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A.I. 8

RP-191161

MOTIVATION FOR SID ON REL-17 STUDY ON SUPPORTING NR ABOVE 52.6 GHZ

Intel Corporation

OUTLINE

Background

- Existing scope and plans for NR
- Current work plan for above 52.6 GHz

Challenges of system operating above 52.6 GHz

- RF impairments
- Pathloss & Coverage
- System Bandwidth

Spectrum above 52.6 GHz & Use Cases

- System Design Consideration: RF aspects
- Global spectrum availability overview
- Identified Use Cases

SID Proposal

- Objectives
- Expected Output & Time Scale

BACKGROUND ON EXISTING SCOPE AND PLANS FOR NR

Scope for NR Study Item (RP-170379)

- Originally targeted to design wireless system that could support up to 100 GHz.
- Many Technical Reports (TR) that included study up to 100 GHz was approved. For example,
  - TR 38.805: study of 60 GHz unlicensed spectrum,
  - TR38.901: study on channel model for frequencies from 0.5 to 100 GHz,
  - TR38.913 next generation access technologies,
  - TR38.803: RF and co-existence aspects.

Scope for Rel-15 NR Work Item (WI) (RP-181474)

- Reduction in scope was placed for Rel-15 WI.
  - NR design in Rel-15 considers frequency ranges up to 49 GHz (later change to 52.6 GHz).
  - NR design for mmWave was optimized for below 49 GHz and more specifically optimized for NR band specified by RAN4, which are band n257 (26.5 ~ 29.5GHz), n258 (24.25 ~ 27.5GHz), n260 (37 ~ 40GHz), n261 (27.5 ~ 28.35GHz).

CURRENT 3GPP WORK PLAN FOR ABOVE 52.6 GHZ

Scope for Rel-16 NR WIs

- Rel-16 NR WIs does not address spectrum above 52.6 GHz

Plenary level Study Item for above 52.6 GHz (RP-182861)

- Target frequency range between 52.6 GHz and 114.25 GHz
- Work Plan
  - RAN #81: TR 38.807 skeleton
  - RAN #82 – 85: Survey global spectrum availability and regulatory requirements
  - RAN #83 – 85: identify potential uses cases and deployment scenarios, and provide design requirements and considerations (including regulatory requirements)
  - RAN #86: Conclude SI and approve TR

SPECTRUM ABOVE 52.6 GHZ & USE CASES

SPECTRUM ABOVE 52.6 GHZ

Although spectrum availability depends on each regional regulatory bodies, in general there is

- between **7 GHz** to **15 GHz** of unlicensed spectrum and
- between **10 GHz** to **18 GHz** of licensed/lightly licensed spectrum.

Spectrum includes bands ideal for IAB operations, harmonized spectrum for ITS/V2X operations, unlicensed operations, and licensed operations.

The identified use cases and unlocked potential of the extremely wide spectrum are tremendous.

GLOBAL SPECTRUM AVAILABILITY AND USAGE

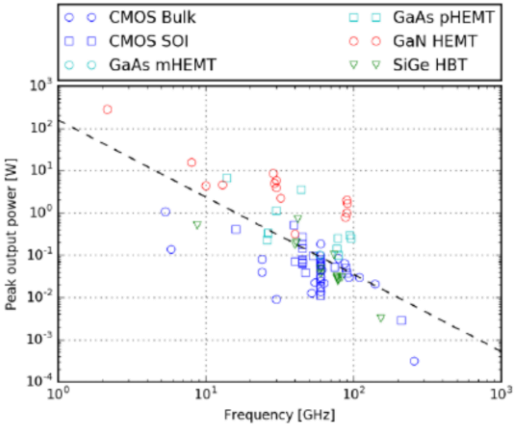
USE CASES FOR NR ABOVE 52.6 GHZ

- High Data Rate eMBB
- Mobile Data Offloading
- Short Range High-Data Rate D2D Communications
- Broadband Distribution Network
- Integrated Access Backhaul (IAB)
- Factory Automation/Industrial IoT (IIoT)
- Wireless Display Transfer & AR/VR Wearables
- Intelligent Transport Systems (ITS) and V2X
- Data Center Inter-Rack Connectivity
- Smart Grid Automation
- High Positioning Accuracy

