DVB-T2 in relation to the DVB-x2 Family of Standards

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The DVB-x2 systems

- Over time, the DVB Project designed the following DVB broadcast standards:

DVB-S, DVB-S2:	for Direct-to-Home (DTH) satellite transmission
DVB-T, **DVB-T2:**	for terrestrial transmission
DVB-C, DVB-C2:	for cable transmission
DVB-CS:	for master antenna and satellite master antenna installations
DVB-MC:	for microwave transmission below 10 GHz
DVB-MS:	for microwave transmission above 10 GHz
DVB-MT:	for the extension of terrestrial networks via microwave bands
DVB-H, DVB-SH, (**DVB-NGH**):	for transmission to handheld devices
DVB-IPTV:	for transmission over a managed IP network

Work in Progress

DVB-S as the starting point

- DVB-S was the first ever system that DVB developed. The specification was completed by the end of 1993
  - DVB-S is something like the mother of the DVB-x1 family of standards
- DVB-S has been deployed around the globe
- A typical data rate provided by DVB-S in a satellite channel of 36 MHz bandwidth would be 38 Mbit/s
- In 2001, DVB started looking at a second generation solution in order to increase the data rate for HDTV

Features of DVB-S2

- Forward error correction is based on a powerful Low Density Parity Check Code (LDPC), concatenated with a BCH-Code.
  - Within 0.8dB of Shannon limit
- The transport layer of DVB-S2 is based around the 'BaseBand Frame'
- Compared to DVB-S, DVB-S2 provides an increase of the data rate of around 30%
- LDPC is significantly more complex than first generation error correction scheme
  - Despite complexity, consumer DVB-S2 receiver still feasible
    - the decoder requires only 14 mm^2 silicon (0.13 µm-technology)

Background to T2 development

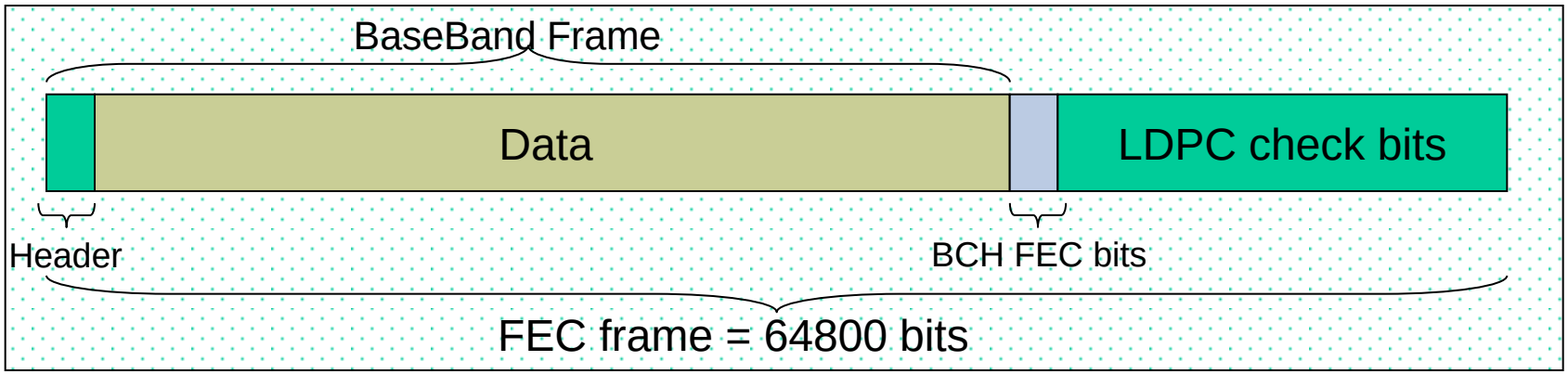
- Initial motivation
  - DVB-S2 successful in providing 30% more capacity
  - Terrestrial HD services required new receivers
  - Why not upgrade modulation scheme while upgrading receivers/set-top boxes for HD?
- UK decided to commit to DVB-T2 based HD services as part of digital switch over
  - Provided at least 30% increase in capacity compared with DVB-T
  - Services to start end 2009 / early 2010
  - UK commitment helped to galvanize industry interest
  - Short timescales drove forward standardisation process
- DVB process
  - TM-T2 ad-hoc group started August 06:
  - More than 40 companies actively participated in development of T2 specification
    - Many meetings; many tens of telecons; thousands of emails
  - T2 specification published June 2008

Commercial Requirements for T2

- Key requirements include
  - 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 planning constraints as DVB-T
  - 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

T2 Key features: BaseBand Frames and LDPC

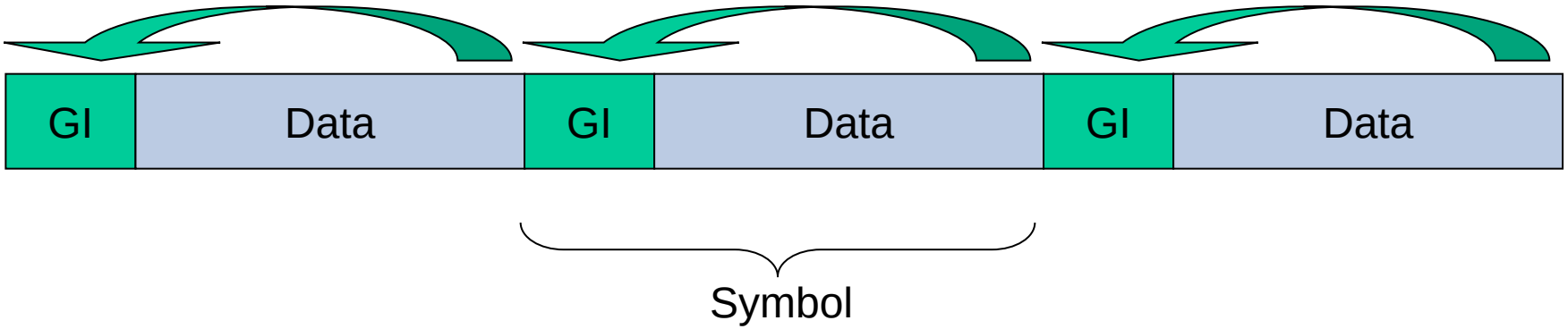
- Data packaged into BaseBand Frames
  - Inherited from S2
- BaseBand Frames protected by the S2 LDPC FEC
  - With an additional small BCH code to mop up any residual errors after LDPC decoding



