RF Exposure Lab

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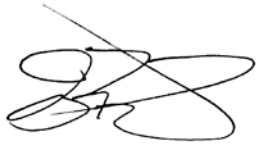
CERTIFICATE OF COMPLIANCE
SAR EVALUATION

Industrial Scientific		Dates of Test:	February 21, 2019
One Life Way		Test Report Number:	SAR.20190203
Pittsburgh, PA 15205			Revision A

Model(s):	Ventis Pro 4 and Ventis Pro 5
Contains WiFi Module:	FCC ID: PHH-WIFICC3220; ISED Certificate: 20727-WIFICC3220
Contains BT Module:	FCC ID: T7V1740; ISED Certificate: 216Q-1740
Contains Zigbee Module:	FCC ID: U9O-SM200; ISED Certificate: 7084A-SM200
Contains NFC Module:	FCC ID: PHH-VPX; ISED Certificate: 20727-VPX
Equipment Type:	Wireless Portable Gas Monitor
Classification:	Portable Transmitter
TX Frequency Range:	2412 – 2462 MHz; 2402 – 2480 MHz; 2405 – 2480 MHz; 13.56 MHz
Frequency Tolerance:	± 2.5 ppm
Maximum RF Output:	2450 MHz (WiFi) – 20.0 dBm, 2450 MHz (BLE) – 0.0 dBm, 2450 MHz (Zigbee) – 3.0 dBm, 13.56 MHz – -43.2 dBm Conducted
Signal Modulation:	DSSS, OFDM, QPSK, 8PSK, O-QPSK, ASK
Antenna Type:	Internal for Each Transmitter
Application Type:	Certification
Standard(s):	47CFR1.1310, 47CFR2.1093, KDB447498 D06, KDB248227 v02r02, RSS-102, Safety Code 6, EN62479:2010, EN 62311:2008,IEC TR-62630, 2014/53/EU
Separation Distance:	0 mm

This wireless portable device has been shown to be excluded for RF exposure requirements for uncontrolled environment/general exposure limits specified in above listed standards for standalone SAR. The device has also been shown to meet the simultaneous requirements of each standard as well (See test report).

I attest to the accuracy of the data. I assume full responsibility for the completeness of these calculations and vouch for the qualifications of all persons making them.



