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EMC Test Report

Application for FCC Grant of Equipment Authorization

FCC Part 15 Subpart C

Model: GFHD254

FCC ID:	AA4RGFHD254
APPLICANT:	Google Inc. 1600 Amphitheatre Pky Mountain View, CA 94043
TEST SITE(S):	National Technical Systems - Silicon Valley 41039 Boyce Road. Fremont, CA. 94538-2435
IC SITE REGISTRATION #:	2845B-3; 2845B-4, 2845B-5, 2845B-7
REPORT DATE:	November 16, 2016
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Testing Cert #0214.26

REVISION HISTORY

Rev#	Date	Comments	Modified By
-	November 16, 2016	First release	
1.0	January 12, 2017	Updated cabling information	MEH
2.0	February 8, 2017	Updated support equipment information	MEH

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SCOPE

An electromagnetic emissions test has been performed on the Google Inc. model GFHD254, pursuant to the following rules:

FCC Part 15 Subpart C

Conducted and radiated emissions data has been collected, reduced, and analyzed within this report in accordance with measurement guidelines set forth in the following reference standards and as outlined in National Technical Systems - Silicon Valley test procedures:

ANSI C63.10-2013
FCC DTS Measurement Guidance KDB558074

The intentional radiator above has been tested in a simulated typical installation to demonstrate compliance with the relevant Industry Canada performance and procedural standards.

Final system data was gathered in a mode that tended to maximize emissions by varying orientation of EUT, orientation of power and I/O cabling, antenna search height, and antenna polarization.

Every practical effort was made to perform an impartial test using appropriate test equipment of known calibration. All pertinent factors have been applied to reach the determination of compliance.

The EUT support an IEEE 802.11 5GHz and Bluetooth radio. This report only covers the Bluetooth Low Energy mode. Refer to NTS reports R103317 and R103316.

OBJECTIVE

The primary objective of the manufacturer is compliance with the regulations outlined in the previous section.

Prior to marketing in the USA, all unlicensed transmitters and transceivers require certification. Receive-only devices operating between 30 MHz and 960 MHz are subject to either certification or a manufacturer's declaration of conformity, with all other receive-only devices exempt from the technical requirements.

Prior to marketing in Canada, Class I transmitters, receivers and transceivers require certification. Class II devices are required to meet the appropriate technical requirements but are exempt from certification requirements.

Certification is a procedure where the manufacturer submits test data and technical information to a certification body and receives a certificate or grant of equipment authorization upon successful completion of the certification body's review of the submitted documents. Once the equipment authorization has been obtained, the label indicating compliance must be attached to all identical units, which are subsequently manufactured.

Maintenance of compliance is the responsibility of the manufacturer. Any modification of the product which may result in increased emissions should be checked to ensure compliance has been maintained (i.e., printed circuit board layout changes, different line filter, different power supply, harnessing or I/O cable changes, etc.).

STATEMENT OF COMPLIANCE

The tested sample of Google Inc. model GFHD254 complied with the requirements of the following regulations:

FCC Part 15 Subpart C

Maintenance of compliance is the responsibility of the manufacturer. Any modifications to the product should be assessed to determine their potential impact on the compliance status of the device with respect to the standards detailed in this test report.

The test results recorded herein are based on a single type test of Google Inc. model GFHD254 and therefore apply only to the tested sample. The sample was selected and prepared by Weifeng Pan of Google Inc..

DEVIATIONS FROM THE STANDARDS

No deviations were made from the published requirements listed in the scope of this report.

TEST RESULTS SUMMARY

DIGITAL TRANSMISSION SYSTEMS (2400 – 2483.5MHz)

FCC Rule Part	RSS Rule Part	Description	Measured Value / Comments	Limit / Requirement	Result
15.247(a)	-	Digital Modulation	Systems uses GFSK modulation techniques	System must utilize a digital transmission technology	Complies
15.247 (a) (2)	-	6dB Bandwidth	0.72 MHz	>500kHz	Complies
15.247 (b) (3)	-	Output Power (multipoint systems)	6.0dBm (4.0mW)	1Watt, EIRP limited to 4 Watts.	Complies
15.247(e)	-	Power Spectral Density	-8.3dBm/3kHz	8dBm/3kHz	Complies
15.247(d)	-	Antenna Port Spurious Emissions 30MHz – 25 GHz	All emissions <20dBc	< -20dBc	Complies
15.247(d) / 15.209	-	Radiated Spurious Emissions 30MHz – 25 GHz	52.1 dBµV/m @ 4880.1 MHz (-1.9 dB)	Refer to the limits section (p19) for restricted bands, all others < -20dBc	Complies

GENERAL REQUIREMENTS APPLICABLE TO ALL BANDS

FCC Rule Part	RSS Rule part	Description	Measured Value / Comments	Limit / Requirement	Result (margin)
15.203	-	RF Connector	Antenna is internal	Unique or integral antenna required	Complies
15.407 (b) (6)	0	AC Conducted Emissions	45.1 dBµV @ 0.447 MHz (-1.8 dB)	Refer to page 18	Complies
15.247 (i) 15.407 (f)	RSS 102	RF Exposure Requirements	Refer to MPE calculations in separate exhibit	Refer to OET 65, FCC Part 1 and RSS 102	Complies

MEASUREMENT UNCERTAINTIES

ISO/IEC 17025 requires that an estimate of the measurement uncertainties associated with the emissions test results be included in the report. The measurement uncertainties given below are based on a 95% confidence level and were calculated in accordance with UKAS document LAB 34.

Measurement Type	Measurement Unit	Frequency Range	Expanded Uncertainty
RF power, conducted (power meter)	dBm	25 to 7000 MHz	± 0.52 dB
RF power, conducted (Spectrum analyzer)	dBm	25 to 7000 MHz	± 0.7 dB
Conducted emission of transmitter	dBm	25 to 26500 MHz	± 0.7 dB
Conducted emission of receiver	dBm	25 to 26500 MHz	± 0.7 dB
Radiated emission (substitution method)	dBm	25 to 26500 MHz	± 2.5 dB
Radiated emission (field strength)	dBµV/m	25 to 1000 MHz	± 3.6 dB
		1000 to 40000 MHz	± 6.0 dB
Conducted Emissions (AC Power)	dBµV	0.15 to 30 MHz	± 2.4 dB

EQUIPMENT UNDER TEST (EUT) DETAILS

GENERAL

The Google Inc. model GFHD254 is a residential set-top box that supports the use of a IEEE 802.11 a/n/ac 5GHz radio and a Bluetooth 4.1 radio. The EUT is powered from an external AC/DC adapter.

The sample was received on May 2, 2016 and tested on October 5, 6, 7, 10 and 13, 2016. The EUT consisted of the following component(s):

Company	Model	Description	Serial Number	FCC ID
Google	GFHD254	Set-top box	See test data	A4RGFHD254
Google	OTD018	External power supply	-	-

OTHER EUT DETAILS

IEEE 802.11a/n/ac 4x4 radio
Indoor Use
DFS Client
Bluetooth 4.1 radio supporting Basic/EDR and Low Energy Modes
Simultaneous Transmission of 802.11 and BT radio supported

ANTENNA SYSTEM

Internal Antenna, -4.0dBi

ENCLOSURE

The EUT enclosure measures approximately 24.3cm by 15.5cm by 3.5cm. It is primarily constructed of uncoated plastic.

MODIFICATIONS

No modifications were made to the EUT during the time the product was at NTS Silicon Valley.

SUPPORT EQUIPMENT

The following equipment was used as support equipment for testing:

Company	Model	Description	Serial Number	FCC ID
Samsung	UN22F5000	LCD monitor	-	-

The following equipment was used as remote support equipment for emissions testing:

Company	Model	Description	Serial Number	FCC ID
Netgear	GS605	Ethernet switch	-	-

EUT INTERFACE PORTS

The I/O cabling configuration during testing was as follows:

Port	Connected To	Cable(s)		
		Description	Shielded or Unshielded	Length(m)
HDMI	LCD	Multiwire	Shielded	1.0
Audio out	LCD	Multiwire	Shielded	1.0
Ethernet	Switch	Cat 5	Unshielded	10.0
DC power	External power supply	2 wire	Unshielded	2.0
AC in (ext supply)	AC mains	2 wire	Unshielded	2.0
USB	Not connected*	-	-	-

* - USB port not supported for the current product release

EUT OPERATION

During testing, the EUT was configured to continuously transmit on the Bluetooth radio, in the LE mode (GFSK) at the maximum output power level. Refer to the test data in the Appendix of this report for details on the duty cycle of the transmission and the channels/frequencies used.

Additional testing was done with both the Bluetooth radio and the Wifi radio transmitting. Both radios were configured for continuous transmission, with the power set to the maximum power setting.

TEST SITE

GENERAL INFORMATION

Final test measurements were taken at the test sites listed below. Pursuant to section 2.948 of the FCC's Rules and section 3.3 of RSP-100, construction, calibration, and equipment data has been filed with the Commission and with industry Canada.

Site	Designation / Registration Numbers		Location
	FCC	Canada	
Chamber 3	US0027	2845B-3	41039 Boyce Road Fremont, CA 94538-2435
Chamber 5	US0027	2845B-5	
Chamber 7	US0027	2845B-7	

ANSI C63.4 recommends that ambient noise at the test site be at least 6 dB below the allowable limits. Ambient levels are below this requirement. The test site(s) contain separate areas for radiated and conducted emissions testing. Considerable engineering effort has been expended to ensure that the facilities conform to all pertinent requirements of ANSI C63.4.

CONDUCTED EMISSIONS CONSIDERATIONS

Conducted emissions testing is performed in conformance with ANSI C63.10. Measurements are made with the EUT connected to the public power network through a nominal, standardized RF impedance, which is provided by a line impedance stabilization network, known as a LISN. A LISN is inserted in series with each current-carrying conductor in the EUT power cord.

RADIATED EMISSIONS CONSIDERATIONS

The FCC has determined that radiation measurements made in a shielded enclosure are not suitable for determining levels of radiated emissions. Radiated measurements are performed in an open field environment or in a semi-anechoic chamber. The test sites are maintained free of conductive objects within the CISPR defined elliptical area incorporated in ANSI C63.4 guidelines and meet the Normalized Site Attenuation (NSA) requirements of ANSI C63.4.

MEASUREMENT INSTRUMENTATION

RECEIVER SYSTEM

An EMI receiver as specified in CISPR 16-1-1 is used for emissions measurements. The receivers used can measure over the frequency range of 9 kHz up to 2000 MHz. These receivers allow both ease of measurement and high accuracy to be achieved. The receivers have Peak, Average, and CISPR (Quasi-peak) detectors built into their design so no external adapters are necessary. The receiver automatically sets the required bandwidth for the CISPR detector used during measurements. If the repetition frequency of the signal being measured is below 20Hz, peak measurements are made in lieu of Quasi-Peak measurements.

For measurements above the frequency range of the receivers, a spectrum analyzer is utilized because it provides visibility of the entire spectrum along with the precision and versatility required to support engineering analysis. Average measurements above 1000MHz are performed on the spectrum analyzer using the linear-average method with a resolution bandwidth of 1 MHz and a video bandwidth of 10 Hz, unless the signal is pulsed in which case the average (or video) bandwidth of the measuring instrument is reduced to onset of pulse desensitization and then increased.

INSTRUMENT CONTROL COMPUTER

Software is used to view and convert receiver measurements to the field strength at an antenna or voltage developed at the LISN measurement port, which is then compared directly with the appropriate specification limit. This provides faster, more accurate readings by performing the conversions described under Sample Calculations within the Test Procedures section of this report. Results are printed in a graphic and/or tabular format, as appropriate. A personal computer is used to record all measurements made with the receivers. The software used for radiated and conducted emissions measurements is NTS EMI Test Software (rev 2.10)

LINE IMPEDANCE STABILIZATION NETWORK (LISN)

Line conducted measurements utilize a fifty microhenry Line Impedance Stabilization Network as the monitoring point. The LISN used also contains a 250 uH CISPR adapter. This network provides for calibrated radio frequency noise measurements by the design of the internal low pass and high pass filters on the EUT and measurement ports, respectively.

FILTERS/ATTENUATORS

External filters and precision attenuators are often connected between the receiving antenna or LISN and the receiver. This eliminates saturation effects and non-linear operation due to high amplitude transient events.

ANTENNAS

A loop antenna is used below 30 MHz. For the measurement range 30 MHz to 1000 MHz either a combination of a biconical antenna and a log periodic or a bi-log antenna is used. Above 1000 MHz, horn antennas are used. The antenna calibration factors to convert the received voltage to an electric field strength are included with appropriate cable loss and amplifier gain factors to determine an overall site factor, which is then programmed into the test receivers or incorporated into the test software.

ANTENNA MAST AND EQUIPMENT TURNTABLE

The antennas used to measure the radiated electric field strength are mounted on a non-conductive antenna mast equipped with a motor-drive to vary the antenna height. Measurements below 30 MHz are made with the loop antenna at a fixed height of 1m above the ground plane.

ANSI C63.10 specifies that the test height above ground for table mounted devices shall be 80 centimeters. Floor mounted equipment shall be placed on the ground plane if the device is normally used on a conductive floor or separated from the ground plane by insulating material from 3 to 12 mm if the device is normally used on a non-conductive floor as specified in ANSI C63.4. During radiated measurements, the EUT is positioned on a motorized turntable in conformance with this requirement.

INSTRUMENT CALIBRATION

All test equipment is regularly checked to ensure that performance is maintained in accordance with the manufacturer's specifications. All antennas are calibrated at regular intervals with respect to tuned half-wave dipoles. An exhibit of this report contains the list of test equipment used and calibration information.

TEST PROCEDURES

EUT AND CABLE PLACEMENT

The regulations require that interconnecting cables be connected to the available ports of the unit and that the placement of the unit and the attached cables simulate the worst case orientation that can be expected from a typical installation, so far as practicable. To this end, the position of the unit and associated cabling is varied within the guidelines of ANSI C63.10, and the worst-case orientation is used for final measurements.

CONDUCTED EMISSIONS

Conducted emissions are measured at the plug end of the power cord supplied with the EUT. Excess power cord length is wrapped in a bundle between 30 and 40 centimeters in length near the center of the cord. Preliminary measurements are made to determine the highest amplitude emission relative to the specification limit for all the modes of operation. Placement of system components and varying of cable positions are performed in each mode. A final peak mode scan is then performed in the position and mode for which the highest emission was noted on all current carrying conductors of the power cord.

