March 18, 2019

BY ELECTRONIC FILING

Marlene H. Dortch
Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, DC 20554

Re: *Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20181108-00083*

Dear Ms. Dortch:

This is to inform you that, on March 14, 2019, representatives of Space Exploration Holdings, LLC ("SpaceX") met with staff of the Commission's International Bureau to discuss the above referenced application to modify SpaceX's existing authorization to deploy and operate a non-geostationary orbit ("NGSO") satellite system.[1] During the meeting, SpaceX discussed its response to the Bureau's request for further technical information with respect to that application.[2]

In particular, SpaceX noted that this version of its satellite design will meet or exceed all FCC requirements for orbital debris mitigation and collision avoidance. Even under worst-case assumptions, this initial design version complies with the prevailing NASA safety standard for collision probability by several orders of magnitude. Moreover, as a result of extensive development work and investment, SpaceX noted that it has achieved 100% demisability for the next iteration of spacecraft design satellites after its initial deployment, achieving further substantial improvements from its already low casualty rate. SpaceX plans to integrate these completely demisable design updates in versions subsequent to the initial deployment of fewer than 75 satellites, which will then reduce casualty risk to zero.

SpaceX also noted that its initial version of satellites will likely be injected into orbit at an altitude of 430 km, slightly above the 350 km injection used for the collision risk analysis in its response. Assuming solar minimum conditions (a worst-case assumption), the risk of collision at this slightly higher injection altitude would be 0.0000031 for the stowed configuration and 0.00000429 for the deployed configuration – still orders of magnitude better than the NASA safety standard.

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1 Attendees at the meeting are listed in Exhibit 1 hereto.

2 *See* Letter from William M. Wiltshire to Jose P. Albuquerque (Mar. 13, 2019). Unless otherwise indicated, all filings referred to herein were submitted in IBFS File No. SAT-MOD-20181108-00083.

SpaceX also briefly discussed the interference-related comments raised in this proceeding. SpaceX specifically noted the reply comments filed by WorldVu Satellites Limited ("OneWeb"),[3] and the irony of OneWeb criticism of the methodology SpaceX used, given that OneWeb used precisely the same approach for the interference analysis it submitted to the International Telecommunication Union ("ITU") in May 2017 in support of its own system modification.[4] OneWeb suggests that SpaceX should use a different methodology that is biased to show additional interference from any proposed modification. The Commission should reject such a cynical argument.

Sincerely,

William M. Wiltshire
Counsel to SpaceX

Attachments

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3 *See* Reply of WorldVu Satellites Limited (Mar. 5, 2019).

4 *See, e.g., id.* at 3-5. The analysis OneWeb submitted to the ITU in support of the modification of its L5 network filing is attached hereto as Exhibit 2. The methodology is discussed in Section 6. OneWeb did not present such an interference analysis to the Commission in connection with its requests for changes to its system. *See* IBFS File Nos. SAT-AMD-20180104-00004 and SAT-MOD-20180319-00022.

EXHIBIT 1

MEETING ATTENDEES

International Bureau

Jose Albuquerque
Troy Tanner
Stephen Duall
Jennifer Gilsenan
Karl Kensinger
Kerry Murray
Jay Whaley

SpaceX

Patricia Cooper
David Goldman
Mihai Albulet (by phone)
Jonathan Herman (by phone)
Zahid Islam (by phone)
Alex Petrov (by phone)
Max Sirenko (by phone)
Bill Wiltshire

EXHIBIT 2

<u>ONEWEB INTERFERENCE ANALYSIS SUBMITTED TO ITU</u>

Interference Analysis to Accompany Request for Modification of Appendix 4 Technical Parameters of Certain Satellites in the L5 Non-Geostationary Satellite System in Ku-Band

18th May 2017

1. Introduction

This report accompanies a request from the United Kingdom administration to modify the orbital parameters of certain satellites in the L5 non-geostationary orbit ("NGSO") satellite system (referred to hereafter as "the L5 system"), to reduce the highest values of the maximum EIRP density levels for transmissions to and from those satellites, and to delete certain transmitting earth stations associated with those satellites. These modifications are designed to reduce the interference into any other co-frequency NGSO satellite system for which a coordination request has been submitted to the ITU-BR between the date of the subject L5 coordination request and the date of this requested modification. Since the minimum EIRP levels of the L5 satellite system and its corresponding earth stations remain unchanged, the modified parameters do not result in additional protection requirement. The report provides the results of detailed analyses of interference using the Appendix 4 data items for the L5 and other NGSO satellite systems and includes both static and dynamic interference assessments.

Potential interference from the L5 system into geostationary orbit ("GSO") satellite networks is not addressed in this report as those effects are governed by the equivalent power flux density (epfd) limits of Article 22 of the ITU Radio Regulations which apply across the Ku-band. Compliance with those limits is based on the satellite PFD and earth station EIRP masks which are not affected by the modifications referred to here.

Similarly, potential interference from the L5 system into terrestrial services is not addressed in this report. Such interference mechanisms are controlled by the ITU's power flux density (PFD) limits in Article 21 of the Radio Regulations. Not only does the L5 system comply with these PFD limits, both before and after the proposed modification, but the actual PFD levels after the modification are significantly lower than before. Therefore, the proposed modification cannot increase the potential interference to terrestrial services.

It should be noted that the proposed modifications involve space stations with frequency assignments only in the Ku-band (uplink 12.75-13.25 GHz and 13.75-14.5 GHz, downlink 10.7-12.75 GHz).

2. Summary of the Requested L5 Modifications

The requested modification applies only to the space stations that appear in the CR/C/3413 MOD-1 and CR/C/3413 MOD-2 publications for the L5 system (referred to hereafter as the "L5 MOD-1/-2 space stations").[1] All other space stations in the L5 system are unchanged. The modifications to these L5 MOD-

[1] These modified space stations are the ones that appear in the cited ITU publications in Orbital Plane id. nos. 19 to 49.

1/-2 space stations are limited to changes in their orbital parameters, reductions in the highest values of the maximum EIRP density levels of the transmitting satellites and associated earth stations, and the deletion of the largest (5m, 55.6 dBi) transmitting earth station (TYP-E) that is associated with these satellites; in all other respects the radio frequency emission and reception characteristics of these space stations and their corresponding earth stations are unchanged. The modifications to the orbital parameters are summarized in Table 1 below, the reductions to the transmitting earth station power and EIRP density levels are summarized in Table 2 below, and the reductions to the transmitting satellite EIRP density levels are summarized in Table 3 below.

Table 1 – Summary of the requested modifications to the orbital parameters of the CR/C/3413 MOD-1 and CR/C/3413 MOD-2 publications for the L5 system

	Before Modification	After Modification
Orbit altitude	900 km	1,200 km
Orbit plane inclination	88.9°	87.9°
Number of space stations	1,612	1,260
Number of orbit planes	31	36

Table 2 – Summary of the requested reductions in the highest values of the uplink power (AP4 item C8a2) and EIRP spectral density levels of the transmitting earth stations of the CR/C/3413 MOD-1 and CR/C/3413 MOD-2 publications for the L5 system

ES Name	ES Ant. Dia. (m)	ES Peak Gain (dBi)	ES -3dB Beam width (°)	Before Modification		After Modification		Δ (Before to After Mod'n) (dB)
				ES Power Density (dBW/Hz)	ES EIRP Density (dBW/Hz)	ES Power Density (dBW/Hz)	ES EIRP Density (dBW/Hz)	
TYP-A	0.1	21.6	14.6	-50.6	-29.0	-53.6	-32.0	-3.0
TYP-B	0.3	31.1	4.9	-55.1	-24.0	-59.1	-28.0	-4.0
TYP-C	0.5	35.6	2.9	-54.5	-18.9	-61.5	-25.9	-7.0
TYP-D	1	41.6	1.5	-55.6	-14.0	-64.6	-23.0	-9.0
TYP-E	5	55.6	0.29	-72.5	-16.9	This transmitting ES deleted		

Note that the power and EIRP densities in Table 2 above are the highest values in the L5 MOD-1/-2 filings. The values in Table 2 show that the maximum power and EIRP density values for the transmitting earth stations are being reduced by between 3 dB and 9 dB, depending on the type of earth station. The TYP-E earth station is being deleted as a corresponding transmitting earth station for the L5 MOD-1/-2 satellites. Similarly, the maximum peak power (Ap4 item C8a1/C8b1) are being reduced by the same values as per table 2 above.

Table 3 – Summary of the requested reductions in the highest values of the downlink EIRP spectral density levels of the transmitting space stations of the CR/C/3413 MOD-1 and CR/C/3413 MOD-2 publications for the L5 system

Satellite Transmit Beam		Maximum Power Density (dBW/Hz)		Maximum EIRP Density (dBW/Hz)		Δ (Before to After Mod'n) (dB)
Type	Gain (dBi)	Before Modification	After Modification	Before Modification	After Modification	
TAR2	25.9	-70.3	-75.3	-44.4	-49.4	-5.0
TBR2	31.9	-76.4	-81.4	-44.5	-49.5	-5.0
TCR2	19.9	-64.3	-69.3	-44.4	-49.4	-5.0

Note that the EIRP density levels in Table 3 above are the highest values in the L5 MOD-1/-2 filings, and are being reduced by 5 dB for these satellites. After the modification, no beam in these satellites will exceed a maximum EIRP density of -49.4 dBW/Hz.

The net result of the proposed modifications to the L5 MOD-1/-2 space stations is to rationalize the orbit parameters of all the L5 space stations from the MOD-1/-2 publications with the space stations from the MOD-3 publication to give a single system operating at the same orbit altitude (1,200 km), the same orbit inclination (87.9°) and a single set of 36 evenly spaced orbital planes.

3. Methodology for the Interference Assessment

The analyses presented in this report address the effect of the modification on the potential worst-case interference into subsequently filed co-frequency NGSO systems. The analysis considers both static worst-case as well as the statistics of the time-varying worst-case interference.

The static worst-case analysis considers the in-line event situation where the interfering and interfered-with ("victim") antennas are pointing directly towards each other.

The starting point for the dynamic analysis is the determination of the reference interference levels that would exist prior to the modification. This takes the form of a cumulative distribution function (CDF) of the interference levels, expressed as an interference-to-noise (I/N) ratio, for varying percentages of time. The CDF of the I/N is derived from a time domain simulation of the two NGSO systems over sufficient time to give stable results. The corresponding interference levels after the modification are then calculated in the same way and compared to the reference situation before the modification. If these new interference levels are less than the reference levels before the modification then the modification has been shown not to increase the potential interference into the subsequently filed NGSO systems.

It should be noted that the criterion adopted here for confirming no increased interference after the modification is particularly stringent. The objective is for the I/N levels for all percentages of time to be lower than the levels before the modification. This approach will more than guarantee that the performance of the victim system, after the L5 modification, is better than before the modification. This is because the performance of the victim system when subject to L5 interference is related to the convolution of the link degradation due to interference with that due to rain, and therefore should take account of the I/N levels at all percentages of time. By adopting the requirement in this study that the I/N must be lower for all percentages of time, there will inevitably be some percentages of time when the I/N is significantly below the levels prior to the modification, even if at some other percentages of time the difference may be only small. A review of the results presented later in this report will confirm this to be the case. Therefore, since the I/N values in this study are always lower for the modified L5 parameters, it must necessarily lead to the conclusion that convolving this CDF with rain fade statistics must absolutely result in lower increase in unavailability than the corresponding case for the original parameters.

The dynamic interference analysis assumes that no interference mitigation takes place between the systems, and it is therefore a worst-case assessment of the interference environment. Any interference mitigation measures can be agreed between the two NGSO system operators during coordination, and the possibilities for such mitigation are equally applicable both before and after the modifications considered here. There is no aspect of the proposed modifications that restricts in any way the interference mitigation techniques that could subsequently be applied. In fact, to the contrary, the rationalization of the L5 orbit characteristics brought about by this modification will make the development of interference mitigation more straightforward after the modification that it was before due to the common characteristics of the modified MOD-1/-2 and current MOD-3 satellite orbits.

4. Subsequently Filed NGSO Systems to Consider

The analyses presented in this report relate to all NGSO systems that could potentially be affected, in terms of interference, by this modification request. This applies to NGSO systems for which a coordination request has been submitted to the ITU-BR between the date of the subject L5 coordination request and the date of this requested modification. At the time of preparation of this report the NGSO systems that fall into this category are those listed in Table 4 below.

For each of these other NGSO systems there are one or more coordination request publications, and these have all been taken into account in the interference analyses performed. This was achieved by using the aggregate of the Appendix 4 parameters for these NGSO systems which are in the ITU's SRS database.

Annex A contains the more detailed parameters of these other NGSO systems that are relevant to this interference assessment and which are used in the analyses.

Table 4 – List of other NGSO systems considered in this assessment

Satellite Name	Administration	Summary Description
3ECOM-1	Liechtenstein	288 LEO satellites in 12 orbital planes
3ECOM-3	Liechtenstein	288 LEO satellites in 12 orbital planes
ASK-1	Norway	7 HEO satellites in 4 orbital planes
ES-SAT-2	France	1,428 LEO and MEO satellites in 174 orbital planes
MCSAT-2 HEO-1	France	36 HEO satellites in 3 orbital planes
MCSAT-2 LEO-1	France	72,576 LEO satellites in 1,008 orbital planes
MCSAT-2 MEO-1	France	624 MEO satellites in 38 orbital planes
MCSAT-2 MEO-2	France	744 MEO satellites in 22 orbital planes

NORSAT-H1	Norway	4 HEO satellites in 2 orbital planes
O3B-C	UK	696 LEO and MEO satellites in 32 orbital planes
STEAM-1	Norway	3,993 LEO satellites in 43 orbital planes

5. Static Interference Assessment

The static worst-case interference assessment is simple and concludes that there is no possible potential increase in interference to any other NGSO system, based on the following:

(a) Downlink: As the orbit altitude has been raised from 900 km to 1,200 km in the L5 MOD-1/-2 modification, and the highest maximum space station transmit EIRP density levels are being reduced by 5 dB, the resulting power flux density (PFD) at the Earth's surface will reduce by 20log(1200/900) + 5 = 7.5 dB in the zenith/nadir direction, and hence the worst-case static downlink interference level will also reduce by up to 7.5 dB. This general conclusion is valid for any orbit geometry relating to the other NGSO systems, although the reduction in PFD related to orbit altitude increase will be a function of the arrival angle at the Earth's surface.

(b) Uplink: As the highest L5 MOD-1/-2 earth station transmit EIRP density levels are being reduced (the amount of the reduction being dependent on the earth station type), the resulting power flux density (PFD) at the victim space stations will reduce accordingly. Hence the worst-case static uplink interference level, which occurs when the victim satellite is located at the beam peak of the interfering transmitting earth station, will reduce by this same amount. This conclusion is also valid for any orbit geometry relating to the other NGSO systems.

6. Dynamic Interference Assessment

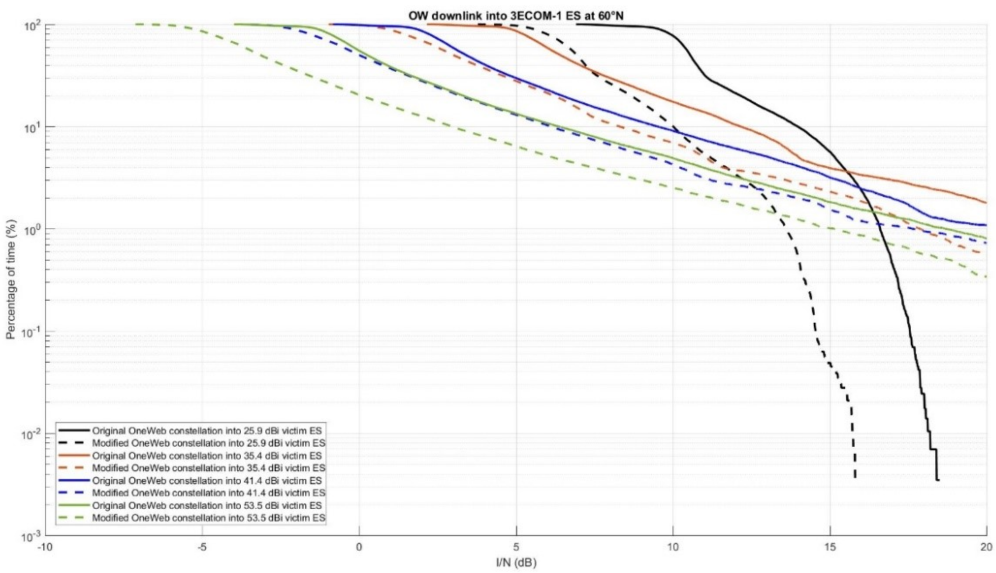
As explained in Section 3 above, the dynamic interference analysis uses a time domain simulation computer program to derive a CDF of the I/N values into the victim NGSO system. The way this simulation is set up for the uplink and downlink cases is described below.

The downlink interference is simulated from the transmitting L5 satellites into the other NGSO systems' receiving earth stations. The victim NGSO system's receiving earth station is located at a particular latitude (the latitude is a variable in the analysis) and is assumed to be tracking the highest elevation satellite in its own system. All L5 satellites with elevation angles greater than 10° as viewed from the victim earth station are then assumed to be simultaneously radiating their peak EIRP density towards the victim earth station.[2] The aggregate interference from these L5 satellites into this victim earth station is then computed over time as the simulation proceeds. The aggregate I/N values for each sample time are collected and the results are shown as a CDF of these I/N values. An example CDF plot of these results in shown in Figure 1 below – in this case for downlink interference into the 3ECOM-1

[2] Although it is extremely unlikely that, in practice, such low elevation L5 satellites would be transmitting towards this same victim earth station location, this is the approach for calculating the worst-case interference, based on the fact that the L5 satellite antenna beams are steerable in the L5 ITU filing. In reality, the L5 system will operate at much higher elevation angles so the total interference into the victim system will be much less than predicted in this analysis.

NGSO system. The solid lines are the results for the original L5 constellation (MOD-1/-2 plus MOD-3) and the dotted lines are the same results but after the modification is applied to MOD-1/-2. The different coloured lines represent the results into different types of victim earth stations which represent the range of earth station gain values provided in the ITU filing for the other NGSO system. Note that, in all cases, the interference levels with the modification are less than without. The results shown in Figure 1 are obtained with the victim earth station located at 60°N but analyses have also been made for other latitudes (e.g., 0°, 40°N and 65°N) and the results (the change in interference level after versus before the modification) are very similar. At no latitude is the interference worse with the modification for any percentage of time.

Figure 1 – Example CDF plot for comparison of the downlink interference into other NGSO systems before and after the modification

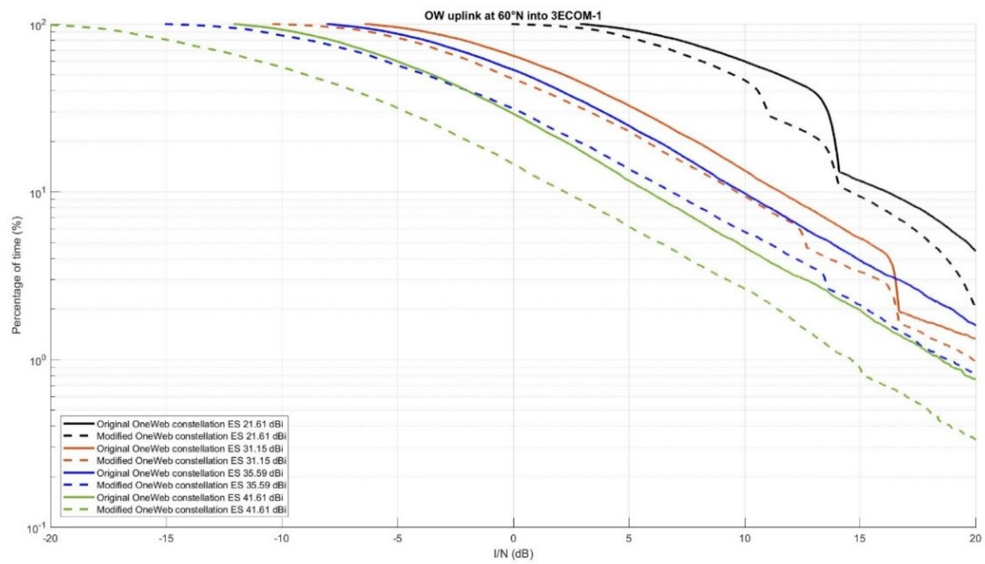


Note that these analysis results extend only up to an I/N of +20 dB for several reasons as follows. Firstly, the interference levels above around +10 dB to +20 I/N are so high that the victim system's link would no longer be viable, and interference mitigation would have to be implemented by some means such as satellite or earth station diversity. Therefore, the interference results are meaningless for such high I/N levels. Secondly, the time domain simulation requires longer run times to provide accurate results at the short-term end of the CDF, because the time step size needs to be very small in order to accurately capture the near-inline events. This can lead to prohibitively long simulation run times, given the sizes of the NGSO constellations and the number of analyses to perform. For this reason, it is prudent to truncate the analysis results at an I/N level of +20 dB in order to allow feasible simulation run times with reliable and accurate results. Despite the very high short-term levels of interference not being calculated in the dynamic analysis, the static analysis results have already shown that the very short-term interference levels, which occur during perfect inline events, are always less with the modification compared to without (see Section 5 above).

The uplink interference is simulated from the transmitting L5 earth station into the other NGSO system's receiving satellites. Interference results are obtained for each of the possible L5 transmitting earth stations. The L5 transmitting earth station is located at a particular latitude (the latitude is a variable in the analysis) and is assumed to be tracking the highest elevation L5 satellite. All visible satellites in the other NGSO system are assumed to be pointing their receive beam towards the interfering L5 transmitting earth station. Essentially, the two systems are assumed to have collocated earth stations. The interference is then calculated from this transmitting L5 earth station into a victim uplink in the other NGSO system, where that victim link is the link from its collocated transmitting earth station to the highest elevation satellite of the constellation.[3] The interference levels on this link are then calculated over time as the simulation proceeds. The aggregate I/N values for each sample time are collected and the results are shown as a CDF of these I/N values. An example CDF plot of these results in shown in Figure 2 below – in this case for uplink interference into the 3ECOM-1 NGSO system. As for the downlink result example presented above, the solid lines are the results for the original L5 constellation (MOD-1/-2 plus MOD-3) and the dotted lines are the same results after the modification to MOD-1/-2. In the uplink case, however, the different coloured lines represent the results from every different type of interfering (L5) earth station included in the L5 filings. Note that, in all cases, the interference levels after the modification are less than without. The results shown in Figure 2 are obtained with the interfering and victim earth stations located at the same point at a latitude of 60° but analyses have also been made for other latitudes and the results (the change in interference level after versus before the modification) are very similar. At no latitude is the interference worse with the modification.

[3] This analysis approach is not only representative of how the L5 system will operate, but it is the simplest and most insightful way to assess the relative impact of the modification on the uplink interference situation. More complex analyses involving multiple interfering earth stations would derive higher aggregate uplink interference levels, but would tend to average out the interference effects of the modification and hence mask the true impact of the modification.

Figure 2 – Example CDF plot for comparison of the uplink interference into other NGSO systems before and after the modification



Note that the I/N results extend only up to an I/N value of +20 dB for the same reasons as explained for the downlink analysis.

In Annex A there is a detailed list of all the relevant parameters of the other NGSO systems considered, together with an explanation of how the analyses are broken down into the various sub-constellations of these other NGSO systems. Annex B contains the detailed uplink and downlink dynamic interference analysis results as described above for all of the other NGSO systems considered. In all cases the results confirm that the aggregate interference of the L5 MOD-1/-2 plus MOD-3 constellation after the L5 MOD-1/-2 modification is always less than before the modification.

Selected results that are presented in Annex B have also been further validated using completely separate software packages which further confirms the validity of the conclusions reached in this report.

7. Acceptance of any Increased Interference into the L5 System

As part of the modification of the L5 MOD-1/-2 parameters, the responsible administration (the United Kingdom) commits to not requiring any more interference protection from other NGSO systems than was required for the original L5 MOD-1/-2 parameters.

8. Conclusions

Based on the results and commitments presented in this report, including the Annexes, it has been shown that the modification to the L5 MOD-1/-2 parameters will not cause higher levels of aggregate interference, nor require additional interference protection, relative to other NGSO systems for which a coordination request has been submitted to the ITU-BR between the date of the original L5 MOD-1/-2 coordination request and the date of this requested modification.

Annex A - Parameters of the Other NGSO Systems Used in the Interference Assessment

The following table provides the Appendix 4 data items extracted from the ITU database for the other NGSO systems that are analyzed in this report. The data items are limited to those necessary for the dynamic analysis described in Section 6 of the report. Also shown in the table below are comments concerning the orbital parameters of the systems (column 6), and a designation of the particular sub-constellation of each system (column 7) in cases where the other NGSO system has multiple sub-constellations (e.g., SC-1, SC-2, etc). A separate interference analysis is made for each of these sub-constellations and those results, presented in Annex B, can be related to these sub-constellation designations in this table.

For some of the parameters in the different NGSO systems in the table below there are multiple values (i.e., for the receive earth station antenna gain and receive satellite antenna gain). These ranges of values are dealt with in the analyses as follows:

(i) All of the systems have multiple different receive earth station antenna gains, varying in number from five to ten depending on the NGSO system. The downlink interference analyses have been performed for each of these antenna gains but, for reasons of clarity, only four such different earth station sizes are shown on each CDF plot in Annex B, with the four gain values shown spread across the range of gains provided.[4]

(ii) Some of the systems have multiple different receive satellite antenna gains. The uplink interference analyses make use of the highest receive gain in each case as this gives rise to the highest levels of interference. However, the selection of any one of the possible antenna gains does not affect the resulting measure of the impact of the modification, as the interference levels, both before and after the modification, will vary proportionally to the assumed victim satellite receive antenna gain, and so the difference between the two will be independent of the assumed antenna gain.

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[4] See Annex B for additional information on which receive earth station gain values are shown in the results.

