HWG | HARRIS, WILTSHIRE & GRANNIS LLP

August 23, 2019

Ex Parte

Marlene Dortch, Secretary
Federal Communications Commission
445 12th Street SW
Washington, DC 20554

Re: *Unlicensed Use of the 6 GHz Band*, ET Docket No. 18-295; *Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz*, GN Docket No. 17-183

Dear Ms. Dortch:

On August 21, 2019, representatives of Broadcom, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Inc., Qualcomm Incorporated, Apple Inc., and Ruckus Networks, a Business Segment of CommScope, met with staff from the FCC's Office of Engineering and Technology. A complete list of attendees is attached. We discussed the attached presentation, which describes direct testing of real FS equipment performance in the presence of interfering RLAN signals. These tests confirm that FS receivers are robust and will not experience harmful interference from RLAN devices. Furthermore, these tests also confirm that even in extreme cases of unrealistically low FS signal-to-noise ratio and unrealistically strong RLAN interference, industry standard adaptive modulation, automatic transmit power control, and strong error correction features will limit the impact of this highly unlikely event to only a marginal, and momentary, decrease in FS link throughput.

Pursuant to the FCC's rules, I have filed a copy of this notice electronically in the above referenced dockets. If you require any additional information, please contact the undersigned.

Sincerely,

Paul Margie
Counsel to Apple Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, and Broadcom Inc.

Enclosure
Cc: Meeting Participants

MEETING PARTICIPANTS

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Michael Ha (FCC OET)
Ira Keltz (FCC OET)
Nicholas Oros (FCC OET)
Barbara Pavon (FCC OET)
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Alan Norman, Facebook Inc.
Matthew Stoneback, Facebook, Inc.
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Paul Margie, Harris, Wiltshire and Grannis LLP
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*Participated via telephone

