PHY proposal for 802.16.3 systems

IEEE 802.16 Presentation Submission Template (Rev. 8)

Document Number:

IEEE 802.16.3p-00/31

Date Submitted:

2000-11-3

Source:

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Venue:

802.16 meeting. Sub 3 task group. Tuesday, 7th October.

Base Document:

Call for contribution: Initial PHY proposals. IEEE 802.16.3-00/14. http://grouper.ieee.org/groups/802/16/sub11/docs/802163-00_14.pdf

Purpose:

This proposal is offered as part of the PHY layer for the IEEE 802.16.3 task group

PHY proposal for 802.16.3 systems

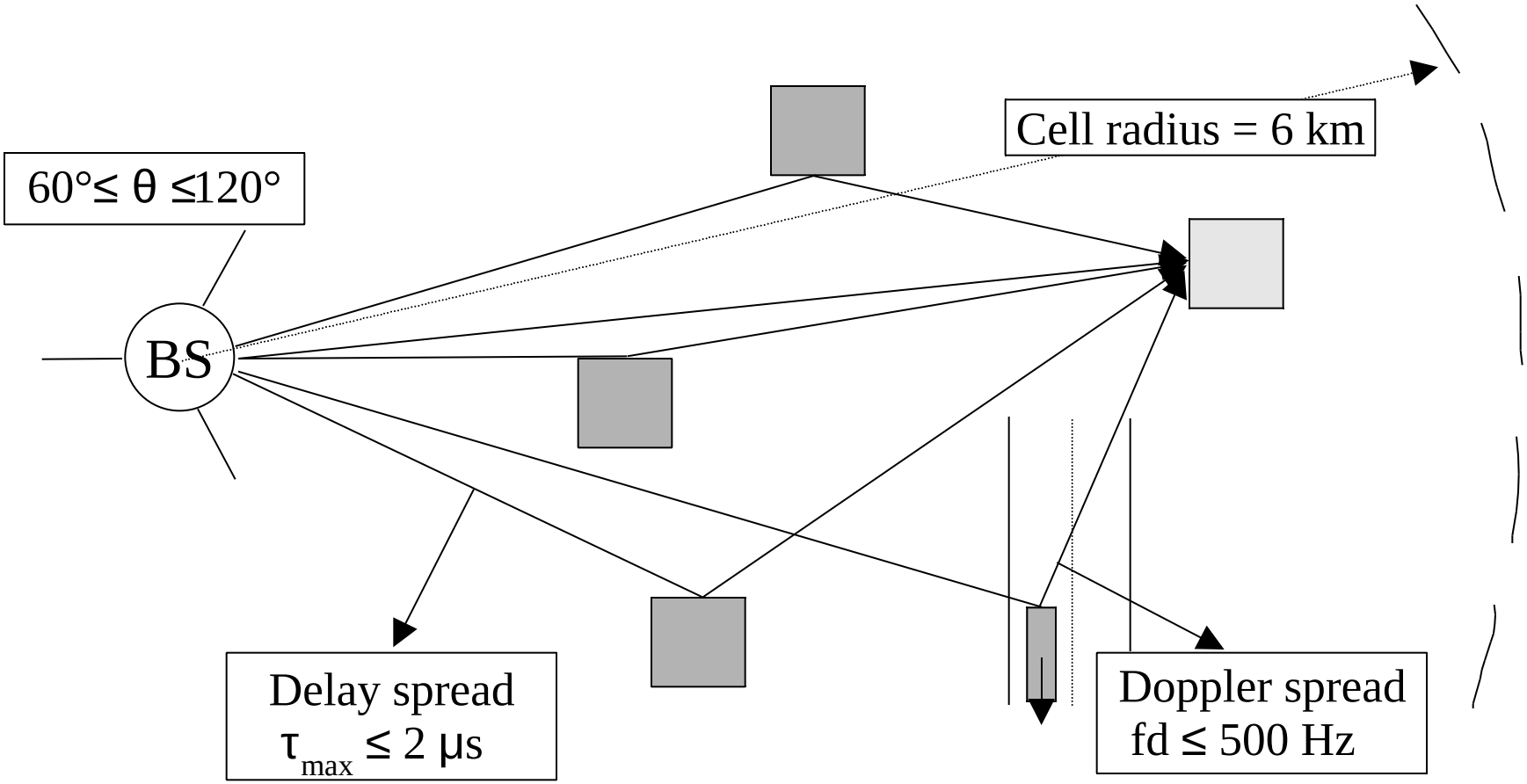
Olivier Seller, SACET.

- System overview,
- Coding scheme performances,
- Low data rates & small packets.

System overview

- OFDM,
- Space-Time block codes,
- High spectral efficiency coding schemes.

