Advanced Multicarrier Waveforms for 5G and Beyond

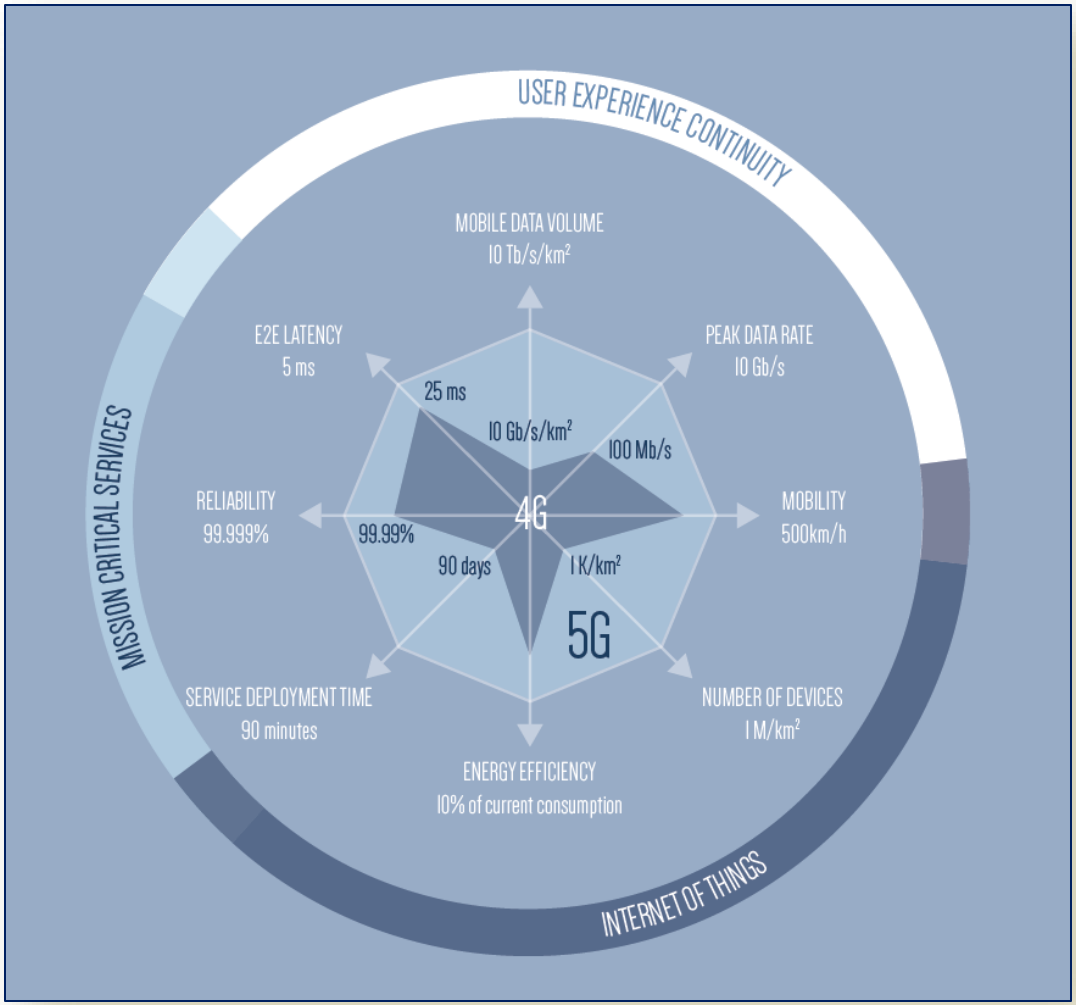
Hanna Bogucka

Poznan University of Technology,
Poland

Plan of this Presentation

- Introduction
- Promissing multicarrier technologies for spectrally and energy-efficient 5G radio
  - Enhanced OFDM, FBMC, GMC,…
- Multicarrier technologies for flexible spectrum usage:
  - Dynamic spectrum access
  - Spectrum aggregation
  - Spectrum sharing

Radar diagram of 5G disruptive capabilities



(from: „5G Vision **The 5G Infrastructure Public Private Partnership:** the next generation of communication networks and services")

5G Vision

- Partnerships will be established on multiple layers ranging from sharing the infrastructure…
- The 5G (…) technology will allow (…) sharing infrastructure and spectrum costs in a flexible way between a rich ecosystem of service providers.
- Designing a wireless access network (…) calls for (…) flexible resource allocation and sharing schemes;
- Methods have been suggested and are investigated involving a more dynamic sharing of spectrum…

Challenges of 5G Radio Interface

- Spectral agility of waveforms,
- Flexibility and efficiency of spectrum usage,
- Spectrum aggregation and sharing, even micro-scale,
- Energy-efficiency,
- The need for practical solutions.

