**3GPP TSG RAN WG1 Meeting #103-e R1-200xxxx**

**e-Meeting, October 26 – November 13, 2020**

**Source: Moderator (Intel Corporation)**

**Title: [103-e-NR-52-71-Waveform-Changes] Discussions Summary #1**

**Agenda item: 8.2.1**

**Document for: Discussion**

# Introduction

In this contribution, we summarize the email reflector discussions for • [103-e-NR-52-71-Waveform-Changes]. Chairman has approved the following email discussion:

* [103-e-NR-52-71-Waveform-Changes] Email discussion/approval on required changes to NR using existing DL/UL NR waveform until 11/2; address any remaining aspects by 11/10 – Daewon (Intel)

# Summary of issues and discussions

## 2.1 Numerology (SCS and CP Length)

* From [1]:
  + Proposal 1: The decision of adding an additional SCS numerology to NR for 60 GHz band should be based on a careful compromise between receiver complexity necessary to keep the existing SCS (240kHz) and the amount of necessary changes to the existing design for the addition a new numerology (480kHz or 960 kHz) including a possible loss in spectrum efficiency.
  + Proposal 2: For the maximum carrier bandwidth choice for the operation between 52.6 GHz and 71 GHz NR should support the largest bandwidth for the FFT size and sampling rate with minimum impact to existing design, for 120, 240, 480, 960 kHz, maximum supported BW of 400, 800, 1600, 3200 MHz, respectively.
* From [2]:
  + Proposal 1: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, higher subcarrier spacing (numerologies) than 120 kHz should be adopted only if there is a significant performance gain in terms of phase noise reduction in comparison to existing subcarrier spacing (numerologies).
  + Proposal 2: For supporting NR operation between 52.6GHz and 71GHz in Rel. 17, if 480kHz SCS is agreed to be supported, then only normal cyclic prefix is sufficient
  + Proposal 3: For supporting single carrier bandwidth of ~2GHz for NR operation between 52.6GHz and 71GHz in Rel. 17, subcarrier spacing of 960kHz with normal cyclic prefix can be supported and higher subcarrier spacing value should not be further considered in NR Rel. 17.
  + Observation 16: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then the selection of SCS value should not limited based on the frequency range .Other factors of channel conditions such as phase noise, ICI, Doppler, CQI, etc. plays an important role in determining the SCS value:
    - For DL channel, UE has all the required estimates related to channel, receiver phase noise and other impairments, etc.
  + Proposal 12: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then UE assistance for SCS/BWP selection could be considered to take in to account all the channel measurements and receiver impairments that are more prominent at higher frequency range.
* From [3]:
  + Proposal 5: If the existing FR2 SCSs are adopted for above 52.6 GHz, the physical layer design of FR2 should be reused for the licensed band and used as a baseline for the unlicensed band with possible modifications due to the regulatory requirements such as LBT and OCB.
* From [4]:
  + Proposal 1: 240 KHz SCS for SSB can be an option for unlicensed band above 52.6GHz.
* From [5]:
  + Observation 5: (960K, NCP) could achieve the highest peak data rate which is more than 7 times as that of (120K, NCP).
  + Proposal 1: For BWP numerology, (960K, NCP) is preferred for scenarios targeting high peak data rate and (120K, NCP) is preferred with no spec impact for scenarios targeting large coverage.
  + Proposal 13: Timeline definition, basic time unit and super long CP per half frame should be discussed for new defined numerology such as (960K, NCP).
* From [7]:
  + Observation 1: Larger subcarrier spacings such as 480 kHz and 960 kHz mitigate the RF impairments in higher frequency especially for higher modulation order.
  + Observation 2: Limiting subcarrier spacing choices to keep the maximum FFT size as in Rel-15/16 can reduce implementation burden for redesigning FFT engine.
  + Proposal 3: The candidate new subcarrier spacing is limited to the subcarrier spacing that is within minimum and maximum FFT sizes in Rel-15.
  + Proposal 4: Considering the available spectrum, corresponding maximum channel bandwidth and the coexistence, 960 kHz should be considered for the specification support.
  + Proposal 5: Considering the different amounts of RMS delay spreads for possible scenarios, supporting multiple subcarrier spacings for higher frequencies would be beneficial.
* From [8]:
  + Proposal 2: SCS 480 KHz is supported for control and data channels for the maximum system bandwidth up to 1.6 GHz in NR operation up to 71 GHz.
  + Proposal 3: For NR operation on above 52.6GHz and up to 71GHz, the CP length of 240 kHz SCS for both data and control channels are sufficient to cover both indoor office and outdoor UMi Street-canyon deployment scenarios for battling of ISI. The CP length of 480 kHz SCS for both data and control channels are sufficient to cover indoor office deployment scenarios for battling of ISI.
  + Proposal 4: The system complexity and benefit of introducing the larger SCS more than 480 KHz for phase noise mitigation shall be carefully analyzed.
  + Proposal 5: Introducing larger SCS, such as 960 kHz is not essential for the mitigation of ICI caused by large phase noise.
* From [10]:
  + Observation 1: Considering outdoor deployment scenario, and close to zero specification effort, it seems that subcarrier spacing (µ=3) for physical data channels is valid option for 60 GHz scenario.
  + Observation 2: Considering indoor deployment scenario from specification effort, coexistence with WiGig, low delay spread, and low implementation complexity, it seems that only one additional subcarrier spacing, particularly value of (µ=6) for physical data channels would be sufficient for 60 GHz scenario.
  + Proposal 6: Support 960kHz for CP-OFDM to enable use of high-order modulations with low complexity CPE compensation.
  + Proposal 8: Support 960kHz SCS for DFT-s-OFDM to robustly enable all MCSs.
  + Proposal 10: Prioritize NCP in 60 GHz studies. ECP can be considered later, if needed.
  + Observation 24: RAN1 shall agree on which new SCS are supported, if any.
* From [13]:
  + Observation 2: The selection of SCSs for Rel-17 NR above 52.6 GHz needs to consider the impacts of frequency band, bandwidth, phase noise, CP overhead and multi-path delay.
  + Proposal 3: Numerology (SCS as well as CP) of NR above 52.6 GHz can be scaled by an integral multiple of current numerology supported by Rel-15/16 NR, i.e. Δf = 2μ × 15 kHz (μ can be set as 3, 4, 5, 6).
  + Proposal 4: 960 kHz can be defined as the SCS for 2.16 GHz channel bandwidth if it is supported for Rel-17 NR beyond 52.6 GHz.
  + Observation 3: If SCSs larger than 240 kHz are supported, the short CP may be not enough to cover delay spread, beam switching time and possible timing errors.
* From [14]:
  + Consider sub-carrier spacings up to 480 kHz for NR operation in 52.6 to 71 GHz.
  + For selection of suitable SCS for the 52.6 – 71 GHz frequency range, it is important to perform link level evaluations with sufficiently large post-beamforming RMS delay spreads that are representative of a suitable range of deployment scenarios including the indoor factory scenario analyzed above (e.g., up to at least 40 ns using the agreed TDL-A model). It is important to consider the margin left over for other sources of time synchronization error such as initial timing error, timing advance setting, timing advance adjustment granularity, and timing differences expected in multi-TRP deployments.
  + Extended CP is not to be considered further for NR operation in 52.6 to 71 GHz.
  + A higher UL SCS puts tighter requirements on UE initial UL timing accuracy.
  + Capture the following observation in TR 38.808: To avoid further tightening the UE requirement on UL timing error in relation to 1/SCSSSB compared to current specifications, the UL SCS should not be more than twice that of the SSB SCS. Using existing Rel-16 specifications for SSB, this can be achieved with 240 kHz SCS for SSB and 480 kHz for UL SCS.
  + A higher UL SCS puts tighter requirements on the absolute UE UL timing advance adjustment accuracy.
  + Capture the following observation in TR 38.808: For 960 kHz, maintaining UL timing within the CP becomes very challenging even without taking multi-TRP deployments into account. When taking multi-TRP deployments into account, it becomes practically infeasible.
  + Capture the following observation in TR 38.808: A higher UL SCS puts tighter requirements on UE UL timing and thus it is essential that the SCS selection and UE UL timing requirements are discussed jointly.
* From [15]:
  + Proposal #1: Consider the followings as candidate numerologies to support NR in FR-X band by taking frequency utilization efficiency, unlicensed band operation, the ICI mitigation, and the UE implementation into account.
  + SCS for other channels/signals
    - Introduce new value as 240 kHz and 480 kHz (and/or 120 kHz)
  + Study further on potential impacts (and relevant handling) due to the shortening of OFDM symbol duration and CP length by adopting larger SCS value.
    - Whether/how to handle impact to cell coverage and/or beam switching time (e.g. by employing the extended CP, grouping multiple OFDM symbols as a unit, and/or putting symbol gap between consecutive DL/UL signals/channels)
* From [16]:
  + Proposal 1: It is proposed to consider up to 480KHz SCS for 52.6GHz~71GHz.
* From [17]:
  + Proposal 1: The subcarrier spacing should be discussed and decided with higher priority.
  + Proposal 2: Support data transmission for 240 KHz for NR above 52.6 GHz to 71 GHz.
  + Proposal 3: Support new subcarrier spacing of 480 KHz and 960 KHz for NR above 52.6 GHz to 71 GHz.
* From [20]:
  + Observation 3: Wider SCS has robustness to frequency offset and phase noise, but impacts on CP duration.
  + Proposal 2: Support up to 960 kHz SCS, in order to support 2.16 GHz bandwidth by single carrier.
* From [21]:
  + Observation 4: the delay spread to be supported sets a lower limit on the SCS.
  + Observation 7: A maximum SCS of 480 kHz has been used for multiple elements of the Rel-15/Rel-16 specification. The use of SCS > 480 kHz should be justified to reduce the specification impact.
  + Proposal 4: Select 120 kHz, 240 kHz and 480 kHz as SCS candidates for NR operation between 52.6 GHz and 71 GHz.
  + Proposal 5: RAN1 to study the need for selecting 960 kHz as an SCS candidate considering specification impact and possible phase noise model changes from RAN4.
* From [22]:
  + Proposal 1: 240kHz SCS should be supported for 52.6-71GHz. 480kHz SCS is FFS.
* From [24]:
  + Proposal 1. The support of extended CP for large numerology or SCS like 480 KHz and above should be studied for NR operation from 52.6 to 71 GHz.
* From [26]:
  + Proposal 4: The study for the high frequency regime should prioritize NCP.
* From [29]:
  + Observation 6: MIMO timing alignment error (TAE) should be considered during the selection of supported subcarrier spacing set for NR in 52.6–71GHz.
  + Proposal 2: Support 480 kHz and 960 kHz SCS for NR operating in 52.6 – 71GHz.
  + Observation 10: Extended CP may not be needed for NR in 52.6–71GHz if MIMO TAE requirement less than 65ns is defined.
  + Observation 11: Advanced phase noise compensation methods, such as direct de-ICI compensation method, may not be suitable for NR operating in 52.6 GHz to 71 GHz.
* From [30]:
  + The following two combinations of maximum channel bandwidth and numerology shall be supported:
    - Maximum carrier bandwidth of 2.16 GHz with SCS of 960 kHz;
    - Maximum carrier bandwidth of 400 MHz with SCS of 120 kHz.
    - Further study whether ECP is needed for 960 kHz SCS.
    - Further study whether the support of other SCS is needed.
    - Further study whether mixed numerology is needed.
* From [31]:
  + Proposal 1: For numerology, at least one higher SCS than 120 kHz should be introduced for 52.6 – 71 GHz NR.
    - The number of SCSs to be newly supported for 52.6 – 71 GHz should be minimized
    - For 960 kHz SCS if supported for 52.6 – 71 GHz, extended CP should be considered

##### Moderator Summary:

* Companies views are somewhat diverse and there seems to be few sub issues, (1) supporting a single SCS or multiple SCS, (2) CP length, (3) supported SCS (for channels/signals other than SSB and PRACH)
  + Many companies seem to hint at supporting multiple SCS, although always not explicitly mentioned.
  + Many companies are gravitating towards use of NCP and FSS on ECP usage.
  + Companies has diverse view on supported SCS, ranging from 120 kHz to 960 kHz.
* Given that SCS and CP length are fundamental aspects needed for further progress on physical layer aspects, try to see we can come to a conclusion (if possible).

