Annex 5

Determination of the interference field strength in the Land Mobile Service

1   General

1.1   This calculation method is based on Recommendation ITU-R P.1546, taking into account aspects of frequency co-ordination.

1.2   When there is no obstacle within the 1st order Fresnel zone, the field strength shall be determined using the free-space attenuation. The formulas for calculating the Fresnel zone and the free-space field strength are contained in Appendix 1.

1.3   The interference field strength at the receiving location shall be determined using the propagation curves given in Annex 4.

For signals with a transmitting to non-transmitting ratio of less than 1:10 and a cycle repetition time of more than 30 sec, the curves for 10 % of the time have to be applied (no continuous carrier). In other cases the 1% curves shall be used (continuous carrier).

1.4   For harmonized systems using harmonized spectrum only the 10 % curves have to be used.

2.   Consideration of different interference situations

In practice, different interference situations occur which call for different calculation methods.

2.1   A base station or a fixed station causes interference to another base station or fixed station

In order to protect a base station or a fixed station from a new station to be installed in a neighbouring country, the interference field strength is determined in relation to the location of the radio station affected.

2.2   A base station or a fixed station causes interference to a mobile station

In order to protect mobile stations from a base station or a fixed station, the interference field strength is determined in relation to the closest point on the edge of the area of operation of the mobile stations.

2.3   A mobile station causes interference to another mobile station

In order to protect mobiles from each other, the interference field strength to be determined is calculated by means of the length of the propagation path between the points closest to the edges of the areas of operation of the mobile stations.

2.4   A mobile station causes interference to a base station or a fixed station

In order to protect a base station or a fixed station from a mobile station, the interference field strength is determined in relation to the edge of the zone of operation of the mobile station closest to the location of the base station or the fixed station affected.

2.5   Assumed position of the mobile station

As an exception to the provisions of 2.2, 2.3 and 2.4 in cases where the operation of a mobile station from a particular place of action causes or suffers from a higher interference field strength than from places at the edge of the zone of operation, the particular place of action shall be taken as the basis for calculation purposes.

As an exception to the provisions of 2.2, 2.3 and 2.4, in cases where the radius of the zone of operation is cut by the borderline in the direction of the affected station, the position of the mobile is limited to the borderline*.*

3.   Factors to be taken into consideration

The accuracy with which the interference field strength at the receiving location is determined is largely dependent on the extent to which the actual conditions along the propagation path (via correction factors θ Tx, θ Rx, Δh) and the technical characteristics of the transmitter and receiver stations are taken into account. The accuracy when calculating the field strength increases with the attention paid to special conditions.

To be able to provide reciprocity for calculations on propagation paths along sloping terrain, the profile used for further calculations is based on the connecting line between the terrain heights of the transmitter and the receiver location (normalized profile).

The inter-dependence between the parameters θ and h1 is summarised in the following table. For the correction factor according to the clearance angle only negative values are applied.

$h_{eff\ Tx}$	$h_{eff\ Rx}$	Use Δh	Use normalized profile	Use θTx	Use θRx	h1
≥3m	≥3m	Y	Y	Y	Y	$h1 = h_{eff\ Tx} * h_{eff\ Rx} / 10m$
≥3m	<3m	Y	Y	Y	Y	$h1 = h_{eff\ Tx} * 0.3$
<3m	≥3m	Y	Y	Y	Y	$h1 = h_{eff\ Rx} * 0.3$
<3m	<3m	Y	Y	Y	Y	$h1 = 1m$
ML	≥3m	Y	Y	N	Y	$h1 = h_m * h_{eff\ Rx} / 10m$
ML	<3m	Y	Y	N	Y	$h1 = h_m * 0.3$
≥3m	ML	Y	Y	Y	N	$h1 = h_m * h_{eff\ Tx} / 10m$
<3m	ML	Y	Y	Y	N	$h1 = h_m * 0.3$
ML	ML	Y	Y	N	N	$h1 = h_{m\ Tx} * h_{m\ Rx} / 10m$
≥3m	coordination line	Y	N	Y	N	$h1 = h_{eff\ Tx} * h2 / 10m$
<3m	coordination line	Y	N	Y	N	$h1 = h2 * 0.3$
ML	coordination line	N	N	N	N	$h1 = h_m * h2 / 10m$

where θ Tx   Clearance angle at the transmitter site
          θ Rx   Clearance angle at the receiver site
          h1   Effective antenna height for the curves in Annex 4
          $h_{eff\ Tx}$ Effective antenna height of the transmitter
          $h_{eff\ Rx}$ Effective antenna height of the receiver
          h2   Receiver antenna height
          ML   Mobile station (4D > 0)

h_m is taken from the input value for the mobile antenna height. If missing or less than 3 m it is set to 3 m.

The curves of Annex 4, which represent the interfering field strength values, apply to h1.
The value of h1 is determined by using the previous table. A process of interpolation and extrapolation is given in Appendix 2.

The following factors shall be taken into consideration

3.1 Terrain clearance angle

If the terrain between the transmitter station and the receiving location is marked by ascents or descents, the interference field strength determined for the receiving location has to be corrected. The clearance angle (see Appendix 4) shall be determined for a maximum distance of 16 km. The correction factors for clearance angles in the range of 0° to +40° are given in Appendix 4.