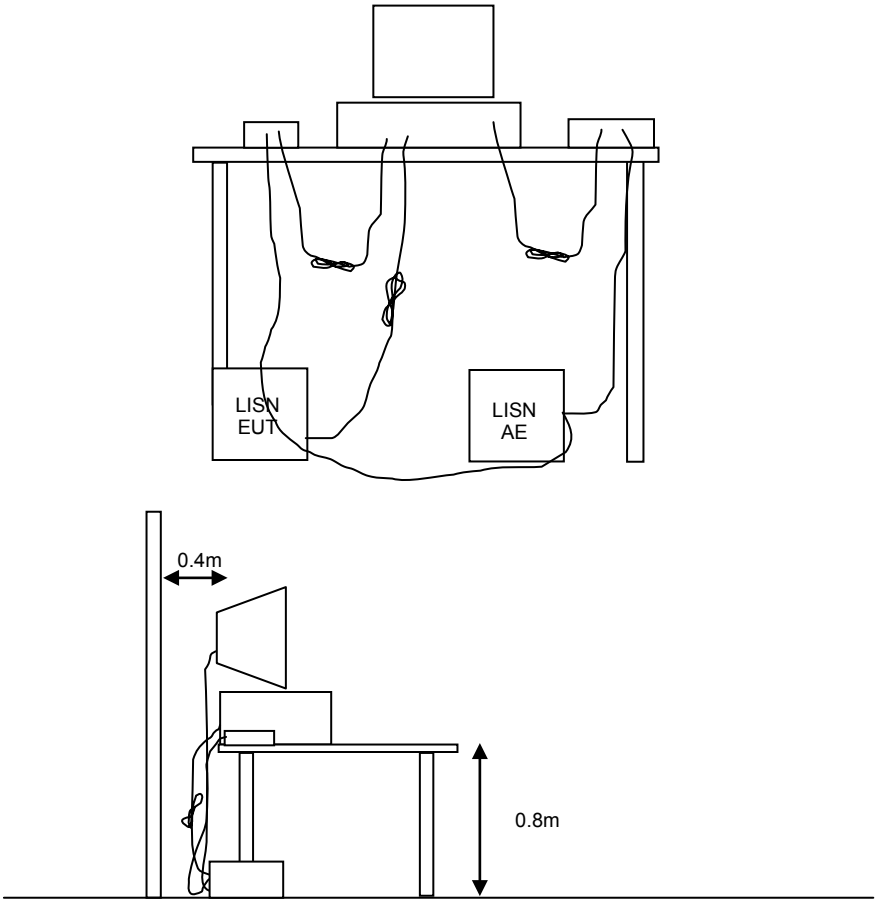


Figure 1 Typical Conducted Emissions Test Configuration

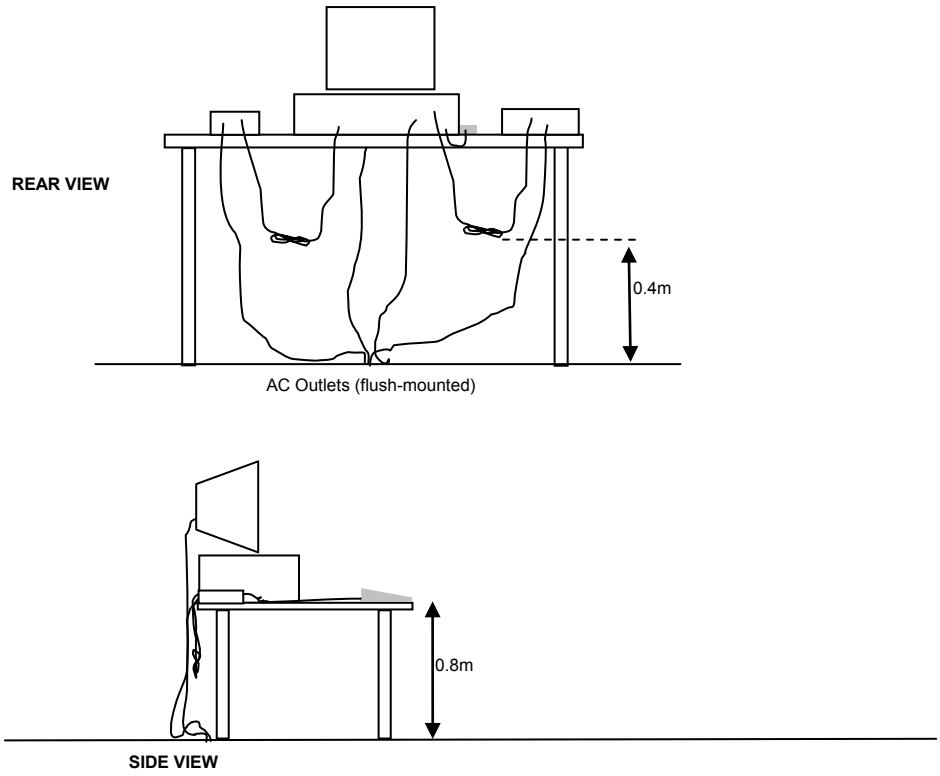
RADIATED EMISSIONS

A preliminary scan of the radiated emissions is performed in which all significant EUT frequencies are identified with the system in a nominal configuration. At least two scans are performed, one scan for each antenna polarization (horizontal and vertical; loop parallel and perpendicular to the EUT). During the preliminary scans, the EUT is rotated through 360˚, the antenna height is varied (for measurements above 30 MHz) and cable positions are varied to determine the highest emission relative to the limit. Preliminary scans may be performed in a fully anechoic chamber for the purposes of identifying the frequencies of the highest emissions from the EUT.

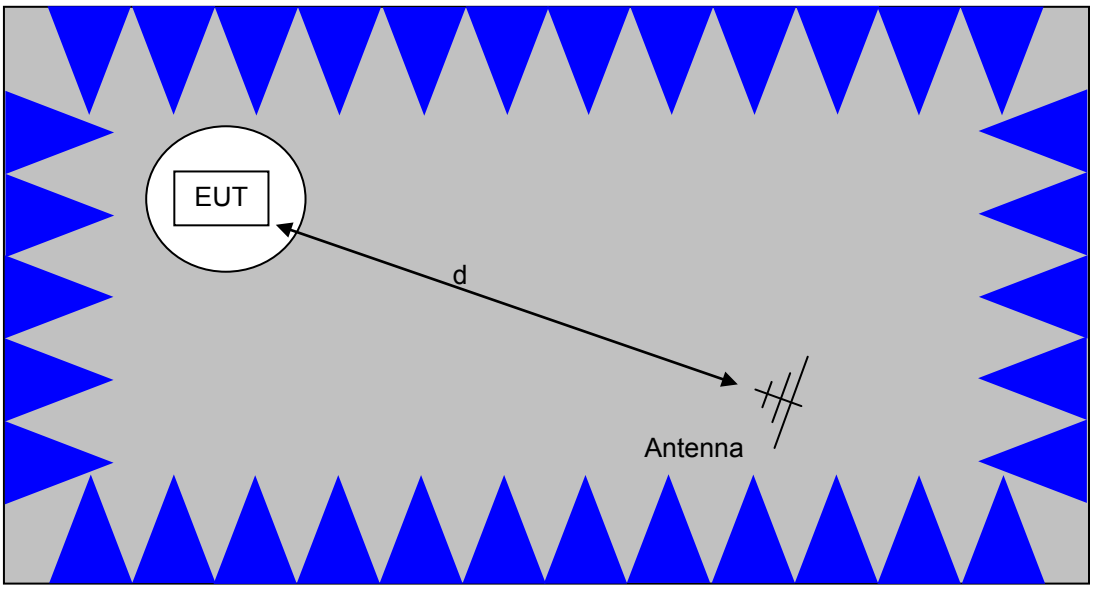
A speaker is provided in the receiver to aid in discriminating between EUT and ambient emissions. Other methods used during the preliminary scan for EUT emissions involve scanning with near field magnetic loops, monitoring I/O cables with RF current clamps, and cycling power to the EUT.

Final maximization is a phase in which the highest amplitude emissions identified in the spectral search are viewed while the EUT azimuth angle is varied from 0 to 360 degrees relative to the receiving antenna. The azimuth, which results in the highest emission is then maintained while varying the antenna height from one to four meters (for measurements above 30 MHz, measurements below 30 MHz are made with the loop antenna at a fixed height of 1m). The result is the identification of the highest amplitude for each of the highest peaks. Each recorded level is corrected in the receiver using appropriate factors for cables, connectors, antennas, and preamplifier gain.

When testing above 18 GHz, the receive antenna is located at 1meter from the EUT and the antenna height is restricted to a maximum of 2.5 meters.

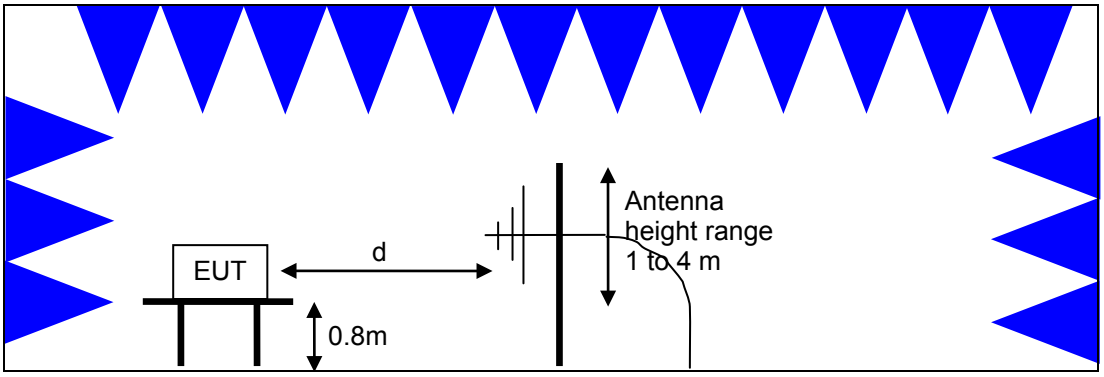


Typical Test Configuration for Radiated Field Strength Measurements



The anechoic materials on the walls and ceiling ensure compliance with the normalized site attenuation requirements of CISPR 16 / CISPR 22 / ANSI C63.4 for an alternate test site at the measurement distances used.

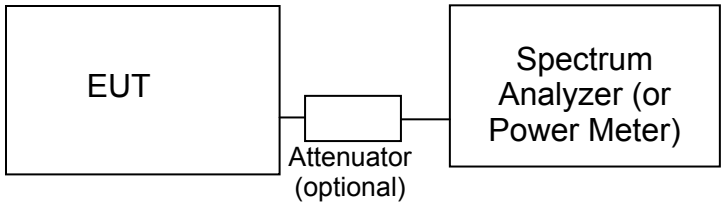
Floor-standing equipment is placed on the floor with insulating supports between the unit and the ground plane.



Test Configuration for Radiated Field Strength Measurements
Semi-Anechoic Chamber, Plan and Side Views

CONDUCTED EMISSIONS FROM ANTENNA PORT

Direct measurements of power, bandwidth and power spectral density are performed, where possible, with the antenna port of the EUT connected to either the power meter or spectrum analyzer via a suitable attenuator and/or filter. These are used to ensure that the front end of the measurement instrument is not overloaded by the fundamental transmission.



Test Configuration for Antenna Port Measurements

Measurement bandwidths (video and resolution) are set in accordance with the relevant standards and NTS Silicon Valley's test procedures for the type of radio being tested. When power measurements are made using a resolution bandwidth less than the signal bandwidth the power is calculated by summing the power across the signal bandwidth using either the analyzer channel power function or by capturing the trace data and calculating the power using software. In both cases the summed power is corrected to account for the equivalent noise bandwidth (ENBW) of the resolution bandwidth used.

If power averaging is used (typically for certain digital modulation techniques), the EUT is configured to transmit continuously. Power averaging is performed using either the built-in function of the analyzer or, if the analyzer does not feature power averaging, using external software. In both cases the average power is calculated over a number of sweeps (typically 100). When the EUT cannot be configured to continuously transmit then either the analyzer is configured to perform a gated sweep to ensure that the power is averaged over periods that the device is transmitting or power averaging is disabled and a max-hold feature is used.

If a power meter is used to make output power measurements the sensor head type (peak or average) is stated in the test data table.

BANDWIDTH MEASUREMENTS

The 6dB, 20dB, 26dB and/or 99% signal bandwidth are measured using the bandwidths recommended by ANSI C63.10 and RSS GEN.

SPECIFICATION LIMITS AND SAMPLE CALCULATIONS

The limits for conducted emissions are given in units of microvolts, and the limits for radiated emissions are given in units of microvolts per meter at a specified test distance. Data is measured in the logarithmic form of decibels relative to one microvolt, or dB microvolts (dBuV). For radiated emissions, the measured data is converted to the field strength at the antenna in dB microvolts per meter (dBuV/m). The results are then converted to the linear forms of uV and uV/m for comparison to published specifications.

For reference, converting the specification limits from linear to decibel form is accomplished by taking the base ten logarithm, then multiplying by 20. These limits in both linear and logarithmic form are as follows:

CONDUCTED EMISSIONS SPECIFICATION LIMITS: FCC 15.207; FCC 15.107(a), RSS GEN

The table below shows the limits for the emissions on the AC power line from an intentional radiator and a receiver.

Frequency (MHz)	Average Limit (dBuV)	Quasi Peak Limit (dBuV)
0.150 to 0.500	Linear decrease on logarithmic frequency axis between 56.0 and 46.0	Linear decrease on logarithmic frequency axis between 66.0 and 56.0
0.500 to 5.000	46.0	56.0
5.000 to 30.000	50.0	60.0

GENERAL TRANSMITTER RADIATED EMISSIONS SPECIFICATION LIMITS

The table below shows the limits for the spurious emissions from transmitters that fall in restricted bands[1].

Frequency Range (MHz)	Limit (uV/m)	Limit (dBuV/m @ 3m)
0.009-0.490	$2400/F_{KHz}$ @ 300m	$67.6-20*\log_{10}(F_{KHz})$ @ 300m
0.490-1.705	$24000/F_{KHz}$ @ 30m	$87.6-20*\log_{10}(F_{KHz})$ @ 30m
1.705 to 30	30 @ 30m	29.5 @ 30m
30 to 88	100 @ 3m	40 @ 3m
88 to 216	150 @ 3m	43.5 @ 3m
216 to 960	200 @ 3m	46.0 @ 3m
Above 960	500 @ 3m	54.0 @ 3m

OUTPUT POWER LIMITS – DIGITAL TRANSMISSION SYSTEMS

The table below shows the limits for output power and output power density.

Operating Frequency (MHz)	Output Power	Power Spectral Density
2400 – 2483.5	1 Watt (30 dBm)	8 dBm/3kHz

The maximum permitted output power is reduced by 1dB for every dB the antenna gain exceeds 6dBi.

TRANSMIT MODE SPURIOUS RADIATED EMISSIONS LIMITS – FHSS and DTS SYSTEMS

The limits for unwanted (spurious) emissions from the transmitter falling in the restricted bands are those specified in the general limits sections of FCC Part 15 and RSS 247. All other unwanted (spurious) emissions shall be at least 20dB below the level of the highest in-band signal level (30dB if the power is measured using the sample detector/power averaging method).

[1] The restricted bands are detailed in FCC 15.205 and RSS-Gen Table 6

SAMPLE CALCULATIONS - CONDUCTED EMISSIONS

Receiver readings are compared directly to the conducted emissions specification limit (decibel form) as follows:

$$R_r - S = M$$

where:
R_r = Receiver Reading in dBuV
S = Specification Limit in dBuV
M = Margin to Specification in +/- dB

SAMPLE CALCULATIONS - RADIATED EMISSIONS

Receiver readings are compared directly to the specification limit (decibel form). The receiver internally corrects for cable loss, preamplifier gain, and antenna factor. The calculations are in the reverse direction of the actual signal flow, thus cable loss is added and the amplifier gain is subtracted. The Antenna Factor converts the voltage at the antenna coaxial connector to the field strength at the antenna elements.

