8. RF EXPOSURE

8.1. RULES AND LIMITS

FCC RULES

§1.1310 The criteria listed in Table 1 shall be used to evaluate the environmental impact of human exposure to radio-frequency (RF) radiation as specified in §1.1307(b), except in the case of portable devices which shall be evaluated according to the provisions of §2.1093 of this chapter.

TABLE 1—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm²)	Averaging time (minutes)
(A) Limits for Occupational/Controlled Exposures				
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	1.0	6
300–1500			f/300	6
1500–100,000			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/f²)	30

TABLE 1—LIMITS FOR MAXIMUM PERMISSIBLE EXPOSURE (MPE)—Continued

Frequency range (MHz)	Electric field strength (V/m)	Magnetic field strength (A/m)	Power density (mW/cm²)	Averaging time (minutes)
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

NOTE 1 TO TABLE 1: 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.

NOTE 2 TO TABLE 1: General population/uncontrolled exposures 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 can not exercise control over their exposure.

IC RULES

IC Safety Code 6, Section 2.2.1 (a) A person other than an RF and microwave exposed worker shall not be exposed to electromagnetic radiation in a frequency band listed in Column 1 of Table 5, if the field strength exceeds the value given in Column 2 or 3 of Table 5, when averaged spatially and over time, or if the power density exceeds the value given in Column 4 of Table 5, when averaged spatially and over time.

Table 5
Exposure Limits for Persons Not Classed As RF and Microwave Exposed Workers (Including the General Public)

1 Frequency (MHz)	2 Electric Field Strength; rms (V/m)	3 Magnetic Field Strength; rms (A/m)	4 Power Density (W/m^2)	5 Averaging Time (min)
0.003–1	280	2.19		6
1–10	$280/f$	$2.19/f$		6
10–30	28	$2.19/f$		6
30–300	28	0.073	2*	6
300–1 500	$1.585f^{0.5}$	$0.0042f^{0.5}$	$f/150$	6
1 500–15 000	61.4	0.163	10	6
15 000–150 000	61.4	0.163	10	$616\ 000/f^{1.2}$
150 000–300 000	$0.158f^{0.5}$	$4.21 \times 10^{-4} f^{0.5}$	$6.67 \times 10^{-5} f$	$616\ 000/f^{1.2}$

* Power density limit is applicable at frequencies greater than 100 MHz.

Notes:
1. Frequency, f, is in MHz.
2. A power density of 10 W/m^2 is equivalent to 1 mW/cm^2.
3. A magnetic field strength of 1 A/m corresponds to 1.257 microtesla (µT) or 12.57 milligauss (mG).

8.2. OPERATING MODES

The setup phase (LRP) and normal operation (HRP) do not occur simultaneously; therefore it is appropriate to consider the RF exposure during these two operating modes independently.

8.3. SETUP PHASE (LRP) RESULTS

The Setup Phase (LRP) is a pulsed emission therefore source-based time-averaging is applicable. Referring to the plots below, the duty cycle of the Setup Phase emission is
100 % * (126 us) / (20.7 ms) = 0.61 %

