Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)

Submission Title: [France Telecom - IHP OFDM mode definition]
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Source: [Pascal Pagani[1], Maxim Piz[2],
Isabelle Siaud[1], Eckhard Grass[2],
Wei Li[1], Klaus Tittelbach-Helmrich[2] ,
Anne-Marie Ulmer-Moll[1], Frank Herzel[2],
Marie-Hélène Hamon[1]]
Company [[1] France Telecom, [2] IHP]
Address []
Voice: [], Fax: [], E-Mail: []

Re: []

Abstract: [Proposition of a high data rate wireless system in the 60 GHz range.]

Purpose: []

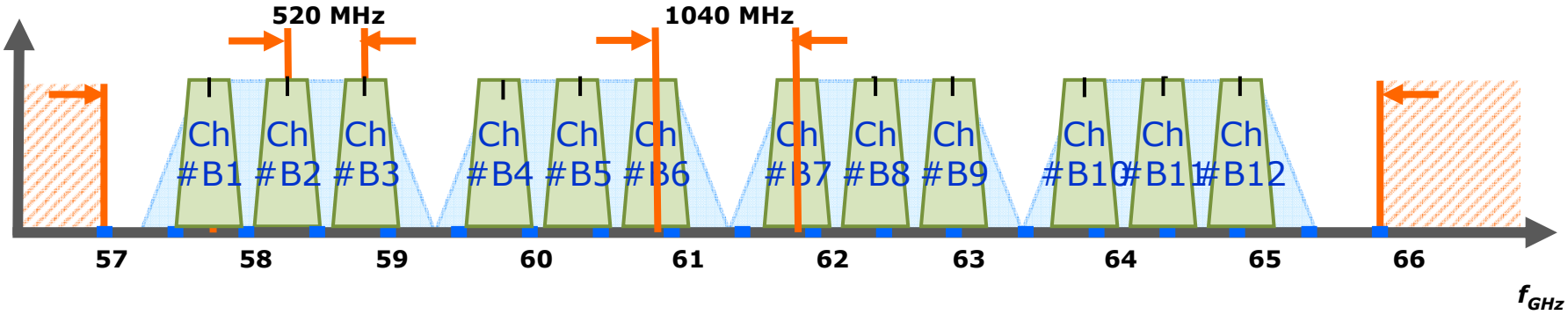
France Telecom – IHP TG3c Proposal OFDM Mode Definition

Motivation

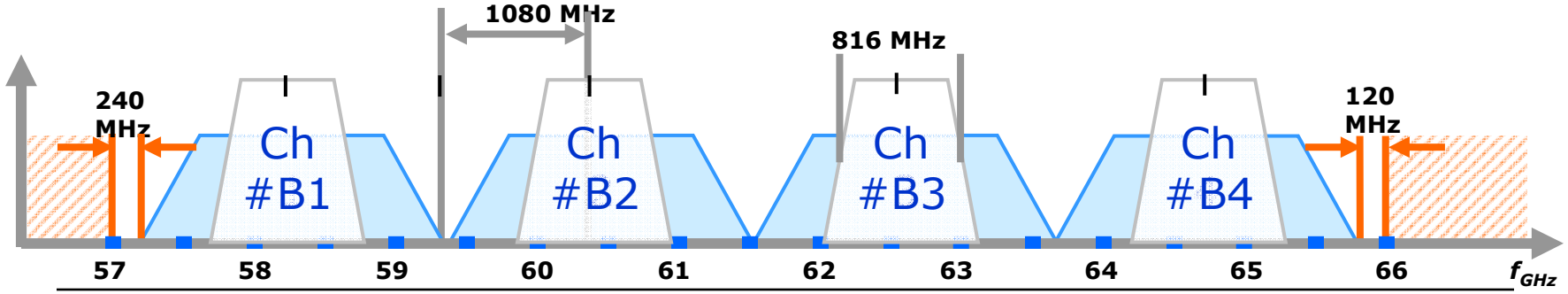
- France Telecom – IHP has agreed to create a joint submission with COMPA
- The proposed system features an LDR common mode and both SC and OFDM HDR modes
- This document details FT-IHP OFDM modes
- Main features
  - One mandatory channel size of 2 GHz and two possible optional channel sizes (500 MHz or 1 GHz)
  - Data rates from 187.5 Mbps to 6 Gbps for applications such as video streaming, file transfer, home network distribution or in-vehicle media supply
  - OFDM based system providing high spectrum efficiency
  - Scalable parameters for increased robustness

