Dynamic Frequency Selection (DFS) Test Report

Product Name	:	ConnectCore 6 Plus
Trade Name	:	DIGI
Model No.	:	CC-WMX-KK8D-TN
FCC ID.	:	MCQ-CCIMX6P
IC ID.	:	1846A-CCIMX6P

Applicant : DIGI INTERNATIONAL INC

Address : 11001 Bren Road East Minnetonka, MN 55343 (USA)

Date of Receipt	:	Dec. 11, 2017
Issued Date	:	Feb. 13, 2018
Report No.	:	17C0115R-RFUSP09V00
Report Version	:	V1.0

Testing Laboratory
3024

DFS Test Report

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Report No.: 17C0115R-RFUSP09V00

Product Name	:	ConnectCore 6 Plus
Applicant	:	DIGI INTERNATIONAL INC
Address	:	11001 Bren Road East Minnetonka, MN 55343 (USA)
Manufacturer	:	DIGI INTERNATIONAL INC
Model No.	:	CC-WMX-KK8D-TN
FCC ID.	:	MCQ-CCIMX6P
IC ID.	:	1846A-CCIMX6P
EUT Rated Voltage	:	AC 100-240V, 50/60Hz
EUT Test Voltage	:	AC 120V/60Hz
Trade Name	:	DIGI
Applicable Standard	:	FCC CFR Title 47 Part 15 Subpart E 15.407 (h): 2015 KDB 905462 D02V02, KDB 905462 D04V01, KDB 905462 D06V02 FCC 16-24 RSS-247 Issue 2 (2017-02)
Laboratory Name	:	Hsin Chu Laboratory
Address	:	No.372-2, Sec. 4, Zhongxing Rd., Zhudong Township, Hsinchu County 31061, Taiwan TEL: +886-3-582-8001 / FAX: +886-3-582-8958
Test Result	:	Complied

Documented By : Lyla Yang

(Lyla Yang / Engineering Adm. Specialist)

Tested By : clemens fang

(Clemens Fang / Engineer)

Approved By : Roy Wang

(Roy Wang / Director)

TABLE OF CONTENTS

1. General Information

1.1. EUT Description

Product Name	ConnectCore 6 Plus	
Trade Name	DIGI	
Model No.	CC-WMX-KK8D-TN	
Frequency Range/ Channel Number	IEEE 802.11a/ IEEE 802.11n (20MHz) / IEEE 802.11ac (20MHz)	5180~5240MHz / 4 Channels 5260~5320MHz / 4 Channels 5500~5700MHz / 11 Channels 5745~5825MHz / 5 Channels
	IEEE 802.11n (40MHz) / IEEE 802.11ac (40MHz)	5190~5230MHz / 2 Channels 5270~5310MHz / 2 Channels 5510~5670MHz / 5 Channels 5755~5795MHz / 2 Channels
	IEEE 802.11ac (80MHz)	5210~5210MHz / 1 Channel 5290~5290MHz / 1 Channel 5530~5610MHz / 2 Channel 5775~5775MHz / 1 Channel
	Canada not be capable of transmitting in the band 5600-5650MHz	
Type of Modulation	IEEE 802.11 a/n/ac	Orthogonal Frequency Division Multiplexing (OFDM)
Data Speed	IEEE 802.11a	6, 9, 18, 24, 36, 48, 54Mbps
	IEEE 802.11n	Support a subset of the combination of GI, MCS 0~MCS 7 and bandwidth defined in 802.11n
	IEEE 802.11ac	Support a subset of the combination of GI, MCS 0~MCS 9 and bandwidth defined in 802.11ac
DFS Function	☐ Master	☒ Slave (Without Radar Detection)
TPC Function	☒ <500mW not required	☐ ≧ 500mW employ a TPC
Communication Mode	☒ IP Based Systems	☐ Frame Based System ☐ Other System

Antenna Information	
MFR. / Model No.	Linx Technologies Inc. / ANT-DB1-RAF-RPS
Antenna Type	dipole Antenna
Antenna Gain	4.6 dBi

Accessories Information	
Power Adatper	GlobTek®, Inc., GT-46180-1605 I/P : 100-240V~, 50-60Hz, 0.6A O/P : 5V⎓3.2A, 16W Cable Out: Non-Shielded, 1.2m

802.11a/n-20MHz Center Working Frequency of Each Channel:

Working Frequency of Each Channel							
Channel	Frequency	Channel	Frequency	Channel	Frequency	Channel	Frequency
36	5180 MHz	40	5200 MHz	44	5220 MHz	48	5240 MHz
52	5260 MHz	56	5280 MHz	60	5300 MHz	64	5320 MHz
100	5500 MHz	104	5520 MHz	108	5540 MHz	112	5560 MHz
116	5580 MHz	120	5600 MHz	124	5620 MHz	128	5640 MHz
132	5660 MHz	136	5680 MHz	140	5700 MHz	149	5745 MHz
153	5765 MHz	157	5785 MHz	161	5805 MHz	165	5825 MHz

802.11n-40MHz Center Working Frequency of Each Channel:

Working Frequency of Each Channel							
Channel	Frequency	Channel	Frequency	Channel	Frequency	Channel	Frequency
38	5190 MHz	46	5230 MHz	54	5270MHz	62	5310 MHz
102	5510 MHz	110	5550 MHz	118	5590MHz	126	5630 MHz
134	5670 MHz	151	5755 MHz	159	5795 MHz		

802.11ac-80MHz Center Working Frequency of Each Channel:

Working Frequency of Each Channel							
Channel	Frequency	Channel	Frequency	Channel	Frequency	Channel	Frequency
42	5210 MHz	58	5290 MHz	106	5530 MHz	122	5610 MHz
155	5775 MHz						

Test Mode	Mode 1: Transmit

1.2. Standard Requirement

FCC Part 15.407:

U-NII devices operating in the 5.25-5.35 GHz band and the 5.47-5.725 GHz band shall employ a TPC mechanism. The U-NII device is required to have the capability to operate at least 6 dB below the mean EIRP value of 30dBm. A TPC mechanism is not required for systems with an E.I.R.P. of less than 500mW.

U-NII devices operating in the 5.25-5.35 GHz and 5.47-5.725 GHz bands shall employ a DFS radar detection mechanism to detect the presence of radar systems and to avoid co-channel operation with radar systems.

1.3. UNII Device Description

(1) The EUT operates in the following DFS band:

1. 5250-5350 MHz
2. 5470-5725 MHz

(2) Below are the available 50 ohm antenna assemblies and their corresponding gains. 0dBi gain was used to set the -63 dBm threshold level (-64dBm +1 dB) during calibration of the test setup.

Antenna Information	
MFR. / Model No.	Linx Technologies Inc. / ANT-DB1-RAF-RPS
Antenna Type	dipole Antenna
Antenna Gain	4.6 dBi

(3) DFS operation description:

WLAN traffic is generated by streaming the video file “ipef.exe” from the Master device to the Slave device in full motion video mode using the media player with the V2.61 Codec package.

(4) This device does not exceed 27dBm eirp, so no transmit power control is implemented.

1.4. Test Equipment

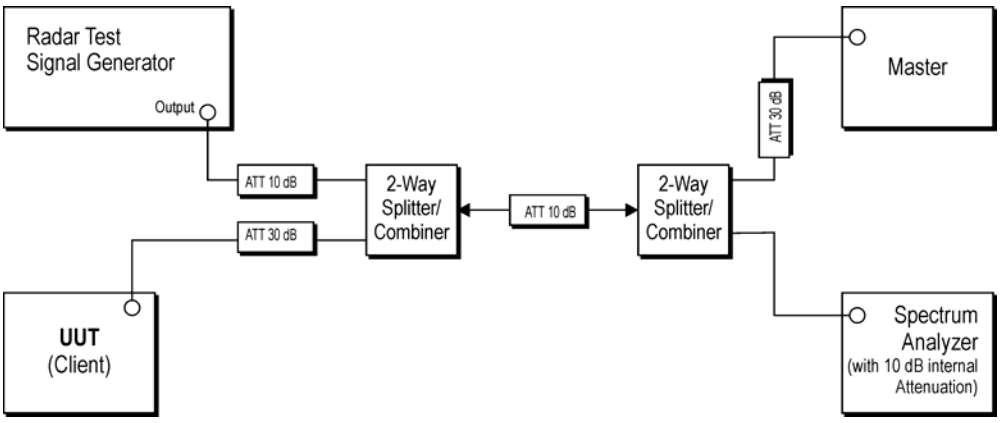
DFS / SR11-H

Instrument	Manufacturer	Model No.	Serial No.	Cal. Date	Next Cal. Date
Spectrum Analyzer	Agilent	N9010A	US47140172	2017/07/26	2018/07/25
ESG Vector Signal Generator	Agilent	E4438C	MY45095759	2017/05/24	2018/05/23
MXG Vector Signal Generator	Keysight	N5182B	MY53052548	2017/04/10	2018/04/09
Wideband Radio Communication Tester	R&S	CMW500	150246	2017/04/19	2018/04/18
Signal & Spectrum Analyzer	R&S	FSV40	101049	2018/01/10	2019/01/09
EXA Signal Analyzer	Keysight	N9010A	MY51440132	2017/03/13	2018/03/12

