International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R S.1856

(01/2010)

Methodologies for determining whether an IMT station at a given location operating in the band 3 400-3 600 MHz would transmit without exceeding the power flux-density limits in the Radio Regulations Nos. 5.430A, 5.432A, 5.432B and 5.433A

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Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R S.1856

Methodologies for determining whether an IMT station at a given location operating in the band 3 400-3 600 MHz would transmit without exceeding the power flux-density limits in the Radio Regulations Nos. 5.430A, 5.432A, 5.432B and 5.433A

(2010)

Scope

This Recommendation contains three methodologies that may be used by the concerned administrations, during their bilateral and/or multilateral discussions, in order to determine whether an IMT base or mobile station proposed to operate in the 3 400-3 600 MHz band would meet the pfd limit in the Radio Regulations (RR) Nos. 5.430A, 5.432A, 5.432B and 5.433A. This Recommendation does not address the criteria required for the application of RR Nos. 9.17, 9.18 and 9.21 which are mentioned in the above four provisions, irrespective of whether or not any earth station is in operation.

The ITU Radiocommunication Assembly,

considering

a) that, following decisions taken by WRC-07, in a number of countries in Region 1 the frequency band 3 400-3 600 MHz is allocated to the mobile service on a primary basis (see Radio Regulations (RR) No. 5.430A);

b) that, following decisions taken by WRC-07, in a number of countries in Region 3 the frequency band 3 400-3 500 MHz is allocated to the mobile service on a primary basis (see RR No. 5.432B) while the frequency band 3 500-3 600 MHz has been allocated for many years to the mobile service on a primary basis in Region 3;

c) that, at WRC-07, the frequency band 3 400-3 600 MHz was identified for use by IMT systems in a number of countries in Regions 1 and 3;

d) that for many years the band 3 400-3 600 MHz has been allocated to the fixed-satellite service (space-to-Earth) on a primary basis throughout Regions 1, 2 and 3;

e) that, in order to protect earth stations in the band 3 400-3 600 MHz from cross-border interference by stations in the mobile service, RR Nos. 5.430A, 5.432A, 5.432B and 5.433A (WRC-07) state that, before an administration specified in these footnotes brings into use a (base or mobile) station of the mobile service in this band it shall ensure that the power flux-density (pfd) produced at 3 m above ground does not exceed -154.5 dB(W/(m^2 · 4 kHz)) for more than 20% of time at the border of the territory of any other administration;

f) that the pfd limit in *considering* e) may be exceeded on the territory of any country whose administration has so agreed;

g) that the RR also state that, in order to ensure that the pfd limit at the border of the territory of any other administration is met, the calculations and verification shall be made, taking into account all relevant information, with the mutual agreement of the administration responsible for the terrestrial station and the administration responsible for the earth station;

h) that, since propagation loss increases with distance, and on overland paths is strongly influenced by the nature of the terrain, IMT stations located at a sufficient distance from the neighbouring country's border may meet the pfd limit without the application of interference mitigation techniques, and therefore methods to identify the areas in a country where this is so would assist administrations to comply with the requirement in *considering* e);

j) that in the application of the methods mentioned in *considering* h) it may be appropriate to use a terrain database covering any country in which it is planned to operate IMT stations in the band 3 400-3 600 MHz;

k) that natural or man-made site shielding could attenuate the signal transmitted by an IMT station in the direction of a neighbouring country's border,

noting

a) that the allocations relating to RR Nos. 5.430A and 5.432B are effective from 17 November 2010,

recommends

1 that the method in either § 1 or § 2 or § 3 of Annex 1, or a combination of these methods, as deemed appropriate by the concerned administrations during their bilateral and/or multilateral discussions, may be used for determining whether an IMT base station proposed to operate in the 3 400-3 600 MHz band would meet the pfd limits in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A;

2 that the method described in § 2 of the annex may be used to determine the size and shape of the area just inside the border of a country outside of which operation of an IMT mobile terminal would meet the pfd limit at 3 m above ground at any point on that border;

3 that the following Note should be considered as part of this Recommendation.

NOTE 1 − The parameters and the methodology to be used should be agreed by the concerned Administrations involved in the bilateral and/or multilateral discussions.

Annex 1

Methodologies for determining whether a transmit IMT station meets the pfd limits in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A

ITU-R has recently developed a Recommendation addressing the calculation of the pfd generated by FSS earth stations transmitting in the band 13.75-14.00 GHz[1]. As described in § 1, 2 and 3 of Annex 1, the methodologies contained in Recommendation ITU-R S.1712 can be adapted for the assessment of compliance with the pfd limit contained in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A[2]. It is also noted that other methodologies beyond adaptations of those in Recommendation ITU-R S.1712 may be appropriate.

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[1] Recommendation ITU-R S.1712 – Methodologies for determining whether an FSS earth station at a given location could transmit in the band 13.75-14 GHz without exceeding the pfd limits in No. 5.502 of the Radio Regulations, and guidelines to mitigate excesses.

[2] The three methods described here are applicable to a fixed base station, while only Method 2 is applicable to a mobile station (see § 2.4).

For a number of characteristics used in the methodology described below, the values assumed in the examples are illustrative only and, in any particular study, the values used for these characteristics could be expected to reflect the actual characteristics of the IMT stations and other parameters under consideration.

1 Adaptation of Method 1 of Recommendation ITU-R S.1712

Method 1 is simple but admittedly overly conservative[3]. This method produces two curves, using a smooth Earth model, showing the minimum separation distance from a neighbouring country's land border that an IMT base station would need to meet in order to respect the pfd limits in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A, as a function of the IMT station e.i.r.p. density toward the horizon. The primary curve gives the line-of-sight separation distance. The secondary curve gives the trans-horizon separation distance. An IMT base station deployed at a distance greater than or equal to the minimum separation distance is assumed to meet the pfd limit criterion. Besides determination of whether the path to the border is line-of-sight or trans-horizon, no further analyses are required. Note that deployment in areas excluded by this method is still possible provided a potential site can be shown to meet the pfd limit criterion through application of an adapted form of Methods 2 or 3 of Recommendation ITU-R S.1712 (see § 2 and 3). In order to fully account for the variability of terrain in the real world, Method 1 is separated into three steps of increasing complexity. Step A is by far the simplest and does not account for terrain. In fact, this step assumes a *flat* Earth where all paths are line-of-sight (LoS). Step B assumes a spherical Earth with a nominal radio horizon but does not consider the effect of intervening terrain. Like Step B, Step C assumes a spherical Earth, but unlike Step B it does take into consideration the effect of intervening terrain, albeit using a conservative but simplified approach. Each step in order will increase the size of the potential IMT deployment area (exposing the largest area using Step C). It is given that if Step A or Step B shows that a potential deployment site meets the pfd limit criterion, then the following step(s) need not be performed. At the discretion of the user, Steps B or C may be employed without previously implementing Step A.

In order to calculate the value of the distance, some basic assumptions and propagation models are required. Those in Recommendation ITU-R P.452 have been used in many similar sharing situations and would appear to be the most appropriate to be used here.

An in-depth description of this method follows:

Step A: All paths are assumed to be LoS. The LoS curve in Fig. 1 is used to determine the minimum separation distance as a function of e.i.r.p./4 kHz radiated by the IMT station towards the border. Note that the curve was derived from the LoS loss from Recommendation ITU-R P.452-12 ($p = 20\%$)[4]. Since this is a flat Earth model, the curve is independent of factors such as local ΔN and

