Compatibility of LYNK's 4 Authorized Satellites with Other NGSO FSS Systems

(Forward link, 29.9 – 30 GHz and Return Link, 20.1 – 20.2 GHz)

All forward links (Earth-to-space) are evaluated at 29.9 GHz and all return links (space-to-Earth) are evaluated at 20.1 GHz.

Annex 1

Interference Results into O3b

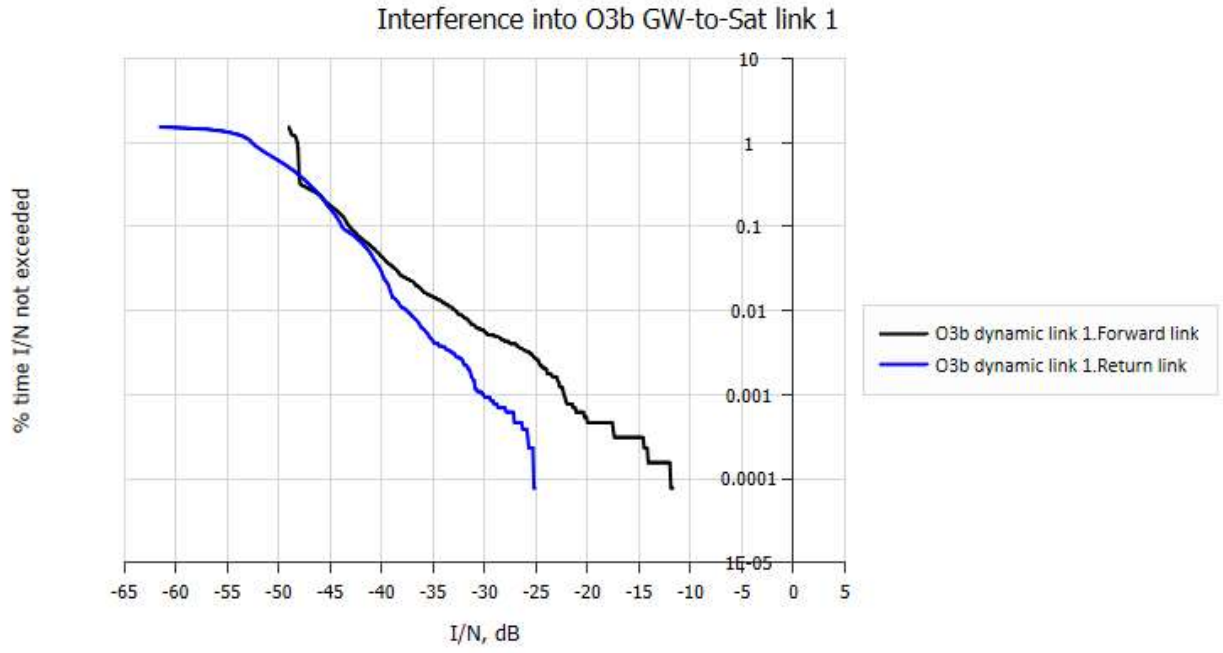
(Forward link only, 29.9 – 30 GHz and Return Link, 20.1 – 20.2 GHz)

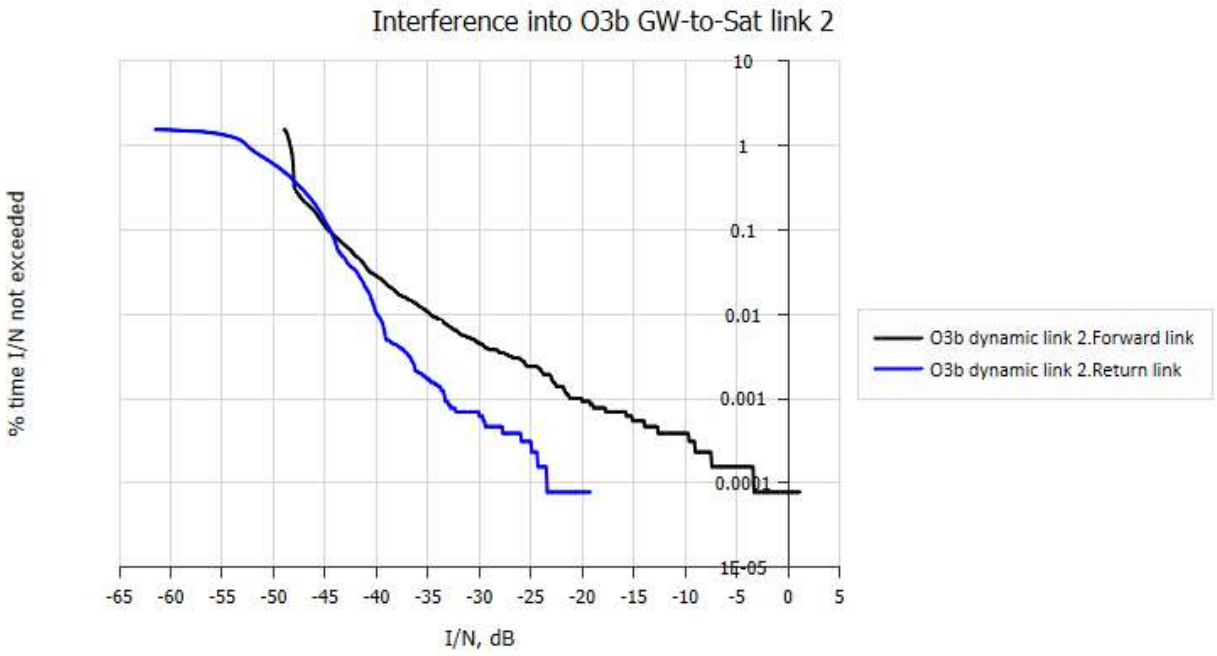
All forward links (Earth-to-space) evaluated at 29.9 GHz and all return links (space-to-Earth) are evaluated at 20.1 GHz.

