DVB-C: Cable Standard

Introduction

- In many countries, good radio and TV coverage is provided via broadband cable, especially in densely populated areas.
- These cable links have either a bandwidth of about 400 MHz (approx. 50 - 450 MHz) or about 800 MHz (approx. 50 - 860 MHz).
- In addition to the VHF and UHF band known from terrestrial television, special channels are occupied.
- Analog television programs can be received easily with a conventional TV set without additional complexities which is why this type of TV coverage is of such great interest to many.

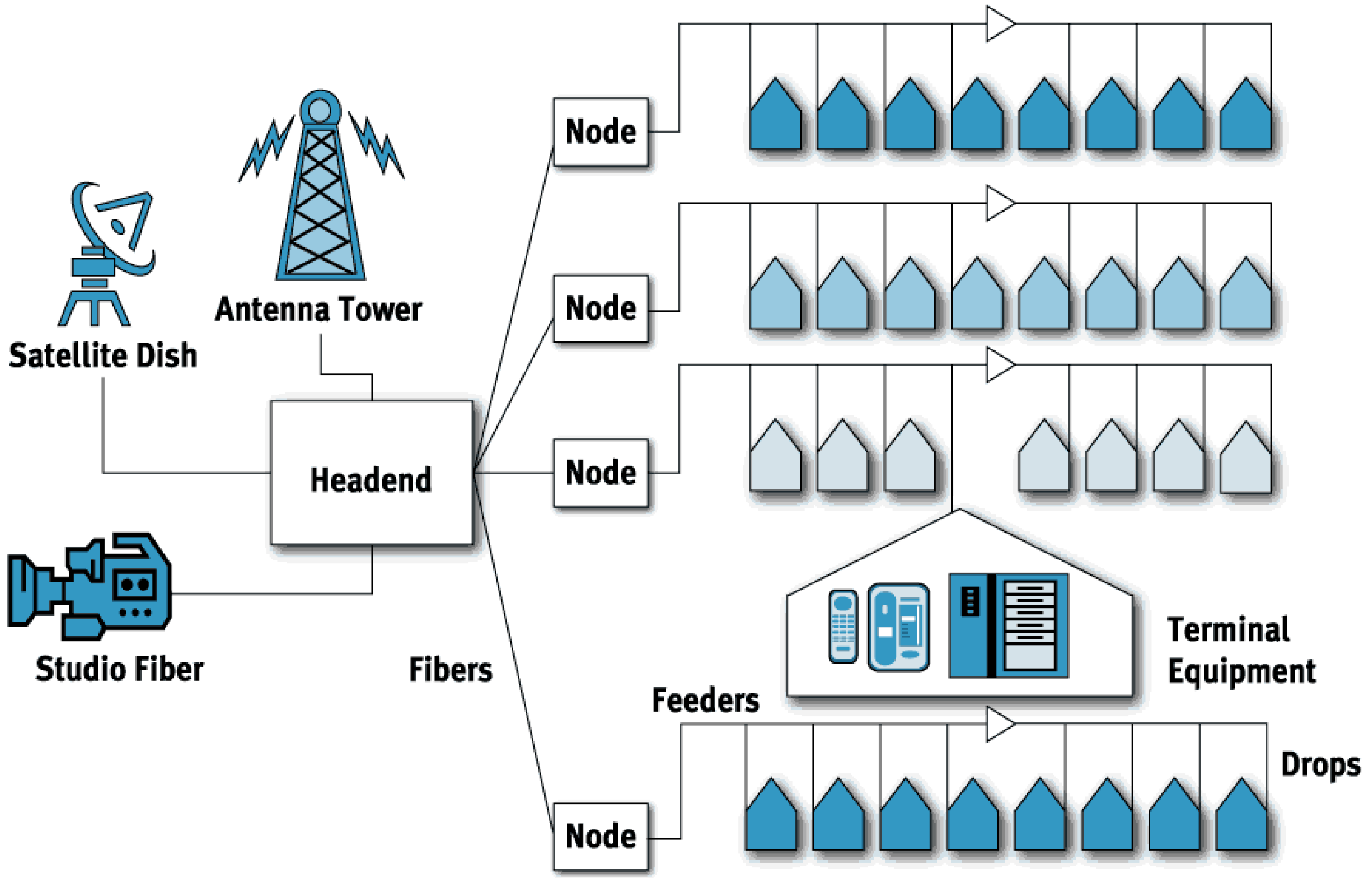
Introduction (cont.)