Chairman has suggested to gather input from companies on various aspects related to numerology. Please provide comments and input for each of the topics. The moderator will try to collect the inputs from the companies and summarize them.

* Number of numerologies
* Specification impacts of numerologies
* Whether design can operate with a single numerology
* Maximum supported numerology
* NCP/ECP
* Observations on performance from evaluations
* Implementation Complexity
* Scenarios enabled by different SCS

##### Company comments on number of supported numerologies:

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| **Company** | **Comments** |
| Futurewei | The numerology selection should be based on few basic principles such as performance, complexity of implementation , impact on the existing specification. Moreover, in the 60 GHz unlicensed band one should consider the abundence of spectrum and the almost inexistent incumbent deployments.  Based on the link evaluations we observed that SCS 240 MHz is a very good compromise of the above criteria. It offers minimal changes to the existing specifications, it operates very well in channel of relative larger delay spread, and with a reduced ICI filtering, it performs very well at lower and high MCS. |
| LG Electronics | Taking into account issues such as implementation complexity, specification impact, and so on, it might be beneficial to minimize the number of numerologies that will be supported for NR above 52.6 GHz. However, how many numerologies are to be supported will be influenced by other aspects (e.g., performance) as well. Therefore, the necessity of each candidate numerology should be justied first. |
| Ericsson | Agree that number of numerologies needs to be limited, e.g., to two. 120 kHz is a natural candidate due to existing FR2 implementations. The value for a (single) larger candidate numerology must be justified considering performance, implementation complexity, and specification impact. It is vital to have a firm view on feasible UE processing timelines and UE and BS timing error tolderances with respect to CP duration, otherwise high performance, and low latency cannot be achieved. Timing error tolerances, while in RAN4 purview, need to be understood in RAN1 before numerology can be decided. Furthermore, SCS and maximum channel BW needs to be selected together (see below for comments on max channel BW). |

##### Company comments on specification impacts of numerologies:

*Moderator note:* For this, I suspect that this can be a long list for each subcarrier spacing. Formulating an exhaustive list during SI may not be feasible, as we may find other aspects as work progresses. Therefore, I would like to ask companies to provide a high-level description of what they think is the most impacting. We could put a disclaimer to this list to state that this is not an exhaustive list.

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| **Company** | **Comments** |
| Futurewei | This request from moderator is not clear to me. Seems redundant. Detailed impacts are addressed in this document sections 2.3-2.13 |
| LG Electronics | Agree with Moderator’s note that we don’t need to put our efforts on making exhaustive list for specification impacts. At the same time, observing high-level view on which specification impact can be foreseen seems essential. With this regard, we provide the below table which can be used for the starting point.   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | 120 kHz SCS | 240 kHz SCS | 480 kHz SCS | 960 kHz SCS | | SS/PBCH block | SS/PBCH block time domain pattern is already supported in Rel-15. | SS/PBCH block time domain pattern is already supported in Rel-15. | SS/PBCH block time domain pattern is not supported in Rel-15/16. | SS/PBCH block time domain pattern is not supported in Rel-15/16. | | Signal or channel other than SS/PBCH block | Already supported in Rel-15. | Not supported in Rel-15/16. | Not supported in Rel-15/16. | Not supported in Rel-15/16.  Time unit should be updated since it is defined as  where Hz. | |
| Ericsson | Agree that the above table can be used as a starting point. UE processing timelines and timing error tolerances need to be established for numerologies not currently supported in Rel-15/16. |

##### Company Comments on whether design can operate with a single numerology:

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| **Company** | **Comments** |
| Futurewei | Prefer a single numerology that performs well at lower and higher MCS, that mitigates ISI due to larger delay using NCP and offers longer SSB cover range. |
| LG Electronics | Similar to start of NR-U SI discussion, we can conclude that being able to operate all DL (and/or UL) signal/channels with the same numerology for a carrier is beneficial in terms of lower complexity and no required measurement gap. However, it doesn’t necessarily mean that we necessitate to design 480 kHz SS/PBCH block in case 480 kHz SCS is to be introduced, e.g., considering non-stand-alone case. |
| Ericsson | From a coverage point of view, it is beneficial to operate an initial DL/UL BWP using existing FR2 numerologies for SS/PBCH and PRACH. Additional BWP(s) can be configured with larger numerology to achieve higher data rates as needed, and when coverage allows. In this sense, support of different numerology for SS/PBCH block and data/control is acceptable compared to re-design of all existing signals/channels to guarantee coverage. Agree with LG in that for NSA operation, it is not necessary to support 480 kHz SS/PBCH block to be able to operate in a 480 kHz BWP. Existing FR2 numerologies (120/240 kHz) work well. |

##### Company Comments on maximum supported subcarrier spacing and NCP/ECP usage:

*Moderator note:* Provide inputs on supported maximum subcarrier spacing and NCP/ECP usage for the supported subcarrier spacing.

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| **Company** | **Comments** |
| Futurewei | Prefer NCP, and a maximum SCS of 240 kHz |
| LG Electronics | We prefer SCS up to 480 kHz, with NCP. |
| Ericsson | Agree with LG – consider up to 480 kHz with NCP. Use of ECP is unjustified – we have demonstrated that 960 kHz + ECP has a 6 dB degradation compared to 480 kHz + NCP at 10% PDSCH BLER when comparing on the basis of equal data rate; ECP requires a larger effective code rate to support the same data rate. |

##### Company Comments on implementation complexity:

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| **Company** | **Comments** |
| Futurewei | {120 kHz, 240 kHz } low spec impact, with ICI filter perform well for low and high MCS, {480 kHz,960 kHz } substantial changes to the specs, potential lower spectrum efficiency with the use of ECP. |
| LG Electronics | At least, numerologies that are already supported for FR2 should be also supported for frequency range over 52.6 GHz, which can minimize additional implementation complexity. |
| Ericsson | Clearly, implementation burden is eased by minimization of the enhancements that are specified for operation in 52.6 – 71 GHz. Only enhancements that have a clear technical and performance benefit should be considered. |

##### Company Comments on Scenarios enabled by different SCS:

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| **Company** | **Comments** |
| Futurewei | Indoor/Outdoor enabled by :{120 kHz,240 kHz,480 kHz }, Indoor mainly{960 kHz }. We do not see necessary to have special numerology for indoor only scenarios if there are numerologies that perform equally well both in idoor and outdoor scenarios. |
| Ericsson | We do not see that 960 kHz enables any more scenarios than 480 kHz SCS. In fact, 960 kHz is penalized, even indoors, due to timing error tolerances exhausting the CP budget. Furthermore, environments such as InF-DH with larger delay spread become especially problematic. |

## 2.2 System Bandwidth & Channelization

* From [3]:
  + Observation 6: There is no significant difference between using multiple component carriers with a smaller SCS or a single carrier with a larger SCS in terms of signalling overhead and spectral efficiency. UE capabilities for aggregating up to 8 component carriers is already specified for NR.
  + Proposal 2: 400 MHz can be the starting point for the maximum bandwidth of a single carrier in the frequency band between 52.6 GHz and 71 GHz.
  + Proposal 3: For NR system operating in 52.6 GHz to 71 GHz, NR should be designed with minimum 32 RBs per carrier. The supported minimum carrier bandwidth for a cell is 50 MHz.
  + Proposal 4: The choice of supported maximum carrier bandwidth for NR operating in 52.6 GHz to 71 GHz should ensure a minimum of at least 6 channels in any regulated range.
* From [5]:
  + Observation 4: (960K, NCP) and (960K, ECP) could achieve a comparable maximum carrier bandwidth (i.e. 2 GHz) as 802.11ad/ay.
  + Proposal 12: NR design in the frequency range of 52.6 – 71 GHz should support multiple channel bandwidths for different deployment scenarios and considering different available regional frequency allocations.
* From [7]:
  + Proposal 1: Study multiples of 400 MHz up to 2 GHz should be considered for frequencies from 52.6 GHz to 71 GHz.
  + Proposal 2: Study potential coexistence issue with other RAT in the spectrum of 52.6 GHz to 71 GHz.
* From [8]:
  + Proposal 1: The maximum system bandwidth should be supported at least 1 GHz and up to 1.6 GHz. The system analysis of supporting more than 1.6 GHz system BW should be carefully evaluated before making the decision.
* From [10]:
  + Proposal 1: Define channelization according to 2.16 GHz CBW, which is preferred from coexistence point of view.
  + Proposal 2: Support sub-channelization for 2.16 GHz channels to facilitate smooth coexistence for narrowband operation.
  + Observation 3: For given bandwidth, 960 kHz SCS supports considerably smaller number of component carriers (CC) compared to 480 kHz SCS. Reduced number of CCs allows for smaller system complexity, smaller system overhead and better RF efficiency (e.g. lower MPR).
  + Proposal 3: For operation without CA, support two CBWs: 400 MHz (120 kHz SCS) and 2.16 GHz (960 kHz SCS)
  + Proposal 4: Support CA within a 2.16 GHz channel, and between 2.16 GHz channels
  + Proposal 5: Consider n x 400 MHz, n=[2, 3, 4, 5] as the supported channel BW options for CA operation within a 2.16 GHz channel.
* From [13]:
  + Proposal 1: The following options are proposed for determining channel bandwidth(s) for Rel-17 NR beyond 52.6 GHz, wherein Option 2 is preferred.
    - Option 1: Align the channelization of Rel-17 NR with Wi-Fi design at least in unlicensed band (e.g. 57 GHz - 71 GHz) and support 2.16 GHz channel bandwidth
    - In other licensed frequency band (e.g. 52.6 GHz - 57 GHz) or in a controlled environment without Wi-Fi devices, it can be designed uniformly with unlicensed band (i.e. 2.16 GHz) or independently (e.g. 400/800/1600 MHz)
    - Option 2: No need to align the channelization of Rel-17 NR with Wi-Fi design even in unlicensed band. Support the same bandwidth(s) (e.g. 400/800/1600 MHz) in licensed and unlicensed frequency bands
    - Option 2-1: No need to support a nominal channel bandwidth of 2.16 GHz
    - Option 2-2: Support a nominal channel bandwidth of 2.16 GHz by the aggregation of above basic bandwidth(s) (e.g. 400/800/1600MHz)
  + Observation 1: Considering the requirement of OCB and the limitation of the maximum number of available RBs, it is difficult to use less than 480 kHz as the candidate SCS for 2.16 GHz bandwidth if it should be supported.
  + Proposal 5: In addition to the existing supported 120 kHz, 240/480/960 kHz can be served as the candidate SCS(s) for the maximum carrier bandwidth(s) 400 MHz, 800 MHz and/or 1600 MHz channel bandwidth.
* From [14]:
  + Capture the following observation in TR 38.808. If NR adopts the same channelization design as IEEE 802.11ad/ay, large wastage of spectrum would occur in many regions.
    - 240 MHz at the lower edge of the band is unused in all regions
    - 800 MHz at the upper edge of the band is unused in USA and Europe
    - 680 MHz of the 5 GHz allocation in China is unused
      * In recognizing the need to have at least three channels for cell planning [22], IEEE 802.11aj standard defined four 1.08 GHz channels nested within the two 2.16 GHz channels for the 60 GHz band in China. As a result, the spectrum wastage issues are left unaddressed in the 802.11aj channelization.
    - 280 MHz of the 7 GHz allocation in Canada/Brazil/Mexico is unused
      * In the IMT (licensed) allocation in Europe, one out of the 2 available 2.16 GHz channels is unusable since it extends outside the IMT allocation
  + Capture the following observation in TR 38.808: It is beneficial to define NR channelization to allow full utilization of the various regional frequency allocations around the world. It is not necessary to align NR channelization with IEEE 802.11ad channelization from a coexistence point of view.
  + There is no regulatory or practical need to align the channel bandwidth (e.g., 2.16 GHz) with other technologies operating in the same 60 GHz band for coexistence purposes.
  + Capture the following observation in the TR: Targeting 2.16 GHz channel bandwidth results in low FFT utilization compared to Rel-15/16, causing larger computation overhead, and thus larger power consumption.
  + Consider channel bandwidths up to 1.6 GHz for NR operation in 52.6 to 71 GHz.
* From [15]:
  + Proposal #1: Consider the followings as candidate numerologies to support NR in FR-X band by taking frequency utilization efficiency, unlicensed band operation, the ICI mitigation, and the UE implementation into account.
  + Maximum carrier BW
    - 800 MHz for the SCS of 240 kHz
    - 1.6 GHz (and/or 800 MHz) for the SCS of 480 kHz
* From [16]:
  + Proposal 2: The maximum supported channel bandwidth in 52.6GHz ~71 GHz should be 1.6GHz.
  + Proposal 3: Carrier aggregation is needed to achieve competitive high peak data rate with 802.11ad/ay in 52.6GHz ~71 GHz
* From [20]:
  + Proposal 1: NR devices support that transmissions occupy a 2.16 GHz bandwidth in 60GHz unlicensed spectrum.
  + Observation 1: CA (either inter-band or intra-band) can be supported, but we prefer not to rely on CA with maximum bandwidth 400MHz per carrier to achieve 2.16GHz bandwidth.
  + Observation 2: To support 2.16 GHz bandwidth by single carrier, 960 kHz SCS is required.
  + Proposal 2: Support up to 960 kHz SCS, in order to support 2.16 GHz bandwidth by single carrier.
* From [21]:
  + Observation 1: There is a need for multi-carrier operation to achieve the high bandwidth allocations in the unlicensed band between 52.6GHz and 71 GHz.
  + Proposal 1: NR operation above 52.6 GHz should support multi-carrier operation to achieve 2 GHz bandwidth utilization. The BW candidates should be in multiples of 400 MHz.
  + Proposal 2: A UE should be able to indicate a capability for a component carrier bandwidth/SCS combination to achieve 2 GHz transmission.
* From [24]:
  + Proposal 2. To support various wide bandwidth and use cases for NR operation from 52.6 GHz to 71 GHz, a wide range of numerologies with the carrier aggregation need to be studied, also considering the LBT bandwidth (or the RB set) for co-existing issues, UE capability, processing time and power consumption.
* From [26]:
  + Proposal 1: For physical control, data, and random access channels and for SSB in the high frequency regime from 52.6GHz to 71GHz, SCSs of 120kHz and 960kHz should be considered.
* From [31]:
  + Proposal 2: For bandwidth, at least wider maximum channel bandwidth than 400 MHz should be defined for 52.6- 71 GHz.
    - 2 GHz or slightly smaller but sufficiently wide bandwidth such as 1 GHz should be considered.
    - FFT size should remain the same or smaller than 4k
    - Wider minimum channel bandwidth for 52.6 – 71 GHz than 50 MHz should be considered.

