Research on millimeter wave spectrum planning for 5G

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Abstract. In order to allocate reasonable frequency resources in millimeter wave band for 5th-Generation (5G), this paper summarizes the position and consideration of USA and China. It analyses the feasibility of sharing and compatibility in 24.25-27.5GHz, 66-71GHz, 81-86GHz with Monte-Carlo simulation. There is a high possibility to allocate 24.75-27.5GHz, 66-71 GHz and 81-86 GHz to 5G in ITU and China. But the commercial deployment in millimeter wave in China will be delayed 1-2 years because of industry bottleneck.

1. Introduction
Nowadays there is a fierce competition of 5G among telecom powers. 5G is urged to fulfill enhanced needs of high data rate, easy usage and low latency. There are three methods to enlarge the capacity of 5G: higher spectrum efficiency, denser coverage and more spectrum resource. The spectrum efficiency of 4G is already very high. Although it can be developed, it can’t meet the growing requirement of the service. More base stations are on the way, they can increase the capacity of the system, but they’re not enough to meet the requirements of wide band and electromagnetic compatibility. As a result, it is urgent to allocate more frequencies for 5G.

Frequency resource is essential for 5G deployment. Many countries have already allocated large amount of frequencies for 5G. USA allocated 13GHz in the high band for 5G in 2016&2017, and scheduled the third auction at the end of 2019. Korea allocated 3.3GHz in the middle and the high band for 5G. China allocated 8.45 GHz in the middle and the high band for 5G technical research and development experiment in 2016&2017, and allocated 460MHz in the middle band to three major operators in 2018. It needs much more frequencies for large scale deployment of 5G. There is little frequency resource that can be allocated to 5G below 6GHz. But there are plentiful frequencies in the millimeter wave band.

Strictly speaking, millimeter wave band starts from 30GHz, but under some conditions, the band above 10 GHz is also called millimeter wave band. For a long time, the characteristic of millimeter wave band is regarded as not suitable for mobile service (MS) because of its high transmitting loss and limitable coverage. Atmospheric attenuation, rain attenuation, leaves attenuation, and building penetration loss [1] contributes to the transmitting loss. But multiple antennas and beam forming can spread the distance of coverage in the light of sight (LOS) in millimeter wave band. Degrading diffraction compensating by strong reflection with beam forming can fulfill the connection [2] out of sight. This means that the low band remains the main operating band in 5G, meanwhile, the millimeter wave band can supplement the coverage with high capacity and high data rate in dense outdoor and indoor deployment scenario.
2. The position and consideration of USA and China on candidate bands

There are many candidate millimeter wave bands for 5G, such as 24.25-27.5 GHz, 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz, in which MS is primary service; and 31.8-33.4 GHz, 40.5-42.5 GHz and 47-47.2 GHz, in which MS isn’t primary service.

2.1. The position and consideration of the USA

The Federal Communications Commission (FCC) issued the 5G FAST plan to establish America’s superiority of 5G on September 28, 2018. It planned to auction millimeter wave spectrum in the first place. It held spectrum auctions in 2018 in 28 GHz and 24 GHz bands. It announced plans for the third auction of 5G frequency resource, which will be held on December 10, 2019, involving about 3.4GHz in 37 GHz, 39 GHz and 47 GHz bands.

However, there is dissension about the compatibility of 5G system and weather satellite in 24 GHz band. According to the report which the American delegation submitted to ITU-R TG5.1, separation distances of 52 km for SRS stations and 6 km for EESS stations are needed to protect the earth station. But the American meteorological society argued that the 5G’s use of 24.25 GHz band would interfere with the weather satellite in the 23.6-24 GHz.

The Senate held hearings for the dispute between the wireless society and the meteorological society on June 12. The two sides couldn’t reach an agreement on the hearings, and the congress will hold another hearing in the future. As a result, there is uncertainty of the American position in World Radio Conference-2019 (WRC-19) which scheduled from October 28 to November 22, 2019.