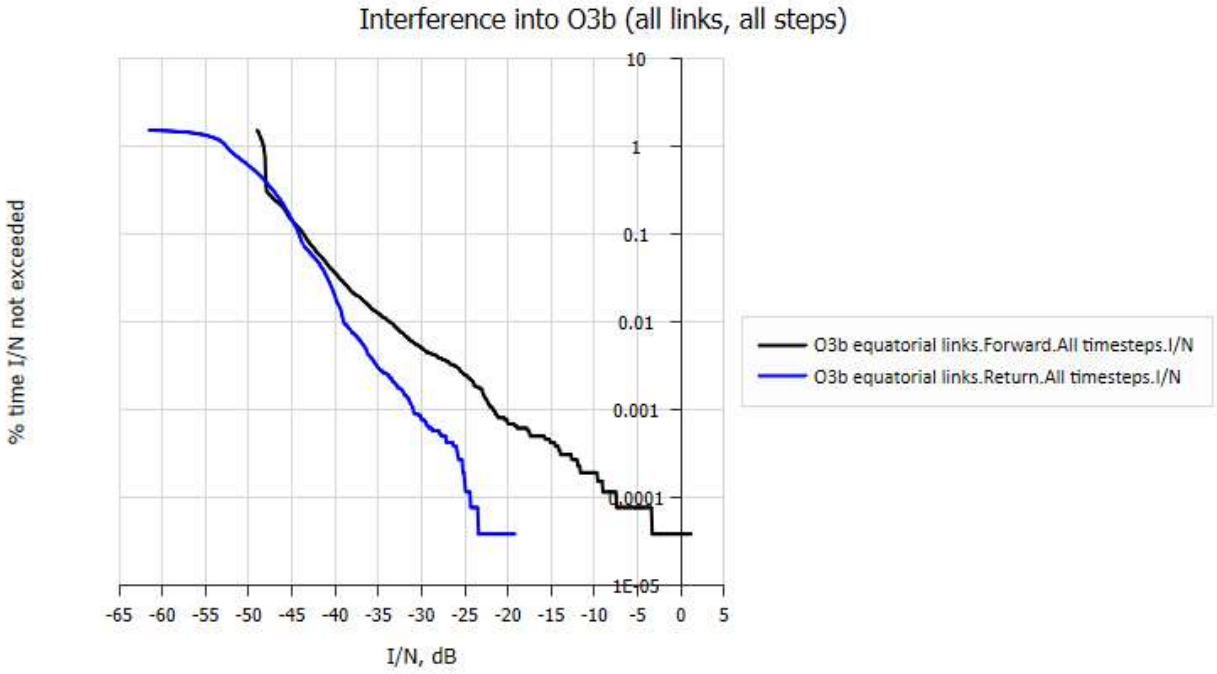
The O3b Hawaii gateway earth station has 2 antennas separately transmitting to satellites in accordance with a specified tracking strategy. To ensure that satellites were selected that would most likely utilize the Hawaiian site for its gateway links, the assumed tracking strategy tracked the highest elevation satellites until one of them was at least 30 degrees away in longitude relative to the Earth station, and then the earth station tracking antenna selected the next highest elevation satellite. The simulation was run for a 30-day period at 2 second time intervals (1,296,000-time steps). This was sufficient to capture short-term events occurring down to percentages of time on the order of 0.0001% or less. While the maximum value of I/N captured during this simulation was +1.2 dB (into the Forward link of O3b link 2) it occurred with a probability of 0.000077% for the overall result. As this level occurred only on one of the two O3b links, its probability in the "all links, all steps" result is a factor of 2 lower (0.00004%) for the overall result.

Results have been generated showing the cumulative distribution function of Interference in the form of the percentage that given values of Interference-to-noise (I/N) ratio are not exceeded.

In the case of O3b, there are three sets of results (of the 2 links to O3b satellites) shown on two separate graphs. Finally, there is an "all links, all steps" graph which shows essentially a combination of all levels and associated overall probabilities and as such can be treated a typical representation.







The results show that the presence of interfering signals from LYNK satellites occur for less than 2% of the time, because that corresponds to the probability of one of the four satellites being serviceable by the Hawaiian gateway site, considering the GSO arc avoidance implemented in this network. I/N levels are negligible (I/N below -20 dB) for all but 0.001% of the time, and are even below the FCC NGSO sharing criterion of -12.2 dB for all but about 0.0005% of the time. This should cause no harmful interference into O3B links as it corresponds to less than 0.3 dB C/N degradation or fade margin loss.

Annex 2

interference Results into OneWeb

(Forward link only, 29.9 – 30 GHz)

All links evaluated at 29.9 GHz frequency for the Earth-to-space path, since OneWeb does not employ the 20.1-20.2 GHz band.

The OneWeb, Hawaii gateway earth station has 15 antennas separately transmitting to various satellites in accordance with a specified tracking strategy. For the simulation, the satellites that would be visible for the longest time (longest track) would be selected by the first antenna, then the next longest track and so on, until on satellite goes below the 5° minimum elevation angle, in which case the next available satellite is selected. The simulation was run for a 10-day period at 2 second time intervals (over 432,000-time steps). This was sufficient to capture short-term events occurring down to percentages of time on the order of 0.0002%. While the maximum value of I/N captured during this simulation was +8.5 dB (into OneWeb Forward Link 12) it occurred with a probability of 0.00023%. As this level occurred only on one of the 15 OneWeb links, its probability in the "all links, all steps" result is a factor of 15 lower (0.000015%) for the overall result. In the overall result, the -12.2 dB I/N level was exceeded for approximately 0.0013% for the forward link, i.e., into a receiving OneWeb satellite. It is expected that if the simulation were to be conducted for much longer time period, all links would eventually exhibit the same I/N curves. The reason that Link 12 was worse in the short-term interference is that it came closest to an full in-line event, whereby the LYNK satellite would be directly between the OneWeb earth station and the Link 12 satellite at a given time step.