Instrument	Manufacturer	Type No.	Serial No
Laptop PC	DELL	Vostro A860	CD8BMH1
Laptop PC	ASUS	K45VD	0343G3110M
ATT (Qty: 3)	Mini-Circuits	BW-S3W2 DC-18GHz	0025
RF Cable (Qty: 6)	Schaffner		25494/6
Laptop PC	DELL	Vostro A860	CD8BMH1
Laptop PC	ASUS	K45VD	0343G3110M

Software	Manufacturer	Function
Agilent DFS_TEST V6.9	Agilent	Radar Signal Generation Software

1.5. Test Setup



1.6. DFS Requirements Prior to Use of a Channel

Requirement	Operational Mode		
	Master	Client Without Radar Detection	Client With Radar Detection
Non-Occupancy Period	Yes	Not required	Yes
DFS Detection Threshold	Yes	Not required	Yes
Channel Availability Check Time	Yes	Not required	Not required
Uniform Spreading	Yes	Not required	Not required
U-NII Detection Bandwidth	Yes	Not required	Yes

1.7. DFS requirements during normal operation

Requirement	Operational Mode		
	Master	Client Without Radar Detection	Client With Radar Detection
DFS Detection Threshold	Yes	Not required	Yes
Channel Closing Transmission Time	Yes	Yes	Yes
Channel Move Time	Yes	Yes	Yes
U-NII Detection Bandwidth	Yes	Not required	Yes

1.8. DFS Detection Thresholds

(1) Interference Threshold value, Master or Client incorporating In-Service Monitoring

Maximum Transmit Power	Value (see note)
≥200 milliwatt	-64 dBm
EIRP < 200 milliwatt and power spectral density < 10 dBm/MHz	-62 dBm
EIRP < 200 milliwatt that do not meet the power spectral density requirement	-64 dBm
Note 1: This is the level at the input of the receiver assuming a 0 dBi receive antenna. **Note 2:** Throughout these test procedures an additional 1 dB has been added to the amplitude of the test transmission waveforms to account for variations in measurement equipment. This will ensure that the test signal is at or above the detection threshold level to trigger a DFS response. **Note3:** EIRP is based on the highest antenna gain. For MIMO devices refer to KDB Publication 662911 D01.	

(2) DFS Response requirement values

Parameter	Value
Non-Occupancy Period	30 Minutes
Channel Availability Check Time	60 Seconds
Channel Move Time	10 seconds See Note 1.
Channel Closing Transmission Time	200 milliseconds + an aggregate of 60 milliseconds over remaining 10 second period. See Notes 1 and 2.
U-NII Detection Bandwidth	Minimum 100% of the U-NII 99% transmission power bandwidth. See Note 3.
Note 1: *Channel Move Time* and the *Channel Closing Transmission Time* should be performed with Radar Type 0. The measurement timing begins at the end of the Radar Type 0 burst. **Note 2:** The *Channel Closing Transmission Time* is comprised of 200 milliseconds starting at the beginning of the *Channel Move Time* plus any additional intermittent control signals required to facilitate a *Channel* move (an aggregate of 60 milliseconds) during the remainder of the 10 second period. The aggregate duration of control signals will not count quiet periods in between transmissions. **Note 3:** During the *U-NII Detection Bandwidth* detection test, radar type 0 should be used. For each frequency step the minimum percentage of detection is 90 percent. Measurements are performed with no data traffic.	

1.9. Radar Test Waveforms

This section provides the parameters for required test waveforms, minimum percentage of successful detections, and the minimum number of trials that must be used for determining DFS conformance. Step intervals of 0.1 microsecond for Pulse Width, 1 microsecond for PRI, 1 MHz for chirp width and 1 for the number of pulses will be utilized for the random determination of specific test waveforms.

(1) Short Pulse Radar Test Waveforms

Radar Type	Pulse Width (μsec)	PRI (μsec)	Number of Pulses	Minimum Percentage of Successful Detection	Minimum Number of Trials
0	1	1428	18	See Note 1	See Note 1
1	1	Test A: 15 unique PRI values randomly selected from the list of 23 PRI values in Table 5a	Roundup $\left\{\left(\frac{1}{360}\right)\cdot\left(\frac{19\cdot 10^6}{PRI_{\mu sec}}\right)\right\}$	60%	30
		Test B: 15 unique PRI values randomly selected within the range of 518-3066 μ sec, with a minimum increment of 1 μ sec, excluding PRI values selected in Test A			
2	1-5	150-230	23-29	60%	30
3	6-10	200-500	16-18	60%	30
4	11-20	200-500	12-16	60%	30
Aggregate (Radar Types 1-4)				80%	120
Note 1: Short Pulse Radar Type 0 should be used for the detection bandwidth test, channel move time, and channel closing time tests.					

A minimum of 30 unique waveforms are required for each of the Short Pulse Radar Types 2 through 4. If more than 30 waveforms are used for Short Pulse Radar Types 2 through 4, then each additional waveform must also be unique and not repeated from the previous waveforms. If more than 30 waveforms are used for Short Pulse Radar Type 1, then each additional waveform is 905462 D02 UNII DFS Compliance Procedures v01 Page 10 generated with Test B and must also be unique and not repeated from the previous waveforms in Tests A or B.

(2) Long Pulse Radar Test Signal

Radar Waveform	Bursts	Pulses Per Burst	Pulse Width (usec)	Chirp Width (MHz)	PRI (usec)	Minimum Percentage of Successful Detection	Minimum Trials
5	8-20	1-3	50-100	5-20	1000-2000	80%	30

The parameters for this waveform are randomly chosen. Thirty unique waveforms are required for the long pulse radar test signal. If more than 30 waveforms are used for the long pulse radar test signal, then each additional waveform must also be unique and not repeated from the previous waveforms.

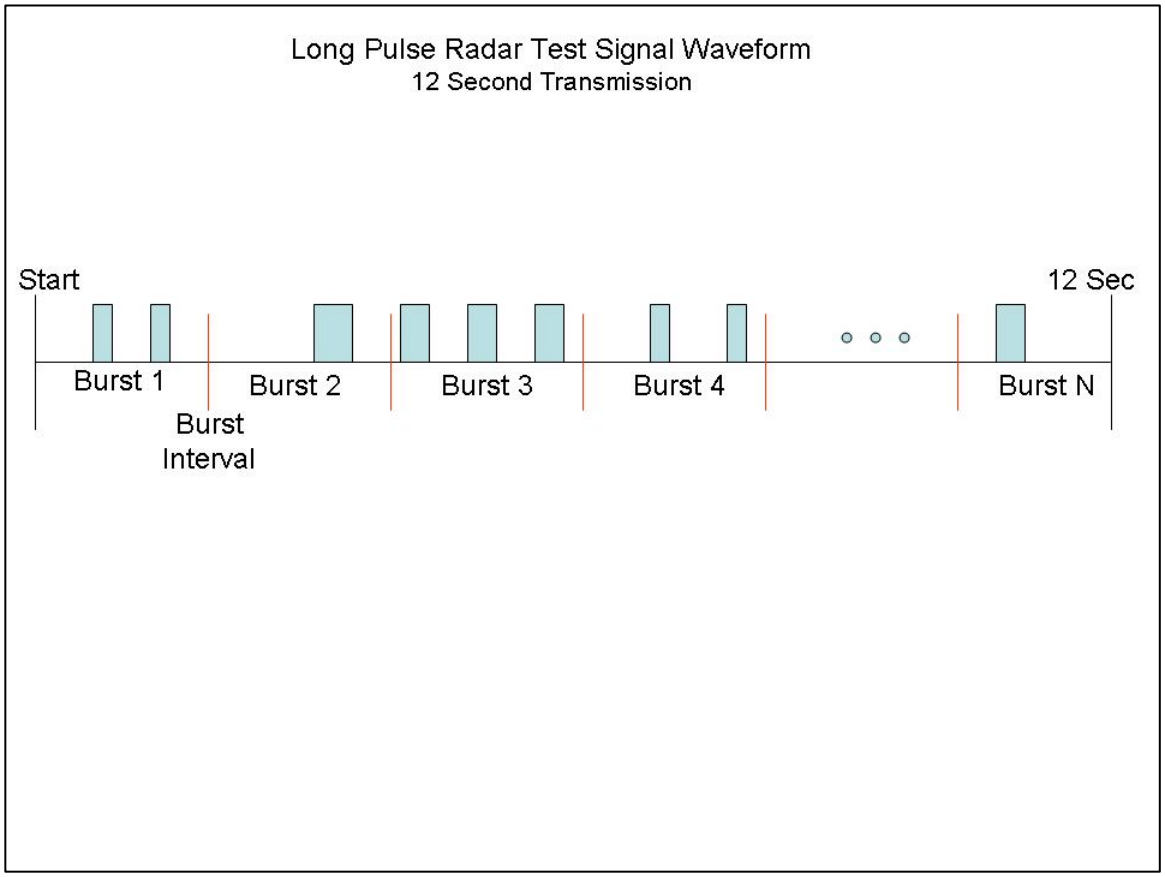
Each waveform is defined as follows:

1) The transmission period for the Long Pulse Radar test signal is 12 seconds.
2) There are a total of 8 to 20 Bursts in the 12 second period, with the number of Bursts being randomly chosen. This number is Burst_Count.
3) Each Burst consists of 1 to 3 pulses, with the number of pulses being randomly chosen. Each Burst within the 12 second sequence may have a different number of pulses.
4) The pulse width is between 50 and 100 microseconds, with the pulse width being randomly chosen. Each pulse within a Burst will have the same pulse width. Pulses in different Bursts may have different pulse widths.
5) Each pulse has a linear FM chirp between 5 and 20 MHz, with the chirp width being randomly chosen. Each pulse within a Burst will have the same chirp width. Pulses in different Bursts may have different chirp widths. The chirp is centered on the pulse. For example, with radar frequency of 5310 MHz and a 20 MHz chirped signal, the chirp starts at 5300 MHz and ends at 5320 MHz.
6) If more than one pulse is present in a Burst, the time between the pulses will be between 1000 and 2000 microseconds, with the time being randomly chosen. If three pulses are present in a Burst, the time between the first and second pulses is chosen independently of the time between the second and third pulses.
7) The 12 second transmission period is divided into even intervals. The number of intervals is equal to Burst_Count. Each interval is of length (12,000,000 / Burst_Count) microseconds. Each interval contains one Burst. The start time for the Burst, relative to the beginning of the interval, is between 1 and [(12,000,000 / Burst_Count) – (Total Burst Length) + (One Random PRI Interval)] microseconds, with the start time being randomly chosen. The step interval for the start time is 1 microsecond. The start time for each Burst is chosen independently.

A representative example of a Long Pulse radar test waveform:

1) The total test signal length is 12 seconds.
2) 8 Bursts are randomly generated for the Burst_Count.
3) Burst 1 has 2 randomly generated pulses.
4) The pulse width (for both pulses) is randomly selected to be 75 microseconds.
5) The PRI is randomly selected to be at 1213 microseconds.
6) Bursts 2 through 8 are generated using steps 3 – 5.
7) Each Burst is contained in even intervals of 1,500,000 microseconds. The starting location for Pulse 1, Burst 1 is randomly generated (1 to 1,500,000 minus the total Burst 1 length + 1 random PRI interval) at the 325,001 microsecond step. Bursts 2 through 8 randomly fall in successive 1,500,000 microsecond intervals (i.e. Burst 2 falls in the 1,500,001 – 3,000,000 microsecond range).

Graphical Representation of a Long Pulse radar Test Waveform



(3) Frequency Hopping Radar Test Signal

Radar Waveform	Pulse Width (μsec)	PRI (μsec)	Hopping Sequence Length (msec)	Pulses Per Hop	Hopping Rate (kHz)	Minimum Percentage of Successful Detection	Minimum Trials
6	1	333	300	9	0.333	70%	30

For the Frequency Hopping Radar Type, the same *Burst* parameters are used for each waveform. The hopping sequence is different for each waveform and a 100-length segment is selected[1] from the hopping sequence defined by the following algorithm:

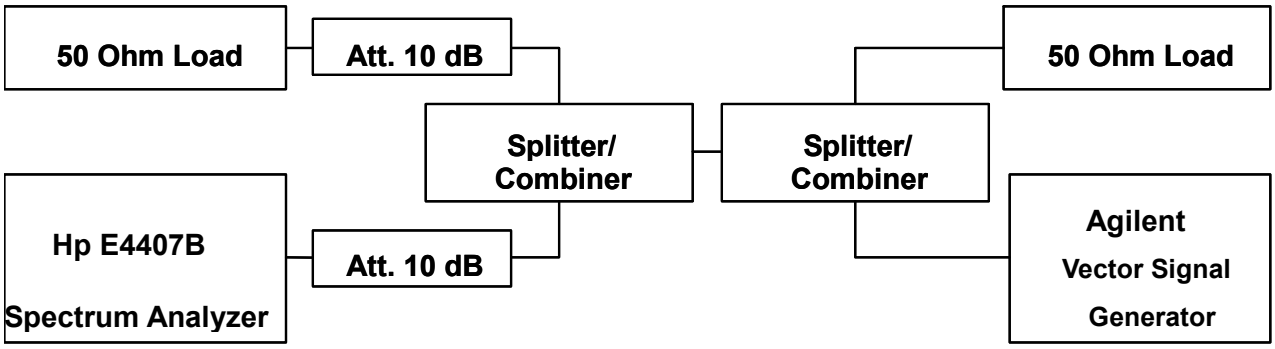
The first frequency in a hopping sequence is selected randomly from the group of 475 integer frequencies from 5250 – 5724 MHz. Next, the frequency that was just chosen is removed from the group and a frequency is randomly selected from the remaining 474 frequencies in the group. This process continues until all 475 frequencies are chosen for the set. For selection of a random frequency, the frequencies remaining within the group are always treated as equally likely.

1.10. Radar Waveform Calibration

The following equipment setup was used to calibrate the conducted radar waveform. A spectrum analyzer was used to establish the test signal level for each radar type. During this process there were replace 50ohm terminal from master and client device and no transmissions by either the master or client device. The spectrum analyzer was switched to the zero span (time domain) at the frequency of the radar waveform generator. Peak detection was utilized. The spectrum analyzer resolution bandwidth (RBW) and video bandwidth (VBW) were set to 3MHz and 3 MHz.

