Report for GSMA on the mitigations required for adjacent channel compatibility between IMT and ubiquitous FSS Earth Stations in the 3.4 – 3.8 GHz frequency band

Transfinite systems
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1 Executive Summary

This study has investigated the mitigations necessary for successful compatibility between IMT services and FSS Earth Stations operating in adjacent frequency bands. By way of example, we consider a problem where IMT services operate in the 3.4 to 3.6 GHz frequency band and FSS Earth Stations operate in the adjacent 3.6 to 3.8 GHz band. However, the results presented in this report are applicable to other boundaries between IMT and FSS operating in C-band.

Since this is an adjacent band compatibility problem, the mitigation considered is based on frequency separation. We firstly perform a co-frequency interference analysis and then determine the Net Filter Discrimination available for a range of possible Guard Bands. These calculations rest on some assumptions regarding the IMT transmitter and FSS receiver spectrum masks.

We present some results which show that an 18 MHz Guard Band is sufficient to mitigate co-frequency interference. This analysis is based on the *median* I/N delivered by our co-frequency analysis, using an example I/N threshold of -10 dB and covering all of the spectrum mask combinations tested in the study. However, our results are presented in a comprehensive manner such that any I/N obtained in the co-frequency analysis and any I/N threshold may be considered for particular spectrum mask combinations or over the entire range of masks.

2 Introduction

In this study, funded by GSMA, we investigate a spectrum compatibility problem where IMT operates in a frequency band adjacent to that used by FSS. Specifically, we consider interference sourced from IMT outdoor Macro and outdoor Small Cell deployments, operating in the frequency band 3.4 to 3.6 GHz, incident to ubiquitous FSS Earth Stations operating in the 3.6 – 3.8 GHz frequency band.

Our focus is on the mitigations required in order for compatibility to be viable. Making some assumptions about the spectrum masks required at the IMT transmitter and FSS receiver, we determine the advantage obtained through frequency separation by calculating the Net Filter Discrimination (NFD) available. The impact of NFD on aggregate I/N at the victim receiver is calculated for a range of possible Guard Band values and we discuss the use of realistic Guard Bands, based on our results and for some example I/N thresholds at the victim receiver.

Further, we consider the problem of LNB overload by comparing long-term aggregate interference levels with the LNB overload threshold.

Whilst this is a very specific problem, it has some challenging features which are common to many other scenarios currently of interest in sharing and compatibility studies. Hence, the methodology described is of wider interest than just the problem at hand.

One challenge is related to the fact that most protection criteria include a threshold interference level that cannot be exceeded for more than a given percentage of time. In our approach this implies that we need a time domain simulation. However, not all variables in a general problem are time dependent, but they are still variable in the problem domain. For example, and pertinent to this study, many future systems will have a fixed infrastructure, the deployment of which is not known at the time decisions about compatibility must be made.

If these systems could impact existing services provided via ubiquitously located and/or unlicensed installations, it is very difficult to say whether there will be any geographic separation or main beam alignment between the two services.

The backstop approach taken by the incumbent services within ITU-R and CEPT is to make a series of worst case assumptions which will ensure the incumbent service suffers zero risk of interference.

This precautionary approach is useful but often mis-used. It can lead to regulatory bodies making binary statements about compatibility and sharing, whereas it is more useful to consider guidance about the circumstances under which sharing or compatibility are possible.

A national regulator needs to know the flip side of the risk of interference – which is the benefit of introducing a new service.

In the consideration of sharing spectrum between 5G IMT and C-band FSS Earth Stations, there are two deployments that are essentially fixed (static) but not known in detail. We need a methodology that allows the regulator to make an informed decision on spectrum sharing before the IMT is deployed and this methodology must be generally applicable and not location specific.

Our proposed approach is based on selecting a deployment which is at a quantifiable level of 'risk' and quantifying the associated 'benefit' from that level of risk. The risk is derived, in our approach, from a simulation model with all of its inherent approximations and simplifications. This is a popular approach in studies because the requirement is often to assess compatibility between an existing system and a proposed new system. The option to base an assessment on measurement or experience is simply not there in most cases.

3 Interference modelling

Using *Visualyse* software, we have simulated both urban Macro and Small Cells in a 5G network using an IMT network and an FSS Earth Station based in Pretoria, South Africa. We have a single test point FSS Earth Station with links to two satellites giving different elevation angles and worst azimuths.

3.1 FSS Parameters

The following parameters are used to represent a typical small dish in a high rise urban environment. We have considered two operational satellite locations – one gives a very low elevation angle of 5°and the other a more typical angle of 27.5°:

a) Central Location: – 25.73° S, 28.22° E (Pretoria, South Africa)
b) Operating Satellite Locations: 100.5°E and 22°W
c) Antenna Height: 30 m above terrain
d) Calculated Link angles:

- Link to 100.5°E – elevation = 5 °, azimuth = 84.17 °
- Link to 22° W – elevation = 27.5 °, azimuth = -70.12 °

e) Antenna Performance:

- Recommendation ITU-R S.465-16
- Dish Size = 1.8 m
- Efficiency = 65%

f) Link Temperature = 100 K
g) Bandwidth = 36 MHz.

The location of the Earth Station relative to the satellite is important only in that it determines the pointing angles of the antenna, and the results are dependent mainly on elevation angle. The fine details of the results are also dependent on the azimuth, but, given the Monte-Carlo elements we have introduced, the overall character of the results and conclusions are insensitive to azimuth.

We expect results to be worse for lower elevation antennas, where a number of IMT stations could be seen at higher gain values.

The 5° used is the operational minimum for FSS in C-band. At equatorial latitudes, all else being equal, Earth Station elevations will tend to be higher than at the latitudes studied so results could only improve – it is not likely that anywhere is served with a 5° elevation satellite. At higher latitudes, results would not be significantly different as we would still look at the minimum elevation angle.

3.2 IMT Parameters

For this study we use the Macro and Small Cell Base Station parameters summarised in Table 1.

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Table 1 **IMT parameters**

Base Station characteristics	Macro urban	Small Cell outdoor
Hexagonal Cell radius	0.3 km	1 per Macro site
Antenna height	20 m	6 m
Antenna pattern	64 element AAS	64 element AAS
Downtilt	10 degrees	10 degrees
Maximum Base Station output power	46 dBm	24 dBm
Maximum Base Station antenna gain	23.06 dBi	23.06 dBi
Bandwidth	80 MHz	80 MHz

3.3 Simulation Approach

The simulations contain two dynamic elements:

1 – Base Station antenna pointing;

2 – FSS Earth Station location.

The Base Station antenna has a fixed mechanical pointing with a downtilt of 10 degrees. For each Monte-Carlo sample in the *Visualyse* simulations, the antenna is electronically steered towards a single randomly located user within the service area. The electronically steerable antenna, which focusses power in the wanted direction is one of the main advantages that 5G systems have in the interference environment.

The Earth Station is randomly located over a 300 m hexagonal area at the centre of the IMT deployment.

The dynamic elements are combined in a Monte-Carlo simulation with 1 million samples.

The propagation model used is Recommendation ITU-R P.452-16 [1] plus the statistical clutter loss of Recommendation ITU-R P.2108 [2]. The percentage time is fixed at 20% (P.452) and the percentage of locations is fixed at 50% (P.2108).

Victim and interferer are initially tuned co-frequency and the results are statistics of I/N in the form of cumulative distribution functions based on the collection of I/N values in 1 dB bins.

3.4 Discussion

The model assumes the full transmit power of the Base Station is applied to a single link in each cell. This will result in an overestimation of the highest levels of interference. This is an acceptable approximation in the simulation and will result in a pessimistic view of the scenario.

The pathloss model used introduces some modelling anomalies in this scenario due to the fact that P.452 is valid only in the far field and the clutter model has a discontinuity at 250 m.

As applied, our model will overestimate the interference from Base Stations close to the Earth Station – at least in a statistical sense. We know that it is possible for very extreme geometries to result in high I/N values but the number of such cases in our simulation will be an overestimate, skewing the I/N distribution to the high end.

One way to understand this is to consider what happens at 0 m separation and at 250 m separation between victim receiver and interfering transmitter. Zero separation implies that the IMT Base Station is on the side of a building at around 20 m height and that the Earth Station is on the same building, on the roof at 30 m height. Our model would include no clutter loss and a very low value of P.452 pathloss in this case. This is obviously incorrect.

