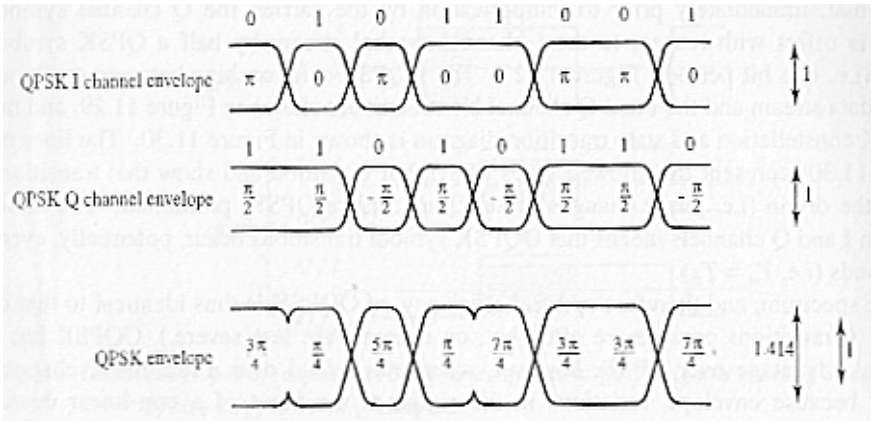
Continuous Phase Modulation

- Offset QPSK (OQPSK)
- Minimum Phase Keying (MSK)
- Continuous Phase FSK (CPFSK)
- Gaussian MSK

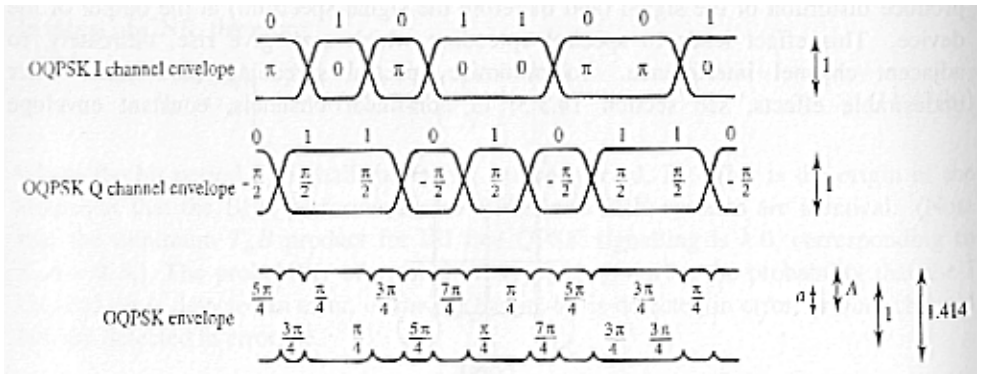
Offset QPSK (OQPSK)

- $1/T_b$ Staggered Phase Transitions between channels
- Reduced Amplitude fluctuations in a filtered system
- Reduced Spectral spreading in a non-linear system

QPSK



OQPSK

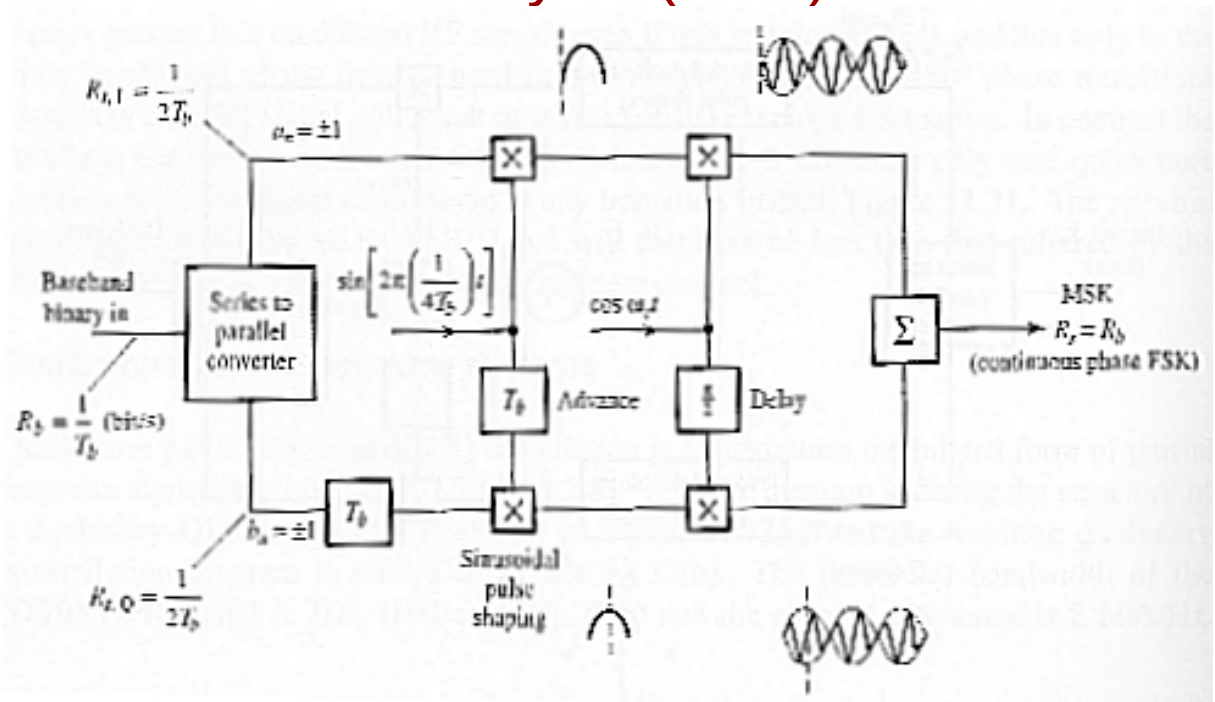


Minimum Phase Keying (MSK)