Channel Plan

- Mandatory channels: four 2 GHz channels
- Option #1 (recommended option): 500 MHz sub-channels



- Option #2: 1 GHz sub-channels

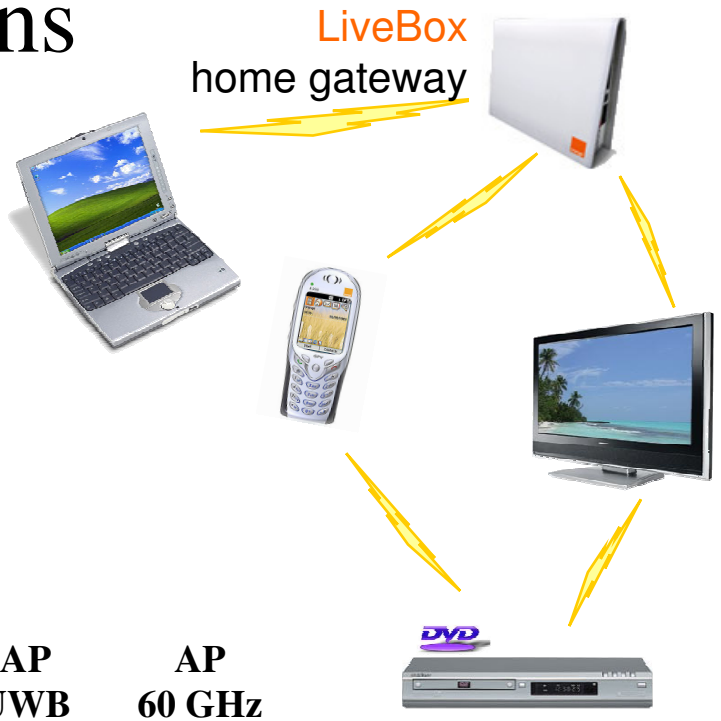


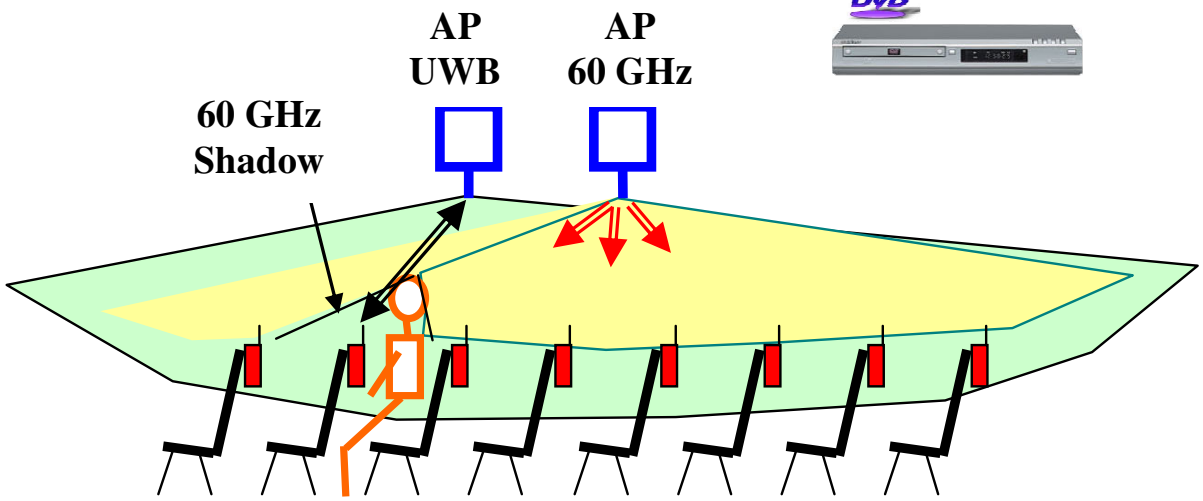
Applications

- Uncompressed video streaming (UM1)
- Kiosk file downloading (UM5)