<table>
<tr><th>NGSO System</th><th colspan="7">Orbit Information</th><th colspan="3">Downlink</th><th colspan="2">Uplink</th></tr>
<tr><th></th><th>Altitude (km)</th><th>Inclination (°)</th><th># Orbit Planes</th><th># Sats per Plane</th><th>RAAN Plane Spacing (°)</th><th>Comments</th><th>Sub-Constellation Designation</th><th>Rx ES Antenna Gain (dBi)</th><th>Rx ES System Noise Temp (K)</th><th>Rx ES Antenna Gain Pattern</th><th>Rx Sat Antenna Gain (dBi)</th><th>Rx Sat System Noise Temp (K)</th></tr>
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26.6
35.4
36 2
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42 2
53 5
54 2
59 5
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20
30</td><td>600</td></tr>
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1059 (perigee)</td><td rowspan="2">63.435</td><td>3</td><td>3 @ 0°
1 @ 120°
1 @ 240°</td><td>120</td><td>Min. operational height = 23,500 km</td><td>SC-1</td><td rowspan="2">35 8
40 2
47 8
51.6
59 3</td><td rowspan="2">100</td><td rowspan="2">Rec. 580-6</td><td rowspan="2">35</td><td rowspan="2">600</td></tr>
<tr><td>42708 (apogee)
8101 (perigee)</td><td>1</td><td>2</td><td>N/A</td><td>Min. operational height = 28,400 km</td><td>SC-2</td></tr>
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<tr><td>1100</td><td>62.5</td><td>5</td><td>9</td><td>36</td><td></td></tr>
<tr><td>1100</td><td>75 25</td><td>5</td><td>9</td><td>36</td><td></td></tr>
<tr><td>1200</td><td>37</td><td>5</td><td>9</td><td>36</td><td>SC-6</td></tr>
<tr><td>1200</td><td>49.75</td><td>5</td><td>9</td><td>36</td><td>SC-7</td></tr>
<tr><td>1200</td><td>62.5</td><td>5</td><td>9</td><td>36</td><td>SC-8</td></tr>
<tr><td>1200</td><td>75 25</td><td>5</td><td>9</td><td>36</td><td>SC-9</td></tr>
<tr><td>1300</td><td>37</td><td>5</td><td>9</td><td>36</td><td></td></tr>
<tr><td>1300</td><td>49.75</td><td>5</td><td>9</td><td>36</td><td></td></tr>
<tr><td>1300</td><td>62.5</td><td>5</td><td>9</td><td>36</td><td></td></tr>
<tr><td>1300</td><td>75 25</td><td>5</td><td>9</td><td>36</td><td></td></tr>
<tr><td>1100</td><td>88</td><td>18</td><td>12</td><td>10 2</td><td rowspan="3">Orbits very similar, so analyze 1200 km only</td><td></td></tr>
<tr><td>1200</td><td>88</td><td>18</td><td>12</td><td>10 2</td><td>SC-10</td></tr>
<tr><td>1300</td><td>88</td><td>18</td><td>12</td><td>10 2</td><td></td></tr>
</table>

NGSO System	Orbit Information							Downlink			Uplink	
	Altitude (km)	Inclination (°)	# Orbit Planes	# Sats per Plane	RAAN Plane Spacing (°)	Comments	Sub-Constellation Designation	Rx ES Antenna Gain (dBi)	Rx ES System Noise Temp (K)	Rx ES Antenna Gain Pattern	Rx Sat Antenna Gain (dBi)	Rx Sat System Noise Temp (K)
MCSAT-2 HEO-1	39275 (apogee) 1072 (perigee)	63.435	1	12	N/A		SC-1	30 36 42 48 56.45 62.75	100	AP8	10 25 40	600
	42708 (apogee) 8890 (perigee)	63.435	1	12	N/A		SC-2					
	48442 (apogee) 23144 (perigee)	90	1	12	N/A		SC-3					
MCSAT-2 LEO-1	800	72	72	72	5	Orbits identical except for altitude. Analyses performed and results confirmed for each but results presented for 800 km and 1400 km only	SC-1	30 36 42 48 56.45 62.75	100	AP8	10 25 40	600
	900	72	72	72	5							
	1000	72	72	72	5							
	1100	72	72	72	5							
	1200	72	72	72	5							
	1300	72	72	72	5							
	1400	72	72	72	5		SC-7					
	800	90	72	72	2 5	Orbits identical except for altitude. Analyses performed and results confirmed for each but results presented for 800 km and 1400 km only	SC-8					
	900	90	72	72	2 5							
	1000	90	72	72	2 5							
	1100	90	72	72	2 5							
	1200	90	72	72	2 5							
	1300	90	72	72	2 5							
	1400	90	72	72	2 5		SC-14					
MCSAT-2 MEO-1	8100	0	1	96	N/A	Almost identical orbits, so analyze 8100 km cases only	SC-1	30 36 42 48 56.45 62.75	100	AP8	10 25 40	600
	8100	15	4	12	90		SC-2					
	8100	47.7	4	12	90		SC-3					
	8100	70	4	12	90		SC-4					
	8100	90	6	12	60		SC-5					
	8000	0	1	96	N/A							
	8000	15	4	12	90							
	8000	47.7	4	12	90							
	8000	70	4	12	90							
	8000	90	6	12	60							
MCSAT-2 MEO-2	7500	47.7	6	12	60		SC-1	30 36 42 48 56.45 62.75	100	AP8	10 25 40	600
	7500	90	6	12	60		SC-2					
	8100	47.7	4	60	90		SC-3					
	8100	90	6	60	60		SC-4					
NORSAT-H1	39308 (apogee) 1059 (perigee)	63.435	1	2	N/A		SC-1	35 8 40 2 47 8 51.6 59 3	100	Rec. 580-6	35	600
	43497 (apogee) 8102 (perigee)	63.435	1	2	N/A		SC-2					
O3B-C	8062	0	1	60	N/A		SC-1	19 8 29.4 39 8 44 9 47.4 51 2 52 9 57.1 59 8	120	AP8	15 25 35 45	600
	8062	40	6	24			SC-2					
	8062	70	6	24			SC-3					
	1400	10	6	24			SC-4					
	9000	0	1	60	N/A		SC-5					
	9000	40	6	24			SC-6					
	9000	70	6	24			SC-7					
STEAM-1	1150	53	32	99	11 25		SC-1	27 31 33 35 39 41 44	439 439 439 374 374 196 196	AP8	26 3 27 9 29 2 32.4 35 9 40 3	424
	1325	70	6	75	60		SC-2					
	1275	81	5	75	72		SC-3					

Annex B - Dynamic Interference Analysis Results

The results presented in this Annex were obtained using the original and modified parameters of the L5 MOD-1/-2 system presented in Section 2 of the report, the analysis methodology described in Sections 3 and 6 of the report, and the parameters of the other NGSO systems provided in Annex A.

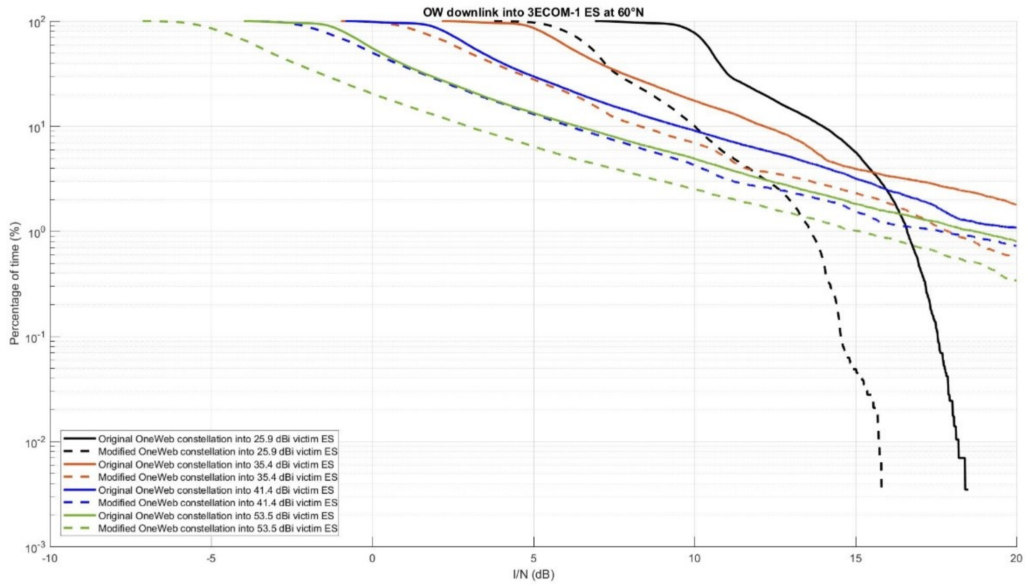
Each CDF plot presented below is for a single latitude value for the collocated earth stations used in the analysis, although the analyses have been made for a wide range of latitude values (typically from 0°N to 60°N). The particular latitude value used in each case has been selected to show the worst-case, based on all the results obtained. The worst-case latitude varies depending on the technical characteristics of the other NGSO system, particularly the orbit inclination. For example, low inclination NGSO systems cannot serve higher latitudes, and so lower latitude test points are used. In other cases, a higher latitude test point yields worse results.

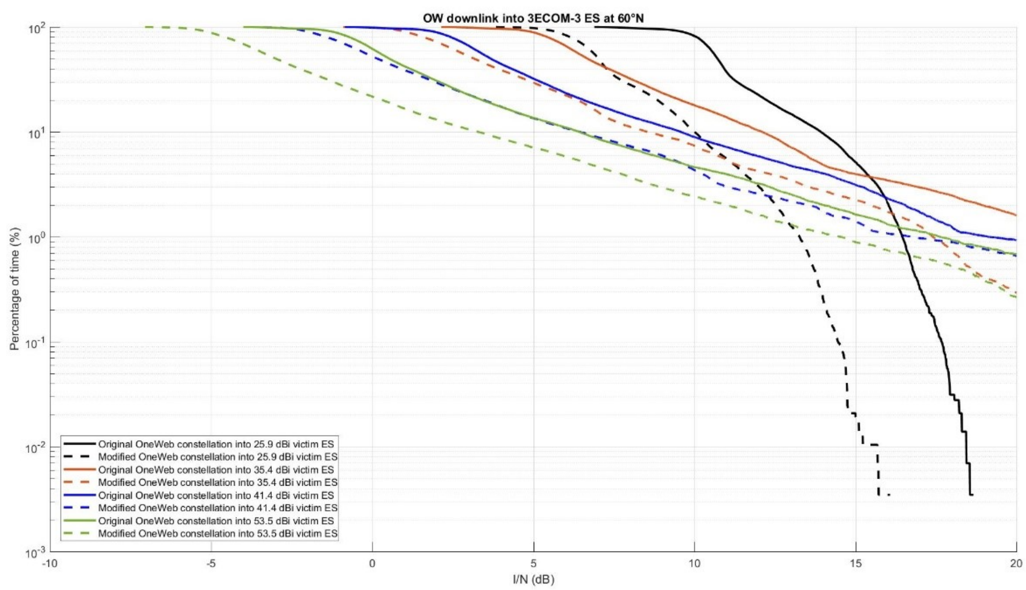
Downlink Interference Analysis

For the downlink interference analyses the solid lines in the CDF plots below are the results for the original L5 constellation (MOD-1/-2 plus MOD-3) and the dotted lines are the corresponding results after the modification to MOD-1/-2 plus the original MOD-3. The different coloured lines represent the results into different types of victim earth stations which represent the range of gain values provided in the ITU filing for the other NGSO system. [5]

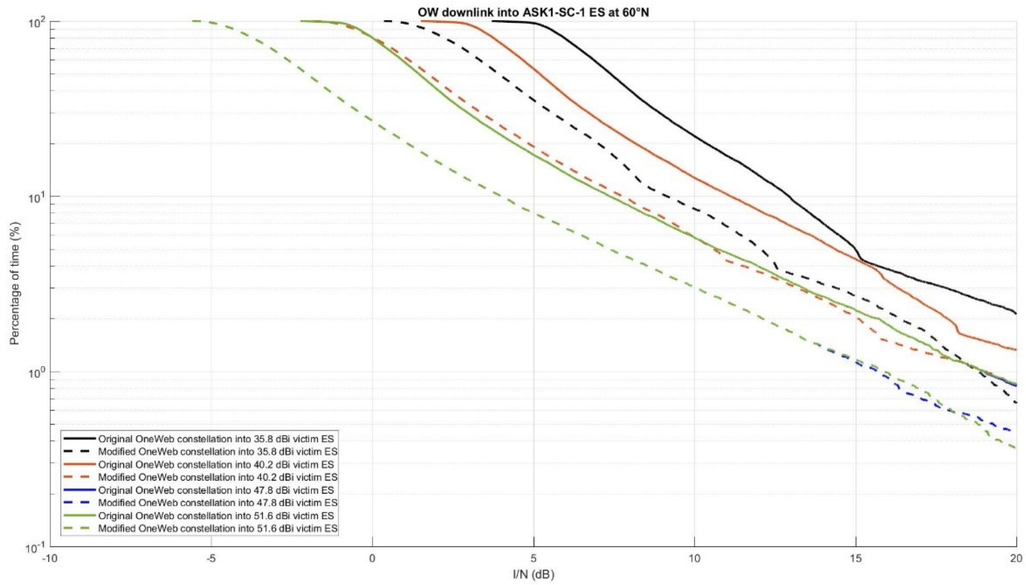
The first set of results below are for downlink interference into the 3ECOM-1 and 3ECOM-3 systems which are near-polar orbiting LEO systems. For these systems, the worst-case latitude was found to be 60°N, although the variation of the impact of the modification (interference after versus interference before) with latitude is small.

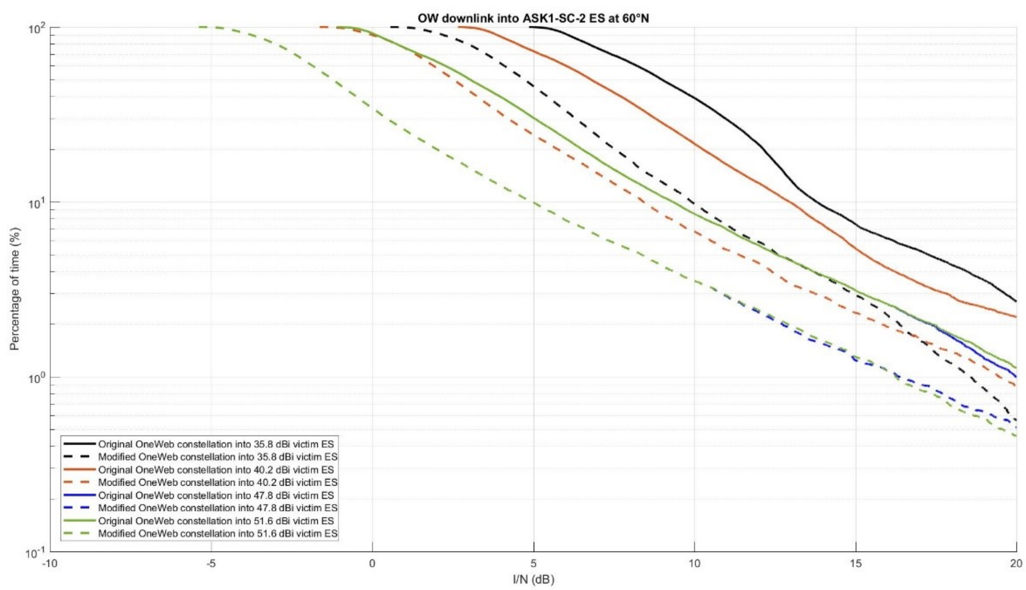
[5] Note that, for the range of I/N values of interest here, the results for the largest victim earth stations are almost identical to each other, because they have identical off-axis gain performance. For this reason, the four representative victim earth stations shown in the analysis are generally biased towards the lower end of the gain range in order to illustrate more variation with antenna gain.



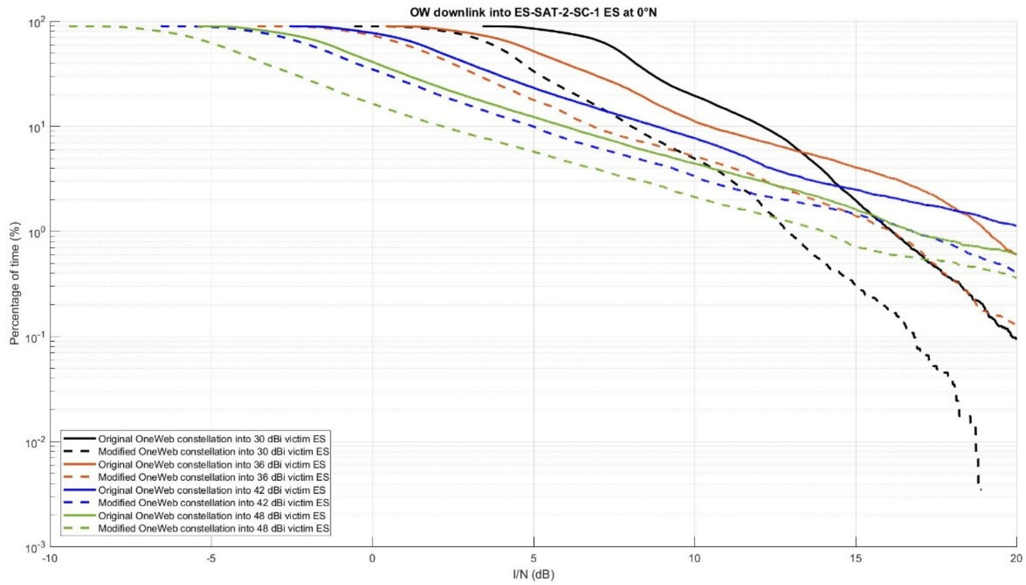


The next set of results are for downlink interference into the ASK-1 HEO system, which is considered to be two sub-constellations for the purpose of the analysis – each with different apogee and perigee altitudes. As the ASK-1 system is intended to provide service to high northern latitudes, the results below are for a latitude of 60°N, although the variation with latitude is in fact minimal.

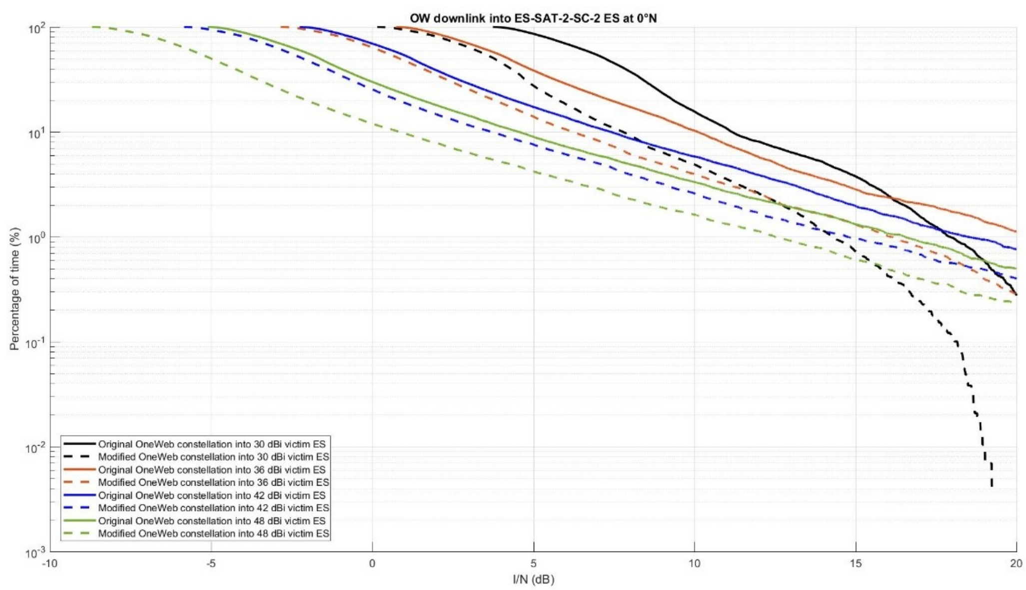




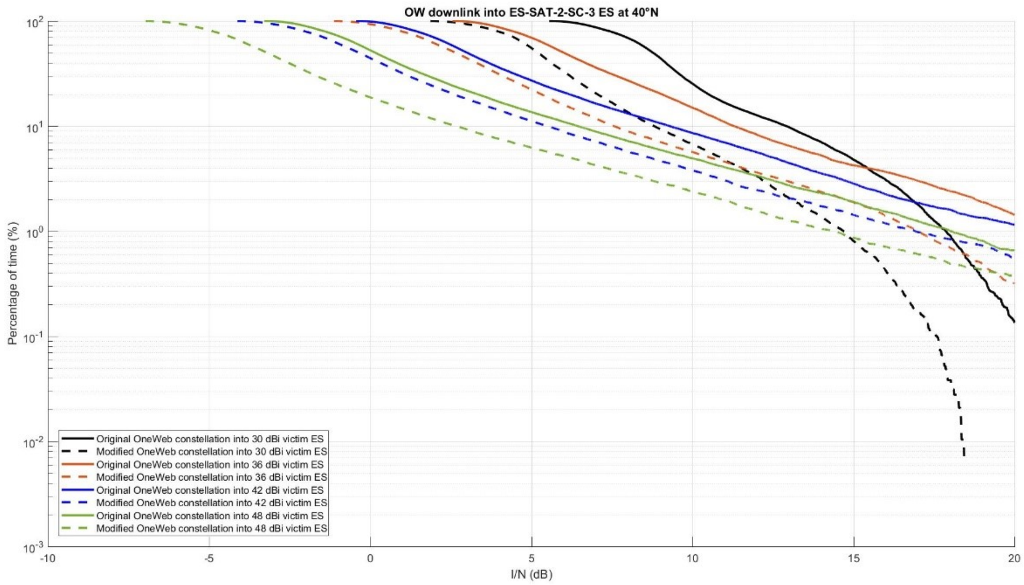
The next set of results are for downlink interference into the ES-SAT-2 system, which includes both MEO and LEO sub-constellations. Ten sub-constellations were selected from the numerous ones in the ES-SAT-2 filing, and these provide a good representation of the range of orbital parameters based on the rationale provided in Annex A. For these systems, the worst-case latitude was dependent on the inclination of the sub-constellation and various values have been used in the CDF plots below.

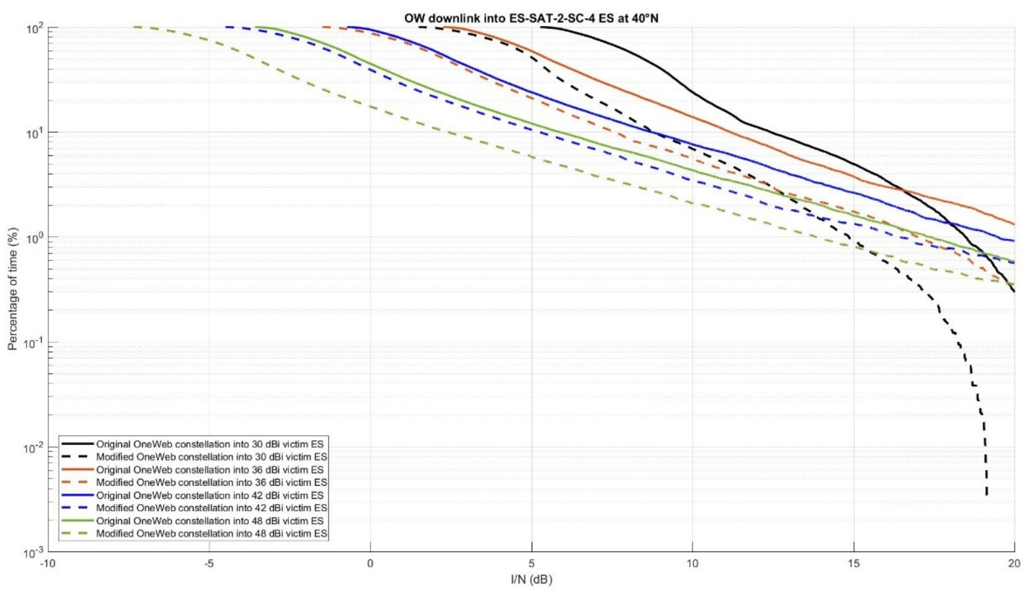


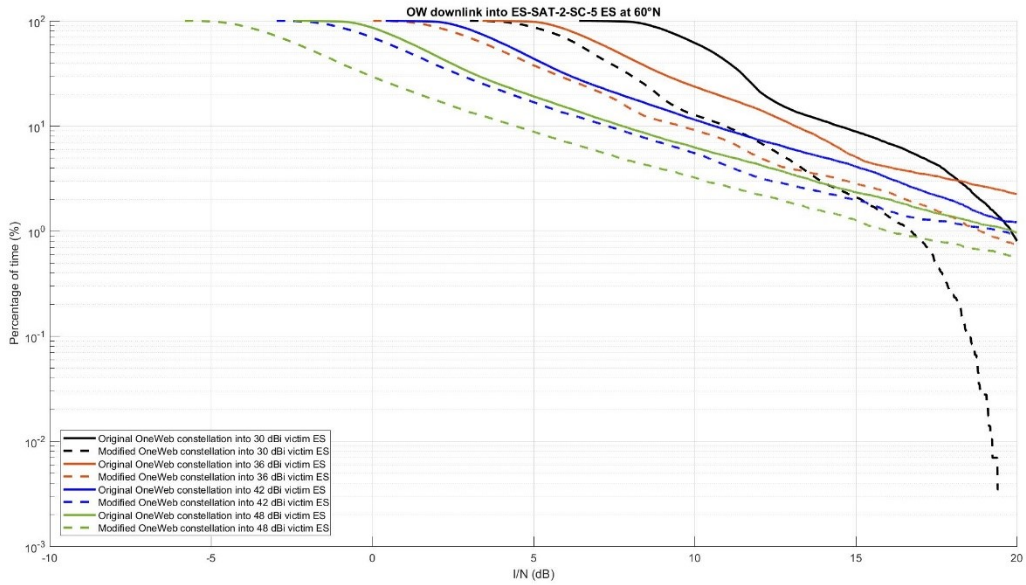
OW downlink into ES-SAT-2-SC-1 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

