RF exposure test exclusion analysis for 60GHz radio

Summary

This document presents analysis to justify test exclusion for RF exposure evaluation for the 60GHz LRP transmitter operating in the head mounted display under FCC ID 2AL8N-RX001 based on a guaranteed transmit duty cycle of 5.9% or less and the total radiated power estimated from the main test report.

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Geometry

The HMD receiver is mounted on the top head in a fixed position. The main beam radiates in a direction away from the head of user, pointing towards the ceiling. The device does not touch the head. The design and shape of the device ensures that there is a separation distance of 25mm between the scalp and the bottom of the device, for the enclosure surface pointing towards the scalp, and guarantees a fixed orientation of the transmitter antenna array in relation to the head. With respect to the transmitter array radiation pattern, zero degrees azimuth/elevation is pointing straight up with the head located at greater than 90° azimuth or 90° elevation.

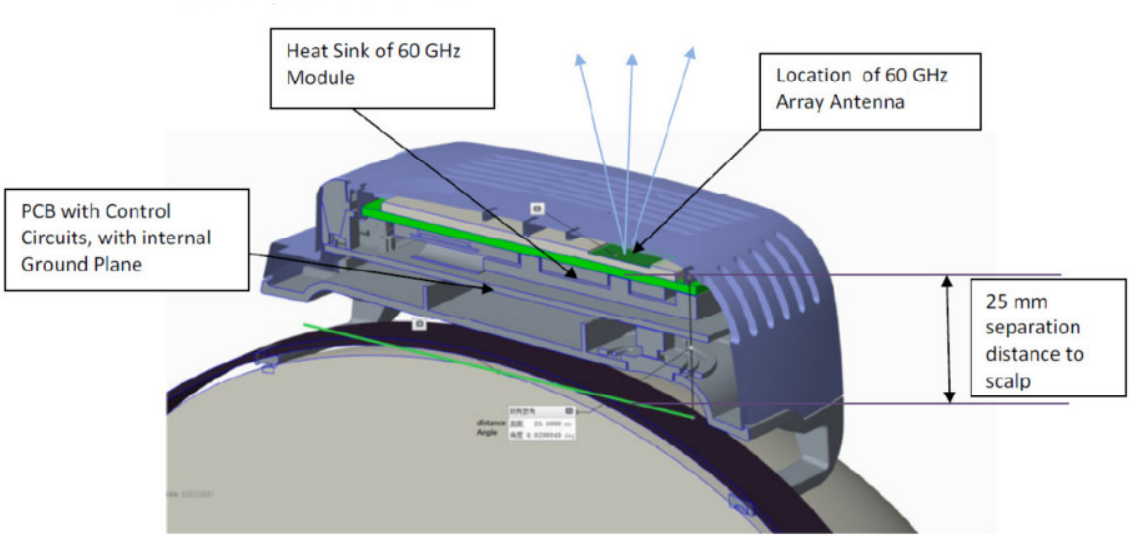

Figure 1: Position of head-mounted display 60GHz transmitter in relation to the head

Transmitter duty cycle

The WirelessHD sink transmitter is guaranteed to operate with a duty cycle of 6% or less.

The device operates a fixed transmit schedule (Figure 2) comprising a beacon with maximum duration 200µs, a 300µs RATB slot and 90 acknowledgement slots of 5.65µs each on a frame period of approximately 20.66ms. Every twelfth acknowledgement packet further contains an additional 27µs of transmit data that is used to provide beam steering feedback to the partner source device along with the acknowledgement information.

The duty cycle is guaranteed by source based duty cycling to be at most:

$$(200\mu s+300\mu s+90x5.65\mu s+90/12x27\mu s)/20660\mu s=5.9\% \quad (1)$$

but will usually measure:

$$(162\mu s+90*5.65\mu s+90/12x27\mu s)/20660\mu s=4.2\% \quad (2)$$

since beacons are usually shorter than maximum and the RATB slot is unused on most frames.

The 5.9% duty cycle will provide 10*log10 (0.059) = 12.32 dB reduction in time averaged power density compared to the average power density within a transmit burst.

Beacon and RATB transmissions operate with an omnidirectional radiation pattern with an average directivity of 6dBi. Acknowledgement packets operate with a directional radiation pattern that may have a directivity of up to 13dBi. Detailed radiation patterns are presented in the operational description document. By design, the total radiated power is the same for both omnidirectional and directional modes of transmission so an EIRP measurement in omnidirectional mode can be used to estimate the common total radiated power.

