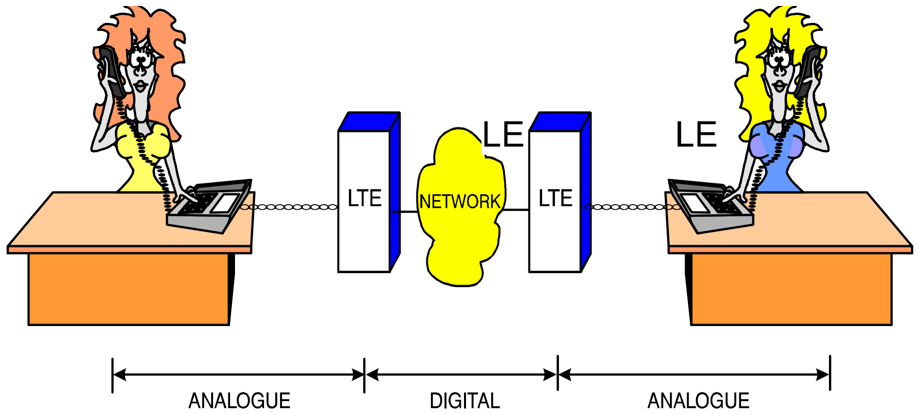
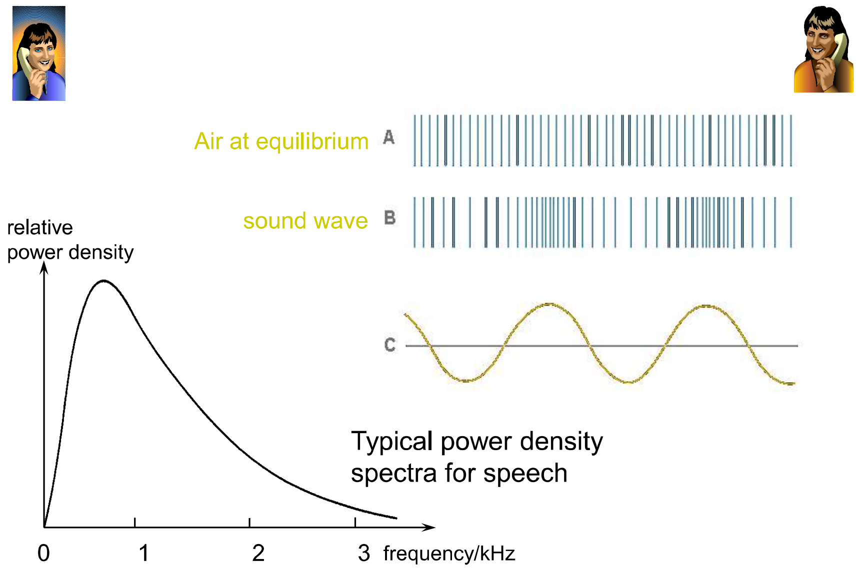
COMMUNICATION SYSTEM REVIEW

