CHAPTER 2

Propagation information

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2.1 General

Recommendation ITU-R P.1546-1 is the basis of a field-strength prediction method applicable for the broadcasting, land mobile, maritime mobile and certain fixed services (e.g. those using point-to-multipoint systems). The complete description of this method is provided in Annex 2.1. The method can be applied using either graphical or automated (computer) procedures. For the latter, tabulated values of the field strength curves are provided in Annex 2.2, along with detailed instructions for interpolation and extrapolation. The curves associated with these tabulated values are provided in Annex 2.3.

Predictions can be made for the following parameter ranges: frequency of 30 to 3 000 MHz; path distance of 1 to 1 000 km; percentage of time of 1 to 50%; and for transmitting antenna heights commensurate with the radiocommunication services concerned. The method draws a distinction between paths over land, cold seas and warm seas, makes due allowance for location variability for land area-service predictions and takes account of local clutter surrounding the receiving location.

Annex 2.1 provides the procedure for treating negative effective transmitting/base antenna heights and mixed-path propagation (i.e. those with combinations of land and sea). The method can be used with or without a terrain height database, although increased prediction accuracy would be expected when such data are available. However, due to the enormous increase in computation time, the use of terrain data in the context of RRC calculations is not foreseen.

For the prediction method applicable to airborne stations of the aeronautical radionavigation service, free-space propagation should be used if there is a line-of-sight path; otherwise, it is assumed that there is no signal. This is because, in general, the exact location of the aircraft is not known.

Administrations in the planning area, in particular those in regions of high refractivity and ducting zones, consider that Recommendation ITU-R P.1546-1 provides better propagation prediction methods than the methods previously used in Stockholm-61 and Geneva-89 Plans. However, any improvements in propagation prediction methods in the future should be taken into consideration during planning exercises and the second session of the conference. ITU-R is invited also, as a matter of urgency, to carry out the necessary studies and provide the results either to the Intersessional Planning Group (IPG) or to the second session of the conference.

2.2 Common elements for propagation prediction in the VHF and UHF bands

The tabulated values of field strength versus distance in Annex 2.2 should be used for the planning of the broadcasting service. They give, on the basis of statistics of measurement results and also of theoretical considerations, the field-strength value exceeded for 50% of locations for time percentages of 50%, 10% and 1%.

The data are given for various types of areas and climates, namely, land, cold sea and warm sea, and the method includes a procedure for extrapolating the data to areas subject to extreme superrefractivity.

Effective transmitting antenna height values should be provided by administrations. Terrain data information could be used to provide a set of effective height values for cases where the relevant administration is not able to supply such information and requests assistance in determining these values.

The definition of "effective height" of the transmitting/base antenna can be found in Annex 2.1.

Because of the very significant differences in propagation conditions for land and sea paths, a coastline must be included in the propagation prediction calculations to permit account to be taken of these differences in the calculation of interference levels.

Information on the type of propagation path, such as land, sea or mixed land-sea paths should be derived from digital maps providing the contours of the coastlines, such as the ITU digitized world map (IDWM) available from BR. Information on cold sea/warm sea divisions and geographic data for other propagation areas and path types is given in § 2.2.2 below.

2.2.1 Propagation curves and their application to geographical zones

The propagation curves represented in the figures in Annex 2.3 establish the relationship between the field strength and the path length. The effective height of the transmitting antenna is the characteristic parameter of each curve in the same figure. The use of the curve indicated as the maximum value is explained in Annex 2.1, § A.2.1.2. The values obtained correspond to a receiving antenna height of 10 m over local ground in open area. The values are expressed in decibels relative to 1 µV/m (dB(µV/m)) for an e.r.p. of 1 kW in the direction of the reception point. The curves give the values of the field strength exceeded at 50% of locations and each figure corresponds to time percentages of 50%, 10% and 1% for one of the geographical zones defined below and shown on the map in the Fig. 2.2-1.

2.2.2 Geographical division

Zone 1: temperate and subtropical regions;

Zone 2: desert regions, displaying propagation conditions found in regions having low humidity and small annual variations in climate;

Zone 3: equatorial regions, displaying propagation conditions found in regions with hot and humid climates;

Zone 4: maritime regions, displaying propagation conditions found over warm seas and in one terrestrial zone (referred to as "coastal land" in Annex 2.1) at low altitude bordering warm seas, where superrefraction conditions occasionally occur (Caspian Sea* and all the seas around the African continent are Zone 4 except Zones A and B designated below);

Zone 5: maritime regions, displaying propagation conditions found over cold seas;

Zone A: maritime zone at low latitudes, frequently displaying superrefractivity;

Zone B: maritime zone at low latitudes, displaying superrefractivity to a lesser extent than Zone A;

Zone C: maritime zone from the junction of the coastline of the Islamic Republic of Iran with its border to Pakistan westward along the coastlines of the Islamic Republic of Iran and of Iraq, through point 48° E, 30° N along the coastline of Kuwait, the eastern coastline of Saudi Arabia, the coastlines of Qatar, the United Arab Emirates and Oman down to the intersection with parallel 22° N;

Zone D: land strip of maximum depth of 100 km surrounding Zone C.

Table 2.2-1 provides all the information on the parameters used to derive the tabulated values (see Annex 2.3) and the curves (see Annex 2.3) for different propagation zones. The d*N*-values are based on vertical refractivity gradient data in the lowest 65 m of the atmosphere (see Recommendation ITU-R P.453).

TABLE 2.2-1

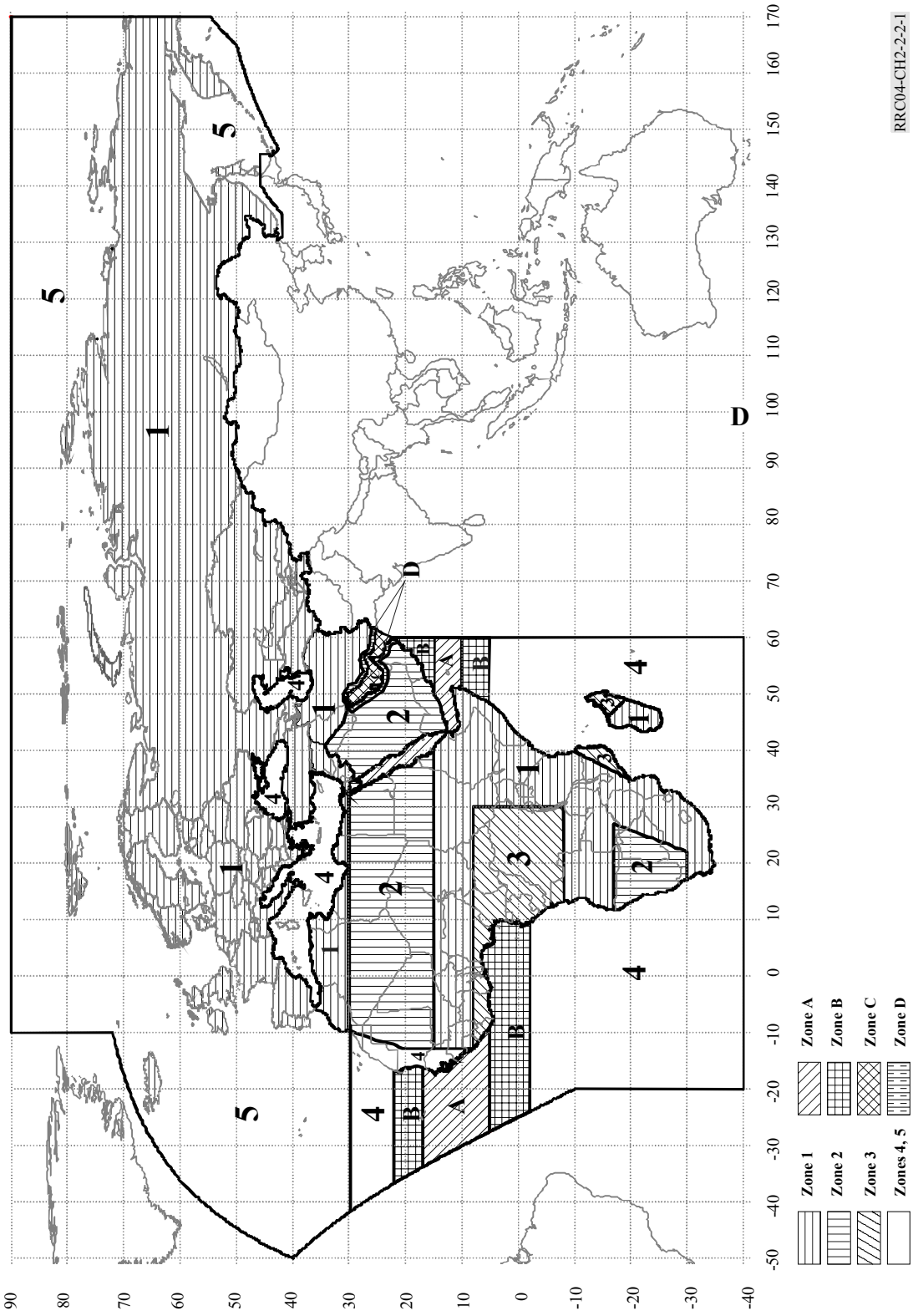
Parameters used when deriving curves in Annex 2.3

Zone	Path type	Derived from zone type	Refractivity gradient, d*N*, not exceeded for		
			1% time	10% time	50% time
1	Land		–301.3	–141.9	–43.3
2	Land	1	–200.0	–110.0	–30.0
3	Land	1	–250.0	–130.0	–40.0
4	Sea		–301.3	–141.9	–43.3
5	Sea		–301.3	–141.9	–43.3
A	Sea	4	–1 150.0	–1 000.0	–720.0
B	Sea	4	–680.0	–500.0	–320.0
C	Sea	4	–1 233.0	–850.0	–239.0
D	Land	1	–694.0	–393.0	–120.0

* *Note by the Secretariat:* In Fig. 2.2-1 the Black Sea shall be considered as part of Zone 4.

FIGURE 2.2-1

Geographical division of the planning area into propagation zones



2.2.3 Receiving antenna height loss correction

For planning purposes, the ground cover at the receiver location is generally not known and, hence, a receiving antenna at a height of 10 m in open or suburban areas is assumed. To correct the predicted values for a receiving height of 1.5 m above ground level, a factor called “height loss” has been introduced.

For the conditions indicated in the previous paragraph, the “height loss” from 10 m to 1.5 m is given in § 3.3.2.1 or can be calculated using the method described in § A.2.1.9.

2.2.4 Prediction of wanted field strengths

When predicting wanted field strengths for an individual transmitter-to-receiver path, it is appropriate to use the values for 50% of the time given in Annex 2.1, since those values are also applicable to the 99% time requirement for wanted signals. For the short distances involved, up to about 60 km, the difference in the field strength values for 50% and 99% of the time is negligible. However, there are differences in propagation over the various zones and it is thus necessary to take account of the nature of any individual propagation path.

2.2.5 Prediction of unwanted field strengths

During the planning and coordination processes, it is necessary to predict the level of interfering field strength produced in the service area of a station by another station. When calculating the level of interfering field strength, the time percentage curves in Annex 2.3 for the service area and propagation zone concerned should be used.

Ideally, the calculation should be made for points defining the service area of the station to be protected. However, in some circumstances, this may not be possible or necessary. Two cases can be distinguished:

2.2.5.1 Prediction for points defining the service area

Predictions of interfering field strengths would normally be made for points on the periphery of the service area of the station to be protected. It is preferable that points defining the edge of the service area be specified or that they be calculated on the basis of 36 equally spaced radials from the transmitter site. In the case where the boundary points are specified, rather than being calculated, there is no particular requirement that they be on equally spaced radials.

2.2.5.2 Prediction for the location of the transmitting site

In some cases it may not be possible or necessary to define the service area in the manner described in the preceding paragraph. An example of this would be where the station to be protected is a low-power station with a service area of very small radius. To define the service area and calculate interference levels at many points would involve unnecessary computation. In this case, the location of the transmitting station can be taken as representative of the service area to be protected, and the prediction of interfering field strength can be made for that point.

2.2.6 Location statistics

Within a small area of 100 m × 100 m to 200 m × 200 m there will be a random variation of field strength with location, which is due to local terrain irregularities and reflection from objects near the receiving location. The statistics of this type of variation may be characterized by a log-normal distribution of the field strengths. Recent measurements for digital signals have shown that for outdoor paths the standard deviation will be about 5.5 dB, depending to some extent on the environment surrounding the receiving location. Any values related to outdoor service in the remainder of this document will be based on a standard deviation of 5.5 dB. For indoor reception, the standard deviation will be larger (see also § 3.3.2.2).

Different percentages of locations can be calculated using the relevant multipliers given in Table A.2.1-2 of Annex 2.1. For example, the difference for 50% and 95% of outdoor locations is taken to be 9 dB for the case where the standard deviation is 5.5 dB. This value takes no account of the inherent inaccuracies of any propagation prediction method.

In the case that the wanted signal is composed of several signals from different transmitters, the resulting standard deviation becomes variable, depending on the individual signal strengths. As a consequence, the difference between wanted signals for 50% and 70% or 95% of locations becomes variable. However, it always will be smaller than that of an individual signal. This item is dealt with in more detail with regard to single-frequency networks in § 5.3.1.2.5.

2.3 Propagation information for shared services

2.3.1 Compatibility between the broadcasting service and the fixed and mobile services

In the case of interference to or from the broadcasting service, the land mobile service or the fixed service, the propagation prediction method and the procedure described in Annex 2.1 are to be used in the VHF and UHF bands, taking into account the following information on transmitting and receiving antenna heights:

– ***Transmitter sited at a base station or other fixed location***

  The propagation prediction method described in Annex 2.1 should be used in the VHF and UHF bands for the effective height of the base station antenna.

– ***Transmitter of a mobile station in the land mobile service***

  The propagation prediction method described in Annex 2.1 should be used in the VHF and UHF bands for an effective transmitting antenna height of 1.5 m.

– ***Receiving antenna height gain***

  The procedure in Annex 2.1 should be used to take into account the effect of the height of the receiving antenna above ground level, irrespective of the polarization.

2.3.2 Compatibility between the broadcasting service and the aeronautical mobile and radionavigation services

In the case of interference to or from ground-based stations in the aeronautical mobile or aeronautical radionavigation services, the propagation prediction method described in Annex 2.1 should be used.

In the case of interference to or from airborne stations in the aeronautical mobile or aeronautical radionavigation services:

– the free-space propagation prediction model should be used in the case where there is a line-of-sight path between the transmitting and receiving antennas; and

– zero interference should be assumed in the case where there is no line-of-sight.

The free-space field strength relative to a half-wave dipole for 1 kW e.r.p. is given by:

$$E = 106.9 - 20 \log d$$

where:

E: free-space field strength (dB(μV/m))

d: distance (km) between transmitting and receiving antenna.

ANNEX 2.1

The propagation prediction method

A.2.1.1 Introduction

This Annex describes separate stages of the calculation. A step-by-step description of the procedure to be followed for the overall method is given in § A.2.1.15.

A.2.1.2 Maximum field-strength values

A field strength for any given propagation zone must not exceed a maximum value E_{max} given by the curve indicated as a maximum in each of the Figures in Annex 2.3. In the case of mixed paths, it will be necessary to calculate the maximum field strength by linear interpolation between the all-land and all-sea values. This is given by:

$$E_{max} = (d_l\, E_{ml} + d_s\, E_{ms})/d_{total} \qquad \text{dB(µV/m)} \qquad (1)$$

where:

E_{ml}: maximum value of field strength for relevant all-land path (dB(µV/m))

E_{ms}: maximum value of field strength for relevant all-sea path (dB(µV/m))

d_l: the total land distance (km)

d_s: the total sea distance (km)

d_{total}: the total path distance (km).

Any correction which increases a field strength shall not be allowed to produce values greater than these limits for the relevant family of curves. However, limitation to maximum values shall be applied only where indicated in § A.2.1.15.

A.2.1.3 Determination of transmitting/base antenna height, h_1

The transmitting/base antenna height, h_1, to be used in calculation depends on the type and length of the path and on various items of height information.

The effective height of the transmitting/base antenna, h_{eff}, is defined as its height in metres over the average level of the ground between the distances of 3 and 15 km from the transmitting/base antenna in the direction of the receiving/mobile antenna.

The value of h_1 to be used in calculation shall be obtained using the method given in § A.2.1.3.1, A.2.1.3.2 or in A.2.1.3.3 as appropriate.

A.2.1.3.1 Land paths shorter than 15 km

For land paths less than 15 km one of the following two methods shall be used.

A.2.1.3.1.1 Terrain information not available

If no terrain information is available for the purpose of propagation predictions, the value of h_1 is calculated according to path length d as follows:

$$h_1 = h_a \quad \text{m} \quad \text{for} \quad d \leq 3 \text{ km} \tag{2}$$

$$h_1 = h_a + (h_{eff} - h_a)\,(d - 3)/12 \quad \text{m} \quad \text{for } 3 \text{ km} < d < 15 \text{ km} \tag{3}$$

where h_a is the antenna height above ground (e.g. height of the mast).

A.2.1.3.1.2 Terrain information available

If terrain information is available for the purpose of propagation predictions:

$$h_1 = h_b \quad \text{m} \tag{4}$$

where h_b is the height of the antenna above terrain height averaged between $0.2d$ and d km.

A.2.1.3.2 Land paths of 15 km or longer

For these paths:

$$h_1 = h_{eff} \quad \text{m} \tag{5a}$$

A.2.1.3.3 Sea paths

For these paths:

$$h_1 = h_{eff} \quad \text{m} \tag{5b}$$

This propagation prediction method shall not be used in the case of an all-sea path for h_1 values less than 1 m.

A.2.1.4 Application of transmitting/base antenna height, h_1

The value of h_1 determines which curve or curves are selected from which to obtain field-strength values, and the interpolation or extrapolation which may be necessary. The following cases are distinguished.

A.2.1.4.1 Transmitting/base antenna height, h_1, in the range 10 to 3 000 m

If the value of h_1 coincides with one of the eight heights for which curves are provided, namely 10, 20, 37.5, 75, 150, 300, 600 or 1 200 m, the required field strength may be obtained directly from the plotted curves or the associated tabulations. Otherwise the required field strength shall be interpolated or extrapolated from field strengths obtained from two curves using:

$$E = E_{inf} + (E_{sup} - E_{inf}) \log (h_1/h_{inf}) / \log (h_{sup}/h_{inf}) \quad \text{dB}(\mu\text{V/m}) \tag{6}$$

where:

h_{inf}: 600 m if h_1 > 1 200 m, otherwise the nearest nominal effective height below h_1

h_{sup}: 1 200 m if h_1 > 1 200 m, otherwise the nearest nominal effective height above h_1

E_{inf}: field-strength value for h_{inf} at the required distance (dB(μV/m))

E_{sup}: field-strength value for h_{sup} at the required distance (dB(μV/m)).

The field strength resulting from extrapolation for h_1 > 1 200 m shall be limited, if necessary, such that it does not exceed the maximum defined in § A.2.1.2.

This propagation prediction method shall not be used for h_1 > 3 000 m.

A.2.1.4.2 Transmitting/base antenna height, h_1, in the range 0 to 10 m

The method when h_1 is less than 10 m depends on whether the path is over land or sea.

For a land path or a mixed path:

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

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 between field strengths for the 10 m height curve at distance d and at the 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 is expressed in the following formulae where $E_{10}(d)$ is the field strength (dB(μV/m)) taken from the 10 m height curve for a distance d (km):

$$E = E_{10}(d_H(10)) + E_{10}(d) - E_{10}(d_H(h_1)) \quad \text{dB(μV/m)} \quad \text{for } d < d_H(h_1) \tag{7a}$$

$$= E_{10}(d_H(10) + d - d_H(h_1)) \quad \text{dB(μV/m)} \quad \text{for } d > d_H(h_1) \tag{7b}$$

If in equation (7b) $d_H(10) + d - d_H(h_1)$ exceeds 1 000 km, even though $d \leq 1\,000$ km, E shall be found from linear extrapolation for log (distance) of the curve, given by:

$$E = E_{inf} + (E_{sup} - E_{inf}) \log (d / D_{inf}) / \log (D_{sup} / D_{inf}) \quad \text{dB(μV/m)} \tag{7c}$$

where:

D_{inf}: penultimate tabulation distance (km)

D_{sup}: final tabulation distance (km)

E_{inf}: field strength at penultimate tabulation distance (dB(μV/m))

E_{sup}: field strength at final tabulation distance (dB(μV/m)).

Note that this propagation prediction method is not to be used for distances greater than 1 000 km. Equation (7c) shall be used only for extrapolating for $h_1 < 10$ m.

For an all-sea path:

Note that for an all-sea path, h_1 shall not be less than 1 m. The procedure requires the distance at which the path has 0.6 of the first Fresnel zone just unobstructed by the sea surface. This is given by:

$$D_{h_1} = D_{06}(f, h_1, 10) \qquad \text{km} \tag{8a}$$

where the function D_{06} is defined in § A.2.1.14 and f is the required frequency.

If $d > D_{h_1}$ it will be necessary to also calculate the 0.6 of the first Fresnel clearance distance for a sea path where the transmitting/base antenna height is 20 m, given by:

$$D_{20} = D_{06}(f, 20, 10) \qquad \text{km} \tag{8b}$$

where f is the required frequency.

The field strength for the required distance, d, and value of h_1, is then given by:

$$E = E_{max} \quad \text{dB(μV/m)} \qquad \text{for} \quad d \le D_{h_1} \tag{9a}$$

$$E = E_{D_{h_1}} + (E_{D_{20}} - E_{D_{h_1}}) \times \log(d / D_{h_1}) / \log(D_{20} / D_{h_1}) \quad \text{dB(μV/m)} \qquad \text{for} \quad D_{h_1} < d < D_{20} \tag{9b}$$

$$E = E'(1 - F_S) + E'' F_S \qquad \text{dB(μV/m)} \qquad \text{for} \quad d \ge D_{20} \tag{9c}$$

where:

E_{max}: maximum field strength at the required distance given in § A.2.1.2

$E_{D_{h_1}}$: E_{max} for distance D_{h_1} as given in § A.2.1.2

$E_{D_{20}} = E_{10}(D_{20}) + (E_{20}(D_{20}) - E_{10}(D_{20})) \log(h_1 / 10) / \log(20/10)$

$E_{10}(x)$: field strength for $h_1 = 10$ m interpolated for distance x (dB(μV/m))

$E_{20}(x)$: field strength for $h_1 = 20$ m interpolated for distance x (dB(μV/m))

$E' = E_{10}(d) + (E_{20}(d) - E_{10}(d)) \log(h_1/10) / \log(20/10)$ (dB(μV/m))

E'': field strength for distance d calculated using the method for land paths given above

$F_S = (d - D_{20}) / d$.

A.2.1.4.3 Negative values of transmitting/base antenna height, h_1

For land paths and mixed paths it is possible for the effective transmitting/base antenna height h_{eff} to have a negative value, since it is based on the average terrain height at distances from 3 km to 15 km. Thus h_1 may be negative.

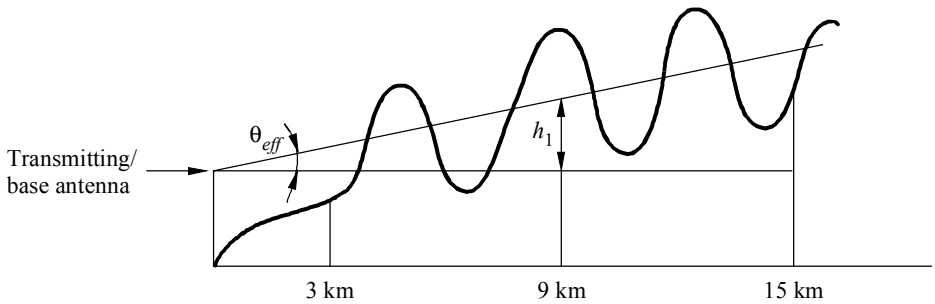
The procedure for negative values of h_1 is to obtain the field strength for $h_1 = 0$ as described in § A.2.1.4.2, and to calculate a correction based on the terrain clearance angle described in § A.2.1.10. The clearance angle is calculated as follows.

a) In cases where a terrain database is available, the terrain clearance angle from the transmitting/base antenna shall be calculated as the elevation angle of a line which just clears all terrain obstructions up to 15 km from the transmitting/base antenna in the direction of (but not going beyond) the receiving/mobile antenna. This clearance angle, which will have a positive value, shall be used instead of θ_{tca} in equation (23f) in the terrain clearance angle correction method given in § A.2.1.10 to obtain a correction, C_a which is added to the field strength obtained for $h_1 = 0$. It should be noted that using this method can result in a discontinuity in field strength at the transition around $h_1 = 0$.

b) In cases where a terrain database is not available, the (positive) effective terrain clearance angle, θ_{eff}, may be estimated assuming an obstruction of height h_1, calculated as in § A.2.1.3.1.1, at a distance of 9 km from the transmitting/base antenna. Note that this is used for all path lengths, even when less than 9 km. That is, the ground is regarded as approximating an irregular wedge over the range 3 km to 15 km from the transmitting/base antenna, with its mean value occurring at 9 km, as indicated in Fig. A.2.1-1. The value of θ_{eff} shall be used instead of θ_{tca} in equation (23f) in the terrain clearance angle correction method given in § 10 to obtain a correction, C_a, which is added to the field strength obtained for $h_1 = 0$. This correction is only to be applied if it results in a reduction of the field strength.

FIGURE A.2.1-1

Effective clearance angle for $h_1 < 0$



θ_{eff}: effective terrain clearance angle (positive)
h_1: transmitting/base antenna height used for calculation

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The effect of tropospheric loss can be taken into account by a correction, C_t, given by:

$$C_t = \max[C_a, C_{tropo}] \tag{10a}$$

where:

$$C_{tropo} = 30 \log\left[\frac{\theta_e}{\theta_e + \theta_{tca}}\right] \tag{10b}$$

and

$$\theta_e = \frac{180d}{a\pi k} \quad \text{degrees} \tag{10c}$$

with:

d: path length (km)

a: 6 370 km, radius of the Earth

k: 4/3, effective Earth radius factor for median refractivity conditions.

It is assumed that θ_{tca} has the value of 0.0 for an effective height of 0 m.

A.2.1.5 Interpolation of field strength as a function of distance

The Figures in Annex 2.3 show field strength plotted against distance, d, between 1 km and 1 000 km. No interpolation for distance is needed if field strengths are read directly from these curves. For greater precision, and for computer implementation, field strengths should be obtained from the associated tabulations (available from the BR). In this case, unless d coincides with one of the tabulation distances given in Table A.2.1-1, the field strength, E (dB(μV/m)), shall be linearly interpolated for the logarithm of the distance using equation (11):

$$E = E_{inf} + (E_{sup} - E_{inf}) \log (d / d_{inf}) / \log (d_{sup} / d_{inf}) \quad \text{dB(μV/m)} \tag{11}$$

where:

d: distance for which the prediction is required (km)

d_{inf}: nearest tabulation distance less than d (km)

d_{sup}: nearest tabulation distance greater than d (km)

E_{inf}: field strength value for d_{inf} (dB(μV/m))

E_{sup}: field strength value for d_{sup} (dB(μV/m)).

This propagation prediction method is not valid for values of d less than 1 km or greater than 1 000 km.

TABLE A.2.1-1

Values of distance (km) used in the tables of field strengths

1	14	55	140	375	700
2	15	60	150	400	725
3	16	65	160	425	750
4	17	70	170	450	775
5	18	75	180	475	800
6	19	80	190	500	825
7	20	85	200	525	850
8	25	90	225	550	875
9	30	95	250	575	900
10	35	100	275	600	925
11	40	110	300	625	950
12	45	120	325	650	975
13	50	130	350	675	1 000

A.2.1.6 Interpolation of field strength as a function of frequency

Field-strength values for a given required frequency shall be obtained by interpolating between the values for the nominal frequency values of 100 MHz, 600 MHz and 2 000 MHz. The required field strength, E, shall be calculated using:

$$E = E_{inf} + (E_{sup} - E_{inf}) \log(f / f_{inf}) / \log(f_{sup} / f_{inf}) \quad \text{dB(µV/m)} \qquad (12)$$

where:

f: frequency for which the prediction is required (MHz)

f_{inf}: lower nominal frequency (100 MHz if f < 600 MHz, 600 MHz otherwise)

f_{sup}: higher nominal frequency (600 MHz if f < 600 MHz, 2 000 MHz otherwise)

E_{inf}: field strength value for f_{inf} (dB(µV/m))

E_{sup}: field strength value for f_{sup} (dB(µV/m)).

A.2.1.7 Interpolation of field strength as a function of percentage time

Field strength values for a required percentage of the time between 1% and 50% shall be calculated by interpolation between the nominal values 1% and 10% or between the nominal values 10% and 50% using:

$$E = E_{sup} (Q_{inf} - Q_t) / (Q_{inf} - Q_{sup}) + E_{inf}(Q_t - Q_{sup}) / (Q_{inf} - Q_{sup}) \quad \text{dB(µV/m)} \qquad (13)$$

where:

$Q_t = Q_i(t/100)$

$Q_{inf} = Q_i(t_{inf}/100)$

$Q_{sup} = Q_i(t_{sup}/100)$

E_{inf}: field strength value for time percentage t_{inf} (dB(μV/m))

E_{sup}: field strength value for time percentage t_{sup} (dB(μV/m))

t: percentage of the time for which the prediction is required

t_{inf}: lower nominal percentage time

t_{sup}: upper nominal percentage time

where $Q_i(x)$ is the inverse complementary cumulative normal distribution function.

This propagation prediction method shall be used for field strengths exceeded for percentage times in the range 1% to 50% only. Extrapolation outside the range 1% to 50% time is not valid.

A method for the calculation of $Q_i(x)$ is given in § A.2.1.12.

A.2.1.8 Mixed paths

When paths occur over different propagation zones, e.g. land, sea, areas of different refractivity, the method given below shall be used for the following conditions:

a) for all frequencies and all percentages of the time and for those combinations of propagation zone which do not involve any land/sea or land/coastal land transitions, the following procedure for calculating the field strength shall be used:

$$E_{m,t} = \sum_i \frac{d_i}{d_T} E_{i,t} \tag{14}$$

where:

$E_{m,t}$: field strength for mixed path for t% of the time (dB(μV/m))

$E_{i,t}$: field strength for path in zone i equal in length to the mixed path for t% of the time (dB(μV/m))

d_i: length of path in zone i (km)

d_T: length of total path (km);

b) for all frequencies and all percentages of time and for those combinations of propagation zone which involve only a single land propagation category and a single sea or coastal land propagation category, the following procedure for calculating the field strength shall be used:

$$E_{m,t} = (1 - A) \cdot E_{l,t} + A \cdot E_{s,t} \tag{15a}$$

where:

$E_{m,t}$: field strength for mixed path for t% of the time (dB(μV/m))

$E_{l,t}$: field strength for land path equal in length to the mixed path for t% of the time (dB(μV/m))

$E_{s,t}$: field strength for sea or coastal land path equal in length to the mixed path for t% of the time (dB(μV/m))

A : interpolation factor as given in § A.2.1.8.1;

c) for all frequencies and all percentages of time and for those combinations of three or more propagation zones which involve at least one land/sea or land/coastal land boundary, the following procedure for calculating the field strength shall be used:

$$E_{m,t} = \{1 - A\} \cdot \frac{\sum_{i=1}^{n_l} d_i E_{li,t}}{d_{lT}} + A \cdot \frac{\sum_{j=1}^{n_s} d_j E_{sj,t}}{d_{sT}} \qquad (15b)^*$$

where:

$E_{m,t}$: field strength for mixed path for t% of the time (dB(μV/m))

$E_{li,t}$: field strength for land path i equal in length to the mixed path for t% of the time, $i = 1, ..., n_l$; n_l is the number of land zones traversed (dB(μV/m))

$E_{sj,t}$: field strength for sea or coastal land path j equal in length to the mixed path for t% of the time, $j = 1, ..., n_s$; n_s is the number of sea and coastal land zones traversed (dB(μV/m))

A: interpolation factor as given in § A.2.1.8.1 (note that the "Fraction of path over sea" is calculated as: d_{sT} / d_T)

d_i, d_j: length of path in zones i, j (km)

d_{lT}: length of total land path $= \sum_{i=1}^{n_l} d_i$ (km)

* Note that equation (15b) reduces to equation (15a) in the case of mixed propagation paths which involve only a single land propagation category and a single sea or coastal land propagation category.

d_{sT}: length of total sea and coastal land path $= \sum_{j=1}^{n_s} d_j$ (km)

d_T: length of total propagation path $= d_{lT} + d_{sT}$ (km)

A.2.1.8.1 The mixed path interpolation factor, *A*

The fraction of path over sea, F_s, used in Fig. A.2.1-2 is given by:

$$F_s = \frac{d_{sT}}{d_T} \tag{16}$$

where:

d_{sT}: length of total sea and coastal land path (km)

d_T: length of total propagation path (km)

The interpolation factor[1], A, is given by:

$$A = F_s^V \tag{17}$$

The procedure to calculate V begins by deriving a field strength value for a given segment of the propagation path from the value obtained by assuming that that zone type extends over the whole path:

$$E_n(d_n) = E_n(d_T)\frac{d_n}{d_T} \qquad \text{dB(µV/m)} \tag{18}$$

where:

n: zone number

d_n: distance in zone type n (km)

d_T: total path length (km)

$E_n(d_n)$: field strength value for distance d_n in zone type n (dB(µV/m))

$E_n(d_T)$: field strength value for distance d_T assumed to be all of zone type n (dB(µV/m)).

The field strength values for the individual land segments, $E_{ln}(d_{ln})$, are summed and the field strength values for the individual sea segments, $E_{sn}(d_{sn})$, are summed and each is divided by the fraction of the path over land and sea, respectively. The weighted difference, Δ, between these two summed results is given by:

---

[1] The interpolation factor is applied to all frequencies and to all time percentages. It must be noted that the interpolation is only applied to land-sea paths and not to land-land or sea-sea paths.

$$\Delta = \left\{ \frac{\sum_{n=1}^{N_s} E_{sn}}{\frac{d_{sT}}{d_T}} - \frac{\sum_{n=1}^{N_l} E_{ln}}{\frac{d_{lT}}{d_T}} \right\} \tag{19}$$

where:

E_{sn}: n-th sea section field strength value (dB(μV/m))

E_{ln}: n-th land section field strength value (dB(μV/m))

N_s and N_l: number of sea and land sections respectively

d_{sT} and d_{lT}: total sea and land path length respectively (km)

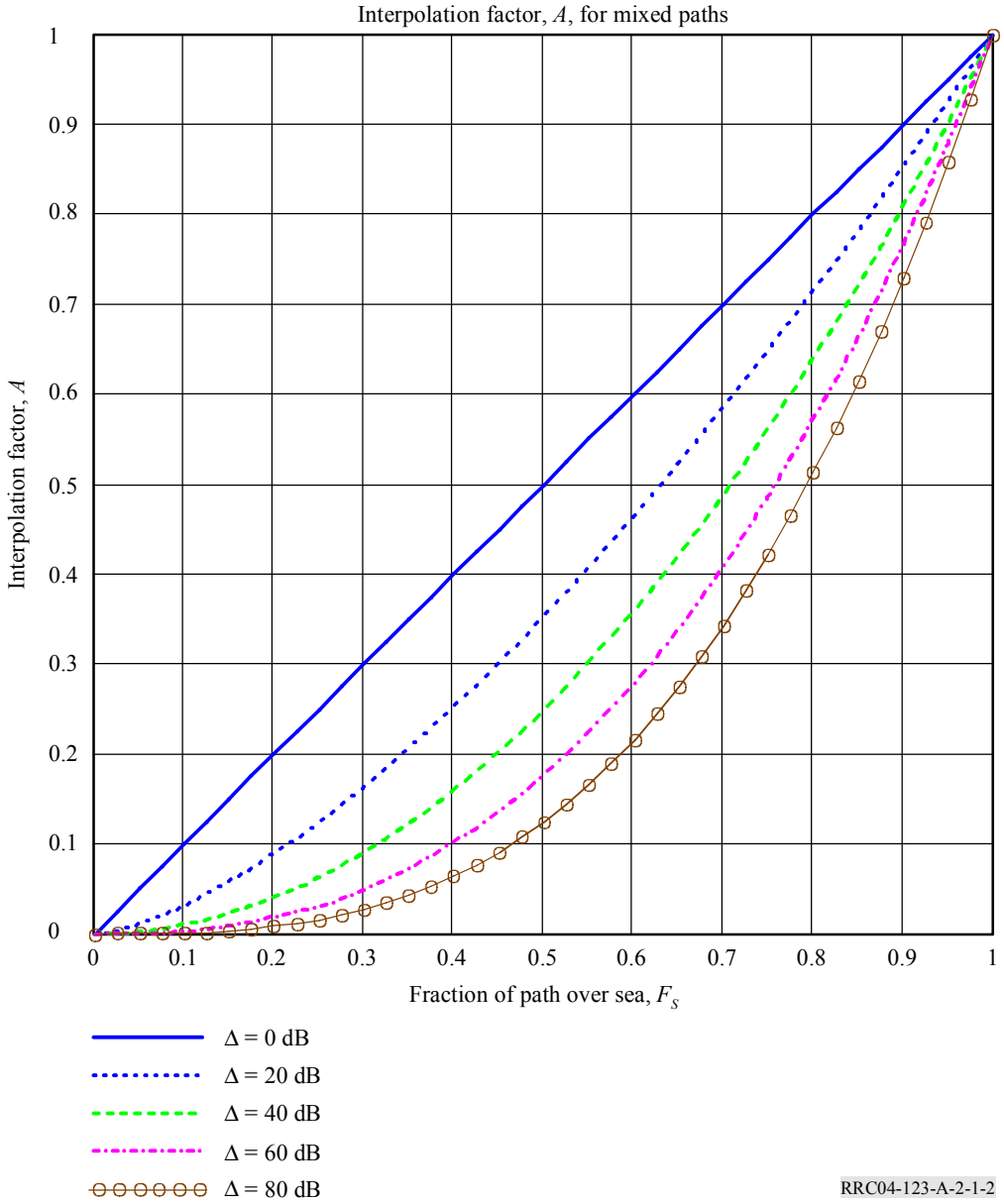
V is calculated using the expression:

$$V = \max\left[1.0, 1.0 + \frac{\Delta}{40.0}\right] \tag{20}$$

Figure A.2.1-2 shows $A(F_s)$ for various values of Δ.

FIGURE A.2.1-2

The mixed path interpolation factor, *A*, as a function of the fraction of path over sea, F_S, for various values of the weighted difference of sea and land field strengths, Δ



A.2.1.9 Correction for receiving/mobile antenna height

The field-strength values given by the land curves and associated tabulations in this propagation prediction method are for a reference receiving/mobile antenna at a height, R (m), representative of the height of the ground cover surrounding the receiving/mobile antenna, subject to a minimum height value of 10 m. For open and suburban area and also for sea paths the notional value of R is 10 m.

Where the site of the receiving/mobile antenna is on land, account shall first be taken of the elevation angle of the arriving ray by calculating a modified representative clutter height R' (m), given by:

$$R' = (1\,000\, d\, R - 15\, h_1)/(1\,000\, d - 15) \qquad \text{m} \qquad (21)$$

where h_1 and R are given in metres and the distance d is in kilometres.

Note that for $h_1 < 6.5d + R$, $R' \approx R$.

The value of R' must be limited, if necessary, such that it is not less than 1 m.

When the receiving/mobile antenna is in either a suburban or urban environment the correction is then given by:

$$\text{Correction} = 6.03 - J(\nu) \qquad \text{dB} \qquad \text{for } h_2 < R' \qquad (22a)$$

$$= K_{h_2} \log (h_2 / R') \qquad \text{dB} \qquad \text{for } h_2 \geq R' \qquad (22b)$$

where $J(\nu)$ is given by equation (23d),

and:

$$\nu = K_{nu} \sqrt{h_{dif} \theta_{clut}} \qquad (22c)$$

$$h_{dif} = R' - h_2 \qquad \text{m} \qquad (22d)$$

$$\theta_{clut} = \arctan (h_{dif} / 27) \qquad \text{degrees} \qquad (22e)$$

$$K_{h_2} = 3.2 + 6.2 \log (f) \qquad (22f)$$

$$K_{nu} = 0.0108 \sqrt{f} \qquad (22g)$$

f: required frequency (MHz).

Where the receiving/mobile antenna is on land in a rural or open environment, the correction is given by equation (22b) for all values of h_2.

Where the site of the receiving/mobile antenna is on the sea for $h_2 \geq 10$ m, the correction shall be calculated using equation (22b) with R' set to 10 m.

Where the site of the receiving/mobile antenna is on the sea for $h_2 < 10$ m, an alternative method shall be used, based upon the path lengths at which 0.6 of the first Fresnel zone is just clear of obstruction by the sea surface. An approximate method for calculating this distance is given in § A.2.1.14.

The distance, d_{10}, at which the path would just have 0.6 Fresnel clearance for the required value of h_1 and for $h_2 = 10$ m shall be calculated as $D_{06}(f, h_1, 10)$ in § A.2.1.14.

If the required distance is equal to or greater than d_{10}, then again the correction for the required value of h_2 shall be calculated using equation (22b) with R' set to 10 m.

If the required distance is less than d_{10}, then the correction to be added to the field strength E shall be calculated using:

$$\text{Correction} = 0.0 \quad \text{dB} \qquad \text{for} \quad d \le d_{h_2} \tag{22h}$$

$$= C_{10} \times \log(d / d_{h_2}) / \log(d_{10} / d_{h_2}) \,\text{dB} \qquad \text{for } d_{h_2} < d < d_{10} \tag{22j}$$

where:

C_{10}: correction for the required value of h_2 at distance d_{10} using equation (22b) with R' set to 10 m

d_{10}: distance at which the path just has 0.6 Fresnel clearance for $h_2 = 10$ m calculated as $D_{06}(f, h_1, 10)$ as given in § A.2.1.14

d_{h_2} : distance at which the path just has 0.6 Fresnel clearance for the required value of h_2 calculated as $D_{06}(f, h_1, h_2)$ as given in § A.2.1.14.

This correction shall not be used for receiving/mobile antenna heights, h_2, less than 1 m when the receiving site is on land or less than 3 m when on the sea.

A.2.1.10 Correction for terrain clearance angle

For land paths, and when the receiving/mobile antenna is on a land section of a mixed path, if greater precision is required for predicting the field strength for reception conditions in specific areas, e.g. in a small reception area, a correction may be made based on a terrain clearance angle. The terrain clearance angle, θ_{tca}, is given by:

$$\theta_{tca} = \theta - \theta_r \qquad \text{degrees} \tag{23a}$$

where θ is measured relative to the line from the receiving/mobile antenna which just clears all terrain obstructions in the direction of the transmitter/base antenna over a distance of up to 16 km but not going beyond the transmitting/base antenna. It is measured relative to the horizontal at the receiving/mobile antenna, being positive if the clearance line is above the horizontal. This is shown in Fig. A.2.1-3.

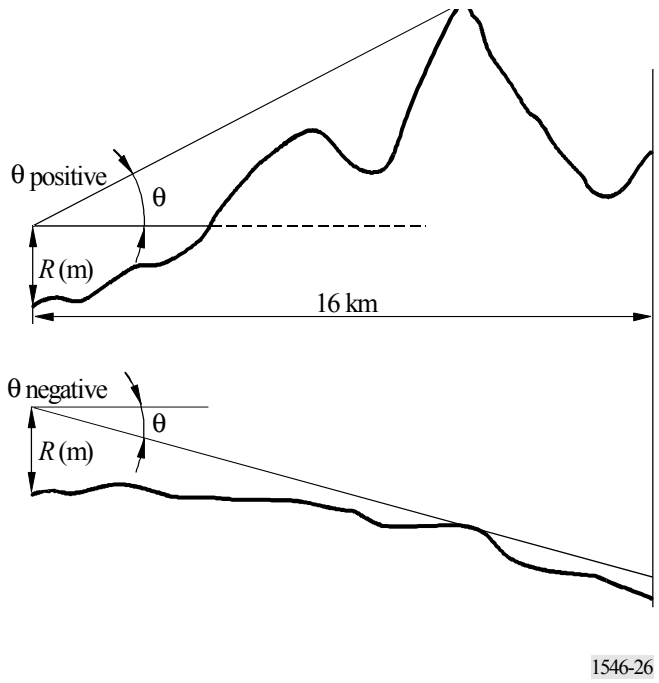
The reference angle θ_r is given by:

$$\theta_r = \arctan\left(\frac{h_{1s} - h_{2s}}{1\,000d}\right) \qquad \text{degrees} \tag{23b}$$

where h_{1s} and h_{2s} are the height of transmitting/base and receiving/mobile antennas above sea level respectively.

FIGURE A.2.1-3

Terrain clearance angle



Where the relevant terrain clearance angle information is available, the correction to be added to the field strength is calculated using:

$$\text{Correction} = J(\nu') - J(\nu) \quad \text{dB} \tag{23c}$$

where $J(\nu)$ is given by:

$$J(\nu) = \left[6.9 + 20\log\left((\sqrt{(\nu - 0.1)^2 + 1} + \nu - 0.1\right)\right] \tag{23d}$$

$$\nu' = 0.036\sqrt{f} \tag{23e}$$

$$\nu = 0.065\,\theta_{tca}\sqrt{f} \tag{23f}$$

θ_{tca}: terrain clearance angle (degrees)

f: required frequency (MHz).

The correction is valid for clearance angle, θ_{tca}, in the range +0.55° to +40°.

The correction for θ_{tca} < +0.55° is the same as for θ_{tca} = +0.55°.