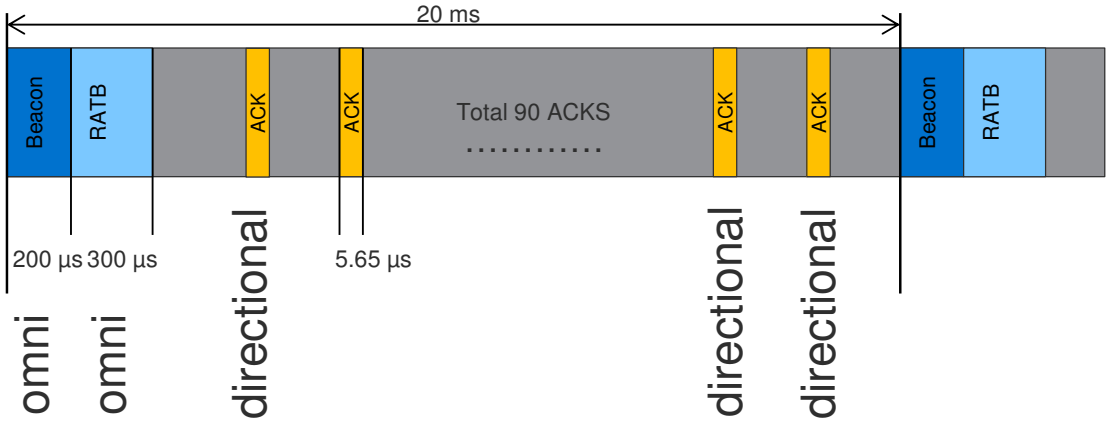

Figure 2: WiHD source-based duty cycle transmit schedule

Measurements to illustrate the duty cycle are shown in Figure 3, Figure 4, Figure 5 and Figure 6. Delta markers in the top right of the plots are used to annotate time intervals of interest. These measurements were taken using a spectrum analyzer in zero span mode with frequency set at 10MHz offset from the center of the LRP channel.