##### Moderator Summary:

* Companies views are somewhat diverse and there seems to be few sub issues, (1) minimum channel bandwidth, (2) maximum channel bandwidth, (3) channelization
  + Note: there may be other issues not listed above. The above are few outstanding issues that moderator noted and does not hint higher priority or otherwise.
* Similarly, system bandwidth is another fundamental aspect needed for further progress on physical layer aspect. Try to see we can come to a conclusion (if possible).

##### Company Comments on supported minimum and maximum channel bandwidth:

Moderator note: provide inputs on supported minimum and maximum channel bandwidth, including potential specification implications, motivation, advantages and disadvantages, and other related aspects.

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| **Company** | **Comments** |
| Futurewei | Min BW: 400MHz; a bandwidth of eight times carrier BW should be supported. For a CC of 400 MHz the max supported should be 3200 MHz for a single connectivity. For dual connectivity it would correspond to 6400 MHz. |
| LG Electronics | Max BW: 1.6 GHz; As we commented in Section 2.1, given the maximum SCS of 480 kHz (based on our preference) and the maximum FFT size of 4096 (based on earlier RAN1 agreement), the channel bandwidth can be up to 1.6 GHz. |
| Ericsson | Maximum carrier BW = 1.6 GHz based on 480 kHz SCS. Minimum carrier bandwidth can be further discussed considering both unlicesned and licensed operation. At most the the minimum should be 400 MHz; smaller values can still be discussed. See comment below on channelization.  With a maximum carrier BW of 1.6 GHz, the FFT utilization can be maintained at Rel-15/16 levels. In contrast, a 2160 MHz carrier BW results in <50% FFT utilization, thus impacting power consumption and/or chip area. |

##### Company Comments on channelization from RAN1 perspective:

Moderator note: channelization is defined in RAN4. Please try to limit the inputs on channelization that would be relevant for RAN1 design and to comments on aspects where RAN1 might have the best expertise.

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| **Company** | **Comments** |
| Futurewei | BW of 400 MHz should be used for initial channel access and for the basic LBT procedure. |
| Ericsson | It is important to choose channelization that avoids spectrum wastage in the various regions of the world. For example, in China and the IMT allocation in Europe, 5 GHz is allocated, and with a maximum bandwidth on the order of 1640 MHz, the 5 GHz allocation can support 3 channels thus fully utilizing the 5 GHz allocation without wastage. This is to be compared, e.g., to a wastage of approximately 680 MHz if channels must be strictly aligned with .11ad channelization in which case only two 2.16 GHz channels are supported in the 5 GHz allocation.  In our contribution (R1-2007982), we have provided a detailed analysis about the drawback of aligning the channelization with .11ad.  The main drawbacks are:   1. extensive evaluation results from different companies shows there are no coexistence issues even without deploying LBT 2. If NR adopts the same channelization design as IEEE 802.11ad/ay, large wastage of spectrum would occur in many regions:  * 240 MHz at the lower edge of the band is unused in all regions * 800 MHz at the upper edge of the band is unused in USA and Europe * 680 MHz of the 5 GHz allocation in China is unused   + In recognizing the need to have at least three channels for cell planning, IEEE 802.11aj standard defined four 1.08 GHz channels nested within the two 2.16 GHz channels for the 60 GHz band in China. As a result, the spectrum wastage issues are left unaddressed in the 802.11aj channelization. * 280 MHz of the 7 GHz allocation in Canada/Brazil/Mexico is unused * In the IMT (licensed) allocation in Europe, one out of the 2 available 2.16 GHz channels is unusable since it extends outside the IMT allocation  1. If .11ad channelization is used, only 2 non-overlapping 2.16 GHz channels are available, and 680 MHz would be wasted. Instead, NR can divide the 5GHz allocation into 3 non-overlapping 1.6 GHz nominal channels which (1) increase the number of available channels, and (2) full use of the allocation. 2. the 802.11ad standard itself supports partially overlapping channels for channel bandwidths >2.16 GHz 3. In R1-2007982, we demonstrate that misaligned channels do not create a coexistence problem either. We evaluated Coexistence scenario between two operators (a) both operators use aligned 2 GHz channels, and (b) Operator #2 uses three 1.6 GHz channels misaligned with the two 2 GHz channels used by Operator #1. We show that misaligned channels do not cause any coexistence issue. |

## 2.3 SSB

### 2.3.1 SSB numerology

* From [2]:
  + Proposal 7: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, coverage enhancement of channels and signals used for initial access should be considered for NR beyond 52.6 GHz.
* From [3]:
  + Observation 5: A SCS larger than 240 kHz for SSB is not well-justified.
  + Proposal 1: Support 120 kHz or 240 kHz SCS with NCP for physical layer signals, control/data channel, and PRACH, SSB, for both licensed and unlicensed band operations.
  + Observation 7: The numerology of 120 kHz or 240 kHz SCS with NCP is sufficient for initial access.
* From [5]:
  + Proposal 2: For SCS pair for SSB and initial DL BWP, support (120K, 240K), (120K, 120K) and (960K, 960K) to maintain 4-bit koffset indication as in FR2.
  + Observation 10: For frequency domain offset estimation during SSB detection, using SSB with low SCS such as 120K/240KHz may increase hardware complexity or cell search latency.
  + Observation 11: For number of buffering samples during SSB detection, using SSB with high SCS such as 960KHz will need larger buffer cost compared to that in FR2 if adopting the same SSB period (20ms).
  + Observation 12: For 960KHz SSB, NCP length is not enough to accommodate the time for beam switching.
* From [7]:
  + Observation 3: Limiting subcarrier spacing choices to keep the minimum FFT size to 512-points can avoid redesign of SS/PBCH block.
* From [8]:
  + Observation 2: The complexity of SCS indication in the PBCH increase as the total number of SCS supported for FR2 increases.
* From [9]:
  + Observation 1: FR2 existing SCS and new numerologies can provide a large number of potential SS/PBCH candidate positions to combat channel uncertainty issues.
  + Proposal 2: It is proposed to investigate how to transmit the indication about additional SS/PBCH candidate positions which can become available with existing FR2 numerologies or future new numerologies.
* From [10]:
  + Observation 16: To provide enough high time synchronization accuracy for the initial uplink transmission when applying 960 kHz SCS the following options could be considered:
    - 1) Introduce 960 kHz SCS for SSB
    - 2) Use RS available also for IDLE mode UEs like DMRS of CORESET#0 in occasions configured for Type0-PDCCH monitoring.
  + Proposal 13: Regarding SSB numerologies: 1) Support existing SSB numerologies and 2) support 960 kHz SCS for SSB or provide UE with additional RS available in IDLE mode to provide sufficient time synchronization accuracy to operate mixed SCS scenario of 240kHz SSB and 960 kHz SCS uplink control and data.
  + Proposal 14: With 960 kHz SCS no explicit beam switching is needed between successive SSB blocks.
* From [14]:
  + Capture the following observation in TR 38.808: By proper choice of SSB SCS, the initial cell search complexity can be kept at the same level as for FR1 and FR2.
  + Capture the following observation in TR 38.808: From a frequency error perspective, an SSB SCS of 240 kHz is sufficient for the 52.6-71 GHz frequency range to maintain similar relative error values as for FR1 and FR2.
  + For NR operations in the 52.6 – 71 GHz band, consider only 120 and 240 kHz SCS for SS/PBCH blocks, as already supported in Rel-15/16.
  + Capture the following observation in TR 38.808: It is beneficial for SSB coverage to reuse the FR2 already supported subcarrier spacings of 120kHz and 240kHz.
  + Only support existing FR2 SSB subcarrier spacings of 120 kHz and 240 kHz.
* From [15]:
  + Proposal #1: Consider the followings as candidate numerologies to support NR in FR-X band by taking frequency utilization efficiency, unlicensed band operation, the ICI mitigation, and the UE implementation into account.
  + SCS for SSB transmission
    - Reuse the existing value of 240 kHz (and/or 120 kHz)
* From [19]:
  + Observation 2: Using larger SCS than FR2 SCS can lead to lower SSB detection complexity due to less frequency shift hypotheses.
* From [21]:
  + Proposal 6: The use of SCS above 240 kHz should be justified for the signals in the SS/PBCH block including the PSS, SSS and PBCH.
* From [22]:
  + Proposal 2: SSB design for SCS 240kHz and 480kHz could be considered.
* From [29]:
  + Proposal 5: For SSB, subcarrier spacing no smaller than 240 kHz is considered for NR operating in 52.6 GHz to 71 GHz. Only support same subcarrier spacing between SSB and CORESET #0 configuration.

