WAVE WIRELESS

LMS3000 Technical Note

Number: TN133

Title: Peak to Average Ratios for LMS3000

Author: Lawrence Gordon

Reviewer:

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Abstract:

Presents data on the Peak to Average Ratio for LMS3000 waveform, including measurements done according to FCC guidelines.

Revision History:

Date	Rev.	Author	Comments
			(only needed for releases past initial release

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1 INTRODUCTION

The FCC and Industry Canada now allow for average power measurements to be done for the output power and power spectral density (PSD) characterizations for a radio under FCC part 15.247. Previously, only peak measurements have been allowed.

Electronics Test Centre (ETC) has been used for compliance testing. However, they do not have the equipment to do power averaging.

The purpose of this tech note is to present the peak to average ratios for the LMS3000 radio, so that we can calculate average power whenever peak power data is presented. For compliance testing, peak measurement data would be collected and presented to FCC and IC. If there is a compliance concern, we can then use this tech note to justify using a correction to peak power to get an average power rating.

1.1 Peak to Average Ratio

This report will show that the peak to average ratio for the WaveRider LMS3000 waveform is between 1.9 and 2.6 dB, depending on which method is used to determine this ratio. The actual ratio using proper averaging equipment is 2.6 dB, but we should use the more conservative 2.4 dB ratio when submitting to FCC, since this is supported by 3 of the FCC methods and variants.

For the PSD peak to average ratio, the evidence is not as clear, with the two FCC average methods giving quite different ratios, 1.4 dB when the average of the peak detector is used and 5.7 dB when the average of the sample detector is used. If the Peak PSD passes the limits, then it is sufficient to claim only 1.4 dB. If the Peak PSD exceeds the limit by no more than 1.4 dB, then this report can be used to support a P:A of 1.4 dB or better for the PSD.

1.2 Previous Testing

The EUM3000, EUM3003 and EUM3004 were all certified using peak power measurements. The PSD limit (8 dBm in any 3 KHz band (15.247(e))) had been the limiting factor on our transmitter power, limiting the peak output to 26 dBm.

With the EUM3005 and EUM3006, we generate a peak power output of 27.3 dBm and peak PSD of 7.3 dBm. The FCC test report shows 25.0 dBm (average) for output power and 6.8 dBm (average) for PSD. The output power shows a P:A (Peak to Average ratio) of 2.3 dB, which is consistent with the results reported herein.

Given the peak readings, there is no real need to resort to average power arguments in most cases. This has been supported by more recent testing on the MMT9000 (EUM3005 PCB), CCU3100 (EUM3006 PCB), EUM3005A and EUM3006A, all of which pass the 15.247 power output and PSD tests using PEAK power.

1.3 Need for Average Power

The LMS3000 does not need to use average power testing to pass FCC and IC for purely conducted and PSD testing. However, we use average power levels for the EUM3006 with respect to its integrated antenna. The EUM3006 conducted power at the antenna port is 27.3

dBm (peak) and the antenna gain is 10.2 dBi, so the EIRP is 37.5 dBm (peak). In order to not lose any TX power for the EUM3006, we present this tech note as evidence that the Peak to Average Ratio is at least 2.4 dB, so the average EIRP is not more than 37.5 – 2.4 = 35.1 dBi, which is compliant.

Also, this is the first step to understanding Peak to Average measurements which we will need for the NG radio, since it uses OFDM waveforms which have high P:A ratios.

2 TEST SETUP

2.1 LMS3000 Waveform

The testing presented herein is done using a continuous, modulated waveform. The modulation is Complementary Code Keying, which is a form of QPSK (Quaternary Phase Shift Keying).

2.2 Equipment

The testing was done on an EUM3005A modem, at the maximum transmit power as set by the ATE, which is a nominal 27.3 dBm. The ATE results for this modem indicate that the max. power was set to 27.4 dBm. Note that the ATE uses different equipment to set this limit, uses a CW signal to set the power level and the PA is not on continuously. Therefore it is expected that the peak level measured by a different spectrum analyzer for a modulated signal at 100% duty cycle will differ from the level reported by the ATE.

