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(11/2014)

Sharing assessment between meteorological-satellite systems and IMT stations in the 1 695-1 710 MHz frequency band

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R SA.2329-0[1]

Sharing assessment between meteorological-satellite systems and IMT stations in the 1 695-1 710 MHz frequency band

(2014)

1 Introduction/Background

In order to support requirements for “mobile broadband”, the frequency band 1 695-1 710 MHz has been called for studies.

This frequency band is allocated to the meteorological-satellite service (MetSat) and used in particular for data downlink from non-geosynchronous orbit (NGSO) satellites and is essential for providing operational and time-critical meteorological information to the users around the world with receiving earth stations operated by almost all national meteorological services and many other users worldwide.

On the basis of some existing MetSat earth stations locations, the present Report provides an assessment of the separation distance that would be required between IMT stations (base stations and user equipment (UE)) and MetSat receiving earth stations in the 1 695-1 710 MHz frequency band.

2 Technical characteristics

2.1 Meteorological systems

There are hundreds of MetSat stations worldwide in the 1 695-1 710 MHz frequency band operated by almost all national meteorological services and many other users worldwide.

Meteorological-satellite systems use the frequency band 1 695-1 710 MHz to disseminate meteorological data directly to the users. The frequency band 1 695-1 698 MHz is used for earth stations to receive data from geostationary MetSat systems, such as FY-2 and FY-4 from China, GOES from USA, Meteosat from EUMETSAT, COMS from Korea, MTSAT from Japan and others. In the frequency band 1 698-1 710 MHz a number of users operate earth stations to receive High Resolution Picture Transmission (HRPT) from NGSO satellites such as FY-3 from China, NOAA from USA and METOP from EUMETSAT.

The characteristics of such stations are provided in Table 1.

TABLE 1

Characteristics used for meteorological earth stations

Parameter	Value
Signal	HRPT, High Resolution Picture Transmission
Nominal carrier centre frequency	Either 1 701.300 MHz or 1 707.000 MHz
RF bandwidth	4.5 MHz (99% of the total signal power)

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[1] This Report was approved jointly by Radiocommunication Study Groups 5 and 7, and any future revision should also be undertaken jointly.

TABLE 1 (*end*)

Parameter	Value
Polarization	RHCP
Antenna diameter	1.8 m
Antenna height	12 m
Antenna gain	29.8 dBi
Antenna pattern	Appendix **8** of the Radio Regulations
Minimum elevation angle	5°
Protection criterion long-term (as per Rec. ITU-R SA.1027 for terrestrial path)	–151 dBW per 2 668 kHz equivalent to –148.7 dBW per 4.5 MHz, no more than 20% of the time
Protection criterion short-term (as per Rec. ITU-R SA.1027 for terrestrial path)	–138 dBW per 2 668 kHz equivalent to –135.7 dBW per 4.5 MHz, no more than 0.009 4% of the time

The permissible interference power $P_r(p)$ is specified with respect to the actual percentage of time the receiver is in visibility of the satellite, and not the total elapsed time.

Similar stations are used by a number of users in almost all countries worldwide. Table 2 below gives some example locations.

TABLE 2

Example locations of meteorological earth stations

Station Name	Country	Operated by	Location (lat, long)
Edmonton	Canada	EC	53.33°N, 113.5°W
Gander			48.95°N, 54.57°W
Gilmore Creek	USA	NOAA	64.97°N, 147.40°W
Monterey			36.35°N, 121.55°W
Ewa Beach			21.33°N, 158.07°W
Miami			25.74°N, 80.16°W
Wallops			37.8°N, 75.3°W
Maspalomas	Spain	INTA/INSA	27.78°N, 15.63°W
Kangerlussuaq	Greenland	DMI	66.98°N, 50.67°W
Svalbard	Norway	KSAT	78.13°N, 15.23°E
Athens	Greece	HNMS	37.81°N, 23.77°E
Lannion	France	CMS	48.75°N, 3.5°W
Saint-Denis (La Réunion)			20.91°S, 55.50°E
Moscow	Russian Federation	SRC Planeta	55.76°N, 37.57°E
Beijing	CHN	CMA	40.05°N, 116.27°E
Guangzhou	CHN	CMA	23.16°N, 113.33°E
Xinjiang	CHN	CMA	43.86°N, 87.57°E

TABLE 2 (*end*)

Station Name	**Country**	**Operated by**	**Location (lat, long)**
Kashi	CHN	CMA	43.86°N, 75.94°E
Jiamusi	CHN	CMA	46.9°N, 130.34°E
Sanya	CHN	CMA	18.26°N, 109.49°E
Antarctic	CHN	CMA	72°S, 2.52°E
Melbourne	AUS	BOM	38.36°S, 145.17°E
Kiruna	S	SSC	68°N, 21°E

2.2 Mobile service (IMT systems)

The following parameters have been considered in the 1 695-1 710 MHz frequency band.

TABLE 3

Selected set of IMT characteristics for base stations (rural case)

Parameter	**Value**
Transmitted power (dBm)	46
Bandwidth (MHz)	10
Activity factor (%)	50
Antenna gain (dBi)	18
Feeder loss (dB)	3
Antenna height (m)	30
Antenna tilt angle (degrees)	3

TABLE 4

Selected set of IMT characteristics for UE (as used in Annex A)

Parameter	**Value**
Average transmitted power	2
Antenna gain (dBi)	–3
Transmission bandwidth (MHz)	10
Antenna height (m)	1.5

TABLE 5

LTE user equipment technical characteristics (as used in Annex C)

<table>
<tr><th>Technical characteristic</th><th colspan="3">Value</th></tr>
<tr><td>Aggregate total UE e.i.r.p for cities with population < 250 000</td><td colspan="3">–53.12 dBW/Hz</td></tr>
<tr><td>Average individual UE e.i.r.p for cities with population < 250 000</td><td colspan="3">8.08 dBm/10 MHz (TBC with the revision of the study in Annex C)</td></tr>
<tr><td>Aggregate total UE e.i.r.p. for cities with population ≥ 250 000</td><td colspan="3">–50.78 dBW/Hz</td></tr>
<tr><td>Average individual UE e.i.r.p. for cities with population ≥ 250 000</td><td colspan="3">5.87 dBm/10 MHz (TBC with the revision of the study in Annex C)</td></tr>
<tr><td>UE channel bandwidth</td><td colspan="3">5, 10 and 15 MHz</td></tr>
<tr><td>UE antenna height</td><td colspan="3">1.5 m</td></tr>
<tr><td>Number of simultaneously transmitting UE per base station sector for each channel bandwidth</td><td>5 MHz
3</td><td>10 MHz
6</td><td>15 MHz
9</td></tr>
<tr><td>Antenna pattern</td><td colspan="3">Omni directional</td></tr>
<tr><td>Cellular deployment scenario</td><td colspan="3">LTE base stations and UE as presented in Annex C</td></tr>
</table>

3 Analysis

Based on the above assumptions and mobile service deployments, three different analyses have been performed and described in:

- Annex A: Compatibility of NNGSO MetSat earth stations with IMT base stations and UE.
- Annex B: Compatibility of NGSO and geosynchronous orbit (GSO) MetSat earth stations with IMT base stations and UE.
- Annex C: Compatibility of NGSO MetSat earth stations with IMT UE.

4 Summary/Conclusions

This Report shows that the required protection area around MetSat stations from which potential IMT base stations in the 1 695-1 710 MHz frequency band would have to be excluded, would be up to several hundred kilometres, as calculated in Annexes A and B. Therefore, sharing between IMT base stations and MetSat stations in the 1 695-1 710 MHz frequency band is not feasible.

This Report also provides assessments of protection areas around MetSat stations from which IMT UE in the 1 695-1 710 MHz frequency band would have to be excluded, with diverging results. Studies in Annexes A and B depict required separation distances from 46 km (GSO case) and 60 km (NGSO case) up to more than 120 km (NGSO case), even considering low rural deployment and conclude that IMT UE deployment is not compatible with MetSat stations in the 1 695-1 710 MHz. The study in Annex C provides an example calculation resulting in separation distances ranging from 32 to 46 km (NGSO case) and concludes that IMT UE can be deployed compatibly with MetSat stations.

Annex A

Compatibility assessment between meteorological-satellite systems and IMT stations in the 1 695-1 710 MHz frequency band

1 Introduction/Background

This frequency band is allocated to the meteorological-satellite service and used in particular for data downlink from NGSO satellites.

This frequency band is essential for providing operational and time-critical meteorological information to the users around the world with receiving earth stations operated by almost all national meteorological services and many other users worldwide.

On the basis of existing MetSat earth stations locations, the present Annex provides an assessment of the separation distance that would be required between IMT base stations and MetSat receiving earth stations in the 1 695-1 710 MHz frequency band.

2 Technical characteristics

2.1 Meteorological systems

Meteorological-satellite systems use the frequency band 1 695-1 710 MHz to disseminate meteorological data directly to the users. A number of users operate earth stations to receive HRPT from NGSO satellites such as METOP from EUMETSAT.

The characteristics of such stations are provided in Table 6.

TABLE 6

Characteristics used for meteorological earth stations

Parameter	Value
Signal	HRPT, High resolution picture transmission
Nominal carrier centre frequency	Either 1 701.300 MHz or 1 707.000 MHz
RF bandwidth	4.5 MHz (99 % of the total signal power)
Polarization	RHCP
Antenna diameter	1.8 m
Antenna height	12 m
Antenna gain	29.8 dBi
Antenna pattern	Appendix 8 to the Radio Regulations
Minimum elevation angle	5°
Protection criterion long-term (as per Rec. ITU-R SA.1027 for terrestrial path)	–151 dBW per 2 668 kHz equivalent to –148.7 dBW per 4.5 MHz, no more than 20% of the time
Protection criterion short-term (as per Rec. ITU-R SA.1027 for terrestrial path)	–138 dBW per 2 668 kHz equivalent to –135.7 dBW per 4.5 MHz, no more than 0.0094% of the time

The permissible interference power $P_r(p)$ is specified with respect to the actual percentage of time the receiver is in visibility of the satellite, and not the total elapsed time.

Similar stations are used by a number of users in almost all countries worldwide. Table 7 below gives some example locations.

TABLE 7

Example locations of meteorological earth stations

Station Name	Country	Operated by	Location (lat, long)
Edmonton	Canada	EC	53.33°N, 113.5°W
Gander			48.95°N, 54.57°W
Gilmore Creek	USA	NOAA	64.97°N, 147.40°W
Monterey			36.35°N, 121.55°W
Ewa Beach			21.33°N, 158.07°W
Miami			25.74°N, 80.16°W
Wallops			37.8°N, 75.3°W
Maspalomas	Spain	INTA/INSA	27.78°N, 15.63°W
Kangerlussuaq	Greenland	DMI	66.98°N, 50.67°W
Svalbard	Norway	KSAT	78.13°N, 15.23°E
Athens	Greece	HNMS	37.81°N, 23.77°E
Lannion	France	CMS	48.75°N, 3.5°W
Saint-Denis (La Réunion)			20.91°S, 55.50°E
Moscow	Russian Federation	SRC Planeta	55.76°N, 37.57°E
Muscat	Sultanate of Oman	DGMAN	23.59°N, 58.29°E

2.2 Mobile service (IMT systems)

In the absence of IMT parameters for this frequency band, the following parameters have been considered in the 1 695-1 710 MHz frequency band, consistent with parameters in the current IMT frequency bands.

TABLE 8

Selected set of IMT characteristics for base stations

Parameter	Value
Transmitted power (dBm)	43 for BW = 5 MHz 46 for BW = 10 MHz 46 for BW = 20 MHz
Antenna gain (dBi)	18
Feeder loss (dB)	3
Antenna height (m)	30
Antenna tilt angle (degrees)	2.5 rural 5 urban

TABLE 9

Selected set of IMT characteristics for UE

Parameter	**Value**
Typical transmitted power (dBm)	23
Antenna gain (dBi)	0
Transmission bandwidth (MHz)	5, 10 or 20
Antenna height (m)	1.5

3 Analysis for base stations and UE

3.1 Methodology for the base station case

As the frequency band is used by EUMETSAT for the NGSO METOP satellites, the MetSat earth station is continuously tracking the satellite when in visibility. The antenna gain of the earth station towards the horizon changes continuously. The distribution of the interference will therefore be the convolution of the distribution of the antenna gain with the distribution of the propagation loss for an IMT base station.

This may be approximated by the time-variant gain (TVG) method described in section 4 of Annex 6 to RR Appendix **7**.

The TVG method closely approximates the convolution of the distribution of the horizon gain of the earth station antenna and the propagation loss. This method may produce slightly smaller distances than those obtained by an ideal convolution. An ideal convolution cannot be implemented due to the limitations of the current model for propagation loss. The propagation loss required distance, at the azimuth under consideration, may be rewritten for the *n*-th calculation in the following form:

$$L_b(p_v) - G_e(p_n) = P_t + G_x - P_r(p) \qquad \text{dB} \qquad (1)$$

with the constraint:

$$p_v = \begin{cases} 100\, p / p_n & \text{for } p_n \geq 2\,p \\ 50 & \text{for } p_n < 2\,p \end{cases} \qquad \%$$

where:

P_t: maximum available transmitting power level (dBW) in the reference bandwidth at the base station

$P_r(p)$: interference power of an interfering emission (dBW) in the reference bandwidth to be exceeded for no more than p% of the time at the terminals of the antenna of a receiving earth station, where the interfering emission originates from a single source

G_x: maximum antenna gain assumed for the base station towards the horizon (dBi)

$G_e(p_n)$: the horizon gain of the earth station antenna (dBi) that is exceeded for p_n% of the time on the azimuth under consideration

$L_b(p_v)$: the minimum required propagation loss (dB) for p_v% of the time.

The values of the percentages of time, p_n, to be used in equation (1) are determined in the context of the cumulative distribution of the horizon antenna gain. This distribution needs to be developed for a predetermined set of values of horizon antenna gain spanning the range from the minimum to the maximum values for the azimuth under consideration. The notation $G_e(p_n)$ denotes the value of horizon antenna gain for which the complement of the cumulative distribution of the horizon antenna gain has the value corresponding to the percentage of time p_n. The p_n value is the percentage of time that the horizon antenna gain exceeds the *n*-th horizon antenna gain value. This is evaluated only when the satellite is in visibility from the earth station.

For each value of p_n, the value of horizon antenna gain for this time percentage, G_e p_n), is used in equation (1) to determine a minimum required propagation loss. The propagation loss is to be lower than this required propagation loss for no more than p_v% of the time, as specified by the constraint associated with equation (1). A series of distances are then determined using Recommendation ITU-R P.452-14.

The antenna gain of the IMT base stations towards the horizon may be determined using Recommendation ITU-R F.1336. Assuming a maximum antenna gain of 18 dBi, and aperture in azimuth of 65°, a down tilt angle of 2.5° and a coefficient *k* of 0.7, this leads to a gain between 8.1 and 16.1 dBi, depending of the azimuth pointing angle of the base station. The maximum value corresponds to a base station pointing in the same direction as the MetSat earth station, the minimum value corresponds to a base station pointing at an angle of 60° from the MetSat earth station.