At 251 m the model includes around 28 dB of urban clutter loss in the median case. At 250 m this value becomes 0 dB, which is a physically unrealistic discontinuity.

In the scenario considered, we might expect clutter loss to decrease at very small distances but only due to some divergence from best practice by the installation engineer.

Whilst very difficult to quantify, it is clear that the distribution of I/N is further skewed to the high end by this clutter discontinuity effect.

In our analysis we are using the I/N value obtained in at least 50% of all possible deployments. Taking into account the anomalies and approximations in the model, this means that the majority of FSS locations will be protected by the Guard Bands we derive. However, this 50% value is arbitrary and could be a useful risk parameter for a regulator to select, when considering the benefits of making spectrum available for a new service. The results from this study are presented in a comprehensive manner such that I/Ns above or below the median value given in the co-frequency analysis may be considered in relation to NFD and the offset I/Ns obtained for discrete frequency separations between FSS receiver and IMT transmitter.

3.5 Results

The cumulative distributions of I/N for the outdoor Macro and Small Cell cases are shown in Figures 1 and 2 and the 50% sample values are given in Table 2.

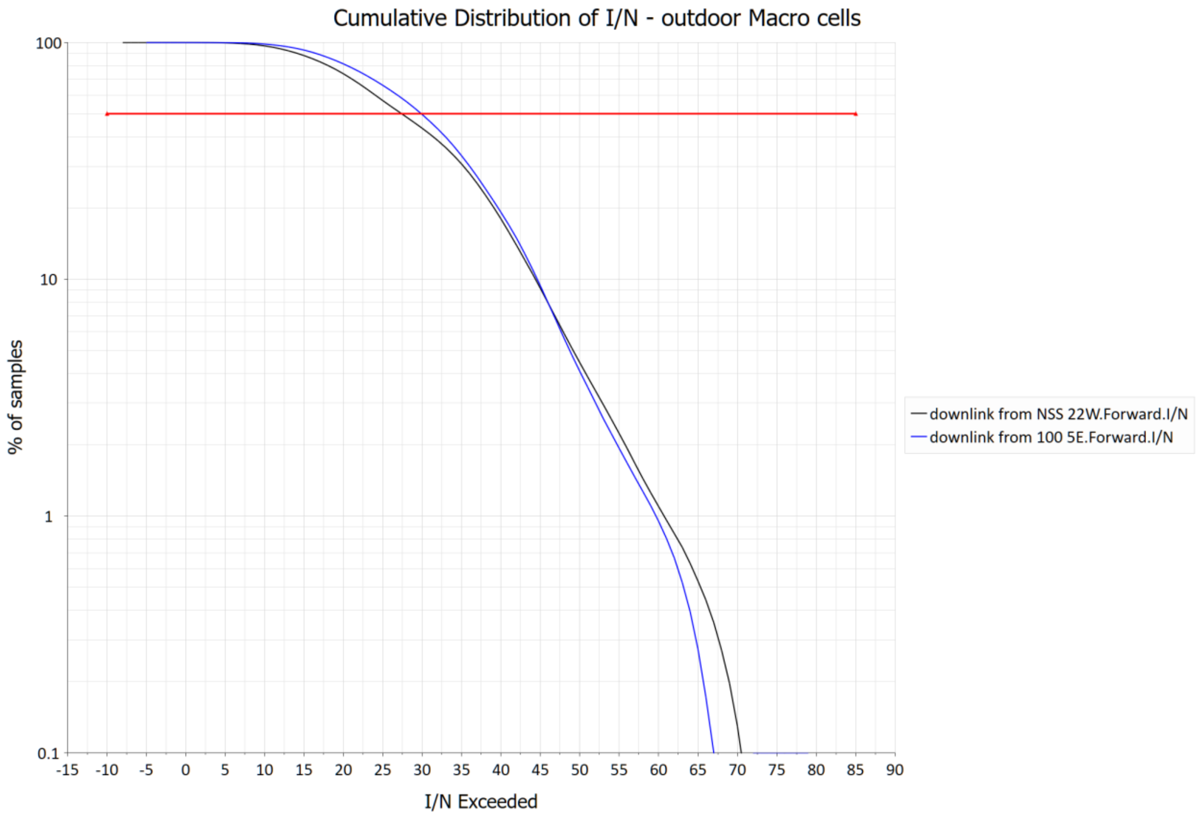

Figure 1 **I/N exceedance for outdoor Macro Cells**

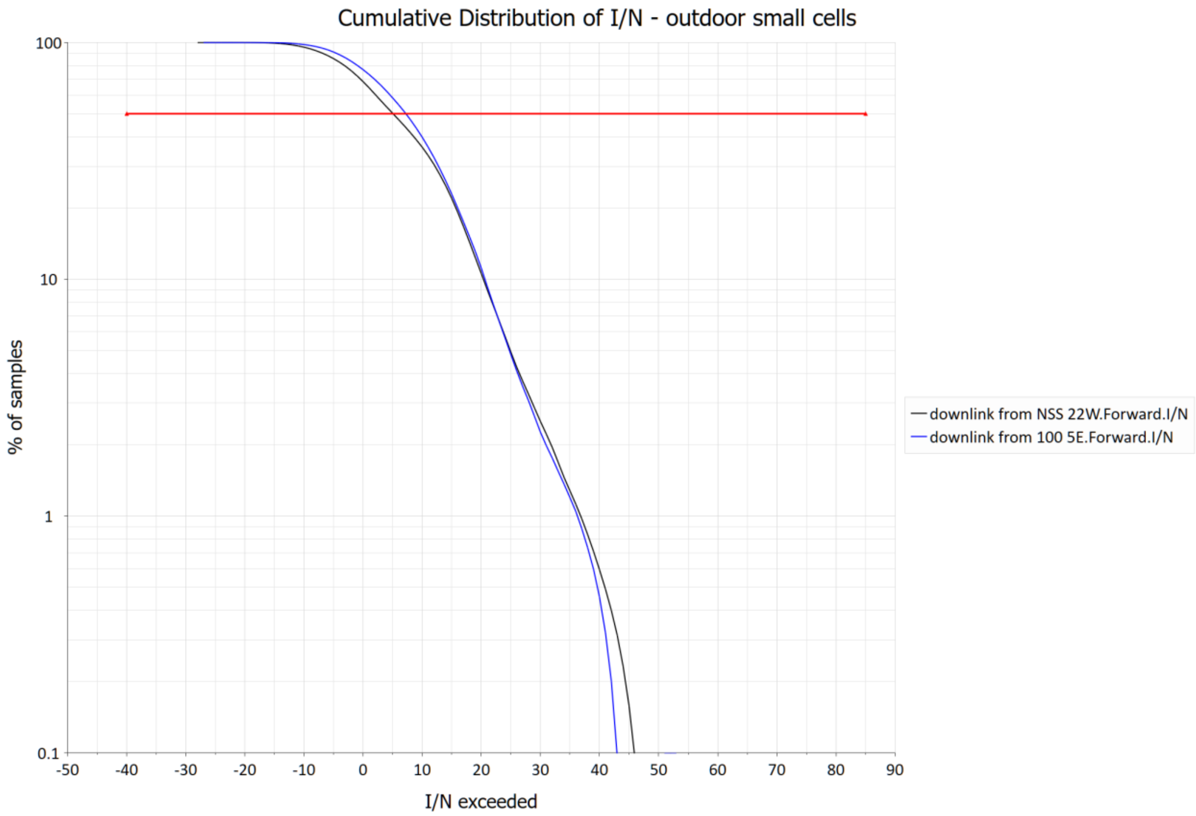

Figure 2 **I/N exceedance for outdoor Small Cells**

Table 2 **aggregate I/N not exceeded for 50% of Monte-Carlo samples**

	Satellite at 22 W	Satellite at 100.5 E
Macro network	27.5 dB	30 dB
Small Cell network	5 dB	7.5 dB

4 Net Filter discrimination and offset I/N

The interference scenarios outlined in Section 3 were simulated with the IMT transmitter and FSS receiver tuned co-frequency, delivering an aggregate I/N at the FSS victim receiver which we denote by $\Sigma I/N$. However, we are investigating a compatibility problem where a frequency offset between interferer and victim receiver *always* exists. Therefore, we calculate NFD using the well-established method specified by ETSI [3]. This approach is widely used in sharing studies, academic investigations and practical frequency assignment work [4, 5, 6].

