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BC Hydro Meter Choices Program
Verification of Radio-Off Meter

Prepared for BC Hydro

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1. Executive Summary

The purpose of this test was to measure and document radio frequency (RF) emissions from a smart meter when the electricity meter is configured in a radio-off mode for the BC Hydro Meter Choices Program.

To characterize RF emissions from a smart meter, measurements for the following conditions were evaluated:

- Baseline Condition.
  The purpose of this test was to assess and characterize any background RF emissions in the test environment. For this test, measurements were made with the smart meter present, but not powered (i.e. the smart meter was not powered on).

- Radio-On Condition.
  The purpose of this test was to characterize RF emissions from the smart meter with both the 900MHz Local Area Network radio and the 2.4GHz Home Area Network radio active, transmitting, and fully functioning. The 2.4GHZ radio was paired with a HAN client device (BC Hydro "Home Energy Monitoring" device).

- Radio-Off Condition.
  The purpose of this test was to determine whether that there are no detectable RF emissions from the smart meter when the meter is in a radio-off state. For this condition the meter was powered, and all radios in the test meter were configured to a non-transmitting state via smart meter configuration software. This is how radio-off meters will be provided to BC Hydro customers that selected the radio-off meter as part of the Meter Choices Program.

All tests were performed using an RF isolation room to remove strong RF signal sources found in nearly all open environments. RF emissions were independently measured, external to the smart meter, using a calibrated spectrum analyzer (Rohde & Schwarz FSH8) and a certified power density analyzer (Narda NBM-550).

The test results show that when smart meters are configured in the radio-off state as offered in the Meter Choices Program, the RF signal levels detected by the instruments are comparable to the background RF levels found in a RF isolation room test environment. The RF signal level detected for a radio-off meter averages 0.000000036% of Health Canada Safety Code 6. This value, compared to the background RF level of 0.000000024% when the smart meter is unpowered, differs by an insignificant amount. At such low levels, the marginal difference between the power density for background to radio-off is lower than the percent attributable to instrument variability.

2. Introduction

2.1 Purpose

The purpose of this test was to measure and document RF emissions from a smart meter when the meter is configured in a radio-off mode for the Meter Choices Program.

2.2 Definitions

The following terms are used in this report:

- Collector – Connected Grid Router.
  Backhaul data aggregation point for smart meters operating on the BC Hydro 900MHz RF Local Area Network.

- HAN – Home Area Network.
  ZigBee wireless network operating in the 2.4GHz ISM band used to connects the smart meter to a local display device to communicate energy profile data. In this test setup, the local display device is a HAN client (BC Hydro Home Energy Monitoring device).

- ISM Band - Industrial, Scientific, Medical radio bands.
  In this setup, the 900Mhz and the 2.4GHz frequency bands used by used by RFLAN and HAN respectively belongs in the ISM Band.

- RF - Radio Frequency.

- RFLAN - RF Local Area Network.
  Wireless network operating in the 900 MHz ISM band used for communication between the smart meter and the collector.

2.3 Test Environment

For the purpose of this test, the smart meter is operated as a sealed unit and therefore no access to internal components or circuitry test points were allowed. Evaluation of any RF emissions was performed using RF spectrum analyzers and RF power density analyzers that are capable of detecting any RF emissions present. This test approach has the advantage of being completely independent of the smart meter.

To characterize RF emissions from a smart meter, measurements for the following conditions were evaluated:

1. Baseline Condition.
   The purpose of this test was to assess and characterize any background RF emissions in the test environment. For this test, measurements were made with the smart meter present, but not powered (i.e. the smart meter was not powered).

2. Radio-On Condition.
   The purpose of this test was to characterize RF emissions from the smart meter with both the meter's 900MHz Local Area Network radio and the 2.4GHz Home Area Network radio active,

transmitting, and fully functioning. The 2.4GHz radio was paired with a HAN client (BC Hydro Home Energy Monitoring device).

