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Prepared by EUMETSAT
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REPORT ON POTENTIAL PROBLEMS FOR OPERATIONAL ORBIT SCENARIOS CAUSED BY FREQUENCY OVERLAP

This document is in response to CGMS action 31.40.

An interference assessment from the meteorological satellite system NPOESS into METOP Earth stations receiving around 1.7 and 7.8 GHz has been conducted. The analysis covers both cases, interference into main Earth stations and interference into user stations performing METOP and NPOESS reception.

The interference potential is caused by the extended bandwidth of NPOESS-L in the band 1690 – 1710 MHz, and due to the use of the METOP downlink frequency 7750 –7850 MHz for NPOESS data direct readout.

REPORT ON POTENTIAL PROBLEMS FOR OPERATIONAL ORBIT SCENARIOS CAUSED BY FREQUENCY OVERLAP

1 INTRODUCTION

An interference assessment from the meteorological satellite system NPOESS into METOP Earth stations receiving around 1.7 and 7.8 GHz has been conducted by means of the radio frequency interference assessment tool RFIAT. One METOP satellite with an orbital altitude of 825 km and an ascending equator crossing time of 21:30 hrs has been assumed. Three NPOESS satellites with orbital heights of 828 km and ascending equator crossing times of 13:30 hrs, 17:30 hrs and 21:30 hrs have been considered. All satellites transmit both in the band 1698-1710 MHz and 7750-7850 MHz and interference will therefore occur for some time when the orbital positions of the METOP and NPOESS satellites overlap. This happens in general every approximately 113 days. Minimum elevation angles of 5 degrees were assumed for all Earth stations. Polarisation and atmospheric losses were not taken into account. Exact spectral overlap and Doppler effects can be taken into account with the interference assessment software so that the actual spectral interference component has been assessed.

2 FREQUENCY INTERFERENCE ASSESMENT

2.1 ANALYSIS FOR THE BAND 1698-1710 MHz

2.1.1 System Characteristics and Assumptions

NPOESS satellites transmit a 12 MHz signal in broadcast mode on a centre frequency of 1704 MHz. METOP earth stations receive A-HRPT data within a 4.5 MHz bandwidth on the frequencies 1701.3 and 1707 MHz, respectively. Main stations with a diameter around 10 meter as well as user stations with around 2 m diameter have been considered. The key simulation parameters are given in table 1. The detailed simulation parameters for the worst case are attached in Annex 1.

	NPOESS	METOP	
Orbital height	828	825	km
Equator crossing time (ascending)	13:30, 17:30, 21:30	21:30	hrs
Inclination	98.727	98.714	deg.
Center frequency	1704	1701.3, 1707	MHz
Signal bandwidth	12	4.5	MHz
Effective power into antenna	13.6	5.5	dBW
Antenna patterns	see Figure 1	see Figure 1	dBi

Earth station antenna gain	n.a.	27, 42	dBi
System noise temperature	n.a.	150	K
Required C/(N+I)	n.a.	17	dB
Required Eb/(No+Io)	n.a.	4	dB

Table 1: Key system parameters for 1.7 GHz systems

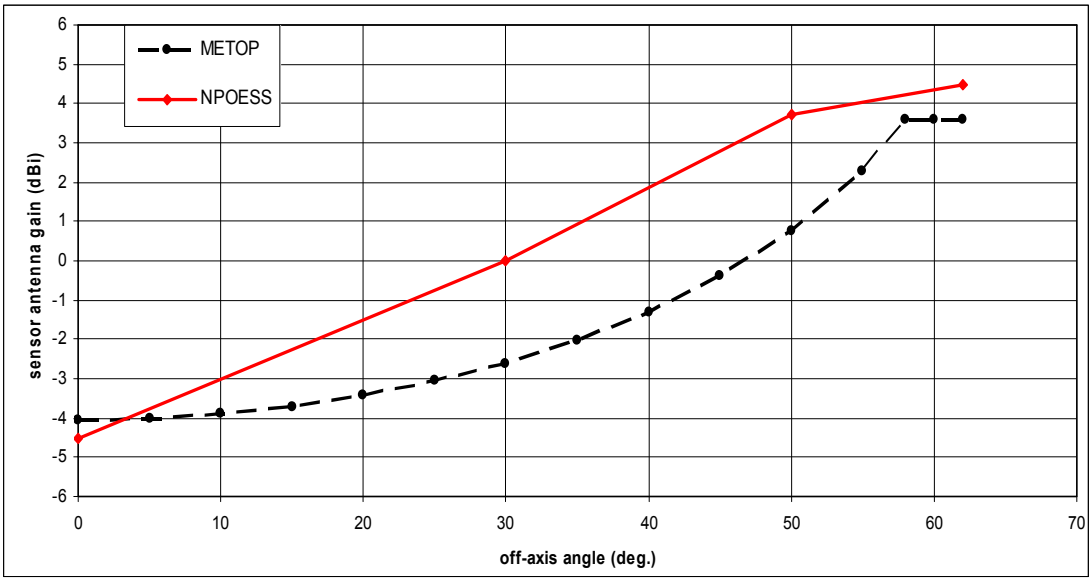


Figure 1: Assumed satellite antenna gains

Figure 1 shows the assumed antenna gains for both satellites. For METOP, only EIRP levels were available. The antenna gains have been estimated by assuming an effective power of approximately 5.5 dBW into the antenna. This power level is based on a maximum peak power of 8 dBW and 2.5 dB feeder loss. For the carrier and data recovery loops, a technical degradation of 1 dB has been taken into account. The assumed carrier loop bandwidth is 3 kHz.

2.1.2 Simulation Results

Table 2 shows a summary of the simulation results for various cases considered. High Resolution User Stations (HRUS) have been assumed at an equatorial location in Kampala and a high latitude location in Svalbard with results showing little dependency on station latitude. Main station locations are Svalbard and Madrid. The highest levels of interference occur for the 21:30 hrs equatorial crossing for both satellites as the orbits overlap approximately every 113 days. The interference around 1701.3 MHz is slightly higher than around 1707 MHz but the difference is practically insignificant.

