



Public Safety Communications Research

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Outline

- A little PSCR history
- Infrastructure Testing
 - 3GPP Tests
 - PSCR Tests
 - PSCR Demos
- The Next Step

The Beginning

- December, 2008 – LTE America's Conference
 - Las Vegas, Nevada
 - 24 Participants!

The Middle

- June 2009
 - Public Safety selects LTE as their broadband technology
- December 2009
 - Demo Network Announced
- January 2010
 - FCC adopts NPRM & selects LTE as technology platform
- February 2010
 - 3GPP Conference in San Francisco, California
- March 2010
 - Kick-Off Webinar
 - National Broadband Plan

The Middle Continued

- April 2010
 - First Stakeholder Meeting
- May 2010
 - FCC Waiver Order approves 21 initial waivers for early deployment of 700 MHz PS LTE and requires waiver certification of vendor participation in PSCR Demo Network
 - Visits to Infrastructure and Test Equipment Providers
- September 2010
 - First LTE System on Campus
 - Manufacturer Testing Begins
- December 2010
 - Second Stakeholder Meeting

Most Recently

- February 2011
 - PSCR Testing Begins
- June 2011
 - Second System On Campus
 - Third System On Campus
- September 2011
 - Phase One Test Plan Draft Released
- October 2011
 - Phase Two Test Plan Draft Released

Last Week

- February 2012
 - Public Safety Gets D-Block

Test Plan History

- Two types of tests: Demonstration and Evaluation.
- The end user's perspective of the LTE network differs from the engineer.
- Demonstration
 - Demonstration tests are tests that illustrate the end user experience. These tests include application level tests as well as some functional, operational, and interoperability tests.
 - Primarily qualitative tests
- Evaluation
 - Evaluation tests examine the systems ability to meet particular engineering criteria. These tests may involve specialized software or instrumentation and are typically quantitative rather than qualitative in nature.

Demonstration Tests

- The demonstration tests are primarily application level tests that are designed to display the capability of the end user experience.
- These tests are designed specifically to emulate public safety (PS) tasks and typify the end user experience.
- These test are primarily derived from the 700MHz Broadband (BB) Statement of Requirements (SoR) v0.6 and the 700MHz Broadband Task Force (BBTF) Final v1.1 Report.

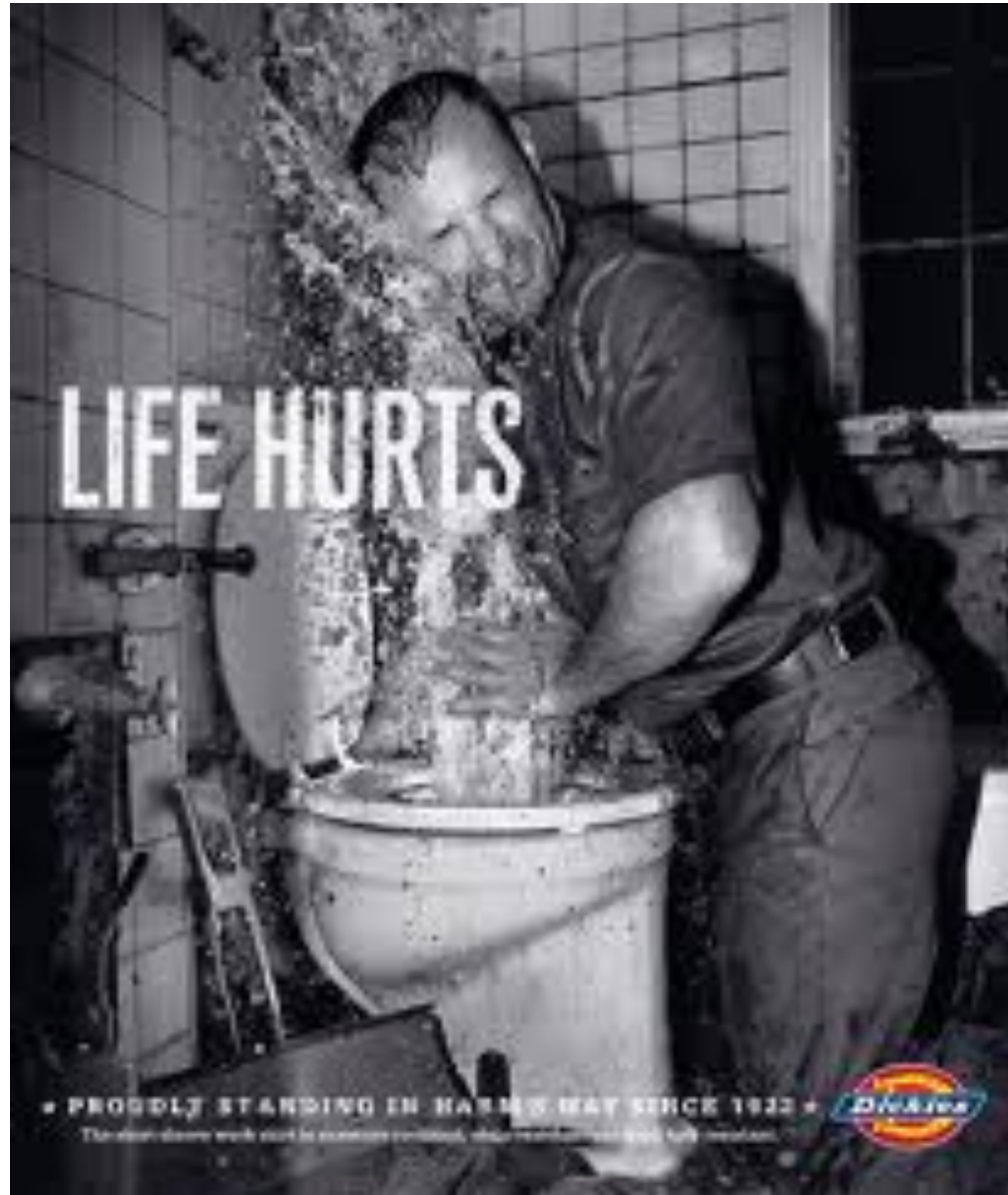
Evaluation Tests

- Originally over 650 3GPP Tests – most were related to eNodeB and UE
- Generally quantitative in nature
- Primary Sources:
 - Release 8 3GPP Documents
 - TS 36.141 - BS Conformance Tests
 - TS 36.143 - FDD Repeater Performance
 - TS 36.521-X - Ue Rx & Tx Conformance
 - TS 36.523-X - Ue Protocol Conformance
 - TS 36.903 – Radio Resource Management (RRM) Conformance; Doesn't exist for R8
 - Publicly Available Verizon Test Plan
 - Compliance test document published in February 2010

PSCR Tests

- Distilled Evaluation Tests and Demonstration Tests into about 162 PSCR Tests
- Most tests concern eNodeB and EPC
- 3 Phases
 - Phase 1
 - Generally nonradiated w/ one exception, eNodeB
 - Phase 2
 - Generally nonradiated, eNodeB, some EPC
 - Phase 3
 - Includes some RF network testing

Testing



Phase One



PSCR

Public Safety Communications Research

LTE Demonstration Network Test Plan

Phase 1: Basic Functionality Tests

Version 1.22

September 12, 2011



The Phase One Tests

- eNodeB Receiver/Transmitter Tests (4)
 - Interference Immunity
 - Out-of-Band Emissions
- Messaging/Protocol Tests (3)
 - Attach, Detach, IP Connectivity
- Applications Tests (9)
 - Various applications
- Sector Characterization Test (1)
 - Radiated, Real World Environment

Applications Tests

- Web Browser
- File Transfer (Up/Down)
- Email
- VPN
- Voice (Mobile Originate/Terminate)
- Instant Message
- Database

Phy & App Results

Test Case Number	Test Case Title	System Under Test		
		Test Completed		
Section 6	Physical Layer Tests	System 1	System 2	System 3
Section 7	Messaging/Protocol Tests			
7.1	Authentication Procedure	Yes	Yes	Yes
7.2	Detach Procedure	Yes	Yes	Yes
7.3	Verification of IP Connectivity	Yes	Yes	Yes
Section 8	Application Tests			
8.1	Internet Access Test Web Browsing	Yes	Yes	Yes
8.2	Internet Access Test - File Transfer Downlink (DL)	Yes	Yes	Yes
8.3	Internet Access Test - File Transfer Uplink (UL)	Yes	Yes	Yes
8.4	Internet Access Test - Email	Yes	Yes	Yes
8.5	Secure Data - VPN Access & Traffic	Yes	Yes	Yes
8.6	Basic Voice Test - MO IP Call	Yes	Yes	Yes
8.7	Basic Voice Test - MT IP Call	Yes	Yes	Yes
8.8	Message Test - Instant Message	Yes	Yes	Yes
8.9	Strategic Data - DB Transactions	Yes	Yes	Yes

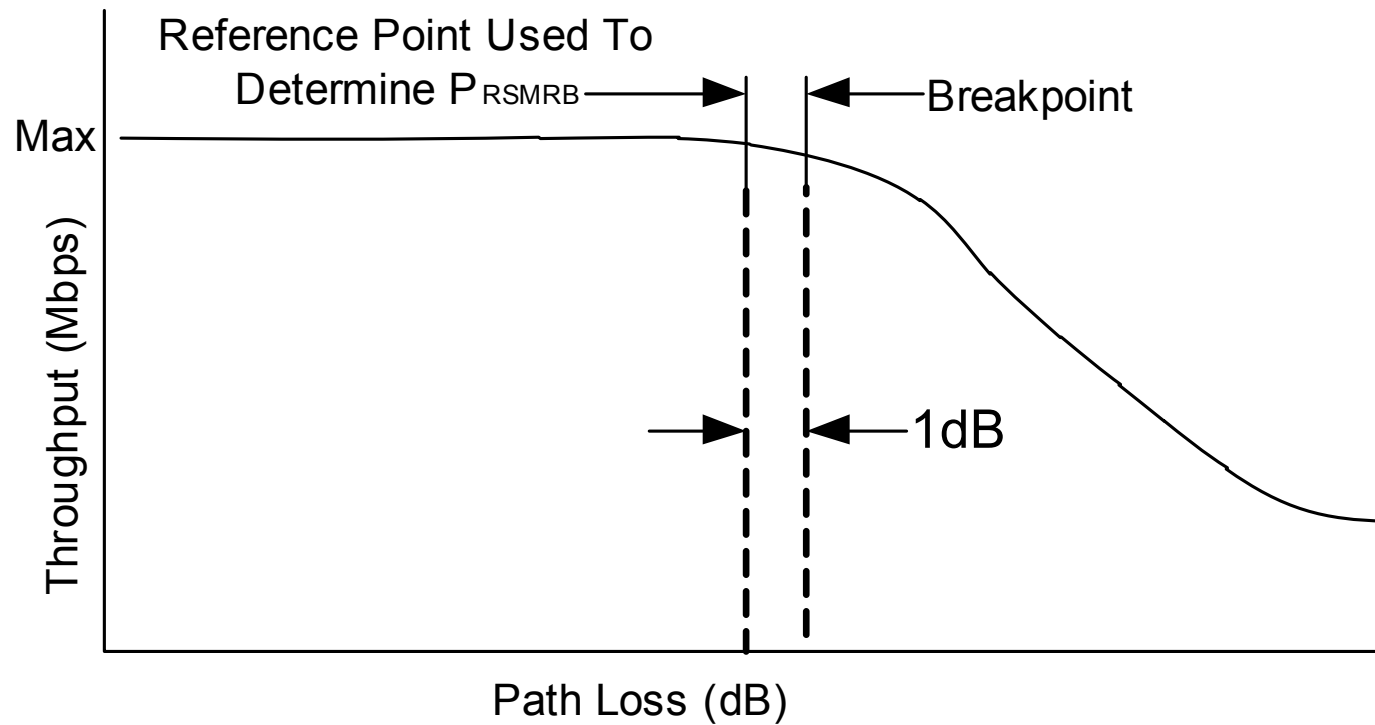
RF Results

Test Case Number	Test Case Title	System Under Test		
		Test Completed		
Section 6	Physical Layer Tests	System 1	System 2	System 3
6.1	Reference Sensitivity at Maximum RB - eNB Receiver	Yes	Yes	Yes
6.2	Adjacent Band Interference Into the eNB Receiver	Yes	Yes	Yes
6.3	eNB Spectral Characteristics	Yes	Yes	Yes
6.3.1	In-Band	Yes	Yes	Yes
6.3.2	Out of Band	Yes	Yes	Yes
6.3.3	Spurious Emissions	Yes	Yes	Yes
6.3.4	Channel Power	Yes	Yes	Yes
Section 9	Performance Tests			
9.1	Basic Cell Throughput - Throughput vs. Cell Location	Yes	Yes	Yes

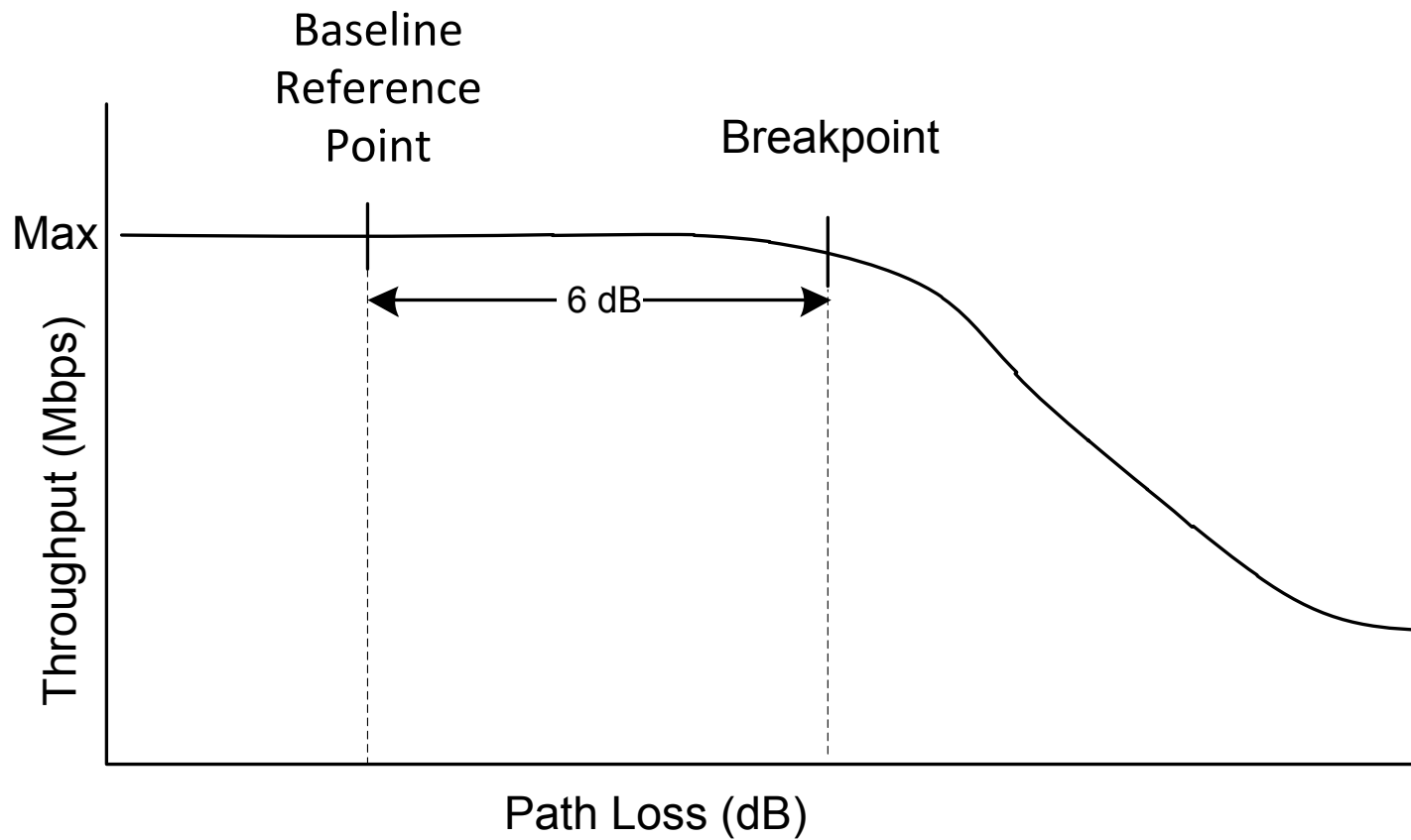
eNodeB Receiver Tests

- **Reference Sensitivity Level at Maximum RB**
 - The reference sensitivity power level at maximum RB allocation (P_{RSMRB}) is the minimum power received at the antenna connector for a specified reference measurement channel. This test is designed to baseline the capabilities of the BS.
 - The purpose of the test is to determine the BS Reference sensitivity level at maximum RB allocation, the throughput at that power level and the breakpoint criteria.

