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ECMA TR/94

Assessment of the Human Exposure to Electromagnetic Fields for Low Power Electronic and Electrical Apparatus according to EN 50371:2002

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Introduction

Assessing compliance with a new standard usually requires additional measurements, which increase cost and time-to-market. Compliance with EMF standards is now required under EU Directives. For low power electronic devices covered by EN 50371, there is an alternative way to demonstrate compliance, usually without additional measurements, provided that the product has previously passed EMC measurements. This Ecma Technical report outlines the computations that allow determining compliance of a low power electronic device, based on an assessment of already available EMC measurement results.

This Ecma Technical Report has been adopted by the General Assembly of December 2007.

Table of contents

1 Scope

This Technical Report addresses the technical assessment of Electromagnetic Fields (EMF) based on CENELEC standard EN 50371 for low power emitting devices with a maximum total of 20 mW average emitted power.

Three different EMC compliance measurements are the basis for the assessment for each of these frequency ranges:

a) 10 MHz – 30 MHz;

b) 30 MHz – 1 GHz;

c) > 1 GHz.

2 References

EN 50371:2002	Generic standard to demonstrate the compliance of low power electronic and electrical apparatus with the basic restrictions related to human exposure to electromagnetic fields (10 MHz – 300 GHz) – General public
EN 55011:1998	Limits and methods of measurement of radio disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment
EN 55013:2001	Sound and television broadcast receivers and associated equipment. Radio disturbance characteristics. Limits and methods of measurement
EN 55014-1:2007	Electromagnetic compatibility Requirements for household appliances, electric tools and similar apparatus Part 1: Emission
EN 55016-1-3:2007	Specification for radio disturbance and immunity measuring apparatus and methods Part 1-3: Radio disturbance and immunity measuring apparatus Ancillary equipment Disturbance power
EN 55016-2-1:2005	Specification for radio disturbance and immunity measuring apparatus and methods Part 2-1: Methods of measurement of disturbances and immunity Conducted disturbance measurements
EN 55022:1998	Information technology equipment – Radio disturbance characteristics – Limits and methods of measurement
EN 61000-6-3:2001	Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments
EN 61000-6-4:2001	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
ETSI TR 102273-2 V1.2.1:2001	Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties; Part 2: Anechoic chamber
ETSI TR 102273-3 V1.2.1.2001	Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties; Part 3: Anechoic chamber with a ground plane

EU Council Recommentadion 1999/519/EC

ICNIRP Guidelines (4-98)

3   Acronyms

CEN	Comité Européen de Normalisation (in English: European Committee for Standardization)
CENELEC	Comité Européen de Normalisation Electrotechnique (in English: European Committee for Electrotechnical Standardization)
EMF	Electromagnetic Fields
ETSI:	European Telecommunications Standards Institute
ICNIRP	International Commission on Non-Ionizing Radiation Protection
SAR	Standard Absorption Rate

4   Assessment of the total emitted power (to be < 20 mW)

Clause 5 describes in general the substitution measurement method. ETSI TR 102273-2 V1.2.1 (2001-12) and ETSI TR 102273-3 V1.2.1 (2001-12) show details of this method to be applied.

This substitution measurement method is the base for the assessment in Clause 6. It allows the application of EMC compliance measurements to be used to demonstrate compliance to EN 50371.

The practical assessment of a low power apparatus may include two steps:

1st Step   Assessment procedure in Clause 6 is followed to determine if a product falls in the scope of EN 50371 based on EMC measurements (e.g. EN 61000-6-3, 61000-6-4, EN 55011, EN 55013, EN 55014, EN 55022).

2nd Step   The substitution measurement method is used if the first step does not provide adequate results.

