October 14, 2016

Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street, SW
Washington, DC 20554

Re: Written *Ex Parte*: *Terrestrial Use of the 2473-2495 MHz Band for Low-Power Mobile Broadband Networks* – IB Docket No. 13-213

Dear Ms. Dortch:

Globalstar, Inc. ("Globalstar") hereby submits into the record the attached responses of Roberson and Associates, LLC ("Roberson and Associates") and AT4 wireless ("AT4"), to the *ex parte* filing by Microsoft Corporation ("Microsoft") regarding the alleged effects of Terrestrial Low Power Service ("TLPS") at 2473-2495 MHz on Xbox 360S game system operations.[1] As Roberson and Associates explains in its response,[2] Microsoft's test results contain such blatant methodological flaws that they should be disregarded by the Commission. Further, the results contained in AT4's report[3] confirm that it is only under the most unrealistic and extreme testing scenarios that Microsoft could show any impact of TLPS on Xbox operations, much less an impact that could actually cause a perceptible degradation in an Xbox user's gaming experience.

As has been conclusively tested and demonstrated over a multi-year process, under the Commission's proposed rules in this proceeding, TLPS will be fully compatible with unlicensed operations within the ISM band at 2400-2483.5 MHz. Microsoft's filing regarding transmissions occurring in the Xbox 360S system presents nothing to challenge these conclusions.

While Microsoft claims to show that TLPS will have a negative impact on Xbox 360S system performance, its tests appear to have been expressly designed to generate such harmful effects. Microsoft's test environment, arrangement of equipment, and choice of operating parameters are all highly unrealistic and unrepresentative of real-world operating scenarios. As a result, Microsoft's data is biased, unreliable, and should be accorded no weight in this proceeding. In its report, Roberson and Associates identifies the following glaring flaws in Microsoft's testing methodology:

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[1] Letter from Paula Boyd, Microsoft Corporation, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 13-213 (dated Sept. 12, 2016) (attaching technical analysis at Attachments A and B).

[2] Attached Exhibit A., "Analysis of Xbox 360S Compatibility Tests Reported in Microsoft Ex Parte Filing," Roberson and Associates, LLC (Oct. 14, 2016).

[3] Attached Exhibit B., "TLPS – Xbox 360S Controller Reliability Testing," AT4 wireless, Inc. (Oct. 14, 2016).

- Although off-the-shelf commercial equipment is widely available, the three Wi-Fi transmitters chosen by Microsoft to conduct its tests (operating on IEEE Channels 1, 6, and 11) were not traditional wireless access points but development boards used to transmit 802.11 modulation. These devices lacked the usual protective casings found in traditional residential and enterprise access points; and even though they operated with exposed circuit boards, Microsoft selectively chose these devices to test interference. In addition, these Wi-Fi devices were randomly oriented within inches of one another (and other equipment) on a workplace bench. Contrary to Microsoft's claims, this configuration is not "a common situation in multi-tenant dwellings, mixed use development, [or] on common campuses," or in any other typical deployment scenario. While minimum separation between access points even in multi-tenant dwellings is typically tens of meters, Microsoft chose to rig the test by clustering all of the equipment within inches of each other (even failing to disclose the exact spacing between the exposed development boards), and attempts to extrapolate dire conclusions from this entirely unrealistic test setup.

- Microsoft chose to run all of the 802.11 transmission devices at a 100% duty cycle, claiming this to be a "worst case scenario." However, Microsoft's duty cycle assumption is beyond "worst case" as *real* access points never transmit at 100% duty cycle unless operating in a test mode. Having all four access points operating at 100% duty cycle is not representative of any real-world environment and certainly not "a common situation in multi-tenant dwellings" as claimed by Microsoft.

- Microsoft indicates that the Wi-Fi devices transmitted at an EIRP of approximately 5 dBm (and possibly lower) while, according to "spectrum analyzer traces," the TLPS access point was transmitting at 8-9 dBm. While Microsoft's measurement of these EIRP levels appears unreliable, the fact that the TLPS access point may have been operating at least *250%* of the power level of the Wi-Fi devices further biases its test results against TLPS, rendering Microsoft's statement that the "Ruckus AP was transmitting at just slightly above that of the [other Wi-Fi devices]" extremely misleading.

- While the Xbox 360S devices were shielded from the Wi-Fi access points located on the other side of the chamber, the TLPS access point used in this test was placed above the Wi-Fi access points and had a clear RF path to the Xbox 360S equipment. Because of this contrived and biased configuration, the effect of TLPS transmissions on the Xbox 360S devices was certainly exaggerated.

- Microsoft used a type of shielded chamber for its tests which is an unsuitable environment for the kind of interference testing described in its filing.[4] The chamber's

[4] Microsoft applied for and obtained an experimental license from the Commission that authorized it to conduct TLPS testing outside a shielded chamber. Despite this fact, Microsoft presents test results only from chamber testing that could have been undertaken without Commission authorization.

flat, conducting walls can yield undesired signal reflections and allow internal reflections that would not occur in a real world residential or enterprise environment. While Microsoft certainly has access to test environments more representative of actual deployment scenarios, the company chose a chamber most likely to result in excess signal reflection apparently in order to further bias the results against TLPS.

- Inconsistent with standard RF engineering practice, Microsoft failed to provide key technical details regarding its testing, and, thus, its results should not be relied upon by the Commission. For example, Microsoft does not provide the physical dimensions of the test chamber or even the distances between the Wi-Fi equipment, TLPS access point, and Xbox 360S devices. It is reasonable to assume that this was done to obscure the unrealistic extreme proximity scenario Microsoft chose - apparently with the goal of contriving interference. Microsoft also fails to specify the test tool or protocol used to generate Wi-Fi traffic or the receiving device for the Wi-Fi transmissions on Channels 1, 6, and 11.

As described in Exhibit B, Globalstar commissioned AT4 to conduct Xbox 360S connectivity testing under very conservative assumptions as well as more realistic scenarios. The results of AT4's tests confirm TLPS will have no perceptible impact on Xbox 360S operations. Even when four access points are simultaneously operating on all four non-overlapping 802.11 channels at distances of only 18 feet apart at 50-60% duty cycles (still unrealistic and extremely conservative scenarios in any residential environment where Xbox 360S would be utilized), there is no discernable impact with button press success rates. In fact, the success rates exceeded 99%. When a TLPS access point was inserted into an existing Wi-Fi environment at AT4's testing facility in very close proximity to the gaming console, this rate increased to 100%. We note that a 60% duty cycle is significantly higher than would be expected in a residential environment, in line with traffic generated by streaming HD video over every channel. This parameter, incidentally, was the mutually agreed testing parameter among all interested stakeholders for the March 2015 compatibility demonstration held at the Commission's Technology Experience Center.

