International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R P.528-3
(02/2012)

Propagation curves for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands

P Series
Radiowave propagation

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at http://www.itu.int/publ/R-REC/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	**Radiowave propagation**
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

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

Electronic Publication
Geneva, 2013

RECOMMENDATION ITU-R P.528-3[*,**]

Propagation curves for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands

(Question ITU-R 203/3)

(1978-1982-1986-2012)

Scope

This Recommendation contains a method for predicting basic transmission loss in the frequency range 125-15 500 MHz for aeronautical and satellite services. The method uses an interpolation method on basic transmission loss data from sets of curves. These sets of curves are valid for ground-air, ground-satellite, air-air, air-satellite, and satellite-satellite links. The only data needed for this method are the distance between antennas, the heights of the antennas above mean sea level, the frequency, and the time percentage.

This Recommendation, also, gives the calculations for the expected protection ratio or wanted-to-unwanted signal ratio exceeded at the receiver for at least 95% of the time, R (0.95). This calculation requires the following additional data for both the wanted and unwanted signals: the transmitted power, the gain of transmitting antenna, and the gain of receiving antenna.

The ITU Radiocommunication Assembly,

considering

a) that there is a need to give guidance to engineers in the planning of radio services in the VHF, UHF, and SHF bands;

b) that the propagation model used to generate the curves given in Annex 2 is based on a considerable amount of experimental data (see Annex 1);

c) that the aeronautical service often provides a safety of life function and therefore requires a higher standard of availability than many other services;

d) that a time availability of 0.95 should be used to obtain more reliable service,

recommends

1 that the curves given in Annex 3 be adopted to determine the basic transmission losses for 1%, 5%, 10%, 50% and 95% of the time for antenna heights (for both the ground station and aircraft) likely to be encountered in the aeronautical services.

NOTE 1 – It must be emphasized that these curves are based on data obtained mainly for a continental temperate climate.

NOTE 2 – The curves give basic transmission loss, that is, the loss between ideal loss-free isotropic antennas. Where surface reflection multipath at the ground station or the facility has been mitigated using counterpoises or a directional vertical radiation pattern suitable antenna radiation patterns should be included within analysis.

---

[*] This Recommendation is brought to the attention of Study Group 5.

[**] Radiocommunication Study Group 3 made editorial amendments to this Recommendation in April 2015 in accordance with Resolution ITU-R 1.

Annex 1

Development and application of the curves

Transmission loss prediction methods have been extended and incorporated into the IF-77 propagation model that determine basic transmission losses for 1%, 5%, 10%, 50% and 95% of the time for antenna heights applicable to the aeronautical services. These methods are based on a considerable amount of experimental data, and extensive comparisons of predictions with data have been made. In performing these calculations, a smooth (terrain parameter $\Delta h = 0$) Earth with an effective Earth radius factor k of 4/3 (surface refractivity $N_s = 301$) was used along with compensation for the excessive ray bending associated with the $k = 4/3$ model at high altitudes. Constants for average ground horizontal polarization, isotropic antennas, and long-term power fading statistics for a continental temperate climate were also used. Although these parameters may be considered either reasonable or worst-case for many applications, the curves should be used with caution if conditions differ drastically from those assumed.

With the exception of a region "near" the radio horizon, values of median basic transmission loss for "within-the-horizon" paths were obtained by adding the attenuation due to atmospheric absorption (in decibels) to the transmission loss corresponding to free-space conditions. Within the region "near" the radio horizon, values of the transmission loss were calculated using geometric optics, to account for interference between the direct ray and a ray reflected from the surface of the Earth. Segments of curves resulting from these two methods were joined to form a curve that shows median basic transmission loss as increasing monotonically with distance.

The two-ray interference model was not used exclusively for within-the-horizon calculations, because the lobing structure obtained from it for short paths is highly dependent on surface characteristics (roughness as well as electrical constants), atmospheric conditions (the effective Earth radius is variable in time), and antenna characteristics (polarization, orientation and gain pattern). Such curves would often be more misleading than useful, i.e., the detailed structure of the lobing is highly dependent on parameters that are difficult to determine with sufficient precision. However, the lobing structure is given statistical consideration in the calculation of variability.

For time availabilities other than 0.50, the basic transmission loss, L_b, curves do not always increase monotonically with distance. This occurs because variability changes with distance can sometimes overcome the median level changes. Variability includes contributions from both hourly-median or long-term power fading and within-the-hour or short-term phase interference fading. Both surface reflection and tropospheric multipath are included in the short-term fading.

The curves provided in Annex 3 are selected curves from a much larger set of computer-generated smoothed curves.

The basic transmission loss, $L_b(0.05)$ curves may be used to estimate L_b values for an unwanted interfering signal that is exceeded during 95% (100% – 5%) of the time. Median (50%) propagation conditions may be estimated with the $L_b(0.50)$ curves. The $L_b(0.95)$ curves may be used to estimate the service range for a wanted signal at which service would be available for 95% of the time in the absence of interference.

The expected protection ratio or wanted-to-unwanted signal ratio exceeded at the receiver for at least 95% of the time, $R(0.95)$, can be estimated using the Annex 3 curves as follows:

$$R(0.95) = R(0.50) + Y_R(0.95) \quad (1)$$

$$R(0.50) = [P_t + G_t + G_r - L_b(0.50)]_{Wanted} - [P_t + G_t + G_r - L_b(0.50)]_{Unwanted} \quad (2)$$

and

$$Y_R = -\sqrt{[L_b(0.95) - L_b(0.50)]^2_{Wanted} + [L_b(0.05) - L_b(0.50)]^2_{Unwanted}} \quad (3)$$

In equation (2), P_t is the transmitted power, and G_t and G_r are the isotropic gains of the transmitting and receiving antennas expressed in dB.

Additional variabilities could easily be included in equation (3) for such things as antenna gain when variabilities for them can be determined. Continuous (100%) or simultaneous channel utilization is implicit in the $R(0.95)$ formulation provided above so that the impact of intermittent transmitter operation must be considered separately.

Although transmission loss values may be read directly from the curves presented as figures in Annex 3 of this Recommendation, there are tabulated transmission loss values available. See that part of the ITU-R website dealing with Radiocommunication Study Group 3. The tabulated data is available on the SG 3 website.

Annex 2

Description of interpolation methods

1 Introduction

This Annex describes separate stages of the calculation. A step-by-step description of the overall interpolation method is given in § 8 of this Annex.

Section 2 gives the calculation for field strength from the transmission loss value(s) taken from the curves in Annex 3. Sections 3 to 8 of this Annex describe how to interpolate for distance, h_1, h_2, frequency and percentage time.

2 Equivalent field strength

The field strength equivalent to a given transmission loss is given by:

$$E = 139.3 - L_t + 20 \log f \qquad \text{dB } (\mu\text{V/m}) \quad (4)$$

where:

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

L_t: transmission loss (dB)

f: frequency (MHz).

3 Antenna heights, h_1 and h_2

If the value of h_1 or h_2 coincides with one of the heights for which curves are provided, the required transmission loss values may be obtained directly from the plotted curves or the associated tabulations. Otherwise the required transmission loss should be interpolated from transmission losses obtained from two curves using:

$$L = L_{inf} + (L_{sup} - L_{inf}) \log(h_{1or2} / h_{inf}) / \log(h_{sup} / h_{inf}) \quad \text{dB} \tag{5}$$

where:

$h_{1,}h_2$: the antenna heights above mean sea level for which the prediction is required (m)

h_{inf}: the nearest nominal effective height below $h_{1 \text{ or } 2}$

h_{sup}: the nearest nominal effective height above $h_{1 \text{ or } 2}$

L_{inf}: transmission loss value for h_{inf} at the required distance

L_{sup}: transmission loss value for h_{sup} at the required distance.

4 Interpolation of transmission loss as a function of distance

Unless d coincides with one of the distances given in the tabulated values, the transmission loss, should be linearly interpolated for the logarithm of the distance using:

$$L = L_{inf} + (L_{sup} - L_{inf}) \log(d / d_{inf}) / \log(d_{sup} / d_{inf}) \quad \text{dB} \tag{6}$$

where:

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

d_{inf}: nearest tabulation distance less than d

d_{sup}: nearest tabulation distance greater than d

L_{inf}: transmission loss value for d_{inf}

L_{sup}: transmission loss value for d_{sup}.

5 Interpolation of transmission loss as a function of frequency

If the frequency for the prediction is not one of the frequencies represented in the figures of this Recommendation or in the tabulated data, the required transmission loss should be calculated using:

$$L = L_{inf} + (L_{sup} - L_{inf}) \log(f / f_{inf}) / \log(f_{sup} / f_{inf}) \quad \text{dB} \tag{7}$$

where:

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

f_{inf}: lower nominal frequency

f_{sup}: higher nominal frequency

L_{inf}: transmission loss value for f_{inf}

L_{sup}: transmission loss value for f_{sup}.

6 Interpolation of transmission loss as a function of percentage time

Transmission loss values for a given percentage of time should be calculated by interpolation using:

$$L = L_{sup}(Q_{inf} - Q_t)/(Q_{inf} - Q_{sup}) + L_{inf}(Q_t - Q_{sup})/(Q_{inf} - Q_{sup}) \quad \text{dB} \quad (8)$$

where:

t: percentage time for which the prediction is required

t_{inf}: lower nominal percentage time

t_{sup}: upper nominal percentage time

$Q_t = Q_i(t/100)$

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

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

L_{inf}: transmission loss value for time percentage t_{inf}

L_{sup}: transmission loss value for time percentage t_{sup}

where $Q_i(x)$ is the inverse complementary cumulative normal distribution function described in § 7.

7 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 $0.01 \le x \le 0.99$:

$$Q_i(x) = T(x) - \xi(x) \quad \text{if } x \le 0.5 \quad (9a)$$

$$Q_i(x) = -\{T(1-x) - \xi(1-x)\} \quad \text{if } x > 0.5 \quad (9b)$$

where:

$$T(x) = \sqrt{[-2\ln(x)]} \quad (9c)$$

$$\xi(x) = \frac{[(C_2 \cdot T(x) + C_1) \cdot T(x)] + C_0}{[(D_3 \cdot T(x) + D_2) \cdot T(x) + D_1] \cdot T(x) + 1} \quad (9d)$$

$C_0 = 2.515517$

$C_1 = 0.802853$

$C_2 = 0.010328$

$D_1 = 1.432788$

$D_2 = 0.189269$

$D_3 = 0.001308$

Values given by the above equations are given in Table 1.

TABLE 1

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		

8 Procedure for interpolating the values in this Recommendation

The step-by-step procedure given below is intended to be applied to values derived from the field strength versus distance tables available from the Radiocommunication Bureau. They may, however, also be applied to values obtained from the curves.

Step 1: For any given percentage of time determine two nominal time percentages as follows:

– record the nearest nominal time percentage below the wanted time percentage (this is the lower nominal value, t_{inf});

– record the nearest nominal time percentage above the wanted time percentage (this is the higher nominal value, t_{sup}).

If the required percentage of time is equal to 1%, 5%, 10%, 50%, or 95%, this value should be regarded as the lower nominal percentage time and the interpolation process of Step 8 is not required.

Step 2: For any wanted frequency determine two nominal frequencies as follows:

– record the nearest nominal frequency below the wanted frequency (this is the lower nominal value, f_{inf});

– record the nearest nominal frequency loss above the wanted frequency (this is the higher nominal value, f_{sup}).

If the wanted frequency equals one of the frequencies in the graphs and tabulated data, this value should be regarded as the lower nominal frequency and the interpolation process of Step 7 is not required.

Step 3: For any wanted distance determine two nominal distances as follows:

– record the nearest nominal distance below the wanted distance (this is the lower nominal value, d_{inf});

– record the nearest nominal distance above the wanted distance (this is the higher nominal value, d_{sup}).

If the wanted distance equals one of the distances in the graphs and tabulated data, this value should be regarded as the lower nominal distance and the interpolation process of Step 7 is not required.

Step 4: For the lower nominal percentage time follow Steps 5 to 8.

Step 5: For the lower nominal frequency follow Steps 6 and 7.

Step 6: Obtain the transmission loss for the required distance and transmitting/base antenna height as follows :

Step 6.1: Determine the lower and higher nominal h_2 values using the method given in Annex 2, § 3. If h_2 coincides with one of the nominal values in the graphs and tabulated data, this should be regarded as the lower nominal value of h_2 and the interpolation process of Step 6.9 is not required.

Step 6.2: Determine the lower and higher nominal h_1 values using the method given in Annex 2, § 3. If h_1 coincides with one of the nominal values in the graphs and tabulated data, this should be regarded as the lower nominal value of h_1 and the interpolation process of Step 6.8 is not required.

Step 6.3: For the lower nominal value of h_2 follow Steps 6.4 to 6.6.

Step 6.4: For the lower nominal value of h_1 follow Steps 6.5 to 6.6.

Step 6.5: For the lower nominal value of distance follow Step 6.6.

Step 6.6: Obtain the transmission loss value for the required values of distance, d, and transmitting/base antenna height, h_1.

Step 6.7: If the required distance does not coincide with the lower nominal distance, repeat Step 6.6 for the higher nominal distance and interpolate the two transmission loss values for distance using the method given in Annex 2, § 4.

Step 6.8: If the required antenna height, h_1, does not coincide with one of the nominal values, repeat Steps 6.5 to 6.7 and interpolate the two transmission loss values for h_1 using the method given in Annex 2, § 3.

Step 6.9: If the required antenna height, h_2, does not coincide with one of the nominal values, repeat Steps 6.5 to 6.8 and interpolate the two transmission loss values for h_2 using the method given in Annex 2, § 3.

Step 7: If the required frequency does not coincide with the lower nominal frequency, repeat Step 6 for the higher nominal frequency and interpolate the two transmission loss values using the method given in Annex 2, § 5.

Step 8: If the required percentage time does not coincide with the lower nominal percentage time, repeat Steps 5 to 7 for the higher nominal percentage time and interpolate the two transmission loss values using the method given in Annex 2, § 6.

Step 9: If required, convert transmission loss to equivalent field strength for the path using method given in Annex 2, § 2.

Annex 3

Description of the curves

The aeronautical curves are contained in Figs 1-1 to 8-5. The following points are to be noted:

1 Figures 1-1 to 8-5 show median values of the basic transmission loss, L_b, for each of $L_b(0.01)$, $L_b(0.05)$, $L_b(0.10)$, $L_b(0.50)$, and $L_b(0.95)$ at the frequencies 125, 300, 600, 1 200, 2 400, 5 100, 9 400 and 15 500 MHz. These correspond to time availabilities of 1, 5, 10, 50 and 95%. For example, $L_b(0.95)$ = 200 dB means that the basic transmission loss would be 200 dB or less during 95% of the time.

2 Each figure consists of three curve sets where the upper, middle and lower sets provide h_2 values of 1000, 10 000, and 20 000 m, respectively.

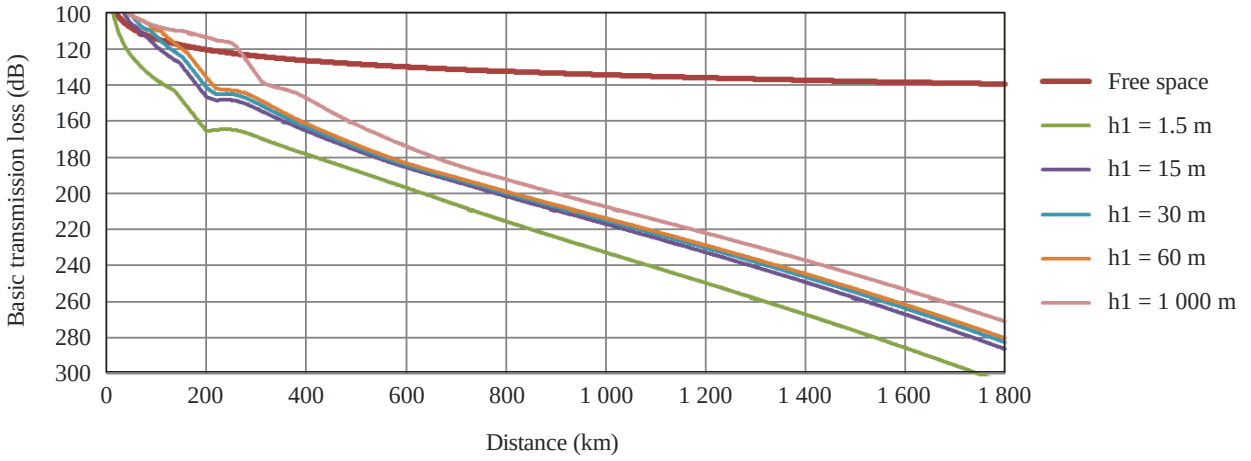
3 The antenna heights, h1, shown vary from 1.5 m to 20 000 m covering both ground station and aircraft heights.

4 The development and application of these curves are discussed in Annex 1.

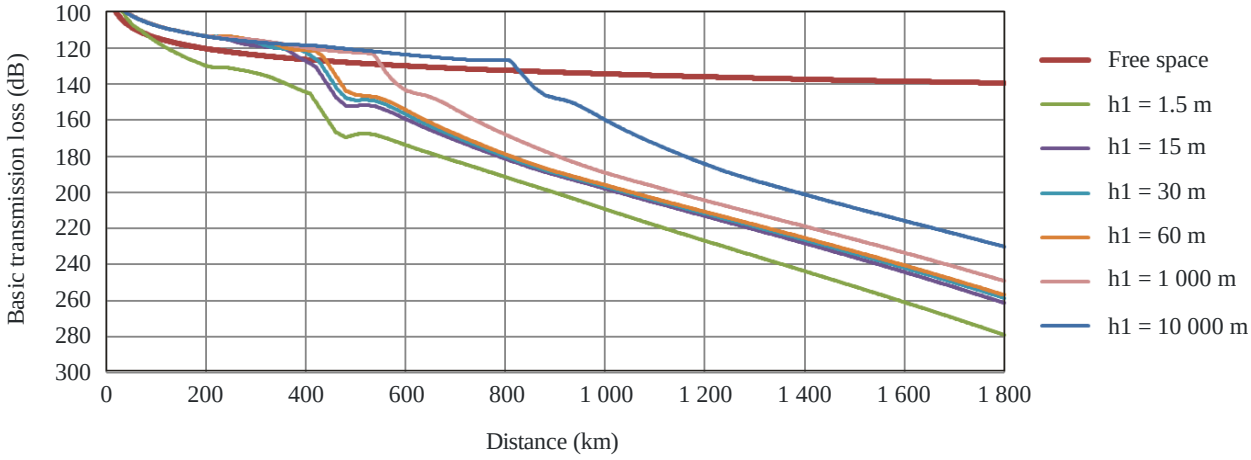
5 At zero distance $L_b(0.50)$ is simply the free-space value corresponding to a path length equal to the difference in antenna heights. The free-space curves shown were calculated for a 19 985 m height difference.

FIGURE 1-1

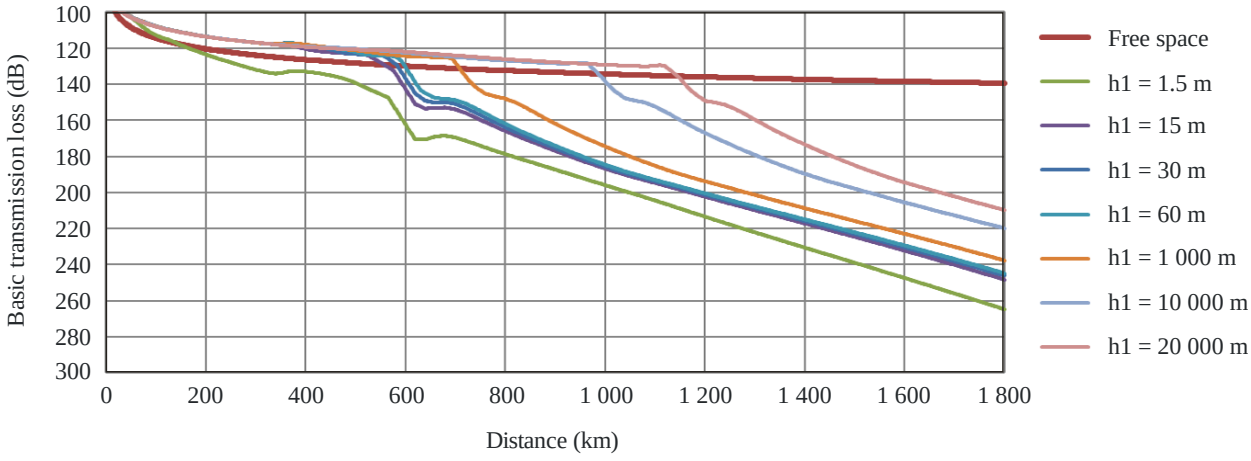
Curve sets for basic transmission loss at 125 MHz for 1% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

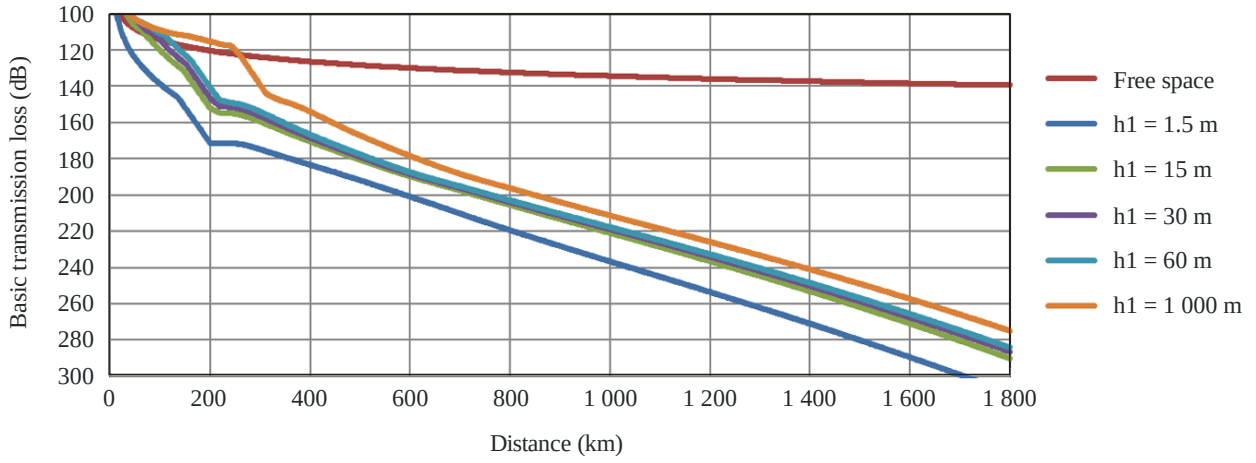


c) h2 = 20 000 m

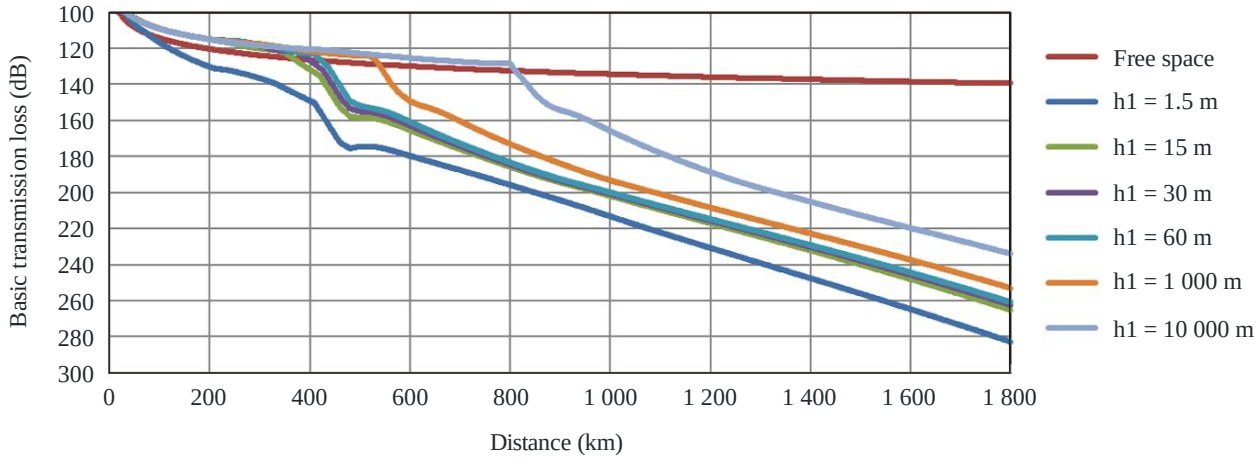
P.0528-01-01

FIGURE 1-2

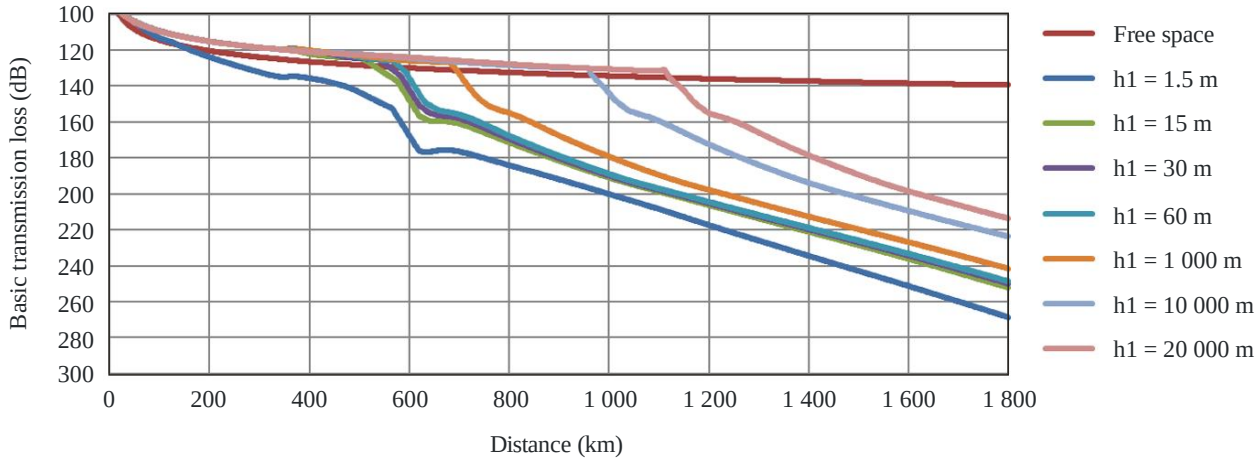
Curve sets for basic transmission loss at 125 MHz for 5% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

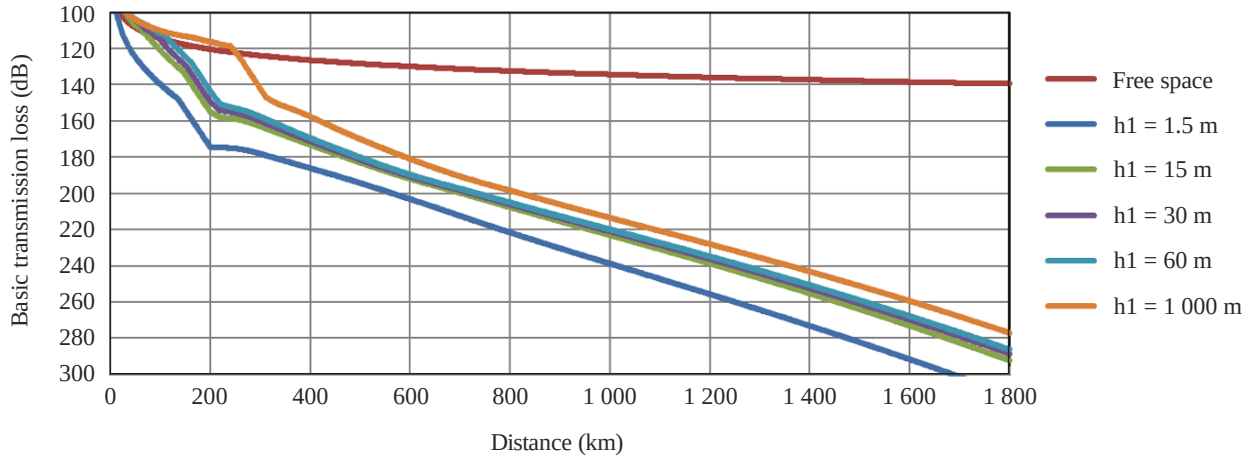


c) h2 = 20 000 m

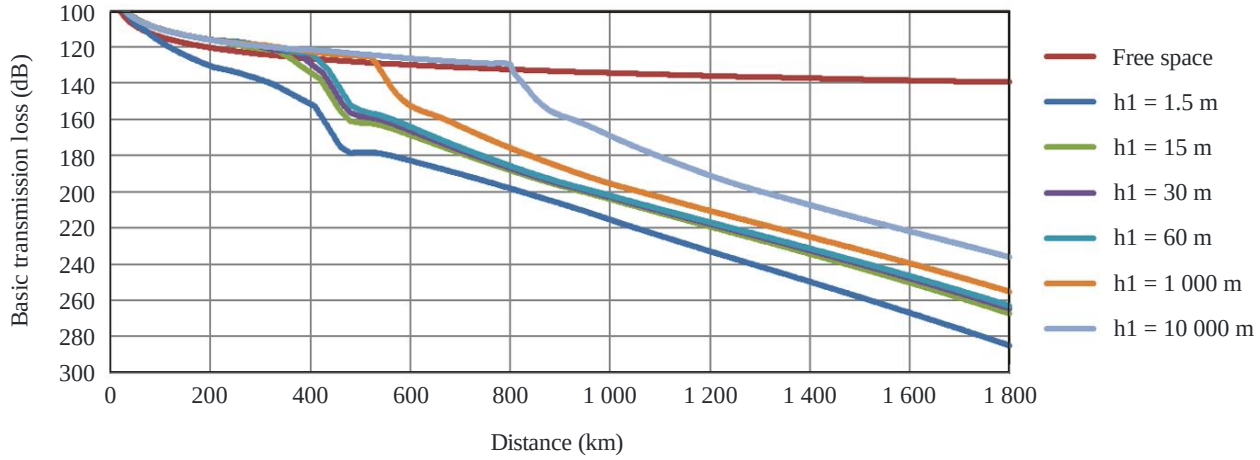
P.0530-01-02

FIGURE 1-3

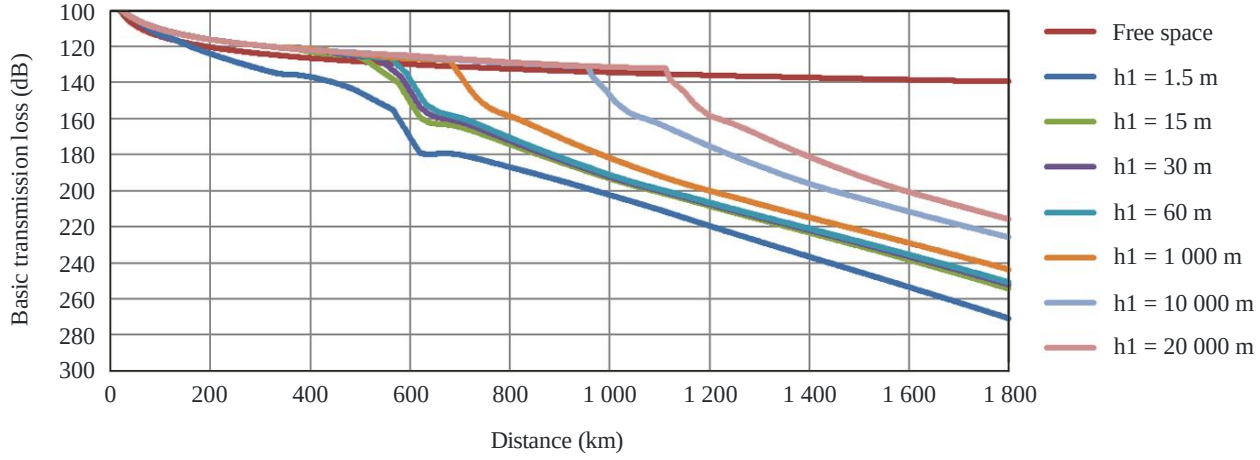
Curve sets for basic transmission loss at 125 MHz for 10% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