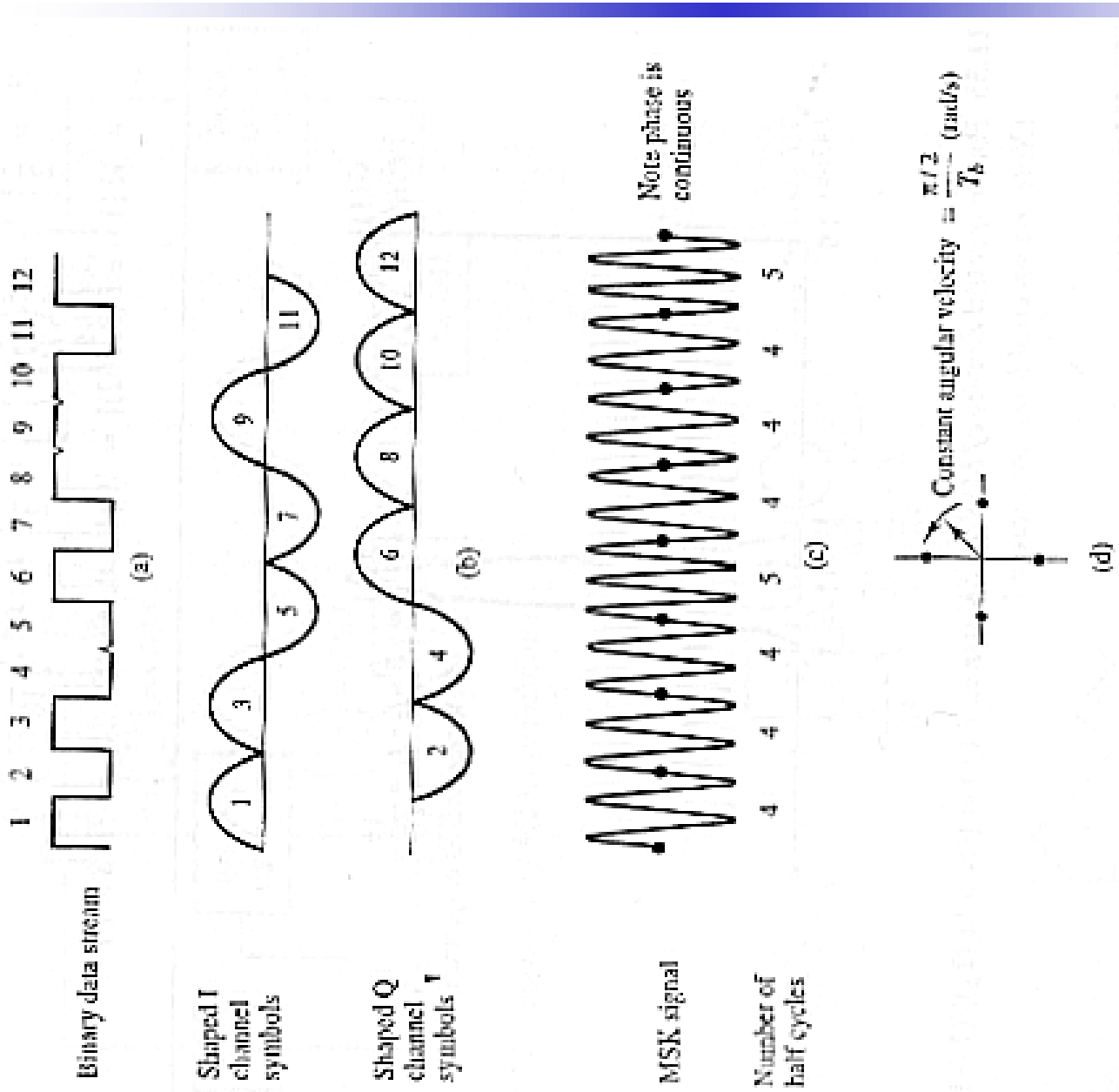
Modified OQPSK with sinusoidal pulse shaping applied to the I and Q channels prior to multiplication by the carrier

$$f(t) = a_n \sin\left(\frac{2\pi t}{4T_b}\right)\cos 2\pi f_c t + b_n \cos\left(\frac{2\pi t}{4T_b}\right)\sin 2\pi f_c t$$

