CISPR TR 16-4-4

Edition 2.0 2017-06

TECHNICAL REPORT

colour inside

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

AMENDMENT 1

Specification for radio disturbance and immunity measuring apparatus and methods –
Part 4-4: Uncertainties, statistics and limit modelling – Statistics of complaints and a model for the calculation of limits for the protection of radio services

CISPR TR 16-4-4:2007-07/AMD1:2017-06(en)

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COMMISSION

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FOREWORD

This amendment has been prepared by subcommittee CISPR H: Limits for the protection of radio services, of IEC technical committee CISPR: International special committee on radio interference.

The text of this amendment is based on the following documents:

DTR	Report on voting
CIS/H/313/DTR	CIS/H/319/RVC

Full information on the voting for the approval of this amendment can be found in the report on voting indicated in the above table.

The committee has decided that the contents of this amendment and the base publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

5.6.2.3 Probability factors

Number the first equation of this subclause as follows:

$$P = P_1 \times P_2 \times P_3 \times P_4 \times P_5 \times P_6 \times P_7 \times P_8 \times P_9 \times P_{10} \qquad (35)$$

Add, at the end of 5.6.4.4, the following new subclauses:

5.6.5 Rationale for determination of CISPR limits in the frequency range below 30 MHz

5.6.5.1 General

With this subclause, a method for the estimation of disturbance limits for a given type of equipment is described. This approach can be applied for the frequency range below 30 MHz.

For radiation coupling, dependence of the permissible disturbance field strength from the wanted signal μ_w, the signal-to-disturbance ratio R_p, and other influence factors can be estimated based on Equations (21) and (22) found in 5.5.

This model should be used by Product Committees to determine the disturbance limits measured on a EUT in standardized test sites. This model is considered suitable for point source magnetic field devices and not for distributed or complex systems.

Ten probability or influence factors P_1 to P_{10} have to be considered according to 5.6.2.3. However, for better alignment with terminology used for statistics the ten influence factors P_1 to P_{10} are further treated in their mean values as μ_{P1} to μ_{P10}. It shall be noted that the values for μ_{P1} to μ_{P10} can be used in logarithmic terms (i.e. in dB) only.

Taking into account Equation (22) we can write

$$E_{\mathrm{Limit}} = \mu_i + t_\beta \sigma_i \qquad (36)$$

Then taking equation (21) into account, noting that t_β = 0,84, and the limit becomes:

$$E_{\mathrm{Limit}} = \mu_w - R_p + \mu_{P1} + \mu_{P2} + \mu_{P3} + \mu_{P4} + \mu_{P5} + \mu_{P6} + \mu_{P7} + \mu_{P8} + \mu_{P9} + \mu_{P10}$$

$$+ t_\beta \sigma_i - t_\alpha(\sigma_{P1}^2 + \sigma_{P2}^2 + \sigma_{P3}^2 + \sigma_{P4}^2 + \sigma_{P5}^2 + \sigma_{P6}^2 + \sigma_{P7}^2 + \sigma_{P8}^2 + \sigma_{P9}^2 + \sigma_{P10}^2)^{1/2} \qquad (37)$$

where

E_{Limit} is the mean value of the permissible disturbance field strength at a specified distance *d* from the disturbance source;

μ_w is the minimum value of the wanted field strength at the edge of the service area of the radio service concerned;

R_p is the minimum acceptable value of the signal-to-disturbance ratio (i.e. the protection ratio) at the receiver's antenna port or feeding point;

μ_{P1} is the mean value of the main lobes of the magnetic dipole radiation in the direction of the victim receiver;

σ_{P1} is the standard deviation of P_1;

μ_{P2} is the expected mean value when the directional receiving antenna has its maximum pick-up in direction of the disturbance source;

μ_{P3} is the expected mean value when the victim receiver is stationary;

μ_{P4} is the expected mean value when there is equipment generating a disturbing signal on a critical frequency;

μ_{P5} is the expected mean margin when the relevant harmonic is below the limit value;

μ_{P6} is the expected mean value when the type of disturbance signal generated will produce a significant effect in the receiving system;

μ_{P7} is the expected mean value when the operation of the disturbance source is coincident with the receiving system;

μ_{P8} is the expected mean value when the disturbance source is located in a distance to the receiving system within which interference is likely to occur;

μ_{P9} is the expected mean value when the value of radiation at the edge of service area for the protected service just meets the limit for the RF disturbance;

μ_{P10} is the expected mean value when buildings provide attenuation.

Equation (37) is valid for mean values of influence factors (given in dB) assuming a log-normal distribution of their figures. Notice that the latter may not be fulfilled for each factor in each individual case. By inserting appropriate practical figures, Equation (37) can be used to estimate a limit E_{Limit} for the permissible disturbance field strength.

NOTE Within these calculations, 20 log has been utilized for distance elements and 10 log for the others, assuming power and not voltage.

5.6.5.2 Consideration and estimated values of μ_{P1} to μ_{P10}

5.6.5.2.1 Radiation pattern of the disturbance source (μ_{P1})

5.6.5.2.1.1 Consideration of μ_{P1}

The horizontal plane radiation pattern on a small purely magnetic antenna is described in dB unit by

$$G(\varphi) = G_{max} + 20 \log (\sin(\varphi)) \quad (38)$$

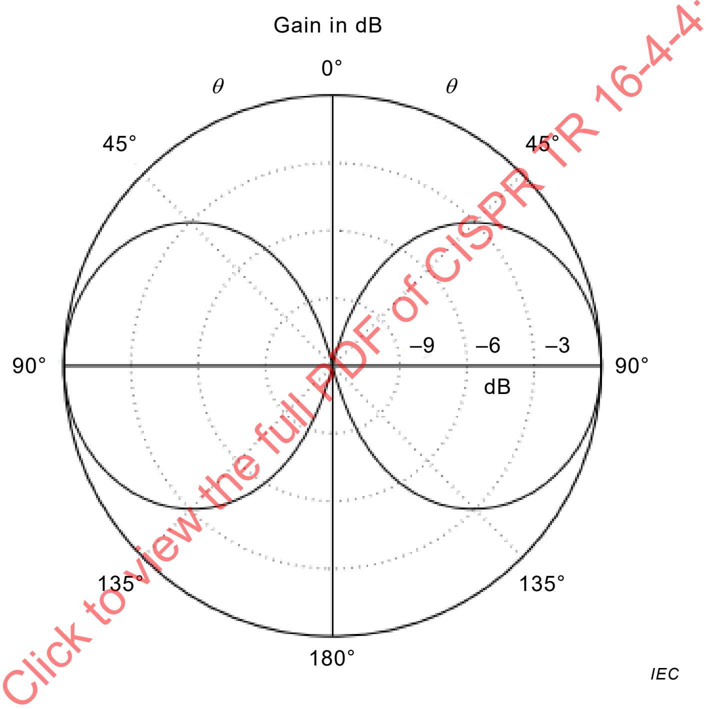


Figure 8 – horizontal plane radiation pattern on a small purely magnetic antenna

In the general case the victim may be in any possible direction with equal-probability. The mean value and standard deviation of the gain can be calculated by the following averages over half of the circle.