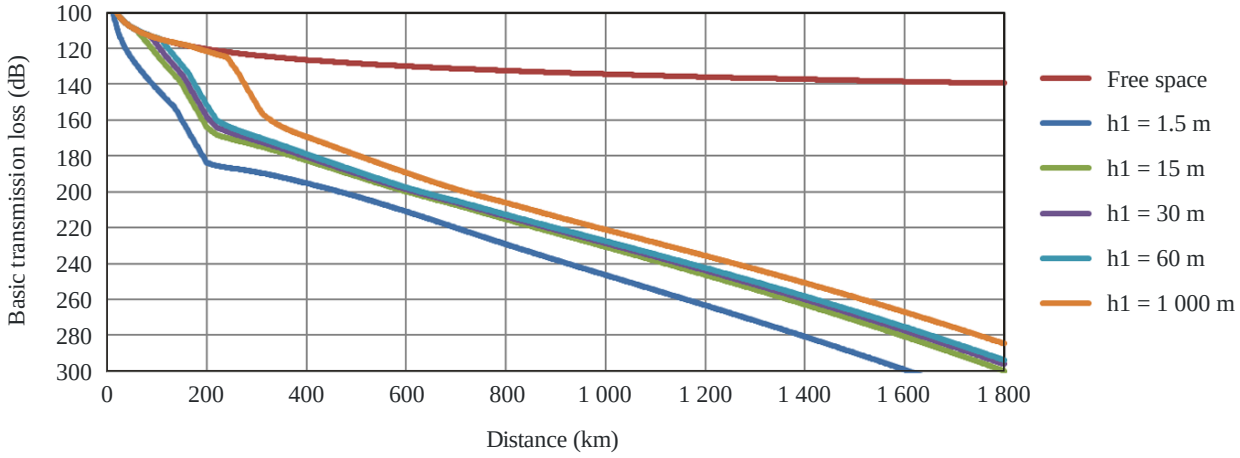


c) h2 = 20 000 m

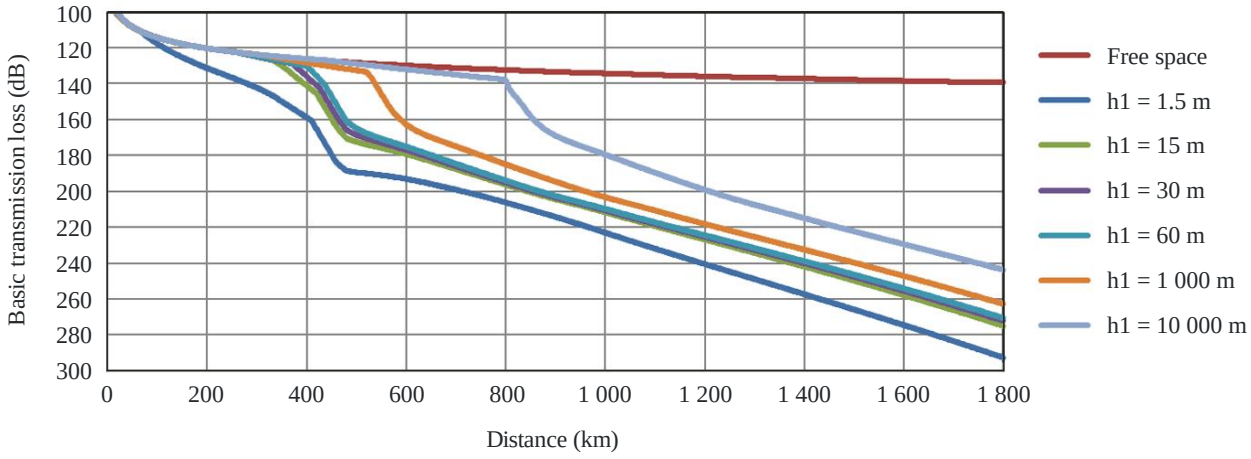
P.0528-01-03

FIGURE 1-4

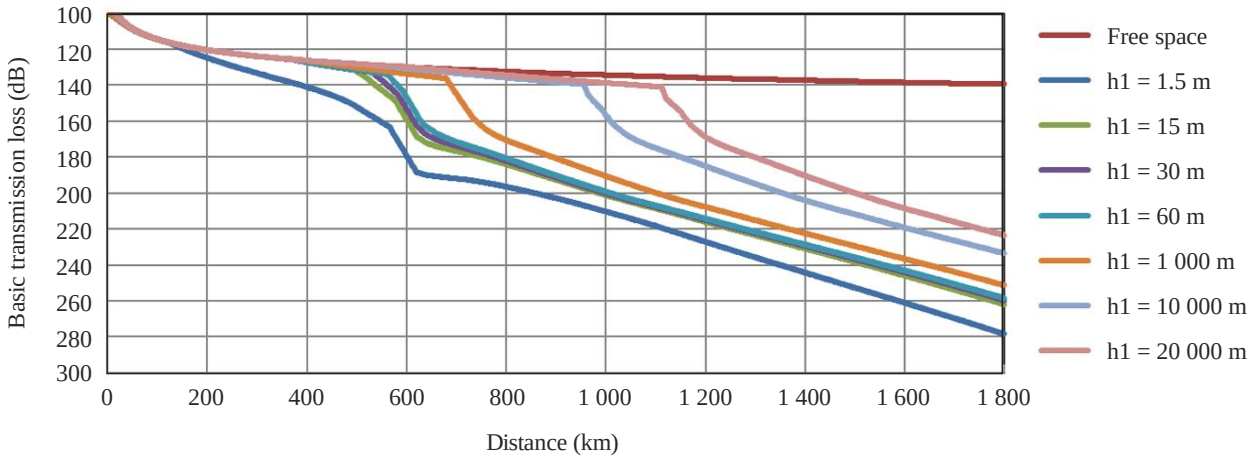
Curve sets for basic transmission loss at 125 MHz for 50% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

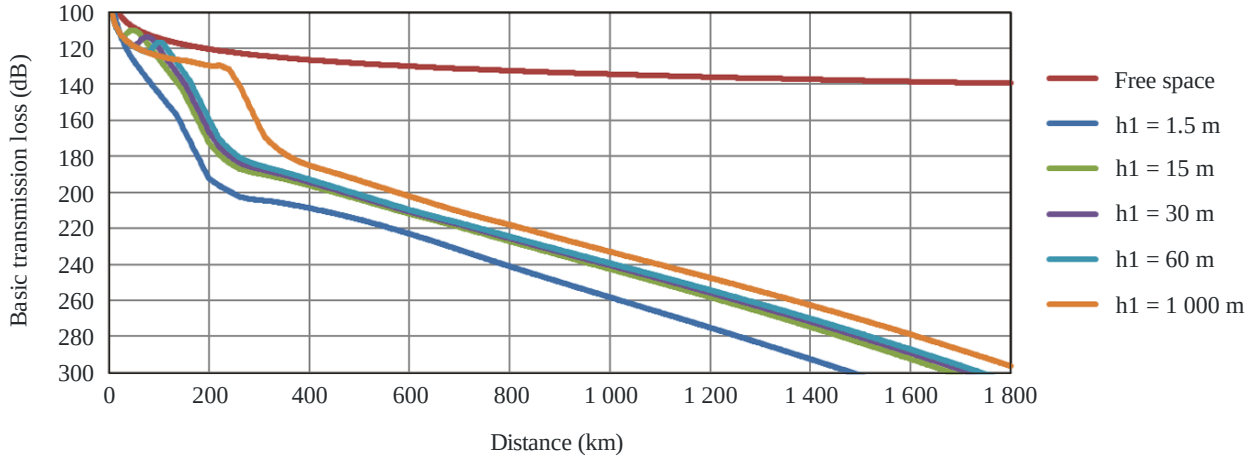


c) h2 = 20 000 m

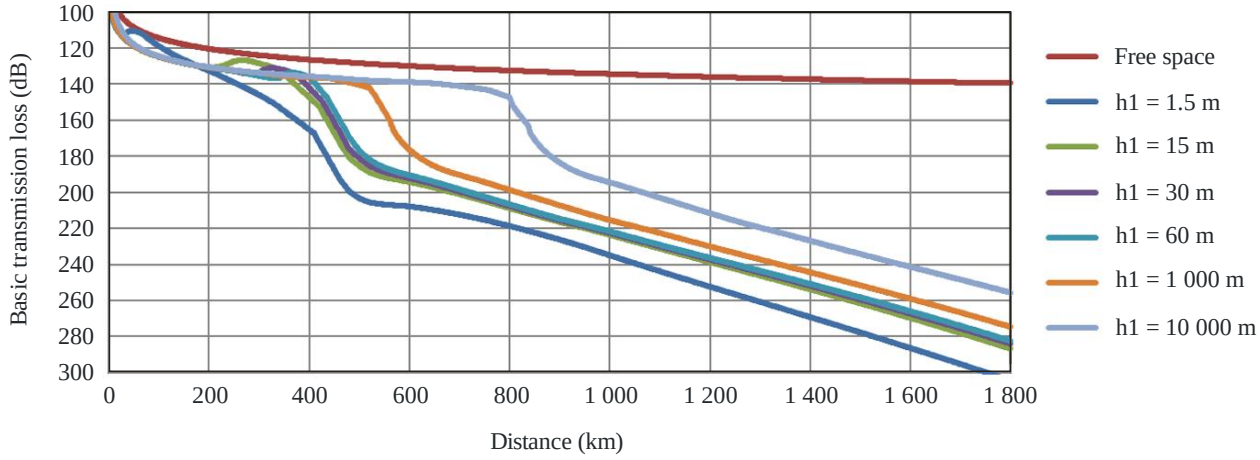
P.0528-01-04

FIGURE 1-5

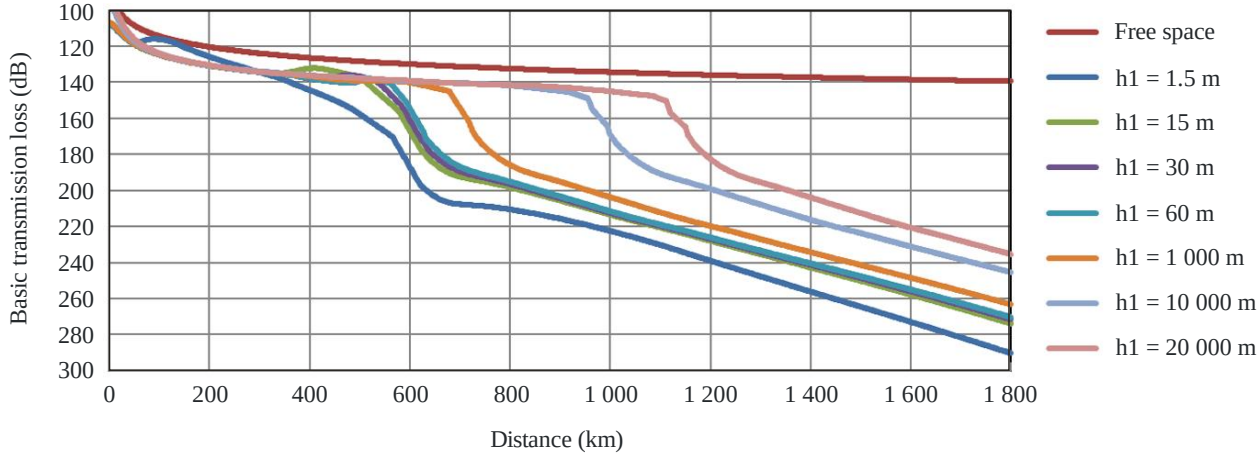
Curve sets for basic transmission loss at 125 MHz for 95% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

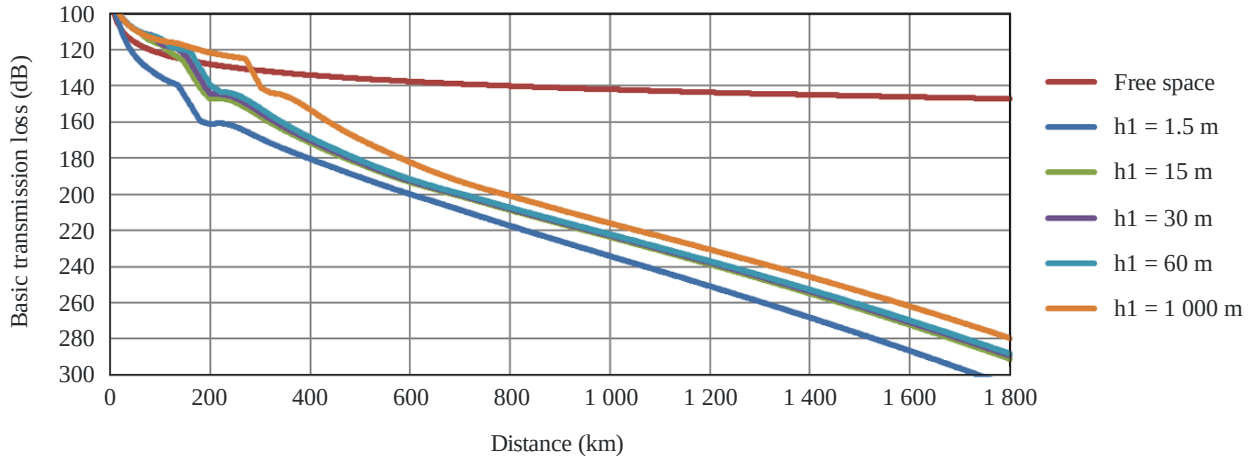


c) h2 = 20 000 m

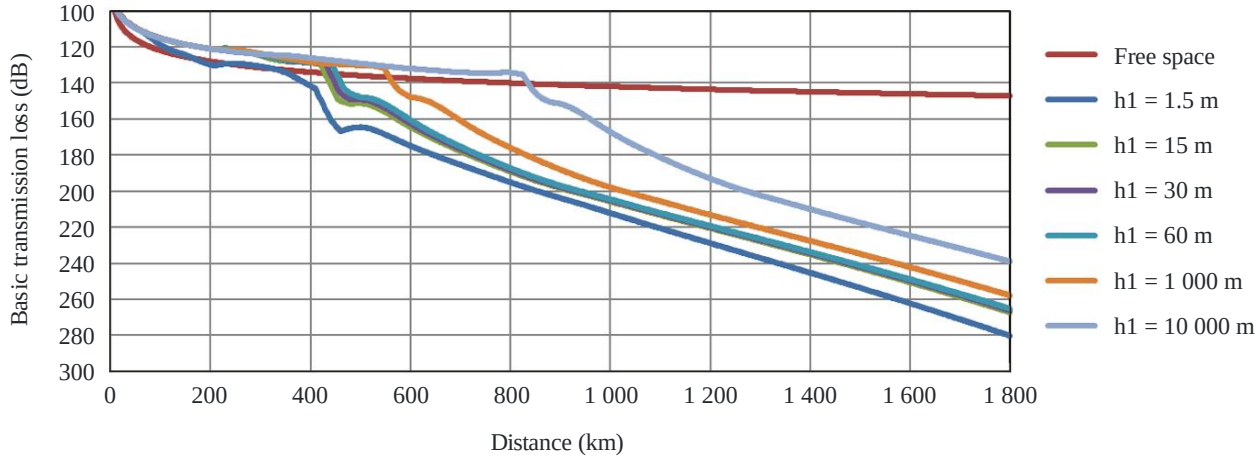
P.0528-01-05

FIGURE 2-1

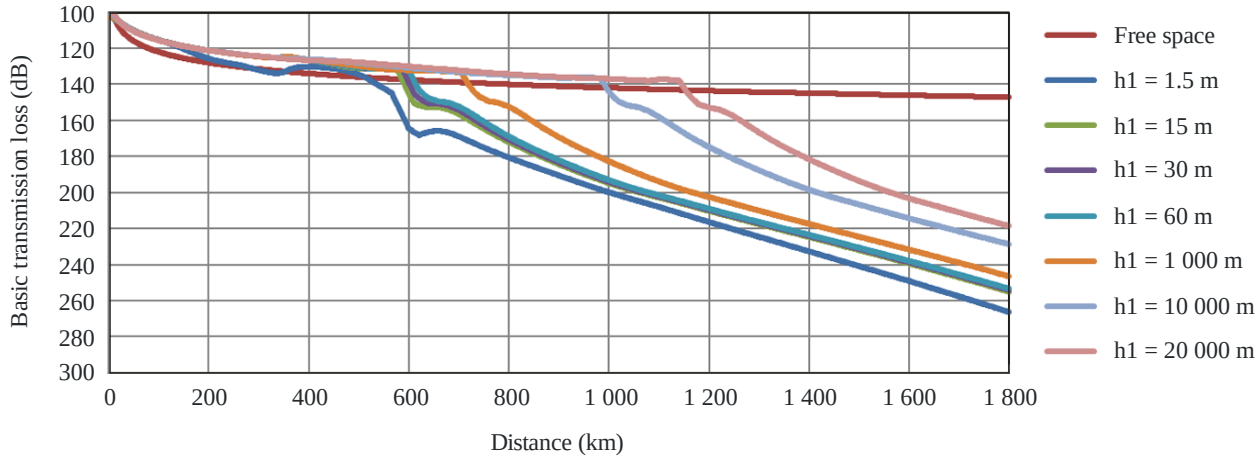
Curve sets for basic transmission loss at 300 MHz for 1% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

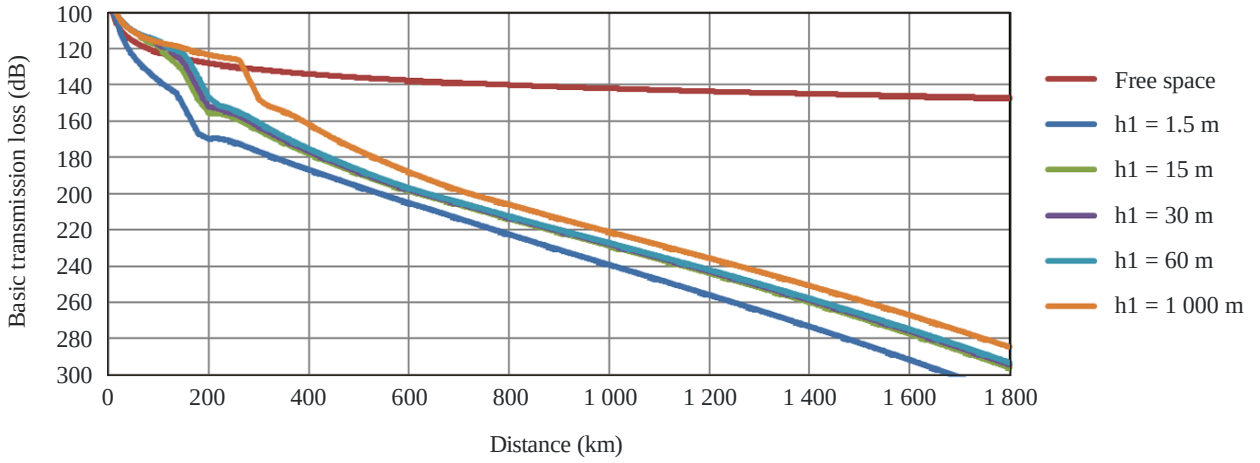


c) h2 = 20 000 m

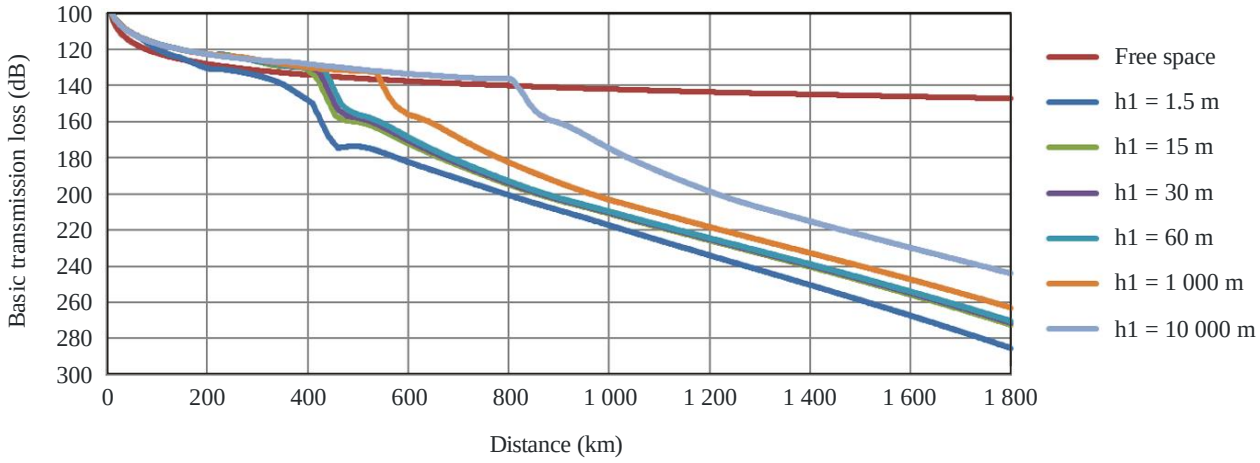
P.0528-02-01

FIGURE 2-2

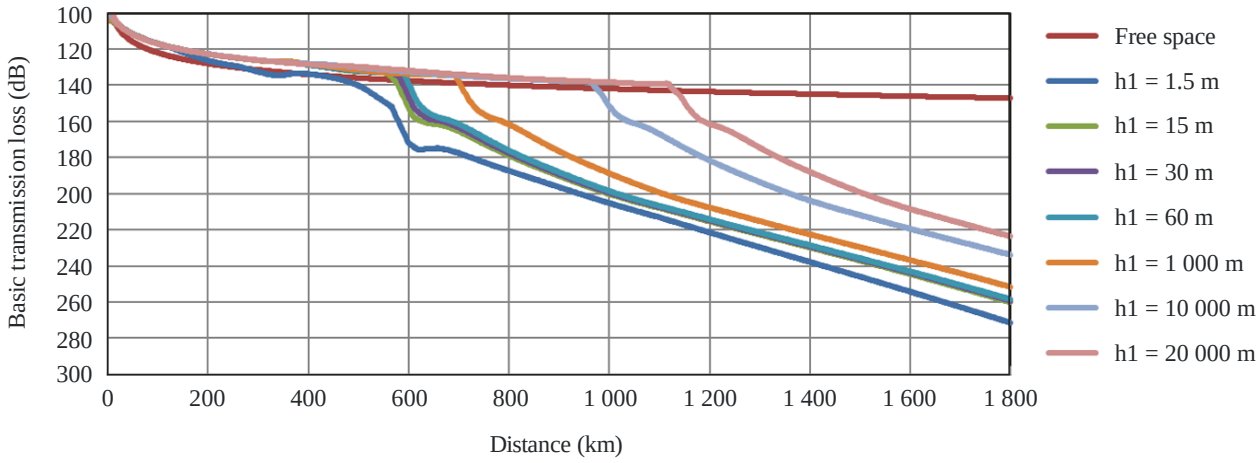
Curve sets for basic transmission loss at 300 MHz for 5% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

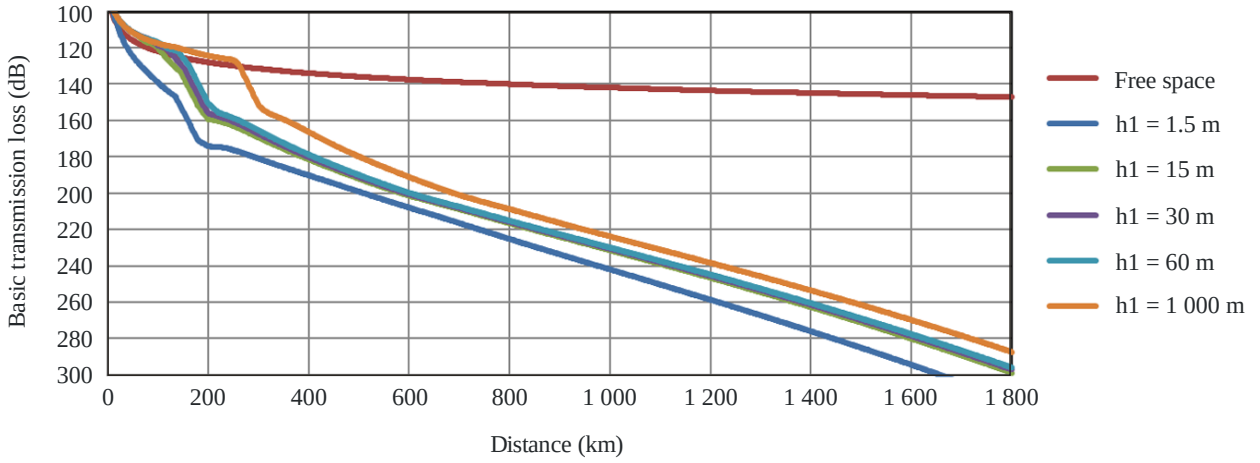


c) h2 = 20 000 m

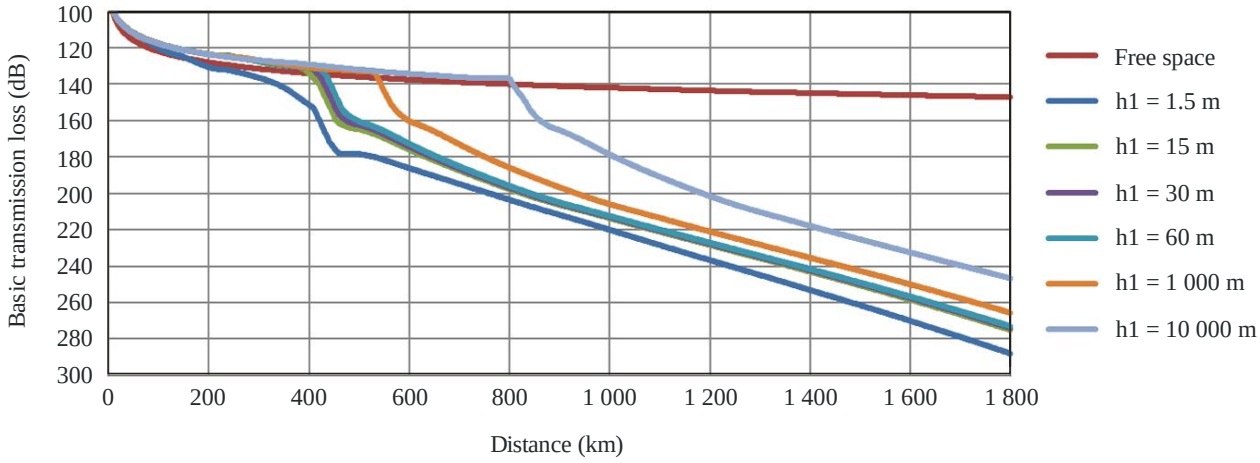
P.0528-02-02

FIGURE 2-3

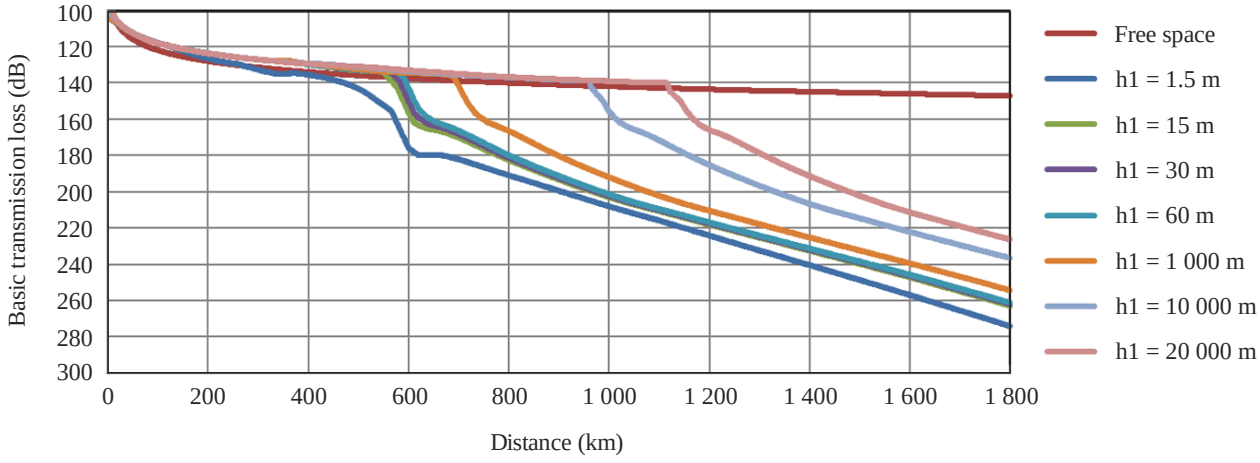
Curve sets for basic transmission loss at 300 MHz for 10% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