##### Moderator Summary:

* Diverse views on SSB numerologies among companies.
* General consensus is that just from performances perspective, SSB is not as affected by phase noise compared to PDSCH/PUSCH.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | Support for the existing SSB numerology 240 kHz with NCP should be considered |

### 2.3.2 SSB pattern and SSB/CORESET multiplexing

* From [2]:
  + Observation 11: With higher SCS values such as 480kHz and 960kHz, if existing SSB structures are used, then the minimum bandwidth requirements for UE will increase significantly in order to accommodate the required number of frequency resources within a time-symbol for PBCH/PSS/SSS and only multiplexing pattern 1 could be supported
  + Proposal 6: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, new SSB structures should be investigated
* From [3]:
  + Proposal 6: The SSB patterns of Case D and Case E can be reused in frequency range above 52.6 GHz for licensed band operation.
  + Proposal 7: More than 64 candidate SSB indexes should be introduced in NR-U-60.
  + Proposal 8: The SSB and CORESET0 multiplexing patterns in Rel-15 can be reused for licensed band operation.
  + Proposal 9: The SSB and CORESET0 multiplexing pattern 2 and 3 are preferred for unlicensed band operation in frequency range above 52.6 GHz when LBT is necessary.
* From [5]:
  + Proposal 3: The following SSB-Coreset 0 multiplexing patterns are supported for each SCS pair:
    - (120K, 240K): Pattern 1, Pattern 2
    - (120K, 120K): Pattern 1, Pattern 3
    - (960K, 960K): Pattern 1, Pattern 3
  + Proposal 5: For initial cell search in 52.6-71GHz, a UE may assume that half frames with SSB occur with smaller period than FR2 (e.g. 5ms).
  + Proposal 6: The following alternatives could be considered to solve beam switching problem for contiguous candidate SSBs:
    - Alt. 1: New SSB pattern introducing gaps between contiguous candidate SSBs;
    - Alt. 2: The same QCL assumptions for contiguous candidate SSBs (e.g. case D in [4]);
    - Alt. 3: Hopping transmission for contiguous candidate SSBs (e.g. case E in [4]).
* From [6]:
  + Proposal 1: For maximum commonality, SSB patterns and multiplexing pattern of SSB and CORESET#0 are same for licensed and unlicensed operation, and the functions/mechanisms (e.g. LBT) dedicated for unlicensed operation can be configurable by RRC signaling.
* From [8]:
  + Proposal 6: The same SSB patterns are supported for licensed and unlicensed bands and NRU mechanism for additional transmission opportunity is reused.
  + Observation 1: No additional gap should be considered to accommodate beam switching delay if only 120 KHz/240 KHz SCS is used for NR operation up to 71GHz.
  + Proposal 7: The beam switching delay during beam sweeping should be taken into consideration in the SSB burst design for higher SCS.
  + Proposal 8: For NR operation in unlicensed spectrum in 52.6-71 GHz, the transmission window defined in Rel-16 NR-U is supported.
  + Proposal 9: More than 64 SSB transmission opportunities shall be defined within a 5ms SSB burst set to support up to 64 beams for SSB beam sweeping in case of occasional LBT failure. The additional bit(s) for the extension of SSB index need to be further study.
  + Proposal 10: Patterns 2 and 3 of SSB and CORESET for Type0-PDCCH can multiplex with periodic CSI-RS/paging PDCCH&PDSCH in frequency.
* From [9]:
  + Proposal 1: Introduce groups of SCS in FR2 and all control/data communication will use the SCS from one such group.
* From [10]:
  + Observation 15: Benefits of reusing FR2 numerologies for both SSB and Type0-PDCCH would be:
    - No CP length or coverage reduction
    - Possibility to reuse FR2 implementation for the initial access
  + Observation 17: FR2 SSB time domain mapping pattern of SSBs can be reused above 52.6 GHz if the FR2 SSB numerologies are used.
  + Observation 18: If LBT was used for the SSBs, to provide multiple SSB transmission opportunities for the same beam in the DRS window against LBT failures, two principles could be considered:
    - Max number of SSB positions remains 64 while some of the positions (e.g. last N positions) can be used as a back-up positions for the SSBs which were not transmitted due to LBT failure. The maximum number of SSB beams would be 64-N. There can be further sub-options as follows:
      * Back-up positions could be used in cyclic manner as in Rel. 16 NR-U.
      * gNB could select certain SSB (not transmitted in the original SSB position) to be transmitted in the back-up position. This case would require that SSB transmitted in the back-up position would indicate the beam index explicitly.
    - Increase max number of SSB positions beyond 64, e.g. up to 128, and use similar cycling mechanism as in Rel. 16 NR-U. This option would require increasing the SSB index space and signalling from 64 to 128.
  + Observation 19: Existing FR2 SSB and Type0-PDCCH multiplexing patterns are a good starting point for above 52.6 GHz operation.
* From [13]:
  + Proposal 2: Rel-17 NR can maintain the maximum SCS with 240 kHz for SSB and/or 120 kHz for Type0-PDCCH, and reuse the initial access procedure in Rel-15/16 NR.
  + Proposal 7: SSB pattern needs to be re-considered irrespective of whether higher SCS is supported or not in Rel-17 NR above 52.6 GHz.
  + Proposal 8: Transmission opportunities, timing and QCI of Rel-17 SSB should be considered.
  + Proposal 9: The following multiplexing patterns and combinations of SCSs of SSB and Type0-PDCCH are preferred for Rel-17 NR beyond 52.6 GHz, that is, 60 kHz SCS for Type0-PDCCH is not supported.
    - (SSB, Type0-PDCCH): (120, 120) kHz
      * Multiplexing patterns: 1, 3
    - (SSB, Type0-PDCCH): (240, 120) kHz
      * Multiplexing patterns: 1, 2
* From [14]:
  + Capture the following observation in TR 38.808: It is observed that from a UE complexity point of view it is beneficial to define the same SS/PBCH patterns for licensed and unlicensed operation.
  + Existing SS/PBCH time domain patterns D and E as specified in Rel-15/16 are proposed to be used also for operation in the 52.6 – 71 GHz band.
  + Proposal 26 Capture the following observation in TR 38.808: It is observed that with 120 and 240 kHz SCS for SS/PBCH block transmissions, the CP length is at least 293 ns which is sufficient for beam switching which typically requires < 100 ns
  + Capture the following observation in TR 38.808: SS/PBCH / CORESET0 multiplexing patterns 2 and 3 are restricted to very small RMSI payloads due to the small number (2) of available OFDM symbols for RMSI PDSCH.
  + Capture the following observation in TR 38.808: For the maximum number of beams (64), it is observed that SS/PBCH / CORESET0 multiplexing pattern 1 can carry larger payload than multiplexing patterns 2 and 3 due to the fact that SS/PBCH and RMSI PDCCH/PDSCH are time division multiplexed.
  + Capture the following observation in TR 38.808: Existing Rel-15/16 framework for initial access including SS/PBCH-CORESET0 multiplexing patterns, multiplexing of SS/PBCH and other signals/channels, and Type0-PDCCH CSS configurations have significant flexibility to cover a large number of deployment scenarios in the 52.6 – 71 GHz band.
* From [15]:
  + Proposal #3: Consider the enhancements for the SSB transmission to provide more opportunities in FR-X unlicensed band.
  + Proposal #4: Study further how to multiplex SSB and corresponding CORESET#0 in case of using new numerologies such as 240/480 kHz SCSs for the DL signal/channels other than SSB.
* From [19]:
  + Observation 3: introducing additional beam switching gap is needed when SSB SCS is beyond 480 KHz.
  + Proposal 1: Strive for a unified SSB time pattern independent of with/without LBT modes.
  + Observation 4: a gap duration larger than 23 us may be enough for LBT gap duration.
  + Observation 5: Rel. 15 FR2 SSB time pattern can support Omni-directional or directional LBT without further introducing LBT gap.
  + Observation 6: The resource limitation for SSB-CORESET pattern 2 and pattern 3 is not obvious and can be workaround.
  + Observation 7: It seems not necessary to preclude pattern 2 and pattern 3 for SSB CORESET#0 multiplexing.
* From [21]:
  + Observation 9: Introduction of a DRS transmission window introduction will depend on (a) the 10% regulatory rule (b) relative duration of signals that may need to be transmitted without LBT and (c) the overall interference provided by these signals.
  + Proposal 7: Allow SSB transmission without LBT in an LBT environment provided load of non-LBT transmission is less than 10% within an observation window of 10 ms.
    - Define a DRS transmission for scenarios where the control signaling exceeds this threshold.
  + Proposal 8: Support Pattern 1, 2 and 3 with additional support of 240 kHz for the SSB and 240 kHz for the Type0-PDCCH for SSB and Type0-PDCCH/RMSI multiplexing.
* From [23]:
  + Proposal 1: For 52.6-71 GHz band, the existing SCSs, i.e., 120 kHz and 240 kHz, and multiplexing pattern between SSB and CORESET#0 in FR2 for SS/PBCH blocks should be reused.
  + Proposal 2: For 52.6-71 GHz band, the existing time domain patterns designed in FR2 for SS/PBCH blocks at least for licensed spectrum should be reused.
* From [27]:
  + Proposal 1: At least one symbol gap in time domain between SS/PBCH blocks with different SSB indices should be considered for higher subcarrier spacing (e.g., equal or larger than 960kHz) taking into account a beam switching gap due to a RF interruption time of Tx/Rx beams and/or LBT gap in unlicensed spectrum.
  + Proposal 2: We propose that SS/PBCH block and CORESET#0/RMSI can be multiplexed in TDM/FDM within a slot considering multi-beam operation and it can be closely located without the gap between SSB and CORESET#0/RMSI for not allowing any in-between channel access operation in the unlicensed band.
* From [29]:
  + Proposal 4: When a large subcarrier spacing is defined, SSB pattern and multiplexing of SSB and CORESET0/RMSI need to be updated to accommodate beam switching time.
* From [30]:
  + Proposal 3: RAN1 shall study the SS/PBCH block pattern for the new numerology, taking into account the beam switching time between neighboring SS/PBCH blocks.
  + Proposal 4: RAN1 shall study the multiplexing pattern of SS/PBCH block and CORESET#0, and supporting both Pattern 2 and Pattern 3 is beneficial for the flexibility of allocating the CORESET#0.
* From [31]:
  + Proposal 3: Whether to introduce gap symbol(s) for beam switching time should be discussed not only for SSB but also for any signal/channels with beam switching in case that higher SCS such as 960 kHz is supported.
  + Proposal 4: For SSB and CORESET multiplexing, following aspects should be discussed
    - Which SCS(s) is supported for SSB and which combination(s) of SCS between SSB and CORESET#0 is supported
      * Whether only single numerology is supported as in Rel-16 NR-U or not
      * Whether the number of supported SCSs for SSB should be minimized
    - Which multiplexing pattern between SSB and CORESET#0 is supported for each combination of SCS between SSB and CORESET#0
      * What are minimum channel bandwidth, minimum required CORESET#0 bandwidth and minimum required bandwidth for RMSI PDSCH
      * Whether beam sweeping overhead should be minimized by FDM between SSB and CORESET#0 and/or RMSI PDSCH

##### Moderator Summary:

* Diverse views among companies on this issue. There are several sub-issues: (1) supported SSB/CORESET multiplexing pattern, (2) SSB pattern within the slots, (3) DRS window, (4) QCL assumption, (5) how to deal with beam switching (if needed to be considered), (6) whether or not to support different SSB and CORESET #0 numerology
  + Note: there may be other issues not listed above. The above are few outstanding issues that moderator noted and does not hint higher priority or otherwise.
* Some conclusion on SSB numerology might be needed for further progress on this topic.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | Our approach is based on minimum changes to the existing design, a lower implementation complexity and a simplified usage in the unlicensed band. Use the same SSB and CORESET# numerology, use existing FR2 multiplexing pattern, reuse initial access procedures Rel15/16, no additional beam switching time gap necessary (100ns switching time is less than NCP of 240 kHz SCS) |