Throughout this multi-year proceeding, Globalstar in association with Roberson and Associates and AT4 have established repeatedly that TLPS will be a good neighbor to unlicensed operations in the ISM band at 2400-2483.5 MHz. Whether documenting a near doubling of wireless throughput on a Chicago university campus or the near doubling of the number of students able to use a school's wireless network in Washington, D.C., Globalstar has shown that the consumer benefits achievable by adding TLPS are undeniable and important to solving the connectivity gaps in our nation's classrooms.

In the end, Microsoft claims that there simply is not enough room in the upper 10.5 MHz of the ISM band to accommodate its Xbox customers' gaming needs and the myriad of different uses consumers could otherwise make of an additional 22 MHz channel. Thus, Microsoft demands that the Commission side with the incumbent and sacrifice any additional consumer benefits that would otherwise be achieved with more intensive, competitive use of the spectrum. Yet, Microsoft's own test results confirm that making such a stark choice between incumbent and

aspiring uses of the spectrum is simply not necessary due to the entirely unrealistic utilization rates and test set-up assumptions required for Microsoft to show any impact on its Xbox 360S operations. Outside of Microsoft's lab and inside our nation's homes, consumers would have the wireless capacity to stream HD videos and complete on-line tutorials over Channel 14 while simultaneously engaging in wireless recreational pursuits. Indeed, the Commission could significantly alleviate existing congestion issues and narrow the "homework gap" affecting students across the United States all without any impact on Xbox.

For these additional reasons, Globalstar urges the Commission to adopt the final order placed on circulation in this proceeding in May and bring this multi-year proceeding to a successful conclusion. [5]

Respectfully submitted,

/s/ *L. Barbee Ponder*
L. Barbee Ponder

cc: Julius Knapp

[5] *Terrestrial Use of the 2473-2495 MHz Band for Low-Power Mobile Broadband Networks; Amendments to Rules for the Ancillary Terrestrial Component of Mobile Satellite Service Systems*, Notice of Proposed Rulemaking, 28 FCC Rcd 15351 (2013).

EXHIBIT A

Roberson and Associates, LLC
Technology and Management Consultants

Analysis of Xbox 360S Compatibility Tests Reported in Microsoft Ex Parte Filing

Prepared for Globalstar, Inc., by:

Roberson and Associates, LLC
Schaumburg, Illinois 60173

Authors:

Kenneth J. Zdunek, Ph.D.
Michael Needham
Nat Natarajan, Ph.D.

Date: October 14, 2016

Analysis of Xbox 360S Compatibility Tests Reported in Microsoft's Ex Parte Filing

Summary

Microsoft Corporation submitted an FCC Ex Parte filing dated September 12, 2016 containing test results which allegedly demonstrate that if the Commission grants Globalstar permission to operate TLPS, then "a broad cross-section of U.S. consumers will lose functionality of their current gaming devices." A Roberson and Associates team of technical experts has reviewed Microsoft's filing and concludes that this sweeping statement is not supported, and that the reported tests are flawed and fail to support the claim that TLPS will adversely impact the functionality of Xbox 360S or other gaming consoles.

The tests of the Xbox 360S are flawed because: 1) the contrived test environment and physical configuration of devices do not represent a real-world operating scenario for gaming devices and concurrent Wi-Fi operations; 2) the test devices and operating parameters used for Wi-Fi and TLPS are not representative of actual equipment in the field or typical operating parameters for such equipment – in particular, simultaneous 100% duty cycle and near equal power levels for all IEEE channels in a consumer environment is a use-case that is not encountered in the real-world; 3) the tests were conducted on the Microsoft Xbox 360S, a device introduced in 2005 and no longer sold. Despite being in the marketplace for a long time, there is no evidence presented that the performance of this one device is representative of the large number of other gaming devices in use.

The transmitted power levels of the Wi-Fi and TLPS devices are described in a conflicting manner; we believe this is likely a technical error and it is likely that the transmitted TLPS power level was significantly higher than the Wi-Fi power levels, unfairly biasing the results against TLPS. Significantly, the actual relative received power levels of the desired Xbox 360S signals and undesired Wi-Fi and TLPS emissions at the Xbox 360S receiver were not specified and therefore cannot be used to ensure that normalized signal power levels were resident on the user terminals. The bandwidth of the modified (non-production) Ruckus access point used for TLPS transmissions was not measured and not shown to be representative of the characteristics of a device that would meet FCC requirements and could be legally sold and operated in the real world. The antenna characteristics, test tool and protocol of the Wi-Fi devices operating on channels 1, 6 and 11 were not specified. Further, the distance between the Wi-Fi devices directly and the distances between the Wi-Fi devices and the Xbox 360S devices were not specified; however, the images demonstrate that the devices were extremely close to one another and do not represent even worst-case real-world network deployments.

Finally, the example of text transmission with errors, allegedly chosen to represent the same type of error rate as produced with Xbox 360S button pushes with simultaneous Wi-Fi and TLPS, is misleading and adds nothing to the issue of TLPS compatibility with gaming devices. The example is not representative of any realistic operating scenario that exists in the unlicensed band, since real-

time gaming device "button pushes" do not use the same transmission protocol used for text, which employs error correction and retransmission. Missed real-time button pushes cannot be equated to bit errors in a text data stream.

Analysis of Xbox 360S Compatibility Tests

Test Environment and Physical Configuration of Devices

1. Attachments A and B of Microsoft's Ex Parte Filing contain a description of the test environment and physical location of the devices in the room used for testing. It is stated that the tests were conducted in a "shielded chamber." Assuming that the shielded chamber was a type of Faraday cage intended to prevent external RF signals from disturbing the test environment, this was an appropriate goal for the testers. However, this type of chamber is an unsuitable environment for conducting the kind of over-the-air RF interference testing described in the filing. The flat, conducting walls of the shielded chamber, evident in Slides 3 and 6 of Attachment B, are not representative of a real-world consumer environment, and produce undesired reflections of the RF signals inside the chamber. This unrealistic environment results in RF standing wave patterns and causes unpredictable, non-repeatable, and unreliable test results highly dependent on the exact placement of the devices under test.

