Subject: FDS RF Exposure calculation at 24 GHz

Summary:

This RF exposure analysis is intended to justify compliance with limits for 24 – 25 GHz transmitters operated within 20 cm of a user. The analysis is based on the total available power being radiated off of the antenna in the near-field.

Guidance was provided through the FCC KDB system and from presentations by the FCC to the TCB council.

Device details:

Chipset: Silicon Radar TRX_024_006 24-GHz IQ Transceiver; operating in low PA gain mode

nominal output power 0dBm

Expected line loss is -1.12 dB (see page 5)

https://siliconradar.com/datasheets/Datasheet_TRX_024_006_V2.1.pdf

Antenna: rectangular patch with underlying truncated ground plane

10 mils of Rogers 4350 substrate under the antenna copper layer, with full ground plane below.

LAYER	MATERIAL	FINISHED THICKNESS
LAYER 1	COPPER	0.0015" ±0.0004"
LAYER 2	COPPER	0.0015" ±0.0004"
LAYER 3	COPPER	0.0015" ±0.0004"
LAYER 4	COPPER	1 OUNCE
LAYER 5	COPPER	1 OUNCE
LAYER 6	COPPER	0.0015" ±0.0004"
DIELECTRIC A	ROGERS 4350	0.010" ±0.002"
DIELECTRIC B	FR-4	0.010" ±0.002"
DIELECTRIC C	FR-4	0.003" ±0.001"
DIELECTRIC D	FR-4	0.003" ±0.001"
DIELECTRIC E	FR-4	0.003" ±0.001"
FINISHED OVERALL THICKNESS:		0.040" ±0.005"

Figure 1 - Antenna Feedline, Co-planar strip line

$G = 4\pi\eta A/\lambda^2$

$\eta = (G \times \lambda^2)/4\pi A$

$\lambda = 12.5$ mm

$G = 1$

$A = 3 \times 5 = 15$ mm^2

0.83 = -0.81 dB

Estimated antenna efficiency = 60% = -2.22

from radar chip datasheet:

Pin 10 controls power output, low is P_OUT_MAX – 4dB;

10	pwr1	Power-amplifier gain control input (with internal 100-kΩ pull-up resistor): 1 – P_{OUT_MAX} ; 0 – P_{OUT_MAX} -4 dB (1 = 3.3 V, 0 = 0 V)

P_OUT_MAX is 4dBm nominal, 6dBm max. Therefore, with pwr1 (pin10) low PTX is 0dBm nominal, +2dBm abs. max.

Transmitter output power	P_{TX}	2.5	4	6	dBm	
Adjustable range output power (pwr1 pin)	P_{TX_ADJ}	0		4	dBm	Power amplifier gain control 1 – P_{OUT_MAX} 0 – P_{OUT_MAX} - 4 dBm

SW controls pwr1 (pin10) to drive it low at all times. The pin is never allowed to go high.

[redacted]

