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May 22, 2017

VIA ELECTRONIC SUBMISSION

Mr. Jose Albuquerque
Chief, Satellite Division
International Bureau
Federal Communications Commission
445 12th Street SW
Washington, DC 20554

Re: O3b Limited Response to Commission Questions
IBFS File No. SAT-AMD-20161115-00116 (Call Sign S2935)

Dear Mr. Albuquerque,

O3b Limited ("O3b") hereby provides the following supplemental information in response to the letter dated March 21, 2017,[1] regarding the above-referenced O3b application.[2] The text of the questions in the Commission Letter is provided below (with footnotes omitted), followed by O3b's response for each question.

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[1] Letter of Jose P. Albuquerque, Chief, Satellite Division, International Bureau, Federal Communications Commission, to Karis Hastings, Counsel to O3b Limited, dated Mar. 21, 2017 in IBFS File No. SAT-AMD-20161115-00116 (the "Commission Letter"). The Commission Letter specified a response deadline of April 20, 2017, but O3b requested and was granted a thirty-day extension of time to respond. *See* Letter of Suzanne Malloy, VP Regulatory Affairs, O3b Limited to Jose Albuquerque, Chief, Satellite Division, International Bureau, Federal Communications Commission, dated Apr. 17, 2017 in IBFS File No. SAT-AMD-20161115-00116 ("Extension Letter"), grant-stamped Apr. 20, 2017.

[2] Amendment of O3b Limited, Call Sign S2935, IBFS File No. SAT-AMD-20161115-00116 (Nov. 15, 2016) ("O3b Amendment").

1. In its prior applications, O3b states that all of its satellite downlink transmissions would not exceed a PFD at the Earth's surface of −118 $dBW/m^2/MHz$, regardless of the angle of arrival, and that this ensures significant margin against any of the PFD limits that exist, to protect terrestrial fixed and mobile services from downlink interference from the O3b satellites. O3b's assurance to operate within such a PFD limit was also evidenced in Section S8 of the associated Schedule S. In O3b's amendment and its associated revised Schedule S, however, O3b has made a representation that it will now operate at less stringent PFD levels. Please clarify whether O3b intends to operate its entire O3b, O3bN, and O3bI constellations at a pfd level greater than −118 $dBW/m^2/MHz$, at all angles of arrival.

The PFD at the Earth's surface of O3b satellites 1-20 will not exceed −118 $dBW/m^2/MHz$, in compliance with the terms of the U.S. market access granted for the original 12 satellites in the O3b system[3] and as stated in the June 2016 Modification application for satellites 13-20.[4] The PFD tables included in the Schedule S submitted with the O3b Amendment have an erroneous value for the transmitting beams[5] associated with satellites 1-20. The value of −115.7 $dBW/m^2/MHz$ shown in the 25°−90° column should be replaced with −118 $dBW/m^2/MHz$. O3b requests that the Commission update its records to reflect this correction.

The O3bN and O3bI satellites will typically operate with a PFD of approximately −118 $dBW/m^2/MHz$. However, when these satellites are operating at maximum power, the resulting PFD will exceed −118 $dBW/m^2/MHz$ at all angles of arrival. These worst-case maximum PFD levels are illustrated in Figure A.8-1 of the Technical Annex to the O3b Amendment. For example, at an angle of arrival of 90°, the maximum PFD is −111.6 $dBW/m^2/MHz$, while at angles of arrival between 0° and 25°, the maximum PFD decreases so that the limits in Section 25.208 of the Commission's rules are not exceeded.

[3] *See* O3b Limited, Call Sign S2935, IBFS File Nos. SAT-LOI-20141029-00118 and SAT-AMD-20150115-00004, granted Jan. 22, 2015, Terms and Conditions of Grant at 1-2, ¶ 4.

[4] *See* Modification Application of O3b Limited, Call Sign S2935, IBFS File No. SAT-MOD-20160624-00060 (June 24, 2016).

[5] Specifically, beams UT1G, UT2G, UT3G, UT4N, UT5N, UT6G, UT7G, UT8G, UT9G, UT10, UT11, UT12, GT1G, GT1N, GT2G, GT2N, GT3G and GT4G.

2. In its modification and amendment to the modification application, O3b proposes operating in the original authorized bands, and requests the following additional frequency bands: 17.7-17.8 GHz, 19.3-19.7 GHz, 19.7-20.2 GHz, 29.1-29.5 GHz, and 29.5-30.0 GHz bands. In the Schedule S provided with the amendment application, O3b indicates that it will operate throughout the entire 17.7-20.2 GHz and 27.5-30 GHz bands, suggesting that O3b Limited will also operate its satellites in the 18.6-18.8 GHz, 27.5-27.6 GHz, and 28.4-28.6 GHz bands. Since there is a discrepancy between the narrative and technical annexes of the application and the Schedule S, the Commission requests that O3b clarify its requested frequencies, and if necessary, provide an updated technical analysis and/or a new Schedule S with information that accurately represents its proposed satellite system. If O3b intends to operate in the 18.6-18.8 GHz band, please also provide the necessary analysis to demonstrate compliance with Section 25.208(d).

O3b is seeking U.S. market access for operations in the bands 17.7-18.6 GHz and 18.8-20.2 GHz in the space-to-Earth direction and 27.5-30 GHz in the Earth-to-space direction. O3b is not seeking U.S. market access for operations in the 18.6-18.8 GHz frequencies, but certain of the proposed satellites will have the capability to use that spectrum. Thus, the Schedule S that was submitted with the O3b Amendment accurately reflects the planned frequency usage.

O3b satellites 1-16 will use frequencies 17.8-18.6 GHz and 18.8-19.3 GHz in the space-to-Earth direction and 27.6-28.4 GHz and 28.6-29.1 GHz in the Earth-to-space direction.

O3b satellites 17-20 will use frequencies 17.8-18.6 GHz, 18.8-19.3 GHz, and 19.7-20.2 GHz in the space-to-Earth direction and 27.6-28.4 GHz, 28.6-29.1 GHz, and 29.5-30 GHz in the Earth-to-space direction.

For O3bN satellites 1-24 and O3bI satellites 1-16, U.S. market access is requested for frequencies 17.7-18.6 GHz and 18.8-20.2 GHz in the space-to-Earth direction and 27.5-30 GHz in the Earth-to-space direction. The O3bN and O3bI satellites will also be capable of operating in the 18.6-18.8 GHz frequencies in the space-to-Earth direction, but O3b is not requesting U.S. market access for this band segment. As a result, O3b did not submit an analysis to demonstrate compliance with Section 25.208(d) of the Commission's rules for this band segment.

For the Commission's convenience, the tables below show the frequencies proposed for use by each system discussed in the O3b Amendment.

Frequency Use for Space-to-Earth Operations

O3b Sats 1-16	O3b Sats 17-20	O3bN and O3bI
		17.7-17.8 GHz
17.8-18.6 GHz	17.8-18.6 GHz	17.8-18.6 GHz
		Can operate in 18.6-18.8 GHz, but not seeking U.S. market access
18.8-19.3 GHz	18.8-19.3 GHz	18.8-19.3 GHz
		19.3-19.7 GHz
	19.7-20.2 GHz	19.7-20.2 GHz

Frequency Use for Earth-to-Space Operations

O3b Sats 1-16	O3b Sats 17-20	O3bN and O3bI
		27.5-27.6 GHz
27.6-28.4 GHz	27.6-28.4 GHz	27.6-28.4 GHz
		28.4-28.6 GHz
28.6-29.1 GHz	28.6-29.1 GHz	28.6-29.1 GHz
		29.1-29.5 GHz
	29.5-30 GHz	29.5-30 GHz

3. Article 22.5I of the ITU Radio Regulations requires NGSO networks to meet the equivalent power flux density (EPFD) limits specified in Articles 22.5C (EPFD ↓), 22.5D (EPFD ↑), and 22.5F ($EPFD_{is}$) for an NGSO system to fulfill its obligations with respect to geostationary satellite orbit (GSO) networks under Article 22.2. O3b provides, in its interference analysis, a narrative showing that it complies with Articles 22.5C (for the 17.8-18.6 GHz and 19.7-20.2 GHz frequency bands), 22.5D (for the 27.5-28.6 GHz and 29.5-30 GHz frequency bands) and Article 22.5F (for the 17.8-18.4 GHz frequency band). We request that O3b submit, for all these frequency bands, a complete set of PFD masks on the surface of the Earth for each of the 56 active space stations in its NGSO FSS system, and a complete set of NGSO FSS earth station EIRP masks as a function of the off-axis angle generated by the NGSO FSS earth station, which are required to run the ITU-R Recommendation S.1503 EPFD Validation Software. Please also supplement the amendment to include the output data files from the ITU EPFD Validation Software, and/or corresponding plots of the computed EPFD levels for the 56 active satellite constellation compared to the EPFD masks for each of the reference GSO and/or BSS earth station antennas.

As noted in our Extension Letter, O3b evaluated compliance with the EPFD ↓ limits in Article 22 of the ITU Radio Regulations with the O3b proprietary software used to manage and operate the O3b constellation. O3b evaluated the EPFD ↑ and $EPFD_{is}$ levels using the ITU software. However, the current implementation of the ITU software does not properly model the O3b satellite system as further described in Annex 1 and Annex 2 attached.