Contemporary Multicarrier Technologies for 5G Radio Systems

Non-contiguous multicarrier techniques, such as

- Non-contiguous Orthogonal Frequency-Division Multiplexing (NC-OFDM) or
- Non-contiguous Filter-Bank Multi-Carrier (NC-FBMC),

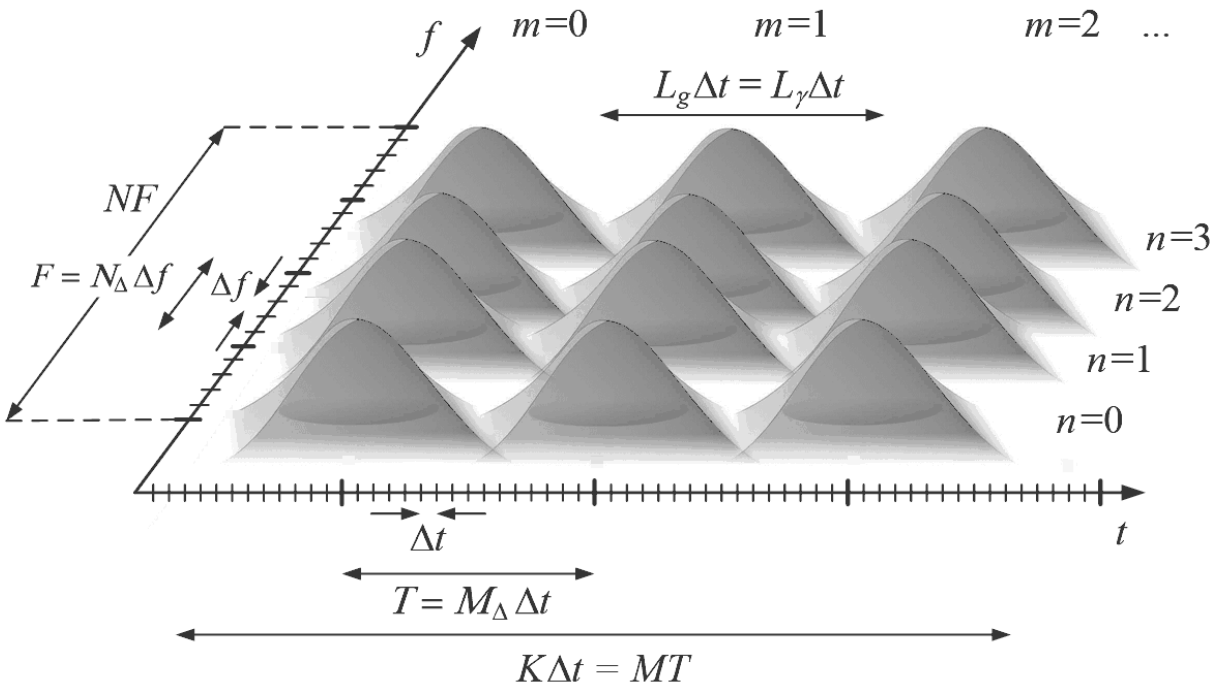
have been recognized as suitable candidates for 5G due to their potential for achieving spectrally efficient communications by aggregating and exploiting fragmented unoccupied spectrum while simultaneously achieving high data rates.

Promissing multicarrier technologies for spectrally- and energy-efficient 5G radio