2.2. The position and consideration of China

Ministry of Industry and Information Technology (MIIT) of China approved 3.4-3.6 GHz, 4.8-5.0 GHz, 24.75-27.5 GHz, 37-42.5 GHz for 5G technological research and development experiment in 2016 and 2017. It promulgated 5G spectrum planning program which includes 3.3-3.4 GHz (indoor), 3.4-3.6 GHz, 4.8-5.0 GHz in November, 2017. Three operators received 5G mobile communication experiment frequencies on December 7, 2018. The allocation is seen as in table 1. MIIT issued four 5G licenses to China Mobile, China Telecom, China Unicom, China Broadcast Network on June 6, 2019.

| Operator         | Allocation (MHz) |
|------------------|------------------|
| China Telecom    | 3400-3500        |
| China Unicom     | 3500-3600        |
| China Mobile     | 2515-2575,2635-2675,4800-4900, 2575-2635 |

China supports to allocate 24.25-27.5 GHz, 37-43.5 GHz for 5G in case of protection of existent services. It opposes to allocate 31.8-33.4 GHz for IMT. In its opinion, there should be sharing and compatibility research in 66-71GHz, 71-76GHz, 81-86GHz.

3. The compatibility between 5G and other radio services

There were already some sharing and compatibility studies between MS and other services in 24.25-27.5 GHz, 37-40.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz [3]. But more sharing and compatibility studies are expected to be carried out.

3.1. The analysis of 24.75-27.5 GHz

There are many services in this band [4][5]. This band gets wide favor all over the world. USA and Korea allocated parts of this band to 5G. Chinese experiment in this band is under the way.

According to the conference preparatory meeting (CPM) report of ITU-R, sharing and compatibility studies for fixed service (FS), fixed-satellite service (FSS), inter-satellite service (ISS) were carried out, but radiolocation service (RLS), radiolocation-satellite service (RLSS), radionavigation service (RNS) were not carried out in this band. Take RNS as an example. Monte-
Carlo simulation [6] is recommended to analyse the compatibility between MS and RNS in this band. Based on ITU-R M.2101 [7], 5G system’s parameters are seen in table 2.

Table 2. 5G system’s parameters.

| Simulation parameter | Value              |
|----------------------|--------------------|
| Frequency            | 24.75-27.5GHz      |
| Network topology     | 30 BSs/km²         |
| Antenna height       | 6 m                |
| Downtilt             | 10 degrees         |
| Antenna deployment   | Roof-top           |
| Network loading factor | 50%              |
| Element gain         | 5dBi               |
| Antenna array        | 8x16 elements      |
| Array Ohmic loss     | 3 dB               |
| Power/antenna element| 8 dBm/200 MHz      |
| Channel bandwidth    | 50/100/200/400 MHz |

Since there are few RNS stations, it is recommended to gain parameters from ITU-R M.1466. RNS radar’s parameters are shown in table 3.

Table 3. Parameters of RNS radar in 24.25-27.5GHz.

| Parameter                        | Units                          | RNS Radar |
|----------------------------------|-------------------------------|-----------|
| Type                             | Aircraft                      |           |
| Altitude                         | m                             | Maximum: from 300 to ground, Nominal: from 150 to ground |
| Center frequency                 | GHz                           | Adjustable from 24.75 to 27.5 GHz |
| Maximum antenna gain             | dBi                           | 30        |
| Receiver noise figure            | dB                            | 6         |

According to ITU-R M.1461, interference to RNS radar caused by 5G system can be calculated as follows:

$$ I = P_T + G_T + G_R - L_r - L_p $$

where:

$I$: peak power of 5G signal at the RNS radar receiver input (dBm).
$P_T$: peak power of the 5G base station transmitter (dBm).
$G_T$: antenna gain of the 5G base station in the direction of the RNS radar (dBi).
$G_R$: the RNS radar receiver antenna gain in the direction of the 5G base station (dBi).
$L_r$: insertion loss in the 5G base station transmitter (dB).
$L_p$: insertion loss in the RNS radar receiver (dB).
$L_P$: propagation path loss between 5G base station and RNS radar antennas (dB).