- 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
- Bit-rate gain compared with DVB-T is typically 30% for same overhead and same level of robustness

T2 Key Features: Modulation (1)

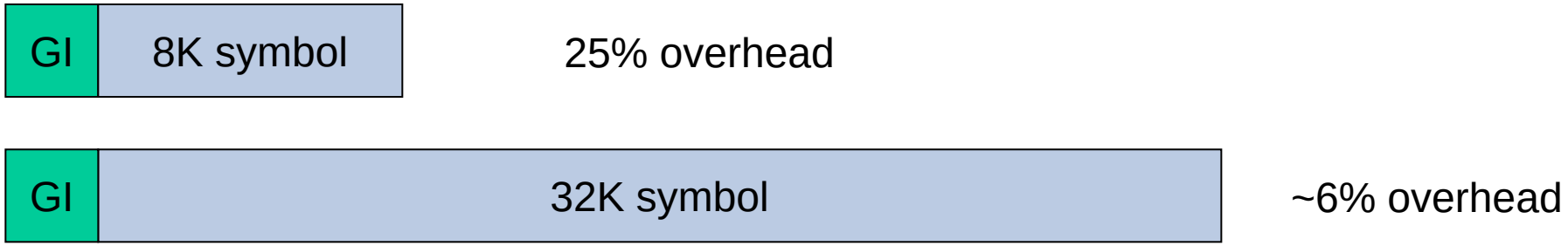
- T2 uses conventional Guard-Interval OFDM (GI-OFDM)
  - as in DVB-T



- Each symbol carries data on a large number of separate carriers
  - 1K, 2K, 4K, 8K, 16K, 32K 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

T2 Key Features: Modulation (2)

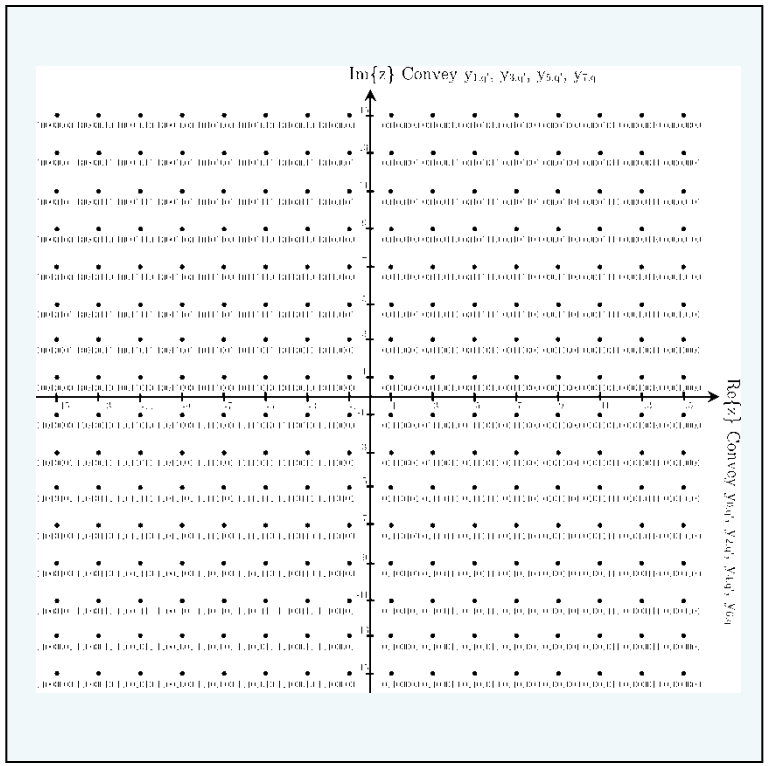
- Increasing the symbol period
  - Can reduce guard interval overhead for given size of SFN
  - Can increase SFN capability for a given fractional GI



- 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, ¼
- Max GI (19/328) in 32K mode gives large-SFN performance

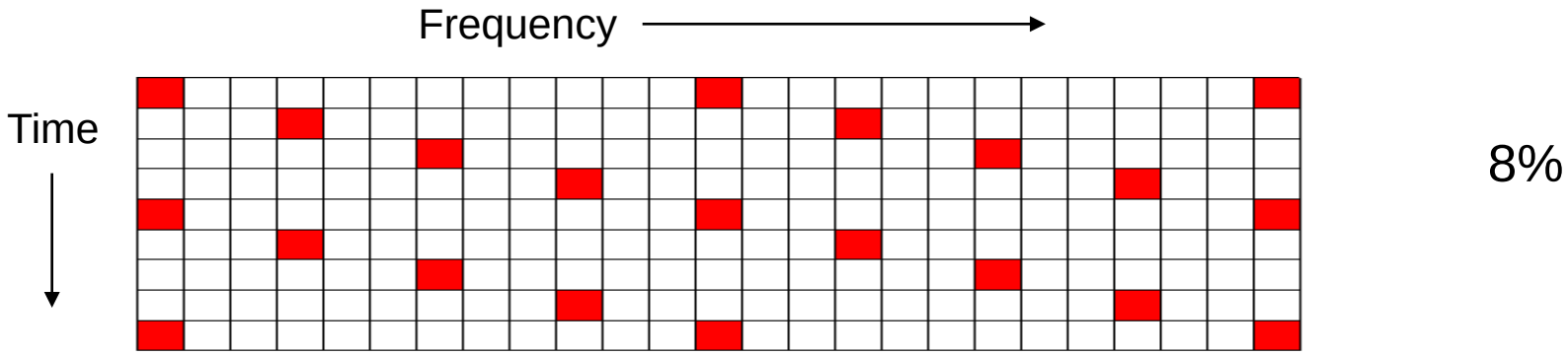
T2 Key Features: Modulation (3)

