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APPROVALS

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Title: CTM2 8880T2 RF DVT Report

Project Name: Clinician Telemetry Module (CTM2)

Authored By: Josh Francis

Version History		
Version	**Description of Change**	**Change Author**
1.0	Initial Release	Josh Francis
2.0	Route for approval	Josh Francis

Document location: *NPD > NDHF-Design History Files > NDHF1405 XTM Instruments Platform >XTM Hardware > HW CTM*

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1 EXECUTIVE SUMMARY

The CTM2 instruments were tested to the RF electrical requirements with the exception of RF-16, whose results are captured in NDHF1405-125441. All units passed the requirements. Results of the testing are summarized below.

Table 1 Summary of Results

Test #	Test Name	Requirement	Acceptance Criteria	Data Sample Size	Pass/Fail
RF-1	Tel M Support	EE553	Use Tel-M module which satisfies A17245 specification	None	PASS
RF-2 (mode 1)	Receiver Sensitivity (mode 1)	EE168 EE177	Max PER of 1% when: -89 dBm ≤ signal level ≤ -22 dBm	183	PASS
RF-2 (mode 3)	Receiver Sensitivity (mode 3)	EE169 EE177	Max PER of 1% when: -83.5 dBm ≤ signal level ≤ -22 dBm	185	PASS
RF-3 (mode 1)	Receiver Intermodulation Rejection (mode 1)	EE170	Max PER of 1% when IMR interferer levels ≤ 47 dB	36	PASS
RF-3 (mode 3)	Receiver Intermodulation Rejection (mode 3)	EE170	Max PER of 1% when IMR interferer levels ≤ 47 dB	36	PASS
RF-4 (mode 1)	Adjacent Channel Rejection (mode 1)	EE171	Max PER of 1% when adj. ch. interferer level (100 kHz offset) ≤ 35 dB	184	PASS
RF-4 (mode 3)	Adjacent Channel Rejection (mode 3)	EE171	Max PER of 1% when adj. ch. interferer level (300 kHz offset) ≤ 40 dB	187	PASS
RF-5 (mode 1)	Alternate Channel Rejection (mode 1)	EE172	Max PER of 1% when alt. ch. interferer level (200 kHz offset) ≤ 44 dB	183	PASS
RF-5 (mode 3)	Alternate Channel Rejection (mode 3)	EE172	Max PER of 1% when alt. ch. interferer level (600 kHz offset) ≤ 50 dB	182	PASS
RF-6 (mode 1)	AM Rejection (mode 1)	EE176	Max PER of 1% AM interferer level (1.5 MHz offset) ≤ -58 dBm	181	PASS
RF-6 (mode 3)	AM Rejection (mode 3)	EE176	Max PER of 1% AM interferer level (1.5 MHz offset) ≤ -58 dBm	180	PASS
RF-7	Rx External	EE175	Max PER of 1% at	66	PASS

(mode 1)	Spurious Response Rejection (worst case)		specified power with specified external spurious interferers		
RF-7 (mode 3)	Rx External Spurious Response Rejection (worst case)	EE175	Max PER of 1% at specified power with specified external spurious interferers	69	PASS
RF-8 (mode 1)	RSSI Linearity and Differentiation	EE178 EE179	RSSI range of -109 dBm min and -55 dBm max and differentiate -109 dBm and -106 dBm across all MICS channels	187	PASS
RF-8 (mode 3)	RSSI Linearity and Differentiation	EE178 EE179	RSSI range of -109 dBm min and -55 dBm max and differentiate -109 dBm and -106 dBm across all MICS channels	187	PASS
RF-9 (mode 1)	Tx output Power	EE158	-8.75 ≤ Tx Power ≤ -15.75 dBm	231	PASS
RF-9 (mode 1)	Tx Adjacent Channel Power Ratio	EE163	ACPR ≤ -34 dBc	231	PASS
RF-9 (mode 1)	Tx Alternate Channel Power Ratio	EE164	AltCPR ≤ -40 dBc	231	PASS
RF-9 (mode 3)	Tx Output Power	EE158	-8.75 ≤ Tx Power ≤ -15.75 dBm	235	PASS
RF-9 (mode 3)	Tx Adjacent Channel Power Ratio	EE163	ACPR ≤ -34 dBc	235	PASS
RF-9 (mode 3)	Tx Alternate Channel Power Ratio	EE164	AltCPR ≤ -40 dBc	235	PASS
RF-10 (mode 1)	Transmitter Error Vector Magnitude	EE166	EVM ≤ 8.4%	233	PASS
RF-10 (mode 1)	Transmitter Frequency Stability	EE156 EE157	Freq Stability ≤ +/- 12 ppm synthesizer shall tune in increments of 300 kHz from 402.15 MHz to 404.85 MHz	233	PASS
RF-10 (mode 3)	Transmitter Error Vector Magnitude	EE166	EVM ≤ 8.4%	242	PASS

RF-10 (mode 1)	Transmitter Frequency Stability	EE156 EE157	Freq Stability ≤ +/- 12 ppm synthesizer shall tune in increments of 300 kHz from 402.15 MHz to 404.85 MHz	242	PASS
RF-11	Active Tel M Antenna Gain	EE187 EE394	Primary gain ≥ 8.0 dBi Secondary gain ≥ -11.5 dBi	35	PASS
RF-12	Tel M Antenna Return Loss	EE188 EE189	Nominal 50 Ohm impedance Return loss ≤ -6 dB	35	PASS
RF-13	Active Bluetooth Antenna Efficiency	EE392	Radiation efficiency ≥ -10 dB	35	PASS
RF-14	Bluetooth Antenna Return Loss	EE67	Return loss ≤ -6 dB	35	PASS
RF-15	Bluetooth Rx Sensitivity (GFSK)	EE393	Rx Sensitivity ≤ -80 dBm	200	PASS
RF-16	Bluetooth Standard Qualification	EE53	Obtain Bluetooth 2.0 certification	N/A	Reported in NDHF1405-125441
RF-17	Tel M I/O	EE142 EE143 EE144 EE145 EE147 EE148 EE149 EE150 EE151 EE152 EE153 EE154 EE155	Meet the EE requirements listed	None	PASS

2 SCOPE

This document describes the Electrical Design Verification Test Report for the radio frequency (RF) aspects of the CTM2 Instrument. All testing performed was to verify the radio performance requirements for both long distance telemetry schemes used by the CTM2. Telemetry M (Tel M) is a MICS band communication protocol used by the instrument to communicate to an implant that supports Tel M. The Bluetooth radio, operating in the ISM band, is used to communicate between the CTM2 and the clinician programmer. In the scope of telemetry, the CTM2 acts as a gateway for communications between the implant and the clinician programmer.

3 PURPOSE / OBJECTIVES

The purpose of this document is to provide a report of the testing results applicable electrical design requirements (long distance telemetry) for the Clinician Telemetry Module. The CTM2 electronics will be evaluated against these requirements using the test plan described in this document.

4 BACKGROUND

4.1 PRODUCT

CTM2, model #8880T2, is a handheld, battery operated, microprocessor-based instrument designed for use by clinicians to assist with the programming of implantable medical devices. The device interacts with a Next Generation Clinician Programmer (NGCP) model 8880CW, to receive and transmit programming commands to an implanted medical device (IMD,collectively referred to as “medical devices” henceforth). Communication to an NGCP occurs through either cabled [system connector] or wireless [Bluetooth] methodologies. Medical device communication occurs through proximal or distance operational telemetry modes. Proximally, Tel-A and ‘downlink only’ Tel-N telemetry will be leveraged as well as distance, Tel-M, telemetry for communication to designated devices. Support of proximal and distance telemetry permits backward device compatibility as well as focused next generation conceptual expansion.

CTM2 will support programmer communication to

- NGCP (Wired – System Connector)
- NGCP (Wireless – Bluetooth)

At the time of the writing of this document, CTM2 will support medical device communication to:

- Synchromed 2 or SM2 (Tel-A)
- Synchromed 3 or SM3 (Tel-A)
- Intellis (Tel-N downlink and Tel-M)

CTM2 components include: an uplink / downlink RF transceiver (comprising of two antennae) for distance telemetry, an internal antenna for proximal telemetry, LED indication lights for power and communication activity, and interactive push buttons as well as Telemetry, Operating, and Application Specific Software. A Bluetooth Module and system connector port provide data transfer options for communication to and from an NGCP.

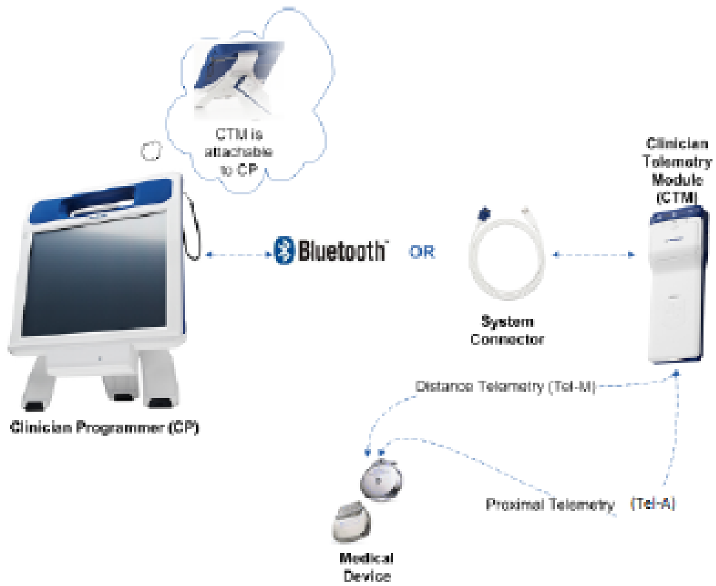
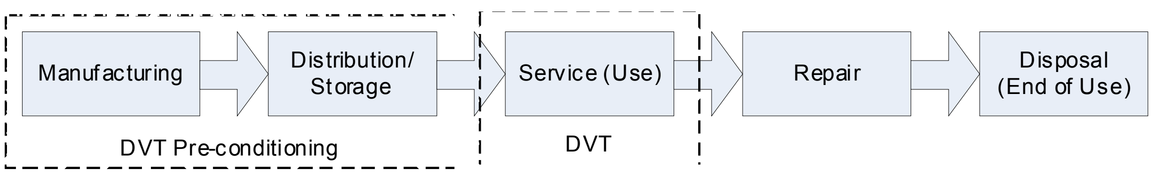


Figure 1 Clinician Telemetry Module 2 (CTM2) System

4.2 PRODUCT LIFECYCLE AND VERIFICATION TESTING

Figure 2 Product Lifecycle



MANUFACTURING EXPOSURE

For the CTM2, as is the case in nearly all instruments, manufacturing exposure occurs naturally as the devices are manufactured using the normal processes and procedures which will be used in production. Thus, the manufacturing exposure is actual and does not need to be simulated, and is not addressed in this Protocol.

DISTRIBUTION/STORAGE EXPOSURE

No formal pre-conditioning testing will be performed on the CTM2, as the additional exposures identified with Distribution/Storage are not deemed to pose a significant risk to the product's safety, performance, or reliability. The CTM2 does have an associated level 5 hazard (Abrupt Loss of Infusion) and an associated level 3 hazard (Misleading Information), outlined in the NGCP-CTM Platform Risk Management Fault Tree Analysis NDHF1205-102404 and the Risk Management Fault Tree Analysis for RS2 (Intellis) Model 97715 System NDHF1405-110640. These hazards were mitigated to an acceptable occurrence as shown in section 6.1.2 Analyze Hazardous Scenarios using Fault Trees; Risk Evaluation and Risk Acceptability. Additionally, the CTM2 Mechanical DMEA Report NDHF1405-116226 did not show a significant patient safety risk in a single fault condition, meaning that in order for a patient safety risk to occur; multiple independent events would need to transpire. Furthermore, the CTM2 poses an acceptable reliability/business risk, based on similarities to past Neuromodulation Instruments experience and expected reliability and performance of this device, which will be confirmed through DVT testing. DVT Testing will also include Packaging Testing per MDT 200572, which will test the packaging against environmental exposures with the product inside, after which the CTM2 will be tested on either production test equipment or a DVT test station, confirming proper product performance.

SERVICE

This portion of the Product Lifecycle is the primary focus of DVT (this protocol) to confirm performance to product specifications during the service portion of the product's life.

REPAIR

Repair policies and procedures for this product will be developed prior to and during the initial release phase of the product by Development and Repair. Repairs which are made to a product prior to return to service would be similar in nature to manufacturing exposure and are not expected to impact DVT results. Prior to being returned to service, any repaired product will be tested on an automated tester and product performance confirmed.

DISPOSAL

Proper procedures for the disposal phase of a product's lifecycle are contained in the user manual for the product.

5 APPLICABLE DOCUMENTS

Table 2: Table of Applicable Documents

Document Number	Version	Description
NDHF1405-112510	2.0	CTM2 8880T2 Tel M DVT Test Protocol
A17245	L	Telemetry M RF Module Requirements Specification
NDHF1405-121834	2.0	xTM Telemetry M Test Environment Verification Report
M938941A005	B	CTMII PWB Assembly
M938941A006	A	CTMII PWB Assembly
NDHF1405-111108	7.0	CTMII Electrical Specification
QMS1795	6.0	Neuromodulation Global Glossary
QMS1850	4.0	TLP Statistics, Monitoring and Analysis
NDHF1405-122707	2.0	xTM Telemetry M Test Sample Justification
NDHF1405-124575	2.0	Supporting Data for CTM2 8880T2 RF DVT Report (NDHF1405-124574)

6 ACCEPTANCE STRATEGY

The purpose of this document and the design verification test (DVT) evaluation is to ensure the RF performance meets the requirements outlined in the electrical specifications. Acceptance criteria will be meeting the electrical requirements with 90% confidence/90% reliability. Any deviations or exceptions from the requirements or test plan procedures will be published in the DVT report with supporting rationale. Test vectors (environmental variables) will be across operating temperature range, across operating voltage range, and also across frequency channels.

7 SAMPLE SIZE JUSTIFICATION

An appropriate device sample size to obtain ≥ 30 variables data points was used to demonstrate specification compliance with a 90/90 confidence/reliability. The samples analyzed were the actual parametric performance measurements per each requirement (i.e. power at which Rx sensitivity is achieved, output Tx power, etc.). Part to part variation is minimized by virtue of 100% trim and calibration at manufacturing. Observed Cpk values were analyzed in this report to demonstrate 90/90 confidence reliability per QMS1850. Historical data and analysis contained in NDHF1405-122707 supports the sample size based off measured performance across environmental conditions rather than device to device variation.

For RF-16 Bluetooth Standard Qualification, a minimum sample size of 1 DUT was the requirement per Bluetooth SIG qualification procedures. Capability analysis does not apply to this requirement and test as this qualification effort is controlled and judged solely by the Bluetooth SIG.

8 ACRONYMS

All acronyms used within this document are defined here.

Table 3: Table of Acronym Definitions

Acronym	Description	Definition
ACPR		Adjacent Channel Power ratio
ADC		Analog to Digital Converter
AltCP		Alternate Channel Power
AltCPR		Alternate Channel Power ratio
AM		Amplitude Modulation
BPSK	Type of digital modulation scheme	Binary Phase Shift Key
CL		Confidence Level
CTM		Clinician Telemetry Module
CW	Unmodulated RF signal	Continuous Wave
DL		downlink
DUT		Device Under Test
DVT		Design Verification Test
EIRP	Antenna parameter	Effective Isotropic Radiated Power
EVM	Metric of the transmitter	Error vector magnitude
F2R1	Version of Tel M module	Fracture 2 ROM 1
F2R1	Version of Tel M module used in DVT build	Fracture 2 ROM 2
FM		Frequency Modulation
GPIB	Common interface between Labview software and test equipment	General Purpose Interface Bus
IMR		Intermodulation Rejection
LSB		Least Significant Bit
MICS	402-405 MHz frequency band	Medical Implant Communication Services (402-405 MHz)
NGCP		Next Generation Clinician Programmer
PCB		Printed circuit Board
PER	Metric used to assess receiver	Packet Error Rate

	performance	
P_{inc}		Power incident at DUT
RF		Radio Frequency
RFM	Telemetry M module that resides on PCB	RF Module
RMS	Power measurement	Root Mean Square
RSSI		Received Signal Strength Indication
Rx		Receive
Rx_{sens}		Receiver sensitivity
TRP	Antenna parameter	Total Radiated Power
Tx		Transmit
UL		uplink
USB	Common interface between computer and test equipment	Universal Serial Bus
WU_{sens}		Wakeup sensitivity

9 TEST PROCEDURE

9.1 SAMPLE CONFIGURATION

The devices to be tested will be built per controlled process, including having RF trims performed after being populated on the CTM2 printed circuit board (PCB). The units will be tested at the PCB level for all tests, with the exception of antenna tests. This is implemented so that test points can be accessed for testing. Testing at the PCB level for conducted testing is acceptable since parametric shifts will not be experienced, due to the tests being conducted rather than radiated. The exception to this configuration is that all antenna testing will be performed in the final assembly form. This is due to the antenna tests being sensitive to the parasitic loading of the entire assembly.

9.2 TEST EQUIPMENT

All equipment used during testing will be documented. Where applicable, recorded information should include, but not be limited to:

Manufacturer	Model	Asset #	Calibration Due	Date of Testing	Test Station
Agilent	E4438C	157632	18Oct2011	30Sep2011	Rx/Tx 2
Agilent	E4438C	152060	20Oct2011	30Sep2011	Rx/Tx 2
Agilent	E8663D	157631	23Apr2012	30Sep2011	Rx/Tx 2
Keithley	2400	157556	27Feb2012	30Sep2011	Rx/Tx 2
Sigma Systems	Temp Chamber	157637	07May2012	30Sep2011	Rx/Tx 2
Agilent	N9020A	152058	28Oct2011	30Sep2011	Rx/Tx 2
Agilent	E4438C	157632	18Oct2011	03Oct2011	Rx/Tx 1
Agilent	E4438C	152060	20Oct2011	03Oct2011	Rx/Tx 1

Agilent	E8663D	157631	23Apr2012	03Oct2011	Rx/Tx 1
Keithley	2400	157556	27Feb2012	03Oct2011	Rx/Tx 1
Sigma Systems	Temp Chamber	157637	07May2012	03Oct2011	Rx/Tx 1
Agilent	N9020A	152058	28Oct2011	03Oct2011	Rx/Tx 1
Agilent	E4438C	155953	15Oct2011	06Oct2011	Spur 1
Agilent	E8663D	157541	29Dec2011	06Oct2011	Spur 1
Keithley	2400	157612	21Jan2012	06Oct2011	Spur 1
JFW	50SA-203	ES043742	N/A	06Oct2011	Spur 1
Agilent	E4438C	157750	19Oct2011	06Oct2011	Spur 2
Agilent	E8664A	152057	26Oct2011	06Oct2011	Spur 2
Agilent	E3631A	ES032778	27Jan2012	06Oct2011	Spur 2
JFW	50SA-203	ES049089	N/A	06Oct2011	Spur 2
CCI	CTM E	161062	N/A	06Oct2011	Spur 1 & Rx/Tx 1
CCI	CTM E	59730	N/A	06Oct2011	Spur 2 & Rx/Tx 2

9.3 REQUIREMENTS

All Rx tests are independent and therefore are not required to be run in a specific order, however, for optimal time efficiency, Rx tests will be run in a specific order. With the exception of Rx spurious response, Rx sensitivity will be run, then subsequent interference tests with the same input parameters (i.e. channel, temp, voltage, etc.) will be run afterwards. All Tx tests are independent and therefore do not need to be run in a specific order and there is no time efficiency to be gained from special sequencing.

Table 4: List of Tests for CTM2 Telemetry M Design Verification Testing

Test Number	CTM2 Tel M Testing	Minimum Test Samples
	Receiver Testing	
RF-1.	Tel M Support	None, BOM/schematic inspection
RF-2.	Receiver Sensitivity	3 DUTs
RF-3.	Receiver Intermodulation Rejection	3 DUTs
RF-4.	Receiver Adjacent Channel	3 DUTs
RF-5.	Receiver Alternate Channel Rejection	3 DUTs
RF-6.	Receiver AM Rejection	3 DUTs
RF-7.	External Spurious Response Rejection (Single Tone, Unmodulated)	3 DUTs
RF-8.	Rx RSSI Linearity and differentiation	3 DUTs
	Transmitter Testing	
RF-9.	Transmitter Output Power, Transmitter Adjacent Channel Power Ratio, Transmitter Alternate Channel Power Ratio	3 DUTs
RF-10.	Transmitter Error Vector Magnitude & Transmitter Frequency Stability	3 DUTs
	Antenna Testing	
RF-11.	Active Tel-M Antenna Gain	7 DUTs
RF-12.	Tel-M Antenna Return Loss	7 DUTs
RF-13.	Active Bluetooth Antenna Efficiency	7 DUTs
RF-14.	Bluetooth Antenna Return Loss	7 DUTs
	Bluetooth Testing	
RF-15.	Bluetooth Rx Sensitivity (GFSK)	3 DUTs
RF-16.	Bluetooth Standard Qualification	1 DUT
	Tel M I/O	
RF-17.	Tel M I/O	None, Datasheet inspection

9.4 REQUIREMENTS, ACCEPTANCE STRATEGY & RESULTS

Prior to beginning DVT testing:

1. Determine the cable loss of all RF coax cables that will be used in the test setup. (Appendix A: Measurement of RF path loss through cables)
2. Build DVT Vector files for Rx test suite, Rx spurious test suite, and Tx test suite.