6GHz FS/WiFi coexistence testing

21 Aug 2019

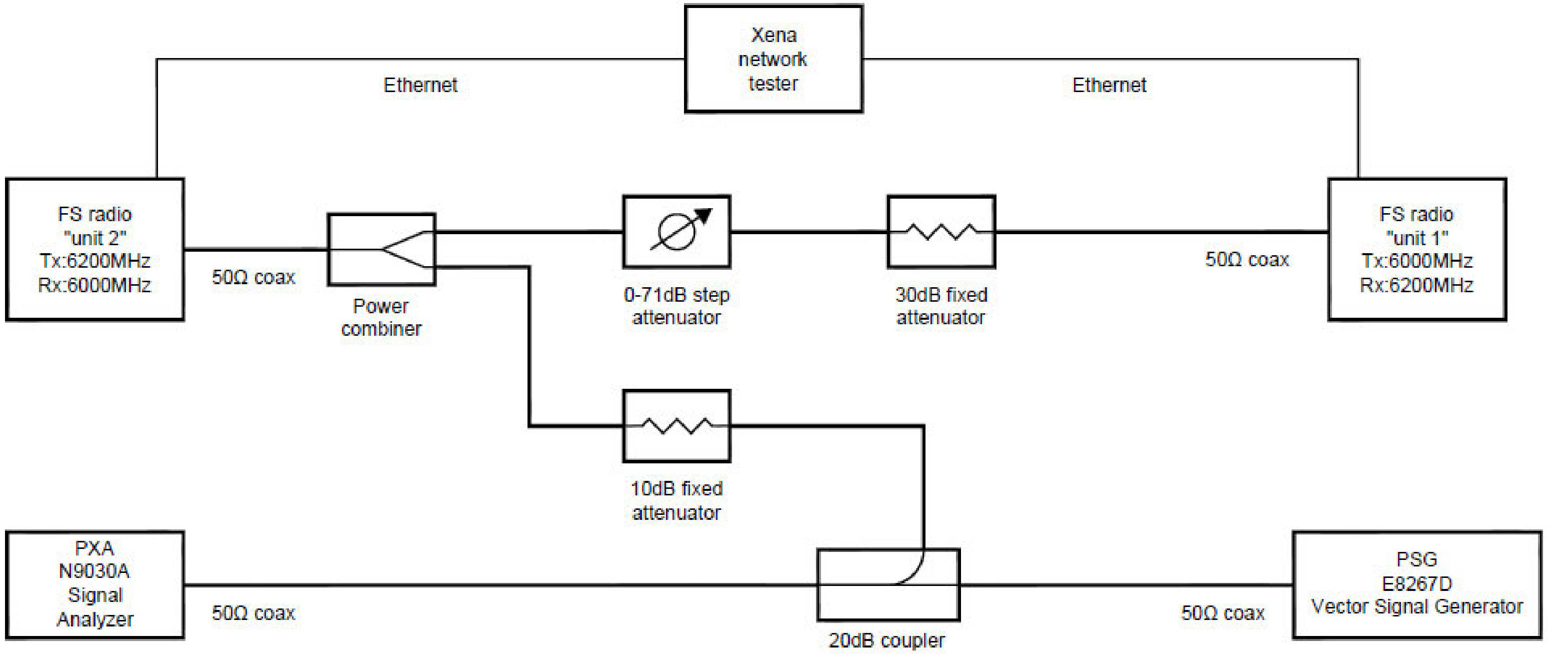
Introduction

- Using an experimental license, we have developed a lab test setup to study coexistence between fixed service (FS) and radio local network (RLAN) devices operating co-channel in the 6GHz band.
- These tests are designed to reflect scenarios where RLAN devices operate in the main beam of FS links or in close proximity to FS receivers. *These levels of noise at FS receivers are much stronger than typical expected use cases.*
- We tested RLAN interference levels -3dB I/N and found FS links to be very robust with little impact on FS performance.
- To better characterize performance thresholds for FS links we also subjected the FS radio to an interference level of 12dB I/N, which is well above the I/N levels that would be caused by RLAN operation. For these scenarios, the FS radio performed well even for the highest and most sensitive modulation.
- This work is intended to supplement multiple other technical analyses in the record by quantifying the effects of FS/RLAN interaction. The data presented can inform the Commission's interference analysis with actual measurements.
- Moreover, these measurements can be used to better understand the worst-case impact of low-power indoor (LPI) and very-low-power (VLP) (non-AFC controlled) RLAN devices on FS performance.
- **Bottom line: Operation of RLAN devices will not cause FS links to fail, even in the rare instances where they experience I/N levels significantly above -6dB.**

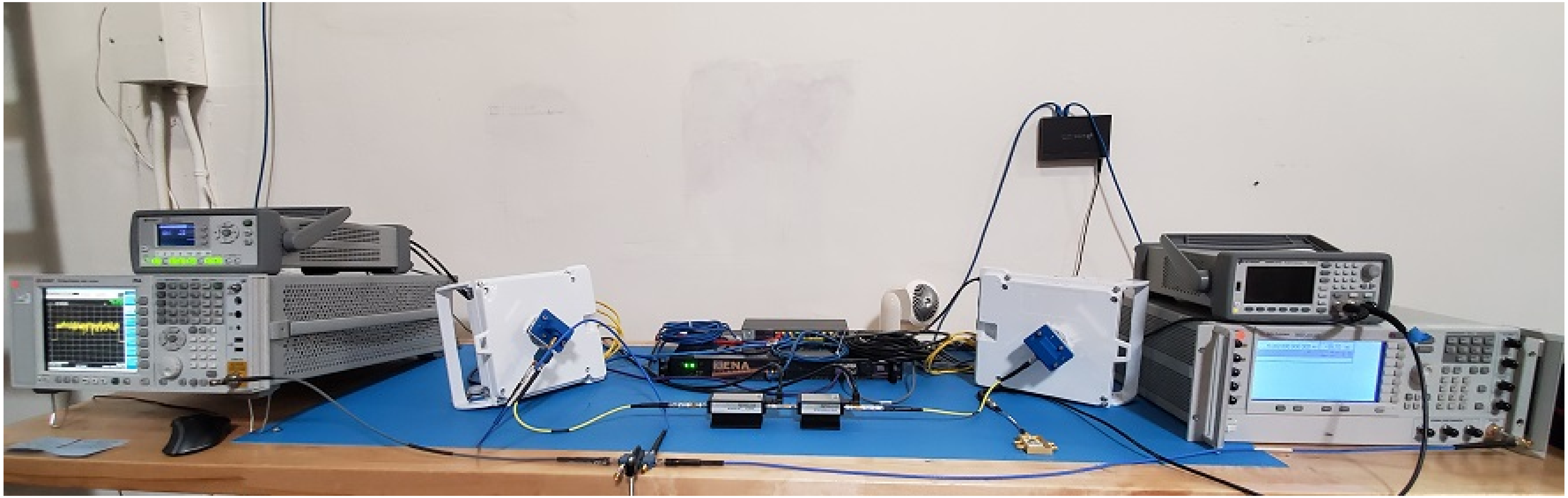
6GHz FS benchtop interference test block diagram & method

TEST METHOD

1. Connect an FS Tx with FS Rx through a variable attenuator on the bench. Observe the received signal level (RSL).
2. Couple a simulated RLAN interference signal with variable duty cycle and power into FS Rx.
3. Inject ethernet frames into the FS link and compare frame ingress at FS Tx with frame egress at FS Rx to obtain frame transfer rate (FTR).
4. Vary attenuation between FS Tx and FS Rx to achieve a range of RSL. Vary duty cycle and power of the simulated RLAN.
5. Repeat frame transfer test and capture the FTR at each test point.