- T2 includes 256 QAM mode
  - Carries 8 bits/ data cell
    - (c.f max. 6 bits / data cell for 64 QAM in DVB-T)
  - Enables greater capacity, exploiting improved FEC performance of LDPC
  - Studies show that typical tuner phase noise should not be a problem



T2 Scattered Pilot Patterns (1)

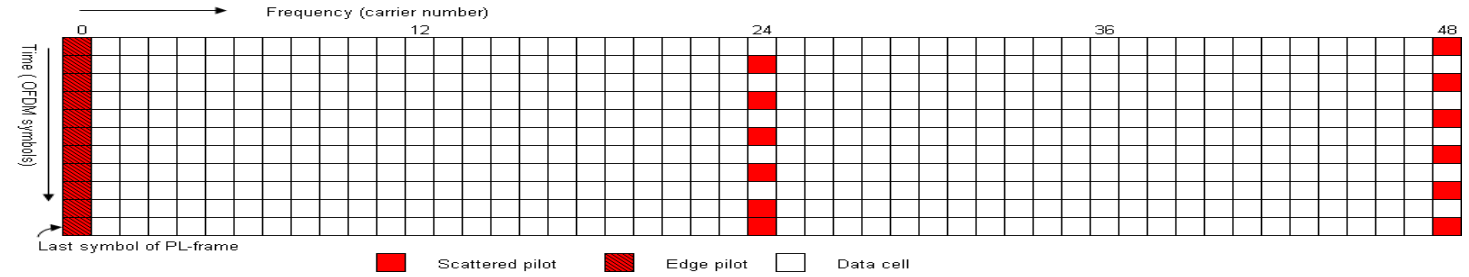
- Scattered pilots are data cells of known amplitude and phase
  - Receiver uses these to compensate for effects of channel changing in frequency and time.
- In DVB-T, 1 in 12 data cells is a scattered pilot
  - 8% overhead
  - Independent of guard-interval fraction



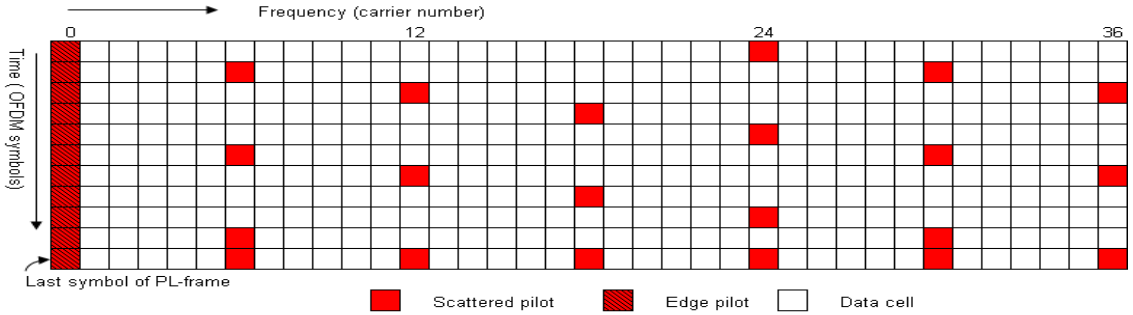
T2 Scattered Pilot Patterns (2)

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

Time



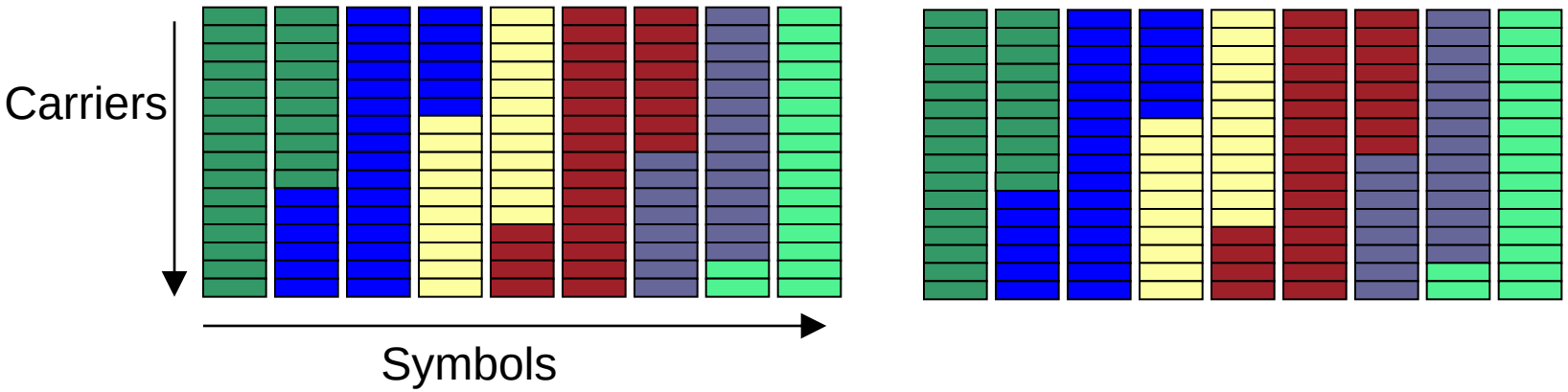
2%



4%

T2 Key features: Service Specific Robustness

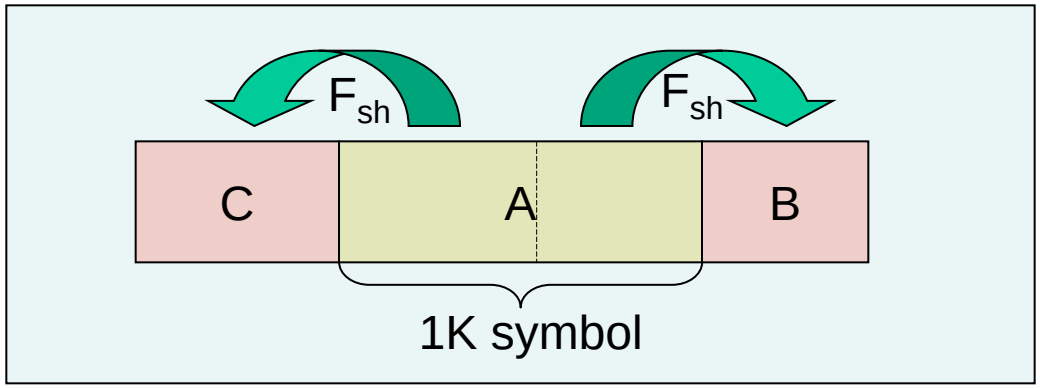
- Each service can be given its own modulation mode (e.g. 256QAM, 16 QAM) and FEC coding rate (e.g. rate 3/5, rate 3/4)
  - Different applications: roof-top reception/portables