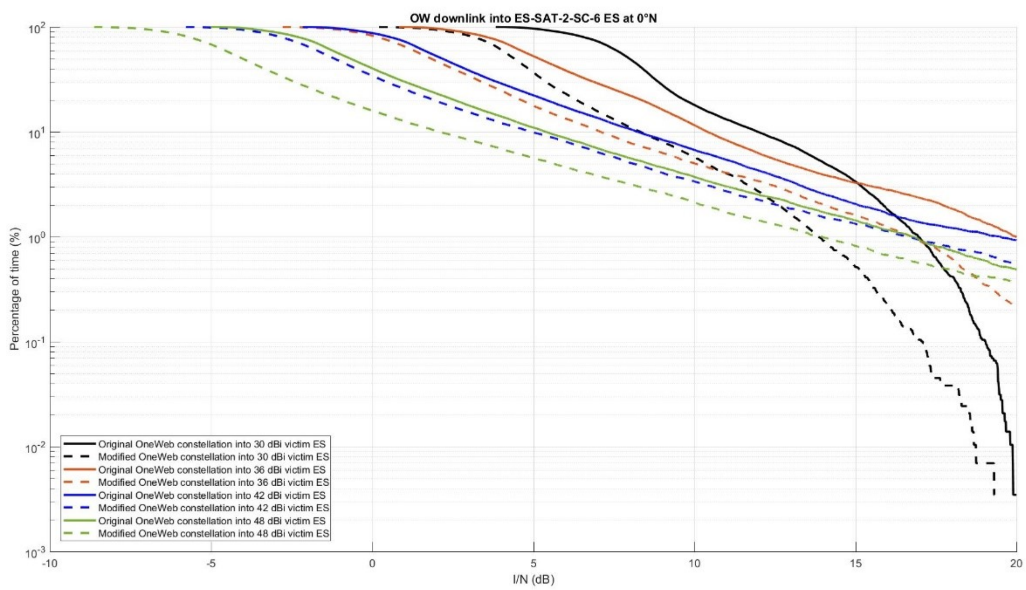


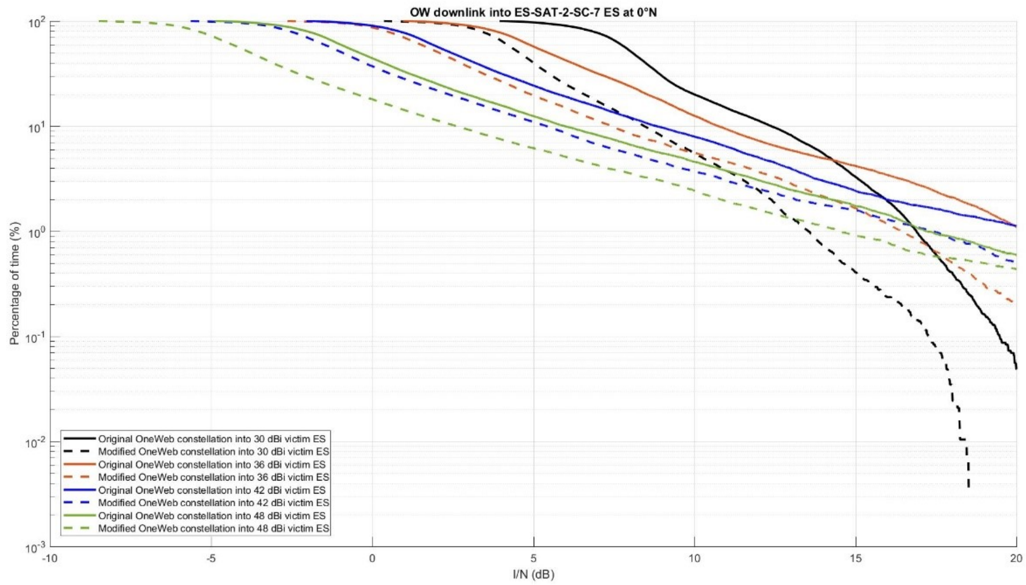
OW downlink into ES-SAT-2-SC-2 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

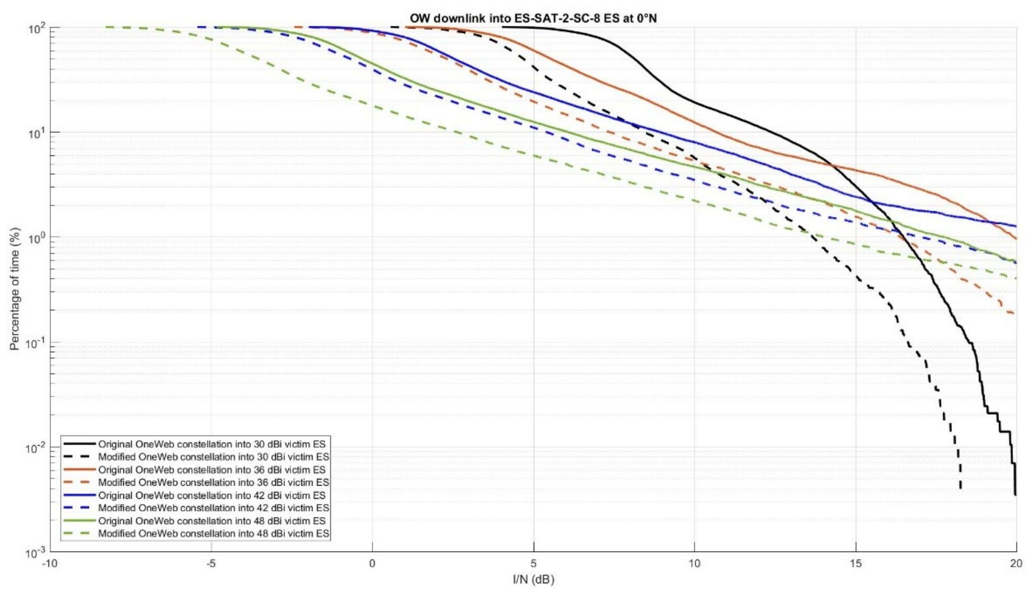

OW downlink into ES-SAT-2-SC-3 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

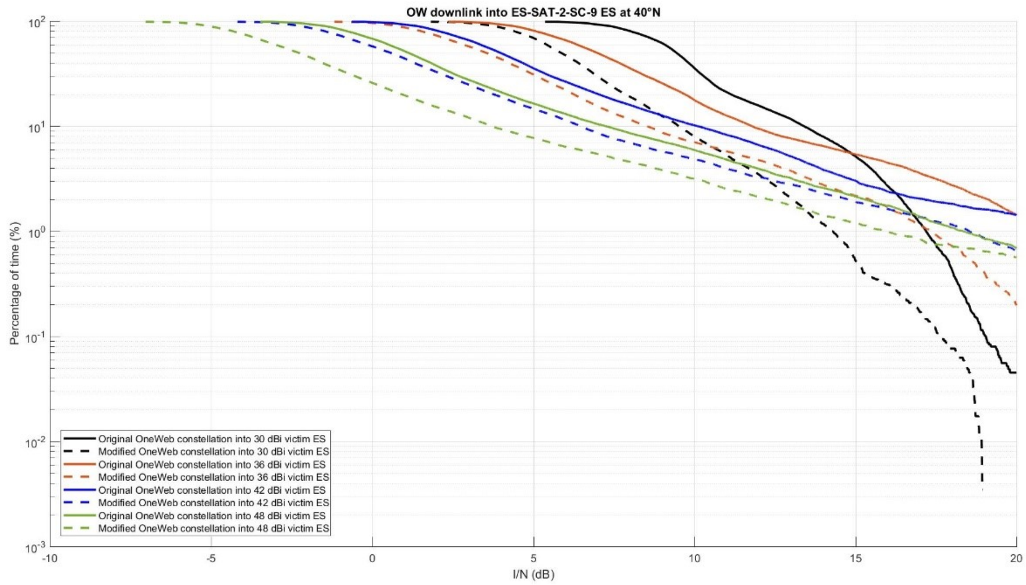

OW downlink into ES-SAT-2-SC-4 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

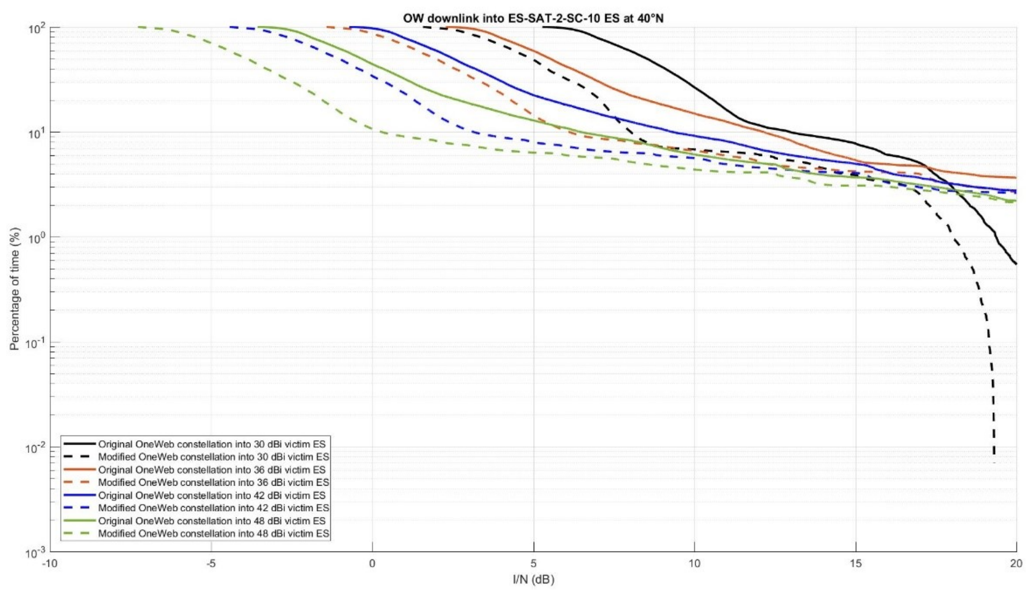

OW downlink into ES-SAT-2-SC-5 ES at 60°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES


OW downlink into ES-SAT-2-SC-6 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

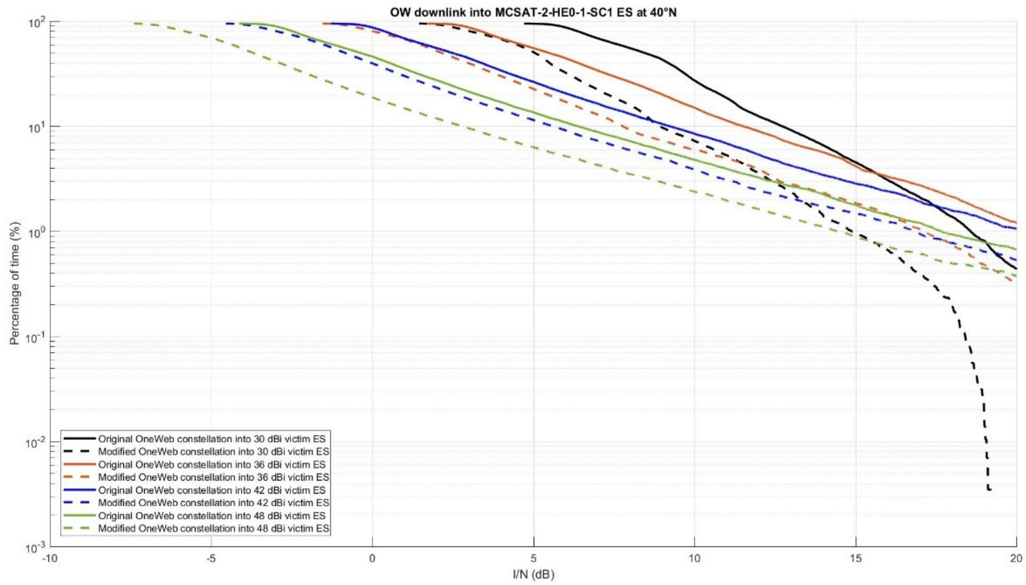

OW downlink into ES-SAT-2-SC-7 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

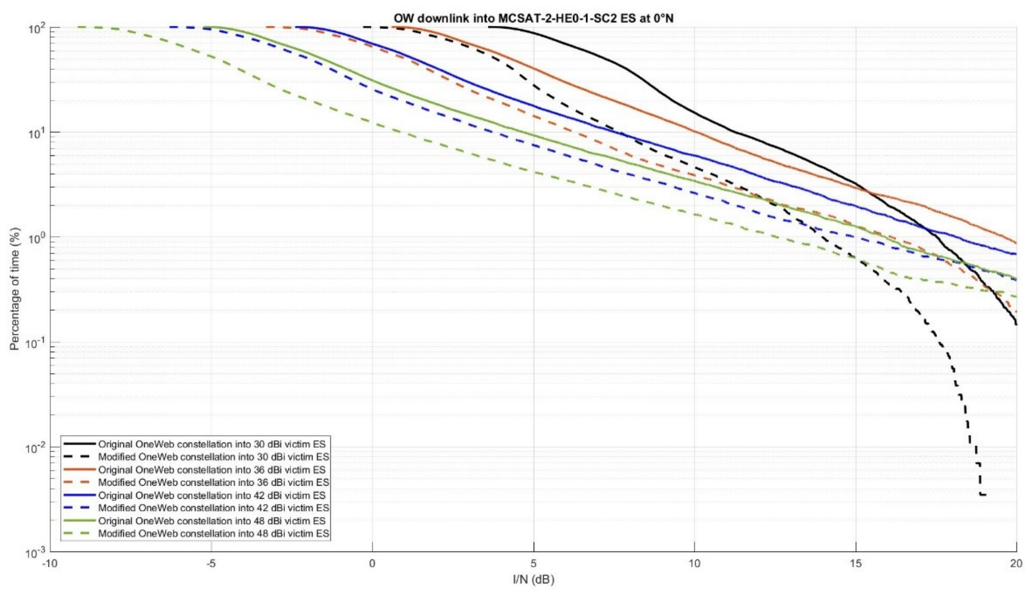

OW downlink into ES-SAT-2-SC-8 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

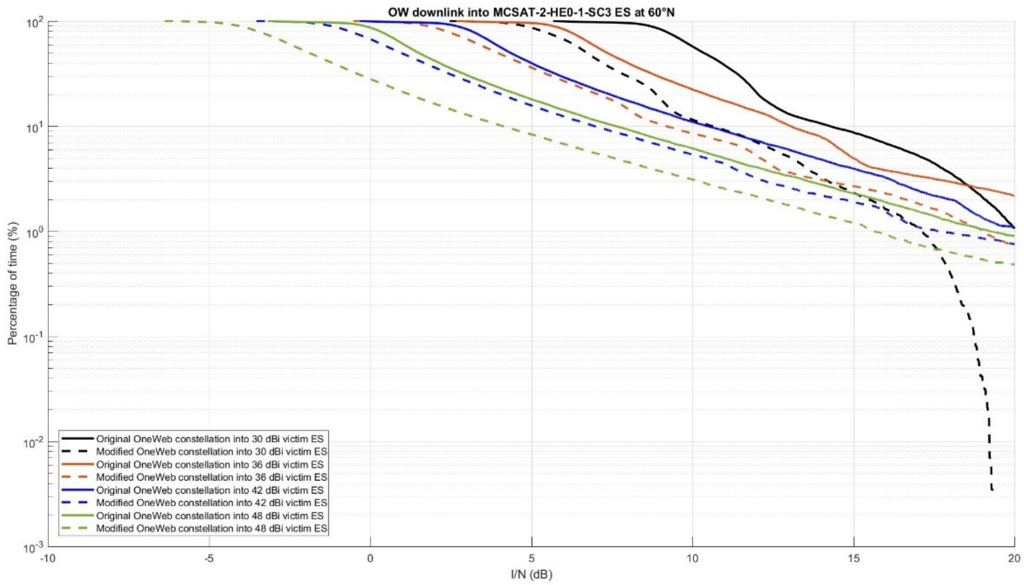




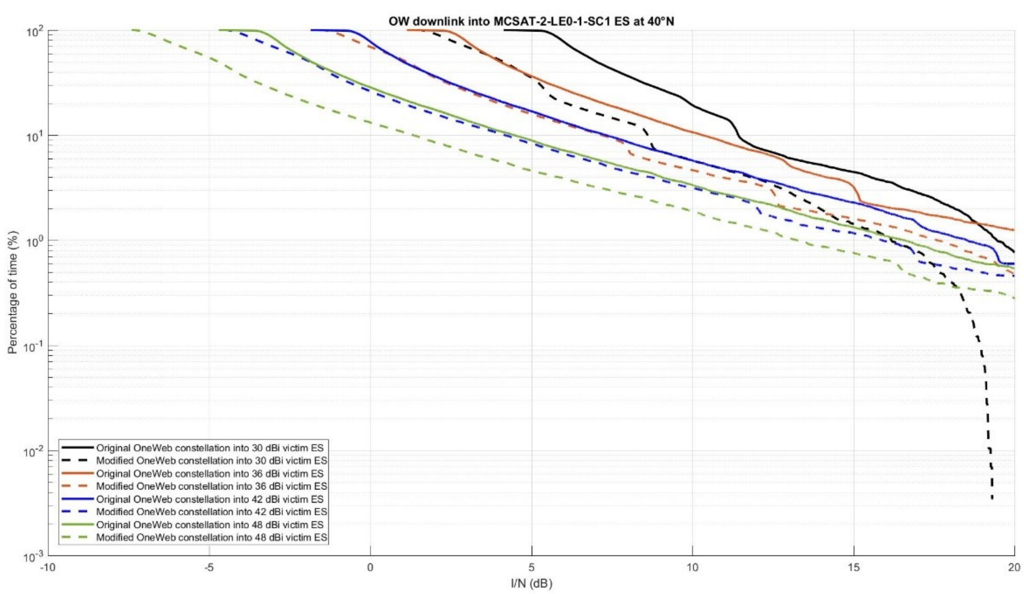
The next set of results are for downlink interference into the MCSAT-2 HEO-1 system, which is considered to be three sub-constellations for the purpose of the analysis – each with different apogee and perigee altitudes. For these systems, the results were very similar for all latitudes, so a range of latitude results are shown for the cases below (40°N, 0°N and 60°N).

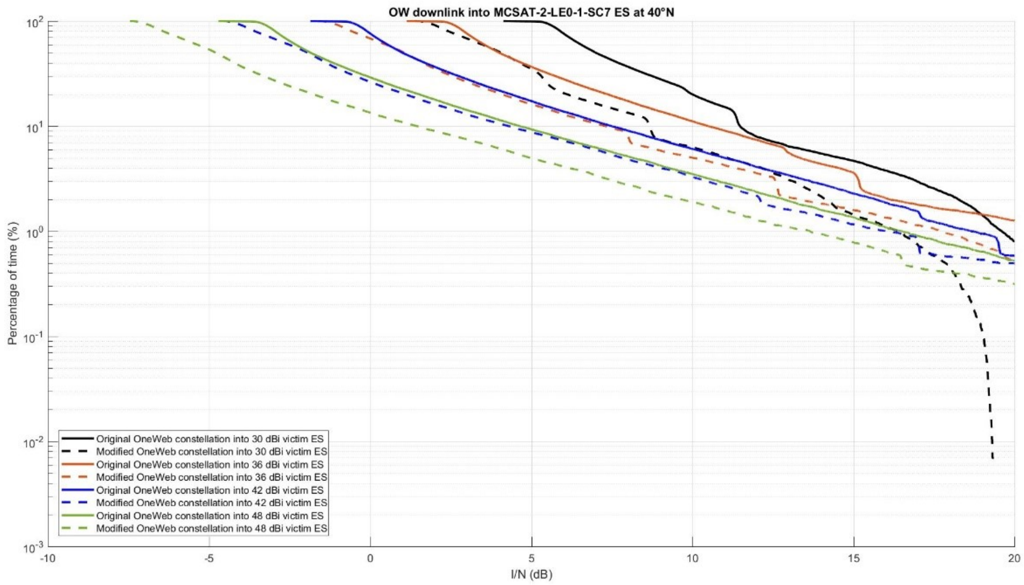

OW downlink into MCSAT-2-HE0-1-SC1 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES


OW downlink into MCSAT-2-HE0-1-SC2 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

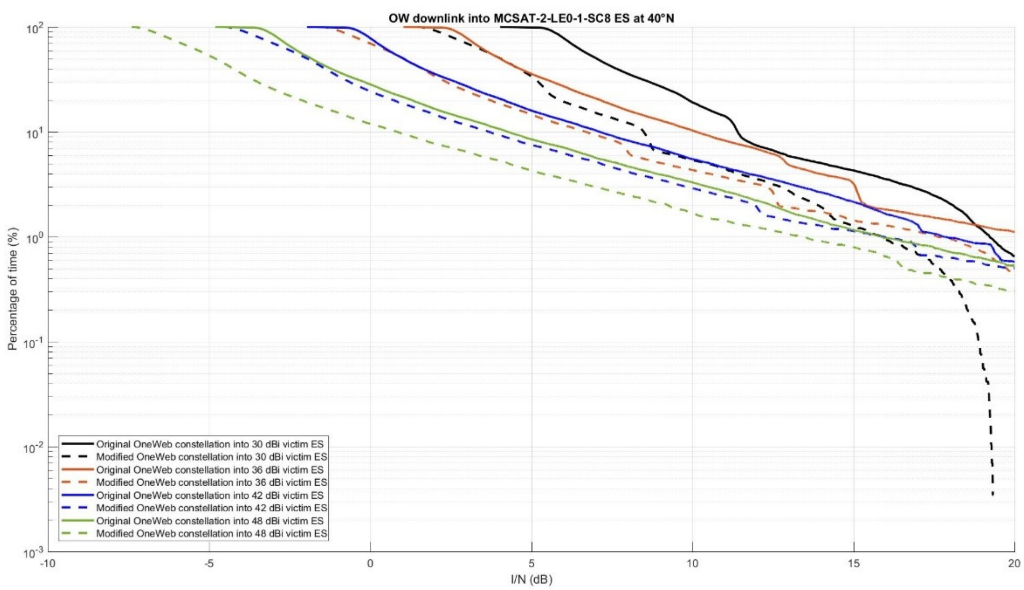


The next set of results are for downlink interference into the MCSAT-2 LEO-1 system, which includes multiple LEO sub-constellations of different altitudes and inclinations. Results were obtained for all the sub-constellations but, for clarity, only the results for the lowest and highest altitude sub-constellations are shown below for each orbit inclination, as explained in Annex A. For these systems, the worst-case latitude was generally 40°N which is shown in the CDF plots below.

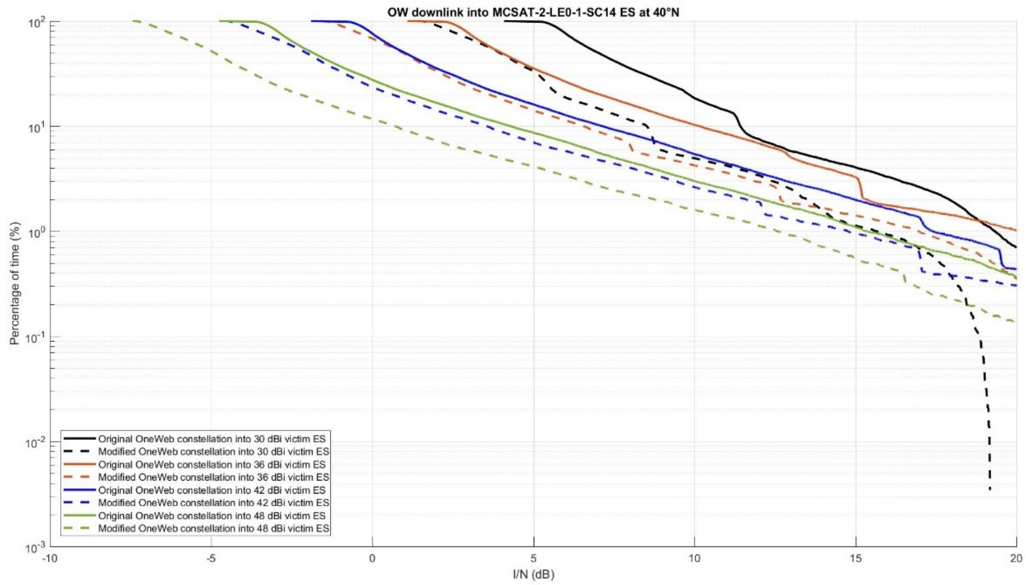




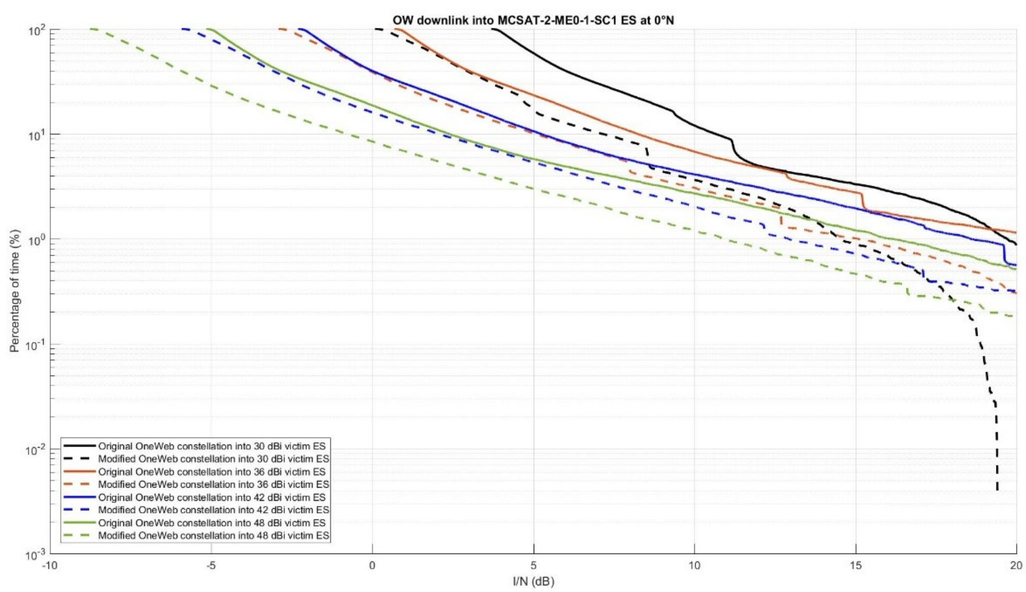
OW downlink into MCSAT-2-LEO-1-SC7 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

