**3GPP TSG RAN WG1 Meeting #104-e R1-2101827**

**e-Meeting, January 25 – February 05, 2020**

**Source: Moderator (Intel Corporation)**

**Title: Summary #1 of email discussion on initial access aspect of NR extension up to 71 GHz**

**Agenda item: 8.2.1**

**Document for: Discussion/Decision**

# Introduction

In this contribution, we summarize all issues submitted on initial access aspects for NR extension up to 71 GHz for RAN1 #104-e meeting. Section 2 contain a summary of issues identified from contributions submitted to RAN1 #104-e [1] ~ [27]. The list of issues in Section 2 are **not** ordered in terms of discussion priority. Section 3 contains list of conclusions/agreements proposed by the moderator based on discussions. Section 4 contains list of conclusions and agreements made in RAN1 #104-e. Please note the conclusions and agreements listed in Section 4 may not be the full list as moderator is updating the list as meeting progresses.

# Summary of Issues and Discussions

## 2.1 SSB Aspects

### 2.1.1 DRS Related Aspects (including potential use of Short Signal Exemption for SSB)

* From [1] FUTUREWEI:
	+ In 60 GHz shared spectrum, support SS/PBCH across discovery burst transmission windows that are quasi co-located with respect to average gain, QCL-Type A, and QCL-Type D properties.
* From [3] ZTE, Sanechips:
	+ More than 64 candidate SSBs can be defined in a half-frame for Rel-17 NR above 52.6 GHz.



* From [4] OPPO:
	+ For above 52.6GH unlicensed spectrum, introduce SSB candidate positions to allow more SSB transmission occasions for a given SSB beam or to allow SSB beam repetitions.
* From [5] Huawei, HiSilicon:
	+ For unlicensed operation in 52.6GHz to 71GHz, support LBT before SSB transmission and reuse the concept of discovery burst window from Rel-16 NR-U.
* From [8] CATT:
	+ For NR operation in unlicensed spectrum in 52.6-71 GHz, the principle of transmission window defined in Rel-16 NR-U is supported.
	+ 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.
* From [12] Intel:
	+ Observation: For 120 kHz SCS SSB, transmission of 64 SSB with 20 msec SSB periodicity exceed 10 msec transmission duration within a 100 msec observation period required for short control signal exemption. For 480 kHz SCS SSB, transmission of 64 SSB and 64 Type0-PDCCH with associated PDSCH with 20 msec SSB periodicity exceed 10 msec transmission duration within a 100 msec observation period required for short control signal exemption. For 960 kHz SCS SSB, transmission of 64 SSB and 64 Type0-PDCCH with associated PDSCH with 20 msec SSB periodicity does not exceed 10 msec transmission duration within a 100 msec observation period required for short control signal exemption.
	+ While SSB may be considered as a candidate for short control signal exemption, RAN1 specification shall support operations of SSB transmission with LBT (at the gNB) at least for 120 kHz SSB.
		- For 480 kHz and 960 kHz SSB, also support operations of SSB transmission with LBT (at the gNB) for commonality with 120 kHz SSB
* From [15] Spreadtrum:
	+ The initial access mechanisms for R16 NR-U can be further adapted for high frequency, e.g., to support up to 64 SSB beams.
* From [18] NEC:
	+ With respect to the 120 kHz SCS SSB pattern for LBT mode operation, CORESET and PDSCH related to SIB1 should be multiplexed with SSB to guarantee the absence of any gaps greater than 16us in the discovery burst set.
* From [20] Samsung:
	+ Discovery burst transmission window should be supported for 60 GHz unlicensed band.
* From [22] Ericsson:
	+ Consistent with EN 302 567, when operating in LBT mode a node can access the channel without LBT for control signal/channel transmissions, the total duration of which shall not exceed 10ms within an observation period of 100ms. The following signals/channels shall be classified as Short control signaling transmissions:
		- SS/PBCH blocks
		- PRACH
		- FFS: Other control transmissions not multiplexed with user data (subject to gNB configuration)
	+ Observation: It is not necessary to optimize the SS/PBCH transmission/reception mechanism by introducing a transmission window, especially since SS/PBCH blocks can be classified as short control signaling transmissions consistent with EN 302 567.
* From [24] Convida:
	+ Increasing the number of SSB candidate positions to above 64 to increase transmission opportunities to cope with LBT failure should be considered.

**Summary of Discussions in Tdoc**

* Discussion on DRS window to cope with LBT failure is supported or not. If supported, the details of the DRS.
	+ Majority of the companies seems to propose support of DRS like windows and corresponding SSB candidate positions similar to NR-U
		- FUTUREWEI, ZTE, Sanechips, OPPO, Huawei, HiSilicon, CATT, Intel, Spreadtrum, Samsung, Convida
	+ Some companies suggested that DRS like operation is not necessary for SSB as short signal exemption (defined in EN 302 567) could be applied.
		- Ericsson

**Summary of Email Discussions**

* Please provide further views on whether DRS window (to cope with LBT failure) should be supported. Also provide further comments on related issues to DRS.

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| --- | --- | --- |
| **Company** | **Support DRS (similar to Rel-16 NR-U)?** | **Discussions/Comments** |
| Samsung | Yes | There is always scenario where short control signal is not applicable, e.g. for the region where regulation doesn’t define short control signal, or for the condition (duty cycle) short control signal is not satisfied. Hence, the SSB transmission subject to LBT always happens, then it’s natural to reuse NR-U DBTW for such cases.  |
| NEC | Yes | The DRS window with necessary modification should be supported as a mechanism to improve the SSB transmission performance for LBT mode operation. Discovery burst transmission may not always meet the restrictions of short control signal. |
| ZTE, Sanechips | Yes | Short control signalling has strict usage requirements. No matter for SSB or DRS including SSB and CORESET#0/RMSI, their transmission time in a periodicity of 100 ms may exceed 10 ms. In such cases, LBT could be used. Thus we support to define DRS window and more candidate SSB positions to increase the opportunities for SSB/DRS. |
| DOCOMO | Yes | We agree to support DRS window to cope with LBT failure. We also see the scenario where short control signal is not applicable while LBT is necessary prior to the transmission. For example, regulation in Japan require LBT before transmissions with transmission power larger than a certain threshold. In other words, there is a case where SSB transmission is subject to LBT. Ok to reuse the one specified in Rel-16 NR-U.  |
| LG Electronics | Yes | For the scenario whether LBT is required for SSB transmission, it would be beneficial to provide more opportunities for SSB to cope with LBT failure. |
| Spreadtrum | Yes |  |
| vivo | Yes | We agree to support DRS window to cope with possible LBT failure if it is needed. |

