PUBLIC CONSULTATION PAPER

WIRELESS LOCAL AREA NETWORK (WLAN)

IN THE 6 GHz FREQUENCY BAND

APPENDIX 7

[7] Test Report on the Effects of 6 GHz Unlicensed RLAN Units on Fortson to Columbus Microwave Link, https://ecfsapi.fcc.gov/file/106231367519302/6%20GHz%20Columbus%20Test%20Report%20-%20June%202021.pdf

ATTACHMENT A

Test Report on the Effects of 6 GHz Unlicensed RLAN Units on Fortson to Columbus Microwave Link

June 21, 2021

Test Report on the Effects of 6 GHz Unlicensed RLAN units on Fortson to Columbus Microwave Link

Prepared in Partnership with Southern Company Services

June 21, 2021

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Abbreviations:

AFC	Automatic Frequency Coordination
AGL	Above Ground Level, used for elevation of antennas
AP	Access Point, the central unit of an RLAN, communicates with Clients
ASR	Antenna Structure Registration
AT&T	Formerly American Telephone and Telegraph
BEL	Building Entry Loss
BER	Bit Error Rate
CFR	Code of Federal Regulations
CTIA	formerly Cellular Telecommunications Industry Association
COTS	Commercial Off The Shelf
dBm	Decibels in relation to 1 milliWatt
dBu	Decibels above a One Microvolt/Meter Field Strength
D/U	Desired signal strength vs Undesired signal strength (in dB)
EIRP	Effective Isotropic Radiated Power
EPRI	Electric Power Research Institute
FCC	Federal Communications Commission
FNPRM	Further Notice of Proposed Rulemaking
FS	Fixed Site, used to refer to the endpoints of the Licensed link
GHz	Giga Hertz, 1000,000,000 Hertz
HAAT	Height Above Average Terrain
IEEE	Institute of Electrical and Electronics Engineers – a standards body
LoS	Line-of-Sight, used in reference to RF paths/propagation
LPI	Low Power Indoor (RLAN unit classification by FCC)
L&W	Lockard & White telecommunications consulting
MHz	Mega Hertz – 1,000,000 Hertz
NAD	North American Datum
NMS	Network Management System
PSC	Preferred Scanning Channel, specified Beacon channels for Wi-Fi 6E
PSD	Power Spectral Density, typically in dBm/MHz or W/Hz
R&O	Report and Order – in this document refers to FCC 20-51 on 6GHz
R&S	Rhode & Swartz, test equipment manufacturer
RF	Radio Frequency
RLAN	Radio Local Area Network
RSL	Received Signal Level
SCS	Southern Company Services, part of Southern Company
Std Power	Standard Power RLAN unit classification – required to use AFC
ULS	Universal Licensing System – Used by FCC, proposed for AFC servers
VLP	Very Low Power (RLAN unit classification by FCC)
VSG	Vector Signal Generator, a piece of RF test gear
WSAT	Wavence Spectrum Analyzer Tool (built into Nokia Wavence radios)

Executive Summary of 6 GHz Interference Testing

In mid-April 2021, Southern Company, along with the Electric Power Research Institute ("EPRI") and Lockard & White ("L&W"), conducted real-world testing of FCC-certified unlicensed Low Power Indoor ("LPI") equipment against a licensed, fixed microwave 6 GHz system between Fortson and Columbus, GA. This document provides a full report of the testing and results. This testing followed a plan developed in advance and documented in SCSWHP 210222 6GHz Unlicensed Test Plan.

Overview of Testing Results. This new testing confirmed that FCC-certified unlicensed LPI devices ***will cause harmful interference to licensed fixed microwave systems***, including those used to monitor and protect the electrical grid and for public safety operations. Unlike prior testing that utilized simulated equipment and configurations, these measurements used commercial off-the-shelf, FCC-approved 6 GHz LPI access points and mobile devices. Moreover, several of the testing locations were co-located with existing Wi-Fi access points, thus making these measurements representative of actual locations used by consumers with real-world devices that are available in the marketplace. The testing described in this report demonstrates that: (1) with beacons only or (2) beacons plus low speed (100 Mbps or less) data, harmful interference was measured for the vast majority of configurations tested (11 out of 13), including a site that was more than ***4.5 kilometers*** from the microwave receiver. Southern also tested higher data rates (750 Mbps or higher) and those configurations presented even more harmful interference to the licensed microwave link and was measurable more than ***9 kilometers*** from the microwave system.

Southern utilized the FCC threshold for reportable harmful interference of -6 Decibel (dB) Interference to Noise ratio (-6 dB I/N) where a fixed microwave system begins to degrade based on outside interference to measure effects to the licensed microwave path. In addition to testing the normal data communications from the unlicensed LPI devices, the April testing also measured the effect associated with beacon transmissions. A beacon transmission is used by a Wi-Fi router to allow devices to find and associate with the access point (these are known as SSIDs and transmit the identification information of the access point—this is the router name that client devices look for when first trying to connect to a Wi-Fi router). This beacon transmission typically occurs every 104 milliseconds continuously per the 802.11 standards—otherwise there would be no way for a new device to scan and find the router to connect. Southern's April testing found that ***just the beacon transmission alone resulted in interference that exceeded the FCC's -6 dB I/N threshold*** in 5 out of the 13 different configurations tested. As these beacon transmissions are continuous, this type of interference would not be intermittent but would be constant.

Moreover, once the unlicensed LPI device begins transmitting actual data information (in addition to any beacon transmission), the interference increases dramatically. Eleven of the thirteen tested configurations had measured interference levels greater than the FCC-defined -6 dB I/N threshold. The interfering power ratio (as a percentage to the interference at -6 dB I/N) ranged from hundreds of percent higher in three locations, thousands of percent higher in four locations, tens of thousands of percent higher in three locations, and **one location measured *149,230 percent*** greater interference power than this reportable level. In effect, interference from a single unlicensed LPI device would result in outage times measured in the tens of hours per year rather than the required design level of approximately 5 minutes per year. This substantial decrease in microwave operation reliability would effectively render the system inoperable. Neither the public nor federal/state government would accept that the electrical grid may be unmonitored tens of hours a year or that the 911 system may not be available for emergency calls tens of hours a year.

Representativeness of the Testing Configurations. As noted above, several of the testing locations had existing Wi-Fi access points operating. Where possible, Southern placed the new 6 GHz unlicensed router directly next or near to the existing Wi-Fi router to replicate the configuration used by the public. In addition, Southern did some rudimentary drive test measurements to determine how many Wi-Fi routers were already in commercial operation along the testing route. Southern found more than ***3,000*** Wi-Fi access points were readily visible along the tested path. Therefore, the locations of the 6 GHz unlicensed LPI devices tested were representative of actual real-world Wi-Fi routers used by the public and the tested path had several thousand Wi-Fi routers already in use, suggesting that it is highly likely that there will be numerous unlicensed 6 GHz LPI devices located along this path.

Testing Configuration Overview. The Fortson to Columbus link is a 9.5-mile microwave path, relatively short and typical of the last hop of many microwave networks links. Microwave antennas are directional in nature – there is a main beam that is quite narrow, with the receive sensitivity reduced by orders of magnitude outside that beam. For Columbus, that beam is 1.7 degrees wide. Below is a pictorial of this area of high receive sensitivity at Columbus on a map.

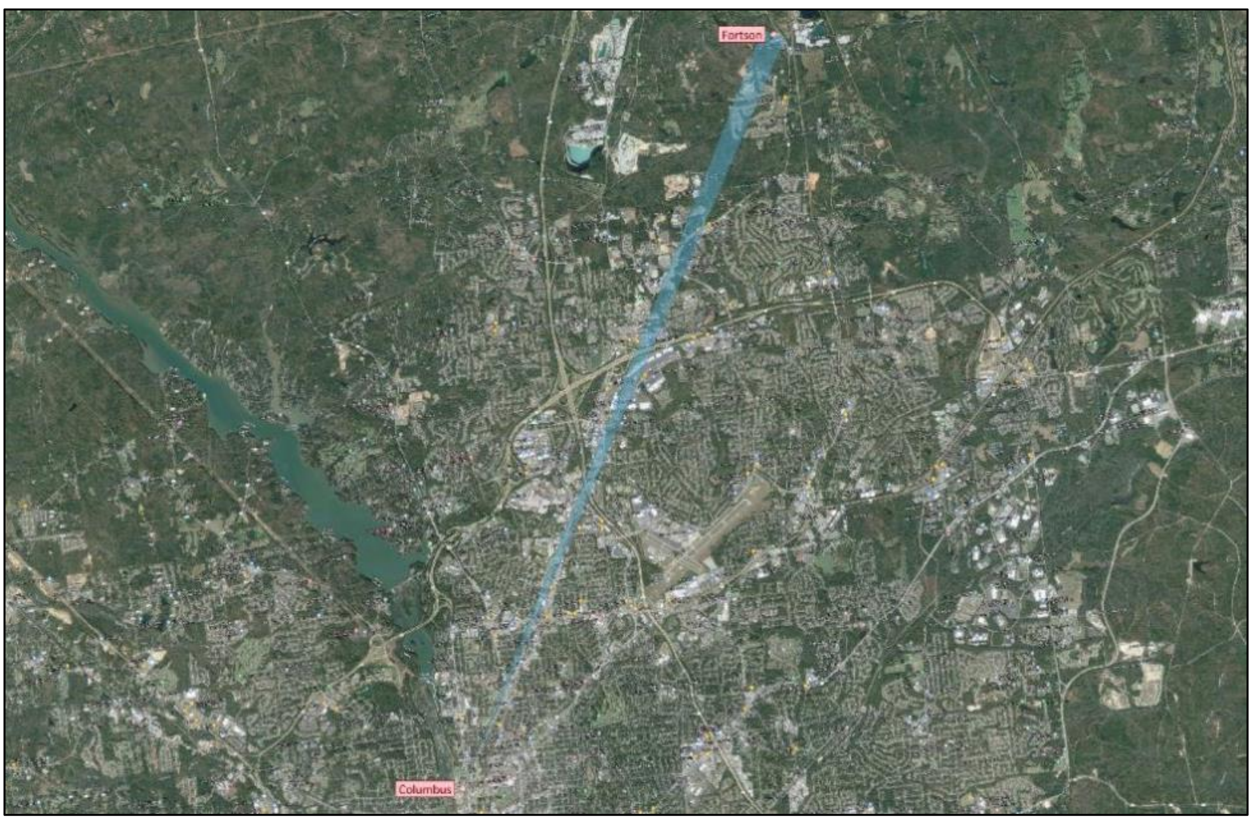

Figure 1: Fortson-Columbus link with Columbus Main Beam

The licensed microwave equipment at both Columbus and Fortson were instrumented for the testing utilizing external power meters, spectrum analyzers, variable attenuators, and Bit Error Rate (BER) testers, as well as the built-in diagnostic and reporting capabilities of the microwave equipment. This allowed measurement of the impact of the unlicensed Wi-Fi network operations on the licensed microwave path and comparison of that impact to the FCC reportable interference metric of -6 dB I/N.

Interference strong enough to impact the licensed microwave Fixed Site (FS) from a Wi-Fi LPI device may be blocked by clutter in the line-of-sight between the LPI and the FS. This clutter can be terrain, buildings, or tall foliage (typically trees). There is no value in testing the impact from areas that are obstructed (clearly many locations in a typical main beam will be obstructed – the issue is those locations that are not obstructed creating interference), so a terrain profile was used to pick test locations that are both inside the main beam and appear to be unobstructed. That profile is shown below, along with 7 test locations picked before arrival in Columbus.

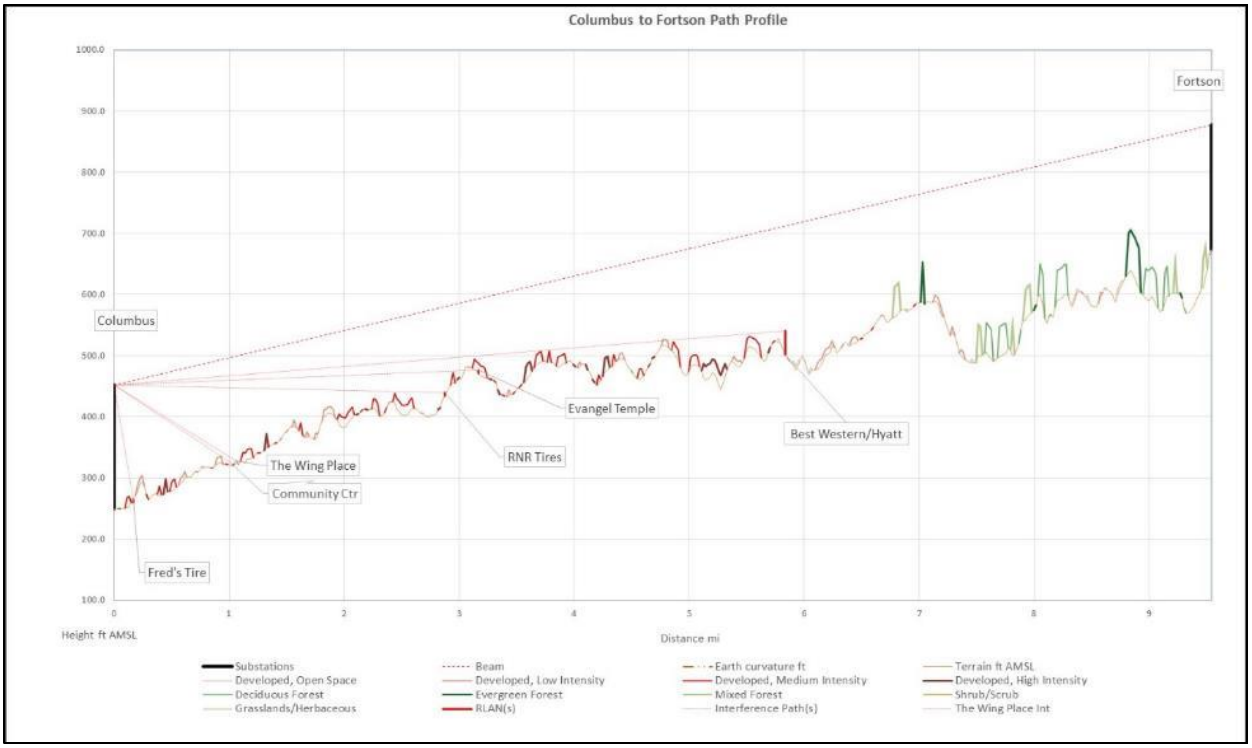

Figure 2: Fortson-Columbus Path Profile with Test Locations

Testing was conducted at seven locations, ranging from 285 meters from the fixed microwave receiver up to 9.4 kilometers. The table below provides details on each location.

Test Location	Address (all are Columbus, GA)	Latitude	Longitude	Distance (meters)
Fred's Tire	1900 2nd Avenue	32-28-56.7 N	84-59-23.0 W	285
Community Ctr	839-867 Belmont Street	32-29-34.2 N	84-58-58.5 W	1606
The Wing Place	3401 Veterns Parkway	32-29-46.0 N	84-58-48.0 W	2058
RNR Tires	5300 Veterans Parkway	32-31-0.30 N	84-58-3.03 W	4627
Evangel Temple	5388 Veterans Parkway	32-31-6.74 N	84-57-55.0 W	4903
Hyatt	2974 Lake Parkway	32-33-4.20 N	84-56-48.0 W	8917
Best Western	4027 Veterans Court	32-33-16.5 N	84-56-36.2 W	9396

Table 1: Test Locations using Columbus Receiver

At each of these test locations, an off-the-shelf LPI Wi-Fi network was assembled with the access point (AP) in various locations and the clients (Samsung Galaxy 21 Ultra phone and Intel AX210 Wi-Fi 6E equipped laptop) in various locations inside and outside. The test set-up is depicted below. Immediately before arriving at Columbus, Southern received an additional FCC-certified AP, the Netgear Nighthawk®, and used it in addition to the ASUS AP in some test locations with comparable results to the ASUS in the same locations.

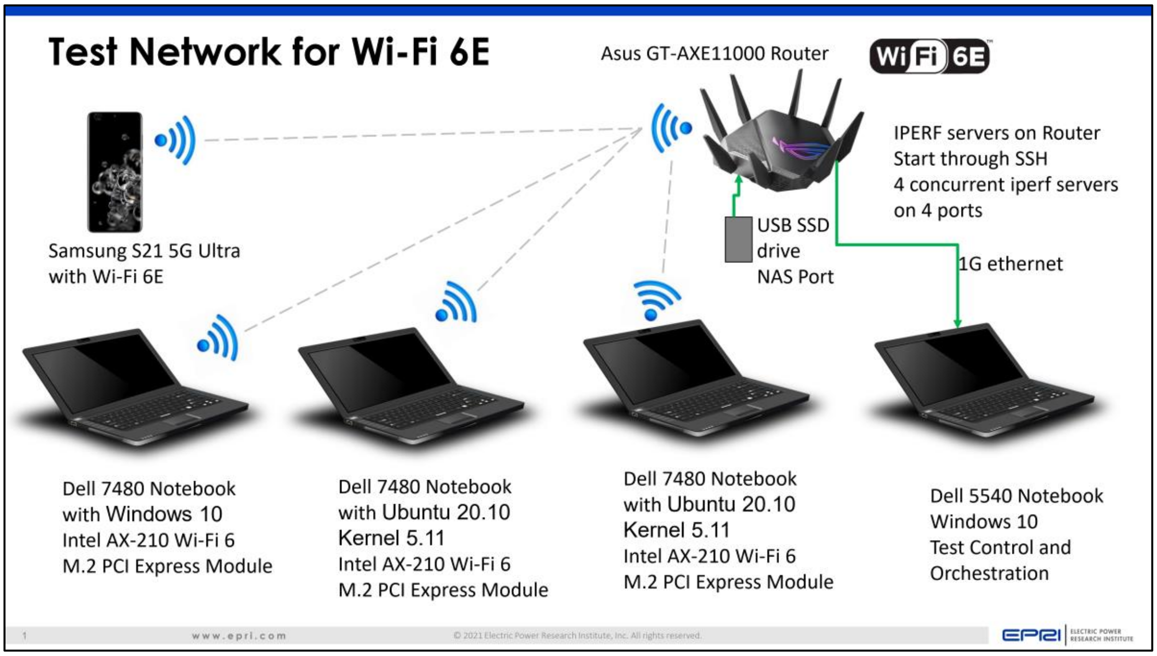

Figure 3: Test Network for Wi-Fi 6E

For each test configuration, multiple test runs were performed: (1) beacons alone (every Wi-Fi access point will attempt to transmit beacon signals on a narrow band, full power channel periodically to broadcast their SSID and other network information); (2) low speed data (10 to 100 megabytes per second average), and; (3) high speed data (approaching 1 gigabyte per second). Impact to the licensed microwave path was measured for each in dB of fade margin reduction which was used to calculate I/N ratios that were compared to the FCC Reportable Interference level of -6 dB I/N.[1] High speed data creates a small additional impact, and the results already analyzed show both beacons alone and data transmissions produce significant impact to the FS microwave receiver. Note also that the bulk of the results are for single Wi-Fi networks - multiple networks operating simultaneously were also tested and the impact was found to be additive, creating large gains in the final I/N dB ratio measured. All testing was performed while the link was stable from an atmospheric fade perspective, and the fade margin was measured before and after each set of test runs to ensure the link remained stable. During testing measurements, it was found that a foggy morning could produce 3 to 8 dB fades of the link from

[1] Note that dBs are a logarithmic measurement – an increase of 3 dB is a doubling of power, 10 dB differential is an order of magnitude increase in power. Note also that dB add together but the power multiplies, so a 26 dB (3 dB + 3 dB + 10 dB + 10 dB) differential is an increase of (2 x 2 x 10 x 10) or ***400*** times the power impacting microwave receiver (40,000%). Small changes in I/N dB can translate to large shifts in the interfering signal power.

atmospheric fading. To avoid this issue, testing was delayed to nearly 11 AM local time to allow the sunshine to burn off the fog so the link stabilized without these atmospheric fades.

Test Results Summary. Overall, the Test Results confirm the theoretical concerns Southern (and many incumbents and industry organizations) have been expressing on the record for the past 18 months: ***certified LPI devices without automated frequency coordination (AFC) or other interference mitigation techniques will harmfully interfere with licensed incumbent 6 GHz microwave networks***. Previous testing by Southern, CTIA, EPRI, and Ameren have been criticized by unlicensed proponents as not being "real-world." The testing detailed here uses off-the-shelf, FCC-certified equipment purchased in the open market and the results are consistent with previous simulations and tests using simulated Wi-Fi signals. Details of the 7 test locations/13 tested configurations and their impact are summarized below:

Test Location	Beacons Only			Low Speed Data (<100Mbps)			High Speed Data (>750Mbps)			MW Data
(Modulation of 1024QAM unless noted)	dB Impact	I/N Ratio	Pwr Ratio	dB Impact	I/N Ratio	Pwr Ratio	dB Impact	I/N Ratio	Pwr Ratio	Rate Tested
Fred's Tire ASUS in window	1.2	-5.2	1.2	3.1	0.1	4.1	3.8	1.4	5.5	230.0
Fred's Tire Netgear in window	1.2	-5.2	1.2	2.7	-0.8	3.3				230.0
Fred's Tire ASUS on counter							6.4	5.2	13.2	230.0
Fred's Tire Asus in front of Counter	2.0	-2.5	2.3				14.2	14.0	99.5	230.0
Fred's Tire ASUS rear corner Service				25.8	25.7	1492.3				230.0
Fred's Tire ASUS front corner of Service	10.8	10.4	43.3	20.6	20.5	447.9				230.0
Community Center (Obstructed)										
The Wing Place ASUS in window	0.4	-10.8	N/A	14.0	13.8	94.9	16.3	16.1	163.9	230.0
The Wing Place ASUS on table 6' in	0.0						10.2	9.7	37.2	230.0
The Wing PlaceASUS ceiling 6' in	1.5	-4.0	1.6				16.0	15.8	152.7	230.0
RnR Tires (Obstructed)										
Evangel Temple Doors Closed	0.0			2.9	-0.3	3.7				230.0
Evangel Temple Doors Open	0.1	-19.4	N/A	4.6	2.7	7.4	5.8	4.4	11.0	230.0
Hyatt Room 503	0.0	No Impact		No Impact			0.2	-13.3	N/A	230.0
Best Western Room 432	0.0	No Impact		No Impact			0.3	-11.5	N/A	230.0
Both Best Western & Hyatt	0.0	No Impact		No Impact			0.5	-9.0	N/A	230.0
The Wing Place in window 1024QAM	0.9	-6.4	N/A	14.1	13.9	98.3				230.0
The Wing Place in window 512QAM	6.7	5.7	14.6	14.4	14.2	105.7				208.0
The Wing Place in window 256QAM	0.8	-6.9	N/A	15.7	15.6	143.9				185.0
The Wing Place in window 128QAM	8.1	7.4	21.7	15.0	14.9	121.9				163.0

Table 2: Test Results Summary (Amber impacted above FCC reportable level)

The -6 dB I/N reportable interference threshold corresponds to 1 dB of impact to the FS microwave receiver. As both Nokia and Aviat (microwave manufacturers) have stated on the record, measuring the microwave receiver threshold with and without interference is a direct reading of the impact and allows calculation of the I/N ratio.[2] That has been done in this analysis, then the resulting I/N ratio is compared to the standard of -6 dB I/N, shaded if greater than -6 dB I/N, and the resulting *increase* in interference power is computed.

As demonstrated in the chart, Wi-Fi access points in beacon-mode (without any data traffic) resulted in interference greater than the FCC threshold in 5 of the 13 different configurations tested. This is significant as ***every*** Wi-Fi access point will transmit these beacons every 104 milliseconds continuously. Interference from beacon operations would therefore be continuous for any microwave receiver that is

[2] Calculated using Reduction in Fade Margin (RFM) = $\{10 \log(10^{N/10} + 10^{I/10})\} - N$, "Studies Regarding RKF's *Frequency Sharing for Radio Local Area Networks in the 6 GHz Band* Proposal" at attachment page 10, March 9 2018, George Kizer, attached to letter to Marlene H. Dortch, Secretary FCC, dated March 13, 2018 and found at: https://ecfsapi.fcc.gov/file/1031332563829/17-183%202018-03-13%206GHz%20Mid%20Band%20Response%20AS%20FILED%20(01170454xB3D1E).PDF

affected in this manner and the only method to remove this interference would be to have some mitigation technique that would preclude beacon operations in the area on the affected frequency.

Low speed data resulted in reportable interference in 11 of the 13 different configurations tested, with the most distant sites more than ***4.5 kilometers*** from the microwave receiver. Note that the Hyatt and Best Western locations, which are approximately 9 kilometers away from the microwave receiver, are included in Table 2 as high speed data in these locations did result in measurable interference, even though beacons and low data rate operations did not. Also, these are large facilities with many rooms on the south side of each facing the Columbus FS and thus have the potential for additive interference. Also notable is that the results show 5 of 13 locations reduce the 30 dB fade margin of the licensed microwave link by 14 to nearly 26 dB, rendering the microwave path too unreliable to be used. Simply stated, if the AP is in the rear corner of the Fred's Tire Service area (adjacent to their *existing* Wi-Fi AP) the interference impact to Southern's microwave link is 25.7 dB, leaving only 5.8 dB of fade margin and resulting in a microwave link that will have tens of hours of outage per year versus the design level of 5 minutes. In fact, if testing occurred during the measured fades during fog, the microwave link would have been taken off the air entirely.