5 Substitution method to determine the emitted power of an EUT
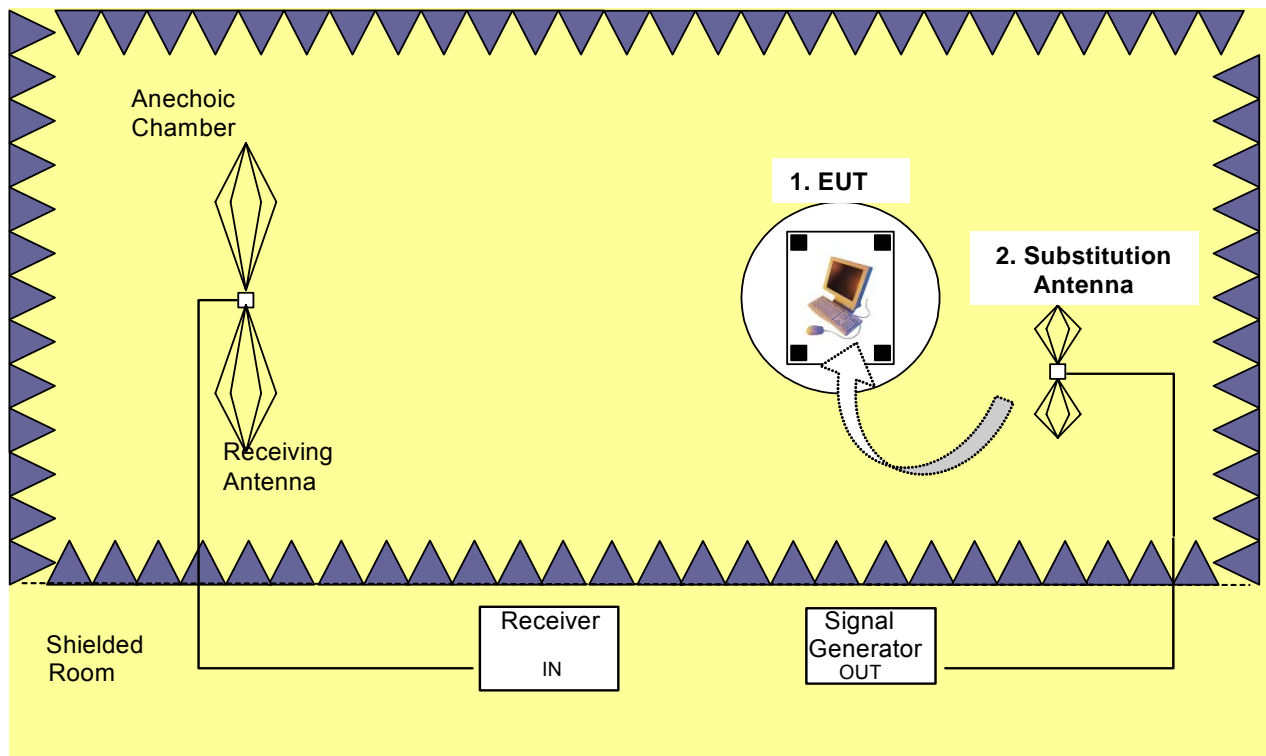
5.1 Setup

Figure 1 – General setup for the substitution method

5.2 Substitution measurement

The substitution measurement should be done in the following steps.

a) Measure each significant emission (maximising emission level by rotating turntable with EUT on it, moving receiving antenna 1m - 4m in height (where applicable) of the EUT and record the receiver reading. An emission is based on the following definition classified as "SIGNIFICANT":

The number and amplitude of spectral lines have to be compared with the *"overestimated real number of spectral lines"* as outlined in Clause 6 using Table 2 or Table 3 for Class B or A respectively and based on this comparison if it is anticipated that the total emitted power will exceed 20 mW, then this emission is classified as "significant".

b) Replace the EUT by an antenna with a known gain which had also be obtained in free space environment and adjust the signal generator output level to the same receiver level for each emission as previously determined in 5.2.a).

