Adjacent band sharing 5G and FSS receiving stations in C-band

0 Executive Summary

In this report, an overview of the impact of 5G in-band emission (IBE) interference into the FSS receiver LNB and of the 5G out of band emission (OOBE) interference into the FSS operating band is presented through both theoretical studies as well as actual field measurements:

1. In order to prevent 5G IBE from saturating the FSS receiver LNB, filtering would need to attenuate 5G signals in the order of 60-70 dB.
2. Taking the 3GPP standard and CEPT ECC unwanted emission profiles lowest power (considering up to 40 MHz of frequency separation) have shown that the 5G OOBE falling within the FSS operating band could still cause harmful levels of interference even when large separation distances are observed.

Based on these conclusions and on the guardband considerations raised in section 4 of this report, we recommend the following:

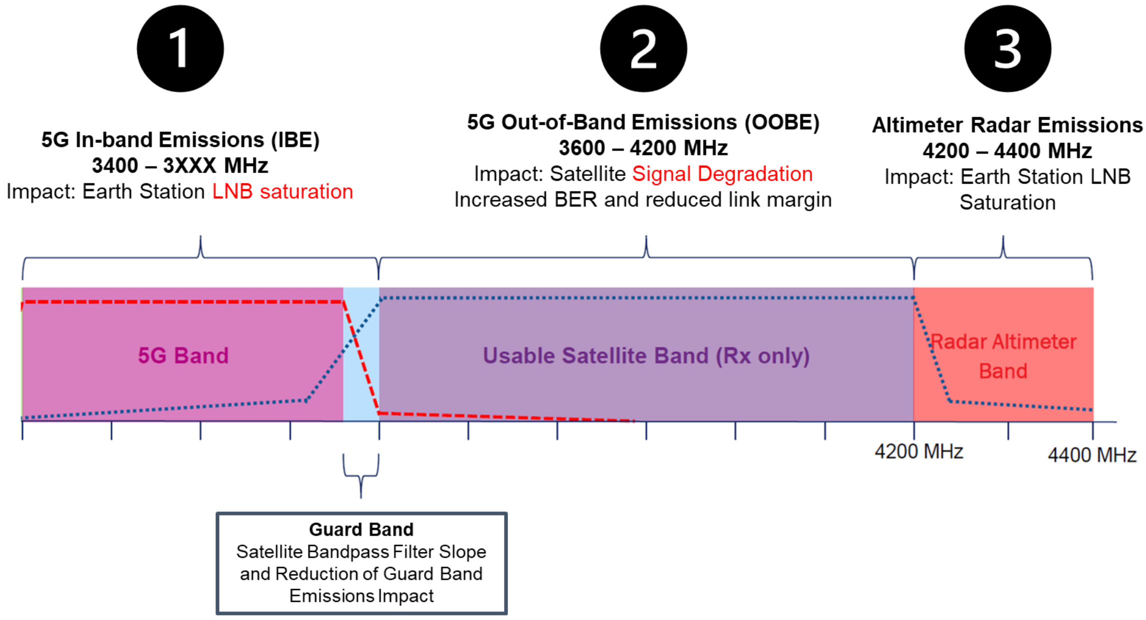
1. Allow sufficient guardband between FSS ES and 5G services to allow:
    a. The filter enough of frequency separation to transition and effectively attenuate the 5G IBE
    b. Enough separation for the 5G OOBE to reach lower emission levels
2. Carefully consider the 5G technical conditions, namely more stringent unwanted emission profile, and their impact on the coexistence with FSS receivers.
3. The need to register all FSS earth station receivers to develop a database of the locations to be protected through the implementation of filters and coordination procedures. This would be in-line with the ICASA guidelines. This third point is critical as highlighted by the following points:
    a. Experience has shown that regulators are unaware of un-coordinated C-band receive only earth stations;
    b. Lack of registration leads regulators to make uninformed decisions about spectrum;
    c. The need for close cooperation between regulator, satellite operator and satellite national customers to solve this issue of antenna registration;
    d. Near term ICASA should do a data gathering using existing E/S registration tool - support from satellite operators and C band customer can be provided;
    e. Long term - enhanced earth station data portal under a Digital Portal Strategy;
    f. Having this data is ESSENTIAL to ensuring the protection of C-band customers.

This report also addresses the fact that 80-100MHz of contiguous spectrum is not a requirement for 5G operation and that 40MHz or non-contiguous carriers in other frequency bands are sufficient to provide 5G services (see section 6).

1 Introduction

The C-band (3400-4200 MHz) has been historically used for satellite receivers, and as such the FSS Earth station equipment, namely the LNB, often operate in the entire 3400-4200 MHz even though the operating signal might only be received in portions of the band often above 3.6 GHz.

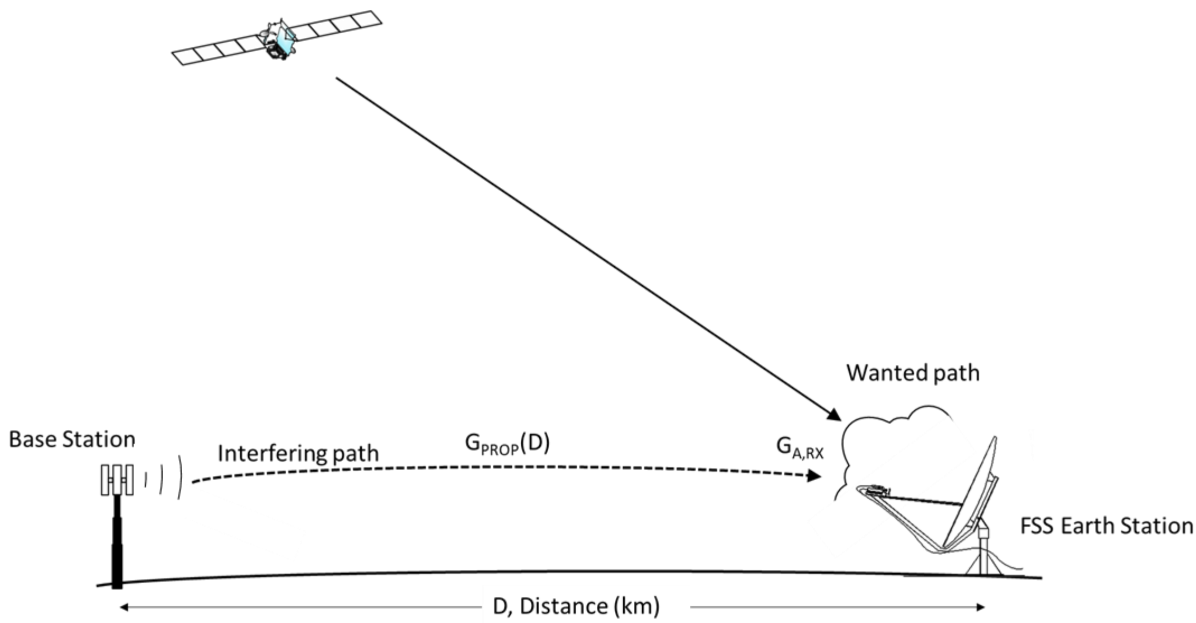
South Africa has decided to open up the band up to 3.6 GHz for 5G deployments. There is therefore a high risk of interference of existing FSS ES receivers from this new planned use of the band. The aim is for IMT to operate while making sure the FSS ES to are still able to receive above 3.6 GHz. There are a number of interference mechanisms at play which are summarized in the figure below.



This report focuses on assessing the interference mechanism ① by studying the impact of 5G 3GPP in band emissions (IBE) into the overlapping LNB receiving capabilities in 3400-3600MHz (section 2). The report then aims to assess the interference mechanism ② to understand the impact of 3GPP OOBE standards into FSS ES receivers in the 3600-4200 MHz (section 3). Finally, based on the results obtained, guardband considerations, OOBE limitation recommendations and filtering solutions are presented.