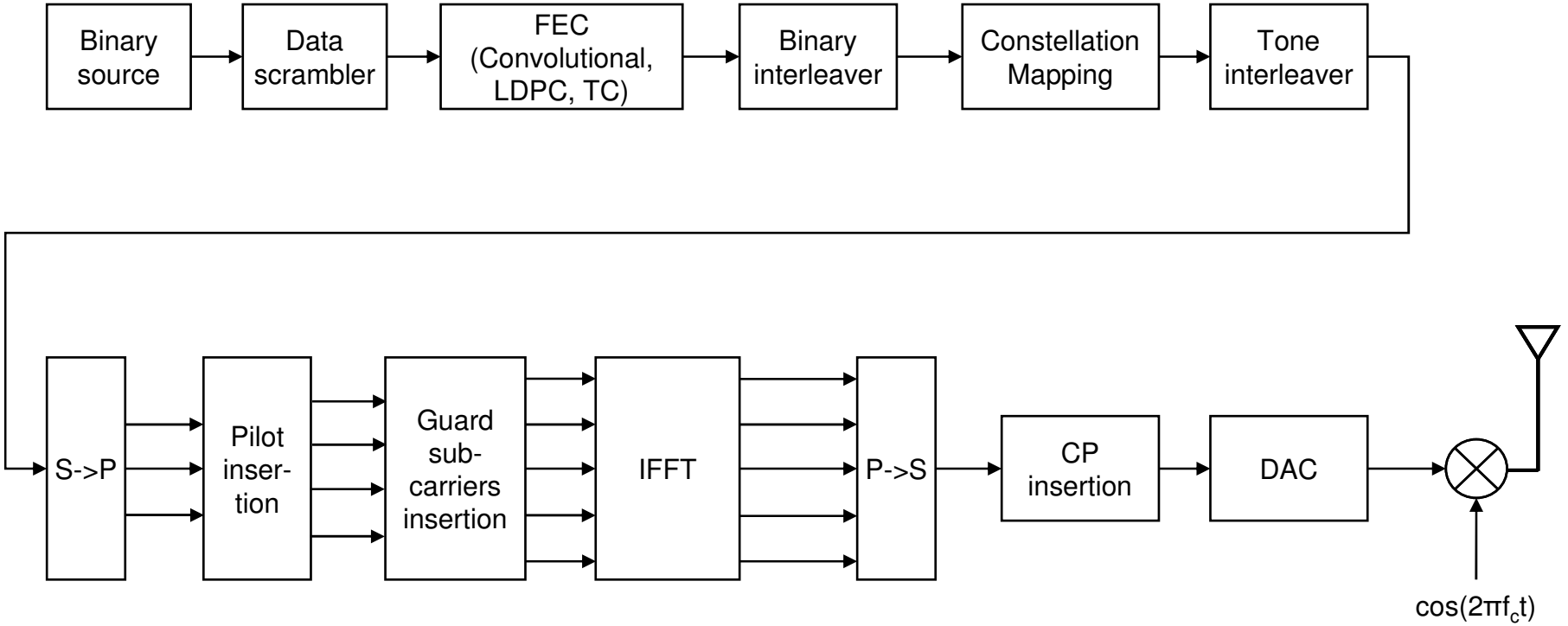
- High data rate WPAN distribution
  - Multiple user high data rate networking
  - Home or office video streaming
  - Express file transfer

- Media supply in trains, busses and aircraft
  - Possibly use of secondary system (e.g. UWB) for 100% coverage





PHY Baseband Architecture



- OFDM system architecture

System Parameters

Parameter	500 MHz channels	1 GHz channels	2 GHz channels
Number of data subcarriers (N_{SD})	420	840	1680
Number of pilot carriers (N_{SP})	33	66	132
Number of DC zero carriers ($N_{DC)}$	5	5	5
Number of guard carriers	54	113	231
FFT size (N_{FFT})	512	1024	2048
Channel bandwidth (B_{FFT})	500 MHz	1 GHz	2 GHz
Subcarrier frequency spacing	0.977 MHz	0.977 MHz	0.977 MHz
IFFT/FFT period	1024 ns	1024 ns	1024 ns
Cyclic prefix duration (T_{CP})	96 ns / 160 ns / 220 ns	96 ns / 160 ns / 220 ns	96 ns / 160 ns / 220 ns
Symbol interval (T_{SYM})	1120 ns / 1184 ns / 1244 ns	1120 ns / 1184 ns / 1244 ns	1120 ns / 1184 ns / 1244 ns

Modulation and Coding Schemes

500 MHz channels

Data Rate	Modulation	Coding Rate	Data bytes per OFDM symbol
187.5 Mbps	BPSK	1/2	26.25
250 Mbps	BPSK	2/3	35
375 Mbps	QPSK	1/2	52.5
500 Mbps	QPSK	2/3	70
750 Mbps	16-QAM	1/2	105
1000 Mbps	16-QAM	2/3	140
1250 Mbps	16-QAM	5/6	175
1500 Mbps	64-QAM	2/3	210

Valid for CP duration of 96 ns.