### 2.1.2 Supported Numerology

* From [2] Lenovo, Motorola Mobility:
	+ For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, support the same numerology of data channel for SSB and PRACH including 480KHz and 960KHz
* From [3] ZTE, Sanechips:
	+ The following options can be considered for determining SCSs of SSB and other initial access signals/channels in initial BWP, wherein Option 1 is preferred.
		- Option 1: both SSB and other initial access signals/channels support SCS (120kHz, 480kHz, 960kHz)
		- Option 2: SSB supports SCS (120kHz, 240kHz); Other initial access signals/channels support SCS (120kHz)
* From [4] OPPO:
	+ For above 52.6GHz, adopt single numerology for initial access, where the numerology candidates are 120kHz, 480kHz and 960kHz.
	+ For above 52.6GHz, 240kHz SSB SCS is not supported.
* From [5] Huawei, HiSilicon:
	+ SCS other than 120 kHz are not supported for SSB and other initial access related signals/channels in initial BWP.
* From [6] Nokia, NSB:
	+ Support 240 kHz SCS for the SSB transmission in NR bands ranging between 52.6 GHz to 71 GHz.
	+ Observation: Supporting 480kHz and 960kHz sub-carrier spacings for SSB can have implications to initial cell search/selection complexity, UE minimum initial RF BW and possibly to synchronisation raster, depending on the minimum carrier BW.
	+ Consider and discuss of support of 480kHz and 960kHz kHz SCS for the SSB transmission in NR bands ranging between 52.6 GHz to 71 GHz.
	+ Observation: It would appear that 480 and 960 kHz cannot be used for initial access related data and control channels in initial BWP for IDLE and Inactive Mode UEs.
	+ Support additional SCS (480 kHz, 960 kHz) for SSB for other use cases than initial cell selection (e.g. for Scell, BM and RRM).
* From [7] CAICT:
	+ SSB design with 480 and 960kHz SCS should be considered.
* From [8] CATT:
	+ The complexity or performance degradation will be introduced if 960 KHz is used for the SCS of SSB.
* From [9] vivo:
	+ Observation: All supported SCS for data/control SCS in FR2 could be used for initial DL BWP.
	+ Support SCS 120KHz, 480KHz and 960KHz for initial DL BWP in NR operation from 52.6-71GHz.
	+ Support the following SCS pairs for SSB and initial DL BWP in NR operation from 52.6-71GHz：(120K, 120K) + (960K, 480K) + (960K, 960K).
	+ Observation: 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. 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).
* From [10] TCL:
	+ Introduce groups of SCS in FR2 and all control/data communication will use the SCS from one such group.
* From [11] MediaTek:
	+ Support only 120 kHz for SSB SCS in initial access.
* From [12] Intel:
	+ Support 480 kHz and 960 kHz SCS for SSB and initial BWP.
* From [13] Fujitsu:
	+ Do not support 240kHz for SSB for the new frequency range (52.6~71GHz).
	+ In addition to 120kHz, support 480 kHz and 960 kHz for SSB at least for the cases other than initial access.
* From [15] Spreadtrum:
	+ Support 120kHz SCS for SSB and initial BWP.
	+ Support 240kHz SCS for SSB.
* From [17] LGE:
	+ Support 240 kHz SCS for SS/PBCH block in frequency range from 52.6 GHz to 71 GHz.
	+ For SS/PBCH block with 480 and/or 960 kHz SCS, the following three alternatives can be taken into account and Alt 3 is preferred considering no specification impact and CSI-RS as an alternative of SS/PBCH block in most use cases.
		- Alt 1: Support SS/PBCH block with 480 and/or 960 kHz SCS for all cases
		- Alt 2: Support SS/PBCH block with 480 and/or 960 kHz SCS for cases other than initial access
		- Alt 3: Do not support SS/PBCH block with 480 and/or 960 kHz SCS for any case
* From [20] Samsung:
	+ Support 480 kHz SCS and 960 kHz SCS for SS/PBCH block after initial access.
* From [22] Ericsson:
	+ Like in Rel-15/16 FR2, for initial access (PCell), support 240 kHz SCS for SS/PBCH block in an initial BWP (in addition to the already supported 120 kHz) and 120 kHz SCS for initial access related signals/channels in an initial BWP.
	+ For cases other than initial access (e.g. for an SCell), support 480 and 960 kHz SCS for SS/PBCH block.
* From [23] Apple:
	+ Support 480kHz SCS for SSB and PRACH in addition to 120kHz SCS for initial access in an initial BWP.
* From [24] Convida:
	+ The support of SSB and SSB burst design for higher SCS like 480 KHz and above should be studied for NR operation from 52.6 to 71 GHz.
* From [25] Qualcomm:
	+ Observation:
		- increasing the SSB SCS will have an effect on the UE initial search complexity which will depend on multiple factors including the number of frequency bins needed and the number of correlations in time. the effect of the initial search timing resolution (for different SSB SCSs) on the performance of channels with high SCS (480 and 960 kHz) needs to be studied
		- larger SSB SCS causes less time domain blockages to other channels
		- explicit beam switching gap between SSBs may be required for larger SSB SCS
		- for NSA mode, increasing the SCS for the SSB may have a different effect on the UE search complexity compared to SA mode
	+ for the SSB for NR operation in the frequency between 52.6GHz and 71GHz:
		- Use SCS = 120 kHz and 240 kHz for SA mode
			* FFS for 480 kHz and 960 kHz
		- Use SCS = 120 kHz, 240 kHz, 480 kHz, and 960 kHz for NSA mode
* From [26] NTT Docomo:
	+ Observation: For SSB, all the candidate SCSs, i.e., from 120 kHz to 960 kHz, would be available in terms of detection/BLER performance.
		- Lower SCS may be slightly better
	+ For SSB SCS, in addition to 120 kHz,
		- 480 and 960 kHz SCS should be supported to achieve single numerology at least for non-initial access cases.
		- FFS: which SSB SCS(s) is assumed for initial access in each band in 52.6 – 71 GHz

**Summary of Discussions in Tdoc**

* Various views on which SCS should be supported for SSB (in addition to 120 kHz)
	+ No other SCS:
		- Huawei, HiSilicon, MediaTek
	+ 240 kHz:
		- Nokia, Spreadstrum, LGE, Ericsson, Qualcomm
	+ 480 kHz:
		- Lenovo, Motorola Mobility, ZTE, Sanechips, OPPO, CAICT, Intel, Fujitsu, Samsung, Ericsson (for SCell only), Apple, Convida(?), Qualcomm (for non-initial access) , NTT Docomo (for non-initial access)
	+ 960 kHz
		- Lenovo, Motorola Mobility, ZTE, Sanechips, OPPO, CAICT, vivo, Intel, Fujitsu, Samsung, Ericsson (for SCell only), Qualcomm (for non-initial access), NTT Docomo (for non-initial access)
* Discuss further on the supported SCS and applicable scenarios (e.g. initial access, non-initial access, PCell, SCell)

**Summary of Email Discussions**

* Please provide further views on supported SCS for SSB and applicable scenarios (e.g. initial access, non-initial access, SCell only, etc).
* Please directly edit the summary of the views below (if there are any errors or require clarifications)
	+ No other SCS:
		- Huawei, HiSilicon, MediaTek
	+ 240 kHz:
		- Nokia, Spreadstrum, LGE, Ericsson, Qualcomm
	+ 480 kHz:
		- Lenovo, Motorola Mobility, ZTE, Sanechips, OPPO, CAICT, Intel, Fujitsu, Samsung, Ericsson (for SCell only), Apple, Convida(?), Qualcomm (for non-initial access) , NTT Docomo (for non-initial access)
	+ 960 kHz
		- Lenovo, Motorola Mobility, ZTE, Sanechips, OPPO, CAICT, vivo, Intel, Fujitsu, Samsung, Ericsson (for SCell only), Qualcomm (for non-initial access), NTT Docomo (for non-initial access)

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| --- | --- |
| **Company** | **Additional Discussions/Comments** |
| Samsung | Support for 480/960 kHz for non-initial access case, and open to 240/480/960 for initial access case, if the UE complexity can be limited. The discussion of SCS for initial access should take into account the sync raster design in RAN4.  |
| NEC | Support 480 and 960 kHz SCSs for non-initial access case and initial access case. |
| ZTE, Sanechips | Support SCS 480/960 kHz for operating with single numerology, to achievie required time synchronization accuracy and reduced synchronization complexity. |
| DOCOMO | As captured by the moderator above, we support 480/960 kHz for non-initial access case. For initial access, we are also open to 240/480/960 kHz, while we slightly prefer to deprioritize 240 kHz as the advantage seems small and the number of supported SCSs should be minimized in our view. As Samsung mentioned above, we should consider factors related to RAN4, including sync raster design and minimum channel bandwidth.  |
| LG Electronics | It is confirmed that our views are correctly captured. From our understanding, the main motivation to introduce new SCS(s) for SSB is to provide a tool for a UE to be operated with single numerology as much as possible. However, as described in our Tdoc [17], CSI-RS having the same numerology with the SCS configured for the active BWP can be considered as an alternative of SSB for most use cases. |
| Spreadtrum | The SSB with 480 and 960kHz SCS could be supported for measurement to reduce UE complexity when UE is receiving data with 480 and 960kHz SCS. For CSI-RS based measurement, in our view, CSI-RS validation is not well supported in NR-U. |
| vivo | Support at least one of 480/960KHz SCS for SSB in non-initial access case and initial access case.Support for 480/960KHz for non-initial access case is needed due to single numerology, measurement complexity, time synchronization accuracy and complexity, as mentioned above.For initial access, we need to determine supported numerology for initial DL BWP first as described in 2.1.4. When looking at FR1&FR2, the SCS for data/control in normal BWP is both supported for initial DL BWP, e.g. 60K/120K in FR2. The benefit is to avoid BWP switching for UE operation. Following this, 480K/960K should be supported for initial DL BWP. If this is the case and only allows 120K SSB for initial access, it will occur (120K, 480K) and (120K, 960K) combination with mixed numerology, which will result in problems such as K\_offset indication, time synchronization accuracy and etc. So it is better to support at least 960K SSB to avoid these problems. |

### 2.1.3 Mixed Numerology between SSB and CORESET#0

* From [1] FUTUREWEI:
	+ The SCS for all SS/PBCH blocks and CORESET #0 on a carrier is always the same for operation in 60GHz shared spectrum.
* From [3] ZTE, Sanechips:
	+ The following multiplexing patterns and combinations of SCSs of SSB and Type0-PDCCH can be considered for Rel-17 NR above 52.6 GHz.
		- (SSB, Type0-PDCCH): SCS (120 kHz, 120 kHz)
			* Multiplexing patterns: 1, 3
		- (SSB, Type0-PDCCH): SCS (480 kHz, 480 kHz)
			* Multiplexing patterns: 1, 3
		- (SSB, Type0-PDCCH): SCS (960 kHz, 960 kHz)
			* Multiplexing patterns: 1, 3
* From [7] CAICT:
	+ In order to match different SCS, different initial BWP should be considered.
* From [9] vivo:
	+ Support the following SCS pairs for SSB and initial DL BWP in NR operation from 52.6-71GHz：(120K, 120K) + (960K, 480K) + (960K, 960K).
* From [12] Intel:
	+ Observation: Single numerology operation can enable efficient transceiver implementation and operation.
* From [14] AT&T:
	+ The same subcarrier spacings are specified for initial access related signals and channels in the initial BWP and cases other than initial access.
* From [25] Qualcomm:
	+ consider the following SSB and CORESET0 SCS combinations:
		- SSB SCS = 120 kHz, CORESET0 SCS = 120, 480, 960 kHz
		- SSB SCS = 240 kHz, CORESET0 SCS = 120 kHz
		- SSB SCS = 480/960 kHz, CORESET0 SCS = SSB SCS