3.2 Calculations for the base station case

The calculations have been done for three different receiving stations in the EUMETSAT Advanced Retransmission Service (EARS) network, namely in Lannion, Moscow and Miami.

Lannion	France	48.75°N; 3.5°W
Moscow	Russian Federation	55.76°N; 37.57°E
Miami	USA	25.74°N; 80.16°W

Several cases have been considered, depending whether the base station is pointing towards the MetSat earth station or not, and depending on the location and height of the first obstacle.

In addition, the required exclusion zone has been determined around each of those stations using actual terrain model elevation and calculated for a base station pointing towards the MetSat station, as well as the antenna gain for the MetSat earth station and the percentage of time for the propagation model which gave the worst case separation distances in the generic calculations over flat terrain (so-called “max flat distance”. This may however underestimate the separation distances in case of obstacles on the path profile.

3.2.1 Results for Lannion

TABLE 10

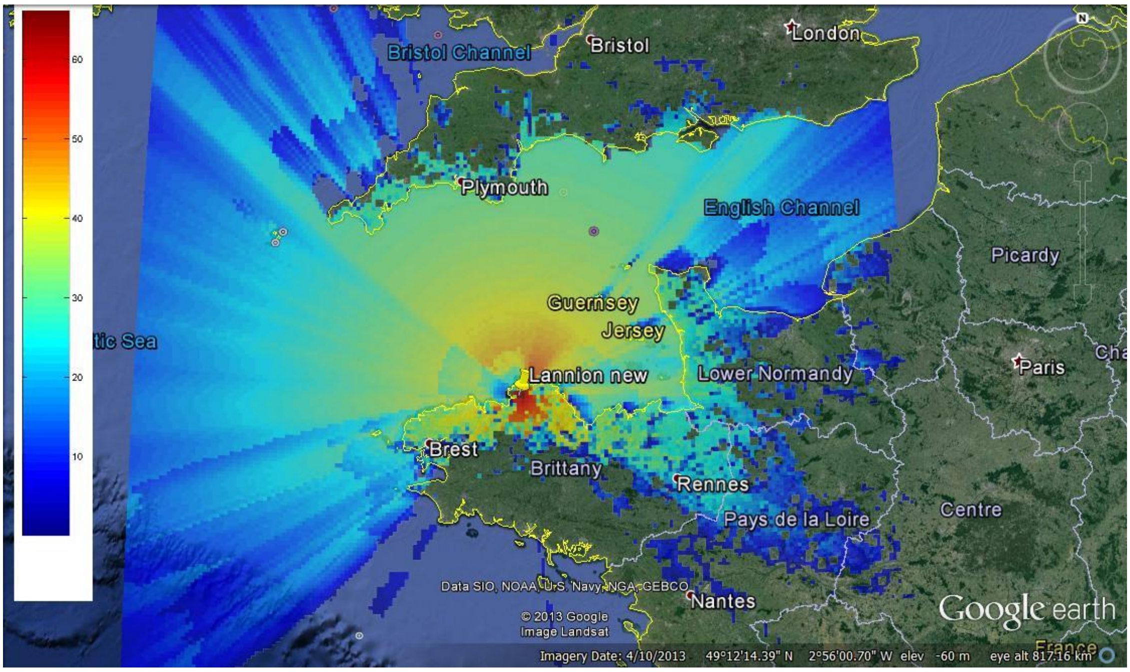
Results for Lannion

Pointing azimuth of the base station	First obstacle	MetSat earth station antenna gain towards the horizon for the "max flat distance"	Percentage of time for the propagation model for the "max flat distance"	Separation distances depending on the azimuth
Towards the MetSat station	None	–2 dBi	0.0094%	354 km
	10 km – 50 m	–2 dBi	0.0094%	315 km
	10 km – 100 m	10 dBi	0.12%	128 to 149 km
	20 km – 200 m	18 dBi	0.9%	90 to 100 km
	10 km – 300 m	18 dBi	0.9%	60 to 68 km
60° off pointing angle	None	11 dBi	0.1%	284 to 294 km
	10 km – 50 m	–2 dBi	0.0094%	239 to 251 km
	10 km – 100 m	16 dBi	0.4%	66 to 75 km
	20 km – 200 m	–2 dBi	0.0094%	21 km
	10 km – 300 m	–2 dBi	0.0094%	11 km

FIGURE 1

Exclusion zones around Lannion for base station

(The colour indicates the level by which the protection criterion is exceeded)



The required separation distance extends up to 369 km in the South East, which is consistent with the calculation in Table 10 above. It can also be noted that the protection of the MetSat station is not limited to a national issue since the protection area extends from France to the UK.

3.2.2 Results for Moscow

TABLE 11

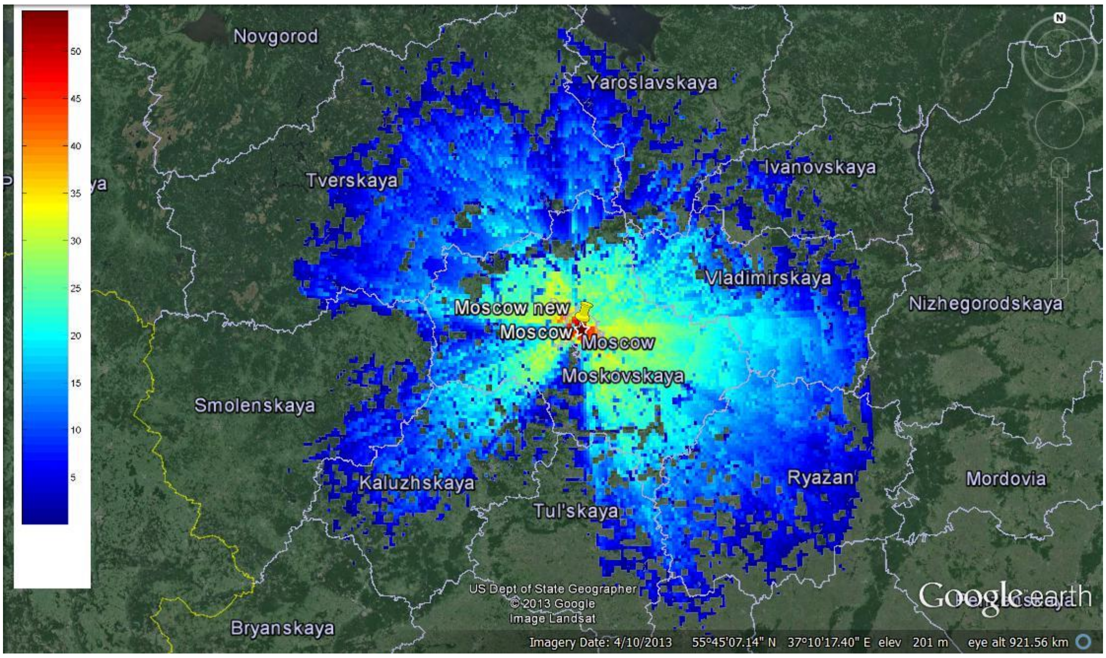
Results for Moscow

Pointing azimuth of the base station	First obstacle	MetSat earth station antenna gain towards the horizon for the "max flat distance"	Percentage of time for the propagation model for the "max flat distance"	Separation distances depending on the azimuth
Towards the MetSat station	None	–2 dBi	0.0094%	339 to 347 km
	10 km – 50 m	–2 dBi	0.0094%	301 to 310 km
	10 km – 100 m	12 dBi	0.1%	84 to 146 km
	20 km – 200 m	18 dBi	0.7%	86 to 102 km
	10 km – 300 m	18 dBi	0.6%	59 to 71 km
60° off pointing angle	None	11 dBi	0.1%	269 to 290 km
	10 km – 50 m	–2 dBi	0.0094%	225 to 248 km
	10 km – 100 m	15 dBi	0.2%	63 to 80 km
	20 km – 200 m	–2 dBi	0.0094%	21 km
	10 km – 300 m	–2 dBi	0.0094%	11 km

FIGURE 2

Exclusion zones around Moscow for base station

(The colour indicates the level by which the protection criterion is exceeded)



The required separation distance extends up to 351 km in the South East, which is consistent with the calculation in Table 11 above.

3.2.3 Results for Miami

TABLE 12

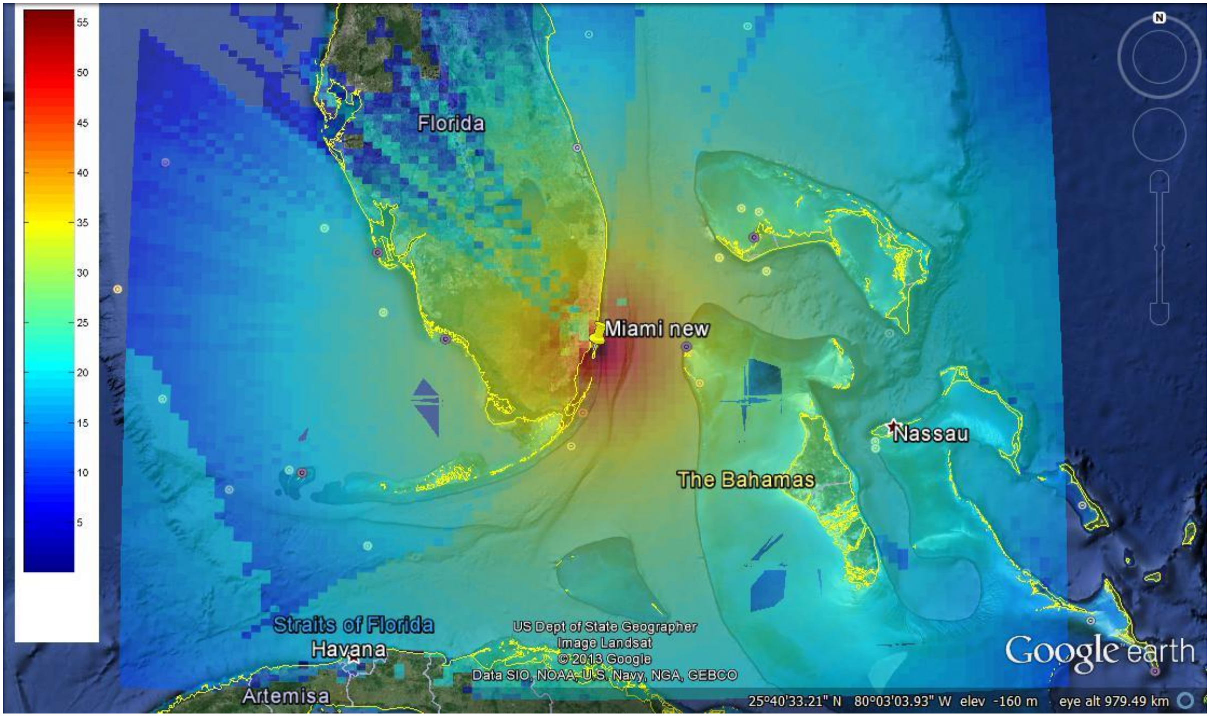
Results for Miami

Pointing azimuth of the base station	First obstacle	MetSat earth station antenna gain towards the horizon for the "max flat distance"	Percentage of time for the propagation model for the "max flat distance"	Separation distances depending on the azimuth
Towards the MetSat station	None	7 dBi	0.1%	382 to 395 km
	10 km – 50 m	–2 dBi	0.094%	367 km
	10 km – 100 m	10 dBi	0.2%	191 to 208 km
	20 km – 200 m	18 dBi	1.4%	99 to 103 km
	10 km – 300 m	18 dBi	1.3%	63 to 66 km
60° off pointing angle	None	–2 dBi	0.0094%	337 to 345 km
	10 km – 50 m	9 dBi	0.2%	293 to 304 km
	10 km – 100 m	11 dBi	0.3%	122 to 138 km
	20 km – 200 m	–2 dBi	0.0094%	21 km
	10 km – 300 m	–2 dBi	0.0094%	11 km

FIGURE 3

Exclusion zones around Miami for base station

(The colour indicates the level by which the protection criterion is exceeded)



In this case, the required separation distance extends even over the maximum distance determined in Table 12 (i.e. 395 km) due to the location of the station close to the sea, where propagation is much more favourable than over land. On the other hand, the distances found over land are consistent with the calculation in Table 12 above. It can also be noted that the protection of the MetSat station is not limited to a national issue since the protection area extends from USA to Cuba and the Bahamas.

3.3 Analysis and results for the terminal user case

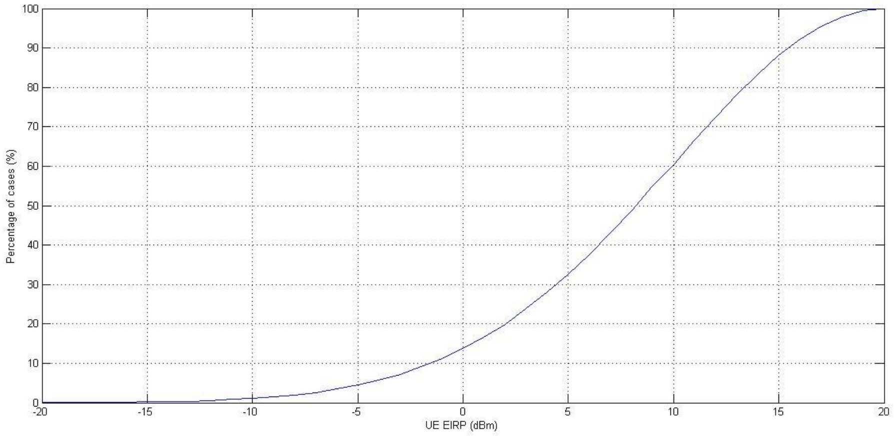
3.3.1 IMT systems deployment

A number of IMT base stations has been deployed over land with a given separation distance from the MetSat earth station. The base stations are deployed in a cellular network with a cell size of 5 km, representative of rural environment. Obviously, a cellular deployment in suburban or urban environment would lead to a higher number of base stations.

For each base station (with three sectors), one active UE per sector is transmitting with an e.i.r.p. following a Rayleigh distribution, as shown in Fig. 4.

FIGURE 4

Distribution of UE e.i.r.p.



Figures 5 and 6 give an example of deployment around respectively Lannion and Miami MetSat stations for a 60 km separation distance. The IMT base stations are represented by the diamond shape, while the UEs are represented with a red plot.

