Radiocommunication Study Groups

Received: 12 February 2014

Document 4-5-6-7/480-E
12 February 2014
English only

North American Broadcasters Association (NABA)

SHARING STUDY ON THE EFFECTS OF INTERNATIONAL MOBILE TELECOMMUNICATIONS-ADVANCED SYSTEMS ON C-BAND EARTH STATIONS (UPDATED)

1 Introduction

The North American Broadcasters Association[1] (NABA, *www.nabanet.com*) is an association of broadcasters in Canada, Mexico and the United States, and the NABA Technical Committee is its standing technical body. NABA is thus in a position to present the technical viewpoints of the most authoritative association of professional North American Broadcasters in television and sound programme production, post-production, and distribution for terrestrial, satellite, and cable broadcasting.

NABA is a Sector Member of ITU-R and a long-time participant in ITU-R Study Groups, Working Parties, Task Groups, Rapporteur Groups, etc. NABA numbers among its members Chairmen, Vice-Chairmen and members of the above groups. NABA also participates widely in the ITU work on radio, television and multimedia services.

1.1 Requirement

This sharing study analysed the potential interference caused by IMT-Advanced (IMT-A) into the fixed satellite service (FSS) space-to-Earth downlink receivers in the C-band frequencies from 3 400-4 200 MHz. Both in-band and adjacent-band cases including short and long-term interference criteria were evaluated, as well as non-linear effects, such as gain compression, low noise block (LNB) overload, and intermodulation. Both macro cell and small cell IMT-A deployment scenarios were analysed.

---

[1] NABA members include: Ad-ID LLC; BBM Canada; Bell Media, CBC/Radio-Canada; CBS Broadcasting, Inc.; DIRECTV, Inc.; Disney/ABC Television Group; Ericsson Television Inc.; Eutelsat America Corp.; Evertz Microsystems Ltd.; Fox Entertainment Group, Inc.; Grupo Televisa S.A.; Harmonic, Inc.; Inmarsat; Intelsat; National Association of Broadcasters (NAB); National Public Radio (NPR); NBC Universal; Public Broadcasting Service (PBS); SES; Shaw Communications; SiriusXM Radio Inc.; Time Warner, Inc.; TV Azteca S.A. de C.V.; Univision Communications Inc.; and ViaSat.

1.2 Actions required

Consideration of the suitability of this band as a potential candidate band should take into account the results and conclusions of this sharing study. It is recommended that the information contained herein be incorporated in the FRAMEWORK FOR A WORKING DOCUMENT TOWARDS A DRAFT NEW REPORT ITU-R [C-BAND DOWNLINK], Sharing studies between IMT-Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 MHz frequency band in the WRC study cycle leading to WRC-15 as contained in Attachment 3 of Annex 7 of Document 4-5-6-7/393. Conclusion statements contained in this report based on the results of the study that state sharing of the band 3 400-4 200 MHz is not feasible should be included in the WORKING DOCUMENT TOWARDS DRAFT CPM TEXT ON C-BAND STUDIES ON SATELLITE ISSUES, as contained in Attachment 5 of Annex 7 of Document 4-5-6-7/393. Conclusion statements contained in this report based on the results of the study that state sharing of the band 3 400-4 200 MHz is not feasible should be included in both Attachment 1 and Attachment 2 of SUMMARY OF JOINT TASK GROUP 4-5-6-7 INPUT CONTRIBUTIONS ON STUDIES RELATING TO CERTAIN FREQUENCY BANDS WHICH MAY BE CONSIDERED UNDER WRC-15 AGENDA ITEM 1.1, Annex 9 of Document 4-5-6-7/393.

1.3 Study elements

The objective of this analysis was to perform a sharing study of IMT-A systems operating in-band and adjacent band to C-band earth stations in the 3 400-4 200 MHz band Fixed-Satellite Service (FSS) primary allocation.

2 Background

The space-to-Earth C-band (3 400-4 200 MHz) has been identified as a suitable band by ITU-R WP 5D for Joint Task Group (JTG) 4-5-6-7. JTG 4-5-6-7 is responsible for collecting sharing studies for the World Radio Conference 2015 (WRC-15).

The North American Broadcasters Association (NABA) represents incumbent commercial users of C-band FSS primary allocation 3 400-4 200 MHz. In North America, the band is used for satellite downlink of video and television broadcasts of programming materials and other data.