	No/Io	Es/(No+Io)	C/(N+I)
NPOESS 13:30 hrs into 2m HRUS at 78° and 1701.3 MHz	6.20%	0.39%	0.03%
NPOESS 17:30 hrs into 2m HRUS at 78° and 1701.3 MHz	7.38%	0.63%	0.06%
NPOESS 21:30 hrs into 2m HRUS at 78° and 1701.3 MHz	9.79%	2.94%	0.84%
NPOESS 21:30 hrs into 2m HRUS at 0° and 1701.3 MHz	9.36%	2.80%	0.62%
NPOESS 21:30 hrs into 2m HRUS at 78° and 1707 MHz	9.39%	2.84%	0.80%
NPOESS 21:30 hrs into 10m main station in Svalbard	4.43%	0.28%	0.13%

Table 2: Interference percentage for various Earth stations

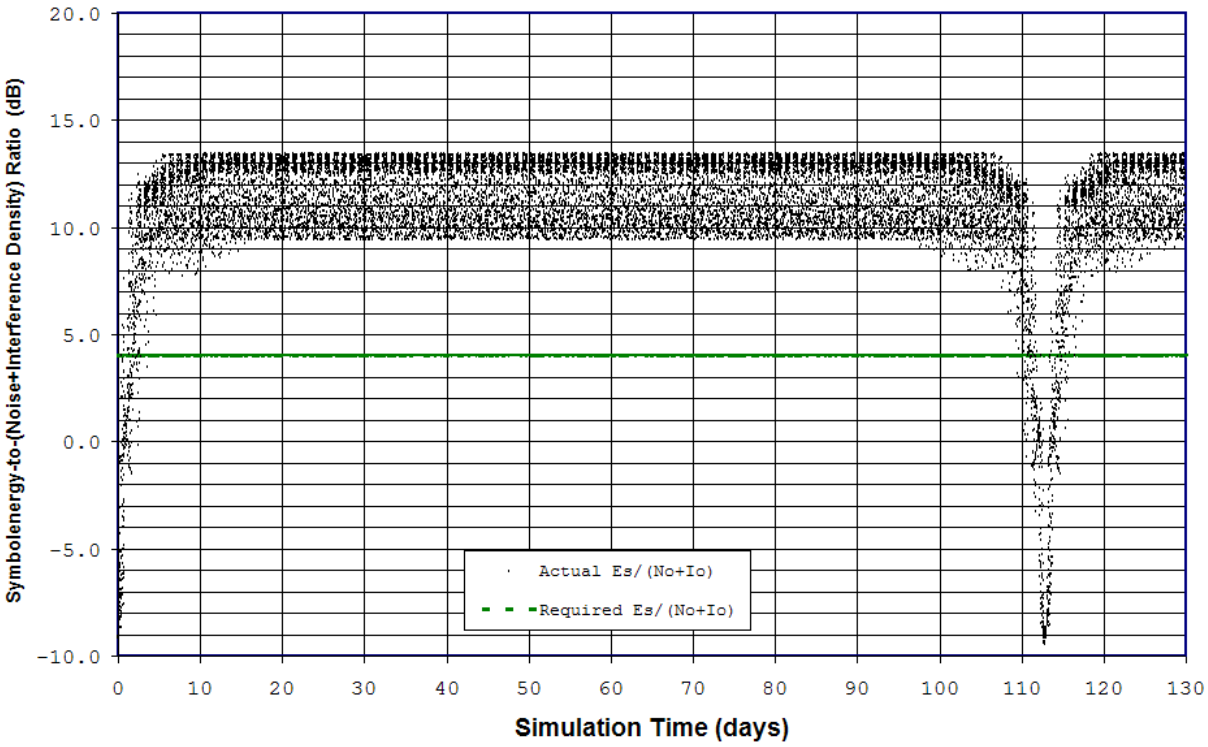


Figure 2: Es/(No+Io) levels at HRUS station

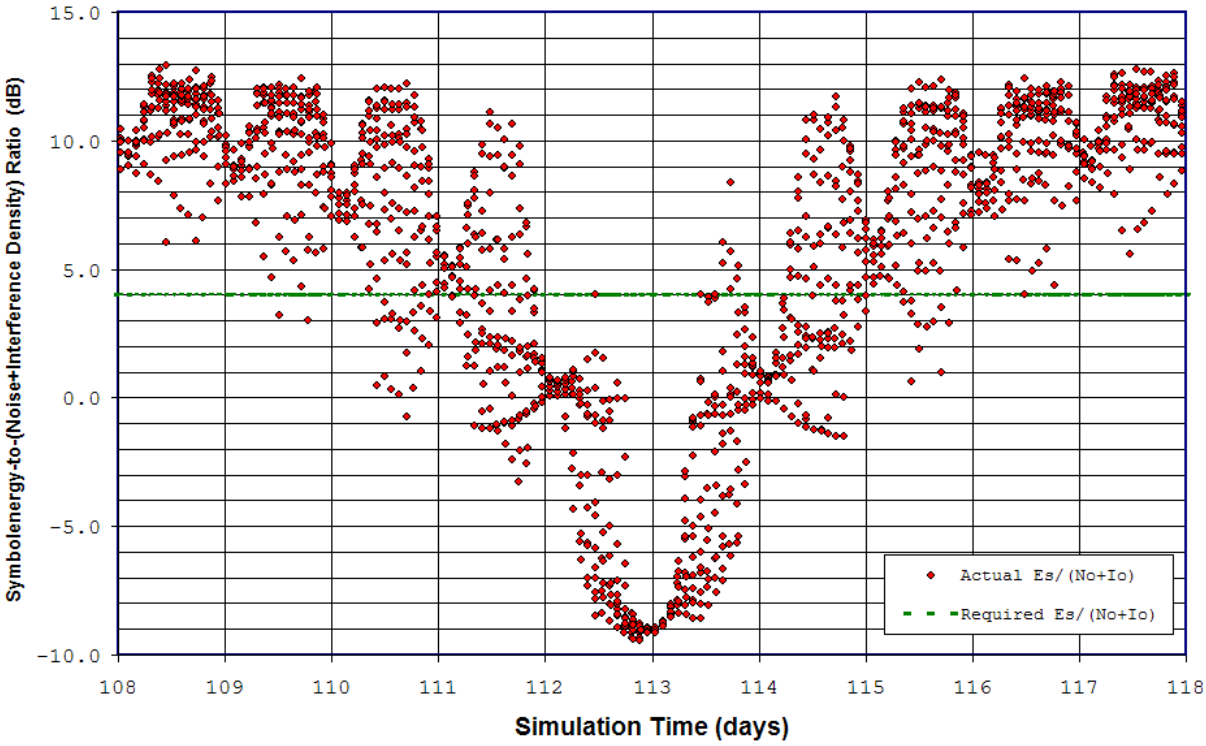


Figure 3: Es/(No+Io) levels during maximum interference at HRUS station

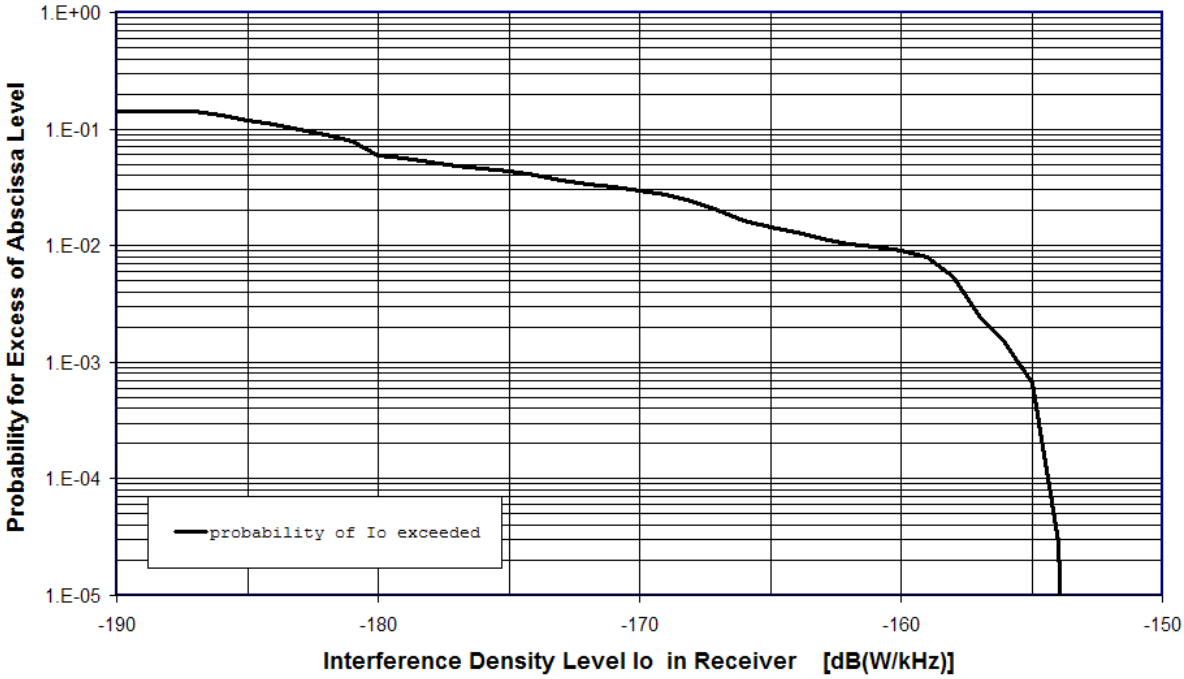


Figure 4: Interference density distribution at HRUS station

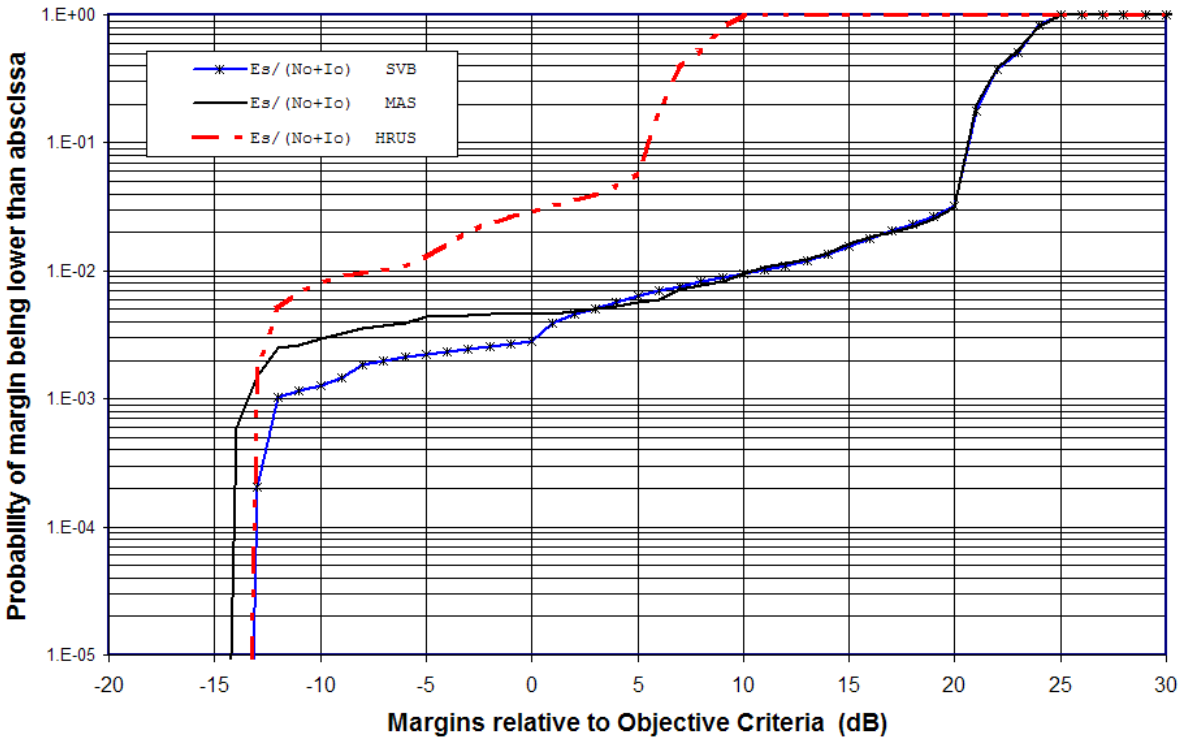


Figure 5: Es/(No+Io) probability distribution at Main and HRUS stations

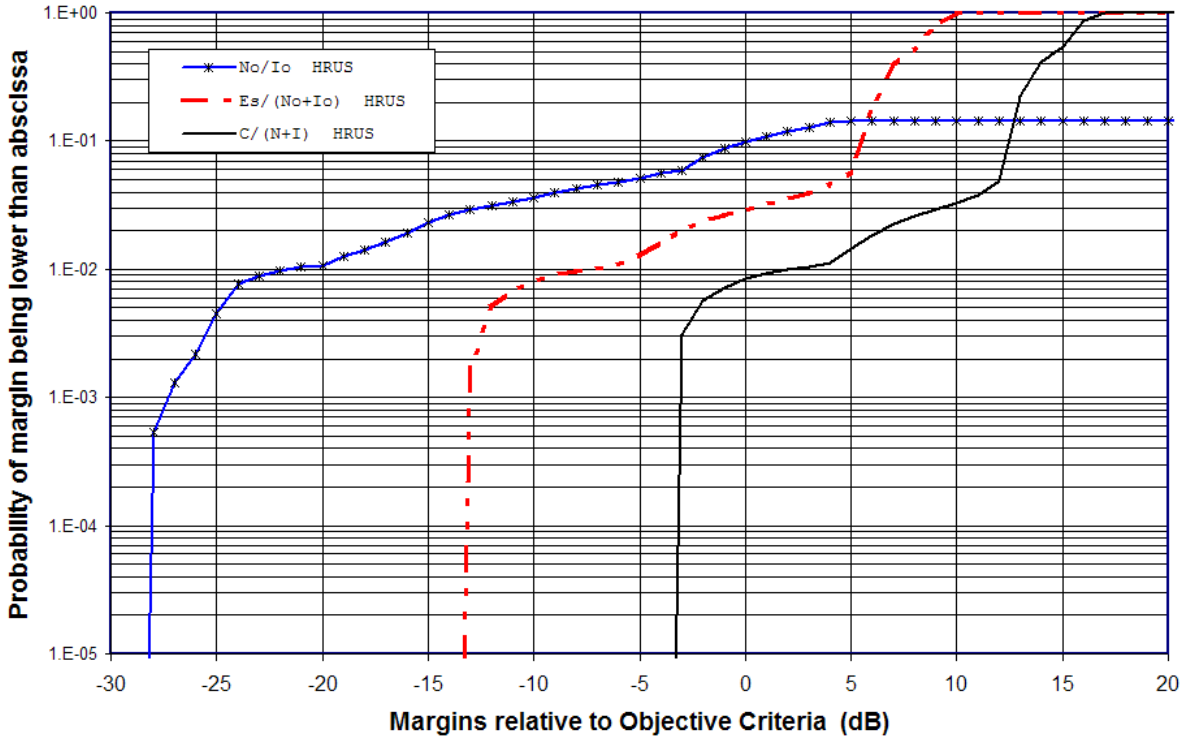


Figure 6: Probability distribution for various parameters at HRUS station