Reference Point Determination



Test Operating Point



Adjacent Band Interference Into the eNB

Band	Frequency	Center Frequency	Modulation
C Block UL	777 - 787 MHz	782 MHz	LTE SC-FDMA
C Block DL	746 - 756 MHz	751 MHz	LTE OFDMA
PS Narrowband UL	799 - 805 MHz	799 MHz	P25 C4FM +1011 test pattern
PS Narrowband DL	769 - 775 MHz	769 MHz	P25 C4FM +1011 test pattern

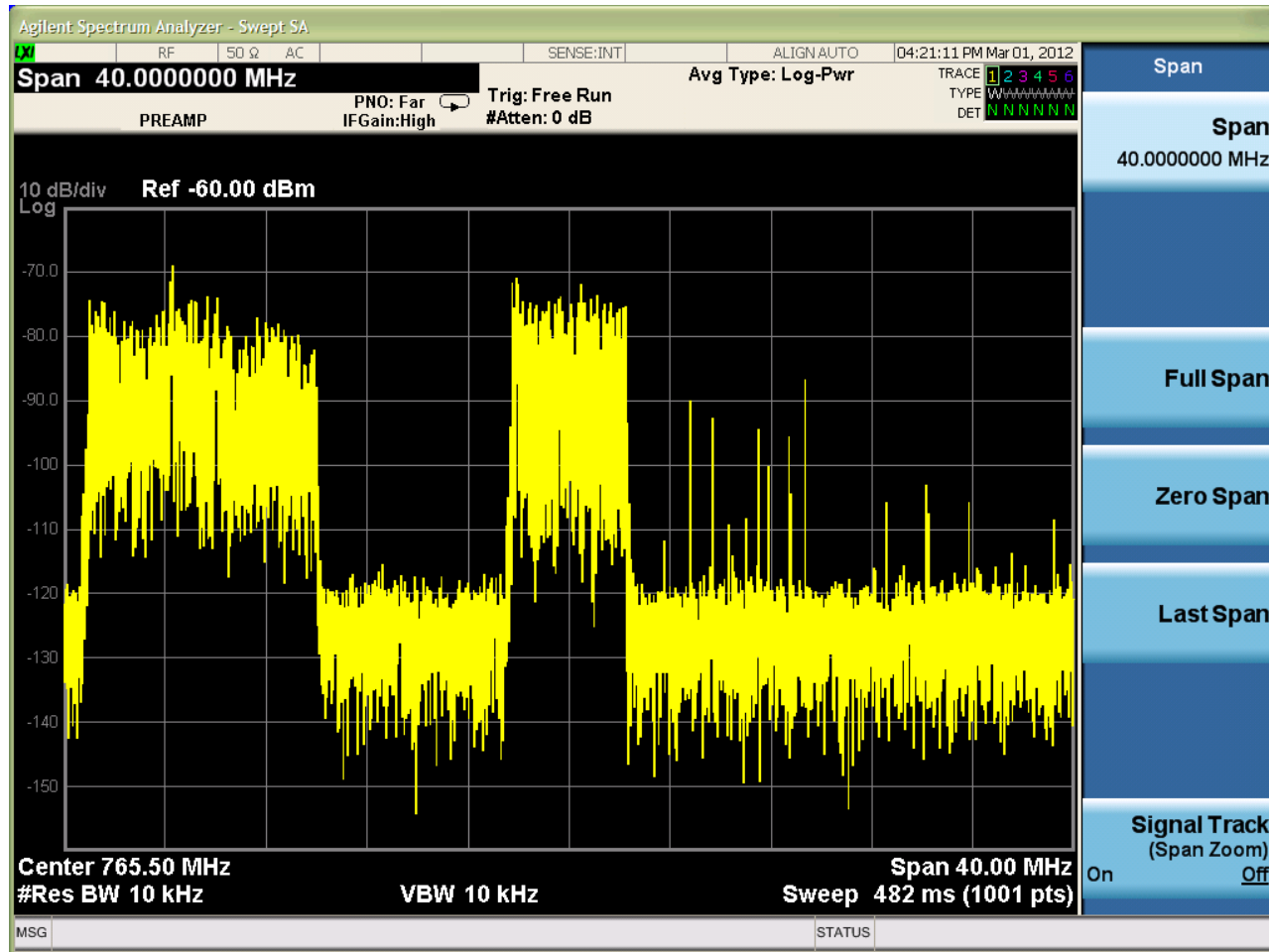
Lab Antenna



Lab Antenna



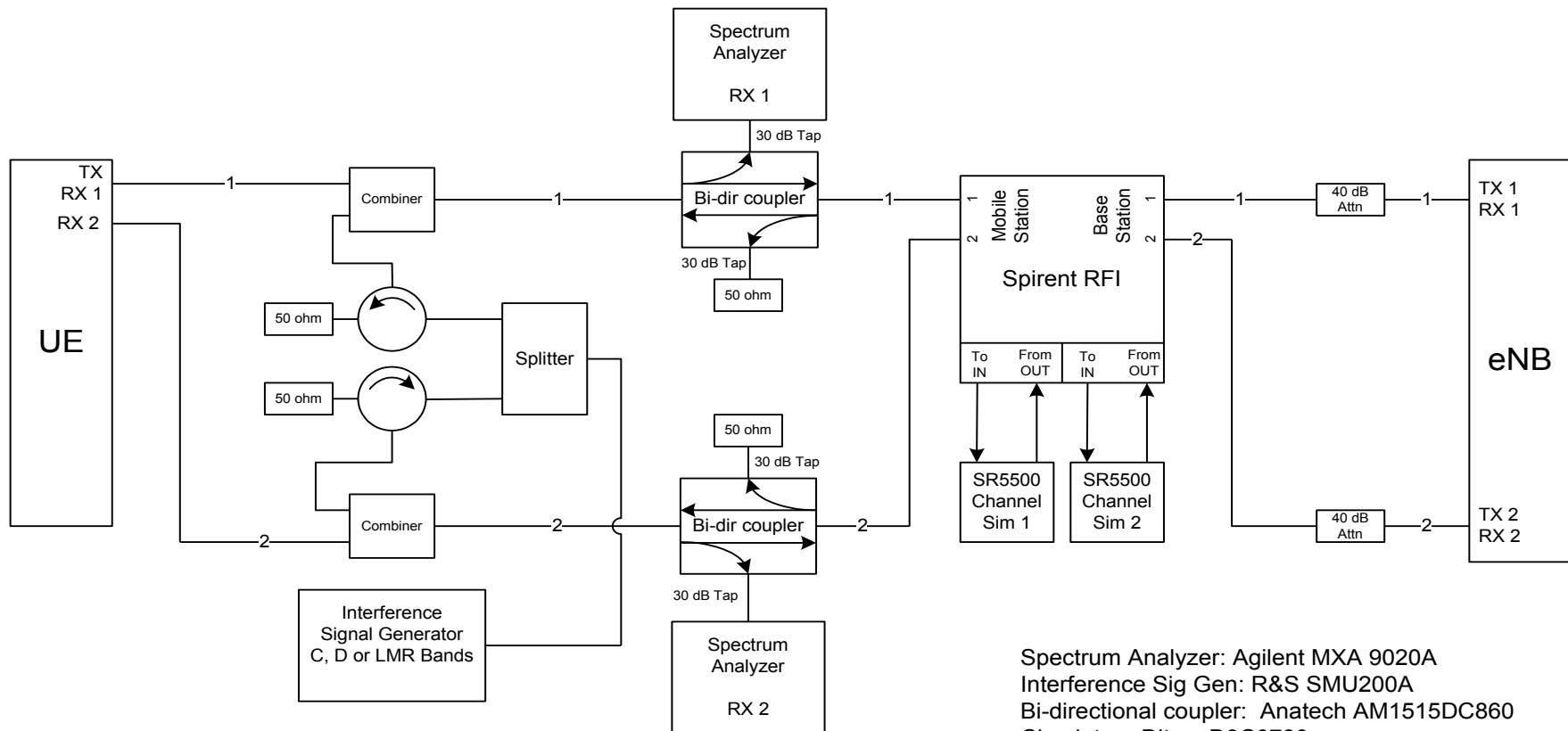
Measured Signal Spectrum



3GPP Test Setup

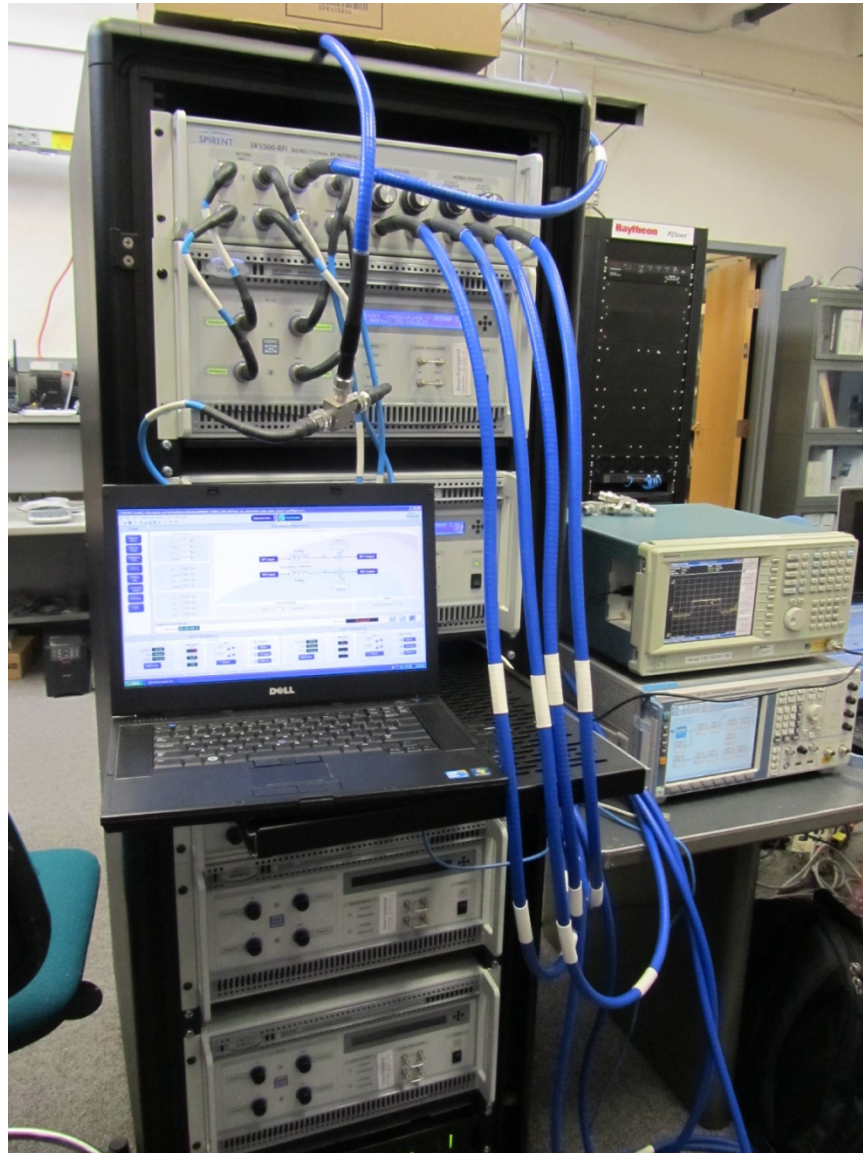


PSCR Test Setup



Spectrum Analyzer: Agilent MXA 9020A
 Interference Sig Gen: R&S SMU200A
 Bi-directional coupler: Anatech AM1515DC860
 Circulator: Ditom D3C0780
 Splitter/Combiner: AEI AM505PD1018-N

