DVB-T2 transmitter

Introduction

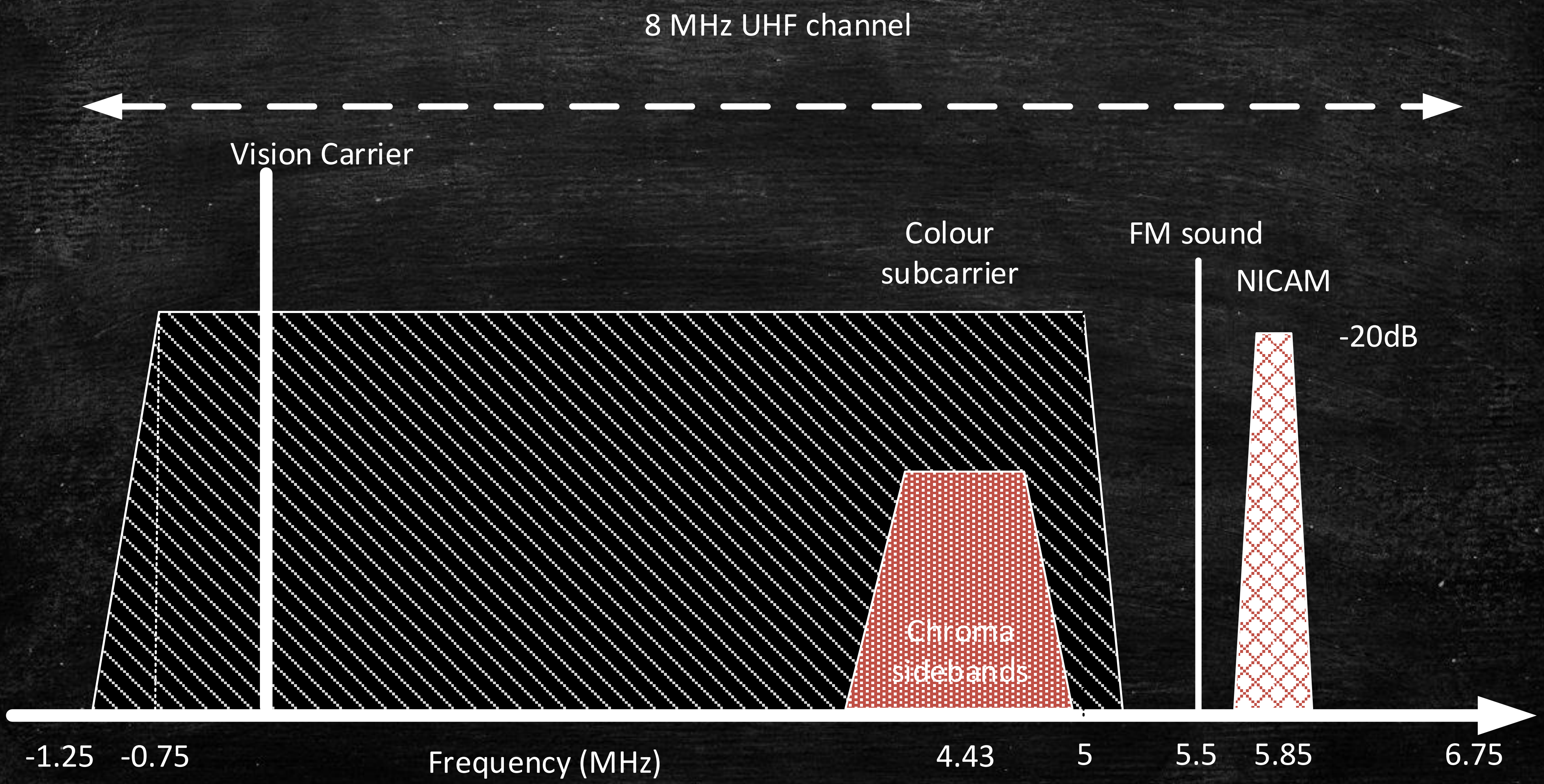
Analogue TV

- Saturation of the radio spectrum
- Rx problems: double image, background noise, interferences ….
- High SNR levels needed in reception
- Data transmission very limited (teletext, not very attractive…)

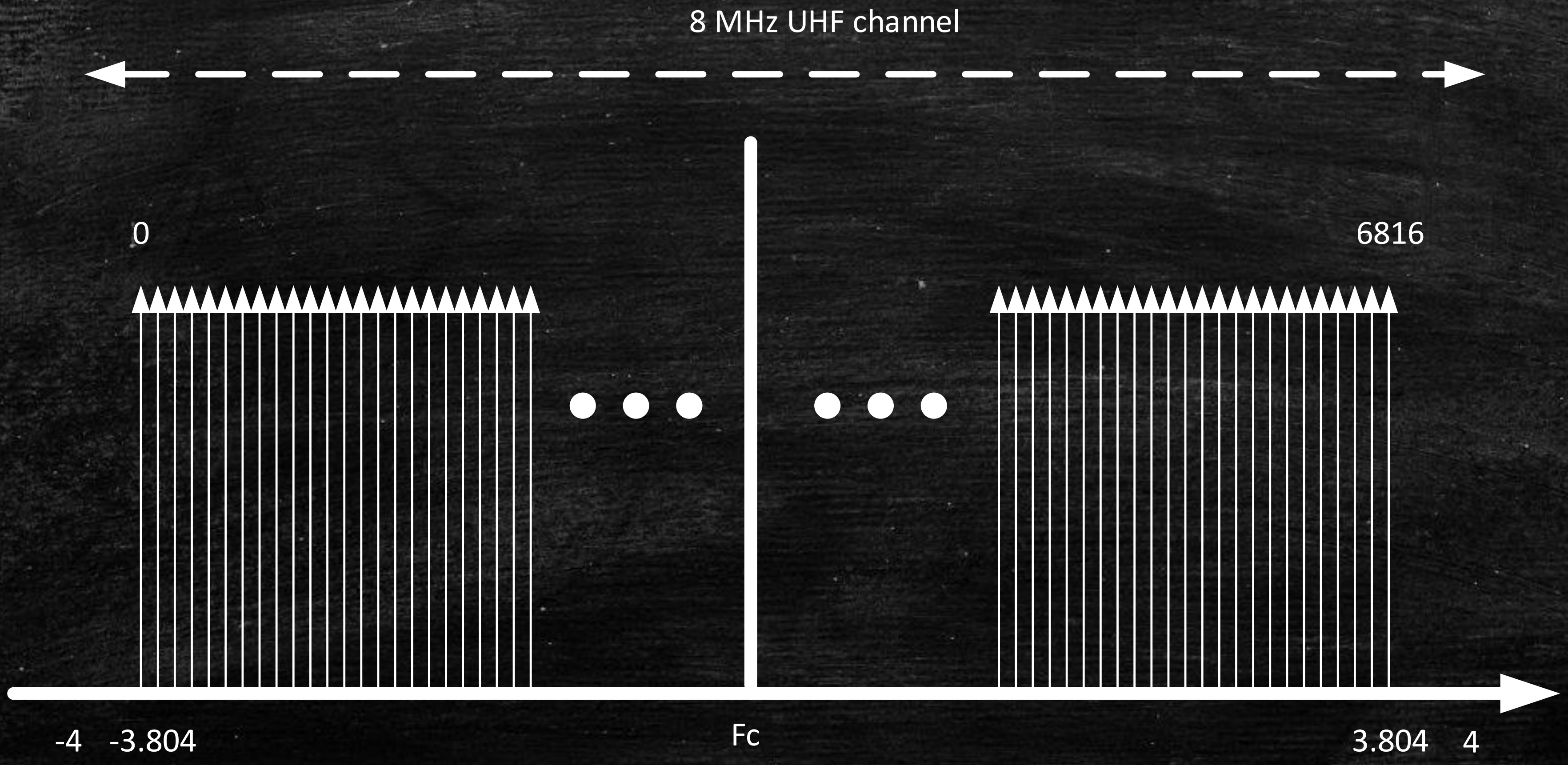
DTT

- Better use of the radio spectrum by allowing more channels
- Better image quality
- Mobile and handheld reception
- Lower Tx power
- Easy home reception
- Interactivity

- An analogue PAL SD TV channel occupies a 8 MHz bandwidth



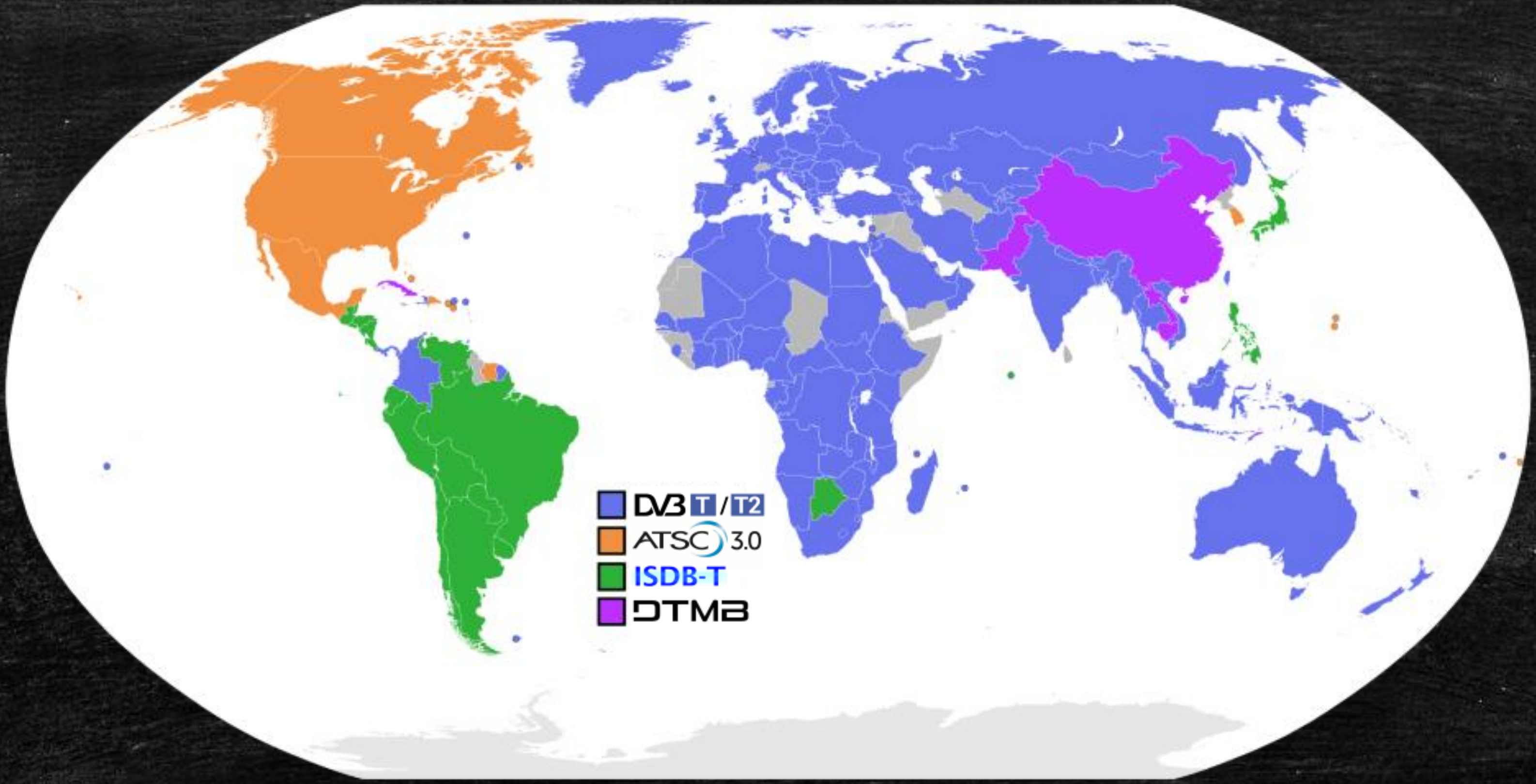
- In an 8MHz bandwidth OFDM channel with a 8k mode we can have:
  - 9 SD TV channels
  - 3 HD TV channels + 1 SD channel