2. Despite the statement that a shielded chamber was used for the tests, the spectrum analyzer display in Slides 9 and 11 indicates that the noise floor in the unlicensed band could be as high as -77 dBm.[1] This level of background noise seems uncharacteristically high for a shielded chamber and with the spectrum analyzer settings shown. This high level of background noise for the test environment could obscure measurements of the impact of TLPS and Wi-Fi on gaming device transmissions.

3. The physical environment within the test chamber, while inadequately described, is clearly not representative of a real-world network setup. While Slide 3 notes that the Xbox 360S controller and console are 6 feet apart, the physical dimensions of the test chamber and separation of the Xbox 360S device on the "left side" of the room in Slide 3, and the Wi-Fi and TLPS devices on the "right side" of the room in Slide 6, are not specified. Furthermore, the location of the Wi-Fi receivers on channels 1 , 6, and 11 are not clearly indicated in the slides or test set-up description. If there were no Wi-Fi receivers, then the MediaTek devices were essentially set up as unlicensed band "jammers" not reflecting any real operating mode. Furthermore, the location of the TLPS receiving device (Nook) is not indicated.

[1] According to the pictures in the filing, the spectrum analyzer was operated in the "peak hold" mode and therefore the noise floor shown might not be the average noise floor.

4. The physical arrangement of the MediaTek Wi-Fi devices and the TLPS access point are contrived and bear no relationship to a real-world deployment scenario. Slide 6 clearly shows the MediaTek Wi-Fi cards used to generate Wi-Fi signals on channels 1, 6, 11 to consist of exposed circuit boards, oriented randomly, placed *within a few inches of one another* on the workbench surface, and with transmit antennas in close proximity to each other and to other equipment on the bench. While the distance between these Wi-Fi devices and the TLPS access point is also not specified, the images appear to show that the distances were not greater than 10 or 12 inches. It cannot be imagined that such a configuration of Wi-Fi access points or clients would occur in a consumer environment. Furthermore, the device arrangement clearly shields the Wi-Fi transmissions from the Xbox 360S device on the other side of the room, biasing the results against TLPS, as the TLPS access point has a clear RF path to the Xbox 360S devices. This is explained further in item 8.

5. The test scenario with 3 MediaTek Wi-Fi devices without protective housings, operating within inches of one another as shown in Slide 6, is in no way representative of a "common situation in multi-tenant buildings, mixed used development, and on college campuses," as stated in Attachment A, page 2 of Microsoft's filing. These devices and their form factor indicate that they are intended to be used by hobbyists and developers and do not represent the types of Wi-Fi devices that would exist in a consumer environment.

<u>Test Devices and Operating Parameters</u>

6. It is stated that the channel utilization for the Wi-Fi channels was 100%. 100% channel utilization cannot occur with a standard data transmission protocol, and typical utilization rates are a fraction of this assumption. Even for high data rate applications such as streaming, there will be time and frequency gaps in the transmissions from the access points and clients that would allow the signals from the gaming device to use the spectrum.

7. The filing does not specify the test tool or protocol used to generate Wi-Fi traffic on the MediaTek devices, nor does the filing specify the receiving device for the Wi-Fi transmissions. It is unknown whether an IEEE standard 802.11 protocol was used. Furthermore, if a non-standard protocol was employed to activate the Wi-Fi devices at 100% bandwidth utilization, the test results comparing the impact of Wi-Fi and Wi-Fi with TLPS on the Xbox 360S are meaningless.

8. The position of the TLPS access point in Slide 6 is such that it generates a higher signal level in the Xbox 360S devices located on the other side of the room. This contrived configuration causes the impact of TLPS on the Xbox 360S to be exaggerated. The TLPS access point in Slide 6 is located on the workbench shelf above the Wi-Fi cards, in a position such that its transmissions have a clear RF path to the Xbox 360S devices on the other side of the room, in contrast to the Wi-Fi devices.

9. Regarding the EIRP of the Ruckus TLPS access point, Page 6 of Microsoft's cover letter states that "the Ruckus AP has a maximum power rating of 23 dBm" and that "based on spectrum analyzer traces" the Ruckus AP was transmitting at just slightly above that of the MediaTek Wi-Fi devices (8-9 dBm). Microsoft's power level measurements were unreliable, however. Microsoft measured the EIRP of the Ruckus device placed on the shelf of the workbench, using a spectrum analyzer and probe that was (i) not under current calibration and (ii) located beneath the Ruckus AP. In addition, these measurements occurred in the highly reflective RF environment of the shielded room as shown in Slide 6. Therefore, the transmit power level of the Ruckus TLPS device in Test 3 relative to the transmit powers of the Wi-Fi devices is unknown, rendering any performance comparisons of Xbox 360S with and without TLPS meaningless. Other information in the Microsoft Ex Parte filing indicates that the EIRP of the Ruckus TLPS was very likely significantly higher than that of the Wi-Fi devices, unfairly biasing the test results against TLPS. Page 5 of cover letter states that the EIRP of the Wi-Fi MediaTek devices was "on the order of 5 dBm," and potentially as low as 3 dBm. Given the logarithmic scale factor, even if the Ruckus AP was transmitting at an EIRP of 9 dBm as stated on page 6 of the cover letter, and the Wi-Fi devices were transmitting at an EIRP of 5 dBm, then the Ruckus TLPS AP was transmitting at a power level fully 250% that of the Wi-Fi devices. This clearly and unfairly biases the test results against TLPS such that the results of any comparison of Xbox 360S performance with and without TLPS are inherently unreliable.

10. Microsoft's filing states that the test protocol used to generate TLPS traffic between the Ruckus AP and the Nook HD+ (client) was iPerf. The filing also stated that the standard 802.11a/g/n protocol was used. The iPerf test tool is intended to measure Wi-Fi channel throughput (speed test), and generates high channel utilization levels that would not normally occur on all Wi-Fi channels simultaneously in a real consumer environment.[2]

11. Coupled with the stated, unrealistic 100% duty cycle of the MediaTek devices, the high utilization of the TLPS channel being driven by a throughput test creates an extremely unlikely operating scenario for the Xbox 360S gaming console. This unrealistic operating scenario cannot be used to draw conclusions about the ability of gaming device transmissions to utilize the unlicensed spectrum and coexist with Wi-Fi and TLPS.

