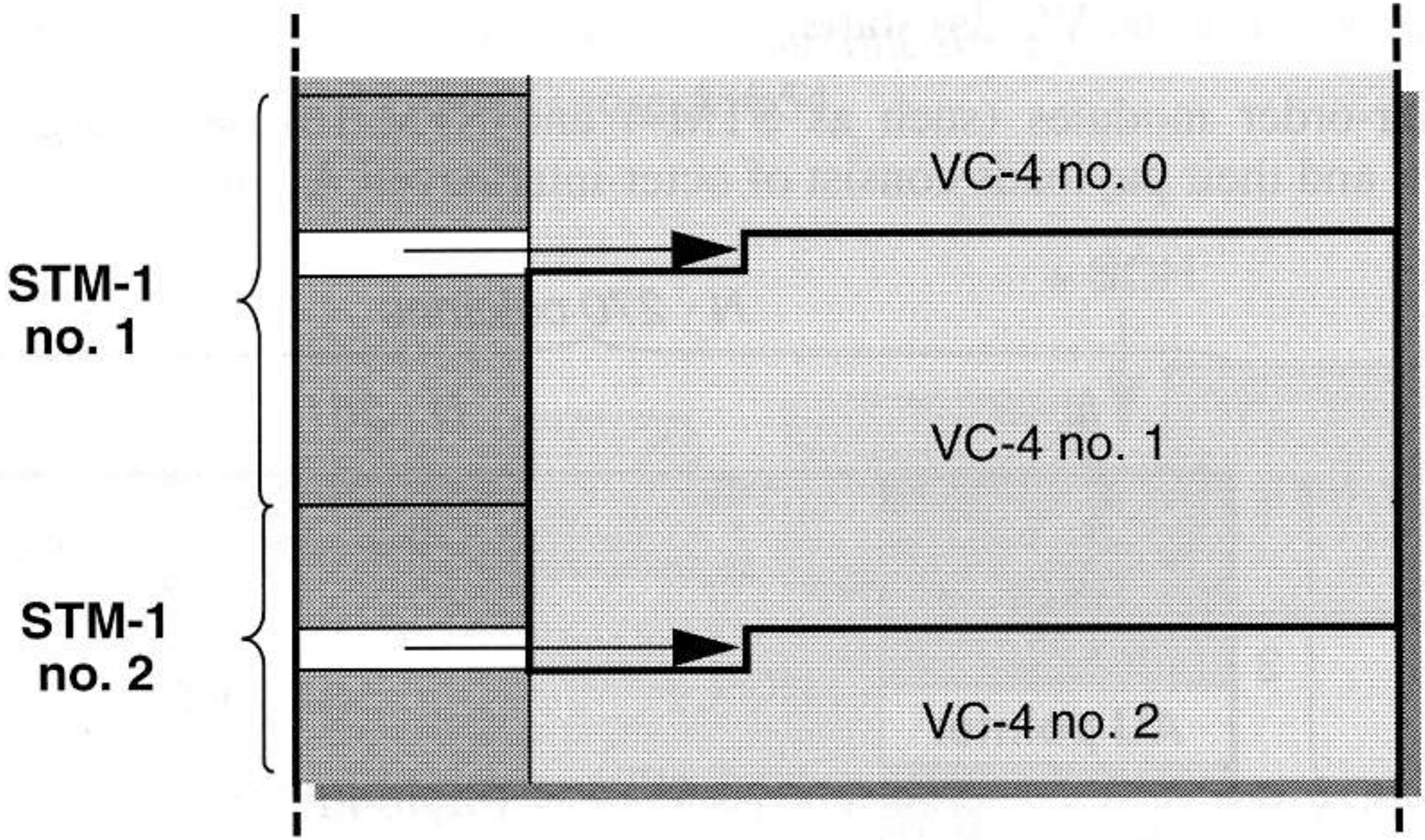
Transport modules

- RSOH – Regenerator Section Overhead
- MSOH – Multiplexer Section Overhead
- AU Pointer – Administrative Unit Pointer (specifies where the payload starts)
- Duration of STM-1 module is 125 µs

General Transport Module

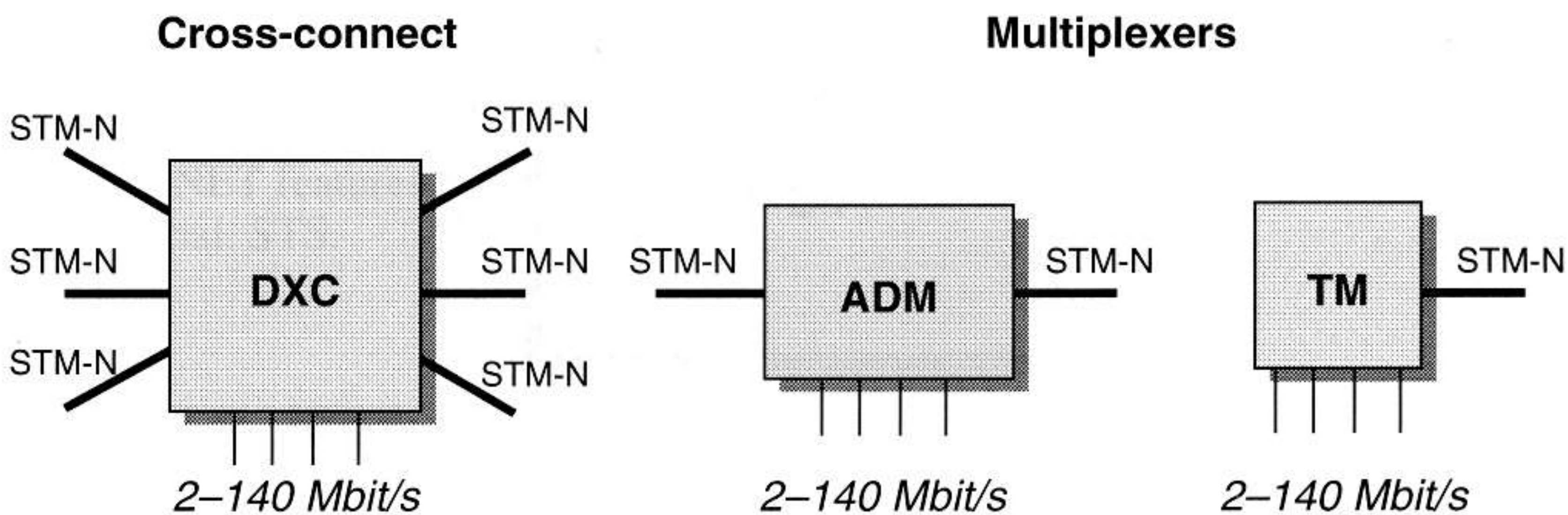


SONET szintek	**STS-1**	**STS-3**	**STS-12**	**STS-48**	**STS-192**
SDH szintek		**STM-1**	**STM-4**	**STM-16**	**STM-64**
névleges átviteli sebesség	52 Mb/s	155 Mb/s	622 Mb/s	2,5 Gb/s	10 Gb/s
beszédcsatornák száma	672	USA: 3×672 = 2016 EU: 1920	EU: 4×1920 = 7680	EU: 4×7680 = 30720	EU: 4×30720 = 122880
átviteli közeg	földfelszíni és műholdas rádió				
	optikai kábel				

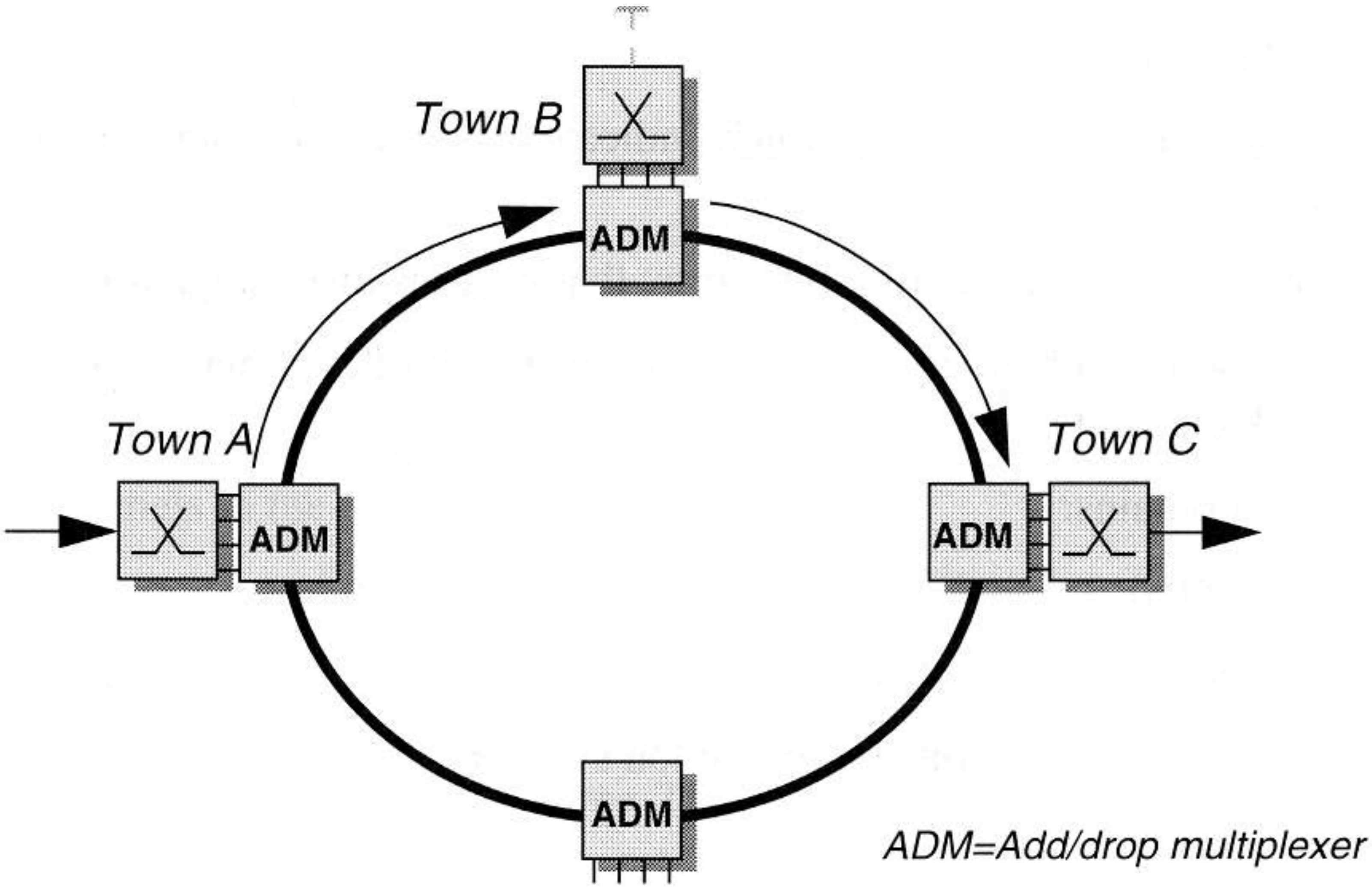

STM-1
no. 1
STM-1
no. 2
VC-4 no. 0
VC-4 no. 1
VC-4 no. 2

SDH Network elements

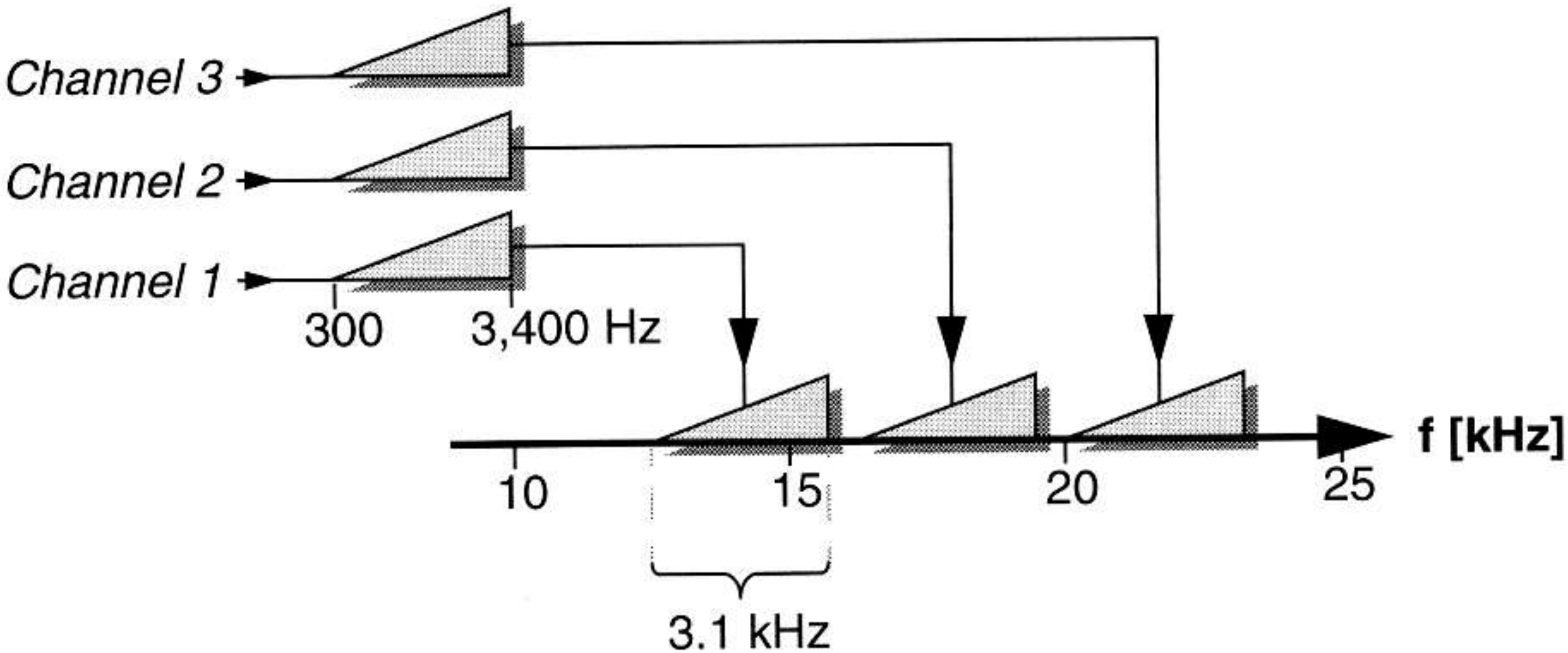
DXC – Digital Cross Connect
ADM – Add-drop Multiplexer
TM – Terminal multiplexer



Example of a physical network



FDM principles

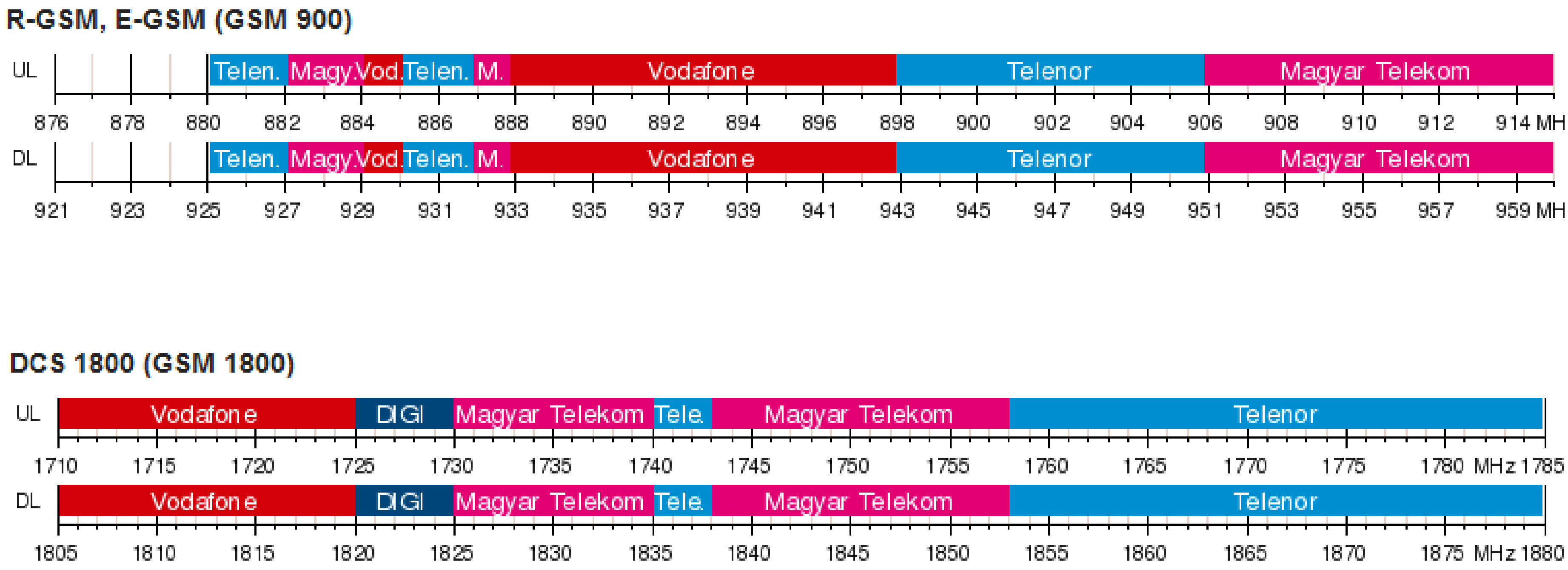


LOCAL VHF-FM BROADCASTING RADIO STATIONS IN OPERATION

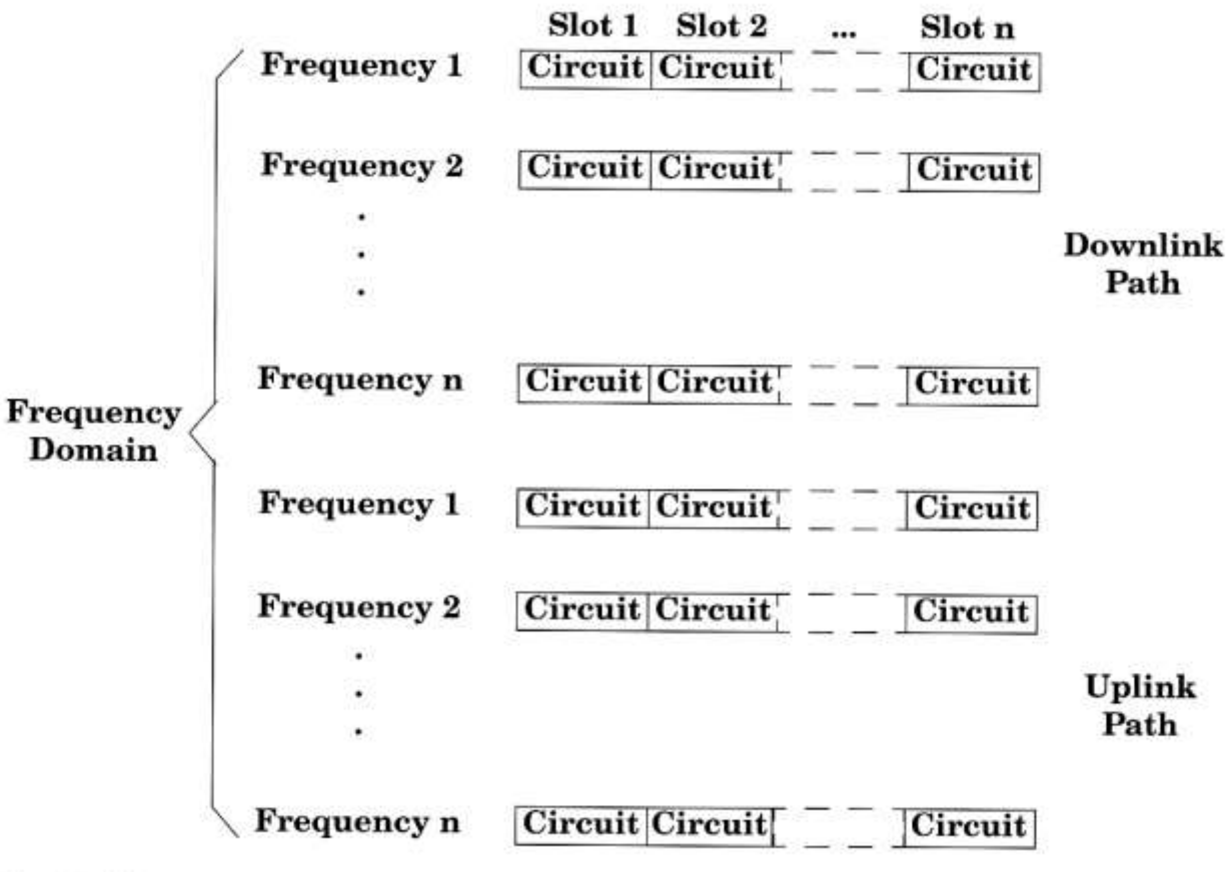
(Frissítve: 2017.07.27./Updated on 27.07.2017)

Telephely Site	Frekvencia (MHz) Frequency (MHz)	Polarizáció Polarization	Műsor neve Programme name
Abádszalók	89,2	V	88,7 MHz, 89,2 MHz Rádió 1
Ajka	93,2	V	Mária Rádió Bakony
Baja	88,7	V	Gong Rádió
Baja	89,8	V	Bajai Rádió
Baja	94,3	V	94,3 Rádió 1
Balassagyarmat	95,7	V	Megafon
Balatonfüred	96,2	V	Lánchíd Rádió
Barcs	102,7	V	Dráva Hullám 102.7
Békés	94,4	V	Torony Rádió