A distance factor, when used for electric field measurements above 30MHz, is calculated by using the following formula:

$$F_d = 20*LOG_{10} (D_m/D_s)$$

where:
F_d = Distance Factor in dB
D_m = Measurement Distance in meters
D_s = Specification Distance in meters

For electric field measurements below 30MHz the extrapolation factor is either determined by making measurements at multiple distances or a theoretical value is calculated using the formula:

$$F_d = 40*LOG_{10} (D_m/D_s)$$

Measurement Distance is the distance at which the measurements were taken and Specification Distance is the distance at which the specification limits are based. The antenna factor converts the voltage at the antenna coaxial connector to the field strength at the antenna elements.

The margin of a given emission peak relative to the limit is calculated as follows:

$$R_c = R_r + F_d$$

and

$$M = R_c - L_s$$

where:
R_r = Receiver Reading in dBuV/m
F_d = Distance Factor in dB
R_c = Corrected Reading in dBuV/m
L_s = Specification Limit in dBuV/m
M = Margin in dB Relative to Spec

SAMPLE CALCULATIONS - FIELD STRENGTH TO EIRP CONVERSION

Where the radiated electric field strength is expressed in terms of the equivalent isotropic radiated power (eirp), or where a field strength measurement of output power is made in lieu of a direct measurement, the following formula is used to convert between eirp and field strength at a distance of d (meters) from the equipment under test:

$$E = \frac{1000000 \sqrt{30 P}}{d} \quad \text{microvolts per meter}$$

where P is the eirp (Watts)

For a measurement at 3m the conversion from a logarithmic value for field strength (dBuV/m) to an eirp power (dBm) is -95.3dB.

Appendix A Test Equipment Calibration Data

Manufacturer	Description	Model	Asset #	Calibrated	Cal Due
Radiated Emissions, 1000 - 18,000 MHz, 02-May-16					
EMCO	Antenna, Horn, 1-18GHz	3115	868	6/26/2014	6/26/2016
Hewlett Packard	High Pass filter, 8.2 GHz	P/N 84300-80039	1152	7/10/2015	7/10/2016
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB7	1538	12/19/2015	12/19/2016
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	2199	10/9/2015	10/9/2016
Micro-Tronics	Band Reject Filter, 5150-5350 MHz	BRC50703-02	2239	9/16/2015	9/16/2016
Hewlett Packard	Spectrum Analyzer (SA40) Purple 9 kHz - 40 GHz,	8564E (84125C)	2415	3/19/2016	3/19/2017
Radiated Emissions, 1000 - 18,000 MHz, 04-May-16					
Narda West	High Pass Filter, 8 GHz	HPF 180	821	1/27/2016	1/27/2017
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	870	1/21/2016	1/21/2017
Hewlett Packard	Spectrum Analyzer (SA40) Red 30 Hz -40 GHz	8564E (84125C)	1148	10/17/2015	10/17/2016
Micro-Tronics	Band Reject Filter, 5725-5875 MHz	BRC50705-02	1682	7/8/2015	7/8/2016
Micro-Tronics	Band Reject Filter, 5470-5725 MHz	BRC50704-02	1730	7/10/2015	7/10/2016
EMCO	Antenna, Horn, 1-18 GHz	3115	2733	11/18/2014	11/18/2016
Radiated Emissions, 1000 - 40,000 MHz, 09-May-16					
NTS	NTS EMI Software (rev 2.10)	N/A	0		N/A
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	870	1/21/2016	1/21/2017
HP / Miteq	SA40 Head (Red)	TTA1840-45-5P-HG-S	1145	7/17/2015	7/17/2016
Hewlett Packard	Spectrum Analyzer (SA40) Red 30 Hz -40 GHz	8564E (84125C)	1148	10/17/2015	10/17/2016
Micro-Tronics	Band Reject Filter, 5725-5875 MHz	BRC50705-02	1682	7/8/2015	7/8/2016
A. H. Systems	Purple System Horn, 18-40GHz	SAS-574, p/n: 2581	2160	8/28/2014	8/28/2017
EMCO	Antenna, Horn, 1-18 GHz	3115	2733	11/18/2014	11/18/2016
Radiated Spurious Emissions, 1000 - 18,000 MHz, 11-May-16					
NTS	NTS EMI Software (rev 2.10)	N/A	0		N/A
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	870	1/21/2016	1/21/2017
Hewlett Packard	Spectrum Analyzer (SA40) Red 30 Hz -40 GHz	8564E (84125C)	1148	10/17/2015	10/17/2016
Micro-Tronics	Band Reject Filter, 5725-5875 MHz	BRC50705-02	1682	7/8/2015	7/8/2016
Micro-Tronics	Band Reject Filter, 5470-5725 MHz	BRC50704-02	1730	7/10/2015	7/10/2016
Micro-Tronics	Band Reject Filter, 5150-5350 MHz	BRC50703-02	2239	9/16/2015	9/16/2016
EMCO	Antenna, Horn, 1-18 GHz	3115	2733	11/18/2014	11/18/2016

Manufacturer	Description	Model	Asset #	Calibrated	Cal Due
Radiated Emissions, 1000 - 40,000 MHz, 11-May-16					
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	870	1/21/2016	1/21/2017
HP / Miteq	SA40 Head (Red)	TTA1840-45-5P-HG-S	1145	7/17/2015	7/17/2016
Hewlett Packard	Spectrum Analyzer (SA40) Red 30 Hz -40 GHz	8564E (84125C)	1148	10/17/2015	10/17/2016
Hewlett Packard	High Pass filter, 8.2 GHz	P/N 84300-80039	1152	7/10/2015	7/10/2016
A. H. Systems	Purple System Horn, 18-40GHz	SAS-574, p/n: 2581	2160	8/28/2014	8/28/2017
EMCO	Antenna, Horn, 1-18 GHz	3115	2733	11/18/2014	11/18/2016
Radiated Emissions, 1000 - 18,000 MHz, 17-May-16					
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	870	1/21/2016	1/21/2017
Hewlett Packard	Spectrum Analyzer (SA40) Red 30 Hz -40 GHz	8564E (84125C)	1148	10/17/2015	10/17/2016
Hewlett Packard	High Pass filter, 8.2 GHz	P/N 84300-80039	1152	7/10/2015	7/10/2016
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB7	1538	12/19/2015	12/19/2016
EMCO	Antenna, Horn, 1-18 GHz	3115	2733	11/18/2014	11/18/2016
Radiated Emissions, 30 - 1,000 MHz, 18-May-16					
NTS	NTS EMI Software (rev 2.10)	N/A	0		N/A
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB7	1538	12/19/2015	12/19/2016
Sunol Sciences	Biconilog, 30-3000 MHz	JB3	1549	6/2/2015	6/2/2017
Hewlett Packard	9KHz-1300MHz pre-amp	8447F	2777	1/26/2016	1/26/2017
Radiated Emissions, 1000 - 6,500 MHz, 18-May-16					
NTS	NTS EMI Software (rev 2.10)	N/A	0		N/A
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB7	1538	12/19/2015	12/19/2016
EMCO	Antenna, Horn, 1-18 GHz	3115	2733	11/18/2014	11/18/2016
Radiated Emissions, 1000 - 6,000 MHz, 18-May-16					
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB7	1538	12/19/2015	12/19/2016
EMCO	Antenna, Horn, 1-18 GHz	3115	2733	11/18/2014	11/18/2016
Radiated Emissions, 1000 - 6,000 MHz, 19-May-16					
EMCO	Antenna, Horn, 1-18 GHz	3115	487	7/29/2014	7/29/2016
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB7	1538	12/19/2015	12/19/2016
Radiated Emissions, 1000 - 6,000 MHz, 20-May-16					
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB7	1538	12/19/2015	12/19/2016
EMCO	Antenna, Horn, 1-18 GHz	3115	2733	11/18/2014	11/18/2016
Radio Antenna Port (Power and Spurious Emissions), 24-May-16					
Agilent Technologies	PSA, Spectrum Analyzer, (installed options, 111, 115, 123, 1DS, B7J, HYX,	E4446A	2139	6/22/2015	6/22/2016

Manufacturer	Description	Model	Asset #	Calibrated	Cal Due
Radiated Emissions, 1000 - 40,000 MHz, 24-Aug-16					
Hewlett Packard	High Pass filter, 8.2 GHz	P/N 84300-80039	1156	5/5/2016	5/5/2017
EMCO	Antenna, Horn, 1-18 GHz	3115	1561	7/8/2016	7/8/2018
Micro-Tronics	Band Reject Filter, 5725-5875 MHz	BRC50705-02	1728	5/11/2016	5/11/2017
HP / Miteq	SA40 Head (Purple)	TTA1840-45-5P-HG-S	1772	12/21/2015	N/A
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	1780	10/9/2015	10/9/2016
A. H. Systems	Spare System Horn, 18-40GHz	SAS-574, p/n: 2581	2162	7/29/2015	7/29/2017
Micro-Tronics	Band Reject Filter, 5150-5350 MHz	BRC50703-02	2239	9/16/2015	9/16/2016
Micro-Tronics	Band Reject Filter, 5470-5725 MHz	BRC50704-02	2240	9/16/2015	9/16/2016
Hewlett Packard	Spectrum Analyzer (SA40) Purple 9 kHz - 40 GHz,	8564E (84125C)	2415	3/19/2016	3/19/2017
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB7	1538	12/19/2015	12/19/2016
Radiated Emissions, 1,000 - 18,000 MHz, 02-Sep-16					
Hewlett Packard	High Pass filter, 8.2 GHz (Blu System)	P/N 84300-80039 (84125C)	1392	5/5/2016	5/5/2017
EMCO	Antenna, Horn, 1-18 GHz	3115	1561	7/8/2016	7/8/2018
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	1780	10/9/2015	10/9/2016
Micro-Tronics	Band Reject Filter, 5725-5875 MHz	BRC50705-02	2241	9/16/2015	9/16/2016
Hewlett Packard	Spectrum Analyzer (SA40) Purple 9 kHz - 40 GHz,	8564E (84125C)	2415	3/19/2016	3/19/2017
Radio Antenna Port (Power and Spurious Emissions), 19-23-Sep-16					
Agilent Technologies	3Hz -44GHz PSA Spectrum Analyzer	E4446A	2796	5/6/2016	5/6/2017
NTS	NTS UNII Power Software (rev 3.8)	N/A	0		N/A
NTS	NTS Capture Analyzer Software (rev 3.8)	N/A	0		N/A
Radio Antenna Port (Power and Spurious Emissions), 27 and 28-Sep-16					
Agilent Technologies	3Hz -44GHz PSA Spectrum Analyzer	E4446A	2796	5/6/2016	5/6/2017
NTS	NTS UNII Power Software (rev 3.8)	N/A	0		N/A
NTS	NTS Capture Analyzer Software (rev 3.8)	N/A	0		N/A
Radiated Emissions, 1,000 - 12,000 MHz, 06-Oct-16 & 07-Oct-16					
EMCO	Antenna, Horn, 1-18GHz	3115	868	6/30/2016	6/30/2018
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	870	1/21/2016	1/21/2017
Hewlett Packard	Spectrum Analyzer (SA40) Red 30 Hz -40 GHz	8564E (84125C)	1148	10/17/2015	10/17/2016
Micro-Tronics	Band Reject Filter, 2400-2500 MHz	BRM50702-02	1683	6/29/2016	6/29/2017

Manufacturer	Description	Model	Asset #	Calibrated	Cal Due
Radiated Spurious Emissions, 1000 - 25,000 MHz, 11-Oct-16					
NTS	NTS EMI Software (rev 2.10)	N/A	0		N/A
EMCO	Antenna, Horn, 1-18GHz	3115	868	6/30/2016	6/30/2018
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	870	1/21/2016	1/21/2017
HP / Miteq	SA40 Head (Red)	TTA1840-45-5P-HG-S	1145	8/24/2016	8/24/2017
Hewlett Packard	Spectrum Analyzer (SA40) Red 30 Hz -40 GHz	8564E (84125C)	1148	10/17/2015	10/17/2016
Micro-Tronics	Band Reject Filter, 2400-2500 MHz	BRM50702-02	1683	6/29/2016	6/29/2017
A. H. Systems	Purple System Horn, 18-40GHz	SAS-574, p/n: 2581	2160	8/28/2014	8/28/2017
Radiated Emissions, 1,000 - 18,000 MHz, 13-Oct-16					
EMCO	Antenna, Horn, 1-18GHz	3115	868	6/30/2016	6/30/2018
Hewlett Packard	Microwave Preamplifier, 1-26.5GHz	8449B	870	1/21/2016	1/21/2017
Hewlett Packard	Spectrum Analyzer (SA40) Red 30 Hz -40 GHz	8564E (84125C)	1148	10/17/2015	11/17/2016
Hewlett Packard	High Pass filter, 8.2 GHz	P/N 84300-80039	1152	6/28/2016	6/28/2017
Micro-Tronics	Band Reject Filter, 2400-2500 MHz	BRM50702-02	2238	9/19/2016	9/19/2017
Micro-Tronics	Band Reject Filter, 5150-5350 MHz	BRC50703-02	2251	9/19/2016	9/19/2017
Rohde & Schwarz	EMI Test Receiver, 20 Hz-40 GHz	ESIB40 (1088.7490.40)	2493	2/20/2016	2/20/2017
Radiated Emissions, 30 - 1,000 MHz, 14-Oct-16					
Micro-Tronics	Band Reject Filter, 5725-5875 MHz	BRC50705-02	1682	5/9/2016	5/9/2017
Micro-Tronics	Band Reject Filter, 2400-2500 MHz	BRM50702-02	1683	6/29/2016	6/29/2017
Micro-Tronics	Band Reject Filter, 5150-5350 MHz	BRC50703-02	2251	9/19/2016	9/19/2017
Rohde & Schwarz	EMI Test Receiver, 20 Hz-40 GHz	ESIB40 (1088.7490.40)	2493	2/20/2016	2/20/2017
Com-Power	Preamplifier, 1-1000 MHz	PAM-103	2885	9/16/2016	9/16/2017
Sunol Sciences	Biconilog, 30-3000 MHz	JB3	1657	7/27/2016	7/27/2018
Radio Antenna Port (Power and Spurious Emissions), 14-Oct-16					
Agilent Technologies	3Hz -44GHz PSA Spectrum Analyzer	E4446A	2796	5/6/2016	5/6/2017
Conducted Emissions - AC Power Ports, 20-Oct-16					
EMCO	LISN, 10 kHz-100 MHz	3825/2	1292	8/1/2016	8/1/2017
EMCO	LISN, 10 kHz-100 MHz	3825/2	1293	6/7/2016	6/7/2017
Rohde & Schwarz	Pulse Limiter	ESH3 Z2	1594	8/31/2016	8/31/2017
Rohde & Schwarz	EMI Test Receiver, 20 Hz-7 GHz	ESIB7	1756	6/29/2016	6/29/2017
Radio Antenna Port (Frequency Stability), 26-Oct-16					
NTS	NTS Capture Analyzer Software (rev 3.8)	N/A	0		N/A
Rohde & Schwarz	Signal Analyzer 20 Hz - 26.5 GHz	FSQ26	2327	6/17/2016	6/17/2017

Manufacturer	Description	Model	Asset #	Calibrated	Cal Due
Honeywell	Chart Recorder	DR45AT-1000-00-001-0 (Trueline)	2406	11/17/2015	11/17/2016
Envirotronics	Temperature/Humidity chamber	SH16C	3195		N/A

Appendix B Test Data

T101543 Pages 28 – 56

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Product	GFHD254	T-Log Number:	T101543
System Configuration:	-	Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Emissions Standard(s):	FCC 15.247 and 15.407	Class:	B
Immunity Standard(s):	-	Environment:	-

EMC Test Data

For The

Google, Inc.