9.4.1 RF-1: TEL-M SUPPORT

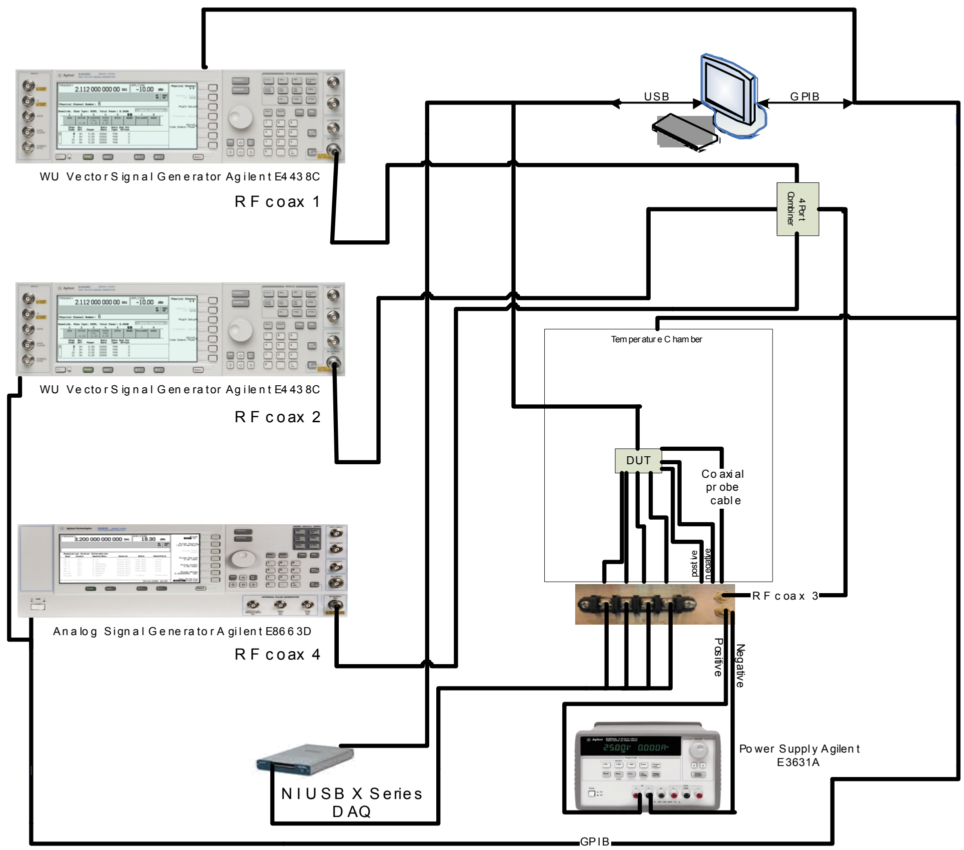
Requirement	EETD59 The CTM2 shall support wireless communications with implantable devices as

	specified in the Tel-M Communication Protocol Specification, A36244 Verifies: EE553 The CTM2 shall support wireless communications with implantable devices as specified in the Tel-M Communication Protocol Specification, A36244
Test Description	This will be verified via inspection of the CTM2 schematic and BOM that the Tel M module was used in the design. By virtue of using a Tel-M module, the hardware is capable of supporting Tel-M communication and adhering to the A36244 Tel-M Communication Protocol Specification
Sample size:	*N/A*
Acceptance Criteria	An acceptance criterion is based on implementing Tel-M support by using a Tel-M module.
Test Objective:	Verify device meets specified requirements.
Test Environment:	N/A
Test Setup:	N/A
Test Procedure:	N/A
Test Results:	Inspection of the printed wiring board assembly (M938941A004) used for this build shows that the Telemetry M RF module (M947150A008) was used. By virtue of using the Telemetry M module, which meets the requirements called out in A17245, this design meets the requirement of supporting the Tel-M Communication Protocol Specification, A36244.
Test Data Traceability	N/A
Test Sample Retention	N/A

9.4.2 RF-2: Receiver Sensitivity

Requirement	EETD25 Tel-M Receiver Sensitivity Verifies: EE168 Mode1 sensitivity shall be ≤ -89 dBm EE169 Mode 3 sensitivity shall be ≤ -83.5 dBm EE177 The Tel-M Receiver shall have effective over the air maximum Rx power ≥ -22 dBm with Rx attenuation setting.
Test Description	This test is automated in DVT. Rx attenuation = 17 dB. The antenna loss makes up the remainder of the needed loss.

	The receiver sensitivity test measures how low in power a Tel M signal can be received by the DUT receiver while achieving a packet error rate (PER) ≤ 1%. The test is conducted in a shielded temp chamber that provides an isolated environment from external interfering signals (e.g., WiFi, Cell phone, etc.). The DUT is powered via an external power supply such that the temperature and power supply can be variable parameters in the test. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 5. A vector signal generator is used to play back arbitrary waveforms consisting of valid framed Tel M data. After a specified number of packets, the number of received packets and packets with Reed Solomon errors are counted. From this, the PER is calculated. The calculation is: PER(%) = [(packets sent – packets received) + packet errors] / (packets sent) * 100 In this test, the interfering signal generators are not used.
Sample size:	*5 DUTs*
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.

Test Environment:	 Figure 3. Test setup for receiver testing
Test Setup:	**Cable connections and initial calibrations:** 1. Measure the signal level at each signal generator with a power meter. Then connect the signal generators to the RF combiner. Now measure the power of each signal generator at the input of the DUT (incident at the DUT from the signal generators). Record these loss factors in the DUT .ini file for software use. These losses will compensate for inaccuracies of the signal generator output, as well as all RF losses due to routing. 2. Place the DUT inside the fixture. 3. Place the fixture inside temperature chamber 4. Connect the measured cable between the DUT and RF Combiner (RF coax 3). 5. Connect the power supply to the DUT fixture. 6. Connect up DAQ to Tel M test bus. 7. Connect GPIB and USB connections to interface with testing software
Test Procedure:	**I. Initial Setup** A. Setup equipment as shown in Figure 3 **II. Labview:**

	A. Open and run “DVT Main Menu.vi” file B. Login with User Name and Password C. Select “Run DVT” button D. When prompted, select “CTM_DVT_Rx_Suite.dvt” script. E. Select “Start” button F. When prompted, fill in “UUT Serial Number” field and “Bench Name” field appropriately. G. Select “OK” button. H. Confirm that the tests have started as expected.
Test Results:	All test samples PASS Rx sensitivity requirements for both modes 1 and 3. All test samples PASS Rx dynamic range requirements for both modes 1 and 3.
Capability Analysis	See figure below

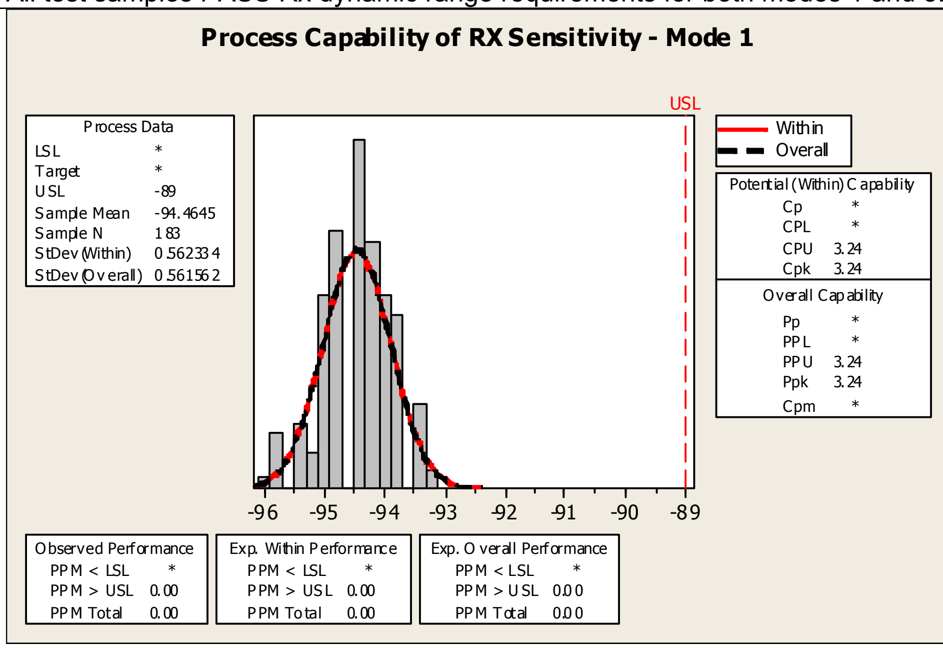


Figure 4 Capability Analysis of Mode 1 Rx Sensitivity (Lower Dynamic Range Level)

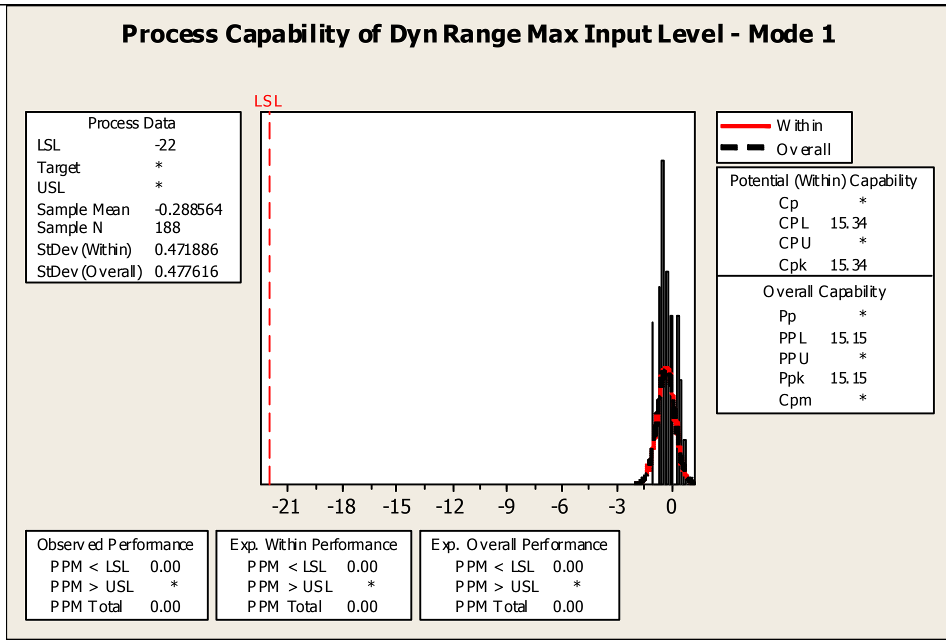


Figure 5 Capability Analysis of Mode 1 Rx Upper Dynamic Range Level

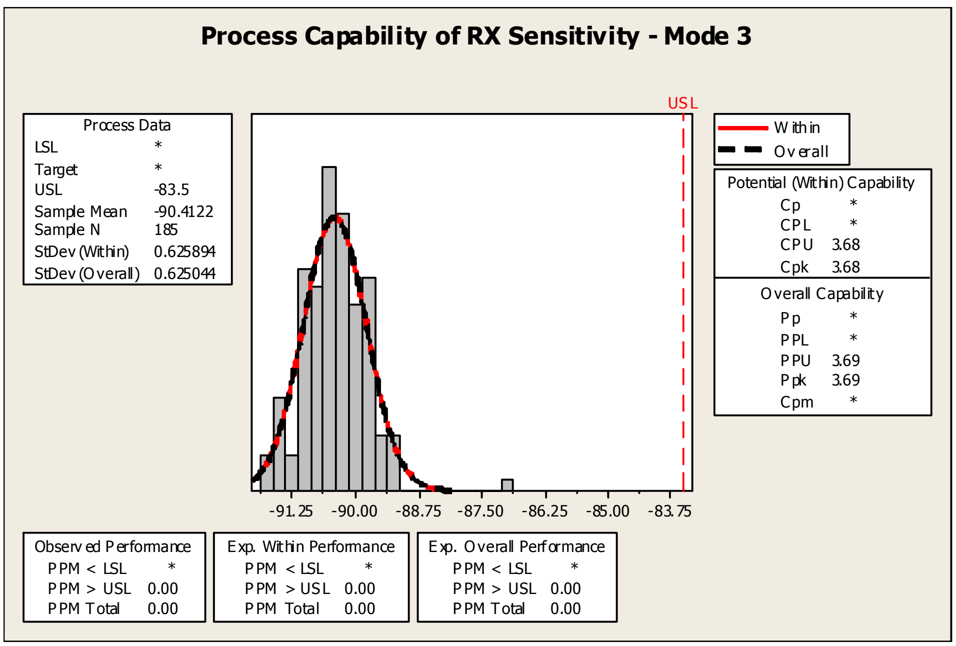


Figure 6 Capability Analysis of Mode 3 Rx Sensitivity (Lower Dynamic Range Level)

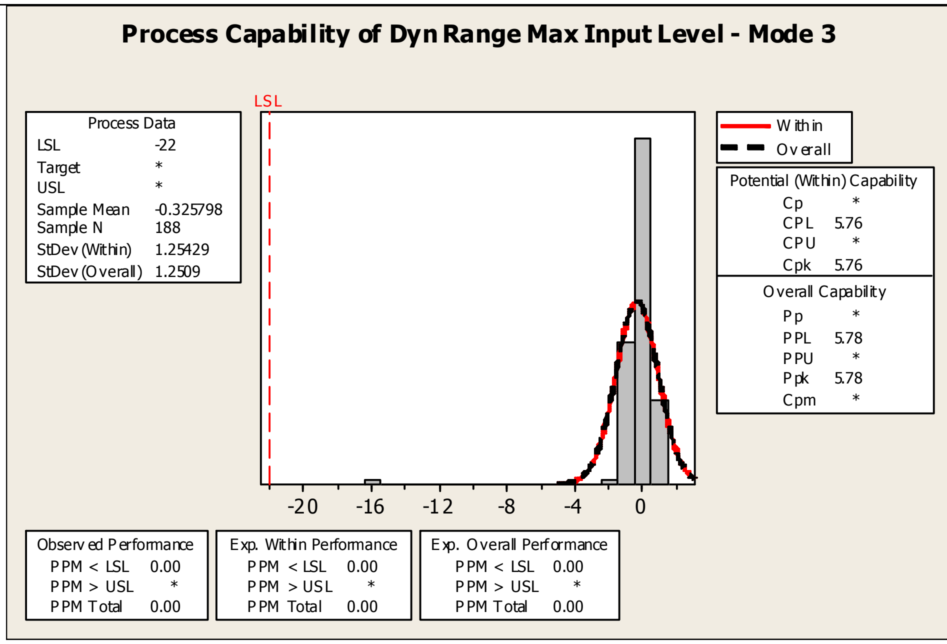


Figure 7 Capability Analysis of Mode 3 Upper Dynamic Range Level

- Mode 1 Rx sensitivity results, Figure 4, show higher than 99%/99% confidence/reliability in achieving a minimum sensitivity of -89 dBm.
- Mode 1 Rx dynamic range results, Figure 5, show higher than 99%/99% confidence/reliability in achieving an upper level dynamic range capability that exceeds -22 dBm.
- Mode 3 Rx sensitivity results, Figure 6, show higher than 99%/99% confidence/reliability in achieving a minimum sensitivity of -83.5 dBm.
- Mode 3 Rx dynamic range results, Figure 7, show higher than 99%/99% confidence/reliability in achieving an upper level dynamic range capability that exceeds -22 dBm.

Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

Table 5: Table of Receiver Tests

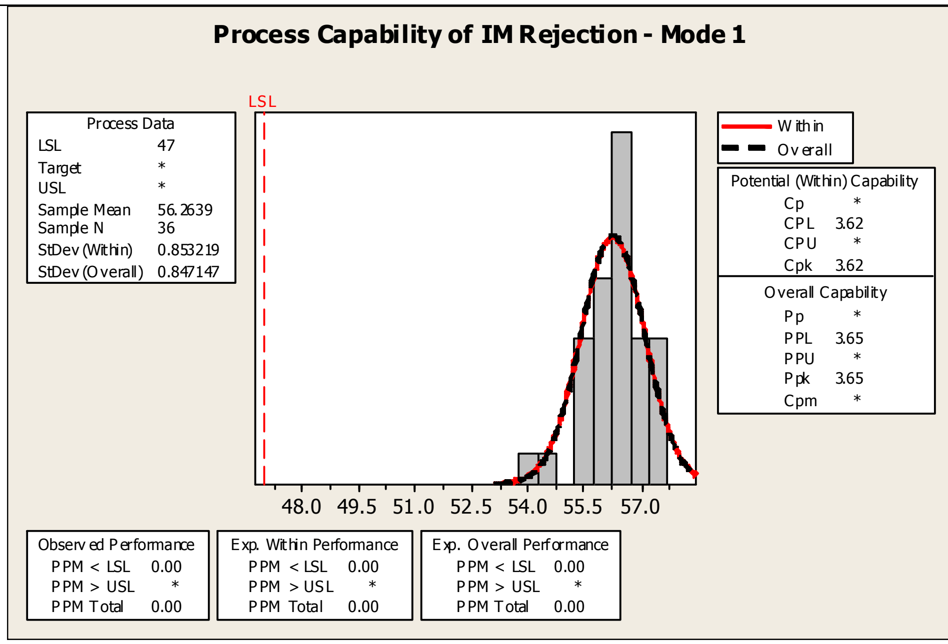
	Mode 1		*Mode 3*	
DUT channel	**Temperature (C)**	**Battery voltage (V)**	**Temperature (C)**	**Battery voltage (V)**
1 (402.15 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2

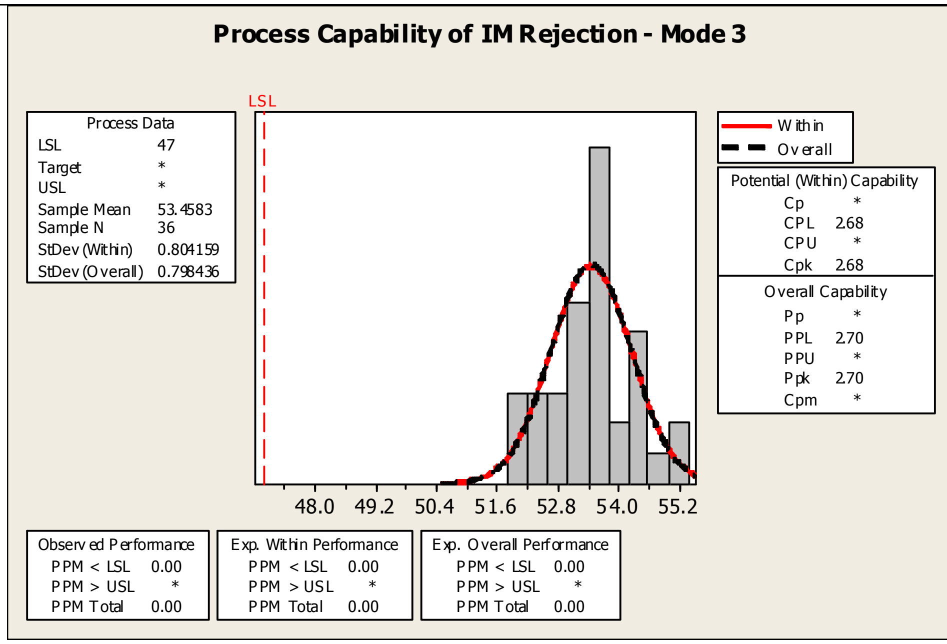
2 (402.45 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
3 (402.75 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
4 (403.05 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
5 (403.35 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
6 (403.65 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
7 (403.95 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
8 (404.25 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
9 (404.55 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2

10 (404.85 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2

9.4.3 RF-3: Receiver Intermodulation Rejection

Requirements	EETD26 Tel-M Receiver Intermodulation Rejection Verifies: EE170 The Tel-M Receiver shall have minimum IM rejection of 47 dB with interferers at 1.5 MHz and 3.0 MHz offset from desired signal
Test Description	This test is automated in DVT. Rx attenuation = 17 dB. The intermodulation rejection test measures the ability of the receiver to prevent two specific interfering signal inputs from causing degradation of reception of the desired signal. The test method is loosely based on Industry standard: TIA/EIA 603-B with deviations as required for differences due to operation in the MICS band. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 5. The test setup is the same as shown in Figure 3. The desired signal is provided by a vector signal generator playing back an appropriate arbitrary waveform consisting of properly formatted Tel M frames of data modulated appropriately. The first interferer, programmed on one signal generator, is five channel spacings away (1.5 MHz) from the desired signal and is an unmodulated CW mode signal. The second interfering signal, programmed on a vector signal generator, is ten channel spacings away (3.0 MHz) from the desired signal and will have BPSK modulation. The performance measurement will be based on measuring PER degradation as the power of the interferers is increased. After a specified number of packets, the number of received packets and packets with Reed Solomon errors are counted. From this, the PER is calculated. The calculation for PER is: PER(%) = [(packets sent – packets received) + packet errors] / (packets sent) * 100
Sample size:	5 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	This test is part of the receiver suite of tests. See test environment in section 9.4.1.

