International Telecommunication Union

# ITU-R

Radiocommunication Sector of ITU

**Report ITU-R F.2327-0**
**(12/2014)**

# Sharing and compatibility study between International Mobile Telecommunication systems and point-to-point fixed wireless systems in the frequency band 4 400-4 990 MHz

**F Series**

**Fixed service**

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# REPORT ITU-R F.2327-0

## Sharing and compatibility study between International Mobile Telecommunication systems and point-to-point fixed wireless systems in the frequency band 4 400-4 990 MHz

(2014)

## 1 Introduction

Fixed service (FS) and mobile service (MS) are the primary allocations in the frequency band 4 400-4 990 MHz, and point-to-point fixed wireless systems constitute a major application in this band. This report provides the results of compatibility studies between International Mobile Telecommunications (IMT) system and point-to-point fixed wireless systems in the frequency band 4 400-4 990 MHz.

## 2 Related ITU-R Recommendations and Reports

| | |
|---|---|
| Recommendation ITU-R-758-5: | System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference |
| Recommendation ITU-R F.1706: | Protection criteria for point-to-point fixed wireless systems sharing the same frequency band with nomadic wireless access systems in the 4 to 6 GHz range |
| Report ITU-R M.2292: | Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses |

## 3 Allocation information

Table 1 lists the allocations contained in Article **5** of the Radio Regulations (RR) (Edition of 2012) in the frequency range 4 400-4 990 MHz.

TABLE 1

**Frequency allocations in the 4 400-4 990 MHz**

| Allocation to services | | |
|---|---|---|
| **Region 1** | **Region 2** | **Region 3** |
| **4 400-4 500** | FIXED<br>MOBILE 5.440A | |
| **4 500-4 800** | FIXED<br>FIXED-SATELLITE (space-to-Earth) 5.441<br>MOBILE 5.440A | |
| **4 800-4 990** | FIXED<br>MOBILE 5.440A 5.442<br>Radio astronomy<br>5.149 5.339 5.443 | |

## 4 Summary of results

Three studies were performed, each of which is presented in a separate Annex to this Report.

The results of these studies can be summarized as follows.

**Study #1:** With regard to the IMT (using 61 dBm e.i.r.p.) interfering FS receiver (assuming 22.5 dBi antenna gain based on Recommendation ITU-R F.758) in the band 4 400-4 500 MHz and 4 800-4 990 MHz analysis, the following observations may be reached:

– Co-channel interference analysis between a single IMT base station and an FS receiver predicts that the required separation distance to protect the FS station receiver is up to 70 km for the worst case, taking into account of terrain. The required separation distance to protect FS stations from an aggregated IMT interference would be worse.

– For adjacent channel interference, 45 dB of adjacent channel leakage ratio (ACLR) is assumed for IMT base station to the FS receiver. This results in a required distance separation on the order of several tens of kilometres. If an additional 30 dB of attenuation can be found through filtering and/or additional guard bands this distance may be reduced to 5 km. It should be noted that at this time, methods to obtain this additional attenuation have not been documented in this report. The adjacent band study assumes that existing systems do not use the whole allocated band and there is free spectrum available to implement the adjacent band solution for administrations. If an administration's incumbent FS systems currently use the all of the frequency band 4 400-4 990 MHz, then the use of adjacent band solutions would result in loss of spectrum for the incumbent FS systems.

**Study #2:** With regards to the IMT base station (using 61 dBm e.i.r.p.) causing interference to FS receivers (assuming 22.5 dBi antenna gain) in the band 4 400-4 500 MHz and 4 800-4 990 MHz the analysis, obtained results show that protection of FS station receivers from interference caused by single outdoor IMT base station transmitters requires separation distances up to 70 km. In the case of network of outdoor IMT base station transmitters the required separation distance grows up to 120 km. It will be difficult to provide compatibility of proposed IMT systems with existing FS stations in the same geographical region where FS networks are widely deployed in the both frequency bands. In case of aggregate interference from a network of IMT stations required separation distance increases that increases the difficulties of providing compatibility of IMT systems with FS systems.

**Study #3:** This study predicted the required separation distance to prevent interference for single IMT base station or a single user equipment (UE) to two representative FS systems. This study also provides an aggregate interference analysis which predicts the size of the area, surrounding a FS system, from which IMT base stations would have to be excluded to protect the FS system from interference.

IMT base stations were modelled using a maximum e.i.r.p. value up to 61 dBm with a 20 MHz bandwidth and 64 dBm with a 40 MHz bandwidth

For FS systems modelled on Recommendation ITU-R F.758-5, typical antenna gains are approximately 22 dBi and an *I/N* threshold of –10 dB is used as an interference criterion.

The propagation model assumed a smooth spherical Earth. This model does not account for potential signal enhancements or reductions due to terrain features.

A summary of the results are shown in the following table:

**Required distance separation or exclusion area between FS systems and IMT**

| IMT Station Type | FS Antenna Coupling | F.758-5 | | Units |
|---|---|---|---|---|
| | | System A | System B | |
| Base station | Main beam | 157 | 145 | km |
| | Back lobe | 78 | 71 | km |
| User Set | Main beam | 28 | 25 | km |
| | Back lobe | 8 | 6 | km |
| Base station | Aggregate | 165 781 | 133 733 | $km^2$ |

# Annex 1
# Study 1

## Compatibility study between IMT system and point-to-point fixed wireless system in the bands 4 400-4 500 MHz and 4 800-4 990 MHz

### 1 Introduction

### 1.1 Scope and objective

Fixed service and MS have primary allocations in the frequency bands 4 400-4 500 MHz and 4 800-4 990 MHz, and point-to-point fixed wireless system is the major application service in the bands. This report provides the compatibility study between IMT system and point-to-point fixed wireless system in the frequency bands 4 400-4 500 MHz and 4 800-4 990 MHz.