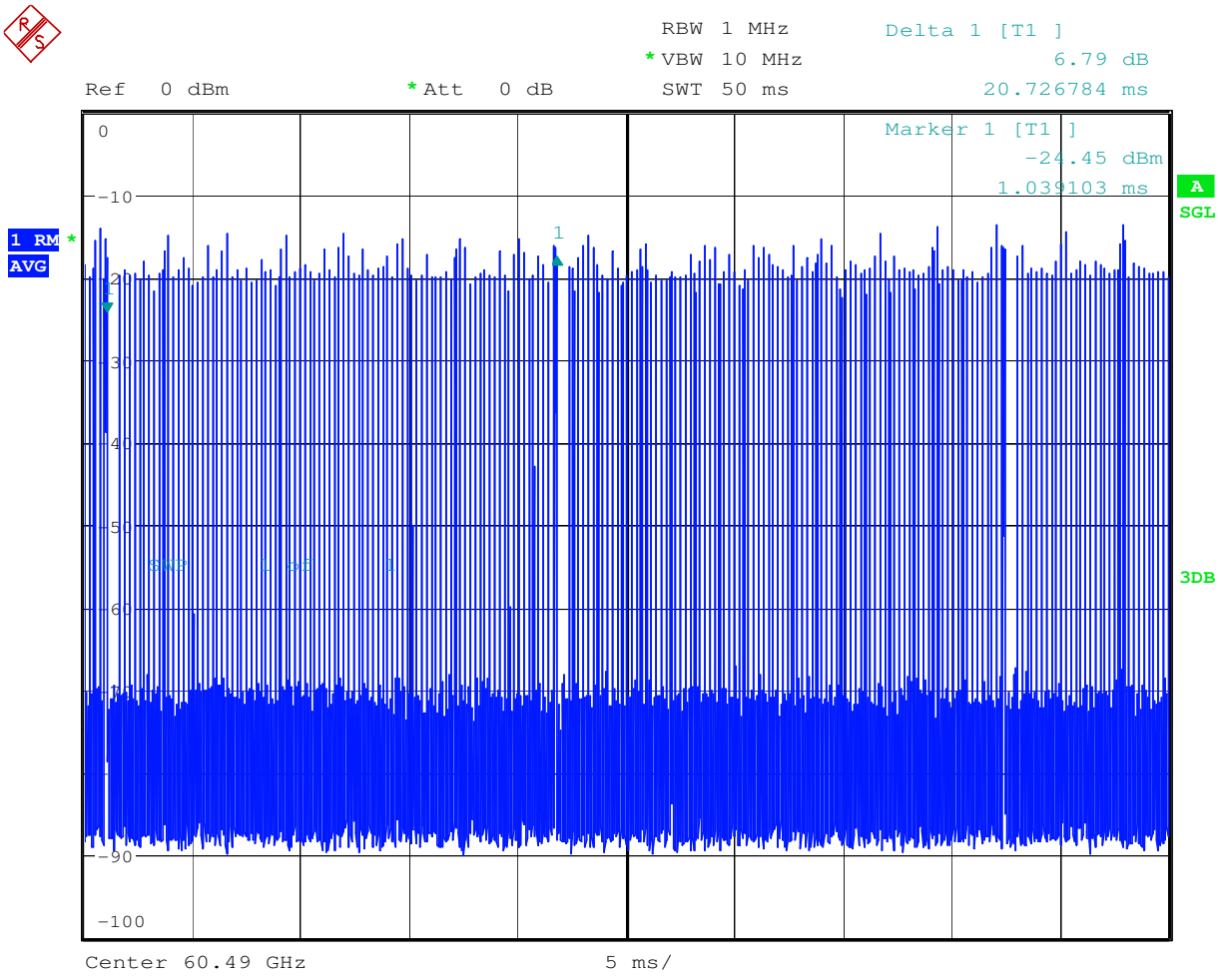

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Figure 3: Transmit activity over 50ms duration illustrating 20.73ms frame period with 90 ACK packets

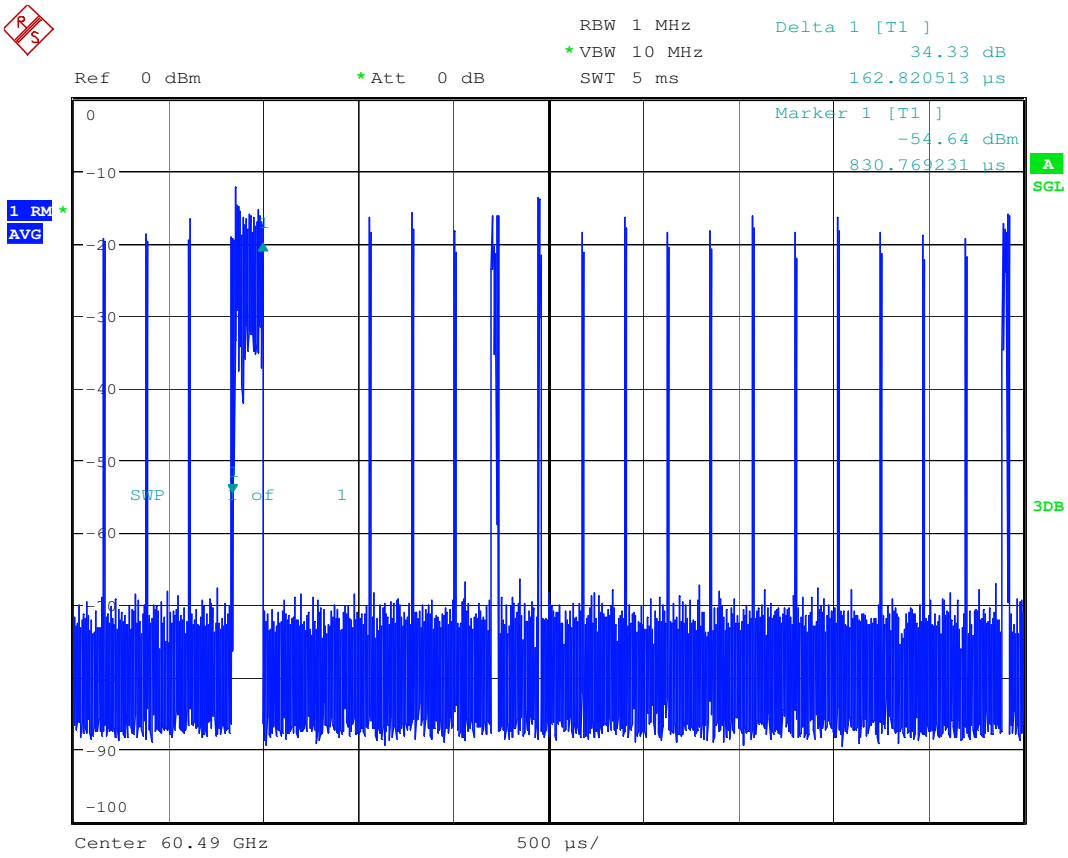

Figure 4: Transmit activity around beacon over 5ms duration illustrating typical 162µs beacon and unused 300µs RATB slot. ACK packets follow on a 225µs period. Note that in this plot, the fourth and the sixteenth ACK packet in the super-frame (12 packets apart) are longer than the others due to the additional beam steering data.

