1 Reference documents

Reference documents used in this RF exposure evaluation for mod. **FS197** (manufactured by HELLA):

-OET Bulletin 65 Ed. 97-01
-April 2013 FCC-TCB conference notes
-November 2017 FCC-TCB conference notes, page 15-16

2 Requirements and limits

As per Part 1.1310(d)(3) of the FCC Rules a RF exposure evaluation at operating frequencies above 6 GHz, based on MPE limits, is required to evaluate the environmental impact of human exposure to RF radiation as specified in Part 1.1307(b) of the FCC Rules.

The object of this RF exposure evaluation is to prove compliance with the RF exposure limit for general population/uncontrolled exposure in the frequency range of 1500 MHz – 100 GHz as set by "Table 1— Limits for Maximum Permissible Exposure (MPE)" in Part 1.1310(e) of the FCC Rules:

TABLE 1—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm^2)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposure				
0.3-3.0	614	1.63	*100	6
3.0-30	1842/f	4.89/f	$*900/f^2$	6
30-300	61.4	0.163	1.0	6
300-1,500			f/300	6
1,500-100,000			5	6
(B) Limits for General Population/Uncontrolled Exposure				
0.3-1.34	614	1.63	*100	30
1.34-30	824/f	2.19/f	$*180/f^2$	30
30-300	27.5	0.073	0.2	30
300-1,500			f/1500	30
1,500-100,000			1.0	30

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

3 Equation used for calculation

Rather than MPE estimates using the far-field power density equation for small spacings, equation (11) on page 27 of OET Bulletin 65 Ed 97-01 was used to calculate a rough estimate of the maximum power density directly in front of the antenna (at the antenna surface) in mW/cm^2 (given that the limit is expressed in mW/cm^2:

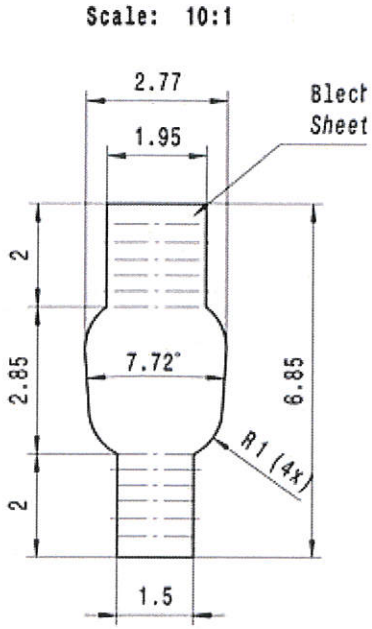
Antenna Surface. The maximum power density directly in front of an antenna (e.g., at the antenna surface) can be approximated by the following equation:

$$S_{surface} = \frac{4P}{A} \qquad (11)$$

where: $S_{surface}$ = maximum power density at the antenna surface
P = power fed to the antenna
A = physical area of the aperture antenna

3.1 Calculation of the physical area of the antenna (A)

For the calculation of the physical area A of the aperture antenna the following drawing of the antenna has been used (dimensions are in mm, the full specifications of the antenna have been uploaded as a separate and confidential exhibit):



Since the shape, especially the mid-section, of the antenna is a bit unusual the following calculation provides a reasonable estimate of the surface area of the antenna. A factor of 0.75 has been used for the mid-section of the antenna in an attempt to approach the real value of the surface area when using a standard true rectangle shape to calculate the surface area of the mid-section. It is assumed that the surface area is underestimated when using a factor of 0.75 and that this approach as such will provide a worst-case prediction of the power density directly in front of the antenna (at the antenna surface):

(1.95 mm * 2 mm) + (1.5 mm * 2 mm) + ((2.85 mm * 2.77 mm) * 0.75) = 3.9 + 3 + (7.89 * 0.75) = 3.9 + 3 + 5.92 = 12.8 mm^2 = A

Or

(0.195 cm * 0.2 cm) + (0.15 cm * 0.2 cm) + ((0.285 cm * 0.277 cm) * 0.75) = 0.039 + 0.03 + (0.079 * 0.75) = 0.039 + 0.03 + 0.059 = 0.128 cm^2 = A

Or

(0.00195 m * 0.002 m) + (0.0015 m * 0.002 m) + ((0.00285 m x 0.00277 m) * 0.75) = $3.9E^{-6}$ + $3E^{-6}$ + ($7.9E^{-6}$ x 0.75) = $3.9E^{-6}$ + $3E^{-6}$ + $5.9E^{-6}$ = $1.28E^{-5}$ m^2 = A

