Analysis on the New Progress of Spectrum Planning of IMT-2020(5G)

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ABSTRACT. In order to allocate reasonable spectrum resources above 6 GHz for 5th-Generation (5G) in China, this paper analyzes the new progress of upcoming World Radio Conference-2019 (WRC-19) agenda 1.13, the 3rd Generation Partnership Project (3GPP) 5G New Radio (NR), and Chinese 5G spectrum planning. It analyses the possibility of Chinese spectrum planning in several candidate frequency bands with Monte-Carlo simulation, including 24.75-27.5 GHz, 31.8-33.4 GHz, 37-43.5 GHz, 64-71 GHz, 71-76 GHz and 81-86 GHz. The compatibility is viable between mobile service (MS) and earth exploration satellite service (EESS), radio astronomy service (RAS), inter-satellite service (ISS) in 24.75-27.5 GHz. It’s likely to allocate 24.75-27.5 GHz to 5G in China. There is coexisting difficulty and adverse propagation condition in 31.8-33.4 GHz. It is almost impossible to allocate 31.8-33.4 GHz to 5G in China. It is compatible between MS and fixed-satellite service (FSS), EESS (passive) with additional isolation and out-of-band emission limitation in 37-43.5 GHz. It is possible to allocate 37-43.5 GHz to 5G in China.

1. INTRODUCTION

International Mobile Telecommunication (IMT) systems have tremendously changed the way of life of people all around the world. IMT-2020, which is well-known as the 5th-Generation of cellular mobile communications (5G), has become a hot topic of the general public and decision makers. Communications of machines, software defined cloud network, driverless vehicles with the support of smart road and internet of industry will contribute to the exponential increase of the applications of 5G. 5G is the beginning of internet of all things, the beginning of intelligent mobile communications, and the combination of communications, artificial intelligence, big data and cloud computing.

5G usage scenario defined by M.2083 of International Telecommunication Union - Radiocommunication Sector (ITU-R) Working Party 5D (WP5D) includes enhanced Mobile Broadband (eMBB), massive Machine Type Communications (mMTC), Ultra-Reliable and Low Latency Communications (URLLC). 5G supports 100 Mbps-1Gbps data rates for verge user, 10-20 Gbps peak data rates of system, 1 million/km\textsuperscript{2} of connecting density, 1millisecond of radio access latency, spectrum efficiency of 3-5 times of 4th-Generation (4G), 500 km/h of mobility, 10 Mbit/(s\times m^2) of data flow density [1].

The number of 5G connections will reach ten billion in 2019 according to the prediction of DAMO Academy of Alibaba [2]. The increase of connections leads to the increase of data flow. According to Ericsson Mobility Report, total mobile data flow of North America, Western Europe and North East Asia will reach 19 EB/month, 14 EB/month and 39 EB/month respectively in 2024 [3]. The increase of
data flow needs more spectrum resources. The band below 1 GHz is useful for 5G to fulfill wide area coverage in low cost, but there are too many radio stations below 1 GHz and interference easily happens. 1-6 GHz is essential for 5G to realize wide area coverage, high speed mobility and enormous connections. 6-100 GHz is important for 5G in supporting high speed and great volume. According to the research of ITU-R WP5D, spectrum requirements of 5G are about 14.8-19.7 GHz by the technology performance in 24.25-86 GHz [4]. It is necessary to integrate the planning of low, middle and high frequency bands of 5G as a whole. Radio administrations all over the world including Chinese National Radio Administration Bureau (NRAB) are busy with allocating reasonable spectrum resources for 5G. Now that China has already ascertained the middle band of 5G radio frequencies, it is urgent to find frequencies in high band to seize the superiority of 5G spectrum exploitation and usage.

2. CONSIDERATION OF 5G SPECTRUM RESOURCES

Everyone supports that we should use spectrum resources in a harmony way, but different people have different needs. The large numbers, the ubiquitous nature and the broadband of 5G represents a great threat to lots of existent radio stations.

