System aspects of DVB-T2 for frequency & network planning

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DVB-T2 System Aspects

- Background and requirements
- Main modulation features
  - Coding, constellations, FFT, guard interval, bandwidth
- Further features
  - Rotated constellations, scattered pilots, time interleaving
- C/N required for network planning
- Advanced options
  - MISO, physical layer pipes, FEF, TFS
- DVB-T2-Lite and DVB-NGH

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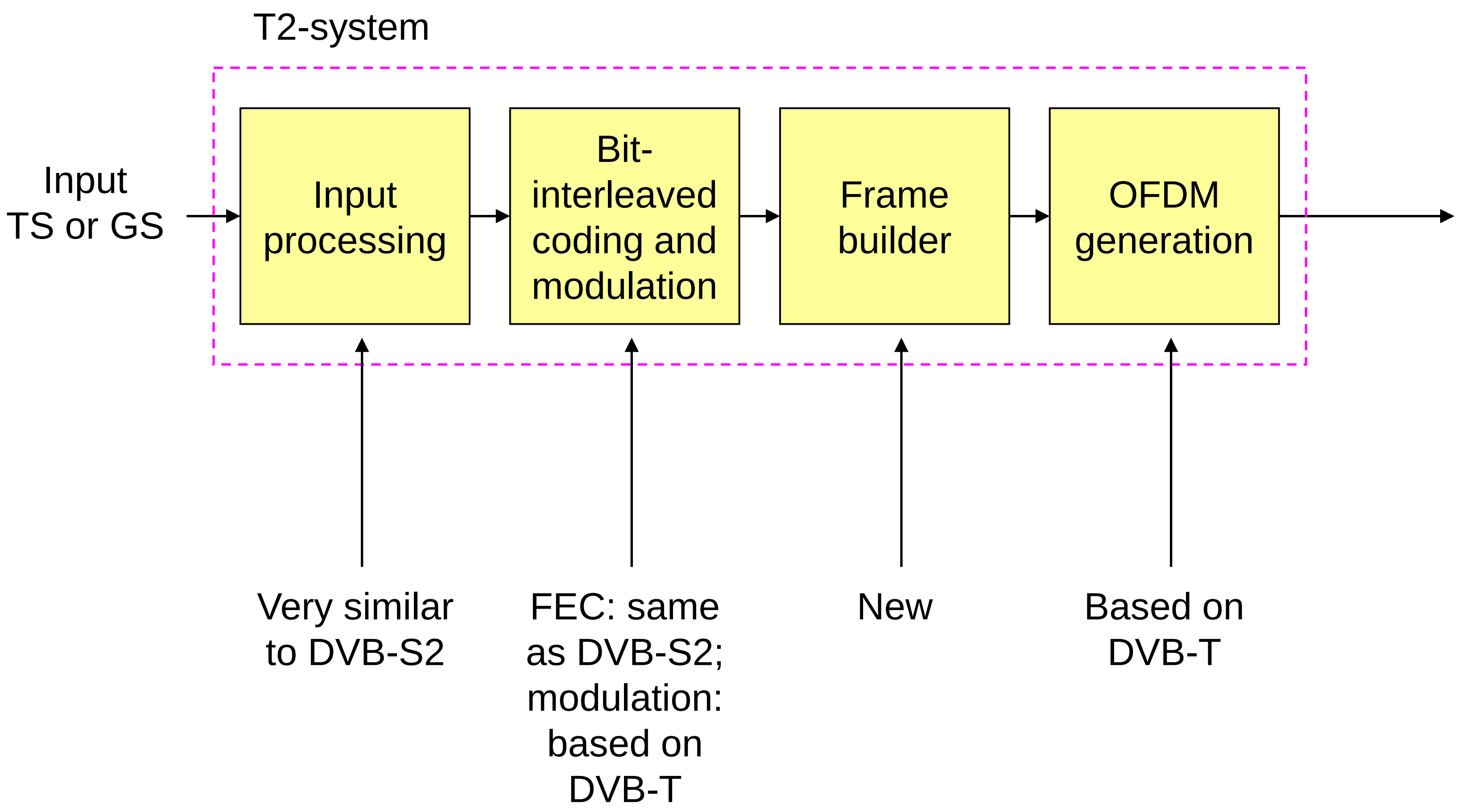
DVB-T2 – background

- DVB-T2 is a 2nd generation terrestrial broadcast transmission system
- Developed by DVB project from 2006
  - to increase capacity, ruggedness and flexibility
  - modulation from DVB-T; channel coding from DVB-S2
  - DVB-T2 group led by BBC R&D
- V1.1.1 published by ETSI as EN 302 755 (2009)
  - V1.3.1 has just been published (13/4/2012)
- Launched in UK as ‘Freeview HD’ in Dec 2009
  - Now deployed in 8 countries and adopted by 29 more