Table : Allowed SSB/CORESET0 SCS Combinations

|  |  |
| --- | --- |
| **SSB SCS (kHz)**  | **CORESET0 SCS (kHz)** |
| **120** | **480** | **960** |
| **120** | Yes | Yes | Yes |
| **240** | Yes | No | No |
| **480** | No | Yes | No |
| **960** | No | No | Yes |

**Summary of Discussions in Tdoc**

* Various views on which SCS combinations of SSB and CORESET#0 (initial DL BWP)
	+ Some companies explicitly listed the SCS combinations for SSB and CORESET#0
		- (SSB 120kHz, CORESET#0 120kHz)
		- (SSB 120kHz, CORESET#0 480kHz)
		- (SSB 120kHz, CORESET#0 960kHz)
		- (SSB 480kHz, CORESET#0 480kHz)
		- (SSB 960kHz, CORESET#0 960kHz)
		- (SSB 960kHz, CORESET#0 480kHz)
		- (SSB 960kHz, CORESET#0 960kHz)
* Suggest to discuss further the supported SCS combination of SSB and CORESET#0 (initial DL BWP)

**Summary of Email Discussions**

* Please provide further views on supported SCS combination for SSB and COERSET#0.

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| **Company** | **Discussions/Comments** |
| Samsung | At least same SCS between SSB and CORESET#0 should be supported and prioritized. Mixed SCS can be evaluated further based on the need.  |
| NEC | Support the same SCS for SSB and CORESET#0 as a baseline, and open to the other SCS combination(s). |
| ZTE, Sanechips | Same SCS for SSB and CORESET#0 should be supported to reduce the complexity of multiplexing and indication of the SCS of CORESET#0, etc. The following three SCS pairs for SSB and CORESET#0 can be considered.* + - (SSB 120kHz, CORESET#0 120kHz)
		- (SSB 480kHz, CORESET#0 480kHz)
		- (SSB 960kHz, CORESET#0 960kHz)
 |
| DOCOMO | We agree same SCS between SSB and CORESET#0 should be supported and prioritized. After that, for mixed SCS, (SSB 120kHz, CORESET#0 480/960kHz) should be discussed at first. We do not see the motivation to support (SSB 480kHz, CORESET#0 120kHz) and (SSB 960kHz, CORESET#0 120/480kHz) |
| LG Electronics | Before discussing multiplexing between SSB and CORESET#0, we should first discuss whether new SCS for SSB/CORESET#0 during initial access is supported or not. If new SCS for SSB/CORESET#0 during initial access is not supported, the current specification would suffice. |
| Spreadtrum  | Qualcomm’s table could be starting point of discussion. |
| vivo | Down selection of the above combinations is needed. The comparison could be based on complexity, spec impact, synchronization accuracy and etc. |

### 2.1.4 Initial Access Support for additional Numerologies

* From [2] Lenovo, Motorola Mobility:
	+ For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, if higher subcarrier spacings (numerologies) are adopted for initial access, new CORESET0 mapping structures should be investigated
* From [6] Nokia, NSB:
	+ Support additional SCS (480 kHz, 960 kHz) for SSB for other use cases than initial cell selection (e.g. for Scell, BM and RRM).
* From [13] Fujitsu:
	+ 480kHz and/or 960kHz SCS for initial BWP can be supported only if 480kHz and/or 960kHz SCS is supported for SSB for initial access.
* From [14] AT&T:
	+ Specify one additional SCS (either 480kHz or 960kHz) for initial access related signals and channels in the initial BWP
* From [16] InterDigital:
	+ Observation: A single numerology operation is beneficial and NR in 52.6 – 71 GHz already supports a single numerology operation with existing SCS. It’s possible to support a single numerology operation with 120 kHz for UE which wants to avoid frequency numerology change and corresponding complex UE implementation while other UE, which is ready to support additional SCSs and numerology changes, achieves performance benefits with relatively complex UE implementation. Designing new SSBs and initial access related signals/channels for additional SCSs may require a lot of evaluations and corresponding discussions under the limited TUs for the WI.
	+ Further study necessity of SSBs and initial access related signals/channels for additional SCSs in Rel-17.
* From [20] Samsung:
	+ Whether extra SCS can be supported for SS/PBCH block in initial access depends on the synchronization raster interval.
		- If any of 480 kHz or 960 kHz SCS is supported as default SCS of SS/PBCH block in initial access, the CORESET#0 configuration corresponding to the same SCS as SS/PBCH block should be supported.
* From [22] Ericsson:
	+ For cases other than initial access (e.g. for an SCell), support 480 and 960 kHz SCS for SS/PBCH block.
	+ Observation: For basic SCell operation, two of the spare bits in IE SubcarrierSpacing can be used to indicate either 480 or 960 kHz SCS for a non-initial BWP via dedicated signaling.

**Summary of Discussions in Tdoc**

* Several companies has discussed whether specific SSB SCS could be used for initial access or whether they should be strictly used only for Scell or non-initial cell selection cases. Some examples of expressed views:
	+ 480/960 kHz SSB used for other than initial cell selection:
		- Nokia, NSB, Ericsson
	+ 480/960 kHz SSB used for initial access:
		- * AT&T, Samsung
* Suggest to discuss together with supported numerology (2.1.2).

**Summary of Email Discussions**

* Please provide further comments in Section 2.1.2

### 2.1.5 SSB Resource Pattern

* From [1] FUTUREWEI:
	+ For 60GHz shared spectrum, consider the support of 120kHz SCS for SS/PBCH (Case D) with necessary changes for LBT opportunities between consecutive SS/PBCH blocks.
* From [2] Lenovo, Motorola Mobility:
	+ Observation: For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, if higher subcarrier spacings (numerologies) are adopted for SSB, beam switching issue would appear between the contiguous SSB beams since the CP length would not be enough for beam switching, and an extra gap might be needed to prevent performance degradation.
	+ For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, if higher subcarrier spacings (numerologies) are adopted for SSB, then to allow the beam switching between contiguous SSBs, a gap (for example a symbol gap or post prefix) should be supported before beam switching.
* From [3] ZTE, Sanechips:
	+ For designing SSB patterns with different SCSs for NR operation above 52.6 GHz, it is proposed to reuse the existing design (i.e. Case A/C, Case B/D and Case E) as much as possible, and take different impacts in single/mixed numerology operation into account.
	+ The following options can be considered for supporting beam switching for SSB with SCS 480 kHz and 960 kHz.
		- Option 1: In a half-frame, any two candidate SSBs are discontinuous in the time domain
			* Option 1-1: SSB pattern with SCS 480/960 kHz can adopt the existing pattern of Case A and Case C in one or two slots defined in Rel-15 NR
			* Option 1-2: SSB pattern with SCS 480/960 kHz should be re-designed to reserve at least one symbol between any two candidate SSBs, e.g. only defining one candidate SSB per slot
		- Option 2: Multiple adjacent candidate SSBs are defined to have a same SSB index or QCL assumption
* From [5] Huawei, HiSilicon:
	+ Reuse SSB pattern case D for 120 kHz SCS without change at least for licensed operation.
* From [7] CAICT:
	+ For the SSB design of 120kHz SCS, the distribution of SSB in each slot could be enhanced.
* From [9] vivo:
	+ Observation: No additional gap can considered to accommodate beam switching gap if 120 KHz/240 KHz/480KHz SCS s are used for NR operation up to 71GHz.
* From [10] TCL:
	+ FR2 existing SCS and new numerologies can provide a large number of potential SS/PBCH candidate positions to combat channel uncertainty issues.
	+ 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 [12] Intel:
	+ Same SSB pattern and Type0-PDCCH CSS configuration to be applicable to 480 kHz and 960 kHz with numerology scaling.
	+ Consider 480 kHz and 960kHz SCS based SSB positions in a slot with SSB symbols 2, 3, 4, 5 and 9, 10, 11, 12 in a slot.
		- Note: symbols numbers are enumerated from 0.
* From [19] Xiaomi:
	+ Observation: For 120k SCS SSB pattern, there is no candidate SSB positions in 5ms window.
	+ At least one SCS beyond 120 kHz should be supported for SSB for initial access and its pattern need update.
* From [20] Samsung:
	+ Support new SS/PBCH block pattern for 480 kHz and 960 kHz SCSs.
		- At least one symbol should be reserved between neighboring SS/PBCH block for beam sweeping delay.
		- Symbols should be reserved for CORESET and HARQ with same SCS as SS/PBCH block.
* From [21] CEWiT:
	+ Observation: At least for 120KHz SCS, existing SSB design can be reused for NR above 52.6GHz
	+ Support for a new SSB design to accommodate more number of SSB beams in the 5ms window and also to accommodate beam switching gap.
	+ 120KHz and one among 480KHz and 960KHz should be supported for SSB transmission in NR above 52.6GHz
* From [22] Ericsson:
	+ Discuss and agree on design principles for defining SSB time domain patterns for 480 and 960 kHz SCS, including whether or not it is needed to include short gaps for beam switching (e.g., 1 OFDM symbol) and/or long gaps (e.g., 2 slots) to allow for UL transmissions.
	+ Use SSB time domain patterns for 120 and 240 kHz SCS as defined for FR2 as a starting point for the design.
* From [23] Apple:
	+ Extending the current 120kHz SCS SSB pattern for 480KHz SCS such that PUCCH occasion(s) can be reserved after two consecutive SSBs.