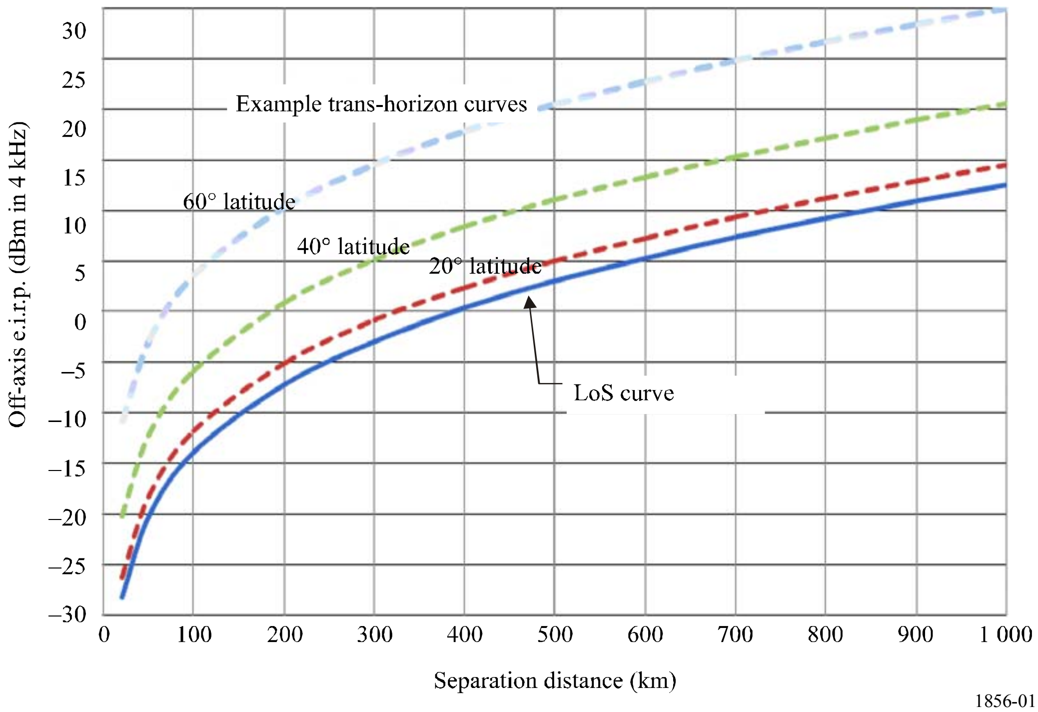
[3] For instance, in the United States of America, instead of defining a pfd, a coordination distance of 150 km was defined to ensure the protection of existing FSS earth stations from interference produced by BWA (broadband wireless access) transmitters with an e.i.r.p. density of 25 W/25 MHz. In addition, the US rules specify a minimum separation distance of 56 km to the Canadian and Mexican borders for fixed stations, unless a shorter distance can be coordinated on a case-by-case basis. The methodology used by the United States of America in the derivation of a coordination distance of 150 km can also be adapted for application to the pfd calculation being addressed here.

[4] Recommendation ITU-R P.452-13 is currently in force and the Recommendation might be further updated in the future. If so, when following this methodology in the future, it would be advisable to use the version of Recommendation ITU-R P.452 in force at the time.

antenna height above terrain. If the potential deployment site is farther from the border than the required separation distance from the LoS curve, then the station is assumed to comply with the pfd limit criterion of RR Nos. 5.430A, 5.432A, 5.432B and 5.433A. If the path length is smaller than the required separation distance, then proceed to Step B.

FIGURE 1

Separation distance curves (minimum distance from the border as a function of the e.i.r.p. density toward the horizon



Step B: This step assumes a spherical Earth and thus requires the determination of a nominal radio horizon. First, find the effective Earth radius (α_e) using the local ΔN and equations (5) and (6) of Recommendation ITU-R P.452-12 (convert to metres). The radio horizon can then be calculated from the following equation:

$$RHorizon_{nominal} = \sqrt{2 \cdot \alpha_e} \cdot \left(\sqrt{h_0} + \sqrt{h_{imt}}\right) / 1\,000 \quad \text{(km)}$$

where h_0 = 3 m, and h_{imt} is the IMT station height (m) above mean sea level.

If the IMT station site is within the nominal radio horizon in the direction of the border, then the required separation distance is found using the LoS curve of Fig. 1. If the IMT station site is beyond the nominal radio horizon, then determine the required separation distance using the trans-horizon curve of Fig. 1. If the potential deployment site is farther from the border than the required separation distance from the applicable curve, then the station is assumed to comply with the pfd limit criterion of RR Nos. 5.430A, 5.432A, 5.432B and 5.433A. If the path length is smaller than the required separation distance, then proceed to Step C.

Step C: This step also assumes a spherical Earth. Furthermore, it requires a more detailed analysis of the paths toward the border. Appendix 2 of Annex 1 of Recommendation ITU-R P.452-12 is used to determine if a path is LoS or trans-horizon. The specific procedure is detailed in § 4.1 of that appendix: "Test for a trans-horizon path". The terrain data can be taken from digital elevation maps or even derived from the elevation contours of printed maps. Since in actual terrain, the path with the lowest loss is not necessarily the shortest path, several paths in radial around the potential IMT station site should be tested. If any path is shown to be LoS, then the required separation distance is found using the LoS curve of Fig. 1 (using the shortest LoS path). If the test shows that all paths are trans-horizon, then the required separation distance is found using the relevant trans-horizon curve of Fig. 1. If the potential deployment site is farther from the neighbouring country's border than the required separation distance from the applicable curve, then the station is assumed to comply with the pfd limit criterion of RR Nos. 5.430A, 5.432A, 5.432B and 5.433A. If the path length is smaller than the required separation distance, the IMT station is likely to be non-compliant with the pfd limit.

It is important to note that the required separation distance found with any of the three steps above may not be an absolute minimum. If the IMT station distance to the neighbouring country's border is smaller than the required value, further analysis using an adaptation of Method 2 or 3 of Recommendation ITU-R S.1712, which includes digital terrain data and propagation modelling, and (where appropriate) other mitigation techniques, may be used to verify whether the pfd limit criterion can be met.

As described above, the use of this method requires two curves (for different path types) that give the minimum distance X to the border, as a function of the e.i.r.p. density toward the horizon, to meet the pfd limit criterion. Deployment sites that are less than X from the border may be possible but require the application of a method using digital terrain data. In order to calculate the LoS value of X, some basic assumptions and propagation models are required. The LoS curve shown in Fig. 1 is calculated directly from the LoS equation of Recommendation ITU-R P.452-12. This is equation (9) of § 4.2 of Annex 1 of the Recommendation. Use the appropriate frequency and set the percentage of time p to 20%. The resulting loss, L, a function of distance, is used with the following equations to find the e.i.r.p./distance combination that satisfies the pfd limit.

$$\text{pfd} = E - G_m + G(\varphi) - L - 10\log(\lambda^2/4\pi) = -154.5 \text{ dB(W/(m}^2 \cdot 4 \text{ kHz)), and therefore}$$

$$\text{IMT off-axis e.i.r.p.} = \{E - G_m + G(\varphi)\} = L - 186.83 \text{ dBW/4 kHz}$$

where:

E: peak e.i.r.p. per 4 kHz,

G_m: maximum gain of the IMT antenna,

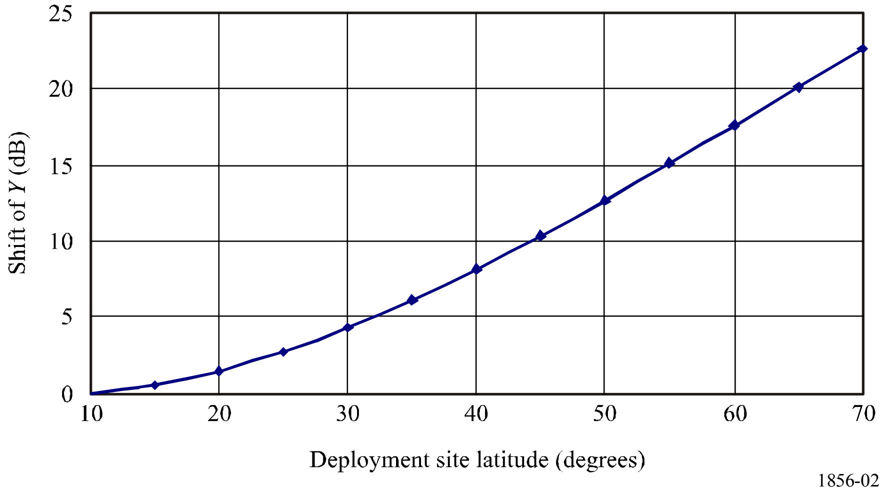
$G(\varphi)$: gain of the IMT antenna in the direction of the border

$\lambda =$ 0.0857 m for a frequency of 3.5 GHz.

The trans-horizon curves shown in Fig. 1 are simply the LoS curve shifted up the e.i.r.p. scale by Y dB. The value of Y depends on the latitude of the transmitting station and is found from the curve in Fig. 2. As noted above, the pfd level given in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A specifies the height above ground at the border of a neighbouring country at which it applies (i.e. 3 m). In reality, diffraction loss is not simply the LoS loss shifted by a constant value. Further analysis of the Recommendation ITU-R P.452-12 model may show that the trans-horizon curve may require some adjustment.

FIGURE 2

Trans-horizon curve shift as a function of latitude



Example of application of the method

In considering Step A, a typical IMT base station likely to operate in the 3.4-3.6 GHz band will transmit with a peak e.i.r.p. density of 16 dBW/MHz, using a 120° sector antenna with a 2° downtilt. Over a wide azimuth range the e.i.r.p. density in horizontal directions will be about 7 dBW/MHz (as per the antenna pattern expressions in Recommendation ITU-R F.1336-2). In a 4 kHz bandwidth the corresponding e.i.r.p. density would be:

$$(\text{e.i.r.p.})_d = 7 - 10 \log(1\,000/4) + 30 = 13 \text{ dBm/4 kHz bandwidth}$$

Further assume that the path length from the IMT station to the border is 500 km, local $\Delta N = 40$, and that the IMT station height is 100 m (antenna on tall building). The latitude is 48º, which yields a 13 dB shift for the trans-horizon curve. Step 1 begins with comparison of the off-axis e.i.r.p. with the LoS curve of Fig. 1. It follows from the curve that the LoS required separation distance would be approximately 1 000 km. Since the actual path length is less than the required minimum separation distance, Step A fails to show compliance with the pfd limit.

