Maximum Permissible Exposure (MPE) Estimation

MPE Calculation for the Essence mobile phone – models GDP-10 and GDP-09

1 Abstract

Essence desktop phone (GDP-10, GDP-09) uses LTE / WCDMA / GSM cellular module to send and receive RF signal. Far-field calculation of maximum permissible exposure (MPE) has been done to determine the compliance of Essence with relevant legislation for the exposure to radio waves. MPE calculation was done at the distance of 20cm. It shows that maximum power density at this distance is less than 10% of the limit value for the respective GSM, WCDMA and LTE bands.

2 Content

3 Version History

Version	Date	Change Description
1.0	9.4.2021	Calculation MPE for GDP-09 LTE
1.1	13.4.2021	Review and final formatting
2.0	12.12.2022	Calculation verified for the GDP-10 model

4 Introduction

Desktop phone Essence (models GDP-06, GDP-06i, GDP-06e, GDP-09, GDP-10) is subscriber equipment for the mobile network. Essence GDP-10 and GDP-09 use the modules manufactured by Quectel which implements such functions as RF signal receiving/transmitting, LTE/WCDMA/GSM protocol processing, data service etc.

The Essence phone (further End User Terminal - EUT) is designed not to exceed the limits for exposure to radio waves recommended by international guidelines. These guidelines were developed by the independent scientific organization ICNIRP and include safety margins designed to assure the protection of all persons, regardless of age and health.

5 Limits and Guidelines on Exposure to Electromagnetic Fields

5.1 FCC guideline

According to the FCC Part 2.1093 (which reference the Part 1.1310), we know that portable device is defined as a transmitting device designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitters radiating structure(s) and the body of the user or nearby persons. And the Cellular radiotelephone service and PCS services are subject to routine environmental evaluation for RF exposure prior to equipment authorization or use if they operate at frequencies of 1.5 GHz or below and their effective radiated power (ERP) is 1.5 watts or more, or if they operate at frequencies above 1.5 GHz and their ERP is 3 watts or more.

General population/uncontrolled exposure apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or cannot exercise control over their exposure. The exposure levels can be expressed in terms of power density, electric field strength, or magnetic field strength, as averaged over 30 minutes for the general public and 6 minutes for trained personnel. The exposure criterion is frequency dependent, and a chart covering the range from 3 kHz to 100 GHz can be found in NCRP No.86 (references IEEE C95.1-1999). The limits are in tables below.

Table 1 - FCC Limits of Maximum Permissible Exposure (MPE) for Occupational/Controlled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0,3-3,0	614	1,63	(100)*	6
3,0-30	1842/f	4,89/f	(900/f2)*	6
30-300	61,4	0,163	1	6
300-1500	--	--	f/300	6
1500-100,000	--	--	5	6

Table 2 - FCC Limits of Maximum Permissible Exposure (MPE) for General Population/Uncontrolled Exposure

Frequency Range (MHz)	Electric Field Strength (E) (V/m)	Magnetic Field Strength (H) (A/m)	Power Density (S) (mW/cm^2)	Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes)
0,3-1,34	614	1,63	(100)*	30
1,34-30	824/f	2,19/f	(180/f2)*	30
30-300	27,5	0,073	0,2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1	30

*f = frequency in MHz, *Plane-wave equivalent power density*

*NOTE: **Occupational/controlled** limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.*

Power density S [mW/cm^2] for controlled area at 850MHz/900MHz band is defined as

$$S = \frac{f(MHz)}{300} = \frac{824}{300} = 2.75\ mW/cm^2$$

Power density S [mW/cm^2] for uncontrolled area at 850MHz/900MHz band

$$S = \frac{f(MHz)}{1500} = \frac{824}{1500} = 0.55\ mW/cm^2$$

Note: Based on the worst-case assumption we will use the same limit values also for the GSM900 band.

Power density S [mW/cm^2] for uncontrolled area at 1900/2400 MHz is defined

$$S = 1\ mW/cm^2$$

Reference levels are provided for exposure assessment to determine whether the basic restrictions on exposure of humans to electromagnetic fields are exceeded. The basic restrictions on exposure to electromagnetic fields are based directly on established health effects and biological considerations.

For the following calculation of power density limits we will consider only the stricter conditions for uncontrolled areas.

