RECOMMENDATION ITU-R P.1146

THE PREDICTION OF FIELD STRENGTH FOR LAND MOBILE AND TERRESTRIAL BROADCASTING SERVICES IN THE FREQUENCY RANGE FROM 1 TO 3 GHz

(Question ITU-R 210/3)

(1995)

The ITU Radiocommunication Assembly,

considering

a) that there is a need to give guidance in the planning of land mobile and terrestrial broadcasting services in the VHF and UHF bands for all climatic conditions;

b) that the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (Malaga-Torremolinos, 1992) (WARC-92) made changes to frequency allocations for land mobile and terrestrial broadcasting services in the frequency range from 1 to 3 GHz;

c) that new studies, including the reassessment of available measurement data, have permitted the development of an empirically based field strength prediction method which is easy to use,

noting

a) that Recommendation ITU-R P.452 provides guidance on the point-to-point evaluation of interference between stations on the surface of the Earth at frequencies above about 0.7 GHz;

b) that Recommendation ITU-R P.529 (based upon data for specific urban areas) provides guidance on the prediction of point-to-area field strength for the land mobile service in the VHF and UHF bands,

recommends

1 that the field strength prediction method contained in Annex 1 be adopted for point-to-area evaluation of land mobile and terrestrial broadcasting services in the frequency range from 1 to 3 GHz.

ANNEX 1

1 Introduction

The prediction is an empirical method based upon an extensive database of field strength and path loss measurements. It is designed to achieve the level of accuracy needed for the preliminary planning of mobile radio and broadcasting services operating in the range 1 to 3 GHz, whilst making limited demands for terrain and other data needed for calculation at these frequencies. It is a point-to-area technique which predicts the median value of the spatial distribution within the selected area. It also estimates the temporal variation of the signal within the limits 1% to 99% time. Where the data are available to provide a more comprehensive description of the path details, the prediction method described in Recommendation ITU-R P.452 has the potential to provide a more precise assessment.

As the prediction method is empirical, the prediction results are most reliable when the method is applied to paths and conditions similar to those on which it is based. The following two conditions can be significantly different from those used in the model's development and an alternative Recommendation may give more reliable results:

– where both transmitting and receiving antennas are greater than about 30 m above ground, and the levels of signals predicted for less than about 5% time are required, the use of Recommendation ITU-R P.452 is to be preferred; or

– where paths are less than about 20 km in urban and dense urban environments, the use of Recommendation ITU-R P.529 is to be preferred.

The prediction follows a sequence of events which successively refine the description of the propagation path, producing a corresponding improvement in the accuracy of the result. A more complete description of the technique, information concerning its accuracy, and overall comments on its application are contained in Annex 2.

The parameters described in this Recommendation employ field strength units; some users may prefer to use the concept of transmission loss. Information concerning conversion from field strength to free-space basic transmission loss is contained in Recommendation ITU-R P.525, and is summarized in § 3.1. Similarly, mobile radio users may prefer to use the term "base station" and "mobile" in preference to "transmitter" and "receiver". To avoid unnecessary repetition, the text of this Recommendation refers throughout to "transmitters" and "receivers".

2 Definitions of terms used in this Recommendation

– The receiver is assumed to occupy any position within a square, with sides 100 m in length.

– The method predicts the median value of the field strength within this square.

– The prediction estimates the temporal variation of field strength expected over a period of one year, and expresses this in terms of percentage time.

3 The prediction method

3.1 The sequence

The prediction is based upon a series of field strength/distance curves, to which a sequence of corrections is applied. The general form of the method can be expressed as:

$$E = E_d + K_1 + K_2 \qquad \text{dB}(\mu\text{V/m}) \qquad (1)$$

where:

E: field strength (dB(μV/m)) for 1 kW e.r.p.

E_d: field strength at distance d km from transmitter

K_1: correction for terrain clearance angle at the receiver

K_2: correction for antenna heights.

Further corrections may be applied for a given time percentage and for location variability, and the result may also be expressed in terms of basic transmission loss.

The step-by-step procedure consists of:

3.1.1 Uncorrected field strength for path category, distance and frequency

a) As described in § 3.2, for the required path category at 1 GHz and for 1% time, obtain the uncorrected field strength for the required distance from Figs. 1-5, or from Appendix 1, with linear interpolation for distance if required.

b) Repeat a) for 3 GHz.

c) Linearly interpolate between the results of a) and b) for the required frequency.

d) Repeat the sequence a) to c) for 50% and 99% times.

3.1.2 Correction for terrain clearance angle

As described in § 3.3, if terrain clearance angles are available the following correction should be made:

e) Obtain the terrain clearance angle correction from Appendix 2 for 1 GHz and 1% time, linearly interpolating for clearance angle if required.

f) Repeat e) for 3 GHz.

g) Linearly interpolate between the results of e) and f) for the required frequency.

h) Repeat the sequence e) to g) for 50% and 99% times.

Note that the terrain clearance angle correction is not applied to category 0 paths defined in § 3.2.

3.1.3 Correction for antenna heights

i) As described in § 3.4 obtain the antenna height corrections from Appendix 3 for 1 GHz for the cover category and heights, linearly interpolating for height if required.

j) Repeat i) for 3 GHz.

k) Linearly interpolate between the results from i) and j) for the required frequency.

3.1.4 Corrected field strength values for 1%, 50% and 99% time for required path category, distance and frequency

l) For 1% time add the field strength obtained from a) to c) to the terrain clearance angle correction to obtain E_1.

m) For 50% time add the field strength obtained from a) to c) to the terrain clearance angle and antenna heights corrections to obtain E_{50}.

n) For 99% time add the field strength obtained from a) to c) to the terrain clearance angle and antenna heights corrections to obtain E_{99}.

3.1.5 Field strength for required time percentage

p) As described in § 3.5, use E_1, E_{50}, and E_{99} as required to produce the field strength E_T prediction for the required time percentage.

3.1.6 Correction for location variability

q) If required, the value of E_T may be corrected for location variability as described in § 3.6.

3.1.7 Equivalent basic transmission loss

r) If required, the equivalent basic transmission loss is given by:

$$L_b = 199 - E_T + 20 \log f \qquad \text{dB} \qquad (2)$$

where:

L_b: basic transmission loss (dB)

E_T: field strength (dB) for 1 kW e.r.p. (dB(μV/m)) for time percentage T

f: frequency (GHz).

3.1.8 Default values

It is emphasized that whilst the demands for data describing the propagation path are relatively modest in this method, the assessment required at each stage of the process should be carried out using the fullest information available. However, certain default conditions are suggested, reducing or eliminating the need for such detail, in order to provide a quick estimate of service and interference conditions.

It is recommended that the relevant default conditions for interference calculations should be used when making inter service compatibility assessments. When the results of such assessments suggest that a potential interference problem exists, sufficient path detail should be obtained to permit the use of Recommendation ITU-R P.452.

3.2 Field strength/distance curves

The decay of field strength with distance for various types of path is shown in Figs. 1-10, and presented in tabular form in Appendix 1. The rate of decay depends upon the category of path, defined as follows:

Category 2: two or more terrain obstacles between transmitter and receiver

Category 1: one terrain obstacle between transmitter and receiver

Category 0: no terrain obstacles between transmitter and receiver

Category –1: oversea path (cold sea) (see Note 1)

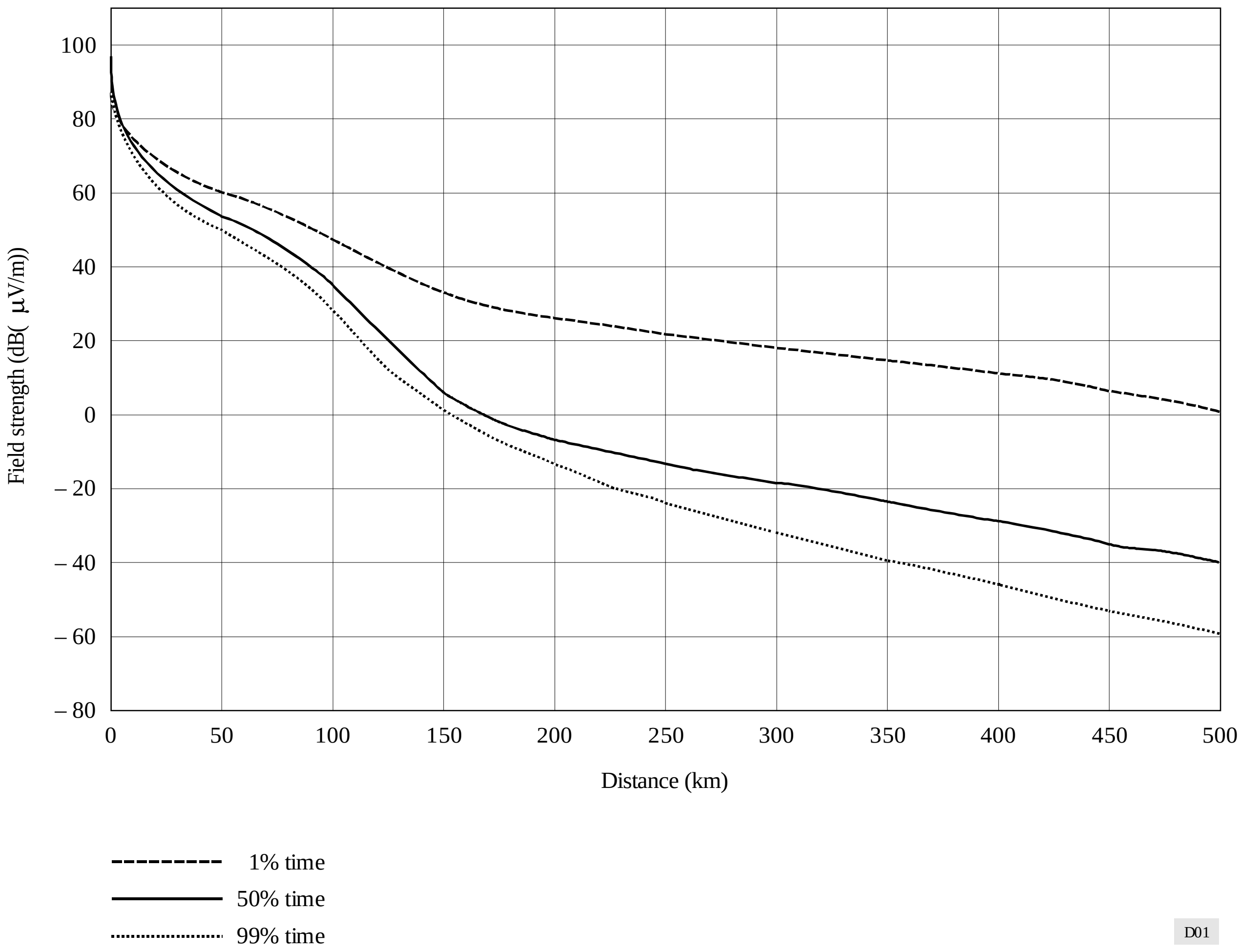
Category –2: oversea path (warm sea; i.e. seas other than cold seas).