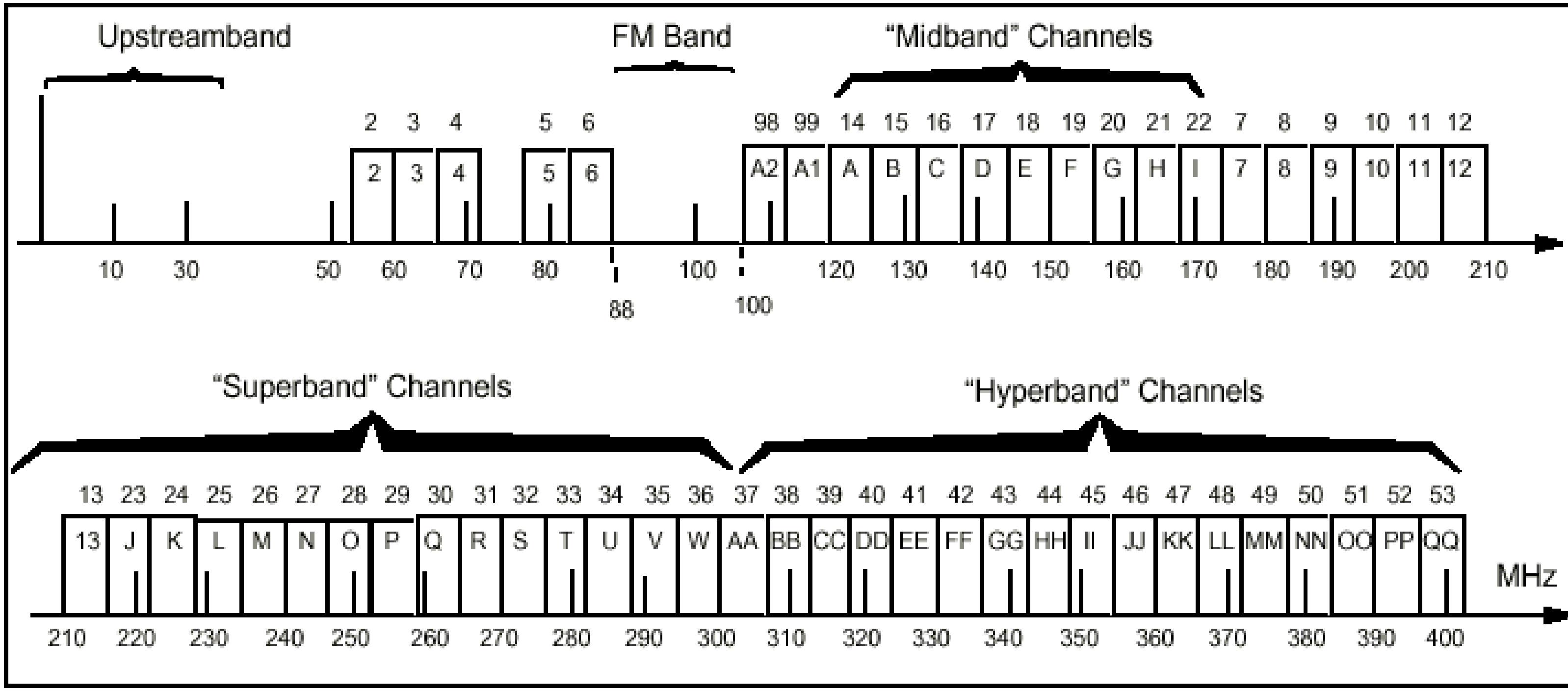
GSM frequency band allocation in Hungary



TDM/FDM channel architecture as used in GSM



FDM in Cable TV network (US Standard)



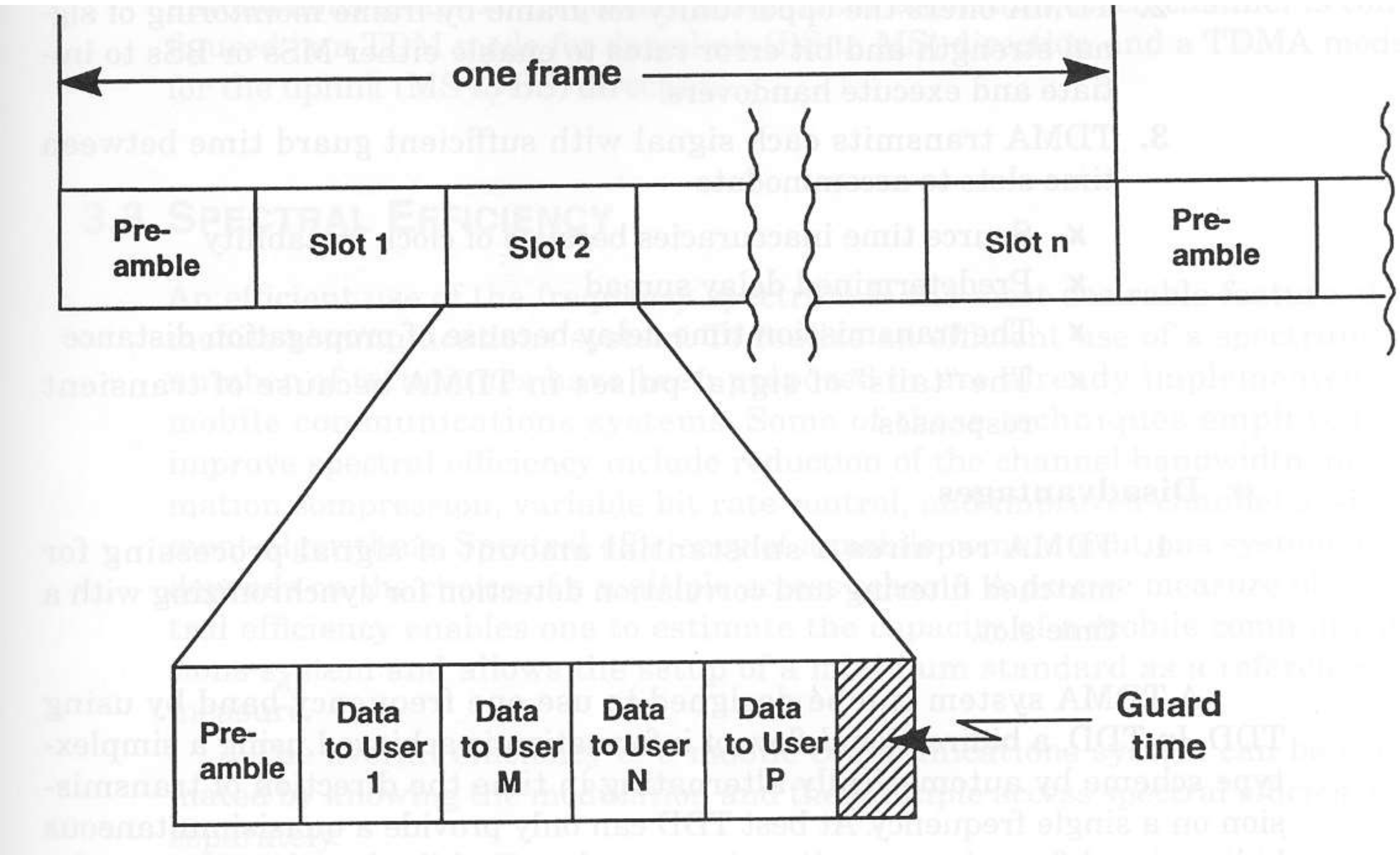
FREQUENCY PLAN

Numbers above the rectangles are the new Electronics Industry Association standard designations. Historical designations are inside the rectangles

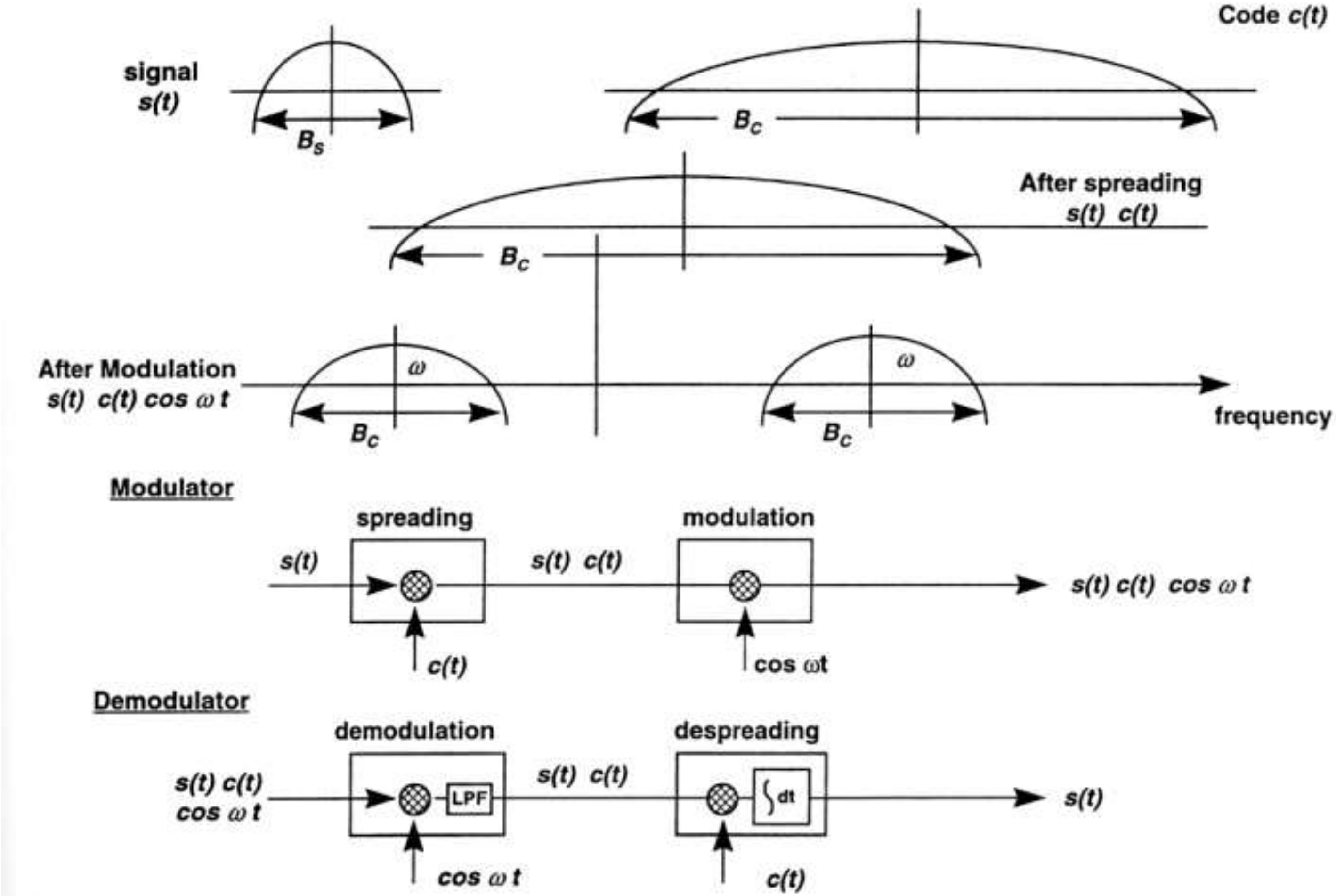
T-HOME Digital channel frequency bands (part)

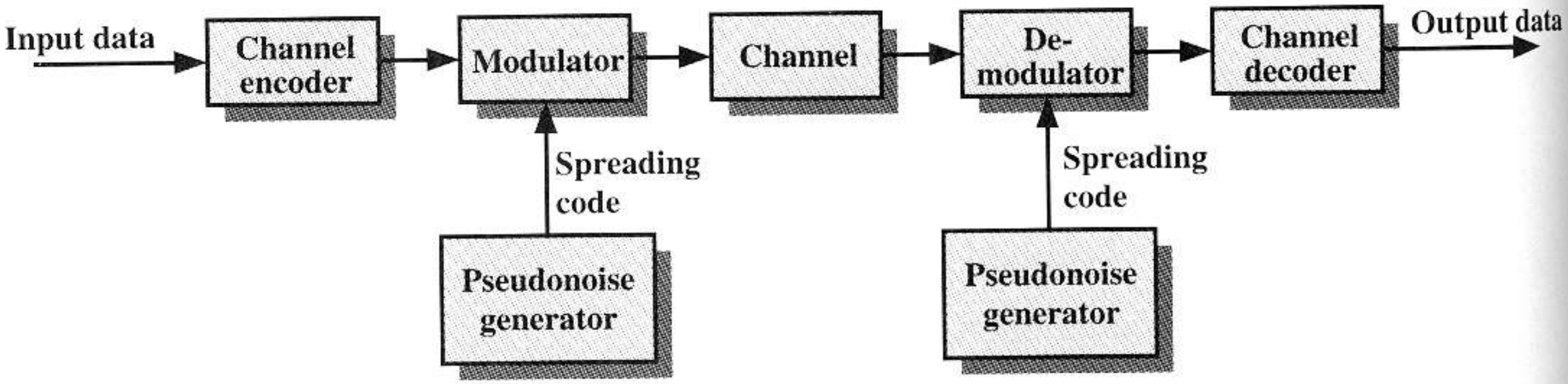
Frekvencia Mhz	SR	QAM	Csatorna	Fizetős	HD
402	6875	64	AXN HD	x	x
402	6875	64	Duna World HD	x	x
402	6875	64	Duna HD	x	x
402	6875	64	M1 HD	x	x
410	6875	64	ORF1	x	
410	6875	64	Animal Planet	x	x
410	6875	64	Discovery Showcase	x	x
410	6875	64	Sport 1 HD	x	x
410	6875	64	STV2 HD	x	x
410	6875	64	ATV HD	x	x