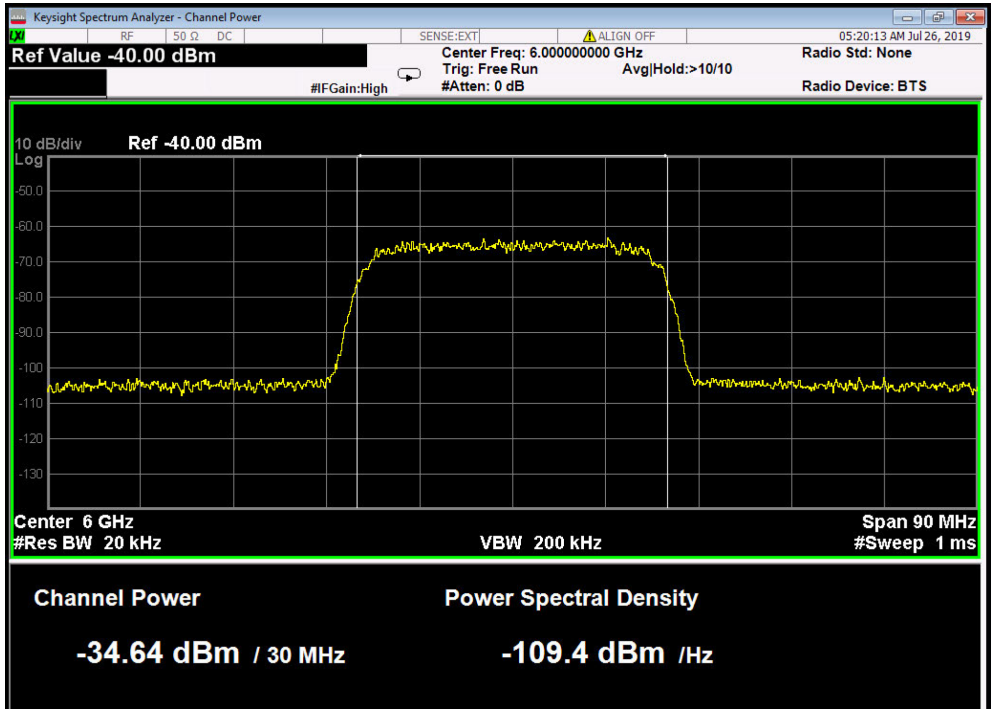
6GHz FS benchtop interference test picture



Benchtop interference test implementation using a vector signal generator

FS radio benchtop test configuration

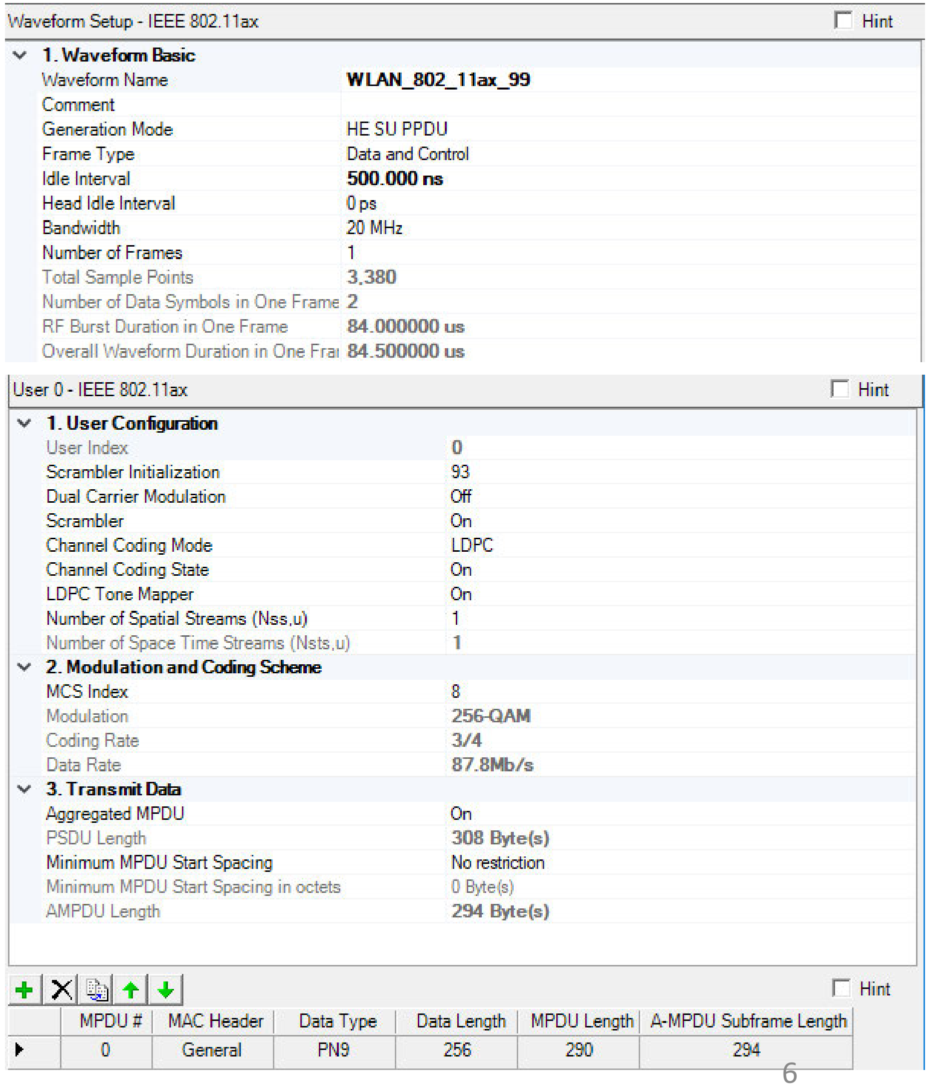
- The FS radio that was tested is representative of a large percentage of modern 6GHz FS radio equipment.
- FS radio parameters:
    - “Unit 1” to “Unit 2” = 6000MHz
    - “Unit 2” to “Unit 1”= 6200MHz
    - Bandwidth = 30MHz
    - Minimum constellation density = 4QAM
    - Maximum constellation density = 2048QAM
    - Configurable Power control (ATPC) and Adaptive Coding Modulation (ACM)



