TEST REPORT

Covering the DYNAMIC FREQUENCY SELECTION (DFS) REQUIREMENTS OF

FCC Part 15 Subpart E (UNII), RSS-247

Google Inc.
Model: H0A

IC CERTIFICATION #:	10395A-H0A
FCC ID:	A4RH0A
COMPANY:	Google Inc. 1600 Amphitheatre Pky Mountain View, CA, 94043
TEST SITE:	National Technical Systems - Silicon Valley 41039 Boyce Road Fremont, CA 94538
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TEST ENGINEER:	Mehran Birgani
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Rev #	Date	Comments	Modified By
-	August 14, 2017	Initial Release	-
1	August 25, 2017	Removed detailed product information for confidentiality	MEH

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SCOPE

Test data has been taken pursuant to the relevant DFS requirements of the following standard(s):

- FCC Part 15 Subpart E Unlicensed National Information Infrastructure (U-NII) Devices.
- RSS-247 Local Area Network Devices.

Tests were performed in accordance with these standards together with the current published versions of the basic standards referenced therein including FCC KDB 905462 D02 and FCC KDB 905462 D03 as outlined in NTS Silicon Valley test procedures. The test results recorded herein are based on a single type test of the Google Inc. model H0A and therefore apply only to the tested sample. The sample was selected and prepared by Dominik Mente of Google Inc.

OBJECTIVE

The objective of the manufacturer is to comply with the standards identified in the previous section. In order to demonstrate compliance, the manufacturer or a contracted laboratory makes measurements and takes the necessary steps to ensure that the equipment complies with the appropriate technical standards. Compliance with some DFS features is covered through a manufacturer statement or through observation of the device.

STATEMENT OF COMPLIANCE

The tested sample of the Google Inc. model H0A complied with the DFS requirements of FCC Part 15.407(h)(2), and RSS-247 Issue 2.

Maintenance of compliance is the responsibility of the manufacturer. Any modifications to the product should be assessed to determine their potential impact on the compliance status of the device with respect to the standards detailed in this test report.

DEVIATIONS FROM THE STANDARD

No deviations were made from the test methods and requirements covered by the scope of this report.

TEST RESULTS

TEST RESULTS SUMMARY – FCC Part 15, CLIENT DEVICE

Table 1 - FCC Part 15 Subpart E Client Device Test Result Summary

Description	Radar Type	EUT Frequency	Measured Value	Requirement	Test Data	Status
Channel closing transmission time	Type 0	5700MHz	0 ms	60 ms	Appendix C	Complies
Channel move time	Type 0	5700MHz	0.1 s	10 s	Appendix C	Complies
Non-occupancy period - associated	Type 0	5700MHz (see note 3)	> 30 minutes	> 30 minutes	Appendix C	Complies
Passive Scanning	N/A	N/A	Refer to manufacturer attestation			

1) Tests were performed using the radiated test method.
2) Channel availability check and detection threshold are not applicable to client devices.
3) After the channel move the client re-associated with the master device on the new channel.

MEASUREMENT UNCERTAINTIES

ISO/IEC 17025 requires that an estimate of the measurement uncertainties associated with the emissions test results be included in the report. The measurement uncertainties given below are based on a 95% confidence level, with a coverage factor (k=2) and were calculated in accordance with UKAS document LAB 34.

Measurement	Measurement Unit	Expanded Uncertainty
Timing (Channel move time, aggregate transmission time)	ms	Timing resolution ± 0.24%
Timing (non occupancy period)	seconds	5 seconds
DFS Threshold (radiated)	dBm	1.6
DFS Threshold (conducted)	dBm	1.2

EQUIPMENT UNDER TEST (EUT) DETAILS

GENERAL

The Google Inc. model H0A is an 802.11abgn/ac SISO Media Streaming Device capable of working both in 2.4GHz and 5.0GHz bands

The sample was received on July 12, 2017 and tested on July 25, 2017. The EUT consisted of the following component(s):

Manufacturer	Model	Description	Serial Number
Google Inc.	H0A	Media Streaming Device	7606LZZ8J0

The manufacturer declared values for the EUT operational characteristics that affect DFS are as follows:

Operating Modes (5250 – 5350 MHz, 5470 – 5725 MHz)

☒ Client Device (no In Service Monitoring, no Ad-Hoc mode)

(Note – for Canada, EUT operation is prohibited in the 5600-5650MHz band)

Antenna Gains / EIRP (5250 – 5350 MHz, 5470 – 5725 MHz)

	5250 – 5350 MHz	5470 – 5725 MHz
Lowest Antenna Gain (dBi)	3.7	3.7
Highest Antenna Gain (dBi)	3.7	3.7
EIRP Output Power (dBm)	19.5	19.8

☐ Power can exceed 200mW eirp

Channel Protocol

☒ IP Based

ENCLOSURE

The EUT enclosure is primarily constructed of uncoated plastic.

MODIFICATIONS

The EUT did not require modifications during testing in order to comply with the requirements of the standard(s) referenced in this test report.

SUPPORT EQUIPMENT

The following equipment was used as support equipment for testing:

Manufacturer	Model	Description	Serial Number	FCC ID
Netgear	ASW105/B1	Ethernet Switch	RP6114ADB039891	-
HP	Pavilion	Laptop Computer	-	-
Cisco	*AIR-AP1252AG-A-K9*	*Access Point*	*FTX1209906V*	*LDK102061*
Nest	A0017	AC/DC Adapter	-	-
Dell	Latitude	Laptop Computer	6DK55S1	DoC

The italicized device was the master device.

EUT INTERFACE PORTS

The I/O cabling configuration during testing was as follows:

		Cable(s)		
Port	Connected To	Description	Shielded or Unshielded	Length (m)
DC Power	AC/DC Adapter	coax	shielded	1.5

EUT OPERATION

The EUT was operating with the following software listed below. The software is secured by encryption to prevent the user from disabling the DFS function.

Client Device: 1.0

The streamed file was iperf and the client device configured to receive the file. The channel loading was evaluated to be 17.8% (refer to figure 9) meeting the approximately 17% loading as required by FCC KDB 905462 D02.

Refer to the H0A theory of operation document for the information about the power-on cycle time, statement about security of radar detection parameters and initial channel selection.

The RF energy emitted from the H0A is below the FCC 15.109 limits for unintentional radiators when it is not transmitting. Refer to separate report covering unintentional emissions.