Variable bit-rate data transfer within TDM time-slots

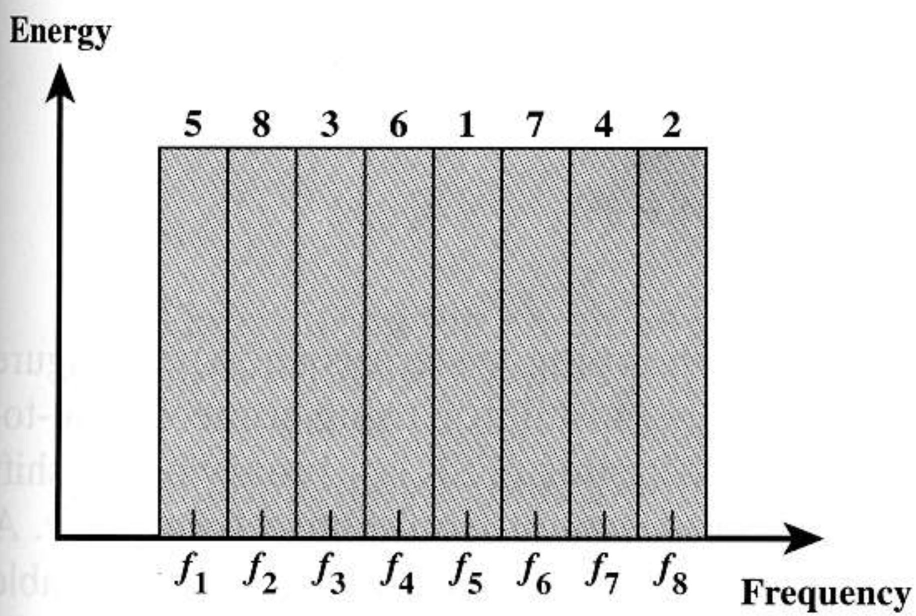


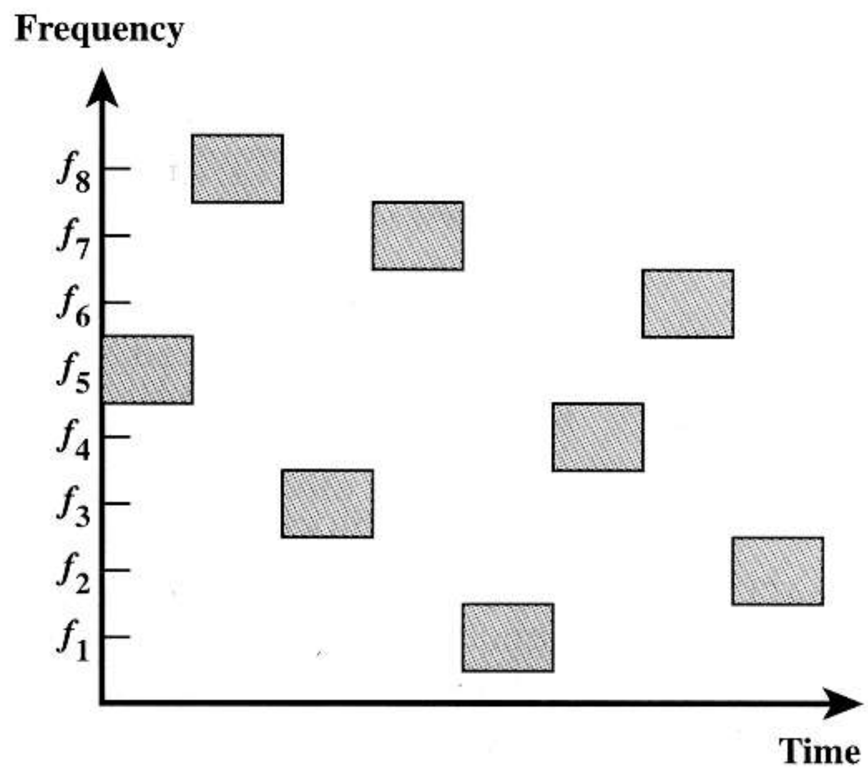
The Spread Spectrum Concept





General Model of Spread Spectrum Digital Communication System

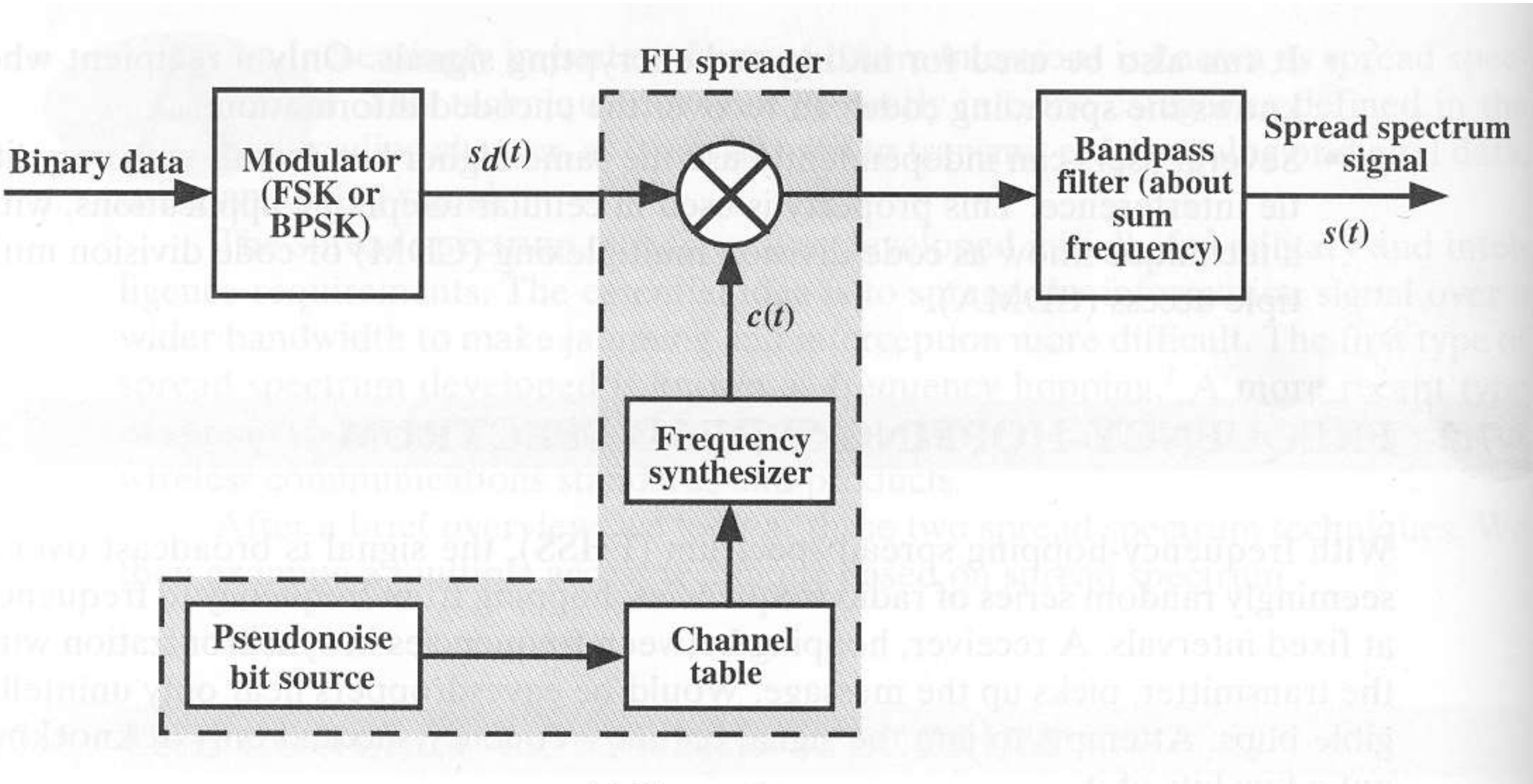




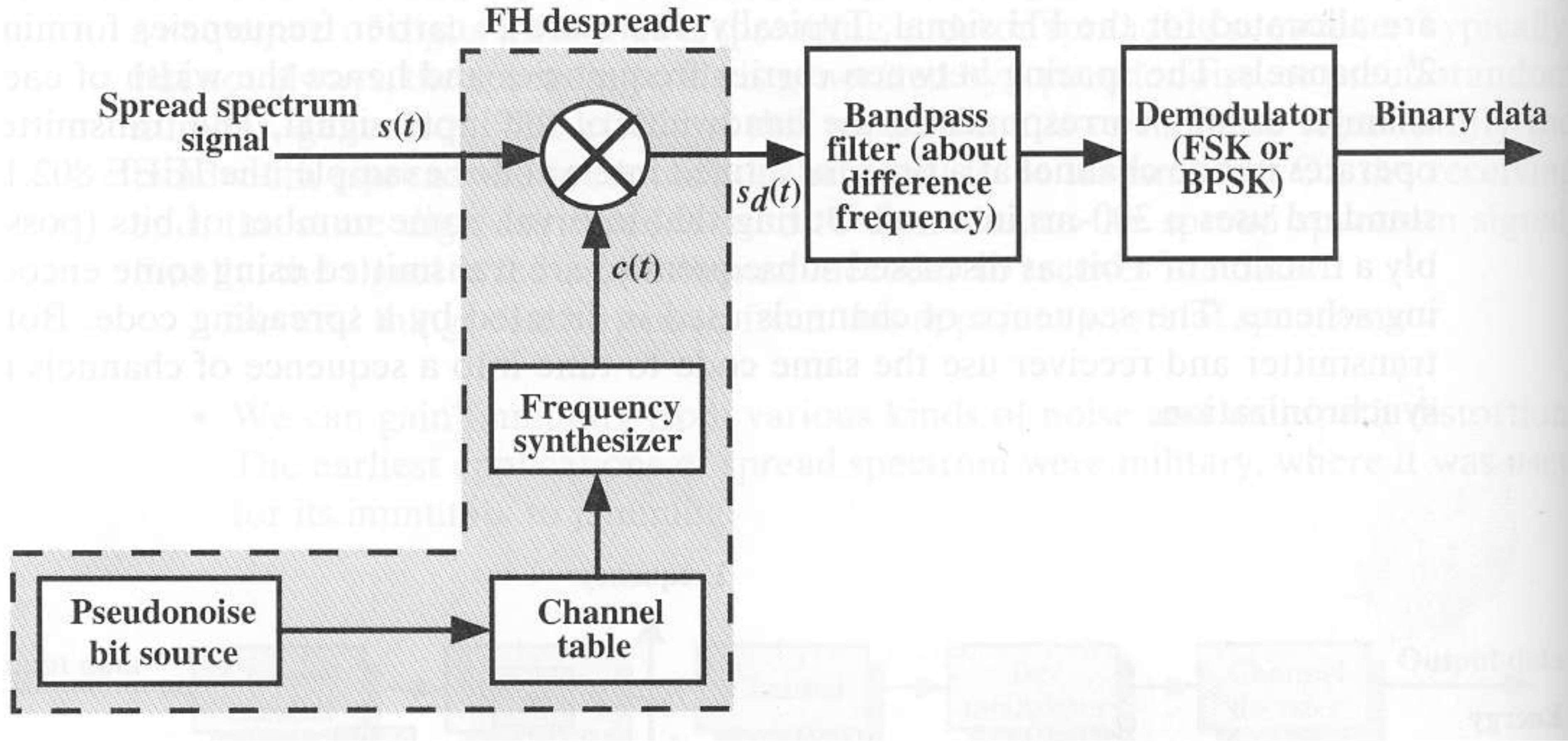
Frequency_Hopping Spread Spectrum FHSS

FHSS

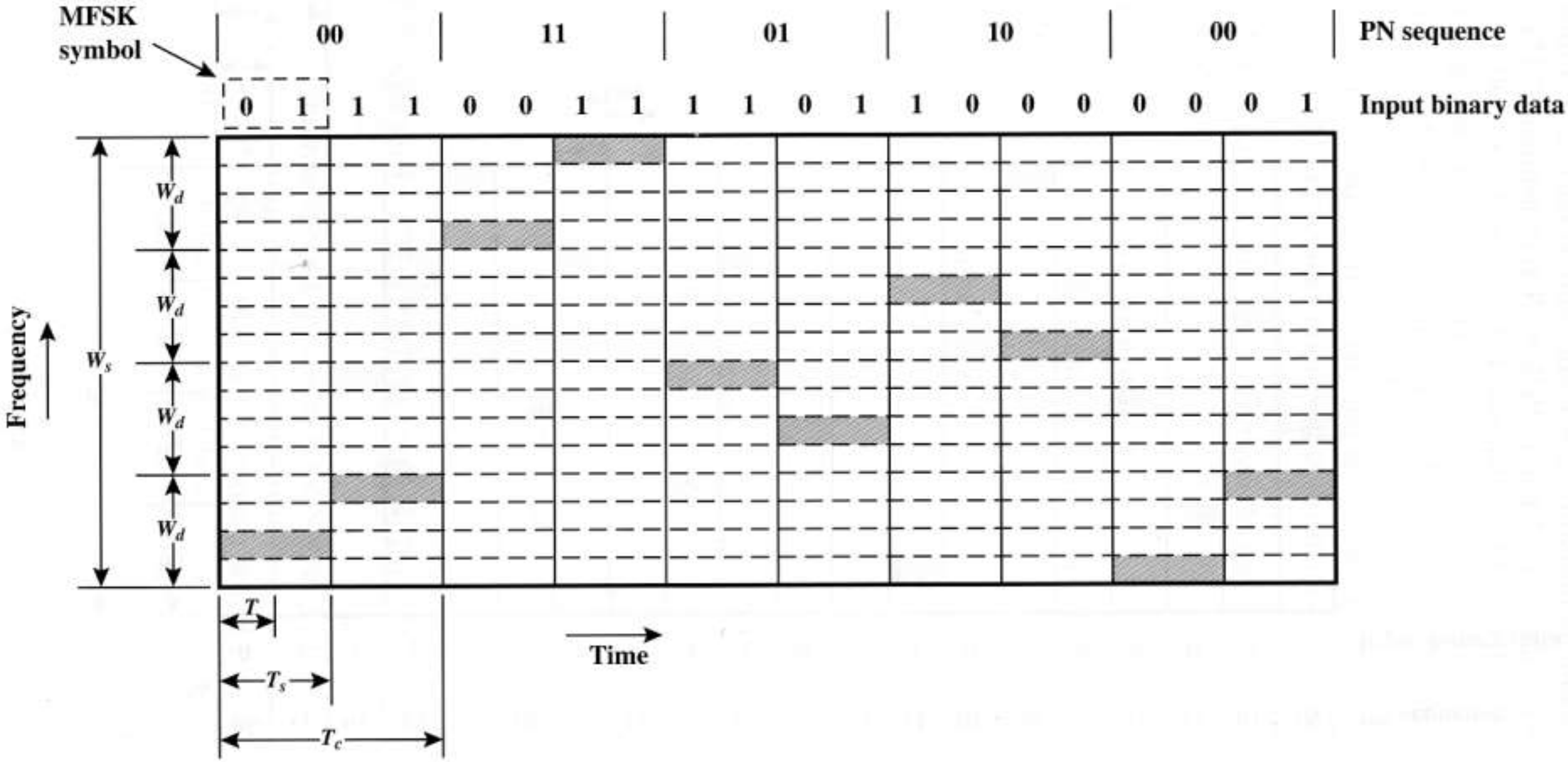
- A number of channels are allocated for FH
- The transmitter operates in one channel at a time for fixed Code Time interval (Tc)
- During that interval, some number of bits or a fraction of a bit are transmitted (signal elements)
- The time interval of signal (Symbol Elements) Ts
- The sequence of the channels used is dictated by spreading code
- Both transmitter and receiver use the same code to tune into a sequence of channels in synchronisation



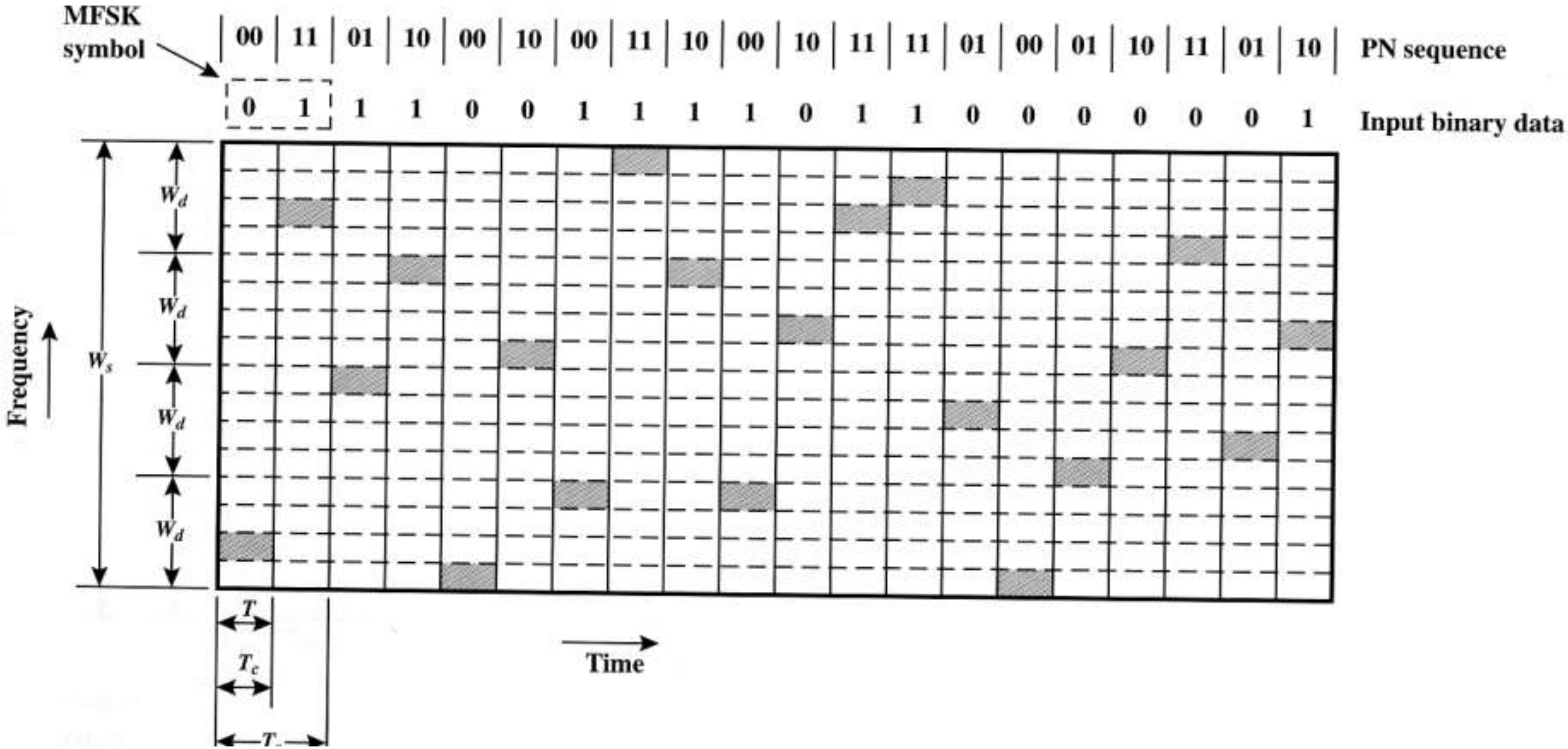
Transmitter of the FHSS System



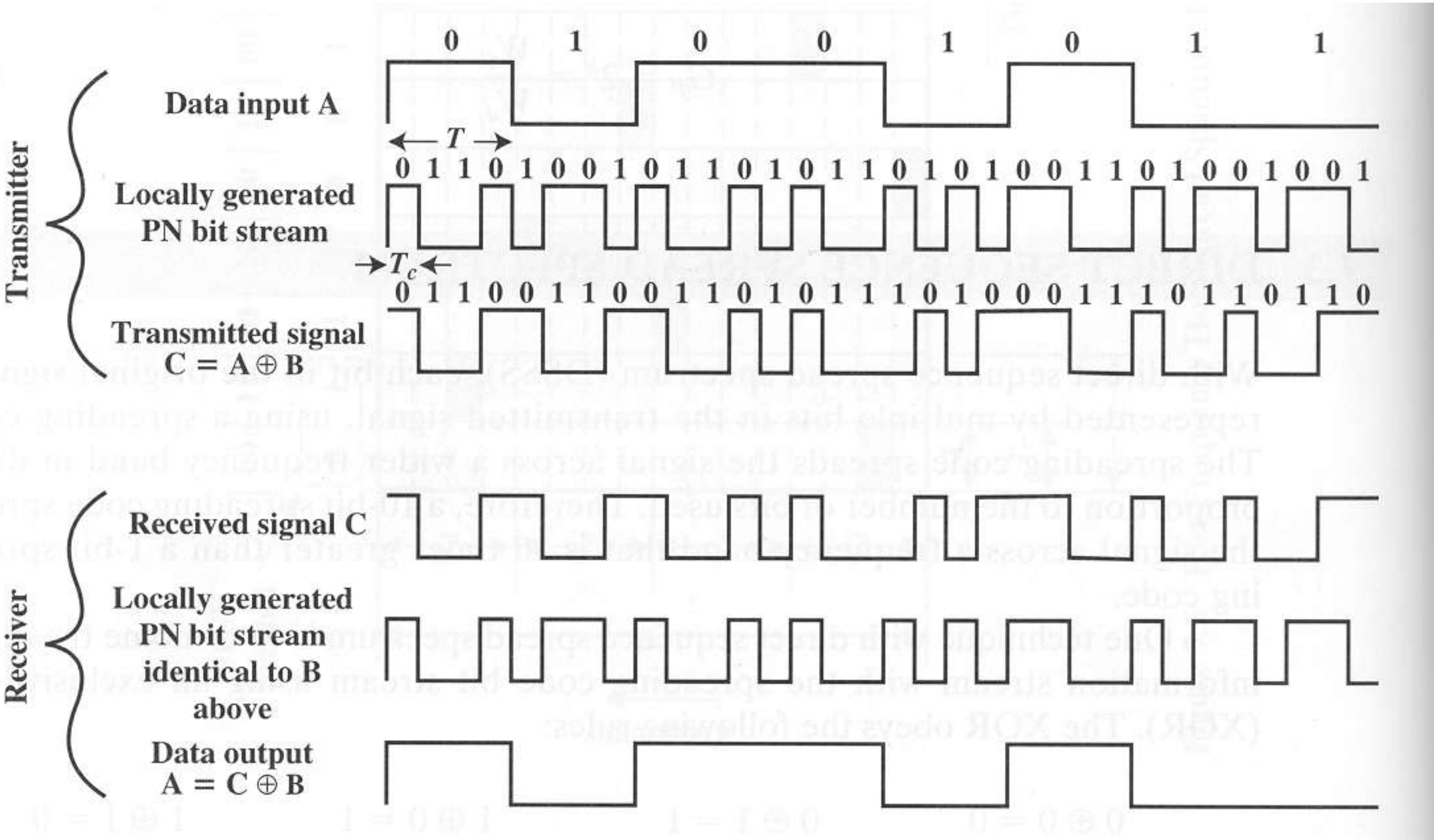
Receiver of the FHSS System



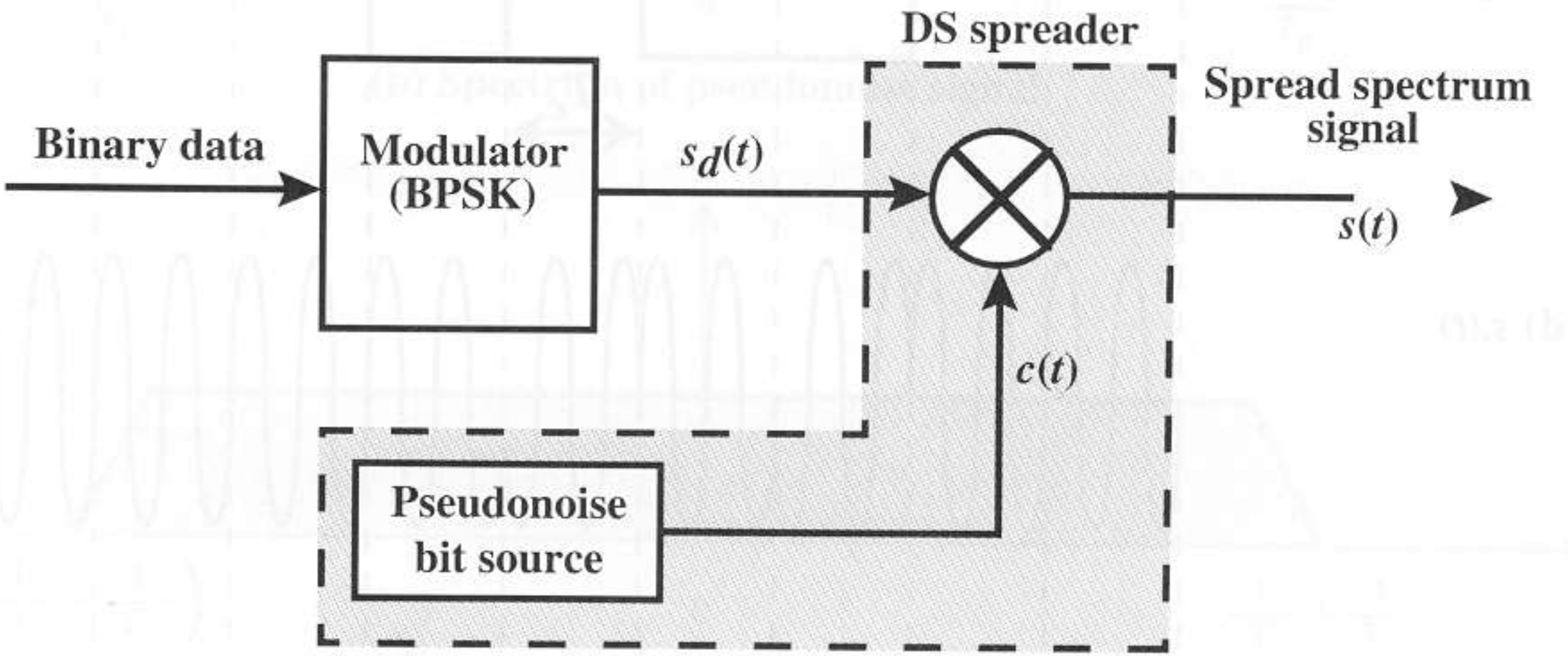
Slow FHSS using Multi Frequency Shift Keying Tc>Ts (in this case 4 subfrequencies for 2 bits)



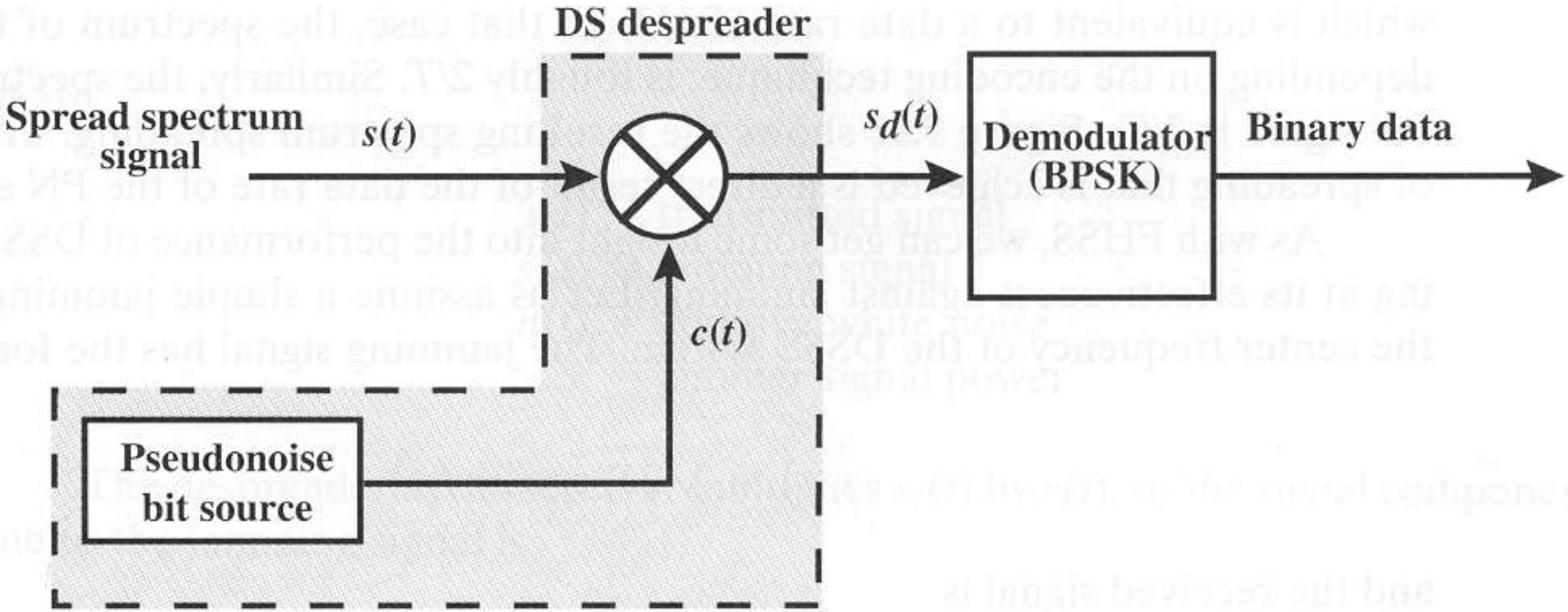
Fast FHSS using Multi Frequency Shift Keying Tc<Ts (in this case 4 subfrequencies for 2 bits)