Representative power spectral density

RLAN interferer operating in 6GHz band

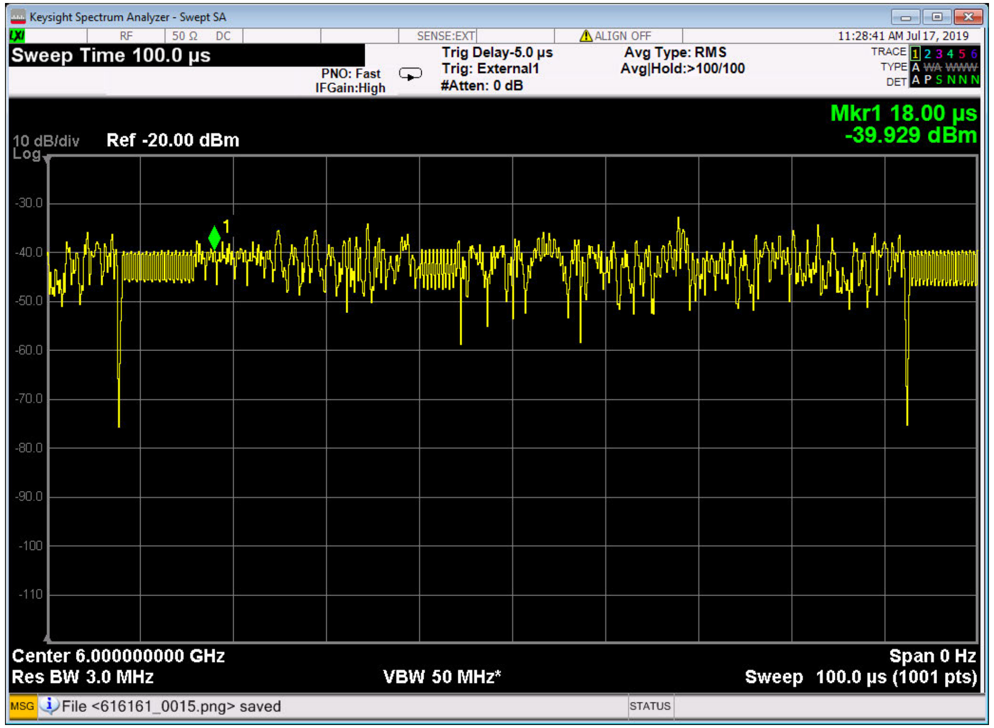
- The RLAN is simulated using a Keysight signal generator to generate RLAN waveforms.
- The center frequency is 6000MHz and the bandwidth is 20MHz so that the RLAN interference is completely contained within the FS receiver passband.
- The duty cycle of the RLAN waveform is controlled by varying the *idle interval*:
    - Idle interval = **0.5µs**; duty cycle ≈ **100%**
    - Idle interval = **756µs**; duty cycle = **10%**
    - Idle interval = **8316µs**; duty cycle = **1%**
- The power of the simulated RLAN is calibrated using a signal generator (see following slide).