The last four sets of measurement data included in Table 2 (taken at the Wing Place) were designed to measure the effect of unlicensed LPI operations when different microwave modulations are used on the fixed microwave path. The testing measured 1024QAM, 512QAM, 256QAM, and 128QAM modes and showed that varying the modulation resulted in increases in harmful interference above the -6 dB I/N level ranging from 11.7 to 21.6 dB (or interference power increase from ***1460 to 14,390 percent***). Further testing by microwave equipment manufacturers in their product laboratories is needed to fully understand the mechanics behind the different interference levels with different modulation modes. Indeed, the measured data is counterintuitive as reducing the modulation speed first increases, then decreases susceptibility, and then increases it again as the modulation speed is further reduced. Understanding this phenomenon is critical as many licensed microwave links operate in a fixed modulation mode and incumbents will need to understand if a particular mode is more susceptible than other operating modes.

RLAN Duty Cycle Discovery. Throughout the rulemaking process for unlicensed use of 6 GHz, a key argument has been the limited duty cycle of RLAN networks. European regulators have used 2%, the FCC mentions 0.4% in the Report & Order (footnote 297), and the RLAN proponents used 0.00022% for 90% of units deployed and 0.11% to 0.44% for the remaining 10% of units deployed. Incumbents have argued that the new uses for gigabit Wi-Fi would drive the duty cycle up significantly and cited industry publications making the same claim. **At no point during this multi-year process did any unlicensed party describe or model the effect of beacon signals** and the fact that these signals would be continuous. Therefore, **this interference case has never been vetted by the Commission** or any other affected incumbent licensee.

Incumbents, admittedly not experts in 802.11, have come to learn that every AP sends a beacon signal, typically every 104 milliseconds. These beacons are sent at *full AP power in a 20 MHz bandwidth channel* using low speed modulation for backwards compatibility. Proponents certainly had knowledge of these beacons and for whatever reason chose to ignore them in their on-the-record discussions. Moreover, if the Commission and RLAN proponents had engaged with incumbent licensees in real-world testing as requested throughout the rulemaking proceeding, this beacon issue would have been discovered.

Testing has now revealed that these beacons are typically (at least as measured here) 0.5 msec wide. If they occurred every 104 msec as expected the resulting duty cycle with no data used would be 0.5/104 or ***0.48%***. This is higher than the duty cycle estimated by the Commission (with no data being transmitted), and ***2,185 times higher than the value used for 90% of deployed AP units*** **in simulations cited by the FCC** in its decision to authorize unlicensed LPI operations.

In reality, the measured data demonstrates that beacons are actually ***five times worse*** than this – both of the certified RLAN AP units tested actually send the beacons every 20 milliseconds regardless of the beacon timing parameter set in their configurations. This makes the ***beacon only duty cycle 2.2****%*. Measurements also revealed the duty cycle with less than 100 Mb data streams to be over 50%. Details are discussed in the report below.

Measurement of Available Wi-Fi Access Points Along the Fortson/Columbus Path. One of the primary assertions of the FCC (and the unlicensed proponents) on the record is that the directional nature of FS microwave antennas reduces the area for LPI operation to potentially impact FS operation to a very small area – a degree or two out of 360 degrees around the FS. But the unlicensed proponents also have stated on the record that they expect 100 percent penetration of 6 GHz-capable APs within a few years. Following this logic, all existing APs in use have a high potential to be replaced with 6 GHz-capable devices over the next few years. A non-exhaustive drive test was performed that was understated because: (1) the speed of the measuring vehicle did not allow capture of all SSID's; (2) only easily accessible roads were driven, and; (3) only 60 percent of the path length was driven. In spite of these limitations, the drive test still found ***3,003*** Wi-Fi APs in the main beam of the Columbus antenna. This is a significant number of potential interferers and certainly demonstrates that the testing is representative of an area highly likely to contain interfering unlicensed LPI devices. Graphic results of the drive test are below:

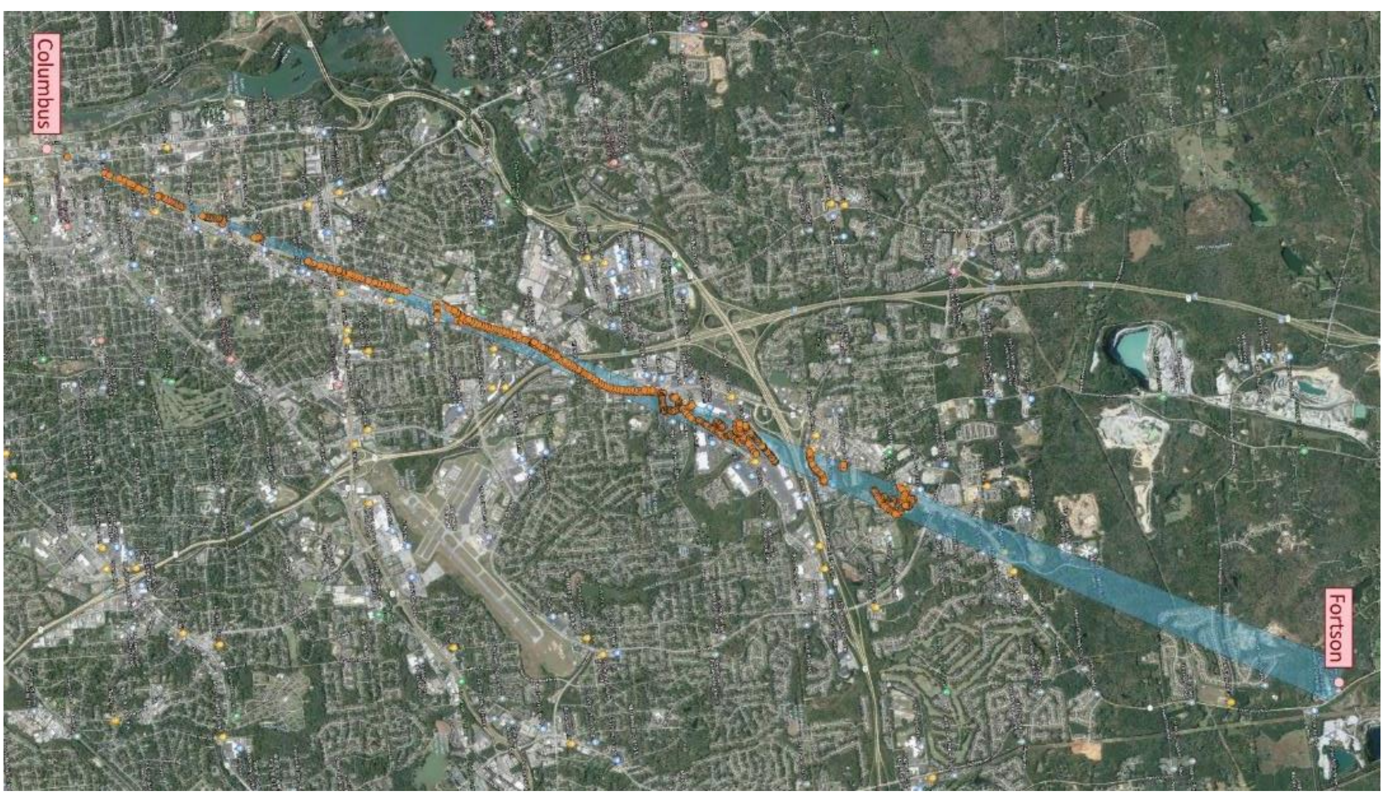

Figure 4: Wi-Fi Access Points in Columbus Main Beam

1. Introduction

This report describes the testing carried out in April 2021 by Electric Power Research Institute (EPRI), Southern Company Services (SCS), and Lockard & White (L&W), collectively "Team". The testing process borrows from the previous testing performed in late 2020: by CTIA, SCS, L&W, and AT&T in Columbus Georgia; and by EPRI, Aviat, and Ameren in Peoria Illinois. This testing is intended to build on the learnings from these two tests and produce a comprehensive test to confirm or contradict the concerns expressed by these entities (and other licensed incumbents) that unlicensed Low Power Indoor (LPI) Wi-Fi Access Points (APs) will interfere with licensed 6 GHz microwave links. Thanks to all involved in the previous testing activities for their contributions and although not footnoted in this document will certainly be recognized by their original authors and appreciated by the Industry moving forward.

FCC Report and Order 20-51 (R&O) has permitted the introduction of unlicensed Radio Local Area Network (RLAN) devices in the 6 GHz band.[3] The portions of the 6 GHz band have been identified as UNII-5, UNII-6, UNII-7 and UNII-8. The Institute of Electrical and Electronics Engineers (IEEE) defined channelization in the 6 GHz band as part of 802.11ax:

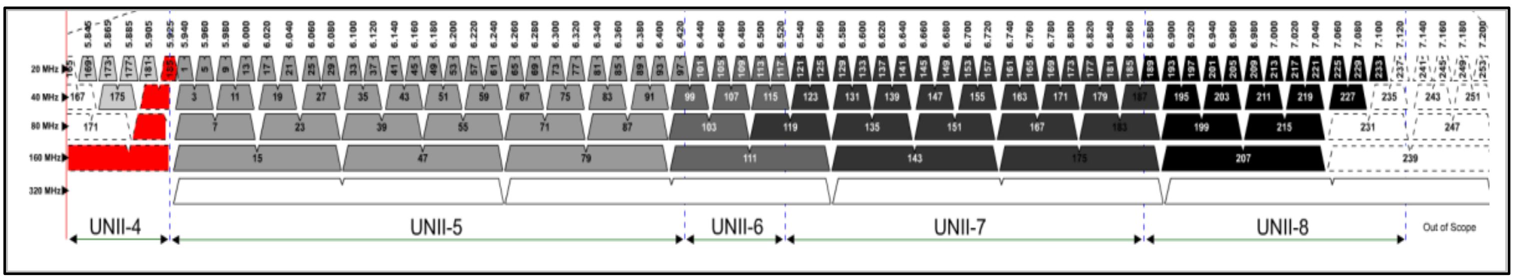

Figure 5: Extended 6 GHz Wi-Fi Channels

The FCC R&O approved two classes of RLAN devices:

- Low Power Indoor (LPI) devices with an EIRP of up to 30 dBm for a 320 MHz channel. LPI devices transmit with a maximum power spectral density of 5 dBm/MHz.
- Standard power indoor/outdoor (Std Pow) devices with an EIRP of up to 36 dBm and controlled with an Automated Frequency Coordination (AFC) system.

The 6 GHz Field Test objective is to measure impacts to incumbent microwave receivers from co-channel unlicensed LPI transmissions located in the main beam of the receiver that are operated indoors. This test report documents the test equipment, settings, processes, and locations for the field tests.

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[3] FCC Report and Order and Further Notice of Proposed Rulemaking, April 23, 2020, available at: https://docs.fcc.gov/public/attachments/FCC-20-51A1.pdf

2. Wi-Fi 6E RLAN equipment used in the test:

2.1. Commercial Off The Shelf (COTS) RLAN equipment

Given that the R&O defines new spectrum and in parallel IEEE Standard 802.11ax was being developed for wider bandwidths and higher bitrates, the equipment envisioned was not initially available. First testing (CTIA/SCS) used a Vector Signal Generator to simulate Wi-Fi signaling in the 6 GHz band. Later testing (EPRI/Ameren/Aviat) used prototype 802.11ax building block modules (not Wi-Fi Alliance certified) and a wireless internet access unit that could be tuned to 6 GHz (proprietary air interface, not Wi-Fi signaling).

Ideally testing would use pre-production (or production) Wi-Fi 6E (802.11ax) units. Unfortunately, the RLAN access point and chipset manufacturers declined any assistance to the test efforts and advised the Team to purchase units on the open market.

In March, the Team succeeded in sourcing a pair of Asus GT-AXE11000 APs on the open market as well as several Intel AX210 laptop client modules and a Samsung Galaxy S21 cell phone. Documentation for these units is very limited and access point manufacturers continue to be unsupportive of testing efforts. This required trial and error testing using these units to determine detailed setup parameters to allow their operation for the test.

Late in plan development, SCS was notified that AP equipment from NetGear was shipping to them in time for testing – once received the Test Team was able to apply learnings from the Asus APs to quickly establish working RLAN networks using the Netgear AP and made it available for testing.

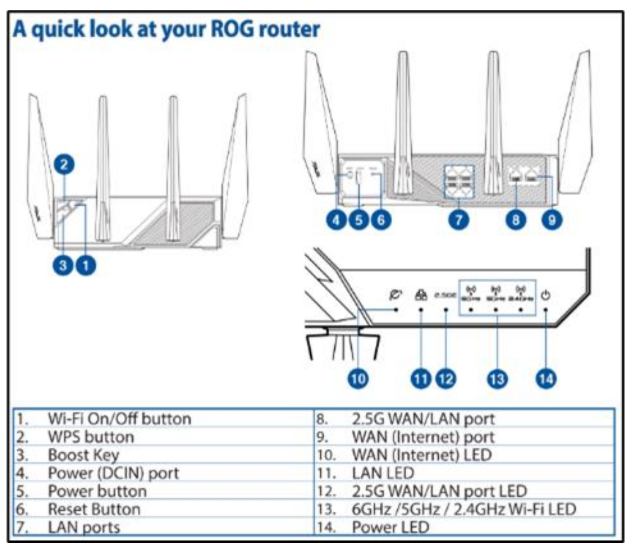


Figure 6: Asus GT-AXE11000 Visual

INTEL® WI-FI 6 AX210 MODULE TECHNICAL SPECIFICATIONS

GENERAL	
Dimensions (H x W x D)	M.2 2230: 22mm x 30mm x 2.4mm [1.5mm Max (Top Side)/ 0.1mm Max (Bottom Side)] M.2 1216: 12mm x 16mm x 1.7 (+-0.1) mm
Weight	M.2 2230: 2.83 +/– 0.3 g M.2 1216: 0.67 +/– 0.1 g
Radio ON/OFF Control	Supported
Connector Interface	M.2: PCIe®, USB
Operating Temperature (Adapter Shield)	0°C to +80°C
Humidity Non-Operating	50% to 90% RH non-condensing (at temperatures of 25°C to 35°C)
Operating Systems	Microsoft® Windows 10®, Linux®
Wi-Fi Alliance[7]	Wi-Fi CERTIFIED® 6, Wi-Fi CERTIFIED® a/b/g/n/ac, WMM®, WMM®-Power Save, WPA3®, PMF®, Wi-Fi Direct®, Wi-Fi Agile Multiband
IEEE WLAN Standard	IEEE 802.11-2016 and select amendments (selected feature coverage) IEEE 802.11a, b, d, e, g, h, i, k, n, r, u, v, w, ac, ax; Fine Timing Measurement based on 802.11-2016, Wi-Fi Location R2 (802.11az) HW readiness[8]
Bluetooth®	Bluetooth® 5.2
SECURITY FEATURES[9]	
Security Methods	WPA2®; WPA3®
Authentication Protocols	802.1X EAP-TLS, EAP-TTLS/MSCHAPv2, PEAPv0 -MSCHAPv2 (EAP-SIM, EAP-AKA, EAP-AKA')
Encryption	128-bit AES-CCMP, 256-bit AES-GCMP
COMPLIANCE	
Regulatory	For a list of country approvals, please contact your local Intel representatives.
US Government	FIPS[10] 140-2
Product Safety	UL, C-UL, CB (IEC 60950-1)

Figure 7: Intel AX210 Visual and Specs

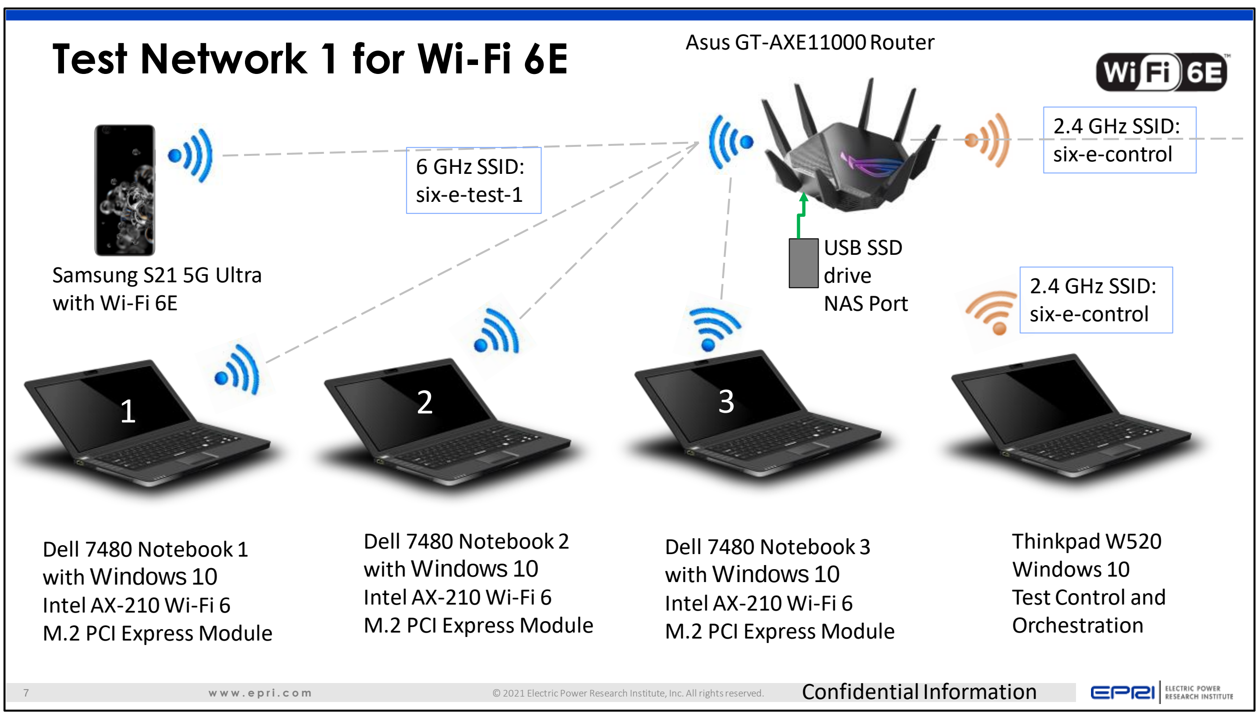


Figure 8: RLAN Asus Test Network Overview

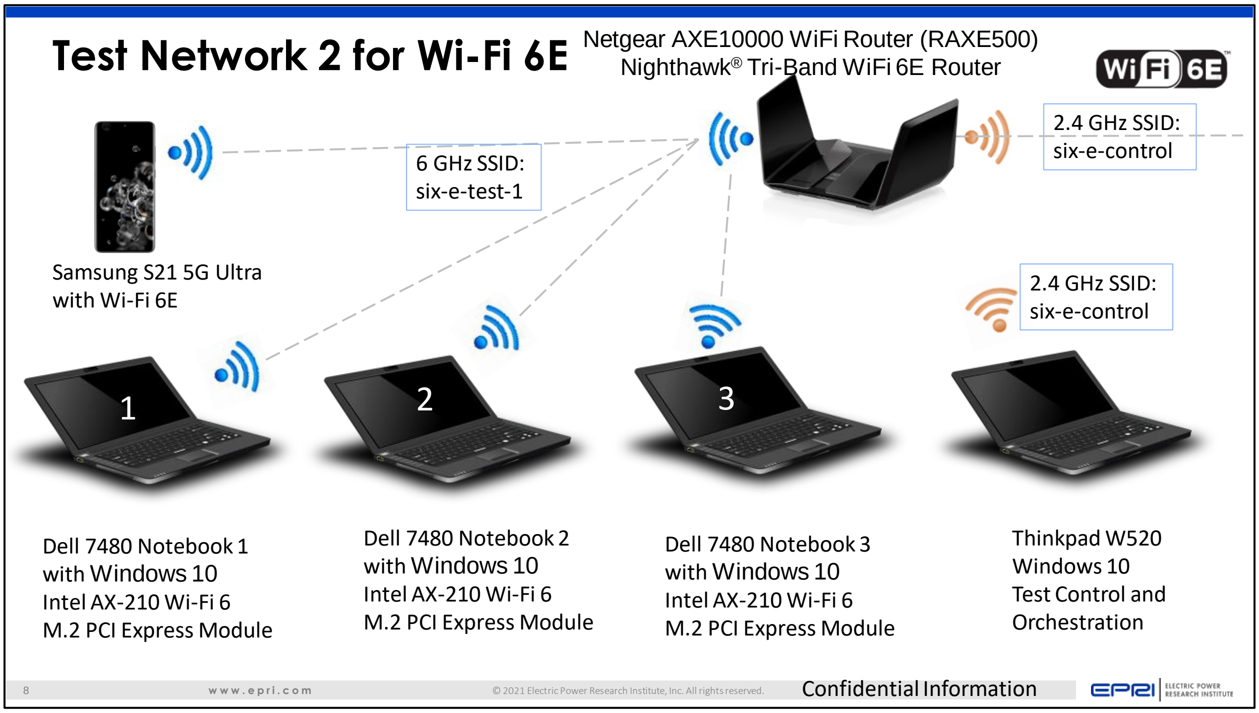


Figure 9: Netgear Test Network Overview

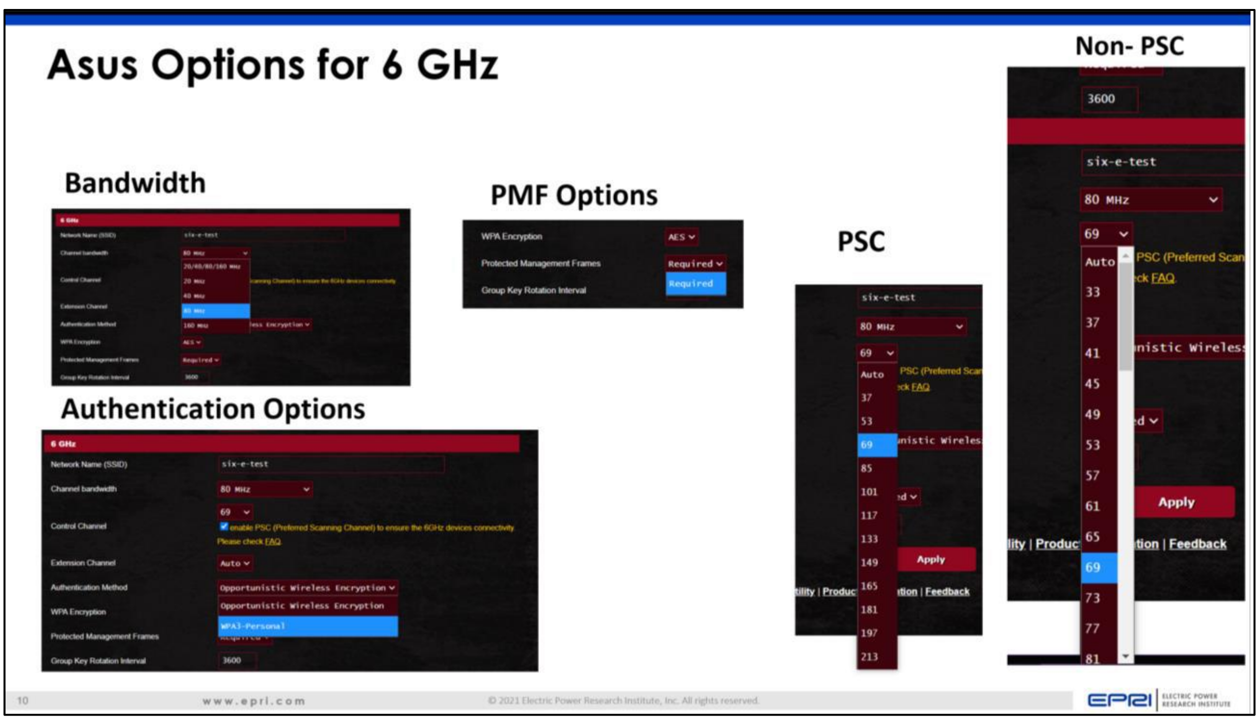


Figure 10: Asus GT-AXE11000 Setup Options

Windows Test Scripts

Name	Traffic Type	Use Case
TestSuite.cmd	(1st parameter delay between tests, 2nd Note)	Runs all tests below
iperf-UDPstream.cmd	Rate-limited stream – specify mbps	Local Video Streaming
iperf-onestream.cmd	Single TCP stream	Web Browsing
iperf-vidbuffer.cmd	1 second flow, 1 second pause	Video Streaming Service
iperf-tenstream.cmd	Bulk data – maximum rate, 10 TCP streams	File Backup
cp-filebounce.cmd	Bulk data transfer by OS to and from client	File Backup / Restore / Verify
movie-2001.cmd	Video Streaming VLC Client	Plays a movie clip from NAS Drive
movie-serenity.cmd	Video Streaming VLC Client	Plays a movie clip from NAS Drive
BackUpToNetandAsus.cmd		Backs up test results to NAS Drive

Figure 11: Windows Client Test Scripts (not all used)

2.2. <u>Mimosa C5 Wireless ISP equipment</u>

In both the original Columbus testing and the Peoria testing, equipment from Mimosa was used to provide unlicensed signals. These devices are intended for Wireless ISP operation on 5 GHz but can be tuned to 6 GHz using instructions from the manufacturer. Operation is using TDMA and the setup splits the channel using 50% of the channel in each direction.