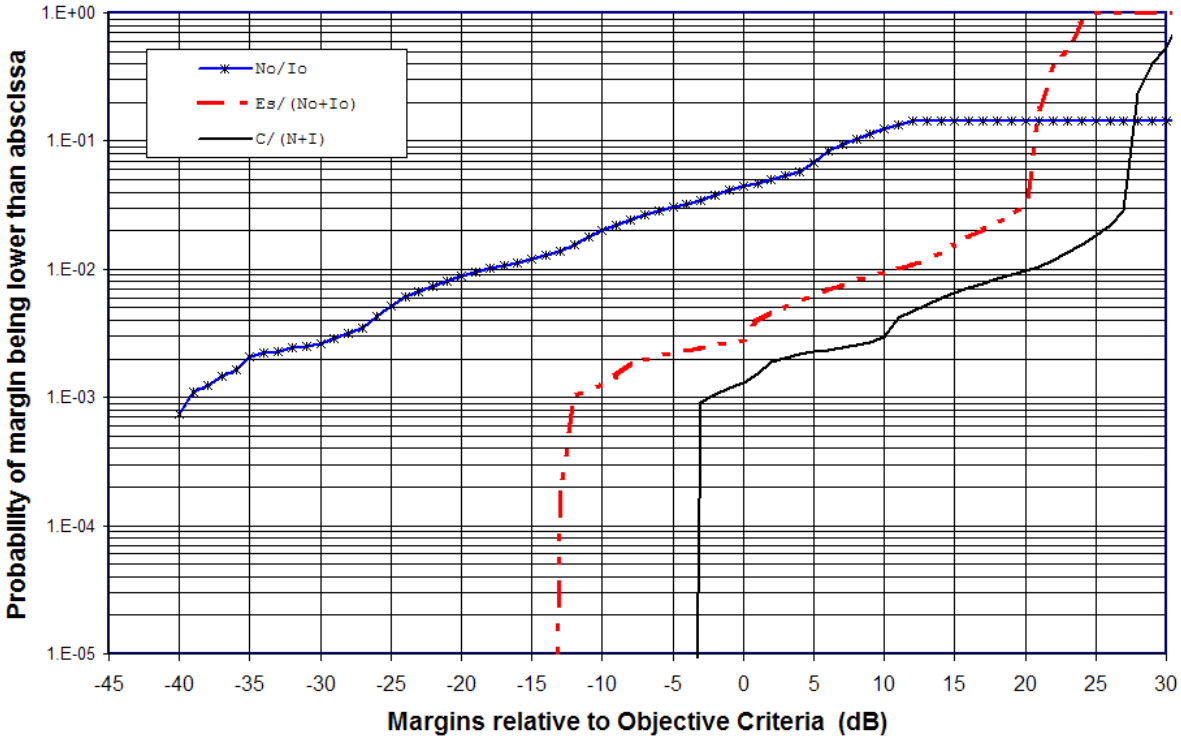


Figure 7: Probability distribution for various parameters at Svalbard main station

Figure 2 shows the obtained Es/(No+Io) levels over a full overlap period for the worst case of both satellites at 21:30 equatorial crossing time and high latitude HRUS location. Figure 3 shows a magnification of figure 2 around the maximum interference occurrence. Figure 4 shows the interference density distribution. Figure 5 shows a comparison between Es/(No+Io) results obtained for an HRUS at Svalbard, a main station at Svalbard and a main station in Mas Palomas. Figure 6 shows the probability distribution for No/Io, Es/(No+Io) and C/(N+I) for an HRUS at Svalbard. Figure 7 shows the probability distribution for No/Io, Es/(No+Io) and C/(N+I) for a main station at Svalbard.

The simulation duration for the most sensitive cases was a full overlap period (113 days) with 1 second intervals. For less sensitive cases, a time interval of 6 seconds has been selected.