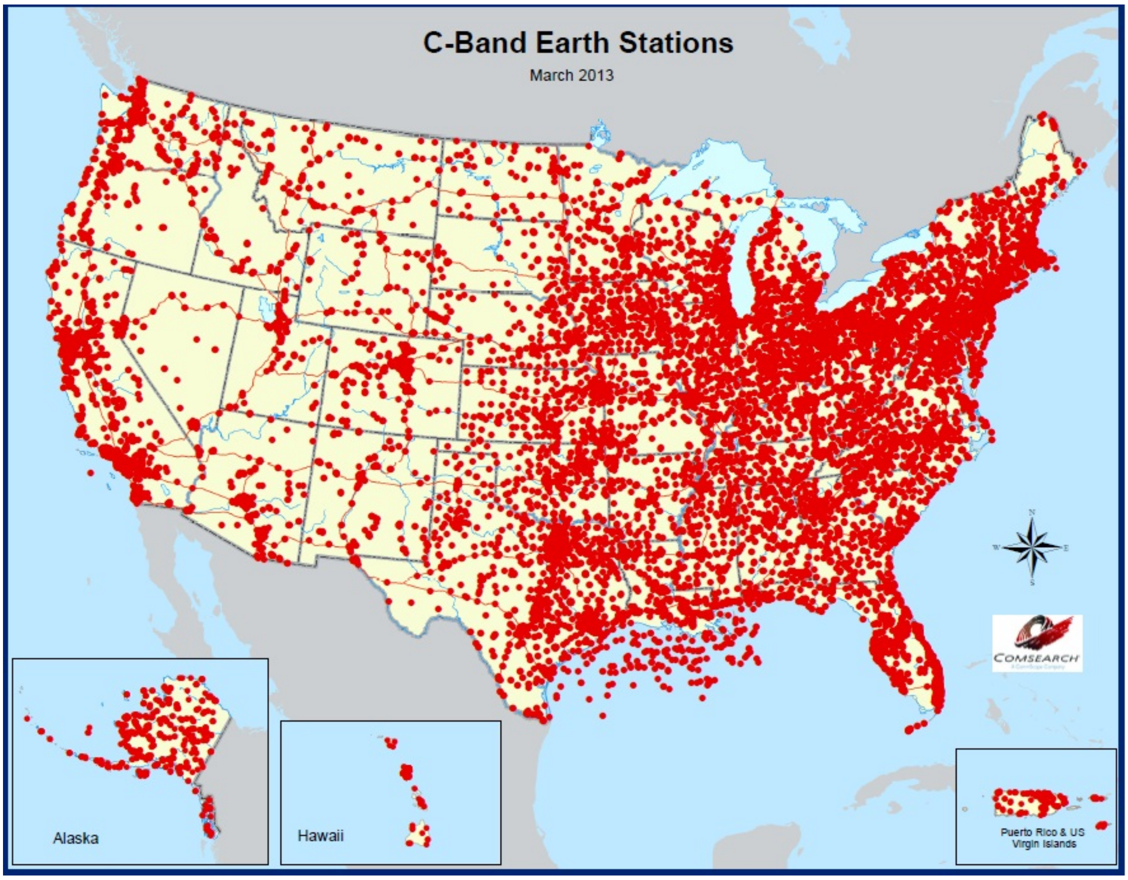
A search of United States Federal Communications Commission (FCC) database records indicated that approximately 5000 earth stations are licensed in the 3700-4200 MHz band[2] in the United States. Since receive-only systems are not required to be licensed, there are additional, but largely unknown, numbers of unlicensed earth stations. For example, as of December 2005, there were approximately 122,000 receive-only earth stations that received programming from the Public Broadcasting System (PBS), a provider of public television programming in the United States, on the 3 700-4 200 MHz band. There are more than 1,300 earth stations that are registered for this band in the Industry Canada database. In addition to these, there are currently over 1,700 unregistered cable head-ends operating in Canada. Figure 1 shows the deployment of C-band earth stations in the United States.

---

[2] http://fjallfoss.fcc.gov/General_Menu_Reports/engineering_search.cfm?accessible=NO, Frequency select performed from Federal Communications Commission (FCC) International Bureau website, 28 March 2013.

FIGURE 1

C-band earth stations in the United States



This band has been in use for this service for many decades and such earth stations are ubiquitous.

3 Technical characteristics

3.1 C-band earth stations

This study used the technical characteristics for C-band earth stations according to what were provided by ITU-R WP 4A in Document 4-5-6-7/133 (that are generally the same as those contained in Report ITU-R M.2109).

3.2 International mobile telecommunications-advanced system technical characteristics

The technical characteristics are the same as those, provided by ITU-R WP 5D as contained in Draft New Report ITU-R M. [IMT. ADV. PARAM] (Document 4-5-6-7/236).