Test Setup:	This test is part of the receiver suite of tests. See test setup in section 9.4.1.
Test Procedure:	**I. Initial setup:** Setup equipment as shown in Figure 3 **II. Labview:** A. Open and run "DVT Main Menu.vi" file B. Login with User Name and Password C. Select "Run DVT" button D. When prompted, select "CTM_DVT_Rx_Suite.dvt" script. E. Select "Start" button F. When prompted, fill in "UUT Serial Number" field and "Bench Name" field appropriately. G. Select "OK" button. H. Confirm that the tests have started as expected.
Test Results:	All samples PASS all Rx intermodulation rejection requirements.
Capability Analysis	 Figure 8 Capability Analysis of Mode 1 Rx Intermodulation Rejection

	 Figure 9 Capability Analysis of Mode 3 Rx Intermodulation Rejection • Mode 1 Rx intermodulation rejection results show higher than 99%/99% confidence/reliability in achieving a minimum rejection of 47 dB. • Mode 3 Rx intermodulation rejection results show higher than 99%/99% confidence/reliability in achieving a minimum rejection of 47 dB.
Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

9.4.4 RF-4: Receiver Adjacent Channel Rejection

Requirements	EETD27 Tel-M Receiver Adjacent Channel Rejection Verifies: EE171 Adjacent channel rejection shall be better than 35dB for Mode 1 (measured at 100 kHz offset from desired) and 40dB for Mode 3 (measured at 300 kHz offset from desired)
Test Description	This test is automated in DVT. Rx attenuation = 17 dB. The adjacent channel interference rejection is a measure of the ability of a receiver to reject an interfering signal in the channel adjacent to the desired signal. All tests will be

	performed with the RF channel, temperature, and voltage combinations outlined in Table 5. The test setup is the same as shown in Figure 3. The desired signal is provided by a vector signal generator playing back an appropriate arbitrary waveform consisting of properly formatted Tel M frames of data modulated appropriately. The interferer, programmed on the vector signal generator, is offset 300 kHz from the desired signal for mode 3 and offset 100 kHz from the desired signal for mode 1 (i.e., in the adjacent channel) and will have BPSK modulation, using a PN23 data sequence as the data source. Note that the other signal generator is not used in this test. The performance measurement will be based on measuring PER degradation as the power of the interferers is increased. After a specified number of packets, the number of received packets and packets with Reed Solomon errors are counted. From this, the PER is calculated. The calculation for PER is: PER(%) = [(packets sent – packets received) + packet errors] / (packets sent) * 100
Sample size:	5 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	This test is part of the receiver suite of tests. See test environment in section 9.4.1.
Test Setup:	This test is part of the receiver suite of tests. See test setup in section 9.4.1.
Test Procedure:	I. **Initial setup:** Setup equipment as shown in Figure 3 II. **Labview:** A. Open and run "DVT Main Menu.vi" file B. Login with User Name and Password C. Select "Run DVT" button D. When prompted, select "CTM_DVT_Rx_Suite.dvt" script. E. Select "Start" button F. When prompted, fill in "UUT Serial Number" field and "Bench Name" field appropriately. G. Select "OK" button. H. Confirm that the tests have started as expected.
Test Results:	All samples PASS all Rx Adjacent Channel rejection requirements.
Capability Analysis	

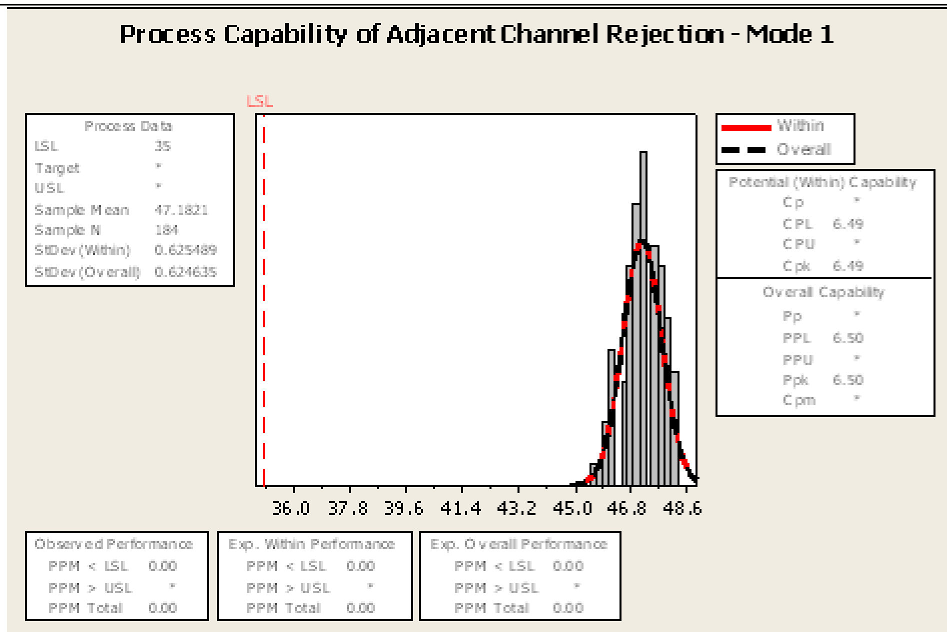


Figure 10 Process Capability of Mode 1 Rx Adjacent Channel Rejection

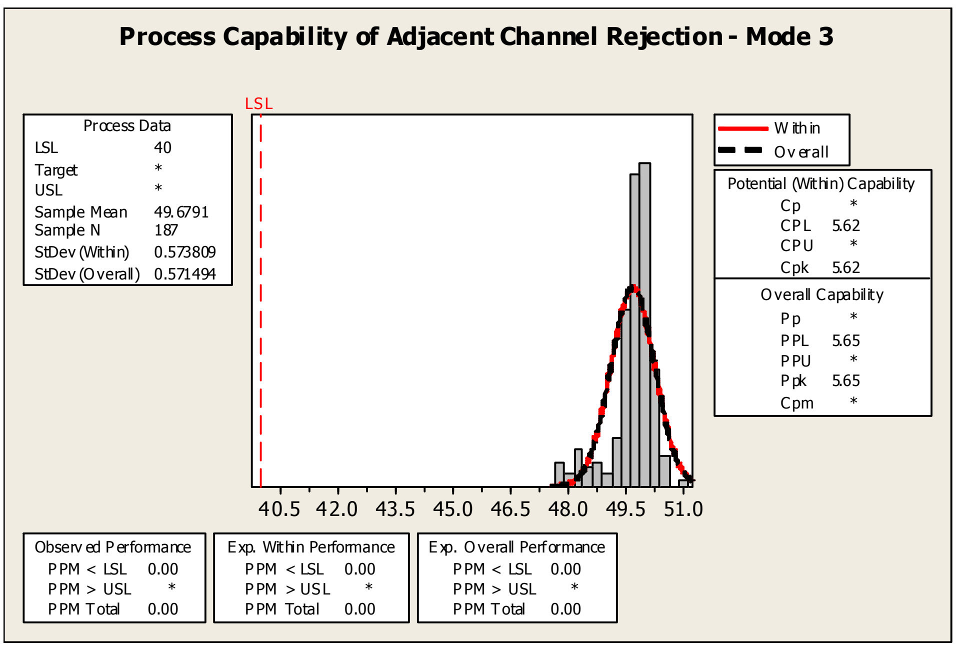


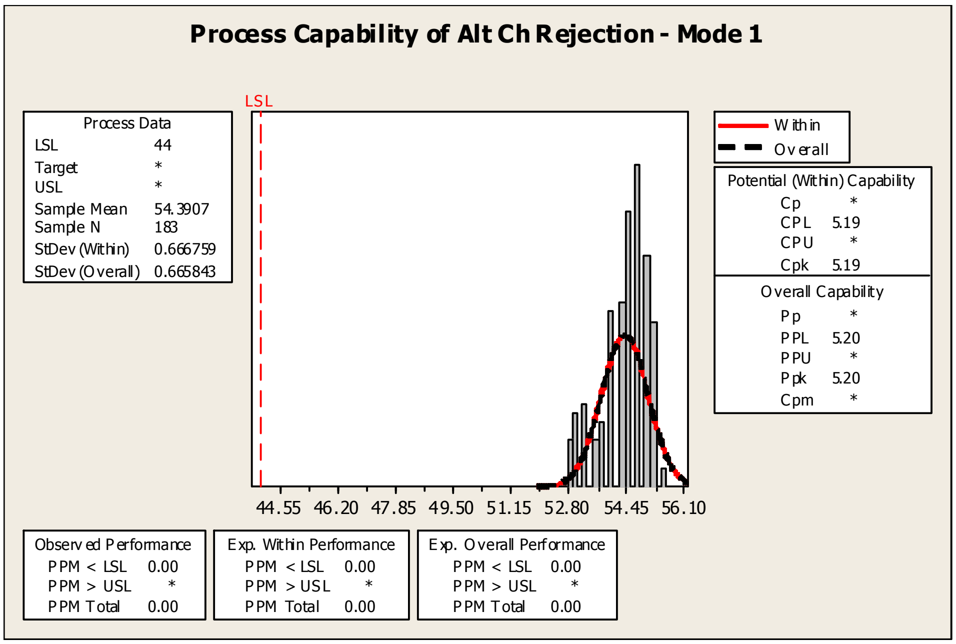
Figure 11 Process Capability of Mode 3 Rx Adjacent Channel Rejection

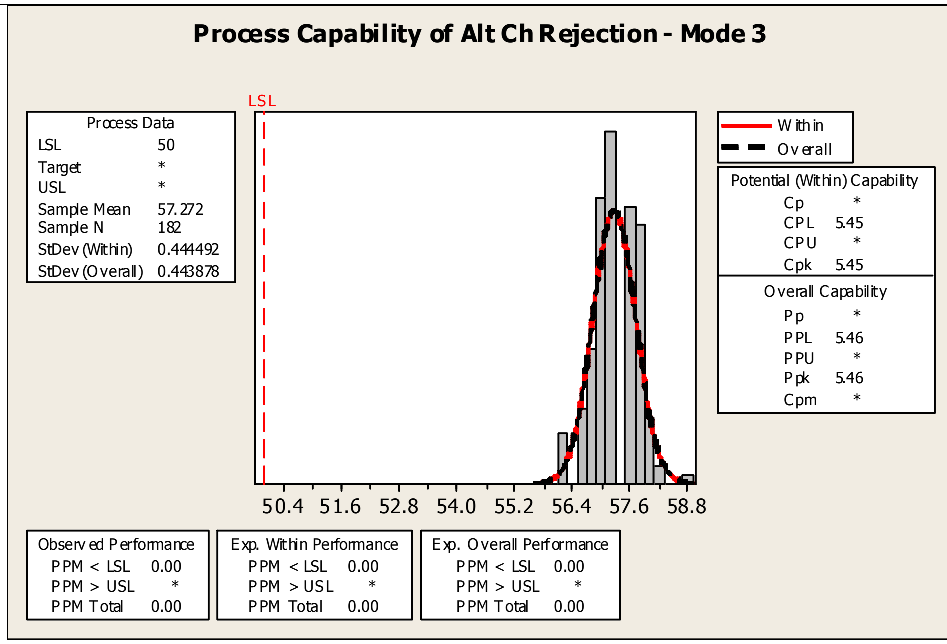
- Mode 1 Rx adjacent channel rejection results, Figure 10, show higher than 99%/99% confidence/reliability in achieving a minimum rejection of 35 dB.
- Mode 3 Rx adjacent channel rejection results, Figure 11, show higher than

	99%/99% confidence/reliability in achieving a minimum rejection of 35 dB.
Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

9.4.5 RF-5: Receiver Alternate Channel Rejection

Requirements	EETD28 Tel-M Receiver Alternate Channel Rejection Verifies: EE172 Alternate channel rejection shall be better than 44dB for Mode 1 (measured at 200 kHz offset from desired) and 50dB for Mode 3 (measured at 600 kHz offset from desired)
Test Description	This test is automated in DVT. Rx attenuation = 17 dB. The alternate channel interference rejection is a measure of the ability of a receiver to reject an interfering signal 2 channels away from the desired signal. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 5. The test setup is the same as shown in Figure 3. The desired signal is provided by a vector signal generator playing back an appropriate arbitrary waveform consisting of properly formatted Tel M frames of data modulated appropriately. The interferer, programmed on the vector signal generator, is 600 kHz for mode 3 and 200 kHz for mode 1 (i.e., in the alternate channel) from the desired signal and will have BPSK modulation, using a PN23 data sequence as the data source. Note that the other signal generator is not used in this test. The performance measurement will be based on measuring PER degradation as the power of the interferers is increased. After a specified number of packets, the number of received packets and packets with Reed Solomon errors are counted. From this, the PER is calculated. The calculation for PER is: PER(%) = [(packets sent – packets received) + packet errors] / (packets sent) * 100
Sample size:	5 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	This test is part of the receiver suite of tests. See test environment in section 9.4.1.
Test Setup:	This test is part of the receiver suite of tests. See test setup in section 9.4.1.
Test Procedure:	I. **Initial setup:** Setup equipment as shown in Figure 3

	II. **Labview:** A. Open and run “DVT Main Menu.vi” file B. Login with User Name and Password C. Select “Run DVT” button D. When prompted, select “CTM_DVT_Rx_Suite.dvt” script. E. Select “Start” button F. When prompted, fill in “UUT Serial Number” field and “Bench Name” field appropriately. G. Select “OK” button. H. Confirm that the tests have started as expected.
Test Results:	All samples PASS all Rx Alternate Channel rejection requirements.
Capability Analysis	 Figure 12 Capability Analysis of Mode 1 Rx Alternate Channel Rejection

	 Figure 13 Capability Analysis of Mode 3 Rx Alternate Channel Rejection • Mode 1 Rx alternate channel rejection results, Figure 12, show higher than 99%/99% confidence/reliability in achieving a minimum rejection of 44 dB. • Mode 3 Rx alternate channel rejection results, Figure 13, show higher than 99%/99% confidence/reliability in achieving a minimum rejection of 50 dB.
Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

9.4.6 RF-6: Receiver AM Channel Rejection

Requirements	EETD29 Tel-M Receiver AM Channel Rejection Verifies: EE176 AM rejection shall be better than -58dBm for 1.5MHz offset.
Test Description	This test is automated in DVT. Rx attenuation = 17 dB. The AM rejection is a measure of the ability of a receiver to reject an amplitude modulated interfering signal 1.5 MHz away from the desired signal. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 5.

	The test setup is the same as shown in Figure 3. The desired signal is provided by a vector signal generator playing back an appropriate arbitrary waveform consisting of properly formatted Tel M frames of data modulated appropriately. The interferer, programmed on a signal generator, is 1.5 MHz from the desired signal and will have 100% AM modulation at an 8 kHz rate (using sinusoidal modulation). Note that the other signal generator is not used in this test. The performance measurement will be based on measuring PER degradation as the power of the interferers is increased. After a specified number of packets, the number of received packets and packets with Reed Solomon errors are counted. From this, the PER is calculated. The calculation for PER is: PER(%) = [(packets sent – packets received) + packet errors] / (packets sent) * 100
Sample size:	5 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	This test is part of the receiver suite of tests. See test environment in section 9.4.1.
Test Setup:	This test is part of the receiver suite of tests. See test setup in section 9.4.1.
Test Procedure:	I. **Initial setup:** Setup equipment as shown in Figure 3 II. **Labview:** A. Open and run “DVT Main Menu.vi” file B. Login with User Name and Password C. Select “Run DVT” button D. When prompted, select “CTM_DVT_Rx_Suite.dvt” script. E. Select “Start” button F. When prompted, fill in “UUT Serial Number” field and “Bench Name” field appropriately. G. Select “OK” button. H. Confirm that the tests have started as expected.
Test Results:	All samples PASS all Rx AM rejection requirements.

Capability Analysis

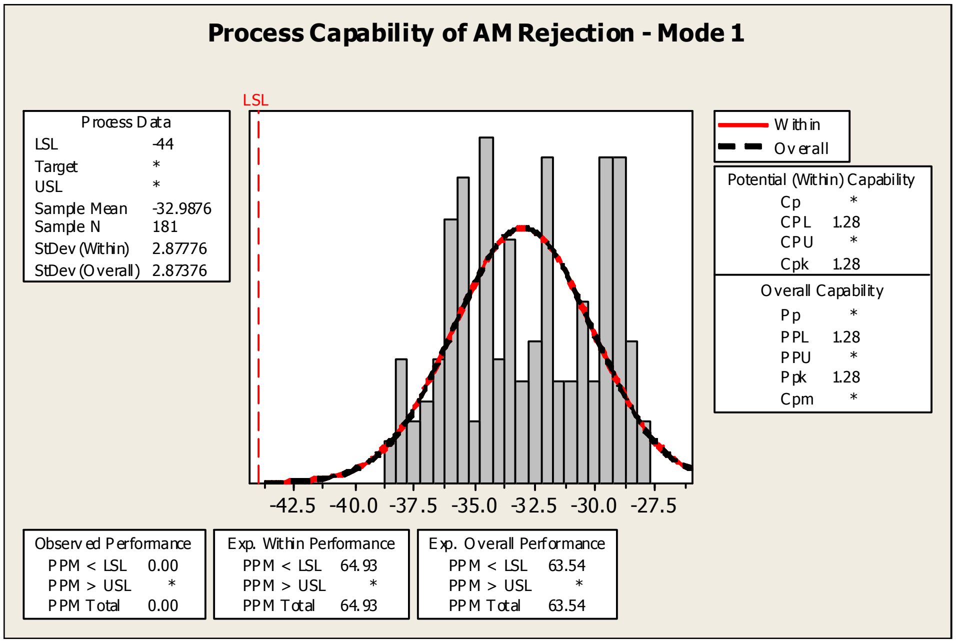


Figure 14 Process Capability of Mode 1 Rx AM Rejection

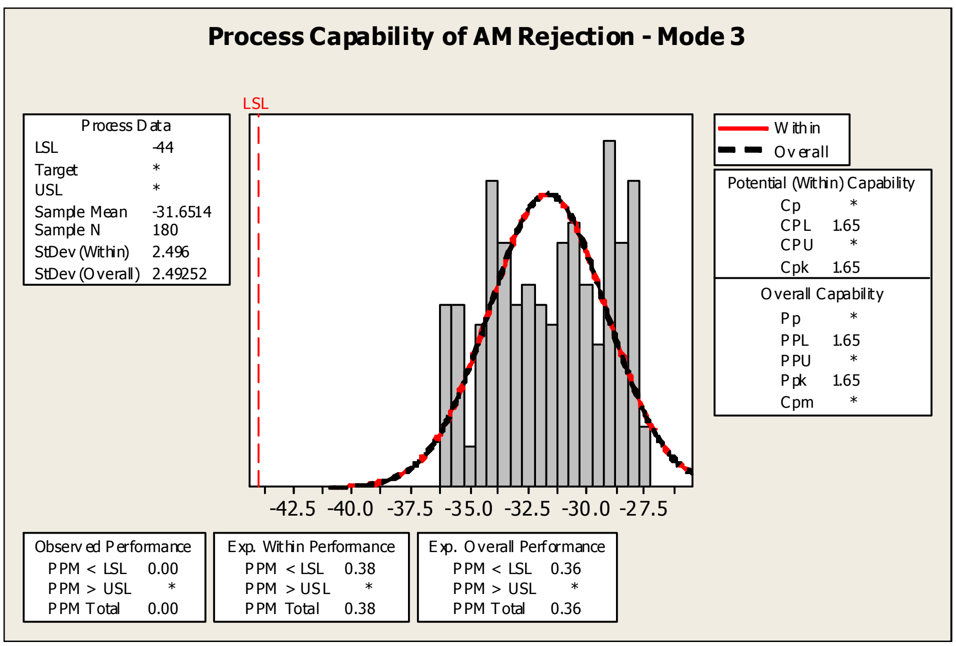


Figure 15 Process Capability of Mode 3 Rx AM Rejection

- Mode 1 Rx AM rejection results, Figure 14, show higher than 99%/99% confidence/reliability in achieving a minimum rejection of -44 dBm.
- Mode 3 Rx AM rejection results, Figure 15, show higher than 99%/99% confidence/reliability in achieving a minimum rejection of -44 dBm.

Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

9.4.7 RF-7 : External Spurious Response Rejection (Single Tone, Unmodulated)

<table>
<tr><td>Requirements</td><td>EETD30 Tel-M External Spurious Response Rejection (Single Tone, Unmodulated)

Verifies:

EE175 External spurious response rejection shall be greater than or equal to -42 dBm for CW interferers ranging from 500 kHz to 3 GHz for all modes with the following exceptions:

For Mode 1: External spurious response rejection shall be ≥ -52 dBm for 250 kHz to 350 kHz offset, ≥ -50.0 dBm for 350 kHz to 450 kHz offset, ≥ -49.5 dBm for 450 kHz to 550 kHz offset, ≥ -48 dBm for 550 kHz to 650 kHz offset, ≥ -46.5 dBm for 650 kHz to 750 kHz offset, -45.5 dBm for 750 kHz to 850 kHz offset, ≥ -45 dBm for 850 kHz to 950 kHz offset, ≥ -44 dBm for 950 kHz to 1050 kHz offset, ≥ -43.5 dBm for 1050 to 1150 kHz offset, ≥ -43 dBm for 1150 kHz to 1250 kHz offset, ≥ -42.5 dBm for 1250 to 1350 kHz offset.

For Mode 3: External spurious response rejection shall be ≥ -44 dBm for 750 kHz to 1050 kHz offset.</td></tr>
<tr><td>Test Description</td><td>This test is automated in DVT.

Rx attenuation = 17 dB.

The external spurious response rejection (single tone, unmodulated) verifies the ability of the receiver to prevent unwanted signals over a broad range of frequencies (500 kHz to 3 GHz) from causing degradation to the reception of the desired signal.

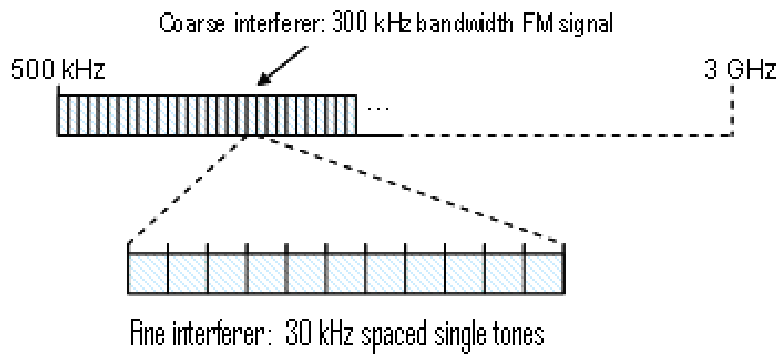


Figure 16. Diagram of interference strategy for single tone spurious harmonics test.

The desired signal is provided by a vector signal generator playing back an appropriate</td></tr>
</table>

	arbitrary waveform consisting of properly formatted Tel M frames of data modulated appropriately. An initial interferer, a 300 kHz bandwidth FM signal, is used to perform a coarse search of the broad frequency range (Figure 16). Each region that does not meet the more stringent coarse search specification must be investigated more thoroughly to fully understand the issue. To do this, a single tone interferer is swept every 30 kHz within the frequency band identified as problematic in the coarse search. Since this test is not expected to perform differently over different modes, the coarse search will be performed with the mode 3 to take advantage of the faster data rate. The faster data rate will enable the test to be run 3 times faster than in mode 1. The fine search will be performed in mode 1 and mode 3. Testing will be conducted under the conditions outlined in Table 6. The performance measurement will be based on measuring PER degradation as the power of the interferers is increased. After a specified number of packets, the number of received packets and packets with Reed Solomon errors are counted. From this, the PER is calculated. The calculation for PER is: PER(%) = [(packets sent – packets received) + packet errors] / (packets sent) * 100
Sample size:	4 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.

Test Environment:

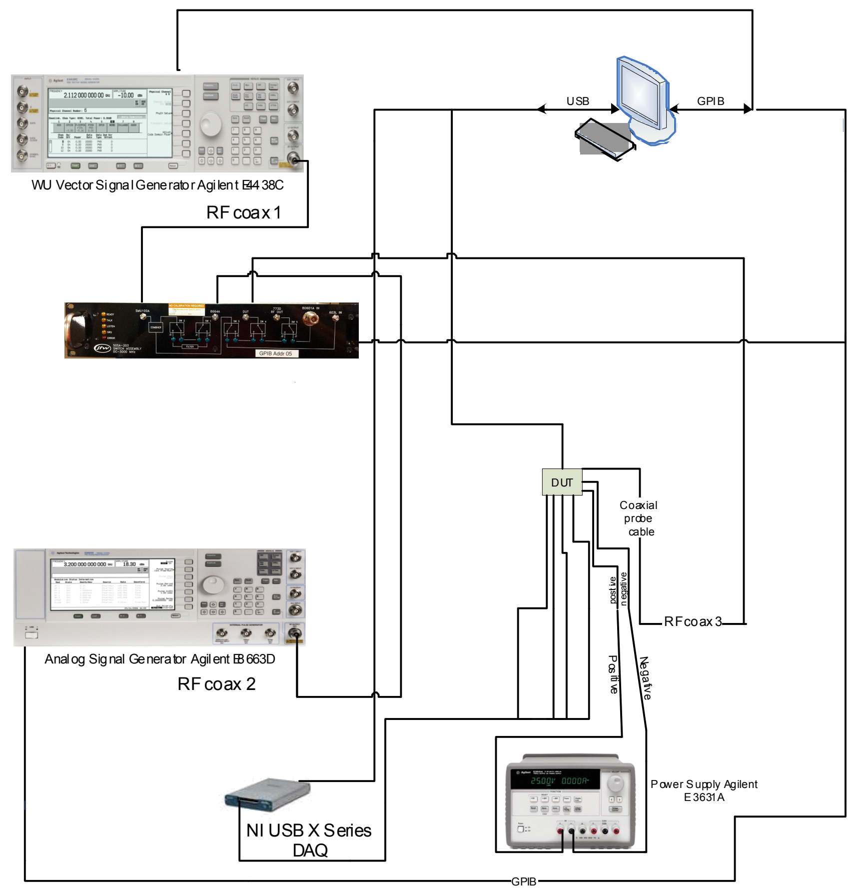


Figure 17 Test setup for Rx spurious response rejection testing

Test Setup: See test setup in section 9.4.1.