c) The radiated power of the EUT is then determined by the formulas in c1) and c2):
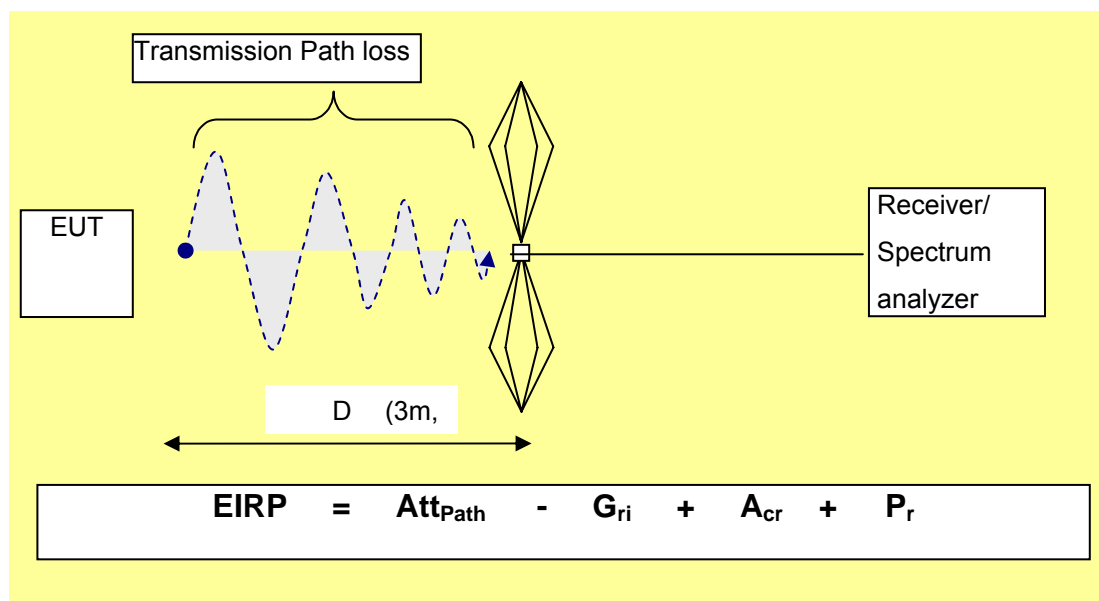
c1)   Measurement of EUT

Transmission Path loss

EUT

Receiver/
Spectrum
analyzer

D   (3m,

$$\text{EIRP} \quad = \quad \text{Att}_{\text{Path}} \quad - \quad G_{\text{ri}} \quad + \quad A_{\text{cr}} \quad + \quad P_{\text{r}}$$

Figure 2 – Radiated power measurement from the EUT

EIRP   :   Effective Isotropic Radiated Power of the EUT

Att_{Path} :   Path loss of the transmission distance (3m or 10m)

G_{ri} :   Gain of the receiving antenna (calibrated as isotropic gain)