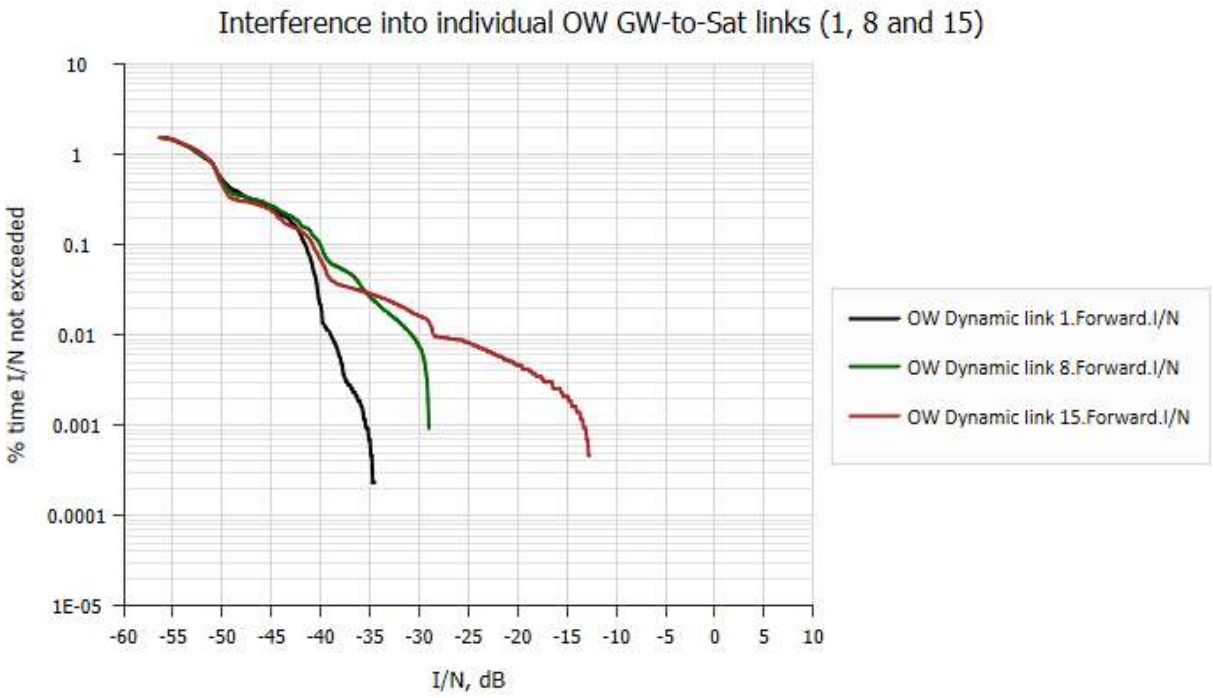
Results have been generated showing the cumulative distribution function of Interference in the form of the percentage that given values of Interference-to-noise (I/N) ratio are not exceeded.

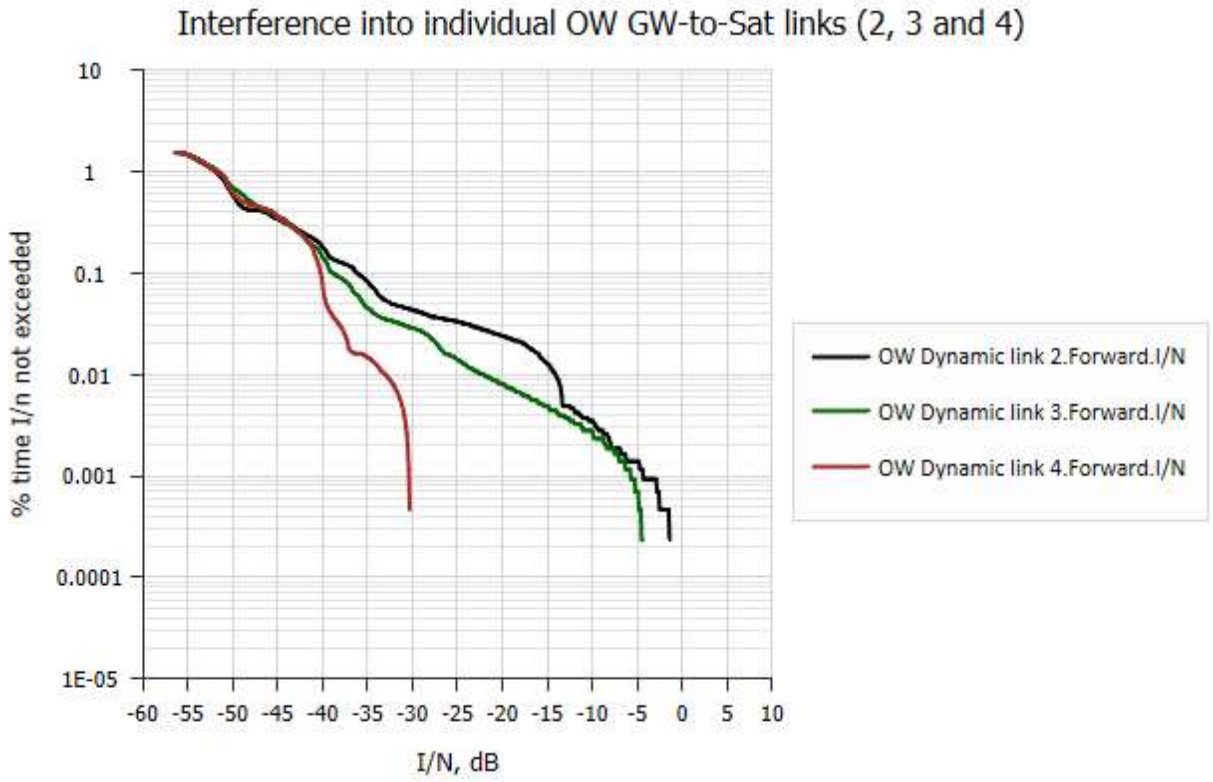
In the case of OneWeb, there are three distinct results for three different links (of the 15 links to OneWeb satellites in total) shown on five separate graphs. Finally, there is an "all links, all steps" graph which shows essentially a combination of all levels and associated overall probabilities and as such can be treated a typical representation.