4 Analysis

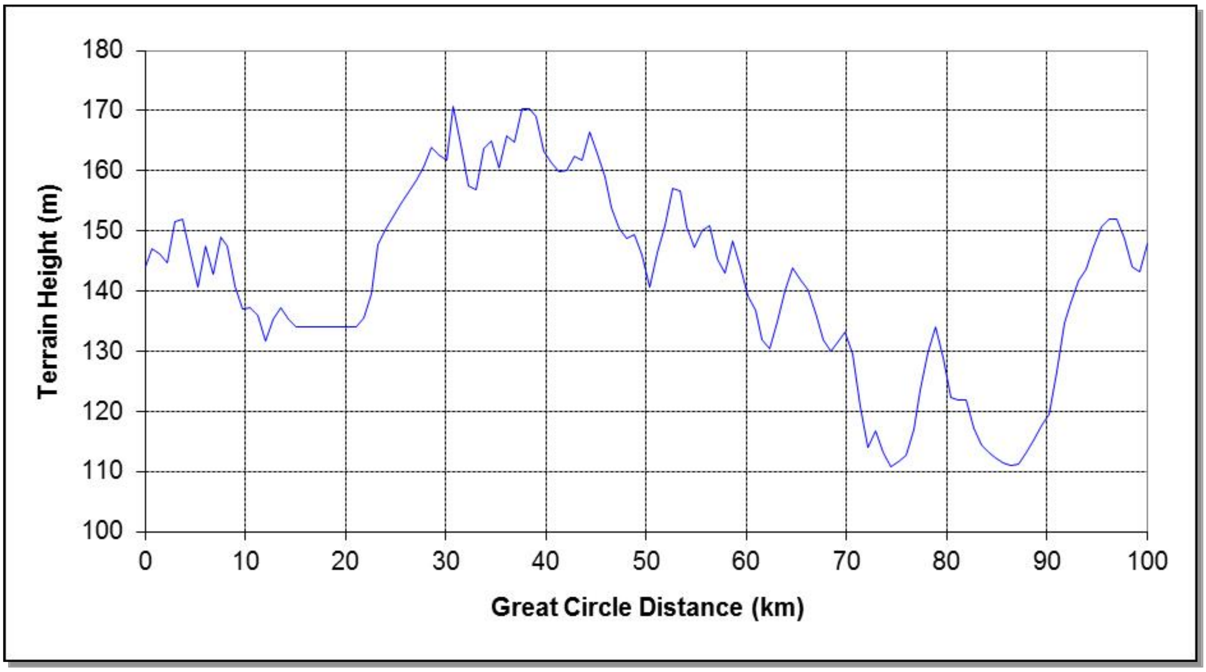
This analysis consisted of performing a sharing study to evaluate the potential interference caused by IMT-A systems operating in-band and adjacent band to C-band earth stations operating in the 3 400-4 200 MHz band FSS primary allocation.

4.1 Assumptions

The study considered single entry and aggregate interference effects of suburban and urban macro cell and urban small cell broadband IMT-A base station deployments in the frequency range 3 400-4 200 MHz to FSS users. In-band and adjacent-band interactions from outdoor and indoor deployment scenarios were examined. The current version of propagation model Recommendation ITU-R P.452-14 was incorporated into the analysis model for this study. Since this propagation model includes the effects of terrain, a representative location with moderate terrain characteristics was used for this analysis. Figure 2 shows the terrain profile for the single-entry path of the base station relative to the C-band earth station.

FIGURE 2

Terrain profile for single-entry analysis



For this analysis, only base stations were modelled.

