3GPP RAN #86
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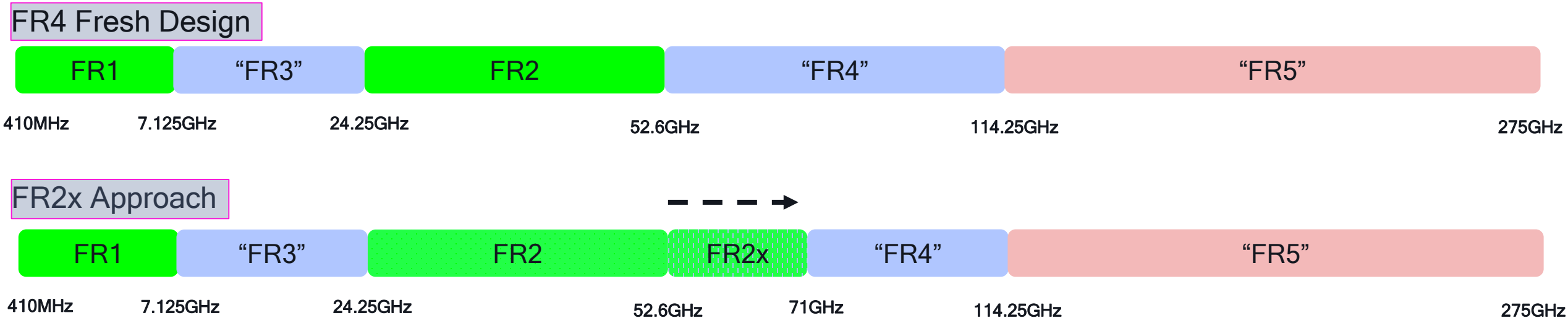
Motivation for Rel-17 WI on NR for 60GHz

Qualcomm

Agenda Item: 9.1.1

NR>52.6GHz

Possible Approaches



- Carefully consider the tradeoffs involved in fresh design versus FR2-extension

Some technical aspects:

- Waveform
  - SC waveforms with lower PAPR than OFDM may allow lower PA back-off / higher EIRP
  - Tradeoffs such as channel multiplexing vs PAPR present another dimension
- Regulatory limits
  - Band-specific EIRP limits: 57-71 GHz (unlicensed) has low EIRP limit compared to licensed bands (40 dBm)

Frequency diagram not at scale

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Are we splitting into two FRs?

- In general, it is preferred to unify the design for a frequency range
  - Design starts with waveform selection
- However, there are obvious differences between the following two sub-ranges
  - FR2x (52.6GHz~71GHz) - Proposal: unify design with FR2
  - FR4 (71GHz~114.25GHz) - Proposal: consider the possibility of new optimized waveform
    - Optimized waveform could be retro-fed to FR2x (or even FR2) range at a later stage if deemed beneficial
  - At the end, we have two ranges only (FR2/FR2x and FR4)
- For FR2x, the band is well defined already as unlicensed band
  - There are **EIRP** limitations, **PSD** limitations, **OCB** requirements, **LBT** requirements, etc
  - In different regions, the unlicensed usage covers a subset of the band
  - The regulation is ready and the band is available NOW
    - Other technologies (11ad/11ay) are starting to occupy the band, thus the time urgency
  - Attempt to **leverage FR2** waveform and multi-beam design as much as possible
- For FR4, the available bands are licensed (71-76, 81-86, etc.)
  - The regulation (though not readily available) is expected to be more aligned with FR2 (higher EIRP limits)
  - There is no immediate market demand, i.e., there is time to fine tune/optimize the waveform design
    - Time will tell whether waveform optimization for this frequency range warrants the additional specification and implementation complexity of a new DL waveform

EIRP Limits & Realized EIRP

Possible Approaches

	16 ant. elements	32 ant. elements	64 ant. elements	128 ant elements	256 ant elements	512 ant elements
Total ant. gain (dB)	17	20	23	26	29	32
Valid for c2 ? (40 dBm limit)	Yes	Yes	Yes	Yes	Yes	Yes
Valid for c3 ? (55 dBm limit)	No	No	No	No	No	Yes
Power per ant. element	EIRP (Assume: 5 dBi antenna element gain)					
0 dBm	29	35	41	47	53	59
3	32	38	44	50	56	62
6	35	41	47	53	59	65