Annex 1 shows the calculation output for the EPFD ↑ and $EPFD_{is}$ levels using the ITU EPFD Validation software.

Annex 2 shows the calculation output for the EPFD ↓ levels using both the ITU software and the O3b proprietary software.

The complete set of PFD ↓, EIRP ↑ and $EIRP_{is}$ masks are provided as XML files in the attached zip file. The corresponding SRS database files are attached as MDB files.

4. We note that O3b Limited requests authority to provide NGSO FSS service to the U.S. market using the 17.7-17.8 GHz frequency band. This band is not designated for NGSO FSS use, its use is limited to feeder links in the broadcasting-satellite service (BSS), in accordance with Footnote US271. As a result, there are no rules in place regarding sharing between NGSO FSS and BSS feeder links in this band, and the International Telecommunications Union (ITU) also has no EPFD limits in place for sharing between these two services. Consequently, O3b Limited must provide an appropriate technical analysis to justify its waiver request to use the band and to demonstrate how its use of this band will not cause interference to BSS feeder links.

O3b is seeking U.S. market access for NGSO operations in the 17.7-17.8 GHz frequencies. Annex 3 demonstrates the compatibility between: (1) the NGSO FSS satellite transmissions into BSS space station receivers; and (2) BSS feeder link transmitting earth stations into NGSO FSS receiving earth stations. The analysis demonstrates that the NGSO FSS satellite transmissions into the BSS space station receivers will not exceed the limits that are in place to protect Region 1 BSS space stations operating in the adjacent 17.8-18.4 GHz frequencies. In addition, Annex 3 shows that a separation distance ranging from a few hundred meters to approximately 7.5 km will allow the NGSO FSS earth stations to operate successfully notwithstanding the co-frequency operations of BSS feeder link transmitting earth stations. O3b is not seeking protection for these NGSO FSS earth stations from BSS feeder link earth stations. This technical showing is purely for completeness.

5. In accordance with Section 25.114(d)(1), applicants are requested to provide an explanation of how the uplink frequency bands would be connected to the downlink frequency bands on their proposed satellite system. To better understand the beam and channel connections on O3b's particular satellite system, please supplement O3b's application with a showing (*e.g.* a strapping table, chart or spreadsheet) that clearly presents this information.

The O3b satellites 1-20 will have a generic strapping table which is shown in Annex 4. The O3bN and O3bI satellites will employ a digital channelizer and therefore will not have a fixed channel plan. Instead, any uplink channel on these satellites can be strapped with any downlink channel in segments as narrow as 5 MHz. It is therefore not possible to illustrate a strapping plan for the O3bN and O3bI satellites.

Please let us know if you have any further questions regarding the O3b Amendment.

Respectfully submitted,

O3b LIMITED

By: */s/ Suzanne Malloy*
Suzanne Malloy
Vice President, Regulatory Affairs

Annex 1 EPFD ↑ and EPFD(is) output plots using ITU EPFD validation software

The EPFD ↑ and EPFD(is) validation results for the O3b system are shown below in Figures 1-1 through 1-3. The XML mask files and associated SRS database used to examine the masks in the ITU EPFD validation software are attached. The validation software used was the Agenium version. The Transfinite version was not able to validate the O3b constellation due to an unknown error that occurred when trying to run the validation.

Since the number of O3b satellites with the frequency bands 17.8-18.4 GHz, 27.5-28.6 GHz and 29.5-30 GHz varies, different configurations were analyzed separately. Next to each figure, the configuration corresponding to the chart is listed.

Figure 1-1: EPFD ↑ results at 27.5 GHz

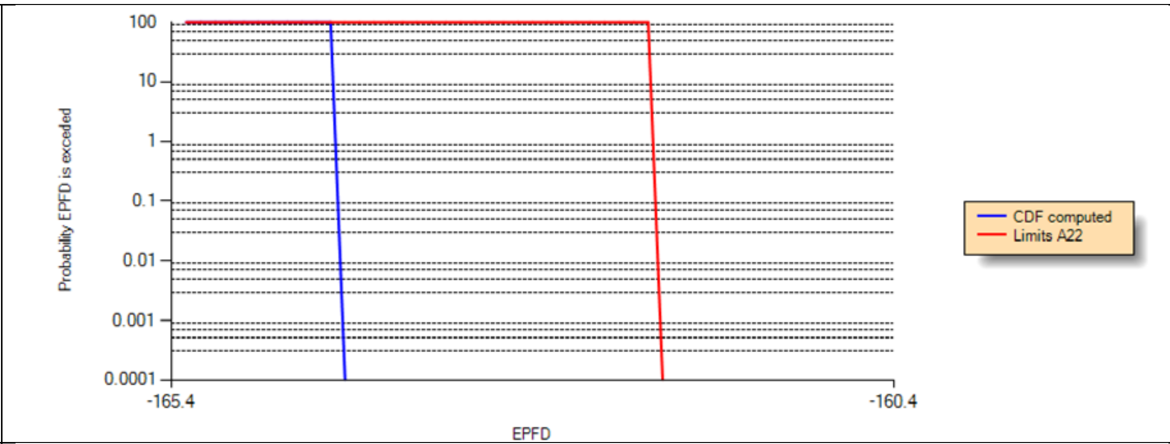
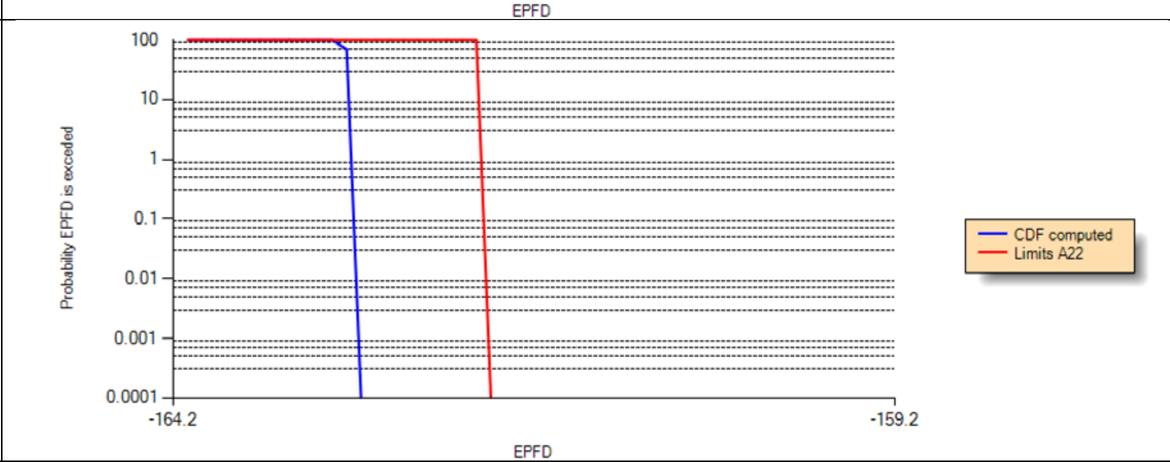
40 equatorial satellites	
16 inclined satellites	