If the distance between transmitter and receiver is less than 16 km, the clearance angle correction factor will be determined according to the equation: $\Delta = \Delta (d) * d / 16$

$\Delta (d)$: correction factor due to clearance angle calculated for the distance between transmitter and receiver
Δ : correction factor due to clearance angle
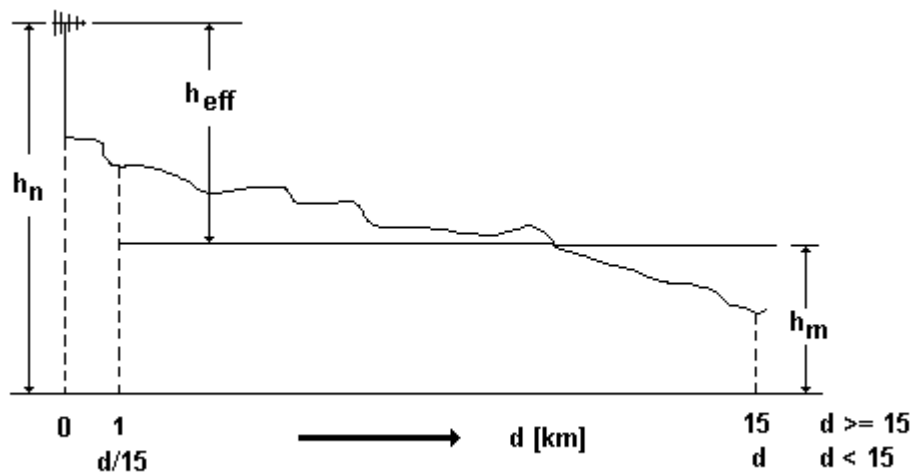d : distance between transmitter and receiver

3.2   Effective antenna height

The effective height of an antenna h_{eff} is defined as the height above the average terrain level in the range 1 to 15 km from the starting point in the direction of the end point:

$$h_{eff} = h_n - h_m$$

where h_{eff} =   effective antenna height in m
         h_n =   physical height of the antenna above sea level in m
         h_m =   average height of the terrain in m

The average height of the terrain h_m is calculated by using the following equation:

$$h_m \quad = \quad \frac{\sum\limits_{i=0}^{140} h_i}{141}$$

For h_i, the heights at $(1000 + i * 100)$ m from the starting point in the direction of the end point shall be taken.

If the path from the starting point to the end point is shorter than 15 km, only height samples from d/15 to d are taken into account.

3.2.1 Effective antenna height of the transmitter

The effective antenna height of a transmitter ($h_{eff\ Tx}$) is defined as the height above the average terrain level in the range defined in 3.2 from the transmitter in the direction of the receiver location.

The effective antenna height of the transmitter has to be taken into account for calculating h1 (see table in 3).

3.2.2 Effective antenna height of the receiver

The effective antenna height of a receiver (h $_{eff\ Rx}$) is defined as the height above the average terrain level in the range defined in 3.2 from the receiver in the direction of the transmitting location.

The effective antenna height of the receiver has to be taken into account for calculating h1 (see table in 3).

3.3   Terrain irregularity Δh

The irregularity of the terrain is defined as follows depending on the distance d between transmitter and receiver. Correction factors for the terrain irregularity shall not be applied to sea-path propagation paths.

<u>For d < 10 km:</u>

No terrain irregularity is taken into account for distances shorter than 10 km.

<u>For 10 km ≤ d ≤ 50 km:</u>

<div align="center">Terrain irregularity Δh   Condition: 10 km $\leq$ d $\leq$ 50 km</div>

d_1 = 4.5 km
d_4 = d - 4.5 km
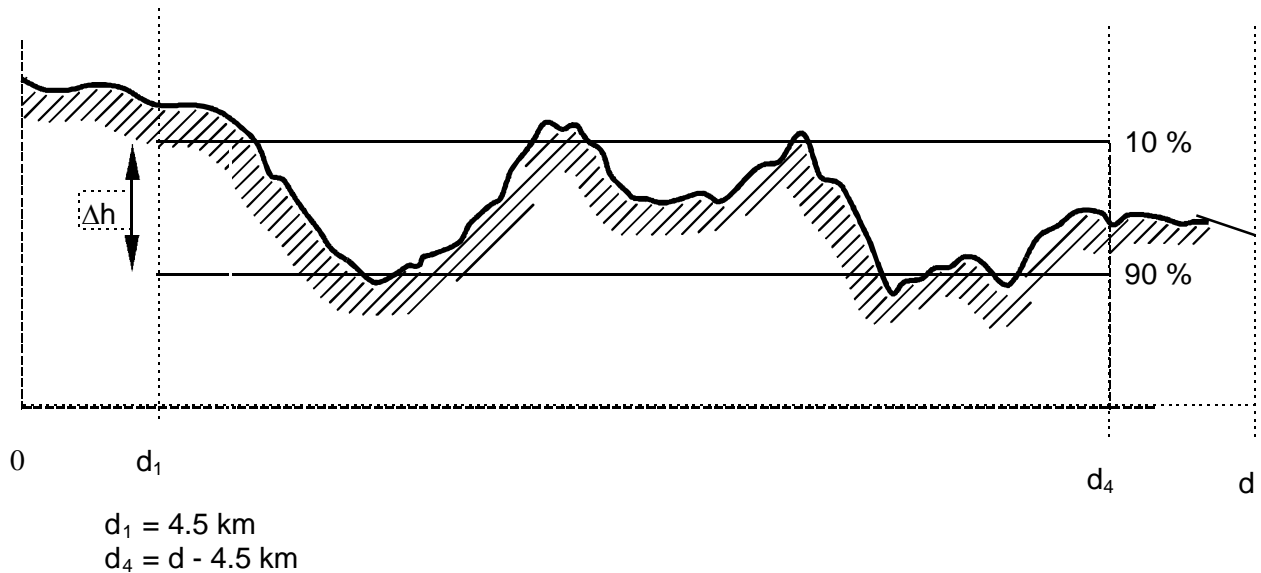
For d > 50 km:

The irregularity of the terrain Δh is defined as the difference between the heights exceeded by 10 % and 90 % respectively of the terrain heights measured in the range 4.5 km to 25 km and in the range d - 25 km to d - 4.5 km from the transmitter in the direction of the receiving location.