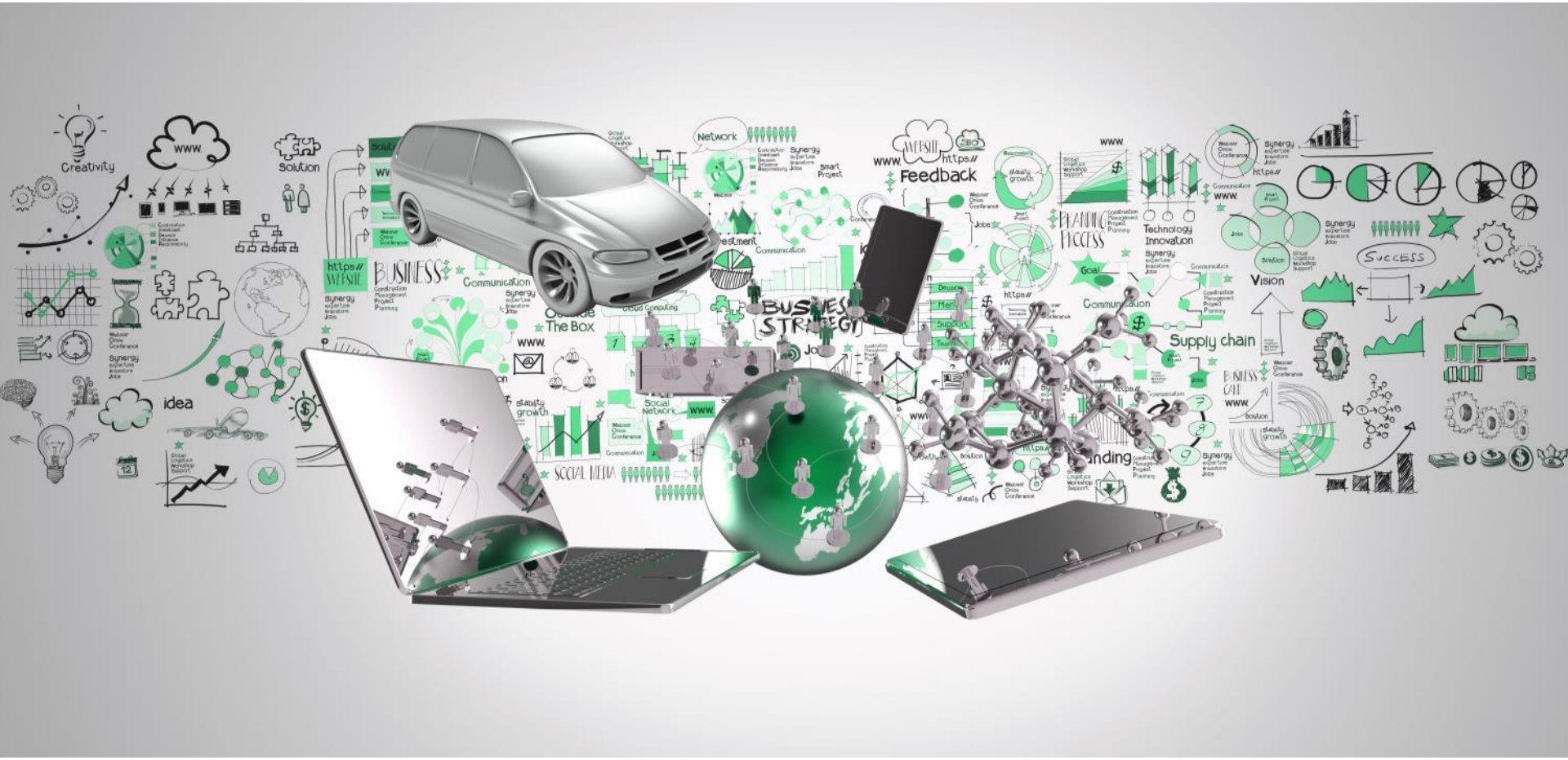
Conclusion

Based on the analysis above, the tests reported by Microsoft: a) are fundamentally flawed, b) provide no useful results, and c) cannot be relied on as valid demonstration of the impact of TLPS on the Xbox 360S in the real world. Further, the results cannot be generalized to apply to other gaming systems.

[2] The filing states that "iPerf was used to saturate the channel."

EXHIBIT B

Exhibit B: TLPS – Xbox 360S Controller Reliability Testing



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Introduction

- Background:
  - Globalstar, Inc. (“Globalstar”) requested AT4 wireless, Inc. (“AT4”) to characterize the reliability of the communication link between Xbox 360S consoles and wireless controller devices in the presence of non-overlapping Wi-Fi Channels (1, 6 and 11) and TLPS.
- Purpose:
  - The purpose of this presentation is to share the data obtained during this testing activity along with details of the test environment and test procedure.
  - Data was collected under multiple scenarios to assess the level of impact, if any, TLPS has on XBOX 360S consoles and wireless controller devices.
- Index:
  - Summary
  - Test Environment
  - Test Conditions
  - Test Procedure
  - Test Results
  - Appendix

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Summary

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Summary

- Summary of Test Cases:
  1. Extreme Scenario I: 4 access points on each of channels 1, 6, 11 and TLPS in close proximity (18 feet), all at ~50% duty cycle.
  2. Extreme Scenario II: 4 access points on each of channels 1, 6, 11 and TLPS in close proximity (18 feet), all streaming HD video (equates to ~60% duty cycle).
  3. Realistic Scenario I: TLPS introduced into existing Wi-Fi environment without adjusting distances between access points. (50-100 feet with TLPS AP ~12 feet from the gaming console and wireless controller at ~50% duty cycle.)
  4. Realistic Scenario II: TLPS introduced into existing Wi-Fi environment streaming HD video without adjusting distances between access points. (50-100 feet with TLPS AP ~12 feet from the gaming console and wireless controller at ~60% duty cycle.)
- Console – Controller Communication:
  - Under Extreme Scenario I and II, the key stroke success rate when TLPS was present was observed to be in excess of 99%.
  - Under Realistic Scenario I and II, the key stroke success rate when TLPS was present was 100%.