FIGURE 5

Example of mobile deployment for Lannion assuming a 60 km separation distance

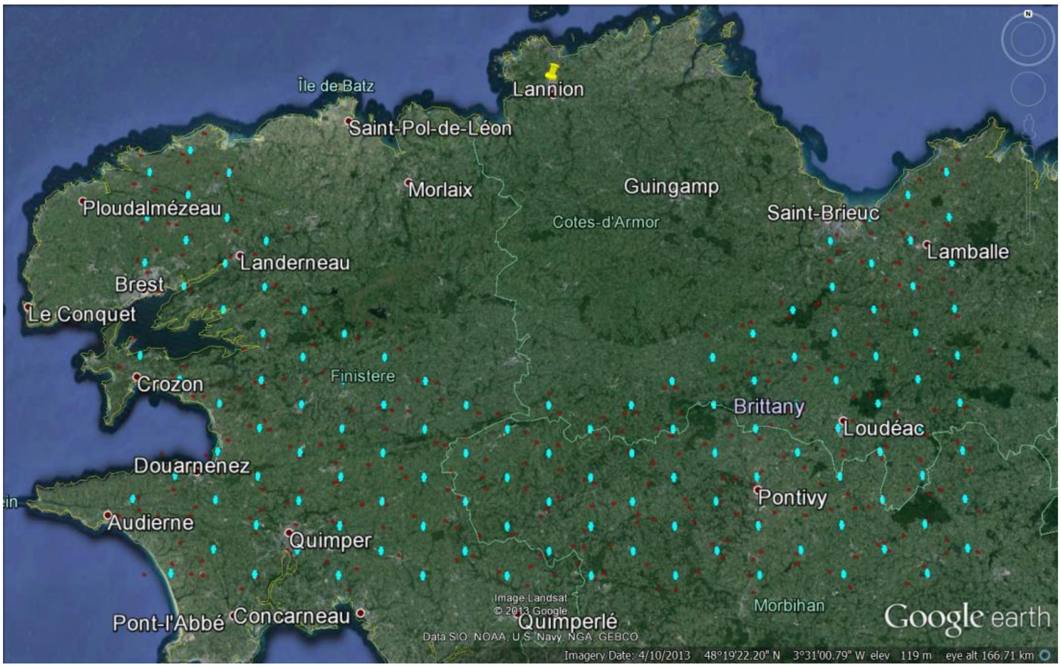
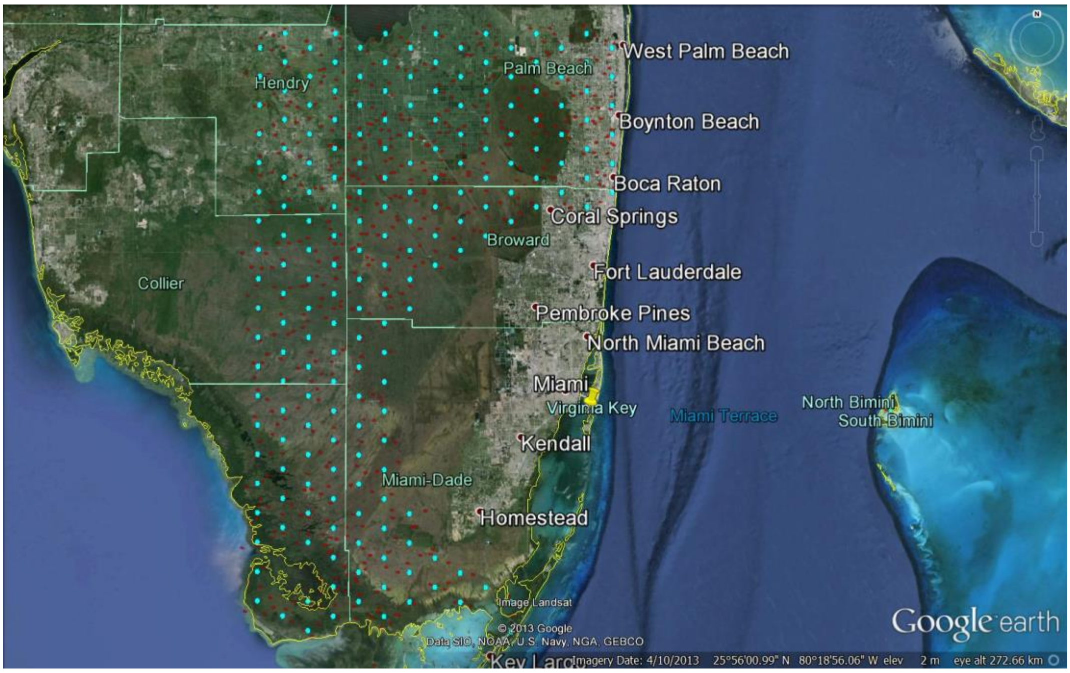


FIGURE 6

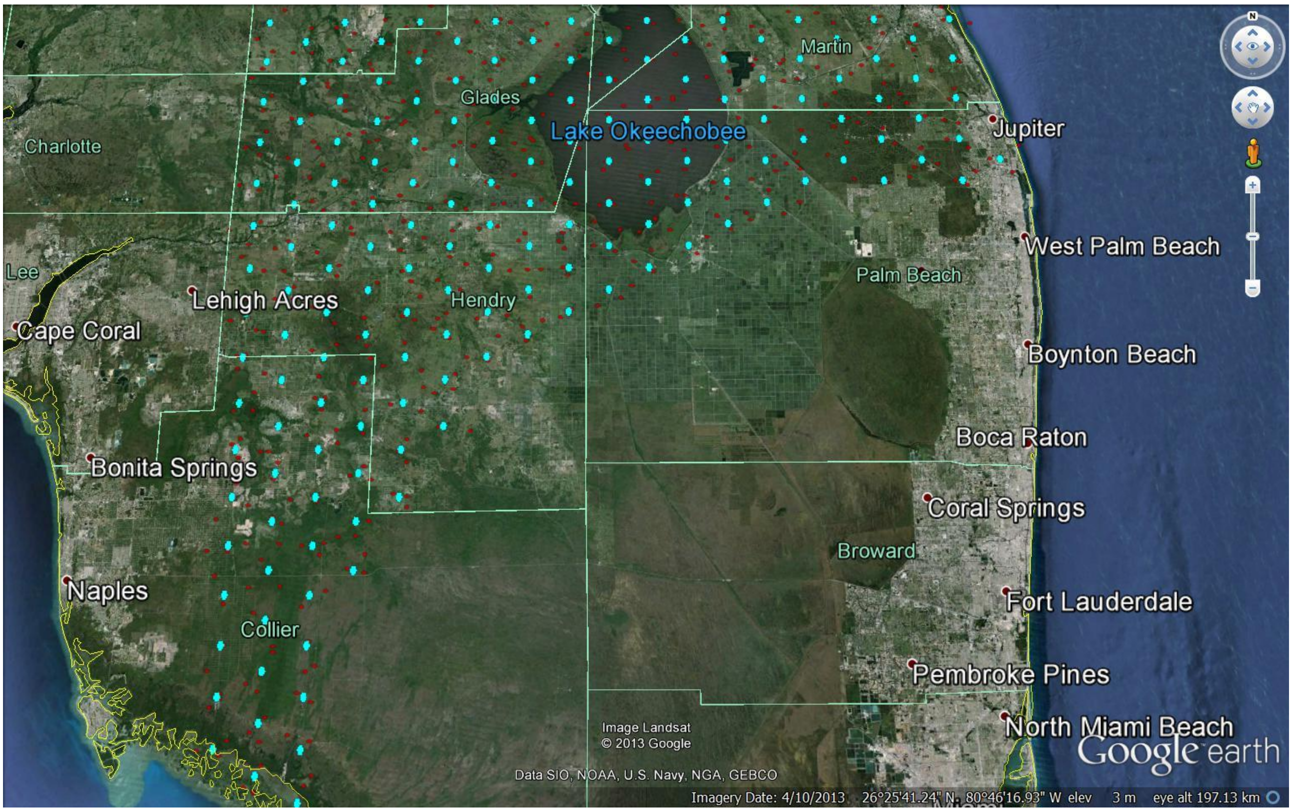
Example of mobile deployment for Miami assuming a 60 km separation distance



One could argue that in an actual IMT deployment, few to no base station or UE might be expected in the everglades in the southwest of Miami. However, this is not the case when considering a separation distance of 120 km as shown in Fig. 7 below.

FIGURE 7

Example of mobile deployment for Miami assuming a 120 km separation distance



In addition, the study considered an IMT deployment limited to a rural environment, whereas one would expect in Miami and close vicinity a much larger number of base stations to cover the urban and suburban environments.

Finally, the present study only considers three UEs per base station whereas in an urban/suburban environment, the number of terminals would be much larger. Thus, the IMT deployment scenario used to assess the interference potential on a MetSat earth station in this study can be considered as quite low and far from being worst case.

3.3.2 Methodology

A Monte-Carlo simulation was developed in order to assess the aggregate interference from multiple UEs deployed at a given distance from the MetSat earth station, taking into account the actual terrain elevation.

For each trial, the following steps are followed:

- the MetSat earth station antenna is randomly pointed with a uniform distribution in the volume (in steradians) above the minimum elevation angle of 5° (a uniform distribution in azimuth and elevation would lead to an overestimation of the high elevation events, not representative of reality);
- the e.i.r.p. of each UE is determined following the Rayleigh distribution as on Fig. 1;
- the propagation loss value over each UE-to-MetSat path follows a distribution given by Recommendation ITU-R P.452 with a percentage that is randomly determined. (a constant value such as 50% would not be correct as it does not allow to encompassing the possibility of anomalous atmospheric events such as ducting);

– the aggregate interference from all UEs at the MetSat receiver level is then computed, taking into account the relative MetSat antenna gain in the direction of each UE, considering the following equation:

$$I = 10\log\left(\sum_{n=1}^{n=N} 10^{\left[e.i.r.p._n - L_n + G_{metsat}\right]/10}\right) \quad \text{(dB)}$$

where:

n: index of the UE (1 to 48)

$e.i.r.p._n$: UE e.i.r.p. (based on the distribution in Fig. 4)

L_n: propagation loss between the UE of index n and the MetSat station (for p% based on Recommendation ITU-R P.452)

$p\%$: random percentage for Recommendation ITU-R P.452 (from 0.0001% to 50%) different

G_{metsat}: Relative antenna gain (dBi) of the MetSat station in the direction of the UE of index n.

3.3.3 Results for the UE case

A number of 30 000 to 40 000 trials have been performed for each separation distance and each MetSat earth station studied allowing to draw the following interference cdf curve shown in Figs 8 and 9.

FIGURE 8

Interference cumulative distribution function from 10 MHz UEs to Lannion MetSat earth station

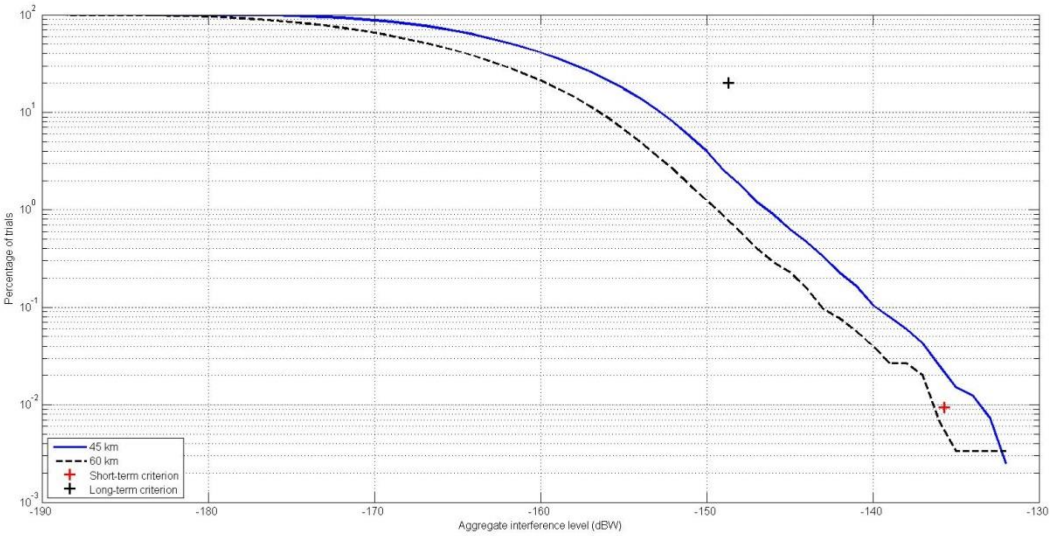


Figure 8 shows that, for the case of the Lannion MetSat earth station, even considering a limited number of UEs with a rural deployment of base stations, assuming a separation distance of 45 km leads to an interference level corresponding to 0.0094% of the time at –133.5 dBW (i.e. 2.2 dB above the MetSat protection short-term criterion).

It should also be noted that these calculations were made with UE bandwidth of 10 MHz whereas the MetSat station bandwidth is of 4.5 MHz (and hence a 3.5 dB bandwidth factor). When considering a UE bandwidth of 5 MHz (and hence a 0.5 dB bandwidth factor), the interference from the same UE deployment would hence be 5.2 dB above the MetSat protection short-term criterion.

Figure 8 also shows that in order to meet the MetSat protection criterion the separation distance should be increased to a 60 km value when considering UE bandwidth of 10 MHz.

FIGURE 9

Interference cumulative distribution function from 10 MHz UE to Miami MetSat earth station

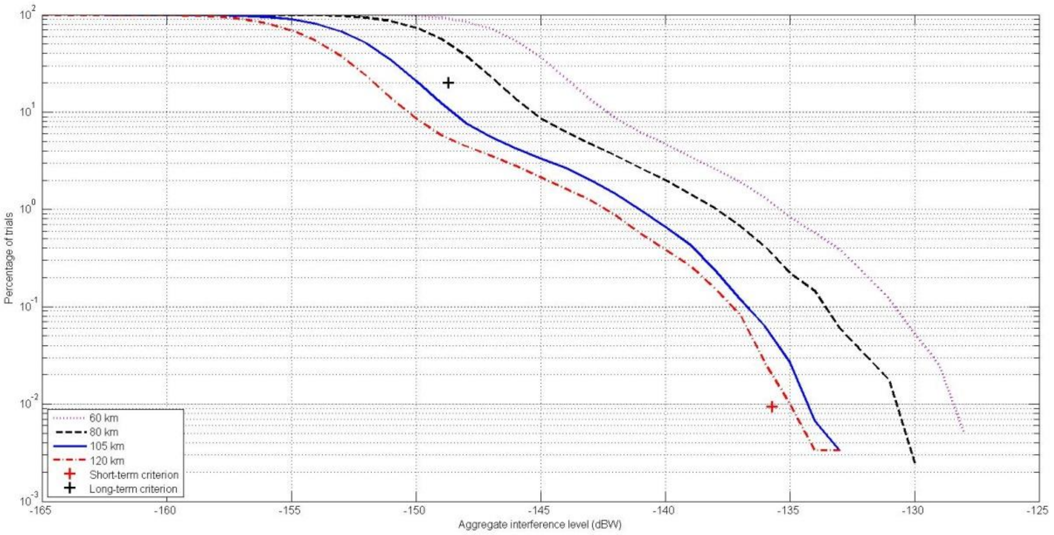


Figure 9 shows that, for the case of the Miami MetSat earth station, even considering a limited number of UEs with a rural deployment of base stations, assuming a separation distance of 60 km leads to an interference level corresponding to 0.009 4% of the time at –128.5 dBW (i.e. 7.2 dB above the MetSat protection short-term criterion). It also shows that for the same separation distance of 60 km, the long-term criterion is also exceeded by 4.7 dB.