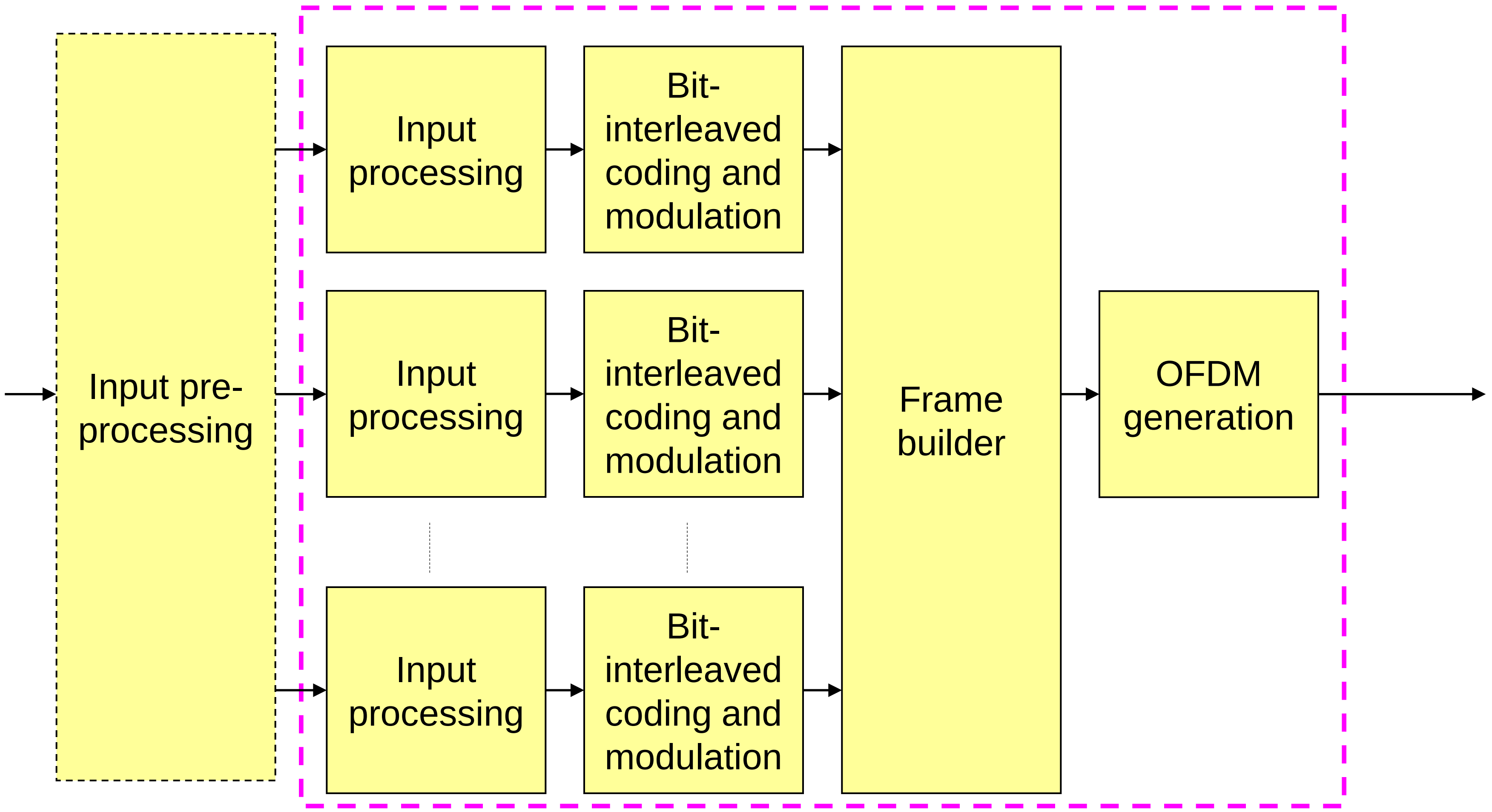
Commercial Requirements for T2

- Key requirements included
  - Must be able to use existing domestic receive antenna and existing transmitter infrastructure
    - Intended primarily for services to fixed and portable receivers
  - Should provide minimum of 30% capacity increase over DVB-T
    - Within same spectrum planning constraints
  - Should provide for improved SFN performance
  - Should have mechanism for providing service-specific robustness
  - Should provide for bandwidth and frequency flexibility
  - Should provide means to reduce peak-to-average power ratio
- The T2 specification has been compared to these requirements and found to meet or exceed all of them

T2 physical layer architecture



Multiple services in Physical Layer Pipes (PLPs)



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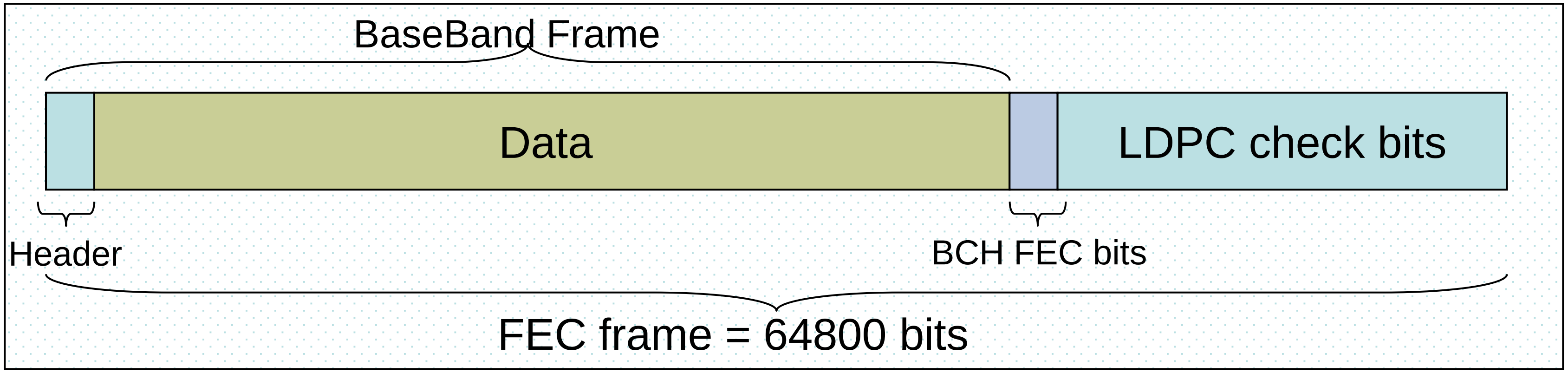
Coding: BB Frames and LDPC

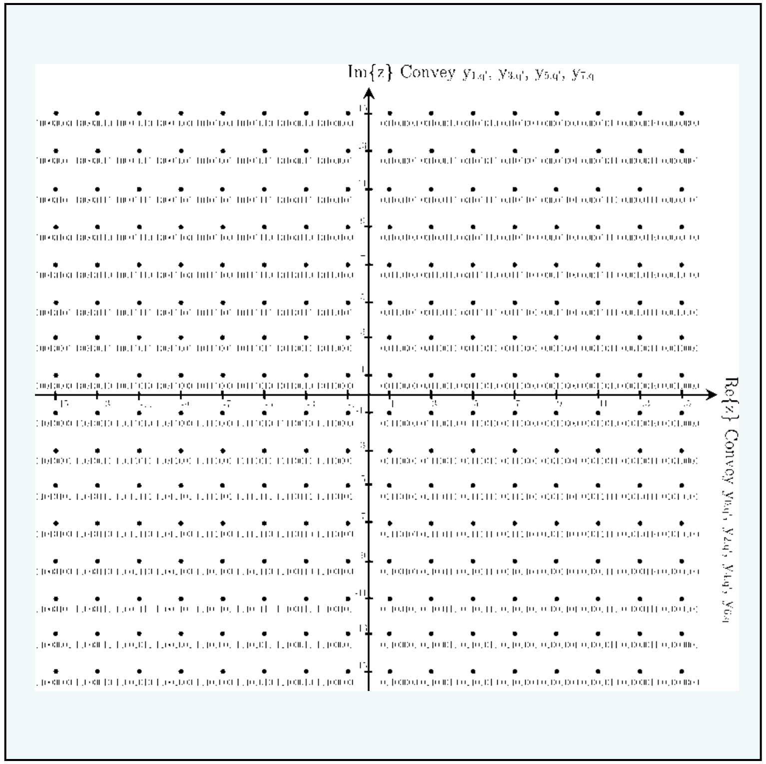
- Data packaged into BaseBand Frames
- BaseBand Frames protected by the S2 LDPC FEC
  - small BCH code to mop up any residual errors after LDPC decoding