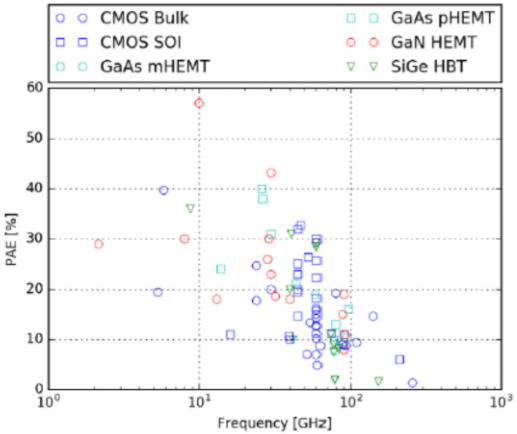
CHALLENGES OF SYSTEM OPERATING ABOVE 52.6 GHZ

PA EFFICIENCY ABOVE 52.6 GHZ

PA Efficiency



From [1]-Power amplifier output power versus frequency for various semiconductor technologies.



From [1] – Saturated power added efficiency (PAE) versus frequency for various semiconductor technologies

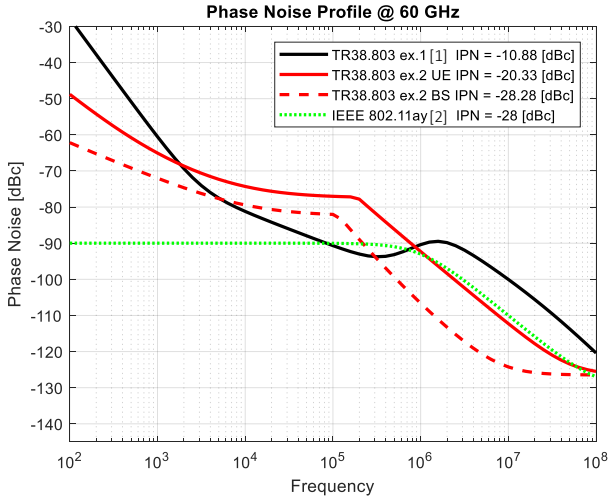
- RF building block performance generally degrades with increasing frequency
- When considering PAE, non-linear behaviors of PA, considerable power back-off may be necessary to meet Tx signal quality requirements such as ACLR, EVM, etc.

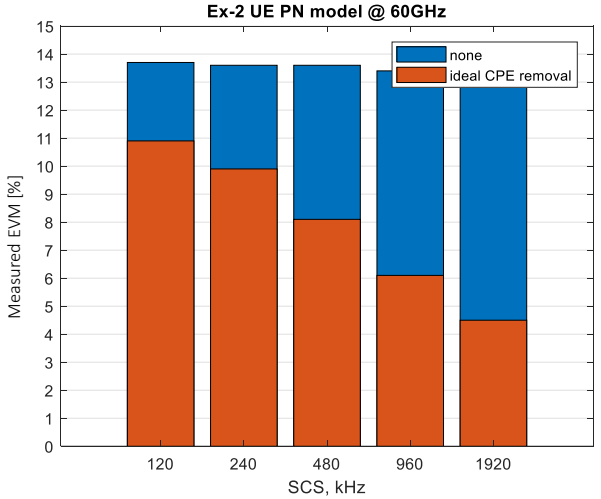
[1] TR38.803, “Study on New Radio Access Technology: Radio Frequency (RF) and co-existence aspects”

PHASE NOISE ABOVE 52.6 GHZ

Phase Noise (PN)

- PN can negatively impact multi-carrier systems with narrow subcarriers, as performance can highly depend on the ability to estimate common PN and perform compensation
- In general, PN increases 6 dB every time carrier frequency, f_0, doubles.