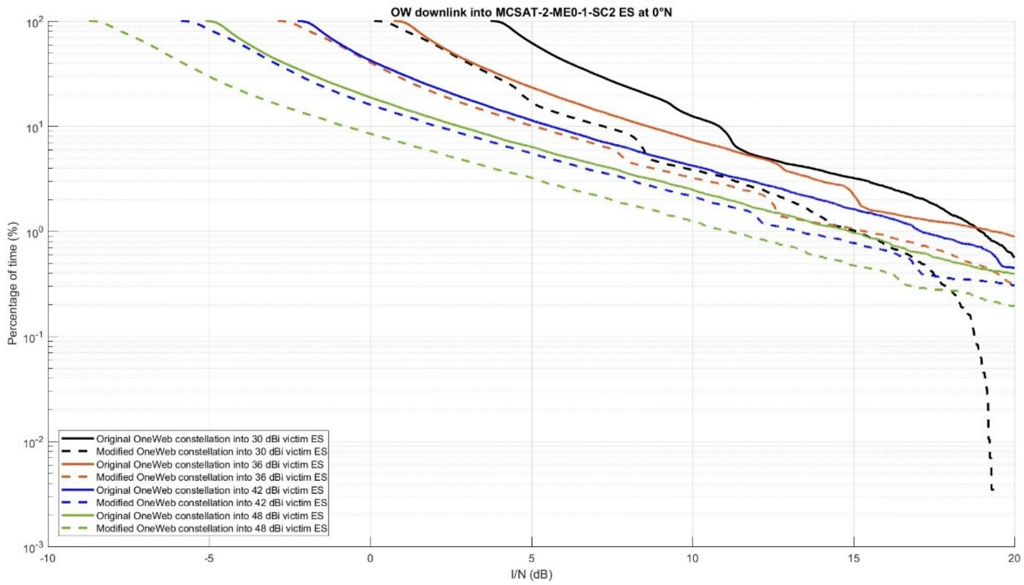


OW downlink into MCSAT-2-LEO-1-SC8 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

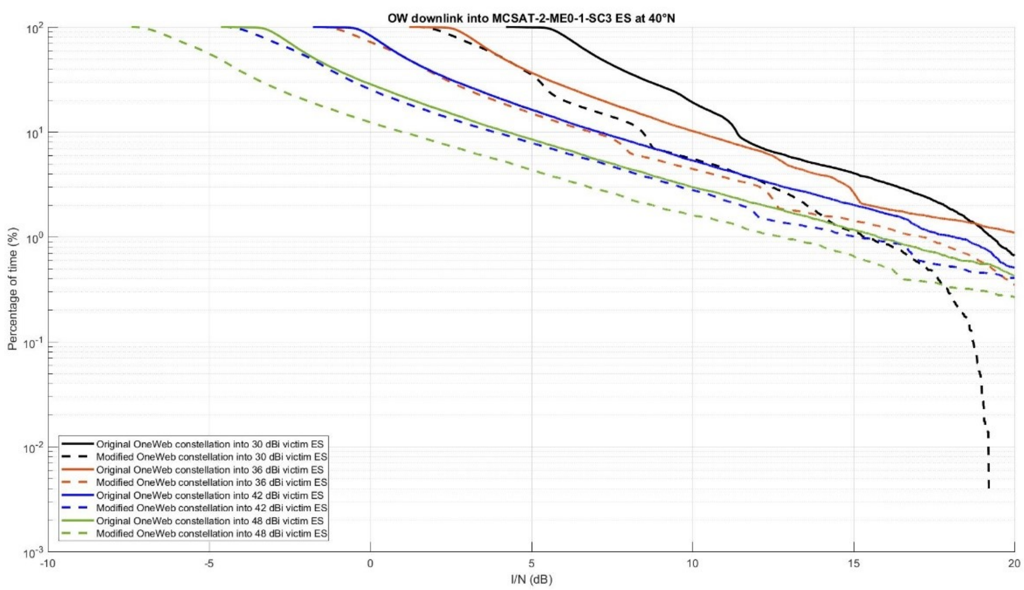


The next set of results are for downlink interference into the MCSAT-2 MEO-1 system, which includes multiple MEO sub-constellations of different inclinations but with very similar altitudes (8,000 and 8,100 km). As explained in Annex A, results were obtained for all the sub-constellations of the higher altitude only. For these systems, the worst-case latitude was dependent on the inclination of the sub-constellation and various values have been used in the CDF plots below.

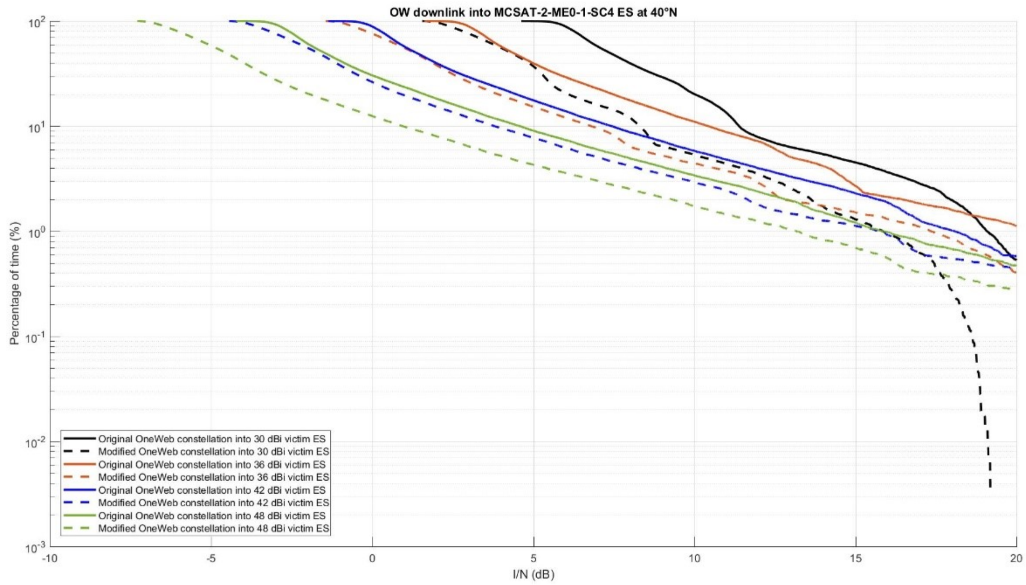


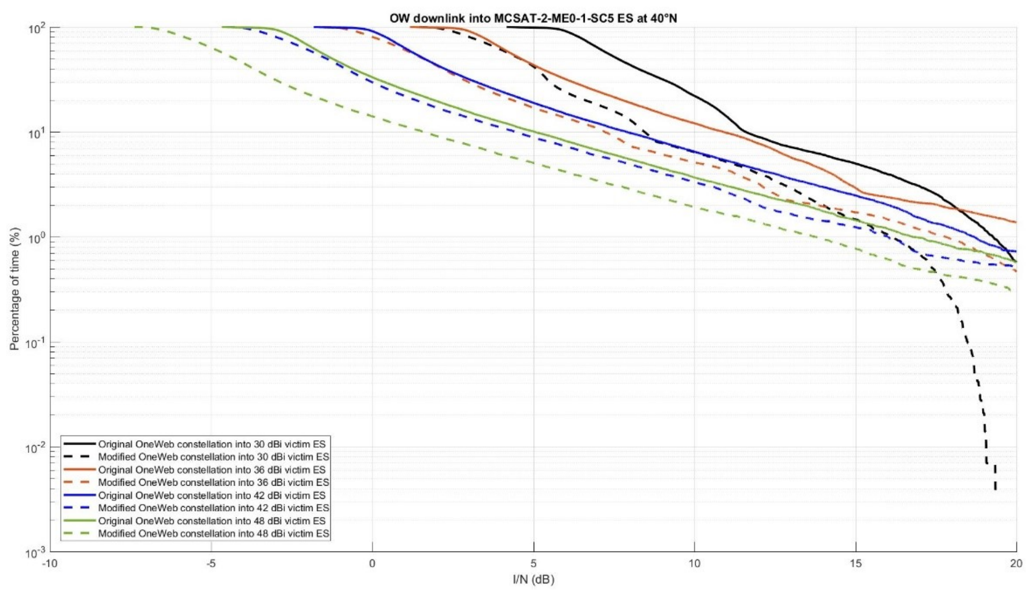


OW downlink into MCSAT-2-ME0-1-SC2 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

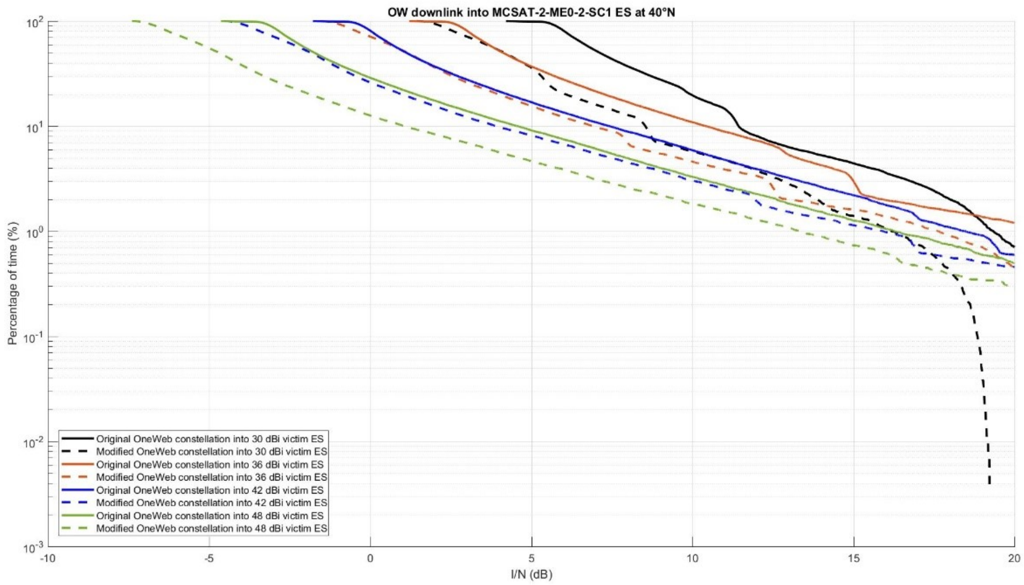


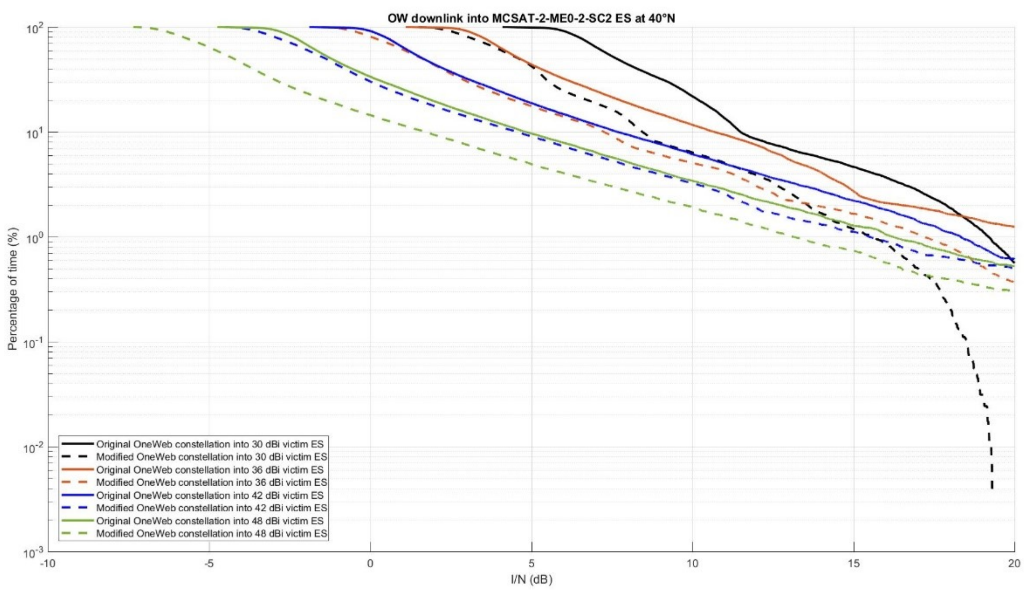
OW downlink into MCSAT-2-ME0-1-SC3 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

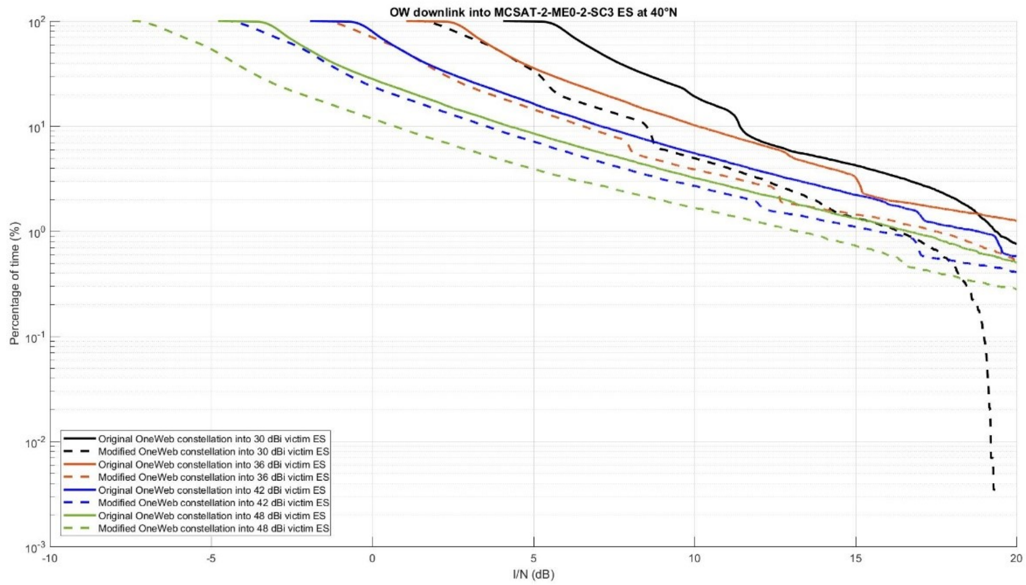


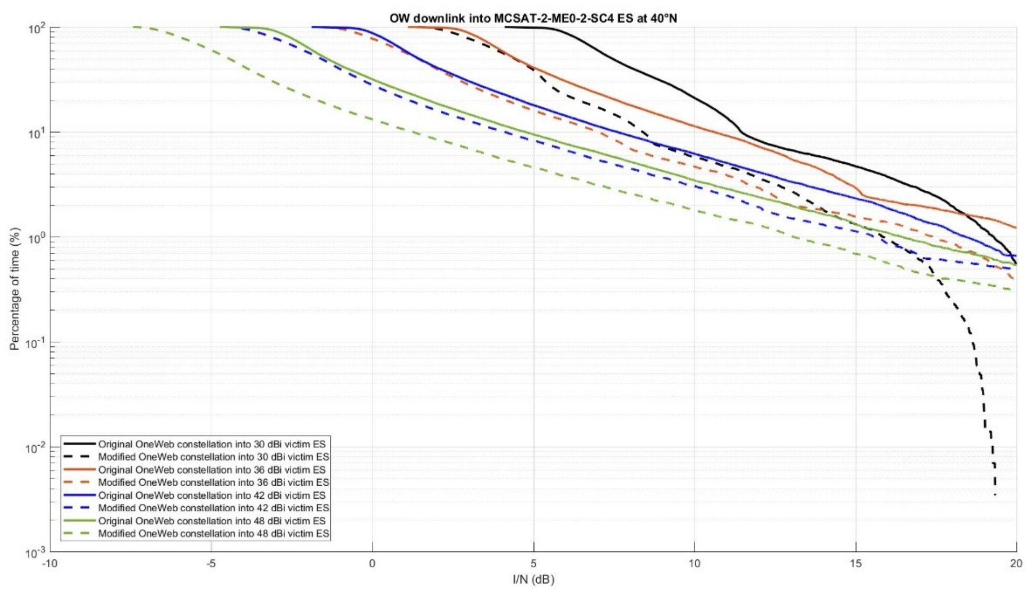


The next set of results are for downlink interference into the MCSAT-2 MEO-2 system, which includes four MEO sub-constellations of different inclinations and altitudes. Results were obtained for all the sub-constellations and the CDF plots are given below. For these systems, the worst-case latitude was generally 40°N although the variation with latitude is in fact minimal.

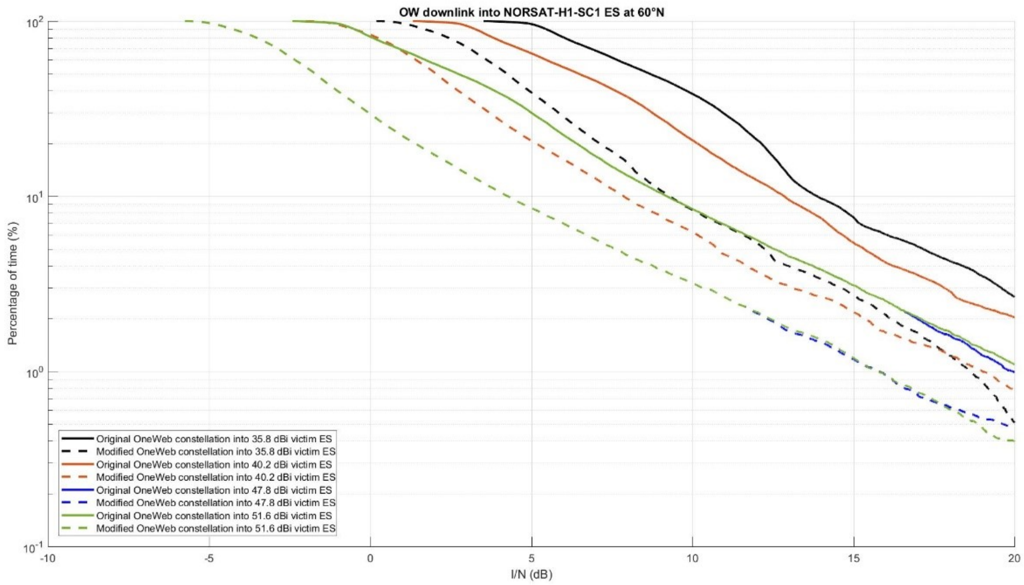

OW downlink into MCSAT-2-ME0-2-SC1 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES

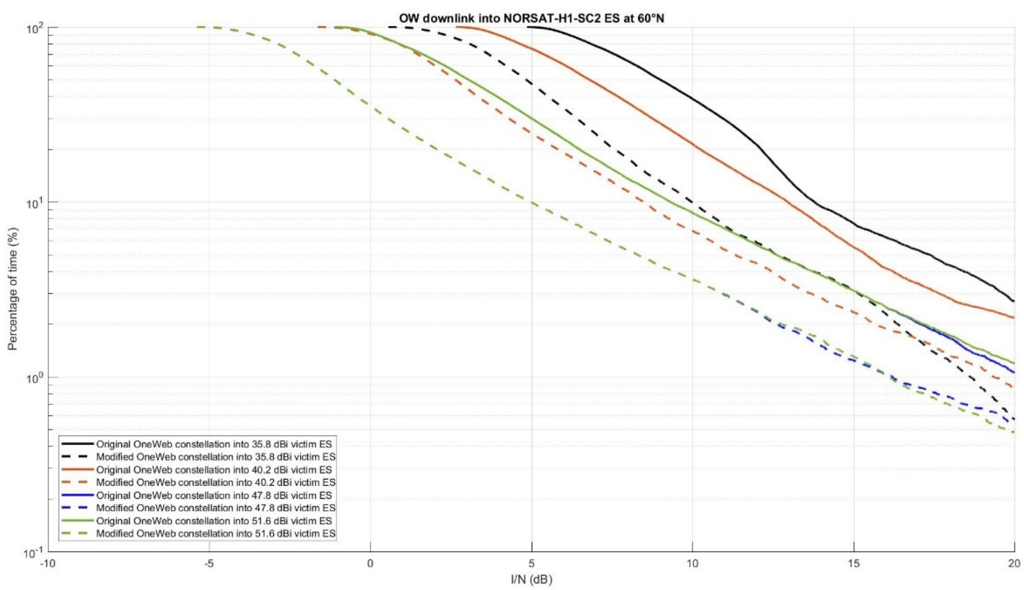

OW downlink into MCSAT-2-ME0-2-SC2 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 30 dBi victim ES
Modified OneWeb constellation into 30 dBi victim ES
Original OneWeb constellation into 36 dBi victim ES
Modified OneWeb constellation into 36 dBi victim ES
Original OneWeb constellation into 42 dBi victim ES
Modified OneWeb constellation into 42 dBi victim ES
Original OneWeb constellation into 48 dBi victim ES
Modified OneWeb constellation into 48 dBi victim ES



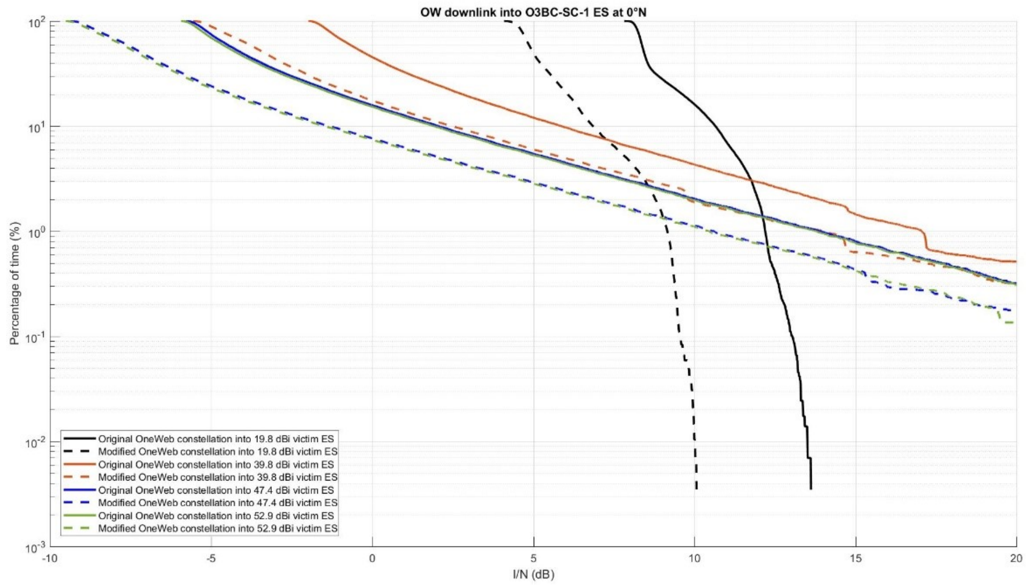


The next set of results are for downlink interference into the NORSAT-H1 HEO system, which is considered to be two sub-constellations for the purpose of the analysis – each with different apogee and perigee altitudes. As the NORSAT-H1 system is intended to provide service to high northern latitudes, the results below are for a latitude of 60°N, although the results for all latitudes show less interference after the modification compared to before.

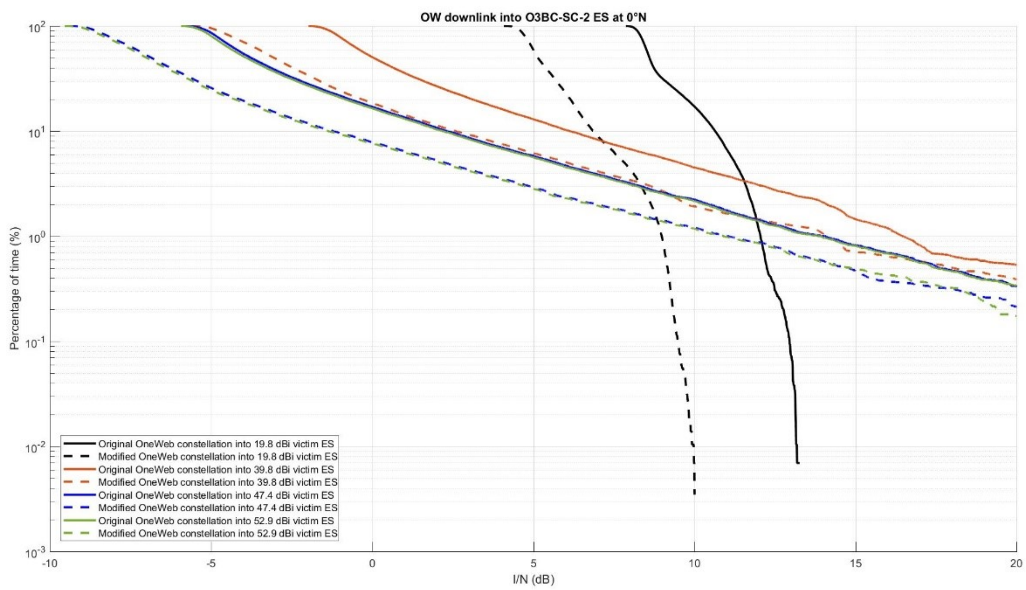




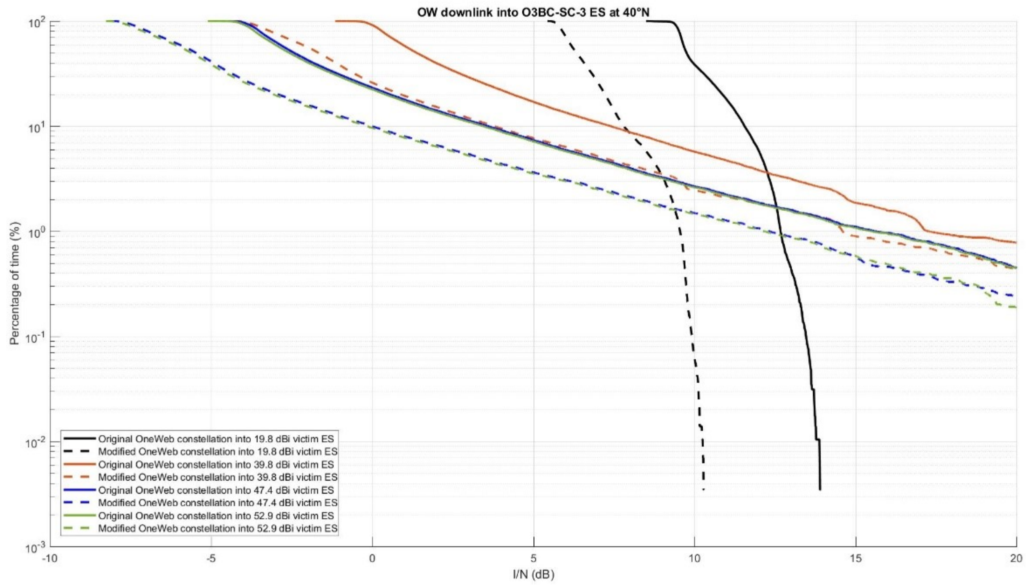
The next set of results are for downlink interference into the O3B-C system, which includes six MEO and one LEO sub-constellation. The MEO sub-constellations have two values for altitude and three orbit inclinations. Results were obtained for all the sub-constellations and the CDF plots are given below. For these systems, the worst-case latitude was dependent on the inclination of the sub-constellation and various values have been used in the CDF plots below, although there was little difference in the impact of the modification as a function of latitude.