NOTE 1 – "Cold" seas, oceans and other large bodies of water (i.e. covering a circle of at least 100 km in diameter) situated at latitudes above 30° (with the exception of the Mediterranean and the Black Sea).

FIGURE 1

Field strength (dB(μV/m)) for 1 kW e.r.p.

1 GHz (Category 0)



The appraisal of the propagation path required to determine the category is carried out assuming the effective radius of the Earth is 4/3 times its actual value, and will be influenced by the terrain information available. The number of obstacles is equal to the number of changes of slope in an imaginary string stretched from the transmitting antenna to the receiving antenna over a profile.

The category of a land path may be determined using the following procedure:

Category 0: if there are no obstructions between the transmitter and receiver

Category 1: if the radio horizon as seen from the transmitter and the radio horizon as seen from the receiver are separated by **less than or equal to** 500 m

Category 2: if the radio horizon as seen from the transmitter and the radio horizon as seen from the receiver are separated by **more than** 500 m.

FIGURE 2

Field strength (dB(μV/m)) for 1 kW e.r.p.

1 GHz (Category 1)

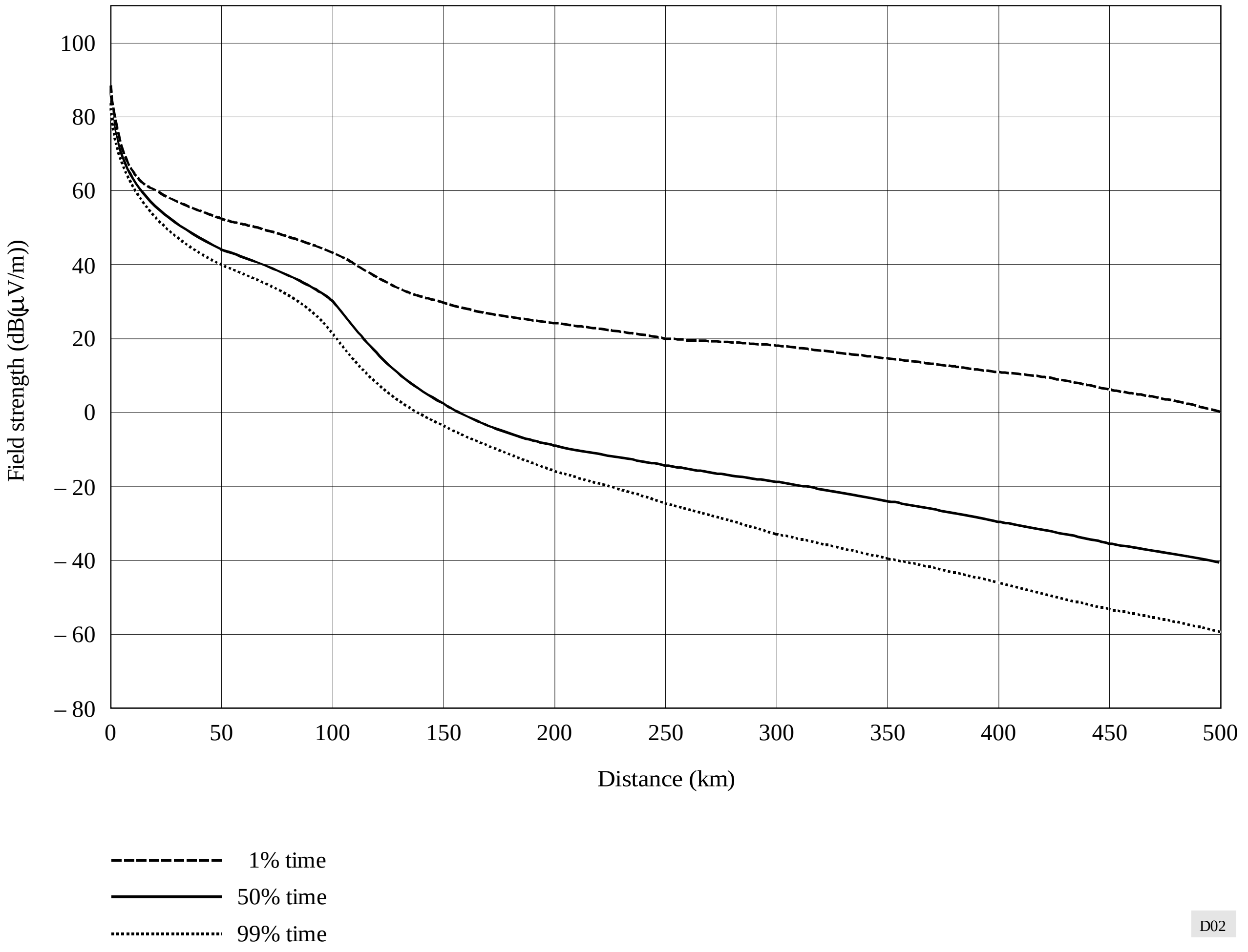
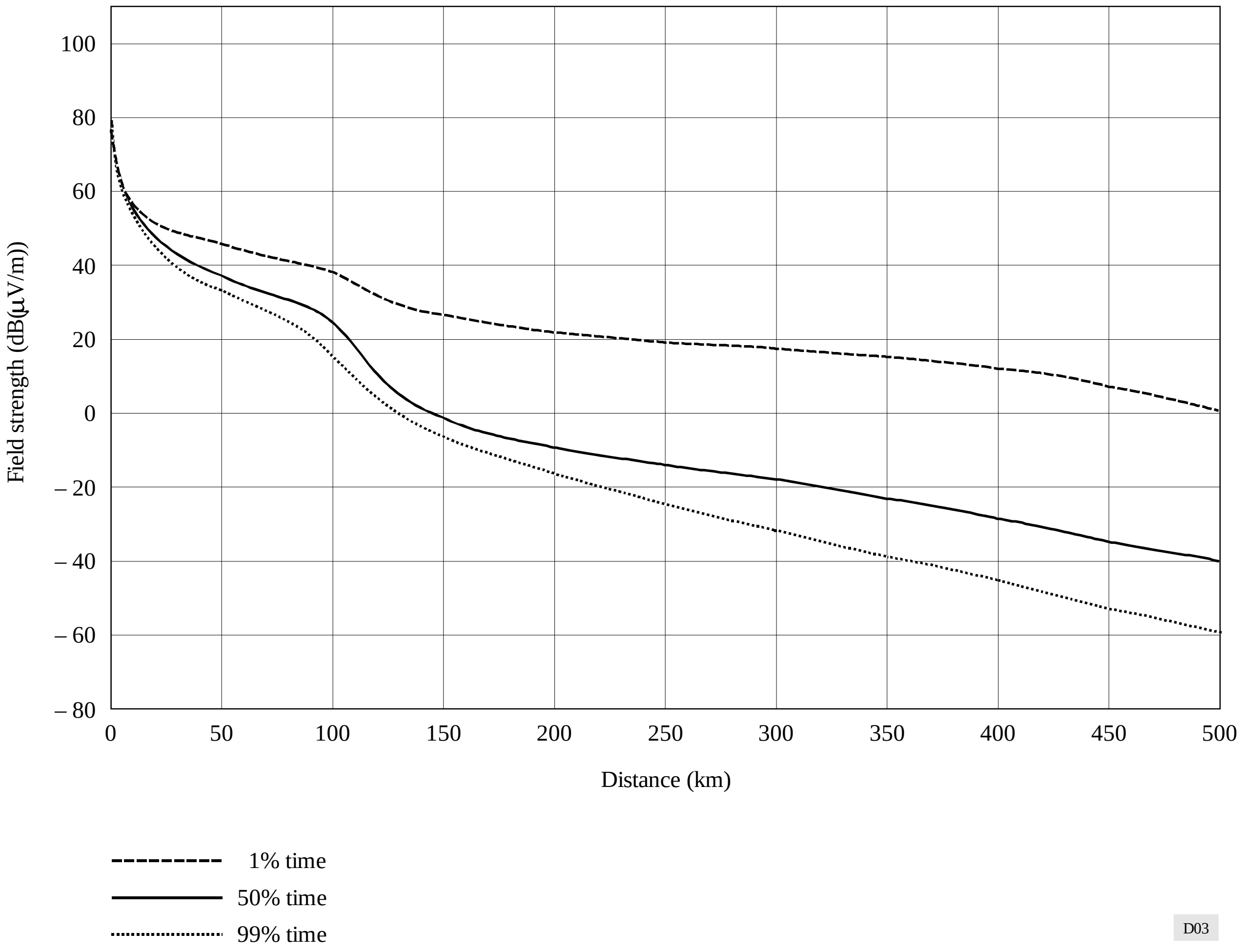


FIGURE 3

Field strength (dB(μV/m)) for 1 kW e.r.p.