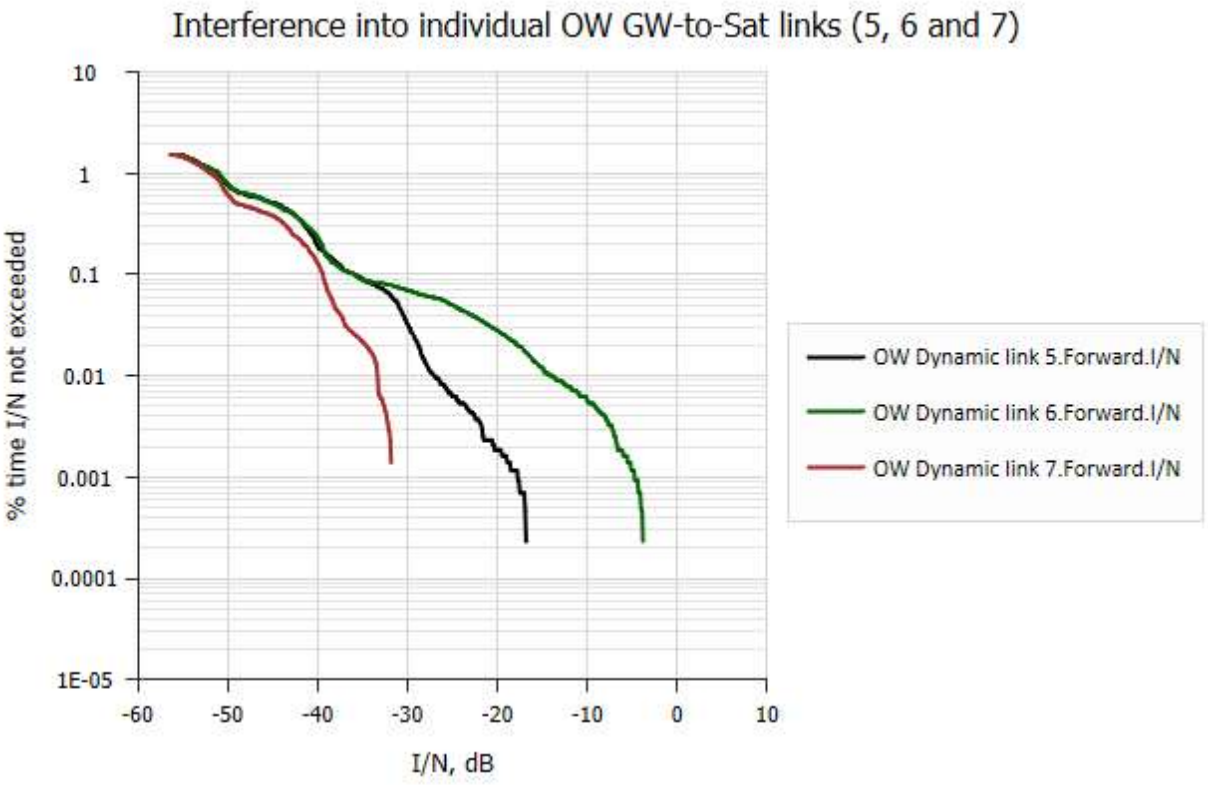
The results show that the presence of interfering signals from LYNK satellites occur for less than 2% of the time, because that corresponds to the probability of one of the four satellites being serviceable by the Hawaiian gateway site, considering the GSO arc avoidance implemented in this network. I/N levels are negligible (I/N below -20 dB) for all but 0.01% of the time for each of the 15 different links, and below 0.007% of the time for the composite interference scenario.

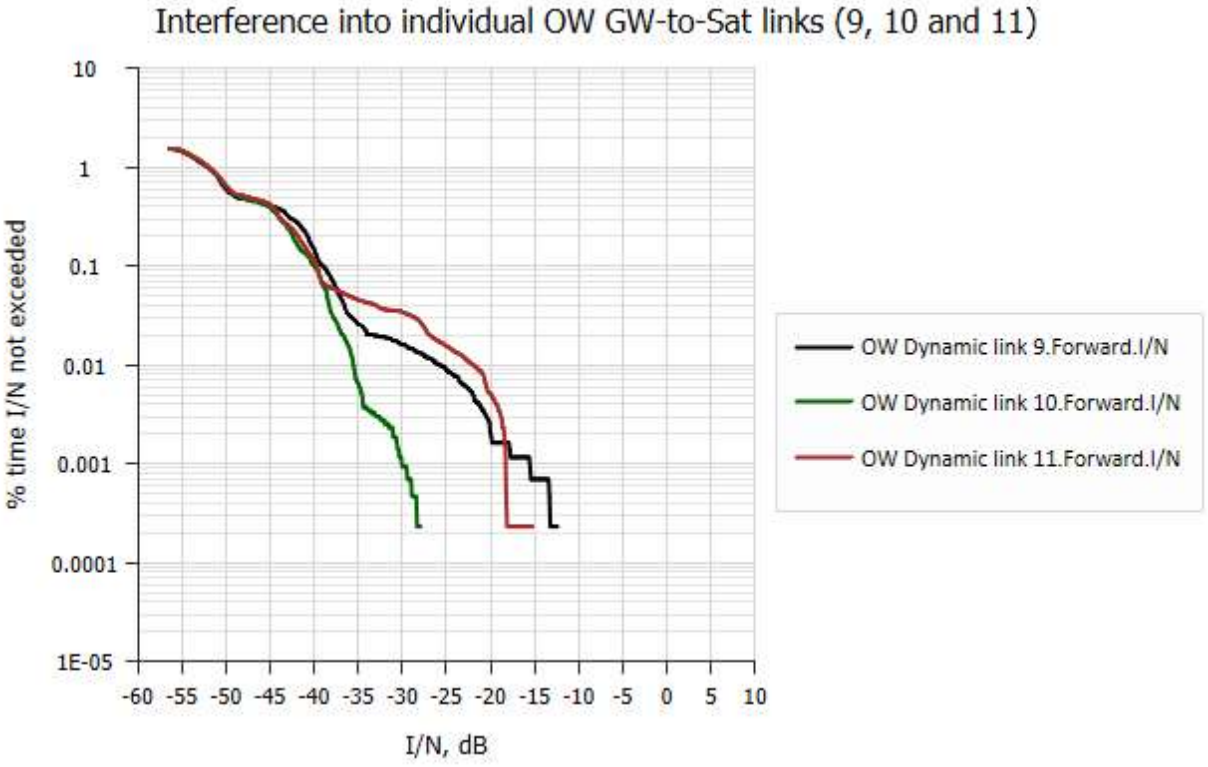
Perhaps more importantly, the I/N levels are even below the FCC NGSO sharing criterion of -12.2 dB for all but about 0.002% of the time. This should cause no harmful interference into OneWeb links, as it corresponds to less than 0.3 dB C/N degradation or fade margin loss.