Test Procedure:

Sweeping with a Coarse Interferer

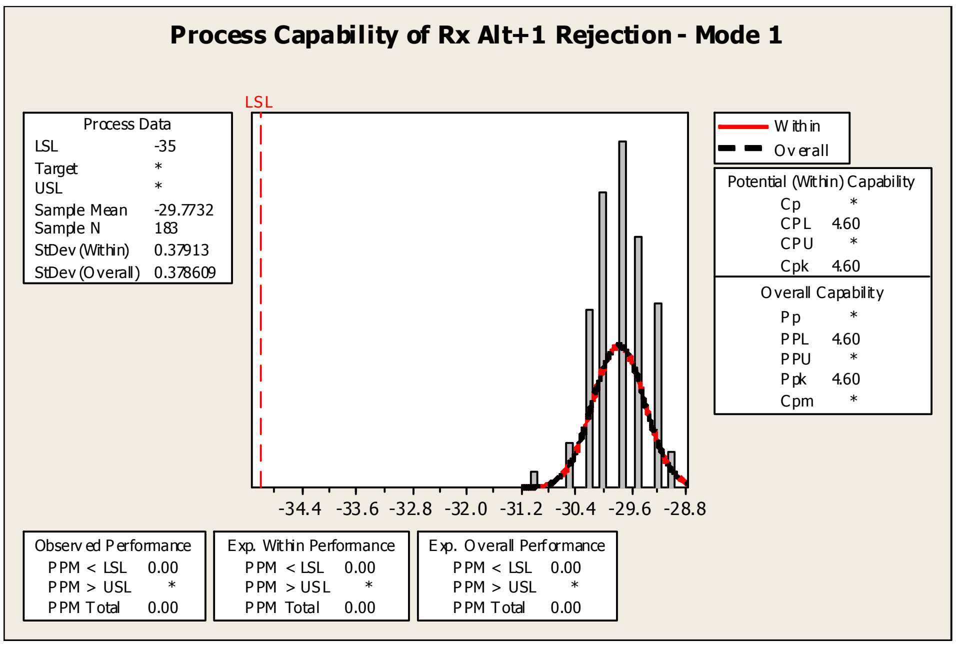
I. **Initial setup:** Setup equipment as shown in Figure 3

II. **Labview:**

A. Open and run “DVT Main Menu.vi” file
B. Login with User Name and Password
C. Select “Run DVT” button
D. When prompted, select “CTM_DVT_Rx_Spurious_Coarse_Suite.dvt” script.
E. Select “Start” button
F. When prompted, fill in “UUT Serial Number” field and “Bench Name” field appropriately.
G. Select “OK” button.
H. Confirm that the tests have started as expected.

Sweeping with a Fine interferer:

I. **Initial setup:** Setup equipment as shown in Figure 3

	II. **Labview:** A. Open and run "DVT Main Menu.vi" file B. Login with User Name and Password C. Select "Run DVT" button D. When prompted, select "CTM_DVT_Rx_Spurious_Fine_Suite.dvt" script. E. Select "Start" button F. When prompted, fill in "UUT Serial Number" field and "Bench Name" field appropriately. G. Select "OK" button. H. Confirm that the tests have started as expected.
Test Results:	All samples PASS all Rx Spurious rejection requirements for modes 1 and 3.
Capability Analysis	 Figure 18 Capability Analysis of Mode 1 Rx Alt+1 Rejection