1 GHz (Category 2)



Examples are shown in Annex 3.

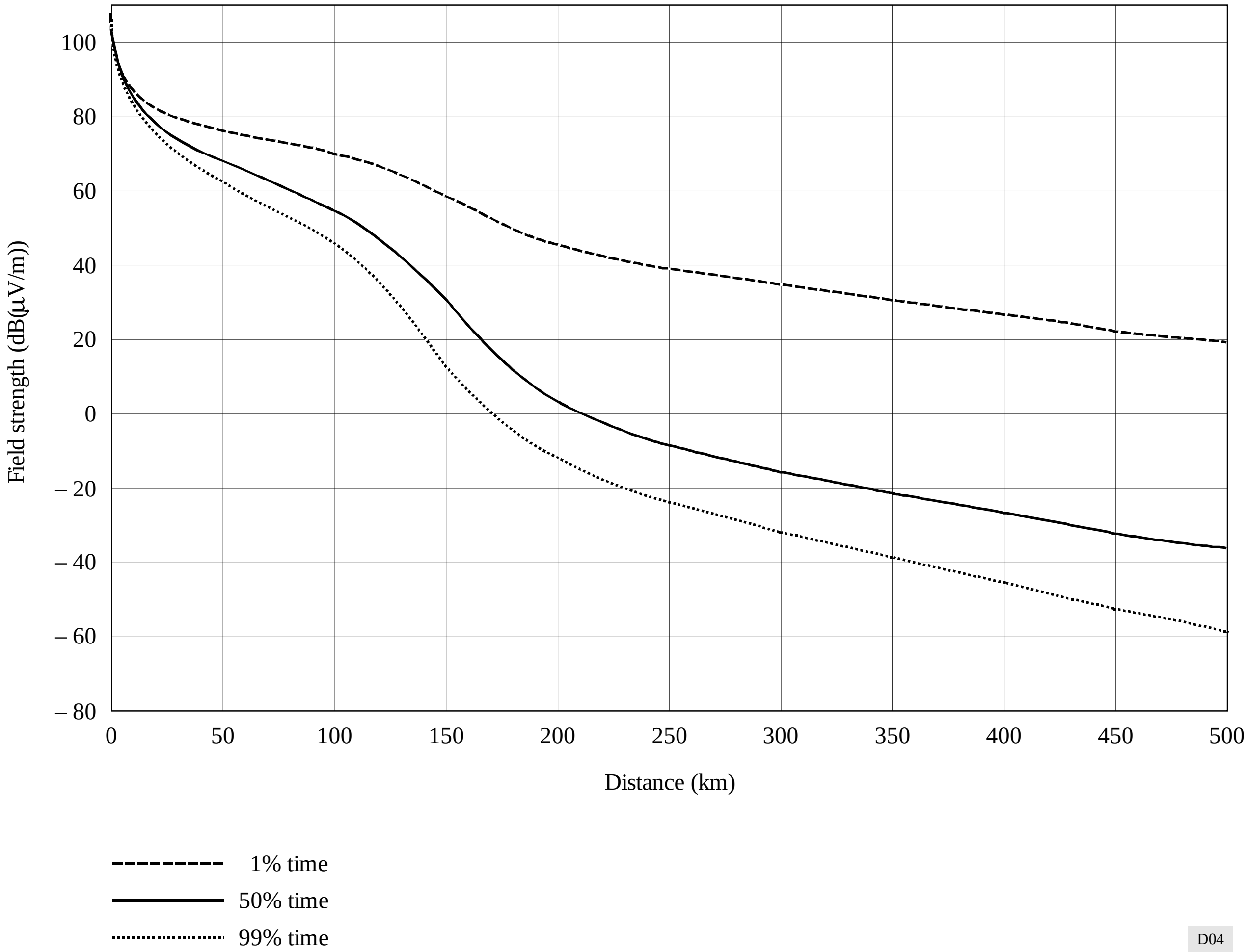
The definition of an oversea path is that at least 75% of the total distance between transmitter and receiver is oversea, and that the surface of the sea is visible from one or both of the terminating antennas.

Where terrain data are not available, or cannot be used, and only the distance measurements can be obtained, the following default conditions of path category should be used:

For the prediction of a service signal:	Category 2
For the prediction of an interfering signal:	Category 0 (overland)
	Category –1 or –2 (oversea).

FIGURE 4

Field strength (dB(μV/m)) for 1 kW e.r.p.
1 GHz (Category –1)



3.3 The terrain clearance angle (TCA) correction

The TCA correction is not applied to Category 0 paths, i.e. where the transmitting and receiving antennas are within line of sight.

This correction quantifies the influence of terrain along the propagation path within 5 km of the receiver. It affects both the amplitude of the signal, and its range of temporal variation. The horizon angle is taken at distances up to 5 km (or to the transmitter location, where this is less than 5 km), and is shown in Fig. 11, which also identifies the sign convention used. The values of correction are tabulated in Appendix 2.

For TCA values greater than +3°, the correction at +3° should be used.

For TCA values less than –7°, the correction at –7° should be used.

The TCA correction is an important element of the prediction, and wherever possible the terrain clearance angle should be accurately determined. Where this cannot be done, the following default values should be used to provide a quick assessment:

For the prediction of a service signal: –1.0°

For the prediction of an interfering signal: +1.0°.

FIGURE 5

Field strength (dB(μ V/m)) for 1 kW e.r.p.

1 GHz (Category –2)

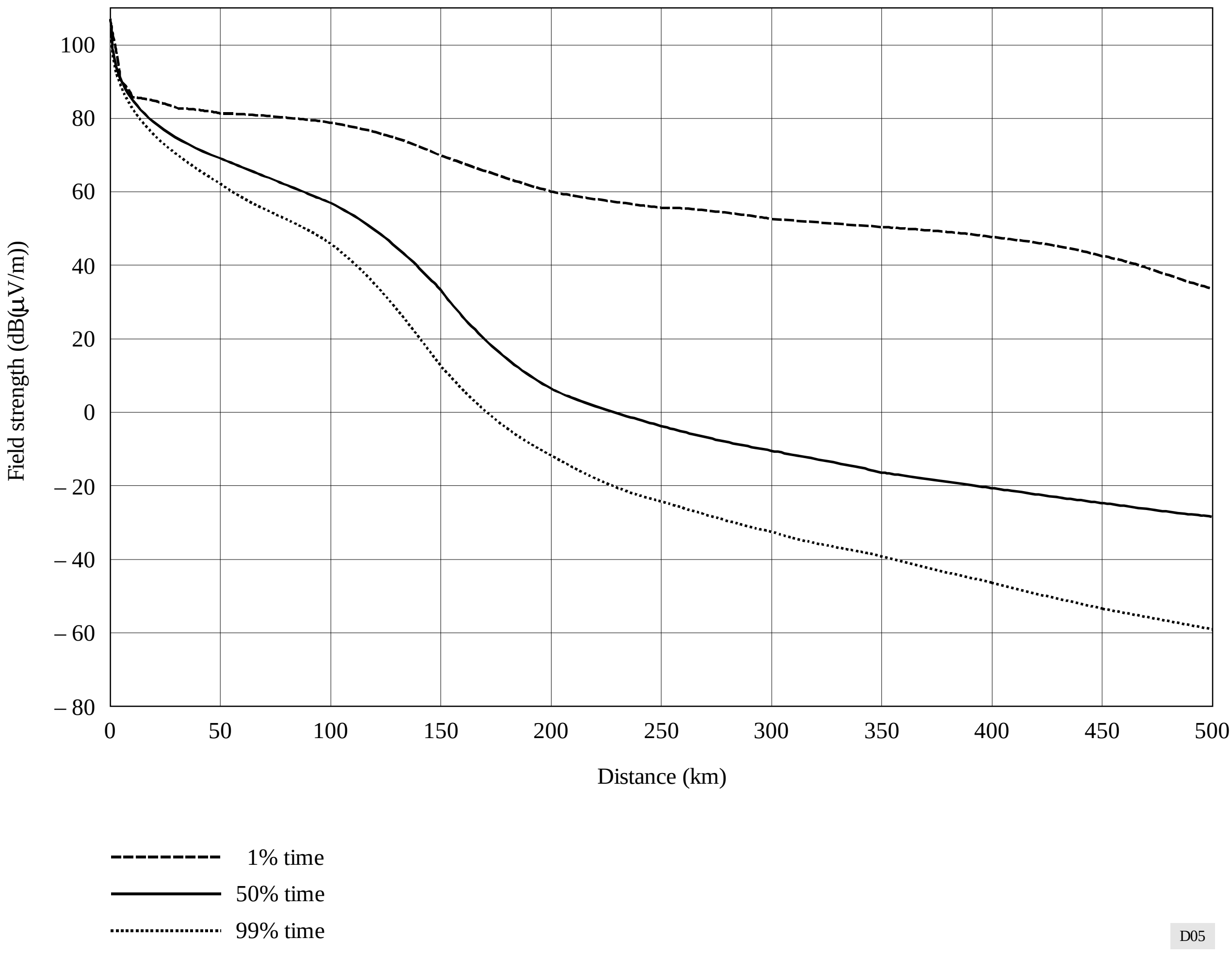
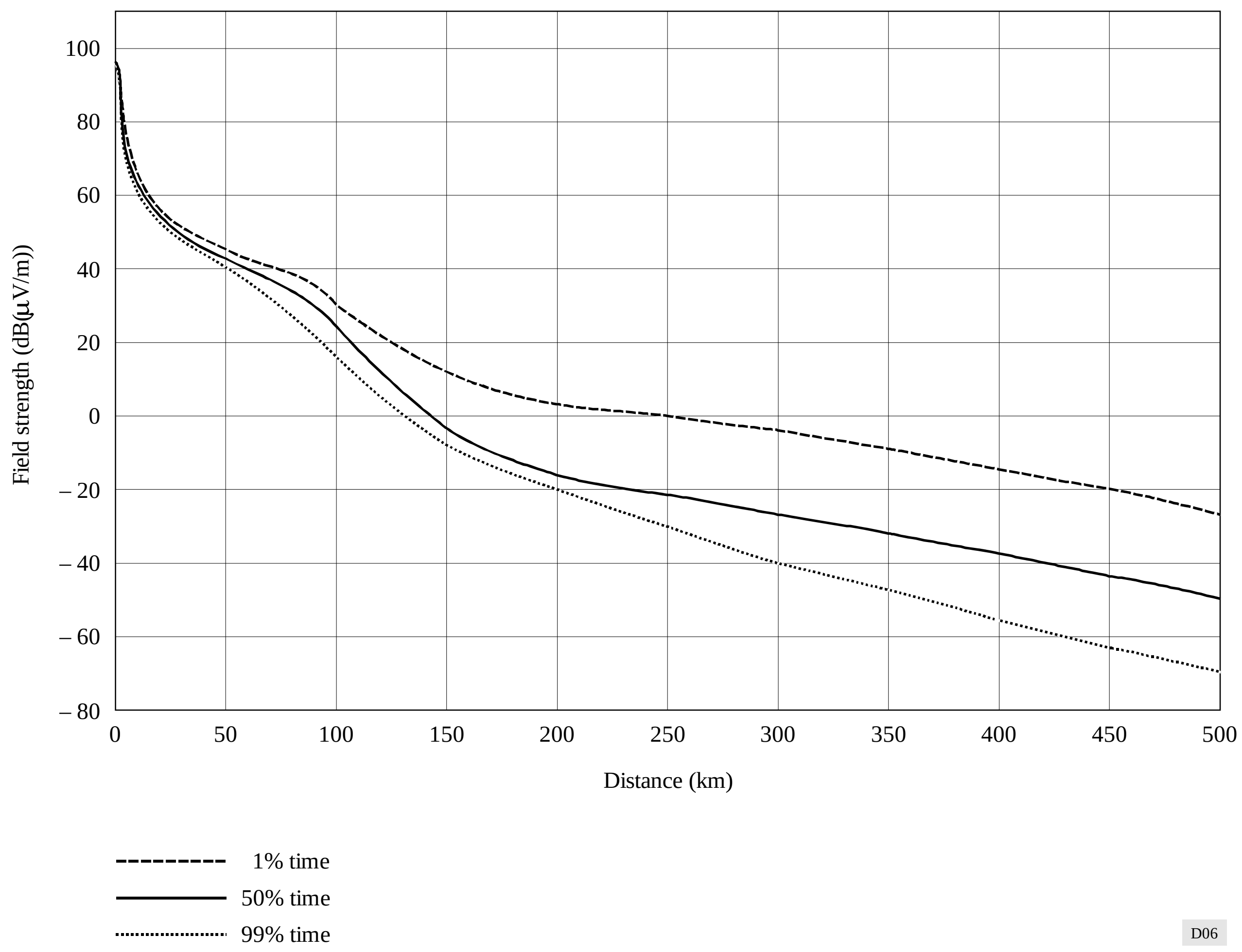