Jay M. Moulton
Vice President

ACCREDITED
Certificate # 2387.01

Table of Contents

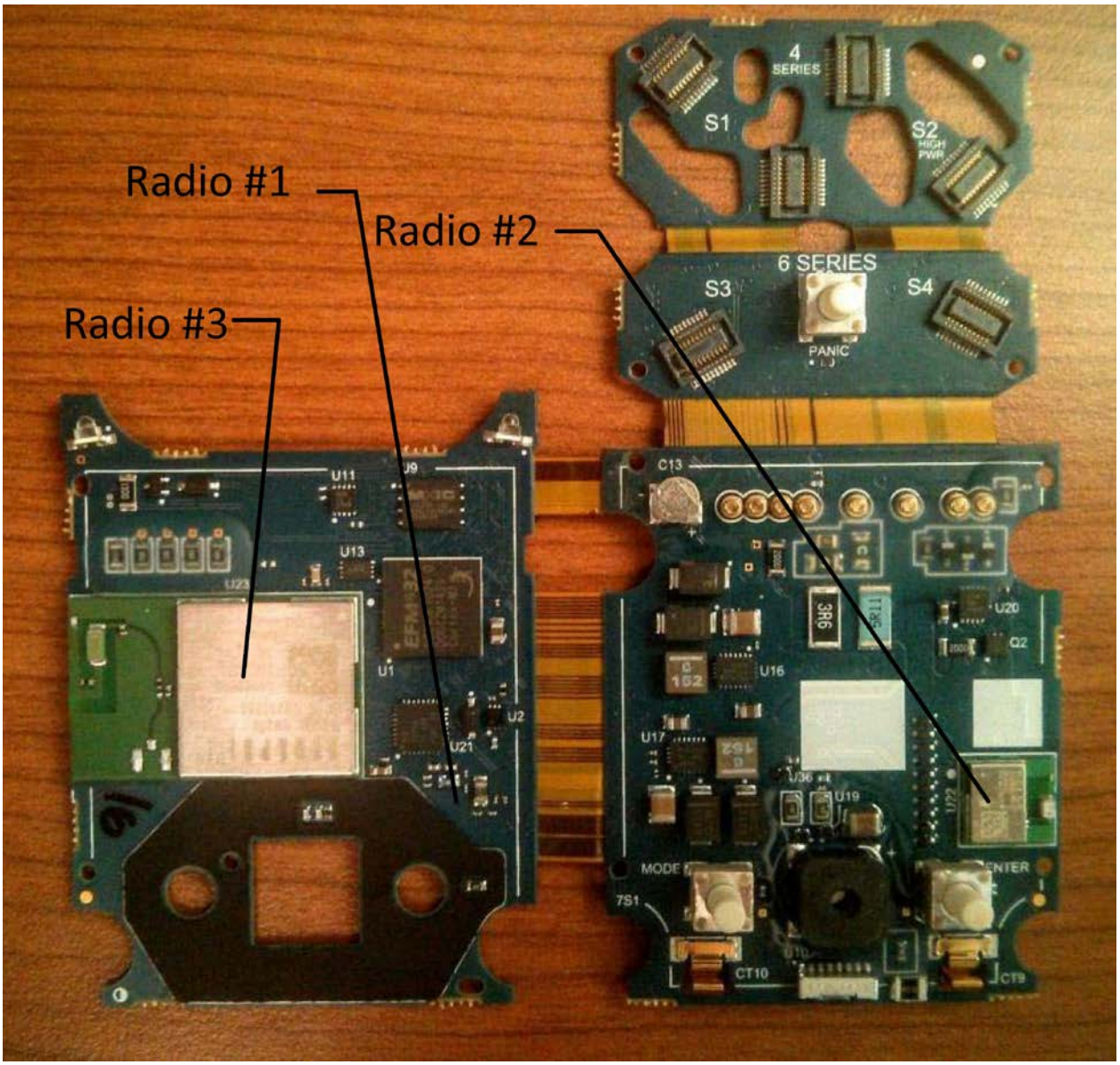
1. Introduction

This report shows exclusion calculations of the Industrial Scientific Model Ventis Pro 4 and Ventis Pro 5 Wireless Portable Gas Monitor with 47CFR1.1310, 47CFR2.1093, KDB447498 D06, KDB248227 v02r02, RSS-102, Safety Code 6, EN62479:2010, EN 62311:2008,IEC TR-62630, 2014/53/EU.

2. Radiation Sources

Radio	Description	
NFC (#1)	Frequency Range (MHz)	13.56 MHz
	Maximum Power (dBm)	-43.2 dBm
	Maximum Duty Cycle (%)	100%
BLE (#2)	Frequency Range (MHz)	2402 – 2480 MHz
	Maximum Power (dBm)	0 dBm
	Maximum Duty Cycle (%)	100%
Zigbee (#3)	Frequency Range (MHz)	2405 – 2480 MHz
	Maximum Power (dBm)	3 dBm
	Maximum Duty Cycle (%)	100%
WiFi	Frequency Range (MHz)	2412 – 2480 MHz
	Maximum Power (dBm)	21.1 dBm
	Maximum Duty Cycle (%)	0.045%

3. Radios



View of the Wi-Fi battery pack assembly showing the encapsulated Wi-Fi radio assembly, battery and PCBA stack up.