RADAR WAVEFORMS

<table>
<tr><th colspan="7">Table 2 - FCC Short Pulse Radar Test Waveforms</th></tr>
<tr><th colspan="2">Radar Type</th><th>Pulse Width (μsec)</th><th>PRI (μsec)</th><th>Pulses / burst</th><th>Minimum Detection Percentage</th><th>Minimum Number of Trials</th></tr>
<tr><td colspan="2">0</td><td>1</td><td>1428</td><td>18</td><td colspan="2">See Note 1</td></tr>
<tr><td rowspan="2">1</td><td>1a</td><td rowspan="2">1</td><td>15 unique PRI values randomly selected from the list of 23 PRI values in Note 2 below</td><td rowspan="2">Round Up 1/360* $19*10^6$/ PRI $_{\mu sec}$</td><td rowspan="2">60%</td><td>15</td></tr>
<tr><td>1b</td><td>518-3066 with minimum increment of 1 μsec, excluding PRI values selected in 1a</td><td>15</td></tr>
<tr><td colspan="2">2</td><td>1-5</td><td>150-230</td><td>23-29</td><td>60%</td><td>30</td></tr>
<tr><td colspan="2">3</td><td>6-10</td><td>200-500</td><td>16-18</td><td>60%</td><td>30</td></tr>
<tr><td colspan="2">4</td><td>11-20</td><td>200-500</td><td>12-16</td><td>60%</td><td>30</td></tr>
<tr><td colspan="5">Aggregate (Radar Types 1-4)</td><td>80%</td><td>120</td></tr>
<tr><td colspan="7">Note 1: Short Pulse Radar Type 0 is used for the detection bandwidth test, channel move time, and channel closing time tests.</td></tr>
<tr><td colspan="7">Note 2: Pulse repetition intervals values for Test 1a above</td></tr>
</table>

Pulse Repetition Frequency Number	**Pulse Repetition Frequency (Pulses Per Second)**	**Pulse Repetition Interval (Microseconds)**
1	1930.5	518
2	1858.7	538
3	1792.1	558
4	1730.1	578
5	1672.2	598
6	1618.1	618
7	1567.4	638
8	1519.8	658
9	1474.9	678
10	1432.7	698
11	1392.8	718
12	1355	738
13	1319.3	758
14	1285.3	778
15	1253.1	798
16	1222.5	818
17	1193.3	838
18	1165.6	858
19	1139	878
20	1113.6	898
21	1089.3	918
22	1066.1	938
23	326.2	3066

Table 3 - FCC Long Pulse Radar Test Waveforms

Radar Type	Pulse Width (µsec)	Chirp Width (MHz)	PRI (µsec)	Pulses / burst	Number of *Bursts*	Minimum Detection Percentage	Minimum Number of Trials
5	50-100	5-20	1000-2000	1-3	8-20	80%	30

Table 4 - FCC Frequency Hopping Radar Test Waveforms

Radar Type	Pulse Width (µsec)	PRI (µsec)	Pulses / hop	Hopping Rate (kHz)	Hopping Sequence Length (msec)	Minimum Detection Percentage	Minimum Number of Trials
6	1	333	9	0.333	300	70%	30

DFS TEST METHODS

RADIATED TEST METHOD

The combination of master and slave devices is located in an anechoic chamber. The simulated radar waveform is transmitted from a directional horn antenna (typically an EMCO 3115) toward the unit performing the radar detection (radar detection device, RDD). Every effort is made to ensure that the main beam of the EUT's antenna is aligned with the radar-generating antenna which is oriented in vertical polarization.

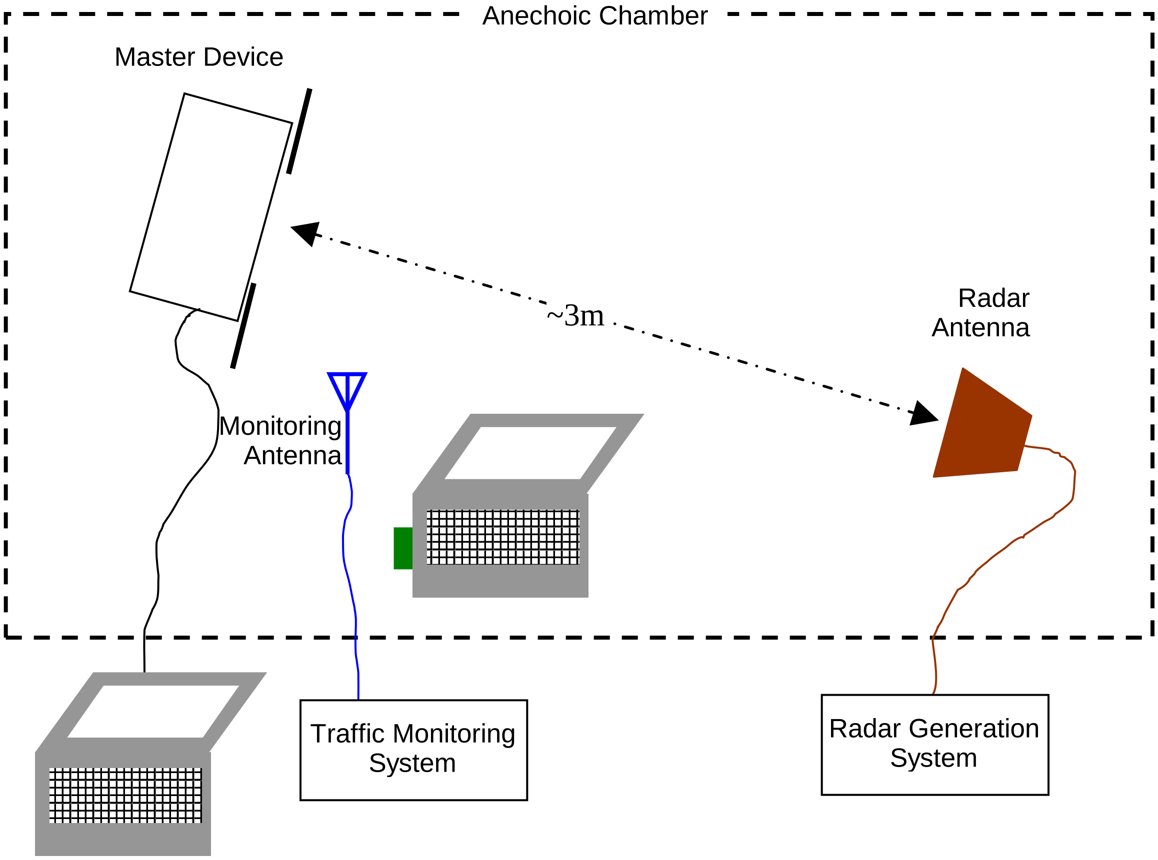

Figure 1 Test Configuration for radiated Measurement Method

The signal level of the simulated waveform is set to a reference level equal to the threshold level (plus 1dB if testing against FCC requirements). Lower levels may also be applied on request of the manufacturer. The level reported is the level at the RDD antenna and so it is not corrected for the RDD's antenna gain. The RDD is configured with the lowest gain antenna assembly intended for use with the device.

The signal level is verified by measuring the CW signal level from the radar generation system using a reference antenna of gain G_{REF} (dBi). The radar signal level is calculated from the measured level, R (dBm), and any cable loss, L (dB), between the reference antenna and the measuring instrument:

$$\text{Applied level (dBm)} = R - G_{REF} + L$$

If both master and client devices have radar detection capability then the device not under test is positioned with absorbing material between its antenna and the radar generating antenna, and the radar level at the non RDD is verified to be at least 20dB below the threshold level to ensure that any responses are due to the RDD detecting radar.

The antenna connected to the channel monitoring subsystem is positioned to allow both master and client transmissions to be observed, with the level of the EUT's transmissions between 6 and 10dB higher than those from the other device.