- Each service is given a slice of data cells within a 'T2 frame'
  - Each slice is part of a *Physical Layer Pipe* for that service
  - Also enables power saving in the receiver
  - Slices can be sub-divided into sub-slices within frame in order to give more time diversity

T2 Key features: Frame Structure

- Start of frame is signalled by a short 'P1 symbol'
  - Based on 1K OFDM symbol with frequency shifted repeats at front and rear of symbol

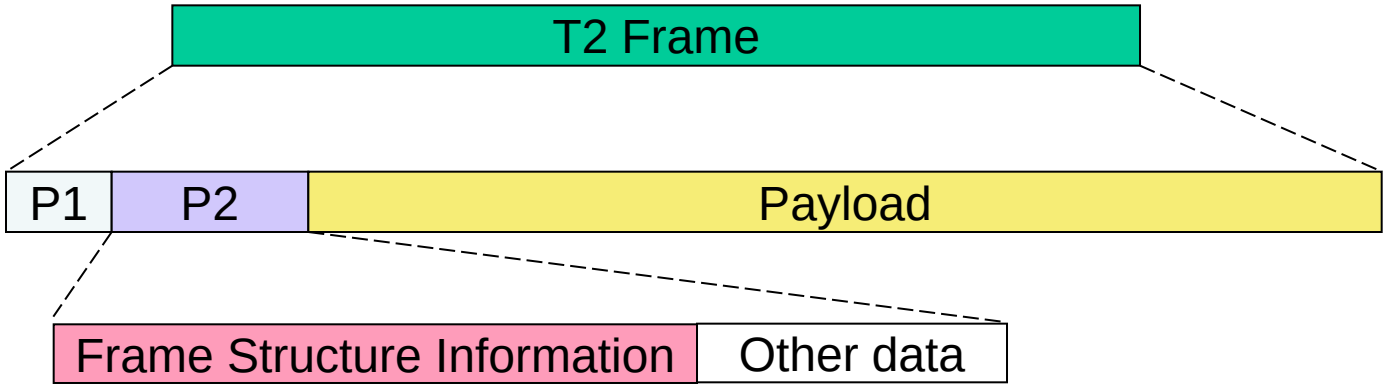


- Only a proportion of 1K carriers occupied
  - Carrying carefully chosen data patterns
- Lengths of segments carefully chosen

- This format of P1 symbol provides
  - Simple and robust mechanism for rapid detection of T2 signal
  - Fast frequency lock mechanism
  - 7 bits of signalling (e.g. for FFT size in main frame)

T2 Frame Structure (3)

- Typical frame duration: 150 -250 ms
  - P1 & P2 overhead typically less than 1%



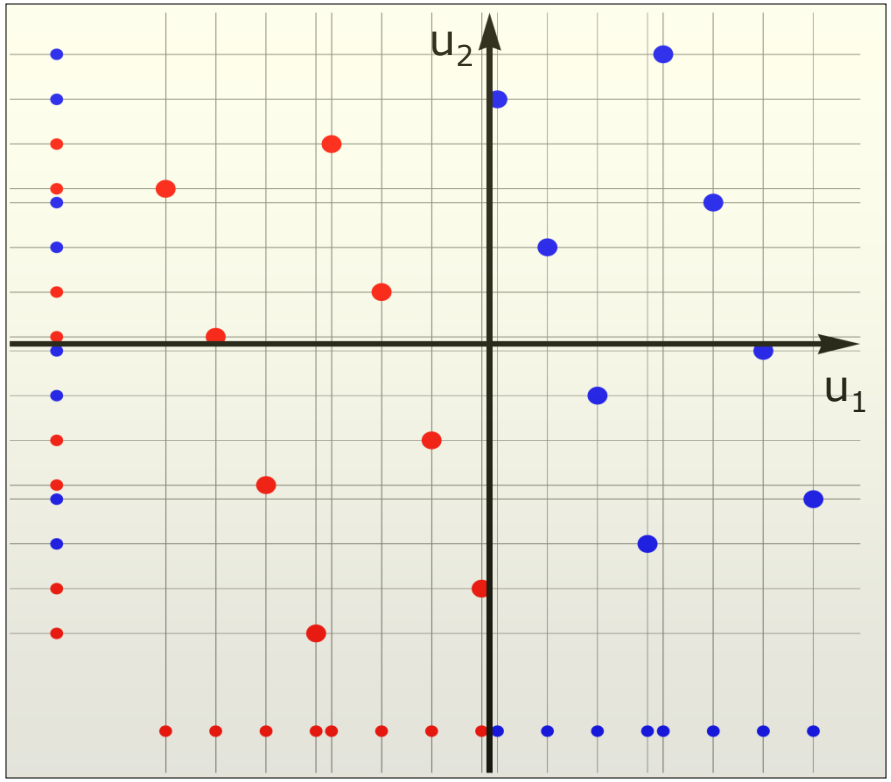
- P2 symbols carry frame structure information
  - must be carried more robustly than payload data
- Other data carried in P2 can include common PSI/SI data for services carried in payload