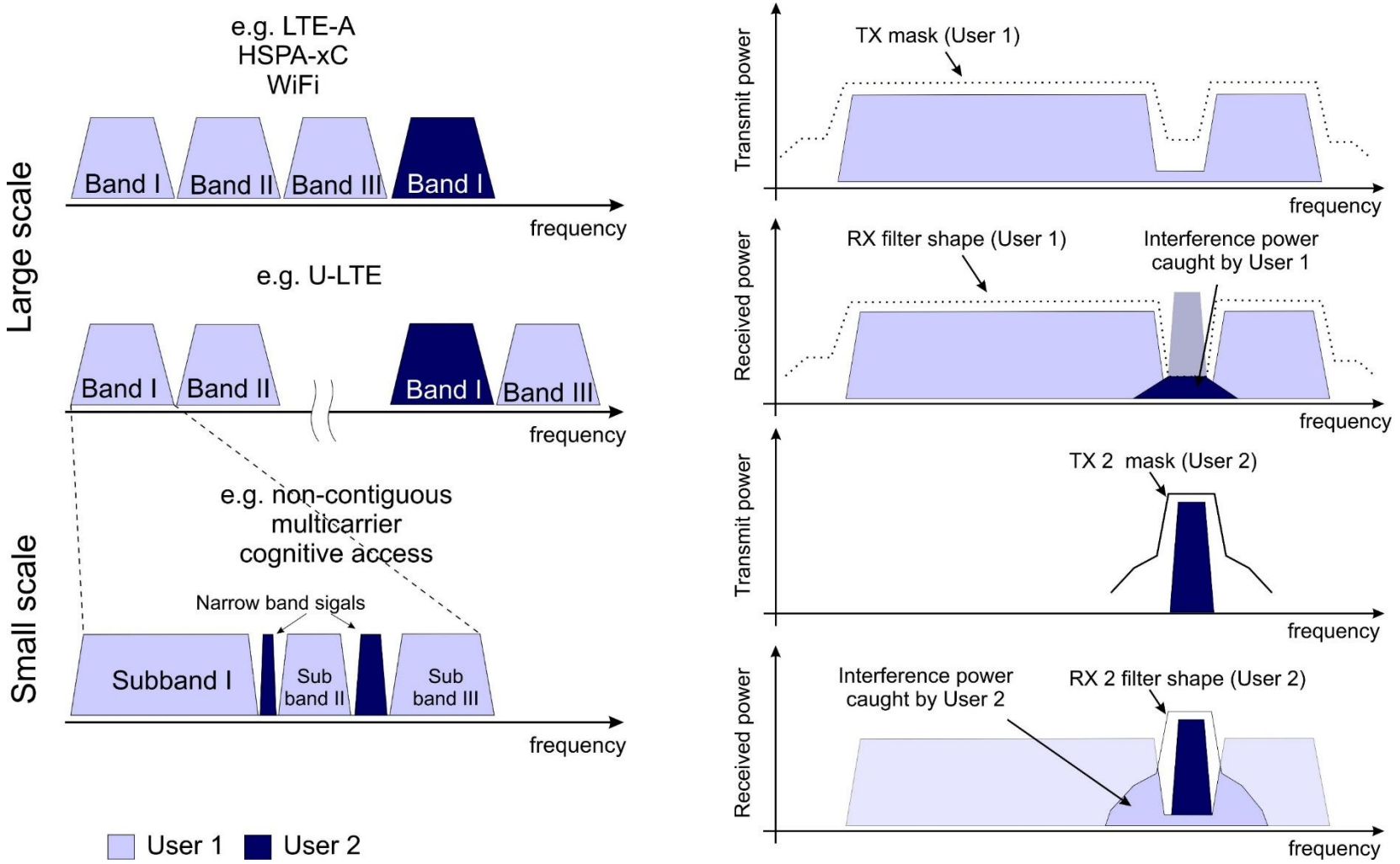
- OFDM and NC-OFDM
- *Enhanced* OFDM: optimization methods for required spectrum shaping, where the design (re-design) of spectrum-shaping filters is not possible.
- *Filtered* OFDM: groups of OFDM subcarriers are filtered, having different subcarrier spacing, symbol durations and guard Times, is a flexible waveform to support multiple access schemes. It can be viewed as a more flexible version of Universal Filtered Multicarrier (UFMC).
- *Filter-Bank* Multi-Carrier (FBMC): based on per-subcarrier filtering. FBMC transmitter possesses a good degree of flexibility in aggregating theoretically any kinds of fragmented frequency resources.
- *Generalized* Frequency Division Multiplexing (GFDM) – close to GMC: a flexible version of OFDM, subcarriers may not be orthogonal to each other.
- UFMC, Biorthogonal Frequency Division Multiplexing (BFDM)

Promissing multicarrier technologies for spectrally- and energy-efficient 5G radio, cont.