$$G_{avg} = Avg(G(\varphi)) \equiv \frac{1}{\pi} \times \int_0^{\pi} G(\varphi) d\varphi \quad (39)$$

$$\begin{aligned} \sigma_G{}^2 &= Avg\left(G(\varphi)^2\right) - \left(Avg(G(\varphi)\right)^2 \\ &= \frac{1}{\pi} \int_0^{\pi} (G(\varphi))^2 d\varphi - G_{avg}{}^2 \end{aligned} \quad (40)$$

Numerical calculation of Equations (39) and (40) gives the average gain G_{avg} = G_{max} – 6,0 dB and the standard deviation σ_G = 7,9 dB, which lead to μ_{P1} = G_{max} – G_{avg} = 6 dB and σ_G = 7,9 dB

5.6.5.2.1.2 Estimation for the μ_{P1}

$$\mu_{P1} = 6 \text{ dB}, \sigma_{P1} = 8 \text{ dB}$$

5.6.5.2.2 Antenna gain of the victim to the disturbance source (μ_{P2}) (the directional receiving antenna have its maximum pick-up in direction of the disturbance source)

5.6.5.2.2.1 Consideration of μ_{P2}

In the frequency range below 30 MHz, a typical receiving antenna used with broadcast receivers is a rod antenna. Other antennas are also used. These antenna gains can vary to as much as –10 dB to 10 dB, however it can be assumed that 67 % of all antennas show a gain of within 3 dB of an isotropic antenna.

5.6.5.2.2.2 Estimation for the possible range of μ_{P2}

$$\mu_{P2} = -3 \text{ dB}, \sigma_{P2} = 3 \text{ dB}$$

5.6.5.2.3 Stationary receiver (μ_{P3})

5.6.5.2.3.1 Consideration of μ_{P3}

Below 30 MHz, it is likely that the victim receiver will be stationary; hence the value should be 0 dB.

5.6.5.2.3.2 Estimation for the possible range of μ_{P3}

$$\mu_{P3} = 0 \text{ dB}, \sigma_{P3} = 0 \text{ dB}$$

5.6.5.2.4 Equipment generating a disturbing signal at a critical frequency and relevant harmonics (μ_{P4})

5.6.5.2.4.1 Consideration of μ_{P4}

For the source of the magnetic disturbance from monitors and plasma TVs, the issue will appear for the fundamental frequency and the harmonics. Assuming the fundamental emission from the disturbance source is at 250 kHz and its harmonics will occupy approximately in the ratio of 5:1. Based upon a variation of ±25 kHz, giving a value of 50 kHz (7 dB).

For the source of the magnetic disturbance from induction cooking equipment, the issue will appear from the fundamental frequency and the harmonics. Assuming the fundamental emission from the disturbance source is at 50 kHz and its harmonics will occupy approximately in the ratio of 2:1. Based upon a variation of ±12,5 kHz, giving a value of 25 kHz (3 dB).

NOTE 1 The values below were derived from 10 log (1/5) = –7 dB and 10 log (1/2) = –3 dB hence the mean values 5 dB and the range of 2 dB.

NOTE 2 Other sources of disturbance may be from electrical car charging stations, phone charging systems and these are estimated to give similar values.

We have assumed no frequency dependency relevant to the limits.

A typical response of a source of magnetic field disturbance is present in Figure 9.