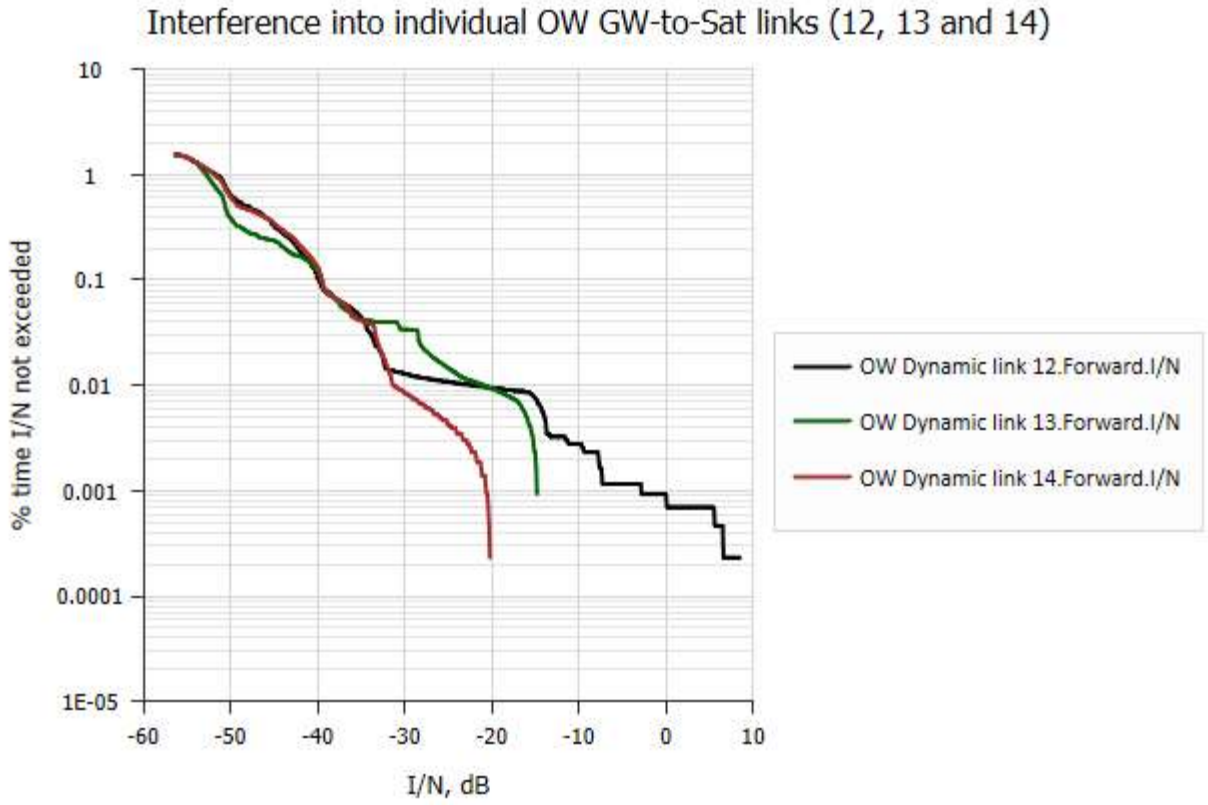
Even I/N of 0 dB, which equals a 3 dB C/N reduction, would not cause any outage in the OneWeb links, because such feederlinks normally would operate with 5 to 10 dB fade margin, and further taking into account that the probability of such I/N levels is less than 0.0001% of the time.