Figure 1-2: EPFD ↑ results at 29.5 GHz

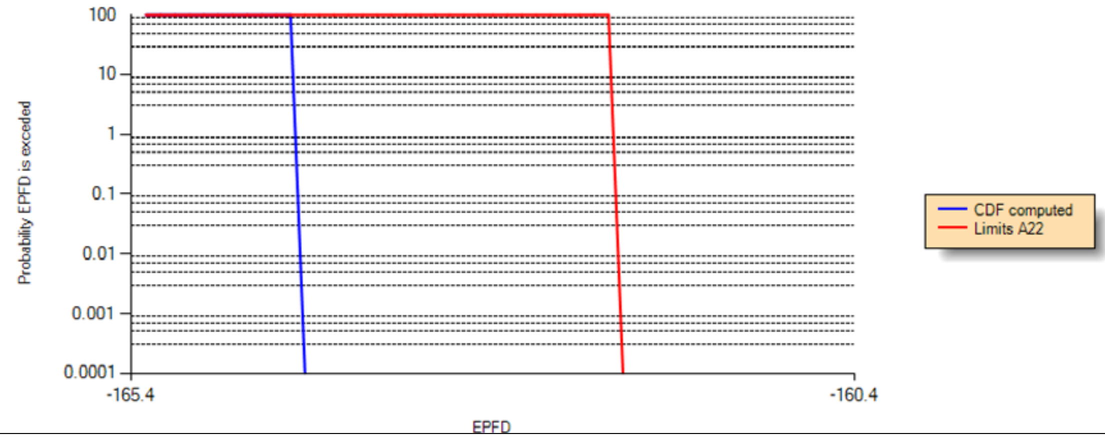
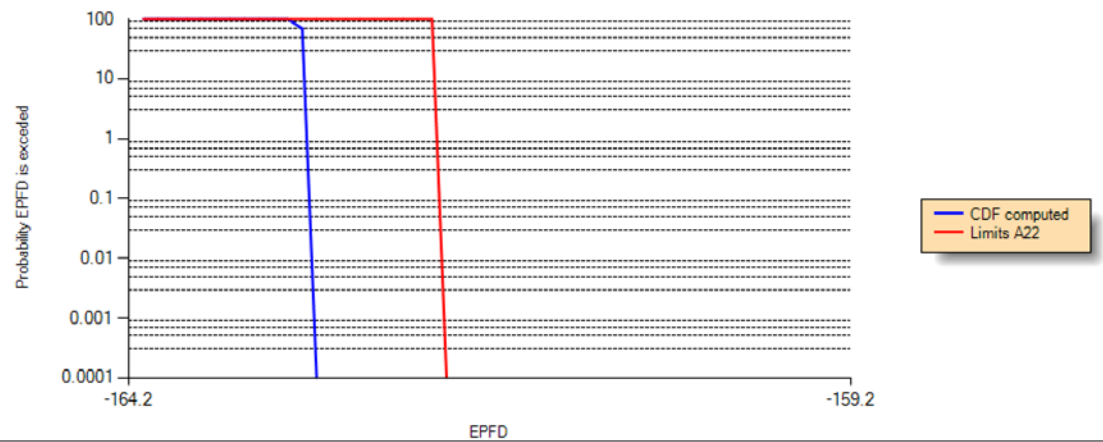
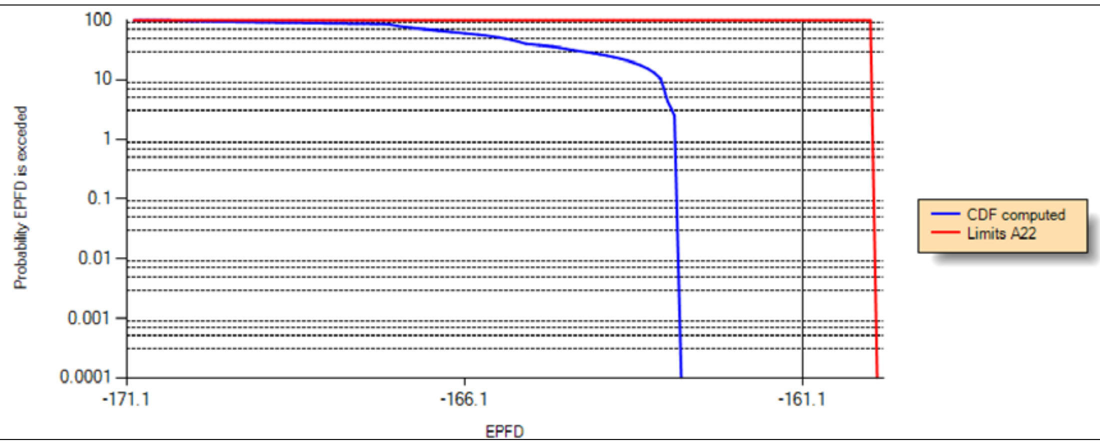
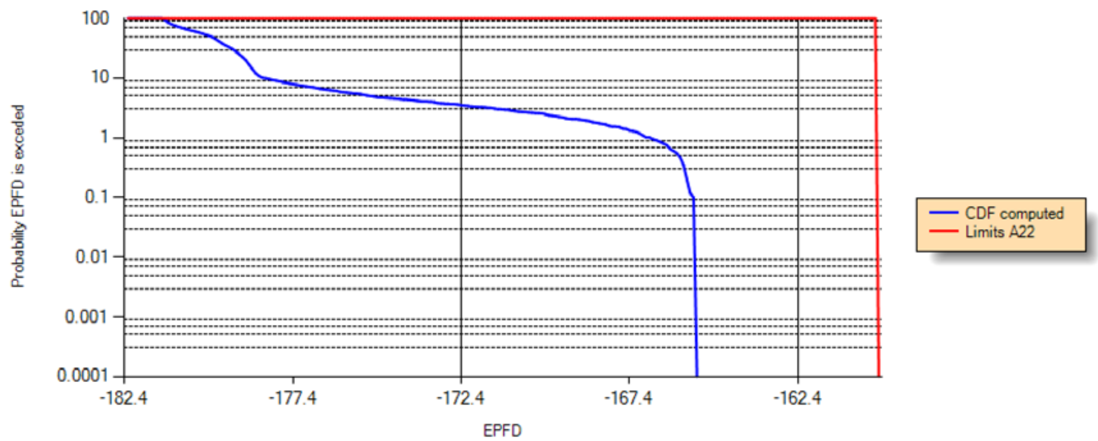
28 equatorial satellites	
16 inclined satellites	

Figure 1-3: EPFD (is) results at 17.8 GHz

40 equatorial satellites	

16 inclined satellites	

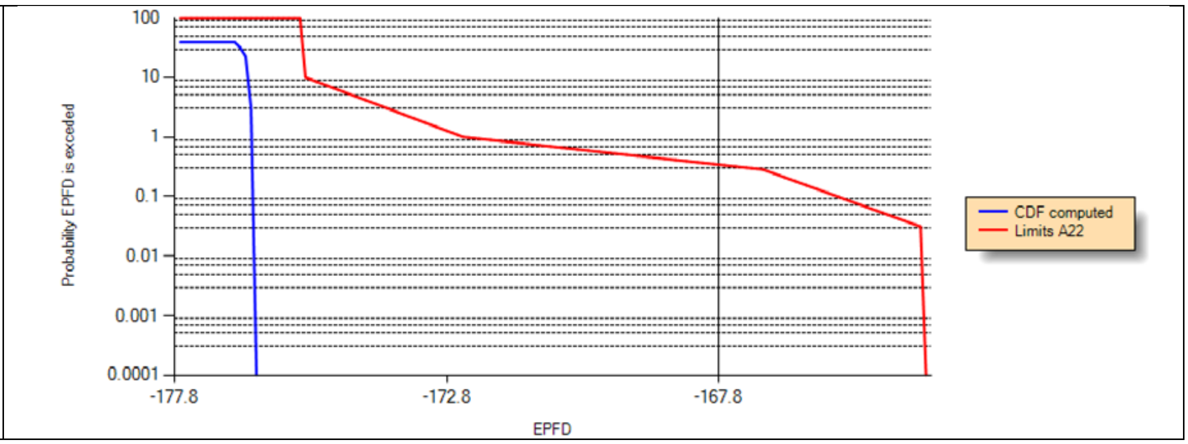
Annex 2 EPFD ↓ using ITU EPFD validation software and O3b internal software

O3b used proprietary software to validate the PFD masks that represent the operations of the O3b satellites. During the World Radiocommunication Conference in 2015 (WRC-15), it was determined that the current version of the ITU validation software may not adequately model certain types of constellations. In particular, with respect to the O3b satellites, the software does not allow for accurate modelling of beams that remain fixed over a single point on the Earth for a specified period of time while the associated satellite passes overhead. Since WRC-15, efforts have been made by the membership of Working Party 4A to revise the underlying Recommendation ITU-R S.1503 to address these concerns. The ITU software developers and Radiocommunication Bureau have also engaged in the revision of the Recommendation to introduce updates and corrections to issues that were discovered while implementing the Recommendation into software. The proprietary O3b software has incorporated the latest changes proposed by Working Party 4A to Recommendation ITU-R S.1503 when validating the PFD masks of the O3b satellites.

The first set of plots below show the EPFD ↓ results for the 17.8-18.6 GHz and 19.7-20.2 GHz frequencies using the ITU validation software. The results are shown for each reference antenna size from Article 22 for these frequencies. Since the number of O3b satellites with the frequency bands 17.8-18.6 GHz and 19.7-20.2 GHz varies, different configurations were analyzed separately. Next to each figure, the configuration corresponding to the chart is listed.