The ETSI method rests on an integration of transmitter and receiver spectrum masks in the frequency domain at discrete frequency offsets. NFD is calculated and expressed in dB using:

Equation 1

$$NFD = 10 \cdot Log\left(\left[\int_{f_0-\Delta_-}^{f_0+\Delta_+} 10^{\left(\frac{Tc+Rc}{10}\right)} \cdot df\right] / \left[\int_{f_0-\Delta_-}^{f_0+\Delta_+} 10^{\left(\frac{To+Rc}{10}\right)} \cdot df\right]\right)$$

where:
Tc is the transmitter spectrum mask sampled co-frequency;
Rc is the receiver spectrum mask sampled co-frequency;
To is the transmitter spectrum mask sampled at some frequency offset from the receiver;
f_0 is the receiver centre frequency;
Δ_- is the delta required for a suitable lower frequency bound on the spectrum masks;
Δ_+ is the delta required for a suitable upper frequency bound on the spectrum masks.

In scenarios where the interfering transmitter's bandwidth is greater than that of the victim receiver's, not all of the interferer's power can be incident to the victim receiver and the NFD procedure includes a bandwidth correction factor, expressed in dB, such that:

Equation 2

$$bwcf = 10 \cdot log\left(\frac{b_{rx}}{b_{tx}}\right)$$

where:
$bwcf$ is the bandwidth correction factor;
b_{rx} is the receiver bandwidth;
b_{tx} is the transmitter bandwidth.

In our *Visualyse* simulations, the FSS receiver's bandwidth = 36 MHz and the IMT interferer's bandwidth = 80 MHz. Hence, $bwcf$ = -3.47 dB.

For this procedure, radio spectrum transmit masks for IMT Macro and Small Cell Base Stations were sourced from the 3GPP Technical Specification [7]. Following the ETSI

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methodology for the calculation of NFD, we adjust these masks, specifying attenuation relative to in-band performance as shown in Figures 3 and 4; that is, with 0 dB attenuation in the assigned channel.

However, these masks are considered to be conservative (unwanted emissions levels may be below the limits given in [7]) and while used in the NFD calculations, they were also adapted in order to capture the performance of real-World systems. Two alternative versions of the 3GPP masks were specified with an extra 10 dB and 20 dB of attenuation over all values of the mask less than 0 dB.

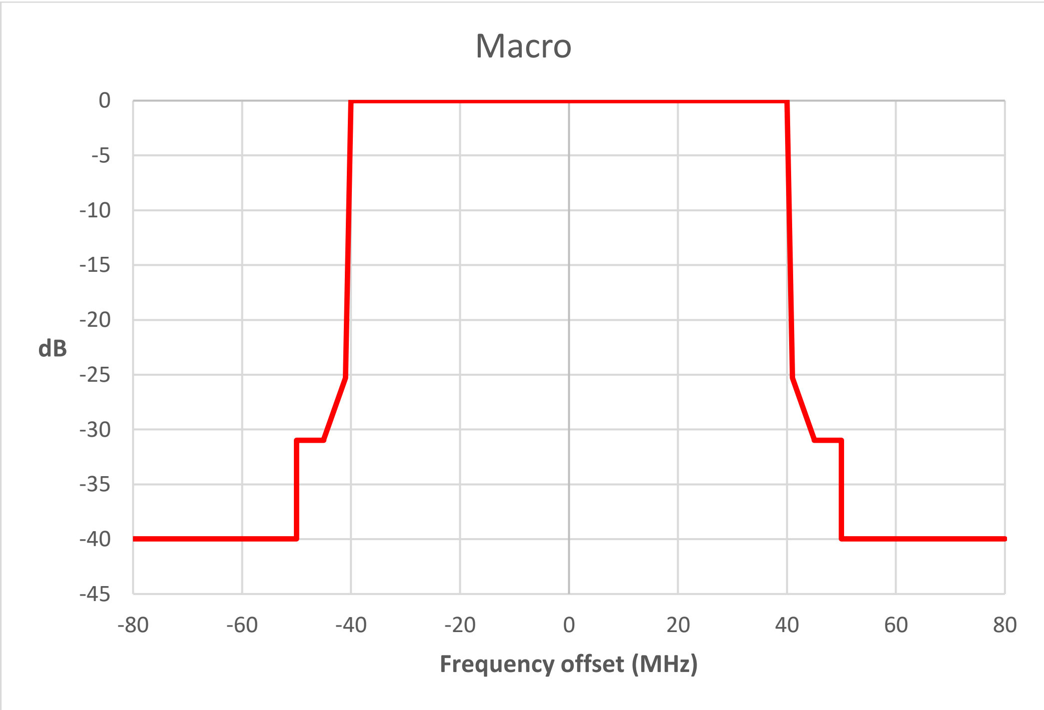

Figure 3 **IMT Macro Cell spectrum mask**

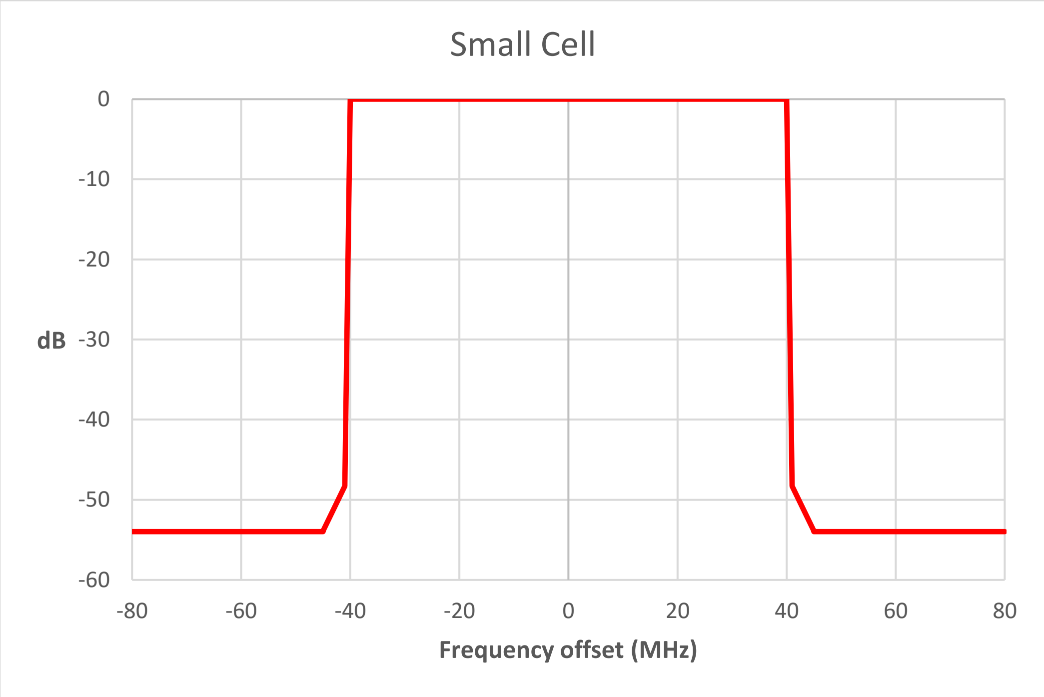

Figure 4 **IMT Small Cell spectrum mask**

FSS receiver spectrum masks are difficult to source and this is a persistent problem in sharing and compatibility studies as well as in practical frequency assignment and coordination work. However, theoretical spectrum masks can be used in studies [8], and *default* masks are a feature of practical frequency assignment and coordination work in cases where spectrum mask data is unavailable [4]. In this study, we use an FSS spectrum mask used in a study by the Info-Communications Development Authority (IDA) of Singapore and reported on in [9] and a range of Gaussian masks that extend two times channel bandwidth with attenuation of -30 dB, -40 dB, -50 dB and -60 dB specified at the end-points of the Gaussian distribution. The IDA mask and a Gaussian mask with -30 dB at the end points are shown in Figures 5 and 6.