Modulation and Coding Schemes

1 GHz channels

Data Rate	Modulation	Coding Rate	Data bytes per OFDM symbol
375 Mbps	BPSK	1/2	52.5
500 Mbps	BPSK	2/3	70
750 Mbps	QPSK	1/2	105
1000 Mbps	QPSK	2/3	140
1500 Mbps	16-QAM	1/2	210
2000 Mbps	16-QAM	2/3	280
2500 Mbps	16-QAM	5/6	350
3000 Mbps	64-QAM	2/3	420

Valid for CP duration of 96 ns.

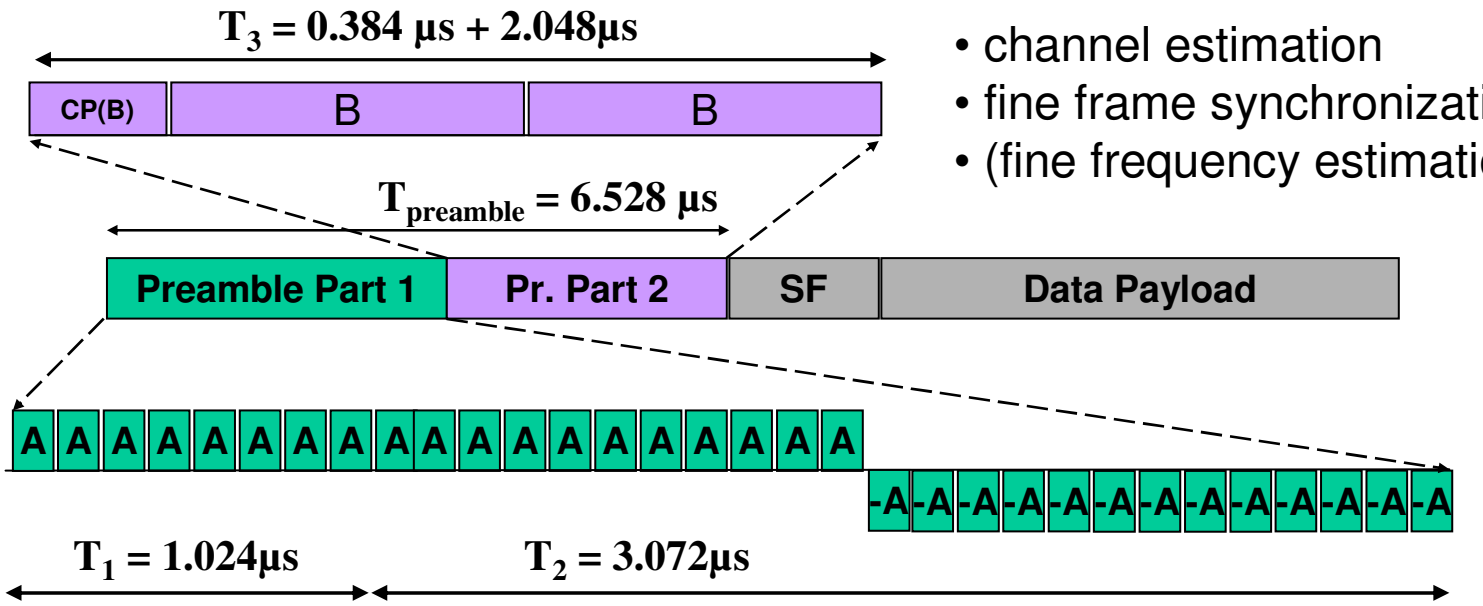
Modulation and Coding Schemes

2 GHz channels

Data Rate	Modulation	Coding Rate	Data bytes per OFDM symbol
750 Mbps	BPSK	1/2	105
1000 Mbps	BPSK	2/3	140
1500 Mbps	QPSK	1/2	210
2000 Mbps	QPSK	2/3	280
3000 Mbps	16-QAM	1/2	420
4000 Mbps	16-QAM	2/3	560
5000 Mbps	16-QAM	5/6	700
6000 Mbps	64-QAM	2/3	840

Valid for CP duration of 96 ns.

