

Enhanced coverage for Rel-18

RAN Rel-18 Workshop

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RWS-210076

Nokia, Nokia Shanghai Bell

Enhanced coverage for Rel-18: Motivation

Coverage remains one critical aspect of on-going deployments and Release 18 should continue improving coverage beyond what is achieved by current Release 17 WID

- RACH coverage
 - Rel-17 does not introduce enhancements for PRACH, even though FR2 would benefit in particular from further improvements, but also FR1
 - It should be noted that even though UEs are expected to support some level of beam correspondence since Rel-15 there are no requirements covering beam corresponding for initial access
- PUSCH coverage: power domain enhancements are captured in TR 38.830, but not carefully studied during Rel-17 NR coverage enhancement study item
 - Our studies show that coverage of QPSK waveform can be improved up to 2 dB by applying frequency domain spectrum shaping (FDSS) with spectrum extension. The gain potential exists for both FR1 and FR2.
 - Tone reservation is another candidate solution captured in TR 38.830.
 - BPSK waveform with FDSS is already being studied by RAN4 (in Rel-17)
- High Power UE
 - Currently UE power class 2 is not supported for many bands of interest, so it can be extended to incorporate the bands supported for UL coverage enhancements

Enhanced coverage for Rel-18: Objectives

Specify multiple msg1 transmissions using same TX beam

- Important for Rural deployments in FR1
- Important for Urban deployments in FR2 [O2O/O2I]

Specify multiple msg1 transmissions using different TX beams

- Important for FR2 deployments in general

Investigate and specify coverage enhancements in power domain:

- Focus on modulation orders > BPSK
- Investigate and specify new methods to reduce PAR/MPR, especially spectrum extension

Extend the usage of PC2 for multiple bands to further extend coverage

RACH enhancements: background

Enhancing PRACH to improve coverage of both msg1 and msg3

RRC-idle operations do not allow

UE	gNB
<p>to have complete information about the beam space during RACH, due to limited presence of reference signals to this end, if any.</p>	<p>to rely on UE to make use of beam correspondence, given the absence of requirements and guarantees in this sense, when UE is in RRC-idle.</p>



Letting UE transmit msg1 multiple times over multiple ROs, prior to retransmission attempts, improves link budget of both msg1 and msg3, thanks to larger antenna array gain at UE and larger SINR at gNB.

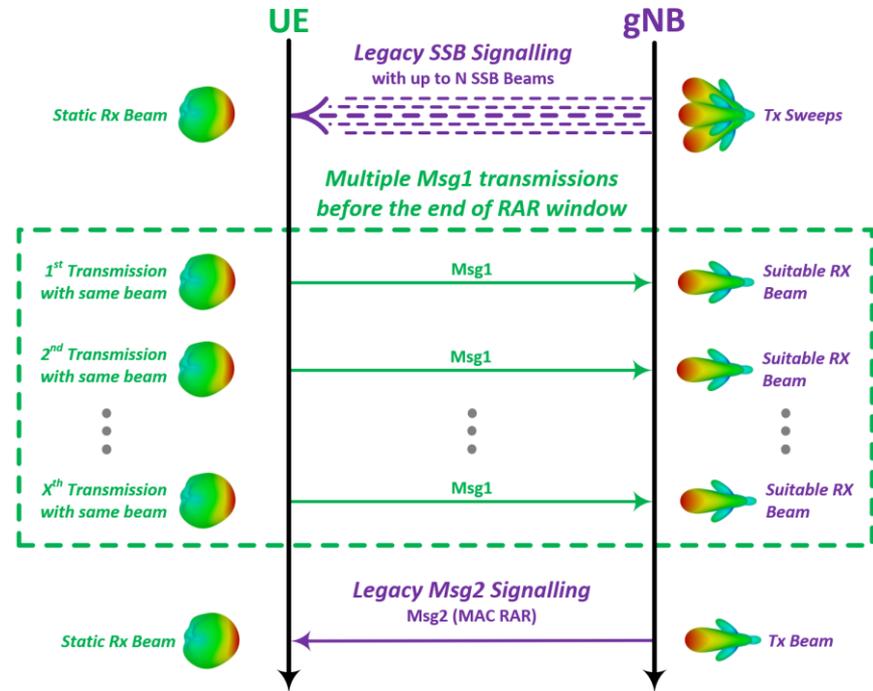
RACH enhancements: FR1

Multiple msg1 transmissions with same Tx beam for each msg1 transmission

Multiple msg1 transmissions using same TX beam

Up to ~5 dB Link budget increase for Rural deployments in FR1 [TS 38.830]