T2 Interleaving

- For LDPC to work well …
  - Must avoid regular patterns of errors and bursts of errors
  - Must randomise mapping of bits from FEC block into constellation points
- T2 uses four main interleavers – applied per PLP
  - Bit Interleaving and Cell Interleaving within an FEC block
    - Randomises errors from errored data cells
  - Time Interleaver
    - Disperses data cells from FEC blocks of a given service throughout slice for that service
    - Provides robustness in presence of impulsive noise and in time varying channels
  - Frequency Interleaving
    - Causes randomisation of possibly-damaged adjacent data cells within an OFDM symbol
    - Provides robustness against a frequency-selective channel

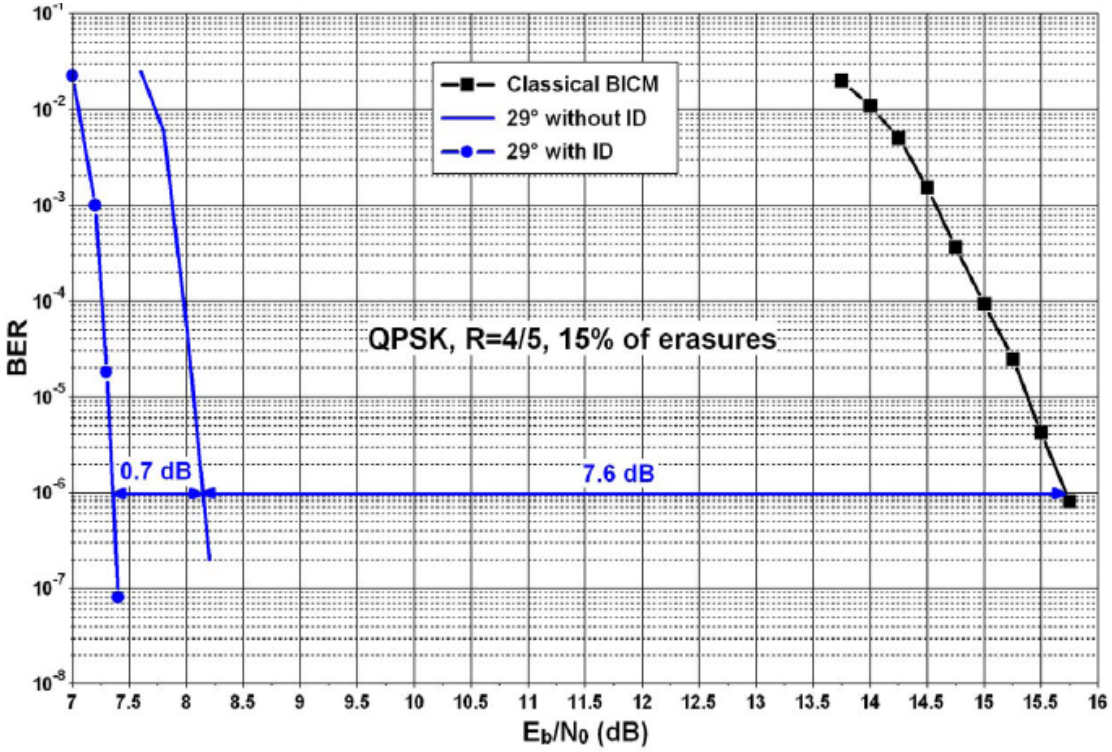
T2 Rotated Constellations (1)

- Map data onto a normal QAM (x,y)
- Rotate constellation (axes now (u_1,u_2)
- Ensure u_1 and u_2 travel in different cells
  - So that they fade independently
  - Gather together in receiver
- Each of u_1,u_2 carries all of the info of original x,y
  - So can decode (less ruggedly) if one is erased completely



Rotated Constellations (2)

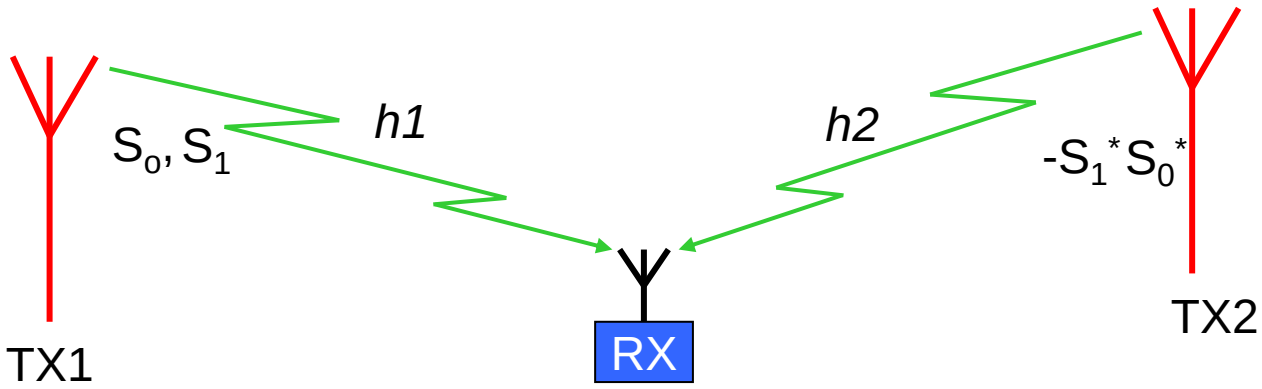
System behaviour with constellation rotation (blue) and without (black)



- 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

T2 Transmit Diversity (MISO)

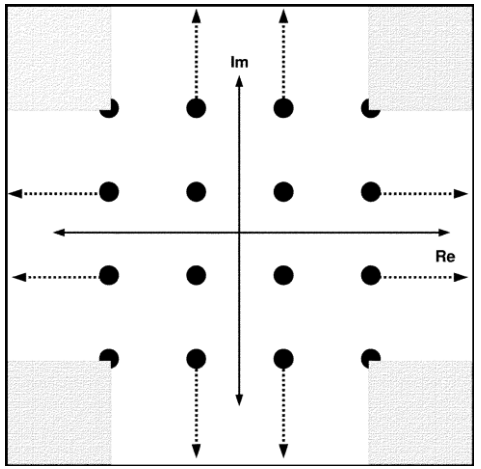
- T2 includes an optional Alamouti coding mode for simple SFNs
  - While Tx1 transmits pair of data cells (S_0,S_1), Tx2 transmits ($-S_1^*$,S_0^*)
  - Also involves modification of pilot patterns to measure *h1 and h2*
  - This prevents possibility of 'flat fading' at receiver