Minimum shift keyed (MSK) Transmitter

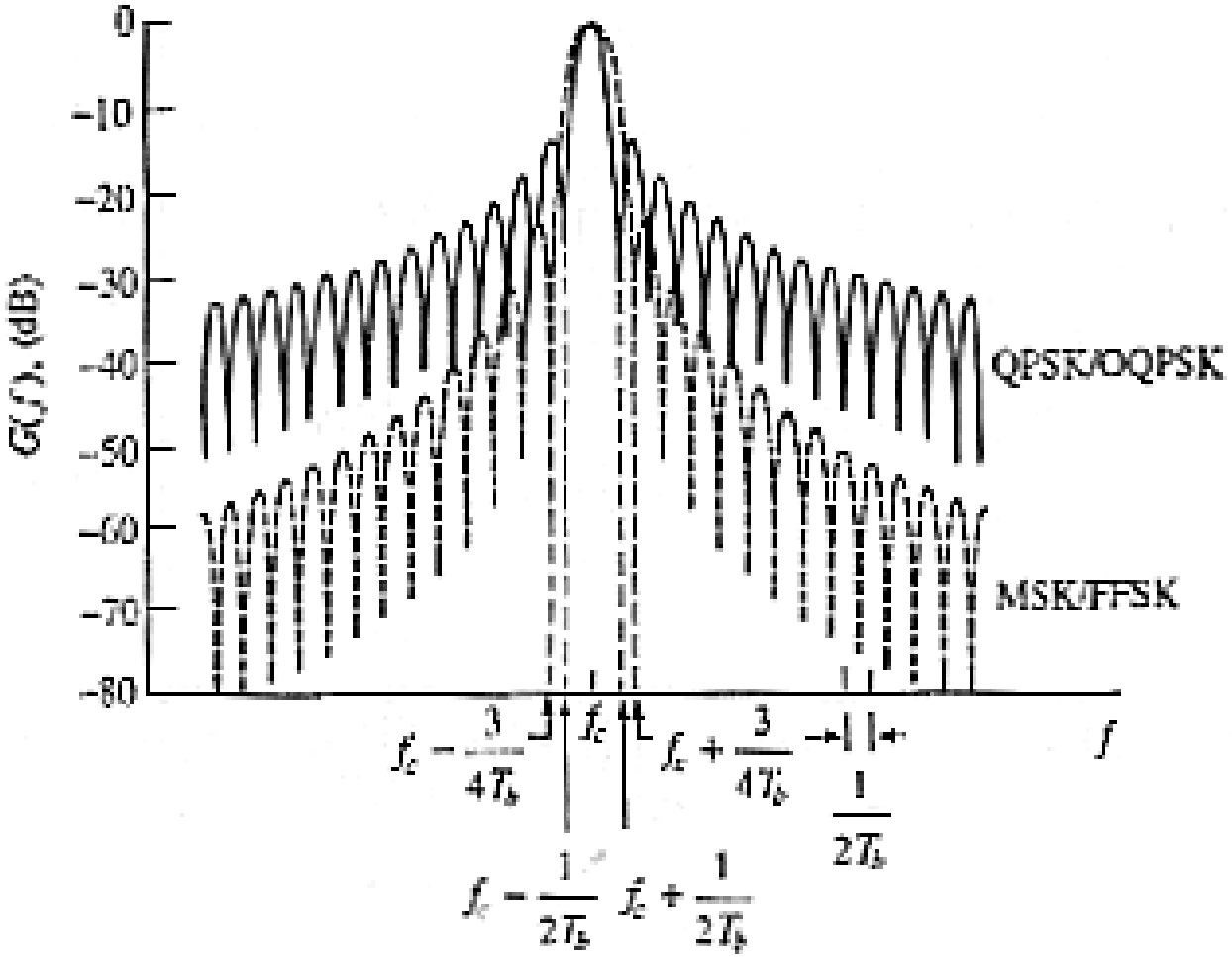


MSK Waveforms



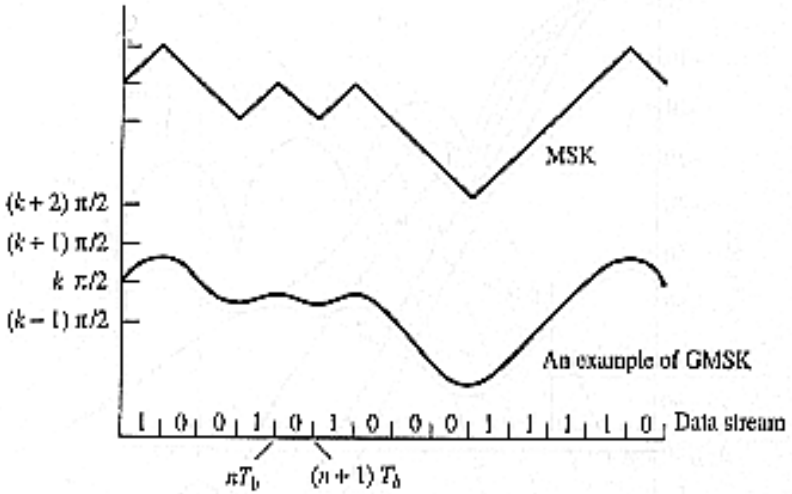
Equivalent to differential binary FSK with frequencies separated by a half cycle in the symbol period

MSK Power Spectra

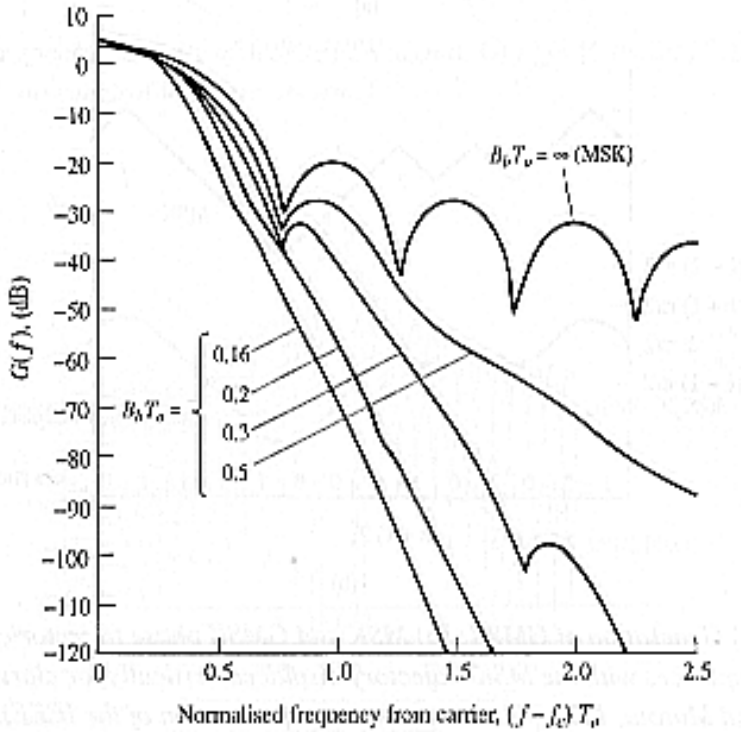


Spectral Envelopes roll off with -6dB/octave and -12dB/octave

Gaussian MSK

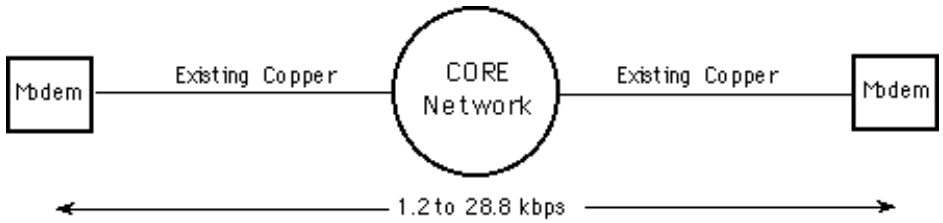


Use Gaussian envelope shaping.
Gaussian width can be wider than the symbol period