- **UE transmits msg1 multiple times using the same beam for each msg1.**
 - multiple msg1s are sent sequentially before the beginning/end of the RAR window.
- **If each msg1 transmission/RO combination is unique then gNB can distinguish between them.**



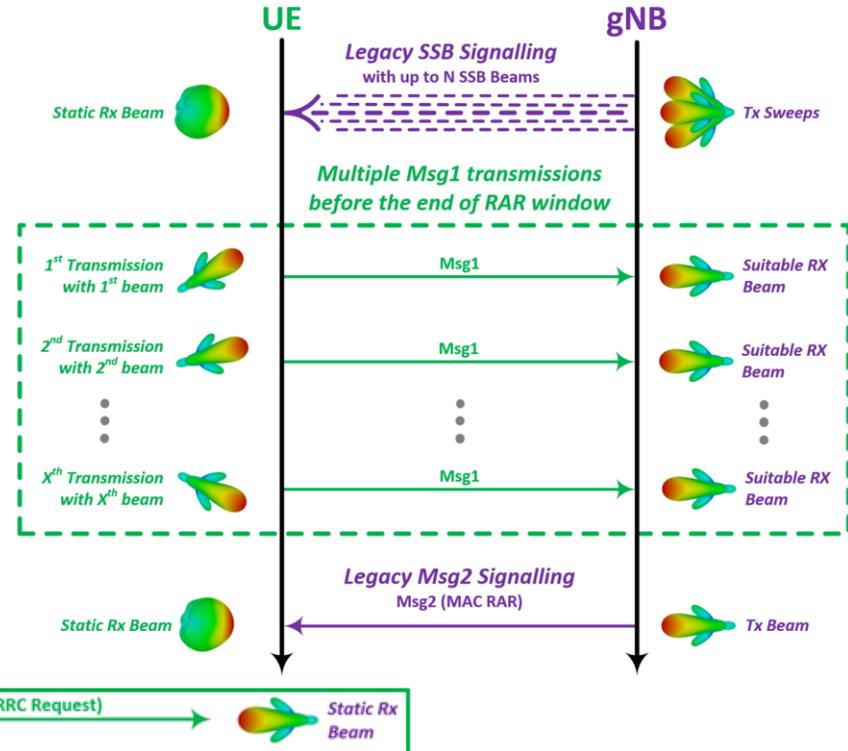
RACH enhancements: FR2

Multiple msg1 transmissions with different Tx beam for each msg1 transmission

Multiple msg1 transmissions using different TX beam

up to ~4 dB Link budget increase for Urban deployments in FR2 (O2O/O2I) [TS 38.830]

- UE transmits msg1 multiple times using a different beam for each msg1.
 - multiple higher gain msg1s are sent sequentially in multiple directions before the beginning/end of the RAR window.
- If each msg1 transmission/RO combination is unique then gNB can distinguish between them.
- UE may use the received information to **configure beam for msg3 transmission and experience high antenna array gain**



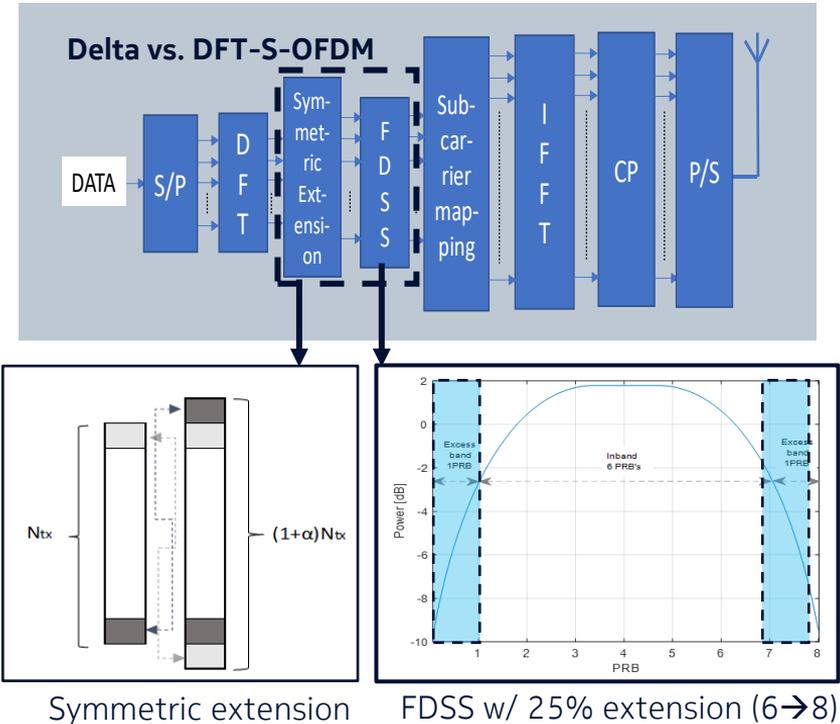
Enhanced coverage for Rel-18: Background