### 2.3.3 Initial access related aspects

* From [8]:
  + Proposal 13: In initial access, the beam adaptation for Msg3 and Msg4 transmission can be adapted based on the beam measurement report from UE.
* From [9]:
  + Observation 2: The transmission of minimum system information with a large number of active beams makes the system inefficient and imposes beam switching constraints, resulting in reduced scheduler flexibility.
  + Observation 3: For shared carriers, the transmission of minimum system information with a large number of active beams brings additional issues related to channel ownership, and potential requirements to perform channel access procedures while switching the beams.
  + Proposal 3: It is proposed to investigate efficient transmission of MSI including the multiplexing patterns for both licensed and shared carriers.
* From [10]:
  + Observation 13: PBCH using QPSK has DMRS in each OFDM symbol where PBCH REs are allocated.
  + Observation 14: PBCH using current FR2 numerologies is robust against phase noise.
* From [14]:
  + Capture the following text in TR 38.808: Increased SCS translates to a loss in coverage for initial access signals and channels (SS/PBCH block, PRACH), fixed payload channels (e.g., PDCCH/PUCCH), and variable payload channels (e.g., PDSCH/PUSCH) due to shorter OFDM symbol duration.
  + For operation in the 52.6 – 71 GHz band, basic tools in the Rel-16 specifications, e.g., FR2 initial access framework, BWP switching, CA/DC activation already support both standalone and non-standalone deployments that can ensure coverage. It is not needed to specify coverage enhancement approaches for larger SCS for initial access signals and channels or for control/data channels.
  + Capture the following observation in TR 38.808: The distribution of interference + noise in the 52.6 – 71 GHz band is typically well below the LBT threshold of -47 dBm, and thus deferral due to LBT failure is rare. Hence, it is not beneficial to introduce a transmission window for SS/PBCH + RMSI transmissions.
* From [20]:
  + Proposal 5: Beam alignment during initial access procedure should be considered for NR above 52.6 GHz

##### Company Comments:

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| **Company** | **Comments** |
| Futurewei | Use FR2 initial access design as the basic framework |

## 2.4 PRACH

* From [3]:
  + Proposal 10: For unlicensed band, ZC lengths such 571 and 1151 can be considered for 120 kHz SCS.
  + Observation 8: Due to the possibility of LBT failure, the support for non-consecutive ROs in the time domain could be beneficial.
* From [5]:
  + Proposal 4: Format 0-3 with special SCS is not supported and the candidate PRACH numerologies for format A, B and C are the same as the candidate BWP numerologies.
  + Proposal 7: Both coverage and capacity should be studied for PRACH design with new defined numerology.
  + Proposal 8: With the usage of higher SCS, the issue of preamble sequence generation needs to be considered to match the certain coverage area.
* From [8]:
  + Proposal 11: Consider supporting the increasing of symbols in time domain to enhance coverage and the extending of frequency domain by repeating and concatenating the RACH preamble sequence in the unlicensed spectrum.
  + Observation 3: The current RO configuration of FR2, based on the 60 KHz slot as the basic unit, which supports two slots configuration when SCS is120KHz.
  + Proposal 12: When the specification supports SCS=240/480 KHz, reusing 120 KHz configuration for each two slots within 60 KHz slot.
* From [10]:
  + Observation 20: 960 kHz SCS for PRACH can support required range for the indoor scenario.
  + Proposal 15: Support 960 kHz SCS for PRACH.
  + Observation 21: Introducing longer sequence lengths for short time domain PRACH preambles, e.g. the ones supported in Rel. 16 NR-U (571 and 1151), would allow transmitting device to achieve 40 dBm EIRP maximum in CEPT scenarios c1 and c2.
  + Proposal 16: Support PRACH sequence lengths 571 and 1151 for NR above 52.6 GHz.
  + Observation 22: It would be better to define fixed LBT gap between valid ROs that do not depend on the time domain allocation of the PRACH. In that case the LBT gap length would not depend on the used PRACH format.
* From [13]:
  + Proposal 10: It is preferred to reuse the existed numerology for PRACH.
* From [14]:
  + Include the following Observation in TR 38.808. Maximum isotropic loss (MIL) and maximum coupling loss (MCL) degrade as the subcarrier spacing is increased, negatively impacting coverage. PRACH 120 kHz SCS is defined for FR2 already in Rel-15 and for the 52.6–71 GHz range yields 4–5 dB better coverage than 480 kHz SCS and 8–9 dB better coverage than 960 kHz SCS.
  + If PRACH uses 120 kHz SCS, data transmission can still use higher subcarrier spacings through BWP switching.
  + Reuse existing FR2 PRACH subcarrier spacing of 120 kHz for 52.6–71 GHz.
  + Include the following observation in TR 38.808: For operation in the 52.6 – 71 GHz band, it is beneficial to support all existing Rel-15/16 sequence lengths L = 139/571/1151 to allow for larger transmit powers in some scenarios depending on the assumed beamforming gain, regulatory regime, and UE power limits.
  + Support PRACH with sequence lengths L = 139/571/1151 (as defined for FR2 in Rel-15/16) for 52.6–71 GHz.
  + Reuse FR2 PRACH configuration tables for 52.6–71 GHz.
  + Include the following observation in TR 38.808. It is not beneficial to optimize RACH configurations to enable LBT gaps between back-to-back PRACH occasions in the same slot for operation in the 52.6 – 71 GHz band.
* From [15]:
  + Proposal #6: Design wide-band PRACH and interlaced or multi-RB based PUSCH/PUCCH considering regulatory requirements such as nominal channel BW, occupied channel BW, maximum allowed output power, and maximum power spectral density.
* From [19]:
  + Observation 12: it is beneficial to introduce larger SCSs for PRACH transmission.
* From [29]:
  + Proposal 7: When a large subcarrier spacing is defined, PRACH configuration related aspects need to be investigated.
* From [30]:
  + Observation 2: The LBT result of the selected RO is highly relying on the usage of previous RO.
  + Observation 3: The consecutive configuration of RO could further increase the LBT failure probability
  + Proposal 5: Non-consecutive RO configuration is beneficial for alleviating the RACH LBT failure, and shall be supported for 60 GHz unlicensed band.
* From [31]:
  + Proposal 5: For PRACH sequence, short PRACH sequence supported in Rel-15 NR should be a baseline.

##### Moderator Summary:

* There are several sub-issues: (1) supported PRACH SCS, (2) RACH RO configuration, (3) Supported PRACH sequence lengths, (4) support of interlace PRACH
  + Note: there may be other issues not listed above. The above are few outstanding issues that moderator noted and does not hint higher priority or otherwise.

##### Company Comments:

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| **Company** | **Comments** |
| Futurewei | Use longer PRACH sequences 571/1151, support non-consecutive RO with fixed (short) LBT , prefer SCS of 240 kHz for PRACH |

## 2.5 PDCCH

### 2.5.1 PDCCH

* From [5]:
  + Proposal 9: Coverage enhancement mechanism such as PDCCH repetition should be studied for PDCCH design especially for high SCS.
* From [7]:
  + Proposal 7: Study channel estimation performance impact of PDCCH and PUCCH with a larger subcarrier spacing.
* From [10]:
  + Proposal 23: Support improved PDCCH coverage for the cases of high SCS.
* From [14]:
  + Capture the following observation in TR 38.808: For operation in 52.6 – 71 GHz, it is beneficial to support UE PDCCH processing capabilities per multi-slot monitoring period that scale with the size of the monitoring period when the UE is configured with a monitoring period larger than a slot.
* From [19]:
  + Observation 11: it is beneficial to increase symbols and reduce RBs for the CORESET configuration for a given large SCS if introduced.

##### Company Comments:

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| **Company** | **Comments** |
| Futurewei | The use of SCS (240kHz) can provide enough coverage for PDCCH. |

### 2.5.2 PDCCH Monitoring

* From [2]:
  + Observation 12: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then the PDCCH monitoring capability would be further reduced and the number of PDCCH candidates per slot would be lower.
  + Observation 13: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then the PDCCH processing in every slot might not be scalable with increasing subcarrier spacing, due to limitations with UE processing capability.
* From [3]:
  + Observation 10: Detection probability of PDCCH may decrease for 960 kHz with the limited maximum number of non-overlapped CCEs per slot which may be lower than 16.
* From [10]:
  + Observation 25: For high SCS, such as 960 kHz and above, PDCCH monitoring capabilities, and especially channel estimation capability of number of unique CCEs per slot is expected to reduce below tolerable limit.
  + Proposal 17: Increase of the minimum scheduling/ PDCCH monitoring unit to avoid excessive increase in PDCCH monitoring rate and excessive reduction in per-slot monitoring capabilities.
  + Proposal 18: Determine BD/CCE limits based on nominal scheduling/monitoring unit such as slot of e.g. 120kHz (defined in R15)/240kHz (FFS).
  + Observation 26: GC-PDCCH is an essential part of unlicensed system, and there seems to be need to supportbeam-dependent information, particularly if some form of directional LBT is chosen as coexistence mechanism.
  + Proposal 19: Changes to DCI format 2\_0 may be beneficial for at least unlicensed 60GHz NR operation.
* From [15]:
  + Proposal #7: It would be beneficial in terms of UE implementation complexity or power consumption to perform slot(or symbol)-group level processing instead of every slot(or symbol) processing, e.g. PDCCH monitoring and CSI processing unit availability check.
* From [20]:
  + Observation 4: The increase of SCS causes frequent PDCCH monitoring, which is not desirable for the UE power consumption.
* From [21]:
  + Proposal 13: To reduce PDCCH monitoring complexity, reduce the limits per slot or define PDCCH monitoring limits over a group of slots.
  + Proposal 14: Use beam cycling to improve the coverage of PDCCH with gaps between CORESETs to account for any beam-switching times.
* From [22]:
  + Proposal 3: The enhancement for PDCCH monitoring for 52.6-71GHz should also consider the requirements from PDSCH scheduling.
* From [23]:
  + Proposal 3: For new SCS, if agreed, the following aspects should be prioritized to address UE PDCCH monitoring complexity concerns.
    - investigation on the maximum number of BDs/CCEs for PDCCH monitoring per slot
    - potential limitation to PDCCH monitoring configurations, e.g., ks=1 and Ts>1 in search space set configuration
    - related UE capabilities for PDCCH monitoring and processing
* From [29]:
  + Proposal 9: When a large subcarrier spacing is defined, maximum number of BDs/CCEs for PDCCH monitoring needs to be investigated.
* From [30]:
  + Proposal 7: RAN1 shall study the mechanism to reduce PDCCH monitoring burden at UE side for new numerology.

##### Moderator Summary:

* Many discussions and issue seem to be dependent on supported SCS, and BD and UE complexity.