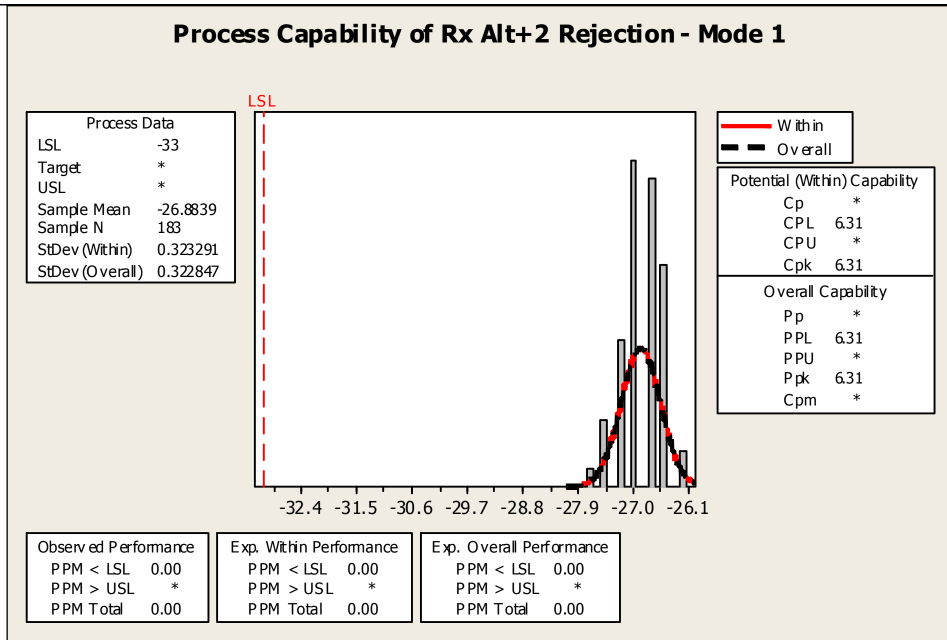


Figure 19 Capability Analysis of Mode 1 Rx Alt+2 Rejection

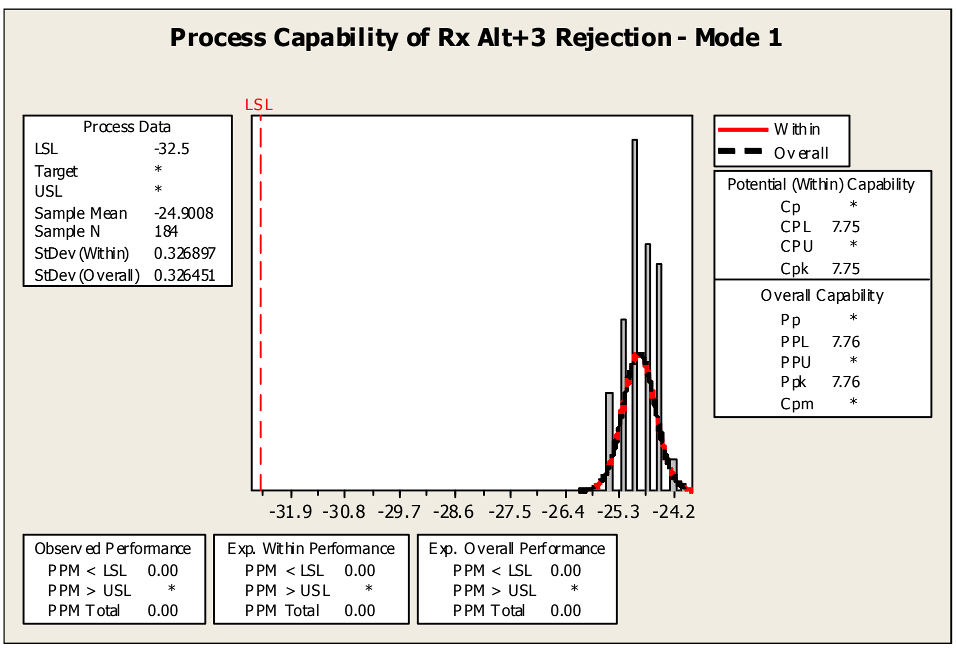


Figure 20 Capability Analysis of Mode 1 Rx Alt+3 Rejection

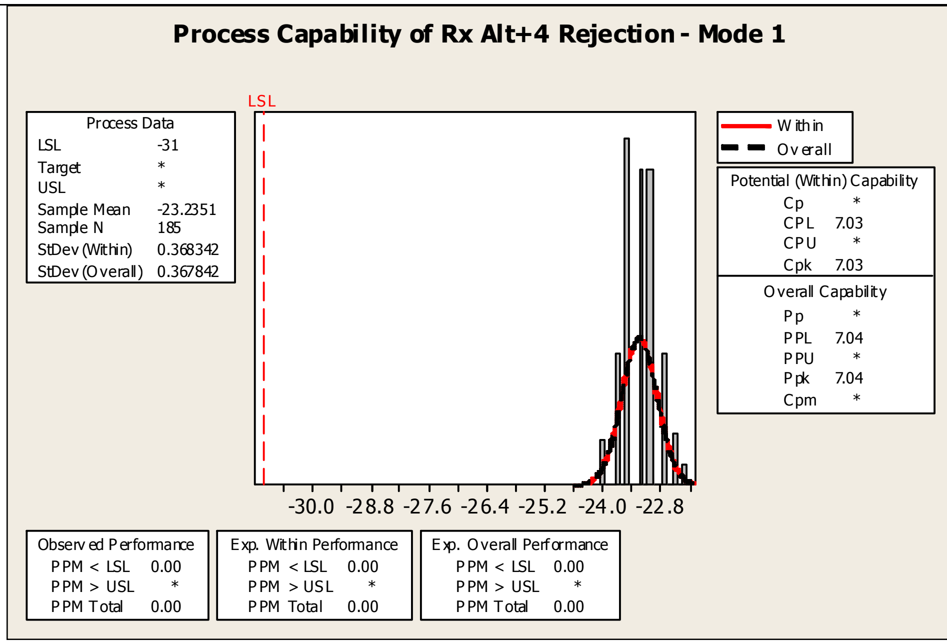


Figure 21 Capability Analysis of Mode 1 Rx Alt+4 Rejection

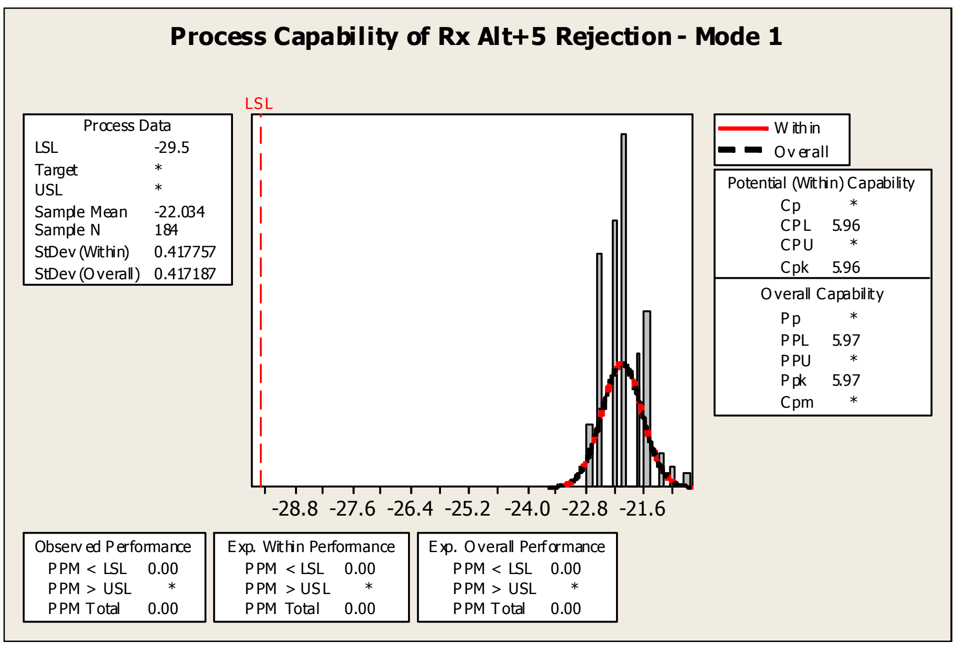


Figure 22 Capability Analysis of Mode 1 Rx Alt+5 Rejection

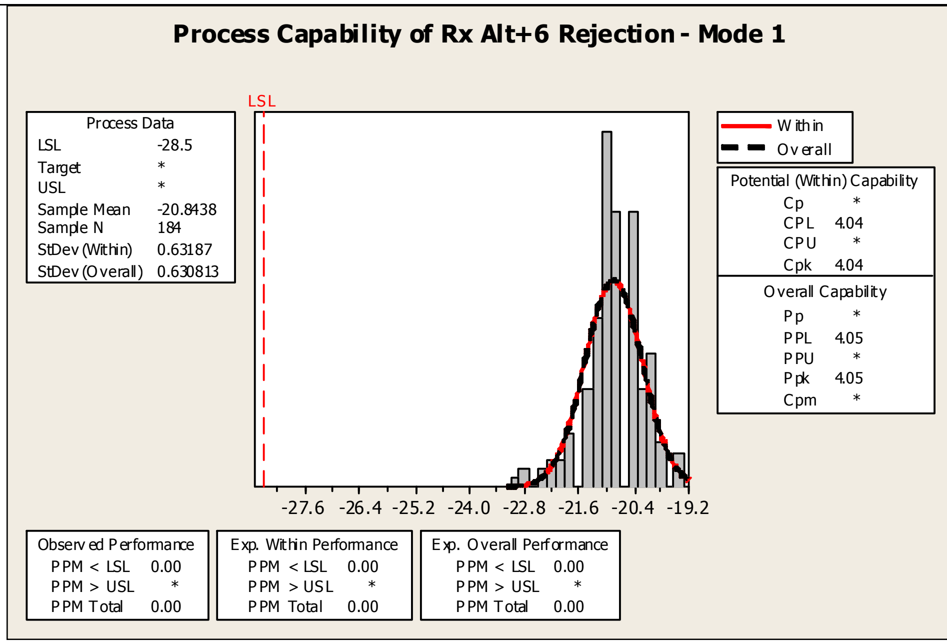


Figure 23 Capability Analysis of Mode 1 Rx Alt+6 Rejection

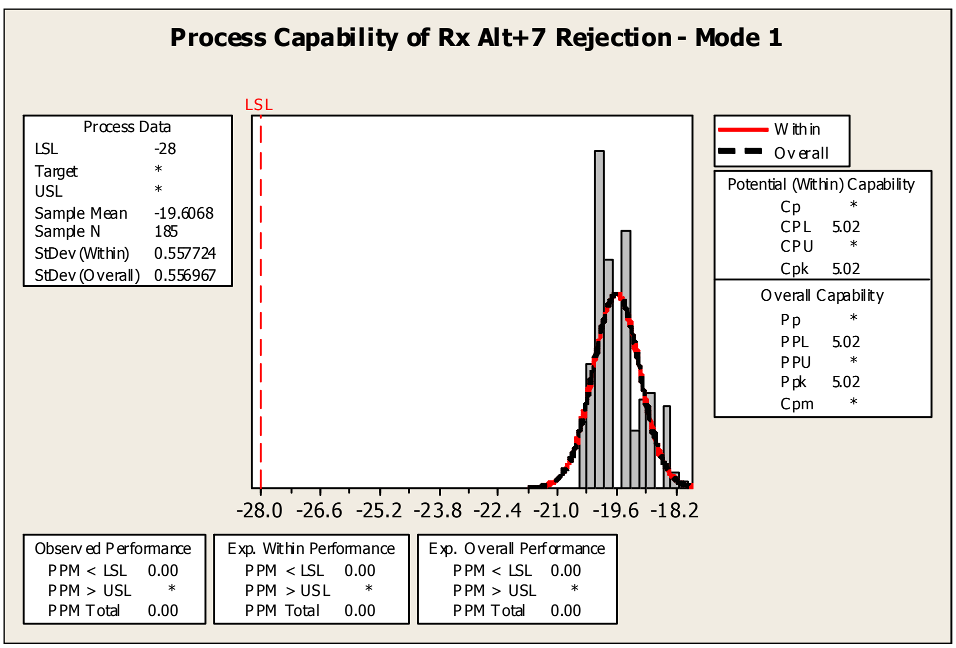


Figure 24 Capability Analysis of Mode 1 Rx Alt+7 Rejection

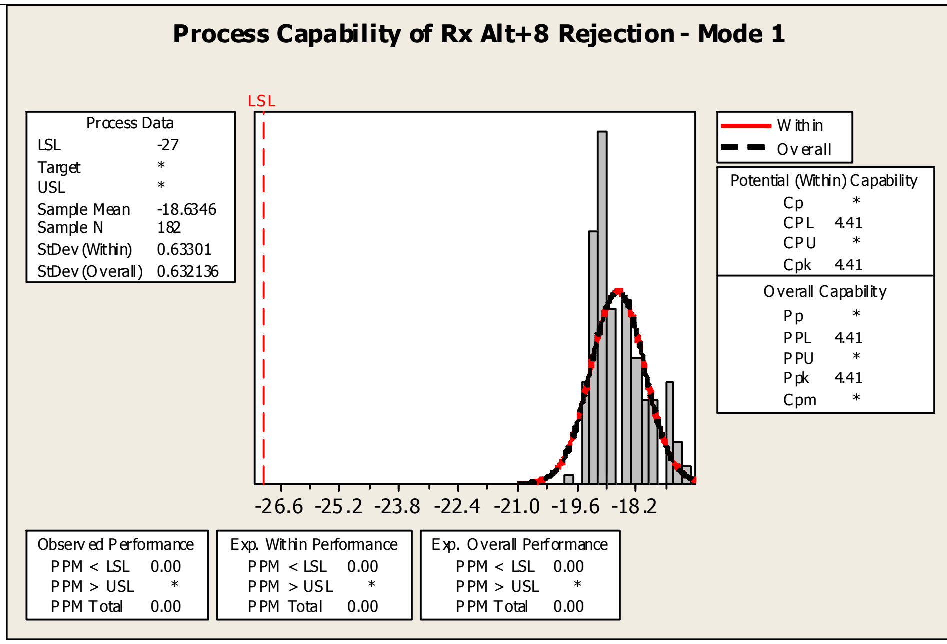


Figure 25 Capability Analysis of Mode 1 Rx Alt+8 Rejection

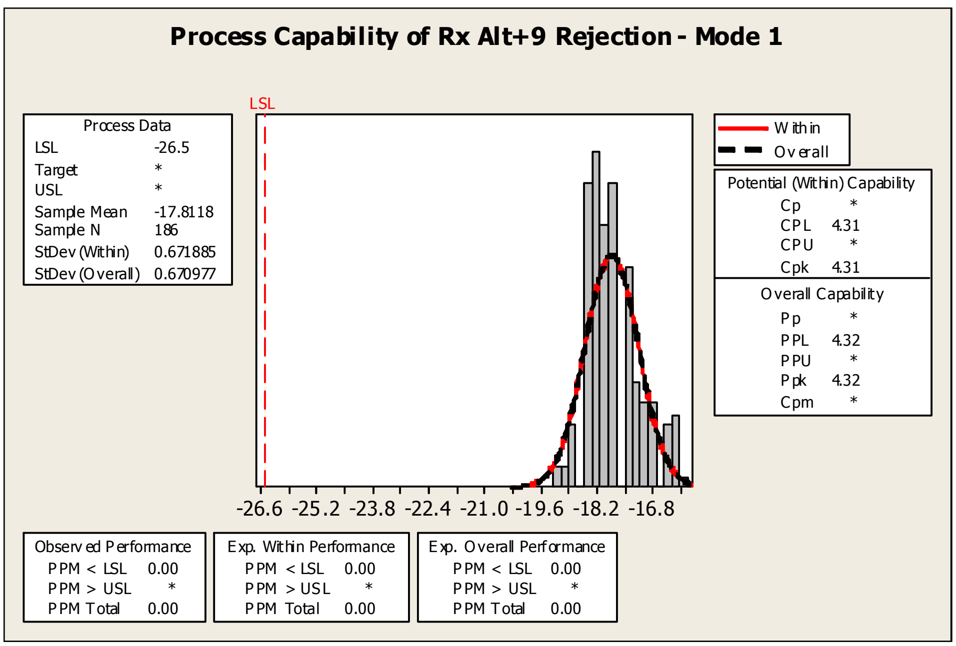


Figure 26 Capability Analysis of Mode 1 Rx Alt+9 Rejection

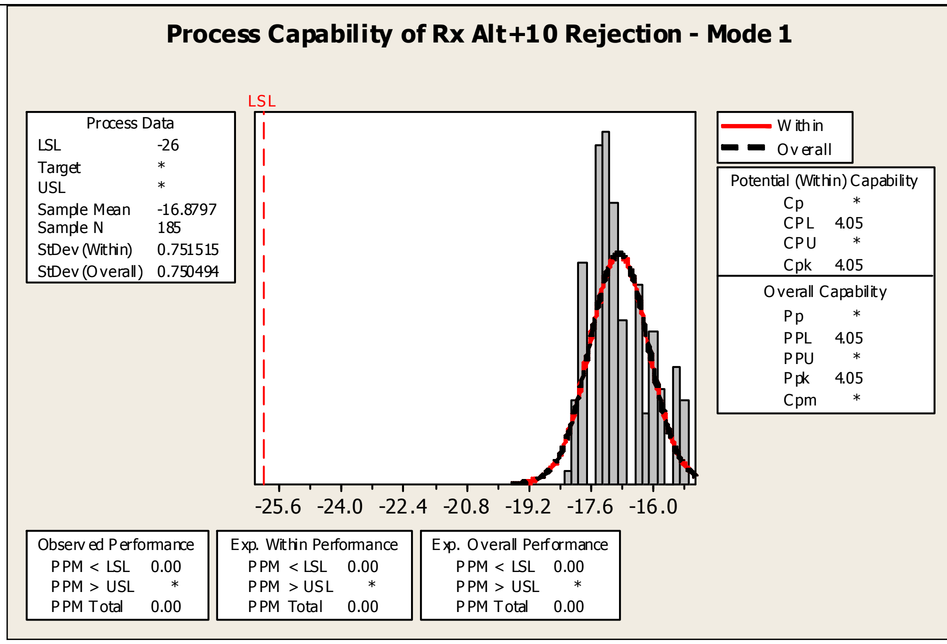


Figure 27 Capability Analysis of Mode 1 Rx Alt+10 Rejection

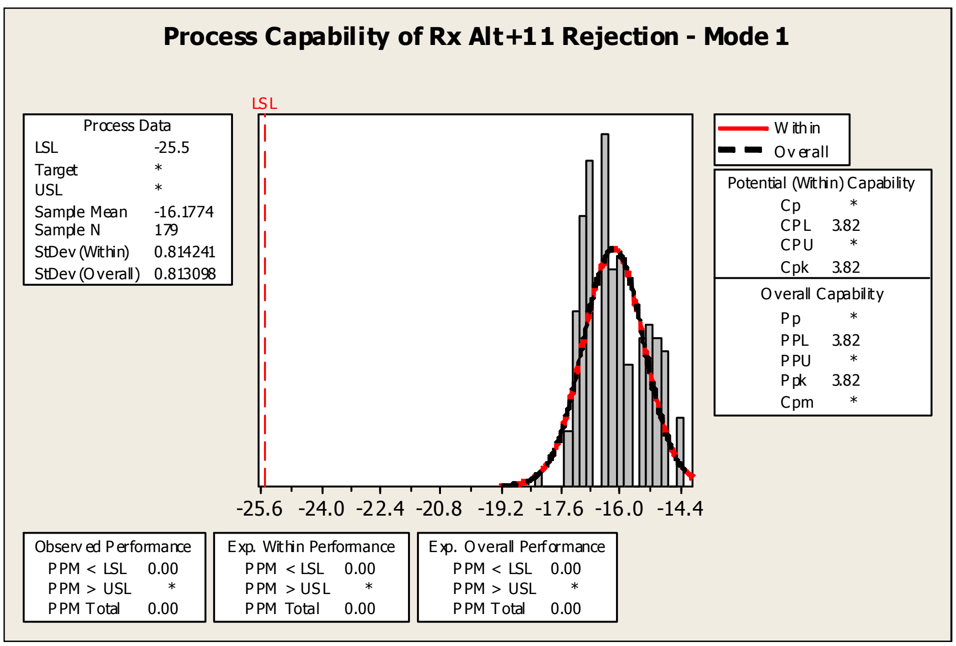


Figure 28 Capability Analysis of Mode 1 Rx Alt+11 Rejection

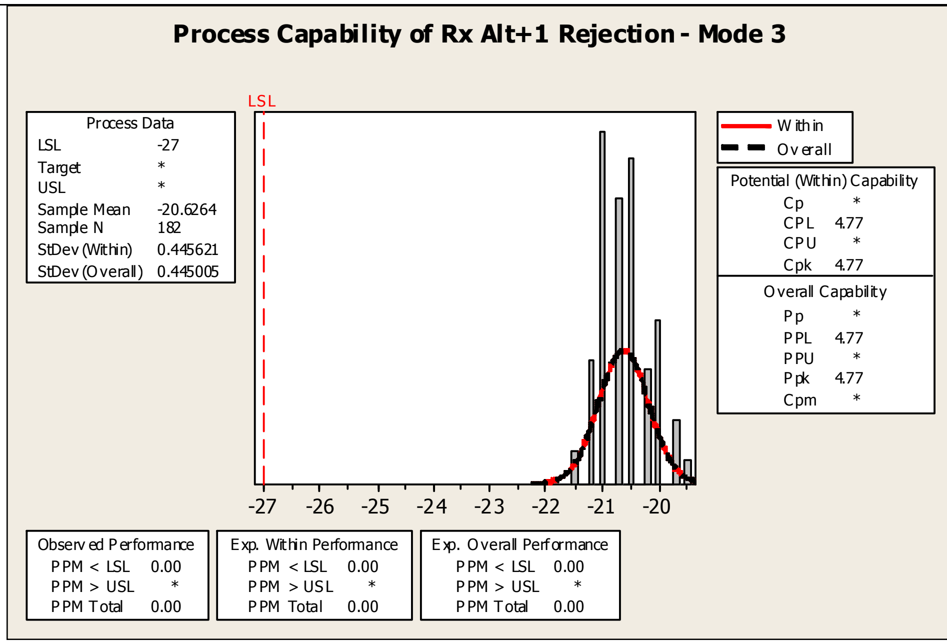


Figure 29 Capability Analysis of Mode 3 Rx Alt+1 Rejection

All other spurs identified for mode 1 (66 spurs), stopped interferer testing when the interferer power level reached -11 dBm due to test limitations. Test to failure was not achievable due to the lack of ability of the test station to create an interfering signal large enough to induce failure. At this point, the test stopped due to sufficient margin (14 dB minimum, which is a 25x factor of margin). Due to all data points reaching this point, a Cpk could not be calculated due to the lack of variation of the data set. Treating this data as attribute data however provides adequate sample size to show 90% confidence/90% reliability of meeting the minimum requirement with margin.

All other spurs identified for mode 3 (69 spurs), stopped interferer testing when the interferer power level reached -11 dBm due to test limitations. Test to failure was not achievable due to the lack of ability of the test station to create an interfering signal large enough to induce failure. At this point, the test stopped due to sufficient margin (14 dB minimum, which is a 25x factor of margin). Due to all data points reaching this point, a Cpk could not be calculated due to the lack of variation of the data set. Treating this data as attribute data however provides adequate sample size to show 90% confidence/90% reliability of meeting the minimum requirement with margin.

Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

Table 6: Table of Receiver Spurious Response Rejection Tests

	Mode 3, Spurious Coarse		Mode 1, Spurious Fine		Mode 3, Spurious Fine	
DUT	Temperature	Battery	Temperature	Battery	Temperature	Battery

channel	(C)	voltage (V)	(C)	voltage (V)	(C)	voltage (V)
1 (402.15 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2
2 (402.45 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2
3 (402.75 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2
4 (403.05 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2
5 (403.35 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2
6 (403.65 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2
7 (403.95 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2
8 (404.25 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2
9 (404.55 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2
10 (404.85 MHz)	Ambient	3.2	Ambient	3.2	Ambient	3.2

9.4.8 RF-8: RX RSSI LINEARITY AND DIFFERENTIATION

Requirements	EETD31 Tel-M Rx RSSI Linearity and differentiation Verifies: EE178 The Tel-M Receiver shall have a minimum monotonic RSSI range of -109dBm to -55dBm for Clear Channel Assessment (CCA) (i.e. no Rx attenuation present). EE179 The Tel-M Receiver shall be able to differentiate -109dBm and -106 dBm across all MICS channels for Clear Channel Assessment (CCA) (i.e. no Rx attenuation present).
Test Description	This test is automated in characterization. The RSSI linearity is the ability of the RSSI ADC to report back values in a monotonic fashion from -106 dBm to -55 dBm. The RSSI differentiation is the ability of the RSSI circuitry to distinguish between a signal at -109 dBm on any channel vs. a signal on any of the other ten channels whose power level is -106 dBm. The LSB of the ADC value should be greater than zero in all cases.

	The test setup is the same as shown in section 9.4.1. The desired signal is provided by a vector signal generator supplying a CW tone 20 kHz offset from the desired channel frequency (e.g. 402.15 MHz + 20 kHz for channel 1). All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 5. The performance measurement will be based on the post processing of ADC values at the varying input power levels across channels.
Sample size:	5 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	This test is part of the receiver suite of tests. See test environment in section 9.4.1.
Test Setup:	This test is part of the receiver suite of tests. See test setup in section 9.4.1.
Test Procedure:	I. **Initial setup:** Setup equipment as shown in Figure 3 II. **Labview:** A. Open and run “DVT Main Menu.vi” file B. Login with User Name and Password C. Select “Run DVT” button D. When prompted, select “CTM_DVT_Rx_Suite.dvt” script. E. Select “Start” button F. When prompted, fill in “UUT Serial Number” field and “Bench Name” field appropriately. G. Select “OK” button. H. Confirm that the tests have started as expected.
Test Results:	All test samples PASS RSSI range requirements as well as ability to differentiate between 3 dB steps of incident signal power.
Capability Analysis	The following capability plots illustrate the highest and lowest signal levels that can be differentiated from the next signal level within 2 dB.

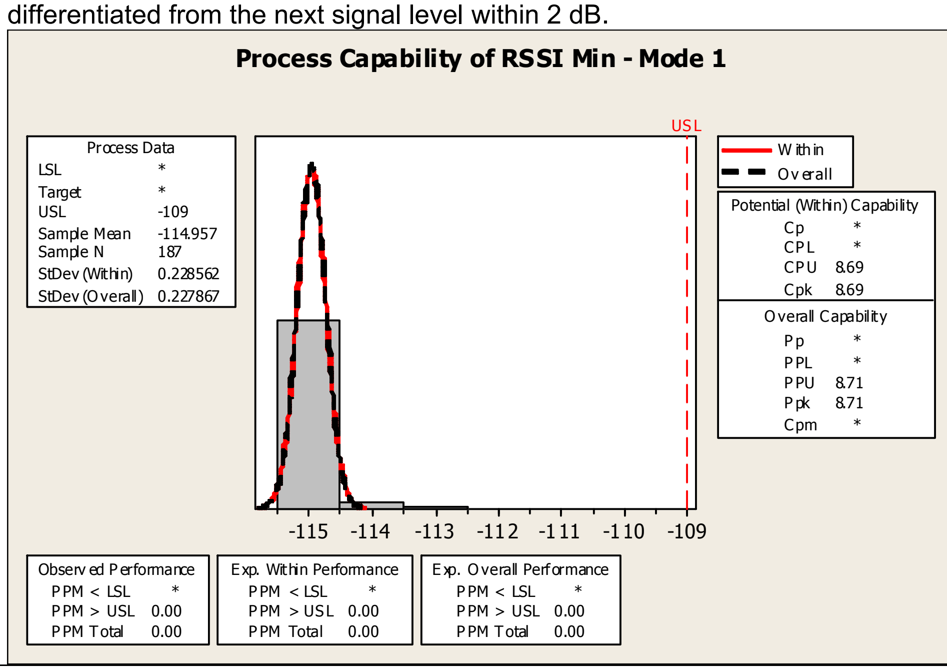


Figure 30 Capability Analysis of Mode 1 RSSI Lower Level Range

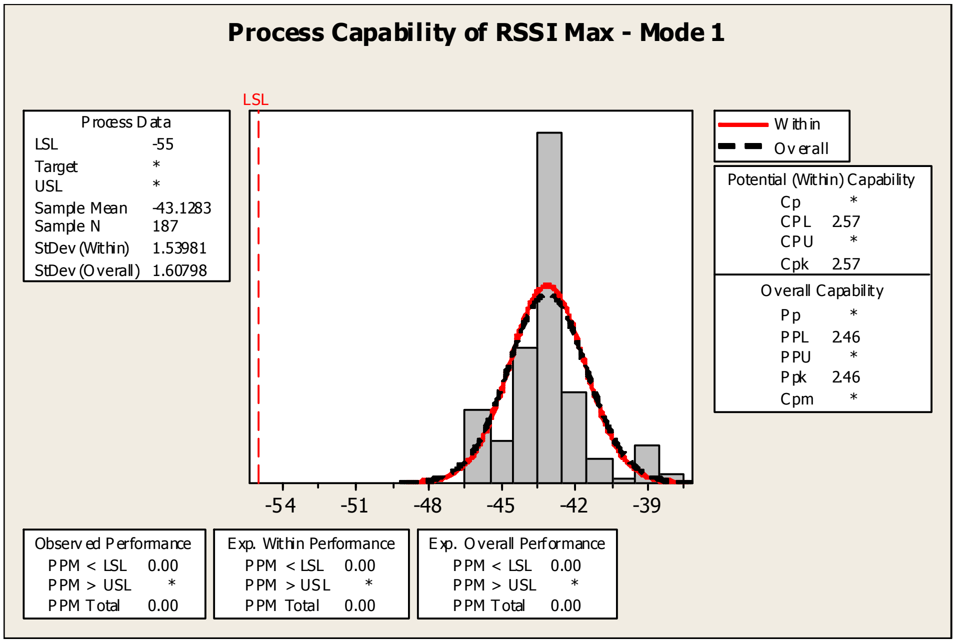


Figure 31 Capability Analysis of Mode 1 RSSI Upper Level Range

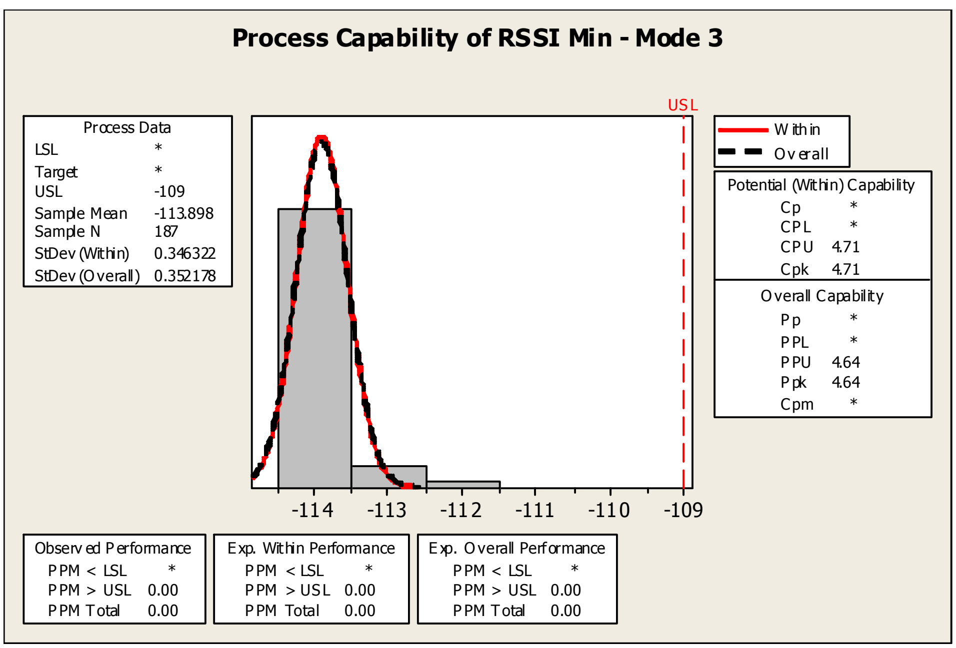
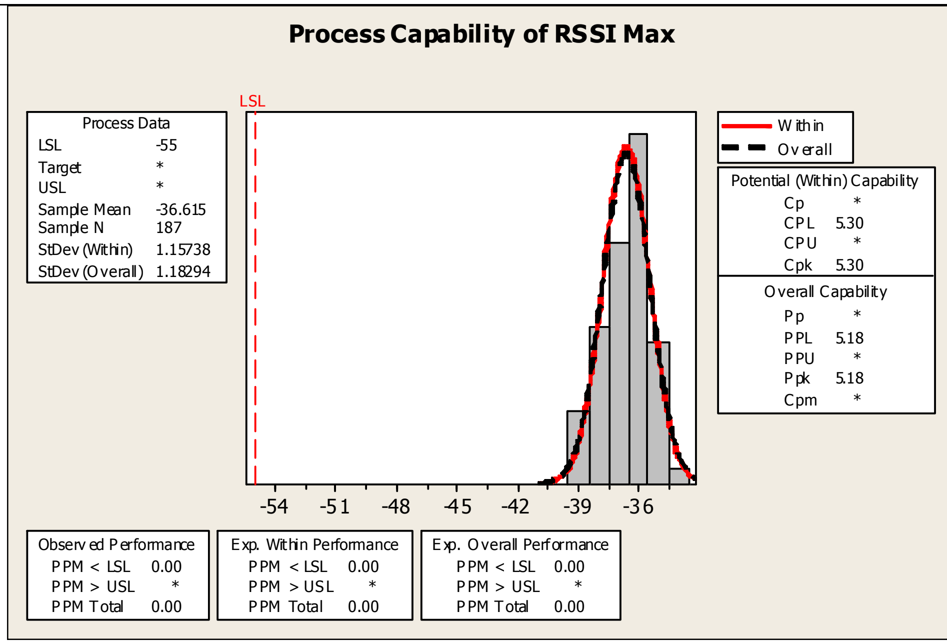
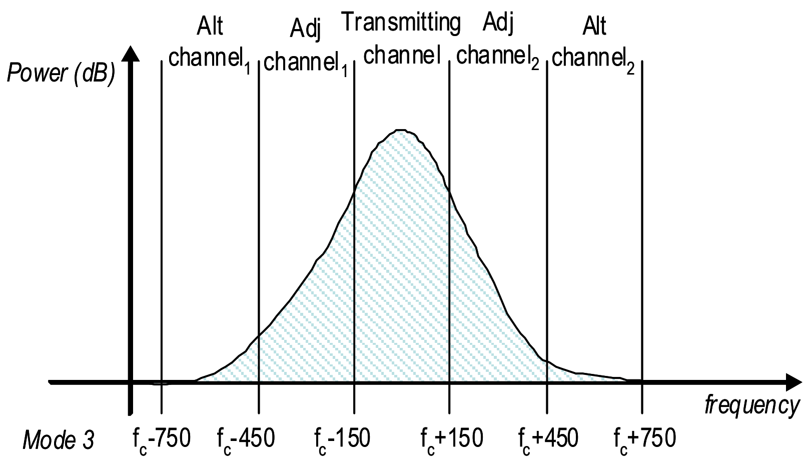


Figure 32 Capability Analysis of Mode 3 RSSI Lower Level Range

	 Figure 33 Capability Analysis of Mode 3 RSSI Upper Level Range • Mode 1 Rx RSSI Min results, Figure 30, show higher than 99%/99% confidence/reliability in achieving the ability of differentiating a minimum signal level of -109 dBm. • Mode 1 Rx RSSI Min results, Figure 31, show higher than 99%/99% confidence/reliability in achieving the ability of differentiating a maximum signal level of -55 dBm. • Mode 3 Rx RSSI Min results, Figure 32, show higher than 99%/99% confidence/reliability in achieving the ability of differentiating a minimum signal level of -109 dBm. • Mode 3 Rx RSSI Min results, Figure 33, show higher than 99%/99% confidence/reliability in achieving the ability of differentiating a maximum signal level of -55 dBm.
Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

9.4.9 RF-9 Transmit Power, Adjacent Channel Power Ratio, and Alternate Channel Power Ratio

Requirements	EETD32 Tel-M Transmitter Output Power, Adjacent Channel Power Ratio, and Alternate Channel Power Ratio Verifies: EE158 The Tel-M Transmitter shall have a minimum conducted output power into a 50 Ohm

	load of -18.75 dBm and a maximum of -15.75dBm. EE163 The Tel-M Transmitter shall have minimum ACPR -34dBc, measured at fc+/-150kHz to fc+/-450kHz for mode 3, and measured at fc+/-50kHz to fc+/-150kHz for mode 1. EE164 The Tel-M Transmitter shall have minimum AltCPR -40dBc, measured at fc+/-450kHz to fc+/-750kHz for mode 3, and measured at fc+/-150kHz to fc+/-250kHz for mode 1.
Test Description	This test is automated in DVT.  Figure 34. Mode 3 Transmit Channel Illustration This transmitter test checks the power of the transmitting channel, adjacent channels and alternate channels with respect to the specification. The transmitter power output test measures the average power output by the transmitter within the transmitting channel. The adjacent channel power ratio (ACPR) is defined as the ratio of the integrated power in the transmitting channel to the maximum of the integrated power in either of the two channels adjacent to the transmitting channel. AltCPR is similarly measured for the Alt channels as indicated in Figure 34. To execute these tests, the DUT is programmed to transmit a continuous frame of data for the appropriate mode and channel. The signal analyzer is used to measure output power, adjacent channel power, and alternate channel power. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 7.
Sample size:	6 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	

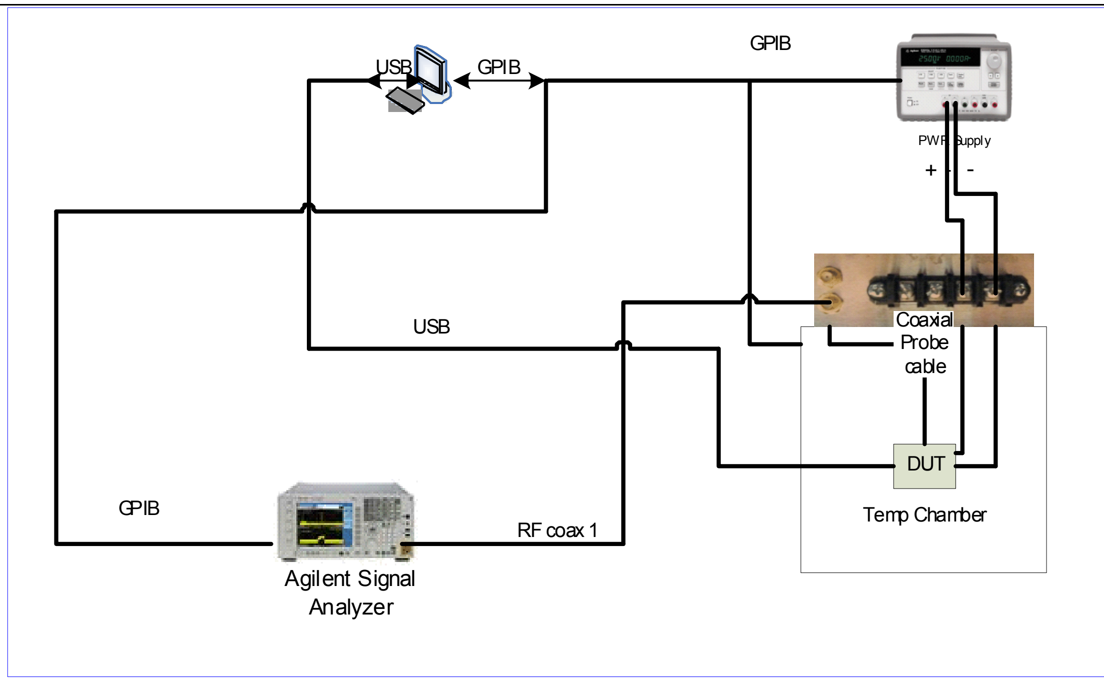


Figure 35 Test setup for Tx testing

Test Setup:	**Cable connections and initial calibrations:** 1. Measure the signal level at the MXA when sourcing with a known signal source (replace DUT for calibration). Record this loss factor in the DUT .ini file for software use. This losses will compensate for all RF losses due to routing. 2. Use a network analyzer to measure the same path as step 1 for a frequency range of 9 kHz to 4.06 GHz. Save the results off to “Ch5_gamma_0.00_phase_0.00_s21.csv”. This file is used for out-of-band emissions loss compensation. 3. Place the DUT inside the fixture. 4. Place the fixture inside temperature chamber 5. Connect the measured cable between the DUT and RF Combiner (RF coax 1). 6. Connect the power supply to the DUT fixture. 7. Connect GPIB and USB connections to interface with testing software
Test Procedure:	I. **Initial setup:** Setup equipment as shown in Figure 35. II. **Labview:** A. Open and run “DVT Main Menu.vi” file B. Login with User Name and Password C. Select “Run DVT” button D. When prompted, select “CTM_DVT_Tx_Suite.dvt” script. E. Select “Start” button F. When prompted, fill in “UUT Serial Number” field and “Bench Name” field appropriately. G. Select “OK” button. H. Confirm that the tests have started as expected.
Test Results:	All test samples PASS Tx power requirements for both modes 1 and 3. All test samples PASS Tx adjacent channel power ratio requirements for both modes 1 and 3. All test samples PASS Tx alternate channel power ratio requirements for both modes 1 and 3.