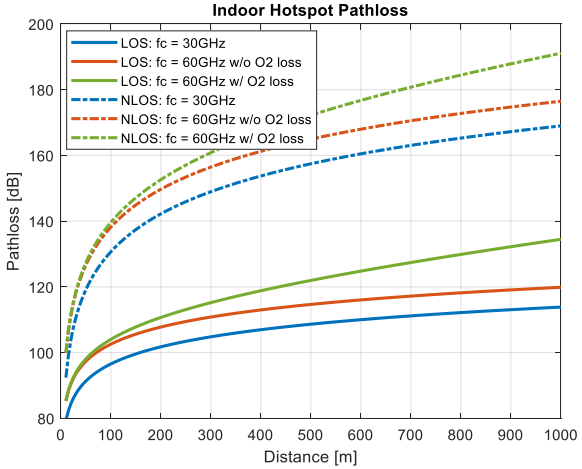


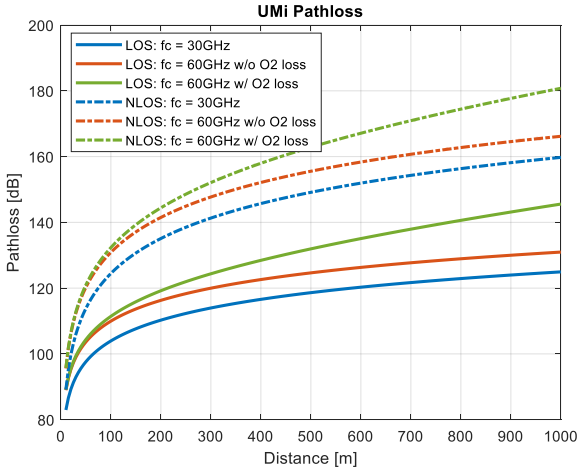
[1] TR38.803, "Study on New Radio Access Technology: Radio Frequency (RF) and co-existence aspects"
[2] IEEE 802.11-15-0390r1 "Considerations on Phase Noise Model for 802.11ay"

PATHLOSS & COVERAGE ABOVE 52.6 GHZ

Pathloss & Coverage

- Pathloss above 52.6 GHz is expected to be more severe
- O_2 absorption around 60 GHz (between 52 ~ 67 GHz) create even harsher pathloss environment
- Reduced antenna aperture size for higher frequencies do allow implementation of needle thin beams within reasonable antenna dimensions that may help alleviate pathloss issues.
- Coverage will be an important system design aspect for consideration





SYSTEM BANDWIDTH ABOVE 52.6 GHZ

Licensed Spectrum Allocations Blocks

- ECC/CEPT recommends 250 MHz block units, also adopted in other countries such as Canada and South Africa.
- UK uses 4.75 GHz allocation block
- US uses 12.9 GHz allocation block

Unlicensed Spectrum Usages

- 802.11ad/ay uses 2.16 GHz block units

Wideband & Power Consumption

- Wide bandwidths exceeding 2 GHz are easily available at spectrum above 52.6 GHz. Allowing extreme data rate to be supported.
- Wideband operations are usually at the cost of large power consumption for transceivers.
- System design should consider support of wide bandwidth and relatively narrow bandwidths to support high data rates & good power efficiency.

TECHNICAL JUSTIFICATION

Operation at frequencies between 52.6GHz to 114.25 GHz have unique characteristics:

- Harsh propagation loss
- Low PA efficiency
- High phase noise
- High power consumption

Need to support wide range of use cases, including both licensed and unlicensed operation, IAB, V2X, and others.

- In addition, operation in 60GHz band may require coexistence with IEEE 802.11 systems

Technical challenges and harmonized specification support for various use cases call out need for Study

PROPOSAL

Proposal - Objectives

Study Objectives

- Study of appropriate waveform for NR system for frequencies between 52.6 GHz to 114.25 GHz.
  - Following aspects are considered as part of the study: multipath robustness, spectrum flexibility, PA efficiency, spectrum localization, robustness to phase noise, implementation complexity, compatibility with existing NR specifications
- Study of NR system components that require enhancements for operations in frequencies between 52.6 GHz to 114.25 GHz
  - Improvement of DL/UL physical channel/signal to cope with extreme propagation loss and to improve coverage
  - Harmonized co-existence with potential radio communication technologies in above 52.6 GHz bands
- Study of channelization suitable for targeted bands between 52.6 GHz to 114.25 GHz

Proposal – Work Plan

Deliverables

- TR capturing studies outlined

Work Plan for Rel-17

- Open SI in beginning of Q1’ 2020
- Target for completion end of Q1’ 2021
- 15 Month period