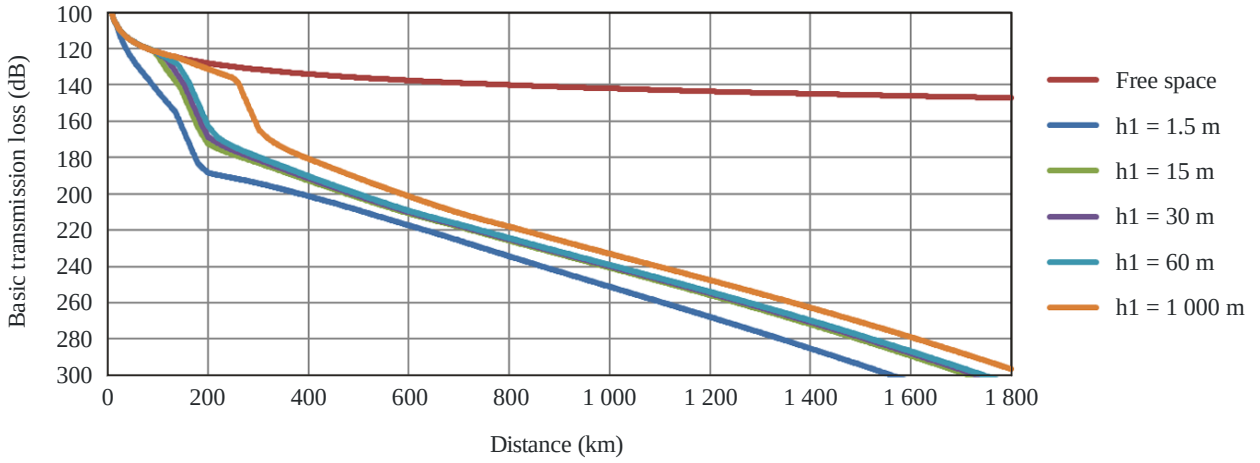


c) h2 = 20 000 m

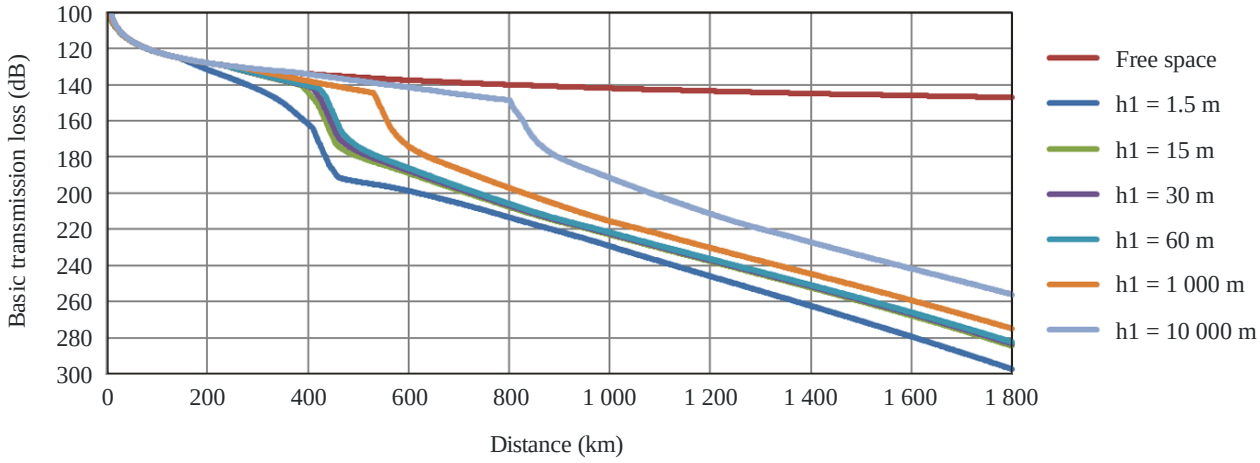
P.0528-02-03

FIGURE 2-4

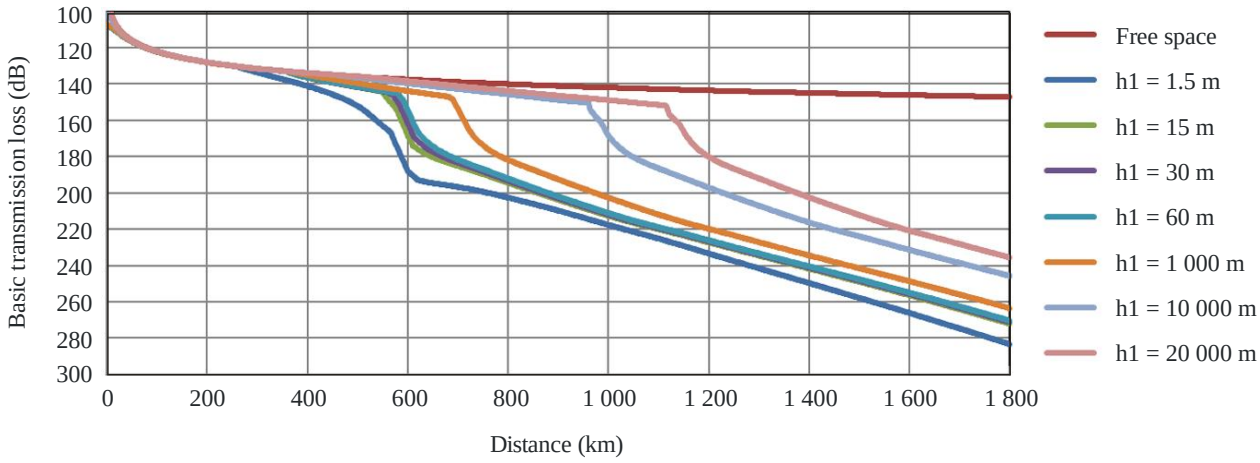
Curve sets for basic transmission loss at 300 MHz for 50% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

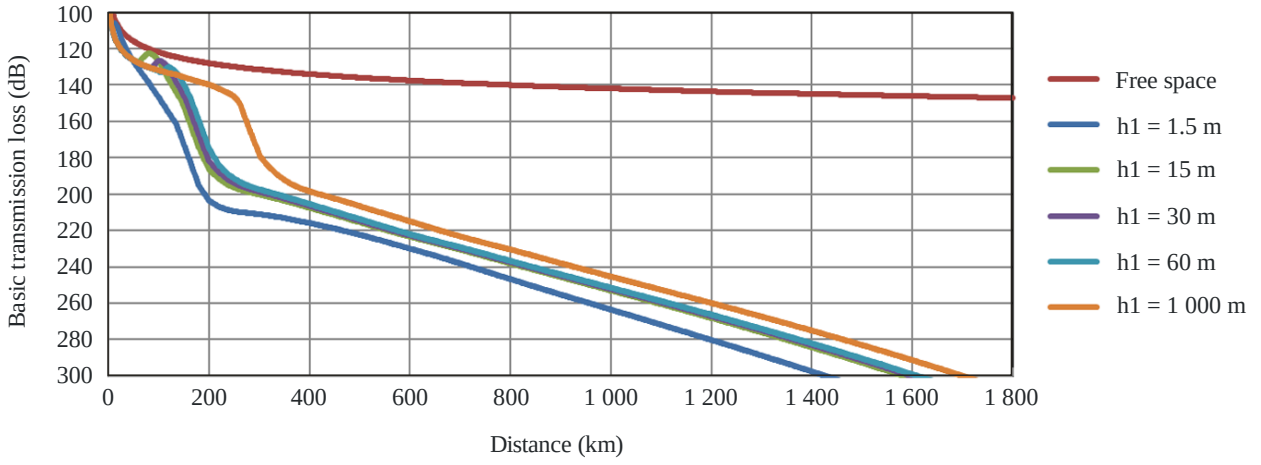


c) h2 = 20 000 m

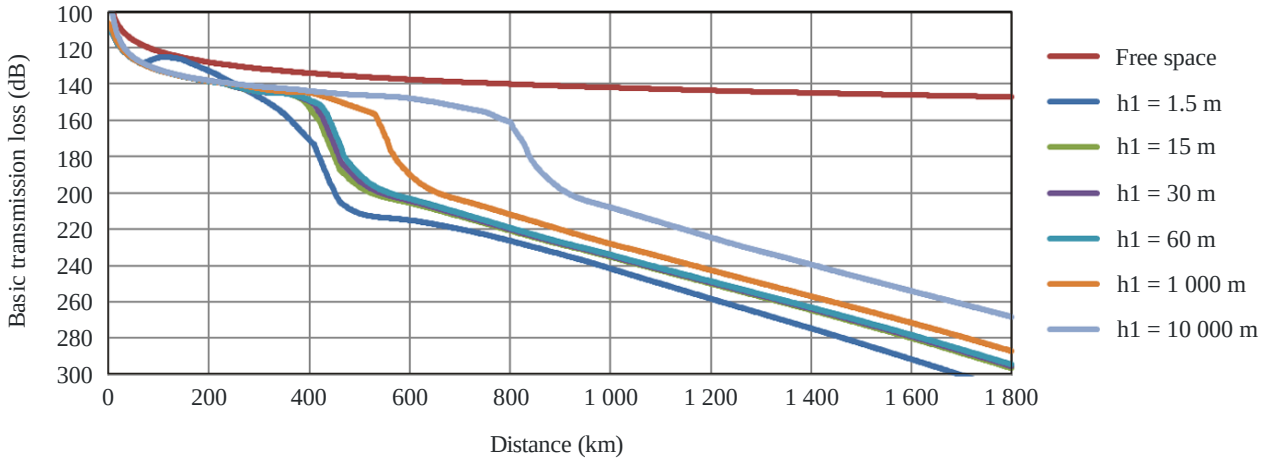
P.0528-02-04

FIGURE 2-5

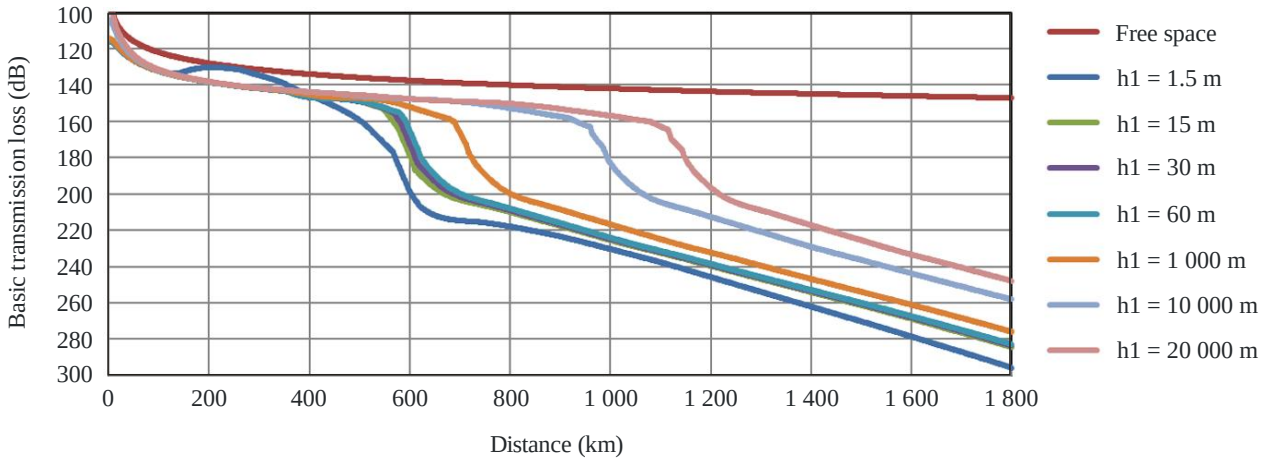
Curve sets for basic transmission loss at 300 MHz for 95% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

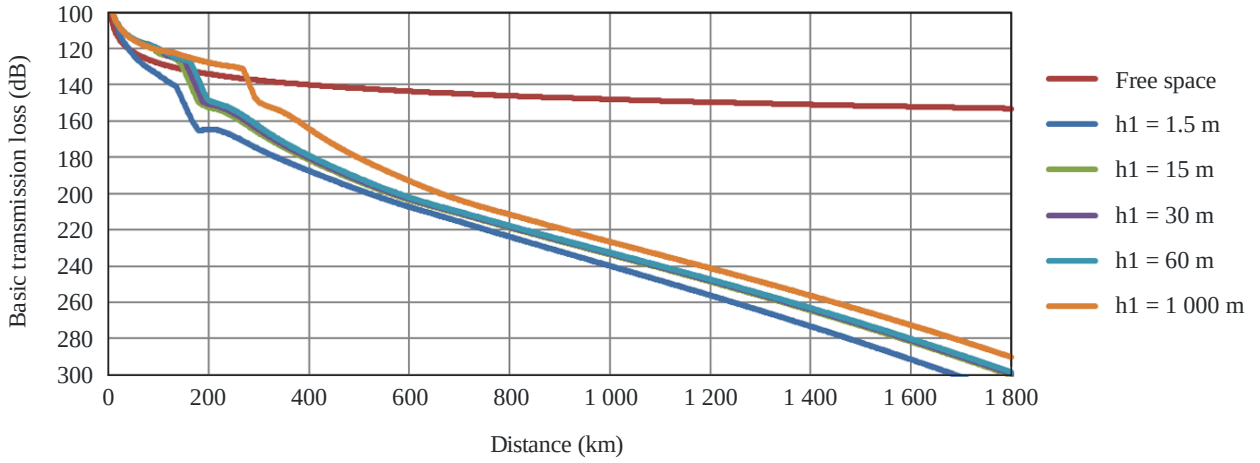


c) h2 = 20 000 m

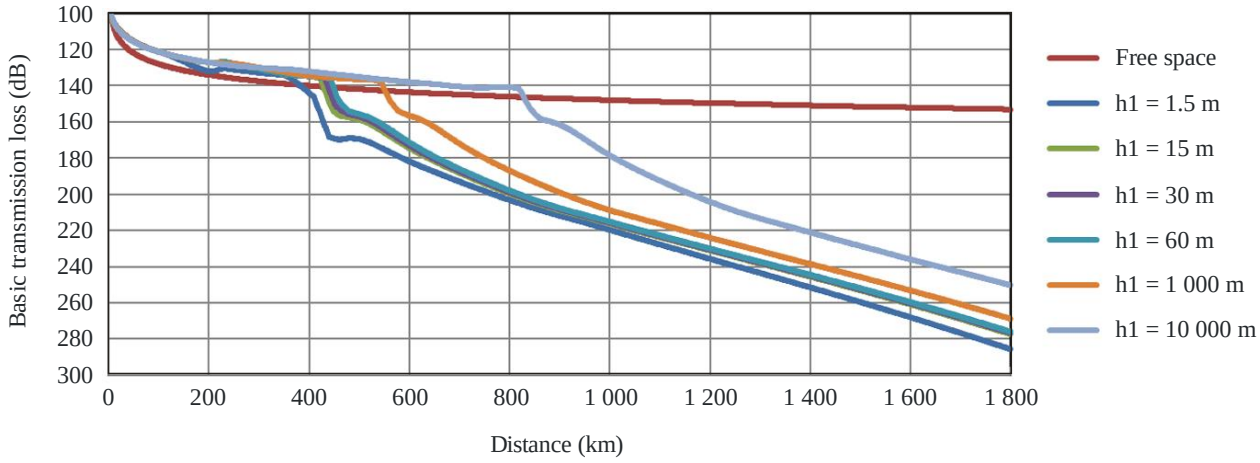
P.0528-02-05

FIGURE 3-1

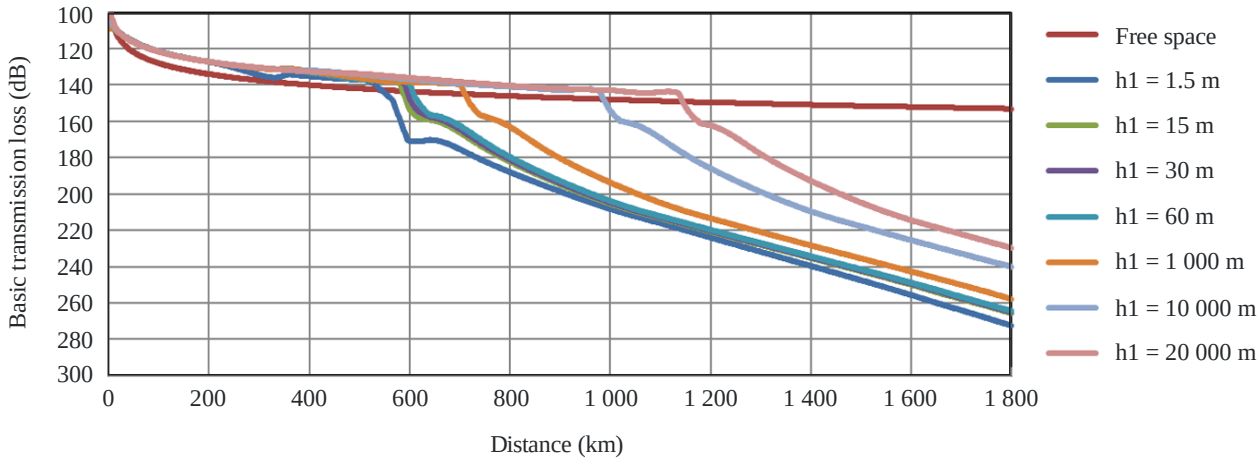
Curve sets for basic transmission loss at 600 MHz for 1% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

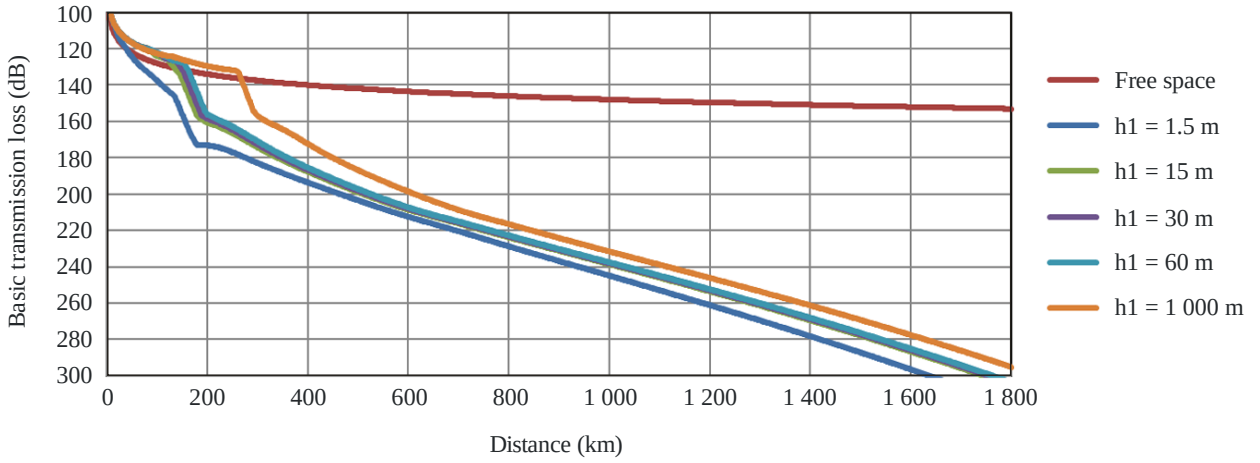


c) h2 = 20 000 m

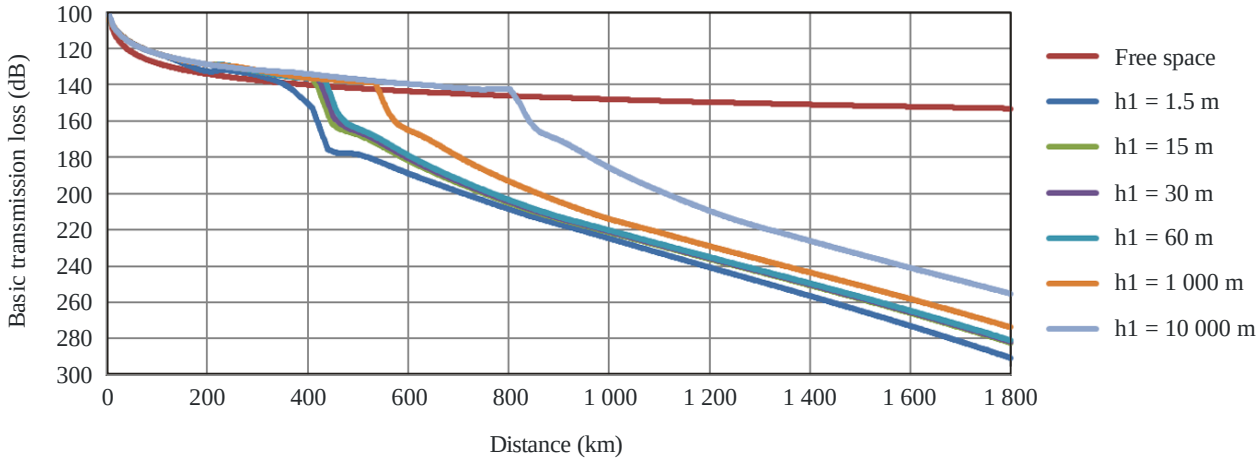
P.0528-03-01

FIGURE 3-2

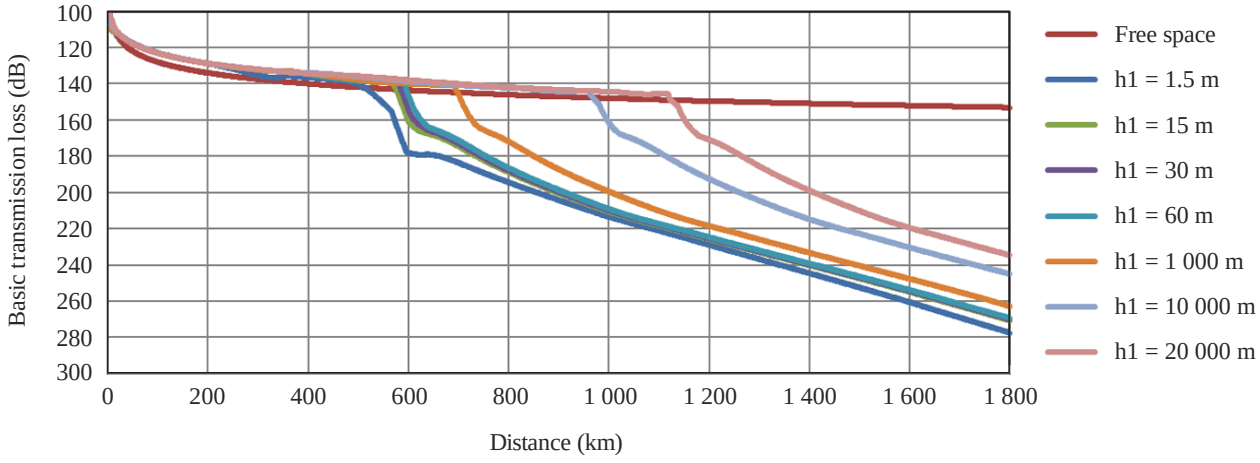
Curve sets for basic transmission loss at 600 MHz for 5% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

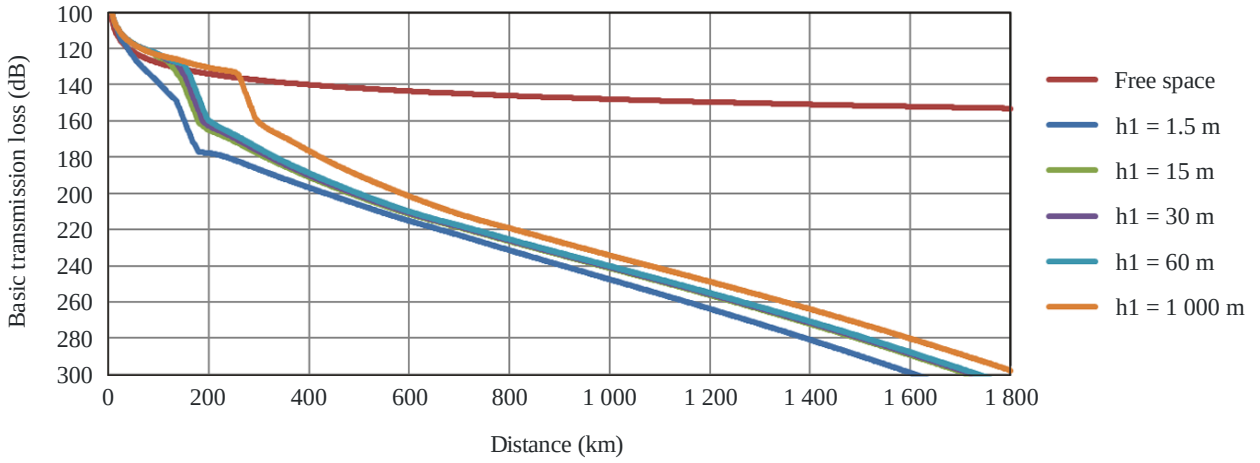


c) h2 = 20 000 m

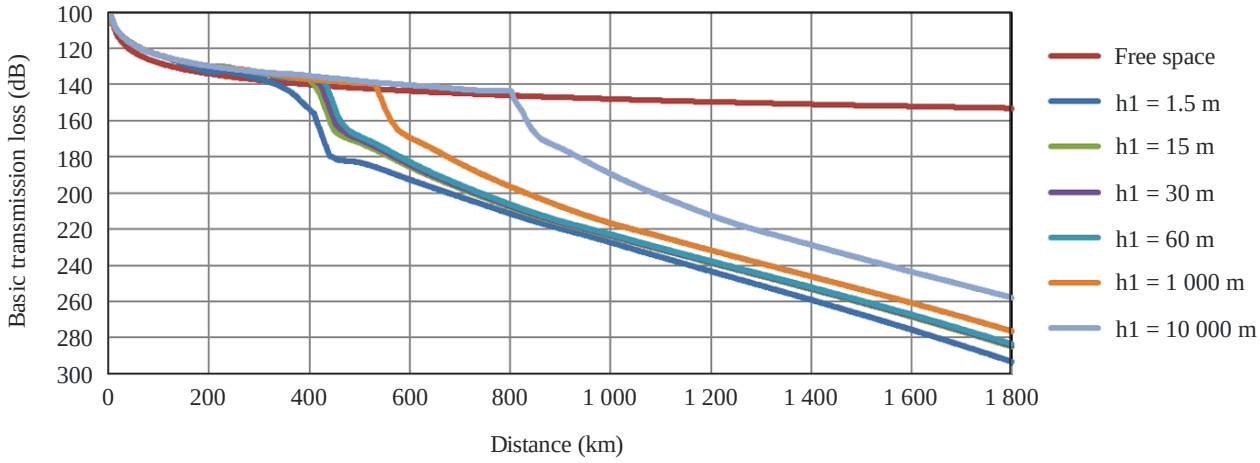
P.0528-03-02

FIGURE 3-3

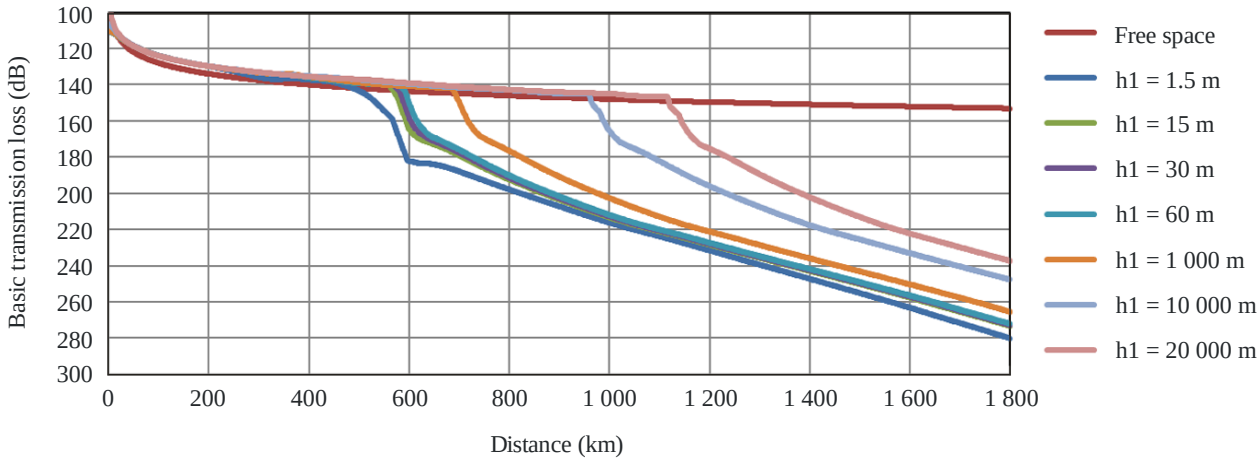
Curve sets for basic transmission loss at 600 MHz for 10% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