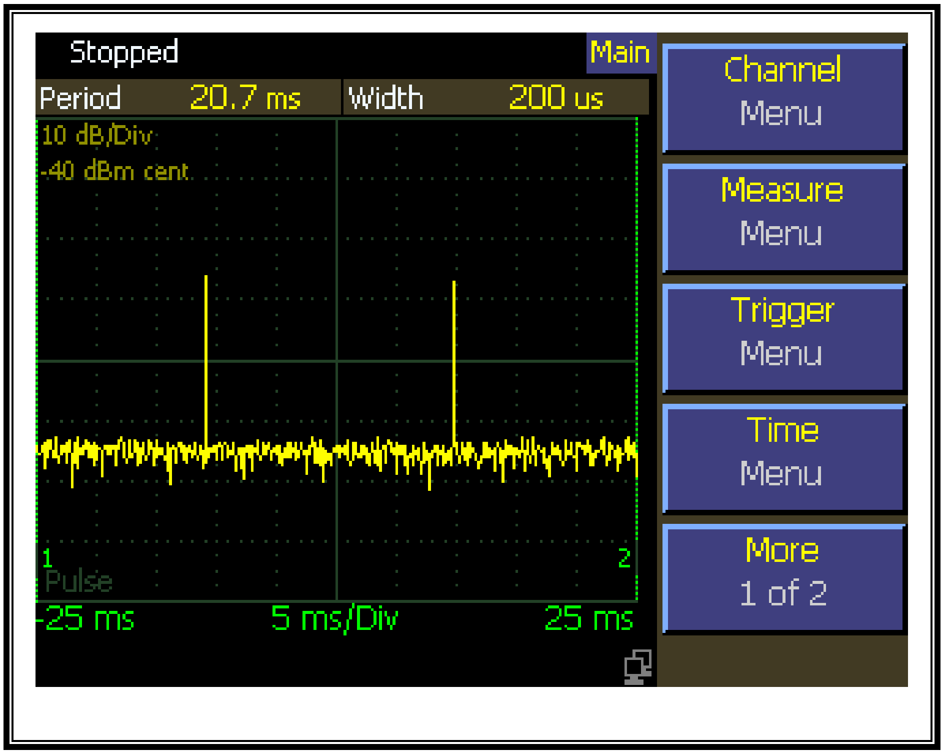
Freq (GHz)	Peak EIRP (dBm)	Peak EIRP (mW)	Duty Cycle (%)	Average EIRP (mW)	Peak Gain (dBi)	Average Power (mW)
60.32	29.1	812.8	0.61	4.958	16.0	0.125
62.64	27.4	549.5	0.61	3.352	16.0	0.084

The orientation of the scanning LRP transmission is unconstrained, therefore the main lobe can be directed toward a person.

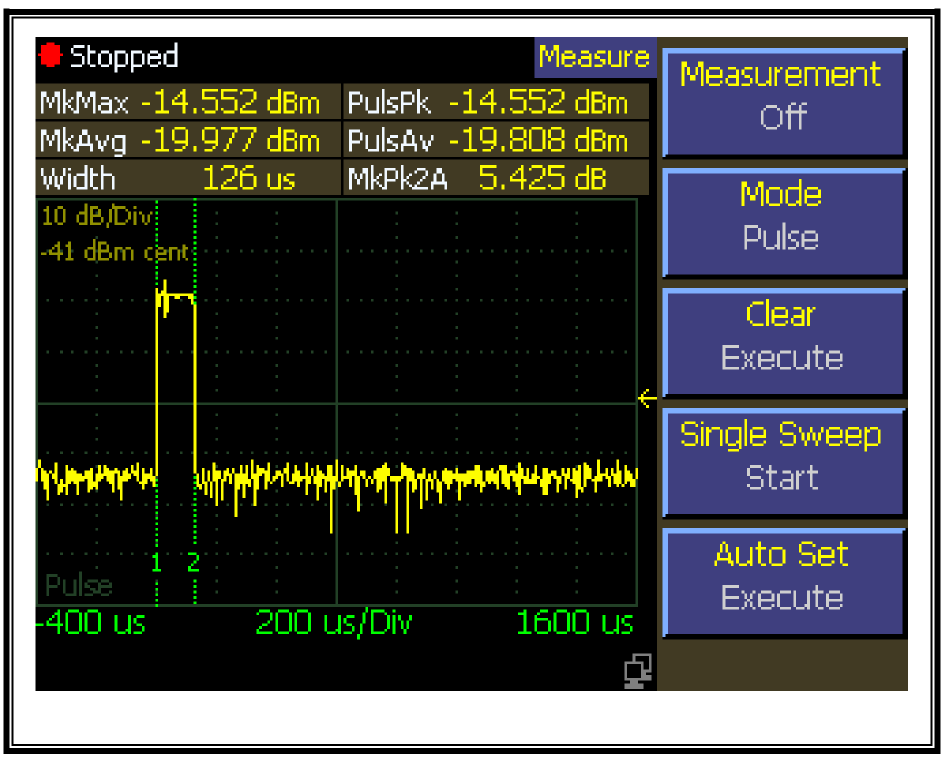
The RF Exposure analysis is made using the peak gain and the source based time average power.

Equations for the Near Field, Transition Field and/or Far Field Regions, as defined by OET 65 and as applicable to the evaluation distance, are used.

