Research on key technologies in the 52.6GHz-71GHz frequency band

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Abstract: In the 3GPP release 17 NR system, the 52.6GHz-71GHz frequency band is standardized. In order to transmit the information with larger bandwidth, the Sub-Carrier Spacing (SCS) of 480KHz and 960KHz are newly defined. At the same time, this frequency band belongs to unlicensed frequency band in some countries or regions, and some signals need to comply with the transmission regulations of unlicensed frequency band. Based on this, this topic mainly focuses on the impact of the newly introduced two Sub-Carrier Spacing and the regulations on the frequency band under the existing NR system.

keyword: B526G; SSB; Beam management

1 Introduction

In June 2022, at the 96-th plenary session of the 3GPP (3rd generation partnership project) of the international communication standards organization, the third version (release 17) of the fifth-generation mobile communication (NR, new radio) was frozen, and marked the successful conclusion of the first stage of NR technology evolution. Different from the both Rel-15 and Rel-16 NR system, Rel-17 NR system mainly focuses on exploring new application scenarios and higher frequency bands, such as the light-weight terminals (redcap, reduced capability UE), virtual reality, non-public terrestrial networks (NTN) and beyond 52.6GHz.

If we deploy the NR system in the frequency band higher than 52.6GHz, it will encounter more problems, such as higher phase noise, propagation loss in the atmosphere, etc..

Until now, the frequency band point in either Real-15 or Rel-16 NR system is less than the 52.6GHz, the technologies in the frequency band higher than 52.6ghz have not been standardized yet. In order to support large bandwidth communication transmission and improve the transmission rate, the frequency band “52.6GHz-71GHz” is standardized in the Rel-17, which named “nr_beyond_52.6GHz” or “B526G”. Meanwhile, the frequency range from 52.6GHz to 71GHz is defined as frequency range 2-2 (FR 2-2, frequency range 2-2). Combining with Rel-15 and Rel-16 NR system, the frequency band for the NR system are shown in Table 1.

Table 1 definition of frequency band

Name of frequency range		frequency range
FR1		410 MHz – 7125 MHz
FR2	Fr 2-1	24250 MHz – 52600 MHz
	Fr 2-2	52600 MHz – 71000 MHz

In the FR 2-2 frequency band, there are both licensed and unlicensed bands, as shown in table 2.

Table 2 FR 2-2 band

<table>
<tr><th rowspan="2">Region</th><th rowspan="2">Country</th><th colspan="11">Freuency (GHz)</th></tr>
<tr><th>52.6-54.25</th><th>54.25-55.78</th><th>55.78-56.9</th><th>56.9-57</th><th>57-58.2</th><th>58.2-59</th><th>59-59.3</th><th>59.3-64</th><th>64-65</th><th>65-66</th><th>66-71</th></tr>
<tr><td rowspan="3">ITU region 1</td><td>Europe/ CEPT</td><td></td><td></td><td></td><td></td><td colspan="6">U (mobile)</td><td></td></tr>
<tr><td>Israel</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>South Africa</td><td></td><td></td><td></td><td colspan="5">U (mobile)</td><td colspan="2">U (mobile)</td><td></td></tr>
<tr><td rowspan="4">ITU region 2</td><td>USA</td><td></td><td></td><td></td><td></td><td colspan="7">U (mobile)</td></tr>
<tr><td>Canada</td><td></td><td></td><td></td><td></td><td colspan="4">U (mobile)</td><td></td><td></td><td></td></tr>
<tr><td>Brazil</td><td></td><td></td><td></td><td></td><td colspan="4">U (mobile)</td><td></td><td></td><td></td></tr>
<tr><td>Mexico</td><td></td><td></td><td></td><td></td><td colspan="4">U (mobile)</td><td></td><td></td><td></td></tr>
</table>

ITU region 3	China							U (mobile)				
	Japan					U (mobile)						
	Korea					U (mobile)						
	India											
	Taiwan					U (mobile)						
	Singapore					U (mobile)						
	Australia					U (mobile)						

