

MPE calculation

The M-Tec tracking device TU500-1 SPOT is a modular approved device that complies with FCC part 2.1091 (b) for mobile devices and RSS-102 Issue 5 for Industry Canada. The TU500-1 SPOT is certified and labeled **“FCC ID: ZMF-ME500”** and **“IC-ID: 9746A-ME500”**. The antenna gain is measured in test report "ME501October2014Ver1.3signed.pdf" as the ME500-x / TU500-x tracking device family are mounted on the same PCB as for the ME501-x / TU501-x family. Thus both tracking device families contain identical antennas.

Frequency	Freespace	
	Antenna efficiency	Peak Gain [dBi]
824 MHz	-2.9 dB ±1.9 dB	1.4 dBi ±1.9 dBi
830 MHz	-2.8 dB ±1.9 dB	2.2 dBi ±1.9 dBi
835 MHz	-2.5 dB ±1.9 dB	1.9 dBi ±1.9 dBi
836 MHz	-2.4 dB ±1.9 dB	2.1 dBi ±1.9 dBi
840 MHz	-2.3 dB ±1.9 dB	1.8 dBi ±1.9 dBi
849 MHz	-3.0 dB ±1.9 dB	1.8 dBi ±1.9 dBi
869 MHz	-2.1 dB ±1.9 dB	2.3 dBi ±1.9 dBi
875 MHz	-2.0 dB ±1.9 dB	3.0 dBi ±1.9 dBi
880 MHz	-2.1 dB ±1.9 dB	3.2 dBi ±1.9 dBi
881 MHz	-2.1 dB ±1.9 dB	3.4 dBi ±1.9 dBi
885 MHz	-2.2 dB ±1.9 dB	3.5 dBi ±1.9 dBi
894 MHz	-2.7 dB ±1.9 dB	3.6 dBi ±1.9 dBi
897 MHz	-3.4 dB ±1.9 dB	2.3 dBi ±1.9 dBi
915 MHz	-4.0 dB ±1.9 dB	-0.5 dBi ±1.9 dBi
925 MHz	-3.5 dB ±1.9 dB	2.2 dBi ±1.9 dBi
942 MHz	-4.1 dB ±1.9 dB	1.5 dBi ±1.9 dBi
960 MHz	-4.9 dB ±1.9 dB	-0.3 dBi ±1.9 dBi
1710 MHz	-7.1 dB ±1.9 dB	-2.7 dBi ±1.9 dBi
1747 MHz	-3.6 dB ±1.9 dB	0.2 dBi ±1.9 dBi
1785 MHz	-2.0 dB ±1.9 dB	1.4 dBi ±1.9 dBi
1805 MHz	-1.7 dB ±1.9 dB	1.5 dBi ±1.9 dBi
1842 MHz	-1.8 dB ±1.9 dB	2.3 dBi ±1.9 dBi
1850 MHz	-1.9 dB ±1.9 dB	2.2 dBi ±1.9 dBi
1880 MHz	-1.6 dB ±1.9 dB	2.7 dBi ±1.9 dBi
1910 MHz	-1.9 dB ±1.9 dB	2.6 dBi ±1.9 dBi
1920 MHz	-1.8 dB ±1.9 dB	2.6 dBi ±1.9 dBi
1930 MHz	-1.7 dB ±1.9 dB	2.8 dBi ±1.9 dBi
1950 MHz	-1.7 dB ±1.9 dB	2.9 dBi ±1.9 dBi
1960 MHz	-1.7 dB ±1.9 dB	3.3 dBi ±1.9 dBi
1980 MHz	-1.7 dB ±1.9 dB	3.1 dBi ±1.9 dBi
1990 MHz	-1.8 dB ±1.9 dB	3.2 dBi ±1.9 dBi
2110 MHz	-2.0 dB ±1.9 dB	3.1 dBi ±1.9 dBi
2140 MHz	-0.8 dB ±1.9 dB	4.6 dBi ±1.9 dBi
2170 MHz	-0.3 dB ±1.9 dB	4.8 dBi ±1.9 dBi