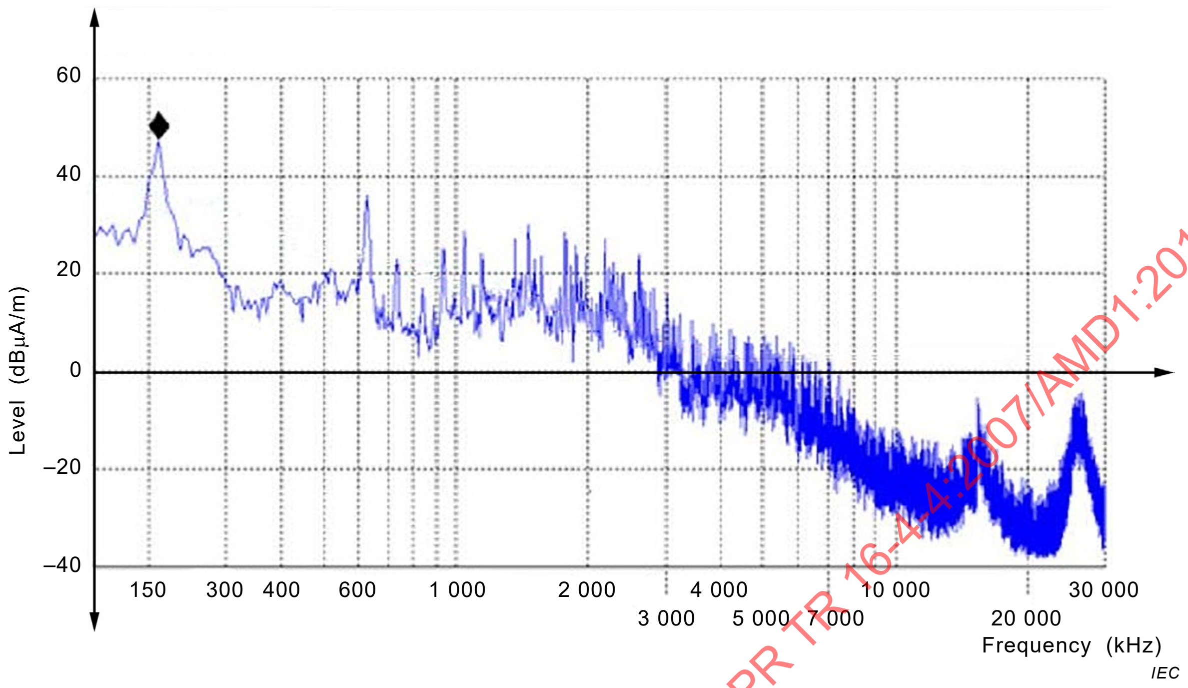


Figure 9 – typical source of magnetic field disturbance

5.6.5.2.4.2 Estimation for the possible range of μ_{P4}

$$\mu_{P4} = 5\text{ dB, Range } \sigma_{P4} = 2\text{ dB}$$

5.6.5.2.5 Margin that the relevant harmonics are below the limit value (μ_{P5})

5.6.5.2.5.1 Consideration of μ_{P5}

This value has been covered in μ_{P4}.

5.6.5.2.5.2 Estimation for the possible range of μ_{P5}

This value has been covered in μ_{P4}.

5.6.5.2.6 Expected mean value that the type of disturbance signal generated will produce a significant effect in the receiving system (μ_{P6})

5.6.5.2.6.1 Consideration of μ_{P6}

In the frequency range below 30 MHz, since the bandwidth of the unwanted signal and bandwidth of the receiver are of similar values, μ_{P6} should be set to 0 dB.

For the example of plasma TVs and induction cookers in the frequency range below 30 MHz, typically since the bandwidth of the disturbance source is greater than the bandwidth of the receiver, μ_{P6} should be set to 0 dB.

NOTE AC mains cable is not an issue of interference to radio receivers at the frequency below 30 MHz because this aspect is already covered by the conducted emission requirement defined in the standard.

5.6.5.2.6.2 Estimation for the possible range of μ_{P6}

$$\mu_{P6} = 0\text{ dB, Range } \sigma_{P6} = 0\text{ dB}$$

5.6.5.2.7 Expected mean value that the operation of the disturbance source is coincident with the receiving system operation of the disturbance source (μ_{P7})

5.6.5.2.7.1 Consideration of μ_{P7}

In the case that a receiver is operated for 24 hours, from the typical sources in 24 hours per day, plasma TV is 8 hours, PV Inverter 8 hours and induction cookers 2 hours operated.

NOTE The estimated values given in 5.6.6.2.7.2 were derived by 10 log (time of operation (hours) /24).

5.6.5.2.7.2 Estimation for the possible range of μ_{P7}

$$\mu_{P7} = 6{,}5 \text{ dB, Range } \sigma_{P7} = 3{,}5 \text{ dB}$$

5.6.5.2.8 The disturbance source is located in a distance to the receiving system within which interference is likely to occur (μ_{P8})

5.6.5.2.8.1 Consideration of μ_{P8}

The limit of the disturbance is specified for the test site with a normative fixed measurement distance *d*. In practice, the actual distance *r* between the disturbance source and the victim is usually quite different when the victim is used as intended.

The normative measurement distance *d* is 3 m. The ratio of the two distances *r* and *d* determines the additional attenuation.

The estimated value μ_{P8} usually increases the permissible limit and has to be added on the right hand side of Equation (37).

5.6.5.2.8.2 Estimation for the possible range of μ_{P8}

The value of μ_{P8} is calculated by:

$$\mu_{P8} = x \times 20 \log (r / d) \qquad (41)$$

where

r is the actual distance between source and victim;

d is the measurement distance;

x is the wave propagation coefficient, typical value to be determined based upon Annex B.

The estimated distance has to take into account the average distance for the intended use of the radio equipment. Inserting practical distances into Equation (41) will provide the possible range of μ_{P8}.

5.6.5.2.9 The value of radiation at the edge of service area for the protected service (μ_{P9})

5.6.5.2.9.1 Consideration of μ_{P9}

Due to propagation complexities related to the transmission properties relating to this frequency range (including solar storms, variation of the reflecting condition at the ionosphere and the time of day) it is difficult to define actual coverage areas of the radio service. There will still be areas were the service will have sufficient signals and other areas where there will be insufficient. Hence a basic approximation could be based upon a simple circularly response and the ratio between the two different coverage areas.

5.6.5.2.9.2 Estimation for the possible range of μ_{P9}

$$\mu_{P9} = 3 \text{ dB, Range } \sigma_{P9} = 3 \text{ dB}$$

5.6.5.2.10 The expected mean value that buildings provide attenuation of the building (μ_{P10})

5.6.5.2.10.1 Consideration of μ_{P10}

In this frequency range the worst case attenuation of buildings will be 0 dB.

NOTE Depending on the situation, building attenuation can be taken into account. Any attenuation may impact both the reception of the radio service and the amount of interference source observed. Hence this may need to be taken into account with the performance of the receiving antenna.

5.6.5.2.10.2 Estimation for the possible range of μ_{P10}

$$\mu_{P10} = 0 \text{ dB, Range } \sigma_{P10} = 0 \text{ dB}$$

5.6.6 Model for limits for the magnetic component of the disturbance field strength for the protection of radio reception in the range below 30 MHz