It is suggested to adopt Recommendation ITU-R P.619 [8] for $L_P$.

$$ L_P = L_{bfs} + A_{xp} + A_g(p) + A_b + L_c(p_{lc}) + L_{be}(p_{lbe}) + L_{attb}(p)(dB) $$

where:

$L_{bfs}$: basic transmitting loss in free space.

$$ L_{bfs} = 92.45 + 20\lg d + 20\lg f $$

$A_{xp}$: loss caused by polarizaiton miss match.
$A_g(p)$: loss caused by air in atmosphere.
$A_b$: loss caused by waves scattering.
$L_c(p_{lc})$: clutter loss.
$L_{be}(p_{lbe})$: building entrance loss.
$L_{attb}(p)$: wave-guide enhancement diffraction loss.

The aggregate IMT system interference towards the RNS system is caculated as follows:
\[
I_A = \sum_j \sum_k I(TX_{BS_j}^{UE_i}, RX_{victim})
\]

\(I(TX_{BS_j}^{UE_i}, RX_{victim})\): Inter-system interference from BS\(_j\) (when its k-th UE is served) to the RNS receiver.

![Graph](image1)

![Graph](image2)

**Figure 1.** The I/N ratio in the RNS radar in 24.75-27.5GHz (dB).

**Figure 2.** The I/N ratio in the RNS radar in 66-71GHz (dB).

According to ITU-R M.1461, an I/N ratio below -6 dB is acceptable by the RNS radar users. As seen in the figure 1, the I/N ratio is below -46 dB. As a result, 5G system is compatible with this RNS radar. Based on the calculation above and the CPM report, sharing is feasible between MS and RNS, EESS/SRS, RAS, FS. So it is possible to allocate 24.75-27.5 to MS in ITU and China.

### 3.2. The analysis of 66-71 GHz

| Parameter                  | Units       | RNS Radar Details                                                                 |
|----------------------------|-------------|----------------------------------------------------------------------------------|
| Tuning type                |             | Fixed frequency, tunes continuously across 66-71 GHz                              |
| Emission type              |             | Unmodulated pulses                                                               |
| RF emission bandwidth      | MHz         | 37                                                                               |
| Pulse duration             | s           | 0.2                                                                              |
| Pulse repetition frequency | pps         | 2,000                                                                            |
| Peak transmitter power     | kW          | 60                                                                               |
| Receiver IF bandwidth (−20 dB) | MHz    | 40                                                                               |
| Receiver noise figure      | dB          | 11                                                                               |
| Antenna type               |             | Parabolic reflector                                                             |
| Antenna main beam gain     | dBi         | 44                                                                               |
| Antenna scan               |             | Elevation: −30 to 10°, manual, azimuth: 360° at 7, 12, or 21 rpm                  |

This band was selected for 5G in the first batch of bands in the USA. China supports to allocate it for 5G in case of protection of existent services. According to the CPM report of ITU-R, sharing and compatibility studies for ISS and MSS (E-S) were carried out, but RNS, radionavigation-satellite service (RNSS), MSS (space to earth, S-E) were not carried out in this band. Take RNS as an example. Monte-Carlo simulation is used to analyse the compatibility between MS and RNS in this band.

There are few RNS stations in this band too, it is suggested to gain parameters from ITU-R M.1466, RNS radar’s parameters in this band are shown in table 4. Interference to RNS radar caused by 5G system can be calculated as in equation (1). Path propagation loss is calculated as in equation (2)(3). The aggregate IMT system interference towards the RNS radar is calculated as in equation (4).
According to ITU-R M.1461, an I/N ratio below -6 dB is acceptable by the RNS radar users. As seen in the figure 2, the I/N ratio is below -40 dB. As a result, 5G system is compatible with this RNS radar. Based on the analysis above and the CPM report, sharing is feasible between MS and RNS, ISS, MSS (E-S). So it is possible to allocate 66-71GHz to MS in ITU and China.