Figure 2-1: EPFD↓ results for 1-meter antenna in 17.8-18.6 GHz

40 equatorial satellites



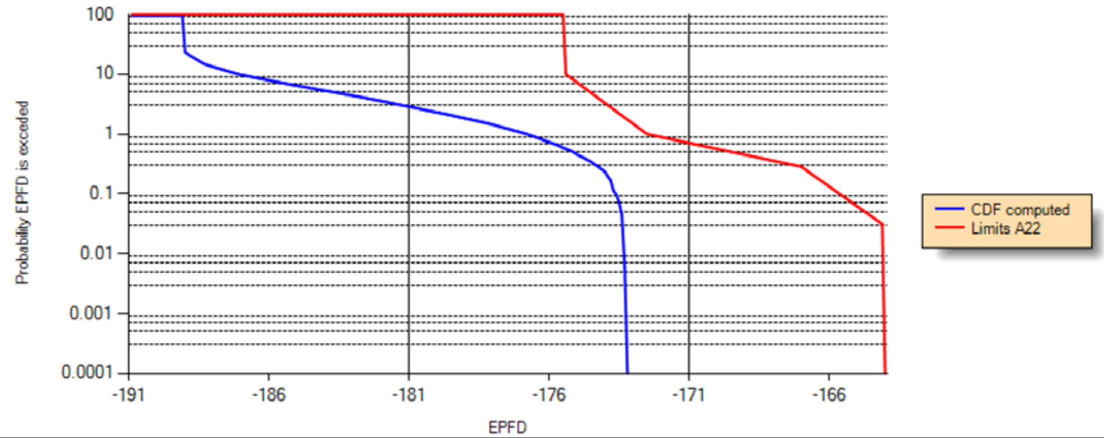
16 inclined satellites	

Figure 2-2: EPFD↓ results for 2-meter antenna in 17.8-18.6 GHz

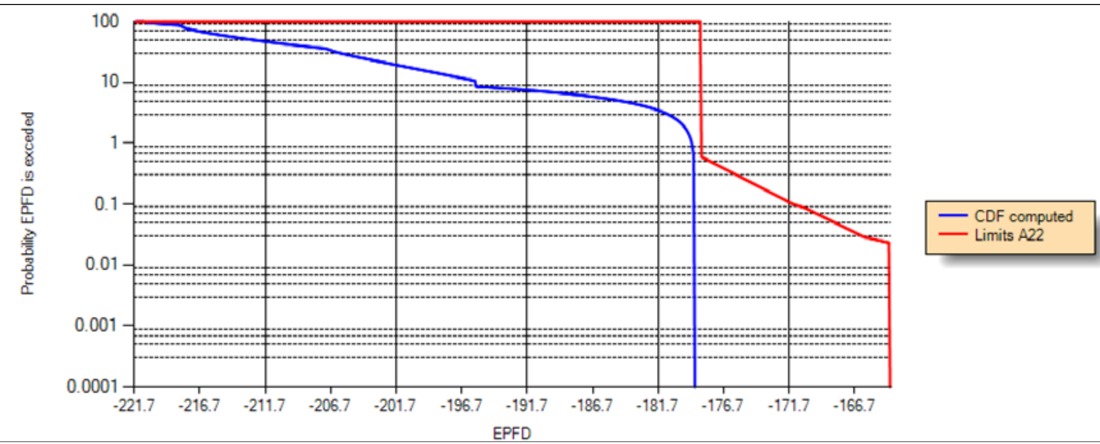
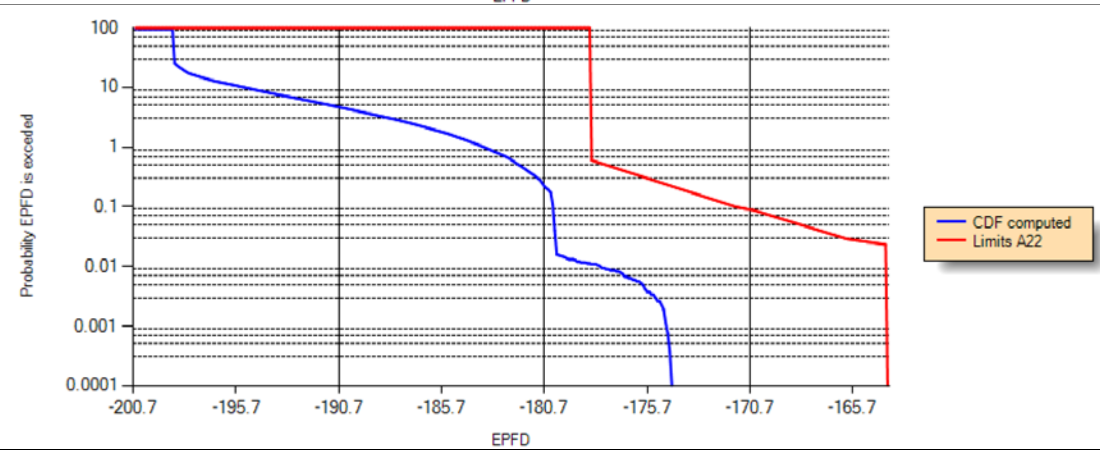
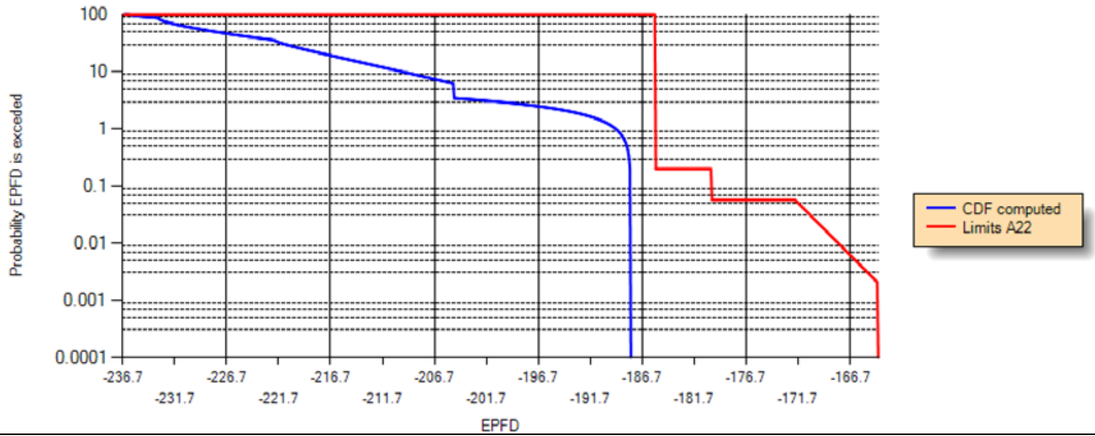
40 equatorial satellites	
16 inclined satellites	

Figure 2-3: EPFD↓ results for 5-meter antenna in 17.8-18.6 GHz

40 equatorial satellites



16 inclined satellites

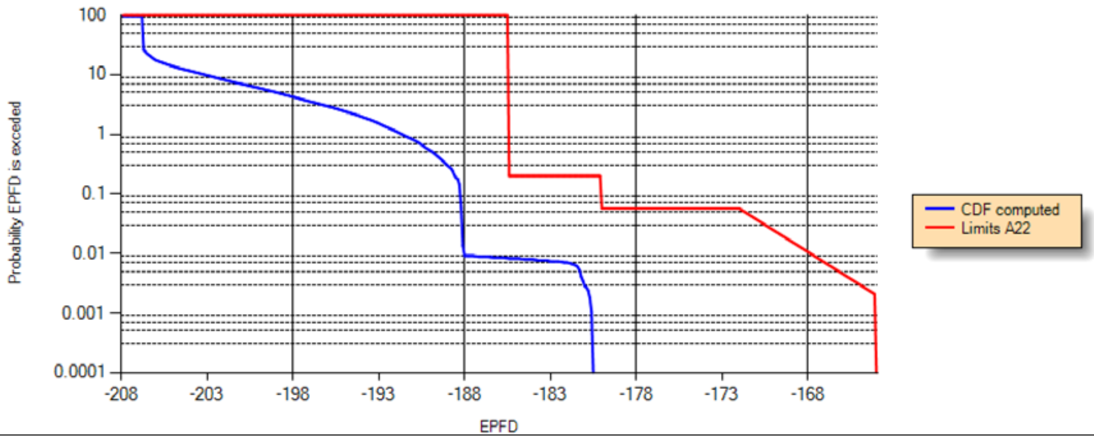
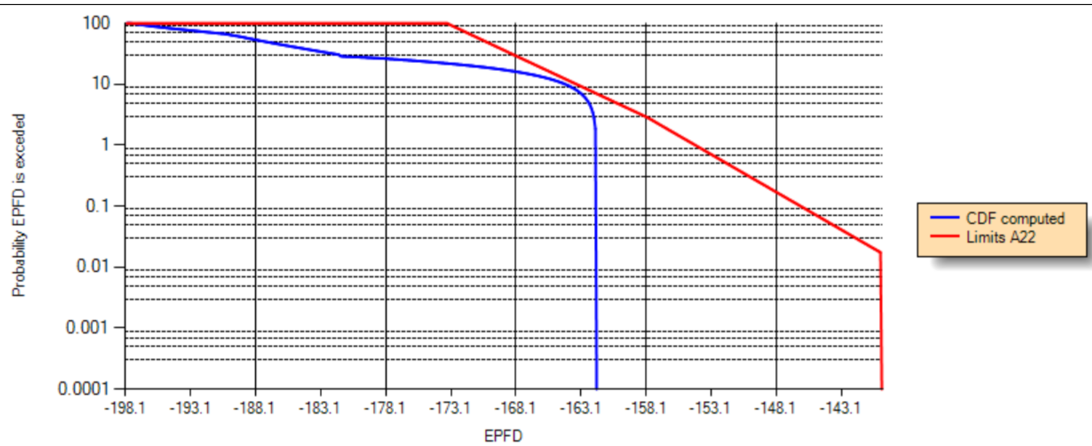