2.1 Consideration of ITU-R

World Radio Conference-2015 (WRC-15) is a big success to have a harmonious frequency allocation worldwide for IMT. It allocates 470-694/698 MHz, 694-790 MHz (Region1), 1427-1518 MHz, 3300-3400 MHz, 3400-3700 MHz, 4800-4990 MHz to mobile service (MS) or for IMT. It is the first time to associate the frequency band with IMT conditional use. The IMT frequency bands had increased by 60%, and IMT spectrum amounts to 1886 MHz after WRC-15. The spectrum allocating for IMT is shown in Figure 1.

Figure 1. The spectrum allocating for IMT

It has been much more difficult to find extra spectrum resources below 6 GHz after WRC-15; thereby spectrum management authorities and research societies have spared no efforts to find more spectrum resources above 6 GHz.

Agenda 1.13 of WRC-19 scheduled from October 28 to November 22, 2019 considers the frequency range between 24.25 and 86 GHz for the future use of 5G, included as follows:

-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 yet.

According to Radio Regulations of ITU, the 6-100 GHz spectrum is diversified allocated for the fixed service (FS), MS, radio determination service (RDS) and several space related services [5].
2.2 Consideration of 3GPP
The 3rd Generation Partnership Project (3GPP) unities, which are the main 5G standard organizations, devote their efforts to 5G standards. 3GPP’S 5G standards are achieved in particular Releases. “Functionality frozen” release is eligible for coming into effect.

3GPP completed Release 15 including what is called as “phase1” standardization for 5G New Radio (NR) standard in June of 2018. 3GPP will publish Release 16 which is completely compatible with IMT-2020 at the end of 2019. Release 16 includes the 3GPP research fruit of “phase2” of 5G NR.

3GPP defines two types of frequency range. FR1 ranges below 6 GHz. FR2 ranges above 6 GHz. Definition of frequency range is shown in table 1. Operating bands in 3-6 GHz are shown in table 2. Operating bands above 6 GHz are shown in table 3.

5G’s channel bandwidth diversifies into 5-100 MHz below 6 GHz and 50-400 MHz above 6 GHz. Its subcarrier spacing (SCS) diversifies into 15/30/60 KHz below 6 GHz and diversifies into 60/120 KHz above 6 GHz. Its bandwidth and SCS above 3 GHz is seen as in table 4&5[6].

2.3 Consideration of China
China has made great progress in 5G. Ministry of Industry and Information Technology (MIIT) issued the 5G spectrum planning which clarifies 3300-3400 MHz (indoor), 3400-3600 MHz and 4800-5000 MHz as 5G system operating frequency band on November 9, 2017. It issued four 5G licenses to operators on June 6, 2019.

| Name | Frequency Range (MHz) |
|------|-----------------------|
| FR1  | 450-6000              |
| FR2  | 24250-52600           |

| Operating Band | Uplink (MHz) | Downlink (MHz) | Duplex Mode |
|----------------|--------------|----------------|-------------|
| n77            | 3300-4200    | 3300-4200      | TDD         |
| n78            | 3300-3800    | 3300-3800      | TDD         |
| n79            | 4400-5000    | 4400-5000      | TDD         |

| Operating Band | Uplink (MHz) | Downlink (MHz) | Duplex Mode |
|----------------|--------------|----------------|-------------|
| n257           | 26500-29500  | 26500-29500    | TDD         |
| n258           | 24250-27500  | 24250-27500    | TDD         |
| n260           | 37000-40000  | 37000-40000    | TDD         |

Table 4. Channel bandwidth in 3-6 GHz

| Operating Band | SCS (KHz) | Channel Bandwidth (MHz) |
|----------------|-----------|-------------------------|
|                | 10        | 20                      | 40  | 50  | 60  | 80  | 100 |
|                |           |                         |     |     |     |     |     |
Table 5. Channel bandwidth above 6 GHz

| Operating Band | SCS (KHz) | Channel Bandwidth (MHz) |
|---------------|-----------|-------------------------|
|               | 50        | 100         | 200       | 400       |
| n257          |           |             |           |           |
| 60            | ✓         | ✓           | ✓         | ✓         |
| 120           | ✓         | ✓           | ✓         | ✓         |
| n258          |           |             |           |           |
| 60            | ✓         | ✓           | ✓         | ✓         |
| 120           | ✓         | ✓           | ✓         | ✓         |
| n260          |           |             |           |           |
| 60            | ✓         | ✓           | ✓         | ✓         |
| 120           | ✓         | ✓           | ✓         | ✓         |