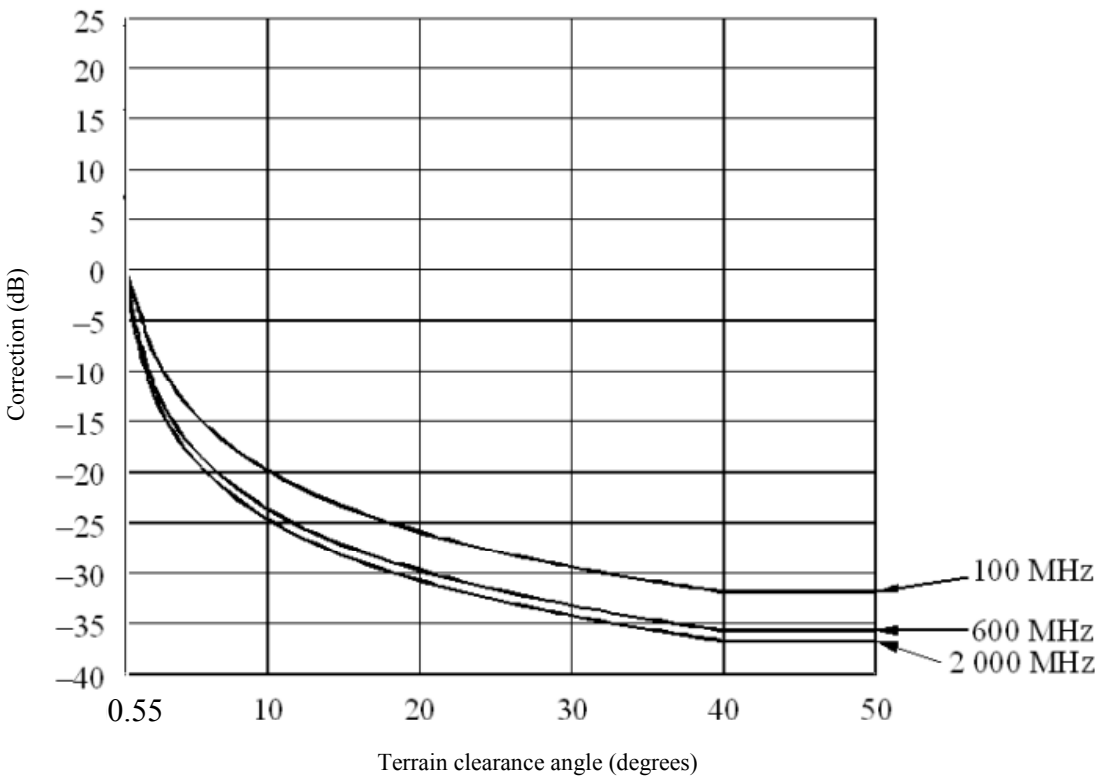
The correction for θ_{tca} > +40° is the same as for θ_{tca} = +40°.

It should be noted that the land field strength curves take account of losses due to typical shielding of the receiving/mobile antenna by gently rolling terrain. Thus the terrain clearance angle corrections are zero at a small positive angle typical of receiving/mobile antenna positions.

Figure A.2.1-4 illustrates the terrain clearance angle correction for the nominal frequencies.

FIGURE A.2.1-4

Terrain clearance angle correction



A.2.1.11 Location variability in land area-coverage prediction

For receiving/mobile antenna locations on land the field strength E which will be exceeded for q% of locations is given by:

$$E(q) = E\ (\text{median}) + Q_i(q\ /\ 100)\ \sigma_L(f) \quad \text{dB}(\mu\text{V/m}) \tag{24}$$

where:

$Q_i(x)$: inverse complementary cumulative normal distribution as a function of probability

σ_L: standard deviation of the Gaussian distribution of the local means in the study area.

Values of standard deviation for digital systems having a bandwidth less than 1 MHz and for analogue systems are given as a function of frequency by:

$$\sigma_L = K + 1.6 \log(f) \quad \text{dB} \tag{25}$$

where:

K = 2.1 for mobile systems in urban locations

= 3.8 for mobile systems in suburban locations or amongst rolling hills

= 5.1 for analogue broadcasting systems

f: required frequency (MHz).

For digital systems having a bandwidth of 1 MHz or greater, a standard deviation of 5.5 dB shall be used at all frequencies.

The percentage of locations q can vary between 1% and 99%. This propagation prediction method shall not be used for percentage locations less than 1% or greater than 99%.

The location variability correction is not to be applied when the receiver/mobile location is on the sea.

A.2.1.12 An approximation to the inverse complementary cumulative normal distribution function

The following approximation to the inverse complementary cumulative normal distribution function, $Q_i(x)$, is valid for $0.01 \le x \le 0.99$:

$$Q_i(x) = T(x) - \xi(x) \qquad \text{if } x \le 0.5 \tag{26a}$$

$$Q_i(x) = -\ \{\ T(1-x) - \xi(1-x)\ \} \qquad \text{if } x > 0.5 \tag{26b}$$

where:

$$T(x) = \sqrt{[-2 \ln(x)]} \tag{26c}$$

$$\xi(x) = \frac{[(C_2 \cdot T(x) + C_1) \cdot T(x)] + C_0}{[(D_3 \cdot T(x) + D_2) \cdot T(x) + D_1] \cdot T(x) + 1} \tag{26d}$$

$$C_0 = 2.515517$$

$$C_1 = 0.802853$$

$$C_2 = 0.010328$$

$$D_1 = 1.432788$$

$$D_2 = 0.189269$$

$$D_3 = 0.001308$$

Values given by the above equations are given in Table A.2.1-2.

TABLE A.2.1-2

Approximate inverse complementary cumulative normal distribution values

q%	$Q_i(q/100)$	q%	$Q_i(q/100)$	q%	$Q_i(q/100)$	q%	$Q_i(q/100)$
1	2.327	26	0.643	51	–0.025	76	–0.706
2	2.054	27	0.612	52	–0.050	77	–0.739
3	1.881	28	0.582	53	–0.075	78	–0.772
4	1.751	29	0.553	54	–0.100	79	–0.806
5	1.645	30	0.524	55	–0.125	80	–0.841
6	1.555	31	0.495	56	–0.151	81	–0.878
7	1.476	32	0.467	57	–0.176	82	–0.915
8	1.405	33	0.439	58	–0.202	83	–0.954
9	1.341	34	0.412	59	–0.227	84	–0.994
10	1.282	35	0.385	60	–0.253	85	–1.036
11	1.227	36	0.358	61	–0.279	86	–1.080
12	1.175	37	0.331	62	–0.305	87	–1.126
13	1.126	38	0.305	63	–0.331	88	–1.175
14	1.080	39	0.279	64	–0.358	89	–1.227
15	1.036	40	0.253	65	–0.385	90	–1.282
16	0.994	41	0.227	66	–0.412	91	–1.341
17	0.954	42	0.202	67	–0.439	92	–1.405
18	0.915	43	0.176	68	–0.467	93	–1.476
19	0.878	44	0.151	69	–0.495	94	–1.555
20	0.841	45	0.125	70	–0.524	95	–1.645
21	0.806	46	0.100	71	–0.553	96	–1.751
22	0.772	47	0.075	72	–0.582	97	–1.881
23	0.739	48	0.050	73	–0.612	98	–2.054
24	0.706	49	0.025	74	–0.643	99	–2.327
25	0.674	50	0.000	75	–0.674		

A.2.1.13 Equivalent basic transmission loss

When required, the basic transmission loss equivalent to a given field strength is given by:

$$L_b = 139 - E + 20 \log f \quad \text{dB} \tag{27}$$

where:

L_b: basic transmission loss (dB)

E: field strength (dB(μV/m)) for 1 kW ERP (dB(μV/m))

f: required frequency (MHz).

A.2.1.14 An approximation of the 0.6 Fresnel clearance path length

The path length which just achieves a clearance of 0.6 of the first Fresnel zone over a smooth curved Earth, for a given frequency and antenna heights h_1 and h_2, is given approximately by:

$$D_{06}(f, h_1, h_2) = \frac{D_f \cdot D_h}{D_f + D_h} \quad \text{km} \tag{28}$$

where:

D_f: frequency-dependent term

$$= 0.0000389\, f\, h_1 h_2 \quad \text{km} \tag{28a}$$

D_h: asymptotic term defined by horizon distances

$$= 4.1(\sqrt{h_1} + \sqrt{h_2}) \quad \text{km} \tag{28b}$$

f: required frequency (MHz)

h_1, h_2: antenna heights above smooth Earth (m).

In the above equations, the value of h_1 must be limited, if necessary, such that it is not less than zero. Moreover, the resulting value of D_{06} must be limited, if necessary, such that it is not less than 0.001 km.

A.2.1.15 Procedure for the application of this propagation prediction method

The step-by-step procedure given below is intended to be applied to values derived from the field strength versus distance tables (see Annex 2.2). It may, however, also be applied to values obtained from the curves, in which case the distance interpolation procedure of Step 8.1.5 is not needed.

Step 1: Determine the type of the propagation path as land, cold sea or warm sea. If the path is mixed then determine two path types which are regarded as first and second propagation types. If the path can be represented by a single type then this is regarded as the first propagation type and the mixed-path method given in Step 11 is not required.

Step 2: For any given percentage of time (in the range 1% to 50%), determine two nominal time percentages as follows:

– if the required percentage of the time is > 1% and < 10%, the lower and higher nominal percentages are 1% and 10%, respectively;

– if the required percentage of the time > 10% and < 50%, the lower and higher nominal percentages are 10% and 50%, respectively.

If the required percentage of time is equal to 1% or 10% or 50%, this value shall be regarded as the lower nominal percentage time and the interpolation process of Step 10 is not required.

Step 3: For any required frequency (in the range 174 to 862 MHz) determine two nominal frequencies as follows:

– where the required frequency < 600 MHz, the lower and higher nominal frequencies are 100 and 600 MHz, respectively;

– where the required frequency > 600 MHz, the lower and higher nominal frequencies are 600 and 2 000 MHz, respectively.

If the required frequency equals 100 or 600 MHz, this value shall be regarded as the lower nominal frequency and the interpolation process of Step 9 is not required.

Step 4: Determine the lower and higher nominal distances from Table A.2.1-1 closest to the required distance. If the required distance coincides with a value in Table A.2.1-1, this shall be regarded as the lower nominal distance and the interpolation process of Step 8.1.5 is not required.

Step 5: For the first propagation type follow Steps 6 to 10.

Step 6: For the lower nominal percentage time follow Steps 7 to 9.

Step 7: For the lower nominal frequency follow Step 8.

Step 8: Obtain the field strength exceeded at 50% locations for a receiving/mobile antenna at the height of representative clutter, R, above ground for the required distance and transmitting/base antenna height as follows:

Step 8.1: For a transmitting/base antenna height h_1 equal to or greater than 10 m, follow Steps 8.1.1 to 8.1.5:

Step 8.1.1: Determine the lower and higher nominal h_1 values using the method given in § A.2.1.4.1. If h_1 coincides with one of the nominal values 10, 20, 37.5, 75, 150, 300, 600 or 1 200 m, this shall be regarded as the lower nominal value of h_1 and the interpolation process of Step 8.1.6 is not required.

Step 8.1.2: For the lower nominal value of h_1 follow Steps 8.1.3 to 8.1.5.

Step 8.1.3: For the lower nominal value of distance follow Step 8.1.4.

Step 8.1.4: Obtain the field strength exceeded at 50% locations for a receiving/mobile antenna at the height of representative clutter, R, for the required values of distance, d, and transmitting/base antenna height, h_1.

Step 8.1.5: If the required distance does not coincide with the lower nominal distance, repeat Step 8.1.4 for the higher nominal distance and interpolate the two field strengths for distance using the method given in § A.2.1.5.

Step 8.1.6: If the required transmitting/base antenna height, h_1, does not coincide with one of the nominal values, repeat Steps 8.1.3 to 8.1.5 and interpolate/extrapolate for h_1 using the method given in § A.2.1.4.1. If necessary, limit the result to the maximum given in § A.2.1.2.

Step 8.2: For a transmitting/base antenna height h_1 less than 10 m, determine the field strength for the required height and distance using the method given in § A.2.1.4.2. If h_1 is less than zero, the method given in § A.2.1.4.3 shall also be used.

Step 9: If the required frequency does not coincide with the lower nominal frequency, repeat Step 8 for the higher nominal frequency and interpolate the two field strengths using the method given in § A.2.1.6. If necessary, limit the result to the maximum field strength as given in § A.2.1.2.

Step 10: If the required percentage of the time does not coincide with the lower nominal percentage time, repeat Steps 7 to 9 for the higher nominal percentage of the time and interpolate the two field strengths using the method given in § A.2.1.7.

Step 11: If the prediction is for a mixed path, follow the procedure given in § A.2.1.8.

Step 12: Correct the field strength for receiving/mobile antenna height h_2 using the method given in § A.2.1.9.

Step 13: If information on the terrain clearance angle at a receiving/mobile antenna location on land is available, correct the field strength for terrain clearance angle at the receiver/mobile using the method given in § A.2.1.10.

Step 14: If the field strength at a receiving/mobile antenna location on land exceeded at a percentage of locations other than 50% is required, correct the field strength for the required percentage of locations using the method given in § A.2.1.11.

Step 15: If necessary limit the resulting field strength to the maximum given in § A.2.1.2.

Step 16: If required, convert field strength to equivalent basic transmission loss for the path using the method given in § A.2.1.13.

ANNEX 2.2

Tabulated values of field strength

Values of field strength (dB(μV/m)) against distance (km) corresponding to the family of propagation curves given in Annex 2.3 are provided in tabulated form and may be accessed from the ITU web page at:

http://www.itu.int/ITU-R/conferences/rrc/rrc-04/index.asp

The detailed instructions for interpolation of these tabulated values are provided in § A.2.1.5, A.2.1.6 and A.2.1.7 of Annex 2.1.

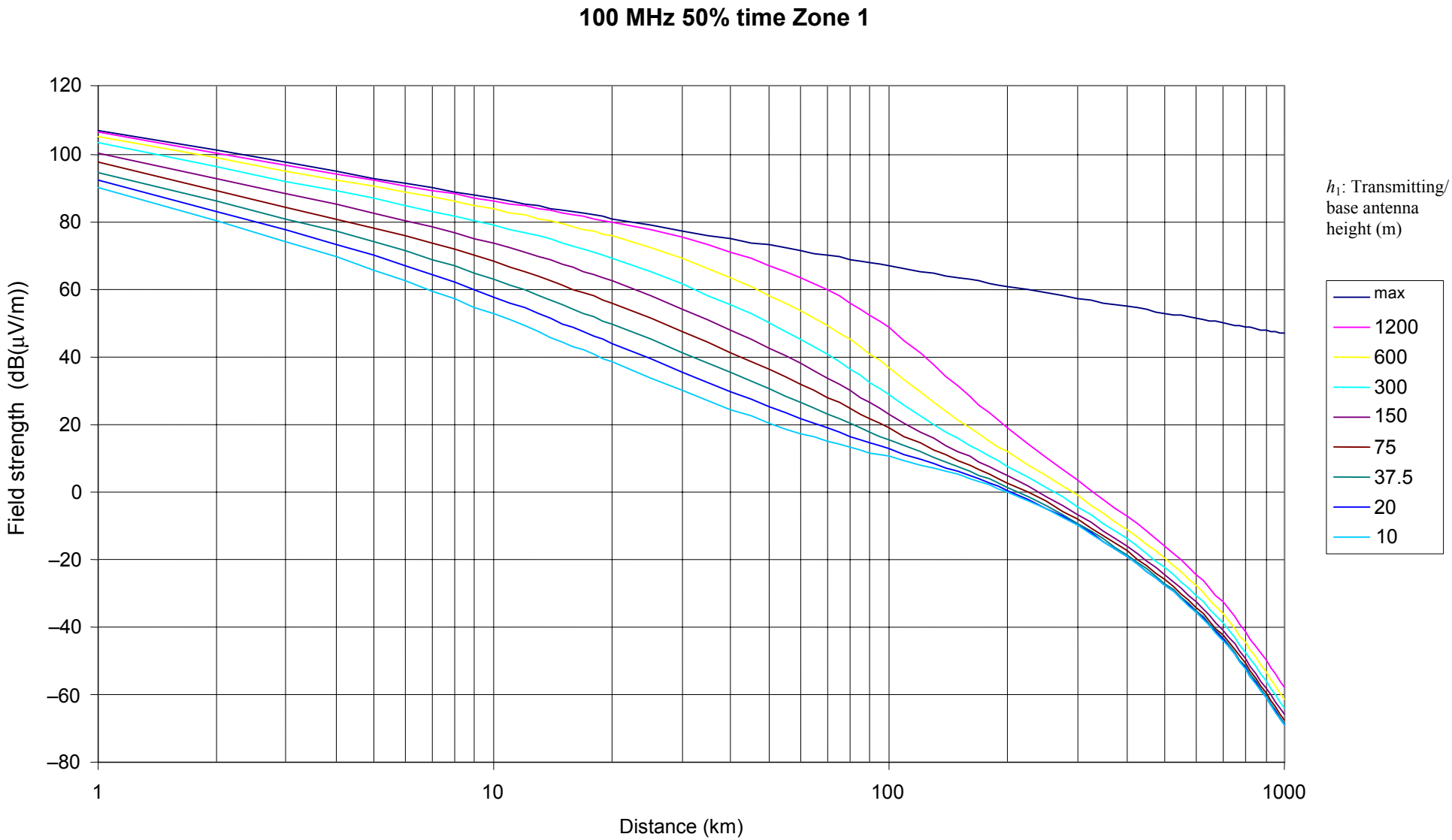
ANNEX 2.3

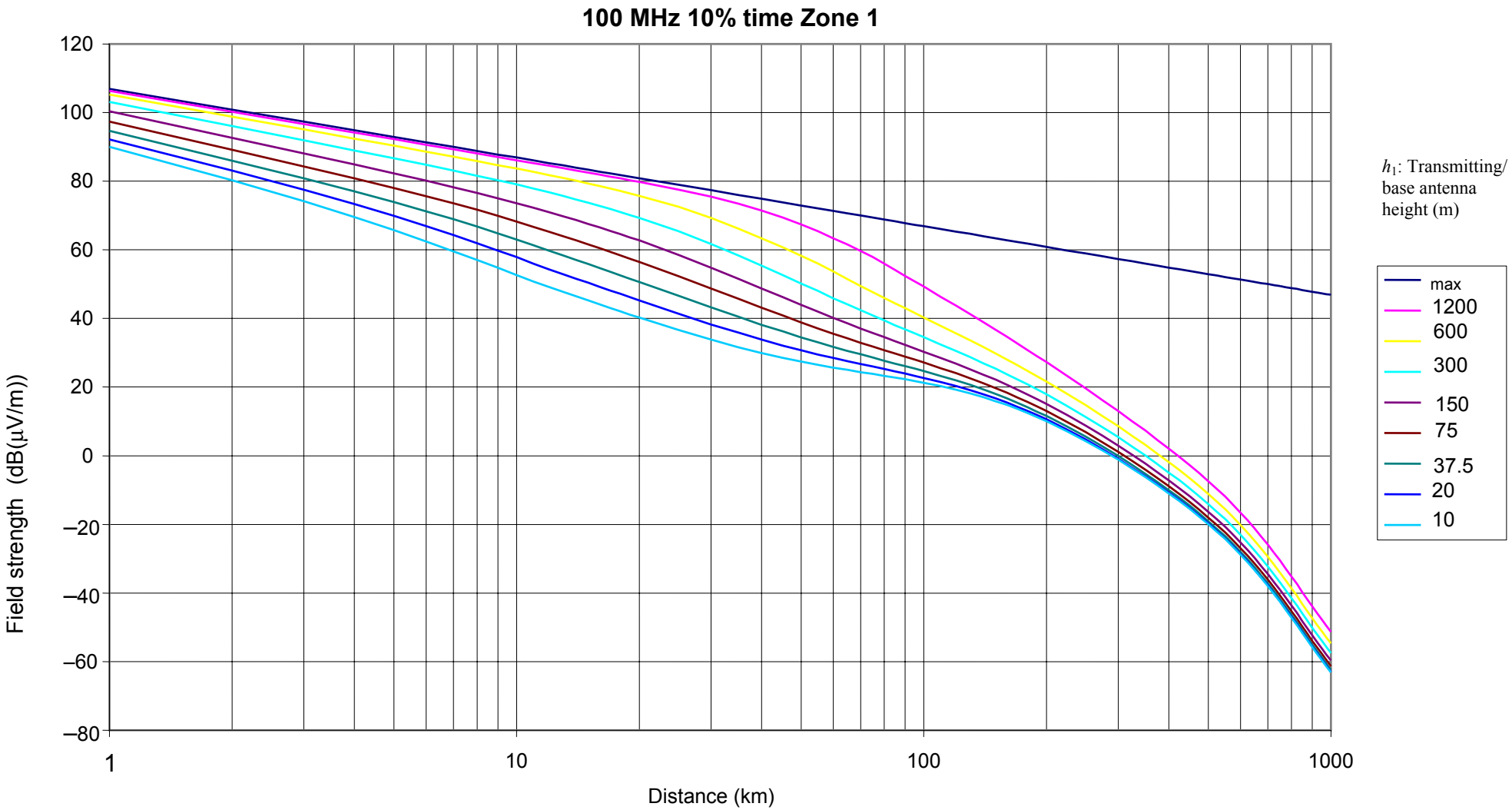
Propagation curves

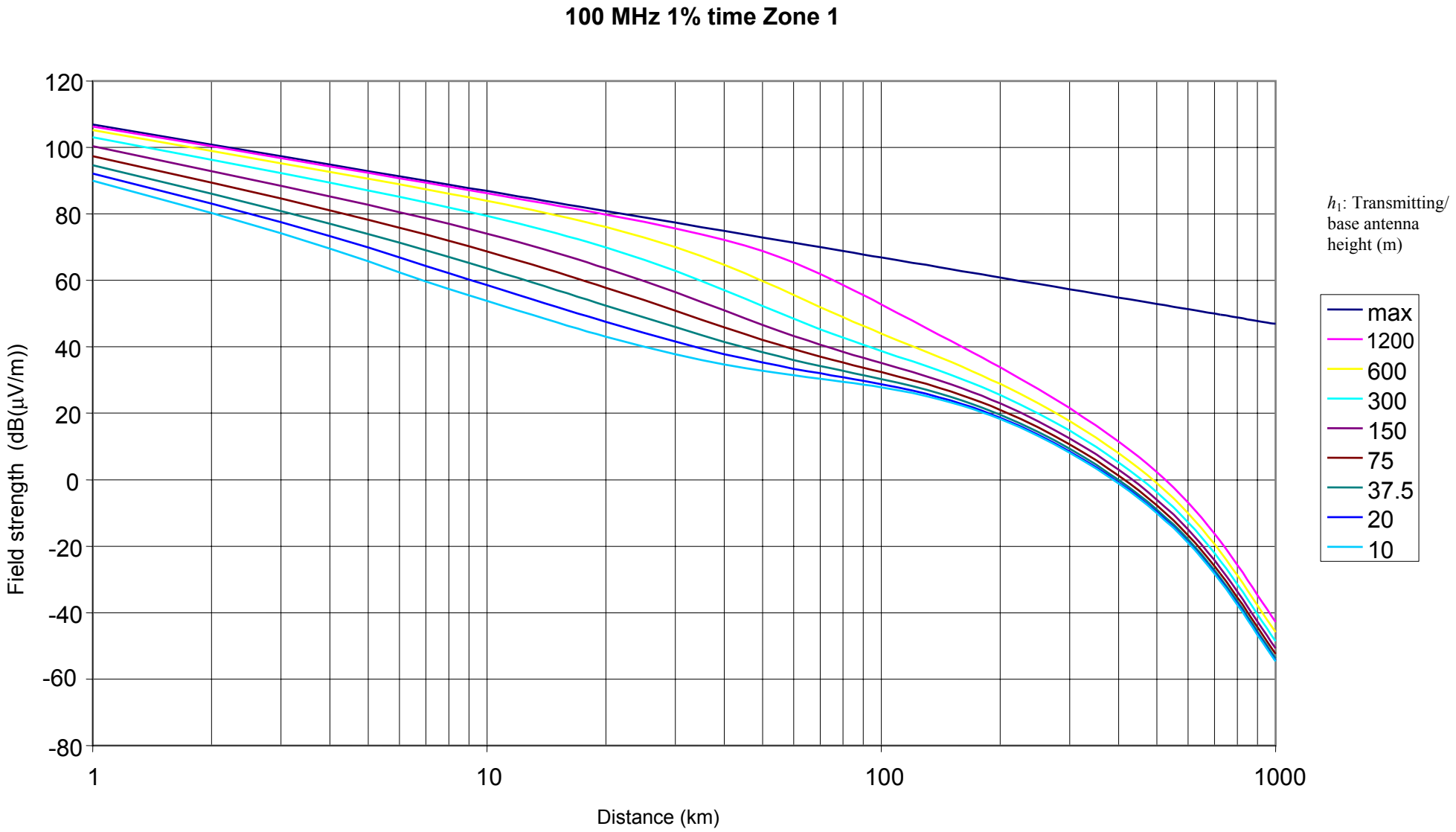
The propagation curves shown in the figures are used, together with the map shown in § 2.2.2, for the planning of the broadcasting service. They give, on the basis of statistics derived from measurement results, and also of theoretical considerations, the field-strength value exceeded for 50% of locations for time percentages of 50%, 10% and 1%.

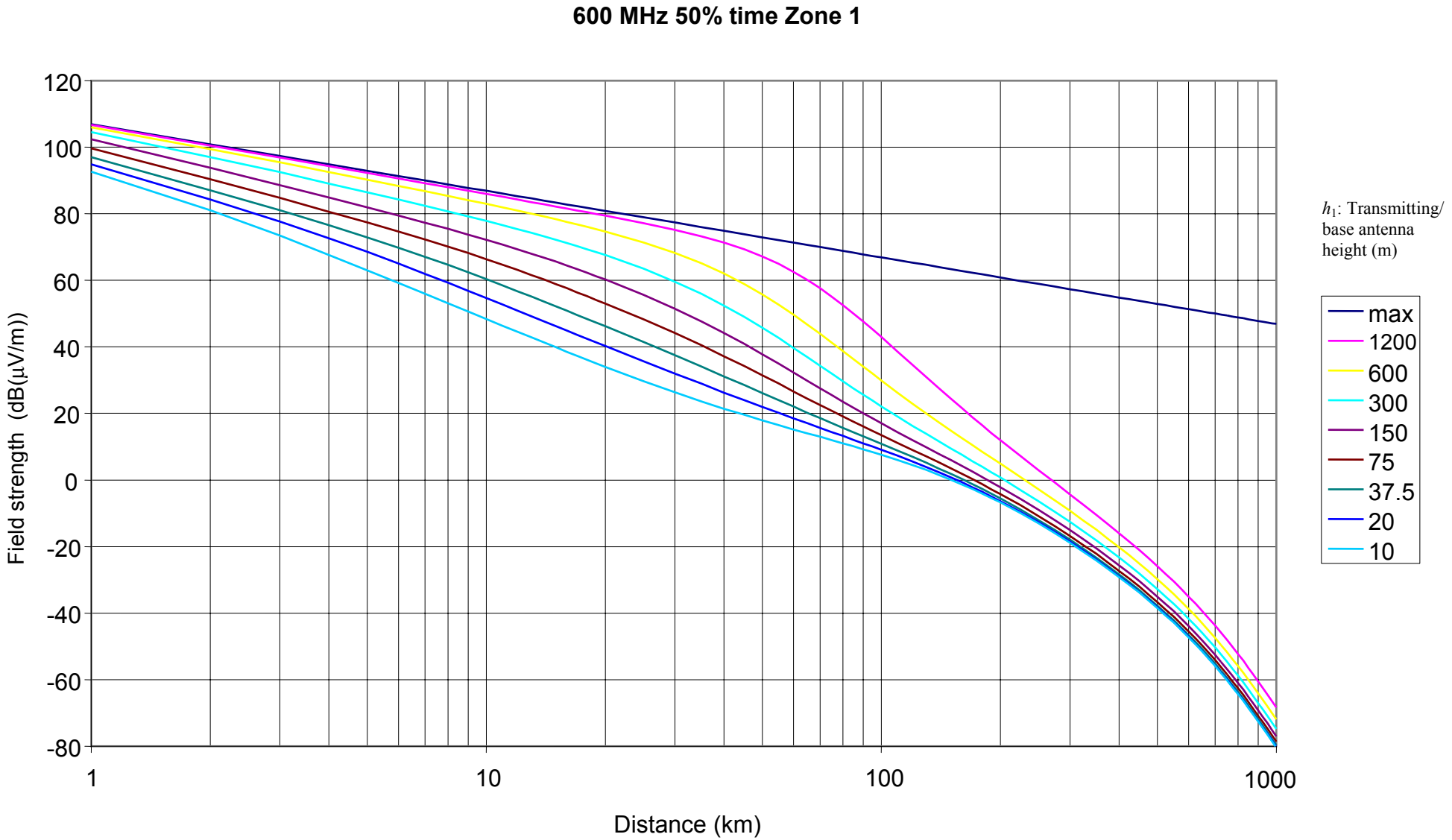
The values obtained correspond to a receiving antenna height of 10 m over local ground in open area. The values are expressed in decibels relative to 1 μV/m (dB(μV/m)) for an e.r.p. of 1 kW in the direction of the reception point. The curves give the values of the field strength exceeded at 50% of locations and each figure corresponds to time percentages of 50%, 10% and 1% for each of the geographical zones.

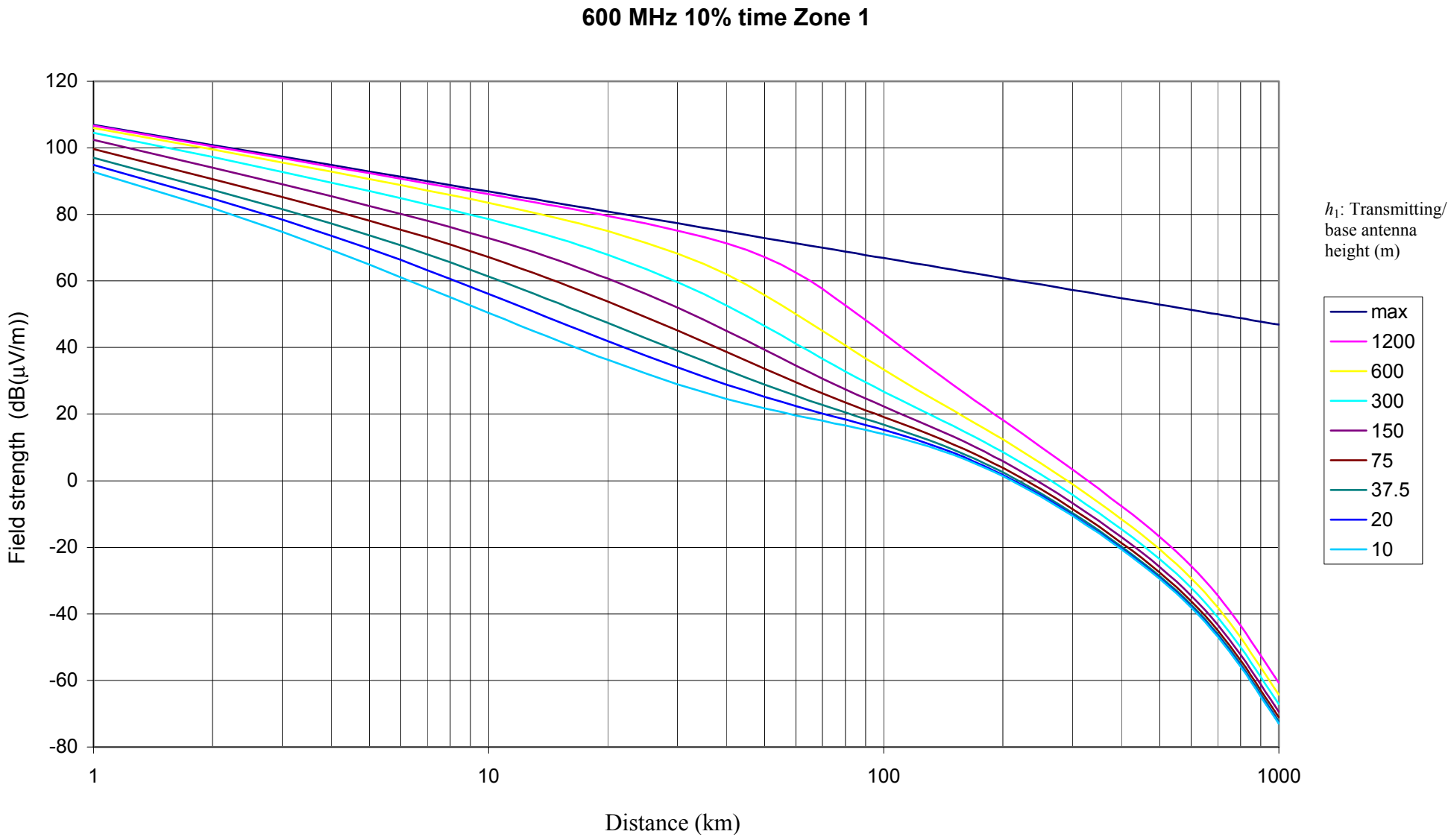
The data are given for various types of areas and climates, namely land, cold sea, warm sea, and areas subject to extreme superrefractivity (see § 2.2.2).

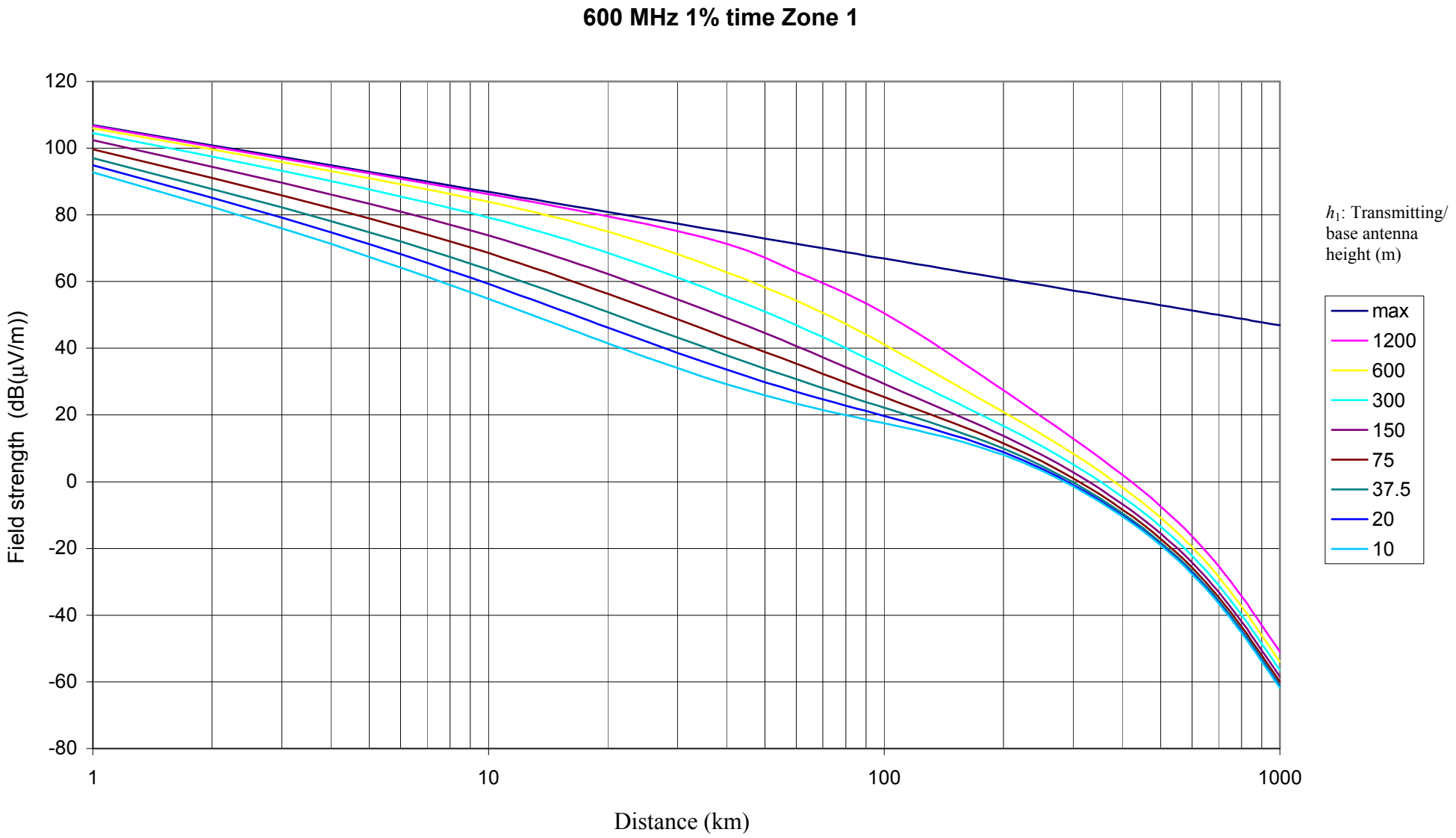

100 MHz 50% time Zone 1
Field strength (dB(µV/m))
120
100
80
60
40
20
0
–20
–40
–60
–80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