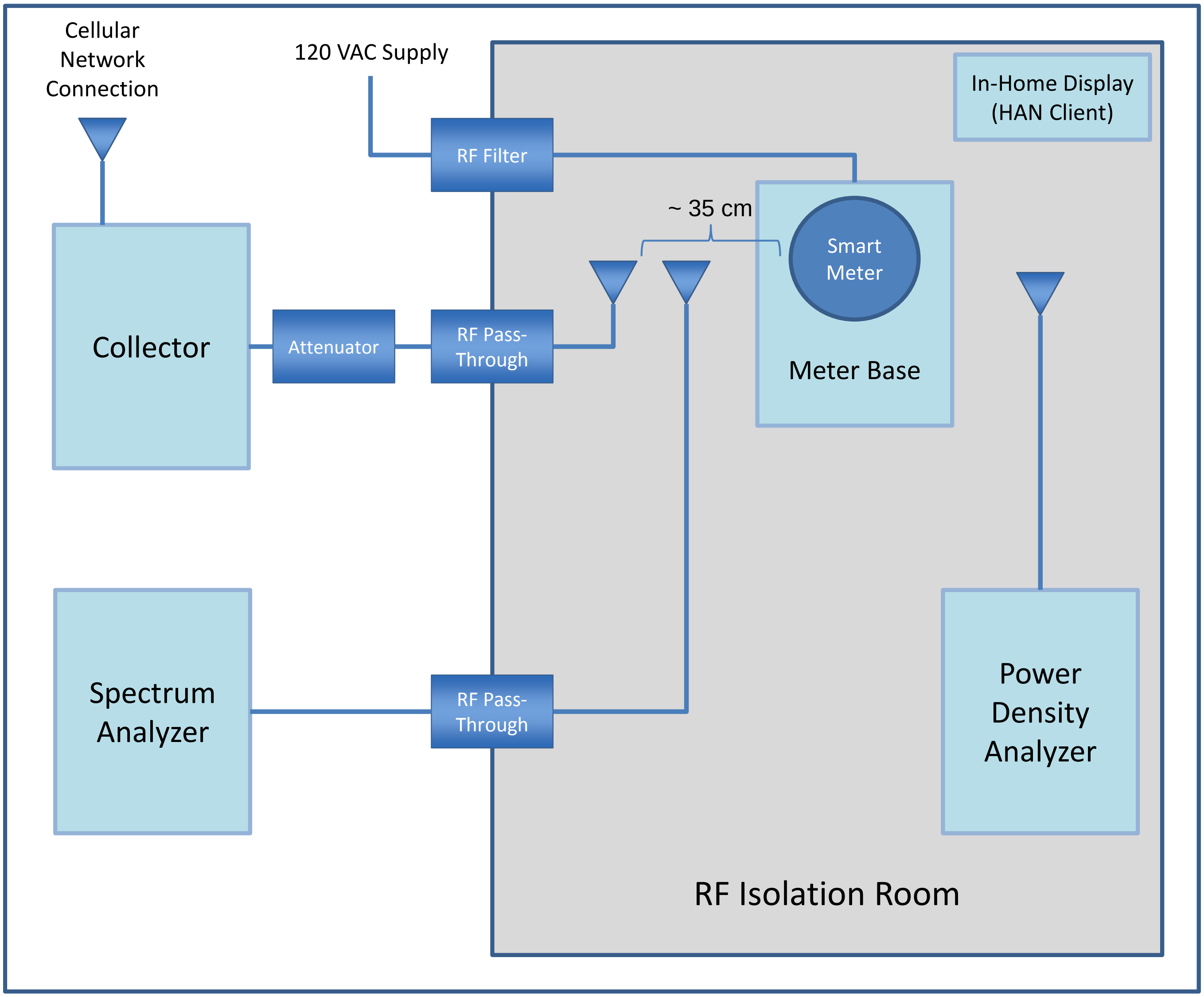
3. Radio-Off Condition.
   The purpose of this test was to determine whether that there are no detectable RF emissions from the smart meter when the meter is in a radio-off state. For this condition the meter was powered, and all radios were configured to a non-transmitting state via smart meter configuration software. This is how radio-off meters will be provided to BC Hydro customers that selected the radio-off meter as part of the Meter Choices Program.

In order to yield unambiguous conclusions from this test it was important to ensure that there was at least a 10,000-fold (or 40 deciBels) difference between RF signals measured in the Baseline Condition versus the Radio-On Condition. In order to achieve this ratio between Radio-On and Background RF levels, an RF isolation room was employed to reduce RF emissions from external background sources.

For all tests, the smart meter was located inside the RF isolation room together with the power density analyzer, spectrum analyzer antenna, collector antenna, and Home Energy Monitoring device (Home Area Network client device). The spectrum analyzer was located outside the RF isolation room; it was connected to its antenna, inside the room, using a coaxial cable through a RF pass-thru connector. To test under real-life conditions, a network controller, also known as a collector, was needed. The collector (located outside the room) was connected to its antenna (inside the room) using an attenuator and coaxial cable through a RF pass-thru connector. A diagram of the configuration is shown in the figure below.