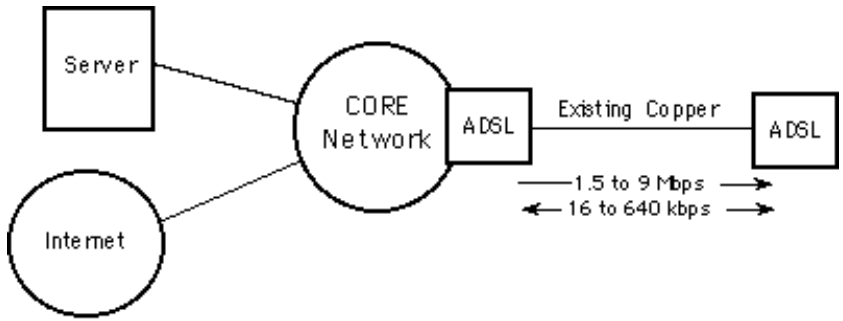


Employed in GSM digital cellular radio systems

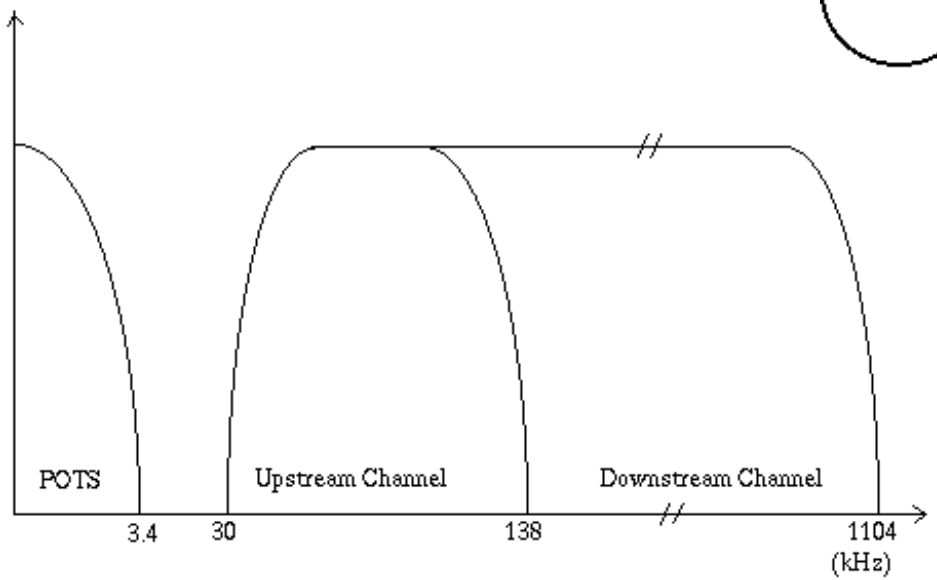
xDSL



Voice Grade Modem Connection



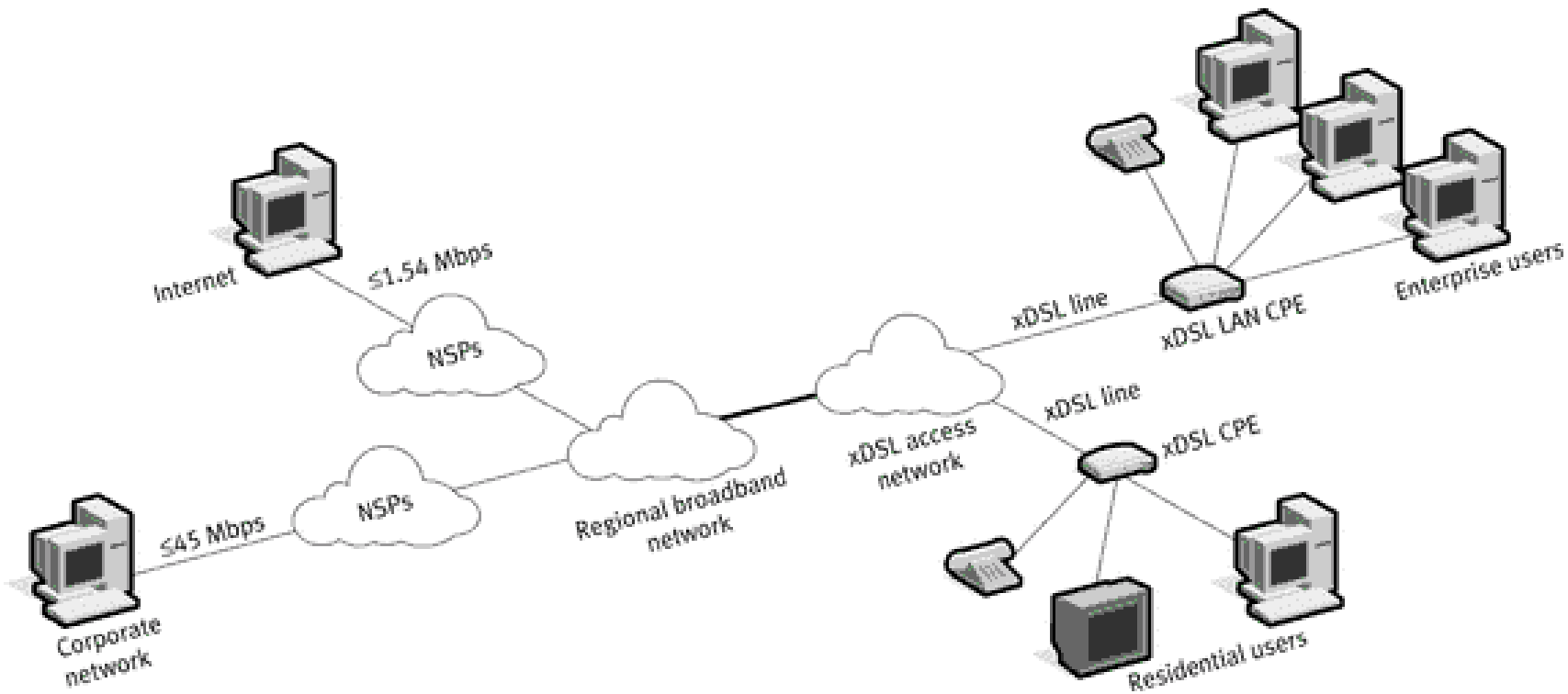
ADSL Connection



Subscriber Loops

- Twister Pair copper wires
- Loop lengths vary
- Signals are carried in differential mode
- Transformer coupled (no DC path)
- May have bridge taps and loading coils (variable impedance)
- Crosstalk between twisted pairs (FEXT and NEXT)
  - NEXT is more severe, increases with frequencies and must be avoided by ADSL
- Radio-frequency Interference (ingress and egress)

xDSL

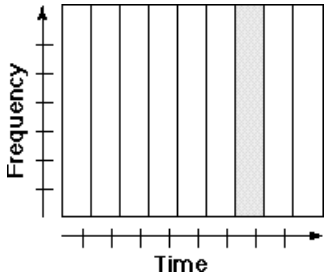

Internet
≤1.54 Mbps
NSPs
Corporate network
≤45 Mbps
NSPs
Regional broadband network
xDSL access network
xDSL line
xDSL LAN CPE
Enterprise users
xDSL line
xDSL CPE
Residential users

xDSL Technologies

Technology	Speed	Distance Limitation (24-gauge wire)	Applications
56 Kbps analog modems	56 Kbps downstream	None 28.8 or 33.6 Kbps upstream	E-mail, remote LAN access, Internet/intranet access
ISDN	Up to 128 Kbps (uncompressed) Full duplex	18,000 feet (additional equipment can extend the distance)	Video conferencing, disaster recovery, leased line backup, transaction processing, call center services, Internet/intranet access
Cable modem	10–30 Mbps downstream 128 Kbps–10 Mbps upstream (shared, not dedicated, bandwidth)	30 miles over coaxial (additional equipment can extend the distance to 200 miles)	Internet access