- This FEC frame, of length 64800 bits, is a fundamental unit within T2
  - Code rates: 1/2, 3/5, 2/3, 3/4, 4/5, 5/6
  - A shorter FEC frame of 16200 bits also provided for low data rate services
- Bit-rate gain compared with DVB-T is typically 30% for same overhead and same level of robustness

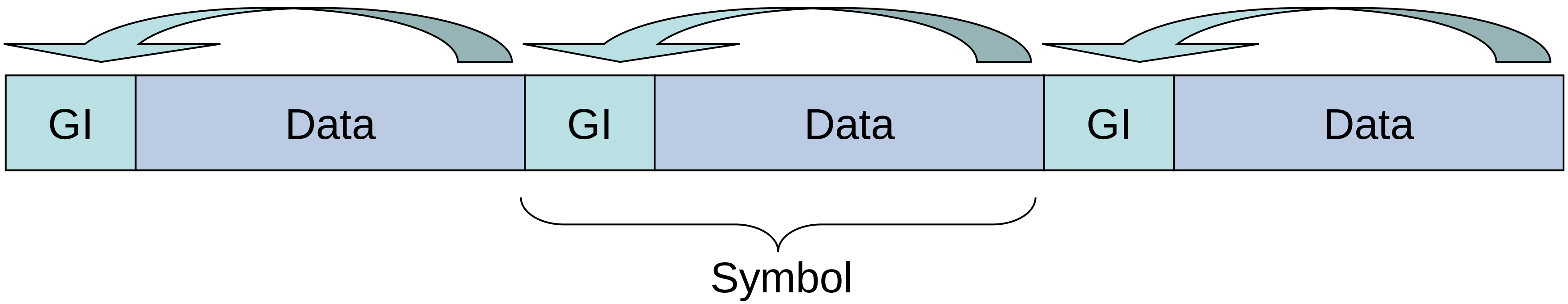
Constellations

- T2 includes 256-QAM mode
  - Carries 8 bits/ data cell
    - c.f. 6 bits / data cell for 64 QAM
  - Enables greater capacity, exploiting improved FEC performance of LDPC
  - T2 also includes DVB-T options of QPSK, 16-QAM and 64-QAM



Guard interval & FFT (1)

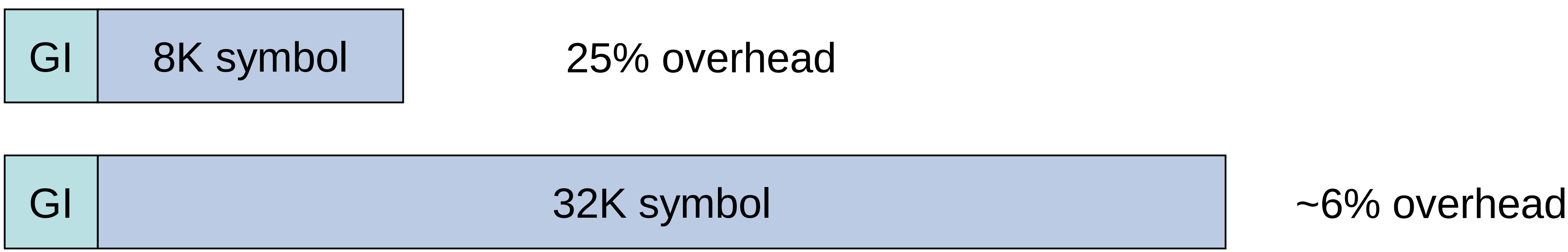
- T2 uses conventional Guard-Interval OFDM (GI-OFDM)
  - as in DVB-T



- Each symbol carries data on a large number of separate carriers
  - 1K, 2K, 4K, 8K, 16K, 32K FFT options are available in T2
    - 16K and 32K: to give improved SFN performance
    - 1K for bandwidth and frequency flexibility
  - Increasing the number of carriers increases the symbol period

Guard interval & FFT (2)

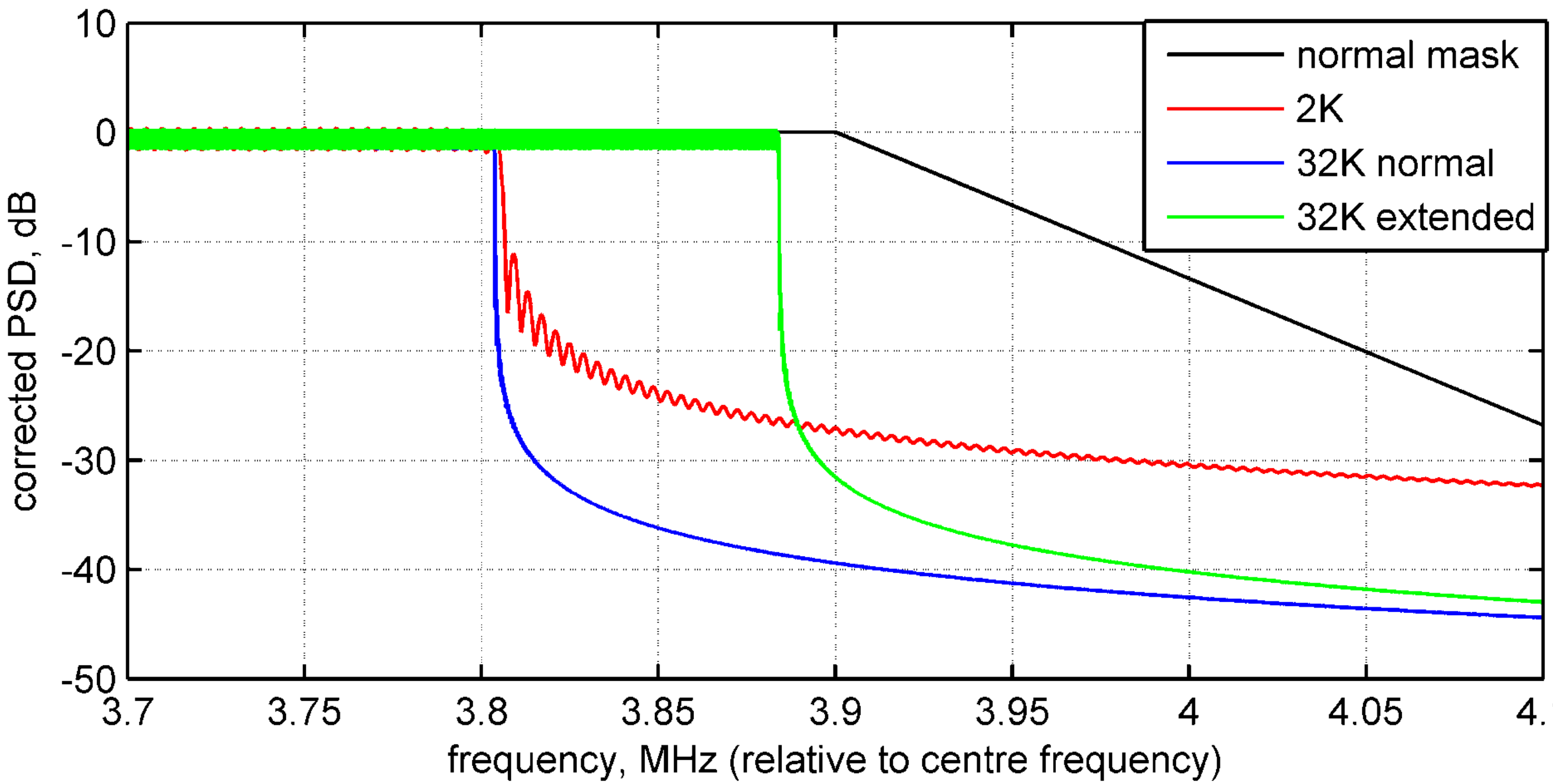
- Increasing the symbol period
  - Can reduce guard interval overhead for given size of SFN
  - Can increase SFN capability for a given fractional GI