5.2 ICNIRP guideline

In Europe the exposure to the electromagnetic fields (EMF) is regulated by Recommendation 1999/519/EC on the basic of the 1998 guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which are recommended by the World Health Organization (WHO). These limits were confirmed as protective against all established health risks by ICNIRP in 2009 and by European Commission scientific advisory committees from 1998-2009 (Directive 2013/35/EU).

Table 3 – Exposure limits established by ICNIRP

FREQUENCY RANGE	E-FIELD STRENGTH (V/M)	H-FIELD STRENGTH (A/M)	EQUIVALENT PLANE WAVE POWER DENSITY S_{EQ} (W/m^2)
Up to 1 Hz	–	$3.2 \cdot 10^4$	–
1-8 Hz	10,000	$3.2 \cdot 10^4/f^2$	–
8-25 Hz	10,000	$4{,}000/f$	–
0.025-0.8 kHz	$250/f$	$4/f$	–
0.8-3 kHz	$250/f$	5	–
3-150 kHz	87	5	–
0.15-1 MHz	87	$0.73/f$	–
1-10 MHz	$87/f^{1/2}$	$0.73/f$	–
10-400 MHz	28	0.073	2
400-2000 MHz	$1.375f^{1/2}$	$0.0037f^{1/2}$	$f/200$
2-300 GHz	61	0.16	10

Note:
1. f is as indicated in the frequency range column.
2. Provided that basic restrictions are met and adverse indirect effects can be excluded, field strength values can be exceeded.
3. For frequencies between 100 kHz and 10 GHz, S_{eq}, E^2 and H^2 are to be averaged over any 6-min period.
4. For peak values at frequencies up to 100 KHz see Table 4, note 3.
5. For peak values at frequencies up to 100 kHz, see Figs. 1 and 2. Between 100 kHz and 10 MHz, peak values for the field strengths are obtained by interpolation from the 1.5-fold peak at 100 MHz to the 32-fold peak at 10 MHz. For frequencies exceeding 10 MHz, it is suggested that the peak equivalent plane-wave power density, as averaged over the pulse width, does not exceed 1,000 times the S_{eq} restrictions, or that the field strength does not exceed 32 times the field strength exposure levels given in the table.
6. For frequencies exceeding 10 GHz, , S_{eq}, E^2 and H^2 are to be averaged over any $68/f^{1.05}$-min period (f in GHz).
7. No E-field value is provided for frequencies <1 Hz, which are effectively static electric fields, perception of surface electric charges will not occur at field strengths less than 25 kVm^{-1}. Spark discharges causing stress or annoyance should be avoided.

The EU Recommendation 1999/519/EC is based on ICNIRP guideline and determines following limits for electromagnetic fields:

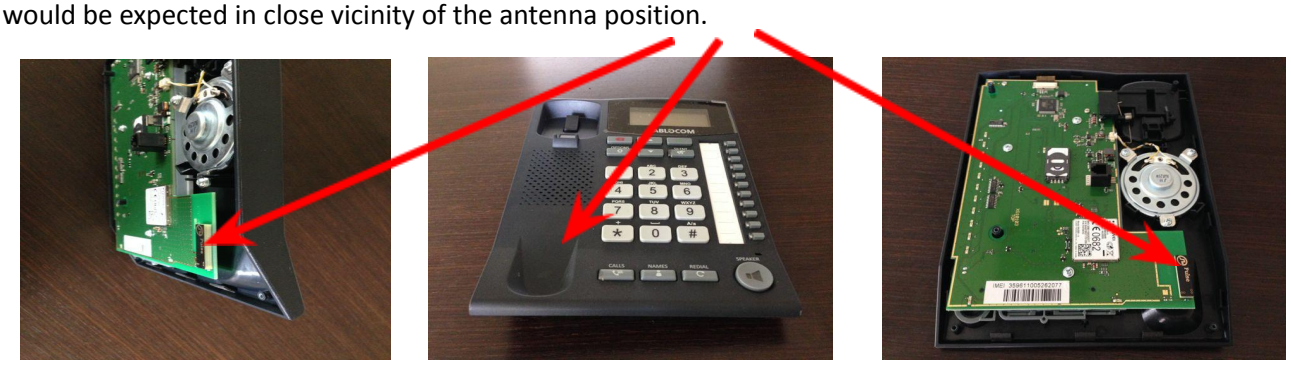
Table 4 – Exposure limits regarding the Recommendation 1999/519/EC