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Test Environment

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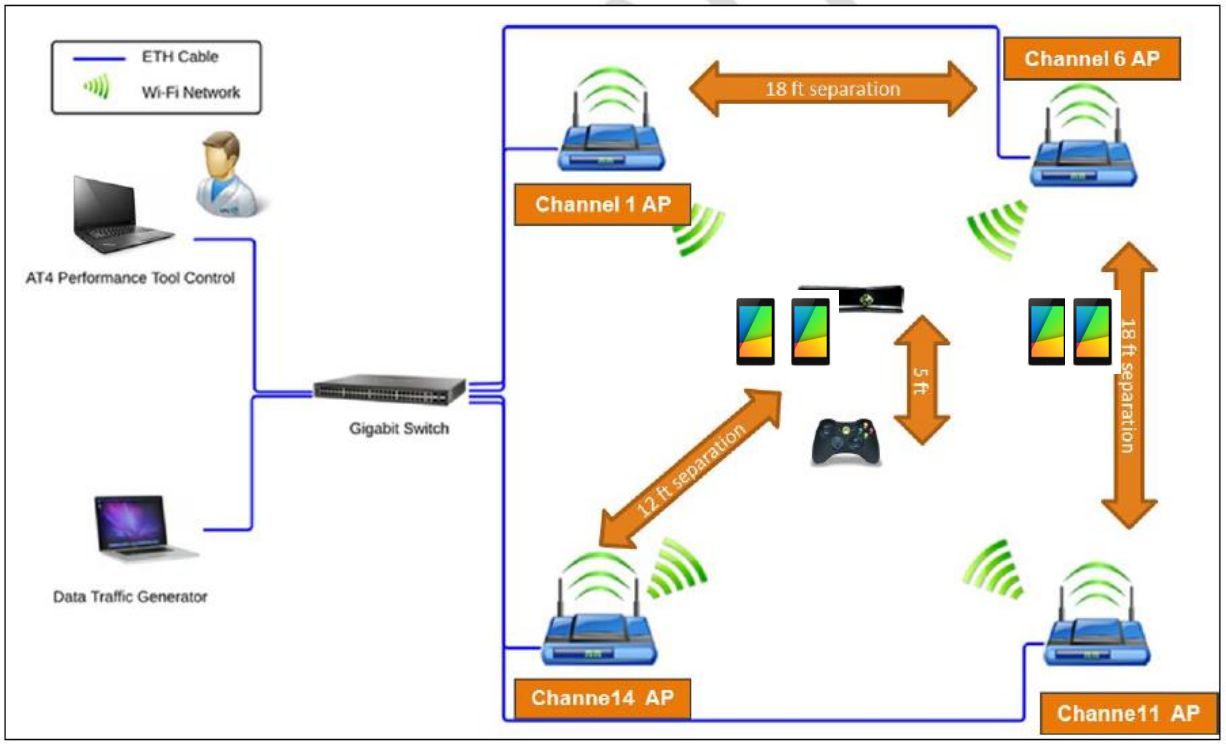
Test Environment – Extreme Scenario I and II

- Below shows the overview of the set-up used for Extreme Scenario I and Extreme Scenario II. APs are separated by 18 feet with clients placed at a distance of 12 feet away from the AP.
  - APs would not be installed this close to one another in any real-world enterprise or residential deployment and would also be normally separated by interior walls.
- XBOX 360S is placed next to the clients with controller separated by 5 feet from the console.



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Test Environment – Extreme and Realistic Scenarios

Each AP mounted on a stand 8 feet above the ground

XBOX console and controller separated by 5 feet.

Note: During Realistic Scenarios, test APs on channels 1, 6 and 11 were turned off while keeping existing APs used for Wi-Fi network.

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Test Conditions

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Test Conditions – Extreme Scenario I and II

- Device Under Test (DUT)
  - Xbox 360S Console
    - Software Version 2.0.17147.0 Model Number 1538
    - Serial Number 011782253308
  - Xbox 360S Controller – Model 1403
- "AT4 wireless Performance Test Tool" was used to generate traffic
    - Additional details can be found at Data Sheet
- Testing assumed a conservative ~50% duty cycle followed by testing assuming the transmission of HD (1080p) streaming video to all channels (1, 6, 11) and TLPS providing a duty cycle of ~60%.
- Below traffic profile was pushed to the clients to keep the Wi-Fi channel occupied during the test activity.

Transport Protocol	Traffic Direction	Duration (s)	Application SDU Size (Bytes)	Data rate (Mbps)	TCP Streams	Video Resolution	Measured Duty Cycle (%)
TCP	DL	1800	131072	3	1	NA	~50%
UDP	DL	1800	343	3.644	NA	1080p	~60%

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Test Conditions – Extreme Scenarios and Realistic Scenarios

- Six different test conditions were defined to measure the operational performance in a Wi-Fi deployment.
  - Extreme Scenario I and II
    - 3 APs no TLPS – 100mW (to establish baseline)
    - 3 APs no TLPS – 200mW (to establish baseline)
    - 4 APs with TLPS – 100mW
    - 4 APs with TLPS – 200mW
  - Realistic Scenario I and II
    - TLPS operating in existing Wi-Fi environment - 50% duty cycle
    - TLPS operating in existing Wi-Fi environment - streaming HD video

* Power level mentioned was the approximate conducted power configured on the access point.

**Additional details about the AP specifications can be found at Data Sheet

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Test Procedure

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Test Procedure – Extreme Scenarios

- 3 APs no TLPS – 100mW
  - Disable AP operating in channel 14
  - Configure Tx power of APs to 100mW
  - Initiate DL data traffic to the different Wi-Fi clients
  - Initiate RF spectrum capture
  - Open an application with on-screen keyboard on the Xbox and move the cursor to select an alphabet character
  - Test engineer to manually push button “A” in the Xbox controller at a frequency of 1 button/sec for a period of 5 and 15 minutes
  - Count the number of successful button triggers received
  - Report percentage of successful triggers
- 4 APs with TLPS – 100mW
  - Enable AP operating in channel 14
  - Configure Tx power of AP to 100mW
  - Repeat the test steps as above to measure the successful triggers

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Test Procedure – Extreme Scenarios

- 3 APs no TLPS – 200mW
  - Disable AP operating in channel 14
  - Configure Tx power of APs to 200mW
  - Initiate DL data traffic to all Wi-Fi clients
  - Initiate RF spectrum capture
  - Open an application with on-screen keyboard on the Xbox and move the cursor to select an alphabet character
  - Test engineer to manually push button “A” in the Xbox controller at a frequency of 1 button/sec for a period of 5 and 15 minutes
  - Count the number of successful button triggers received
  - Report percentage of successful triggers
- 4 APs with TLPS – 200mW
  - Enable AP operating in channel 14
  - Configure Tx power of AP to 200mW
  - Repeat the test steps as above to measure the successful triggers

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Test Procedure – Realistic Scenarios