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

T2 Peak to Average Power Reduction

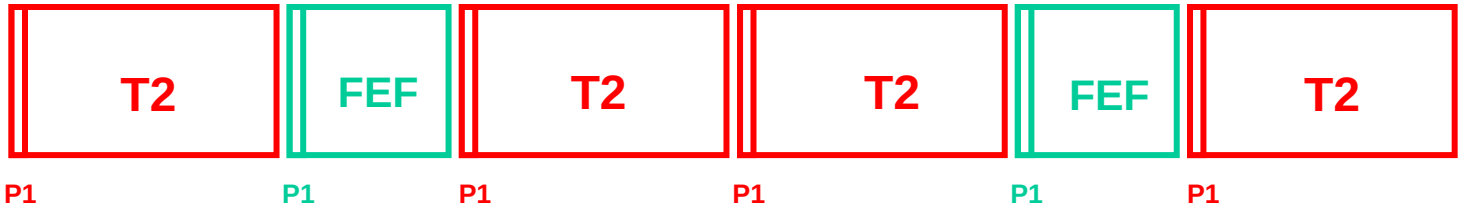
- T2 can use a combination of 2 PAPR reduction techniques
  - Tone reservation
    - 1% of carriers reserved to counteract any peaks
  - 'ACE'
    - Constellation distortion to counteract peaks



- Reduction in peak-to-average power ratio allows peak amplifier power rating to be reduced by 25%

T2 Additional Features

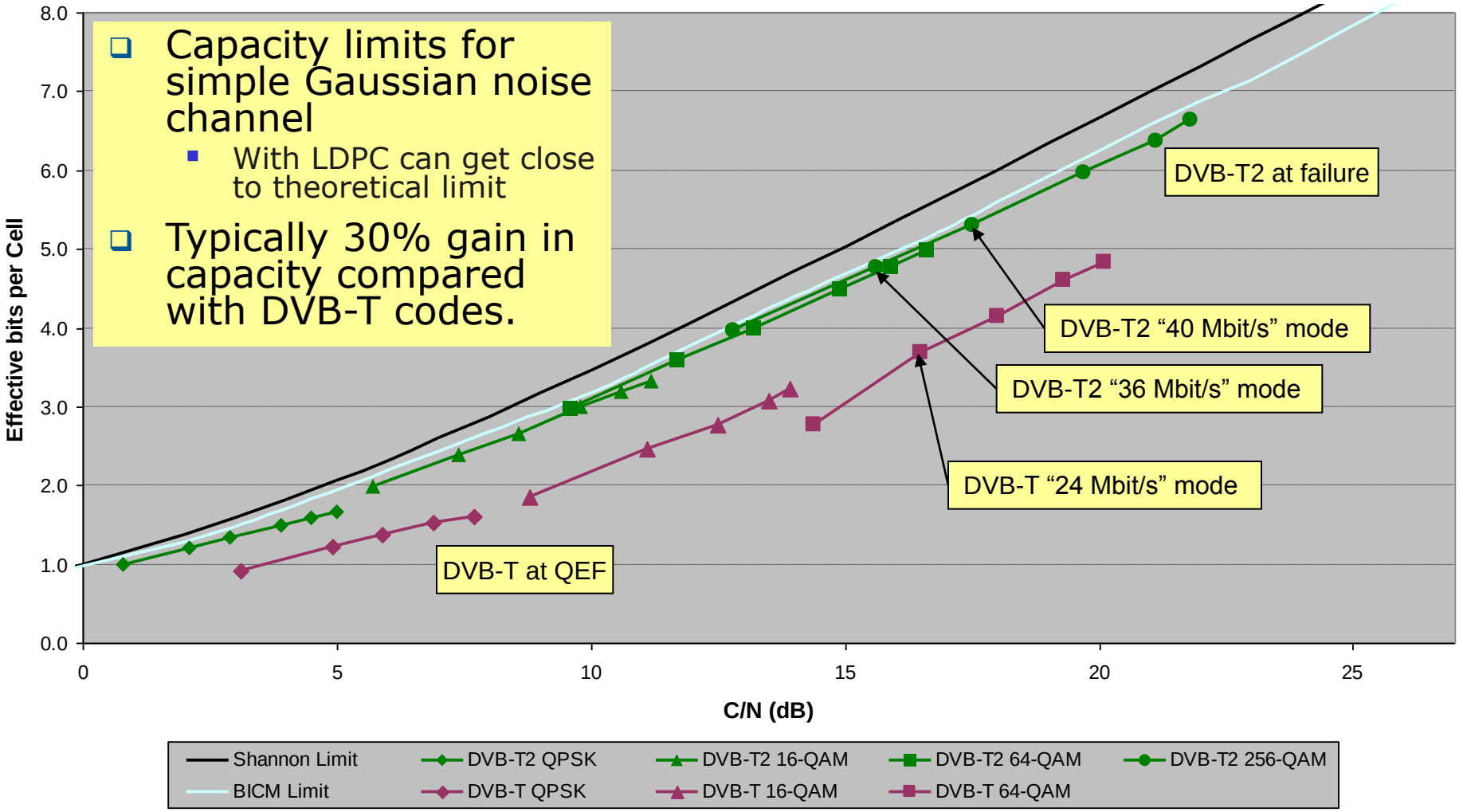
- Future Extension Frames (FEFs)
  - Provide a mechanism for future compatible enhancements – e.g. MIMO



- Time Frequency Slicing
  - Enables 'frequency hopping' reception
  - If receiver has 2 tuners, a large multiplex of signals can be spread across several linked frequencies
    - Can give significant Stat Mux gain (20%) and frequency planning gain (5dB)

T2 Modulation and Coding Performance

- Capacity limits for simple Gaussian noise channel
  - With LDPC can get close to theoretical limit
- Typically 30% gain in capacity compared with DVB-T codes.