##### Company Comments:

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | Reducing PDCCH monitoring to reduce UE monitoring complexity should be supported |

### 2.5.3 DCI Formats

* From [2]:
  + Proposal 9: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then consider enhancements to current PDCCH design that includes the following possibilities:
    - To introduce new single DCI format that could simultaneously schedule DL transmission and UL grants for one or more transmission time intervals
    - To limit the monitoring to PDCCH in slots when the UE receives a multi-slot scheduling grant
* From [4]:
  + Observation 1: The current DCI 0-2/1-2 can be reused to allow frequency domain resource by multi-PRB granularity.
* From [6]:
  + Proposal 2: If time domain scheduling enhancements for PDSCH is needed, multi-PDSCH scheduled by one DCI should be supported for less standardization workload.
* From [7]:
  + Observation 8: If the maximum FFT size of Rel-15/16 is kept, it is observed that maximum number of RBs and required payloads of DCI for frequency domain resource allocation do not increase.
* From [10]:
  + Proposal 20: Support Multi-PDSCH DCI for reaching peak data-rates for the cases of high SCSs
    - R16 Multi-PUSCH DCI design principle shall be the starting point.
* From [13]:
  + Proposal 12: The combination of multi-PDSCH scheduled by one DCI and enhanced dynamic HARQ-ACK codebook and one-shot HARQ-ACK feedback should be studied.
* From [14]:
  + Capture the following observation in TR 38.808: For operation in 52.6 – 71 GHz it is beneficial to support scheduling multiple PDSCH using one DCI by extending the multi-PUSCH scheduling feature introduced in Rel-16 to the scheduling of multiple PDSCH using one DCI in Rel-17
* From [15]:
  + Proposal #8: Consider to support multi-PDSCH scheduling by a single DCI.
* From [20]:
  + Proposal 3: Multi-PDSCH/PUSCH scheduling by one DCI should be supported for NR above 52.6 GHz.
* From [28]:
  + Proposal 1: Consider enhanced multi-carrier operation where a single DCI can schedule multiple cells, including SCells with a dormant BWP, for energy-efficient and low-latency NR performance.
* From [30]:
  + Proposal 8: RAN1 shall study more flexible resource allocation in both time and frequency domain for different scenarios, including increasing the time-domain scheduling unit to be larger than one symbol, multi-PDSCH scheduling by one DCI, one TB mapped to multiple slots and subcarrier bundling/sub-PRB.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | Support multi-PDSCH scheduling per DCI |

## 2.6 PDSCH/PUSCH

### 2.6.1 Scheduling Aspects

* From [2]:
  + Proposal 9: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then consider enhancements to current PDCCH design that includes the following possibilities:
    - To introduce new single DCI format that could simultaneously schedule DL transmission and UL grants for one or more transmission time intervals
    - To limit the monitoring to PDCCH in slots when the UE receives a multi-slot scheduling grant
* From [4]:
  + Observation 1: The current DCI 0-2/1-2 can be reused to allow frequency domain resource by multi-PRB granularity.
* From [6]:
  + Proposal 2: If time domain scheduling enhancements for PDSCH is needed, multi-PDSCH scheduled by one DCI should be supported for less standardization workload.
* From [7]:
  + Observation 7: The enhancement of time domain resource allocation may be a crucial part for efficient operation in higher frequencies.
  + Proposal 10: Study the enhanced time domain resource allocation method considering the scheduling efficiency, the UE implementation impacts and the specification impacts.
  + Observation 8: If the maximum FFT size of Rel-15/16 is kept, it is observed that maximum number of RBs and required payloads of DCI for frequency domain resource allocation do not increase.
  + Proposal 11: The benefits from frequency domain resource allocation enhancements should be carefully studied.
* From [10]:
  + Observation 23: Scheduling principle needs to be revisited for the cases with high SCS.
  + Proposal 20: Support Multi-PDSCH DCI for reaching peak data-rates for the cases of high SCSs
    - R16 Multi-PUSCH DCI design principle shall be the starting point.
  + Observation 27: There seems to be no need to modifying the existing frequency domain resource allocation mechanisms with high SCSs.
  + Proposal 21: Reuse NR R15 RBG size determination, which is FR and SCS agnostic.
* From [13]:
  + Proposal 12: The combination of multi-PDSCH scheduled by one DCI and enhanced dynamic HARQ-ACK codebook and one-shot HARQ-ACK feedback should be studied.
* From [14]:
  + Capture the following observation in TR 38.808: For operation in 52.6 – 71 GHz it is beneficial to support scheduling multiple PDSCH using one DCI by extending the multi-PUSCH scheduling feature introduced in Rel-16 to the scheduling of multiple PDSCH using one DCI in Rel-17
  + Capture the following observation in TR 38.808: For operation in 52.6 – 71 GHz, it is beneficial to reduce the FDRA fields size by supporting larger RBG sizes.
  + Capture the following observation in TR 38.808: For operation in the 52.6 – 71 GHz band, consider gNB initiated polling approach for UL traffic management to reduce UL data latency.
* From [15]:
  + Proposal #8: Consider to support multi-PDSCH scheduling by a single DCI.
* From [20]:
  + Proposal 3: Multi-PDSCH/PUSCH scheduling by one DCI should be supported for NR above 52.6 GHz.
  + Observation 5: Multi-PUSCH scheduling introduced in Rel-16 NR-U can be reused for NR above 52.6 GHz.
* From [21]:
  + Proposal 15: Support frequency domain scheduling enhancements, time domain scheduling enhancements and updates to the Scheduling request for NR operation above 52.6 GHz.
* From [26]:
  + Proposal 5: Multi-slot-based UE capabilities can be considered for new SCSs with short slot lengths.
  + Observation 9: The span-based UE capability in Rel-16 can be a baseline for multi-slot-based UE capability for high SCSs.
* From [28]:
  + Proposal 1: Consider enhanced multi-carrier operation where a single DCI can schedule multiple cells, including SCells with a dormant BWP, for energy-efficient and low-latency NR performance.
* From [29]:
  + Proposal 10: When a large subcarrier spacing is defined, multi-TTI based scheduling can be considered to relax scheduler implementation and higher layer processing burden.
* From [30]:
  + Proposal 8: RAN1 shall study more flexible resource allocation in both time and frequency domain for different scenarios, including increasing the time-domain scheduling unit to be larger than one symbol, multi-PDSCH scheduling by one DCI, one TB mapped to multiple slots and subcarrier bundling/sub-PRB.
* From [31]:
  + Proposal 7: How to allocate resource for data in frequency domain needs to be considered especially for higher SCS if introduced.
    - PDSCH/PUSCH allocated on more than 14 symbols would be beneficial.
    - In 60 GHz unlicensed band, the necessity of interlaced PUCCH/PUSCH would be questionable.
    - Enhancements on RB allocation for PUCCH format 0/1 should be considered.
  + Observation 11: The current granularity in time/frequency domain in Rel-15/16 may be too fine, assuming less opportunity for FDM between UEs due to narrower beam width and larger number of symbols required for coverage performance.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | Support multi-PDSCH and multi-PUSCH scheduling with a single DCI |

### 2.6.2 UL Interlace Transmission

* From [2]:
  + Proposal 13: For supporting NR beyond 52.6 GHz in unlicensed band in Rel. 17, study the enhancement of PRB/sub-PRB interlacing designs for NR with higher SCS, if agreed to be supported.
* From [3]:
  + Observation 12: Sub-PRB based resource allocation for PUSCH is not necessary due to an increased channel estimation complexity and a higher payload for FDRA.
  + Proposal 12: PRB based interlace resource mapping for PUSCH/PUCCH/SRS should be studied further in NR-U-60.
* From [9]:
  + Observation 4: Due to very wide BW, the number of PRBs per interlace will increase significantly.
  + Proposal 5: RAN1 shall study the possibility to assign NR-U PUCCH onto partial interlaces for high BW channels.
* From [10]:
  + Observation 28: OCB requirement or PSD limitation does not require interlaced UL allocation on 60 GHz unlicensed band.
  + Proposal 24: No interlaced transmission is defined for 60 GHz unlicensed band.
* From [13]:
  + Proposal 11: It may not be necessary to support interlaced uplink transmission for unlicensed operation in 52.6~71 GHz band.
* From [14]:
  + PRB-based interlacing is not beneficial for SCS ≥ 120 kHz
  + Sub-PRB interlacing is not beneficial for SCS ≥ 960 kHz
  + Both PRB and sub-PRB interlacing is not beneficial for large frequency resource allocations
  + Capture the following observation in TR 38.808: Neither PRB or sub-PRB interlacing is beneficial for the expected large frequency resource allocations applicable for NR operation in 52.6 – 71 GHz spectrum. The support of UL interlace allocation is not considered for NR operation in 52.6 – 71 GHz.
* From [19]:
  + Observation 10: interlace seems not necessary in 60GHz unlicensed operation, due to the OCB requirement does not need to be constantly met and the power boosting benefit seems disappear with wider RB bandwidth envisioned in 60GHz.
* From [20]:
  + Proposal 4: Sub-PRB based interlace design should be supported for 60 GHz unlicensed spectrum.
* From [22]:
  + Proposal 4: In order to meet the requirements of minimum OCB, some enhancement on interlace design with unregular RB number might be considered.
* From [23]:
  + Proposal 4: PRB and sub-PRB Interlace are not supported for UL transmission in 60 GHz band.
* From [30]:
  + Proposal 9: RAN1 shall study sub-PRB level interlace for UL transmission.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | Sub-PRB interlace may not be beneficial at lower SCS (240 kHz) |

### 2.6.3 Transmission Rank

* From [10]:
  + Proposal 11: Consider supporting rank-2 SU-MIMO for DFT-s-OFDM in 60GHz band.
* From [14]:
  + Do not further discuss Rank-2 transmission for DFT-s-OFDM in the 52.6 – 71 GHz SI/WI. This should be addressed under a MIMO SI/WI.
* From [28]:
  + Proposal 2: It is beneficial to allow higher UL throughput without sacrificing power efficiency by enabling more than 1 spatial layer with UL transform precoding.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | The rank discussion for DFT-s-OFDm belongs to MIMO SI/WI |

### 2.6.4 HARQ Processes

* From [4]:
  + Proposal 6: HARQ-ACK feedback mechanism for multi-TTI scheduling should be studied.
* From [5]:
  + Proposal 11: The default set of PDSCH-to-HARQ\_feedback timing indicator should be adapted to the SCS of PDSCH.
* From [14]:
  + Because of larger processing latencies, the numbers of DL and UL HARQ processes may need to be increased. Otherwise, physical layer specification and implementation changes compared to Rel-15 may be needed to sustain high data throughput.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
|  |  |

### 2.6.5 Processing Timelines

* From [3]:
  + Proposal 11: Reuse the processing timeline for FR2 for 120 kHz. If a new SCS is supported, reusing processing timeline for FR2 based on a fixed time unit defined as a slot duration of 120 kHz can be considered with slot bundling within the fixed time unit for PDSCH/ PUSCH resource allocation, mapping, and PDCCH monitoring.
* From [4]:
  + Proposal 2: For PUSCH scheduled by RAR or by the fallback RAR, Δ value should also be considered for new SCS if agreed.
  + Proposal 3: Specify different default K1 value sets for different SCS, and each K1 set with a maximum number of 8 values to keep the K1 bit field in DCI 1-0 unchanged.
  + Proposal 4: Configure different K1 value sets for different SCS, and each K1 set with a maximum number of 8 values to keep the K1 bit field in DCI 1-1/DCI 1-2 unchanged.
  + Proposal 5: Impacts on PDSCH/PUSCH processing time(N1/N2) should be considered if defining maximum number of BDs/CCEs for PDCCH monitoring per multiple slots.
* From [7]:
  + Proposal 8: Study required UE processing time for higher frequencies considering the differences on antenna/panel structure, beam width, BWP size and new subcarrier spacings.
  + Observation 6: Existing processing time determination methods are based on worst case scenarios and may require more redundant processing time for higher frequencies.
  + Proposal 9: Study application of different processing time requirements based on parameters which contribute UE processing time.
* From [13]:
  + Proposal 14: If introducing new numerology, the impacts on processing time and scheduling operation should be considered.
* From [14]:
  + UE processing timelines for SCS > 120 kHz need to be further tightened vis-à-vis those for 120 kHz SCS to enable high performance NR operation in 52.6 to 71 GHz.
  + The times provisioned for UE processing grow exponentially with the numerology. Large processing latencies restrict the achievable throughputs, defeating the purpose of enabling large bandwidths with large sub-carrier spacings.
  + Capture the following observation in TR 38.808: For selection of suitable SCS for the 52.6 – 71 GHz frequency range, the expected increases in processing latencies and decreases in processing capabilities associated with large SCS are important factors. To enable high performance NR operation in 52.6 to 71 GHz, UE processing timelines and capabilities for SCS > 120 kHz need to be further tightened. Such issues put pressure to define SCS(s) as low as possible preferably leveraging existing SCS(s) in the current spec, i.e., ≤480 kHz.
  + Add the following aspects to the list of processing timelines for new SCS (if agreed) that are not currently supported,
    - Processing capability for PUSCH scheduled by RAR UL grant
    - Dynamic SFI and SPS/CG cancellation timing
    - Timeline for HARQ-ACK information in response to a SPS PDSCH release/ dormancy.
    - Minimum time gap for wake-up and SCell dormancy indication (DCI format 2\_6)
    - BWP switch delay
    - Multi-beam operation timing (timeDurationForQCL, beamSwitchTiming, beam switch gap, etc.)
    - Timeline for multiplexing multiple UCI types
  + RAN1 should investigate the different factors that contribute to the PDSCH processing time and consider possible latency reduction opportunities.
* From [21]:
  + Proposal 11: To reduce the timing constraints due to increasing the SCS, modify the UE timing parameter values and their associated signaling.
  + Proposal 12: To accommodate timeline changes from the increased number of slots due to a possible increase in the SCS , increase the number of HARQ processes and/or increase the number of slots a HARQ codebook is tied to.
* From [29]:
  + Proposal 8: When a large subcarrier spacing is defined, processing time related aspects, including PDSCH/PUSCH processing time, CSI computation time, etc., need to be investigated.
* From [30]:
  + Proposal 6: RAN1 shall study proper value for processing timing for new numerology, and enhancement for relevant procedures and signaling with the consideration of UE complexity, latency and signaling overhead.
* From [31]:
  + Proposal 10: For higher SCS, the appropriate configuration of k0, k1, k2 need to be discussed to meet UE minimum processing timeline.
    - If the current candidate values don’t meet UE processing limitation, extending, limiting or shifting the range of k0, k1, k2 may be necessary.