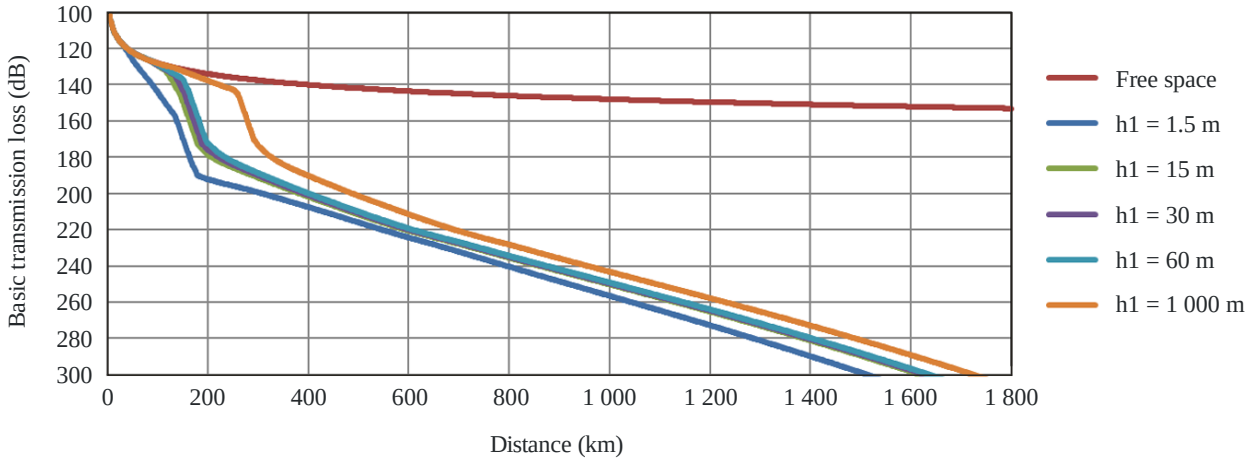


c) h2 = 20 000 m

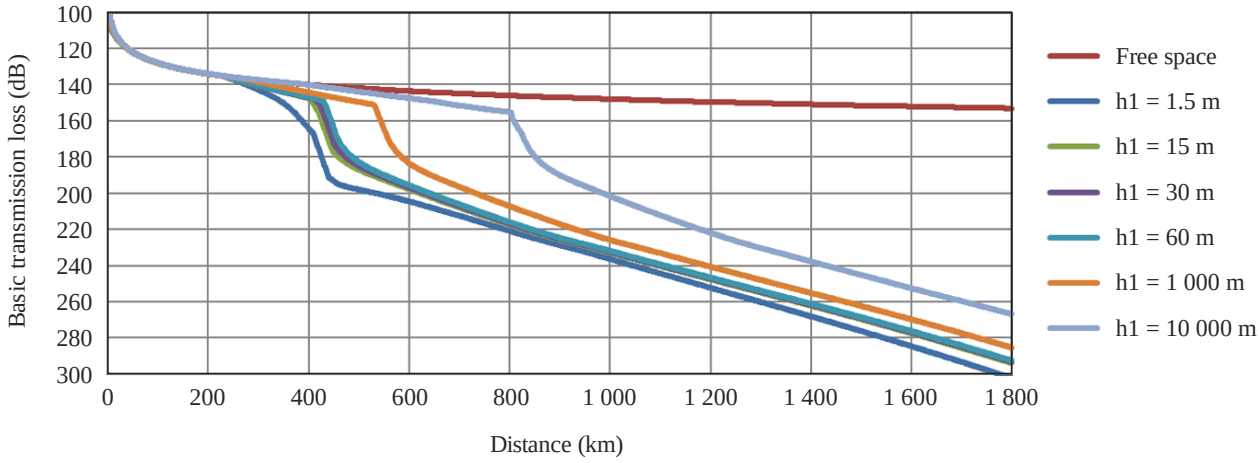
P.0528-03-03

FIGURE 3-4

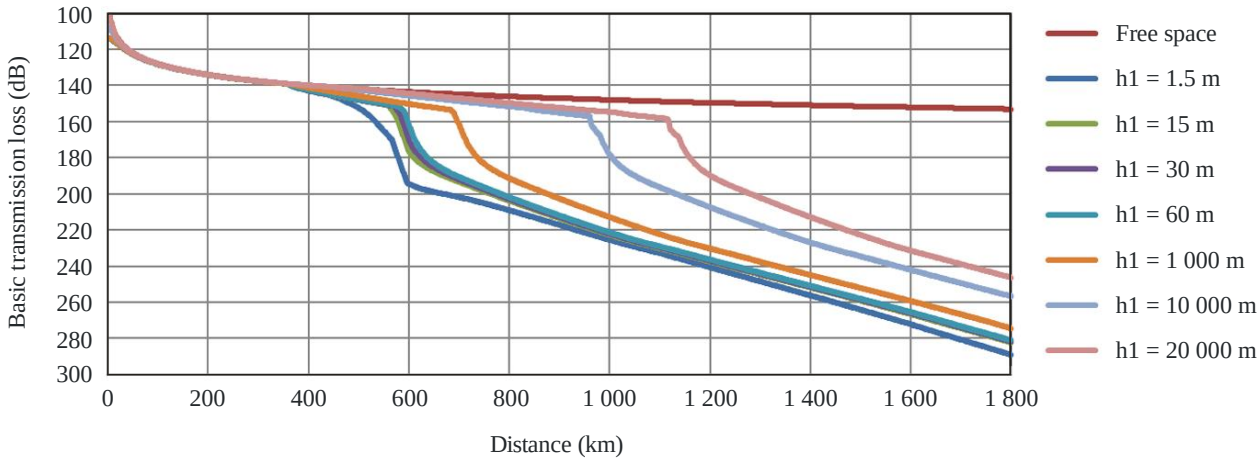
Curve sets for basic transmission loss at 600 MHz for 50% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

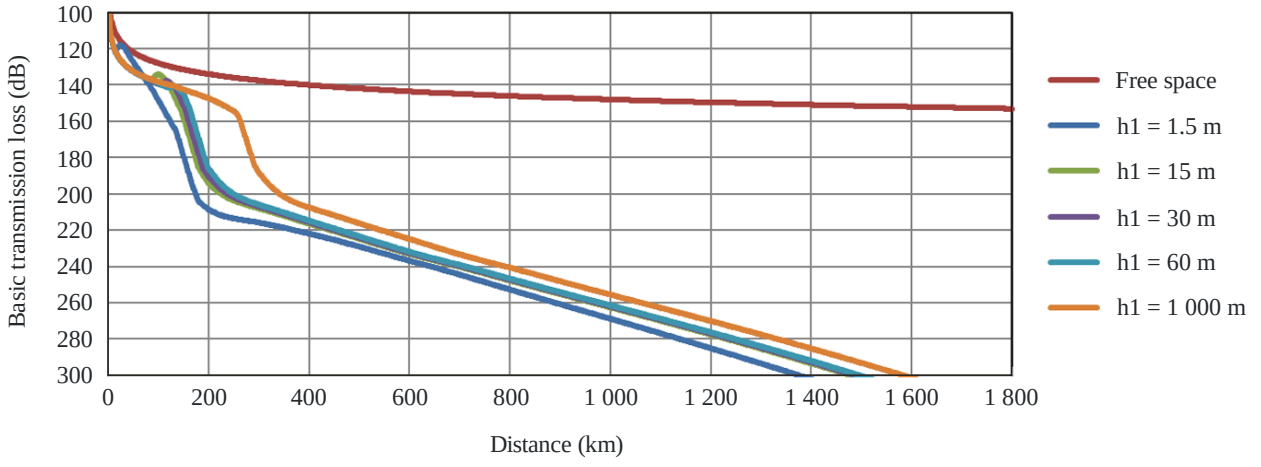


c) h2 = 20 000 m

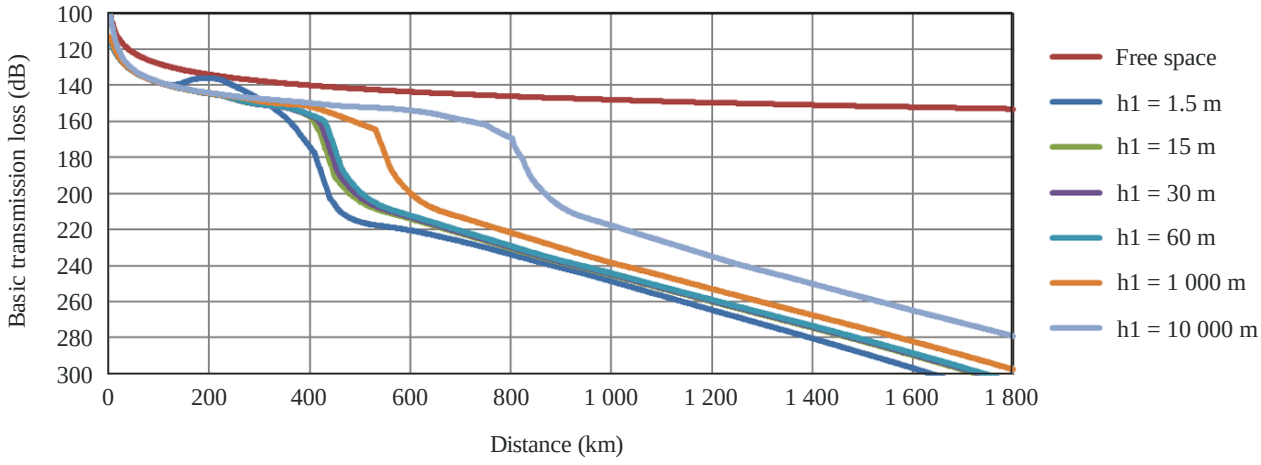
P.0528-03-04

FIGURE 3-5

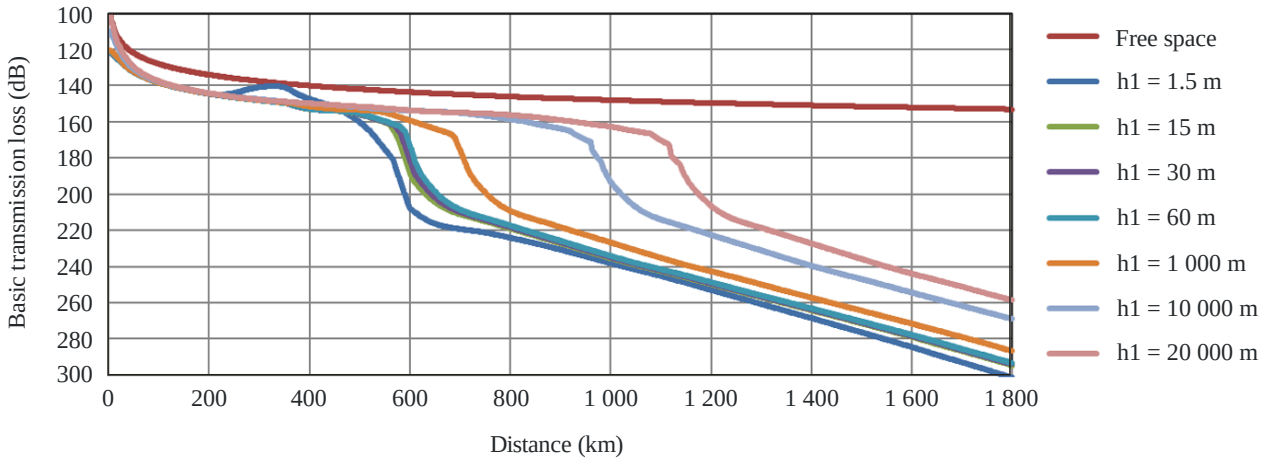
Curve sets for basic transmission loss at 600 MHz for 95% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

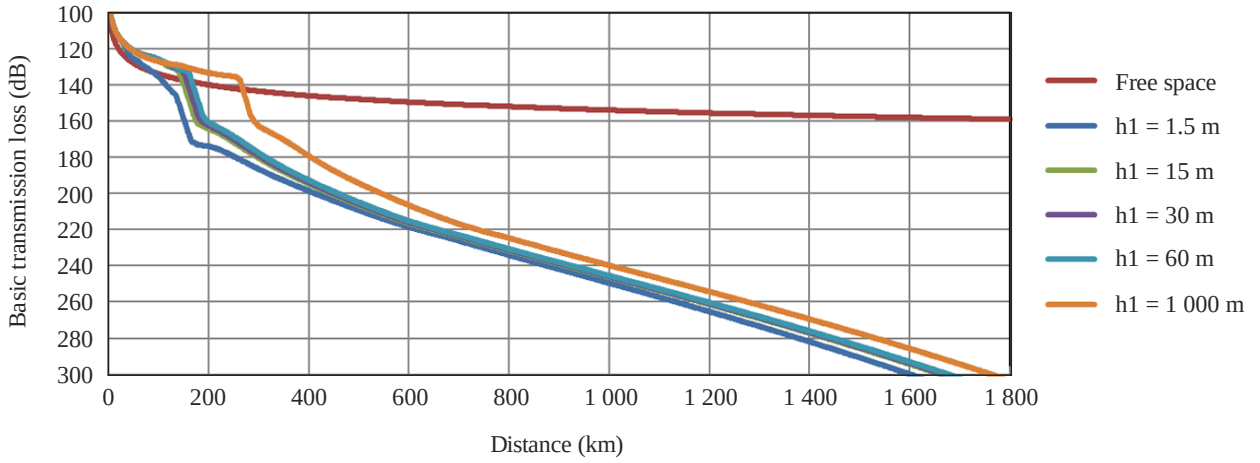


c) h2 = 20 000 m

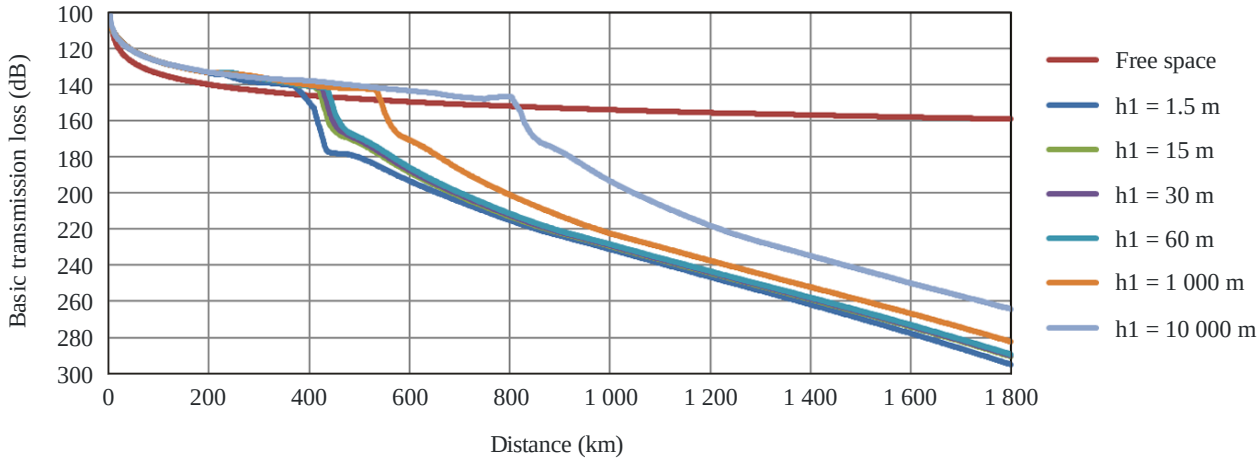
P.0528-03-05

FIGURE 4-1

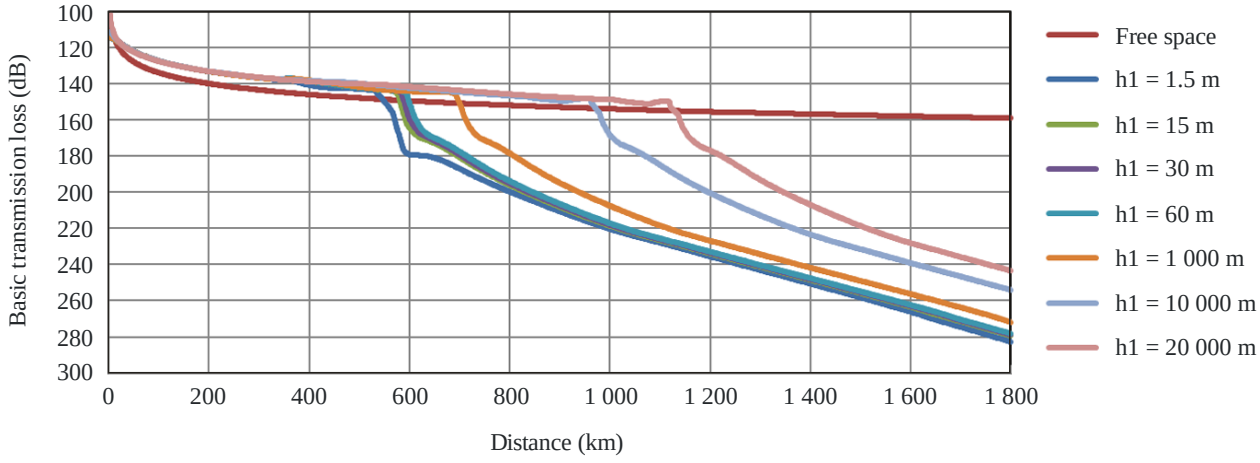
Curve sets for basic transmission loss at 1 200 MHz for 1% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

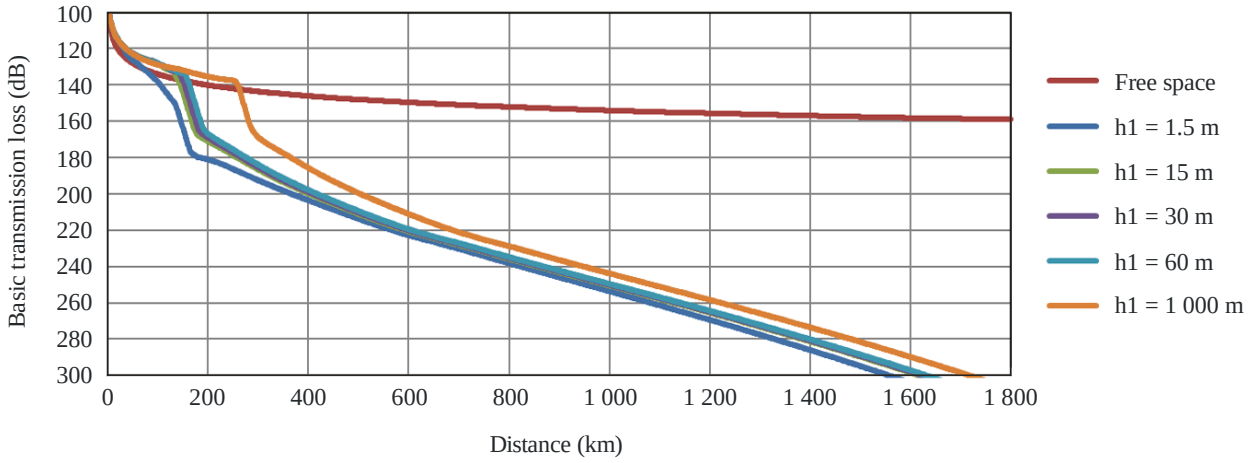


c) h2 = 20 000 m

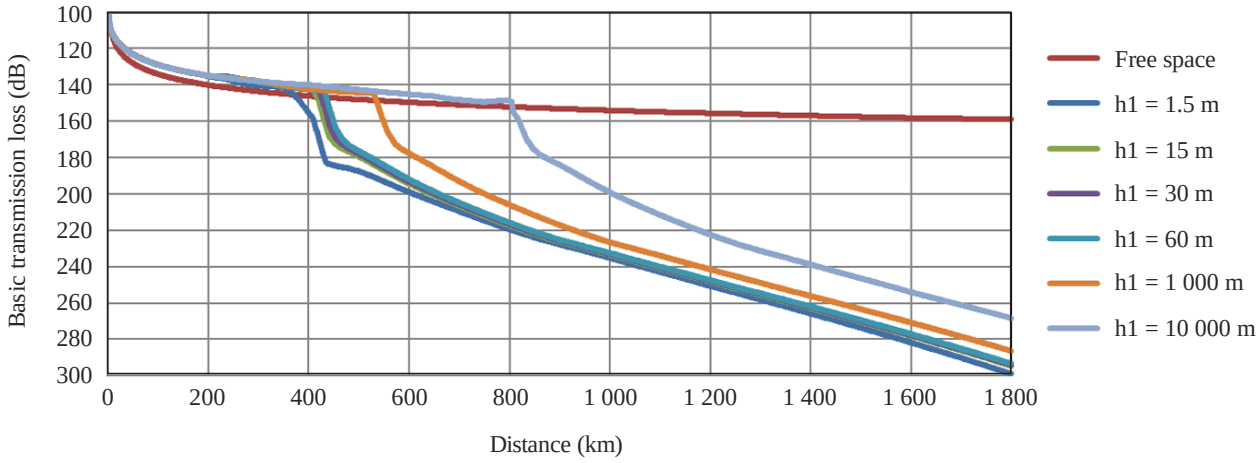
P.0528-04-01

FIGURE 4-2

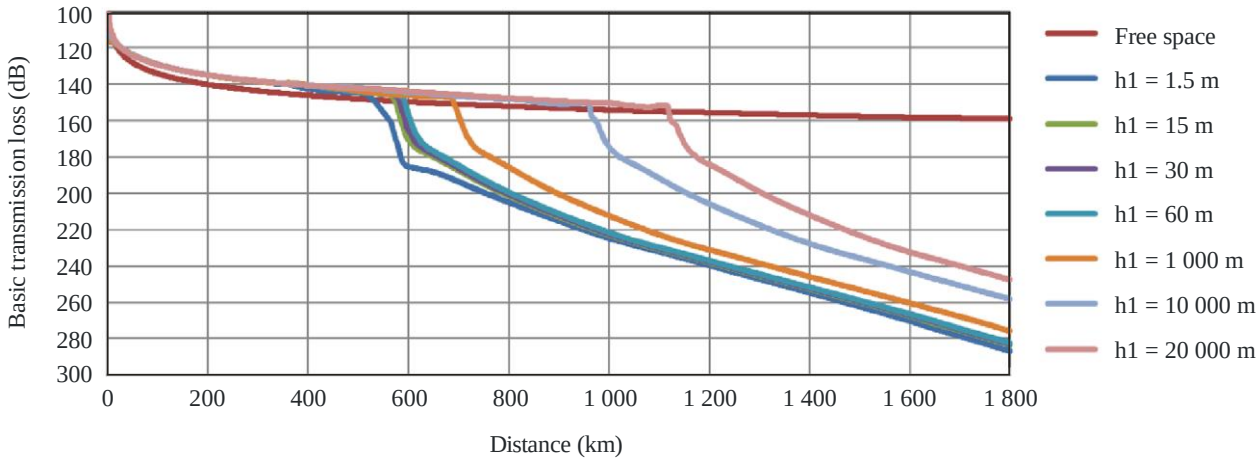
Curve sets for basic transmission loss at 1 200 MHz for 5% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

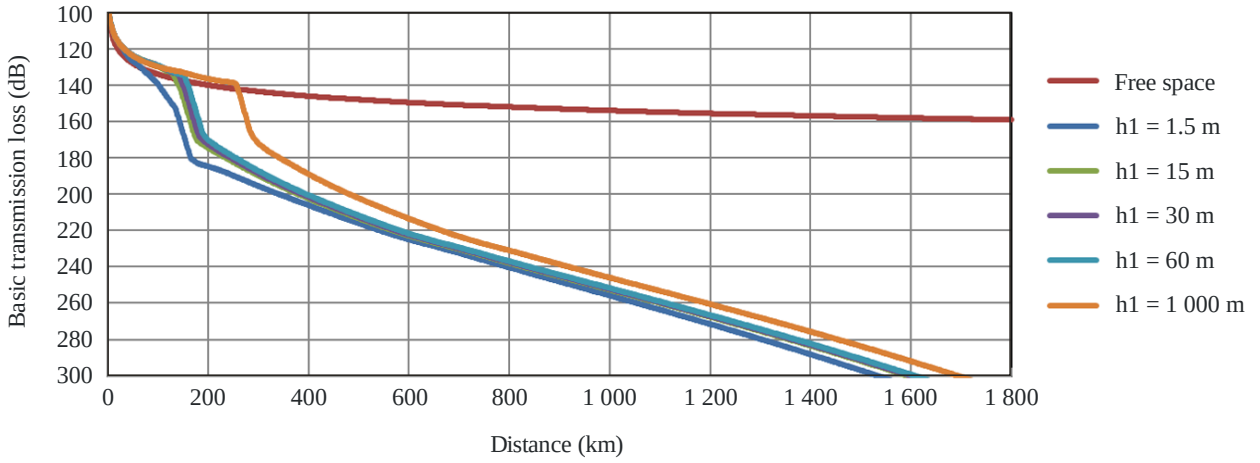


c) h2 = 20 000 m

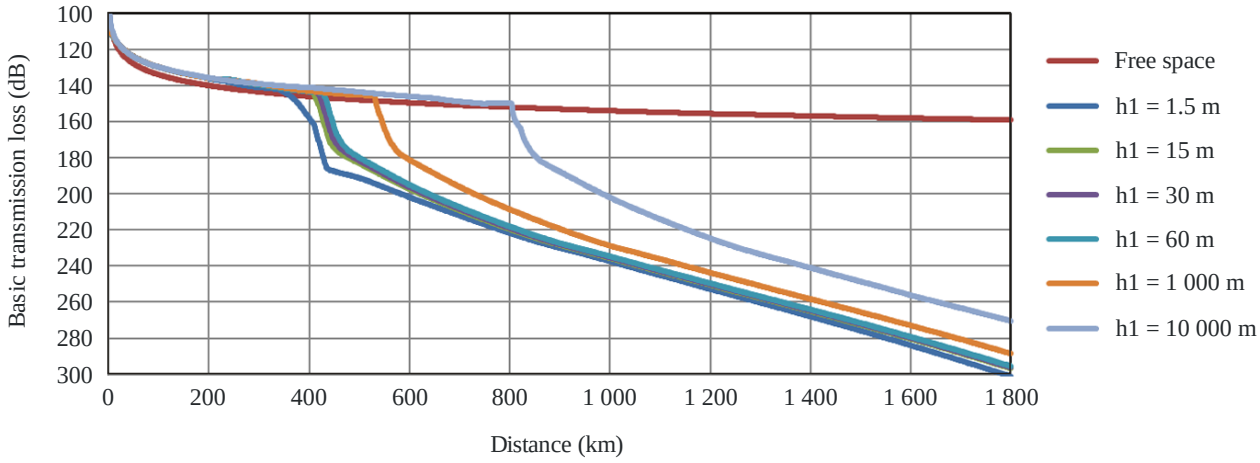
P.0528-04-02

FIGURE 4-3

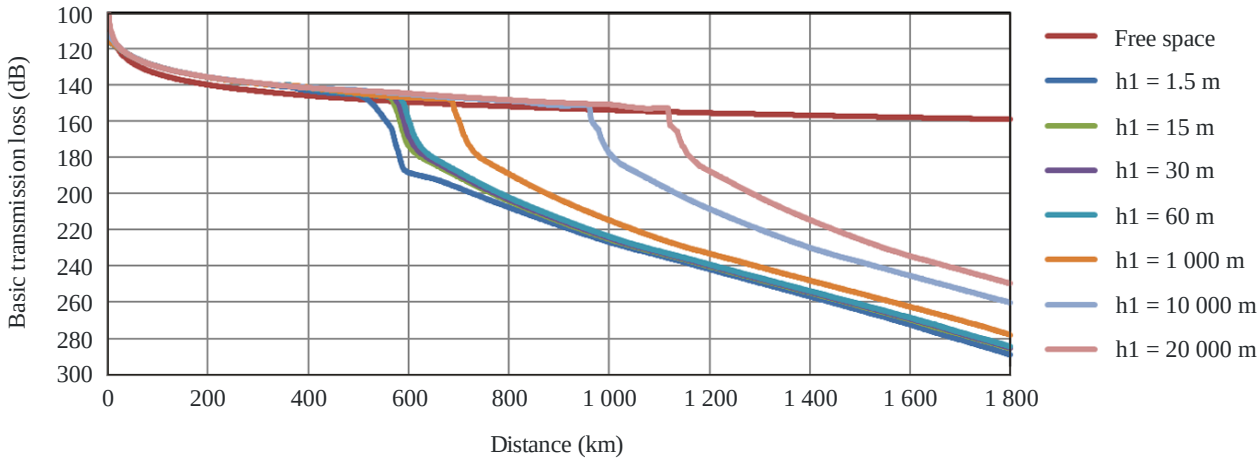
Curve sets for basic transmission loss at 1 200 MHz for 10% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

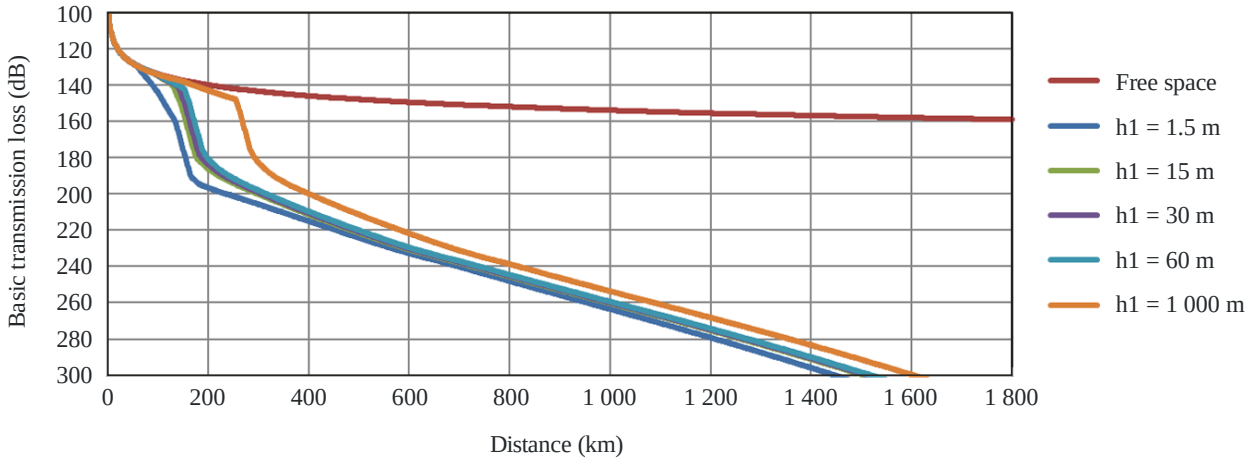


c) h2 = 20 000 m

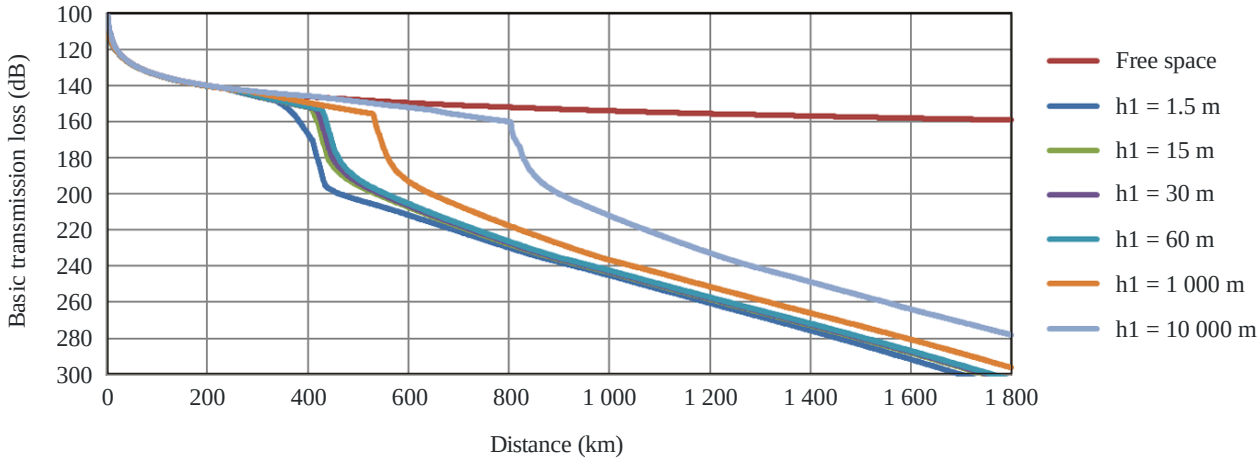
P.0528-04-03

FIGURE 4-4

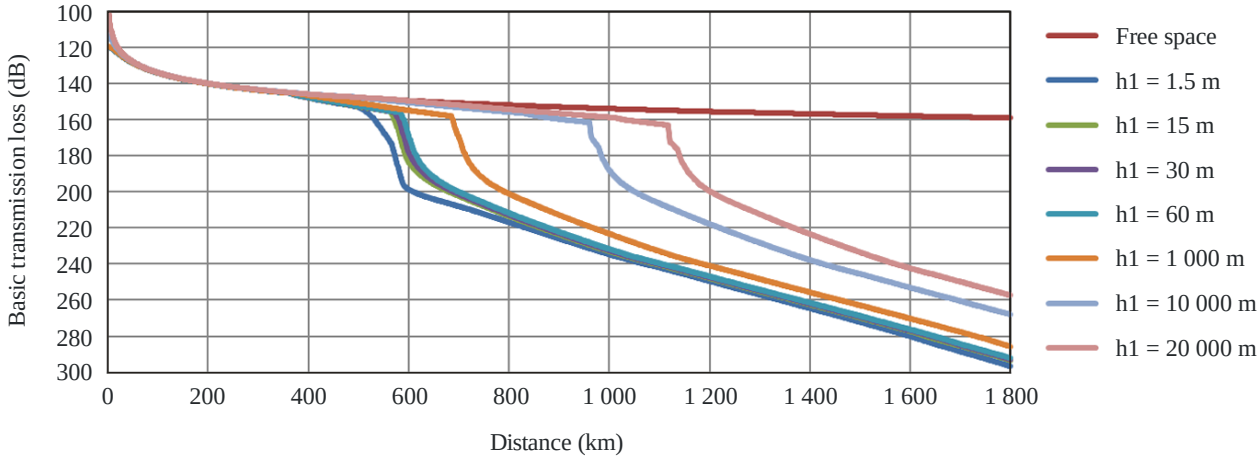
Curve sets for basic transmission loss at 1 200 MHz for 50% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