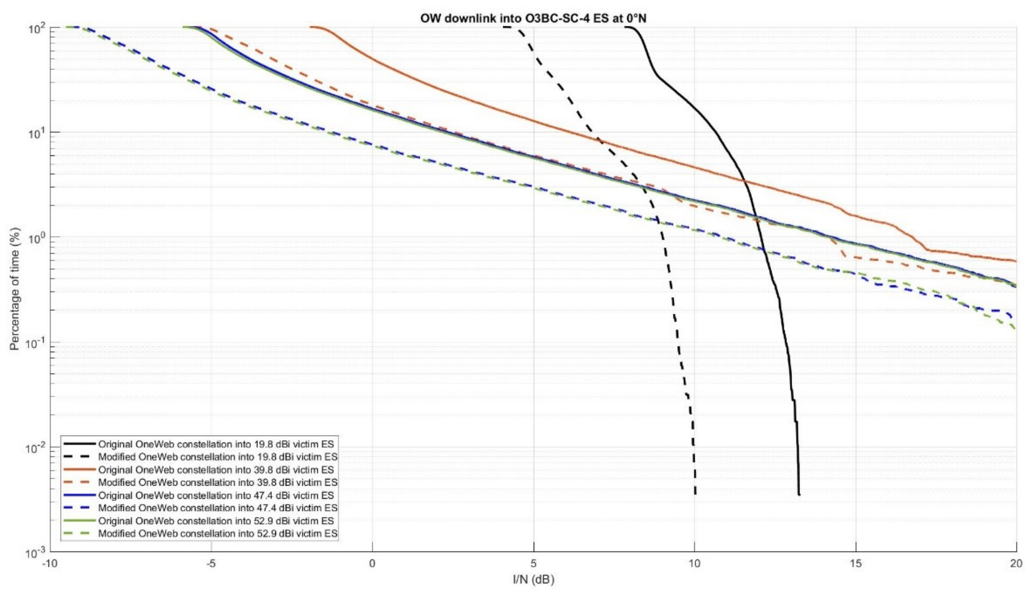


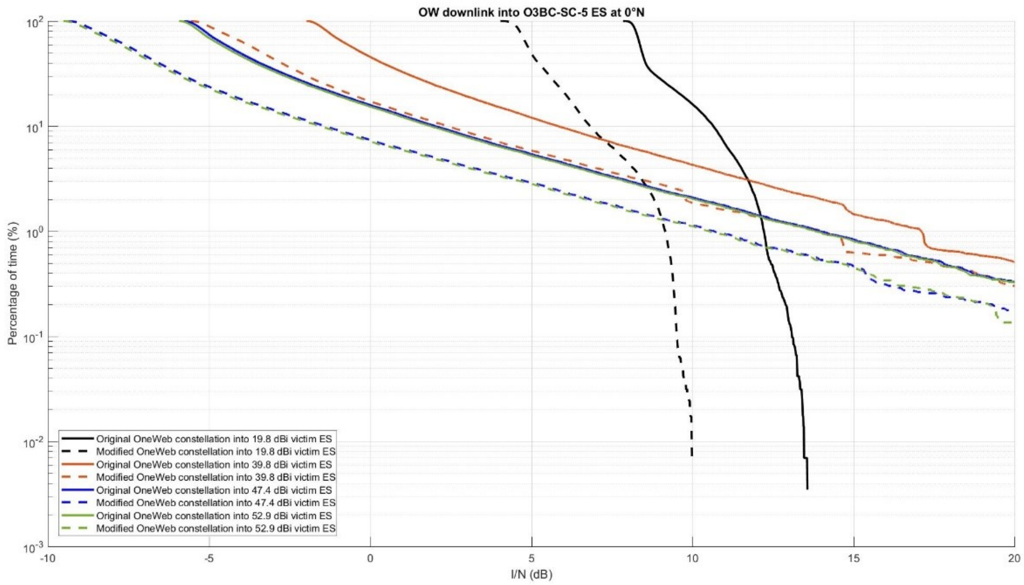
OW downlink into O3BC-SC-1 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 19.8 dBi victim ES
Modified OneWeb constellation into 19.8 dBi victim ES
Original OneWeb constellation into 39.8 dBi victim ES
Modified OneWeb constellation into 39.8 dBi victim ES
Original OneWeb constellation into 47.4 dBi victim ES
Modified OneWeb constellation into 47.4 dBi victim ES
Original OneWeb constellation into 52.9 dBi victim ES
Modified OneWeb constellation into 52.9 dBi victim ES

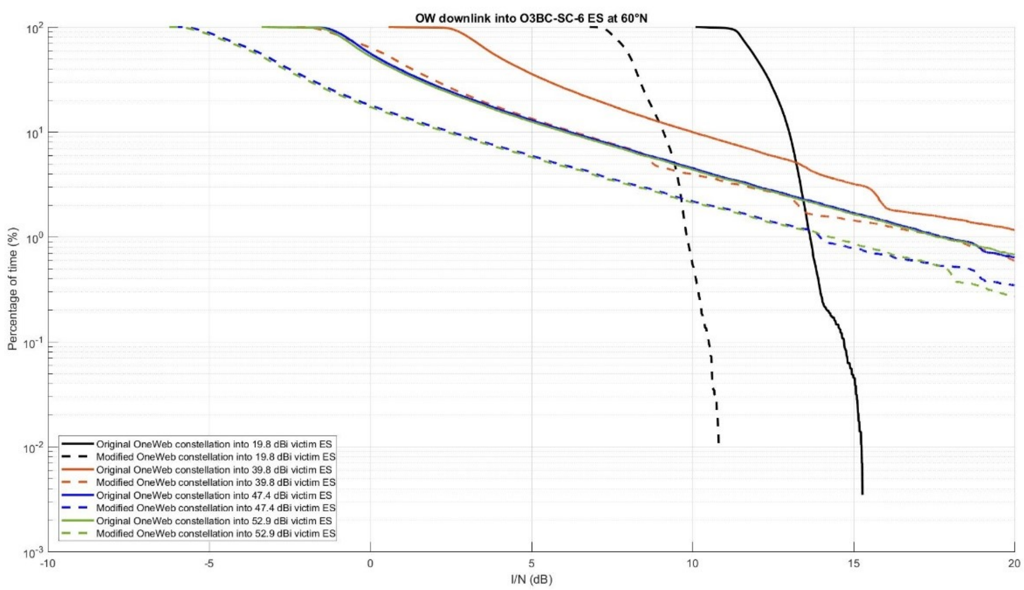


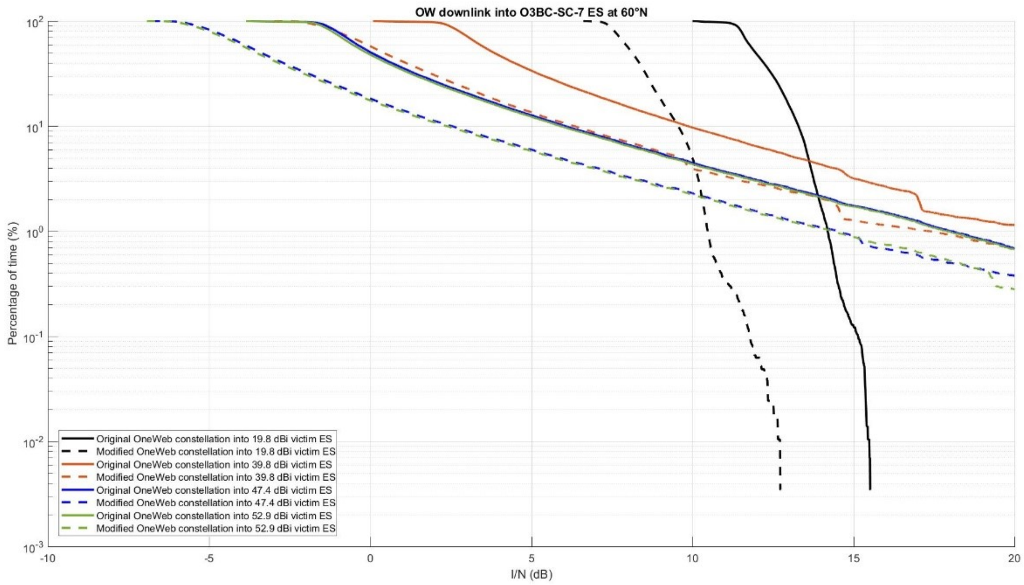
OW downlink into O3BC-SC-2 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 19.8 dBi victim ES
Modified OneWeb constellation into 19.8 dBi victim ES
Original OneWeb constellation into 39.8 dBi victim ES
Modified OneWeb constellation into 39.8 dBi victim ES
Original OneWeb constellation into 47.4 dBi victim ES
Modified OneWeb constellation into 47.4 dBi victim ES
Original OneWeb constellation into 52.9 dBi victim ES
Modified OneWeb constellation into 52.9 dBi victim ES


OW downlink into O3BC-SC-3 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 19.8 dBi victim ES
Modified OneWeb constellation into 19.8 dBi victim ES
Original OneWeb constellation into 39.8 dBi victim ES
Modified OneWeb constellation into 39.8 dBi victim ES
Original OneWeb constellation into 47.4 dBi victim ES
Modified OneWeb constellation into 47.4 dBi victim ES
Original OneWeb constellation into 52.9 dBi victim ES
Modified OneWeb constellation into 52.9 dBi victim ES

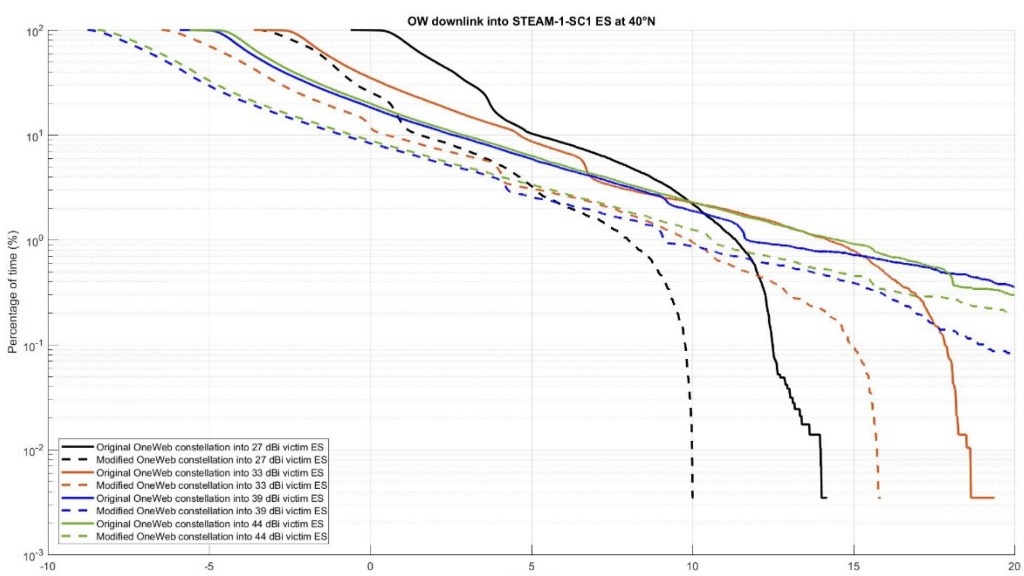

OW downlink into O3BC-SC-4 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 19.8 dBi victim ES
Modified OneWeb constellation into 19.8 dBi victim ES
Original OneWeb constellation into 39.8 dBi victim ES
Modified OneWeb constellation into 39.8 dBi victim ES
Original OneWeb constellation into 47.4 dBi victim ES
Modified OneWeb constellation into 47.4 dBi victim ES
Original OneWeb constellation into 52.9 dBi victim ES
Modified OneWeb constellation into 52.9 dBi victim ES

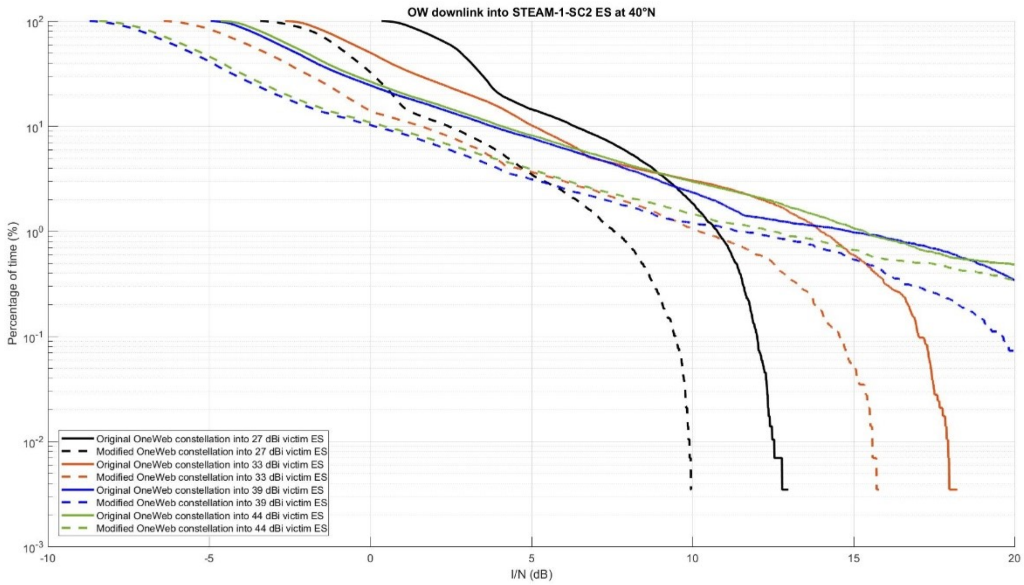

OW downlink into O3BC-SC-5 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 19.8 dBi victim ES
Modified OneWeb constellation into 19.8 dBi victim ES
Original OneWeb constellation into 39.8 dBi victim ES
Modified OneWeb constellation into 39.8 dBi victim ES
Original OneWeb constellation into 47.4 dBi victim ES
Modified OneWeb constellation into 47.4 dBi victim ES
Original OneWeb constellation into 52.9 dBi victim ES
Modified OneWeb constellation into 52.9 dBi victim ES

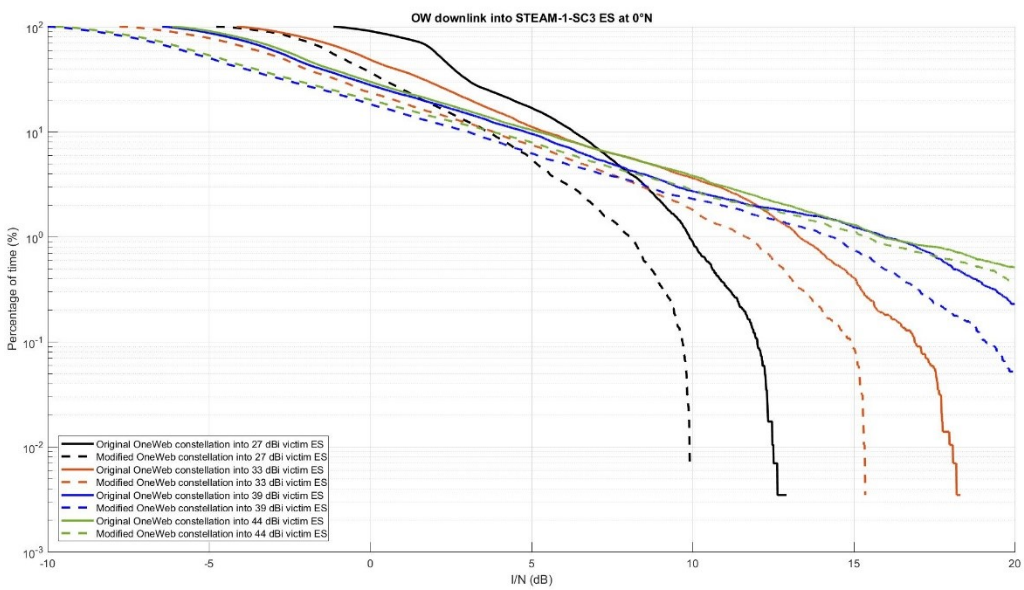

OW downlink into O3BC-SC-6 ES at 60°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 19.8 dBi victim ES
Modified OneWeb constellation into 19.8 dBi victim ES
Original OneWeb constellation into 39.8 dBi victim ES
Modified OneWeb constellation into 39.8 dBi victim ES
Original OneWeb constellation into 47.4 dBi victim ES
Modified OneWeb constellation into 47.4 dBi victim ES
Original OneWeb constellation into 52.9 dBi victim ES
Modified OneWeb constellation into 52.9 dBi victim ES



The next set of results are for downlink interference into the STEAM-1 system, which includes three LEO sub-constellations of different altitudes and inclinations. Results were obtained for all the sub-constellations and the CDF plots are given below. For these systems, the worst-case latitude was 40°N for SC-1 and SC-2 and 0°N for SC-3, and these results are shown in the CDF plots below.



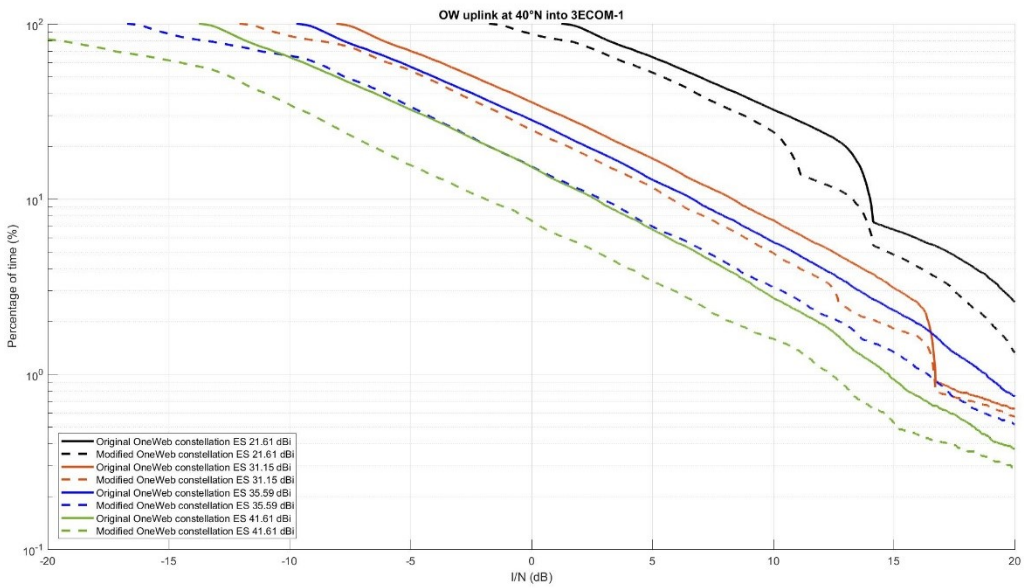

OW downlink into STEAM-1-SC2 ES at 40°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 27 dBi victim ES
Modified OneWeb constellation into 27 dBi victim ES
Original OneWeb constellation into 33 dBi victim ES
Modified OneWeb constellation into 33 dBi victim ES
Original OneWeb constellation into 39 dBi victim ES
Modified OneWeb constellation into 39 dBi victim ES
Original OneWeb constellation into 44 dBi victim ES
Modified OneWeb constellation into 44 dBi victim ES

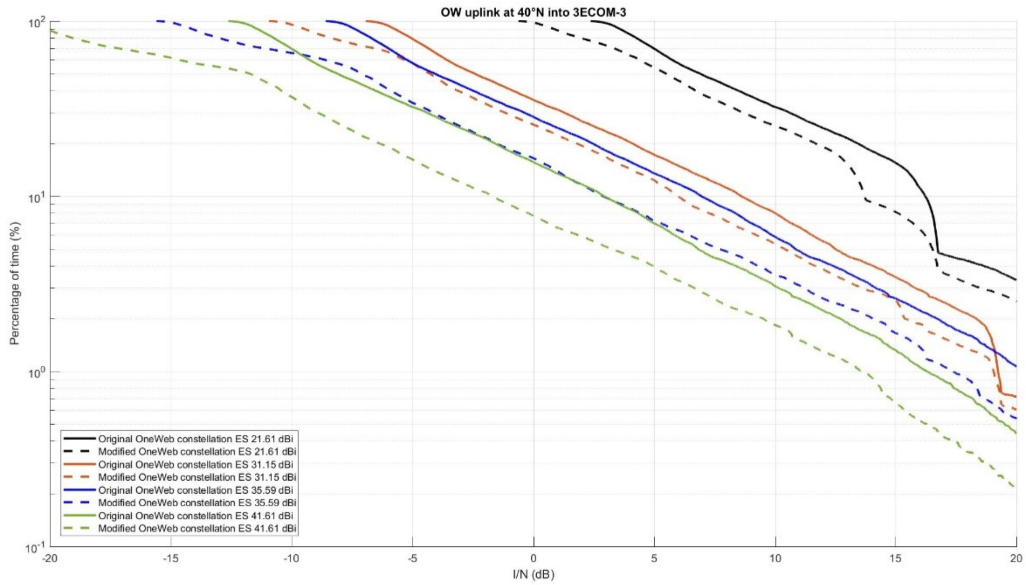

OW downlink into STEAM-1-SC3 ES at 0°N
Percentage of time (%)
I/N (dB)
Original OneWeb constellation into 27 dBi victim ES
Modified OneWeb constellation into 27 dBi victim ES
Original OneWeb constellation into 33 dBi victim ES
Modified OneWeb constellation into 33 dBi victim ES
Original OneWeb constellation into 39 dBi victim ES
Modified OneWeb constellation into 39 dBi victim ES
Original OneWeb constellation into 44 dBi victim ES
Modified OneWeb constellation into 44 dBi victim ES

Uplink Interference Analysis

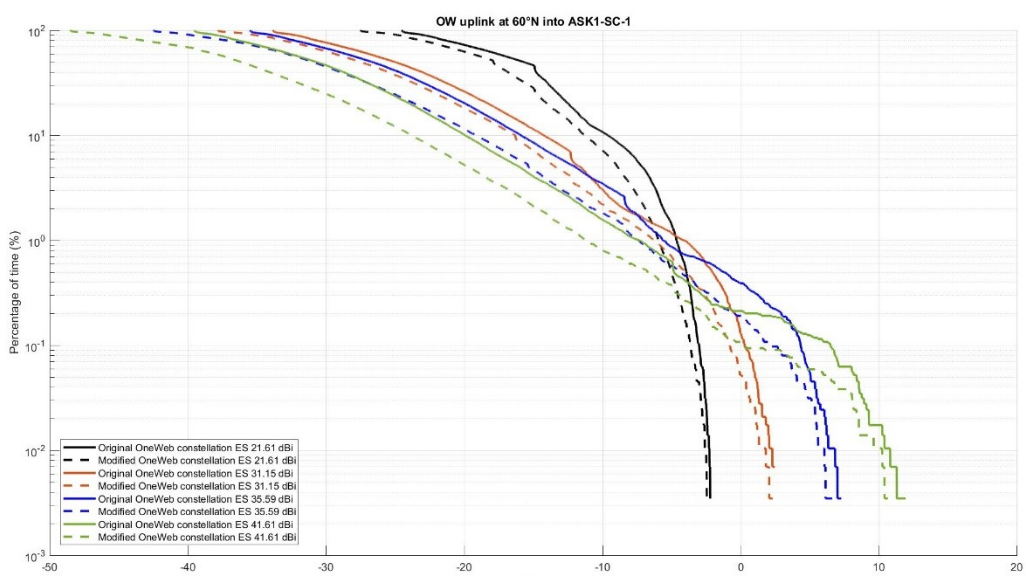
For the uplink interference analyses the solid lines in the CDF plots below are the results for the original L5 constellation (MOD-1/-2 plus MOD-3) and the dotted lines are the corresponding results after the modification to MOD-1/-2. The different coloured lines represent the results from every different type of interfering (L5) earth station included in the modified L5 filings (MOD-1/-2).

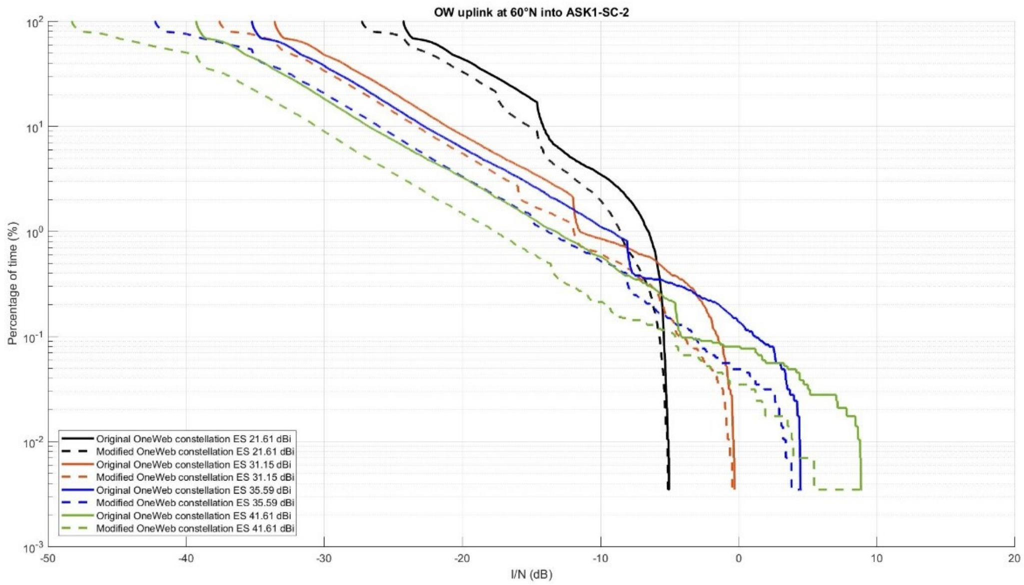
The first set of results below are for uplink interference into the 3ECOM-1 and 3ECOM-3 systems which are near-polar orbiting LEO systems. For these systems, the worst-case latitude was found to be 40°N, although the variation of the impact of the modification (interference after versus interference before) with latitude is small.