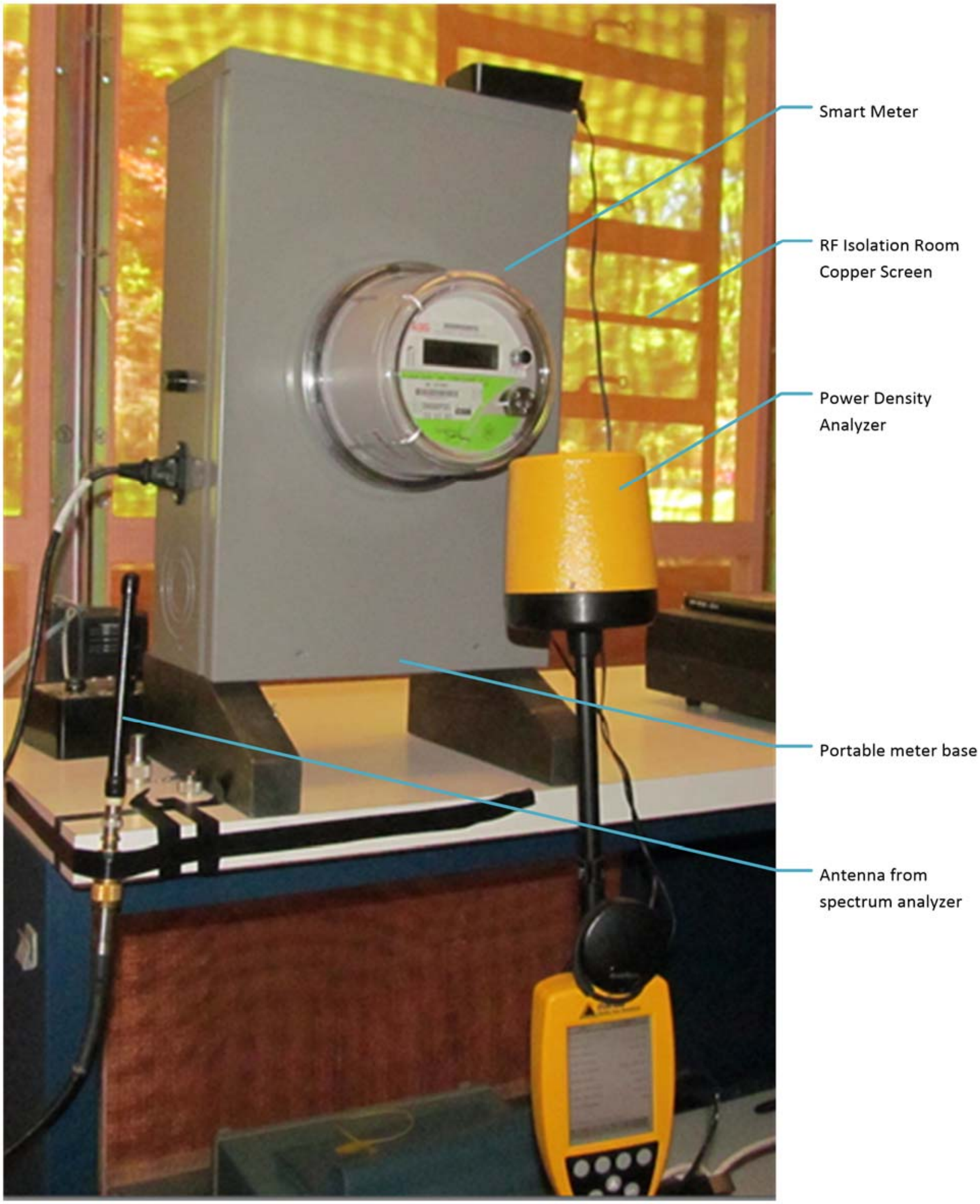
The collector attenuator was chosen to ensure sufficient signal level to permit meter communications while still maintaining radio-on to background RF level ratio described above.

All tests were performed with the collector connected to the BC Hydro metering network and actively transmitting signals over the 900MHz RF Local Area Network to any smart meter within range. For all tests, the smart meter in the room was periodically queried, via the collector, to determine if a response or RF transmission could be elicited.



Test Environment Configuration

A photograph of the test setup inside the RF Isolation Room is shown below.



Note: HAN Client device not shown.

2.4 **Test Equipment**

The following test equipment was used for this test:

- RF Isolation Room: Lindgren RF Enclosures, Model 18-2/2-0
- Spectrum Analyzer: Rohde & Schwarz, Model FSH8

Configured as follows:

Setting	Value
Center Frequency	2 GHz
Span	3 GHz
Attenuation	0 dB
Reference Level	-10 dBm
Resolution Bandwidth	3 MHz
Video Bandwidth	3 MHz
Sweep Time	38 ms
Trace	Max Hold

- Power Density Analyzer: Narda Safety Test Solutions, Model NBM 550 and Model EC5091

Configured as follows:

Configuration	Value
Standard	Health Canada Safety Code 6
Dataset Type	Timer Logging
Timer Interval	10s

3. Test Conditions

3.1 Baseline Condition Test

The purpose of this test was to assess and characterize any background RF emissions in the test environment. Test Configuration was as follows:

- Smart Meter State: De-energized. AC power removed which disables all meter functions.
- Collector State: Active and connected to the network. Transmitting on RFLAN and polling for smart meters.
- HAN Client Device State: Depowered
- Spectrum Analyzer State: Active and recording maximum levels of any sweep for all RF signals within configured span.
- Power Density Analyzer State: Active and recording the power density for each interval, averaging over 6 minutes as defined in Safety Code 6.

The following test procedure was utilized:

1. Smart meter was installed in meter base with no AC power connection
2. Power density analyzer timer logging was initiated
3. The RF isolation room was exited and the door sealed
4. The spectrum analyzer trace was re-initialized
5. The test was run for a minimum of 60 minutes
6. A screen capture of the spectrum analyzer trace was recorded
7. The RF isolation room was un-sealed
8. Power density analyzer timer logging was halted

Note that between steps 2-3 and between steps 7-8 the RF isolation room door was un-sealed and the Power Density Analyzer may be exposed to external (i.e. outside this test) RF sources. For this reason the first and last two interval recordings from the Power Density Analyzer were discarded in case outside radio energy had caused corrupted reading.