A_{cr} :   Attenuation of coaxial receiving signal cable

P_{r} :   Received power at the input of the receiver/spectrum analyser

c2)   Substitution of the EUT

After measuring the emissions of the EUT, the EUT is removed and a substitute antenna is placed instead of the EUT at the same height and same distance from receiving antenna. For each frequency under measurement the signal generator level is adjusted to obtain the same reading level as recorded before as EUT emission level.
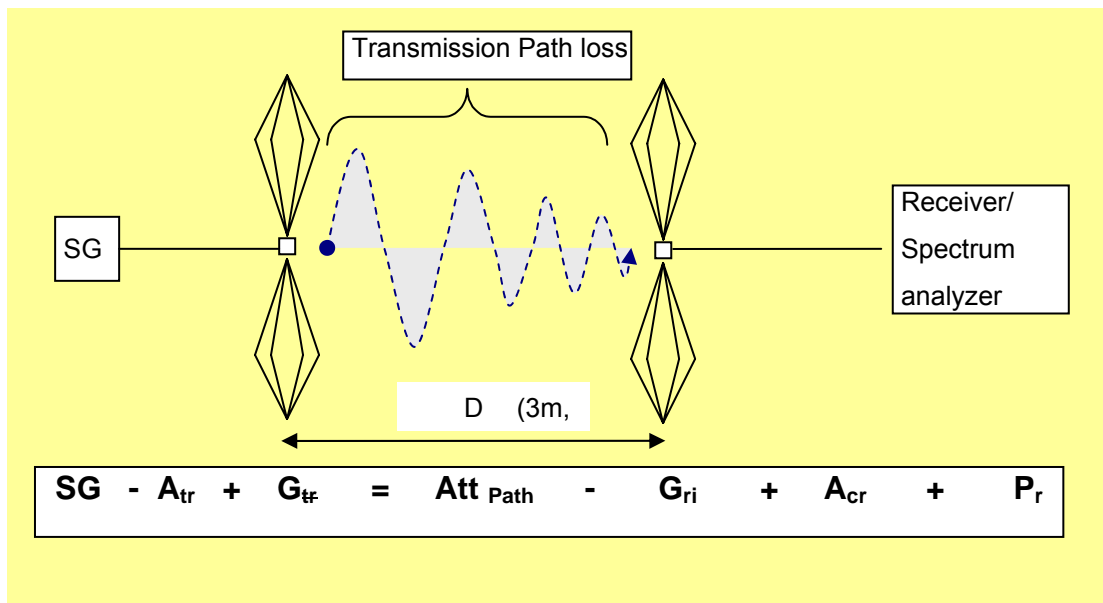
Figure 3 – Radiated power measurement from the reference antenna + signal generator

SG : Signal generator output level

Atr : Attenuation of the cable between SG and transmit antenna

Gtr : Gain of the transmitting antenna (calibrated as isotropic gain)

AttPath : Path attenuation of the transmission distance (3m or 10m)

Gri : Gain of the receiving antenna (calibrated as isotropic gain)

Acr : Attenuation of coaxial receiving signal cable

Pr : received power at the input of the receiver/spectrum analyser

The resulting value for the EIRP for each individual emitted frequency can be calculated by the following formula:

$$EIRP = SG - A_{tr} + G_{tr} \tag{1}$$

If ERP (reference is λ/2 dipole as transmit antenna) is being used as reference:

$$ERP = EIRP - 2.15 \text{ dB}. \tag{2}$$

Further details on the substitution method can be found in 7.2.3 of ETSI TR 102273-2 V1.2.1 (2001-12) and ETSI TR 102273-3 V1.2.1 (2001-12).

5.3 Simplified substitution method to determine the emitted power of an EUT

NOTE
The simplified substitution method can only be applied, when the following conditions are fulfilled:

- *The measurement environment (Fully Anechoic Chamber) must provide free space environment in terms of electromagnetic radio wave propagation.*

- *The measurement distance d must meet far field conditions: d ≥λ/2π.*

When the simplified substitution method is applied, the EIRP can be determined by calculation only, when path loss, gain of the receiving antenna, and cable loss of the coaxial cable between receiving antenna and receiver/spectrum analyser are known.

The EIRP can then be calculated as follows:

$$EIRP = Att_{Path} - G_n + A_{cr} + P_r \tag{3}$$

5.3.1 Determination of free space path attenuation (Att$_{Path}$)

The free space path attenuation is defined as the ratio between the transmitted power and the power received at a distance (d):

$$\frac{P_t}{P_r} = \frac{(4\pi df)^2}{(C_0)^2} \Rightarrow 10 \log \frac{P_t}{P_r} = 20 \log(\frac{4\pi}{C_0}) + 20 \log d + 20 \log f \tag{4}$$

This equals if distance d is in [m] and frequency f is in [MHz]:

$$Att_{path} = -27{,}56 + 20 \log d + 20 \log f \tag{5}$$

and if distance is in [m] and frequency f is in [GHz]:

$$Att_{path} = 32{,}44 + 20 \log d + 20 \log f \tag{6}$$

For a measurement distances of 3 m and 10 m the resulting path attenuation is:

Table 1 – Path attenuation at 3 and 10 m

Frequency/GHz	Path attenuation/ dB Distance d = 3 m	Path attenuation/dB Distance d = 10 m
0.03	11.52	21.98
0.05	15.96	26.42
0.1	21.98	32.44
0.2	28.00	38.46
0.3	31.52	41,98
0.6	37.54	48,00
0.8	40.04	50.50
1.0	41.98	52,44
2.0	48.00	58,46
3.0	51.52	61.98
4.0	54.02	64,48
6.0	57.54	68.00
8.0	60.04	70.50
10.0	61.98	72,44
12.0	63.56	74,02
15.0	65.50	75,96
20.0	68.00	78.46
25.0	69.94	80.40
30.0	71.52	81.98

Example:

The EUT emission is measured at 200 MHz, the Receiver input signal is indicated as -57 dBm, the measurement distance is 3 m.

P$_r$:   - 57 dBm

A$_{cr}$:   2.5 dB

Gri   :   3.5 dB

Att Path   :   28 dB

$$EIRP = Att_{Path} - G_n + A_{cr} + P_r$$

EIRP = -30 dBm

6 Determination of the total emitted power by assessing its value based on the substitution method and EMC measurements

It is assumed – as a worst case - that the EUT emits its radiated power over the whole frequency range of EN 50371 between 10 MHz and 300 GHz as wide band spectrum. Consecutive spectral lines are separated by the EN 55016 resolution bandwidth and are emitting exactly on the limits of the applicable EMC standards:
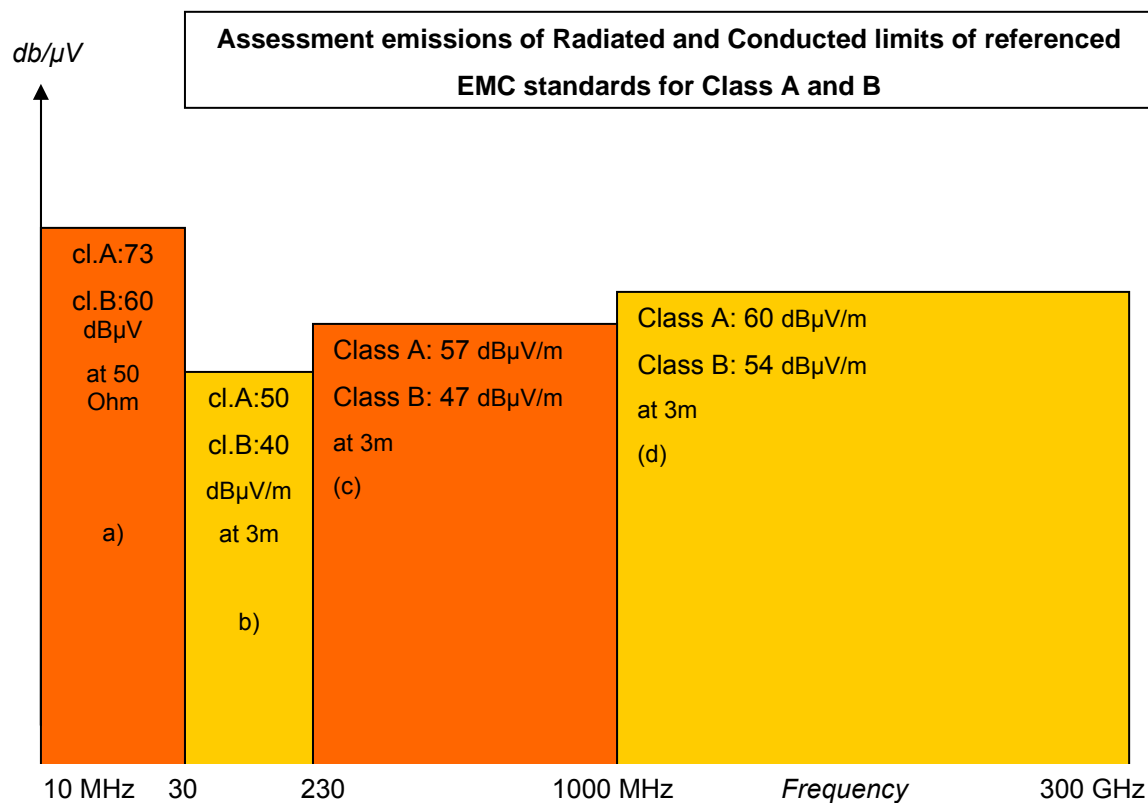