### 2 Technical characteristics and parameters

### 2.1 Fixed wireless service parameters

The parameters is according to Recommendation ITU-R F.758-5 as following:

**Typical technical characteristics of FS systems in the frequency bands 4 400-4 500 MHz and 4 800-4 990 MHz**

| **Frequency range (GHz)** | **4.400-5.000** | |
|---|---|---|
| **Modulation** | **16-QAM** | **256-QAM** |
| Channel spacing and receiver noise bandwidth (MHz) | 8, 9, 10, 13, 16.6, 20, 28, 33.2, 40, 60, 80 | 9, 10, 13, 20, 28, 40, 60, 80 |
| Feeder/multiplexer loss range (dB) | 0 | 3 |
| Antenna gain range (dBi) | 21.5…22.5 | 22.5 |
| Receiver noise figure typical (dB) | 6.5…7 | 6.5 |
| Receiver noise power density typical (=NRX) (dBW/MHz) | −137.5…−137 | −137.5 |
| Normalized Rx input level for 1 × 10−6 BER (dBW/MHz) | −117.0… −116.5 | −104.9 |
| Nominal long-term interference power density (dBW/MHz)(2) | −137.5… −137 + *I/N* | −137.5 + *I/N* |

According to Recommendation ITU-R F.699, in cases where only the maximum antenna gain is known, $D/\lambda$ may be estimated from the following expression:

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

where $G_{max}$ is the main lobe antenna gain (dBi):

$$\frac{D}{\lambda} = 5.495$$

For frequencies in the range 1 GHz to about 70 GHz, in cases where the ratio between the antenna diameter and the wavelength is less than or equal to 100 the following equations should be used:

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

$$G(\varphi) = G_1 \quad \text{for} \quad \varphi_m \le \varphi \le 100 \frac{\lambda}{D}$$

$$G(\varphi) = 52 - 10 \log \frac{D}{\lambda} - 25 \log \varphi \quad \text{for} \quad 100 \frac{\lambda}{D} \le \varphi < 48°$$

$$G(\varphi) = 10 - 10 \log \frac{D}{\lambda} \quad \text{for} \quad 48° \le \varphi \le 180°$$

$G_1$: gain of the first side-lobe = $2 + 15 \log \frac{D}{\lambda}$ = 13.1 dB.

$$\varphi_m = \frac{20\lambda}{D} \sqrt{G_{max} - G_1} \quad \text{degrees} = 1.28 \text{ degree}$$

If $G$ = 3.5, then the degree will be 11.15 degree.

### 2.2 IMT system parameters

The technical characteristics and system parameters of IMT are shown in the following table.

TABLE 2

**IMT technical characteristics and parameters**

| Parameters | Values (LTE) | |
|---|---|---|
| | Macro base station | User equipment |
| Maximum output power (dBm/20 MHz) | 46 | 23 |
| Bandwidth (MHz) | 20 | |
| Cell radius (m) | Macro urban: 300 | |
| Antenna height (m) | Macro urban: 20 | 1.5 |
| Maximum base station antenna gain (dBi) | Macro urban: 18 | 0 |
| Antenna pattern | Recommendation ITU-R F.1336 (*recommends* 3.1)<br>$k_a$ = 0.7<br>$k_p$ = 0.7<br>$k_h$ = 0.7<br>$k_v$ = 0.3<br><br>Horizontal 3 dB beamwidth: 65 degrees<br>Vertical 3 dB beamwidth: determined from the horizontal beamwidth by equations in Recommendation ITU-R F.1336. | Omni |
| Downtilt (degree) | Macro urban: 10 | – |
| Feeder Loss/ Body Loss (dB) | 3 | 4 |
| ACLR (dB @ ± BW MHz) | 45 | 30 |

## 3 Methodologies and propagation models

### 3.1 Possible types of interference to the FS

Two possible types of interference from IMT have been identified to impact FS reception:

a) Unwanted emissions from IMT at adjacent channel

Interference from Unwanted emissions generated by IMT base station transmitter operating in an adjacent channel to FS receiver.

b) Co-frequency emissions

Co-channel interference case between IMT system and point-to-point FS receivers is not evaluated because it can be avoided by operating in different frequency bands for the two systems in the same geographical area.

### 3.2 FS interference criteria

The following methodology is adopted in Recommendation ITU-R F.758-5.

An interference criterion of $I/N = -10$ dB should be applied to the FS for the long-term interference.

$$I/N = -10 \text{ dB}$$

A receiver bandwidth of 28 MHz was considered in this study.

Based on the nominal long-term interference power density from Table 1 acceptable levels of interference power $I_{maxD}$ were determined for indicated FS channel bandwidth:

– For 28 MHz channel bandwidth, $I_{maxD} = -103$ dBm.

The IMT base station (20 MHz) effective e.i.r.p. value for different FS receiver (28 MHz) channels is 28 dBW.

### 3.3 Methodologies

Assuming one IMT macro cell base station interferes with a FS receiver, the received interference power spectral density at the FS receiver is calculated according to the equation:

$$I_{IMT} = P_{IMT} + G_{IMT} + G_{FS}(\theta) - L(f,d) - S - F$$

$I_{IMT}$: the received interference power level in 1 MHz bandwidth at the FS receiver (dBm)

$P_{IMT}$: transmission power per MHz bandwidth of IMT system (dBm)

$G_{IMT}$: antenna gain of IMT system (dB)

$G_{FFS}(\varphi)$: reception antenna gain of FS system (dB)

$L(f,d)$: the path loss (dB)

$S$: shadowing loss (dB) with standard deviation of 10 dB in log-normal distribution. In determined study, it is set to 0 dB

$F$: frequency offset factor dependant on the frequency offset between IMT macro base station and FS receiver. In determined study, it is set to 45 dB, which is IMT macro base station transmission power suppression at the first adjacent frequency.