Preamble Format and Utilization



2 long B-symbols for

- channel estimation
- fine frame synchronization
- (fine frequency estimation)

8 A-symbols for

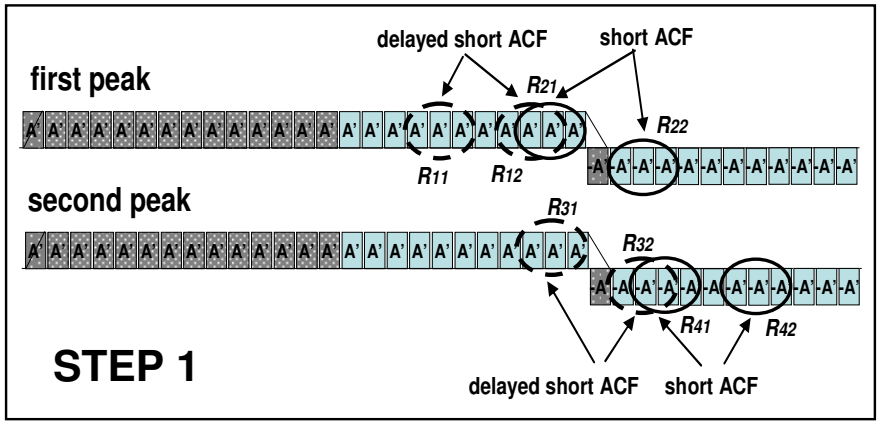
- AGC settling

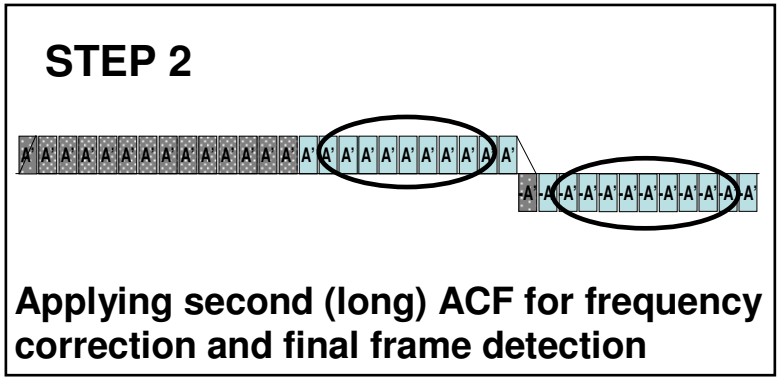
11 A-symbols + 13 inverted A-symbols for

- frame detection
- frequency correction
- coarse frame synchronization

Frame Detection Mechanism

- a normalized autocorrelator is related to a delayed version
- samples satisfying an “antiphase-condition” are marked
- marked samples are grouped in clusters, such that the distance of adjacent cluster samples is below some value d
- the middle point in each cluster is defined as a peak at position x_k
- two peaks must be found in the frame with a distance $|x_{k+1} - x_k| \in [D_{\min}, D_{\max}]$
- with the first peak as a time reference, a second ACF is evaluated for final frame detection and frequency offset correction



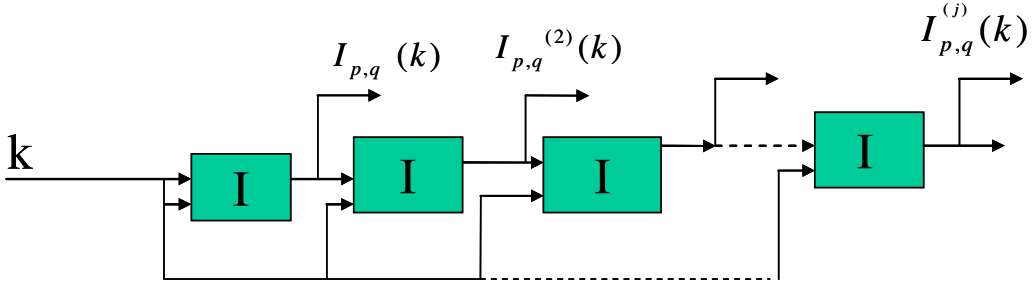


Channel Coding

- Convolutional encoder should be used for low complexity implementation
- We propose to use an outer Reed-Solomon code with a code rate of about 95% to reduce the error floor.
- Possibly, the convolutional codes can be replaced by advanced codes:
  - **Turbo Codes**
  - **LDPC codes**