- The analogue switch off has been carried out in this and the past decade in the different countries:

Country	Launch	Analogue switch off start	Analogue switch off end	DTT transmission	AV standard
Russia	2010	2015	2019 (planned)	DVB-T2	H.264
France	2005	2009	2011	DVB-T	H.262
Spain	2000/2005	2009	2010	DVB-T	H.262/H-264
U.K.	1998	2007	2012	DVB-T/T2	H.262/H.264
Italy	2004	2008	2012	DVB-T	H.262/H.264
Germany	2003	2003	2008	DVB-T	H.262/H.264
U.S.A.	1998	2008	2009	ATSC	H.262/H-264 ATSC 2.0

- More tan 200 million devices all over the world receive DVB compliant service
- DVB-T and DVB-T2 are used in more than 70 countries



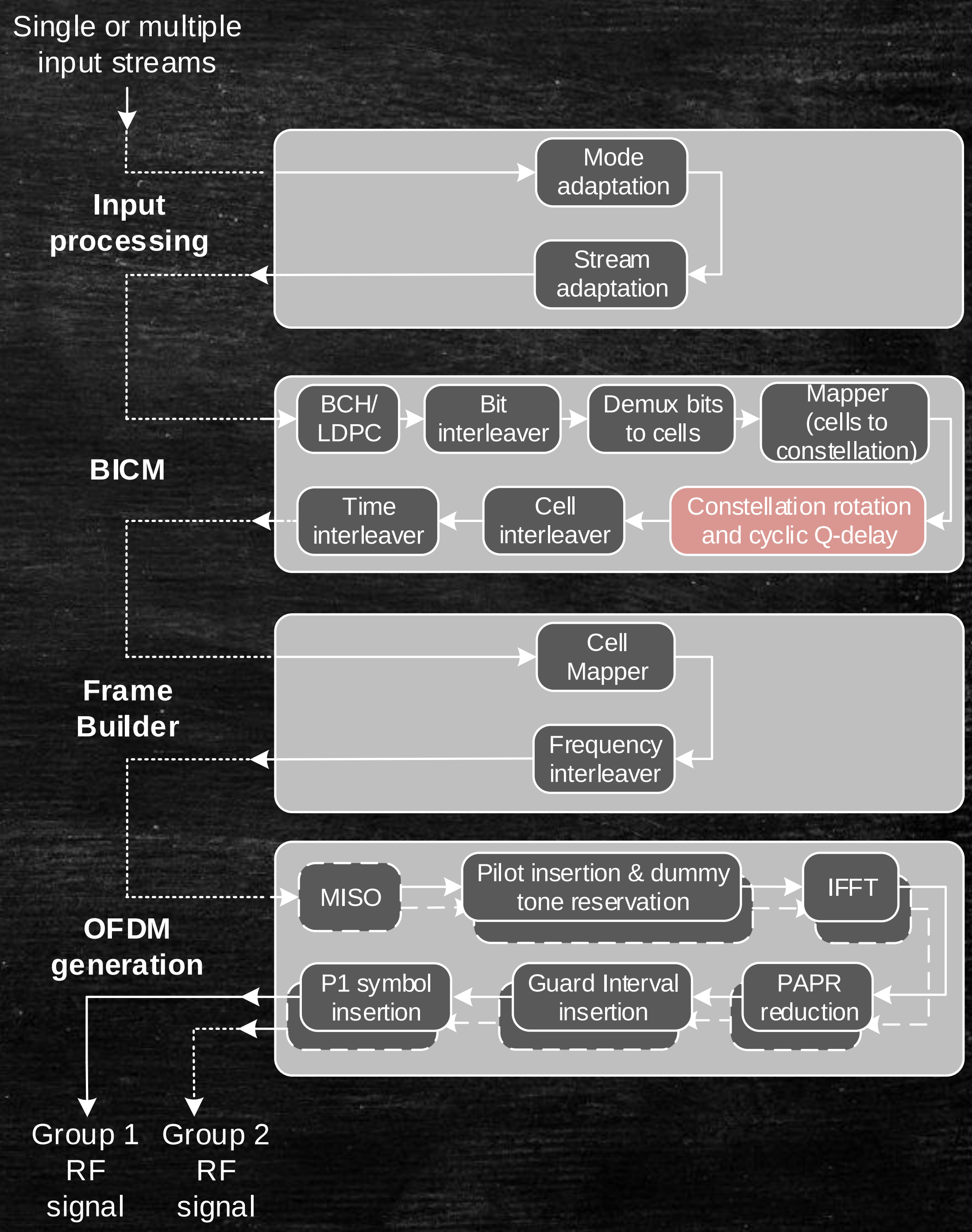
DVB-T2 standard

- An impetus to update the mature and well-established standard DVB-T was generated
  - The availability of frequencies in the UHF band after the full analog television switch-off in Europe
  - The new opportunities in digital terrestrial television markets based on new multichannel HDTV services have
- The DVB Project developed DVB-T2 to introduce HDTV services or new datacasting services
- The DVB-T2 technology did not replace its predecessor DVB-T
  - Both systems will coexist in the market for many years

- The DVB Steering Board approved the DVB-T2 specification at the end of June 2008

- DVB-T2 specification has been the fulfillment of a set of Commercial Requirements where the key requirements were:
  - The DVB-T2 standard should provide a minimum capacity increase of a 30% over DVB-T
  - Flexible and configurable robustness for each transmitted service

- The structure of the transmitter is similar to the one in DVB-T
- It has additional blocks to perform tasks as PAPR reduction, additional interleaving stages, MISO, rotated constellations …



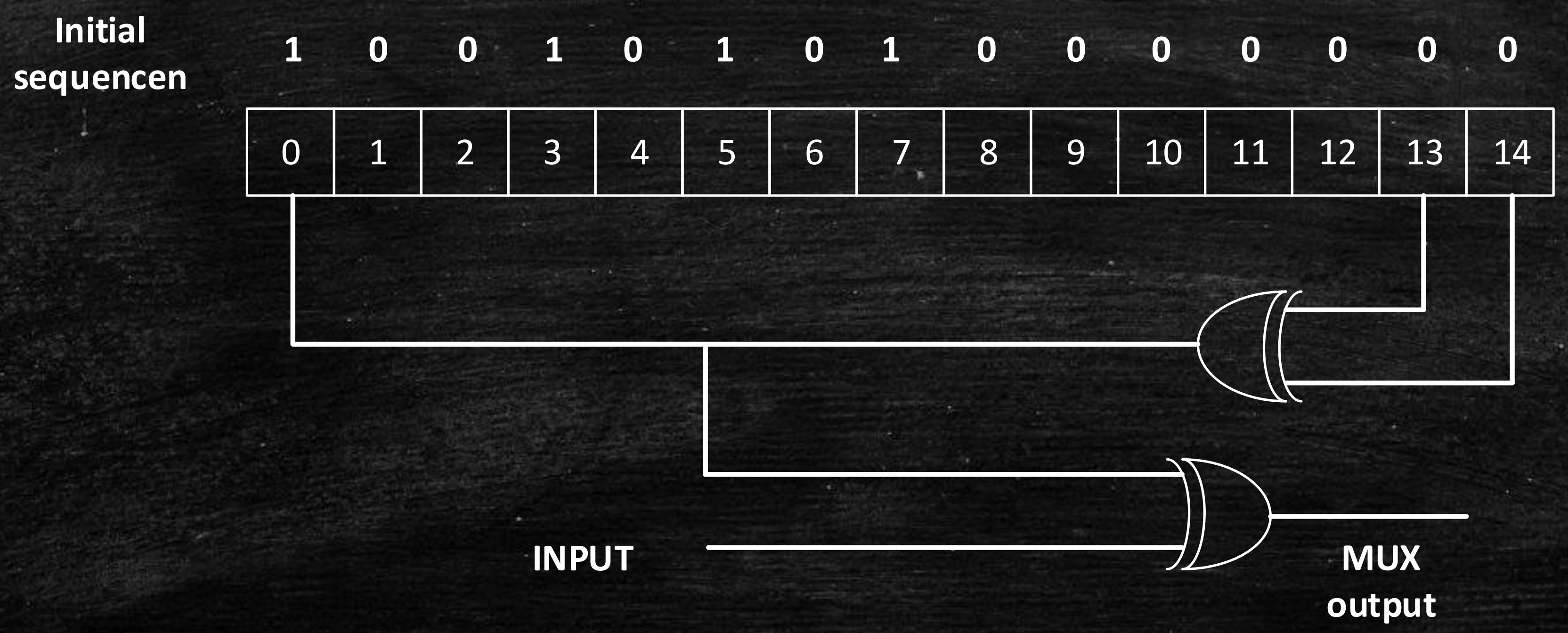
Input processing

- The input of the system can be one or more different streams, known as Physical Pipelines (PLPs)
  - Every PLP has a defined FEC protection and modulation (statically configurable)
- The input of the system can be one of the followings:
  - Transport stream (188 bytes being the first a synchronization byte)
  - Generic encapsulated stream
  - Generic continuous stream (variable length of the information)
  - Generic fixed-length packetized stream (DVB-S2 legacy)
- The first received bit will be indicated as the Most Significant Bit (MSB)
- Input interfacing is applied separately for each single physical layer pipe (PLP)

- **Baseband scrambling**
  - After having all the input bits they must be randomized
  - This is performed by applying a PRBS (Pseudo Random Bit Sequence) generated by the polynomial:

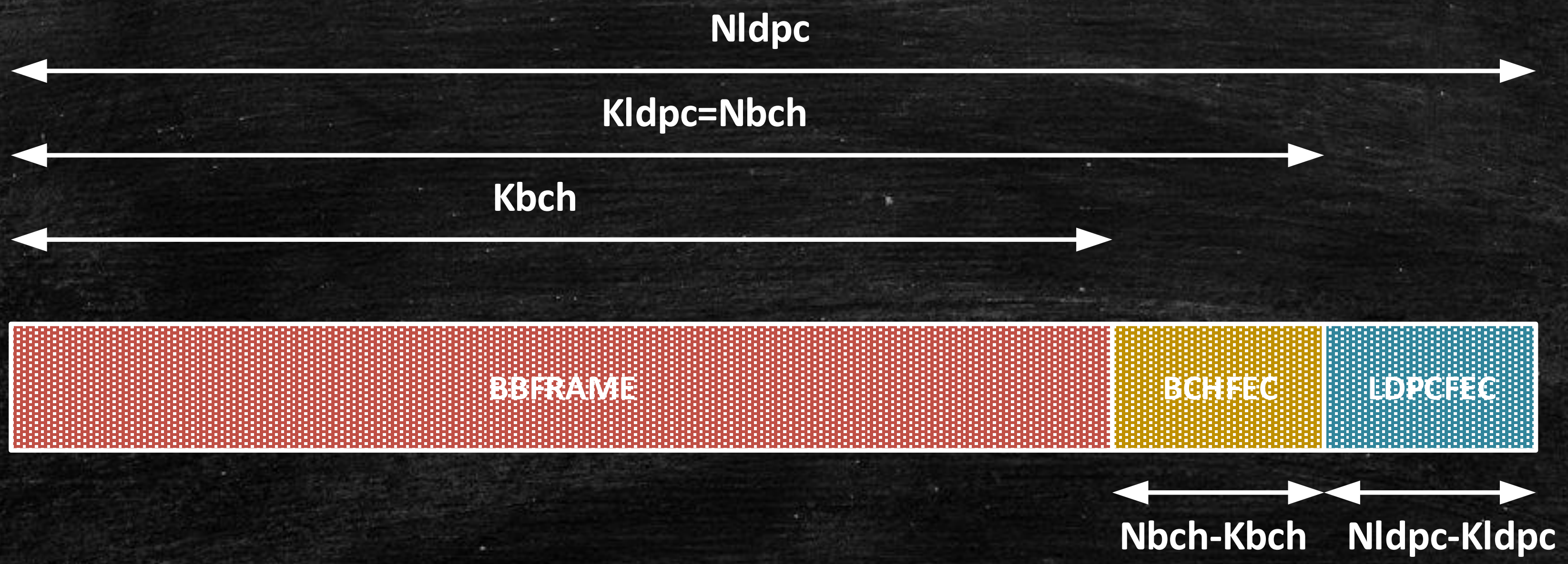
$$1 + x^{14} + x^{15}$$

  - Being the initial state of the registers 100101010000000



BICM (Bit Interleaving, Coding, and Modulation)

- The first blocks in the BICM are the ones devoted to protect our data against errors in the transmission, Forward Error Correction (FEC)
- DVB-T2 uses a concatenation of BCH+LDPC codes plus a bit interleaving stage



- The bit interleaving is performed in 2 steps
  - A parity interleaving (only affects to the parity bits inserted by the LDPC)
  - Column twist interleaving
- In the parity check we only change the position of the parity bits inside the header following this expression

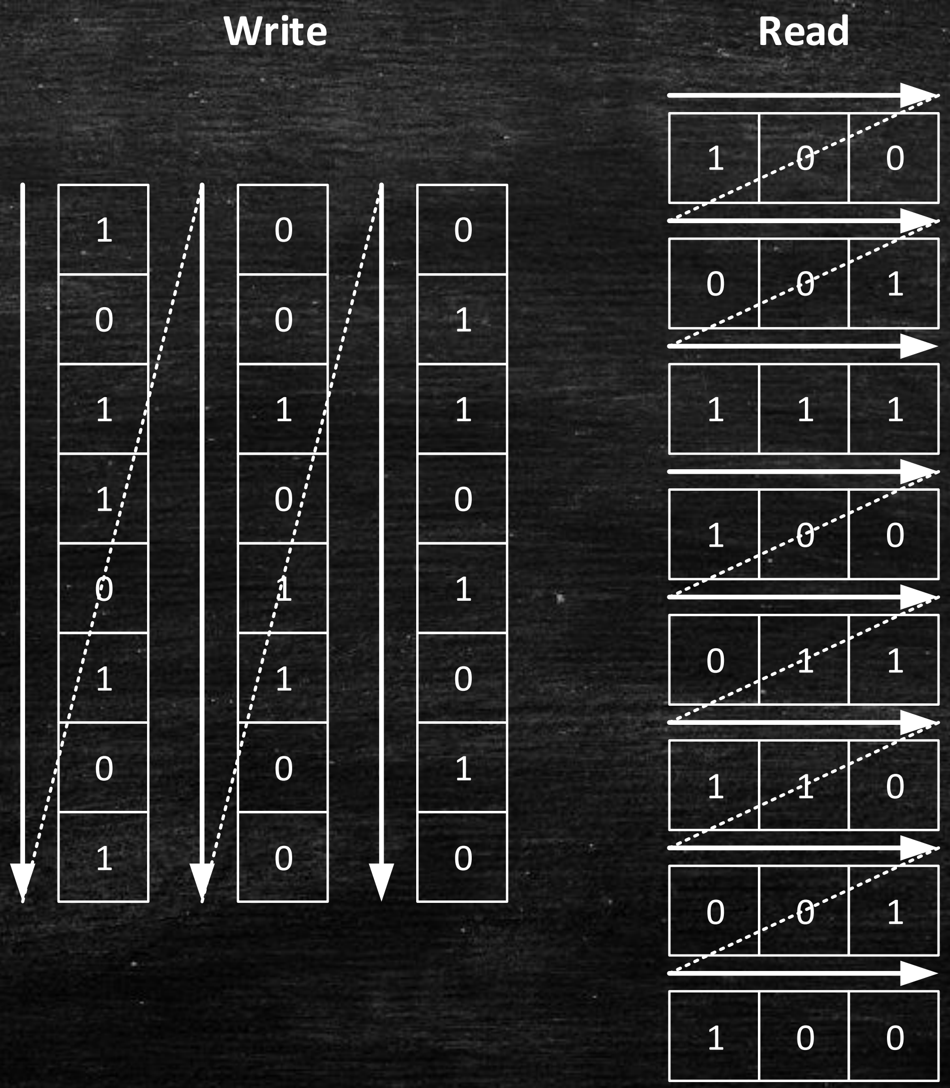
$$u_{K_{LDPC}+360t+s} = \lambda_{K_{LDPC}+Q_{LDPC}s+t}$$

  - We are only performing an index change
- In the column twist interleaving we write the data bits in a matrix, that has a determinate number of columns and rows (depending on the FEC configuration) column wise, after we obtain the output of the interleaving by reading the data stored in the matrix row wise.
  - The starting point to write in a column comes determinate by the t_c parameter

- As an illustrative example

INPUT SEQUENCE

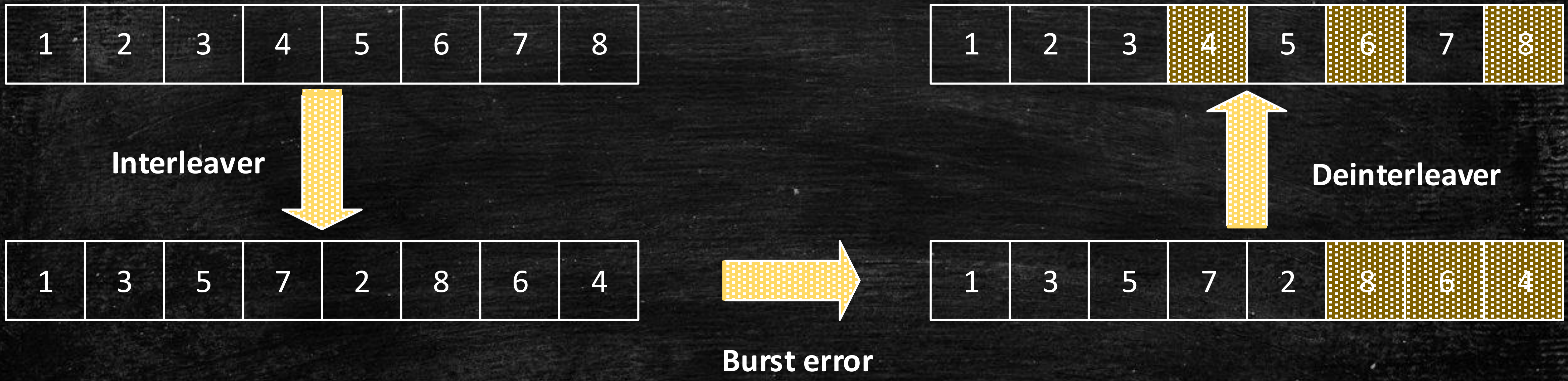
10110101 00101100 01101010



Output sequence

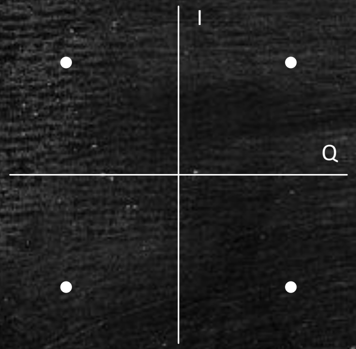
10000111 11000111 10001100

- The interleaver is used to optimize the correction properties of the LDPC
  - LDPC doesn't offer a homogeneous protection to all the bits (the columns with more weight in the codification matrix give more protection)
  - LDPC works optimally when the errors are uniformly distributed in the codeword

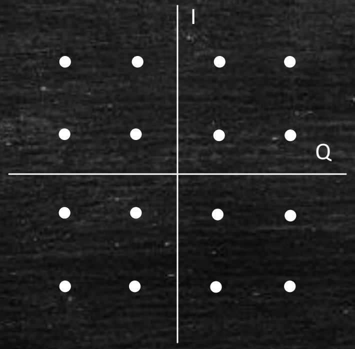


Mapping bits into constellations

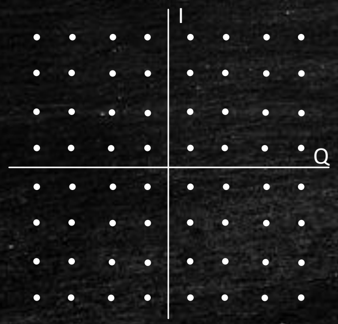
- **DVB-T2 has 4 constellations: QPSK, 16-QAM, 64-QAM, and 256-QAM**