Example T2 Capacity figures

	DVB-T (UK mode)	DVB-T2 (Option A)	DVB-T2 (UK mode)
Modulation	64QAM	256QAM	256QAM
FFT size	2K	32K	32K
Guard Interval	1/32	1/128	1/128
FEC	2/3 CC + RS (8%)	3/5LDPC + BCH (0.3%)	2/3LDPC + BCH (0.3%)
Scattered Pilots	8%	1%	1%
Continual Pilots	2.6%	0.53%	0.53%
Frame structure overhead	1%	0.53%	0.53%
Bandwidth	Normal	Extended	Extended
Data Capacity	24.1 Mbit/s	36.1 Mbit/s	40.1 Mbit/s

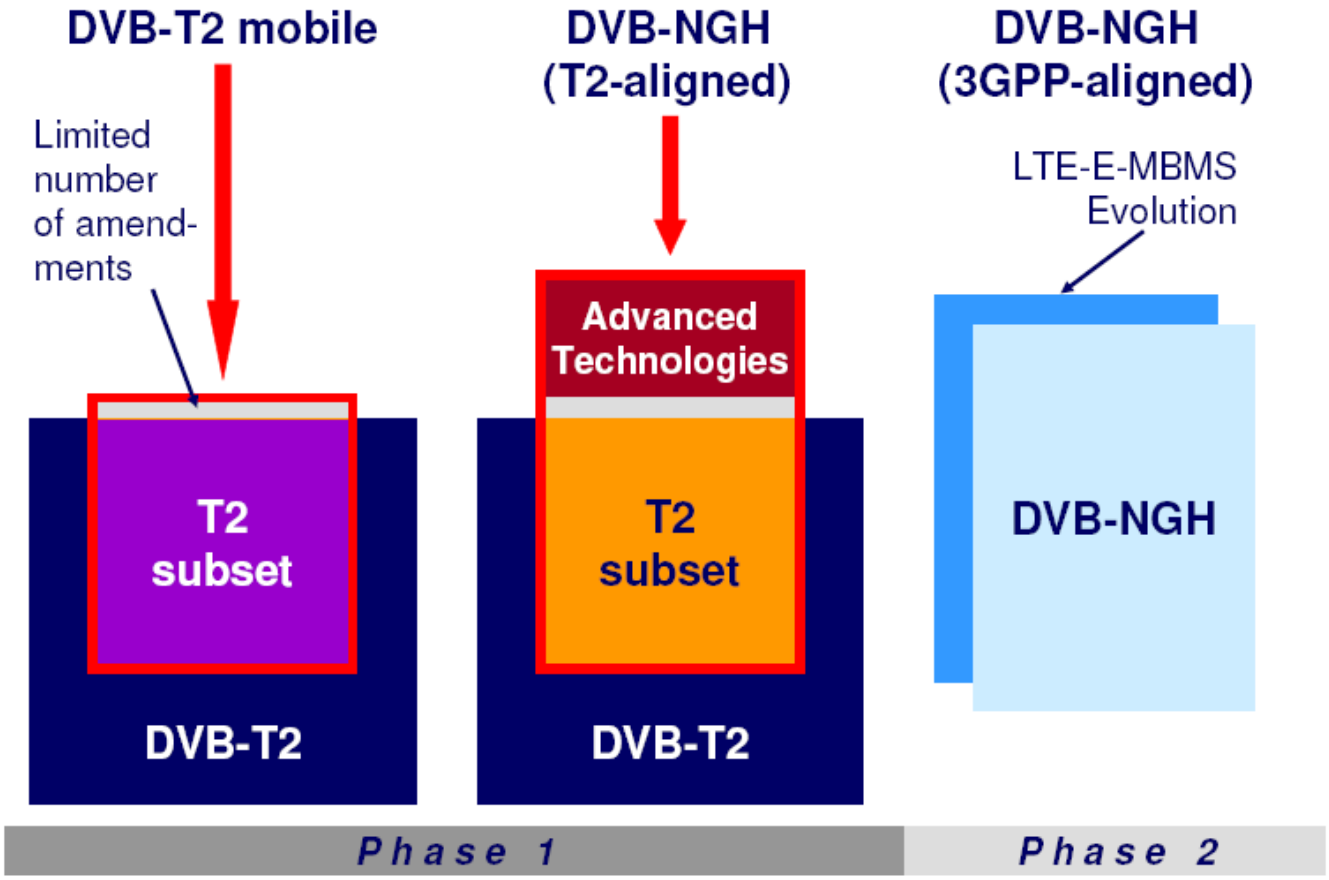
Capacity = DVB-T + [50→70]%

Status of T2 developments

- UK DVB-T2 based HD broadcasts started end 2009 / beginning of 2010
  - Currently 4 x H264-encoded HD services in one statistical multiplex (8MHz)
  - More than 50% of UK population already covered
    - Full coverage by mid 2012
  - Many tens of consumer T2 products available at reasonable prices
    - 1 million receivers sold to date
- Also, several countries currently planning new T2-based services

DVB NGH

- Work is in progress to define a second generation standard for broadcasting to handheld receivers