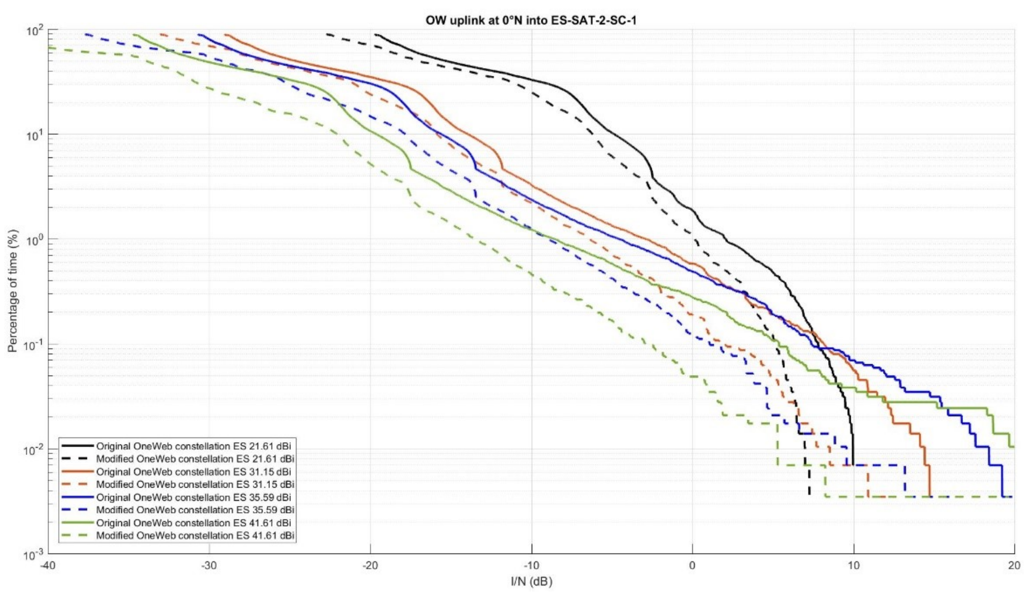


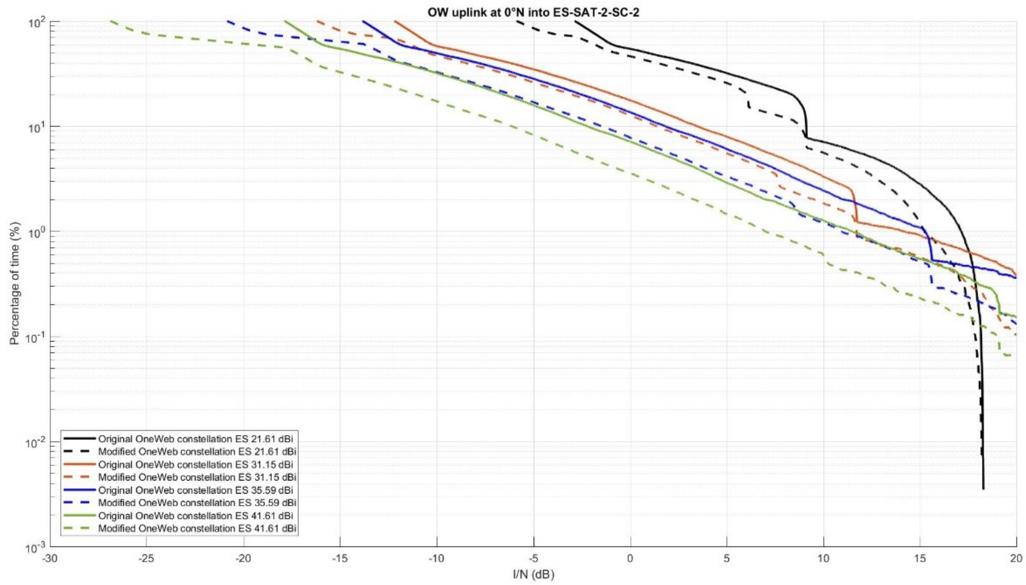
The next set of results are for uplink interference into the ASK-1 HEO system, which is considered to be two sub-constellations for the purpose of the analysis – each with different apogee and perigee altitudes. As the ASK-1 system is intended to provide service to high northern latitudes, the results below are for a latitude of 60°N, although the variation with latitude is in fact minimal.

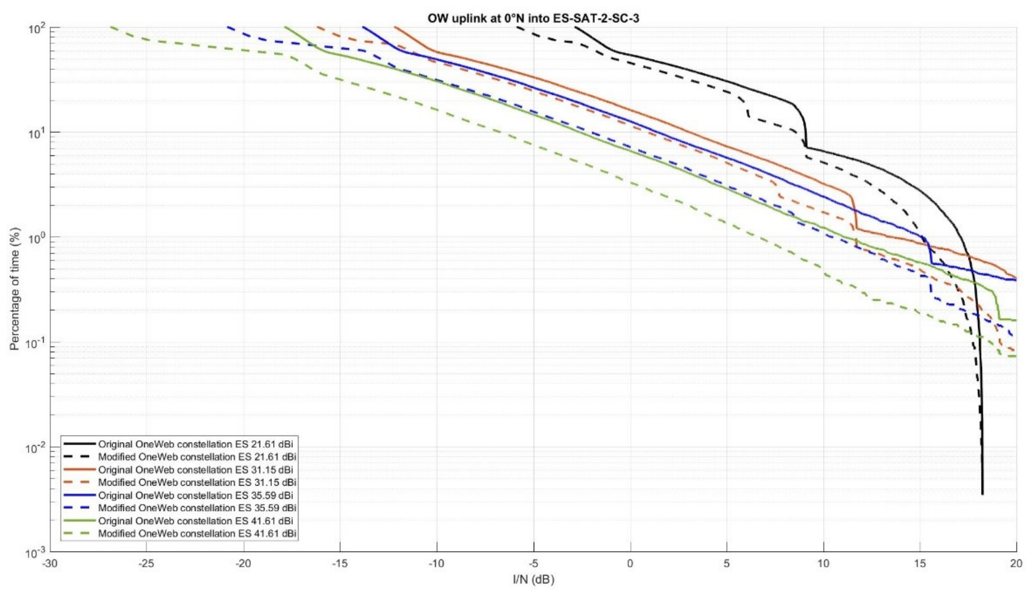


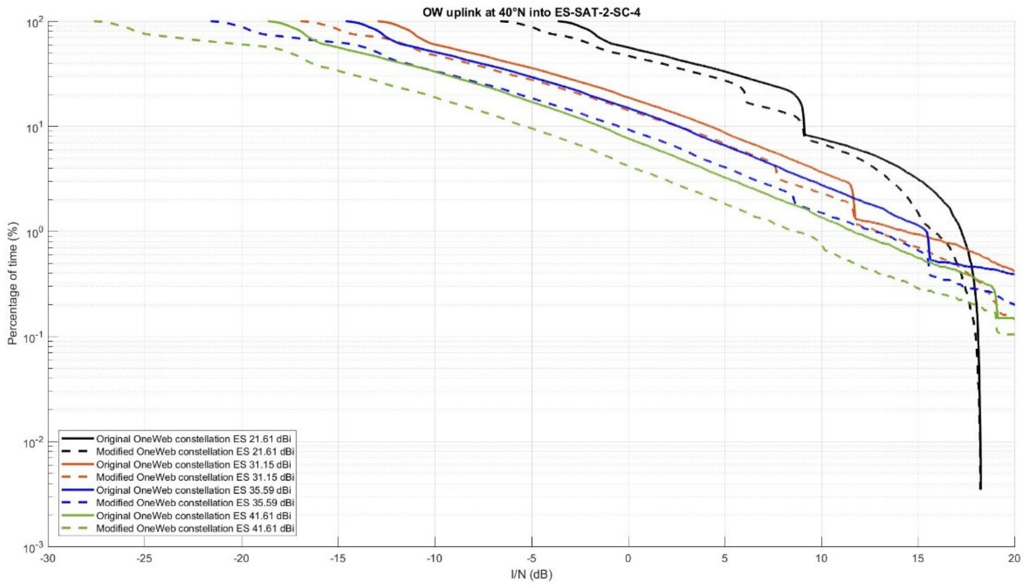


The next set of results are for uplink interference into the ES-SAT-2 system, which includes both MEO and LEO sub-constellations. Ten sub-constellations were selected from the numerous ones in the ES-SAT-2 filing, and these provide a good representation of the range of orbital parameters based on the rationale provided in Annex A. For these systems, the worst-case latitude was dependent on the inclination of the sub-constellation and various values have been used in the CDF plots below.

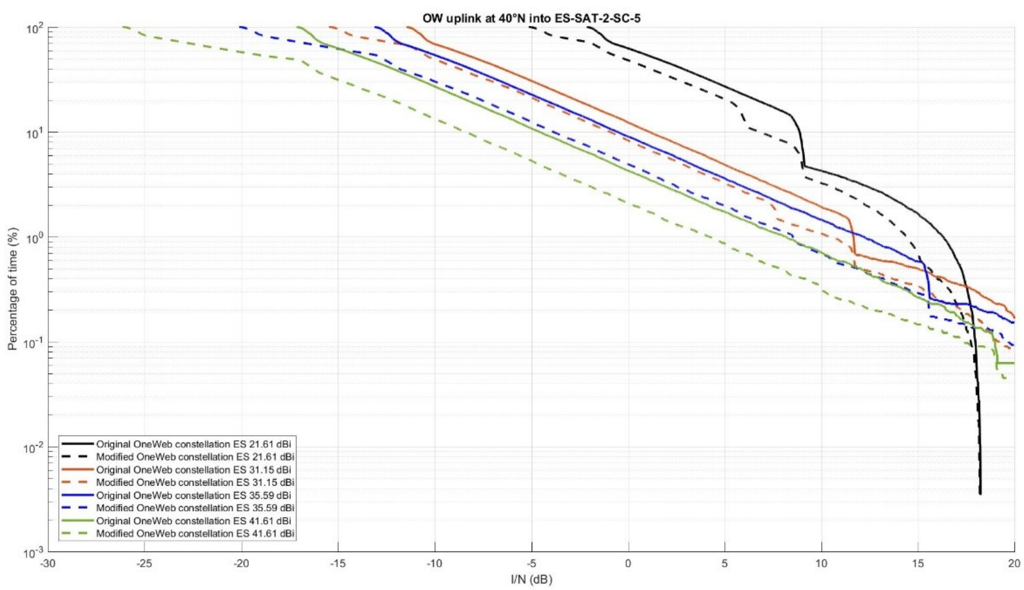



OW uplink at 0°N into ES-SAT-2-SC-2
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

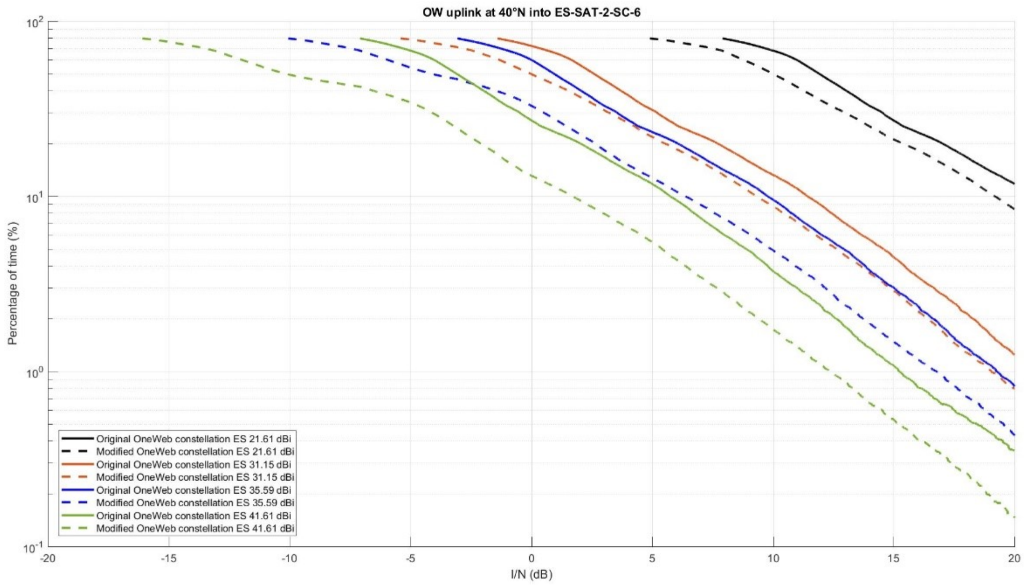

OW uplink at 0°N into ES-SAT-2-SC-3
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

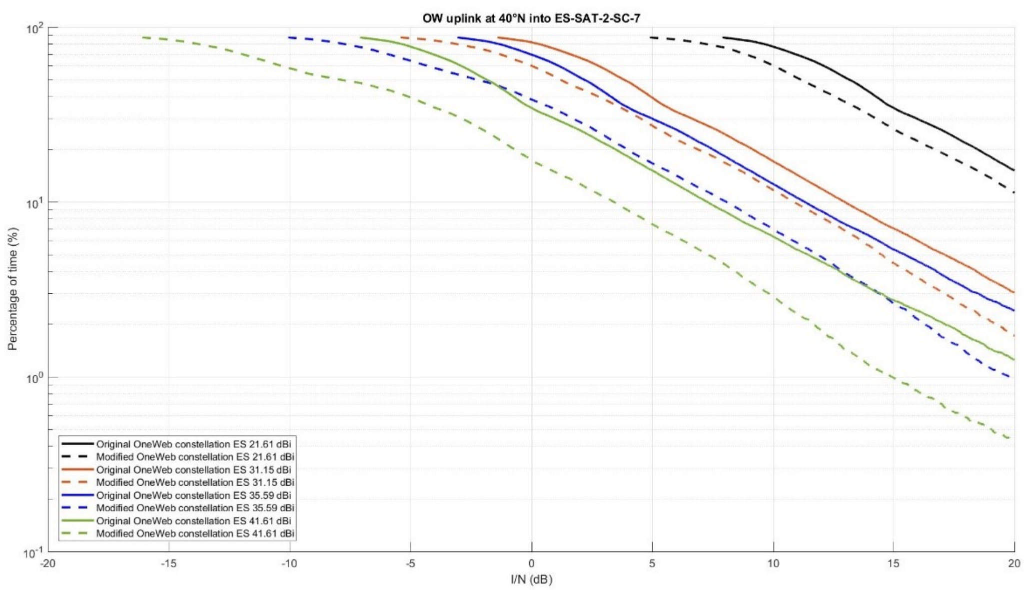


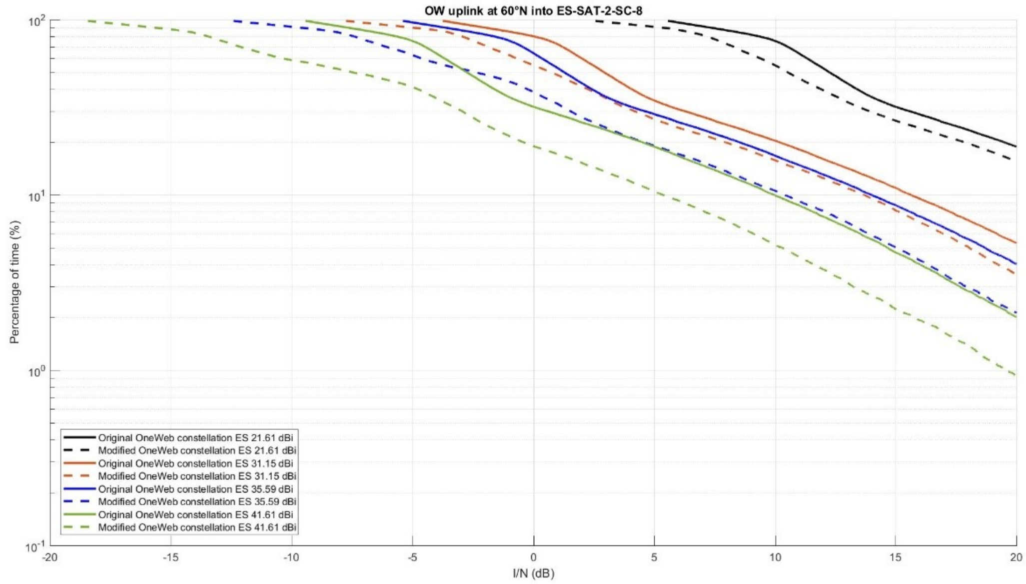
OW uplink at 40°N into ES-SAT-2-SC-4
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

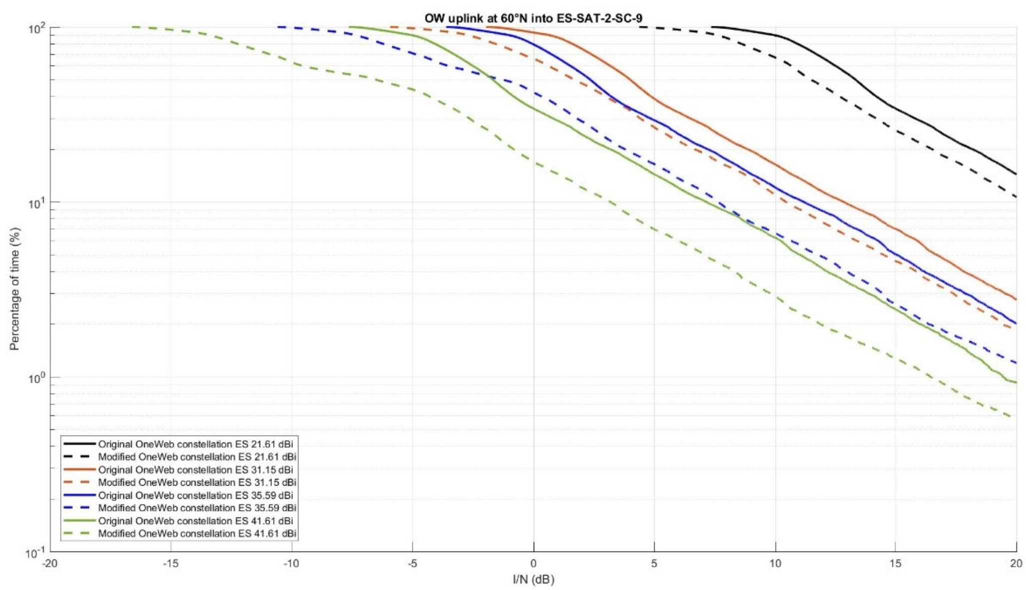


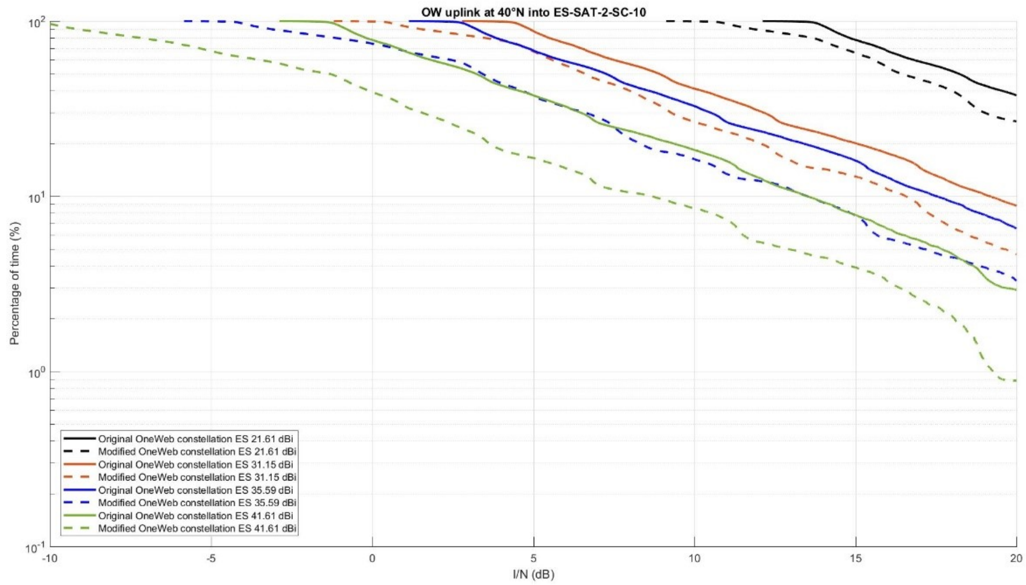
OW uplink at 40°N into ES-SAT-2-SC-5
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi


OW uplink at 40°N into ES-SAT-2-SC-6
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

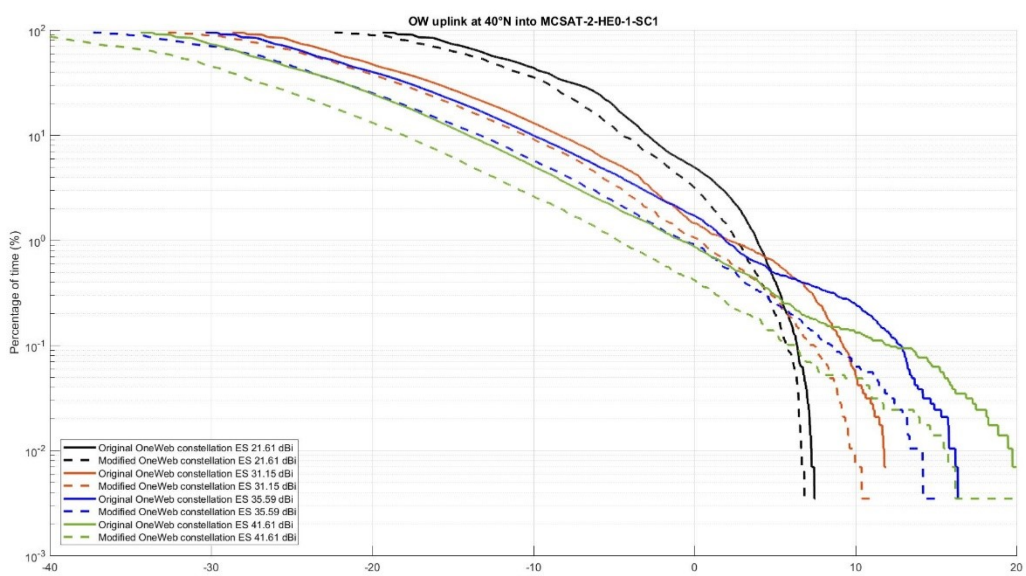

OW uplink at 40°N into ES-SAT-2-SC-7
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

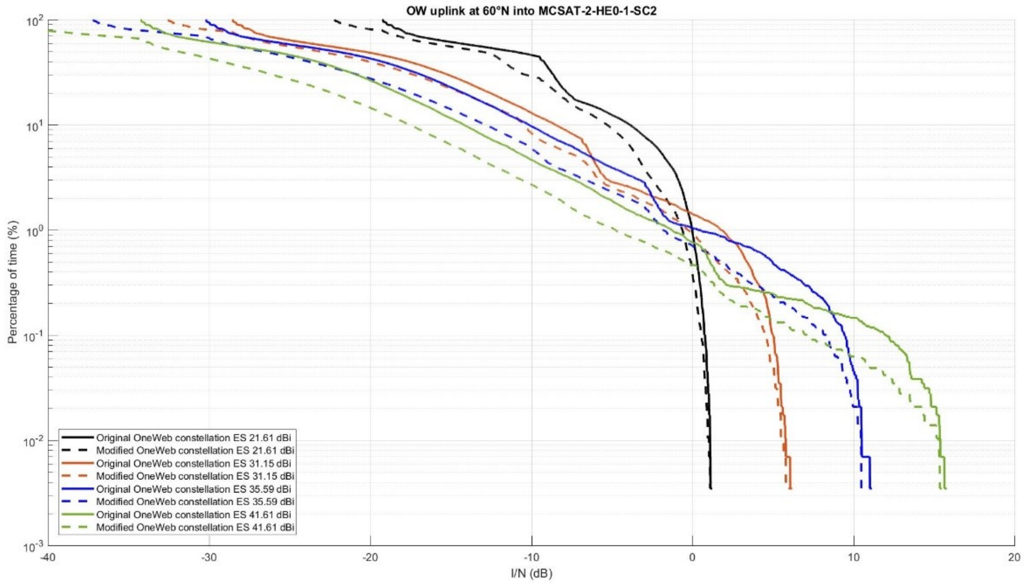

OW uplink at 60°N into ES-SAT-2-SC-8
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

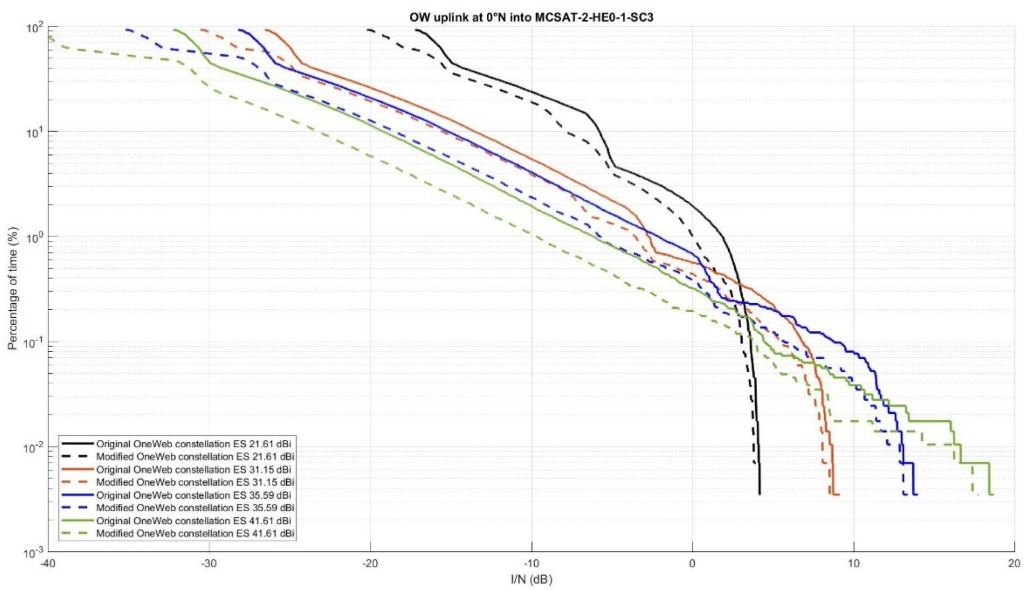

OW uplink at 60°N into ES-SAT-2-SC-9
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi



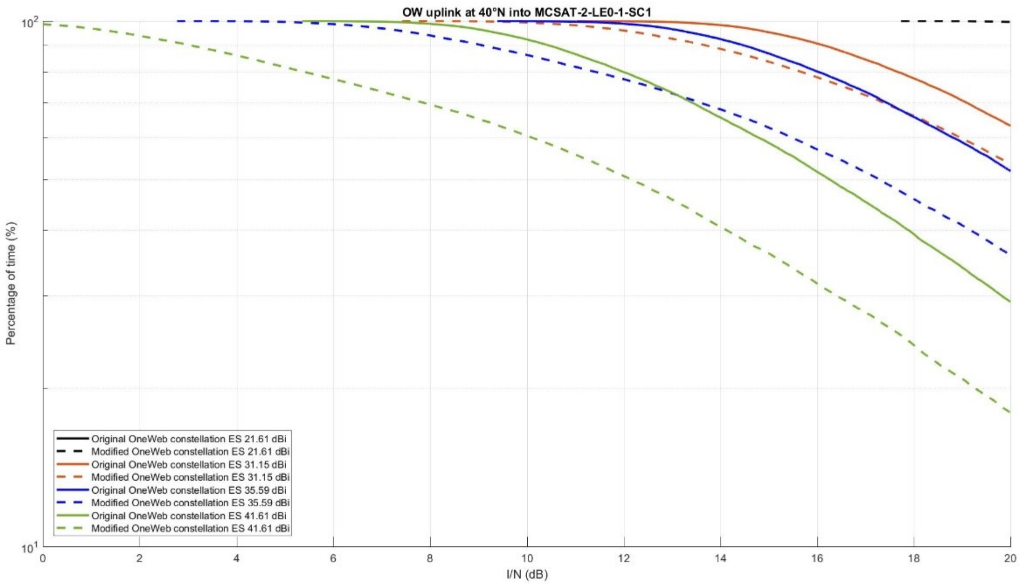
The next set of results are for uplink interference into the MCSAT-2 HEO-1 system, which is considered to be three sub-constellations for the purpose of the analysis – each with different apogee and perigee altitudes. For these systems, the results were similar for all latitudes, so a range of latitude results are shown for the cases below (40°N, 60°N and 0°N).