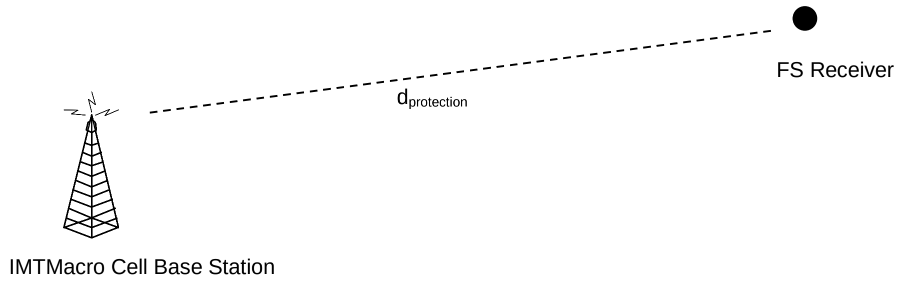
### 3.4 IMT Macro cell scenario topology

#### 3.4.1 Single entry interference scenario

IMT macro cell at the urban scenario is deployed near the FS receiver.

FIGURE 1

**IMT macro cell scenario topology**



where:

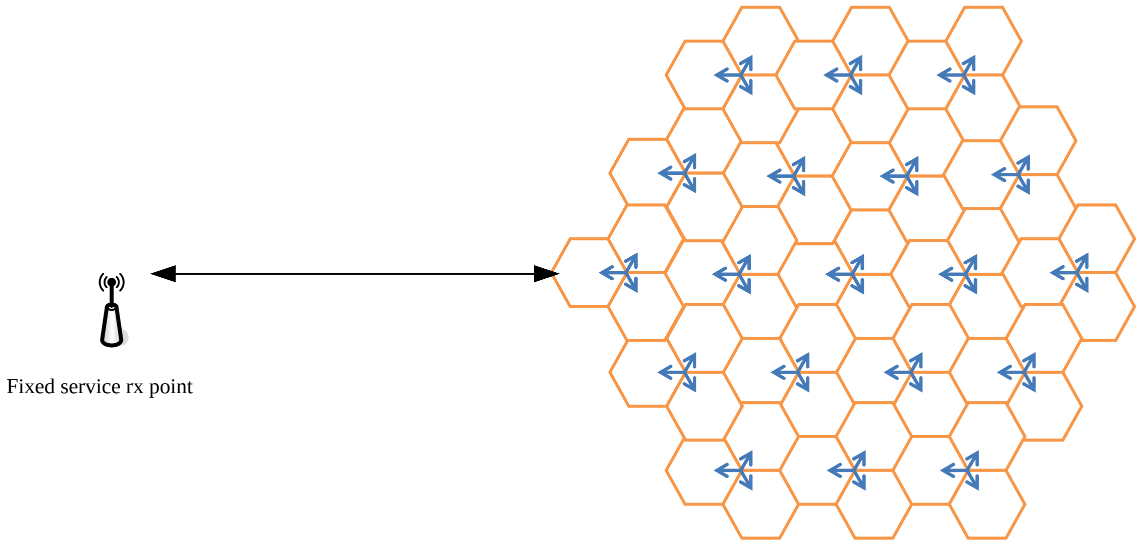
$d_{protection}$ Separation distance, the distance between the FS receiver and IMT macro cell base station.

### 3.4.2 Aggregated interference scenario

The IMT network layout is illustrated in the following Fig. 2. Nineteen cells are deployed in a hexagonal pattern with each cell consisting of three sectors. An IMT base station is located at the centre of each cell and operates with a 3-sector antenna. Each antenna serves a single sector covering 120 degrees of the cell. The FS station is adjacent to the IMT network base stations. The aggregated interference into the FS station is computed assuming varying separation distances. FS antenna is random setting for each snapshot.

FIGURE 2

**IMT macro cell scenario topology**




### 3.5 Propagation models

The propagation model is referenced Recommendation ITU-R P.452-15.

Basic transmission loss is from Recommendation ITU-R P.452-15 as follows:

$$L_{bfsg} = 92.5 + 20 \log f + 20 \log d + Ag + L_{d50} + + A_{ht} + A_{hr} \qquad \text{dB}$$

where:

*L*: transmission loss due to free-space propagation and attenuation by diffraction loss (dB)

*f*: frequency (GHz)

*d*: path length (km)

*Ag*: total gaseous absorption (dB)

$L_{d50}$: the median diffraction losses (dB) have considered spherical-Earth diffraction loss:

$$L_{d50} = L_{m50} + \left(1 - e^{-\frac{L_{m50}}{6}}\right)\left(L_{t50} + L_{r50} + 10 + 0.04d\right) \quad \text{for } \nu_{m50} > -0.78$$

$$= 0 \quad \text{otherwise}$$

where:

$L_{m50}$: the median knife-edge diffraction loss for the main edge (dB)

$L_{t50}$: the median knife-edge diffraction loss for the transmitter-side secondary edge (dB)

$L_{r50}$: the median knife-edge diffraction loss for the receiver-side secondary edge (dB)

$\nu_{m50}$: the diffraction parameter of the main edge (dB)

$A_{ht,hr}$: additional losses to account for clutter shielding the transmitter and receiver.

Recommendation ITU-R P.452-15 requires the terrain information as input for diffraction loss. The proposal below uses the typical terrain information contained in the Table 4 of Recommendation ITU-R P.452-15.

TABLE 3

**Nominal clutter heights and distances**

| **Clutter (ground-cover) category** | **Nominal height** $h_a$ **(m)** | **Nominal distance** $d_k$ **(km)** |
|---|---|---|
| High crop fields<br>Park land<br>Irregularly spaced sparse trees<br>Orchard (regularly spaced)<br>Sparse houses | 4 | 0.1 |
| Village centre | 5 | 0.07 |
| Deciduous trees (irregularly spaced)<br>Deciduous trees (regularly spaced)<br>Mixed tree forest | 15 | 0.05 |
| Coniferous trees (irregularly spaced)<br>Coniferous trees (regularly spaced) | 20 | 0.05 |
| Tropical rain forest | 20 | 0.03 |
| Suburban | 9 | 0.025 |
| Dense suburban | 12 | 0.02 |
| Urban | 20 | 0.02 |
| Dense urban | 25 | 0.02 |
| High-rise urban | 35 | 0.02 |
| Industrial zone | 20 | 0.05 |

NOTE – $h_a$: Nominal clutter height (m) above local ground level

$d_k$: Distance (km) from nominal clutter point to the antenna

For transmitter and receiver side, the terrain info is according to the above table. The specific value is based on which scenario where the node is located.