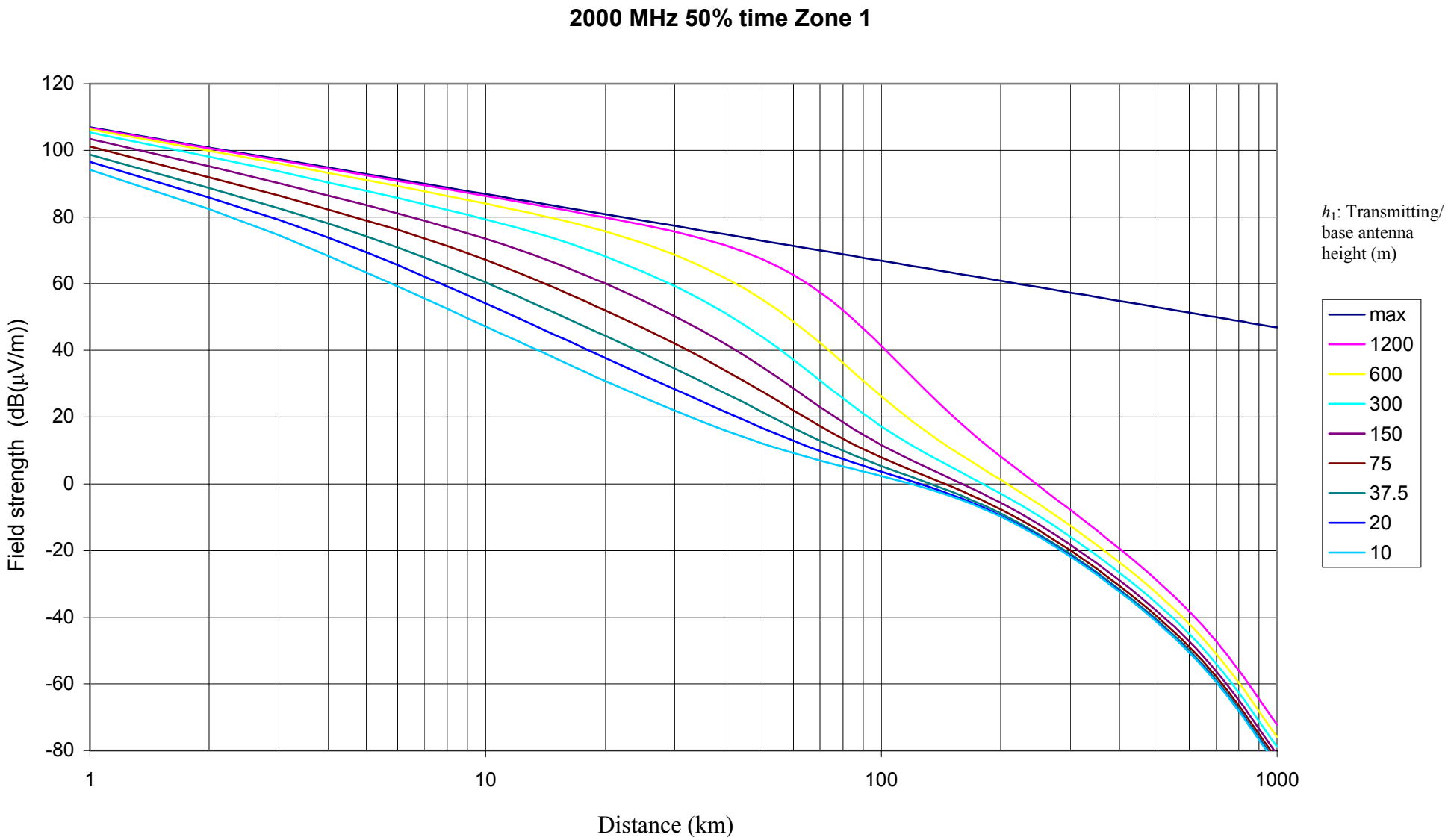

100 MHz 10% time Zone 1
120
100
80
60
40
20
0
–20
–40
–60
–80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

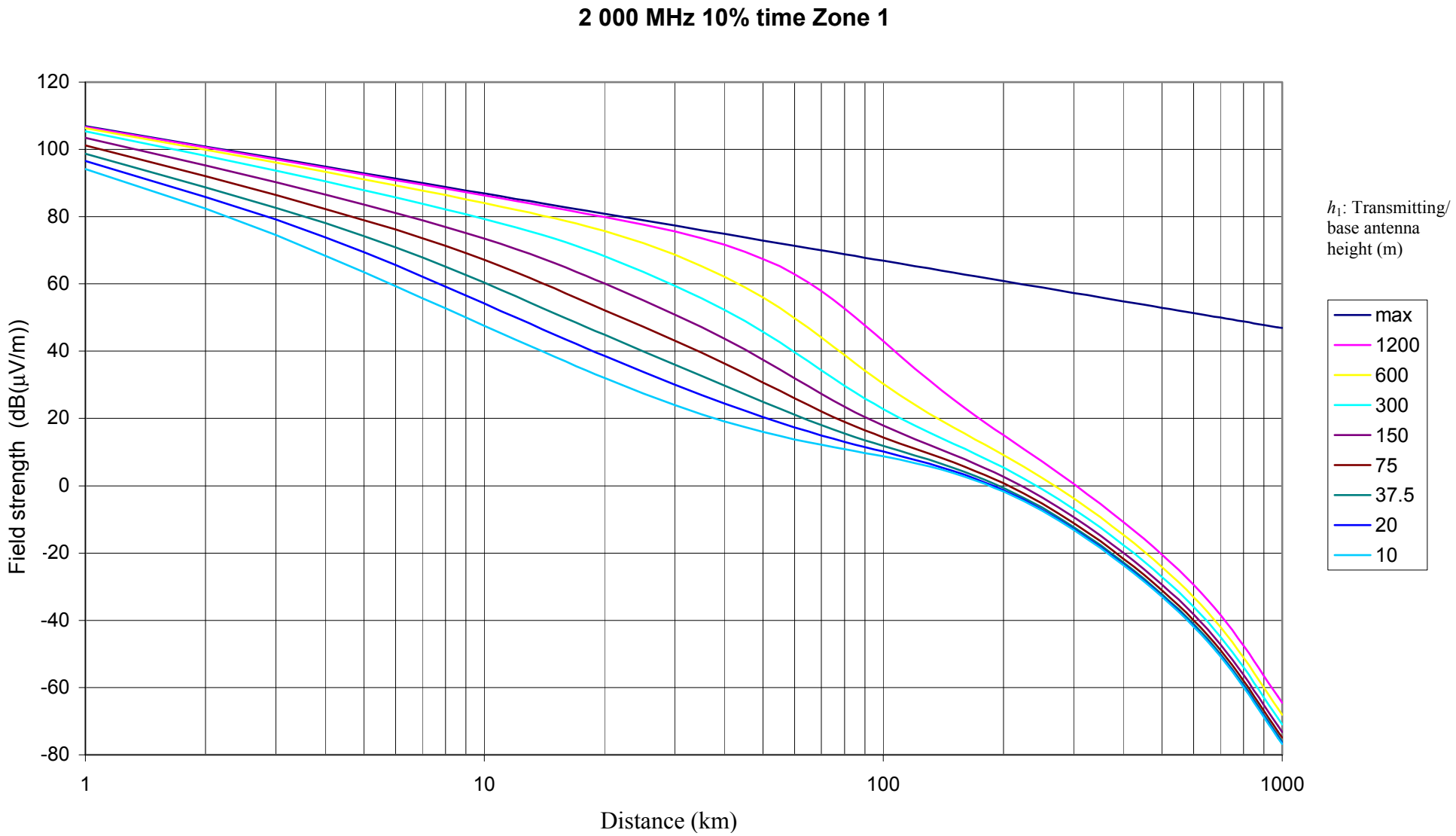

100 MHz 1% time Zone 1
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

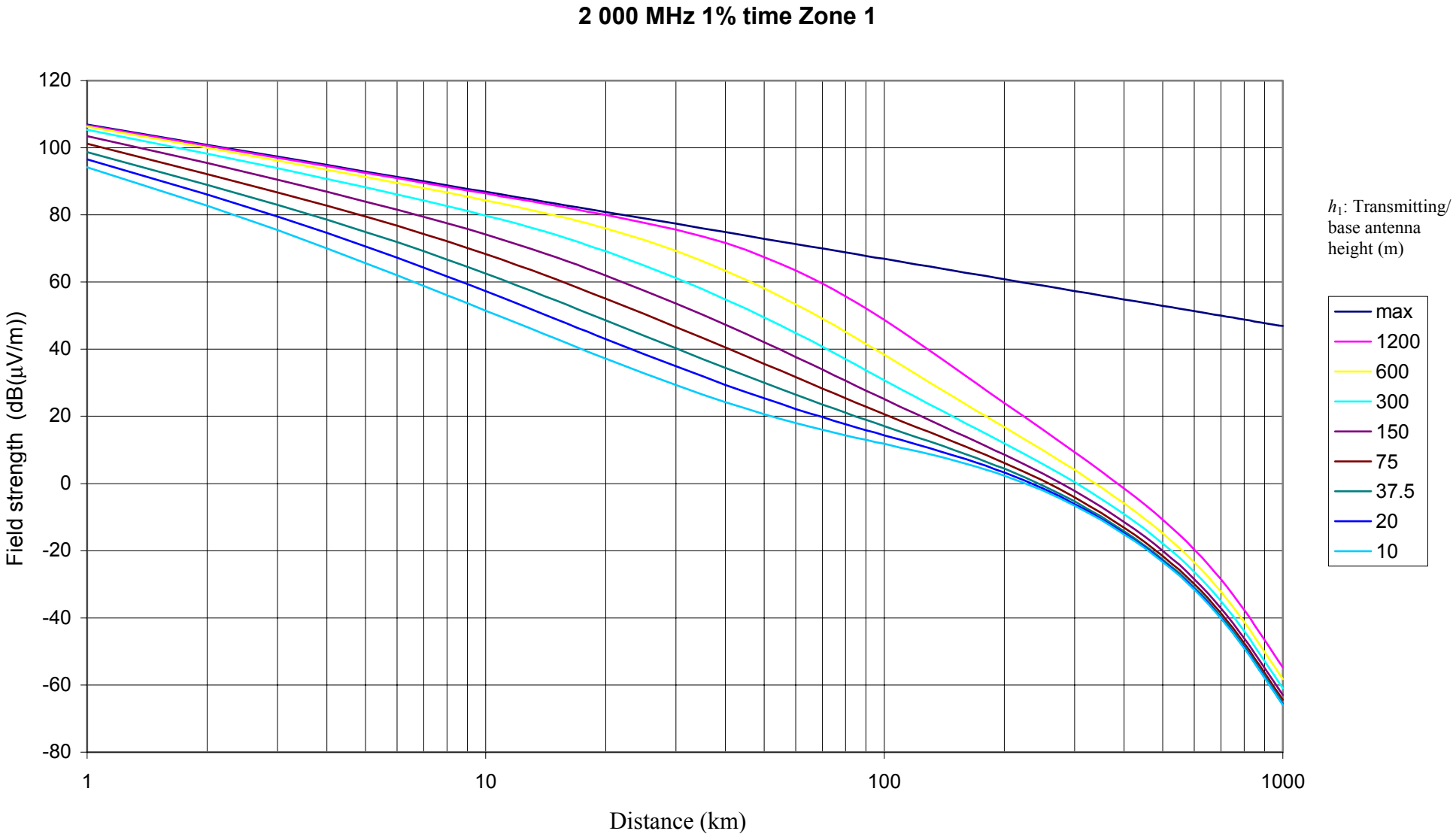

600 MHz 50% time Zone 1
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

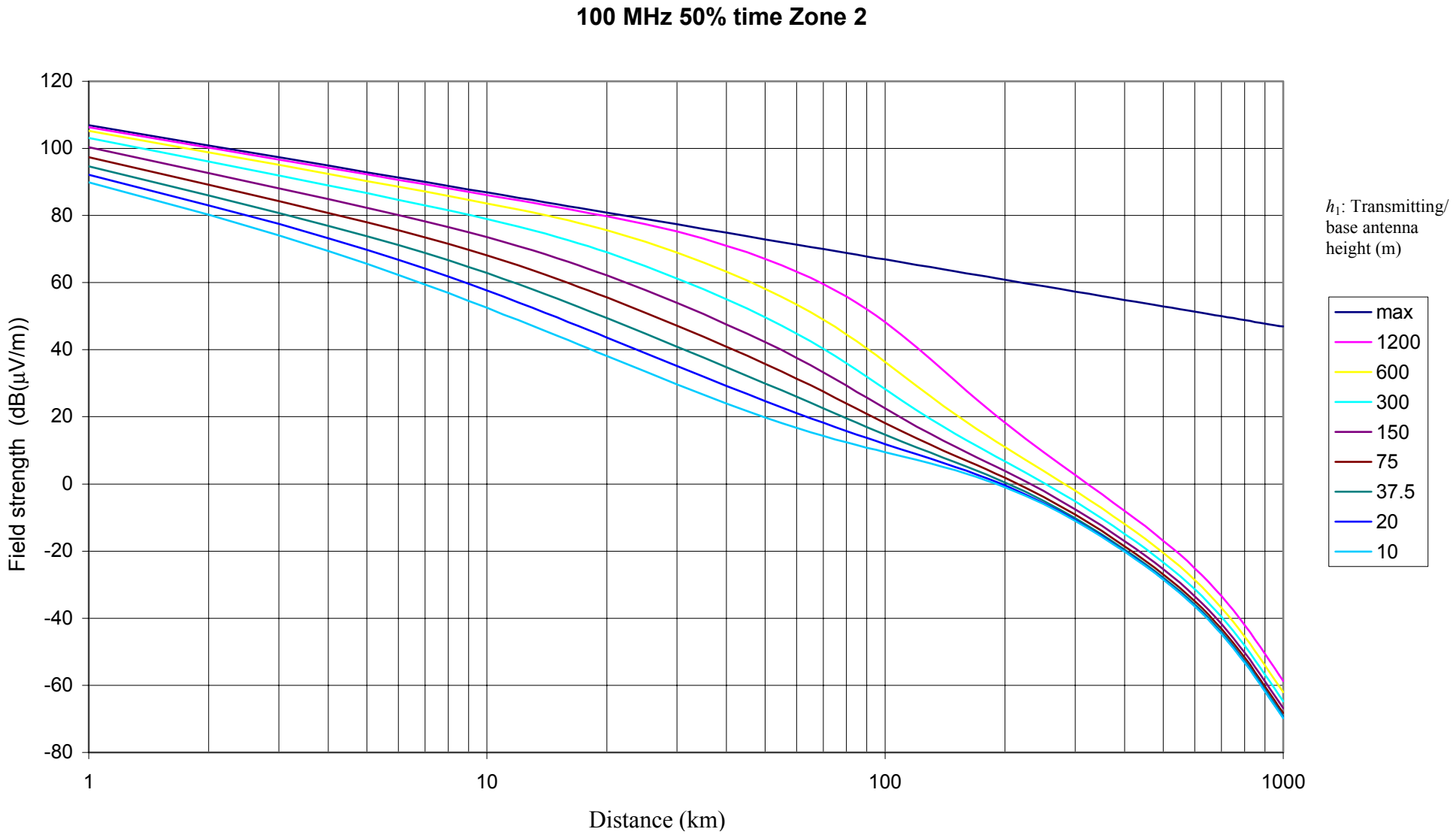

600 MHz 10% time Zone 1
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

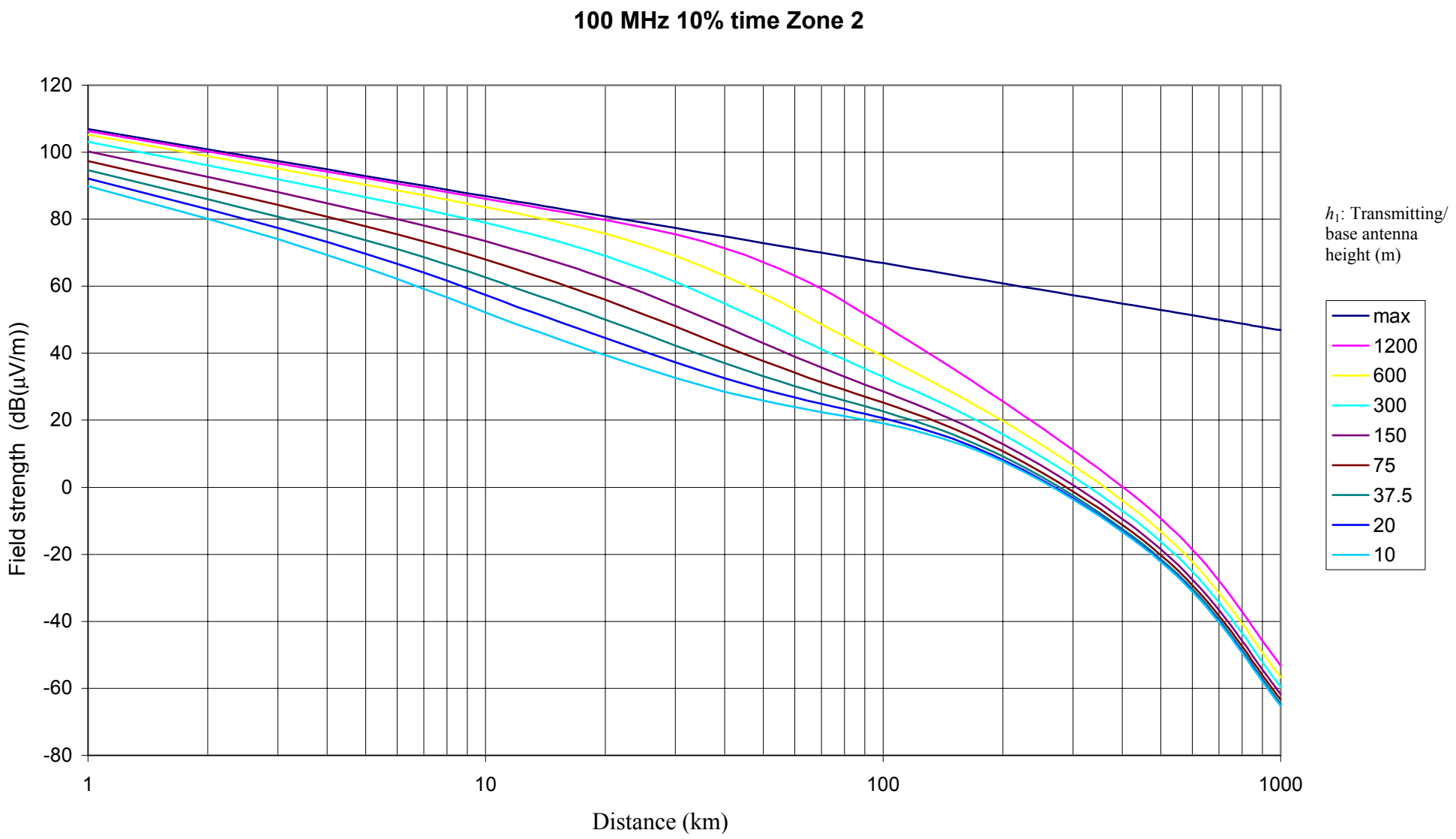

600 MHz 1% time Zone 1
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

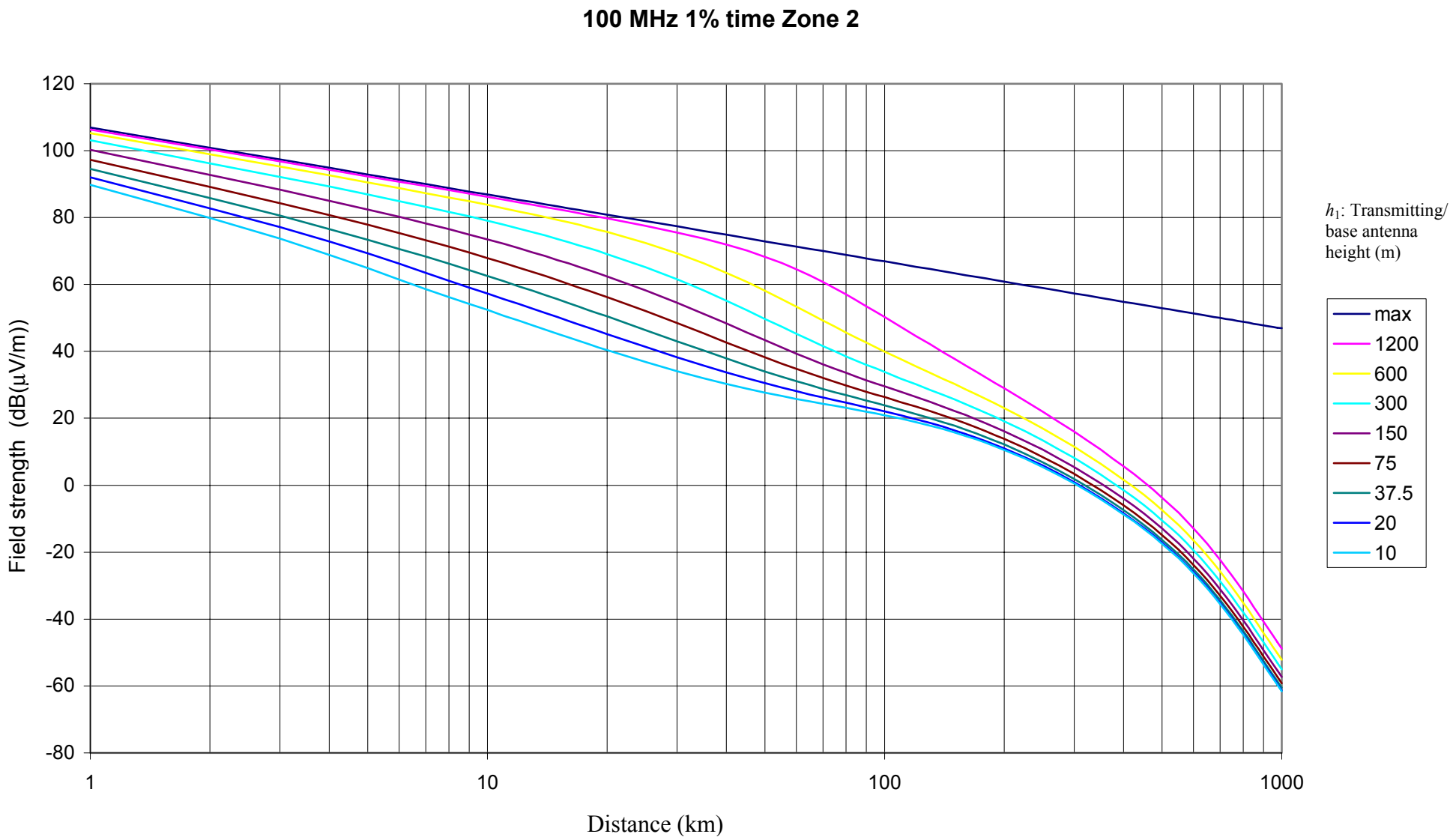

2000 MHz 50% time Zone 1
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

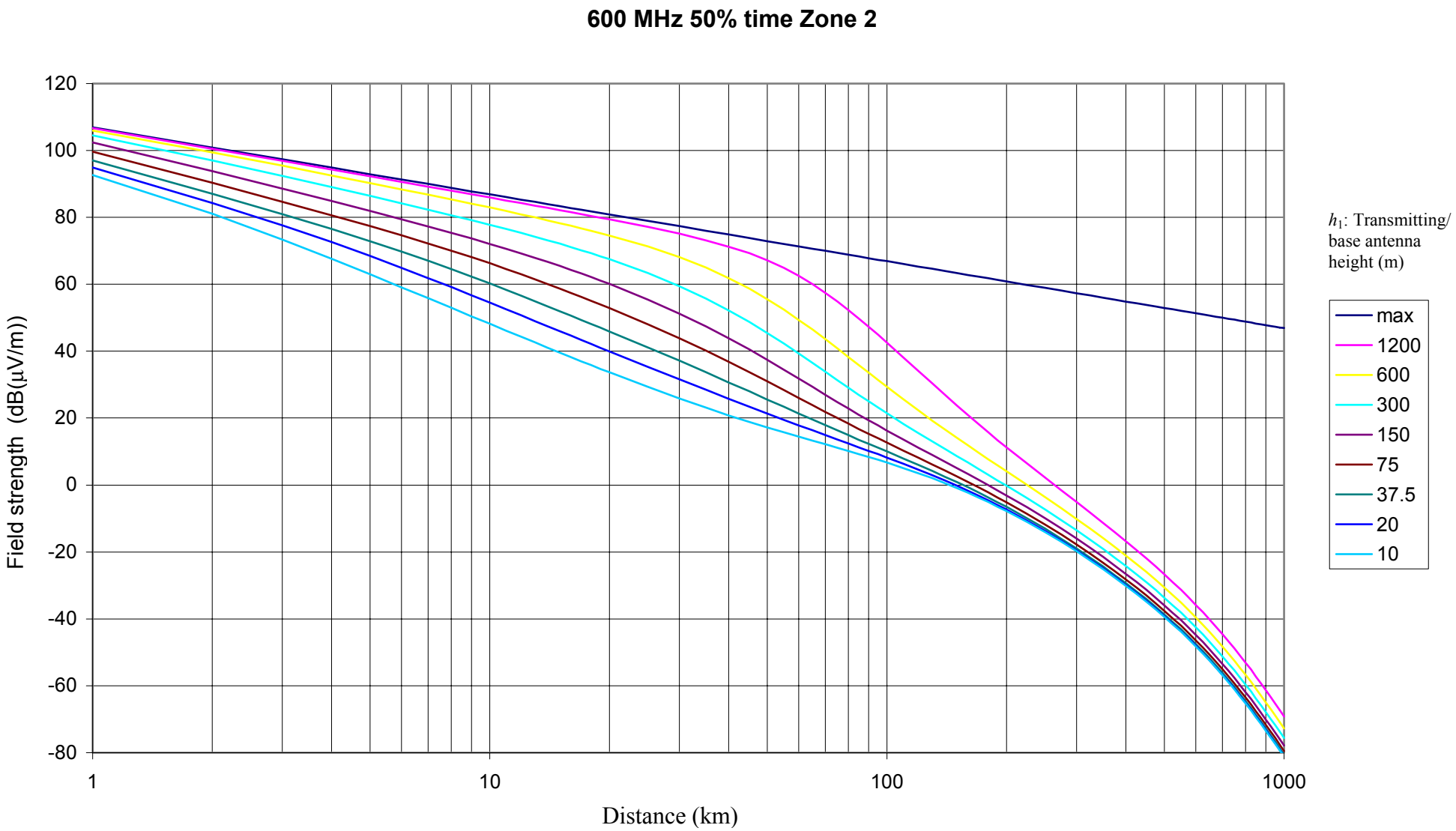

2 000 MHz 10% time Zone 1
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

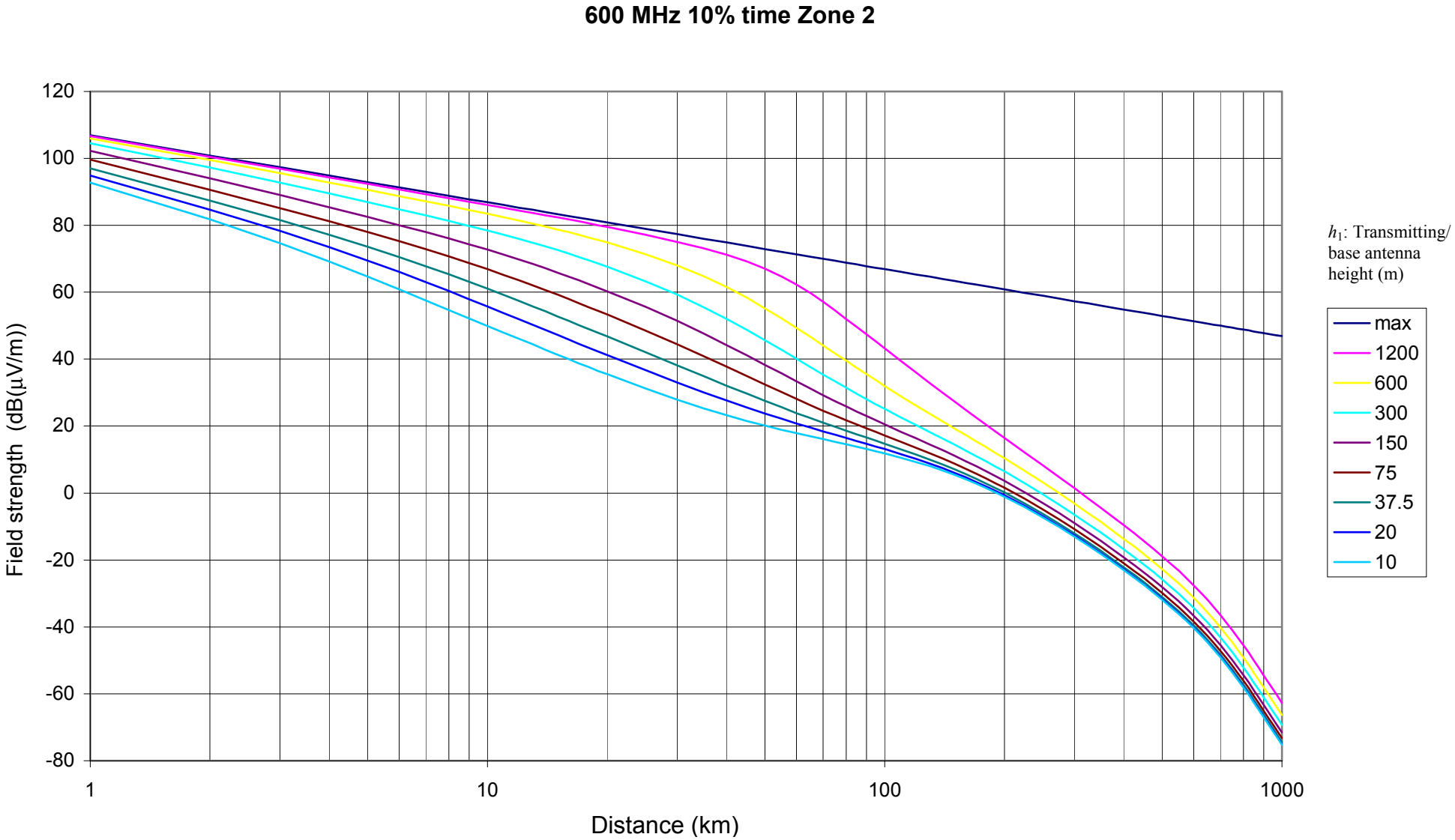

2 000 MHz 1% time Zone 1
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

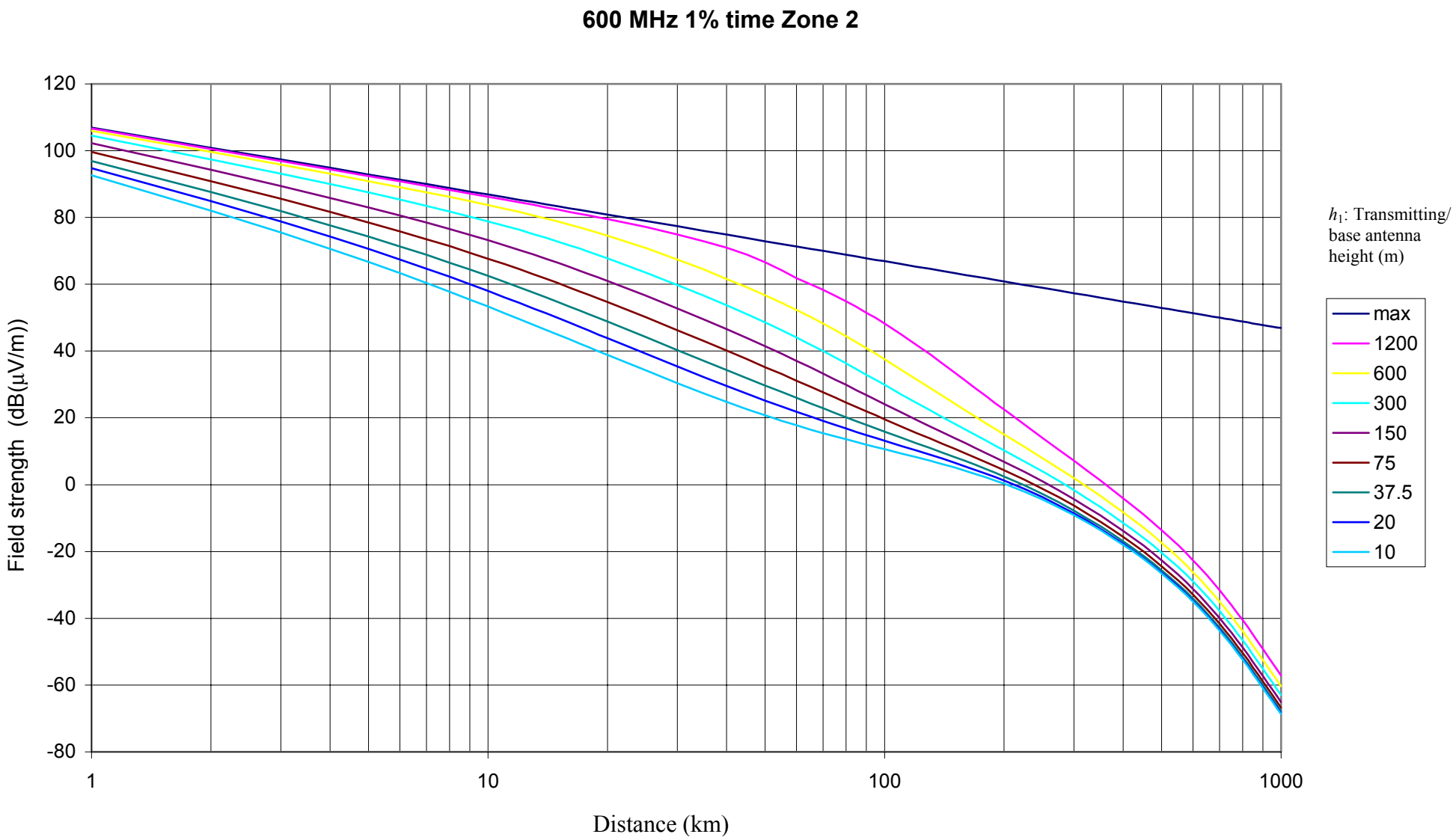

100 MHz 50% time Zone 2
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

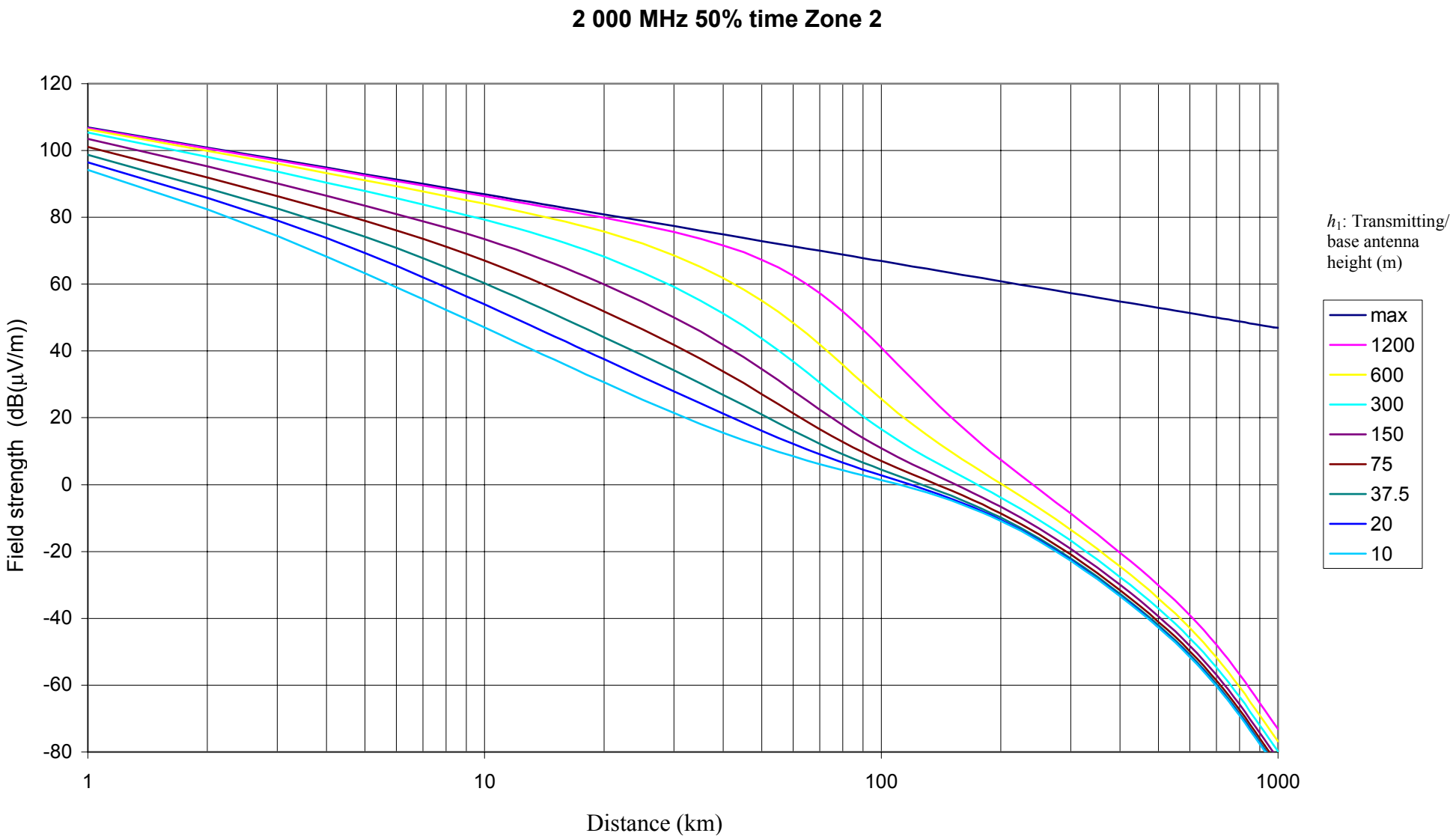

100 MHz 10% time Zone 2
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

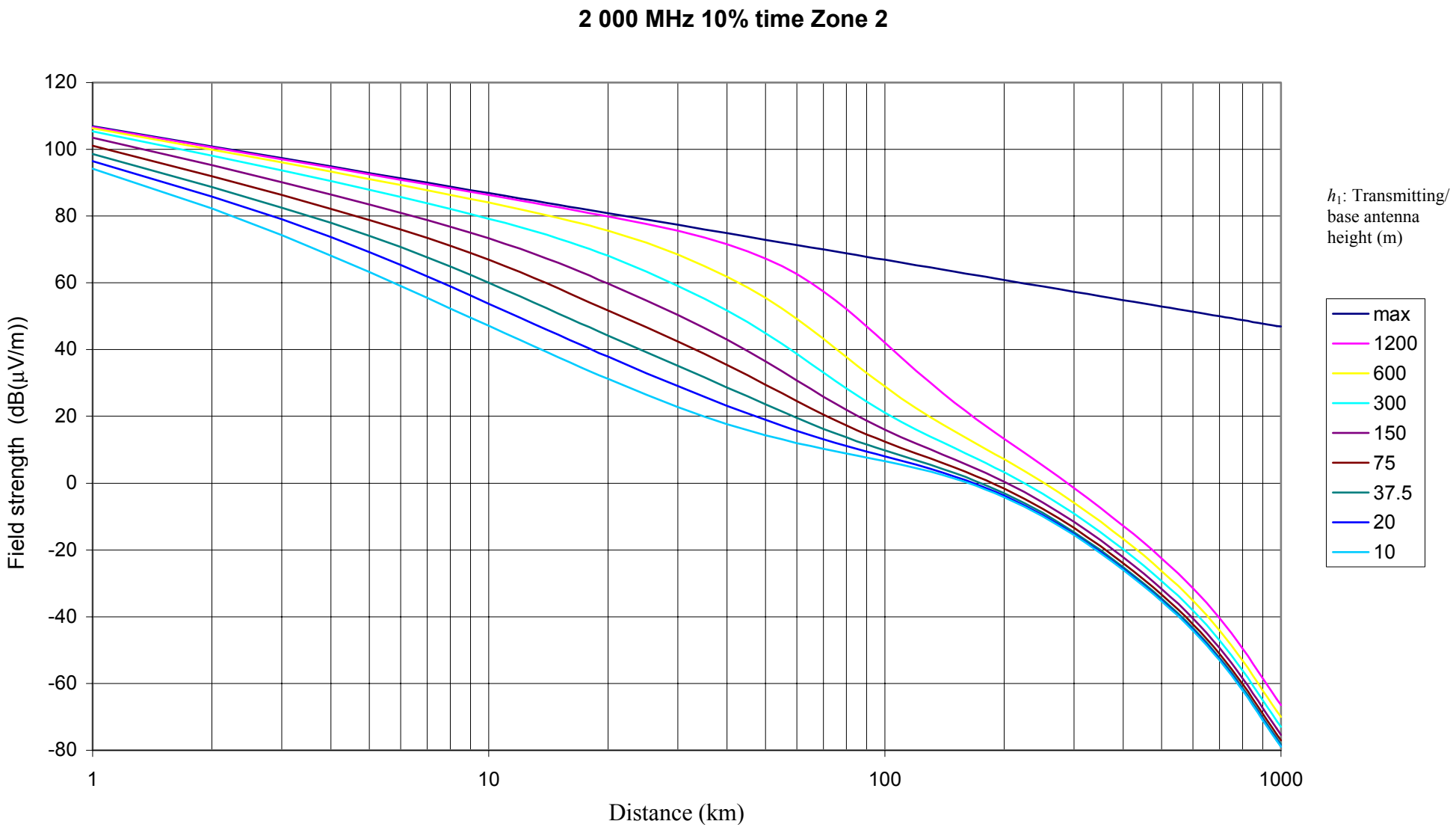

100 MHz 1% time Zone 2
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

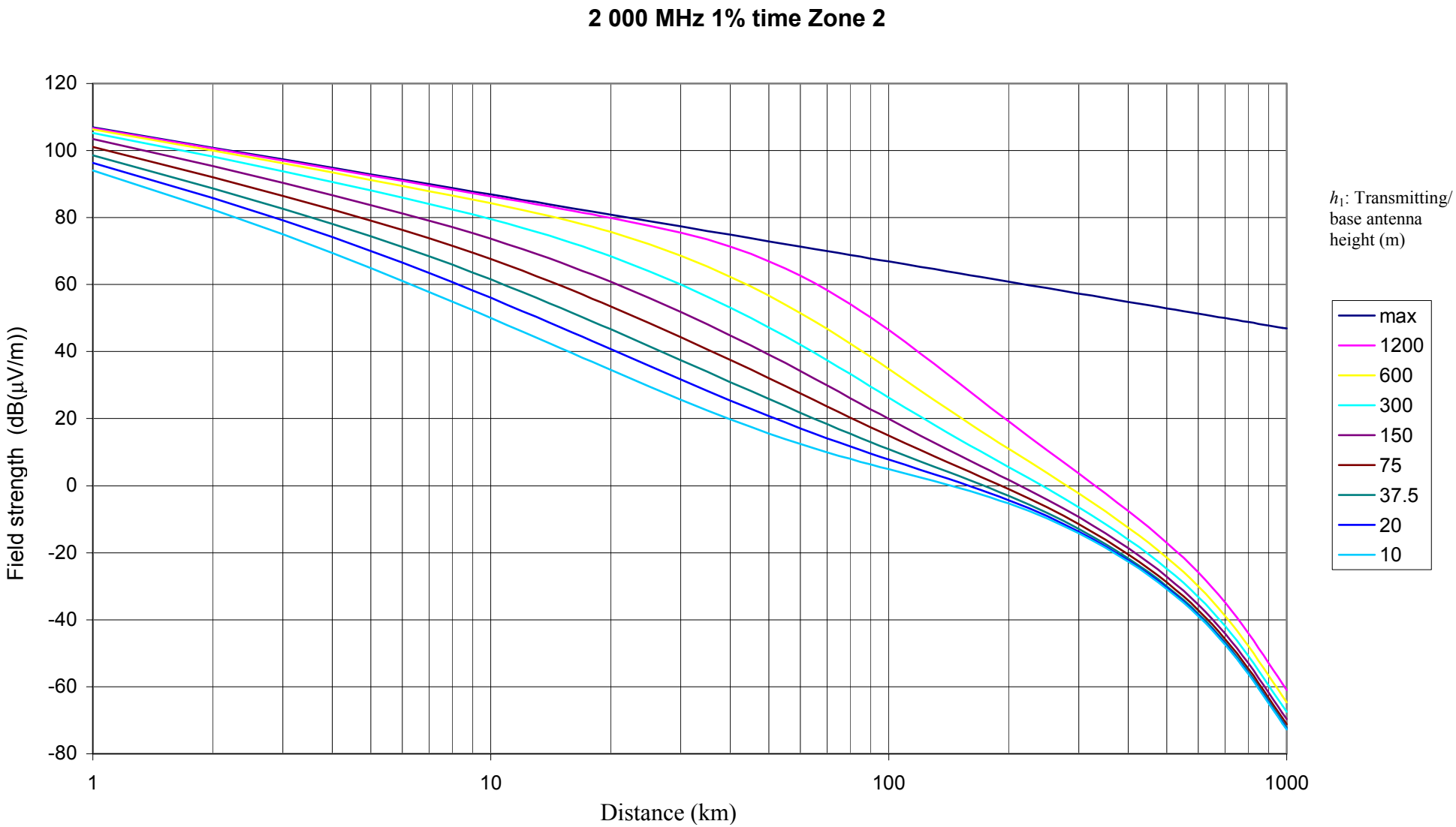

600 MHz 50% time Zone 2
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

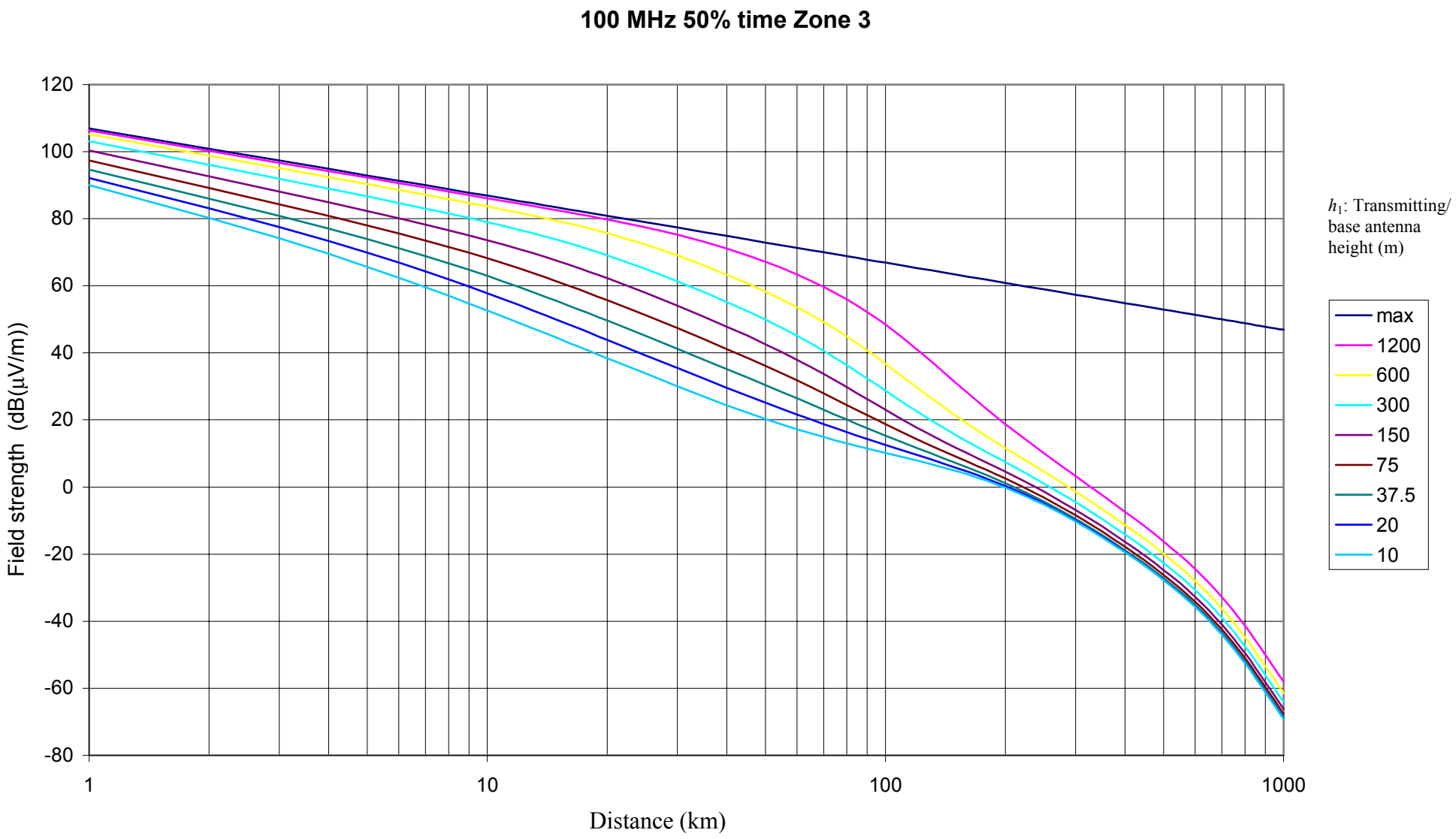