Similarly, when considering a UE bandwidth of 5 MHz, the interference from the same UE deployment would hence be 10.2 dB above the MetSat protection short-term criterion and 7.7 dB above the MetSat protection long-term criterion when considering a 60 km separation distance.

Figure 9 also shows when considering UE bandwidth of 10 MHz, at 80 km separation distance, both protection criteria are still exceeded and that in order to meet the MetSat protection criterion the separation distance should be even higher than 120 km (at this distance the short-term protection criterion is still exceeded, although by a very small amount).

4 Summary/Conclusions of Annex A

The present Annex shows that the required protection area around MetSat stations from which potential IMT base stations in the 1 695-1 710 MHz frequency band would have to be excluded would be very large, of several hundred kilometres and that, for UE, large separation distances of 60 km up to 120 km are also required in order to ensure the protection of MetSat earth stations supporting NGSO meteorological satellites.

In addition, the following elements have to be taken into consideration when assessing the suitability of this band for mobile broadband systems:

- There are hundreds of MetSat stations worldwide in the 1 695-1 710 MHz frequency band operated by almost all national meteorological services and many other users worldwide.
- The necessary protection of these stations will require large exclusion zones, in which IMT operators will not be able to deploy their stations.

- In a number of countries, probably the majority, the protection of MetSat earth stations will totally preclude deployment of IMT stations (terminals and base stations) in large areas including major cities as well as it would impact the deployment of IMT in neighbouring countries.

On this basis, it appears obvious that a deployment of IMT systems in the 1 695-1 710 MHz frequency band is not compatible with MetSat and will not reach the goal set by Resolution **233 (WRC-12)** of a worldwide and harmonized spectrum.

One can therefore conclude that an IMT identification (base stations or UE) is not compatible with current and planned MetSat use of the 1 695-1 710 MHz band.

Annex B

Compatibility assessment between meteorological-satellite systems and IMT stations in the 1 695-1 710 MHz frequency band

1 Introduction

This Annex provides an analysis of the compatibility between IMT system and meteorological-satellite (MetSat) systems in the frequency band 1 695-1 710 MHz. The following interference scenarios for sharing situations are considered:

- the single-entry and aggregated interference from IMT base station to GSO MetSat earth station;
- the single-entry and aggregated interference from IMT base station to NGSO MetSat earth station;
- the aggregated interference from IMT UE to GSO MetSat earth station;
- the aggregated interference from IMT UE to NGSO MetSat earth station.

2 Background

Up to now, the 1 695-1 710 MHz band is used by all meteorological-satellite systems with earth stations operated by almost all National Meteorological and Hydrological Services (NMHS) and many other users. This frequency band is essential for providing operational and time-critical meteorological information to the users around the world.

Considering that each of these two services may be provided by GSO satellite systems and NGSO satellite systems, based on Recommendation ITU-R SA.1158, MetSat operators have agreed to separate the band 1 695-1 710 MHz and its adjacent band 1 670-1 695 MHz into two sub-bands which are being used and are expected to continue to be used as follows:

- the 1 670-1 698 MHz band should be used by GSO meteorological satellites;
- the 1 698-1 710 MHz band should be used by NGSO meteorological satellites.

Although only a very few countries have their own MetSat systems, all the data collected by meteorological satellites are provided freely to all the countries and regions of the world, and are performed for the benefit of the whole international community.

3 Technical characteristics

3.1 MetSat service

3.1.1 FENGYUN MetSat systems deployment

There are several FENGYUN (FY) MetSat systems operating in the 1 695-1 710 MHz band in China currently, including polar-orbiting satellites such as FY-3A, FY-3B and FY-3C, and also geostationary satellites such as FY-2D, FY-2E and FY-2F; and the second generation FY geostationary meteorological satellites FY-4 series will continue to use this band. Chinese current and future FY series MetSat systems in the band 1 695-1 710 MHz are provided in Table 13.

TABLE 13

Uses of the band 1 695-1 710 MHz by FY MetSat systems

Mission name(Orbit)	Status	Frequency (MHz)	Direction	Polarization	Service
FY-2C (123.5°E) FY-2D (86.5°E) FY-2E (105°E) FY-2F (112°E)	In orbit	1 699.487 – 1 699.513	S-E	V	S-WEFAX
FY-4 satellites	Planned	1 690-1 696	S-E	H	Ranging
		1 696-1 698	S-E	V	LRIT/EWAIB
FY-3A (NGSO)	In orbit	1 701.1-1 707.9	S-E	CR	HRPT
FY-3B (NGSO)	In orbit	1 701.1-1707.9	S-E	CR	HRPT
FY-3C (NGSO)	In orbit	1 698.7-1 703.9	S-E	M	HRPT
FY-3D (NGSO)	Planned	1 704.1-1 709.3	S-E	M	HRPT

Table 14 gives some example locations of meteorological-satellite earth stations.

TABLE 14

Example locations of FY meteorological earth stations

Station Name	Country	Operated by	Location (lat, long)
Beijing	CHN	CMA	40.05°N, 116.27°E
Guangzhou			23.16°N, 113.33°E
Xinjiang			43.86°N, 87.57°E
Kashi			43.86°N,75.94°E
Jiamusi			46.9°N, 130.34°E
Sanya			18.26°N, 109.49°E
Antarctic		CMA	72°S, 2.52°E
Melbourne	AUS	BOM	38.36°S,145.17°E
Kiruna	Sweden	SSC	68°N, 21°E

3.1.2 FY MetSat system parameters

The key parameters of FY-3 and FY-4 meteorological-satellite earth stations to be used in interference assessment from IMT system are listed in Tables 15 and 16, respectively.

TABLE 15

Characteristics for FY-3 (NGSO) meteorological-satellite earth stations

Parameter	Value
Signal	HRPT, High Resolution Picture Transmission
Centre frequency	Either 1 701.300 MHz or 1 706.7 MHz
RF bandwidth	5.2 MHz
Elevation angle	5° ~ 90°
Antenna diameter	2.4 m
Antenna height	15 m
Antenna gain	30.05 dBi
Antenna pattern	RR Appendix **8**

TABLE 16

Characteristics for FY-4 (GSO) meteorological-satellite earth stations

Parameter	Value
Signal	LRIT/EWAIB
Centre frequency	1 697 MHz
RF bandwidth	2 MHz
Elevation angle	34.48°
Antenna diameter	1.8 m
Antenna height	15 m
Antenna gain	28 dBi
Noise temperature	249 K
Antenna pattern	RR Appendix **8**

3.1.3 Interference criteria

Based on Recommendation ITU-R SA.1027, two interference criteria were identified for use in the 1 695-1 710 MHz band when assessing the interference from terrestrial service to NGSO MetSat systems:

– Long-term interference criteria: –151 dBW per 2 668 kHz corresponding to the total interference to be exceeded no more than 20% of the time, which is equivalent to −148.1 dBW per 5.2 MHz.

– Short-term interference criteria: –138 dBW per 2 668 kHz corresponding to the total interference to be exceeded no more than 0.0094% of the time, which is equivalent to −135.1 dBW per 5.2 MHz.

For GSO MetSat system, Recommendation ITU-R S.1432 provides the long-term interference criteria: $I/N = -12.2$ dB ($\Delta T/T = 6\%$) corresponding to the total interference from other systems having co-primary status for 100% of the worst month, or I/N = –10 dB ($\Delta T/T$ = 10%) corresponding to the aggregate interference from co-primary allocation for 20% of any month.

3.2 Mobile service (IMT systems)

The following IMT parameters have been used in this study, and were taken from Report ITU-R M.2292.

TABLE 17

IMT base station parameters

Cell structure / **Characteristics**	**Macro rural**	**Macro suburban**	**Macro urban**
Cell radius/ Deployment density	> 3 km (typical figure to be used in sharing studies 5 km)	0.5-3 km (typical figure to be used in sharing studies 1 km)	0.25-1 km (typical figure to be used in sharing studies 0.5 km)
Antenna height	30 m	30 m	25 m
Sectorization	3-sectors	3-sectors	3-sectors
Downtilt	3 degrees	6 degrees	10 degrees
Antenna pattern	Recommendation ITU-R F.1336 (see “Antenna Pattern” *recommends* 3.1) • $k_a = 0.7$ • $k_p = 0.7$ • $k_h = 0.7$ • $k_v = 0.3$ Horizontal 3 dB beamwidth: 65 degrees Vertical 3 dB beamwidth: determined from the horizontal beamwidth by equations in Recommendation ITU-R F.1336. Vertical beamwidths of actual antennas may also be used when available.		
Below rooftop antenna deployment	0%	0%	30%
Feeder loss	3 dB	3 dB	3 dB
Maximum output power (5/10/20 MHz)	43/46/46 dBmW	43/46/46 dBmW	43/46/46 dBmW
Maximum antenna gain	18 dBi	16 dBi	16 dBi
Maximum output power (e.i.r.p.)	58/61/61 dBmW	56/59/59 dBmW	56/59/59 dBmW
Average activity	50%	50%	50%

TABLE 18

IMT UE parameters

Cell structure / Characteristics	Macro rural	Macro suburban	Macro urban
Indoor UE usage	50%	70%	70%
Indoor UE penetration loss	15 dB	20 dB	20 dB
Maximum UE output power	23 dBm	23 dBm	23 dBm
Average UE output power	2 dBm	–9 dBm	–9 dBm
Typical antenna gain for UEs	–3 dBi	–3 dBi	–3 dBi
Body loss	4 dB	4 dB	4 dB

4 Analysis for IMT base station

4.1 Methodology

This Annex analyses the interference from IMT base stations to GSO and NGSO MetSat systems, including single-entry interference and aggregated interference.

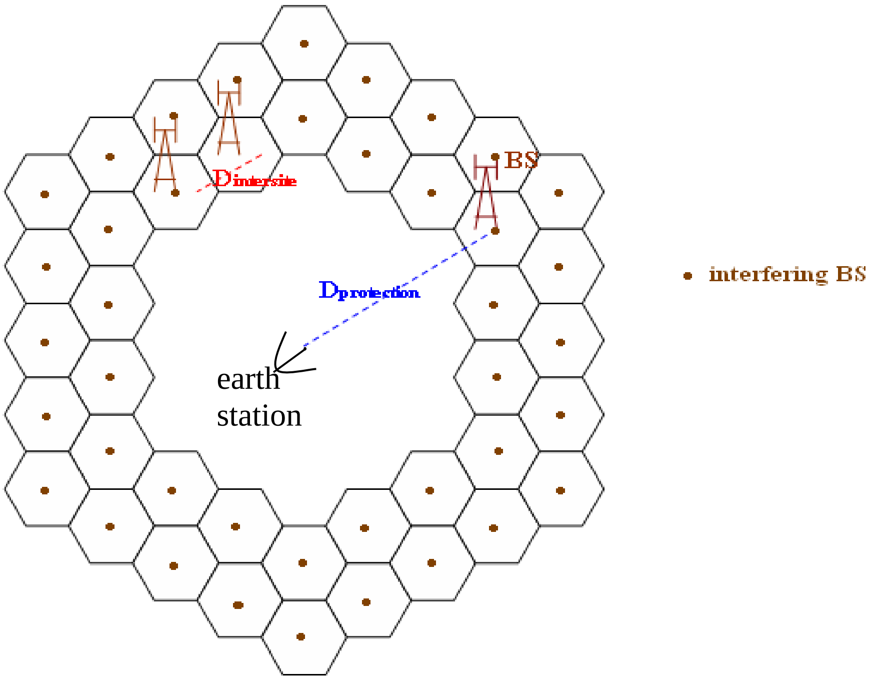
For the single-entry interference, the worst case is taken into account, i.e. the antenna main-lobe of the IMT base station is facing the antenna of the MetSat earth station.

In the case of the aggregated interference from the multiple IMT base stations, it is assumed that there are two rings of equi-spaced IMT base stations located around the MetSat earth station. Thus the radius of the inner ring is the required separation distance meeting the interference criterion. The number of IMT base stations is assessed according to the separation distance and the base station inter-site distance as following:

$$N(i) = \frac{\pi}{\arcsin\left[\dfrac{D_{\text{intersite}}}{2D_{\text{protection}}}\right]} + \frac{\pi}{\arcsin\left[\dfrac{D_{\text{intersite}}}{2\left(D_{\text{protection}} + D_{\text{intersite}}\right)}\right]}$$

FIGURE 10

Aggregated IMT base stations scenario



The analyses are based on the propagation models described in Recommendation ITU-R P.1546. Different building losses and clutter effects representing urban suburban and rural environment respectively have been assumed in these analyses.

4.2 Calculations

In order to calculate the antenna gain of MetSat earth station in the direction of IMT base station, the off-axis angle of IMT base station from MetSat earth station antenna boresight must be determined firstly. Figure 11 illustrates the geometry, where MetSat earth station is at point O and IMT base station is at point A. So the angle between line OA and line OB is the off-axis angle, and it is given by:

$$\varphi = \cos^{-1}\left(\frac{\cos(\alpha 2-\alpha 1) * (h^2\cos^2\alpha 1 + R^2\cos^2\theta\cos^2\alpha 1 + h^2\cos^2\theta)}{2 * R^2\cos\theta}\right)$$

where:

$\alpha 1$: IMT base station’s elevation angle (degrees)

θ: IMT base station’s azimuth angle (degrees)

$\alpha 2$: MetSat earth station’s elevation angle (degrees)

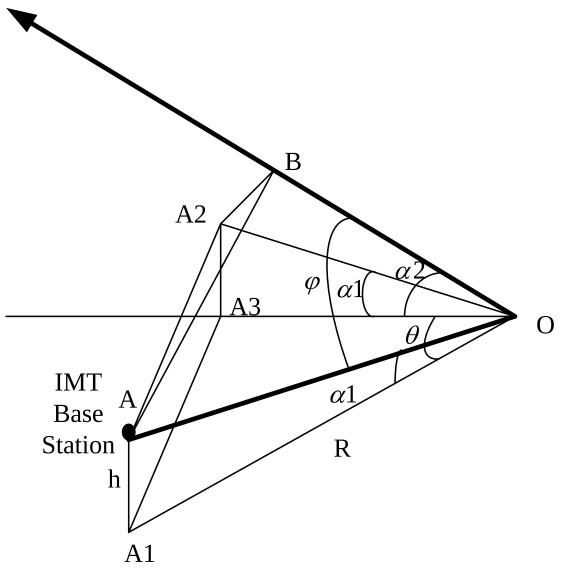
R: distance from IMT base station to MetSat earth station (m)

h: relative height between IMT base station and MetSat earth station (m)

φ: off-axis angle (degrees).