Product

GFHD254

Date of Last Test: 10/20/2016

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B

Conducted Emissions

(NTS Silicon Valley, Fremont Facility, Semi-Anechoic Chamber)

Test Specific Details

Objective: The objective of this test session is to perform final qualification testing of the EUT with respect to the specification listed above.

Date of Test: 10/20/2016
Test Engineer: Rafael Varelas
Test Location: Fremont Chamber #3
Config. Used: 1
Config Change: None
EUT Voltage: 120V/60Hz

General Test Configuration

For tabletop equipment, the EUT was located on a wooden table inside the semi-anechoic chamber, 40 cm from a vertical coupling plane and 80cm from the LISN. A second LISN was used for all local support equipment. Remote support equipment was located outside of the semi-anechoic chamber. Any cables running to remote support equipment where routed through metal conduit and when possible passed through a ferrite clamp upon exiting the chamber.

Ambient Conditions:

Temperature: 23.2 °C
Rel. Humidity: 39 %

Summary of Results

Run #	Test Performed	Limit	Result	Margin
1	CE, AC Power,120V/60Hz	Class B	Pass	45.1 dBµV @ 0.447 MHz (-1.8 dB)

Modifications Made During Testing

No modifications were made to the EUT during testing

Deviations From The Standard

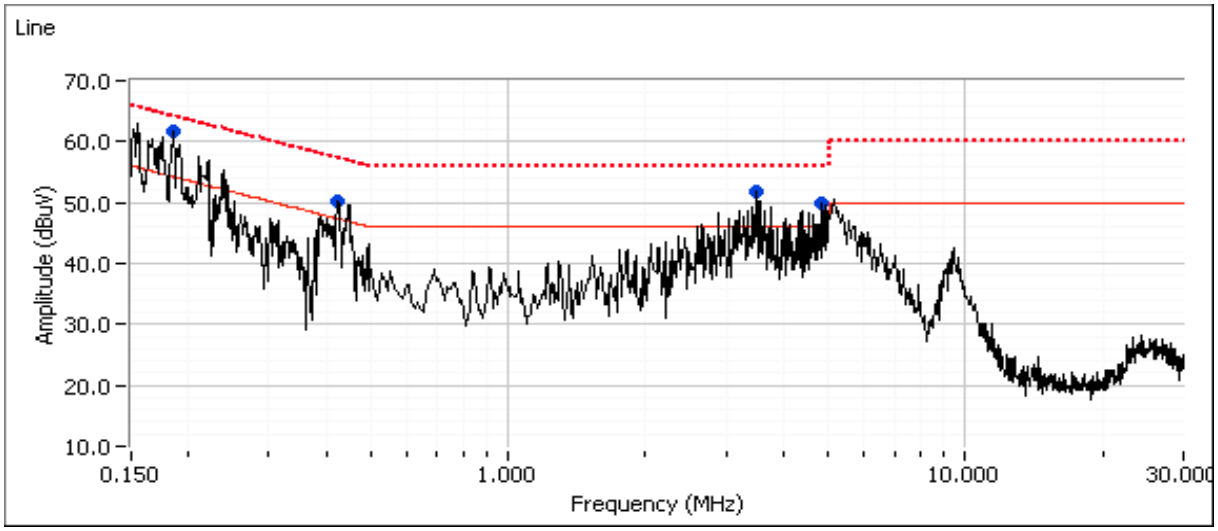
No deviations were made from the requirements of the standard.

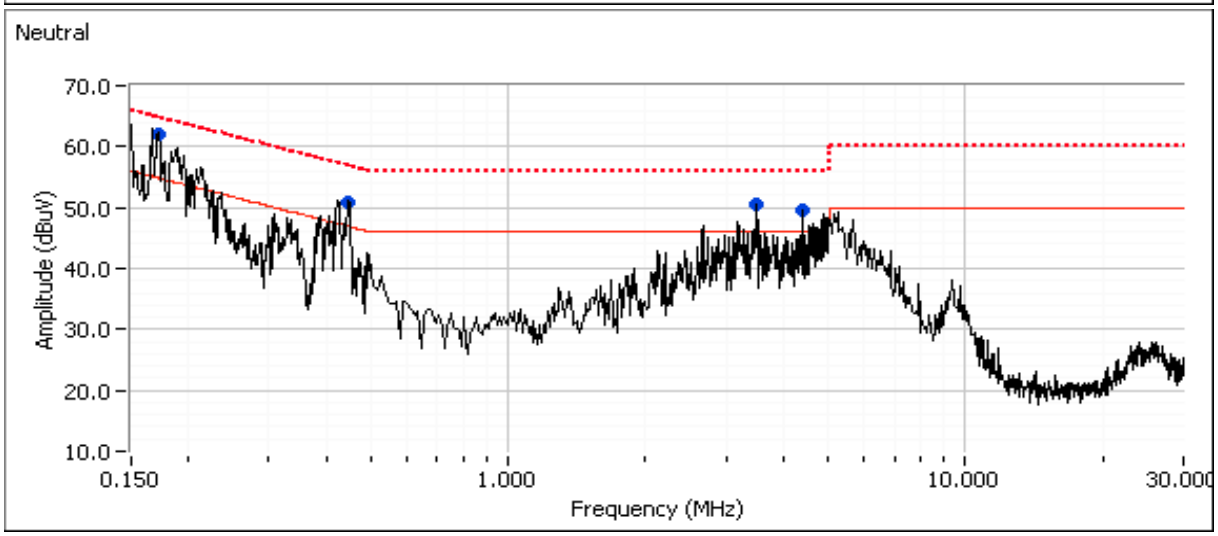
Sample Notes

Sample S/N: GTCFNS1630E0091
Driver:

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B

Run #1: AC Power Port Conducted Emissions, 0.15 - 30MHz,120V/60Hz
The EUT was configured to transmit at 2440 MHz (BLE) and 5785 MHz (802.11a)





Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B

Preliminary peak readings captured during pre-scan (peak readings vs. average limit)

Frequency	Level	AC	Class B		Detector	Comments
MHz	dBµV	Line	Limit	Margin	QP/Ave	
0.188	61.7	Line 1	54.2	7.5	Peak	
0.423	50.3	Line 1	47.4	2.9	Peak	
3.501	51.7	Line 1	46.0	5.7	Peak	
4.865	49.8	Line 1	46.0	3.8	Peak	
0.174	62.0	Neutral	54.8	7.2	Peak	
0.447	50.9	Neutral	46.9	4.0	Peak	
3.499	50.4	Neutral	46.0	4.4	Peak	
4.421	49.5	Neutral	46.0	3.5	Peak	

Final quasi-peak and average readings

Frequency	Level	AC	Class B		Detector	Comments
MHz	dBµV	Line	Limit	Margin	QP/Ave	
0.447	45.1	Neutral	46.9	-1.8	AVG	AVG (0.10s)
0.423	44.3	Line 1	47.4	-3.1	AVG	AVG (0.10s)
0.188	50.1	Line 1	54.1	-4.0	AVG	AVG (0.10s)
0.188	58.4	Line 1	64.1	-5.7	QP	QP (1.00s)
0.447	50.7	Neutral	56.9	-6.2	QP	QP (1.00s)
0.423	50.7	Line 1	57.4	-6.7	QP	QP (1.00s)
3.501	47.7	Line 1	56.0	-8.3	QP	QP (1.00s)
4.865	37.6	Line 1	46.0	-8.4	AVG	AVG (0.10s)
4.865	47.1	Line 1	56.0	-8.9	QP	QP (1.00s)
0.174	55.6	Neutral	64.8	-9.2	QP	QP (1.00s)
3.499	46.5	Neutral	56.0	-9.5	QP	QP (1.00s)
3.501	36.4	Line 1	46.0	-9.6	AVG	AVG (0.10s)
3.499	35.6	Neutral	46.0	-10.4	AVG	AVG (0.10s)
4.421	41.5	Neutral	56.0	-14.5	QP	QP (1.00s)
0.174	40.2	Neutral	54.8	-14.6	AVG	AVG (0.10s)
4.421	29.5	Neutral	46.0	-16.5	AVG	AVG (0.10s)

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B

RSS-247, FCC 15.247, FCC 15.407 Radiated Spurious Emissions

Test Specific Details

Objective: The objective of this test session is to perform final qualification testing of the EUT with respect to the specification listed above.

Date of Test: See below
Test Engineer: See below
Test Location: Fremont CH 5
Config. Used: 1
Config Change: None
EUT Voltage: 120V/60Hz

General Test Configuration

The EUT and all local support equipment were located on the turntable for radiated spurious emissions testing.
For radiated emissions testing the measurement antenna was located 3 meters from the EUT, unless otherwise noted.

Ambient Conditions:

Temperature: 21.8 °C
Rel. Humidity: 43 %

Summary of Results

Run #	Mode	Freq.	Power Setting	Passing Power Setting	Test Performed	Limit	Result / Margin
Simultaneous Tx operation							
1	BLE a	2440 5300	Max 15	Max 15	Radiated Emissions, 30 - 1000MHz	FCC 15.209 / 15.247 / 15 E	31.0 dBµV/m @ 75.51 MHz (-9.0 dB)
	BLE a	2440 5300	Max 15	Max 15	Radiated Emissions, 1 - 40 GHz		53.0 dBµV/m @ 21199.8 MHz (-1.0 dB)
2	BLE a	2440 5785	Max 19	Max 19	Radiated Emissions, 30 - 1000MHz		35.2 dBµV/m @ 226.92 MHz (-10.8 dB)
	BLE a	2440 5785	Max 19	Max 19	Radiated Emissions, 1 - 40 GHz		52.1 dBµV/m @ 4880.1 MHz (-1.9 dB)

Modifications Made During Testing

No modifications were made to the EUT during testing

Deviations From The Standard

No deviations were made from the requirements of the standard.

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B

Procedure Comments:

Measurements performed in accordance with FCC KDB 789033
Peak measurements performed with: RBW=1MHz, VBW=3MHz, peak detector, max hold, auto sweep time
Unless otherwise stated/noted, emission has duty cycle ≥ 98% and was measured using RBW=1MHz, VBW=10Hz, peak detector, linear average mode, auto sweep time, max hold 50 traces. (method VB of KDB 789033)

Mode	Data Rate	Duty Cycle (x)	Constant DC?	T (ms)	Pwr Cor Factor*	Lin Volt Cor Factor**	Min VBW for FS (Hz)
BLE	1Mbps	62.6%	Yes	2.44	2.03	4.07	410
11a	6Mbps	90.1%	Yes	0.567	0.45	0.90	1764

Sample Notes

Sample S/N: GTCFNS1630E0091
Driver:
Antenna: Internal

Measurement Specific Notes:

Note 1:	For emissions outside of the restricted bands the limit is -27dBm/MHz eirp (68.3dBuV/m). The measurement method required is a peak measurement (RB=1MHz, VB≥3MHz, peak detector). Per KDB 789033 2) c) (i), compliance can be demonstrated by meeting the average and peak limits of 15.209, as an alternative.
Note 2:	Emission has constant duty cycle < 98%, average measurement performed: RBW=1MHz, VBW>1/T but not less than 10Hz, peak detector, linear averaging, auto sweep,max hold 50*1/DC traces (method VB of KDB 789033)

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B

Run #1, Radiated Spurious Emissions

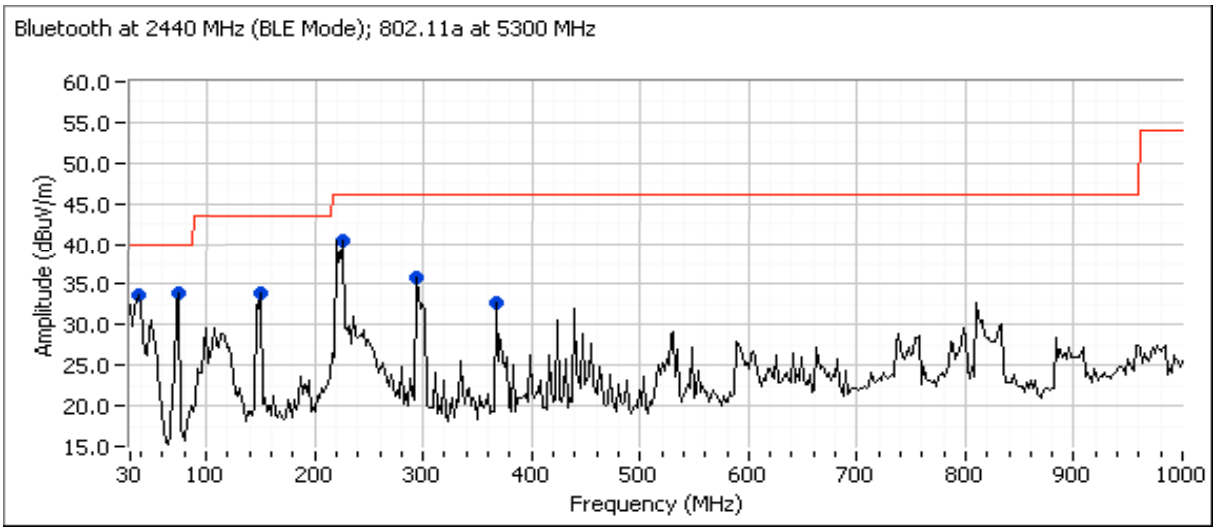
Date of Test: 10/13-14/16
Test Engineer: M. Birgani
Test Location: Chamber 5

Config. Used: 1
Config Change: -
EUT Voltage: 120V/ 60Hz

Freq: 2440 Mode: BLE
Tx Chain: - Data Rate: 1Mbps
Freq: 5300 Mode: 11a
Tx Chain: 4Tx Data Rate: 6Mbps

Run #1a: 30-1000MHz

Frequency	Level	Pol	15.209 / 15.247 / 15E		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
75.514	31.0	V	40.0	-9.0	QP	267	1.0	QP (1.00s)
223.709	35.4	H	46.0	-10.6	QP	200	1.0	QP (1.00s)
151.209	30.7	H	43.5	-12.8	QP	231	1.2	QP (1.00s)
296.014	29.9	H	46.0	-16.1	QP	191	1.9	QP (1.00s)
31.956	22.3	V	40.0	-17.7	QP	116	1.0	QP (1.00s)
370.370	23.8	H	46.0	-22.2	QP	214	1.5	QP (1.00s)