4.2 Methodology with formulas

4.2.1 Mutual coupling characterization

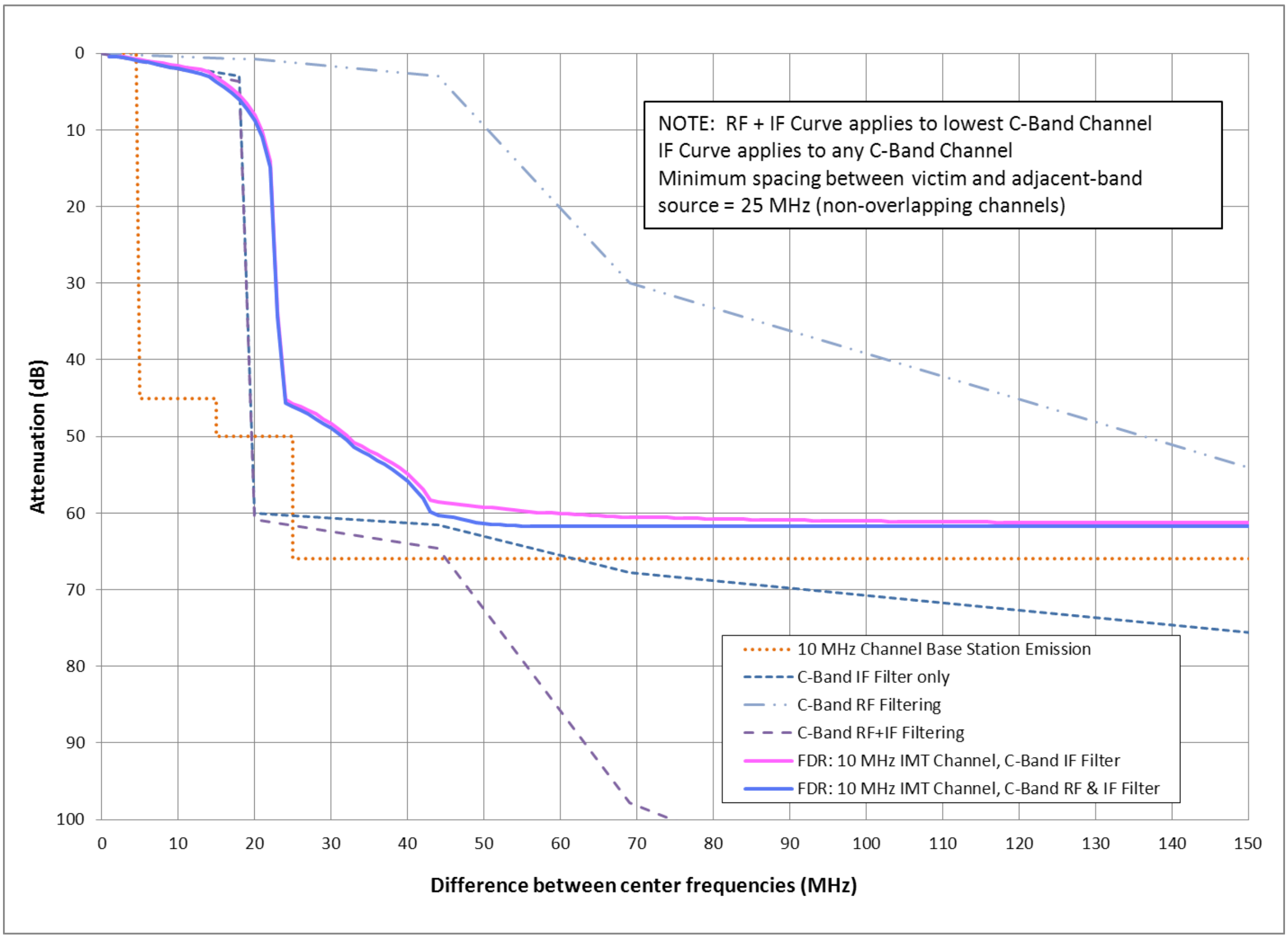
Frequency-Dependent Rejection (FDR) is used in the computation of received interference levels. More information on FDR can be obtained from Recommendation ITU-R SM.337-6 (current version).

IMT-A transmitter emissions were modelled using the Adjacent-Channel Leakage Power Ratio (ACLR) specification documented in Report ITU-R M.2109. The C-band earth station receiver intermediate frequency (IF) selectivity characteristic was assumed.

The calculated FDR curves that were used in this analysis are shown in Figure 3.

FIGURE 3

Input data and mutual coupling results



4.2.2 Interference criteria

The analysis used ITU-R-defined protection criteria as specified in Recommendations ITU-R S.1432 and ITU-R SF.1006.

4.2.3 Apportionment of interference

Per Document 4-5-6-7/133, the apportionment was assumed for this study that 50% of the interference to the C-band earth station receiver was allocated to IMT-A systems for which the long-term interference criteria applied. For the cases in which the short-term interference criteria were applicable, and also the large-signal analysis, 100% of the interference was allocated to IMT-A systems.

4.3 Calculations

4.3.1 Small signal analysis (in-band and out-of-band emissions)

For the single-entry analysis, a single IMT-A base station was placed along a path relative to the earth station location, aligned with the antenna azimuth. For the adjacent-band cases, it was assumed that the IMT-A base station was tuned to the closest adjacent-band channel to the lowest C-band earth station receiver channel. For the in-band cases, it was assumed that the IMT-A base station was co-channel with the C-band earth station receiver. The IMT-A base station was moved along this path and a protection distance was determined based on the separation distance necessary to reduce the interference level below the interference threshold.

For the aggregate analysis, the frequency for each IMT-A base station was randomly selected for each model iteration from the available pool of frequencies. For the three-sector base stations, each sector was assigned a random channel. The model incrementally increases the protection distance relative to the C-band earth station receiver and calculates the received aggregate interference power. IMT-A base stations are shut off within this protection distance. For the minimum protection distance, if the calculated aggregate interference at a C-band earth station receiver remained below the interference threshold for a minimum of 100 model iterations, this result was reported. For each deployment scenario, the base stations were spaced in a grid with the C-band earth station receiver in the centre. The aggregate scenario includes the single-entry base station. It is positioned at the inner radius of the grid scenario and along the azimuth axis of the earth station antenna. The IMT-A system bandwidth was assumed to be 10 MHz, so the channels were spaced at 10-MHz intervals. IMT-A base stations were modelled using three-sector or omnidirectional antennas, depending on the type of scenario.