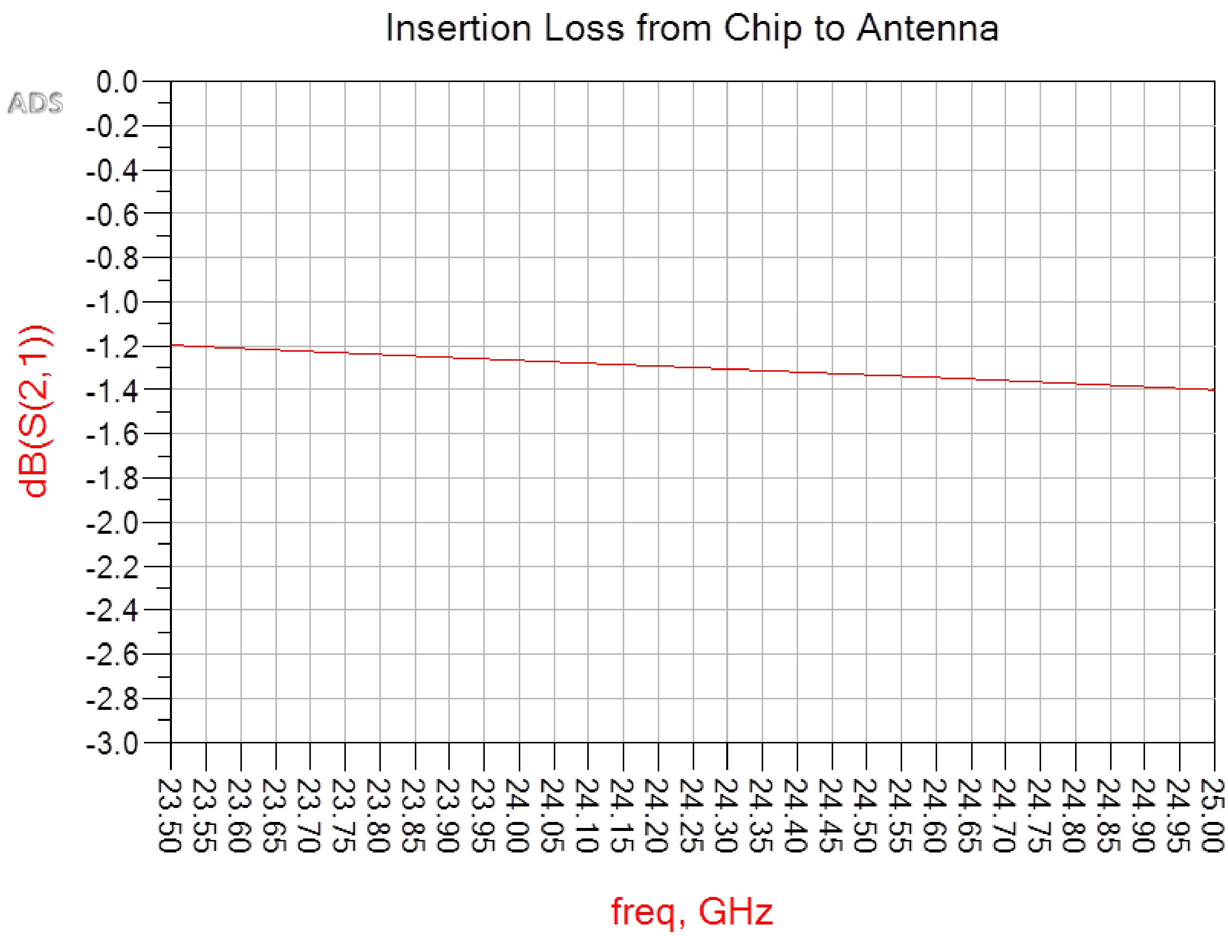

Figure 2 - Expected line loss of 1cm feed,-1.2 dB max.