600 MHz 10% time Zone 2
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

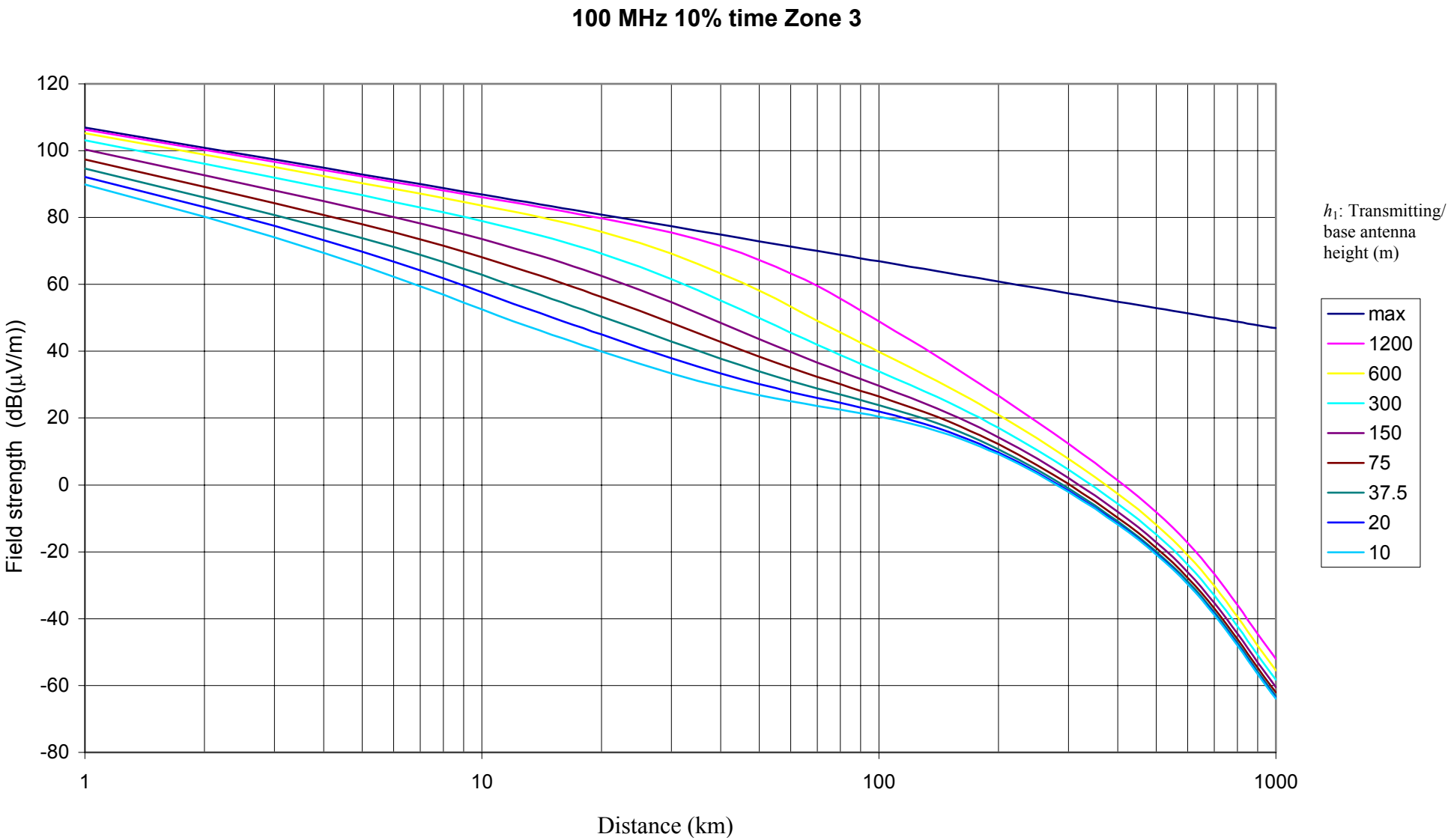

600 MHz 1% time Zone 2
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

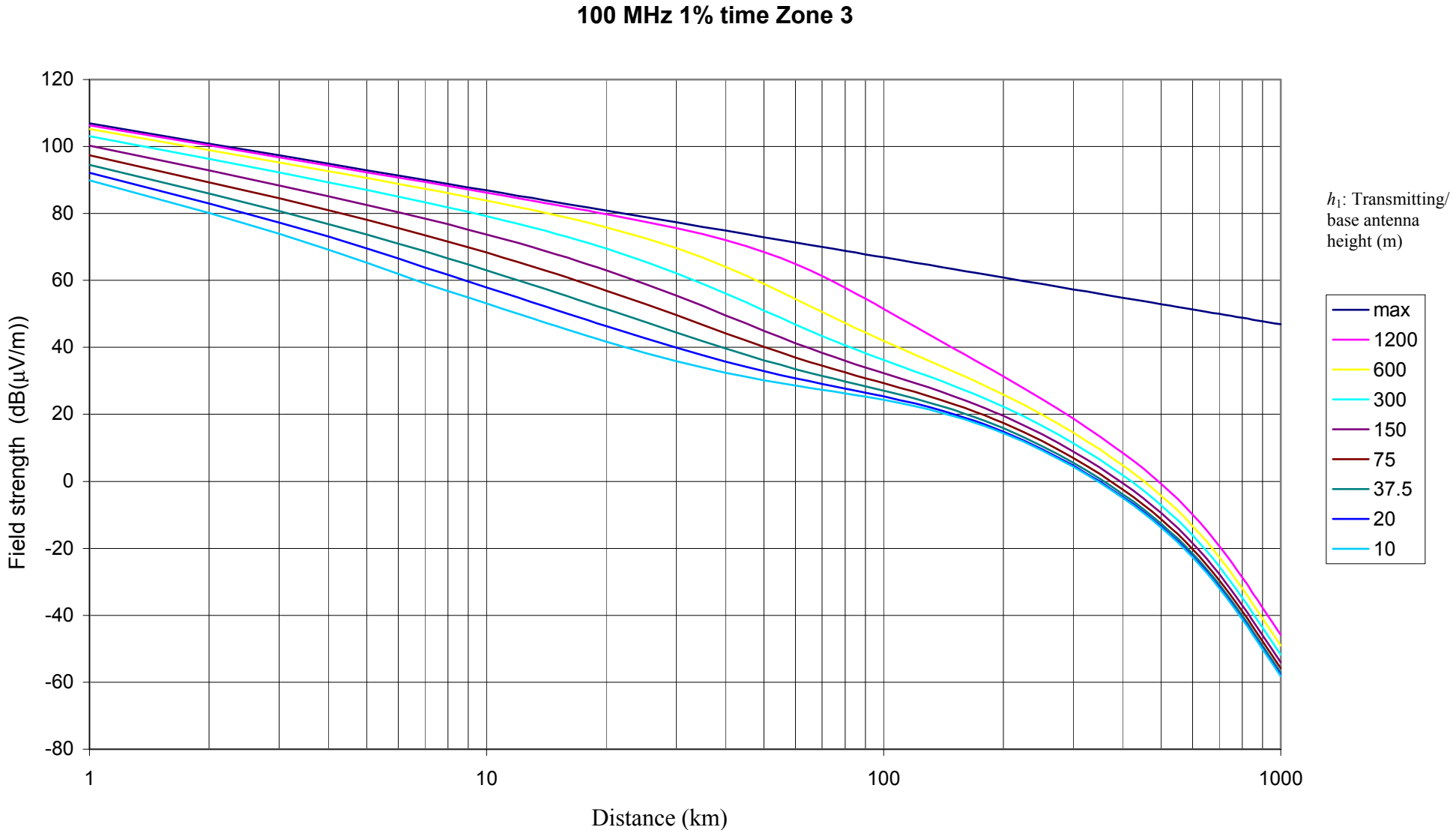

2 000 MHz 50% time Zone 2
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

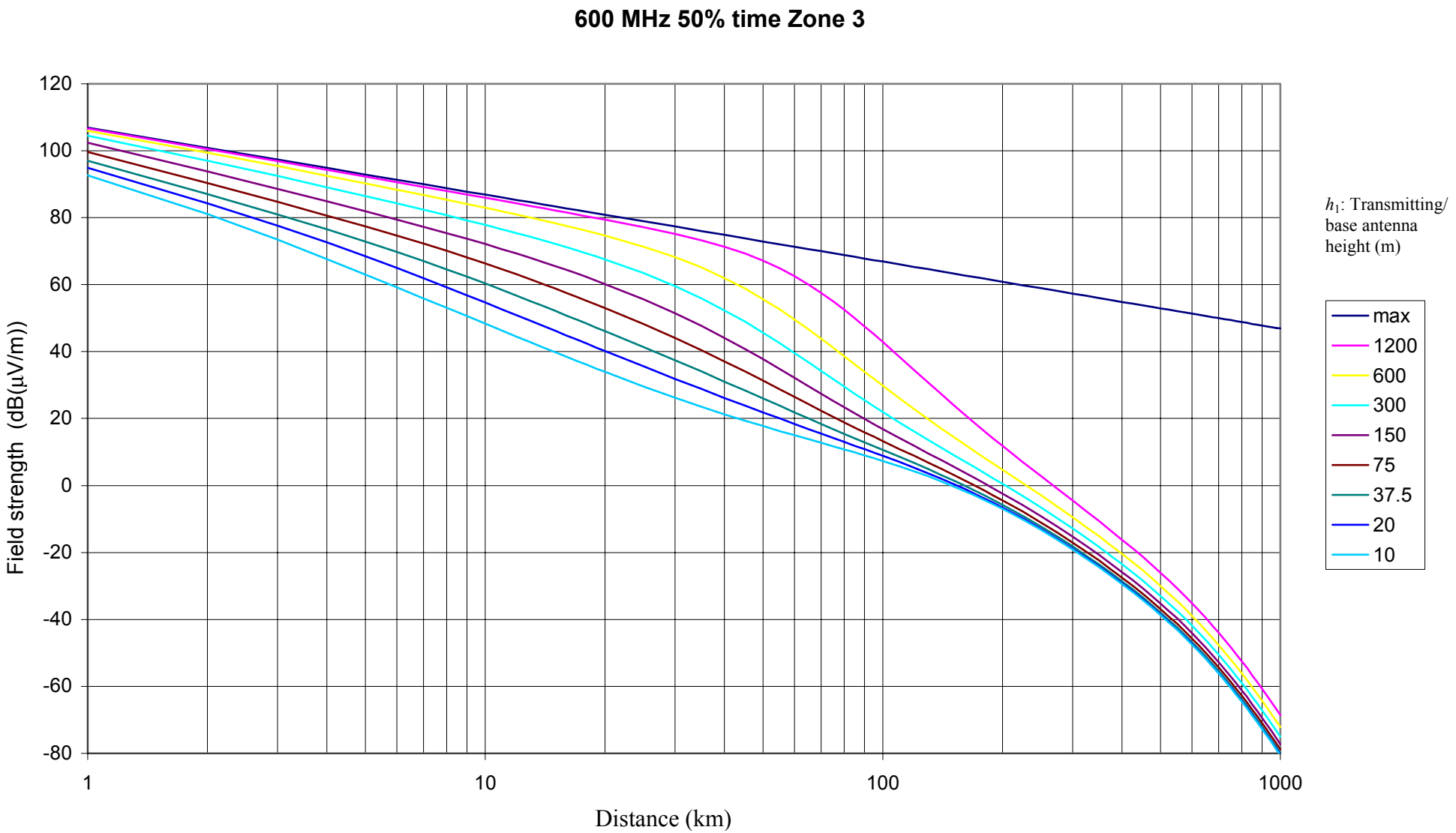

2 000 MHz 10% time Zone 2
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

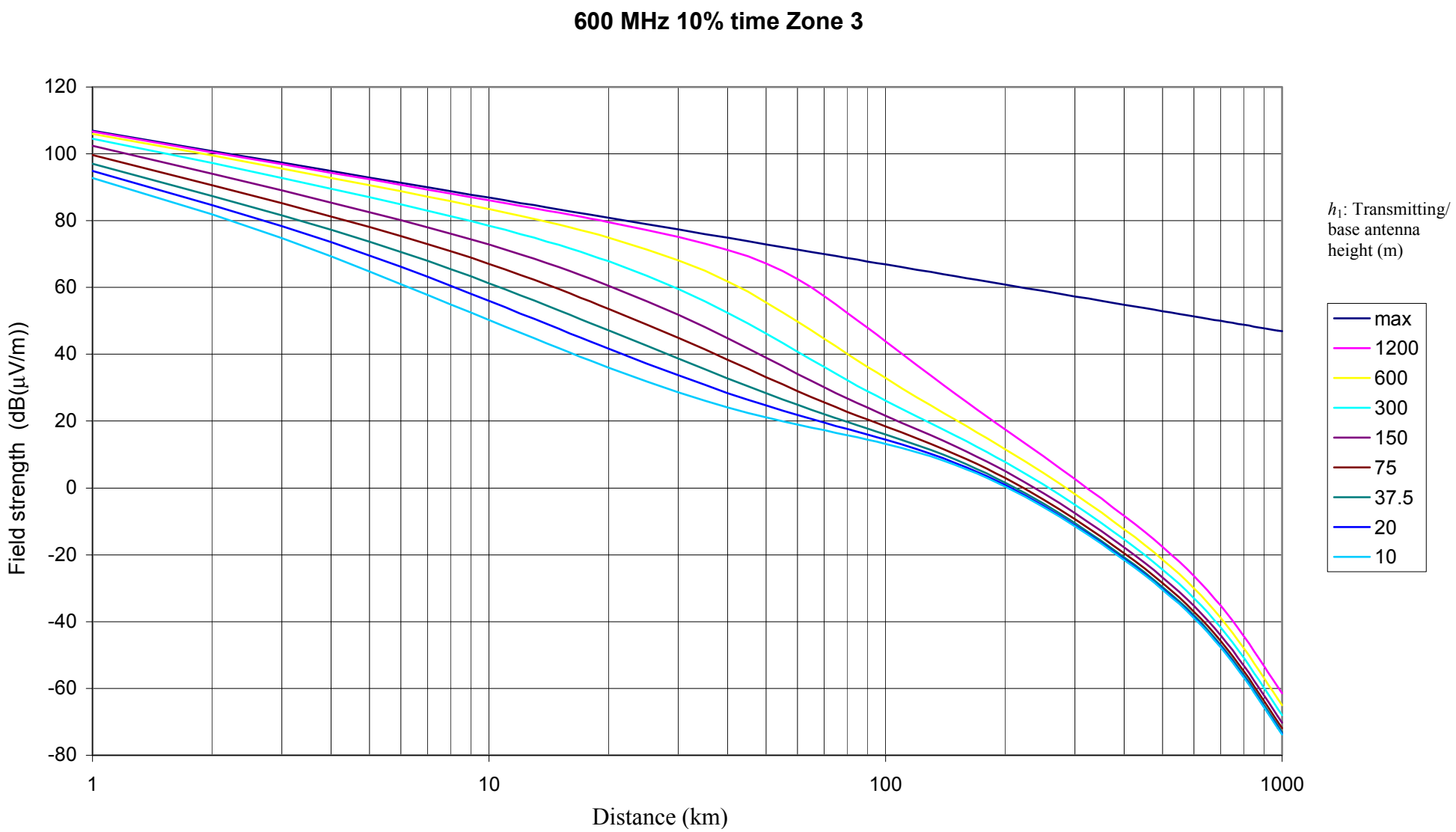

2 000 MHz 1% time Zone 2
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

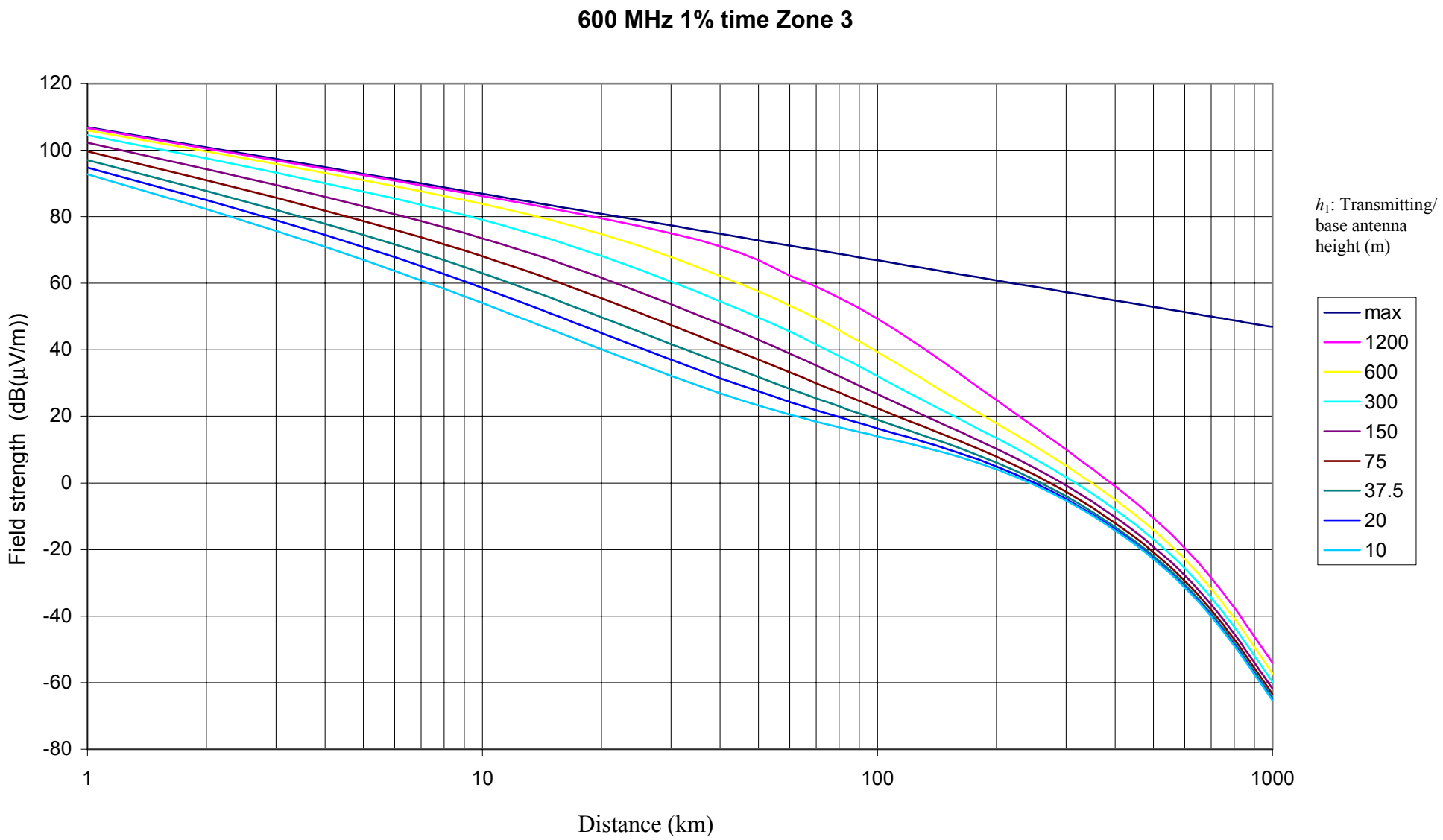

100 MHz 50% time Zone 3
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

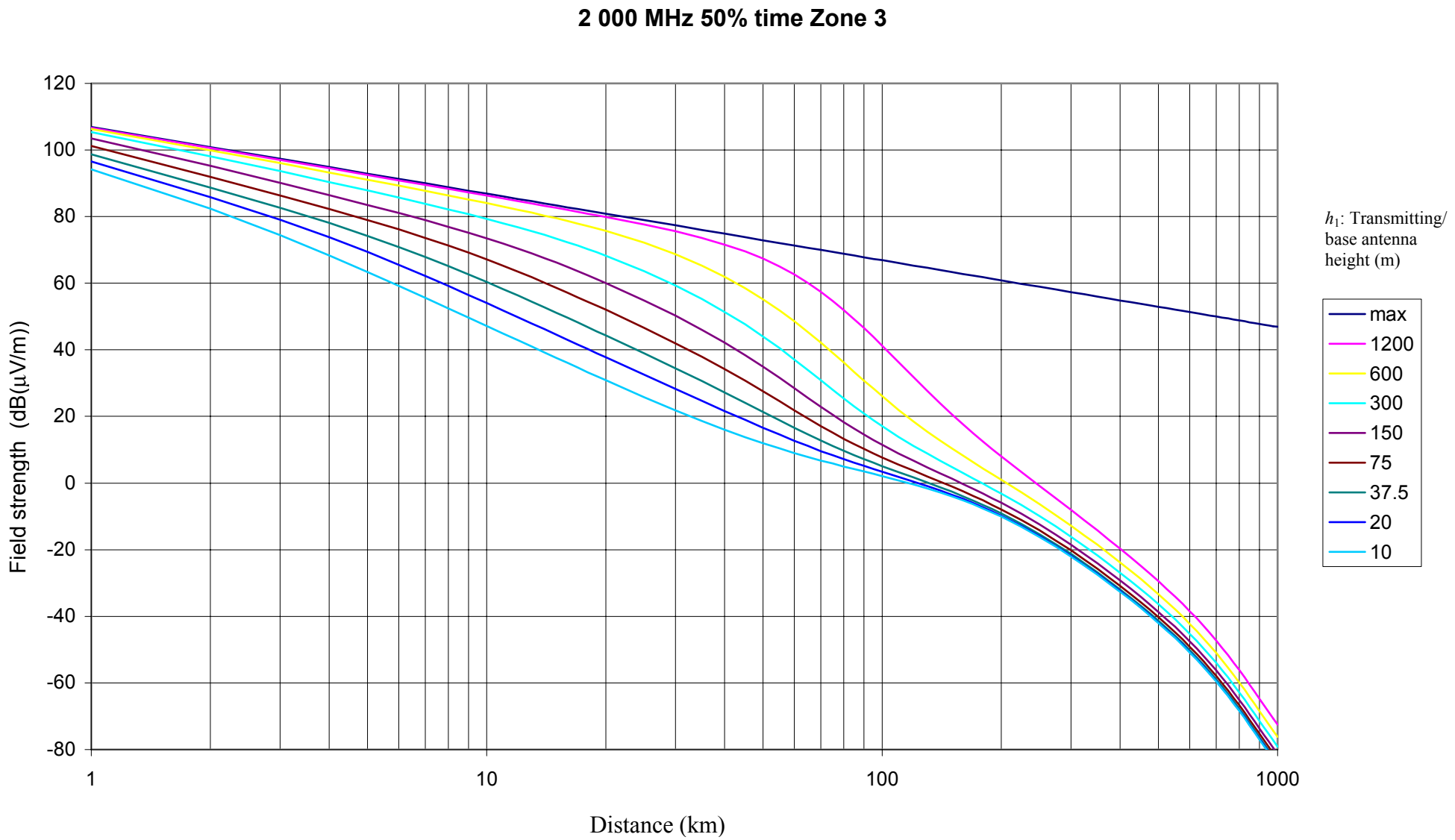

100 MHz 10% time Zone 3
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

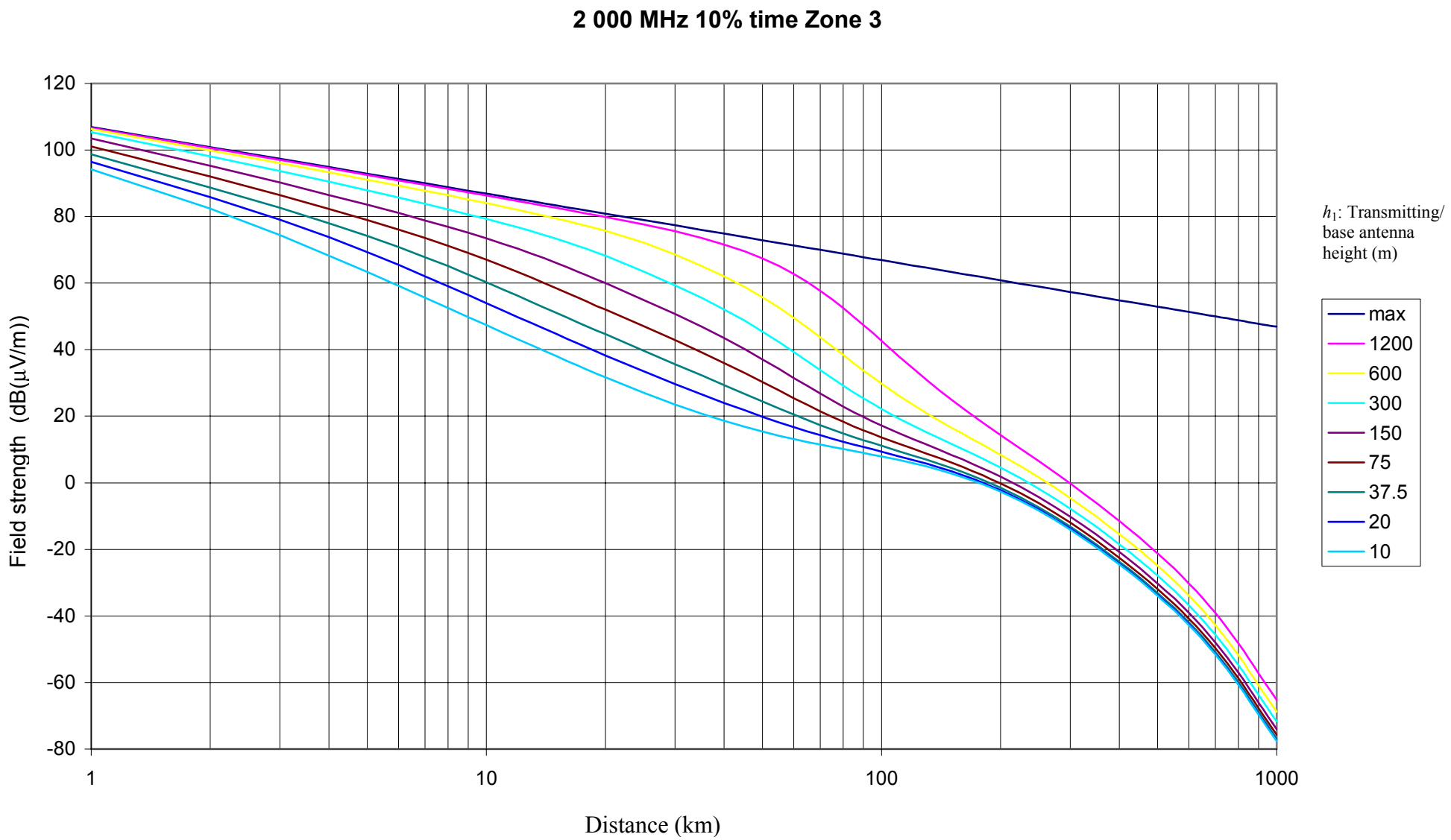

100 MHz 1% time Zone 3
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

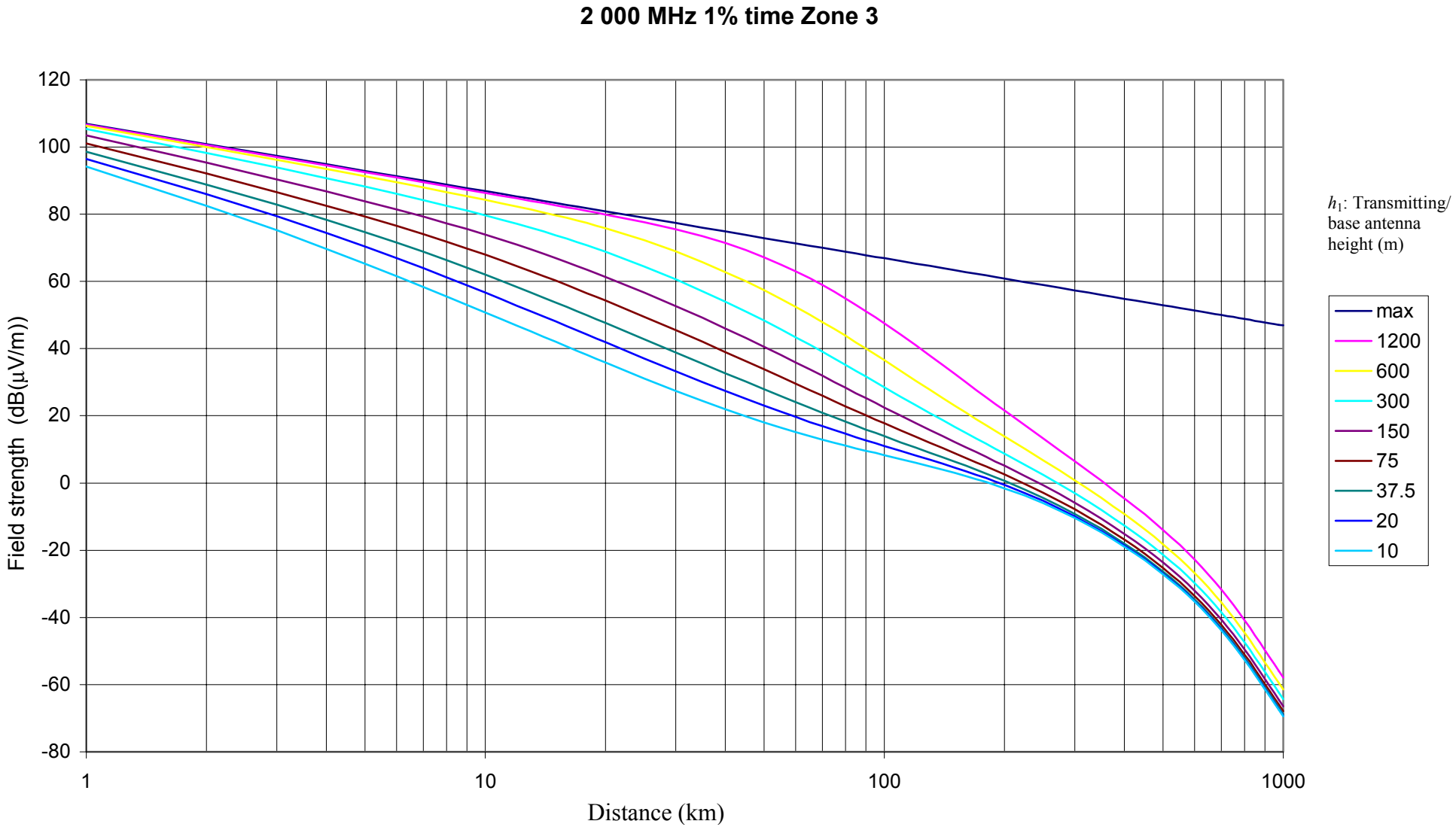

600 MHz 50% time Zone 3
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

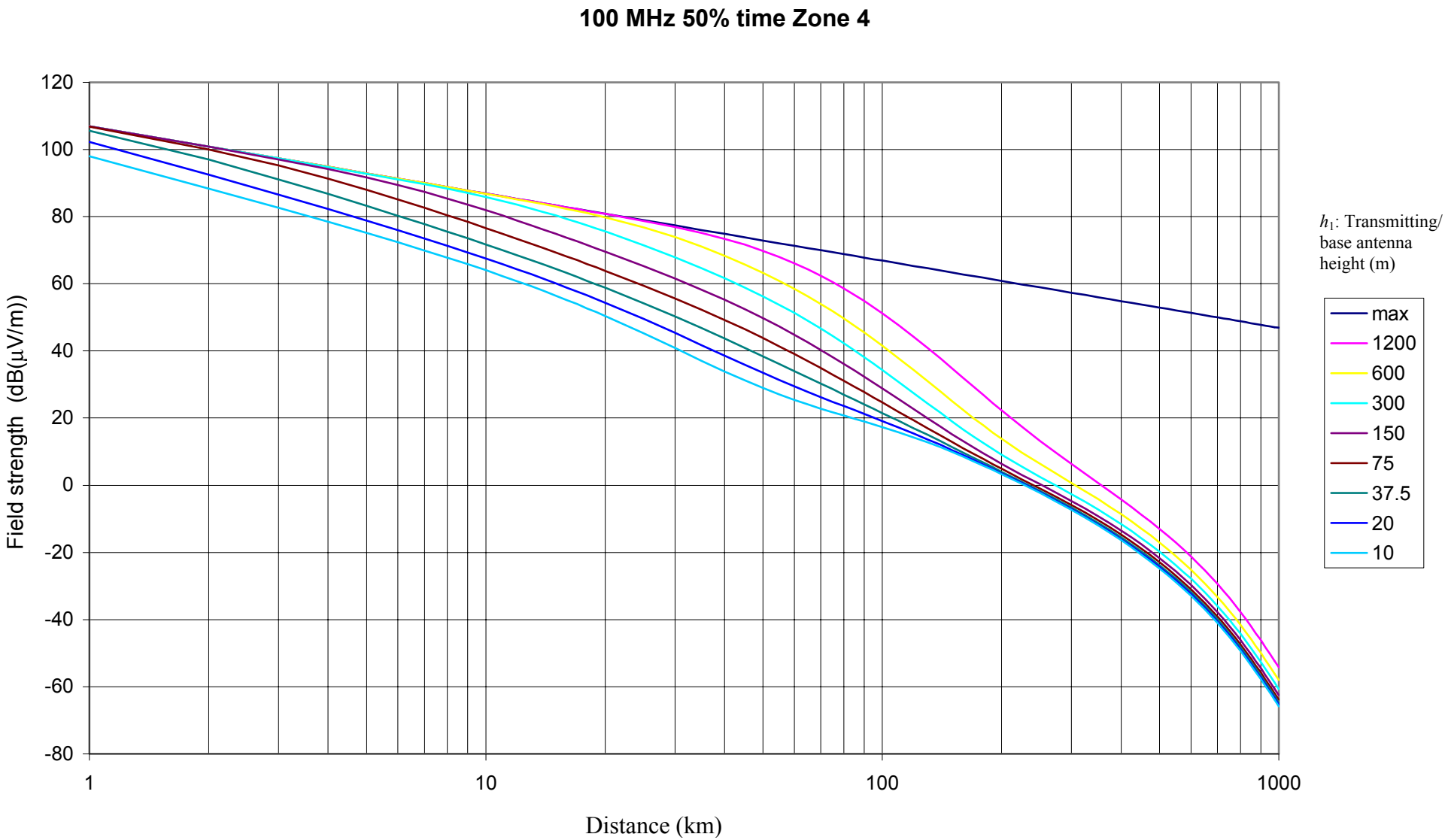

600 MHz 10% time Zone 3
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

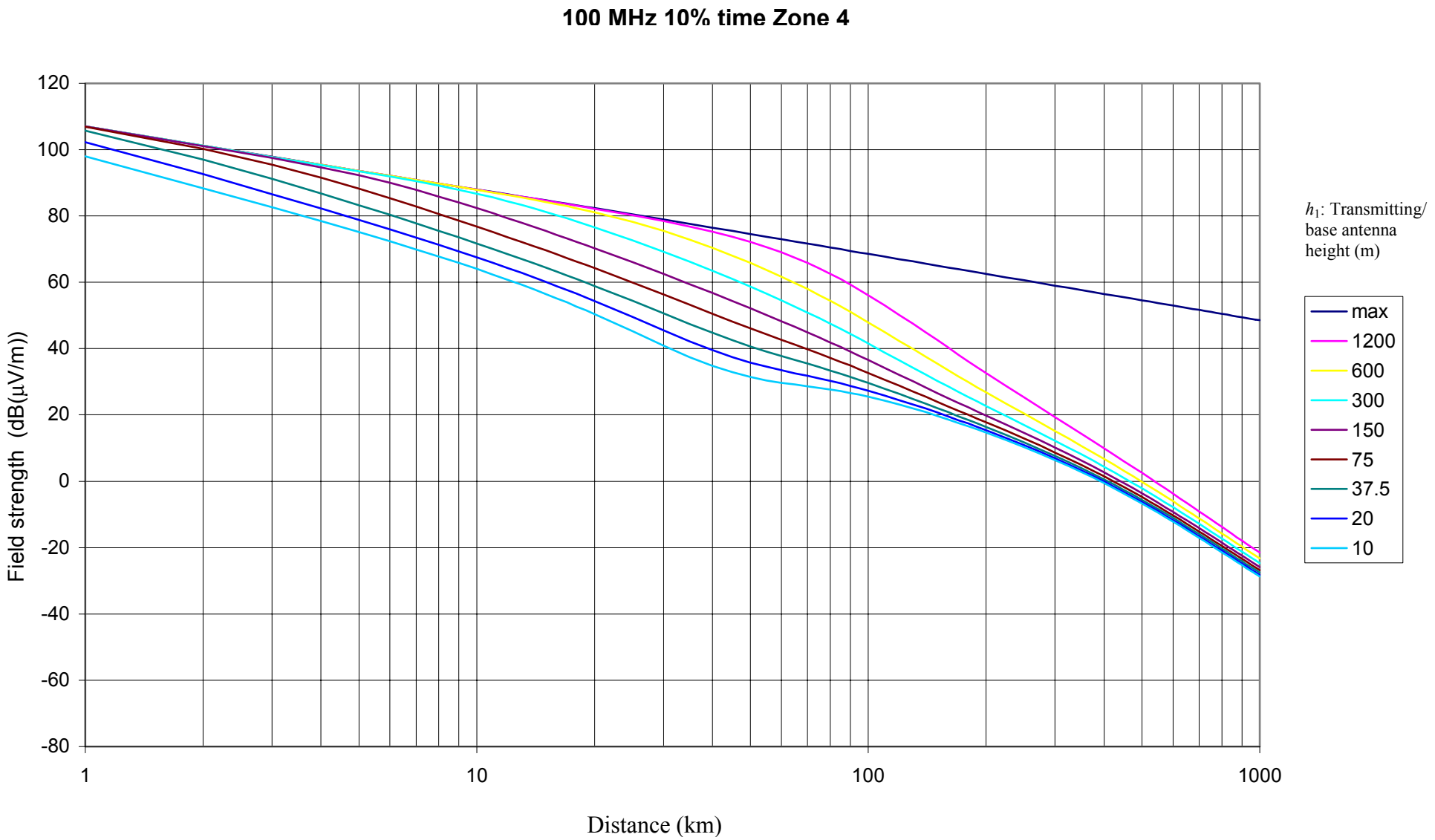

600 MHz 1% time Zone 3
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

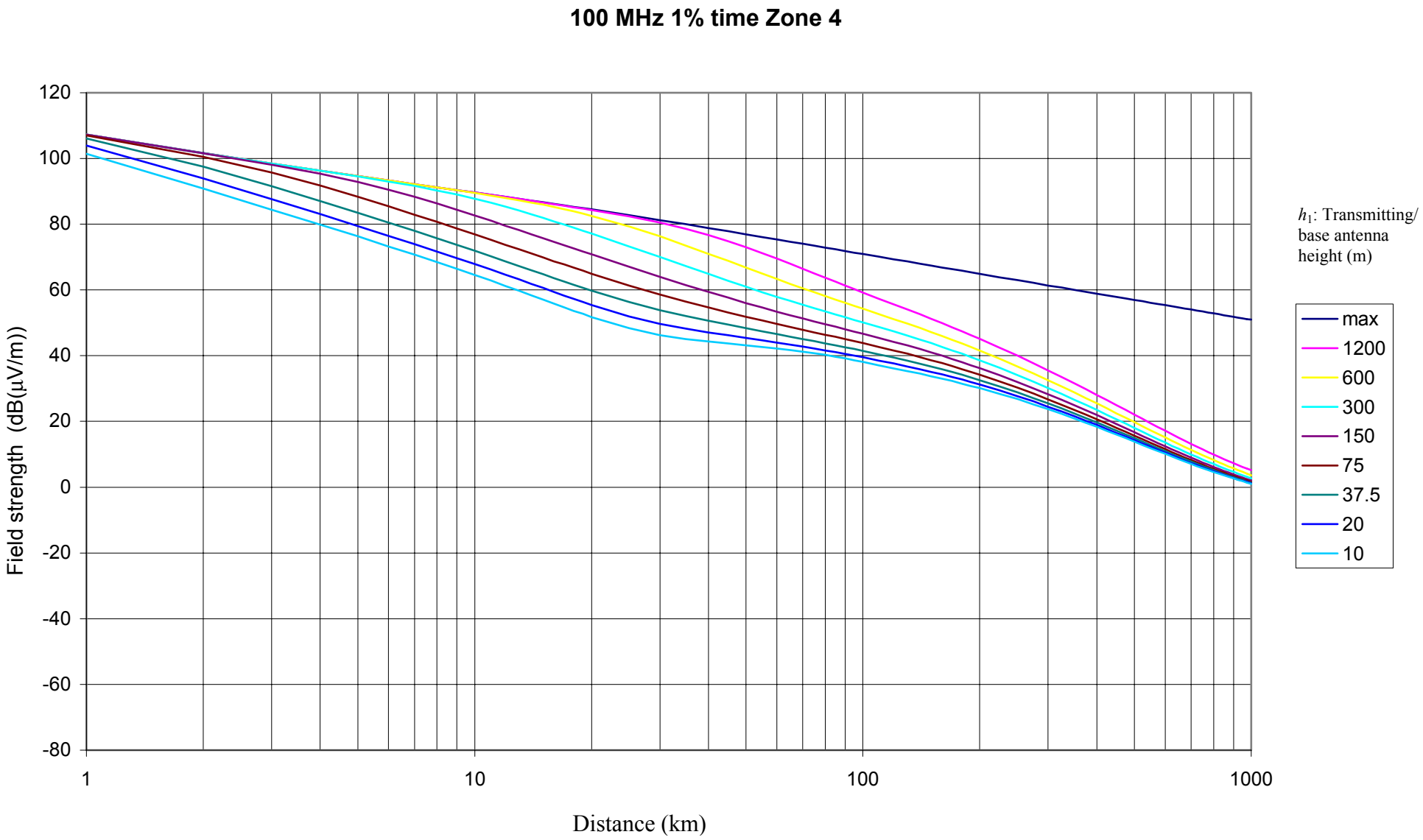

2 000 MHz 50% time Zone 3
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

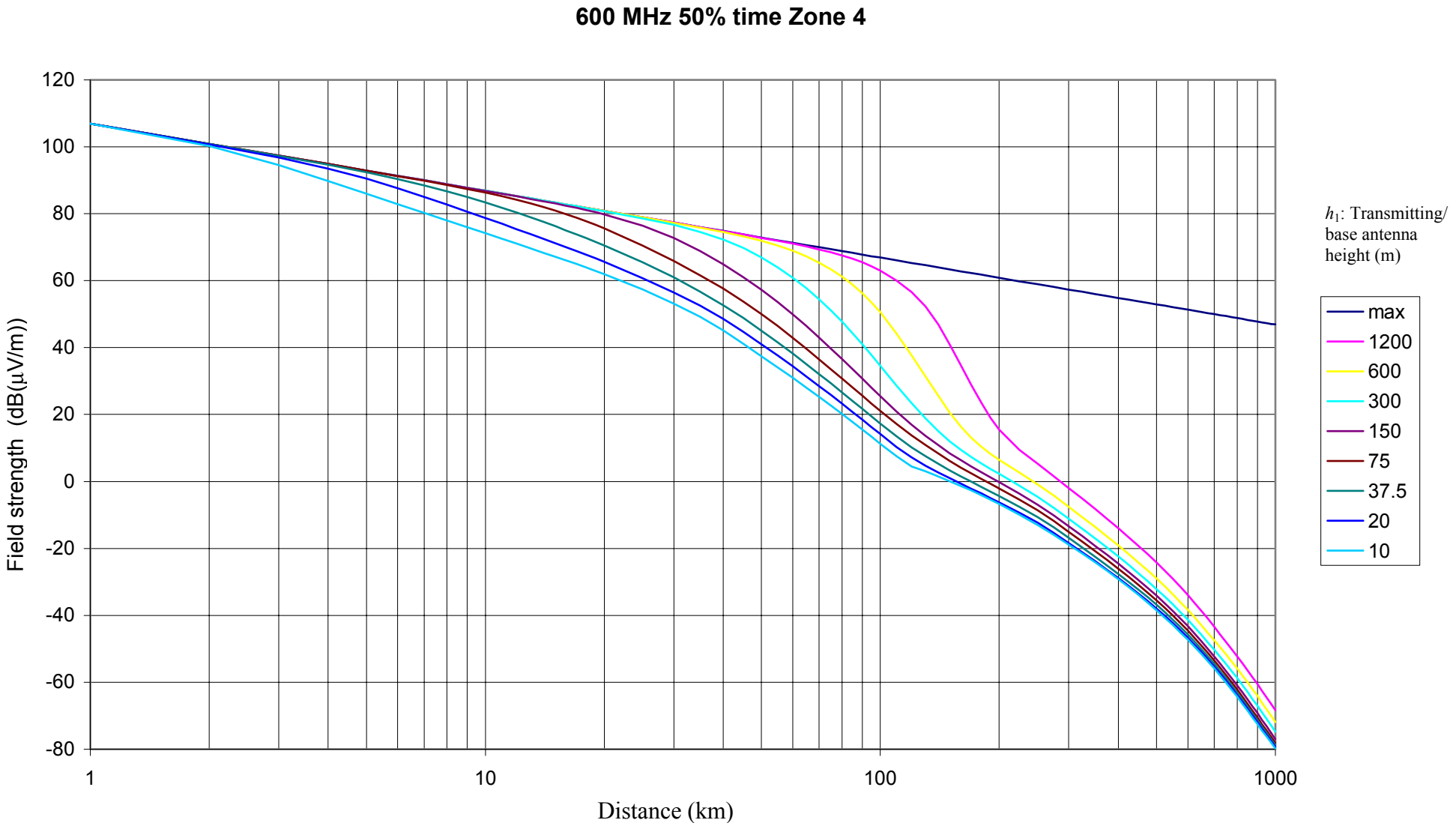

2 000 MHz 10% time Zone 3
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