It shall be noted that in this assessment, the C/(N+I) is the actually available signal to noise and interference ratio in the carrier tracking loop based on 12 dB double squaring loss with respect to the full signal power fed into the suppressed carrier recovery circuit. It is not the often erroneously used ITU terminology for C/N as the general signal to noise ratio. The actual data quality assessment is based upon the Eb/No requirements.

2.2 ANALYSIS FOR THE BAND 7750-7850 MHz

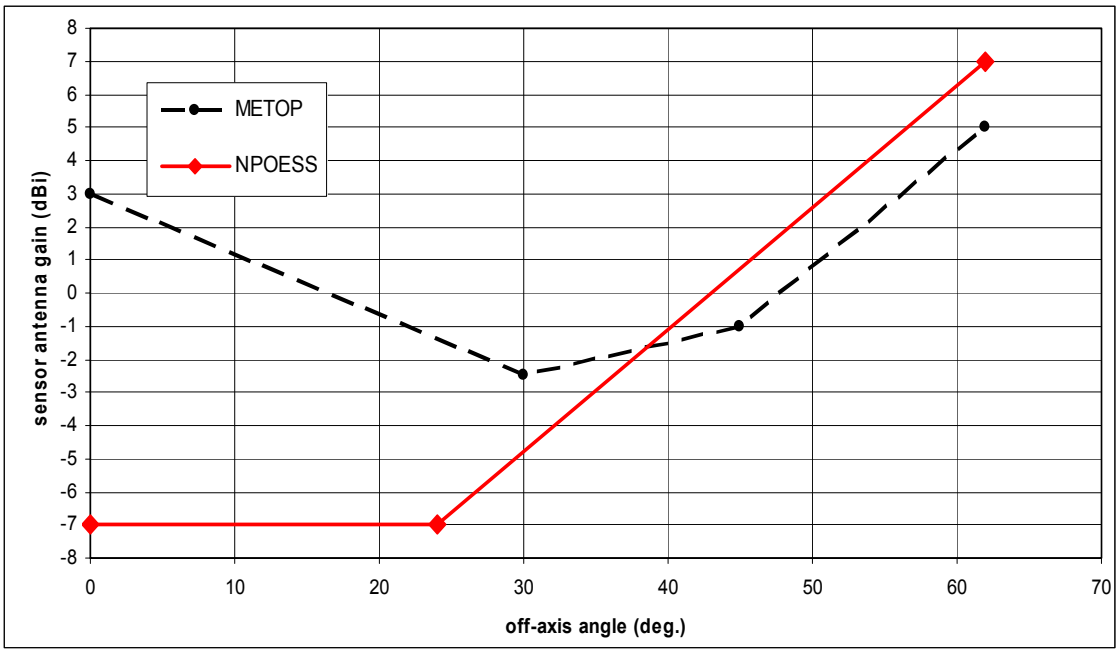
2.2.1 System Characteristics and Assumptions

NPOESS operates an HRD service in broadcast mode with a carrier frequency of 7812 MHz and a bandwidth of 35 MHz. METOP Earth stations receive data dumps within a 63 MHz bandwidth on a carrier frequency of 7800 MHz. Three main stations with a diameter between 10 and 13 meters have been considered for METOP data reception. The locations are Svalbard, Madrid and Fairbanks. The key simulation parameters are given in Table 3. The detailed simulation parameters for the main station in Svalbard are attached in Annex 2.