The Spectrum Analyzer is a Rhodes&Schwarz FSEM-20. This analyzer can display data on a linear power (uW) scale as well a log (dB) scales. Averaging when in a log display can be in the log scale or in a linear scale, before conversion to dB. In all cases, averaging here is done using linear power averaging. The R&S has RBW and VBW ranges up to 10 MHz, but 5 MHZ is the limit used here.

The EUM is connected to the R&S using a fixture with a loss of 29.52 dB at 925 MHz.

All measurements are done at 925 MHz. Other testing not reported herein has been done at other frequencies and show the same P:A ratios.

2.3 FCC Test Methods Translated

The FCC test methods are taken from “New Guidance on Measurement for Digital Transmission Systems In Section 15.247”. This document provides 3 methods to measure average Power Output and one for Power Spectral Density (PSD). All methods are reported herein.

2.3.1.1 EBW

The term EBW (Emissions Bandwidth) is used a number of times in the document without properly defining the term. However, one clue is provided in Method #1 “across the 26 dB EBW of the signal”. Therefore, the EBW is interpreted herein as the bandwidth between the points -26dBc, which is 4.6 MHz. This is rounded up to 5 MHz when used to set span or RBW.

2.3.1.2 FCC Power Output Option 1 – Peak

This method is the standard peak power measurement that ETC uses. The FCC guidance document states:

"Set the RBW > 6dB bandwidth of the emission or use a peak power meter."

For the LMS3000, the 6 dB bandwidth is 2.7 to 2.9 MHz. Therefore, setting the RBW to 3 MHz is the standard setting, using the peak detector and MAX Hold.

This peak is used for one side of the Peak-to-Average ratio.

2.3.1.3 FCC Output Power Average - Method #1

From the FCC guidance document:

Table 1 – FCC Output Power Average – Method #1

FCC Guidance	Interpretation for this report
• Set span to encompass the entire emission bandwidth (EBW) of the signal.	EBW = 4.6 MHz, Span = 7 MHz so that we ensure the margins are included.
• Set RBW = 1 MHz.	RBW= 1 MHz
• Set VBW ≥ 3 MHz.	VBW = 3 MHz
• Use sample detector mode if bin width (i.e., span/number of points in spectrum display) < 0.5 RBW. Otherwise use peak detector mode	Span/# pts = 7 MHz/500 = 14KHz per pt. << 0.5 * 1000 = 500 KHz, so use Sample Detector.
• Use a video trigger with the trigger level set to enable triggering only on full power pulses. Transmitter must operate at full control power for entire sweep of every sweep. If the device transmits continuously, with no off intervals or reduced power intervals, the trigger may be set to "free run".	TX is continuous for these tests, so Trigger set to free run.
• Trace average 100 traces in power averaging mode.	Scale set to Linear Power (uW), so averaging is linear. Sweep count set to 100.
• Compute power by integrating the spectrum across the 26 dB EBW of the signal. The integration can be performed using the spectrum analyzer's band power measurement function with band limits set equal to the EBW band edges or by summing power levels in each 1 MHz band in linear power terms. The 1 MHz band power levels to be summed can be obtained by averaging, in linear power terms, power levels in each frequency bin across the 1 MHz.	a) Data is captured from R&S and processed as EXCEL spreadsheet. Average of all 7 readings in a 1 MHz band computed. Centre freq. = 925 MHz, so the 1 MHz bands (7 of them) are: 921.5-922.5, 922.5-923.5, 923.5-924.5, 924.5-925.5, 925.5-926.5, 926.5-927.5, 927.5-928.5. The average is in uW. These 7 averages are summed and converted from uW to dBm. b) Alternative: Use Spectrum Analyzer's band power measurement, with bandwidth set to 5 MHz.