3.2 Radio-On Condition Test

The purpose of this test was to characterize RF emissions from the smart meter with both the 900MHz Local Area Network radio and the 2.4GHz Home Area Network radio active, transmitting, and fully functioning. Test Configuration was as follows:

- Smart Meter State: Energized. RFLAN and HAN radios configured as active
- Collector State: Active and connected to the network. Transmitting on RFLAN and polling for data from smart meters.
- HAN Client Device State: Energized and paired with the smart meter. Actively polling smart meter for electricity use data over the HAN network.
- Spectrum Analyzer State: Active and recording maximum levels of any sweep for all RF signals within configured span.
- Power Density Analyzer State: Active and recording the power density for each interval, averaging over 6 minutes as defined in Safety Code 6.

The following test procedure was utilized:

1. Smart meter was installed in meter base with AC power connection
2. Smart meter was configured using local programming port to set the test meter's RFLAN and HAN radios to active state
3. Smart meter confirmed to be communicating with the collector through the RFLAN
4. Power density analyzer timer logging was initiated
5. The RF isolation room was exited and the door sealed
6. The spectrum analyzer trace was re-initialized
7. The test was run for a minimum of 20 minutes or until RFLAN and HAN RF level peaks no longer increased to max peak
8. A screen capture of the spectrum analyzer trace was recorded
9. The RF isolation room was un-sealed
10. Power density analyzer timer logging was halted

3.3 Radio-Off Condition Test

The purpose of this test was to determine whether that there are no detectable RF emissions from the smart meter with the meter in a radio-off state. For this condition the meter was powered by AC power (wall socket), and all radios were configured to a non-transmitting state via smart meter configuration software, as they will be for BC Hydro customers that selected the Radio-Off meter as part of the Meter Choices Program.

Test Configuration was as follows:

- Smart Meter State: Energized. RFLAN and HAN radios configured as Off
- Collector State: Active and connected to the network. Transmitting on RFLAN and polling for data from the smart meter
- HAN Client Device State: Powered off
- Spectrum Analyzer State: Active and recording maximum levels of any sweep for all RF signals within configured span.
- Power Density Analyzer State: Active and recording the power density for each interval, averaging over 6 minutes as defined in Safety Code 6.

The following test procedure was utilized:

1. Smart meter was installed in meter base with AC power connection
2. Smart meter configured using local programming port to set both the RFLAN and the HAN radios in off state
3. Confirm smart meter displays "OPtOUt"
4. Power density analyzer timer logging was initiated
5. The RF isolation room was exited and the door sealed
6. The spectrum analyzer trace was re-initialized to start measurements
7. Power cycle the smart meter at least 5 times over a 30 minute interval to simulate power outages/smart meter resets
8. The test was run for a minimum of 12 hours
9. A screen capture of the spectrum analyzer trace was recorded
10. The RF isolation room was un-sealed
11. Power density analyzer timer logging was halted

4. Test Results

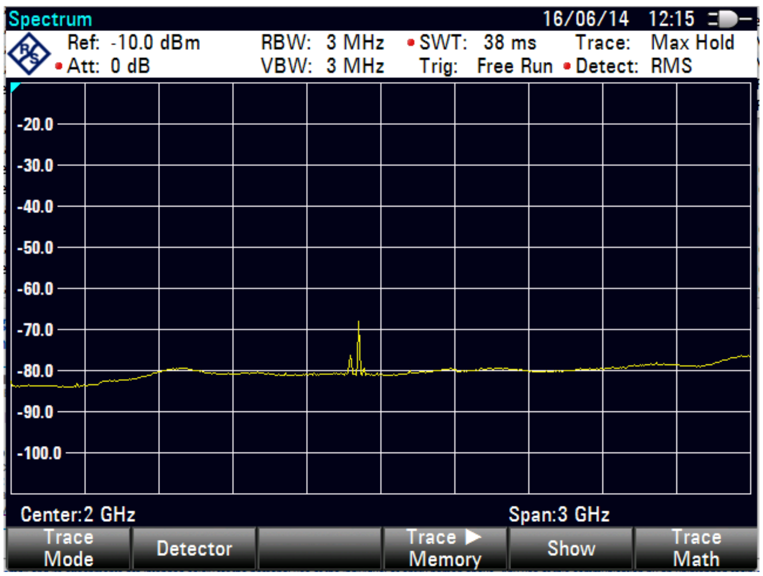
The following tests were run:

1. Baseline Condition Test
2. Radio-On Condition Test - Smart Meter RFLAN and HAN active and connected
3. Radio-Off Condition Test - Smart Meter RFLAN and HAN deactivated