It is assumed that the path includes transmit terrain, receive terrain and dense suburban terrain in the middle path; the 12 metre high terrain that characterizes the dense suburban is chosen as default for the dense urban middle path. If the transmitter or receiver side terrain is lower than 12 metres, the minimum value among the transmitter and receiver is chosen for the middle path terrain's height.

# 4 Studies and results of compatibility

## 4.1 Adjacent case

### 4.1.1 Single entry interference

The required separation distance between FS receiver and IMT in adjacent channel scenario based on determined study is shown as following table:

TABLE 4

**Results of adjacent channel compatibility analysis from IMT to FS receiver**

| Deployment type | Macro urban base station | Macro urban user equipment |
|---|---|---|
| IMT bandwidth (MHz) | 20 | 20 |
| IMT maximum base station output power (dBm) | 46 | 23 |
| IMT tx antenna gain of mainlobe (dBi) | 18 | 0 |
| IMT feeder loss/body loss (dB) | 3 | 4 |
| IMT antenna height(m) | 20 | 1.5 |
| FS receiver feeder loss (dB) | 0 | 0 |
| FS bandwidth (MHz) | 28 | 28 |
| Maximum permissible interference power | –103 | –103 |

TABLE 4 (*end*)

| **Deployment type** | **Macro urban base station** | | | | **Macro urban user equipment** | | | |
|---|---|---|---|---|---|---|---|---|
| FS receiver antenna gain (dB) | 22.5 for main lobe | | 3.5 for side lobe | | 22.5 for main lobe | | 3.5 for side lobe | |
| Isolation requirement (dB) | 188.3 | | 149.3 | | 146.3 | | 107.3 | |
| Frequency (GHz) | 4.5 | 4.9 | 4.5 | 4.9 | 4.5 | 4.9 | 4.5 | 4.9 |
| Required Protect distance (km) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Adjacent channel interference rejection requirement | 59.7 | 59.1 | 20.7 | 20.1 | 17.7 | 17.1 | –21 | –21 |
| Adjacent channel interference rejection requirement using an example of 25 dB XPD* | 34.7 | 34.1 | –4.3 | –4.9 | –7.3 | –7.9 | –21 | –21 |

* Cross polarization discrimination (XPD) between the FS and IMT stations from the evaluation results, adjacent co-exist can be feasible according to reasonable adjacent channel interference rejection requirement for IMT station and terminal. See Recommendation ITU-R F.1334 applicable to the frequency range 1-3 GHz.

### 4.1.2 Aggregated interference

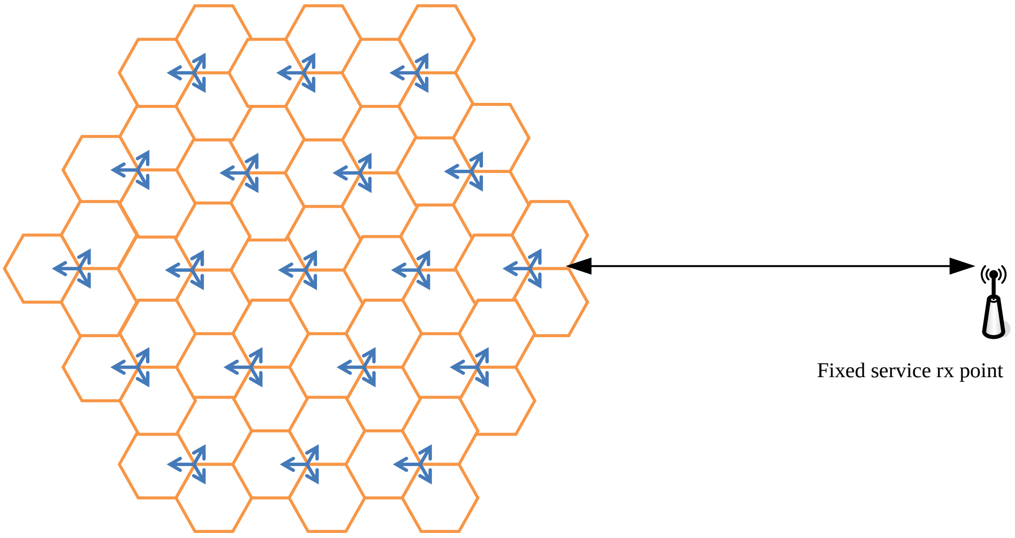
According to the topology of aggregated scenario defined in Fig. 2, a total of 1 000 snapshots are simulated in a certain separation distance assumption. For this analysis it was assumed 95% percent snapshots satisfy the isolation requirement, the separation distance is determined.

For IMT base station:

| **Deployment type** | Macro urban | |
|---|---|---|
| Frequency (GHz) | 4.5 | 4.9 |
| Required separation distance (km) | 5 | 5 |
| Adjacent channel interference rejection requirement | 75 | 71 |

If IMT antenna bore sight is optimized as the following, the adjacent channel interference rejection will be reduced to:

FIGURE 3




| Deployment type | Macro urban | |
|---|---|---|
| Frequency (GHz) | 4.5 | 4.9 |
| Required separation distance (km) | 5 | 5 |
| Adjacent channel interference rejection requirement | 55 | 55 |

For IMT UE:

| Deployment type | Macro urban | | | |
|---|---|---|---|---|
| Frequency (GHz) | 4.5 | 4.9 | 4.5 | 4.9 |
| Required Protect distance (km) | 1 | 1 | 5 | 5 |
| Adjacent channel interference rejection requirement | 0 | 0 | 0 | 0 |

## 4.2 Co-channel case

TABLE 5

**Results of co-channel compatibility analysis from IMT base station to FS receiver**

| Deployment type | Macro urban | | | |
|---|---|---|---|---|
| IMT bandwidth (MHz) | 20 | | | |
| IMT maximum base station output power (dBm) | 46 | | | |
| IMT base station antenna gain of mainlobe (dBi) | 18 | | | |
| IMT feeder loss (dB) | 3 | | | |
| IMT base station antenna height(m) | 20 | | | |
| FS receiver feeder loss (dB) | 3.5 | | | |
| FS bandwidth (MHz) | 30.2 | | | |
| Maximum permissible interference power (dBm) | –107.5 | | | |
| FS receiver antenna gain (dB) | 22.5 for main lobe | | 3.5 for side lobe | |
| Isolation requirement (dB) | 186.5 | | 147.5 | |
| Frequency (GHz) | 4.5 | 4.9 | 4.5 | 4.9 |
| Required Protect distance (km) | 72.0 | 71.1 | 46.1 | 45.8 |