DUTY CYCLE



Note: Pulse width measurement has limited resolution in 5 ms/Div scan.



FAR FIELD BOUNDARY CALCULATIONS

The far-field boundary is given by OET 65 Equation 16 as:

$$R_{far\ field} = (0.6 * L^2) / \lambda$$

where:
L = Largest Antenna Dimension
λ = Wavelength

Frequency (GHz)	L (cm)	Lambda (cm)	R (Far Field) (cm)
60.32	2.0	0.497	4.826
62.64	2.0	0.479	5.011

The Mobile evaluation distance is in the far field region for all frequencies. For 60.32 GHz the Portable evaluation distance is also in the far field region.

For 62.64 GHz the Portable evaluation distance is less than the far field region boundary distance.

FAR FIELD RF EXPOSURE EVALUATION

For far-field distances EIRP is converted to Power Density using OET 65 Equation 18:

$$S = EIRP / (4 * Pi * D_S^2)$$

where:
D_S = Separation Distance

Freq (GHz)	Average EIRP (mW)	Separation Distance (cm)	Power Density (mW/cm^2)	FCC Limit (mW/cm^2)	Power Density (W/m^2)	IC Limit (W/m^2)
Mobile Evaluation Distance						
60.32	4.958	20	0.000987	1	0.010	10
62.64	3.352	20	0.000667	1	0.007	10
Portable Evaluation Distance						
60.32	4.958	5	0.015790	1	0.158	10

NEAR FIELD BOUNDARY CALCULATIONS

The near-field boundary is given by OET 65 Equation 12 as:

$R_{near\ field} = (L^2) / (4 * \lambda)$

where:
L = Largest Antenna Dimension
λ = Wavelength

Frequency (GHz)	L (cm)	Lambda (cm)	R (Near Field) (cm)
62.64	2.0	0.479	2.088

For 62.64 GHz the Portable evaluation distance is greater than the near field region boundary distance and less than the far field region boundary, therefore transition field region equations are applicable.

TRANSITION FIELD RF EXPOSURE EVALUATION

Aperture efficiency is given by OET 65 Equation 14 as:

$\eta = (G * (\lambda^2) / (4 * Pi)) / ((Pi * (L^2) / 4)$

where:
G = Power gain of antenna
L = Largest Antenna Dimension
λ = Wavelength

Freq (GHz)	Gain (dBi)	Gain (linear)	Lambda (cm)	L (cm)	Aperture Efficiency (linear)
62.64	16.0	39.8	0.479	2.0	0.232

The maximum value of the near-field power density is given by OET 65 Equation 13 as:

$S_{near\ field}$ = (16 * η * P) / (Pi * (L^2))

where:
η = Aperture efficiency
P = Power fed to the antenna
L = Largest Antenna Dimension

Freq (GHz)	Aperture Efficiency (linear)	Power (mW)	L (cm)	Near Field Power Density (mW/cm^2)
62.64	0.232	0.084	2.0	0.025

The power density in the transition region is given by OET 65 Equation 17 as:

$S_{transition}$ = ($S_{near\ field}$ * $R_{near\ field}$) / D_S
where:
D_S = Separation Distance

Freq (GHz)	Near Field Power Density (mW/cm^2)	Near Field Boundary (cm)	Separation Distance (cm)	Power Density (mW/cm^2)	FCC Limit (mW/cm^2)
62.64	0.025	2.088	5	0.010	1

Freq (GHz)	Power Density (W/m^2)	IC Limit (W/m^2)
62.64	0.104	10

8.4. NORMAL OPERATION (HRP) RESULTS

The orientation of the adaptive beam-forming HRP transmission is constrained to avoid persons by using free-space multipath between the transmitter and receiver, with 90% of the beam energy going through free space. The process of finding the best path is defined as *beam search*. Beam search occurs continuously in the background, such that the channel is actively monitored and adjusted to maximize the receive signal, hence the HRP beam is never oriented at directions occupied by persons. The effective gain at the portion of the main lobe of the HRP beam that could graze a person is 10 dB lower than the peak gain.

The RF Exposure analysis is made using the effective gain at the direction of interest, which is toward the grazing point.