2 LNB saturation interference analysis

2.1 Overview of the analysis



The interference analysis is performed for a number of separation distances between the 5G BS interferer and the FSS ES receiver. For each separation distance, the interference power perceived by the FSS ES is calculated and stored.

2.2 Mobile characteristics

The mobile characteristics are used are taken from 3GPP specification that was sent to the ITU.[1]

The assumption is that the 5G BS is pointing towards the FSS ES. Two cases are considered:

1. Worst Case: The maximum eirp density (72.28 dBm/40MHz) is considered in the entire 200 MHz overlap (3400-3600 MHz).
   - ⇨ Total 5G in-band eirp considered falling in LNB receiver: 49.27 dBW
2. Single Carrier: As suggested by its name, the first case is a worst case and as it is unlikely that multiple BSs with different carriers spread out in 3400-3600MHz would all point with the maximum eirp towards the FSS receiver. Therefore, this second case considers the maximum eirp interference from a single 5G BS carrier.
   - ⇨ Total 5G in-band eirp considered falling in LNB receiver: 42.28 dBW

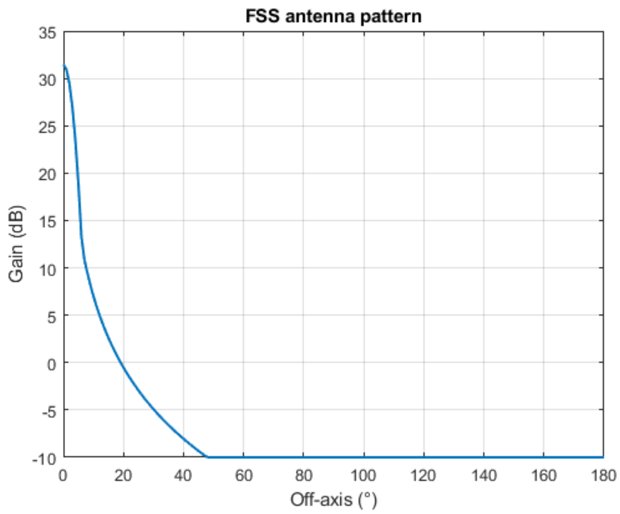
The 5G BS are assumed to be at 20m height.

It is important to note that the satellite LNB is assumed to be operating in the entire 3.4-4.2 GHz and therefore could receive both an aggregation of the in-band and the out-of-band emission of 5G. The assumption taken here is that the main contributor for LNB saturation is the 5G in-band emissions from the 3400-3600 MHz.

[1] WP 5D Chairman's Report Annex 4.4 (Document 5D/716)

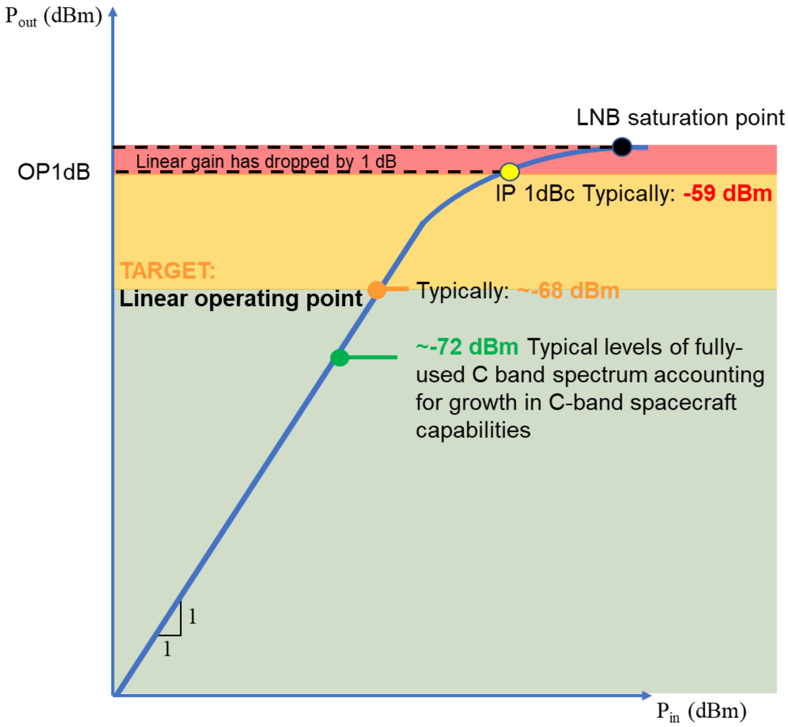
2.3 Fixed satellite characteristics

- The fixed satellite receive Earth station is assumed to be pointing in azimuth towards the transmitting BS.
- The FSS ES is assumed to be at a height of 10m
- Several elevations are considered for the FSS earth station pointing: 10˚, 20˚, 30˚, 45˚, 60˚
- The following figure presents the antenna pattern described in Recommendation ITU-R S.465 for an antenna diameter of 1.2meter antenna and the antenna pattern used is Recommendation ITU-R S.465 is considered



Note that since the elevation of the ES is at least 10 degrees, any diameter ES antenna will have the same gain towards the 5G interfering BS for a given elevation as per the S.465 antenna pattern (i.e. 32-25log(off-axis) or -10 dBi).

- LNB linear operating point threshold level: -68dBm (see below figure explaining the various LNB operating ranges). This level relates to the total input power perceived by the LNB which in this case is from both the wanted signal (C for carrier) and the 5G interference (I for interference).



- Estimation of potential carrier level in 3600-4200 MHz:
  - 600 MHz bandwidth
  - 16 carriers of 36 MHz assumed with a transponder eirp of 44 dBW

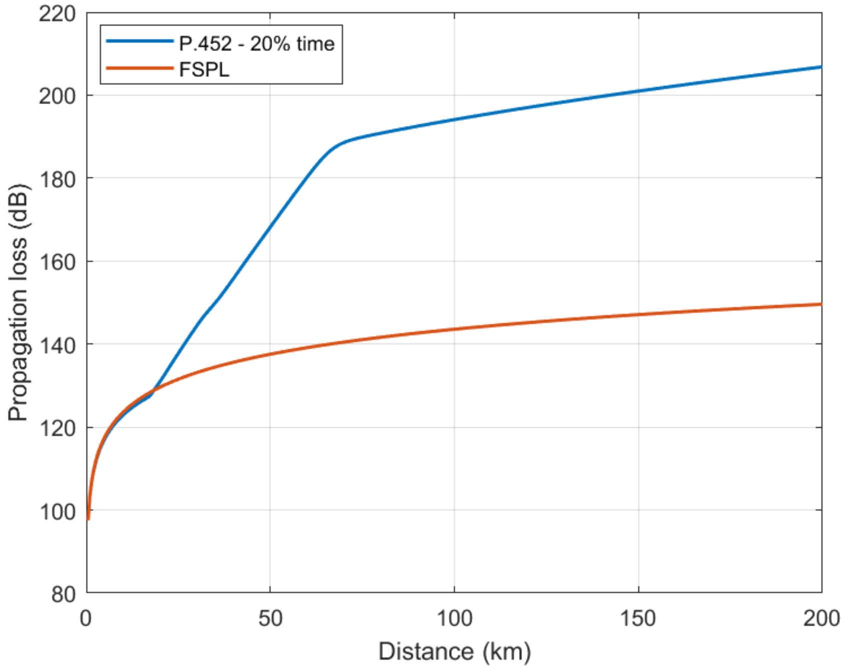
$$C = EIRP_{satCarrier} + 10\log_{10}(N_{carrier}) - \mathrm{FSL}(GSO\ to\ ES) + Grx$$

$$C = 44 + 10\log_{10}(16) - 190 + 32 \approx -102\ dBW = -72\ dBm$$

2.4 Propagation model

- Propagation model ITU-R P.452 to model terrestrial path
- Smooth earth considered to have results that are generic
- Percentage of time linked to the propagation model: 20% time (based on FSS long term protection criteria time percentage)
- The propagation environment is assumed to be suburban. It is important to note that the nominal clutter height specified in ITU-R recommendation P.452 for the suburban environment is 9m. Both antennas being above this level, no clutter loss is taken into account.