Assuming an example 25 dB cross polarization discrimination (XPD) according to Recommendation ITU-R F.1334, for the cross-polar case. This Recommendation is applicable to the frequency range 1-3 GHz:

| | | | | | | |
|---|---|---|---|---|---|---|
| Isolation requirement (dB) | 161.5 | | 147.1 | | 122.5 | |
| Frequency (GHz) | 4.5 | 4.9 | 4.5 | 4.9 | 4.5 | 4.9 |
| Required Protect distance (km) | 55.7 | 55.2 | 45.8 | 45.6 | 7 | 6.5 |

## 5 Summary

With regard to the IMT (using 61 dBm e.i.r.p.) interfering FS receiver (assuming 22.5 dBi antenna gain based on Recommendation ITU-R F.758) in the band 4 400-4 500 MHz and 4 800-4 990 MHz analysis, the following observations may be reached:

– Co-channel interference analysis between a single IMT base station and a FS receiver predicts that the required separation distance to protect the FS station receiver is up to 70 km, taking into account of terrain. The required separation distance to protect FS stations from an aggregated IMT interference would be worse.

– For adjacent channel interference, 45 dB of adjacent channel leakage ratio (ACLR) is assumed for IMT base station to the FS receiver. This results in a required distance separation on the order of several tens of kilometres. If an additional 30 dB of attenuation can be found through filtering and/or additional guard bands this distance may be reduced to 5 km. It should be noted that at this time, methods to obtain this additional attenuation have not been documented in this report. The adjacent band study assumes that existing systems do not use the whole allocated band and there is free spectrum available to implement the adjacent band solution for administrations. If an administration's incumbent FS systems currently use the all of the frequency band 4 400-4 990 MHz, then the use of adjacent band solution would result in loss of spectrum for the incumbent FS systems.

# Annex 2
# Study 2

## Compatibility studies of proposed IMT stations with the fixed service stations in the bands 4 400-4 500 MHz and 4 800-4 990 MHz

### 1 Background

It should be noted that review of ITU-R Recommendations did not identify ITU-R Recommendations providing the technical characteristics of MS systems operating in these frequency bands.

At the same time, this review showed that the technical characteristics of FS systems operating in these frequency bands are contained in Recommendations ITU-R F.758-5 and ITU-R F.1099. In this regard, the Russian Federation conducted compatibility studies of proposed IMT systems with the FS systems, the results of which are presented below.

### 2 Technical characteristics of IMT systems

Technical characteristics of IMT systems are provided by Report ITU-R. M.2292. Table 1 below presents the technical characteristics of IMT, recommended for compatibility and sharing studies in the bands of frequencies range 3-6 GHz.

TABLE 1

**Technical characteristics of IMT systems that were user in the sharing studies**

| | **Macro suburban** | **Macro urban** |
|---|---|---|
| **Base station characteristics/ Cell structure** | | |
| Cell radius / Deployment density | 0.3-2 km (typical figure to be used in sharing studies 0.6 km) | 0.15-0.6 km (typical figure to be used in sharing studies 0.3 km) |
| Antenna height | 25 m | 20 m |
| Sectorization | 3-sectors | 3-sectors |
| Frequency reuse | 1 | 1 |
| Antenna polarization | linear / +- 45 degrees | linear / +- 45 degrees |
| Maximum base station output power (5/10/20 MHz) | 43/46/46 dBm | 43/46/46 dBm |
| Maximum base station antenna gain | 18 dBi | 18 dBi |
| Maximum base station output power (e.i.r.p.) | 58/61/61 dBm | 58/61/61 dBm |
| Average base station activity | 50% | 50% |
| Average base station power/sector (to be used in sharing studies) | 55/58/58 dBm | 55/58/58 dBm |

## 3 Technical characteristics and protection criteria of FS stations

Typical characteristics of FS systems in the bands presented in Recommendations ITU-R F.758-5 and ITU-R F.1099. Typical technical characteristics of FS networks used in compatibility studies with proposed IMT systems are presented in Table 2 below.

TABLE 2

**Typical technical characteristics of FS systems in the frequency bands 4 400-4 500 MHz and 4 800-4 990 MHz**

| **Frequency range (GHz)** | **4 400-5 000** | |
|---|---|---|
| Modulation | 16-QAM | 256-QAM |
| Channel spacing and receiver noise bandwidth (MHz) | 8, 9, 10, 13, 16.6, 20, 28, 33.2, 40, 60, 80 | 9, 10, 13, 20, 28, 40, 60, 80 |
| Feeder/multiplexer loss range (dB) | 0 | 3 |
| Antenna gain range (dBi) | 21.5…22.5 | 22.5 |
| Receiver noise figure typical (dB) | 6.5…7 | 6.5 |
| Receiver noise power density typical (=NRX) (dBW/MHz) | −137.5…−137 | −137.5 |
| Normalized Rx input level for 1 × 10−6 BER (dBW/MHz) | −117.0… −116.5 | −104.9 |
| Nominal long-term interference power density (dBW/MHz) | −137.5… −137 + *I/N* | −137.5 + *I/N* |

## 4 Methodology and study results

Estimation of compatibility of the proposed IMT stations was made by minimum coupling losses method (MCL) for outdoor IMT BS. Different FS system bandwidths were taken into account (see Table 2). Therefore only channels with 8, 9, 28 and 80 MHz bandwidth were considered in this study. Based on the nominal long-term interference power density from Table 2 acceptable levels of interference power $I_{acc}$ were determined for indicated FS channel bandwidth:

– for 8 MHz channel bandwidth – minus 138.5 dBW;

– for 9 MHz channel bandwidth – minus 138 dBW;

– for 28 MHz channel bandwidth – minus 133 dBW;

– for 80 MHz channel bandwidth – minus 128.5 dBW.