4.3.1.1 Outdoor deployments

For the outdoor deployments, both macro and small cell IMT-A base station scenarios were analyzed. Each simulation was performed for C-band earth station antenna elevation angles of 5°, 10°, 20°, and 30°.

An adjacent-band aggregate analysis was also performed to investigate the use of a guard band adjacent to the 3400-4200 MHz band. The guard band was made up of the difference in frequency between the high frequency channel edge of the adjacent-band base stations tuned closest to the C-band earth station receiver channel and the low frequency channel edge of the C-band earth station receiver. The size of guard band was varied parametrically and protection distances were determined.

4.3.1.2 Indoor deployments

For the indoor deployment portion of the analysis, only small cell IMT base stations were considered. Simulations were performed for C-band earth station elevation angles of 5° and 30°. Scenarios were examined using building attenuation values equal to 5, 10, 15, and 20 dB.

The indoor deployments were analysed for in-band and adjacent band both for single-entry (long-term and short-term interference) and aggregate (long-term interference only).

4.3.2 Large Signal Analysis (LNB Overdrive, and Intermodulation)

Large-signal interactions were also analysed. These interactions include gain compression and receiver intermodulation (IM). C-band earth station systems with and without RF filters were considered. For interfering signals in the adjacent frequency band, RF filter attenuation will reduce the potential for degradation. No IF attenuation was considered for this analysis because gain compression and IM products occur prior to the IF filtering.

Distances to mitigate potential gain compression were determined. This is referred to as LNB overdrive in Document 4-5-6-7/133. These calculations were performed using the Recommendation ITU-R P.452-14 propagation model.

Intermodulation interference effect on the earth station LNA/LNB from IMT operation was also analysed. For the LNB under analysis, the onset of IM occurs at 10 dB below the gain compression level of 2 dBm, or –8 dBm at the LNB output. The onset of IM at the input of the LNB was determined by subtracting the LNB gain of 63 dB from the –8 dBm output level resulting in –71 dBm at the LNB input. IM was analysed based on the third-order intercept point, and the fact that the input/output response slope for the desired RF input is 1, while the slope for 3rd order IM is 3. The onset of IM translated to the 3rd order results in an IM threshold at the LNB input of –55.7 dBm.

4.4 Results

4.4.1 Small signal results (in-band and out-of-band emissions)

4.4.1.1 Outdoor deployments

Results for the in-band, long-term interference threshold case with IF filtering only are presented in Table 1.

TABLE 1

In-band, long-term interference threshold protection distances from IMT-Advanced base stations to C-band earth stations, with IF filtering only

Receiver antenna elevation angle, degrees	Single-entry protection distance, on Azimuth, km	Aggregate protection distance, km
Macro Cell Suburban		
5	58.1	63.0
10	50.5	55.0
20	45.7	53.0
30	44.6	52.0
Macro Cell Urban		
5	51.2	53.0
10	45.2	48.0
20	40.0	45.0
30	35.7	44.0
Small Cell Urban		
5	20.3	20.3
10	9.0	10.0
20	8.3	9.0
30	6.2	9.0

Results for the adjacent-band, long-term interference threshold case with IF filtering only are presented in Table 2.

TABLE 2

Adjacent-band, long-term interference threshold protection distances from IMT-Advanced base stations to C-band earth stations, with IF filtering only

Receiver antenna elevation angle, degrees	Single-entry protection distance, on Azimuth, km	Aggregate protection distance, km
Macro cell suburban		
5	13.8	19.0
10	9.4	18.0
20	8.7	17.0
30	8.2	17.0
Macro cell urban		
5	9.3	12.0
10	8.5	10.0
20	6.4	9.0
30	5.1	9.0
Small cell urban		
5	3.8	3.8
10	2.8	2.8
20	1.5	1.5
30	0.90	0.90

Results for the adjacent-band, long-term interference threshold case with IF and RF filtering are presented in Table 3.

TABLE 3

Adjacent-band, long-term interference threshold protection distances from IMT-Advanced base stations to C-band earth stations, with IF and RF filtering

Receiver antenna elevation angle, degrees	Single-entry protection distance, on Azimuth, km	Aggregate protection distance, km
Macro cell suburban		
5	13.4	18.0
10	9.4	17.0
20	8.6	17.0
30	8.2	15.0
Macro cell urban		
5	9.3	12.0
10	8.4	10.0
20	6.4	9.0
30	5.0	9.0
Small cell urban		
5	3.8	3.8
10	2.8	2.8
20	1.4	1.4
30	0.90	0.90

The results can be seen to be comparable to those presented in Table 2. This is due to the similarity of the FDR curves in these two cases.