Mimosa equipment use in earlier tests indicate it causes interference to licensed paths sooner and more severely than RLAN equipment. This finding, combined with feedback from ex-parte discussions that more test locations would be favorable, has resulted in modification of test plans as documented below. Mimosa equipment was used to test locations for impact before the RLAN equipment was unloaded and turned up. If the Mimosa equipment did not produce impact to the licensed link, no further testing of the location was made based on the assumption there is some obstruction to the path from that test location to the FS receive site (terrain, buildings, foliage, etc.). If the Mimosa equipment does impact the link, the remainder of the testing was performed and results documented.

Figure 12: Mimosa C5x Setup Visual

Radio

- **MIMO and Modulation:** 2x2:2 MIMO OFDM, up to 256 QAM
- **Bandwidth:** 20/40/80 MHz channels, tunable to 5 MHz increments for Mimosa SRS and WiFi Interop mode
- **Frequency Range:** PTP/PTMP: 4900–6400 MHz (restricted by country of operation)
- **Max Output Power:** 27 dBm
- **Sensitivity (MCS0):**
  -87 dBm @ 80 MHz
  -90 dBm @ 40 MHz
  -93 dBm @ 20 MHz

Figure 13: Mimosa Radio Specifications

2.3. Testing and Measurements on RLAN equipment

As mentioned previously, the RLAN equipment was obtained from commercial channels and lacked mature documentation (and firmware as was learned through experience). In particular:

- Asus as shipped (and as used for testing with updated firmware) would not cover the entire 6 GHz band. It supports from 6105 MHz to 7065 MHz, omitting support for the 5945-6105 and 7065-7125 MHz bands.

- Early clients would only connect if the beacon (and operating channel) was on one of the Preferred Scanning Channels (PSCs). PSCs were defined by the Wi-Fi standards agencies to speed the scanning of the 6 GHz band's 200+ channels so clients will find an AP within seconds instead of minutes. Beacons on the PSCs will affect a large percentage of licensed 6 GHz channels, see appendix for details.
  Later client firmware/drivers would connect to beacons on any of the supported channels.

- During post-test analysis it was discovered that both the Asus and the Netgear AP's *did not transmit beacons every 104 milliseconds* as expected, and *in fact did not vary the interval when the setup parameter is changed*. Both are transmitting at 20.5 ms intervals and have a beacon duration of 500 microseconds (ranges from 464 µs to 549 µs depending on measuring lower or higher signal level – rise time of approximately 25 µs). Picture of measurement is below, numbers come from file exported by test set.

- Given the numbers above, the *minimum duty cycle* for a 6 GHz AP with no data is .464/20.5 or ***2.2%.*** This is far in excess of the 0.4% cited by the Commission in the rulemaking decision or the 0.00022% used in the proponent's Monte Carlo analyses for 90% of the RLAN APs or the 0.11%, 0.22%, and 0.44% used for the remaining 10% of RLAN APs (all duty cycles used in their analysis clearly ignoring the effect of beacon transmissions).[4] It should come as no surprise that the beacons alone demonstrated impact to the licensed microwave link in testing.

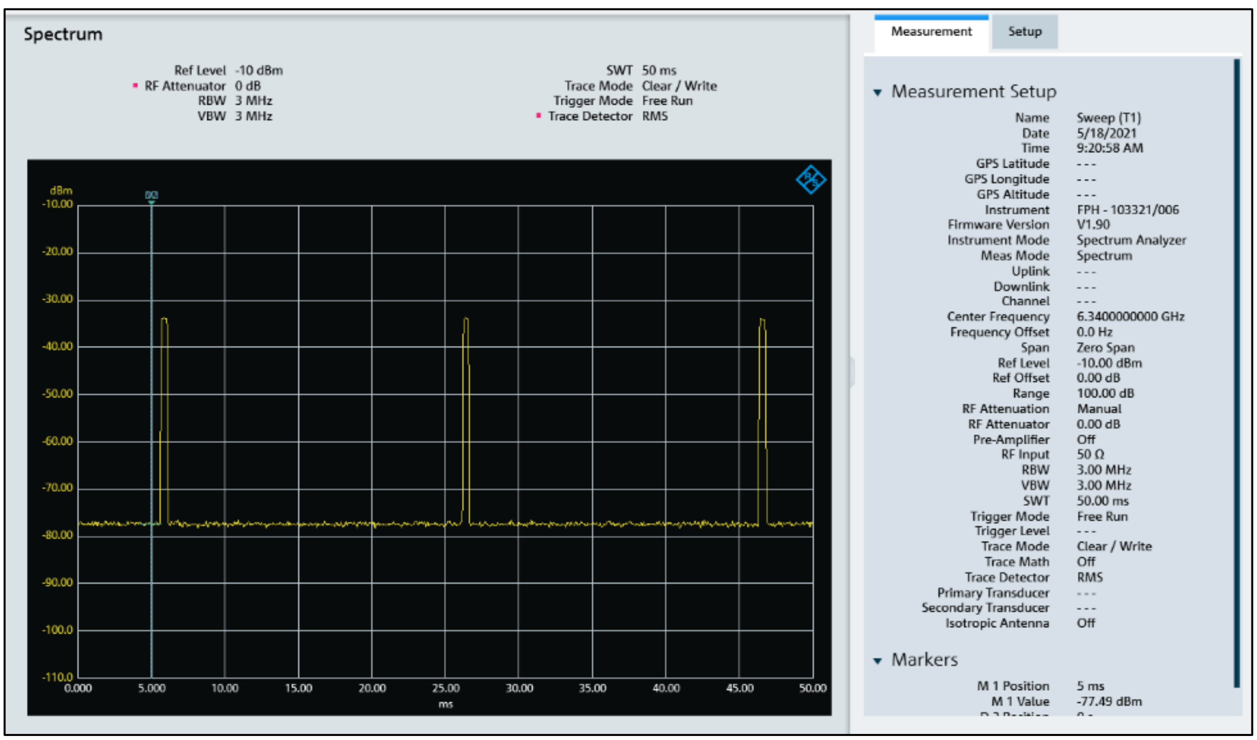


Figure 14: Time Domain view of Beacons

[4] RKF Engineering Solutions, *Frequency Sharing for Radio Local Area Networks in the 6 GHz Band* (Jan. 2018), Table 3-1 https://s3.amazonaws.com/rkfengineering-web/6USC+Report+Release+-+24Jan2018.pdf.

- We also measured duty cycle with various data streams as shown below using raw data outputs of signal level from test equipment and summarized here:
  - Beacons only (as noted above): 2.2%
  - 10 Mbps UDP stream: 5.3%
  - Single iperf TCP stream: 57.5%
  - Ten parallel iperf TDP streams: 89.6%

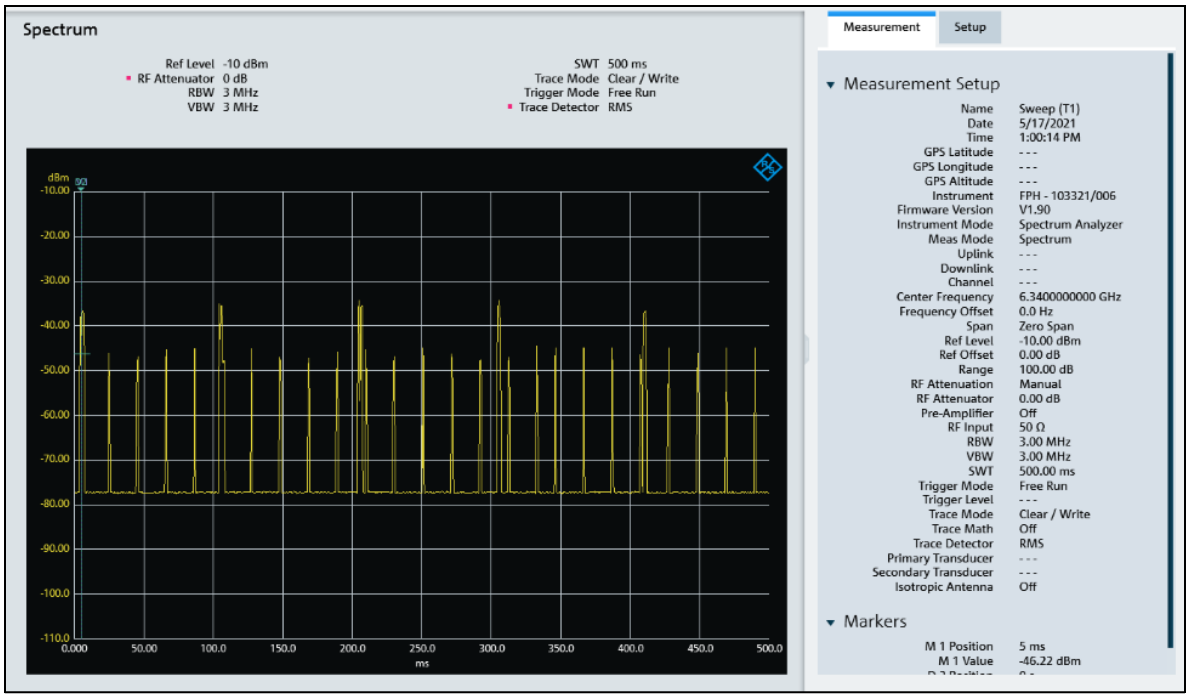


Figure 15: UDP 10 Megabits/second data

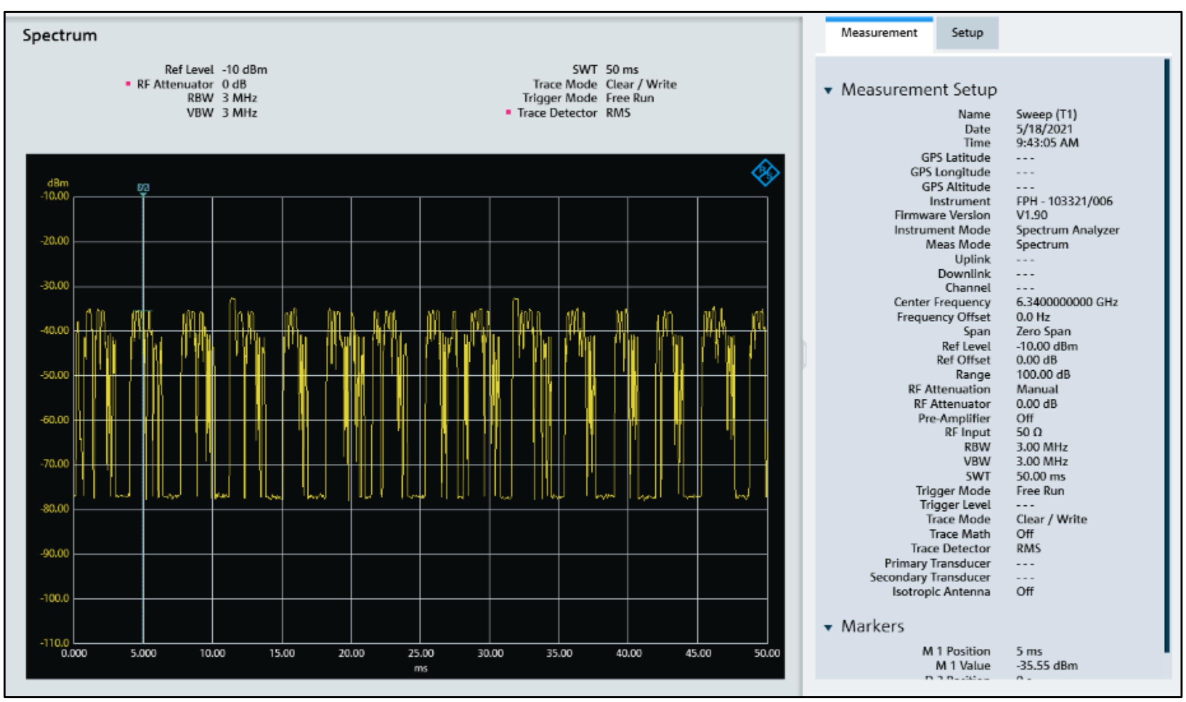


Figure 16: Single iperf (<100Mbps) data

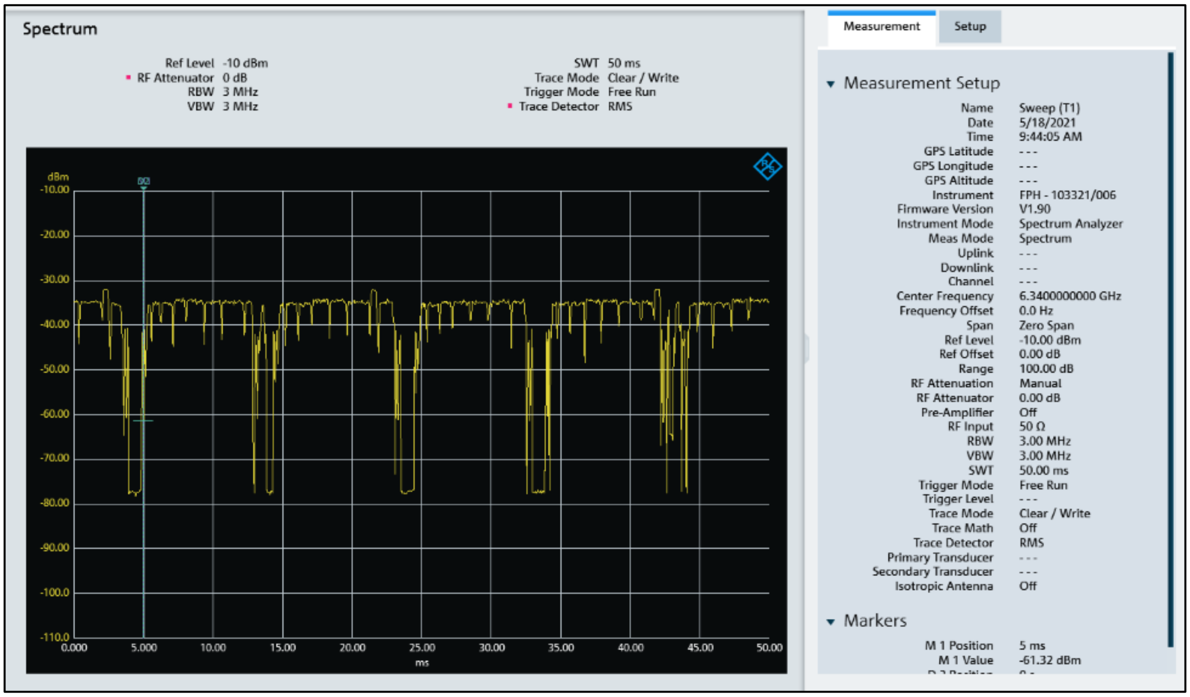


Figure 17: Ten iperf stream (>750Mbps) data

- The frequency domain was also measured as shown below. Of note, the fixed frequency of the licensed link to Columbus allowed Wi-Fi 6E channels 77 or 81 to be used and fully overlap Columbus's receiver in either 80 or 160 MHz data bandwidth.

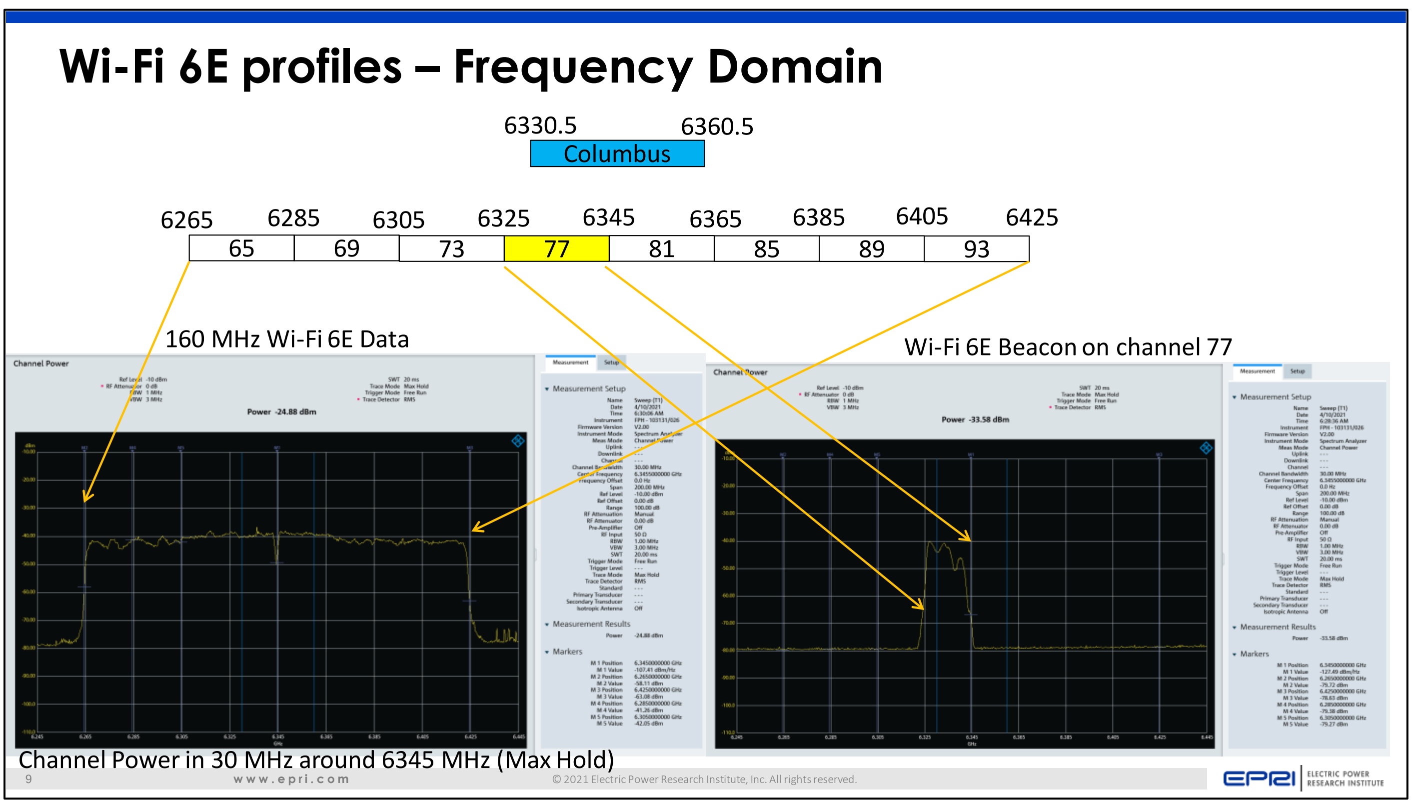


Figure 18: Frequency Domain view of Overlaps

- Note that the frequency domain plots are not calibrated for signal levels – the analyzer must be air coupled to the LPI given the lack of external antenna connections allowed on LPI's. Calibrating an air coupled measurement accurately was beyond the scope of our testing facilities.
- Beacon signals from both Wi-Fi channels 77 and 81 only partially overlapped Columbus' receiver – with Wi-Fi channel 77 overlapping the bottom half (15 MHz) of Columbus' channel and Wi-Fi channel 81 overlapping the top half (15 MHz). The channel 77 beacon signal is shown above, channel 81 would be similar but starting at 6345 MHz and extending 20 MHz above that (with the upper 5 MHz outside Columbus' channel).
- It was also noted that a burst of data communication activity occurs whenever a client is added to the network, with periodic data activity thereafter (presumed to be handshake packets). This was accommodated in testing of beacons only by ensuring no clients were registered (or registering) on the test RLAN network.
- It was also noted that this burst of data communication activity was more disruptive to the microwave network (our presumption is that the initial handshake is at full power) and this was accommodated in the data testing by ensuring any clients needed for the test were connected to the AP before measurements were taken.
- During testing, a spectrum analyzer was used to monitor the RLAN channel both to ensure expected activity (beacons or beacons plus data) and to ensure desired channel for test was being used.

3. Path analysis and measurements on Fortson to Columbus path:

3.1. Path Technical Details:

The microwave path from Fortson to Columbus has been recently rebuilt due to a tornado destroying the original tower at Fortson. Given it was at new coordinates, it was renamed Fortson2 for coordination and licensing purposes but is called Fortson herein. The coordination sheet, which includes manufacturer models and high-level specifications is reproduced below.[5]

Microwave Path Data Sheet Page 1 of 2
COMSEARCH
19700 Janelia Farm Boulevard, Ashburn, VA, 20147
(858)232-4372 www.comsearch.com

PCN Date: 11/19/2019 New Path
Job Number: 191119COMSSL01 RCN Number: 19111949

Administrative Information	**COLUMBUS GA**	**FORTSON2 GA**
City/County	Columbus city (balan/Muscogee	Columbus city (balan/Muscogee
Status / License Basis	Engineering Proposal / PRIMARY OPERATION	Engineering Proposal / PRIMARY OPERATION
Call Sign	WPNC893	
Licensee Code	SOUCOM	SOUCOM
Licensee Name	Southern Company Services, Inc.	Southern Company Services, Inc.
Radio Service / Station Class	MG -- Microwave Industrial/Business Pool	FXO -- Fixed
Site Information		
Latitude (NAD 83)	32 ° 28' 48.6" N	32 ° 36' 2.1" N
Longitude (NAD 83)	84 ° 59' 28.3" W	84 ° 54' 40.6" W
Ground Elevation (m/ft-AMSL)	78.03 / 256.0	206.96 / 679.0
Antenna Structure Registration #	1022947	
Path Azimuth (°)	29.321	209.364
Path Length (km / miles)	15.319 / 9.519	
Transmit Antenna	G63926	57140A
Manufacturer	GABRIEL ELECTRONICS	Commscope
Model	DRFB6-59BSE	VHLP6-6WB (CAT A)
Gain(dBi) / Beamwidth(°) / Tilt(°)	39.1 / 1.70 / 0.43	39.3 / 1.80 / -0.54
Centerline (m / ft - AGL)	61.57 / 202.0	62.48 / 205.0
Receive Antenna	Same As Transmit	
Manufacturer		
Model		
Gain (dBi) / Beamwidth (°)		
Centerline (m / ft - AGL)		
Diversity Receive Antenna	G63926	57140A
Manufacturer	GABRIEL ELECTRONICS	Commscope
Model	DRFB6-59BSE	VHLP6-6WB (CAT A)
Gain (dBi) / Beamwidth (°)	39.1 / 1.70	39.3 / 1.80
Centerline (m / ft - AGL)	51.51 / 169.0	51.21 / 168.0
Radio Information	X06S00[2]	X06S00[2]
Manufacturer	Nokia	Nokia
Model	WVCE61-L1-1024A30S-230	WVCE61-L1-1024A30S-230
Model Description	Wavence MPT-HLC 1024QAM-4QAM (MAX)	Wavence MPT-HLC 1024QAM-4QAM (MAX)
Emission Designator / Modulation	30M0D7W 1024 QAM	30M0D7W 1024 QAM
Loading	1 CH DIG 230000.000	1 CH DIG 230000.000
Stability (%)	0.001	0.001

	Nominal	Coordinated	Maximum	Nominal	Coordinated	Maximum
Power (dBm)		32.5			32.5	
Received Level (dBm)		-32.6			-32.6	
EIRP (dBm)		65.9			66.0	

Fixed Loss: Tx / Common (dB)	0.0 / 5.7	0.0 / 5.8
Free Space Loss (dB)	132.0	
Transmit Frequencies (MHz)	6093.4500V(16T)	6345.4900V(26T)

Table 3: Frequency Coordination Sheet for Columbus-Fortson

[5] Note that the path was coordinated with receive diversity (as the old site was used with diversity) but the analysis showed diversity was not needed so the receive diversity equipment was not installed.

The Nokia Wavence WVCE61-L1-1024A30S-230 receiver at Columbus was updated with the latest software and set to operate at a fixed (non-adaptive) modulation level, 1024QAM unless otherwise noted. It was also closely monitored with the NMS and a local laptop connection. Nokia was queried on the recovery time of this receiver and specified “less than 1 second” – this allowed rapid testing with care taken to allow recovery time on each adjustment.

3.2. Analysis of Fortson to Columbus path:

The licensed microwave link from Fortson to Columbus was (re)designed for the new Fortson tower using industry standard ComSearch IQLink and Pathloss RF design software packages. The output of this design and analysis is shown below. The antenna heights were chosen to provide adequate Fresnel zone clearance at Earth Curvature (K) values of 2/3 and 4/3 per industry standards for microwave design.