PHY constraints

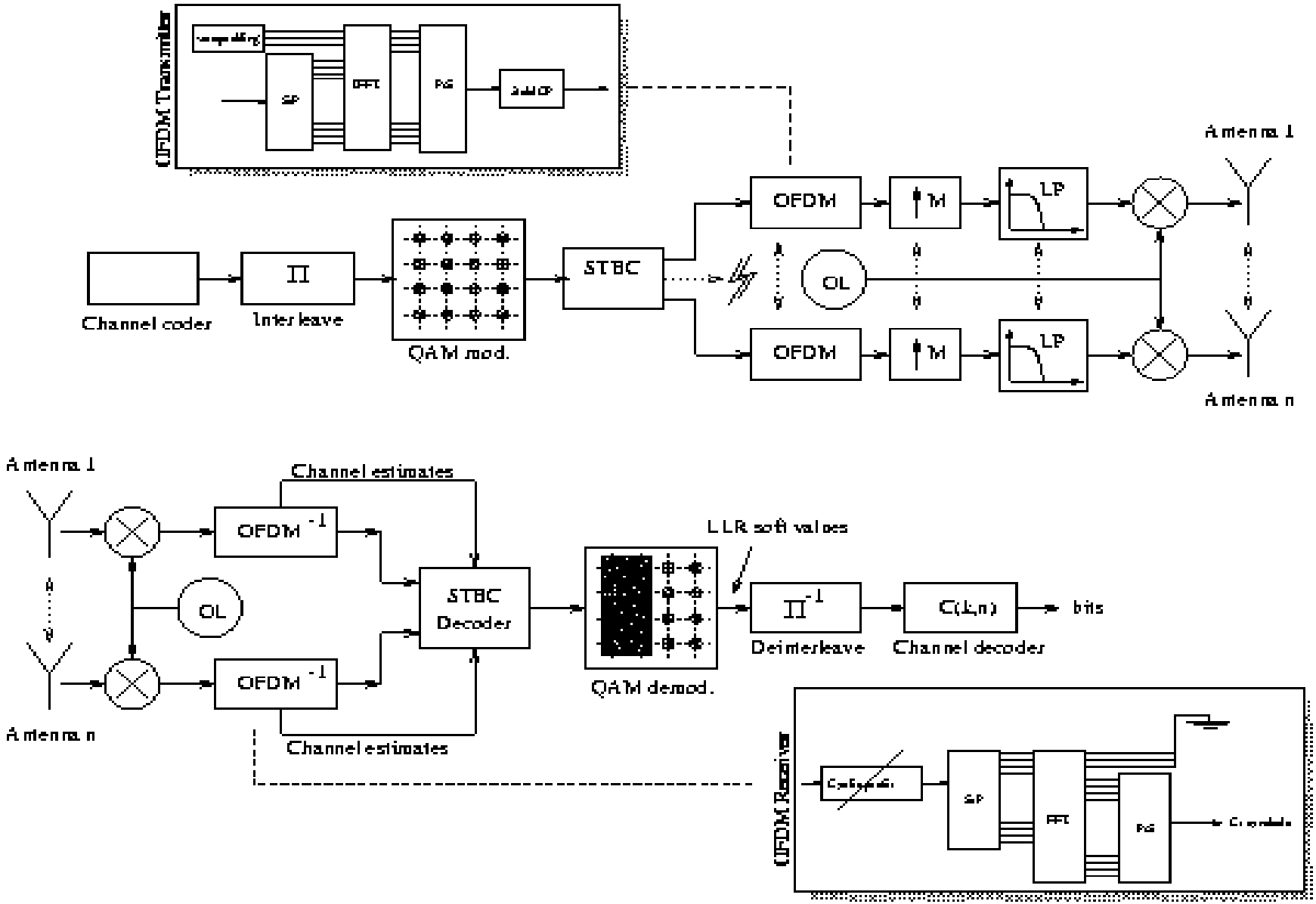


OFDM parameters

- Low ICI $\Leftrightarrow$ subcarrrier spacing $\geq 100 * f_d \approx$ 50 KHz,
- Cyclic prefix (τ_{max} = 2 µs = 6 samples at 3 Msymbols / s),
- PSAM for channel estimation,
- Suited OFDM waveforms:

Bandwidth	FFT size	Nb of used Carriers	PSAM Pattern	CP size	CP + PSAM Efficiency
3,5 MHz	64	TBD	4 * 16	10	0.85
7 MHz	128	TBD	4 * 16	16	0.875
14 MHz	256	TBD	4 * 16	28	0.89

System overview



OFDM existing standards

- 802.11a, Hiperlan2, DVBT,
- OFDM technology already exists,
- Development:
  - ASIC:
    - Use 802.11a or DVBT chips,
    - Fast redesign (main change: FFT size, pilots).
  - FPGA / DSP:
    - Possible since computing power ↑ and prices ↓,
    - Software → time to market, product evolutivity.

