

TECHNICAL ANNEX

5G In-Band and Out-Of-Band Limits and Protection of FSS Earth Stations

The C-Band Alliance (“CBA”) reviewed and analyzed key technical questions raised in the opening round of comments and discussed them with its customers, mobile equipment manufacturers and mobile carriers. Based on these inputs, the CBA was able to optimize its analysis for the protection of Fixed Satellite Services (“FSS”). This optimization allowed for a more accurate definition of power limits and out-of-band emission limits for 5G, and of protection mechanisms for the FSS. As a result, the CBA proposes that the Commission adopt the technical rules described below.

I. IN-BAND POWER LIMITS AND PROTECTION OF FSS EARTH STATIONS OPERATING IN THE 3900-4200 MHZ BAND

a. Power Limits for Fixed and Base Stations

In the NPRM, the Commission proposed the following power limits for Fixed and Base Stations for emission bandwidths greater than one megahertz:

- 3280 watts/MHz (65 dBm/MHz) in rural areas and
- 1640 watts/MHz (62 dBm/MHz) in other areas.¹

The CBA’s ultimate objective is to ensure that all FSS services in the C-band Downlink are fully protected while, at the same time, not placing overly restrictive limitations on 5G deployment that would inhibit it from achieving its full potential. In its comments, the CBA proposed a maximum EIRP density limit of 46 dBm/MHz.² This EIRP density limit was based

¹ Expanding Flexible Use of the 3.7 to 4.2 GHz Band, GN Docket No. 18-122 et al., Order and Notice of Proposed Rulemaking, FCC 18-91, ¶ 164 (rel. July 13, 2018) (“NPRM”).

² Comments of the C-Band Alliance, Technical Annex at 9, GN Docket Nos. 18-122, 17-183 (Oct. 29, 2018) (“CBA Comments”).

on information the CBA had at its disposal at the time, and it represented an EIRP density limit not to be exceeded directly in the line of sight of any FSS earth station in order to avoid saturation of the earth station LNB.

Since then, the CBA has acquired a deeper understanding of mobile technology through research and analysis, and a direct dialogue with mobile equipment manufacturers and operators, particularly when it comes to the use of active antenna array technology, commonly referred to as Massive MIMO.³ Massive MIMO technology will be a key and necessary component to enable 5G networks. When used in terrestrial 5G deployments and radio network management, it could allow for higher overall base station EIRP levels while limiting power levels in the direction of FSS earth stations, for example, by creating nulls in antenna patterns in specific directions or by preventing beams from pointing in the direction of the FSS earth stations.

In order to ensure greater flexibility for deployment of 5G services while ensuring continued protection of FSS earth stations, the CBA proposes that, in lieu of including the referenced 46 dBm/MHz limit in technical rules, technical rules similar to those set forth in Section 96.17 for the protection of FSS earth stations should be adopted by the Commission. In order to ensure that FSS users also have flexibility to maintain and grow their business, the technical rules should establish that, for any given earth station location registered in IBFS, antennas with various sizes will be protected and have full-band full-arc access. In addition, all earth station antennas within a 150 meters radius from the location of the registered earth station should be protected. This allows for a single earth station site to accommodate multiple C-band downlink antennas. Considering the freeze on earth station registrations, it is necessary to protect

³ Multi-input, multi-output.

additional antennas to be deployed at existing sites so that FSS users can continue and grow the services they are providing.

The CBA proposes that the Commission adopt the following rules, which would apply individually to each 5G licensee:

- the aggregate radiofrequency (RF) power density at the output of a reference RF filter and antenna of an FSS earth station, produced by emissions from all Fixed and Base Stations of a 5G licensee within 40 kilometers shall not exceed a value of -81.6 dBm/MHz⁴ in the band 3700-3900 MHz;
- the reference antenna pattern⁵ is the following:

$G = 52.6 \text{ dBi}$	for $0^\circ \leq \phi < 1.5^\circ$
$G = 29 - 25 \log \phi \text{ dBi}$	for $1.5^\circ \leq \phi < 7^\circ$
$G = 8 \text{ dBi}$	for $7^\circ \leq \phi < 9.2^\circ$
$G = 32 - 25 \log \phi \text{ dBi}$	for $9.2^\circ \leq \phi < 48^\circ$
$G = -10 \text{ dBi}$	for $48^\circ \leq \phi \leq 180^\circ$

where ϕ is the off-axis angle from the main beam of the antenna;

- the reference RF filter between the feed-horn and LNA/LNB has an attenuation of 43 dB between 3700 and 3900 MHz;⁶
- the -81.6 dBm/MHz value shall be complied with for any pointing of the antenna towards the GSO arc with an elevation angle greater than or equal to 5 degrees;⁷ and
- the -81.6 dBm/MHz value shall be complied with for all earth station antennas within a radius of 150 meters of the location of the registered earth station.

⁴ A value of -81.6 dBm/MHz translates into a total power of -59 dBm over the band 3700-3900 MHz. This value was referenced in the CBA Comments Technical Annex. CBA Comments, Technical Annex at 5, 9.

