SPINAL MODULATION, INC	
DOCUMENT TYPE: VERIFICATION REPORT	**VR#:** 167-3
TITLE: LISTEN BEFORE TALK TEST REPORT	**Rev:** A

REVISION HISTORY

Rev	Change Description	CO	Effective Date	By
A	Initial Release. SoMo Programmer AD1634 with SoMo BS PCB AD1621			Erik Johnson

1. PURPOSE

This Report describes the MICS/MedRadio Listen Before Talk testing performed on the SMI Programmer Basestation. This test was performed by SMI personnel.

System Description

The Spinal Modulation (SMI) MICS/MedRadio 402 to 405 MHz system is required to scan all of its channels and select the lowest ambient noise channel prior to initiating an RF link (transmitting). The MICS/MedRadio system uses a master-slave type communication where the handheld Programmer initiates all RF communication. The Implantable NeuroStimulator (INS) or Temporary NeuroStimulator (TNS) respond to the Programmer RF link and are not permitted to initiate a RF link. SMI does not use any of the allowed special emergency transmissions from the INS or TNS. SMI uses the Least Interfered Channel (LIC) method and not the LBT threshold power level.

2. SCOPE

This document describes the testing of the Listen Before Talk (LBT) protocol required by applicable parts of MICS standard EN 301 839-1, EN 301 839-2 and MedRadio FCC Part 95.628.a. The SMI radio system uses the Least-Interfered-Channel (LIC). It does not use pre-scanned alternate channel and this test will not be performed.

3. REFERENCE DOCUMENTS

3.1. SMI Reference Documents

VP239	Applicable V & V Plan Neurostimulator System (to be filled in report, e.g. VP239 for DP1005)
PS1300	Product Requirements Specification Connector Cable
HW015	Hardware Requirements Specification Programmer
OP033	Design Verification
FM130	Report Template
ER079	SMI Standard Terminology Definitions and Acronyms
VR068	Programmer Emissions Test Report

3.2. Regulatory Agency Documents

EN 301 839-1	Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Ultra Low Power Active Medical Implants (ULP-AMI) and Peripherals (ULP-AMI-P) operating in the frequency range 402 MHz to 405 MHz; Part 1: Technical characteristics and test methods
EN 301 839-2	Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Radio Equipment in the Frequency Range 402 MHz to 405

	MHz for Ultra Low Power Active Medical Implants and Accessories; Part 2: Harmonized EN Covering Essential Requirements of Article 3.2 of the R&TTE Directive
EN 301 489-1	Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 1: Common technical requirements
EN 301 489-27	Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 27: Specific conditions for Ultra Low Power Active Medical Implants (ULP-AMI) and related peripheral devices (ULP-AMI-P)
FCC Part 95	Federal Communications Commission PART 95 MedRadio

4. DEFINITIONS

Refer to ER079 for the various definitions, acronyms and terminology used in this document.

Abbreviations

BS	Basestation. PCB in Programmer that has RF and RF MCU control circuitry.
BSDiag	Basestation API (Patch Code) allows GUI control of BS Product Code
CA	Clear Channel Assessment
GUI	Graphical User Interface
LBT	Listen Before Talk
LIC	Least Interfered Channel
NS PCB	Neurostimulator printed circuit board.
CW	Continuous Wave
IF	Intermediate Frequency
MICS	Medical Implant Communication Service
RSSI	Receive Signal Strength Indicator
SMI	Spinal Modulation, Inc.

5. EQUIPMENT AND SUPPLIES

Log information in table below.

Equipment	Mfgr	Model Number	Serial Number	SW/FW Version	Date of Next Calibration (if required)
BS PCBA	SMI	AD1616	520066	5.1.0	N/A
BS PCBA	SMI	AD1616	520042	5.1.0	N/A
PC	Dell	OptiPlex GX745	7648706m-0011903-00102	win XP SP3	N/A
~~Digital Multimeter~~				N/A	
Power Supply	Agilent	E3640B	EQ066	N/A	1/11/14
20 dB Directional coupler	Mini-ckts	ZFDC-20-4L	SF800301017	N/A	N/A
20 dB Directional coupler	Mini-ckts	ZFDC-20-4L		N/A	N/A
~~30 dB attenuator~~ x3	Mini-ckts	~~VAT-30+~~ SMA	3.0931	N/A	N/A
~~30 dB attenuator~~	Mini-ckts	~~VAT-30+~~	3.1008	~~N/A~~	N/A
3 ft. Coax Cable	Johnson	415-033-036	N/S	N/A	N/A
3 ft. Coax Cable	Johnson	415-033-036	N/S	N/A	N/A
~~3 ft. Coax Cable~~	~~Johnson~~	~~415-033-036~~		~~N/A~~	N/A
~~3 ft. Coax Cable~~	~~Johnson~~	~~415-033-036~~		N/A	N/A
Cable USB A-B ~~mini~~ micro	Qualtek	3021003-03	N/A	N/A	N/A
Oscilloscope	Agilent	DSO 80604B	EQ0111	N/A	4/11/14
Spectrum Analyzer	Agilent	GXA N9010A	EQ0516	N/A	5/10/14
Signal Generator	HP	8656B	EQ077	N/A	N/C
BS display	3M C	SL1078	N/A	2.05.0	N/A