Recommendation 1999/519/EC	Electric field strength [V/m]	Magnetic flux density [uT]	Equivalent plain wave power density [W/m^2]	Equivalent plain wave power density [mW/cm^2]
900 MHz	41	0.14	4.5	0.45
1800 MHz	58	0.20	9	0.9
> 2000 MHz	61	0.20	10	1.0

The RF exposure limits adopted by FCC are similar but not as strict as the ICNIRP reference levels. To show the RF compatibility we can consider the stricter EU limits (based on ICNIRP) for the rest of this document.

6 Antenna location

The source of the radiation is mounted inside of the terminal body (EUT). The highest level of emission would be expected in close vicinity of the antenna position.



As for the desktop phone the normal working distance is much bigger than 20 cm, we may use the MPE calculation. Regarding the EN 50566:2013 the normal working distance must be clearly must be indicated in the EUT user guide:

„To comply with the international guidelines for the exposure to radio waves, the phone is to be placed in a position where the distance from the user body is normally greater than 20 cm.“

7 Prediction of the Exposure to Electromagnetic Fields

Calculations can be made on a site-by-site basis to ensure the power density is below the limits given above, or guidelines can be done beforehand to ensure the minimum distances from the antenna is maintained through the site planning. The calculations are based on the INCIRP 1998 Guideline for EMF with frequencies between 100kHz and 300GHz confirmed in 2009 and comply with FCC OET 65 Appendix B.

7.1 Calculation of the Safe Distance

Below method describes a theoretical approach to calculate possible exposure to electromagnetic radiation around a EUT transceiver antenna. Precise statements are basically only possible either with measurements or complex calculations considering the complexity of the environment (e.g. soil conditions, near buildings and other obstacles) which causes reflections, scattering of electromagnetic fields.

The maximum output power (given in EIRP) of the transmitter is limited to 2 Watts by 3GPP definitions.

A rough estimation of the expected exposure in power flux density on a given point can be made with the following equation.

$$S = \frac{P*G}{4*\pi*r^2}$$

Whereas: P = Maximum output power in W of the site, $G_{numeric}$ = Numeric gain of the antenna relative to

isotropic antenna, r = distance between the antenna and the point of exposure in meters.

MPE estimation cannot be used for distance lower than 20cm from the antenna. When MPE estimation is used the EUT User Guide must clearly declare the minimal installation distance from the user body (more than 20cm) for normal use.

7.2 Technical specification - measured values

Maximum values of radiated RF output power were measured in the TELEFICATION laboratories (Notified Body 0560):
LTE Modul EC21-EU QUECTELCertificate No.: 182140407/AA/01

The embedded antenna characteristics were measured by Unictron Tech.:
Chip Antenna CC40D7J Test report from 2020/12/04

The highest values of output power are used for calculation. Antenna cable attenuation is considered as 0dB.

Band	GSM 900	GSM 1800
TX Band [MHz]	880-915	1710-1785
Output power at RF power amplifier output [dBm]	33	30
Input to antenna [W]	1.99	1.00
Antenna peak gain [dBi]	-1.1	3.7
Antenna gain numeric	0.77	2.34
Calculated maximal power density S_{max} [mW/cm²]	0.048	0.074

Note: Output power has been measured in 1/8 duty factor mode for GSM (one timeslot).

WCDMA Band	Band VIII	Band I
TX Band [MHz]	880-915	1920-1980
Output power at RF power amplifier output [dBm]	24	
Input to antenna [W]	0.25	
Antenna peak gain [dBi]	-1.1	4.1
Antenna gain numeric	0.77	2.57
Calculated maximal power density S_{max}[mW/cm²]	0.038	0.128