Freq (GHz)	Peak Gain (dBi)	Delta (dB)	Effective Gain at Direction of Interest (dBi)	Average Output Power (dBm)	Average EIRP (dBm)
60.48	22.0	10.0	12.0	6.80	18.8
62.64	22.0	10.0	12.0	5.70	17.7

Freq (GHz)	Effective Gain at Direction of Interest (linear)	Average Output Power (mW)	Average EIRP (mW)
60.48	15.85	4.79	75.86
62.64	15.85	3.72	58.88

Equations for the Near Field, Transition Field or Far Field Regions, as defined by OET 65 and as applicable to the evaluation distance, are used.

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FAR FIELD BOUNDARY CALCULATIONS

The far-field boundary is given by OET 65 Equation 16 as:

$R_{far\ field} = (0.6 * L^2) / \lambda$

where:
L = Largest Antenna Dimension
λ = Wavelength

Frequency (GHz)	L (cm)	Lambda (cm)	R (Far Field) (cm)
60.48	2.0	0.496	4.838
62.64	2.0	0.479	5.011

The Mobile evaluation distance is in the far field region for all frequencies. For 60.48 GHz the Portable evaluation distance is also in the far field region.

For 62.64 GHz the Portable evaluation distance is less than the far field region boundary distance.

FAR FIELD RF EXPOSURE EVALUATION

For far-field distances Power Density is calculated using OET 65 Equation 18:

$S = (P * G) / (4 * Pi * D_S^2)$

where:
P = Power fed to antenna
G = Power Gain of the antenna in the direction of interest
D_S = Separation Distance

Freq (GHz)	Average Power (mW)	Gain (linear)	Separation Distance (cm)	Power Density (mW/cm^2)	FCC Limit (mW/cm^2)
Mobile Evaluation Distance					
60.48	4.79	15.85	20	0.015	1
62.64	3.72	15.85	20	0.012	1
Portable Evaluation Distance					
60.32	4.79	15.85	5	0.242	1

Freq (GHz)	Separation Distance (cm)	Power Density (W/m^2)	IC Limit (W/m^2)
Mobile Evaluation Distance			
60.48	20	0.151	10
62.64	20	0.117	10
Portable Evaluation Distance			
60.32	5	2.418	10

NEAR FIELD BOUNDARY CALCULATIONS

The near-field boundary is given by OET 65 Equation 12 as:

$R_{near\ field} = (L^2) / (4 * \lambda)$

where:
L = Largest Antenna Dimension
λ = Wavelength

Frequency (GHz)	L (cm)	Lambda (cm)	R (Near Field) (cm)
62.64	2.0	0.479	2.088

For 62.64 GHz the Portable evaluation distance is greater than the near field region boundary distance and less than the far field region boundary, therefore transition field region equations are applicable.

TRANSITION FIELD RF EXPOSURE EVALUATION

Aperture efficiency is given by OET 65 Equation 14 as:

$\eta = (G * (\lambda^2) / (4 * Pi)) / ((Pi * (L^2) / 4)$

where:
G = Power gain of antenna in the direction of interest
L = Largest Antenna Dimension
λ = Wavelength

Freq (GHz)	Gain (linear)	Lambda (cm)	L (cm)	Aperture Efficiency (linear)
62.64	15.85	0.479	2.0	0.092

The maximum value of the near-field power density is given by OET 65 Equation 13 as:

$S_{near\ field} = (16 * \eta * P) / (Pi * (L\hat{}2))$

where:
η = Aperture efficiency
P = Power fed to the antenna
L = Largest Antenna Dimension

Freq (GHz)	Aperture Efficiency (linear)	Power (mW)	L (cm)	Near Field Power Density (mW/cm^2)
62.64	0.092	3.72	2.0	0.436

The power density in the transition region is given by OET 65 Equation 17 as:

$S_{transition} = (S_{near\ field} * R_{near\ field}) / D_S$
where:
D_S = Separation Distance

Freq (GHz)	Near Field Power Density (mW/cm^2)	Near Field Boundary (cm)	Separation Distance (cm)	Power Density (mW/cm^2)	FCC Limit (mW/cm^2)
62.64	0.436	2.088	5	0.182	1

Freq (GHz)	Separation Distance (cm)	Power Density (W/m^2)	IC Limit (W/m^2)
62.64	5	1.821	10

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