Crossed-out items represent equipment not used for this test

6. TEST RESULTS AND TEST SIGNATURES

Test results will be reported in VR167.

Test signatures:

Function	Printed name	Signature	Date

Firmware Engineer	Erik Johnson		11/6/13

7. SAMPLE SIZE AND JUSTIFICATION

Refer to OP033 for the sample size justification. In general, outside laboratory emissions testing is performed on a sample size of one. Refer to the outside laboratory reports for sample sizes used for particular tests.

8. DEVICE UNDER TEST CONFIGURATION

8.1 Circuit Description

The SMI Programmer (Clinical or Patient) uses the Zarlink ZL70102 transceiver for MICS radio communication with an INS or TNS neurostimulator.
Specifications summary:

- 10 channels equally spaced from 402 to 405 MHz
- 300 kHz channel spacing.
- Emission bandwidth 20 dB: 250 kHz nominal.
- +/- 25 ppm channel frequency accuracy.
- 20 dB LBT RSSI measurement bandwidth: 500 kHz nominal.
- -103 dBm LBT Rx Sensitivity.
- Antenna Gain typical: –7dB.
- LIC Threshold Power Pth = -103 dBm.
- Channel monitoring period 10.5 msec.
- Channel Nominal Center Frequency.
    - Ch0 402.150 MHz
    - Ch1 402.450 MHz
    - Ch2 402.750 MHz
    - Ch3 403.050 MHz
    - Ch4 403.350 MHz
    - Ch5 403.650 MHz
    - Ch6 403.950 MHz
    - Ch7 404.250 MHz
    - Ch8 404.550 MHz
    - Ch9 404.850 MHz

Prior to initiation of a RF link the Programmer scans all 10 channels in Rx mode only. The Rx 450 kHz IF is ported out of the Zarlink transceiver to the analog RSSI measurement circuit. The analog RSSI measurement circuit is comprised of a balanced passive bandpass filterwith a nominal 500 kHz 20 dB bandwidth. The bandpass filter

output goes to an AD8310 Log Detector (U10) amplifier that demodulates the 450 kHz IF Rx signal. The output is ten 10.5 msec pulsed DC signals each representing one channel RSSI amplitude in order of Ch0 to Ch9. See sample display with no RF input figure 1.

NEW PHOTO Sample Display

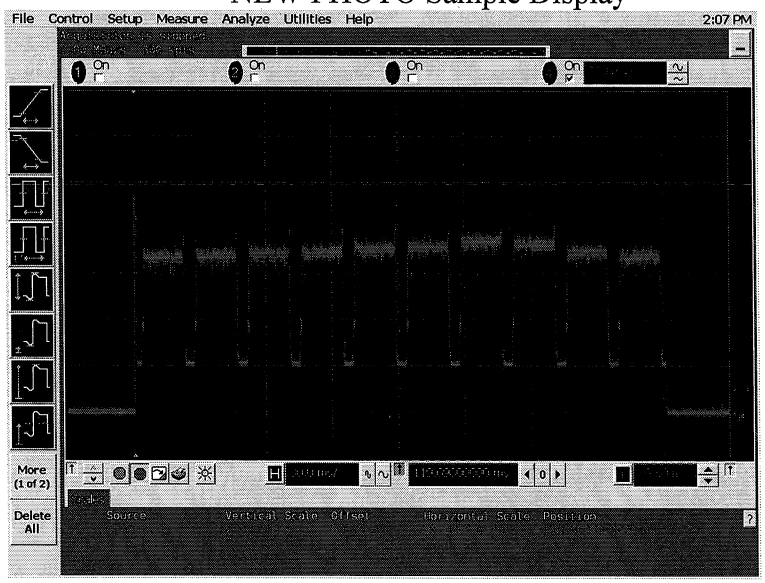


Figure 1. J6 Pin 12 RSSI. 30 msec/div. 200 mV/div AD8310 Output to MCU ADC. No RF Input.