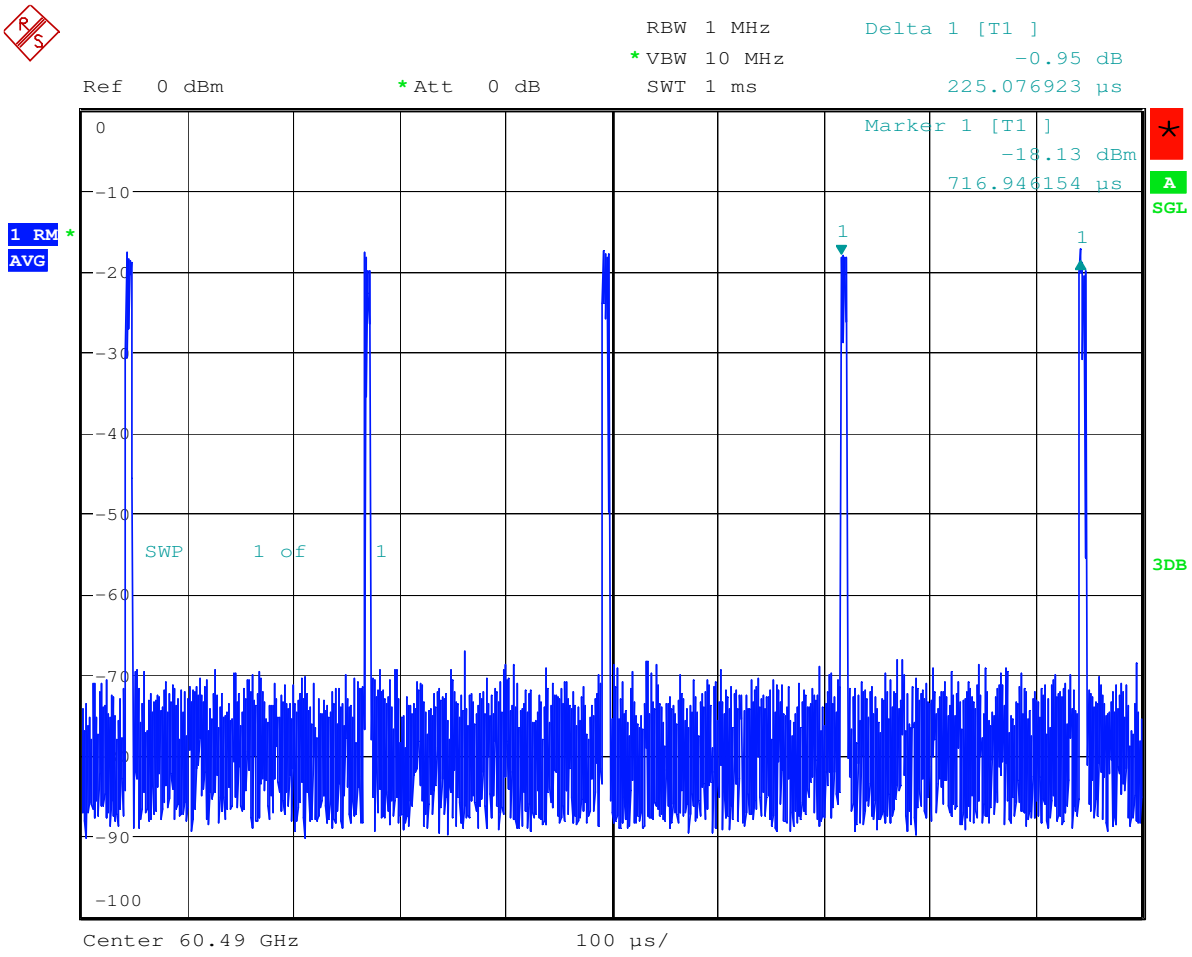

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Figure 5: Transmit activity over 1ms interval during main body of frame structure illustrating ACK duration and interval 225µs. Note that 90x225+200+300=20750µs or the frame duration.