Figure 2-4: EPFD↓ results for 0.70-meter antenna in 19.7-20.2 GHz

28 equatorial satellites



16 inclined satellites

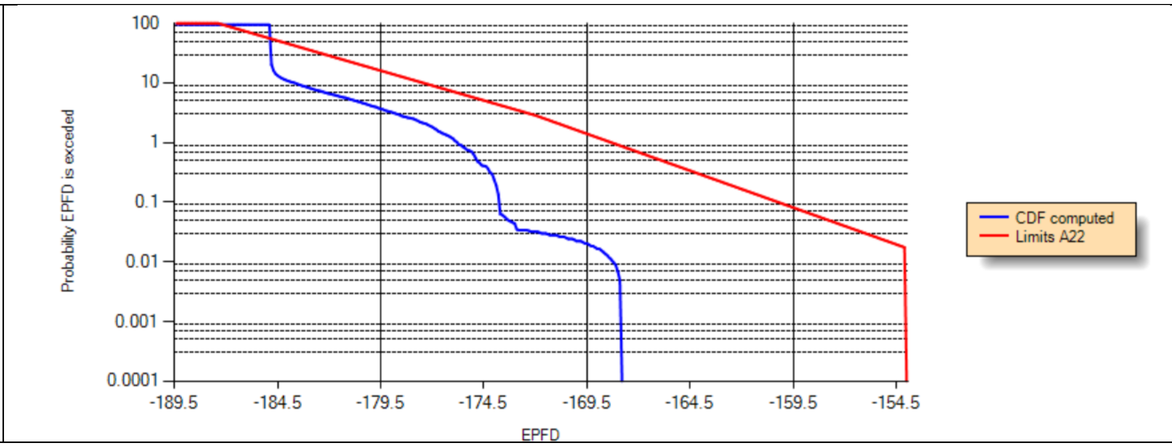
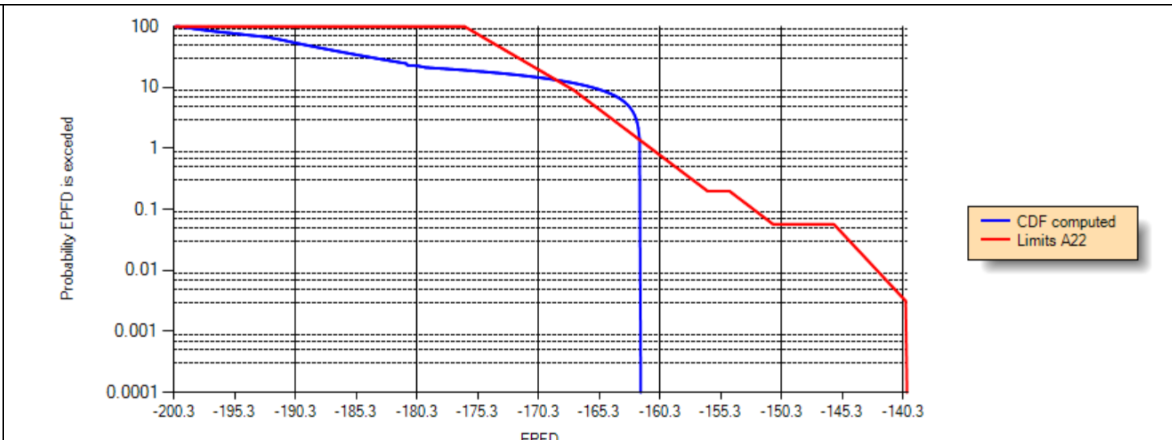


Figure 2-5: EPFD↓ results for 0.90-meter antenna in 19.7-20.2 GHz

28 equatorial satellites



16 inclined satellites

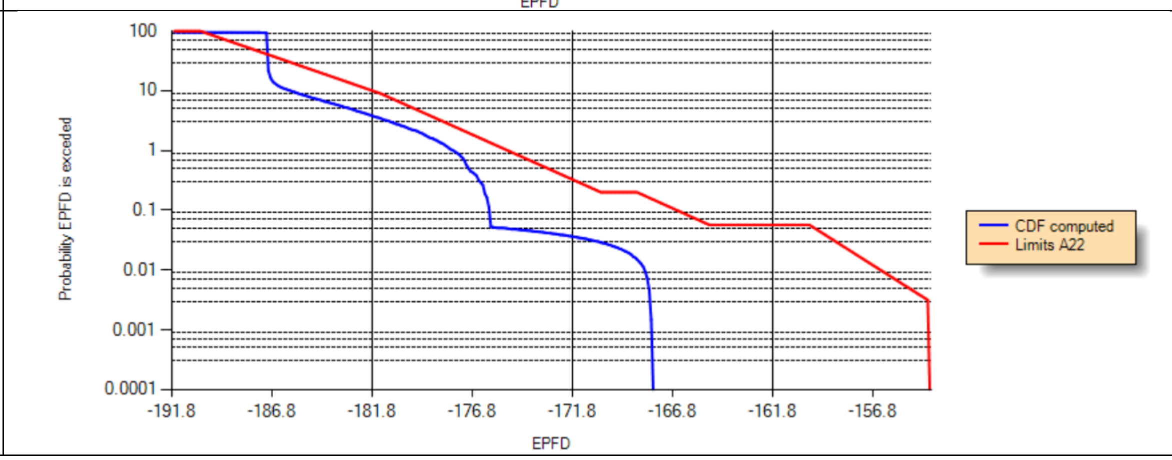


Figure 2-6: EPFD↓ results for 2.5-meter antenna in 19.7-20.2 GHz

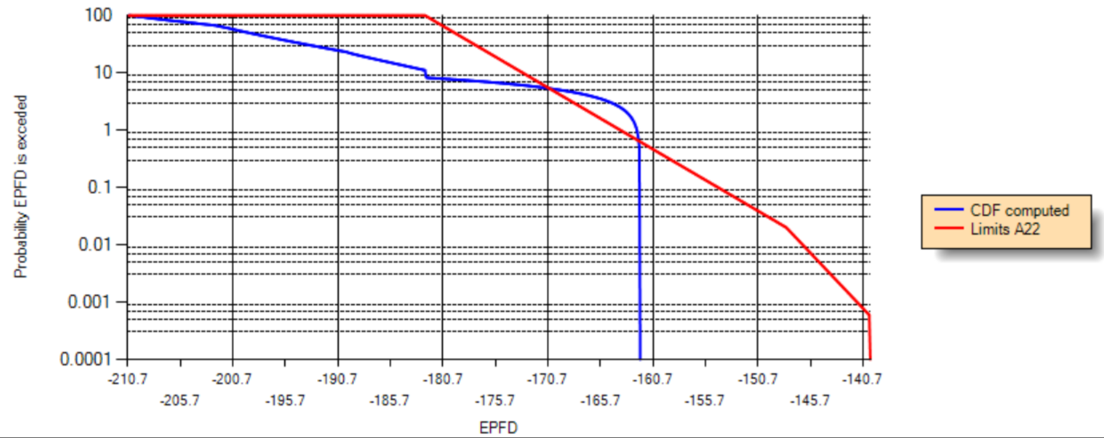
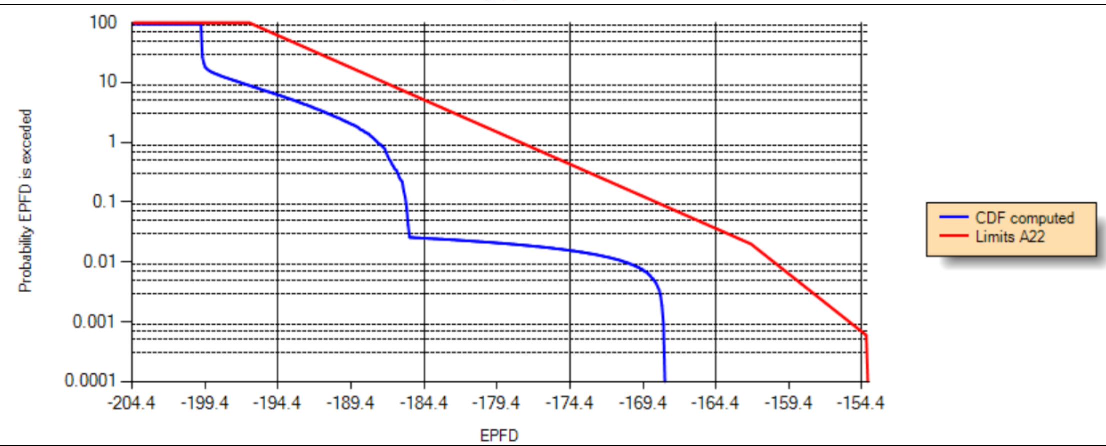
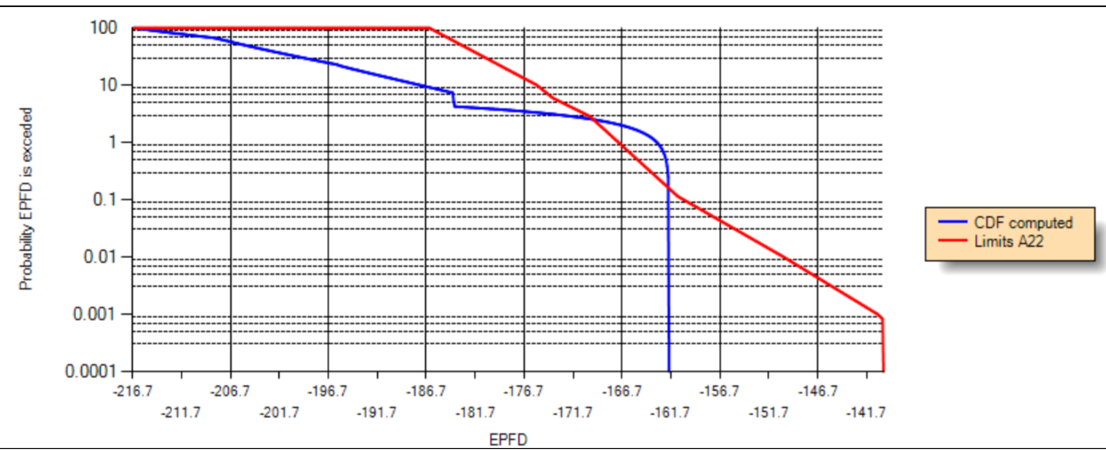
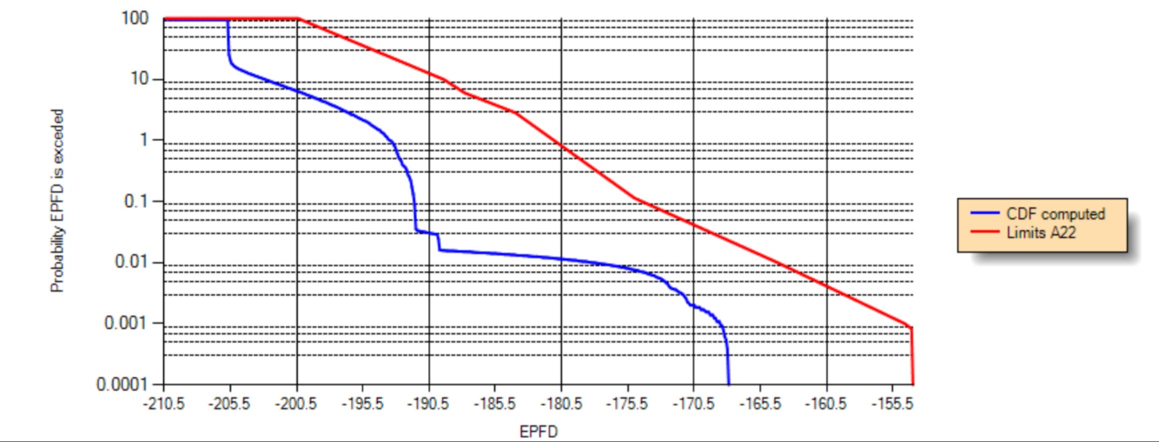
28 equatorial satellites	
16 inclined satellites	