DFS MEASUREMENT INSTRUMENTATION

RADAR GENERATION SYSTEM

An Agilent PSG is used as the radar-generating source. The integral arbitrary waveform generators are programmed using Agilent's "Pulse Building" software and NTS Silicon Valley custom software to produce the required waveforms, with the capability to produce both un-modulated and modulated (FM Chirp) pulses. Where there are multiple values for a specific radar parameter then the software selects a value at random and, for FCC tests, the software verifies that the resulting waveform is truly unique.

With the exception of the hopping waveforms required by the FCC's rules (see below), the radar generator is set to a single frequency within the radar detection bandwidth of the EUT. The frequency is varied from trial to trial by stepping in 5MHz steps. For radar types with variable parameters, each detection probability trial is performed using a unique set of parameters obtained by a random selection with uniform distribution for each of the variable parameters.

Frequency hopping radar waveforms are simulated using a time domain model. A randomly hopping sequence algorithm (which uses each channel in the hopping radar's range once in a hopping sequence) generates a hop sequence. A segment of the first 100 elements of the hop sequence are then examined to determine if it contains one or more frequencies within the radar detection bandwidth of the EUT. If it does not then the first element of the segment is discarded and the next frequency in the sequence is added. The process repeats until a valid segment is produced. The radar system is then programmed to produce bursts at time slots coincident with the frequencies within the segment that fall in the detection bandwidth. The frequency of the generator is stepped in 1 MHz increments across the EUT's detection range.

The radar signal level is verified during testing using a long duration pulse waveform generated in the same manner as the normal radar generated signals.

The generator output is connected to the coupling port of the conducted set-up or to the radar-generating antenna. The radar generating antenna (when used) is oriented for vertical polarization.

CHANNEL MONITORING SYSTEM

Channel monitoring is achieved using a spectrum analyzer and digital storage oscilloscope. The analyzer is configured in a zero-span mode, center frequency set to the radar waveform's frequency or the center frequency of the EUT's operating channel. The IF output of the analyzer is connected to one input of the oscilloscope.

A signal generator output is set to send either the modulating signal directly or a pulse gate with an output pulse co-incident with each radar pulse. This output is connected to a second input on the oscilloscope and the oscilloscope displays both the channel traffic (via the if input) and the radar pulses on its display.

For in service monitoring tests the analyzer sweep time is set to > 20 seconds and the oscilloscope is configured with a data record length of 10 seconds for the short duration and frequency hopping waveforms, 20 seconds for the long duration waveforms. Both instruments are set for a single acquisition sequence. The analyzer is triggered 500ms before the start of the waveform and the oscilloscope is triggered directly by the modulating pulse train. Timing measurements for aggregate channel transmission time and channel move time are made from the oscilloscope data, with the end of the waveform clearly identified by the pulse train on one trace. The analyzer trace data is used to confirm that the last transmission occurred within the 10-second record of the oscilloscope. If necessary the record length of the oscilloscope is expanded to capture the last transmission on the channel prior to the channel move.

Channel availability check time timing plots are made using the analyzer. The analyzer is triggered at start of the EUT's channel availability check and used to verify that the EUT does not transmit when radar is applied during the check time.

The analyzer detector and oscilloscope sampling mode is set to peak detect for all plots.

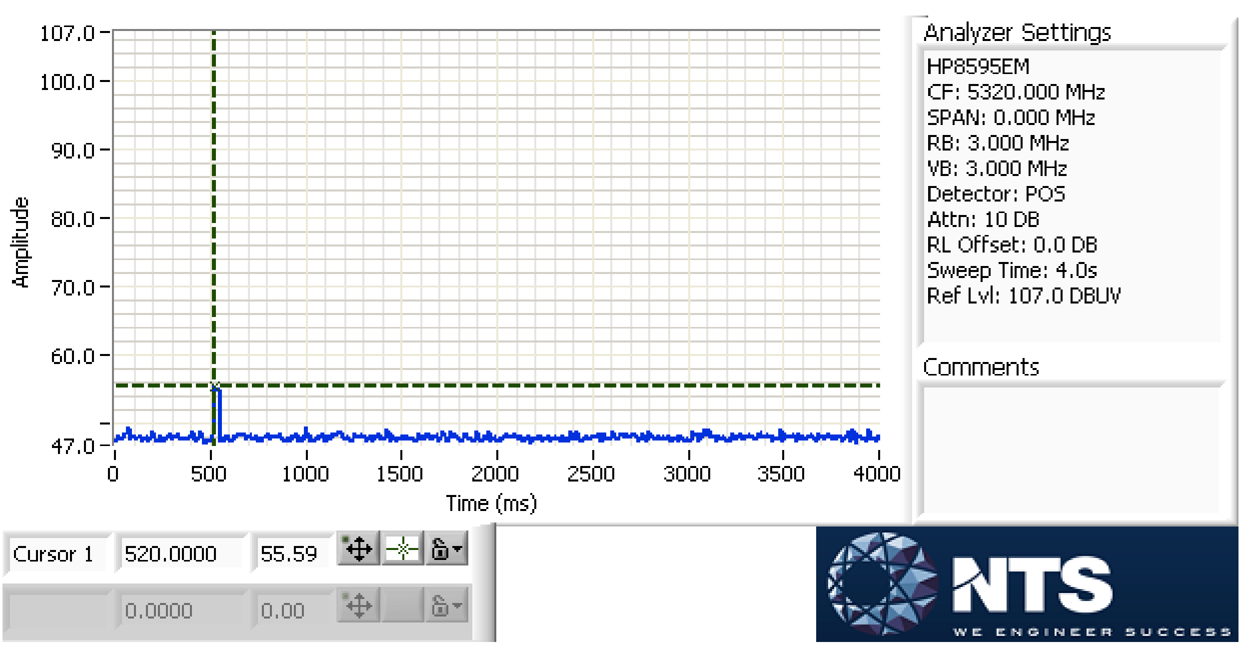

Figure 2 SA Noise Floor During Testing (radar shown at 520 ms)

RADAR GENERATOR PLOTS

The radar generator was connected to Spectrum Analyzer (SA) input, with the SA set to zero span, 3 MHz RBW, 3 MHz VBW. The SA IF output was connected to an oscilloscope to provide timing plots.