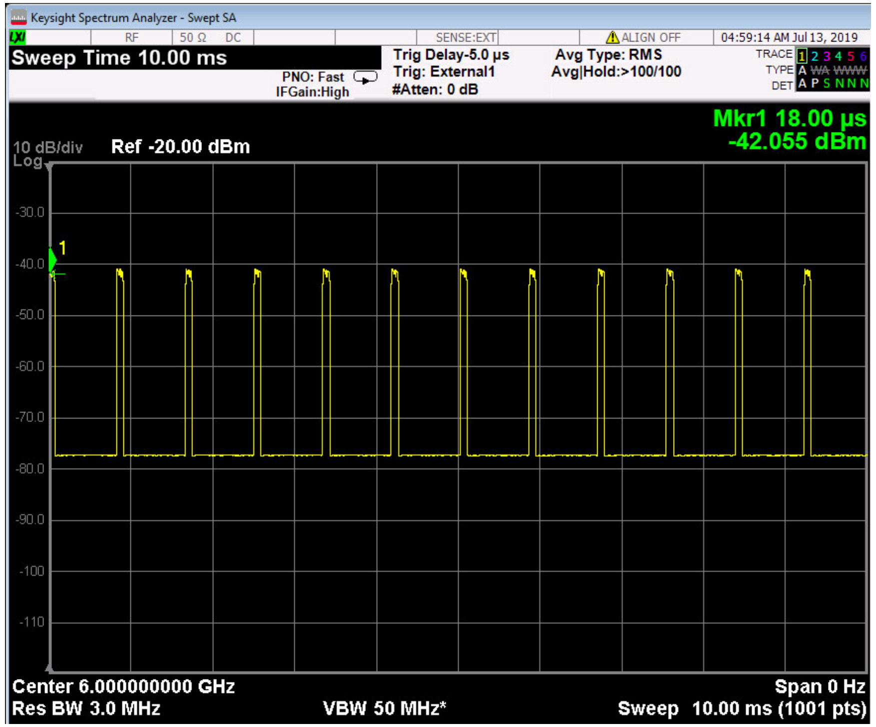
Calibrating the power of the simulated RLAN

- The simulated RLAN power is calibrated to a reference plane at the output of the power combiner.
- Signal analyzer settings:
  - Mode = **Zero Span**
  - Frequency = **6000MHz**
  - Sweep time = **100µs**
  - Trigger offset = **-5µs**
  - Resolution bandwidth = **3MHz**
- An arbitrary marker location (18µs) is chosen as a constant place to monitor the power spectral density for each waveform.

Continuous RLAN interference



10% duty cycled RLAN waveform



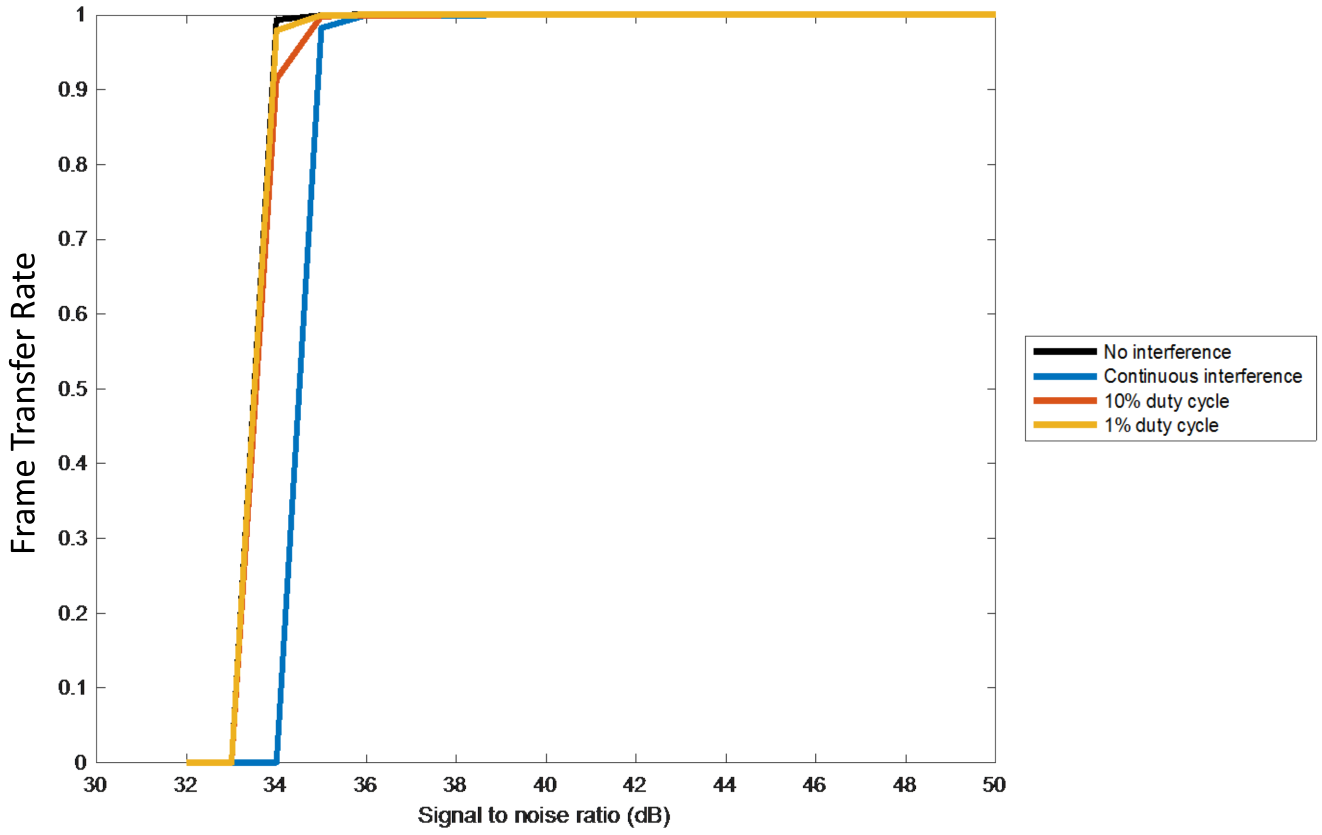
Note: The 10% duty cycle is unrealistically high compared to expected duty cycles for RLAN.