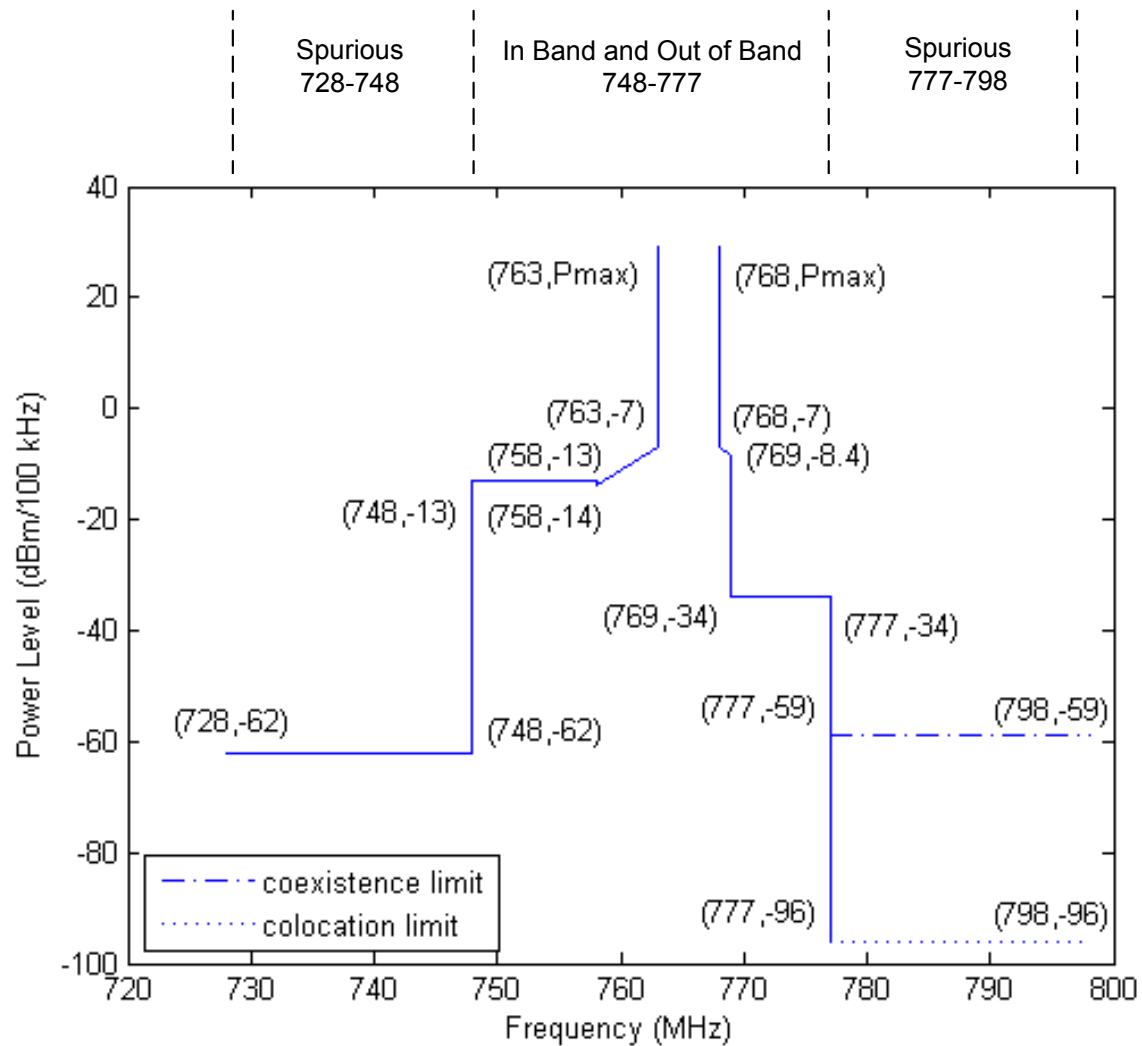
Channel Emulator



eNodeB Transmitter Testing

- We use a test waveform (E-TM1.1, E-TM1.2) if possible, or a 64 QAM modulated waveform if test waveforms are unavailable
- We test in-band channel power, out-of-band power (edge frequency +/- 10 MHz), and spurious emissions (> 10 MHz offset)
- Tests use 100 kHz measurement bandwidth
- Co-existence and Co-location specifications

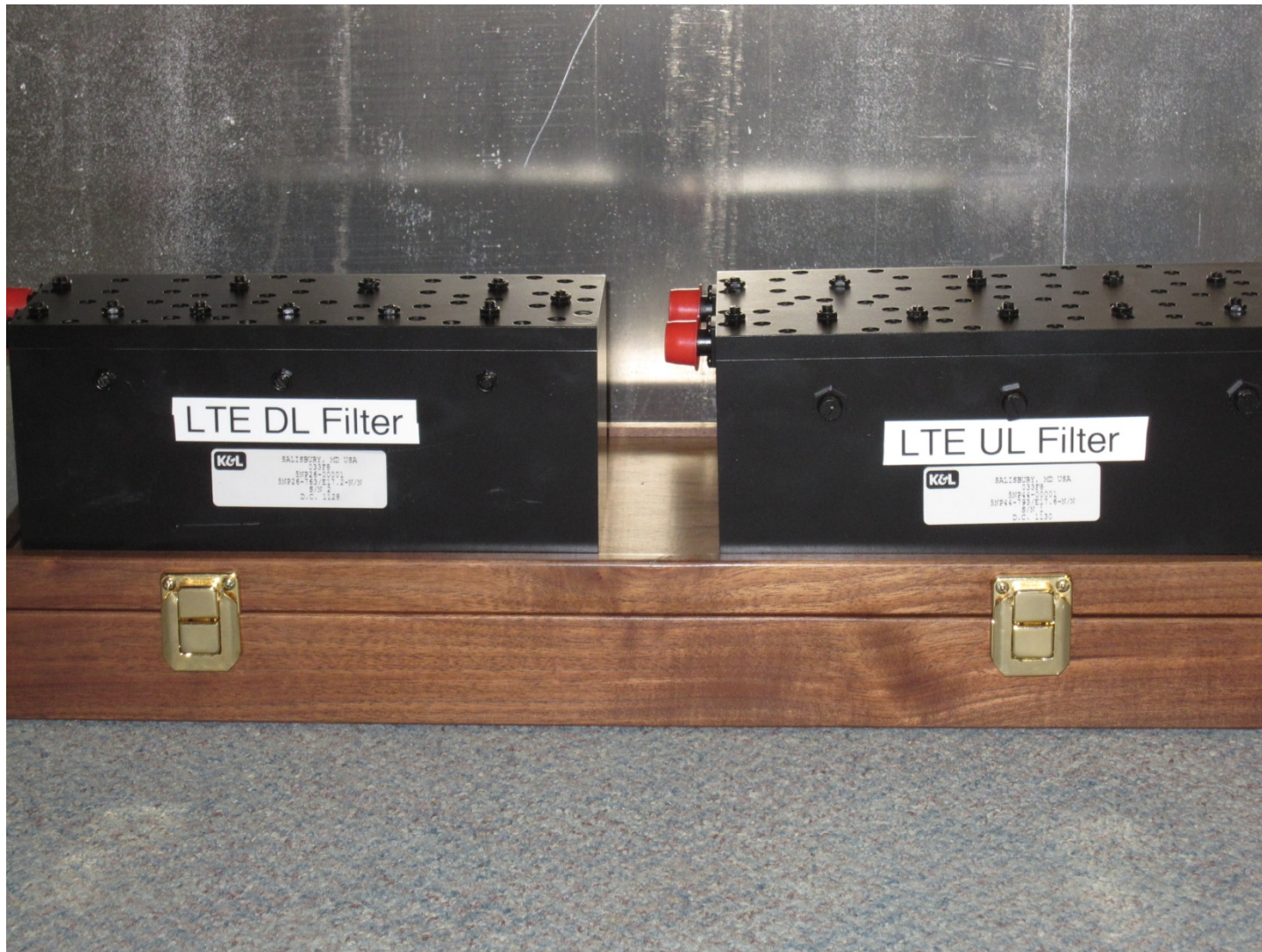
eNb 5 MHz Spectral Emissions Mask



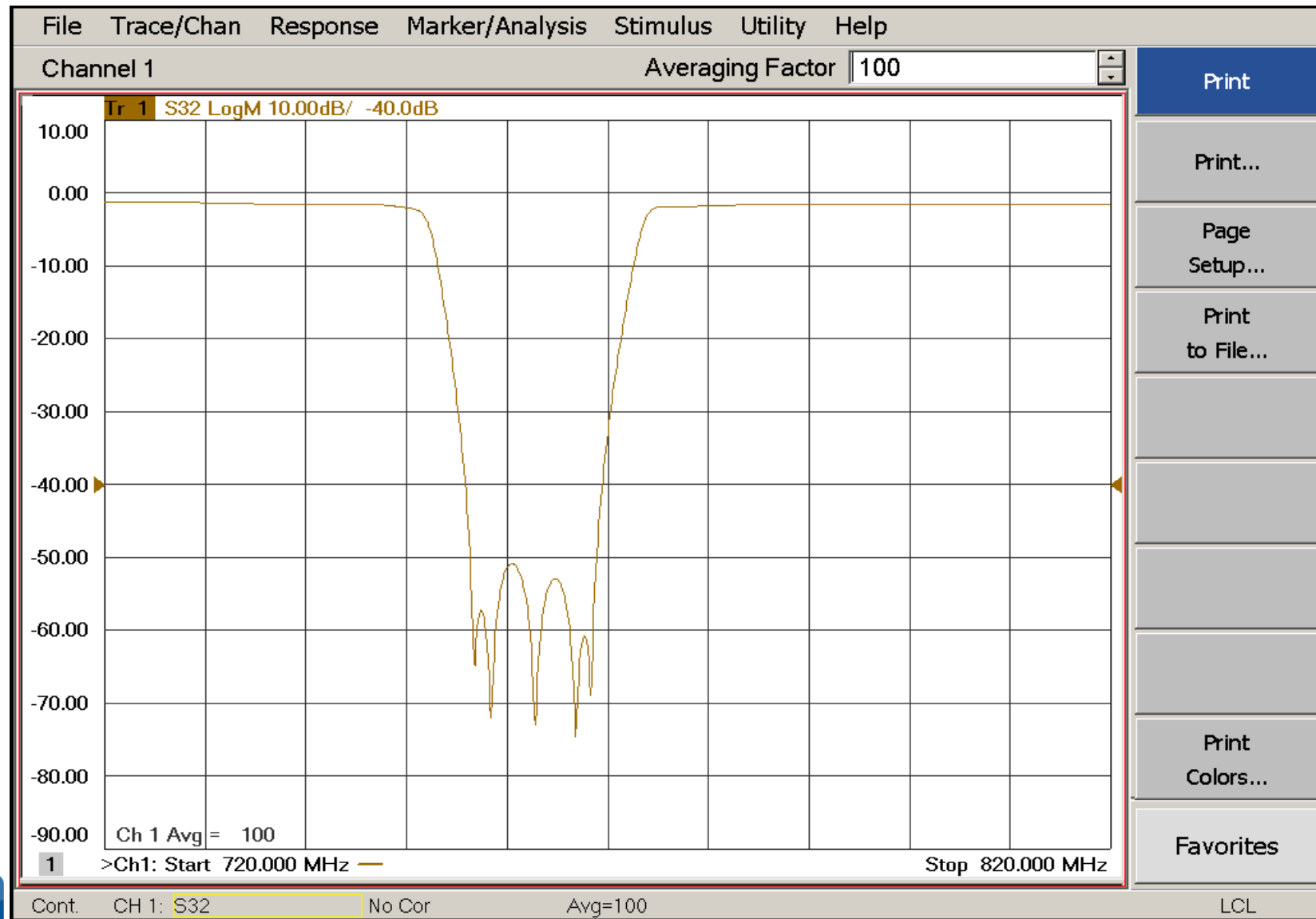
10 MHz eNB Spectral Emissions Limits

DL Frequency Bands	DL Frequency Range (MHz)	Power Level (dBm/100 kHz)	3GPP TS 36.104 version 8.8.0 Reference
In Band	758-768	Pmax	Clause 6.2.1
Out-of-Band	748-753 Lower	-14	Table 6.6.3.1-3
	753-753.7 Lower	-14 to -13	Table 6.6.3.1-3 FCC rule 27.53
	753.7-758 Lower	-13	Table 6.6.3.1-3
	768-769 Upper	-7 to -8.4	Table 6.6.4.3.1-3
	769-777 Upper	-34	
Spurious	728-748 Lower	-62	Table 6.6.4.3.1-1 with Note 1
Co-location	777-798 Upper	-96	Tables 6.6.4.2-1 and 6.6.4.4.1-1
Spurious Co-existence	728-748 Lower	-62	Table 6.6.4.3.1-1 with Note 1
	777-788 Upper	-59	Table 6.6.4.3.1-1
	788-798 Upper	-96	Table 6.6.4.2-1