Figure below provides the attenuation of the propagation model versus distance for the FSS ES and 5G BS heights, namely 10m and 20m, respectively. The free space path loss model is also represented for comparison.



2.5 Results

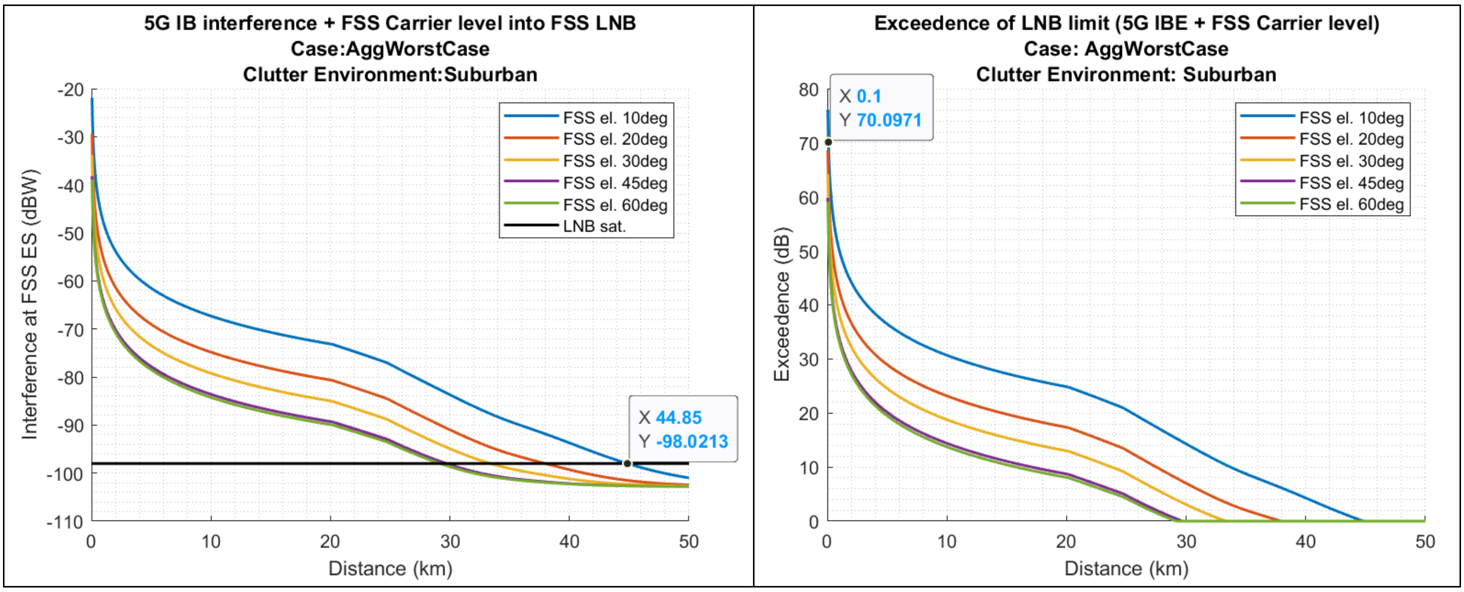
2.5.1 Case 1: Worst case analysis

For this case, 1. The maximum eirp density is considered in the entire 200 MHz overlap (3400-3600 MHz). In other words, the eirp density per MHz was calculated by taking a single 40 MHz carrier that has a total max eirp of 72.28 dBm. When spreading this eirp density over the 200 MHz of potential overlap, one obtains the following total maximum eirp falling within the LNB receiver:

$$72.28 - 30 + 10\log_{10}\left(\frac{200}{40}\right) = 49.27\ dBW$$

The following figure shows the level of power perceived at the LNB receiver from 5G in band interference on top of the FSS ES carrier power, as a function of distance. Each coloured curve specifies a different ES elevation. The black line corresponds to the LNB no-linear operation threshold. The figure on the right-hand side specifies the amount the interference needs to be attenuated.

Interference vs. distance	Exceedance vs. distance

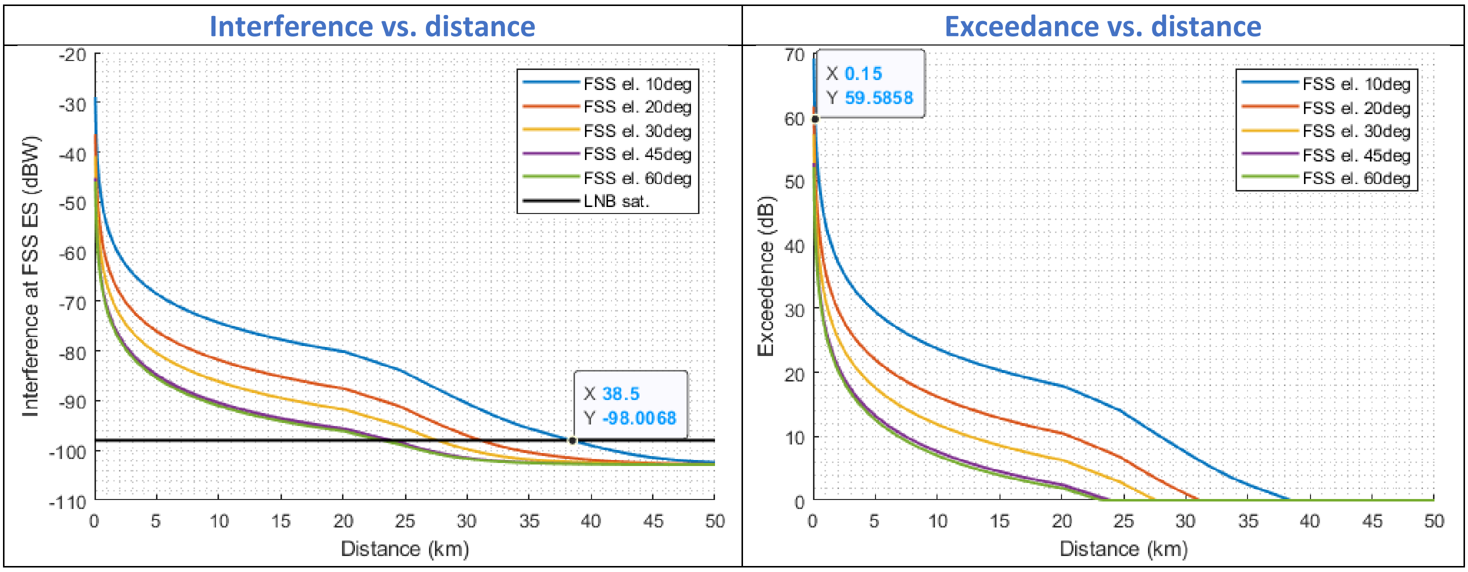


One can note that at 100m of separation distance, the potential interference from 5G deployment can exceed the LNB linear threshold by 70 dB. If the 5G deployment is deployed closer to the FSS ES, i.e. a minimum separation distance of 100m cannot be guaranteed, higher exceedance levels can be reached. The 5G deployments can impact the LNB performances at distances of up to 45 km from the FSS ES receiver.