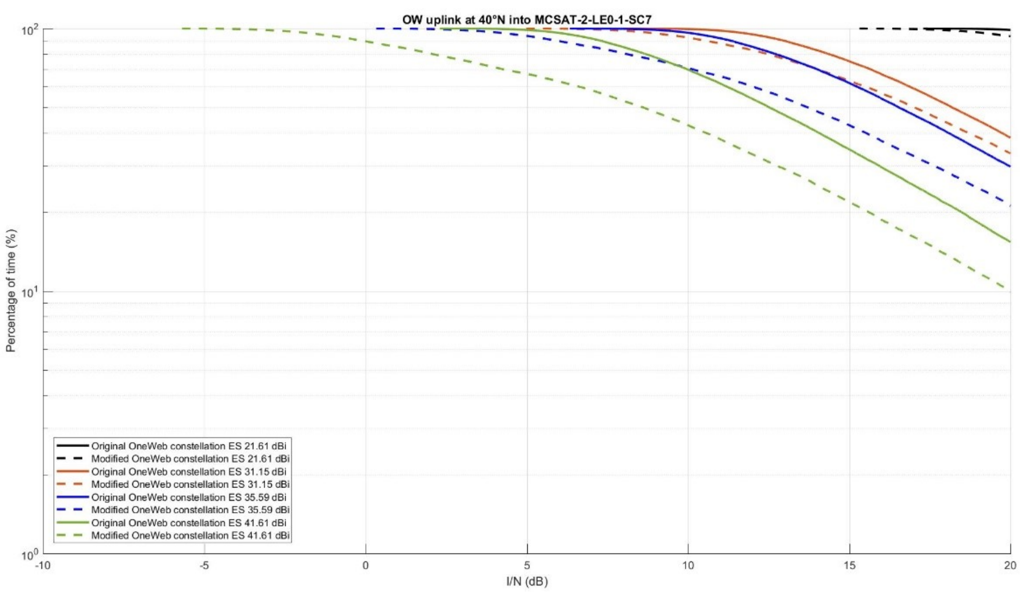


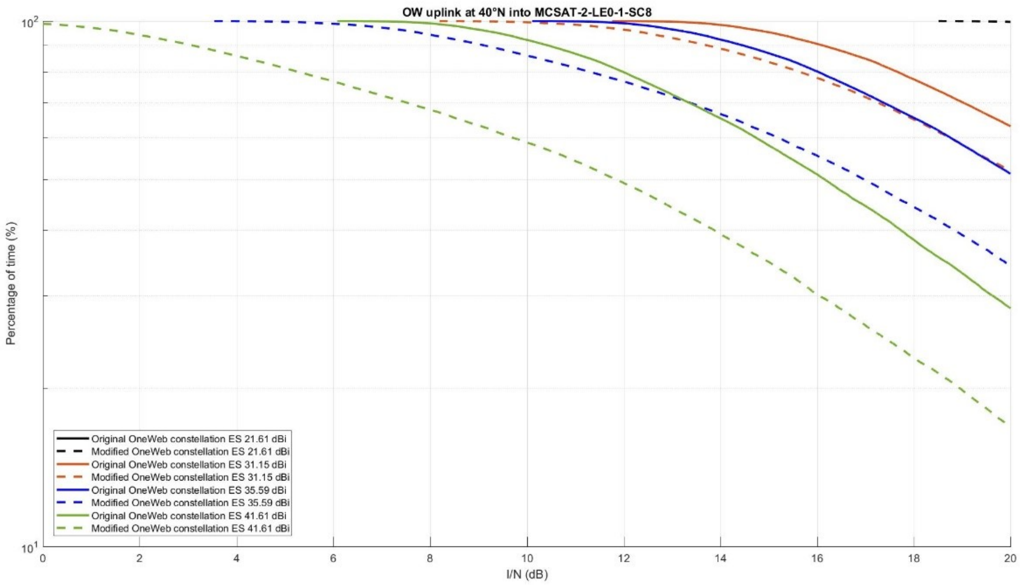


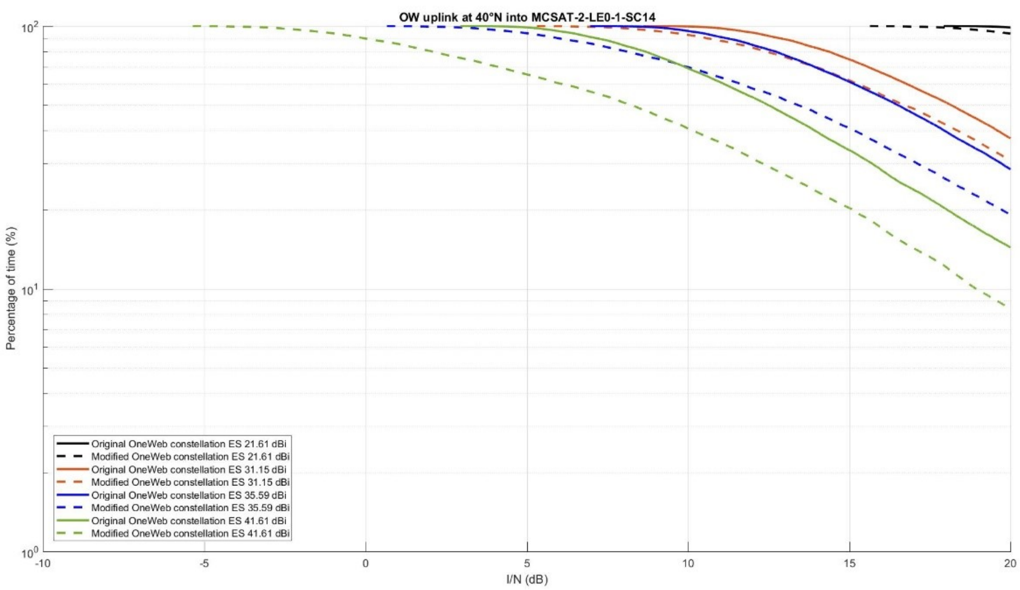


The next set of results are for uplink interference into the MCSAT-2 LEO-1 system, which includes multiple LEO sub-constellations of different altitudes and inclinations. Results were obtained for all the sub-constellations but, for clarity, only the results for the lowest and highest altitude sub-constellations are shown below for each orbit inclination, as explained in Annex A. For these systems, the worst-case latitude was generally 40°N which is shown in the CDF plots below.

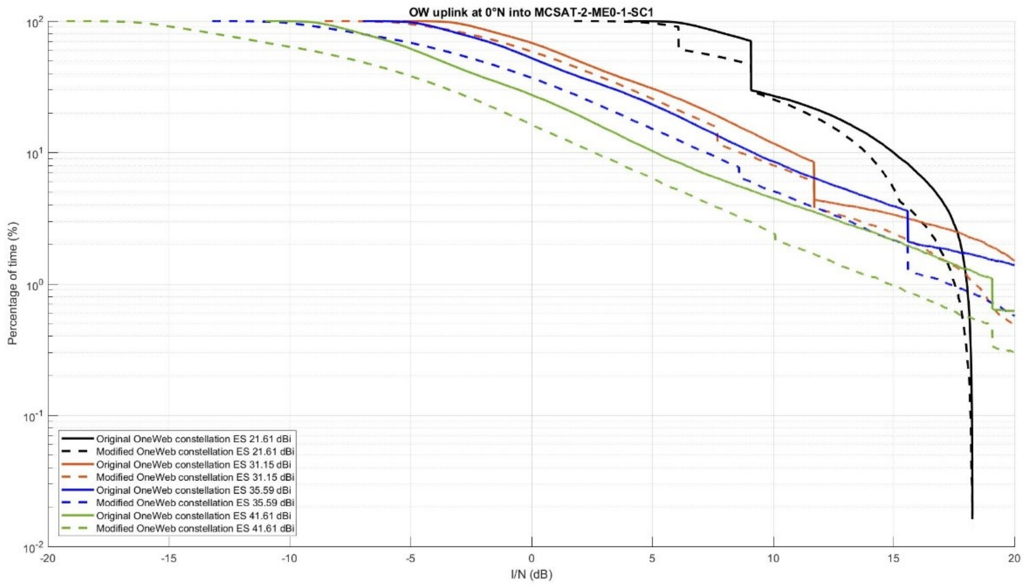

OW uplink at 40°N into MCSAT-2-LE0-1-SC1
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

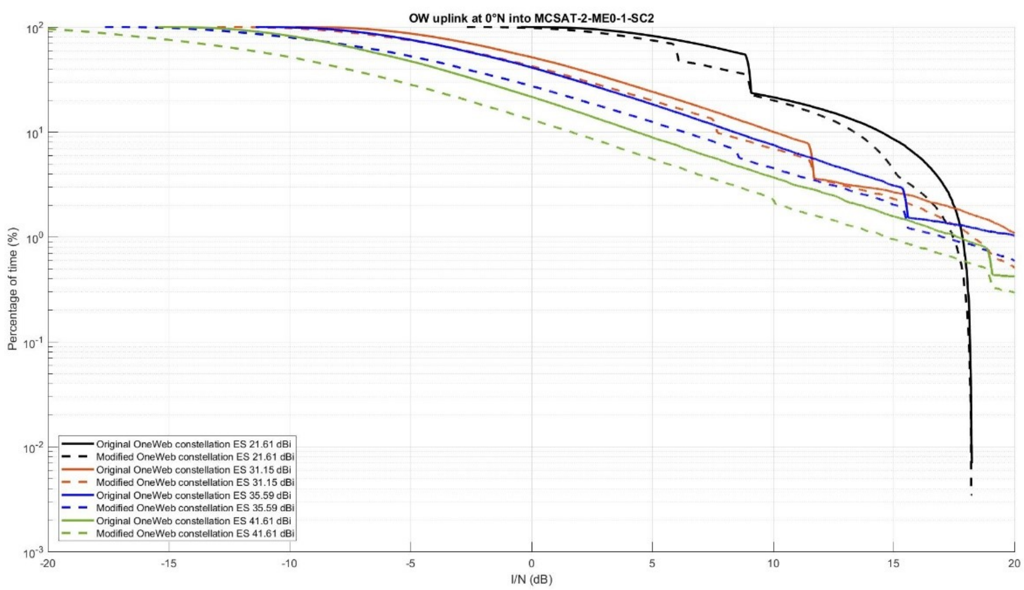

OW uplink at 40°N into MCSAT-2-LE0-1-SC7
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

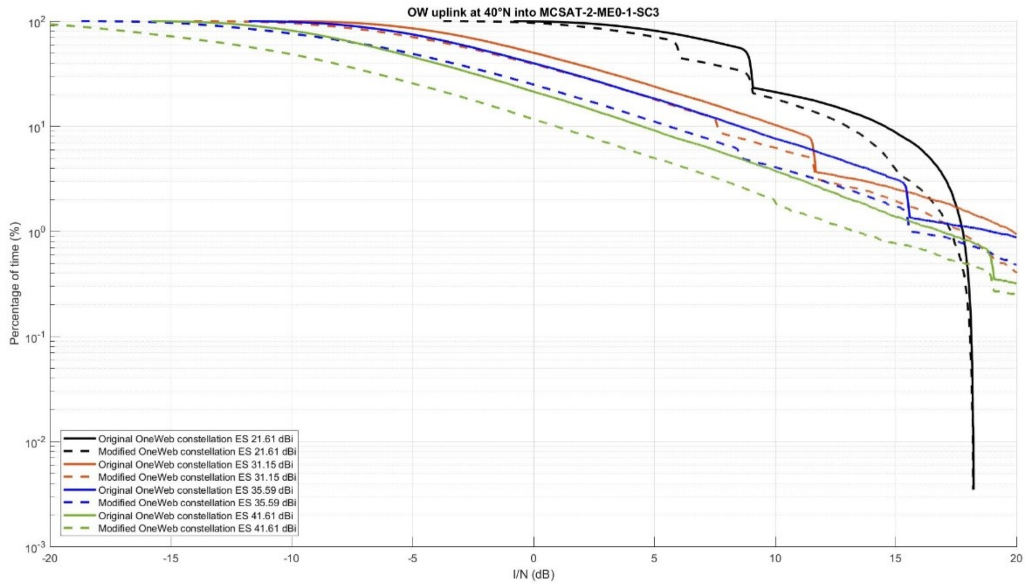




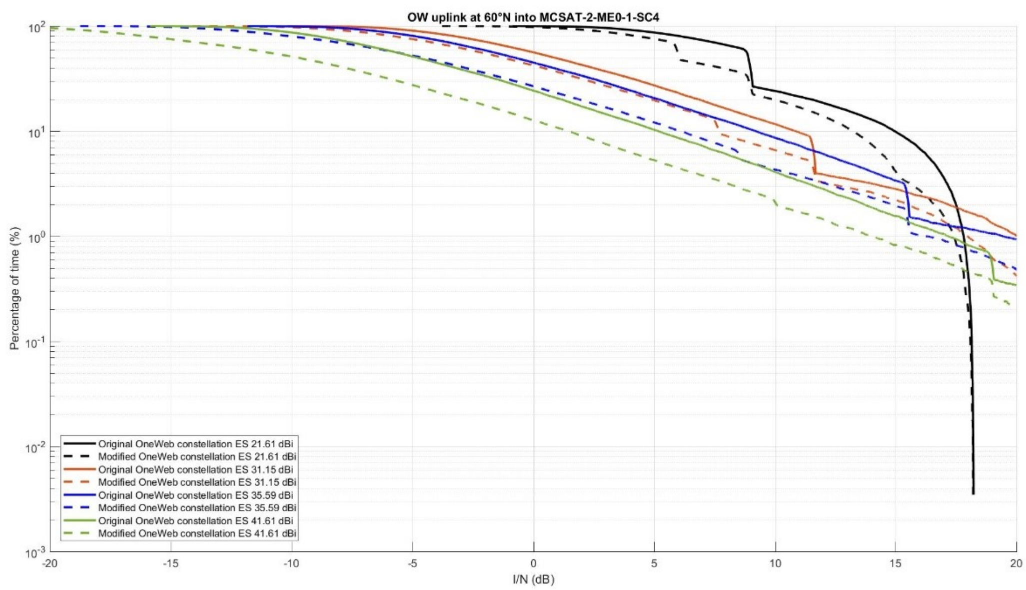
The next set of results are for uplink interference into the MCSAT-2 MEO-1 system, which includes multiple MEO sub-constellations of different inclinations but with very similar altitudes (8,000 and 8,100 km). As explained in Annex A, results were obtained for all the sub-constellations of the higher altitude only. For these systems, the worst-case latitude was dependent on the inclination of the sub-constellation and various values have been used in the CDF plots below.


OW uplink at 0°N into MCSAT-2-ME0-1-SC1
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

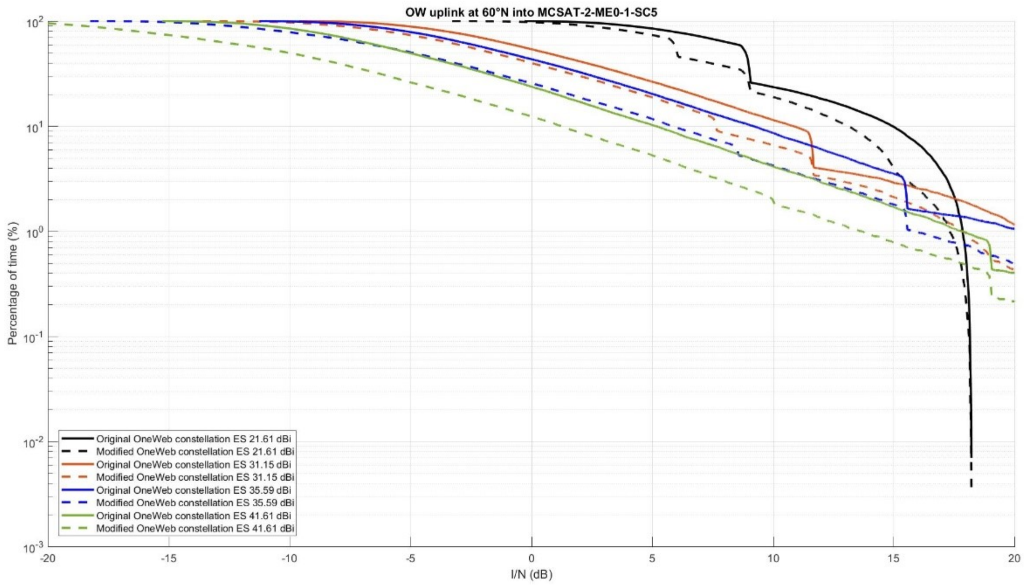

OW uplink at 0°N into MCSAT-2-ME0-1-SC2
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi



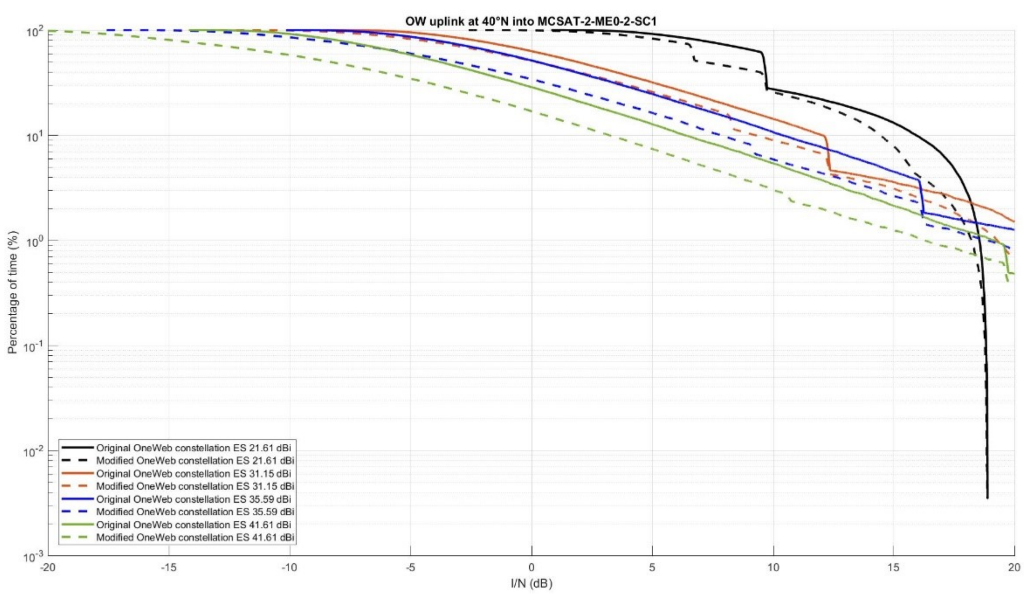
OW uplink at 40°N into MCSAT-2-ME0-1-SC3
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

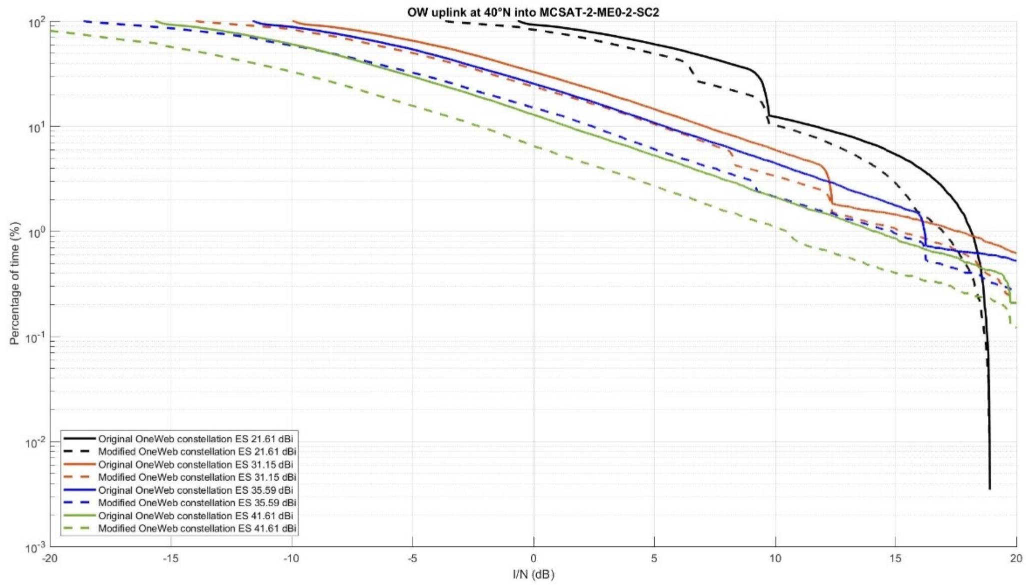


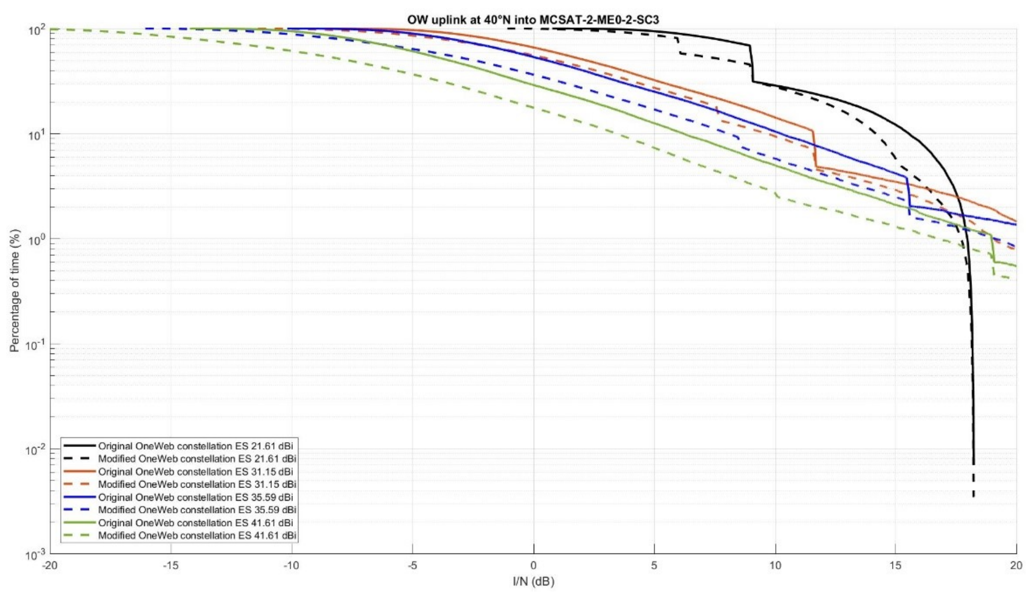
OW uplink at 60°N into MCSAT-2-ME0-1-SC4
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

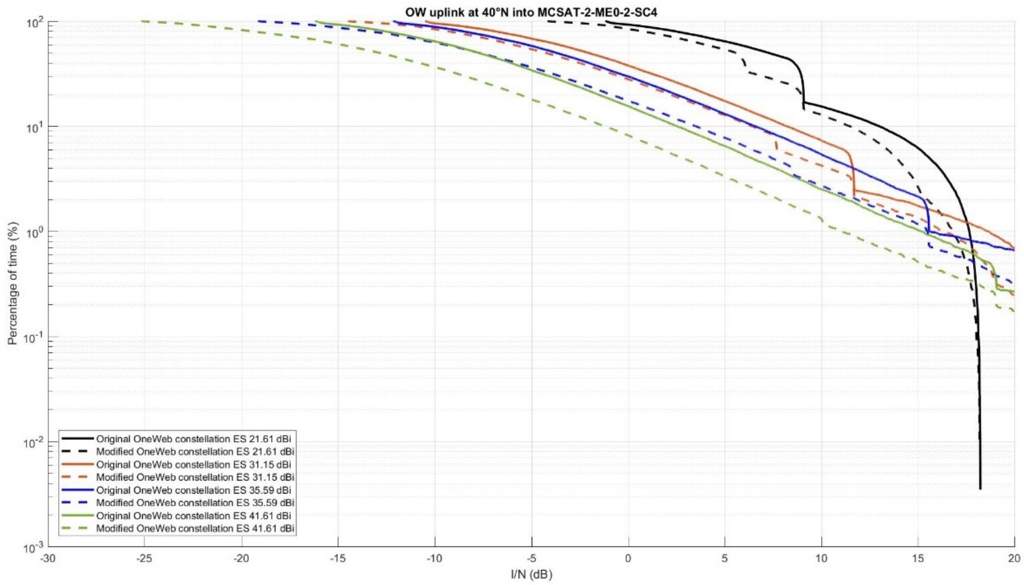


The next set of results are for uplink interference into the MCSAT-2 MEO-2 system, which includes four MEO sub-constellations of different inclinations and altitudes. Results were obtained for all the sub-constellations and the CDF plots are given below. For these systems, the worst-case latitude was generally 40°N although the variation with latitude is in fact minimal.