The effective e.i.r.p. of IMT transmitter was defined for FS receivers with channel bandwidths mentioned above. These values were defined as follows:

$$EIRP_{eff} = \begin{cases} EIRP + 10\lg\left(\Delta F_{FS} / \Delta F_{IMT}\right), if \ \ \Delta F_{FS} < \Delta F_{IMT}; \\ EIRP, if \ \ \Delta F_{FS} \geq \Delta F_{IMT}; \end{cases}$$

where:

$\Delta F_{FS}$ – channel FS receiver bandwidth, MHz

$\Delta F_{IMT}$ – IMT channel bandwidth, MHz.

Table 3 contains effective e.i.r.p. values for FS channel bandwidth mentioned above and IMT channel bandwidth of 5 MHz, 10 MHz and 20 MHz.

TABLE 3

**IMT base station effective e.i.r.p. values for different FS receiver channels**

| | **Effective e.i.r.p., dBW** | | | | | |
|---|---|---|---|---|---|---|
| | **4 400-4 500 MHz** | | | **4 800-4 990 MHz** | | |
| $\Delta F_{FS}$, MHz ➔ | 8 | 28 | 80 | 9 | 28 | 80 |
| $\Delta F_{IMT}$, MHz ➔ | | | | | | |
| 5 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 |
| 10 | 27.0 | 28.0 | 28.0 | 27.5 | 28.0 | 28.0 |
| 20 | 24.0 | 28.0 | 28.0 | 24.5 | 28.0 | 28.0 |

Minimum coupling losses required for interference-free operation were calculated as follows:

$$L_{\min} = EIRP_{eff} + G_{FS} - I_{acc},$$

where:

$G_{FS}$ – FS station antenna Gain.

Obtained e.i.r.p. values were used for estimations of the required minimum coupling losses given in Table 4.

TABLE 4

**Minimum coupling losses required for FS station receivers protection**

| | $L_{min}$**, dB** | | | | | |
|---|---|---|---|---|---|---|
| | **4 400-4 500 MHz** | | | **4 800-4 990 MHz** | | |
| $\Delta F_{FS}$, MHz ➔ | 8 | 28 | 80 | 9 | 28 | 80 |
| $\Delta F_{IMT}$, MHz ➔ | | | | | | |
| 5 | 186.0 | 180.5 | 176.0 | 185.5 | 180.5 | 176.0 |
| 10 | 188.0 | 183.5 | 179.0 | 188.0 | 183.5 | 179.0 |
| 20 | 185.0 | 183.5 | 179.0 | 185.0 | 183.5 | 179.0 |

Required minimum coupling losses given in Table 4 were used for estimations of separation distances providing protection for FS receivers from outdoor IMT base station. The propagation model described in Recommendation ITU-R P.452 was used in the studies. The results of minimum required separation distances are presented in Table 5.

TABLE 5

**Separation distances R for protection of FS receivers**

| | R, km | | | | | |
|---|---|---|---|---|---|---|
| | 4 400-4 500 MHz | | | 4 800-4 990 MHz | | |
| $\Delta F_{FS}$, MHz → | 8 | 28 | 80 | 9 | 28 | 80 |
| $\Delta F_{IMT}$, MHz ↓ | | | | | | |
| 5 | 67 | 59.5 | 54.0 | 66.0 | 58.0 | 52.0 |
| 10 | 70.0 | 63.5 | 58.0 | 68.0 | 61.0 | 55.0 |
| 20 | 66.0 | 63.5 | 58.0 | 65.0 | 61.0 | 55.0 |

Analysis of the results presented in Table 5 shows the required separation distances vary from 54 km to 70 km for the frequency band 4 400-4 500 MHz and from 52 km to 68 km for the frequency band 4 800-4 990 MHz. The decrease in the required separation distance is due to larger propagation losses in the upper frequency band.

It should be noted that mentioned separation distances were obtained for case of single-source interference from an IMT base station transmitter. For aggregate interference caused by a network IMT base station transmitters the separation distances given in Table 5 will increase.

Analysis of Recommendation ITU-R F.758-5 showed that this Recommendation does not contain a detailed description of FS antenna patterns which is necessary for estimation of interference from IMT stations.

That is why in the estimations of aggregate interference impact from an IMT network to an FS receiver only IMT stations that are in the main beam of an FS antenna pattern were used. The results show that in this case an additional minimal coupling loss of up to 12-14 dB is required. This leads to an increase in the required protection distances of up to 120 km.

## 5 Conclusions

With regard to the IMT base station (using 61 dBm e.i.r.p.) causing interference to FS receivers (assuming 22.5 dBi antenna gain) in the band 4 400-4 500 MHz and 4 800-4 990 MHz, the analysis obtained results showing that the protection of FS station receivers from interference caused by single outdoor IMT base station transmitters requires separation distances of up to 70 km. In the case of a network of outdoor IMT base station transmitters the required separation distance increases to 120 km. It will be difficult to provide compatibility of proposed IMT systems with existing FS stations in the same geographical region where FS networks are widely deployed the both frequency bands. In case of aggregate interference from a network of IMT stations the required separation distance increases which in turn increases the difficulties of providing compatibility between IMT and FS systems.

# Annex 3
# Study 3

## Technical assessment of potential interference between IMT systems and the fixed service in the 4 400-4 990 MHz band

### 1 Introduction

The frequency band 4 400-4 990 MHz is allocated on a primary basis to the fixed and mobile services in all three Regions. In addition, 4 500-4 800 MHz is also allocated to the fixed-satellite service (space-to-Earth) on a primary basis in all three Regions in accordance with the allotment plan of Appendix **30B** to the Radio Regulations.

This analysis assesses the potential impact of introducing IMT systems on current fixed systems operating in the 4 400-4 990 MHz band. Analyses are provided to identify the minimum required separation distance required to protect a receiver in the FS from a single IMT base station or UE under worst-case assumptions, as well as aggregate analyses to identify the area around a fixed station where the aggregate interference from multiple IMT base stations may exceed the protection criteria.