RLAN impact on FS radio is extremely limited at interference of -3dB I/N even for highest and most sensitive modulation

Observation: -3dB I/N is equivalent to 1.75dB margin reduction, which matches our results for continuous interference. RLANs, which transmit intermittently, have significantly smaller impact on link margin.

Actual FS links operate at an SNR far higher than 35dB, which represents the minimum SNR for the tested modulation — most have 40-50dB of additional margin beyond that minimum. Nonetheless, even just above the minimum SNR of 35dB, our testing shows that interference at -3dB I/N will not cause link outages.

Note that this result does not include the effects of adaptive modulation, transmit power control, and other measures that will make the link even more robust to interference.



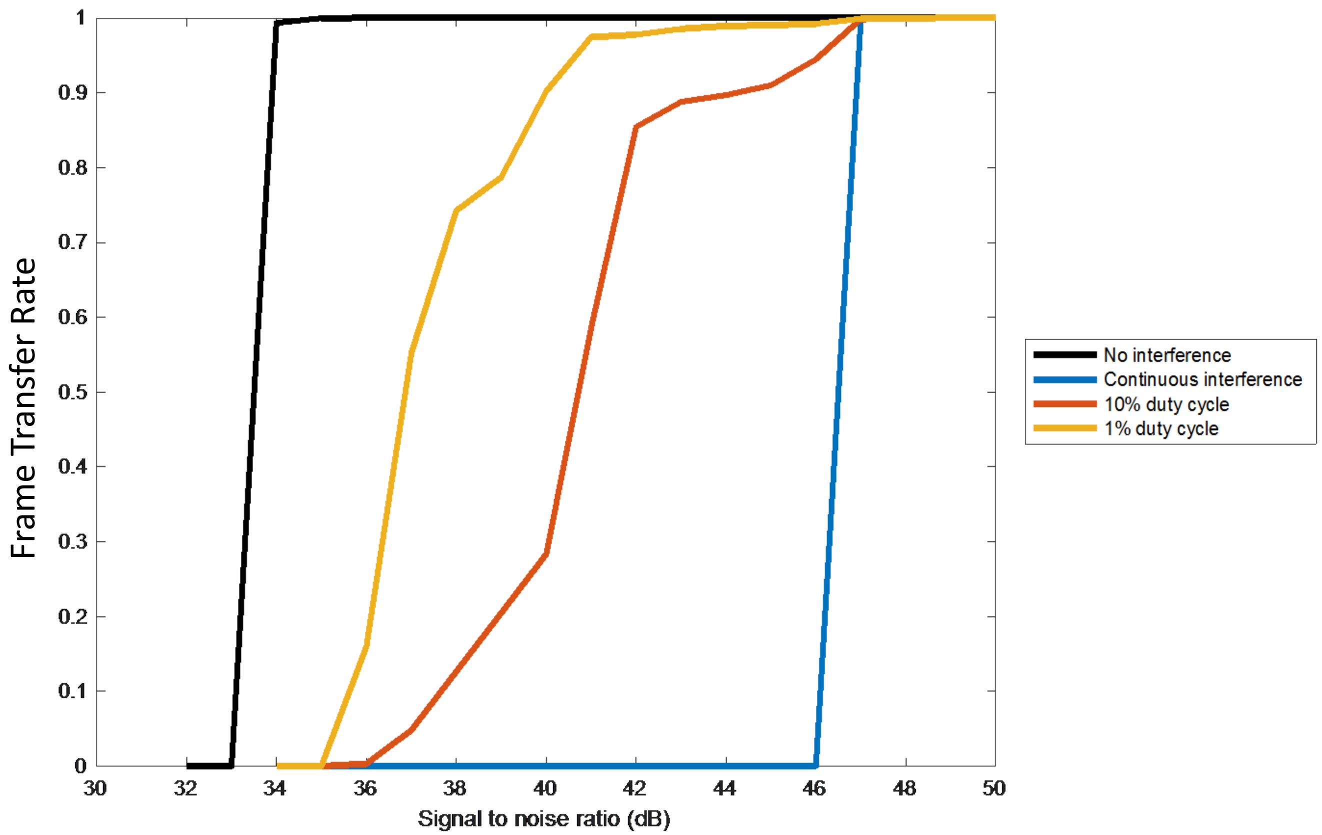
RLAN interference I/N = -3dB: 2048QAM; ACM off; ATPC off