FIGURE 11

Geometry of off-axis angle from MetSat earth station to IMT base station



4.3 Results

4.3.1 For GSO MetSat earth station

The maximum allowable interference into FY-4 earth station is –126.84 dBmW/MHz calculated according to its characteristic parameters and protection criteria.

For single-entry interference, the relationship between the interference power and the separation distance is shown in Fig. 12. In urban environment, the separation distance is 17 km. For suburban and rural environment, the distance increases to 43.8 km and 47.6 km respectively.

FIGURE 12

Separation distance for FY-4 earth station with single-entry interference

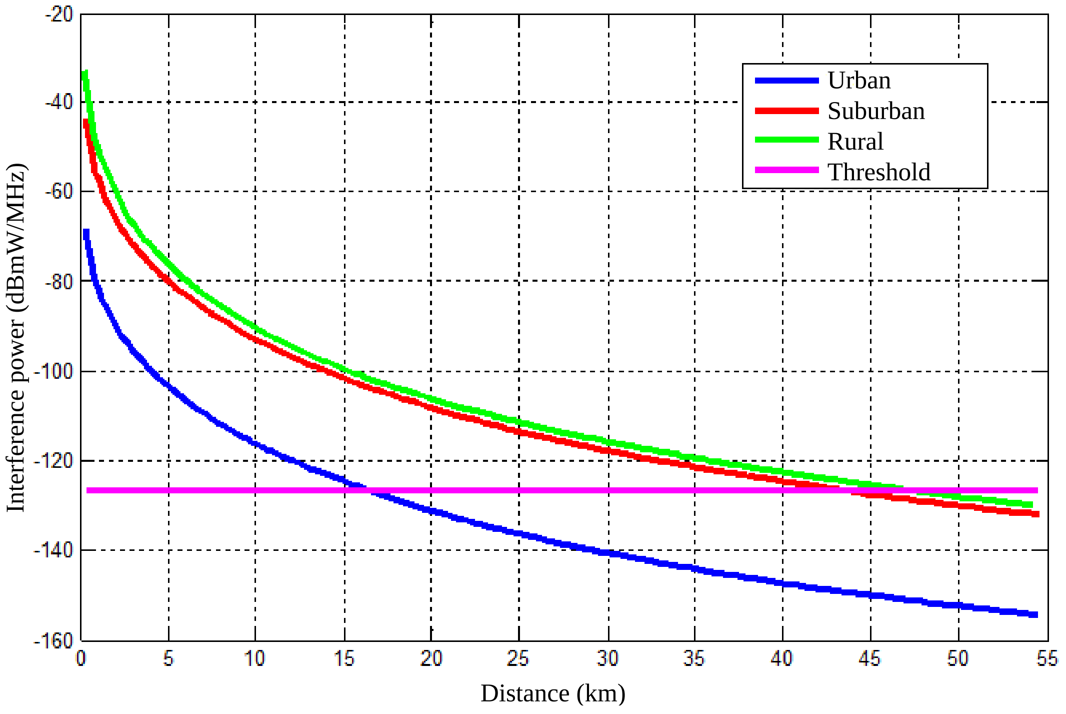
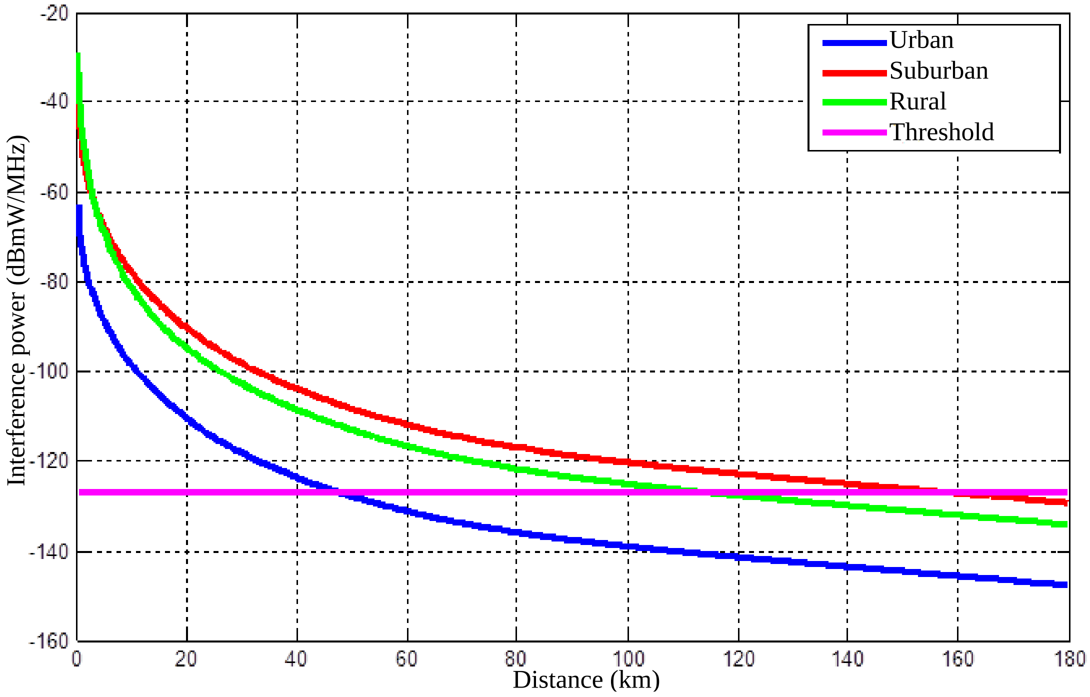


Figure 13 shows the separation distance relative to different interference power for the aggregated interference scenario. The separation distance is 47.3 km for urban, 157.1 km for suburban, and 113.8 km for rural.

FIGURE 13

Separation distance for FY-4 earth station with aggregated interference



4.3.2 For NGSO MetSat earth station

The calculation of separation distances for FY-3 earth station is the same as that for FY-4, except that the elevation angle of FY-3 earth station antenna is not constant. The results of single-entry interference with short-term criteria are given in Table 19 and Fig. 14, with long-term criteria given in Table 20 and Fig. 15. The results for aggregated interference scenario are given in Table 21, Fig. 16 (short-term criteria) and Table 22, Fig. 17 (long-term criteria).

TABLE 19

Single-entry interference results for FY-3 earth station with short-term criteria

Interference criteria	–138 dBW/2 668 kHz, i.e. –135.1 dBW/5.2 MHz					
Environment	Urban		Suburban		Rural	
Earth station elevation angle	5°	90°	5°	90°	5°	90°
Separation distance	17.4 km	6.3 km	45.8 km	19.6 km	49.9 km	23.4 km

FIGURE 14

Single-entry interference results for FY-3 earth station with short-term criteria

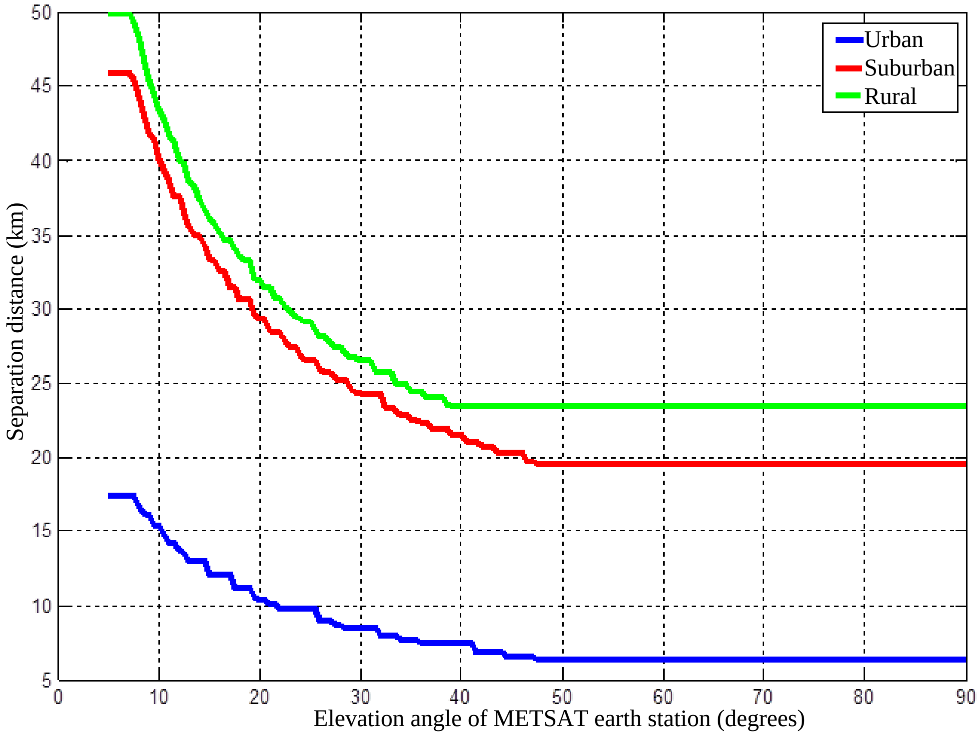


TABLE 20

Single-entry interference results for FY-3 earth station with long-term criteria

Interference criteria	–151 dBW/2 668 kHz, i.e. –148.1 dBW/5.2 MHz					
Environment	Urban		Suburban		Rural	
earth station elevation angle	5°	90°	5°	90°	5°	90°
Separation distance	30.3 km	13 km	81.3 km	34.4 km	89.7 km	36.7 km

FIGURE 15

Single-entry interference results for FY-3 earth station with long-term criteria

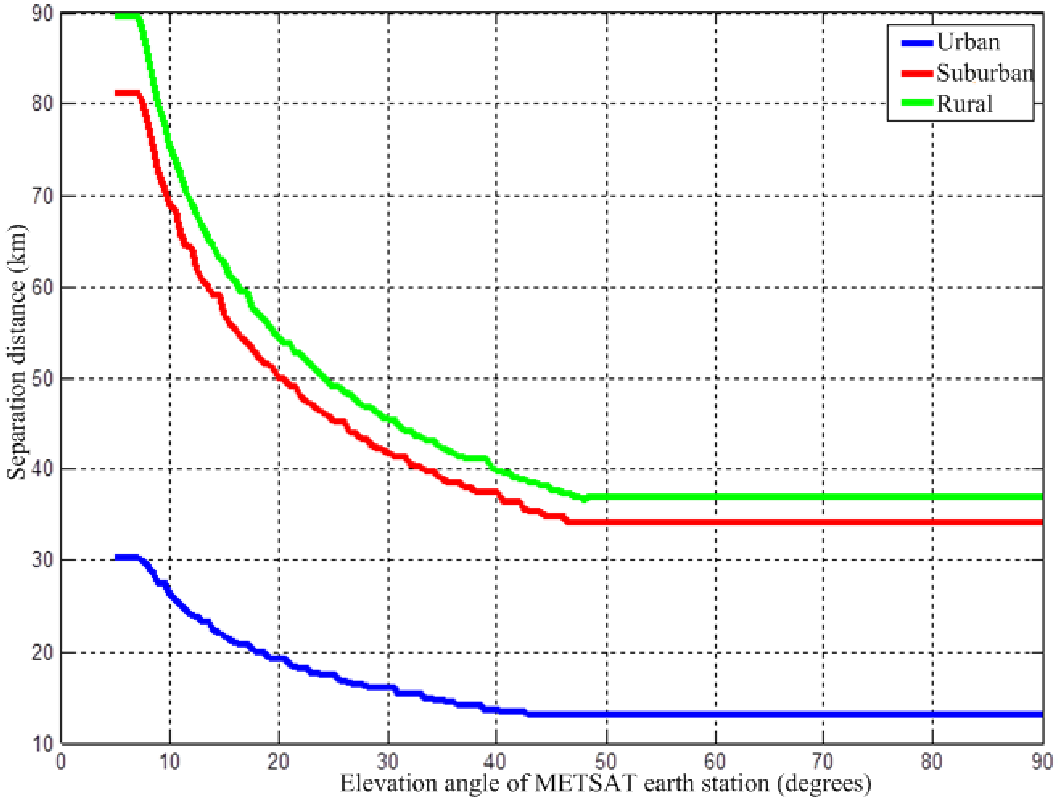


TABLE 21

Aggregated interference results for FY-3 earth station with short-term criteria

Interference criteria	–138 dBW/2 668 kHz, i.e. –135.1 dBW/5.2 MHz					
Environment	Urban		Suburban		Rural	
earth station elevation angle	5°	90°	5°	90°	5°	90°
Separation distance	36.2 km	20 km	126.9 km	60.8 km	79.1 km	43.2 km