Figure 2-7: EPFD↓ results for 5-meter antenna in 19.7-20.2 GHz

28 equatorial satellites	

16 inclined satellites	

As seen in the above figures for the 19.7-20.2 GHz downlink EPFD evaluations, the results from the ITU software suggest that the applicable ITU limits are exceeded for the 0.9-meter, 2.5-meter and 5-meter antenna diameters in the equatorial configuration and for the 0.7-meter and 0.9-meter antenna diameters in the inclined configuration. This is due to the ITU software’s inability to model certain types of steerable beams.

The set of plots below show the EPFD ↓ results for the 19.7-20.2 GHz frequencies using the O3b proprietary software. The results are shown for each reference antenna size from Article 22 for these frequencies. The O3b software operates very similarly to the ITU validation software except for the inclusion of a parameter called minimum duration time, which allows for the modeling of steerable beams. This parameter is being discussed at the ITU Working Party 4A meeting as one of the enhancements to allow the software to model satellites whose beams track, or remain oriented toward, a fixed point on the Earth during the pass of the satellite. The O3b satellite beams will operate in this manner by pointing toward and tracking an earth station as the satellite passes overhead. The plots below show that the equatorial and inclined constellations meet the Article 22 single entry EPFD ↓ limits in these frequency bands for all antenna sizes using the proprietary O3b software.

Figure 2-8: EPFD↓ results for 0.70-meter antenna in 19.7-20.2 GHz

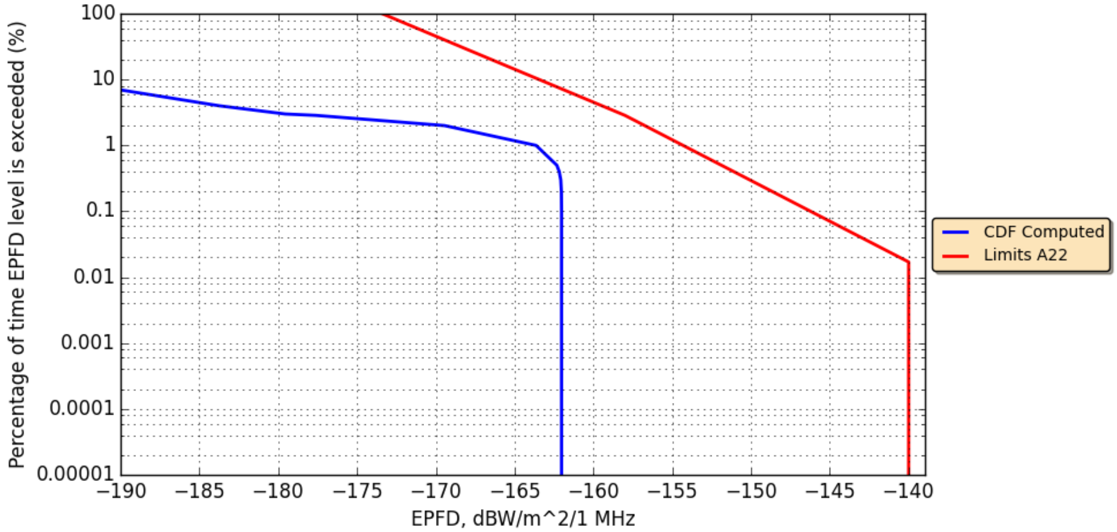
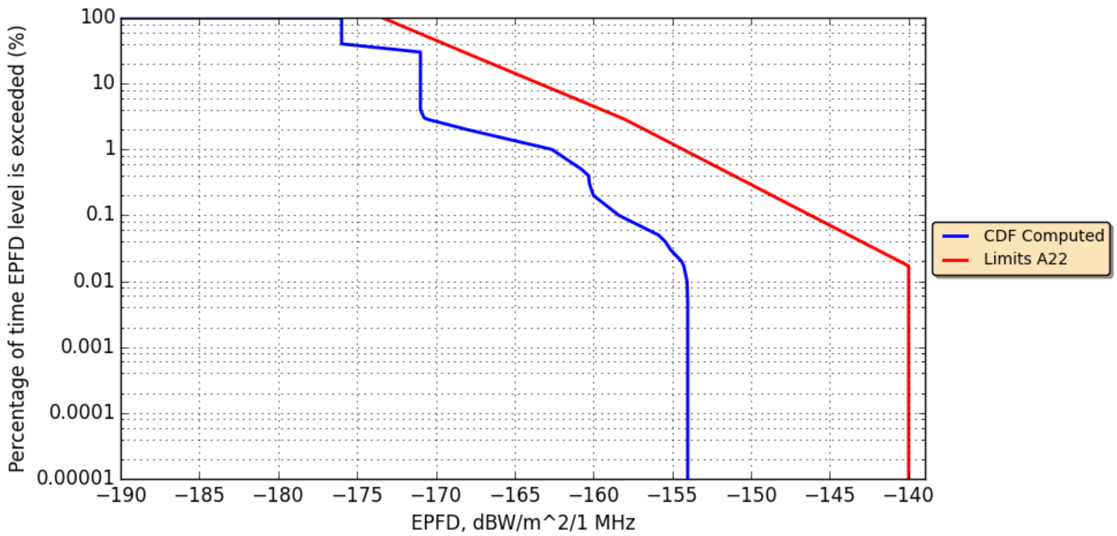
28 equatorial satellites	
16 inclined satellites	