Results for the in-band, short-term interference threshold case with IF filtering only are presented in TABLE 4.

TABLE 4

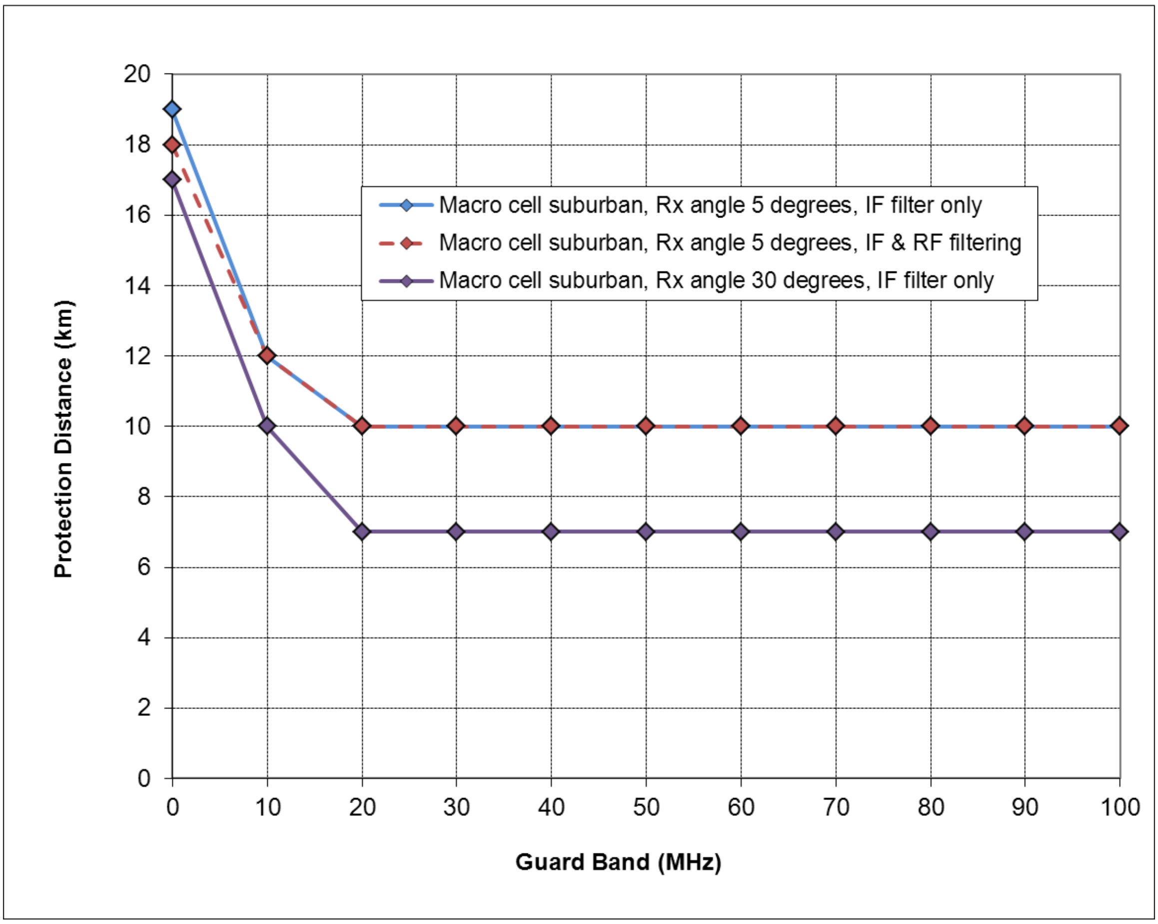
In-band, short-term interference threshold protection distances from IMT-Advanced base stations to C-band earth stations, with IF filtering only

Receiver antenna elevation angle, degrees	Single-entry protection distance, on Azimuth, km
Macro cell suburban	
5	525
10	498
20	393
30	312
Macro cell urban	
5	477
10	393
20	311
30	262
Small cell urban	
5	225
10	119
20	54.1
30	5.1

Results for the guard band aggregate analysis performed to investigate the use of a guard band adjacent to the 3400-4200 MHz band are presented in Figure 4. The results show the required protection distance as the guard band size is increased. The guard band size was increased by parametrically eliminating the base station 10 MHz transmit channels closest to the earth station receive channel. There is an initial decrease in the required separation distance as the guard band increases from 0 to 10 MHz, however, as the guard band increases to 20 MHz and beyond, the separation distance does not continue to decrease. The reason for this plateau in the required protection distance from 20 MHz and beyond is due to the fact that the ACLR emissions specification does not continue to “roll-off” with additional frequency separation. It can be concluded from Figure 8 that increasing the size of the guard band beyond 20 MHz has no effect on reducing the separation distance required to protect the FSS receiving earth station, i.e. for example if the guard band were to increase from 20 MHz to100 MHz, the same separation distance would still be required to ensure protect the FSS receiving earth station from harmful interference from IMT-A systems..