Example of Direct Sequence Spread Spectrum DSSS

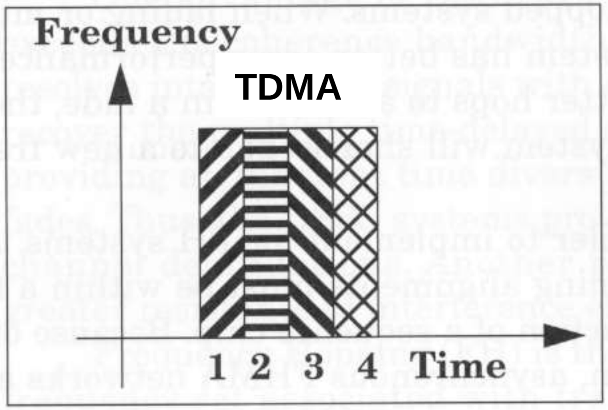


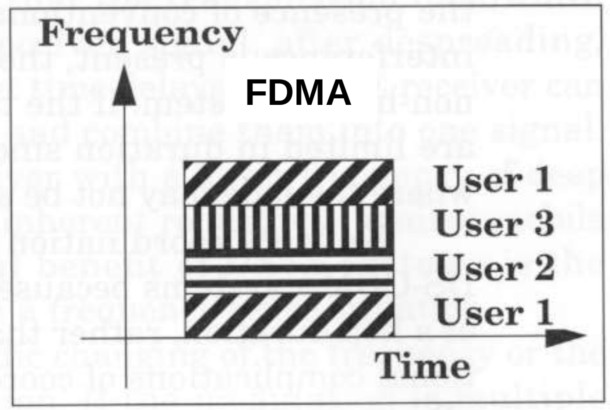
DSSS system Transmitter

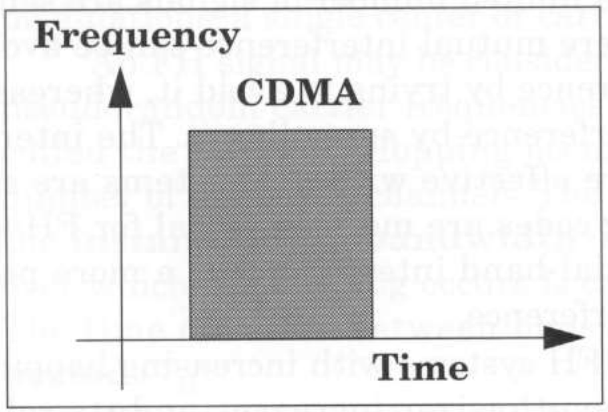


DSSS system Transmitter

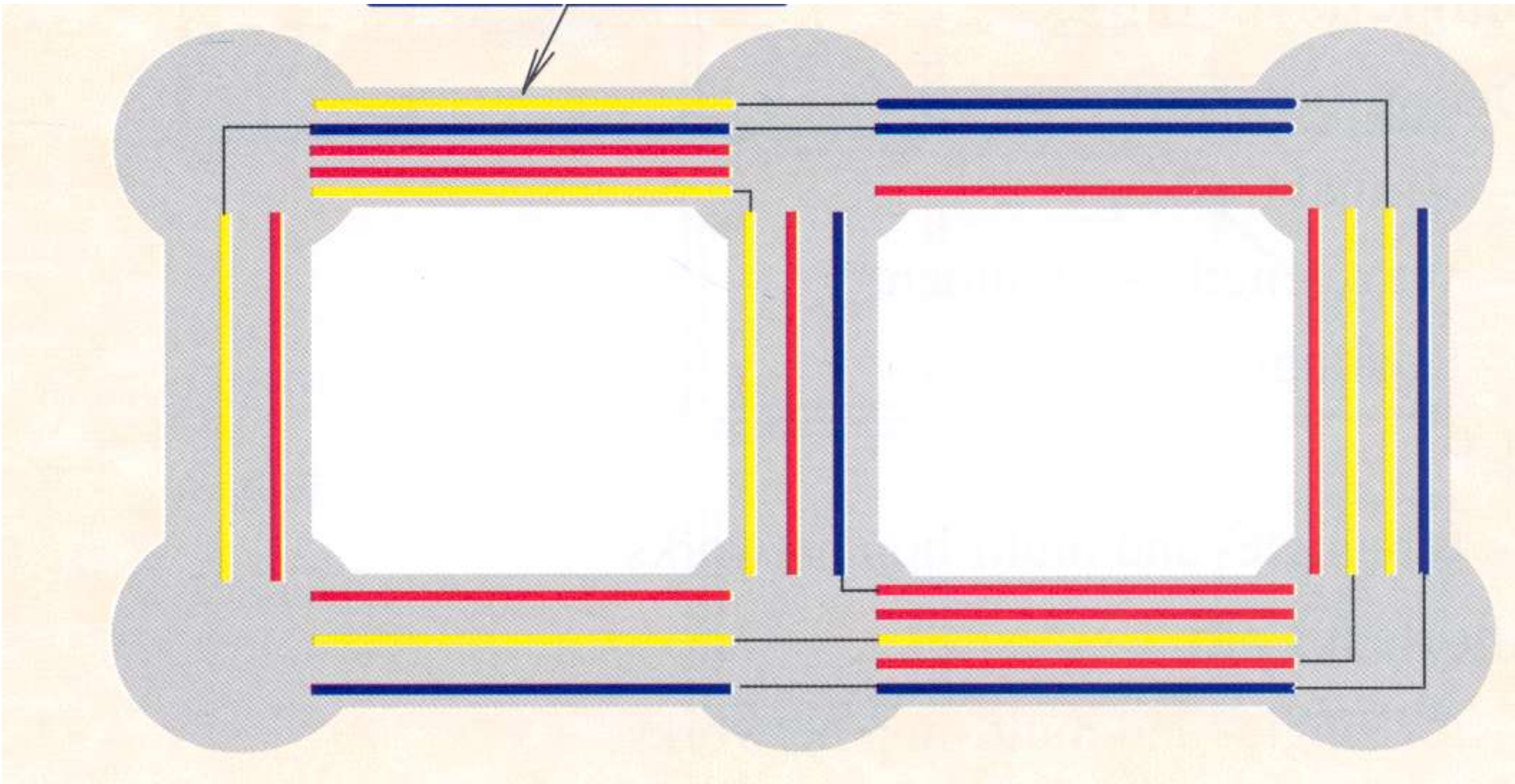
Comparison of FDM –TDM -- CDM

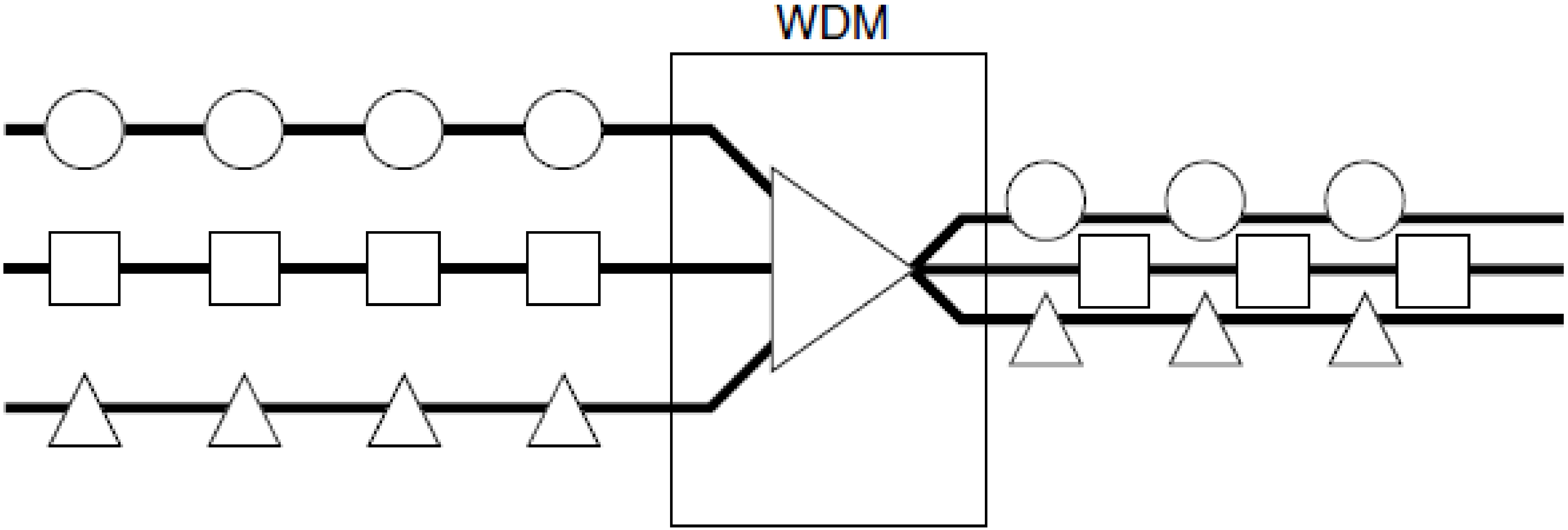




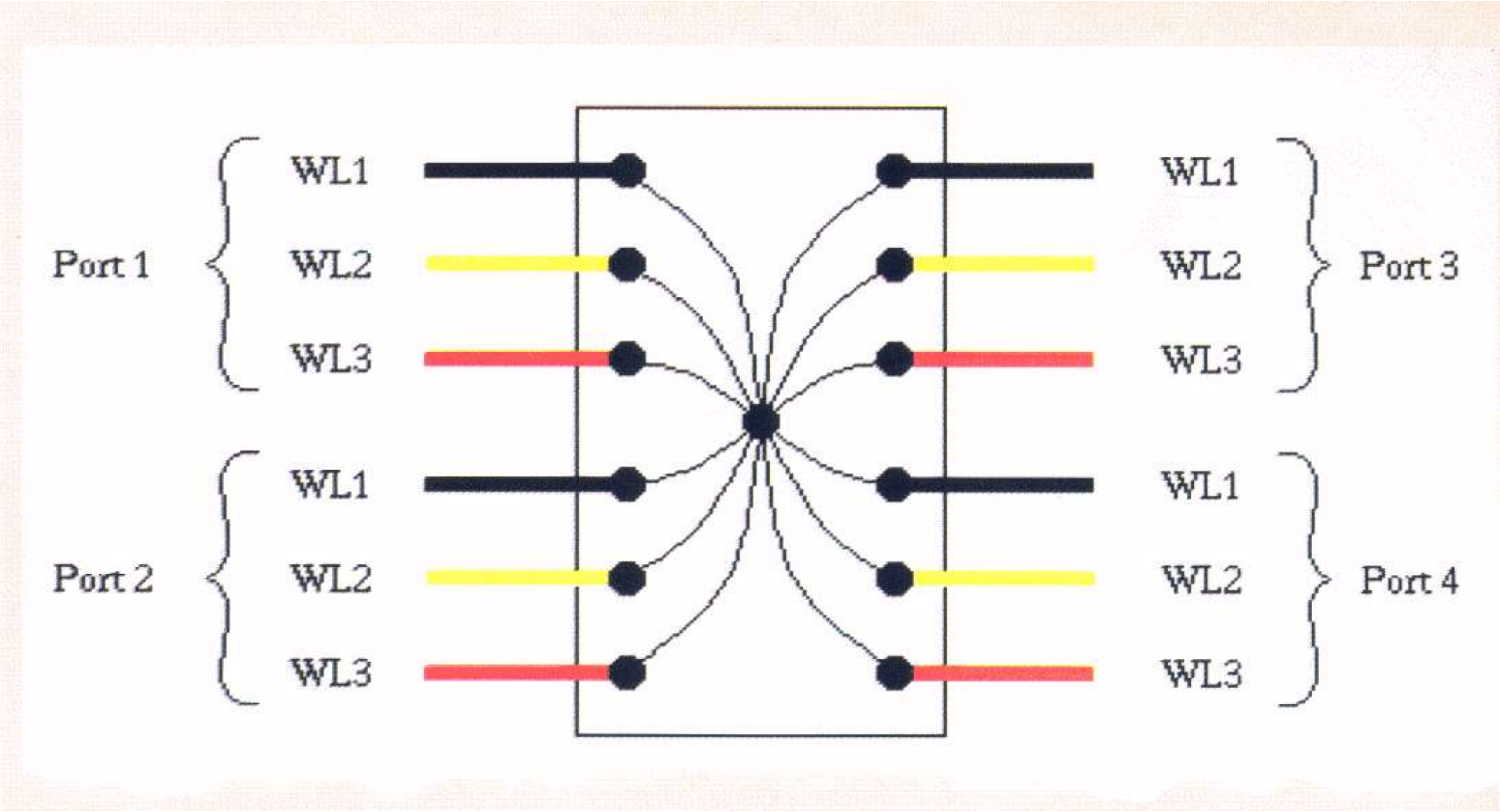


Principle of WDM

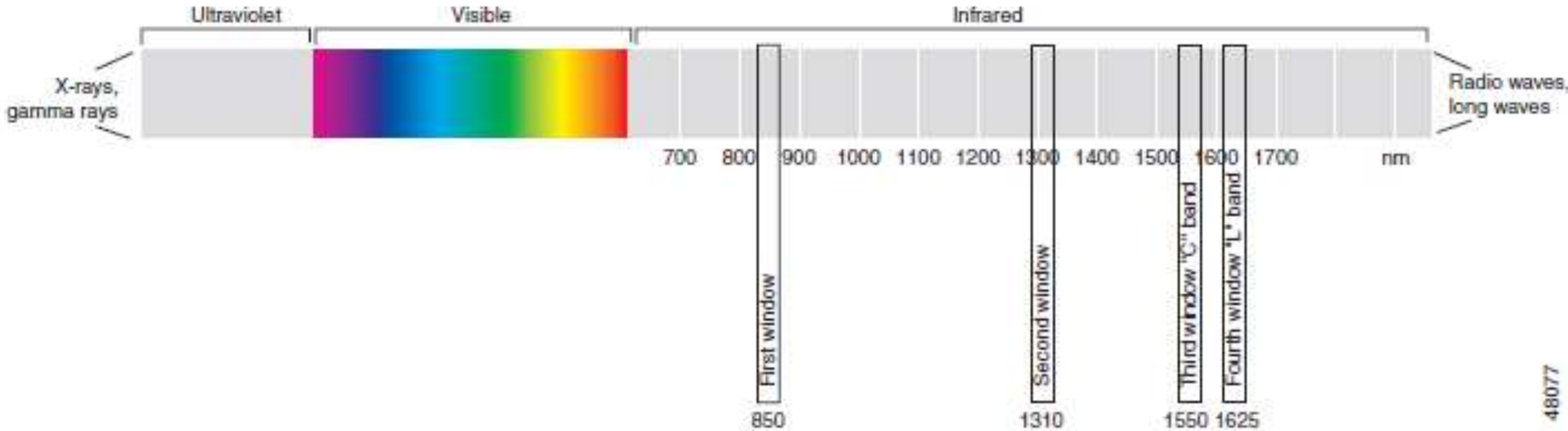


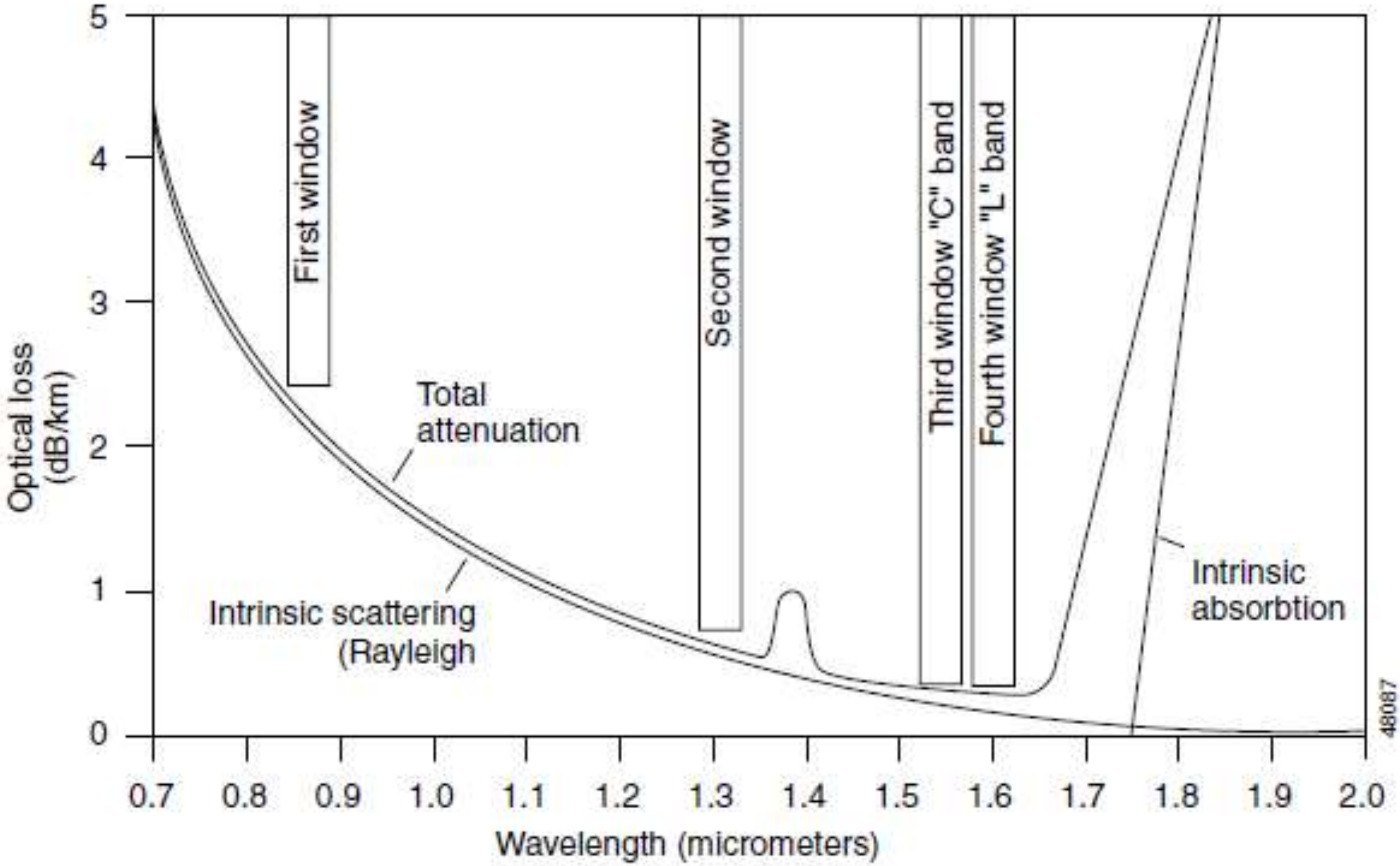

WDM

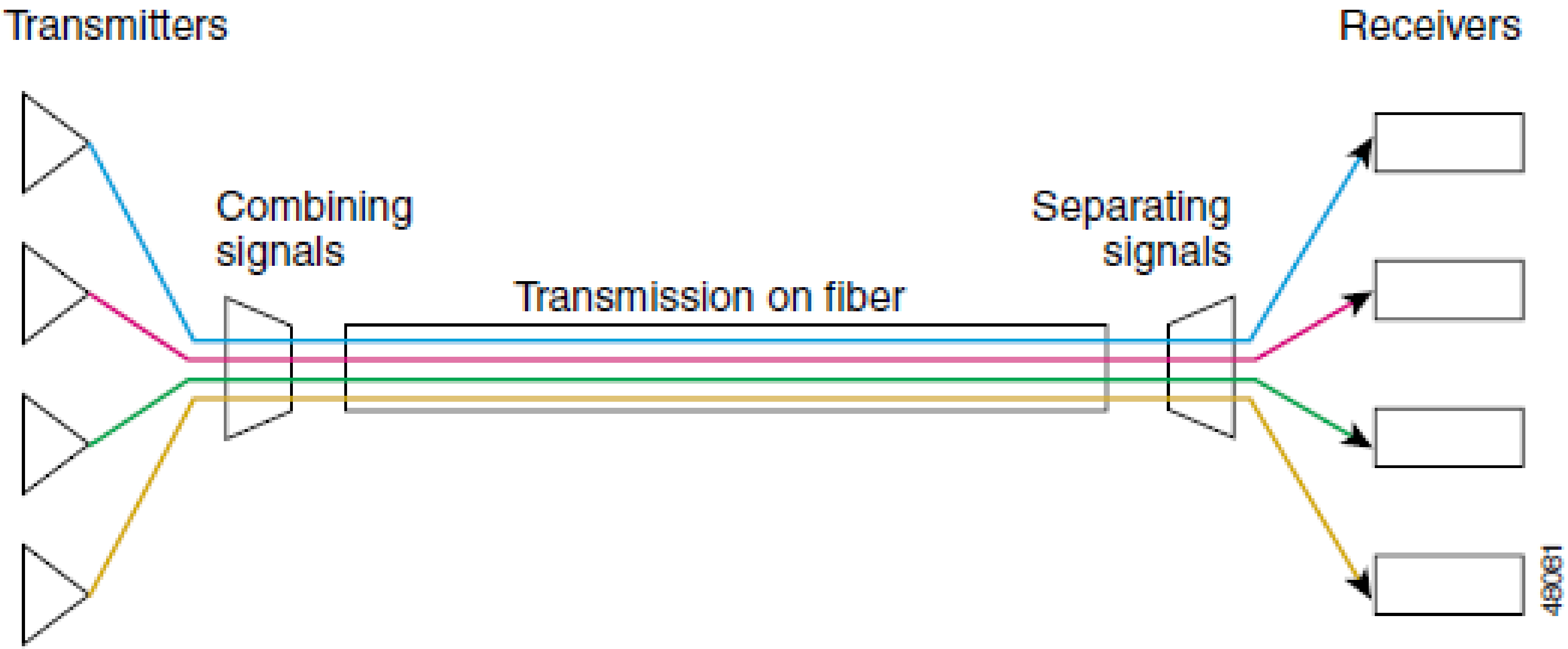
Principle of WDM



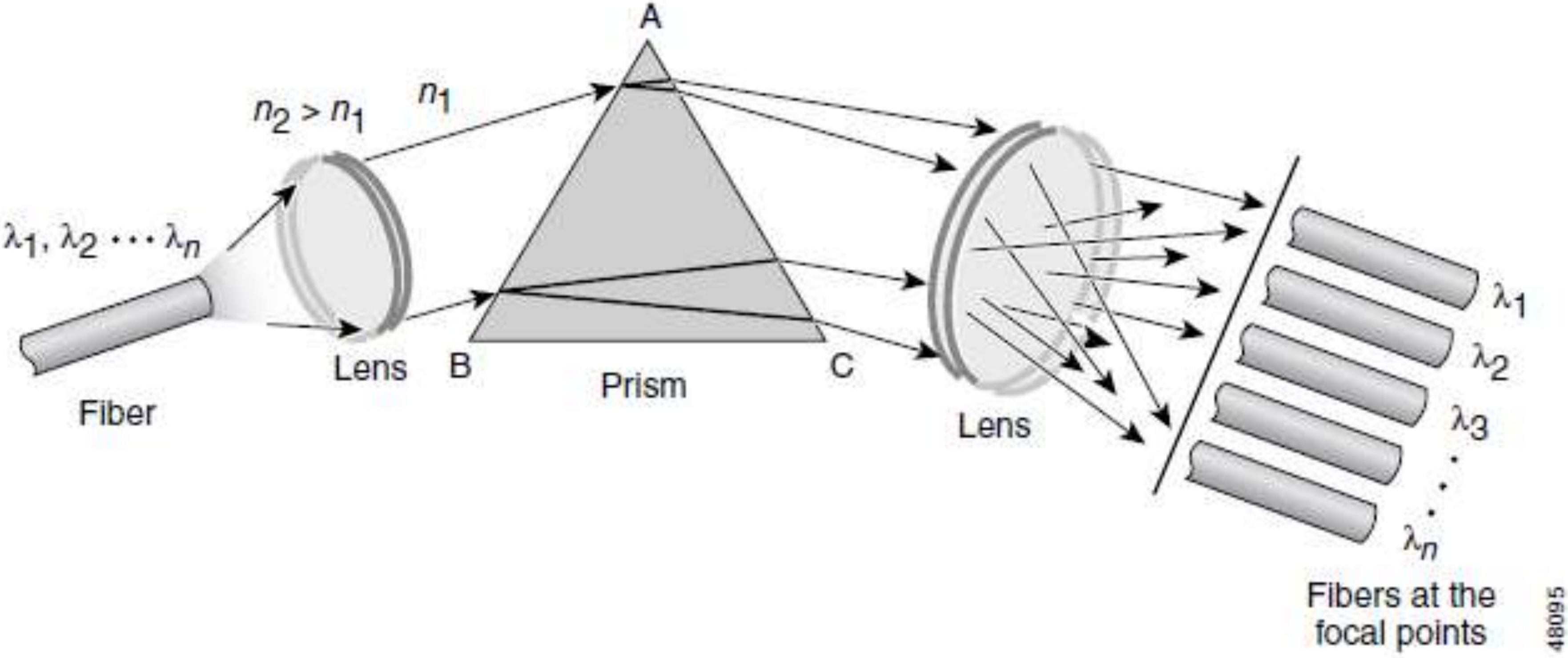
Wavelenght Regions



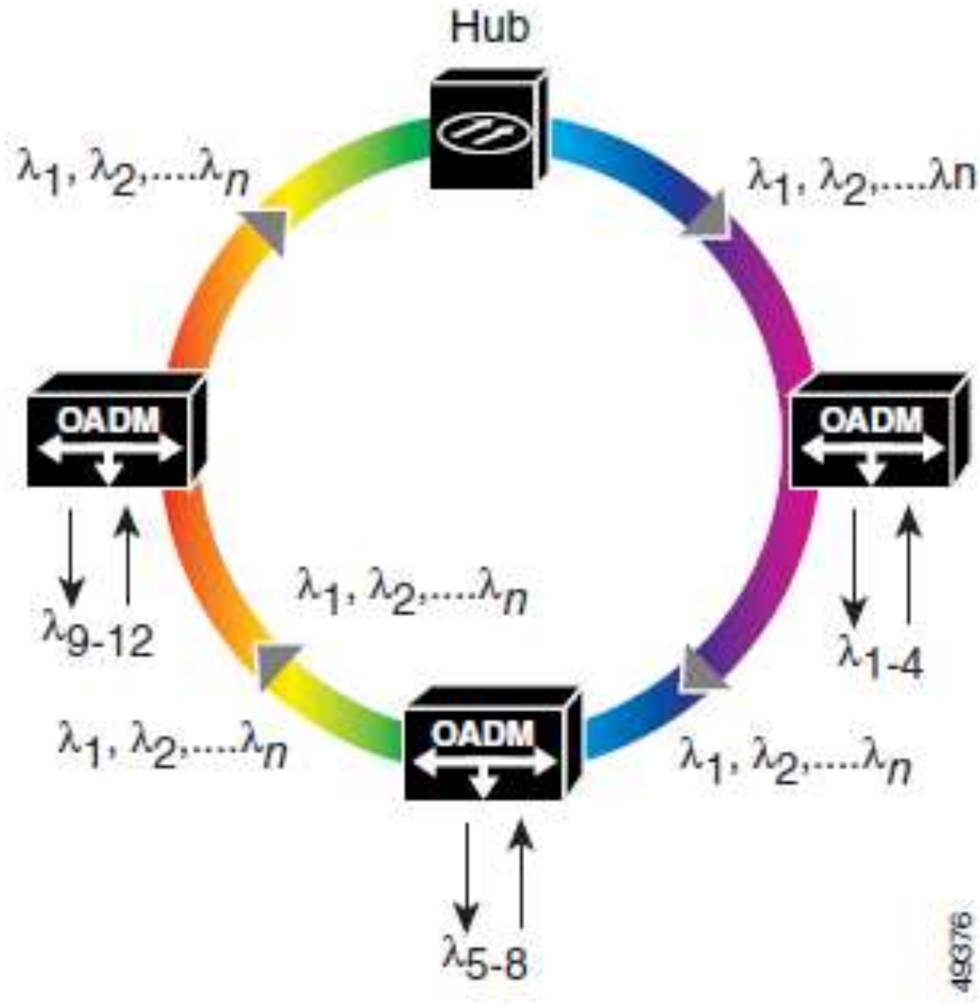

First window
Second window
Third window "C" band
Fourth window "L" band
Total
attenuation
Intrinsic scattering