- The only obstacle in comparison with analogue satellite TV reception is the additional monthly line charge with which a satellite receiving system would pay for itself within one year in many cases.
- If the satellite dish is large enough, the picture quality is often better than via broadband cable since intermodulation products sometimes result in visible interference due to the multiple channel allocation in broadband cable.

Introduction (cont.)

- The decision between cable and satellite reception simply depends on the following considerations:
  - Convenience
  - Cable reception charges
  - Single- and multiple-channel reception
  - Picture quality
  - Personal requirements/preferences

Overall Cable System Network



System Characteristics

Modern approach: direct connection to the broadcaster or provider from the node, via coaxial or optical cable

- Advantages:
  - High bandwidth
  - Constant bandwidth
  - Low noise
  - Good quality, reliable service
- Disadvantages:
  - Cable must be laid underground for every user
  - Any change in technology may be very expensive

Cable Systems

- Head-end: operator receives programmes/ services from the broadcaster over-the-air (OTA), via satellite link, or by direct wired connection
- Connections of head-end to node connections are via optical fibre
- Cable can supply high-speed broadband internet services, TV, and radio
- Typical bandwidth per channel in a cable system
  - 8 MHz in Europe;
  - 6 MHz in North America

Noise

- For cable systems: ambient noise is low
- Unwanted signal (interference) from other sources or noise from amplifiers (e.g., repeaters for long cables): all considered as ‘noise’
  - Filters are needed to remove noise & reshape signal before amplification (repeater)
  - Filters change effect of noise
  - Roll-off factor of the filter at the receiver is the main factor that determines the symbol rate (baud) that can be supported in a particular channel bandwidth

Temperature Effect

- Re-amplification of signal along cable length uses trunk amplifier (TA)
  - TA separation: ~ 400 m
  - Up to 20 TAs connected $\Rightarrow$ max. 8 km
- TAs' amplification drifts with temperature
- Remedy: TA amplitude is monitored and controlled by pilot signal at 80.15 MHz

Reflections

- If cables are not ideally connected then there will be reflections at splitters because of impedance mismatch at junctions between transmission line (backbone network) and user stubs (connected to TV sets)

- Backward travelling waves thus arise, in addition to desired forward travelling wave. This is then reflected again and travels forward, but with a delay
- Reflection cause shadowing in picture (similar to free-field reflections from buildings in cities)
- Higher-order reflections (echoes) can be neglected due to attenuation in coax cable
- For 1st-order echo with relative amplitude a, delay τ, additional phase shift θ at carrier frequency f_c:

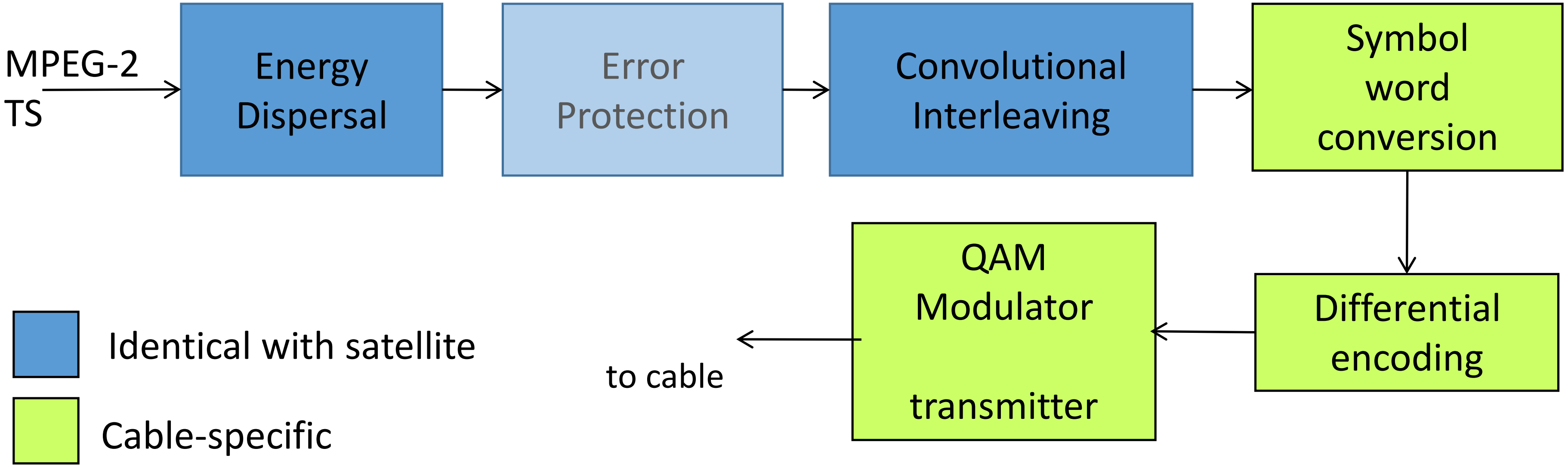
$$h(t) = \frac{1 + a\, e^{j2\pi(f_c\tau + \theta_k)}}{\sqrt{1 + a^2}}$$