- T2 extends guard interval range to allow reduced overhead and additional flexibility
  - GIs in T2: 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4
  - GI 1/8 in 32K mode gives large-SFN performance

Extended carrier mode

- Out of band spectrum for 32K mode falls away more quickly than spectrum for 2K mode
  - Allows 2% extra bandwidth/capacity whilst remaining within normal spectrum mask



DVB-T2 Bandwidth options

- DVB-T2 has three additional bandwidth options compared to DVB-T

DVB-T	DVB-T2
–	1.7 MHz
–	5 MHz
6 MHz	6 MHz
7 MHz	7 MHz
8 MHz	8 MHz
–	10 MHz

(10 MHz is for professional applications only)

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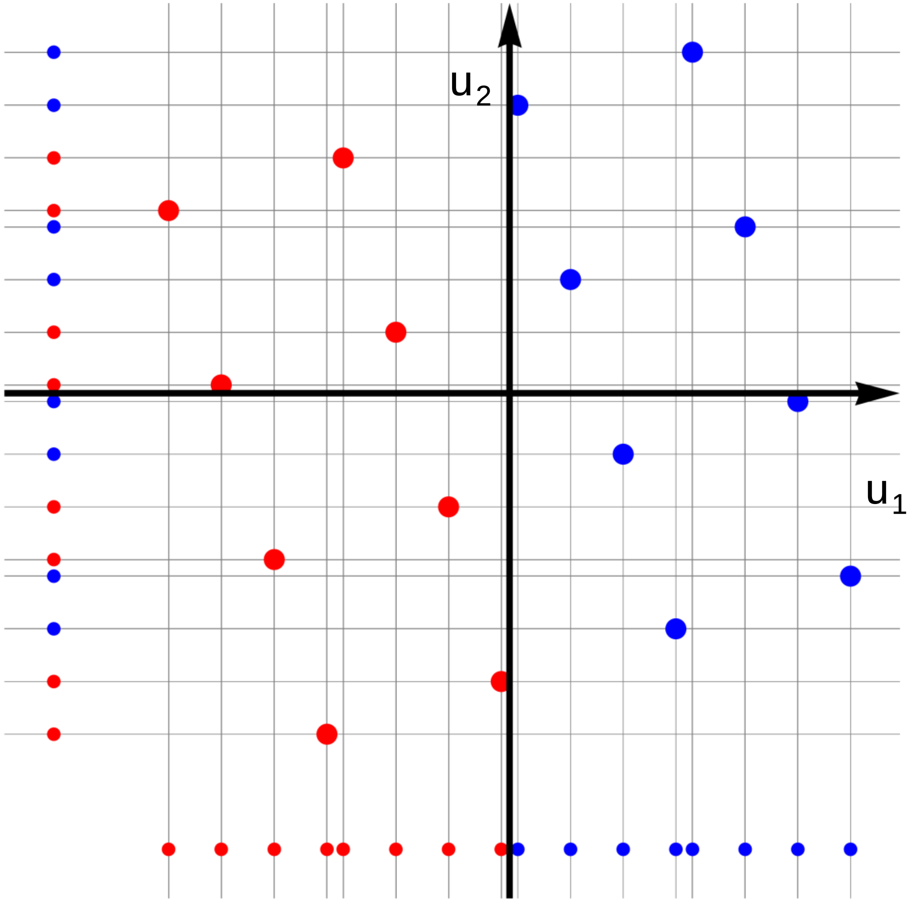
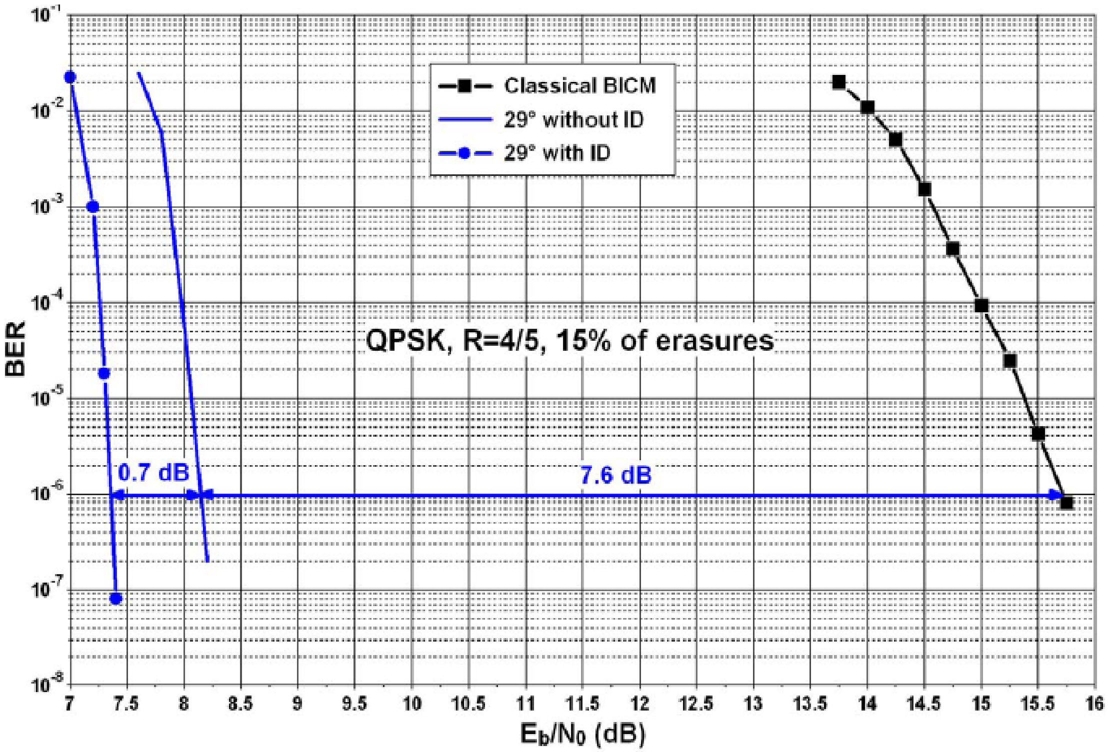
Rotated Constellations (1)