FIGURE 4

Aggregate protection distance versus guard band size



4.4.1.2 Indoor deployments

Small cell urban indoor deployment results for the in-band, long-term interference threshold case with IF filtering only are presented in Table 5.

TABLE 5

Small cell indoor urban in-band, long-term interference threshold protection distances from IMT-Advanced base stations to C-band earth stations, with IF filtering only

Receiver antenna elevation angle, degrees	Building attenuation, dB	Single-entry protection distance, on Azimuth, km	Aggregate protection distance, km
5	5	8.4	8.4
30		3.9	4.0
5	10	8.1	8.1
30		3.8	3.8
5	15	4.2	4.2
30		3.0	3.0
5	20	4.1	4.1
30		1.5	1.5

Small cell urban indoor deployment results for the adjacent-band, long-term interference threshold case with IF filtering only are presented in Table 6.

TABLE 6

Small cell indoor urban adjacent-band, long-term interference threshold protection distances from IMT-Advanced base stations to C-band earth stations, with IF filtering only

Receiver antenna elevation angle, degrees	Building attenuation, dB	Single-entry protection distance, on Azimuth, km	Aggregate protection distance, km
5	5	1.5	1.5
30		0.4	0.4
5	10	1.4	1.4
30		0.2	0.2
5	15	1.1	1.1
30		0.2	0.2
5	20	0.5	0.5
30		< 0.1	< 0.1

Small cell urban indoor deployment results for the in-band, short-term interference threshold case with IF filtering only are presented in Table 7.

TABLE 7

Small cell indoor urban in-band, short-term interference threshold protection distances from IMT-Advanced base stations to C-band earth stations, with IF filtering only

Receiver antenna elevation angle, degrees	Building attenuation, dB	Single-entry protection distance, on Azimuth, km
5	5	8.3
30		3.7
5	10	4.2
30		1.5
5	15	4.0
30		1.4
5	20	3.8
30		1

4.4.2 Large signal results (LNB overdrive, and intermodulation)

Table 8 presents the results for gain compression and onset of non-linear interactions for co-channel interference.

TABLE 8

Large-signal protection distances for C-band earth station without RF filtering

E/S Antenna		Gain compression computation (LNA Input Threshold = -61 dBm)
Off-Axis Angle, degrees	Gain, dBi	Required distance to mitigate, km
Macro cell suburban		
5	14.5	9.0
10	7.0	8.3
20	-0.5	6.2
30	-4.9	4.9
Macro cell urban		
5	14.5	8.7
10	7.0	7.9
20	-0.5	5.0
30	-4.9	4.4
Small cell urban		
5	14.5	1.1
10	7.0	0.5
20	-0.5	0.2
30	-4.9	0.1
* For distances less than 1 km, free-space propagation loss was used.		

Table 9 presents the results for C-band earth systems with RF filtering and assuming immediately adjacent-channel interference (0 MHz separation between edges of channels).

TABLE 9

Large-signal protection distances for C-band earth stations, with RF filtering

E/S Antenna		Gain compression computation (LNA Input Threshold = -61 dBm)
Off-Axis Angle, degrees	**Antenna gain, dBi**	**Required distance to mitigate, km**
Macro cell suburban		
5	14.5	8.8
10	7.0	8.3
20	-0.5	6.0
30	-4.9	4.1
Macro cell urban		
5	14.5	8.5
10	7.0	7.9
20	-0.5	4.9
30	-4.9	4.1
Small cell urban		
5	14.5	0.9
10	7.0	0.4
20	-0.5	0.2
30	-4.9	0.1
* For distances less than 1 km, free-space propagation loss was used.		

Tables 10 and 11 present the results for the IM protection distances required. It is assumed that the IM source signals are not co-channel with the desired signal, but operating within the pass- band of the LNB.

TABLE 10

Intermodulation protection distances for C-band earth stations, without RF filtering

Earth station system		**IM protection zone (LNA Input Threshold = -55.7 dBm)**
Off-Axis Angle, degrees	**Antenna gain, dBi**	**Required distance to mitigate, km**
Macro cell suburban		
5	14.5	8.5
10	7.0	6.5
20	-0.5	4.4
30	-4.9	2.6
Macro cell urban		
5	14.5	6.7
10	7.0	5.1
20	-0.5	4.3
30	-4.9	2.6
Small cell urban		
5	14.5	0.6
10	7.0	0.2
20	-0.5	0.1
30	-4.9	0.1
* For distances less than 1 km, free-space propagation loss was used.		

