RF6555KW24D512-410 Reference Design (RFMD-KW2X Extended Range Board)

Introduction

The RF6555KW24D512-410 reference design is a partnership between RFMD and Freescale Semiconductor, Inc. presenting a complete 2.4GHz IEEE 802.15.4 2006 Standard-Compliant radio solution with a 126dB link budget that conforms to FCC CFR47 part 15 and CE.

Freescale's MKW2xDxxx system in package (SiP) family is its latest generation ZigBee™ platform which incorporates a low power 2.4GHz radio frequency transceiver and a Kinetis family low power, mixed-signal ARM® Cortex™ M4 MCU into a single package.

RFMD presents a truly world class highly integrated front end module (FEM), the RF6555 for efficient extended output power above 18dBm with integrated: DP2T Diversity Switch, Balun, SPST Switch, LNA with bidirectional bypass and harmonic filtering onto a single 24-pin LGA package.

Applications

- ZigBee 802.15.4 Based Systems for Remote Monitoring and Control
- Communications Hub for Smart Energy/Home Automation
- Building/ Warehouse Automation
- Smart metering for Energy Management Applications
- Connected Home and appliances

Figure 1. Top view of RF6555KW24D512-410 Reference Design

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Overview

RF6555:

The RF6555 integrates a complete solution in a single front end module (FEM) for ZigBee® applications in the 2.4GHz ISM band which can operate from 2.0V to 4.0V. This FEM integrates the PA plus harmonic filter in the transmit path, plus the LNA with bypass mode internally. The RF6555 also provides a single balanced TDD access for Rx and Tx paths along with two ports on the output for connecting a diversity solution or a test port. The device is provided in a 5mm x 5mm x 1mm, 24-pin laminate package.

MKW24D512/MKW22D512/MKW21D256:

The MKW2xDxxx family of devices contains an RF transceiver which is an 802.15.4 Standard-compliant radio that operates in the 2.4GHz ISM band and supports 2.36GHz to 2.4GHz Medical Band (MBAND) frequencies. The transceiver includes 1mW nominal output power PA, hardware acceleration for dual Personal Area Networks (PAN) modes, integrated transmit/receive switch, on-board power supply regulation, and full spread-spectrum encoding and decoding. They support Freescale's extensive offering of IEEE 802.15.4 based protocol stacks.

The RF6555KW24D512-410 demo boards can be purchased at https://estore.rfmd.com/RFMD_Onlinestore/Products.aspx?Catalog=RFMD+Parts&DetailsPage=yes&ProductID=P_RF6555&DC=25

- **Purpose – Hardware:** The RF6555KW24D512 reference design serves as a proven >18dBm range extension for the MKW2x series wireless MCUs with a link budget of 126dB. The reference design is designed around the Kinetis KW2x Tower System form factor. This document describes the hardware design specifications necessary in order to successfully implement the ref design. The RFFM6204, RFFM6201, and RF6505 can also serve as range extensions for the MKW2x wireless MCUs with rated output powers of 14dBm, 23dBm, and 27dBm respectively.
- **Purpose – Software:** The RF6555KW24D512-410 demo board comes pre-flashed with the MKW2x SMAC Connectivity Test Application Demo Test software modified to support the FEM. This allows for performance verification and evaluation.
- **Summary:** This document briefly describes the RF6555KWD512 reference design and how it is set up and configured for engineering evaluation of the RF6555 FEM using Freescale's MKW24D512VHA5. This application note also serves to provide a developer with data, and the design tools necessary to implement a ZigBee solution using the RF6555KW24D512 reference design.

Features

- -107dBm Rx Sensitivity and +19dBm Tx output power
- Peak typical current consumption: 110mA Tx (19dBm) and 30mA Rx
- 2.5µA RTC standby typical current consumption
- Operating Range: 2.0V to 3.6V, -40°C to +105°C
- IEEE® 802.15.4 compliant
- Integrated PCB inverted F-type antenna and SMA RF port

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Contents

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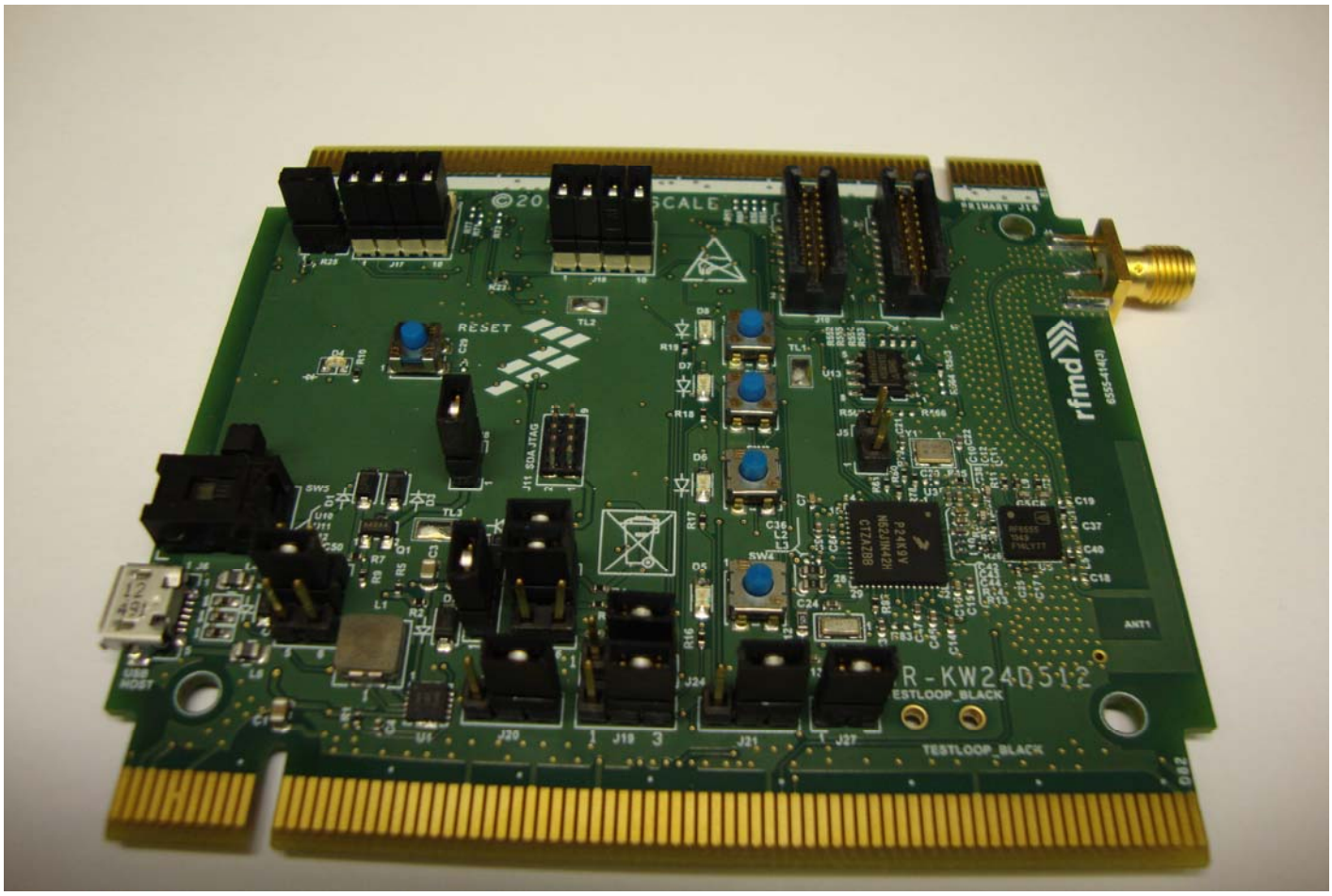