Power domain –based solutions

- R15 spectrum shaping (+R17 SI) covers only BPSK with FDSS
- R18 studies should focus on
 - higher modulation orders **and**
 - new solutions to reduce PAR/MPR
- Our studies indicate that power domain enhancements have considerable potential for improving UL coverage in both FR1 & FR2 scenarios
 - Spectrum extension is a key enabler behind the gain

Frequency domain spectrum w/ spectrum extension

- Spectrum is extended symmetrically by factor of α
→ Excess band
- Both Inband and excess band are weighted by the FDSS function
- gNB receiver can utilize the excess band signal without knowing the actual FDSS function
 - The FDSS function can be left for UE implementation.
 - Performance requirements need to be specified (as for Rel-15 BPSK with FDSS)



Enhanced coverage for Rel-18: Background

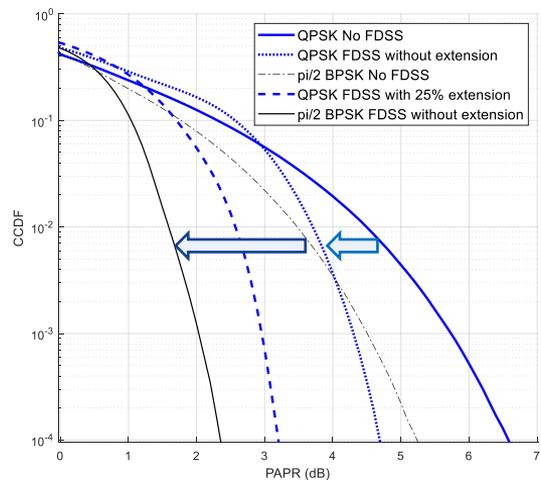
PAR and Cubic metric

- FDSS w/o spectrum extension provides significant PAR reduction for BPSK but only moderate PAR reduction for QPSK
 - $\pi/2$ BPSK: >2 dB@1% CCDF
 - QPSK: <1 dB@1% CCDF
- FDSS w/ spectrum extension provides significant PAR reduction for QPSK
- Cubic metric for QPSK
 - only minor CM reduction from FDSS w/o spectrum extension
 - significant CM reduction from FDSS with spectrum extension

Learnings from PAR and CM analysis

- Spectrum extension + FDSS is a good candidate method for reducing PAR/MPR
- It has potential for coverage improvements (also) for modulation orders >BPSK
 - Improved data rates for cases with higher spectral efficiency
 - Improved power amplifier efficiency
 - Reduced emissions

PAR for $\pi/2$ BPSK and QPSK modulations with and without FDSS and spectrum extension



CM for QPSK with and without FDSS and spectrum extension

Waveform	CM [dB]
QPSK No FDSS	1.0
QPSK FDSS without extension	0.9
QPSK FDSS with 25% extension	0.1

Enhanced coverage for Rel-18: Performance FR1

UE Tx power gain/loss (for QPSK FDSS 25% ext.)

- 1.0 ... 1.7dB gain compared to baseline QPSK (no FDSS, no ext)
- 0 ... 0.7 dB loss compared to pi/2 BPSK with FDSS (no ext)
 - less than 0.3dB loss for relevant PRB allocations