- Map data onto a normal QAM (x,y)
- Rotate constellation (axes now (u1,u2)
- Ensure u1 and u2 travel in different cells
  - So that they fade independently
  - Gather together in receiver
- Each of u1,u2 carries all of the info of original x,y
  - So can decode (less ruggedly) if one is erased completely



Rotated 16-QAM constellation, showing bit 0 mapping. Blue points represent a 0 and red points represent a 1

Rotated Constellations (2)



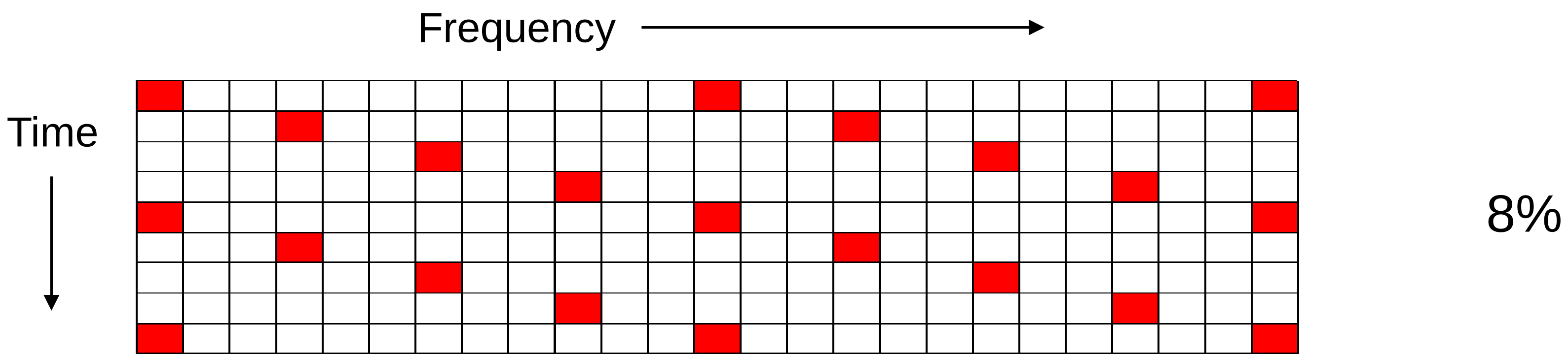
System behaviour with constellation rotation (blue) and without (black)

Rotated constellations provide significantly improved robustness against loss of data cells

- Can achieve gains of up to 7 dB on difficult channels
  - e.g 15% cell loss channel
- Can translate into increased bit rate by choosing less robust FEC with lower overhead

Scattered Pilot Patterns (1)

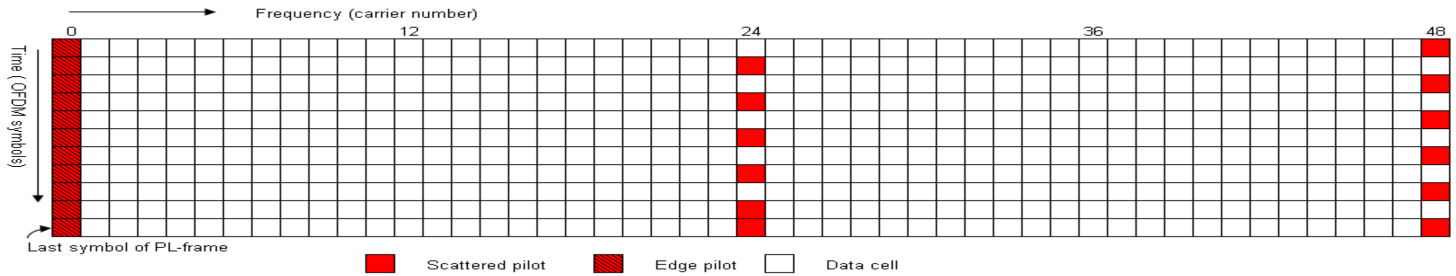
- Scattered pilots are OFDM cells of known amplitude and phase
  - Receiver uses these to compensate for effects of channel changing in frequency and time.
- In DVB-T, 1 in 12 OFDM cells is a scattered pilot
  - 8% overhead
  - Independent of guard-interval fraction



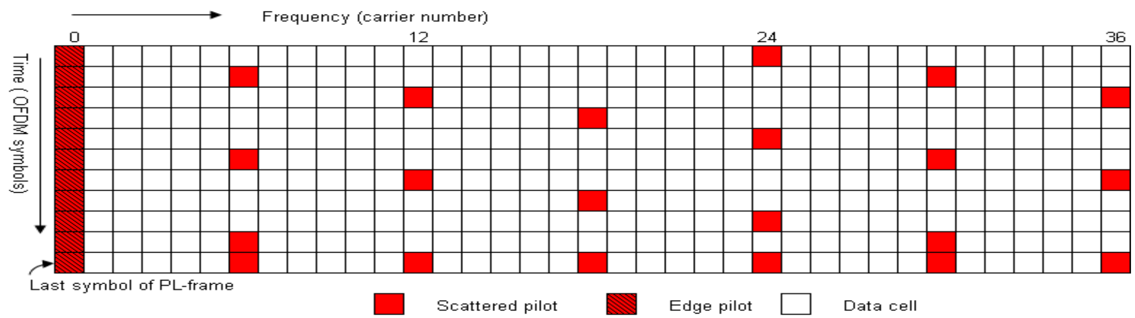
Scattered Pilot Patterns (2)

- T2 has 8 different scattered pilot pattern options
  - Aim: to minimise pilot pattern overhead for a given fractional guard interval; e.g. ….

