CAMBIUM NETWORKS

Test Report

Listen Before Talk (LBT)

Test of Canopy PMP450i AP - 0a-00-3e-45-11-78, 3.6GHz MIMO OFDM

11/21/2016

The unrestricted contention based protocol for devices operating in the 3650 – 3700 MHz under Part 90Z of the FCC rules permit operation on a co-channel with like systems (similar systems) and unlike systems.

This report was prepared by:			
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Rajesh Vijayakumar	Vice President, Engineering	11-21-16	

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1. Customer Information

Company name:	Cambium Networks Ltd.
Address:	3800 Golf Road, Suite 360, Rolling Meadows, IL 60008 United States of America

2. Summary of Testing

2.1 General Information

Specification Reference:	Section 90.7 of Part 90 of the US FCC rules
Specification Description of Contention Based Protocol (CBP):	A protocol that allows multiple users to share the same spectrum by defining the events that must occur when two or more transmitters attempt to simultaneously access the same channel and establishing rules by which a transmitter provides reasonable opportunities for other transmitters to operate. Such a protocol may consist of procedures for initiating new transmissions, procedures for determining the state of the channel (available or unavailable), and procedures for managing retransmissions in the event of a busy channel. The 'Listen Before Talk' (LBT) operational procedure is the most well-known Contention-based Protocol (CBP)
Test Dates:	From 27 September till 30 September 2016

2.2 Summary of Test Results

Reference	Part	Measurement	Result
Section 90.7 of US FCC rules	Part 90	Verification of Unrestricted Contention Based Protocol operation	PASSED

Notes:

1) The Device Under Test (DUT) is operating in OFDM mode in the 3.65 – 3.70 GHz frequency band.
2) The DUT was operating in the following channel bandwidth: 20 MHz.

2.3 Methods and procedures

Reference:	Section 90.7 of Part 90 of the US FCC rules
Title:	Private land mobile radio services

3. Equipment Under Test (EUT)

3.1 Identification of Equipment Under Test (EUT)

Brand Name:	Cambium Networks
Model Name:	Canopy 450i 3.6GHz MIMO OFDM - Access Point
MAC Address:	0a-00-3e-45-11-78
Hardware Version Number (Board Type):	P13
Software Version Number:	14.3 (Build 9) AP-None

3.2 Description of EUT

The device under test was a Point to Multipoint (PMP) Access Point

3.3 Modifications Incorporated in the EUT

No modifications were made to the EUT during testing.

3.4 Additional Information Related to Testing

Technology Tested:	Unrestricted Contention Based Protocol operation: Listen Before Talk	
Type of Unit:	Access Point	
Modulation:	OFDM	
Antenna Gain:	17 dBi (90° sector)	
Power Supply Requirement:	Nominal	30.0 V, CMM3 & CMM4, 802.3af PoE Supply
Transmit & Receive Frequency Range:	3650 MHz to 3700 MHz	
Channel Bandwidth:	20 MHz	
Transmit & Receive Channel Tested:	Channel Frequency (MHz):	3660, 3675, 3690

3.5 Support Equipment

The following support equipment was used to exercise the EUT during testing:

Description:	450i Subscriber Module
Brand Name:	Cambium Networks
Model Name or Number:	Canopy 3.6GHz MIMO OFDM – Subscriber Module
MAC Address:	0a-00-3e-40-6b-3f

Description:	450 Access Point
Brand Name:	Cambium Networks
Model Name or Number:	Canopy 3.6GHz MIMO OFDM – Subscriber Module
MAC Address:	0a-00-3e-40-30-bd

Description:	AC/DC Power Supply Unit
Brand Name:	Phihong
Model Name or Number:	PSA 15R-295(MOT)

Serial Number:	P81000498A1

Description:	AC/DC Power Supply Unit
Brand Name:	Phihong
Model Name or Number:	PSA 15R-240(MOT)
Serial Number:	P74215491A1

Description:	Laptop Computer
Brand Name:	HP Compaq
Model Name or Number:	85010w
Serial Number:	CNU8311Z1P

Description:	Laptop Computer
Brand Name:	Dell Latitude
Model Name or Number:	D600
Serial Number:	2CCHQ31

4. Operation and Monitoring of the EUT during Testing

4.1 Operating Modes

The EUT was tested in the following operating modes, unless otherwise stated

- The EUT was tested as a Master unit connected to a Slave transmitting on full power using OFDM modulation as the manufacturer declared that as a representative modulation mode for LBT testing and further declared that the modulation mode used would not impact the results.
- The EUT has two receive channels which normally connect to vertically and horizontally polarized antennas.
- Here is the list of frequencies the DUT is operating.