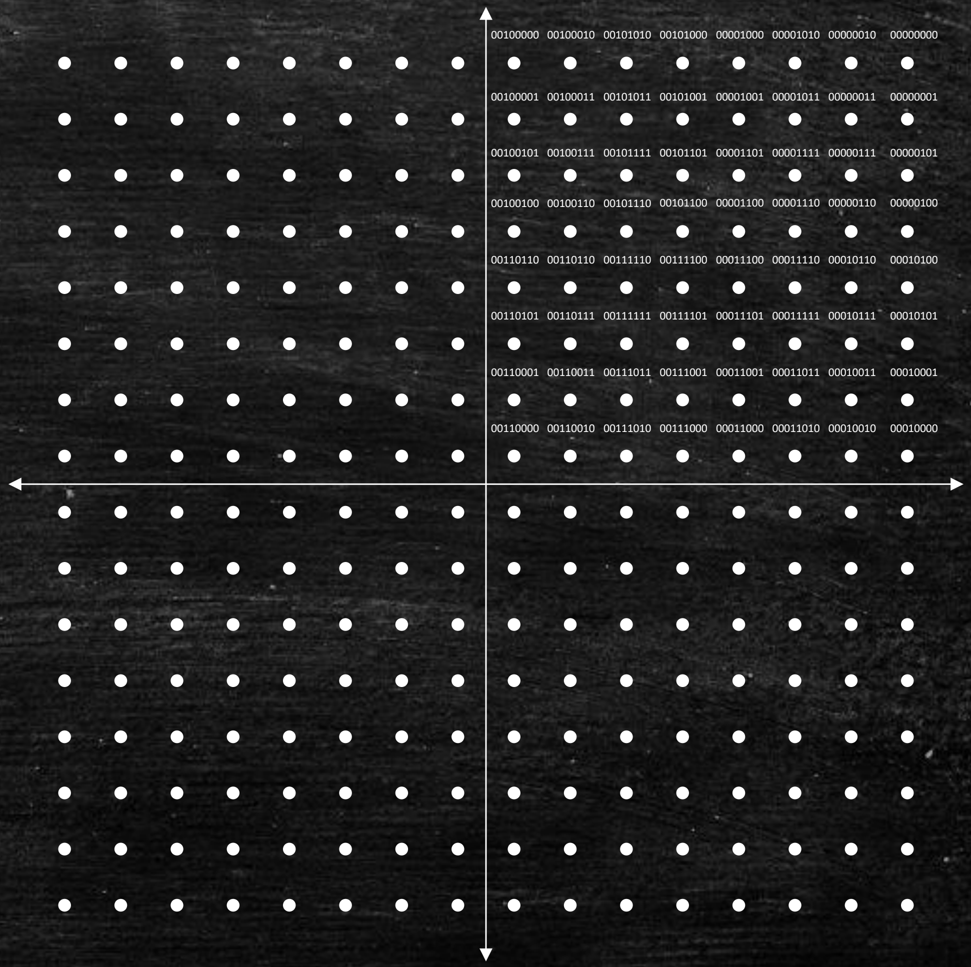
QPSK



16-QAM

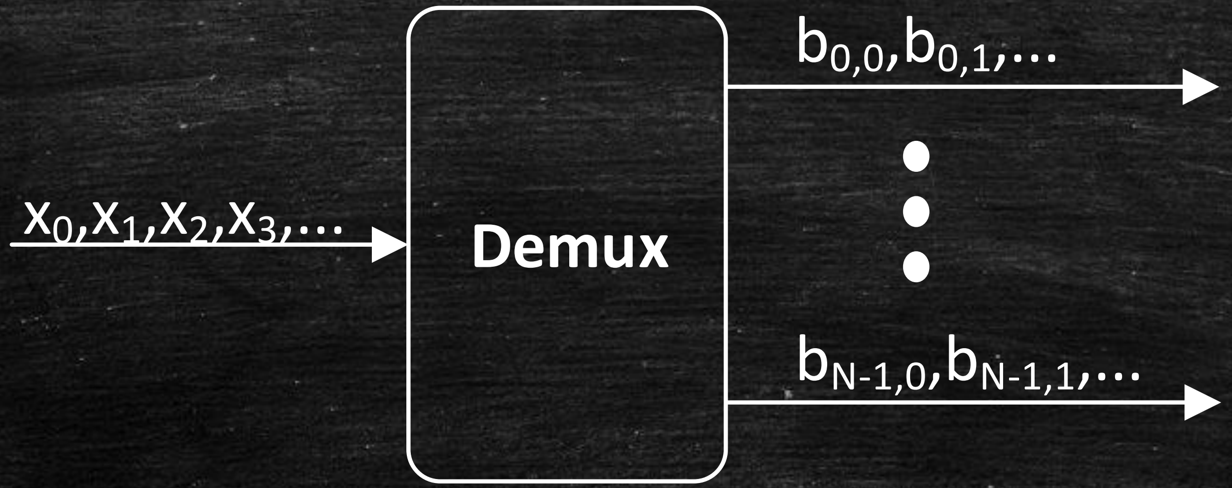


64-QAM



256-QAM

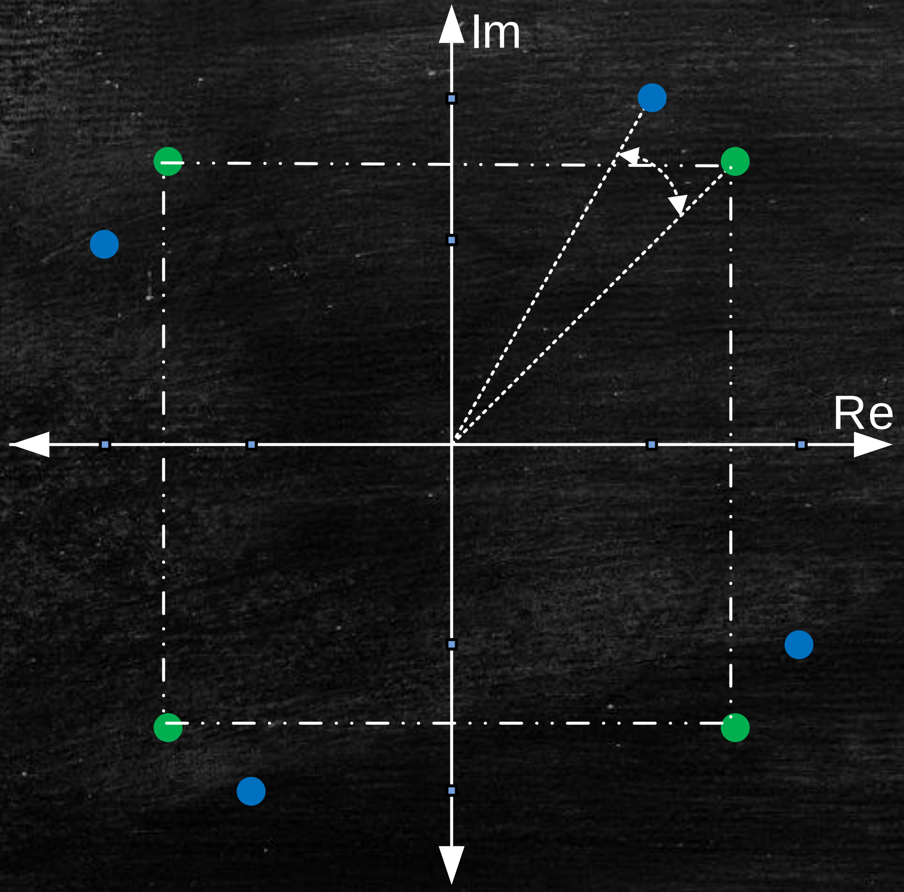
- **The bits coming from the bit interleaver are not mapped directly onto the constellations**
- **A bit demux process is carried out, the bits are separated in *N* sub streams**

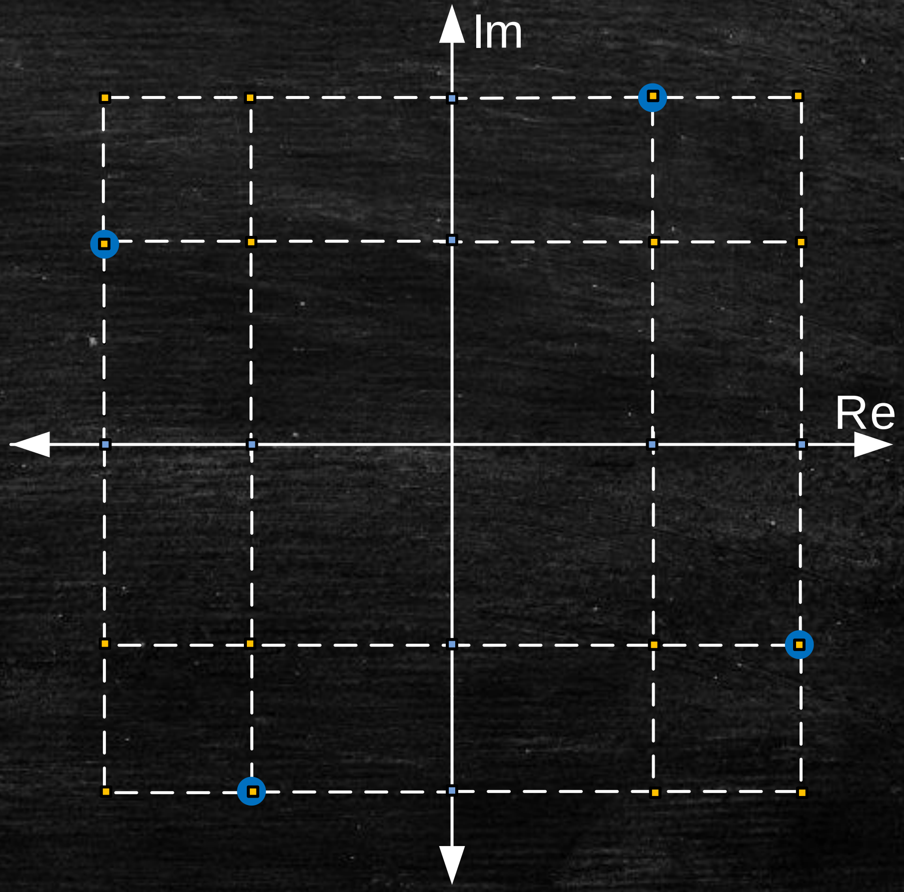


  - **The first index needs to be checked in the tables of the standard but is based on $mod(in_{idx}, N)$**
  - **The second index is the entire division between in_{idx} and *N***
- ***Generally the output of the demux gives the bits to map 2 constellation points (0:N/2-1 first symbol and N/2:N1 the second one)***