DIGITAL TELEPHONY

The Telephone System

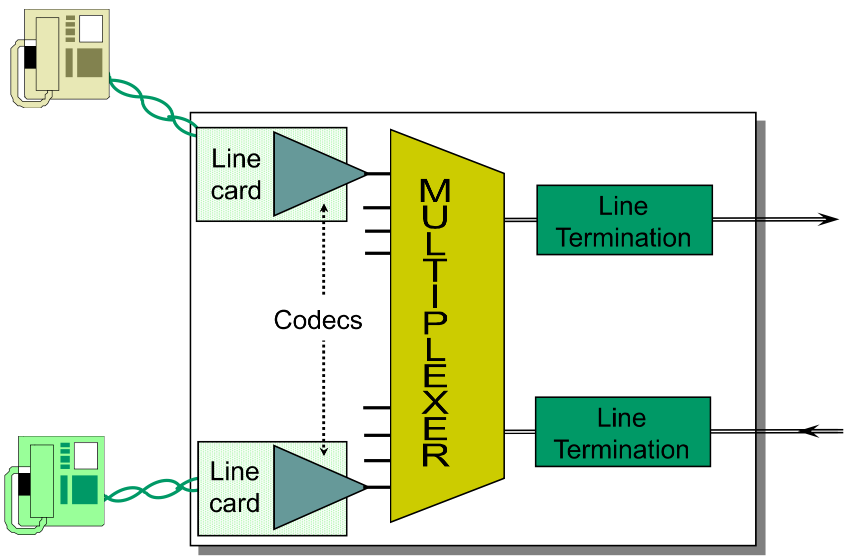


Power in the Human Voice

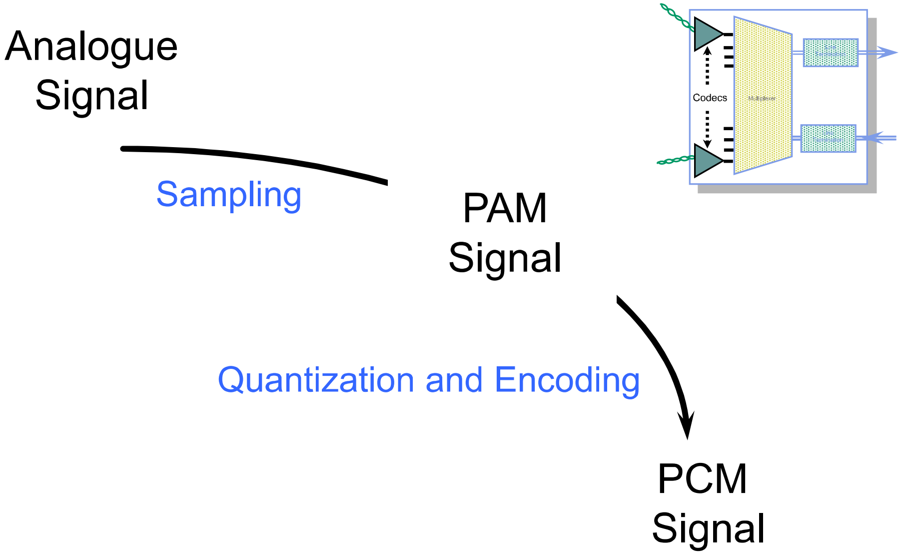


Typical power density spectra for speech

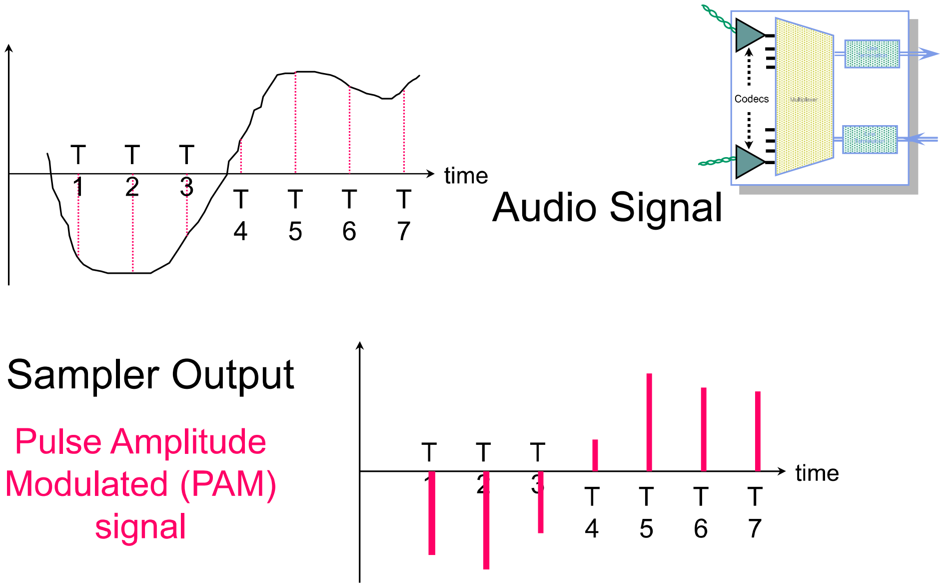
Local Exchange



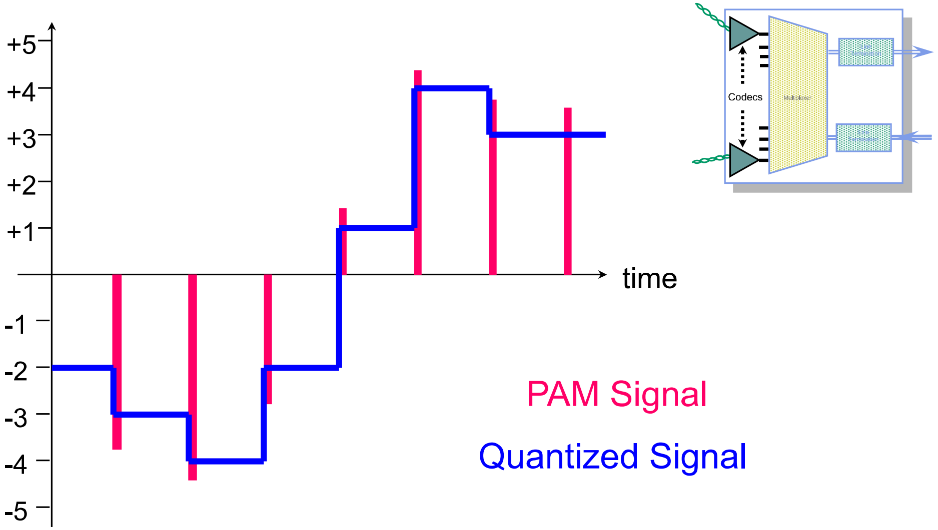
The CODEC



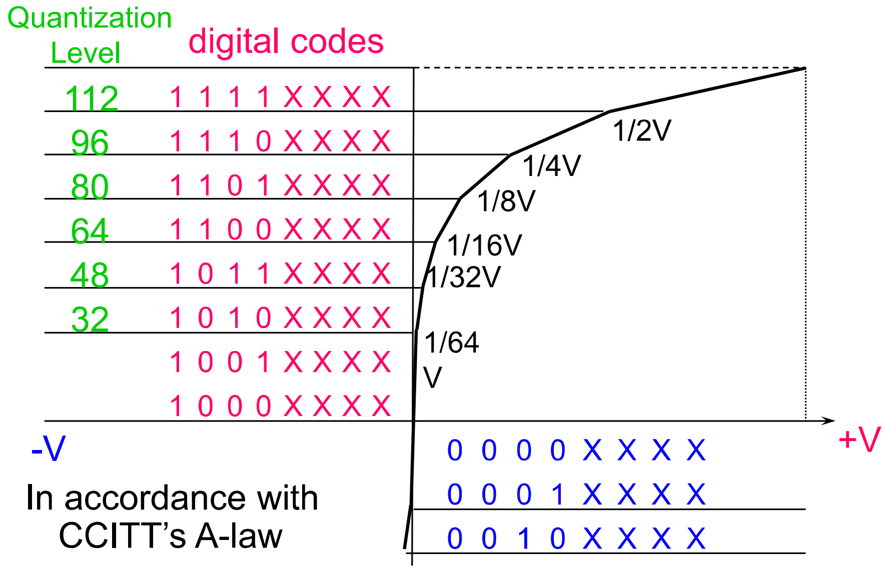
Sampling



Linear Quantization



Non-Linear Quantization & Encoding



CODEC Quantizing - USA

The North American standard for assigning and decoding a signal's amplitude is μ-law 255. This law defines how many quantizing levels are used and how they are arranged

The Formula

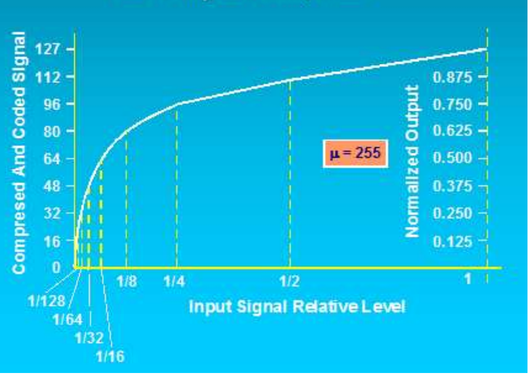
$$F\mu(\chi) = sgn(\chi)\,\frac{\ln(1+\mu|\chi|)}{\ln(1+\mu)}$$

$\mu = 255$ (compression parameter)

Character Signal Binary Code *

1	0	0	0	0	0	0	0
1	0	0	0	1	1	1	1
1	0	0	1	1	1	1	1
1	0	1	0	1	1	1	1
1	0	1	1	1	1	1	1
1	1	0	0	1	1	1	1