FIGURE 6

Field strength (dB(μV/m)) for 1 kW e.r.p.
3 GHz (Category 0)



3.4 Antenna height corrections

Antenna height corrections are applied only to the 50% and 99% time prediction results.

The corrections to be applied for changes in the height of the receiving antenna are tabulated in Appendix 3 for four categories of ground cover:

Category	Reference height (m above ground level (a.g.l.))
Rural or no cover	10
Suburban	10
Urban/wooded	15
Dense urban	30

The reference height is the representative height of the ground cover, except for the rural category, where a value of 10 m is assumed.

The correction is also applied to the transmitting end of the path in those cases where the transmitting antenna is at or below the reference height for the ground cover category.

In the case of mobile/portable reception in built-up areas, where information is available concerning the orientation of roads relative to the propagation path, a further adjustment should be made. If the angle in the horizontal plane between the road and the propagation path is less than 20°, the correction for receiving antennas below the height of the ground cover should be reduced by one ground cover category; for example, in a "dense urban" area, "urban" adjustments would be made.

FIGURE 7

Field strength (dB(μV/m)) for 1 kW e.r.p.

3 GHz (Category 1)

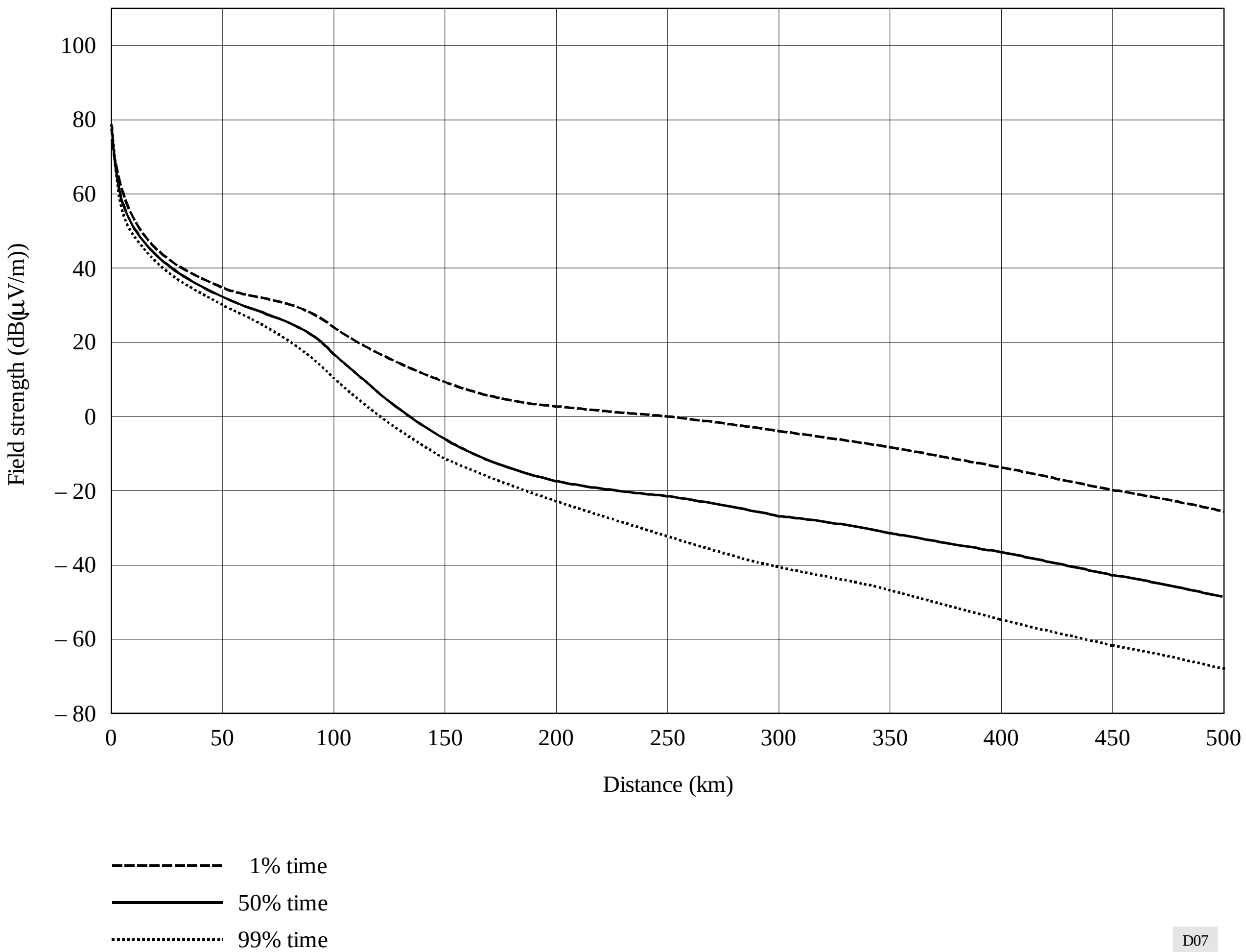
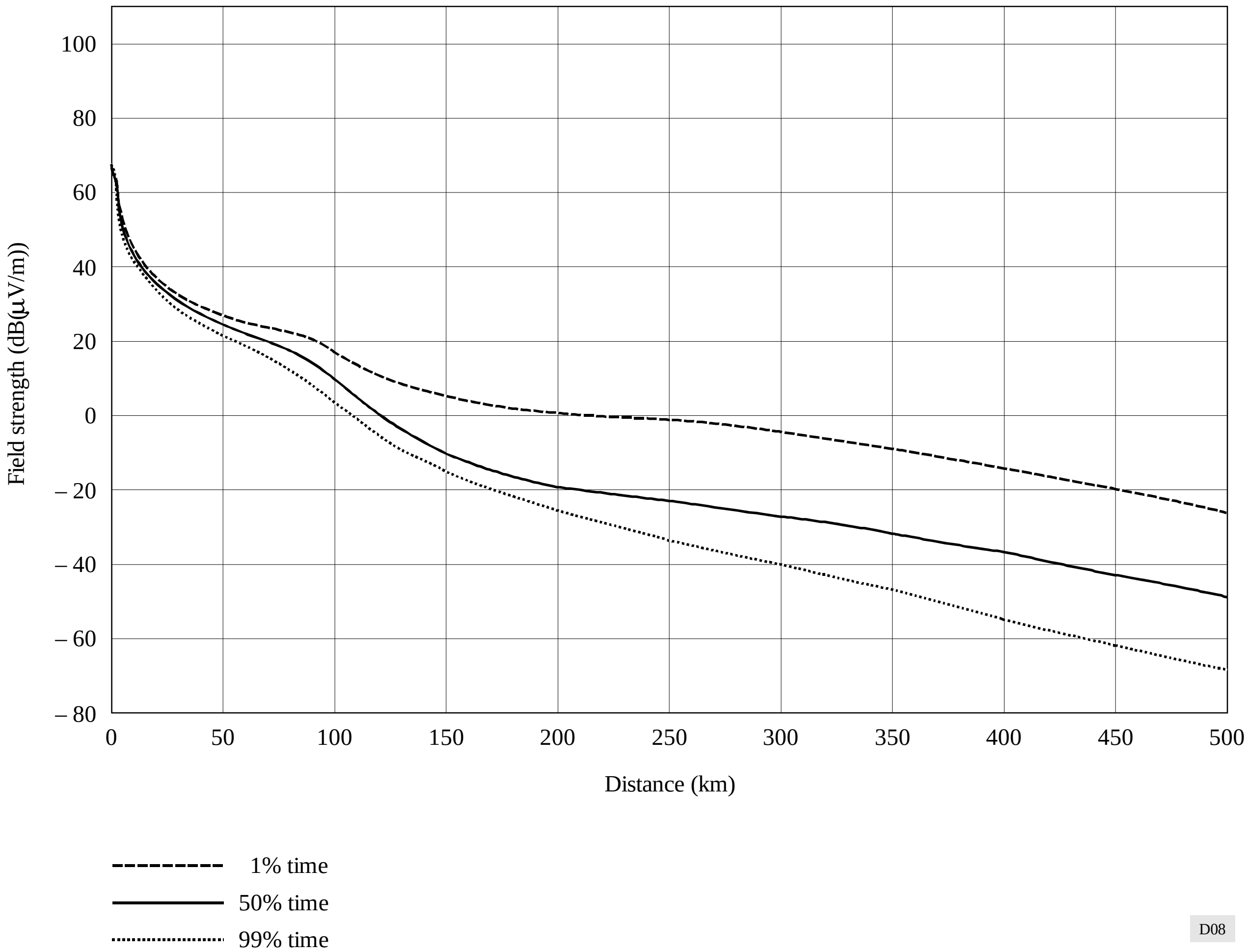