(Rayleigh
Intrinsic
absorbtion
Optical loss
(dB/km)
Wavelength (micrometers)
5
4
3
2
1
0
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
48087


Transmitters
Receivers
Combining signals
Separating signals
Transmission on fiber

Prism refraction demultiplexing

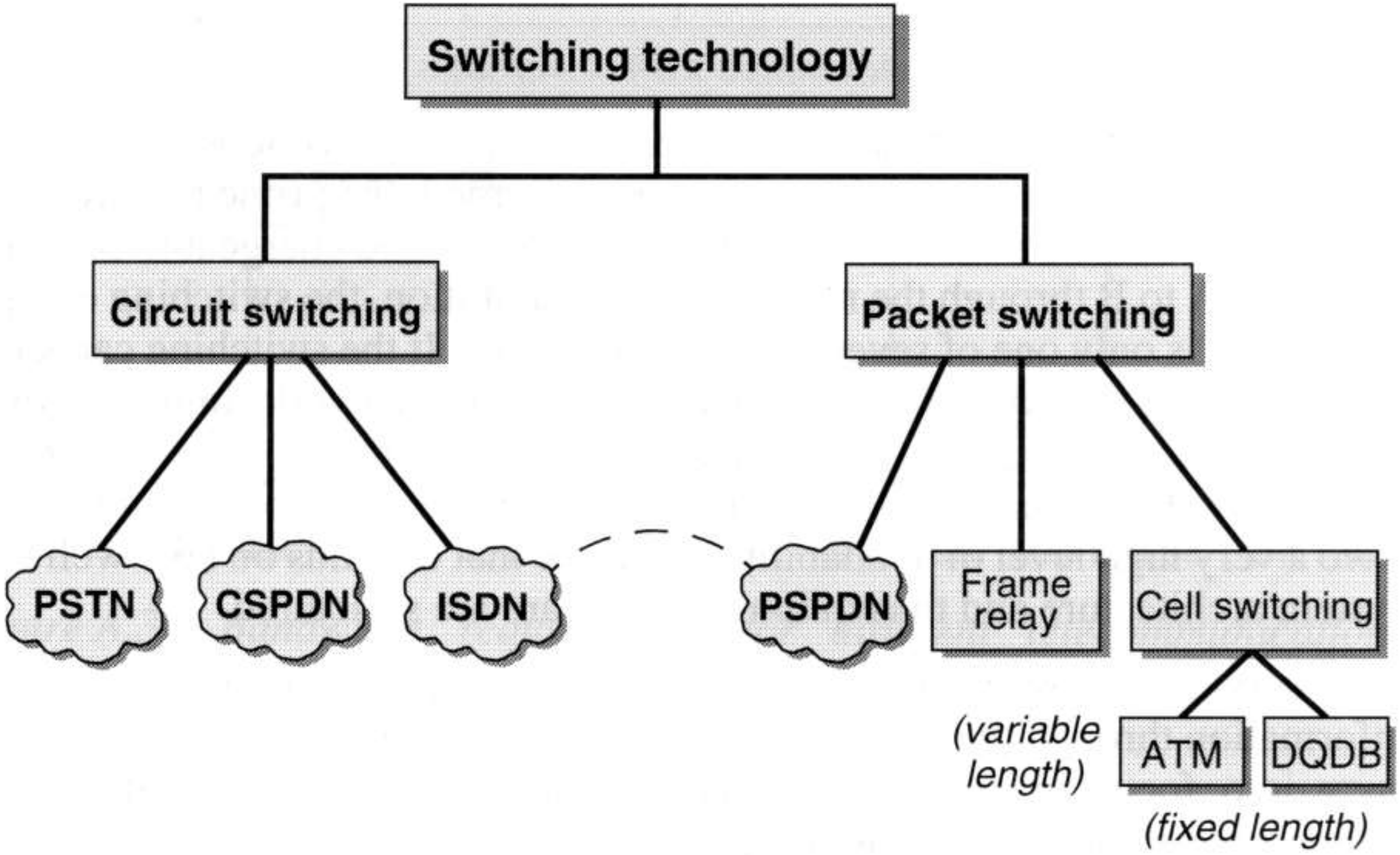


DWDM Ring Arhcitecure

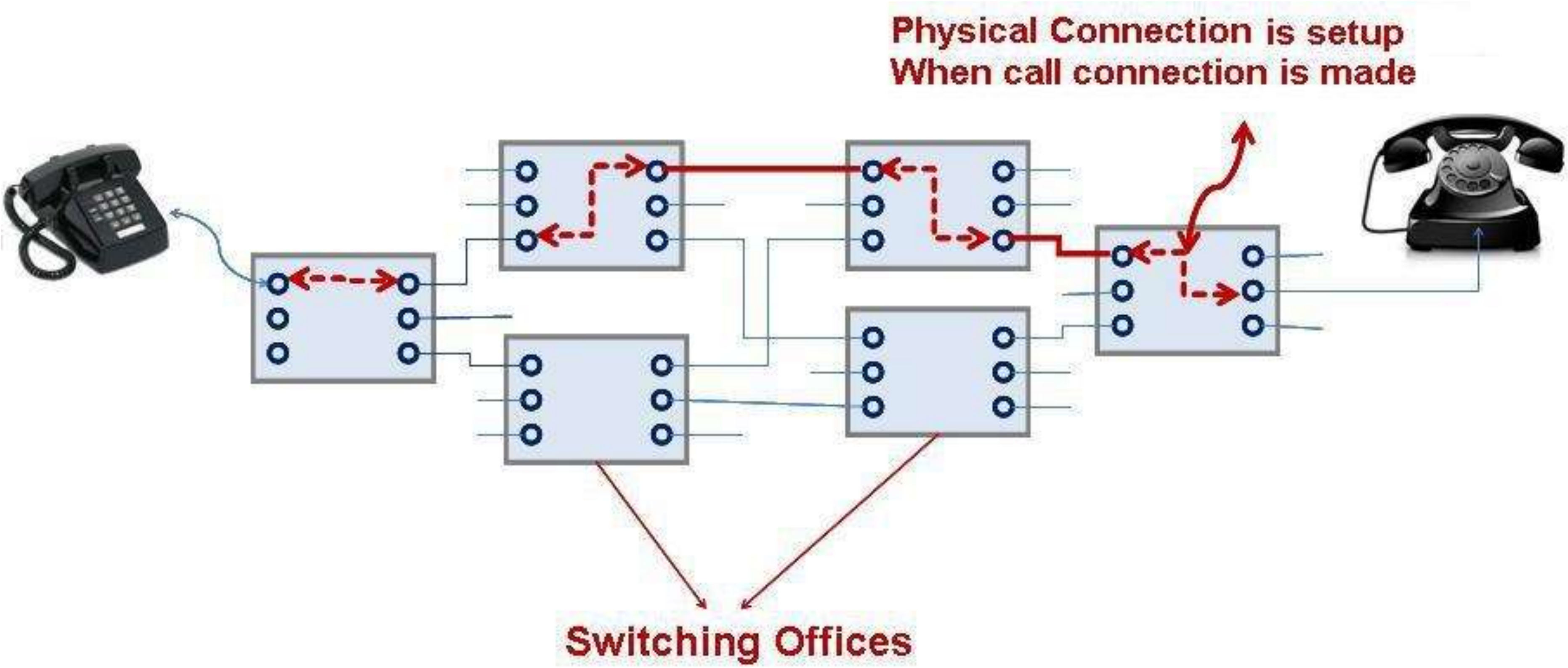


Point-to point like network node solution in a modern highway system

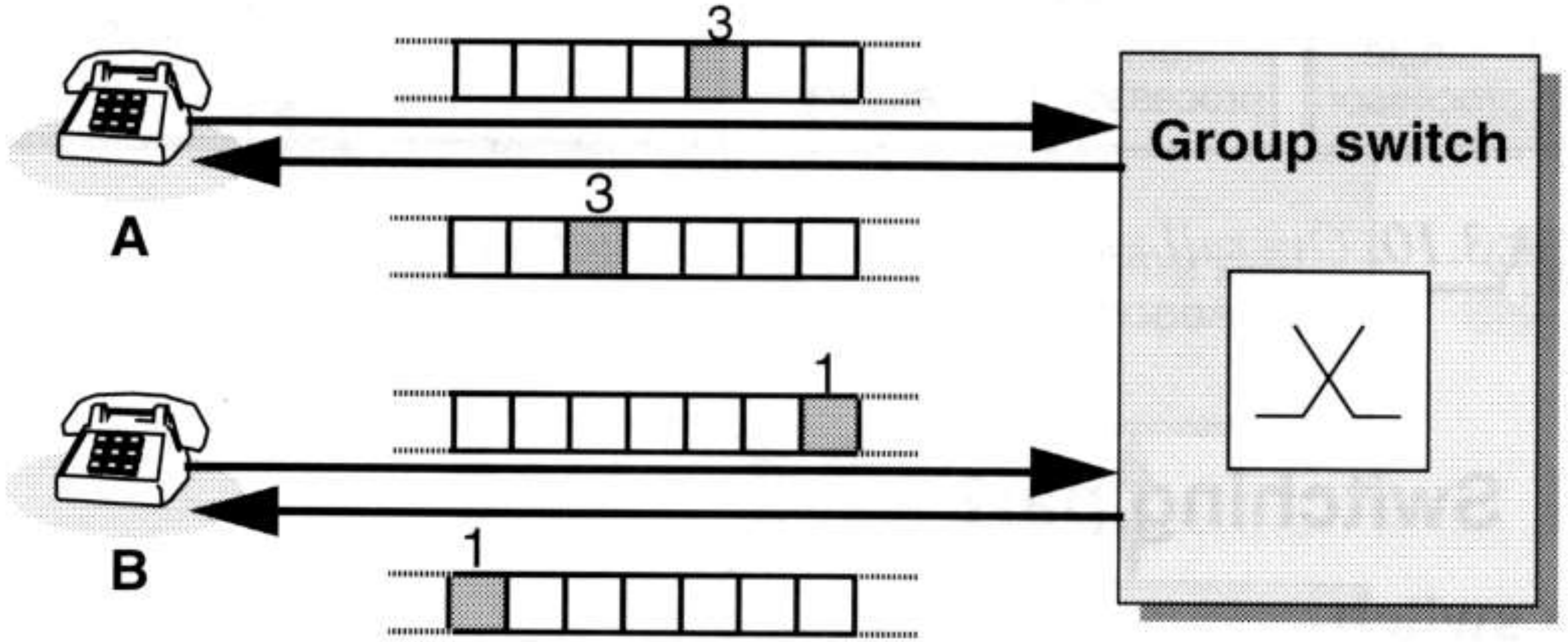
Switching techniques in public networks



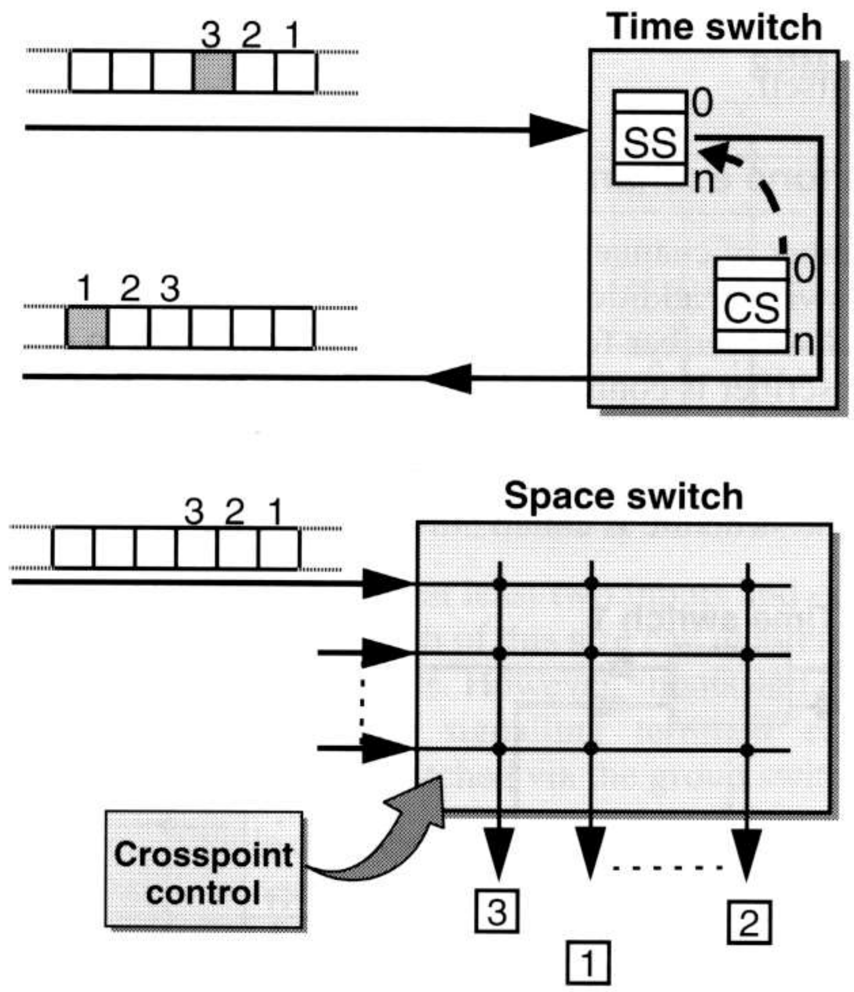
Principles of circuit switching



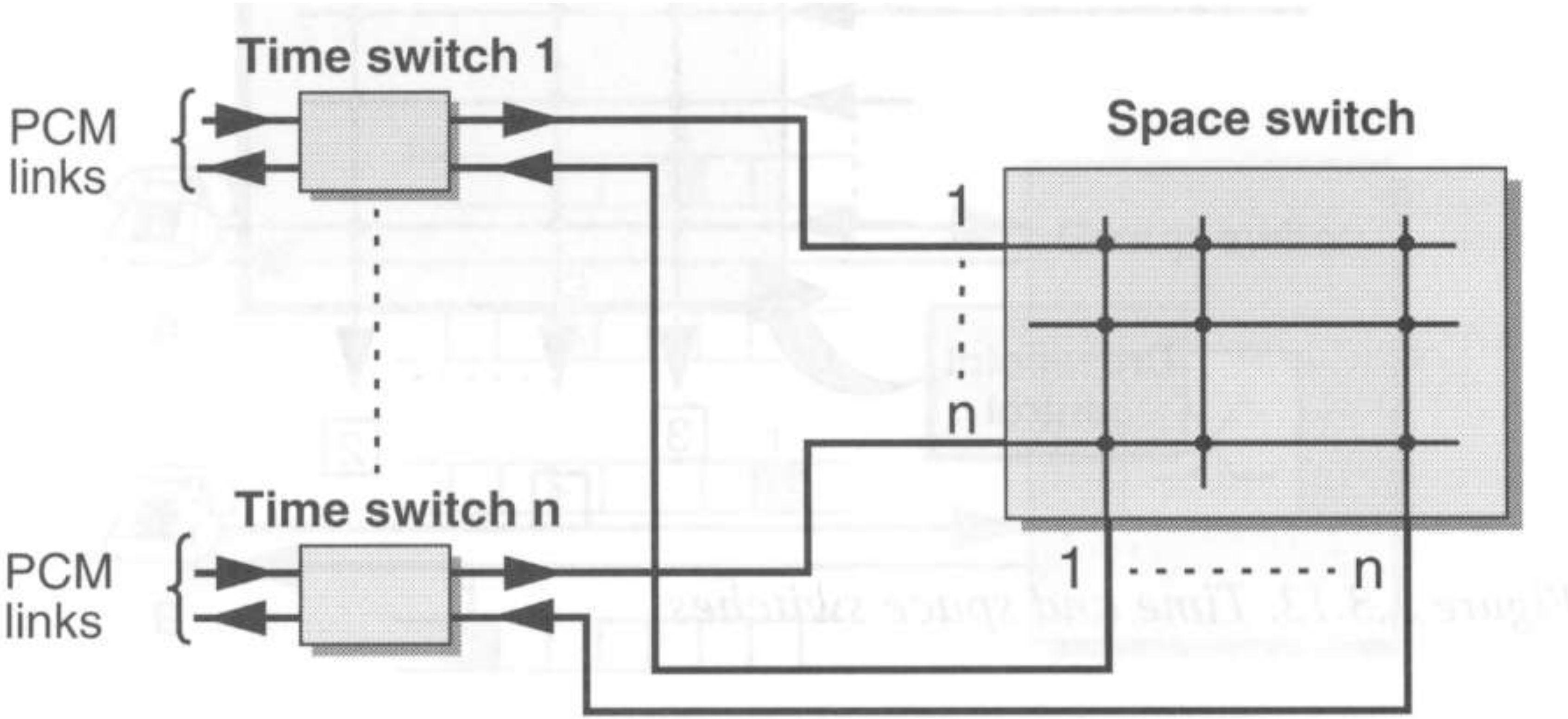
The realisation of circuit switch in a time division multiplexing system by interconnecting incoming and outgoing time slots