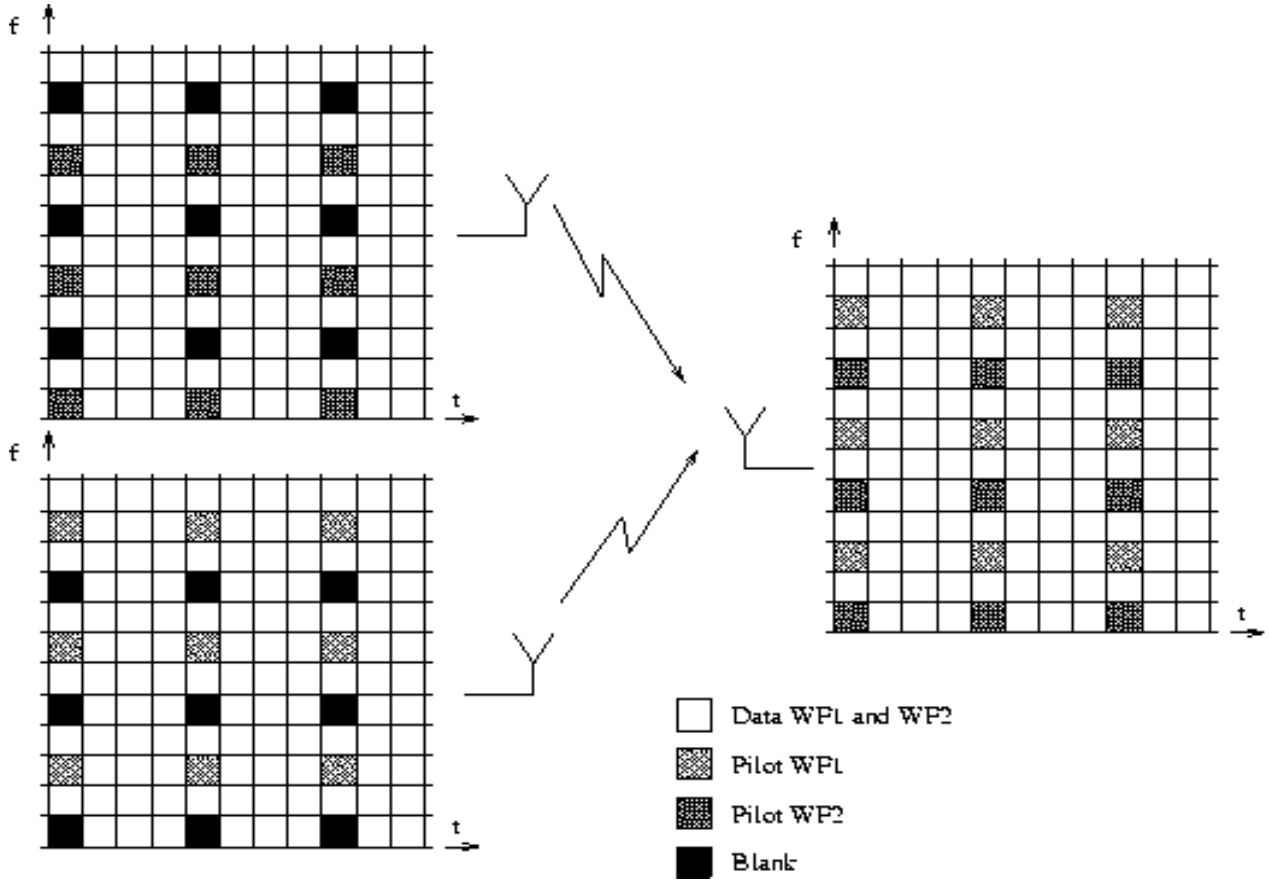
Improving spectral efficiency

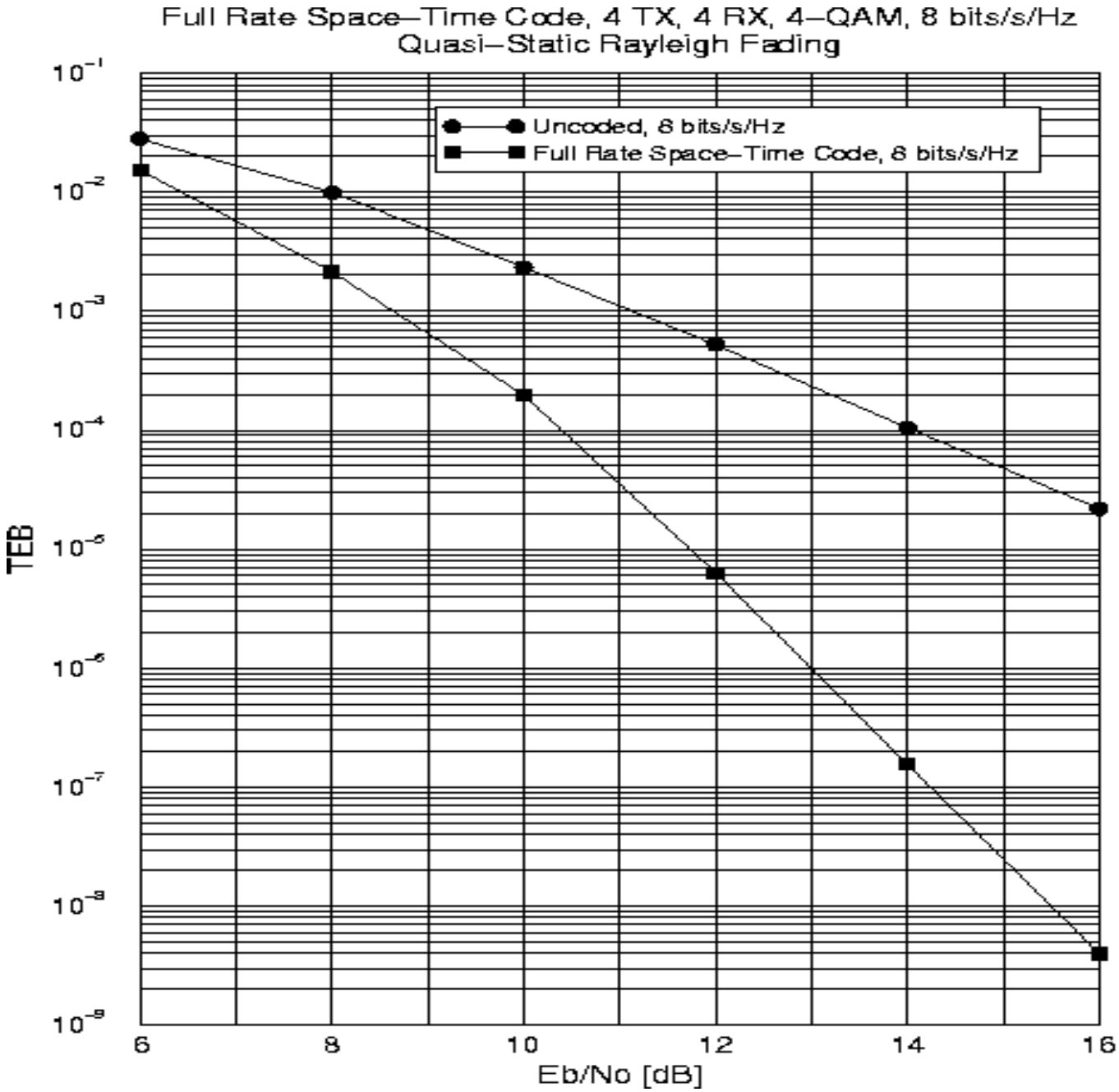
- Channel estimation: slow fading channel
  → low density PSAM,
- Channel coding: non binary (TCM),
  TurboBICM, Turbo Product Codes,
- Space-Time block codes:
  - $R_{ST} < 1$ increases throughput,
  - $R_{ST} > 1$ increases diversity Rc can be higher.

Space-Time block codes

- Multiple antennas reduce power on each amplifier cheaper and more linear amplifiers,
- « Interspaced » PSAM: nominal performances, simple MIMO channel estimation (next figure),
- OFDM can shift Space-Time to Space-Frequency codes, within Bc: slow frequency varying channel $\Leftrightarrow$ slow time varying channel.