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* From [25] Qualcomm:
	+ Observation:
		- to accommodate explicit SSB beam switching gaps, a new SSB pattern may be required for larger SSB SCS (SCS = 480 kHz and 960 kHz)
		- a symbol-level (1 symbol) SSB beam switching gap may be required for larger SSB SCS (SCS = 480 kHz and 960 kHz)
		- for larger SSB SCS (480 kHz and 960 kHz), accommodating UL segments within the SSB burst may require accounting for DL/UL switching delays taking considerable number of symbols (possibly slot-level)
	+ for the SSB for NR operation in the frequency between 52.6GHz and 71GHz and SCS = 480 kHz and 960 kHz, consider defining an SSB pattern consisting of multiple “SSB slots” where SSB symbols for one or more beams are contained in the “SSB slot”
		- A beam switching gap of 1 symbol is inserted between SSBs within the “SSB slot”
		- Additional control symbols may be defined in the SSB slots with beam switching gaps between control and SSB symbols of different beams
		- Additional “gap slots” may be inserted between “SSB slots” to account for URLLC and UL traffic





* From [26] NTT Docomo:
	+ When new SCSs are supported for SSB, the two alternatives below can be considered for SSB mapping in time domain:
		- Two SSBs per slot, with guard period of at least 1 symbol between the SSBs
		- One SSB per slot
* From [27] WILUS:
	+ 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., 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.

**Summary of Discussions in Tdoc**

* For the not yet specified SSB SCS (i.e. 480 and 960 kHz), several companies provided proposals on which OFDM symbols and slots the SSB should be mapped on.
* For 120 kHz SSB SCS, few companies suggested to update the SSB pattern (OFDM symbols and slots SSB is defined for).
* Suggest to discuss first supported SSB numerology. For the agreed SSB numerology, e.g. 120 kHz, suggest to discuss SSB resource patterns (including whether existing pattern should be applicable).

**Summary of Email Discussions**

* While moderator suggest to first discuss SSB numerology, companies are encourage to provide additional discussions to SSB pattern for the (potentially) supported SSB SCS, including whether 120 kHz SSB pattern (OFDM symbol, slot placement) could be used as is or further update is needed.
* For issues related to SSB pattern update due to support of DRS, please provide comments in 2.1.1 to keep the relevant discussions in the same section.

|  |  |
| --- | --- |
| **Company** | **Discussions/Comments** |
| Samsung | If 480/960 kHz is supported for SSB, the corresponding SSB pattern should reserve 1 symbol between neighboring SSB for beam sweeping gap.  |
| NEC | Support considering the effect of switching time requirement on SSB pattern for 480 and 960kHz SSB SCS. |
| ZTE, Sanechips | We provide several options related to SSB pattern/transmission that can be considered to support beam switching and/or LBT operation.* Option 1: Any two candidate SSBs are discontinuous in the time domain
* Option 1-1: SSB pattern with SCS 480/960 kHz can adopt the existing pattern of Case A and Case C in one or two slots defined in Rel-15 NR
* Option 1-2: SSB pattern with SCS 480/960 kHz should be re-designed to reserve at least one symbol between any two candidate SSBs, e.g. only defining one candidate SSB per slot
* Option 2: Multiple adjacent candidate SSBs are defined to have a same SSB index or QCL assumption

Among above, we think Option 2 is preferred as it has no limitation on SSB pattern design. With it, Case D SSB pattern for 120 kHz can also be reused for 480kHz/960kHz. |
| DOCOMO | We agree with Samsung that beam sweeping gap with at least 1 symbol should be considered for SSB with 480/960 kHz SCS if supported. We also think that how to utilize resources in a SSB slot efficiently should be considered with beam switching gap. To minimize the overhead due to beam switching gap, a different SSB pattern within a slot for new SCSs, e.g., one SSB per slot, can be considered so that SSB/CORESET#0/SIB1 with same beam can be transmitted within a same slot and only one beam sweeping cycle per period can be achieved.  |
| LG Electronics | For 120 kHz SSB which is already agreed to be supported, existing SSB pattern applied for 120 kHz, i.e., Case D, should be reused. |
| vivo | Agree that beam switching gap problem needs to be considered for SSB with 480K/960K SCS. The following alternatives could be considered:* + - 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 TS38.213);
		- Alt. 3: Hopping transmission for contiguous candidate SSBs (e.g. case E in TS38.213).
 |

### 2.1.6 SSB and CORESET#0 Multiplexing

* From [1] FUTUREWEI:
	+ Support a configuration of SS/PBCH and Type-0 PDCCH multiplexed in the same slot using the same QCL.
	+ Support SSB and CORESET#0 multiplexing pattern 1 (different slots), and pattern 3 (same slots).
	+ Support a configuration where the PDSCH scheduled by Type-0 PDCCH can be rate-matched around the corresponding SSBs.
* From [2] Lenovo, Motorola Mobility:
	+ Observation: For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, 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
* From [3] ZTE, Sanechips:
	+ The following multiplexing patterns and combinations of SCSs of SSB and Type0-PDCCH can be considered for Rel-17 NR above 52.6 GHz.
		- (SSB, Type0-PDCCH): SCS (120 kHz, 120 kHz)
			* Multiplexing patterns: 1, 3
		- (SSB, Type0-PDCCH): SCS (480 kHz, 480 kHz)
			* Multiplexing patterns: 1, 3
		- (SSB, Type0-PDCCH): SCS (960 kHz, 960 kHz)
			* Multiplexing patterns: 1, 3
* From [7] CAICT:
	+ At most two SSB and CORESET#0 multiplexing patterns are used for 480 and 960 kHz SCS.
* From [8] CATT:
	+ While 480 kHz and 960 kHz SCS are introduced, the 1bit indication in MIB provides the information ofType0-PDCCH SCS along with the detected SSB SCS in a given band in 52.7 -71 GHz ,
		- Issue on multiplexing pattern type(s) (Pattern 1, 2, and/or 3) for SSB and CORESET#0 multiplexing, and other signals

|  |  |
| --- | --- |
| SCS of SS/PBCH in extended FR2 | Associated Type0-PDCCH SCS in extended FR2 |
| 120KHz  | 120KHz |
| 480KHz |
| 480KHz | 480KHz |
| 960KHz |

* + Patterns 2 and 3 of SSB and CORESET for Type0-PDCCH can multiplex with periodic CSI-RS/paging PDCCH&PDSCH in frequency.
* From [9] vivo:
	+ 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 TS38.213);
		- Alt. 3: Hopping transmission for contiguous candidate SSBs (e.g. case E in TS38.213).
	+ The following SSB-Coreset 0 multiplexing patterns are supported for each SCS pair:
		- (120K, 120K): Pattern 1, Pattern 3
		- (960K, 960K): Pattern 1, Pattern 3
		- (960K, 480K): Pattern 1, Pattern 2
* From [12] Intel:
	+ Consider only SSB and CORESET#0 multiplexing pattern 1 for 480 and 960 kHz SCS.
	+ Type0-PDCCH CSS may utilize symbols {0,1} and {7,8} that correspond to SSB in the first half and second half of the slot.
* From [19] Xiaomi:
	+ Configuration of SSB and CORESET0 multiplexing tables need update to support additional SCS other than 120k for NR from 52.6GHz to 71 GHz.
* From [23] Apple:
	+ SSB and CORESET 0/RMSI PDSCH multiplexing pattern 1 can be considered to increase the allowable RMSI payload size with reasonable coverage.
* From [25] Qualcomm:
	+ consider the following SSB and CORESET0 SCS combinations:
		- SSB SCS = 120 kHz, CORESET0 SCS = 120, 480, 960 kHz
		- SSB SCS = 240 kHz, CORESET0 SCS = 120 kHz
		- SSB SCS = 480/960 kHz, CORESET0 SCS = SSB SCS

Table : Allowed SSB/CORESET0 SCS Combinations

|  |  |
| --- | --- |
| **SSB SCS (kHz)**  | **CORESET0 SCS (kHz)** |
| **120** | **480** | **960** |
| **120** | Yes | Yes | Yes |
| **240** | Yes | No | No |
| **480** | No | Yes | No |
| **960** | No | No | Yes |

* + consider ways to have 1 extra bit to indicate the common SCS in the SSB structure or contents in case more than 2 values for the common SCS are allowed
	+ NR Rel-16 SSB/CORESET0 multiplexing pattern 1 design may be reused with possibly some changes to the table (e.g., the need for < 2.5 ms options for the start of the CORESET0 wrt frame boundary) which depends on the outcome of the SSB pattern design
	+ SSB/CORESET0 multiplexing pattern 2:
		- For the 240 kHz + 120 kHz combination: reuse the same design as in NR Rel-16
		- For the 120 kHz + 480/960 kHz combination: the CORESET0 symbols may be placed in the gap symbols between the SSBs (similar to the existing NR Rel-16 design)



* + NR Rel-16 SSB/CORESET0 multiplexing pattern 3 design may be reused for the valid combinations of 120 + 120 kHz, 480 + 480 kHz, and 960 + 960 kHz.
	+ Consider introducing an SSB/CORESET0 multiplexing pattern for higher SCS SSB (480 and 960 kHz), where a time domain fixed location for the CORESET0 and SIB1 is considered





* + consider introducing an SSB/CORESET0 multiplexing pattern for higher SCS SSB (480 and 960 kHz), where TDM grouping of the SSB and the corresponding CORESET0/SIB1 is considered



* From [26] NTT Docomo:
	+ When new SCS(s) is supported for SSB and a single numerology is used for both SSB and CORESET#0/SIB1, at least TDM between SSB and CORESET#0/SIB1 can be supported.
	+ When lower SCS is used for SSB compared with that used for CORESET#0/SIB1, FDM between SSB and SIB1 PDSCH such as in pattern 2 can be considered.
* From [27] WILUS:
	+ 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.