Terrain irregularity Δh Condition: d > 50 km
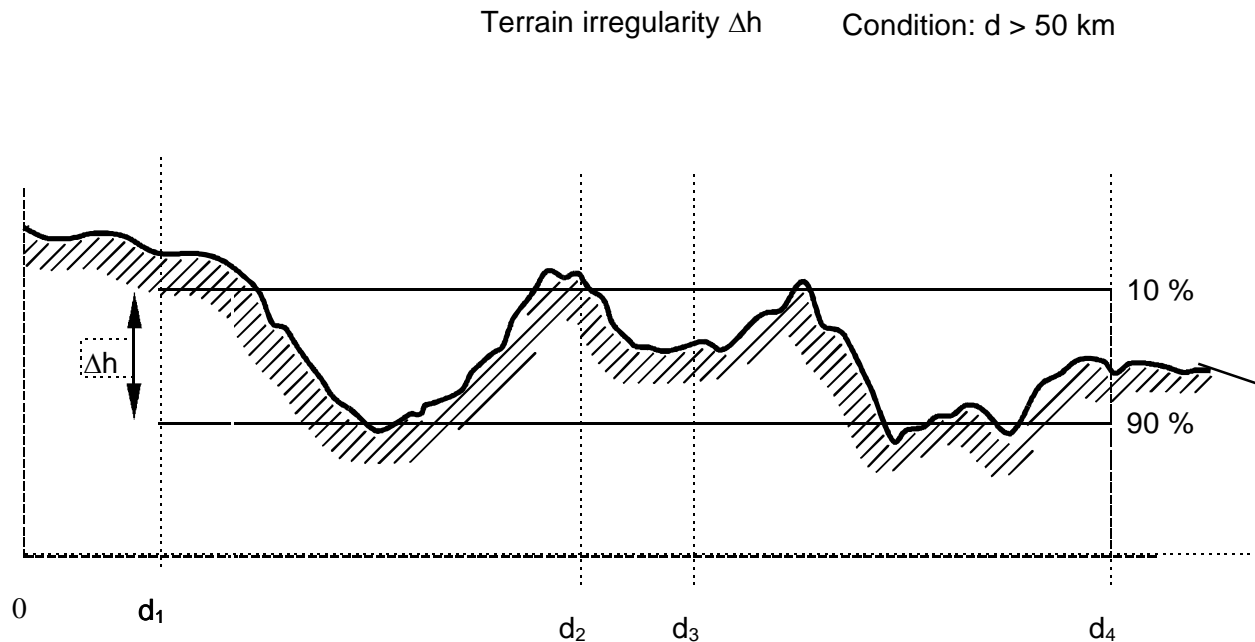
d_1 = 4.5 km
d_2 = 25 km
d_3 = d - 25 km
d_4 = d - 4.5 km

The propagation curves for propagation paths over land are based on Δh = 50 m. If the measure of terrain irregularity deviates from Δh = 50 m, correction factors have to be applied to the interference field strengths derived from the propagation curves. The appropriate correction factors are given in Appendix 3. If the distance between transmitter and receiver is greater than 200 km, the value for d = 200 km is used.

3.4   Correction factors for frequencies

Propagation curves, clearance angle corrections and terrain irregularity corrections apply only to the frequencies 100 MHz, 600 MHz and 2 GHz. For other frequencies, inter- or extrapolations according to Appendix 2 are required.

3.5   Antenna diagram

If directional or tilted antennas are used as transmitting antennas at the interfering base station or fixed station, these factors shall be taken into account in the determination of the interference field strength. In case of directional antennas, the angle orientation is taken into account clockwise.

If directional or tilted antennas are used as receiving antennas, the gain of the receiving antenna in the direction of the interference shall be subtracted from the maximum permissible interference field strength.

Annex 6 contains the diagrams of some typical directional antennas. These diagrams shall be used to derive the decrease of the maximum effective radiated power in relation to the receiving location or the reduction of the interference signal at the receiver. A method for combining the horizontal and vertical antenna patterns is given in Annex 8.

3.6   Mixed path propagation

When paths occur over zones of different propagation characteristics, the following method is used which takes account of the different characteristics of the various parts of the path:

a) For percentages of time < 10%, the following procedure for calculating the field strength for paths crossing a land/sea boundary is used:

$$E_{m,t} = E_{l,t} + A\,(E_{s,t} - E_{l,t})$$

where $E_{m,t}$ field strength for mixed path for t% of the time

$E_{l,t}$ field strength for land path equal in length to the mixed path for t% of the time

$E_{s,t}$ field strength for sea path equal in length to the mixed path for t% of the time