Bandwidth, MHz	Lower frequency, MHz	Middle frequency, MHz	Upper frequency, MHz
20	3660	3675	3690

- The device was tested with different power level depending on the channel bandwidth and EIRP power limit.
- The LBT detection threshold is based on the following equation:
  LBT Detection Threshold (dBm) = -73 dBm/MHz + 10*log (BW) + 23 – P_T + A, where
  BW is the channel bandwidth value;
  P_T is the sum of the conducted transmit power Pc and the transmit antenna gain A;
  A is the antenna gain.
- The device was tested with different power level for each bandwidth and antenna gain of 0 dBi. Therefore the target LBT Detection Threshold is following:
  for BW = 20 MHz: Detection Threshold = -73 + 13 + 23 – 25 = -62 dBm (-65 dBm per chain);
- The device was tested with different power level for each bandwidth and antenna gain of 17 dBi. Therefore the target LBT Detection Threshold is following:
  for BW = 20 MHz: Detection Threshold = -73 + 13 + 23 – 25 + 17 = -45 dBm (-48 dBm per chain);

4.2 Configuration and Peripherals

The EUT was tested in the following configurations(s):

- All measurements were made using a conducted link. The antenna ports gave independent access to horizontal and vertical antenna connections;
- A laptop PC was used to configure the EUT parameters during the testing using a standard web browser and via SSH. The laptop was connected to the EUT via Ethernet to set EUT parameters;
- The EUT's command line interface was used to report radar detection events;
- When the system required channel loading a UDP data stream with predefined parameters was generated with iperf network testing tool. This stream was transferred from the laptop, connected to the master device (AP) to the laptop, connected to the slave device (SM).

5. Measurements, Examinations and Delivered Results

5.1 Test Results

Test Summary: CW signal was used as an interferer for unlike systems

Test Engineer:	Pavel Polyakov	**Test Dates:**	27 September 2016
Test Sample MAC Address:	0a-00-3e-45-11-78		

Environmental Conditions:

Temperature (°C):	27.6
Relative Humidity (%):	32

Results: 20 MHz bandwidth, power level 25 dBm and antenna gain 0 dBi

Test #	Frequency (MHz)	Channel Bandwidth (MHz)	Unwanted Signal Level (dBm)	TX Off
1	3660	20	-72	No
2			-71	No
3			-70	No
4			-69	No
5			-68	Yes
6			-67	Yes
7			-66	Yes
8			-65	Yes
9			-64	Yes
10			-63	Yes

Test #	Frequency (MHz)	Channel Bandwidth (MHz)	Unwanted Signal Level (dBm)	TX Off
1	3675	20	-72	No
2			-71	No
3			-70	No
4			-69	No
5			-68	Yes
6			-67	Yes
7			-66	Yes
8			-65	Yes
9			-64	Yes
10			-63	Yes

Test #	Frequency (MHz)	Channel Bandwidth (MHz)	Unwanted Signal Level (dBm)	TX Off
1	3690	20	-72	No
2			-71	No
3			-70	No
4			-69	No
5			-68	Yes