**Summary of Discussions in Tdoc**

* Several companies discuss the applicability of SSB/Type0-PDCCH multiplexing pattern 1/2/3 for specific SSB SCS
* Suggest to discuss further for each supported SSB/CORESET#0 SCS combination, which Type0-PDCCH multiplexing pattern (1, 2, and/or 3) would be supported.

**Summary of Email Discussions**

* Please provide comments on which Type0-PDCCH multiplexing pattern should be supported for each SSB/CORESET#0 SCS combination.
* Additionally, please provide comments on supported bandwidth/PRB for CORESET#0 and any other issues related with Type0-PDCCH CSS/CORESET#0 configuration.

|  |  |
| --- | --- |
| **Company** | **Discussions/Comments** |
| Samsung | • If synchronization raster interval is larger than FR2, additional CORESET#0 RB offsets are needed for 120 kHz SS/PBCH block SCS;• If 480 kHz and/or 960 kHz SS/PBCH block SCS is supported, at least CORESET#0 configuration table with same SCS as SS/PBCH block should be supported;• If there are reserved configurations, all of multiplexing Pattern 1, Pattern 2 and Pattern 3 can be supported in a CORESET#0 configuration table;• If there are reserved configurations, 96 RB can be added to the CORESET#0 configuration table for 120 kHz SS/PBCH block SCS. |
| ZTE, Sanechips | As commented in 2.1.3, same SCS for SSB and CORESET#0 should be supported to reduce the complexity of multiplexing and indication of the SCS for CORESET#0, etc. Thus, multiplexing pattern 1 and 3 can be considered. In addition, bandwidth/PRB for CORESET#0 also depends on minimum bandwidth, multiplexing pattern and the SCS of SSB and CORESET#0. |
| DOCOMO | At least TDM like pattern should be supported considering the available resource for CORESET#0/SIB1. Even for TDM pattern, beam switching gap overhead should be minimized. For example, TDM between SSB and CORESET#0/SIB1 in the same slot should be considered. FDM like pattern can be considered if mixed numerology between SSB and CORESET#0 is supported, and if minimum channel bandwidth is large enough.  |
| LG Electronics | As we commented in Section 2.1.3, before discussing multiplexing between SSB and CORESET#0, we should first discuss whether new SCS for SSB/CORESET#0 during initial access is supported or not. If new SCS for SSB/CORESET#0 during initial access is not supported, the current specification would suffice. |
| vivo | The multiplexing pattern should be discussed after the SCS pair for SSB and CORESER#0 is determined. Current pattern should be the baseline with minimum spec impact. In our view, the following SCS pair could be supported by reusing current multiplexing pattern:* + The following SSB-Coreset 0 multiplexing patterns are supported for each SCS pair:
		- (120K, 120K): Pattern 1, Pattern 3
		- (960K, 960K): Pattern 1, Pattern 3
		- (960K, 480K): Pattern 1, Pattern 2
 |

### 2.1.7 CORESET#0 Configuration

* From [5] Huawei, HiSilicon:
	+ For licensed operation, both 24 PRB and 48 PRB can be configured for CORESET0. For operation in shared spectrum, CORESET0 with 48 PRB and 96 PRB can be configured to make full use of allowed transmit power.
* From [9] vivo:
	+ To solve the problem of the limited CORESET and RMSI payload, two solutions can be utilized:
		- Assuming two consecutive SSB beams have QCL relationship
		- Assuming only one SSB is transmitted every two consecutive SSB beams
* From [10] TCL:
	+ Observation: 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: 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.
	+ It is proposed to investigate efficient transmission of MSI including the multiplexing patterns for both licensed and shared carriers.
* From [13] Fujitsu:
	+ Further discuss SCS of SSB for initial access at least considering maximum mandatory bandwidth of UE.
		- If the maximum mandatory bandwidth of UE is as for the current FR2 and RedCap UE should be considered for the new frequency range, neither of 480kHz and 960kHz can be supported.
		- If the maximum mandatory bandwidth of UE is as for the current FR2 and RedCap UE should not be considered for the new frequency range, 480kHz can be supported.
		- If the maximum mandatory bandwidth of UE is 400MHz, 480kHz and/or 960kHz can be supported.
* From [19] Xiaomi:
	+ Configuration of SSB and CORESET0 multiplexing tables need update to support additional SCS other than 120k for NR from 52.6GHz to 71 GHz.
* From [20] Samsung:
	+ For COREST#0,
		- if synchronization raster interval is larger than FR2, additional CORESET#0 RB offsets are needed for 120 kHz SS/PBCH block SCS;
		- if 480 kHz and/or 960 kHz SS/PBCH block SCS is supported, at least CORESET#0 configuration table with same SCS as SS/PBCH block should be supported;
		- if there are reserved configurations, both multiplexing Pattern 2 and Pattern 3 can be supported in a CORESET#0 configuration table;
		- if CORESET#0 bandwidth can be increased, 96 RB can be added to the CORESET#0 configuration table for 120 kHz SS/PBCH block SCS.

**Summary of Discussions in Tdoc**

* Following up discussions on supported SSB/Type0-PDCCH multiplexing pattern, companies have provided further discussion on supported bandwidth (#PRB) and configured Type0-PDCCH CSS resources.
* Suggest to discuss further along with SSB/CORSET#0 multiplexing issue (2.1.6)

**Summary of Email Discussions**

* Moderator suggests to discuss this issue along with SSB/CORESET#0 multiplexing issue.
* Please provide comments in Section 2.1.6.

### 2.1.8 Various other aspects on SSB Design

* From [2] Lenovo, Motorola Mobility:
	+ For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, if higher subcarrier spacings (numerologies) are adopted for initial access, new SSB structures should be investigated.
	+ For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, if higher subcarrier spacings (numerologies) are adopted for initial access, coverage enhancement of channels and signals used for initial access should be considered for NR beyond 52.6 GHz.
* From [7] CAICT:
	+ Initial BWP includes only one LBT bandwidth for unlicensed deployment.
* From [9] vivo:
	+ 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), or lower RAN4 requirement for the cell search time.
* From [13] Fujitsu:
	+ For further study on initial access for the new frequency range (52.6~71GHz), it should be clarified whether to consider RedCap UE.
	+ For further study on initial access for the new frequency range (52.6~71GHz), RAN1 can send LS to RAN4 asking about at least the minimum channel BW (50MHz or 400MHz) and the maximum mandatory bandwidth of UE (including RedCap UE if it should be considered), or wait for the progress in RAN4.
* From [14] AT&T:
	+ Observation: For both single carrier and intra-band multi-carrier deployments regardless of time or frequency division multiplexing of multiple numerologies a myriad of complexities arise during every step of the system design and operation, from standardization, to implementation, to orchestrating the resources during actual deployment which result in additional and unnecessary costs and performance impairments
* From [15] Spreadtrum:
	+ The initial access mechanisms for R16 NR-U can be kept, e.g. candidate SSB index, SSB (beam) index, discovery burst transmission window, ssb-PositionQCL-r16, new interpretation of ssb-PositionInBurst and off-raster SSB for cgi report.
* From [18] NEC:
	+ Upon LBT based SSB transmission for initial access, the sensing beam group with multiple concurrent LBT/sensing beams could be used to improve the SSB transmission performance.
	+ For LBT based initial access, transmission beam(s) for certain SSB should be covered by corresponding LBT/sensing beam(s) on which the channel is sensed to be idle.
	+ The energy detection threshold adaptation procedures for LBT based initial access should take into account the maximum transmission power difference between transmission on a single beam and multiple concurrent beams.
* From [21] CEWiT:
	+ For SSB with 120KHz SCS, solutions for mitigating effect of phase noise need to be defined.
* From [24] Convida:
	+ SSB coverage enhancement should be studied for higher SCS if it is supported.
	+ Introduction of TRS/CSI-RS in idle/inactive mode UE in Rel 17 should be studied for NR operation from 52.6 to 71 GHz.
* From [25] Qualcomm:
	+ Wider bandwidth than 50 MHz should be considered as minimum channel bandwidth for a band in 52.6 - 71GHz

**Summary of Discussions in Tdoc**

* Companies have provided discussion on considerations for SSB design. The discussion includes, how to handle the 5 msec SSB periodicity, enhanced SSB (e.g. larger number of symbols for PBCH), applicability of reduced capability UEs and how RedCap UE would be handled, support of TRS/CSI-RS in idle/inactive mode, relationship between initial BWP and LBT bandwidth, and minimum channel bandwidth considered.
* Suggest to discuss these issues further.

