Spectrum-Domain Communications

— An outlook on 5G

International Center for Wireless Collaborative Research

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Outline

1. Introduction

2. Fundamental of spectrum-domain communications

3. Spectrum-domain communications Systems

4.Testbed development

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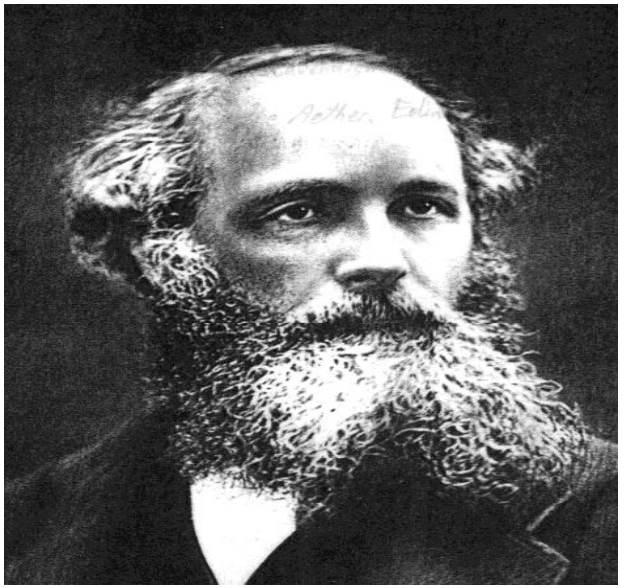
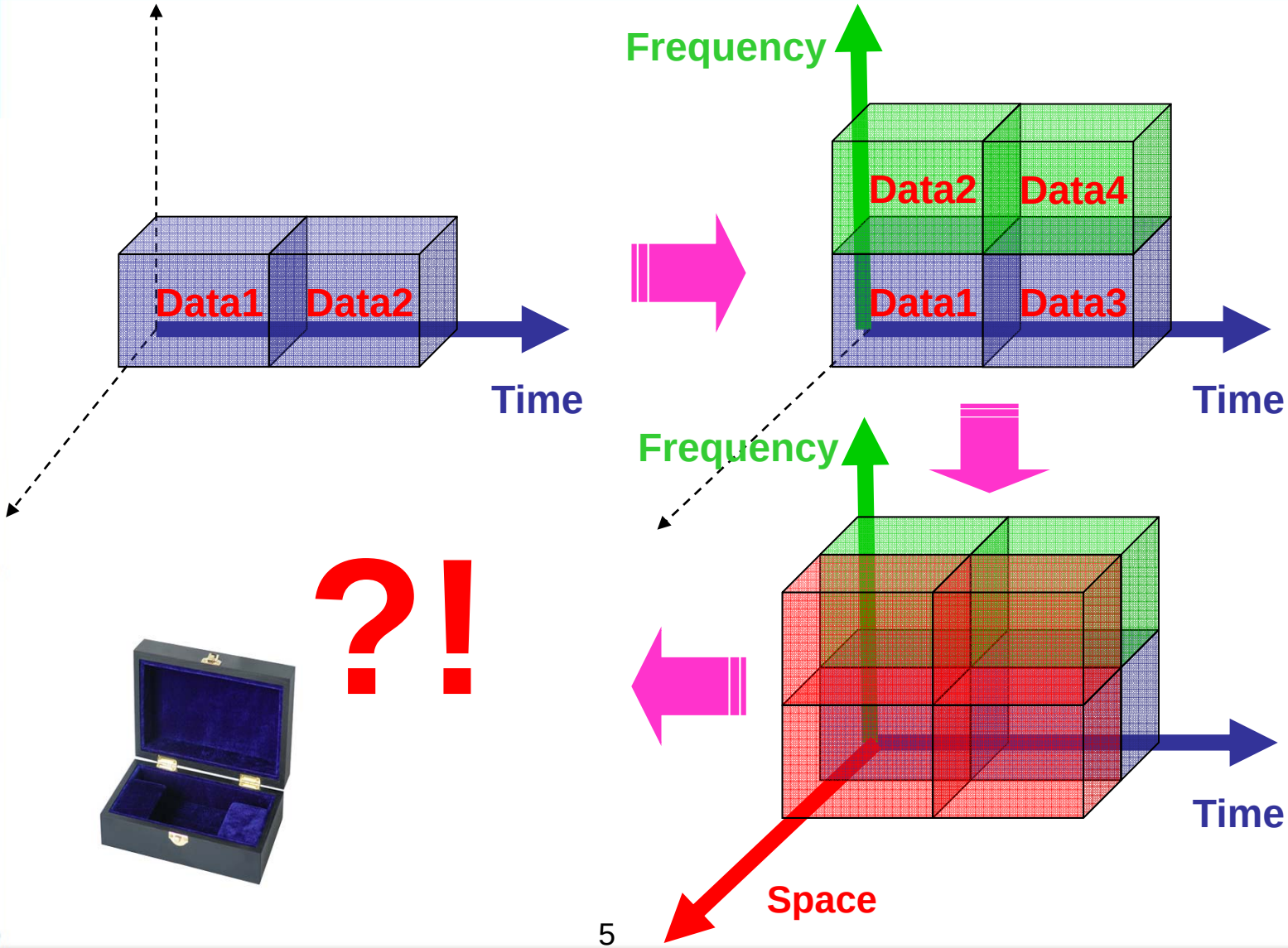
Expansion of human territory