In Table 2 above, for example, in China, the frequency band range from 64GHz to 71GHz belongs to the licensed frequency band, but in the United States, this frequency band belongs to the unlicensed band. Therefore, when the information is transmitted in the United States within this frequency range, it must comply with the regulatory requirements defined in the unlicensed frequency band. Considering the different parameter configurations and system requirements of the system under different frequency band types, the broadcast information is also different. In the initial access process, when the terminal device accesses to a cell without any prior information, it needs to distinguish the frequency band type in which the cell is working on; otherwise, it will increase the accessing delay for the terminal.

Specifically, for the "B526G" issue, 3GPP mainly standardized and studied it through two stages: the research stage (SI, study item) and the work stage (WI, work item). In the SI phase, some simulation works such as scenario assumption and simulation assumption are mainly studied, including:

(1) The design of uplink and downlink waveforms, such as the maximum and minimum bandwidth that can be supported, Sub-Carrier Spacing (SCS), and the impact when introducing the new SCS under the existing NR system.

(2) Considering the hidden nodes and exposed nodes in the unlicensed frequency band and the narrow beam used in the high frequency band, it is necessary to study new channel access mechanism.

This article focuses on Rel-17 "B526G" topic.

2 Key technologies

For the NR system working in the "B526G" band, in addition to supporting 120kHz SCS, it can also support 480kHz and 960kHz SCS, but the maximum number of Resource Blocks (RB) in the bandwidth is still 275.

2.1 Initial access

Among the sub-topics in initial access, the maximum number of candidate Synchronization Signal and PBCH block (SSB) in both licensed and unlicensed frequency bands is still 64. Considering the channel accessing mechanism in the unlicensed frequency band, the base station needs to implement the Listen Before Talk (LBT) mechanism on the target frequency band before sending SSB.

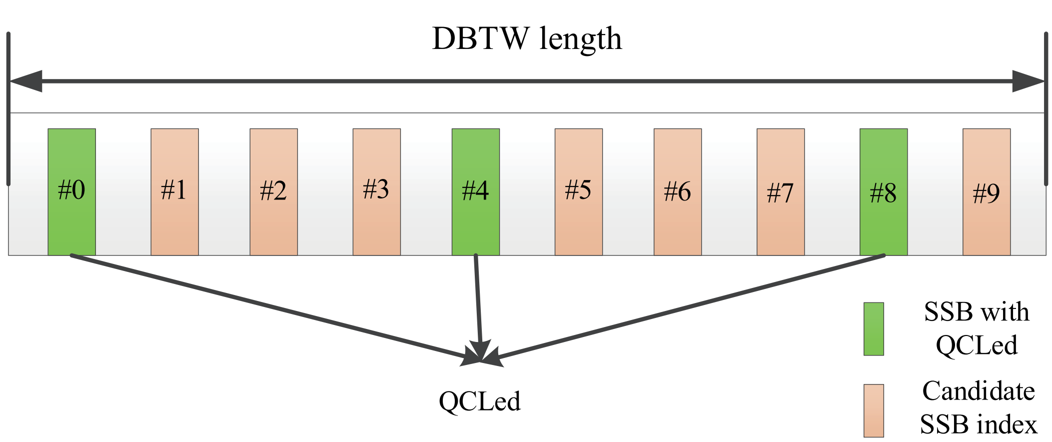

Figure 1 Relationship between SSB index and candidate SSB index in DBTW window.

For the terminal, because SSB is sent at the pre-defined position, in order to save the power consumption from the terminal, the system working on the "B526G" band introduces the concept of Discovery Burst Transmission Window (DBTW), that is, in the DBTW window, SSBs with the same index sent by the base station have the same Quasi Co-Location (QCL) relationship in different candidate SSB locations, which can be indicated by the Radio Resource Control (RRC) parameter "subcarrierspacingcommon" with 1 bit, the number of candidate SSBs are 32 and 64, respectively. The DBTW concept mentioned here is from R16 NR unlicensed NR-U (NR-U) system, the schematic diagram is shown in Fig. 1.