4.1 Baseline Condition Test

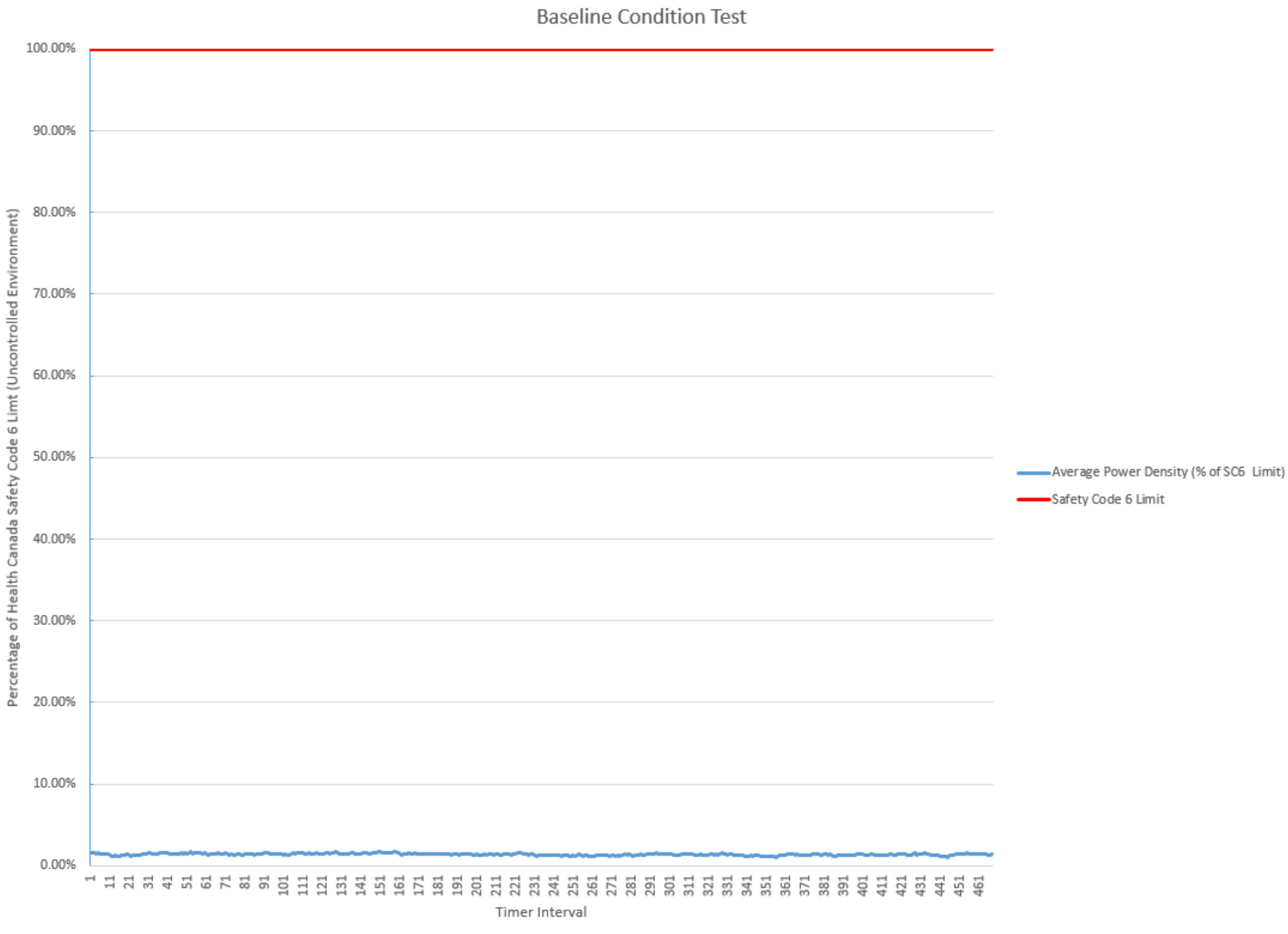
This test was run for 1 hour 17 minutes and 50 seconds.

The Spectrum analyzer capture is shown in the following figure:



Emissions from nearby cellular transmitters (outside the test environment) can be observed in the 1.9 and 1.8 GHz cellular bands. Peak cellular RF levels inside the RF isolation room were measured at -68 dBm (0.000162 microwatt). Any collector transmissions that occurred are below the noise floor of -82 dBm (0.00000631 microwatt). This indicates that while RF Isolation Room significantly reduces signals, as expected, some cellular signals in non-smart meter frequency bands are present at low levels.

Power density analyzer captures over the test duration are shown in the following figure:



All measurements taken over this test were at or below the noise floor of the Power Density Analyzer. No peaks were identified during the test duration. This further verifies that the RF Isolation Room does not contain any significant stray RF signals.