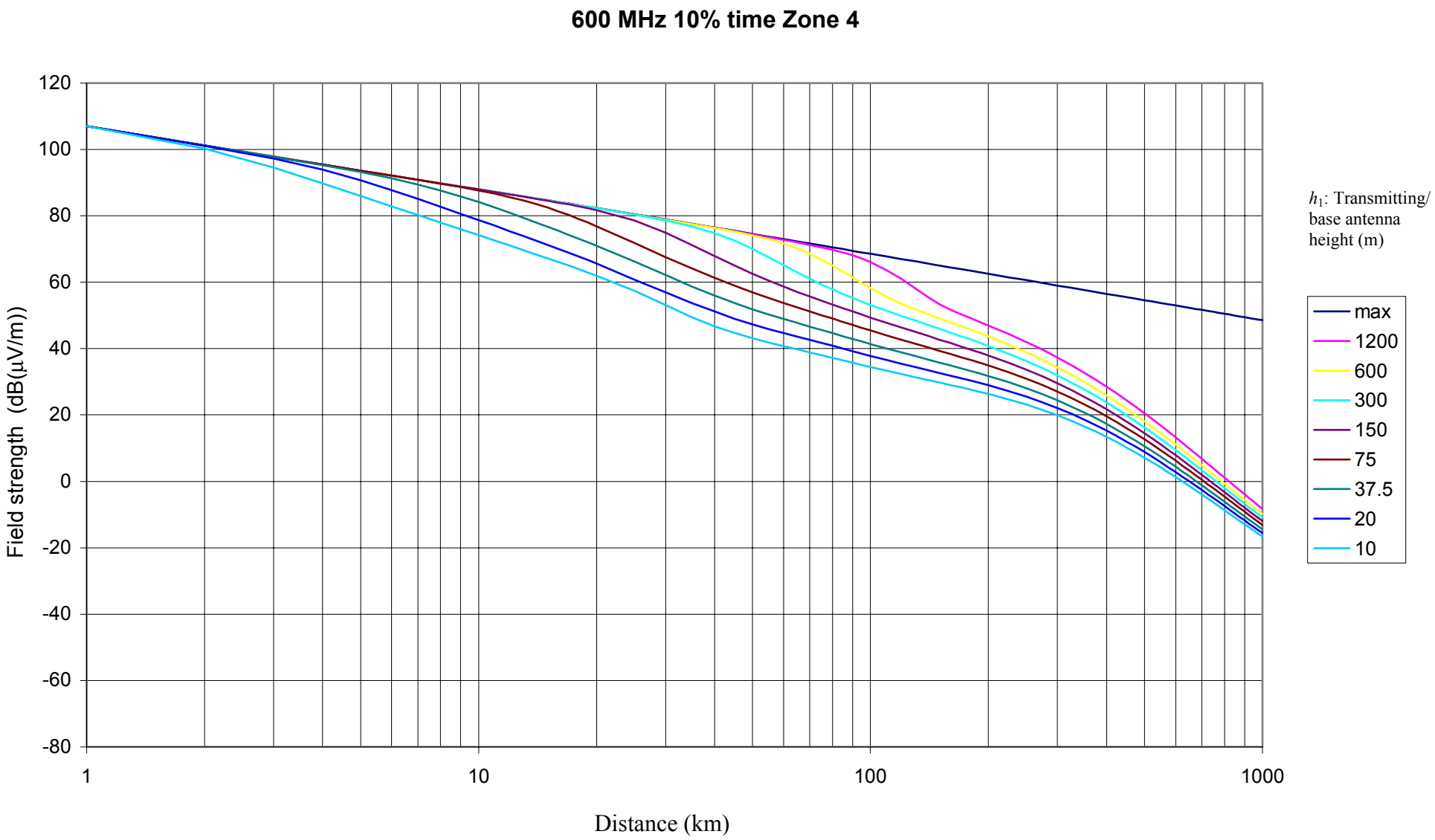

2 000 MHz 1% time Zone 3
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

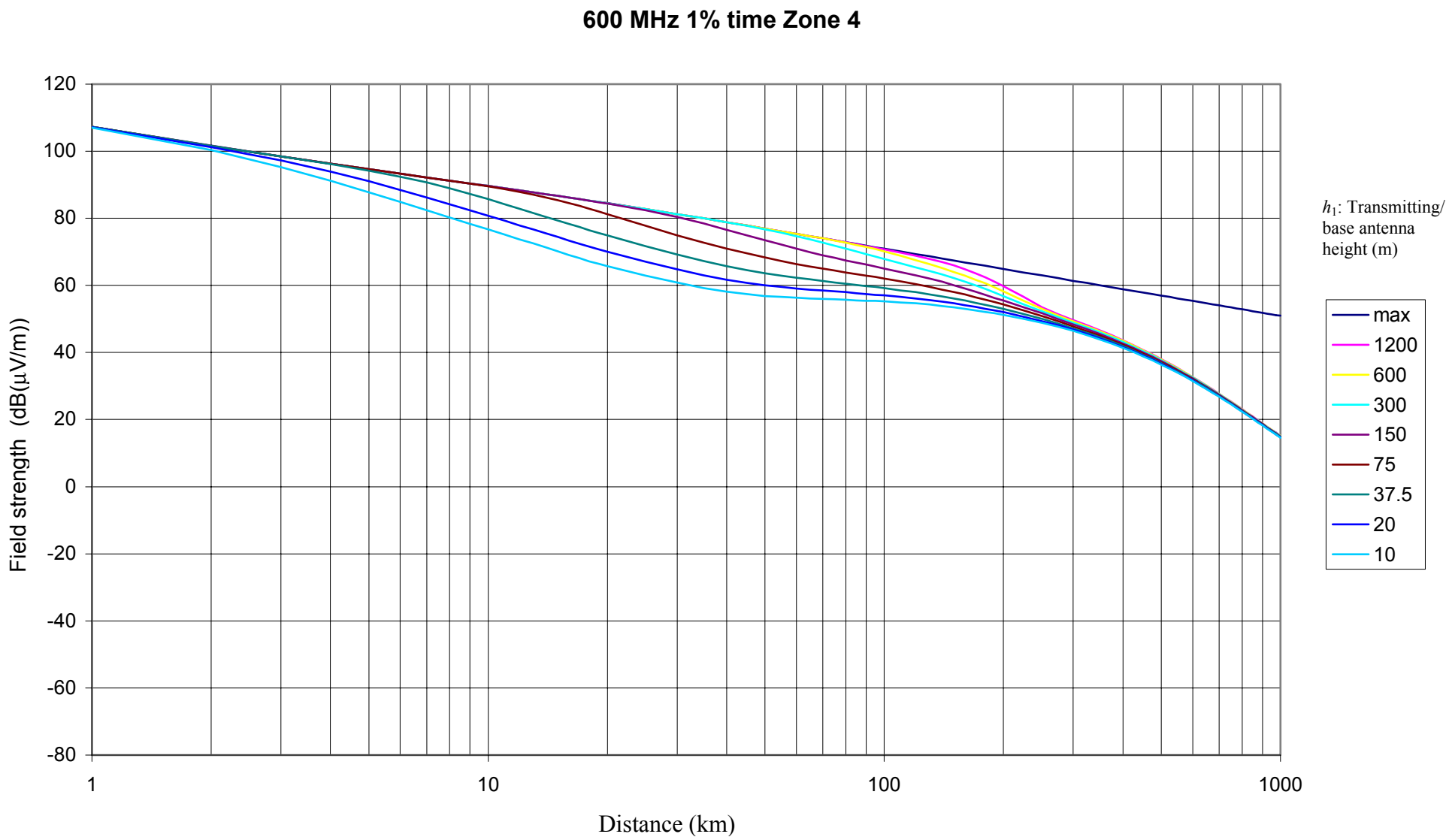

100 MHz 50% time Zone 4
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

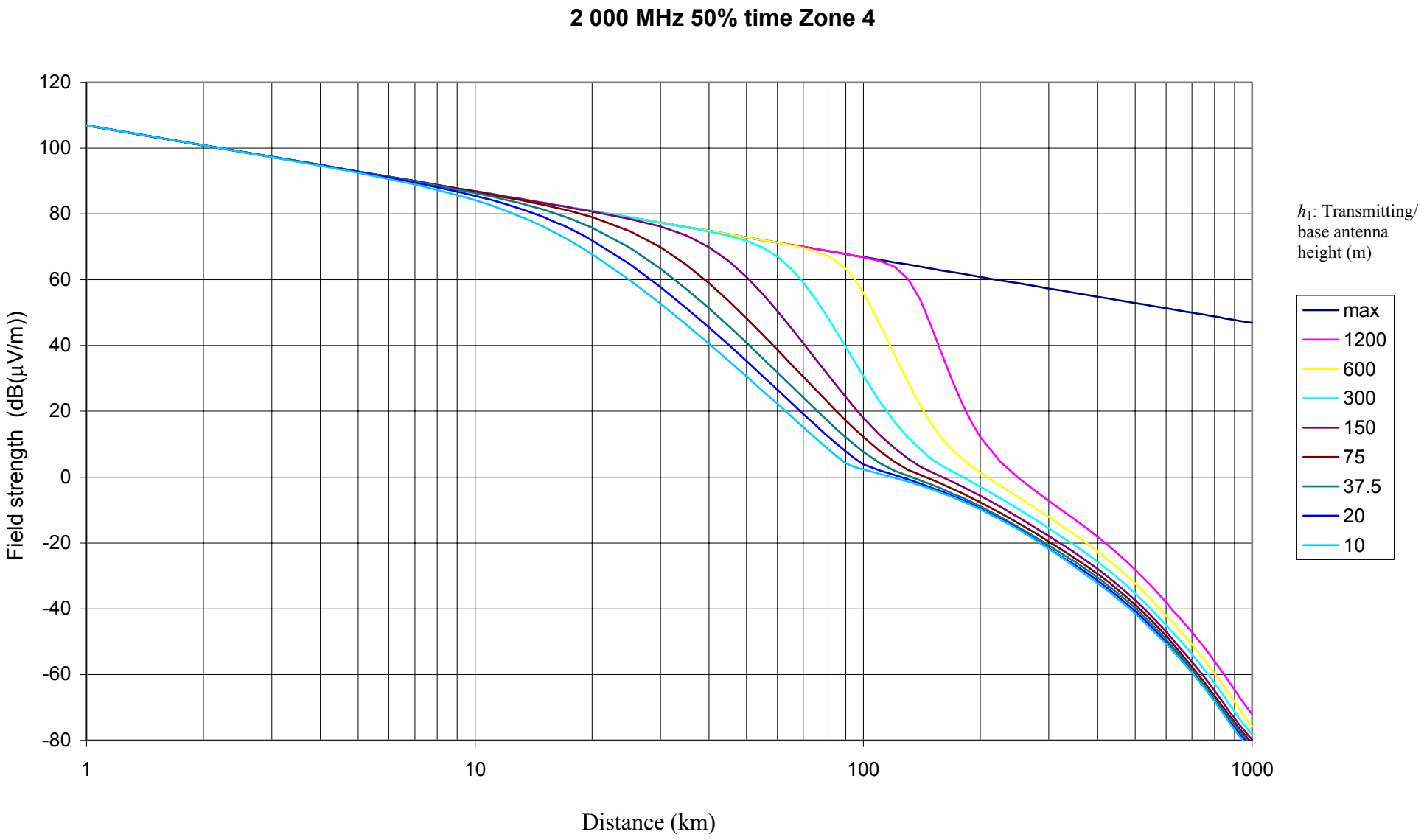

100 MHz 10% time Zone 4
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

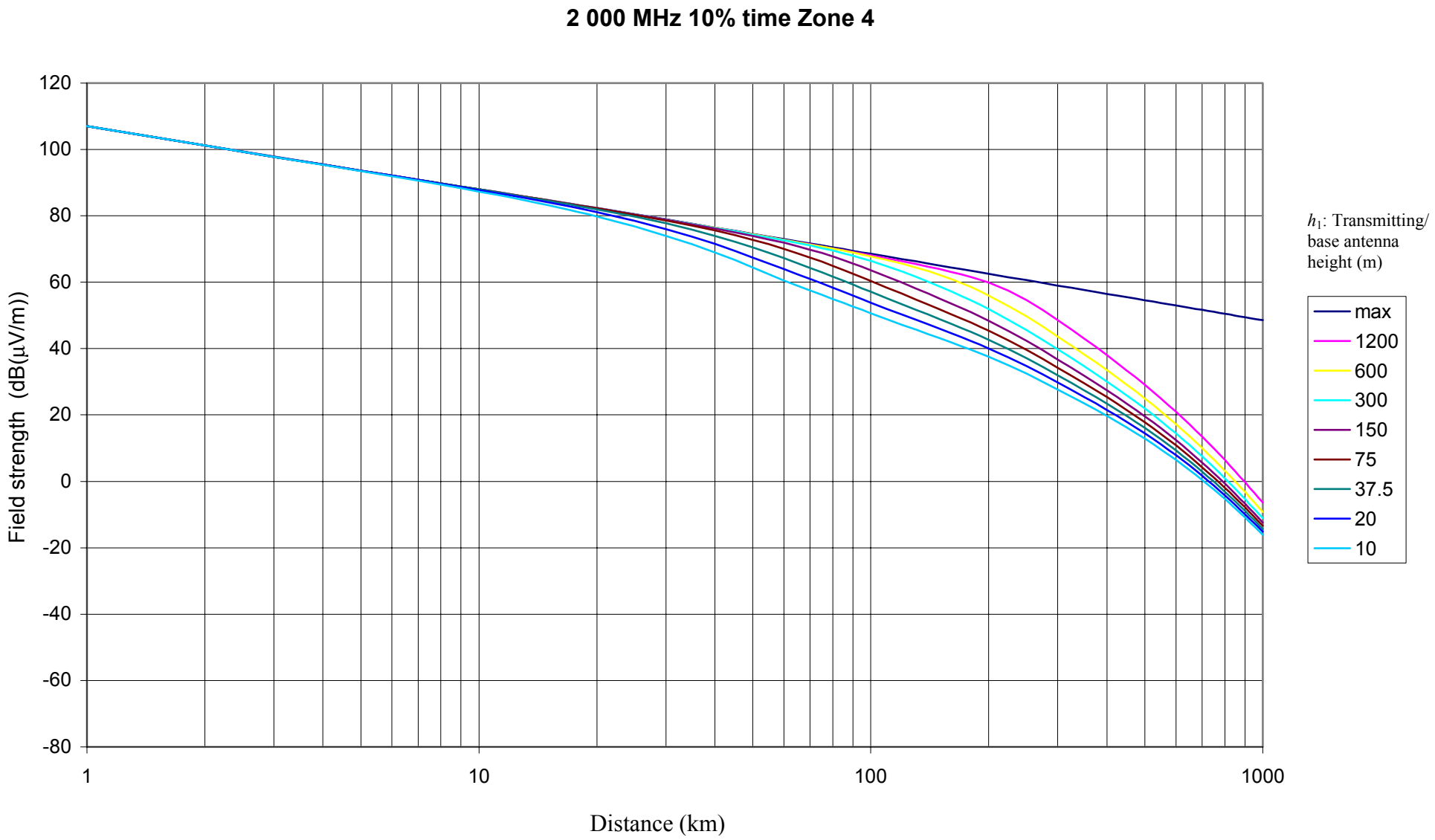

100 MHz 1% time Zone 4
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

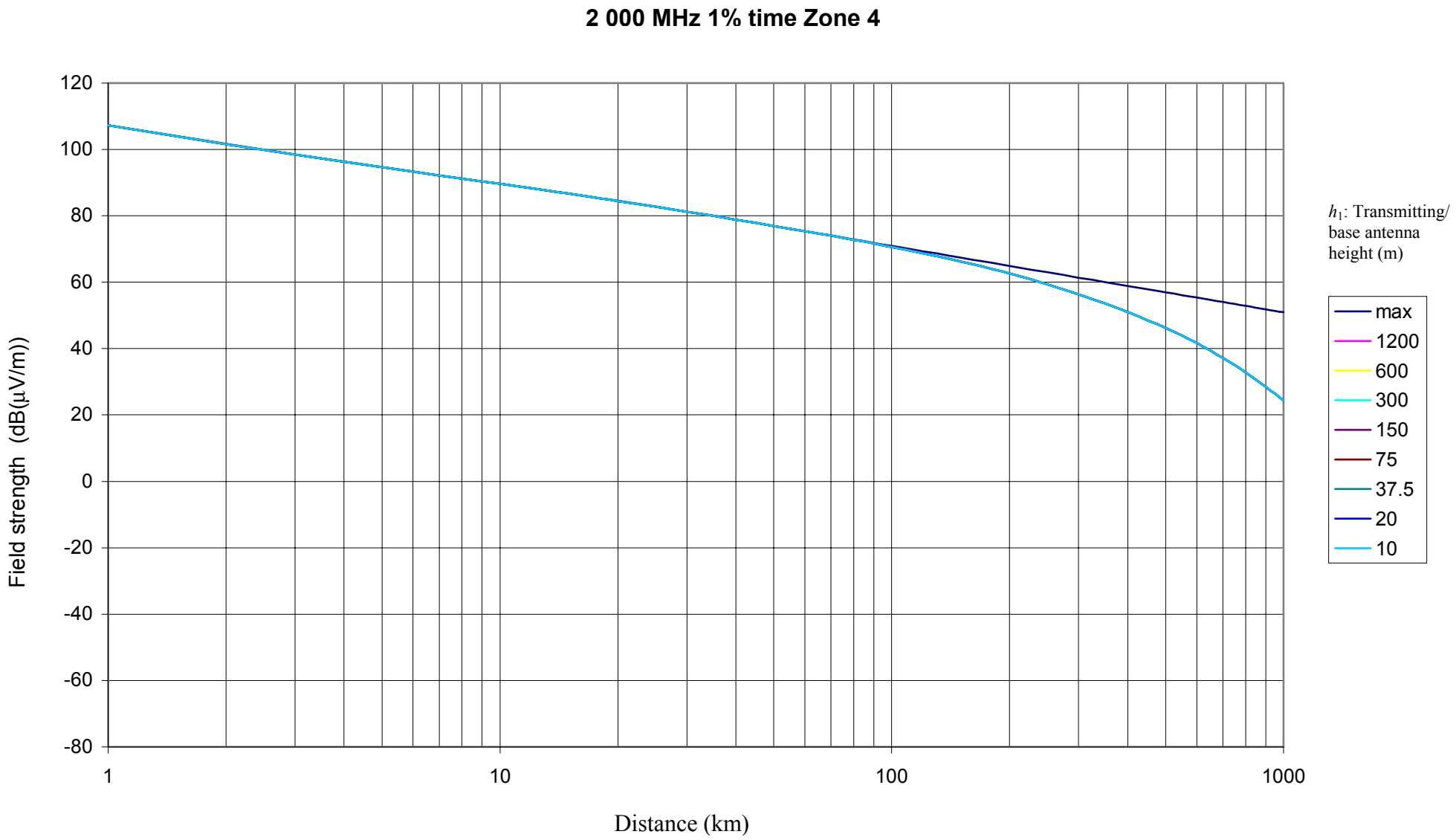

600 MHz 50% time Zone 4
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

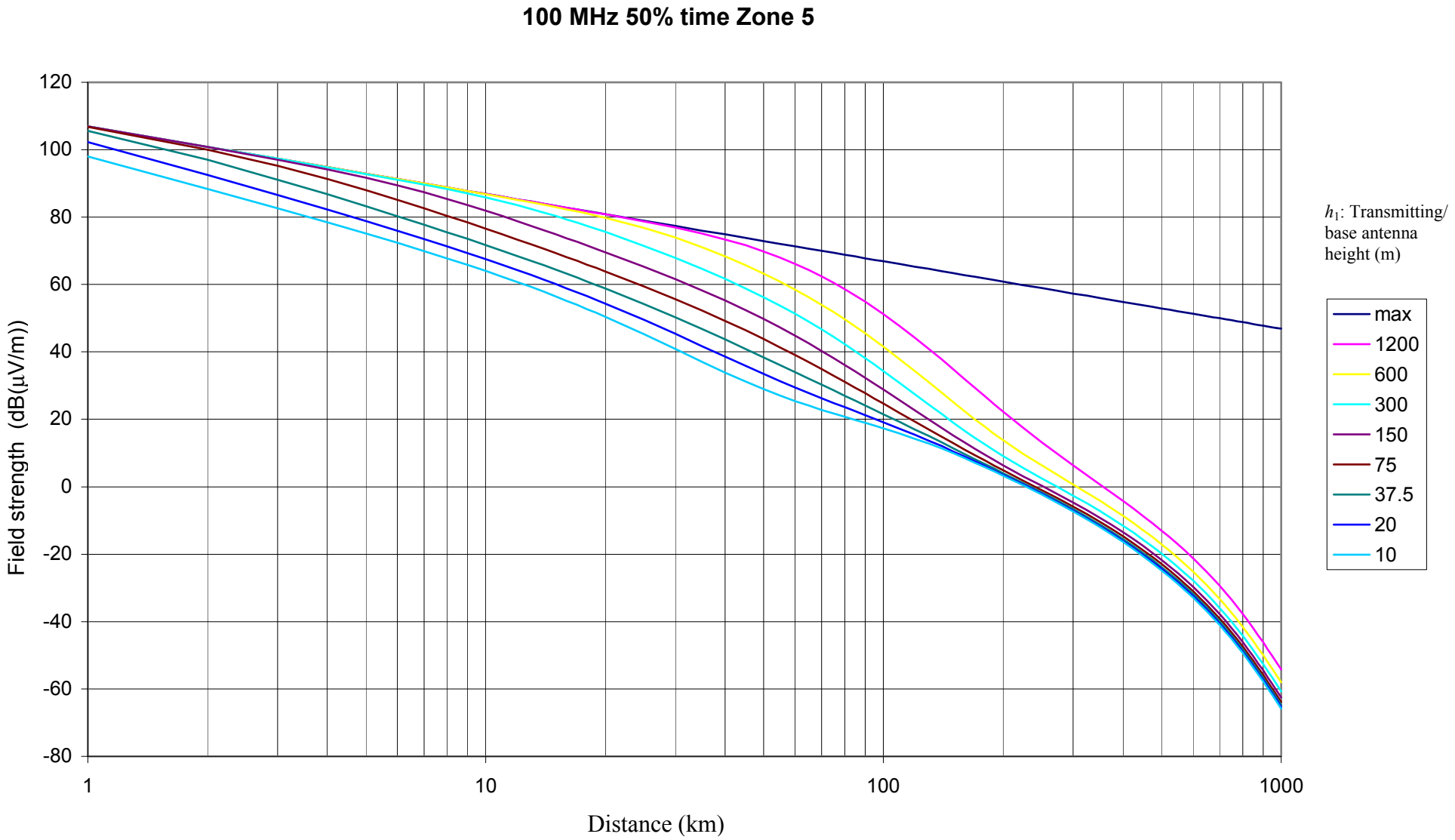

600 MHz 10% time Zone 4
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

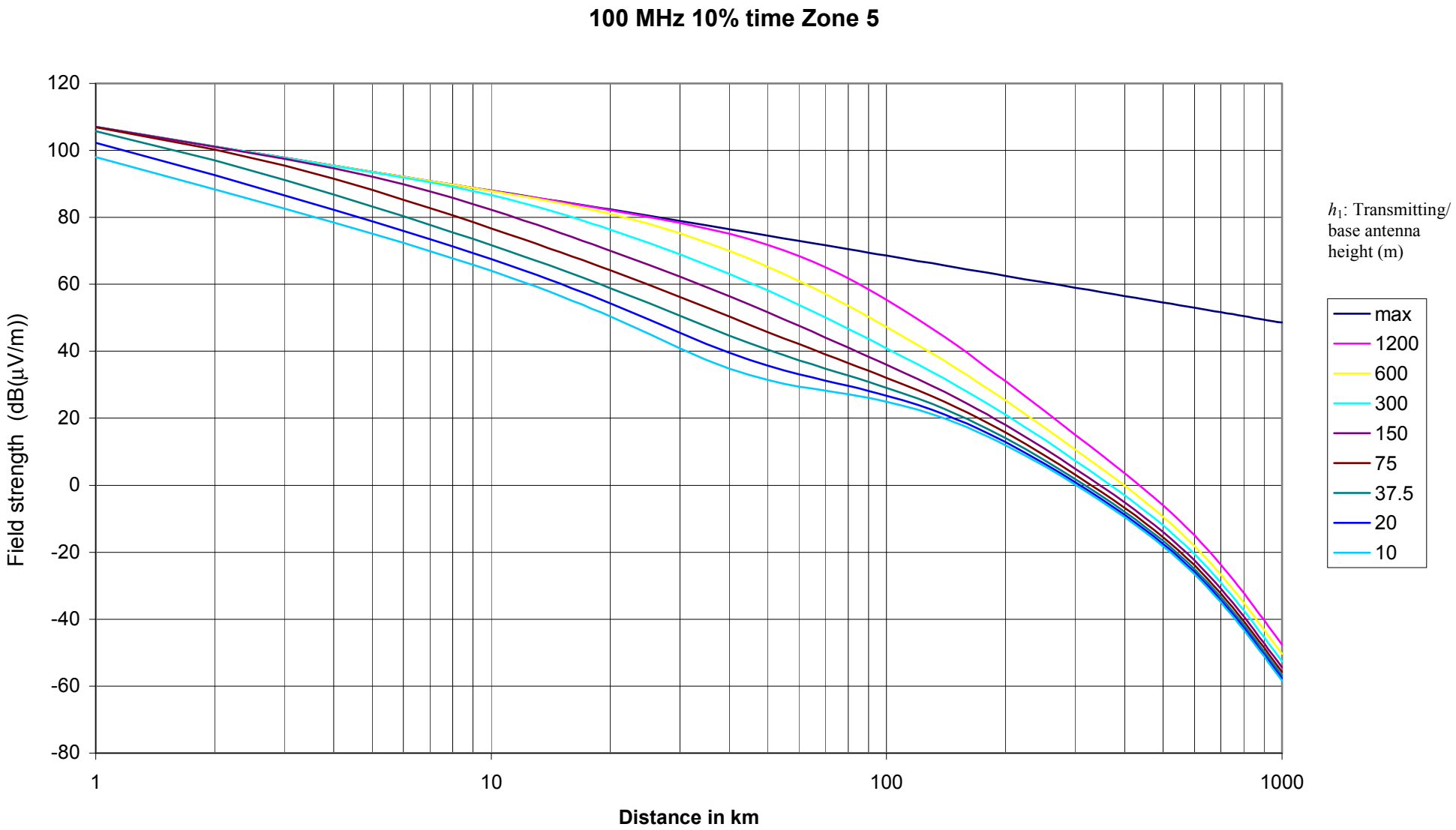

600 MHz 1% time Zone 4
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

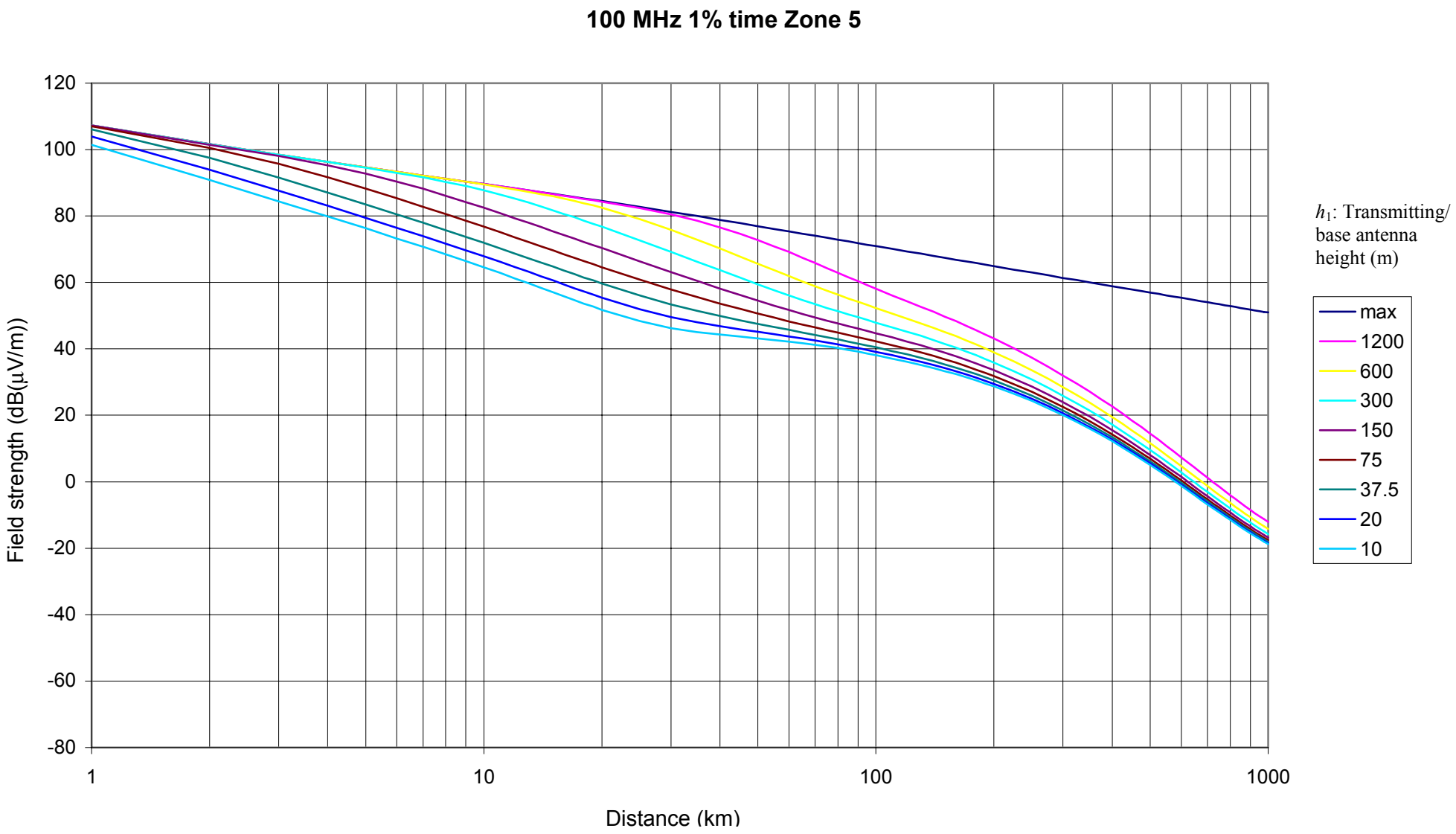

2 000 MHz 50% time Zone 4
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

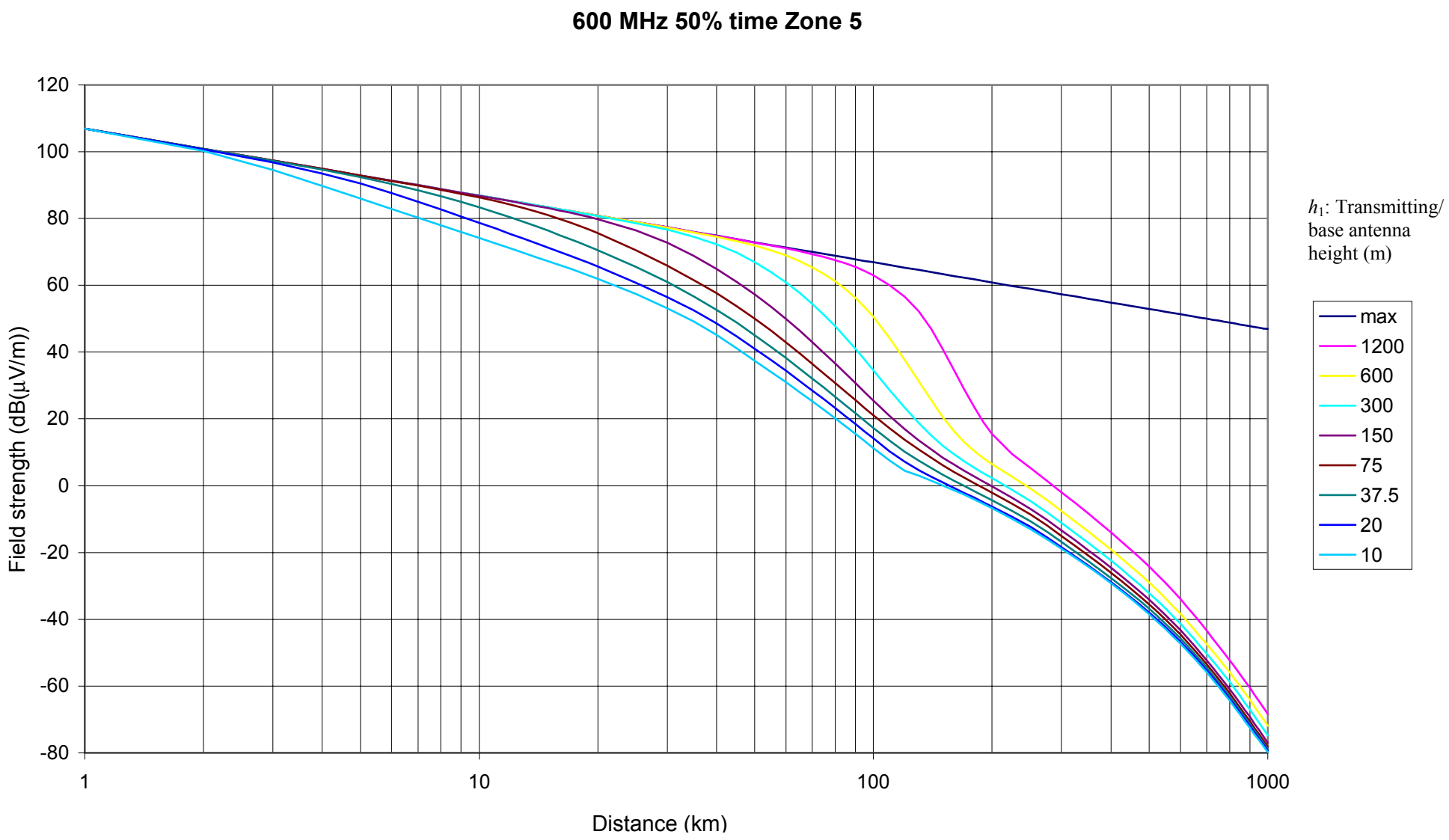

2 000 MHz 10% time Zone 4
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

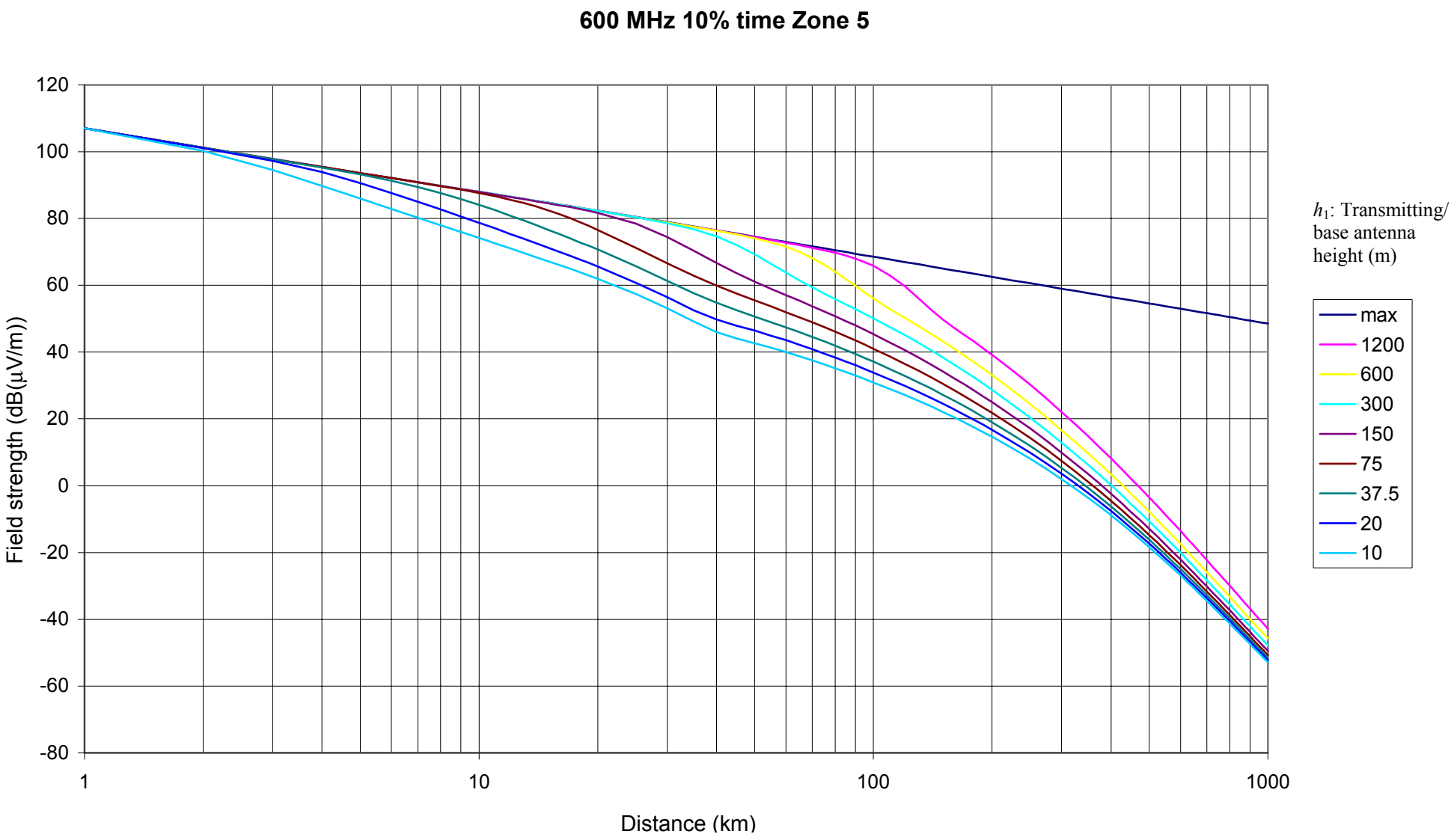

2 000 MHz 1% time Zone 4
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

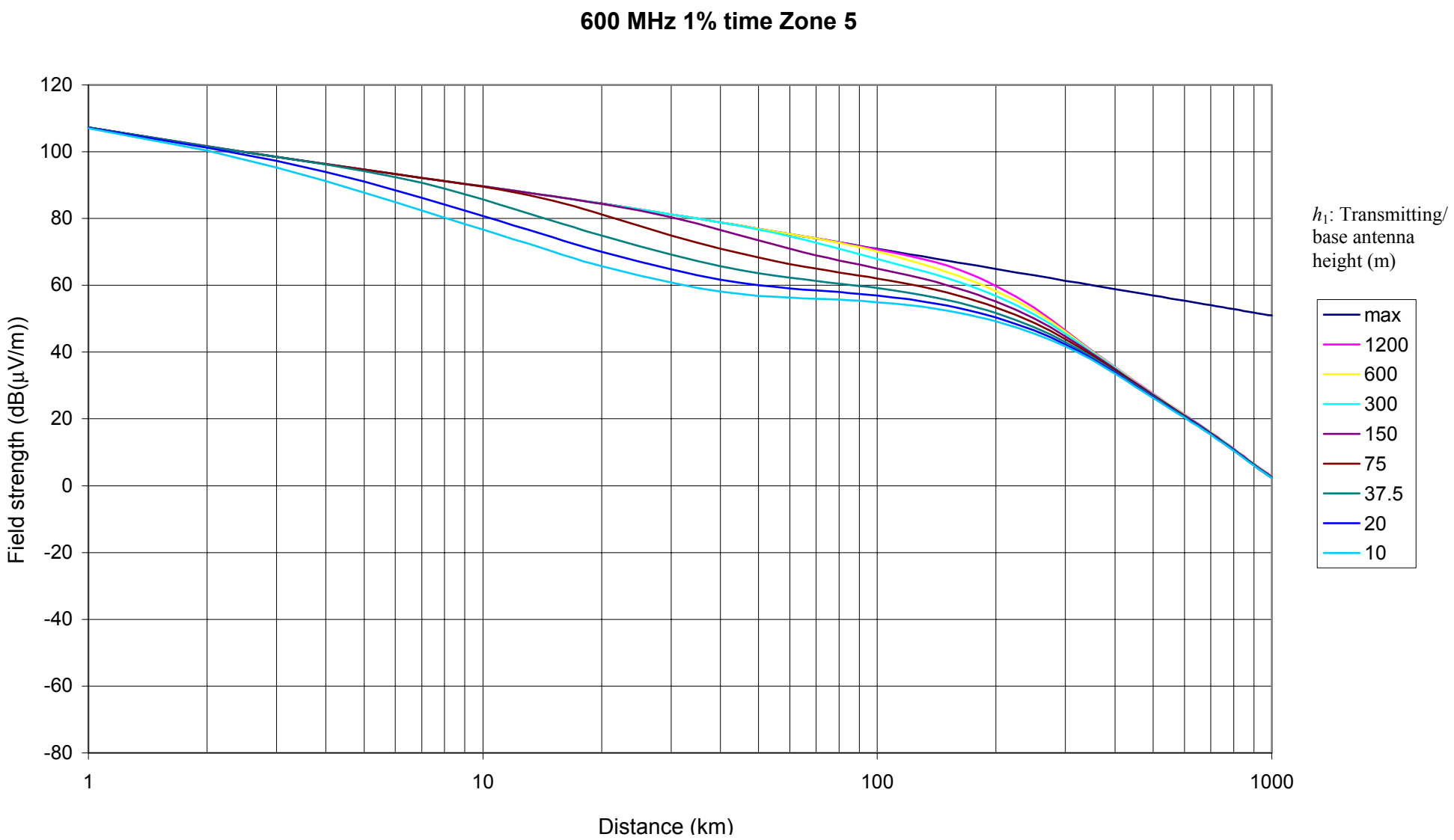

100 MHz 50% time Zone 5
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

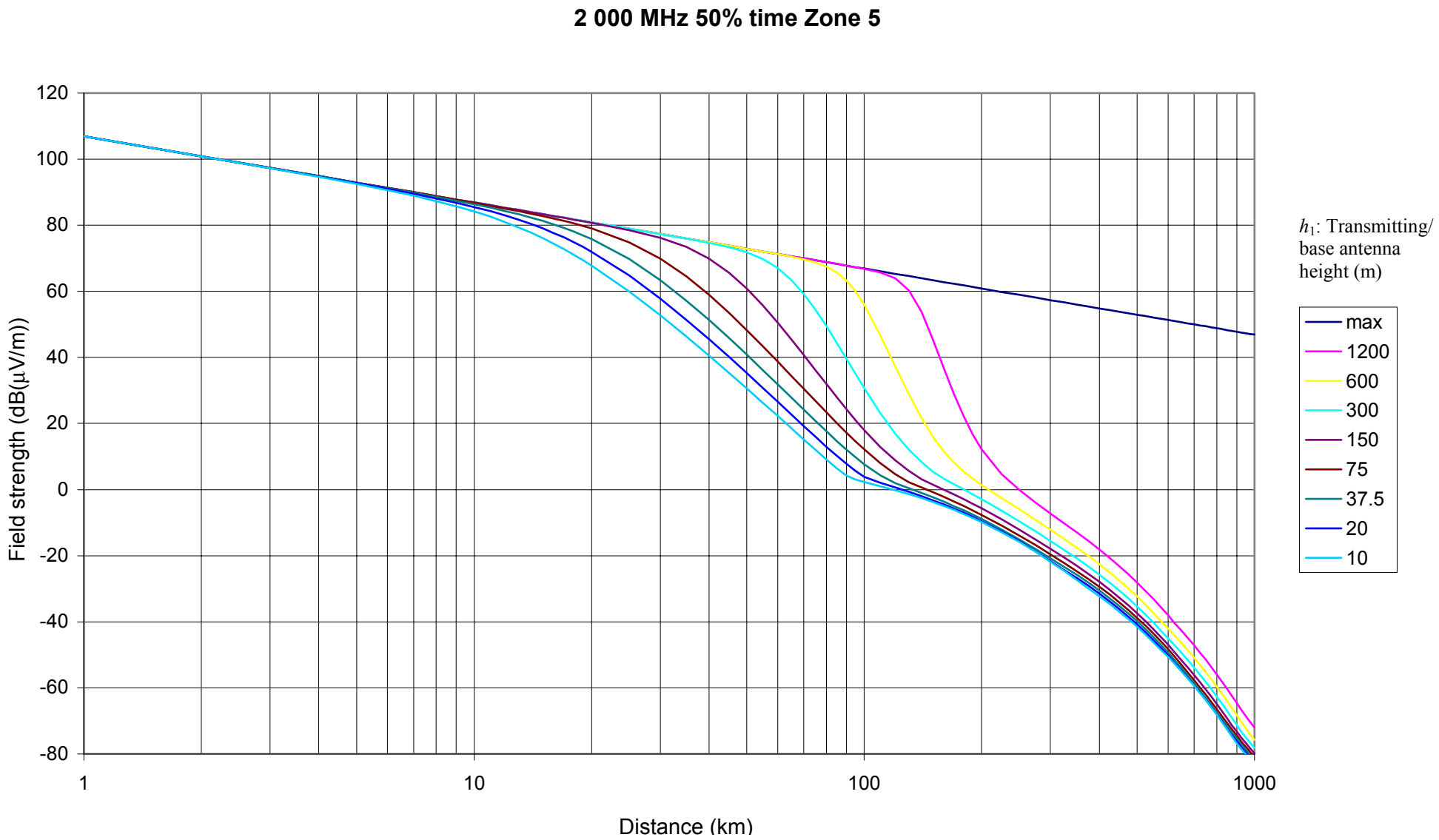

100 MHz 10% time Zone 5
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance in km
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