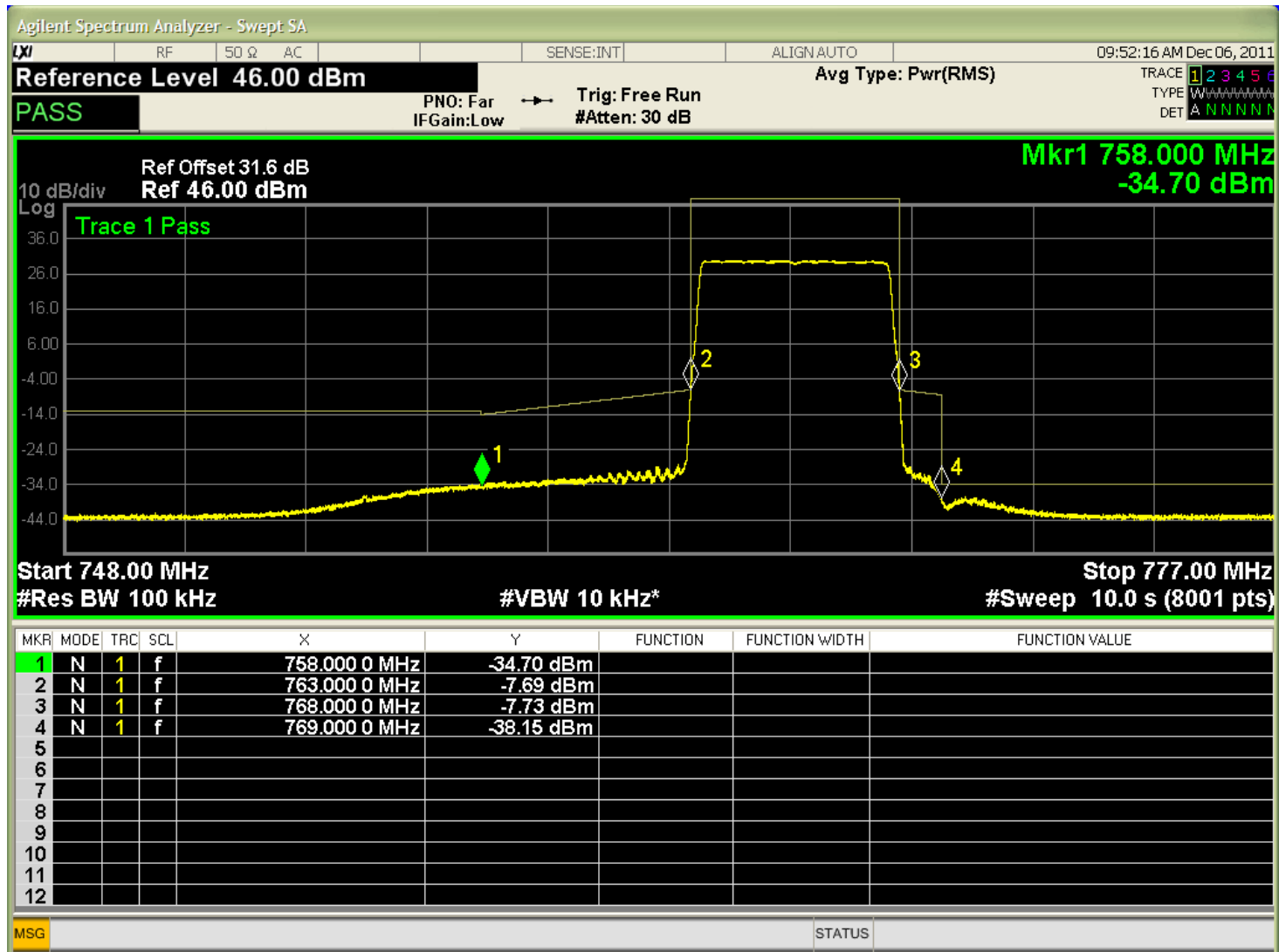
Filters



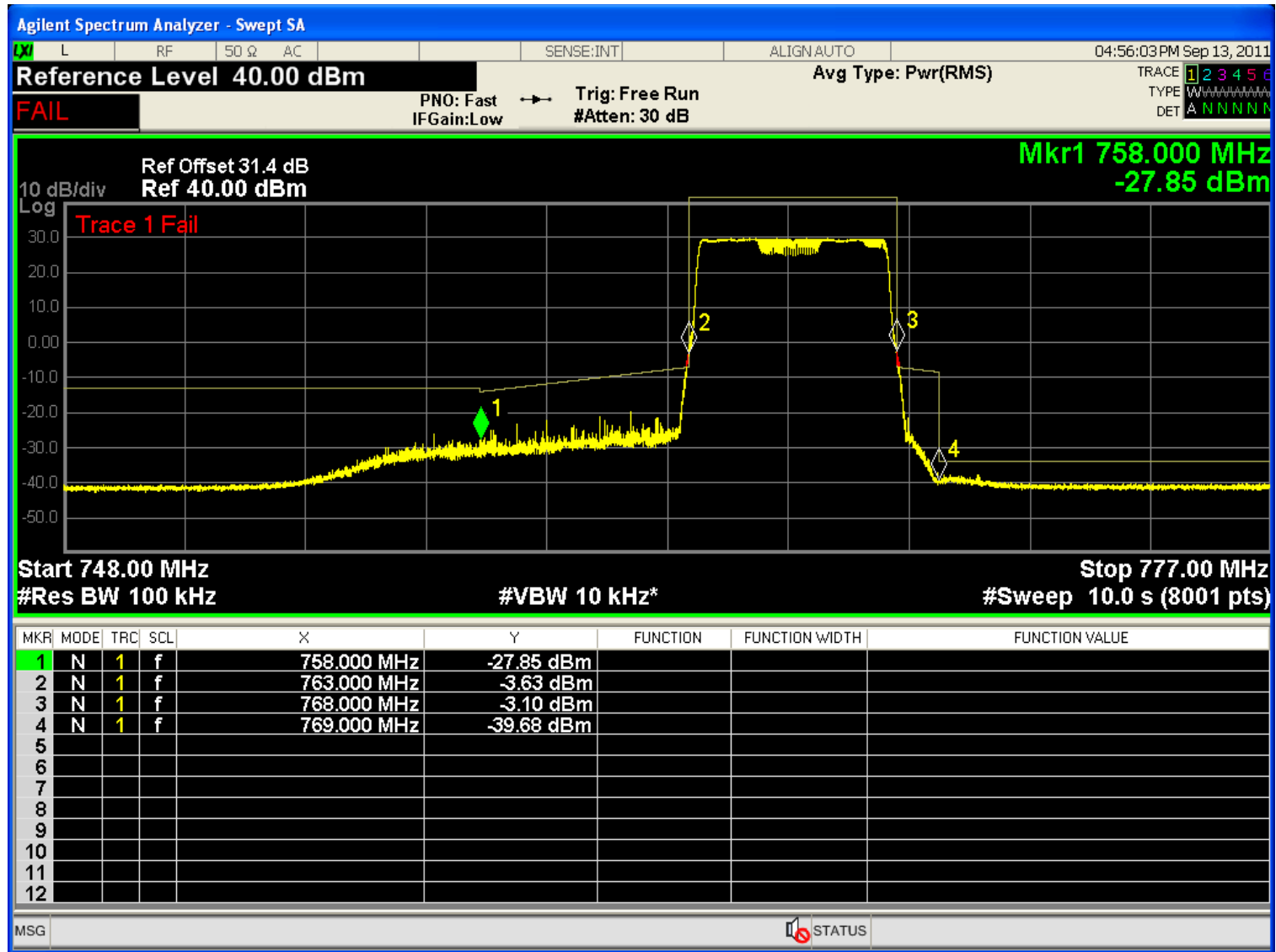
Bandstop Filter



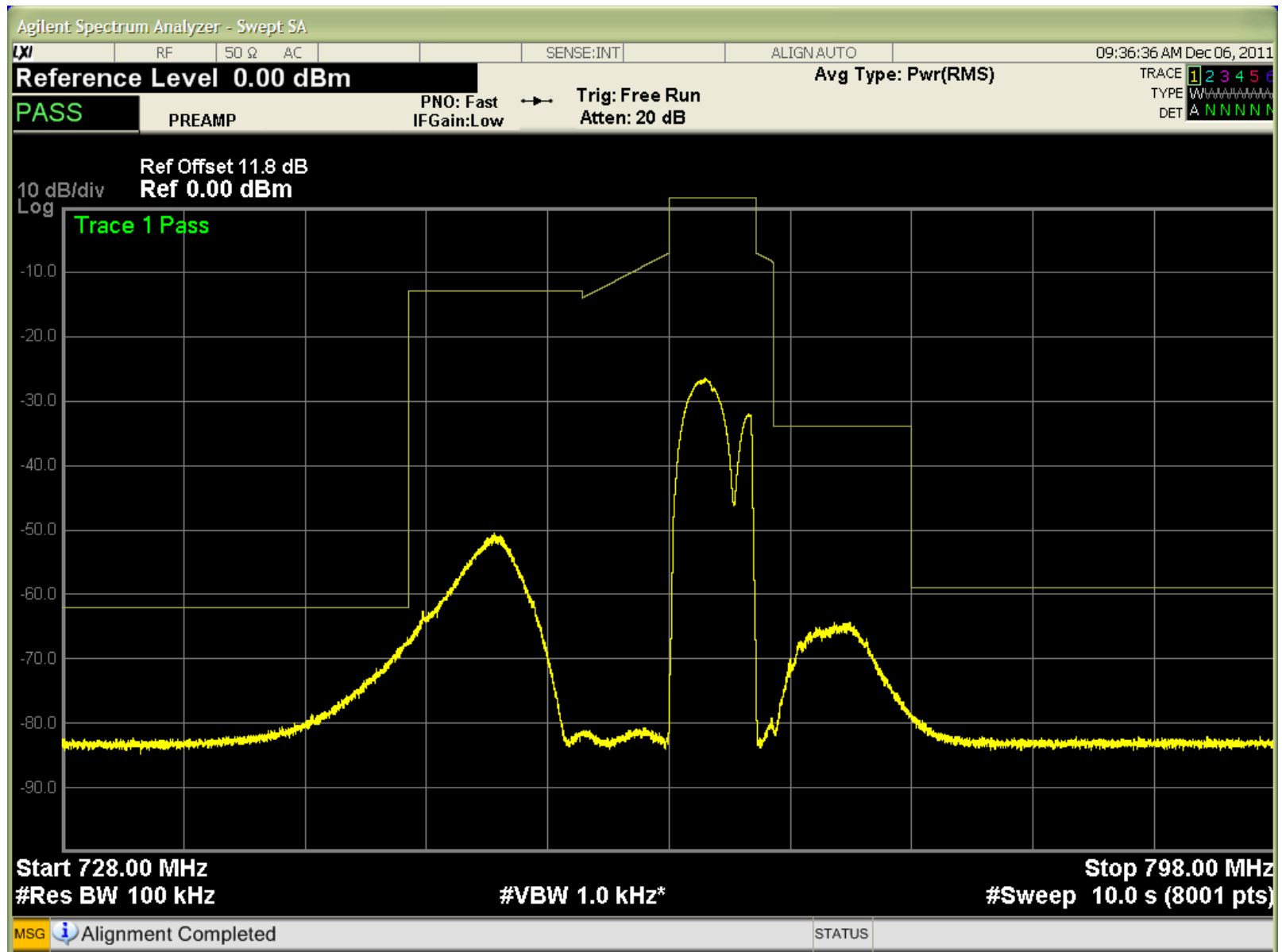
In-Band/Out-of-Band Emissions



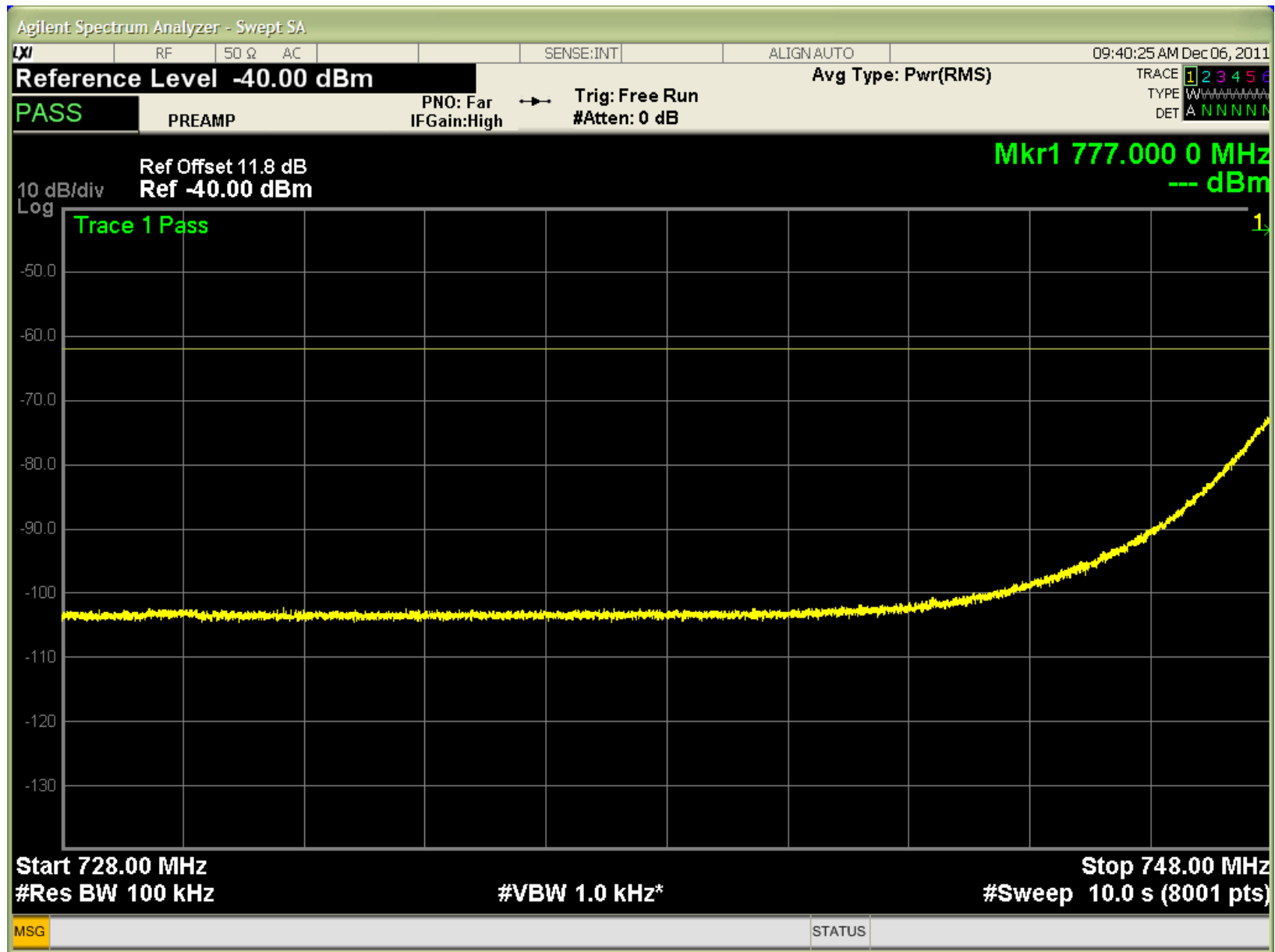
In-Band Failure



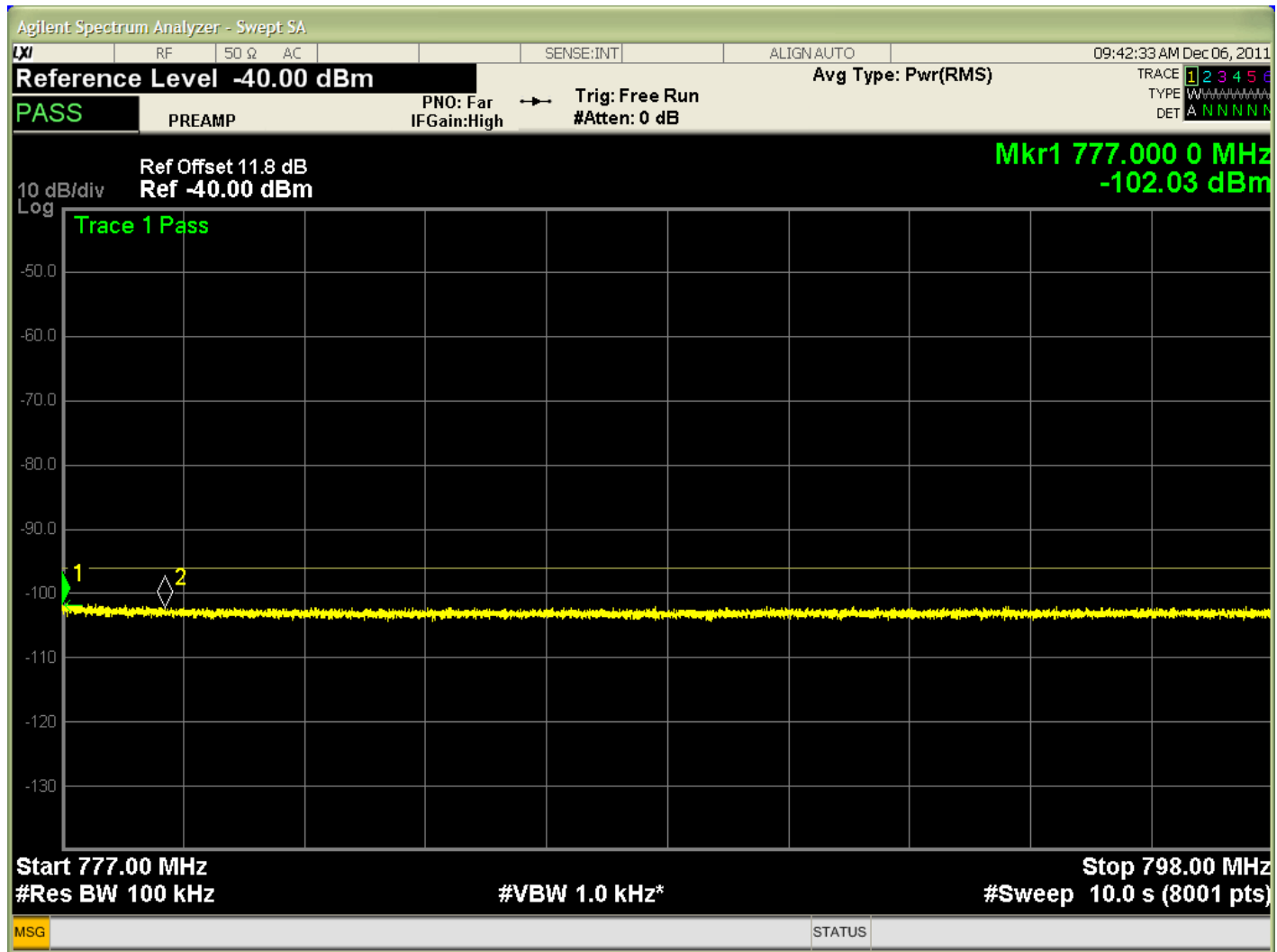
Coexistence



Colocation lower



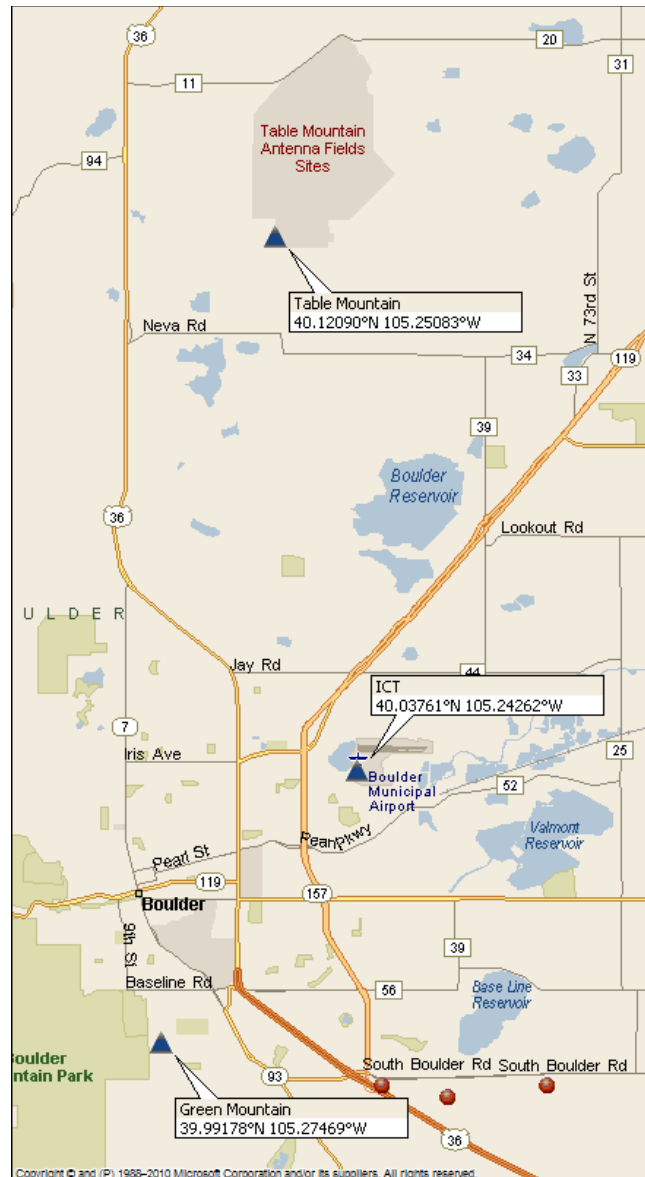
Colocation upper



Sector Characterization Test

- This test is designed to determine the throughput at near, mid, and cell edge locations.
- The near, mid and cell edge locations will be determined at the 10th, 50th and 95th percentiles of the CDF of the SNR.
- This test will be conducted between a loaded and unloaded, single sector of an eNB and a nomadic UE in the presence of co-channel interference.