Channel	RSSI ADC
0	1100
1	1112
2	1133
3	1144
4	1170
5	1184
6	1219
7	1201
8	1145

9	1119

Table 1. MCU ADC output of Figure1.

The RSSI timing of each channel scan is driven by the ZL70102 transceiver (U3) RX_EN pin to the MCU (U2). The MCU in turn outputs RSSI_EN that provides timing and scan width that controls the enable pins for all the Op Amp filters and Log Detector.

The Log Detector Output goes to the MCU 12 bit ADC with range of 4096 counts. The no-RF signal input on any channel is typically less than 2400 ADC counts (see figure and table 1). The MCU ADC uses a free running mode and averages 140 measurements.

8.2 Test Firmware

SWxxxx Basestation Compiled Executable (to be filled in report, e.g. SW1077 for DP1005)
SW1078 BsDiag Compiled Executable
ED1335 Source Code Basestation
ED2040 Source Code BsDiag

The firmware is controlled from BsDiag, a PC based test interface, for most testing of the LBT circuitry. It is used to initiate a communication session and read the MCU RSSI values used to determine the LBT channel.

Circuit connections are provided by SMT coax connections to the Basestation board.

Test Parameters:

8.3.1 Minimum Power Detection Threshold (< -103 dBm).
8.3.2 Monitoring System Bandwidth > Emission Bandwidth (250 kHz).
8.3.3 Monitoring System Scan Cycle Time ≤ 5 seconds.
8.3.4 Minimum Channel Monitoring Period ≥ 10 msec.
8.3.5 Discontinuation of RF Session after ≤ 5 second silent period.

8.3.1 Minimum Power Detection Threshold (< -103 dBm).

The minimum power detection threshold (Pth) is based on an Agency provided equation that includes Antenna Gain (Gt) and Emission bandwidth (EBW) as input parameters from the system.

Measured 238 Pth (dBm) = 10 log EBW (Hz) -150 + Gt (dBi)

Typical EBW is ~~250~~ kHz and Gt is ~~-7~~ -2.69 dB.

Calculated Pth: -107.924 dBm

Test setup: 14/7/13

Measure the Signal Generator output power on the spectrum analyzer:

Frequency 402.150 MHz
300 kHz steps
-103 dBm ~~-72.3 dBm + 30dB physical Att~~ cf 11/6/13 (extra physical attenuator not needed)
-102.2 +2 cables @ -.54 + -.57

Spectrum analyzer settings:

RBW: 5 KHz
VBW: 8 kHz
Span: 3 MHz
Sweep: 1.17s
Atten: Ø dB

Verify Generator output is -103 dBm +/- 0.5 dBm. Pmeasured: 103 +/- .21 (.13) dBm

Verify signal generator frequency accuracy on all 10 channel frequencies is +/- 25ppm (+/- 10 kHz):

Ch0	402.150 MHz	402.156 MHz
Ch1	402.450 MHz	402.456 MHz
Ch2	402.750 MHz	402.756 MHz
Ch3	403.050 MHz	403.056 MHz
Ch4	403.350 MHz	403.356 MHz
Ch5	403.650 MHz	403.656 MHz
Ch6	403.950 MHz	403.956 MHz
Ch7	404.250 MHz	404.256 MHz
Ch8	404.550 MHz	404.556 MHz
Ch9	404.850 MHz	404.856 MHz

Measure RSSI baseline levels with No RF.

Terminate BS J42 output into 50 Ohms.
Start RF connection sequence.
Measure Tx frequency/channel number on spectrum analyzer.
Read RSSI and verify the Tx channel agrees with the lowest (or the 1st lowest if two channels have the same lowest reading) RSSI reading

Freq: 403.95 MHz
Ch #: ~~7~~ 6
Lowest RSSI Ch #: ~~7~~ 6

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	1470	1424	36	41	56	45	10	12	24	21

Verify RSSI circuit can distinguish a -103 dBm CW signal on all 10 channels.
Inject a CW signal at - -103 dBm into BS RF port J42 on all 10 channels and read MCU RSSI measurement with the BsDiag status command. Verify BS transmits on lowest RSSI measured channel.
Using the signal generator inject a -103 dBm signal sequentially on each channel, one at a time, and record the RSSI levels for all 10 channels from the MCU. Verify the -103 dBm signal is the highest RSSI level on all 10 channels for each of the 10 tests.