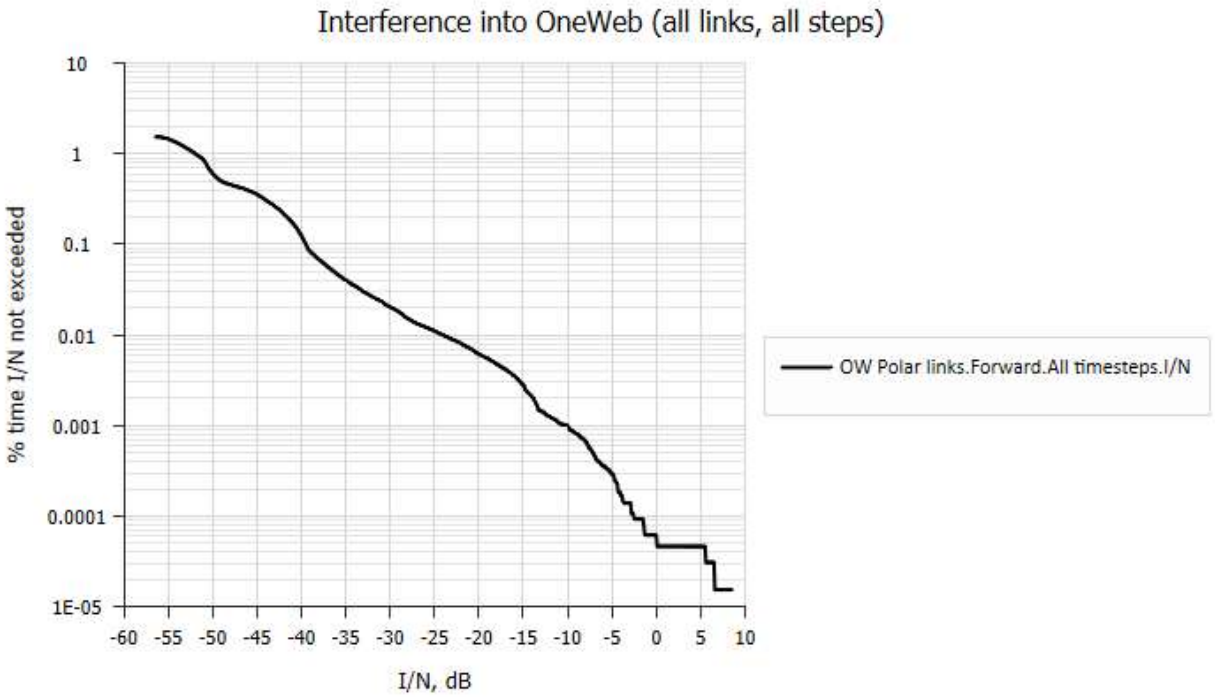

Interference into individual OW GW-to-Sat links (1, 8 and 15)
% time I/N not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
-60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10
I/N, dB
OW Dynamic link 1.Forward.I/N
OW Dynamic link 8.Forward.I/N
OW Dynamic link 15.Forward.I/N


Interference into individual OW GW-to-Sat links (2, 3 and 4)
% time I/n not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
-60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10
I/N, dB
OW Dynamic link 2.Forward.I/N
OW Dynamic link 3.Forward.I/N
OW Dynamic link 4.Forward.I/N


Interference into individual OW GW-to-Sat links (5, 6 and 7)
% time I/N not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
-60
-50
-40
-30
-20
-10
0
10
I/N, dB
OW Dynamic link 5.Forward.I/N
OW Dynamic link 6.Forward.I/N
OW Dynamic link 7.Forward.I/N


Interference into individual OW GW-to-Sat links (9, 10 and 11)
% time I/N not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
-60
-55
-50
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
I/N, dB
OW Dynamic link 9.Forward.I/N
OW Dynamic link 10.Forward.I/N
OW Dynamic link 11.Forward.I/N


Interference into individual OW GW-to-Sat links (12, 13 and 14)
% time I/N not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
-60
-50
-40
-30
-20
-10
0
10
I/N, dB
OW Dynamic link 12.Forward.I/N
OW Dynamic link 13.Forward.I/N
OW Dynamic link 14.Forward.I/N


Interference into OneWeb (all links, all steps)
% time I/N not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
-60
-55
-50
-45
-40
-35
-30
-25
-20
-15
-10
-5
0
5
10
I/N, dB
OW Polar links.Forward.All timesteps.I/N

Annex 3

Interference Results into SpaceX

(Forward link, 29.9 – 30 GHz and Return Link, 20.1 – 20.2 GHz)

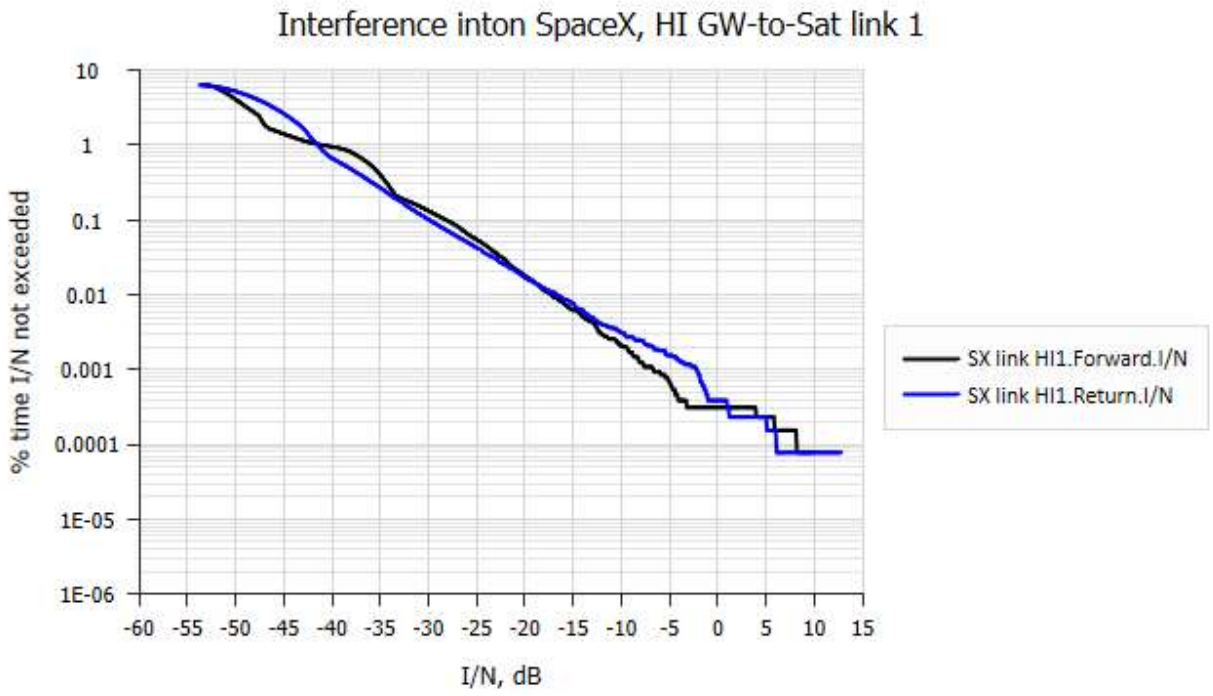
All forward links (Earth-to-space) are evaluated at 29.9 GHz and all return links (space-to-Earth) are evaluated at 20.1 GHz.