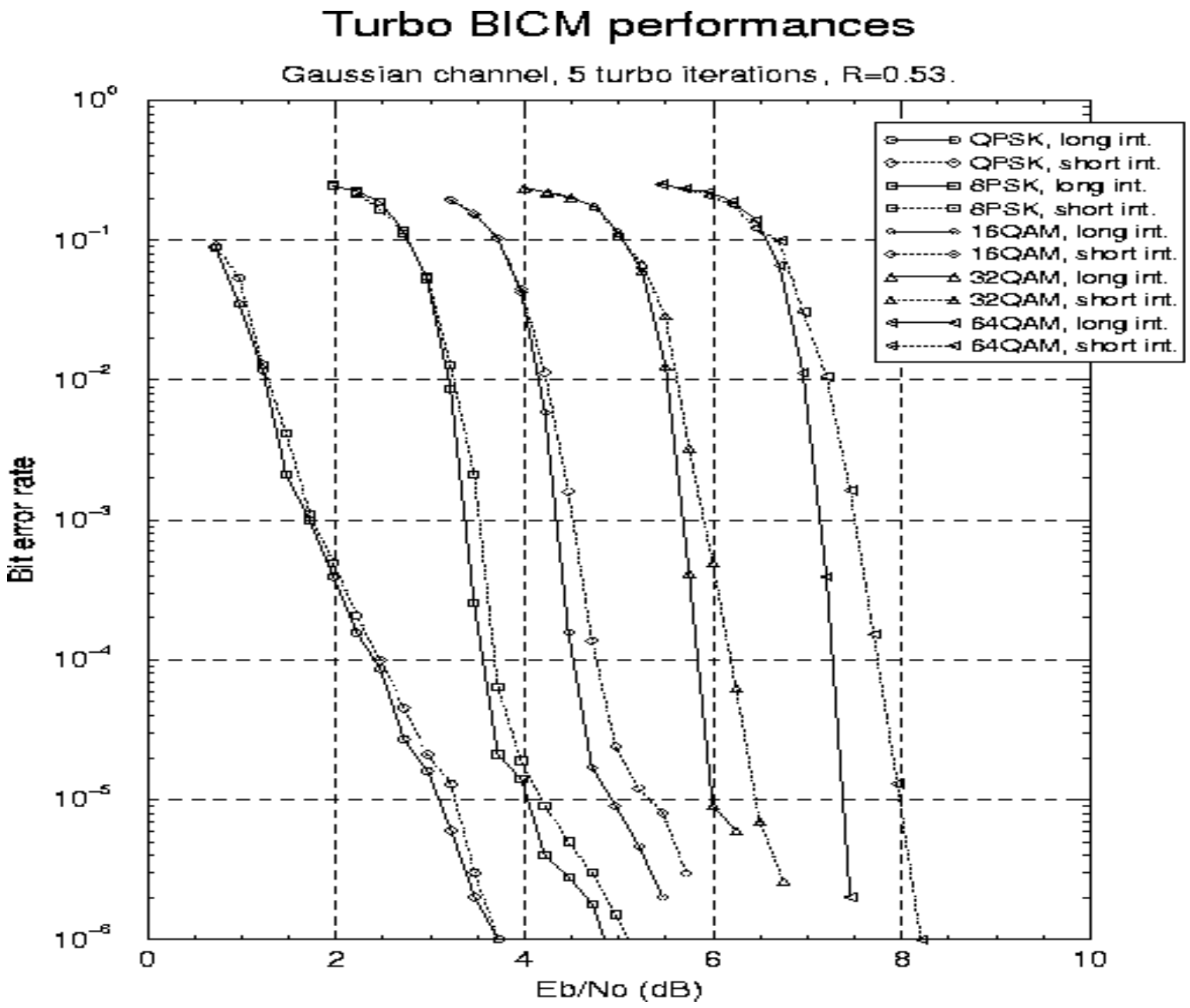
Space-Time block codes: interspaced PSAM