Note: 2-digit values all begin w/ 14, ex 22 → 1422

Ch 0 (-103 dBm) Highest Channel RSSI: 0 Lowest Channel RSSI: 6 Tx Ch 6

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	1764	1434	22	52	48	48	14	15	29	23

Ch 1 (-103 dBm) Highest Channel RSSI: 1 Lowest Channel RSSI: 7 Tx Ch 7

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	1592	1765	1438	58	51	50	14	09	27	23

Ch 2 (-103 dBm) Highest Channel RSSI: 2 Lowest Channel RSSI: 6 Tx Ch 6

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	1434	1583	1757	1461	54	44	05	14	27	17

Ch 3 (-103 dBm) Highest Channel RSSI: 3 Lowest Channel RSSI: 6 Tx Ch 6

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	1426	26	1581	1755	1464	47	07	14	22	23

Ch 4 (-103 dBm) Highest Channel RSSI: 4 Lowest Channel RSSI: 7 Tx Ch 7

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	23	18	33	1592	1756	1608	1416	12	23	25

Ch 5 (-103 dBm) Highest Channel RSSI: 5 Lowest Channel RSSI: 7 Tx Ch 7

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	27	19	32	50	1596	1758	1599	1418	1419	23

Ch 6 (-103 dBm) Highest Channel RSSI: 6 Lowest Channel RSSI: 1/9 Tx Ch 1

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	27	19	33	56	49	44	1763	1604	1425	19

Ch 7 (-103 dBm) Highest Channel RSSI: 7 Lowest Channel RSSI: 1 Tx Ch 1

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	28	18	27	55	46	38	25	1767	1610	23

Ch 8 (-103 dBm) Highest Channel RSSI: 8 Lowest Channel RSSI: 6 Tx Ch 6

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	26	16	30	51	56	37	11	23	1768	1611

Ch 9 (-103 dBm) Highest Channel RSSI: 9 Lowest Channel RSSI: 7 Tx Ch 7

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	29	27	26	62	49	47	12	15	36	1769

All 10 channels verified -103 dBm signal input was highest RSSI value: PASS

All 10 channels verified Tx Channel was on lowest RSSI channel: PASS

8.3.2 Monitoring System Band width > Emission Bandwidth (250 kHz).

Inject a CW signal at -75 dBm into BS RF port J42 on channel 5, 403.650 MHz (+/- 10 kHz) and read MCU RSSI measurement with the BsDiag status command. Lower the signal 20 dB to -95 dBm and record the RSSI values. The channel 5 RSSI value will be used to determine the -20 dB bandwidth points.

Ch 5 (-75 dBm) RSSI: 2522

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	1395	1394	1485	1809	2357	2522	2370	1809	1411	1395

Ch 5 (-95 dBm) RSSI: 1987

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	1425	1427	1425	1965	1818	1987	1837	1430	1423	1422

Inject a CW signal at -75 dBm into BS RF port J42 on channel 5, 403.650 MHz (+/- 10 kHz) and read MCU RSSI measurement with the BsDiag status command.
Lower the signal generator frequency until the channel 5 RSSI value matches the -95 dBm RSSI value within 10 ADC counts and record the Minus Signal Generator Frequency.

Ch 5 (-75 dBm) RSSI: 1982 Minus Signal Generator Frequency: 403.265 kHz

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	1405	1477	1725	2495	2792	1982	1724	1897	1395	1392

Raise the signal generator frequency until the channel 5 RSSI value matches the -95 dBm RSSI value within 10 ADC counts and record the Plus Signal Generator Frequency.

Ch 5 (-75 dBm) RSSI: 1988 Plus Signal Generator Frequency: 403.942 kHz

Channel	0	1	2	3	4	5	6	7	8	9
RSSI	1796	1391	1399	1507	1812	1988	2534	2349	1810	1402

Monitor system bandwidth:
Subtract the Minus Signal Generator Frequency from the Plus Signal Generator Frequency:

(fo Plus) 403.942 - (fo Minus) 403.265 = 677 kHz

Verify Monitor System Bandwidth is ≥ 300 kHz: PASS

Verify Monitor System Bandwidth ≥ Emission Bandwidth: PASS
Note: VR068 document is source of emission bandwidth.