2.5.2 Case 2: Single carrier case analysis

For this second case, and as explained in section 2.2, a more realistic case is taken by considering that the FSS ES is receiving the in-band interference from a single BS carrier. According to the 5G characteristics, the BS has a maximum eirp of 72.28 dBm = 42.28 dBW for a single carrier, about 7 dB lower than case 1.

Similar figures as presented for case 1 are presented below.



For this second case, we can see from the right hand side figure that the LNB linear operation threshold is exceeded by 60dB at a separation distance of 150m.

In this case of a single IMT carrier transmitting with maximum eirp towards the FSS ES, the 5G deployment can cause degradation to the LNB performances for distances of up to 38.5 km.

2.6 Conclusion of IBE interference analysis

In order to avoid in-band interference from 5G deployment and given the fact that these deployments could be at any distance of the FSS ES, filters should be implemented to provide an attenuation of at least 60-70 dB at the FSS ES receiver to keep the LNB in its linear operation.

It is important to note that this only considers the impact of 5G in band emissions in the 3400-3600 MHz on the LNB and does not take into account the impact of the 5G out of band on the FSS earth station signal degradation (see section 3).

3 Out of Band emission interference analysis

As highlighted in section 2.6, on top of potential LNB saturation, 5G out of band emissions falling within the FSS earth station wanted signal band (3600-4200 MHz) could degrade the FSS earth station link margins. Contrary to the case studied above, these signals cannot be filtered out. The following analysis therefore determines the out of band emission impact of a single 5G BS transmitting towards the FSS earth station receiver.

3.1 Overview of the analysis

The analysis is similar to the one performed in section 2 but in this case the out of band emission levels of 5G are considered.

3.2 Mobile characteristics

A single mobile BS is considered to be transmitting towards the FSS earth station receivers. The following unwanted emission limits were extracted from the 3GPP standards. There are two categories A and B of BS with the following unwanted emission limits for frequencies >1 GHz[2].

[2] Tables 6.6.4.2.1-2 and 6.6.4.2.2.1-2 taken from 3GPP TS 38.104 v.16.6.0 (2020-12), “NR; Base Station (BS) radio transmission and reception”.

Table 6.6.4.2.1-2: Wide Area BS *operating band* unwanted emission limits (NR bands above 1 GHz) for Category A

Frequency offset of measurement filter -3dB point, Δf	Frequency offset of measurement filter centre frequency, f_offset	*Basic limits* (Note 1, 2)	*Measurement bandwidth*
0 MHz ≤ Δf < 5 MHz	0.05 MHz ≤ f_offset < 5.05 MHz	$-7dBm-\frac{7}{5}\cdot\left(\frac{f\_offset}{MHz}-0.05\right)dB$	100 kHz
5 MHz ≤ Δf < min(10 MHz, Δf_{max})	5.05 MHz ≤ f_offset < min(10.05 MHz, f_offset_{max})	-14 dBm	100 kHz
10 MHz ≤ Δf ≤ Δf_{max}	10.5 MHz ≤ f_offset < f_offset_{max}	-13 dBm (Note 3)	1MHz

NOTE 1: For a BS supporting *non-contiguous spectrum* operation within any *operating band*, the emission limits within *sub-block gaps* is calculated as a cumulative sum of contributions from adjacent *sub-blocks* on each side of the *sub-block gap*, where the contribution from the far-end *sub-block* shall be scaled according to the *measurement bandwidth* of the near-end *sub-block*. Exception is Δf ≥ 10MHz from both adjacent *sub-blocks* on each side of the *sub-block gap*, where the emission limits within *sub-block gaps* shall be -13 dBm/1 MHz.
NOTE 2: For a *multi-band connector* with *Inter RF Bandwidth gap* < 2*Δf_{OBUE} the emission limits within the *Inter RF Bandwidth gaps* is calculated as a cumulative sum of contributions from adjacent *sub-blocks* or RF Bandwidth on each side of the *Inter RF Bandwidth gap*, where the contribution from the far-end *sub-block* or RF Bandwidth shall be scaled according to the *measurement bandwidth* of the near-end *sub-block* or RF Bandwidth.
NOTE 3: The requirement is not applicable when Δf_{max} < 10 MHz.

Table 6.6.4.2.2.1-2: Wide Area BS operating band unwanted emission limits (NR bands above 1 GHz) for Category B

Frequency offset of measurement filter -3dB point, Δf	Frequency offset of measurement filter centre frequency, f_offset	*Basic limits* (Note 1, 2)	*Measurement bandwidth*
0 MHz ≤ Δf < 5 MHz	0.05 MHz ≤ f_offset < 5.05 MHz	$-7dBm-\frac{7}{5}\cdot\left(\frac{f\_offset}{MHz}-0.05\right)dB$	100 kHz
5 MHz ≤ Δf < min(10 MHz, Δf_{max})	5.05 MHz ≤ f_offset < min(10.05 MHz, f_offset_{max})	-14 dBm	100 kHz
10 MHz ≤ Δf ≤ Δf_{max}	10.5 MHz ≤ f_offset < f_offset_{max}	-15 dBm (Note 3)	1MHz

NOTE 1: For a BS supporting *non-contiguous spectrum* operation within any *operating band*, the emission limits within *sub-block gaps* is calculated as a cumulative sum of contributions from adjacent *sub-blocks* on each side of the *sub-block gap*, where the contribution from the far-end *sub-block* shall be scaled according to the *measurement bandwidth* of the near-end *sub-block*. Exception is Δf ≥ 10MHz from both adjacent *sub-blocks* on each side of the *sub-block gap*, where the emission limits within *sub-block gaps* shall be -15 dBm/1 MHz.
NOTE 2: For a *multi-band connector* with *Inter RF Bandwidth gap* < 2*Δf_{OBUE} the emission limits within the *Inter RF Bandwidth gaps* is calculated as a cumulative sum of contributions from adjacent *sub-blocks* or RF Bandwidth on each side of the *Inter RF Bandwidth gap*, where the contribution from the far-end *sub-block* or RF Bandwidth shall be scaled according to the *measurement bandwidth* of the near-end *sub-block* or RF Bandwidth.
NOTE 3: The requirement is not applicable when Δf_{max} < 10 MHz.

In addition, the table below provides the European CEPT framework for the unwanted emission limits[3].

BEM Element	Frequency Range (MHz)	AAS TRP limit dBm/(5 MHz) per cell (Pmax')
In-Block	3400-3800	47

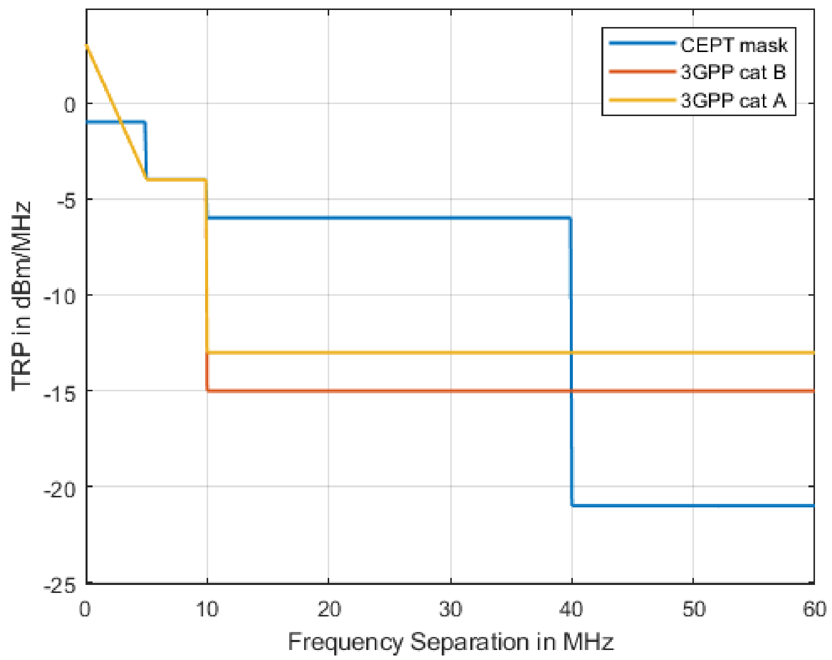
[3] Table 7 of the European Decision (EU) 2019/235 of 24 January 2019 EUR-Lex - 32019D0235 - EN - EUR-Lex (europa.eu)