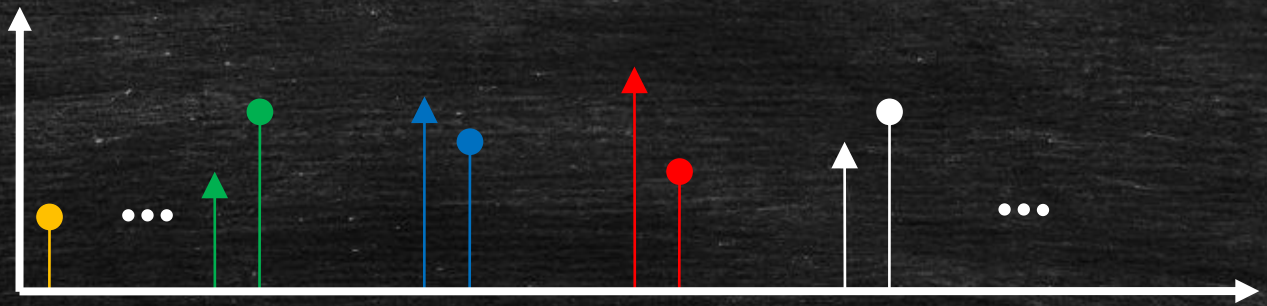
Rotated constellations

- A rotation to the original constellation is performed in the complex plane to the original constellation
- After the rotation a cyclic delay in the imaginary component is performed
  - Real and imaginary part of the same symbol are separated



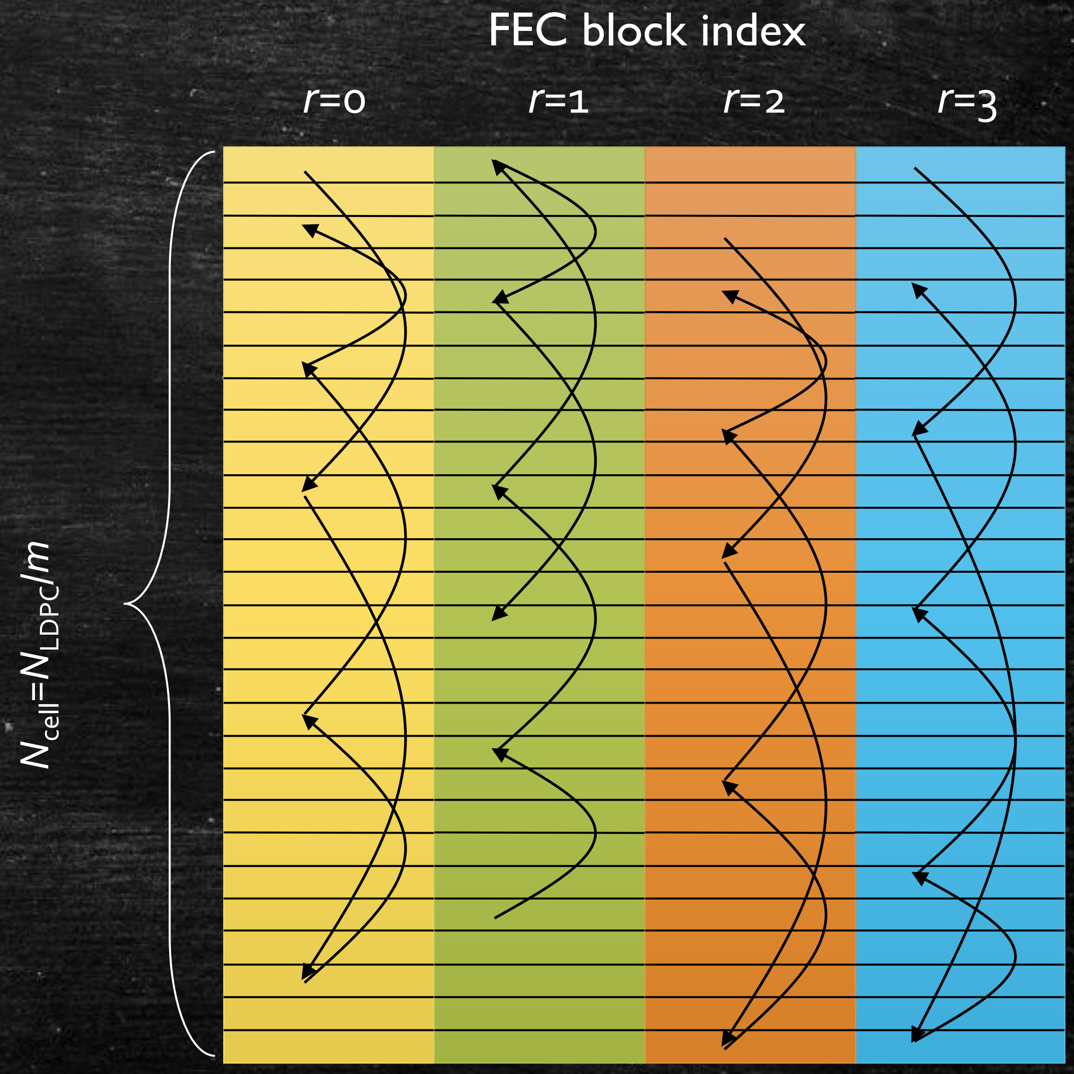


- After the cyclic delay and the cell interleaver the real part and the imaginary part of the same data are transmitted in different and separated carriers



- If a carrier is lost (because of fadings or any cause) the transmitted data can be still decoded at the receiver receiving the carrier that contains the other half of the information

- The cells are interleaved inside a FEC block using a pseudorandom sequence
- The interleaver used changes for every FEC block
  - The difference is an offset dependant on the FEC block index

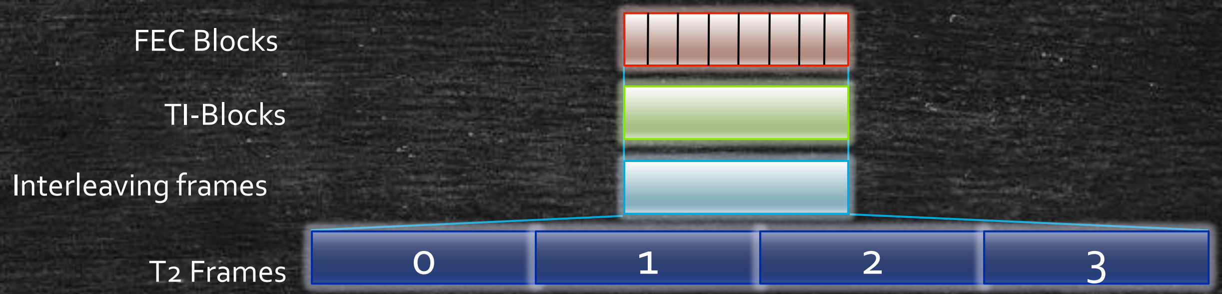


Time interleaver

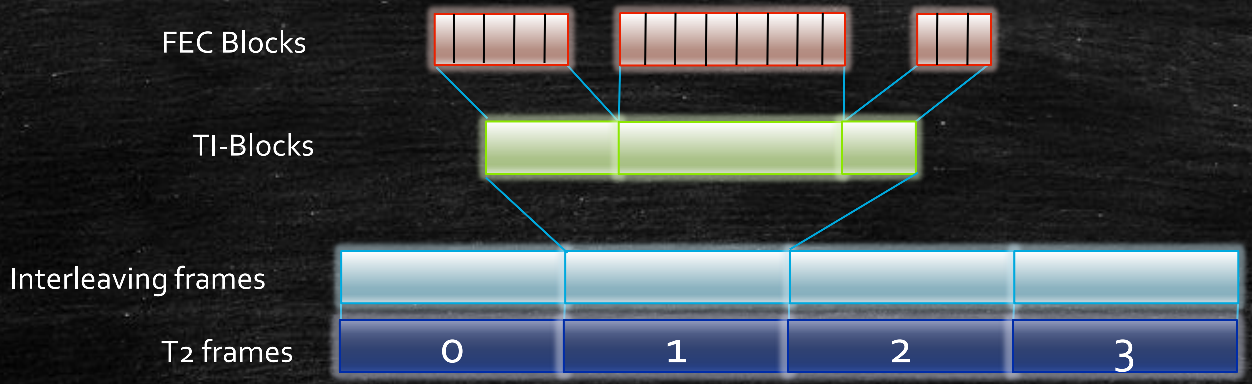
- Scatters the cells between FEC blocks in a same frame
- This improves the robustness against impulsive noise and time selective propagation scenarios
- The depth of the interleaver can be configured for each PLP
- The maximum interleaving depth is of 500000 cells (about 10Mbits)
- For low rate services the interleaving can be extended to several frames

- The FEC blocks are grouped in interleaving frames of variable length
- Every interleaving frame is divided also in interleaving blocks
- The interleaving process is carried out over these interleaving blocks
- Is a block interleaver where the data is written by columns in memory and read by rows (similar to the bit interleaver)
- There are 3 possible cases

1 Interleaver Frame= 1 Interleaver Block = 1 T2 Frame



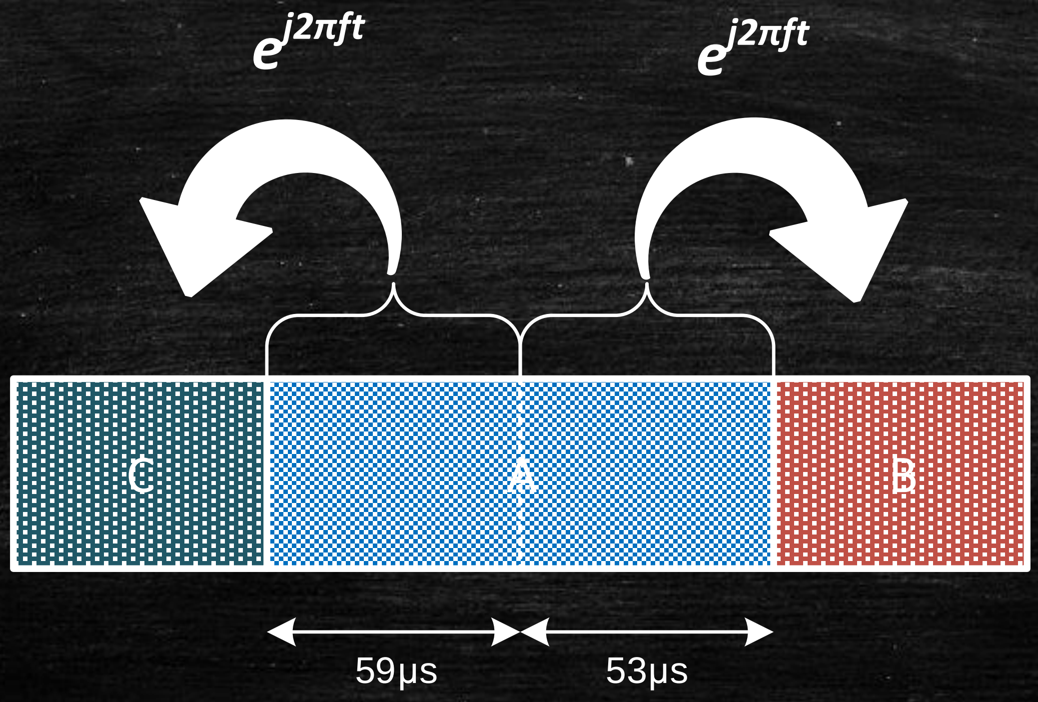
1 Interleaving frame = 1 TI-Block = Several T2 frames