ADSL Lite	Up to 1 Mbps downstream Up to 512 Kbps upstream	18,000 feet	Internet/intranet access, Web browsing, IP telephony, video telephony
ADSL/R-ADSL	1.5–8 Mbps downstream Up to 1.544 Mbps upstream	18,000 feet (12,000 feet for fastest speeds)	Internet/intranet access, video-on-demand, remote LAN access, VPNs, VoIP
IDSL	Up to 144 Kbps full duplex	18,000 feet (additional equipment can extend the distance)	Internet/intranet access, Web browsing, IP telephony, video telephony
HDSL	1.544 Mbps full duplex (T1) 2.048 Mbps full duplex (E1) (uses 2–3 wire pairs)	12,000–15,000 feet	Local, repeatered T1/E1 trunk replacement, PBX interconnection, Frame Relay traffic aggregator, LAN interconnect
SDSL	1.544 Mbps full duplex (T1) 2.048 Mbps full duplex (E1) (uses 1 wire pair)	10,000 feet	Local, repeatered T1/E1 trunk replacement, collaborative computing, LAN interconnect
VDSL	13–52 Mbps downstream 1.5–2.3 Mbps upstream (up to 34 Mbps if symmetric)	1,000–4,500 feet (depending on speed)	Multimedia Internet access, high-definition television program delivery

Source: 3Com, March 1998.

ADSL Modulation Formats



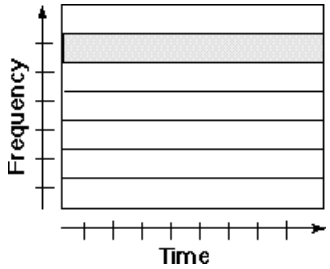
CAP

Carrierless AM/PM

Based on Suppressed Carrier QAM

orthogonal signal modulation is executed digitally, using two digital transversal bandpass filters with equal amplitude characteristics and a $\pi/2$ difference in phase response (Hilbert Pair). The signals are then combined, fed to a digital analogue converter (DAC), and transmitted.