- TLPS operating in existing Wi-Fi environment – 100mW
  - Introduce TLPS access point on top of current Wi-Fi network utilizing channels 1, 6 and 11
  - Configure Tx power of AP to 100mW
  - Initiate DL data traffic to the Wi-Fi client connected to TLPS AP.
  - Initiate RF spectrum capture
  - Open an application with on-screen keyboard on the Xbox and move the cursor to select an alphabet character
  - Test engineer to manually push button “A” in the Xbox controller at a frequency of 1 button/sec for a period of 5 and 15 minutes
  - Count the number of successful button triggers received
  - Report percentage of successful triggers
- TLPS operating in existing Wi-Fi environment – 200mW
  - Configure Tx power of AP to 200mW
  - Repeat the test steps as above to measure the successful triggers
  - Same procedure was used for 50% duty cycle and HD video streaming scenario of Realistic Scenario I and Realistic Scenario II, respectively

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Test Procedure

- Measurement procedure to count XBOX 360S button triggers
  - Power on the Xbox 360S and sign in to the test profile
  - Navigate to the Apps and run “Internet Explorer”
  - Open www.gmail.com website and sign-in with credentials
  - Navigate to the on-screen keyboard with the controller, select a character on the keyboard
  - Start composing in the body of the email with 1 button click (character) per second for a period of 5 and 15 minutes
  - Measure the number of characters actually typed at the end of the test
  - Calculation:
    - Total number of key inputs = 300 and 900 (equating to 5 minutes and 15 minutes)
    - Total number of successful key inputs = count of letters typed
    - Total number of failed key inputs = count of letters missed

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Test Results

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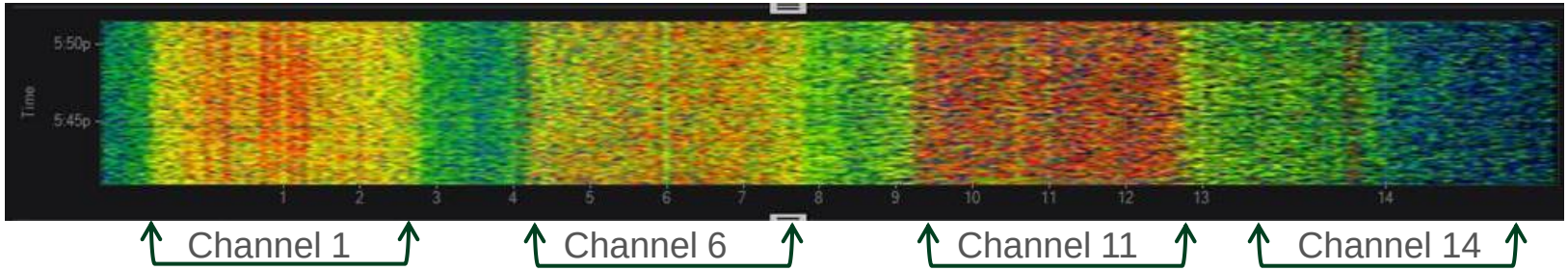
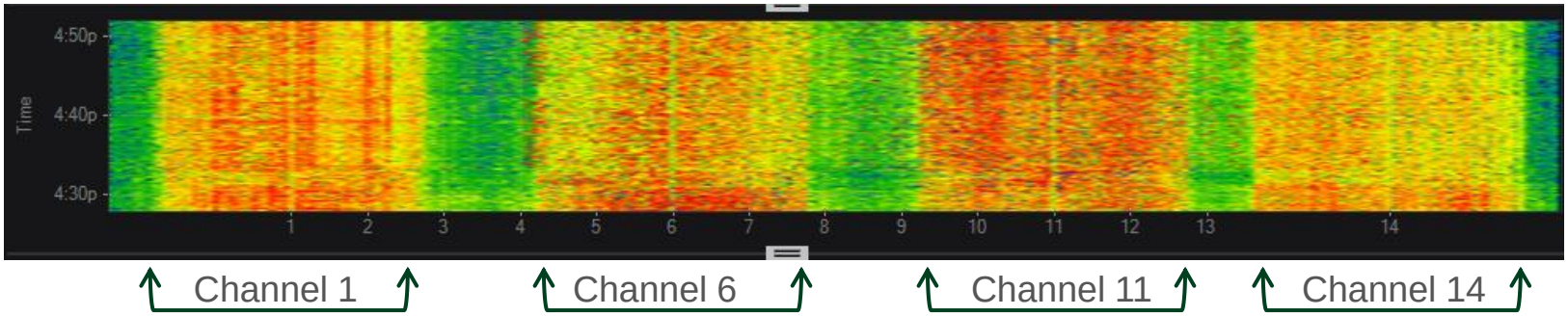
Test Results – Extreme Scenario I

- Spectrum Usage – TCP 3Mbps traffic pushed to clients
  - Below graph shows the spectrum usage of the 2.4 GHz band while clients are sending traffic with and without TLPS along with channel utilization
  - Channels 1, 6 and 11 are in operation:



  - Channels 1, 6, 11 and TLPS are in operation:



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Test Results – Extreme Scenario I

- Key Input Performance
  - Below table contains the data showing the number of successful/failed key strokes across multiple iterations

Scenarios	Power Level	Channels Utilization				Controller Inputs	Success	Fail	Success Rate
		1	6	11	14				
3APs No TLPS	100 mW	55.40%	53.80%	43.50%	X	300	300	0	100.0%
4APs with TLPS	100 mW	52.30%	56.50%	44.60%	49.50%	300	299	1	99.7%
3APs No TLPS	200 mW	55.20%	54.40%	42.40%	X	300	300	0	100.0%
4APs with TLPS	200 mW	62.40%	52.80%	47.10%	51.20%	300	299	1	99.7%
3APs No TLPS	100 mW	55.40%	53.80%	43.50%	X	900	900	0	100.0%
4APs with TLPS	100 mW	52.30%	56.50%	44.60%	49.50%	900	898	2	99.8%
3APs No TLPS	200 mW	55.20%	54.40%	42.40%	X	900	900	0	100.0%
4APs with TLPS	200 mW	62.40%	52.80%	47.10%	51.20%	900	897	3	99.7%

- Various channel utilization rates due to spectrum usage from existing APs, however, average in excess of 50%
- As shown in the above tables, no reasonably perceivable impact observed in terms of key strokes lost