Time



2%



4%

- Pilot cells are boosted by up to 7 dB depending on density
  - Improves signal to noise on channel estimate

Allocation of Pilot Patterns

- Choice of scattered pilot pattern depends on guard interval and FFT size

FFT size	Pilot patterns available for each guard interval (SISO)						
	1/128	1/32	1/16	19/256	1/8	19/128	1/4
32K	PP7	PP4 PP6	PP2 PP8 PP4	PP2 PP8 PP4	PP2 PP8	PP2 PP8	NA
16K	PP7	PP7 PP4 PP6	PP2 PP8 PP4 PP5	PP2 PP8 PP4 PP5	PP2 PP3 PP8	PP2 PP3 PP8	PP1 PP8
8K	PP7	PP7 PP4	PP8 PP4 PP5	PP8 PP4 PP5	PP2 PP3 PP8	PP2 PP3 PP8	PP1 PP8
4K, 2K	NA	PP7 PP4	PP4 PP5	NA	PP2 PP3	NA	PP1
1K	NA	NA	PP4 PP5	NA	PP2 PP3	NA	PP1

T2 Interleaving

- LDPC works well only for randomly distributed bit errors
  - Must avoid regular patterns of errors and bursts of errors
  - Must randomise mapping of bits from FEC block into constellation points and frame structure

- T2 uses four main interleavers
  - Bit, cell, time and frequency interleaving
    - Bit, cell, and time interleavers applied separately to each PLP
      - receiver's de-interleaving memory is used efficiently
    - Frequency interleaving
      - Mixes cells from different PLPs
      - Protects against frequency-selective fading

Time Interleaver

- Time Interleaver
  - Disperses data cells from FEC blocks of a given service throughout the sub-slices within a T2-frame
  - Provides robustness against impulsive noise
    - and other time varying channels
  - Depth of interleaving is configurable, within limit of fixed memory size for receiver
    - allows a minimum of 70ms of time interleaving
    - can be extended by the use of multiple PLPs
  - For low data rate services, time interleaving can extend over more than one frame
    - provides a much greater interleaving depth with same memory

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C/N required for network planning

- Required C/N depends on
  - Choice of modulation parameters
  - Target transmission channel
  - Receiver implementation factors

- Method derived to take these into account and derive a required C/N value for any combination
  - Use ‘raw’ (simulation) values: $C/N_{Gauss\text{-}raw}$
  - Simulation values assume
    - ‘ideal’ receiver performance (channel estimation)
    - no allowance for pilot boosting

- Calculated values show reasonable agreement with measured values across a range of receivers

Constellation	**Code rate**	**Gaussian Channel** ($C/N_{Gauss-raw}$)	**Constellation**	**Code rate**	**Gaussian Channel** ($C/N_{Gauss-raw}$)
QPSK	1/2	***1.0***	64-QAM	1/2	***10.5***
QPSK	3/5	***2.2***	64-QAM	3/5	***12.3***
QPSK	2/3	***3.1***	64-QAM	2/3	***13.6***
QPSK	3/4	***4.1***	64-QAM	3/4	***15.1***
QPSK	4/5	***4.7***	64-QAM	4/5	***16.1***
QPSK	5/6	***5.2***	64-QAM	5/6	***16.7***
16-QAM	1/2	***6.2***	256-QAM	1/2	***14.4***
16-QAM	3/5	***7.6***	256-QAM	3/5	***16.7***
16-QAM	2/3	***8.9***	256-QAM	2/3	***18.1***
16-QAM	3/4	***10.0***	256-QAM	3/4	***20.0***
16-QAM	4/5	***10.8***	256-QAM	4/5	***21.3***
16-QAM	5/6	***11.3***	256-QAM	5/6	***22.0***

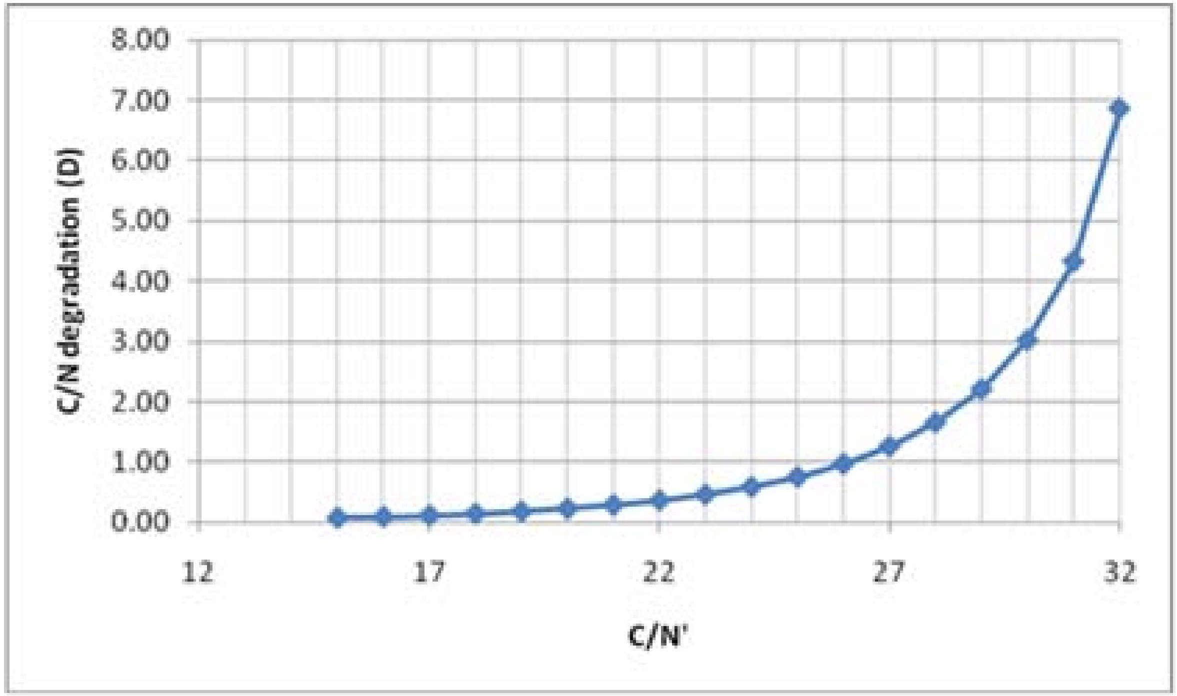
C/N corrections

- $C/N_{Gauss} = C/N_{Gauss\text{-}raw} + A + B + C + D$
  - A: Correction for BER of 10^{-7} (0.1 dB)
  - B: Correction for pilot boosting
  - C: Correction for real channel estimation
  - D: Correction for 'backstop' noise in receiver

Correction (dB)	Pilot Pattern							
	PP1	PP2	PP3	PP4	PP5	PP6	PP7	PP8
B = Pilot Boost Correction	0.4	0.4	0.5	0.5	0.5	0.5	0.3	0.4
C = Real Channel Estimation	2.0	2.0	1.5	1.5	1.0	1.0	1.0	1.0