Public Safety Broadband Demo Network



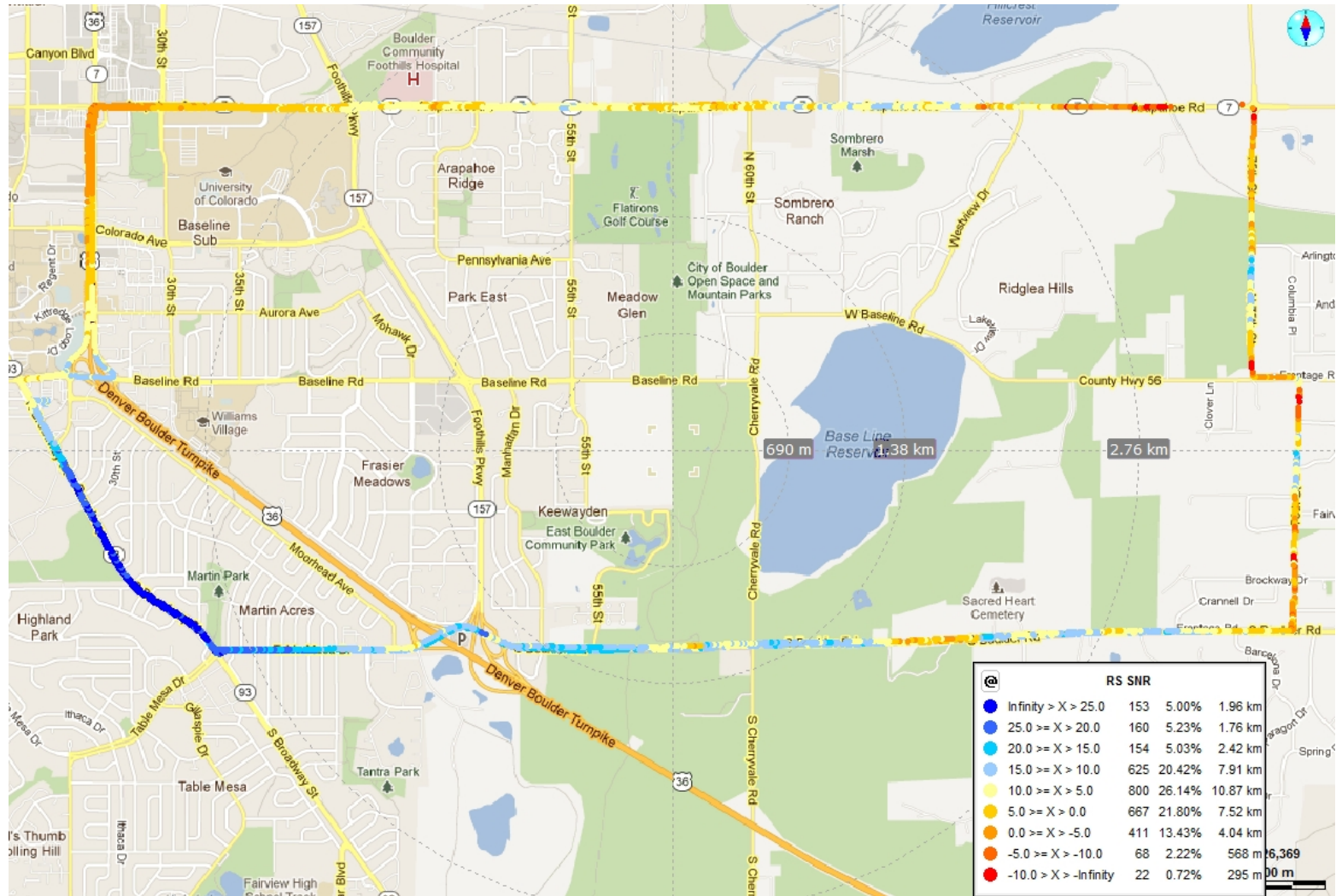
ICT/COLT



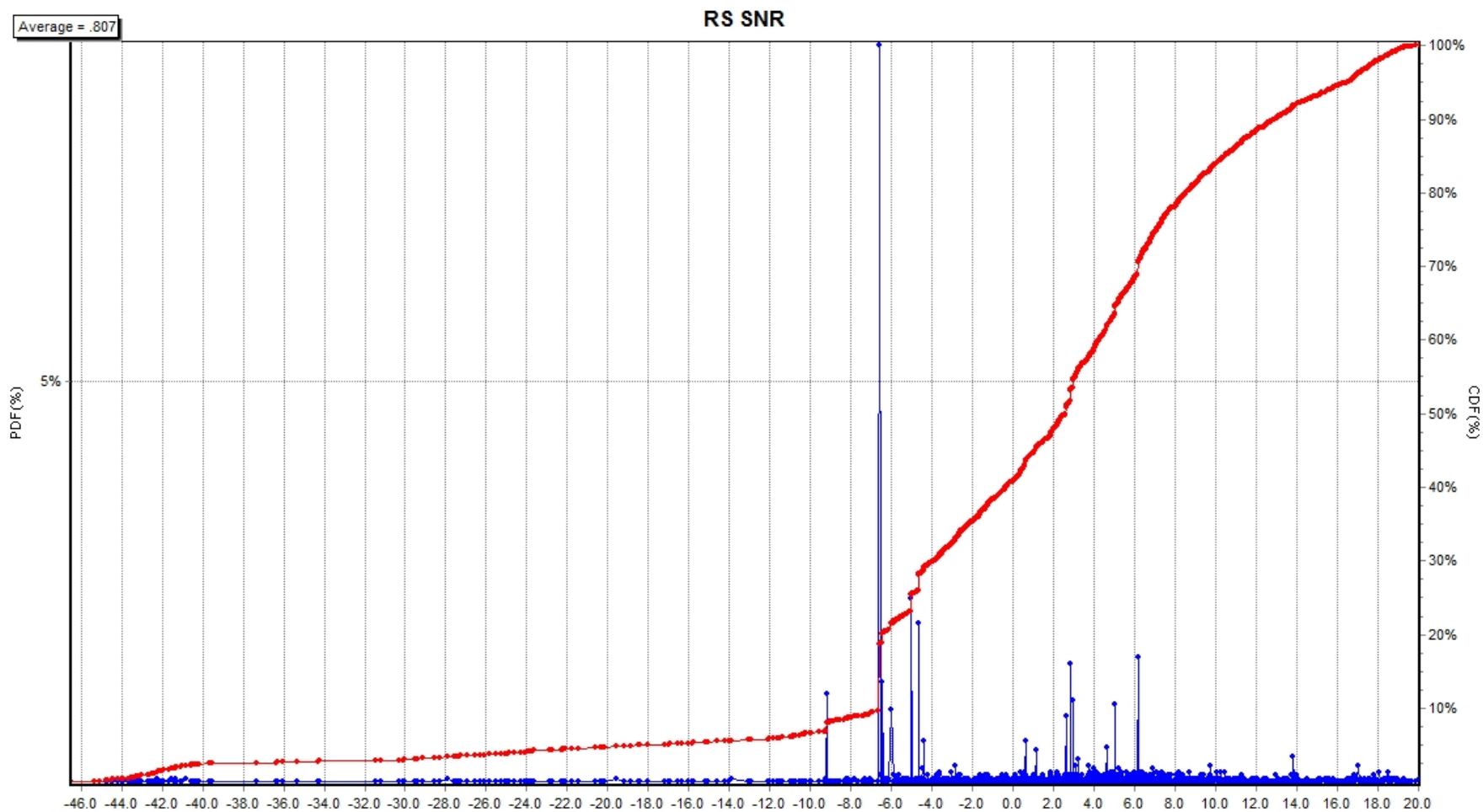
eNodeB Antennas



Drive Test Route

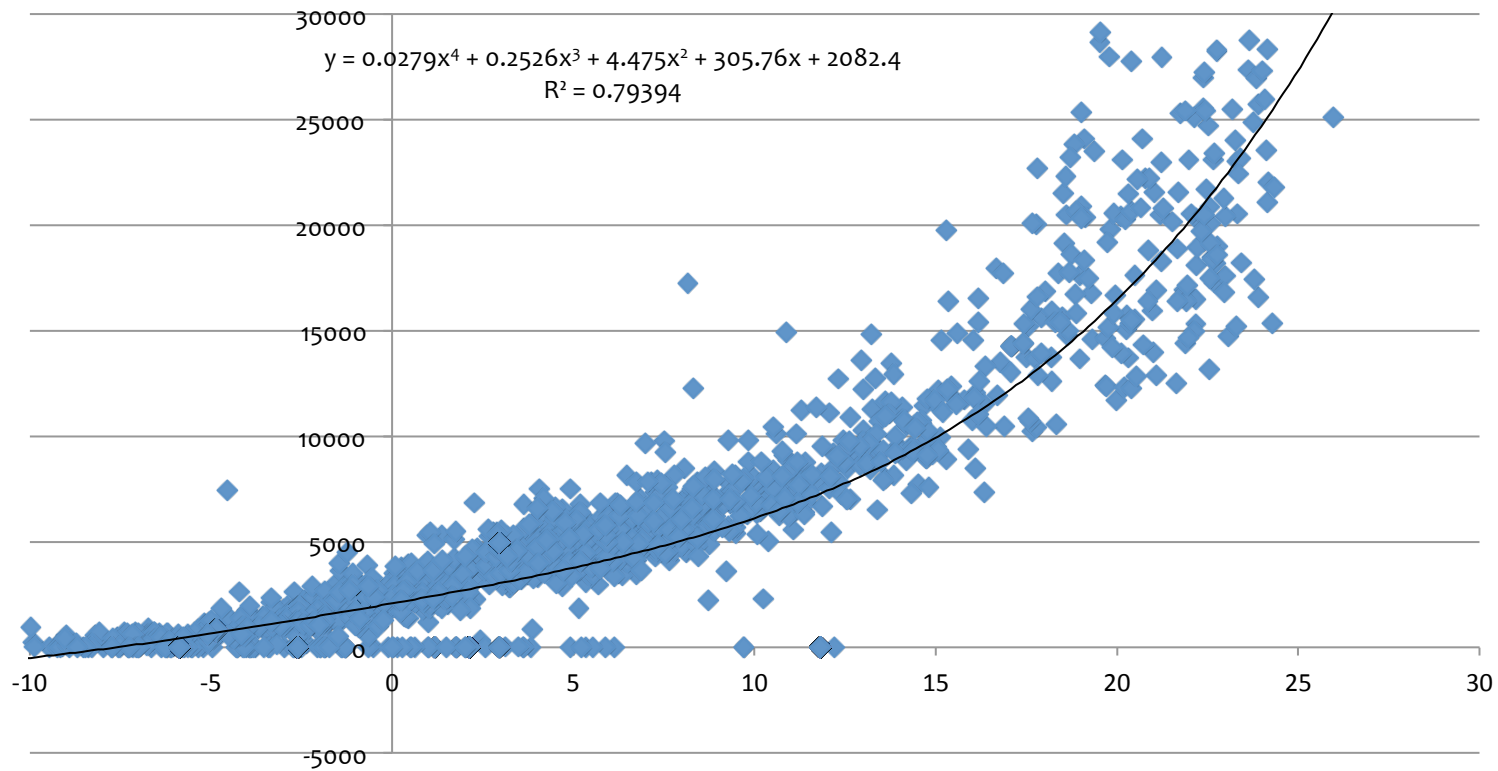


CDF of SNR Values

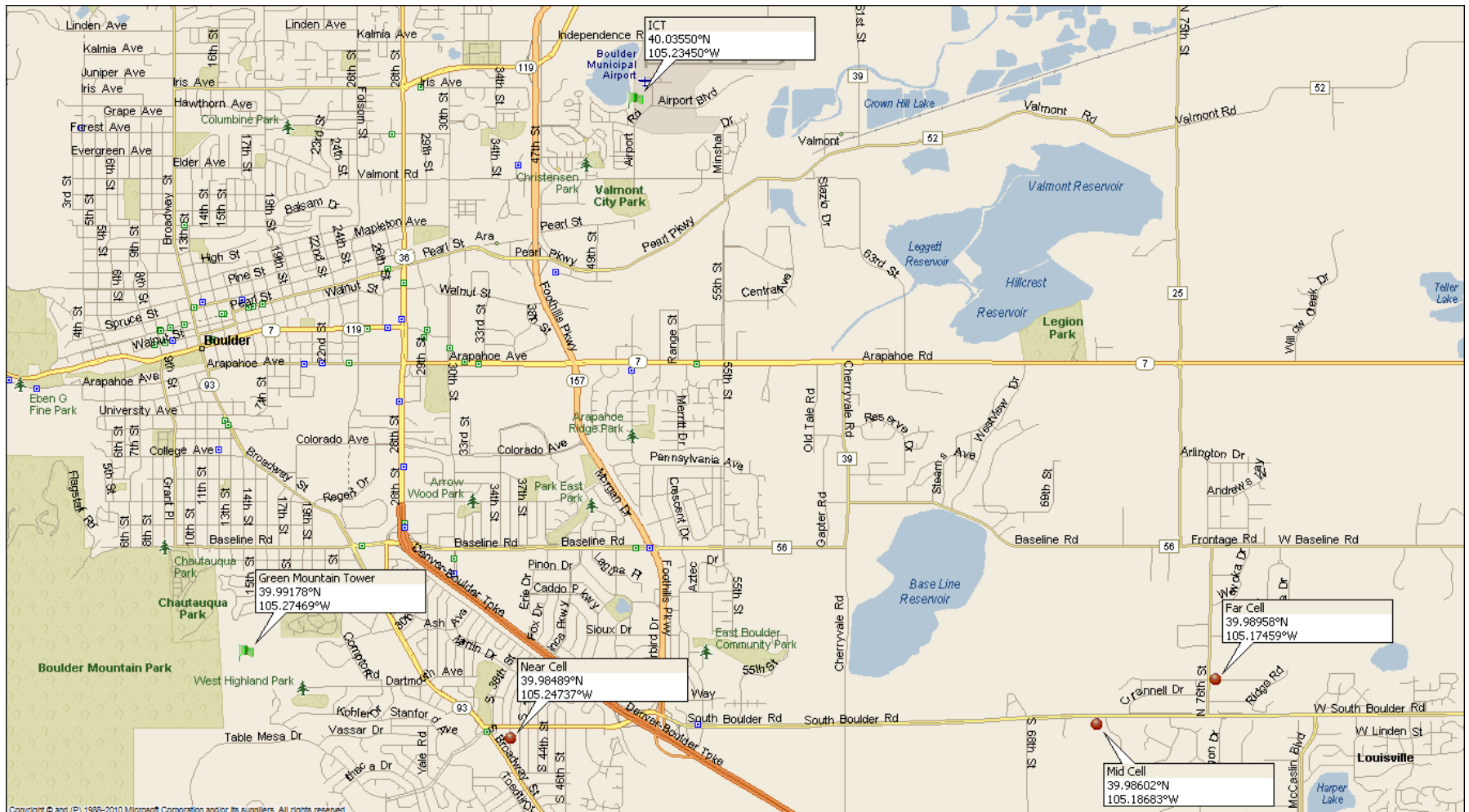


Typical Throughput versus SNR

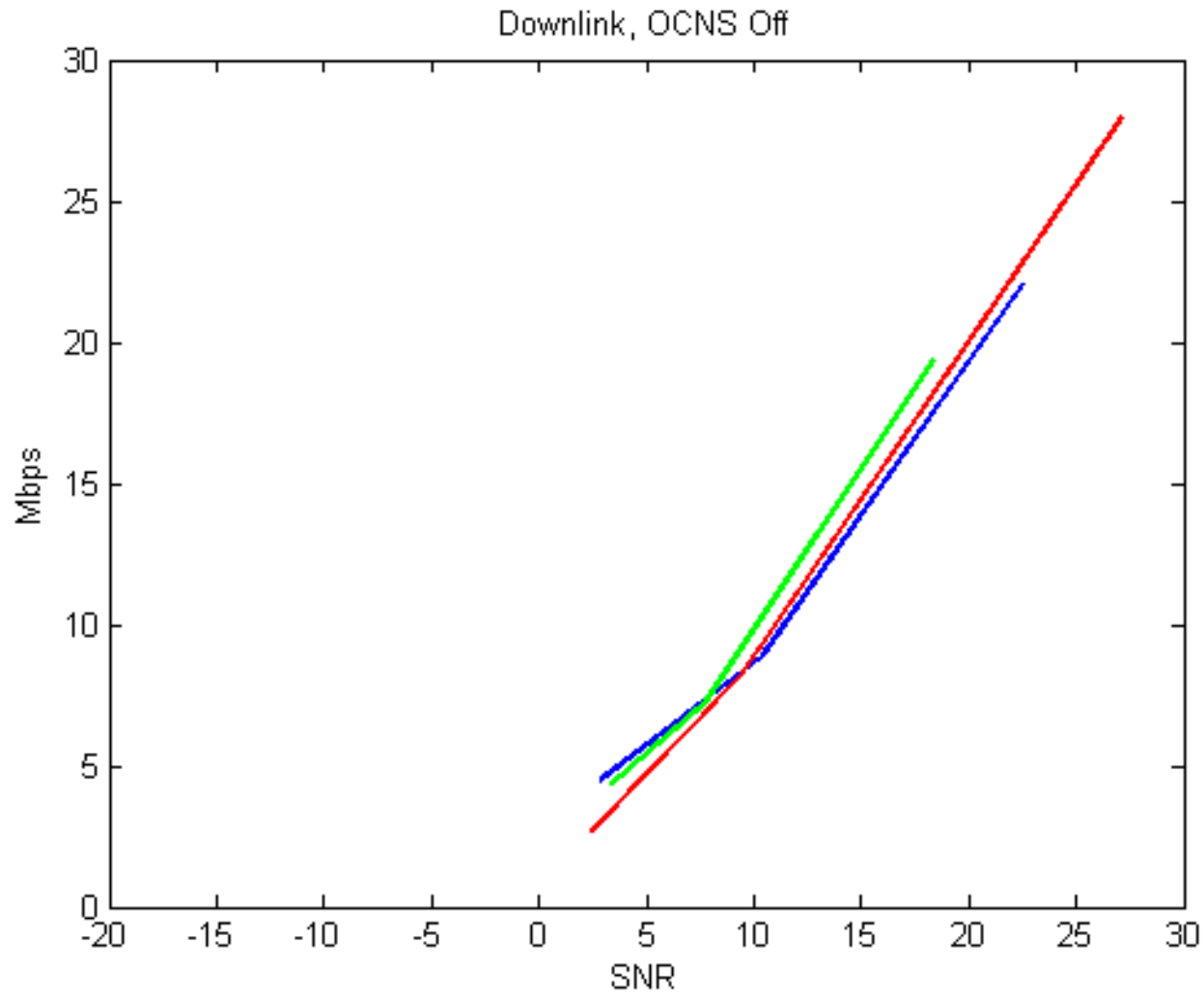
PDSCH PHY Throughput vs SNR



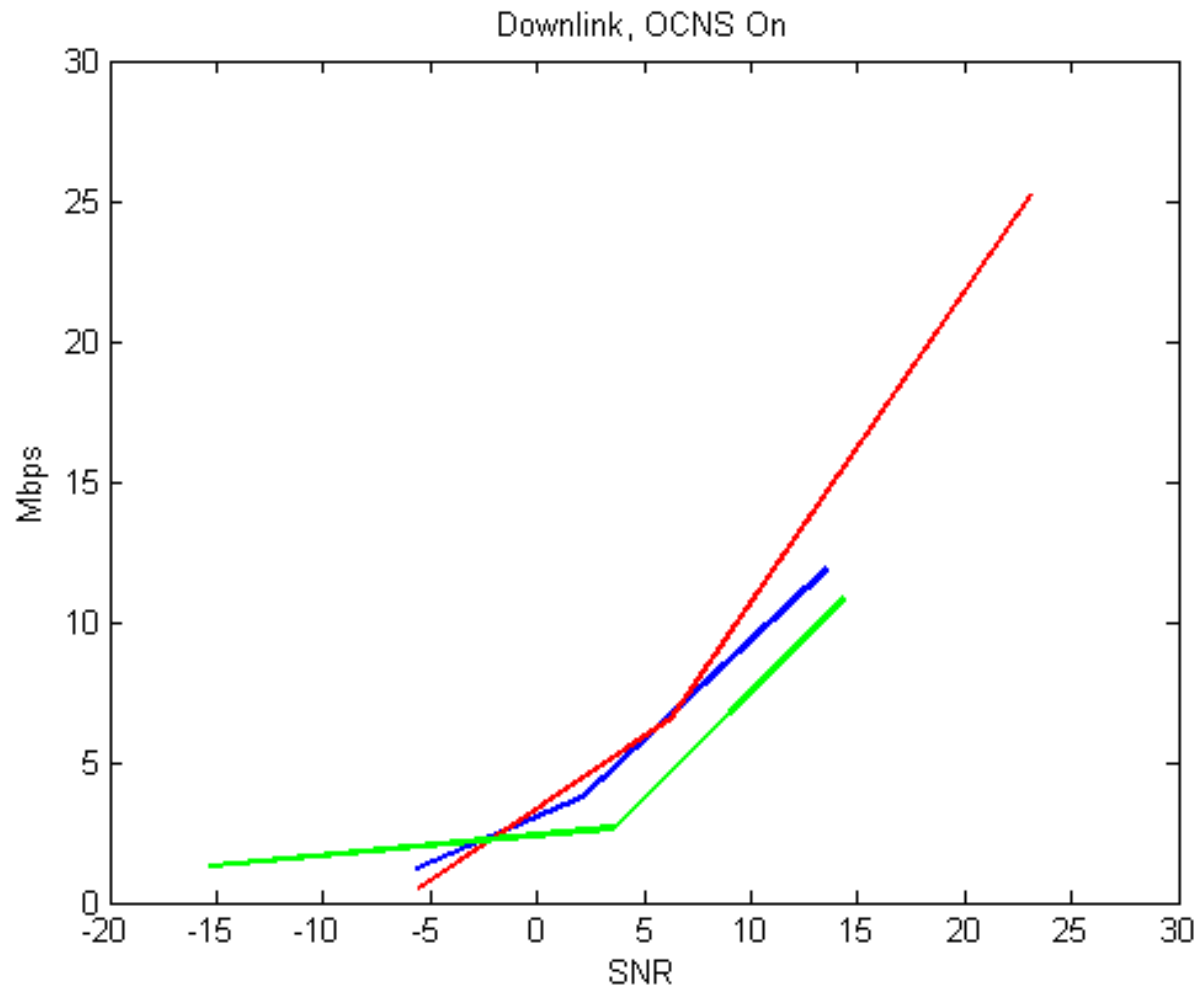
Near, Mid and Far Cell Locations



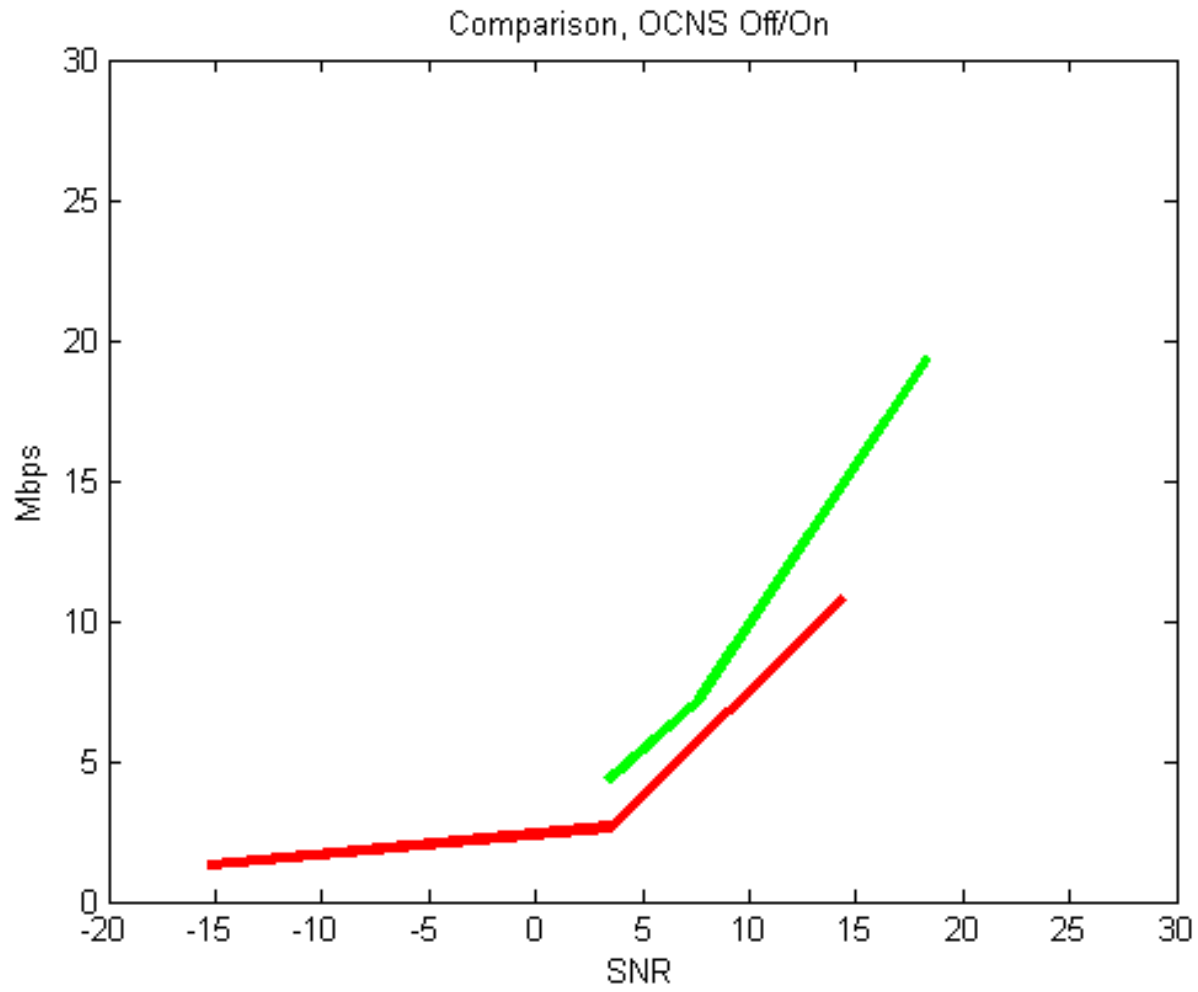
Downlink, Network Unloaded



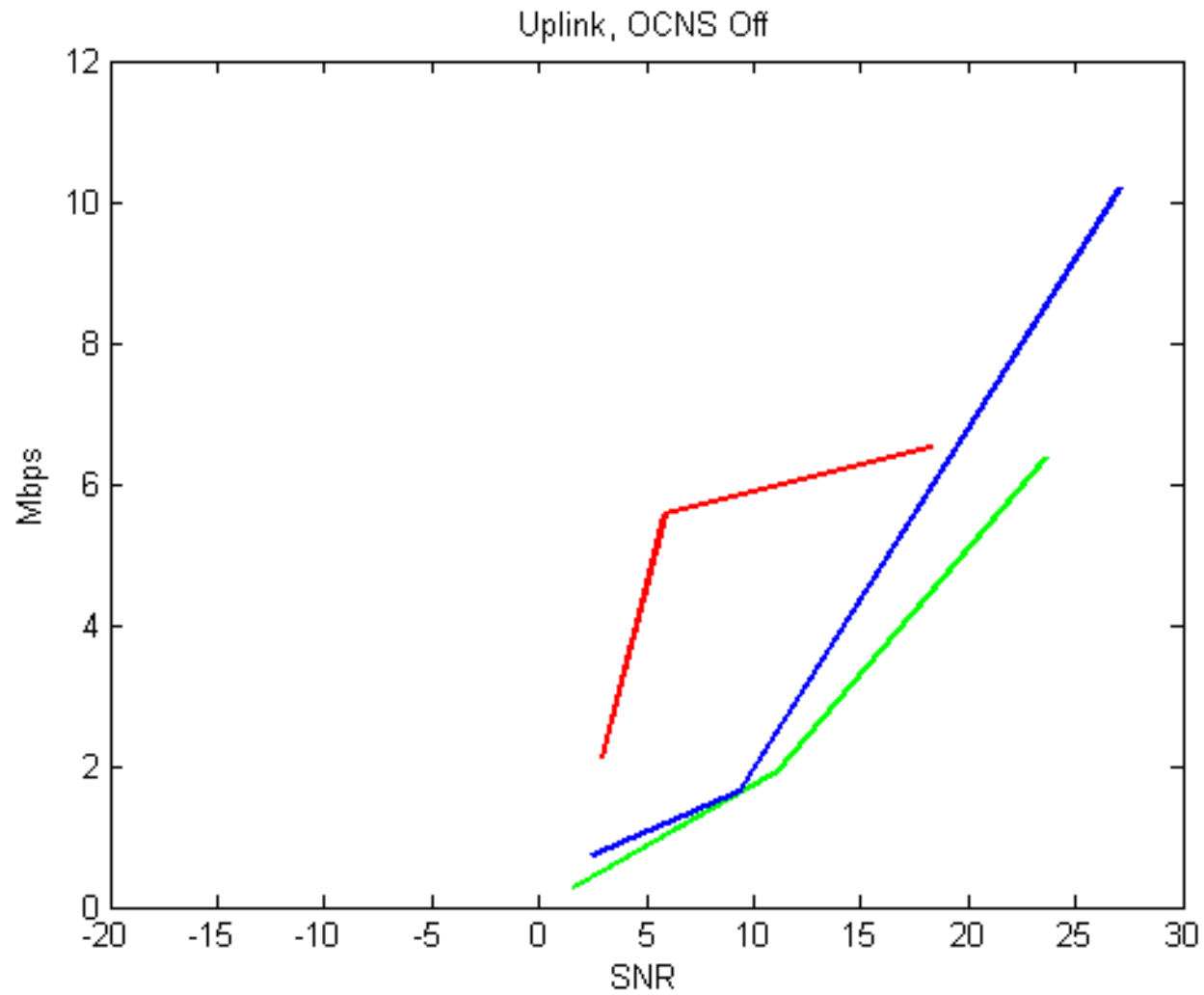
Downlink , Network Loaded