Conventional 3-D space

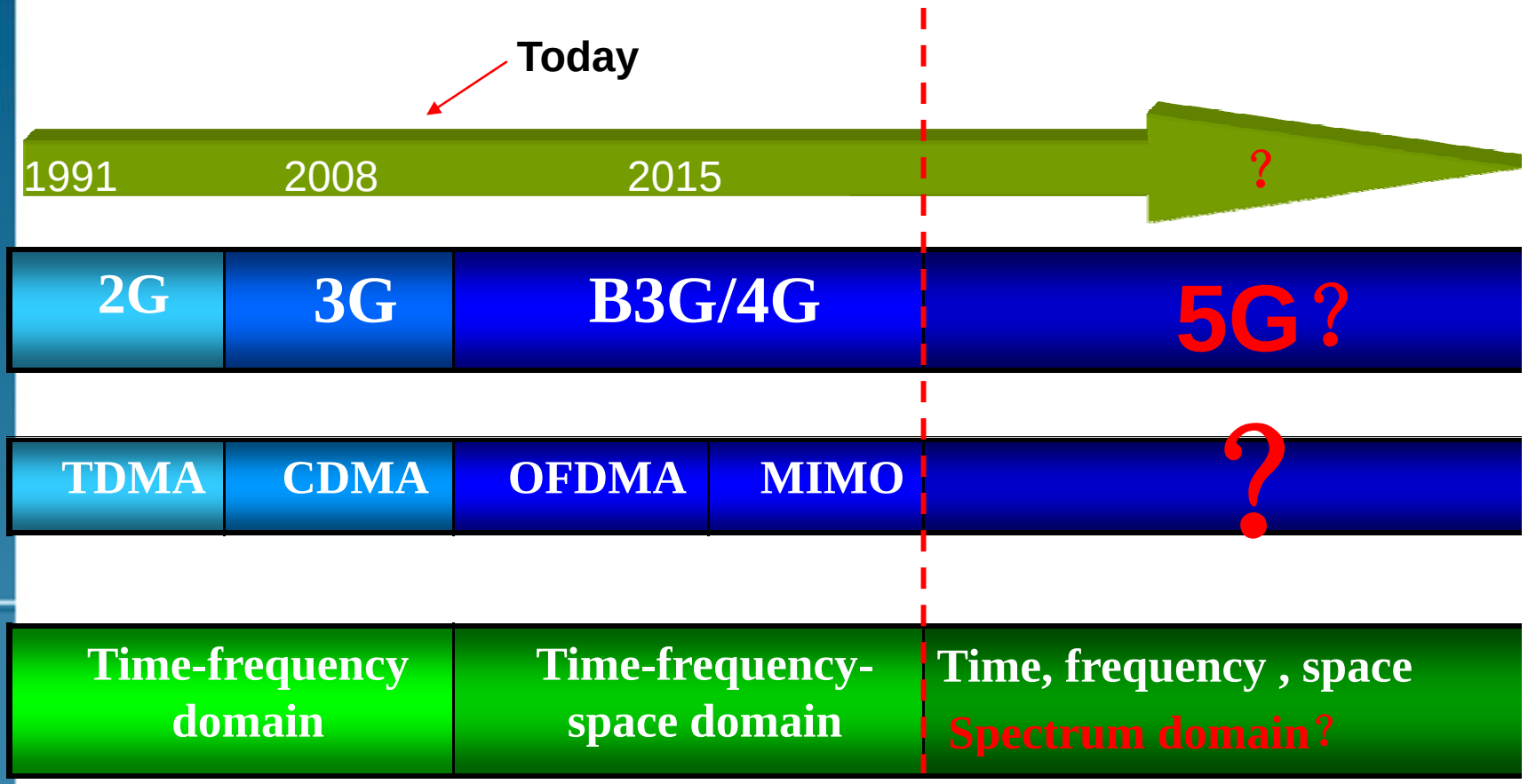
Electromagnetic field



Dimension expansion for information transmission



What is the next?



In addition to conventional time, frequency, and space domains, does other transmission domain exist?