5.6.6.1 General

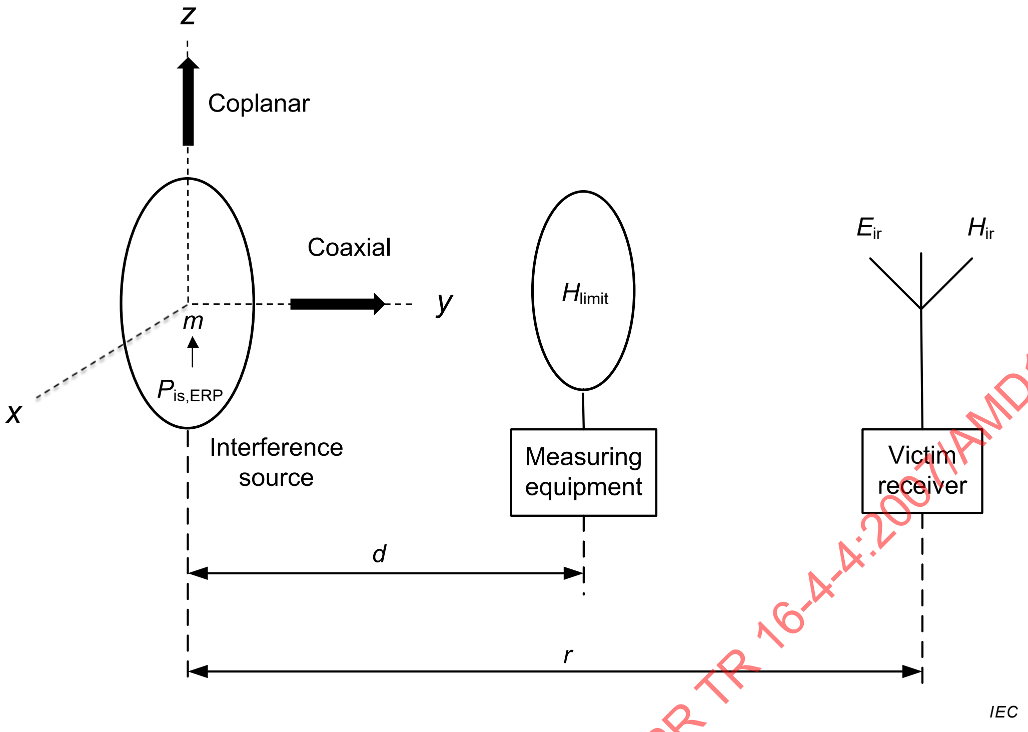
Recently, new electric or electronic devices having unintentional emissions below 30 MHz were introduced in the market. As the classical examples of these devices, there are plasma TV sets, power line communications devices, wireless power transfer, induction cooking devices, and so on. As the devices have been using increasingly, it is required to establish an appropriate model for deriving radiation limits in order to protect existing radio services at frequencies below 30 MHz.

This document contains statistics of complaints and mathematical models for the calculation of electric field limits related to the protection of radio services without the consideration of magnetic radiation within the near field region. Hence, development of other analytical models is required for the derivation of radiation limits on the devices having magnetic disturbances.

NOTE Other organisations also working within the area including CEPT and ITU-R.

5.6.6.2 Model for magnetic field limits below 30 MHz

This model is established for calculation magnetic field limits required for the protection of radio services against interference from various types of magnetic field sources using below 30 MHz. This method for calculation of magnetic field limits for protection of radio services below 30 MHz is depicted in Figure 10.



Key

m	magnetic dipole moment
E_{ir}	permissible interference electric field of victim receiver
H_{ir}	permissible interference magnetic field of victim receiver
$P_{is,ERP}$	effective radiated power of interference source at distance r from victim receiver
H_{limit}	magnetic field limits for interference source at measuring distance d, i.e. at the position of the antenna of the measuring equipment

Figure 10 – Model for magnetic field limit at measuring equipment

The permissible interference electric or magnetic field (E_{ir} or H_{ir}) of victim receiver can be derived from a method considering noise level or a method considering signal to disturbance ratio (R_P).

The method considering noise level is as follows:

E_{noise} (dBμV/m) of a victim service is corrected for the bandwidth of the victim receiver:

$$E_{noise} = E_{noise,b} + 10 \log (b_{victim} / b_{noise}) \qquad (42)$$

where

b_{noise}	is the measuring bandwidth of noise (kHz);
b_{victim}	is the bandwidth of victim (kHz);
$E_{noise,b}$	is the electric field strength of noise from Recommendation ITU-R P.372 (dBμV/m).

NOTE $E_{noise,b}$ is defined by an ITU-R document as the background Gaussian noise level (excluding impulse and burst noises), assuming the reception with a loss-less omni-directional antenna and an ideal receiver. In the case that the antenna and feeder losses or receiver noise cannot be negligible, reference noise level should be defined by the system noise level.

In case of broadband interference, the bandwidth ratio BWR (dB) should be included to calculate the permissible interference electric field E_{ir} (dBμV/m):

$$E_{ir} = E_{noise} + \mathrm{BWR} \tag{43}$$

The bandwidth ratio is defined:

$$BWR = 10 \log (b_{measuring} - b_{victim}) \tag{44}$$

where

$b_{measuring}$ is measuring bandwidth of interferer (kHz).

When the bandwidth of the interfering signal is not wider than the victim receiver bandwidth, *BWR* = 0 dB should be assumed.

The method considering R_P is as follows.

In the case where the minimum received field strength E_{min} (dBµV/m) and the R_P (dB) of the victim receiver are known, the permissible interference electric field is calculated:

$$E_{ir} = E_{min} - R_P + BWR \tag{45}$$

From the permissible interference electric field, the permissible interference magnetic field H_{ir} (dBµA/m) can be obtained:

$$H_{ir} = E_{ir} - 51{,}5 \tag{46}$$

And then, the effective radiated power ERP of interference source at distance r from victim receiver can be determined by propagation attenuation loss between interference source and victim receiver. Propagation attenuation loss exponent is normally in the range of 2 to 4 (where 2 is for propagation in free space, 4 is for relatively lossy environments). In some environments, such as buildings, stadiums and other indoor environments, the propagation attenuation loss exponent can reach values in the range of 4 to 6.

The magnetic dipole moment *m* (Am²) can be calculated from the effective radiated power of interference source at distance *r* from victim receiver, $P_{is,ERP}$ (kW) level.

$$m = \left(\frac{\lambda}{2\pi}\right)^2 \cdot \sqrt{50 \cdot P_{is,ERP}} \tag{47}$$

where

λ is the wavelength.

Finally, the magnetic field limits H_{limit} (A/m) for interference source at measuring distance d, i.e. at the position of the antenna of the measuring equipment can be calculated. The radiation direction from interference source is divided into coaxial and coplanar directions. The magnetic fields for these directions are computed by

$$H_{coaxial} = m \cdot \frac{\sqrt{\lambda_r^{\,2} + d^2}}{2\pi\, \lambda_r d^3} \tag{48}$$

$$H_{coplanar} = m \cdot \frac{\sqrt{\lambda_r^{\,4} - \lambda_r^{\,2} d^2 + d^4}}{4\pi\, \lambda_r^{\,2} d^3} \tag{49}$$

where

λ_r is the radian wavelength and is equal to $\lambda/2\pi$.