1	1	0	1	1	1	1	1
1	1	1	0	1	1	1	1
1	1	1	1	1	1	1	1

* This is the bit pattern transmitted for positive input values. The left-most bit is a 0 for negative input values



CODEC Quantizing - Europe

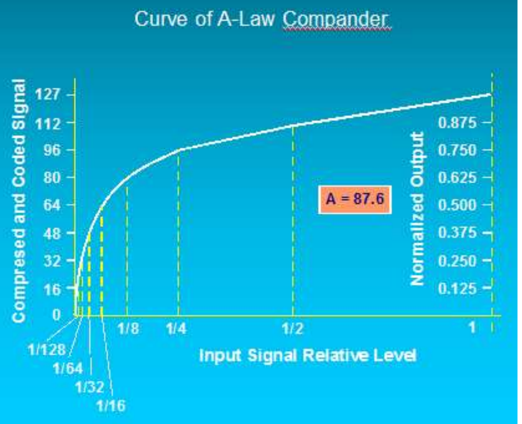
The European standard is the A-law and its formula is:

$$F(\chi) = sgn(\chi)\,\frac{A|\chi|}{1+\ln(A)} \quad \text{when} \quad 0 \le |\chi| < \frac{1}{A} \quad \text{and} \quad F(\chi) = sgn(\chi)\,\frac{1+\ln A|\chi|}{1+\ln(A)} \quad \text{when} \quad \frac{1}{A} \le |\chi| \le 1$$

Character Signal Binary Code *

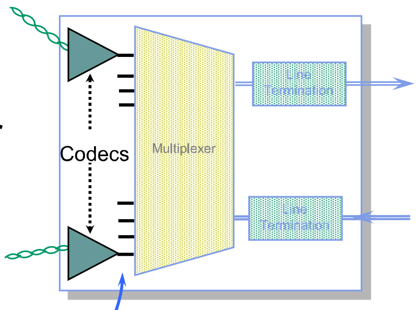
1	1	1	1	1	1	1	1
1	1	1	1	0	0	0	0
1	1	1	0	0	0	0	0
1	1	0	1	0	0	0	0
1	1	0	0	0	0	0	0
1	0	1	1	0	0	0	0
1	0	1	0	0	0	0	0
1	0	0	1	0	0	0	0
1	0	0	0	0	0	0	0

* For positive input values. The left-most bit is a 0 for negative input values. Even bits (beginning with 1 at the left) are inverted before transmission