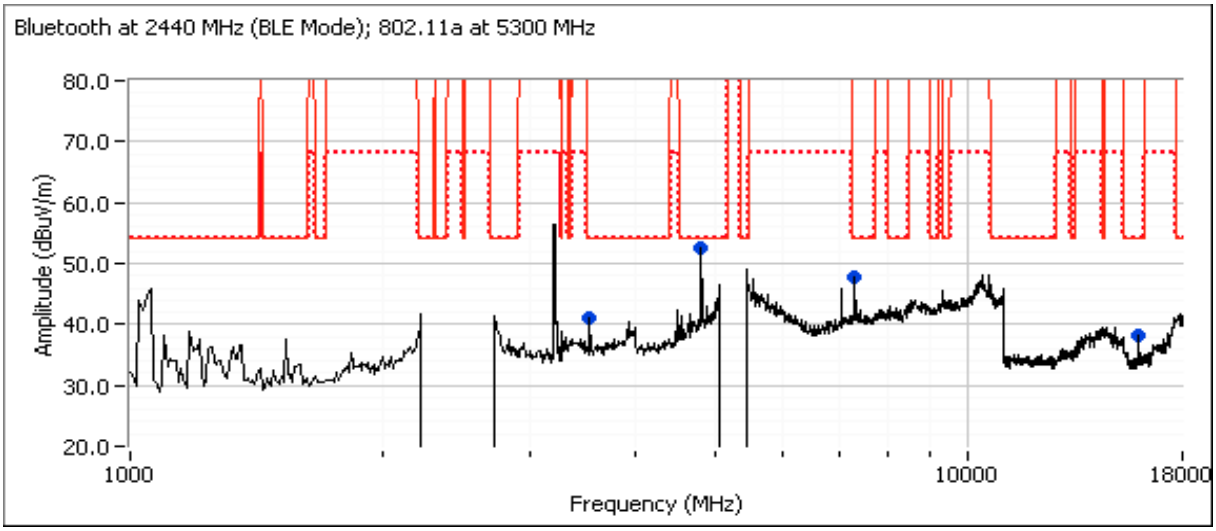
Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B

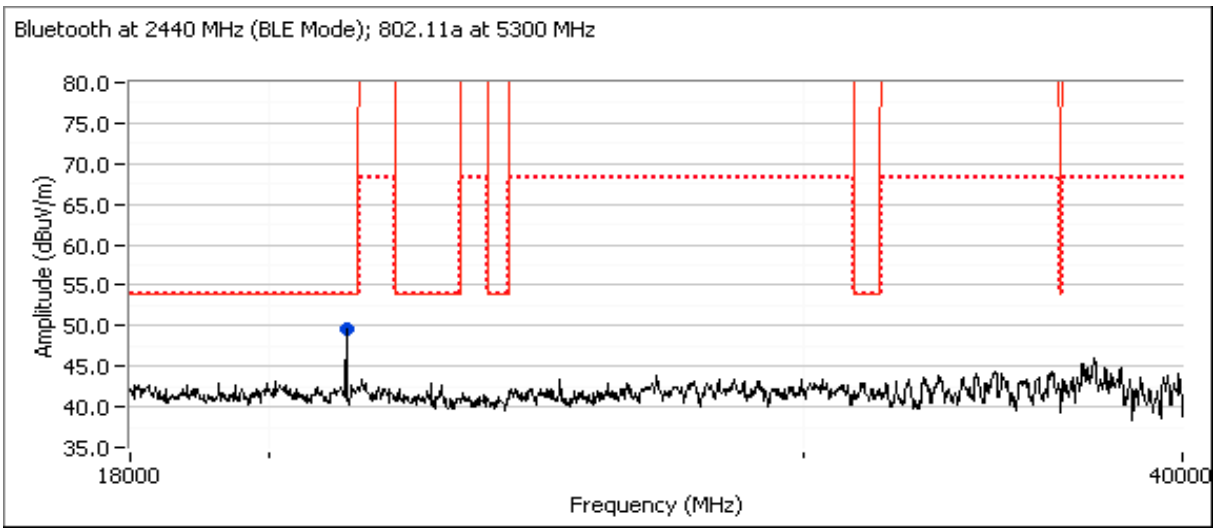
Run #1b: 1000-40000MHz

Freq:	2440	Mode:	BLE
Tx Chain:	-	Data Rate:	1Mbps
Freq:	5300	Mode:	11a
Tx Chain:	4Tx	Data Rate:	6Mbps

Frequency	Level	Pol	15.209 / 15E		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
21199.770	53.0	V	54.0	-1.0	PK	338	0.97	RB 1 MHz;VB 3 MHz;Peak
4880.080	52.1	H	54.0	-1.9	VAVG	295	1.67	BLE 2nd Harmonic
21199.770	47.0	V	54.0	-7.0	VAVG	338	0.97	RB 1 MHz;VB 3 kHz;Peak
3533.380	45.7	V	54.0	-8.3	PK	88	1.08	RB 1 MHz;VB 3 MHz;Peak
15899.800	42.9	V	54.0	-11.1	Avg	203	1.96	VB 3 kHz, note 2
3533.350	40.6	V	54.0	-13.4	VAVG	88	1.08	RB 1 MHz;VB 1 kHz;Peak
4880.530	54.6	H	74.0	-19.4	PK	295	1.67	BLE 2nd Harmonic
15900.270	52.2	V	74.0	-21.8	PK	203	1.96	

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B





Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B

Run #2, Radiated Spurious Emissions

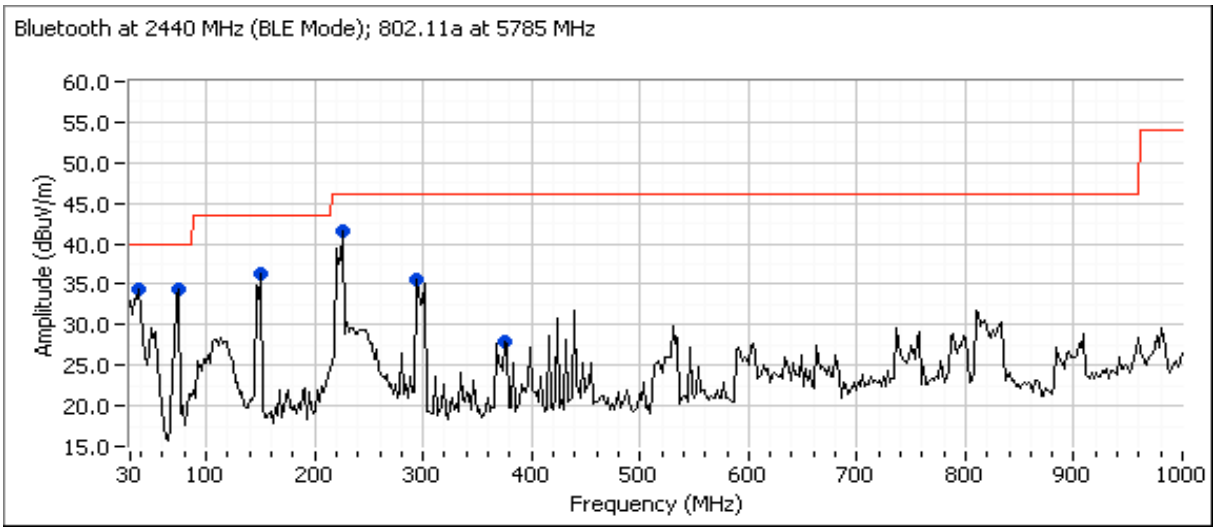
Date of Test: 10/13-14/16
Test Engineer: M. Birgani
Test Location: Chamber 5

Config. Used: 1
Config Change: -
EUT Voltage: 120V/ 60Hz

Freq:	2440	Mode:	BLE
Tx Chain:	-	Data Rate:	1Mbps
Freq:	5785	Mode:	11a
Tx Chain:	4Tx	Data Rate:	6Mbps

Run #2a: 30-1000MHz

Frequency	Level	Pol	15.209 / 15.247 / 15E		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
226.916	35.2	H	46.0	-10.8	QP	178	2.9	QP (1.00s)
75.152	27.4	V	40.0	-12.6	QP	242	1.0	QP (1.00s)
34.669	25.1	V	40.0	-14.9	QP	121	1.0	QP (1.00s)
149.378	27.6	H	43.5	-15.9	QP	59	1.1	QP (1.00s)
296.025	29.5	H	46.0	-16.5	QP	178	2.1	QP (1.00s)
384.060	21.4	H	46.0	-24.6	QP	173	1.6	QP (1.00s)



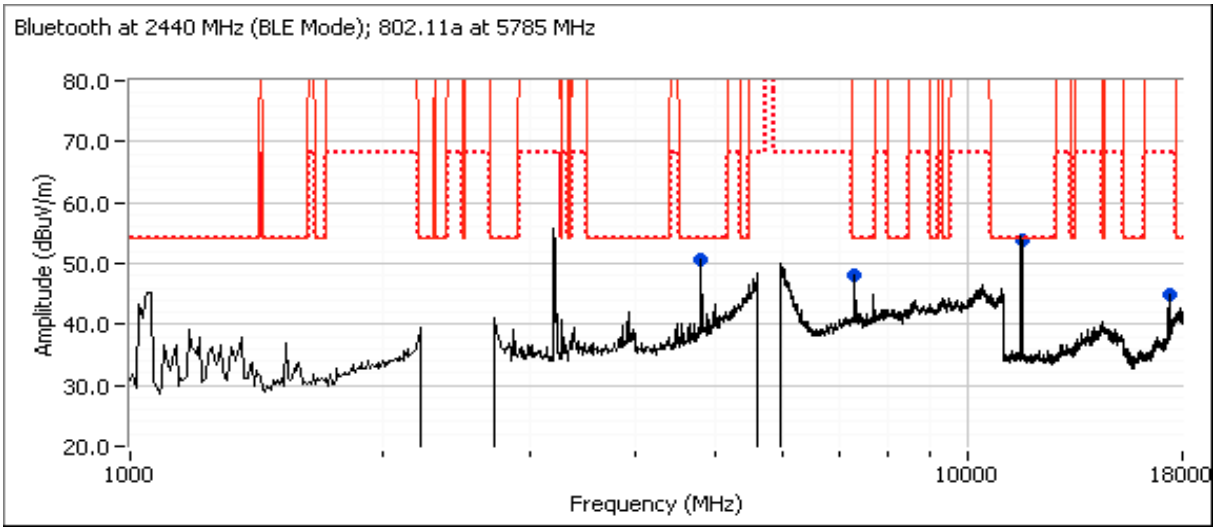
Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B

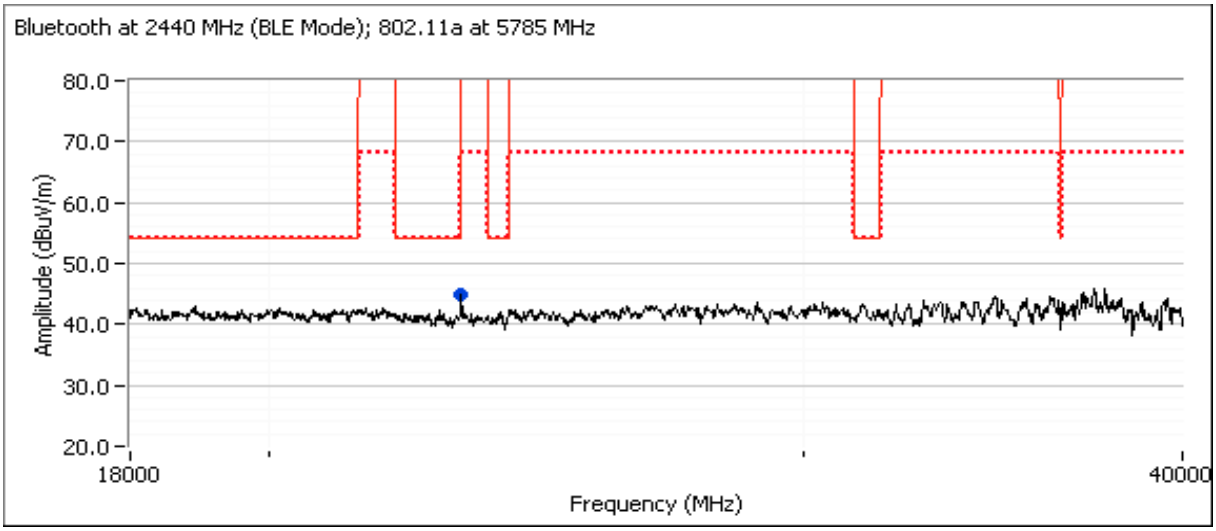
Run #2b: 1000-40000MHz

Freq:	2440	Mode:	BLE
Tx Chain:	-	Data Rate:	1Mbps
Freq:	5785	Mode:	11a
Tx Chain:	4Tx	Data Rate:	6Mbps

Frequency	Level	Pol	15.209 / 15E		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
4880.080	52.1	H	54.0	-1.9	VAVG	295	1.67	BLE 2nd Harmonic
11569.940	50.6	H	54.0	-3.4	Avg	130	1.11	VB 3 kHz, note 2.
17359.600	64.0	H	68.3	-4.3	PK	242	2.49	
11569.940	61.4	H	74.0	-12.6	PK	130	1.11	
23139.830	51.7	V	68.3	-16.6	PK	144	1.51	
4880.530	54.6	H	74.0	-19.4	PK	295	1.67	BLE 2nd Harmonic

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	B





Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

RSS-247 and FCC 15.247 (DTS) Radiated Spurious Emissions

Test Specific Details

Objective: The objective of this test session is to perform final qualification testing of the EUT with respect to the specification listed above.

General Test Configuration

The EUT and all local support equipment were located on the turntable for radiated spurious emissions testing.
For radiated emissions testing the measurement antenna was located 3 meters from the EUT, unless otherwise noted.

Ambient Conditions:

Temperature: 22-24 °C
Rel. Humidity: 35-40 %

Summary of Results - Device Operating in the 2400-2483.5 MHz Band

Run #	Mode	Channel	Target Power	Power Setting	Test Performed	Limit	Result / Margin
1	BLE	2402MHz	Max	Max	Restricted Band Edge (2390 MHz)	FCC Part 15.209 / 15.247(c)	39.0 dBµV/m @ 2382.0 MHz (-15.0 dB)
	BLE	2480MHz	Max	Max	Restricted Band Edge (2483.5 MHz)		39.7 dBµV/m @ 2500.0 MHz (-14.3 dB)
2	BLE	2402MHz	Max	Max	Radiated Emissions, 1 - 25 GHz		51.9 dBµV/m @ 4804.1 MHz (-2.1 dB)
	BLE	2440MHz	Max	Max			52.1 dBµV/m @ 4880.1 MHz (-1.9 dB)
	BLE	2480MHz	Max	Max			48.8 dBµV/m @ 4960.0 MHz (-5.2 dB)

Modifications Made During Testing

No modifications were made to the EUT during testing

Deviations From The Standard

No deviations were made from the requirements of the standard.

Sample Notes

Sample S/N: GTCFNS1630E0091
Driver:

	Chain 1
Port Assignment:	J21

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

Procedure Comments:

Measurements performed in accordance with FCC KDB 558074
Peak measurements performed with: RBW=1MHz, VBW=3MHz, peak detector, max hold, auto sweep time
Unless otherwise stated/noted, emission has a duty cycle ≥ 98% and was measured using RBW=1MHz, VBW=10Hz, peak detector, linear average mode, auto sweep time, max hold.

Mode	Data Rate	Duty Cycle (x)	Constant DC?	T (ms)	Pwr Cor Factor*	Lin Volt Cor Factor**	Min VBW for FS (Hz)
BLE	1Mbps	62.6%	Yes	2.44	2.03	4.07	410

Measurement Specific Notes:

Note 1:	Emission in non-restricted band, but limit of 15.209 used.
Note 2:	Emission in non-restricted band, refer to antenna conducted results
Note 4:	Emission has constant duty cycle < 98%, average measurement performed: RBW=1MHz, VBW>1/T but not less than 10Hz, peak detector, linear averaging, auto sweep, trace average 100 traces, measurement corrected by Linear voltage correction factor
Note 5:	Emission has constatnt duty cycle < 98%, average measurement performed: RBW=1MHz, VBW=3MHz, RMS, Power averaging, auto sweep, trace average 100 traces, measurement corrected by Pwr correction factor
Note 8:	Plots of the average and peak bandedge do not account for any duty cycle correction. Refer to the tabular results for final measurements.