Then, H_{limit} is chosen to the maximum value of $H_{coaxial}$ and $H_{coplanar}$ in the view point of worst case as follows:

$$H_{limit} = \max (H_{coaxial}, H_{coplanar}) \quad (50)$$

Add, after Annex A, the following new Annex B:

Annex B
(informative)

Conversion of H-field limits below 30 MHz for measurement distances

B.1 Background

In order to determine the H-field conversion factor within the boundary of the test environment containing the ground plane, a commercial 3D full wave simulation tool has been used and the calculation thereof along with measurement records are provided in the following paragraphs.

Figure B.1 illustrates a designed model using a commercial tool. The dimension of the ground plane is 30 m x 40 m. The radius of the loop antenna, which is 0,6 m and the centre of the antenna is 1,3 m above the surface of the ground plane. For the measurement of field, the probes are located at 3 m and 10 m, both at coaxial and coplanar direction (a: coaxial at 3 m, b: coaxial at 10 m, c: coplanar at 3 m, d: coplanar at 10 m).

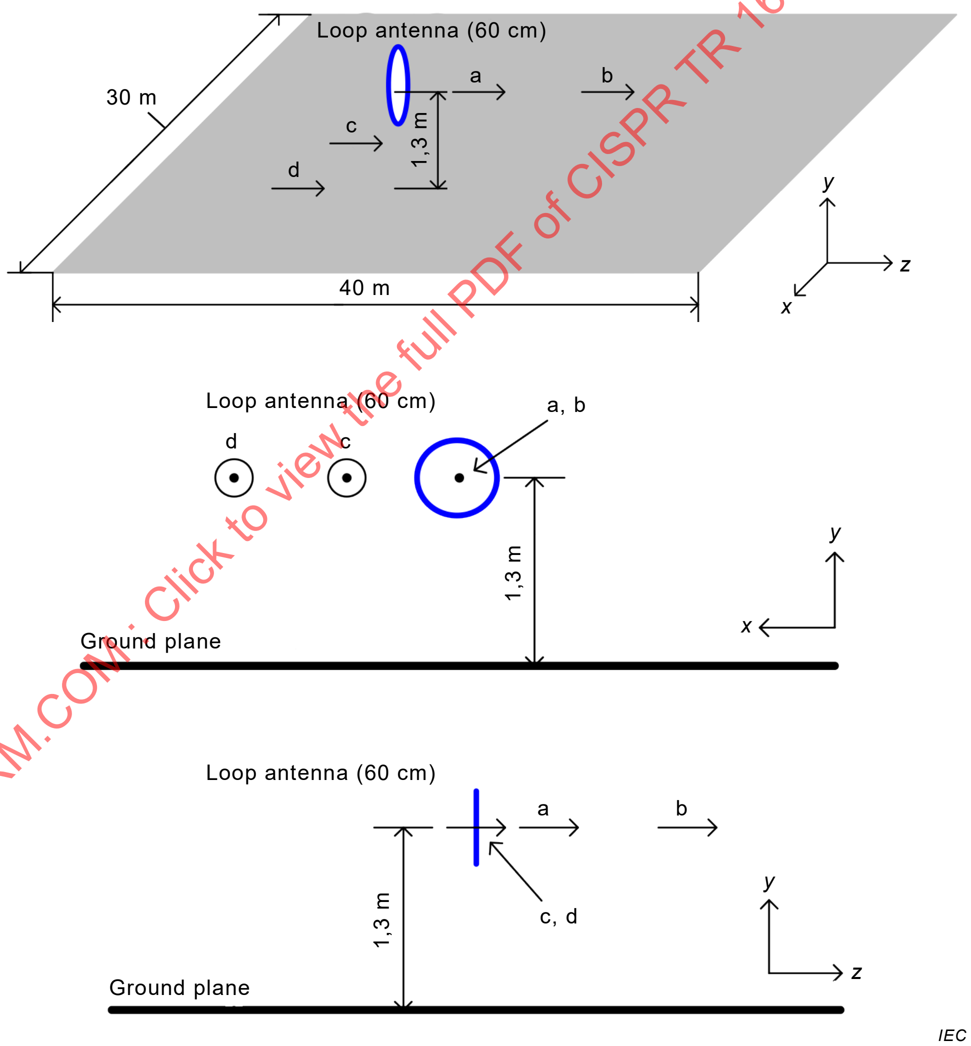


Figure B.1 – Commercial tool model for H-field conversion

Figure B.2 depicts another designed model using a commercial tool, and the ground plane has been removed in order to apply image theory with an additional virtual loop antenna positioned at 1,3 m below the ground plane that has been removed. This model is intended to measure coaxial and coplanar direction component from the same probe.