**Summary of Email Discussions**

* Among the issues discussed, please highlight issues that companies think would benefit from having agreements/conclusions in RAN1 #104-e. Also provide issues that were not captured by the moderator in this document.

|  |  |
| --- | --- |
| **Company** | **Discussions/Comments** |
| Samsung | * No need to change the minimum periodicity of 5 ms. There are examples the SSB burst is much shorter than 5 ms, and there is no issue with that.
* We didn’t see an issue with PBCH coverage from the SI, so no need to modify the SSB structure.
* We don’t think Rel-17 RedCap is targeted for and applicable to 52.6 GHz to 71 GHz
* Support of TRS/CSI-RS in idle/inactive mode is discussed in power saving enhancement
* We didn’t see a need for special treatment of LBT bandwidth for initial access
* We support the proposal of supporting a minimum carrier bandwidth to be larger than 50 MHz (to allow larger sync raster interval), but the discussion should be made in RAN4.
 |
| NEC | 1. Considering the SSB transmission for initial access in shared channel, we are open to discuss the SSB periodicity.2. We support keeping the same SSB structure for higher SCS.3. Upon the minimum channel bandwidth, we support leaving it to RAN4. |
| ZTE, Sanechips | Similar view with Samsung. Most of the issues above do not need a specific discussion. Among them, some have been excluded from WID above 52.6 GHz e.g. SSB coverage enhancement, some are being discussed in other WI group e.g. TRS/CSI-RS, and some enhancements seem unnecessary e.g. smaller half-frame periodicity. We only need to consider the impact of the minimum channel bandwidth on initial access signals/channels. |
| DOCOMO | If 480/960 kHz is supported for SSB, SSB burst may be much shorter than 5 ms. Then SSB measurement window shorter than 1 ms could be beneficial to reduce UE monitoring burden, as described in [28]. We support the minimum carrier bandwidth should be larger than 50 MHz. Ok to discuss the minimum carrier bandwidth itself in RAN4, but we believe it is related to SSB SCS selection for initial access.  |
| vivo | Clarification on the SSB period issue here: In FR2, UE will assume 20ms SSB period for initial cell search. Here we propose to change this default SSB period to be smaller (e.g. 5 or 10ms) considering the increasing SSB synchronization complexity for NR operation from 52.6-71GHz. Another alternative is to relax the time requirement in RAN4 for cell search. To maintain the performance, we prefer to have a smaller default SSB period. |

## 2.2 PRACH Aspects

### 2.2.1 PRACH BW and Sequence Length

* From [1] FUTUREWEI:
	+ With RAN 1 interpretation the OCB restriction does not imply that each of PRACH possible format transmissions should occupied 70% of the nominal channel bandwidth.
	+ For 60 GHz shared spectrum, support 400MHz as the default channel bandwidth for the initial channel access and as the default channel bandwidth for the CCA (LBT) operations.
	+ Consider the necessity of interlaced based PRACH mappings to achieve the maximum radiated power as well as at least one PRACH format that satisfies the minimum OCB condition.
* From [3] ZTE, Sanechips:
	+ Support sequence length 139, 571 and 1151 for PRACH, and further study the corresponding SCS when channel bandwidth and SCS are determined.
* From [5] Huawei, HiSilicon:
	+ PRACH sequence length 571 and 1151 are supported for 120 kHz SCS above 52.6 GHz.
* From [6] Nokia, NSB:
	+ Observation: Initial BWP bandwidth options for 120 kHz CORESET#0 in FR2 are 34.56 MHz and 69.12 MHz. PRACH preamble using 120 kHz SCS and sequency length of 1151 would not fit into initial BWP defined by 120 kHz SCS CORESET#0 in FR2.
	+ Consider supporting wider initial BWP bandwidth options than supported in FR2, e.g. 96 PRBs with 120 kHz SCS.
	+ Support PRACH preamble length 571 and 1151 at least for 120 kHz SCS.
* From [9] vivo:
	+ Observation: With the usage of higher SCS, the PRACH sequence capacity is very limited when the preamble sequence length is 139.
	+ With the usage of higher SCS, the issue of preamble sequence generation needs to be considered to match the certain coverage area.
* From [11] MediaTek:
	+ Support PRACH sequence lengths 139/571/1151 for NR above 52.6GHz.
* From [16] InterDigital:
	+ Observation: For 52.6 – 71 GHz, longer PRACH sequences are needed for the case that the transmit power is limited, however, no additional specification enhancements are needed as the existing PRACH sequences with the existing sequence lengths 571 and 1151 can be reused for with existing SCS.
	+ For 52.6 – 71 GHz, the existing PRACH sequences with the existing PRACH sequence lengths 571 and 1151 should be reused.
* From [17] LGE:
	+ The PRACH sequence lengths (i.e., L=139, L=571 and L=1151) can be supported for 120 kHz considering the regulatory requirements in the unlicensed band but it needs to clarify whether all of these lengths of PRACH sequence are required in the licensed band where regulatory requirements are not defined on PSD limit.
* From [20] Samsung:
	+ Support short PRACH format for all PRACH sequence lengths LRA ϵ {139, 571, 1151} and all SCSs µ ϵ {3, 5, 6}, and don’t support long PRACH format.
* From [22] Ericsson:
	+ Observation: While L = 139/571/1151 is beneficial for 120 kHz PRACH from a coverage perspective, the longer sequence lengths (L = 571/1151) lead to excessive PRACH bandwidth for 480/960 kHz PRACH, and are not needed in order to maximize PRACH transmission power given regulatory/UE power limits.
	+ Specify support for all sequence lengths (139/571/1151) for 120 kHz PRACH. For 480/960 kHz PRACH, specify support for only L = 139.
* From [25] Qualcomm:
	+ consider using the following for the PRACH preamble sequence lengths for higher bands:
		- SCS = 120 kHz: 139 and 571
		- SCS = 480/960 kHz: 139 only

**Summary of Discussions in Tdoc**

* Companies have provided views on supported PRACH sequence lengths for each supported SCS
	+ Support L=139
		- ZTE, Sanechips, MediaTek, Intel, Interdigital, LGE, Ericsson, Qualcomm (for 120,480,960kHz)
	+ L=571, 1151
		- ZTE, Sanechips, Huawei, HiSilicon , Nokia, NSB (at least for 120kHz), MediaTek, Intel, LGE, Interdigital, Ericsson, Qualcomm (for 120kHz only)
* Discuss further supported PRACH sequence lengths for each supported SCS

**Summary of Email Discussions**

* Please provide comments on supported PRACH sequence length (e.g. L=139, 571, 1151), PRACH Format (e.g. 0-3, A, B, C), PRACH SCS (and applicable scenarios).

|  |  |
| --- | --- |
| **Company** | **Discussions/Comments** |
| Samsung | Support all PRACH sequence length (L=139, 571, 1151) for short PRACH format (A, B, C)* Support SCS = 480 kHz and 960 kHz for non-initial access case
* Support SCS same as initial BWP SCS for initial access case (depending on the outcome from SSB discussion)
 |
| ZTE, Sanechips | * Support sequence length 139, 571 and 1151 for PRACH format A, B, C.
* Support 120kHz SCS for PRACH, jointly discuss additional SCSs (480kHz and 960kHz) for PRACH and SSB if single subcarrier spacing is supported.
 |
| DOCOMO | We support PRACH sequency length L=139 and 571. We are open to L=1151. We support all short PRACH format. We support 480/960 kHz SCS for PRACH for non-initial access case, and the same SCS as initial BWP SCS for initial access case.  |
| LG Electronics | For PRACH sequence lengths, the lengths (i.e., L=139, L=571 and L=1151) can be supported for the PRACH format (A, B, C). If 480 or 960 kHz subcarrier spacing is supported for PRACH, the corresponding PRACH sequence length can be L=139 and/or L=571. However, it is necessary to clarify whether all of these lengths of PRACH sequence are required in the licensed band where regulatory requirements are not defined on PSD limit.Support of 480/960 kHz SCS for PRACH is not preferred considering the specification impact on the RO configuration and RA-RNTI issue for 480/960 kHz SCS. |
| Spreadtrum | The PRACH with 480 and 960kHz for non-initial access could be supported to reduce UE complexity when UE is sending data with 480 and 960kHz SCS. |
| vivo | Support all PRACH sequence length (L=139, 571, 1151) for short PRACH format (A, B, C) and not support PRACH format 0-3.We support 480K and 960K SCS for PRACH and initial UL BWP with single numerology. |