Observation: For a 40 dBm EIRP limit,

- With 32 ant. elements or higher, the EIRP is determined by regulatory limit as opposed to realizability

For a 55 dBm EIRP limit, approx. 512 elements are needed to meet 30 dB ant. gain requirement,

- With this configuration, EIRP is again limited by regulatory limits

From ETSI BRAN latest operating mode identification:

Mode	Power / Magnetic Field	Notes
c1	40 dBm e.i.r.p., 23 dBm/MHz e.i.r.p. density	Fixed outdoor installations are not allowed.
c2	40 dBm e.i.r.p., 23 dBm/MHz e.i.r.p. density and maximum transmit power of 27 dBm at the antenna port or ports	
c3	55 dBm e.i.r.p., 38 dBm/MHz e.i.r.p. density and transmit antenna gain ≥ 30 dBi	Applies only to fixed outdoor installations

- Observations:
  - Depending on the specific design, single carrier waveforms can provide 2-3 dB PAPR gain over OFDM
  - However, 57-71 GHz band has a low EIRP limit (unlicensed) → Hence, EIRP is more likely to be determined by regulatory limits than by waveform limitations

Frequency diagram not at scale

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Regulatory survey and FR2 suitability

- ETSI BRAN is revisiting regulations for extended 60GHz band (57-71GHz)
  - e.g., c1, c2, c3 operating mode definition in previous slide
  - So far, only 11ad/11ay community is engaged in the discussion (very much centered around fixed wireless access)
- 3GPP has the opportunity to influence the regulation to guarantee a fair technology coexistence
- FR2 upper frequency limit of 52.6GHz was arbitrary
  - Compared to 802.11ad/11ay solutions, NR has a reach set of features and procedures for multi-beam operation which can take 60GHz operation to the next level (sims in Annex)
  - FR2 can be easily extended for operation up to 71GHz by increasing the subcarrier spacing (SCS)
    - Better resilience to increased phase noise (PN) at this frequency regime
      - Larger SCS → shorter OFDM symbols → better PN tracking capabilities & shorter CP
    - Adequate SCS value(s) for FR2x has to be assessed based on phase noise vs. delay spread resilience
  - Relatively low EIRP limit for 60GHz band renders optimizing waveform of little practical use
    - EIRP limit will kick in earlier than the PAPR gain of single-carrier waveform

Looking ahead

- Doing normative work on 60GHz in Rel-17 (functional freeze expected June ‘21) would deliver:
  - Functional NR operation in 60GHz in Rel-17
  - Possibility for more sophisticated aspects, e.g., 60GHz-based sidelink for commercial use case, in Rel-18 (functional freeze expected Sept ’22 or later)

- Not having a 60GHz system defined in Rel-17 could make 3GPP “miss the train” for 60GHz commercial opportunities
  - Other incumbent technologies would prevail uncontested

Conclusion

- We see urgency in extending NR operation up to 71GHz in Rel-17
  - **Proposal 1**: Open Rel-17 WI on extending NR operation up to 71GHz
- Exploratory work on optimized DL waveform for NR>52.6GHz can be done
  - There is no perceived commercial urgency to get it done
  - Proper evaluation should be carried out to identify the benefits of changing the DL waveform
  - **Proposal 2**: Study DL optimized waveforms for NR>52.6GHz in parallel (Rel-17) or at a later stage (Rel-18)

Annex: 60GHz and FR4

Prelim Evaluations

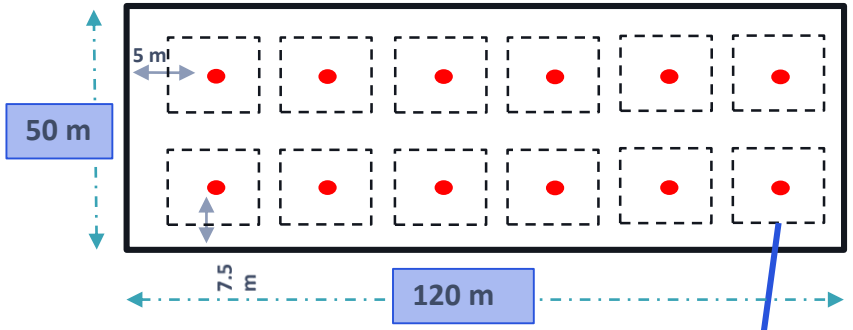
System Evaluation Assumptions

- System level evaluation to compare FR2 with FR4
  - Single operator, 28/60/82 GHz
  - DL Only, UL Only: Full buffer traffic