1 Interleaving frame= Several TI-Blocks = 1 T2 Frame

Frame builder

- A DVB-T2 frame starts with a special symbol : P1
  - A 1K OFDM symbol with two "guard interval-like" portions added
  - The total symbol lasts 224 µs in 8 MHz system, being 112 µs, the duration of the useful part 'A' of the symbol plus two modified 'guard-interval' sections 'C' and 'B' of roughly 59 µs (542 samples) and 53 µs (482 samples)
  - The copies are frequency displaced to avoid common wave interference

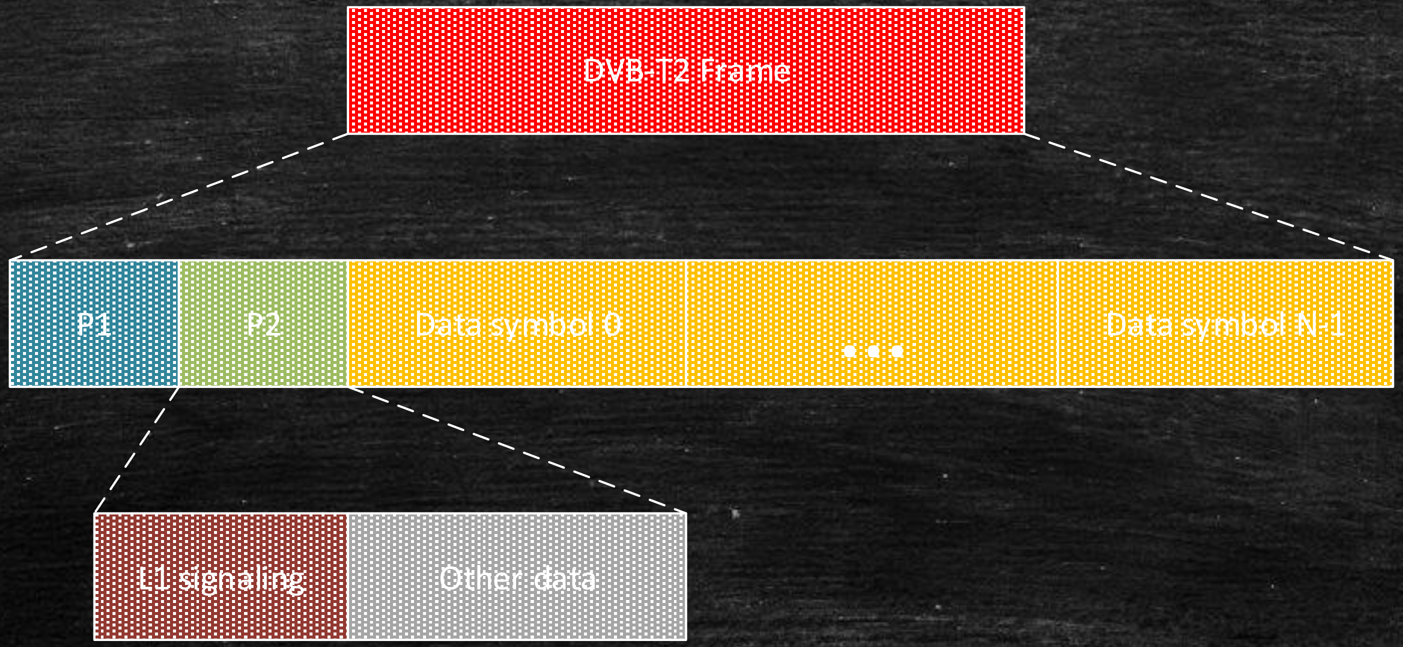


- The shape of the symbol allows fast and robust detection of the DVB-T2 frame, fast frequency synchronization and allows to give basic signalization with 7 bits (NFFT ...)

- At the beginnig of the frame its structure must be signalized
  - Beginning and length of every PLP inside the frames

- P2 symbols are the ones in charge of this task
  - The number of P2 symbols depend on the FFT size
  - They have a very robust codification (1/4, *N*ldpc=16 200), and use BPSK modulation
  - The pilot pattern used for channel equalization is a very dense one to enable accurate and fast channel estimation

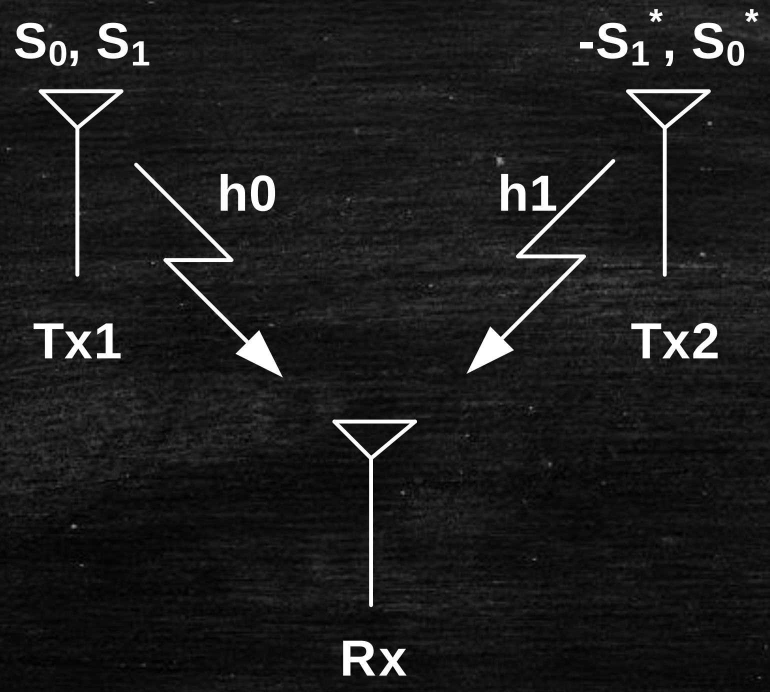
- The DVB-T2 frame has a typical duration of 150-250 ms
  - In this way the overhead inserted by P1 and P2 symbols is kept under 1% of the total capacity of the system



- After the frame builder the data cells are mapped in the corresponding available carriers by using the corresponding transformations of the frequency interleaver

MISO processing

- DVB-T already included SFNs
  - The presence of signal with the same power level could lead to severe fadings in the propagation path
  - Field evidences show that portable reception can suffer fadings and to compensate it a higher transmission power is needed
- To cope with this DVB-T2 includes MISO Alamouti coding



- This codification is a 2 transmitter one receiver MISO scheme
  - One of the transmitters transmits an unaltered signal
  - The other inverts the order of each couple of symbols, inverts the sign of the first one and conjugates both
- The technique brings an equivalent performance to the diversity in reception (two receiver antennas)
  - The operations performed in the receiver result in an optimum combination of both signals
    - The equivalent SNR at the receiver increases
  - The complexity increase is not very noticeable
    - Some multipliers added

- Mathematically the propagation can be described as:

$$r(k) = h_0 s_0 - h_1 s_1^* + n_0$$
$$r(k+1) = h_0 s_1 + h_1 s_0^* + n_1$$

- Then combining $r(k)$ and $r(k+1)$

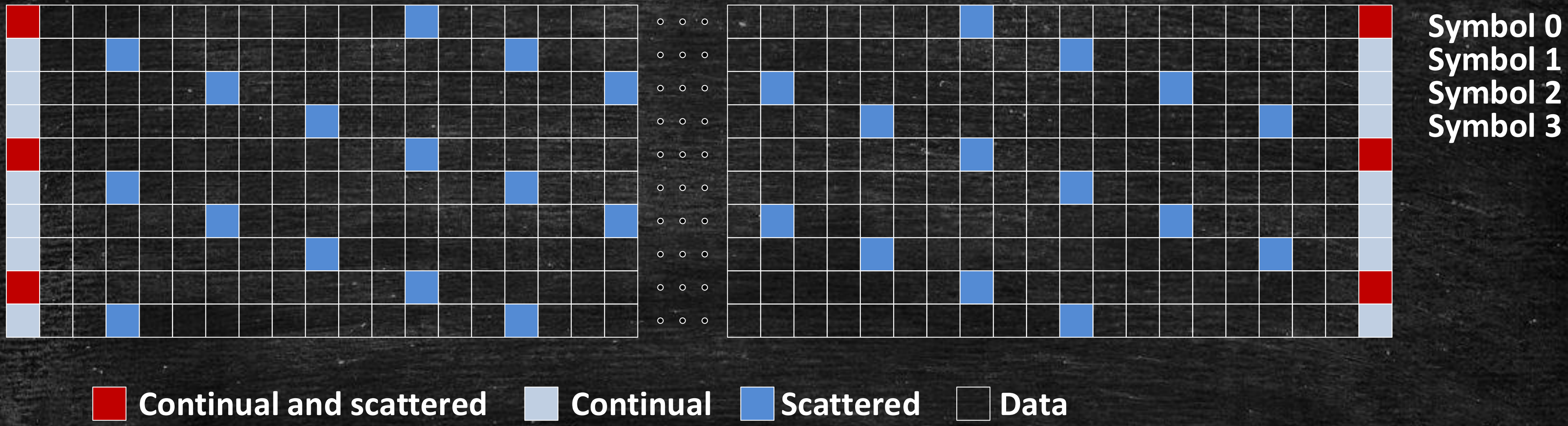
$$\hat{s}_0 = r(k+1)^* h_1 + r(k) h_0^* = (|h_1|^2 + |h_2|^2) s_0 + n_0 h_0^* + n_1^* h_1$$
$$\hat{s}_1 = r(k+1)\, h_0^* - r(k)^* h_1 = (|h_1|^2 + |h_2|^2) s_1 - n_0^* h_1 + n_1 h_0^*$$

- The noise is a random variable with cero mean then the equivalent noise is attenuated

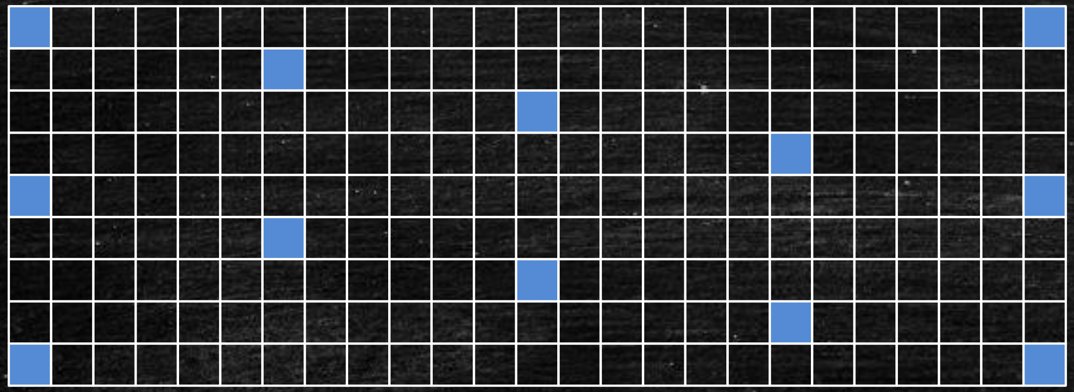
Pilot insertion

- Pilots are used for channel estimation, synchronization, …
- We have scattered, continual, and edge pilots
- **Continual pilots**
  - **Their position is fixed in the symbol**
  - **Modulated with a BPSK**
  - **The data is known (coming from a PRBS)**
  - **Synchronism purpose**
- **Scattered pilots**
  - **Their position varies in each symbol**
  - **Modulated with a BPSK and with known data from a PRBS**
  - **They are used for channel estimation purpose at the receiver**