##### Moderator Summary:

* Many discussions and issue seem to be dependent on supported SCS.

##### Company Comments:

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | Having a single SCS of 240 kHz would not require re-evaluating the processing timelines already supported. We may reuse the FR2 timelines. |

## 2.7 Reference Signals

### 2.7.1 PT-RS

* From [2]:
  + Proposal 4: For supporting NR operation between 52.6GHz and 71GHz in Rel. 17, no PT-RS configuration should also be supported, depending up on the MCS range, if higher subcarrier spacing values are agreed to be supported.
* From [3]:
  + Observation 11: Block PTRS enables low complexity ICI compensation for smaller SCSs such as 120 kHz and 240 kHz and helps the smaller SCS to perform even better than a larger SCS such as 960 kHz. A new PTRS pattern with more PTRS groups within one DFT-s-OFDM symbol should be considered.
* From [5]:
  + Proposal 10: DM-RS/PT-RS enhancement should be further studied to solve the problem caused by RF impairment such as phase noise, I-Q imbalance and PA non-linear work range.
* From [10]:
  + Observation 8: For ICI compensation, two approaches are discussed,
    - Enhanced PT-RS design (e.g. localized/block PT-RS)
    - Implementation-based method (e.g. data-aided direct filtering.)
  + Proposal 7: Support ICI compensation for NR beyond 52.6GHz, and study and compare different ICI compensation schemes with respect to performance as well as implementation complexity.
  + Proposal 9: Consider defining new PTRS configurations for DFT-s-OFDM.
* From [11]:
  + Proposal 1: Support block-based PT-RS patterns for OFDM waveform.
  + Proposal 2: Support cyclic PT-RS sequence for OFDM waveform.
  + Proposal 3: A PT-RS sequence for OFDM waveform composed of KP samples includes a cyclic prefix of floor(KP/2) samples.
  + Proposal 4: Support density extension of current Rel.15 PT-RS for DFTsOFDM waveform.
* From [14]:
  + Capture the following observation in TR 38.808: Clustered PT-RS structure can frequently collide with existing NR reference symbols (such as CSI-RS and TRS) with no simple avoidance solution.
  + Capture the following observation in TR 38.808: A clustered PT-RS structure does not offer any performance advantage over the existing Rel-15 NR distributed PT-RS structure.
  + Retain the same Rel-15 distributed PT-RS structure for OFDM for NR operation in 52.6 to 71 GHz.
* From [15]:
  + Proposal #5: Investigate the necessity to enhance the structure of DM-RS for data as well as control DL/UL channels and that of PT-RS for DFT-s-OFDM considering UE multiplexing and efficient data transmission.
* From [19]:
  + Observation 8: with legacy PTRS pattern, phase noise impact is more visible for MCS 22.
  + Observation 9: the ICI compensation can further reduce the BLER floor compared with simple CPE compensation, but displays a 2~2.5 dB gap to phase noise off performance.
* From [21]:
  + Observation 2: The total PN increases when compared to below 52.6 GHz operation.
  + Observation 3: By using PN ICI compensation, we can reduce the maximum SCS selected when compared with CPE compensation only.
  + Proposal 3: Consider the use of a new PTRS and/or Phase Noise ICI compensation to improve performance to limit need for specifying higher SCS.
  + Proposal 9: Support an update to Rel-15 PTRS to enable improved ICI compensation.
* From [26]:
  + Proposal 2: As PTRS enhancement for assisting ICI compensation, increasing the frequency domain PTRS density for small RB allocation can be considered. New PTRS patterns other than the Rel-15 design, such as the block PTRS pattern is not necessary.
* From [30]:
  + Proposal 11: RAN1 shall study the enhancement to reference signals (e.g. chunk based PT-RS pattern) for the new carrier frequency range to mitigate the impact of ICI, taking into consideration of the impact from the new numerology.

##### Moderator Summary:

* Many discussions and issue seem to be dependent on supported SCS.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | New PTRS design may not be necessary. The time density of PTRS signal may be increased. |

### 2.7.2 DM-RS

* From [2]:
  + Proposal 5: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, new DM-RS configurations should be considered with following criterion:
    - High frequency density of the DM-RS for high SCS for better channel estimation when channel coherence bandwidth is less than the configured SCS
    - Reduced number of DM-RS ports as the performance gain of high rank MIMO channels is expected to be limited in high FR2
* From [5]:
  + Proposal 10: DM-RS/PT-RS enhancement should be further studied to solve the problem caused by RF impairment such as phase noise, I-Q imbalance and PA non-linear work range.
* From [7]:
  + Observation 5: The performance loss from channel estimation error gets reduced as DM-RS density increases especially when a higher modulation order is used.
  + Proposal 6: Study enhanced DM-RS designs for a larger subcarrier spacing for PDSCH and PUSCH.
* From [10]:
  + Observation 30: Existing Rel-15 DMRS type-1 is a feasibile solution for 480kHz and 960kHz sub-carrier spacing options.
  + Observation 31: Existing Rel-15 DMRS type-1 is also feasible solution with higher transmission ranks (e.g. rank 2) for 480kHz and 960kHz sub-carrier spacing options.
  + Proposal 26: Use existing Rel-15 DMRS type-1 for 480 kHz and 960 kHz sub-carrier spacing options. No need to design any new DMRS structure for 480 KHz and 960 sub-carrier options in Rel-17.
* From [14]:
  + Capture the following observation in TR 38.808. For 480 kHz SCS and below with large delay spread, the room for performance improvement with a change to the Rel-15 DMRS design is very limited.
* From [15]:
  + Proposal #5: Investigate the necessity to enhance the structure of DM-RS for data as well as control DL/UL channels and that of PT-RS for DFT-s-OFDM considering UE multiplexing and efficient data transmission.
* From [21]:
  + Proposal 10: To account for transmission with large SCSs in low coherence BW channels,
    - turn on or off the FD-OCC based on the scenario the channel is in
    - configure the UE with a DMRS pattern robust to frequency selective fading
* From [25]:
  + Proposal 3: For DMRS enhancement for high SCSs, higher DMRS RE density and new multiplexing patterns should be studied.
* From [29]:
  + Proposal 6: For subcarrier spacing 480 kHz and 960 kHz, PDSCH (and potentially PUSCH) reception performance is impacted by frequency domain OCC in DMRS, and therefore we suggest that RAN1 further investigate on frequency domain OCC for DMRS.
* From [31]:
  + Proposal 6: How to allocate resource for RS (e.g. DMRS, PTRS) in frequency domain needs to be considered for higher SCS if introduced
    - DMRS density in frequency domain may not be sufficient
    - DMRS ports multiplexing may not work well

##### Moderator Summary:

* Many discussions and issue seem to be dependent on supported SCS.

##### Company Comments:

|  |  |
| --- | --- |
| **Company** | **Comments** |
| Futurewei | New DM-RS design for SCS less or equal to 480 kHz may not be necessary |

### 2.7.3 TRS

* From [10]:
  + Observation 32: For P-TRS transmissions in the cell, it would be beneficial to have a mechanism to be able to transmit P-TRSs dropped due to LBT failure.

##### Company Comments:

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| **Company** | **Comments** |
|  |  |

## 2.8 PUCCH

### 2.8.1 PUCCH

* From [7]:
  + Proposal 7: Study channel estimation performance impact of PDCCH and PUCCH with a larger subcarrier spacing.
* From [9]:
  + Proposal 4: RAN1 shall study high BW formats, up to 2.16 GHz, for NR-U PUCCH in 60 GHz band.
  + Observation 5: Due to increased BW, Rel16 NR-U PUCCH format would have a very low spectral efficiency in the 60GHz band (down to less than 1%)
  + Proposal 5: RAN1 shall study the possibility to assign NR-U PUCCH onto partial interlaces for high BW channels.
* From [10]:
  + Observation 29: There is need to enhance PUCCH Format 0 and 1 transmissions to achieve higher transmit power when PSD limits apply.
  + Proposal 25: Support contiguous multi-PRB allocation for PUCCH format 0 and format 1 or use of PUCCH format 2 and format 3 for SR and before dedicated PUCCH configuration for 1 or 2 bit payloads.
* From [14]:
  + Capture the following observation in TR 38.808: it is beneficial to enhance PUCCH format 0 and 1 to span multiple RBs to allow larger transmit power.
* From [23]:
  + Proposal 5: Potential enhancements for PUSCH/PUCCH transmissions to achieve higher transmit power should be considered in WI, e.g., PUCCH repetition in time/frequency domain.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | Potential enhancements for PUSCH/PUCCH transmissions to achieve higher transmit power should be considered |

### 2.8.2 SR

* From [14]:
  + Proposal 49 Capture the following observation in TR 38.808: For operation in the 52.6 – 71 GHz band, consider enhancements to SR (PUCCH) resource configuration and spatial relation management to reduce UL data latency

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
|  |  |

### 2.8.3 UL Interlace Transmission

* From [2]:
  + Proposal 13: For supporting NR beyond 52.6 GHz in unlicensed band in Rel. 17, study the enhancement of PRB/sub-PRB interlacing designs for NR with higher SCS, if agreed to be supported.
* From [3]:
  + Proposal 12: PRB based interlace resource mapping for PUSCH/PUCCH/SRS should be studied further in NR-U-60.
* From [9]:
  + Observation 4: Due to very wide BW, the number of PRBs per interlace will increase significantly.
  + Proposal 5: RAN1 shall study the possibility to assign NR-U PUCCH onto partial interlaces for high BW channels.
* From [10]:
  + Observation 28: OCB requirement or PSD limitation does not require interlaced UL allocation on 60 GHz unlicensed band.
  + Proposal 24: No interlaced transmission is defined for 60 GHz unlicensed band.
* From [13]:
  + Proposal 11: It may not be necessary to support interlaced uplink transmission for unlicensed operation in 52.6~71 GHz band.
* From [14]:
  + PRB-based interlacing is not beneficial for SCS ≥ 120 kHz
  + Sub-PRB interlacing is not beneficial for SCS ≥ 960 kHz
  + Both PRB and sub-PRB interlacing is not beneficial for large frequency resource allocations
  + Capture the following observation in TR 38.808: Neither PRB or sub-PRB interlacing is beneficial for the expected large frequency resource allocations applicable for NR operation in 52.6 – 71 GHz spectrum. The support of UL interlace allocation is not considered for NR operation in 52.6 – 71 GHz.
* From [19]:
  + Observation 10: interlace seems not necessary in 60GHz unlicensed operation, due to the OCB requirement does not need to be constantly met and the power boosting benefit seems disappear with wider RB bandwidth envisioned in 60GHz.
* From [20]:
  + Proposal 4: Sub-PRB based interlace design should be supported for 60 GHz unlicensed spectrum.
* From [22]:
  + Proposal 4: In order to meet the requirements of minimum OCB, some enhancement on interlace design with unregular RB number might be considered.
* From [23]:
  + Proposal 4: PRB and sub-PRB Interlace are not supported for UL transmission in 60 GHz band.
* From [30]:
  + Proposal 9: RAN1 shall study sub-PRB level interlace for UL transmission.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | Some per PRB interlace may be considered to achieve a mode with minimum OCB |