### 2.2.2 Supported PRACH Numerology

* From [1] FUTUREWEI:
	+ Support only 120kHz SCS for PRACH for initial access.
* From [2] Lenovo, Motorola Mobility:
	+ For supporting NR from 52.6 GHz to 71 GHz in Rel. 17, support the same numerology of data channel for SSB and PRACH including 480KHz and 960KHz
* From [3] ZTE, Sanechips:
	+ Support 120kHz SCS for PRACH, jointly discuss additional SCSs (480kHz and 960kHz) for PRACH and SSB if single subcarrier spacing is supported.
* From [5] Huawei, HiSilicon:
	+ For PRACH and Msg3 in initial UL BWP, only 120 kHz should be used in the frequency band from 52.6GHz to 71GHz.
* From [6] Nokia, NSB:
	+ Observation: 960 kHz SCS for PRACH can support required range for the indoor scenario. It would be beneficial to support e.g. 960 kHz PRACH for SCell operating with 960 kHz SCS.
* From [9] vivo:
	+ Observation: All supported SCS for data/control SCS could be used for initial UL BWP in NR FR2 operation. There are only two applicable SCSs for PRACH format (A, B, C) in NR FR2 operation.
	+ Support 120KHz, 480KHz and 960KHz as candidate SCS of initial UL BWP.
* From [11] MediaTek:
	+ Support only 120 kHz for PRACH SCS in initial access.
* From [12] Intel:
	+ Support 480 kHz and 960 kHz SCS for PRACH in NR extension up to 71 GHz.
* From [13] Fujitsu:
	+ In addition to 120kHz, support 480kHz and 960kHz for PRACH at least for the cases other than initial access.
	+ Select combinations of SCS and sequence length for PRACH for initial access at least considering maximum mandatory bandwidth of UE.
		- If the maximum mandatory bandwidth of UE is as for the current FR2 and RedCap UE should be considered for the new frequency range, only consider the combinations with BW not larger than 100MHz, i.e. (L=139, SCS=120kHz), (L=139, SCS=480kHz), and (L=571, SCS=120kHz).
		- If the maximum mandatory bandwidth of UE is as for the current FR2 and RedCap UE should not be considered for the new frequency range, only consider the combinations with BW not larger than 200MHz, i.e. (L=139, SCS=120kHz), (L=139, SCS=480kHz), (L=139, SCS=960kHz), (L=571, SCS=120kHz) and (L=1157, SCS=120kHz).
		- If the maximum mandatory bandwidth of UE is 400MHz, only consider the combinations with BW not larger than 400MHz, i.e. (L=139, SCS=120kHz), (L=139, SCS=480kHz), (L=139, SCS=960kHz), (L=571, SCS=120kHz), (L=571, SCS=480kHz), and (L=1157, SCS=120kHz).
* From [16] InterDigital:
	+ Observation: PRACH with 120 kHz generally outperforms PRACHs with additional SCSs.
	+ Further study necessity of PRACH for additional SCSs in Rel-17.
* From [22] Ericsson:
	+ For cases other than initial access (e.g. for an SCell), support 480 and 960 kHz SCS for PRACH
* From [25] Qualcomm:
	+ Observation: for the PRACH performance of different numerologies in the high frequency regime,
		- No noticeable difference in the misdetection performance is identified among SCSs.
		- With the same CINR, the false alarm rate increases as the SCS or sequence length (i.e., bandwidth) increases
	+ consider using the following for the PRACH preamble sequence lengths for higher bands:
		- SCS = 120 kHz: 139 and 571
		- SCS = 480/960 kHz: 139 only
	+ Observation: for higher RACH SCS (480 and 960 kHz), the CP length may not be long enough to absorb the gNB beam switching delay requirement
* From [26] NTT Docomo:
	+ For SCS of PRACH preamble, in addition to 120 kHz,
		- 480 and 960 kHz SCS should be supported to achieve single numerology operation

**Summary of Discussions in Tdoc**

* Companies provided proposals on supported SCS for PRACH. Some proposal suggest to limit specific SCS for PRACH to initial access or SCell operation.
	+ Support only 120kHz
		- FUTUREWEI (for initial access), Huawei, HiSilicon, MediaTek
	+ Support 120, 480, 960 kHz
		- Lenovo, Motorola Mobility, Intel, Fujitisu, Ericsson (non-initial access cases), Qualcomm, NTT Docomo
* Suggest to discuss further on the supported SCS for PRACH along with supported sequence lengths (2.2.1)

**Summary of Email Discussions**

* Moderator suggest to discuss together with supported sequence lengths.
* Please provide comments in Section 2.2.1.

### 2.2.3 PRACH Format

* From [5] Huawei, HiSilicon:
	+ For PRACH SCS = 120 kHz, the PRACH formats A1, A2, A3, C2 with reduced guard time or reduced PRACH duration NdurRA should be supported.
* From [8] CATT:
	+ 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.
* From [9] vivo:
	+ Format 0-3 with special SCS is not supported
	+ Support 120KHz and 960KHz SCS for PRACH format (A, B, C) in NR operation from 52.6-71GHz.
* From [25] Qualcomm:
	+ for higher bands consider reusing the PRACH formats defined in NR Rel-16 (with appropriate SCS scaling)

**Summary of Discussions in Tdoc**

* Several companies provided proposals on supported PRACH Formats (0~3, A, B, C) for 52.6 ~ 71 GHz band. The discussion includes potential updates to guard time for existing PRACH formats, and increasing number of symbols in time domain.
* Suggest to discuss further supported PRACH Formats and related issues.

**Summary of Email Discussions**

* Moderator suggest to discuss together with supported sequence lengths.
* Please provide comments in Section 2.2.1.

### 2.2.4 RACH Occasion Resources

* From [1] FUTUREWEI:
	+ Support non-consecutive RO to reduce possibility of LBT failure.
* From [4] OPPO:
	+ set the reference SCS for RACH slot determination as 120kHz.
	+ RAN1 should design a unified RO configuration for both licensed and unlicensed spectrums.
	+ On top of RO configuration, a mask can be further added for unlicensed spectrum to switch off certain RO from being selected.
* From [5] Huawei, HiSilicon:
	+ A gap between two consecutive TDM ROs should be introduced to avoid a LBT failure at the UE due to a RACH transmission from another UE in the previous RO.
* From [6] Nokia, NSB:
	+ Observation: If LBT gaps are needed between ROs, it would be better to define fixed LBT gap time 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 [8] CATT:
	+ Observation: The current RO configuration of FR2, based on the 60 KHz slot as the basic unit, which supports two slots configuration when SCS is 120KHz.
	+ When the specification supports SCS=/480/960 KHz, 120 KHz configuration is reused for each 8/16 slots within 60 KHz slot.
* From [9] vivo:
	+ With the introduction of larger SCS in 52.6-71GHz, such as 480/960kHz, how to configure time domain ROs should be considered.
	+ One approach is to reuse FR2 RO slot configuration rule but to define new reference slot and re-interpret RACH slot index for high PRACH SCS in 52.6-71GHz.
* From [11] MediaTek:
	+ There is no need to support non-consecutive RACH occasions configuration.
* From [13] Fujitsu:
	+ Support RO configuration for non-consecutive ROs in time domain.
* From [16] InterDigital:
	+ Observation: In NR-U, introduction of non-consecutive RACH occasions was discussed, but agreements on the specification support weren’t made as it could be handled by gNB implementationn. For 52.6 – 71 GHz, non-consecutive RACH occasions still can be handled by gNB implementation and CCA failure may be a relatively rare event due to a narrower beam.
	+ For 52.6 – 71 GHz, supporting non-consecutive RACH occasions is not preferred
* From [17] LGE:
	+ If 480 or 960 kHz subcarrier spacing is supported for PRACH, the corresponding PRACH sequence length can be L=139 and/or L=571, and the following FFS points can be considered:
		- How to express slot indexes within the 10ms window for 960 kHz subcarrier spacing PRACH by using existing 16 bits RA-RNTI
		- How to configure RACH slot for 480 or 960 kHz subcarrier spacing PRACH
	+ When LBT is used to transmit the PRACH preamble, consider to insert CCA gap between adjacent RACH occasions in time domain (e.g. X usec or Y symbol) to avoid inter-UE LBT blocking due to the propagation delay of PRACH transmitted in an earlier RO.
* From [19] Xiaomi:
	+ Inconsecutive RO time domain configuration need be discussed.
* From [20] Samsung:
	+ Using the RO pattern for SCS = 120 kHz derived from the PRACH configuration table as the reference for larger SCS cases.
	+ For RO configuration, both direction 1 (indication on which one(s) of the 8 eighty-slots) and direction 2 (keep 80slots in total but redesign the RACH period and RACH duration location) can be considered.
	+ Support non-consecutive RO configuration to alleviate the RACH LBT failure.
* From [22] Ericsson:
	+ For 480/960 kHz PRACH, support PRACH configurations that allow maintaining the same PRACH processing load (operations/unit time) as for 120 kHz PRACH configurations.
	+ Observation: The current PRACH configuration table for FR2 which defines PRACH slot positions based on a reference numerology of 60 kHz can be reused as is for 480/960 kHz. What needs to be specified is a rule on which 1 or 2 480/960 kHz slots within the reference 60 kHz slot contain PRACH occasion(s).
	+ Support configuration of PRACH occasion(s) in only 1 or 2 480/960 kHz slots within a 60 kHz reference slot.
	+ For 480/960 kHz PRACH, reuse the current PRACH configuration table in 38.211 for FR2 "as is." Specify rule for which 1 or 2 480/960 kHz slots within a 60 kHz reference slot are used depending on the value in the existing column "Number of PRACH slots within a 60 kHz slot" in the current PRACH configuration table. The rule should be common for all PRACH configurations in the table.
* From [25] Qualcomm:
	+ a maximum of 4 FD multiplexed ROs for SCS = 120 kHz and sequence length = 571. For all other SCS and sequence length combinations, a maximum of 8 FD multiplexed ROs can be used
	+ for higher RACH SCS (480 and 960 kHz), consider including a symbol-level gap between ROs to allow for gNB beam switching delay
	+ for higher RACH SCS (480 and 960 kHz), consider including a symbol-level gap between POs to allow for gNB beam switching delay

**Summary of Discussions in Tdoc**

* Large number of companies discusses issue of supporting (or not supporting) non-contiguous RO.
* Suggest to discuss further on support of non-contiguous RO.