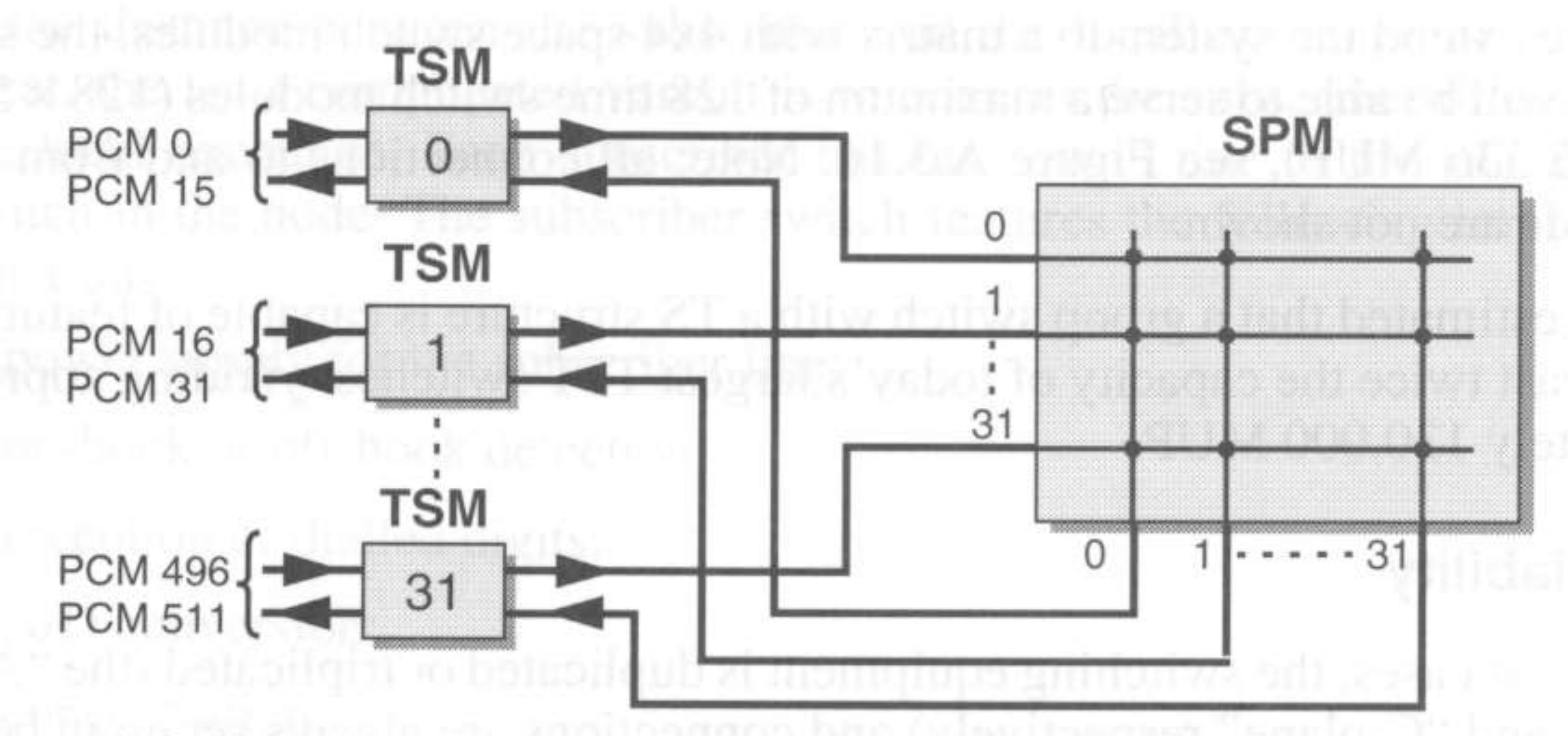
Time and space switches



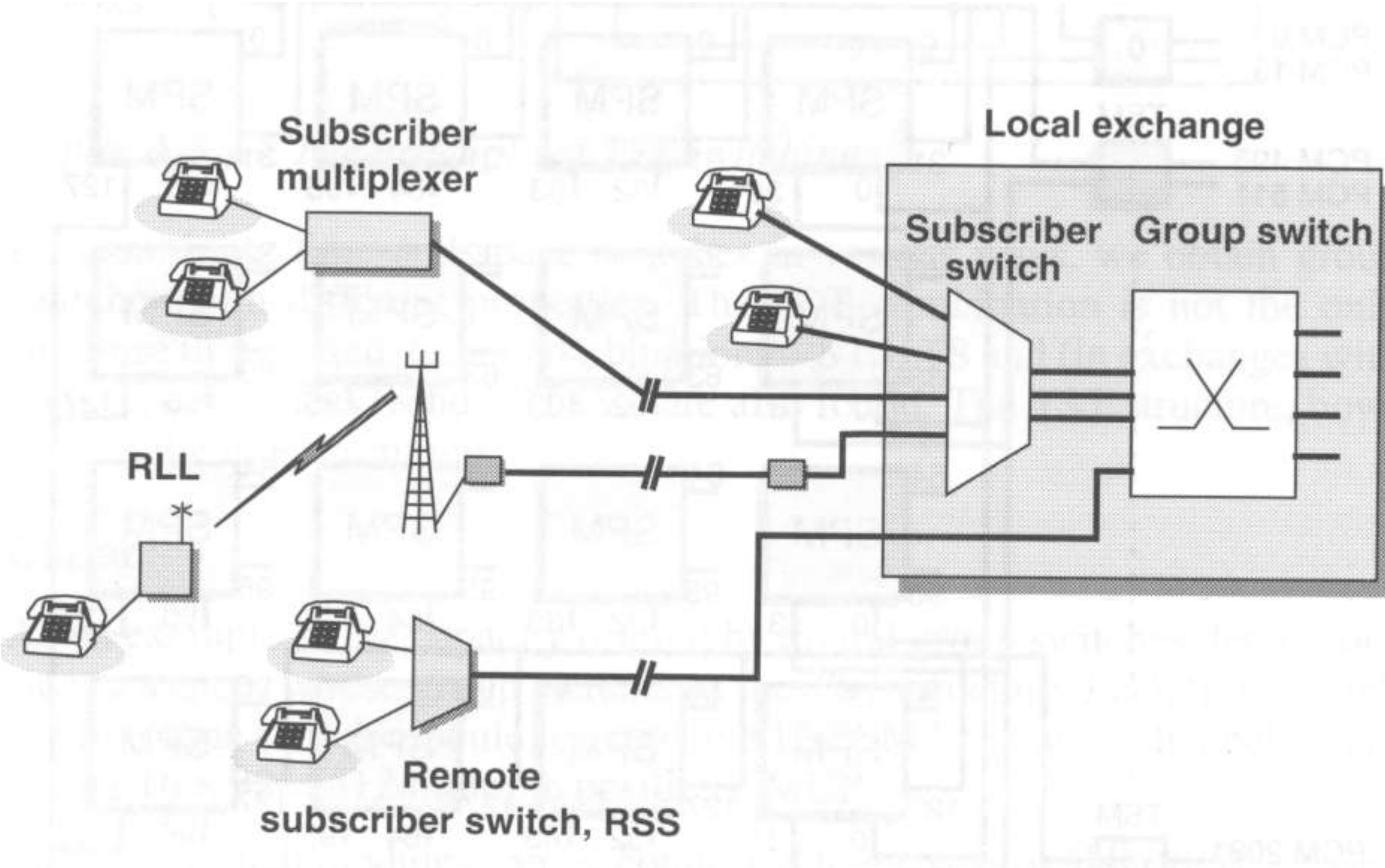
The principle of TST switching



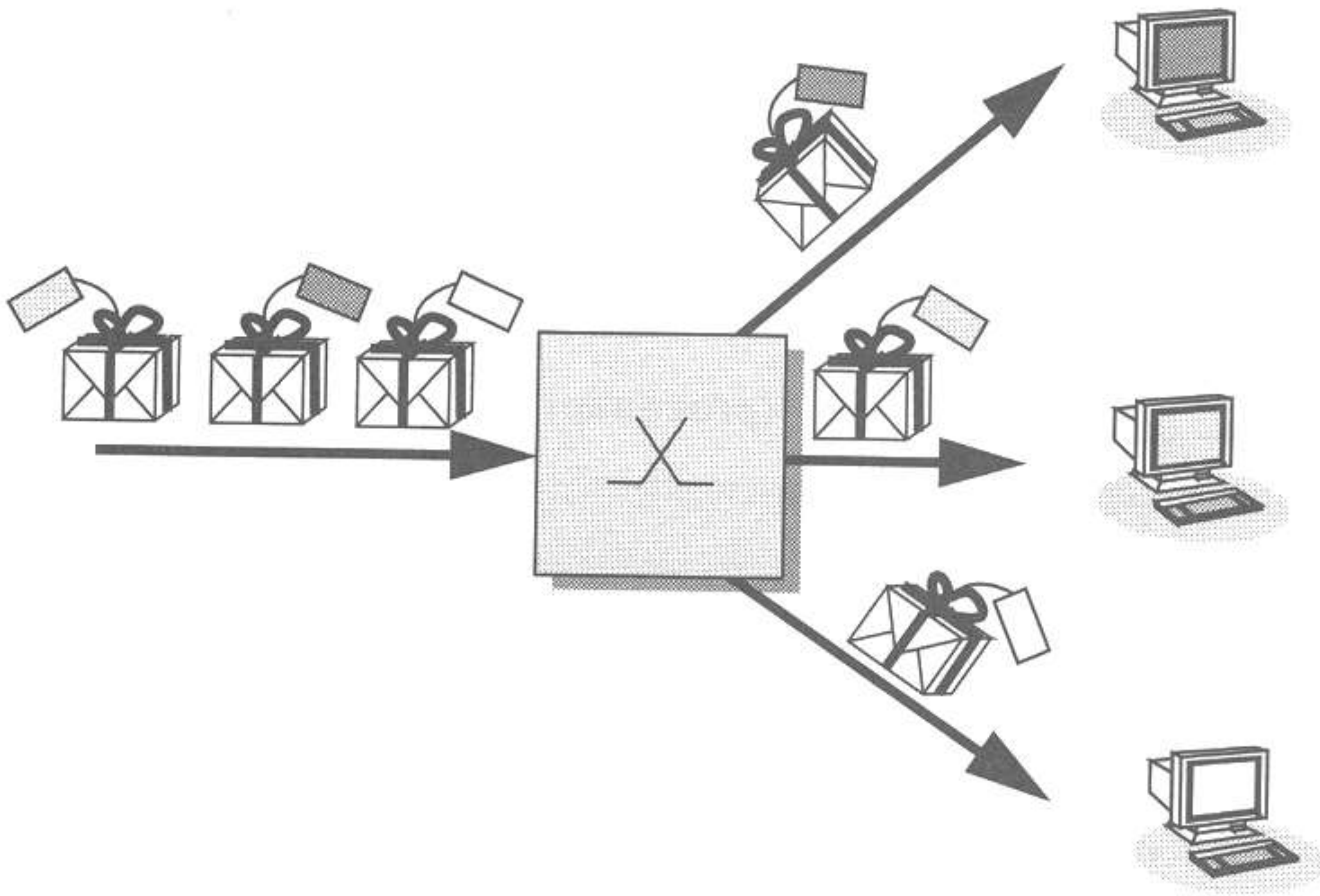
Group switch with 512 multiple position



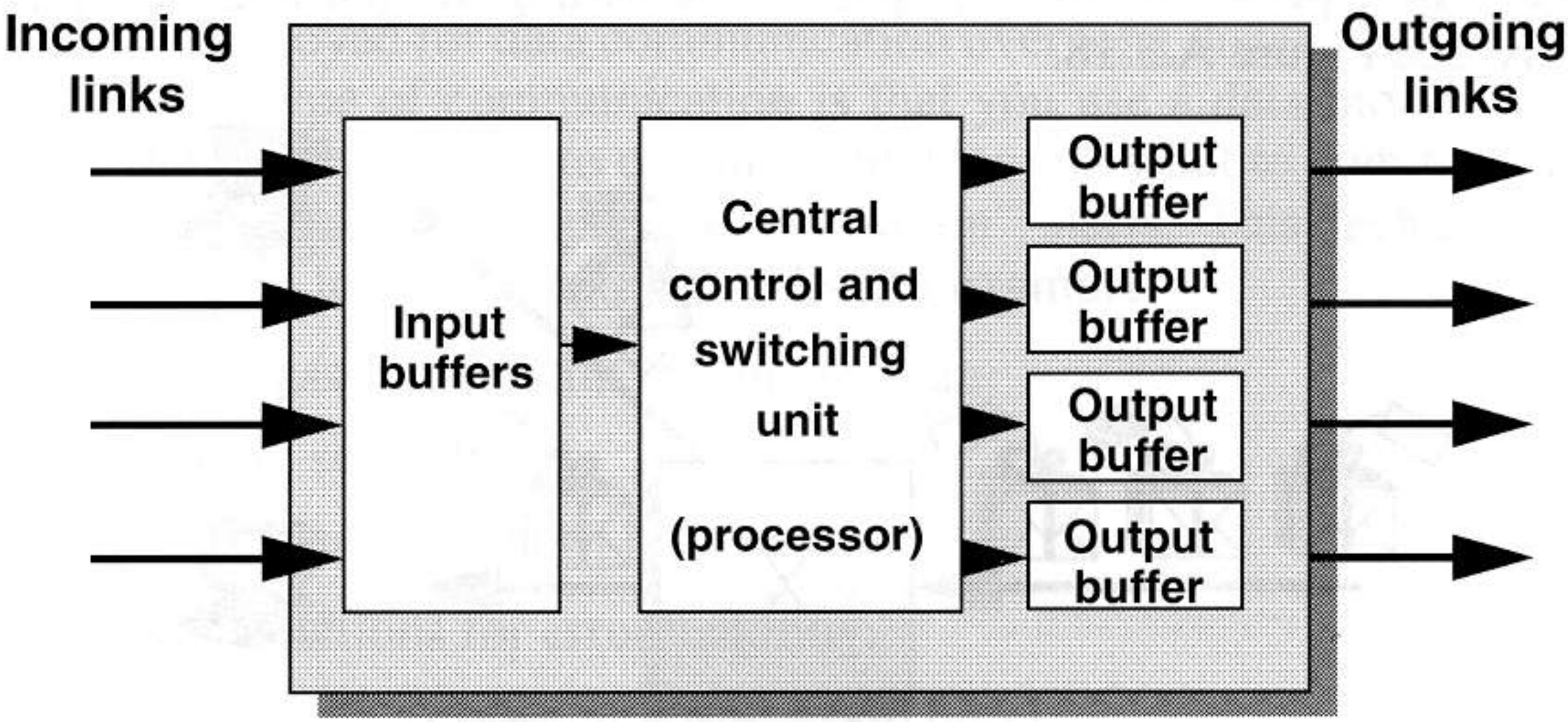
Connections to the local exchange



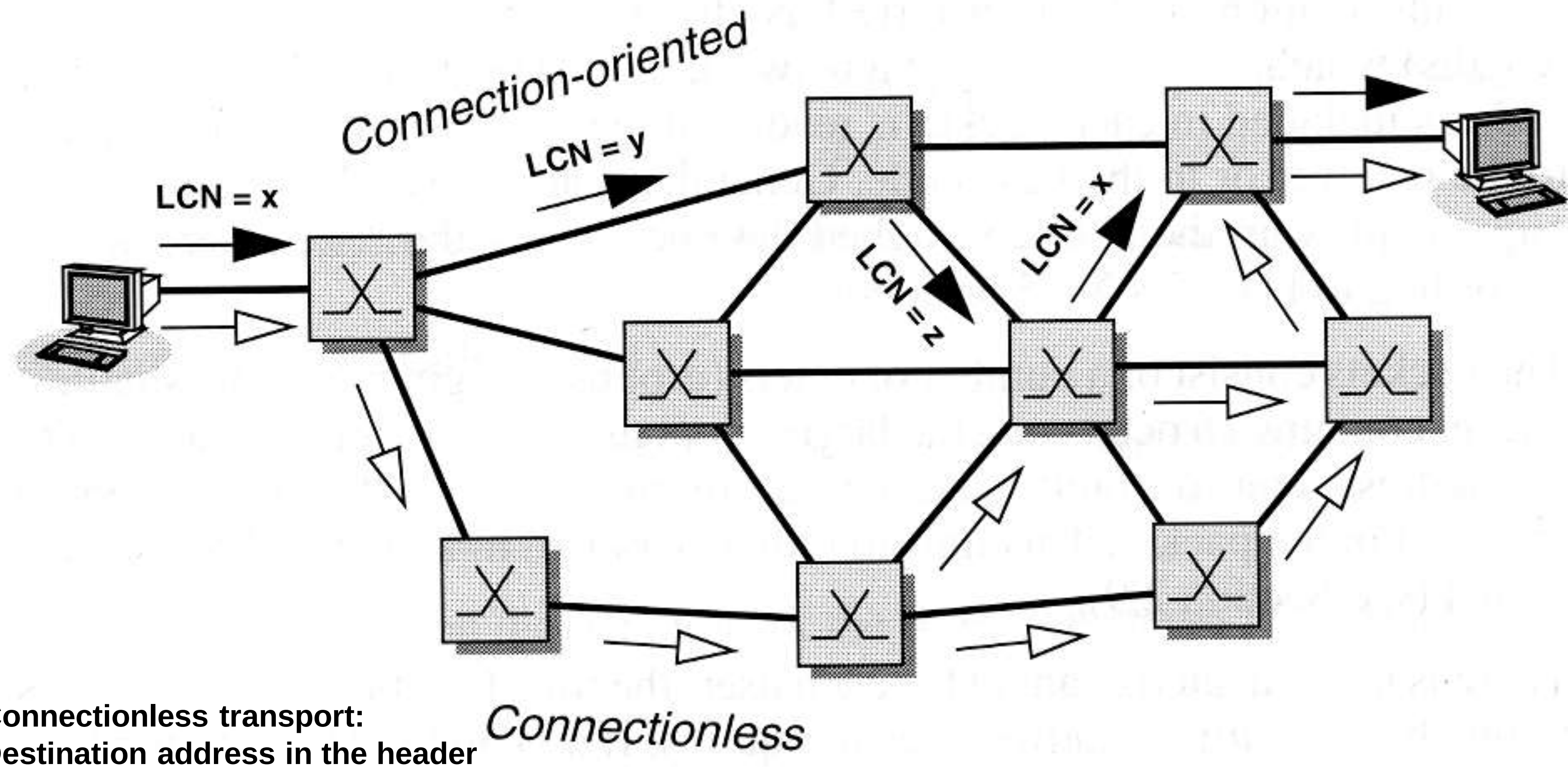
Node for packet switching



Packet node structure

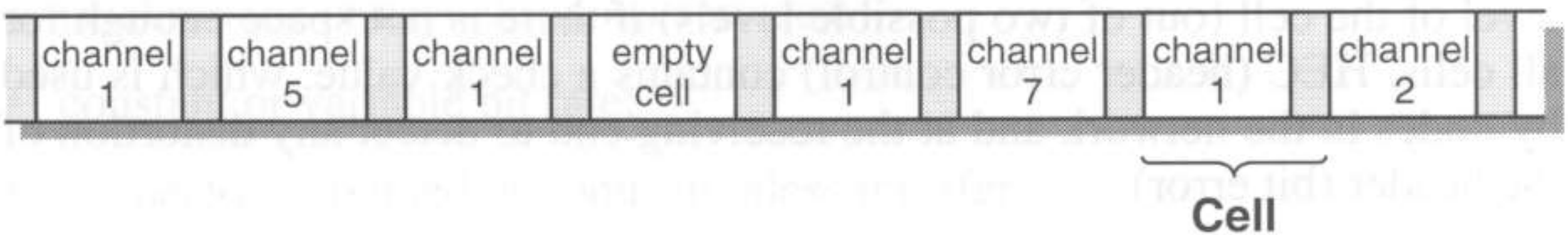


Connection oriented transfer phases:
Connection setup (setup packet with complete address, Logical Channel Number stored in each node
Data transmission (only LCN in the header)
Release



Connectionless transport:
Destination address in the header
Path selection in the nodes
Different packets have different delay
The order of received packets has no guarantee

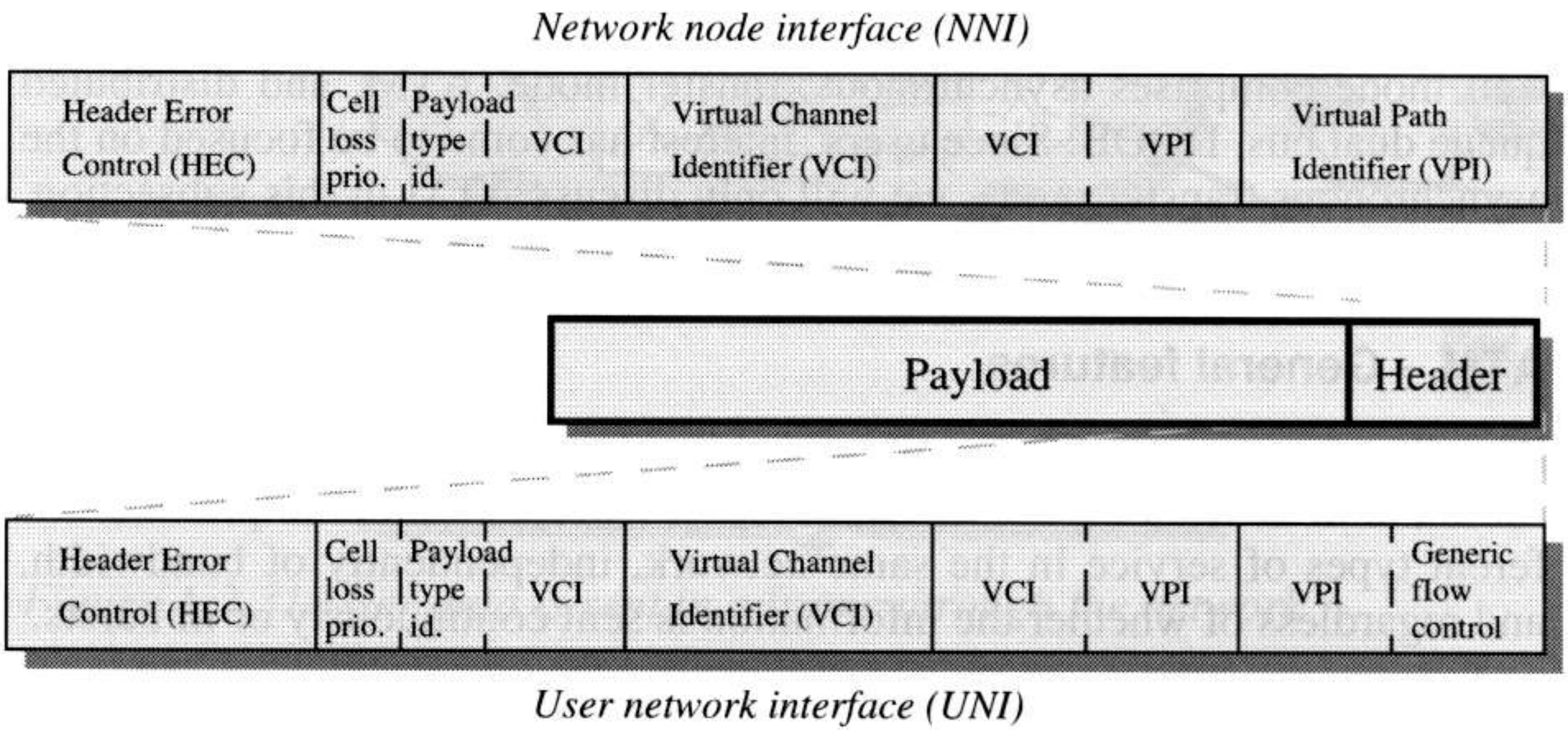
ATM cell switching principle
Fixed cell (packet) length – 53 bytes
5 octets header, 48 octet payload