Parameters	
Carrier freq.	28 / 60 / 82 GHz
gNB ant array	128/256 antenna elements
UE ant array	16 antenna elements per pol
Traffic	DL only/ UL only, Full buffer traffic
Codebook	L3-only codebook at gNB and UE

InH Deployment

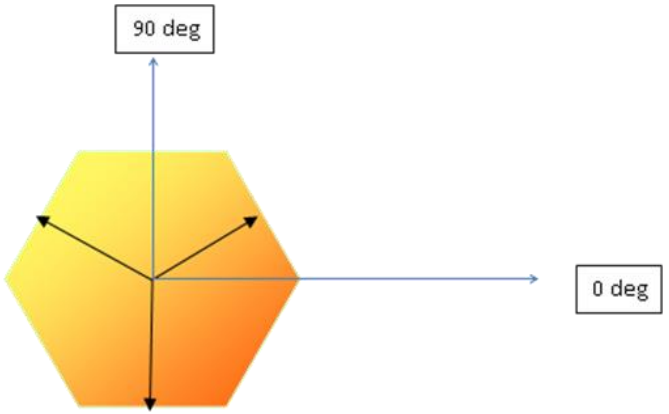
- Single sector pointing down
- 12 gNB over 120 m x 50 m
- 10 UE per gNB



5 m x 5 m box – No Walls

UMi Deployment

- Three sector pointing vertical
- 19 gNB, with three sectors each
- 10 UE per sector
- ISD: 20/50/100/200m



- Nodes are slot synchronized

InH, Open Office: DL Spectral Efficiencies in FR2/FR2x/FR4

	Cfg 1	Cfg 2	Cfg 3	Cfg 4	Cfg 5	Cfg 6
BW (MHz)	100	100	400	400	800	800
EIRP (dBm)	52	40	52	40	52	40
gNB (M,N,P)	128 per pol (16,8,2)					
UE ant (M,N,P)	Two panels at UE: 16 per pol (4,4,2) 1 (max. RSRP) panel is chosen at association					

28 GHz (Cfg 1,3,5 are typical)

20 ms ISD 78.57% FS eff 90% BW eff	5th Percentile UE SE (bps/Hz)	Median UE SE (bps/Hz)	Mean Cell SE (bps/Hz)
Cfg 1	0.45	0.95	8.83
Cfg 2	0.46	0.95	8.75
Cfg 3	0.47	0.95	8.82
Cfg 4	0.39	0.92	8.40
Cfg 5	0.44	0.96	8.80
Cfg 6	0.35	0.88	8.06

	Cfg 1	Cfg 2	Cfg 3	Cfg 4	Cfg 5	Cfg 6
BW (MHz)	50	50	500	500	2160	2160
EIRP (dBm)	52	40	52	40	52	40
gNB (M,N,P)	128 per pol (16,8,2)					
UE ant (M,N,P)	Two panels at UE: 16 per pol (4,4,2) 1 (max. RSRP) panel is chosen at association					

60 GHz (Cfg 2,4,6 are current regulatory limits)

20 ms ISD 78.57% FS eff 90% BW eff	5th Percentile UE SE (bps/Hz)	Median UE SE (bps/Hz)	Mean Cell SE (bps/Hz)
Cfg 1	0.49	0.92	8.51
Cfg 2	0.44	0.89	8.24
Cfg 3	0.46	0.93	8.58
Cfg 4	0.28	0.79	7.14
Cfg 5	0.40	0.91	8.15
Cfg 6	0.15	0.54	5.59

	Cfg 1	Cfg 2	Cfg 3	Cfg 4	Cfg 5	Cfg 6
BW (MHz)	100	100	625	625	1250	1250
EIRP (dBm)	52	40	52	40	52	40
gNB (M,N,P)	128 per pol (16,8,2)					
UE ant (M,N,P)	Two panels at UE: 16 per pol (4,4,2) 1 (max. RSRP) panel is chosen at association					