Capability Analysis

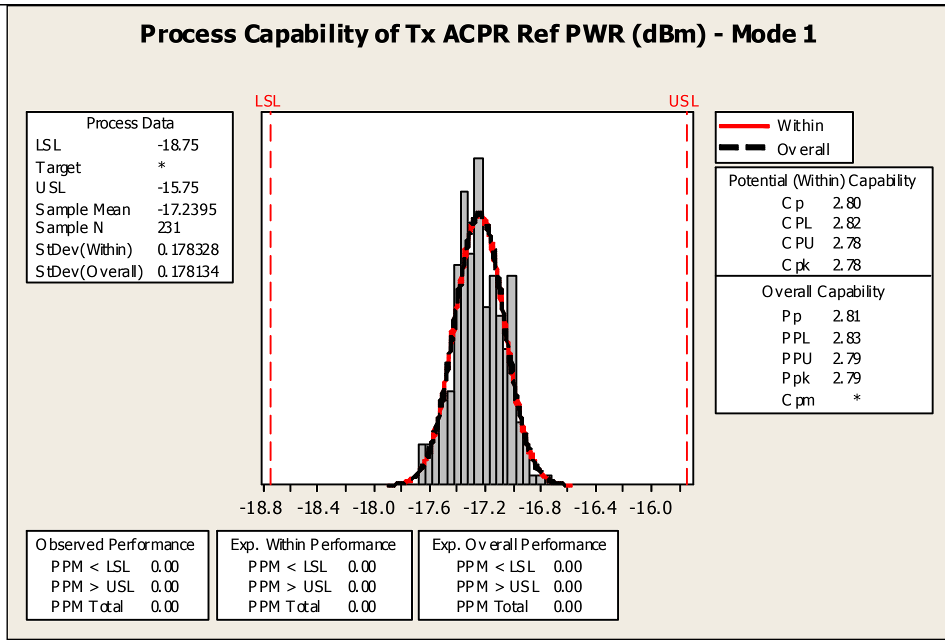


Figure 36 Capability Analysis of Mode 1 Tx Power

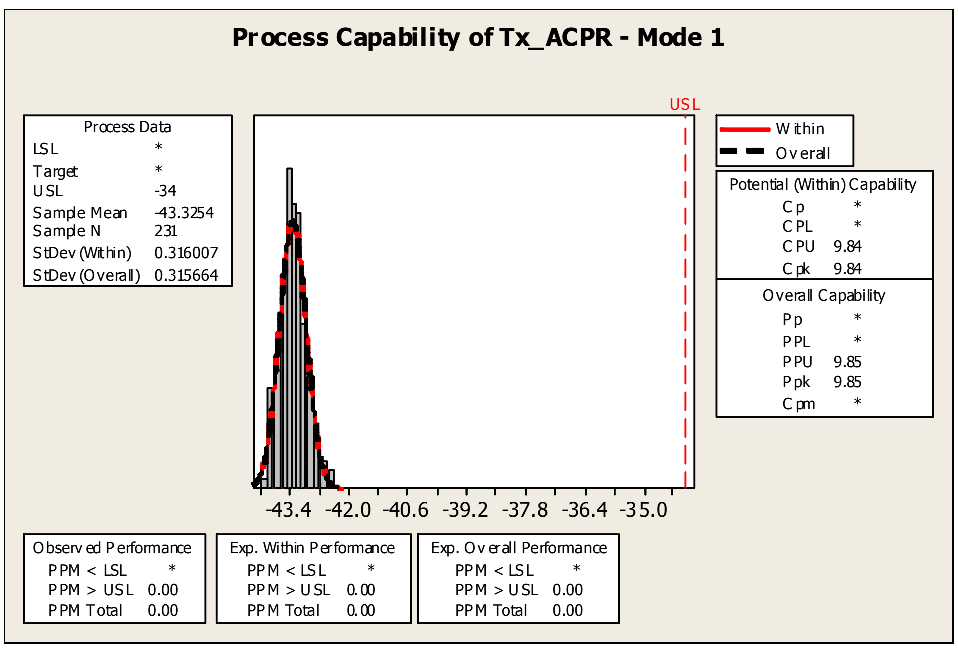


Figure 37 Capability Analysis of Mode 1 Tx ACPR

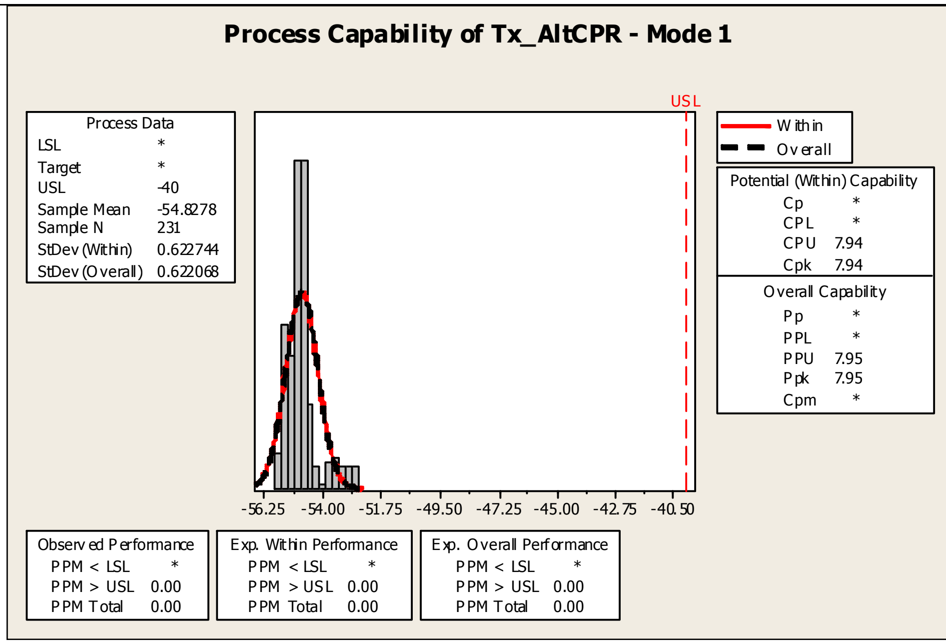


Figure 38 Capability Analysis of Mode 1 Tx AltCPR

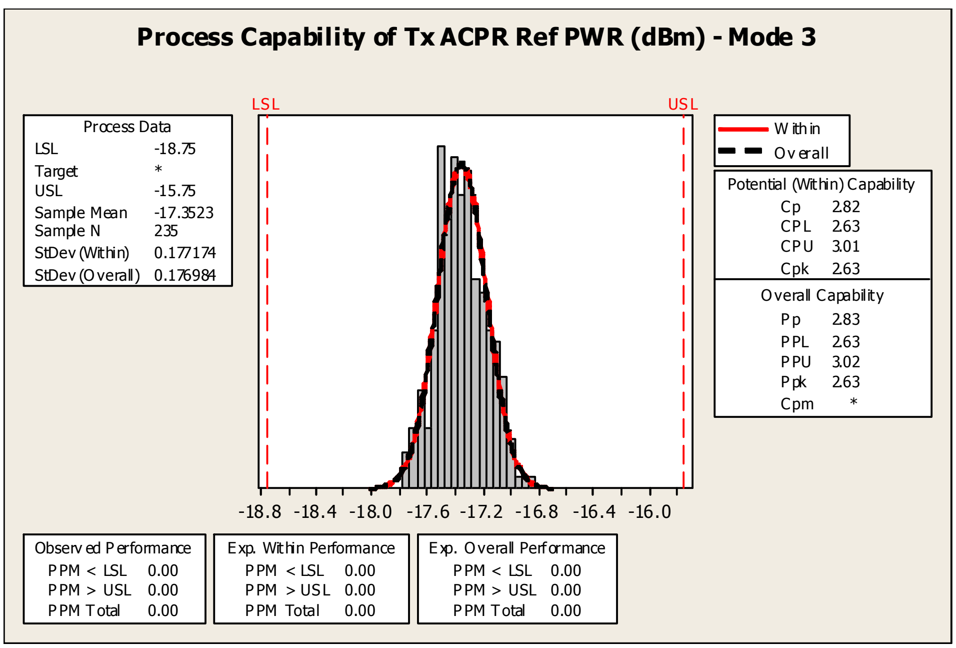


Figure 39 Capability Analysis of Mode 3 Tx Power

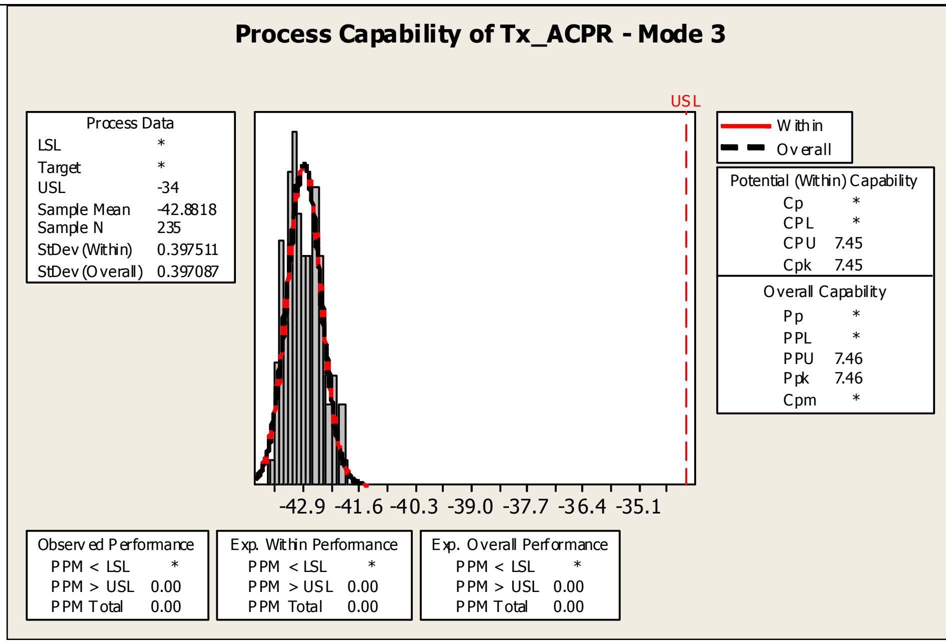


Figure 40 Capability Analysis of Mode 3 Tx ACPR

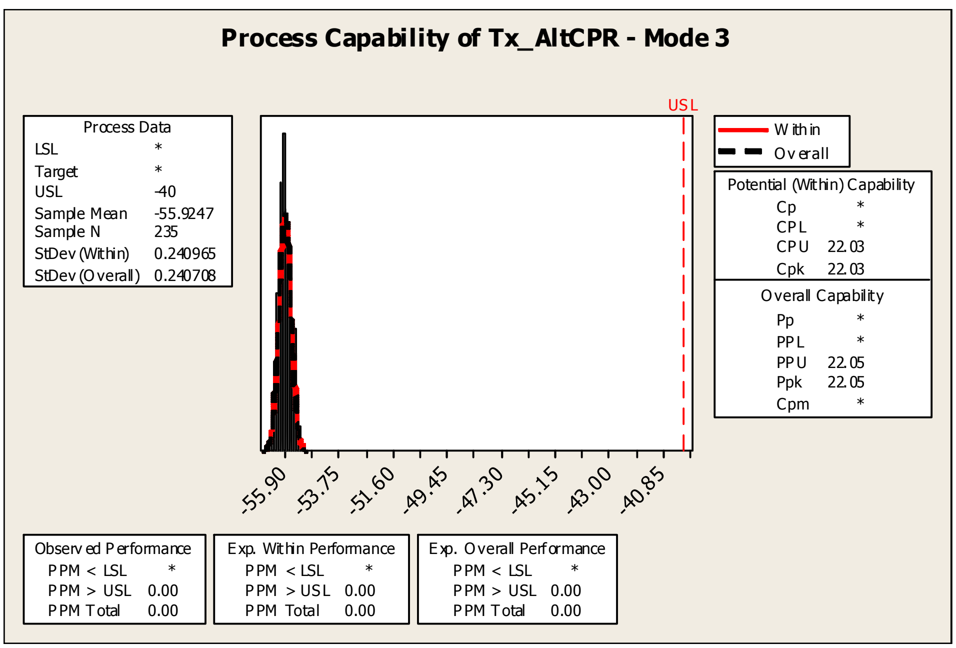


Figure 41 Capability Analysis of Mode 3 Tx AltCPR

- Mode 1 Tx power results, Figure 36, show higher than 99%/99% confidence/reliability in achieving the ability to transmit at a power level of -18.75 dBm minimum to -15.75 dBm maximum.
- Mode 1 Tx adjacent channel power ratio (ACPR) results, Figure 37, show higher than 99%/99% confidence/reliability in achieving the ability to maintain ACPR performance of

	-34 dB maximum. • Mode 1 Tx alternate channel power ratio (AltCPR) results, Figure 38, show higher than 99%/99% confidence/reliability in achieving the ability to maintain AltCPR performance of -40 dB maximum. • Mode 3 Tx power results, Figure 39, show higher than 99%/99% confidence/reliability in achieving the ability to transmit at a power level of -18.75 dBm minimum to -15.75 dBm maximum. • Mode 3 Tx adjacent channel power ratio (ACPR) results, Figure 40, show higher than 99%/99% confidence/reliability in achieving the ability to maintain ACPR performance of -34 dB maximum. • Mode 3 Tx alternate channel power ratio (AltCPR) results, Figure 41, show higher than 99%/99% confidence/reliability in achieving the ability to maintain AltCPR performance of -40 dB maximum.
Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

Table 7: Table of Transmitter Tests

	Mode 1		*Mode 3*	
DUT channel	**Temperature (C)**	**Battery voltage (V)**	**Temperature (C)**	**Battery voltage (V)**
1 (402.15 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	55	2.2
	44	3.2	55	3.2
2 (402.45 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	55	2.2
	44	3.2	55	3.2
3 (402.75 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	55	2.2
	44	3.2	55	3.2
4 (403.05 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	55	2.2
	44	3.2	55	3.2

5 (403.35 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	55	2.2
	44	3.2	55	3.2
6 (403.65 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
7 (403.95 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
8 (404.25 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
9 (404.55 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2
10 (404.85 MHz)	10	2.2	10	2.2
	10	3.2	10	3.2
	44	2.2	44	2.2
	44	3.2	44	3.2

9.4.10 RF-10 Transmitter Error Vector Magnitude & Transmitter Frequency Stability

Requirements	EETD33 Tel-M Transmitter Error Vector Magnitude & Transmitter Frequency Stability Verifies: EE156 The Tel-M RF synthesizer shall tune in increments of 300 kHz from 402.15 MHz to 404.85 MHz EE166 The Tel-M Transmitter in mode 1 and 3 shall have EVM ≤ 8.4%

	EE157 The Tel-M RF synthesizer shall have a minimum frequency stability of 12ppm.
Test Description	This test is automated in DVT. This transmitter test checks the error vector magnitude (EVM) of the transmitting signal by demodulating the DUT RF output and comparing the result to an ideal signal. From the demodulation, the frequency error can be measured. This frequency error can then be verified to meet the frequency requirements outlined in EE157. To execute these tests, the DUT is programmed to transmit a continuous frame of data for the appropriate mode and channel. The signal analyzer is used to demodulate the transmissions from the DUT and also perform the frequency accuracy measurements. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 7.
Sample size:	6 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	This test is part of the transmitter suite of tests. See test environment in section 9.4.9.
Test Setup:	This test is part of the transmitter suite of tests. See test setup in section 9.4.9.
Test Procedure:	I. **Initial setup:** Setup equipment as shown in Figure 35. II. **Labview:** A. Open and run “DVT Main Menu.vi” file B. Login with User Name and Password C. Select “Run DVT” button D. When prompted, select “CTM_DVT_Tx_Suite.dvt” script. E. Select “Start” button F. When prompted, fill in “UUT Serial Number” field and “Bench Name” field appropriately. G. Select “OK” button. H. Confirm that the tests have started as expected.
Test Results:	All data samples PASS minimum EVM requirements for both mode 1 and mode 3 operation. All data samples PASS synthesizer frequency stability requirements for both mode 1 and mode 3 operation. All data samples PASS the synthesizer tuning resolution requirement, which was demonstrated in the synthesizer frequency stability testing.