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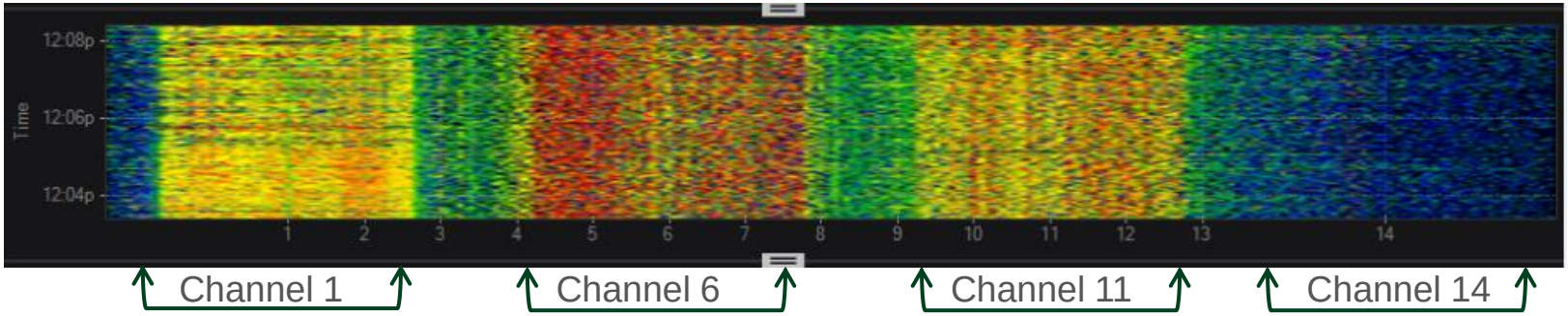
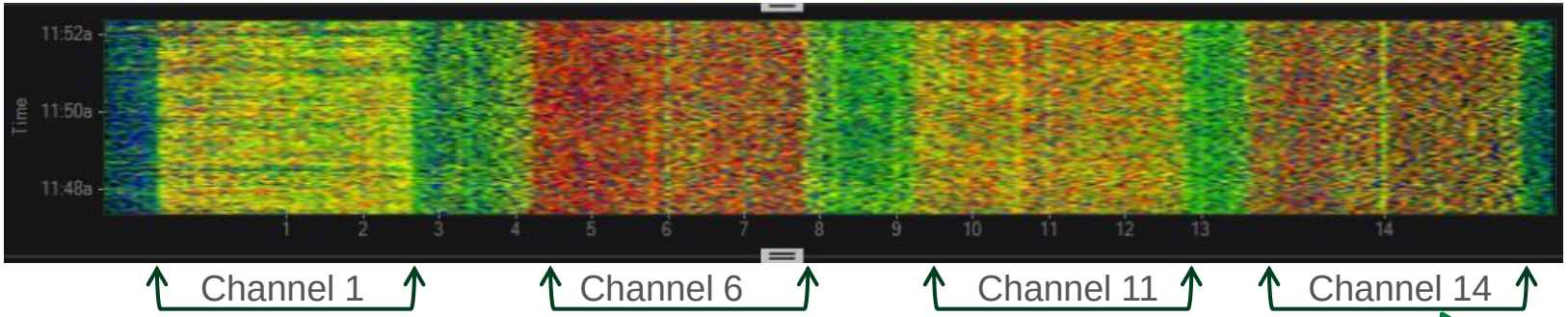
Test Results – Extreme Scenario II

- Spectrum Usage – HD video streamed to clients
  - Below graph shows the spectrum usage on the 2.4 GHz band while clients are sending traffic with and without TLPS along with channel utilization
  - Channels 1, 6 and 11 are in operation:



  - Channels 1, 6, 11 and TLPS are in operation:



Slide 19
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Test Results – Extreme Scenario II

- Key Input Performance
  - Below table contains the data showing the number of successful/failed key strokes across multiple iterations

Scenarios	Power Level	Channels Utilization				Controller Inputs	Success	Fail	Success Rate
		1	6	11	14				
3APs No TLPS	100 mW	54.80%	58.30%	62.00%	X	300	300	0	100.0%
4APs with TLPS	100 mW	50.70%	56.70%	65.30%	58.60%	300	298	2	99.3%
3APs No TLPS	200 mW	58.90%	60.23%	69.20%	X	300	300	0	100.0%
4APs with TLPS	200 mW	59.10%	62.20%	72.10%	54.0%	300	298	2	99.3%
3APs No TLPS	100 mW	54.80%	58.30%	62.00%	X	900	900	0	100.0%
4APs with TLPS	100 mW	50.70%	56.70%	65.30%	58.60%	900	897	3	99.7%
3APs No TLPS	200 mW	58.90%	60.23%	69.20%	X	900	900	0	100.0%
4APs with TLPS	200 mW	59.10%	62.20%	72.10%	54.0%	900	896	4	99.6%

- Various channel utilization rates due to spectrum usage from existing APs, however, average in excess of 60%
- As shown in the above tables, no reasonably perceivable impact observed in terms of key strokes lost

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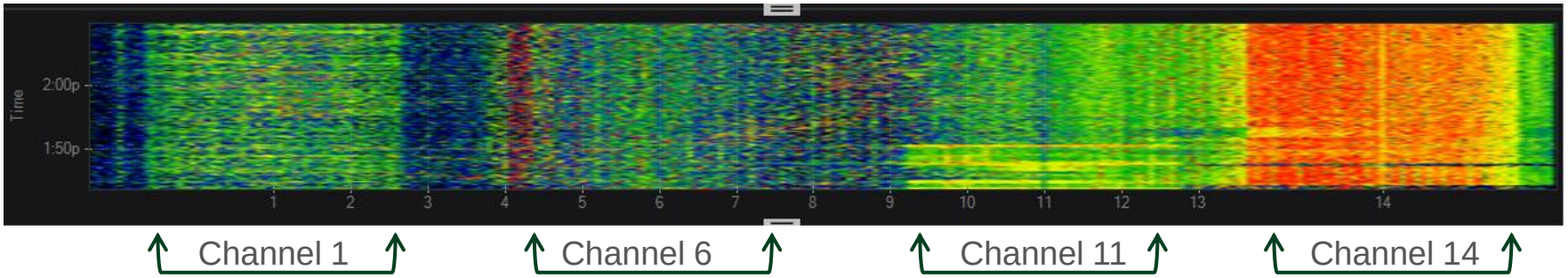
Test Results – Realistic Scenario I