- As an example, PP7



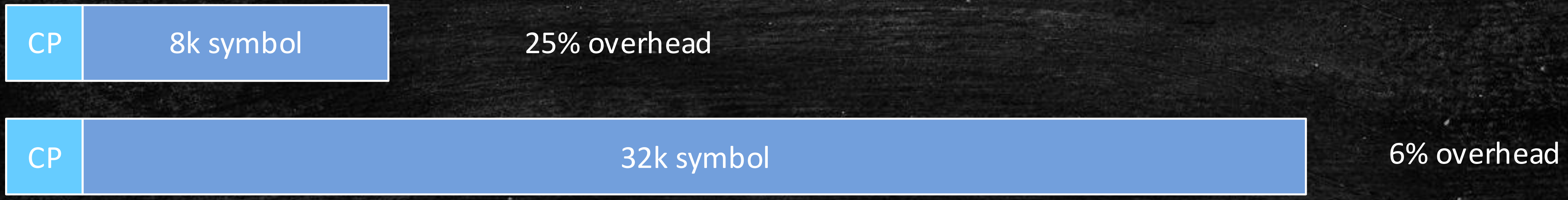
- PP3



- overhead is reduced from 8% to 4% by using the PP3 with a 1/8 CP

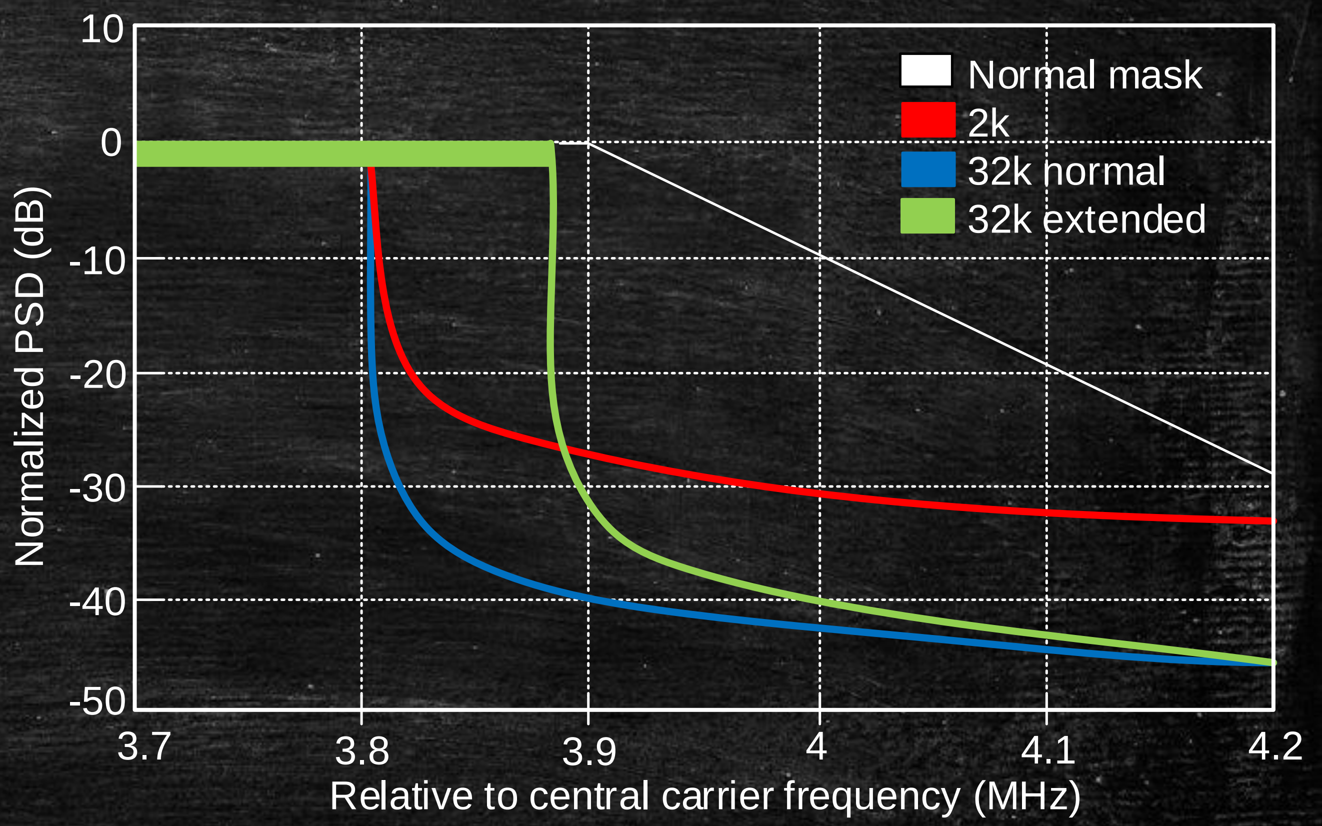
IFFT

- Modes of 1k, 2k, 4k, 8k, 16k, and 32k
- Increasing the FFT size we get a narrower spacing between carriers, but a longer symbol time
  - Worsens the reception because of the ICI
  - Having longer symbols in time eases the operation in SFNs
  - Lower Doppler frequency tolerated (16k and 32k modes are not conceived for mobile reception)
- For a fixed CP length the fraction is lower for a longer symbol reducing the capacity loss



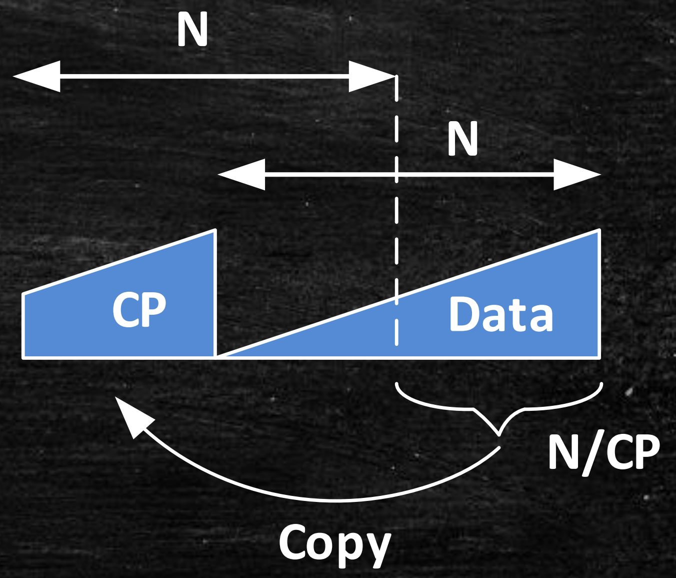
- Capacity increases form 2.3% to a 17.6%

- **Extended carrier mode**
  - **This mode is available for 8k, 16k, 32k FFT sizes**
  - **The rectangular part of the spectrum falls more quickly for higher FFT sizes**
  - This allows higher FFT size modes to extend the edges of the spectrum
  - The gain is between 1.4% (8k) and 2.1% (32k)
  - This is an optional feature
  - Doesn’t meet the critical spectrum mask



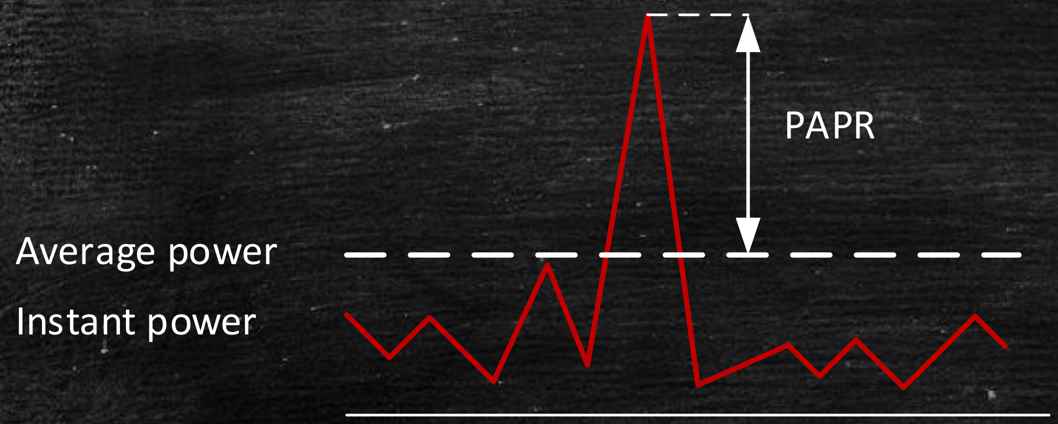
Cyclic prefix

- There are 7 possible cyclic prefix : 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 of NFFT
- Not all the cyclic prefixes are available for every transmission mode
- The higher the number of samples of the cyclic prefix is:
  - More robustness to the multipath channel echoes
  - Lower data rate



PAPR reduction

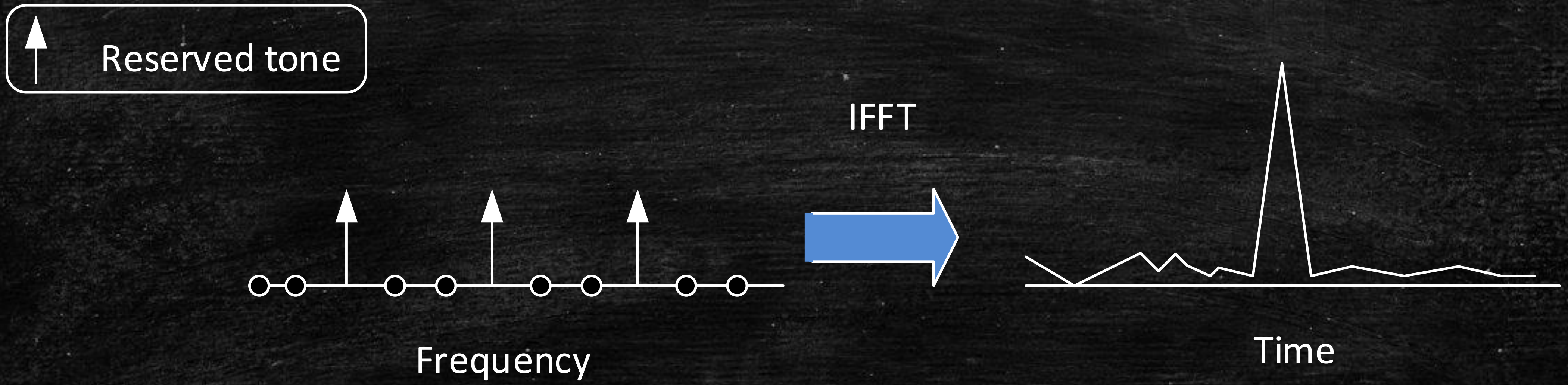
- PAPR is the ratio between the maximum power peak and the average power of a signal