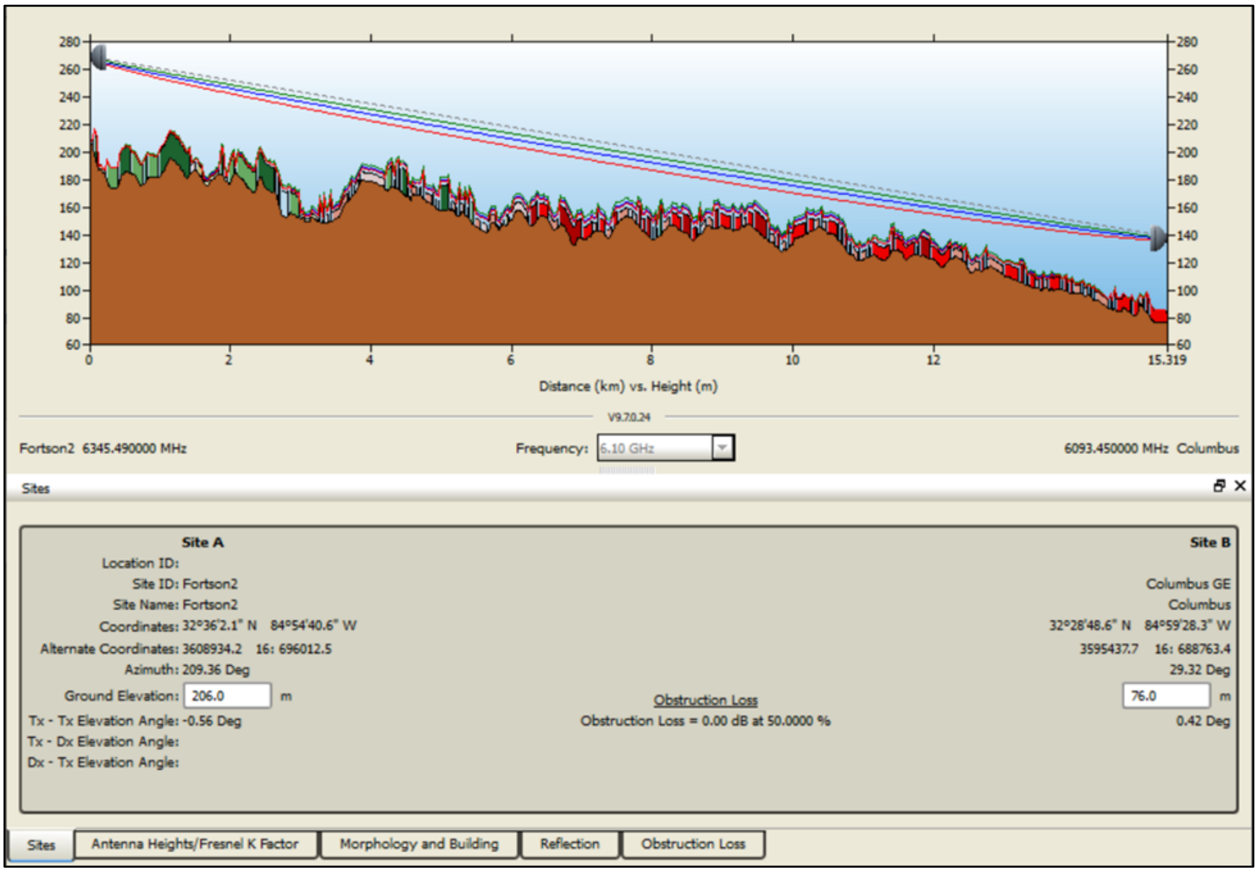


Figure 19: Path Profile for Fortson2 to Columbus

Using these antenna heights, the specifications of the antennas, and experience/industry standards for average temperature and climate factor in this geographic region, a detailed analysis of the microwave path was performed and is shown below. It should be noted that microwave design for critical infrastructure (99.999% availability/reliability) is done conservatively to ensure the link as constructed will meet that standard. Experience shows that the measured Receive Signal Level (RSL) and Fade Margin will almost always be better than the design values once the path is constructed, typically by fractions of a dB to a couple dB. On this path the analysis predicts fade margin of 30.6 dB (based on receive threshold spec of -67.5) and testing as documented below found the fade margin to be in the 31.5 to 32.1 dB range.

COMSEARCH® iQ•linkXG - Main Engineering Report - Lockard & White for SCS

	Site A	Site B
Sites		
Location ID:		
Site/Sector ID:	Fortson2	Columbus GE
Name:	Fortson2	Columbus
Gov't Approval #:		
Latitude:	32-36- 2.1 N	32-28-48.6 N
Longitude:	84-54-40.6 W	84-59-28.3 W
Ground Elevation:	206.00 m	76.00 m
Structure Height:	0.00 m	0.00 m
Antenna/Path Azimuth:	209.36 Deg	29.32 Deg
Mech./Elec./Path Tilt:	0.54 Down	0.44 Up
Path Length/Loss:	15.32 km / 132.00 dB	
Frequencies		
Band:	6.10 GHz	
Plan:	High	Low
Channel/Frequency Pol.:	L6-6 6345.490 V	L6-6 6093.450 V
Radios		
Make:	NOKIA	NOKIA
Model:	WVCE61 L 1024A30S 230-SP	WVCE61 L 1024A30S 230-SP
Bit Rate:	230.00 Mb/s / 1024QAM ACM (HSB (1:10) Dip Main)	230.00 Mb/s / 1024QAM ACM (HSB (1:10) Dip Main)
Bandwidth:	29.65 MHz	29.65 MHz
Emission:	30M0D7W	30M0D7W
Power:	29.50 dBm	29.50 dBm
Branching Loss:	Tx: 1.80 dB | Rx: 2.10 dB	Tx: 1.80 dB | Rx: 2.10 dB
Antennas		
Primary		
Make:	ANDREW CORPORATION	GABRIEL ELECTRONICS
Model:	VHLP6-6W	DRFB6-64BSE(1)
Gain:	39.30 dBi	39.10 dBi
Height:	62.50 m AGL	61.60 m AGL
Latitude/Longitude:	32-36- 2.1 N/84-54-40.6 W	32-28-48.6 N/84-59-28.3 W
EIRP:	63.10 dBm	61.83 dBm
Secondary		
Make:		
Model:		
Gain:		
Height:		
Waveguides		
Models:	EW63	EW63
Total Length:	83.80 m	106.70 m
Total Loss:	3.90 dB	4.97 dB
Attenuators		
Common Tx Rx:	dB dB dB	dB dB dB
Other Common Losses:	0.00 dB	0.00 dB
Other		
Field Margin:	0.50 dB	
Absorption Loss:	0.14 dB	
Free Space Loss:	131.86 dB	
Total Propagation Loss:	132.00 dB	
Receive Signal Level:	-36.87 dBm	-36.87 dBm

Table 4: Predicted transmission details Fortson2 to Columbus

The receive antenna specifications at Columbus are a key input to the impact testing planning and execution. Columbus has the original Gabriel Electronics DRFB6-64BSE antenna which has a 39.1 dB gain factor, a 1.7 degree 3 dB beam width, and the pattern produced from Gabriel's spec sheet below.

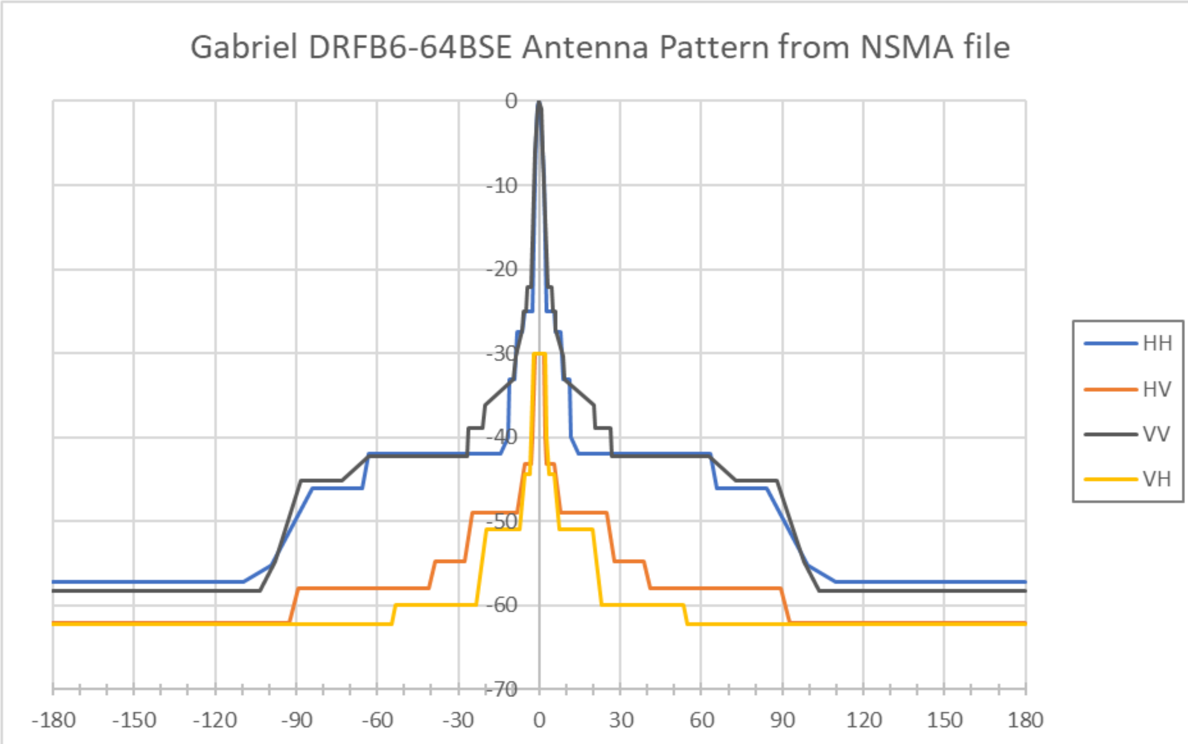


Figure 20: Gabriel DRFB6-64BSE Antenna Pattern

3.3. Baseline existing interference environment:

3.3.1. Pre-testing measurements

Prior to equipping Fortson to support the testing, measurements were taken and documented. RSL was observed at -36.3 dBm and continued to be in a tight range (+/-.2dB) around that figure throughout the stable portions of the day used for testing.

RSL history from the Network Management System (NMS) was also pulled and showed the path having a median measurement of -38 dBm across a month of 24 hour per day monitoring with a minimum of -46 dBm and a max of -34 dBm (standard deviation of 1.8 dBm). Given the spring season and the use of a single month (maintenance and updates to the link had rendered previous data unusable), the maximum fade span of 12 dB was not surprising. The data is plotted below, note that the path does show fade activity up to the noon hour on some days and it restarts around 6 PM local time. On one day of the testing the path was fading due to fog and prevented beginning the testing until nearly 11 AM. The baseline fade margin was tested at the beginning and end of each group of tests to ensure the path remained stable and the measurements were impacted by RLAN interference and not atmospheric fades. Through the course of four days of testing and nearly twenty baseline checks the fade margin was measured at 31.5 dB or 31.6 dB. These are nearly identical given the accuracy of the test equipment so 31.55 dB (the average) was used in this report. The only exception is the baselines were measured for each modulation when testing sensitivity to the modulation index. These tests were run late in the day and measured 32.1 dB for 1024QAM.

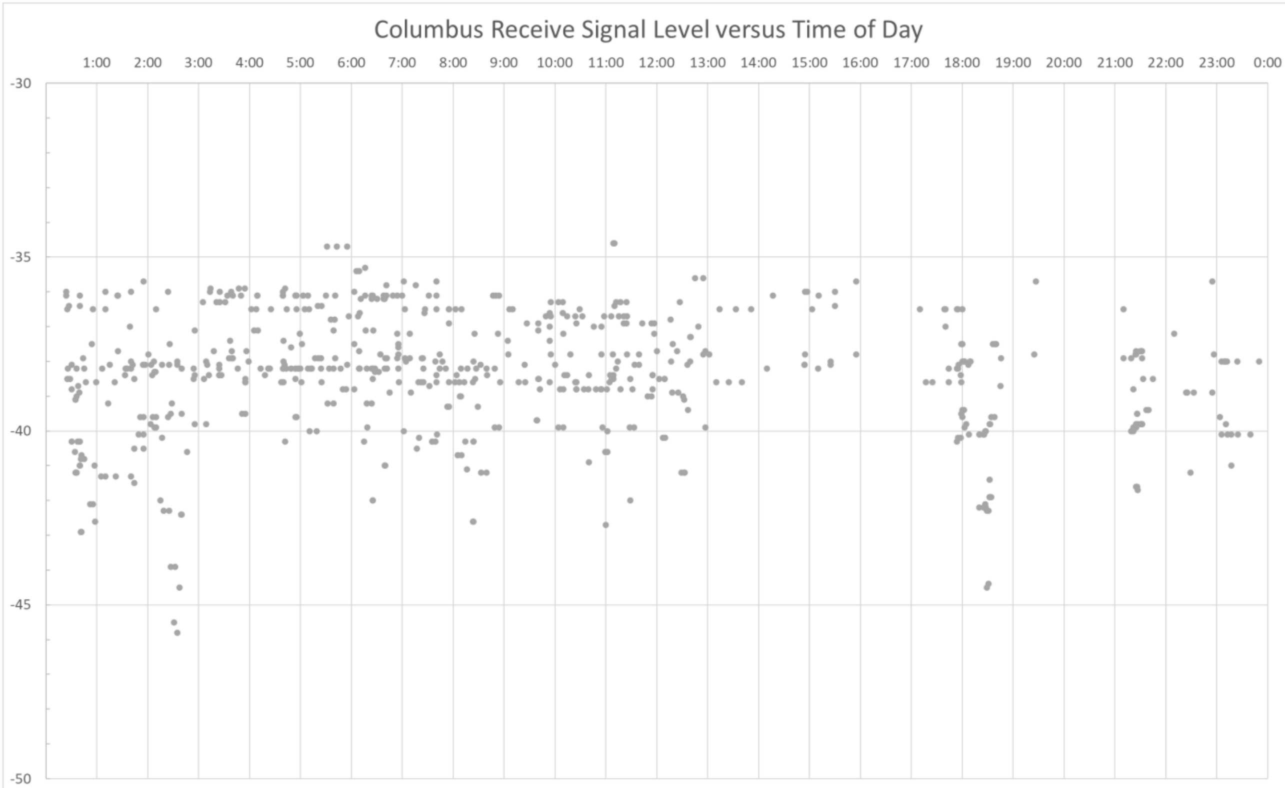


Figure 21: Columbus RSL versus Time of Day over 1 month

The next step in the process was to observe received signal at Columbus both with and without transmit operation at Fortson to determine spectrum occupancy and levels in normal operation and any pre-existing interference. None was found as shown in the pictures below. The small signal around 6093 MHz is most likely a reflection of the Columbus transmitter since it is on the Columbus transmit channel. The scans follow measured levels reasonably closely (Fortson RSL at -36.3 dBm, noise at -99 dBm [thermal], -96.5 dBm [with receiver noise figure of 2.5 dB]).

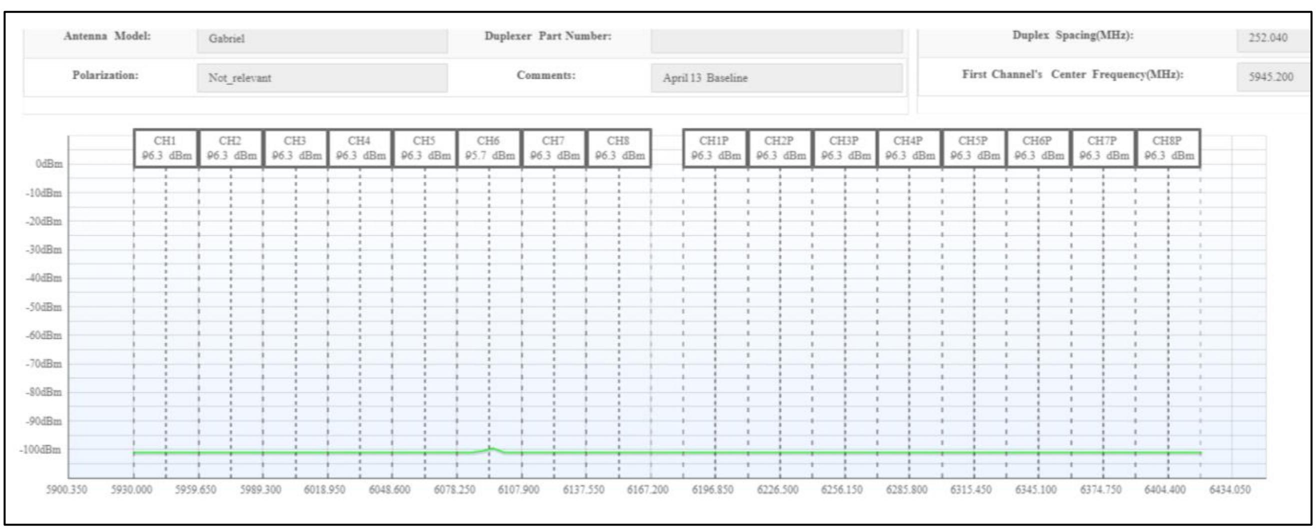


Figure 22: Columbus Wavence Receiver Scan with Fortson transmitter off

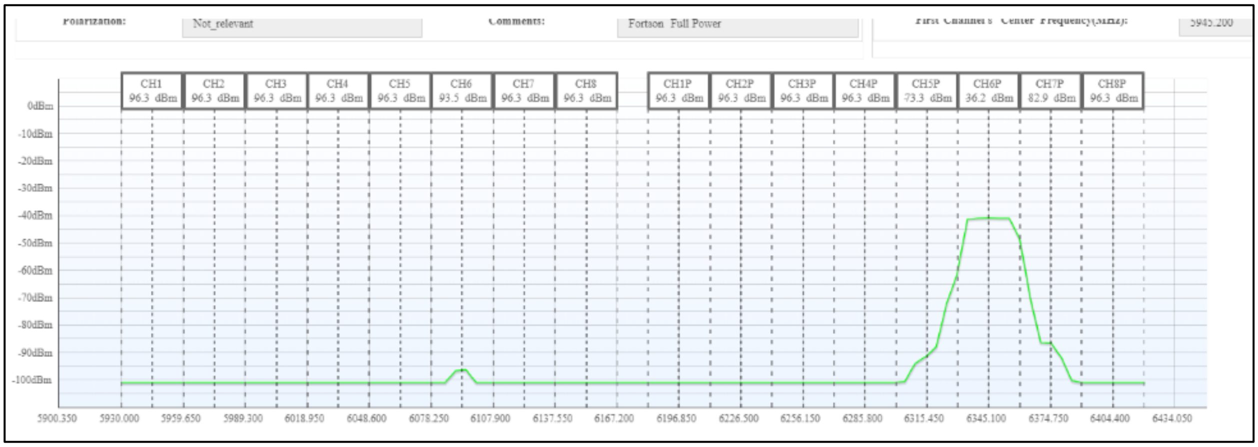


Figure 23: Columbus Wavence Receiver Scan with Fortson transmitting

Since the transmit power control on the Fortson microwave transmitter has limited dynamic range, and it is desired to measure impacts down to the FCC reportable level (-6 dB I/N, equivalent to a 1 dB reduction in fade margin), adjustable attenuation was added inline with the Fortson transmitter. Below is the diagram of this arrangement – the step attenuator allows setting a range for measurement and the Vernier attenuator provides continuously variable attenuation for measurements.

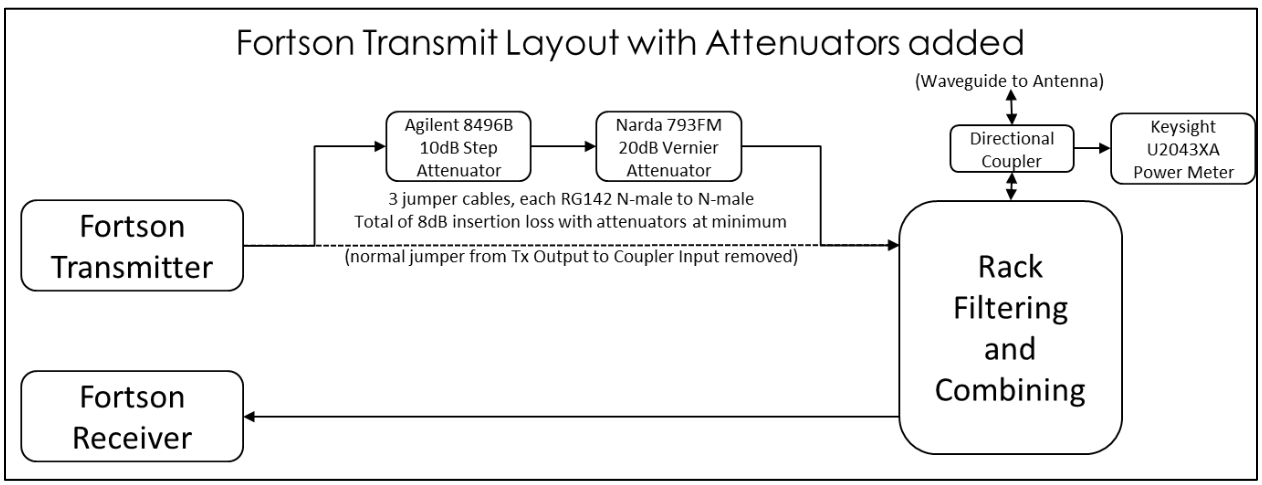


Figure 24: Fortson Transmit Test Setup

The process for the actual measurements was as follows:

- T-Berd test sets were set to run over the link at full link data rate (230 Mbps for the 1024QAM modulation index used on most tests) and measure the Bit Error Rate (BER). Industry standards are that BER over 10^{-6} are considered a link failure, this level was used to measure the point where fade margin was exhausted.
- For each measurement, an estimate was made of the expected result and the step attenuator was adjusted to put that result in the upper quartile of the Vernier attenuator. If the result was significantly different than expected (10 dB), the step attenuator was adjusted and the measurement repeated.

- Each measurement started with a strong signal from Fortson to ensure link stability, then attenuation was increased in large (3 to 5 dB steps) with settling time after each adjustment. BER was monitored for increases, Mean Squared Error (MSE) on the NMS was monitored for decreases. As these measurements changed, the step size was decreased (1, then 0.5, then 0.1 dB steps) and attenuation increased by the new step size. Using this methodology, the exhaustion of fade margin (10^{-6} BER, MSE in low 20's) was reached and noted. If the measurement was overshot or there was any question about the process, this step was repeated from the beginning.
- The total attenuation at this point (including the insertion loss of the variable attenuators) is equal to the fade margin of the link.

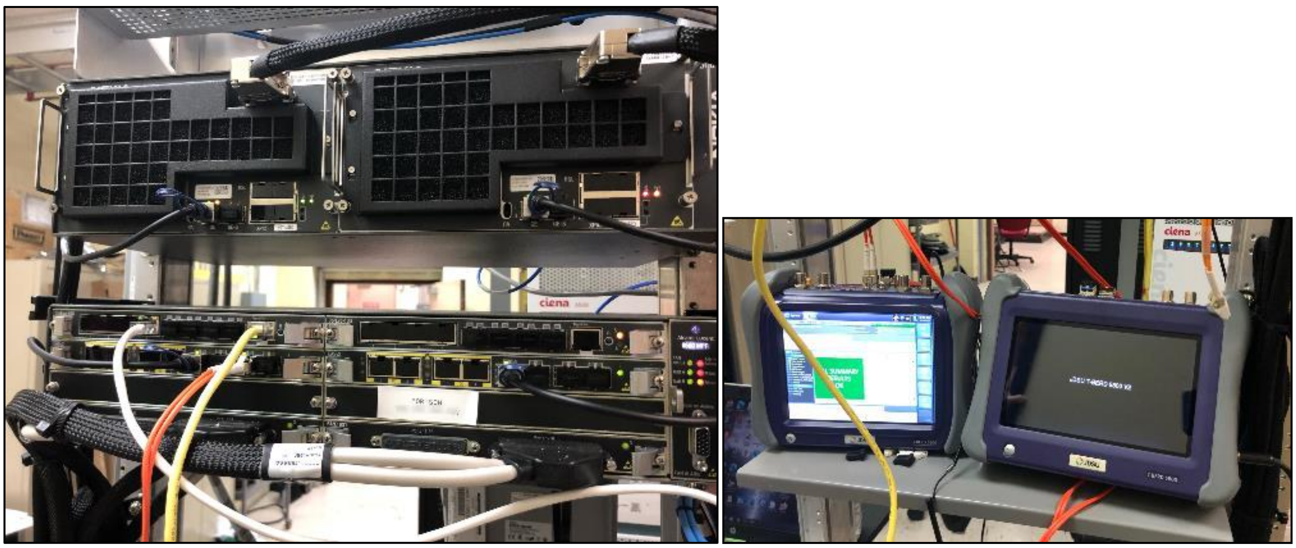


Figure 25: Columbus Receiver setup with BER testers

The Fortson to Columbus link was baselined using this procedure before and after every set of tests and those levels are noted in each report section. Typically, the un-impacted fade margin was found to be 31.2 dB to 31.6 dB depending on the day and time of testing. This tight range was deemed acceptable and was used as a starting point each morning to ensure testing after the link had recovered from any early day fading (typically caused by inversions, fog, etc).

4. Selection of Test Locations for RLAN equipment:

4.1. Notes on selection process:

It is unreasonable to expect that every location or every combination of RLAN statistical events can be tested given the forecasts for RLAN equipment in *almost every home and business* with a large percentage of them using 6 GHz due to the lack of Wi-Fi interference there. The goal of this testing was to evaluate the impact a single or small number of RLAN units can have on a licensed microwave path when they do fall in problematic areas.

Thus, the location selection process focused on potential problem areas. The first criteria was the location should be in the main beam of the microwave receiving antenna – as noted previously the Columbus antenna has a 1.7 degree beam width. This beam is 3 dimensional – the same type of pattern applies vertically and horizontally. Test locations within the main beam are constrained by both the angle horizontally away from the centerline of the microwave path as well as the relative altitude of the location versus the altitude of the microwave antenna and the distance between them.

The second criteria was unobstructed line-of-sight between the test location and the microwave receive antenna. Obstruction of the path between the RLAN and the microwave receive antenna protects the licensed receiver by attenuating the interfering signal from the RLAN. Given this fact, and the limited time for the actual testing, the focus was on locations believed to be unobstructed. The unknown under test was whether RLAN signals that are in the unobstructed main beam (clear line-of-sight to licensed receiver) will cause interference.

The third criteria is access – particularly for Low Power Indoor (LPI) RLAN testing this is critical as the test will take physical space inside the test location facility for a few hours which must be approved by the facility's owner. This drove the focus to be on businesses versus homes.