- Magnitude of reflections: typically ~ -34 dBc (dB relative to carrier) in 64-QAM that can be neglected

Requirements for DVB-C

- Existing analogue cable systems must be useable for digital cable where possible (don’t dig up the road again)
- Adding digital signals should not significantly degrade the analogue signals (analogue-to-digital change-over phase)
- As many TV channels as possible should be transmitted on one cable channel to be competitive to satellite
- Set top box (STB) should be as low-cost as possible.
    - Sharing some components with satellite and terrestrial equipment keeps costs low
- Timing of introduction: should be similar to the introduction of digital satellite
- Cable system should be as similar as possible to satellite system

Encoder



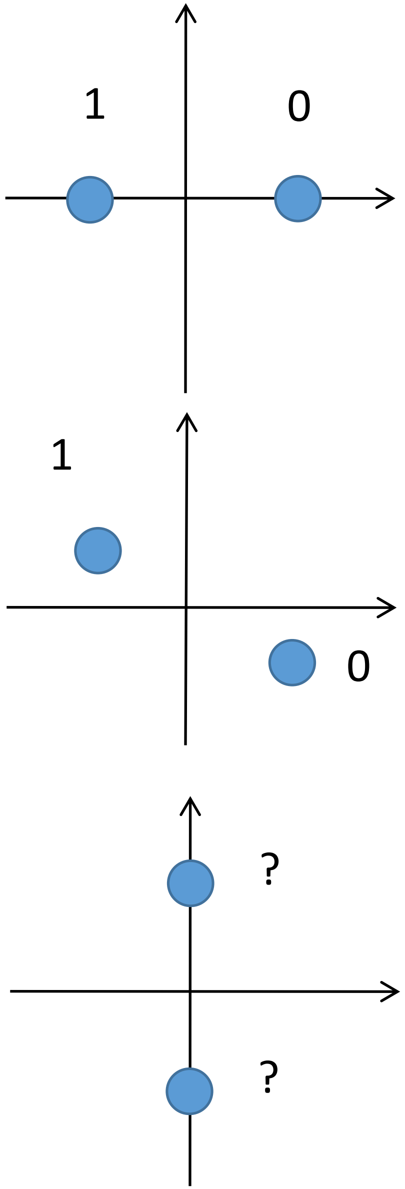
Decoder is the reverse of the encoder

- Less FEC protection needed than DVB-S
- Higher-order QAM possible (why?): 16- to 256-QAM (more bits per symbol)