FIGURE 16

Aggregated interference results for FY-3 earth station with short-term criteria

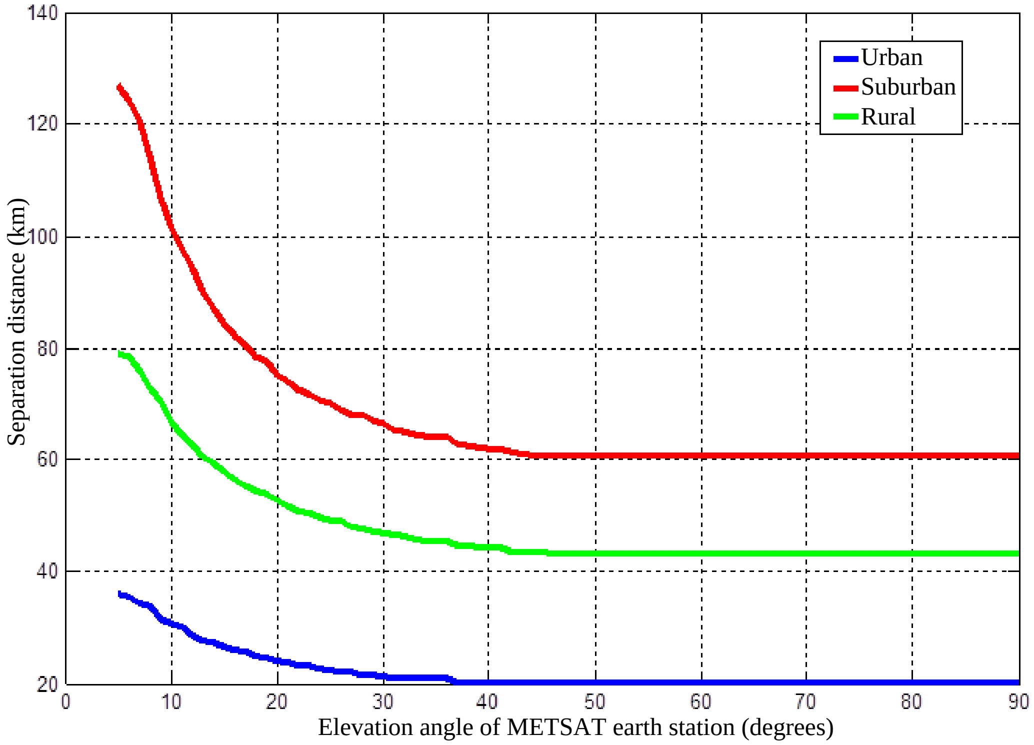


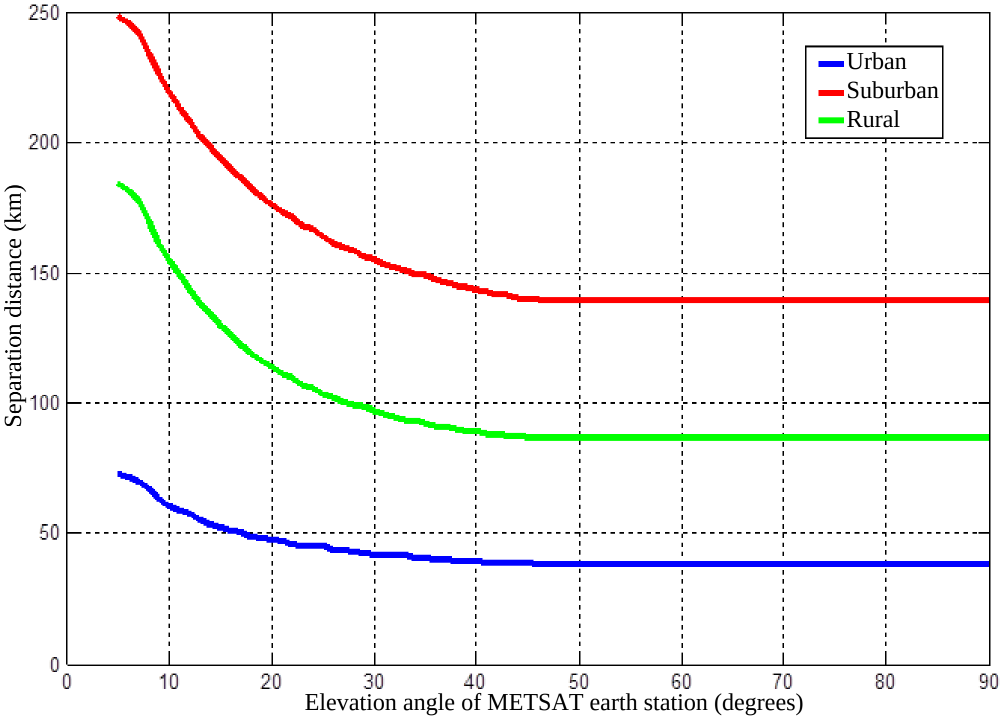
TABLE 22

Aggregated interference results for FY-3 earth station with long-term criteria

Interference criteria	–151 dBW/2 668 kHz, i.e. –148.1 dBW/5.2 MHz					
Environment	Urban		Suburban		Rural	
Earth station elevation angle	5°	90°	5°	90°	5°	90°
Separation distance	73.2 km	38.7 km	248.7 km	139.1 km	184.5 km	86.9 km

FIGURE 17

Aggregated interference results for FY-3 earth station with long-term criteria



5 Analysis for IMT UEs

5.1 Methodology

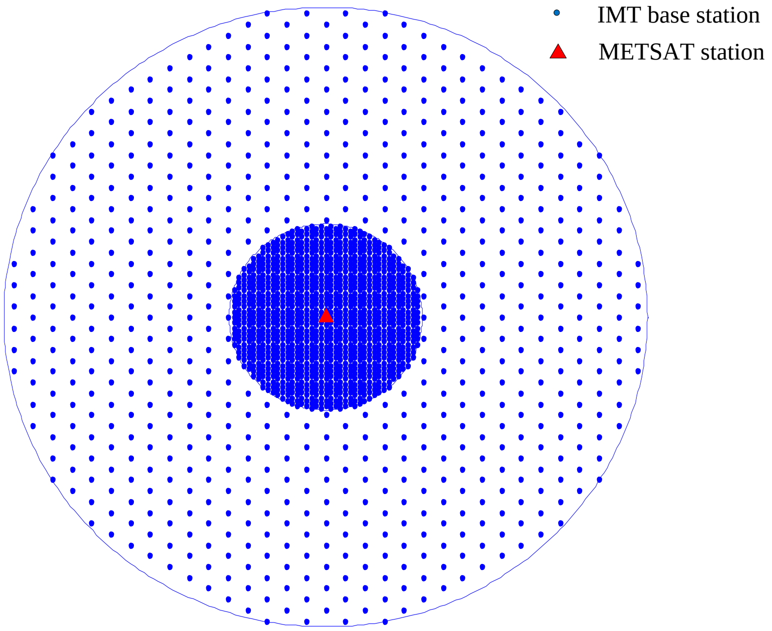
The following paragraphs describe what kind of methodology is used to analyse the aggregate interference from IMT UEs into the MetSat earth station receivers.

Figure 18 shows a view of the IMT base station distribution around a MetSat station, the MetSat station is at the centre of the distribution.

There are two different densities of the IMT base stations: from the centre out to a 30 km distance is the urban/suburban region with a 1.732 km inter-site distance (ISD) between base stations, and from a distance of 30 km out to a distance of 100 km is the rural region with a 7 km ISD, so the 1 090 base stations in the urban/suburban region and 664 base stations in the rural region is concerned.

FIGURE 18

Distribution of IMT base stations



There are three hexagonal sectors with each IMT base station. And several UEs are randomly distributed within each sector from 10 m from the base station out to the edge of its coverage. The number of simultaneously transmitting UEs per base station sector for each channel bandwidth is shown in Table 23.

TABLE 23

Number of simultaneously transmitting UE

Channel bandwidth	5 MHz	10 MHz	15 MHz
Number of simultaneously transmitting UE per sector	3	6	9
Number of simultaneously transmitting UE per base station	9	18	27

A Monte Carlo simulating method was used in this analysis. The aggregated interfering power from IMT UEs into MetSat earth station is computed by randomizing the location of the UE for different separation distance. Then the protection distance is achieved according to the interference criteria of MetSat service. When this procedure is iterated for many times, the probability of interference can be calculated finally. The separation distance changes from 1 to 99 km with one kilometre increments. If one IMT base station is out of a separation distance circle, then its associated UEs would be included in the aggregate interference calculation for the separation distance radius. Otherwise if the base station is in the separation distance circle, its associated UEs should be excluded in the aggregate interference calculation.

Table 24 gives the propagation model used in the analysis.

TABLE 24

Propagation Model

Distance between the IMT base station and the IMT UE (km)	≤ 0.04	≥ 0.1	0.04 ~ 0.1
Propagation model	Free space	COST-231 Hata	Linear log interpolation of the former

5.2 Calculations

The interference power I from one IMT UE received by the MetSat earth station is:

$$I = e.i.r.p. - G_r - L_p - L_a - FDR$$

where:

$e.i.r.p.$: IMT UE’s e.i.r.p. (dBm)

G_r: antenna gain of MetSat station receiver at the direction of UE (dB)

L_p: propagation loss of electromagnetic wave from IMT UE to MetSat station (dB)

L_a: additional loss including indoor UE penetration loss and body loss (dB)

FDR: frequency dependent rejection (dB).

So the aggregated interference power I_{ag} from all of the IMT UEs can be calculated as:

$$I_{ag} = 10lg\left(\sum I_i\right)$$

where:

I_i: interference power I from ith IMT UE (mW).

It should be noted that in the simulation the transmitting power P_t of the IMT UE is determined by the following equation:

$$P_t = P_{max} \times min\left\{1, max\left[R_{min}, \left(\frac{L_p}{L_{p_{x-ile}}}\right)^{\gamma}\right]\right\}$$

where:

P_{max}: maximum IMT UE’s transmitting power (dBm)

R_{min}: ratio of the maximum IMT UE’s transmitting power to the minimum

L_p: propagation loss of electromagnetic wave from IMT UE to MetSat station (dB)

$L_{p_{x-ile}}$: predefined propagation loss (dB)

γ: balance factor.

The parameters controlling P_t used in the study is given in Table 25.

TABLE 25

Parameters controlling the IMT UE's transmitting power

γ	$L_{p_{x-ile}}$			
	20 MHz bandwidth	15 MHz bandwidth	10 MHz bandwidth	5 MHz bandwidth
1	109	110	112	115

5.3 Results

5.3.1 For GSO MetSat earth station

The protection distances around FY-4 earth station for 10 MHz channel bandwidth of the IMT UEs is provided in Table 26 and Fig. 19.

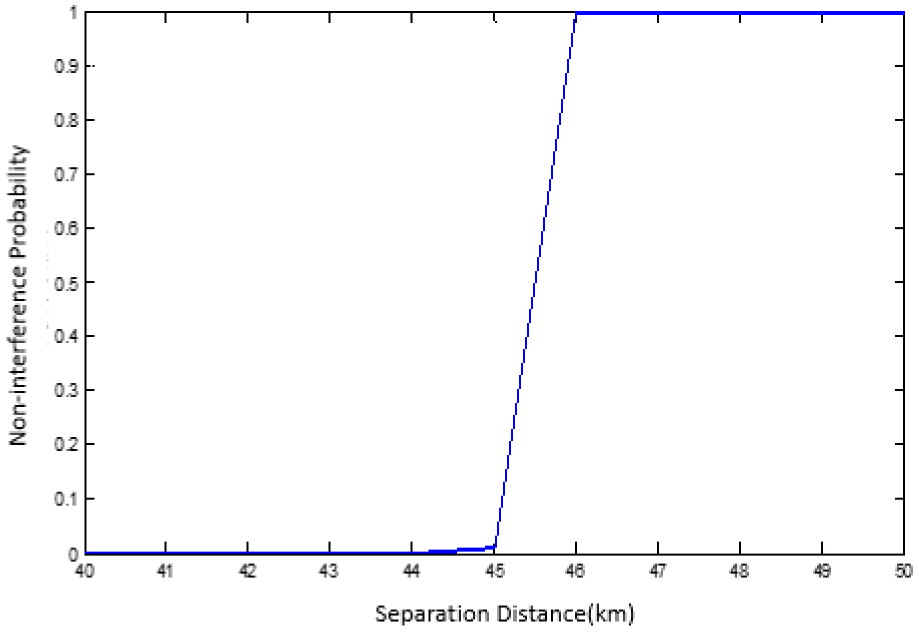
TABLE 26

FY-4 earth station protection distances (10 MHz channel bandwidth)

Number of iterations	**Minimum distance (km)**	**Mean distance (km)**	**Maximum distance (km)**
1	46	46	46
10	46	46	46
100	45	45.98	46
500	45	45.98	47
1000	45	46.99	47

FIGURE 19

FY-4 earth station protection distances (10 MHz channel bandwidth)



5.3.2 For NGSO MetSat earth station

The protection distances around FY-3 earth station for 10 MHz channel bandwidth of the IMT UE is provided in Table 27 and Fig. 20.

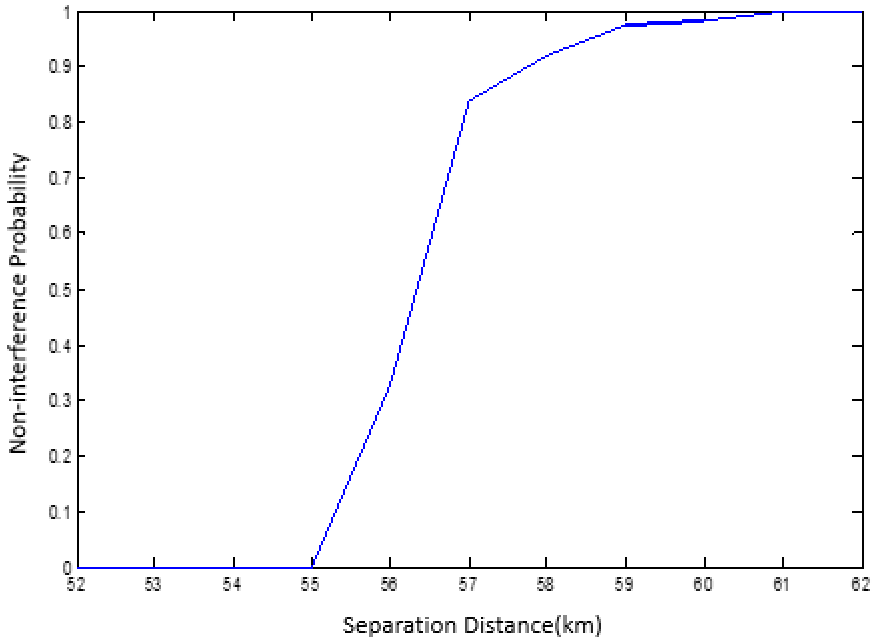
TABLE 27

FY-3 earth station protection distances (10 MHz channel bandwidth)

Number of iterations	Minimum distance (km)	Mean distance (km)	Maximum distance (km)
1	56	56	56
10	56	56.5	57
100	56	56.84	59
500	56	56.92	61
1000	56	56.95	61

FIGURE 20

FY-3 earth station protection distances (10 MHz channel bandwidth)



6 Summary

6.1 From IMT base station into MetSat earth station

From the results mentioned above, the required separation distances around MetSat stations in the 1 695-1 710 MHz band are summarized as below:

– 47.3 km, 157.1 km and 113.8 km with urban, suburban and rural scenario respectively to prevent the aggregated interference from the IMT base station to GSO MetSat earth station;

- 73.2 km, 248.7 km, 184.5 km with urban, suburban and rural scenario respectively for long-term interference criteria to prevent the aggregated interference from the IMT base station to NGSO MetSat earth station;
- 36.2 km, 126.9 km, 79.1 km with urban, suburban and rural scenario respectively for the short-term interference criteria to prevent the aggregated interference from the IMT base station to NGSO MetSat earth station.

If more than two rings of base stations are considered, the protection distances will be much larger obviously.

6.2 From IMT UE into MetSat earth station

Based on the results mentioned above simulation result from IMT UE into MetSat earth station, the required separation distances around MetSat stations in the 1 695-1 710 MHz band are summarized as below:

- 46 km separation distance is needed to prevent the aggregated interference from IMT UE into GSO MetSat earth station;
- 61 km separation distance is needed to prevent the aggregated interference from IMT UE into NGSO MetSat earth station;

7 Conclusion of Annex B

Based on the above study results, further considering that there are one or more typical MetSat receiving systems in the 1 695-1 710 MHz band in almost every large and medium-sized cities of China, it appears that sharing between MetSat service and IMT applications in this frequency band is incompatible.

Annex C

Protection of the meteorological-satellite service from proposed mobile broadband applications in the mobile service in the frequency band 1 695-1 710 MHz

1 Introduction

The analysis methodology used for computing the separation distances necessary to protect the meteorological-satellite receivers operating in and adjacent to the 1 695-1 710 MHz frequency band from interference by mobile broadband user equipment (UE) transmitters is described. The protection distances can be used to establish the geographic sharing arrangements for mobile broadband applications in the mobile service in this frequency band.