View of the Wi-Fi encapsulated radio assembly

4. RF Exposure Classifications

Device Types	
Fixed	A fixed device is defined as a device physically secured at one fixed location and cannot be easily re-located.
Mobile	A mobile device is defined as a transmitting device designed to be used in other than fixed locations and to generally be used in such a way that a separation distance of at least 20 centimeters is normally maintained between the transmitter's radiating structure(s) and the body of the user or nearby persons. (47 CFR 2.1091)
Portable	A portable device is defined as a transmitting device designed to be used so that the radiating structure(s) of the device is/are within 20 centimeters of the body of the user. (47 CFR 2.1093)

Exposure Categories	
Occupational / Controlled	Limits apply in situations in which persons are exposed as a consequence of their employment provided those persons are fully aware of the potential for exposure and can exercise control over their exposure. Limits for occupational/controlled exposure also apply in situations when an individual is transient through a location where occupational/controlled limits apply provided he or she is made aware of the potential for exposure.
General population / uncontrolled	Exposures apply in situations in which the general public may be exposed, or in which persons that are exposed as a consequence of their employment may not be fully aware of the potential for exposure or cannot exercise control over their exposure.

5. RF Exposure Limits Standalone And Simultaneous SAR

FCC Requirements

The FCC SAR test exclusion for standalone SAR is determined for each operating configuration and exposure condition the device can operate.

The 1-g and 10-g SAR test exclusion thresholds for **100 MHz to 6 GHz** at *test separation distances* **≤ 50 mm** are determined by:

$$\frac{max.\ power\ of\ channel\ [mW]}{min.\ test\ separation\ distance\ [mm]} \cdot \sqrt{f[GHz]} \leq \begin{cases} 3.0 & 1g\ SAR \\ 7.5 & 10g\ SAR \end{cases}$$

- f [GHz] is the RF channel transmit frequency in GHz
- Power and distance are rounded to the nearest mW and mm before calculation
- The result is rounded to one decimal place for comparision

The test exclusions are applicable only when the minimum test separation distance is ≤ 50 mm and for transmission frequencies between 100 MHz and 6 GHz. When the minimum test separation distance is < 5 mm, a distance of 5 mm is applied to determine SAR test exclusion.

For simultaneous evaluation, the sum of the individual SAR values of each of the transmitters must be less than the limit to comply. If the transmitter is excluded from SAR testing, the SAR value is estimated based on the formula below.

[(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)] * [$\sqrt{f_{(GHz)}}/x$] W/kg, for test separation distances ≤ 50 mm;
Where x = 7.5 for 1-g SAR

ISED Requirements

SAR evaluation is required if the separation distance between the user and/or bystander and the antenna and/or radiating element of the device is less than or equal to 20 cm, except when the device operates at or below the applicable output power level (adjusted for tune-up tolerance) for the specified separation distance defined in Table 1.

Table 1: SAR evaluation – Exemption limits for routine evaluation based on frequency and separation distance[4,5]

Frequency (MHz)	Exemption Limits (mW)				
	At separation distance of ≤5 mm	At separation distance of 10 mm	At separation distance of 15 mm	At separation distance of 20 mm	At separation distance of 25 mm
≤300	71 mW	101 mW	132 mW	162 mW	193 mW
450	52 mW	70 mW	88 mW	106 mW	123 mW
835	17 mW	30 mW	42 mW	55 mW	67 mW
1900	7 mW	10 mW	18 mW	34 mW	60 mW
2450	4 mW	7 mW	15 mW	30 mW	52 mW
3500	2 mW	6 mW	16 mW	32 mW	55 mW
5800	1 mW	6 mW	15 mW	27 mW	41 mW

Frequency (MHz)	Exemption Limits (mW)				
	At separation distance of 30 mm	At separation distance of 35 mm	At separation distance of 40 mm	At separation distance of 45 mm	At separation distance of ≥50 mm
≤300	223 mW	254 mW	284 mW	315 mW	345 mW
450	141 mW	159 mW	177 mW	195 mW	213 mW
835	80 mW	92 mW	105 mW	117 mW	130 mW
1900	99 mW	153 mW	225 mW	316 mW	431 mW
2450	83 mW	123 mW	173 mW	235 mW	309 mW
3500	86 mW	124 mW	170 mW	225 mW	290 mW
5800	56 mW	71 mW	85 mW	97 mW	106 mW

For simultaneous evaluation, the sum of the individual SAR values of each of the transmitters must be less than the limit to comply. If the transmitter is excluded from SAR testing, the SAR value is estimated based on the formula below.