FIGURE 8

Field strength (dB(μV/m)) for 1 kW e.r.p.
3 GHz (Category 2)



In the absence of precise information, the following default conditions should be applied:

– for the prediction of mobile radio service areas: receiving antenna 1 m a.g.l.

– for the prediction of mobile radio interference: receiving antenna at reference height of ground cover

– for the prediction of broadcast service areas: receiving antenna 10 m a.g.l.

– for the prediction of broadcast interference: receiving antenna at reference height of ground cover.

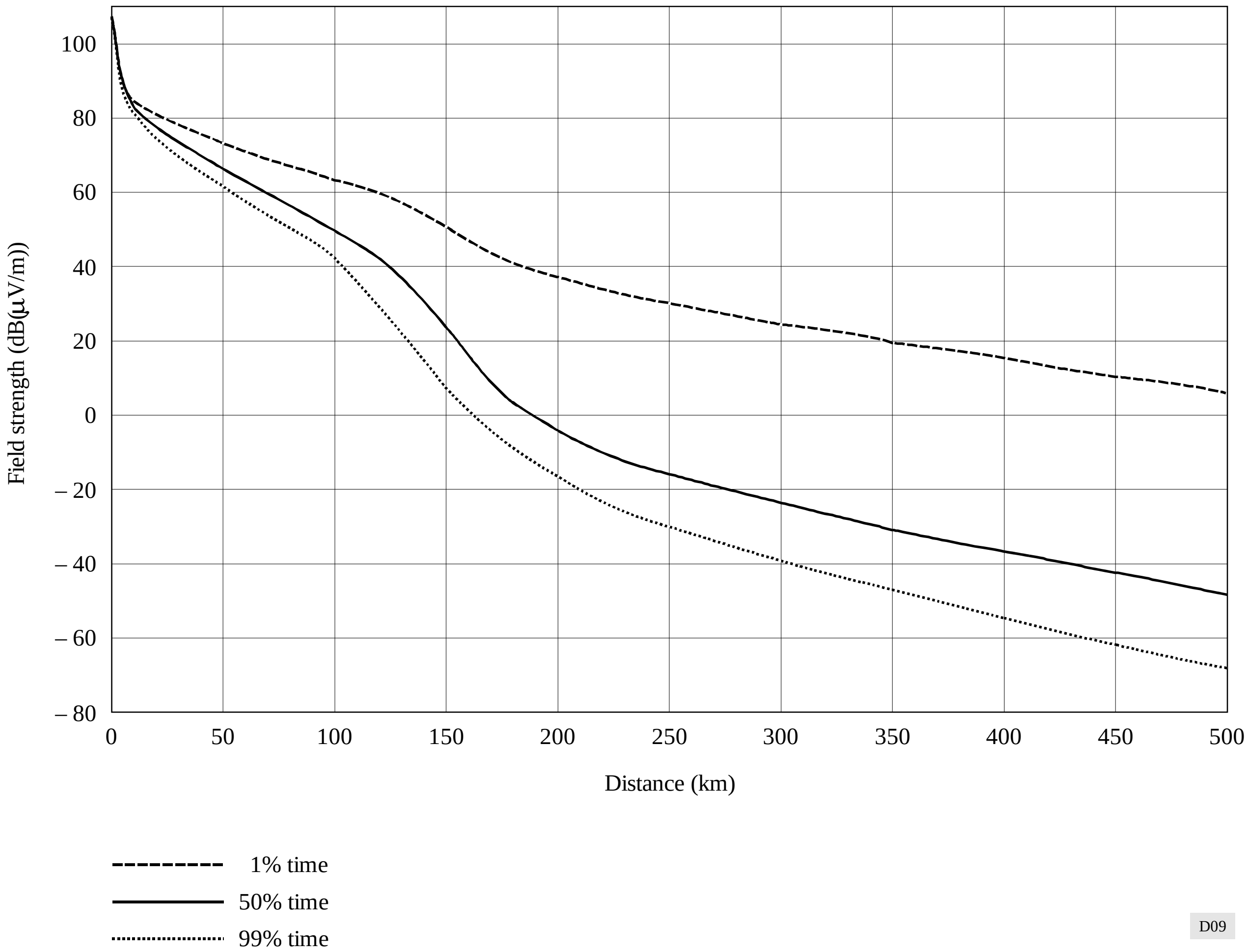
In all the above cases, a transmitting antenna height of 30 m a.g.l. should be used where the transmitting antenna height is less than 30 m.

Where no ground cover information is available, the rural ground cover category should be used.

FIGURE 9

Field strength (dB(μV/m)) for 1 kW e.r.p.

3 GHz (Category –1)



3.5 The prediction of temporal variation

The field strength for T% of time, E_T, is obtained from:

$$E_T = E_{50} + M\,\sigma_L \qquad \text{for } 1 < T < 50 \qquad (3)$$

$$E_T = E_{50} + M\,\sigma_H \qquad \text{for } 50 < T < 99 \qquad (4)$$

where:

$$\sigma_L = \frac{E_1 - E_{50}}{2.33} \qquad \text{dB} \qquad (5)$$

and:

$$\sigma_H = \frac{E_{50} - E_{99}}{2.33} \qquad \text{dB} \qquad (6)$$

and:

σ_L: standard deviation (1% to 50% time)

σ_H: standard deviation (50% to 99% time)

E_1: predicted field strength (1% time)

E_{50}: predicted field strength (50% time)

E_{99}: predicted field strength (99% time).

E_1, E_{50} and E_{99} are obtained from § 3.2 to 3.4 as described in § 3.1.1 to § 3.1.4 and M is obtained from Fig. 12.

If $E_{50} > E_1$, new values of E_1, σ_L and E_T are derived:

$$E_1 = E_{50} + 2.33\,\sigma_H \tag{7}$$

$$\sigma_L = \sigma_H \tag{8}$$

$$E_T = E_{50} + M\,\sigma_L \tag{9}$$

FIGURE 10

Field strength (dB(μV/m)) for 1 kW e.r.p.