### 2 System parameters

Parameters of IMT base stations and UEs are taken from Table D of Report ITU-R M.2292 Characteristics of Terrestrial IMT-Advanced Systems for Frequency Sharing/Interference Analyses.

Table 1 summarizes the parameters of typical FS systems from Recommendation ITU-R F.758 in the band 4.4 to 5 GHz. The parameters for Systems A and B are taken from Table 6 of Recommendation ITU-R F.758-5, which is currently in force.

TABLE 1

**Fixed service parameters**

| **Fixed System** | **A** | **B** |
|---|---|---|
| Modulation | 64-QAM | 256-QAM |
| Channel spacing (MHz) | 10 | 20 |
| Maximum antenna gain (dBi) | 22.5 | 22.5 |
| Multiplexer/feeder loss (dB) | 0 | 3 |
| Noise Figure (dB) | 6.5 | 6.5 |
| Receiver Noise Power (dBW) | — | — |
| Long-term interference threshold (dBW) | — | — |
| *I/N* threshold (dB) | –10 | –10 |

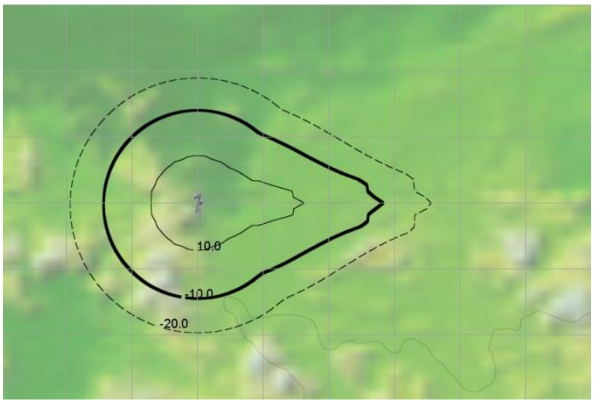
### 3 Single entry interference analyses

Single entry analyses were performed to determine the separation distance required to protect an FS receiver from an IMT base station operating on the same frequency. It is assumed that base stations are operating across the FS receiver bandwidth. The analyses assume a maximum IMT base station e.i.r.p. of 61 dBm in the direction of the fixed system for calculating interference into fixed systems with bandwidths of 10 and 20 MHz, and 64 dBm for the case of the 40 MHz fixed systems. Antenna heights of 25 meters are assumed for both the fixed and IMT base stations. The reference antenna pattern specified in Recommendation ITU-R F.699 is assumed for the fixed station and the Recommendation ITU-R F.1336 antenna pattern is assumed for the base station. The Recommendation ITU-R P.452-15 propagation model is used to calculate the p = 20% probability path loss at 4 695 MHz without consideration of terrain.

Figure 4 displays contours of the *I/N* produced by an IMT base station into Fixed Systems A.

FIGURE 4

***I/N* contours for IMT base station interference into fixed systems A**




Fixed System A

The required separation distances for the systems listed in Table 1 are presented in Table 2. In general, the required separation between an IMT base station and a fixed station varies from about 145-157 km, when the base station is located along the azimuth of the fixed station antenna main beam, and about 71-78 km, when the base station is located in the far sidelobes.

TABLE 2

**Required single entry separation distances for IMT base stations**

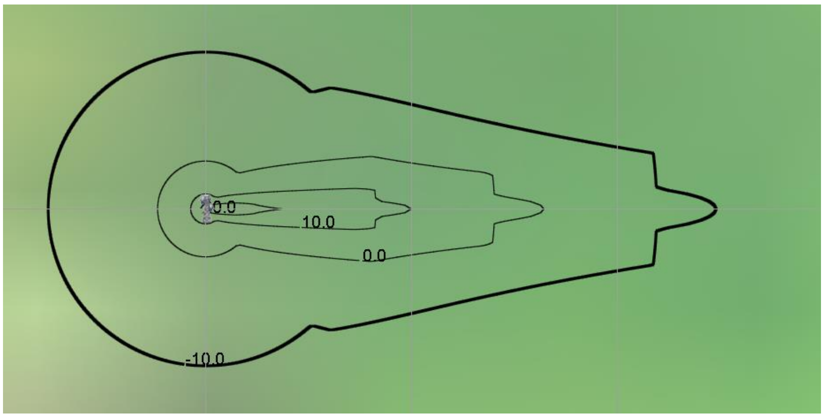
| Fixed System | A | B |
|---|---|---|
| Along main beam azimuth (km) | 157 | 145 |
| In backlobe regions (km) | 78 | 71 |

Similar single entry analyses were performed to determine the required separation distance for interference from outdoor IMT UE. The IMT UE maximum output power spectral density is 23 dBm/5 MHz. It is assumed that UE are operating across the FS receiver bandwidth, $BW_{fixed}$ (MHz), so that the single entry UE e.i.r.p. is equal to 23 dBm/5 MHz + 10·log10($BW_{fixed}$/5 MHz). This will lead to increased separation distances compared to typical UE when using 23 dBm across the whole operating bandwidth. See Report ITU-R M. 2292.

Figure 5 illustrates the *I/N* contours for an IMT UE interfering with Fixed System A.

FIGURE 5

***I/N*** **Contours for IMT UE Interference into Fixed System A**




The same analysis was applied to the other fixed system listed in Table 1 and the required separation distances for both systems are presented in Table 3.