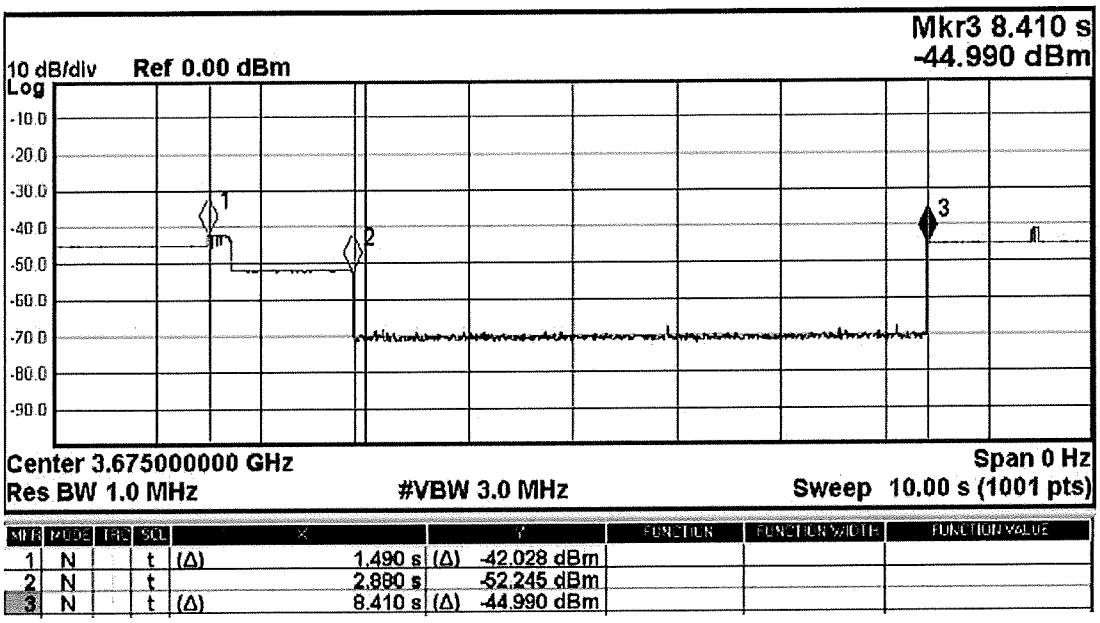
6			-67	Yes
7			-66	Yes
8			-65	Yes
9			-64	Yes
10			-63	Yes

Results: 20 MHz bandwidth, power level 8 dBm and antenna gain 17 dBi

Test #	Frequency (MHz)	Channel Bandwidth (MHz)	Unwanted Signal Level (dBm)	TX Off
1	3660	20	-58	No
2			-57	No
3			-56	No
4			-55	No
5			-54	Yes
6			-53	Yes
7			-52	Yes
8			-51	Yes
9			-50	Yes
10			-49	Yes

Test #	Frequency (MHz)	Channel Bandwidth (MHz)	Unwanted Signal Level (dBm)	TX Off
1	3675	20	-58	No
2			-57	No
3			-56	No
4			-55	No
5			-54	Yes
6			-53	Yes
7			-52	Yes
8			-51	Yes
9			-50	Yes
10			-49	Yes

Test #	Frequency (MHz)	Channel Bandwidth (MHz)	Unwanted Signal Level (dBm)	TX Off
1	3690	20	-58	No
2			-57	No
3			-56	No
4			-55	No
5			-54	Yes
6			-53	Yes
7			-52	Yes
8			-51	Yes
9			-50	Yes
10			-49	Yes



Comment: red line (1) – interferer signal is turned on, green line (2) – interferer signal is turned off, blue line (3) – the connection between the AP and SM is restored.

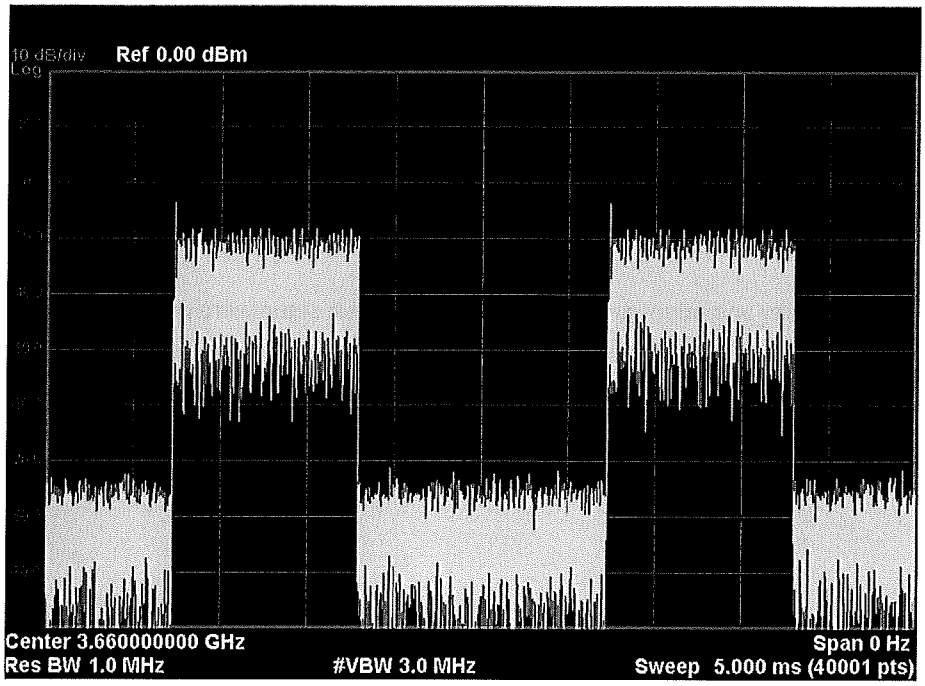
Test Summary: OFDM signal from the similar AP was used as an interferer