Figure 2. RF6555KW24D512-410

PCB Board Features

- Extended RF Range – The +19dBm RF6555 FEM with LNA and bypass and integrated harmonic filtering.
- Interfacing -The RF6555KW24D512-410 can be evaluated on the Freescale Tower System Serial Module (TWR-SER) or the Tower System Elevator Module (TWR-ELEV).
- Extensions – Includes two 20-Pin connectors for Tower TWRPI daughter card interface.
- PCB Stackup – The PCB is designed on a 62 mils thick, 4-Layer metal, FR4 material. See Layer Stack up for details.
- RF Connectivity – Performance verification can be evaluated via an SMA connector or a printed metal inverted F-type antenna.
- Debugging – The board comes with a 10-pin (0.05”) JTAG debug port.
- Serial Communications – The board comes with a Micro USB Type AB which can be used for serial communications and a power supply.

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Mechanical Descriptions

*NOTE: It is highly recommended by RFMD and Freescale to follow the PCB layout as closely as possible as deviations from the layout can change the reference designs performance. It is required to follow the product outline drawings of the data sheets of the RF6555 and MKW2x for stencil, solder paste and PCB metal land pattern requirements.

Layer Stack up - The RF6555KW24D512-410 is made using a 4-layer design on standard FR4 material (IS400) with a total thickness of 62 mils. The top and bottom layers are large copper planes whose grounds are stitched together with through-hole vias that are in close proximity of GND pins of critical RF components. Silk screen and solder mask are required.

1. Layer 1 is the Top Layer Metal and contains a solid 1oz base copper and plating for digital ground plane and is used for RF and digital signal routing. It has isolation in-between digital and RF traces.

2. Layer 2 is a solid Ground Layer.

3. Layer 3 is a Power Layer which is a solid power plane. The power plane should be surrounded with through-hole ground vias which connect the ground layers together.

4. Layer 4 is the Bottom Layer Metal and ground plane and made with solid 1oz base copper and plating. See figure 3 for layer stack-up details.

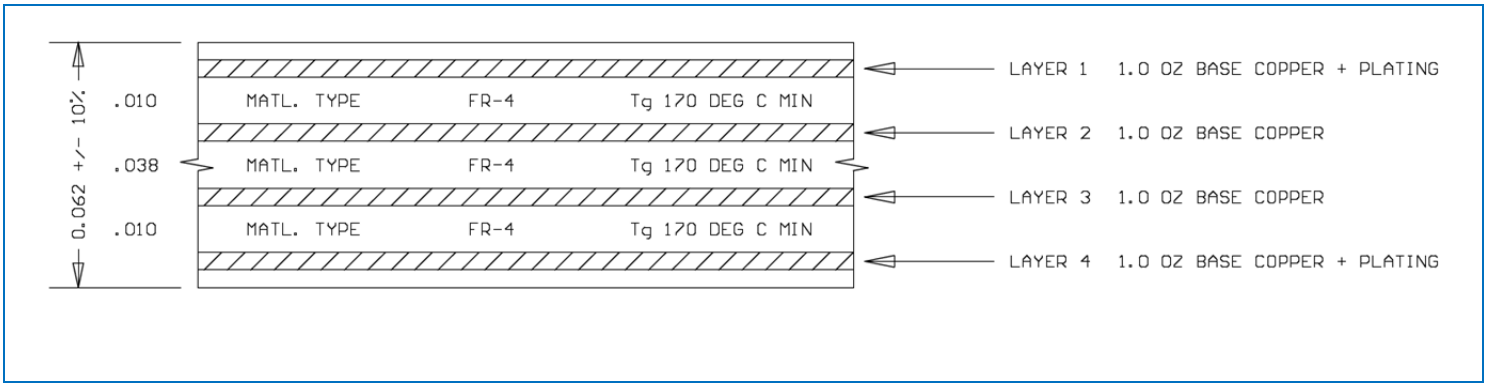

Figure 3. RF6555KW24D512-410 Layer Stack-Up

- Shielding – A metal shield is not provided with the reference design but may be necessary to protect the ICs from external noise and strong interferers. The shield can also be used to suppress radiated harmonics from the reference design even lower but is not necessary.
- RF Layout Optimization – The RF6555 ground pad via pattern is a 6 X 6 pattern (See Figure 4), with through-hole vias that route from the top layer to the bottom layer. The hole size of the vias are 8mils and the diameter is 18mils. This is for thermal dissipation and to provide a short return path for the signal. The final product may include removing the solder mask or solder resist from the bottom layer beneath the ground pad for improved thermal dissipation.

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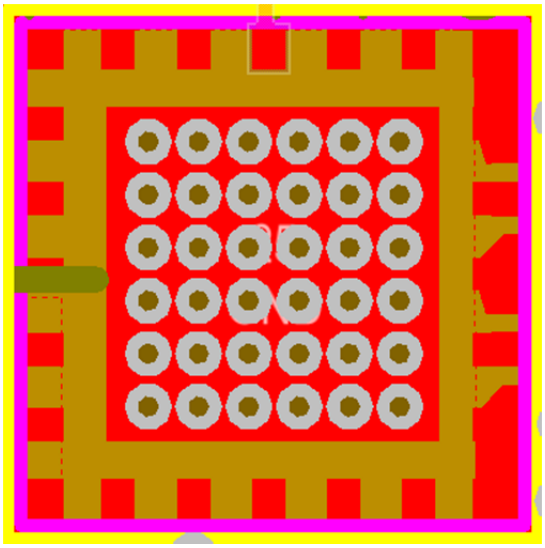