⁵ The antenna pattern is based on Section 25.209 for off-axis-angles greater than 1.5 degrees. For off-axis-angles less than 1.5 degrees, it is proposed to use a flat gain of 52.6 dBi in order to ensure that antenna diameters between 3 meters and 13 meters are being protected.

⁶ This value is the measured effective filter rejection in 3700 MHz to 3900 MHz of the filter described in Figure 1 and Figure 2 of the Comments of the C-Band Alliance. CBA Comments, Technical Annex at 6.

⁷ Considering the freeze on earth station registrations it is necessary to maintain full arc flexibility so that FSS users can continue and grow the services they are providing.

The list of FSS earth stations to be protected by this limit will be based on the earth stations registered in IBFS within 30 days of the FCC Order.⁸ Using the list of earth stations, each 5G licensee will be able to verify that it complies with the rules when developing its deployment in the vicinity of the registered earth stations.

In conclusion, the CBA agrees with the Commission's proposed power limits for Fixed and Base Stations and does not see a need to limit the overall EIRP to 75 dBm, provided that the rules proposed by the CBA to limit the aggregate power density in the 3700-3900 MHz band at the earth station are adopted.

b. Power Limits for Mobiles and Portables

The Commission proposed to limit the power of mobiles and portables to 1 Watt. This proposal was supported by Nokia, Ericsson and Verizon, while Qualcomm, CTIA and T-Mobile proposed a higher limit. In order to minimize the impact of multiple mobile and portable devices transmitting in the vicinity of FSS earth stations, the CBA supports a power limit of 1 Watt and the Commission proposal that mobile and portable stations must employ a means for limiting power to the minimum necessary for successful communications.

II. OUT-OF-BAND EMISSION LIMITS AND PROTECTION OF FSS EARTH STATIONS OPERATING IN 3900-4200 MHZ

In the NPRM, the Commission proposed to apply “the longstanding limit on out of band emissions of -13 dBm/MHz at the authorized channel edge . . .”⁹ The Commission also

⁸ To further ensure inclusion of all eligible incumbent users, the FCC should again, temporarily for a period of 30-days following publication of the Report and Order in the Federal Register, lift the freeze on receive-only registrations and license applications for operations in the C-band Downlink for earth stations that were in operation as of April 18, 2018. This additional filing window would enable earth station operators to register any existing antennas that were not registered by the prior filing window deadline and thus accord those antennas protection from interference at the earth station from licensed terrestrial flexible use operations.

⁹ NPRM ¶ 168.

referenced the existing conducted power limits for out-of-band emission in the Citizens Broadband Radio Service, i.e. -25 dBm/MHz at or beyond 10 megahertz outside of the band edge and -40 dBm/MHz at or beyond 20 megahertz outside of the band edge.¹⁰ In its comments, Ericsson supported a conducted power level of -40 dBm/MHz at about 25 megahertz from the band edge for base stations.¹¹ Nokia proposed -3 dBm from the band edge to 20 megahertz from band edge, -40 dBm/MHz from 20 megahertz to 40 megahertz from the band edge and -50 dBm/MHz beyond 40 megahertz from the band edge for base stations.¹²

The out-of-band emissions limits for base stations referenced by the CBA were more stringent. The CBA referenced a limit of -50 dBm/MHz for 20 megahertz to 40 megahertz from the band edge and -60 dBm/MHz beyond 40 megahertz from the band edge.¹³ The CBA also assumed in its comments that these out-of-band emissions are transmitted in the line of sight of FSS earth stations.

The CBA has subsequently confirmed that the out-of-band emissions levels proposed by Nokia are acceptable provided that the following rules, which would apply individually to each 5G licensee, are adopted:

- the aggregate passband radiofrequency (RF) power spectral density at the output of a reference RF filter and antenna at the location of an FSS earth station operating in the 3900-4200 MHz band, produced by emissions from all from all Fixed and Base Stations of a 5G licensee within 40 kilometers shall not exceed a value of -133 dBm/MHz¹⁴ for

¹⁰ NPRM ¶ 169.

¹¹ Comments of Ericsson at 21, GN Docket No. 18-122 (Oct. 29, 2018).

¹² Correction of Technical Proposal, Comments of Nokia at 1, GN Docket No. 18-22 (Dec. 3, 2018).

¹³ CBA Comments, Technical Annex at 9.