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

Run #1: Radiated Bandedge Measurements

Date of Test: 10/06/16 Config. Used: 1

Test Engineer: Mehran Birgani Config Change: -

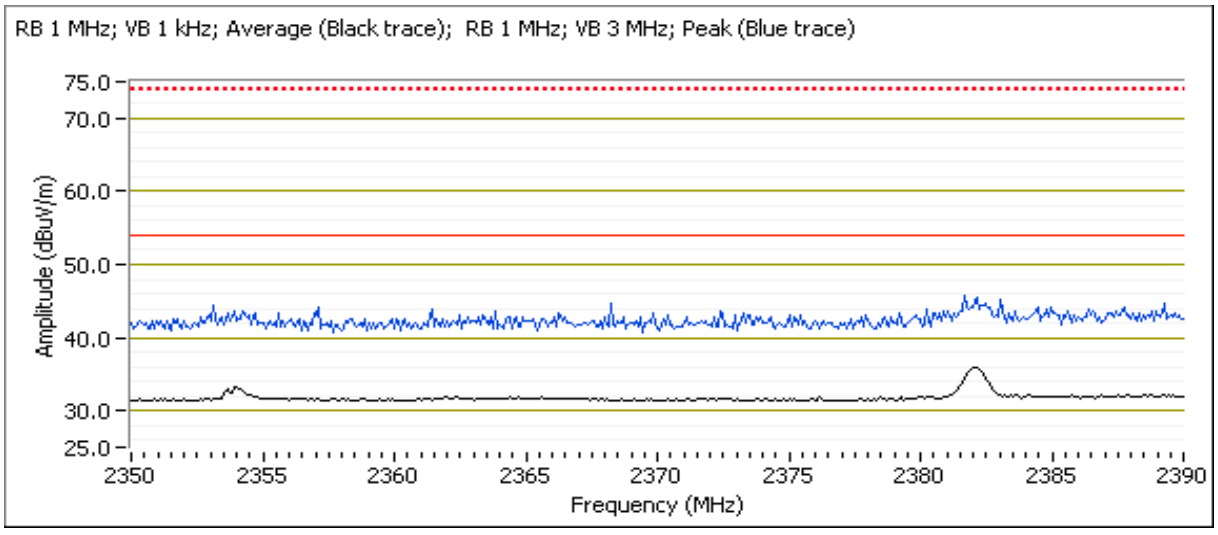
Test Location: Chamber 7 EUT Voltage: 120V/ 60Hz

Frequency: 2402 Mode: BLE

Tx Chain: J21 Data Rate: 1Mbps

Band Edge Signal Field Strength - Direct measurement of field strength

Frequency	Level	Pol	15.209 / 15.247		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
2382.020	39.0	H	54.0	-15.0	AVG	45	1.9	POS; RB 1 MHz; VB: 1 kHz
2382.060	37.4	V	54.0	-16.6	AVG	151	1.0	POS; RB 1 MHz; VB: 1 kHz
2381.920	45.8	H	74.0	-28.2	PK	45	1.9	POS; RB 1 MHz; VB: 3 MHz
2382.140	45.2	V	74.0	-28.8	PK	151	1.0	POS; RB 1 MHz; VB: 3 MHz

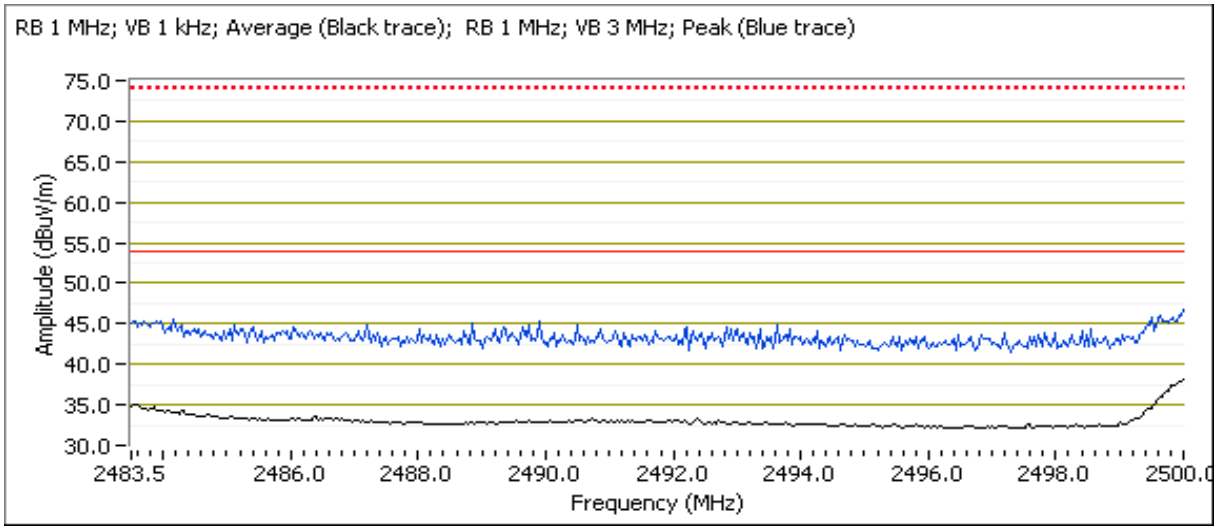


Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

Frequency: 2480 Mode: BLE
Tx Chain: J21 Data Rate: 1Mbps

Band Edge Signal Field Strength - Direct measurement of field strength

Frequency	Level	Pol	15.209 / 15.247		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
2500.000	39.7	H	54.0	-14.3	AVG	228	1.9	POS; RB 1 MHz; VB: 1 kHz
2500.000	37.1	V	54.0	-16.9	AVG	141	1.1	POS; RB 1 MHz; VB: 1 kHz
2483.930	46.7	H	74.0	-27.3	PK	228	1.9	POS; RB 1 MHz; VB: 3 MHz
2483.800	45.2	V	74.0	-28.8	PK	141	1.1	POS; RB 1 MHz; VB: 3 MHz



Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

Run #2: Radiated Spurious Emissions, 1,000 - 25000 MHz. Operating Mode: BLE

Date of Test: 10/6/2016 & 10/7/16 Config. Used: 1

Test Engineer: Mehran Birgani & John Caizzi Config Change: -

Test Location: Chamber 7 EUT Voltage: 120V/ 60Hz

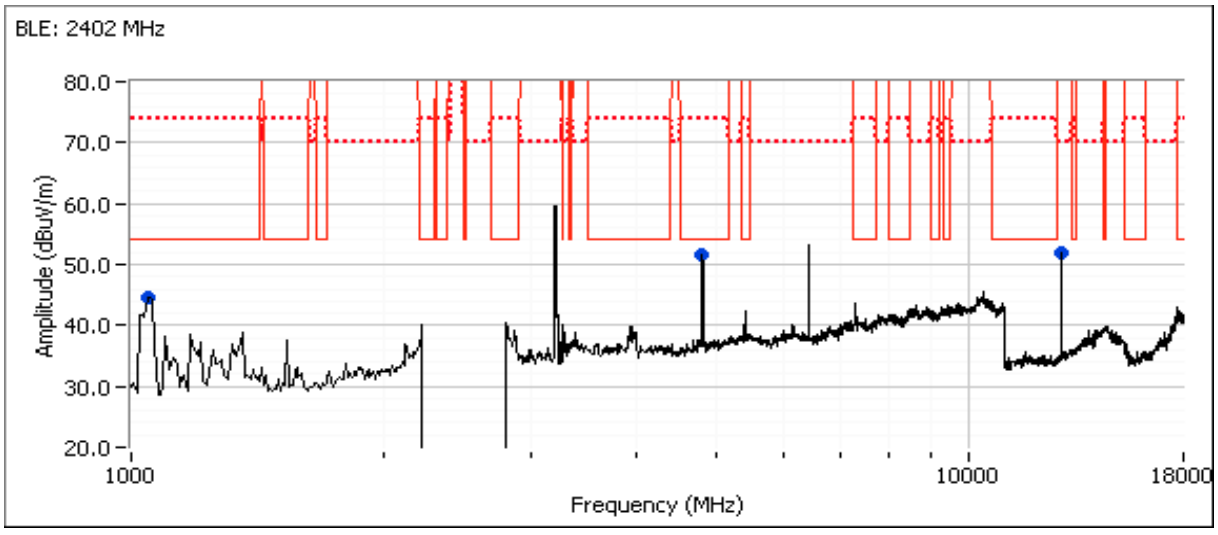
Run #2a: Low Channel

Frequency: 2402 Mode: BLE

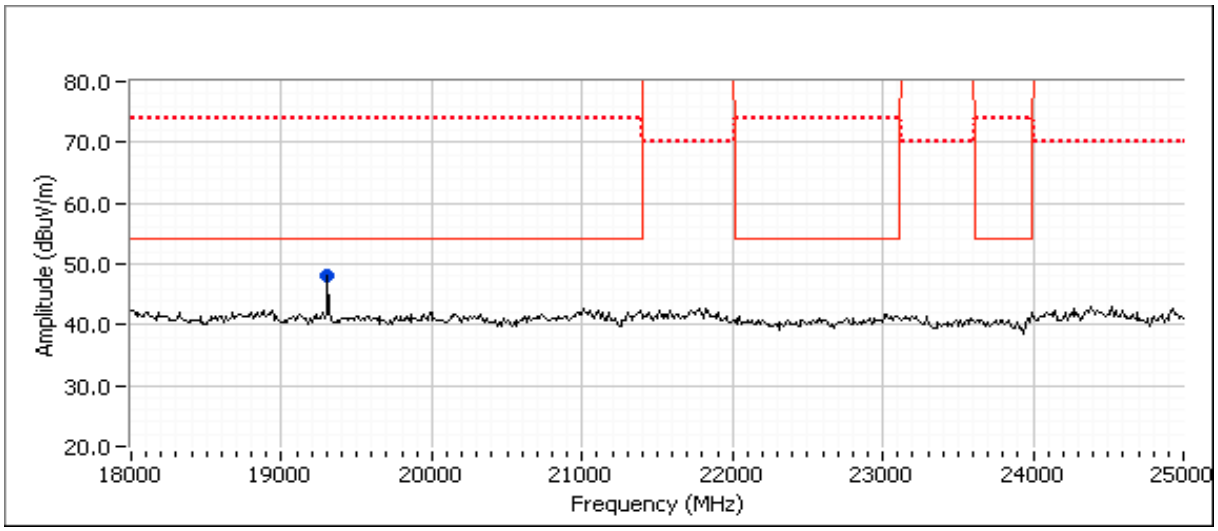
Tx Chain: J21 Data Rate: 1Mbps

Frequency	Level	Pol	15.209 / 15.247		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
4804.070	51.9	H	54.0	-2.1	AVG	284	1.9	RB 1 MHz;VB 1 kHz;Peak
4804.420	54.7	H	74.0	-19.3	PK	284	1.9	RB 1 MHz;VB 3 MHz;Peak
7319.920	47.9	H	54.0	-6.1	AVG	178	2.0	see note 6 below
7320.000	53.2	H	74.0	-20.8	PK	178	2.0	see note 6 below
Emissions from the EUT not related to the Bluetooth Radio								
1035.280	27.3	V	54.0	-26.7	AVG	155	2.2	see note 6 below
1035.380	57.8	V	74.0	-16.2	PK	155	2.2	see note 6 below
12855.000	52.0	V	-	-	Peak	252	2.0	Measured in run 2b.
19306.670	49.0	V	-	-	Peak	309	2.5	Measured in run 2b.

Note 6:	The signal field strength or frequency would not change with stopping the transmission or change of frequency of transmission.



Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A



Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

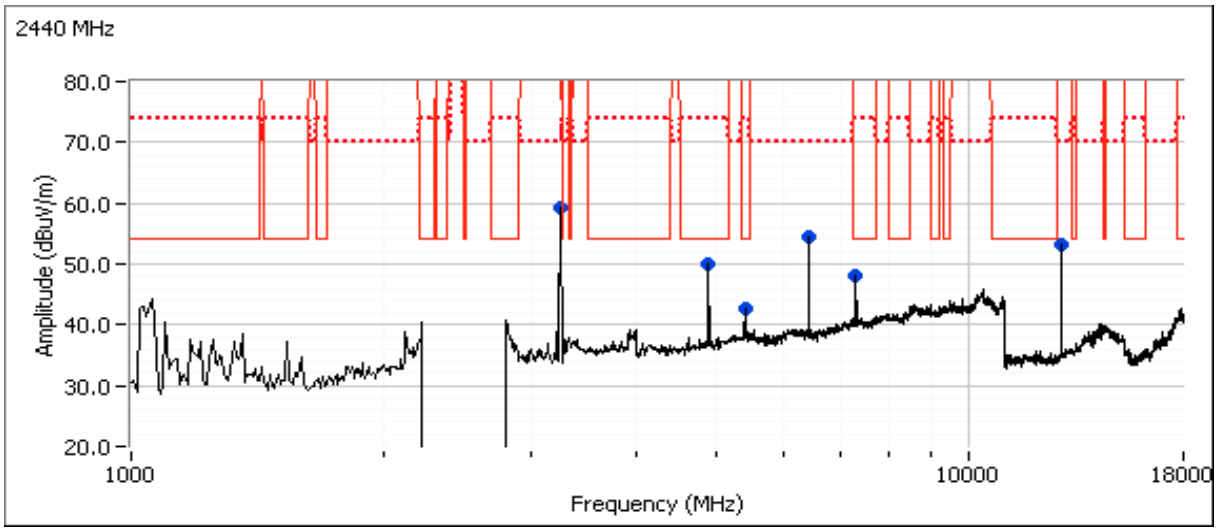
Run #2b: Center Channel

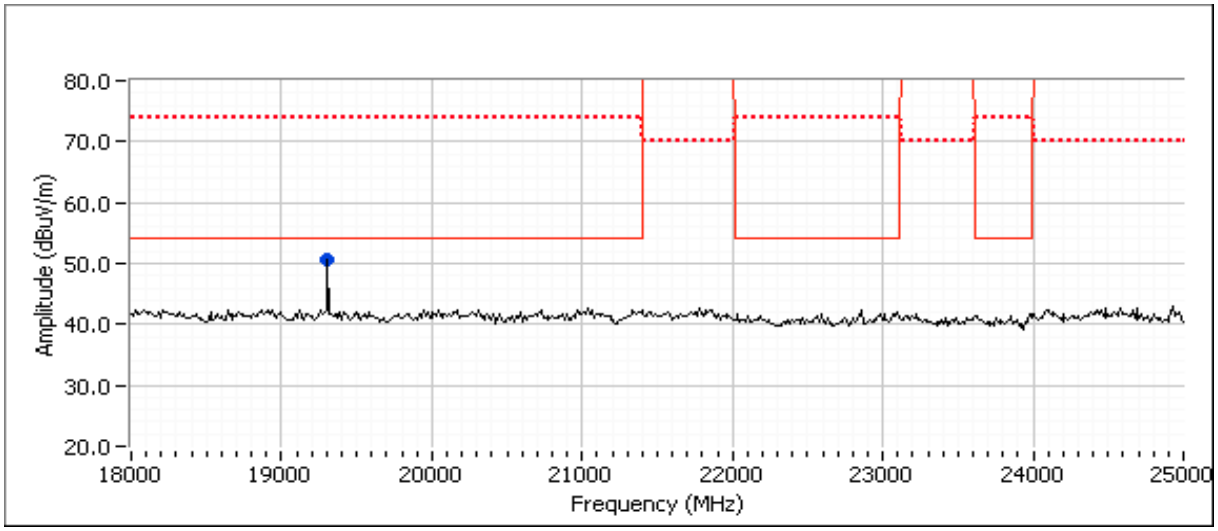
Frequency: 2440 Mode: BLE
Tx Chain: J21 Data Rate: 1Mbps

Frequency	Level	Pol	15.209 / 15.247		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
4880.080	52.1	H	54.0	-1.9	AVG	295	1.67	RB 1 MHz;VB 1 kHz;Peak
4880.530	54.6	H	74.0	-19.4	PK	295	1.67	
3253.360	59.8	H	-	-	Pk	289	1.13	Note 2
7316.670	48.2	H	54.0	-5.8	Pk	200	2.2	Note 6
Emissions from the EUT not related to the Bluetooth Radio								
6431.960	55.0	V	-	-	Pk	131	2.48	Note 2
5400.000	42.7	V	54.0	-11.3	Pk	83	1.6	
12864.020	56.0	V	-	-	Pk	245	2.44	Note 2
19295.970	49.5	V	54.0	-4.5	AVG	303	2.42	RB 1 MHz, VB 10 Hz, note 3
19295.920	54.2	V	74.0	-19.8	PK	303	2.42	

Note 3	Emission has 100% duty cycle, and is there when transmission is stopped.
Note 6	The signal field strength or frequency would not change with stopping the transmission or change of frequency of transmission.