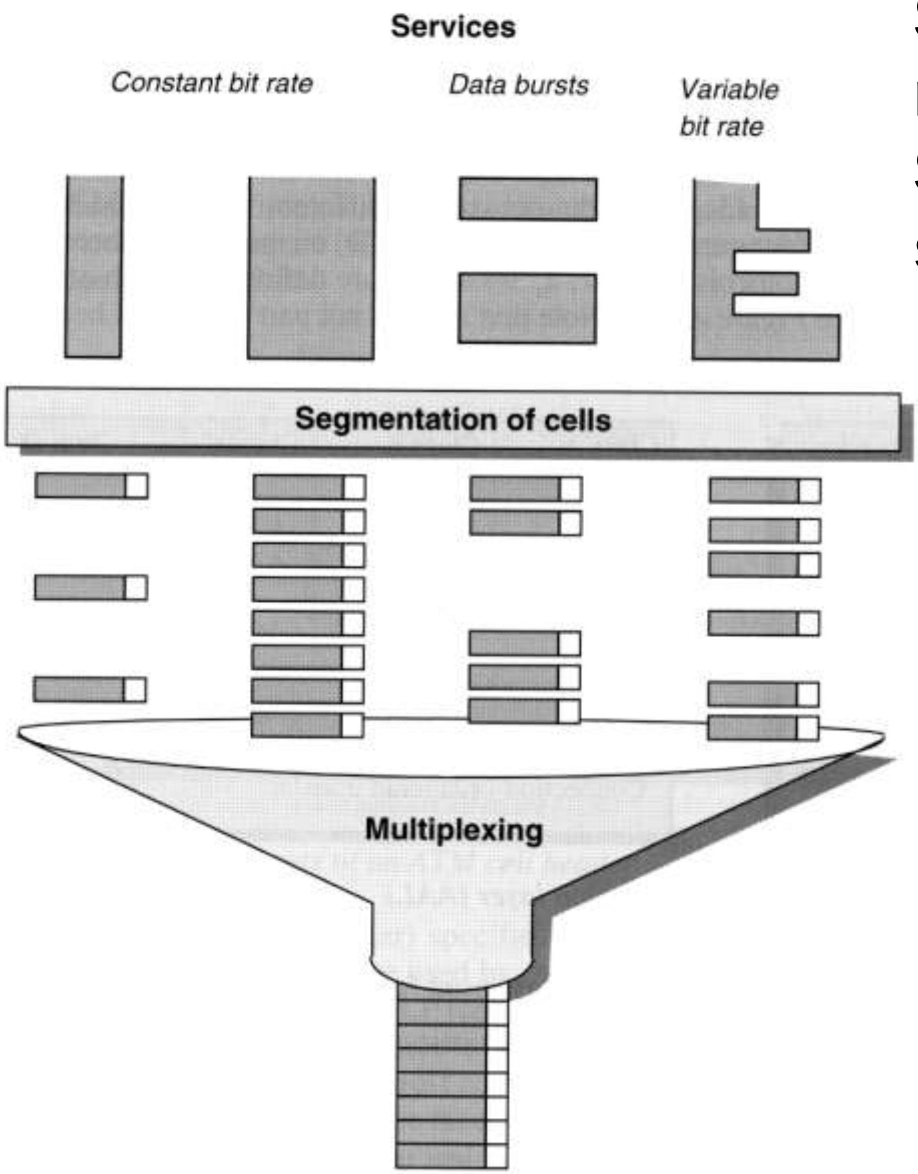
Why connection oriented packet switching?

- Connectionless – only best effort quality (www = world wide waiting)
- Connection oriented – QoS guarantee is possible
- Quality measures: delay, jitter, packet loss.

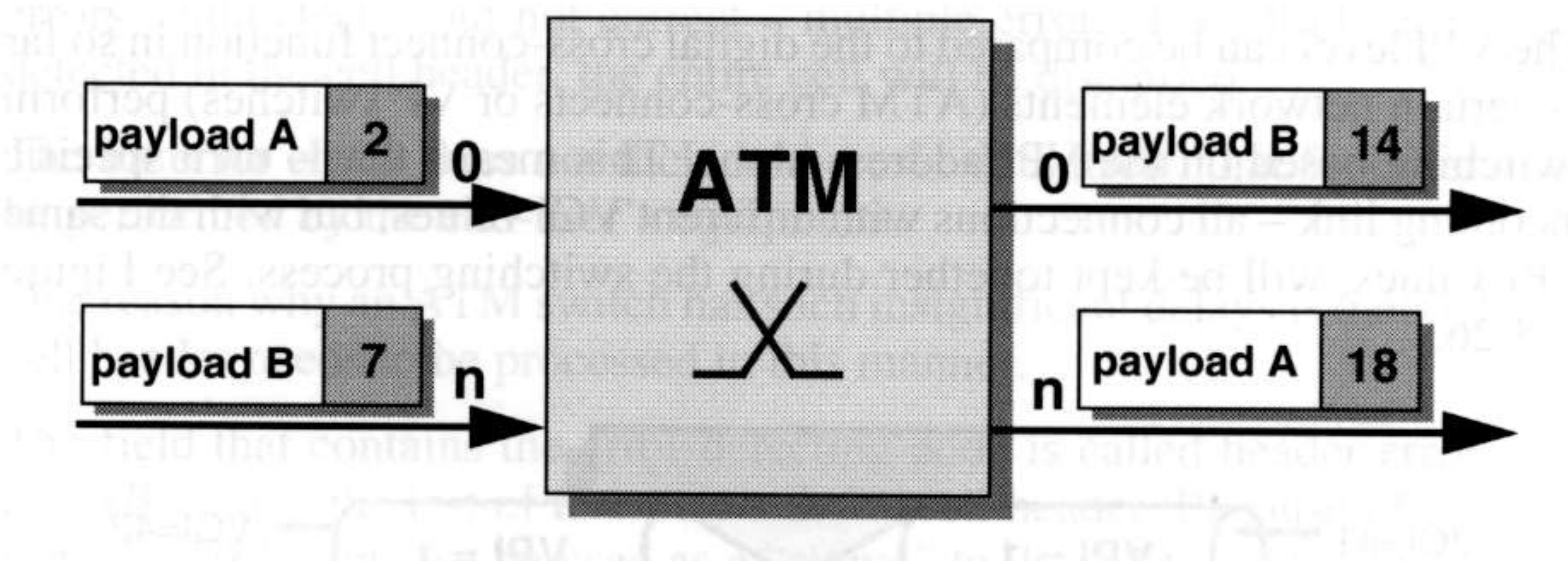
Content of ATM cell header



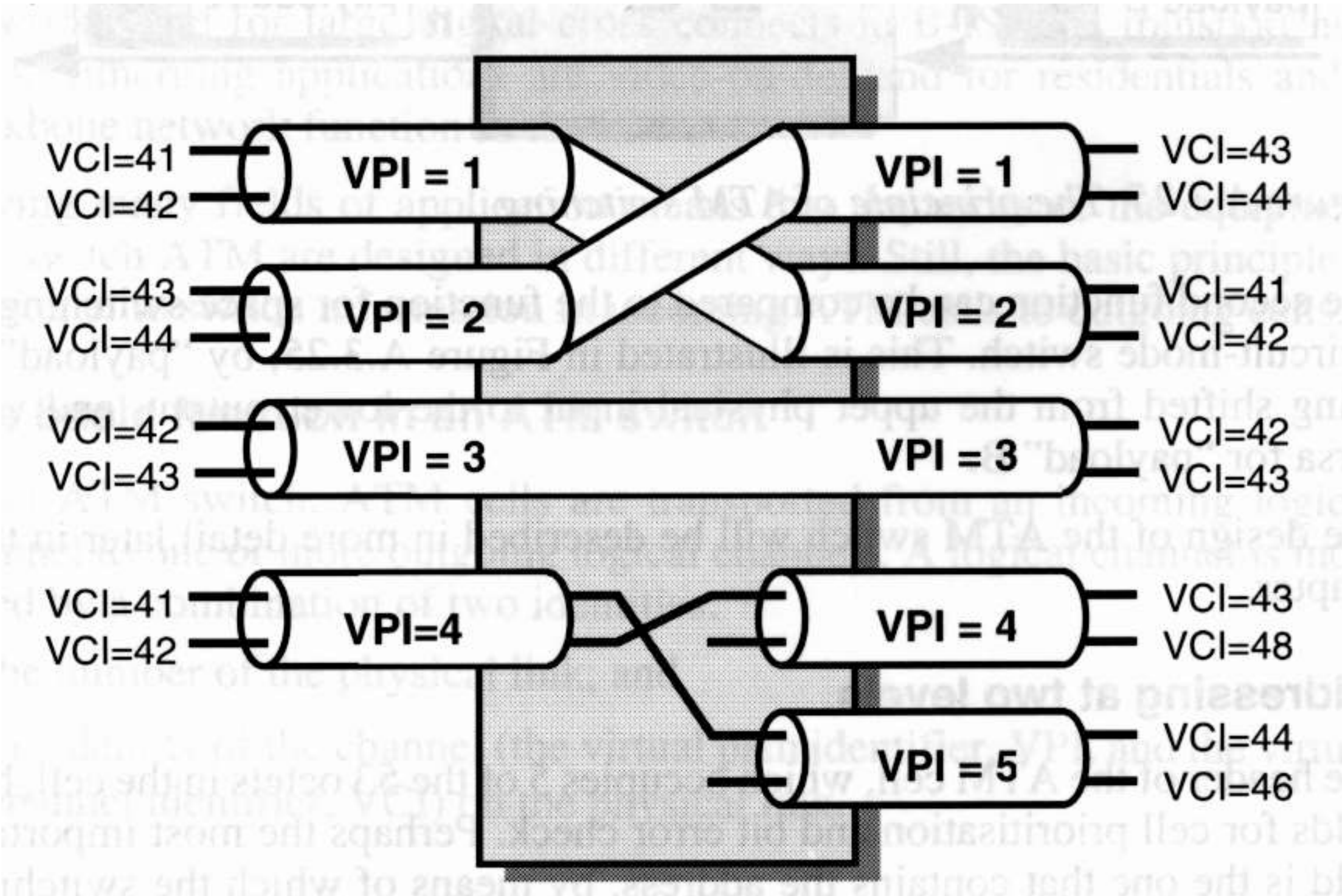
Segmentation and multiplexing of different Services in cell based systems



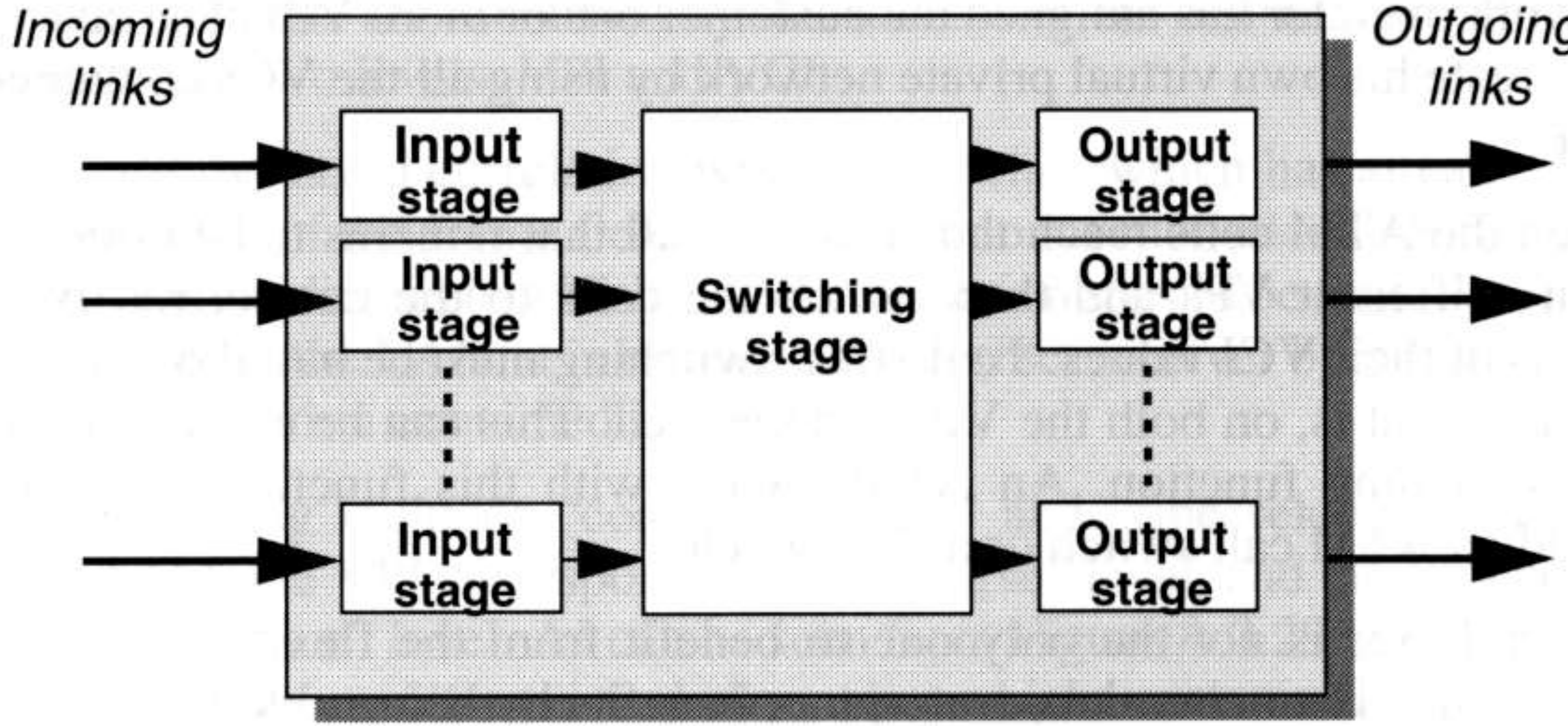
The principle of ATM switching



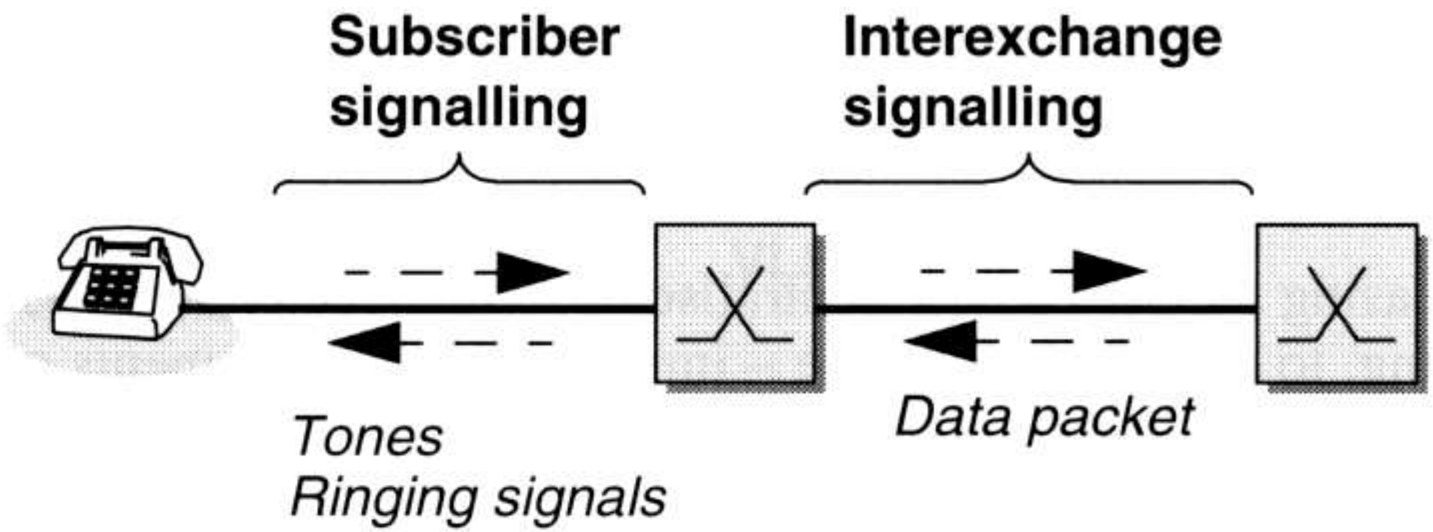
VP (Virtual Path „coarse level addressing”) and VC (Virtual Channel „fine level addressing”)



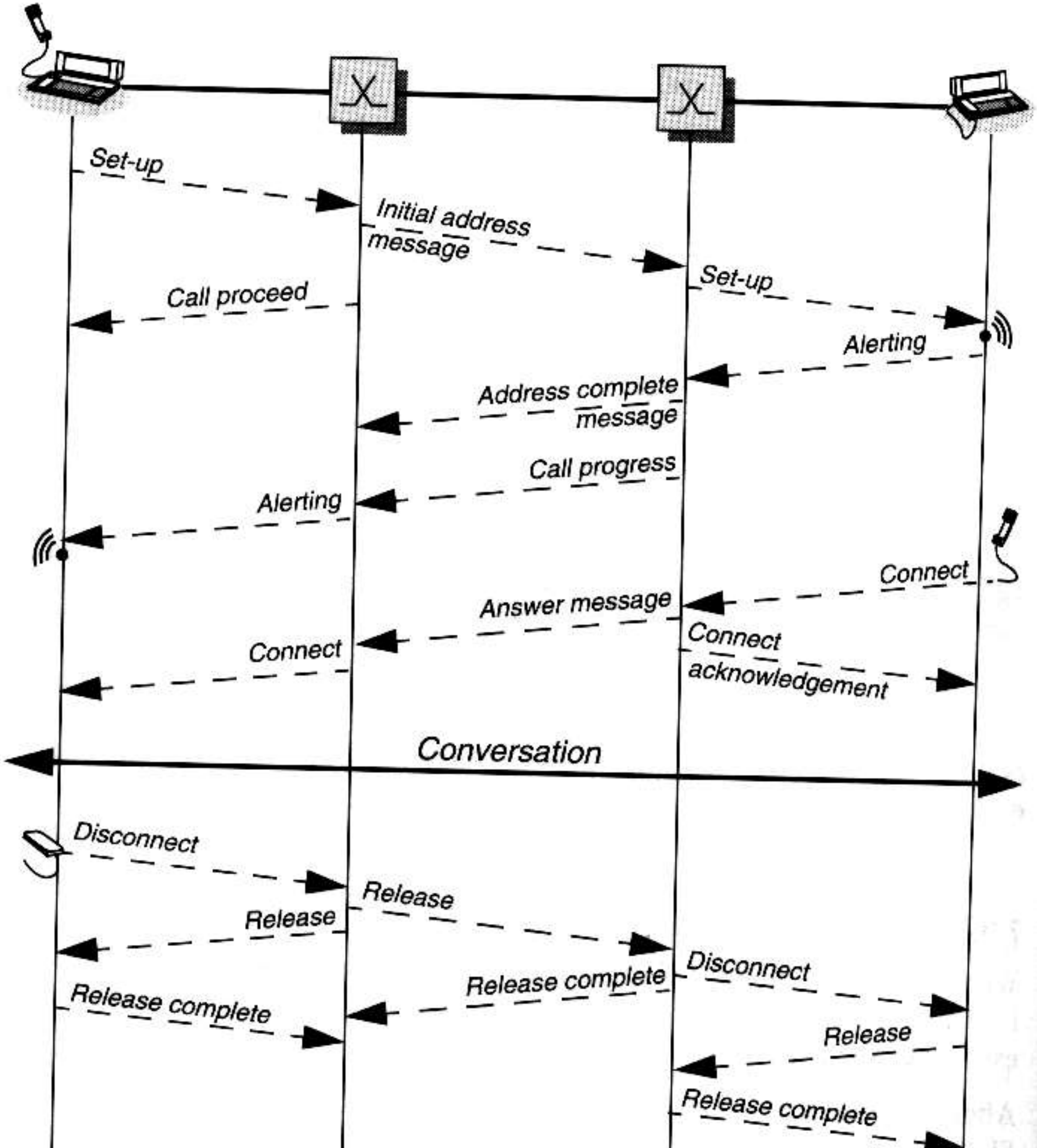
The structure of the ATM switch



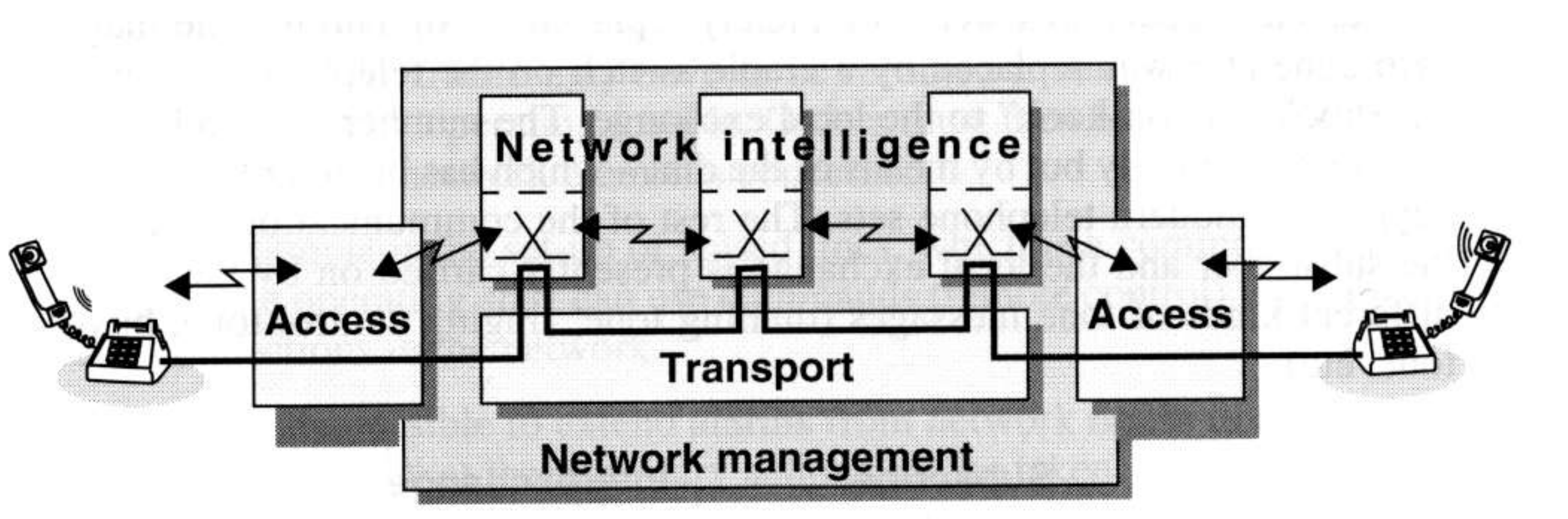
Signalling principles in circuit switching