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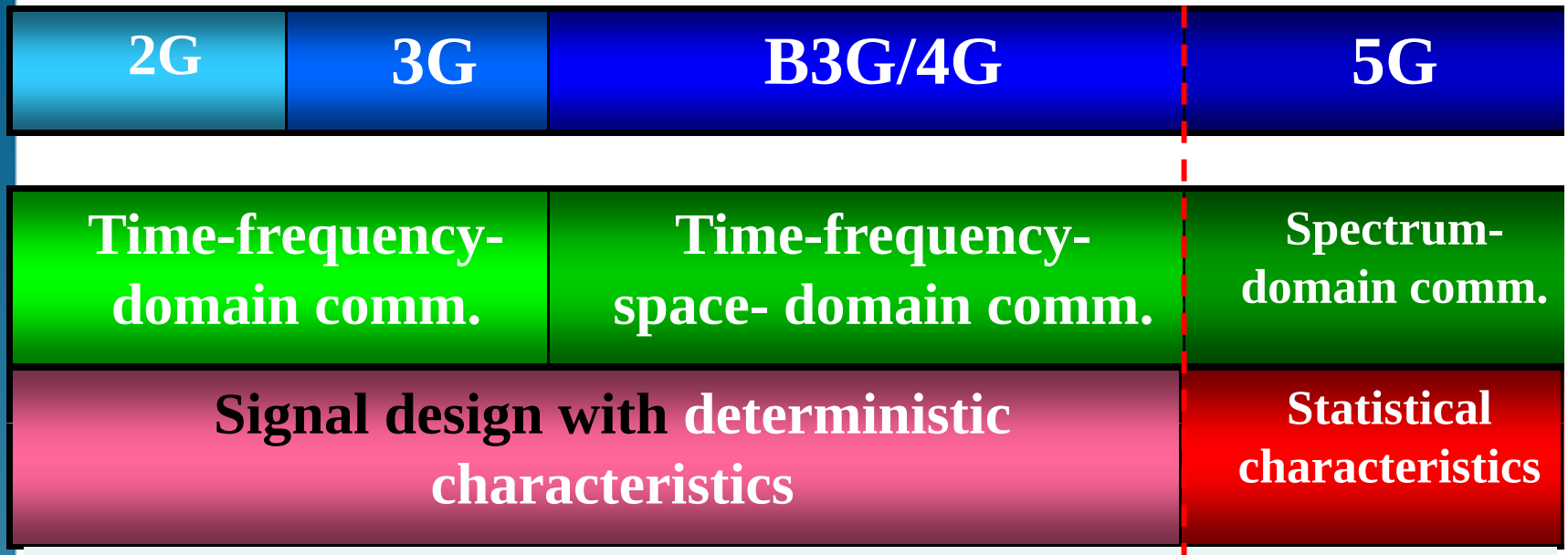
What's spectrum-domain communications?



Spectrum-domain communications specify a digital transmission procedure over statistical spectrum-domain, in which the transmitter maps binary digits into the statistical characteristics of transmit signals and the receiver recoveries these digits by extracting the modulated statistical characteristics of the received signals.

Modulation strategy over spectrum domain

- **Design purposely induced cyclostationary communication signal:**

  Bandwidth cost and inflexible

- **Exploit cyclostationarity in conventional communication signals:**

  Green communications and flexible

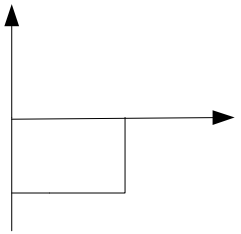
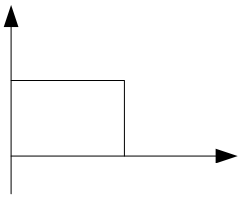
Digital modulation：A mapping between binary digits and symbols

Primitive communications：Mapping binary digit into grin or smile

Binary digit	Expression symbol	Detection method
0		
1		

Traditional digital modulation

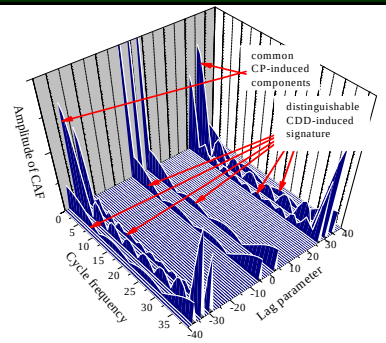
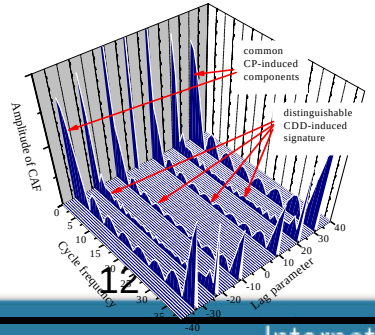
Digital modulation over traditional domain:
A mapping between binary digits and deterministic characteristics of transmit signal.
Binary digits modulate the amplitude, phase and frequency of transmit signal.

Binary digit	Transmit signal	Detection method
0		Classify the deterministic characteristics of signals
1		

Digital modulation over spectrum domain

Binary digits → Cyclic delay vector → Statistical characteristics of transmit signal

Binary digits modulate pulse positions of the Cyclic Autocorrelation Function (CAF) of the CDD-OFDM signal.