Under Step B, the nominal radio horizon is calculated to be 48.5 km. As the actual path length is greater than the nominal radio horizon, the path must be trans-horizon. Therefore, the minimum separation distance can be found using the trans-horizon curve of Fig. 1. Using that figure and interpolating for 48° latitude, a station with an off-axis e.i.r.p. of 13 dBm requires a minimum separation distance of approximately 400 km. In this case, the actual path length is greater than the required minimum separation distance. Therefore, Step B shows that this base station complies with the pfd limit. If Step B had failed to show compliance, analysis using a more accurate estimation of the true radio horizon would follow under Step C.

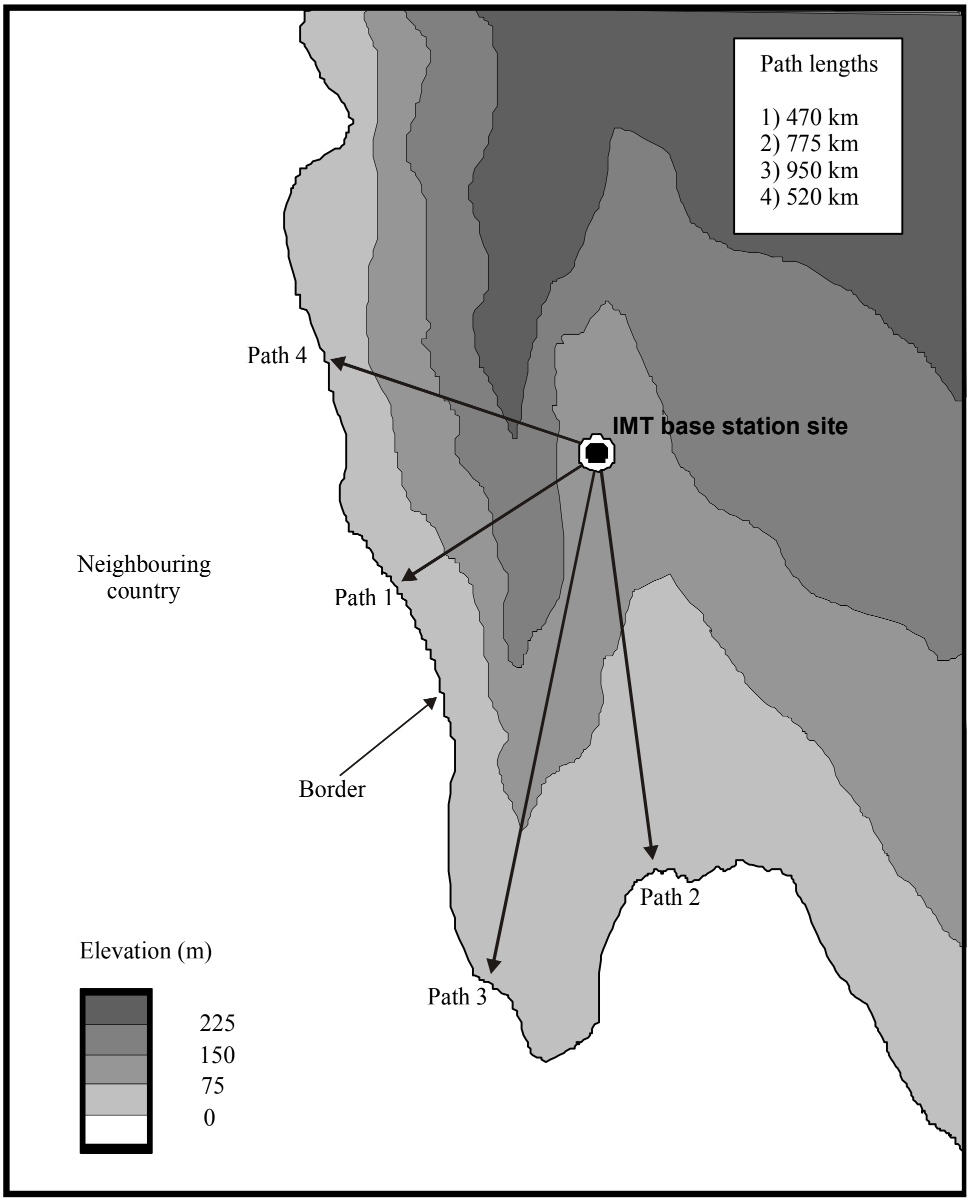
Example of Step C

In considering Step C, a potential IMT base station site is indicated on the hypothetical example map in Fig. 3. Terrain contours from the map will be used to estimate the radio horizon on selected paths between the site and different points along the border. Assume the following parameters:

IMT base station e.i.r.p. toward horizon in all directions = 13 dBm/4 kHz
IMT base station height AMSL = 100 m
Local annual mean $\Delta N = 45$
Latitude is 48°.

FIGURE 3

Example contour map showing potential IMT base station site



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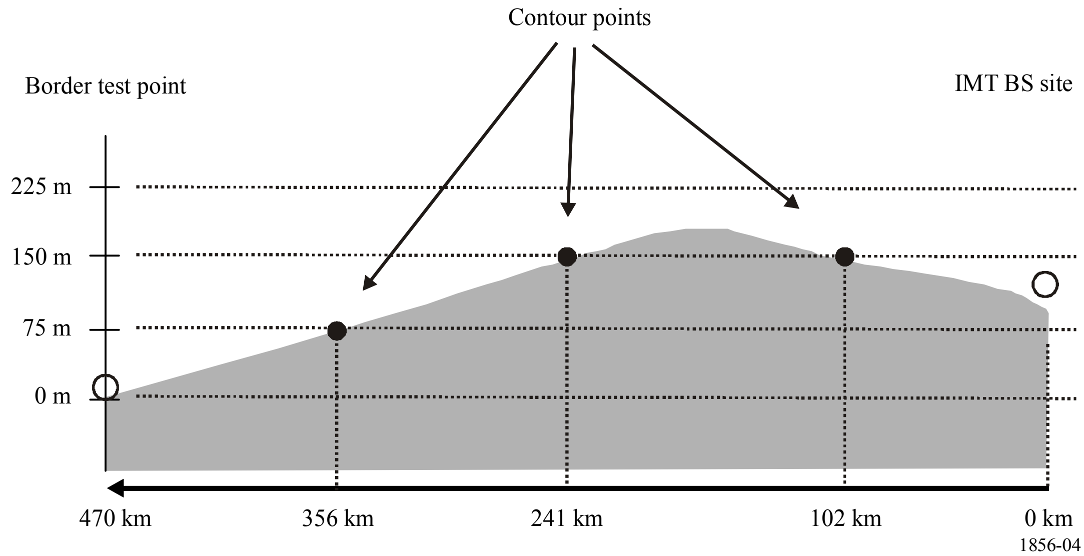
A quick check of Fig. 1 shows that the LoS required separation distance for this IMT station is 1 000 km. The shortest path to the border (Path 1) is clearly much less than the required LoS distance.

Step C begins with the trans-horizon test found in Appendix 2 to Annex 1 of Recommendation ITU-R P.452-12. The paths are divided into sections to reflect the different elevations along each part of each path. Evenly spaced increments are recommended but this is not necessary. The Recommendation ITU-R P.452-12 test checks if the physical horizon elevation angle as seen by the IMT base station (θ_{IMT}) is greater than the angle (θ_{TP}) subtended at the IMT base station between the border test point and the horizontal plane. See the Recommendation for full details of the procedure. Making the necessary calculations with Path 1 shows that $\theta_{IMT} = 5.8$ mrad and $\theta_{TP} = -4.7$ mrad. Since $\theta_{IMT} > \theta_{TP}$, this path is trans-horizon. Note that while Paths 2 and 3 do not cross contours higher than the IMT base station, similar calculations show that they are also trans-horizon. Path 4 is both longer than Path 1 and crosses a higher contour. Calculation of the angles shows this path is indeed trans-horizon. By inspection, there are no other paths that would be expected to produce results different from the paths shown in the map above. Therefore, this IMT base station site is not within LoS of any point on the border. The trans-horizon curve of Fig. 1 shows that the required separation distance for this IMT base station is about 400 km. Since the length of the shortest path (Path 1) is greater than this value, the IMT base station site is found to be compliant with the pfd criterion.