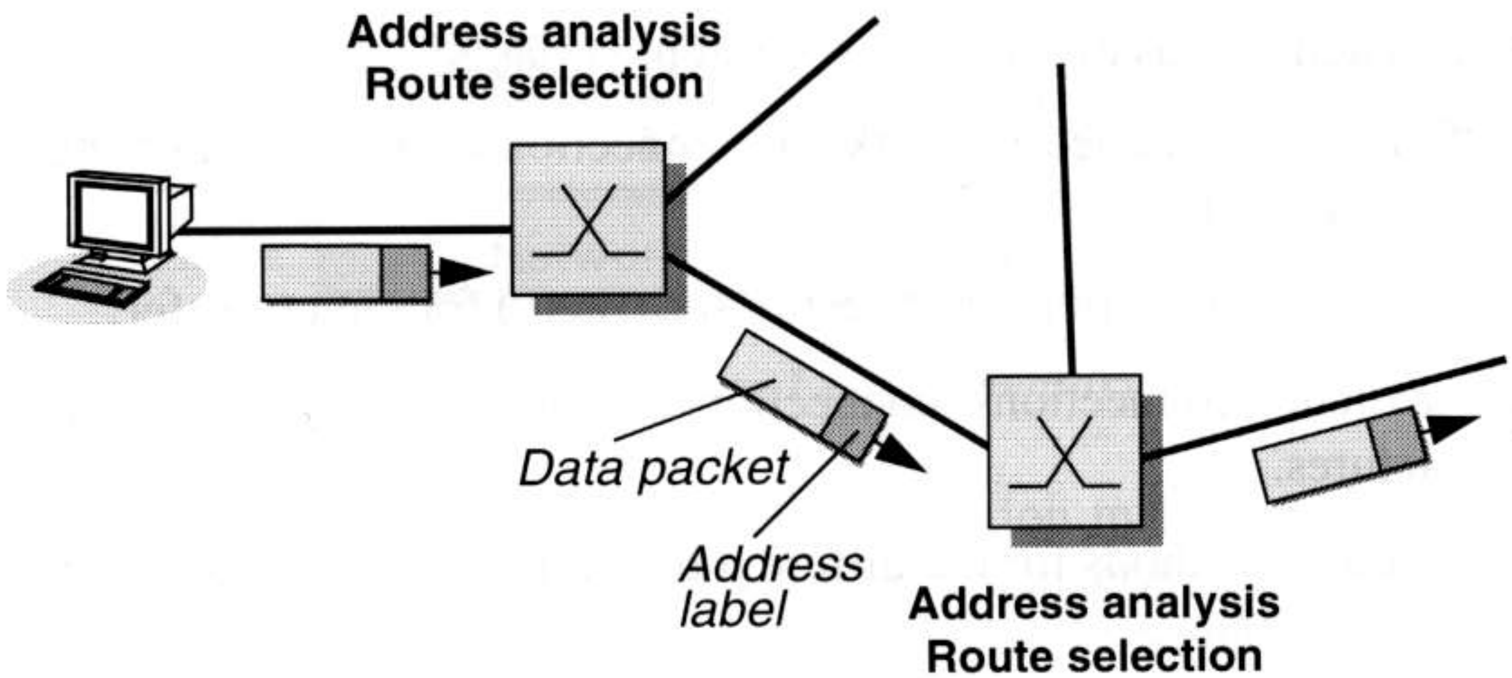
Signalling flow in a telephone call



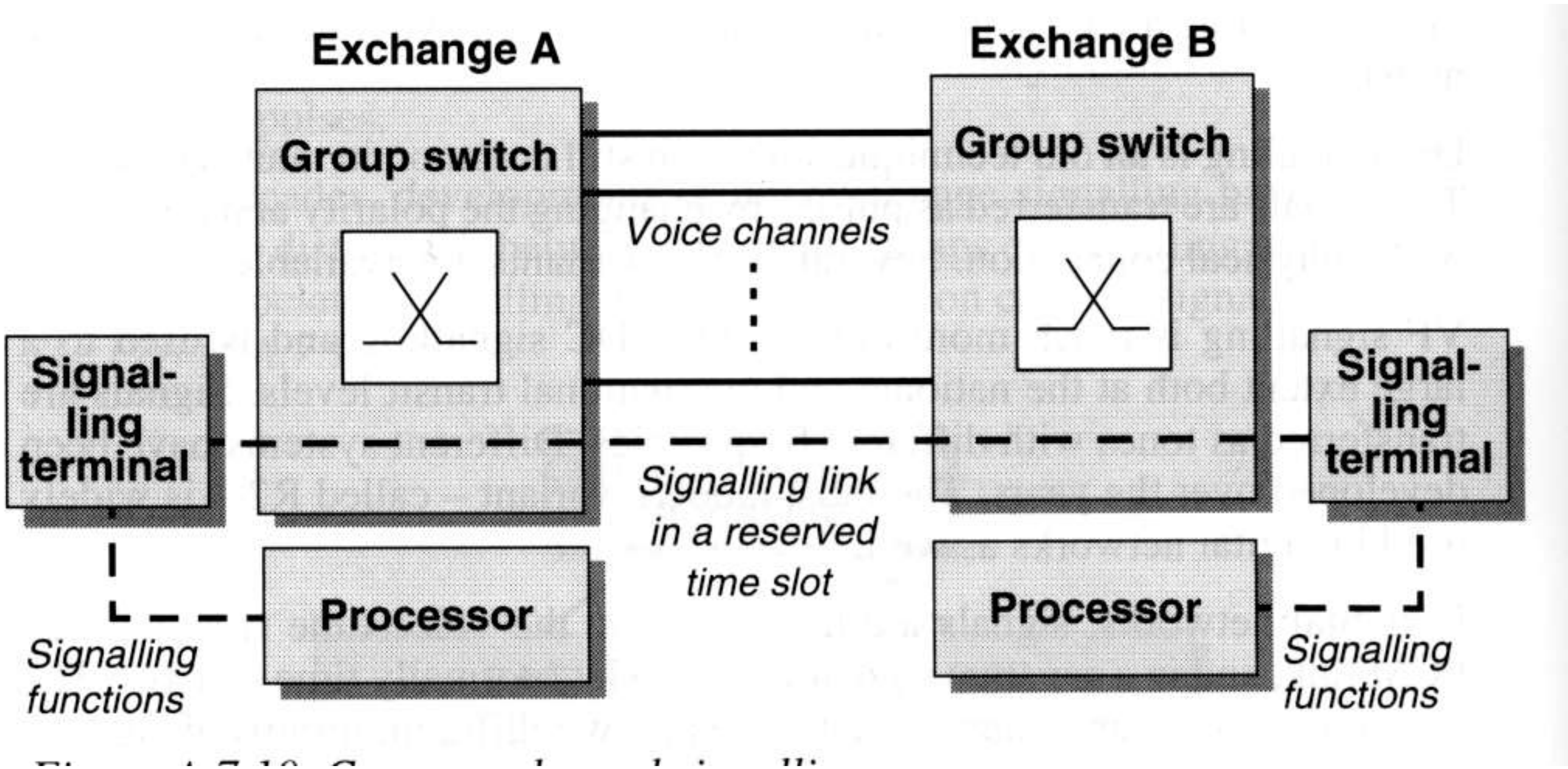
Signalling for distributed supplementary services or a mobile telephone call



Signalling in packet switched networks



Principles of Common Channel Signalling CCS



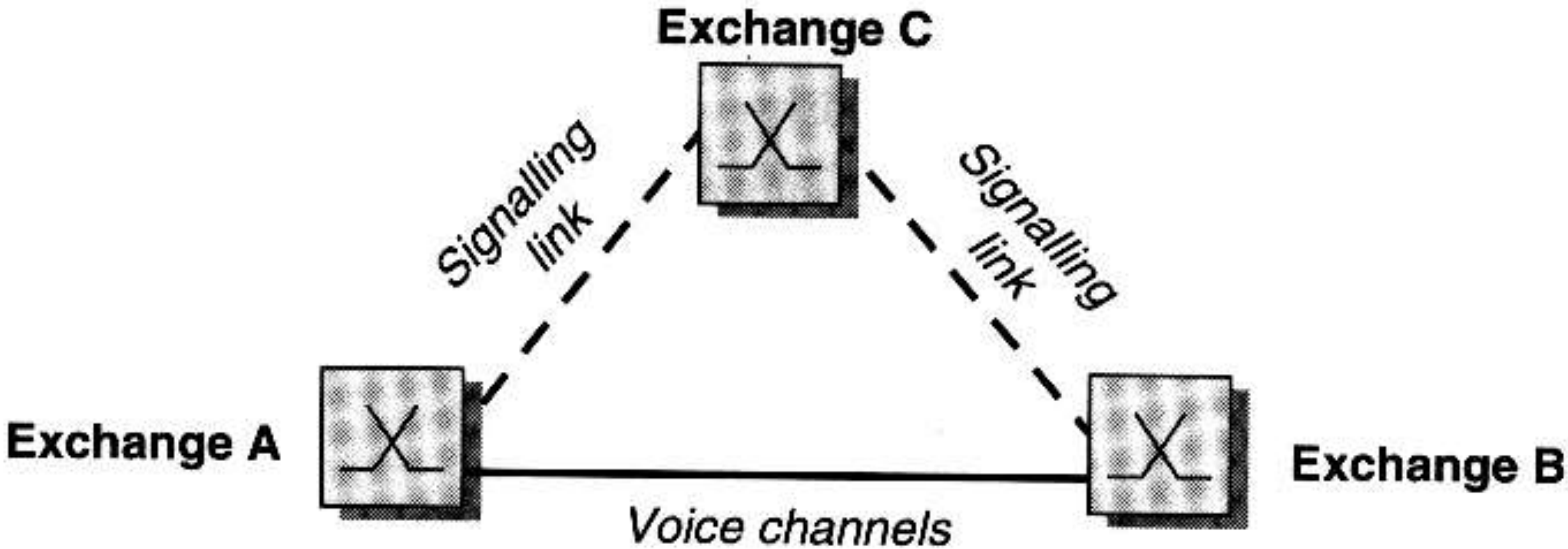
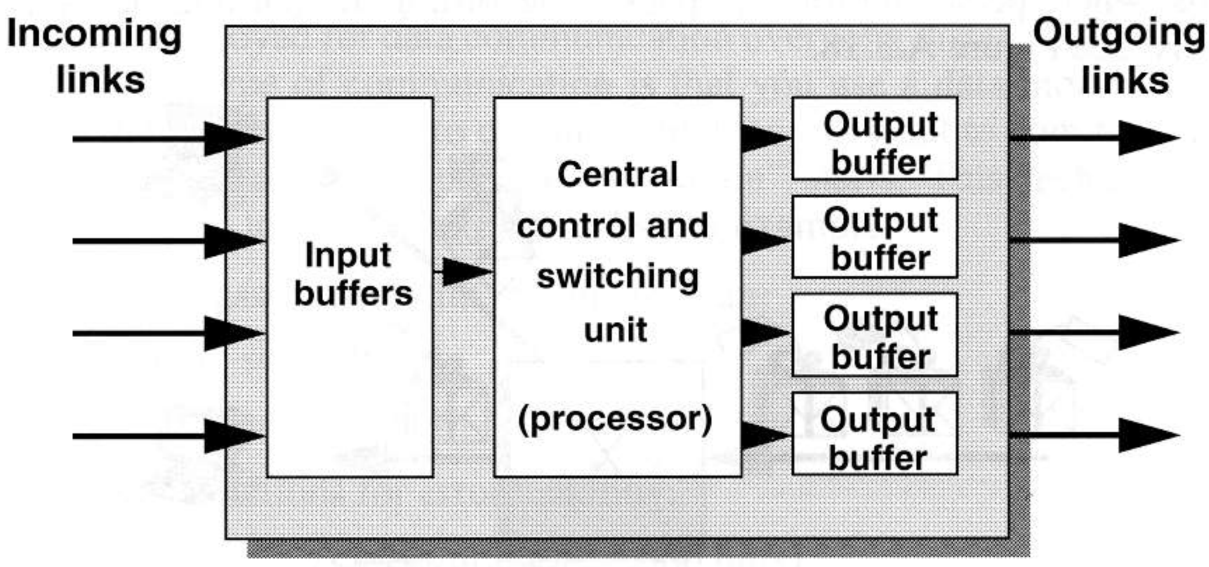


Figure A.7.11. Signalling links

Circuit or packet switching???

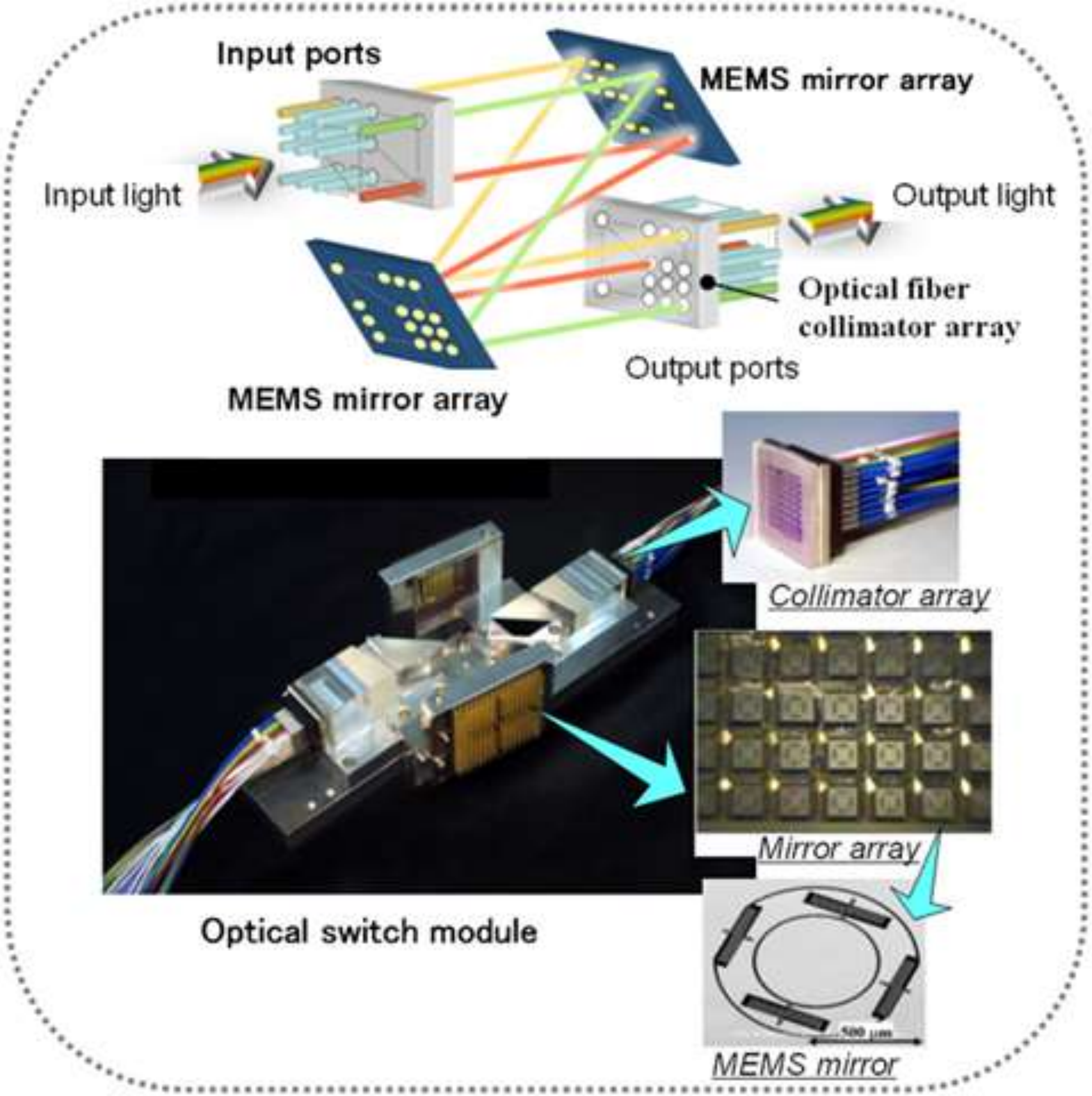
- A rule of thumb:
  - Band is cheap: circuit switching
  - Processing is cheap: packet switching
- Distributed vs. centralized intelligence in the network
- Packet processing by 10^{16} b/s ????



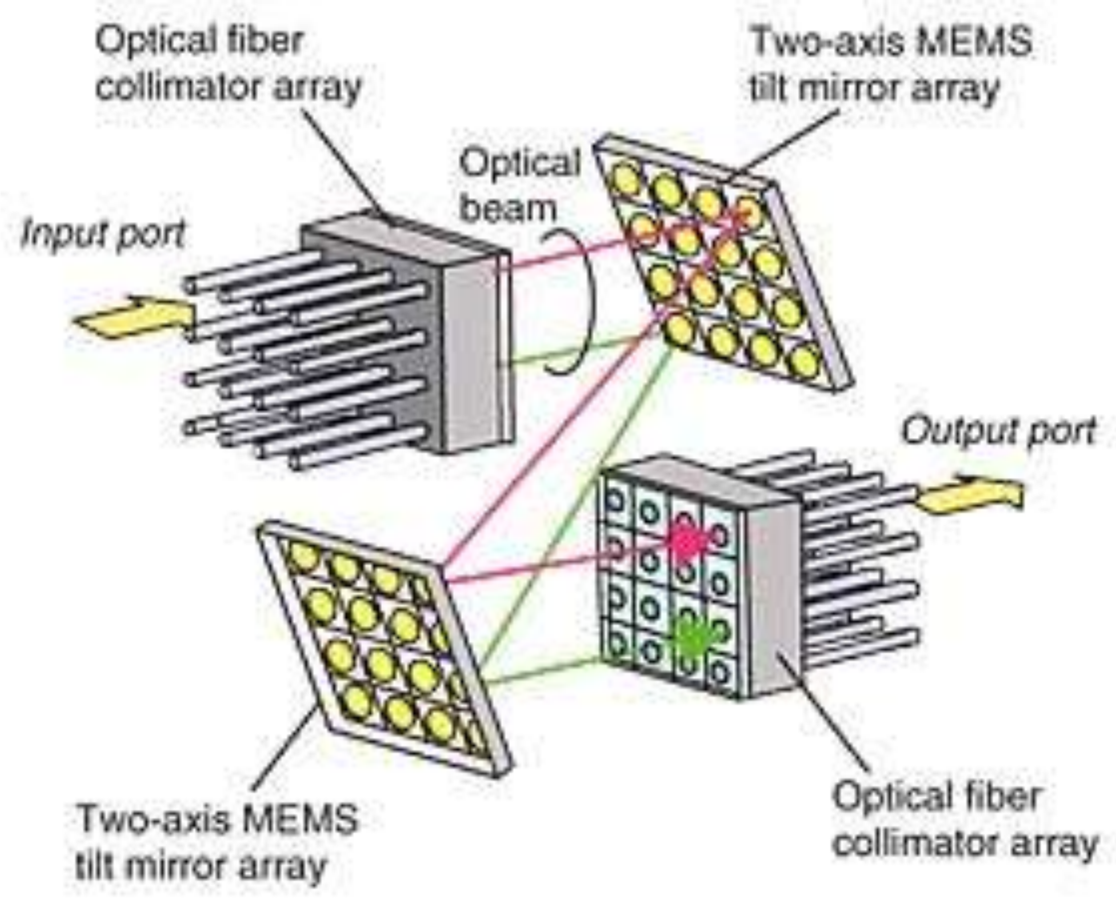
Photonic Fibre Switches

- In free-space devices, the light is focused from the input fibre, deflected by a micro-mirror (typically several times) and finally launched into the output fibre. The Micro-Electro-Mechanical Systems (MEMS) technology is mature and can produce switch matrices with up to hundreds of input and output ports (128x128 or 256x256), low insertion loss (IL), very low cross talk, low power consumption, millisecond switching speed, and broadband operation. The mirrors can typically be controlled electro-magnetically, electro-statically or by piezoelectric actuators.

Operational principle and example of 3D MEMS array



collimator


Optical fiber
collimator array
Two-axis MEMS
tilt mirror array
Optical
beam
Input port
Output port
Two-axis MEMS
tilt mirror array
Optical fiber
collimator array

Point-to point like network node solution in a modern highway system