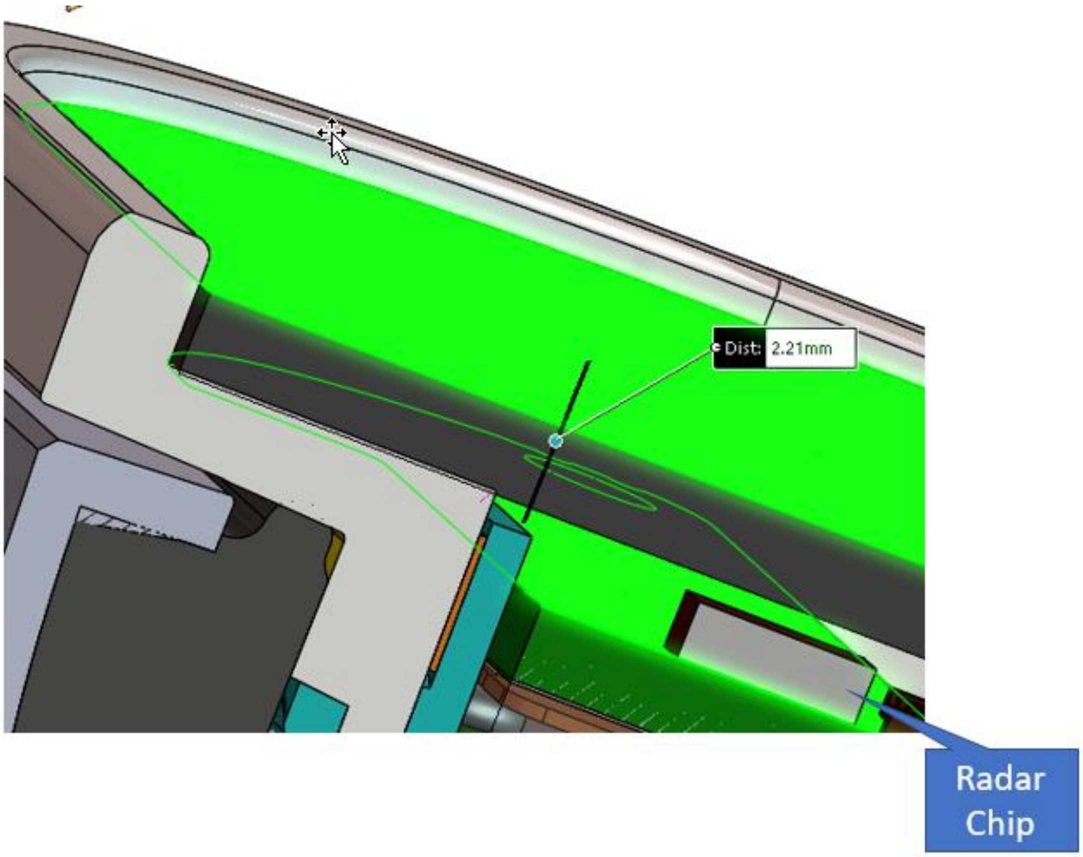

Figure 3 - distance from patch antenna to outer enclosure

Limits from FCC Part 1.1310

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

Note: allowance for 1 mW/cm^2 limit to be averaged over 4 cm^2

https://transition.fcc.gov/oet/ea/presentations/files/oct18/5.1-TCB-RF-Exposure-OrderNPRM-Issues-MD.PDF

Calculations: needs to be 0.6 mW / 0.1 dB loss

Output power = -3.5 dBm = 0.45 mW (combination of nominal output power – feed line loss – antenna efficiency, 0 dBm – 1.3 dB - 2.2 dB)

Exposure limit per FCC Part 1.1310 = 1 mW/cm^2

Area of antenna = 0.3 x 0.5 cm = 0.15 cm^2 (only 1 element transmits)

0.45 mW / 0.15 cm^2 = 3 mW/cm^2 (all power distributed over area of antenna)

Averaged over 4 cm^2 = 3/4 = **0.75 mW/cm^2**

See Page 3 of this document for the allowance of averaging over 4 cm^2.

This value takes all of the available power and assumes all of it radiates directly off the surface area of the antenna and the user would be infinitely close to the antenna. This would be considered a worse-case evaluation. Assuming the separation due to the case and any layers of clothing the user would be wearing, the field would normally disperse over a larger area. Actual exposure is expected to be much lower. In addition, the antenna is a single element and not an array. The gain is not expected to increase as the user enters the far field.

Each of the patches was measured to be 0.3 x 0.5 cm. the patch on the right is the transmit antenna.

Conclusion:

Based on the nominal power output, feed line loss, antenna efficiency and apperature size, it was found that the exposure would be less than 1 mW/cm^2 averaged of 4 cm^2.

Attachment Details:

2018-04_to_2013-04_RF-Expos-TCB-Slides_mmw-60GHz-excerpts

2018-10_5.1-TCB-RF-Expos-OrderNPRM-Issues-MD_QUALIFIER