In Figure 1 above, assuming that the length of the DBTW is 10ms, which contains 10 candidate SSB indexes, Q=4, and the number of SSBs sent by the base station is 4 (for example, sent on the candidate SSB index potions #0~#3). At this time, the terminal device determines that the SSB in candidate SSB index potions #0, candidate SSB index potions #4 and candidate SSB index potions #8 have the same QCL relationship, that is, the terminal device uses the same downlink receiving beam direction to receive the among candidate SSBs. In addition, we find that the value of Q can also represent the time-domain interval of SSB received by the terminal device using the downlink receiving beam direction.

Except the SSB, for the initial DL and UL Band-Width Part (BWP) in the initial access process, the terminal device must support 120kHz SCS and optional support 480kHz or 960kHz. For SSB, only None-Cell Define SSB (NCD-SSB) can support the SCS of both 480kHz and 960kHz, the SSB pattern is {2, 9} + 14*n, n=0,..., 31.

For the multiplexing patten between the SSB and Physical Downlink Control Channel (PDCCH) carrying Control Resource Set #0 (CORESET#0), multiplexing patten 1 and 3 are supported, and only the SCS combinations of {120kHz, 120kHz}, {480kHz, 480kHz} and {960kHz, 960kHz} are standardized.

For the Physical Random Access Channel (PRACH), the standardization working focus on the new sequences, the Random Occasion (RO) configuration and the modification of Radio Network Temporary Identity (RNTI) formula.

Consideration the requirements for the transmission power density in the unlicensed frequency band, it is necessary to meet the regulatory requirements of the Occupied Channel Bandwidth (OCB), that is, the occupied available bandwidth should not be less than 70%. Therefore, for the channel of PRACH with different SCS, the supported preamble sequences (L) are shown in table 3 below, that is, when the SCS of the configured PRACH is 120kHz, the available preamble sequences are 139, 571 and 1151, when the SCS of the configured PRACH is 480kHz, the available preamble sequences are 139 and 571, and only the preamble sequence of 139 can be utilized in case of the 960kHz SCS for the PRACH.

Table 3 preamble sequences with different SCS.

SCS (kHz)	preamble sequences
120	139, 571, 1151
480	139, 571
960	139

For the PRACH in the time domain, the SCS can be extended to 15kHz, 30kHz, 60kHZ and 120kHz. When the configured SCS of the PRACH is 30kHz or 120kHz, the density of defined RO in the time domain is based on the reference time slot, where the reference time slot is the corresponding time slot length (or number) in case of the 15kHz SCS and 60kHz SCS in FR1 and FR2 frequency band, respectively. In the Rel-15 and Rel-16 NR system, when the reference time slot and the SCS of the RO is 60kHz and 120kHz respectively, at most two time slots (PRACH slots) with SCS of 120kHz can be used for transmission within one reference time slot.

In FR 2-2 band, after introducing the RO of 480kHz and 960kHz SCS, 60kHz is still used as the reference time slot, and the RO density in time domain is the same as that in 120kHz. For the slot position of the RO, when the SCS of the RO is configured to 480kHz, and only one PRACH slot in a reference slot, the parameter named equals to 7, the parameter with 15 is configured in case of the 960kHz SCS for a RO. For the case that there are two PRACH slots in a reference slot, the equals to 3 and 7 for 480kHz SCS of the RO, the equals to 7 and 15 for 960kHz SCS of the RO. In fact, this design can avoid the RNTI repetition in the Random-Access Response (RAR) window, and also reduce the standardization work to the extent.

In addition, 3GPP also standardizes the relationship between SSB and RO through the parameters of System Information Block 1 (SIB1), terminal device receives the SSB using the same downlink receiving beam direction which is the same as the transmitting beam direction for the RO in the uplink. Considering the switching delay between the uplink and downlink, a new time interval with several slots is defined between SSB and RO, concretely, when the SCS of the initial BWP (which contains the RO or PRACH) are 480kHz and 960kHz, the new added time interval between SSB and RO is at least 8 and 16 time slots respectively.