- Spectrum Usage – TCP 3Mbps traffic pushed to TLPS client
  - Below graph shows the spectrum usage of the 2.4 GHz band while clients are sending traffic with TLPS along with channel utilization
  - TLPS in operation with existing usage of channels 1, 6 and 11



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Test Results – Realistic Scenario I

- Key Input Performance
  - Below table contains the data showing the number of successful/failed key strokes across multiple iterations

Scenarios	Power Level	Channels Utilization				Controller Inputs	Success	Fail	Success Rate
		1	6	11	14				
1AP operating on TLPS	100 mW	16.30%	16.30%	31.70%	49.70%	300	300	0	100.0%
1AP operating on TLPS	100 mW	17.10%	16.60%	28.40%	48.23%	900	900	0	100.0%
1AP operating on TLPS	200 mW	18.00%	15.80%	35.00%	50.10%	300	300	0	100.0%
1AP operating on TLPS	200 mW	20.80%	15.30%	38.10%	50.50%	900	900	0	100.0%

- Various channel utilization rates on 1, 6 and 11 due to spectrum usage from existing APs
- No connectivity loss observed between controller and XBOX 360S console with TLPS

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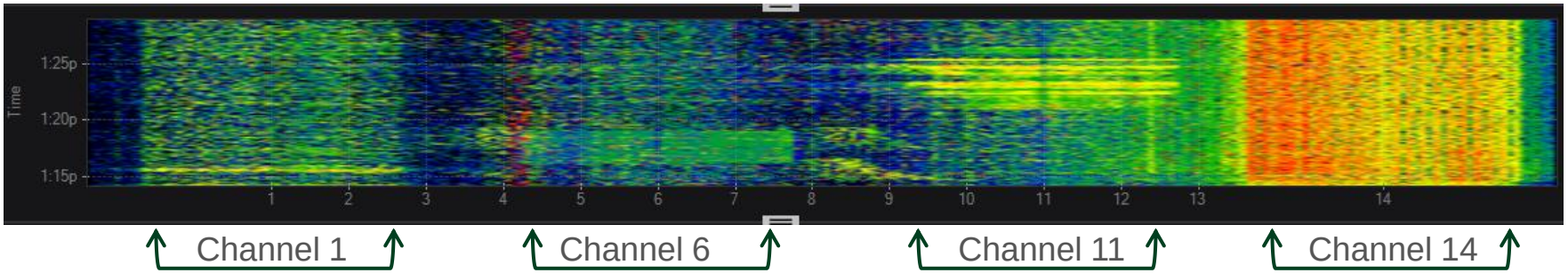
Test Results – Realistic Scenario II

- Spectrum Usage – 1080p video streamed to TLPS clients
  - Below graph shows the spectrum usage of the 2.4 GHz band while clients are sending traffic with TLPS along with channel utilization
  - TLPS in operation with existing usage of channels 1, 6 and 11



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Test Results – Realistic Scenario II

- Key Input Performance
  - Below table contains the data showing the number of successful/failed key strokes across multiple iterations.

Scenarios	Power Level	Channels Utilization				Controller Inputs	Success	Fail	Success Rate
		1	6	11	14				
1AP operating on TLPS	100 mW	17.00%	18.00%	39.00%	58.20%	300	300	0	100.0%
1AP operating on TLPS	100 mW	20.36%	19.89%	30.52%	56.82%	900	900	0	100.0%
1AP operating on TLPS	200 mW	19.20%	15.70%	26.60%	59.90%	300	300	0	100.0%
1AP operating on TLPS	200 mW	17.90%	12.70%	33.20%	60.21%	900	900	0	100.0%

- Various channel utilization rates on 1, 6 and 11 due to spectrum usage from existing APs
- No connectivity loss observed between controller and XBOX 360S console with TLPS

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Appendix

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Appendix – Test Location

- Test performed in AT4wireless Lab in Herndon, VA

Test Date	Test Period	Test Engineer	Location
10/4/2016 10/5/2016 10/6/2017 10/7/2016 10/10/2017	9am-8pm	Hemant Kocherlakota/ Indusha Chitepu	Open Lab Area

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Appendix – Test Equipment

Device	Profile	Control Number	Serial Number	Mac Address	Software Version	Tool Version	AT4-Agent Version	Settings	Power Level
Samsung Ultrabook	Laptop	00543/44	HY2S91GCB01726J	c8:f7:33:47:75:89	Windows 10	Channelyzer 5.8.8.39	-	-	-
Lenovo Thinkpad Edge	Laptop	PC-29	LR-296PF	60:eb:69:c8:d6:75	Windows 7	AT4 Performance Tool 5.0.8	5.0.0.9	-	-
Macbook	Laptop	STA1	C02J5ES2DTY4	40:6c:8f:50:17:e9	10.10.5	-	5.0.0.9	Data Generator	-
Nexus 7	Tablet	1236.25	0a9d9281	ac:9e:17:c9:b8:6a	4.4.4	-	5.0.7.9	1 Spatial Stream, Channel 14	-
Samsung Galaxy Note 10.1	Tablet	STA 9	4107b31f22e68fdf	20:02:af:be:c1:72	4.4.2	-	5.0.7.9	1 Spatial Stream, Channel 11	-
Dell Venue	Tablet	1109.59	73740000316139	90:20:3a:0a:9e:8b	4.4.4	-	5.0.7.9	1 Spatial Stream, Channel 6	-
Nexus 7	Tablet	1240.37	0a83beb5	ac:9e:17:c9:7c:38	4.4.4	-	5.0.7.9	1 Spatial Stream, Channel 1	-
Ruckus 7982	Access Point	1639.04	471463900746	F0:B0:52:20:8F:90	9.5.2.0.14189422	-	-	DHCP Disabled/Open SSID/Channel 14	Full/-3dB
Ruckus 7982	Access Point	1639.05	131403000399	6C:AA:B3:14:34:90	9.5.2.0.14189422	-	-	DHCP Disabled/Open SSID/Channel 11	Full/-3dB
Ruckus 7982	Access Point	1429.02	921403001224	2C:5D:93:13:99:E0	9.5.2.0.14189422	-	-	DHCP Disabled/Open SSID/Channel 6	Full/-3dB
Ruckus 7982	Access Point	00543/144	291205002714	C0:8A:DE:22:52:00	9.5.2.0.14189422	-	-	DHCP Disabled/Open SSID/ Channel 1	Full/-3dB

- **1 spatial stream client used during the test**
- **Each client is connected to corresponding AP operating on same channel**

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Appendix – Disclaimer

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