A interpolation factor as given in the figure

Interpolation for mixed land/sea paths
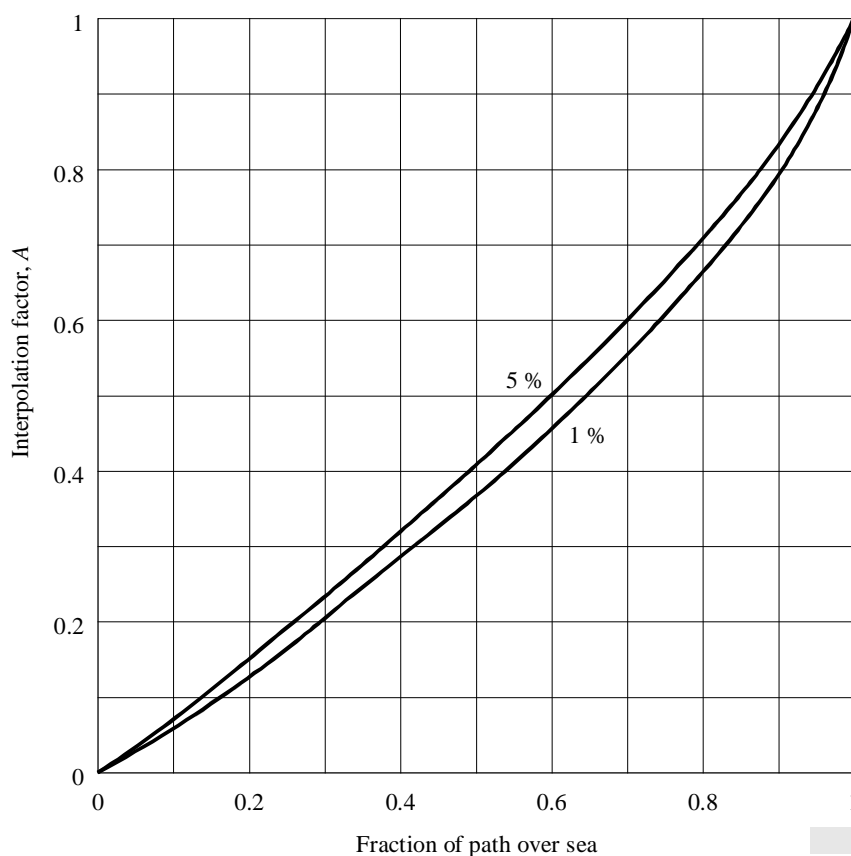
b)   For percentages of time ≥ 10%, the following procedure is to be used:

$$Em,t = \sum_i \frac{d_i}{d_T} E_{i,t}$$

where: $E_{m,t}$ Field strength for mixed path for t% of time

           $E_{i,t}$ Field strength for path in zone i equal in length to the mixed path for t% of time

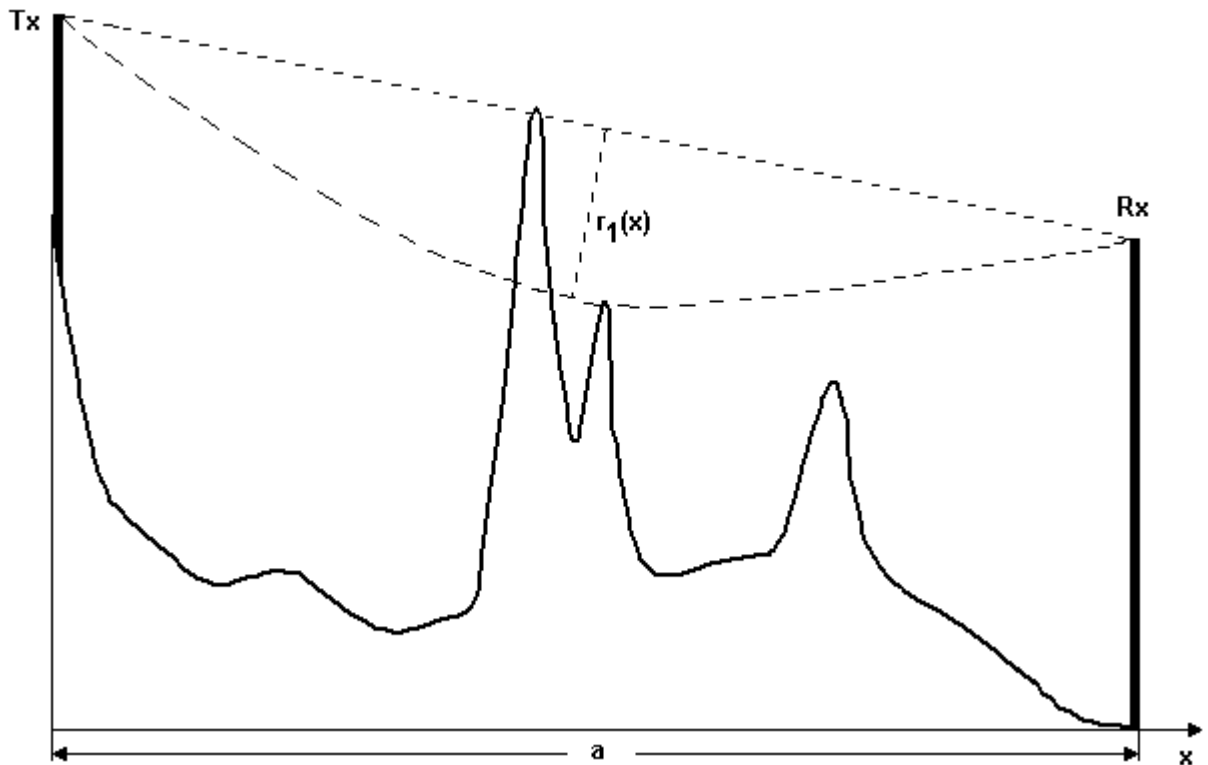 d_i Length of path in zone i and

           d_T Length of total path.

Figure 1: Fresnel Zone

Calculation of the first order Fresnel zone:

Fresnel zone $r_1(x) = -\sqrt{x * \dfrac{(a-x)*\lambda}{a}} = -1.73*10^4 * \sqrt{\dfrac{x*(a-x)}{f*a}}$

λ represents the wavelength. The other symbols are depicted in Figure 1. All values are to be entered into the formulas as base units (paths in meters, the frequency f in Hertz).