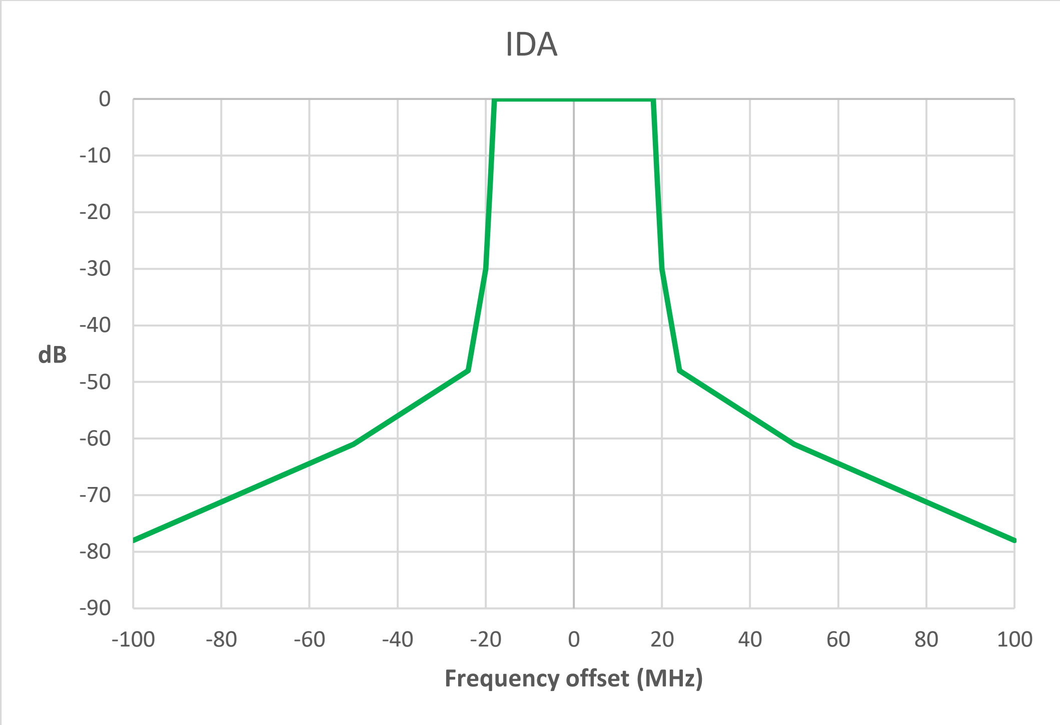

Figure 5 **IDA spectrum mask**

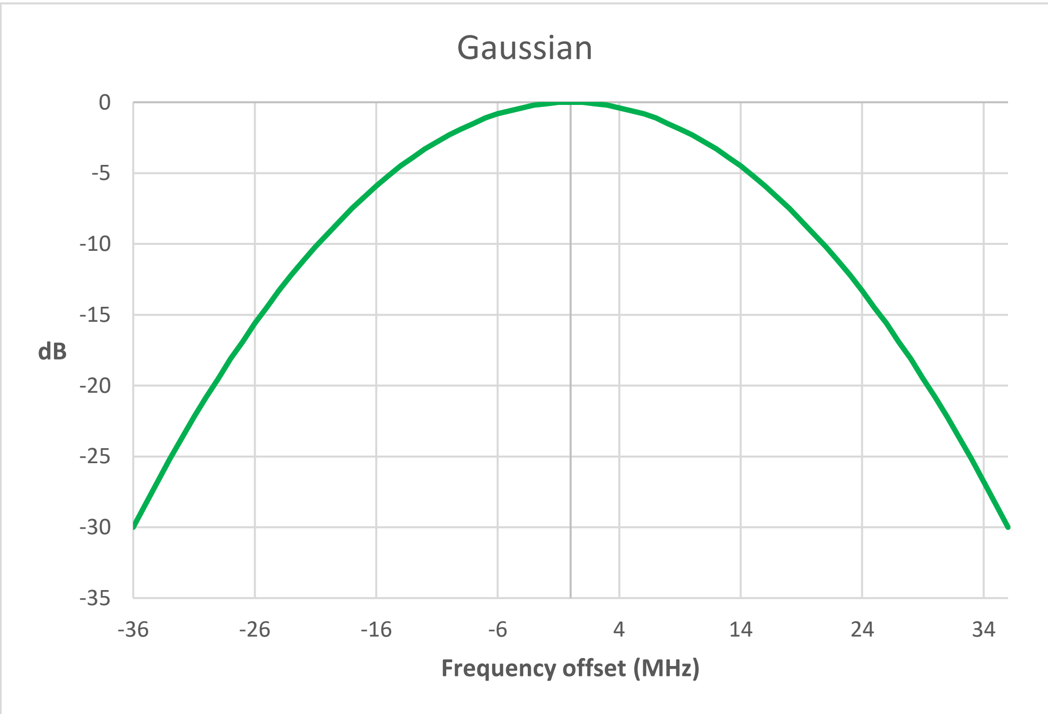

Figure 6 **Gaussian spectrum mask**

The minimum separation between the carrier centre frequencies of an IMT and FSS system is given by:

Equation 3

$$\Delta f_{min} = \frac{b_{FSS}}{2} + \frac{b_{IMT}}{2}$$

where b_{FSS} and b_{IMT} are the channel bandwidths of the FSS receiver and IMT transmitter, respectively. In these studies, the IMT system operates in an 80 MHz channel and the FSS system in a 36 MHz channel, hence Δf_{min} = 58 MHz.

When a Guard Band is introduced then frequency separation is calculated using:

Equation 4

$$\Delta f = \Delta f_{min} + b_{GB}$$

and b_{GB} is the extent of the Guard Band. We consider b_{GB} in the range 0 to 40 MHz in increments of 2 MHz.

Having determined NFD over the range of b_{GB} considered, we calculate a revised ΣI/N obtained through frequency separation using:

Equation 5

$$\Sigma I/N_{off} = \Sigma I/N_{co} - NFD(\Delta f).$$

Here, $\Sigma I/N_{off}$ is ΣI/N when the interferer is offset in frequency from the victim receiver, $\Sigma I/N_{co}$ is ΣI/N for the baseline co-frequency case (Table 2) and $NFD(\Delta f)$ is the NFD available at the discrete frequency separation Δf.

5 Results from the NFD analysis

We present results for NFD for the range of Guard Band values considered where the IDA mask and each of the Gaussian masks is used in combination with the masks specified by 3GPP. We also use the alternative versions of the 3GPP masks in combination with both the IDA and -60 dB Gaussian masks.

Using the NFD results from this study and results for aggregate interference obtained in our interference simulations, we calculate and present Tables of $\Sigma I/N_{off}$ over the range of Guard Bands studied. These results can be compared against any threshold for I/N but we have colour coded our results to show which Guard Bands allow the example threshold I/N = -10 dB to be satisfied (Green when satisfied). This corresponds to a 10% degradation of noise at the victim receiver and an interference margin of 0.41 dB.

Table 4 shows the NFD obtained when the IMT spectrum mask associated with Macro deployments is used in combination with the Gaussian and IDA masks considered in the study. In addition, NFD is calculated using the two alternative IMT masks in combination with the –60 dB Gaussian and IDA masks. Tables 5 and 6 show the $\Sigma I/N_{off}$ values obtained when co-frequency aggregate interference obtained in the simulations is attenuated by NFD for the two FSS links considered. We can see that Guard Bands of 16 MHz and 18 MHz are required in order that a threshold I/N = -10 dB is satisfied *over all* combinations of spectrum masks. Therefore, our results indicate that a 18 MHz Guard Band would allow an FSS protection criterion of $\Sigma I/N_{thresh}$ = -10 dB to be satisfied on both of the FSS links, over all combinations of spectrum masks considered in this study.

Table 7 shows the NFD obtained when the IMT spectrum mask associated with Small Cell deployments is used in combination with the Gaussian and IDA masks. Again, NFD is calculated using the two alternative IMT masks combined with the – 60 dB Gaussian and IDA masks. Tables 8 and 9 show the $\Sigma I/N_{off}$ values obtained for the two FSS links. Here, a 0 MHz Guard Band allows for a threshold I/N = -10 dB to be satisfied over all combinations of spectrum masks.