Binary digit	Cyclostationary spectrum of transmit signal	Detection method
0		Classify the statistical characteristics of signals
1		

Exploration for spectrum-domain communications

Cyclostationary signatures in OFDM

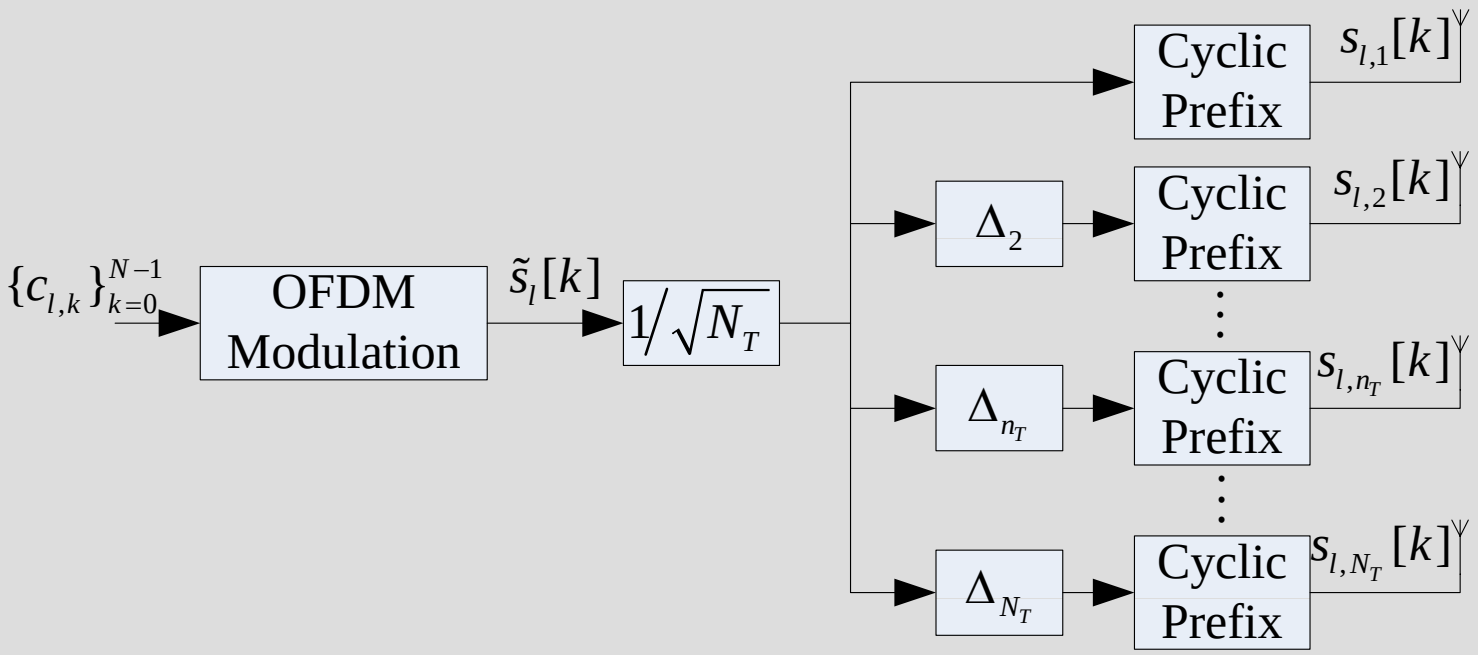
1. P. D. Sutton et. al. , IEEE JSAC. vol. 26, pp. 13-24, Jan. 2008.
2. Design CAF through time-frequency domain.
3. Show the possibility to send information over spectrum domain
4. Impractical
5. unable to achieve multiplexing gain due to spectrum domain

Cyclic Delay Modulation（CDM）

1. H. Guo, H. Hu and Y. Yang, IEEE ICC 2009
2. Design CAF through space domain.
3. A overlaying scheme over a CDD-OFDM system (standard compatibility)
4. Practical and green communications
5. Capability to achieve multiplexing gain due to spectrum domain

CDD-OFDM systems

CDD-OFDM transmitter（3GPP-LTE standard）



CDD-OFDM: Appealing features

1. Standard conformability

Standard conformability

- **Implement only in transmitter being transparent to receiver side**
- **It can be incorporated within the OFDM-based standards such as WiMAX, 3GPP-LTE, and IEEE 802.11a etc.**

CDD-OFDM: Appealing features

1. Standard conformability
2. Delay diversity gain

Delay diversity gain

- Convert MISO channel into an equivalent SISO channel with increased frequency diversity.
- Transform delay diversity into frequency diversity
- Collect increased diversity by an outer error control coding such as convolutional coding

CDD-OFDM: Appealing features

1. Standard conformability
2. Delay diversity gain
3. Saturation effect

Saturation effect

- In the saturation region, the system can achieve almost the same delay diversity gain approaching to the maximum.
- Saturation effect allows for tuning cyclic delays for other metrics, while keeping the desirable performance of antenna system.