Capability Analysis

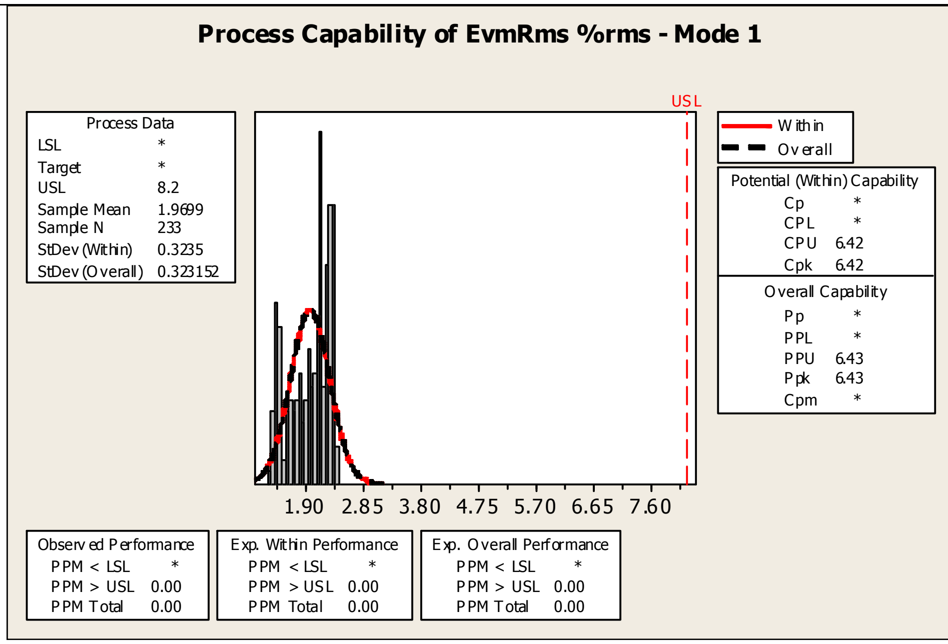


Figure 42 Capability Analysis of Mode 1 Tx EVM

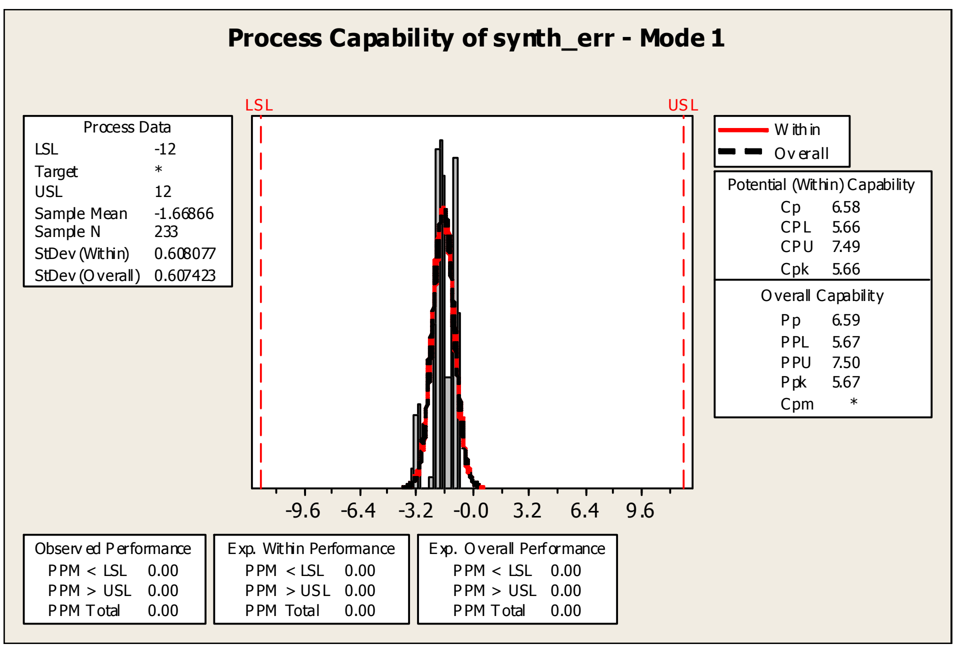


Figure 43 Capability Analysis of Mode 1 Synthesizer Frequency Stability

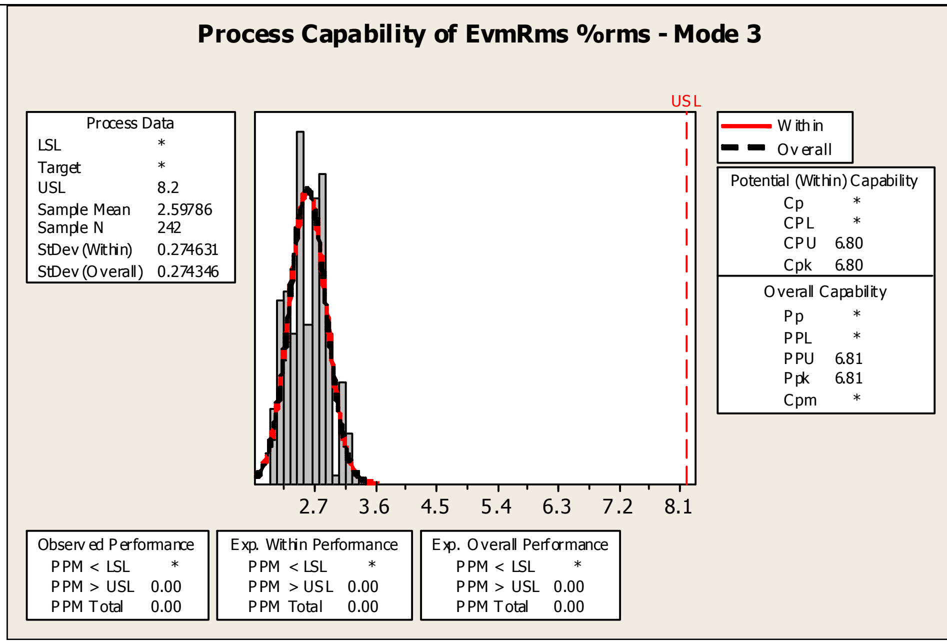


Figure 44 Capability Analysis of Mode 3 Tx EVM

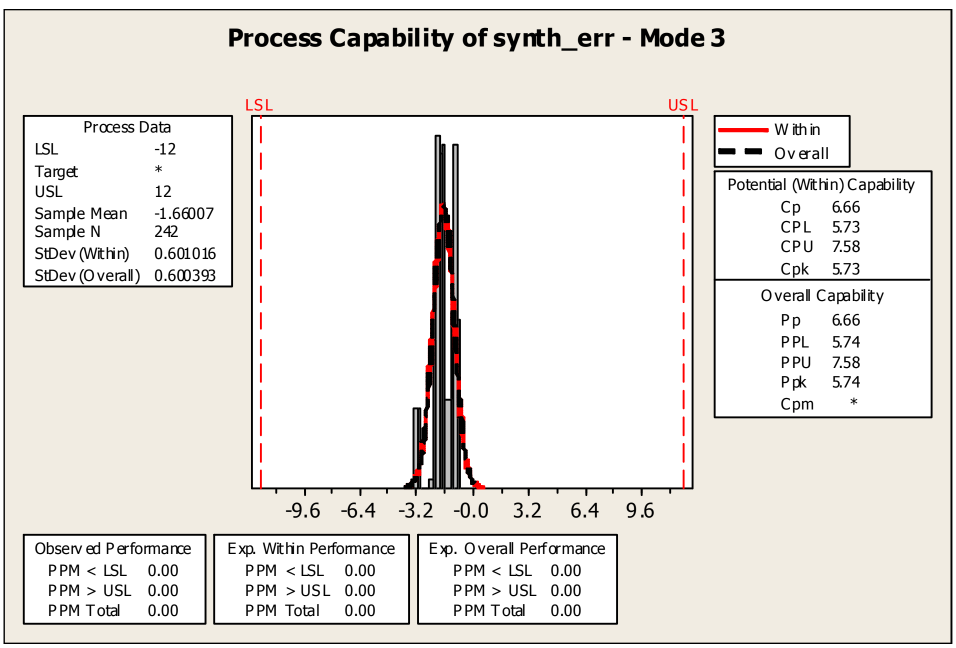


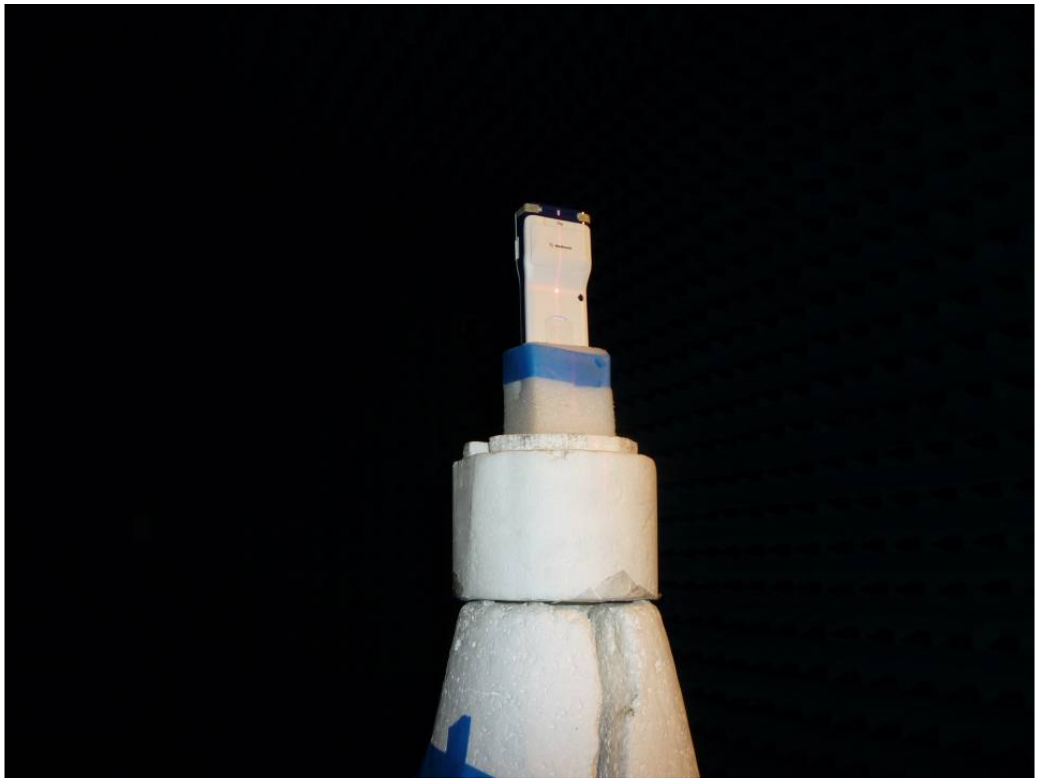
Figure 45 Capability Analysis of Mode 1 Synthesizer Frequency Stability

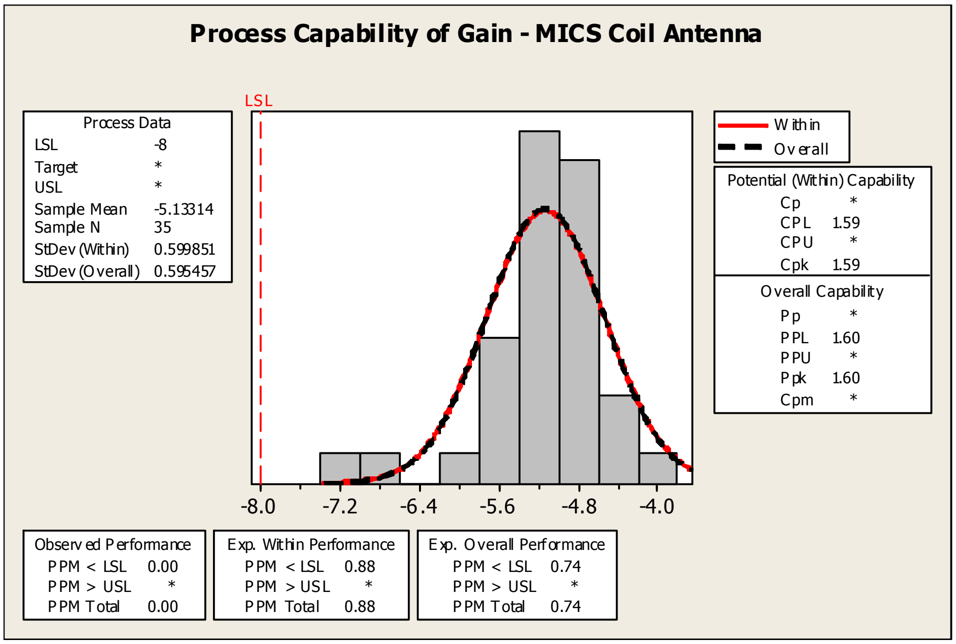
- Mode 1 Tx error vector magnitude (EVM) results, Figure 42, show higher than 99%/99% confidence/reliability in achieving the ability to transmit with an EVM of 8.2% maximum.
- Mode 1 Tx synthesizer error results, Figure 43, show higher than 99%/99%

	confidence/reliability in achieving the ability of the frequency synthesizer to maintain frequency accuracy within -12 parts per million (ppm) minimum to +12 ppm maximum. • Mode 3 Tx error vector magnitude (EVM) results, Figure 44, show higher than 99%/99% confidence/reliability in achieving the ability to transmit with an EVM of 8.2% maximum. • Mode 3 Tx synthesizer error results, Figure 45, show higher than 99%/99% confidence/reliability in achieving the ability of the frequency synthesizer to maintain frequency accuracy within -12 ppm minimum to +12 ppm maximum.
Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

9.4.11 RF-11: Active Tel-M Antenna Gain

Requirements	EETD40 Active Tel-M Antenna Gain Verifies: EE187 The primary Tel-M antenna shall have minimum gain of -8.0 dBi in free space EE394 The secondary Tel-M antenna shall have a minimum gain of -11.5 dBi in free space.
Test Description	This test is done at Satimo in Atlanta, GA. For this test, a fully functional, form, fit DUT is used to check the antenna performance. The test interface is used to put the devices into a CW transmit mode. The transmitting device is placed inside the calibrated anechoic chamber at Satimo at a specified location. The test antennas are configured to receive the DUT signal. The received signals are collected through Satimo's data collection system that automates the antenna switching and accounts for calibration losses. The resulting measurement provides the EIRP and TRP. The gain and efficiency can be calculated from EIRP and TRP, respectively. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 8.
Sample size:	7 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.

Test Environment:	 Figure 46 Zoom in picture of CTM in Star Gate with laser placement
Test Setup:	Test setup is included in the procedure
Test Procedure:	**I. Calibration** A. Set the laser to a location centered within the Satimo antenna Stargate B. Place the calibration antenna at the laser location C. Shut the chamber door and collect the calibration data **II. Put device in Continuous Transmit mode** A. Power up CTM B. Discover device using ActiveX OsirisGUI. C. Run appropriate script for desired transmit channel. **III. Device Setup** A. Center the device on the laser beam. **IV. Measurement** A. Close the chamber door B. Measure the EIRP and TRP using Satimo's data collection system **V. Iterations**

	A. Repeat measurements for 403.5 MHz and 404.85 MHz **VI. Analysis** A. Calculate Gain: Gain=EIRP - transmit power B. Calculate efficiency: efficiency=TRP- transmit power
Test Results:	All data samples PASS minimum primary antenna gain requirements. All data samples PASS minimum secondary antenna gain requirements.
Capability Analysis	 Figure 47 Capability Analysis of MICS Primary Antenna Gain

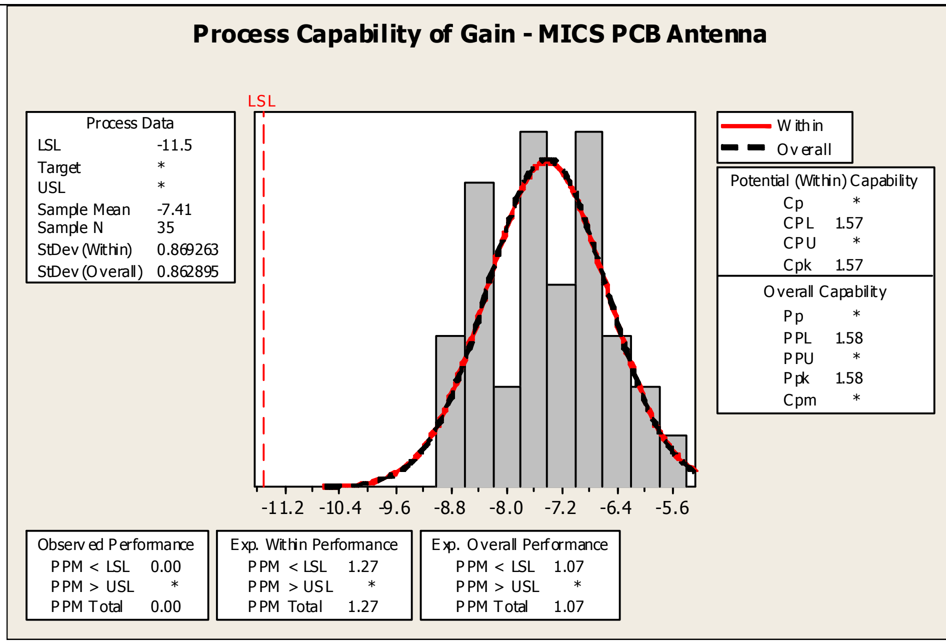


Figure 48 Capability Analysis of MICS Secondary Antenna Gain

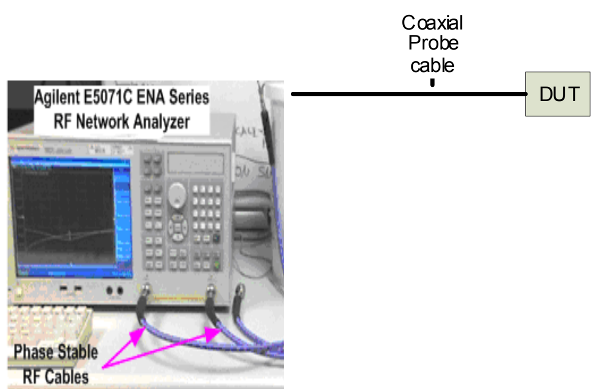
- MICS coil antenna gain results, Figure 47, show higher than 99%/99% confidence/reliability in achieving the ability of the MICS coil antenna to achieve a maximum of -8 dBi minimum.
- MICS PCB antenna gain results, Figure 48, show higher than 99%/99% confidence/reliability in achieving the ability of the MICS PCB antenna to achieve a maximum of -11.5 dBi minimum.

Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

Table 8 List of test cases for MICS active antenna testing

Channel	Mode	Modulation
1	Test	CW
3	Test	CW
5	Test	CW
7	Test	CW
10	Test	CW

9.4.12 RF-12: Tel-M Antenna Return Loss

Requirements	EETD35 Tel-M Antenna Return Loss Verifies: EE188 Including off module matching, the antennas shall have 50 Ohm nominal impedance. EE189 Both Tel-M antennas shall have return loss less than -6 dB in MICS band (402 MHz – 405 MHz).
Test Description	For this test, a fully functional, form, fit DUT is used to check the antenna performance. The antenna probe connector is reversed from the normal placement so that the network analyzer will be looking into the antenna. The network analyzer frequency span is setup for a center frequency of 403.5 MHz (center of MICS band) and the span is set to 20 MHz. The number of points should be a minimum of 201 (this will provide a minimum of 100 kHz resolution). The network analyzer is then calibrated. Then the network analyzer is connected to the DUT (which is fully assembled), and return loss is measured directly. The resulting sweep is saved off to a .csv file. The resulting measurement is a direct measurement of return loss. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 8.
Sample size:	7 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	 Figure 49 Return Loss Test Setup
Test Setup:	Test setup is included in the procedure
Test Procedure:	**I. Calibration** **A.** Set center frequency to 403.5 MHz.

B. Set span to 20 MHz.

C. Set number of points to 201.

II. Measurement

A. Connect network analyzer to MICS antenna 1 port of DUT

B. Measure return loss of MICS antenna 1

C. Save off return loss sweep to appropriately named .csv file (DUT serial # and antenna port should be included).

D. Connect network analyzer to MICS antenna 2 port of DUT

E. Measure return loss of MICS antenna 2

F. Save off return loss sweep to appropriately named .csv file (DUT serial # and antenna port should be included).

Test Results:

All data samples PASS maximum primary antenna return loss requirements.
All data samples PASS maximum secondary antenna return loss requirements.

Capability Analysis

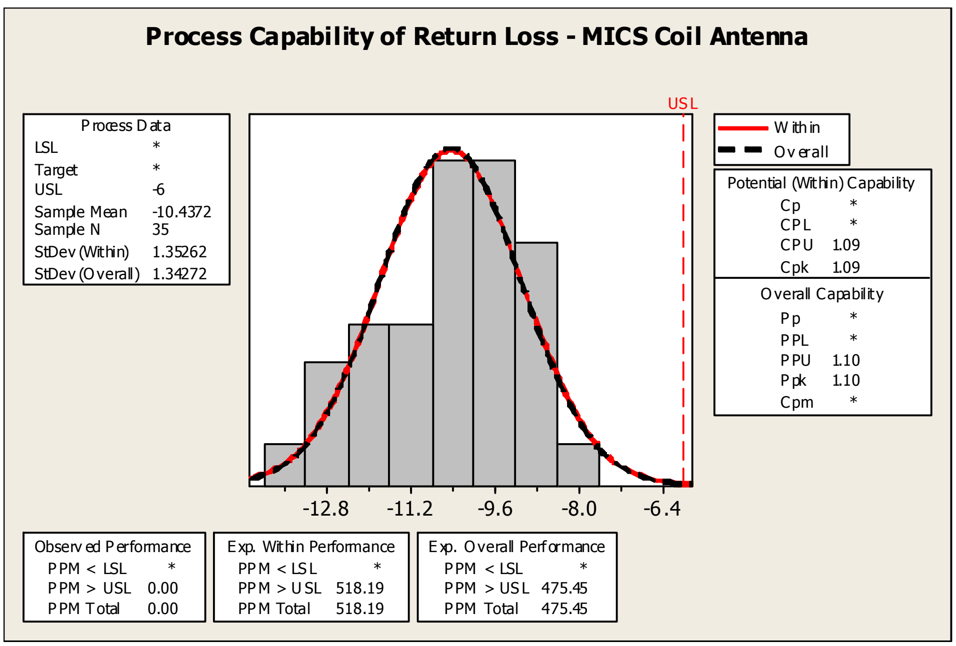


Figure 50 Capability Analysis of MICS Primary Antenna Return Loss

Since the Tel M primary antenna return loss data, Figure 50, was shown to be normal and have a Cpk less than 1.33, additional analysis was conducted. The analysis showed that there is 95/99.5 confidence/reliability with the current specification limit. It can also be represented by 99/98.9 confidence/reliability with the current specification limit. The analysis is included in the supporting data file.

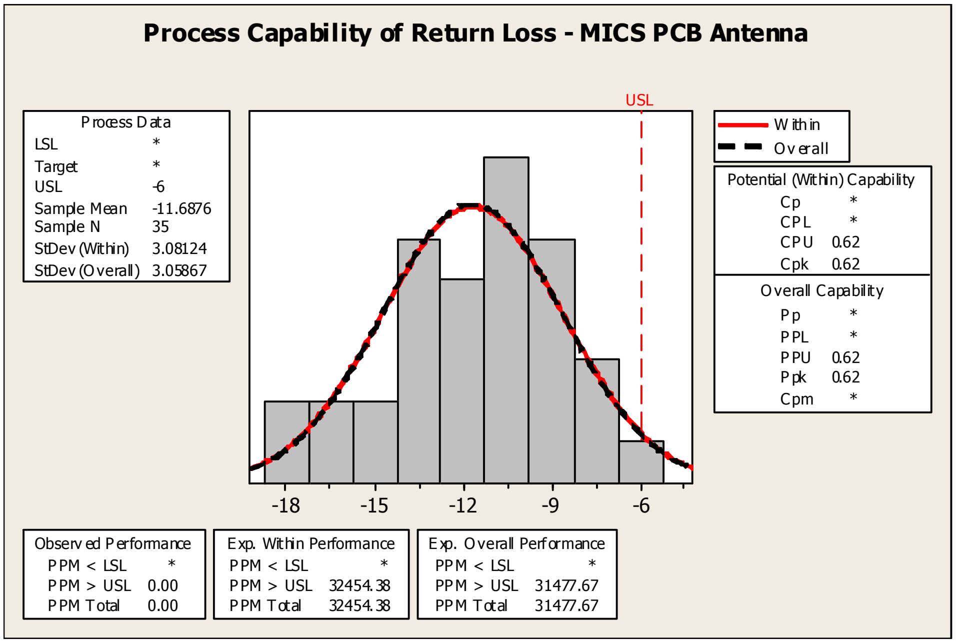


Figure 51 Capability Analysis of MICS Secondary Antenna Return Loss

Since the Tel M secondary antenna return loss data, Figure 51, was shown to be normal and have a Cpk less than 1.33, additional analysis was conducted. The analysis showed that there is 95/91.5 confidence/reliability with the current specification limit. It can also be represented by 99/88.5 confidence/reliability with the current specification limit. The analysis is included in the supporting data file.

Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

9.4.13 RF-13: Active Bluetooth Antenna Efficiency

Requirements	EETD36 Active Bluetooth Antenna Efficiency Verifies: EE392 The Bluetooth antenna shall have minimum radiation efficiency of -10 dB in open air environment.
Test Description	This test is done at Satimo in Atlanta, GA. For this test, a fully functional, form, fit DUT is used to check the antenna performance. The test interface is used to put the devices into a CW transmit mode. The transmitting device is placed inside the calibrated anechoic chamber at Satimo at a specified location. The test antennas are configured to receive the DUT signal. The received signals are collected through Satimo's data collection system that automates the antenna switching

	and accounts for calibration losses. The resulting measurement provides the EIRP and TRP. The gain and efficiency can be calculated from EIRP and TRP, respectively. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 9.
Sample size:	7 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	This test is part of the radiated antenna suite of tests. See test environment in section 9.4.11.
Test Setup:	Test setup is included in the procedure
Test Procedure:	**I. Calibration** A. Set the laser to a location centered within the Satimo antenna Stargate B. Place the calibration antenna at the laser location C. Shut the chamber door and collect the calibration data **II. Put device in Continuous Transmit mode** A. Power up CTM B. Discover device using ActiveX OsirisGUI. C. Run appropriate script for desired transmit channel. **III. Device Setup** A. Center the device on the laser beam. **IV. Measurement** A. Close the chamber door B. Measure the EIRP and TRP using Satimo's data collection system **V. Iterations** A. Repeat measurements for 2441.165 MHz and 2480.165 MHz **VI. Analysis** A. Calculate Gain: Gain=EIRP - transmit power B. Calculate efficiency: efficiency=TRP- transmit power
Test Results:	All data samples PASS minimum radiation efficiency requirements.