4.2 Smart Meter RFLAN and HAN Radio-On Condition Test

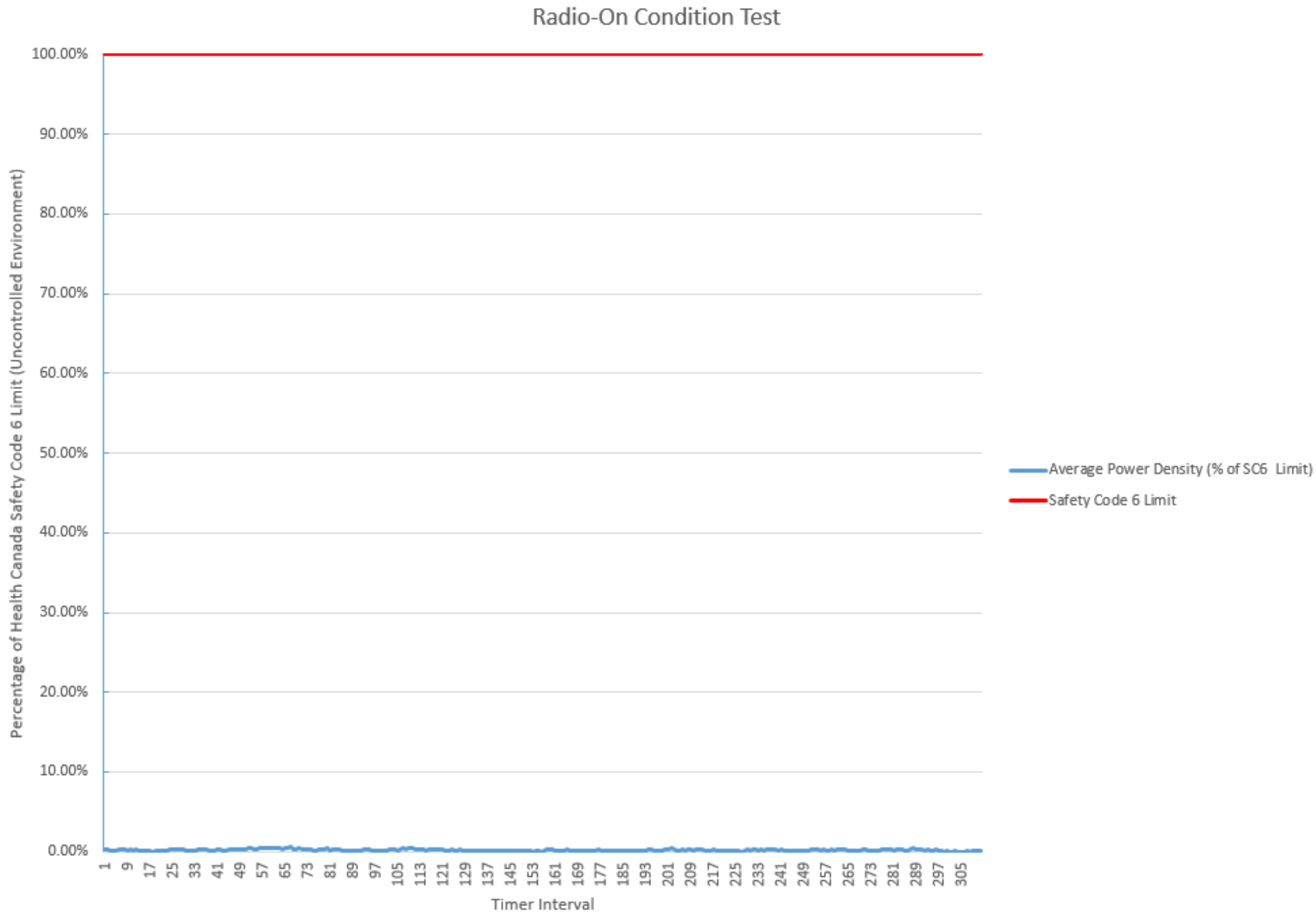
This test was run for 51 minutes and 50 seconds.

The Spectrum analyzer capture is shown in the following figure:

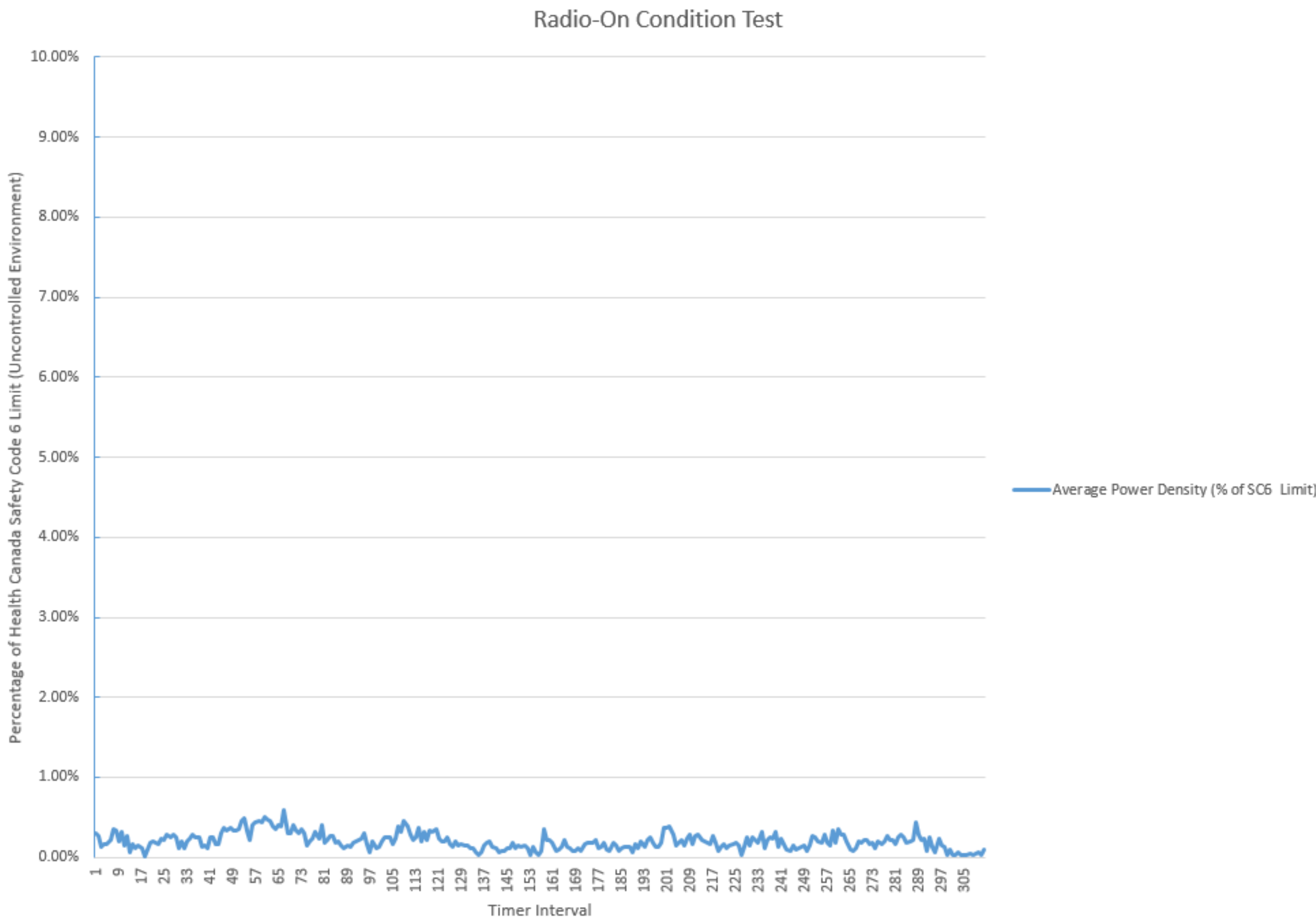
Smart meter peak 900 MHz RFLAN transmissions over the test duration can be observed at a level of -14 dBm (39.8 microwatt). Smart meter peak 2.4GHz HAN transmissions over the test duration can be observed at a level of -38 dBm (0.1568 microwatt) Emission from nearby cellular transmitters (outside the test environment) can be observed in the 1.9 and 1.8 GHz cellular bands. Peak cellular RF levels inside the RF isolation room were measured at -58 dBm (0.00158 microwatt). Any collector transmissions that occurred were below the peak levels emitted by the smart meter.

This indicates that the smart meter and the HAN client device are operating within normal parameters and are communicating using very low power RF signals.

Power density analyzer captures over the test duration are shown in the following figure:



The following figure provides an expanded view of the area between 0% and 10% of the Safety Code 6 Uncontrolled Environment limit.



The majority of measurements taken over this test period were at or below the noise floor of the Power Density Analyzer. As expected, the maximum power density level observed was 0.59% of the Safety Code 6 Uncontrolled Limit

4.3 **Smart Meter RFLAN and HAN Radio-Off Condition Test**

This test was run for 2 Days 22 hours 50 minutes.