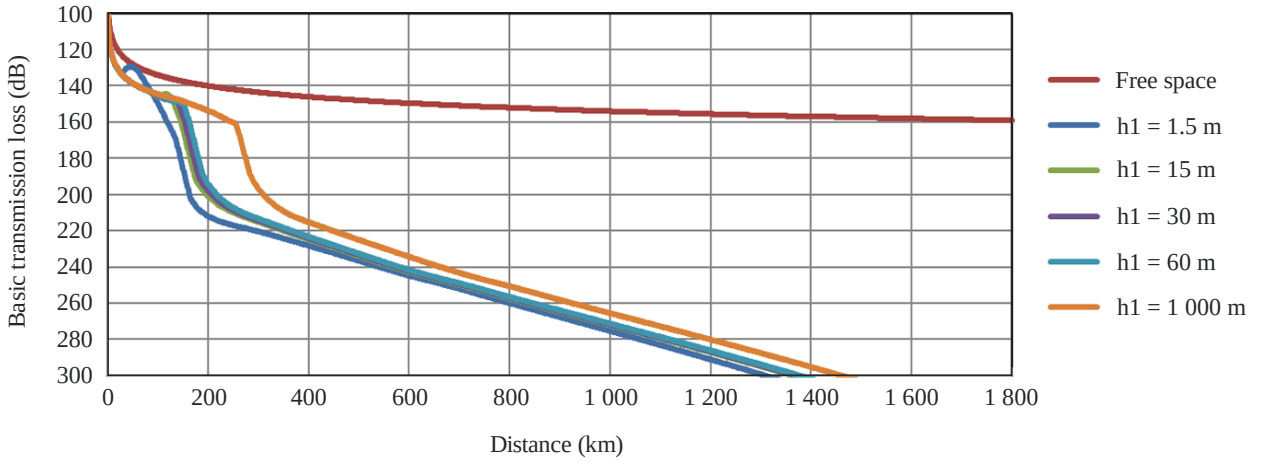


c) h2 = 20 000 m

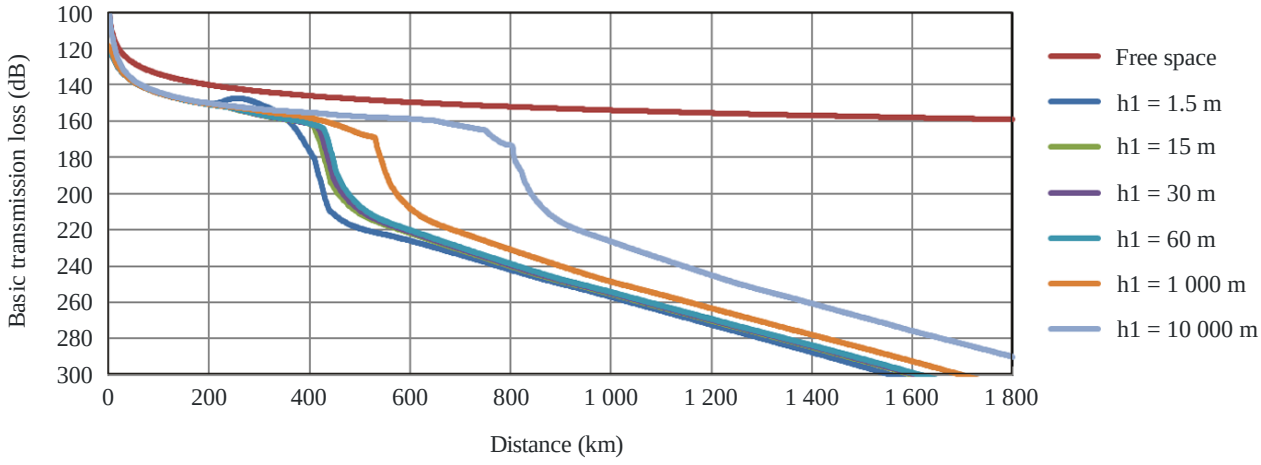
P.0528-04-04

FIGURE 4-5

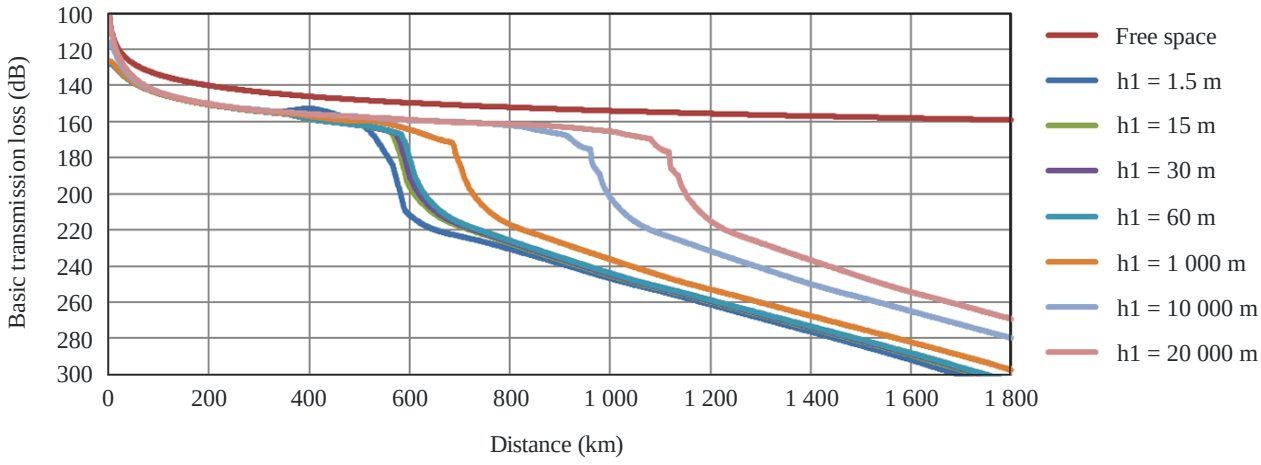
Curve sets for basic transmission loss at 1 200 MHz for 95% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

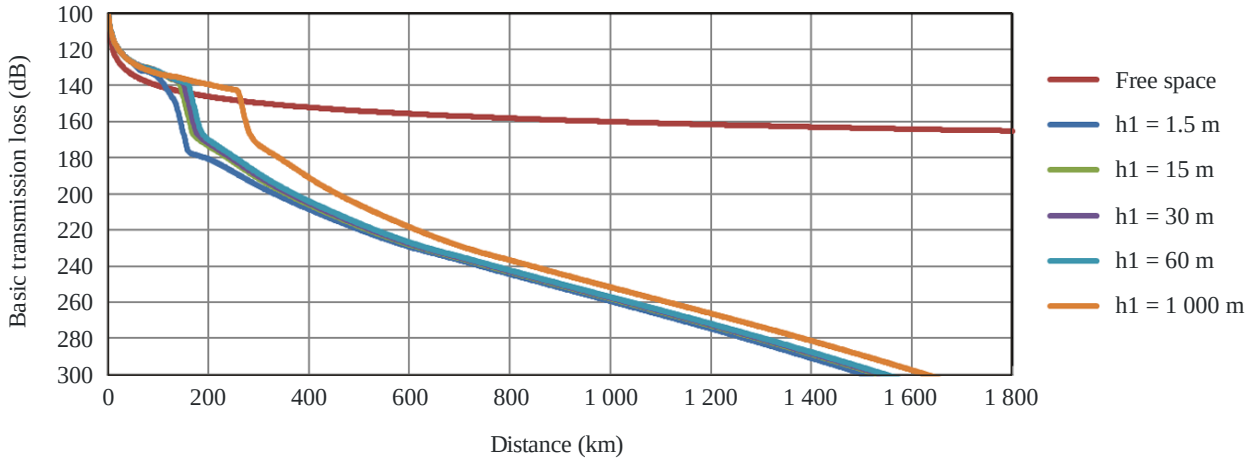


c) h2 = 20 000 m

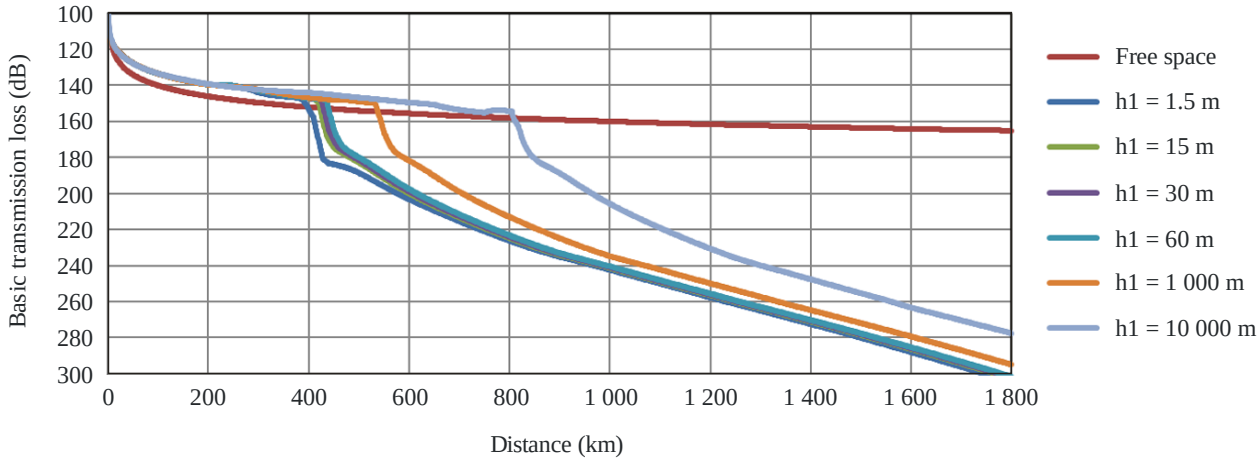
P.0528-04-05

FIGURE 5-1

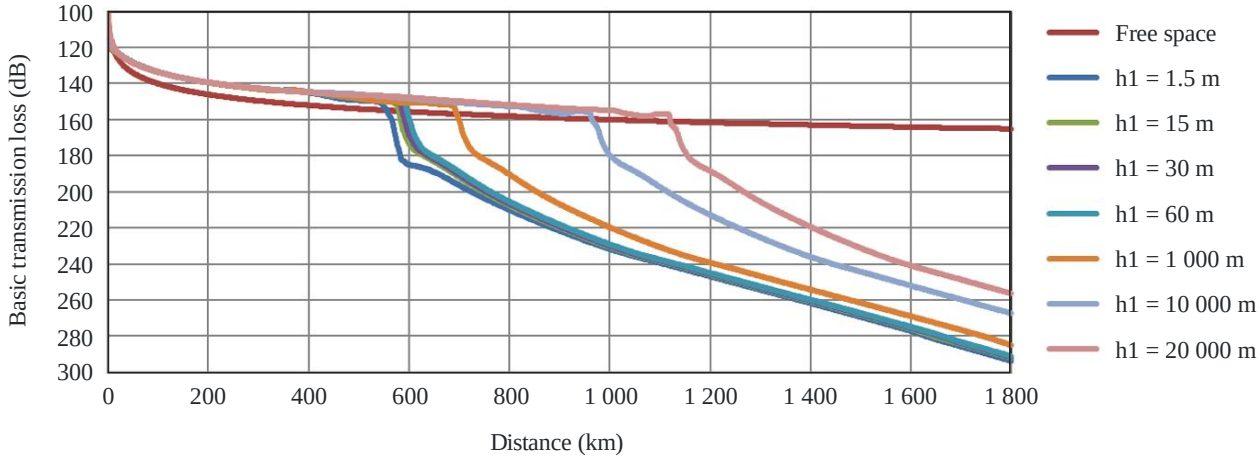
Curve sets for basic transmission loss at 2 400 MHz for 1% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

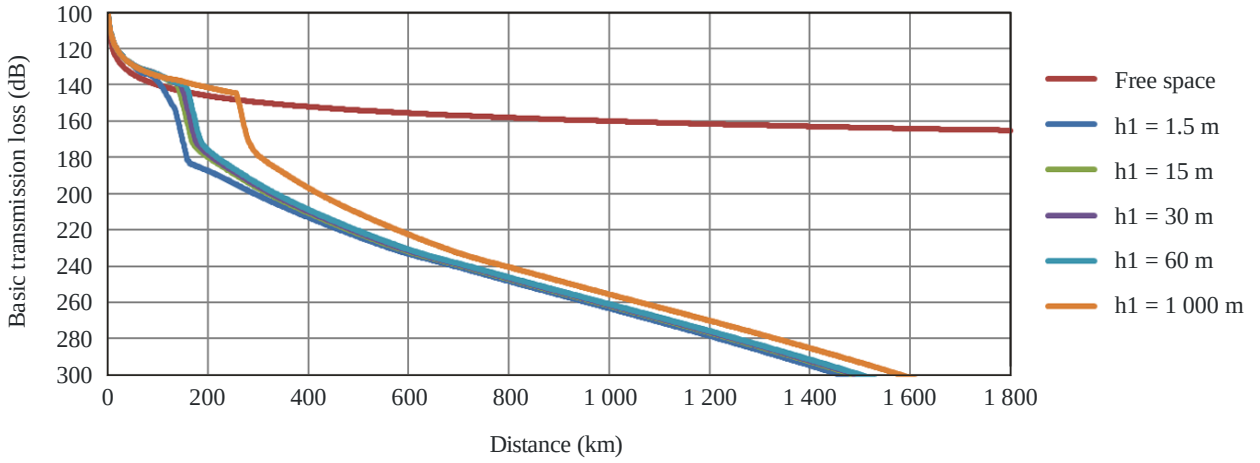


c) h2 = 20 000 m

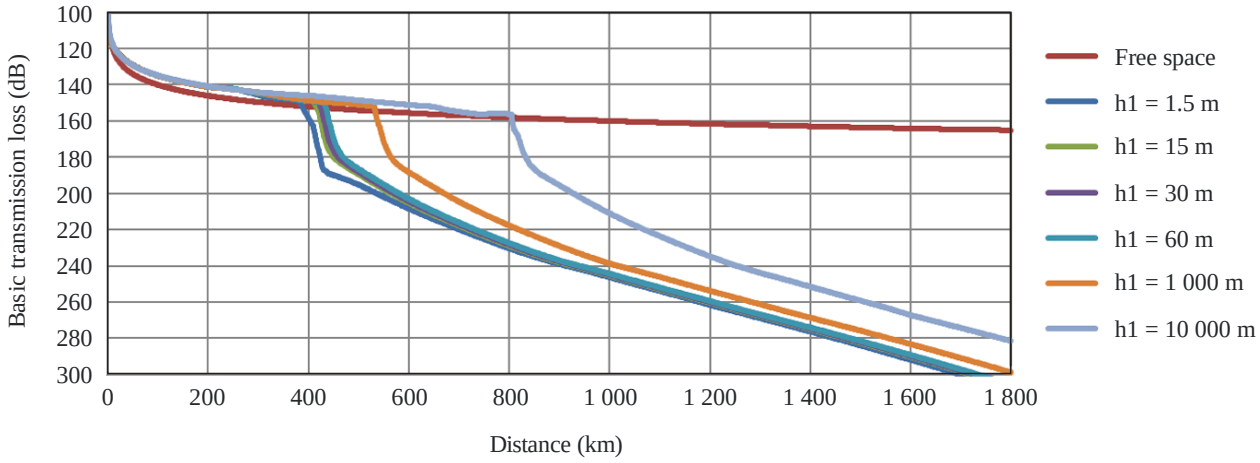
P.0528-05-01

FIGURE 5-2

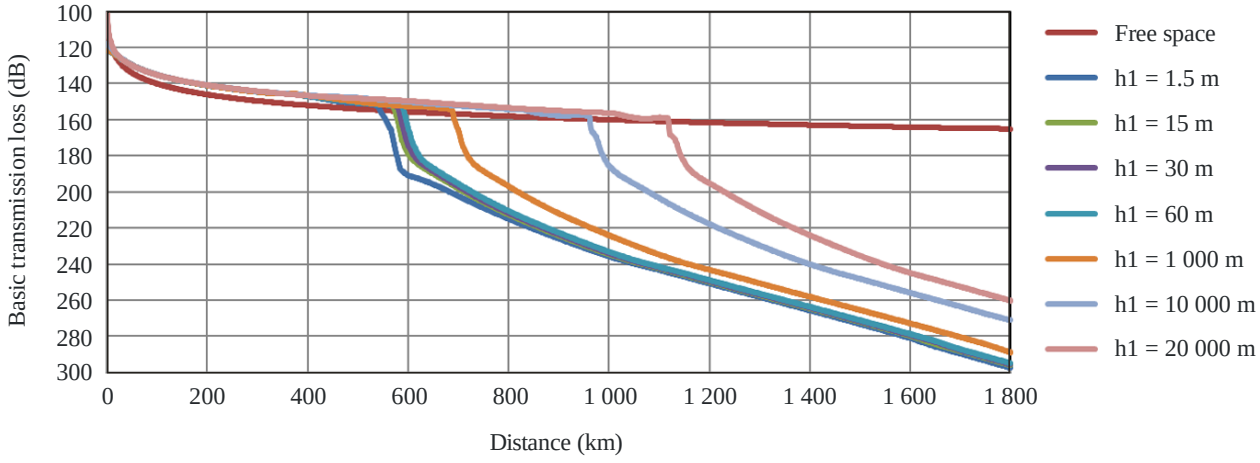
Curve sets for basic transmission loss at 2 400 MHz for 5% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

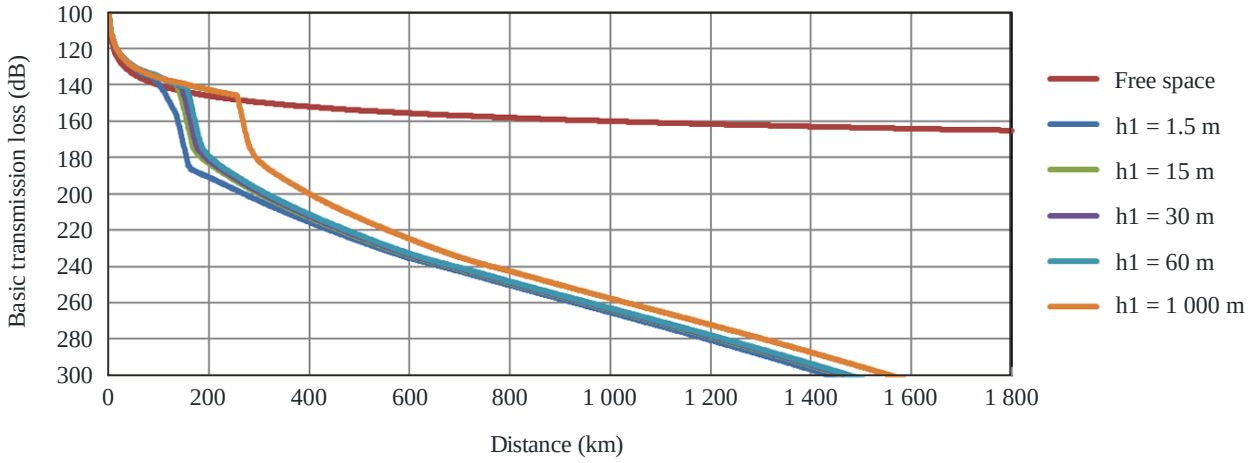


c) h2 = 20 000 m

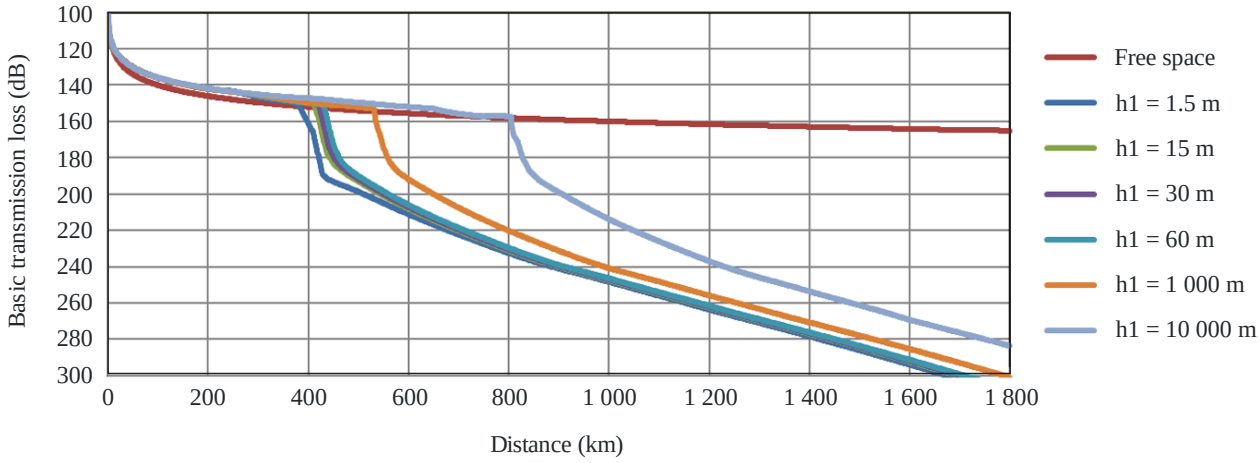
P.0528-05-02

FIGURE 5-3

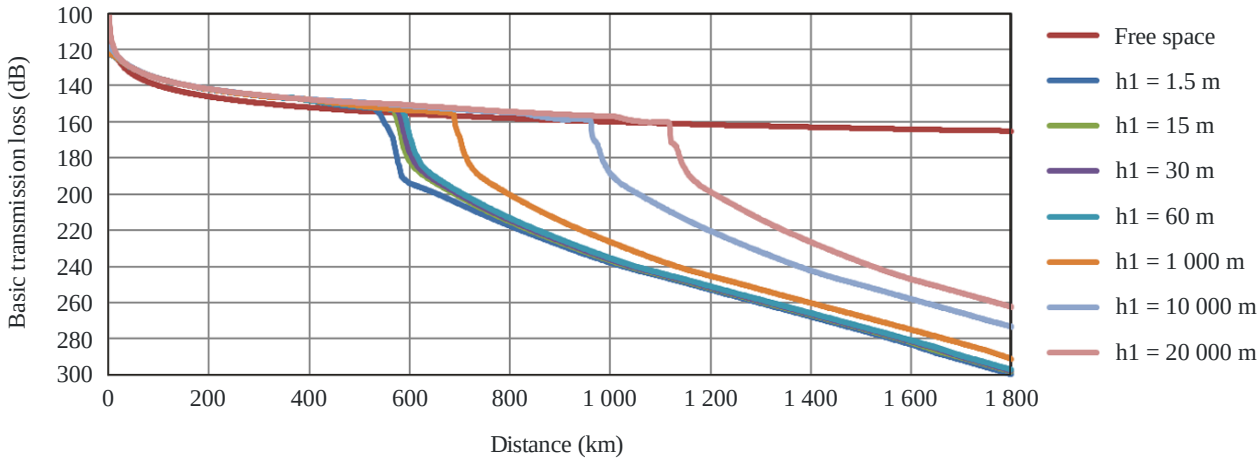
Curve sets for basic transmission loss at 2 400 MHz for 10% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

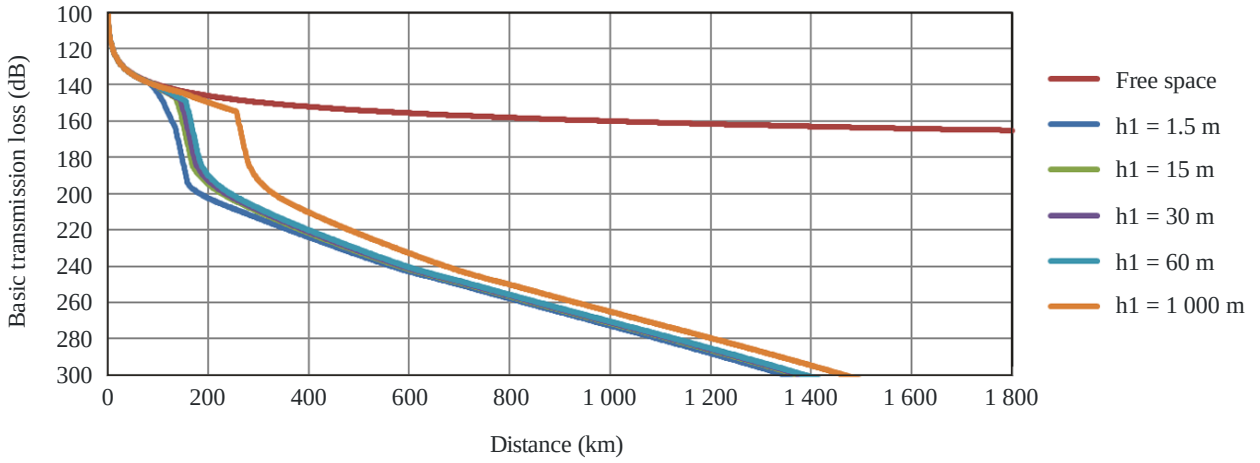


c) h2 = 20 000 m

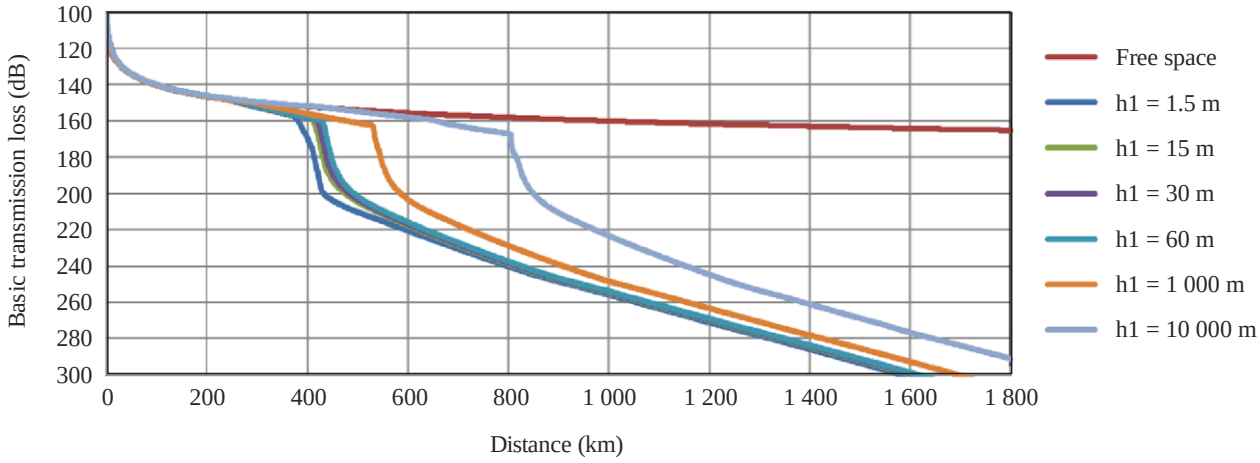
P.0528-05-03

FIGURE 5-4

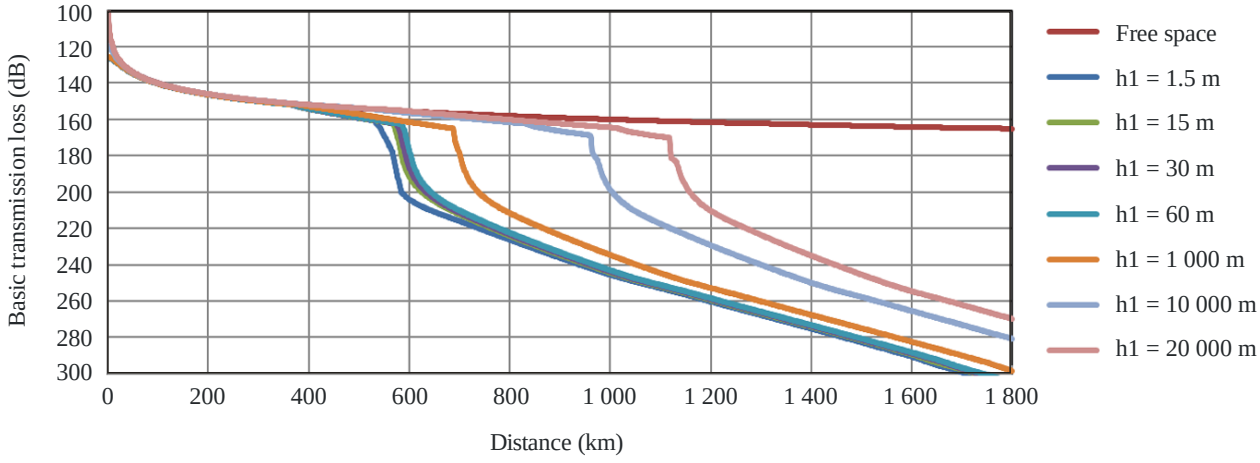
Curve sets for basic transmission loss at 2 400 MHz for 50% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