China initiated 5G experiment in 2016. The experiment is guided by MIIT and organized by the IMT-2020 (5G) Promotion Group. According to the plan, 5G technology research and development experiment was conducted during 2016-2018, 5G products research and development experiment will be conducted during 2019-2020. 5G technology research and development experiment includes key technology verification, technology scheme verification and network of system verification and has three phases. The main task of phase III of 5G technology research and development experiment is to test the equipment of single station, network, interconnection and intercommunication, and to promote main sections of industry chain to the level of commercial usage. IMT-2020 (5G) Promotion Group completed phase III of 5G technology research and development experiment on September 28, 2018. It laid a strong emphasis on the much quicker pace of commercial development of 5G network at the Central Economic Work Conference in December, 2018. The three major telecommunications operators gained the 5G experimental radio frequency spectrum resources on December 7, 2018. Chinese 5G experimental radio frequency bands are seen in the table 6.

Table 6. Chinese 5G experimental frequency band

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

Chinese companies have been making great progress in 5G. Huawei released 5G spectrum public policy position in November 2017. It declared that every operator needs 100 MHz successive band in the bands of 3 GHz and 6 GHz to meet the needs of Massive MIMO and 5G standard speed, and 800 MHz successive band in the bands of 26 GHz and 40 GHz to meet the needs of wireless broad band access and high speed MS. It released its first commercial 5G cell phone on July 26, 2019.
3. ANALYSIS OF 5G CANDIDATE FREQUENCY BAND ABOVE 6 GHZ IN CHINA

MITT approved 24.75-27.5 GHz and 37-42.5 GHz for 5G technology research and development experiment in July 3, 2017. Other possible spectrum bands planning for 5G in China include 31.8-33.4 GHz, 64-71 GHz, 71-76 GHz and 81-86 GHz.

3.1 Analysis of 24.75-27.5 GHz

24.75-27.5 GHz gets much favor because its device maturity and high coverage capability compared with other frequency bands above 6 GHz. NRAB is collecting suggestions using this band for researching and development experiments. There are radionavigation service (RNS), FS, MS, intersatellite service (ISS), fixed-satellite service (FSS) (earth-to-space, ES) and standard frequency and time signal-satellite service (SFTSS) (E-S) in this band in the Table of Frequency Allocations (TFA) of Chinese mainland. SFTSS (E-S) is secondary service and MS is the primary service in this band. Accordingly, there are millimeter wave relay communication stations, satellite communication earth stations, fixed broadband wireless access stations. FS station, such as millimeter wave relay communication stations, can solve the interference problem caused by 5G station by using highly-directional antenna. FS and SFTSS stations are in E-S direction in this band, so there is low possibility for 5G station to interfere them. But there is earth exploration satellite service (EESS) (passive) in the adjacent 23.6-24 GHz band, it is essential to analyze the possibility of interference between EESS station and 5G station.

Recommendation ITU-R M.2101 is used as the model of 5G system for compatibility calculation with EESS earth stations in this band. It is proposed to use Recommendation ITU-R P.452 for sharing studies between 5G systems and EESS earth stations with the exception of calculating additional loss due to clutter. It usually adopts 20% of time criterion for the long-term criterion simulation and 0.001667% of time criterion for the short-term criterion simulation based on Recommendation ITU-R P.452. 5G base station (BS) is deployed in this band as outdoor urban and sub-urban hotspots. EESS earth stations are supposed to be deployed in urban and sub-urban areas. It usually adopts 30 BS/km² as the density of coverage. Backed up by a Monte-Carlo simulation, CDF (Cumulative Distribution Function) and linear average values for numerable snapshots representing 5G BS interference to EESS earth stations in this band are summed. Chinese document submitted to ITU-R proves that the compatibility is viable between 5G BS in hot places and EESS earth stations with 16.4 dB of isolation and -36/-40dBW/200MHz of out-of-band emission limitation in this band. There are similar results between radio astronomy service (RAS) and MS, ISS and MS. If there is high possibility to allocate this band to 5G in China.