CDD-OFDM: Appealing features

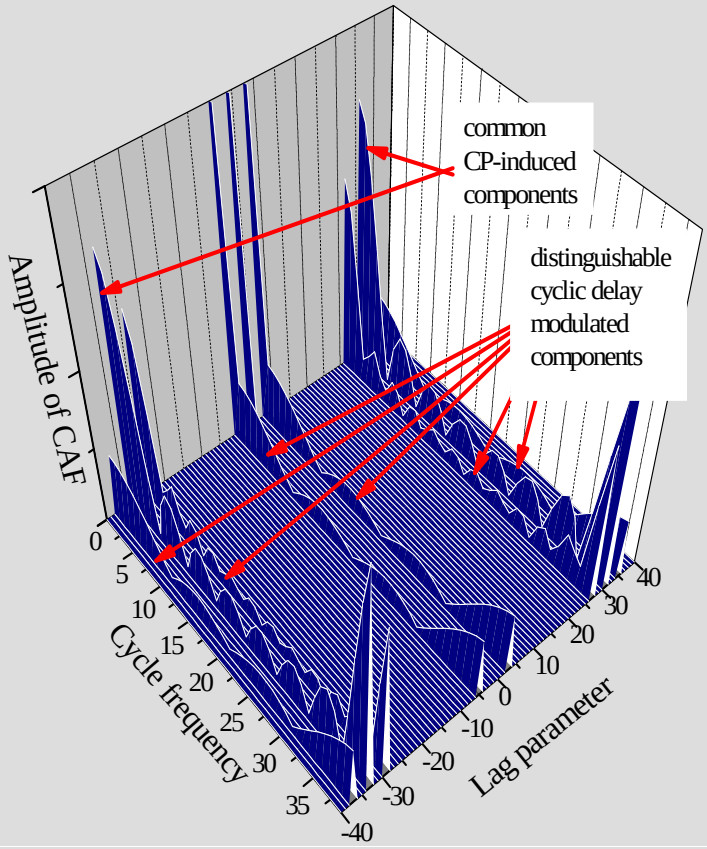
1. Standard conformability
2. Delay diversity gain
3. Saturation effect
4. Cyclostationarity

Cyclostationarity

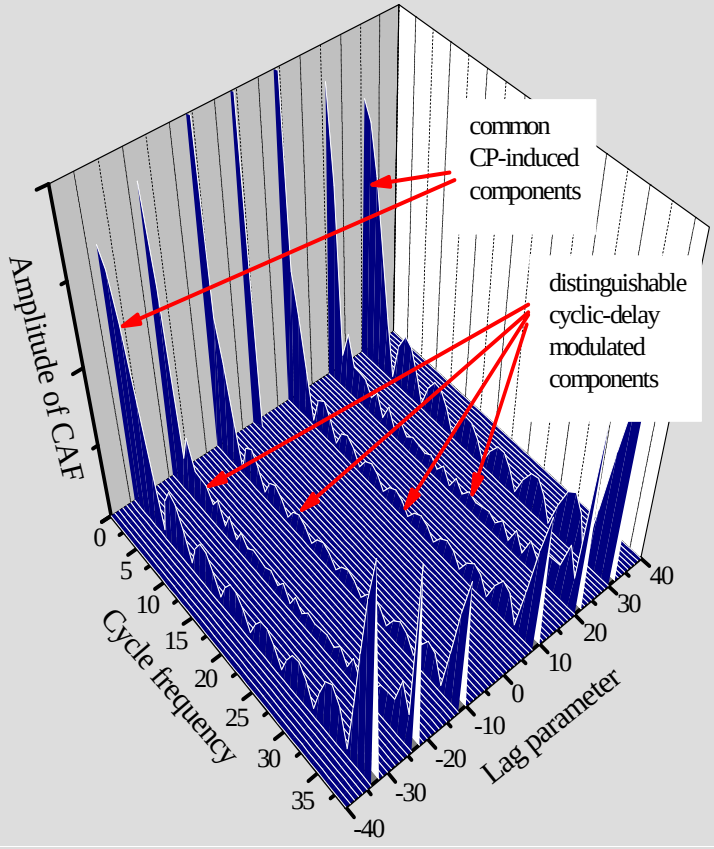
- CP-induced CAF pulses: At the fixed positions
- CDD-induced CAF pulses: Its position can be tuned by cyclic-delay intervals.