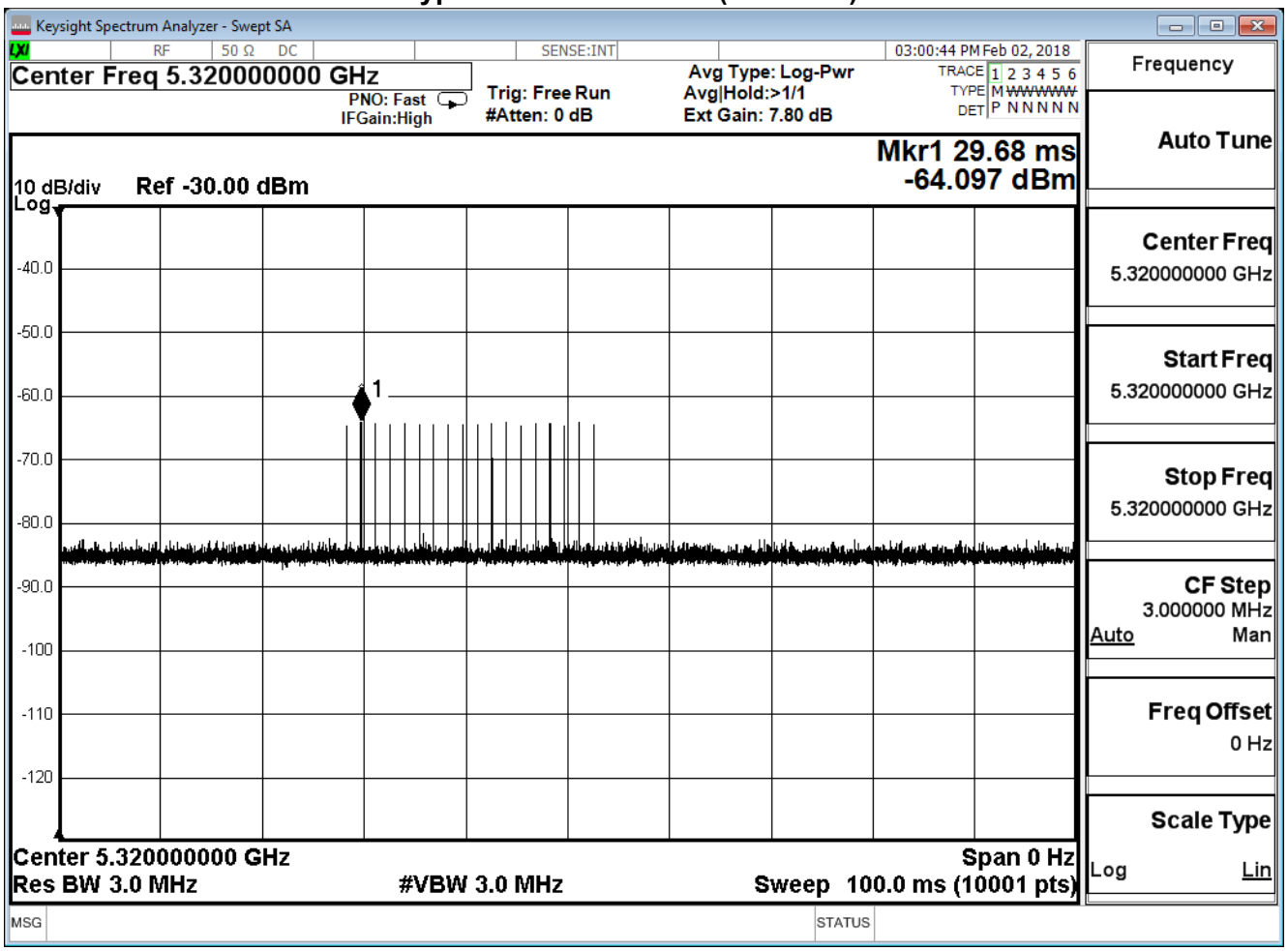
The signal generator amplitude was set so that the power level measured at the spectrum analyzer was -64dBm due to the interference threshold level is not required.

Conducted Calibration Setup



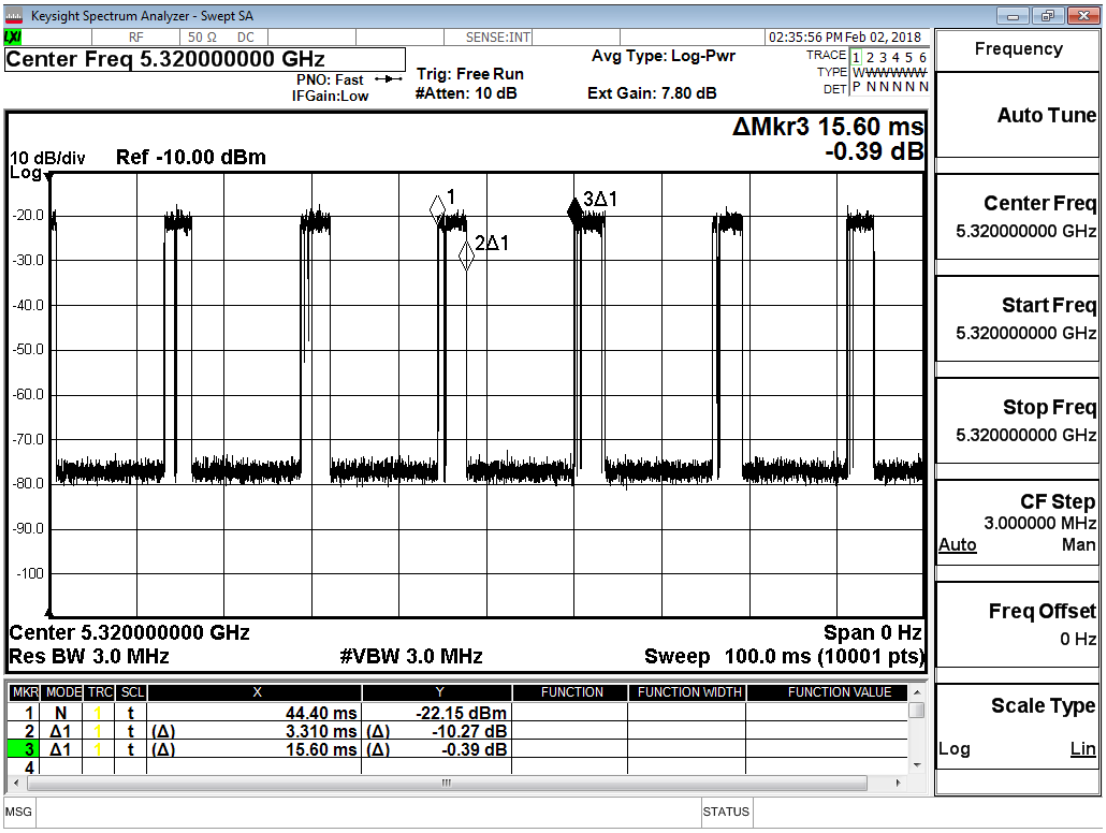
1.11. Radar Waveform Calibration Result

Radar Type 0 Calibration Plot (5510MHz)

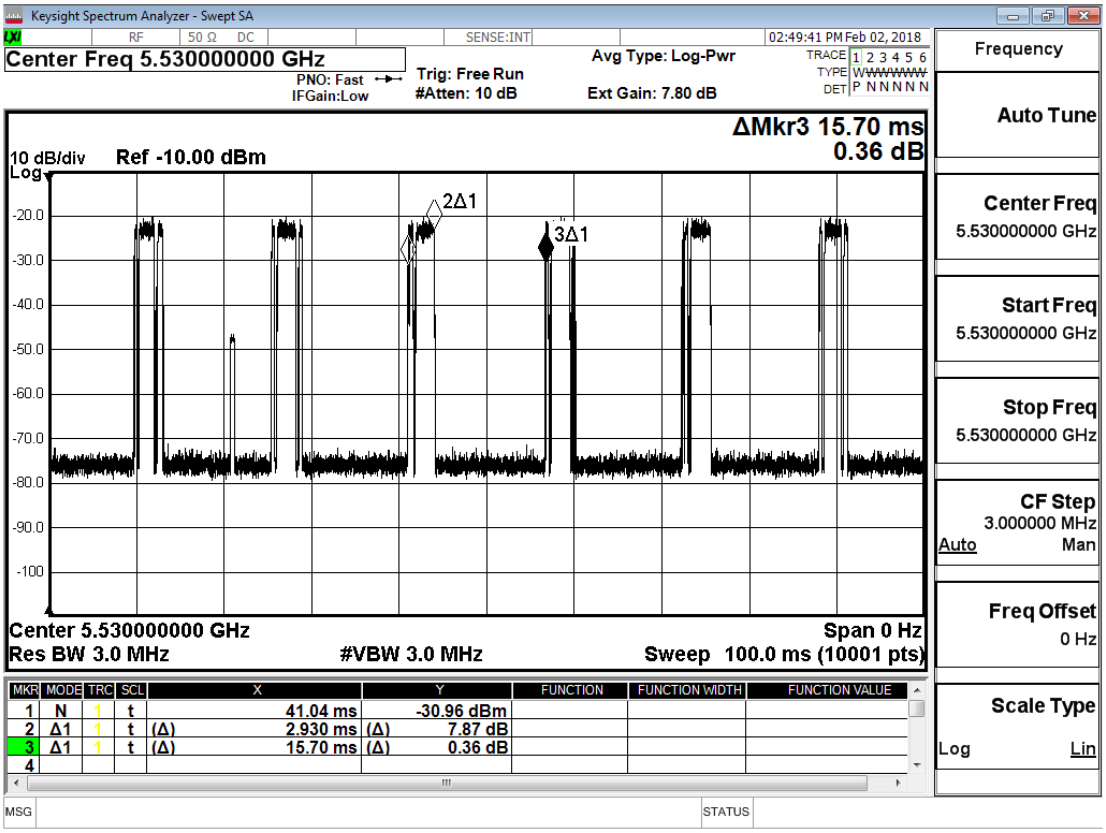


1.12. Slave Data Traffic Plot Result

Plot of Slave Traffic at 5320MHz



Plot of Slave Traffic at 5530MHz



2. In-Service Monitoring for Channel Move Time and Channel Closing Transmission Time and Non-Occupancy Period

2.1. Test Procedure

These tests define how the following DFS parameters are verified during In-Service Monitoring;

Channel Closing Transmission Time, Channel Move Time, and Non-Occupancy Period.. The steps below define the procedure to determine the above mentioned parameters when a radar Burst with a level equal to the DFS Detection Threshold + 1dB (-63dBm) is generated on the Operating Channel of the U-NII device.