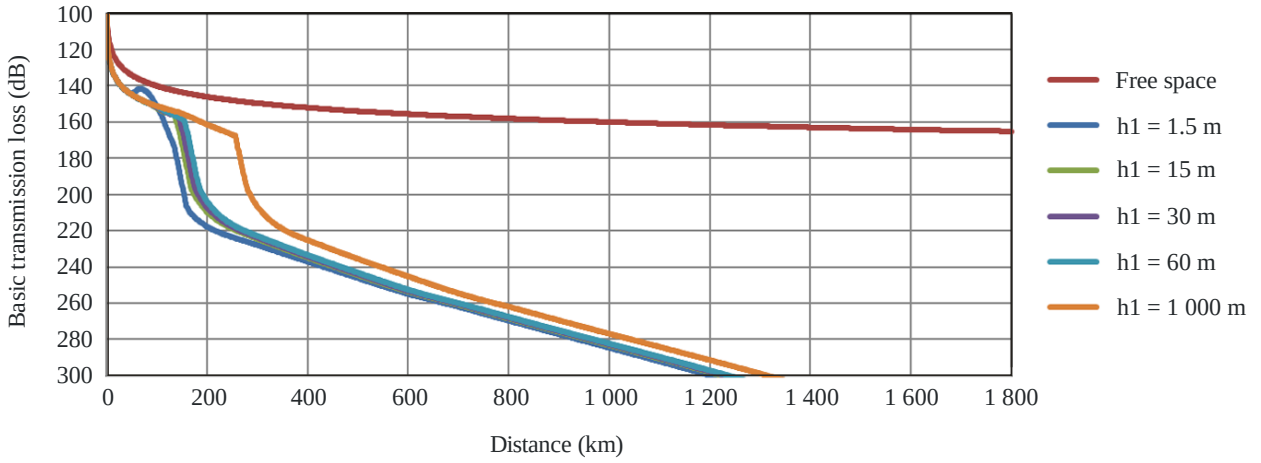


c) h2 = 20 000 m

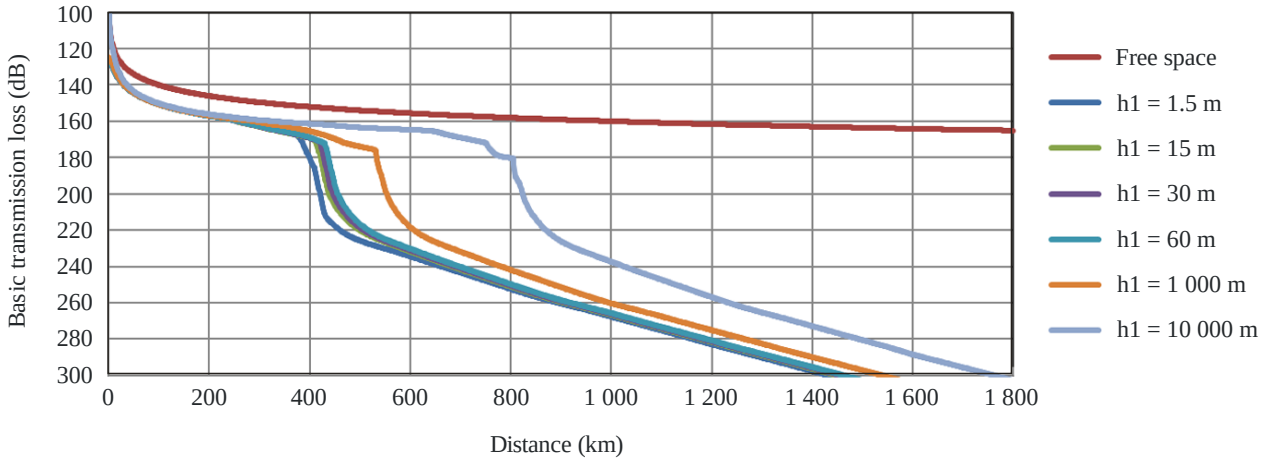
P.0528-05-04

FIGURE 5-5

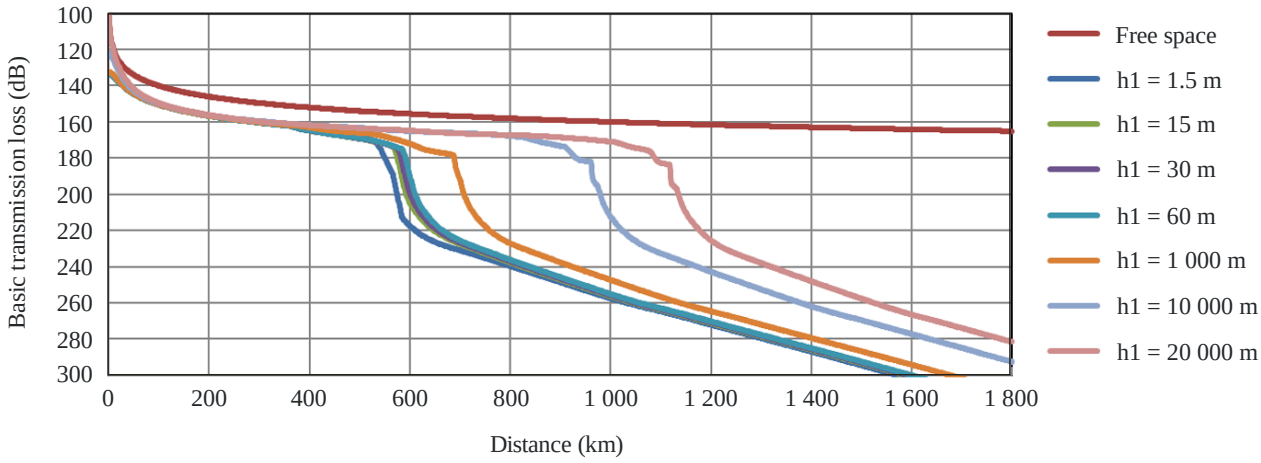
Curve sets for basic transmission loss at 2 400 MHz for 95% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

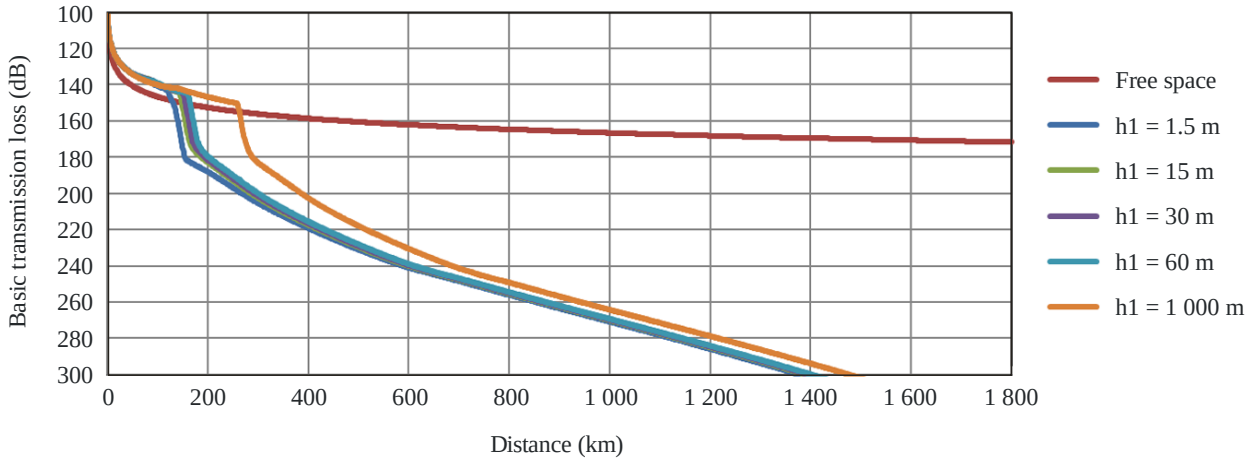


c) h2 = 20 000 m

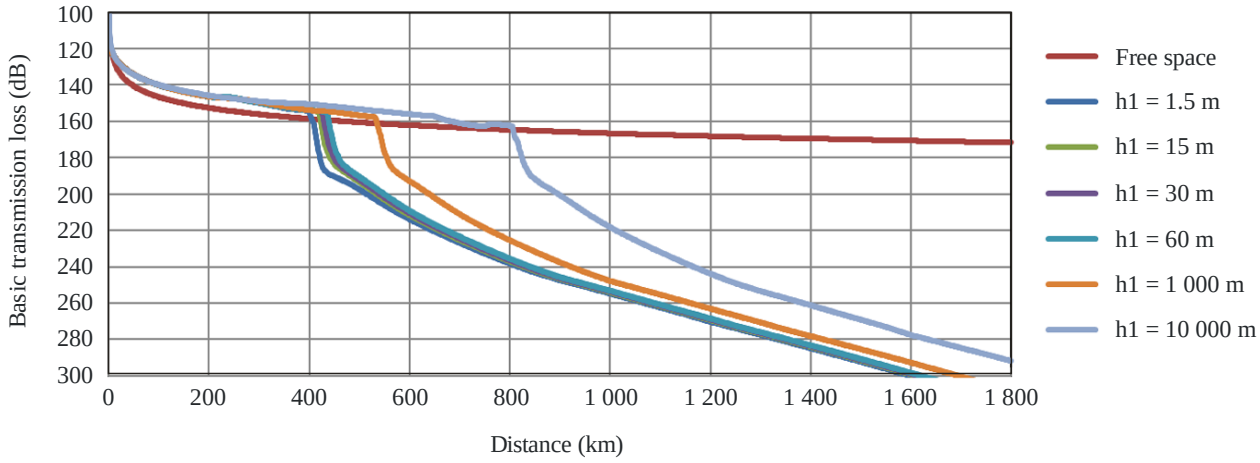
P.0528-05-05

FIGURE 6-1

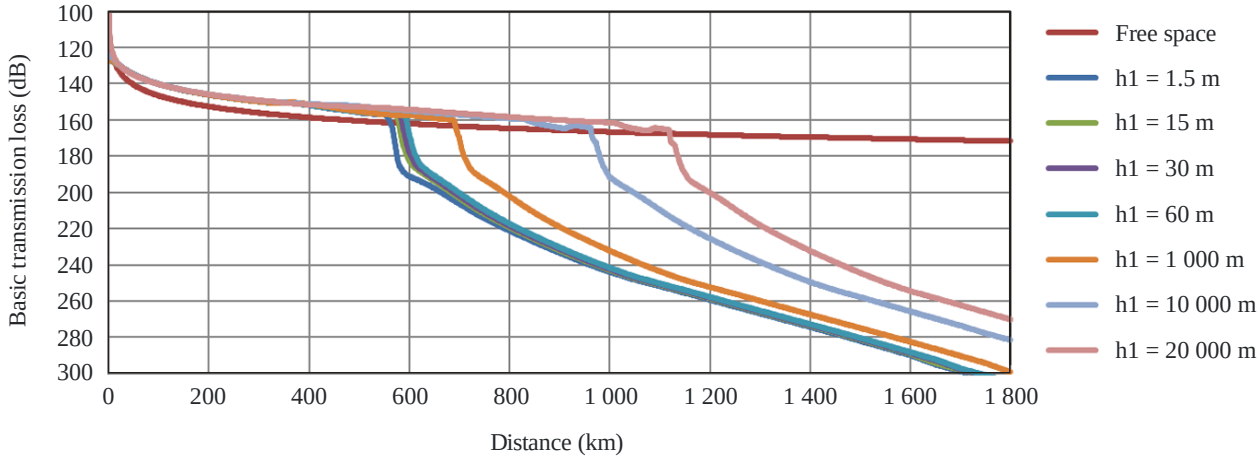
Curve sets for basic transmission loss at 5 100 MHz for 1% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

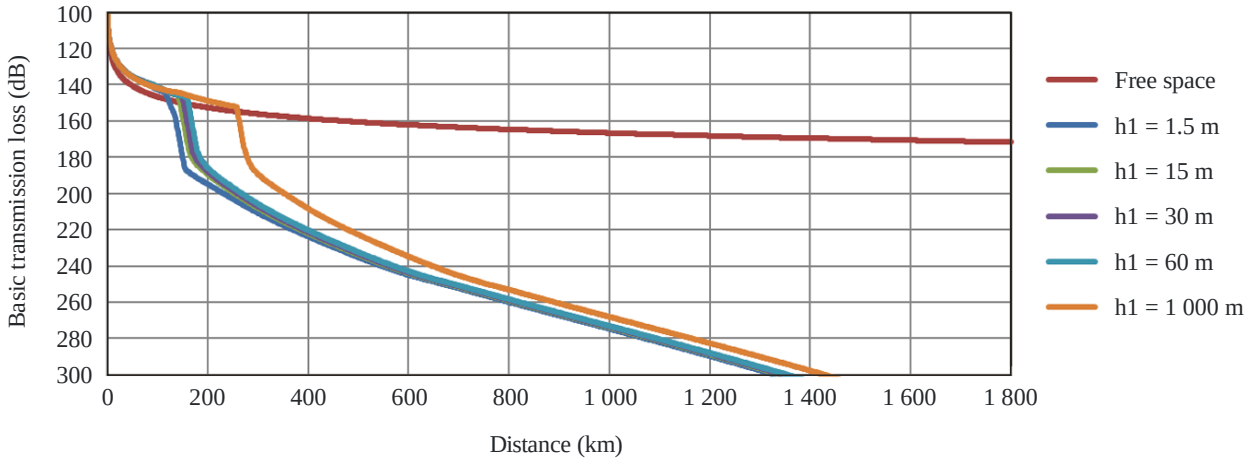


c) h2 = 20 000 m

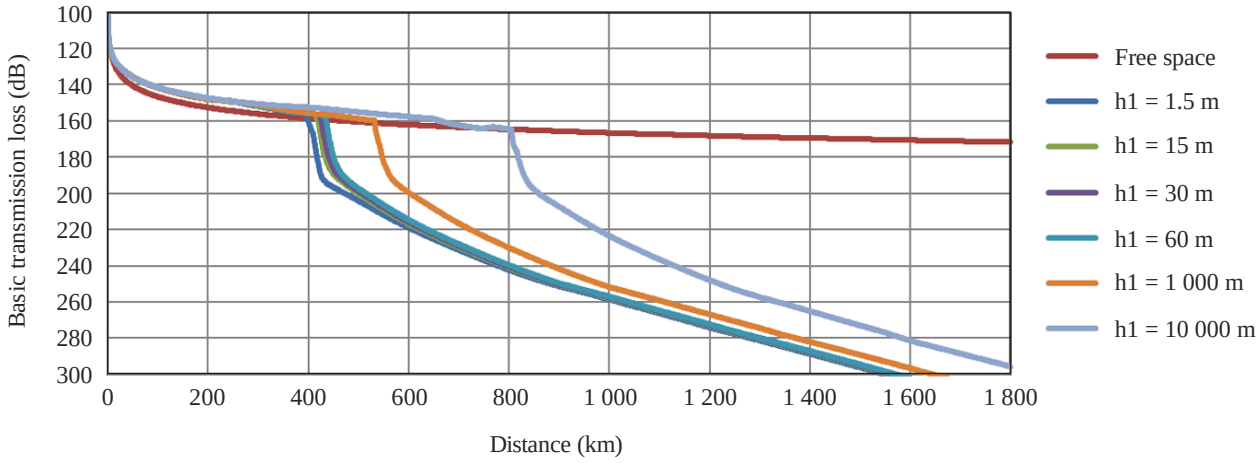
P.0528-06-01

FIGURE 6-2

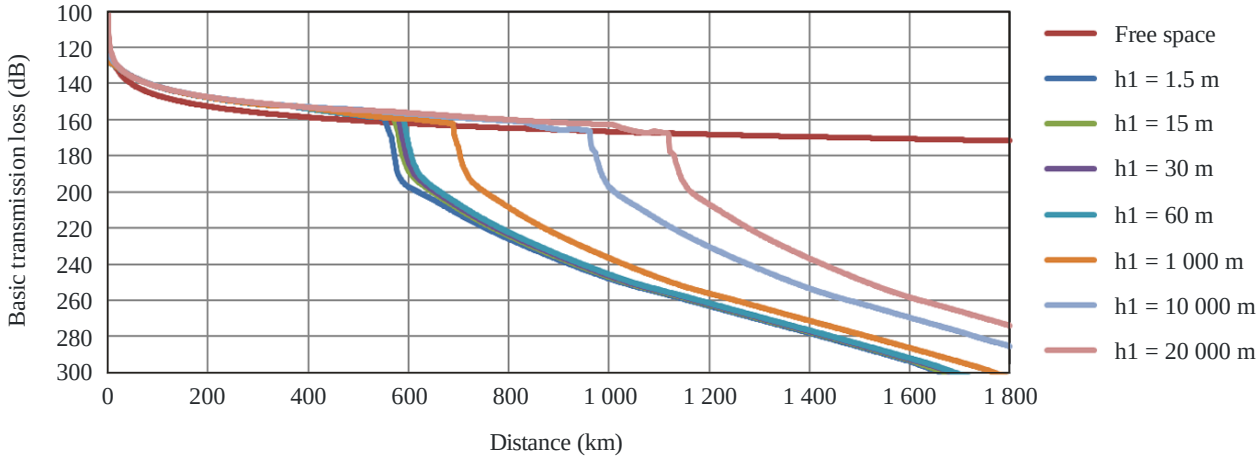
Curve sets for basic transmission loss at 5 100 MHz for 5% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

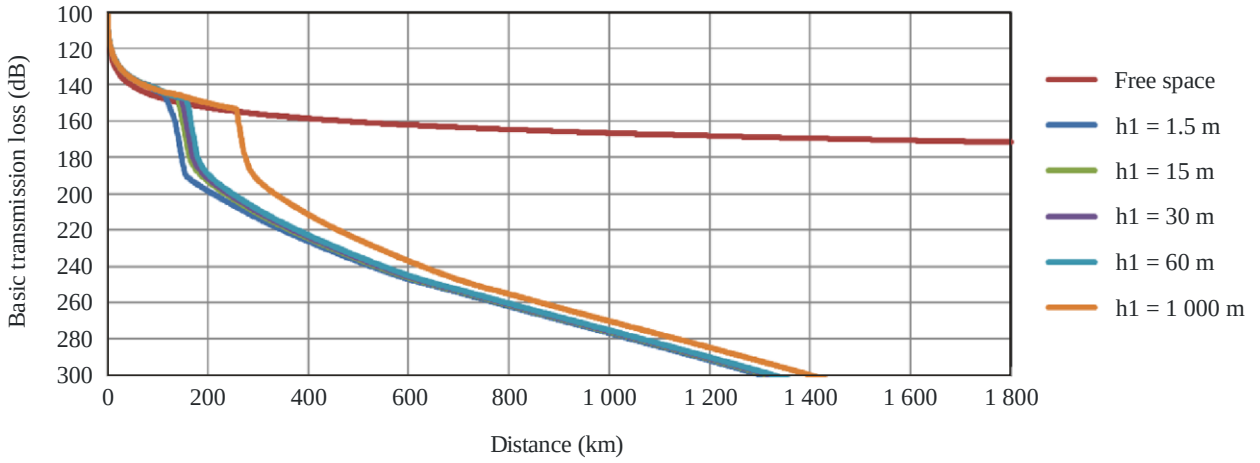


c) h2 = 20 000 m

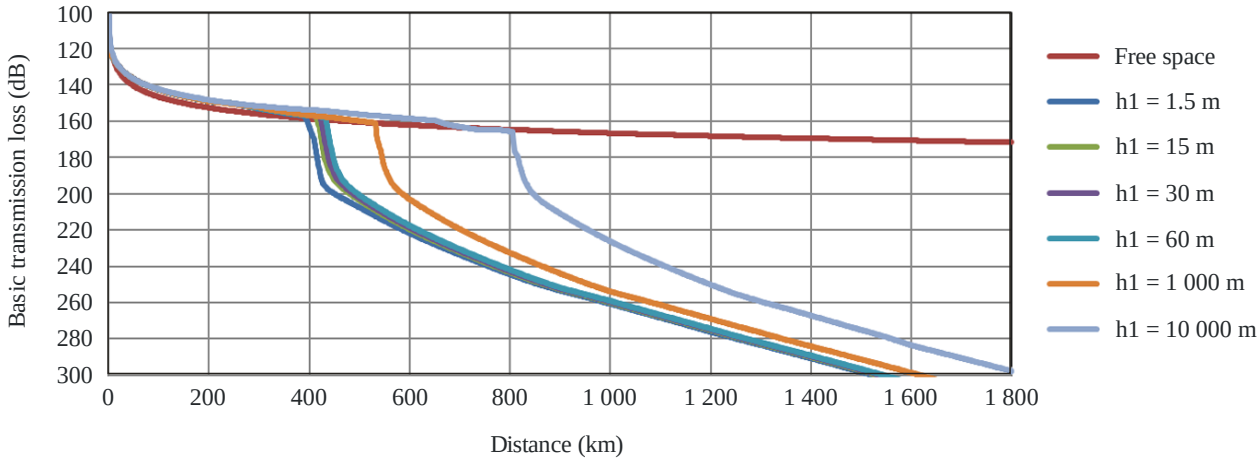
P.0528-06-02

FIGURE 6-3

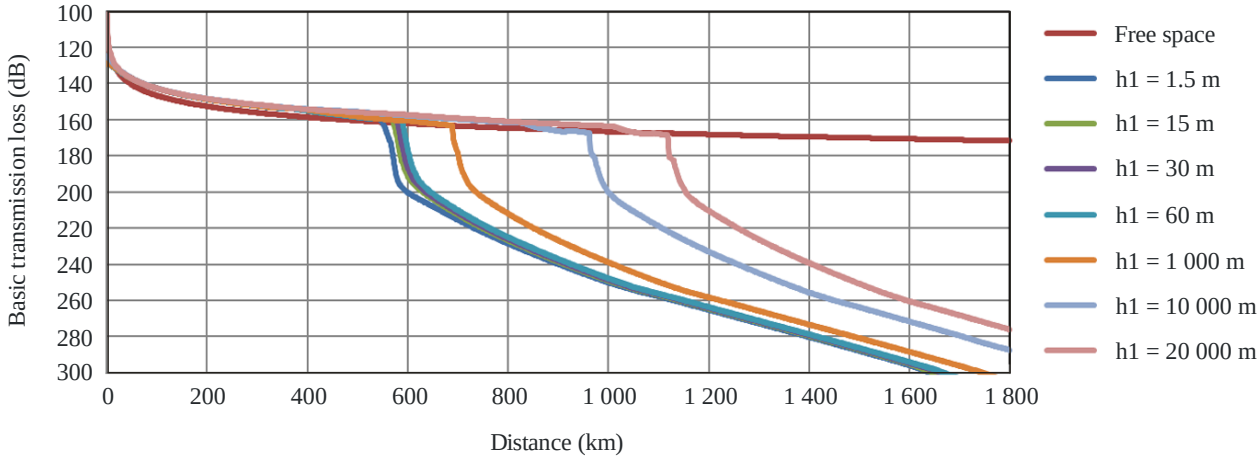
Curve sets for basic transmission loss at 5 100 MHz for 10% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

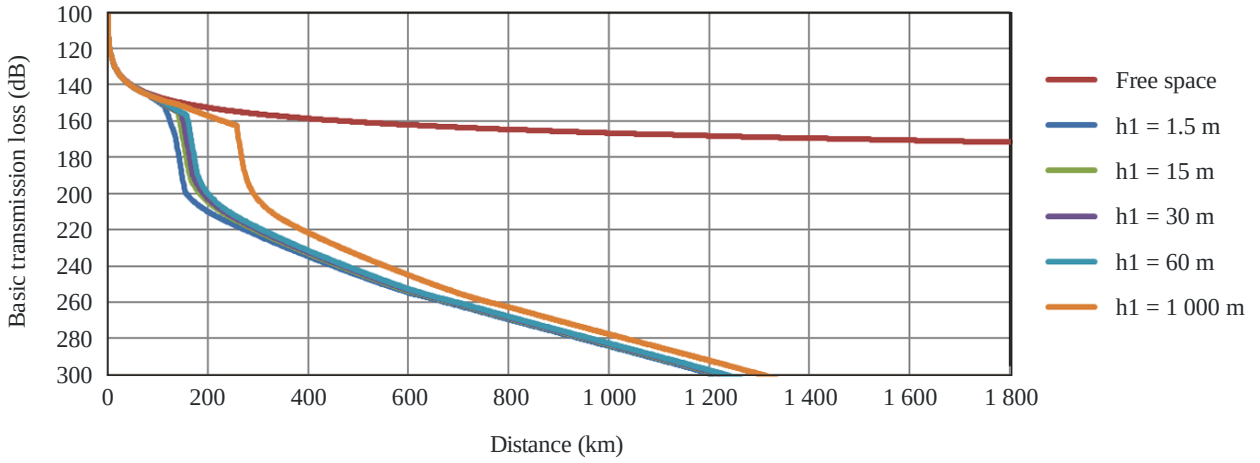


c) h2 = 20 000 m

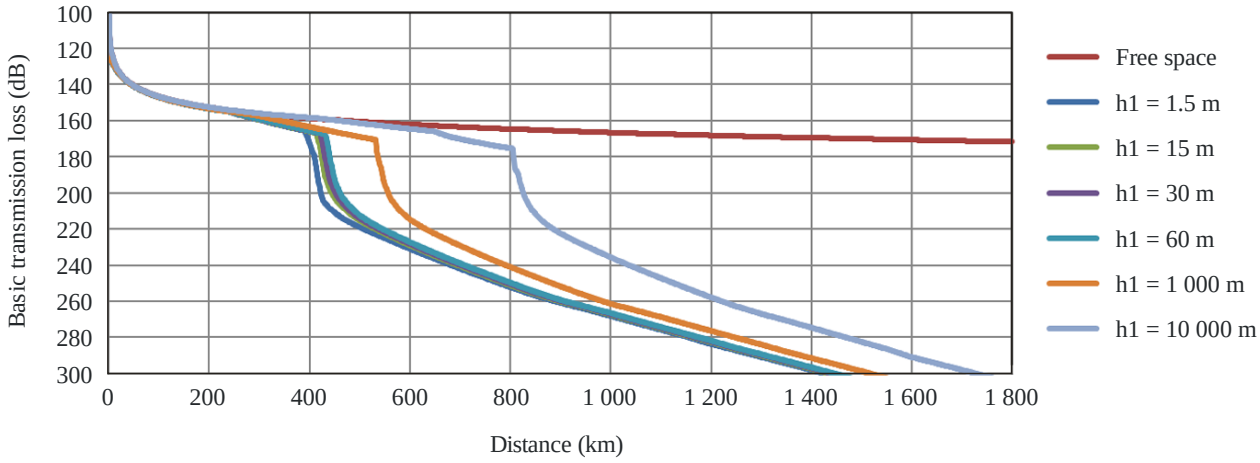
P.0528-06-03

FIGURE 6-4

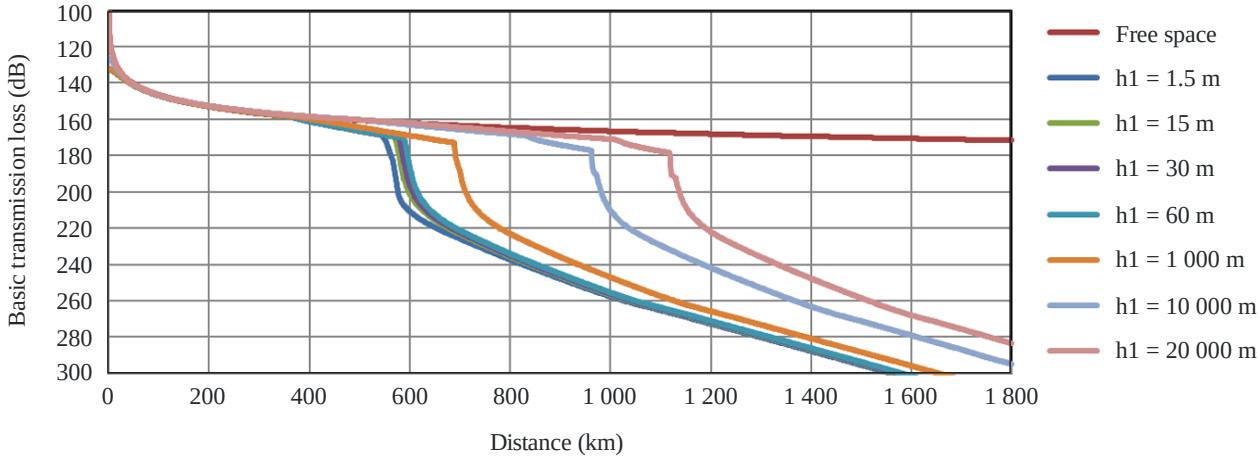
Curve sets for basic transmission loss at 5 100 MHz for 50% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