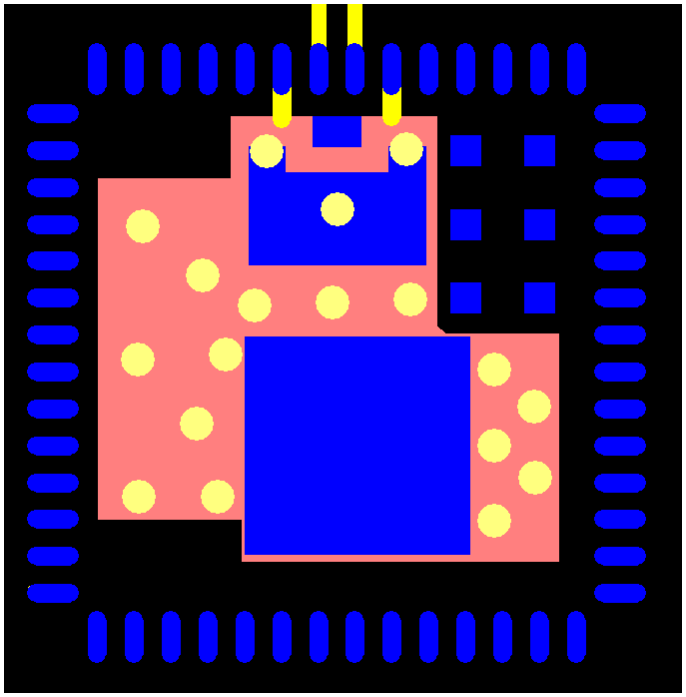

Figure 4. RF6555 Ground Slug Via Pattern, MK24D512 Ground Slug Via Pattern

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CONTROLLED IMPEDANCE: ☒ YES ☒ NO

CPW LAYER 1: 0.0131 +/-0.001 REF LAYER 2

TARGET IMPEDANCE: 50 OHMS +/-5%
TARGET FREQUENCY: 2.5GHz to 6GHz
DIELECTRIC CONSTANT: 4.26

* DIELECTRIC(S) THAT CAN BE ADJUSTED TO OBTAIN FINISHED THICKNESS: LAYER 2-4

* GERBER DATA SUPPLIED WITH DESIRED FINAL TRACE WIDTHS. PROCESS COMPENSATION TRACE WIDTH ADJUSTMENT TO BE DONE BY PCB FABRICATOR.

VIA TYPES/ASSOCIATED LAYERS: THRU-HOLE LAYER 1-4

Figure 5. Fabrication Specifications

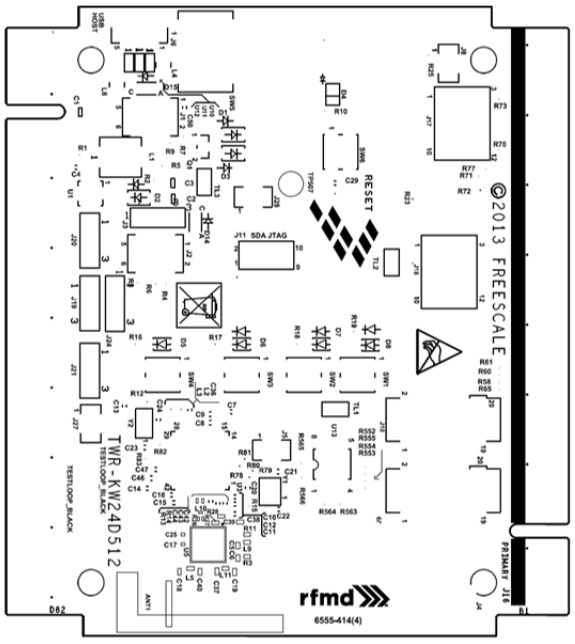

Figure 6. RF6555KW24D512-410 Top View

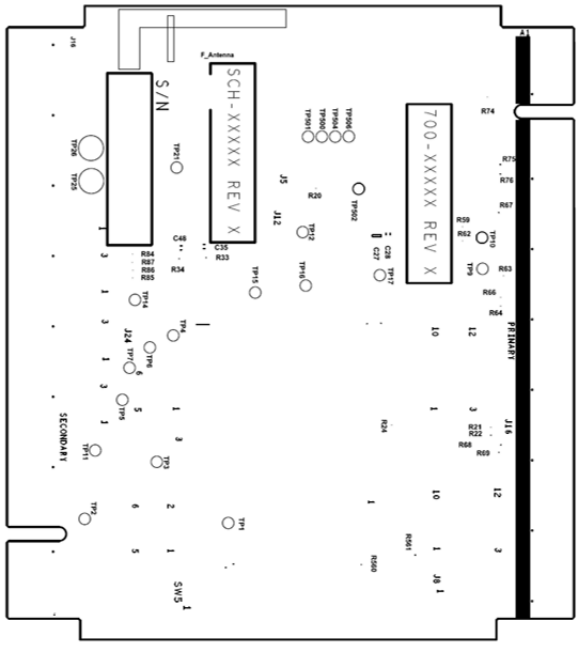

Figure 7. RF6555KW24D512-410 Bottom View

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Evaluation and Configuration

Equipment needed for evaluation

- Freescale's Tower System Modular Development Platform
- Signal or Spectrum analyzer for conducted measurements
- Computer with terminal emulator application
- SMA Cable
- DB9 Serial Cable
- Mini-USB AB cable
- Power meter

Run Connectivity Test

1. Connect the serial cable to the Tower System and a PC, also connect the USB Mini cable to J5 on the TWR board labeled 'PWR (ONLY)' and to a PC.
2. With the RF6555KW24D512-410 reference design connected to the TWR module and connected to a PC via UART, a terminal emulator can establish communication with a COM port.
3. Make sure the COM port is set for: 115200, 8, N, 1, and No Flow Control
4. Flip the power switch to the 'on' position and the four blue LEDs will begin to blink indicating that the firmware is properly loaded. The Freescale icon will appear on the computer monitor.
5. Press the 'Enter' key to initiate Connectivity Test and the Connectivity Test Interface short cuts menu will appear as in Figure 8 and the LEDs will stop blinking.