Cable-Specific Blocks

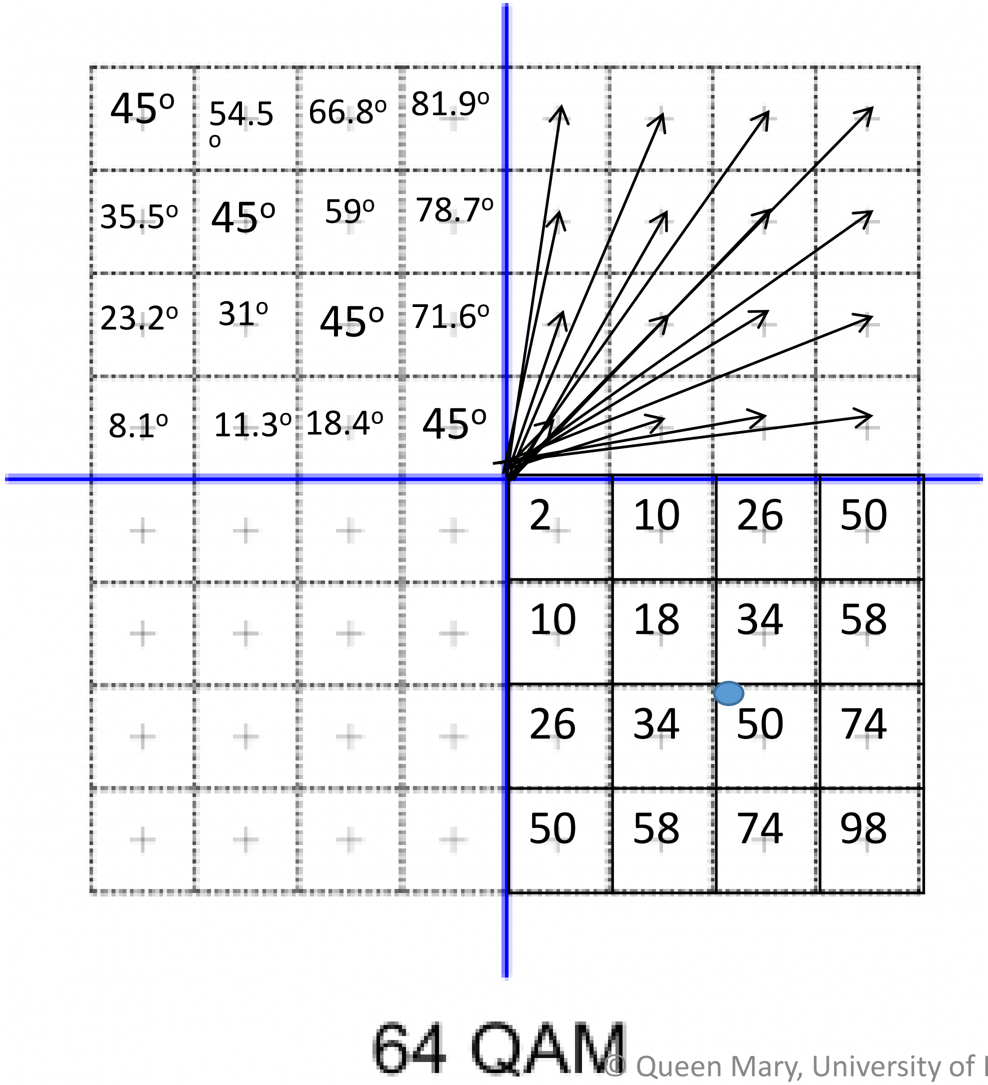
- Symbol word conversion block: take input 8-bit data word from channel coder, then combine bits into *b*-bit output symbols: *n* words become *m* symbols
  - Example for 64-QAM conversion (*b* = 6 bits/symbol):
    - Bits 0 to 5 of word 1: to symbol 1
    - Bits 6 to 7 of word 1 and bits 0 to 3 of word 2: to symbol 2
    - Bits 4 to 7 of word 2 and bits 0 to 1 of word 3: to symbol 3
    - Bits 2 to 7 of word 3: to symbol 4

Phase Noise



- Absolute phase is lost due to carrier suppression at transmitter
- In PSK systems, correct recovery of the phase shift is essential
- During transmission the signal may experience phase noise (e.g. time jitter, non-linear phase amplification)
- This can cause the constellation to rotate and the phase to be ambiguous
- Not only issue in PSK, but also in OFDM

Intermodulation in *M*-QAM



Intermodulation: when image carriers of different DTV signals interfere

RMS mean power P_{RMS} of all *M* channels in constellation = $2(M-1)/3 = 2(64-1)/3=42$