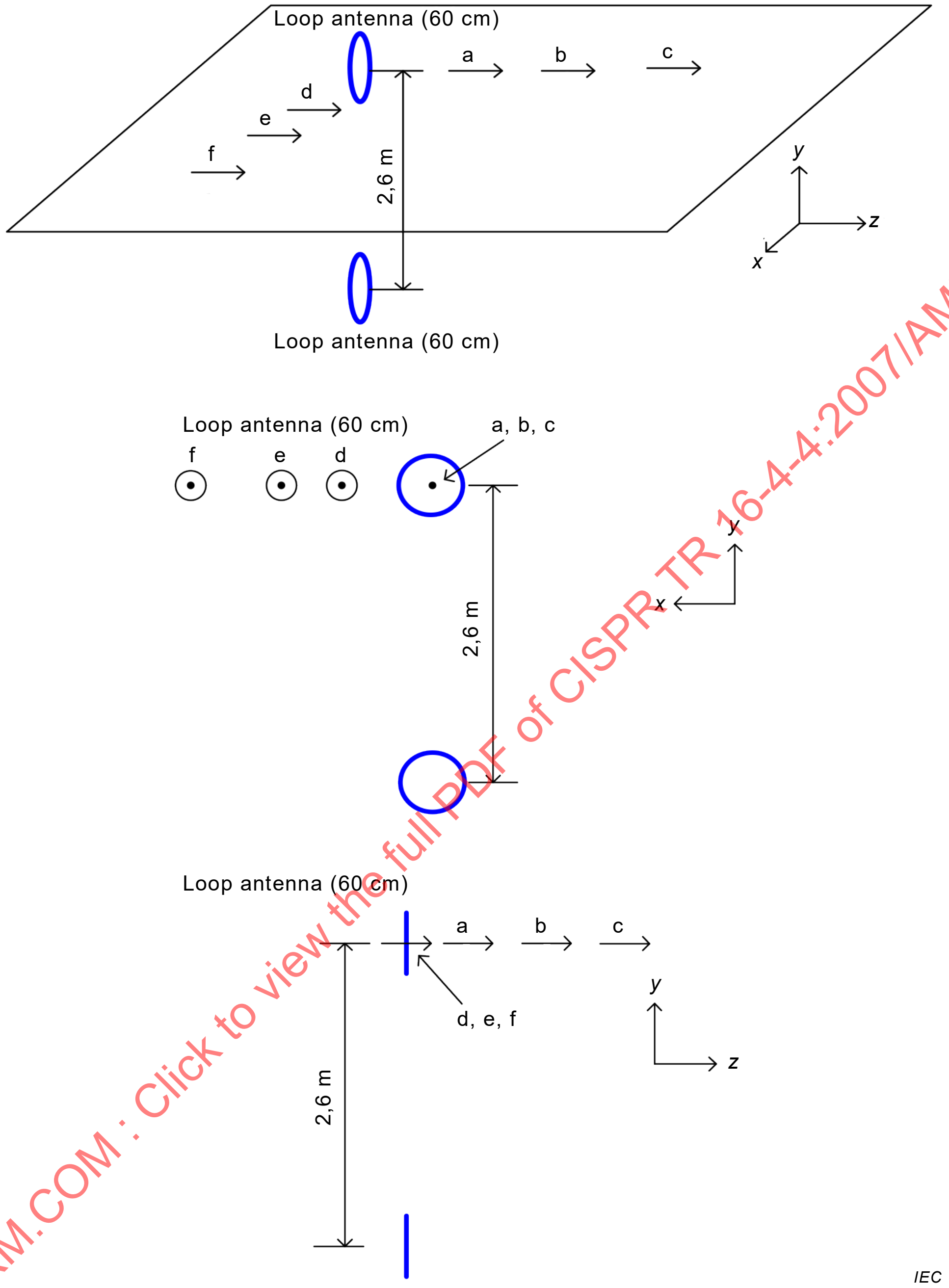


Figure B.2 – Commercial tool model for the application of image theory

Figure B.3 shows the scene of OATS where measurement is carried out at 1,3 m height from the centre of the antenna with 3 m distance between antennas at coaxial and coplanar direction, respectively.

a) **Measurement at coaxial direction at 3 m**   b) **Measurement at coplanar direction at 3 m**

Figure B.3 – Photos of OATS measurement setup

Figure B.4 is a graphical presentation which allows us to compare the results from a simulation both at coaxial and coplanar directions where the ground plane using a commercial tool is included and where image theory has been applied. It suggests that the simulation result from each model almost agrees.

Figure B.5 presents comparison results between the H-field conversion factors determined by using commercial tools and measurement data.

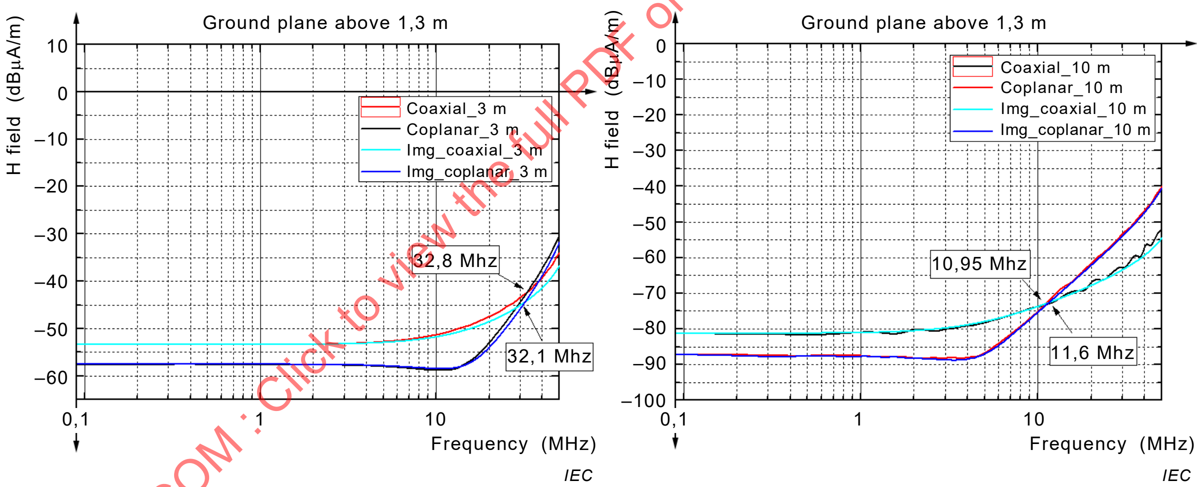


Figure B.4 – Comparative simulation result with ground plane and with image theory

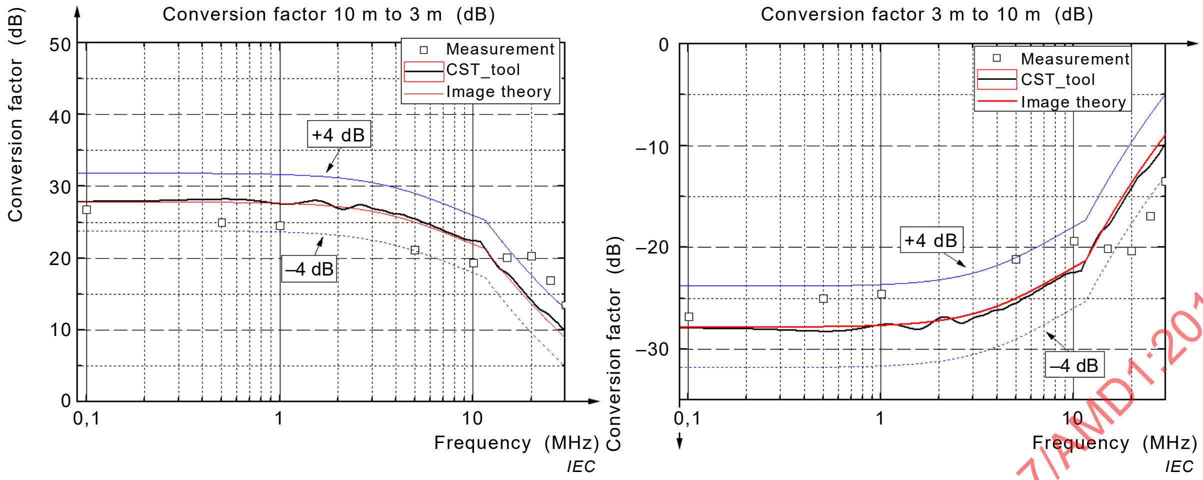


Figure B.5 – Comparison between the simulated conversion factors and the measurement results

B.2 H-field conversion factors obtained from simulation results

The conversion factors of measurement distances of 3 m and 10 m are derived from the measurement distance of 30 m under the test environment with the ground plane for H-field measurement.