Additional Baseline	3800-3805	Min(Pmax'-40,16)
	3805-3810	Min(Pmax'-43,12)
	3810-3840	Min(Pmax'-43,1)
	Above 3840	-14

(1) In a multi-sector base station, the radiated power limit applies to each one of the individual sectors.
(2) The transitional regions and the baseline power limits apply to the synchronised operation of MFCN networks as defined in ECC Report 281.
(3) PMax is the maximum mean carrier power in dBm for the base station measured as e.i.r.p. per carrier, interpreted as per antenna
(4) PMax' is the maximum mean carrier power in dBm for the base station measured as TRP per carrier in a given cell.

The figure below presents the 3 emission profiles for comparison:

Figure 1: OOBE profile comparison



One can note the difference between the 3GPP standard and the proposed unwanted limit proposed by CEPT. Two important points are:

1. The frequency separation to reach the minimum unwanted Total Radiated Power: 10 MHz for the 3GPP for bands above 1 GHz versus 40 MHz for the CEPT framework. This is quite an important factor as this frequency separation would need to be considered when assessing the impact into FSS receivers in the adjacent band. When considering guardband, this transition area represents a key parameter into determining the width of the separation between the two services.
2. The lowest unwanted power limit to be respected: -15 to -13 dBm/MHz for the 3GPP standards against -14dBm/5MHz = -21 dBm/MHz for the CEPT framework. This leads to a difference of 6-8 dB between the two levels which is quite important.

In this study, the lowest limit of the 3GPP category A (i.e. -13 dBm/MHz) and of the CEPT limit (i.e. -21 dBm/MHz) for the BS unwanted emissions. This means that a 10 or 40 MHz frequency separation is assumed to reach these levels, respectively. **The study will therefore show the impact into FSS earth station assuming the lowest 5G out of band power limit level.**

The limit is given as a TRP (total radiated power). The 5G BS antenna gain is therefore required to conduct the study. The maximum BS gain of 26 dBi is taken.

3.3 Fixed satellite characteristics

The only difference in assumption as compared to the study in section 2 is the FSS protection criteria considered. As noted above, this study models the interference of a service (5G) operating in the adjacent band. In this case, the FSS earth station adjacent protection level is considered in the form of a maximum allowable interference over noise level: I/N = -20 dB not to be exceeded for more than 20% time.

The FSS earth station noise temperature was assumed to be 100K.

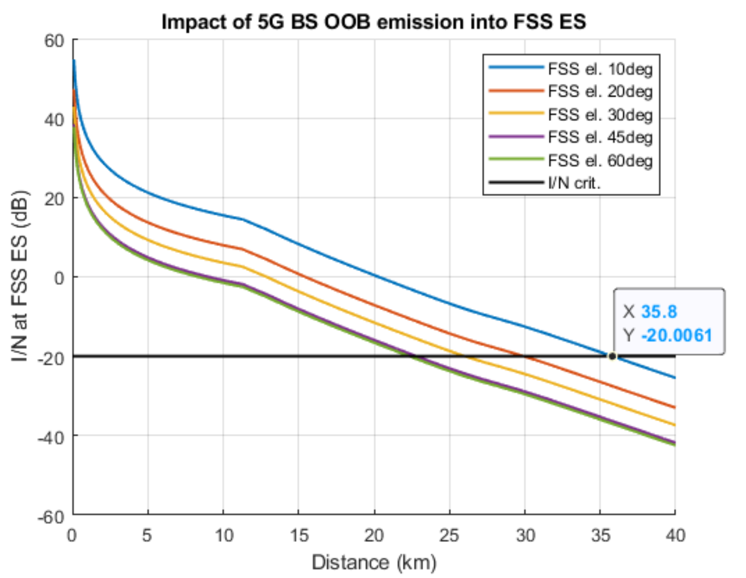
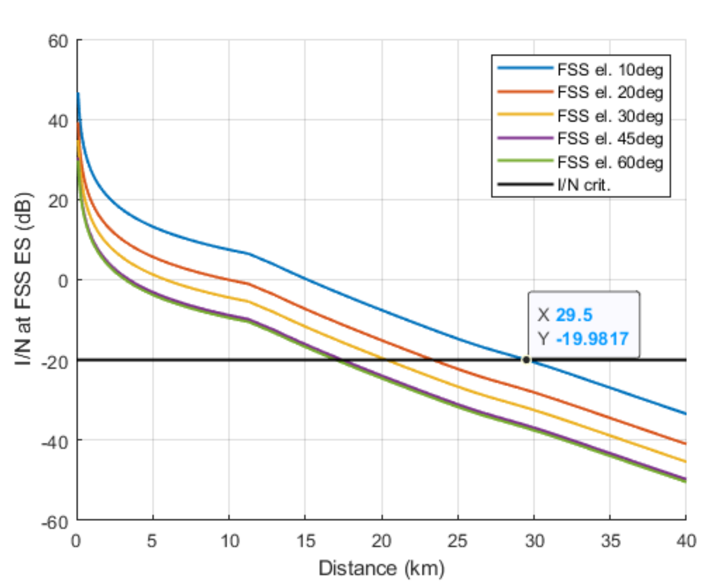
3.4 Propagation model

See section 2.4

3.5 Results

The figures below provide the resulting I/N levels perceived at the FSS caused by the 5G BS unwanted emissions depending on the separation distance.

Figure 2. FSS I/N caused by the 5G BS unwanted emissions depending on the separation distance

Assuming the 3GPP cat A standard: BS unwanted power -13dBm/MHz	Assuming the CEPT framework limits: BS unwanted power -21dBm/MHz
	

The impact of the 5G BS out of band emissions can be felt up to 35.8 km from the FSS ES in the case of the 3GPP unwanted emission level versus 29.5km when using the CEPT unwanted emission profile. Even with 8 dB lower levels compared to the 3GPP levels, the CEPT profile levels can still cause worrisome levels of interference even when large separation distances are observed.

It is important to note that these results consider a maximum OOBE TRP limit of -14dBm/5MHz 40 MHz away from the 5G operating band in the case of the CEPT unwanted emission profile. These separation distance could be reduced if more stringent OOBE limits were to be adopted for 5G as well as larger frequency separation between the two services could help ensure lower 5G unwanted emissions falling into the FSS operating band.

3.6 Conclusion of OOBE interference analysis

Although filtering might be applied to counteract the impact of 5G in band emissions from saturating the FSS earth station LNB, the only mitigation technique to prevent the impact of out of band emissions from degrading the FSS earth station reception are:

- lower out of band emission limits applicable to 5G deployments,
- coordination areas around FSS earth stations to ensure their protection. This entails knowing the locations of both the FSS earth stations to be protected as well as the location of the intended mobile deployment.

4 Inter-service guardbands

4.1 Definition

Inter-service guardband, or guardband for short, is the name given to the frequency separation between the nominal edge of band of one service and the nominal start of band of the service in the immediately adjacent spectrum allocation. This dedicated portion of the spectrum acts as a “buffer” to help avoid interference between two adjacent services.