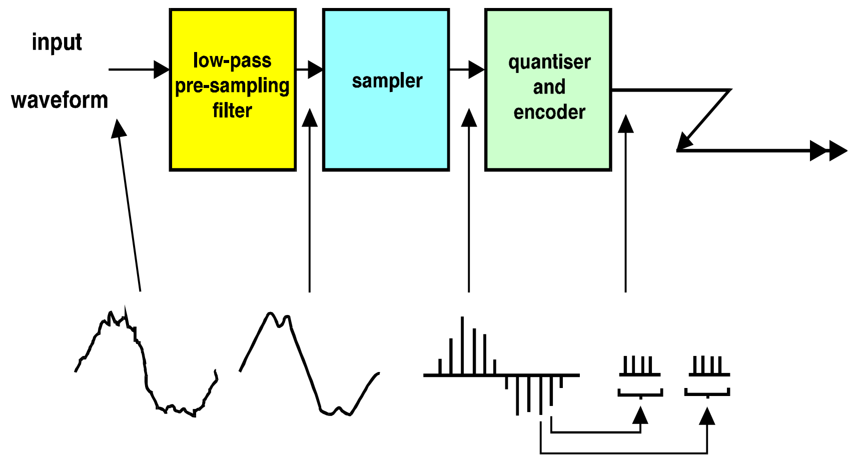
PCM Signal Data Rate

8000 samples per sec X 8 bits per sample

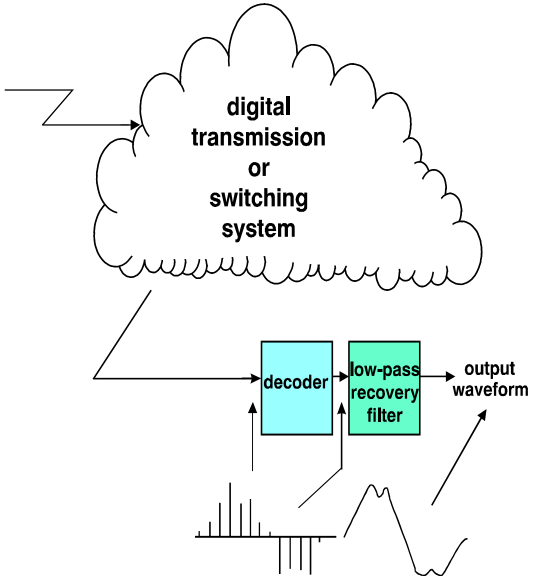


64kbit/s

The Processes of PCM ?

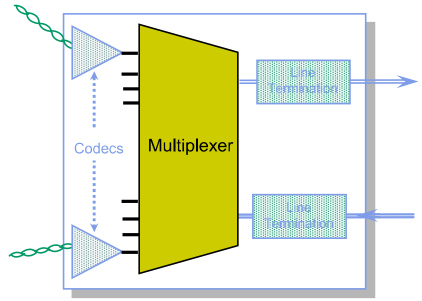


The Processes of PCM ?

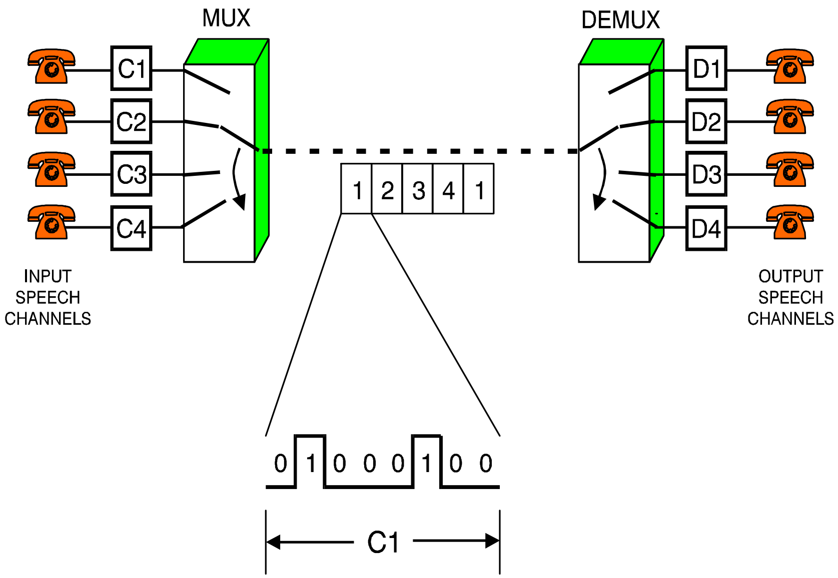


Digital Multiplexing

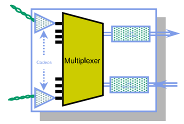
- Time Division Multiplexing
- 2Mbit/s PCM Frame
- Digital Hierarchy

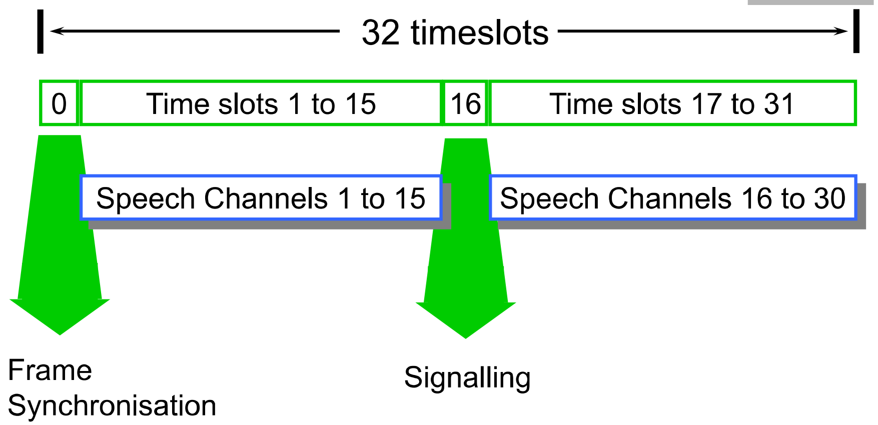


Time Division Multiplexing (TDM)