Calculation of the free space field strength

$F_{free\,space}(1\,\text{kWerp}) = 107\,\text{dB}\mu\text{V/m} - 20 * \log_{10} d$ (d in km)

Appendix 2 to Annex 5

1. Inter- or extrapolation of field strength according to h_1

1.1 $10m \leq h_1 \leq 3000$ m

If h_1 has precisely one of the values of 10, 20, 37.5, 75, 150, 300, 600 or 1200 m, the field strength can be directly read off the curves in Annex 4. Otherwise the field strength has to be inter- or extrapolated according to the following formula:

$$E = E_{inf} + (E_{sup} - E_{inf}) \log(h_1 / h_{inf}) / \log (h_{sup} / h_{inf})$$

where:
h_{inf}:   600 m if $h_1 > 1200$ m, otherwise the nearest nominal effective height below h_1
h_{sub}:   1200 m if $h_1 > 1200$ m, otherwise the nearest nominal effective height above h_1
E_{inf}:   field strength for h_{inf} at the required distance
E_{sub}:   field strength for h_{sub} at the required distance

h_1 is limited to 3000 m, and the field strength is limited to the free space field strength.

1.2 0 m $\leq h_1 < 10$ m

The procedure for extrapolating field strength at a required distance d [km] for values of h_1 in the range 0 m to 10 m is based on smooth-Earth horizon distances in km written as $d_H(h) = 4.1\sqrt{h}$, where h is the required value of antenna height h_1 in meters.

For $d < d_H(h_1)$ the field strength is given by the 10 m height curve at its horizon distance plus ΔE, where ΔE is the difference in field strength on the 10 m height curve at distances d and h_1 horizon distance.

For $d \geq d_H(h_1)$ the field strength is given by the 10 m height curve at distance Δd beyond its horizon distance, where Δd is the difference between d and the h_1 horizon distance.

This may be expressed in the following formulae where $E_{10}(d)$ is the field strength in dBµV/m taken from the 10 m height curve for a distance d [km]:

$$E = E_{10}(d_H(10)) + E_{10}(d) - E_{10}(d_H(h_1)) \qquad dBµV/m \qquad d < d_H(h_1)$$

$$E = E_{10}(d_H(10) + d - d_H(h_1)) \qquad dBµV/m \qquad d \geq d_H(h_1)$$

If in the last equation $d_H(10) + d - d_H(h_1)$ exceeds 1000 km, even though $d \leq 1000$ km, E_{10} may be found from linear extrapolation for log(distance) of the curve, given by:

$$E_{10} = E_{inf} + (E_{sup} - E_{inf}) \log(d / D_{inf}) / \log(D_{sup} / D_{inf}) \qquad dbµV/m$$

where:
D_{inf}:   penultimate tabulation distance [km]
D_{sup}:   final tabulation distance [km]
E_{inf}:   field strength at penultimate tabulation distance [dbµV/m]
E_{sup}:   field strength at final tabulation distance [dbµV/m]

2.   Interpolation of field strength as a function of the distance

The figures in Annex 4 show field strength plotted against distance d [km] in the range from 1 km to 1000 km. No interpolation for distance is needed if field strengths can be read directly from these graphs. For intermediate values of d, interpolation is required according to the following formula:

$$E = E_{inf} + (E_{sup} - E_{inf}) \log(d / d_{inf}) / \log(d_{sup} / d_{inf}) \qquad \text{dBµV/m}$$

where:

    d: distance for which the prediction is required
    d_{inf}:   nearest tabulation distance less than d
    d_{sup}:   nearest tabulation distance greater than d
    E_{inf}:   field strength value for d_{inf}
    E_{sup}:   field strength value for d_{sup}

With d < 1 km, the free space field strength should be calculated.

3.   Inter- or extrapolation of the field strength as a function of the frequency

Field strength values for a given frequency have to be interpolated between the values for the nominal frequency values 100, 600 and 2000 MHz. In the case of frequencies below 100 MHz or above 2000 MHz, the interpolation must be replaced by an extrapolation from the two nearest nominal frequency values.

The used formula is:

$$E = E_{inf} + (E_{sup} - E_{inf}) \log(f / f_{inf}) / \log(f_{sup} / f_{inf}) \qquad \text{dBµV/m}$$

where:

    f: frequency for which the prediction is required   [MHz]
    f_{inf}:   lower nominal frequency (100 MHz if f < 100 MHz, 600 MHz if f > 2000 MHz)
    f_{sup}:   higher nominal frequency (600 MHz if f < 100 MHz, 2000 MHz if f > 2000 MHz)
    E_{inf}:   field strength value for f_{inf}
    E_{sup}:   field strength value for f_{sup}
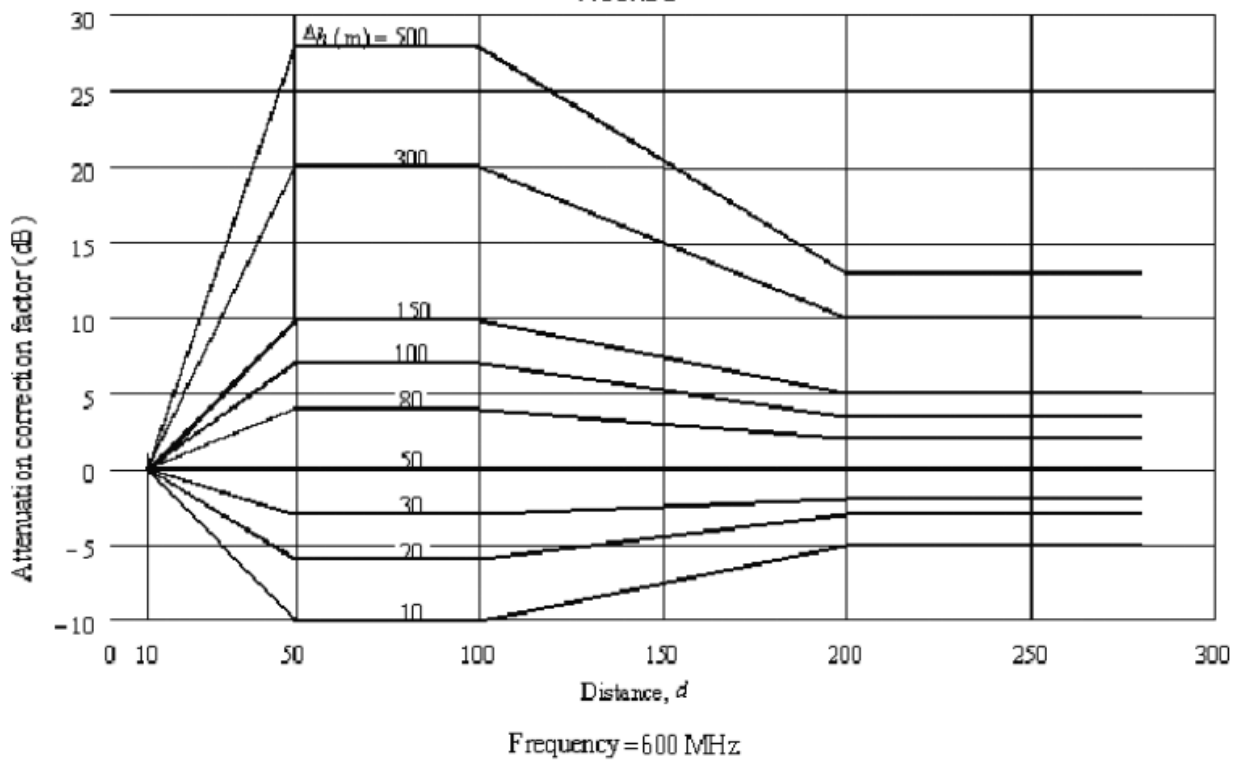
Appendix 3 to Annex 5
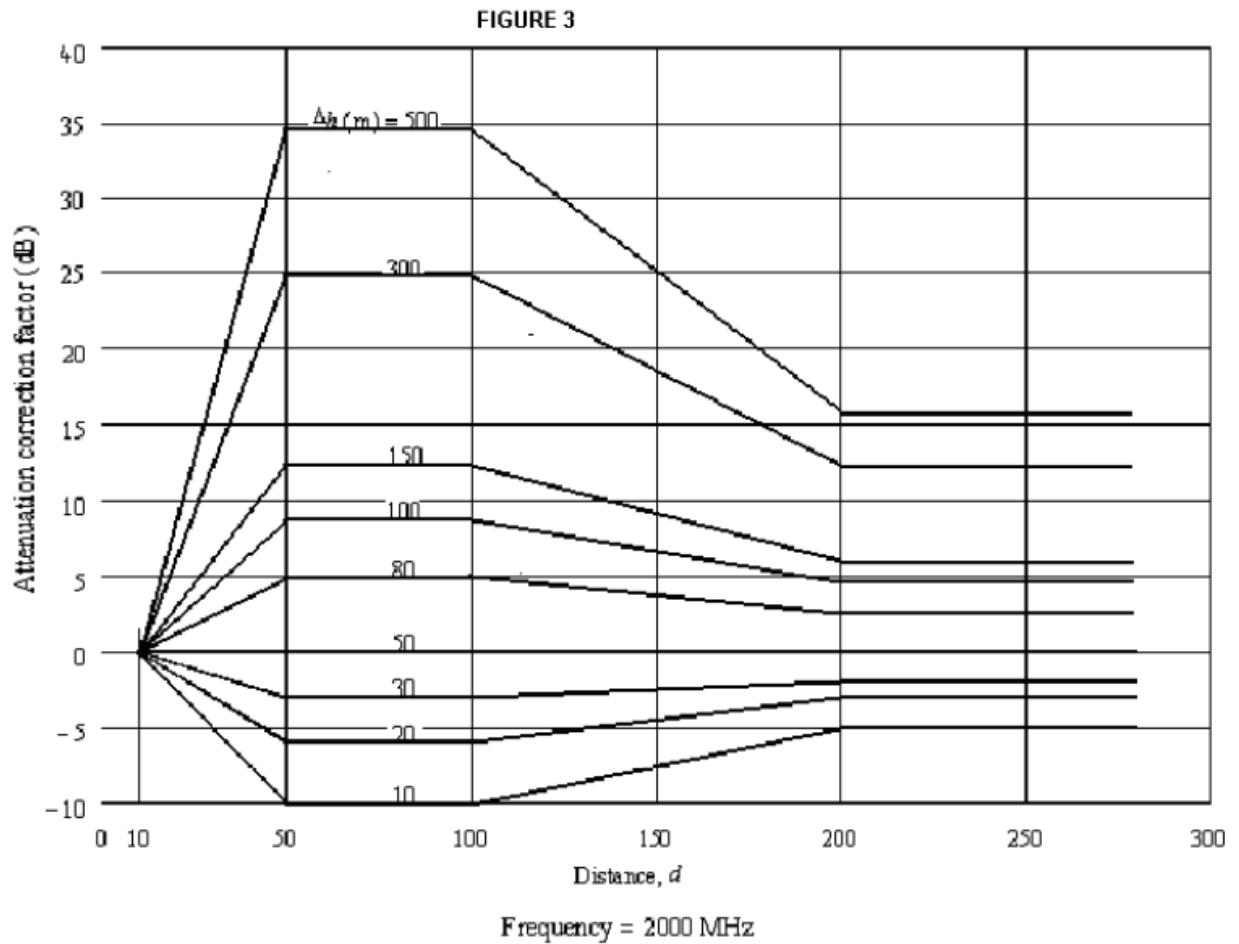
Attenuation correction factor curves

This Appendix contains the correction curves according to terrain irregularity Δh for frequencies 100 MHz (FIGURE 1), 600 MHz (FIGURE 2) and 2000 MHz (FIGURE 3).