In the specific case of 5G deployments, a guardband is necessary to guarantee that the out-of-band emissions (OOBE) from the 5G service reach a sufficiently low level that does not exceed the value of the protection criterion defined to ensure adjacent band compatibility with the FSS service.

Figure 3. Example of an adjacent band service deployment

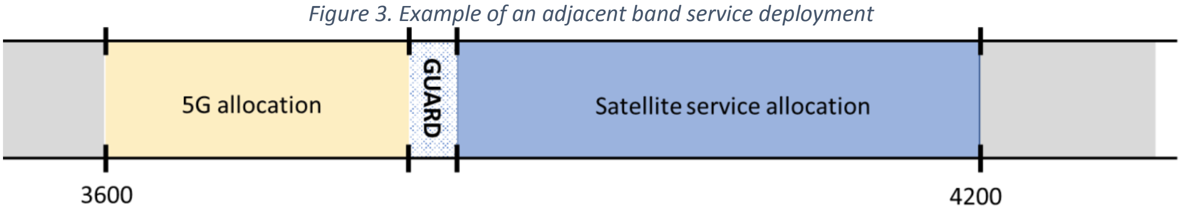
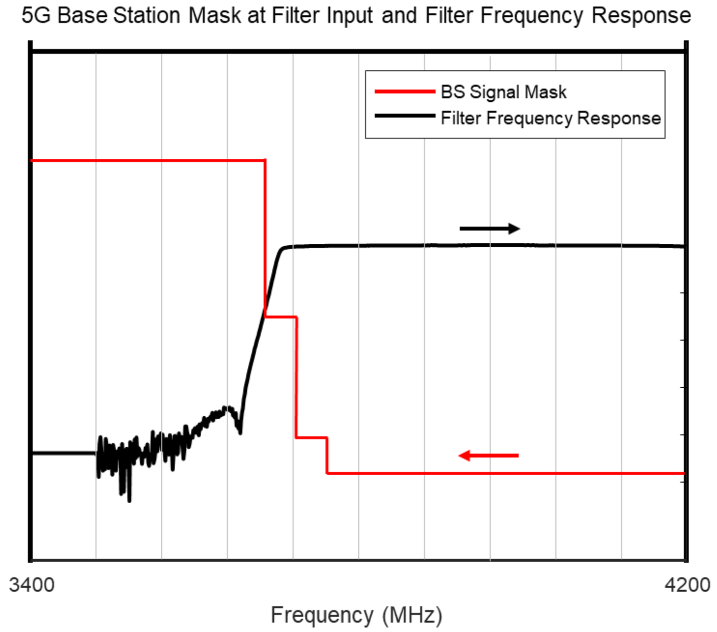


Figure 4. Illustration of the relationship between an IMT emission profile (BEM), and an RF filter response. The guardband is needed to allow the levels of the IMT service to fall to the lowest levels possible, and to permit the response of the RF filter to transition to the pass-band insertion loss regime.



A guardband separating the operations of IMT/5G and FSS services has **two objectives**:

i. On the one hand, the guardband ensures that in the band assigned to the FSS, the emissions of IMT stations reach the lowest levels of unwanted emissions (spurious levels). An inspection of the 5G emission profile in the figure 2 above reveals the need to establish a guardband between services to allow the emissions from the IMT stations to reach the lowest levels in the profile. The size of the guardband must then correspond to the characteristics of the emission profile of the IMT stations in the adjacent band. In most cases, it is found that a guardband larger than 40 MHz is required to ensure that IMT interfering emissions into the FSS band reach the spurious regime.

ii. On the other hand, when RF filters are used as a technique to protect the LNB of an FSS earth station, the guardband ensures that the emissions in the transition regions of the filter decrease *monotonically* with increasing frequency. Otherwise, the RF filter will not be effective in its main task of mitigating interference. Without a suitable guardband, even in the presence of RF filters, a portion of the high-power levels of IMT signals will pass unattenuated and reach the LNB input, resulting in a complete loss of the FSS signal.

Therefore, when designing of a guardband, one must consider:

i) The emission profile of the 5G service (usually in the form of a block edge mask or BEM) highlighted in section 3
ii) The value of the protection criterion for FSS service compatibility (usually in the form of an I/N ratio in dB)

A guardband is always needed despite the mitigation techniques of physical separation, or filtering.

4.2 Designing filters to operate with narrow guardbands results in degradation to the satellite services.

One of the fundamental trade-offs to perform when designing an RF filter for IMT-FSS compatibility is that of balancing the width of a transition region with the acceptable degradation of signal within the band where the filter is operating.

The transition regions of a filter are those specific bandwidths where the response of an RF filter changes from the rejection signals (rejecting) to the letting them through (passing). In a transition region, the filter is not fully attenuating the incoming signal.

Designing a filter for narrow transition regions will result in a degradation of the signal expected in the operating band. This is an undesired but inherent side effect of a highly selective filter response.

In the specific case of satellite services, this means:

i. Additional signal attenuation within the spectrum allocated to the satellite service
ii. Increase in the noise temperature of the system

The two combined effects cause a reduction in the earth station figure of merit (G/T) and a reduction in the services carrier to noise and interference ratio (C/(N+I)).

Therefore, the width of a guardband has a direct effect on the performance of an RF filter, and narrow guardbands unavoidably provoke a degradation of the satellite signal that leads to a negative impact on the associated satellite service.

4.3 The definition of a guardband must consider both IMT and FSS deployment conditions.

In summary, it is necessary to plan a guardband between services that satisfies the following conditions simultaneously:

a) Allow the 5G emission profile to reach the low spurious level
b) Allow the filter to perform a good transition into the passband, minimizing unwanted impacts in the FSS signals

Studies in Asia, Europe, and the U.S. indicate that:

i. values between 40 MHz and 80 MHz would be adequate, without increasing complexity and cost in filtering devices; and
ii. the guardband start frequency can be accommodated within the IMT spectrum sub-band without major impact on the 5G service targets.

For example:

i. The 100 MHz guardband proposed by the Hong Kong Communications Authority, located at the end of the 3.6-3.7 GHz band within the IMT allocation
ii. The 50 MHz guardband proposed by the Communications Authority of Singapore, at the end of the 3.45-3.65 GHz band
iii. The 100 MHz bandwidth dedicated to low power, indoor 5G services acting as a buffer between FSS and IMT, in Germany or The Netherlands
iv. The 50 MHz identified in Luxembourg

5 Some conclusions from South Africa C-Band In Field Measurement Report

Field measurements done in South Africa in the 3.4-4.2 GHz have shown similar conclusions to the studies presented in this report. The following conclusions were extracted from a report presenting field measurements conducted in South Africa. The italic text below are excerpts of that field measurement report.

"A coordinated effort from FSS operators in South Africa was initiated and resulted in 15 different sites from 13 operators being tested. Some of the sites are of national importance and highlights the importance of ensuring sharing feasibility. The presence of 3 mobile operators were present at most receive FSS sites. Two were in the adjacent band 3400-3600MHz and one in the 3600-4200MHz. So the measured results give a real view of what the impact will be if IMT and FSS were to use the same band. The results that follow clearly show that for all sites except one, co-band use between FSS and IMT is not possible. The energy from 5G base stations is too high, in all instances it ends up saturating the FSS receiver's LNB. The one site where co-band use is possible is due to geographic protection, where the FSS receivers are in a valley that provides natural protection from interfering signals. The measurements also show that for most sites adjacent band use for IMT is possible where FSS LNB's are filtered. Without filtering in place the out of band (OOB) emissions from 5G base stations saturate the FSS LNBs. In some instances even with filtering in place the 5G OOB emission levels are still high enough to saturate the FSS LNB, this is mainly due to the proximity of the 5G base station relative to the FSS site. These scenarios emphasize the importance of coordination between FSS operators and Mobile operators. To facilitate the coordination, it is imperative that both parties are aware of existing sites and any planned new sites to determine impact and mitigation up front."