FS radio continues to function at I/N = 12dB even for highest and most sensitive modulation

Observation: +12dB I/N is equivalent to 12.3dB margin reduction, which matches our results for continuous interference. RLANs, which transmit intermittently, have a significantly smaller impact on frame transfer rate.

Here, our testing shows that even a strong interferer at 12dB I/N will cause no degradation to FS receivers with more than 48dB SNR. Real-world FS receivers have a far higher SNR. And below 48dB SNR, our testing shows that even strong interference—far beyond any likely RLAN interference levels—is unlikely to cause link outages.

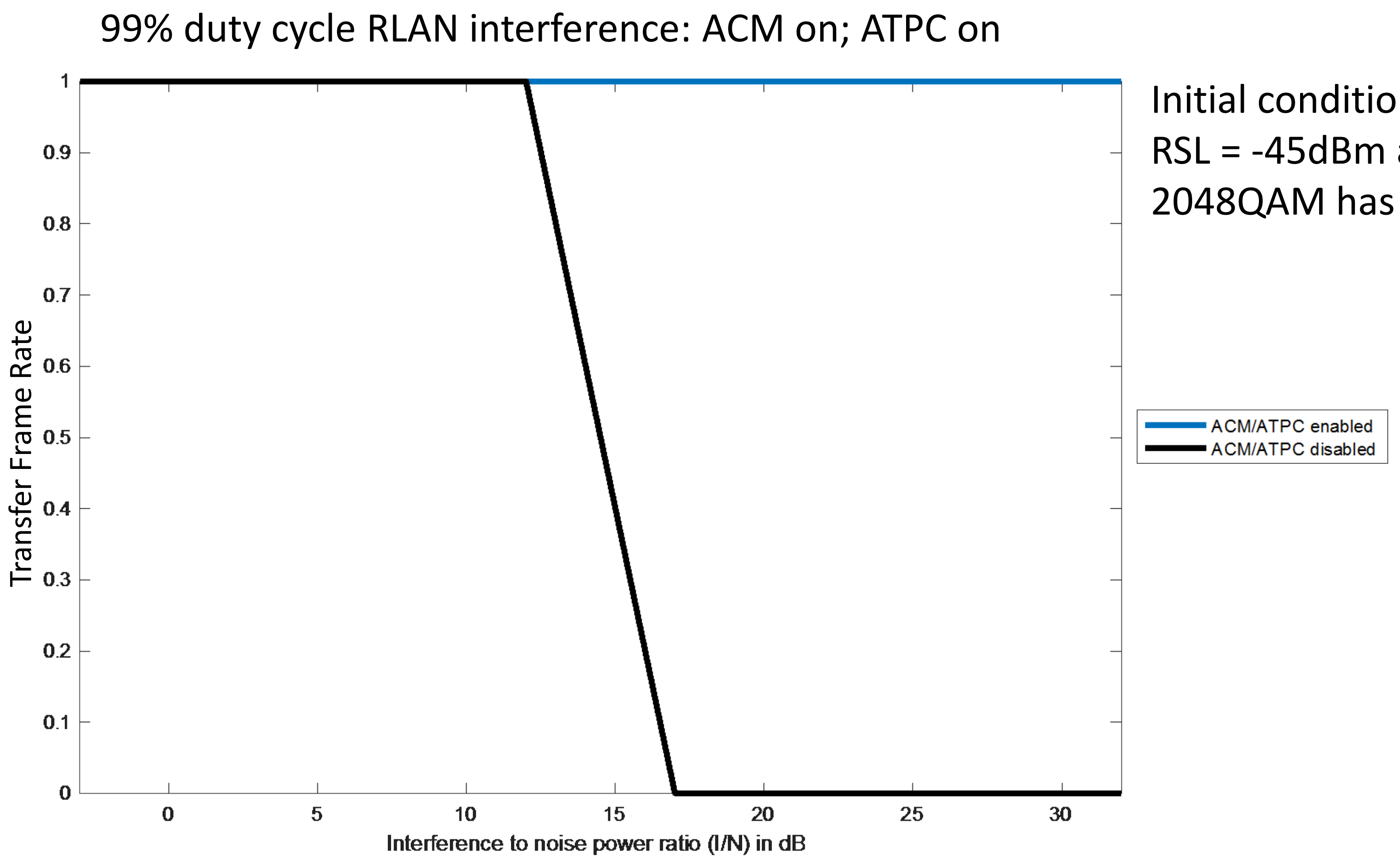
Note that this result does not include the effects of adaptive modulation, transmit power control, and other measures that will make the link even more robust to interference.