CAF of the received CDD-OFDM

$\Delta_2 = 4$



$\Delta_2 = 10$



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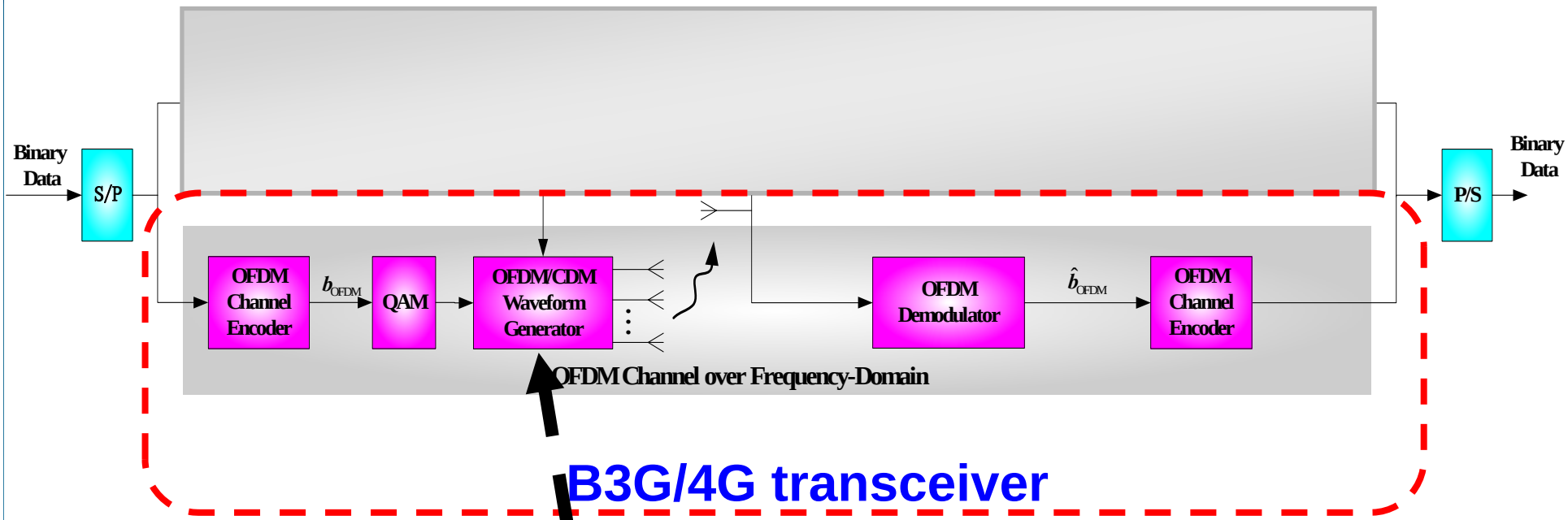
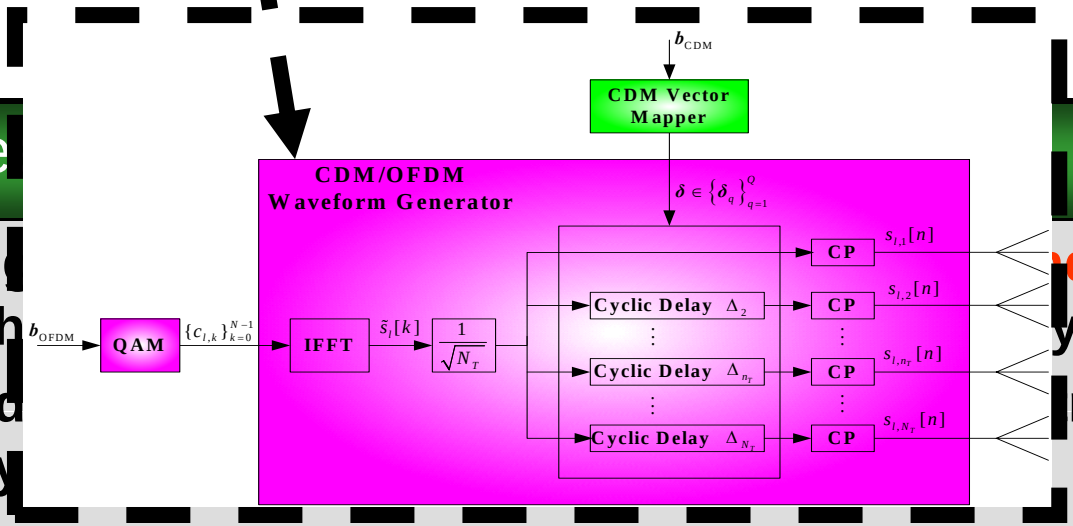
Parallel transmission based on Cyclic-Delay Modulation (CDM)



B3G/4G transceiver



Practical gre

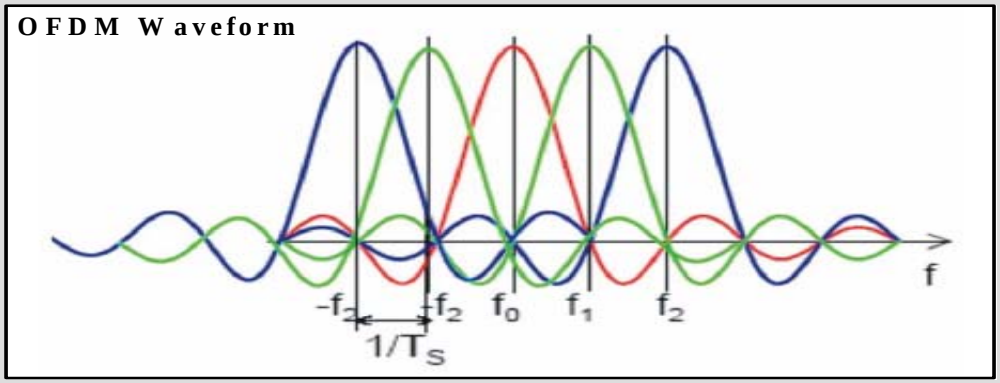
- Increasin dwidth and power, wh ystem
- Sending d ness against stationary