FIGURE 4

Profile of Path 1



Note that the true peak in the profile in Fig. 4 was not actually used in the calculations. The contour map in the previous figure only provided elevation data in 25 m increments. Use of a higher resolution terrain data map would have taken advantage of the true height of the intervening terrain.

2 Adaptation of Method 2 of Recommendation ITU-R S.1712

In this section pfd contours are developed based on actual terrain data, the propagation model in Recommendation ITU-R P.452-12, the IMT base station's e.i.r.p. in 1 MHz bandwidth in the direction of the border, and the height above ground of its antenna.

2.1 Generalities

This method produces a set of contours, using actual terrain data, showing the minimum separation distance from the neighbouring country's border an IMT base station would need to meet in order to respect the pfd limit in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A, as a function of the base station e.i.r.p. and the height of its antenna. An IMT base station deployed within the contour based on its e.i.r.p. toward the horizon is assumed to meet the pfd limit criterion. No further analyses are required. This method, using more accurate data than Method 1 described in § 1, results in larger areas inside which an IMT base station can be deployed while meeting the pfd limit in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A. However, it should be noted that deployment in a location excluded by this method would still be possible if a potential site could be shown to meet the pfd limit criteria through application of the site-specific procedures outlined in § 3. To account for different path loss due to different antenna heights, contours may also be defined if required for a range of base station antenna heights above local terrain level.

Four example cases of the use of this method are described in § 2.3.4 and 2.4.

2.2 Step-by-step description of this method

1) *Definition of contours*

A beam radiated by a typical IMT base station has a relatively narrow beamwidth in the vertical plane (e.g. 2.5°) and a wide beamwidth in the horizontal plane (e.g. 120°). Since a base station is likely to need to serve IMT user terminals all around itself, it may be assumed that the nearest part of the border falls within the horizontal beamwidth of one of its beams. Some base station antennas may be deployed with a small downtilt (e.g. 2°) in order to maximize the illumination in a relatively small "cell" around them, and in these cases the e.i.r.p. toward the horizon will be reduced. For a range of e.i.r.p. densities toward the horizon a set of contours can be defined as figuring the areas where an IMT base station can be deployed without exceeding the pfd limit anywhere along the border. Taking into account the discrimination between the peak gain in the vertical plane and the gain toward the horizon in the direction of the border, a value of necessary path loss can be associated with each defined contour.

2) *Computation of contours*

Knowing the value of the path loss to be associated with each contour, and taking into account an actual terrain database, it is possible to compute each contour on a map. The propagation model to be used is the one described in Recommendation ITU-R P.452-12.

3) *Compliance with the pfd limit in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A*

This compliance is assessed by comparing the position of the IMT base station intended to be deployed with the contour associated with the corresponding profile:

– if the position of the base station intended to be deployed is inside the associated contour (i.e. on the side away from the nearest part of the border), the base station can be deployed with no additional measures while respecting the pfd criterion;

– if the position of the base station intended to be deployed is outside the associated contour, additional considerations on the actual site environment are required.

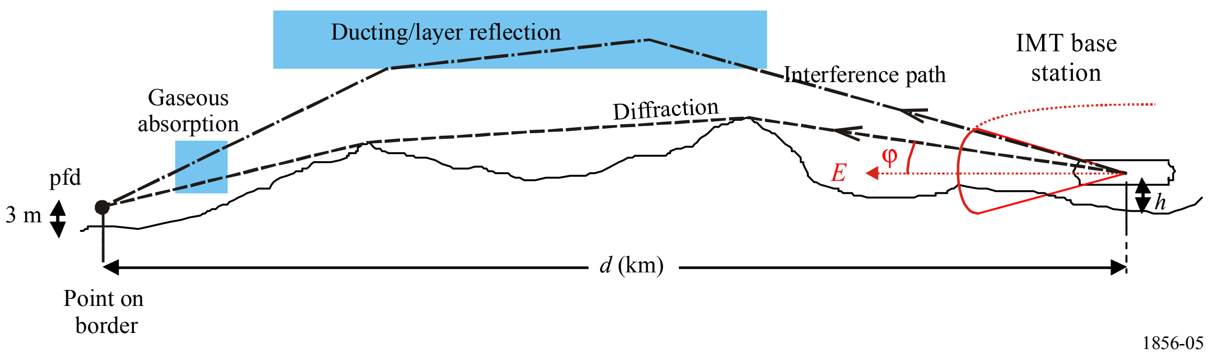
2.3 Possible application of this method

2.3.1 Interference scenario

The scenario for interference at the border of a country produced by an IMT base station within the country is illustrated in Fig. 5. The height (h) above ground of a typical base station antenna is 30 m.

FIGURE 5

Loss on interference path



The pfd at the border may be calculated by the following expression:

$$pfd = E - G_m + G(\varphi) - L - 10 \log(\lambda^2/4\pi) \text{ dB(W/(m}^2 \cdot 4 \text{ kHz))} \quad (1)$$

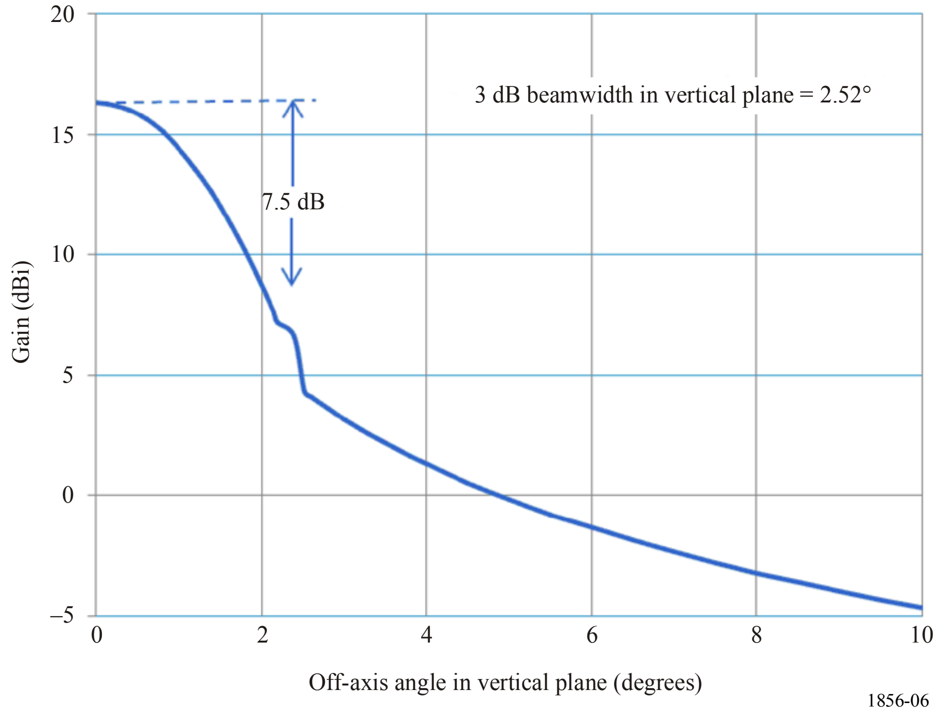
where E is the maximum e.i.r.p. per 4 kHz of the IMT base station, L is the loss in dB of the interference path (length d km) between isotropic antennas exceeded for all but 20% of the time (dB), λ is the wavelength (m), G_m is the peak gain of the IMT antenna and $G(\varphi)$ is the gain toward the horizon in the direction of the border. At the mid-band frequency of 3.5 GHz $\lambda = 0.08571$ m, so $10 \log(\lambda^2/4\pi) = -32.33$. Then, to meet the required pfd limit of −154.5 dB(W/(m^2 · 4 kHz)), the path loss is, from equation (1), given by:

$$L = E - (G_m - G(\varphi)) + 186.83 \quad \text{dB} \quad (2)$$

In many locations the elevation of the horizon is less than 1°, so for base stations with no downtilt the antenna discrimination toward the border ($G_m - G(\varphi)$) will be small. From studies in the former WP 8F a typical base station is likely to deploy 120° sector beams with peak gain about 16.3 dBi. Figure 6 was plotted using the expressions for sector antennas in Recommendation ITU-R F.1336, showing that this peak gain corresponds to a beamwidth of about 2.5° vertically, and that a 2° downtilt would result in a discrimination ($G_m - G(\varphi)$) of about 7.5 dB toward the horizon.