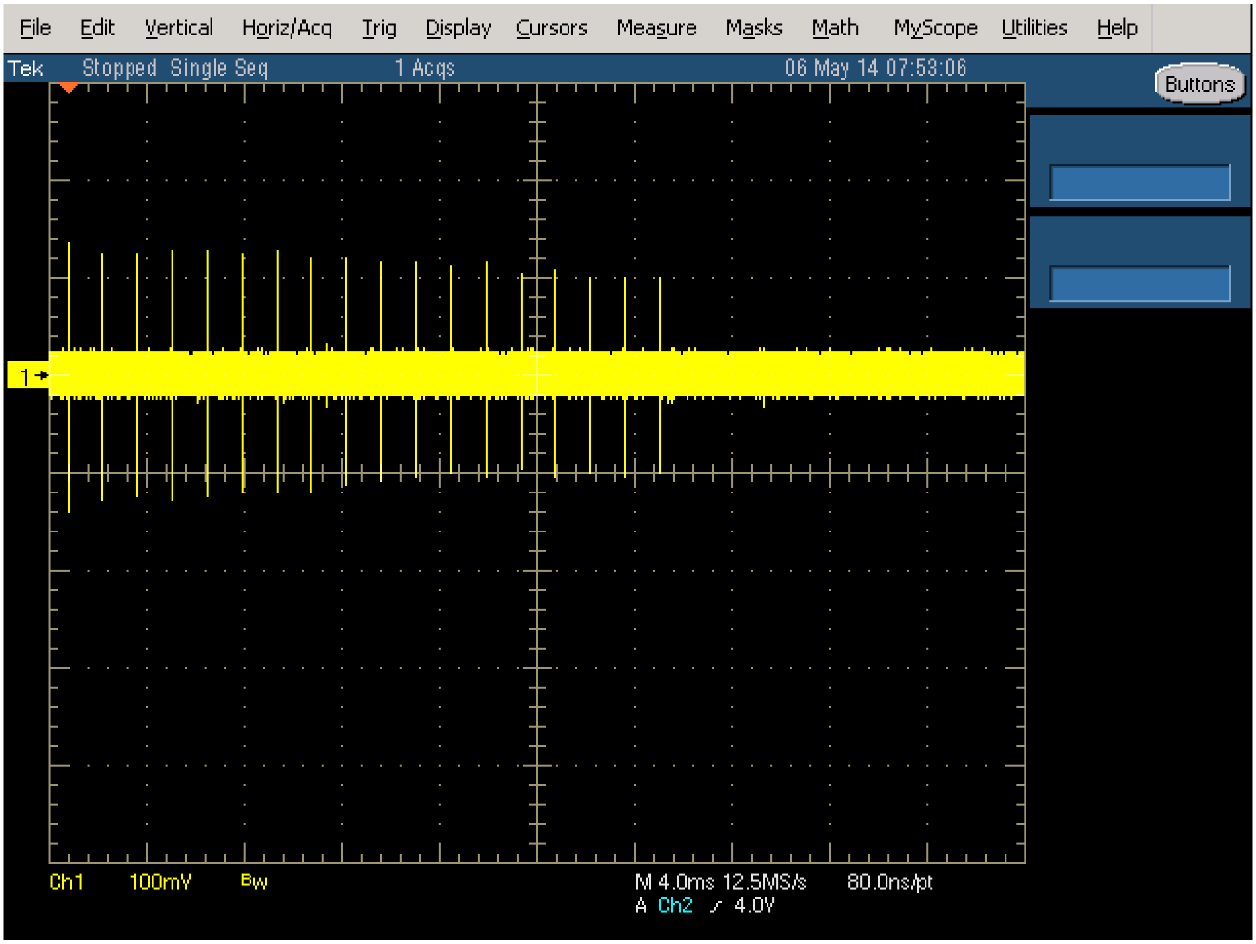

Figure 3 FCC Type 1 Radar (18 pulses)

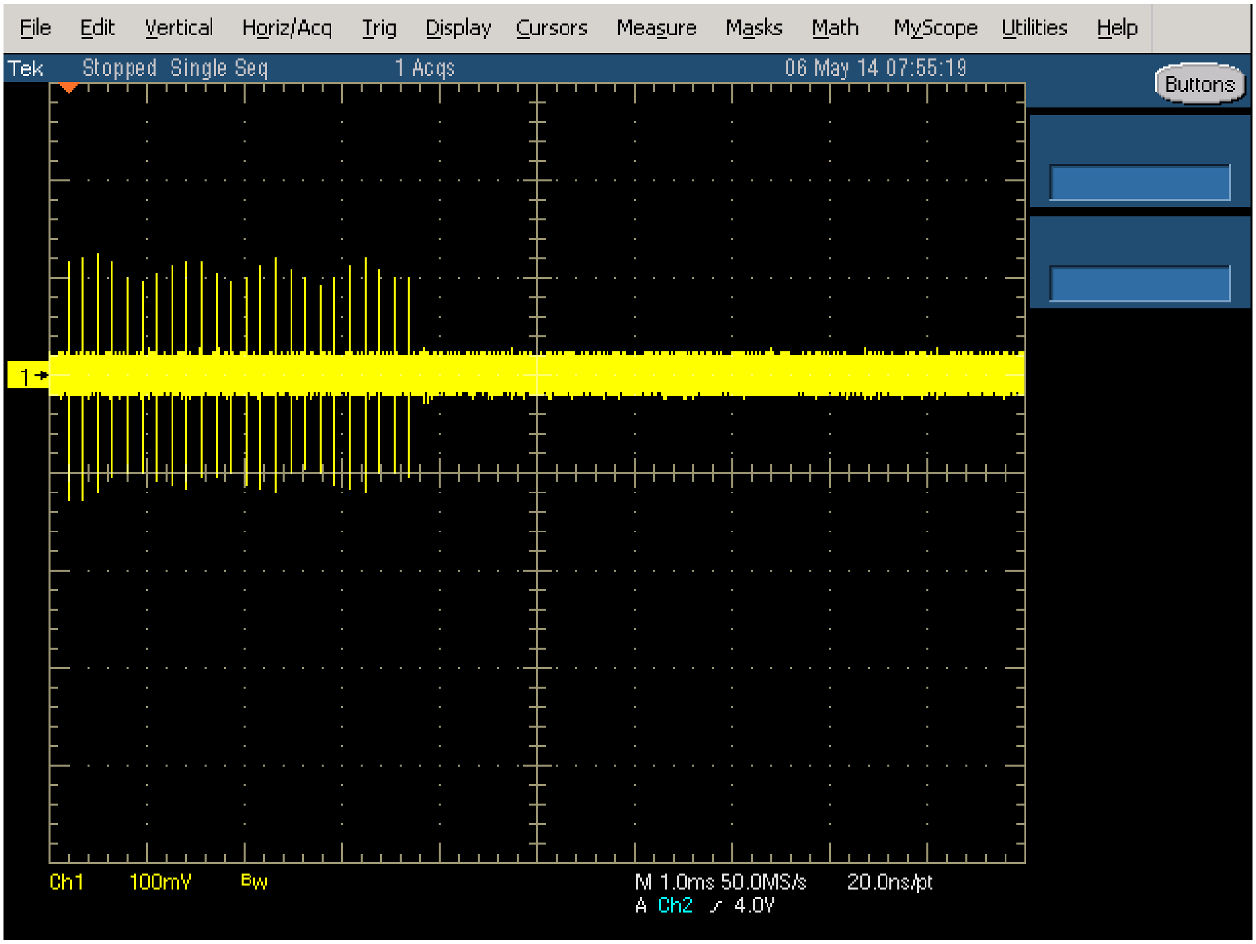

Figure 4 FCC Type 2 Radar (24 pulses)