RLAN interference I/N = +12dB: 2048QAM; ACM off; ATPC off

Continuous RLAN interference for range of I/N with ACM/ATPC on

Many FS radios support ACM and ATPC. For the nominal received power of -45dBm (2048QAM), a continuous increase of interference from -5dB below the noise floor to +30dB above the noise floor resulted in continuous operation of the FS radio with ACM and ATPC on.



Initial conditions:

RSL = -45dBm and Pint = -95dBm

2048QAM has excess of margin of 15dB

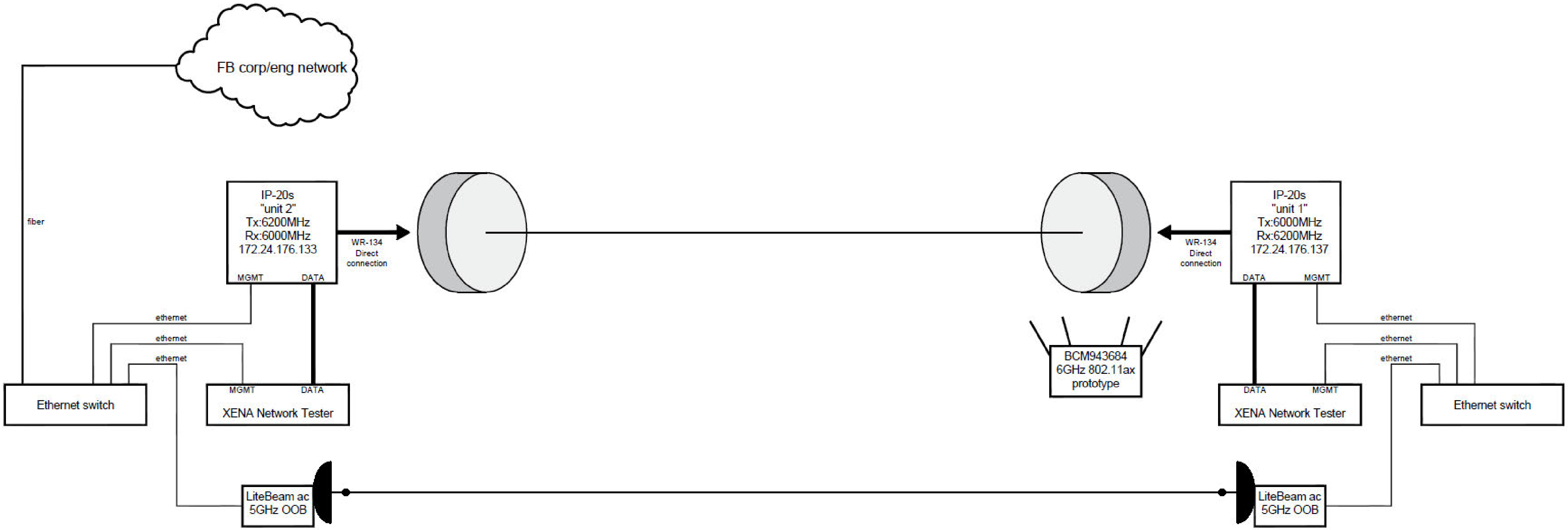
Conclusions from benchtop testing

- The performance of FS links in the presence of duty cycled RLAN interference, even where the I/N level is greater than -6dB, will not be significantly impaired.
- Commonly used equipment uses error-correction coding, which is resilient to high levels of interference.
- We will follow-up on these results, captured in a controlled lab environment, with over-the-air field measurements from a representative outdoor test range using functional prototype 802.11ax RLAN devices.
- RLAN operation, which has a duty cycle well under 10%, will have a small impact on the frame transfer rate of an FS link compared to equal magnitude interference at 100% duty cycle. The impact increases predictably as the duty cycle is increased.

FS outdoor testing in progress

A 2.5km line-of-sight link using FS radios operating in 6GHz

6GHz FS wireless interference test block diagram



6GHz FS link to be used for testing

View from FS installation "unit 1" on MPK 61 roof. MPK 12 is indicated by red arrow.

Satellite view highlighting 2.5km FS link MPK 12 to MPK 61

MPK 61 installation

View of FS installation "unit 1" on MPK 61 roof