We define margin, $M,$ as the delta between the I/N threshold and $\Sigma I/N_{off}$. Negative values for M indicate additional I/N is available from the Guard Band once the threshold is satisfied. That is:

Equation 6

$$M = \Sigma I/N_{off} - \Sigma I/N_{thresh}.$$

In the presentation of these results, $\Sigma I/N_{thresh}$ is the threshold of -10 dB.

If we consider an 18 MHz Guard Band for the Macro problem, Tables 5 and 6 show that M is in the range -3.02 to -22.86 dB over both FSS links and the range of spectrum mask combinations considered. For the Small Cell problem, Tables 8 and 9 indicate that a 0 MHz Guard Band delivers M in the range -0.91 to -8.61 dB over both FSS links and the range of spectrum mask combinations considered.

Although the results for $\Sigma I/N_{off}$ are coloured to indicate when $\Sigma I/N_{thresh}$ = - 10 dB is satisfied, the results are presented such that any value for $\Sigma I/N_{thresh}$ can be considered and M evaluated. If, say, we select $\Sigma I/N_{thresh}$ = - 12.2 dB, corresponding to a 6% degradation of noise at the victim receiver and an interference margin of 0.25 dB, we can see that a Guard Band of 18 MHz will also satisfy this criterion for the Macro analysis over both links and all combinations of masks with M now in the range -0.82 to -20.66 dB. For the Small Cell analysis, this threshold is satisfied over both links and all combinations of masks with a Guard Band of 2 MHz and with M in the range -2.99 to -33.41 dB.

We may also wish to consider alternative I/Ns from the co-frequency analysis. Let us say that, from Figure 1, we select the I/N = 43 dB exceeded for no more than 10% of Monte-Carlo samples in the simulation of Macro Cell interference incident to the Earth Station linked to a satellite at 22 degrees West. This means we have a co-frequency I/N that is 15.5 dB higher than that used in our Table 5 analysis. However, looking at Table 5 and running Equation 6 for M we can see that a 16 MHz Guard Band is still possible for four of the spectrum mask combinations . That is, in cases where $\Sigma I/N_{thresh}$ is satisfied and $M \leq -15.5$ dB.

5.1 LNB Overload

In this study, we also test aggregate long-term interference against a threshold for LNB overload. We calculate aggregate interference incident to the FSS receiver, expressed in dBm, using:

Equation 7

$$\Sigma I_{off} = N + \Sigma I/N_{off}$$

where:
ΣI_{off} = aggregate interference when interferers are offset in frequency (dBm);
N = Noise in the receiver's bandwidth (dBm);
$\Sigma I/N_{off}$ = aggregate I/N when interferers are offset in frequency (dB).

Noise at the FSS receiver, expressed in dBm, is given by:

Equation 8

$$N = 10 \cdot log(kTB) + 30$$

where:
k= Boltzmann's Constant ($J.K^{-1}$);

T= Temperature (Kelvin);
B= receiver bandwidth (Hz);

Therefore, for k = 1.38*10^{-23} J.K^{-1} , T = 100 Kelvin and B = 36*10^{6} Hz, N = -103 dBm.

According to [10], the LNB 1 dB compression point corresponds to a signal level of -50 dBm at the LNB input but with non-linear behaviour apparent at -60 dBm. Therefore, we test aggregate interference against an overload threshold O_{thresh} = -60 dBm which has also been used in other studies [11,12]. Clearly, this threshold is satisfied in our analysis when:

$$\Sigma I_{off} \leq O_{thresh}.$$

Our results are presented in Tables 10 to 13 where we show values for ΣI_{off}. These results are coloured green when O_{thresh} is satisfied. We can see that, for the long-term interference considered in our study, O_{thresh} is always satisfied.

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Table 3 NFD(Δf) for the IMT Macro Cell case

Guard Band (MHz)	$NFD(\Delta f)$ Macro vs -30 dB Gauss (dB)	$NFD(\Delta f)$ Macro vs -40 dB Gauss (dB)	$NFD(\Delta f)$ Macro vs -50 dB Gauss (dB)	$NFD(\Delta f)$ Macro vs -60 dB Gauss (dB)	$NFD(\Delta f)$ Macro -10 vs -60 dB Gauss (dB)	$NFD(\Delta f)$ Macro -20 vs -60 dB Gauss (dB)	$NFD(\Delta f)$ Macro vs IDA (dB)	$NFD(\Delta f)$ Macro -10 vs IDA (dB)	$NFD(\Delta f)$ Macro -20 vs IDA (dB)
0	18.29	21.15	23.92	26.62	26.88	26.95	22.34	22.92	23.23
2	20.36	23.80	27.13	30.33	30.74	30.83	37.93	45.18	47.80
4	22.59	26.67	30.55	34.17	34.93	35.06	39.73	48.68	53.74
6	25.01	29.72	34.05	37.81	39.37	39.62	40.76	50.01	55.89
8	27.58	32.87	37.42	40.70	43.94	44.52	41.78	51.02	56.89
10	30.33	36.02	40.22	42.39	48.17	49.65	43.10	52.29	57.97
12	33.24	38.90	42.07	43.11	51.28	54.86	43.35	52.65	58.70
14	36.34	41.18	42.97	43.35	52.79	59.42	43.37	52.80	59.31
16	39.61	42.64	43.31	43.42	53.30	62.30	43.38	52.91	59.86
18	43.02	43.37	43.43	43.44	53.43	63.41	43.39	53.01	60.36
20	43.38	43.43	43.44	43.44	53.44	63.44	43.40	53.09	60.80
22	43.41	43.43	43.44	43.44	53.44	63.44	43.41	53.15	61.18
24	43.43	43.44	43.44	43.44	53.44	63.44	43.41	53.20	61.51
26	43.43	43.44	43.44	43.44	53.44	63.44	43.42	53.24	61.79
28	43.44	43.44	43.44	43.44	53.44	63.44	43.42	53.27	62.03
30	43.44	43.44	43.44	43.44	53.44	63.44	43.42	53.30	62.23
32	43.44	43.44	43.44	43.44	53.44	63.44	43.43	53.32	62.39
34	43.44	43.44	43.44	43.44	53.44	63.44	43.43	53.34	62.53
36	43.44	43.44	43.44	43.44	53.44	63.44	43.43	53.35	62.66
38	43.44	43.44	43.44	43.44	53.44	63.44	43.43	53.37	62.76
40	43.44	43.44	43.44	43.44	53.44	63.44	43.43	53.38	62.86

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Table 4 $\Sigma I/N_{off}$ for aggregate interference from IMT Macro Cells incident to an FSS Earth Station linked to a satellite 22 degrees West

Guard Band (MHz)	$\Sigma I/N_{off}$ Macro vs -30 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro vs -40 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro vs -50 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro -10 vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro -20 vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro vs IDA (dB)	$\Sigma I/N_{off}$ Macro -10 vs IDA (dB)	$\Sigma I/N_{off}$ Macro -20 vs IDA (dB)
0	9.21	6.35	3.58	0.88	0.62	0.55	5.16	4.58	4.27
2	7.14	3.70	0.37	-2.83	-3.24	-3.33	-10.43	-17.68	-20.30
4	4.91	0.83	-3.05	-6.67	-7.43	-7.56	-12.23	-21.18	-26.24
6	2.49	-2.22	-6.55	-10.31	-11.87	-12.12	-13.26	-22.51	-28.39
8	-0.08	-5.37	-9.92	-13.20	-16.44	-17.02	-14.28	-23.52	-29.39
10	-2.83	-8.52	-12.72	-14.89	-20.67	-22.15	-15.60	-24.79	-30.47
12	-5.74	-11.40	-14.57	-15.61	-23.78	-27.36	-15.85	-25.15	-31.20
14	-8.84	-13.68	-15.47	-15.85	-25.29	-31.92	-15.87	-25.30	-31.81
16	-12.11	-15.14	-15.81	-15.92	-25.80	-34.80	-15.88	-25.41	-32.36
18	-15.52	-15.87	-15.93	-15.94	-25.93	-35.91	-15.89	-25.51	-32.86
20	-15.88	-15.93	-15.94	-15.94	-25.94	-35.94	-15.90	-25.59	-33.30
22	-15.91	-15.93	-15.94	-15.94	-25.94	-35.94	-15.91	-25.65	-33.68
24	-15.93	-15.94	-15.94	-15.94	-25.94	-35.94	-15.91	-25.70	-34.01
26	-15.93	-15.94	-15.94	-15.94	-25.94	-35.94	-15.92	-25.74	-34.29
28	-15.94	-15.94	-15.94	-15.94	-25.94	-35.94	-15.92	-25.77	-34.53
30	-15.94	-15.94	-15.94	-15.94	-25.94	-35.94	-15.92	-25.80	-34.73
32	-15.94	-15.94	-15.94	-15.94	-25.94	-35.94	-15.93	-25.82	-34.89
34	-15.94	-15.94	-15.94	-15.94	-25.94	-35.94	-15.93	-25.84	-35.03
36	-15.94	-15.94	-15.94	-15.94	-25.94	-35.94	-15.93	-25.85	-35.16
38	-15.94	-15.94	-15.94	-15.94	-25.94	-35.94	-15.93	-25.87	-35.26
40	-15.94	-15.94	-15.94	-15.94	-25.94	-35.94	-15.93	-25.88	-35.36