The fourth criteria was to favor locations already used for testing in the simulated RLAN tests executed and reported by CTIA and Southern in the fall of 2020, both for consistency and to determine if the criticisms of those test results was justified.

4.2. Selected Test Locations:

Utilizing local knowledge of the area, Google Earth, IQLink, and Pathloss, locations were selected that by visual inspection appear to be in the main beam and likely have unobstructed line-of-sight to microwave receive site. Horizontal and Vertical angles were used to determine Columbus antenna net gain using the antenna gain table detailed in the site analysis section.

Test Location	Address (all are Columbus, GA)	Latitude	Longitude	Distance (meters)	Hor Angle (degrees)	Vert Angle (degrees)	Columbus Net Gain
Fred's Tire	1900 2nd Avenue	32-28-56.7 N	84-59-23.0 W	285	-0.33	-11.25	6.90
Community Ctr	839-867 Belmont Street	32-29-34.2 N	84-58-58.5 W	1606	-0.37	-1.77	31.30
The Wing Place	3401 Veterns Parkway	32-29-44.9 N	84-58-48.3 W	2025	1.71	-1.38	31.30
RNR Tires	5300 Veterans Parkway	32-31-0.30 N	84-58-3.03 W	4627	-0.57	-0.51	39.10
Evangel Temple	5388 Veterans Parkway	32-31-6.74 N	84-57-55.0 W	4903	0.46	-0.36	39.10
Hyatt	2974 Lake Parkway	32-33-4.20 N	84-56-48.0 W	8917	-1.35	-0.36	36.80
Best Western	4027 Veterans Court	32-33-16.5 N	84-56-36.2 W	9396	-0.77	-0.27	38.00

Table 5: Test Locations using Columbus Receiver

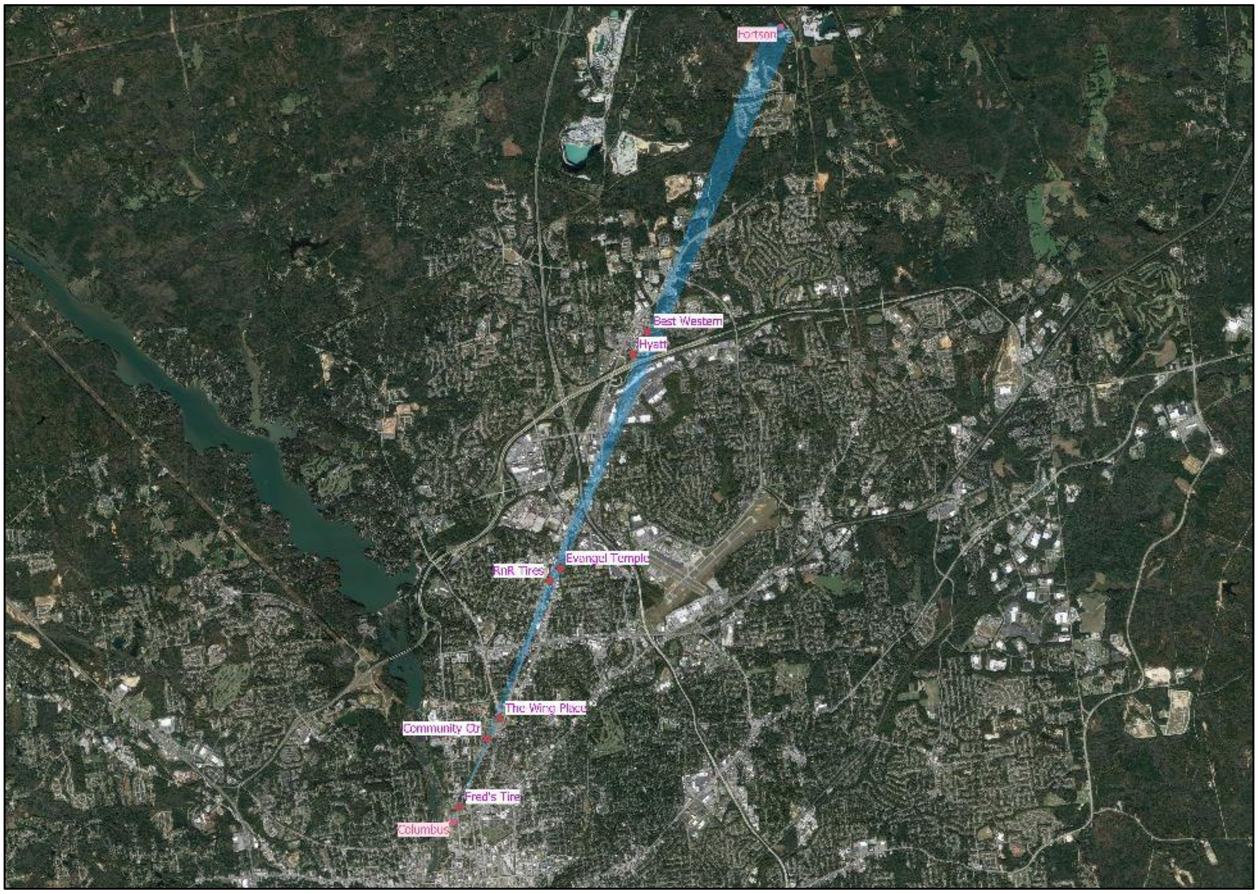


Figure 26: Columbus antenna main beam and test locations

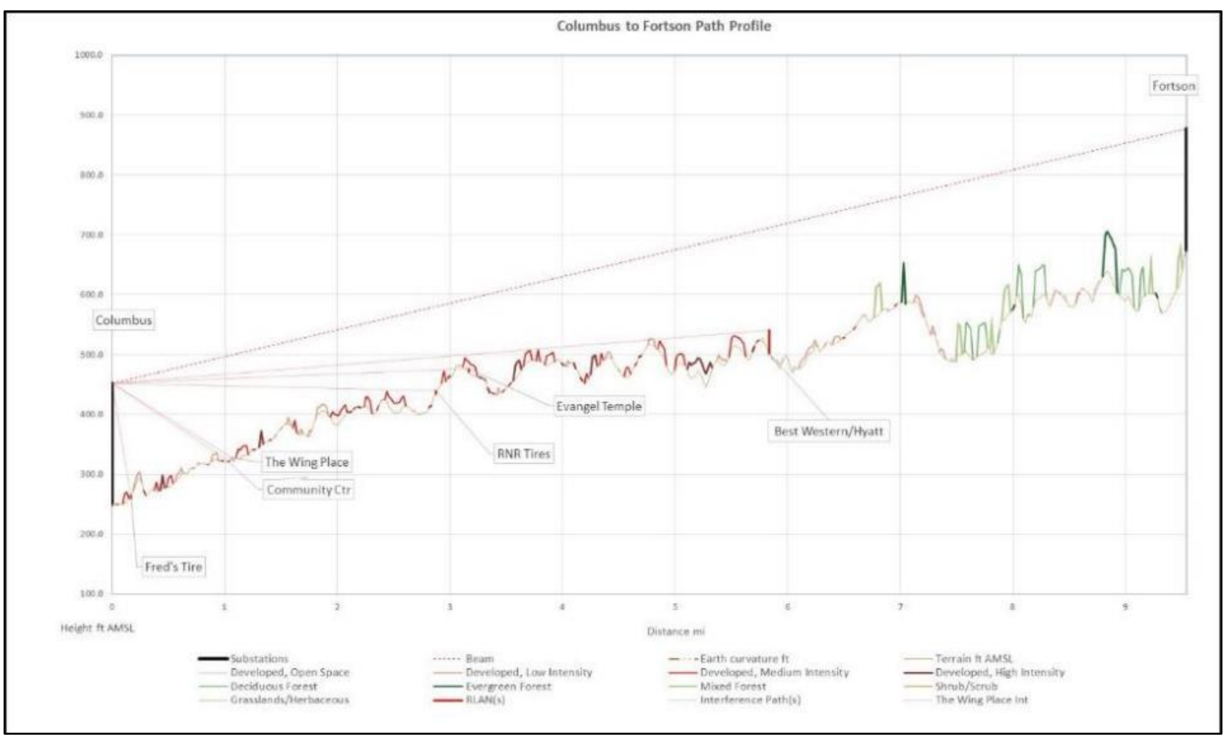


Figure 27: Fortson-Columbus Path Profile with Test Locations

5. Unlicensed 6 GHz RLAN impact on Licensed Microwave Results

The following sections each detail one test location in full detail. The results are summarized in the Executive Overview section of this document.

Each test location is documented with information, path profile, and pictures of the location and configurations tested. Each configuration is discussed inline in the text and detailed by a row in the results table.

Test Location (Modulation of 1024QAM unless noted)	Date	Beacons Only		Low Speed Data (<100Mbps)		High Speed Data (>750Mbps)		Data Rate Tested over MW Link
		dB Impact	I/N Ratio	dB Impact	I/N Ratio	dB Impact	I/N Ratio	
Fred's Tire ASUS in window	4/12/2021	1.2	-5.2	3.1	0.1	3.8	1.4	230.0
Fred's Tire Netgear in window	4/13/2021	1.2	-5.2	2.7	-0.8			230.0
Fred's Tire ASUS on counter	4/13/2021					6.4	5.2	230.0
Fred's Tire Asus in front of Counter	4/13/2021	2.0	-2.5			14.2	14.0	230.0
Fred's Tire ASUS rear corner Service	4/13/2021			25.8	25.7			230.0
Fred's Tire ASUS front corner of Service	4/13/2021	10.8	10.4	20.6	20.5			230.0
Community Center (Obstructed)	4/14/2021							
The Wing Place ASUS in window	4/14/2021	0.4	-10.8	14.0	13.8	16.3	16.1	230.0
The Wing Place ASUS on table 6' in	4/14/2021	0.0				10.2	9.7	230.0
The Wing PlaceASUS ceiling 6' in	4/14/2021	1.5	-4.0			16.0	15.8	230.0
RnR Tires (Obstructed)	4/14/2021							
Evangel Temple Doors Closed	4/14/2021	0.0		2.9	-0.3			230.0
Evangel Temple Doors Open	4/14/2021	0.1	-19.4	4.6	2.7	5.8	4.4	230.0
Hyatt Room 503	4/13/2020	0.0				0.2	-13.3	230.0
Best Western Room 432	4/13/2021	0.0				0.3	-11.5	230.0
Both Best Western & Hyatt	4/13/2020	0.0				0.5	-9.0	230.0
The Wing Place in window 1024QAM	4/15/2021	0.9	-6.4	14.1	13.9			230.0
The Wing Place in window 512QAM	4/15/2021	6.7	5.7	14.4	14.2			208.0
The Wing Place in window 256QAM	4/15/2021	0.8	-6.9	15.7	15.6			185.0
The Wing Place in window 128QAM	4/15/2021	8.1	7.4	15.0	14.9			163.0

Table 6: Test Results by Location and Configuration

5.1. Fred's Tire Testing and Results:

Test Location	Address (Columbus, GA)	Contact	Phone	Latitude	Longitude	Dist	H Angle	V Angle
Fred's Tire	1900 2nd Ave	Manager	706-323-7353	32-28-56.7 N	84-59-23.0 W	285m	0.33	11.2

Table 7: Fred's Tire location details

Fred's tire was picked both because it was part of the CTIA/Southern testing in the fall of 2020 and also because it meets most of the criteria for a test location. This site is outside the main beam of the antenna vertically (11.2 degrees versus 0.85 degrees, including Columbus up-tilt of 0.42 degrees) but the closeness to the site results in low free-space loss that more than compensates for lost antenna gain. The most thorough testing was performed at Fred's both because of it being the first test location but also the variety of test configurations possible and cooperation of their management.

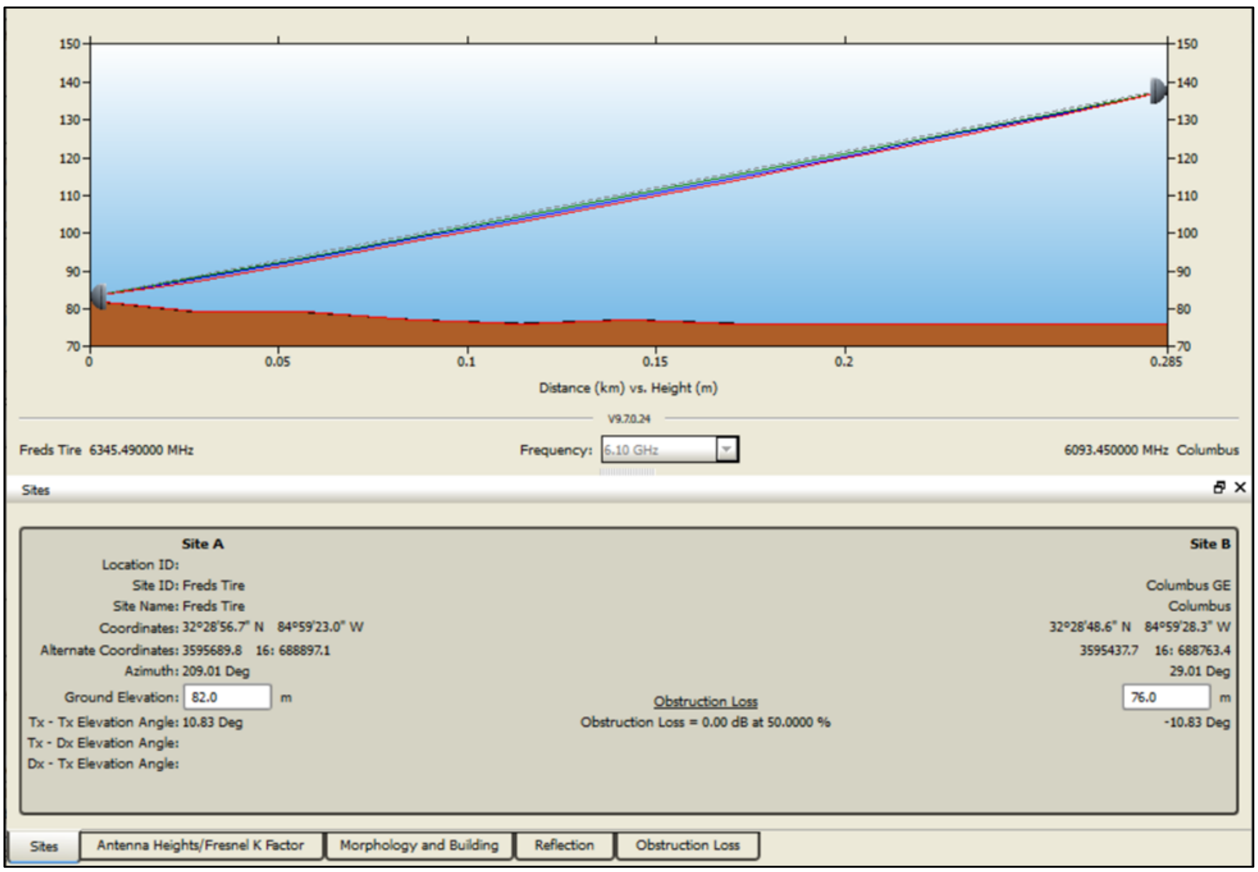


Figure 28: Fred's Tire Path Profile

Fred's Tire as viewed from 2nd Avenue is shown below. The second window from the corner in the front was used for the "in window" test location. The doors in the middle of the nearer portion of the building are across from the counter used as "on counter" test location. And the far corner where the service bay section turns to the south, under the green "Shocks" sign, is the area used for the "Service bay" test locations. Also note the reflective film on the windows discussed below.

Figure 29: Fred's Tire view from 2nd Avenue

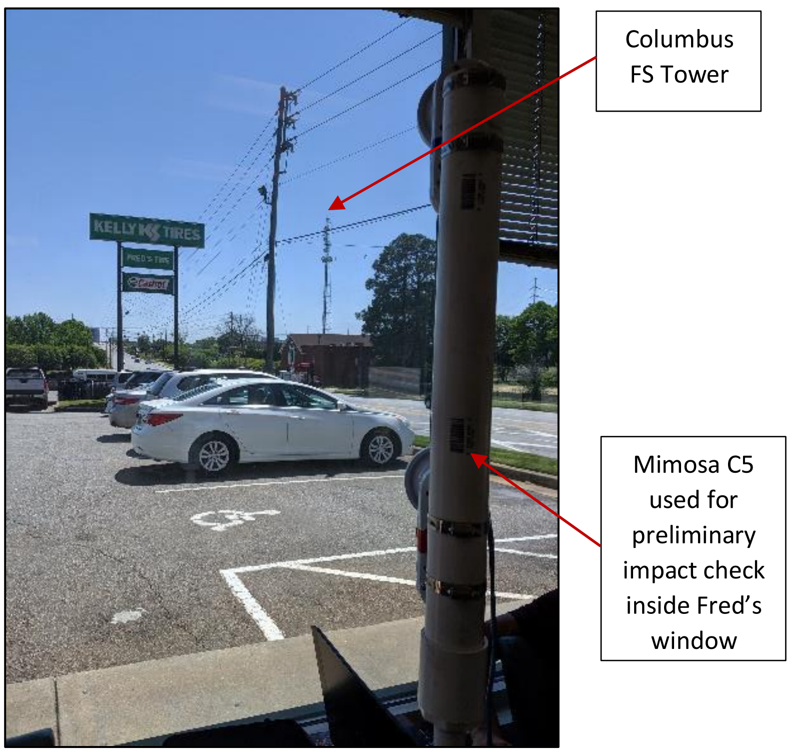


Figure 30: Fred's TIre looking out window towards Columbus FS

The second picture shows the view from inside Fred's Tire, through the front window, and towards the Columbus FS site tower. This shows a clear line-of-site from Fred's to the Columbus receive antenna with minimal clutter to either side of the LoS. It also shows the vertical angle from Fred's to the receive antenna, about 11 degrees of elevation (total in charts includes the 0.42° up-tilt on the Columbus antenna).

Preliminary impact check with the Mimosa gear pictured above resulted in impacts of 1.5 to 2 dB reduction in Fade Margin at +24 dBm EIRP and 4 to 4.5 dB reduction in Fade Margin at +27 dBm EIRP so detailed testing with the RLAN gear was performed.

Curious about the building entry loss given the criticism of window locations previously, loss through the window was measured by using a vector signal generator (which was calibrated) at Columbus center frequency (6345 MHz) into a directional antenna and measuring the field strength with a spectrum analyzer 1 meter from the antenna both inside and outside the building with the antenna rotated 180 degrees between measurements. The difference between the two measurements was -22.0 dBm inside versus -43.1 dBm outside or 21.1 dB Building Entry Loss (BEL). Notably this BEL exceeded the number cited in the FCC R&O footnote 297 (20.5 dB) by 0.6 dB.

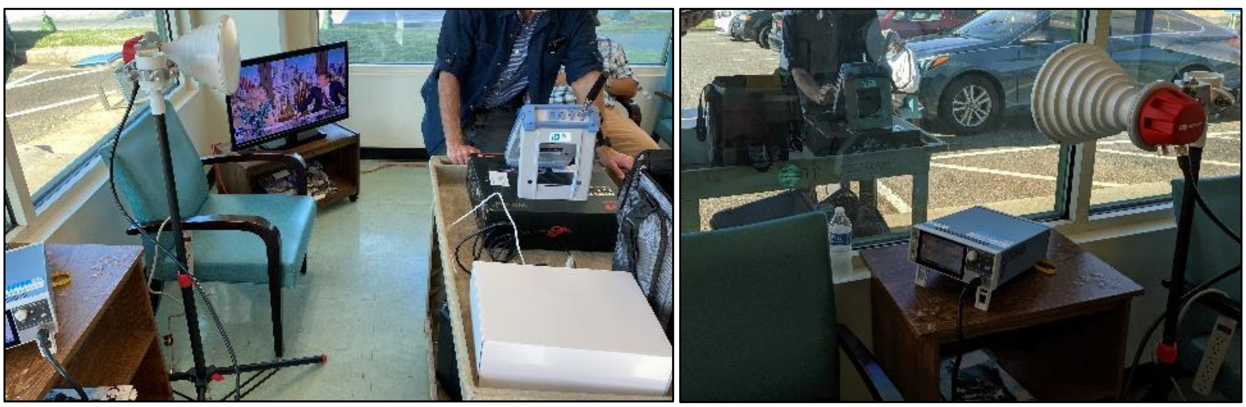


Figure 31: BEL Test setup at Fred's Tire

Baseline Fade Margin was measured and found to be 31.6 dBm, consistent as noted in the baseline measurements section previously.

Initial testing at Fred's was with the AP in the second window over from the west corner of their waiting room, sitting on a magazine table already in the window. Given it was the first testing with a commercial off the shelf AP, many different settings were tried and the impact of changes recorded. Notably a 1.2 dB of fade margin impact was measured with beacons only on channel 77 (15 MHz bandwidth overlap as noted previously) on both Asus and Netgear routers. With low speed data the fade margin impact increased to 3.1 dB with Asus but somewhat less, 2.7 dB with Netgear. High speed data increased the impact by approximately a dB so going forward the focus on repeating measurements was dropped to save time but it was noted if the testing was with Samsung (low data rate) or laptop (high data rate).

Beacon only impact was tested with the Asus setup screen set to 50 millisecond beacon spacing, 100 msec (default), and 200 msec and noted identical impacts – a bit puzzling at the time but later explained when it was found in post testing that the beacons repeated at 20 msec rate regardless of the setup parameter value on both Asus and Netgear APs.

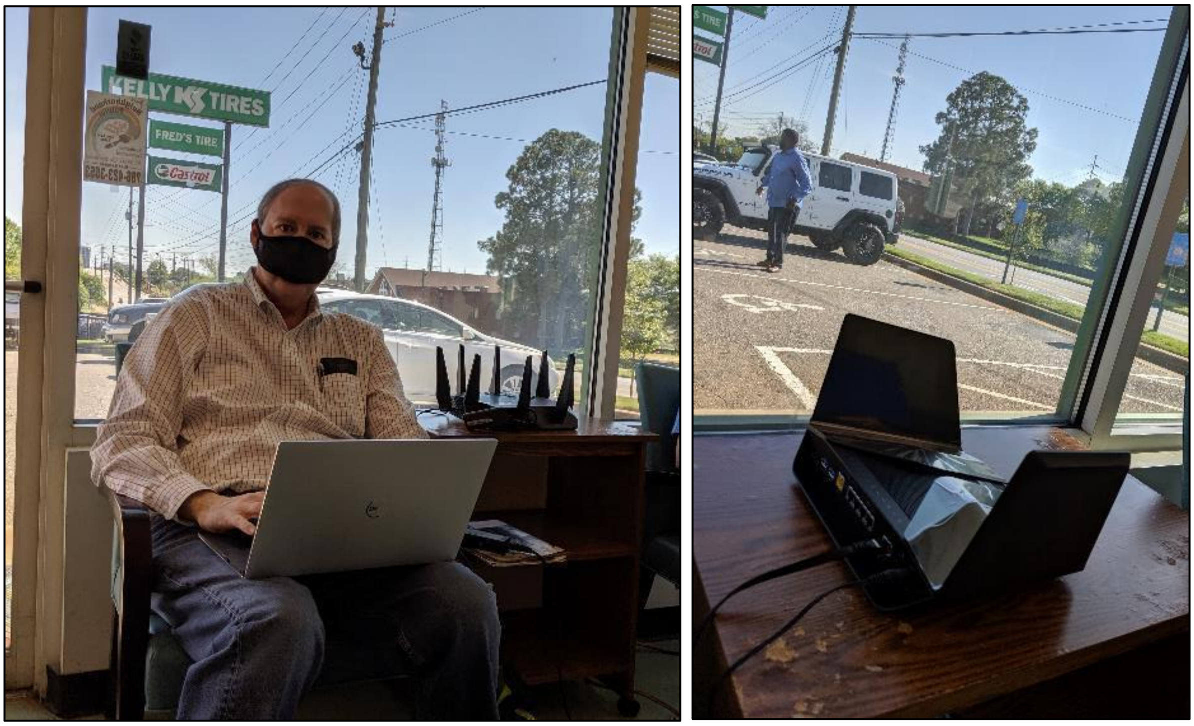


Figure 32: Fred's TIre "in window" test location

It was noticed that the reflective film was missing on one of the two doors so a test was performed with the Asus on the counter, 4 meters inside the door with line-of-site to tower through clear pane. Results were 6.4 dB impact with beacons plus data, the beacons only test was inadvertently omitted as was a photograph of that arrangement. The AP was then moved straight down to the floor in front of the counter with a clear Line-of-Sight to the tower and results were 2.0 dB impact with beacons only, 14.2 dB impact with data.

Figure 33: Counter test locations at Fred's

Fred's tire also has existing Wi-Fi coverage in their service bays to support employee tools as well as customers. The service bay building is an "L" shaped complex with 6 service bays adjacent to the front office, then a 90 degree bend, and 3 more service bays extending from there to the South. We found the existing access point at the corner of the "L" as shown below and testing was performed in the area below it (7 meters from front wall and bay doors). Fred's personnel informed us that the bay doors are open from opening (7AM) to closing (varies by day) unless weather does not permit. Note that from the location below the existing access point there is a clear line-of-sight to Columbus tower as shown below.