CAP operates in the time domain



DMT

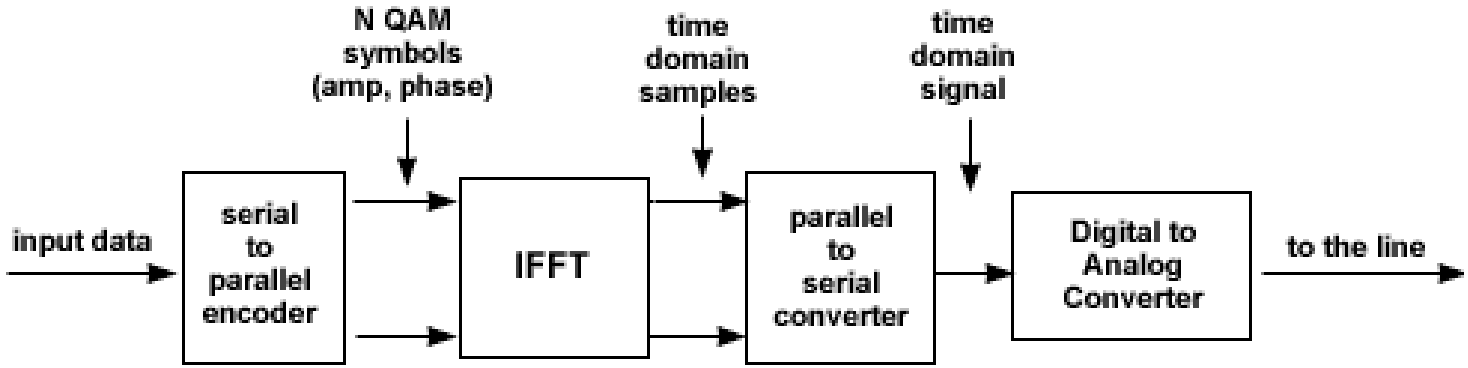
Discrete Multitone

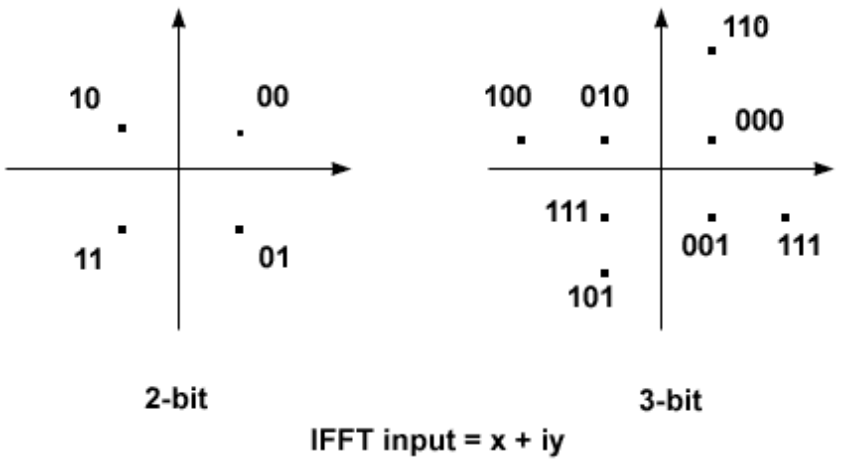
closely related to OFDM orthogonal frequency division multiplexing

many narrow-band carriers, all transmitting at once in parallel, and each carrying a small fraction of the total information.

DMT operates in the frequency domain

DMT (FDM Transmitter)