Figure 2-9: EPFD↓ results for 0.90-meter antenna in 19.7-20.2 GHz

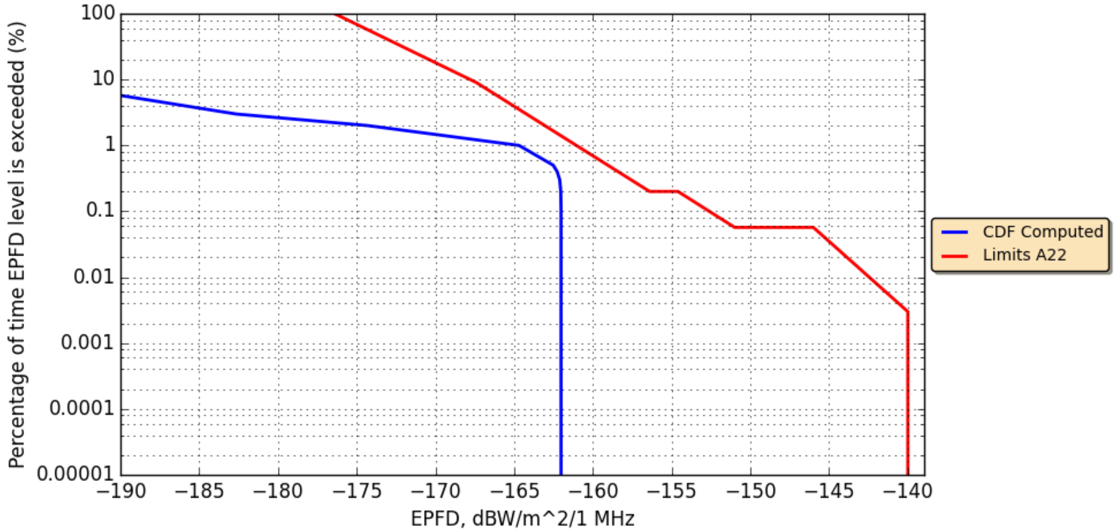
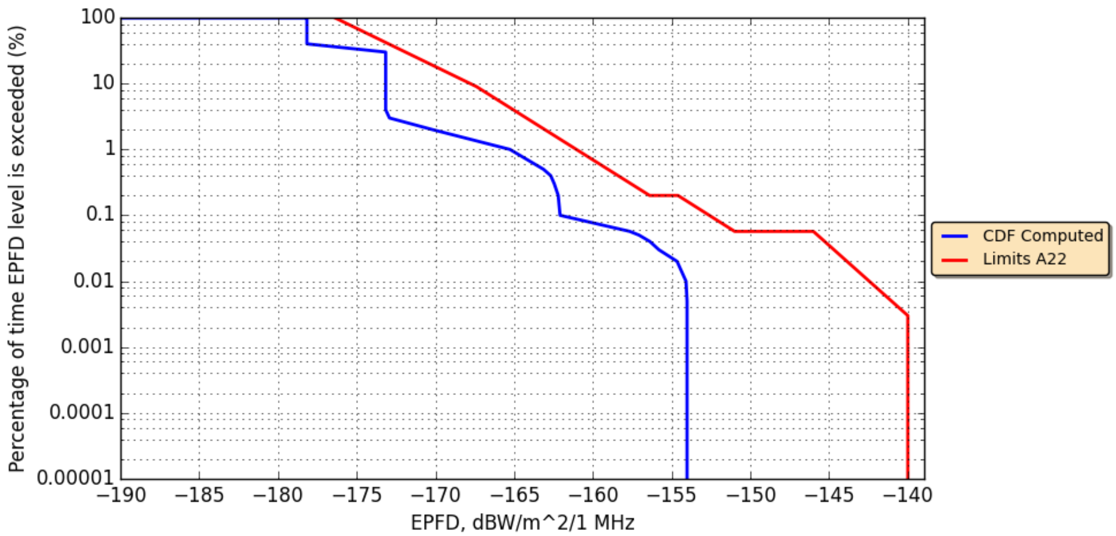
28 equatorial satellites	
16 inclined satellites	

Figure 2-10: EPFD↓ results for 2.5-meter antenna in 19.7-20.2 GHz

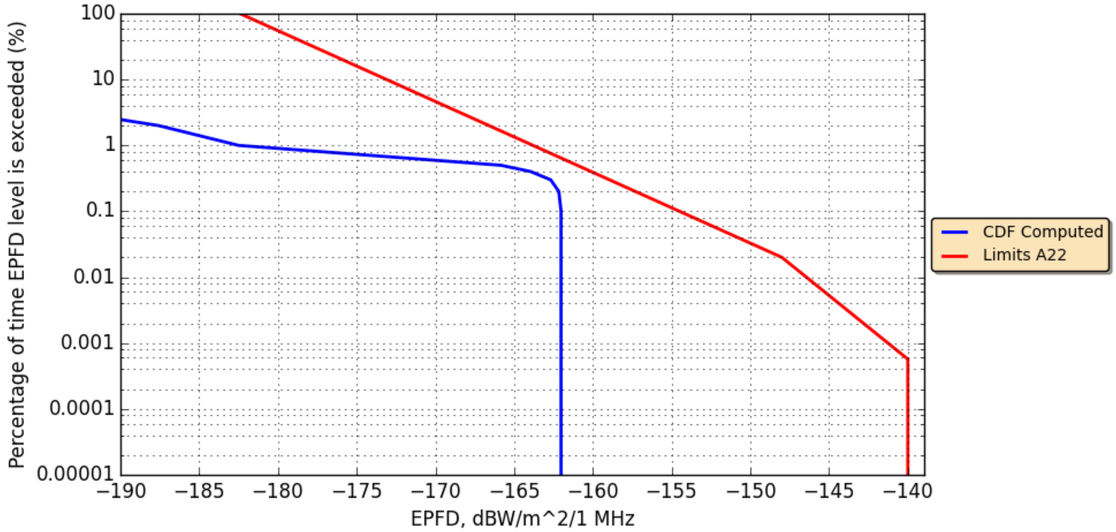
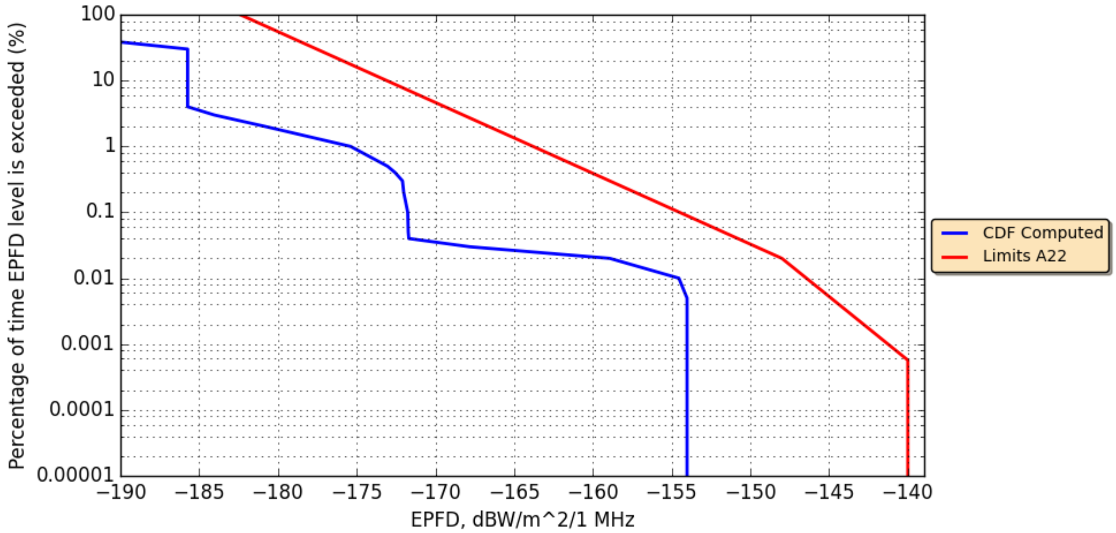
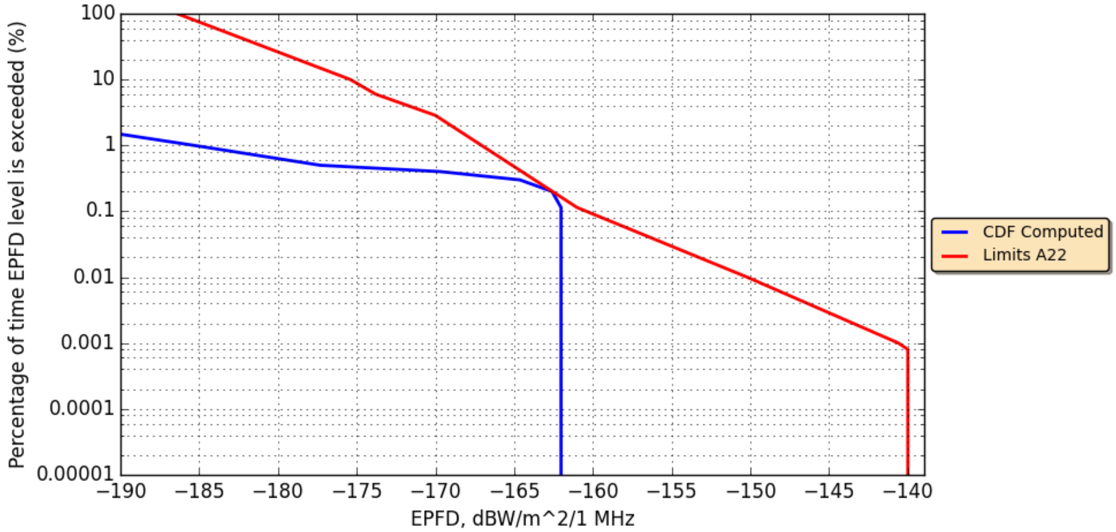
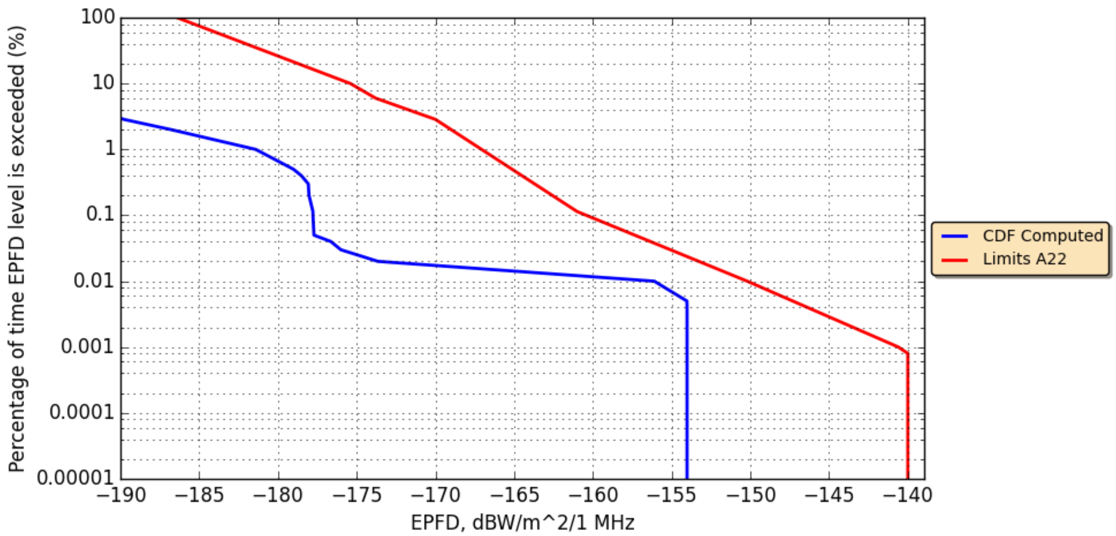
28 equatorial satellites	
16 inclined satellites	