3.2 Analysis of 31.8-33.4 GHz

There are few countries and experts paying attention to 31.8-33.4 GHz because it is difficult to coexist for 5G system and RNS in this band. RNS is primary service in TFA in mainland of China in this band. There is no MS in this band in China. There is rain and snow absorption, scattering and distortion of refraction. There are reflected, scattered and diffracted waves caused by buildings. There is also hiding effects in mountain area. Due to coexisting difficulty and adverse propagation condition, it is almost impossible to allocate this band to 5G in China.

3.3 Analysis of 37-43.5 GHz

37-43.5 GHz is a favorite cake of many nations. NRAB is seeking advice on this band. There are FSS (space-to-earth, S-E), space research service (SRS) (S-E), EESS (S-E) in this band in the TFA of Chinese mainland. MS is primary service in 37-38 GHz (aeronautical mobile service not included) and 38-40.5 GHz. It is secondary service in 40.5-42.5 GHz. Resolution 75 of WRC-2000 (revised by WRC-12) decided that 37-40 GHz and 40.5-43.5 GHz are available for high-density applications in the FS. Resolution 75 of WRC-12 declared that co-frequency sharing between high-density fixed-satellite service (HDFSS) and MS is difficult in the same geographical area, but it can be realized using interference alleviation techniques. Spectrum manager
should take into further account of potential constraints of the deployment of high-density FSS and FS to 5G system.

Figure 2. The deployment scenario

Take 42.5-43.5 GHz for example. In order to simulate the worst case, the elevation angle of the main lobe of the BS is directed to the space station. It is proposed to use Recommendation ITU-R P.619 for sharing studies between 5G systems and FSS earth stations. 5G base stations are deployed in 42.5-43.5 GHz as outdoor urban and sub-urban hotspots. FSS earth stations are supposed to be deployed in urban and sub-urban areas. The supposed density of coverage is 30 BS/km². Recommendation ITU-R M.2101 is used as the model of 5G system for compatibility analysis with FSS earth stations in this band.

| Simulation parameter       | Value                        |
|----------------------------|------------------------------|
| Frequency                  | 42.5-43.5 GHz                |
| 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              | 8×16 elements                |
| Array Ohmic loss           | 3 dB                         |
| Power/antenna element      | 8 dBm/200 MHz                |

Table 8. FSS’s uplink parameters

| Frequency range            | 42.5-43.5 GHz                |
|----------------------------|------------------------------|
| Noise bandwidth            | 250-600 MHz                  |

**Satellite**

| Antenna diameter           | 0.3-1 m                      |
|----------------------------|------------------------------|
| Antenna gain               | 40.8-47 dBi                  |
| Noise temperature          | 250-400 K                    |

**Earth Station**

| Antenna gain               | 43.5 dBi                     |
|----------------------------|------------------------------|
| Height of antenna          | 25 m                         |

**Interference protection criteria**

| I/N                        | -6 and -10 dB                |
CDF and linear average values of 5G BS interference to FSS earth stations in this band can be got through a Monte-Carlo simulation. Interference of space station received is calculated as follows:

\[ I_{IMT} = P_{IMT} + G_{IMT} + G_{FSS} - L_b - CL - ACLR (dB) \]

- \( P_{IMT} \): IMT base station transmitter power.
- \( G_{IMT} \): the gain of IMT base station antenna.
- \( G_{FSS} \): the gain of FSS space station antenna.
- \( L_b \): the transmitting path loss.
- \( CL \): scattering loss.
- \( ACLR \): adjacent channel emission ratio.