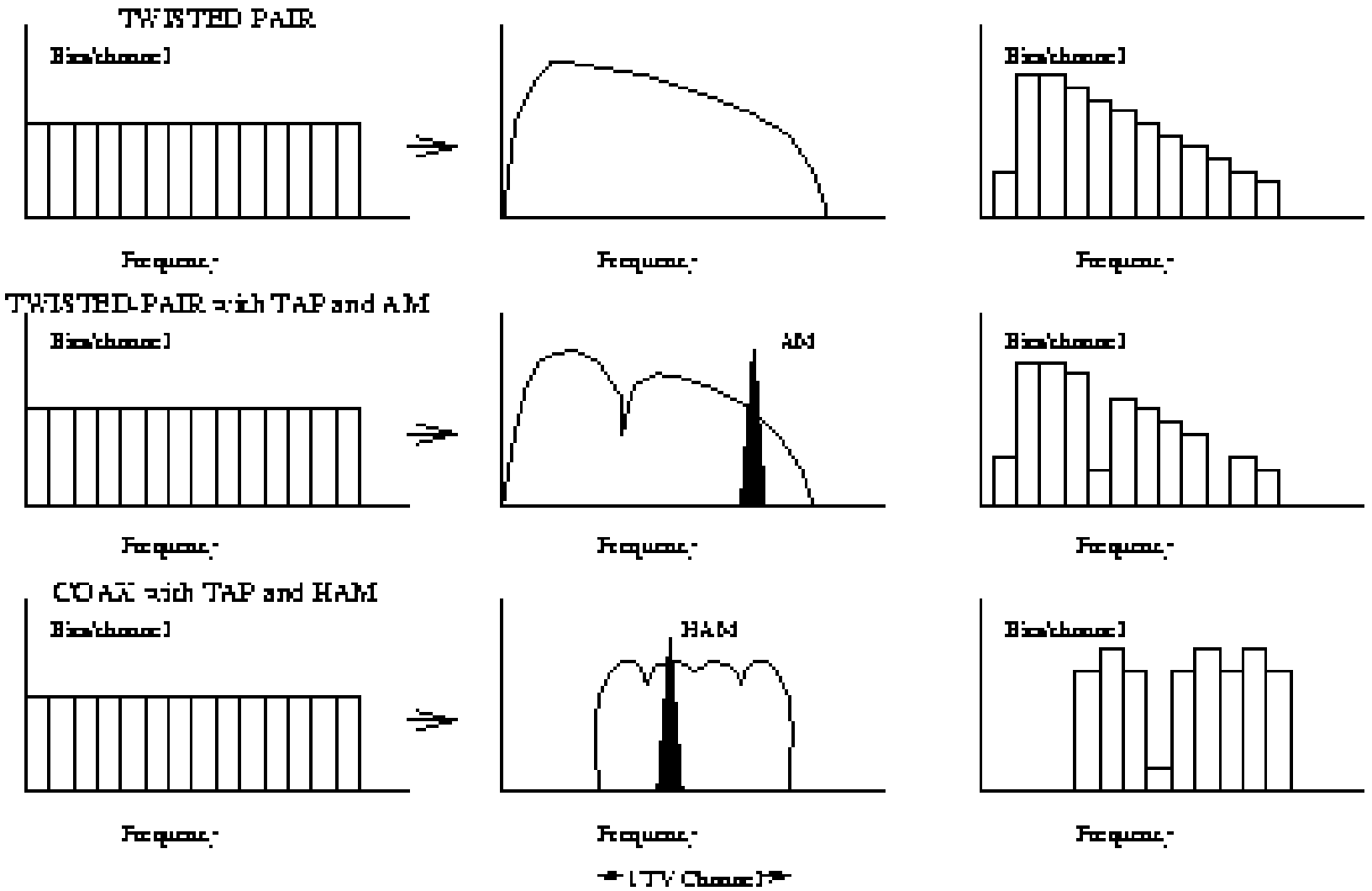




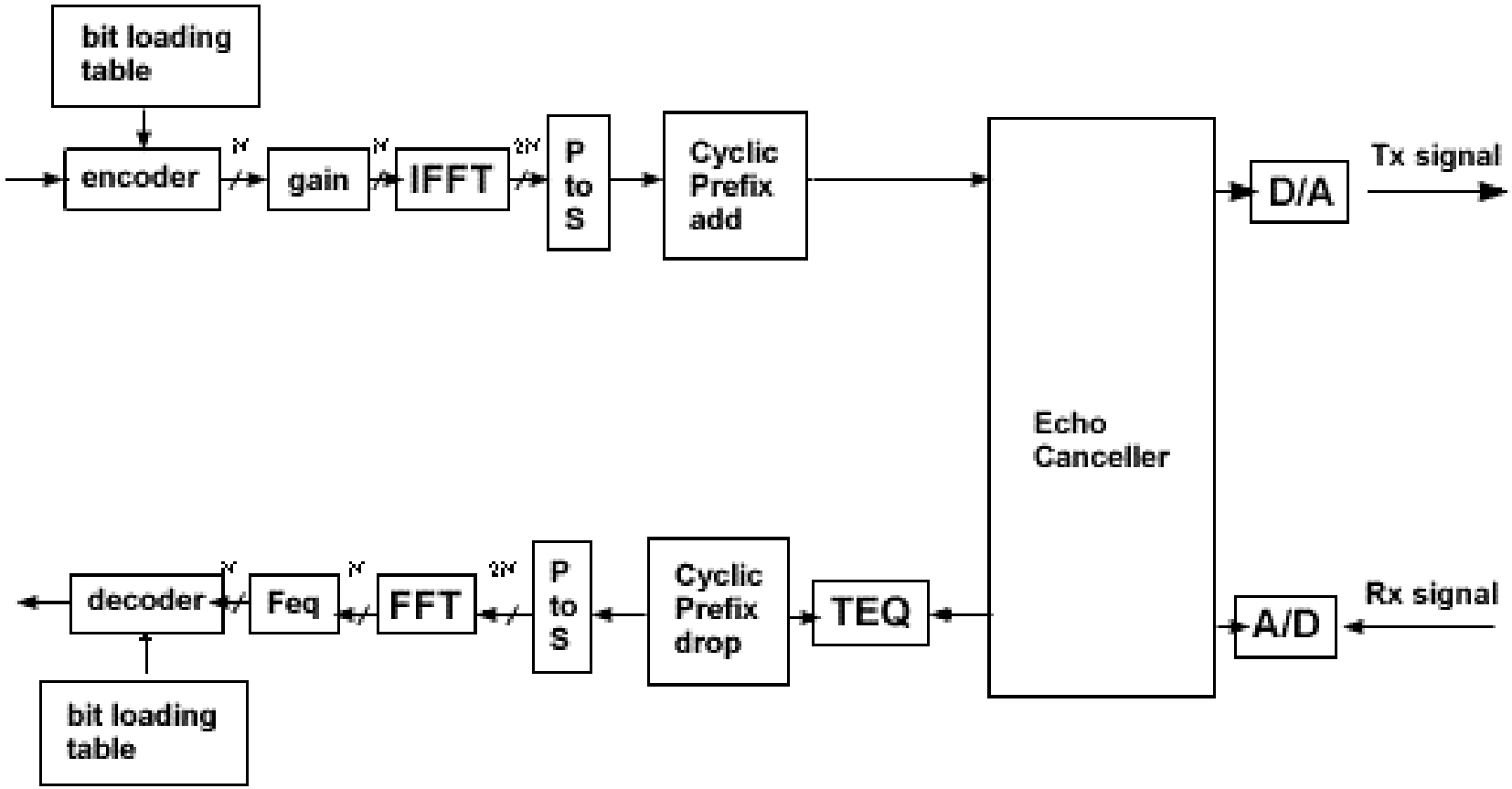
2 & 3 bit constellations

256 frequency bands (or channels)
of 4.3125KHz each
e.g. channels 6-31 for upstream (24KHz-136KHz),
32-250 for downstream (136KHz-1.1MHz)
Other transforms (apart from FFT) such as wavelet would perform better