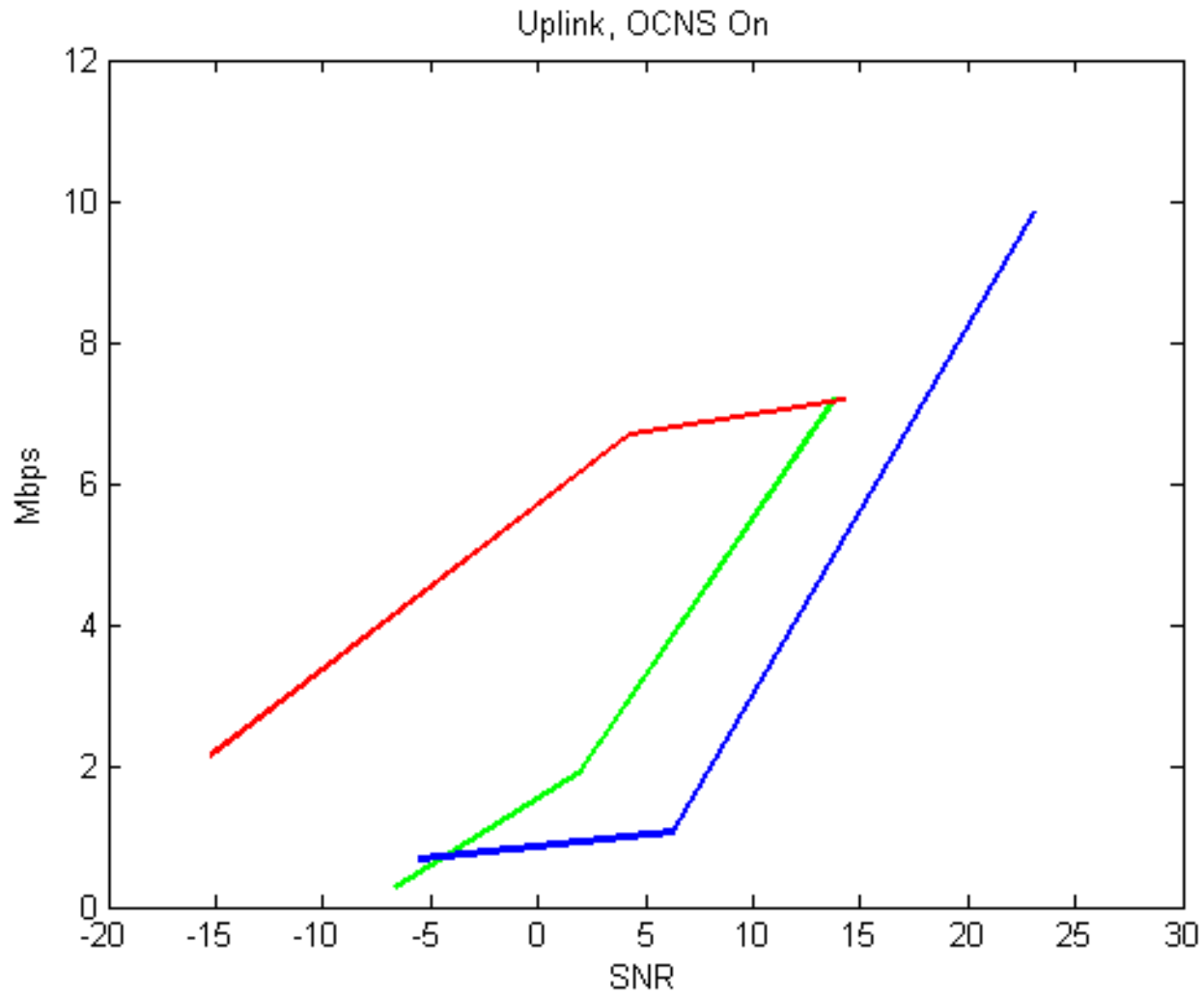
Downlink Comparison



Uplink, Network Unloaded



Uplink, Network Loaded

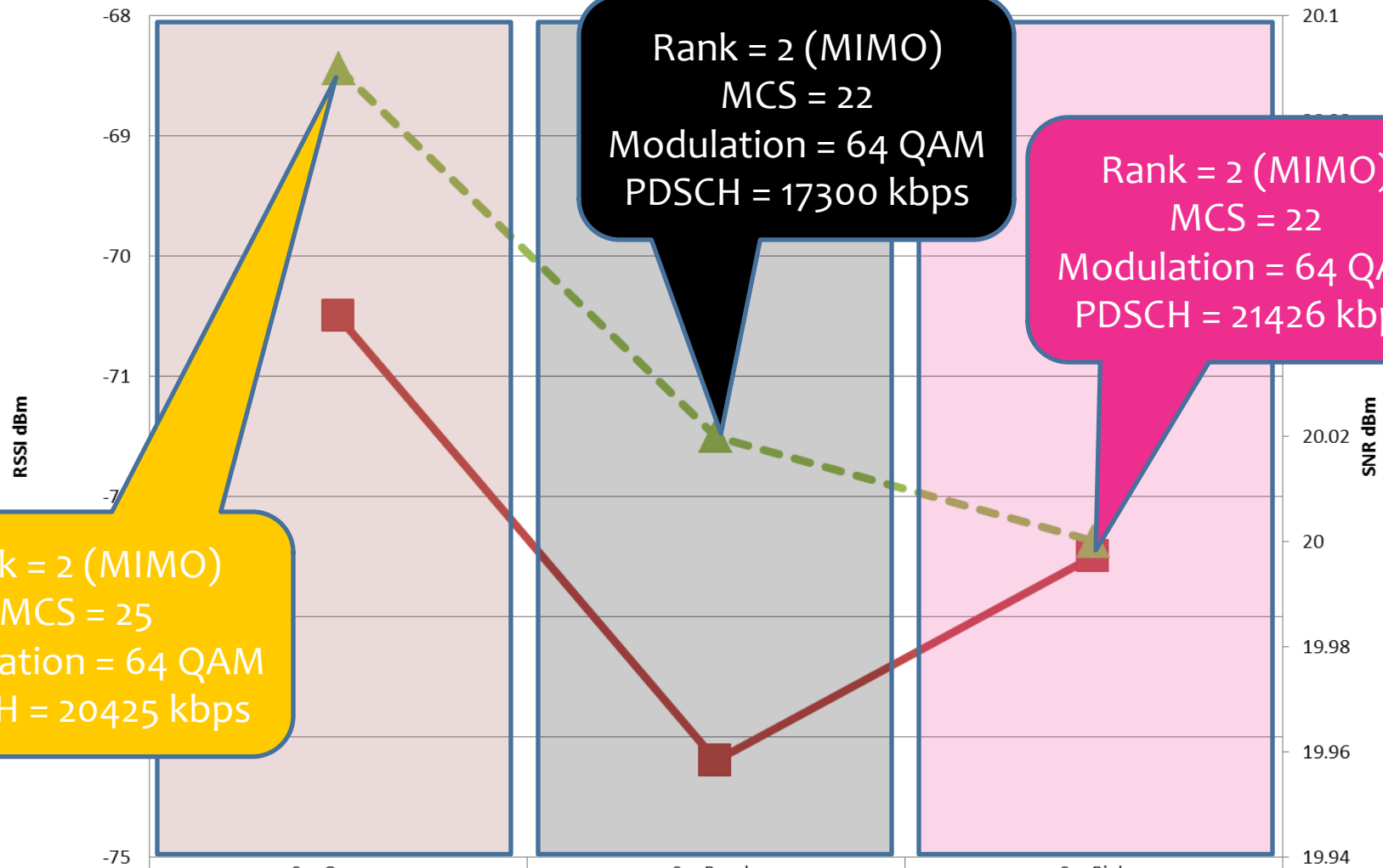


Everything is not created equal



DL Data - SNR = ~20 dBm

DL Data - OCNS On



Rank = 2 (MIMO)
MCS = 22
Modulation = 64 QAM
PDSCH = 17300 kbps

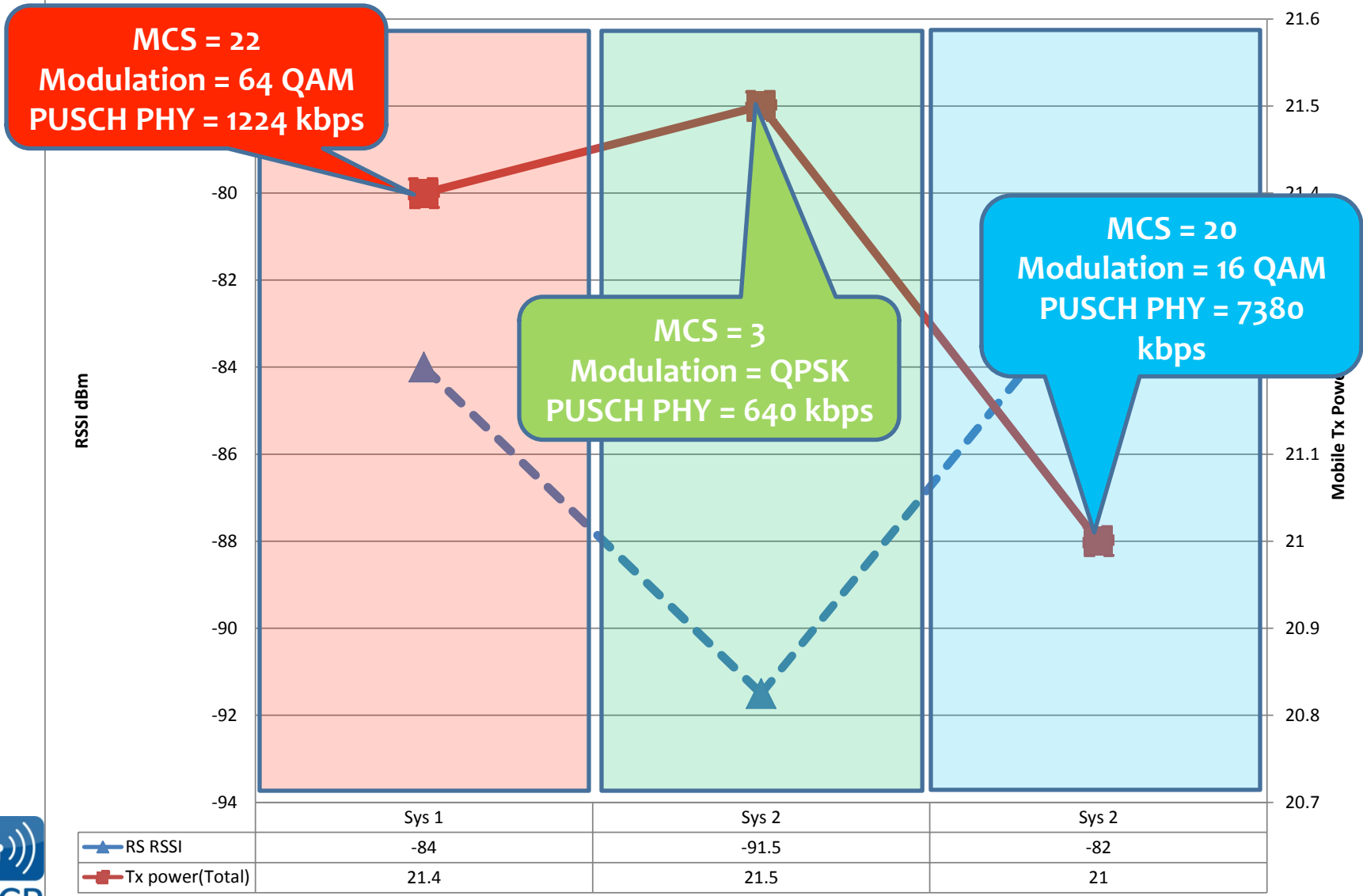
Rank = 2 (MIMO)
MCS = 22
Modulation = 64 QAM
PDSCH = 21426 kbps

Rank = 2 (MIMO)
MCS = 25
Modulation = 64 QAM
PDSCH = 20425 kbps



UL Data

UL Data - OCNS On - SNR= 4.82 dB



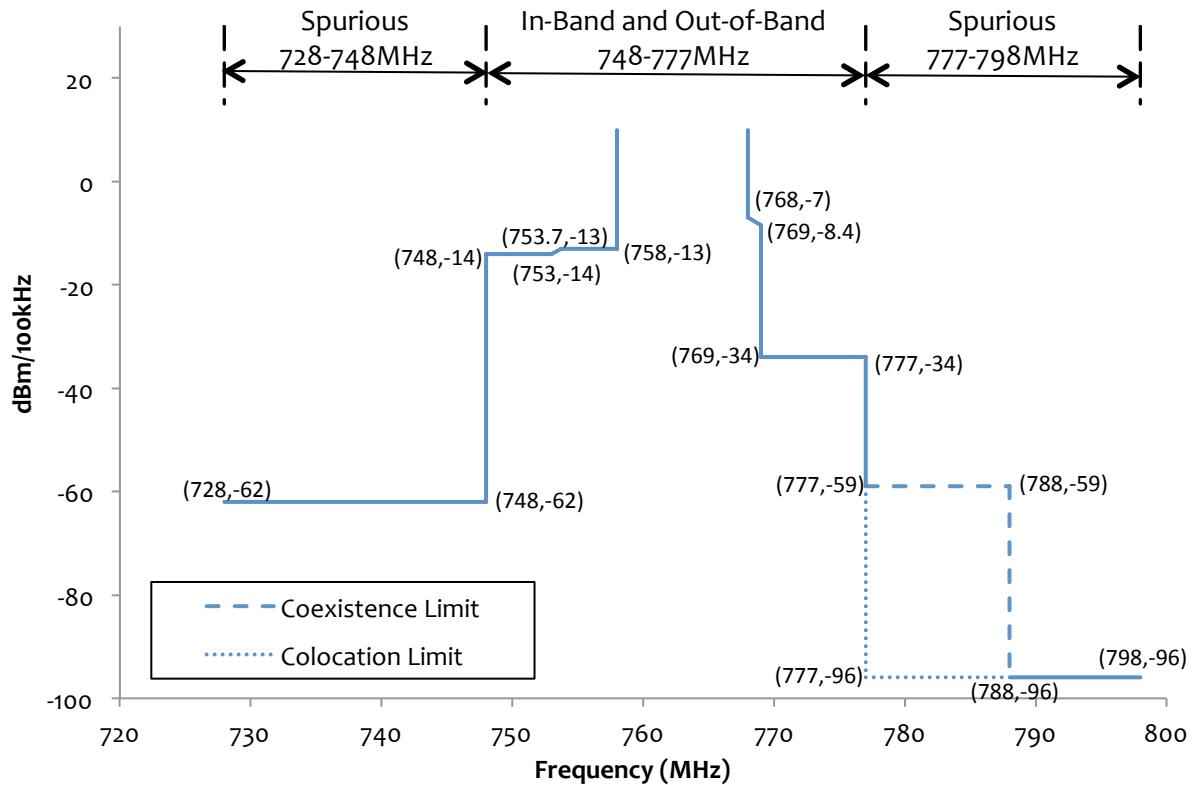
Why the Differences?

- **Different MCS values assigned for a given SNR (some more aggressive than others)**