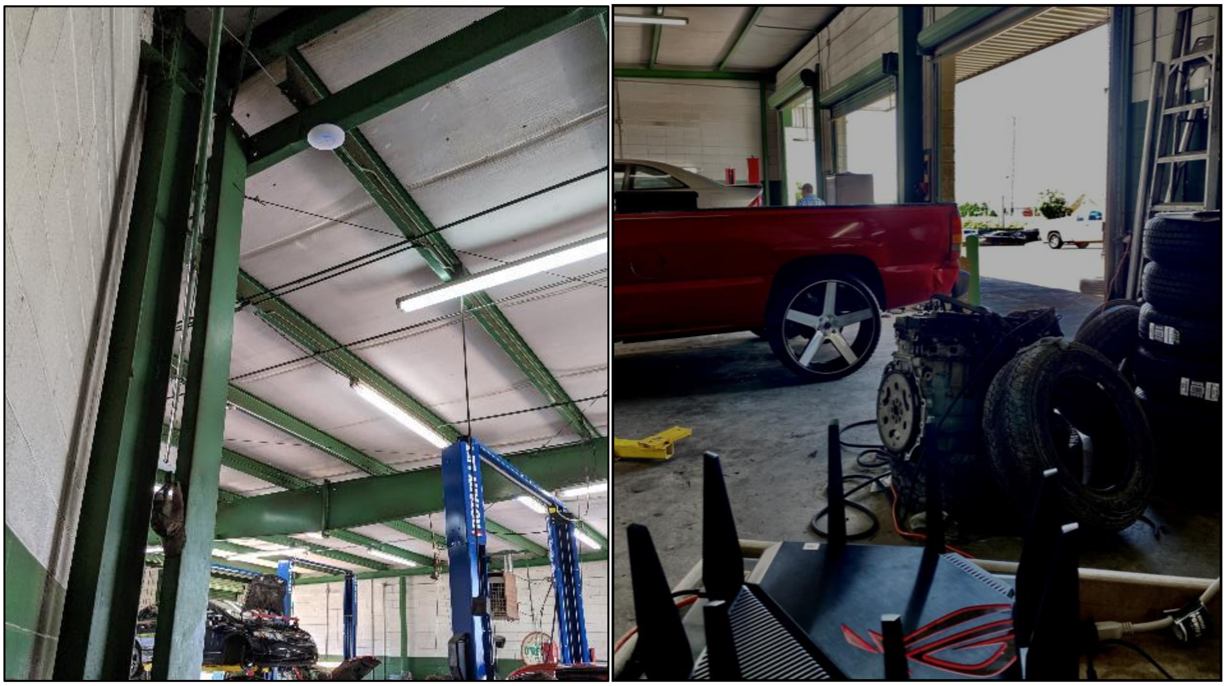


Figure 34: Fred's Service Area existing AP and LoS to FS

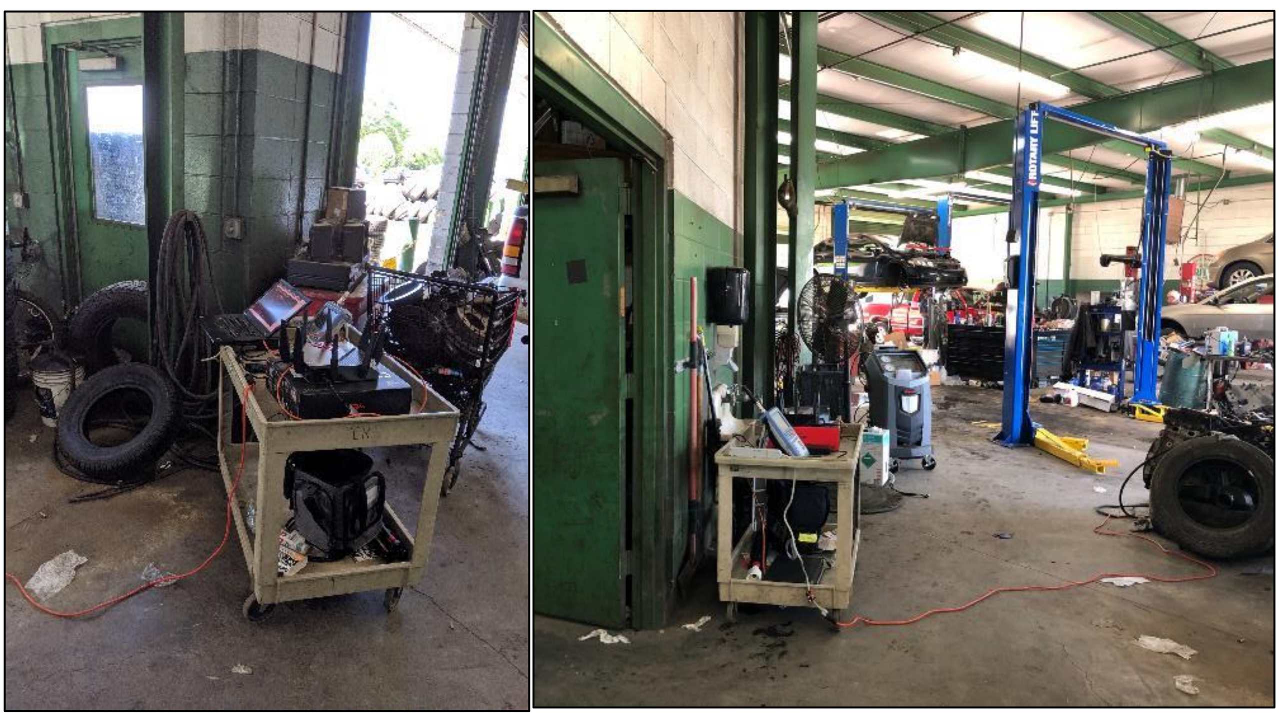


Figure 35: Service Bay Test Locations at Fred's

Initial testing from this location resulted in significant bit errors on the link as the AP powered up and with low speed data (the Samsung phone) the link was totally down even with all variable attenuation set to 0. In other words, the insertion loss of the attenuation equipment (8 dB as noted previously) did not allow the link to function with data flowing here (i.e. the impact was more than the net fade margin of 31.5 dB minus 8 dB insertion or 23.5 dB. The attenuation equipment was removed at Fortson and the transmit power control was used via NMS to measure the impact at 25.8 dB, leaving only 5.8 dB of fade margin on the Fortson to Columbus link.

Test Location (Modulation of 1024QAM unless noted)	Date	Beacons Only		Low Speed Data (<100Mbps)		High Speed Data (>750Mbps)		Data Rate Tested over MW Link
		dB Impact	I/N Ratio	dB Impact	I/N Ratio	dB Impact	I/N Ratio	
Fred's Tire ASUS in window	4/12/2021	1.2	-5.2	3.1	0.1	3.8	1.4	230.0
Fred's Tire Netgear in window	4/13/2021	1.2	-5.2	2.7	-0.8			230.0
Fred's Tire ASUS on counter	4/13/2021					6.4	5.2	230.0
Fred's Tire Asus in front of Counter	4/13/2021	2.0	-2.5			14.2	14.0	230.0
Fred's Tire ASUS rear corner Service	4/13/2021			25.8	25.7			230.0
Fred's Tire ASUS front corner of Service	4/13/2021	10.8	10.4	20.6	20.5			230.0

Table 8: Fred's Tire Test Results

5.2. Community Center Testing (obstructed):

Investigation revealed what appeared to be a Community Center on Google Earth and it looked good as a test location. Southern's local personnel made contact, found it was a housing management office for the complex with common areas, and arranged for us to visit. Upon arrival, preliminary testing found the area was obstructed by buildings and foliage between the location and the Columbus FS tower, as well as the lay of the land appearing lower than expected from Google Earth – there was no visibility of the tower. No additional testing was performed here.

Test Location	Address	Contact	Phone	Latitude	Longitude	Dist (m)	H Angle	V Angle
Community Center	839-867 Belmont St, Columbus, GA	?	?	32°29'34.2"N	84°58'58.5"W	1606	0.37	1.77

Table 9: Community Center location details

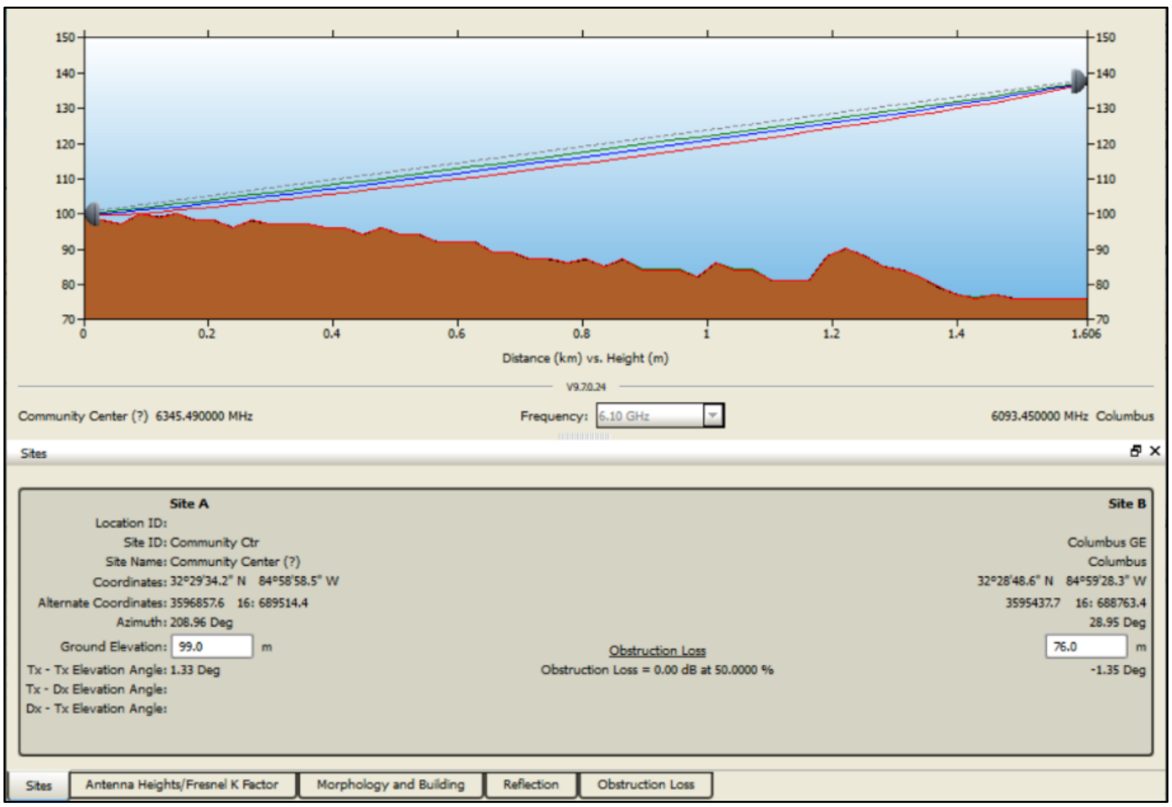


Figure 36: Community Center Path Profile

Figure 37: Community Center outside view

Figure 38: View from Community Center towards FS

5.3. The Wing Place Testing and Results:

The Wing Place was selected because it had been discovered by onsite investigation during the CTIA/Southern testing in the fall of 2020. Preparation revealed that the location may have terrain challenges as it shows being back from the leading edge of a plateau and thus susceptible to small changes in terrain or close-in clutter. And when the actual building was found it is slightly outside the main beam of the Columbus antenna. But it had shown impact in the CTIA testing so we included it in this test process and found it does indeed impact Columbus receive site.

Test Location	Address	Contact	Phone	Latitude	Longitude	Dist (m)	H Angle	V Angle
The Wing Place	3401 Veterans Pkwy	Manager	706-940-0020	32°29'44.9"N	84°58'48.3"W	2025	1.43	1.31

Table 10: The Wing Place location details

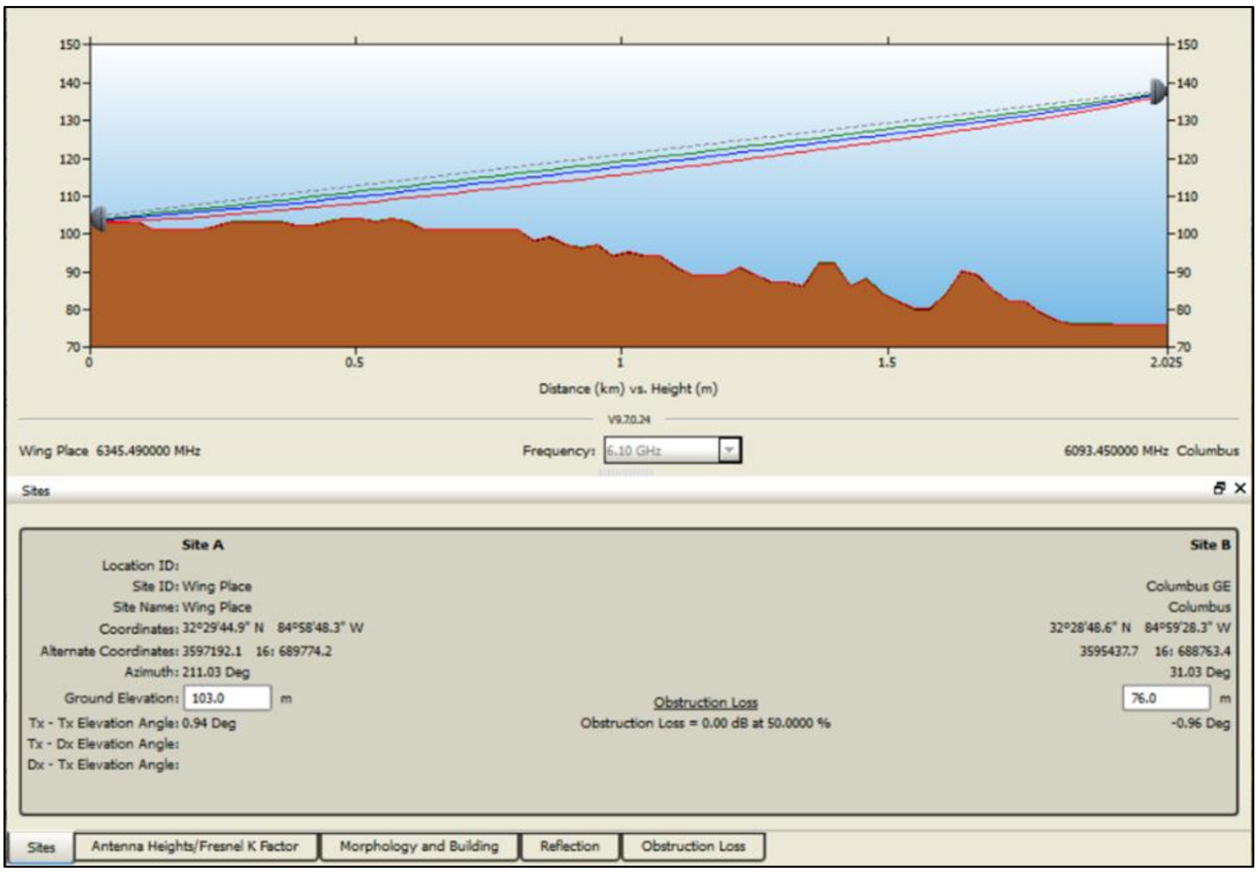


Figure 39: The Wing Place Path Profile

Upon arrival another concern was discovered – the windows facing Columbus FS had bars across them. In the picture below, taken looking north from the traffic island in front of the building, Columbus FS tower is behind us and slightly to the west. This is apparent in the following picture and its enlarged inset showing the tower. Notably this is also how testing was done – from the traffic island across the connector. This second picture also shows the "in window" test location.

The second picture also shows concerns about terrain and clutter were unfounded – there is a clear Line-of-Sight view of the tower from the window as seen in the inset to the picture. Notably, this location that would have been eliminated from consideration by concerns from several intellectual analyses ended up being a very impactful site and the second most used site in this testing.

Figure 40: The Wing Place view from traffic island

Figure 41: Wing Place "in window" location with Columbus FS inset

Wing Place testing started with the Asus AP in the window as shown above and a variety of tests were run. Baseline was checked at 31.6 dB fade margin, consistent with the rest of testing time. Beacons alone resulted in 0.4 dB impact to fade margin. Adding low speed data increased the impact to 14.0 dB and adding high speed data increased the impact further to 16.3 dB.

Testing was also performed away from the window, on the other side of the room. A table there was used, placing the AP approximately two meters from the window and fifteen centimeters below it. Then a tall stool was placed on the table, raising the AP to over two meters high and near the ceiling. These locations are shown in the pictures below and testing there resulted in the following results: Tabletop, beacons alone created no impact to the fade margin, adding high speed data resulted in a 10.2 dB impact. Near the ceiling two meters from window, beacons alone resulted in a 1.5 dB impact to fade margin, adding high speed data increased that to 16.0 dB impact.

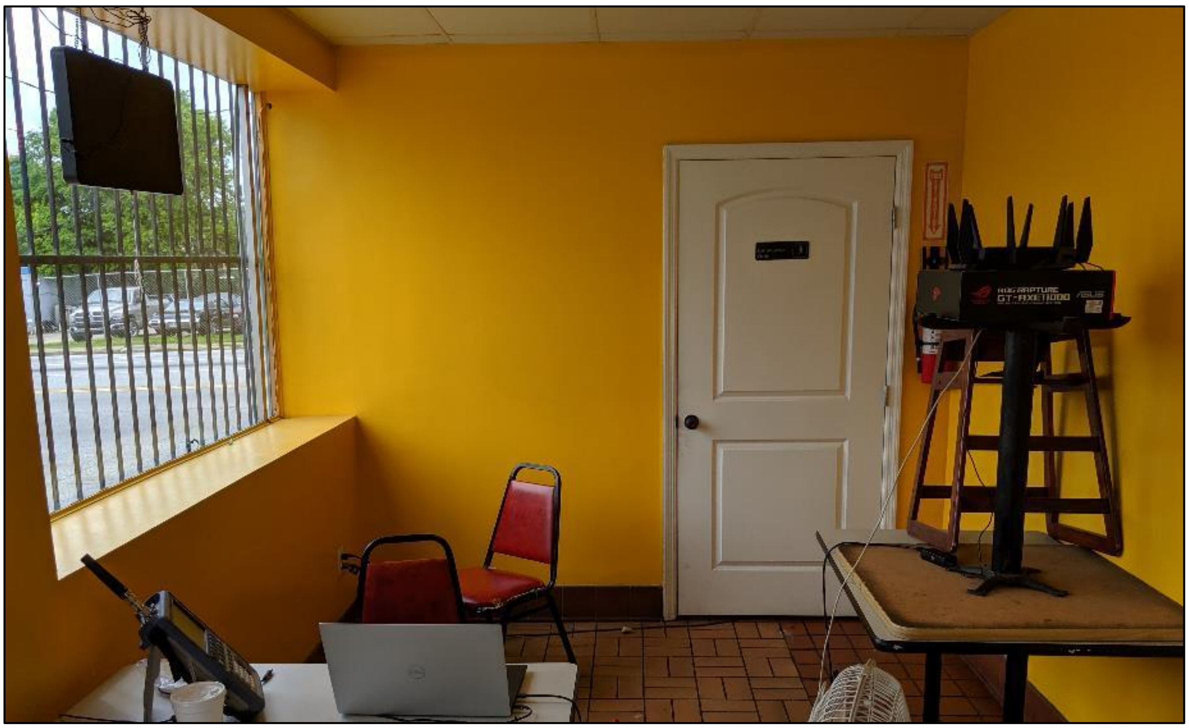


Figure 42: Wing Place inside near ceiling test location

Test Location (Modulation of 1024QAM unless noted)	Date	Beacons Only		Low Speed Data (<100Mbps)		High Speed Data (>750Mbps)		Data Rate Tested over MW Link
		dB Impact	I/N Ratio	dB Impact	I/N Ratio	dB Impact	I/N Ratio	
The Wing Place ASUS in window	4/14/2021	0.4	-10.8	14.0	13.8	16.3	16.1	230.0
The Wing Place ASUS on table 6' in	4/14/2021	0.0				10.2	9.7	230.0
The Wing PlaceASUS ceiling 6' in	4/14/2021	1.5	-4.0			16.0	15.8	230.0

Table 11: The Wing Place Test Results

5.3.1. Modulation Index Testing:

Final testing at Wing Place was focused on the question of Adaptive Modulation and what the effects of reducing Licensed Microwave modulation index from the normal 1024 or 512QAM to lower index levels. For this test the Asus AP was placed back in the window and for each modulation index a baseline fade margin was measured, then the impact of beacons only, then the impact of low speed data. This testing showed slightly better baseline fade margin at 1024QAM than the previous three and a half days had (32.1 dB versus previous 31.6 dB). Also, the data rate on the BER test equipment was varied to match the full throughput of the microwave at that modulation level and only low speed RLAN data was tested.

This testing resulted in counter-intuitive results. It was expected that each step down in modulation index would increase the baseline fade margin and lower any impacts by 2 to 3 dB with variability being the efficiency of the demodulation. Instead, certain modulation levels were found to be inexplicably more and less susceptible to interference. EPRI is approaching the manufacturers of the microwave radios (Aviat, Nokia, etc.) to solicit further testing in their labs to understand the causes and effects.

Test Location (Modulation of 1024QAM unless noted)	Date	Base Fade Margin	Beacons Only		Low Speed Data (<100Mbps)		Data Rate Tested over MW Link
			dB Impact	I/N Ratio	dB Impact	I/N Ratio	
The Wing Place in window 1024QAM	4/15/2021	32.1	0.9	-6.4	14.1	13.9	230.0
The Wing Place in window 512QAM	4/15/2021	35.4	6.7	5.7	14.4	14.2	208.0
The Wing Place in window 256QAM	4/15/2021	38.3	0.8	-6.9	15.7	15.6	185.0
The Wing Place in window 128QAM	4/15/2021	41.2	8.1	7.4	15.0	14.9	163.0

Figure 43: The Wing Place Test Results

5.4. RNR Tire Express Testing (obstructed):

RNR Tires building appeared to have high probability of impact to Columbus. The picture below is misleading, Google Earth shows the vacant building before RnR moved in. Preliminary testing found the area was obstructed by buildings, billboards, and foliage and did not impact Columbus so no further testing was performed.

Test Location	Address	Contact	Phone	Latitude	Longitude	Dist (m)	H Angle	V Angle
RNR Tires	5300 Veterans Pkwy, Columbus, GA	Manager	706-887-6614	32°31'0.3"N	84°58'3.03"W	4627	0.57	0.51

Table 12: RNR Tires location details

Figure 44: RNR Tires outside view

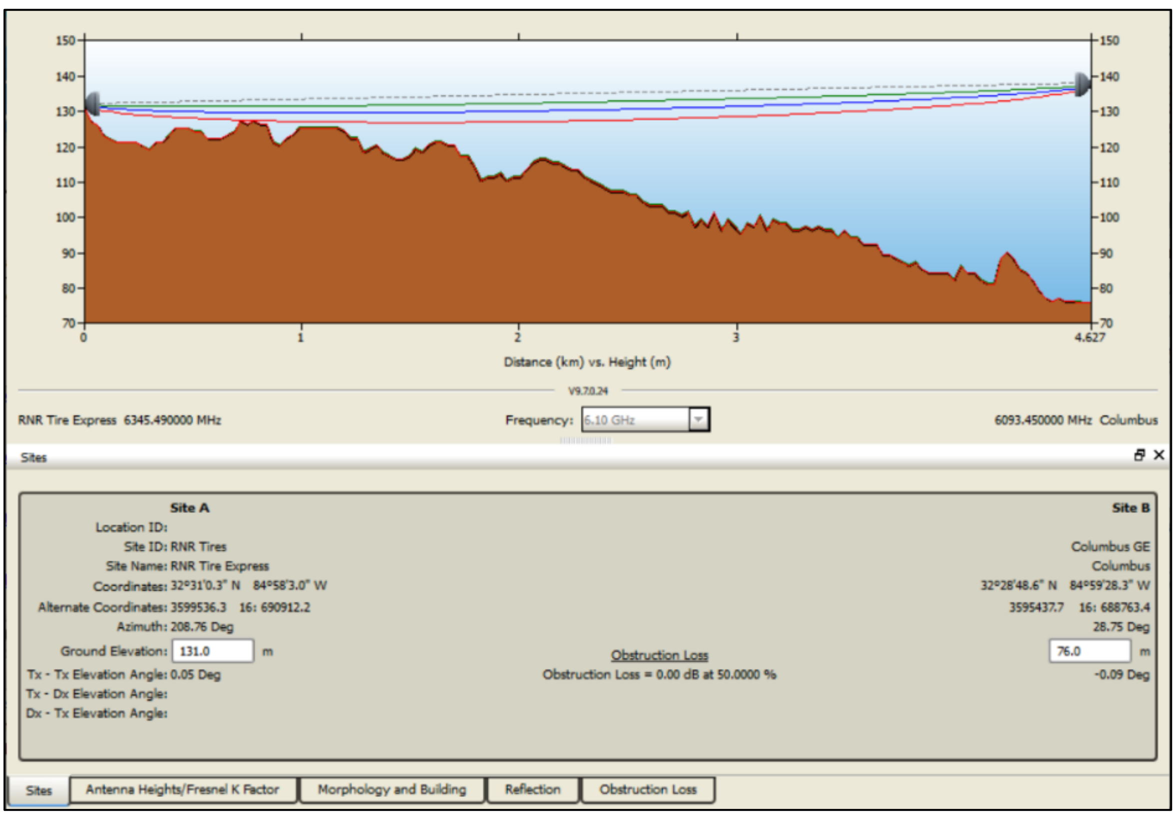


Figure 45: RNR Tires Path Profile

5.5. Evangel Temple Testing and Results:

Evangel Student Center looks good on paper but may be on the backside of a hump in the terrain. Evangel Temple looks closer, and local investigation confirmed that Temple was a better option. The picture below shows both, the student center is on the left side in the background and the temple is in the center – and the entry that was tested through is marked with an added arrow.