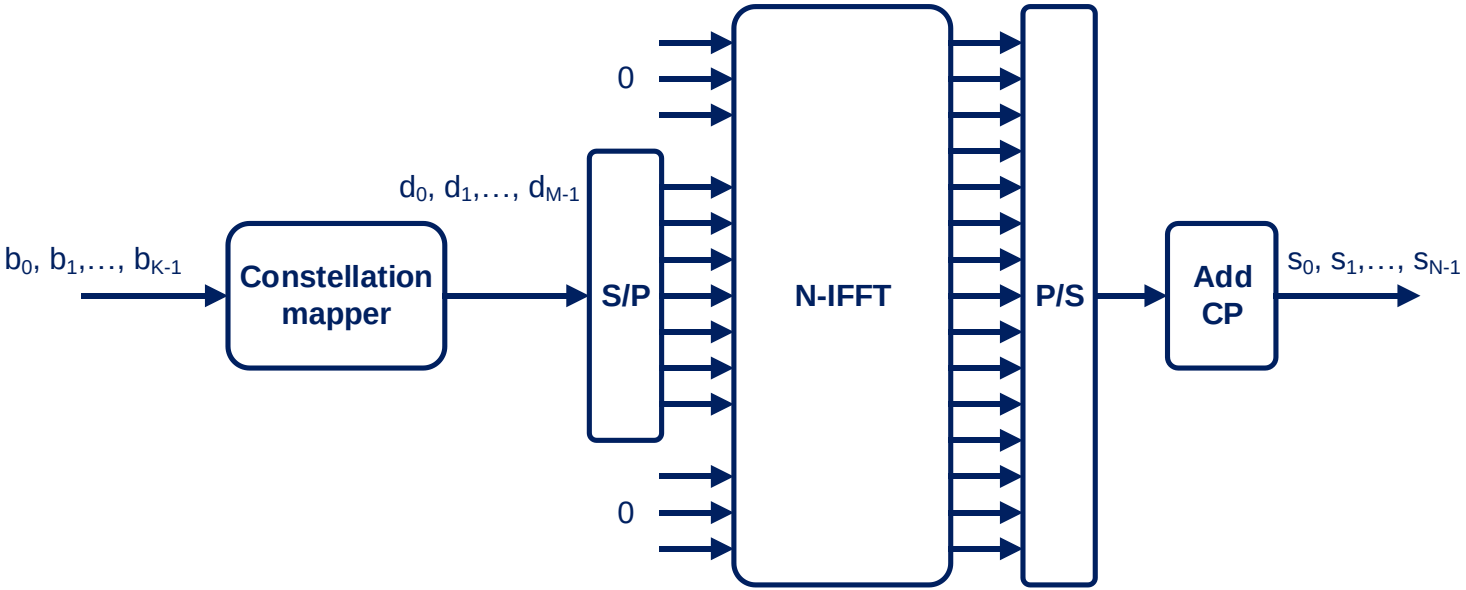
WAVEFORM CANDIDATES

WAVEFORM

Waveform Candidates

- Waveform candidates are describe for background purposes and starting point for further study in SI
- Multi-carrier waveforms
  - CP-OFDM: currently supported in DL and UL in NR
  - FBMC, UFMC, etc
- Single-carrier waveforms
  - DFT-s-OFDM (a.k.a. SC-FDM): currently supported in UL in NR (other variants under this family such as cluster DFT-s-OFDM should be categorized in the multi-carrier family category)
  - SC-QAM: pure single carrier waveform
  - SC-FDE: single carrier waveform with modification that allow efficient frequency domain equalization and block processing. Some variants of this would be SC-FDE with cyclic prefix (CP) or unique word (UW).