[(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)] * [$\sqrt{f_{(GHz)}}/x$] W/kg, for test separation distances ≤ 50 mm;
Where x = 7.5 for 1-g SAR

EU Requirements

If the average power emitted by the device operating in the frequency range of 10MHz to 300GHz is less than or equal to 20mW average then the device is deemed to comply with the basic restrictions without testing.

For simultaneous evaluation, the sum of the individual SAR values of each of the transmitters must be less than the limit to comply. If the transmitter is excluded from SAR testing, the SAR value is estimated based on the formula below.

[(max. power of channel, including tune-up tolerance, mW) / (min. test separation distance, mm)] * [$\sqrt{f_{(GHz)}}$/x] W/kg, for test separation distances ≤ 50 mm;
Where x = 18.75 for 10-g SAR

6. Duty Cycle Evaluation for WiFi

The WiFi transmitter has a duty cycle of 0.045%. The evaluation of the transmitter is shown in appendix A. The evaluation shows a maximum transmit period of 45 ms in a 15 second period. The maximum allowable period is 100 seconds. Therefore, the evaluation in this report is based on a 45 ms transmit period for a 100 second interval yielding the 0.045% duty cycle.

7. Standalone SAR Exclusion Assessment

FCC Requirements

Based on the formula in section 5, the exclusion calculation for each of the transmitters is listed below.

NFC – (0.00005 mW / 5 mm) * $\sqrt{0.01356}$ = 1 x 10^{-6} which is less than 3.0
BLE – (1 mW / 5 mm) * $\sqrt{2.48}$ = 0.3 which is less than 3.0
Zigbee – (2 mW / 5 mm) * $\sqrt{2.48}$ = 0.6 which is less than 3.0
WiFi – (0.058 mW / 5 mm) * $\sqrt{2.462}$ = 0.02 which is less than 3.0

Therefore, all transmitters are excluded from standalone SAR evaluations.

ISED Requirements

Based on the table in RSS-102, the BLE, Zigbee, and WiFi transmitters must be less than 4 mW to be excluded. The Zigbee radio has the highest power which is 2 mW. Therefore, all three are excluded. The NFC radio must be less than 71 mW which the radio is below. Therefore, the NFC is also excluded from SAR evaluation.

EU Requirements

All transmitters are less than 20 mW. Therefore, all transmitters are excluded from SAR testing.

8. Simultaneous SAR Assessment

FCC Requirements

Since all transmitters are excluded from standalone SAR, each transmitter's SAR value is estimated using the formula in section 6 above. The estimated SAR value for each transmitter is listed below.

NFC – (0.00005 mW / 5 mm) * (√0.01356 / 7.5) = 0 W/kg
BLE – (1 mW / 5 mm) * (√2.48 / 7.5) = 0.04 W/kg
Zigbee – (2 mW / 5 mm) * (√2.48 / 7.5) = 0.08 W/kg
WiFi – (0.058 mW / 5 mm) * (√2.462 / 7.5) = 0.002 W/kg

The sum of all four transmitter is 0.122 W/kg. The sum is less than the limit of 1.6 W/kg. Therefore, the device meets the simultaneous requirements.

ISED Requirements

Since all transmitters are excluded from standalone SAR, each transmitter's SAR value is estimated using the formula in section 6 above. The estimated SAR value for each transmitter is listed below.

NFC – (0.00005 mW / 5 mm) * (√0.01356 / 7.5) = 0 W/kg
BLE – (1 mW / 5 mm) * (√2.48 / 7.5) = 0.04 W/kg
Zigbee – (2 mW / 5 mm) * (√2.48 / 7.5) = 0.08 W/kg
WiFi – (0.058 mW / 5 mm) * (√2.462 / 7.5) = 0.002 W/kg

The sum of all four transmitter is 0.122 W/kg. The sum is less than the limit of 1.6 W/kg. Therefore, the device meets the simultaneous requirements.