A U-NII device operating as a Master Device will associate with the UUT (Client) at 5300 MHz and 5500MHz.

Stream the MPEG test file from the Client (TX) Device to the Master (RX) Device on the selected Channel for the entire period of the test.

At time T0 the Radar Waveform generator sends a Burst of pulses for each of the radar types at

-63dBm.

Observe the transmissions of the UUT at the end of the radar Burst on the Operating Channel for duration greater than 10 seconds. Measure and record the transmissions from the UUT during the observation time (Channel Move Time). Compare the Channel Move Time and Channel Closing

Transmission Time results to the limits defined in the DFS Response requirement values table.

Measure the UUT for more than 30 minutes following the channel close/move time to verify that the UUT does not resume any transmissions on this Channel.

2.2. Test Requirement

Parameter	Value
Channel Move Time	10 Seconds
Channel Closing Transmission Time	200 milliseconds + an aggregate of 60 milliseconds over remaining 10 seconds period
Non-Occupancy Period	Minimum 30 minutes

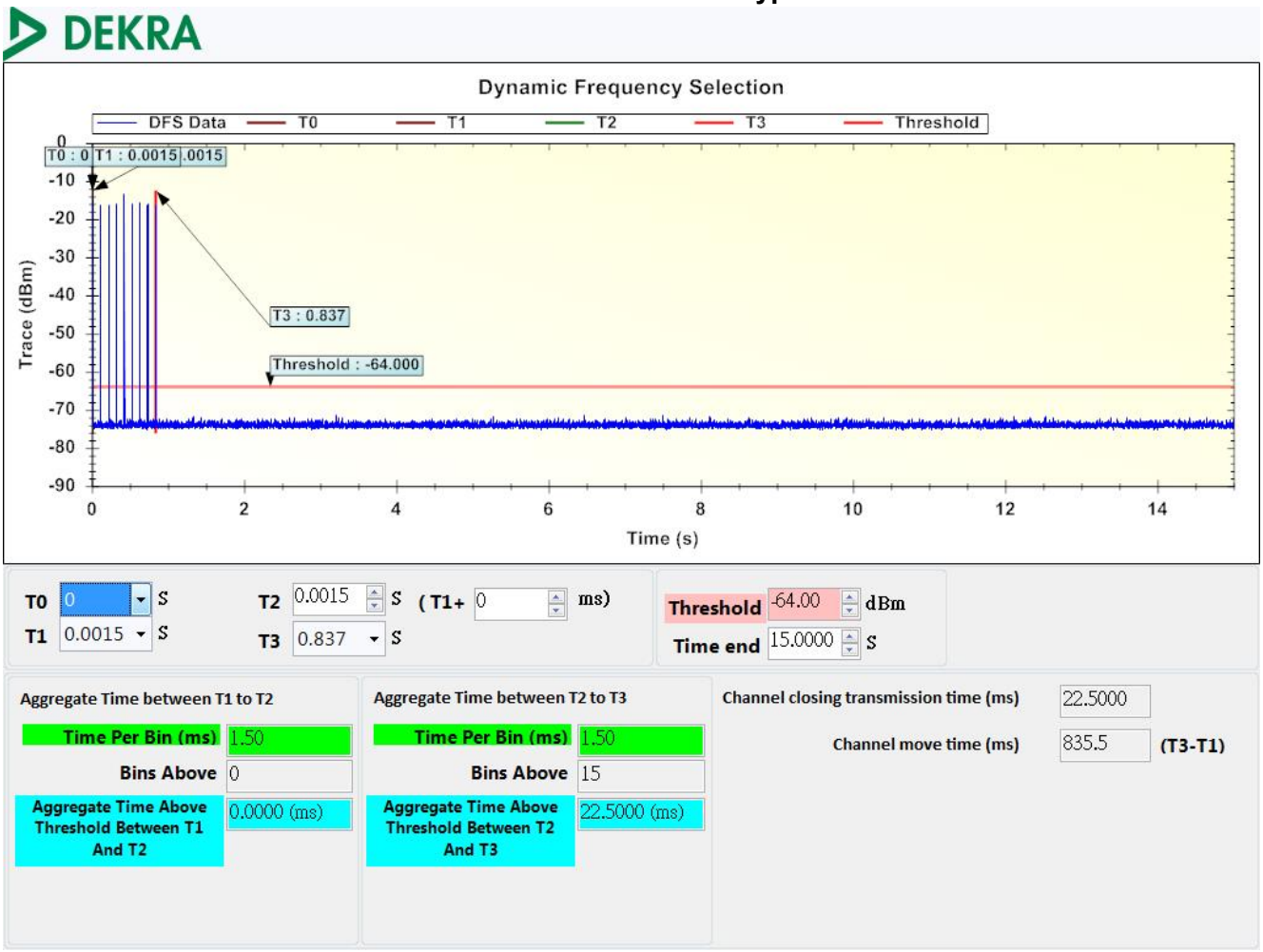
2.3. Uncertainty

± 1ms.

2.4. Test Result of Channel Move Time and Channel Closing Transmission Time and Non-Occupancy Period

Product	:	ConnectCore 6 Plus
Test Item	:	Channel Move Time Test
Radar Type	:	Type 0
Test Mode	:	Mode 1: Transmit