Table 5 $\Sigma I/N_{off}$ **for aggregate interference from IMT Macro Cells incident to an FSS Earth Station linked to a satellite 100.5 degrees East**

Guard Band (MHz)	$\Sigma I/N_{off}$ Macro vs -30 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro vs -40 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro vs -50 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro -10 vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro -20 vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Macro vs IDA (dB)	$\Sigma I/N_{off}$ Macro -10 vs IDA (dB)	$\Sigma I/N_{off}$ Macro -20 vs IDA (dB)
0	11.71	8.85	6.08	3.38	3.12	3.05	7.66	7.08	6.77
2	9.64	6.20	2.87	-0.33	-0.74	-0.83	-7.93	-15.18	-17.80
4	7.41	3.33	-0.55	-4.17	-4.93	-5.06	-9.73	-18.68	-23.74
6	4.99	0.28	-4.05	-7.81	-9.37	-9.62	-10.76	-20.01	-25.89
8	2.42	-2.87	-7.42	-10.70	-13.94	-14.52	-11.78	-21.02	-26.89
10	-0.33	-6.02	-10.22	-12.39	-18.17	-19.65	-13.10	-22.29	-27.97
12	-3.24	-8.90	-12.07	-13.11	-21.28	-24.86	-13.35	-22.65	-28.70
14	-6.34	-11.18	-12.97	-13.35	-22.79	-29.42	-13.37	-22.80	-29.31
16	-9.61	-12.64	-13.31	-13.42	-23.30	-32.30	-13.38	-22.91	-29.86
18	-13.02	-13.37	-13.43	-13.44	-23.43	-33.41	-13.39	-23.01	-30.36
20	-13.38	-13.43	-13.44	-13.44	-23.44	-33.44	-13.40	-23.09	-30.80
22	-13.41	-13.43	-13.44	-13.44	-23.44	-33.44	-13.41	-23.15	-31.18
24	-13.43	-13.44	-13.44	-13.44	-23.44	-33.44	-13.41	-23.20	-31.51
26	-13.43	-13.44	-13.44	-13.44	-23.44	-33.44	-13.42	-23.24	-31.79
28	-13.44	-13.44	-13.44	-13.44	-23.44	-33.44	-13.42	-23.27	-32.03
30	-13.44	-13.44	-13.44	-13.44	-23.44	-33.44	-13.42	-23.30	-32.23
32	-13.44	-13.44	-13.44	-13.44	-23.44	-33.44	-13.43	-23.32	-32.39
34	-13.44	-13.44	-13.44	-13.44	-23.44	-33.44	-13.43	-23.34	-32.53
36	-13.44	-13.44	-13.44	-13.44	-23.44	-33.44	-13.43	-23.35	-32.66
38	-13.44	-13.44	-13.44	-13.44	-23.44	-33.44	-13.43	-23.37	-32.76
40	-13.44	-13.44	-13.44	-13.44	-23.44	-33.44	-13.43	-23.38	-32.86

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Table 6 NFD(Δf) for the IMT Small Cell case

Guard Band (MHz)	$NFD(\Delta f)$ Small Cell vs -30 dB Gauss (dB)	$NFD(\Delta f)$ Small Cell vs -40 dB Gauss (dB)	$NFD(\Delta f)$ Small Cell vs -50 dB Gauss (dB)	$NFD(\Delta f)$ Small Cell vs -60 dB Gauss (dB)	$NFD(\Delta f)$ Small Cell -10 vs -60 dB Gauss (dB)	$NFD(\Delta f)$ Small Cell -20 vs -60 dB Gauss (dB)	$NFD(\Delta f)$ Small Cell vs IDA (dB)	$NFD(\Delta f)$ Small Cell -10 vs IDA (dB)	$NFD(\Delta f)$ Small Cell -20 vs IDA (dB)
0	18.41	21.31	24.16	26.96	26.99	27.01	23.30	23.48	23.61
2	20.49	24.01	27.45	30.83	30.88	30.90	47.71	48.29	48.41
4	22.75	26.94	31.02	35.06	35.12	35.14	53.00	54.76	55.00
6	25.21	30.11	34.86	39.58	39.69	39.72	54.49	57.15	57.54
8	27.85	33.49	38.98	44.37	44.61	44.66	54.95	58.03	58.51
10	30.72	37.12	43.31	49.16	49.82	49.92	55.35	58.88	59.46
12	33.86	41.02	47.81	53.37	55.30	55.58	55.69	59.69	60.41
14	37.50	45.26	52.08	56.04	60.67	61.62	55.98	60.47	61.34
16	42.20	50.13	55.48	57.13	65.06	68.29	56.23	61.20	62.26
18	54.52	56.98	57.38	57.43	67.39	77.03	56.44	61.89	63.15
20	57.44	57.44	57.44	57.44	67.44	77.44	56.61	62.53	64.02
22	57.44	57.44	57.44	57.44	67.44	77.44	56.75	63.11	64.87
24	57.44	57.44	57.44	57.44	67.44	77.44	56.87	63.64	65.68
26	57.44	57.44	57.44	57.44	67.44	77.44	56.96	64.10	66.46
28	57.44	57.44	57.44	57.44	67.44	77.44	57.04	64.52	67.19
30	57.44	57.44	57.44	57.44	67.44	77.44	57.10	64.87	67.88
32	57.44	57.44	57.44	57.44	67.44	77.44	57.15	65.18	68.51
34	57.44	57.44	57.44	57.44	67.44	77.44	57.19	65.45	69.11
36	57.44	57.44	57.44	57.44	67.44	77.44	57.23	65.69	69.70
38	57.44	57.44	57.44	57.44	67.44	77.44	57.26	65.91	70.27
40	57.44	57.44	57.44	57.44	67.44	77.44	57.29	66.11	70.83

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Table 7 $\Sigma I/N_{off}$ for aggregate interference from IMT Small Cells incident to an FSS Earth Station linked to a satellite 22 degrees West

Guard Band (MHz)	$\Sigma I/N_{off}$ Small Cell vs -30 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell vs -40 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell vs -50 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell -10 vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell -20 vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell vs IDA (dB)	$\Sigma I/N_{off}$ Small Cell -10 vs IDA (dB)	$\Sigma I/N_{off}$ Small Cell -20 vs IDA (dB)
0	-13.41	-16.31	-19.16	-21.96	-21.99	-22.01	-18.30	-18.48	-18.61
2	-15.49	-19.01	-22.45	-25.83	-25.88	-25.90	-42.71	-43.29	-43.41
4	-17.75	-21.94	-26.02	-30.06	-30.12	-30.14	-48.00	-49.76	-50.00
6	-20.21	-25.11	-29.86	-34.58	-34.69	-34.72	-49.49	-52.15	-52.54
8	-22.85	-28.49	-33.98	-39.37	-39.61	-39.66	-49.95	-53.03	-53.51
10	-25.72	-32.12	-38.31	-44.16	-44.82	-44.92	-50.35	-53.88	-54.46
12	-28.86	-36.02	-42.81	-48.37	-50.30	-50.58	-50.69	-54.69	-55.41
14	-32.50	-40.26	-47.08	-51.04	-55.67	-56.62	-50.98	-55.47	-56.34
16	-37.20	-45.13	-50.48	-52.13	-60.06	-63.29	-51.23	-56.20	-57.26
18	-49.52	-51.98	-52.38	-52.43	-62.39	-72.03	-51.44	-56.89	-58.15
20	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-51.61	-57.53	-59.02
22	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-51.75	-58.11	-59.87
24	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-51.87	-58.64	-60.68
26	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-51.96	-59.10	-61.46
28	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-52.04	-59.52	-62.19
30	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-52.10	-59.87	-62.88
32	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-52.15	-60.18	-63.51
34	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-52.19	-60.45	-64.11
36	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-52.23	-60.69	-64.70
38	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-52.26	-60.91	-65.27
40	-52.44	-52.44	-52.44	-52.44	-62.44	-72.44	-52.29	-61.11	-65.83