2.3.1.4 FCC Output Power Average – Method #2

From the FCC guidance document:

Table 2 – FCC Output Power Average – Method #2

FCC Guidance	Interpretation for this report
• Set zero span mode. Set center frequency to the midpoint between the -26 dB points of the signal.	Span = 0, Centre = 925 MHz.
• Set RBW ≥ EBW.	RBW= 5 MHz (EBW = 4.6 MHz)
• Set VBW ≥ 3 RBW. [If VBW ≥ 3 RBW is not available, use highest available VBW, but VBW must be ≥ RBW]	VBW = 5 MHz. (R&S can set VBW to 10 MHZ, but the accuracy in that mode is not as good.)
• Set sweep time = T	TX is continuous, but when TX is packet based, the longest packet is 4.8 ms on. So set Sweep = 5 ms.
• Use sample detector mode.	Detector = Sample
• Use a video trigger with the trigger level set to enable triggering only on full power pulses.	Trigger = free run, since TX continuous.
• Trace average 100 traces in power averaging mode.	Scale is linear power (uW) so averaging is proper power averaging,
• Find the peak of the resulting average trace.	Peak Search.

2.3.1.5 FCC Output Power Average Method #3

From the FCC guidance document:

Table 3 – FCC Output Power Average – Method #3

FCC Guidance	Interpretation for this report
• Set span to encompass the entire emission bandwidth (EBW) of the signal.	Span = 7 MHz
• Set sweep trigger to "free run".	Trigger = Free Run
• Set RBW = 1 MHz. Set VBW ≥ 1/T	RBW = 1 MHz. T = 4.8 msec for max. packet size, so 1/T = 208 Hz. Set VBW = 1000 Hz.
• Use linear display mode.	Scale = uW, linear
• Use sample detector mode if bin width (i.e., span/number of points in spectrum) < 0.5 RBW. Otherwise use peak detector mode.	Span/# pts = 7 MHz/500 = 14KHz per pt. << 0.5 * 1000 = 500 KHz, so use Sample Detector.
• Set max hold.	MAX Hold
• Allow max hold to run for 60 seconds.	OK

FCC Guidance	Interpretation for this report
• Compute power by integrating the spectrum across the 26 dB EBW or apply a bandwidth correction factor of 10 log(EBW/1 MHz) to the spectral peak of the emission. The integration can be performed using the spectrum analyzer's band power measurement function with band limits set equal to the EBW band edges or by summing power levels in each 1 MHz band in linear power terms. The 1 MHz band power levels to be summed can be obtained by averaging, in linear power terms, power levels in each frequency bin across the 1 MHz.	a) Data is captured from R&S and processed as EXCEL spreadsheet. Average of all 7 readings in a 1 MHz band computed. Centre freq. = 925 MHz, so the 1 MHz bands (7 of them) are: 921.5-922.5, 922.5-923.5, 923.5-924.5, 924.5-925.5, 925.5-926.5, 926.5-927.5, 927.5-928.5. The average is in uW. These 7 averages are summed and converted from uW to dBm. b) Alternative: Use analyzer's Power Measurement function, with bandwidth set to 5 MHz.

2.3.1.6 FCC PSD Option 1 - Peak

The FCC guidance document has a peak and an average method for determining PSD. Option 1 is the peak method:

Table 4 – FCC PSD – Method #1

FCC Guidance	Interpretation for this report
Locate and zoom in on emission peak(s) within the pass band. Set RBW = 3 kHz, VBW > RBW, sweep= (SPAN/3 kHz) e.g., for a span of 1.5 MHz, the sweep should be $1.5 \times 10^6 \div 3 \times 10^3$ = 500 seconds. The peak level measured must be no greater than + 8 dBm. If external attenuation is used, don't forget to add this value to the reading. Use the following guidelines for modifying the power spectral density measurement procedure when necessary.	RBW = 3 KHz, VBW = 3 MHz, Span = 1.5 MHz, Sweep = 500 s.

2.3.1.7 FCC PSD Option 2 - Average

The FCC guidance document for average PSD power says:

Table 5 – FCC PSD – Method #2

FCC Guidance	Interpretation for this report
Locate and zoom in on emission peak(s) within the pass band.	
•Set RBW = 3 kHz.	RBW = 3kHz
•Set VBW $\geq$ 9 kHz.	VBW = 10 kHz
•Set Sweep time to Automatic	Sweep = Auto
•Use a peak detector. A sample detector mode can be used only if the following can be achieved with automatic sweep time and adjusting the bin width.	a) Peak Detector for one trial. b) Sample Detector for 2^{nd} trial