3 GHz (Category – 2)

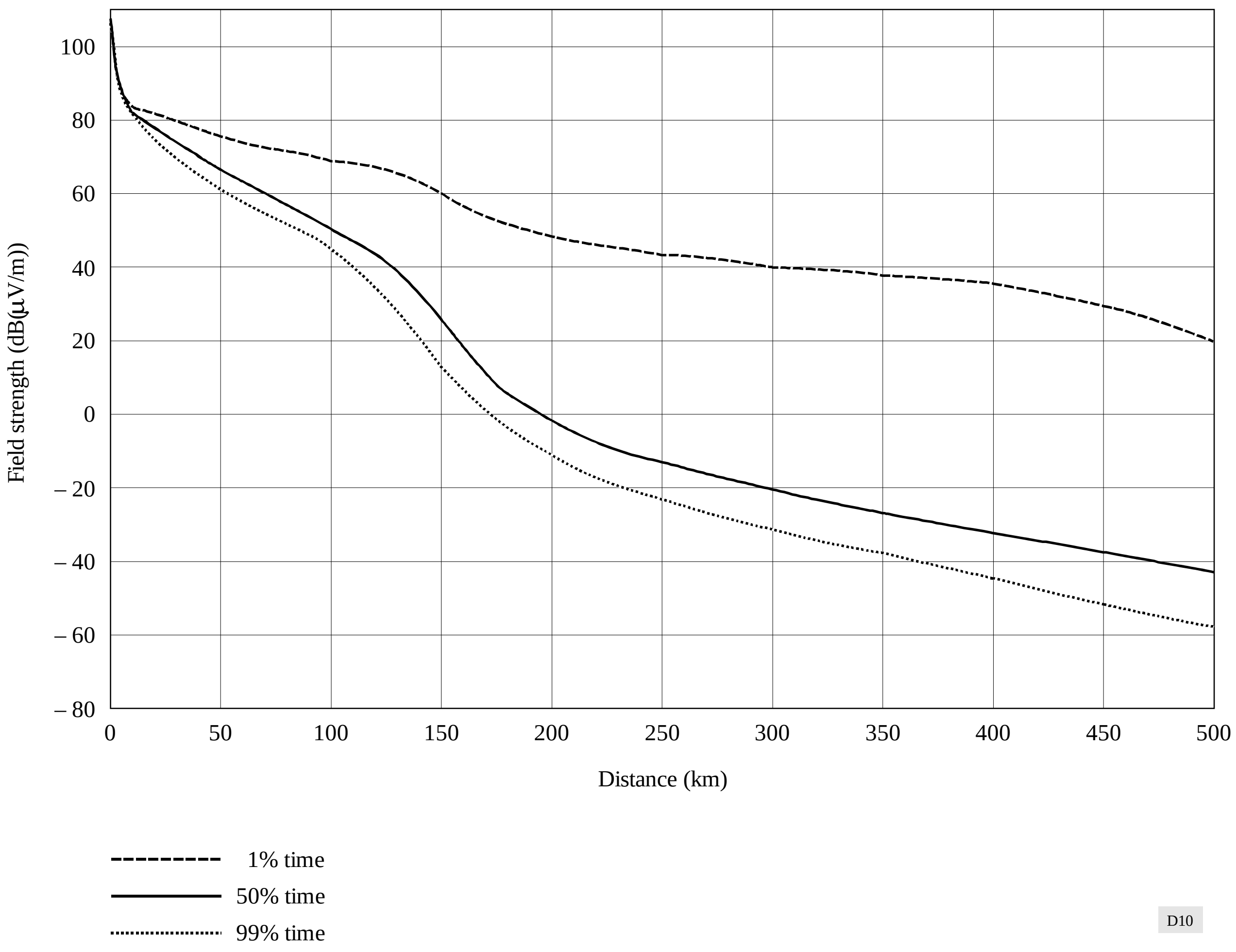
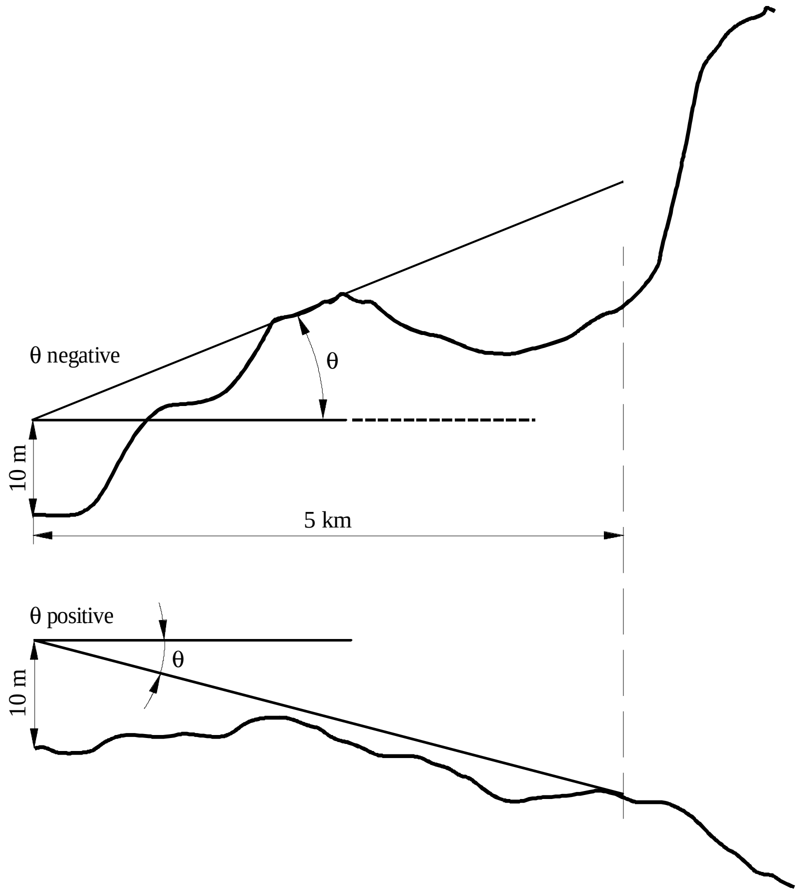


FIGURE 11

Terrain clearance angle



3.6 Spatial variation within the 100 m square

The field strength at X% of locations, E_X, may be derived from

$$E_X = E_T + M\sigma \tag{10}$$

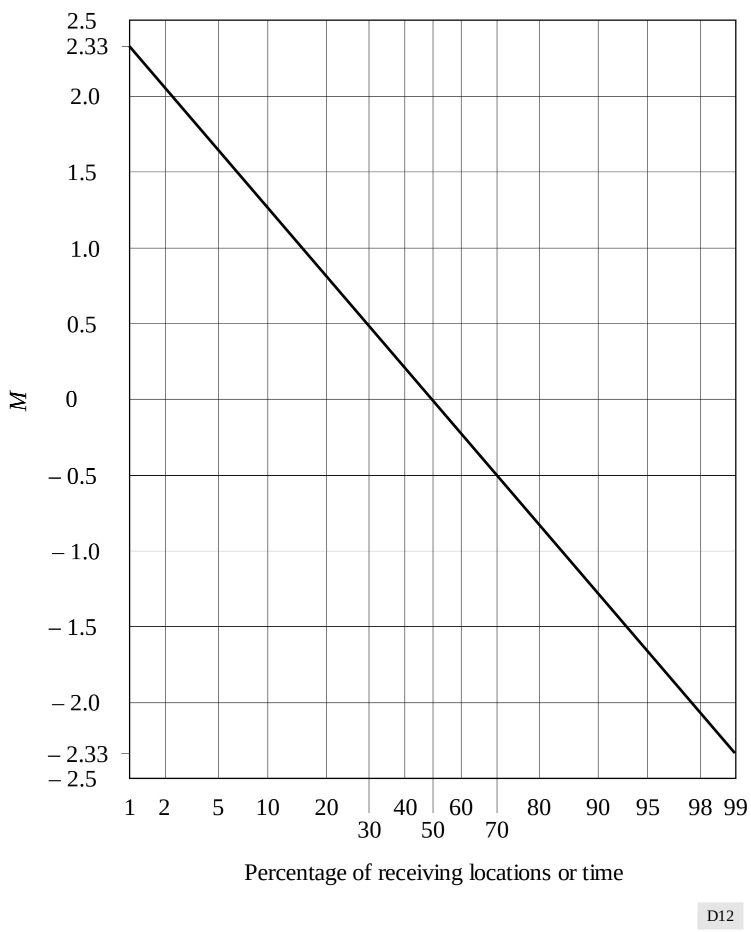
where σ is given in Table 1 and M is derived from Fig. 12.

TABLE 1

Frequency (GHz)	Polarization H/V	Ground cover	Standard deviation, σ (dB)
1.0	V	Rural	6.0
1.0	H	Rural	6.8
1.0	V	Suburban	7.9
1.0	H	Suburban	9.2
1.0	H/V	(1)	7.0
3.0	V	Rural	7.1
3.0	H	Rural	7.1
3.0	V	Suburban	11.4
3.0	H	Suburban	11.2
3.0	H/V	(1)	9.4

(1) Open sites within suburban areas.

FIGURE 12



APPENDIX 1

TO ANNEX 1

Field strength/distance tables

Values tabulated are for field strength (dB(μV/m)) for an effective radiated power of 1 kW.

CATEGORY 0 (no terrain obstacle)

Distance (km)	1 GHz			3 GHz		
	1% time	50% time	99% time	1% time	50% time	99% time
1	96	96	96	96	96	96
2	90	90	90	90	90	90
3	85.5	85.5	85.5	81.5	81.5	81.5
4	82.5	82.5	82.5	77.5	77.5	77.5
5	80	80	80	74	74	74
6	78	78	78	70.5	70.5	70.5
7	77	77	77	68	68	68
8	76	76	76	66	66	66
9	75	75	75	64	64	64
10	75	74	72	63	62	60.5
20	70	66	62.5	56	54	52.5
30	65.5	61	56.5	51	49	47
40	62.5	57	52.5	47.5	45	43.5
50	60	53.5	50	45	42	40
60	58	51	46	42	39	36.5
70	56	48	42.5	40	36	31.5
80	53	44	38.5	38.5	33.5	27
90	50	40	34	35.5	29.5	21.5
100	47.5	35	28	30.5	24	16.5
125	39.5	19.5	11.5	20.5	9	2.5
150	33	5.5	1	12.5	–3	–7.5
175	28.5	–2.5	–7.5	7	–11	–14.5
200	26	–7	–13.5	4	–16	–20
225	23.5	–10.5	–20	2	–19	–25.5
250	21.5	–13.5	–24	0.5	–21.5	–30.5
275	19.5	–16.5	–28.5	–2	–24	–35.5
300	18	–18.5	–32	–4	–27	–40
325	16.5	–21	–36	–6	–29	–43.5
350	14.5	–23.5	–39.5	–8.5	–31.5	–47
375	13	–26	–42	–11	–34	–50.5
400	11	–29	–45.5	–13.5	–36.5	–54.5
425	9.5	–31.5	–49	–16.5	–39.5	–58
450	6.5	–35	–52.5	–19.5	–42.5	–61.5
475	4	–37	–56	–22	–45	–65
500	0.5	–40	–59	–25.5	–48.5	–68

CATEGORY 1 (one terrain obstacle)