Test Engineer:	Pavel Polyakov	**Test Dates:**	30 February 2014
Test Sample MAC Address:	0a-00-3e-45-11-78		

Environmental Conditions:

Temperature (°C):	27.6
Relative Humidity (%):	32

450 Access Point that was used as a source of interference was configured to have 20 MHz channel bandwidth and 50/50 Downlink/Uplink ratio. With 2.5 ms frame the interfering signal is supposed to be turned on 50 % of the time, i.e. 1.25 ms. However, measurements showed that the actual 'on time' is less than that. Based on the calculations the time that the TX is open is 42.86 %. Please see the screenshot below:



Taking in consideration the fact that the Access Point is not transmitting 100 % of the time the tme domain correction factor should be taking into the account whilst calculating the detection threshold. This correction factor is calculated based on the following equation: Factor=10*log10(Duty Cycle), for this particular case the correction factor is 10*log10(0.43)=-3.68 dB. Therefore all the threshold calculated earlier goes up by 3.68 dB.

Results: 20 MHz bandwidth, power level 25 dBm and antenna gain 20 dBi

Test #	Frequency (MHz)	Channel Bandwidth (MHz)	Antenna Gain (dBi)	Unwanted Signal Level (dBm)	TX Off
1	3660	20	0	-68 dBm	No
2	3660	20	0	-67 dBm	Yes
3	3675	20	0	-68 dBm	No
4	3675	20	0	-67 dBm	Yes
5	3690	20	0	-68 dBm	No
6	3690	20	0	-67 dBm	Yes
7	3660	20	17	-50 dBm	No
8	3660	20	17	-49 dBm	Yes
9	3675	20	17	-49 dBm	No
10	3675	20	17	-48 dBm	Yes
11	3690	20	17	-50 dBm	No
12	3690	20	17	-49 dBm	Yes

Appendix 1: Test Equipment Used

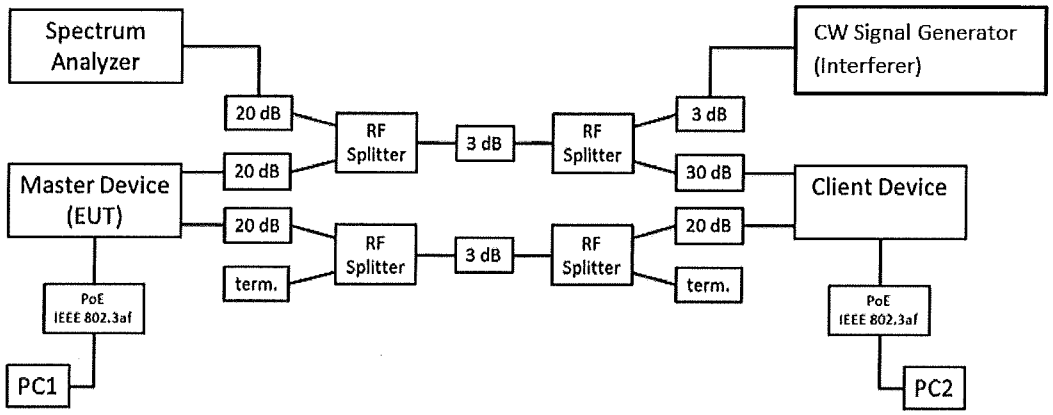
Manufacturer	Description	Model	Date Calibration Due
Agilent Technologies	MXA Signal Analyzer 20 Hz – 8.4 GHz	N9020A	14 May 2018
Agilent Technologies	PSG Analog Signal Generator 250 kHz – 50 GHz	E8257D	17 Dec 2016

Note: all cables, splitter and attenuators that were used for test setup were preliminary calibrated.

Appendix 2: Monitoring Methods Diagrams

All tests were performed as conducted measurements using the setups as shown below.

Setup Diagram – EUT – Master, CW signal Injection at Master. Client Device acts as a Slave Device for this scenario.



Note: for the test when a similar Canopy AP was used as an interferer, the CW Signal Generator was substituted for this AP for unlike system.