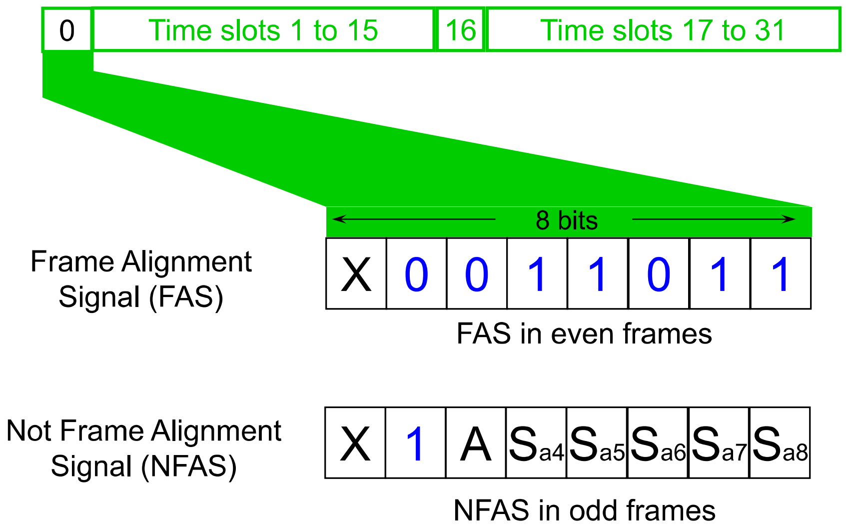


The 2Mbit/s PCM Frame

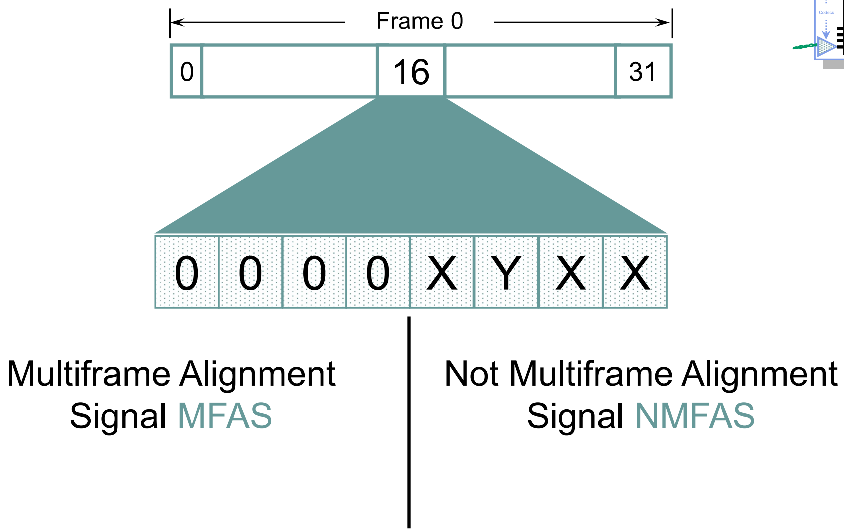




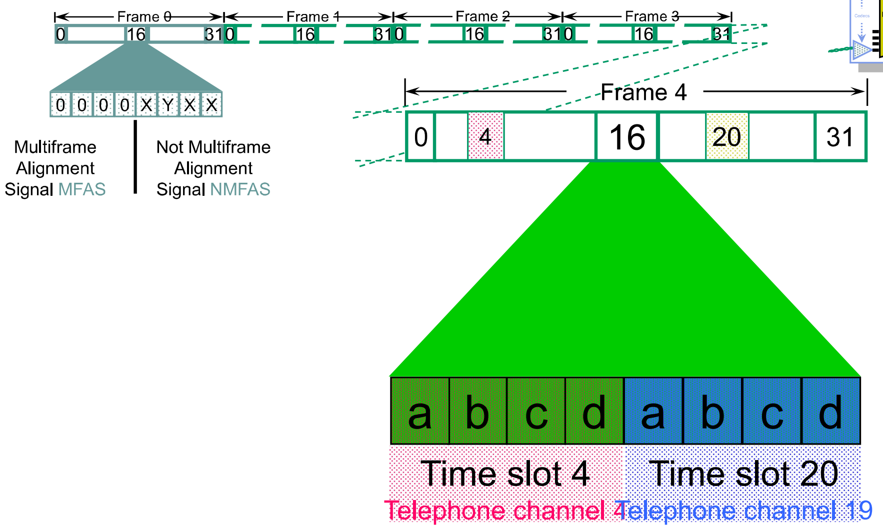
Frame Synchronization



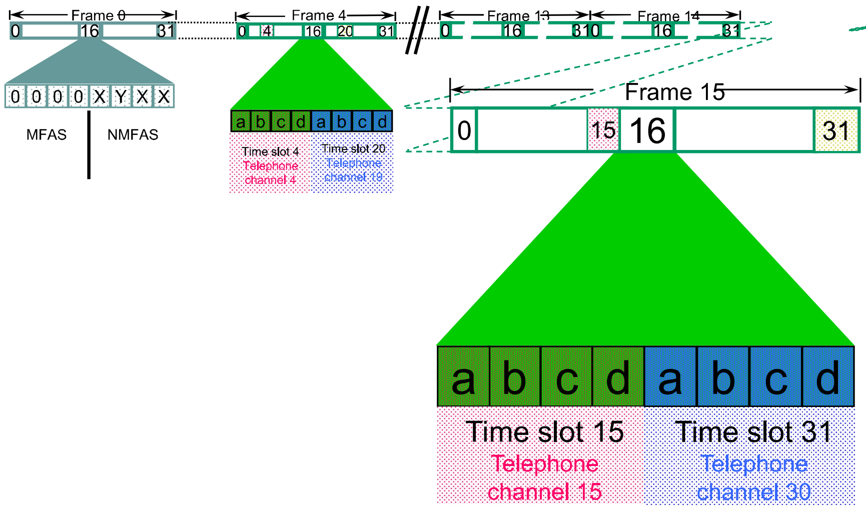
Signalling Multiframe



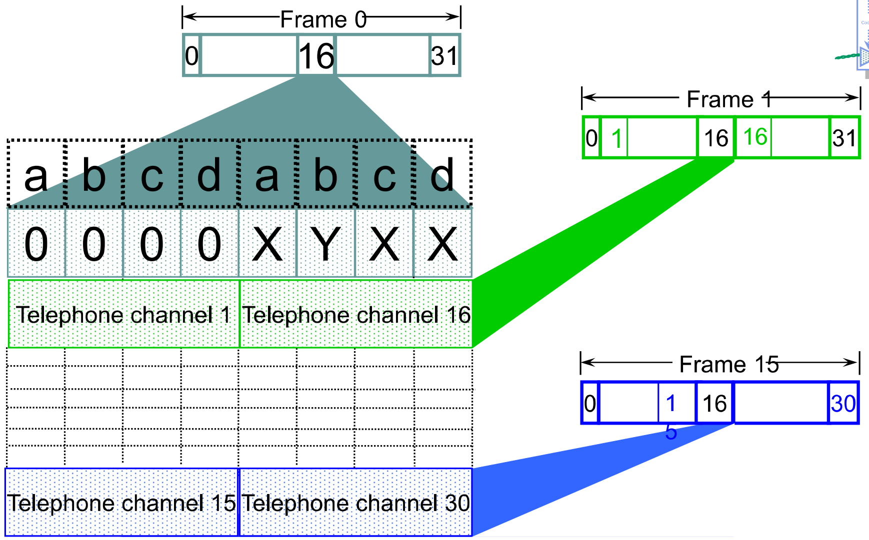
Signalling Multiframe



Signalling Multiframe



Signalling Multiframe



CAS Signalling

PCM frame number	Bits in time slot 16							
	a	b	c	d	a	b	c	d
0	0	0	0	0	X	Y	X	X
1	Telephone channel 1				Telephone channel 16			
2	Telephone channel 2				Telephone channel 17			
3	Telephone channel 3				Telephone channel 18			
4	Telephone channel 4				Telephone channel 19			
5	Telephone channel 5				Telephone channel 20			
6	Telephone channel 6				Telephone channel 21			
7	Telephone channel 7				Telephone channel 22			
8	Telephone channel 8				Telephone channel 23			
9	Telephone channel 9				Telephone channel 24			
10	Telephone channel 10				Telephone channel 25			
11	Telephone channel 11				Telephone channel 26			
12	Telephone channel 12				Telephone channel 27			
13	Telephone channel 13				Telephone channel 28			
14	Telephone channel 14				Telephone channel 29			
15	Telephone channel 15				Telephone channel 30			