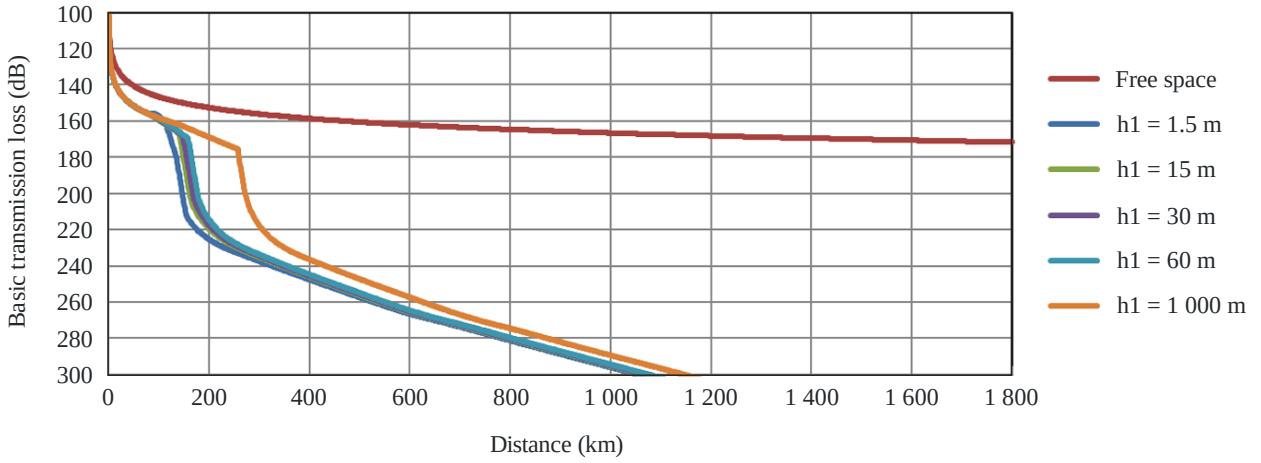


c) h2 = 20 000 m

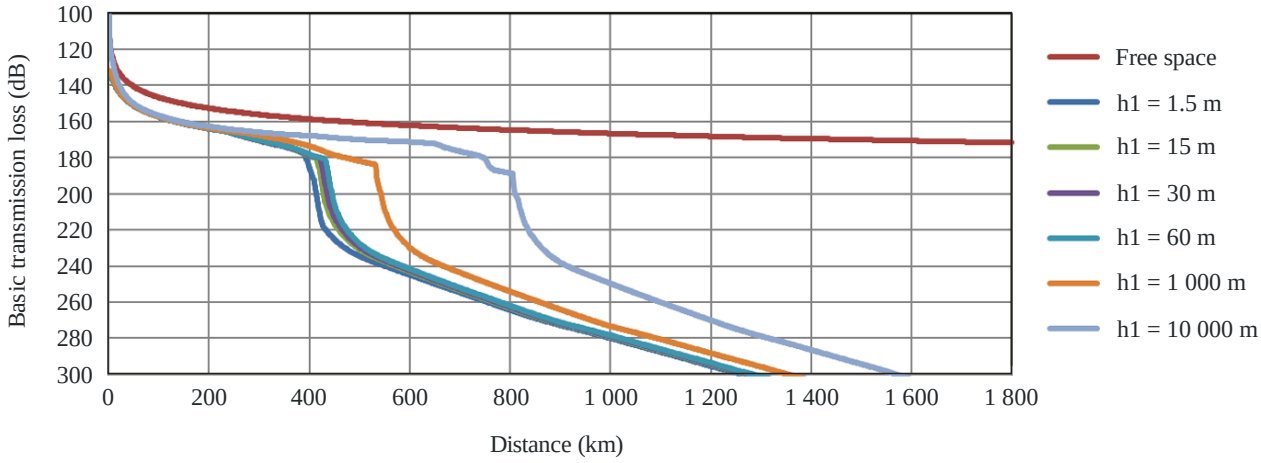
P.0528-06-04

FIGURE 6-5

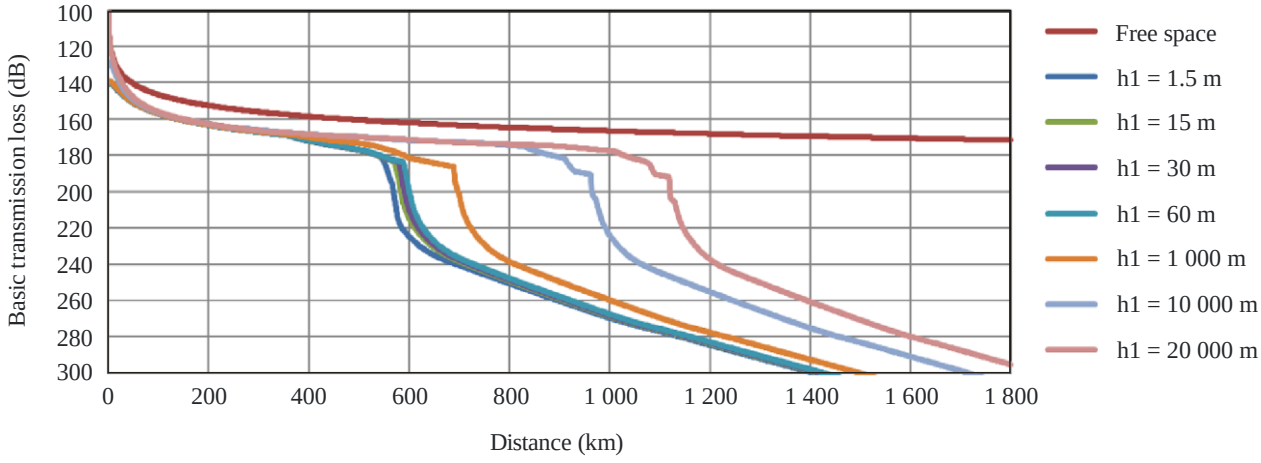
Curve sets for basic transmission loss at 5 100 MHz for 95% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

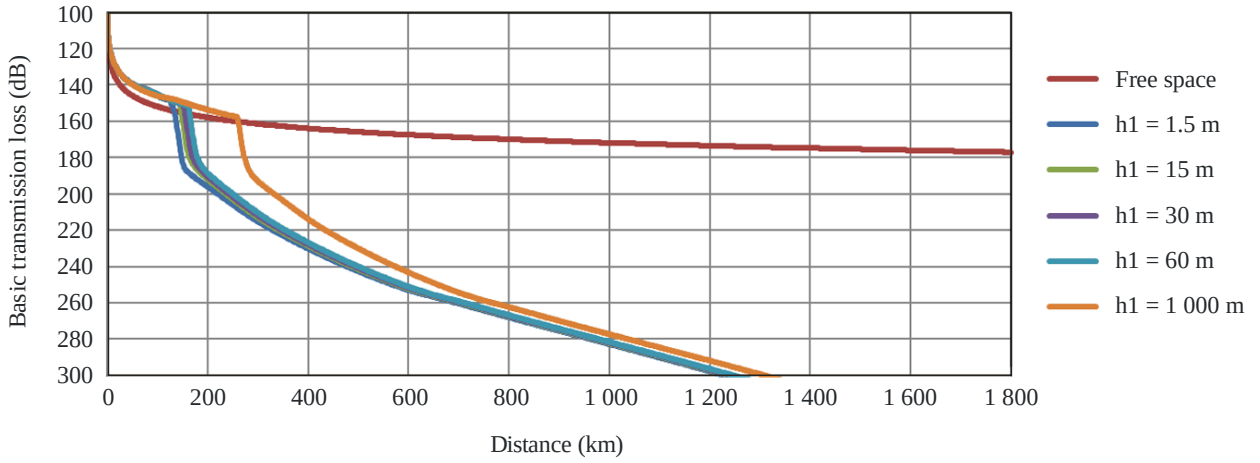


c) h2 = 20 000 m

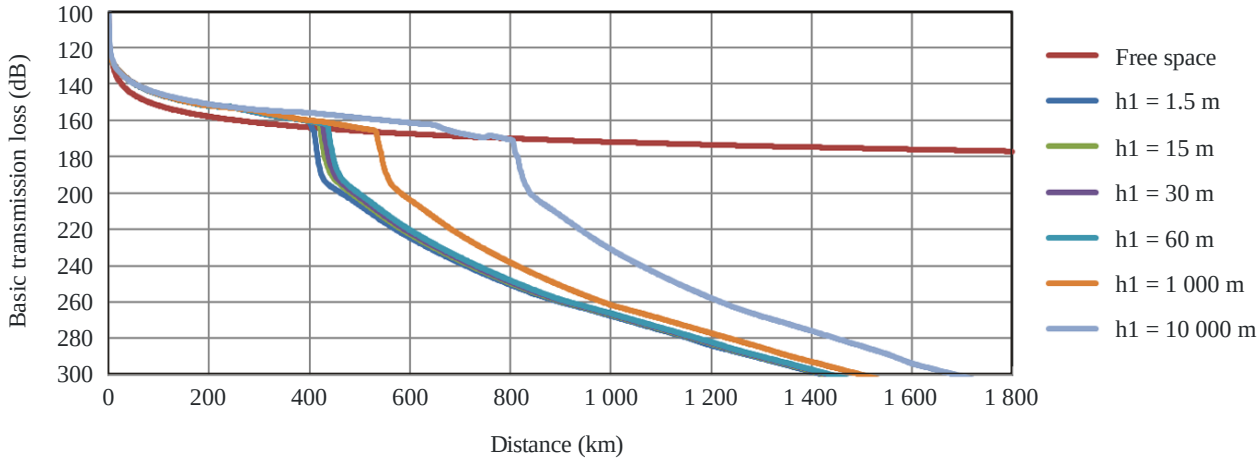
P.0528-06-05

FIGURE 7-1

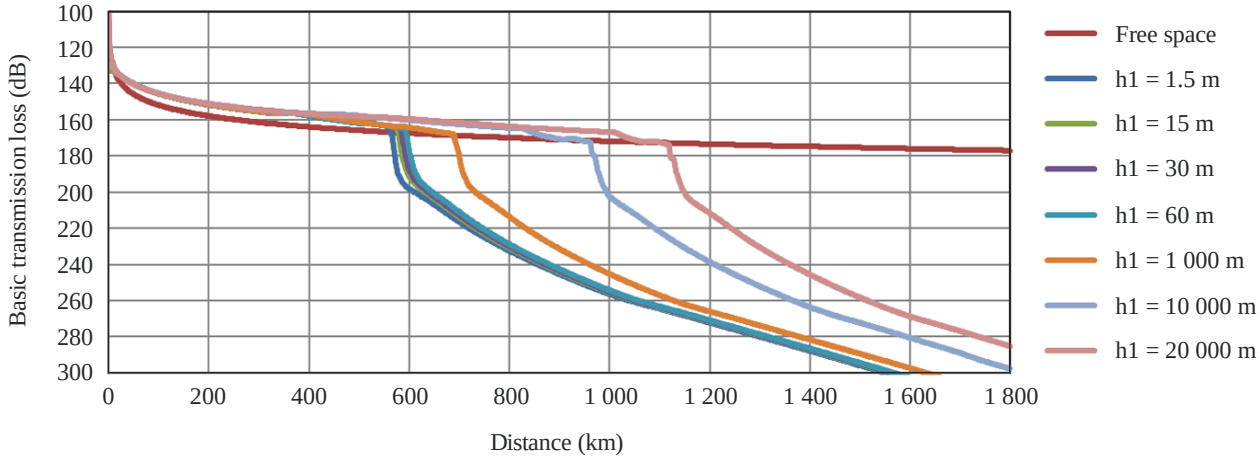
Curve sets for basic transmission loss at 9 400 MHz for 1% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

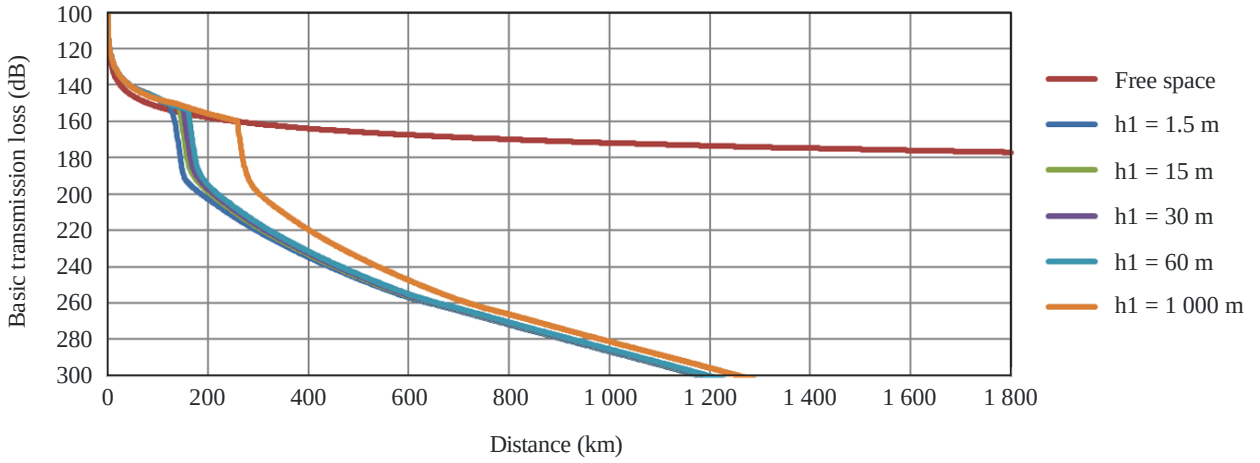


c) h2 = 20 000 m

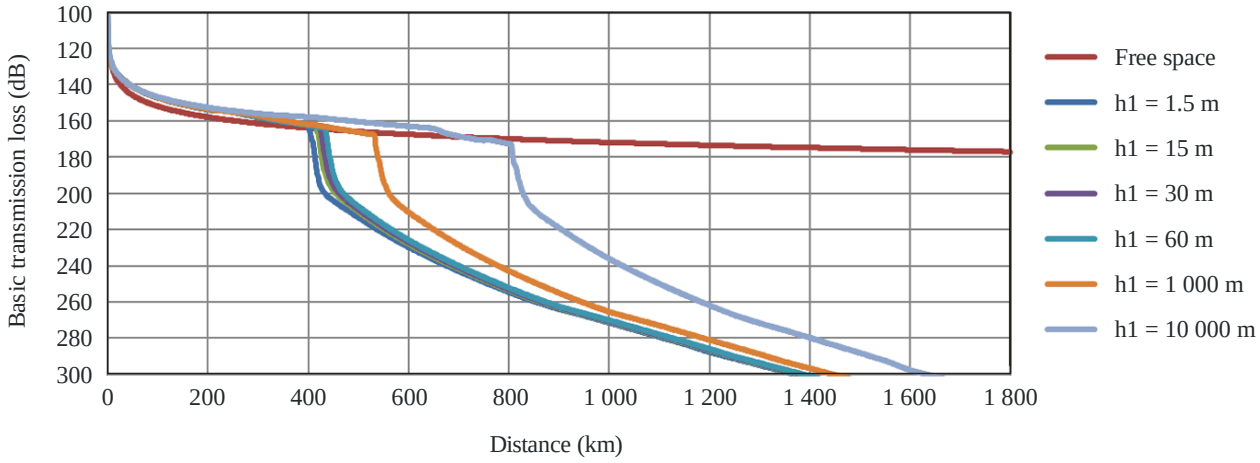
P.0528-07-01

FIGURE 7-2

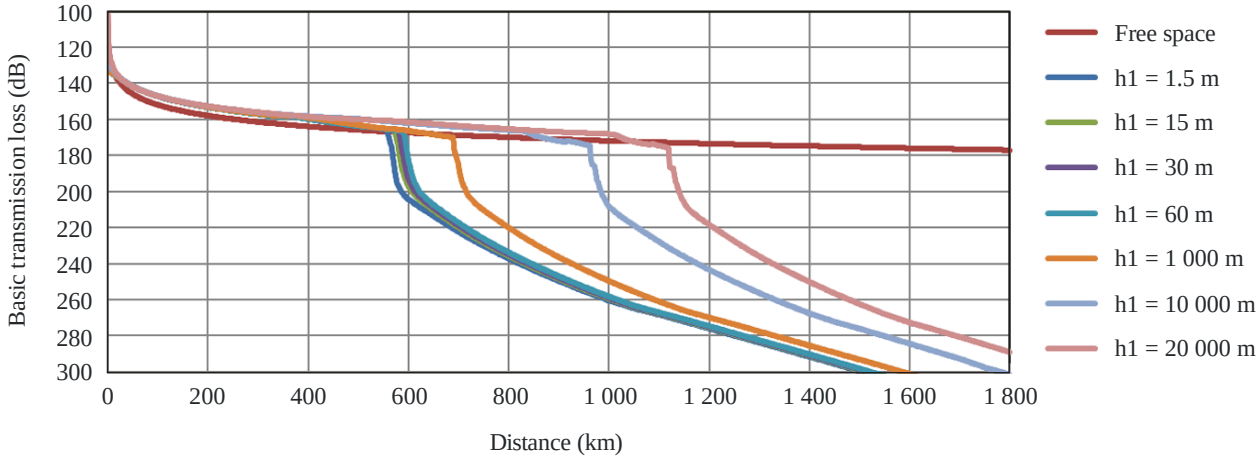
Curve sets for basic transmission loss at 9 400 MHz for 5% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

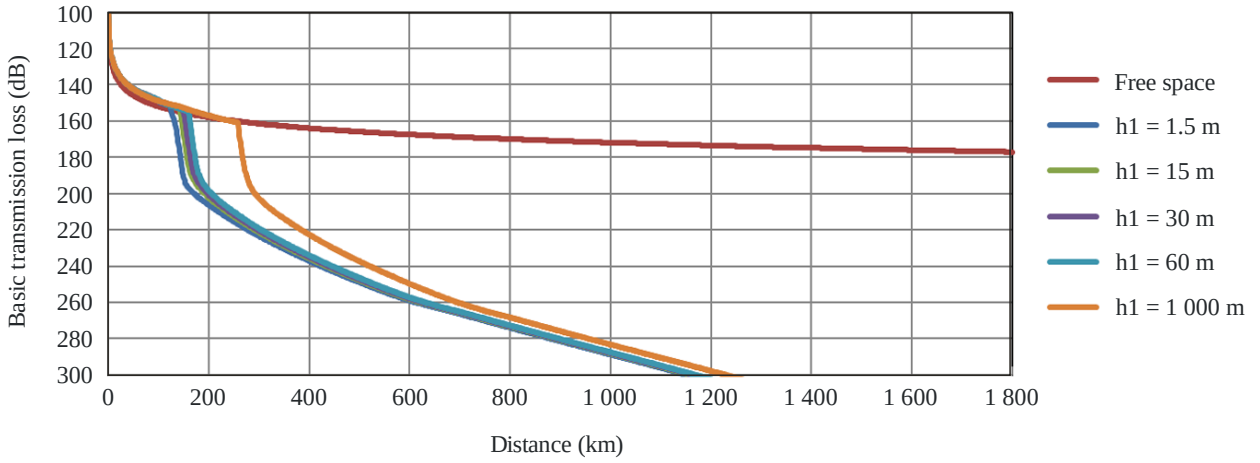


c) h2 = 20 000 m

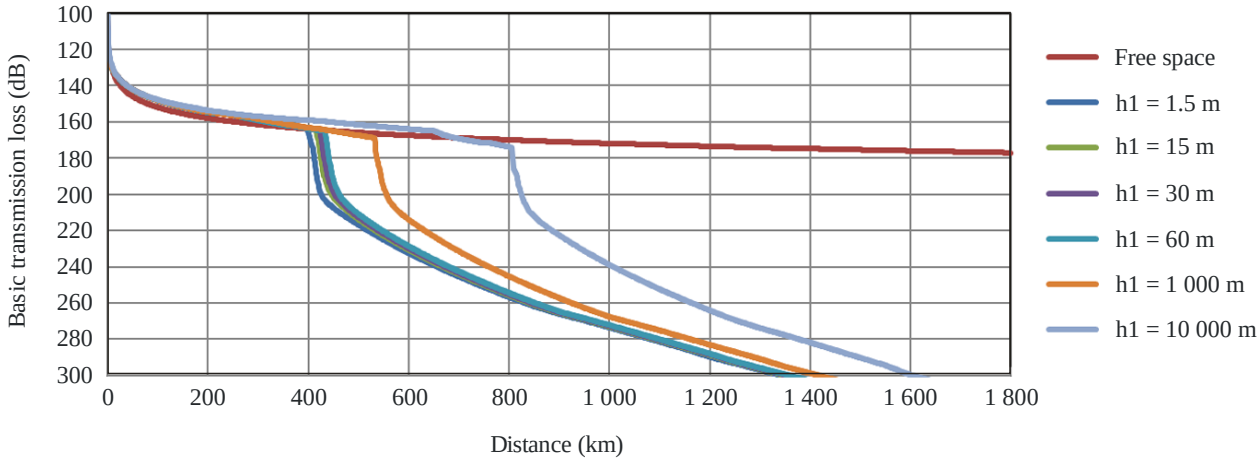
P.0528-07-02

FIGURE 7-3

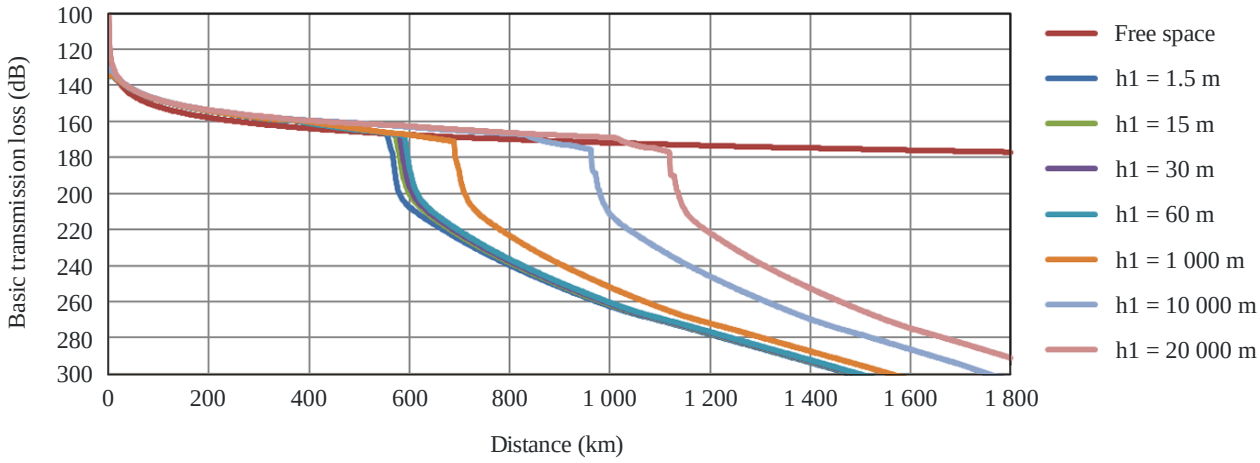
Curve sets for basic transmission loss at 9 400 MHz for 10% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

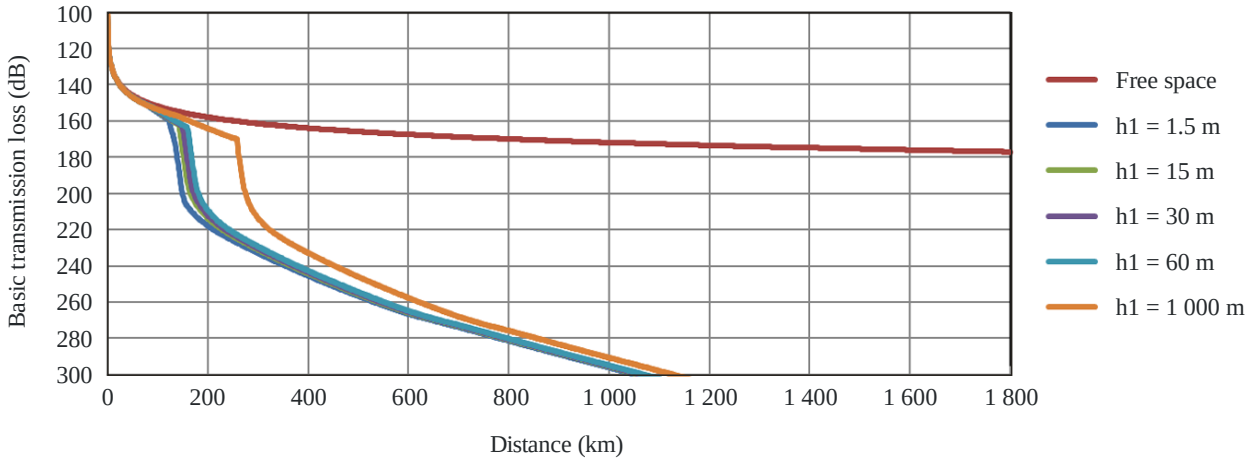


c) h2 = 20 000 m

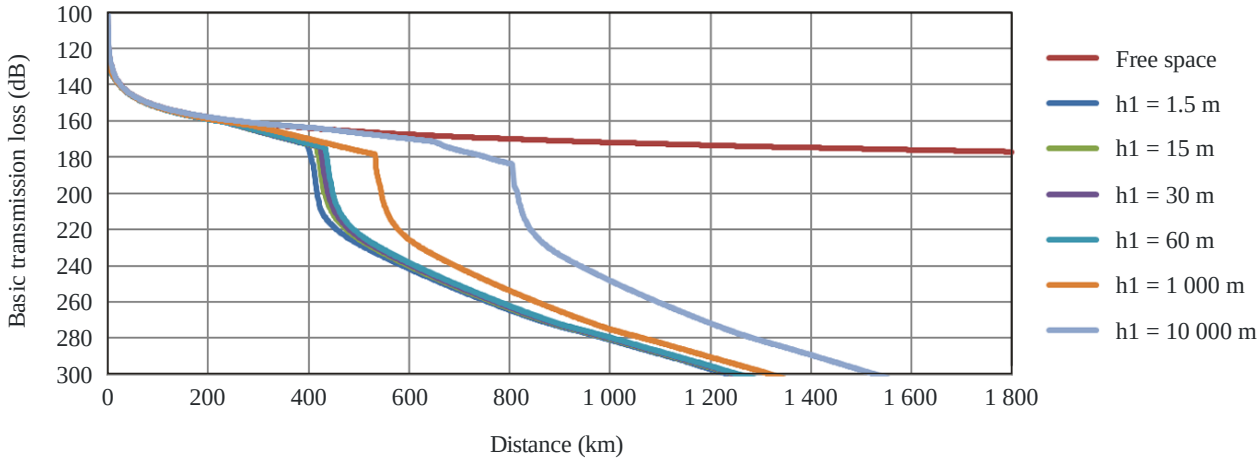
P.0528-07-03

FIGURE 7-4

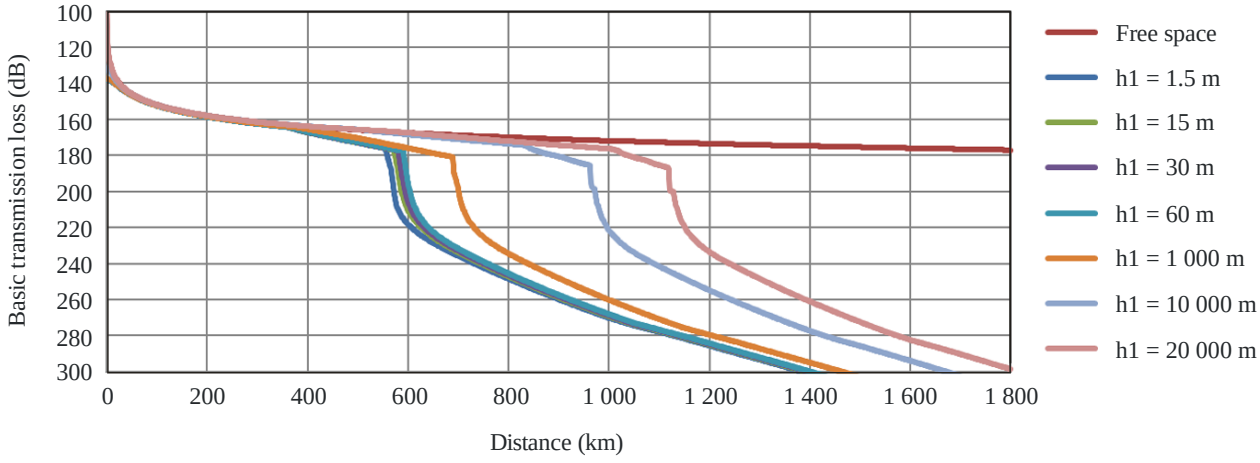
Curve sets for basic transmission loss at 9 400 MHz for 50% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

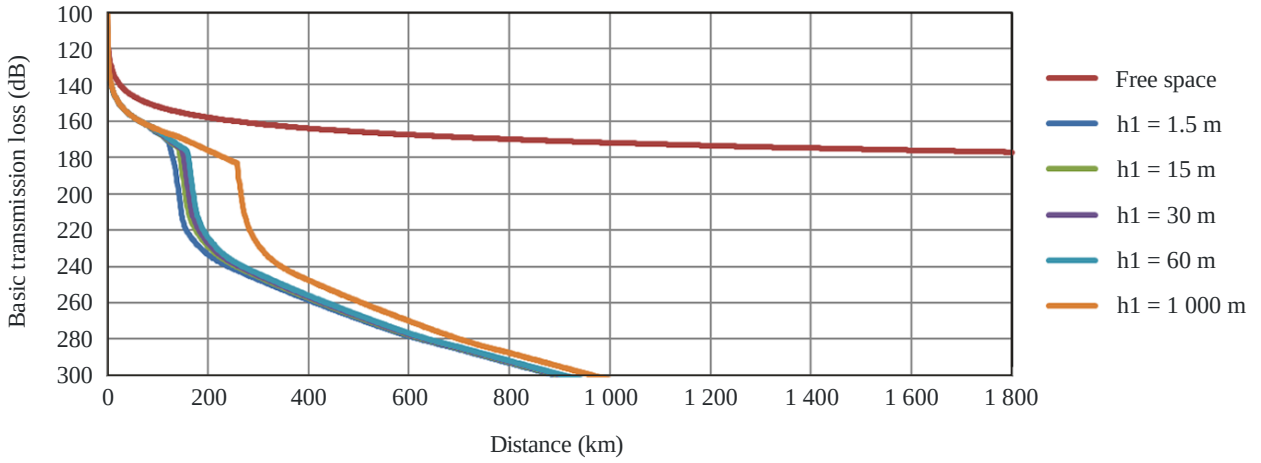


c) h2 = 20 000 m

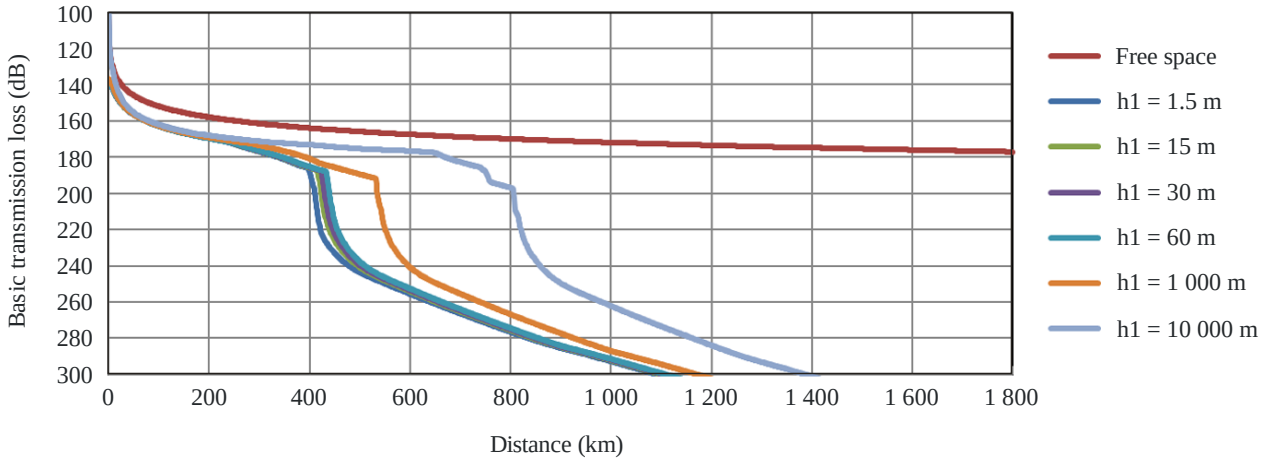
P.0528-07-04

FIGURE 7-5

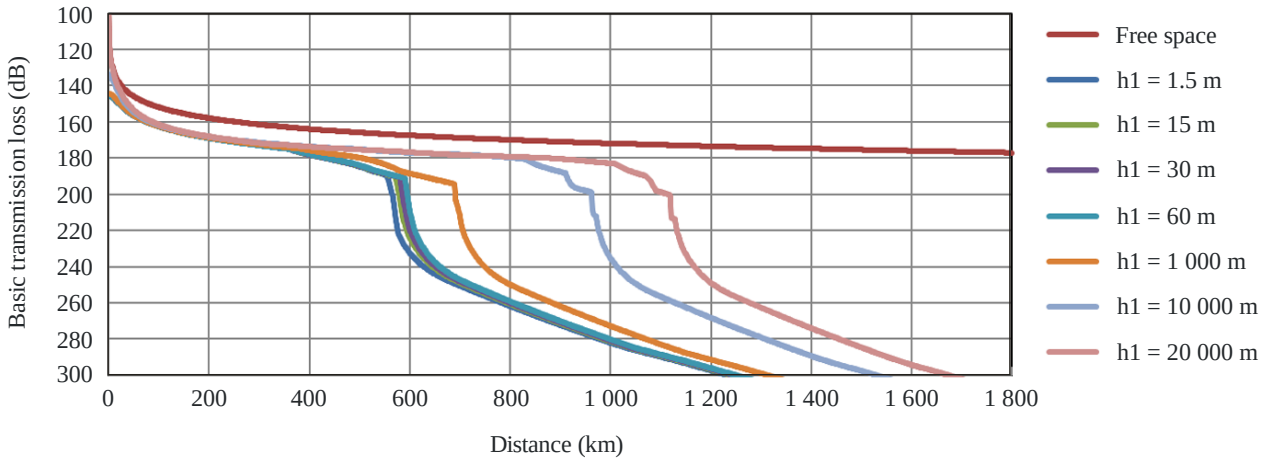
Curve sets for basic transmission loss at 9 400 MHz for 95% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