	NPOESS	METOP	
Orbital height	828	825	km
Equator crossing time (ascending)	13:30, 17:30, 21:30	21:30	hrs
Center frequency	7812	7800	MHz
Signal bandwidth	35	63	MHz
Effective power into antenna	19	14.3	dBW
Antenna patterns	see Figure 8	see Figure 8	dBi
Earth station antenna gain	n.a.	55, 58.6	dBi
System noise temperature	n.a.	180	K
Required C/(N+I)	n.a.	17	dB
Required Eb/(No+Io)	n.a.	7	dB

Table 3: Key system parameters for 7.8 GHz systems

Figure 8 shows the assumed antenna gains for both satellites. For METOP, a peak power level of 14.3 dBW has been assumed with feeder losses around 2.5 dB. For the carrier and data recovery loops, a technical degradation of 1 dB has been taken into account. The assumed carrier loop bandwidth is 30 kHz.



2.2.2 Simulation Results

Table 4 shows a summary of the simulation results for various cases considered. Main station locations are Svalbard, Madrid and Fairbanks. The highest levels of interference occur for the 21:30 hrs equatorial crossing for both satellites.

	No/Io	Es/(No+Io)	C/(N+I)
NPOESS 13:30 hrs into Svalbard	0.003%	0.002%	0.000%
NPOESS 17:30 hrs into Svalbard	0.007%	0.004%	0.000%
NPOESS 21:30 hrs into Svalbard	0.954%	0.143%	0.066%
NPOESS 21:30 hrs into Madrid	0.898%	0.229%	0.133%
NPOESS 21:30 hrs into Fairbanks	0.978%	0.169%	0.084%

Table 4: Interference percentage for various earth stations

Figure 9 shows the obtained Es/(No+Io) levels over a full overlap period for the case of both satellites at 21:30 equatorial crossing time and the main station at Svalbard. Figure 10 shows a magnification of figure 9 around the maximum interference occurrence. Figure 11 shows the probability distribution for No/Io, Es/(No+Io) and C/(N+I) for the main station in Svalbard. Figure 12 shows a comparison between Es/(No+Io) results obtained for the 3 main station locations at Svalbard, Madrid and Fairbanks. Figure 13 shows the interference density distribution for the main station at Svalbard. The simulation duration for all cases was a full overlap period based on 113 days with 1 second intervals.