FIGURE 6

Gain pattern of 120° sector antenna with G_m = 16.3 dBi



2.3.2 Considerations concerning IMT base station e.i.r.p. (E)

In previous ITU studies a peak e.i.r.p. of 16 dBW/MHz was assumed for an IMT base station but more recent CEPT studies have used 23 dBW/MHz. Thus it is appropriate to compute contours corresponding to these two e.i.r.p. density values, with no antenna downtilt and also with a 2° downtilt. Coincidentally, the e.i.r.p. in horizontal directions for 23 dBW/MHz peak with 2° downtilt is within 0.5 dB of that for 16 dBW/MHz peak with no downtilt, so a single contour can be used to cover both cases. To allow for the possibility that some IMT base stations may be able to operate with reduced e.i.r.p. it is worthwhile computing an additional contour for a lower value of E, and

Table 1 evaluates equation (2) to give the 20%-of-time path loss, *L*, required to just meet the pfd limit in each of these cases.

TABLE 1

IMT base station characteristics

Contour	Peak e.i.r.p. (dBW/MHz)	Downtilt (degrees)	Antenna discrimination toward horizon $Gm - G(\varphi)$ (dB)	Hence, e.i.r.p. toward horizon (dBW/4 kHz)	Hence, path loss required to be exceeded for 80% of time to meet pfd limit (from equation (2)) (dB)
A	23	0	0	−1	185.8
B	23 16	2 0	7.5 0	−8.5	178.3
C	16 8.5	2 0	7.5 0	−15.5	171.3
D	1	0	0	−23	163.8
F (Mobile)	−22.4	0	0	−46.4	140.4 (see § 2.4)

Thus, for example, IMT base stations with sector antennas with 2º downtilt transmitting a peak e.i.r.p. of up to 16 dBW in a 1 MHz bandwidth would meet the pfd limit at the border, without interference mitigation, if they were located anywhere further from the border than a contour defined by a path loss of 171.3 dB exceeded for all but 20% of the time (contour reference C).

In order to evaluate locations for base stations transmitting intermediate e.i.r.p. densities it is possible to interpolate between contours based on these four path losses.

2.3.3 Computation of contours

Losses on an overland path may be calculated by modelling the effects of free-space propagation, gaseous absorption, diffraction, tropospheric ducting and layer reflection, using the data and algorithms in Recommendation ITU-R P.452[5]. For a given IMT base station location, to ensure that the pfd limit is not exceeded it is necessary to find the lowest-loss line to the border. For flat terrain this will be the line between the base station and the nearest point on the neighbouring country's border, but that will not always be the case where the intervening terrain is either moderately or very hilly. Thus a software database containing the heights above sea level over the whole of the area concerned, with a resolution as fine as practicable, is required for the present exercise. The following technique may be used here.

Taking the terrain profile in Fig. 5 as an example, the pfd measurement point may be replaced by a receiver fed by an isotropic receiving antenna, and the IMT base station may be replaced by an isotropic transmitting antenna fed by transmit power of 0 dBW at the frequency concerned (in the present case 3.5 GHz) − as in Fig. 7.

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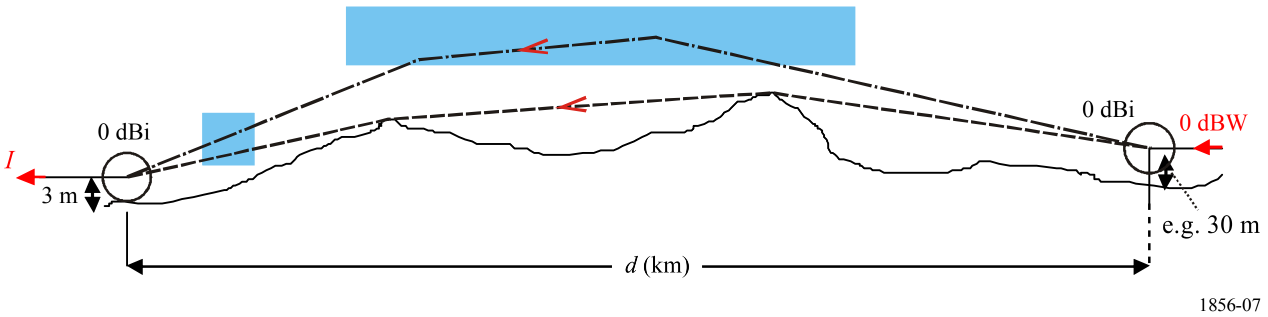
[5] Although the examples given in § 2.3.4 and 2.4 were prepared using Recommendation ITU-R P.452-12. The Recommendation ITU-R 452-13 is currently in force and might be further updated in the future. If so, when following this methodology in the future it would be advisable to use the version of that Recommendation in force at the time. In addition, administrations involved in a bilateral or a multilateral coordination discussion should agree on the values of the relevant parameters when applying the propagation prediction methodology in Recommendation ITU-R P.452 (see also for example RR No. 5.430A).

FIGURE 7



Then the level of the received signal I is given by $I = 0 + 0 - L + 0$ dBW. In other words, the level of I in dBW is numerically equal to minus the value of the path loss L in dB, and this is so regardless of the bearing of the receiver with respect to the transmitter. For the present purpose I should be computed in the manner described in Recommendation ITU-R P.452-12, for 20% of the time.

A software model should be constructed, incorporating a terrain database for the country or area of interest, and containing isotropic receiving terminals at appropriately small intervals along the border. A grid of equally spaced 0 dBW isotropic radiators should be added covering the entire country or area concerned. Then the contribution to I at each and every receiver, generated by each and every transmitter should be computed, using Recommendation ITU R P.452-12 techniques to evaluate the loss exceeded for all but 20% of the time, and all the values for each receiver should be separately stored. The software should be arranged to identify the maximum individual contribution to I for each receiver. Then, by selecting the transmitters for which the maximum I contribution is closest to minus the value of L required, a contour may be constructed by drawing a line between those transmitters. For improved accuracy it is possible to use linear interpolation between pairs of transmitters corresponding to the maximum I contributions that are the closest above and below the target value, as illustrated in Fig. 8.