Binary Interleaving

- Optimized binary interleaver based on an iterative structure
- Effectively maximizes both intra- and inter- symbols interleaving spreading
- Efficiently improves decoder performance



$$X_{OUT}(k) = X_{IN}\left(I_{p,q}^{(j)}(k)\right)$$

$$I_{p,q}^{(0)}(k) = \left[\alpha + k + q \cdot p \cdot \left[-k - p \cdot k\right]_K\right]_K$$

$$I_{p,q}^{(j)}(k) = \left[\alpha + k + q \cdot p \cdot \left[-k - p \cdot I_{p,q}^{(j-1)}\right]_K\right]_K$$

K : Block size,

p, q, j : Interleaver parameters

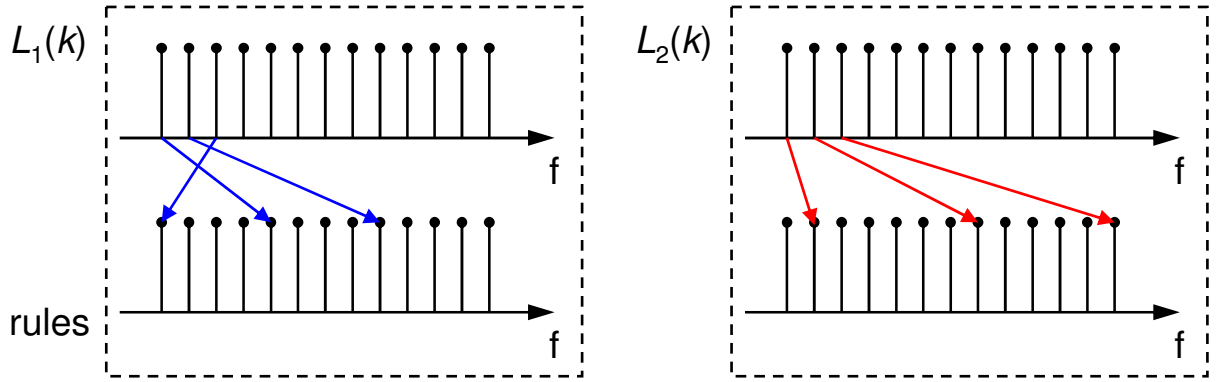
$\alpha < \frac{K}{p}$: Offset parameter

Tone Interleaving

- After constellation mapping, the complex symbols assigned to different frequency tones are interleaved over 1 or 4 OFDM symbols
- Purpose : increase the system frequency diversity and reduce interference from narrow band interferers
- Similar interleaving scheme is used as for binary interleaving
- Dynamic implementation: two different permutation rules are used cyclically