FIGURE 1

Frequency = 100 MHz

FIGURE 2

Frequency = 600 MHz

FIGURE 3

Frequency = 2000 MHz
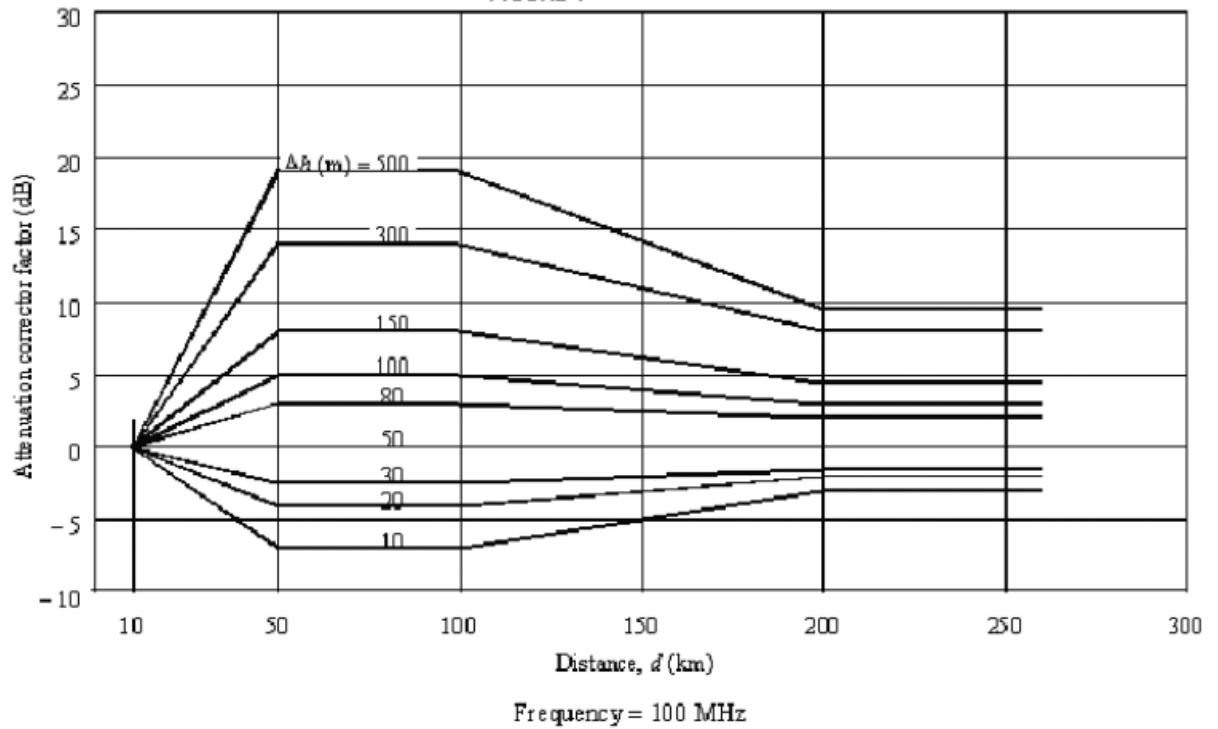
Correction factors according to Δh [dB]

Δh [m]	100 MHz		600 MHz		2000 MHz	
	50 km	200 km	50 km	200 km	50 km	200 km
10	-7.0	-3.0	-10.0	-5.0	-10.0	-5.0
20	-4.0	-2.0	-6.0	-3.0	-6.0	-3.0
30	-2.5	-1.5	-3.0	-2.0	-3.0	-3.0
50	0.0	0.0	0.0	0.0	0.0	0.0
80	3.0	2.0	4.0	2.0	5.0	2.5
100	5.0	3.0	7.0	3.5	8.7	4.3
150	8.0	4.5	10.0	5.0	12.4	6.2
300	14.0	7.0	20.0	10.0	24.8	12.4
500	19.0	9.5	28.0	13.0	34.7	16.1

Inter- or extrapolation of the correction factor according to terrain irregularity as a function of the frequency

The correction factor according to terrain irregularity for a given frequency has to be interpolated between the values of the nominal frequency values 100, 600 and 2000 MHz. In the case of frequencies below 100 MHz or above 2000 MHz, the interpolation must be replaced by an extrapolation from the two nearest nominal frequency values.

The used formula is:

$$C = C_{inf} + (C_{sup} - C_{inf}) \log(f / f_{inf}) / \log(f_{sup} / f_{inf}) \qquad dB\mu V/m$$

where:
- f: frequency for which the correction factor is required [MHz]
- f_{inf}: lower nominal frequency (100 MHz if $f < 100$ MHz, 600 MHz if $f > 2000$ MHz)
- f_{sup}: higher nominal frequency (600 MHz if $f < 100$ MHz, 2000 MHz if $f > 2000$ MHz)
- C_{inf}: correction factor according to terrain irregularity for f_{inf}
- C_{sup}: correction factor according to terrain irregularity for f_{sup}