TABLE 11

Intermodulation protection distances for C-band earth stations, with RF filtering

Earth station system (1.4 dB RF filter attenuation)		IM protection zone (LNA Input Threshold = -55.7 dBm)
Off-Axis Angle, degrees	**Antenna gain, dBi**	**Required distance to mitigate, km**
Macro cell suburban		
5	14.5	8.4
10	7.0	6.3
20	-0.5	3.7
30	-4.9	2.2
Macro cell urban		
5	14.5	7.2
10	7.0	5
20	-0.5	3.7
30	-4.9	2.2
Small cell urban		
5	14.5	0.5
10	7.0	0.2
20	-0.5	0.1
30	-4.9	0.1
* For distances less than 1 km, free-space propagation loss was used.		

5 Summary

This sharing study determined the protection distances that are required to prevent interference from IMT-A devices and ensure compliance with the requisite protection criteria at FSS C-band space-to-Earth downlink receivers. The range of required protection distances provided in this summary section is dependent on the C-band earth station receiver elevation angle.

In order to mitigate long term interference:

The required protection distance for IMT-A operating in-band with the C-band earth stations for both the single entry case and aggregate case, were found to be at least tens of kilometres for the macro cell cases considered in this study. The required protection distance for the small cell urban outdoor deployment in-band cases ranged from several kilometres to over twenty kilometres. Depending on the amount of building attenuation assumed, the required protection distance for the small cell urban indoor deployment in-band cases ranged from over one kilometre to over several kilometres. Similarly, the required protection distance for IMT-A operating in the band adjacent to the C-band earth stations for both the single entry case and aggregate case, were found to be at least several kilometres for the macro cell cases considered in this study. The required protection distance for the small cell urban outdoor deployment adjacent band cases ranged from approximately one kilometre to over several kilometres. Depending on the amount of building attenuation assumed, the required protection distance for the small cell urban indoor deployment adjacent-band cases ranged from less than one hundred metres to several kilometres.

Moreover, since the required protection distance for IMT-A operating in the band adjacent to the C-band earth stations with RF filters were found to be in the same order of magnitude of those without RF filters, it can be concluded that RF filters would not have an appreciable effect in mitigating interference received from IMT-Advanced systems into FSS receiver earth stations.

In order to mitigate short term interference:

The required protection distance for IMT-A operating in-band with the C-band earth stations for both the single entry case and aggregate case, were found to be at least several hundred kilometres for the macro cell cases considered in this study. The required protection distance for the small cell urban outdoor deployment in-band cases ranged from several kilometres to several hundred kilometres. Depending on the amount of building attenuation assumed, the required protection distance for the small cell urban indoor deployment in-band cases ranged from one kilometre to over several kilometres.

6 Recommendations

The results of the study showed that the required protection distances were dependent on the type of base station scenario with the macro cell cases requiring the largest exclusion zones.

For the in-band case, the required protection distance for a macro cell deployment regardless of environment (i.e. in both a suburban and urban environment) was found to be several hundred kilometres. The required protection distance for an outdoor small cell deployment in an urban environment ranges were found to be several kilometres and extend up to hundreds of kilometres. The required protection distance for an indoor small cell deployment was not as extensive due to the fact that some degree of building attenuation was assumed. However, the required protection distance was found to be more than several kilometres in cases where an indoor small cell might be operating close to a window where building attenuation is significantly reduced.

For the adjacent band case, the deployment of IMT-A systems will create unacceptable restrictions to avoid RF interference or large-signal interactions with C-band earth stations for macro cell base station scenarios. For the small cell scenario, the size of the exclusion zones was smaller due to the fact that they have been specified to be installed lower to the ground and limited in transmit power. However, the required protection distances would still prevent small cell urban deployments over a protection area centred about a C-band earth station receiver ranging from 2.5 to over 45 sq km – a result which makes sharing not feasible. The protection distance required to avoid RF interference to C-band earth stations from small cell indoor deployments was found to range from one kilometre to several kilometres, even with up to 15 dB of building attenuation assumed, for the lower receiver elevation angles.

The results show that an IMT implementation of any deployment scenario sterilizes large geographical areas preventing future deployment of satellite earth stations, e.g., VSATs.

The results also show that the use of a common representative front-end RF filter provides an insignificant decrease in the required separation distance. Moreover, inclusion of an RF filter provides little additional rejection over what is already provided by the IF selectivity of the tuner.

The conclusion of this study is that sharing the band from 3 400 MHz to 4 200 MHz is not feasible due to the size of the needed exclusion zones, up to an area of over 865,000 sq km, and the large number of C-band earth stations that would need to be protected. Prior ITU studies, as are summarized in Report ITU-R M.2109, drew the same conclusions.

____