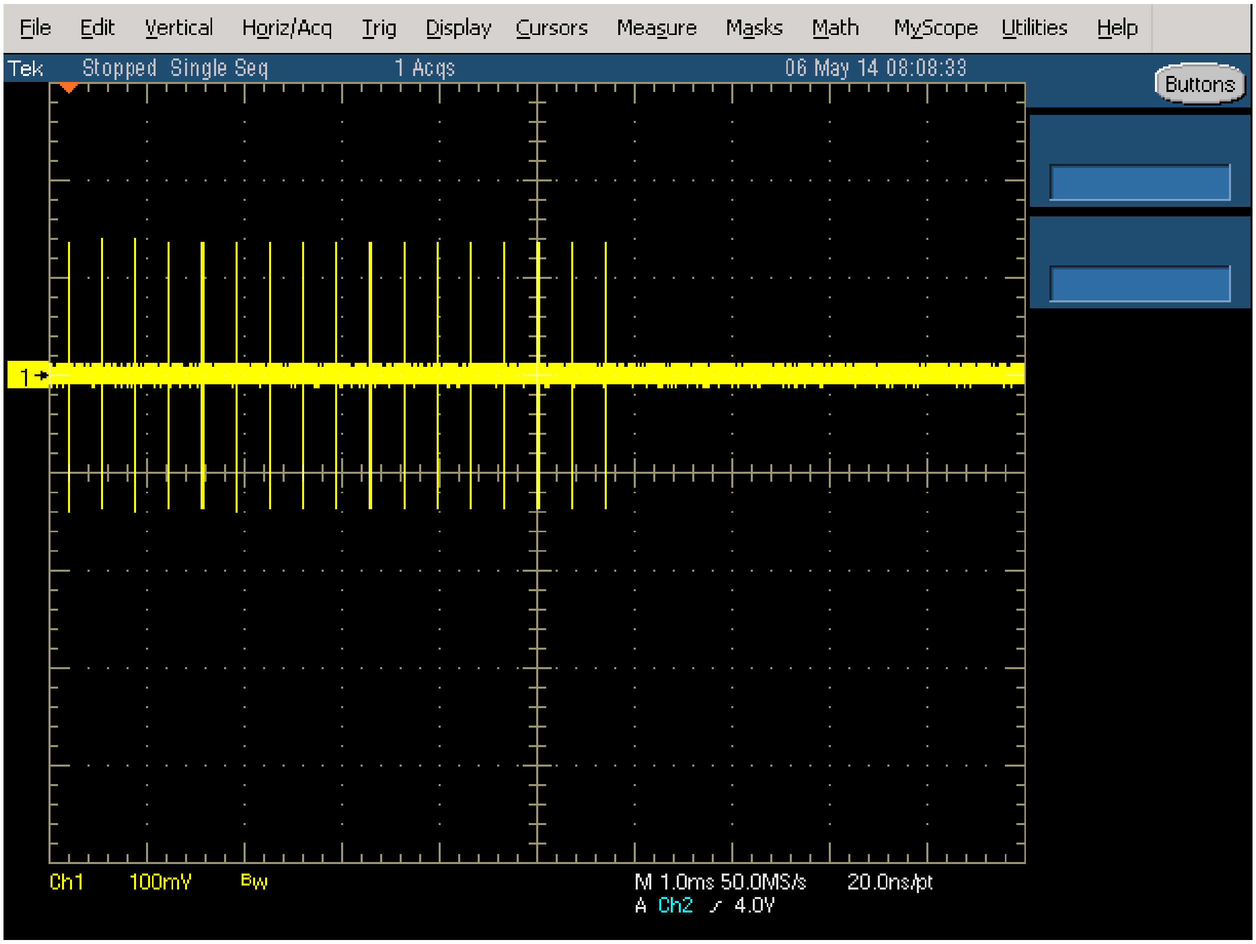

Figure 5 FCC Type 3 Radar (17 pulses)

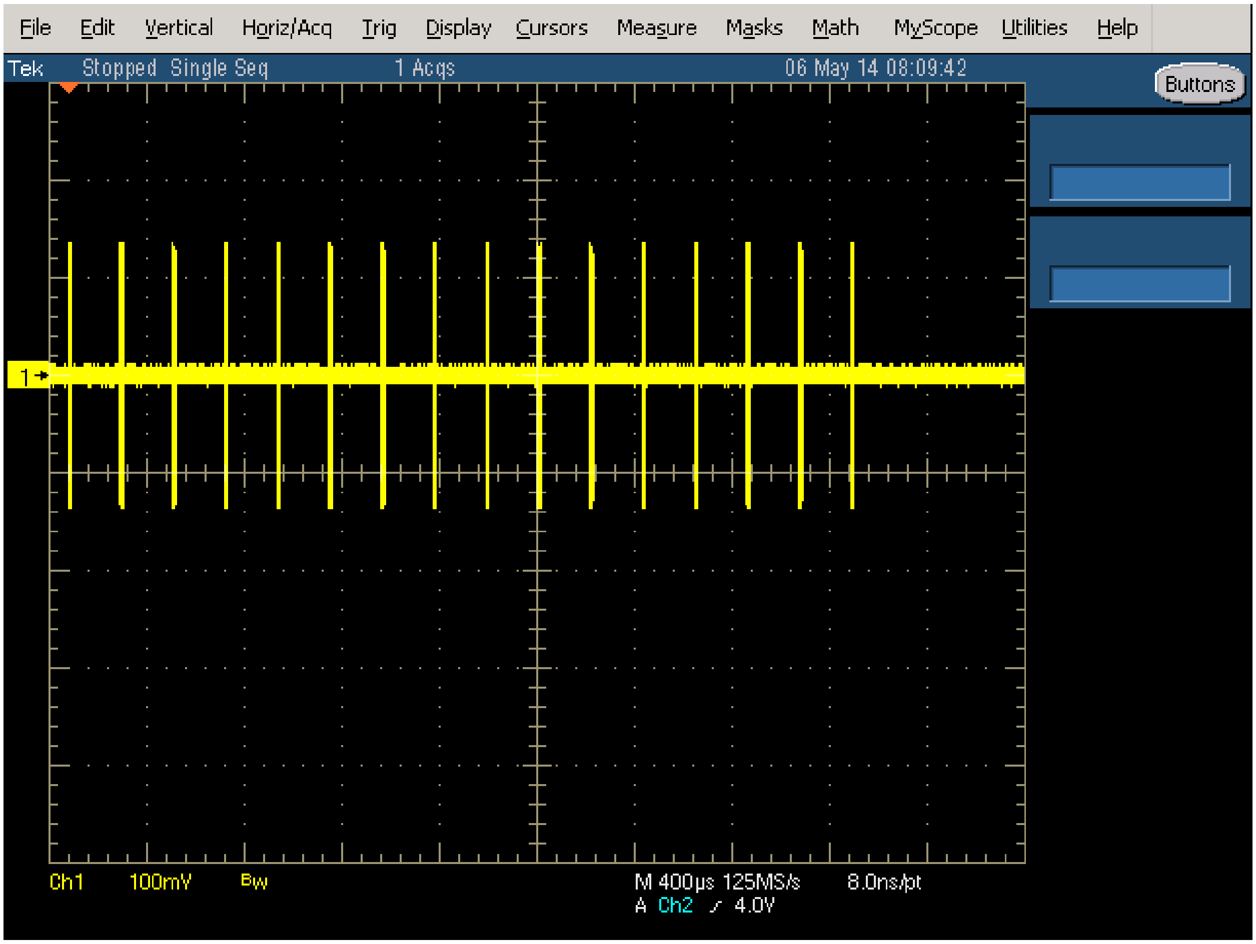

Figure 6 FCC Type 4 Radar (16 pulses)