Channel Move Time for Radar Test Type 0 at 5320MHz

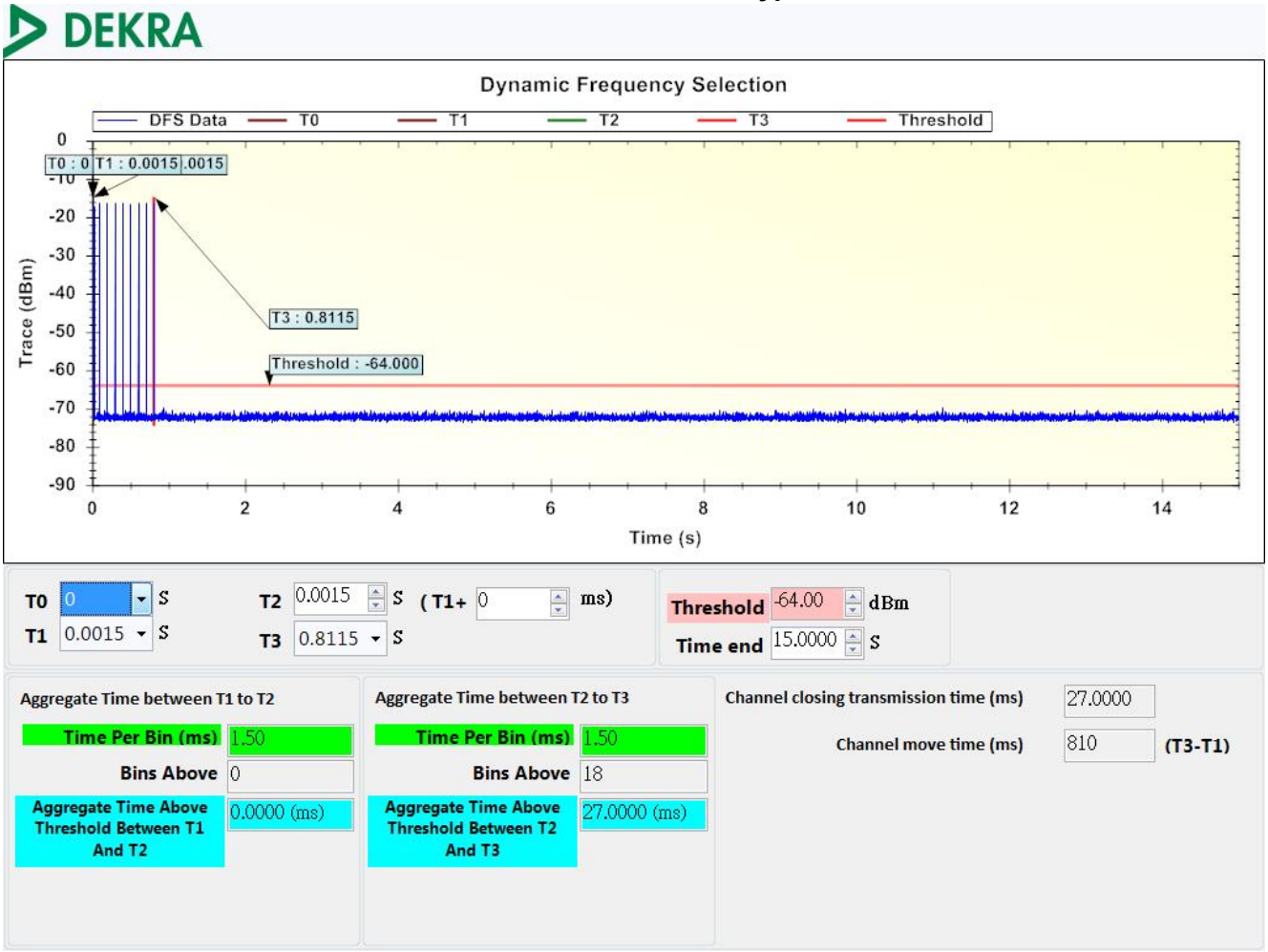


Test Item	Test Result (Sec)	Limit (Sec)
Channel Move Time	0.8355	10
Channel Closing Transmission	0.0225	200 milliseconds + approx. 60 milliseconds over remaining 10 seconds period

The results showed that after radar signal injected the channel move time was less than 10 seconds.

Product	:	ConnectCore 6 Plus
Test Item	:	Channel Move Time Test
Radar Type	:	Type 0
Test Mode	:	Mode 1: Transmit

Channel Move Time for Radar Test Type 0 at 5500MHz

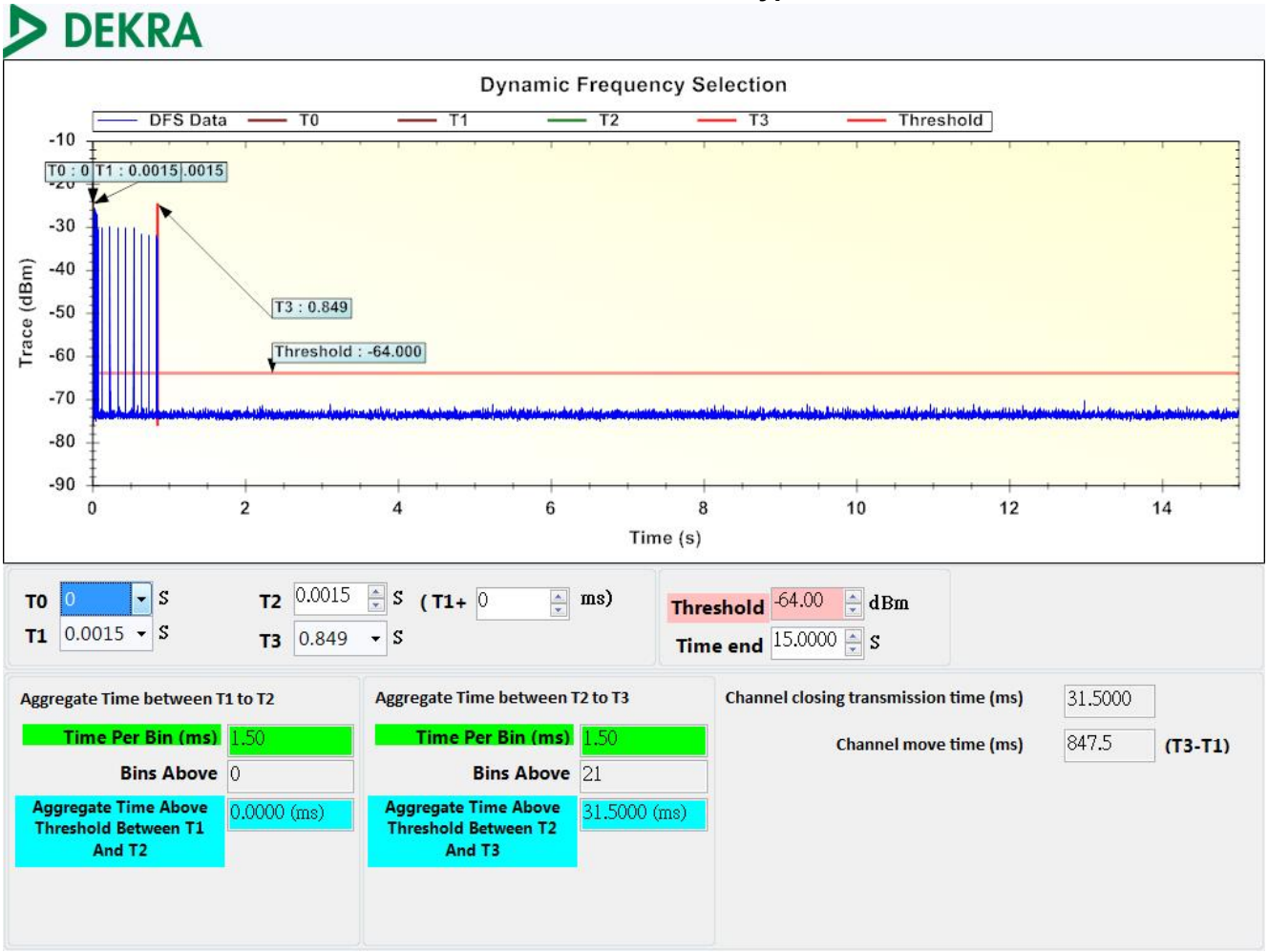


Test Item	Test Result (Sec)	Limit (Sec)
Channel Move Time	0.8100	10
Channel Closing Transmission	0.0270	200 milliseconds + approx. 60 milliseconds over remaining 10 seconds period

The results showed that after radar signal injected the channel move time was less than 10 seconds.

Product	:	ConnectCore 6 Plus
Test Item	:	Channel Move Time Test
Radar Type	:	Type 0
Test Mode	:	Mode 1: Transmit