\( L_b \) is calculated as follows:

\[ L_b = L_{bfs} + A_{xp} + A_g (p) + A_{bs} + L_c (p_{lc}) + L_{be} (p_{lbe}) + L_{dtb} (p) (dB) \]

- \( L_{bfs} \): basic transmitting loss in free space.
- \( A_{xp} \): loss caused by polarizaition miss match.
- \( A_g (p) \): loss caused by air in atmosphere.
- \( A_{bs} \): loss caused by waves scattering.
- \( L_c (p_{lc}) \): clutter loss.
- \( L_{be} (p_{lbe}) \): building entrance loss.
- \( L_{dtb} (p) \): wave-guide enhancement diffraction loss.

The aggregate IMT system interference \( I_{IMT} \) towards the FSS system. The total interference \( I_{IMT} = \sum_{i} \sum_{k} I_{IMT} (TX_{UEi}^{UEi}, RX_{victim}^{RX}) \)

\( I_{IMT} (TX_{UEi}^{UEi}, RX_{victim}^{RX}) \): Inter-system interference from BS_i (when its k-th UE is served) to the FSS receiver.

The simulation results depicted below are for numerable 42.5-43.5 GHz 5G base stations aggregate interference. The CDF curve of the numerable 5G base stations aggregated interference is depicted on Figures 3 for the protection distances of 1 km.

Ten thousand snapshots on Figure 3 depict that all the aggregated interferences are less than -135 dBm/MHz (corresponds to -10 dB I/N long-term criterion, 250/500 K noise temperature) which is below the protection criteria 250 K noise temperature: -124.6-120.6 dBm/MHz. Outcomes prove that the compatibility is viable in 1km or 1.4km of separate distance between 5G BS in hot places and FSS earth stations in this band. It is compatible with additional isolation and out-of-band emission limitation between EESS (passive) in 36-37 GHz and MS in 37-43.5 GHz. Based on the analysis above, it is possible to allocate 37-43.5 GHz to 5G in China.

![Figure 3. IMT interference(dBm/MHz)](image-url)
3.4 Preliminary analysis of other possible candidate frequency bands

64-71 GHz, 71-76 GHz and 81-86 GHz are the other possible candidate frequency bands. There are ISS, RNS, radionavigation-satellite service (RNSS), radiolocation service (RLS), FS, FSS (S-E), mobile-satellite service (MSS) (S-E), broadcasting service (BS), broadcasting-satellite service (BSS), RAS, Space research service (SRS) (S-E) in these bands in the TFA of Chinese mainland. SRS(S-E) is secondary service and MS is primary service in these bands.

According to China Radio Frequency Allocation Regulation, 5G stations may be operated in the condition that they don’t cause harmful interference to the space radio communication services in the band 64-71 GHz.

5G and FS station can coexist in certain separate distance in 71-76 GHz and 81-86 GHz. 5G and RAS station can meet the requirements of coexisting and compatibility in certain separate distance in 79-92 GHz based on Chinese documents submitted to ITU-R. The possibility of compatibility between 5G and EESS (passive) station in 86-92 GHz needs further research in the future.

4. CONCLUSION

5G is the beginning of internet of all things. Its spectrum requirement is enormous. Since its low and middle bands of frequency are determined, it is essential to look for high band of frequency for it. 24.75-27.5 GHz, 31.8-33.4 GHz, 37-43.5 GHz, 64-71 GHz, 71-76 GHz and 81-86 GHz are possible candidate frequency bands for 5G in China. The compatibility is viable between MS and EESS, RAS, ISS in 24.75-27.5 GHz and adjacent band. It’s likely to allocate 24.75-27.5 GHz to 5G in China. There is coexisting difficulty and adverse propagation condition in 31.8-33.4 GHz. It is almost impossible to allocate 31.8-33.4 GHz to 5G in China.

It is compatible between MS and FSS, EESS (passive) with additional isolation and out-of- band emission limitation in 37-43.5 GHz and adjacent band. It is possible to allocate 37-43.5 GHz to 5G in China. 64-71 GHz, 71-76 GHz and 81-86 GHz need further research in the future.

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