TABLE 3

**Required single entry separation distances for IMT UEs**

| **Fixed System** | **A** | **B** |
|---|---|---|
| Along main beam azimuth (km) | 28 | 25 |
| In back lobe regions (km) | 8 | 6 |

## 4 Aggregate interference analyses

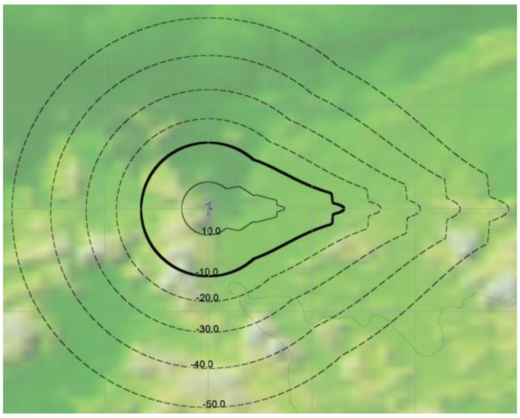
An aggregate analysis of IMT base station interference into Fixed System A was performed by constructing a rectangular grid of base stations with a 1.2 km separation corresponding to the 0.6 km radius for suburban macro cells, with each base station operating at a 58 dBm average e.i.r.p. into fixed systems with bandwidths of 10 and 20 MHz, and 61 dBm for the case of the 40 MHz fixed systems. From the assumed IMT station separations, the total number of IMT base stations would be about 80 000. With respect to the use of these power levels for aggregate analyses, that use of these average e.i.r.p. values does not take account of the varying nature of an IMT network in which inter-cell interference is minimised and parameters such as power levels adjusted in order to optimize the operational performance and capacity of the network. Aggregate interference levels may be reduced if such factors are taken into account. However, it is also recognized that there is no guidance on how to determine such factors or to what level the parameters should be adjusted to account for inter-cell interference.

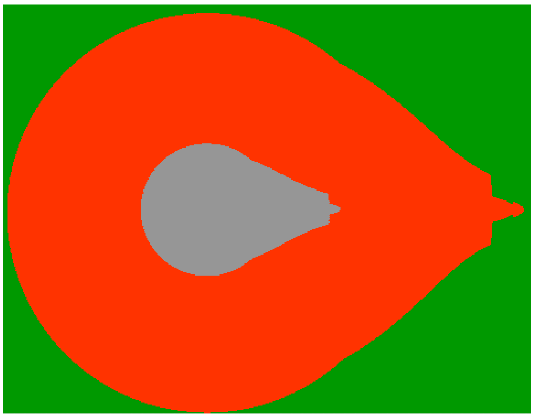
Figure 6 displays a plot of these grid cells, with the colours grey, red or green assigned to each pixel. A pixel is coloured grey if the *I/N* produced by a base station at the location of the pixel exceeds the FS *I/N* threshold of –10 dB and is not included in the calculation of the aggregate interference. An initial aggregate *I/N* from base stations at the other grid points is then calculated. In this case the initial aggregate *I/N* from base stations located outside of the grey area was 26.9 dB.

In order to achieve an aggregate *I/N* interference level of –10 dB, the remaining grid cells were sorted by the *I/N* produced by the base station at the FS receiver in the order of highest *I/N* to lowest *I/N*. Cells were then removed one-by-one from the aggregate *I/N* calculation, starting with the highest *I/N* and working downwards, until the aggregate *I/N* reached –10 dB. These removed cells are coloured red in Fig. 6. The remaining cells are coloured green to indicate that base stations could be operated at these points without the aggregate *I/N* exceeding the *I/N* threshold for Fixed Station A.

FIGURE 6

**Illustration of base station excluded areas to satisfy *I/N* threshold for Fixed System A**



| | |
|---|---|
| *I/N* Contours For Fixed Station A and Average IMT Base Station Power | Area (Green) Outside of Which IMT Base Station Operations Satisfy Aggregate *I/N* Criterion |

Similar analyses were run for the other fixed system listed in Table 1, and the results are presented in Table 4. The maximum distance for a single interferer in Table 4 is slightly smaller than the corresponding distance in Table 2 because the average IMT base station e.i.r.p. is used instead of the maximum e.i.r.p.

TABLE 4

**Dimensions of base station excluded areas to protect Fixed Service Systems**

| | **System A** | **System B** |
|---|---|---|
| Maximum distance from FS receiver where *I/N* threshold could be exceeded by a single IMT base station with average power | 145 km | 123 km |
| Area covered by cell sites producing interference exceeding *I/N* threshold | 20 452 $km^2$ | 13 741 $km^2$ |
| Maximum distance from FS receiver where cell site is excluded in order to satisfy the aggregate *I/N* threshold. The required maximum distance in other directions will be less than this maximum value, as shown in Figure 3 | 332 km | 297 km |
| Area covered by cell sites not exceeding single entry *I/N* threshold but excluded in order to satisfy the aggregate *I/N* threshold | 145 329 $km^2$ | 119 992 $km^2$ |
| Total exclusion area needed to protect FS system A | 165 781 $km^2$ | 133 733 $km^2$ |
| The above area corresponds to a circle with a radius of about | 230 km | 200 km |

The separation distances required for protecting a FS receiver from a single IMT UE operating at maximum power is less than the corresponding single entry separation distance for an IMT base station. Consequently, the area within which aggregate interference from use terminals exceeds the FS receiver interference threshold will also be smaller than the corresponding exclusion area identified for a base station.

## 5 Conclusion

This study predicted the required separation distance to prevent interference for single IMT base station or a single UE to two representative FS systems. This study also provides an aggregate interference analysis which predicts the size of the area, surrounding an FS system, from which IMT base stations would have to be excluded to protect the FS system from interference.

IMT base stations were modelled using maximum e.i.r.p. values of up to 61 dBm with a 20 MHz bandwidth and 64 dBm with a 40 MHz bandwidth.

For FS systems modelled on Recommendation ITU-R F.758-5, typical antenna gains are approximately 22 dBi and an *I/N* threshold of –10 dB is used as an interference criterion.

The propagation model assumed a smooth spherical Earth. This model does not account for potential signal enhancements or reductions due to terrain features.

A summary of the results are shown in the following table:

TABLE 5

**Required distance separation or exclusion area between FS Systems and IMT**

| IMT Station Type | FS Antenna Coupling | F.758-5 | | Units |
|---|---|---|---|---|
| | | System A | System B | |
| Base station | Main beam | 157 | 145 | km |
| | Back lobe | 78 | 71 | km |
| User equipment | Main beam | 28 | 25 | km |
| | Back lobe | 8 | 6 | km |
| Base station | Aggregate | 165 781 | 133 733 | $km^2$ |

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