3.3. The analysis of 81-86 GHz

China supports to allocate this band for 5G in case of protection of existent systems. According to the CPM report of ITU-R, sharing and compatibility studies for FS, FSS, RAS and RLS were carried out, but ARS, ARSS, MSS were not carried out in this band. Take MSS as an example. Monte-Carlo simulation is recommended to analyse the compatibility between MS and MSS in this band. The potential interference from the 5G base station (BS) and user equipment (UE) to the MSS receiving satellite in a geostationary orbit (GSO) is considered. MSS earth stations are supposed to be deployed in urban and sub-urban areas. The MSS’s uplink parameters are shown in table 5.

| Table 5. MSS’s uplink parameters. |
|-----------------------------------|
| **Frequency range** | **81-86 GHz** |
| Noise bandwidth | 250-600 MHz |
| Satellite Antenna diameter | 0.3-1m |
| Antenna gain | 40.8-47 dBi |
| Noise temperature | 250-400K |
| Earth Station Antenna gain | 43.5dBi |
| Height of antenna | 25m |
| Interference protection criteria | I/N = -6 and -10 dB |

The aggregate IMT system interference towards the MSS system is calculated as in equation (4).

10 thousand snapshots on Figure 3 depict that all the aggregated interferences are less than -130 dBm/MHz which is below the protection criteria of 250 K noise temperature: -124.6-120.6 dBm/MHz. The outcomes prove that the compatibility is viable in 1km or 1.4km of separate distance between 5G BS in hot places and MSS earth stations in this band. Based on the analysis above and the CPM report, sharing is feasible between MS and MSS, FS, FSS, RAS, EESS(p) and RLS. So it is possible to allocate 81-86GHz to MS in ITU and China.

4. CONCLUSION

The development of 5G system is a fierce competition, therefore big powers spare no effort to allocate more frequency resources for it. The USA made great progress in 5G millimeter wave spectrum planning. It had planned 24.25-24.45GHz, 24.75-25.25GHz, 64-71GHz etc. for 5G. China is just on the threshold of 5G millimeter wave spectrum planning. Technical experiments in millimeter are on the way. There is a high possibility to allocate 24.75-27.5GHz, 66-71 GHz and 81-86 GHz to 5G in
ITU and China. But the commercial deployment in millimeter wave in China will be delayed 1-2 years because of industry bottleneck.

Figure 3. IMT interference to MSS space station in 81-86GHz (dBm/MHz).

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References
[1] E. Semaan, F. Harrysson, A. Furuksar, H. Asplund 2014 *Outdoor-to-indoor coverage in high frequency bands*, Globecom 2014 Workshop-Mobile Communications in Higher Frequency Bands
[2] M.Akdeniz, et al. 2014 *Millimeter wave channel modeling and cellular capacity evaluation*, IEEE J. Sel. Area. Comm.32(6)
[3] ITU-R, Task Group 5/1 2018 *Draft CPM text for WRC-19 agenda item 1.13*, Document 5-1/TEMP/146-E
[4] ITU-R 2016 *Radio Regulation* ( Geneva: ITU)
[5] Radio Regulation Bureau of Ministry of Industry and Information Technology 2018 *Regulations on the radio frequency allocation of People’s Republic of China* (Beijing: Posts and Telecommunications Press)
[6] Jiajia C, Zhaojun Q and Tan W 2017 3rd *IEEE International Conference on Computer and Communications* pp 920-924
[7] ITU-R 2017 *Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies* ITU-R M.2101-0
[8] ITU-R 2017 *Propagation data required for the evaluation of interference between stations in space and those on the surface of the Earth* ITU-R P.619-3