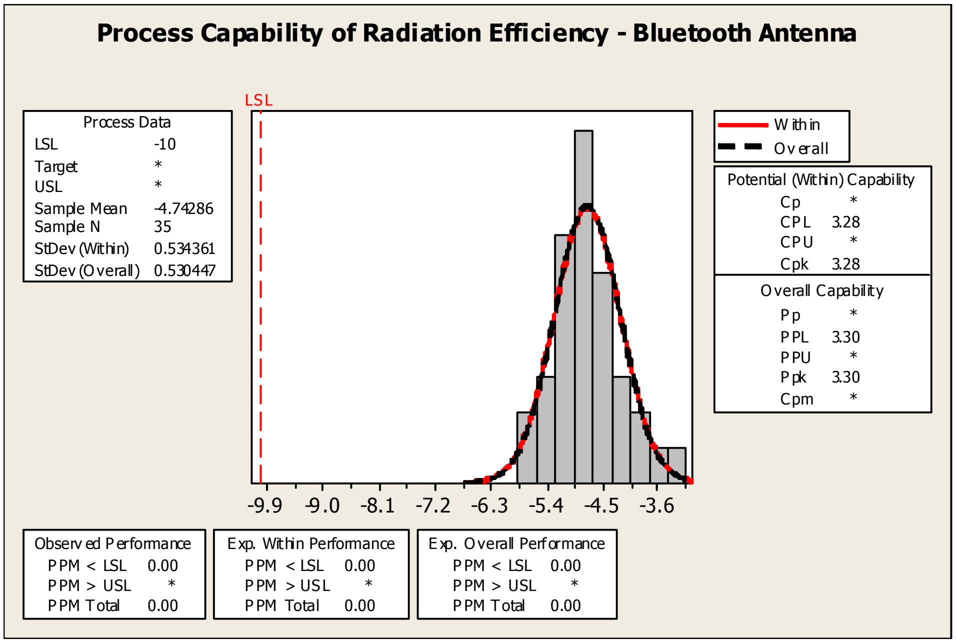
Capability Analysis	 Figure 52 Capability Analysis of Radiation Efficiency of Bluetooth Antenna • Bluetooth antenna radiation efficiency results, Figure 52, show higher than 99%/99% confidence/reliability in achieving the ability of the Bluetooth antenna to achieve a radiation efficiency of -10 dB minimum.
Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample Retention	Test samples will be retained per work instructions.

Table 9 List of test cases for Bluetooth active antenna testing

Channel	Frequency (MHz)	Mode	Modulation
0	2402.165	Test	CW
20	2422.165	Test	CW
39	2441.165	Test	CW
59	2461.165	Test	CW
78	2480.165	Test	CW

9.4.14 RF-14: Bluetooth Antenna Return Loss

Requirements	EETD37 Bluetooth Antenna Return Loss

	Verifies: EE67 The Bluetooth transceiver antenna shall have a maximum return loss of -6 dB for frequency range between 2.4GHz and 2.4835GHz.
Test Description	For this test, a fully functional, form, fit DUT is used to check the antenna performance. The antenna probe connector is reversed from the normal placement so that the network analyzer will be looking into the antenna. The network analyzer frequency span is setup for a center frequency of 2441 MHz and the span is set to 200 MHz. The number of points should be a minimum of 1601. The network analyzer is then calibrated. Then the network analyzer is connected to the DUT (which is fully assembled), and return loss is measured directly. The resulting sweep is saved off to a .csv file. The resulting measurement is a direct measurement of return loss. All tests will be performed with the RF channel, temperature, and voltage combinations outlined in Table 9.
Sample size:	7 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	This test is part of the radiated antenna suite of tests. See test environment in section 9.4.12.
Test Setup:	Test setup is included in the procedure
Test Procedure:	**I. Calibration** A. Set center frequency to 2441 MHz. B. Set span to 200 MHz. C. Set number of points to 1601. **II. Measurement** A. Connect network analyzer to Bluetooth antenna port of DUT B. Measure return loss of Bluetooth antenna C. Save off return loss sweep to appropriately named .csv file (DUT serial # and antenna port should be included).
Test Results:	All data samples PASS maximum antenna return loss requirements.

Capability Analysis

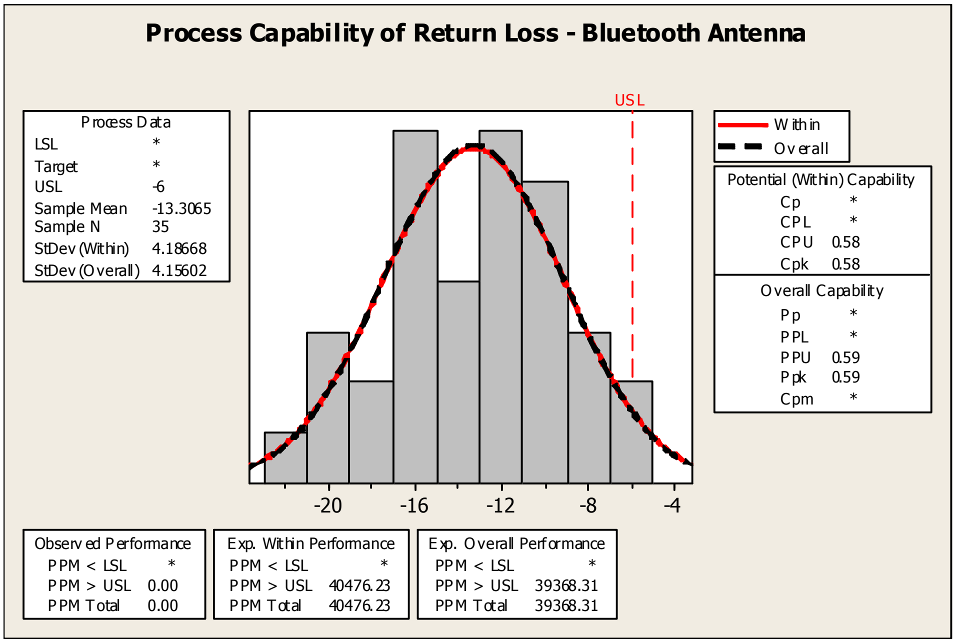


Figure 53 Capability Analysis of Return Loss of Bluetooth Antenna

Since the Bluetooth antenna return loss data, Figure 53, was shown to be normal and have a Cpk less than 1.33, additional analysis was conducted. The analysis showed that there is 95/90.3 confidence/reliability with the current specification limit. It can also be represented by 99/86.9 confidence/reliability with the current specification limit. The analysis is included in the supporting data file.

Test Data Traceability

Test data can be found in the supporting documents archival file NDHF1405-124575.

Test Sample Retention

Test samples will be retained per work instructions.

9.4.15 RF-15: Bluetooth Rx Sensitivity (GFSK)

Requirements

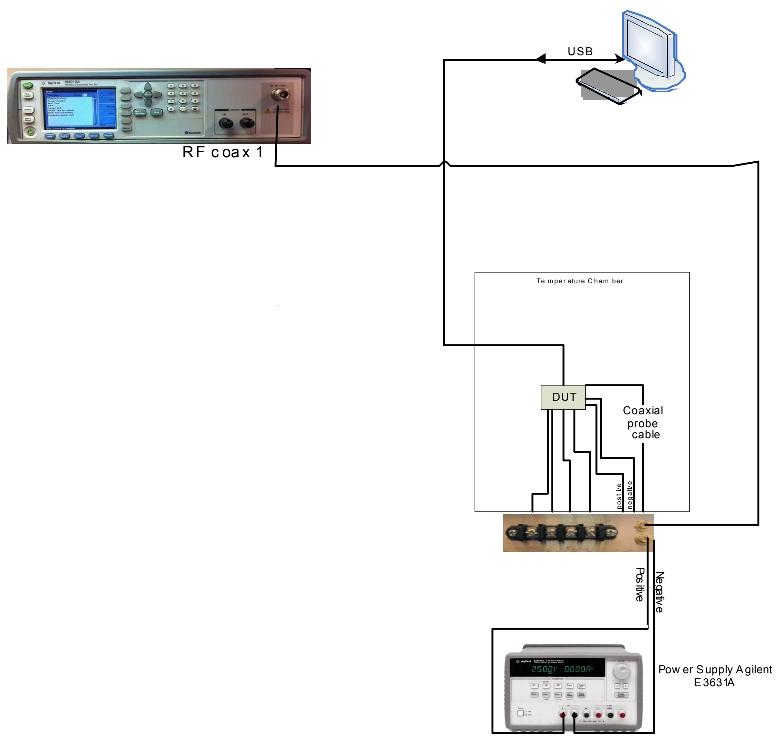
EETD38 Bluetooth Rx Sensitivity (GFSK)

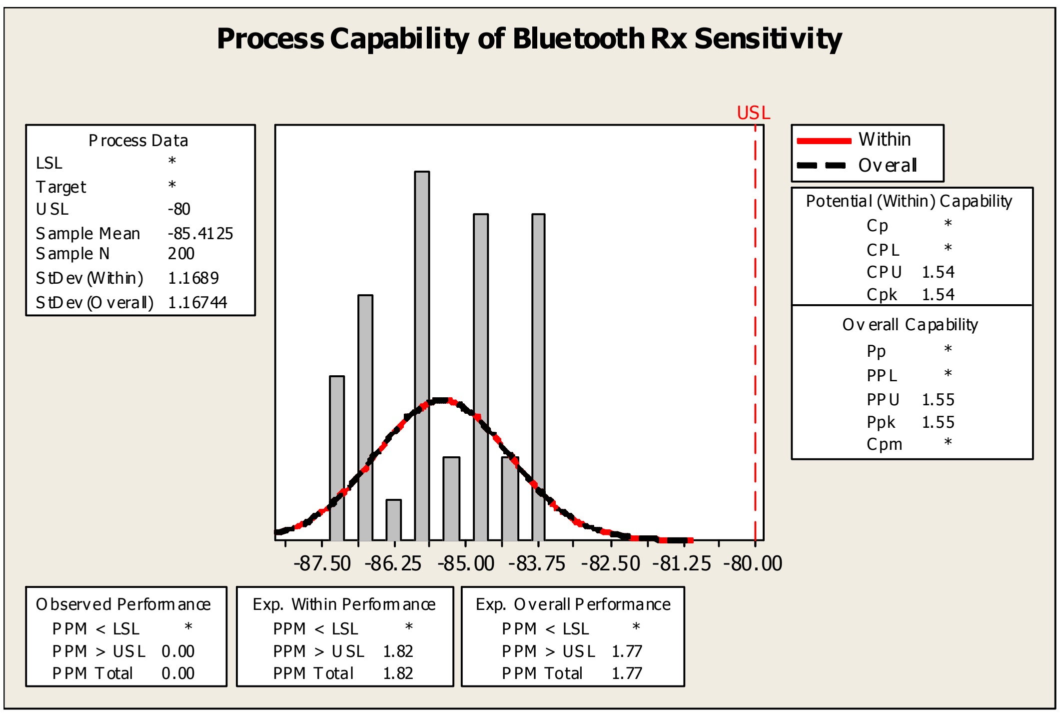
Verifies:

EE393 The Bluetooth transceiver shall have min Rx sensitivity equal or less than -80 dBm (GFSK modulation)

Test Description

The receiver sensitivity test measures how low in power a Bluetooth signal can be received by the DUT receiver and achieve a raw bit error rate (BER) ≤ 0.1%. The test is conducted in a shielded temp chamber that provides an isolated environment from external interfering signals (e.g., WiFi, Cell phone, etc.). The DUT is powered via an external power supply such that the temperature and power supply can be variable parameters in the test.

	A dedicated Wireless Connectivity Test Set (Agilent N40101A) is used to perform this test. After a specified number of packets, the number of received bits and bits with errors are counted. Testing will be done on all combinations of channels 0, 29, 39, 49, and 78, over temperatures of 0°C and 44°C, over battery voltages of 2.2 V and 3.2 V.
Sample size:	5 DUTs
Acceptance Criteria	An acceptance criterion is based on successful completion of tests within specified range of error or meeting the requirements set forth.
Test Objective:	Verify device meets specified requirements.
Test Environment:	 Figure 54 Test setup for Bluetooth receiver testing
Test Setup:	**Cable connections and initial calibrations:** 1. Measure the loss of coax1. Record this loss factor and program it into the N40101A. 2. Place the DUT inside temperature chamber 3. Connect the measured coaxial cable. 4. Connect the power supply to the DUT.
Test Procedure:	**I. Calibration** A. Set channels to non frequency hopping.

	B. Set channels to test channel 0, 39, and 78. C. Set number of bits to send to 16e6. D. Ensure data whitening is enabled. E. Ensure interference is on. F. Ensure DUT has custom “Bluetooth Test Mode” firmware installed. G. Set Rx power to -85 dBm. **II. Measurement** A. Run Rx test suite. B. Record Rx results. C. Repeat steps A & B after incrementing Rx power by 1 dB until Rx sensitivity is achieved.
Test Results:	All data samples PASS minimum Bluetooth Rx sensitivity.
Capability Analysis	 Figure 55 Capability Analysis of Bluetooth Rx Sensitivity • Bluetooth Rx sensitivity results, Figure 55, show higher than 99%/99% confidence/reliability in achieving a minimum sensitivity of -80 dBm.
Test Data Traceability	Test data can be found in the supporting documents archival file NDHF1405-124575.
Test Sample	Test samples will be retained per work instructions.

Retention	

9.4.16 RF-16: Bluetooth Standard Qualification

Requirements	EETD39 Bluetooth Standard Qualification Verifies: EE53 CTM2 electrical design shall provide a Bluetooth transceiver compatible with the Bluetooth 2.0 specification as a class 1 device with a maximum output power of 10dBm.
Test Description	This test is done at 7 Layers, Inc. located in Irvine, CA. For this test, a fully functional, form, fit DUT is provided to 7 Layers, Inc. for Bluetooth certification. 7 Layers is accredited and has Bluetooth Qualification Test Facility (BQTF) status, thus formally recognized as competent to perform “Category A” Bluetooth qualification conformance tests.
Sample size:	1 DUTs + 1 spare DUT
Acceptance Criteria	An acceptance criterion is based on successful completion of tests and attaining Bluetooth EDR 2.0 certification.
Test Objective:	Verify device meets specified requirements.
Test Environment:	This requirement will be tested at 7 Layers, Inc. located in Irvine, CA.
Test Setup:	Test setup is included in the procedure
Test Procedure:	**I. Calibration** A. Record the loss of the RF coaxial cable provided to 7 Layers and provide that information to them. **II. Firmware** A. Load a custom F/W version on the DUT(s) to be tested. This firmware puts the Bluetooth radio in Bluetooth test mode, rather than normal power up conditions.
Test Results:	This testing will be reported in NDHF1405-125441 (CTM2 Model 8880T2 Bluetooth Qualification Report).
Test Data Traceability	N/A
Test Sample Retention	N/A

9.4.17 RF-17: Tel M I/O

Requirement	EETD97 Tel M I/O Verifies:

	EE142 Digital input shall have a maximum 10%-90% rise time <=40 ns EE143 Digital input shall have a maximum 90%-10% fall time <=40 ns EE144 Input logic high voltage shall have minimum of DVDD-0.1V and maximum of DVDD EE145 Input logic low voltage shall have maximum of 0.3V EE147 SPI shall use nominal clock frequency 4 MHz, +/-20ppm EE148 SCK shall have a duty cycle of 50% +/-10% EE149 SDI setup time (before rising edge of SCK) shall be greater than 62ns EE150 SDI hold time (after rising edge of SCK) shall be greater than 125ns but less than 187ns EE151 SDO setup time (before rising edge of SCK) shall be greater than 30ns but less than 125ns EE152 SDO hold time (after rising edge of SCK) shall be greater than 125ns but less than 187ns EE153 SCS duration for high shall be greater than 50 ns EE154 The delay between last falling edge of SCK and SCS inactive shall be greater than 125ns EE155 The delay between SCS inactive and module stop driving SDO (hiz state) shall be less than 62ns
Test Description	This will be verified via inspection of the Tel M module requirement (A17245).
Sample size:	*N/A*
Acceptance Criteria	An acceptance criterion is based on the Tel M module supporting the I/O requirements as stated above.
Test Objective:	Verify device meets specified requirements.
Test Environment:	N/A
Test Setup:	N/A
Test Procedure:	N/A
Test Results:	Inspection of the Telemetry M RF Module Requirements Specification (A17245) shows that the module meets the requirements set forth.
Test Data Traceability	N/A
Test Sample Retention	N/A

10 SAMPLE BUILD TRACEABILITY

S/N	Configuration/PCB Assembly #	Test Used On	Traceability Documentation	Alterations
NKW001296N	PCBA/ M938941A005	RF-1 – RF-8, RF-15		
NKW001345N	PCBA/ M938941A005	RF-9 – RF-10, RF-15		
NKW001348N	PCBA/ M938941A005	RF-15, RF-9 – RF 10		
NKW001358N	PCBA/ M938941A005	RF-1 – RF -10, RF-15		
NKW001354N	PCBA/ M938941A005	RF-1 – RF-10, RF-15		
NKW001367N	PCBA/ M938941A005	RF-1 – RF-10		
NKW001347N	PCBA/ M938941A005	RF-1 – RF-10		
NKW001678N	HLA/ M938941A006	RF-11 – RF-14		RF switches (J1-J3) reversed for RF-12 & RF-14
NKW001671N	HLA/ M938941A006	RF-11 – RF-14		RF switches (J1-J3) reversed for RF-12 & RF-14
NKW001676N	HLA/ M938941A006	RF-11 – RF-14		RF switches (J1-J3) reversed for RF-12 & RF-14
NKW001677N	HLA/ M938941A006	RF-11 – RF-14		RF switches (J1-J3) reversed for RF-12 & RF-14
NKW001672N	HLA/ M938941A006	RF-11 – RF-14		RF switches (J1-J3) reversed for RF-12 & RF-14

NKW001674N	HLA/ M938941A006	RF-11 – RF-14		RF switches (J1-J3) reversed for RF-12 & RF-14
NKW001682N	HLA/ M938941A006	RF-11 – RF-14		RF switches (J1-J3) reversed for RF-12 & RF-14

Sample build traceability will be documented in the DVT Test report.

11 CONCLUSION

Instruments from the CTM electrical DVT build were used to execute the testing in the CTM2 8880T2 Tel M DVT Test Protocol. All testing passed as described in this report. All tests passed with no modifications to the test protocol with the exception of Bluetooth qualification testing, which is not included in this report. The results of the Bluetooth qualification testing (EETD39, which verified EE53) will be reported in a separate report (NDHF1405-125441 CTM2 Model 8880T2 Bluetooth Qualification Report).

12 RECOMMENDATIONS

Based on the results within this report, the CTM2 instrument meets all RF specifications reflected in this report. The exception is EETD39, which verifies EE53, is not reflected in this report. EETD39 will be satisfied in the CTM2 Model 8880T2 Bluetooth Qualification Report (NDHF1405-125441). The recommendation is to move forward with system testing.

13 APPENDIX

13.1 APPENDIX A: MEASUREMENT OF RF PATH LOSS THROUGH CABLES

13.1.1 NARROWBAND CABLE LOSS MEASUREMENTS

All losses due to cable connections must be accounted. Each cable must be measured using the following procedure and then the losses can be input into the Labview code to be accounted properly in the calculations.

1. Connect the suitable extension cables to network analyzer ports 1 and 2
2. Preset the Network Analyzer to get to a common and known state
3. Select a span from 200 MHz to 600 MHz
4. Perform appropriate calibration on the network analyzer using the E Cal module
5. Connect the cable(s) to the network analyzer.
6. Select Log magnitude display mode
7. Select measurement type “S21”
8. Turn on averaging and/or smoothing ON (optional)
9. Place the marker at 403 MHz
10. Read the transmission loss (in dB)
11. Enter this value into the Labview application

13.1.2 BROAD BAND CABLE LOSS MEASUREMENTS

The spurious harmonics test is over a broad range of frequency. To account for the change in RF losses over frequency, all path losses (e.g., cables, connectors, and SAM3 path) must be measured across the broadband. During the test, the large frequency band (500 kHz to 3 GHz) is measured in 300 kHz increments. Table 10 breaks up the measurement to capture data at the center point of each of these 300 kHz increments. The data will be input into a table for import by the Labview application and accounting during measurements.

1. Connect the suitable extension cables to network analyzer ports 1 (and 2)
2. Preset the Network Analyzer to get to a common and known state
3. Select a span from 650 kHz to 224.75 MHz and 748 data points
4. Perform (two port) calibration on the network analyzer using the E Cal module
5. Move SW1 and SW2 in the SAM3 to position 2
6. Connect RF coax 2 between port 1 of the network analyzer and Sig Gen C on the SAM3. (Remove any circulators/isolators for this measurement since they are band limited.)
7. Connect RF coax 3 between port 2 of the network analyzer and DUT on the SAM3.
8. Select Log magnitude display mode
9. Select measurement type “S21”
10. Turn on averaging and/or smoothing ON (optional)
11. Save the data to a .csv file
12. Move SW1 and SW2 in the SAM3 to position 1.
13. Repeat steps 3-11each of the spans and data points listed in Table 10.
14. Concatenate all of the .csv files into a single file with two columns: Frequency (Hz), Path loss in dB
15. Use the Labview application to input this file for the spurious harmonics test

Table 10 Frequency spans and number of data points to create the broadband path loss table for test RF-7

start frequency (Hz)	number of data points	stop frequency (Hz)
100000	1601	1125000000
1125000000	1601	2250000000
2250000000	1601	3375000000
3375000000	1601	4500000000

13.2 APPENDIX C: REQUIREMENTS TRACE

Table 11: Requirements Trace (Imported from ReqPro)

EETD Tag	Requirement text	Requirement Status	Traced-to
EETD25	Tel-M Receiver Sensitivity	Approved	EE168(s), EE169(s), EE177(s)
EETD26	Tel-M Receiver Intermodulation Rejection	Approved	EE170
EETD27	Tel-M Receiver Adjacent Channel Rejection	Approved	EE171
EETD28	Tel-M Receiver Alternate Channel Rejection	Approved	EE172
EETD29	Tel-M Receiver AM Channel Rejection	Approved	EE176
EETD30	Tel-M External Spurious Response Rejection (Single Tone, Unmodulated)	Approved	EE175
EETD31	Tel-M Rx RSSI Linearity and differentiation	Approved	EE178, EE179
EETD32	Tel-M Transmitter Output Power, Adjacent Channel Power Ratio, and Alternate Channel Power Ratio	Approved	EE158, EE163, EE164
EETD33	Tel-M Transmitter Error Vector Magnitude & Transmitter Frequency Stability	Approved	EE156, EE157, EE166
EETD34	Tel-M Transmitter Spectral Emissions	Deleted	
EETD35	Tel-M Antenna Return Loss	Approved	EE188, EE189
EETD36	Active Bluetooth Antenna Efficiency	Approved	EE392
EETD37	Bluetooth Antenna Return Loss	Approved	EE67
EETD38	Bluetooth Rx Sensitivity (GFSK)	Approved	EE393
EETD39	Bluetooth Standard Qualification	Approved	EE53
EETD40	Active Tel-M Antenna Gain	Approved	EE187, EE394

EETD59	The CTM2 shall support wireless communications with implantable devices as specified in the Tel-M Communication Protocol Specification, A36244	Approved	EE553
EETD97	Tel M I/O	Approved	EE142, EE143, EE144, EE145, EE147, EE148, EE149, EE150, EE151, EE152, EE153, EE154, EE155