Cyclic Redundancy Check

CRC - 4 example

Data block X 2^4 ÷ Generator polynomial

$x^4 + x + 1$

1 0 1 0 0 0 0 0   1 0 0 11

1 0 0 11

1 1 1 00

1 0 0 1

1 1 1 1 1

1 0 0 1

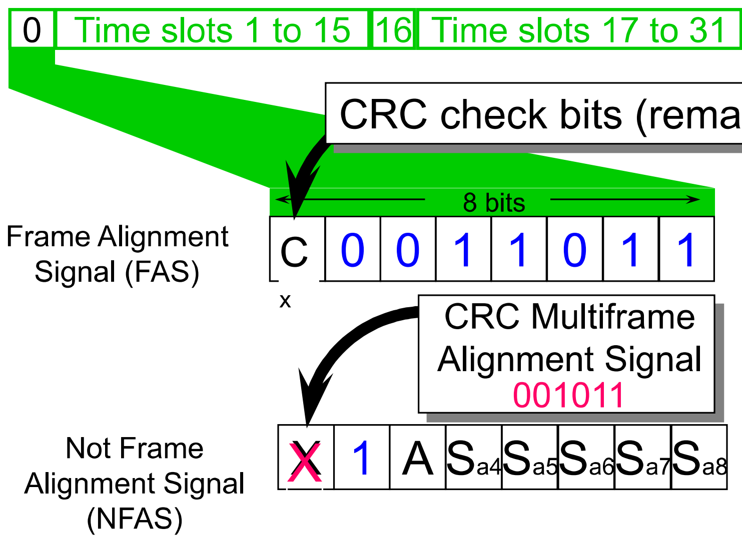
0

1 1 0

1

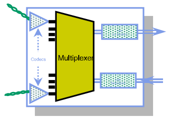
Remainder or *Signature*

CRC-4 bits



CRC Multiframe

Sub-multiframe (SMF)	Frame number	Bits 1 to 8 of the frame							
		1	2	3	4	5	6	7	8
I	0	C_1				FAS			
	1	0	1	A	S_n	S_n	S_n	S_n	S_n
	2	C_2				FAS			
	3	0	1	A	S_n	S_n	S_n	S_n	S_n
	4	C_3				FAS			
	5	1	1	A	S_n	S_n	S_n	S_n	S_n
	6	C_4				FAS			
	7	0	1	A	S_n	S_n	S_n	S_n	S_n
II	8	C_1				FAS			
	9	1	1	A	S_n	S_n	S_n	S_n	S_n
	10	C_2				FAS			
	11	1	1	A	S_n	S_n	S_n	S_n	S_n
	12	C_3				FAS			
	13	E	1	A	S_n	S_n	S_n	S_n	S_n
	14	C_4				FAS			
	15	E	1	A	S_n	S_n	S_n	S_n	S_n

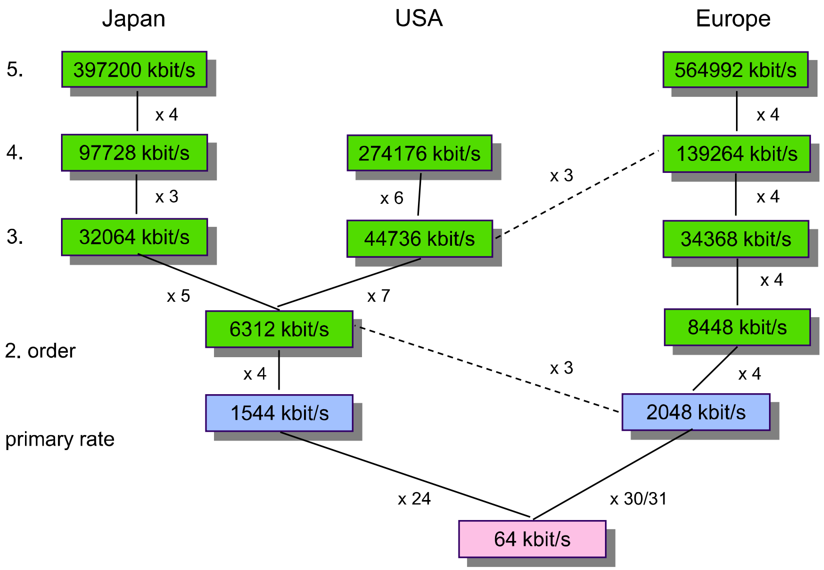


Comparison between E1 and T1

Common characteristics	PCM-30 and PCM-24
Sampling frequency	8kHz
Number of samples per telephone signal	8000
Length of PCM frame	125µs
Number of bits in each word	8
Telephone channel bit rate	64kbit/s

Differing characteristics	PCM 30	PCM 24
Encoding / decoding	A-law	µ-law
Number of segments in characteristic	13	15
Number of time slots per PCM frame	32	24
Number of bits per PCM frame	256	193
Length of an 8-bit time slot	approx. 3.9µs	approx. 5.2µs
Bit rate of time-division multiplexed signal	2048kbit/s	1544kbit/s

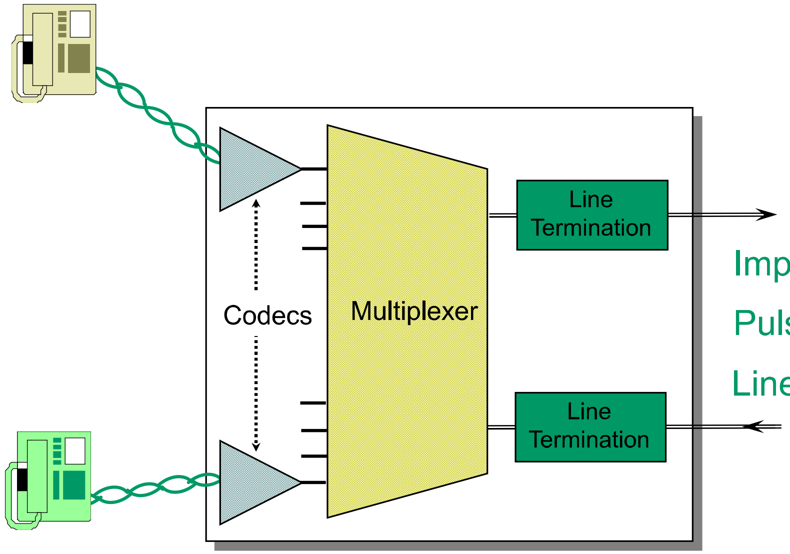
PDH Systems Worldwide



Primary Framing Structures

- **PCM30**
  30 channels - CAS in TS16
- **PCM31**
  31 channels - common channel signalling(CCS)
- **PCM30C**
  30 channels - CAS in TS16 - CRC-4 error checking
- **PCM31C**
  31 channels - CCS - CRC-4 error checking