¹⁴ This value is the result of the analysis performed by the CBA for the protection of its TT&C earth stations where a maximum I/N of -15 dB is necessary to not materially degrade a TT&C downlink.

earth stations used for satellite telemetry, tracking, and control (“TT&C”) operations and -128 dBm/MHz¹⁵ for other earth stations;

- the reference antenna pattern¹⁶ to be used is the following:

$G = 52.6 \text{ dBi}$	for $0^\circ \leq \phi < 1.5^\circ$
$G = 29 - 25 \log \phi \text{ dBi}$	for $1.5^\circ \leq \phi < 7^\circ$
$G = 8 \text{ dBi}$	for $7^\circ \leq \phi < 9.2^\circ$
$G = 32 - 25 \log \phi \text{ dBi}$	for $9.2^\circ \leq \phi < 48^\circ$
$G = -10 \text{ dBi}$	for $48^\circ \leq \phi \leq 180^\circ$

where ϕ is the off-axis angle from the main beam of the antenna;

- the reference RF filter has a 1 dB insertion loss in the passband;
- the -133 dBm/MHz and -128 dBm/MHz values shall be complied with for any pointing of the antenna towards the GSO arc with an elevation angle greater than 5 degrees;
- the -133 dBm/MHz and -128 dBm/MHz values shall be complied with for all earth station antennas within a radius of 150 meters of the location of the registered earth station.

The FSS earth stations to be protected by this limit are the same as defined in Section I. a.

In conclusion, the CBA agrees to the out-of-band emission limits as proposed by Nokia: - 3 dBm/MHz from band edge to 20 megahertz from band edge, -40 dBm/MHz from 20 megahertz to 40 megahertz from the band edge and -50 dBm/MHz beyond 40 megahertz from the band edge for base stations, provided that the rules proposed by the CBA to limit the aggregate power density in the 3900-4200 MHz band at the earth station are adopted.

¹⁵ This value was referenced in the CBA comment Technical Annex. CBA Comments, Technical Annex at 7.

¹⁶ The antenna pattern is based on Section 25.209 for off-axis-angles greater than 1.5 degrees. For off-axis-angles less than 1.5 degrees, it is proposed to use a flat gain of 52.6 dBi in order to ensure that antenna diameters between 3 meters and 13 meters are being protected.

III. PROTECTION OF FSS EARTH STATIONS OPERATING IN 3700-3900 MHZ

The CBA identified a list of 14 FSS TT&C and teleport earth stations¹⁷ that will need to continue operating in the 3700-3900 MHz band to ensure safe operation of the satellites and continuity of a limited number of services.

In order to protect these earth stations, the CBA proposes that the following rules be adopted by the Commission and apply individually to each 5G licensee:

- the aggregate passband radiofrequency (RF) power spectral density at the output of a reference antenna of an FSS earth station operating in the 3700-3900 MHz band, produced by emissions from all Fixed and Base Stations of a 5G licensee within 150 kilometers shall not exceed a value of -133 dBm/MHz for earth stations used for satellite telemetry, tracking, and control (“TT&C”) operations¹⁸ and -128 dBm/MHz for other earth stations;
- the reference antenna pattern¹⁹ to be used is the following:

$G = 52.6 \text{ dBi}$	for $0^\circ \leq \phi < 1.5^\circ$
$G = 29 - 25 \log \phi \text{ dBi}$	for $1.5^\circ \leq \phi < 7^\circ$
$G = 8 \text{ dBi}$	for $7^\circ \leq \phi < 9.2^\circ$
$G = 32 - 25 \log \phi \text{ dBi}$	for $9.2^\circ \leq \phi < 48^\circ$
$G = -10 \text{ dBi}$	for $48^\circ \leq \phi \leq 180^\circ$

where ϕ is the off-axis angle from the main beam of the antenna;

- the -133 dBm/MHz and -128 dBm/MHz values shall be complied with for any pointing of the FSS earth station antenna towards the GSO arc with an elevation angle greater than 5 degrees; and

¹⁷ CBA Comments, Technical Annex at 3.

¹⁸ The CBA provided a list of 14 earth stations used for TT&C in its comments. CBA Comments, Technical Annex at 3.

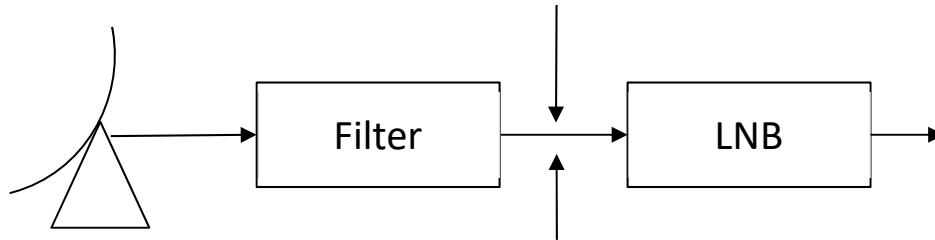
¹⁹ The antenna pattern is based on Section 25.209 for off-axis-angles greater than 1.5 degrees. For off-axis-angles less than 1.5 degrees, it is proposed to use a flat gain of 52.6 dBi in order to ensure that antenna diameters between 3 meters and 13 meters are being protected.

- the -133 dBm/MHz and -128 dBm/MHz values shall be complied with for all earth station antennas within a radius of 150 meters from the location of the registered earth station.

Appendix – Protection of FSS Operations in 3900-4200 MHz other than TT&C

Maximum aggregate power density per 5G licensee in 3700-3900 MHz

$< -81.2 \text{ dBm/MHz}$



$< -128 \text{ dBm/MHz}$

Maximum aggregate power density per 5G licensee in 3900-4200 MHz