FIGURE 8

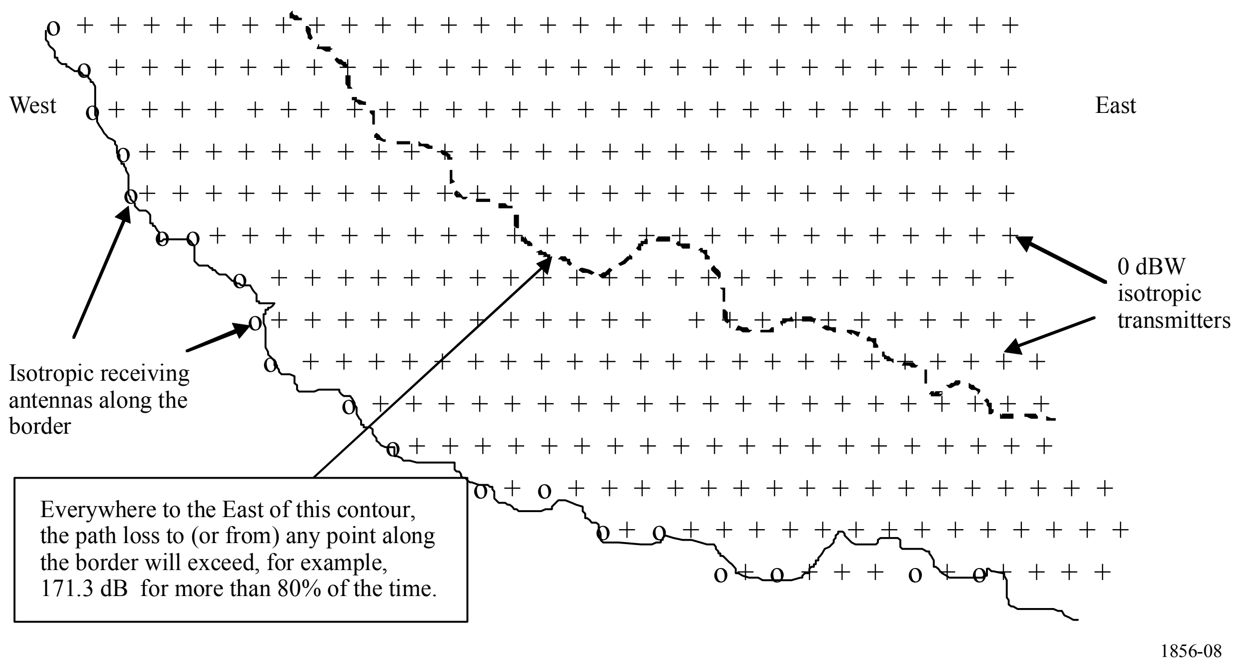
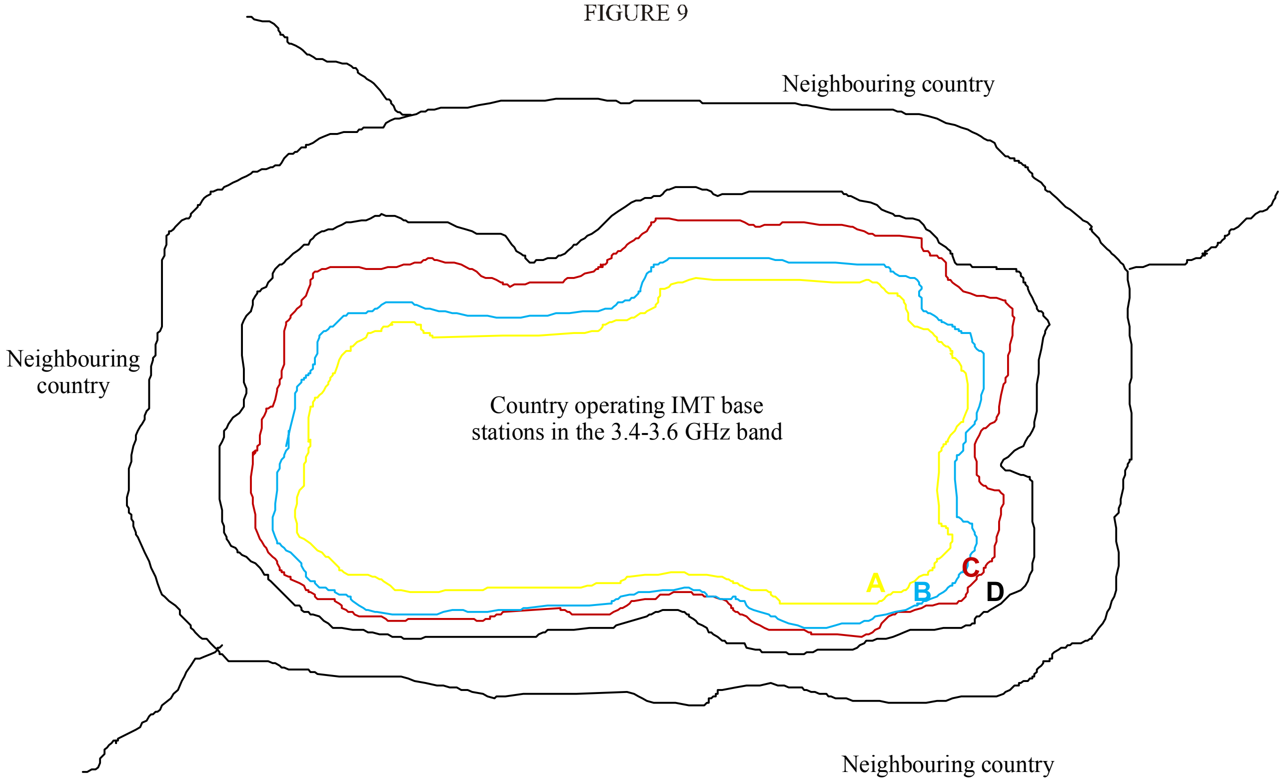


Figure 9 is a schematic diagram illustrating the format of the result for four contours, e.g. corresponding to the cases in Table 1.

FIGURE 9



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In the area between a contour and the border it may be possible to operate IMT base stations if interference mitigation techniques such as reducing the e.i.r.p. can be applied, but that would have to be determined on a case-by-case basis. In each such case the present methodology could be used to determine the degree of mitigation required, by plotting contours for successively reduced values of *L*.

2.3.4 Examples of applying the methodology described in § 2.3.1 to 2.3.3

For the selection of example areas it is necessary only to consider those countries for which the band 3.4-3.6 GHz has been identified for IMT use and the pfd limit at the border applies. For the purposes of this document the following three areas were chosen as examples:

– *North-eastern France (Example 1)*

RR No. 5.430A applies in France and all of its bordering countries with the exception of Luxembourg. In addition to imposing the pfd limit at the border, RR No. 5.430A includes the sentence "*This limit may be exceeded on the territory of any country whose administration has so agreed*". Thus it seems possible that two neighbouring countries might reach agreement on a more relaxed limit at their common border[6].

– *North-eastern Ukraine (Example 2)*

RR No. 5.430A applies in Ukraine but does not apply in the countries to the north or east.

– *Sierra Leone (Example 3)*

RR No. 5.430A applies in Sierra Leone but does not apply in any of its bordering countries.

6 The results given in Figs 10, 11 and 12 do not take account of any such relaxation.

Using a proprietary software package incorporating a global terrain database having a horizontal resolution of 1 km and a vertical resolution of 1 m, the foregoing methodology was employed to construct models of the three areas. For each receive point on the border (see Fig. 8) the antenna height above local ground level was set at 3 m, and for each transmit point an antenna height of 30 m was used. The details are listed in Table 2.

TABLE 2

Characteristics of software models constructed

Geographical area	Size of country	Climate (ΔN)(1)	Type of terrain	Receiver spacing (km)	Transmitter grid interval (km)	No. of paths computed(2)
NE France (Example 1)	Medium	45	Mixed	11	6	522 678
NE Ukraine (Example 2)	Medium	45	Non-hilly	13	10	564 108
Sierra Leone (Example 3)	Small	70	Hilly	7	4.5	397 096

(1) ΔN is the average radio-refractive index lapse-rate through the lowest 1 km of the atmosphere, which depends significantly on climate and is needed for the path loss calculation method of Recommendation ITU-R P.452.

(2) Number of transmit points in grid multiplied by number of receive points on border.

The results obtained for the example areas listed in Table 2 are shown in Figs. 10, 11 and 12, in which it can be seen that contours corresponding to the IMT base station e.i.r.p. and downtilt combinations defined in Table 1 are shown. For convenience the contours are labelled A, B, C and D as shown in Table 1 and Fig. 9, and they are displayed in contrasting colours to aid legibility.

Overall the results were found to adequately demonstrate the effectiveness of the methodology in this section in determining where the great majority of IMT base stations using the band 3.4-3.6 GHz could be placed without exceeding the pfd limit in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A.

2.4 Application to mobile IMT terminals

IMT systems normally adopt an arrangement of hexagonal cells where wide area coverage is provided via a number of base stations, each serving its own individual cell and providing connection for mobile terminals while they are within that cell. The radius of a cell depends on system design and will typically be 2 or 3 km, and is unlikely to be greater than 5 km. From the distance scales of Figs. 10, 11 and 12 it can be seen that, in the great majority of cases, an IMT base station as close to a border as 5 km would have to grossly attenuate its transmissions toward the border in order to meet the pfd limit. Thus that base station would not be able to serve mobiles near the border, so those mobiles would not operate near the border and thus would be unlikely themselves to breach the pfd limit. In this context it noteworthy that in the ITU-R preparatory studies for WRC-07, whereas an IMT base station e.i.r.p. density of 16 dBW/MHz was adopted, the corresponding e.i.r.p. density for a mobile terminal was −22.4 dB(W/MHz).

The methodology described in § 2 may be used to determine contours within which mobile terminals could operate without exceeding the pfd limit at the border. An example (Example 4) is shown in Fig. 13, where each mobile terminal was assumed transmit an e.i.r.p. density of

−22.4 dBW/MHz in all azimuth directions at an antenna height above ground of 1 m. These results were obtained by developing an additional computer model for part of NE Ukraine for the lower e.i.r.p. density and height figures. By adding the relevant part of one of the base station contours it is demonstrated that, as might be expected, the contour for IMT mobiles is much closer to the border than the contours for IMT base stations.

3 Adaptation of Method 3 of Recommendation ITU-R S.1712

This method checks compliance of an IMT base station with the pfd limit in RR Nos. 5.430A, 5.432A, 5.432B and 5.433A based on a case-specific analysis.

3.1 General

The basis of this method is to perform a case-specific analysis for each IMT base station to be deployed. Deployment may go forward if the analysis shows that the earth station can meet the pfd limit everywhere on the border of the country containing the site. The analysis is accomplished by using digital terrain data in conjunction with the IMT base station parameters, appropriate propagation models and any other mitigation techniques that may be used (e.g., sector disabling or multiple input, multiple output). It is expected that this method will only be employed when a potential deployment site cannot be shown to be compliant with the pfd limits using either the Method 1 described in § 1 or the Method 2 described in § 2.

3.2 Description of the method

1 Digital terrain data that includes the IMT base station site and surrounding area is required. The data should encompass a sufficient area to reasonably perform the pfd analysis. It is recommended that the resolution of the digital terrain data used is at least 30 arc sec horizontally and 1 m vertically.

2 The parameters of the IMT base station to be deployed will be required for the analysis. This includes the peak gains, beamwidths and pointing angles of the base station's antenna beam in the horizontal and vertical planes, the height of the antenna above terrain, and the IMT carrier spectral density. The appropriate reference earth station radiation pattern for this method could be the one provided by the earth station operator or the one found in the relevant ITU-R Recommendation (e.g. Recommendation ITU-R F.1336).