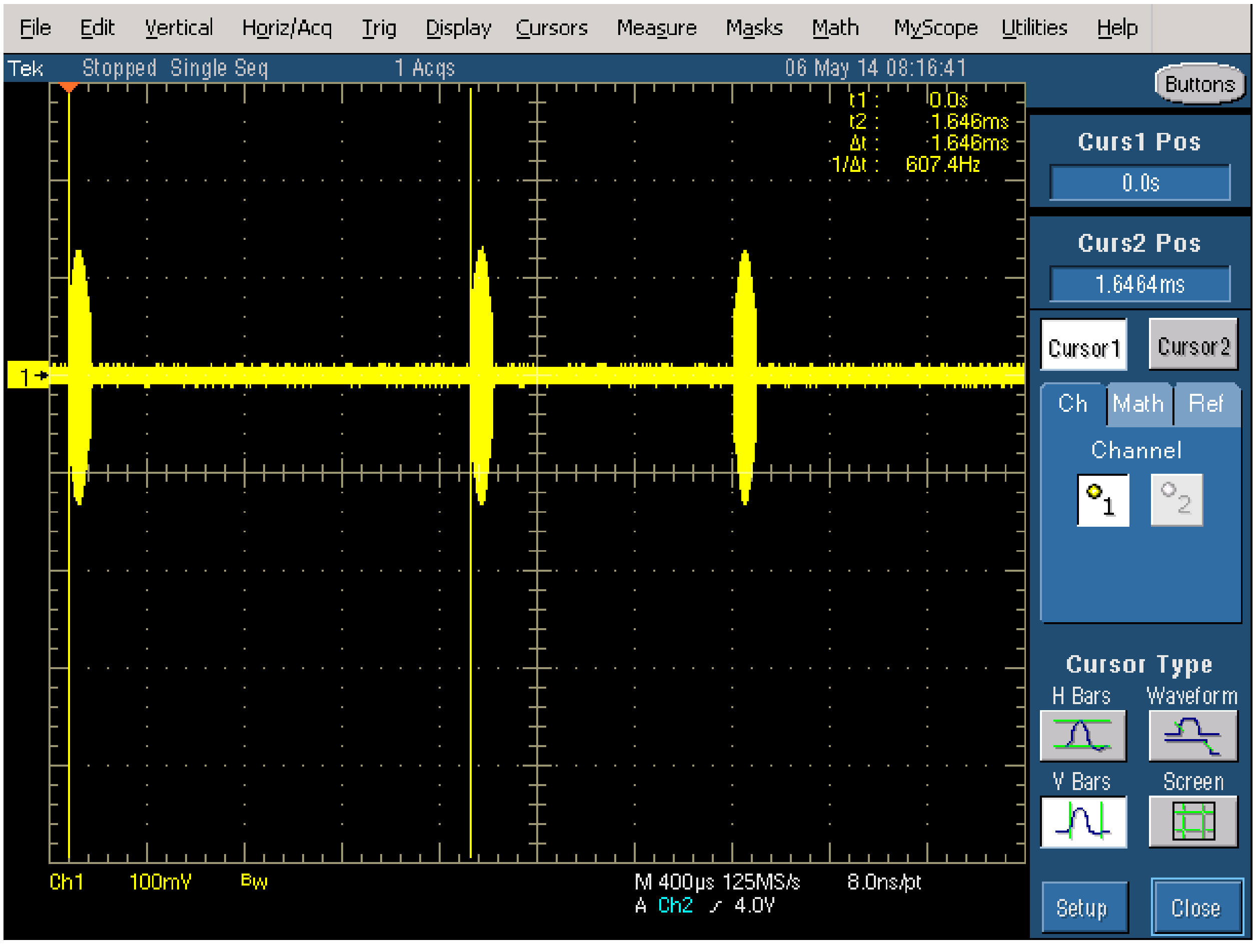

Figure 7 FCC Type 5 Radar (burst with three pulses, 1650 μs first period)

The shape is round due to chirped frequency during pulse as the SA is in zero span with 3 MHz BW.