Table-1 ME/TU500 or ME/TU501 antenna gain from ME501October2014Ver1.3signed.pdf test report

With reference to **“KDB 447498 D01 General RF Exposure Guidance v06”** and the **“Health Canada’s RF exposure guideline, Safety Code 6”** the ME500 is classified as a mobile device. The

TU500-1 SPOT is subject for further evaluation according the FCC part 2.1093/RSS-102 for exposures levels defined in FCC part 1.1310/RSS-102 for the general population/uncontrolled environment.

TU500-1 SPOT maximum output power in single GMSK/GPRS transmitting mode:

GSM 850 conducted power (Max): 1.730 W (1 slot)

PCS 1900 conducted power (Max): 0.975 W (1 slot)

TU500-1 SPOT operates as a data only device designed for GPRS multislot class 10 operation.

- Maximum number of active timeslots (TS): 5
- Maximum number of downlink TS: 4
- Maximum number of uplink TS: 2

The worst case operations of the TU500-1 SPOT that will create the maximum output power density of the device occur when using two uplink timeslots for GPRS.

Prediction of MPE limit

Equation from page 18 of OET 65, Edition 97-01

$$S = \frac{PG}{4\pi R^2}$$

Where:

- S = Power density
- P = Power input to the antenna.
- G = Power gain of the antenna in the direction of interest relative to an isotropic radiator.
- R = Distance to the center of radiation of the antenna.

The calculation is performed for each frequency band at the worst case conditions:

Reference table values

The conductivity of the human head and body at various frequencies are listed in the table below:

Target Frequency	Head		Body	
(MHz)	ϵ_r	σ (S/m)	ϵ_r	σ (S/m)
150	52.3	0.76	61.9	0.80
300	45.3	0.87	58.2	0.92
450	43.5	0.87	56.7	0.94
835	41.5	0.90	55.2	0.97
900	41.5	0.97	55.0	1.05
915	41.5	0.98	55.0	1.06
1450	40.5	1.20	54.0	1.30
1610	40.3	1.29	53.8	1.40
1800 – 2000	40.0	1.40	53.3	1.52
2450	39.2	1.80	52.7	1.95
3000	38.5	2.40	52.0	2.73
5800	35.3	5.27	48.2	6.00

(ϵ_r = relative permittivity, σ = conductivity and $\rho = 1000 \text{ kg/m}^3$)

FCC rules

The limits for uncontrolled RF exposure (W/cm^2) over the frequency range 0.3 MHz to 100 GHz are defined as:

(B) Limits 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/f ²)*	30
30-300	27.5	0.073	0.2	30
300-1500	--	--	f/1500	30
1500-100,000	--	--	1.0	30

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

The human body limits are also defined in (W/kg) for uncontrolled exposure in relation to the body mass as:

(B) Limits for General Population/Uncontrolled Exposure (W/kg)

Whole-Body	Partial-Body	Hands, Wrists, Feet and Ankles
0.08	1.6	4.0

IC rules

The limits for uncontrolled RF exposure (W/cm²) over the frequency range 0.003 MHz to 300 GHz are defined as:

Table 4: RF Field Strength Limits for Devices Used by the General Public (Uncontrolled Environment)

Frequency Range (MHz)	Electric Field (V/m rms)	Magnetic Field (A/m rms)	Power Density (W/m ²)	Reference Period (minutes)
0.003-10 ²¹	83	90	-	Instantaneous*
0.1-10	-	0.73/ f	-	6**
1.1-10	87/ $f^{0.5}$	-	-	6**
10-20	27.46	0.0728	2	6
20-48	58.07/ $f^{0.25}$	0.1540/ $f^{0.25}$	8.944/ $f^{0.5}$	6
48-300	22.06	0.05852	1.291	6
300-6000	3.142 $f^{0.3417}$	0.008335 $f^{0.3417}$	0.02619 $f^{0.6834}$	6
6000-15000	61.4	0.163	10	6
15000-150000	61.4	0.163	10	616000/ $f^{1.2}$
150000-300000	0.158 $f^{0.5}$	4.21 x 10 ⁻⁴ $f^{0.5}$	6.67 x 10 ⁻³ f	616000/ $f^{1.2}$
Note: f is frequency in MHz. *Based on nerve stimulation (NS). ** Based on specific absorption rate (SAR).				