The H-field limit in dBμA/m at 3 m, H_{3m}, is determined from H_{30m} by the following equation:

$$H_{3m} = H_{30m} + C_{3\_min} \quad \text{(B.1)}$$

where

H_{30m} is the H-field limit in dBμA/m at 30 m distance;

C_{3_min} is a conversion factor in dB as shown in Figure B.6 and Table B.1

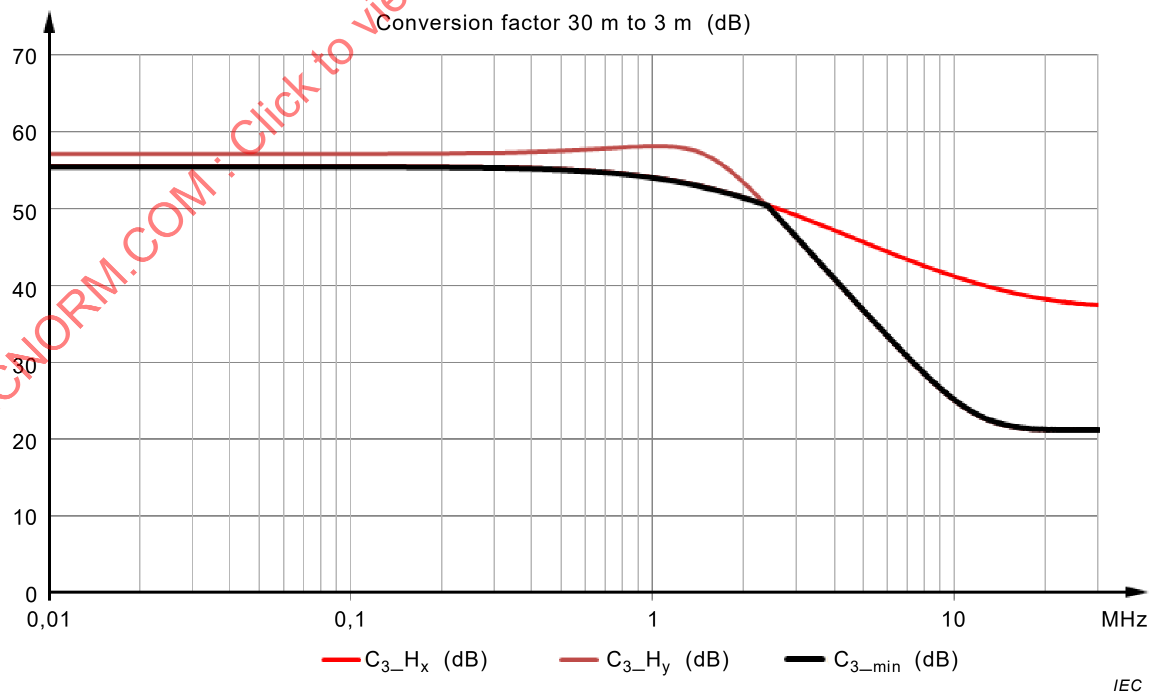


Figure B.6 – Conversion factor C_{3_min}

Table B.1 – Conversion factor C_{3_min}

Frequency MHz	$C_3\_H_x$ dB	$C_3\_H_y$ dB	C_{3_min} dB
0,01 (or 0,009)	55,3	57,2	55,3
0,15	55,5	57,3	55,5
1	54,1	58,2	54,1
2	51,5	53,6	51,5
2,4	50,5	50,5	50,5
3	49,1	46,3	46,3
5	45,7	36,7	36,7
10	41,2	25,1	25,1
11	40,7	23,9	23,9
12	40,3	23,0	23,0
13	39,9	22,4	22,4
14	39,5	22,0	22,0
15	39,3	21,7	21,7
20	38,3	21,2	21,2
30	37,5	21,1	21,1

The H-field limit in dBμA/m at 10 m, H_{10m}, is determined from H_{30m} by the following equation:

$$H_{10m} = H_{30m} + C_{10\_min} \tag{B.2}$$

where

H_{30m} is the H-field limit in dBμA/m at 30 m distance;

C_{10_min} is a conversion factor in dB as shown in Figure B.7 and Table B.2.