8.3.3 Monitoring System Scan Cycle Time ≤ 5 seconds.

Connect oscilloscope to J6, Pin12, RSSI.

Initiate an RF communication session by issuing a Start Session command from BsDiag.
Verify the RSSI scope display that all 10 channels were scanned, 10 pulses. See figure 1.
The RSSI scope display will update every 5 seconds.
Verify BS is transmitting on Spectrum Analyzer. The Spectrum display will drop every 5 seconds to re-evaluate the LIC and may come up on another channel.

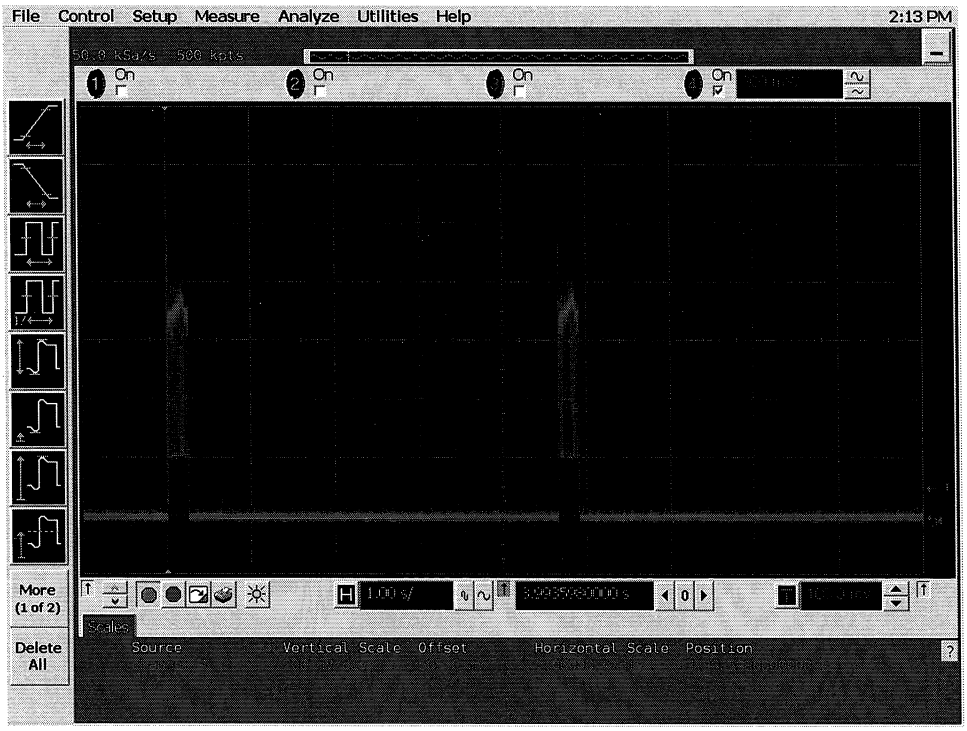
Scope settings:

Trigger:	Positive
Horizontal:	1 second/div
Vertical:	200 mV/div
Trigger Mode:	Triggered

Adjust 0V line to one graticule from bottom of screen.
Measure the time from the beginning of one 10 channel scan to the next 10 channel scan.

Record the time and verify it is less than ≤ 5 seconds: 4.65 seconds.

Sample Display



Example of Scan Cycle Time Scope Display. 1 sec/div, 200 mV/div

8.3.4 Minimum Channel Monitoring Period ≥ 10 msec.

Using the setup in step 3, expand the horizontal display and measure each of the 10 channel RSSI scans and verify they are each ≥ 10 msec.