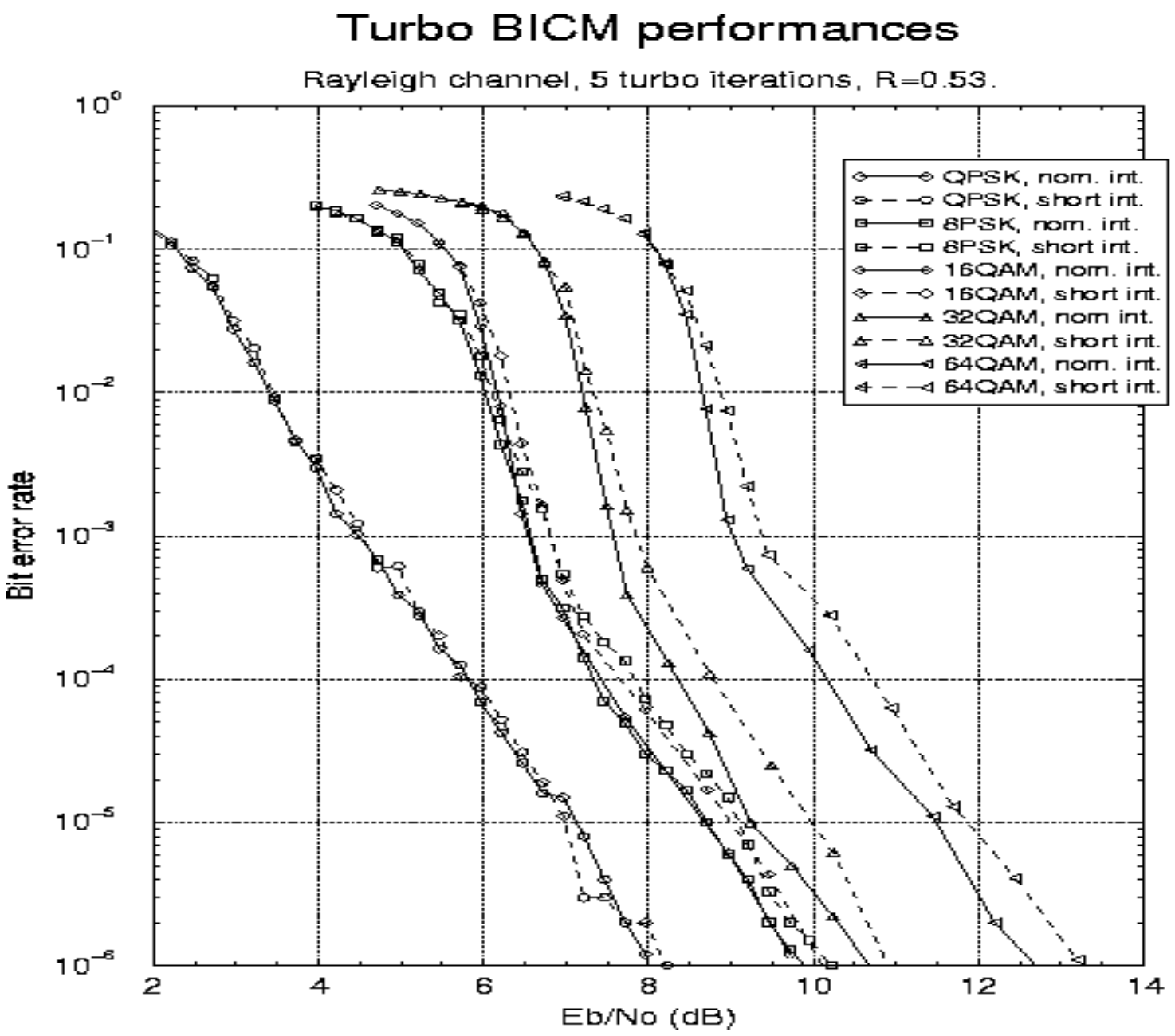



Full Rate Space–Time Code, 4 TX, 4 RX, 4–QAM, 8 bits/s/Hz
Quasi–Static Rayleigh Fading
Uncoded, 8 bits/s/Hz
Full Rate Space–Time Code, 8 bits/s/Hz
TEB
Eb/No [dB]
6
8
10
12
14
16

Turbo BICM

- New coding scheme which combines Iterative decoding (Turbo) and Bit Interleaved Coded Modulations (BICM),
- High spectral efficiency at low SNR:
  - Block code, rates from _ to 2/3,
  - Works at constellation level (like TCM).
- Lower complexity than turbo-codes:
  - 1 turbo-iteration is only one decoding (instead of 2),
  - Short constituant codes: e.g. RS (15,8) over GF (2^4).


Turbo BICM performances
Gaussian channel, 5 turbo iterations, R=0.53.
Bit error rate
Eb/No (dB)
QPSK, long int.
QPSK, short int.
8PSK, long int.
8PSK, short int.
16QAM, long int.
16QAM, short int.
32QAM, long int.
32QAM, short int.
64QAM, long int.
64QAM, short int.


Turbo BICM performances
Rayleigh channel, 5 turbo iterations, R=0.53.
Bit error rate
Eb/No (dB)
QPSK, nom. int.
QPSK, short int.
8PSK, nom. int.
8PSK, short int.
16QAM, nom. int.
16QAM, short int.
32QAM, nom int.
32QAM, short int.
64QAM, nom. int.
64QAM, short int.