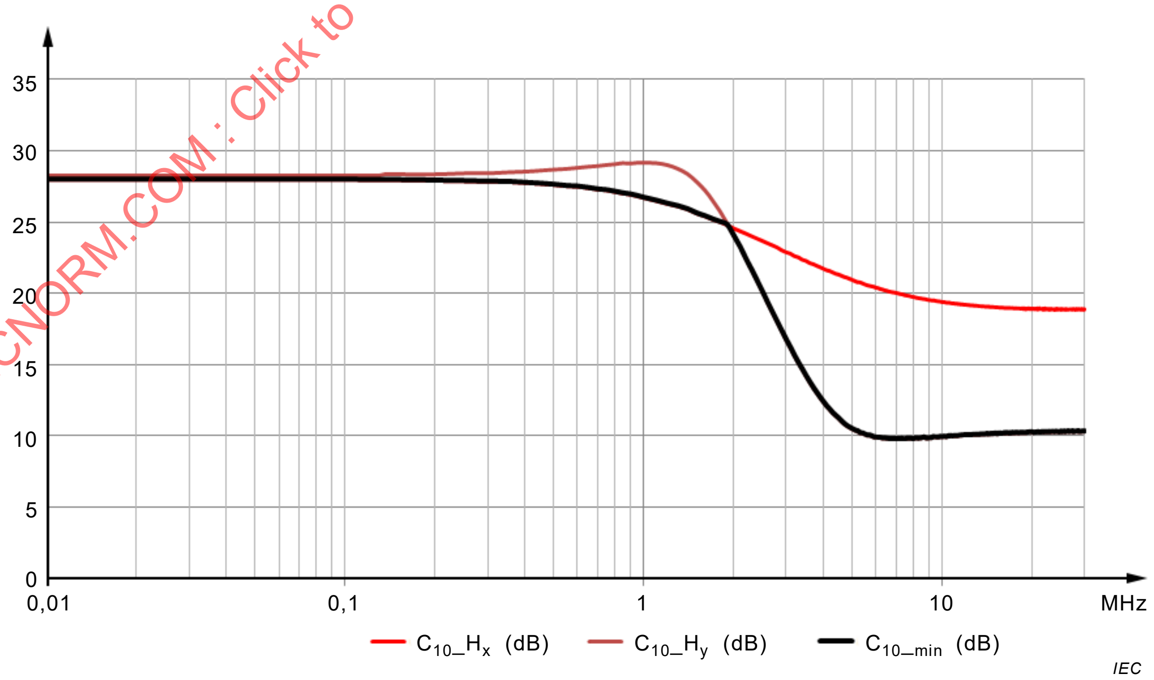


Figure B.7 – Conversion factor C_{10_min}

Table B.2 – Conversion factor C_{10_min}

Frequency MHz	C_{10}–H_x dB	C_{10}–H_y dB	C_{10_min} dB
0,01 (or 0,009)	28,0	28,3	28,0
0,10	28,0	28,3	28,0
0,15	28,0	28,3	28,0
0,2	27,9	28,3	27,9
0,3	27,9	28,4	27,9
0,4	27,8	28,5	27,8
0,5	27,7	28,7	27,7
0,6	27,5	28,8	27,5
0,7	27,3	28,9	27,3
0,8	27,2	29,0	27,2
0,9	27,0	29,1	27,0
1	26,7	29,1	26,7
1,9	24,8	24,9	24,8
2	24,6	24,1	24,1
3	22,9	16,7	16,7
5	21,0	10,5	10,5
10	19,4	9,9	9,9
20	19,0	10,3	10,3
30	18,9	10,3	10,3

The H-field limit in dBμA/m at 3 m, H_{3m}, can be also determined from H_{10m} by the following equation:

$$H_{3m} = H_{10m} + C_{10\text{-}3\_min} \quad \text{(B.3)}$$

where

H_{10m} is the H-field limit in dBμA/m at 10 m distance;

$C_{10\text{-}3\_min}$ is a conversion factor in dB as shown in Figure B.8 and Table B.3.

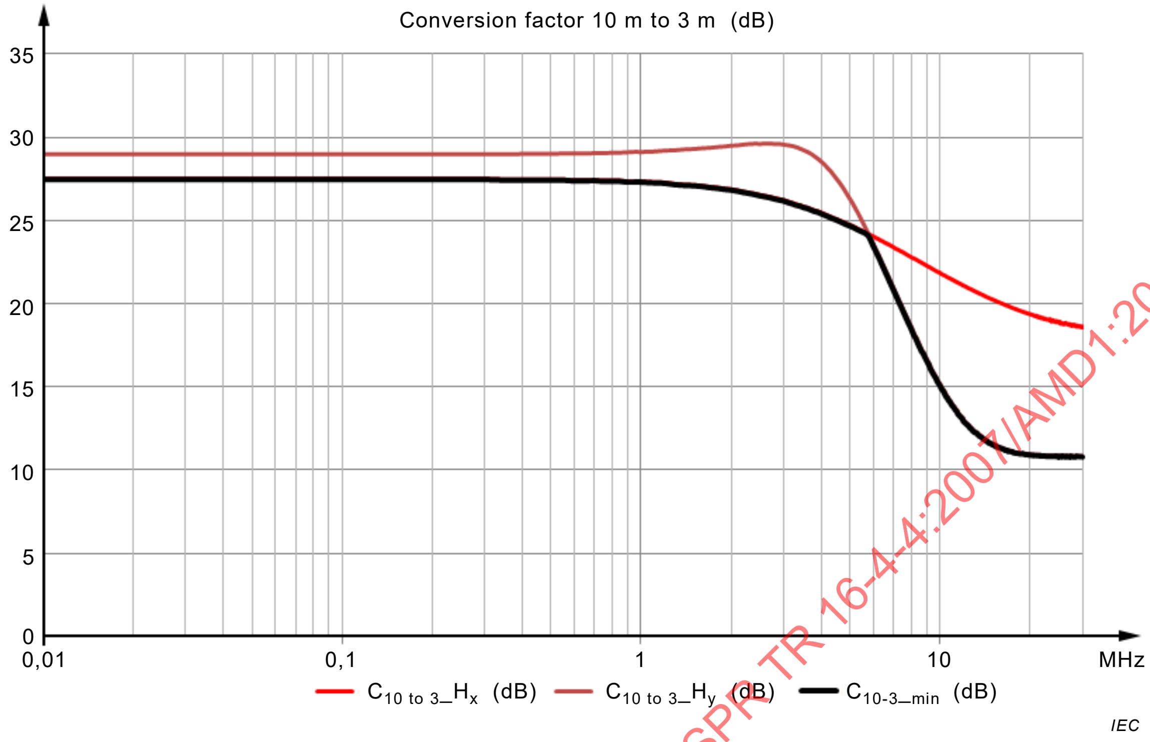


Figure B.8 – Conversion factor $C_{10\text{-}3\_min}$

Table B.3 – Conversion factor $C_{10\text{-}3\_min}$

Frequency MHz	$C_{10\text{ to }3}\_H_x$ dB	$C_{10\text{ to }3}\_H_y$ dB	$C_{10\text{-}3\_min}$ dB
0,01 (or 0,009)	27,5	29,0	27,5
0,15	27,5	29,0	27,5
1	27,4	29,1	27,4
2	26,9	29,5	26,9
3	26,2	29,6	26,2
5	24,7	26,2	24,7
5,8	24,2	24,1	24,1
10	21,8	15,1	15,1
11	21,4	13,9	13,9
12	21,1	13,0	13,0
13	20,7	12,3	12,3
14	20,5	11,9	11,9
15	20,0	11,6	11,6
20	19,3	10,9	10,9
30	18,6	10,8	10,8