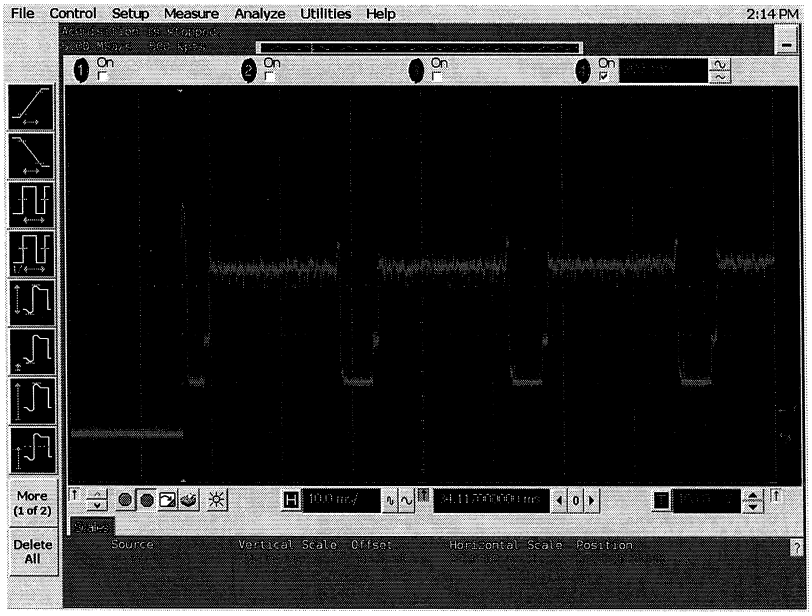
Scope settings:
Horizontal: 5 msec/div

Scroll horizontally thru each channels scan pulse; measure and record each scan pulse width.

Channel	0	1	2	3	4	5	6	7	8	9
Width msec	18.63	18.63	18.63	18.63	18.97	18.18	18.41	18.30	18.41	18.41

Verify all 10 channels monitoring period is ≥ 10 msec: PASS

Sample Display



Example of Channel Monitoring Period Scope Display. 10 msec/div, 200 mV/div

8.3.5 Discontinuation of RF Session after ≤ 5 second silent period.

Monitor BS RF output from J42 thru a 20 dB Directional Coupler to Spectrum Analyzer. Connect J42 Thru connection to a NS PCB to establish a link.

Spectrum Analyzer settings:
Increase the RBW to 4 MHz to capture RF on any channel in the MICS band. Increase sweep time to 7.5 seconds to capture the 5 second dropouts in BS transmission.

RBW	4MHz
Center Freq.	403.650 MHz
Span	3 MHz
Sweep time	30 msec

Initiate a RF communication session with No RF Link by issuing a Start Session command from BsDiag. NS PCB should be powered OFF.

Verify BS RF is transmitting on the Spectrum Analyzer.

Spectrum Analyzer settings:

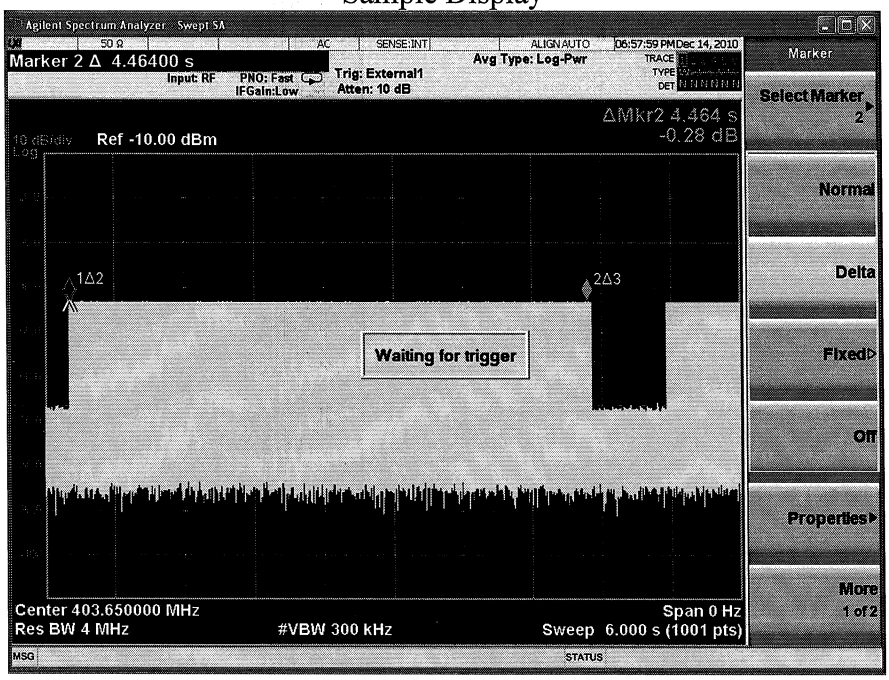
SPAN:	Zero Span
Trigger:	Video

Adjust trigger level for a stable video pulse display.

Adjust Sweep time for 6 seconds.