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Table 8 $\Sigma I/N_{off}$ for aggregate interference from IMT Small Cells incident to an FSS Earth Station linked to a satellite 100.5 degrees East

Guard Band (MHz)	$\Sigma I/N_{off}$ Small Cell vs -30 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell vs -40 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell vs -50 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell -10 vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell -20 vs -60 dB Gauss (dB)	$\Sigma I/N_{off}$ Small Cell vs IDA (dB)	$\Sigma I/N_{off}$ Small Cell -10 vs IDA (dB)	$\Sigma I/N_{off}$ Small Cell -20 vs IDA (dB)
0	-10.91	-13.81	-16.66	-19.46	-19.49	-19.51	-15.80	-15.98	-16.11
2	-12.99	-16.51	-19.95	-23.33	-23.38	-23.40	-40.21	-40.79	-40.91
4	-15.25	-19.44	-23.52	-27.56	-27.62	-27.64	-45.50	-47.26	-47.50
6	-17.71	-22.61	-27.36	-32.08	-32.19	-32.22	-46.99	-49.65	-50.04
8	-20.35	-25.99	-31.48	-36.87	-37.11	-37.16	-47.45	-50.53	-51.01
10	-23.22	-29.62	-35.81	-41.66	-42.32	-42.42	-47.85	-51.38	-51.96
12	-26.36	-33.52	-40.31	-45.87	-47.80	-48.08	-48.19	-52.19	-52.91
14	-30.00	-37.76	-44.58	-48.54	-53.17	-54.12	-48.48	-52.97	-53.84
16	-34.70	-42.63	-47.98	-49.63	-57.56	-60.79	-48.73	-53.70	-54.76
18	-47.02	-49.48	-49.88	-49.93	-59.89	-69.53	-48.94	-54.39	-55.65
20	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.11	-55.03	-56.52
22	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.25	-55.61	-57.37
24	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.37	-56.14	-58.18
26	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.46	-56.60	-58.96
28	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.54	-57.02	-59.69
30	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.60	-57.37	-60.38
32	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.65	-57.68	-61.01
34	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.69	-57.95	-61.61
36	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.73	-58.19	-62.20
38	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.76	-58.41	-62.77
40	-49.94	-49.94	-49.94	-49.94	-59.94	-69.94	-49.79	-58.61	-63.33

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Table 9 ΣI_{off} sourced from IMT Macro Cells incident to an FSS Earth Station linked to a satellite 22 degrees West

Guard Band (MHz)	ΣI_{off} Macro vs -30 dB Gauss (dBm)	ΣI_{off} Macro vs -40 dB Gauss (dBm)	ΣI_{off} Macro vs -50 dB Gauss (dBm)	ΣI_{off} Macro vs -60 dB Gauss (dBm)	ΣI_{off} Macro-10 vs -60 dB Gauss (dBm)	ΣI_{off} Macro -20 vs -60 dB Gauss (dBm)	ΣI_{off} Macro vs IDA (dBm)	ΣI_{off} Macro -10 vs IDA (dBm)	ΣI_{off} Macro -20 vs IDA (dBm)
0	-93.79	-96.65	-99.42	-102.12	-102.38	-102.45	-97.84	-98.42	-98.73
2	-95.86	-99.30	-102.63	-105.83	-106.24	-106.33	-113.43	-120.68	-123.30
4	-98.09	-102.17	-106.05	-109.67	-110.43	-110.56	-115.23	-124.18	-129.24
6	-100.51	-105.22	-109.55	-113.31	-114.87	-115.12	-116.26	-125.51	-131.39
8	-103.08	-108.37	-112.92	-116.20	-119.44	-120.02	-117.28	-126.52	-132.39
10	-105.83	-111.52	-115.72	-117.89	-123.67	-125.15	-118.60	-127.79	-133.47
12	-108.74	-114.40	-117.57	-118.61	-126.78	-130.36	-118.85	-128.15	-134.20
14	-111.84	-116.68	-118.47	-118.85	-128.29	-134.92	-118.87	-128.30	-134.81
16	-115.11	-118.14	-118.81	-118.92	-128.80	-137.80	-118.88	-128.41	-135.36
18	-118.52	-118.87	-118.93	-118.94	-128.93	-138.91	-118.89	-128.51	-135.86
20	-118.88	-118.93	-118.94	-118.94	-128.94	-138.94	-118.90	-128.59	-136.30
22	-118.91	-118.93	-118.94	-118.94	-128.94	-138.94	-118.91	-128.65	-136.68
24	-118.93	-118.94	-118.94	-118.94	-128.94	-138.94	-118.91	-128.70	-137.01
26	-118.93	-118.94	-118.94	-118.94	-128.94	-138.94	-118.92	-128.74	-137.29
28	-118.94	-118.94	-118.94	-118.94	-128.94	-138.94	-118.92	-128.77	-137.53
30	-118.94	-118.94	-118.94	-118.94	-128.94	-138.94	-118.92	-128.80	-137.73
32	-118.94	-118.94	-118.94	-118.94	-128.94	-138.94	-118.93	-128.82	-137.89
34	-118.94	-118.94	-118.94	-118.94	-128.94	-138.94	-118.93	-128.84	-138.03
36	-118.94	-118.94	-118.94	-118.94	-128.94	-138.94	-118.93	-128.85	-138.16
38	-118.94	-118.94	-118.94	-118.94	-128.94	-138.94	-118.93	-128.87	-138.26
40	-118.94	-118.94	-118.94	-118.94	-128.94	-138.94	-118.93	-128.88	-138.36

Table 10 ΣI_{off} sourced from IMT Macro Cells incident to an FSS Earth Station linked to a satellite 100.5 degrees East

Guard Band (MHz)	ΣI_{off} Macro vs -30 dB Gauss (dBm)	ΣI_{off} Macro vs -40 dB Gauss (dBm)	ΣI_{off} Macro vs -50 dB Gauss (dBm)	ΣI_{off} Macro vs -60 dB Gauss (dBm)	ΣI_{off} Macro -10 vs -60 dB Gauss (dBm)	ΣI_{off} Macro -20 vs -60 dB Gauss (dBm)	ΣI_{off} Macro vs IDA (dBm)	ΣI_{off} Macro -10 vs IDA (dBm)	ΣI_{off} Macro -20 vs IDA (dBm)
0	-91.29	-94.15	-96.92	-99.62	-99.88	-99.95	-95.34	-95.92	-96.23
2	-93.36	-96.80	-100.13	-103.33	-103.74	-103.83	-110.93	-118.18	-120.80
4	-95.59	-99.67	-103.55	-107.17	-107.93	-108.06	-112.73	-121.68	-126.74
6	-98.01	-102.72	-107.05	-110.81	-112.37	-112.62	-113.76	-123.01	-128.89
8	-100.58	-105.87	-110.42	-113.70	-116.94	-117.52	-114.78	-124.02	-129.89
10	-103.33	-109.02	-113.22	-115.39	-121.17	-122.65	-116.10	-125.29	-130.97
12	-106.24	-111.90	-115.07	-116.11	-124.28	-127.86	-116.35	-125.65	-131.70
14	-109.34	-114.18	-115.97	-116.35	-125.79	-132.42	-116.37	-125.80	-132.31
16	-112.61	-115.64	-116.31	-116.42	-126.30	-135.30	-116.38	-125.91	-132.86
18	-116.02	-116.37	-116.43	-116.44	-126.43	-136.41	-116.39	-126.01	-133.36
20	-116.38	-116.43	-116.44	-116.44	-126.44	-136.44	-116.40	-126.09	-133.80
22	-116.41	-116.43	-116.44	-116.44	-126.44	-136.44	-116.41	-126.15	-134.18
24	-116.43	-116.44	-116.44	-116.44	-126.44	-136.44	-116.41	-126.20	-134.51
26	-116.43	-116.44	-116.44	-116.44	-126.44	-136.44	-116.42	-126.24	-134.79
28	-116.44	-116.44	-116.44	-116.44	-126.44	-136.44	-116.42	-126.27	-135.03
30	-116.44	-116.44	-116.44	-116.44	-126.44	-136.44	-116.42	-126.30	-135.23
32	-116.44	-116.44	-116.44	-116.44	-126.44	-136.44	-116.43	-126.32	-135.39
34	-116.44	-116.44	-116.44	-116.44	-126.44	-136.44	-116.43	-126.34	-135.53
36	-116.44	-116.44	-116.44	-116.44	-126.44	-136.44	-116.43	-126.35	-135.66
38	-116.44	-116.44	-116.44	-116.44	-126.44	-136.44	-116.43	-126.37	-135.76
40	-116.44	-116.44	-116.44	-116.44	-126.44	-136.44	-116.43	-126.38	-135.86