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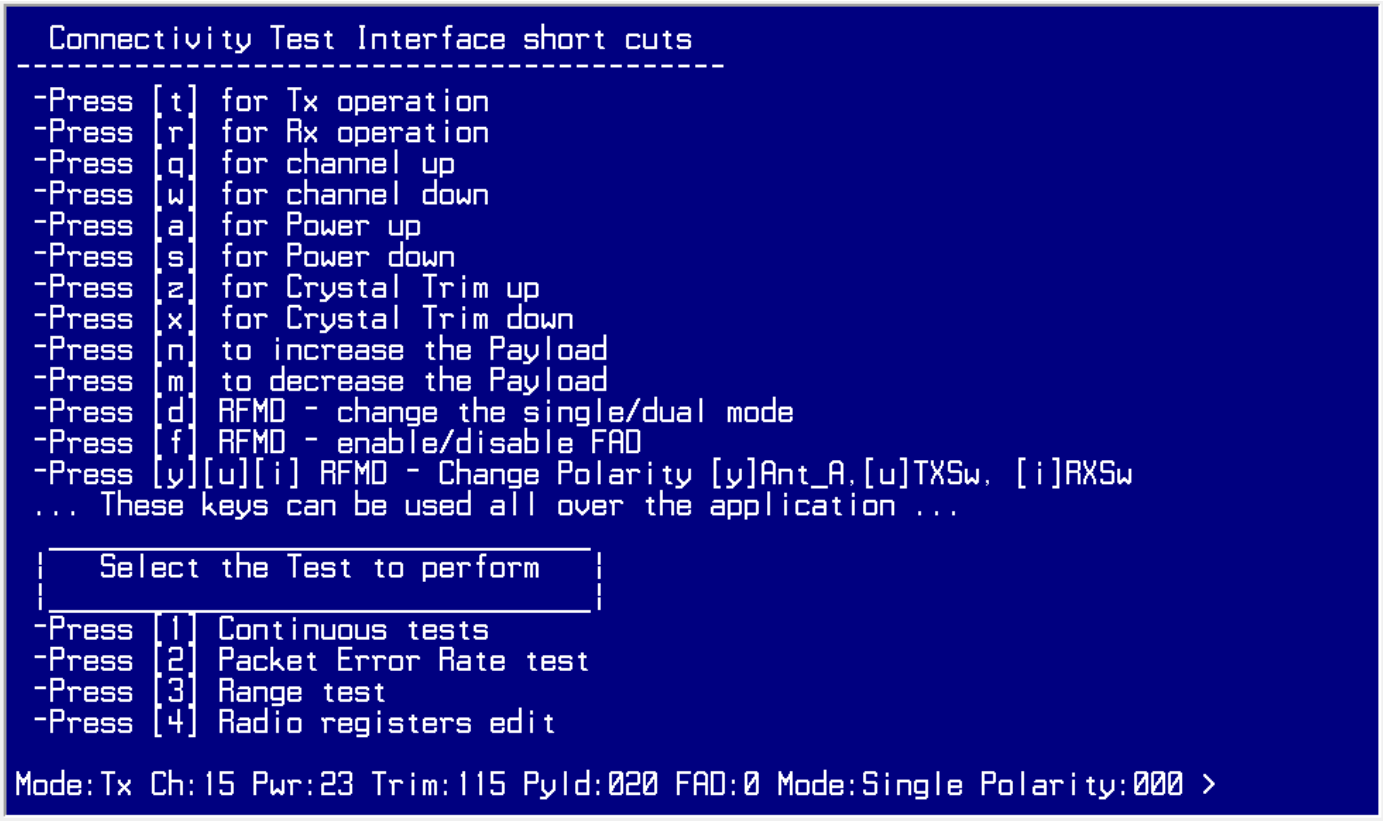

Figure 8. RF6555KW24D512-410 Top View

6. Press the ‘f’ key to enable the FAD mode. The FAD mode must be enabled at least once for the control signals: TX_SWITCH, RX_SWITCH, and ANTA to initialize.
7. Press the ‘y’ key to set the polarity of control signal of ANTA. This sets the ANTA control signal to be able to change between ANT1 and ANT2 alone.
8. Press the ‘d’ key until the FAD is in Single Mode. Note: this step may be skipped if FAD is already in single mode by default. Pressing the ‘d’ key alternates between single or dual mode.
9. Figure # shows all of the test that can be performed using Connectivity Test. Each test is selected via it’s number. It also shows an example of pressing the ‘1’ key for Idle.

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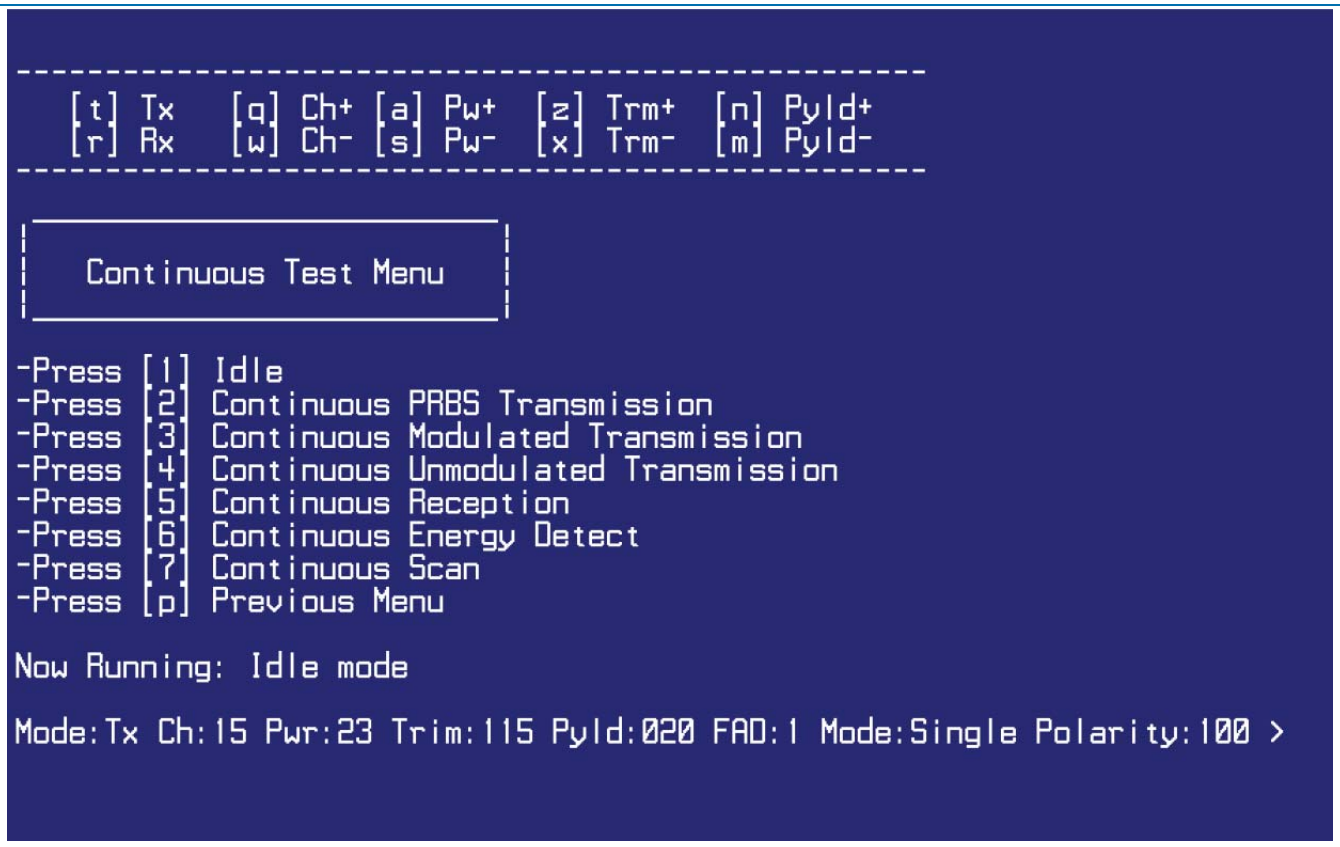

Figure 9. RF6555KW24D512-410 Top View

Direct additional questions to the RFMD Wireless Connectivity Business Unit (WCBU) Application Engineering Team at WCBUApps@rfmd.com.