EU Requirements

Since all transmitters are excluded from standalone SAR, each transmitter's SAR value is estimated using the formula in section 6 above. The estimated SAR value for each transmitter is listed below.

NFC – (0.00005 mW / 5 mm) * (√0.01356 / 18.75) = 0 W/kg
BLE – (1 mW / 5 mm) * (√2.48 / 18.75) = 0.02 W/kg
Zigbee – (2 mW / 5 mm) * (√2.48 / 18.75) = 0.04 W/kg
WiFi – (0.058 mW / 5 mm) * (√2.462 / 18.75) = 0.001 W/kg

The sum of all four transmitter is 0.061 W/kg. The sum is less than the limit of 2.0 W/kg. Therefore, the device meets the simultaneous requirements.

Appendix A

Duty Cycle Analysis for WiFi

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ENGINEERING ASSESSMENT REPORT

Wi-Fi Enabled Battery Pack Transmission Duty Cycle Determination

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Product Certification Specialist

Tested and Reviewed By: Jonathan Dinsmore
Senior Electrical Engineer

Contents

1. Purpose

This report details testing and results to determine transmission characteristics of a Wi-Fi + GPS enabled battery pack for use with the Industrial Scientific Corporation Ventis Pro 4 and Ventis Pro 5 wireless enabled portable multi-gas monitors. The information contained within this report along with information in another report will be used to demonstrate compliance of the Ventis Pro 4 and Pro 5 to FCC, ISED-Canada and EU RF Exposure limitations for portable apparatus worn near the user's body and head.

2. Subject of Investigation

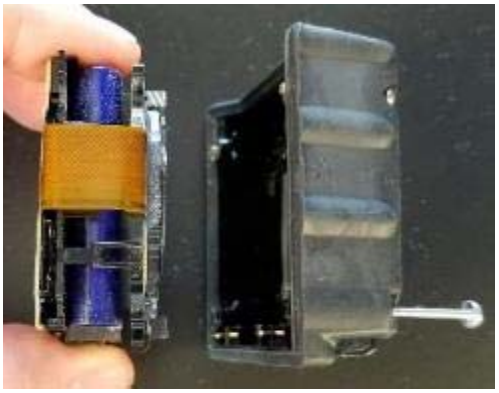
The Ventis Pro 4 and Ventis Pro 5 are multi-gas monitors designed to be worn by a user to detect and warn when hazardous concentrations of toxic or combustible gases or low or enriched concentrations of oxygen have been detected. Both monitors share the exact same hardware platform. The difference between the 2 models is firmware that enables additional variations and combinations of gas sensors in the Ventis Pro 5 than in the Ventis Pro 4.

Both monitors employ the same 3 radio frequency technologies, they are: Near Field Communications; Bluetooth Low Energy and LENS which is a proprietary low power mesh radio based on the IEEE 802.4.15 radio standard. The radios are used for functions ranging from user identification, area identification and access control as well as forming a mesh network to report status of other linked monitors. Combined radio exposure levels of all 3 radios have been assessed to and verified as meeting compliance to FCC, ISED-Canada and European Council Recommendation 199/519/EC requirements for RF exposure for portable apparatus in Elite Electronic Engineering Test Report 1604486-01 Rev A RF Exposure Assessment Report for the Ventis Pro 4 and Ventis Pro 5 Portable Gas Monitors.