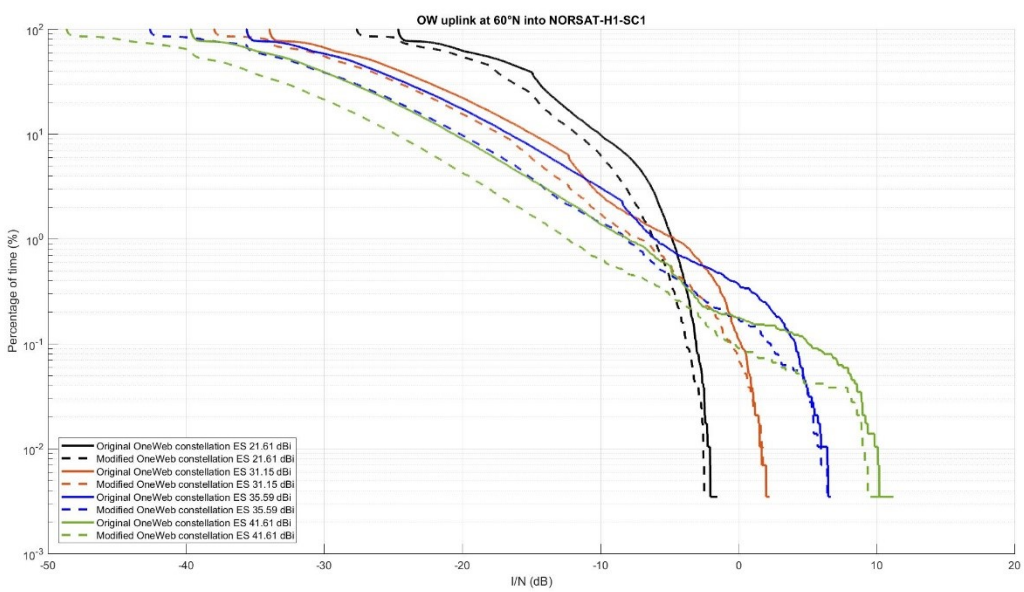


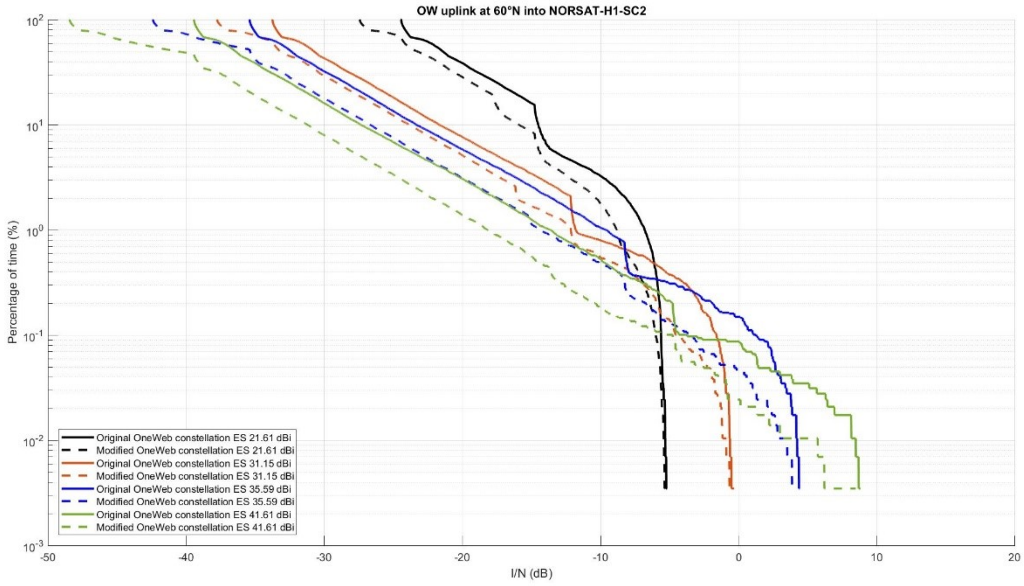

OW uplink at 40°N into MCSAT-2-ME0-2-SC2
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi


OW uplink at 40°N into MCSAT-2-ME0-2-SC3
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

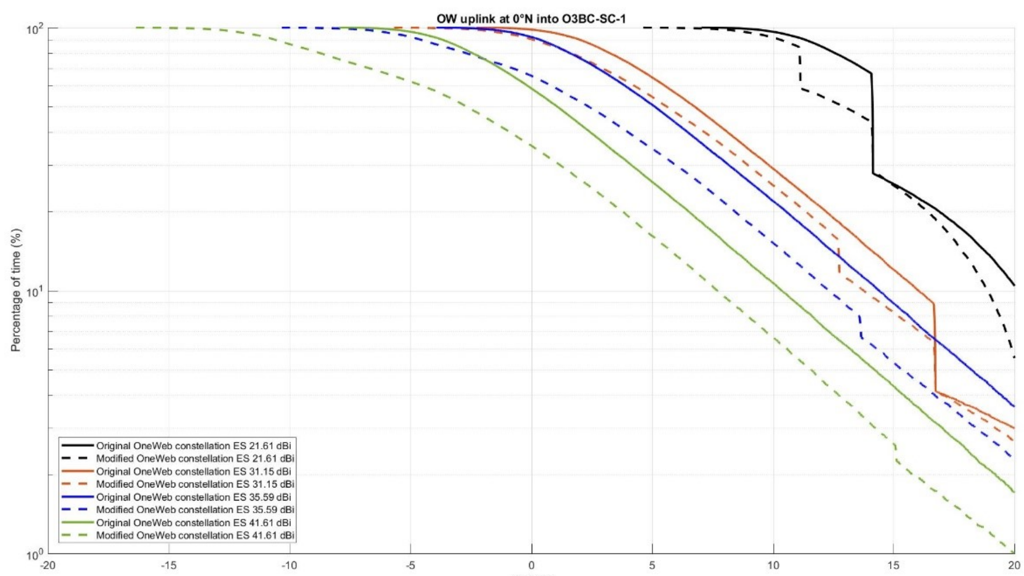


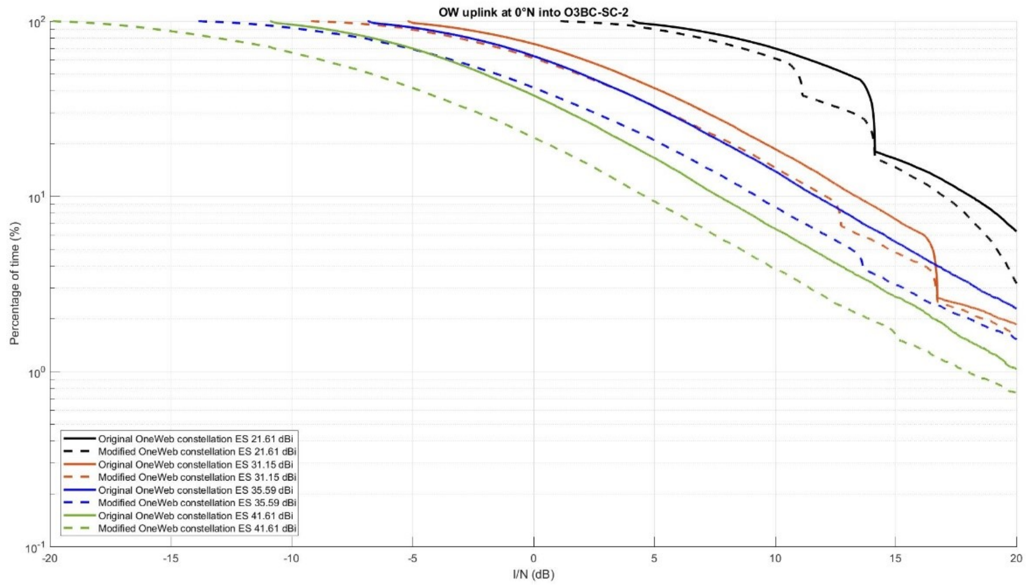
The next set of results are for uplink interference into the NORSAT-H1 HEO system, which is considered to be two sub-constellations for the purpose of the analysis – each with different apogee and perigee altitudes. As the NORSAT-H1 system is intended to provide service to high northern latitudes, the results below are for a latitude of 60°N, although the results for all latitudes show less interference after the modification compared to before.



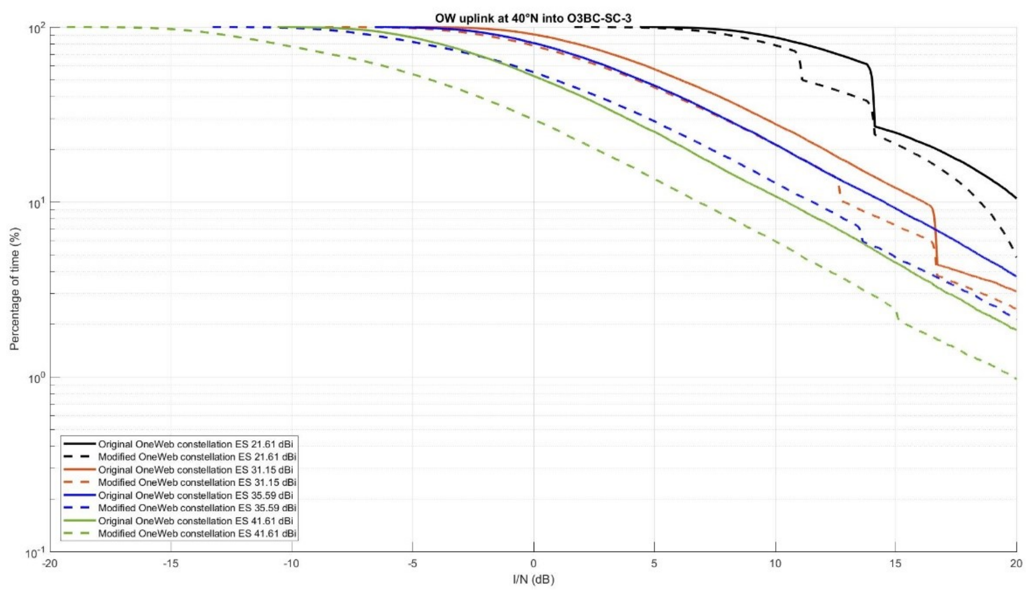


The next set of results are for uplink interference into the O3B-C system, which includes six MEO and one LEO sub-constellation. The MEO sub-constellations have two values for altitude and three orbit inclinations. Results were obtained for all the sub-constellations and the CDF plots are given below. For these systems, the worst-case latitude was dependent on the inclination of the sub-constellation and so various values have been used in the CDF plots below.

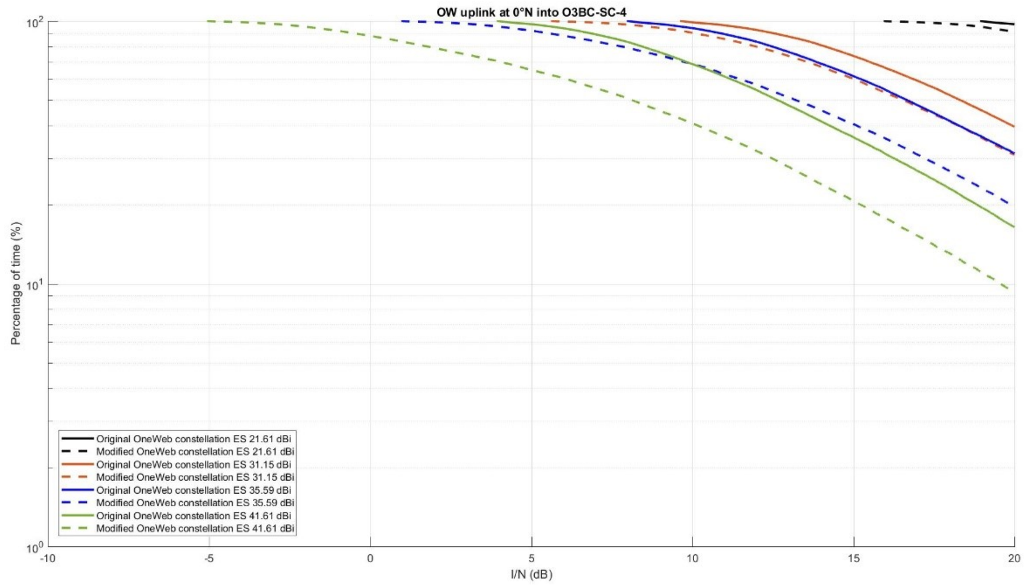


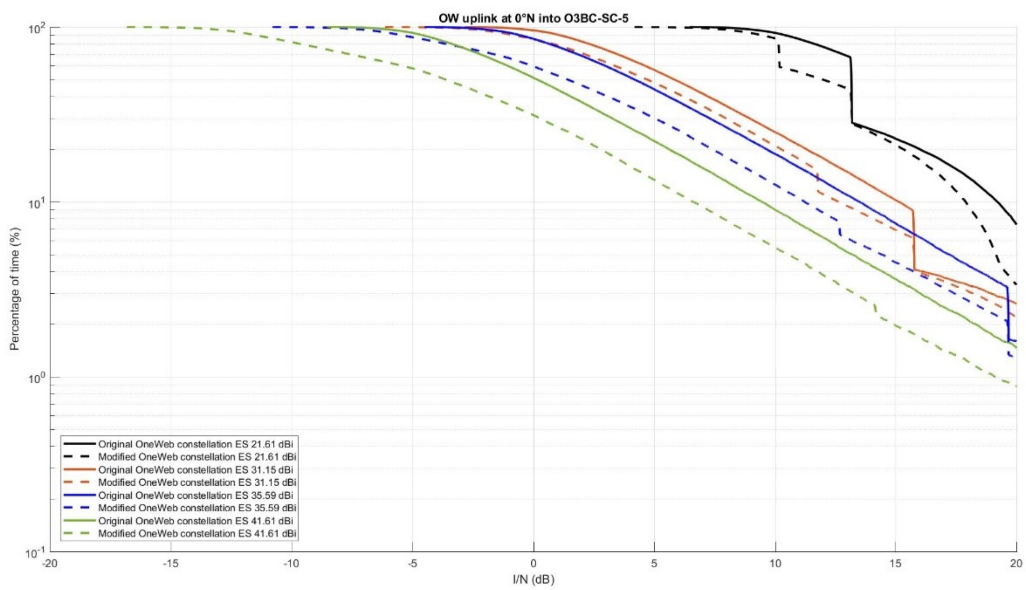


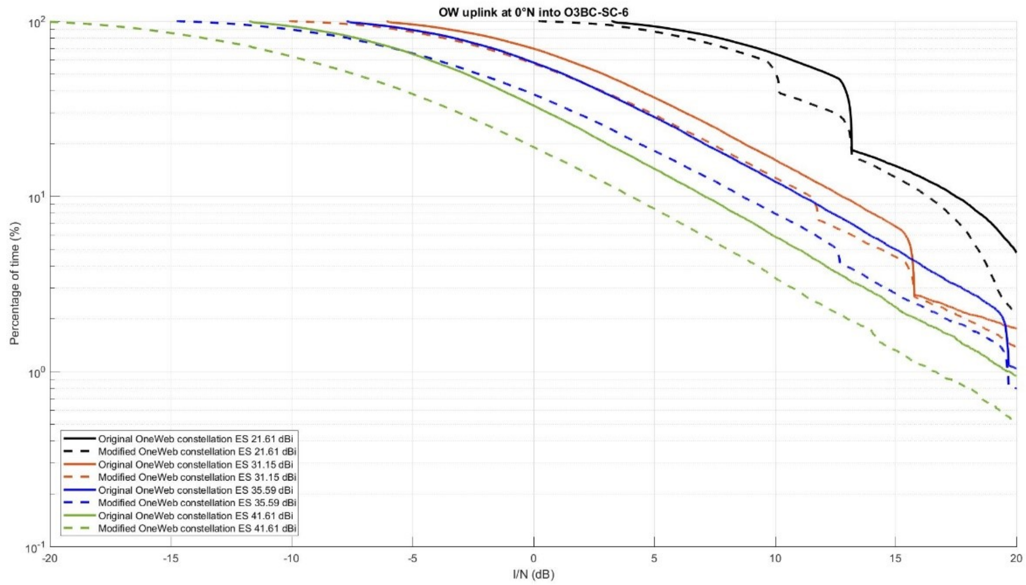
OW uplink at 0°N into O3BC-SC-2
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

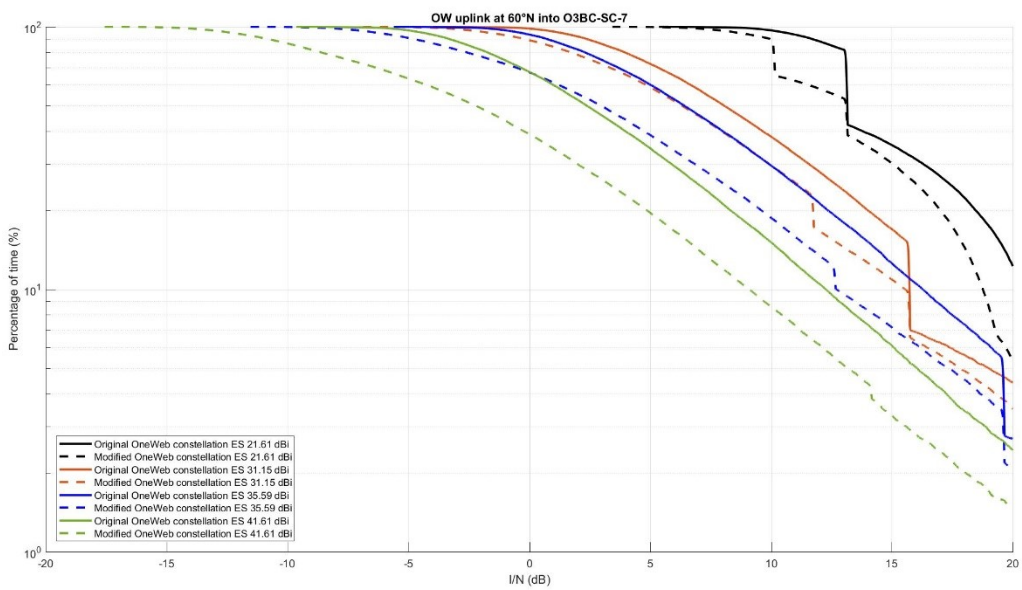


OW uplink at 40°N into O3BC-SC-3
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

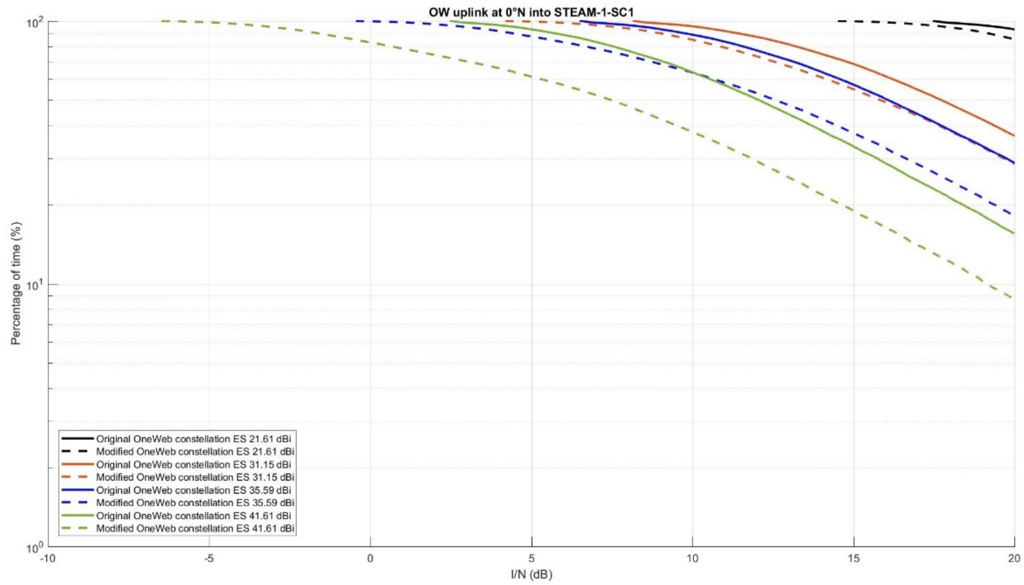

OW uplink at 0°N into O3BC-SC-4
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

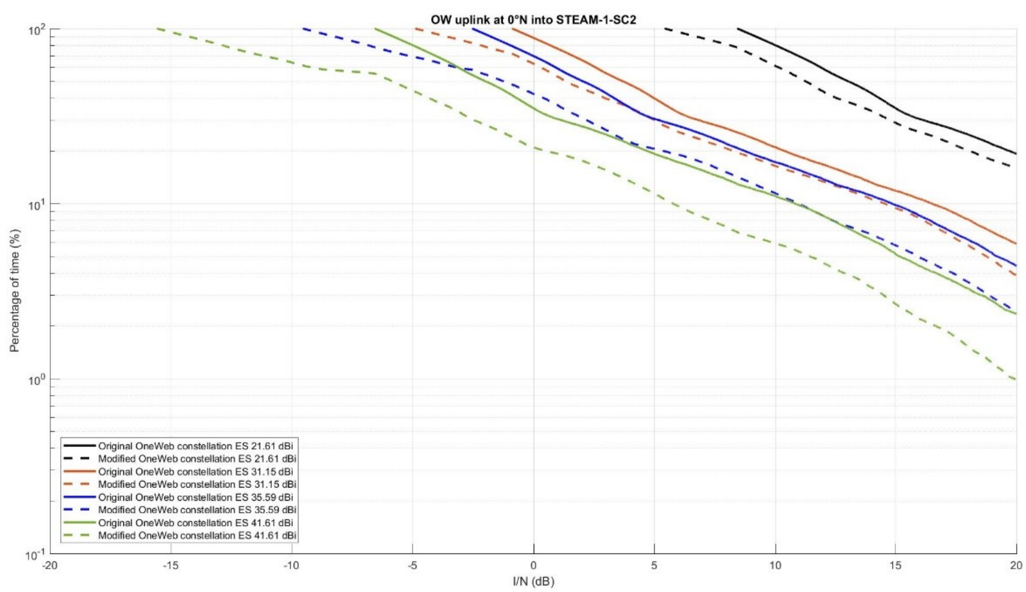

OW uplink at 0°N into O3BC-SC-5
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi

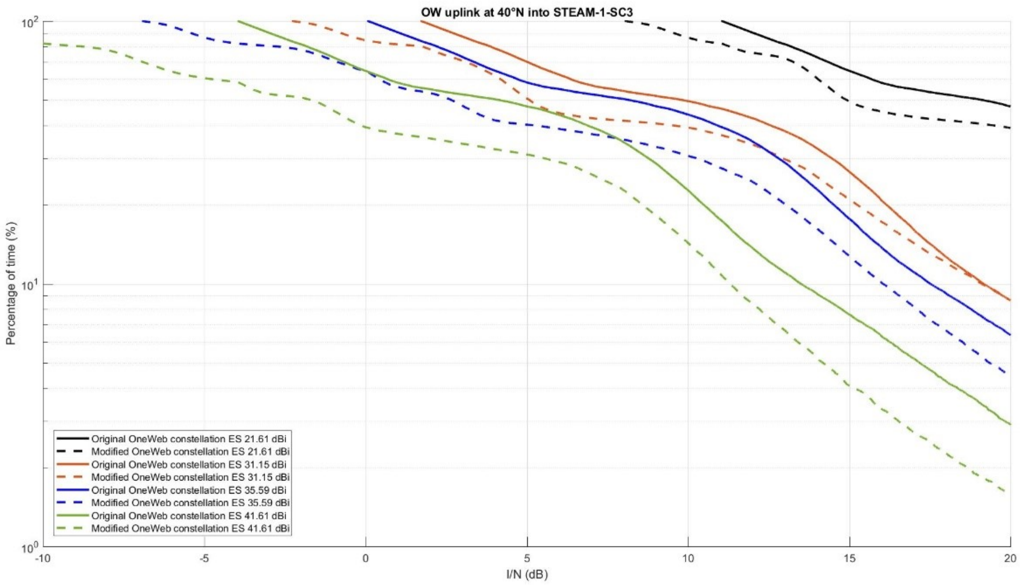




The next set of results are for uplink interference into the STEAM-1 system, which includes three LEO sub-constellations of different altitudes and inclinations. Results were obtained for all the sub-constellations and the CDF plots are given below. For these systems, the worst-case latitude was 0°N for SC-1 and SC-2 and 40°N for SC-3, and these results are shown in the CDF plots below.


OW uplink at 0°N into STEAM-1-SC1
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi


OW uplink at 0°N into STEAM-1-SC2
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi


OW uplink at 40°N into STEAM-1-SC3
Percentage of time (%)
I/N (dB)
Original OneWeb constellation ES 21.61 dBi
Modified OneWeb constellation ES 21.61 dBi
Original OneWeb constellation ES 31.15 dBi
Modified OneWeb constellation ES 31.15 dBi
Original OneWeb constellation ES 35.59 dBi
Modified OneWeb constellation ES 35.59 dBi
Original OneWeb constellation ES 41.61 dBi
Modified OneWeb constellation ES 41.61 dBi