Figure 4 – Assessment emissions of Radiated and Conducted limits of referenced EMC standards for Class A and B

The whole frequency band of EN 50371 is not covered by a single EMC standard. The following EMC standard requirements are the base for the limits stated in figure 4.

a) EN 55022:1998 Table 5.1 and 5.2: Power line conducted emission

10 MHz to 30 MHz   limit: ⇨ class A: 73 / class B: 60 [dbµV/]   (a)

b) and c) EN 55022:1998 Tables 5 and 6: measurement distance: 3m

30 MHz to 230 MHz   limit: ⇨ class A: 50 / class B: 40 [dbµV/m]   (b)

230 MHz to 1000 MHz   limit: ⇨ class A: 57 / class B: 47 [dbµV/m]   (c)

d) FCC Part 15 Subpart B (2003) measurement distance 3m

> 1000 MHz   limit: ⇨ class A: 60 / class B: 54 [dbµV/m]   (d)

The total emitted power is assessed under the theoretical assumption that the EUT radiates with an equal distance between the spectral lines, which leads to following equations:
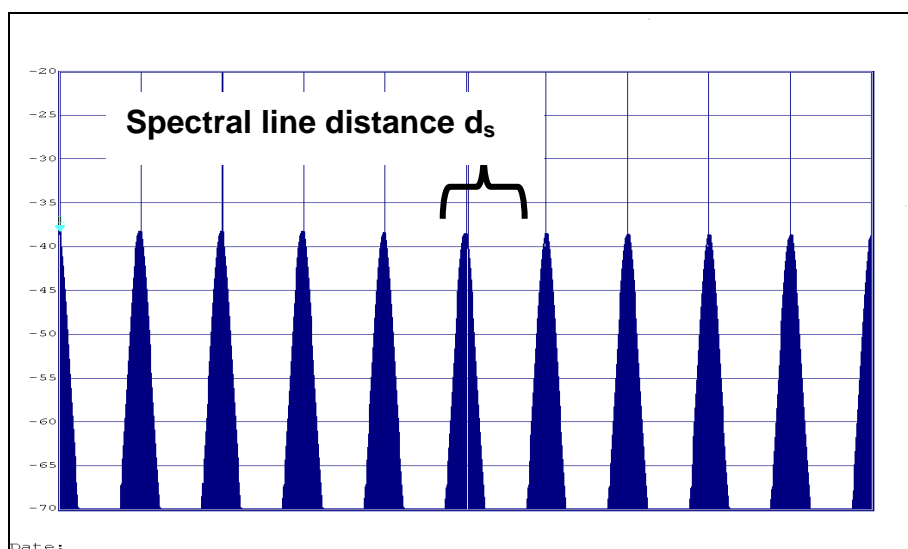

Figure 5 – Spectral lines and spectral line distance

10 MHz to 30 MHz

In band a) a receiver (EN 55016) resolution bandwidth of 9kHz as the spectral line distance d_s leads to the following maximum number of spectral lines:

$$\frac{30MHz - 10MHz}{9kHz} = 2222[Spectral\_Lines]$$

30 MHz to 230 MHz and 230 MHz to 1000 MHz

In bands b) and c) a receiver (EN 55016) resolution bandwidth of 120kHz as spectral distance d_s leads to the following maximum numbers of spectral lines:

$$\frac{230MHz - 30MHz}{120kHz} = 1667[Spectral\_Lines]$$

And

$$\frac{1000MHz - 230MHz}{120kHz} = 6417[Spectral\_Lines]$$

1 GHz to 300 GHz

In band d) a receiver (EN 55016) resolution bandwidth of 1 MHz as spectral distance d_s leads to the following maximum number of spectral lines:

$$\frac{300GHz - 1GHz}{1MHz} = 299000[Spectral\_Lines]$$

Under this assumption, over the whole frequency band from 10 MHz to 300 GHz; the total power of 309306 (= 299000 [d] + 6417[c] + 6417 [b] + 2222 [a]) spectral lines has to be determined.

The radiated power is to be determined as follows:

$$P_{Total} = \sum_1^n P_{SL} \qquad (7)$$

PSL = EIRP of a single spectral line n = total No of spectral lines

EMC measurements provide electrical field strength measured at a given distance from the source of radiation. The relationship between field strength and source power is as follows:

$$E = \frac{1}{2r}\sqrt{\frac{Ps \times Z_0 \times 1.64}{\pi}} \qquad (8)$$

The above equation is valid for far field free space conditions. The electrical field strength E_r is the field strength present at distance r from an RF power source.

Here the RF power is given as ERP through dissipation by a λ/2 Dipole which has a numeric gain of 1.64.

When radiated EMC measurements are performed above a metallic ground plane, both direct and reflected RF wave reach the receiving antenna. By 360° rotation of the EUT and positioning the receiving antenna between 1 m and 4 m height, an attempt is made to maximise field strength. In-phase adding of both waves can lead to an increase of Field strength of up to 6 dB compared to free space conditions.

For the further analysis this is neglected, which results in an additional margin to the limit.

Then the logarithmic equation for the determination of the substituted ERP is:

$$P_{ERP} = E_r - 7.4 - 20 \times \log\left(\frac{3}{r}\right) \qquad (9)$$

With P_{ERP} in [dBpW], E_r in [dBμV/m], distance r in [m]

If reference is EIRP, combination of (2) and (9) gives:

$$P_{EIRP} = E_r - 5.25 - 20 \times \log\left(\frac{3}{r}\right) \qquad (10)$$

Table 1 shows the results at a given distance r of 3 m or as power line conducted over 50 Ohm for Class B equipment.

Table 2 – Class B

	Band a) 10 – 30 MHz over 50 Ohm		Band b) 30–230 MHz	Band c) 230-1000 MHz	Band d) 1 – 300 GHz	**Power** **Sum** **a) – d)**
EMC limit (dBµV/50Ohm)	60 (dBµV/50Ohm)	EMC limit (dBµV/m)	40 dBµV/m	47 dBµV/m	54 dBµV/m	
PEIRP per spectral line (dBm)	- 47 dBm	PEIRP per spectral line (dBpW)	34.75 dBpW	41.75 dBpW	48.75 dBpW	
PEIRP per spectral line (mW)	0.00002	PEIRP per spectral line (mW)	0.00000299	0.00001496	0.00007499	
max number of spectral lines	2222	max number of spectral lines	1667	6417	299000	
max Total Power 2 x lines inside Band (mW)	0.089	Total Power inside Band (b-d); (mW)	0.00498	0.096	22.42	**22.61**
Total Power for 2 x lines inside Band (dBm)	- 10.05	Total Power inside Band (b-d); (dBm)	- 23.03	- 10.18	13.51	**13.54**
overestimated real number of spectral lines	500	overestimated real number of spectral lines	400	1000	1000	
overestimated real Power for 2 x lines inside Band a); (mW)	0.02	overestimated real Power inside Band (b-d); (mW)	0.001196	0.01496	0.07499	**0.1111**
overestimated real Power for 2 x lines inside Band a); (dBm)	-16.989	overestimated real Power inside Band b-d) (dBm)	-29.22	- 18.25	-11.25	**-9.54**

With (7) the maximum total emitted power(P_{EIRP}) when all spectral lines are measured up to its EMC-limit is:

$$P_{Total} = \sum_{1}^{309306} P_{SL} = \sum P_{a)} + P_{b)} + P_{c)} + P_{d)} = 22.61 \text{ mW} \qquad (11)$$

The maximum emitted overestimated real power(P EIRP) is: 0.1111 mW for Class B products.