3.2 Calculation of power fed to the antenna (P)

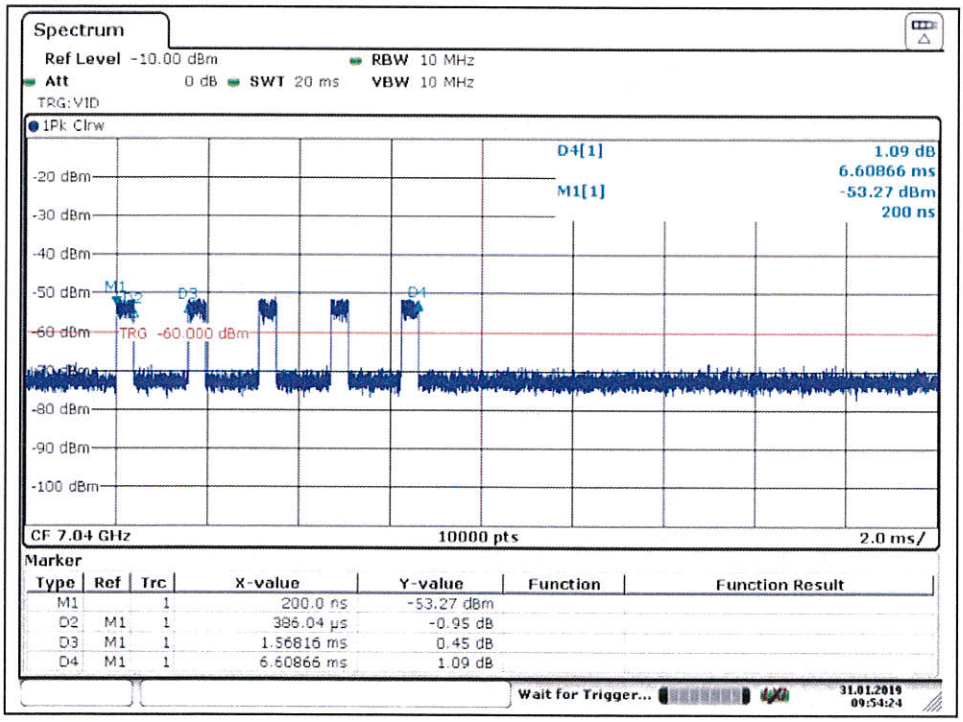
The maximum RF output power fed to the antenna is 0.00056 W or 0.56 mW.

Considering that "Table 1—Limits for Maximum Permissible Exposure (MPE)" in Part 1.1310(e) of the FCC Rules assumes an averaging time of 30 minutes when assessing compliance with the limit(s) this implies that the RF output power fed to the antenna also needs to be adjusted for an averaging time of 30 minutes.

The UWB transmitter in this device will transmit an absolute maximum of 5 pulses after which the transmitter will, as per Part 15.519(a)(1) of the FCC Rules, not transmit within 10 seconds of the last pulse. A worst-case approach to the averaging of the RF output power fed to the antenna is to calculate a duty cycle correction factor for a window of (10 seconds + length of the pulse train) and apply this duty cycle correction factor to the RF output power fed to the antenna of 0.00056 W (0.56 mW).

Given the behavior of the UWB transmitter the duty cycle factor correction would be the same for an averaging window of 30 minutes and this would assume that there will be a transmission of the pulse train every 10 seconds in a period of 30 minutes. While this particular UWB transmitter will not be used as such in normal operation the following is considered to be an absolute worst-case approach where it concerns the averaging of the RF output power fed to the antenna.

As demonstrated by the plot below, the pulse width of a single pulse ($TX\text{-}PULSE_{on}$) is 386 µs, the time between pulses ($TX\text{-}PULSE_{off}$) is 1.182 ms (1.568 ms – 0.386 ms).



The maximum total ON-time in a window of (10 seconds + length of the pulse train) is:

$(5 * \text{TX-PULSE}_{on}) = (5 * 386\ \mu s) = 1.93\ ms = TX_{on}$

The window of (10 seconds + length of the pulse train) is:

$(10\ seconds + (5 * \text{TX-PULSE}_{on}) + (4 * \text{TX-PULSE}_{off}))$

$(10\ seconds + (5 * 386\ \mu s) + (4 * 1.182\ ms)) = 10.00666\ s$

The duty cycle factor correction is therefore:

$(TX_{on} / (10\ seconds + length\ of\ the\ pulse\ train))$

$(1.93\ ms / 10.00666\ s) = 1.92E^{-4}$ (or, 0.0192%)

The average RF output power fed to the antenna (in either a 10 second window or in a 30 minute window assuming a transmission every 10 seconds) is therefore:

$(0.00056\ W) * 1.92E^{-4} = 107.5E^{-9}\ W = 1.075E^{-4}\ mW = P$

3.3 Calculation (estimate) of the maximum power density directly in front of the antenna

Using equation (11) on page 27 of OET Bulletin 65 Ed 97-01 yields the following result:

$S_{surface} = (4 * P) / A = (4 * 1.075E^{-4}\ mW) / 0.128\ cm^2 = 4.3E^{-4}\ mW / 0.128\ cm^2 = 3.36E^{-3}\ mW/cm^2$ (in either a 10 second windows or in a 30 minute window assuming a transmission every 10 seconds)

4 Conclusion

The RF exposure limit for the general population/uncontrolled exposure in the frequency range of 1500 MHz – 100 GHz as set by "Table 1—Limits for Maximum Permissible Exposure (MPE)" in Part 1.1310(e) of the FCC Rules is 1.0 mW/cm^2.

The calculated (estimated) maximum power density directly in front of the antenna is $3.36E^{-3}$ mW/cm^2 (or, 0.00336 mW/cm^2) in either a 10 second windows or in a 30 minute window assuming a transmission every 10 seconds).

As demonstrated by the detailed drawings of the device in question (uploaded as a separate and confidential exhibit), there is also an additional and inherent minimum separation distance of 4.419 mm between the body of the user and the radiating element inside the device.

Conclusion: this UWB transmitter complies with the limit for the general population/uncontrolled exposure in the frequency range of 1500 MHz – 100 GHz as set by "Table 1—Limits for Maximum Permissible Exposure (MPE)" in Part 1.1310(e) of the FCC Rules and therefore with the requirements of the Part 1.1307(b) of the FCC Rules.

Ratingen (Germany), 06th AUG 2019

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