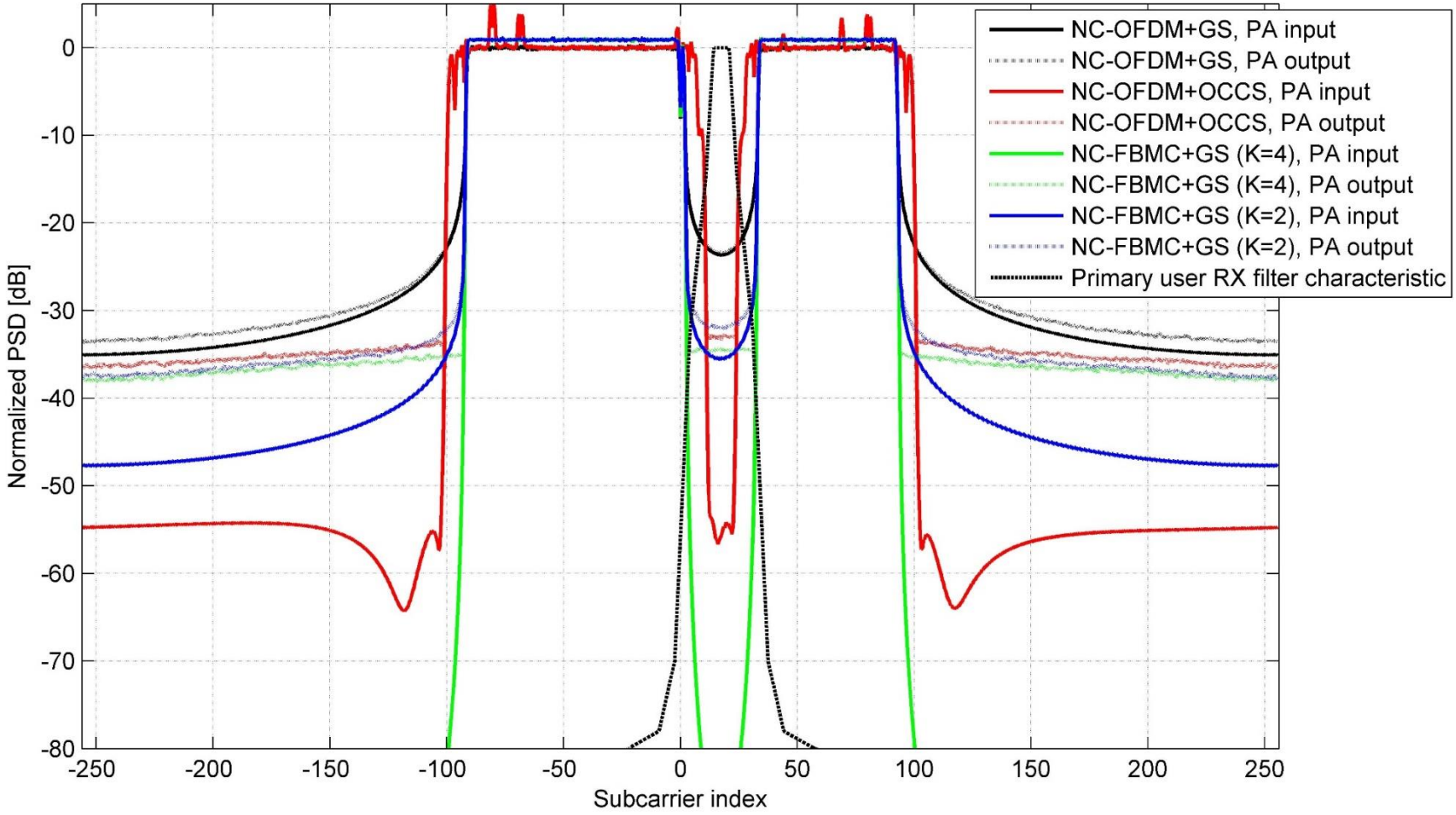
- Generalized Multicarrier (GMC) scheme - any kind of signal can be defined by a set of parameters (such as the pulse shape, the density of the TF grid, etc.



Spectrum aggregation and sharing

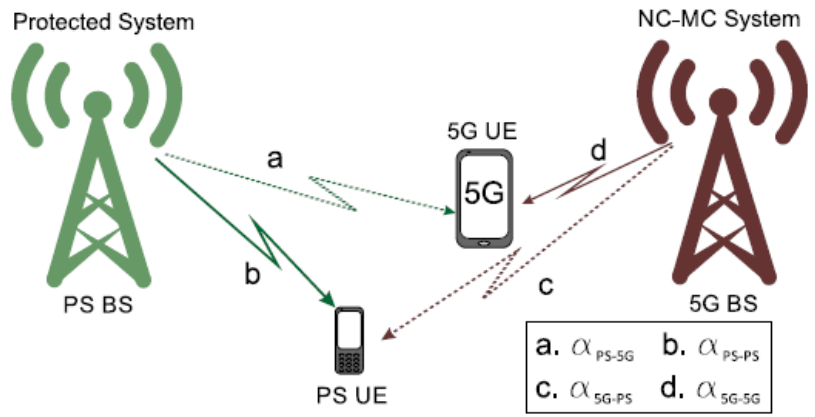


NC-OFDM and NC-FBMC spectra in 5G scenario



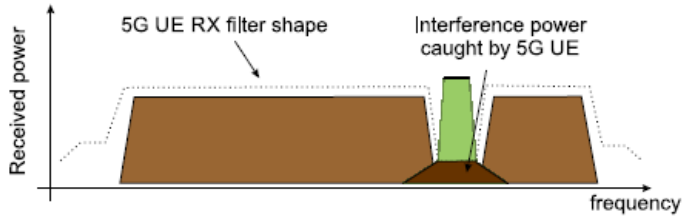
Small-scale spectrum sharing with NC-OFDM/NC-FBMC

A.