$Y_{OUT}(k) = Y_{IN}(L(k))$

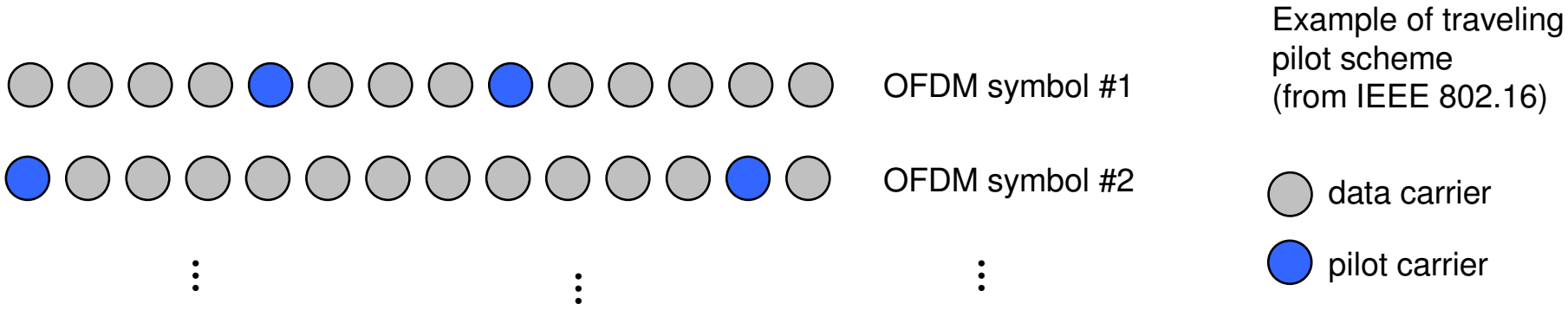
Two different permuation rules



	Permutation rule #1	Permuation rule #2	Permutation rule #1	Permuation rule #2
OFDM symbol	#1	#2	#3	#4

OFDM Pilot Tones

- Channel estimation symbols and OFDM pilot tones carry highly sensitive information for the mitigation of channel and RF impairments
- It is recommended to allocate more power to these signals
- In addition, pilots should be assigned to different subcarriers in successive OFDM symbols, for a more efficient estimation of phase noise and frequency offsets ("Traveling pilots")
- These concepts have been implemented and assessed in the WiMax system (IEEE 802.16).



OFDM LRT Modes (up to 2 Gbps)

PHY Mode	Transmission Mode	PHY-SAP data rate	Bandwidth	Modulation	Coding	Code Rate
OFDM mode	LRT1	187.5 Mbps	500 MHz (incl. guard band)	BPSK	Convolutional Code + RS, LDPC, Turbo Codes [TBD]	1/2
	LRT2	250 Mbps		BPSK		2/3
	LRT3	375 Mbps		QPSK		1/2
	LRT4	500 Mbps		QPSK		2/3
	LRT5	750 Mbps		16-QAM		1/2
	LRT6	1000 Mbps		16-QAM		2/3
	LRT7	1250 Mbps		16-QAM		5/6
	LRT8	1500 Mbps		16-QAM		2/3
	LRT9	375 Mbps	1 GHz (incl. guard band)	BPSK		1/2
	LRT10	500 Mbps		BPSK		2/3
	LRT11	750 Mbps		QPSK		1/2
	LRT12	1000 Mbps		QPSK		2/3
	LRT13	1500 Mbps		16-QAM		1/2
	LRT14	750 Mbps	2 GHz (incl. guard band)	BPSK		1/2
	LRT15	1000 Mbps		BPSK		2/3
	LRT16	1500 Mbps		QPSK		1/2

OFDM MRT Modes (from 2 to 3 Gbps)

PHY Mode	Transmission Mode	PHY-SAP data rate	Bandwidth	Modulation	Coding	Code Rate
OFDM mode	MRT1	2000 Mbps	1 GHz (incl. guard band)	16-QAM	Convolutional Code + RS, LDPC, Turbo Codes [TBD]	2/3
	MRT2	2500 Mbps		16-QAM		5/6
	MRT3	3000 Mbps		64-QAM		2/3
	MRT4	2000 Mbps	2 GHz (incl. guard band)	QPSK		2/3
	MRT5	3000 Mbps		16-QAM		1/2

OFDM HRT Modes (over 3 Gbps)

PHY Mode	Transmission Mode	PHY-SAP data rate	Bandwidth	Modulation	Coding	Code Rate
OFDM mode	HRT1	4000 Mbps	2 GHz (incl. guard band)	16-QAM	Convolutional Code + RS, LDPC, Turbo Codes [TBD]	2/3
	HRT2	5000 Mbps		16-QAM		5/6
	HRT3	6000 Mbps		64-QAM		2/3

Conclusion

- In order to meet the requirements for different applications (file transfer, video streaming…), a dual PHY with both SC and OFDM modes is desirable
- This proposal describes the baseband design for an OFDM mode allowing 60 GHz transmission at data rates from 187 Mbps to 6 Gbps
- A scalable baseband design is proposed, allowing for transmission over 500 MHz, 1 GHz and 2 GHz wide channels
- We presented advanced techniques increasing the system efficiency and robustness

- We are open to discussions with any companies interested in OFDM and encourage exchanges to further improve the definition of the TG3c OFDM modes

Thank you !

Questions ?

pascal.pagani@orange-ftgroup.com
wei3.li@orange-ftgroup.com
grass@ihp-microelectronics.com