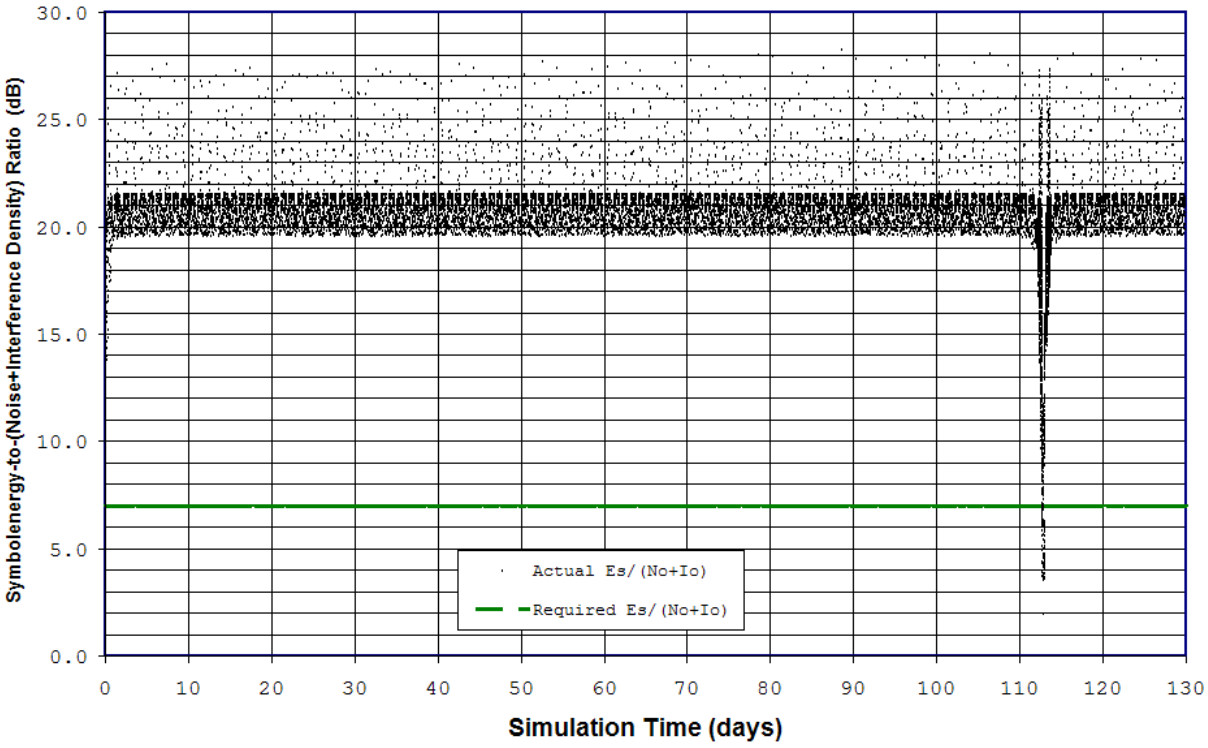


Figure 9: Es/(No+Io) levels at Svalbard station

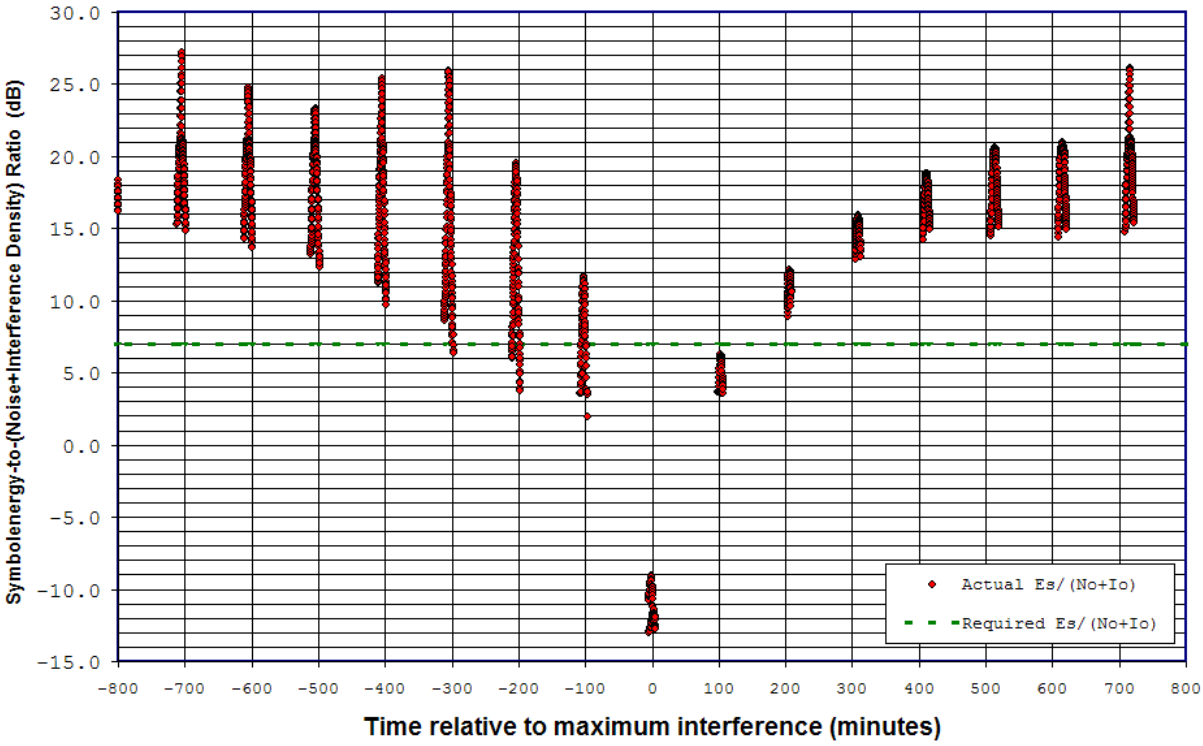


Figure 10: Es/(No+Io) levels during maximum interference at Svalbard

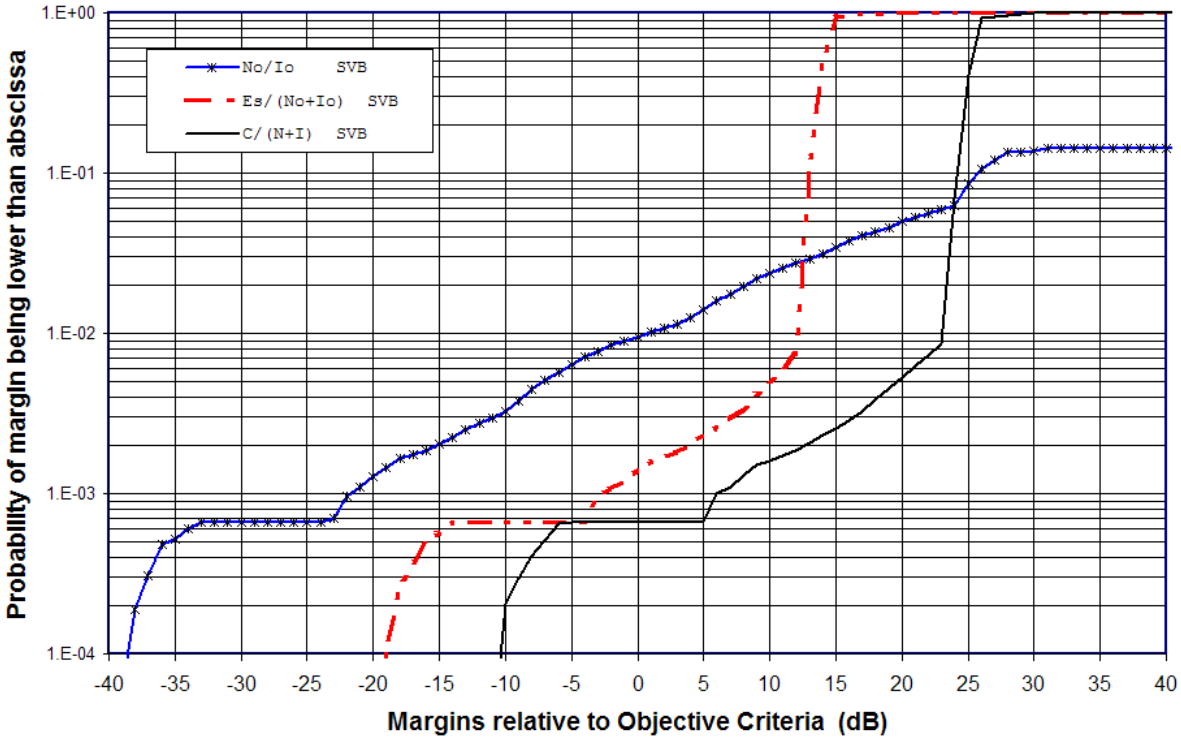


Figure 11: Probability distribution for various parameters at Svalbard

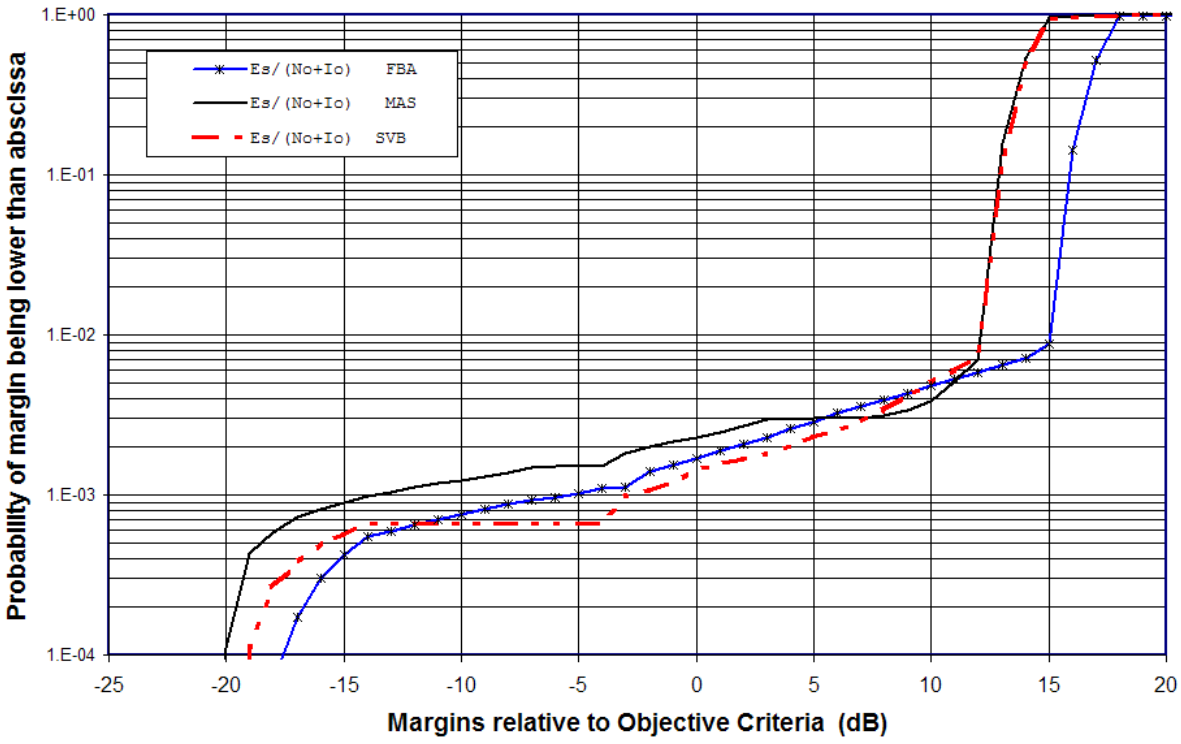


Figure 12: Es/(No+Io) probability distribution at Main stations

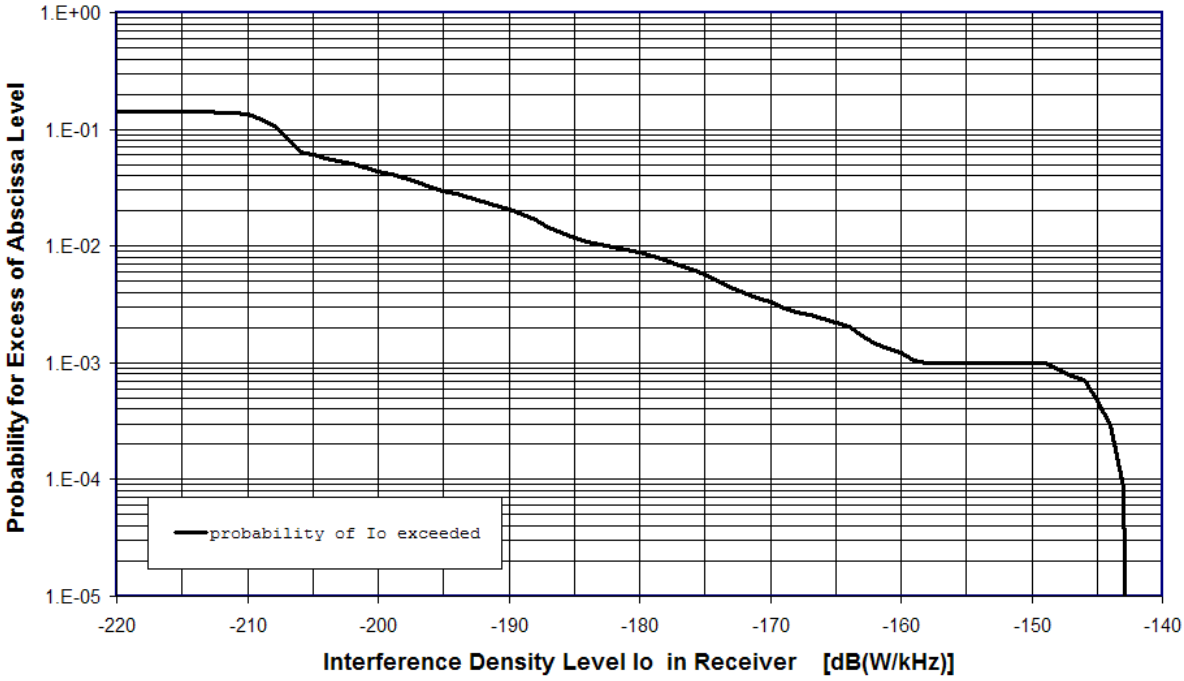


Figure 13: Interference density distribution at Svalbard

3 CONCLUSIONS

- Worst cases are obtained when both satellites have the same equatorial crossing times as the orbits will occasionally overlap. For the selected orbit heights, this would occur approximately every 113 days.

- Significant data loss for up to 3% of time will occur around 1.7 GHz

- Data loss for up to 0.23% of time will occur around 7.8 GHz

- Interference levels and statistics are rather independent of station locations.

- Interference could be minimised by phasing the satellites in a way that they have identical orbital periods but a small orbital separation angle. This technique is already successfully applied to a number of low Earth orbiting satellites operating around 8.2 GHz. At 7.8 GHz. less than 1 degree orbital separation would already be sufficient for a 10-m antenna to reduce interference levels by more than 30 dB.

While data losses of up to 3% every 113 days at HRUS and HRD user stations appear to be acceptable, the interference into the main data downlink of METOP by NPOESS MRD needs to be avoided by implementation of operational procedures.

Annex 1 - INTERFERENCE ASSESSMENT SUMMARY EXAMPLE FOR 1.7 GHz

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------------------------------------------------------------
------------
Set-Up File     = METOP-NPOESS-1701-2130    Date: 26.03.2004 -
21:52:17
Simulation time = 170.000 days   Time step = 1.00 s

VICTIM TRANSMITTER   =  Satellite  METOP
  semimajor axis                        = 7203.144 km
  eccentricity                          = 0.00000
  inclination angle                     = 98.714 deg.
  right ascension angle                 = 322.500 deg.
  argument of perigee                   = 0.000 deg.
  mean anomaly                          = 0.000 deg.
  satellite epoch                       = 24.02.2004 -
12:00:00
  RF power level                        = 8.00 dBW
  feeder loss                           = 2.50 dB
  antenna type                          = User-Design
  maximum antenna gain                  = 6.00  dBi