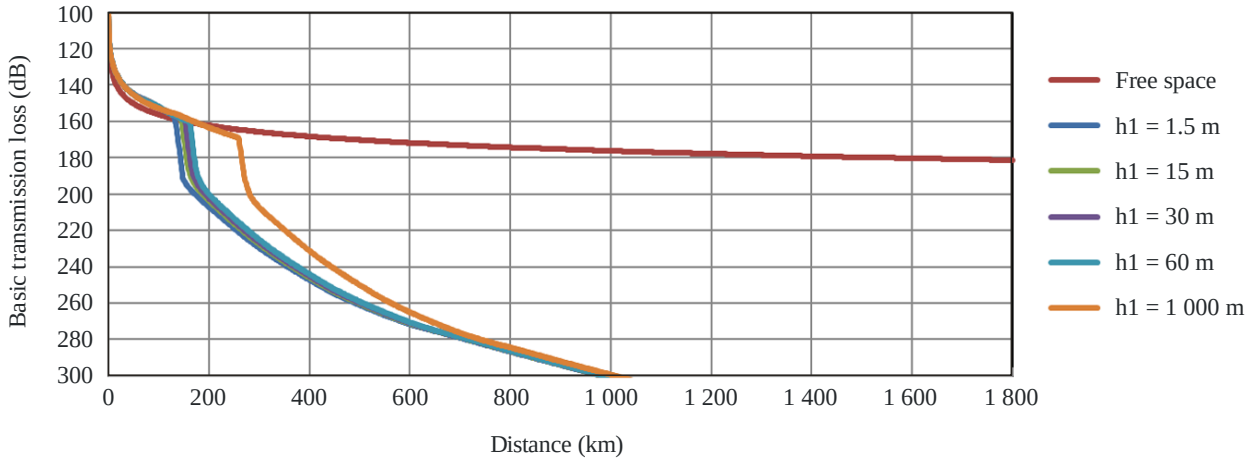


c) h2 = 20 000 m

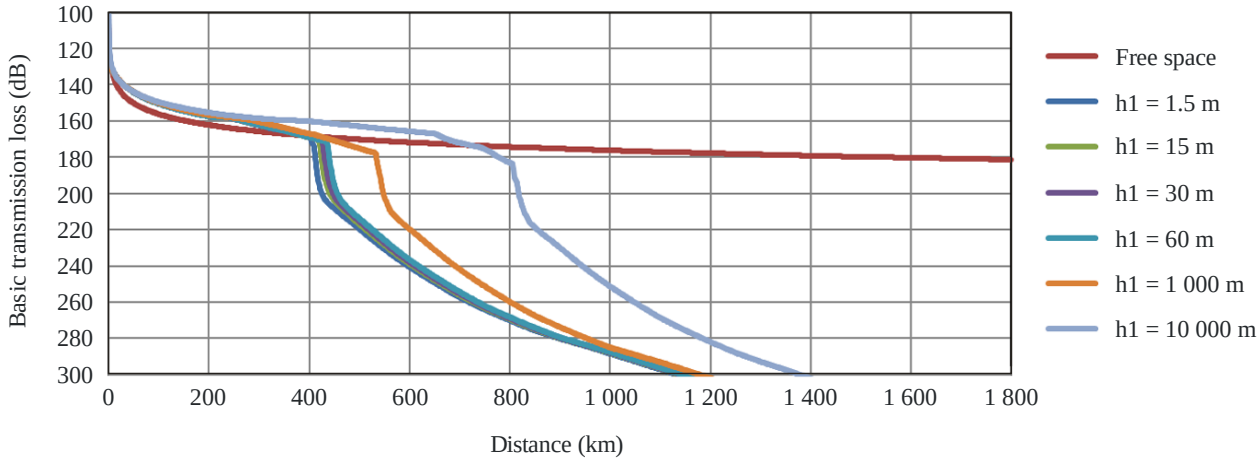
P.0528-07-05

FIGURE 8-1

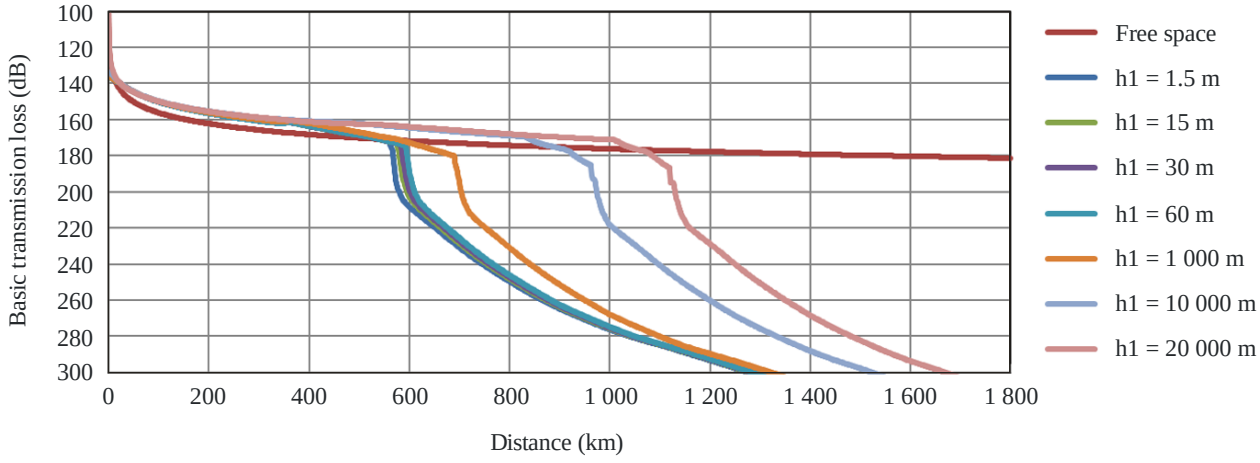
Curve sets for basic transmission loss at 15 500 MHz for 1% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

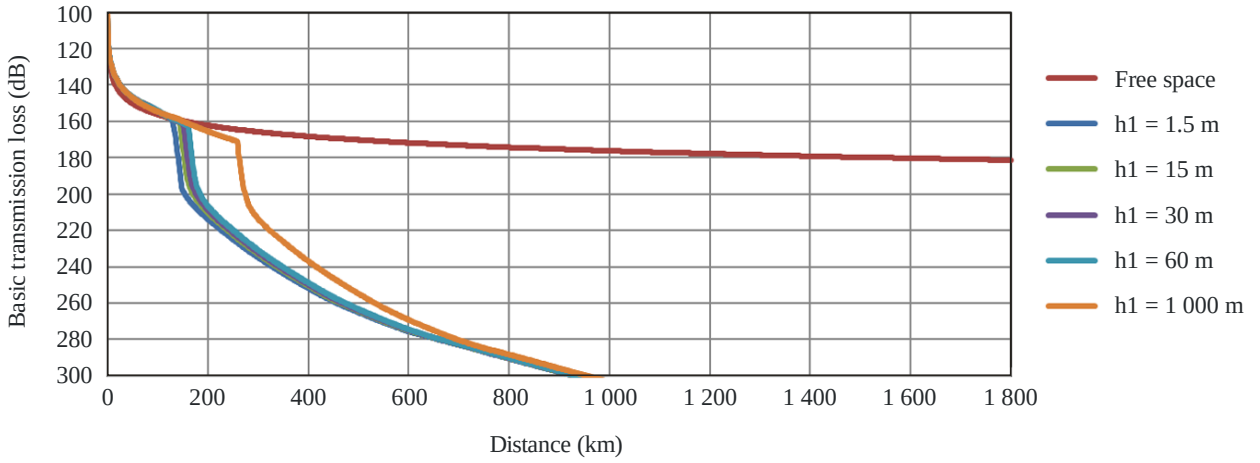


c) h2 = 20 000 m

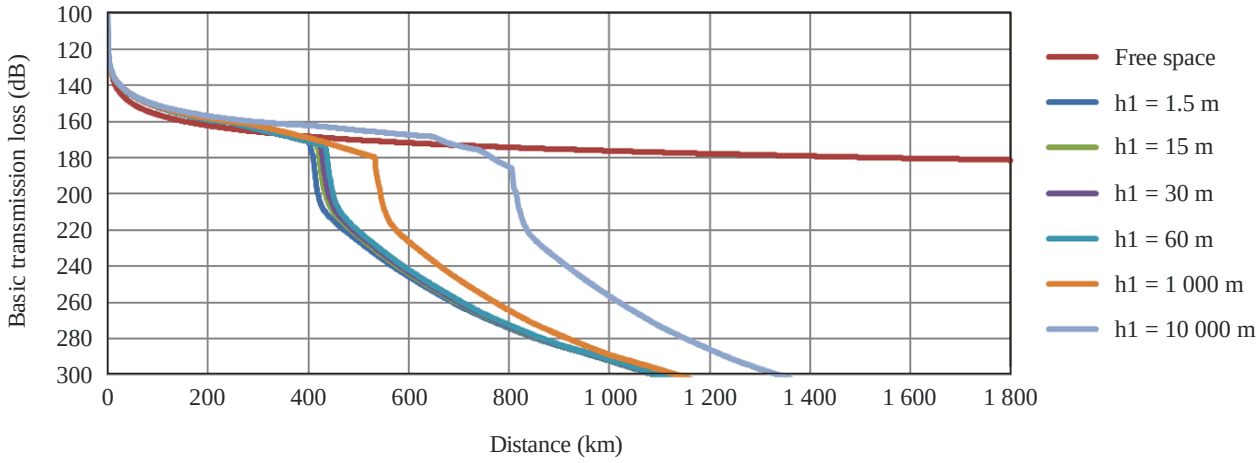
P.0528-08-01

FIGURE 8-2

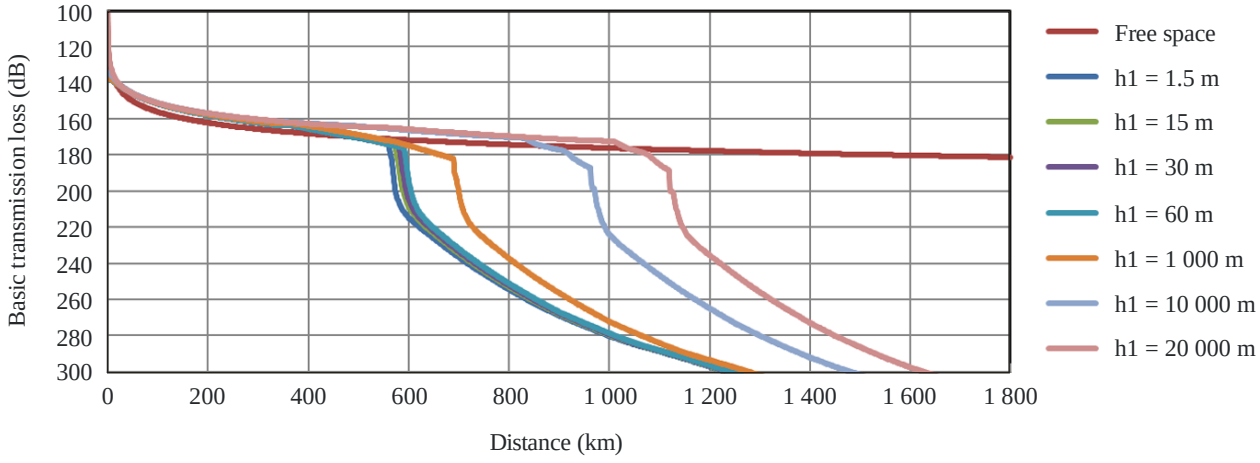
Curve sets for basic transmission loss at 15 500 MHz for 5% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

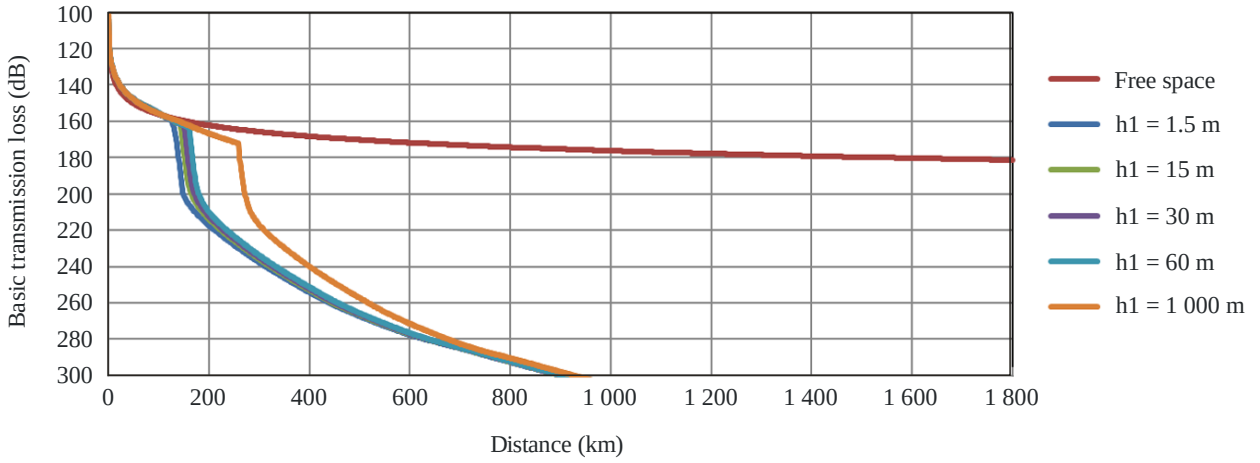


c) h2 = 20 000 m

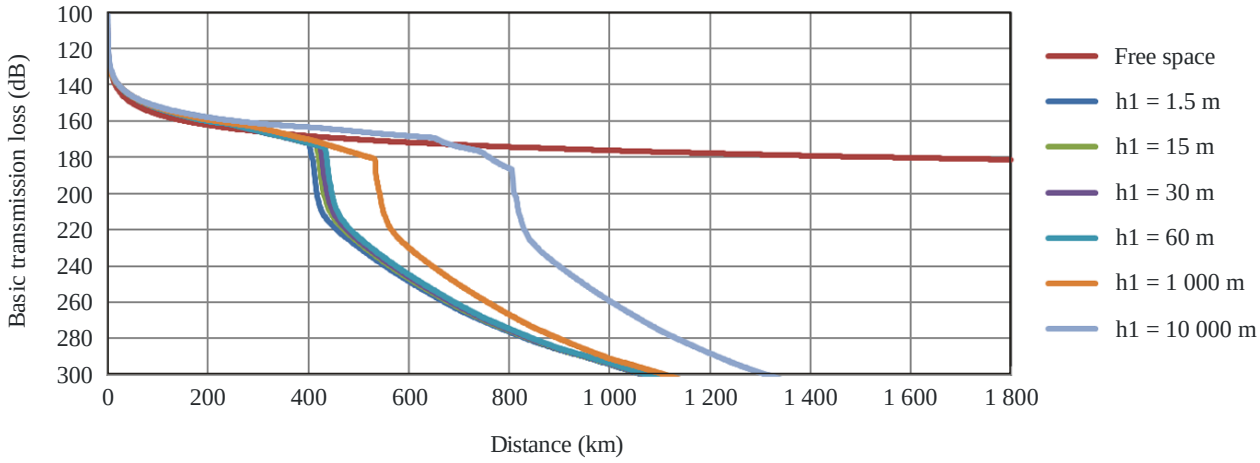
P.0528-08-02

FIGURE 8-3

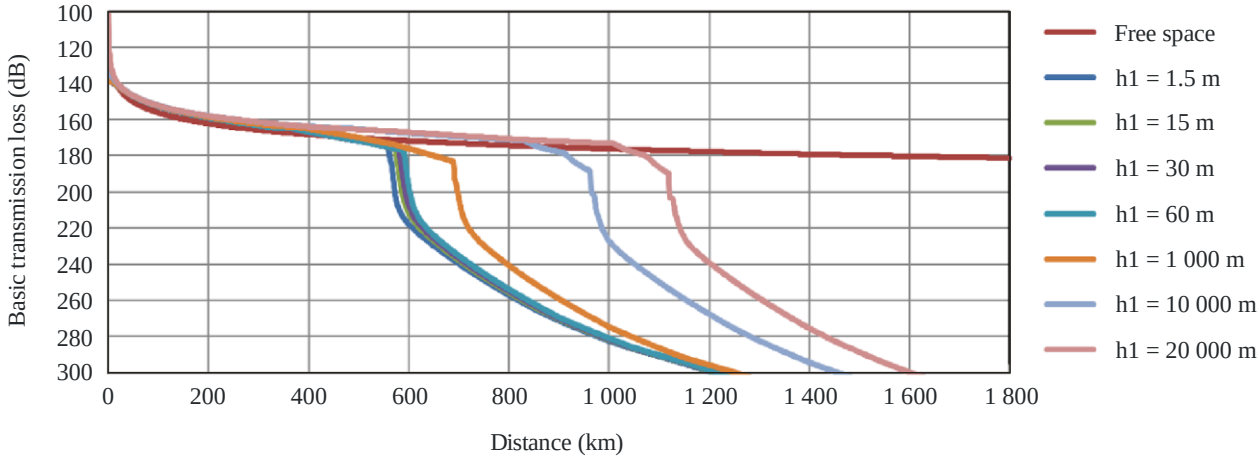
Curve sets for basic transmission loss at 15 500 MHz for 10% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

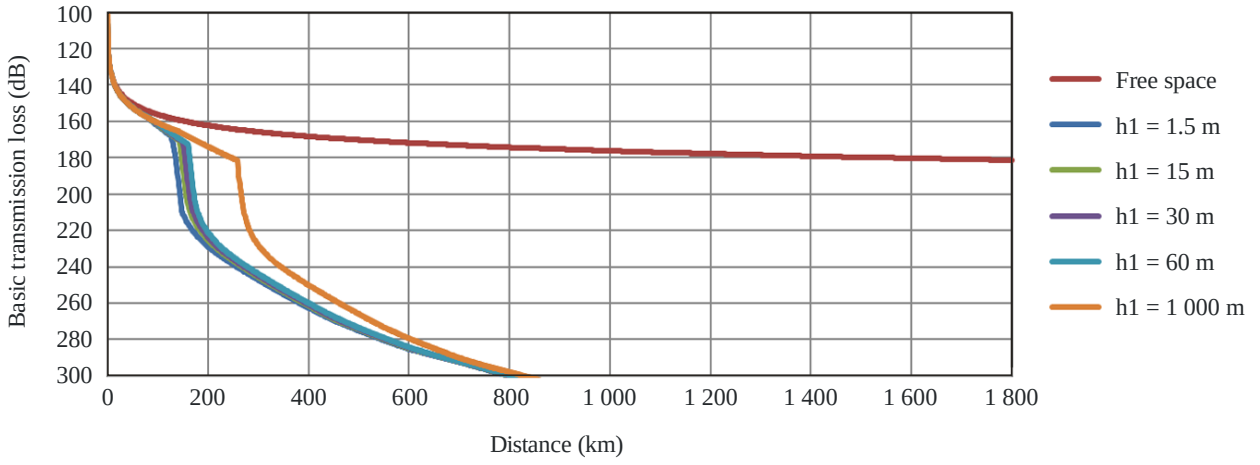


c) h2 = 20 000 m

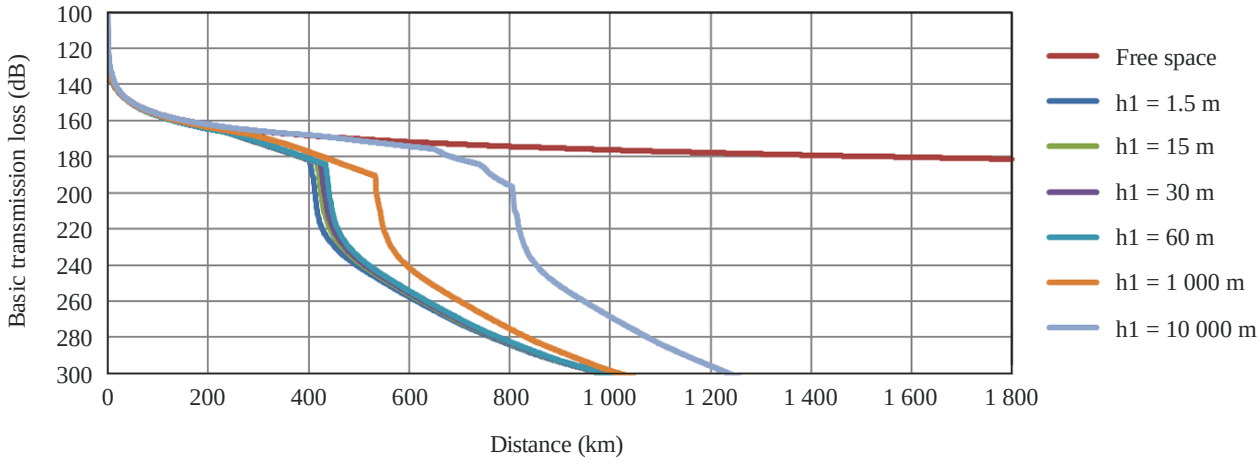
P.0528-08-03

FIGURE 8-4

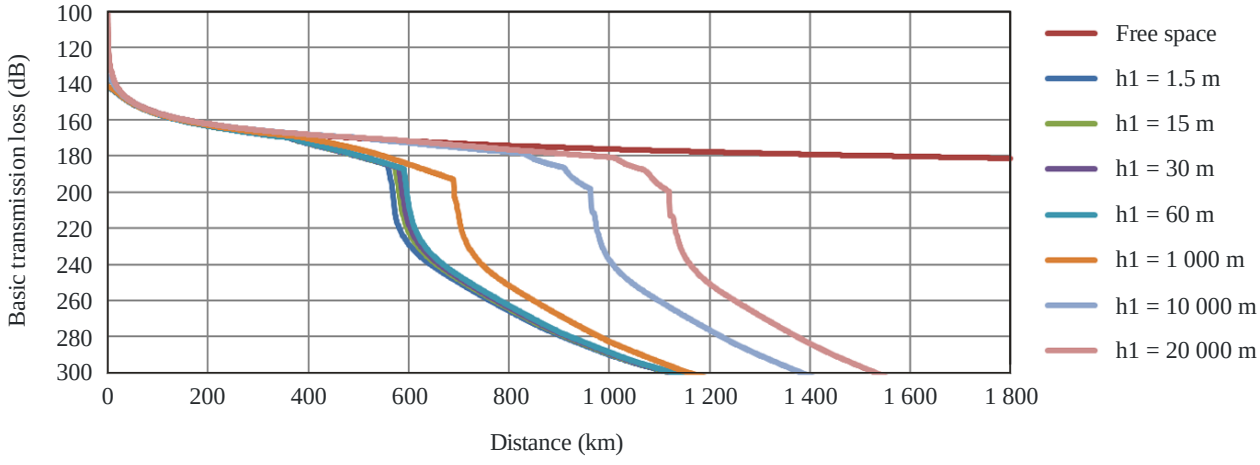
Curve sets for basic transmission loss at 15 500 MHz for 50% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m

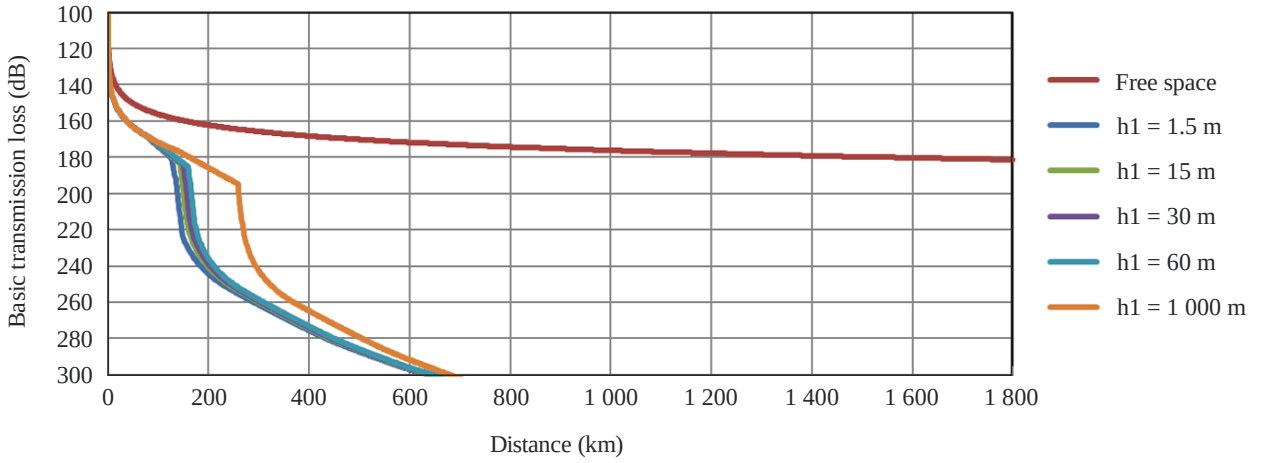


c) h2 = 20 000 m

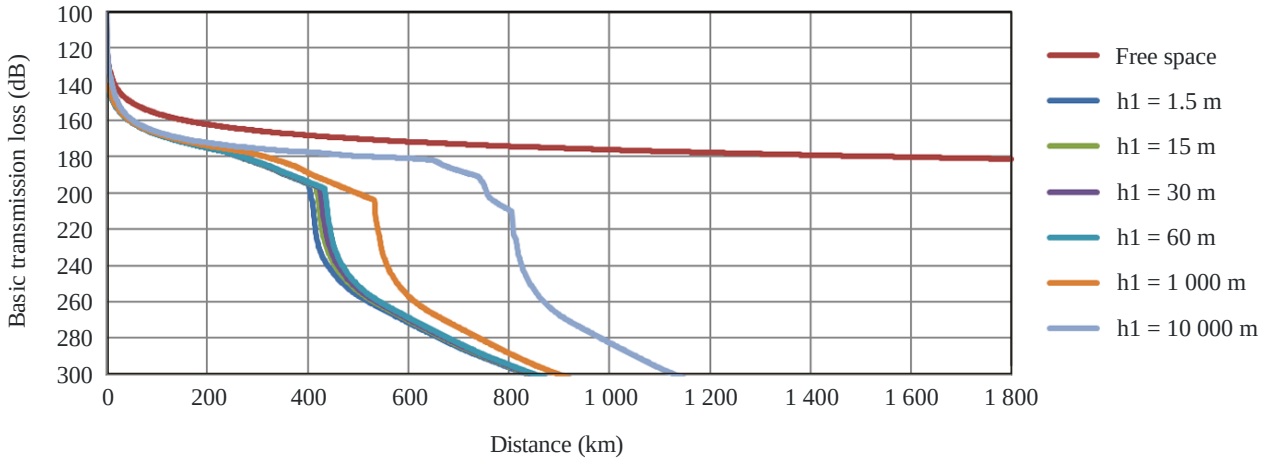
P.0528-08-04

FIGURE 8-5

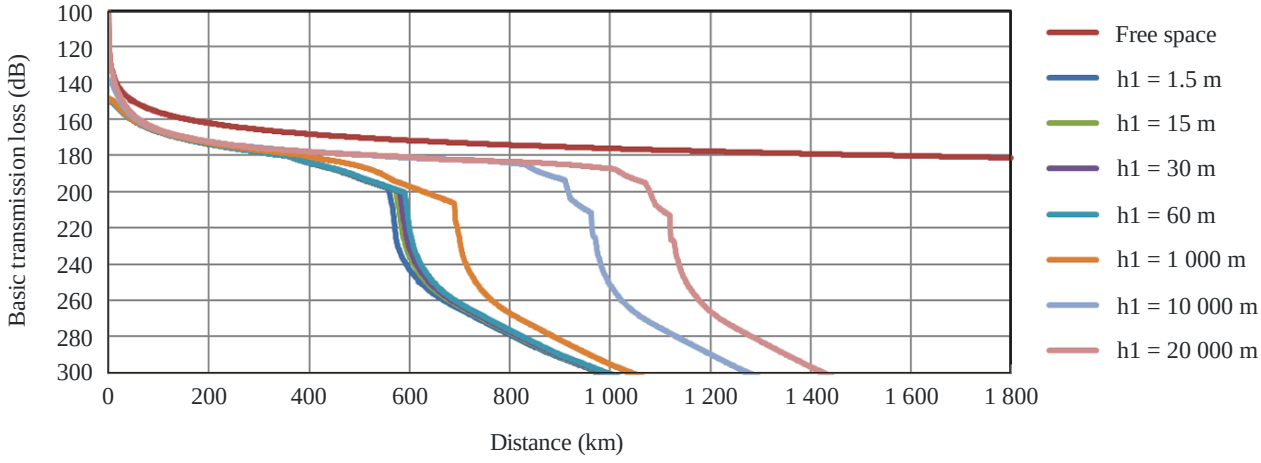
Curve sets for basic transmission loss at 15 500 MHz for 95% of the time for values of h1



a) h2 = 1 000 m



b) h2 = 10 000 m



c) h2 = 20 000 m

P.0528-08-05

Annex 4

Experimental results

Propagation tests at 930 MHz were conducted on air-to-ground paths in Japan in November 1982 and April and June 1983. According to the test results, propagation losses within line-of-sight agreed well with free space values. The line-of-sight distance as calculated from the measured data at an altitude of 10 000 m was shorter than the distance implied by the curves in Annex 3.