Verify the BS stops transmitting and re-evaluates the MICS band LIC in a period ≤ 5 second with No RF Link. PASS 4.630c

Sample Display



Example of Spectrum Analyzer display.

Initiate a RF communication session with a RF Link by issuing a Start Session command from BsDiag. NS PCB should be powered ON.

Verify BS RF is transmitting on the Spectrum Analyzer.

Spectrum Analyzer settings:

SPAN: Zero Span

Trigger: Video

Adjust trigger level for a stable video pulse display.

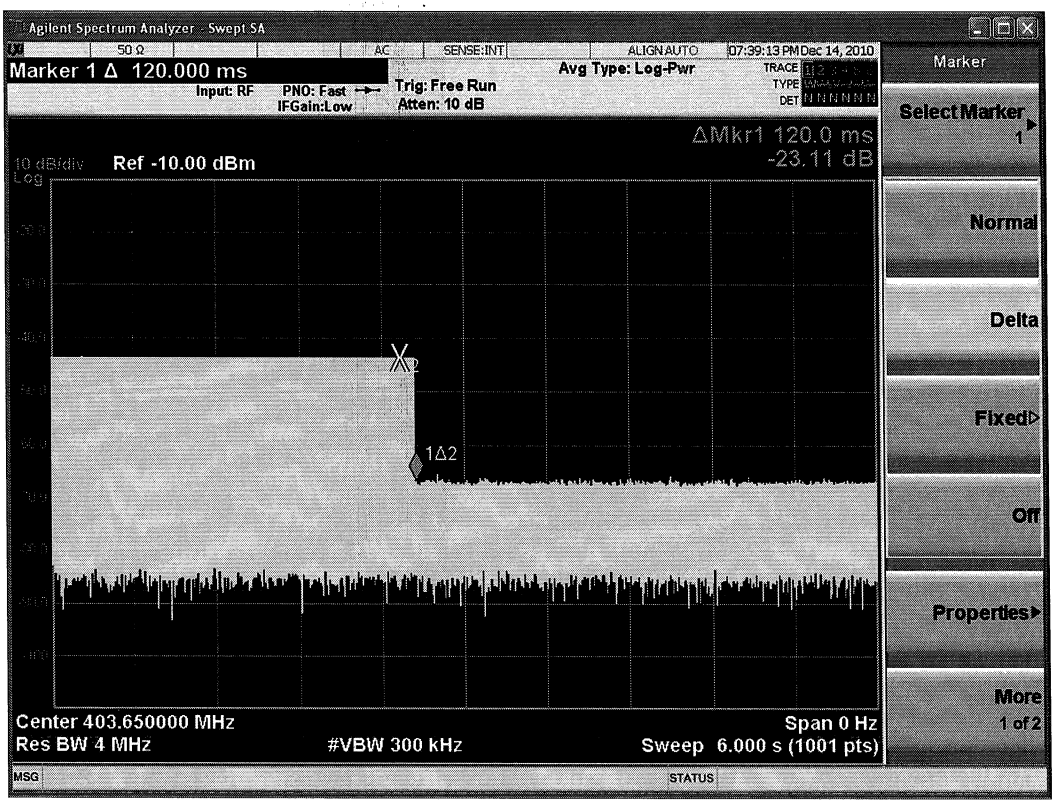
Adjust Sweep time for 6 seconds.

Verify the BS is transmitting and RF Link is continuously maintained.

Set Spectrum Analyzer Trigger to Single Sweep and wait 1 second to shutdown NS PCB power supply.

Verify BS stop transmitting in ≤ 5 seconds. PASS 4.36 sec

Sample Display


Agilent Spectrum Analyzer - Swept SA
50 Ω
AC
SENSE:INT
ALIGN AUTO
07:39:13 PM Dec 14, 2010
Marker 1 Δ 120.000 ms
Input: RF
PNO: Fast
IFGain:Low
Trig: Free Run
Atten: 10 dB
Avg Type: Log-Pwr
TRACE 1 2 3 4 5 6
TYPE A WWWWW
DET N N N N N N
ΔMkr1 120.0 ms
-23.11 dB
10 dB/div
Log
Ref -10.00 dBm
1Δ2
Center 403.650000 MHz
Res BW 4 MHz
#VBW 300 kHz
Span 0 Hz
Sweep 6.000 s (1001 pts)
MSG
STATUS
Marker
Select Marker
1
Normal
Delta
Fixed
Off
Properties
More
1 of 2