The human body limits are also defined in (W/kg) for uncontrolled exposure in relation to the body mass as:

Table 3: SAR Limits for Devices Used by the General Public (Uncontrolled Environment)

Body Region	Average SAR (W/kg)	Averaging Time (minutes) ²⁰	Mass Average (g)
Whole Body	0.08	6	Whole Body
Localized Head, Neck and Trunk	1.6	6	1
Localized Limbs	4	6	10

MPE calculation

For devices operating close to or in relation to the human body the uncontrolled exposure are measured as SAR in (W/kg) and for devices that does not operate in close relation to the human body a MPE calculation determines the uncontrolled exposure level (mW/cm²).

The TU500-1 SPOT is intended to be fixed mounted in vehicles, construction and moving machinery, lifts, cranes, tractors etc. in a minimum distance of 20 cm from the human body that is equal to a MPE calculation in order to comply with the approval requirements for high power devices.

Prediction of MPE limit at a given distance for the 850 MHz band

Measured parameter	Measured Value GPRS	Units
Conducted peak power - 1 slot (Tune-up)	33.5	dBm
Conducted peak power - 1 slot	2238,7	mW
Duty cycle (12.5% per. Timeslot)	25,0	%
Maximum antenna gain*	+1.8	dBi
Maximum antenna gain	1.514	numeric
PAR for GMSK modulation	0	dB
EIRP (mW) - Averaged	717,70	mW
EIRP (mW) - Time-averaged in active slots only	2870.78	mW
Prediction distance (R)	20	cm
Prediction frequency (Pf)	847.8	MHz
FCC: MPE limit for uncontrolled exposure at $P_f (f_{MHz}/1500)$	0.565	mW/cm ²
IC: MPE limit for uncontrolled exposure at $P_f (0.02619 \cdot f_{MHz}^{0.6834})$	0.263	mW/cm ²
Calculated power density for TU500-1 SPOT at P_f (Average)	0.169	mW/cm²
Calculated power density for TU500-1 SPOT at P_f (Time-Average)**	0.674	mW/cm²
* Antenna gain report ME501October2014Ver1.3signed.pdf		
** Gated average over TX slots only.		

Prediction of MPE limit at a given distance for the 1900 MHz band

Measured parameter	Measured Value GPRS	Units
Maximum peak output power (conducted) (Tune-up)	30.5	dBm
Maximum peak output power (conducted)	1122,0	mW
Duty cycle (12.5% per. Timeslot)	25.0	%
Maximum antenna gain*	+2.6	dBi
Maximum antenna gain	1.820	numeric
PAR for GMSK modulation	0	dB
EIRP (mW) - Averaged	453.88	mW
EIRP (mW) - Time-averaged in active slots only	1815.52	mW
Prediction distance (R)	20	cm
Prediction frequency (Pf)	1909.8	MHz
FCC: MPE limit for uncontrolled exposure at Pf	1.0	mW/cm ²
IC: MPE limit for uncontrolled exposure at P _f ($0.02619 \cdot f_{\text{MHz}}^{0.6834}$)	0.458	mW/cm ²
Calculated power density for TU500-1 SPOT at Pf (Average)	0.102	mW/cm²
Calculated power density for TU500-1 SPOT at Pf (Time-Average)**	0.406	mW/cm²
* Antenna gain report ME501October2014Ver1.3signed.pdf		
** Gated average over TX slots only.		