DVB-C2

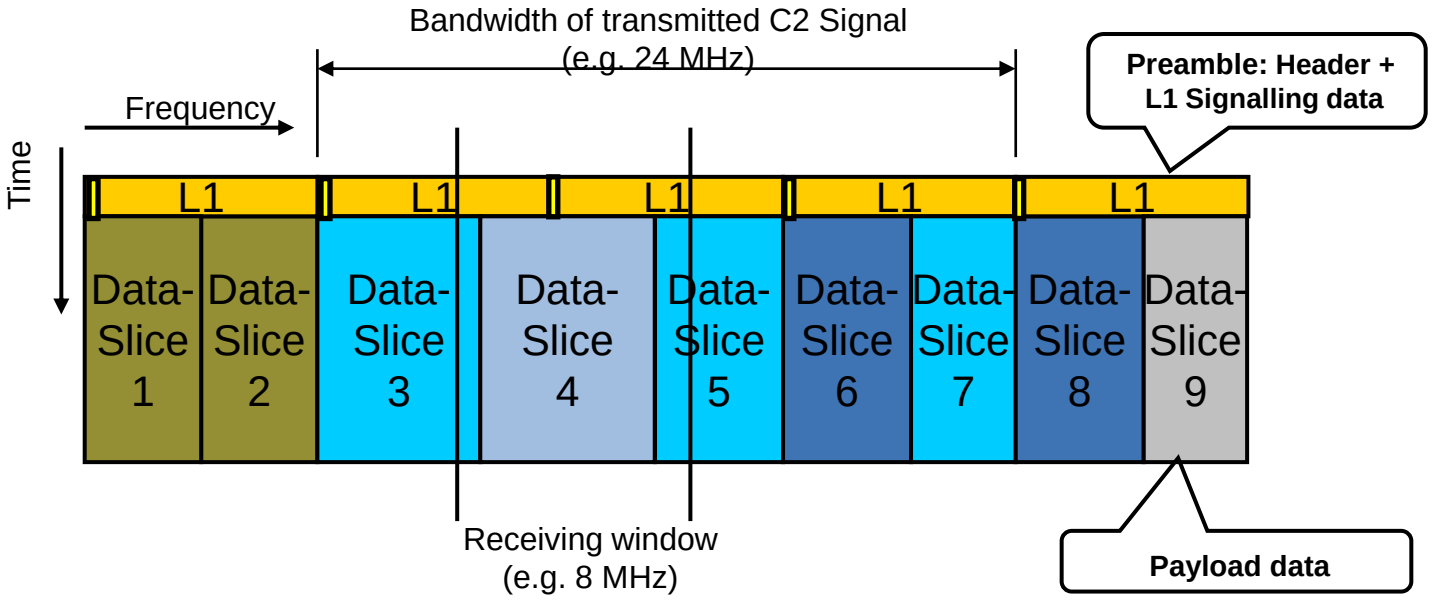
- DVB chose to use OFDM system for 2nd-generation cable standard
  - Flexible channel bandwidth: 6 MHz up to 64 MHz
  - Easy implementation of narrowband or broadband notches
  - Signal level adjustments of sub-bands easily possible
  - Easier handling of cable-specific interference configurations
  - Insensitivity regarding echoes up to a certain echo delay

- C2 builds on features of S2 and T2
  - LDPC + BCH with 64800/16200 length FEC frames
  - Baseband Frames
  - Physical Layer Pipes

DVB-C2 new features

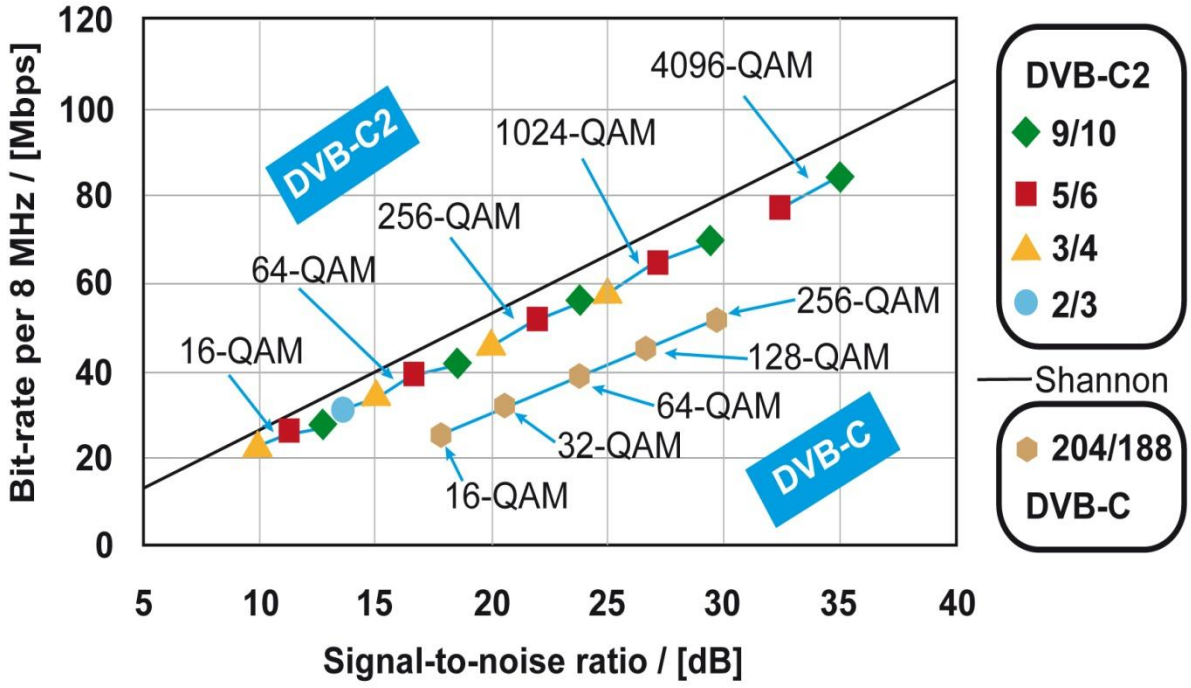
- Constellation options up to 4096-QAM

- Data slices and sliding 'receiver windows'



DVB-C2 Performance

- Maximum total capacity of C2 is 60% greater than DVB-C
  - 30% FEC; 5% broader channels; 20% 4096-QAM



Conclusion

- DVB-S2, DVB-T2 and DVB-C2 form a clear family of 2nd generation transmission standards
- 2nd generation standards offer significant increase in data capacity for given transmission conditions.
  - As well as bringing many other advantages
- DVB-S2 in use for new satellite HD services in Europe and US
  - (10m receivers in Europe)
- UK has launched T2-based HD terrestrial services
  - Full coverage of UK by 2012; already 1m receivers sold
  - Many countries planning T2-based services
- Some German cable operators committed to migration to DVB-C2
- Development work continuing within DVB on next generation standard for broadcasting to mobiles