Test Location	Address	Contact	Phone	Latitude	Longitude	Dist (m)	H Angle	V Angle
Evangel Temple	5388 Veterans Pkwy, Columbus, GA	Reception at Office	706-323-5463	32°31'6.74"N	84°57'55.0"W	4903	0.46	0.53

Table 13: Evangel Student Center location details

Figure 46: Evangel Complex outside view

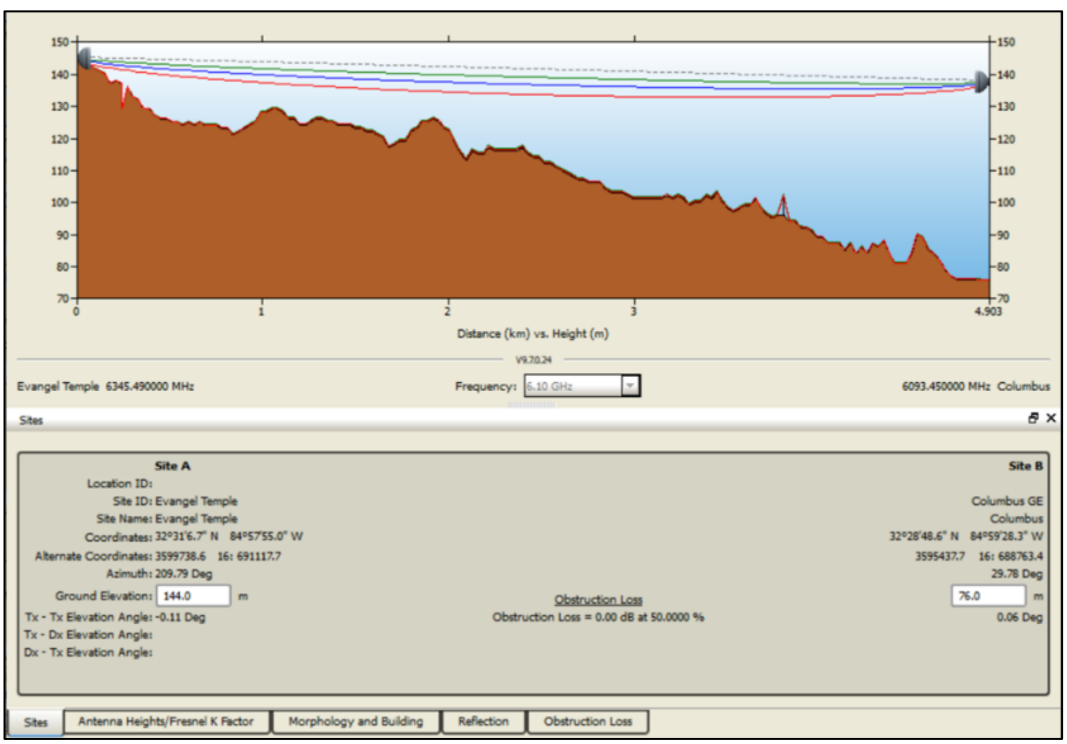


Figure 47: Evangel Student Center Path Profile

Figure 48: Evangel Temple entryway from outside and inside

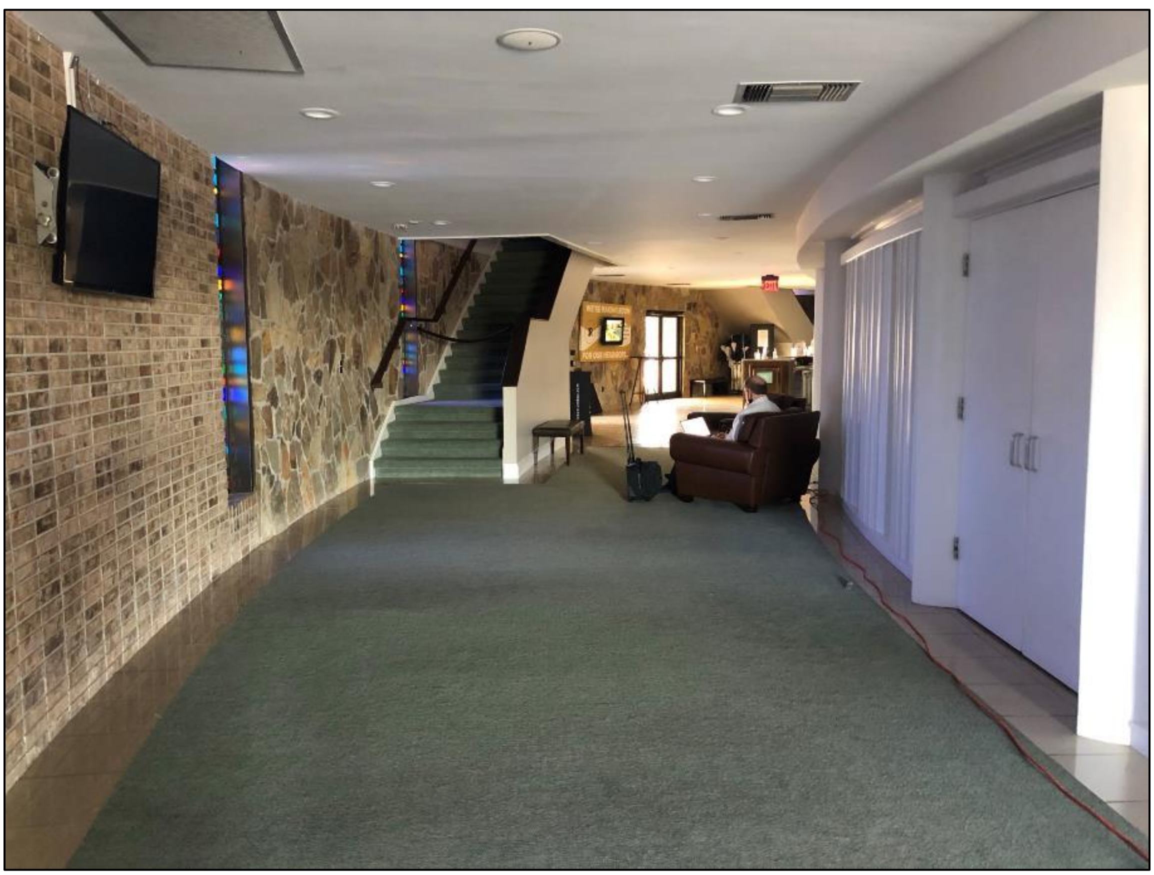


Figure 49: Evangel Temple from Entrance - main entry hall from Entrance

Evangel temple has no clear view of the tower – it is hidden behind trees to the south of the complex. But preliminary testing showed impact to Columbus receive, so full testing was performed. The entryway used is the main entrance from their parking lot into the Temple, feeding the sanctuary on the right with multiple doors along the curved hall as well as the balcony level up the stairs on the left. Access points and boxes with ethernet stubs for new access points were noted in multiple places on the ceiling.

The access doors are equipped with film, testing was done both with doors open (as pictured, and noted to be common by local Evangel personnel) and with the doors closed. The Asus AP was placed on an existing table near the door. With the doors closed there was no impact with beacons only and 2.9 dB of impact to fade margin with low speed data running. With the doors open there was 0.1 dB of impact to fade margin with beacons only, increasing to 4.6 dB of impact with low speed data running. When high speed data was launched the impact increased again to 5.8 dB.

Test Location (Modulation of 1024QAM unless noted)	Date	Beacons Only		Low Speed Data (<100Mbps)		High Speed Data (>750Mbps)		Data Rate Tested over MW Link
		dB Impact	I/N Ratio	dB Impact	I/N Ratio	dB Impact	I/N Ratio	
Evangel Temple Doors Closed	4/14/2021	0.0		2.9	-0.3			230.0
Evangel Temple Doors Open	4/14/2021	0.1	-19.4	4.6	2.7	5.8	4.4	230.0

Table 14: Evangel Temple Test Results

5.6. Hyatt Place Columbus North Testing and Results:

The Hyatt was added to the list based on visual inspection. It is slightly outside the main beam but 5 stories tall which was thought might make up the loss from being off-beam.

Test Location	Address	Contact	Phone	Latitude	Longitude	Dist (m)	H Angle	V Angle
Hyatt Place	2974 N Lake Pkwy, Columbus GA 31909	Front Desk	706-507-5000	32-33-4.2 N	84-56-48.0 W	8917	1.35	0.27

Table 15: Hyatt Place location details

Figure 50: Hyatt Place outside view

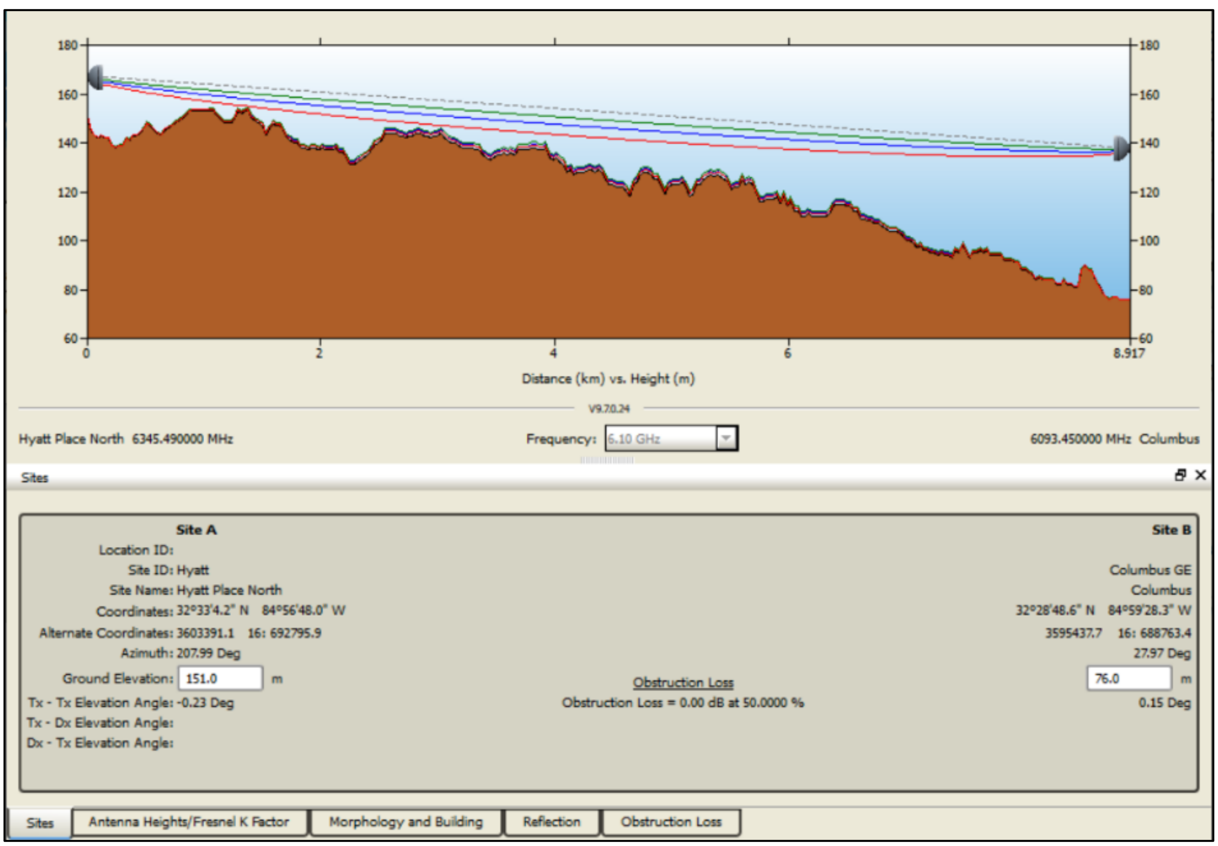


Figure 51: Hyatt Place to Columbus Path Profile

Hyatt room 503 was rented by a team member and initial investigation and preliminary testing were successful. Room 503 had a clear view of the Columbus FS tower with no clutter or foliage in the path. And the Mimosa C5 units resulted in approximately 1 dB of impact to fade margin so detailed testing was performed. With Asus AP on the bed near the window as shown below, beacons only, produced no impact to Columbus receiver. High speed data running resulted in 0.2 dB of impact to fade margin. This is a relatively small impact but the Hyatt has eight to ten rooms with a similar view of the site and that many more that have only local trees obstructing them and would be additive if more than one overlapped Columbus frequency.

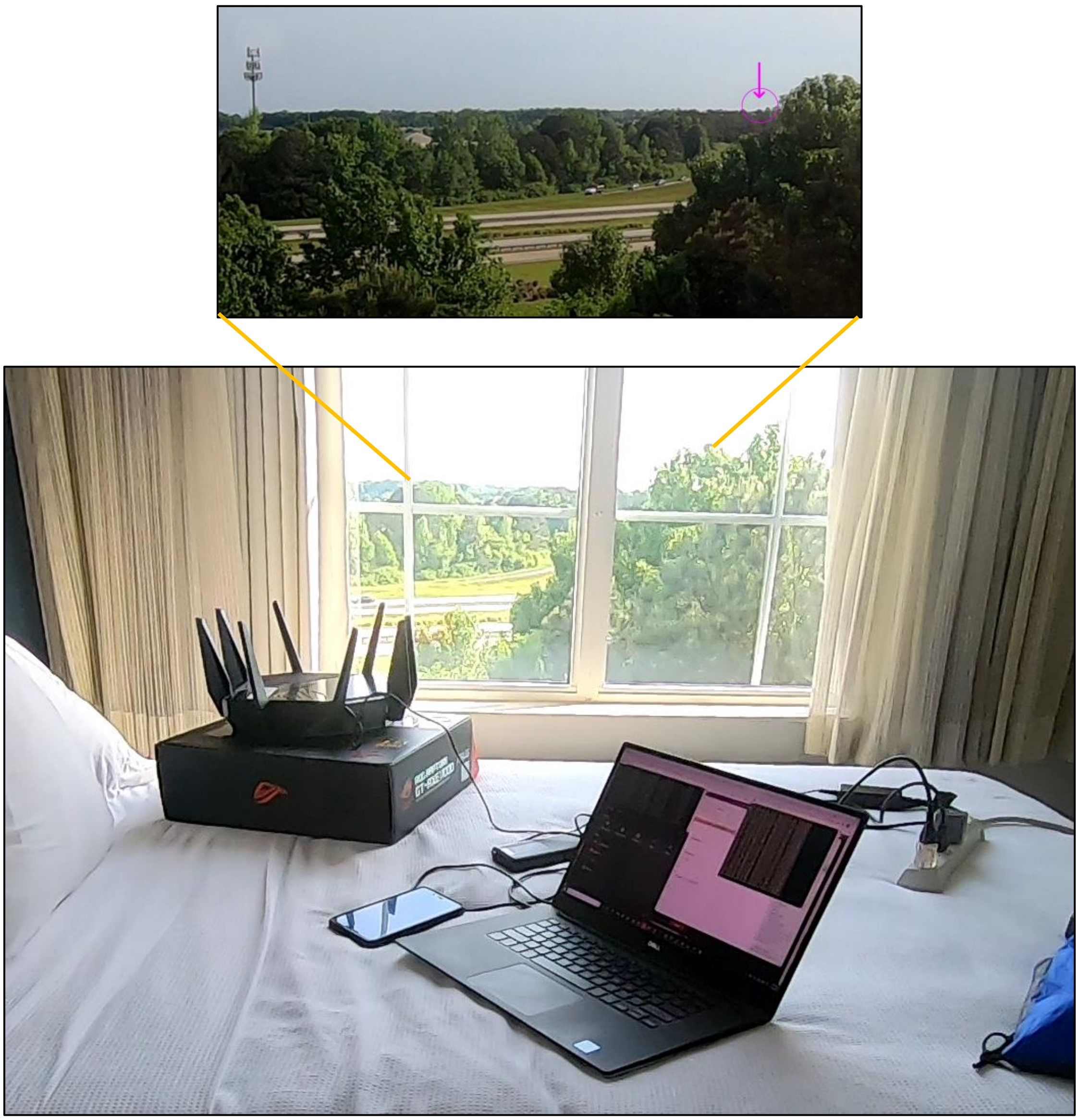


Figure 52: Hyatt Test Location with Site Enlarged

Test Location (Modulation of 1024QAM unless noted)	Date	Beacons Only dB Impact	Beacons Only I/N Ratio	Low Speed Data (<100Mbps) dB Impact	Low Speed Data (<100Mbps) I/N Ratio	High Speed Data (>750Mbps) dB Impact	High Speed Data (>750Mbps) I/N Ratio	Data Rate Tested over MW Link
Hyatt Room 503	4/13/2020	0.0				0.2	-13.3	230.0

Table 16: Hyatt Test Results

5.7. Best Western Plus Testing and Results:

Best Western was selected as it was part of the CTIA/Southern testing in fall 2020 and had shown impact to the Columbus receiver. Preliminary testing resulted in 1.5 dB impact to fade margin so detailed testing was performed.

Test Location	Address	Contact	Phone	Latitude	Longitude	Dist (m)	H Angle	V Angle
Best Western	4027 Veterans Ct, Columbus, GA	Front Desk	706-507-1111	32-33-16.5 N	84-56-36.2 W	9396	0.77	0.19

Table 17: Best Western Plus location details

Figure 53: Best Western Plus outside view

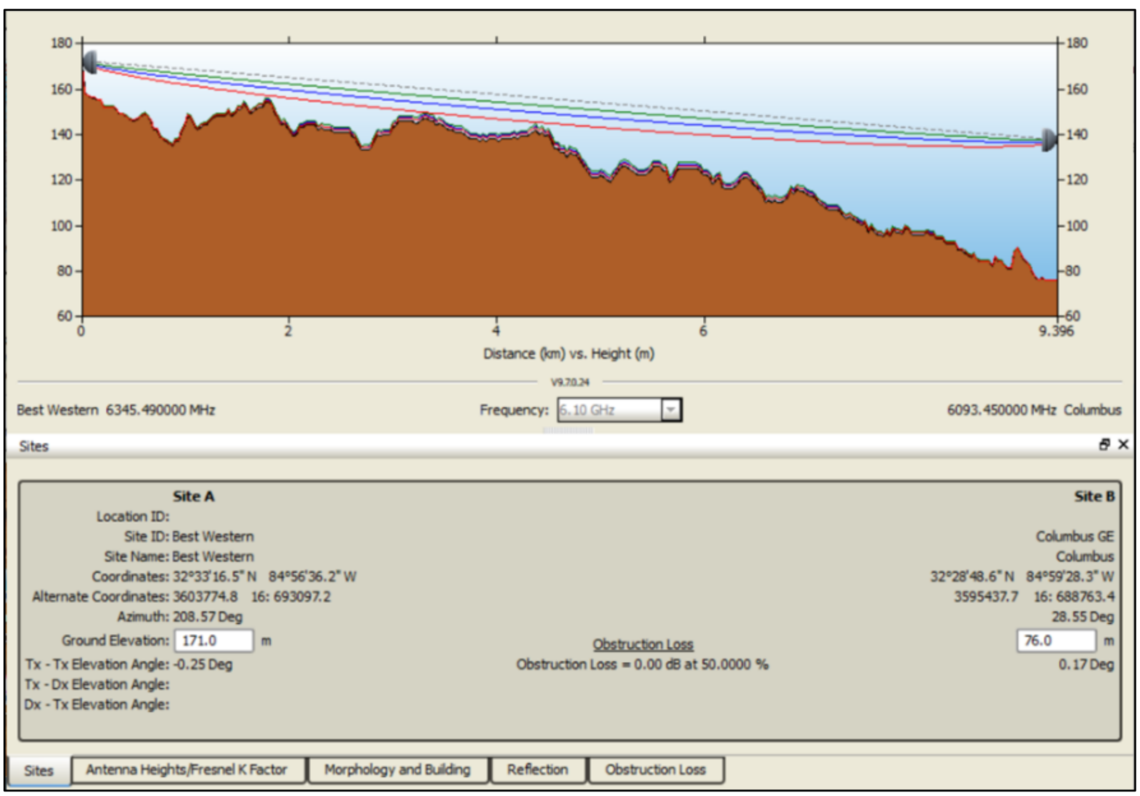


Figure 54: Best Western to Columbus Profile

Best Western room 432 was rented for one night for testing. Room 432 had a clear view of the Columbus FS tower with no clutter or foliage in the path. With Asus AP in the window as shown below, beacons only, produced no impact to Columbus receiver. High speed data running resulted in 0.3 dB of impact to fade margin. This is a relatively small impact but most of the rooms on this side of the Best Western have a similar view of the site and impact would be additive if more than one overlapped Columbus frequency.

For the final testing at the hotels, there was one Asus AP in each room (Hyatt and Best Western) and both were turned on with high speed data running. It was found the aggregate impact was additive, as seen in the blue highlighted area below. This is not an exhaustive test and the impacts are quite small but it does initially validate the concept and merits further investigation.

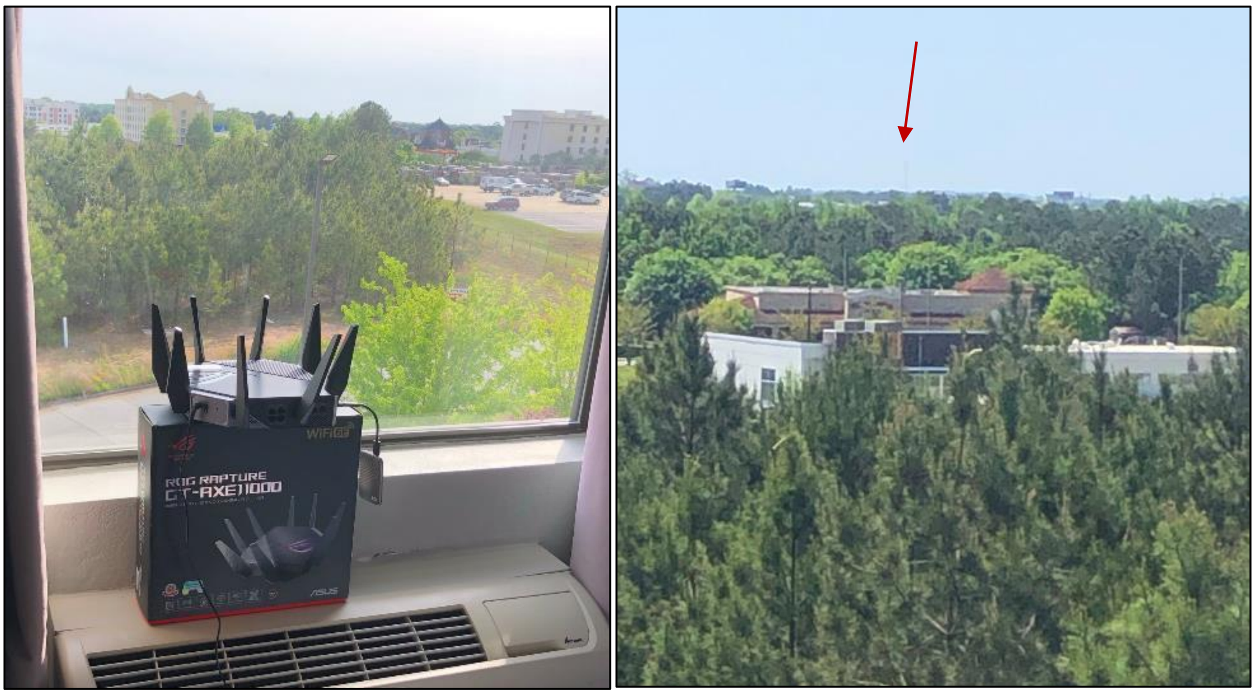


Figure 55: Best Western Test Location and View of Columbus FS

Test Location (Modulation of 1024QAM unless noted)	Date	Beacons Only dB Impact	I/N Ratio	Low Speed Data (<100Mbps) dB Impact	I/N Ratio	High Speed Data (>750Mbps) dB Impact	I/N Ratio	Data Rate Tested over MW Link
Hyatt Room 503	4/13/2020	0.0				0.2	-13.3	230.0
Best Western Room 432	4/13/2021	0.0				0.3	-11.5	230.0
Both Best Western & Hyatt	4/13/2020	0.0				0.5	-9.0	230.0

Table 18: Best Western Test Results with Hyatt and Sum

6. Census of Existing Wi-Fi APs in the Columbus Main Beam

One of the primary assertions of the FCC (and the unlicensed proponents) on the record is that the directional nature of FS microwave antennas reduces the area for LPI operation to potentially impact FS operation to a very small area – a degree or two out of 360 degrees around the FS. But the unlicensed proponents also have stated on the record that they expect 100 percent penetration of 6 GHz-capable APs within a few years. Following this logic, all existing APs in use have a high potential to be replaced with 6 GHz-capable devices over the new few years.