2 Analysis methodology description

An electromagnetic compatibility analysis was performed between UE transmitters and meteorological-satellite receivers operating in and adjacent to the 1 695-1 710 MHz frequency band. The analyses supported the determination of the required separation distances necessary to preclude potential interference between meteorological-satellite receivers and UE transmitters. The analysis methodology is applicable to both earth station receivers for geostationary and polar satellites. The methodology was used to develop protection zones for both geostationary and polar receive stations.

2.1 Overview of LTE UE technical parameters

The UE technical characteristics are presented in Table 28.

TABLE 28

LTE user equipment technical characteristics

Technical characteristic	Value
Aggregate total UE e.i.r.p. for cities with population < 250 000	–53.12 dBW/Hz
Average individual UE e.i.r.p. for cities with population < 250 000	8.08 dBm/10 MHz
Aggregate total UE e.i.r.p. for cities with population ≥ 250 000	–50.78 dBW/Hz
Average individual UE e.i.r.p. for cities with population ≥ 250 000	5.87 dBm/10 MHz
Antenna pattern	Omni Directional
Cellular deployment scenario	Same as LTE base stations presented in § 3.2.1

2.2 Overview of MetSat receiver characteristics

Technical characteristics for the Miami, Florida (PEOS) site

Parameter	Value
Latitude/longitude	254405 N/0800945 W
Centre frequency (MHz)	1702.5, 1707, 1698
Receiver 3 dB intermediate frequency bandwidth (MHz)	2.4
Noise temperature (K)	100
Mainbeam antenna gain (dBi)	27.5
Antenna height (metres) above local terrain	11
Elevation angle (degrees)	3
Worst case azimuth angle (degrees)	335
Protection threshold (dBm)	–124.8

2.3 Calculation of mobile broadband UE aggregate interference level

The interference power levels at the meteorological-satellite receiver are calculated using equation (1) for each UE transmitter considered in the analysis.

$$I = e.i.r.p. + G_R - L_{Add} - L_P - FDR \tag{1}$$

where:

I:	Received interference power at the output of the meteorological-satellite receive antenna (dBm)
$e.i.r.p.$:	UE transmitter e.i.r.p. (dBm)
G_R:	Antenna gain of the meteorological-satellite receiver in the direction of the UE transmitter (dBi)[2]
L_{Add}:	Additional losses (dB)
L_P:	Propagation loss (dB)
FDR:	Frequency dependent rejection (dB).

Using equation (1), the values of interference power level are calculated for each mobile/portable station being considered in the analysis. These individual interference power levels from each UE transmitter are then used in the calculation of the aggregate interference to the meteorological-satellite receivers using equation (2).[3]

$$I_{AGG} = 10 \log \left[\sum_{j=1}^{N} I_j \right] + 30 \tag{2}$$

where:

I_{AGG}	Aggregate interference to the meteorological-satellite receiver from UE transmitters (dBm)
N	Number of UE transmitters
I	Interference power level at the input of the meteorological-satellite receiver from an individual UE transmitter (watts).

The difference between the received aggregate interference power level computed using equation (2) and the receiver interference protection criteria represents the available margin. When the available margin is positive, compatible operation is possible. The distance at which the available margin is zero represents the minimum distance separation that is necessary to protect the meteorological-satellite receiver.

2.4 Mobile broadband UE e.i.r.p.

The e.i.r.p. of each UE used to compute the aggregate interference level can be randomly selected using Monte-Carlo analysis techniques. There will be a need to establish separate sets of potential UE e.i.r.p. values for each of the urban/suburban and rural regions. The maximum and minimum values for the e.i.r.p. levels used in the analysis will also need to be determined.

2.5 Meteorological-satellite receive earth station antenna model

The antenna model for the meteorological-satellite receiving earth stations is based on Recommendation ITU-R F.1245-1.[4] The model is used to represent the azimuth and elevation antenna gain.

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[2] Additional losses for polarization mismatch are not included.

[3] The interference power calculated in equation (1) must be converted from dBm to watts before calculating the aggregate interference seen by meteorological-satellite system receiver using equation (2).

[4] Recommendation ITU-R F.1245-2 – Mathematical model of average or related radiation patterns for line-of-sight point-to-point radio relay system antenna for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz (2012).

In cases where the ratio between the antenna diameter and the wavelength is greater than 100 ($D/\lambda > 100$), the following equations will be used:

$$G(\varphi) = G_{max} - 2.5 \times 10^{-3}\left(\frac{D}{\lambda}\varphi\right)^2 \quad \text{for } 0° < \varphi < \varphi_m \tag{3}$$

$$G(\varphi) = G_1 \quad \text{for } \varphi_m \leq \varphi < \max(\varphi_m, \varphi_r) \tag{4}$$

$$G(\varphi) = 29 - 25\log\varphi \quad \text{for } \max(\varphi_m, \varphi_r) \leq \varphi < 48° \tag{5}$$

$$G(\varphi) = -13 \quad \text{for } 48° \leq \varphi \leq 180° \tag{6}$$

where:

G_{max}: maximum antenna gain (dBi)

$G(\varphi)$: gain relative to an isotropic antenna (dBi)

φ: off-axis angle (degrees)

D: antenna diameter (m)

λ: wavelength (m)

G_1: gain of the first side lobe = $2 + 15\log(D/\lambda)$.

$$\varphi_m = \frac{20\lambda}{D}\sqrt{G_{max} - G_1} \ \text{degrees} \tag{7}$$

$$\varphi_r = 12.02(D/\lambda)^{-0.6} \ \text{degrees} \tag{8}$$

In cases where the ratio between the antenna diameter and the wavelength is less than or equal to 100 ($D/\lambda \leq 100$), the following equation will be used:

$$G(\varphi) = G_{max} - 2.5 \times 10^{-3}\left(\frac{D}{\lambda}\varphi\right)^2 \quad \text{for } 0° < \varphi < \varphi_m \tag{9}$$

$$G(\varphi) = 39 - 5\log(D/\lambda) - 25\log\varphi \quad \text{for } \varphi_m \leq \varphi < 48° \tag{10}$$

$$G(\varphi) = -3 - 5\log(D/\lambda) \quad \text{for } 48° \leq \varphi \leq 180° \tag{11}$$

D/λ is estimated using the following expression:

$$20\log\frac{D}{\lambda} \approx G_{max} - 7.7$$

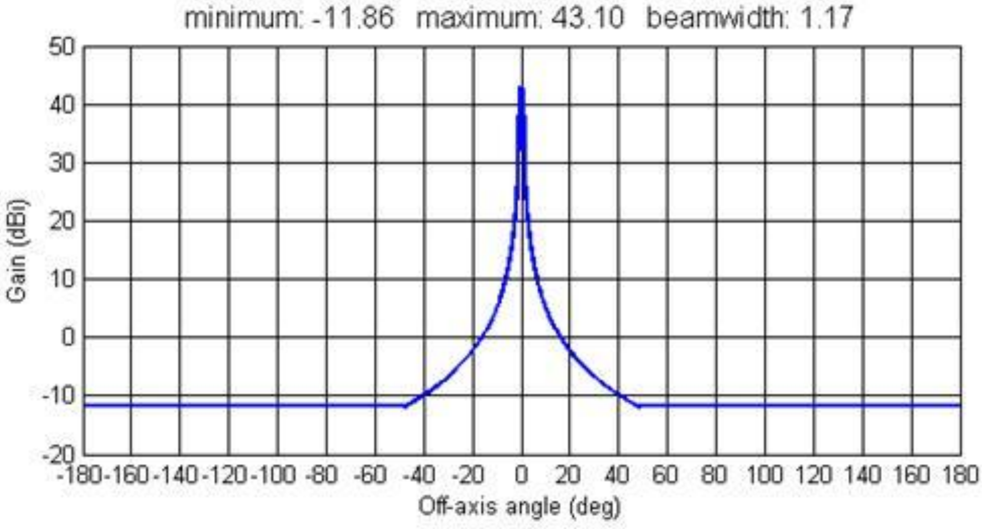
where:

G_{max}: Maximum antenna gain (dBi).

The antenna pattern for a 43 dBi mainbeam antenna gain is shown in Fig. 21.

FIGURE 21

Azimuth and elevation antenna pattern



The minimum elevation angle for each meteorological-satellite receive antenna is used to determine the antenna gain in the direction of the UE.

Signals from the polar orbiting meteorological-satellites can be received at any azimuth angle. An analysis was performed using minimum propagation loss to determine the worst-case azimuth angle used in the analysis. The worst case azimuth angle for each of the polar orbiting meteorological-satellite receivers should be determined.

Signals from the geostationary meteorological-satellites are received at fixed azimuth angles that should be used in the analysis.

2.6 Additional losses

An additional factor is included for additional losses associated with meteorological-satellite receiver insertion loss, cable loss, polarization mismatch loss, etc. A nominal value of 1 dB will be included in the analysis.

2.7 Propagation model

A propagation model that takes into account the terrain around a meteorological-satellite receive site should be used.

2.8 Frequency dependent rejection

Frequency dependent rejection (FDR) accounts for the fact that not all of the undesired transmitter energy at the receiver input will be available at the detector. FDR is a calculation of the amount of undesired transmitter energy that is rejected by a victim receiver. This FDR attenuation is composed of two parts: on-tune rejection (OTR) and off-frequency rejection (OFR). The OTR is the rejection provided by a receiver selectivity characteristic to a co-frequency transmitter as a result of an emission spectrum exceeding the receiver bandwidth, in dB. The OFR is the additional rejection, caused by specified detuning of the receiver with respect to the transmitter, in dB. The FDR values used in this analysis were computed using an automated program.

In the case of an undesired transmitter operating co-frequency to a victim receiver, the FDR is represented by the OTR using the following simplified form shown in equation (12).

$$OTR = \max\left[0.10\log\left(\frac{B_{tx}}{B_{rx}}\right)\right] \tag{12}$$

where:

B_{tx}: emission bandwidth of the transmitter

B_{rx}: intermediate frequency (IF) bandwidth of the receiver.

The transmitter emission spectrum and receiver selectivity curves used to compute the FDR are defined in terms of a relative attenuation level specified in decibel as a function of frequency offset from centre frequency in megahertz.

2.9 Meteorological-satellite receiver interference protection criteria

The interference protection criteria (I_T) for the meteorological-satellite receivers are determined using equation (13).[5]

$$I_T = {}^{I}/_{N} + N \tag{13}$$

where:

I/N: Maximum permissible interference-to-noise ratio at the receiver IF output (detector input) necessary to maintain acceptable performance criteria (dB)

N: Receiver inherent noise level at the receiver IF output referred to the receiver input (dBm).

For a known receiver IF bandwidth and receiver noise figure (NF) or system noise temperature, the receiver inherent noise level is given by:

$$N = -114\ [\text{dBm}] + 10\log(B_{IF}[\text{MHz}]) + NF \tag{14}$$

$$N = kT_sB_{IF} = -198.6\ [\text{dBm/K/Hz}] + 10\log(T_s\ [\text{K}]) + 10\log(B_{IF}\ [\text{Hz}]) \tag{15}$$

where:

B_{IF}: receiver IF bandwidth (see equations for units)

NF: receiver noise figure (dB)

k: Boltzmann's constant, 1.38×10^{-23} (Watts/K/Hz)

T_s: system noise temperature (Kelvin).

The analysis will use an I/N of –10 dB, corresponding to a 0.4 dB increase in the receiver noise to establish the interference protection criteria for the meteorological-satellite receivers.

Recommendations ITU-R SA.1026-3 and ITU-R-SA.1158 which recommends an interference criteria of –180 dBW/4kHz for long-term interference (favourable sharing case). For a receiver with a noise temperature of 269 K and a 4 kHz bandwidth the system noise is –168.3 dBW. This results in an I/N of –11.7 dB.

So the value of I/N of –10 dB is between the I/N of –8.3 dB (Recommendation ITU-R SA.1026-3) and the I/N of –11.7 dB (Recommendation ITU-R SA.1158).

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[5] The receiver interference protection criteria are referred to as long-term criteria because their derivation assumes that the interfering signal levels are present most of the time.

3 Analysis

Here we show how the analysis methodology, presented above, can be used to compute the required separation distances to protect meteorological-satellite receivers based on controlling aggregate interference by eliminating base stations and their associated user equipment (UE). The Miami, Florida polar earth orbiting system (PEOS) site is used as an example calculation for the separation distances necessary to protect the earth station.

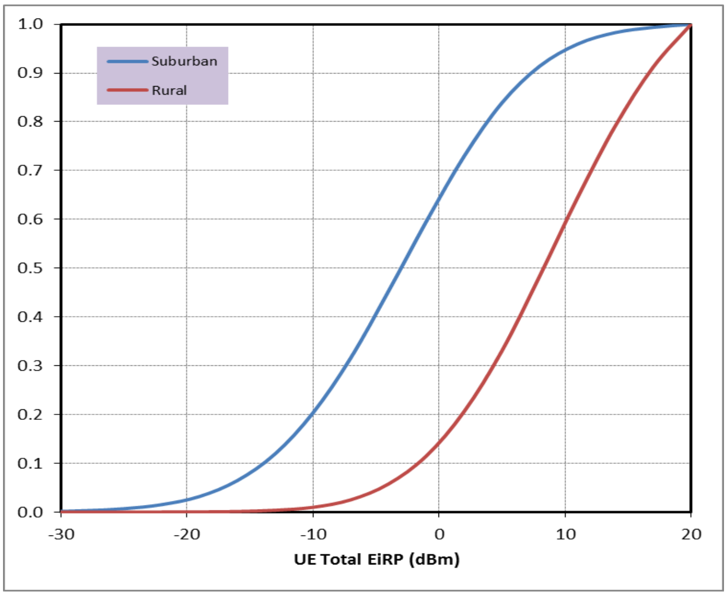
Commercial system technical parameters

UE transmitter power levels

The e.i.r.p. CDF curves shown in Fig. 22 were generated for UE operating in suburban and rural environments.

FIGURE 22

Suburban and rural UE CDF



The e.i.r.p. for each UE will be randomly selected in accordance with the CDF curves shown in Fig. 22 for each independent Monte-Carlo analysis trial.

UE channel bandwidth

The analysis considered channel bandwidths of 5 MHz, 10 MHz, and 15 MHz for the UE in the analysis[6]. For UE transmissions all of the frequencies within a channel are not used simultaneously under the LTE standard. Rather, transmissions are scheduled using subcarriers referred to as Physical Resource Blocks (PRBs), containing 12 subcarriers that each have a bandwidth of 180 kHz. There are various options on how to allocate PRBs but they limit the maximum throughput available for a particular UE. Channel bandwidths of 5 MHz, 10 MHz and 15 MHz should be considered in the analysis.