- **Two types of MIMO are used amongst the vendors tested Closed Loop and Open Loop Spatial Multiplexing (CL-SM & OL-SM)**
- **eNB scheduling in Frequency & Time Domain or some in just the Time Domain**
- **Some vendors use Frequency Selective Scheduling on single data stream in either the UL or DL and some on both**
- **Others... To Be Yet Determined**

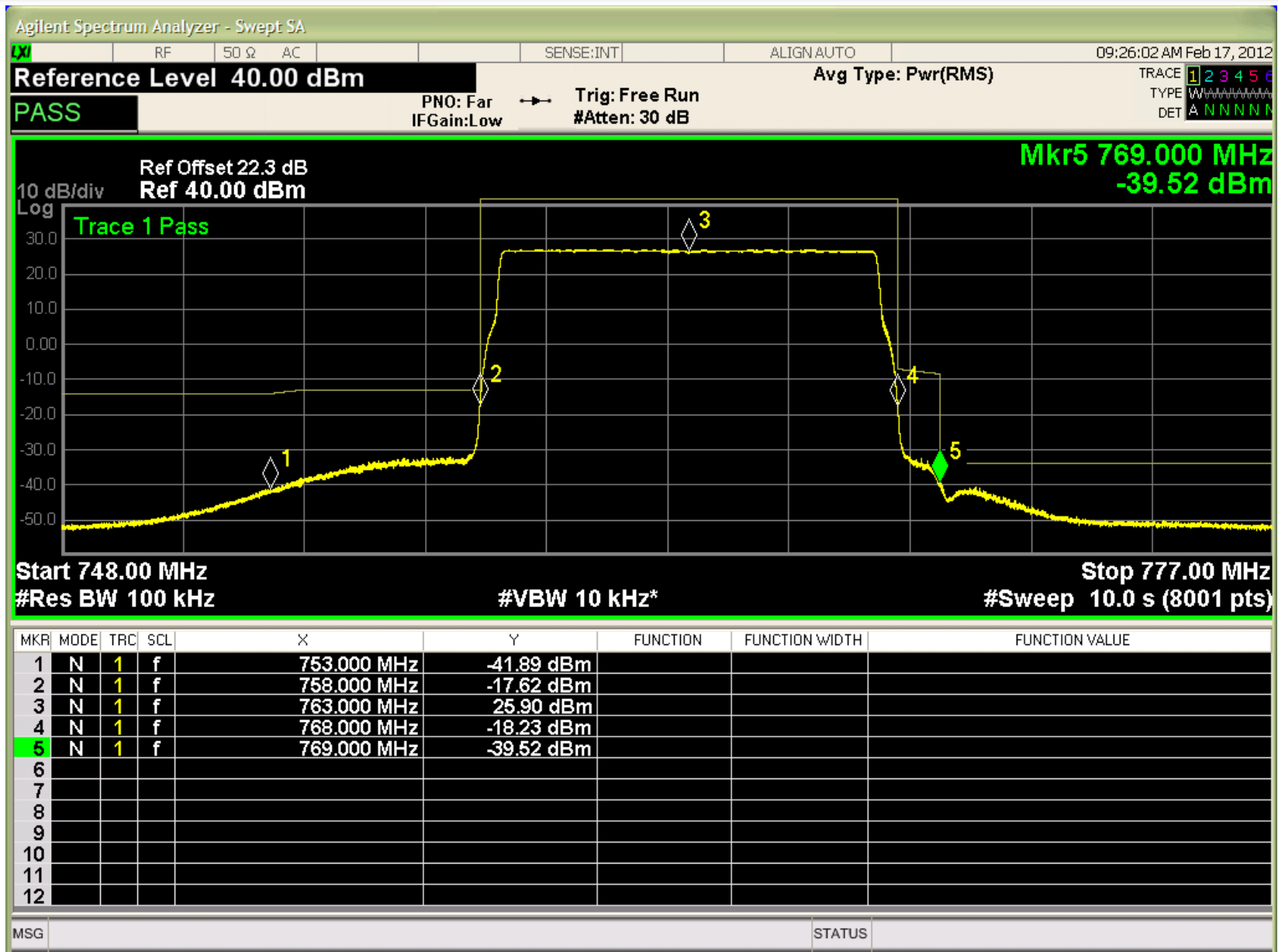
What Is Next?

- 10 MHz Regression Results
- Phase 2
- Phase 3

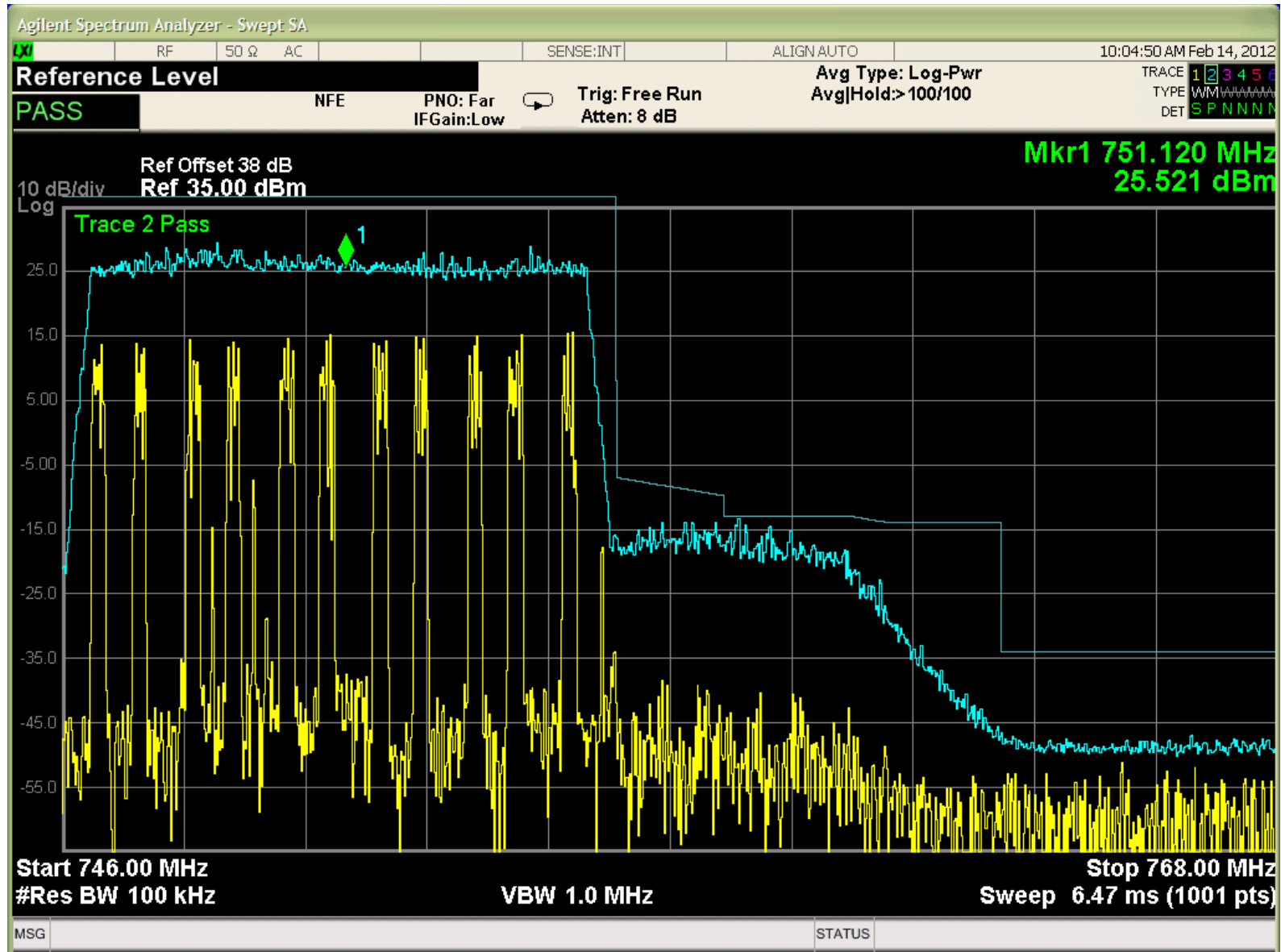
10 MHz eNB Spectral Emission Mask



10 MHz Test



D Block Interference



Evaluation Test Plan—Phases of Testing

- Phase 2 and Beyond
 - Evolved Packet Core Tests (Conformance, Interoperability, etc.)
 - EPC S10 (MME to MME)
 - EPC S11 (MME to S-GW)
 - EPC S12 (RNC to MME)
 - EPC S1-MME (MME to eNB)
 - EPC S1-U (eNB to S-GW)
 - EPC S4 (SGSN to S-GW)
 - EPC S5/S8 (S-GW to P-GW)
 - EPC S6a (HSS to MME)
 - EPC S6b (3GPP AAA to P-GW)
 - EPC SGi (P-GW to Internet and P-GW to IMS)
 - EPC SWn (ePDG to Untrusted Access) (IPSec)
 - EPC X2 (eNB to eNB)

UE Emulator



Scanner





PSCR

For Additional Information:

<http://www.pscr.gov>

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