FCC Guidance	Interpretation for this report
1) Bin width (i.e., span/number of points in spectrum display) < 0.5 RBW.	a) 1st trial – Span = 1.5 MHz (same as peak), so bin width = 1500/500 = 3 kHz = RBW b) 2nd trial – Span = 0.7 MHz, centered on peak freq. found during peak search. Bin width = 700/500 = 1.4 kHz < 0.5 RBW.
2) The transmission pulse or sequence of pulses remains at maximum transmit power throughout each of the 100 sweeps of averaging and that the interval between pulses is not included in any of the sweeps (e.g., 100 sweeps should occur during one transmission, or each sweep gated to occur during a transmission).	Transmission is continuous and at max. power.
* If condition 2 cannot be achieved, then PSD Option 1 (peak detector on max hold) must be used and trace averaging cannot be used.	Condition 2 met
•Use a video trigger with the trigger level set to enable triggering only on full power pulses. Transmitter must operate at full control power for entire sweep of every sweep. If the device transmits continuously, with no off intervals or reduced power intervals, the trigger may be set to "free run".	Trigger = free run
•Trace average 100 traces in power averaging mode. Do not use video averaging mode.	Use Linear Scale and power averaging.
* Some analyzers will automatically select sample mode when trace averaging is selected. If a peak detector is used, then peak detector must be manually selected when trace averaging is enabled.	Ensured Peak used for 1st trial and sample for 2nd trial.

3 TEST RESULTS

3.1 The Real Peak-to-Average ratio

This is determined by using the Rhode&Schwarz capabilities and collecting data over more than 5000 sweeps. Two sets of data were collected, one in dBm scale and one in uW linear scale. In both cases the R&S computed linear averages.

Also, data was collected for RBW= 3 MHz as per the FCC Peak measurement as well as for RBW = 5 MHZ to ensure the EBW was spanned. The VBW is left at 3 MHz, since there is a problem with VBW = 5 MHz and this reduces the number of changes between traces.

The table below reports the peak measurement for the resulting trace. The test fixture path loss is 29.52 dB. The tests that report in uW were done using the linear uW scale, the others were done using the dBm log scale.

Table 6 – Real Peak to Average Ratio

#	RBW	VBW	Det.	Storage	Span	Sweep	uW	dBm	Corr (dBm)	P:A (dB)
Peak	3 MHz	3 Mhz	Peak	Max Hold	5 MHz	50 ms		-2.83	26.7	
Avg.	3 MHz	3 Mhz	Sample	Average	5 MHz	50 ms		-5.47	24.1	2.6
Peak	3 MHz	3 Mhz	Peak	Max Hold	5 MHz	50 ms	530	-2.76	26.8	
Avg.	3 MHz	3 Mhz	Sample	Average	5 MHz	50 ms	285	-5.45	24.1	2.7
Peak	5 MHz	3 Mhz	Peak	Max Hold	5 MHz	50 ms		-2.46	27.1	
Avg.	5 MHz	3 Mhz	Sample	Average	5 MHz	50 ms		-5.10	24.4	2.7
Peak	5 MHz	3 Mhz	Peak	Max Hold	5 MHz	50 ms	568	-2.46	27.1	
Avg.	5 MHz	3 Mhz	Sample	Average	5 MHz	50 ms	322	-4.92	24.6	2.5

The following is concluded from these figures:

1) the real P:A ratio is 2.6 dB.

2) the difference between RBW = 3 MHz and RBW = 5 MHz is 0.3 to 0.5 dB.

3) the Peak power as would be presented to the FCC is the 3 MHz RBW Peak/MAX Hold value. For this study, the uncorrected value of –2.8 dBm = 525 uW is used which is a corrected power level of 26.7 dBm.

The corrected output power is about 0.6 dB below the level set by the ATE. This is predominantly due to the heating of the PA during these tests, since the PA is being run continuously. Some of the difference may also be due to the different instruments being used.