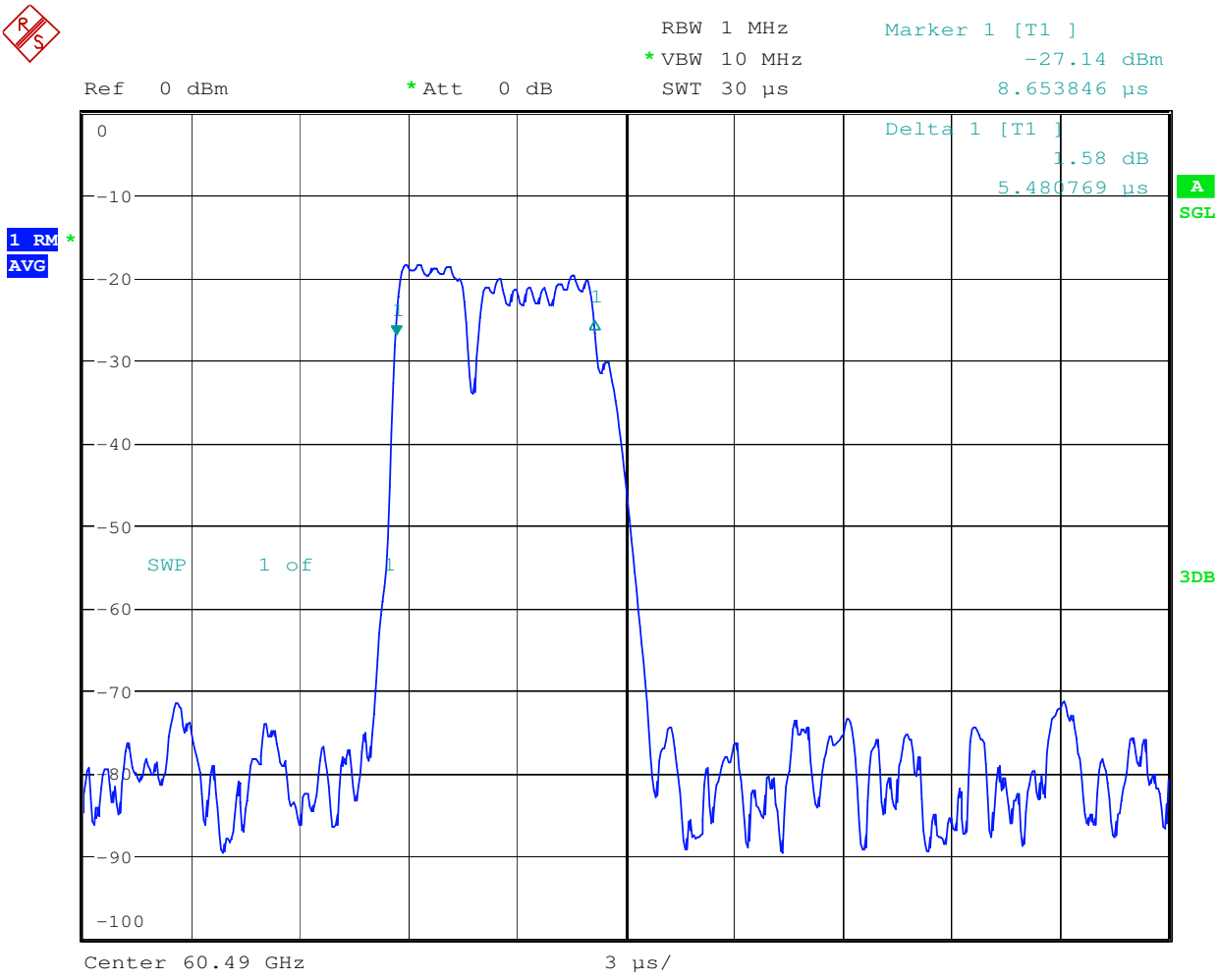

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Figure 6: Transmit activity over 30µs interval illustrating ~5.5µs duration ACK packet (exact value 5.65µs by design)