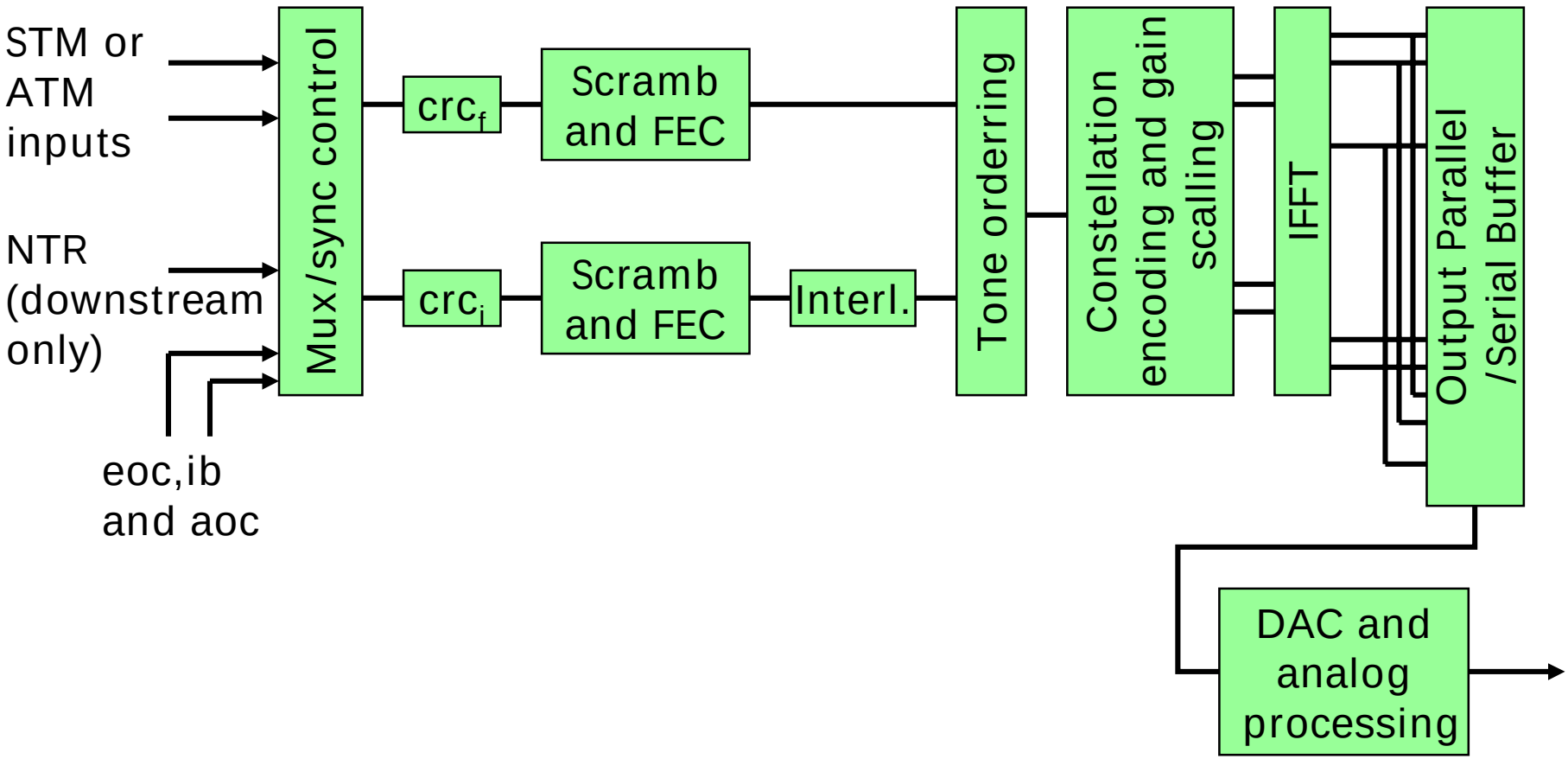
Adaptive Spectrum



DMT Modem


bit loading table
encoder
N
gain
N
IFFT
2N
P to S
Cyclic Prefix add
Echo Canceller
D/A
Tx signal
decoder
N
Feq
N
FFT
2N
P to S
Cyclic Prefix drop
TEQ
A/D
Rx signal
bit loading table

Block disgram of a DMT transmitter



xDSL Links

ADSL Deployment Worldwide
<http://www.geocities.com/Paris/Metro/5013/adsl.html>

ADSL Forum <http://www.adsl.com>

Avalon Trials <http://dsl.avalon.net>

Computing Central Bandwidth Forum
<http://computingcentral.com/forums/bandwidth/>

Dan Kegel's ADSL Page
<http://alumni.caltech.edu/~dank/isdn/adsl.html>

DSL Prime <http://www.dslprime.com>

DSL Reports <http://www.dslreports.com>

High Bandwidth Web Page <http://www.specialty.com/hiband/>

Network World DSL Resources <http://www.nwfusion.com/dsl/>

Randy Day's xDSL page <http://www.tuketu.com/dsl/xdsl.htm>

Telechoice Inc. <http://www.xdsl.com>

Universal ADSL Working Group <http://www.uawg.com>

Main sources of noise in an xDSL system

- Unavoidable
  - Alien Crosstalk
  - kindred FEXT
  - AWGN
- Unavoidable
  - Kindred NEXT
  - RFI (AM radio and amateur radio)
  - POTS signalling
  - Linear distortion
  - Non-linear distortion
  - Down/up interference leak through FDD filters and/or echo canceller
  - Clipping
  - Quantising noise in DAC and ADC
  - DSP round-off noise
  - Noise and/or distortion introduced by clock jitter

A xDSL Transmitter

- Transport of the Network Timing Reference
- Input multiplexer and Latency (Interleave) Path Assignment
- Scrambler
- Reed-Solomon Forward Error Correction
- Interleaving
- Tone Ordering
- Trellis Code Modulation
- Pilot Tone
- Inverse Discrete Fourier Transform
- PAR Reduction
- Digital-to-Analogue Converter
- Line Drivers

A xDSL Receiver

- Analog Receiver?
- Analog-to-Digital Converter
- Timing Recovery and Loop Timing
- Time-Domain Equalisers
- FFT
- Frequency-Domain Equaliser
- Trellis Decoder (Viterbi Decoder)
- De-interleaver
- Reed-Solomon Decoder
- Descrambler

COFDM

- Coded Orthogonal Frequency Division Multiplexing (COFDM) - similar to DMT
- Uses Soft decision decoding taking account of channel-state information (measured SNR in each channel)
- Used in DVB-T - terrestrial digital television broadcasting - see
  http://www.bbc.co.uk/rd/pubs/papers/paper_15/paper_15.html
  http://www.bbc.co.uk/validate/paper_17.htm
- Also used in digital audio (DAB)