Line Termination



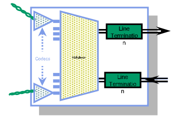
Impedances

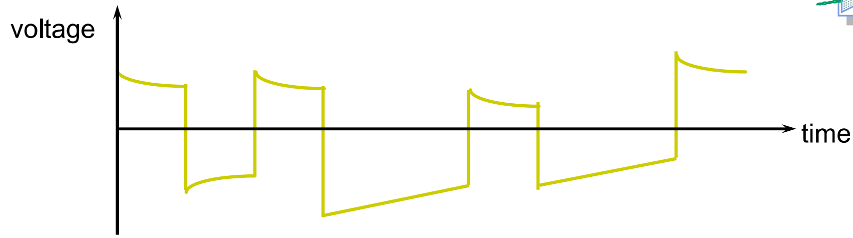
Pulse shape

Line Coding

Physical/Electrical Characteristics - G.703

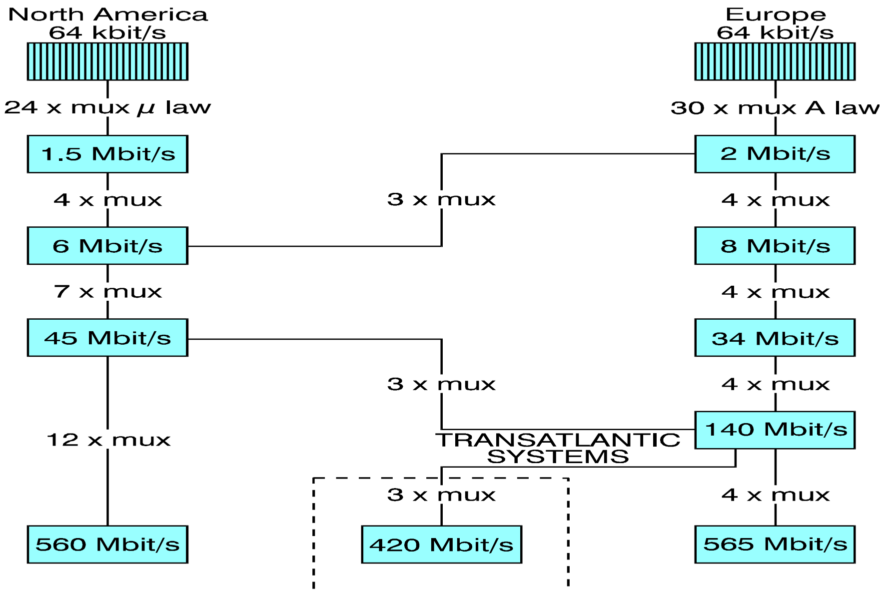
Line Codes



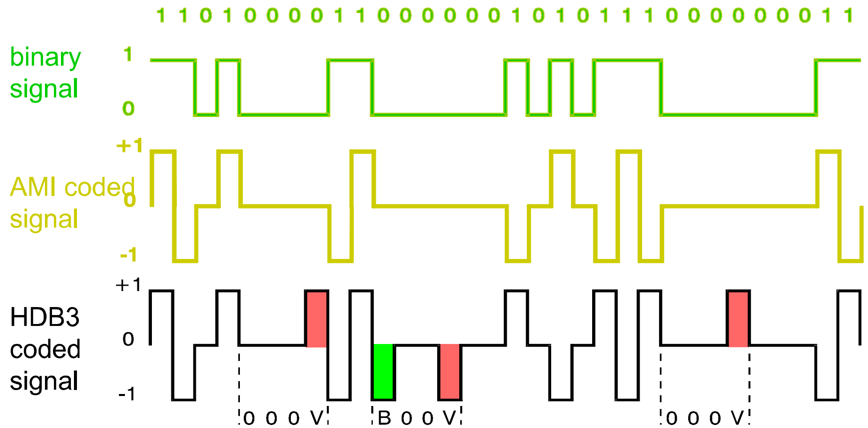


- Prevent "droop"
- Ensure sufficient timing information is included in the data

AMI



HDB3 Coding



V pulse violating the AMI sequence

- dc balancing pulse

What is E1?

- Serial synchronous bit stream at 2.048 Mbps
- Specifications defined in CCITT recommendations:
  - G.704/G.732 Frame definition (for framing over E1 and T1)
  - G.703 Interface physical specs (pulse mask, etc.)
  - G.823 Jitter requirements
- Interface (G.703) - two alternatives
  - 4-wire, balanced
    120Ω, pulse = 3.00 volts nominal
  - 4-wire, unbalanced, 2 coaxial connectors
    75Ω, pulse = 2.37 volts nominal

The Telephone System