82 GHz (Cfg 1,3,5 estimated parameters)

20 ms ISD 78.57% FS eff 90% BW eff	5th Percentile UE SE (bps/Hz)	Median UE SE (bps/Hz)	Mean Cell SE (bps/Hz)
Cfg 1	0.45	0.92	8.42
Cfg 2	0.36	0.86	7.67
Cfg 3	0.45	0.93	8.24
Cfg 4	0.19	0.63	6.17
Cfg 5	0.37	0.91	8.03
Cfg 6	0.13	0.53	5.46

Conclusion:

- FR2x / FR4 can support indoor use cases, as in FR2
- 60 GHz: 5th PC UE data rates: 324 Mbps (10 UE / cell) Mean cell throughput: 12.07 Gbps
- 82 GHz: 5th PC UE data rates: 462 Mbps (10 UE / cell) Mean cell throughput: 10.04 Gbps

FR2x GHz in UMi Deployment

Config, ISD, 78.57% FS eff 90% BW eff	SU / MU Order	5th Pct-ile UE SE (bps/Hz)	Median UE SE (bps/Hz)	Mean Cell SE (bps/Hz)	5th Pct-ile UE SE (bps/Hz)	Median UE SE (bps/Hz)	Mean Cell SE (bps/Hz)
Config 1, 200	SU	0	0.06	1.08	0.002	0.10	1.52
Config 2, 200	SU	0.06	0.52	5.28	0.005	0.20	2.49
Config 3, 200	SU	0	0.006	0.25	0	0.01	0.45
Config 4, 200	SU	0.009	0.26	3.16	0	0.05	1.04
Config 5, 200	SU	0	0.001	0.08	0	0.002	0.16
Config 6, 200	SU	0.002	0.12	1.76	0	0.01	0.44
Config 1, 100	SU	0.02	0.23	2.78	0.05	0.31	3.40
Config 2, 100	SU	0.27	0.70	7.76	0.10	0.44	4.63
Config 3, 100	SU	0.002	0.05	0.86	0.005	0.10	1.36
Config 4, 100	SU	0.12	0.56	6.00	0.02	0.22	2.59
Config 5, 100	SU	0	0.01	0.27	0.001	0.03	0.51
Config 6, 100	SU	0.06	0.36	4.17	0.004	0.10	1.32
Config 1, 50	SU	0.06	0.33	3.93	0.09	0.40	4.10
Config 2, 50	SU	0.30	0.80	8.22	0.14	0.50	4.88
Config 3, 50	SU	0.006	0.10	1.48	0.01	0.16	1.95
Config 4, 50	SU	0.21	0.67	6.96	0.05	0.30	3.29
Config 5, 50	SU	0.001	0.03	0.55	0.003	0.05	0.87
Config 6, 50	SU	0.11	0.48	5.38	0.01	0.16	1.91
Config 1, 20	SU	0.07	0.31	3.80	0.05	0.25	2.92
Config 2, 20	SU	0.19	0.59	7.08	0.06	0.25	2.79
Config 3, 20	SU	0.01	0.11	1.49	0.02	0.14	1.88
Config 4, 20	SU	0.16	0.53	6.34	0.04	0.20	2.48
Config 5, 20	SU	0.002	0.03	0.58	0.004	0.06	0.98
Config 6, 20	SU	0.11	0.42	5.03	0.02	0.14	1.80

Cfg 1,3,5 are with 40 dBm EIRP (Current regulatory)

Cfg 2,4,6 are with 60 dBm EIRP limit (same as EIRP assumed for FR2)

- Common Assumptions: Up to rank 2, OFDM, up to 256 QAM are used for link performance

	Config 1	Config 2	Config 3	Config 4	Config 5	Config 6
Bandwidth (MHz)	50	50	500	500	2160	2160
	Reduce BW to increase PSD density					
DL EIRP (dBm)	40	60	40	60	40	60
UL EIRP (dBm)	25	31	25	31	25	31
gNB ant (M,N,P)	256 per pol (32,8,2)					
UE ant (M,N,P)	Two panels at UE: **16 per pol (4,4,2)** 1 (max. RSRP) panel is chosen at association					

- Given low EIRP, increasing PSD density (i.e., lowering BW) helps increase coverage → See 50 MHz, 500 MHz results vs. 2.16 GHz
- Other techniques to increase coverage → Slot aggregation, lower code rates / MCS
- UL / DL imbalance is lower in FR2x (DL is limited due to lower EIRP limit)

- **Summary:** 60 GHz can support dense urban use cases for a few 10s of meters
  - R-15 / R-16 NR techniques can be used to optimize coverage

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