Distance (km)	1 GHz			3 GHz		
	1% time	50% time	99% time	1% time	50% time	99% time
1	86	86	86	78	78	78
2	80	80	80	72	72	72
3	75	75	75	66	66	66
4	72	72	72	62	62	62
5	69	69	69	58	58	58
6	67	67	67	56	56	56
7	66	66	66	55	55	55
8	64.5	64.5	64.5	53	53	53
9	63	63	63	52	52	52
10	63	62	61	52	51	49
20	59.5	55	52	45	43	41
30	56.5	50.5	46	40.5	38.5	36.5
40	54	47	42.5	37	35	33
50	51.5	43.5	39.5	34.5	32	29.5
60	50.5	41.5	36.5	32.5	29.5	27
70	48.5	39.5	35	31	27	24
80	46.5	37	31.5	30	25	20
90	44.5	34	27.5	27.5	21.5	15.5
100	43	30	21	23.5	16.5	10
125	34.5	12	4.5	15	3.5	–2.5
150	29.5	2	–3.5	9	–6.5	–11.5
175	26	–5	–10	4.5	–13.5	–18
200	24	–8.5	–15.5	2.5	–17.5	–23
225	22	–11.5	–20	1	–20	–28
250	20	–14	–24	0	–22	–32.5
275	19	–16.5	–28.5	–2	–24	–37
300	18	–18.5	–32	–4	–27	–41
325	16.5	–21	–36	–6	–29	–43.5
350	14.5	–23.5	–39.5	–8.5	–31.5	–47
375	13	–26	–42	–11	–34	–50.5
400	11	–29	–45.5	–13.5	–36.5	–54.5
425	9.5	–31.5	–49	–16.5	–39.5	–58
450	6.5	–35	–52.5	–19.5	–42.5	–61.5
475	4	–37	–56	–22	–45	–65
500	0.5	–40	–59	–25.5	–48.5	–68

CATEGORY 2 (two or more terrain obstacles)

Distance (km)	1 GHz			3 GHz		
	1% time	50% time	99% time	1% time	50% time	99% time
1	77	77	77	67	67	67
2	71	71	71	61	61	61
3	66	66	66	56	56	56
4	63	63	63	52	52	52
5	61	61	61	50	50	50
6	59	59	59	48	48	48
7	58	58	58	47	47	47
8	56.5	56.5	56.5	46	46	46
9	55	55	55	45	45	45
10	55	54	53	44	43	41
20	51.5	47.5	44.5	37	35.5	33.5
30	49	43	39	33	31	28
40	47	39	35	29	27	24.5
50	45.5	36.5	32.5	27	24.5	21.5
60	43.5	34	30	25	22	19
70	42	31.5	27	23.5	19.5	16
80	41	30	24.5	22.5	17.5	12
90	39.5	28	20.5	20.5	14.5	8
100	38	24.5	15	17	10	3.5
125	30	6	1	9.5	–2	–7.5
150	26.5	–1.5	–6.5	5.5	–10	–15
175	24	–7	–12	2.5	–15.5	–21
200	22	–10	–16.5	1	–19	–25.5
225	21	–12	–21	0	–21	–29.5
250	19.5	–14.5	–24.5	–1	–23	–33.5
275	19	–16.5	–28.5	–2	–25	–37
300	18	–18.5	–32	–4	–27	–40
325	16.5	–21	–36	–6	–29	–43.5
350	14.5	–23.5	–39.5	–8.5	–31.5	–47
375	13	–26	–42	–11	–34	–50.5
400	11	–29	–45.5	–13.5	–36.5	–54.5
425	9.5	–31.5	–49	–16.5	–39.5	–58
450	6.5	–35	–52.5	–19.5	–42.5	–61.5
475	4	–37	–56	–22	–45	–65
500	0.5	–40	–59	–25.5	–48.5	–68

CATEGORY –1 (cold sea path, e.g., NW Europe)

Distance (km)	1 GHz			3 GHz		
	1% time	50% time	99% time	1% time	50% time	99% time
1	107	107	107	107	107	107
2	100	100	100	100	100	100
3	97	97	97	97	97	97
4	92.5	92.5	92.5	92.5	92.5	92.5
5	89	89	89	89	89	89
6	88	88	88	88	88	88
7	87.5	87.5	87.5	86.5	86.5	86.5
8	87	87	87	85	85	85
9	86	86	86	84	84	84
10	86	85	82.5	84	83	81.5
20	82.5	78	75.5	81	78	74.5
30	79.5	74	70	78.5	74	69.5
40	77.5	70	66	75.5	70	65.5
50	76.5	68	62	73	66	61.5
60	75	65	58	71	63	57
70	73.5	62.5	55.5	69	59.5	54
80	72.5	60	52.5	66.5	56	50
90	71	57.5	49.5	65	53	47
100	70	55	46	63	49.5	42.5
125	65.5	45.5	32.5	58.5	40.5	26
150	58.5	30.5	12.5	50.5	23.5	7
175	51.5	13.5	–2.5	42	5	–7
200	46	3	–11.5	37	–4.5	–16.5
225	42.5	–3	–19.5	33	–11.5	–25
250	39.5	–8	–24	29.5	–16	–30
275	37	–12	–28.5	27	–20	–34.5
300	34	–15.5	–32	24	–24	–39.5
325	32	–18.5	–36	22	–27.5	–43.5
350	30	–21.5	–38.5	19	–31	–47
375	28	–24	–42	17	–34	–50.5
400	26.5	–26.5	–45.5	15	–36.5	–54.5
425	24.5	–29	–49	12	–39.5	–58
450	22.5	–31.5	–52.5	10	–42.5	–61.5
475	21	–34	–56	8	–45	–65
500	19.5	–36	–59	5.5	–48.5	–68

CATEGORY –2 (warm sea path, e.g., W Mediterranean)

Distance (km)	1 GHz			3 GHz		
	1% time	50% time	99% time	1% time	50% time	99% time
1	107	107	107	107	107	107
2	100	100	100	100	100	100
3	97	97	97	97	97	97
4	92.5	92.5	92.5	92.5	92.5	92.5
5	89	89	89	89	89	89
6	88	88	88	88	88	88
7	87.5	87.5	87.5	86.5	86.5	86.5
8	87	87	87	85	85	85
9	86	86	86	84	84	84
10	85.5	85	82.5	84	83	82.5
20	85	78.5	75.5	82.5	78.5	75.5
30	83	75	70	80.5	74.5	70
40	82	71	66	78	71	66
50	81.5	69	62	76.5	67	62
60	81	66.5	58	75	64.5	58
70	80.5	64	55.5	73	60.5	55.5
80	80	61.5	52.5	72	57.5	52.5
90	79.5	59.5	49.5	71	54.5	49.5
100	79	57	46	69.5	51	46
125	75.5	48	32.5	66.5	42	32.5
150	70	33	12.5	59.5	25.5	12.5
175	64.5	16.5	–2.5	52	7	–2.5
200	60	6	–11.5	48	–2.5	–11.5
225	57.5	0.5	–19.5	45	–9.5	–19.5
250	55.5	–4	–24	43	–13.5	–24
275	54.5	–7.5	–28.5	41.5	–17.5	–28.5
300	52.5	–10.5	–32	39.5	–21	–32
325	51.5	–13	–36	38.5	–24.5	–36
350	50.5	–16	–38.5	37	–27.5	–38.5
375	49.5	–18	–42	36	–30.5	–42
400	48	–20	–45.5	35	–33	–45.5
425	46	–22	–49	32	–35.5	–49
450	43	–24	–52.5	29	–38.5	–52.5
475	38.5	–26	–56	24.5	–41	–56
500	33.5	–28	–59	19	–44	–59

APPENDIX 2

TO ANNEX 1

Terrain clearance angle correction

The correction (dB) is not applied to Category 0 paths.

Angle (degrees)	1 GHz			3 GHz		
	1% time	50% time	99% time	1% time	50% time	99% time
–7.0	–16	–23.5	–30	–22	–32.5	–37
–6.5	–15.5	–22.5	–29.5	–22	–32	–36.5
–6.0	–15	–22	–28.5	–21.5	–31.5	–36.5
–5.5	–14	–21	–28	–21	–31	–36
–5.0	–13.5	–20	–27	–20.5	–30	–35.5
–4.5	–13	–19	–25.5	–19.5	–29	–34.5
–4.0	–12	–18	–24	–18.5	–28	–33.5
–3.5	–11	–17	–22	–17	–26.5	–32.5
–3.0	–10	–15.5	–19.5	–16.5	–25	–31
–2.5	–9	–13.5	–16	–15	–23.5	–29.5
–2.0	–7.5	–11.5	–13	–13.5	–21.5	–27
–1.5	–6	–9.5	–10	–11	–18	–23.5
–1.0	–4	–6	–6	–8	–13.5	–16.5
–0.5	–2	–3	–3	–4	–6	–6
0.0	0	0	0	0	0	0
+0.5	+2	+2	+2	+2.5	+2.5	+2.5
+1.0	+4	+4	+4	+4.5	+4.5	+4.5
+1.5	+5	+5	+5	+6	+6	+6
+2.0	+6.5	+6.5	+6.5	+7.5	+7.5	+7.5
+2.5	+7.5	+7.5	+7.5	+9	+9	+9
+3.0	+8.5	+8.5	+8.5	+10	+10	+10

APPENDIX 3

TO ANNEX 1

Receiving antenna height gain

This correction (dB) is only applied to 50% and 99% time results.