## 2.9 Measurements

### 2.9.1 RLM and RRM

* From [3]:
  + Proposal 13: Study the use of aperiodic CSI-RS for BFR procedure in NR-U-60.
  + Proposal 14: RSSI measurement with directional reception should be studied in NR-U-60.
* From [14]:
  + Scheduling restrictions during RRM, RLM and beam management procedures are the responsibility of RAN4 and thus need not to be discussed further in RAN1.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
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### 2.9.2 CSI Processing Timelines

* From [2]:
  + Proposal 8: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then potential enhancements should be considered on how to efficiently utilize UE’s limited processing capability to reduce latency and efficiently handle processing/preparation of CSI reports associated with multiple numerologies in parallel:
    - Same reference symbols duration (possibly the shortest duration corresponding to maximum supported SCS value) could be used for checking CPU availability corresponding to different CSI reports associated with different SCS values

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
|  |  |

## 2.10 TDD Configuration and Transition Time

* From [3]:
  + Observation 9: Overhead caused by DL/UL switching (14 μs) is large under SCS of 480 kHz (half a slot) and 960 kHz (almost a full slot).
* From [14]:
  + TDD switching time requirements for the 52.6 – 71 GHz band are the responsibility of RAN4 and thus do not need to be further discussed in RAN1.

##### Moderator Summary:

* Many discussions and issue seem to be dependent on supported SCS.

##### Company Comments:

|  |  |
| --- | --- |
| **Company** | **Comments** |
|  |  |

## 2.11 Multi-Carrier Operations

* From [13]:
  + Proposal 13: Multi-carrier operation (carrier aggregation and bonding) can be considered to achieve a wider bandwidth, e.g. 2.16 GHz if it should be supported.
* From [14]:
  + For operation in the 52.6 – 71 GHz band, it is beneficial to support both single and multi-carrier operation to achieve wideband operation as is already supported in Rel-15/16. The maximum carrier bandwidth still requires further discussion.
* From [15]:
  + Proposal #10: Consider carrier-group based operation for NR unlicensed band in frequency range above 52.6 GHz, with consideration of multi-RAT coexistence as well as control signalling efficiency.
* From [24]:
  + Proposal 4. The signaling overhead for scheduling large number of aggregated carriers should be studied for NR operation from 52.6 to 71 GHz.

##### Moderator Summary:

* Some discussion on multi-carrier operations is entangled with supported system bandwidth aspects.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | Support multi-carrier operation for wider bandwidth |

## 2.12 Beam Management

### 2.12.1 Beam Management

* From [7]:
  + Observation 9: Due to the narrow beamwidth in higher frequencies, UE may experience reliability issue to recover dynamic blockage via the existing BFR operation.
  + Proposal 12: Enhanced BFR operation to provide better reliability and efficiency should be studied for higher frequencies.
* From [10]:
  + Proposal 22: Consider potential enhancements for SR, CG-PUSCH and GC-PDCCH spatial relation updating mechanisms.
  + Proposal 28: If new subcarrier spacing is introduced the UE shall provide timeDurationForQCL for that subcarrier spacing.
* From [14]:
  + Capture the following text in TR 38.808: For operation in the 52.6 – 71 GHz band, due to the large number of beams expected to be used, it is beneficial to enhance triggering of aperiodic CSI-RS and SRS resources to support flexible multi-slot triggering with a single DCI.
* From [15]:
  + Proposal #9: Study potential enhancements for beam management CSI-RS or SRS considering beam switching time and coverage loss for large SCS.
* From [21]:
  + Proposal 16: Support multiple non-periodic A-CSI-RS to mitigate the problem of LBT failure or allow for gNB scheduling flexibility in BFD.
  + Proposal 17: Support modification of the hypothetical PDCCH used in BFD in the case that the RS for BFD is not sent by the gNB.
  + Proposal 18: Support modification of the following capabilities/concepts based on the SCSs selected and the need for symbol level beam switching:
    - BeamSwitchTiming, BeamReportTiming, TimeDurationforQCL, maxNumberRxTxBeamSwitchDL, tdd-MultiDL-UL-SwitchPerSlot, SFI Pattern
* From [23]:
  + Proposal 6: Aperiodic CSI-RS should not be used for BFR purpose.
* From [30]:
  + Proposal 10: RAN1 shall consider the beam adjustment mechanism in initial access procedure to alleviate the beam alignment delay.
* From [31]:
  + Observation 10: SSB beam may not be narrow enough for subsequent transmissions considering large propagation loss.
  + Proposal 8: Coverage enhancements for transmissions during initial access should be discussed.
  + Proposal 9: BFR procedure enhancement needs to be considered with at least following points
    - The number of candidate beams included in set
    - The minimum time gap to apply new beam configuration after receiving BFR response from gNB
    - Simultaneous update of beam configuration for multiple SCells
    - Monitoring aperiodic transmissions for beam failure detection

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | Balanced coverage between SSB beam and the beam for data transmission should be considered |

### 2.12.2 Beam Switching

* From [2]:
  + Observation 14: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, beam switching issue would appear between the contiguous transmissions (such as SSB beams) since the CP length would not be enough for beam switching, and an extra gap such a might be needed to prevent performance degradation.
  + Proposal 10: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then to allow the beam switching between contiguous transmissions, ECP or a symbol gap could be applied before beam switching, otherwise NCP is applied to all other symbols
  + Observation 15: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17, if higher subcarrier spacings (numerologies) are adopted, then to increase the possibility of periodic RS transmissions for LBT based channel access in unlicensed bands, it is not resource efficient to schedule a burst of resources within RS period
  + Proposal 11: For supporting NR beyond 52.6 GHz with existing waveforms in Rel. 17 in unlicensed bands, if higher subcarrier spacings (numerologies) are adopted and directional LBT is supported, then potential enhancements related to periodic transmissions of RS such as periodic/semi-persistent CSI-RS should be considered to deal with LBT failure:
    - RAN1 could study on the potential dynamic switching of beam for periodic RS transmission on same time-frequency resources after consecutive LBT failures on one of the configured beams
* From [10]:
  + Proposal 27: No beam switching gap handling is needed for the signals and channels for which 960 kHz or lower subcarrier spacing is applied.
  + Proposal 29: If new subcarrier spacing is introduced the UE shall provide beamSwitchTiming for the A-CSI-RS triggering for that subcarrier spacing.
* From [14]:
  + Capture the following text in TR 38.808: For operation in the 52.6 – 71 GHz band, Rel-15/16 already supports functionality to configure gaps between CSI-RS and SRS resources for beam management. Furthermore, for SCS <= 480 kHz, the CP duration is sufficient for beam switching which typically requires < 100 ns.
* From [31]:
  + Proposal 11: Whether to introduce beam switching gap (i.e., whether guard period is necessary for beam switching between transmissions/receptions with different beam directions) should be discussed for potential high SCS.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
| Futurewei | For lower SCS of 240 kHz beam switching gap is not necessary |

## 2.13 Issues with RF impairments

* From [5]:
  + Observation 8: The impact of I/Q imbalance needs to be evaluated by RAN4 to decide whether it is necessary to consider additional design on standard to mitigate the side effect.
  + Observation 9: The PA model for frequencies above 52.6GHz and the PAPR performance need further evaluation by RAN4 to decide whether it is necessary to consider additional design on standard to mitigate the side effect.
* From [10]:
  + Proposal 12: Send an LS to RAN4 on updating the MIMO TAE minimum requirements.
* From [14]:
  + Capture the following in TR 38.808: Link evaluation based on phase model Ex 2, with characteristics not reflecting realistic devices or current state of the technology, can lead to pessimistic assessment of smaller sub-carrier spacings. It is important for 3GPP to adopt more suitable phase noise models in the discussion and system designs for NR operation in 52.7 – 71 GHz range.

##### Company Comments:

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| --- | --- |
| **Company** | **Comments** |
|  |  |

# Summary of Conclusions

To be filled once agreements/conclusions are made in RAN1.

# Reference

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2. R1-2007558, “Discussion on physical layer impacts for NR beyond 52.6 GHz,” Lenovo, Motorola Mobility
3. R1-2007604, “PHY design in 52.6-71 GHz using NR waveform,” Huawei, HiSilicon
4. R1-2007642, “Physical layer design for NR 52.6-71GHz,” Beijing Xiaomi Software Tech
5. R1-2007652, “Discussion on requried changes to NR using existing DL/UL NR waveform,” vivo
6. R1-2007785, “Consideration on required changes to NR using existing NR waveform,” Fujitsu
7. R1-2007790, “Consideration on supporting above 52.6GHz in NR,” InterDigital, Inc.
8. R1-2007847, “System Analysis of NR opration in 52.6 to 71 GHz,” CATT
9. R1-2007883, “Required changes to NR using existing DL/UL NR waveform,” TCL Communication Ltd.
10. R1-2007926, “Required changes to NR using existing DL/UL NR waveform,” Nokia, Nokia Shanghai Bell
11. R1-2007929, “On phase noise compensation for NR from 52.6GHz to 71GHz,” Mitsubishi Electric RCE
12. R1-2007941, “Discussion on Required Changes to NR in 52.6 – 71 GHz,” Intel Corporation
13. R1-2007965, “On the required changes to NR for above 52.6GHz,” ZTE, Sanechips
14. R1-2007982, “On NR operations in 52.6 to 71 GHz,” Ericsson
15. R1-2008045, “Consideration on required physical layer changes to support NR above 52.6 GHz,” LG Electronics
16. R1-2008076, “Discussion on required changes to NR using existing DL/UL NR waveform in 52.6GHz ~ 71GHz,” CMCC
17. R1-2008082, “Study on the numerology to support 52.6 GHz to 71GHz,” NEC
18. R1-2008156, “Design aspects for extending NR to up to 71 GHz,” Samsung
19. R1-2008250, “Discusson on required changes to NR using DL/UL NR waveform,” OPPO
20. R1-2008353, “Considerations on required changes to NR from 52.6 GHz to 71 GHz,” Sony
21. R1-2008457, “A Discussion on Physical Layer Design for NR above 52.6GHz,” Apple
22. R1-2008493, “Discussions on required changes on supporting NR from 52.6GHz to 71 GHz,” CAICT
23. R1-2008501, “On required changes to NR using existing DL/UL NR waveform for operation in 60GHz band,” MediaTek Inc.
24. R1-2008516, “On NR operation between 52.6 GHz and 71 GHz,” Convida Wireless
25. R1-2008547, “Evaluation Methodology and Required Changes on NR from 52.6 to 71 GHz,” NTT DOCOMO, INC.
26. R1-2008615, “NR using existing DL-UL NR waveform to support operation between 52p6 GHz and 71 GHz,” Qualcomm Incorporated
27. R1-2008726, “Discussion on physical layer aspects for NR beyond 52.6GHz,” WILUS Inc.
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29. R1-2008805, “Discussion on Required Changes to NR in 52.6 – 71 GHz,” Intel Corporation
30. R1-2008872, “Design aspects for extending NR to up to 71 GHz,” Samsung
31. R1-2009062, “Evaluation Methodology and Required Changes on NR from 52.6 to 71 GHz,” NTT DOCOMO, INC.
32. R1-2009313, “Issue Summary for physical layer changes for supporting NR from 52.6 GHz to 71 GHz,” Moderator (Intel Corporation)