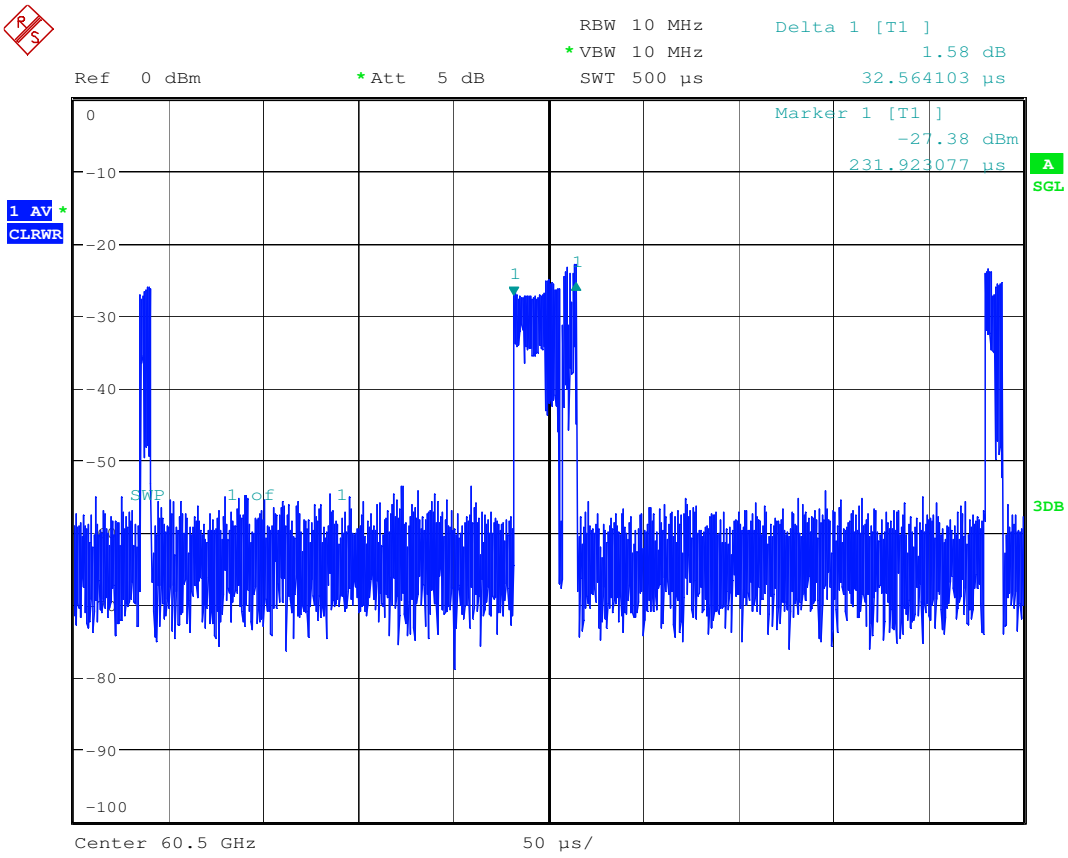

Figure 7: Transmit activity during periodic beam steering ACK packets with additional beam steering feedback payload with 32µs total duration, approximately 27µs longer than a regular ACK.

Measurement of total radiated power

To measure the total radiated power, a far-field measurement of EIRP is done using LRP omnidirectional beacons using both H and V polarizations and using average detection.

For each polarization, the single element directivity 6dBi is subtracted from the EIRP to give the total radiated power in that polarization. Then the overall total radiated power is summed over the two polarizations.

From the main RF test report for 2AL8N-RX001, the average LRP EIRP in omnidirectional mode for the LRP channel with highest output power is 14.99dBm. The total radiated power is thus 14.99dBm-6dBi=8.99dBm. The EIRP in directional mode may be up to 6dB higher than in omnidirectional mode due to the array gain but the total radiated power is the same as in omnidirectional mode.

Power density estimation

The aperture of the transmit antenna array is 11mmx7mm with diagonal dimension 13mm.

The far-field distance, calculated by $2D^2/\lambda$ is around 7cm. The distance to human body is 2.5cm which is less than 7cm so a near field evaluation is required.

The power density spatially averaged over a 1cmx1cm square for a contact exposure condition is approximately equal to the total radiated power (after allowing for duty cycle) divided by $1cm^2$.

As discussed above, the LRP transmitter employs source based duty cycling to provide a maximum duty cycle of 6.0% with 2.5% in omnidirectional mode and 3.5% in directional mode. So duty cycling thus provides a 12.32dB reduction in time-averaged total radiated power to -3.33dBm.

The total radiated power of -3.33dBm = 0.468 mW divided by 1cm^2 gives 0.468 mW/cm^2, which does not exceed 1 mW/cm^2.

The actual exposure condition is much lower than this due to the fact that the transmit antenna array is pointing away from the body (more than10dB below peak beyond 90° azimuth or elevation from the radiation pattern contained in the operational description document) and there is 2.5cm separation between the transmitter array and the body due to the mechanical design of the helmet.

Thus the LRP transmitter satisfies the requirement with margin sufficient that no further near field testing is required.