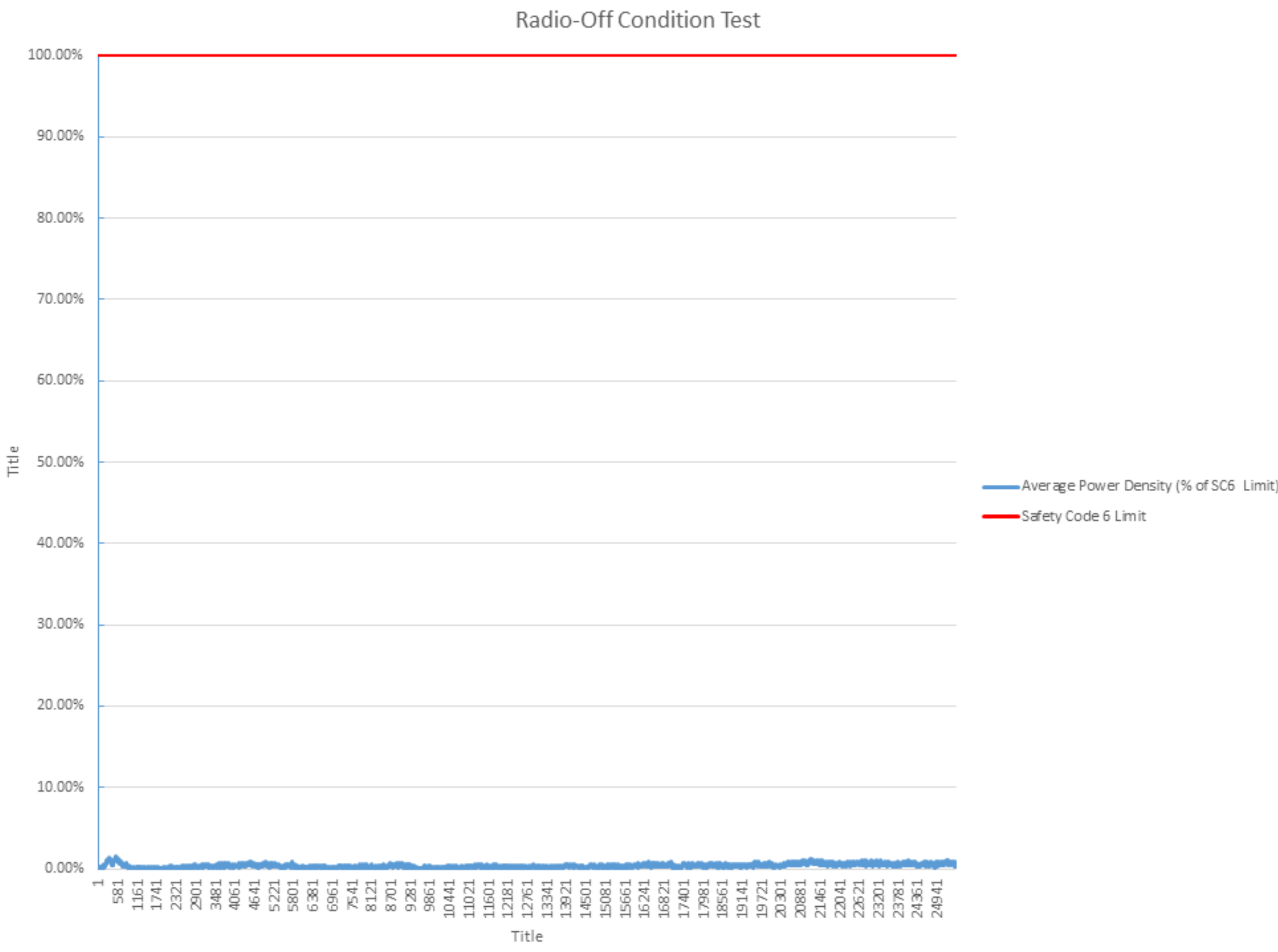
The Spectrum analyzer capture is shown in the following figure:

As a result of this test being run for an extended period over the weekend additional external cellular signals were captured. To assist in the differentiation of the various frequencies a second screen capture with markers is shown below.

Collector signal peak 900 MHz RFLAN transmissions over the test duration can be observed at a level of -80.2 dBm (0.00000955 microwatt). Emissions from nearby cellular transmitters (outside the test environment) can be observed in the 800 MHz, 1.8 GHz and 1.9 GHz cellular bands. Peak cellular RF levels inside the RF isolation room were measured at -53.5 dBm (0.00447 microwatt). Transmissions in the 2.4 GHz ISM band can also be observed at -73.8 dBm (0.0000417 microwatt).

As expected, the 900MHz frequency band has no signal present, indicating that the smart meter's RFLAN radio was not emitting any signals. In the 2.4GHz frequency band, very low level signal was captured during the 70 hour test window. This signal likely came from WiFi usage from outside the isolation room. If the signal came from a HAN client device or Smart Meter HAN radio inside the RF isolation room, the signal is expected to appear much strong on the spectrum analyzer. Alternatively, if the signal is from a HAN client device or Smart Meter HAN radio outside of the RF isolation room, the signal would be diminished by the RF isolation room physical effects. Therefore, the 2.4GHz signal at the level observed did not originate from any devices within the RF isolation room and likely originated from the WiFi service present in the test environment building outside the RF isolation room.

Power density analyzer levels over the test duration are shown in the following figure:



All measurements taken over this test were at or below the noise floor of the Power Density Analyzer. No peaks were observed during the test duration.

5. Findings

The data from the test results show that when smart meters are configured in the radio-off state as offered in the Meter Choices Program, the RF emissions detected are comparable to the background RF levels found in an RF isolation room test environment.

The average power density value detected for each test can be summarized below.

Test Conditions	Per cent of Health Canada Safety Code 6
Background	0.000000024%
Radio-On with active HAN client in close proximity	0.59%
Radio-Off	0.000000036%

It should be noted that the power density level detected at the background and radio-off test conditions are at the threshold of Narda device sensitivity. As such low levels, the marginal difference between the power density for background to radio-off is lower than the per cent attributable to instrument variability.