2.2 control channel

Larger SCS (i.e., 480kHz and 960kHz) means shorter time granularity, which also effect the Physical Downlink Control Channel (PDCCH) and Physical Uplink Control Channel (PUCCH) design under the NR system.

2.2.1 PDCCH enhancement

The concept of monitoring group is added, so that the terminal device can monitor PDCCH on multiple time slots, in case of the 480kHz and 960kHz SCS configurations for PDCCH, each monitoring group contains 4 and 8 slots, respectively. In the communication scenario with single service cell, the maximum number of candidate PDCCHs that can be monitored in each monitoring group is 20, the maximum number of non-overlapping Control Channel Elements (CCE) configured in every 4 or 8 time slots is 32. At the same time, the concept of slot group is also defined, which contains x slots with continuously monitors y slots. (x, y) equals to (4,1) or (8,1) is mandatory configured for the 480kHz SCS, and optional supports (x, y) with (4,2). When the SCS is 960kHz, both the configuration of (8,4) and (4,2) are optional.

For the scenario where the terminal device switches back from any non-zero search space group to the search space group #0, it is necessary to define a new timer based on the SCS of 120kHz, the maximum value of the timer expands to 3200 and 6400 time slots for 480kHz and 960kHz SCS, respectively. Moreover, new monitoring cycle and slot offset for terminal device is defined during the PDCCH monitoring period.

2.2.2 PUCCH enhancement

NR system defines five PUCCH formats from #0 to #4. For the PUCCH formats with format #0, #1 and #4, and working in the "B526G" band, the terminal device can be configured with minimum of 1 Resource Block (RB) and maximum of 16 RB of the frequency domain resources through the RRC parameter. This design also meets the power limit requirements in unlicensed band.

2.3 Data channel and reference signal

Working on the "B526G" band, the base station can schedule multiple Physical Uplink Shared Channels (PUSCH) or physical downlink shared channels (PDSCH) through a downlink control information (DCI), the corresponding DCI format is either DCI 0-1 or DCI 1-1, and each PDSCH or PUSCH channel is limited to one slot. The maximum number of PDSCH or PUSCH scheduled by a DCI is 8 for SCS with 120kHz, 480kHz and 960kHz. Furthermore, it also supports the configuration of indicating multiple Hybrid Automatic Repeat reQuest (HARQ) processes through a DCI. When the SCS of PUSCH or PDSCH is 480kHz or 960kHz, the value of k0/k2 is in the range from 0 to 128, k1 is from 1 to 127. It should be noted that this scheduling mechanism is not supported in the Code Block Group (CBG) based transmission scenario.

In addition, considering the higher frequency band of FR 2-2, the Phase Tracking Reference (PTR) has also been enhanced. The phase noise is related to the crystal oscillator. Enhancing PTRs can solve the constellation rotation problem caused by relative noise in high frequency .

2.4 Beam management

Higher frequency and narrower beam can alleviate the path loss, which is related to the beam management mechanism of NR system. In the time domain, after introducing 480kHz and 960kHz SCS, the parameters "timedurationforqcl", "beamswitchtiming" and "beamreporttiming" need to be redefined because of the narrower time domain width. Concretely, on the basis of the SCS of 120kHz, the SCS of 480kHz and 960kHz are expanded with scale factor of 4 and 8, respectively.

In fact, the three parameters above can be understood as a threshold value, "timedurationforqcl" is related to the time interval between the DCI and the scheduled PDSCH, that is, when the time interval between the DCI and the scheduled PDSCH is not less than the threshold configured by "timedurationforqcl", the downlink receiving beam used by the terminal device to receive the PDSCH is determined by State Configuration Index (TCI state) in the DCI. In addition, the downlink receiving beam used by the terminal device to receive PDSCH information is also related to the DCI format. The parameter "beamswitchtiming" indicates the switching beam time delay. The parameter "beamreporttiming" is defined as the time interval between the Channel System Information Reference Signal (CSI-RS) configuration and CSI-RS reporting based on the capability of a terminal device (i.e., CSI calculation delay requirement 2).