Backstop noise correction

- Assumes 'backstop' noise of -33dBc
  - e.g. phase noise and quantising noise in demod
  - Correction depends on required C/N
    - $C/N' = C/N_{Gauss\text{-}raw} + A + B + C$
    - $C/N_{Gauss} = C/N' + D$



C/N – other channels

- Similar method for non-Gaussian channels
  - $C/N'_{Rice} = C/N_{Gauss\text{-}raw} + DELTA_{Rice} + A + B + C$
  - $C/N_{Rice} = C/N'_{Rice} + D$
  - $C/N'_{Rayleigh} = C/N_{Gauss\text{-}raw} + DELTA_{Rayleigh} + A + B + C$
  - $C/N_{Rayleigh} = C/N'_{Rayleigh} + D$

Constellation	Code Rate	DELTA C/N Rice (dB)	DELTA C/N Rayleigh (dB)	Constellation	Code Rate	DELTA C/N Rice (dB)	DELTA C/N Rayleigh (dB)
QPSK	1/2	**0.2**	**1.0**	64-QAM	1/2	**0.3**	**2.0**
QPSK	3/5	**0.2**	**1.3**	64-QAM	3/5	**0.3**	**2.0**
QPSK	2/3	**0.3**	**1.8**	64-QAM	2/3	**0.3**	**2.1**
QPSK	3/4	**0.3**	**2.1**	64-QAM	3/4	**0.3**	**2.6**
QPSK	4/5	**0.3**	**2.4**	64-QAM	4/5	**0.5**	**3.1**
QPSK	5/6	**0.4**	**2.7**	64-QAM	5/6	**0.4**	**3.4**
16-QAM	1/2	**0.2**	**1.5**	256-QAM	1/2	**0.4**	**2.4**
16-QAM	3/5	**0.2**	**1.7**	256-QAM	3/5	**0.2**	**2.2**
16-QAM	2/3	**0.2**	**1.9**	256-QAM	2/3	**0.3**	**2.3**
16-QAM	3/4	**0.4**	**2.4**	256-QAM	3/4	**0.3**	**2.6**
16-QAM	4/5	**0.4**	**2.8**	256-QAM	4/5	**0.4**	**3.0**
16-QAM	5/6	**0.4**	**3.1**	256-QAM	5/6	**0.4**	**3.4**

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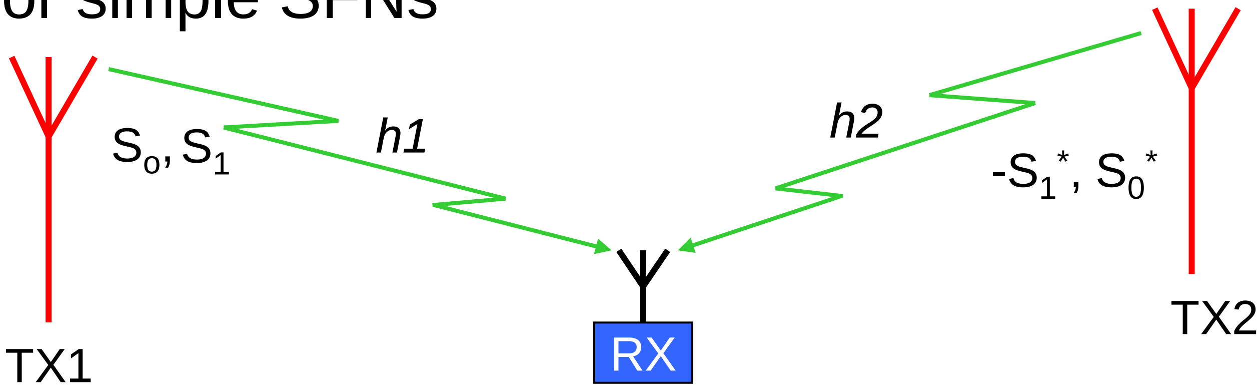
Transmit Diversity – MISO (1)

- T2 includes Alamouti coding mode for simple SFNs
  - ‘MISO’ – ‘Multiple input single output’
  - While Tx1 transmits pair of data cells S_0,S_1, Tx2 transmits -S_1*,S_0*
  - Also involves modification of pilot patterns to measure h1 and h2
  - This prevents possibility of ‘fading’ caused by two transmitters at receiver

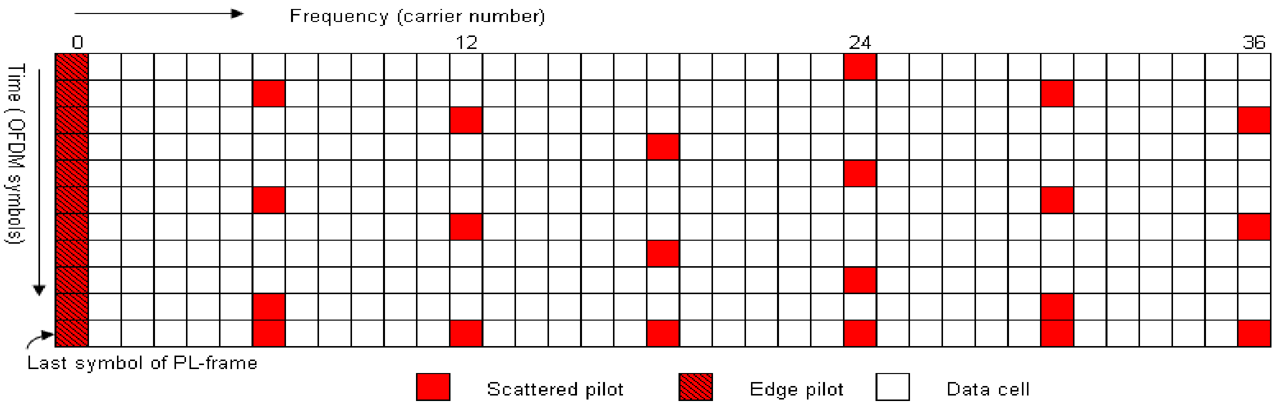
- Initial planning studies predict 30% increase in coverage area for simple SFNs