**Summary of Email Discussions**

* Please provide further comments on support of non-contiguous RO to cope with LBT.

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| **Company** | **Is there a need to consider LBT failure in RO design (e.g. by supporting non-contiguous RO configuration)?** | **Discussions/Comments** |
| Samsung | Yes | We observed more severe issue of RO blocking by LBT due to shorter symbol duration for 60 GHz unlicensed band, so we support configuring symbol gaps before RO for LBT purpose.  |
| NEC  | Yes | Support no-contiguous RO to reduce the impact of failure LBT. |
| ZTE, Sanechips | Neutral | We agree that non-contiguous RO configuration has benefit on LBT, so if LBT is required for RACH transmission, non-contiguous RO can be considered; otherwise, it’s not needed. |
| DOCOMO | Yes | We agree non-contiguous RO could be discussed from both perspective of beam switching gap with 480/960 kHz SCS as well as LBT failure, though the probability of LBT failure may be low. |
| LG Electronics | Yes | Consider to insert CCA gap between adjacent RACH occasions in time domain (e.g. X usec or Y symbol) to avoid inter-UE LBT blocking due to the propagation delay of PRACH transmitted in an earlier RO. |
| Spreadtrum | Neutral |  |
| vivo | Yes | We support non-contiguous RO is needed to avoid LBT blocking. Besides, RO configuration details for new SCS should also be discussed, e.g. reference slot and RO mapping within the slot |

### 2.2.5 RA Preamble ID calculation

* From [9] vivo:
	+ When a larger PRACH SCS is introduced in 52.6-71GHz, the issue of RA-RNTI calculation needs to be investigated.
* From [17] LGE:
	+ If 480 or 960 kHz subcarrier spacing is supported for PRACH, the corresponding PRACH sequence length can be L=139 and/or L=571, and the following FFS points can be considered:
		- How to express slot indexes within the 10ms window for 960 kHz subcarrier spacing PRACH by using existing 16 bits RA-RNTI
		- How to configure RACH slot for 480 or 960 kHz subcarrier spacing PRACH
* From [25] Qualcomm:
	+ for higher RACH SCS (480 and 960 kHz), consider the following options for the RA-RNTI:
		- Option A: using the following equation for the RA-RNTI calculations µmax is the maximum µ for the FR used) and defining rules in case RA-RNTI conflicts with pre-allocated RNTIs or in case multiple ROs have the same RA-RNTI
			* RA-RNTI = (1 + s\_id + 14×t\_id + 14×max(80,Nslotframe,µmax)×f\_id + 14×max(80,Nslotframe,µmax) × 8 × ul\_carrier\_id) mod 216
		- Option B: reuse the same RA-RNTI equation in NR Rel-16, divide the RAR window into N segments (each segment is 80 slots using the used SCS), and signal the segment index in the DCI that schedules the MSG2/B

**Summary of Discussions in Tdoc**

* Some companies noted that RA-RNTI calculation (RA preamble ID) could overflow for larger PRACH SCS (i.e. 480 and 960 kHz) and suggest some potential modifications of this including methods to avoid issues by RO configuration definition.

**Summary of Email Discussions**

* Please provide further comments on RA-RNTI calculation issue identified by companies.

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| **Company** | **Discussions/Comments** |
| Samsung | We agree this issue should be further investigated in the WI.  |
| ZTE, Sanechips | We agree to discuss this issue. Among the solutions above, Option B proposed by Qualcomm seems a more straightforward solution. |
| DOCOMO | We agree to discuss this issue further.  |
| LG Electronics | If 960 kHz subcarrier spacing is supported for PRACH, further discussions are needed for how to express slot indexes within the 10ms window for 960 kHz subcarrier spacing PRACH by using existing 16 bits RA-RNTI. |
| vivo | We agree to discuss this issue after RO configuration for new SCS is determined. |

### 2.2.5 Short Signal Exception for PRACH

* From [12] Intel:
	+ Observation: For 120 kHz, 480kHz, and 960 kHz PRACH transmission, UE does not exceed total transmission duration of 10 msec for PRACH within a 100 msec observation period.
	+ Consider applying short control signal exemption to PRACH transmission by the UE.
* From [22] Ericsson:
	+ It is not necessary to optimize PRACH design to allow for gaps between consecutive PRACH occasions within a PRACH slot, especially since SS/PBCH blocks can be classified as short control signaling transmissions consistent with EN 302 567.

**Summary of Discussions in Tdoc**

* Few companies discussed whether short signal exemption defined in EN302 567 can be applied to PRACH.
* Suggest to discuss further on short signal exemption to PRACH.

**Summary of Email Discussions**

* Please provide further comments applicability of short signal exemption for PRACH.

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| **Company** | **Discussions/Comments** |
| Samsung | Support including PRACH as short control signal. |
| NEC  | Support treat the PRACH as a shot control signal. |
| ZTE, Sanechips | Support including PRACH as short control signal. |
| DOCOMO | Support including PRACH as short control signal  |
| LG Electronics | Support transmission of short control signaling without LBT can be considered for transmitting information without any user plane data such as SSB, PRACH considering the updated ETSI EN 302 567. |
| vivo | Support including PRACH as short control signal |

# Summary of Moderator Proposals and Conclusions

[To be filled by Moderator]

# Summary of Agreements/Conclusion in RAN1 #104e

[To be filled once agreements and conclusions are available]

# Reference

1. R1-2100051, “Considerations on initial access for additional SCS in Beyond 52.6GHz,” FUTUREWEI
2. R1-2100057, “Initial access enhancements for NR from 52.6 GHz to 71GHz,” Lenovo, Motorola Mobility
3. R1-2100073, “Discussion on the initial access aspects for 52.6 to 71GHz,” ZTE, Sanechips
4. R1-2100149, “Discusson on initial access aspects,” OPPO
5. R1-2100200, “Initial access signals and channels for 52-71GHz band,” Huawei, HiSilicon
6. R1-2100257, “Initial access aspects,” Nokia, Nokia Shanghai Bell
7. R1-2100299, “Some views on initial access aspects for 52.6-71GHz,” CAICT
8. R1-2100370, “Initial access aspects for up to 71GHz operation,” CATT
9. R1-2100429, “Discussions on initial access aspects for NR operation from 52.6GHz to 71GHz,” vivo
10. R1-2100541, “Initial access aspects,” TCL Communication Ltd.
11. R1-2100607, “Initial access aspects for NR operations in 52.6-71 GHz,” MediaTek Inc.
12. R1-2100643, “Discussion on initial access aspects for extending NR up to 71 GHz,” Intel Corporation
13. R1-2100740, “Considerations on initial access for NR from 52.6GHz to 71 GHz,” Fujitsu
14. R1-2100781, “Further Discussion of Initial Access Aspects,” AT&T
15. R1-2100825, “Discussion on initial access aspects for NR from 52.6GHz to 71GHz,” Spreadtrum Communications
16. R1-2100836, “Discussions on initial access aspects,” InterDigital, Inc.
17. R1-2100892, “Initial access aspects to support NR above 52.6 GHz,” LG Electronics
18. R1-2100939, “Discussion on initial access aspects supporting NR from 52.6 to 71GHz,” NEC
19. R1-2101109, “On initial access aspects for NR from 52.6GHz to 71GHz,” Xiaomi
20. R1-2101194, “Initial access aspects for NR from 52.6 GHz to 71 GHz,” Samsung
21. R1-2101286, “Discussion on Initial access aspects for NR beyond 52.6 GHz,” CEWiT
22. R1-2101306, “Initial Access Aspects,” Ericsson
23. R1-2101372, “On Initial access signals and channels,” Apple
24. R1-2101417, “Consideration for NR Initial Access from 52.6 GHz to 71 GHz,” Convida Wireless
25. R1-2101453, “Initial access aspects for NR in 52.6 to 71GHz band,” Qualcomm Incorporated
26. R1-2101605, “Initial access aspects for NR from 52.6 to 71 GHz,” NTT DOCOMO, INC.
27. R1-2101672, “Discussion on initial access aspects for NR beyond 52.6GHz,” WILUS Inc.