Antenna height (m) (a.g.l.)	Rural		Suburban		Urban/Wooded		Dense urban	
	1 GHz	3 GHz	1 GHz	3 GHz	1 GHz	3 GHz	1 GHz	3 GHz
1.0	–22	–25	–24	–34	–30	–45	–36	–51
2.0	–14	–16	–17	–27	–25	–40	–30	–45
3.0	–10	–10	–15	–24	–22	–37	–28	–43
4.0	–8	–8	–13	–22	–20	–34	–24	–40
5.0	–6	–6	–10	–18	–19	–32	–23	–37
6.0	–4	–4	–8	–16	–16	–30	–22	–35
7.0	–3	–3	–6	–13	–14	–28	–22	–34
8.0	–2	–2	–4	–11	–13	–25	–21	–33
9.0	–1	–1	–2	–8	–10	–20	–20	–30
10.0	0	0	0	–6	–8	–16	–19	–28
15.0	+4	+4	+7	+2	0	–10	–13	–20
30.0	+6	+8	+10	+7	+6	0	0	–6

Transmitting antenna height gain

This correction (dB) is only applied to the 50% and 99% time results in those cases where the transmitting antenna is at or below the reference height of the ground cover (see § 3.4 of Annex 1).

Antenna height (m) (a.g.l.)	Rural		Suburban		Urban/Wooded		Dense urban	
	1 GHz	3 GHz	1 GHz	3 GHz	1 GHz	3 GHz	1 GHz	3 GHz
1.0	–22	–25	–24	–34	–30	–45	–36	–51
2.0	–14	–16	–17	–27	–25	–40	–30	–45
3.0	–10	–10	–15	–24	–22	–37	–28	–43
4.0	–8	–8	–13	–22	–20	–34	–24	–40
5.0	–6	–6	–10	–18	–19	–32	–23	–37
6.0	–4	–4	–8	–16	–16	–30	–22	–35
7.0	–3	–3	–6	–13	–14	–28	–22	–34
8.0	–2	–2	–4	–11	–13	–25	–21	–33
9.0	–1	–1	–2	–8	–10	–20	–20	–30
10.0	0	0	0	–6	–8	–16	–19	–28
15.0	0	0	0	0	0	–10	–13	–20
30.0	0	0	0	0	0	0	0	–6

ANNEX 2

General information

1 Basic concept of prediction method

The method is based upon a series of "look-up" field strength/distance curves derived from many tens of thousands of measurements, which identified the sequence of important factors determining field strength distribution:

– the length of propagation path;

– the number of terrain obstructions, if any;

– the "exposure" of the reception area with respect to terrain obstacles in the propagation path within 5 km;

– the environment and height of the transmitting and receiving antennas with respect to immediate ground cover in the propagation path;

– the extent of tropospheric and other variations in the path which lead to temporal changes, and the need to quantify the distribution of the signal with time;

– other factors, e.g., polarization, multipath, type of receiving antenna.

To minimize the requirements for path data, a point-to-area approach has been adopted, and in common with similar methods the principle of reciprocity cannot be observed. Despite the relatively modest demands for path data, it is acknowledged that even these may not be met in circumstances where a quick assessment is required. This Recommendation contains default conditions to meet these demands, but it must be appreciated they are only intended to provide a first approximation.

With a point-to-area method, it is important to state clearly the significance of each prediction. Standards defining the spatial and temporal variations of the predicted field are described.

2 Elements of the prediction method

The decision concerning the categorization of the path in terms of the number of terrain obstructions appears simple, and may be interpreted as the number of changes of slope in an imaginary string stretched between the terminating antennas. However, the process is influenced by the nature of data used to make the assessment, and the methods of interpretation (see also Annex 3 and § 3 of Annex 1).

The analysis of measurements led to the adoption of the 100 m square as the reception unit in the prediction, which gives the median value of the spatial distribution within this area. The series of field strength/distance curves (Figs. 1 to 10) forming the basis of the technique have been derived using measurements obtained in flat, open country, with receiving antennas at a height of 10 m a.g.l. They are 50% location/50% time results.

The terrain clearance angle (TCA) correction, tabulated in Appendix 2, is a simple but effective means of adjusting the 50% location/50% time field strength prediction for variations in the level of the terrain along the propagation path within 5 km of the receiving site. This correction is most effective when used on obstructed paths, and is therefore confined to those in Categories 1 or 2.

The correction for changes in height of the receiving (or transmitting) antenna is combined with adjustment for ground cover, because of the clear interdependence of these two factors. Five types of ground cover were originally adopted in the analysis of measurements, and have been used in the prediction although two of these – "urban" and "wooded" – gave substantially similar results and are combined in the tables. With the exception of the 3 GHz results, the field strength at the average roof level is equal to that at 10 m a.g.l. in open country (the datum of the field strength/distance curves).

The values for height correction are applicable only to 50% and 99% time/50% location field strength values (see § 3 of this Annex).

Height corrections are also applied at the transmitting end of the propagation path in those situations where the antenna is below the reference height of the ground cover.

Table 1 gives the variation about the median in certain, simple conditions. These situations, in which the receiving antenna is generally clear of any ground cover, produce substantially normal distributions, allowing the range to be forecast with some certainty. In other cases, the prediction may be less accurate.

3 The prediction of temporal variation

The prediction of temporal variation has been based upon a number of long-distance recording experiments which individually occupied periods from one month to several years. To avoid biasing the results, experimental results covering a period of one year have been used in the development of this prediction method.

Section 2 of this Annex has already described how the exposure of the receiving site, as measured by the TCA, affects the temporal range of the signal. Changes in the height of the receiving antenna have relatively little effect on the field strength recorded during periods of abnormal propagation, i.e., approximately less than 10% time. In the prediction method, the temporal variation curve is divided into two parts, above and below 50% time, and the intervening values have been deduced assuming normal distributions between 1%, 50% and 99% values.

In certain circumstances, usually affecting shorter propagation paths, the field strength prediction for 50% time, with positive height gain/ground cover correction, could exceed the 1% time value predicted. Alternatively, a negative correction could indicate a relatively high 1% time result. This is not inconsistent with the method, because the latter is based upon best fit curves which may over or under estimate results at some sites. Measurements at short ranges revealed less skewed distributions, and in these cases a new 1% time value is deduced assuming a single normal distribution as defined by the 50% and 99% time predictions.

ANNEX 3

Path categorization

Examples are given below in Figs. 13-15 indicating the procedure for identifying obstacles on the path, from which the path categorization 0, 1 or 2 may be determined.

FIGURE 13

Path with no obstacles (Category 0)

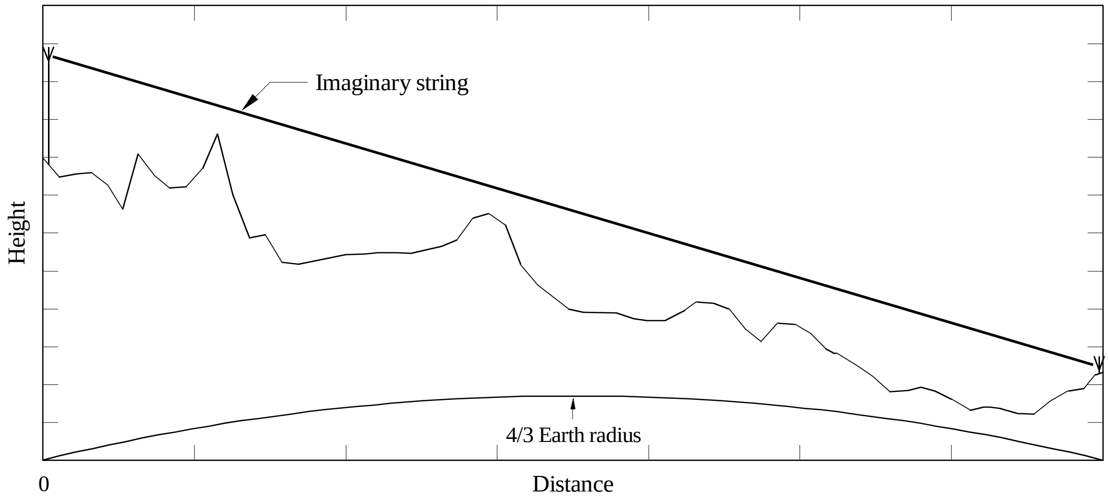


FIGURE 14

Path with one obstacle (Category 1)

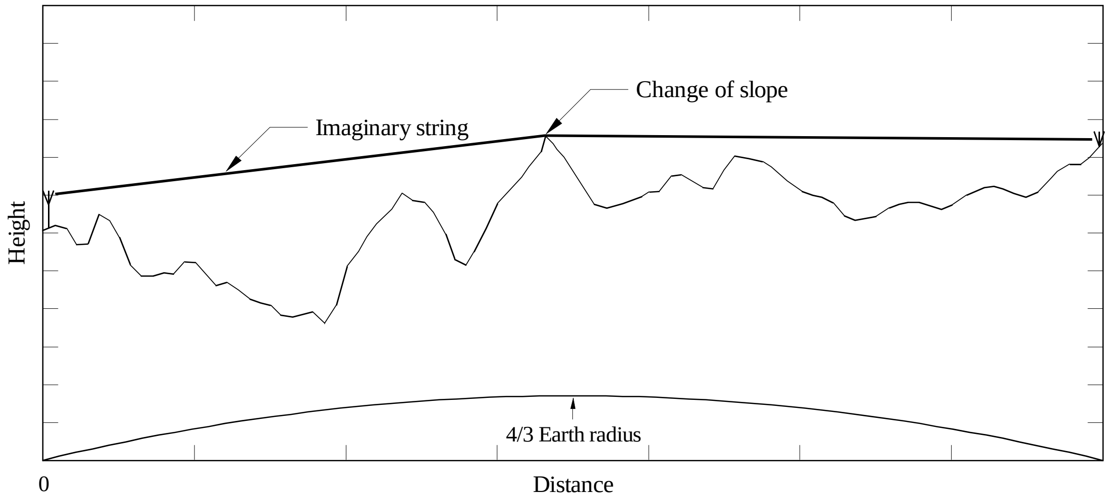


FIGURE 15

Path with two obstacles (Category 2)