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A





Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

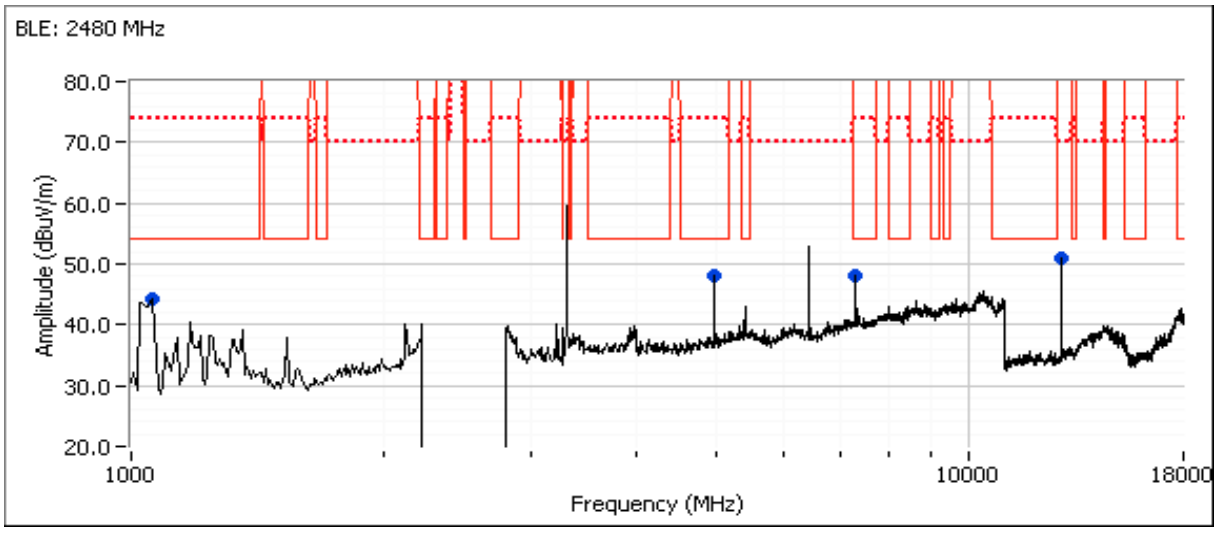
Run #2c: High Channel

Frequency: 2480 Mode: BLE

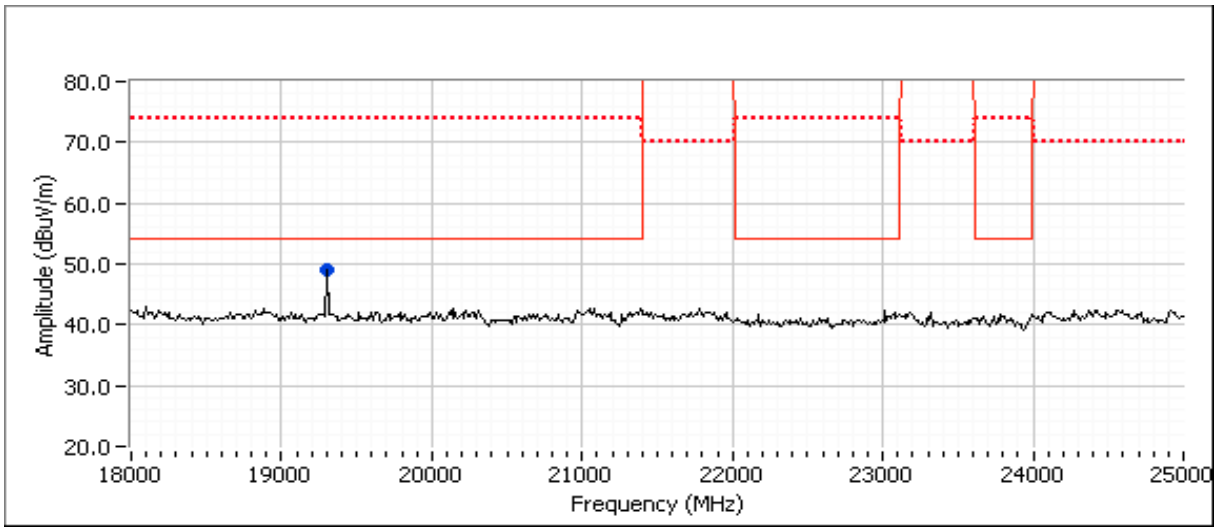
Tx Chain: J21 Data Rate: 1Mbps

Frequency	Level	Pol	15.209 / 15.247		Detector	Azimuth	Height	Comments
MHz	dBµV/m	v/h	Limit	Margin	Pk/QP/Avg	degrees	meters	
4960.040	48.8	H	54.0	-5.2	AVG	284	1.7	RB 1 MHz;VB 1 kHz;Peak
4959.740	52.6	H	74.0	-21.4	PK	284	1.7	RB 1 MHz;VB 3 MHz;Peak
7319.900	47.5	H	54.0	-6.5	AVG	181	2.0	see note 6 below
7319.840	53.6	H	74.0	-20.4	PK	181	2.0	see note 6 below
Emissions from the EUT not related to the Bluetooth Radio								
19306.670	49.0	V	54.0	-5.0	PK	309	2.5	Measured in run 2b.
1035.290	27.4	V	54.0	-26.6	AVG	157	2.2	see note 6 below
1035.370	57.6	V	74.0	-16.4	PK	157	2.2	see note 6 below
12855.000	51.0	V	-	-	PK	252	2.0	Measured in run 2b.

Note 6	The signal field strength or frequency would not change with stopping the transmission or change of frequency of transmission.



Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A



Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

RSS-247 and FCC 15.247 (DTS) Antenna Port Measurements

Power, PSD, Bandwidth and Spurious Emissions

Test Specific Details

Objective: The objective of this test session is to perform final qualification testing of the EUT with respect to the specification listed above.

Date of Test: 10/5/2016
Test Engineer: Mehran Birgani
Test Location: Fremont EMC Lab #4A

Config. Used: Conducted
Config Change: -
EUT Voltage: 120V/60Hz

General Test Configuration

The EUT was connected to the spectrum analyzer or power meter via a suitable attenuator. All measurements were made on a single chain.

All measurements have been corrected to allow for the external attenuators used.

Ambient Conditions:

Temperature: 23-24 °C
Rel. Humidity: 43-45 %

Summary of Results

Run #	Pwr setting	Avg Pwr	Test Performed	Limit	Pass / Fail	Result / Margin
1	Max		Output Power	15.247(b)	Pass	6.0dBm (4.0mW)
2	Max		Power spectral Density (PSD)	15.247(d)	Pass	-8.3dBm/3kHz
3	Max		Minimum 6dB Bandwidth	15.247(a)	Pass	0.72 MHz
3	Max		99% Bandwidth	RSS GEN	-	1.05 MHz
4	Max		Spurious emissions	15.247(b)	Pass	All emissions <20dBc

Modifications Made During Testing

No modifications were made to the EUT during testing

Deviations From The Standard

No deviations were made from the requirements of the standard.

Sample Notes

Sample S/N: GTCFNS1630E0091
Driver:

	Chain 1
Port Assignment:	J21

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

Procedure Comments:

Measurements performed in accordance with FCC KDB 558074

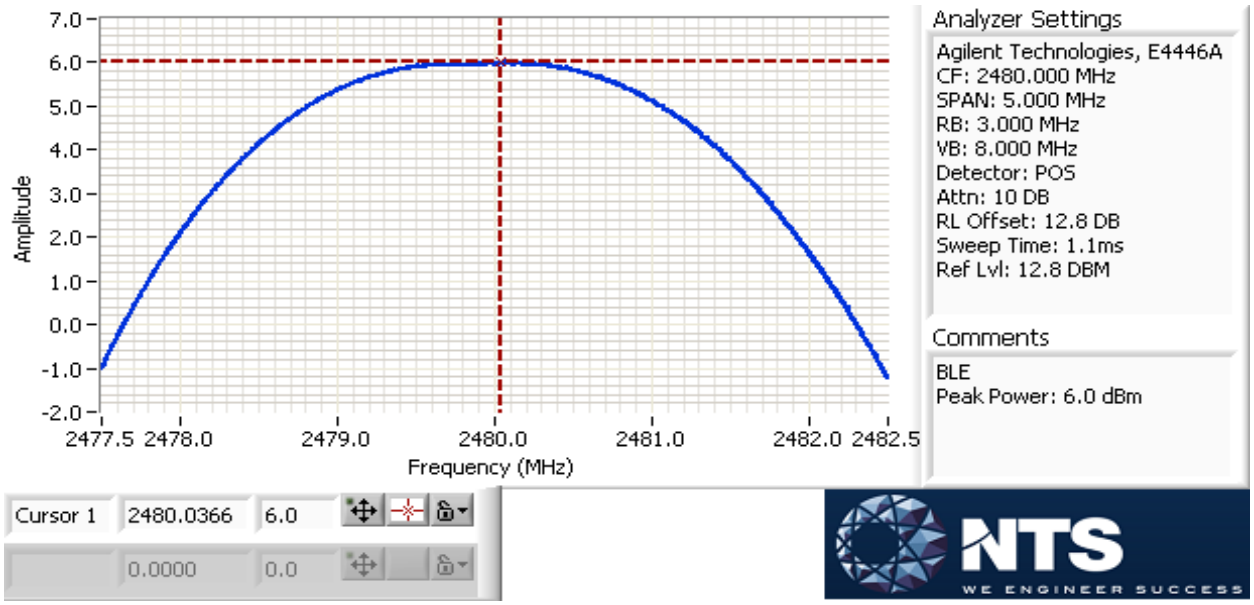
Mode	Data Rate	Duty Cycle (x)	Constant DC?	T (ms)	Pwr Cor Factor*	Lin Volt Cor Factor**	Min VBW for FS (Hz)
BLE	1Mbps	62.6%	Yes	2.44	2.03	4.07	410

Run #1: Output Power

Mode: BLE

Power Setting[2]	Frequency (MHz)	Output Power (dBm) [1]	Output Power mW	Antenna Gain (dBi)	Result	EIRP dBm	EIRP W	Output Power (dBm) [3]	Output Power mW
Max	2402	5.1	3.2	-4.0	Pass	1.1	0.001		
Max	2440	5.5	3.5	-4.0	Pass	1.5	0.001		
Max	2480	6.0	4.0	-4.0	Pass	2.0	0.002		

Note 1:	Output power measured using a spectrum analyzer with RBW = 3MHz VBW = 8MHz, Span = 5MHz, auto sweep time, Peak detector, Trace = Max hold. Spurious limit becomes -20dBc.
Note 2:	Power setting - the software power setting used during testing, included for reference only.



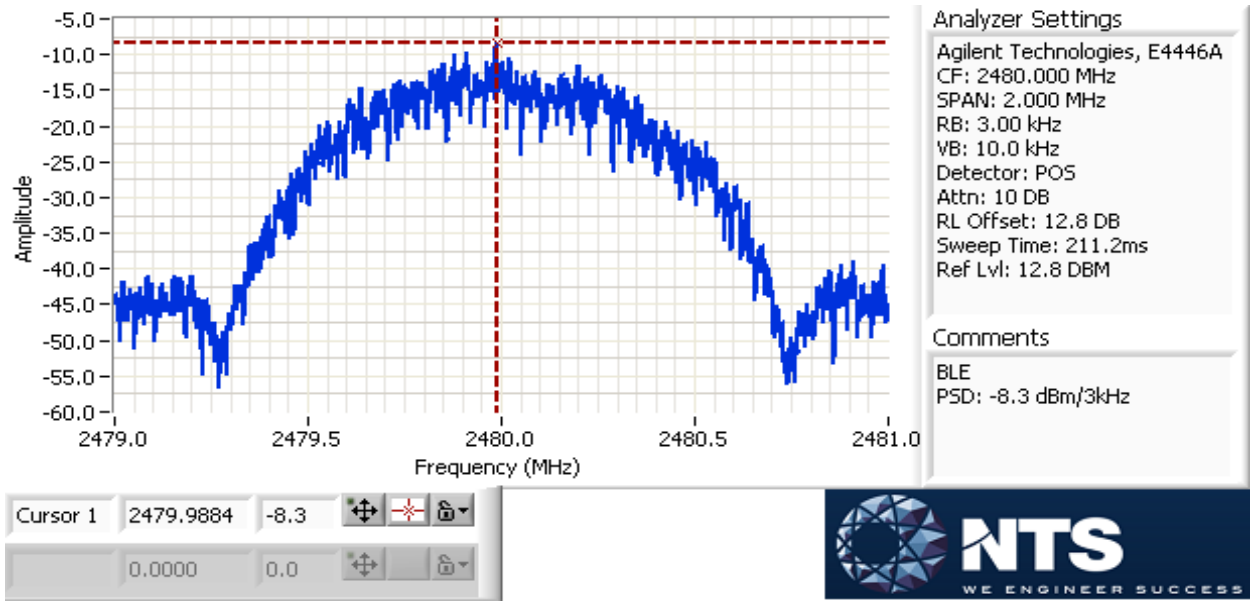
Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

Run #2: Power spectral Density

Mode: BLE

Power Setting	Frequency (MHz)	PSD (dBm/3kHz) Note 1	Limit dBm/3kHz	Result
Max	2402	-9.2	8.0	Pass
Max	2440	-8.7	8.0	Pass
Max	2480	-8.3	8.0	Pass

Note 1: Test performed per method PKSPD, in KDB 558074. Power spectral density measured using: 3kHz ≤ RBW ≤ 100kHz, VBW=3*RBW, peak detector, span = 1.5*DTS BW, auto sweep time, max hold.