  transmitter frequency                 = 1.70130 GHz
  modulation                            = QPSK
  modulation index                      = 1.57  rad
  rel. carrier power level              = -12.000 dB
  rel. data power level                 = 0.000 dB
  subcarrier frequency                  = 0.000 kHz
  symbol rate                           = 4500.000 ks/s

VICTIM RECEIVER   =  Earth Station  Svalbard
  location longitude                    = 16.033 deg.
  location latitude                     = 78.158 deg.
  location altitude                     = 0.100 km
  minimum elevation                     = 5.000 deg.
  noise temperature                     = 150.00 K
  antenna type                          = Parabolic-APP 8
  maximum antenna gain                  = 27.12 dBi
  antenna diameter                      = 1.80 m
  antenna efficiency                    = 50.00 %
  RF data bandwidth                     = 4500.000 kHz
  data loop degradation                 = 1.000 dB
  carrier loop bandwidth                = 3.000 kHz
  carrier loop degradation              = 1.000 dB


INTERFERING TRANSMITTER  - 1  = Satellite  NPOESS
  semimajor axis                        = 7206.144 km
  eccentricity                          = 0.00000
  inclination angle                     = 98.727 deg.
```

```
  right ascension angle                    = 322.500 deg.
  argument of perigee                      = 0.000 deg.
  mean anomaly                             = 0.000 deg.
  satellite epoch                          = 24.02.2004 -
12:00:00
  RF power level                           = 13.60 dBW
  antenna type                             = User-Design
  maximum antenna gain                     = 6.00  dBi
  transmitter frequency                    = 1.70400 GHz
  modulation                               = QPSK
  modulation index                         = 1.57  rad
  rel. carrier power level                 = -12.000 dB
  rel. data power level                    = 0.000 dB
  subcarrier frequency                     = 0.000 kHz
  symbol rate                              = 12000.000 ks/s
  RF interferer bandwidth                  = 12000. kHz
  Polarisation discrimination              = 0.0 dB
  Environmental attenuation                = 0.0 dB
  Continuous Interference Transmission     = ON

INTERFERING RECEIVER  -   1  = Earth Station  Svalbard-NPOESS
  location longitude                       = 15.450 deg.
  location latitude                        = 78.220 deg.
  location altitude                        = 0.100 km
  minimum elevation                        = 5.000 deg.