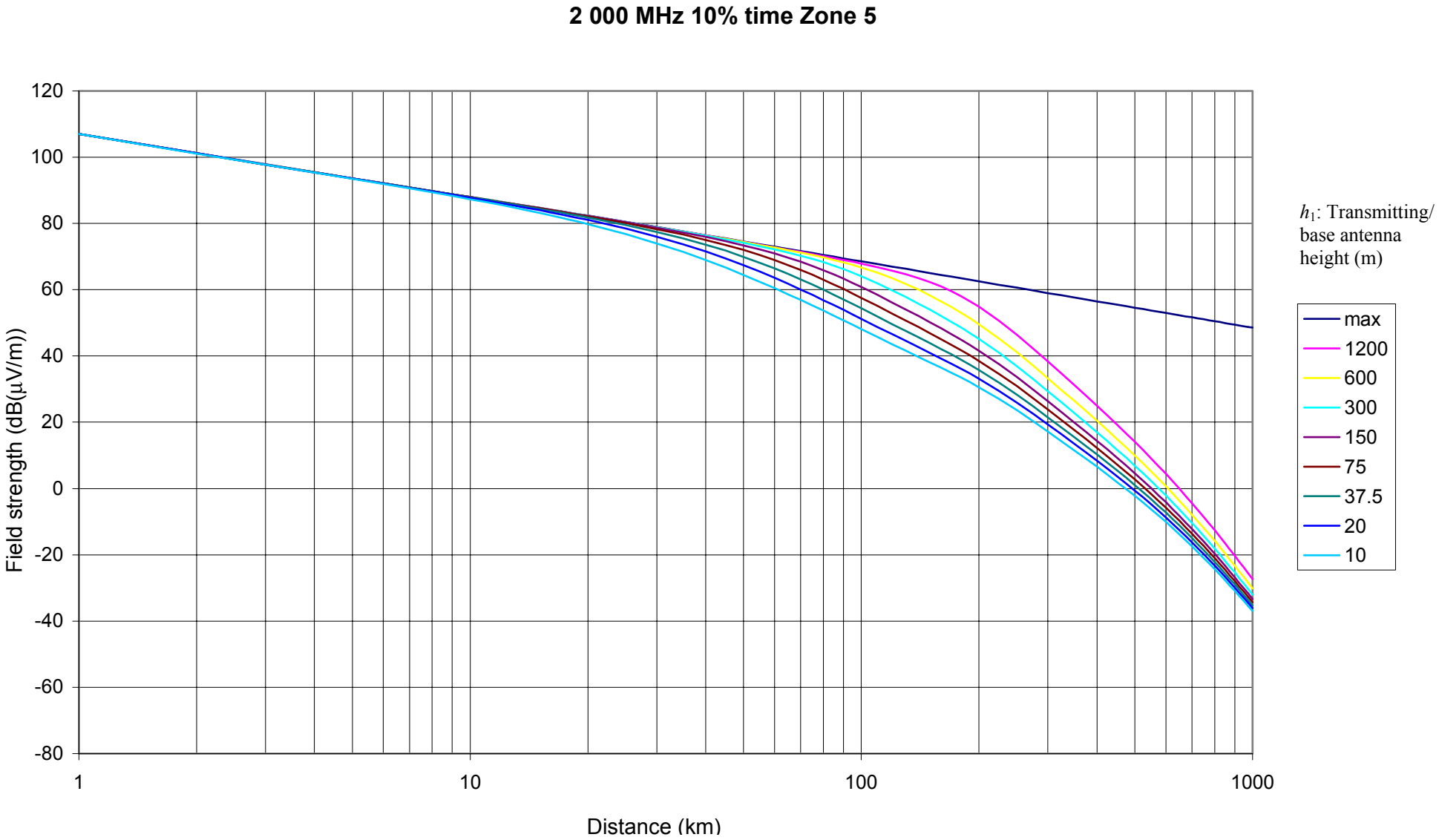

100 MHz 1% time Zone 5
Field strength (dB(μV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

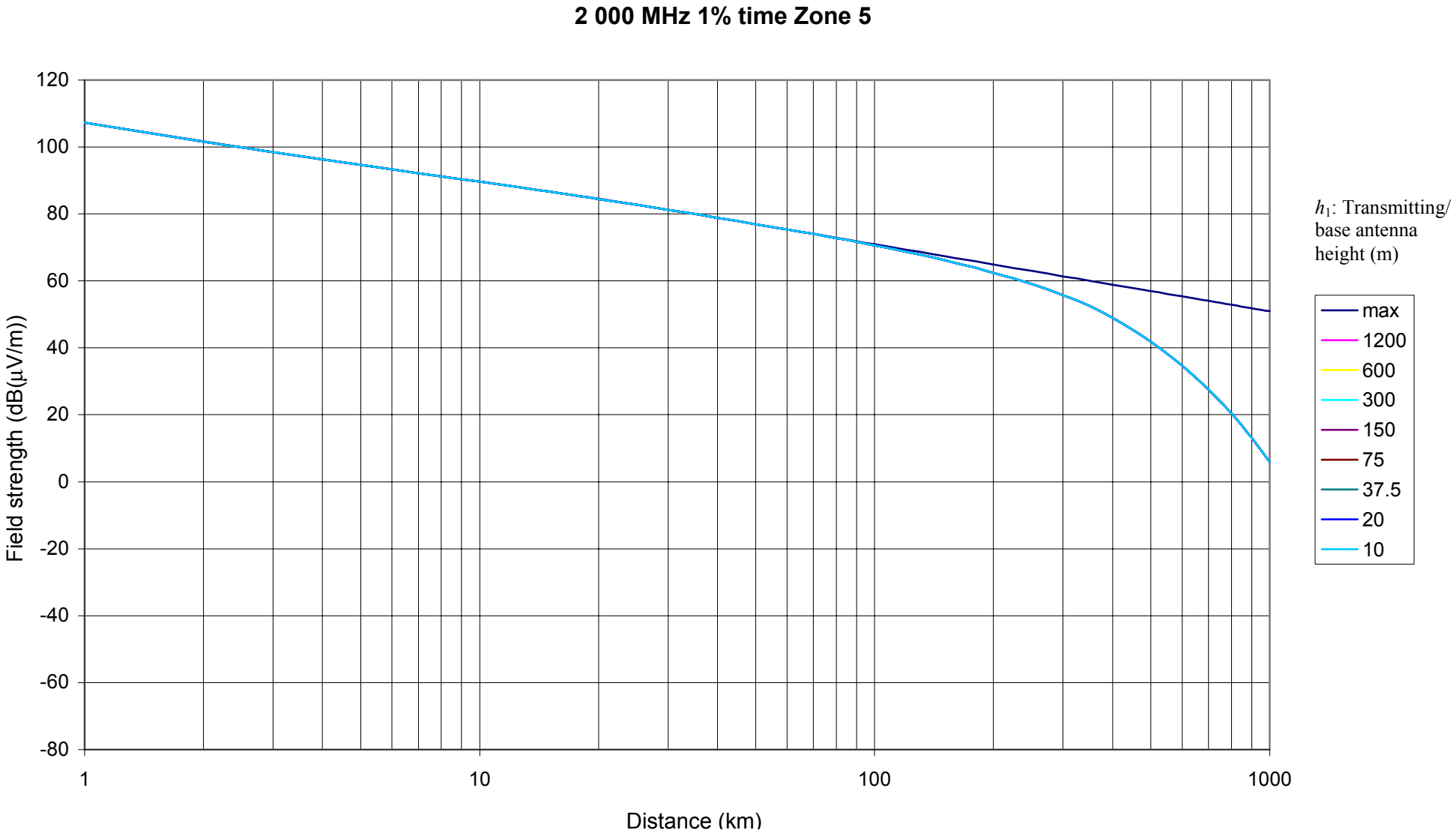

600 MHz 50% time Zone 5
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

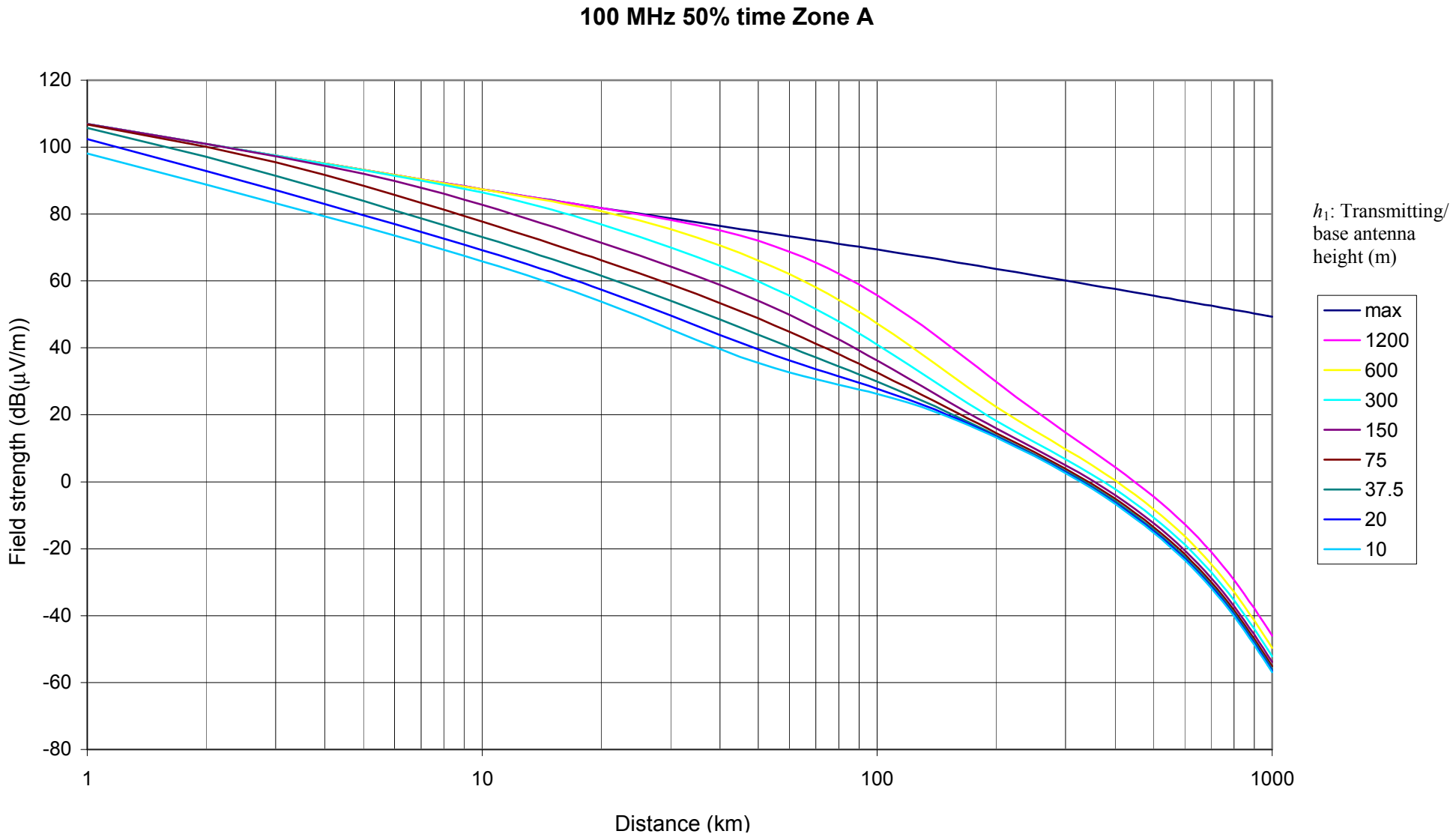

600 MHz 10% time Zone 5
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

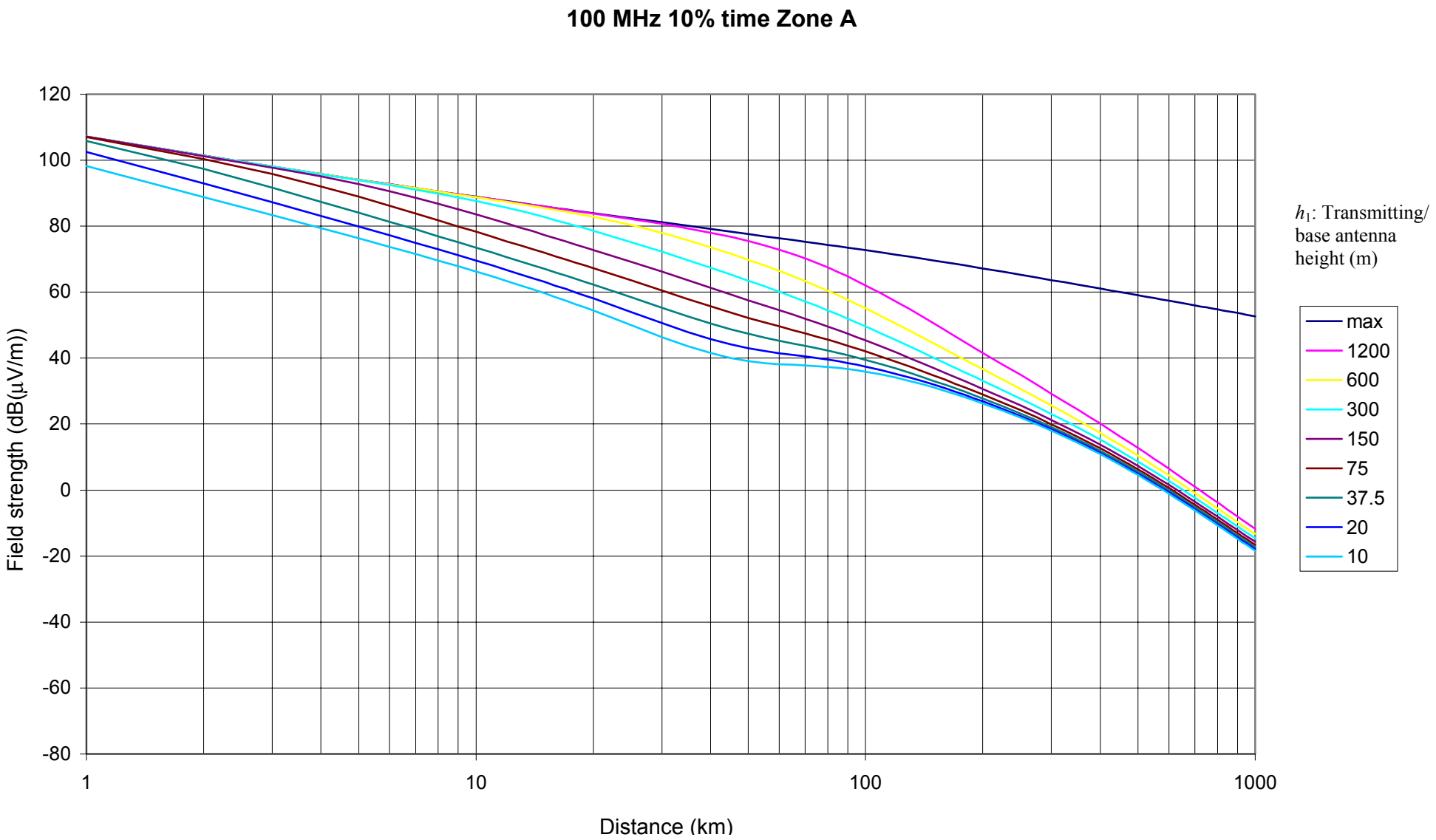

600 MHz 1% time Zone 5
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

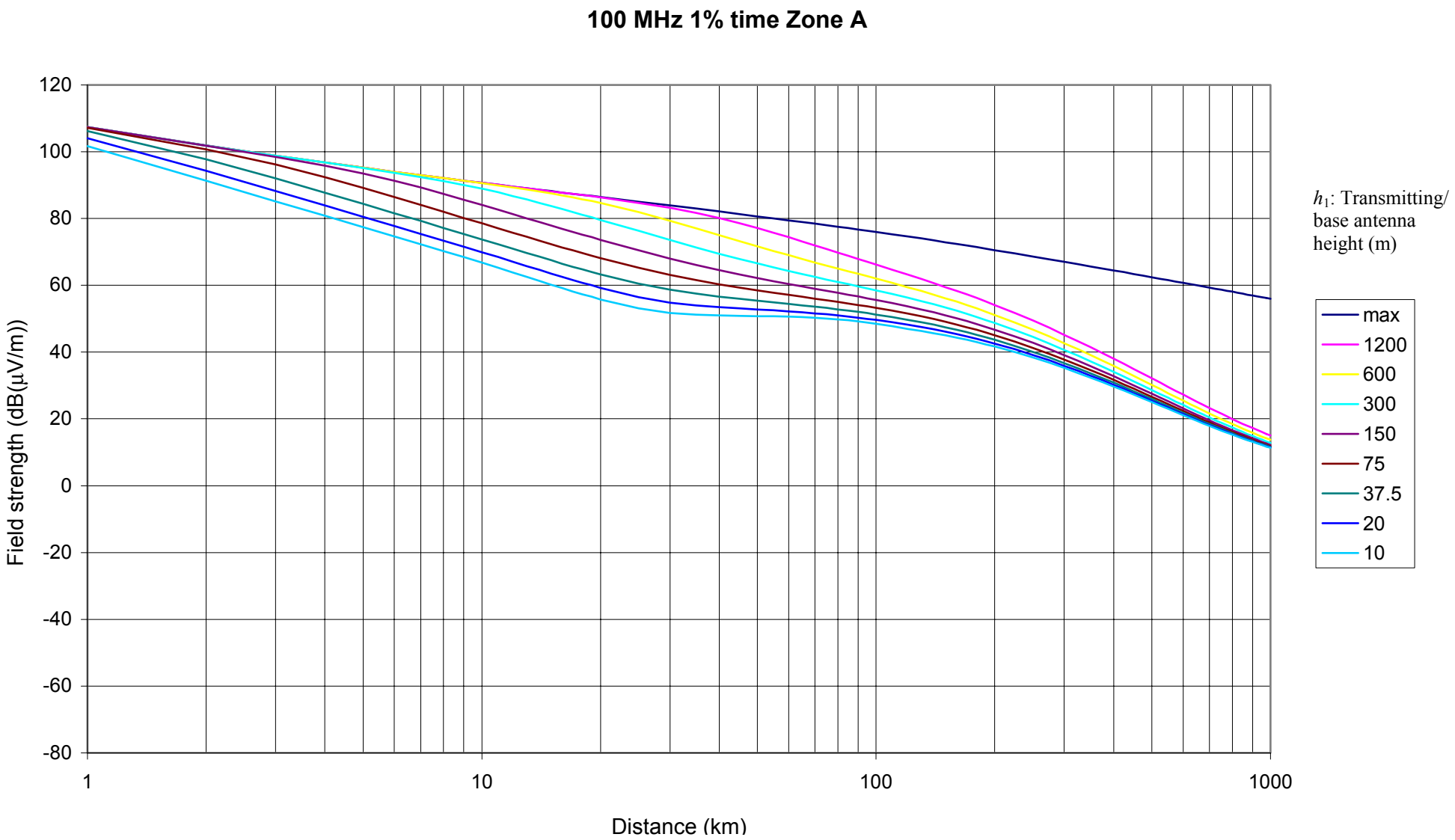

2 000 MHz 50% time Zone 5
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

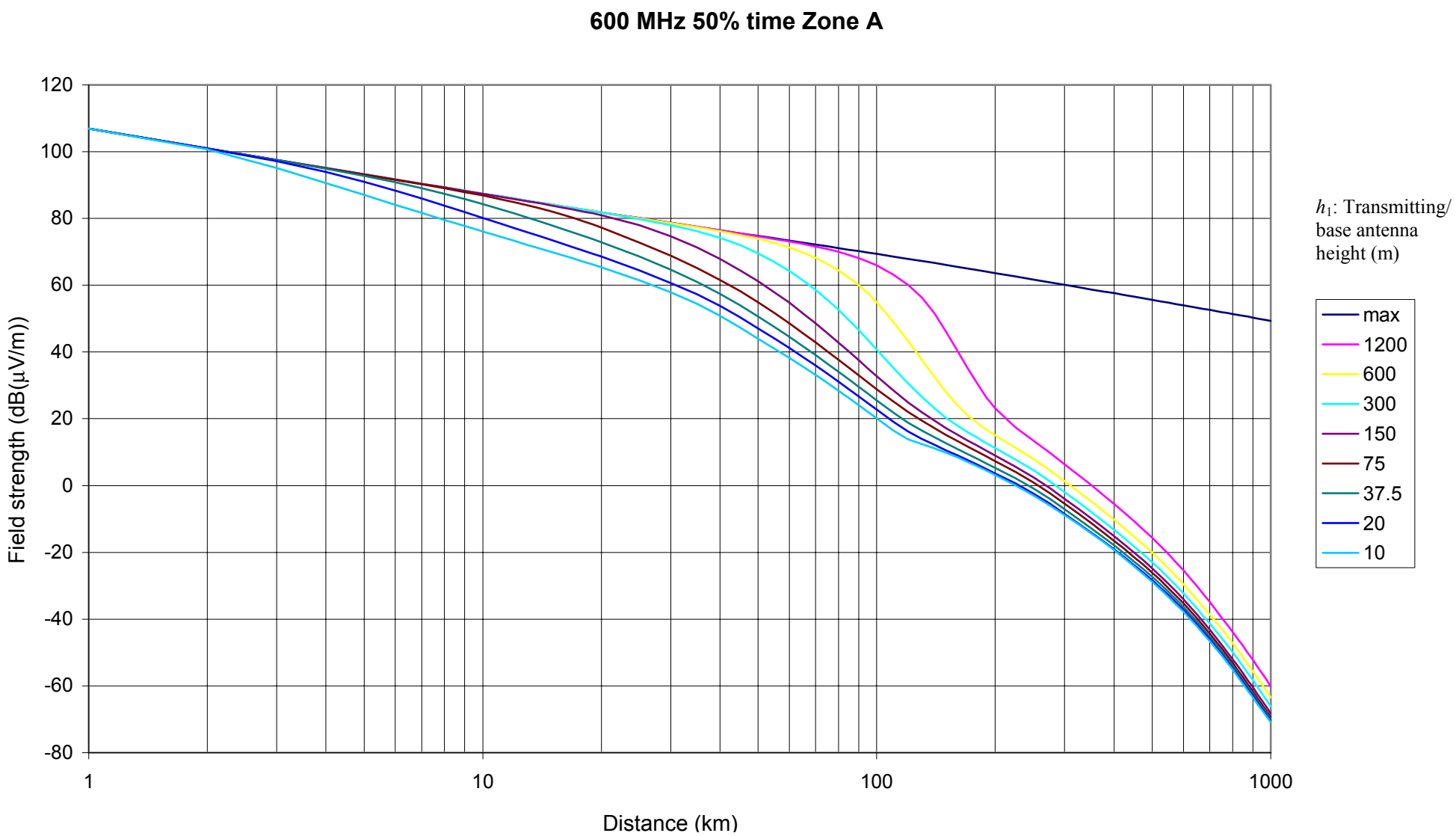

2 000 MHz 10% time Zone 5
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

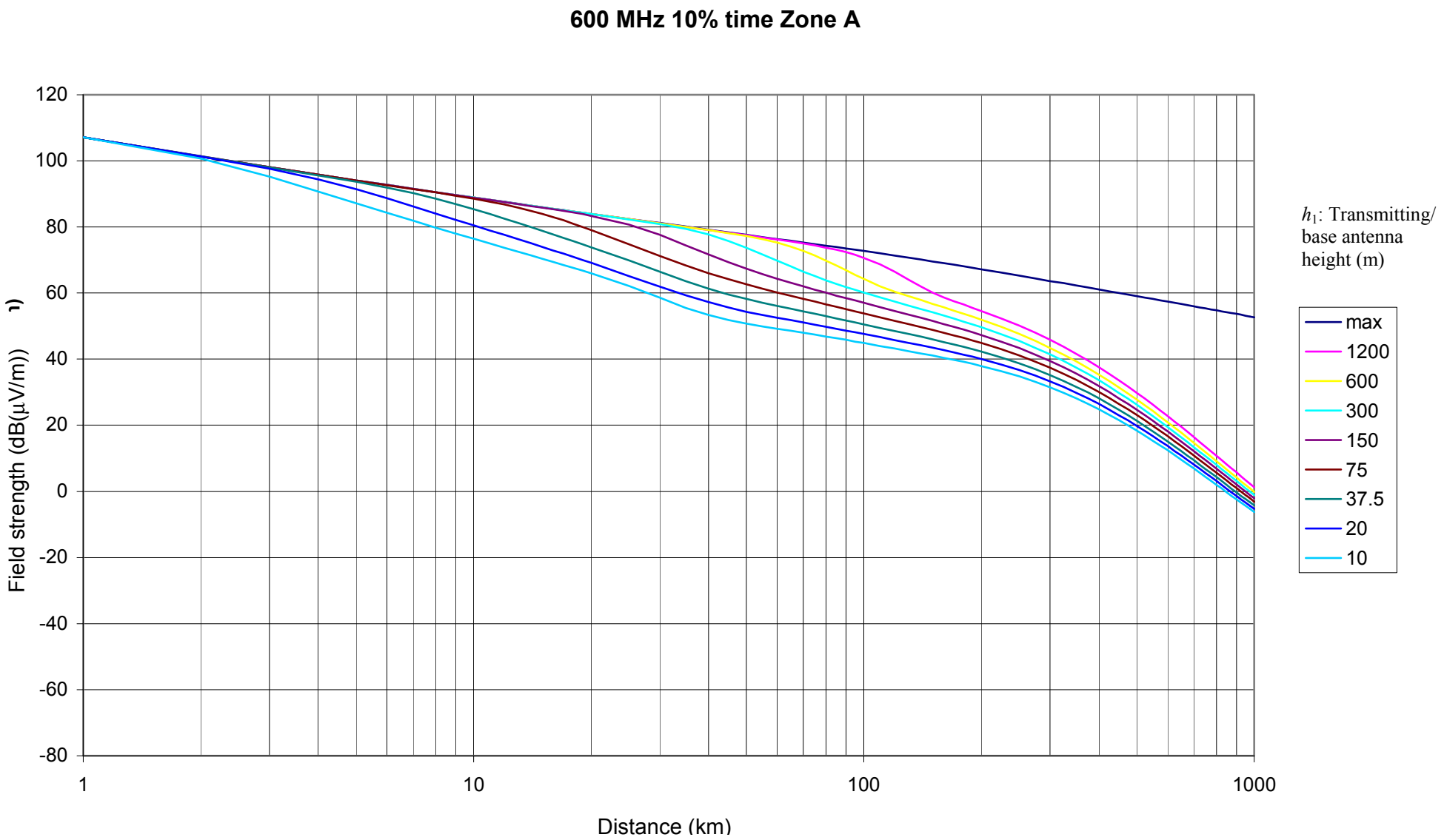

2 000 MHz 1% time Zone 5
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

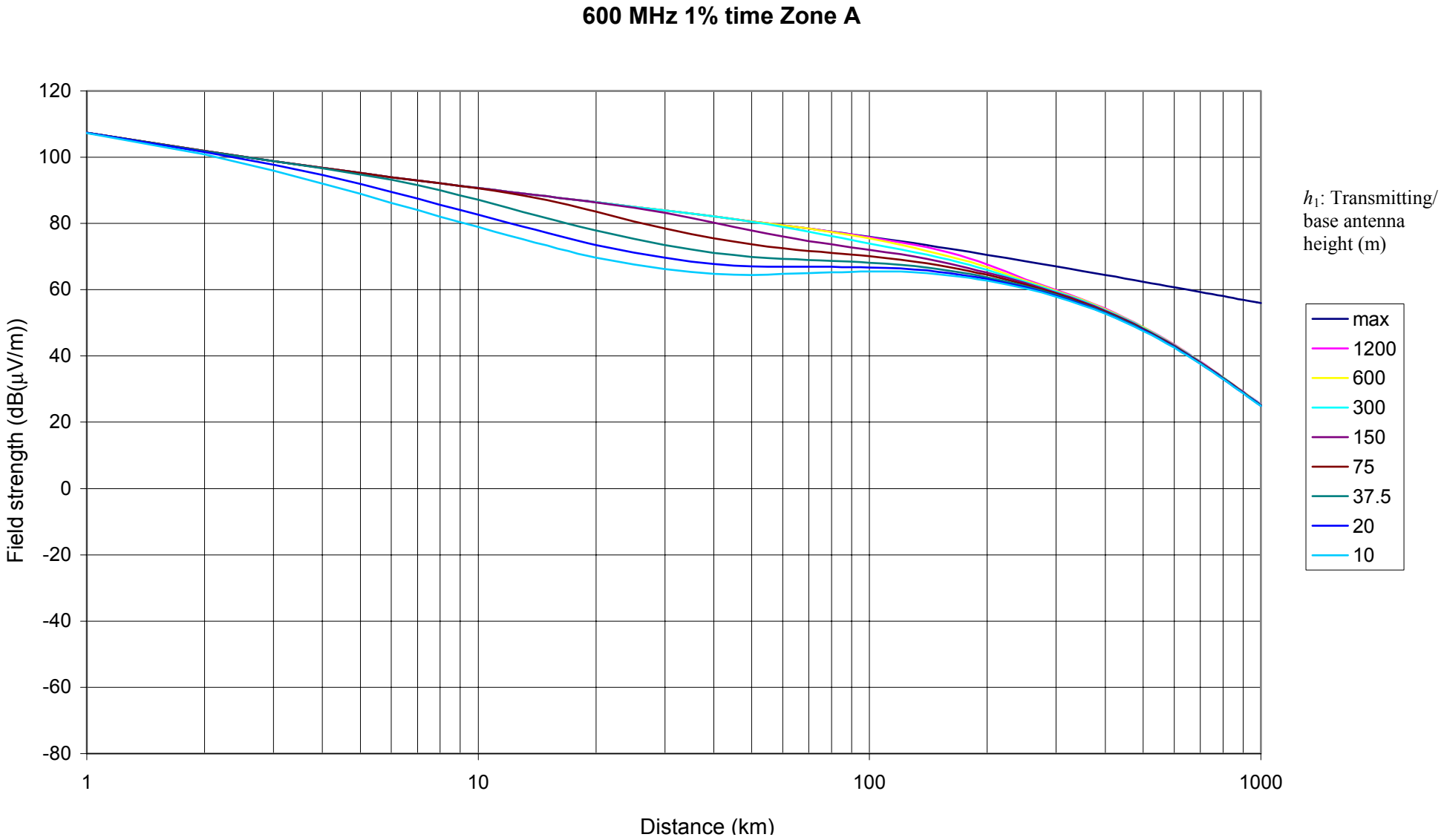

100 MHz 50% time Zone A
Field strength (dB(μV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

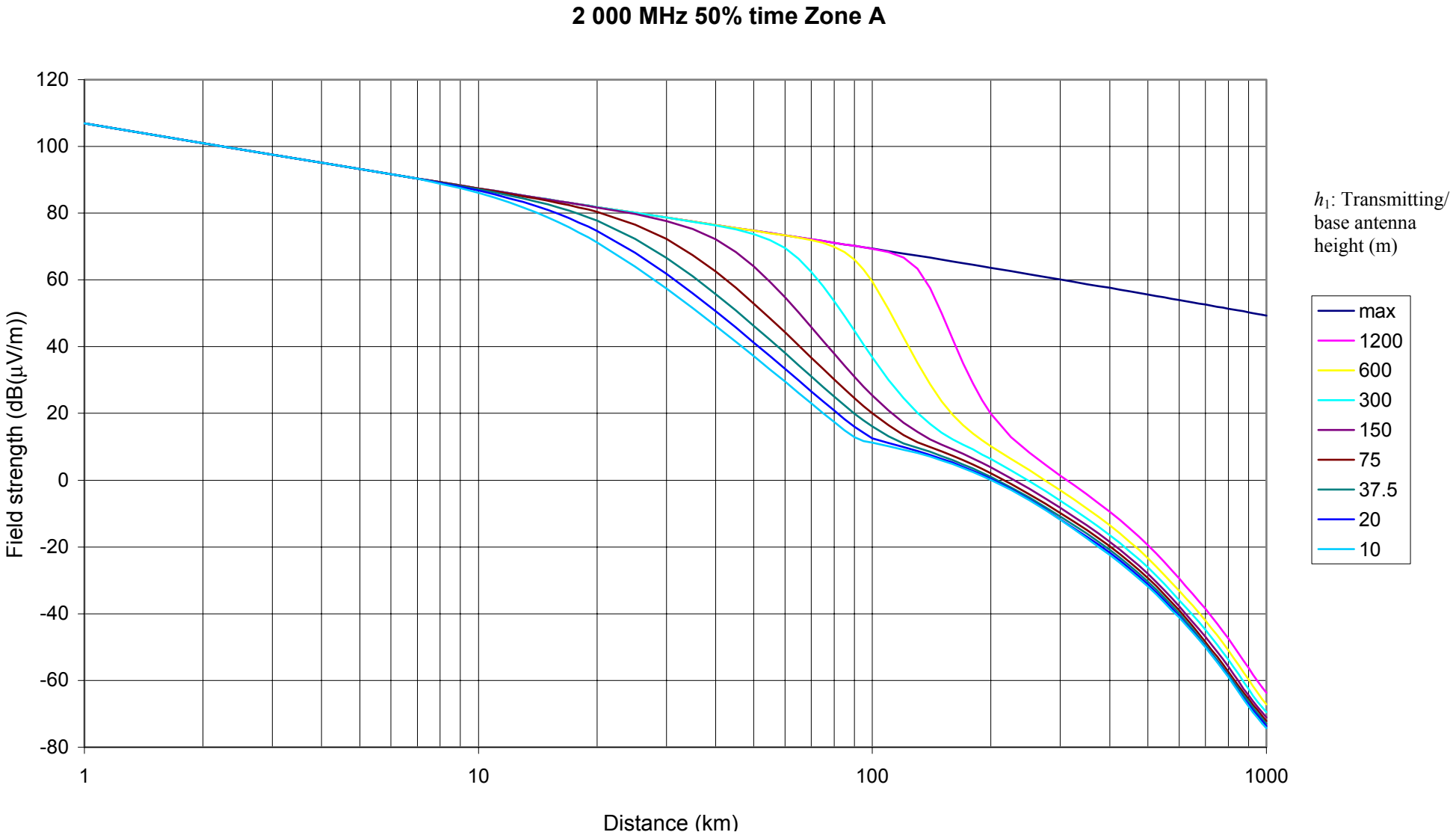

100 MHz 10% time Zone A
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

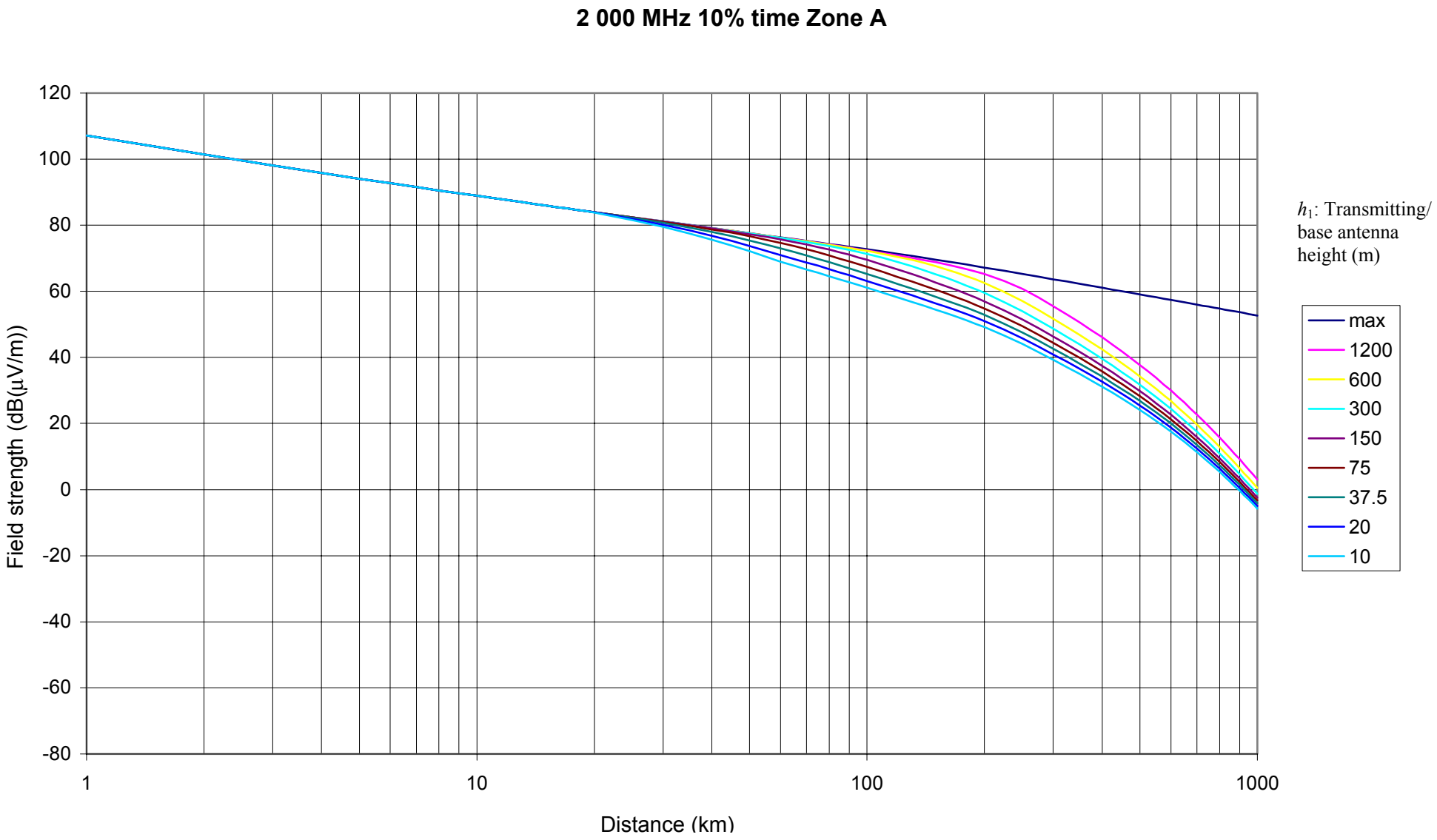

100 MHz 1% time Zone A
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

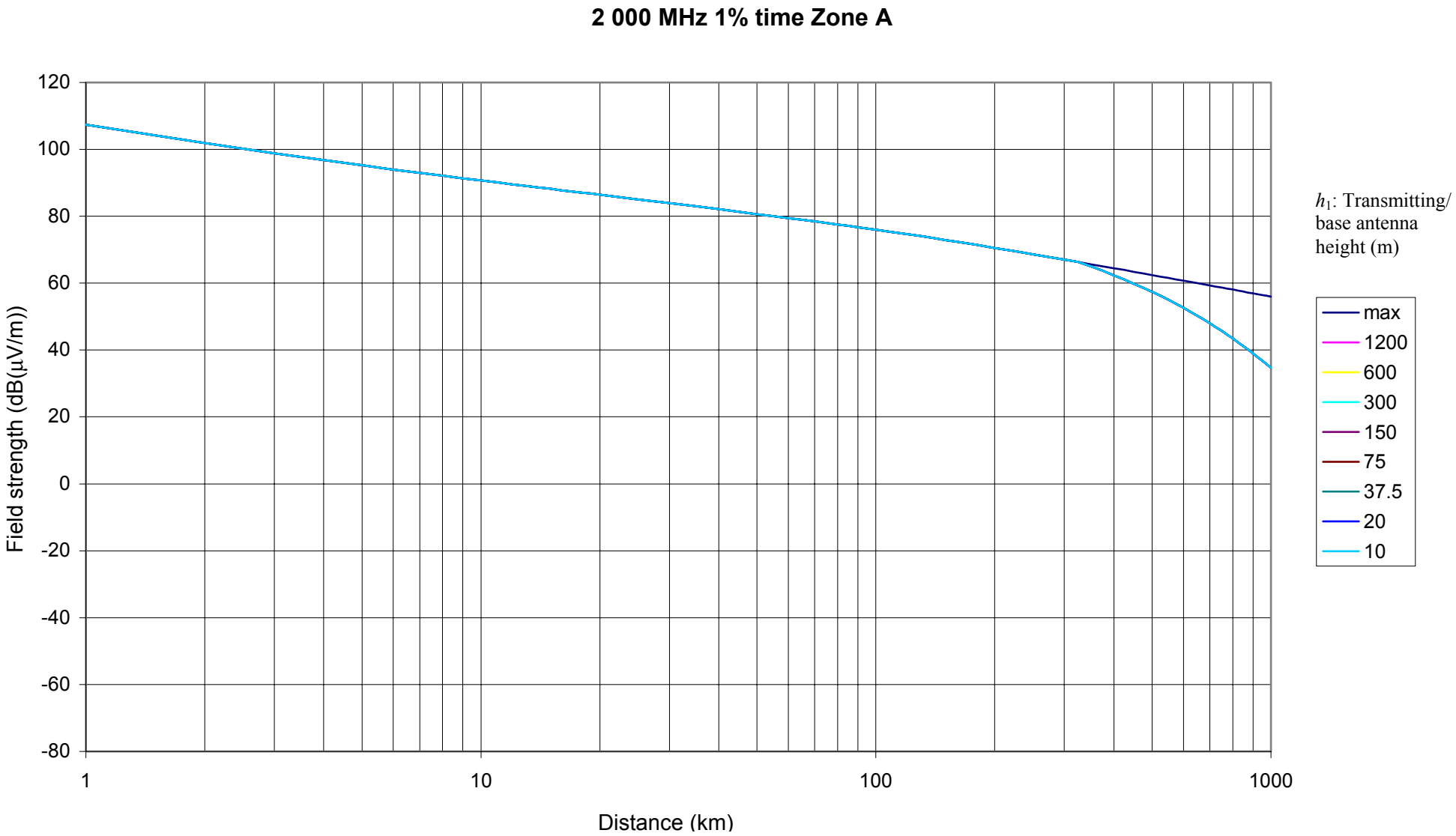

600 MHz 50% time Zone A
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

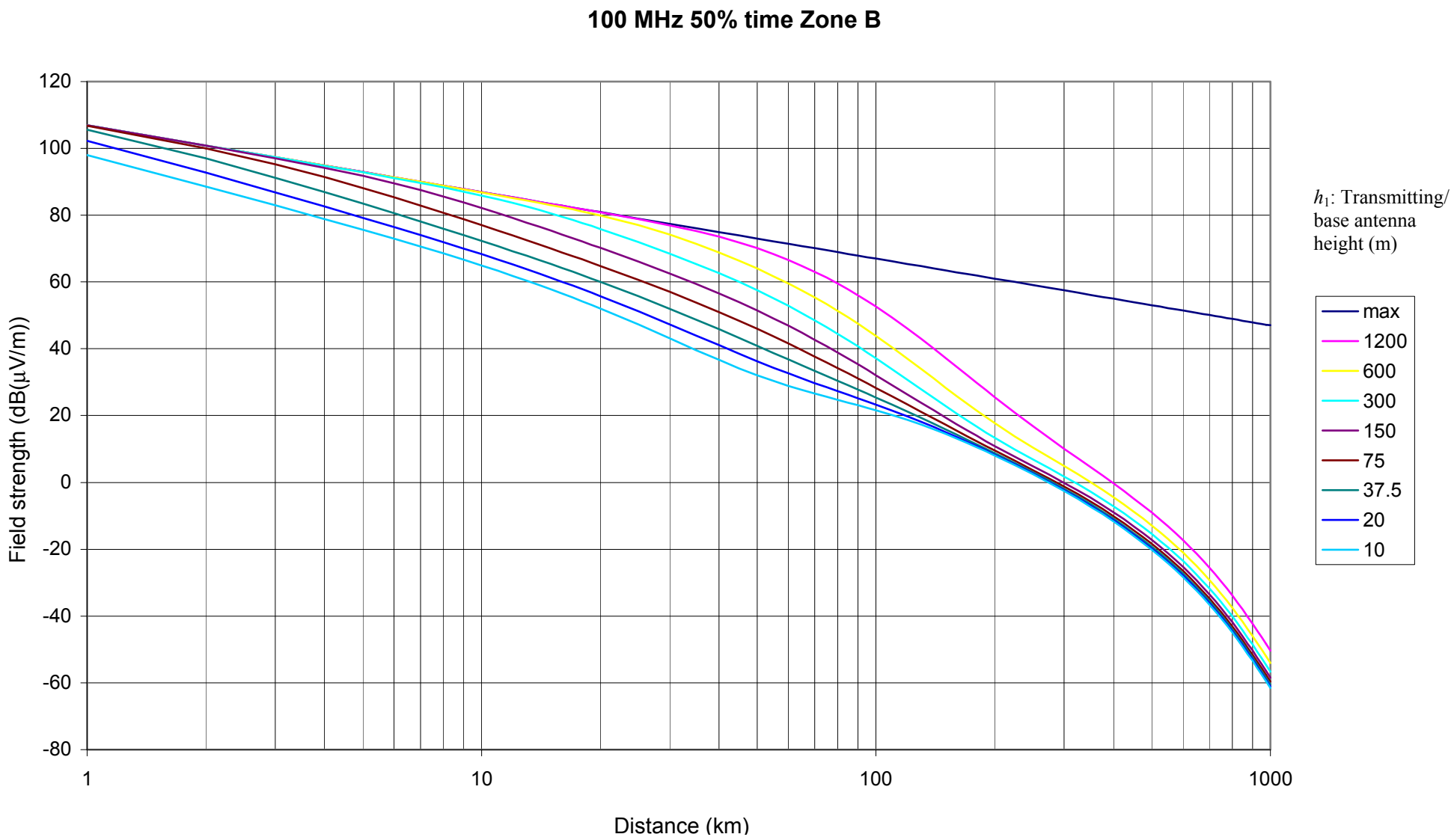

600 MHz 10% time Zone A
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

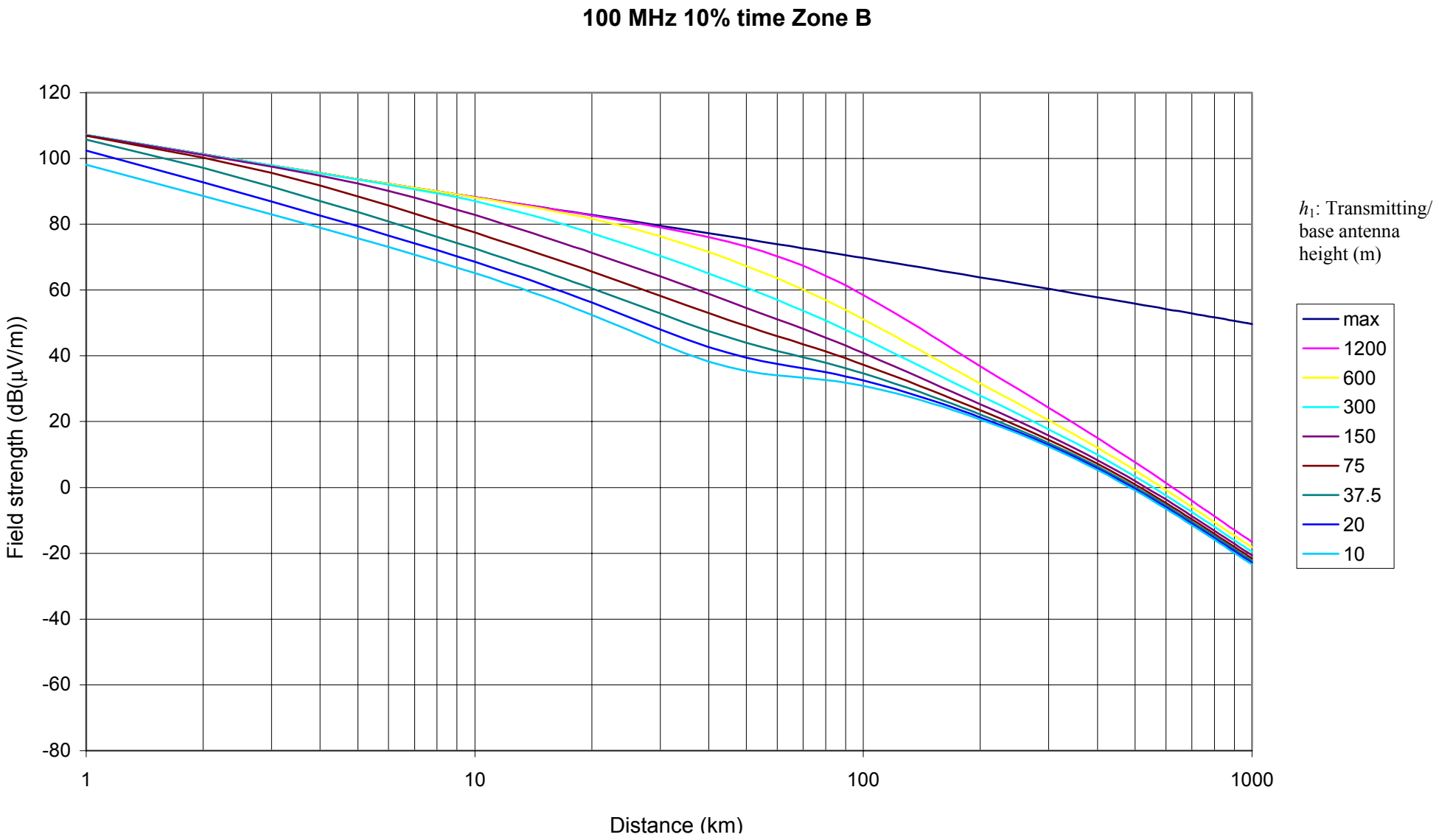

600 MHz 1% time Zone A