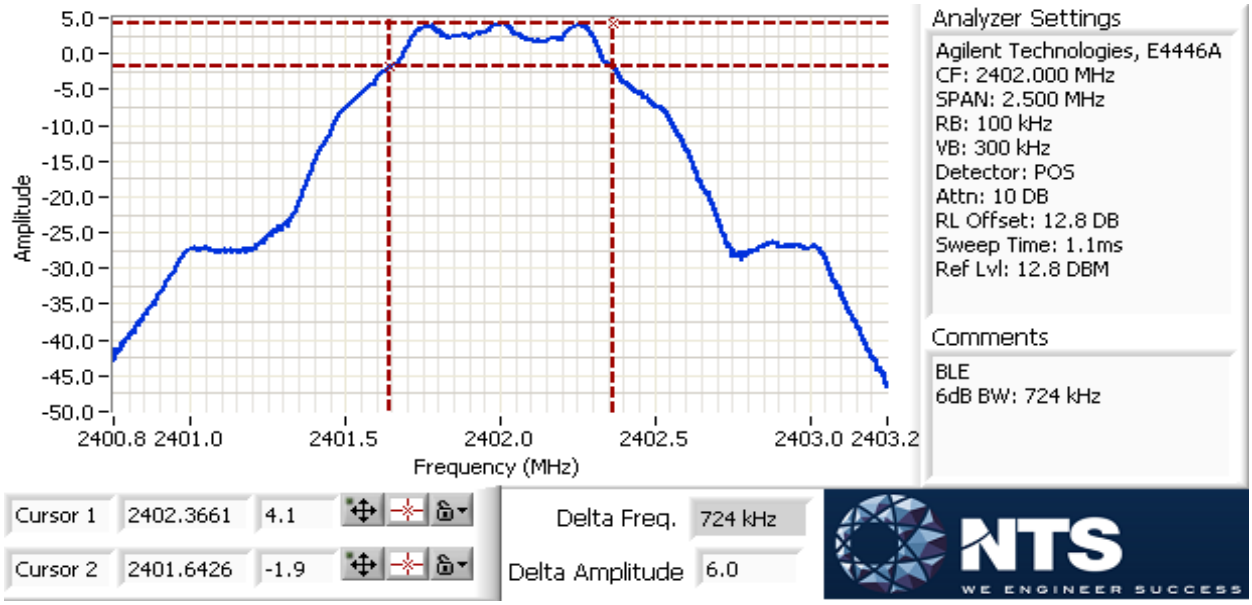
Run #3: Signal Bandwidth

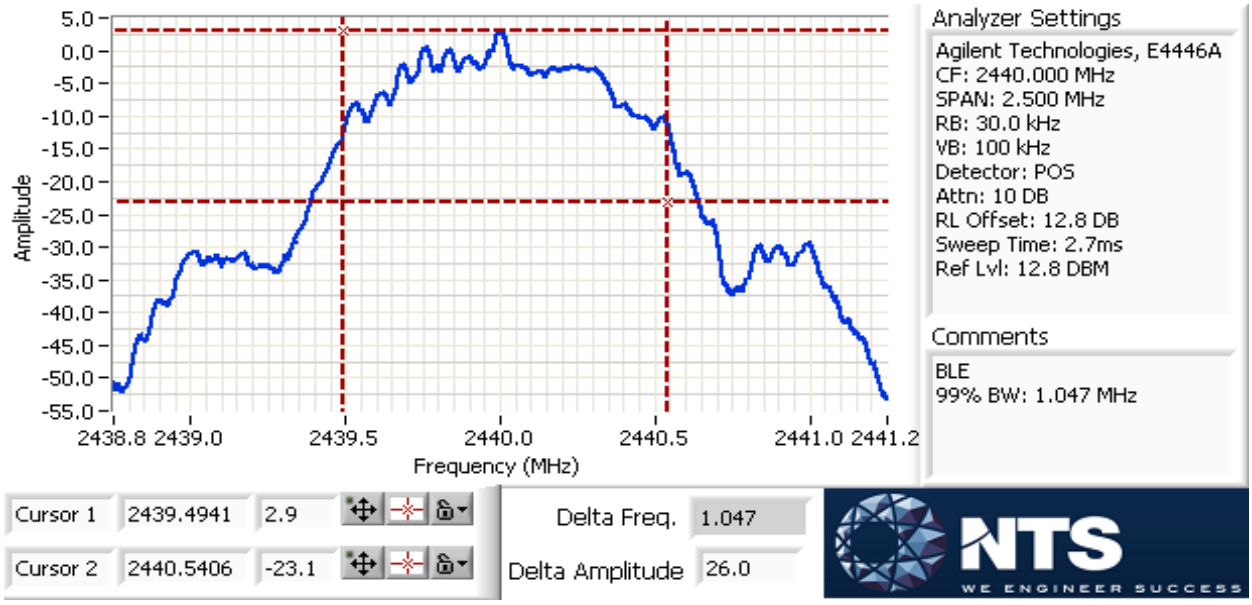
Mode: BLE

Power Setting	Frequency (MHz)	Bandwidth (MHz) DTS	Bandwidth (MHz) 99%	RBW Setting (kHz) DTS	RBW Setting (kHz) 99%
Max	2402	0.72	1.05	100	30
Max	2440	0.73	1.05	100	30
Max	2480	0.73	1.05	100	30

Note 1: DTS BW: RBW=100kHz, VBW ≥ 3*RBW, peak detector, max hold, auto sweep time, Span 2-5 times measured BW.
99% BW: RBW=1-5% of 99%BW, VBW ≥ 3*RBW, peak detector, max hold, auto sweep time. Span 1.5-5 times OBW.

Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A





Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

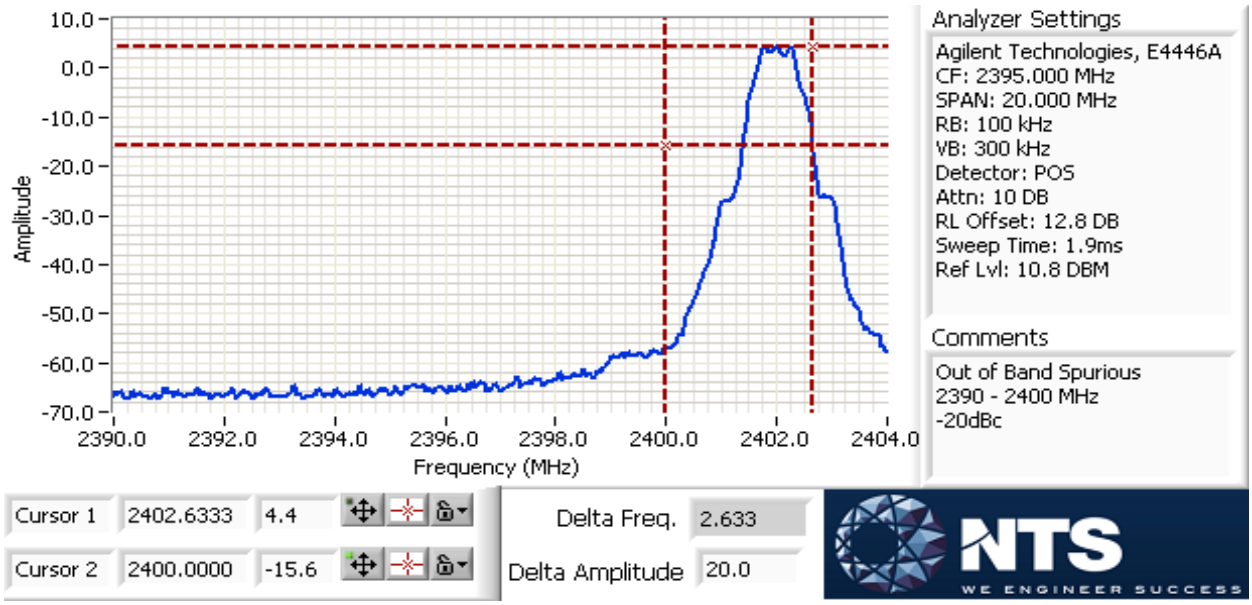
Run #4a: Out of Band Spurious Emissions

Frequency (MHz)	Power Setting	Mode	Limit	Result
2402	Max	BLE	-20dBc	Pass
2440	Max	BLE	-20dBc	Pass
2480	Max	BLE	-20dBc	Pass

RBW = 100 kHz and VBW = 300 kHz for all plots.

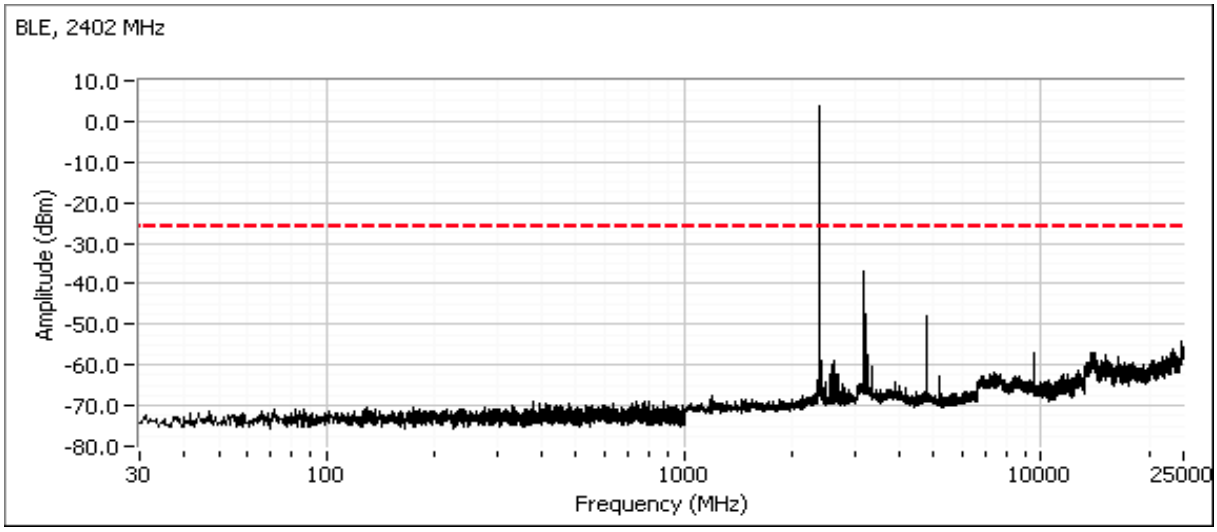
Plots for low channel

Additional plot showing compliance with -20dBc limit from 2390 MHz to 2400 MHz. Radiated measurements used to show compliance with the limits in the restricted band below 2390 MHz.

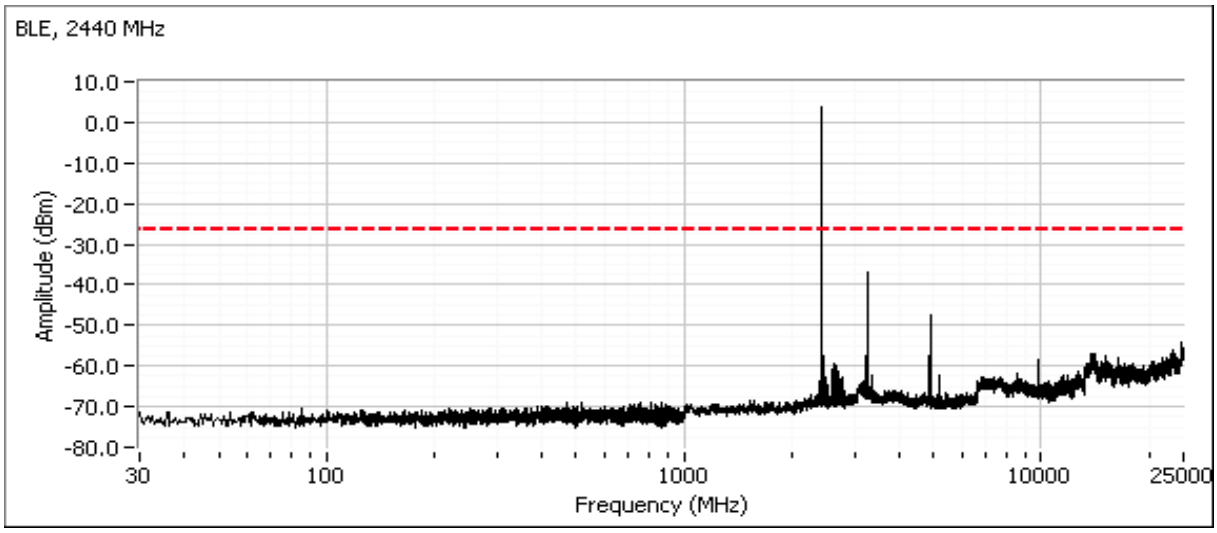


Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

Plots for low channel

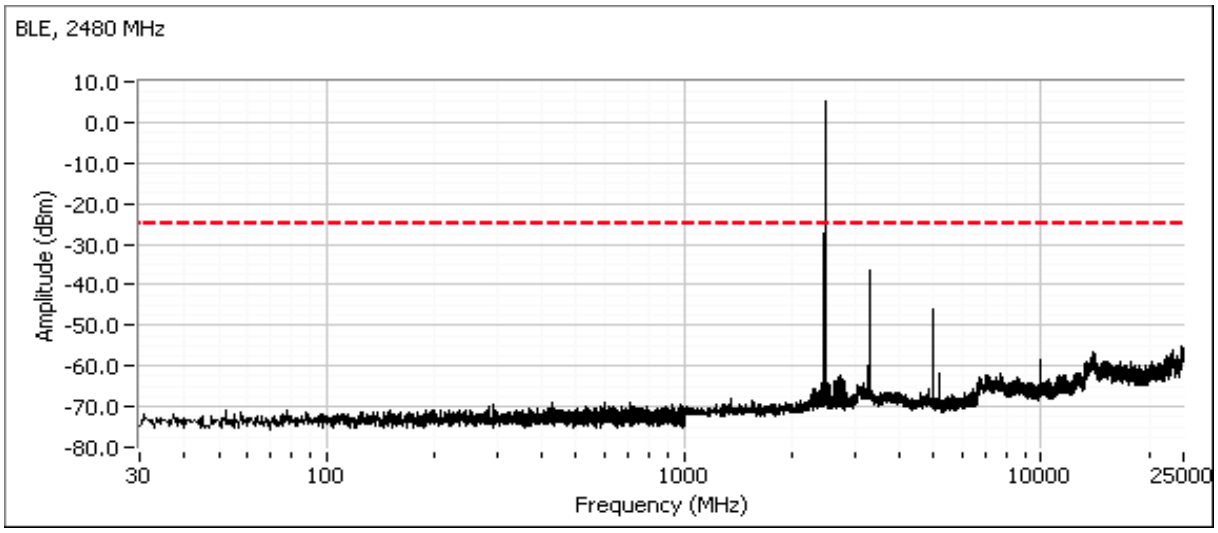


Plots for center channel



Client:	Google, Inc.	Job Number:	JD101521 and JD101837
Model:	GFHD254	T-Log Number:	T101543
		Project Manager:	Deepa Shetty
Contact:	Weifeng Pan	Project Coordinator:	-
Standard:	FCC 15.247 and 15.407	Class:	N/A

Plots for high channel



End of Report

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