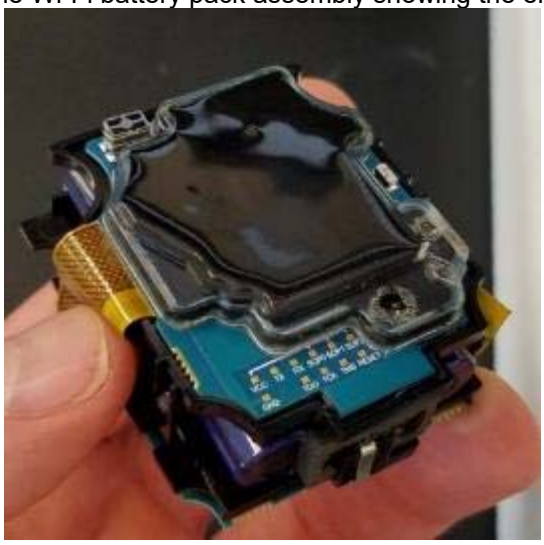
An additional option to the NFC, BLE and LENS radios is a certified Wi-Fi (IEEE 802.11 b/g/n) radio that is placed into a replaceable lithium ion battery assembly. This radio will extend the communications link out to Wi-Fi access points located within the plant site infrastructure. Located with the Wi-Fi radio there is an embedded GPS receiver that allows gas readings and location information of the monitor to be reported to a central monitoring system.

These monitors can be had in either support either diffusion or aspirated (pumped) mode of operation. This Wi-Fi enabled battery will only be compatible with the diffusion only mode of operation. It will not be usable in the aspirated version.

Diffusion mode Ventis™ Pro (4 or 5) with the Wi-Fi battery assembly and disassembly of the Wi-Fi battery assembly from the battery pack cover.



View of the Wi-Fi battery pack assembly showing the encapsulated Wi-Fi radio assembly, battery and PCBA stack up.



View of the Wi-Fi encapsulated radio assembly

3. Radio Transmission Measurements

The Wi-Fi radio pack uses the Texas Instruments CC3220 Single Chip Wi-Fi and Internet of Things Wireless MCU. The implementation has the following physical parameters:

Wi-Fi TX Power:	18 dBm (63.1 mW) @ 1 DSS 14.5 dBm (28.18 mW) @ 54 OFDM
Antenna Gain:	+1.1 dBi
Wi-Fi TX Reporting Interval:	Settable from once every 15 seconds to up to 300 seconds
Operating Voltage Range:	3.2 VDC to 4.2 VDC
Operating Temperature Range:	-20C to +55C

Testing was performed with a production printed circuit board set utilizing battery firmware V1.0 Build10 and instrument firmware V3.5 Build 11. Operation of this firmware is fully representative of final firmware regarding transmit interval, duration and data package size sent.

Testing consisted of using a Tektronix MSO56 5 Series Mixed Signal Oscilloscope and a Tektronix ADA400 Differential Preamplifier. The differential preamplifier was used to measure the current increase to the Wi-Fi circuit across a series resistance when the transmitter circuit is active. This is represented in the blue trace in the images below. Actual RF