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

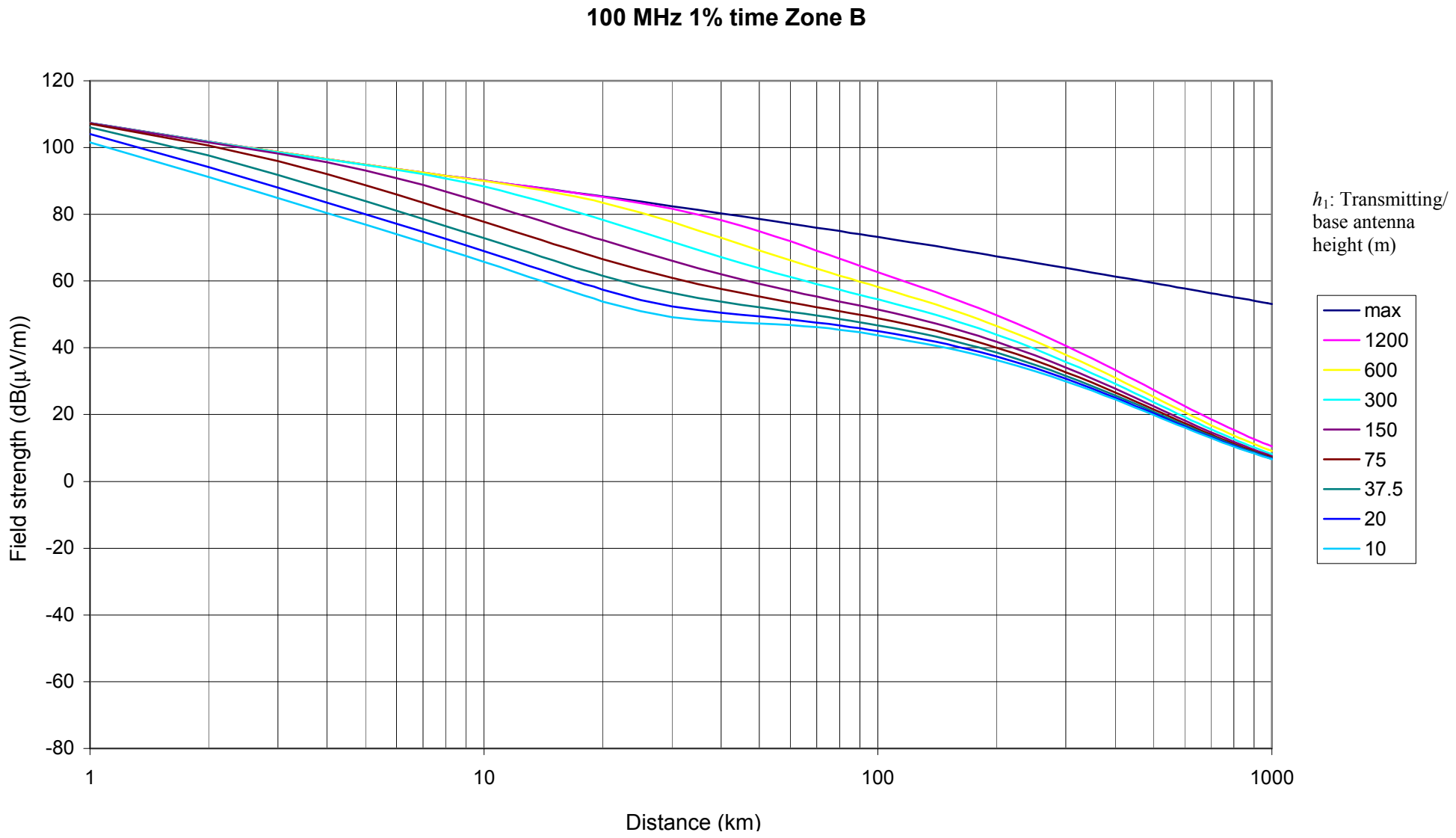

2 000 MHz 50% time Zone A
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

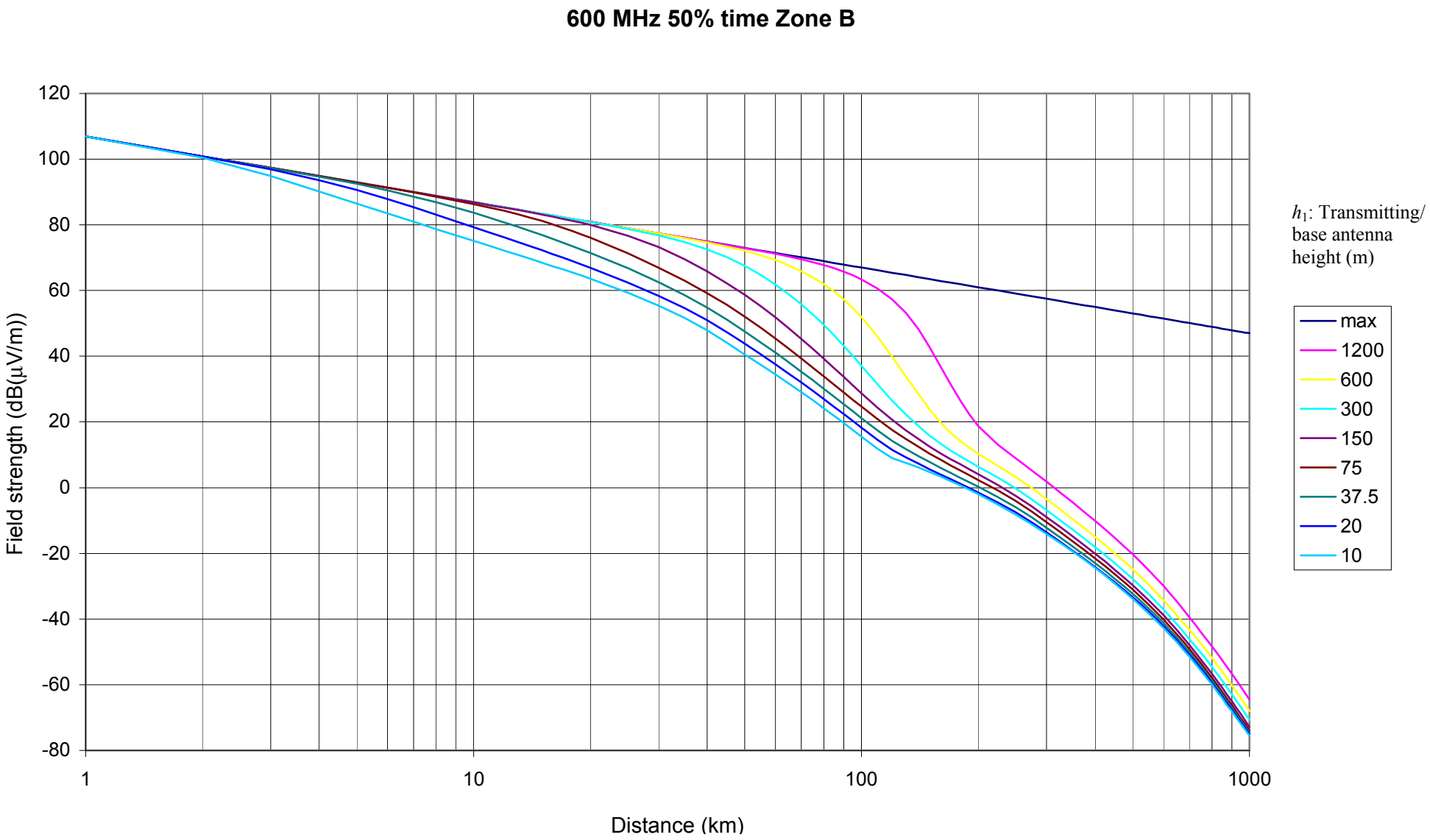

2 000 MHz 10% time Zone A
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

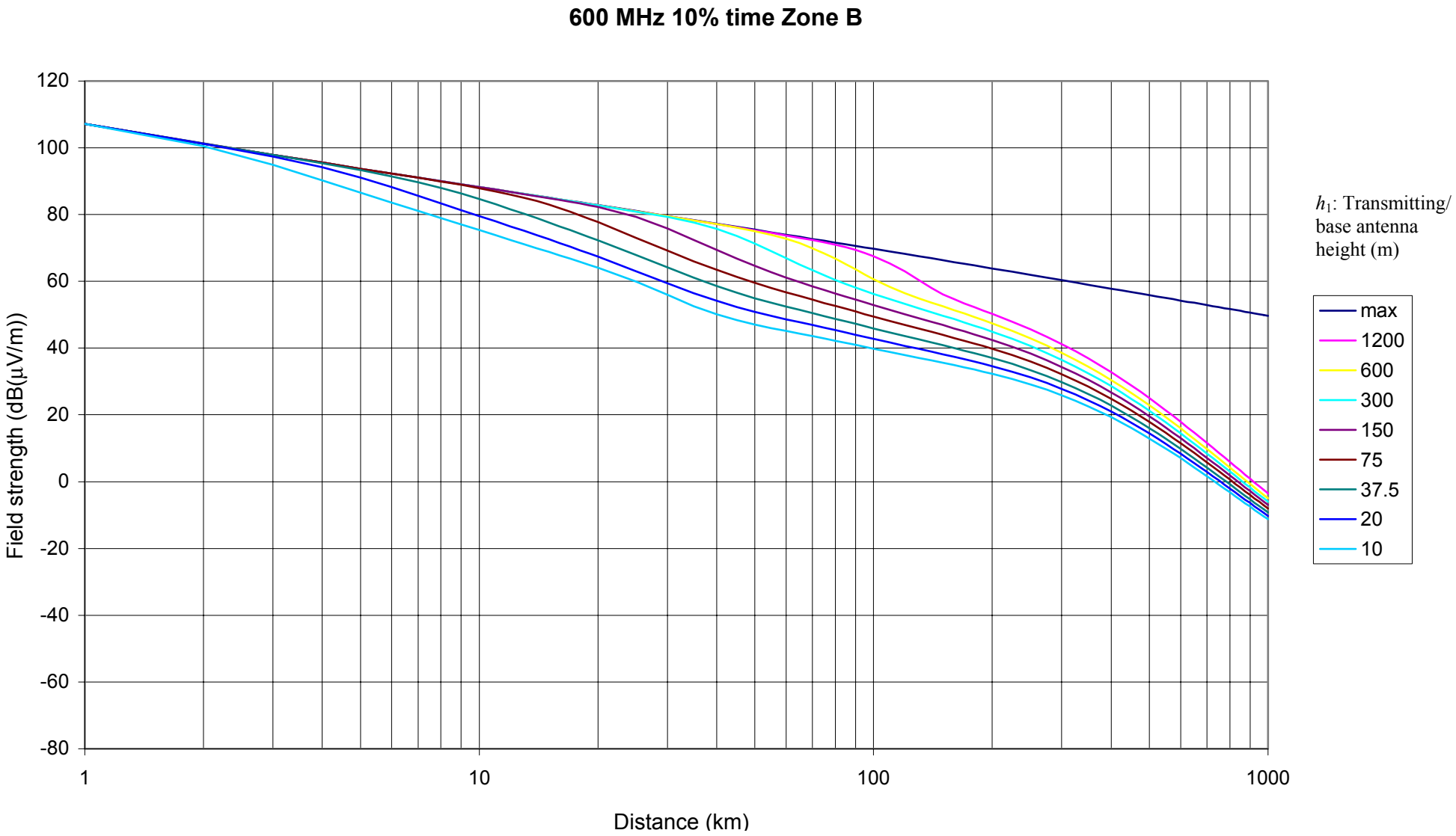

2 000 MHz 1% time Zone A
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

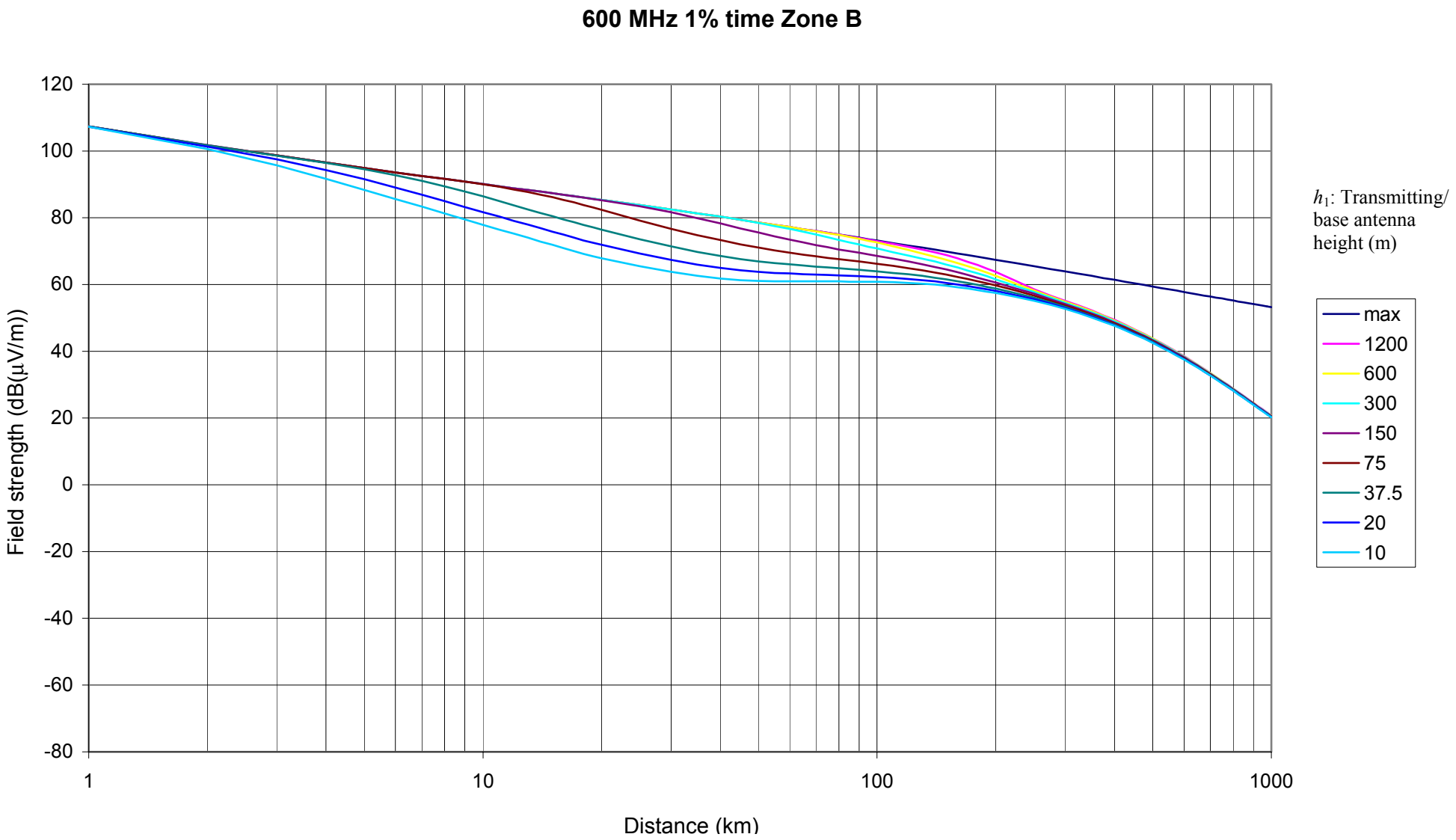

100 MHz 50% time Zone B
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

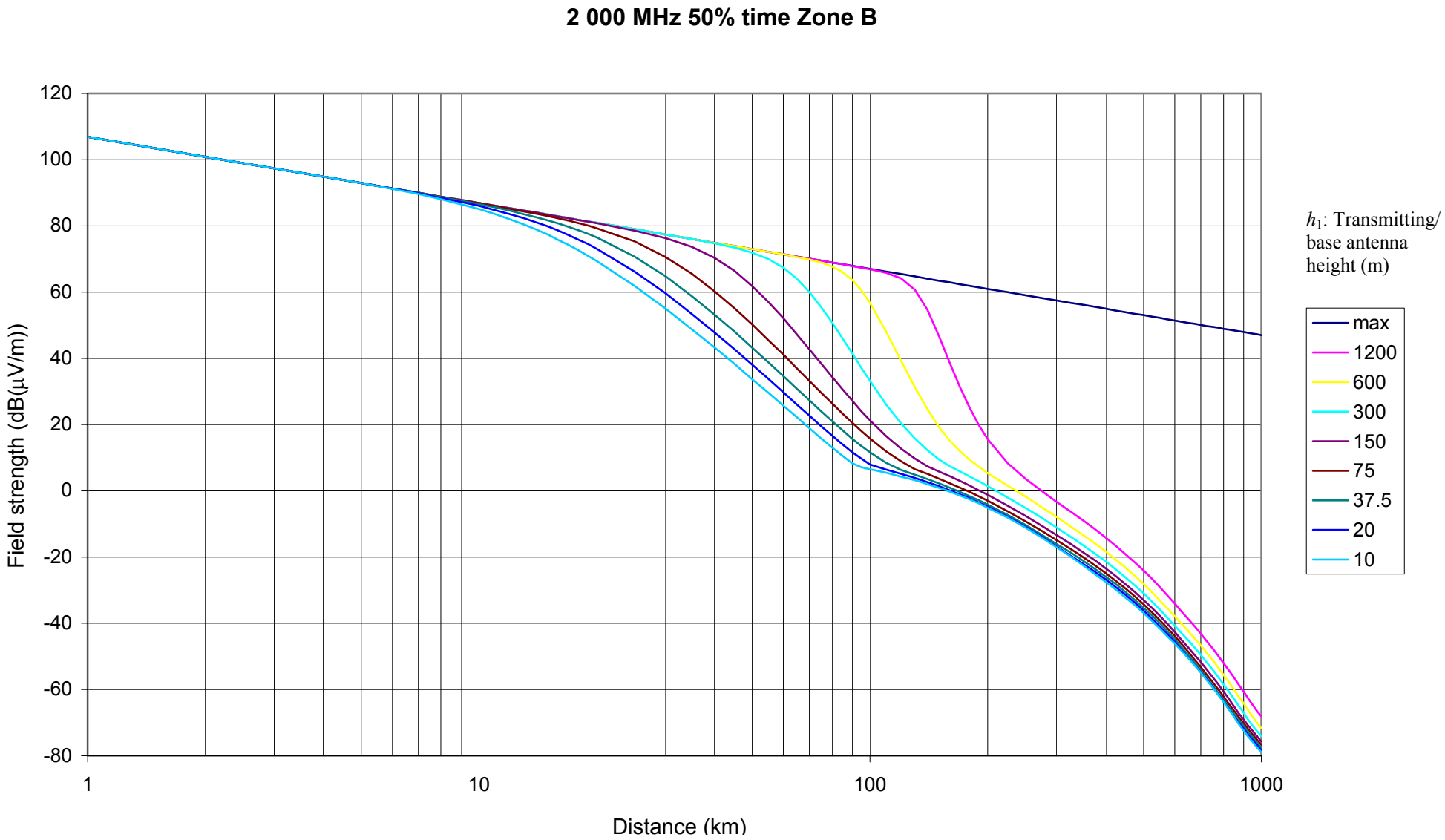

100 MHz 10% time Zone B
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

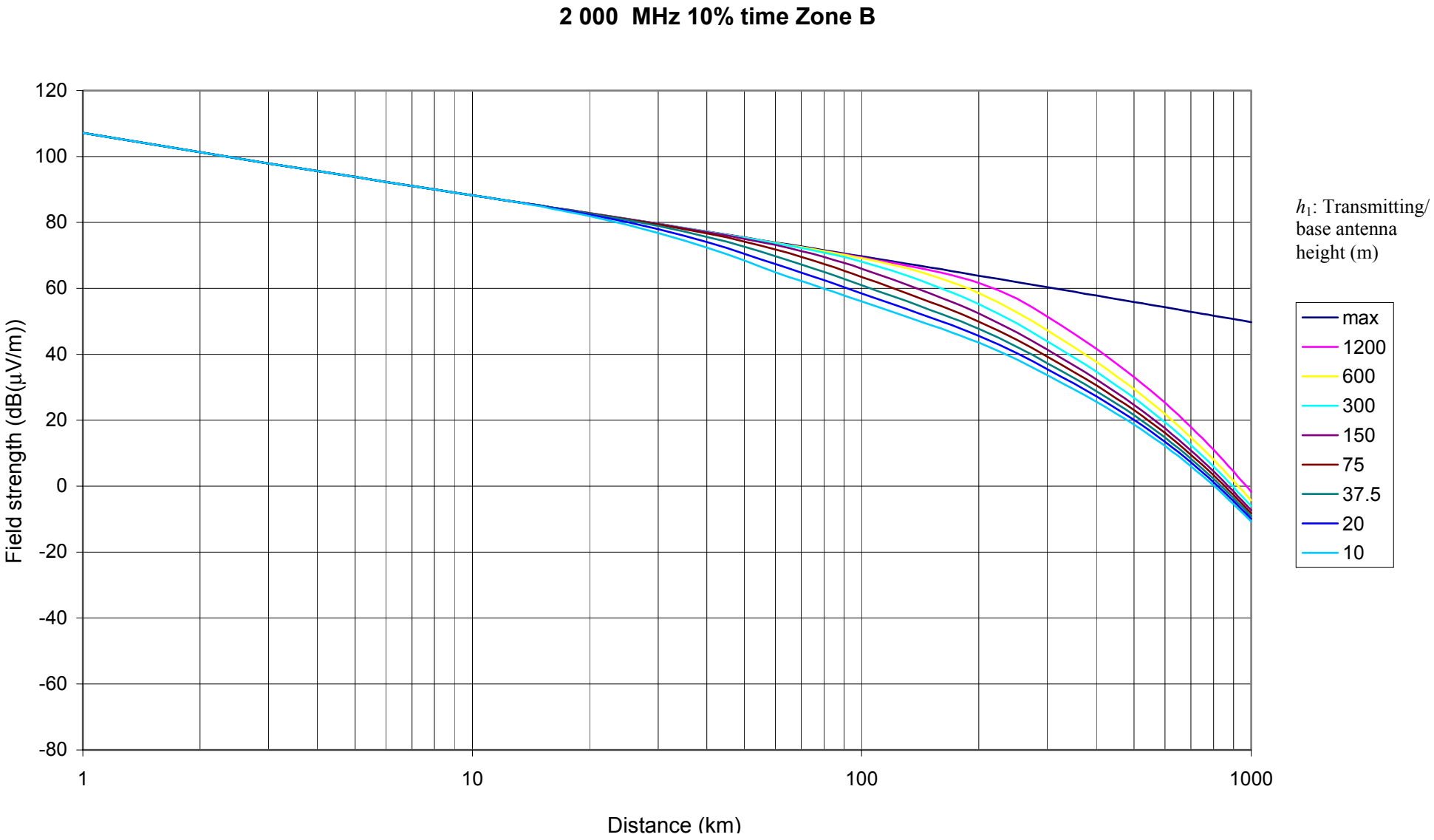

100 MHz 1% time Zone B
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

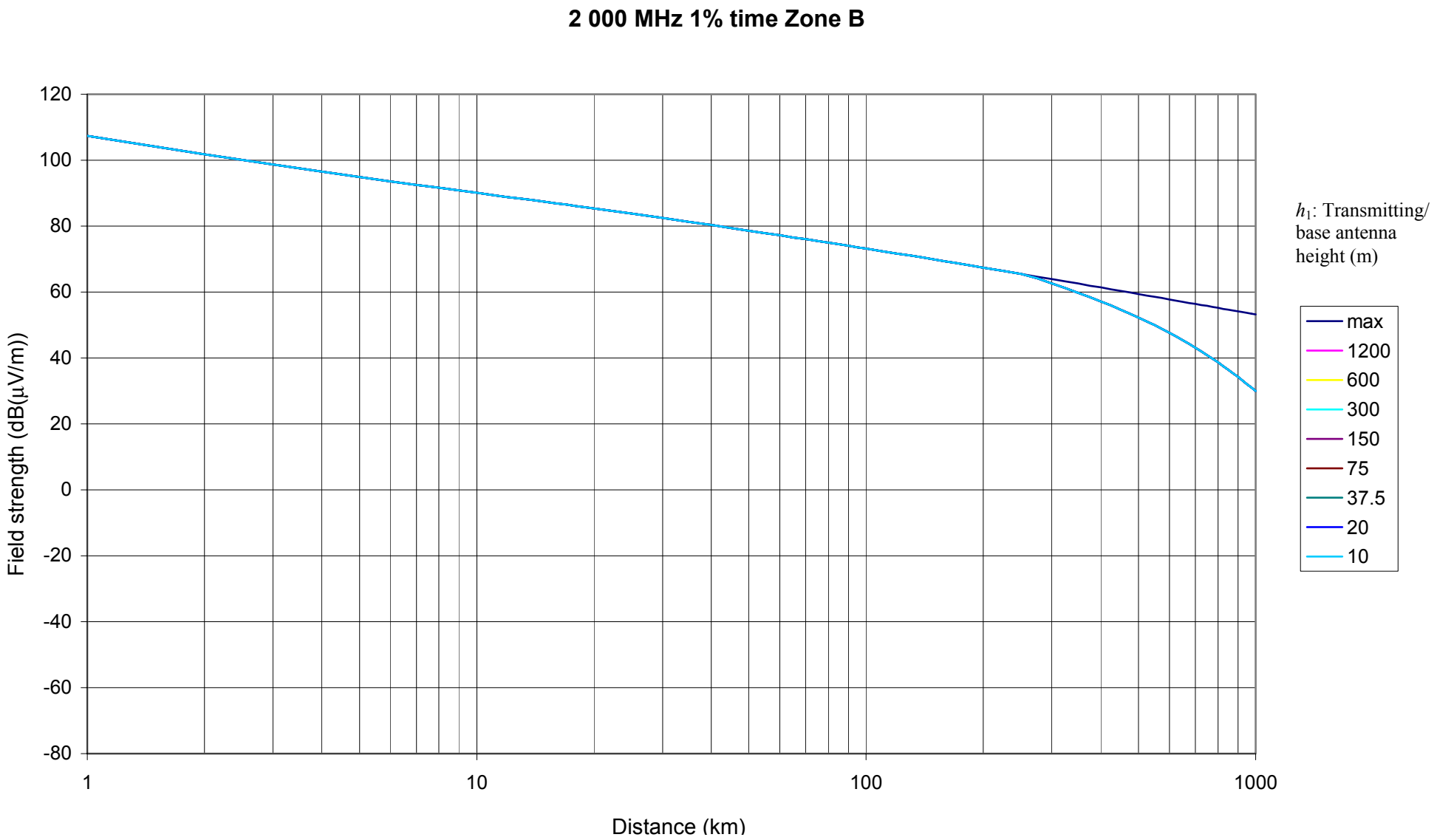

600 MHz 50% time Zone B
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

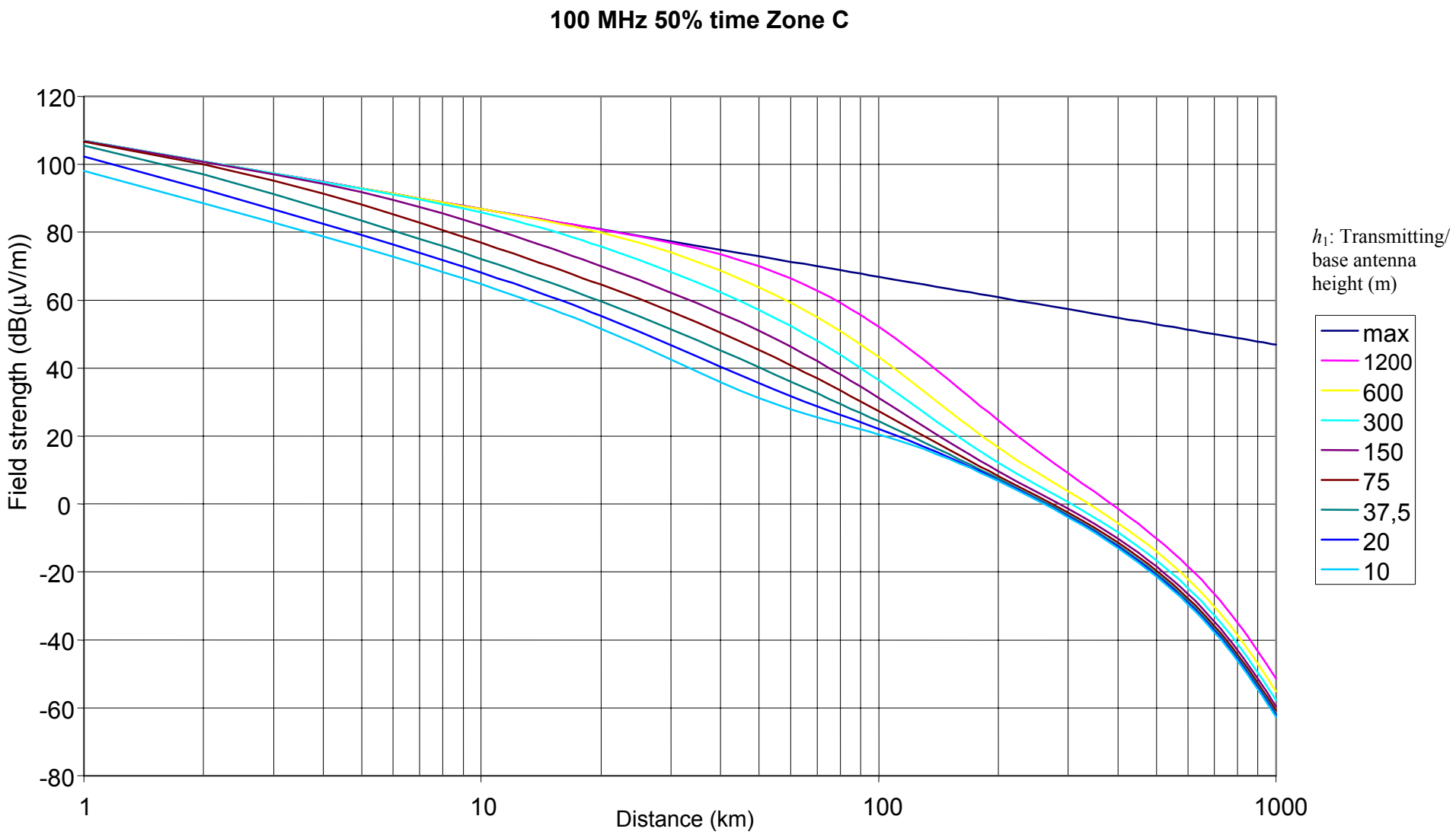

600 MHz 10% time Zone B
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

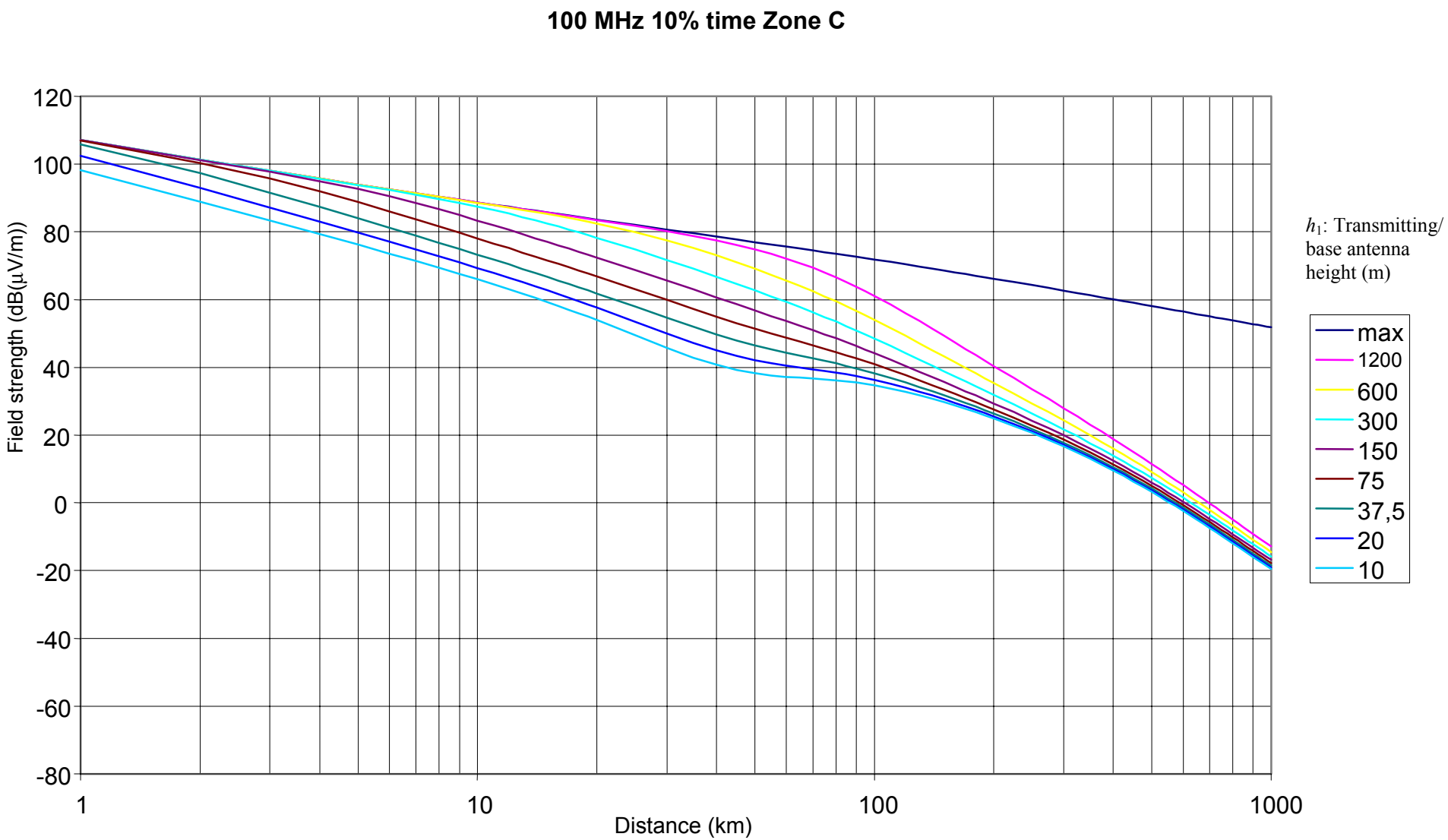

600 MHz 1% time Zone B
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

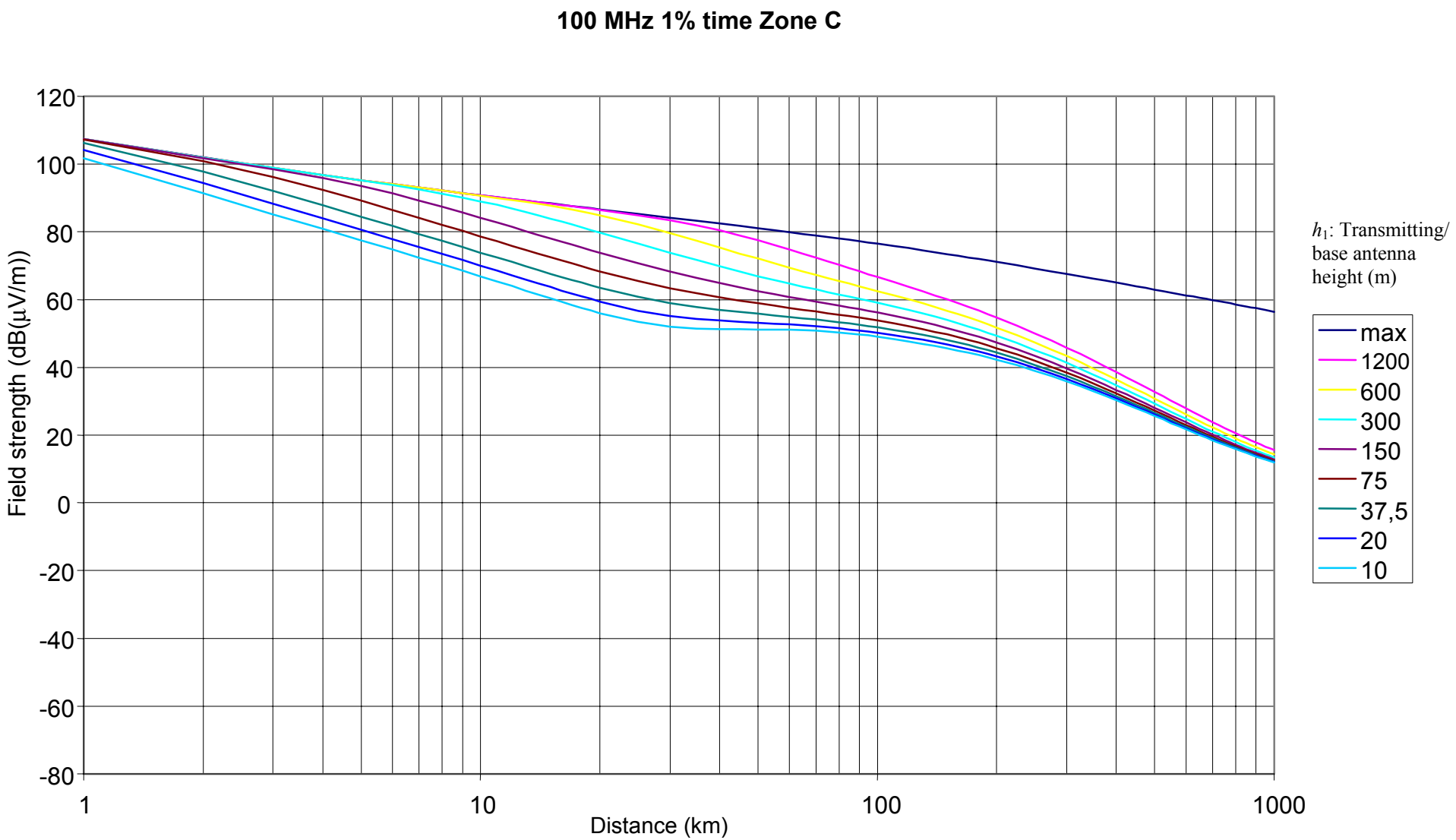

2 000 MHz 50% time Zone B
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

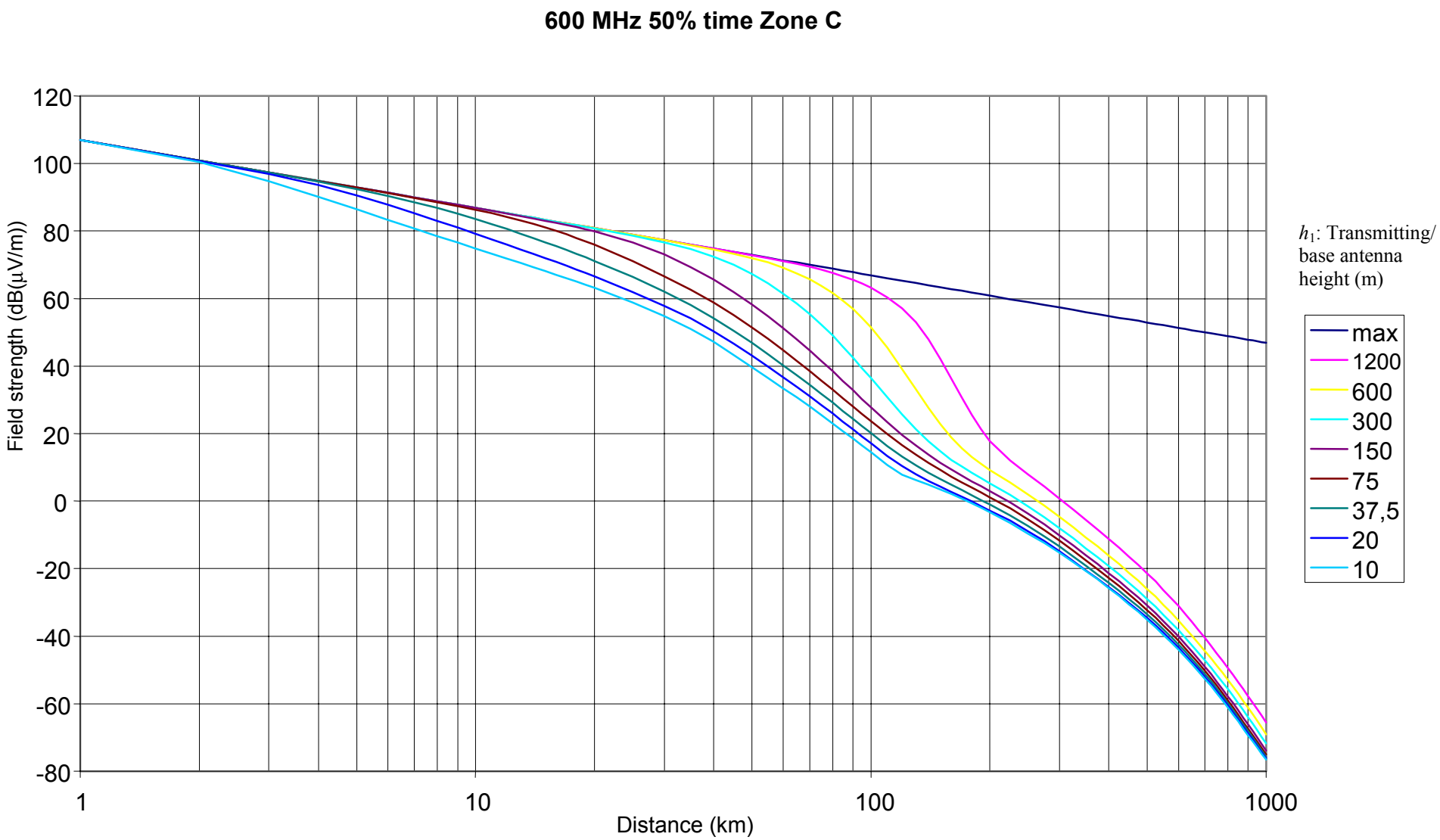

2 000 MHz 10% time Zone B
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

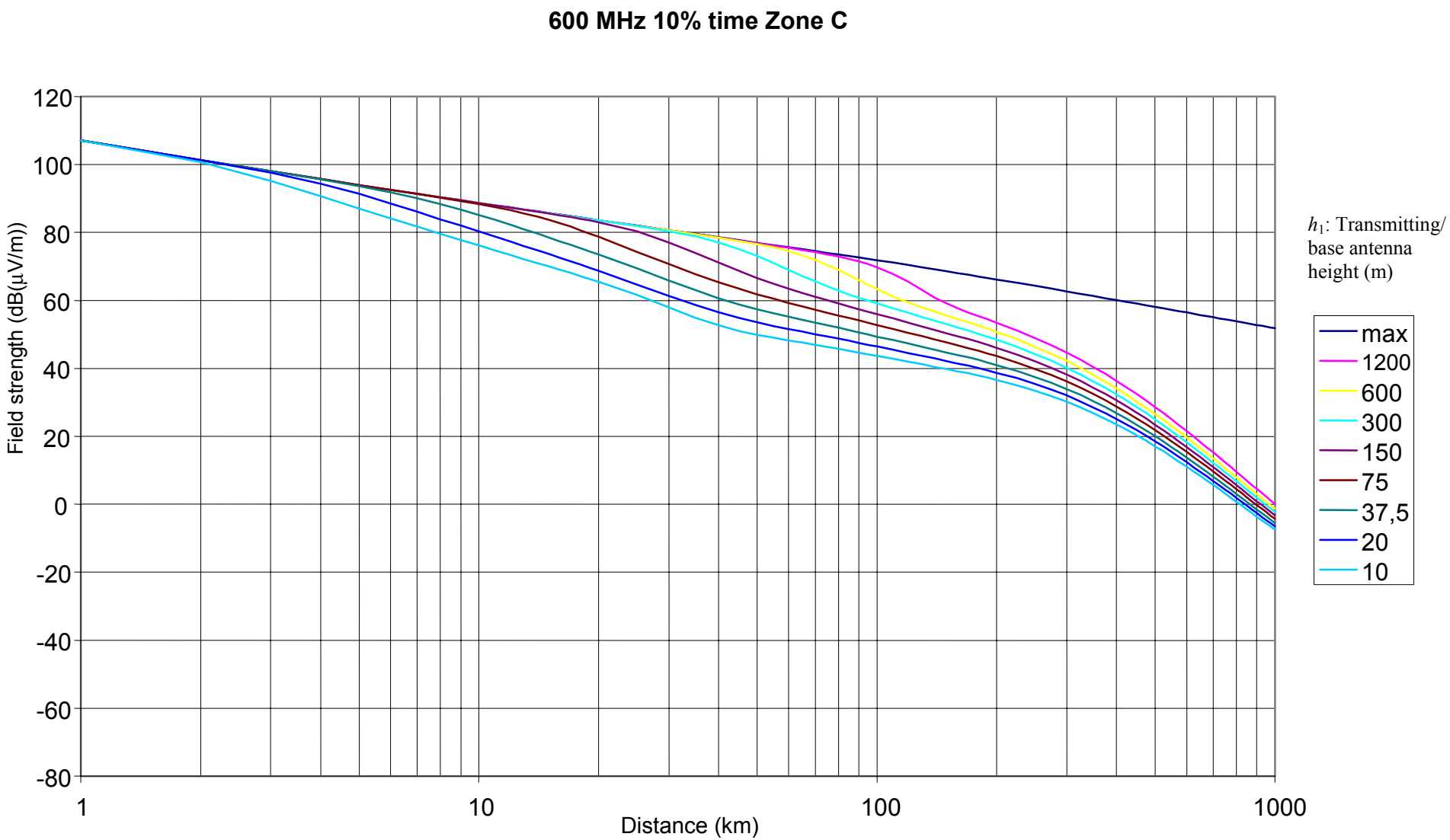

2 000 MHz 1% time Zone B
120
100
80
60
40
20
0
-20
-40
-60
-80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