"It is clear that co-existence between IMT and C-Band in the same band is not feasible without great separation distance in excess of 40km as reported by (Rep. ITU-R M.2109) that presents results of 11 studies. A recent submission into WP5A (R19-WP5A-C-0433-E) also supports the above finding, the submission is from neighboring administrations, namely Burkina Faso, Cote d Ivoire, Ghana, Guinea, Mali, Niger and Togo.

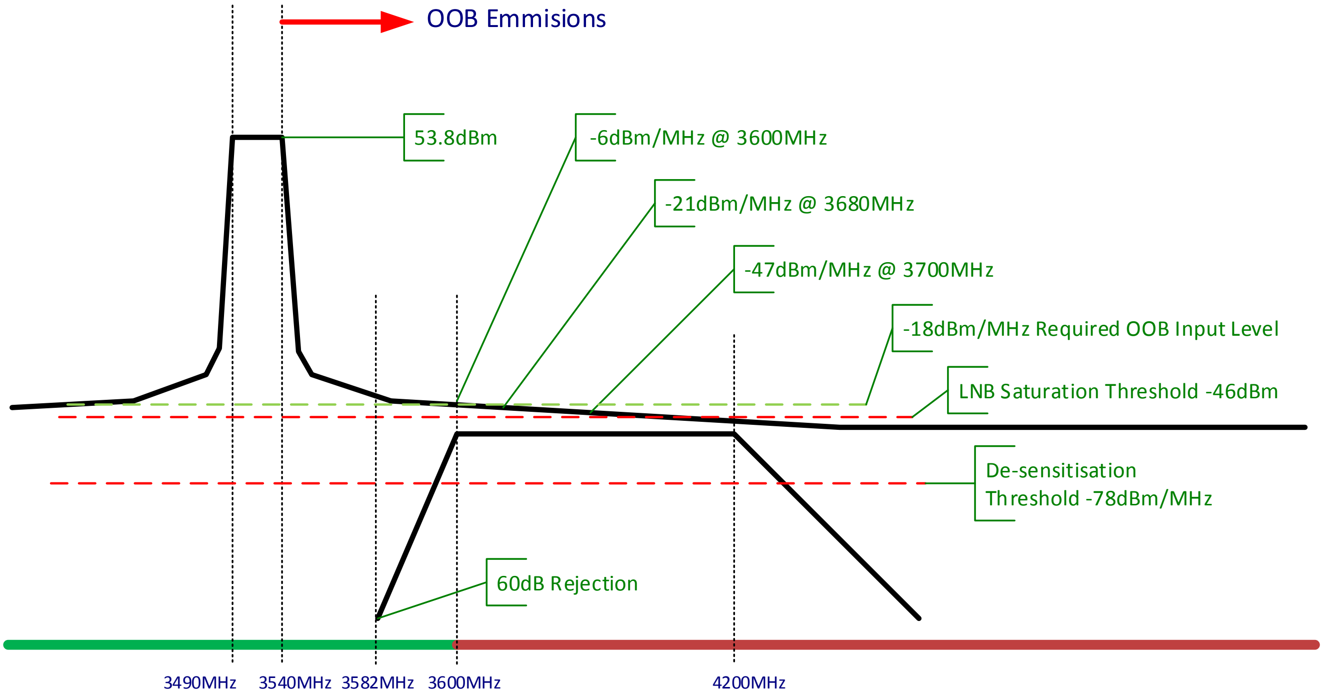
The measurements also indicate that good results can be obtained with IMT in adjacent band (3400-3600MHz) when C-Band Receivers are properly filtered. Filtering can only achieve so much, it is seen that when 5G base stations are in close proximity to FSS receive sites, the OOB emission levels are still high enough to saturate and de-sensitise the FSS LNB.

The current situation is that most FSS receive sites are not equipped with filters and will have to do so at a cost to counter act interference from adjacent band. It is especially prudent to do so, since most unfiltered LNB de-sensitisation takes place without operators knowing about it. With regards to secondary users in C-Band, the lack of co-ordination between operators has led to interference that can't be countered by filters alone."

"The measurements clearly indicates that continued C-Band (3600-4200MHz) use is still possible with IMT in the adjacent band (3400-3600MHz) if FSS sites are fitted with filters. What is also very apparent is that this is only possible with proper coordination. The below figure shows the typical OOB emissions to be expected from a NR Base station that uses 50MHz BW and is 60MHz away from the lower C-Band edge. The expected emissions are in band and are still high enough to cause de-sensitisation to the filtered LNB. So there are two things that can be done. Lower the transmit power

of the Base Station (dependent on proximity of BS to FFS site), or increase guard Band between two bands.

Figure 5: Required BS OOB emission mask



The above is definitely a workable solution but requires close coordination between operators to succeed. It is also imperative that there is a clearly defined band edge for C-Band operators so that appropriate filter selection can be made."

6 Reasons why mobile does not require 100 MHz contiguous spectrum here

This section is to address the myth that 5G cannot operate unless contiguous 80-100MHz bandwidth are afforded for their operations. Some of the arguments exposed in this section are based on the LS Telcom report intitled "*TEN GOOD REASONS why mobile operators in Africa do not need 100 MHz of contiguous C-band spectrum each*".[4]

The main reasons why IMT/5G operators are demanding 100 MHz of contiguous spectrum in the C-band have been as follows:

- 100 MHz is the MNO's ideal situation (and one never argues for a compromise as an opening gambit).
- C-band is green-field spectrum in which operators can deploy their networks without needing to re-farm spectrum in other bands allowing more rapid deployment and lower roll-out costs.

[4] [2021-12-8-AFRICA10GoodReasonsC-Band.pdf (gsoasatellite.com)]

IMT operators have exposed their arguments arguing for 100 MHz of contiguous spectrum in the C-band is important to ensure 5G headline speeds and to satisfy what they believe their users are expecting.

There is however no evidence that 80-100 MHz of contiguous C-band spectrum per MNO is an absolute requirement to achieve 5G, as proven by the fact that most 5G auctions occurred globally did not imply the grant of 100 MHz contiguous spectrum. In the response to the MNOs' claims they need access to at least 80 MHz of contiguous spectrum, Ofcom, the communications regulator in the United Kingdom 5, researched the ability of mobile operators to launch 5G services with 40 MHz of spectrum. Such research found that *"(…) there was no evidence that 5G could not be delivered with smaller [e.g. 40 MHz blocks] or non-contiguous carriers in other frequency bands [i.e. spectrum other than C-band]."* To support its finding that 40 MHz of C-band spectrum was sufficient to provide 5G services, Ofcom developed a theoretical cell site throughput model to estimate network performance based on various assumptions on the type of antenna used, bandwidth of C-band carrier, and signal strength received by the user. The results clearly demonstrate that terrestrial mobile operators will be able to deliver all the main services anticipated under 5G – including, but not limited to, connected cars, virtual reality cloud broadband, and live 4K streaming – with 40 MHz of spectrum. Figures 1 and 2 shows that results of Ofcom studies clearly demonstrate that mobile operators will be able to provide all the main services provided for in the 5G - including, among others, connected cars, broadband in the virtual reality cloud and streaming to live in 4K - with 40 MHz of spectrum. Mobile operators may want an 80 to 100 MHz spectrum from the C-band for optimal performance, but they don't need it to offer high quality to remain competitive.