Parallel digital transmission

Multiplexing of CDM channel and OFDM channel

OFDM Channel Over Frequency Domain

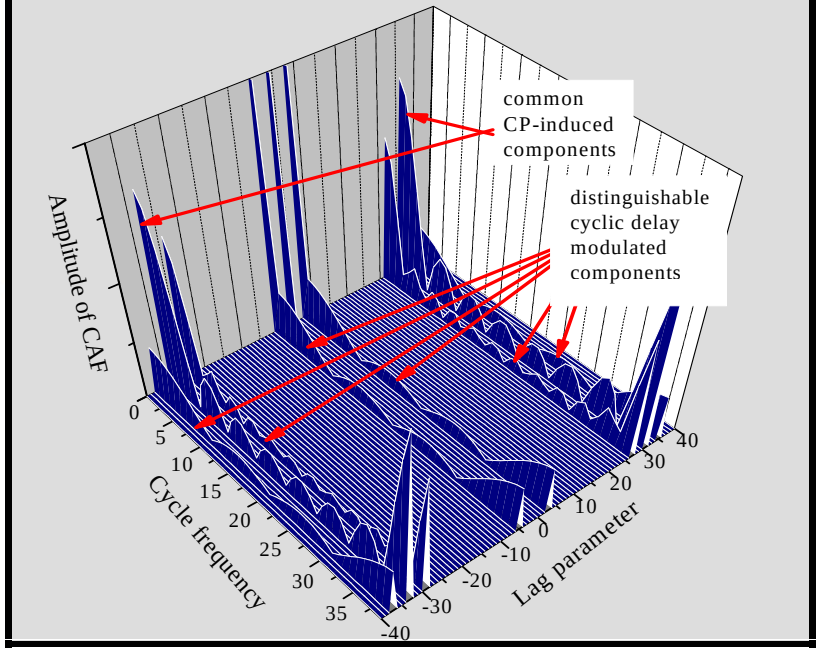
Signal Design with Deterministic Characteristics



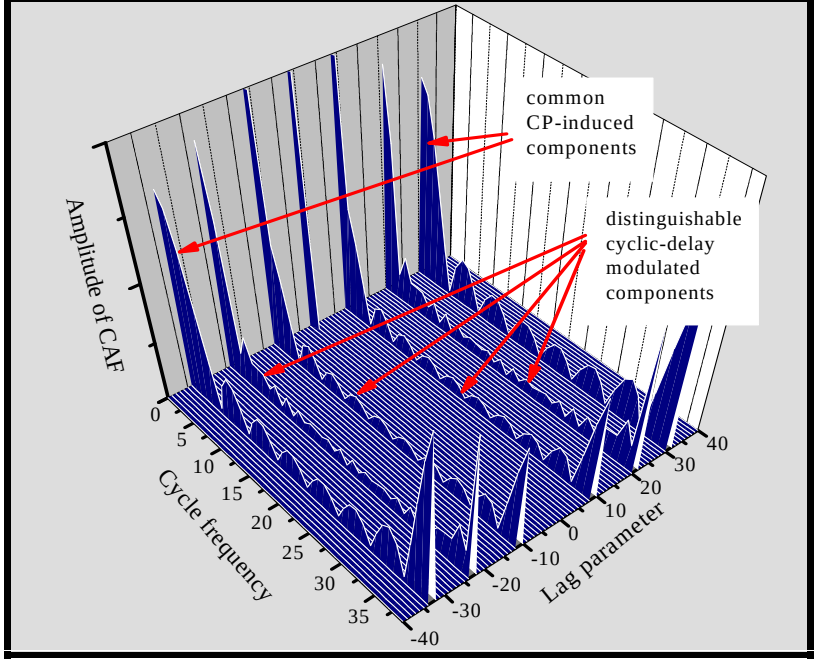
Mapping from binary digits to statistical waveforms

Binary digits modulate the pulse position of CAF of the CDD-OFDM signal.

$\Delta_2 = 4 \Leftrightarrow 00100$



$\Delta_2 = 10 \Leftrightarrow 01010$



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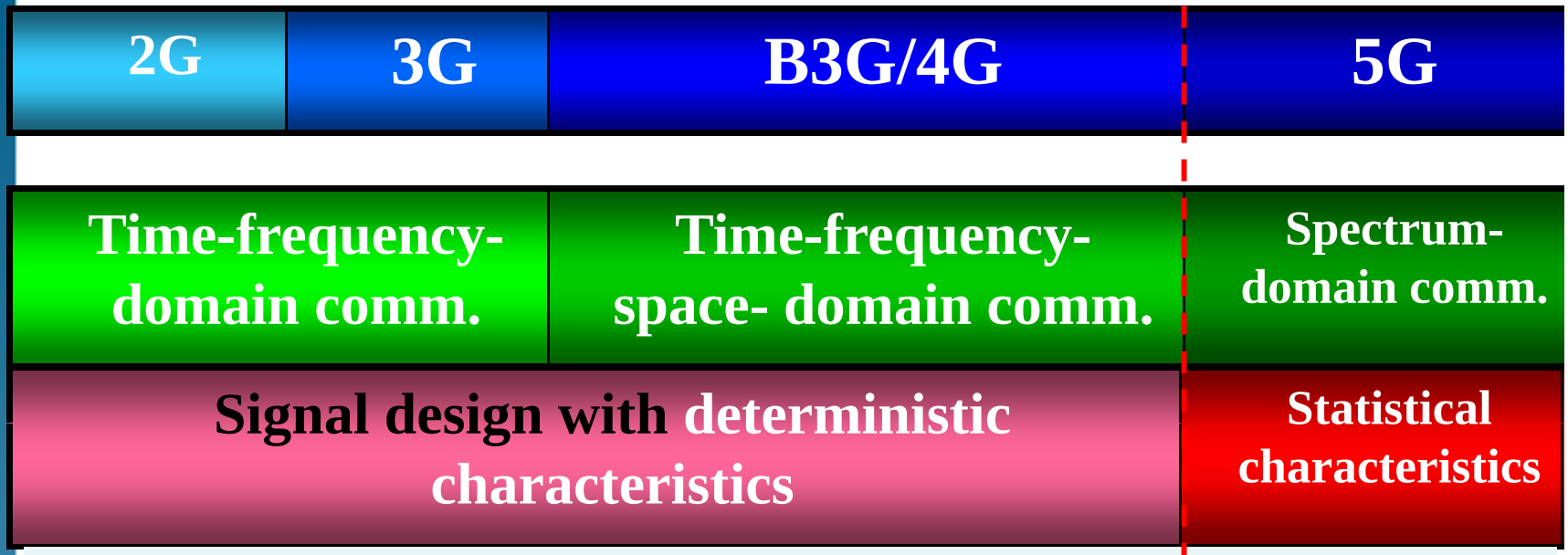