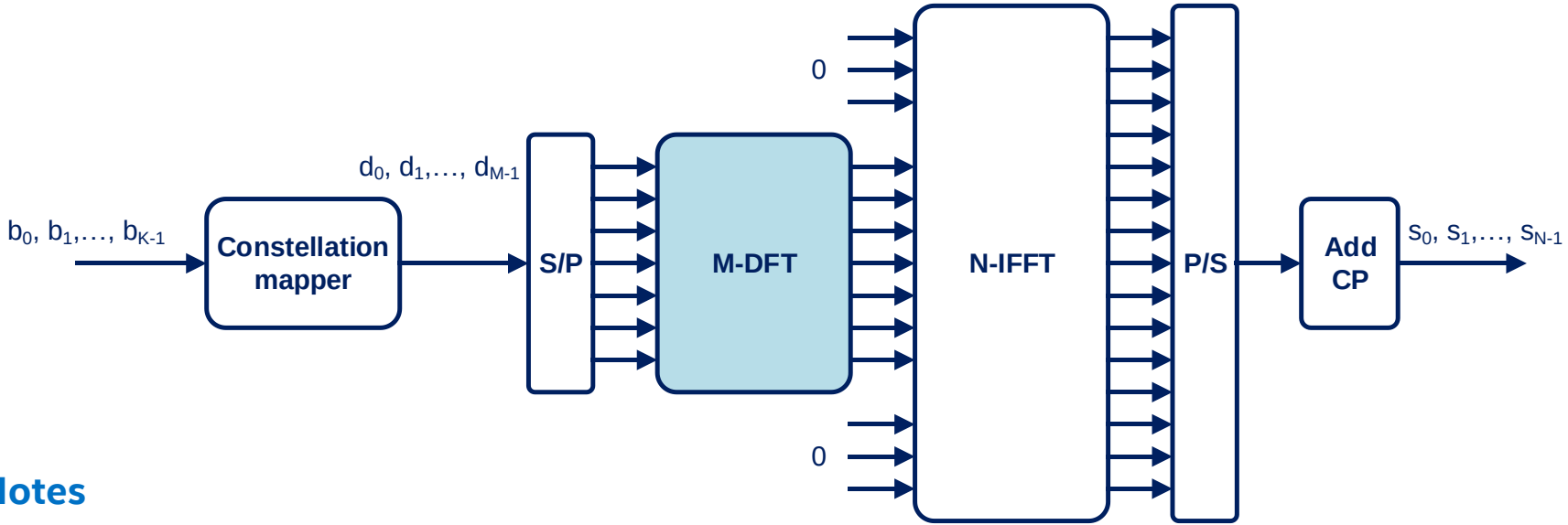
WAVEFORM: CP-OFDM



Notes

- Supported in NR DL and UL
- Larger subcarrier spacing may need to studied to cope with higher phase noise

WAVEFORM: SC-FDM (DFT-S-OFDM)

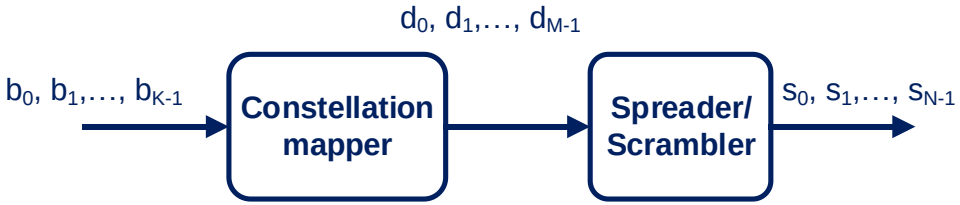


Notes

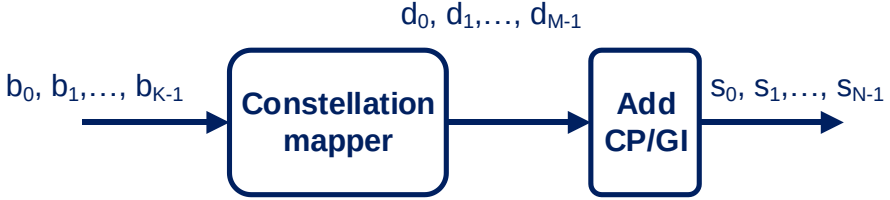
- Supported in NR UL
- Spectrum flexibility
  - Limited flexibility in SC-FDM can be achieved via localized/interleaved frequency mapping.
  - Additional flexibility in spectrum allocation is achievable with multiple DFT precoders at the sacrifice of PAPR

WAVEFORM: SINGLE CARRIER FAMILY

SC-QAM



SC-FDE



Notes

- Low Complexity
  - The highest implementation simplicity can be achieved for SC-QAM especially when the limited time-domain equalization is used.
- Achieving multipath robustness
  - High multipath robustness can be achieved for SC-FDE via the Frequency Domain Equalization (FDE)
  - For SC-QAM, the FDE can be enabled by the Overlap-and-Add (OLA) signal processing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