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Tx Test Data

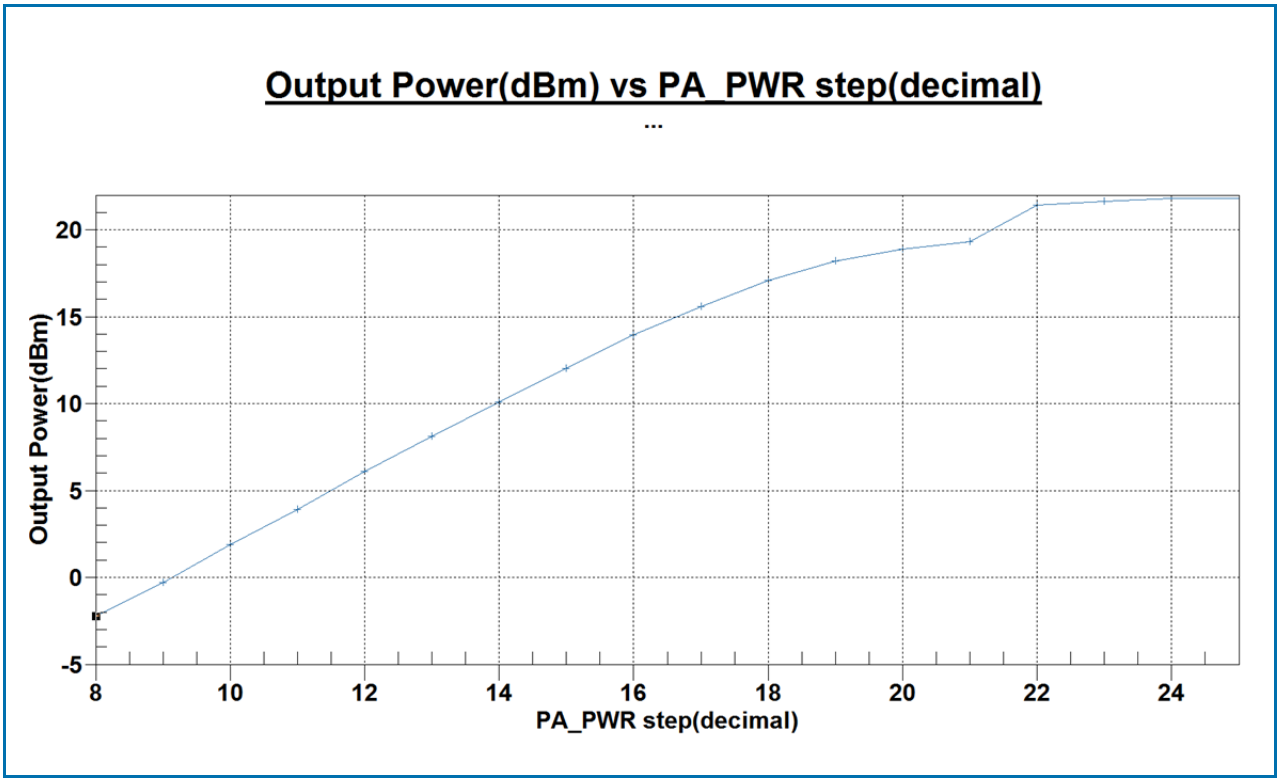
Peak Power Output (dBm) across channel (Typical), Conducted, Temp = 25°C

PWR Setting	Channel 11	Channel 15	Channel 19	Channel 23	Channel 26
20	18.5	18.6	18.7	18.8	18.8
19	17.8	18.0	18.1	18.2	18.2

Tx Harmonic Data

Harmonic Measurements (Typical); Output Power = 18.5dBm (Detector set to Peak per ETSI), Temp = 25°C

Channel/MHz	2fo(dBm/MHz)	3fo(dBm/MHz)	4fo(dBm/MHz)	5fo(dBm/MHz)
Channel 11 (2405)	-50	-57	-57	-45
Channel 19 (2450)	-56	-56	-54	-46
Channel 26 (2480)	-55	-57	-53	-46



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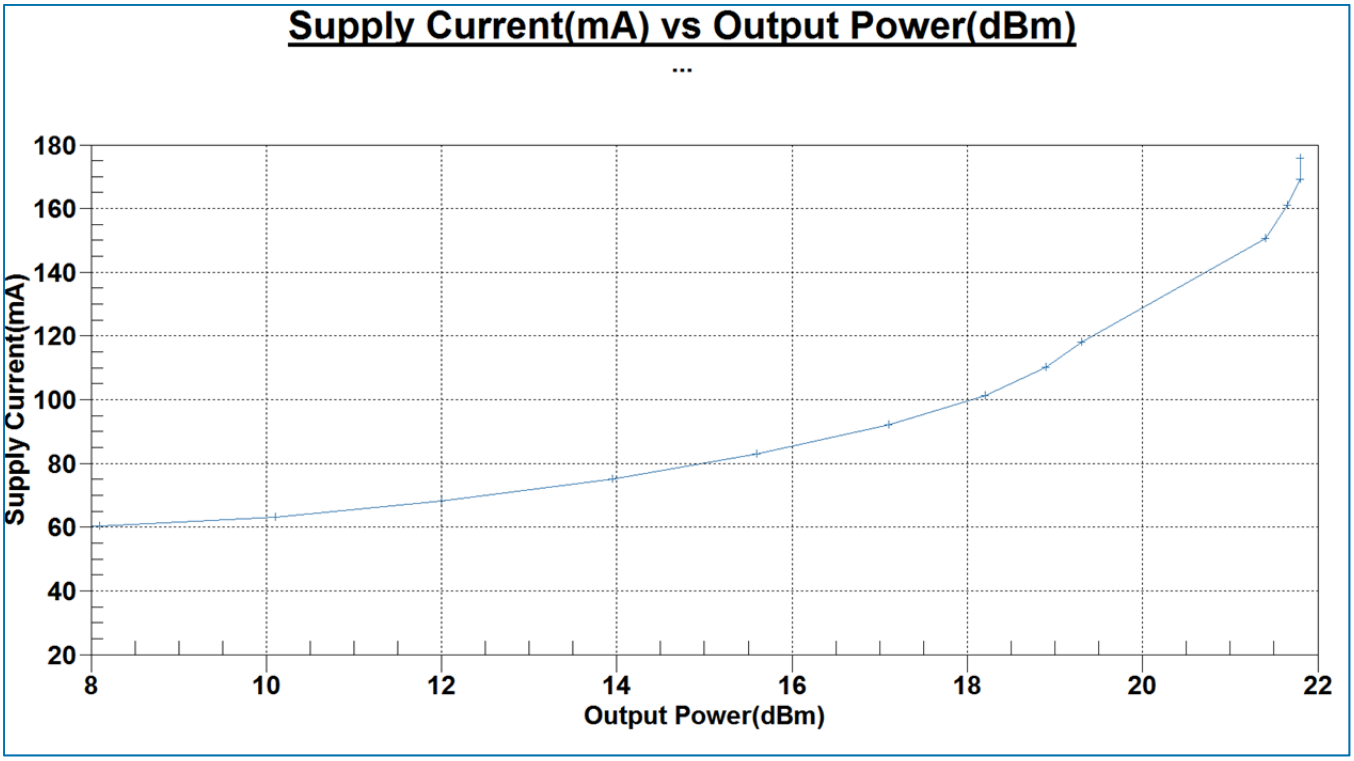