The frequency bandwidth of a UE at any instant in time will depend on the data rate of the transmission. The analysis assumed the channel bandwidth is divided equally among the number of UEs actively transmitting within a sector. For example, if the UEs have a channel bandwidth of 10 MHz and there are six transmitting UEs within the sector, the transmitter bandwidth for each UE is 1.6667 MHz.

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[6] The 3GPP standard specifies channel bandwidths of 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz.

UE antenna height

The antenna height of 1.5 metres is used for all of the UE.

Number of simultaneously transmitting UE

In the LTE technology, each UE only occupies a fraction of the available channel bandwidth. The LTE base station provides uplink resource allocations for the UE, distributing 100 percent of the resources equally among the transmitting UEs in each base station sector. The number of simultaneously transmitting UE per base station sector for each channel bandwidth is shown in Table 29.

TABLE 29

Number of simultaneously transmitting UE

Channel bandwidth	5 MHz	10 MHz	15 MHz
Number of simultaneously transmitting UE per sector	3	6	9
Number of simultaneously transmitting UE per base station	9	18	27

Propagation model

A propagation model that takes into account the actual terrain around the meteorological-satellite receiver was used in the analysis. For the aggregate compatibility analysis associated with the meteorological-satellite receivers, the propagation model described in Recommendation ITU-R P.452 was used[7]. This propagation model uses actual terrain data and it should provide a better estimate of the propagation loss. The statistical and environmental parameters used with the actual terrain profiles in calculating propagation loss are shown in Table 30.

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[7] Recommendation ITU-R P.452-15 – Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz.

TABLE 30

Parameters used in application Recommendation ITU-R P.452

Parameter	Value
Surface refractivity	301 N-units
Refractivity Gradient	50 N-units
Polarization	Vertical
Percentage of Time	50 percent
Frequency	1 702.5 MHz
Transmitter antenna height	1.5 metres
Receiver antenna height	Variable
Terrain database	United States Geological Survey (USGS) – 3 second[8] GLOBE – 30 second[9]

There were no additional losses associated with clutter or building attenuation included in the analysis.

Meteorological-satellite receive earth station antenna model

The antenna model for the meteorological-satellite receive earth stations is based on Recommendation ITU-R F.1245.[10] The model is used to represent the azimuth and elevation antenna gain.

In cases where the ratio between the antenna diameter and the wavelength is greater than 100 ($D/\lambda > 100$), the following equations will be used:

$$G(\varphi) = G_{max} - 2.5 \times 10^{-3}\left(\frac{D}{\lambda}\varphi\right)^2 \quad \text{for } 0° < \varphi < \varphi_m \tag{16}$$

$$G(\varphi) = G_1 \quad \text{for } \varphi_m \leq \varphi < \max(\varphi_m, \varphi_r) \tag{17}$$

$$G(\varphi) = 29 - 25\log\varphi \quad \text{for } \max(\varphi_m, \varphi_r) \leq \varphi < 48° \tag{18}$$

$$G(\varphi) = -13 \quad \text{for } 48° \leq \varphi \leq 180° \tag{19}$$

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[8] The USGS terrain data downloadable from the following links:
http://ntiacsd.ntia.doc.gov/msam/TOPO/USGS_CDED/T3Sec01.zip
http://ntiacsd.ntia.doc.gov/msam/TOPO/USGS_CDED/T3Sec02.zip
http://ntiacsd.ntia.doc.gov/msam/TOPO/USGS_CDED/T3Sec03.zip
http://ntiacsd.ntia.doc.gov/msam/TOPO/USGS_CDED/T3Sec04.zip

[9] The GLOBE 30 second terrain data can be downloaded from the http://www.ngdc.noaa.gov/mgg/topo/gltiles.html website. The GLOBE data was used in areas where there is no USGS terrain data.

[10] Recommendation ITU-R F.1245-2 – Mathematical model of average or related radiation patterns for line-of-sight point-to-point radio relay system antenna for use in certain coordination studies and interference assessment in the frequency range from 1 GHz to about 70 GHz (2012).

where:

G_{max}: maximum antenna gain (dBi)

$G(\varphi)$: gain relative to an isotropic antenna (dBi)

φ: off-axis angle (degrees)

D: antenna diameter (m)

λ: wavelength (m)

G_1: gain of the first side lobe = $2 + 15 \log (D/\lambda)$.

$$\varphi_m = \frac{20\lambda}{D}\sqrt{G_{max} - G_1} \quad \text{degrees} \tag{20}$$

$$\varphi_r = 12.02(D/\lambda)^{-0.6} \quad \text{degrees} \tag{21}$$

In cases where the ratio between the antenna diameter and the wavelength is less than or equal to 100 ($D/\lambda \leq 100$), the following equations will be used:

$$G(\varphi) = G_{max} - 2.5 \times 10^{-3}\left(\frac{D}{\lambda}\varphi\right)^2 \quad \text{for } 0° < \varphi < \varphi_m \tag{22}$$

$$G(\varphi) = 39 - 5\log(D/\lambda) - 25\log\varphi \quad \text{for } \varphi_m \leq \varphi < 48° \tag{23}$$

$$G(\varphi) = -3 - 5\log(D/\lambda) \quad \text{for } 48° \leq \varphi \leq 180° \tag{24}$$

D/λ is estimated using the following expression:

$$20\log\frac{D}{\lambda} \approx G_{max} - 7.7 \tag{25}$$

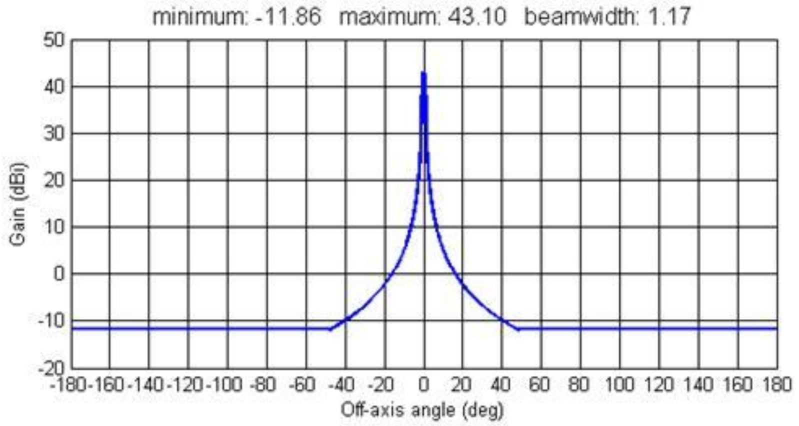
where:

G_{max}: Maximum antenna gain (dBi).

The azimuth and elevation antenna pattern for a 43 dBi mainbeam antenna gain is shown is shown below in Fig. 23.

FIGURE 23

Azimuth and elevation antenna pattern



The minimum elevation angle for each meteorological-satellite receive antenna is used to determine the antenna gain in the direction of the UE. Signals from the polar orbiting meteorological-satellites can be received at any azimuth angle. An analysis was performed using minimum propagation loss to determine the worst-case azimuth angle used in the analysis.

Example protection distances

This section provides an example of the meteorological-satellite receiver protection distances. The analysis considered channel bandwidths of 5 MHz, 10 MHz, and 15 MHz. The protection distances for each meteorological-satellite receiver were computed for various iterations of the analysis model randomizing the equivalent isotropically radiated power levels and the location of the user equipment (UE). Randomizing the UE location also varies the meteorological-satellite receive antenna gain.

The technical characteristics for the Miami Florida PEOS site are provided in Table 31.

TABLE 31

Technical characteristics for the Miami, Florida (PEOS) site

Parameter	Value
Latitude/Longitude	254405 N/0800945 W
Centre frequency (MHz)	1702.5, 1707, 1698
Receiver 3 dB intermediate frequency bandwidth (MHz)	2.4
Noise temperature (K)	100
Mainbeam antenna gain (dBi)	27.5
Antenna height (metres) above local terrain	11
Elevation angle (degrees)	3
Worst case azimuth angle (degrees)	335
Protection threshold (dBm)	–124.8

The protection distances for each user equipment channel bandwidth are provided in Tables 32 through 34.

TABLE 32

Miami Florida PEOS protection distances – 5 MHz channel bandwidth

Number of iterations	Minimum distance (km)	Mean distance (km)	Maximum distance (km)
1	34	34	34
10	30	32.6	40
100	30	33.5	40
500	30	33.8	40
1 000	34	38.3	46

FIGURE 24

Miami Florida PEOS protection distances – 5 MHz channel (1 000 iterations)

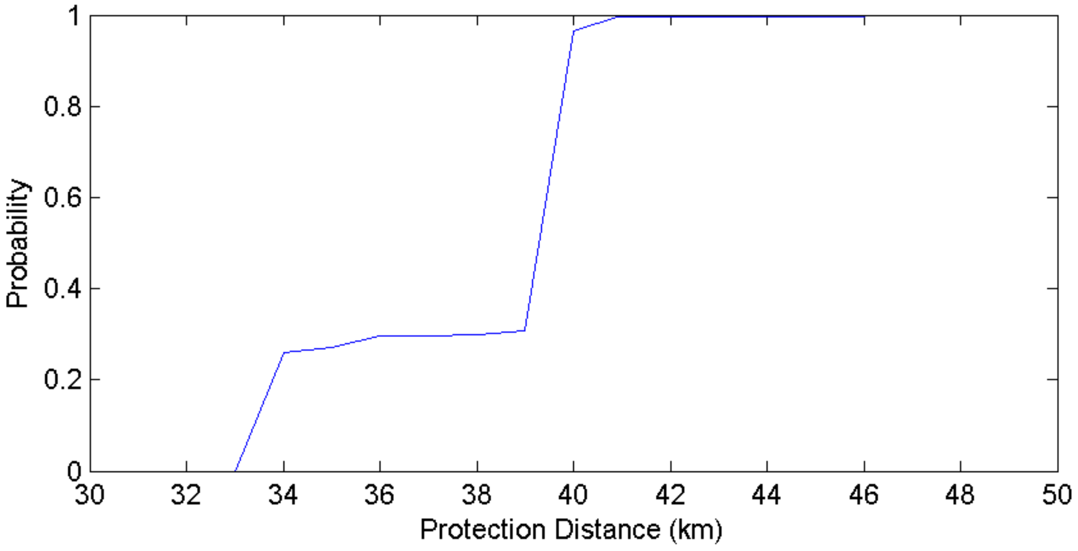


TABLE 33

Miami Florida PEOS protection distances – 10 MHz channel bandwidth

Number of iterations	Minimum distance (km)	Mean distance (km)	Maximum distance (km)
1	40	40	40
10	34	38.8	40
100	34	37.4	40
500	43	37.6	46
1 000	40	41.1	46

FIGURE 25

Miami Florida PEOS protection distances – 10 MHz channel (1 000 Iterations)

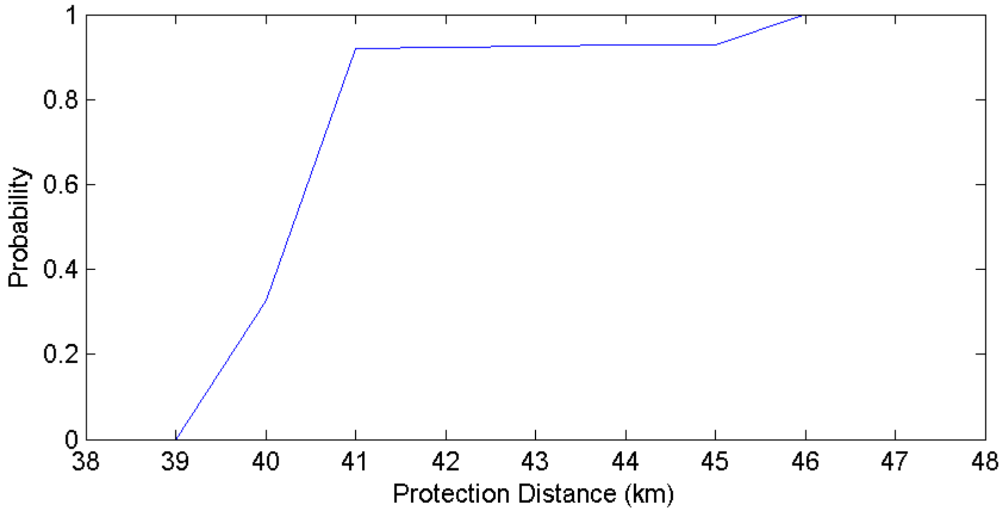


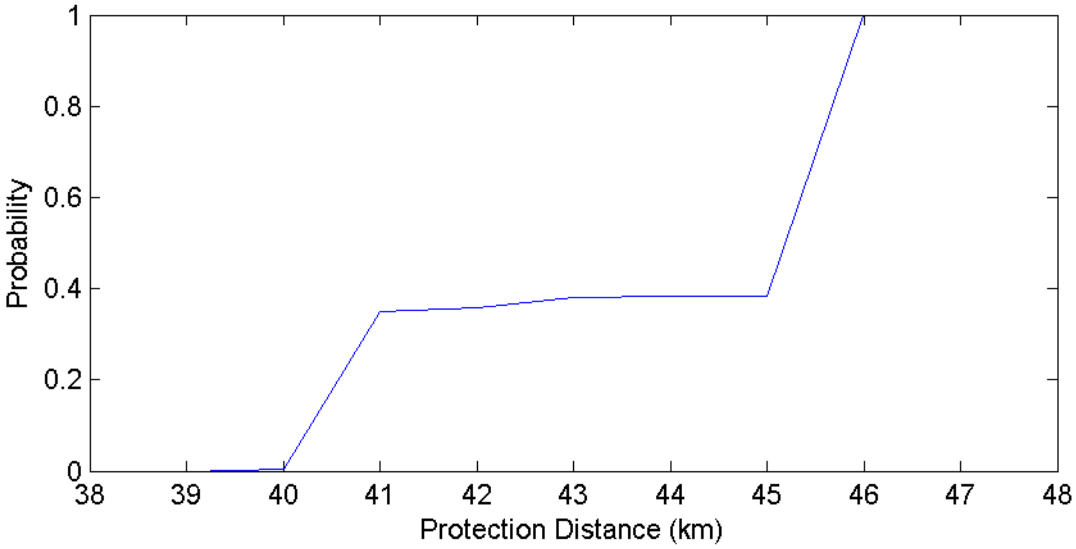
TABLE 34

Miami Florida PEOS protection distances – 15 MHz channel bandwidth

Number of iterations	Minimum distance (km)	Mean distance (km)	Maximum distance (km)
1	46	46	46
10	40	40.6	46
100	34	39.5	46
500	34	39.9	46
1 000	40	44.1	46

FIGURE 26

Miami Florida PEOS protection distances – 15 MHz channel (1 000 Iterations)



Conclusion of Annex C

Based on the results presented here, the use of geographical limitations on terrestrial mobile broadband, computed using the analysis methodology described above, shows that the proposed mobile broadband applications in the mobile service in the frequency band 1 695-1 710 MHz are compatible with the incumbent meteorological-satellite service operating in and adjacent to this band.