Figure 2-11: EPFD↓ results for 5-meter antenna in 19.7-20.2 GHz

28 equatorial satellites	
16 inclined satellites	

Annex 3 17.7-17.8 GHz analysis between BSS uplinks and O3b downlinks

Interference in the 17.7-17.8 GHz band may occur in two ways:

1. interference from transmitting O3b satellites into a receiving BSS satellite and
2. interference from a transmitting BSS feeder link earth station into a receiving O3b earth station.

For Case 1, the interference from O3b satellites into receiving BSS satellites over the U.S. is the same interference scenario as into Region 1/3 BSS satellites operating in the adjacent 17.8-18.4 GHz band. There are limits in place to ensure that Regions 1/3 BSS satellites are protected from this inter-satellite interference. Table 22-3 of Article 22 to the ITU Radio Regulations specifies that a PFD of −160 $dBW/m^2/40kHz$ shall not be exceeded. As demonstrated in Annex 1, the O3b system satisfies this requirement using the ITU's EPFD validation software. Because the O3b system will be operated in the same manner across the 17.7-18.4 GHz frequency range, BSS satellites operating in Region 2 in the 17.7-17.8 GHz range will be protected to the same level as those in Regions 1 and 3.

For Case 2, O3b has experience with this type of interference in Region 1. In one specific scenario, O3b worked closely with the teleport operator and the BSS feeder link earth station operator to resolve interference occurring between our collocated earth stations. O3b is not seeking protection from BSS feeder link earth stations, but based on its experience in Region 1, O3b believes that its earth stations can successfully operate in Region 2 notwithstanding predicted interference from BSS feeder link earth stations in the United States. The analysis below shows the worst-case interference between a transmitting BSS feeder link earth station and a receiving O3b earth station. Worst case is assumed to be when the O3b earth station is pointing directly towards the BSS feeder link earth station as shown in Figure 3.1.

Figure 3-1: GSO and O3b earth station antenna gain towards the horizon

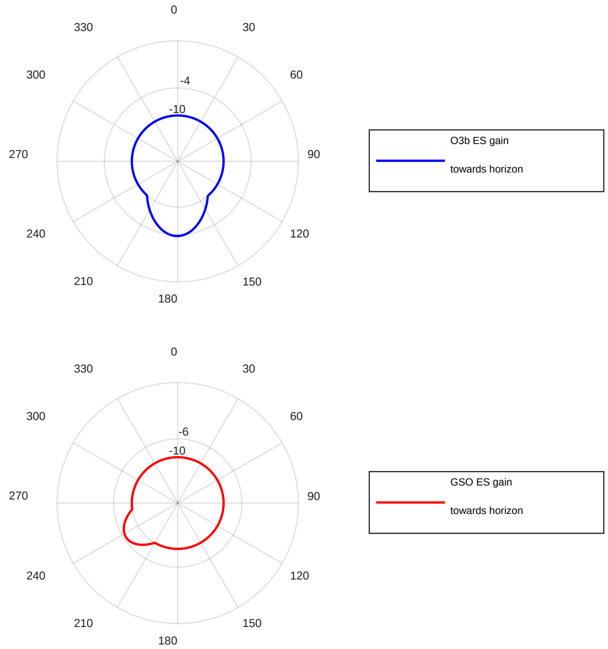


Table 3-1: BSS transmit earth station parameters

Earth station longitude (°W)	78.2
Earth station latitude (°N)	40
GSO satellite longitude (°W)	120
Antenna diameter (m)	13.2
Carrier bandwidth (MHz)	24
Carrier peak EIRP (dBW)	87.4
Antenna pattern	AP30A
GSO earth station antenna gain towards O3b earth station (dBi)	−10

Table 3-2: O3b receive earth station parameters

Earth station longitude (°W)	78.2
Earth station latitude (°N)	40+ε
O3b satellite longitude (°W)	78.2
Antenna diameter (m)	2.4
Carrier peak pfd ($dBW/m^2/MHz$)	−125
Antenna pattern	S.465
O3b earth station antenna gain towards GSO earth station (dBi)	−4
Target C/I (dB)	20

Here, ε represents an insignificant latitude increase such that the BSS and O3b earth stations are very close to each other with the O3b earth station just north of the BSS earth station. In these circumstances, the required separation distance between the transmitting BSS feeder link earth station and the receiving O3b earth station is approximately 7.5 km, assuming typical antenna patterns and no losses due to terrain and/or clutter. O3b calculated this distance using the following equation:

$$D = \sqrt{\frac{1}{4\pi} 10^{\frac{EIRP_{BSS} - (PFD_{O3b} + G_{max} - G_{offaxis} - C2I)}{10}}}$$

Where *D* is the required distance to achieve the target C/I (*C2I*). However, in the specific Region 1 scenario discussed above, O3b was able to site a receiving earth station less than 100 meters from a transmitting BSS feeder link earth station. This experience suggests that when local terrain and losses between the earth stations are taken into account, the separation distance between earth stations needed to prevent interference could be significantly less than 7.5 km.

Again, O3b is not seeking protection from BSS feeder link earth stations, but the analysis herein demonstrates that O3b earth stations can operate compatibly with BSS feeder link earth stations with very limited separation distances in certain conditions. Given the relatively small number of BSS feeder link earth stations in the United States, O3b expects that it can site future earth stations without experiencing harmful interference in most areas of the country.

Annex 4 Uplink and downlink frequency strapping table for O3b satellites

The following table shows the beam strapping for the O3b satellites 1-20 and the O3bN and O3bI satellites. The O3bN and O3bI satellites will not have a specific strapping plan but are included here so that the corresponding Schedule S information is clear regarding Receive Channel ID "R001" being associated with Transmit Channel ID "T001". As discussed above, the O3bN and O3bI satellites are capable of a wide range of strapping configurations. The channel arrangement shown below is only one example of a configuration that could occur on the O3bN and O3bI satellites.

RX Channel ID	Bandwidth (MHz)	Center Frequency (MHz)		TX Channel ID	Bandwidth (MHz)	Center Frequency (MHz)	Satellites
R001	2500	28750	↔	T001	2500	18950	O3bN 21-44, O3bI 1-16
R1L	300	27750	↔	T1L	300	17950	O3b 1-20
R1R	300	27750	↔	T1R	300	17950	O3b 1-20
R2L	260	28020	↔	T2L	260	18220	O3b 1-20
R2R	260	28020	↔	T2R	260	18220	O3b 1-20
R3L	260	28270	↔	T3L	260	18470	O3b 1-20
R3R	260	28270	↔	T3R	260	18470	O3b 1-20
R4L	250	28725	↔	T4L	250	18925	O3b 1-20
R4R	250	28725	↔	T4R	250	18925	O3b 1-20
R5L	250	28962.5	↔	T5L	250	19162.5	O3b 1-20
R5R	250	28962.5	↔	T5R	250	19162.5	O3b 1-20
R6L	500	29750	↔	T6L	500	19950	O3b 17-20
R6R	500	29750	↔	T6R	500	19950	O3b 17-20

CERTIFICATION OF PERSON RESPONSIBLE FOR PREPARING ENGINEERING INFORMATION

I hereby certify that I am the technically qualified person responsible for preparation of the engineering information contained in this application, that I am familiar with Part 25 of the Commission's rules, that I have either prepared or reviewed the engineering information submitted in this application and that it is complete and accurate to the best of my knowledge and belief.

/s/Zachary Rosenbaum

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