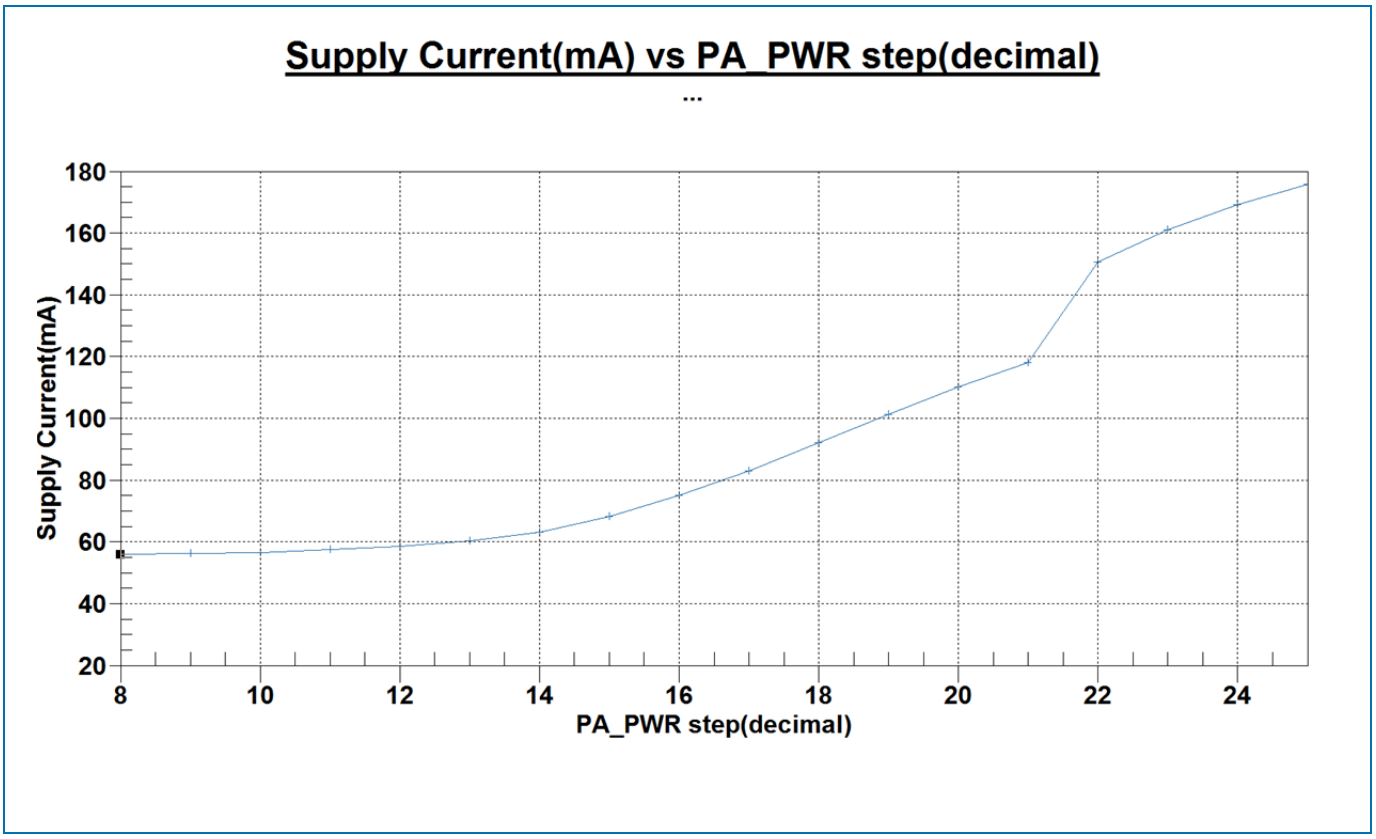

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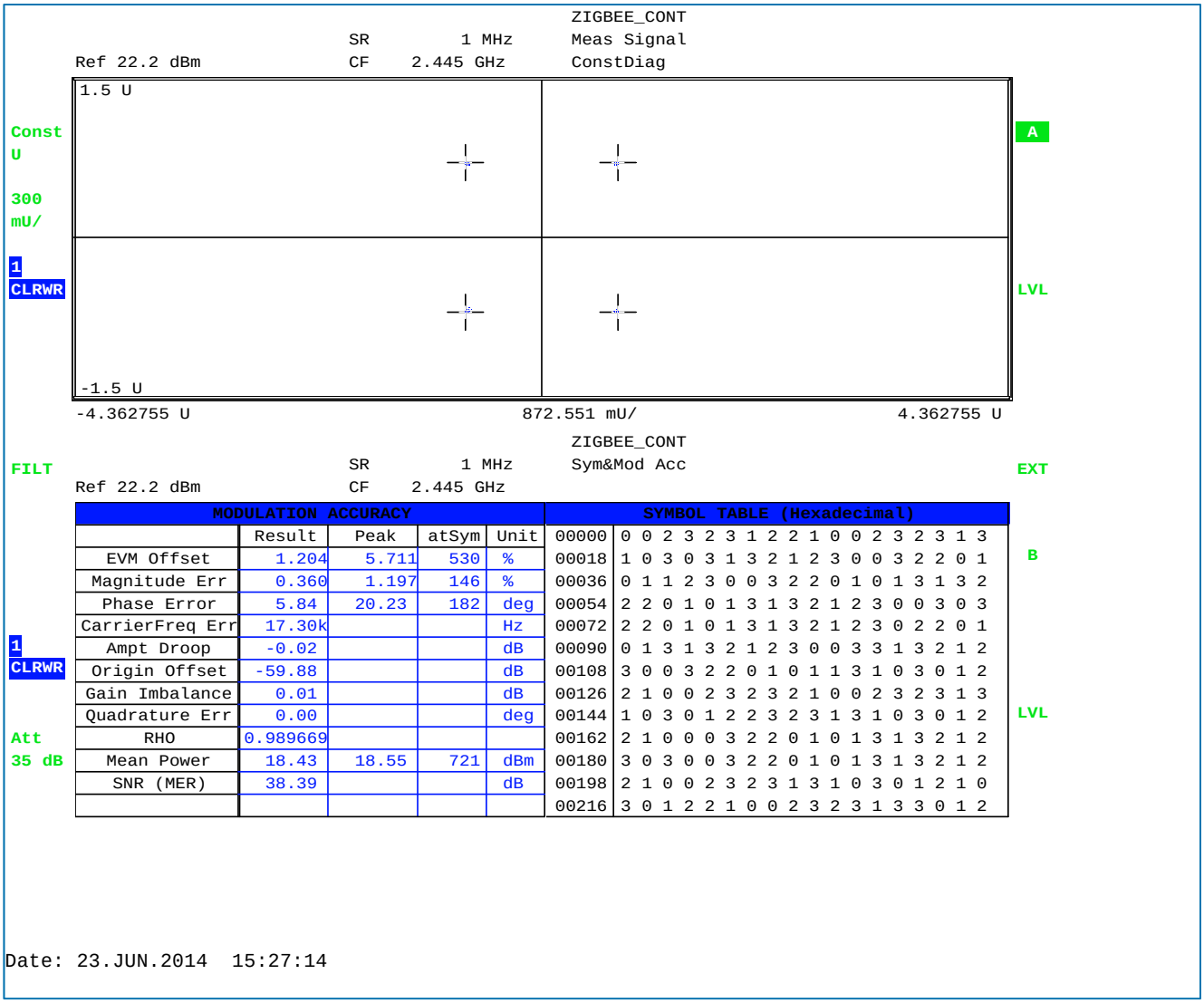