[5] *See,* Ofcom, *§A7.39, Award of the 700 MHz and 3.6-3.8 GHz spectrum bands: Annexes* (13 March 2020), available online at https://www.ofcom.org.uk/data/assets/pdf_file/0017/192410/annexes-award-700mhz-3.6-3.8ghz-spectrum.pdf.

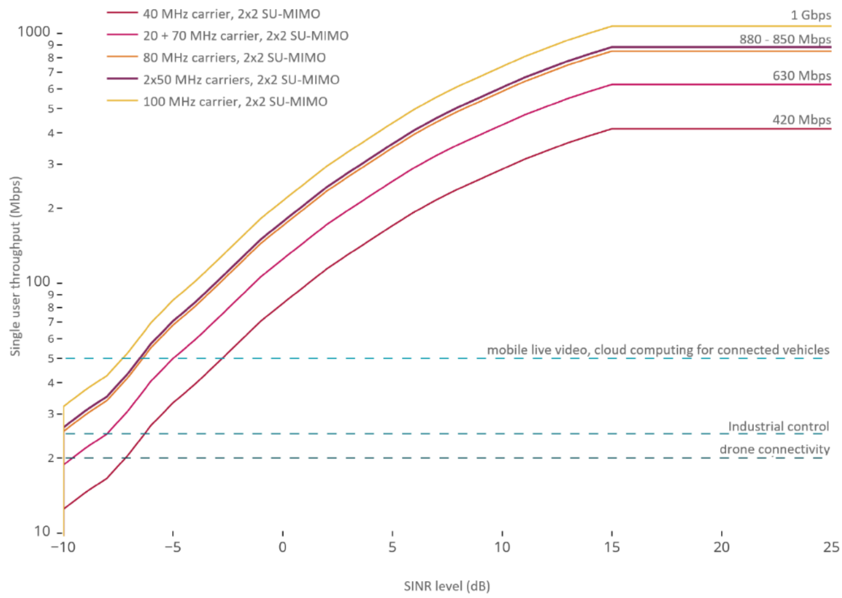


Figure 6. Downlink throughput for a single user (SUT) across different signal levels in a cell compared to the minimum rate required for some 5G services[6]

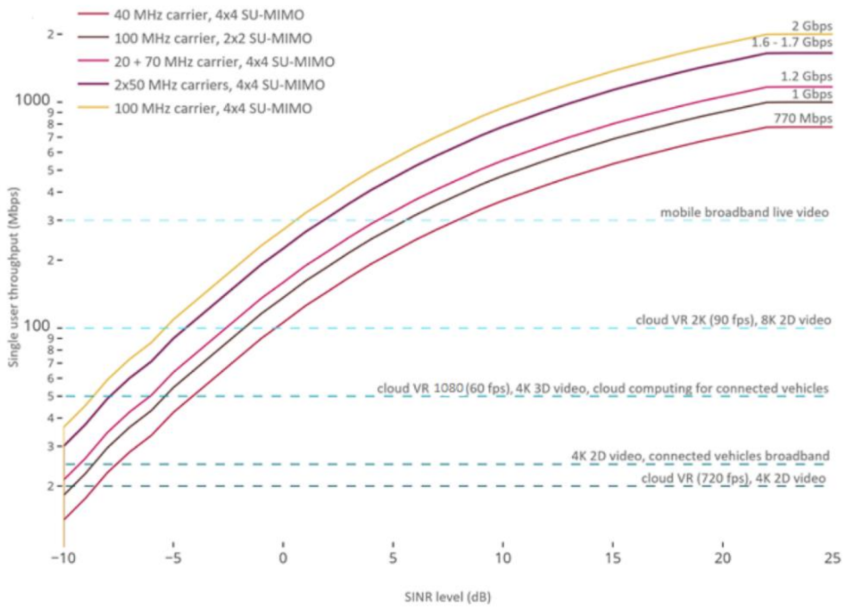


Figure 7. Downlink throughput for a single user (SUT) across different signal levels in a cell compared to the minimum rate required for some 5G services[7]

In addition, the mobile industry is arguing for 100MHz of contiguous spectrum for the delivery of Ultra-reliable Low Latency Communications (URLLC). URLLC is a specialist application more suited to specific instances and not for general (public) use and as such is unlikely to generate the revenues needed to

[6] *See,* Ofcom, *Figure A7.26, Award of the 700 MHz and 3.6-3.8 GHz spectrum bands: Annexes* (13 March 2020), available online at https://www.ofcom.org.uk/data/assets/pdf_file/0017/192410/annexes-award-700mhz-3.6-3.8ghz-spectrum.pdf.

[7] *See,* Ofcom, *Figure A7.27, Award of the 700 MHz and 3.6-3.8 GHz spectrum bands: Annexes* (13 March 2020), available online at https://www.ofcom.org.uk/data/assets/pdf_file/0017/192410/annexes-award-700mhz-3.6-3.8ghz-spectrum.pdf.

fund widespread 5G roll-out. ITU-R Report M.2410-2017 "Minimum requirements related to technical performance for IMT-2020 radio interface(s)" recommends 100 MHz as the minimum bandwidth required for URLLC (and eMBB). However, it also says that the required 100 MHz can be achieved through multiple carriers: there is no requirement to achieve the 100 MHz through a single carrier using a single contiguous block. URLLC is also not considered a high bandwidth or data-hungry service.

The 5G standard allows for the resource block sizes needed for URLLC in a 50MHz bandwidth which has additional advantages regarding the required signal strength and therefore the service range of the site.[8] It is important to emphasize that this specialist application would be deployed at specific locations such as campus and industrial sites but not on a general network. URLLC would be better suited to unencumbered bands free from neighboring operators, making the mmWave spectrum far better suited for this application than C-band.

7 Conclusions

In this report, an overview of the impact of 5G in-band emission (IBE) interference into the FSS receiver LNB and of the 5G out of band emission (OOBE) interference into the FSS operating band is presented:

1. In order to prevent 5G IBE from saturating the FSS receiver LNB, filtering would need to attenuate 5G signals in the order of 60-70 dB.
2. Taking the 3GPP standard and CEPT ECC unwanted emission profiles lowest power (considering up to 40 MHz of frequency separation) have shown that the 5G OOBE could still cause harmful levels of interference even when large separation distances are observed.

Based on these conclusions and on the guardband considerations raised in section 4 of this report, we recommend the following:

1. Allow sufficient guardband between FSS ES and 5G services to allow:
    a. The filter enough of frequency separation to transition and effectively attenuate the 5G IBE
    b. Enough separation for the 5G OOBE to reach lower emission levels
2. Carefully consider the 5G technical conditions, namely more stringent unwanted emission profile, and their impact on the coexistence with FSS receivers.
3. The need to register all FSS earth station receivers to develop a database of the locations to be protected through the implementation of filters and coordination procedures. This would be in-line with the ICASA guidelines. This third point is critical as highlighted by the following points:
    a. Experience has shown that regulators are unaware of un-coordinated C-band receive only earth stations;
    b. Lack of registration leads regulators to make uninformed decisions about spectrum;
    c. The need for close cooperation between regulator, satellite operator and satellite national customers to solve this issue of antenna registration;
    d. Near term ICASA should do a data gathering using existing E/S registration tool - support from satellite operators and C band customer can be provided;
    e. Long term - enhanced earth station data portal under a Digital Portal Strategy;
    f. Having this data is ESSENTIAL to ensuring the protection of C-band customers.

[8] ShareTechNote.com. 5G Frame Structure. https://www.sharetechnote.com/html/5G/5G_FrameStructure.html

This report also addresses the fact that 80-100MHz of contiguous spectrum is not a requirement for 5G operation and that 40MHz or non-contiguous carriers in other frequency bands are sufficient to provide 5G services (see section 6).