3 As with the first two methods, the propagation model best suited to the site-specific analysis is Recommendation ITU-R P.452-12.

4 The IMT base station parameters, digital terrain data, and propagation models enable calculation of the path loss in all directions around the potential site. This in turn yields the pfd at the neighbouring country's border produced by the station. If the pfd criterion of RR Nos. 5.430A, 5.432A, 5.432B and 5.433A is met, then deployment may proceed. Otherwise, additional interference mitigation techniques may need to be applied.

4 Conclusions

This annex describes three different methods for determining whether or not a prospective IMT base station in a given location would meet the pfd criterion in the band 3.4-3.6 GHz at the border of the country concerned.

The three methods described here are applicable to an IMT base station, and the method in § 2 is also applicable to IMT mobile stations.

FIGURE 10

Example 1 – Contours beyond which a 30 m IMT base station would not exceed a pfd limit of −154.5 dB(W/(m^2 · 4 kHz)) for more than 20% of time, 3 m above the border of NE France

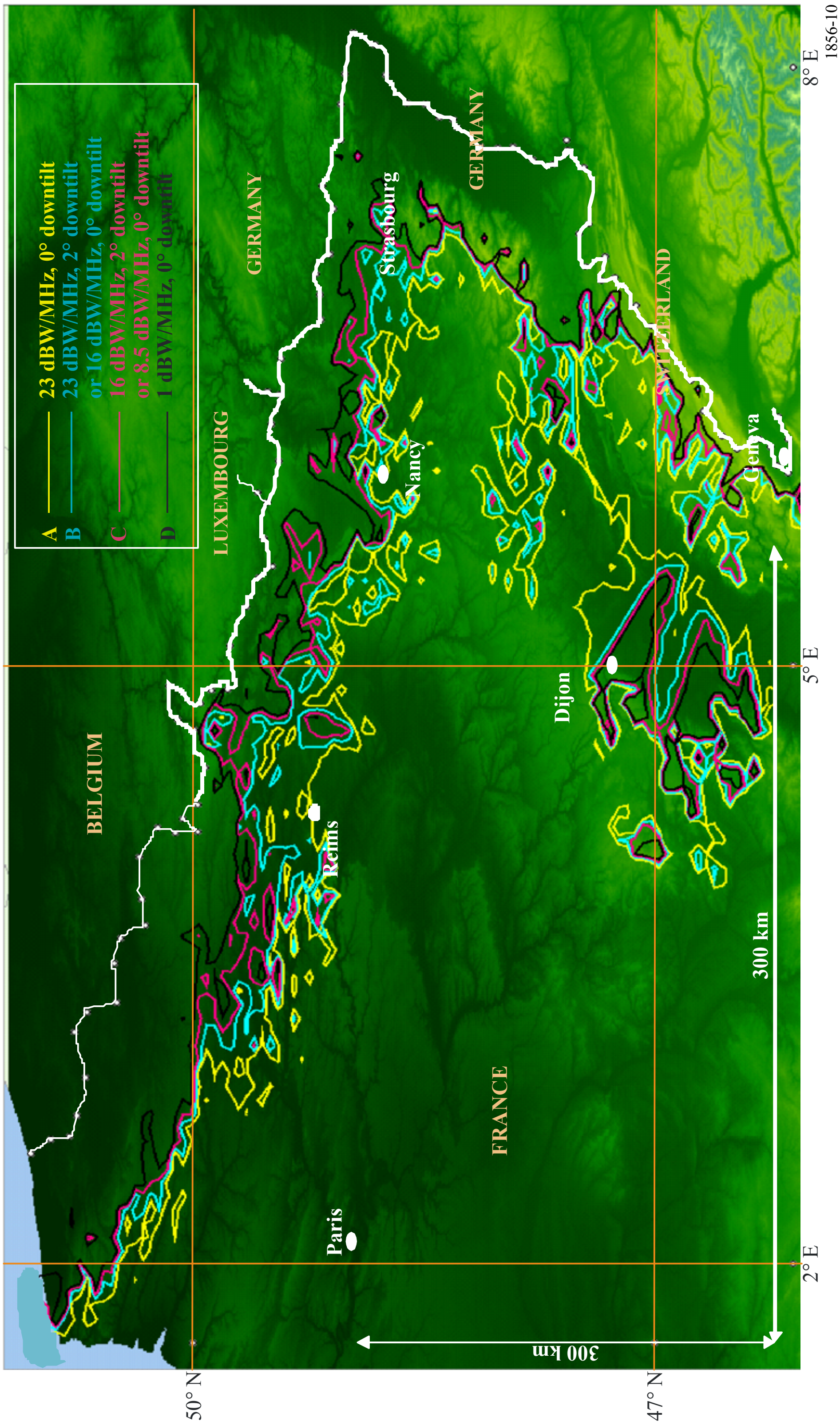


FIGURE 11

Example 2 – Contours beyond which a 30 m IMT base station would not exceed a pfd limit of –154.5 dB(W/(m² · 4 kHz)) for more than 20% of time, 3 m above the border of NE Ukraine

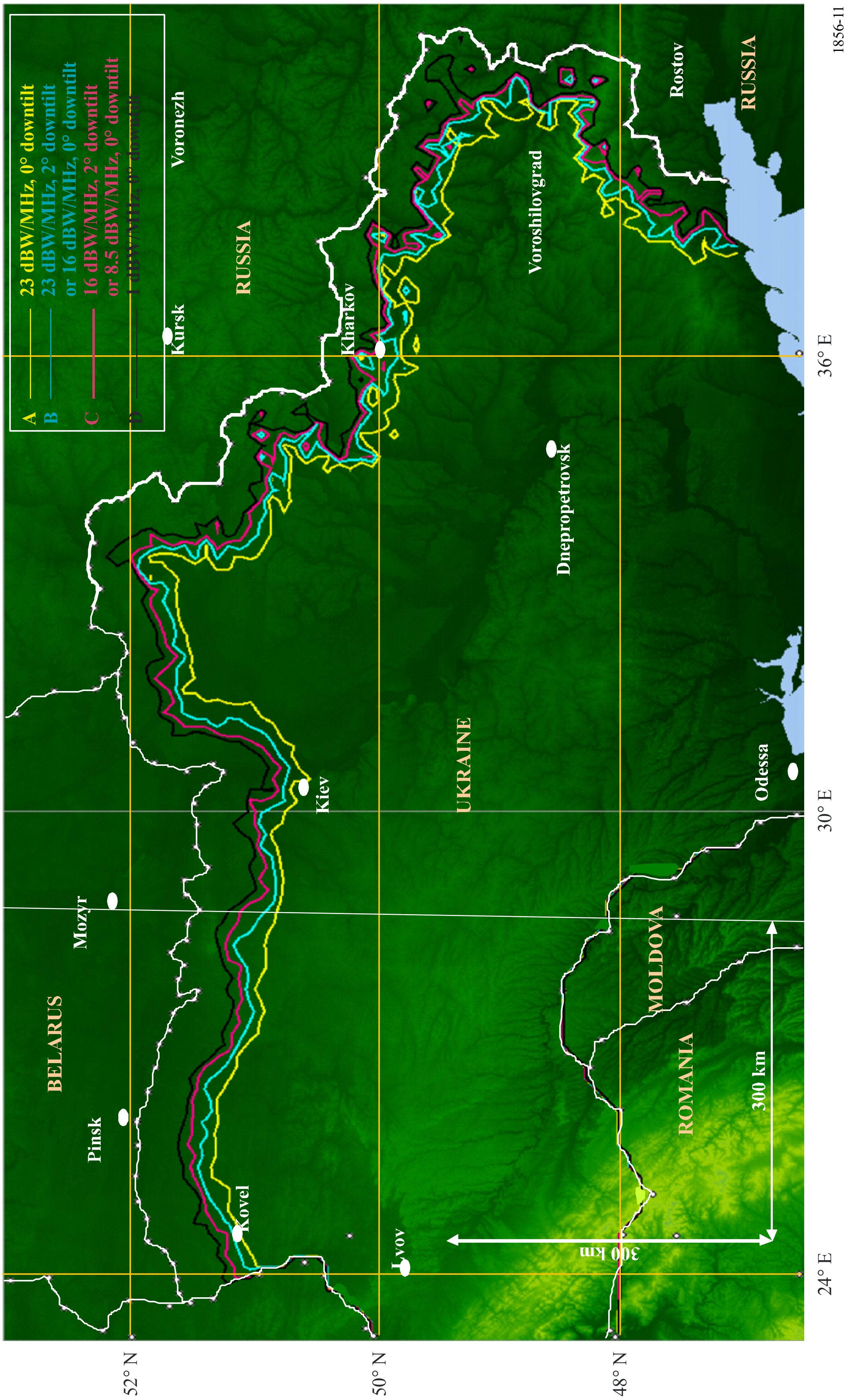


FIGURE 12

Example 3 – Contours beyond which a 30 m IMT base station would not exceed a pfd limit of −154.5 dB(W/(m² · 4 kHz)) for more than 20% of time, 3 m above the border of Sierra Leone