Objective Criterion:     Io                = -182.8 dBW/kHz

Interferer main lobe approximation         = ON
Interferer full spectrum calculation       = OFF
Doppler Assessment at Victim Receiver      = ON
Earth Oblateness Compensation              = ON


  Victim RX is in view of Victim TX for        22509.70 min  =    13.83 %
  Victim RX has a link to Victim TX for        17502.90 min  =    10.76 %

  Victim RX is in view of Interferer   1       22556.70 min  =    13.86 %
  Active Victim RX is in view of Interferer     2499.20 min  =    1.54 %
  Interfering RX is in view of Interferer      22569.00 min  =   13.87 %
  Active Victim RX receives Interference        2499.20 min  =    1.54 %

                                      No/Io        Es/Io      Es/(No+Io)
C/(N+I)
                                    ------------------------------------------
-----
  Objective Criterion in dB            5.96        10.97         4.00
17.00
  Objective Criterion not met         9.7887%      3.7325%      2.9378%
0.8404%
  Maximum criterion deviation (dB)    28.88        17.54        13.59
3.85
```

Number of events with criteria not met		306	150	134	41
Total duration of such events	(min)	1713.30	653.30	514.20	147.10
Shortest event duration	(min)	0.10	0.10	0.10	0.10
Longest event duration	(min)	12.90	12.90	12.90	12.50
Average duration of events	(min)	5.60	4.36	3.84	3.59
Number of events with criteria met		252	96	83	20
Shortest event duration	(min)	0.10	0.10	0.10	0.10
Longest event duration	(min)	13857.60	16106.20	16346.90	17250.10
Average duration of events	(min)	62.66	175.52	204.68	867.79

Annex 2 - INTERFERENCE ASSESSMENT SUMMARY EXAMPLE FOR 7.8 GHz

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------------
Set-Up File     = METOP-NPOESS-7800-2130-SVB-1s Date:
27.03.2004 - 15:09:48
Simulation time = 170.000 days   Time step = 1.00 s

VICTIM TRANSMITTER   =  Satellite  METOP
  semimajor axis                        = 7203.144 km
  eccentricity                          = 0.00000
  inclination angle                     = 98.714 deg.
  right ascension angle                 = 322.500 deg.
  argument of perigee                   = 0.000 deg.
  mean anomaly                          = 0.000 deg.
  satellite epoch                       = 24.02.2004 -
12:00:00
  RF power level                        = 14.30 dBW
  feeder loss                           = 2.50 dB
  antenna type                          = User-Design
  maximum antenna gain                  = 6.00  dBi
  transmitter frequency                 = 7.80000 GHz
  modulation                            = QPSK
  modulation index                      = 1.57  rad
  rel. carrier power level              = -12.000 dB
  rel. data power level                 = 0.000 dB
  subcarrier frequency                  = 0.000 kHz
  symbol rate                           = 63000.000 ks/s

VICTIM RECEIVER   =  Earth Station  Svalbard
  location longitude                    = 16.033 deg.
  location latitude                     = 78.158 deg.
  location altitude                     = 0.100 km
  minimum elevation                     = 5.000 deg.
  noise temperature                     = 180.00 K
  antenna type                          = Parabolic-APP 8
  maximum antenna gain                  = 55.07 dBi
  antenna diameter                      = 10.00 m
  antenna efficiency                    = 48.00 %
  RF data bandwidth                     = 63000.000 kHz
  data loop degradation                 = 1.000 dB
  carrier loop bandwidth                = 30.000 kHz
  carrier loop degradation              = 1.000 dB


INTERFERING TRANSMITTER  - 1  = Satellite  NPOESS
  semimajor axis                        = 7206.144 km
  eccentricity                          = 0.00000
  inclination angle                     = 98.727 deg.
```

```
  right ascension angle                    = 322.500 deg.
  argument of perigee                      = 0.000 deg.
  mean anomaly                             = 0.000 deg.
  satellite epoch                          = 24.02.2004 -
12:00:00
  RF power level                           = 19.00 dBW
  antenna type                             = User-Design
  maximum antenna gain                     = 6.00  dBi
  transmitter frequency                    = 7.81200 GHz
  modulation                               = QPSK
  modulation index                         = 1.57  rad
  rel. carrier power level                 = -12.000 dB
  rel. data power level                    = 0.000 dB
  subcarrier frequency                     = 0.000 kHz
  symbol rate                              = 35000.000 ks/s
  RF interferer bandwidth                  = 35000. kHz
  Polarisation discrimination              = 0.0 dB
  Environmental attenuation                = 0.0 dB
  Continuous Interference Transmission     = ON

INTERFERING RECEIVER  -   1  = Earth Station  Svalbard-NPOESS
  location longitude                       = 15.450 deg.
  location latitude                        = 78.220 deg.
  location altitude                        = 0.100 km
  minimum elevation                        = 5.000 deg.


Objective Criterion:     Io                = -182.0 dBW/kHz

Interferer main lobe approximation         = OFF
Interferer full spectrum calculation       = OFF
Doppler Assessment at Victim Receiver      = ON
Earth Oblateness Compensation              = ON


  Victim RX is in view of Victim TX for        33865.34 min  =    13.83 %
  Victim RX has a link to Victim TX for        26326.78 min  =    10.75 %

  Victim RX is in view of Interferer   1       33936.45 min  =    13.86 %
  Active Victim RX is in view of Interferer     3733.13 min  =    1.52 %
  Interfering RX is in view of Interferer      33959.14 min  =   13.87 %
  Active Victim RX receives Interference        3733.13 min  =    1.52 %

                                      No/Io        Es/Io      Es/(No+Io)
C/(N+I)
                                    ------------------------------------------
-----
  Objective Criterion in dB           6.00        13.97         7.00
17.00
  Objective Criterion not met        0.9540%      0.1909%      0.1433%
0.0662%
  Maximum criterion deviation (dB)   39.65        24.03        20.06
11.39
```

Number of events with criteria not met		69	37	23	2
Total duration of such events	(min)	251.15	50.27	37.72	17.42
Shortest event duration	(min)	0.02	0.02	0.03	7.78
Longest event duration	(min)	12.55	9.63	9.63	9.63
Average duration of events	(min)	3.64	1.36	1.64	8.71
Number of events with criteria met		35	30	18	2
Shortest event duration	(min)	0.02	0.03	0.02	17482.75
Longest event duration	(min)	17246.50	17439.23	17452.13	17482.75
Average duration of events	(min)	745.02	875.88	1460.50	13154.68