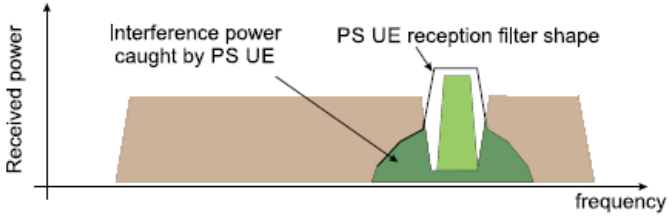
$$\mathbf{P}^* = \underset{\mathbf{P}}{\operatorname{argmin}} \left[-\Delta f \chi \sum_{n \in \mathbf{I}_{\mathrm{DC}}} \log_2 \left(1 + \frac{\alpha_{5\mathrm{G}-5\mathrm{G}} P_n \left| H_{5\mathrm{G}-5\mathrm{G}} \left(\frac{n f_s}{N} \right) \right|^2}{F N_0 \Delta f + \alpha_{\mathrm{PS}-5\mathrm{G}} P_{In}^{\mathrm{RX}}} \right) \right]$$

B.



$$s.t. \sum_{n \in \mathbf{I}_{\mathrm{DC}}} \alpha_{5\mathrm{G}-\mathrm{PS}} P_n g_n - \frac{P_{\mathrm{RX}}^{\mathrm{PS\ UE}}}{\mathrm{SIR}_{\min}} \leq 0,$$

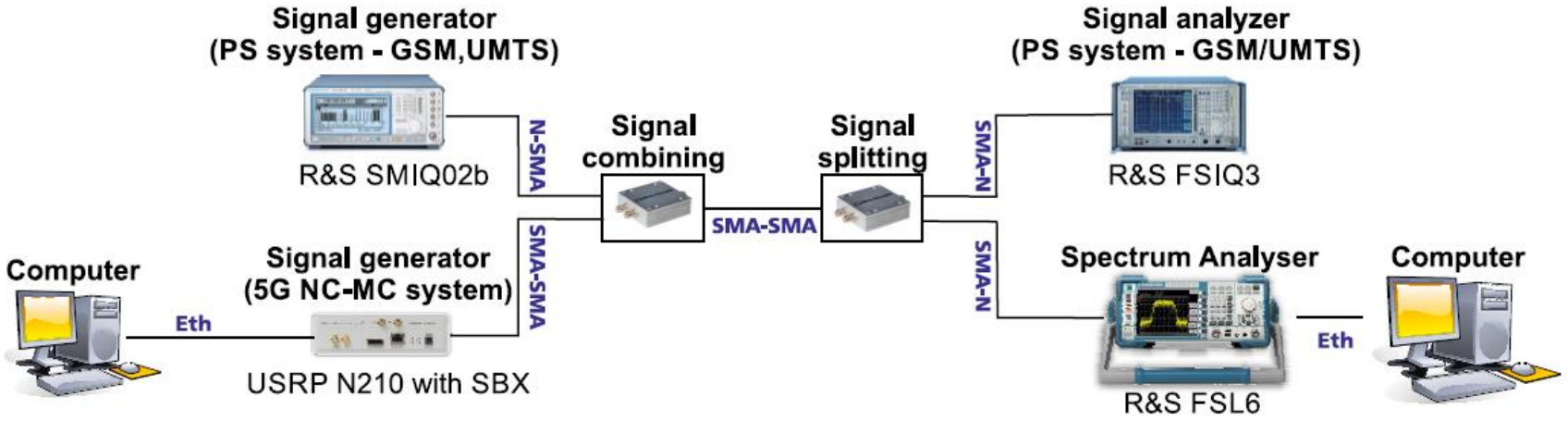
C.