MODULATION ACCURACY				
	Result	Peak	atSym	Unit
EVM Offset	1.204	5.711	530	%
Magnitude Err	0.360	1.197	146	%
Phase Error	5.84	20.23	182	deg
CarrierFreq Err	17.30k			Hz
Ampt Droop	-0.02			dB
Origin Offset	-59.88			dB
Gain Imbalance	0.01			dB
Quadrature Err	0.00			deg
RHO	0.989669			
Mean Power	18.43	18.55	721	dBm
SNR (MER)	38.39			dB

SYMBOL TABLE (Hexadecimal)																
00000	0	0	2	3	2	3	1	2	2	1	0	0	2	3	2	3	1	3
00018	1	0	3	0	3	1	3	2	1	2	3	0	0	3	2	2	0	1
00036	0	1	1	2	3	0	0	3	2	2	0	1	0	1	3	1	3	2
00054	2	2	0	1	0	1	3	1	3	2	1	2	3	0	0	3	0	3
00072	2	2	0	1	0	1	3	1	3	2	1	2	3	0	2	2	0	1
00090	0	1	3	1	3	2	1	2	3	0	0	3	3	1	3	2	1	2
00108	3	0	0	3	2	2	0	1	0	1	1	3	1	0	3	0	1	2
00126	2	1	0	0	2	3	2	3	2	1	0	0	2	3	2	3	1	3
00144	1	0	3	0	1	2	2	3	2	3	1	3	1	0	3	0	1	2
00162	2	1	0	0	0	3	2	2	0	1	0	1	3	1	3	2	1	2
00180	3	0	3	0	0	3	2	2	0	1	0	1	3	1	3	2	1	2
00198	2	1	0	0	2	3	2	3	1	3	1	0	3	0	1	2	1	0
00216	3	0	1	2	2	1	0	0	2	3	2	3	1	3	3	0	1	2

Figure 10. EVM O-QPSK

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FCC Power Spectral Density (PSD):