Coding options with Turbo BICM and STBC

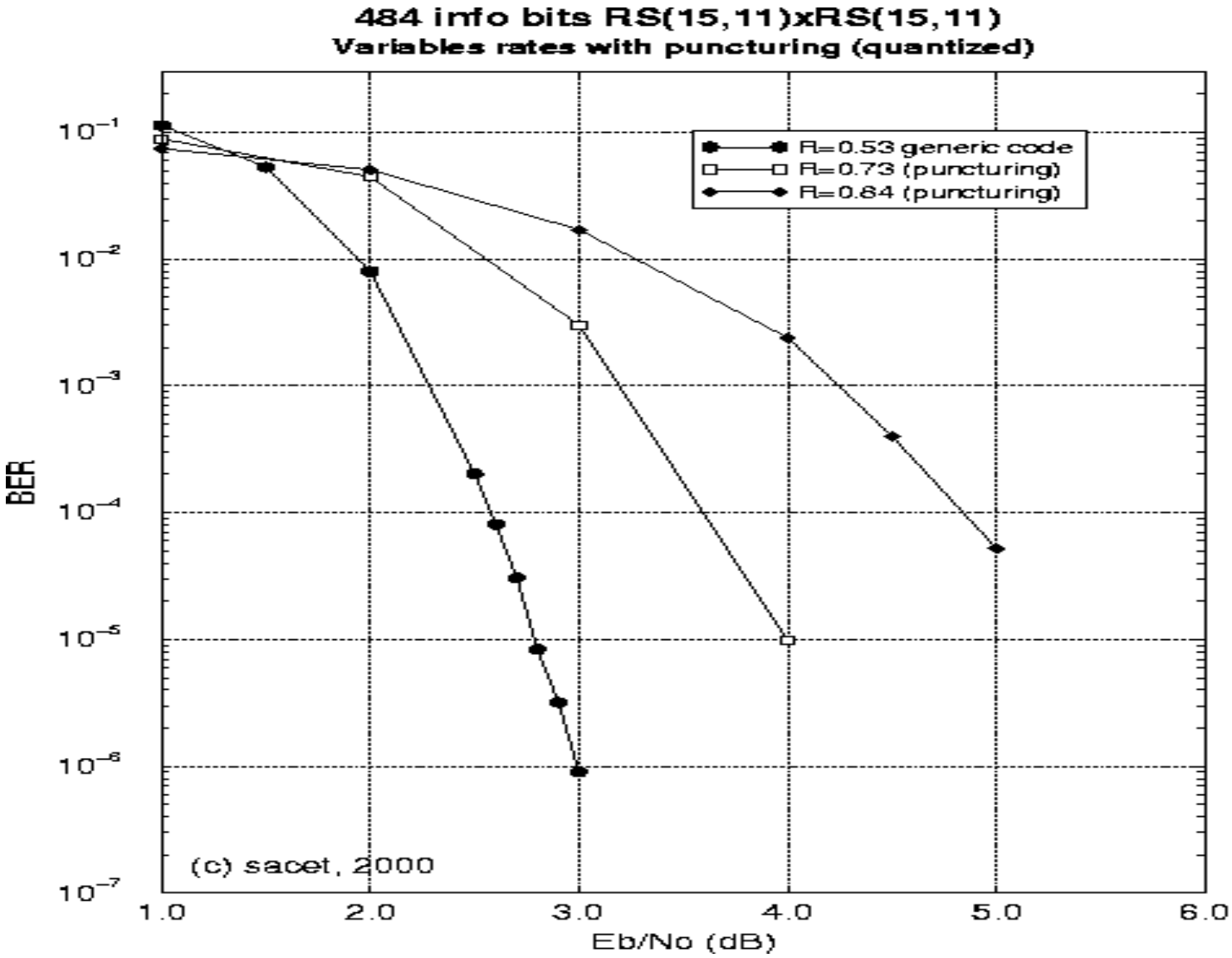
OFDM waveform + Turbo BICM channel coder

Bandwidth	QPSK	8PSK	16QAM	32QAM	64QAM
3,5 MHz	3,17 Mb/s	4,76 Mb/s	6,34 Mb/s	7,93 Mb/s	9,52 Mb/s
7 MHz	6,53 Mb/s	9,80 Mb/s	13,07 Mb/s	16,33 Mb/s	19,60 Mb/s
14 MHz	13,29 Mb/s	19,94 Mb/s	26,58 Mb/s	33,23 Mb/s	39,87 Mb/s

OFDM waveform + STBC (4+4 antennas) + Turbo BICM

Bandwidth	QPSK	8PSK	16QAM	32QAM	64QAM
3,5 MHz	12,68 Mb/s	19,04 Mb/s	25,36 Mb/s	31,72 Mb/s	38,08 Mb/s
7 MHz	26,12 Mb/s	39,20 Mb/s	52,28 Mb/s	65,33 Mb/s	78,40 Mb/s
14 MHz	53,16 Mb/s	79,76 Mb/s	106,32 Mb/s	132,92 Mb/s	159,48 Mb/s

Turbo Product Code performances



Coding schemes comparison

Scheme	Implementation	Performances
Conv 7,1/2	Simple, exists	Average
Turbo BICM	Dev. Needed	Very good
TPC	Dev. Needed	Very good

Low data rates, small packets

Low SNR, high spectral efficiency required:

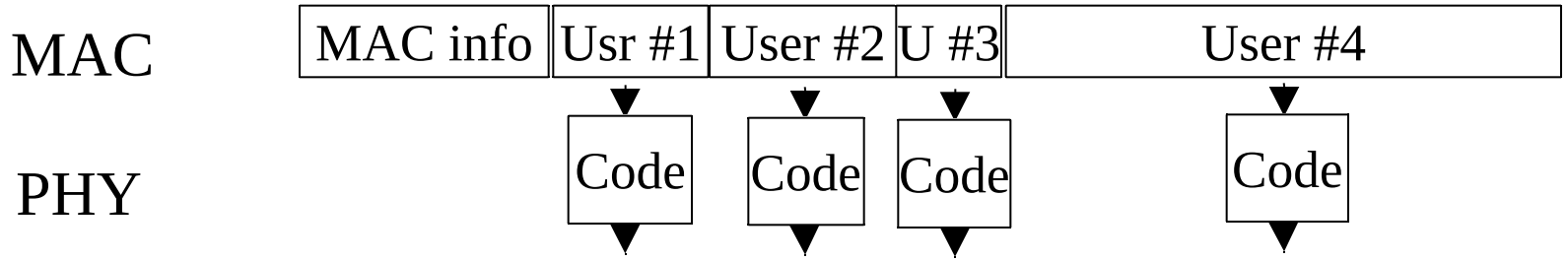
- Long codes or long interleavers (Shannon's capacity: BER $\rightarrow 0$ with size $\rightarrow +\inf.$)
  - Turbo codes (e.g. NASA's : 65536 bits),
  - Turbo BICM: interleaver size is critical,
  - Turbo Product Codes: long interleaving.
- Problem: long delay for low rate connexions, small packets get poor BER,
  $\rightarrow$Proposed solution: « interleaved » TDM.

« Interleaved » TDM

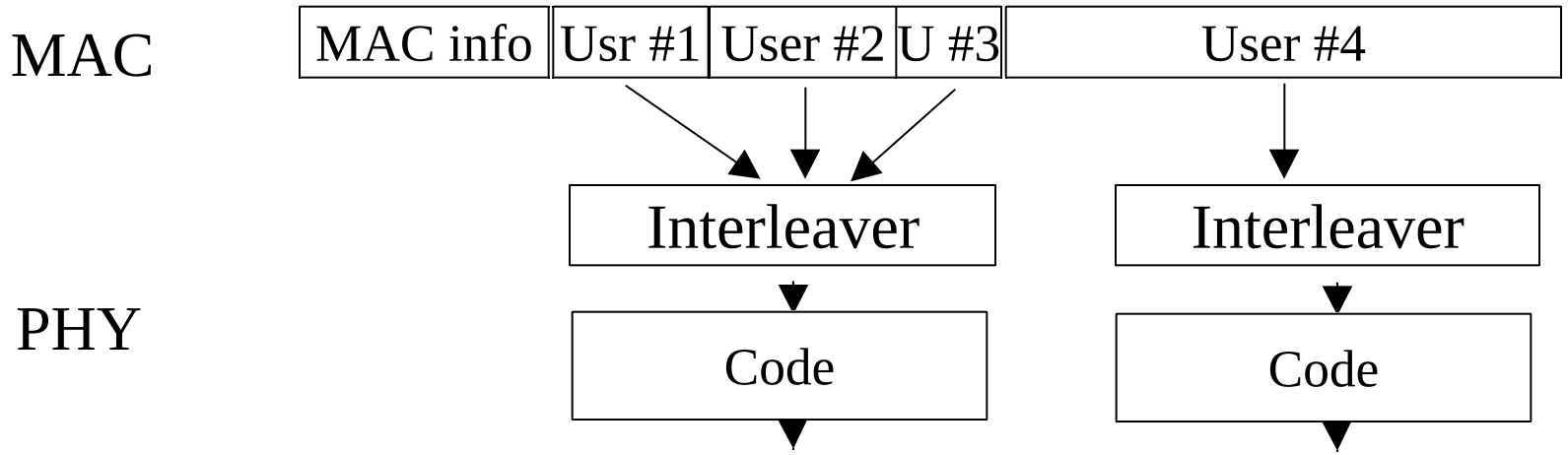
- On DownLink only,
- Small packets are interleaved together inside one (long) coding or interleaving block,
- Interleaved packets share the same constellation,
- Keeps high spectral efficiency for small packets,
- Small modification of MAC.

« Interleaved » TDM

TDM:



Interleaved TDM:



Conclusion, remarks

- NLOS channel OFDM,
- High spectral efficiency coding schemes,
- Systems uses TDM/TDMA MAC, but OFDMA is possible with more carriers,
- OFDM raises PAPR problem. Some work to do, but solutions exist.