$$\sum_{n \in \mathbf{I}_{\mathrm{DC}}} P_n - P_{\max} \leq 0,$$

$$\forall_{n \in \mathbf{I}_{\mathrm{DC}}} - P_n \leq 0.$$

Small-scale spectrum sharing experiment



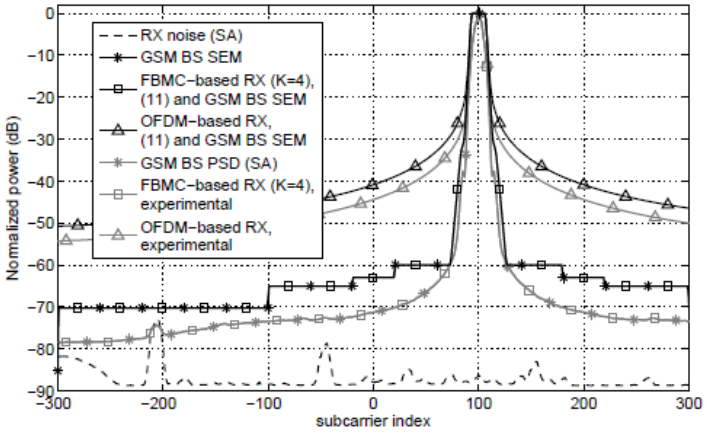


Fig. 6. PSD and SEM of GSM BS signal and interference power caused by these signals at MC RX.

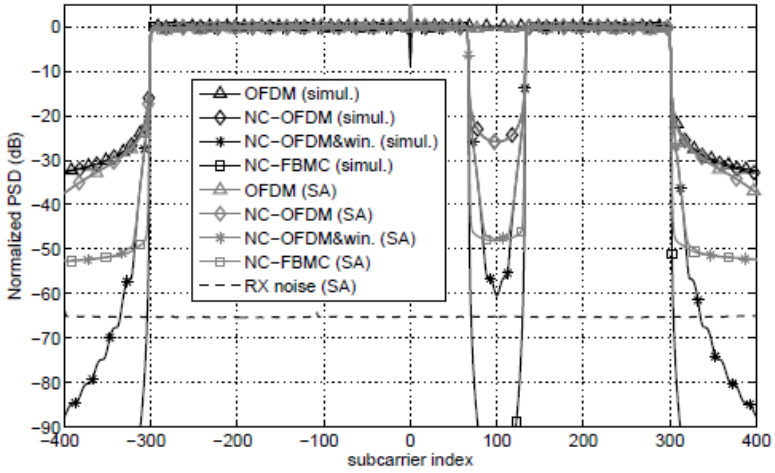
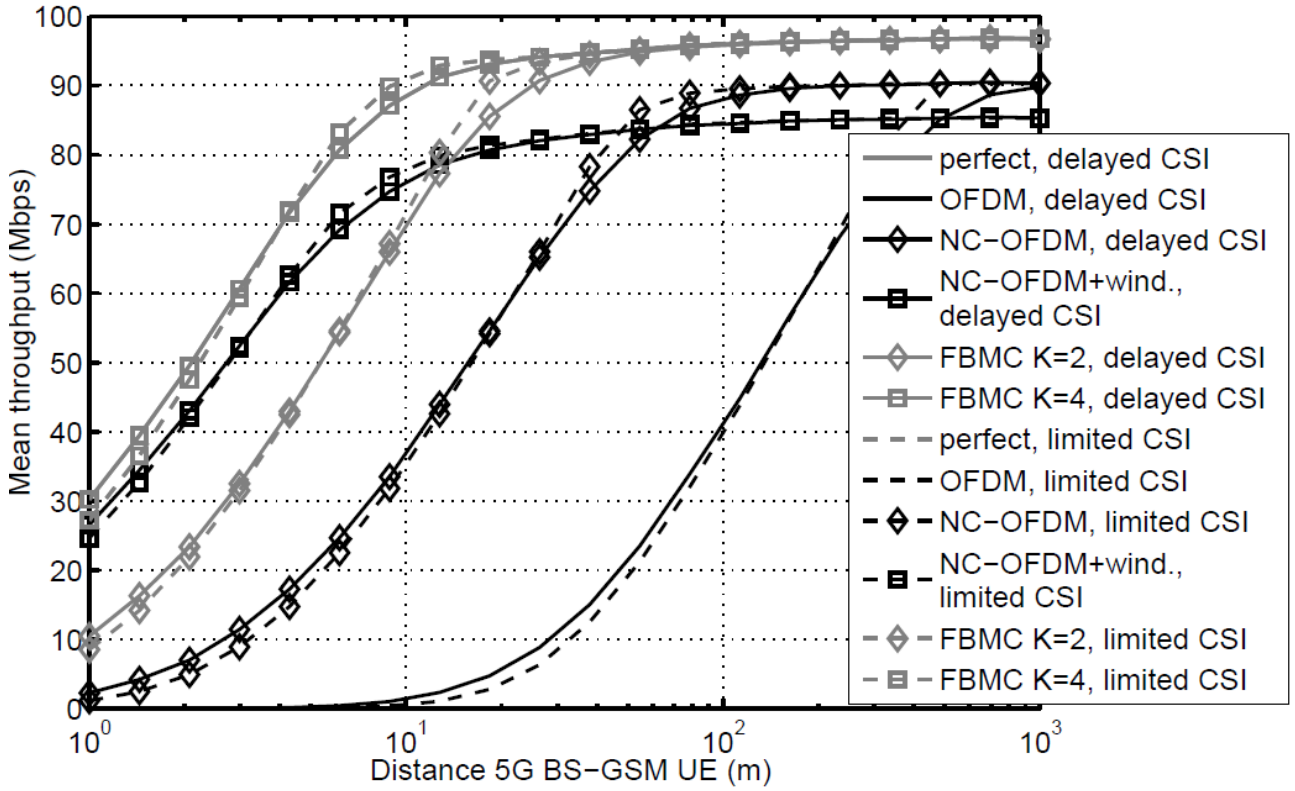