The parameter "maxnumberrxtxbeamswitchdl" indicates the switching times of transceiver beam within a slot, which is configured for the terminal device, when SCS is 480kHz, the value is 2, 4 or 7, when SCS is 960kHz, the value is 1, 2, 4 or 7.

2.5 Channel access

In the NR-U issue discussed in Rel-16 NR system, the channel access mechanism is divided into two modes: Listen Before Talk (LBT) mode and Non LBT mode. In the LBT mode, transmitter needs to sense the energy of the target channel or carrier, the signal can be transmitted only when the energy is less than a threshold. These two LBT modes are also introduced in "B526G" unlicensed band. Except that, the short control signal transmission is also added considering the narrower transmitting time for larger SCS. The short control signal means that within a certain time, if the actual transmitting time within a channel is not higher than the threshold (e.g., 10%), the transmitter can directly transmit the short control signal without LBT. For example, during the random access process, The terminal device can send PRACH message (including msg.A) in the form of short control signal. Where msg.A is defined in the topic of "2-step RACH" in Rel-16

NR system .

In the "B526G" band, three LBT schemes for channel sensing are discussed: omnidirectional channel sensing LBT scheme, wide beam directional channel sensing LBT scheme, and narrow beam channel sensing LBT scheme. The omnidirectional LBT scheme is similar to the LBT scheme defined in 3GPP R16 NR-U system for low frequency band. Considering the transmission characteristics of high frequency band, the omnidirectional channel LBT scheme is not suitable for "B526G" band. In the LBT scheme of wide beam direction channel sensing, a wide LBT beam can contain multiple transmission beams, and the multiple narrow beams used for information transmission within the wide LBT beam are QCLed, that is, within the range of wide LBT beam, the receiver can use the same signal reception beam direction to receive signals in different narrow beam directions within the wide LBT beam range, as shown in Fig. 2.

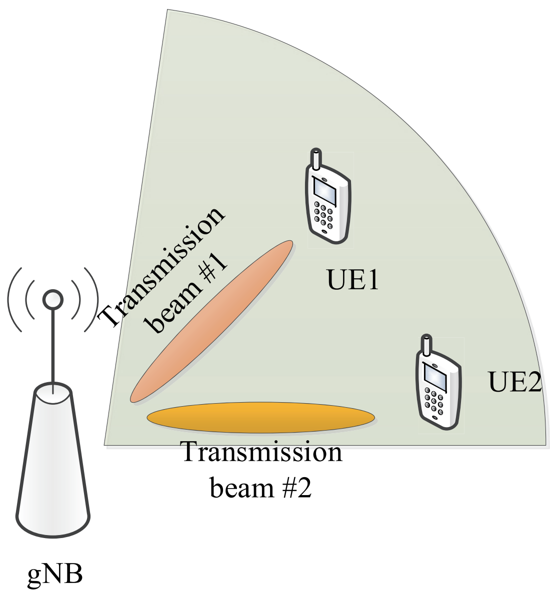

Figure 2 wide LBT beam contains multiple narrow information transmission beam.

For the narrow beam channel sensing LBT scheme, the LBT beam sensed in each channel has the same direction as the beam of information transmission. The disadvantage of this design is that the base station needs to configure a variety of reference signals for the terminal devices to determine the received beam direction, which reduces the spectral efficiency of the system in some extent.

3 Concluding remarks

Introducing larger SCS within a larger bandwidth in the frequency range from 52.6GHz to 71GHz for the NR system can improve the transmission rate. Meanwhile, larger SCS can also reduce the delay of signaling interaction between the terminal device and the base station to some extent.

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