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Table 11 ΣI_{off} sourced from IMT Small Cells incident to an FSS Earth Station linked to a satellite 22 degrees West

Guard Band (MHz)	ΣI_{off} Small Cell vs -30 dB Gauss (dBm)	ΣI_{off} Small Cell vs -40 dB Gauss (dBm)	ΣI_{off} Small Cell vs -50 dB Gauss (dBm)	ΣI_{off} Small Cell vs -60 dB Gauss (dBm)	ΣI_{off} Small Cell -10 vs -60 dB Gauss (dBm)	ΣI_{off} Small Cell -20 vs -60 dB Gauss (dBm)	ΣI_{off} Small Cell vs IDA (dBm)	ΣI_{off} Small Cell -10 vs IDA (dBm)	ΣI_{off} Small Cell -20 vs IDA (dBm)
0	-116.41	-119.31	-122.16	-124.96	-124.99	-125.01	-121.30	-121.48	-121.61
2	-118.49	-122.01	-125.45	-128.83	-128.88	-128.90	-145.71	-146.29	-146.41
4	-120.75	-124.94	-129.02	-133.06	-133.12	-133.14	-151.00	-152.76	-153.00
6	-123.21	-128.11	-132.86	-137.58	-137.69	-137.72	-152.49	-155.15	-155.54
8	-125.85	-131.49	-136.98	-142.37	-142.61	-142.66	-152.95	-156.03	-156.51
10	-128.72	-135.12	-141.31	-147.16	-147.82	-147.92	-153.35	-156.88	-157.46
12	-131.86	-139.02	-145.81	-151.37	-153.30	-153.58	-153.69	-157.69	-158.41
14	-135.50	-143.26	-150.08	-154.04	-158.67	-159.62	-153.98	-158.47	-159.34
16	-140.20	-148.13	-153.48	-155.13	-163.06	-166.29	-154.23	-159.20	-160.26
18	-152.52	-154.98	-155.38	-155.43	-165.39	-175.03	-154.44	-159.89	-161.15
20	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-154.61	-160.53	-162.02
22	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-154.75	-161.11	-162.87
24	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-154.87	-161.64	-163.68
26	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-154.96	-162.10	-164.46
28	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-155.04	-162.52	-165.19
30	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-155.10	-162.87	-165.88
32	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-155.15	-163.18	-166.51
34	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-155.19	-163.45	-167.11
36	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-155.23	-163.69	-167.70
38	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-155.26	-163.91	-168.27
40	-155.44	-155.44	-155.44	-155.44	-165.44	-175.44	-155.29	-164.11	-168.83

Table 12 ΣI_{off} sourced from IMT Small Cells incident to an FSS Earth Station linked to a satellite 100.5 degrees East

Guard Band (MHz)	ΣI_{off} Small Cell vs -30 dB Gauss (dBm)	ΣI_{off} Small Cell vs -40 dB Gauss (dBm)	ΣI_{off} Small Cell vs -50 dB Gauss (dBm)	ΣI_{off} Small Cell vs -60 dB Gauss (dBm)	ΣI_{off} Small Cell -10 vs -60 dB Gauss (dBm)	ΣI_{off} Small Cell -20 vs -60 dB Gauss (dBm)	ΣI_{off} Small Cell vs IDA (dBm)	ΣI_{off} Small Cell -10 vs IDA (dBm)	ΣI_{off} Small Cell -20 vs IDA (dBm)
0	-113.91	-116.81	-119.66	-122.46	-122.49	-122.51	-118.80	-118.98	-119.11
2	-115.99	-119.51	-122.95	-126.33	-126.38	-126.40	-143.21	-143.79	-143.91
4	-118.25	-122.44	-126.52	-130.56	-130.62	-130.64	-148.50	-150.26	-150.50
6	-120.71	-125.61	-130.36	-135.08	-135.19	-135.22	-149.99	-152.65	-153.04
8	-123.35	-128.99	-134.48	-139.87	-140.11	-140.16	-150.45	-153.53	-154.01
10	-126.22	-132.62	-138.81	-144.66	-145.32	-145.42	-150.85	-154.38	-154.96
12	-129.36	-136.52	-143.31	-148.87	-150.80	-151.08	-151.19	-155.19	-155.91
14	-133.00	-140.76	-147.58	-151.54	-156.17	-157.12	-151.48	-155.97	-156.84
16	-137.70	-145.63	-150.98	-152.63	-160.56	-163.79	-151.73	-156.70	-157.76
18	-150.02	-152.48	-152.88	-152.93	-162.89	-172.53	-151.94	-157.39	-158.65
20	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.11	-158.03	-159.52
22	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.25	-158.61	-160.37
24	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.37	-159.14	-161.18
26	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.46	-159.60	-161.96
28	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.54	-160.02	-162.69
30	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.60	-160.37	-163.38
32	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.65	-160.68	-164.01
34	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.69	-160.95	-164.61
36	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.73	-161.19	-165.20
38	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.76	-161.41	-165.77
40	-152.94	-152.94	-152.94	-152.94	-162.94	-172.94	-152.79	-161.61	-166.33

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6 Conclusions

In this study work, we calculate the NFD available between IMT transmitter and FSS receiver for a range of spectrum mask combinations over a range of possible Guard Bands. The consequent impact on I/N at the FSS receiver is calculated.

When interference is sourced from an IMT Macro deployment, our results indicate that an 18 MHz Guard Band would allow an FSS protection criterion of I/N = -10 dB to be satisfied on both of the FSS links over all combinations of spectrum masks considered in this study. The margins available between aggregate interference and noise are in the range -3.02 to -22.86 dB. We note that this Guard Band delivers some very significant margins for the combinations of spectrum masks with the best Out-of-Band attenuation.

If the interference is sourced from an IMT Small Cell deployment, then a 0 MHz Guard Band allows for the FSS protection criterion of I/N = -10 dB to be satisfied on both of the FSS links over all combinations of spectrum masks. Margins are in the range -0.91 to -8.61 dB over both links and all combinations of spectrum masks, again with very significant margins for some spectrum mask combinations.

Therefore, based on the assumptions and inputs used in this study, we conclude that an 18 MHz Guard Band mitigates co-frequency interference to acceptable levels, covering both Macro and Small Cell analyses.

Our study highlights the problem of selecting appropriate spectrum masks when no data is available (particularly for FSS receivers). Theoretical spectrum masks are used in academic studies and in practical frequency assignment and co-ordination work. In this study, we consider a range of inputs in order to determine the mitigation required for successful spectrum compatibility between IMT and FSS.

Our study also introduces the idea that this scenario is an exemplar of a class of sharing scenario which are amenable to a cost benefit analysis. The risk of interference is quantified and can be traded against the benefit of a smaller Guard Band.

Our consideration of an LNB overload threshold = -60 dBm indicates that this threshold is satisfied in all cases when we model long-term interference incident to the FSS receiver.

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