The following table 2 shows the results at a given distance r of 3 m or as power line conducted over 50 Ohm for Class A equipment.

Table 3 – Class A

	Band a) 10 – 30 MHz over 50 Ohm		Band b) 30–230 MHz	Band c) 230-1000 MHz	Band d) 1 – 300 GHz	**Power Sum a) – d)**
EMC limit (dBµV/50Ohm)	73 (dBµV/50Ohm)	EMC limit (dBµV/m)	50 dBµV/m	57 dBµV/m	60 dBµV/m	
PEIRP per spectral line (dBm)	- 34 dBm	PEIRP per spectral line (dBpW)	44.75 dBpW	51.75 dBpW	54,75 dBpW	
PEIRP per spectral line (mW)	0.0004	PEIRP Per spectral line (mW)	0.0000299	0.0001496	0.000298	
max number of spectral lines	2222	max number of spectral lines	1667	6417	299000	
max Total Power 2 x lines inside Band (mW)	1,78	Total Power inside Band (b-d); (mW)	0.049	0.96	89.40	**92.189**
Total Power for 2 x lines inside Band (dBm)	2.50	Total Power inside Band (b-d); (dBm)	-13.09	-0,177	19.51	**19.65**
overestimated real number of spectral lines	500	overestimated real number of spectral lines	400	1000	1000	
overestimated real Power for 2 x lines inside Band a); (mW)	0.4	overestimated real Power inside Band (b-d); (mW)	0.012	0.1496	0.299	**0.861**
overestimated real Power for 2 x lines inside Band a); (dBm)	-3.979	overestimated real Power inside Band (b-d); (dBm)	-19.21	-8.25	-5.24	**-0.65**

With (7) the maximum total emitted power (P_{EIRP}) when all spectral lines are measured up to its EMC-limit is:

$$P_{Total} = \sum_{1}^{309306} P_{SL} = \sum P_{a)} + P_{b)} + P_{c)} + P_{d)} = 92.189 \text{ mW} \qquad (12)$$

The maximum emitted overestimated real power (P_{EIRP}) is **0.861 mW** for Class A products.

The emitted power calculated by this way is overestimated for Class B as well as Class A products, but is still lower than 1/20 of the of 20 mW limit of EN 50371.

This assumption is very conservative because all the different frequencies radiate in different directions and will never reach at the same time any 10 g of human tissue.

Conclusion

Compliance with EN 50371 may be demonstrated based on EMC standard measurements and an EMF assessment based on this Technical Report.

Such assessment takes the power line Conducted Emissions and the Radiated Electromagnetic Emissions in the frequency range between 10 MHz to 40 GHz (300 GHz at later stage) in consideration and proofs that the total emitted power is less than the 20 mW limit.

The following steps should be performed to assess the EUT emitted power based on the EMC limits shown in Figure 5.

1) If all the frequencies are measured within the limits and an engineering analysis according to the number of measured emissions shows that the total of emitted power is clearly below the 20 mW limit, compliance with EN 50371 can be concluded without the need of substitution measurements.

2) If the limits as shown above are exceeded and if these emissions are found to be significant with respect to the definition in 5.2, then for those frequencies the emitted power has to be evaluated by applying the substitution method (simplified substitution, if the site fulfils free space conditions). If results show that the total emitted power is less than 20 mW, compliance with EN 50371 can be concluded.

6.1 Measurement method and uncertainties to determine the emitted power

All measurement should be done as described within the referenced standards.

Consideration of measurement uncertainties

Measurements uncertainties are well described within EN 55016.

NOTE
The uncertainty can increase if the margin of the results of an assessment to any limit also increases.