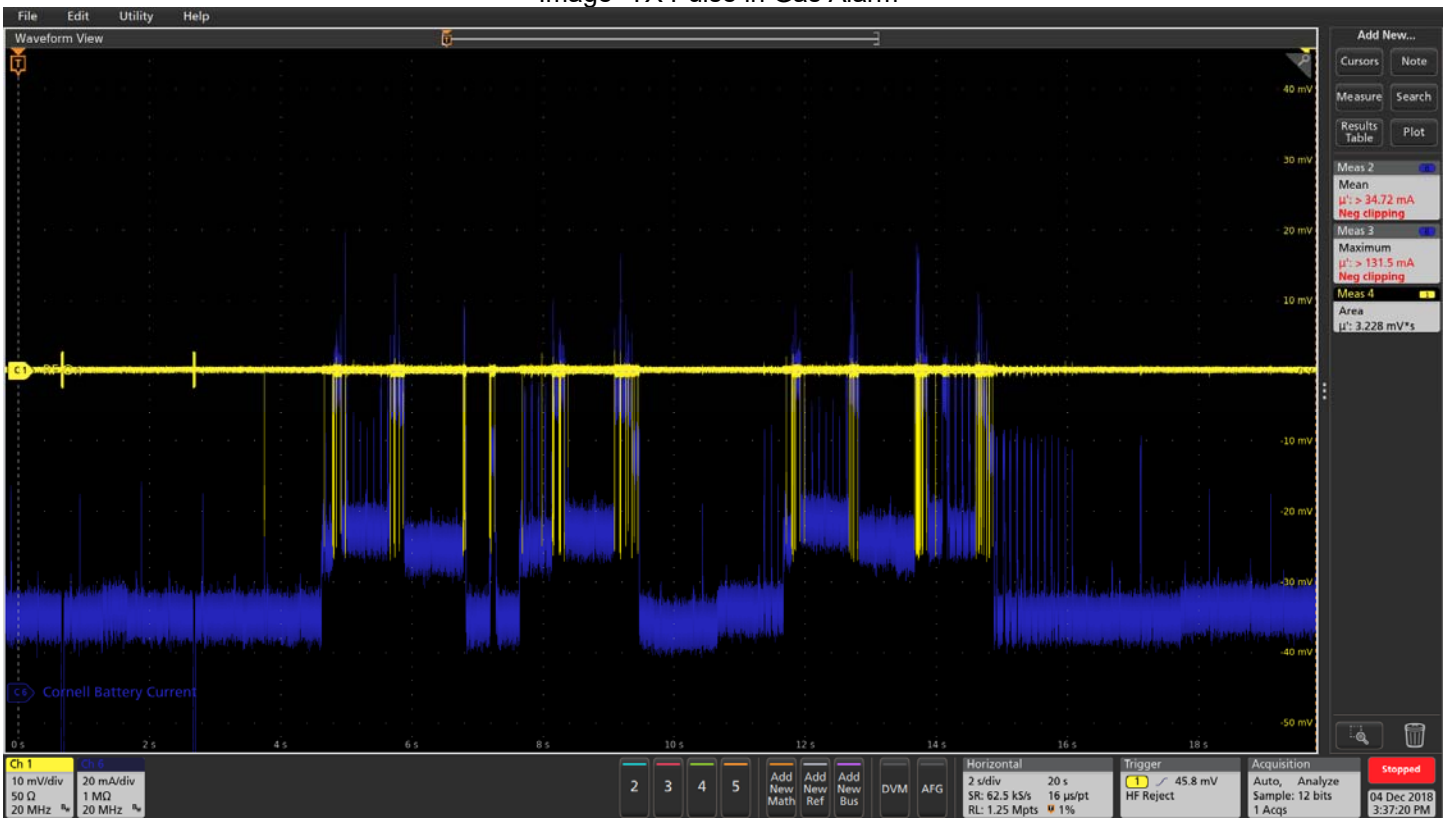
transmissions were captured by loop antenna connected to the oscilloscope represented by the yellow trace. The transmit pulses were inverted on the scope display to allow them to be correlated to the current increases.

Once RF transmissions have been captured they were validated by ensuring there was a corresponding increase of current indicating that the circuit was active.

Transmission readings were taken while the monitor was in gas alarm mode. This mode is when the Ventis Pro 4 and 5 respond to a gas sensor alarm reading. This mode represents the worst case transmit duration and data package size sent as anytime a gas alarm is activated sensor data is sent for all installed sensors. RF transmissions were captured over a 15 second transmission period which is the fastest interval the monitor can be set to transmit Wi-Fi information.

The duration of each RF trace was then summed up across the capture period resulting in a cumulative transmit period of approximately 45 ms over the entire 15 second transmit interval.

Image “TX Pulse in Gas Alarm”



4. Test Equipment List

ISC Asset Number / SN	Description	Cal Date	Cal Period
C011797	Tektronix Mixed Signal Oscilloscope, MSO56	March 14, 2018	1 year
E286	Tektronix ADA400A Differential Preamplifier	May 30, 2018	1 year

5. Results / Conclusions

Test results show that in the worst case transmit condition the total accumulated transmit period of the Wi-Fi battery pack is approximately 45 ms during the monitor’s fastest allowable transmit interval of 15 second. These results can be used for determination of the RF exposure assessment.