Channel Move Time for Radar Test Type 0 at 5290MHz

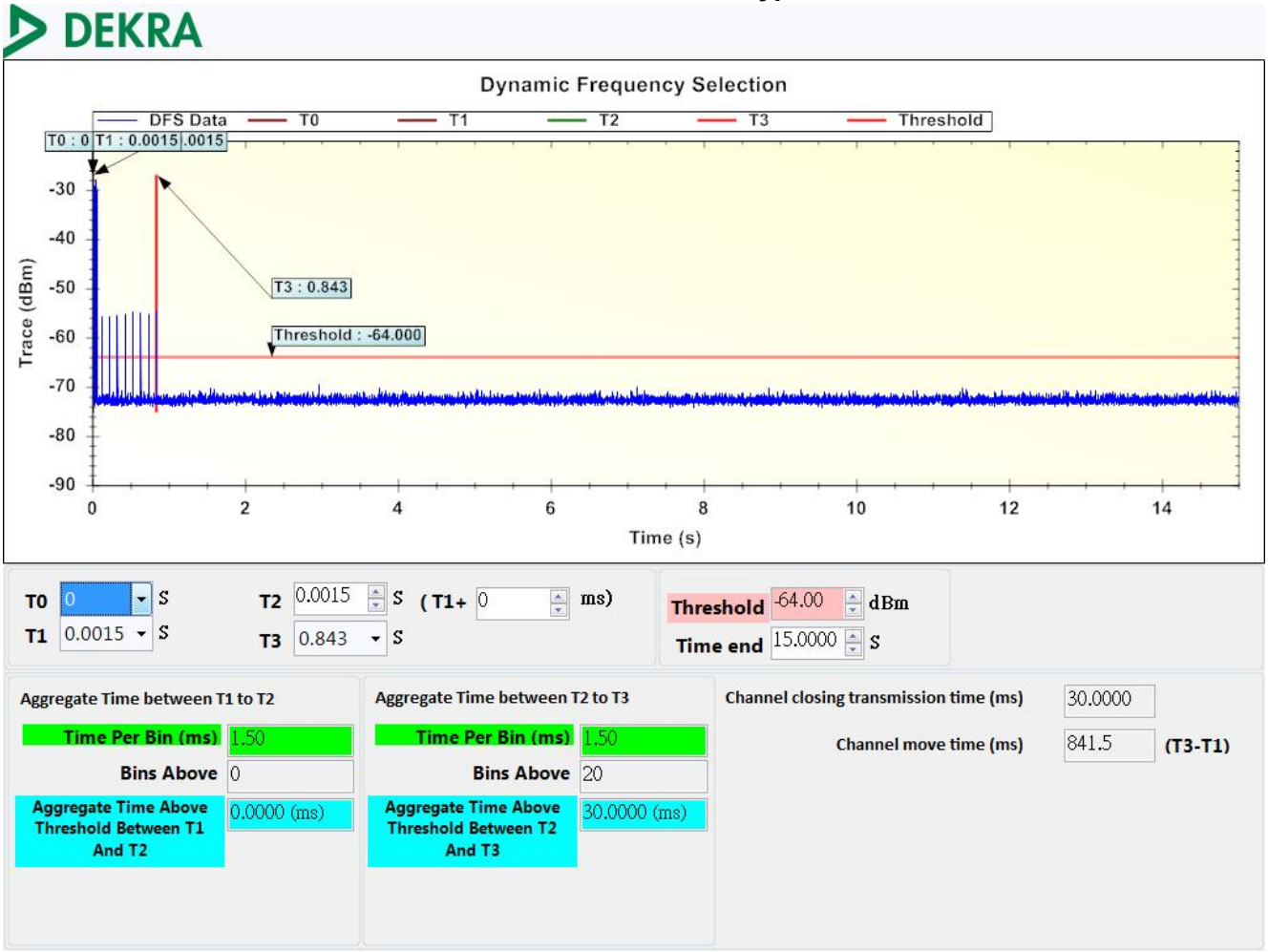


Test Item	Test Result (Sec)	Limit (Sec)
Channel Move Time	0.8475	10
Channel Closing Transmission	0.0315	200 milliseconds + approx. 60 milliseconds over remaining 10 seconds period

The results showed that after radar signal injected the channel move time was less than 10 seconds.

Product	:	ConnectCore 6 Plus
Test Item	:	Channel Move Time Test
Radar Type	:	Type 0
Test Mode	:	Mode 1: Transmit

Channel Move Time for Radar Test Type 0 at 5320MHz

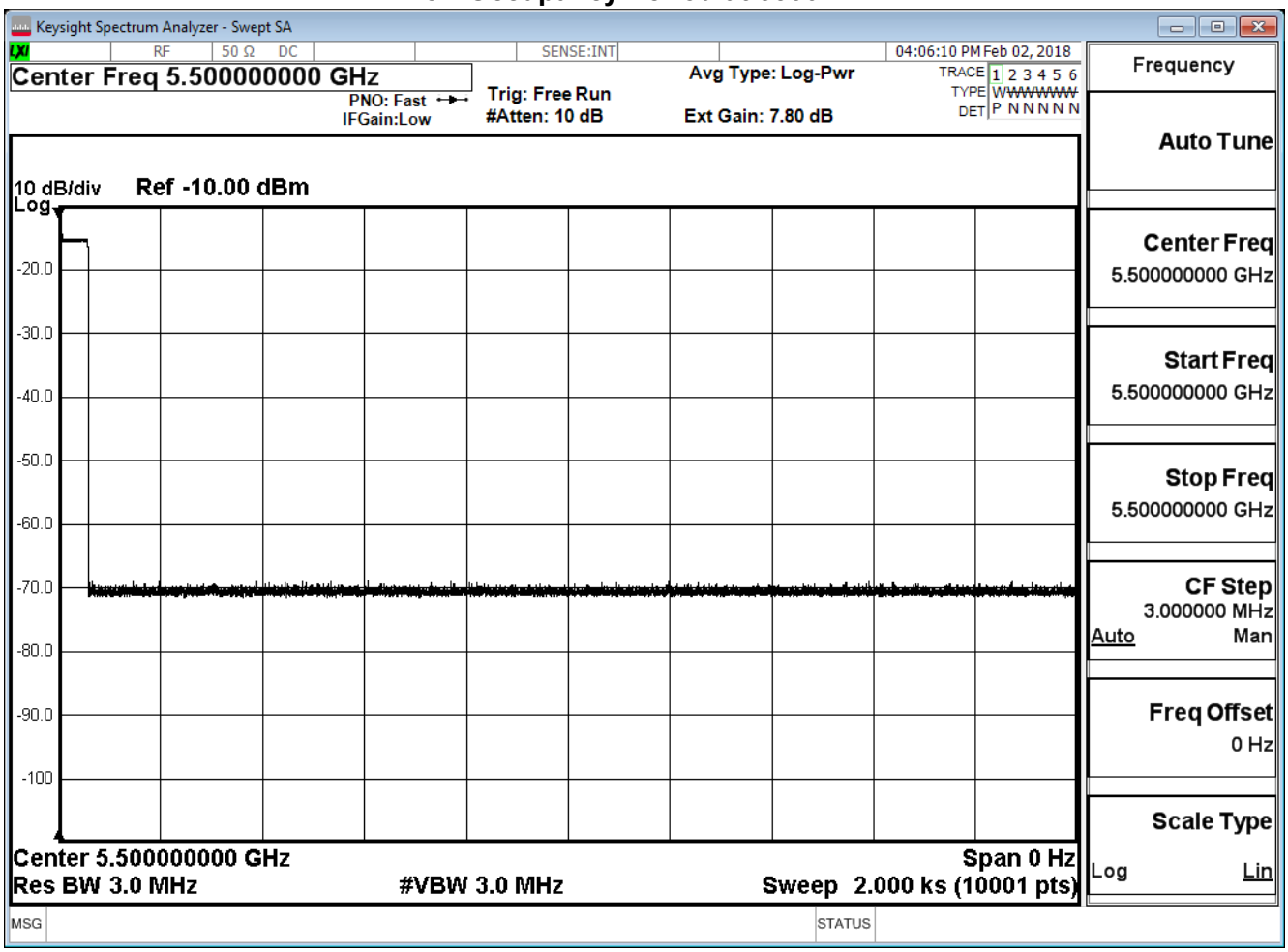


Test Item	Test Result (Sec)	Limit (Sec)
Channel Move Time	0.8415	10
Channel Closing Transmission	0.0300	200 milliseconds + approx. 60 milliseconds over remaining 10 seconds period

The results showed that after radar signal injected the channel move time was less than 10 seconds.

Product : ConnectCore 6 Plus
Test Item : Non-Occupancy Period
Radar Type : Type 0
Test Mode : Mode 1: Transmit