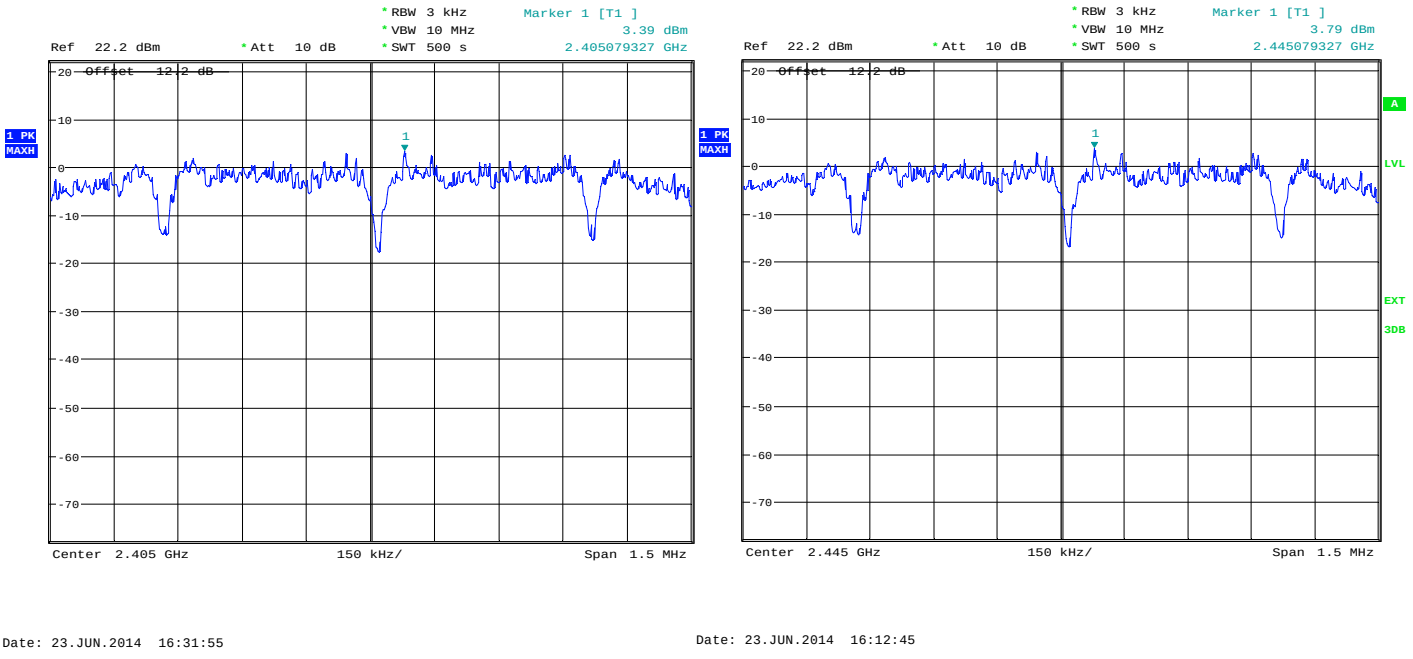

Figure 11. PSD for channels 11 and 19

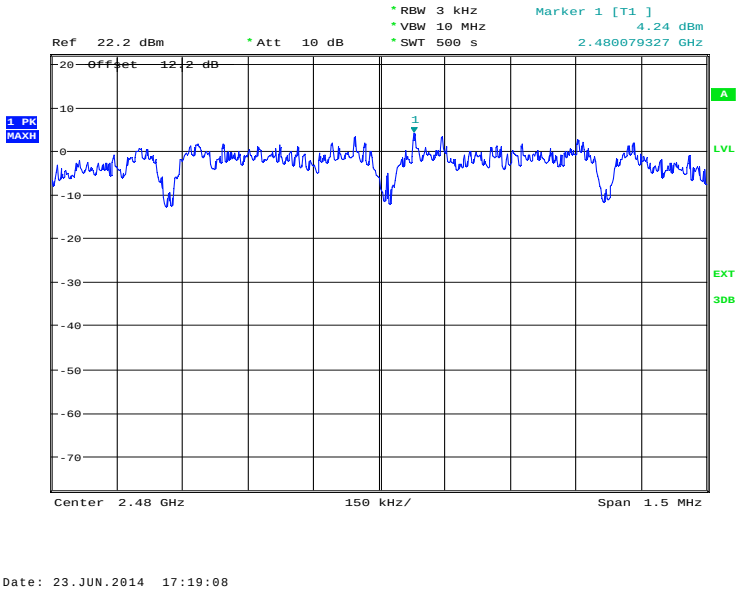

Figure 12. PSD for channel 26

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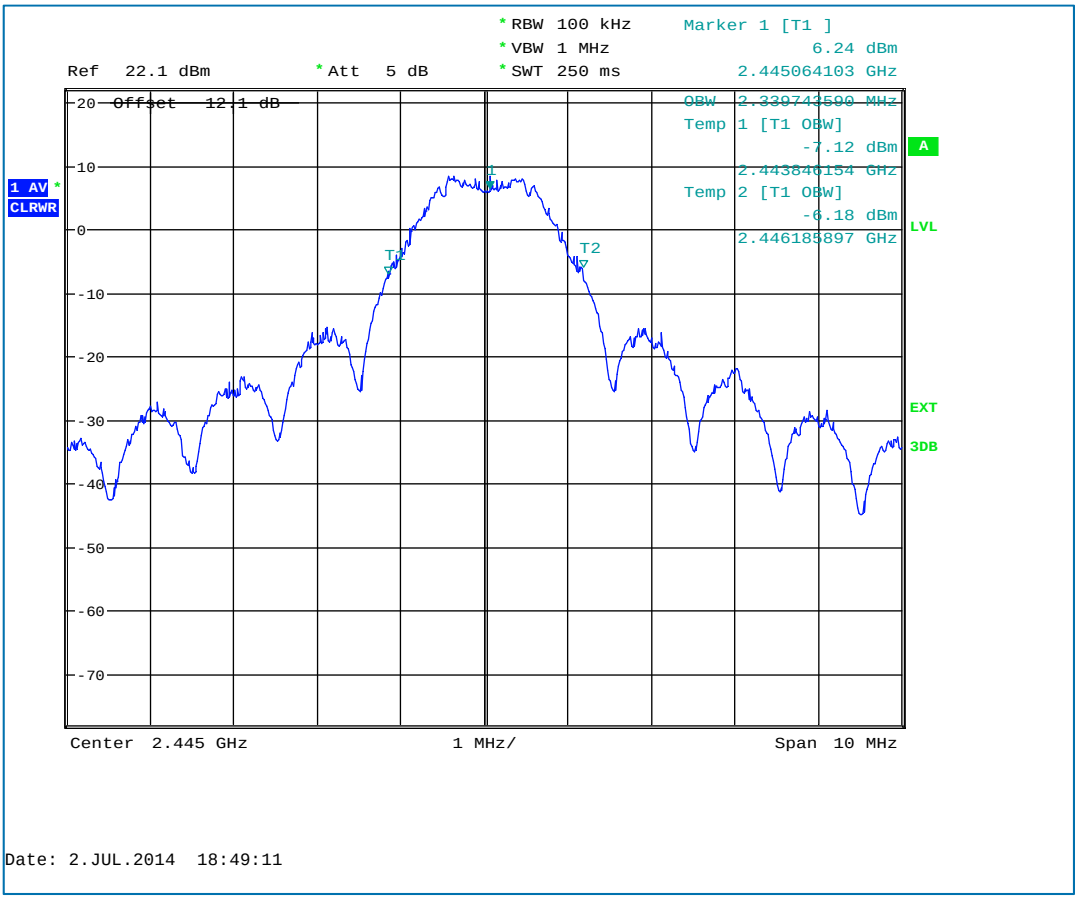

Figure 13. Occupied Channel Bandwidth(19dBm)

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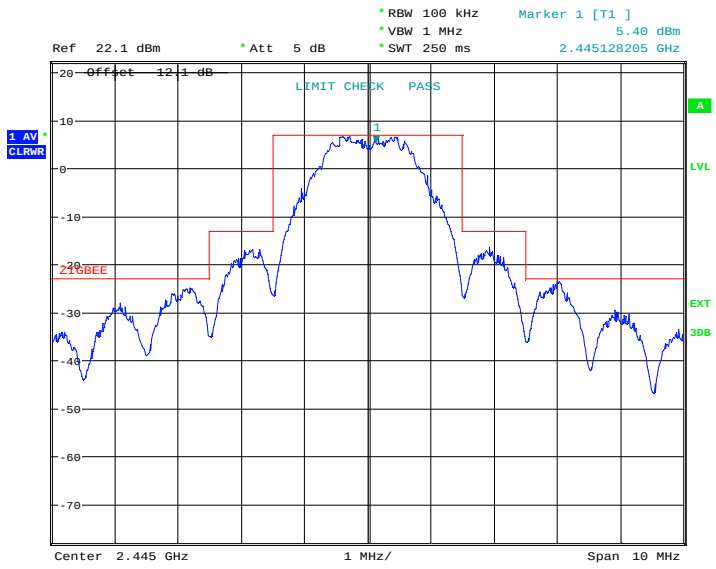

Figure 14. Power Spectral Density Mask Relative (18dBm)

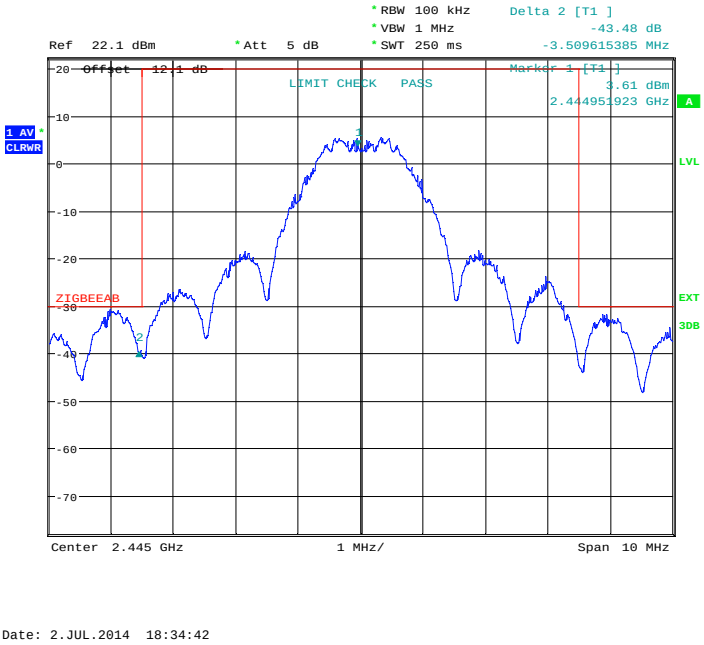

Figure 15. Power Spectral Density Mask Absolute(16dBm)

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Receive Performance of RF6555KW24D512-410

Rx Performance (250kbps)	Typical	Unit	Conditions
Sensitivity	-107	dBm	≤1% packet error rate at 250kbps
Input Saturation Max	+15	dBm	

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References

1. RF6555 Datasheet, http://www.rfmd.com/CS/Documents/RF6555DS.pdf
2. Please email smartgrid@rfmd.com with any additional questions.

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