3.2 FCC Power Output Methods

3.2.1 Method #1

Table 7 – FCC Power Output Power – Method #1 Results

Start (MHz)	921.5	922.5	923.5	924.5	925.5	926.5	927.5
Stop (MHz)	922.5	923.5	924.5	925.5	926.5	927.5	928.5
Average Pwr (uW)	1.20	20.46	81.07	108.11	71.28	15.95	1.05

Pwr Sum (uW) (7 MHz)	299.11	Peak (uW)	525
Pwr Sum (dBm)	-5.24	Peak (dBm)	-2.8
P:A (dB)	2.4		

The Power sum over the three 1 MHz bands centred on 925 MHz is 81.07 + 108.11 + 71.28 = 260.46. Compared to the full seven 1 MHz bands, this gives 10*log(260.46/299.11) = -0.6 dB, which is close to the 0.3 to 0.5 dB difference measured between RBW = 3 MHz and RBW = 5 MHz above.

The alternative method of using the band power measurement provided a power level of 303 uW = -5.2 dBm, with a P:A of 2.4 dB.

3.2.2 Method #2

Method #2 takes the peak of the averages in the trace after 100 sweeps.

Table 8 – FCC Power Output Power – Method #2 Results

Trial	Peak/MAX Hold (uW)	Sample/Average (uW)
1	539	333
2	539	330
3	539	327
4	539	328
5	539	326
Avg.	539	329
dBm	-2.7	-4.8
P:A	2.1	

3.2.3 Method #3

Table 9 – FCC Power Output Power – Method #3 Results

Start (MHz)	921.5	922.5	923.5	924.5	925.5	926.5	927.5	Sum (uW)
Stop (MHz)	922.5	923.5	924.5	925.5	926.5	927.5	928.5	
Average Pwr (uW) #1	1.03	18.93	85.01	127.70	82.75	19.64	1.41	336
Average Pwr (uW) #2	1.03	18.95	85.04	127.73	82.80	19.66	1.41	337
Average Pwr (uW) #3	1.03	18.91	84.94	127.59	82.66	19.62	1.40	336
Average Pwr (uW) #4	1.03	18.89	84.86	127.50	82.57	19.60	1.40	336
Average Pwr (uW) #5	1.03	18.89	84.80	127.47	82.54	19.60	1.40	336

Pwr Sum (uW)	336	Peak (uW)	525
Pwr Sum (dBm)	--4.7	Peak (dBm)	-2.8
P:A (dB)	1.9		

The three bands around 925 MHz have a sum power of 295.05 uW, so the ratio with the full power is 10*log(295/336) = -0.57 dB, supporting the data from Method #1.

The alternative, which uses the analyzer's bandwidth measurement function with bandwidth = 5 MHZ, linear scale produced a value of 297 uW = -5.3 dBm, for a P:A of 2.5 dB.

3.2.4 FCC Power Output Summary

The following shows the power for each of the FCC Power Output methods:

Table 10 – FCC Power Output Power – Summary of Results

FCC Method	P:A (dB)	Comments
#1a	2.4	Close to real P:A. Best done if the set of actual values can be read back from the Spectrum Analyzer, otherwise hand estimating will reduce accuracy.
#1b	2.4	Close to real P:A. Easily done if SA provides appropriate function. Need power averaging.
#2	2.1	Using the 5 MHz RBW adds about 0.4 dB to Peak/MAX Hold power, so this result is consistent since the PEAK here is the RBW = 3MHz power.
#3a	1.9	Biased to a lower P:A ratio since using MAX Hold to gather data. If wider VBW is used, then ratio gets closer to 0 dB.
#3b	2.5	Quite accurate.

3.3 Power Spectral Density

The PSD was measured with the following results:

Table 11 – FCC PSD Results

#	RBW	VBW	Det.	Storage	Span	Sweep	dBm	Corr (dBm)	P:A (dB)
Peak	3 kHz	3 Mhz	Peak	Max Hold	1.5 MHz	500s	-22.23	7.29	
Avg. 1	3 kHz	3 Mhz	Peak	Average	1.5 MHz	500 ms (100 sweeps)	-23.65	5.87	1.4
Avg. 2	3 kHz	3 Mhz	Sample	Average	700 kHz	500 ms (100 sweeps)	-27.9	1.62	5.7

Since the peak PSD passes the required limit, the averages are not really needed. There is no obvious correlation between the P:A ratio of the overall waveform as determined for the Power Output methods and the P:A ratio for the PSD function. The narrower span and sample averaging provides the largest P:A of 5.7 dB.