Southern undertook a non-exhaustive drive test to evaluate the significance of that risk by counting the Access Points in the main beam of the Columbus antenna. Equipment and Applications capable of automating this process were investigated and an application for Android phones (Wi-Fi Collector) was selected and downloaded onto a Southern technician's Samsung Galaxy 5S phone. The phone was placed in its dash-mount in the Southern service truck (pickup with metal toolbox behind the cab, ladder racks, etc) – the phone only had a clear line-of-site out the windshield, partial out the side windows, and obstructed to the rear. The Columbus main beam was overlaid on Google Earth and maps produced for the driver to maximize drive coverage of the main beam. The maps were driven as slowly and as completely as was convenient – Busy roads (like Veteran's Parkway) required flowing with traffic and some neighborhoods were not very accessible. Testing was stopped just past the Best Western hotel based on the analysis of the path and the likely areas of interference along the path. The goal was not an exhaustive count of AP's but to get an order of magnitude with reasonably efficient test methods.

The drive testing resulted in capture of over 4500 APs in the area driven, but when the KMZ file output of Wi-Fi Collector was imported to Google Earth it was clear that APs outside the beam had been captured through drive routes needed to connect areas of interest as well as Wi-Fi radio frequency propagation causing the phone being used to receive AP's from all directions. This raw census is pictured to the right of this paragraph.

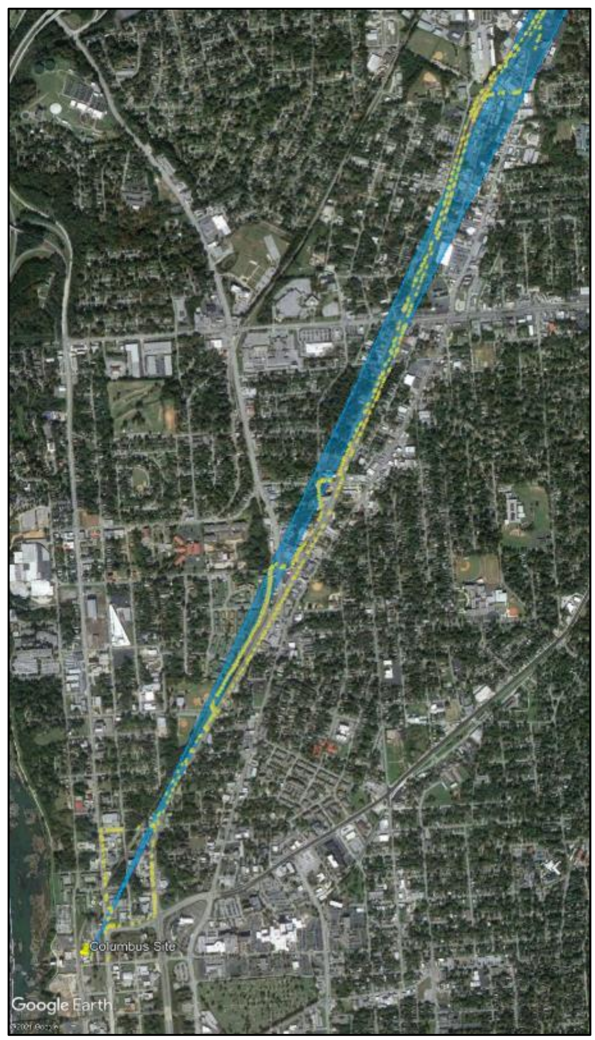


Figure 56: AP Census Drive Test Raw Data

The output from Wi-Fi Collector was then imported into QGIS along with the polygon that defines the main beam from Columbus towards Fortson. QGIS was used to filter the AP data to eliminate any data outside the main beam. Again for expedience a sharp edge was used for the beam, even though it is clear that the edge represents a gain point and although the Columbus receive gain is less outside the beam it is not zero – as evidenced by the impact measured from test locations physically outside the edge of the beam (i.e. The Wing Place and Hyatt Place). With this sharp filtering applied, the census of AP's in the first 10 km of the main beam of Columbus totals **3,003**.

This is a significant number of potential interferers and certainly validates that the area tested is representative of an area highly likely to contain interfering unlicensed LPI devices. This result is especially troubling because the actual potential location count is likely understated by as much as 50% due to: (1) the speed of the measuring vehicle not allowing capture of all SSID's; (2) only easily accessible roads were driven, and; (3) only 60 percent of the path length was driven. Graphic results of the drive test are shown to the right.

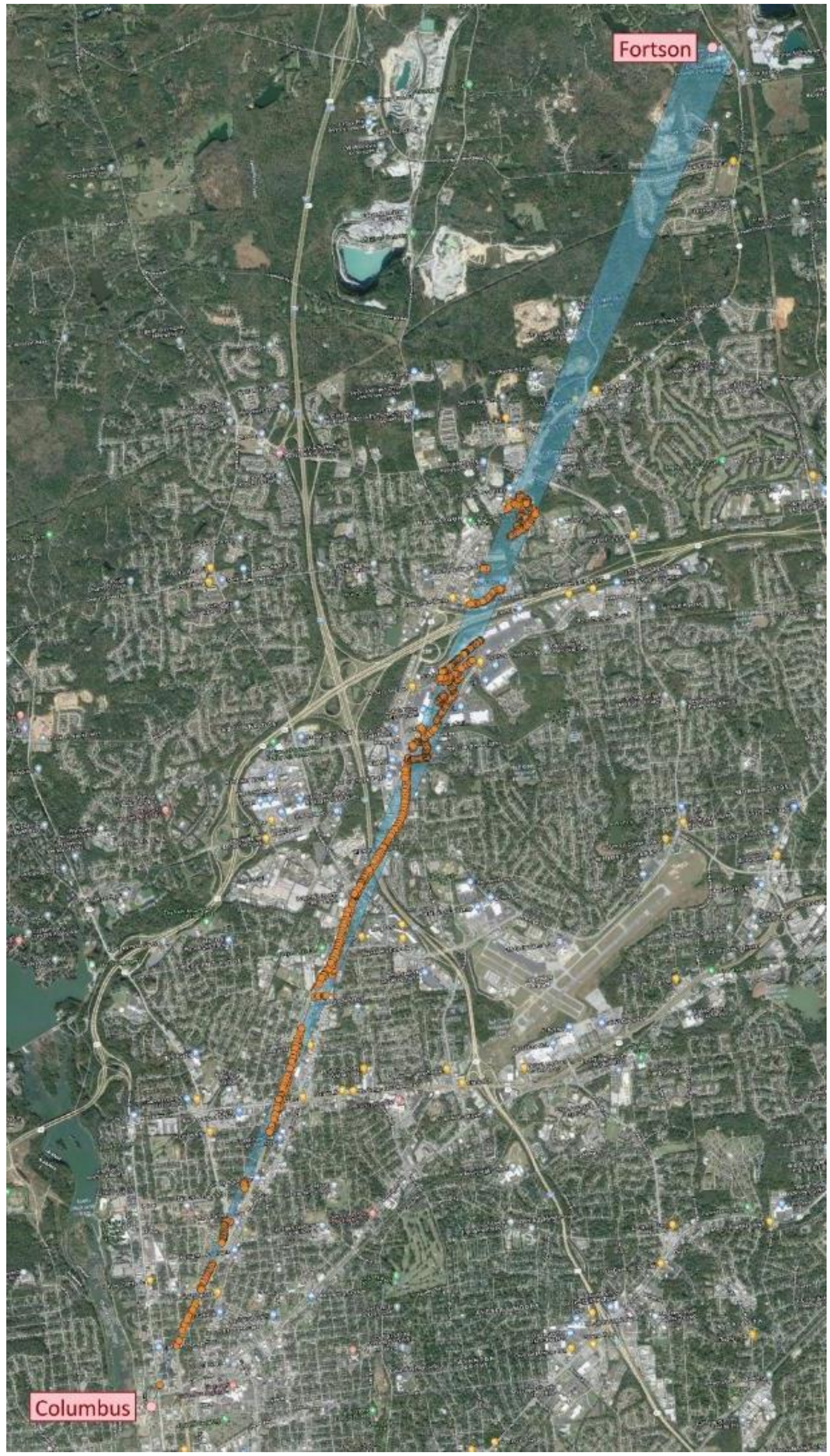


Figure 57: AP Census showing only APs in Main Beam

Conclusion

Southern, EPRI, and L&W have tested and measured commercial off the shelf RLAN AP units. These devices were procured (without any assistance from AP manufacturers), test plans developed and provided to the FCC OET for review, and tested. The measurements from this real-world testing demonstrate that a single Commercial off the Shelf RLAN unit, operating co-channel with a licensed link and in the main beam of that link's receive antenna, WILL impact that link significantly. And that multiple units so operating will additively impact the link and likely render the link unusable.

Test Location	**Beacons Only**			**Low Speed Data (<100Mbps)**			**High Speed Data (>750Mbps)**			**MW Data**
(Modulation of 1024QAM unless noted)	**dB Impact**	**I/N Ratio**	**Pwr Ratio**	**dB Impact**	**I/N Ratio**	**Pwr Ratio**	**dB Impact**	**I/N Ratio**	**Pwr Ratio**	**Rate Tested**
Fred's Tire ASUS in window	1.2	-5.2	1.2	3.1	0.1	4.1	3.8	1.4	5.5	230.0
Fred's Tire Netgear in window	1.2	-5.2	1.2	2.7	-0.8	3.3				230.0
Fred's Tire ASUS on counter							6.4	5.2	13.2	230.0
Fred's Tire Asus in front of Counter	2.0	-2.5	2.3				14.2	14.0	99.5	230.0
Fred's Tire ASUS rear corner Service				25.8	25.7	1492.3				230.0
Fred's Tire ASUS front corner of Service	10.8	10.4	43.3	20.6	20.5	447.9				230.0
Community Center (Obstructed)										
The Wing Place ASUS in window	0.4	-10.8	N/A	14.0	13.8	94.9	16.3	16.1	163.9	230.0
The Wing Place ASUS on table 6' in	0.0						10.2	9.7	37.2	230.0
The Wing PlaceASUS ceiling 6' in	1.5	-4.0	1.6				16.0	15.8	152.7	230.0
RnR Tires (Obstructed)										
Evangel Temple Doors Closed	0.0			2.9	-0.3	3.7				230.0
Evangel Temple Doors Open	0.1	-19.4	N/A	4.6	2.7	7.4	5.8	4.4	11.0	230.0
Hyatt Room 503	0.0	No Impact		No Impact			0.2	-13.3	N/A	230.0
Best Western Room 432	0.0	No Impact		No Impact			0.3	-11.5	N/A	230.0
Both Best Western & Hyatt	0.0	No Impact		No Impact			0.5	-9.0	N/A	230.0
The Wing Place in window 1024QAM	0.9	-6.4	N/A	14.1	13.9	98.3				230.0
The Wing Place in window 512QAM	6.7	5.7	14.6	14.4	14.2	105.7				208.0
The Wing Place in window 256QAM	0.8	-6.9	N/A	15.7	15.6	143.9				185.0
The Wing Place in window 128QAM	8.1	7.4	21.7	15.0	14.9	121.9				163.0

Figure 58: Test Results showing COTS RLAN products impact licensed links

Appendix A: PSC Effect on Licensed Channels

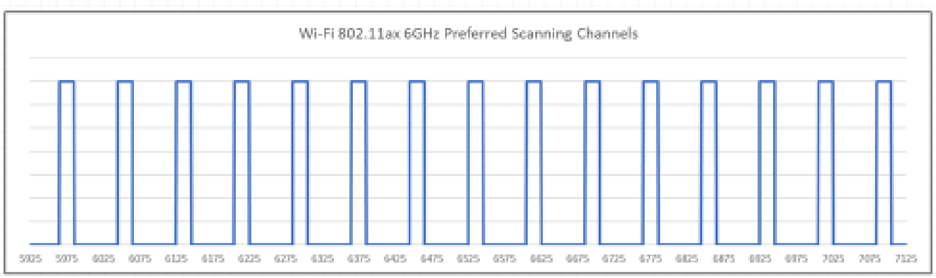
Preferred Scanning Channel (PSC)
Overlap with Licensed Channels

Wi-Fi 802.11ax Preferred Scanning Channels and their Effect on Licensed 6GHz Operation

May 5, 2021

802.11ax Preferred Scanning Channels

- Wi-Fi specifications call out 15 Preferred Scanning Channels (PSCs) across 6GHz
- PSCs are used for Beacon operation – limiting number of default channels speeds SSID Scanning for clients looking for APs
- Beacons are method for Wi-Fi Access Points (APs) to transmit SSID info
- All APs send Beacon signals every 104 milliseconds (by default, can be configured) using 20MHz bandwidth, full transmit power, and low speed data modulation

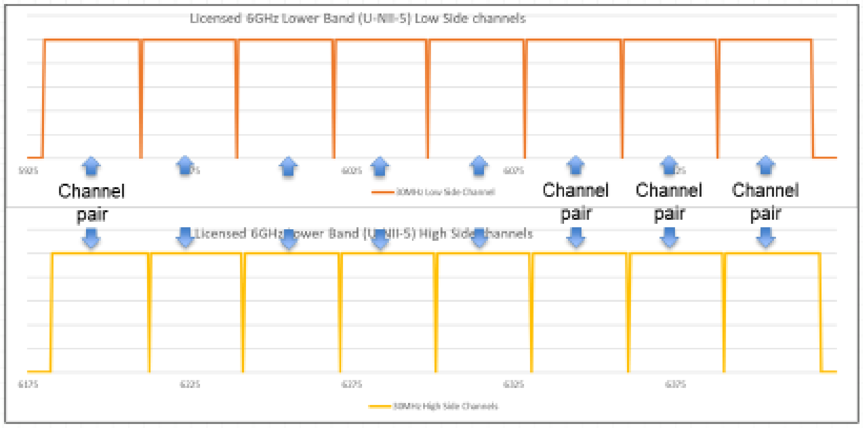


Licensed Lower 6GHz Band (U-NII-5), showing Channel Pairing

- Licensed Microwave uses Paired Channels – one for each direction of the link, and assigned together as a pair

Channel for one direction

Channel for other direction



- 30 MHz bandwidth pairs on U-NII-5 used for this example, most are similar other than U-NII-7 10 MHz has some channels offset

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Effect of Beacons on Licensed 6GHz Microwave

- Testing conducted by Southern Company, Electric Power Research Institute (EPRI), and Lockard & White (L&W) has demonstrated that FCC Certified, purchased off-the-shelf APs from Asus and Netgear with only beacons being transmitted impact a licensed 6GHz path. Data transmission adds to the impact but Beacons alone cause impact.
- Because Licensed Microwave and Unlicensed Wi-Fi have evolved separately over different time spans the channelization is not aligned
- Each microwave "Channel" is two frequencies – one for each direction of link – either direction can be impacted by unlicensed operation
- Also note that Licensed Microwave on 6GHz is available in different bandwidths from 800KHz to 60MHz. Typically used are 5, 10, 30, and 60
- Testing was on a 30MHz bandwidth licensed channel that overlapped the Beacon's 20MHz bandwidth by 15MHz – it impacted licensed link
- Slides following will examine overlaps for common bandwidths on both the Upper 6GHz (U-NII-7) and Lower 6GHz (U-NII-5)

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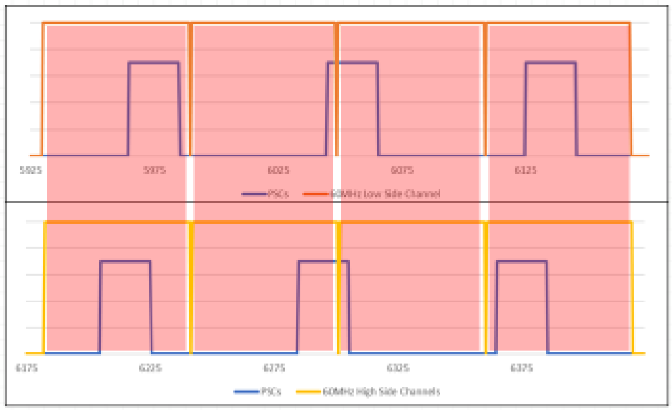
Licensed Lower 6GHz Band (U-NII-5), 60MHz Bandwidth

Note that EVERY available 60MHz channel is impacted in one or both directions



Channel pair shading: Green=no overlap, Yellow=some overlap, Red=significant overlap

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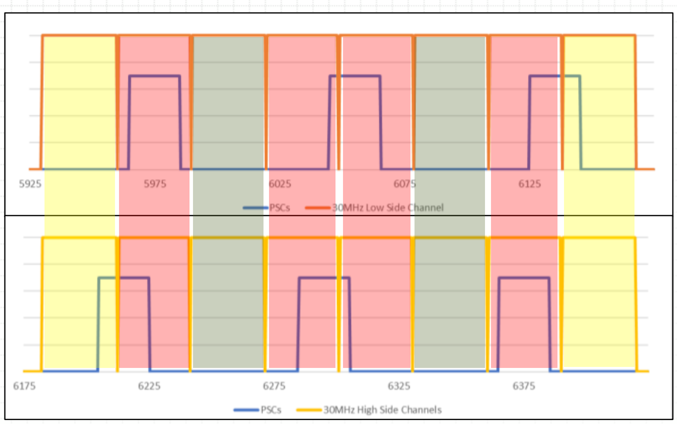
Licensed Lower 6GHz Band (U-NII-5), 30MHz Bandwidth

30MHz channels show 2 unimpacted, 2 slightly impacted, and 4 significantly impacted



Channel pair shading: Green=no overlap, Yellow=some overlap, Red=significant overlap

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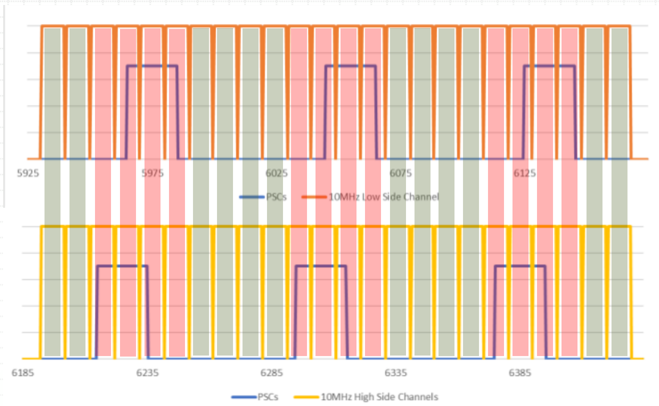
Licensed Lower 6GHz Band (U-NII-5), 10MHz Bandwidth

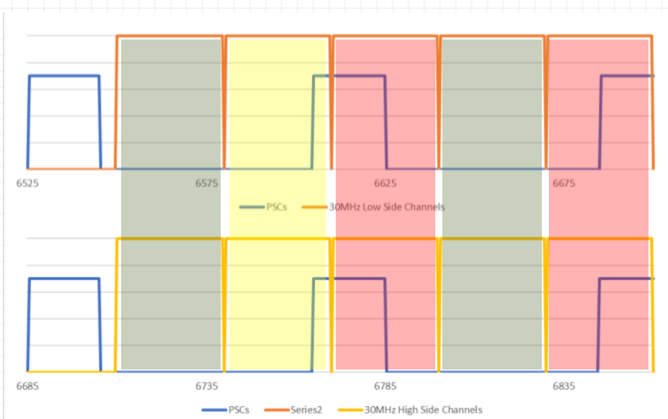
10MHz channels show 12 unimpacted and 12 significantly impacted



Channel pair shading: Green=no overlap, Yellow=some overlap, Red=significant overlap

Licensed Upper 6GHz Band (U-NII-7), 30MHz Bandwidth

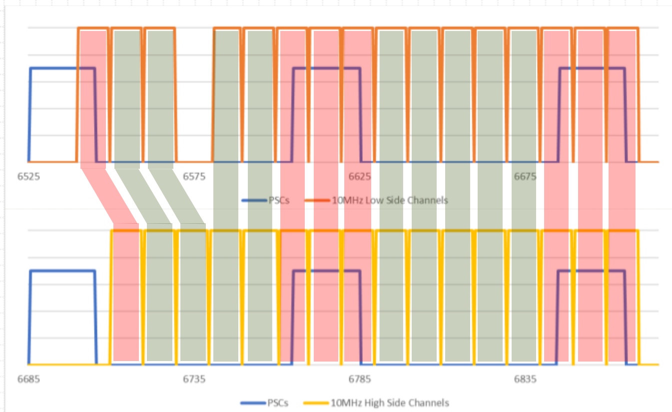
30MHz channels show 2 unimpacted, 1 slightly impacted, and 2 significantly impacted



Channel pair shading: Green=no overlap, Yellow=some overlap, Red=significant overlap

Licensed Upper 6GHz Band (U-NII-7), 10MHz Bandwidth

10MHz channels show 9 unimpacted and 7 significantly impacted



Channel pair shading: Green=no overlap, Yellow=some overlap, Red=significant overlap

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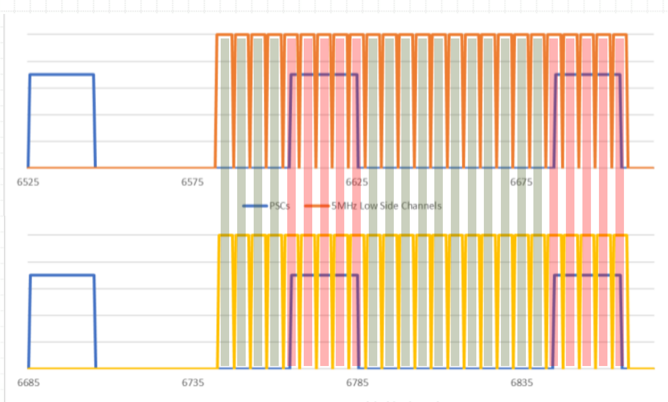
Licensed Upper 6GHz Band (U-NII-7), 5MHz Bandwidth

5MHz channels show 15 unimpacted and 10 significantly impacted



Channel pair shading: Green=no overlap, Yellow=some overlap, Red=significant overlap

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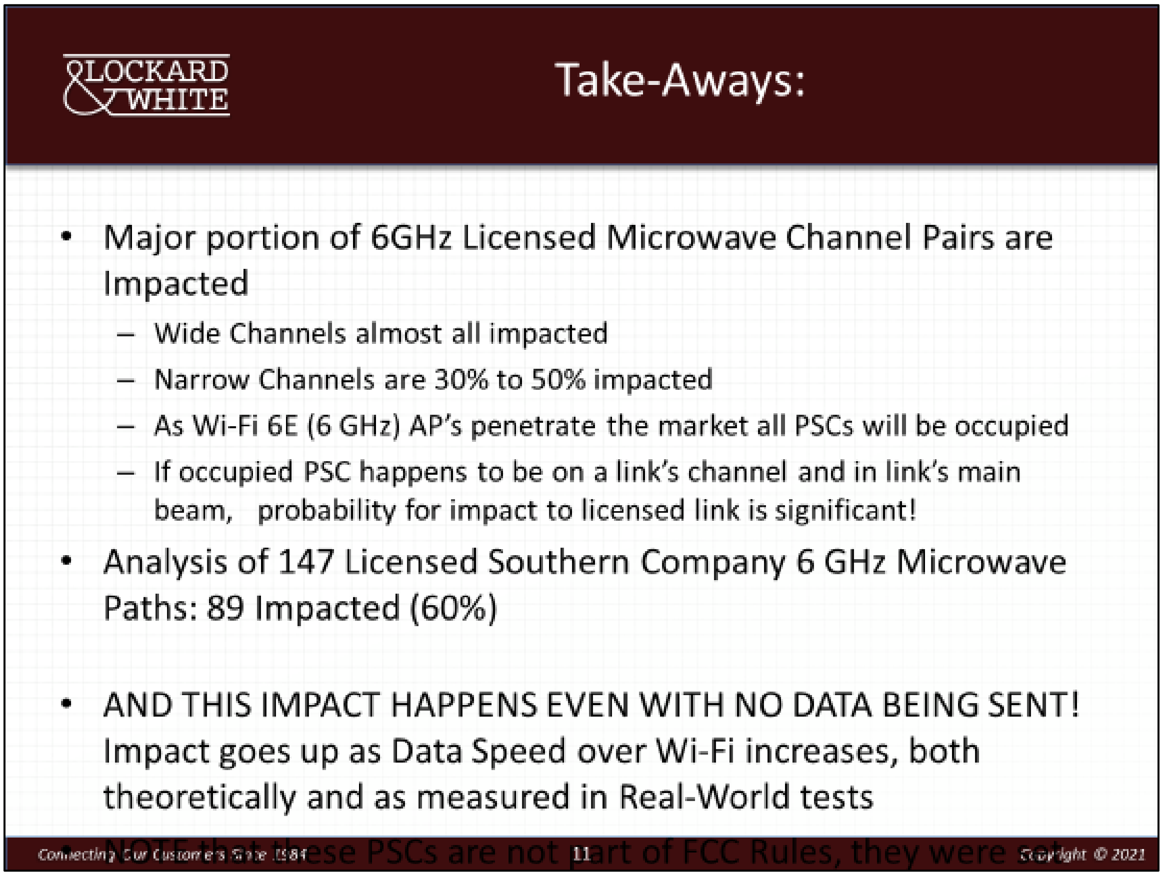
LOCKARD & WHITE
Take-Aways:
• Major portion of 6GHz Licensed Microwave Channel Pairs are Impacted
– Wide Channels almost all impacted
– Narrow Channels are 30% to 50% impacted
– As Wi-Fi 6E (6 GHz) AP's penetrate the market all PSCs will be occupied
– If occupied PSC happens to be on a link's channel and in link's main beam, probability for impact to licensed link is significant!
• Analysis of 147 Licensed Southern Company 6 GHz Microwave Paths: 89 Impacted (60%)
• AND THIS IMPACT HAPPENS EVEN WITH NO DATA BEING SENT! Impact goes up as Data Speed over Wi-Fi increases, both theoretically and as measured in Real-World tests
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