Note: 0dBm = 1mW, $P[W] = 1W * 10^{\frac{X-30}{10}}$ *, where X is power in dBm*

LTE FDD Band	B1	B3	B7	B8	B20	B28A
Uplink freq. [MHz]	1920-1980	1710-1785	2500-2570	880-915	832-862	832-862
Module RF Output power (max.) [W]	23					
Input to antenna [W]	0.20					
Antenna peak gain [dBi]	4.1	3.7	2.9	-1.1	0.5	0.5
Antenna gain numeric	2.57	2.33	1.95	0.77	1.12	1.12
Calculated maximal power density S_{max}[mW/cm²]	0.102	0.093	0.077	0.030	0.044	0.044

Note: For the worst-case scenario the maximal output power is used according the 3GPP TS 36.101 R8 Class 3 *compliance.*

7.3 Estimation of compliance boundary for built-in antenna

To determine the final compliance boundary the model for far-field calculation is used since this overestimates the field strength in the near-field region. Thus, the calculated compliance boundary should be rather more conservative and on the safe side. The following compliance boundary is calculated:

7.3.1 GSM900 Band

For the r=20cm and 900MHz GSM we get

$$S_{max} = \frac{P*G_{Numeric}}{8*4*r^2*\pi} * 1.27 = \frac{1990mW*0.77*1.27}{8*4*20^2*\pi} = 0.048mW/cm^2$$

The maximal power density S_{max} for GSM900 band is less than 10% of EU limit of power density (ICNIRP limit S_{limit} = 0.45mW/cm²).

7.3.2 GSM1800 Band (DCS)

For EUT the following compliance boundary is calculated:

$$S_{max} = \frac{1000mW*2.34*1.27}{8*4*20^2*\pi} = 0.074mW/cm^2$$

The maximum power density S_{max} is significantly lower than ICNIRP based limit S_{limit} = 0.9mW/cm² for GSM1800 band.

1.1.1 WCDMA Bands

Based on the worst possible case assuming we consider the following condition for the S_{max} estimation:

- Activity factor = 1 (15 slots are used per TTI, non-moving device - velocity 0km/h, no additional uplink power reduction is considered)
- Maximal Output Power 24dBm = 0.25 Watts for Power class device 3 regarding the 3GPP TS 25.101 6.2.1 (Theoretical value is higher than measured maximal output power – see table above)

$$S_{15/15}(800MHz) = \frac{250mW*0.77}{4*20^2*\pi} = 0.038mW/cm^2$$

The maximum power density S_{max} for WCDMA Band VIII is significantly lower than allowed limits (FCC limit 0.55mW/cm² resp. ICNIRP limit 0.45mW/cm²).

$$S_{15/15}(1900MHz) = \frac{250mW*2.57}{4*20^2*\pi} = 0.128mW/cm^2$$

The maximum power density S_{max} for WCDMA Band I is significantly lower than allowed limits (1mW/cm²).

1.1.2 LTE Bands

Based on the worst possible case assuming we consider the following condition for the S_{max} estimation:

- Full duty of radio transmitting is considered
- Maximal Output Power 23dBm = 0.20 Watts for Power class device 3 regarding the 3GPP TS 25.101 6.2.1
- Frequency dependency of antenna gain is considered, highest gains are calculated only

$$S_{max}(900MHz) = \frac{200mW*1.12}{4*20^2*\pi} = 0.044mW/cm^2$$

The maximum power density S_{max} for LTE B8, B20 and B28A bands is lower than allowed limits (FCC limit 0.55mW/cm² resp. ICNIRP limit 0.45mW/cm²).

$$S_{max}(1800MHz) = \frac{200mW*2.57}{4*20^2*\pi} = 0.102mW/cm^2$$

The maximum power density S_{max} for LTE B1 and B3 bands is lower than allowed limits (0.9mW/cm²).

$$S_{max}(> 2000MHz) = \frac{200mW*1.95}{4*20^2*\pi} = 0.077mW/cm^2$$

The maximum power density S_{max} for B7 band is lower than allowed limits (1mW/cm²).

8 Conclusion

Considering the worst-case conditions, we showed that estimated values of power density are below the limits for all respective bands and for MPE condition of 20cm distance from the human body.

The desktop phone Essence (GDP-10, GDP-09) complies with all EMF exposure related international regulations, including the Radio and Telecommunications Terminal Equipment Directive 1999/5/EC (R&TTE Directive), Part 15 of the FCC Rules, EC Recommendation 1999/519/EC and ICNIRP 1998 guideline.

9 References

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