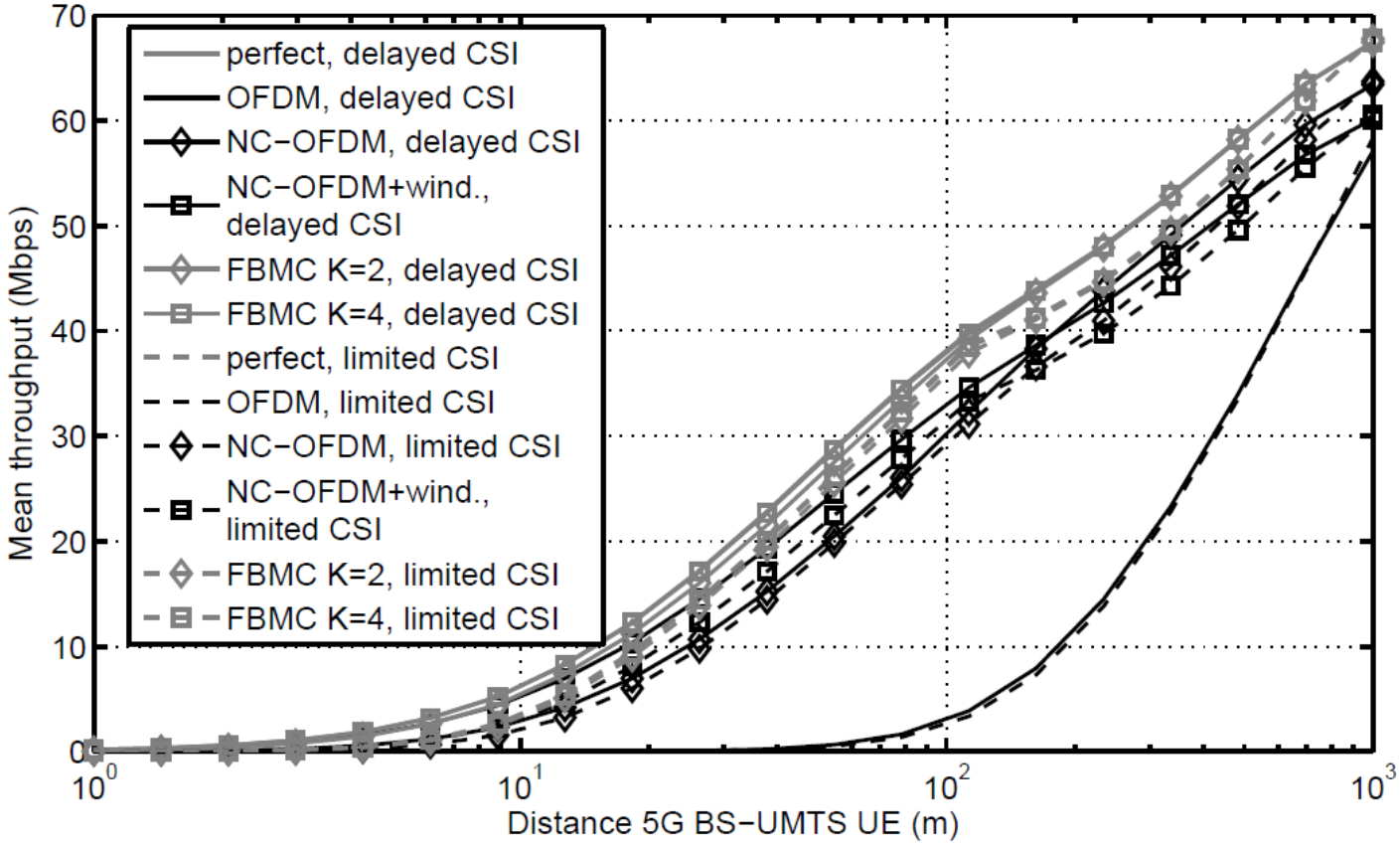
Fig. 7. Power Spectral Density of the 5G signal for PS being GSM.