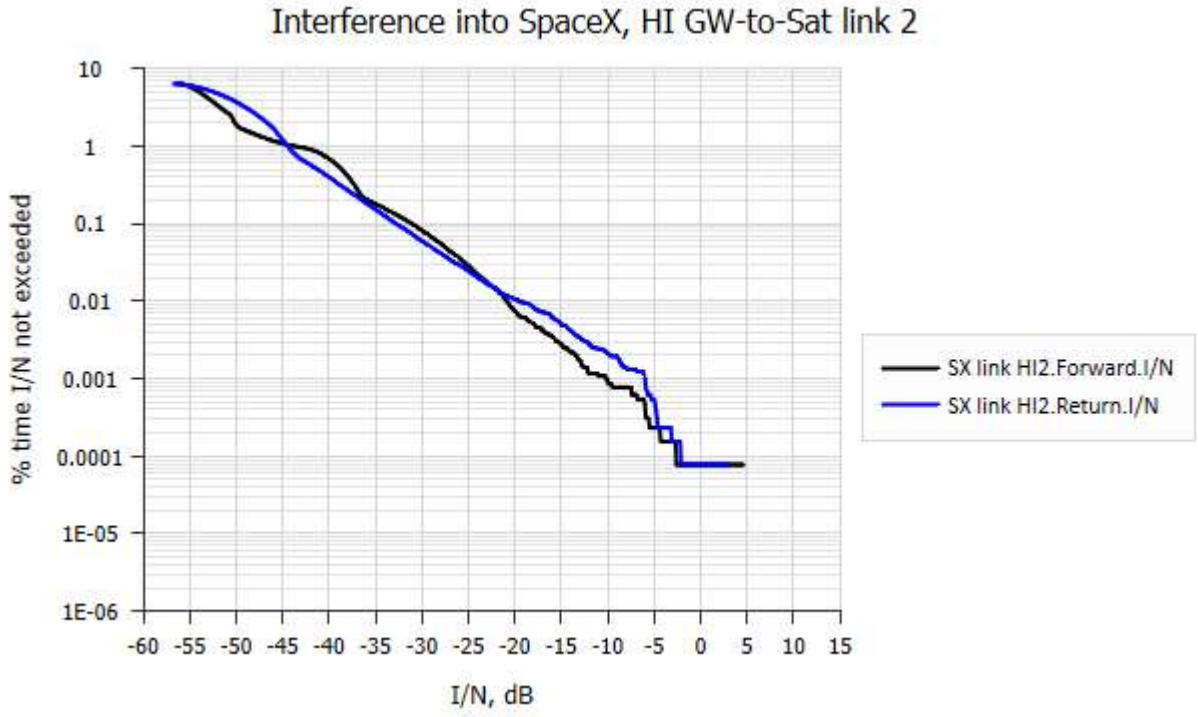
The SpaceX Hawaii gateway earth station has 4 antenna antennas transmitting separately to various satellites in accordance with a specified tracking strategy. In these simulations, considering the vast amount of SpaceX satellites, a random tracking strategy was employed. The simulation was run for a 30-day period at 2 second time intervals (1,296,000-time steps). This was sufficient to capture short-term events occurring down to percentages of time on the order of 0.0001% for the forward and return links. While the maximum values of I/N captured during this simulation was approximately +9.8 dB and +12.8 dB for the forward and return links respectively (into SpaceX Link 1) both levels occurred with a probability of 0.000077%. As this level occurred only on one of the 4 SpaceX links, its probability in the "all links, all steps" result is a factor of 4 lower (0.000019%) for the combined results. In the overall result, the -12.2 dB I/N level was exceeded for approximately 0.003% for the return link and 0.0019% for the forward link, which is not that different than the statistics for each of the 4 separate links.

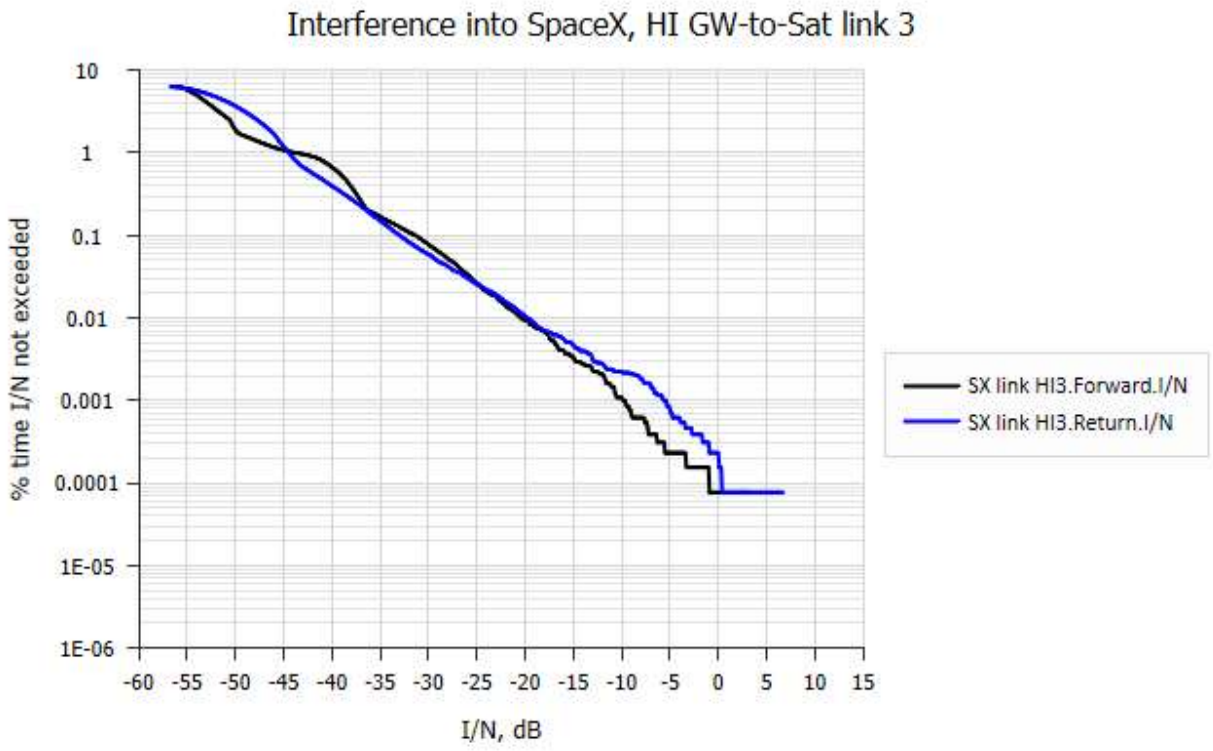
Results have been generated showing the cumulative distribution function of Interference in the form of the percentage that given values of Interference-to-noise (I/N) ratio are not exceeded.