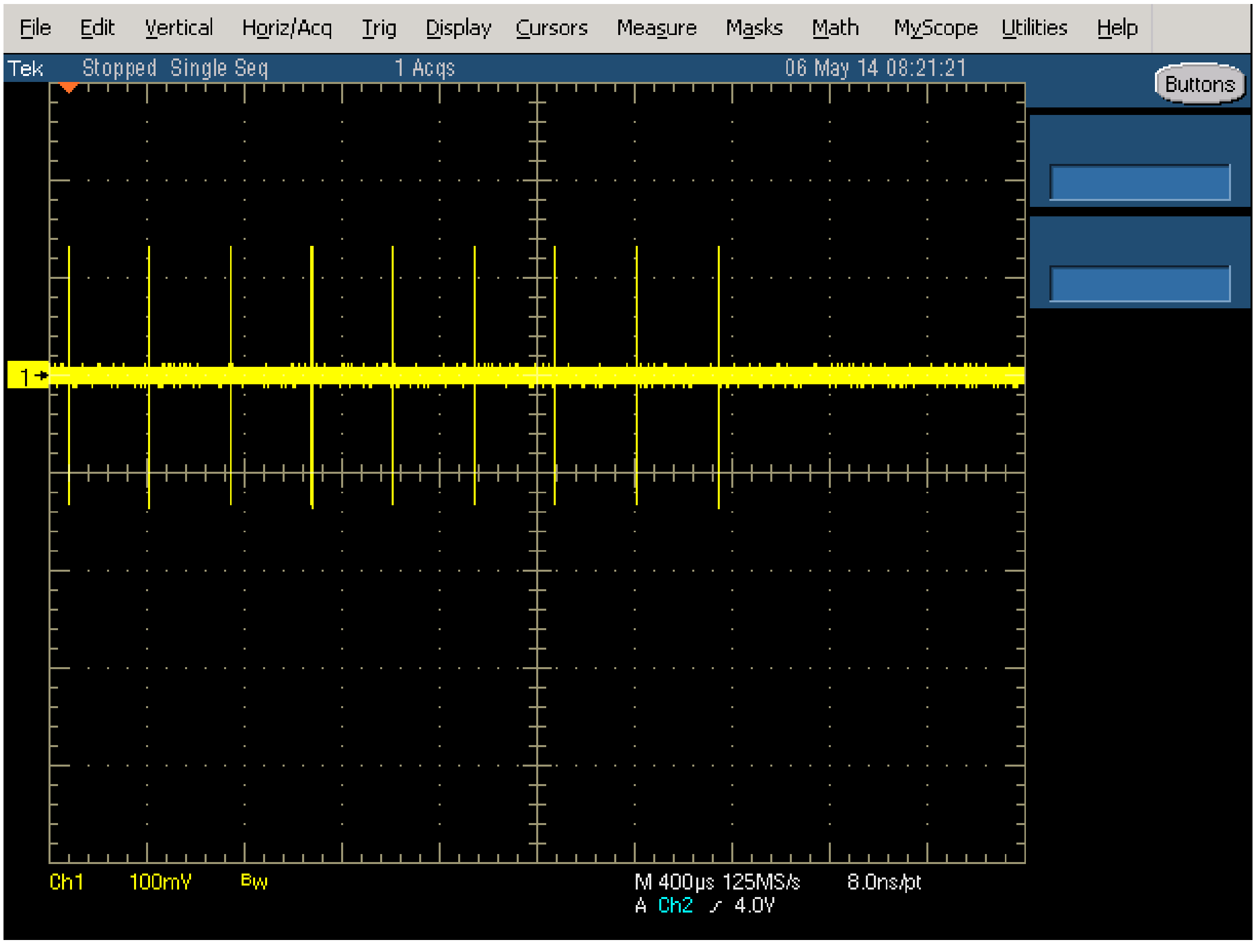

Figure 8 FCC Type 6 Radar (9 pulses in each burst)

DFS MEASUREMENT METHODS

DFS – CHANNEL CLOSING TRANSMISSION TIME AND CHANNEL MOVE TIME

Channel clearing and closing times are measured by applying a burst of radar with the device configured to change channel and by observing the channel for transmissions. The time between the end of the applied radar waveform and the final transmission on the channel is the channel move time.

The aggregate transmission closing time is measured using the following way:

> FCC/MSIP Notice No. 2015-95 – the total time of all individual transmissions from the EUT that are observed starting 200ms at the end of the last radar pulse in the waveform. This value is required to be less than 60ms.

DFS – CHANNEL NON-OCCUPANCY AND VERIFICATION OF PASSIVE SCANNING

The channel that was in use prior to radar detection by the master is additionally monitored for 30 minutes to ensure no transmissions on the vacated channel over the required non-occupancy period. This is achieved by tuning the spectrum analyzer to the vacated channel in zero-span mode and connecting the IF output to an oscilloscope. The oscilloscope is triggered by the radar pulse and set to provide a single sweep (in peak detect mode) that lasts for at least 30 minutes after the end of the channel move time.

For devices with a client-mode that are being evaluated against FCC rules the manufacturer must supply an attestation letter stating that the client device does not employ any active scanning techniques (i.e. does not transmit in the DFS bands without authorization from a Master device).

Appendix A Test Equipment Calibration Data

Manufacturer	Description	Model #	Asset #	Cal Due
Hewlett Packard	EMC Spectrum Analyzer, 9 kHz - 6.5 GHz DFS	8595EM	787	01-Sep-17
ETS Lindgren	Antenna, Horn, 1-18 GHz	3117	1662	13-Jun-18
Tektronix	500MHz, 2CH, 5GS/s OscilloScope	TDS5052B	2118	07-Dec-17
EMCO	Antenna, Horn, 1-18 GHz	3115	2733	06-Dec-18
Agilent Technologies	PSG, Vector Signal Generator, (250kHz - 20GHz)	E8267D	3011	25-Feb-18

Appendix B Test Data Tables for Radar Detection Probability

The plot below shows the channel loading during testing as evaluated over a 0.4 second period. The traffic was generated by iperf.

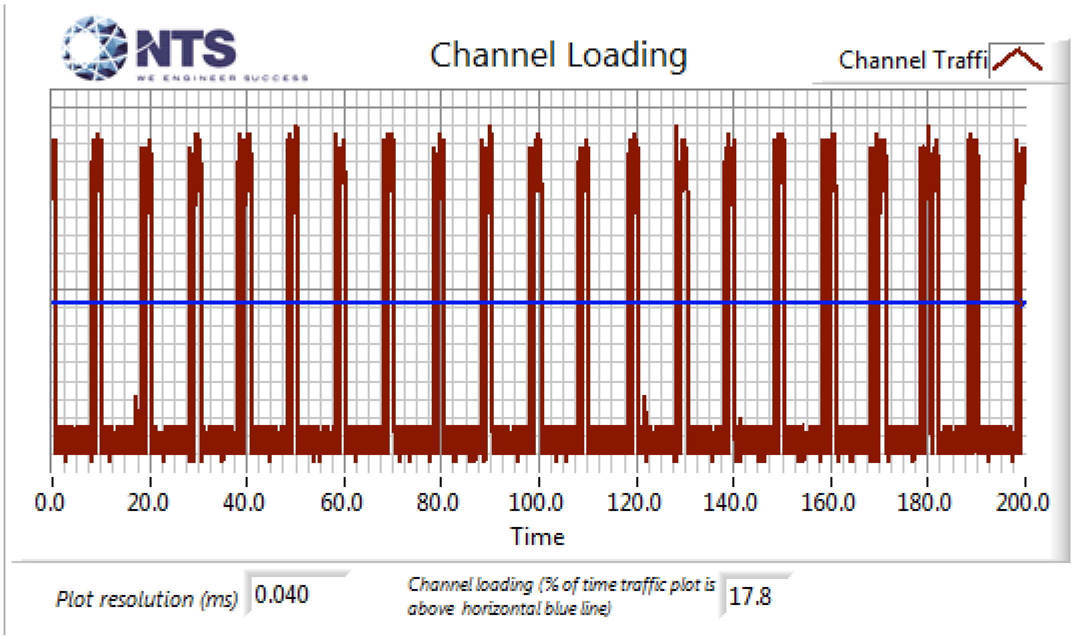

Figure 9 Channel Utilization during In-Service Detection Measurements (20MHz mode)

Appendix C Test Data Tables and Plots for Channel Closing

FCC PART 15 SUBPART E Channel Closing Measurements

Table 5 - FCC Part 15 Subpart E Channel Closing Test Results

Waveform Type	Channel Closing Transmission Time [1]		Channel Move Time		Result
	Measured	Limit	Measured	Limit	
Radar Type 0	0 ms	60 ms	0.1 s	10 s	Pass