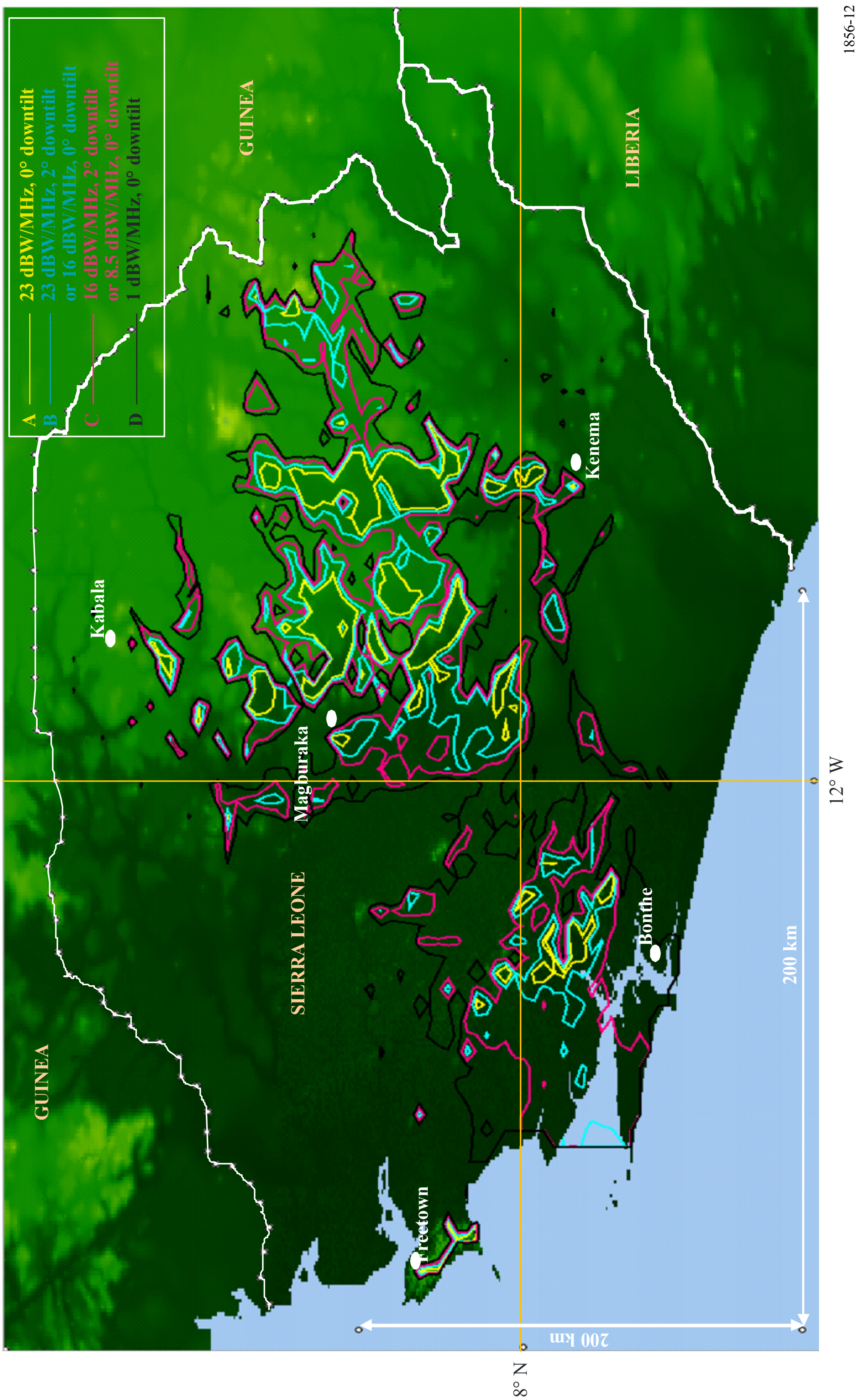
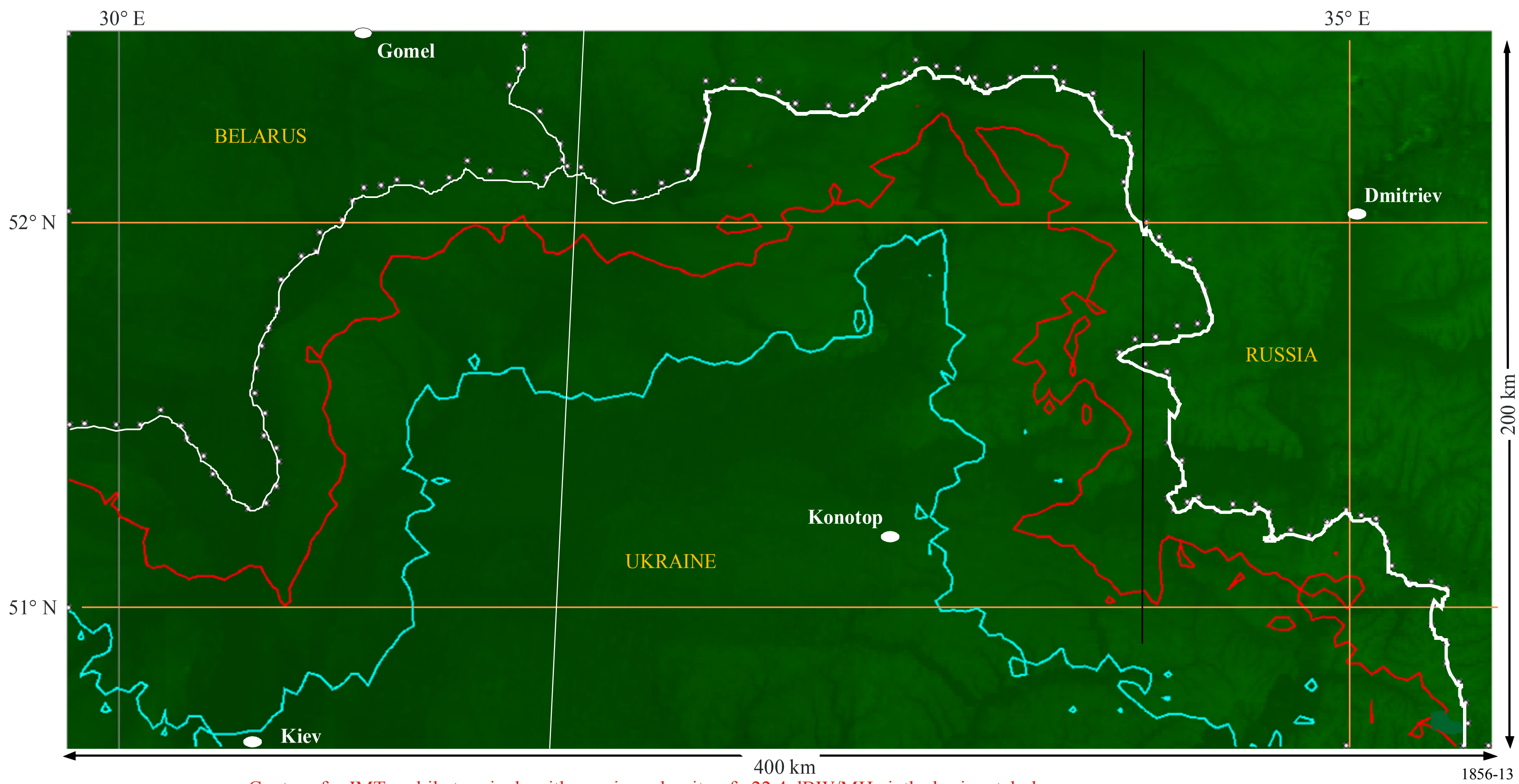


FIGURE 13

Example 4 **– Contours beyond which an IMT mobile station would not exceed a pfd limit of –154.5 dB(W/(m² · 4 kHz)) for more than 20% of time, 3 m above the border of northern Ukraine**



Contour for IMT mobile terminals with an e.i.r.p. density of –22.4 dBW/MHz inthe horizontal plane

Contour for IMT bas stations with a peak e.i.r.p. density of 23 dB(W/MHz), but 2° downtilt (i.e. 15.5 dB(W/MHz) in the horizontal plane)