For single sinusoidal interferer: $P_{RMS}=1/2$

$\Rightarrow$ For 64-QAM: minimum $C/I = 10 \log_{10}(84) = 19.2$ dB

Differential Encoding

- Differential coding provides unambiguous signal reception for some types of modulation.
- For BPSK (for example), if a carrier is recovered incorrectly then the received data are inverted.
- Differential coding makes transmitted data dependent not only on current bit (or symbol), but also on previous one.
  - Method: two MSBs of each m-bit symbol are separated from rest of symbol words
  - Use of Boolean expressions to recover I/Q of actual MSBs for uncoded symbols

Differential Encoding

- assume x_i is the bit intended for transmission and y_i is the bit transmitted (differentially encoded)

transmitted $$y_i = y_{i-1} \oplus x_i$$ i.e. modulo 2 addition

on the decoding side $$x_i = y_i \oplus y_{i-1}$$ can be reconstructed

- now x_i depends only on a difference between y_i and y_{i-1} and not their individual values.
- whether the data stream is inverted or not during transmission, decoded data will always be correct.

Variations on DVB-C: SMATV

- DVB-C can be used for satellite master antenna TV (SMATV) systems
  - SMATV: group of users share one satellite dish
  - Single channel has sufficient capacity to transmit the data from one satellite transponder
  - To keep cost and/or attenuation low, satellite signals (after frequency down-conversion) can be distributed directly via cable
  - SMATV can suffer more from echoes than CATV, needs equalization

Variations on DVB-C: MMDS

- Another alternative to CATV are microwave multichannel/multipoint distribution systems (MMDS)
  - local terrestrial transmission using microwaves (below 10 GHz).
  - Only for relatively short distances (≤ 60 km) and line-of-sight (LoS) propagation
- Uses different frequency bands
- Described in DVB-MC

DVB-C2

- An improved version of the DVB-C standard, DVB-C2 was approved and introduced in 2010.
- Some problems that DVB-C2 attempts to overcome:
  - Lack of capacity on cable networks for additional programmes.
  - Need to remain competitive with telecom and satellite operators.
  - New tools to cater for both private and business customers, particularly with IP-based content
  - Performance improvements, e.g. channel changing time, are needed to increase subscriptions

Key Advantages of DVB-C2

- > 30% higher spectrum efficiency than DVB-C
- After analogue switch-off, gains in downstream capacity are > 60% for optimized networks
- COFDM is used in DVB-C2
  - insensitive to echoes by in-house coaxial networks
  - very robust to impulsive (bursty) noise interference
- Flexibility in terms of bandwidth (32 MHz or more) is possible in a single frequency
  - yields very efficient sharing of the available resources between individual customers and services.

DVB-C2 changes

	DVB-C	DVB-C2
Input Interface Modes	Single Transport Stream (TS) Constant Coding & Modulation	Multiple Transport Stream and Generic Stream Encapsulation (GSE) Variable Coding & Modulation and Adaptive Coding & Modulation
FEC	Reed Solomon (RS)	LDPC + BCH
Interleaving	Bit Interleaving	Bit Time- and Frequency-Interleaving
Modulation	QAM	COFDM
Pilots	Not Applicable	Scattered and Continual Pilots
Guard Interval	Not Applicable	1/64 or 1/128
Dig. Modulation Schemes	16-to 256-QAM	16- to 4096-QAM

Data over Cable

- Key standards: DOCSIS 1, 2, 3 (Data Over Cable Service Interface Specification generations 1, 2, 3).
- Separate modulated carriers for up- and downstream connections.
- Cable modems to connect home equipment to the Internet.
- Actual data rates obtained depend partially on number of homes connected to same section of coax cable (contention issues).

DOCSIS Data Rates

Standard	Downstream Data Rate	Upstream Data Rate
DOCSIS 1	50 Mbit/s	9 Mbit/s
DOCSIS 2	50 Mbit/s	27 Mbit/s
DOCSIS 3	*m* x 50 Mbit/s	*n* x 27 Mbit/s

- DOCSIS 3 binds channels together to get high data rates, so the maximum data rate depends on the number of channels used.
- DOCSIS 2 and 3 support IPv6