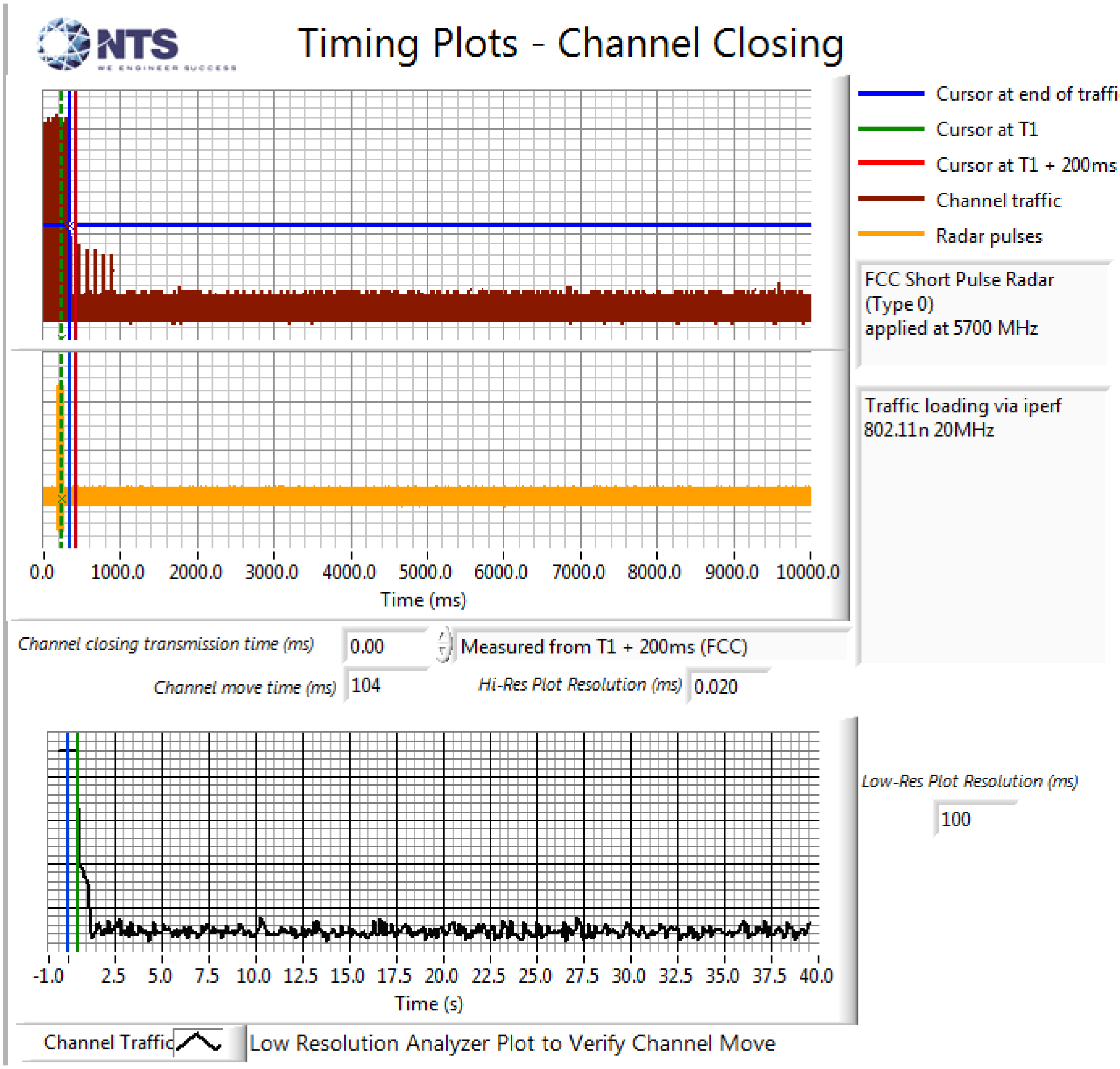

Figure 10 Channel Closing Time and Channel Move Time (20MHz mode) – 40 second plot

[1] Channel closing time for FCC measurements is the aggregate transmission time starting from 200ms after the end of the radar signal to the completion of the channel move.

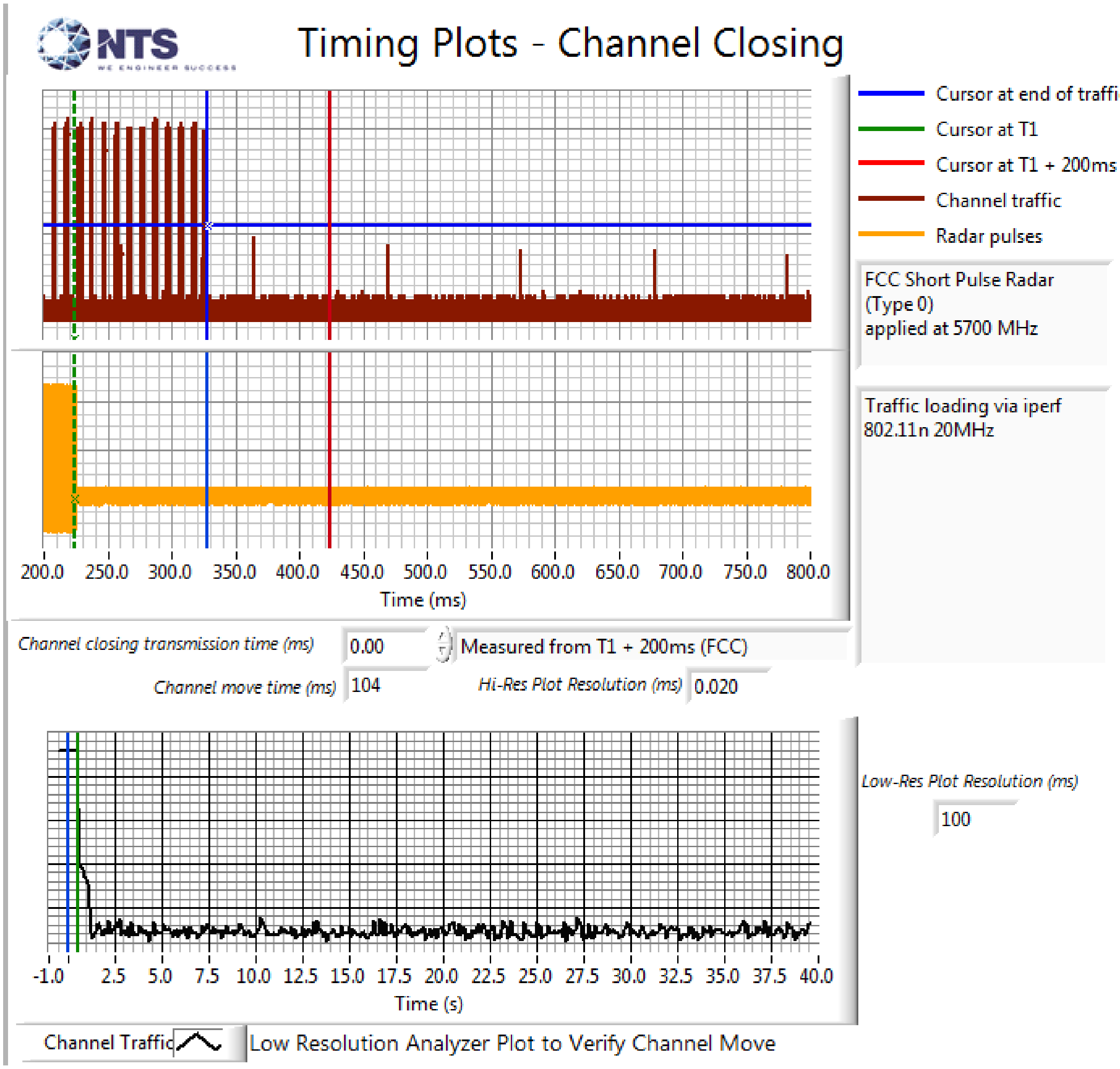

Figure 11 Close-Up of Transmissions Occurring More Than 200ms After The End of Radar (20MHz mode)

End of Report

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