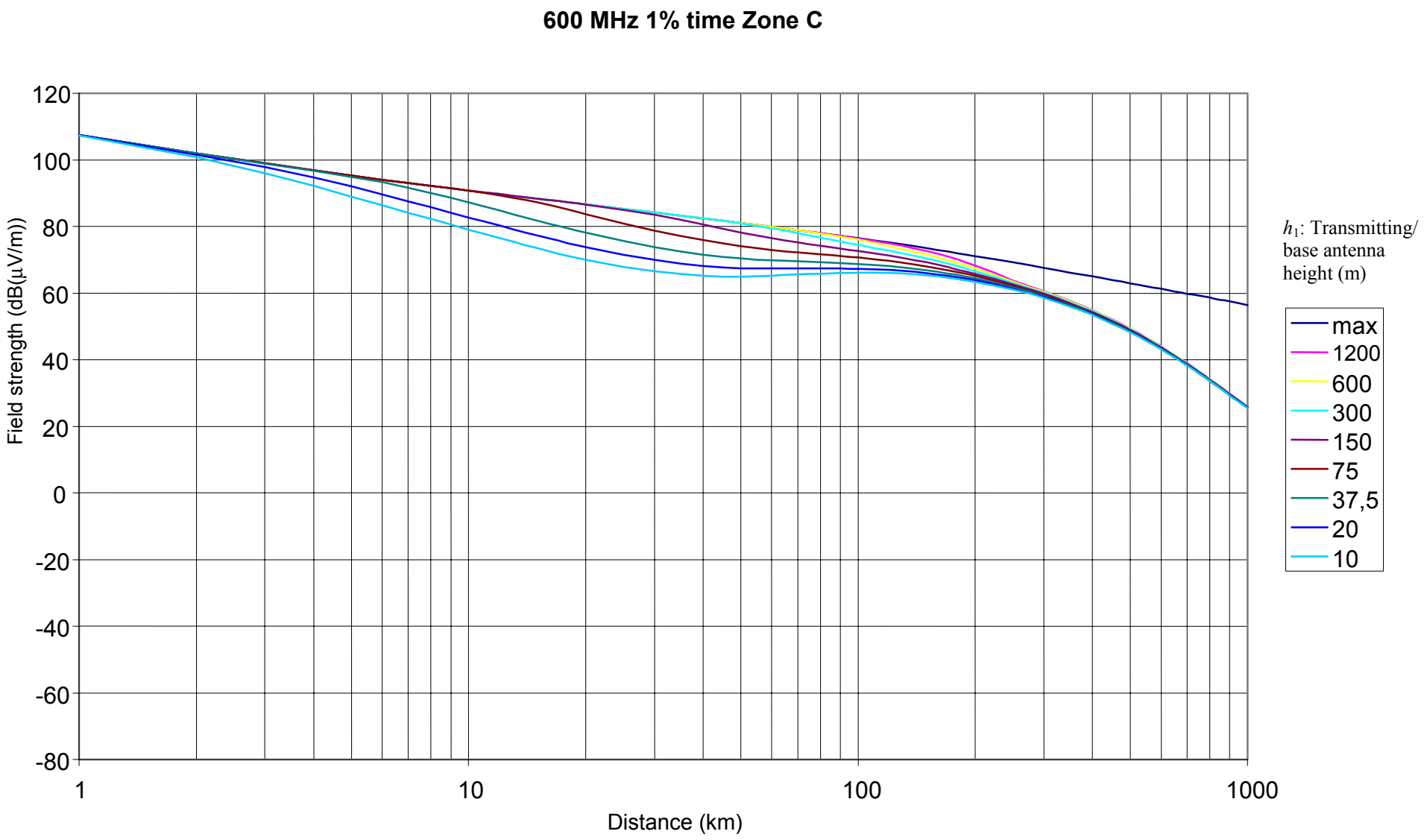

100 MHz 50% time Zone C
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37,5
20
10

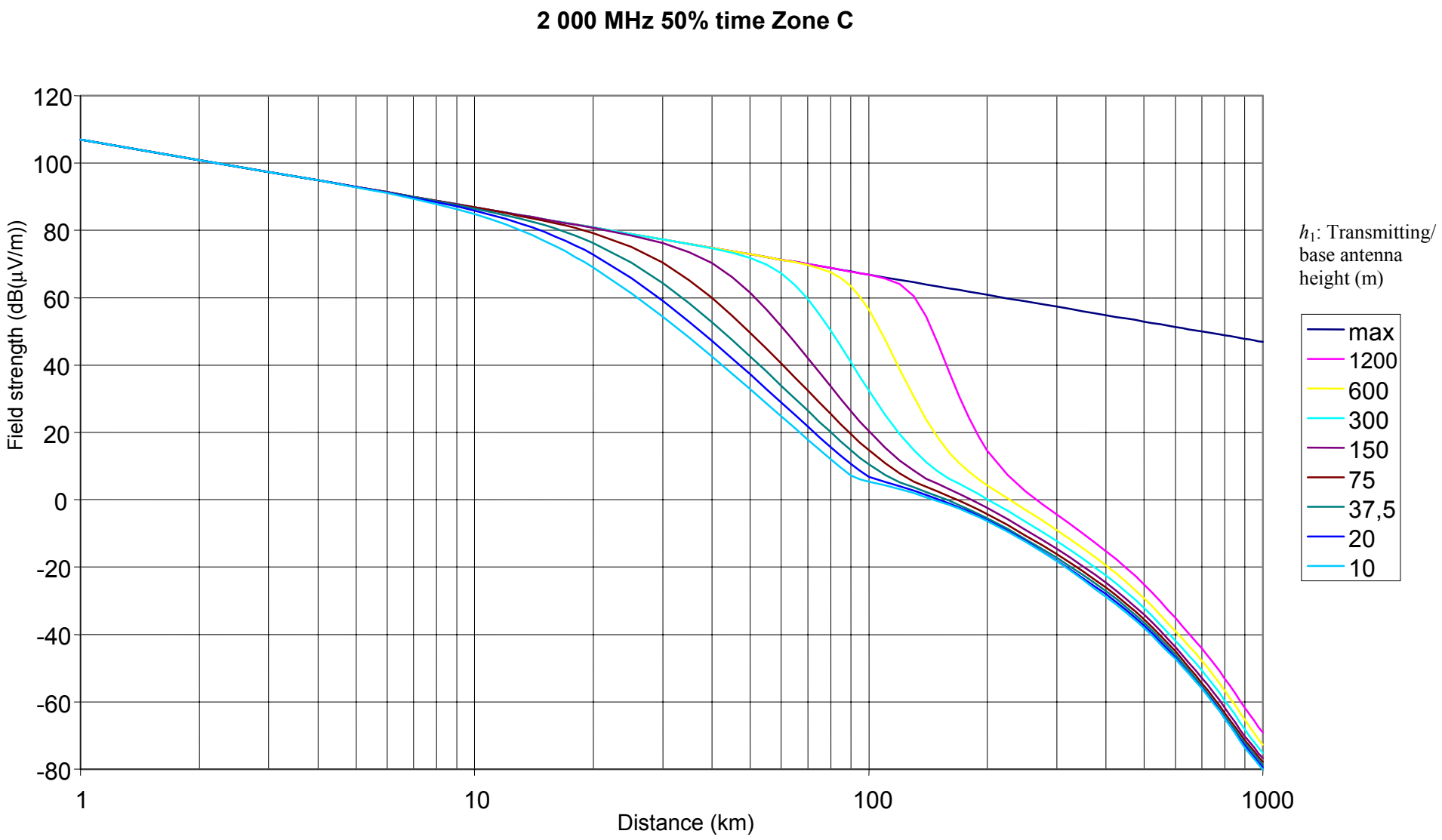

100 MHz 10% time Zone C
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37,5
20
10

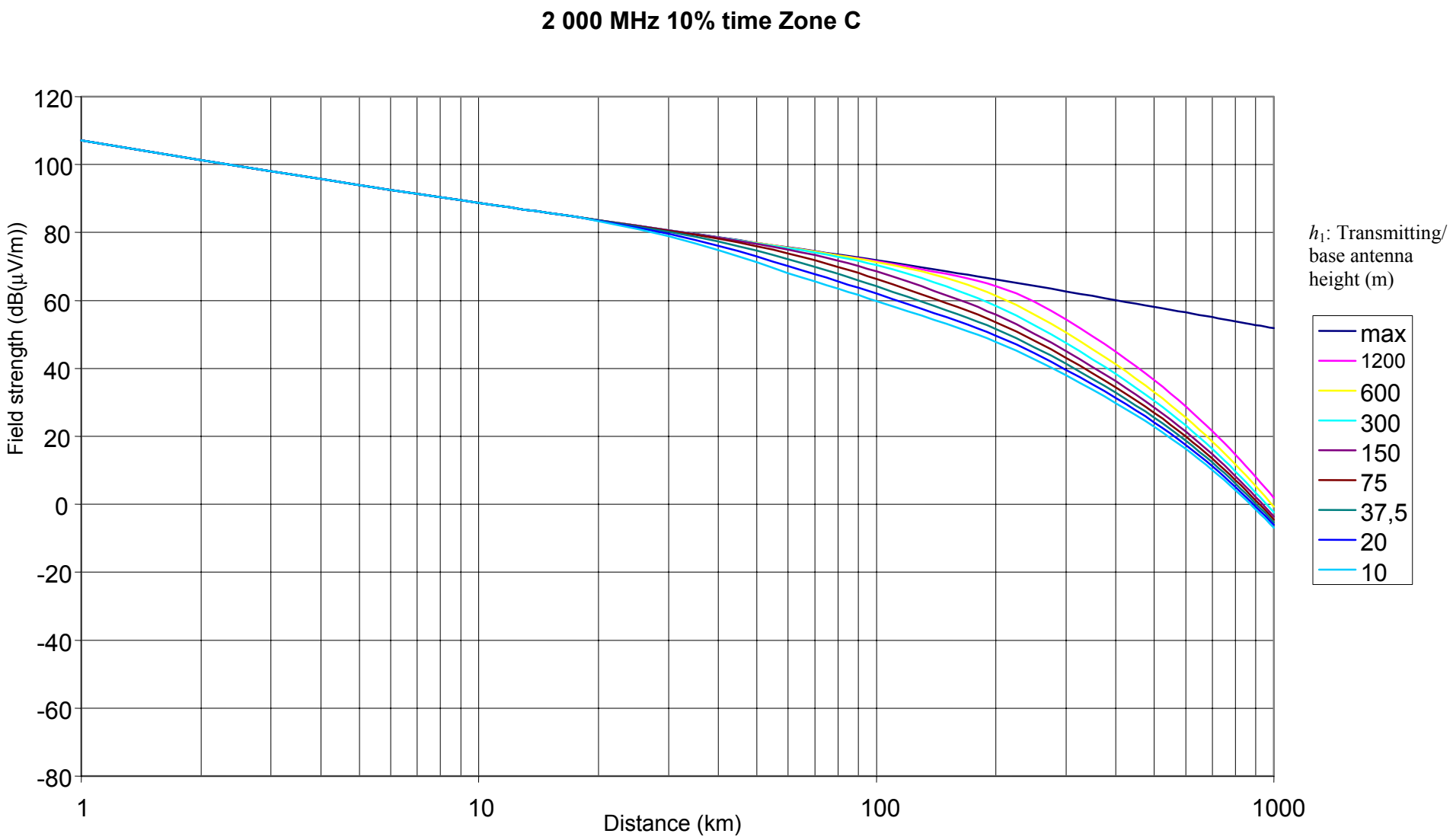

100 MHz 1% time Zone C
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37,5
20
10

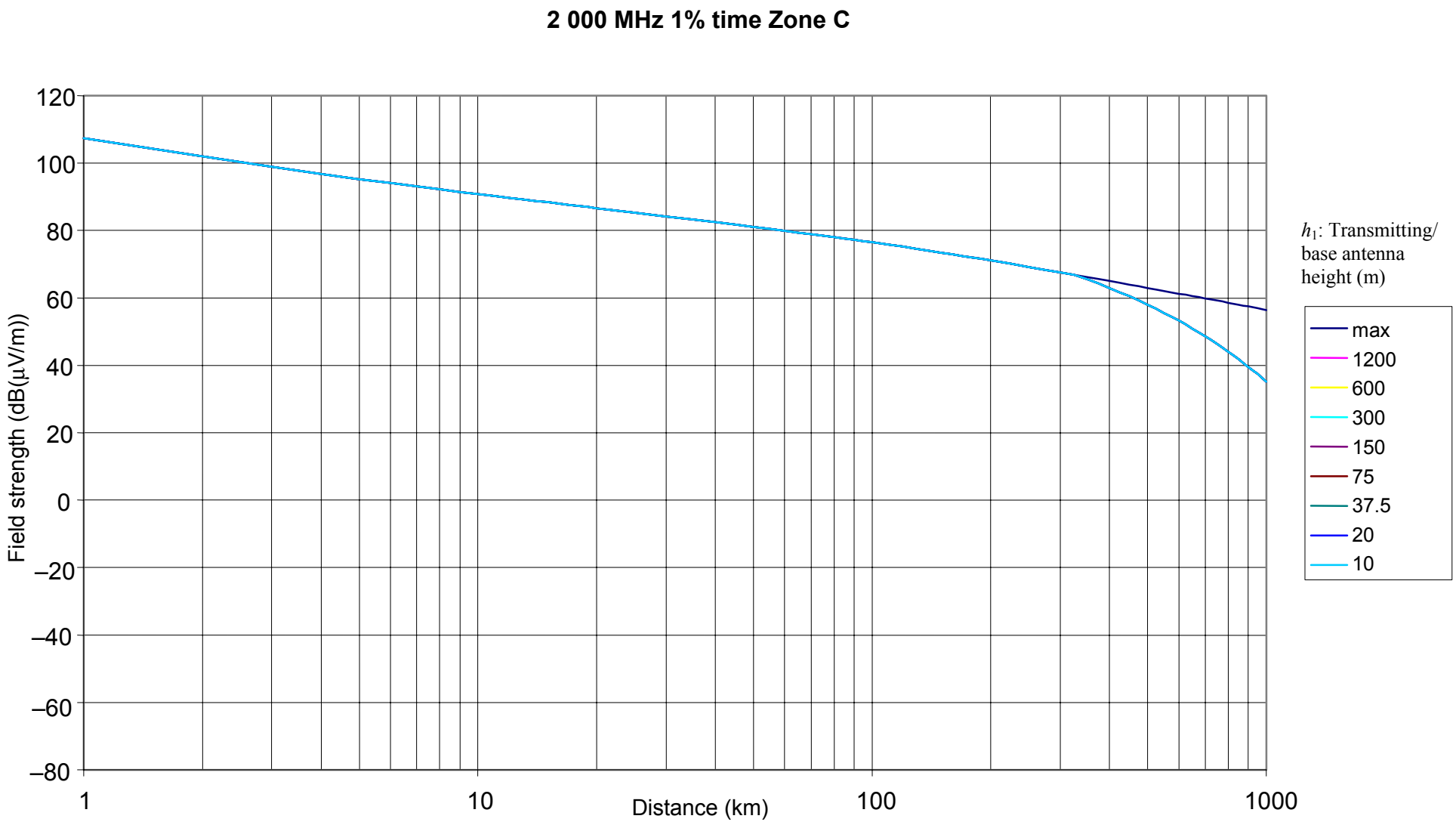

600 MHz 50% time Zone C
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37,5
20
10


600 MHz 10% time Zone C
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37,5
20
10

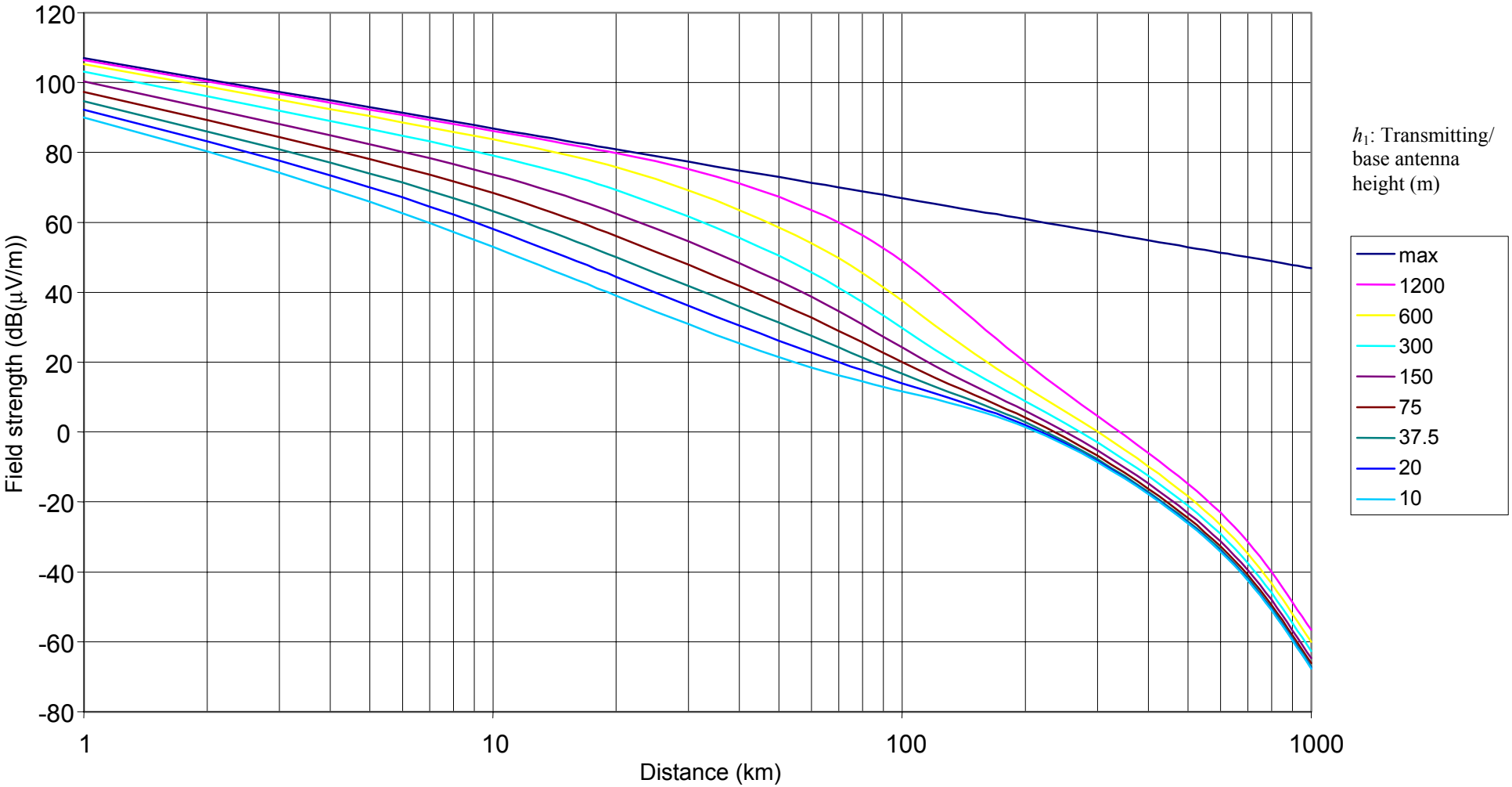

600 MHz 1% time Zone C
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37,5
20
10


2 000 MHz 50% time Zone C
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37,5
20
10

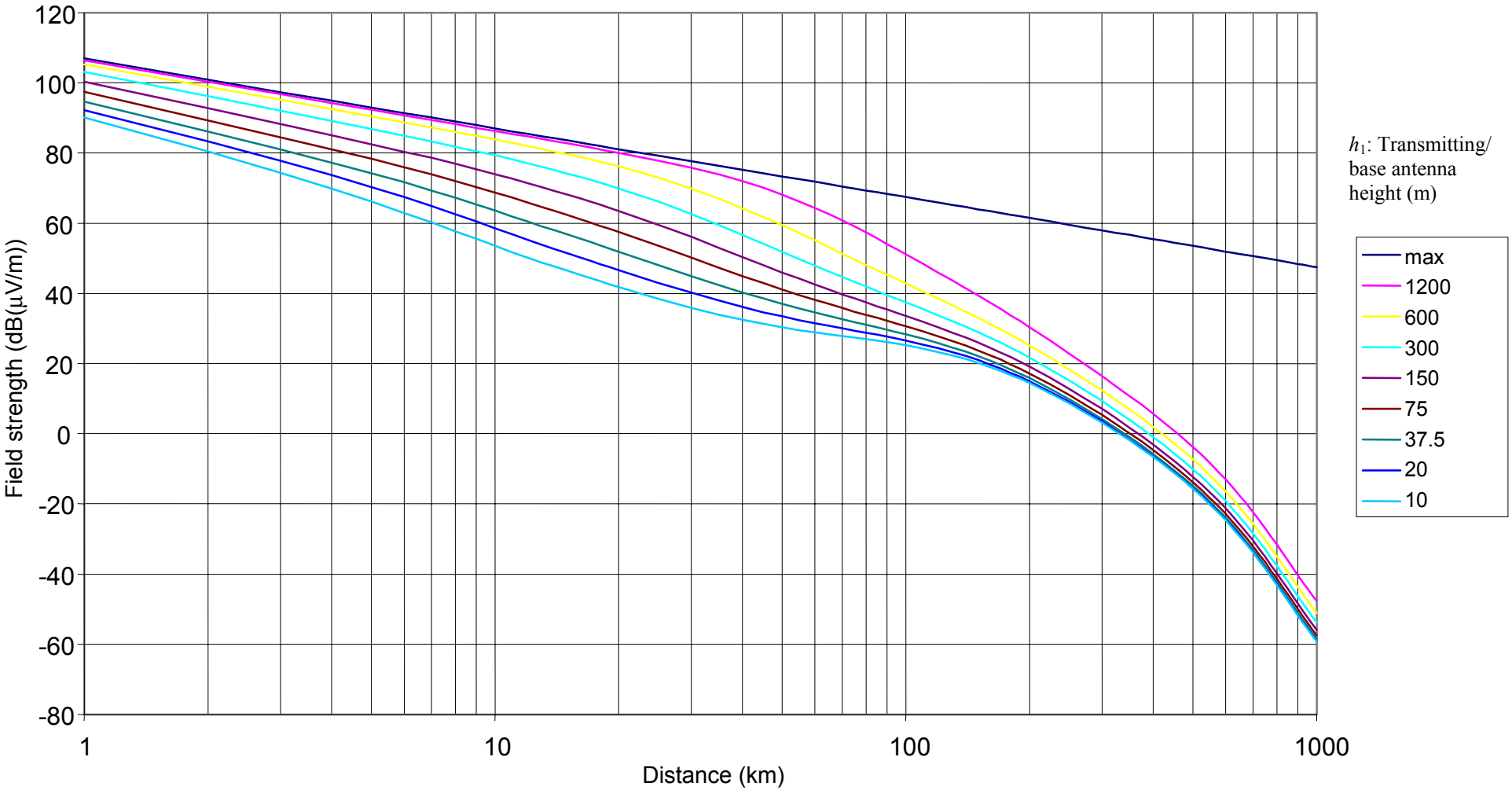

2 000 MHz 10% time Zone C
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37,5
20
10


2 000 MHz 1% time Zone C
120
100
80
60
40
20
0
–20
–40
–60
–80
Field strength (dB(µV/m))
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10

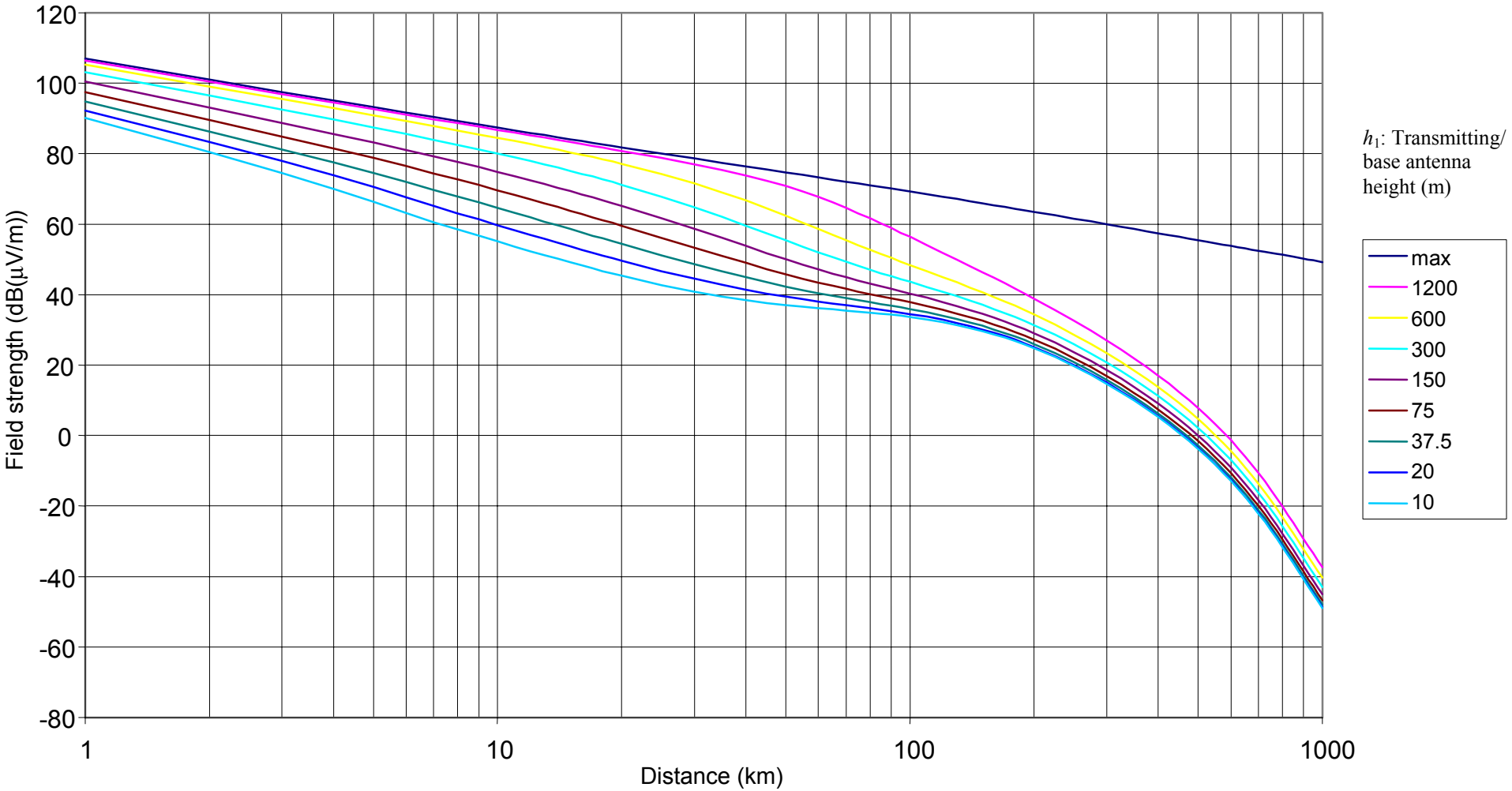
100 MHz 50% time Zone D



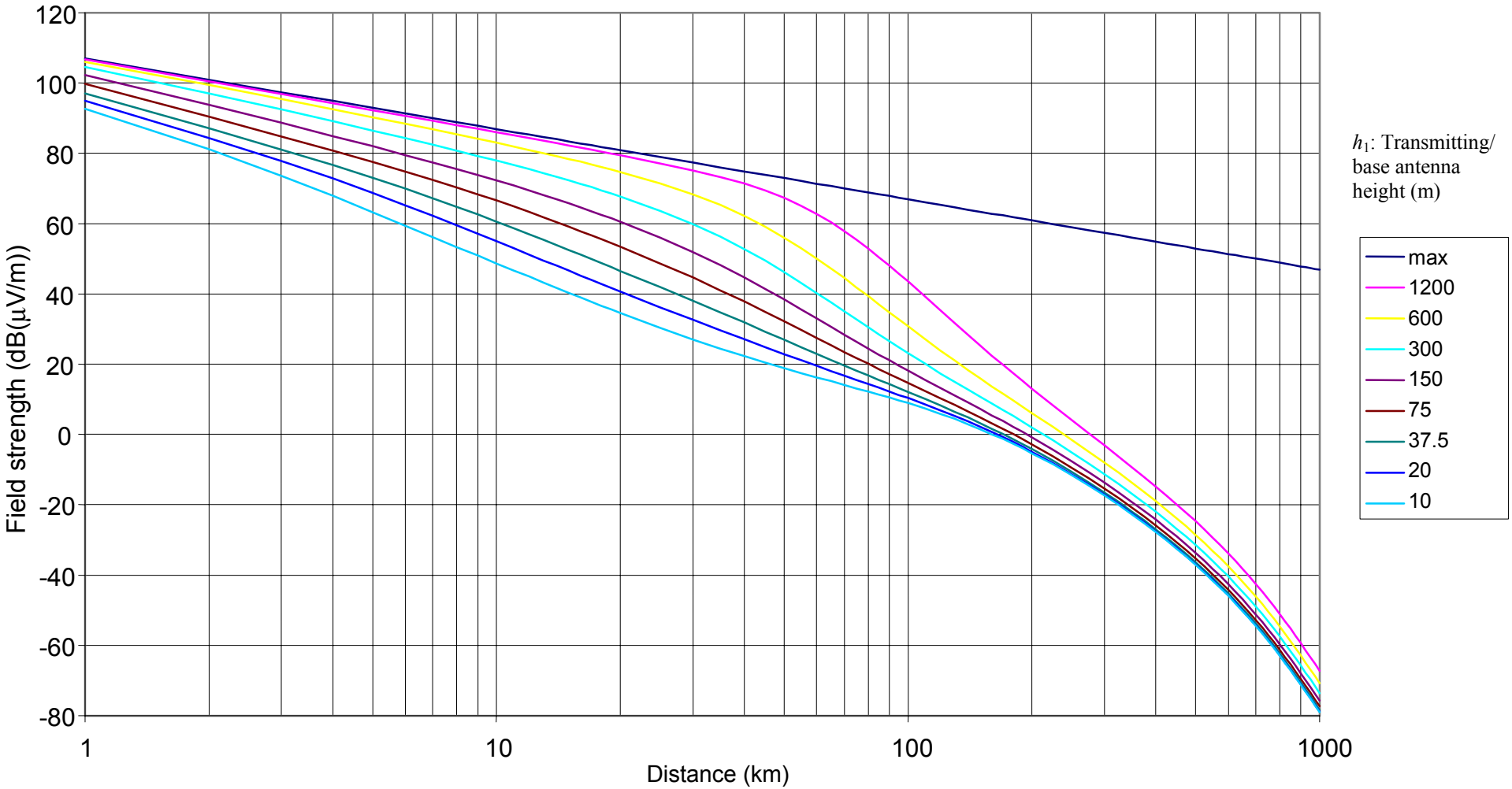
100 MHz 10% time Zone D



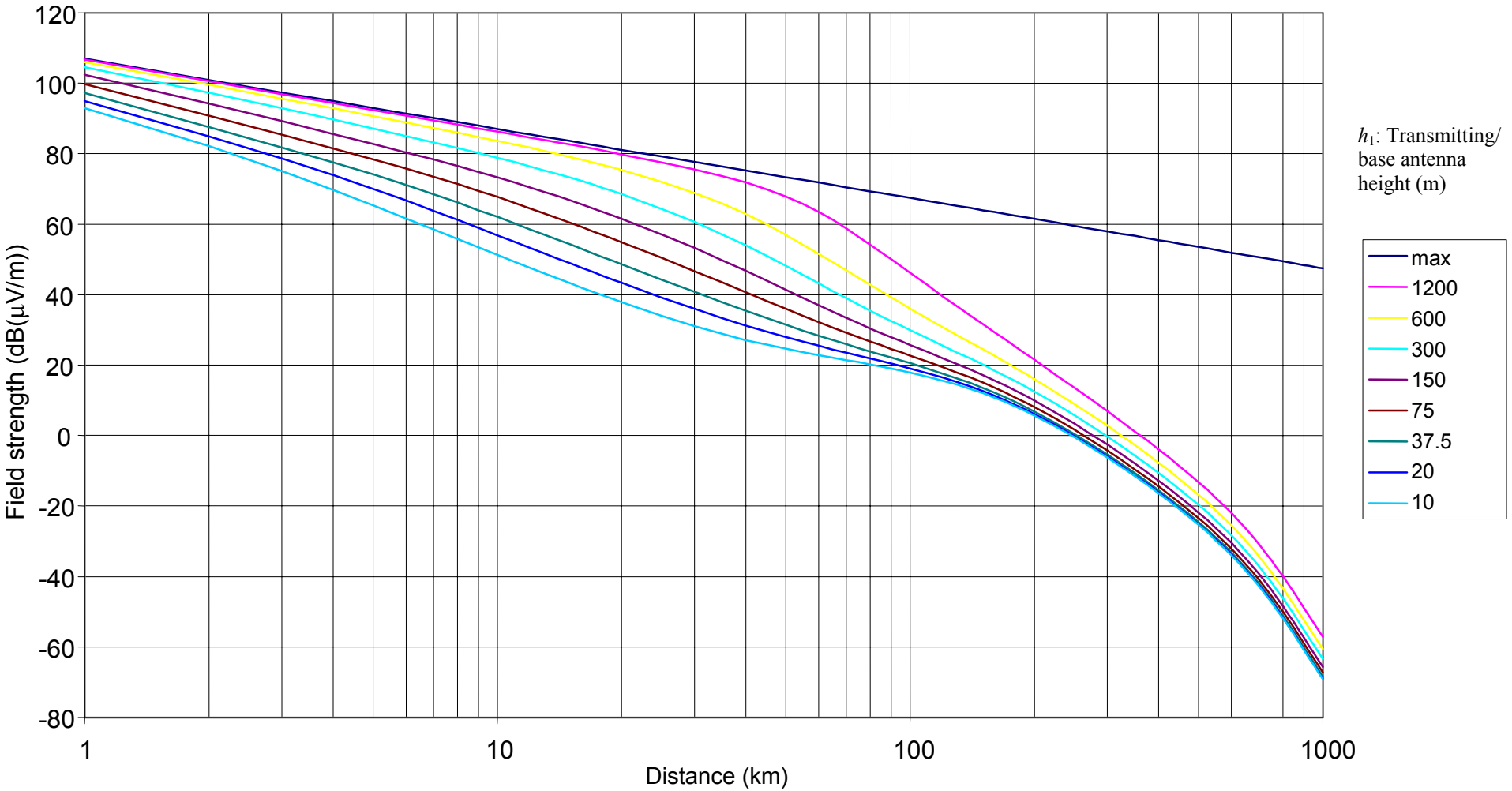
100 MHz 1% time Zone D



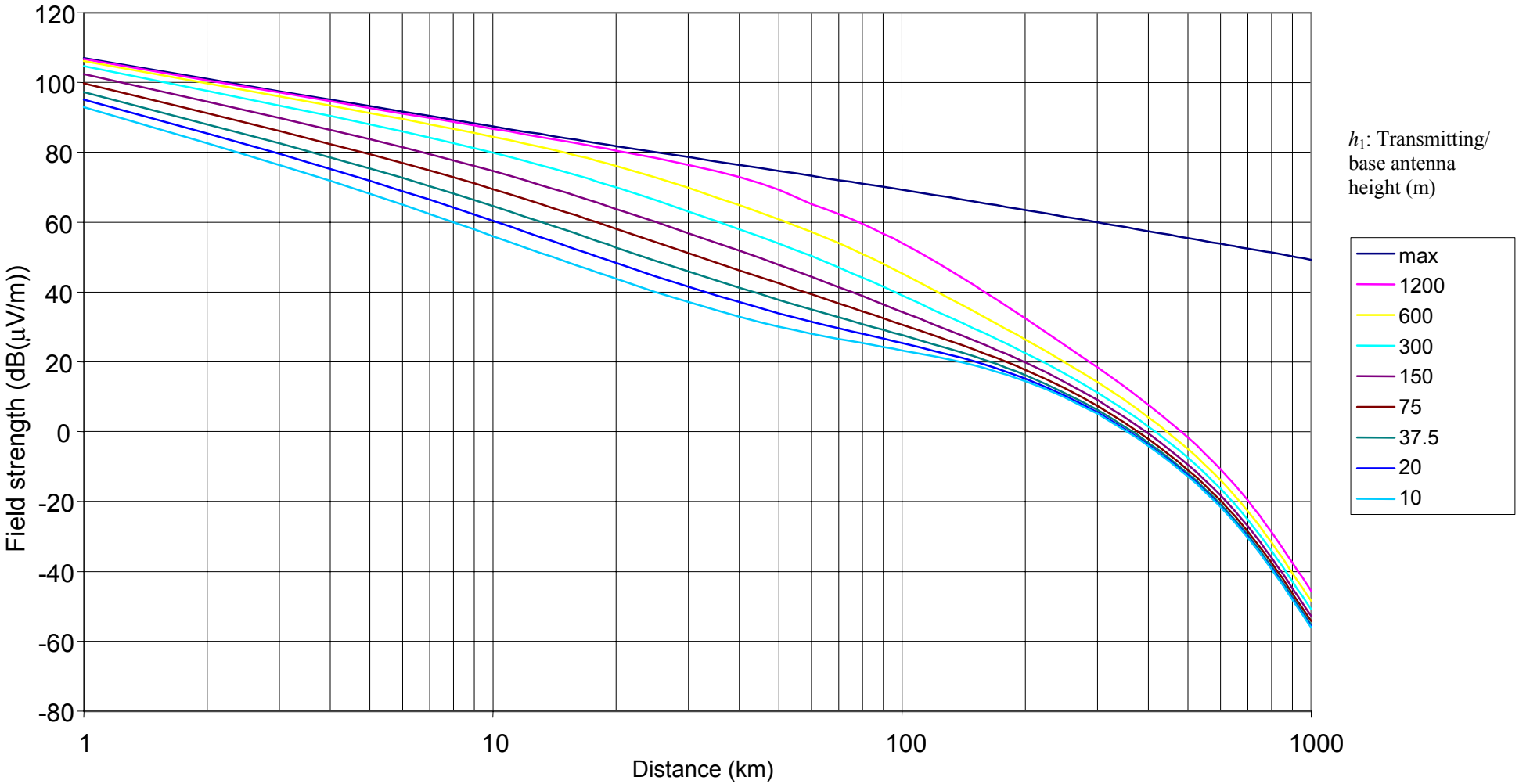
600 MHz 50% time Zone D

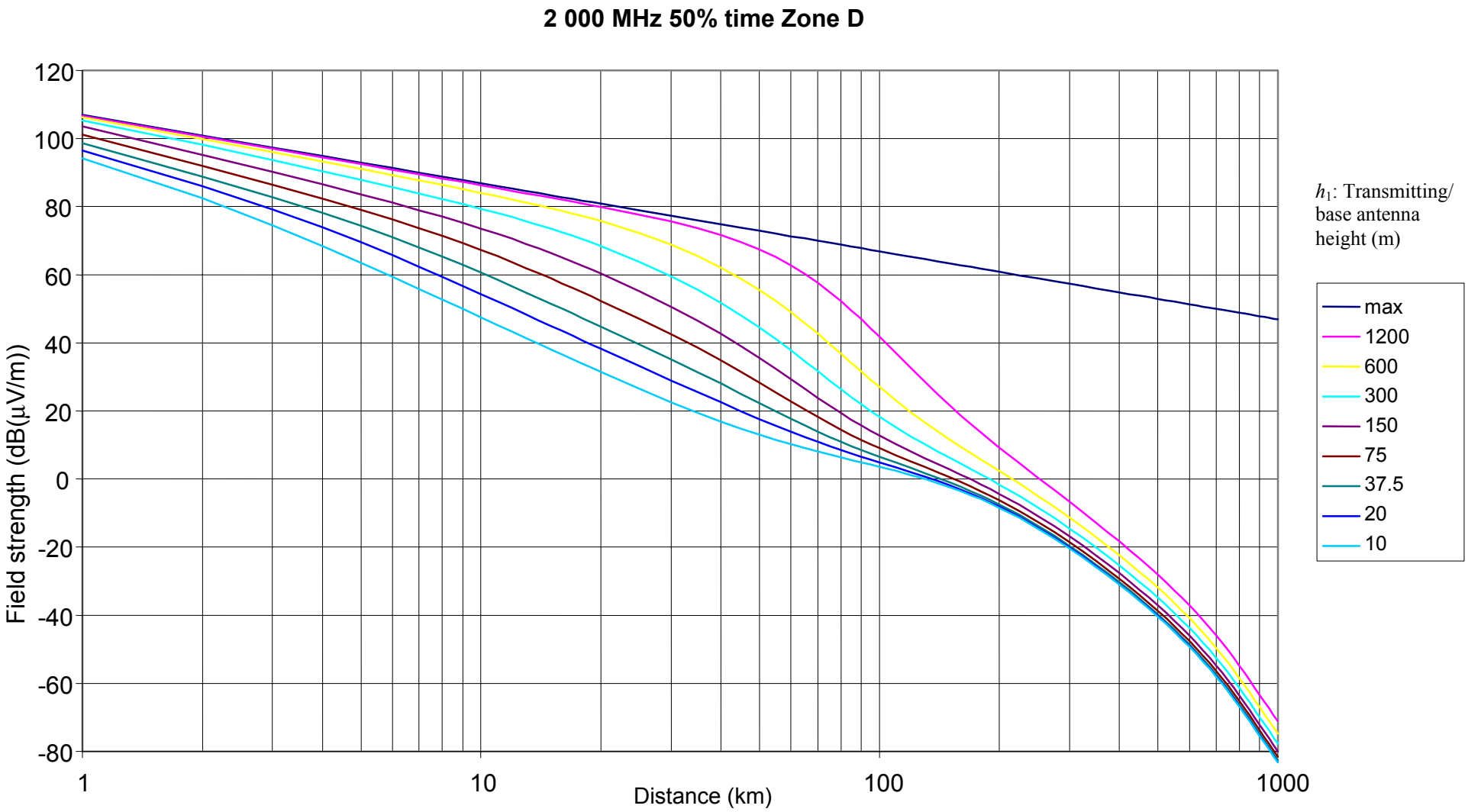


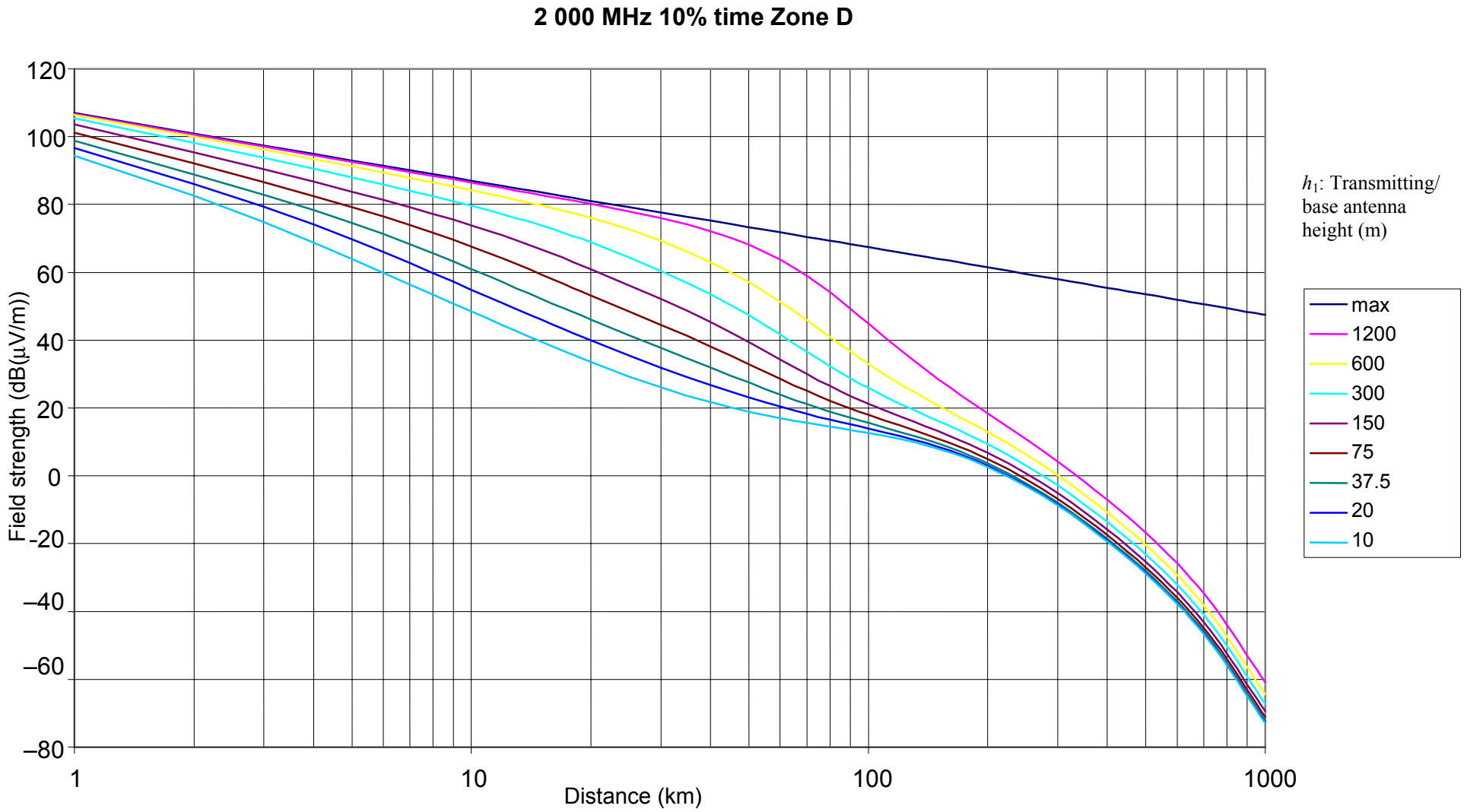
600 MHz 10% time Zone D

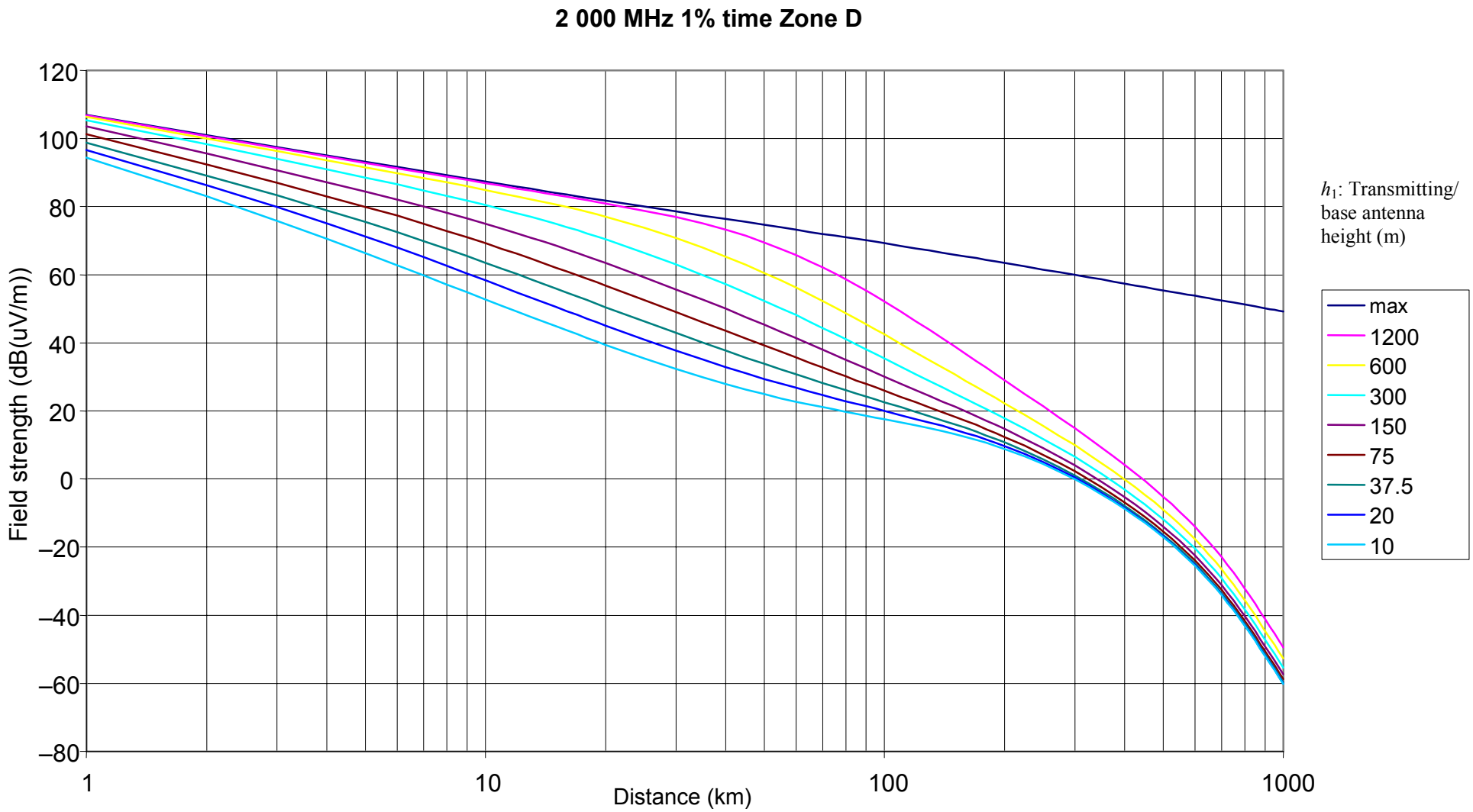


600 MHz 1% time Zone D




2 000 MHz 50% time Zone D
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
-40
-60
-80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10


2 000 MHz 10% time Zone D
Field strength (dB(µV/m))
120
100
80
60
40
20
0
-20
–40
–60
–80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
max
1200
600
300
150
75
37.5
20
10


2 000 MHz 1% time Zone D
Field strength (dB(uV/m))
120
100
80
60
40
20
0
–20
–40
–60
–80
1
10
100
1000
Distance (km)
h_1: Transmitting/ base antenna height (m)
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