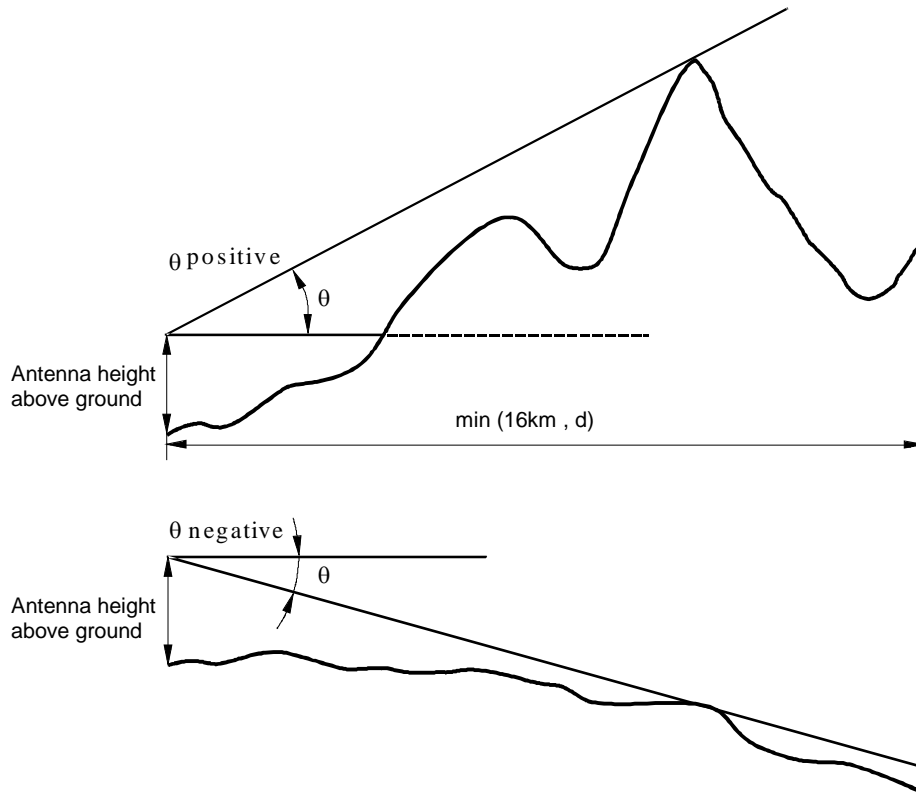Terrain clearance angle correction factor

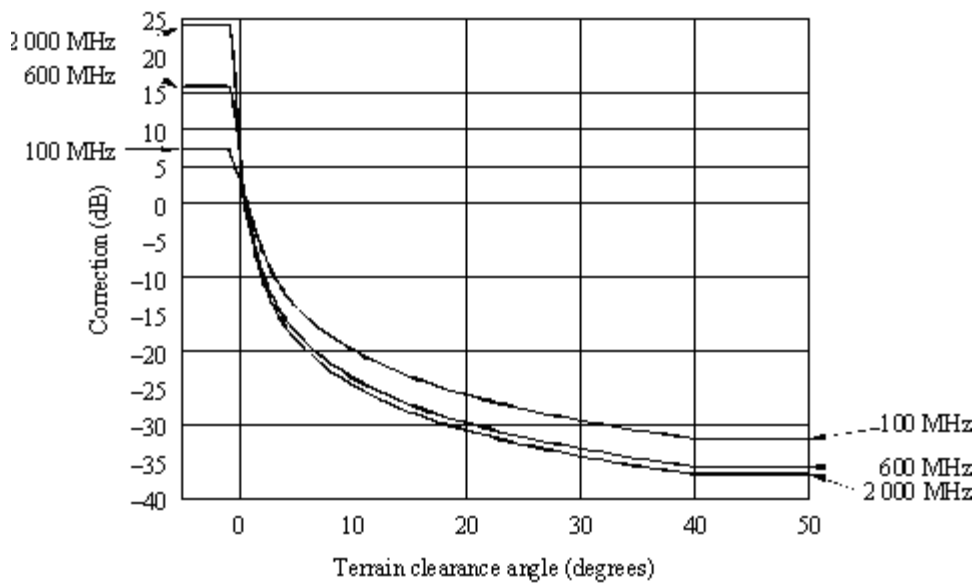FIGURE 1: Terrain Clearance Angle

FIGURE 2: Terrain Clearance Angle Correction

Figure 2 is only for information. The correction according to the terrain clearance angle should be calculated as follows:

For distances greater than or equal to 16 km

For 100 MHz the equation is:

$$Correction = 9.1 - \left[6.9 + 20 \log \left(\sqrt{(v - 0.1)^2 + 1} + v - 0.1 \right) \right]$$

$$v = 37.2 * \theta \qquad\qquad \theta \text{ (rad)},$$

with limiting values of 0 dB at small angles and -32 dB at 40 degrees.

For 600 MHz the equation is:

$$Correction = 13.1 - \left[6.9 + 20 \log \left(\sqrt{(v - 0.1)^2 + 1} + v - 0.1 \right) \right]$$

$$v = 91.2 * \theta \qquad\qquad \theta \text{ (rad)},$$

with limiting values of 0 dB at small angles and -35 dB at 40 degrees.

For 2000 MHz the equation is:

$$Correction = 17.3 - \left[6.9 + 20 \log \left(\sqrt{(v - 0.1)^2 + 1} + v - 0.1 \right) \right]$$

$$v = 167 * \theta \qquad\qquad \theta \text{ (rad)},$$

with limiting values of 0 dB at small angles and -36 dB at 40 degrees.

For distances up to 16 km:

Correction = correction calculated above * d / 16 km.

Inter- or extrapolation of the terrain clearance angle correction as a function of the frequency

Terrain clearance angle correction for a given frequency has to be interpolated between the values for the nominal frequency values 100, 600 and 2000 MHz. In the case of frequencies below 100 MHz or above 2000 MHz, the interpolation must be replaced by an extrapolation from the two nearest nominal frequency values.

The used formula is:

$$TCA\_c = TCA\_c_{inf} + (TCA\_c_{sup} - TCA\_c_{inf}) / \log(f / f_{inf}) \, \log(f_{sup} / f_{inf}) \qquad dB$$

where:
f: frequency for which the prediction is required   [MHz]
f_{inf}:   lower nominal frequency (100 MHz if f < 100 MHz, 600 MHz if f > 2000 MHz)
f_{sup}:   higher nominal frequency (600 MHz if f < 100 MHz, 2000 MHz if f > 2000 MHz)
TCA_c_{inf}: terrain clearance angle correction for f_{inf}
TCA_c_{sup}: terrain clearance angle correction for f_{sup}