Non-Occupancy Period at 5500 MHz

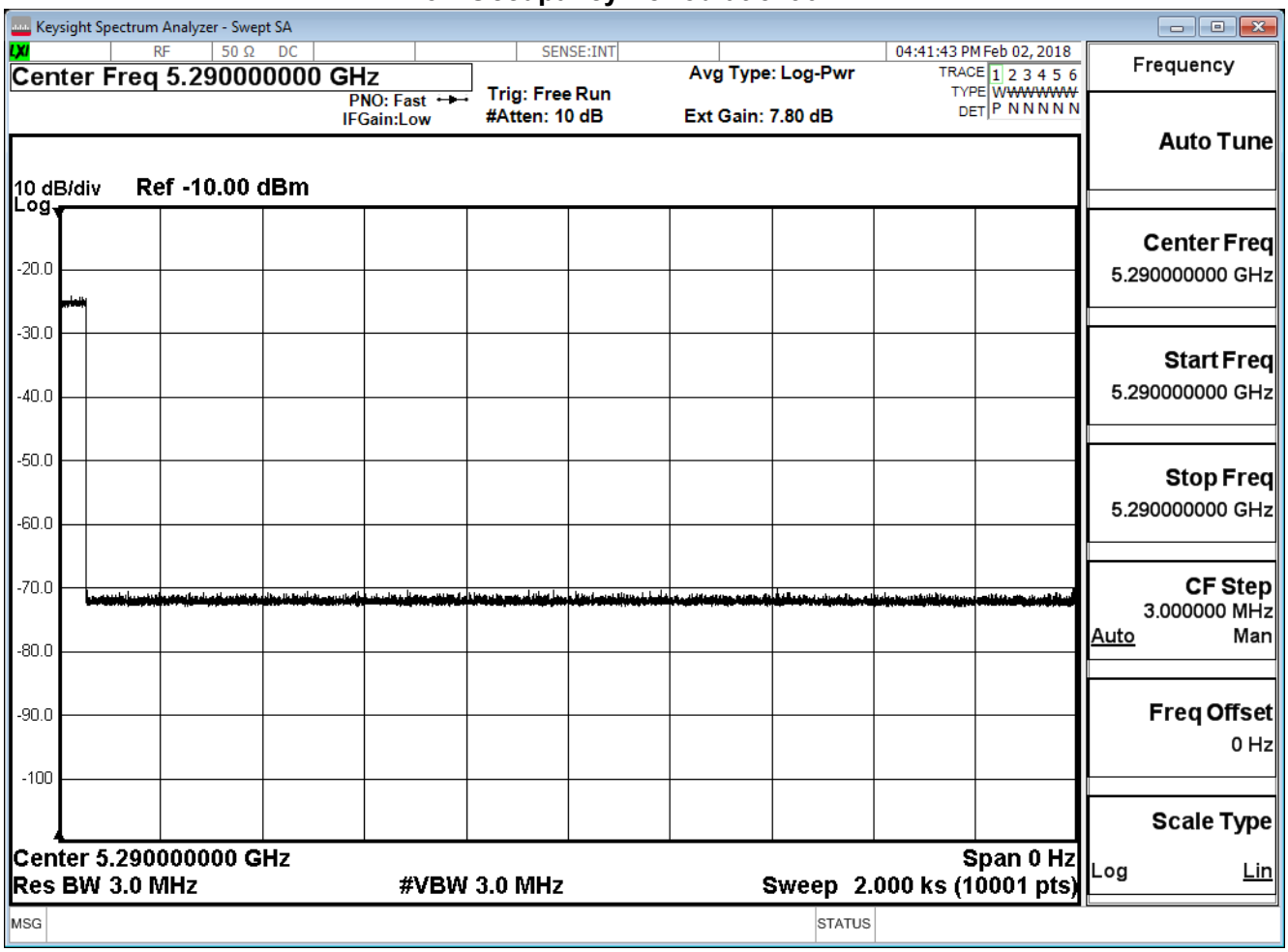


Test Item	Test Result (Minutes)	Limit (Minutes)
Non-Occupancy Period	>30	≧30

No EUT transmissions were observed on the test channel during 30 minutes observation time.

Product : ConnectCore 6 Plus
Test Item : Non-Occupancy Period
Radar Type : Type 0
Test Mode : Mode 1: Transmit

Non-Occupancy Period at 5290 MHz

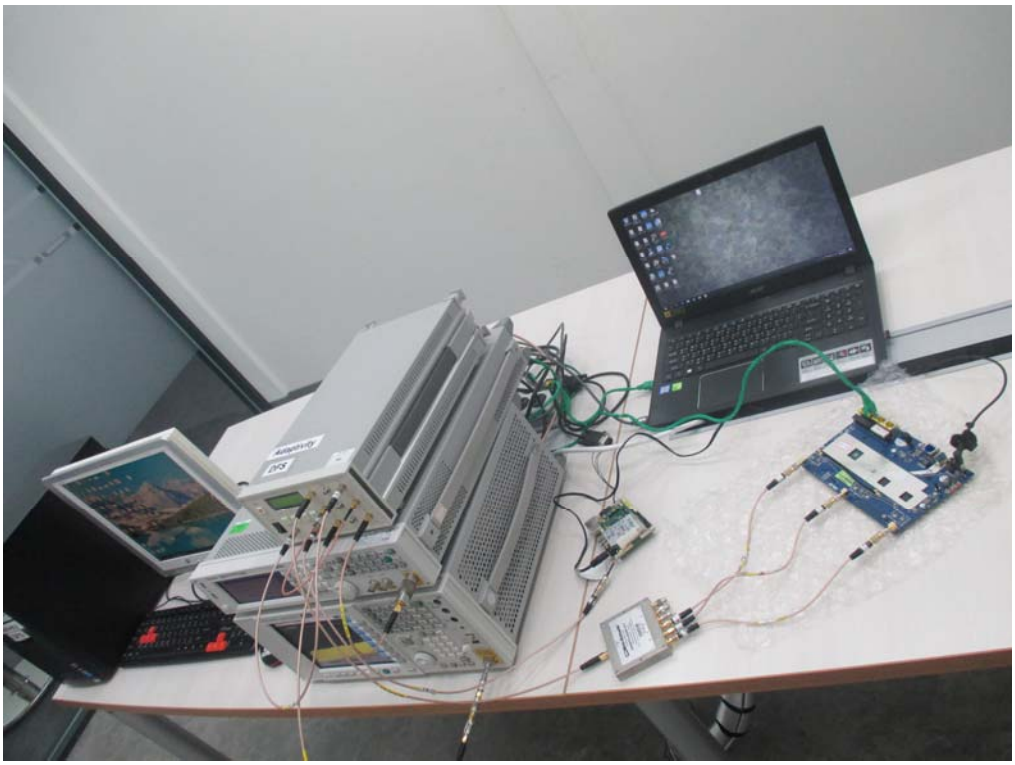


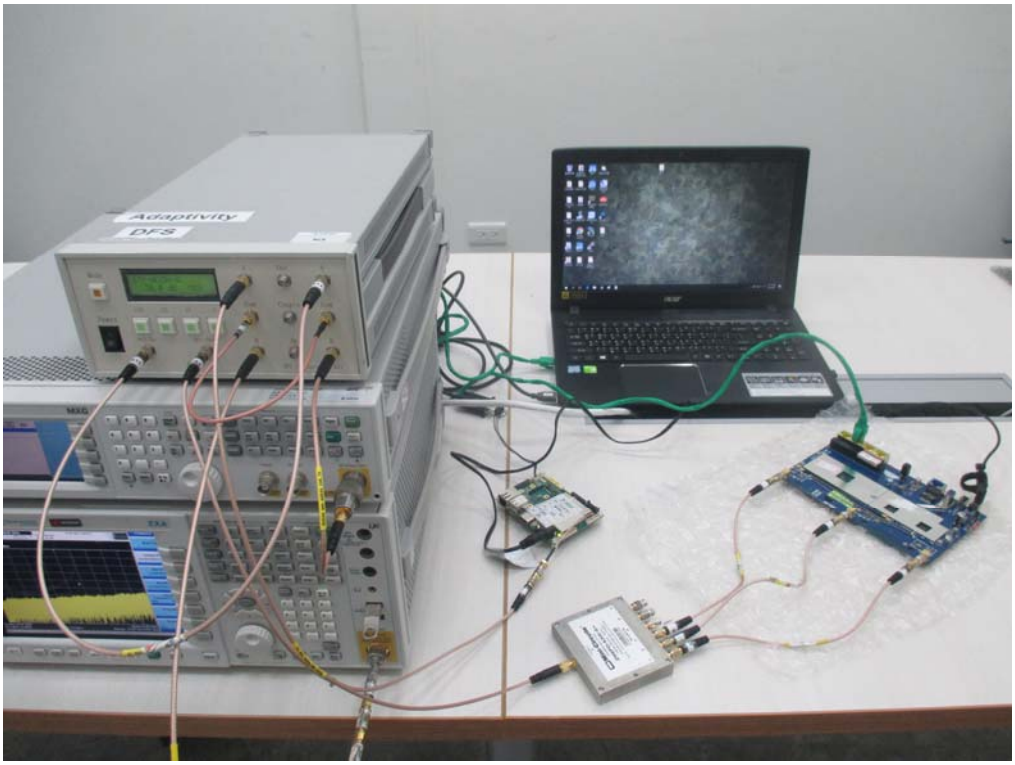
Test Item	Test Result (Minutes)	Limit (Minutes)
Non-Occupancy Period	>30	≧30

No EUT transmissions were observed on the test channel during 30 minutes observation time.

DFS Test Setup Photo

Full DFS Test Setup Photo






Adaptivity
DFS