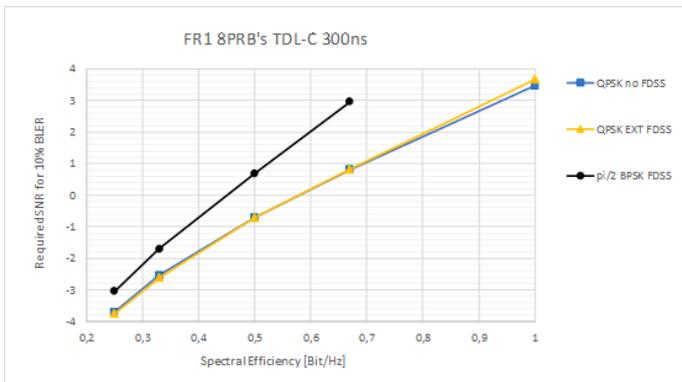
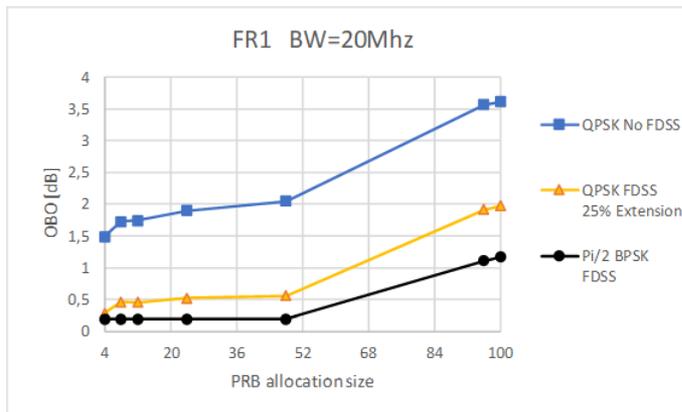
TDD/duty cycle based operation is required to realize the power gain in FR1

gNB receiver gain/loss (for QPSK FDSS 25% ext.)

- ± 0.2 dB gain/loss compared to baseline QPSK (no FDSS, no ext)
- 0.3 ... 2 dB gain compared to pi/2 BPSK with FDSS (no ext)

Coverage gain = Tx power gain/loss + gNB receiver gain/loss

- Up-to 1.5 dB compared to baseline QPSK (no FDSS, no ext)
- Up-to 1.7 dB compared to pi/2 BPSK with FDSS (no ext)



Enhanced coverage for Rel-18: Performance FR2

UE Tx power gain/loss (for QPSK FDSS 25% ext.)

- 1.0 ... 1.3 dB gain compared to baseline QPSK (no FDSS, no ext)
- 0 ... 1.0 dB loss compared to pi/2 BPSK with FDSS (no ext)
 - less than 0.3dB loss for relevant PRB allocations

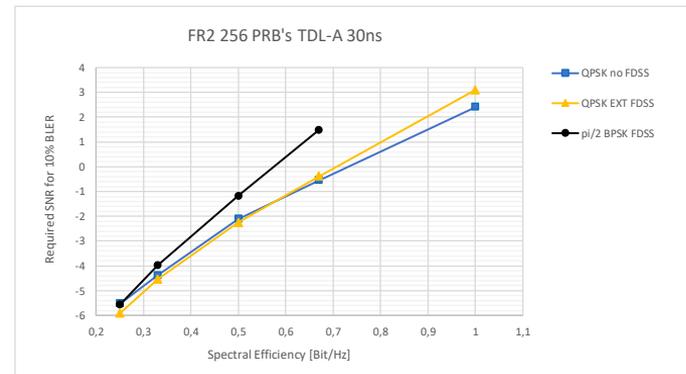
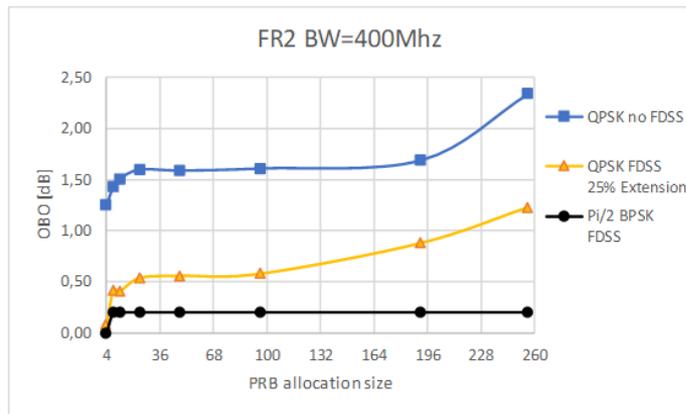
In FR2, Tx power gain allows for higher EIRP with smaller antenna array

gNB receiver gain/loss (for QPSK FDSS 25% ext.)

- 0.2 gain – 0.4 loss compared to baseline QPSK (no FDSS, no ext)
 - The loss is due to reduced coding gain
- 0.3 ... 2 dB gain compared to pi/2 BPSK with FDSS (no ext)

Coverage gain = Tx power gain/loss + gNB receiver gain/loss

- Up-to 1.5 dB compared to baseline QPSK (no FDSS, no ext)
- Up-to 2 dB compared to pi/2 BPSK with FDSS (no ext)



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