Small-scale spectrum sharing experiment results (1)



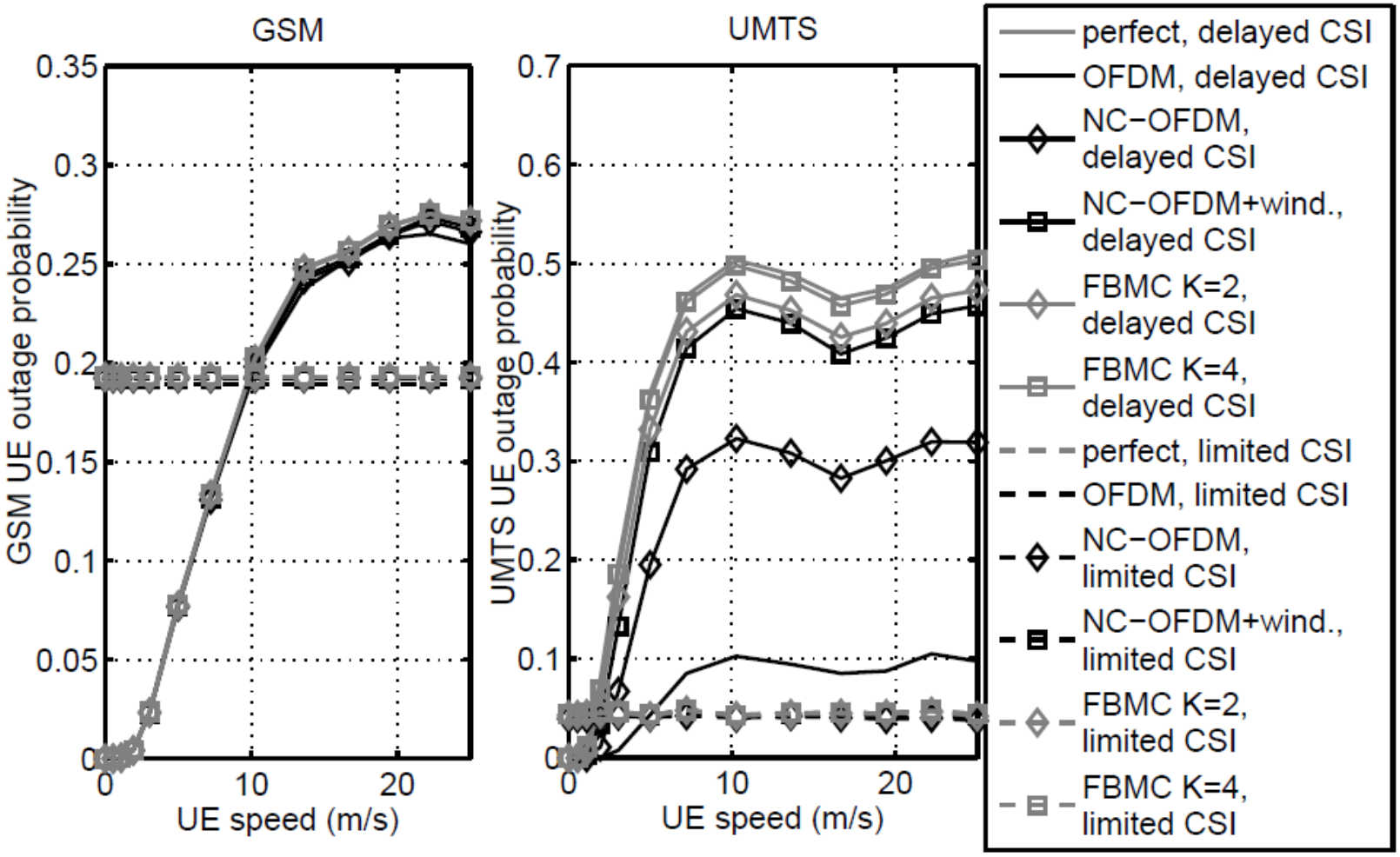
Throughput obtained with non-contiguous multicarrier schemes while protecting GSM downlink transmission

Small-scale spectrum sharing experiment results (2)



Throughput obtained with non-contiguous multicarrier schemes while protecting UMTS downlink transmission

Small-scale spectrum sharing experiment results (3)



Thank you for your attention!