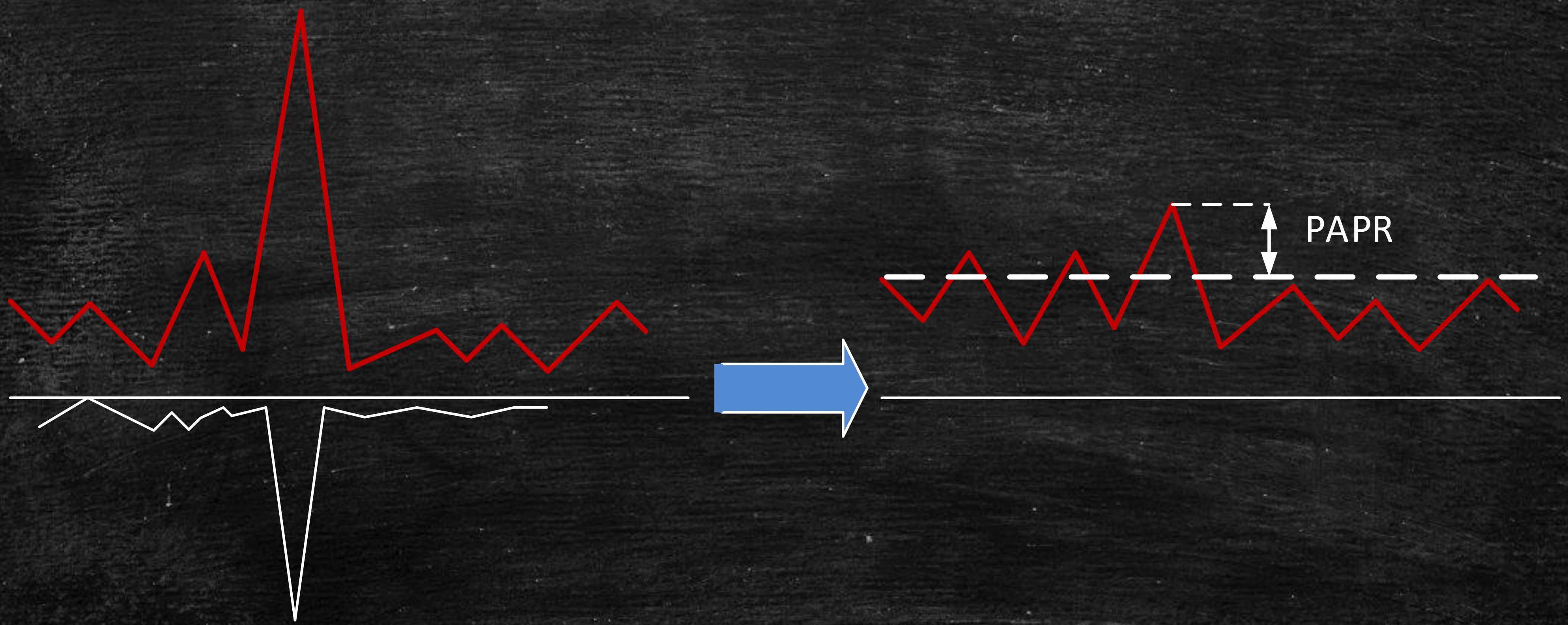
Power amplifier gain characteristic

- A high PAPR makes the power amplifier to lose efficiency

- The techniques implemented in DVB-T2 to reduce this make the average power higher while reducing the peak
  - A higher efficiency when amplifying is obtained
- **Tone reservation**
  - Some subcarriers in the OFDM signal are reserved for this purpose
  - A symbol with only these subcarriers is transformed to the time (IFFT) domain to try to cancel the peaks in the temporal signal

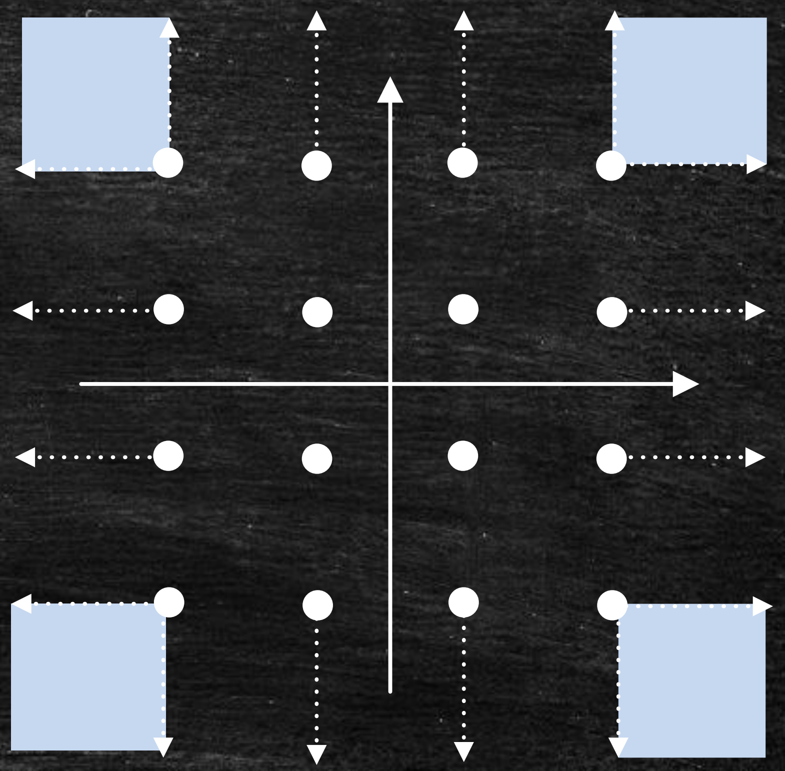


- After the resulting signal in time is subtracted from the original OFDM symbol

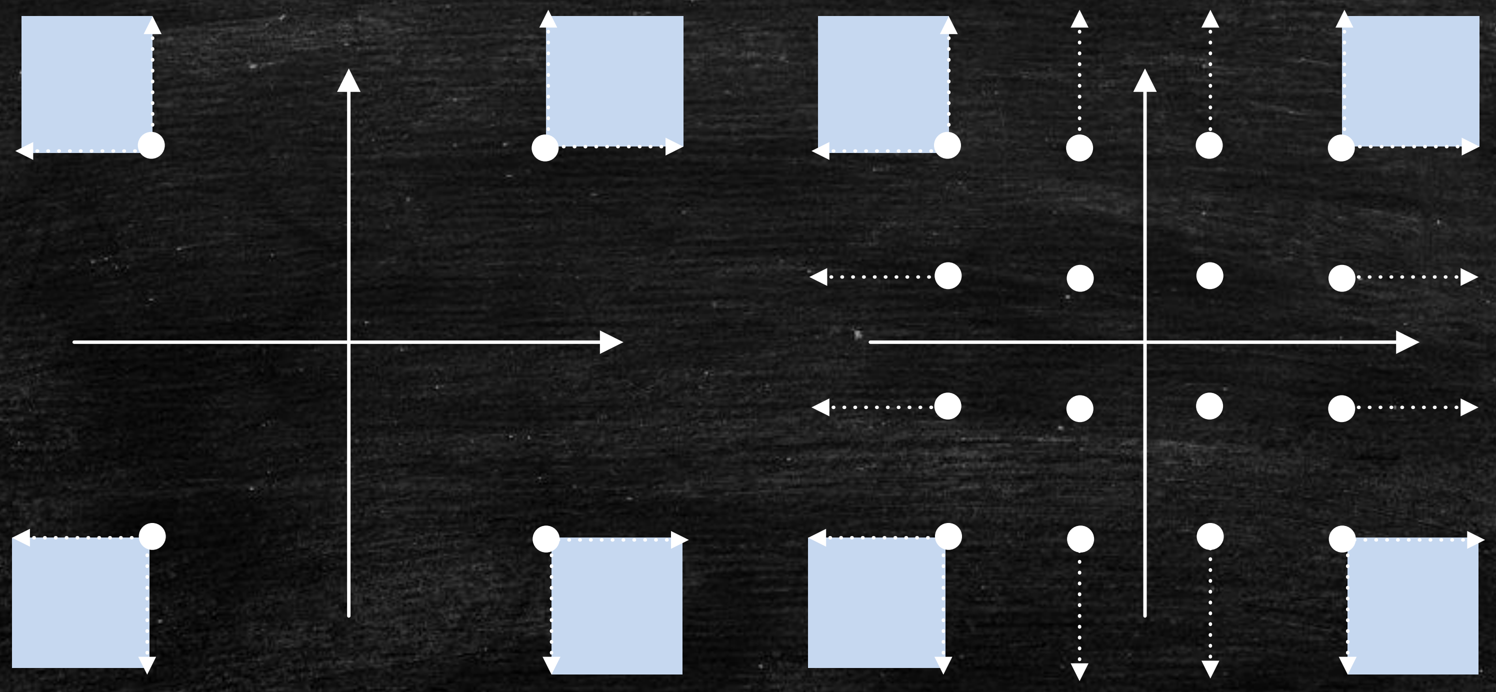


- This is an iterative process, the more reserved tones and more iterations the more PAPR reduction
- This reduces the capacity and is time consuming, so a trade off must be found

- Active Constellation Extension
  - Saturate the signal in time to a certain level
  - This produces the original constellation points to move
  - The constellation points in allowed areas will be selected instead of the original ones
  - This process needs a FFT and IFF
  - The allowed region coincides with the external points of the constellation

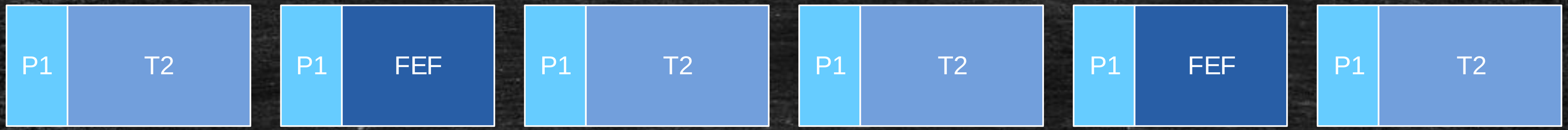


- The criteria to select the allowed sections is not to reduce the minimum distance between constellation points
- This makes in theory not to loose performance in the system
- This technique is more effective in low order constellations



Future Extension Frames

- In order to make a way to include future advances (as MIMO systems) or a mobile branch of the standard these containers are added



- The only defined attributes for FEFs are
  - They are inserted between DVB-T2 frames
  - They start with a P1 symbol
  - Their position in the super frame is defined by the L1 signaling in the T2 frames
    - This allows receivers to ignore FEFs if they are DVB-T2 receivers

THANKS !

Any questions?

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