In the case of SpaceX, each graph shows the I/N level into forward (uplink) and return (downlink) paths with a single link (of the 4 links to SpaceX satellites in total) shown on four separate graphs. Because the limited simulation time, combined with the infrequent passes of the 4 LYNK satellites over Hawaii, each curve represents only a snapshot of the potential interference into a given link. If the simulation were run for a much longer simulation period, all four links would be expected to show similar statistics. Therefore, there is an "all links, all steps" graph which shows essentially a combination of all levels and associated overall probabilities and as such can be treated a typical representation.

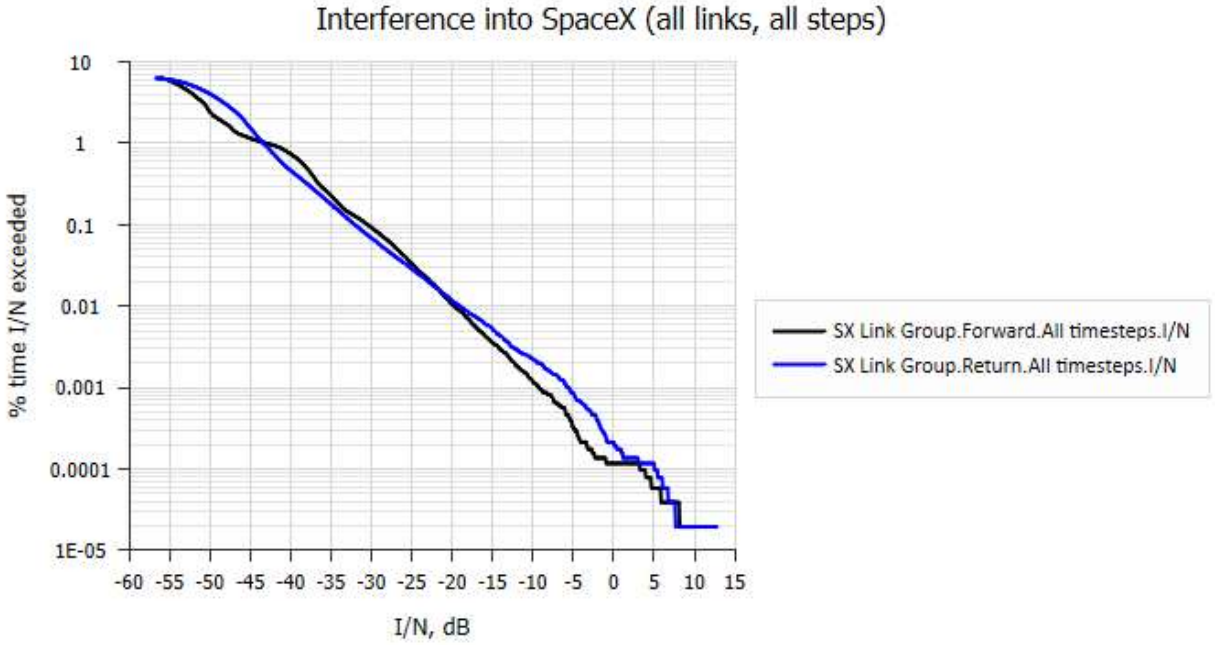
As indicated above, using this combined CDF curve, the FCC interference trigger of I/N equal to -12.2 dB is expected to occur for less than 0.003% of the time, and it is worth noting that this level would only degrade the SpaceX link by 0.25 dB, which would hardly be noticeable, and in fact much below other variations and uncertainties in link design. The average link may see a 3 dB degradation, resulting from an I/N level of 0 dB, at an order of magnitude lower probability, i.e., for less than 0.0002% of the time. Such SpaceX links will most certainly have more than 3 dB fade margin, and so during normal clear-sky conditions, the predicted interference levels would never cause an outage to the SpaceX links. In fact, even the highest predicted I/N levels (+13 dB), occurring less than 0.0001% of the time may not cause an outage to the SpaceX links. If it is strong enough to impact link availability, it would do so for such rare occurrence that its impact on overall link availability would be negligible. Therefore, it can be concluded that interference from LYNK's 4 authorized satellites will not be severe and compatibility with SpaceX's Gen1 Starlink satellites can be ensured.


Interferenceinton SpaceX, HI GW-to-Sat link 1
% time I/N not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
1E-06
-60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15
I/N, dB
SX link HI1.Forward.I/N
SX link HI1.Return.I/N


Interference into SpaceX, HI GW-to-Sat link 2
% time I/N not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
1E-06
-60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15
I/N, dB
SX link HI2.Forward.I/N
SX link HI2.Return.I/N


Interference into SpaceX, HI GW-to-Sat link 3
% time I/N not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
1E-06
-60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15
I/N, dB
SX link HI3.Forward.I/N
SX link HI3.Return.I/N


Interference into SpaceX, HI GW-to-Sat link 4
% time I/N not exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
1E-06
-60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15
I/N, dB
SX link HI4.Forward.I/N
SX link HI4.Return.I/N


Interference into SpaceX (all links, all steps)
% time I/N exceeded
10
1
0.1
0.01
0.001
0.0001
1E-05
-60 -55 -50 -45 -40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15
I/N, dB
SX Link Group.Forward.All timesteps.I/N
SX Link Group.Return.All timesteps.I/N