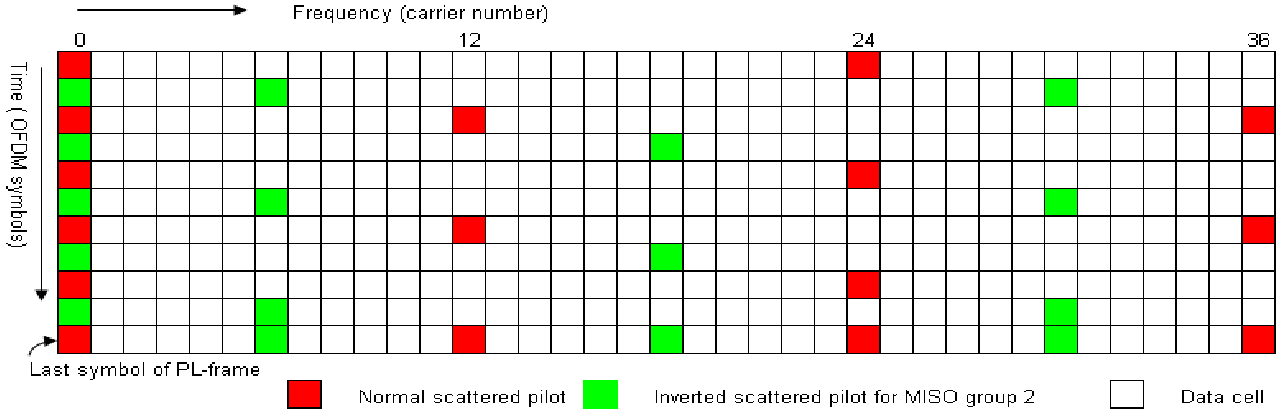
Transmit Diversity – MISO (2)

- Scattered pilot patterns are modified (for second transmitter) to enable measurement of channels h1 and h2; e.g. -

Transmitter 1

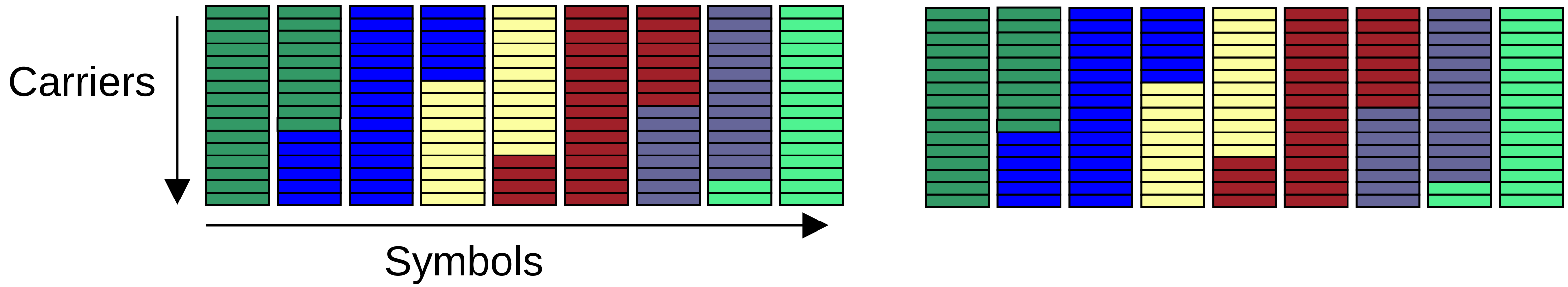


Transmitter 2



Physical Layer Pipes

- Time slicing at physical layer
  - Different Physical Layer Pipes can have different levels of robustness
    - different applications: roof-top reception/portables
  - Enables power saving



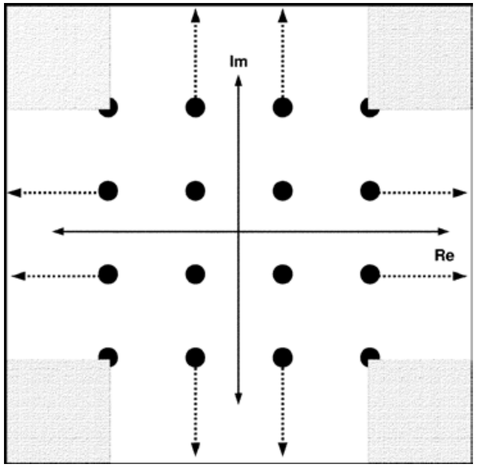
- Sub-slicing within frame
  - Increases time diversity/interleaving depth without increasing de-interleaver memory

Single vs. Multiple PLP

- Typical use – single PLP
  - Complete transport stream is contained within single PLP
    - Including all PSI/SI
- Typical use – multiple PLP
  - Each PLP carries a transport stream
    - or a stream of transport packets (with minimum PSI for contained service)
  - PSI/SI information common to a group of PLPs (e.g. EPG) is carried in a 'Common PLP'
    - This Common PLP is always carried at beginning of frame
    - Receiver must be able to decode Common PLP & one data PLP

Peak to Average Power Reduction

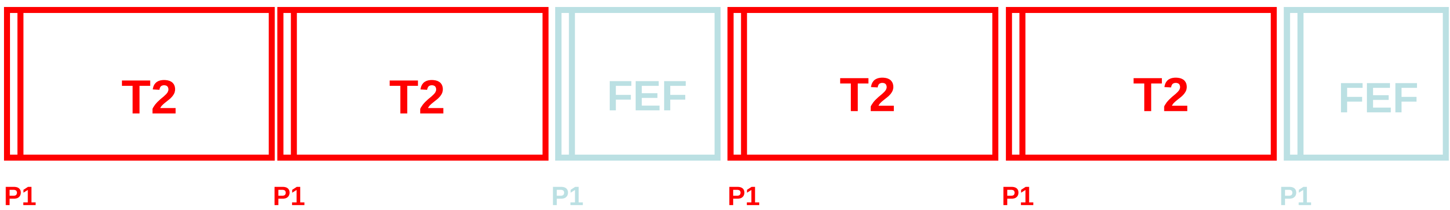
- T2 uses a combination of 2 PAPR reduction techniques
  - Tone reservation
    - 1% of carriers reserved for arbitrary modulation to counteract any peaks
  - ‘ACE’
    - Constellation distortion to counteract peaks



- Reduction in peak to average power allows amplifier peak power requirement to be reduced by 20%

FEF & TFS

- Future Extension Frames (FEFs)
  - Provide a mechanism for future compatible enhancements – e.g. T2-Lite or DVB-NGH
  - Only requirement is for FEF to start with P1 symbol



- Time Frequency Slicing
  - Multiplex of signals is spread across several linked frequencies
    - Can give significant Stat Mux gain (20%) and frequency planning gain (5dB)
  - T2 signalling and system is compatible with Time Frequency Slicing system provided receivers have 2 tuners

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DVB-T2-Lite / NGH

- V1.3.1 of T2 specification introduced DVB-T2-Lite
  - A profile of DVB-T2 with a sub-set of modes
  - Allows receiver simplifications
    - Less memory, lower processing speeds
  - Aimed at simpler receivers especially for mobile and hand-held applications
  - Also adds two new code rates for robustness (1/3, 2/5)

- DVB-NGH
  - Next generation handheld specification being developed
    - first draft expected 2012
  - Full specification for hand-held applications
    - New features such as MIMO, support for scalable coding and options for combined terrestrial-satellite

Thanks for your attention!

Any questions?

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