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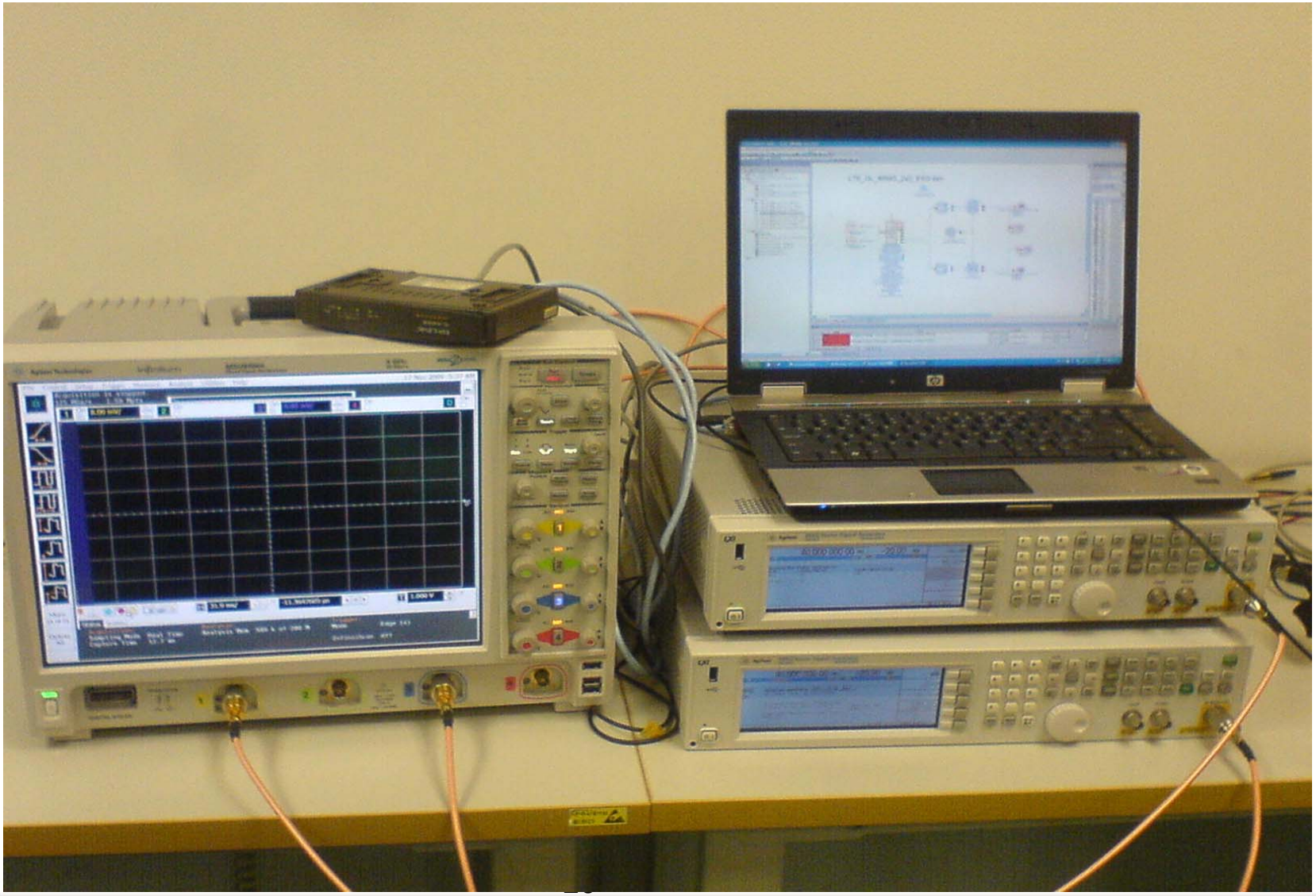
Instrument-based prototype



Thanks !

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