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Wireline Access Network

Leakage Detection in a High-Split World: Industry Progress Toward a Viable Solution

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2021 Fall Technical Forum
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PAPER INTRODUCTION (ABSTRACT MOD) FOR REFERENCE

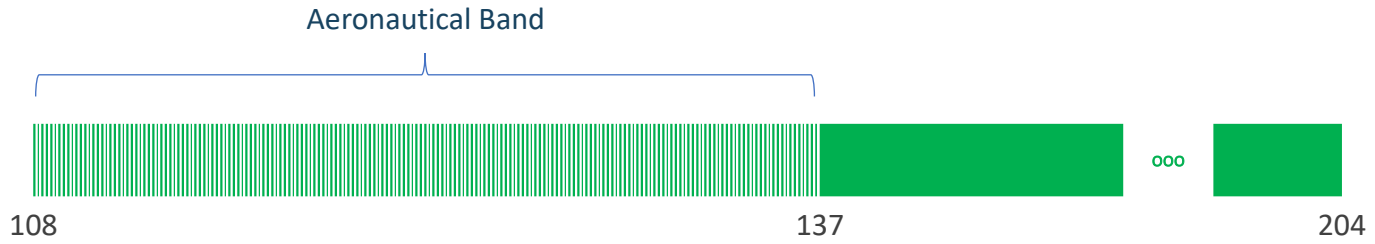
System leakage monitoring and detection in a Low-Split and Mid-Split world involves detecting leakage of transmissions originating from a CMTS, CCAP, R-MACPHY node and R-PHY node. Legacy methods for accomplishing this have been in place for many years and are well-understood.

In Low and Mid-Split scenarios, the aeronautical band from 108 to 137 MHz lies within the downstream spectral band. With DOCSIS® 3.1 High-Split and DOCSIS® 4.0 Ultra-High Split, the aeronautical band will fall within the upstream spectral band. As a result, system leakage monitoring and detection in High-Split and Ultra-High Split scenarios involves detecting leakage of transmissions that originate from a Cable Modem. This requires a completely new way of approaching the problem.

The cable industry has made significant recent progress analyzing the alternatives available to solve the High-Split and Ultra-High Split leakage detection problem, specifying the necessary support in industry standards, and validating in laboratory and controlled field environments. This paper will discuss progress that has been made on the most promising of these alternatives.

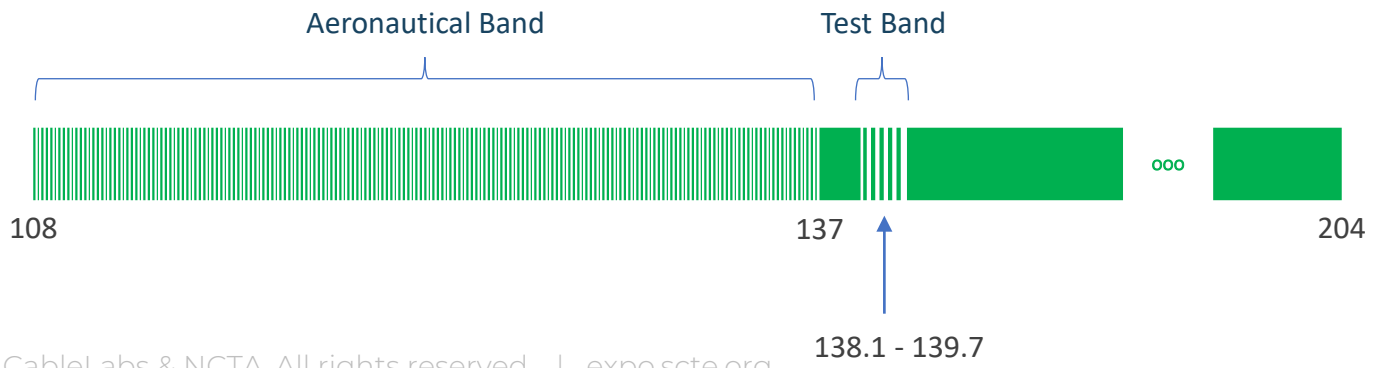
Problem Statement

- Aeronautical band is 108 to 137 MHz
- Downstream leakage detection signals today come from CMTS/CCAP/fiber node
  - Strength of signal is higher closest to CMTS/CCAP/fiber node
  - Plant is likely cleaner where signal is strongest
- Upstream leakage detection signals with High-Split need to come from CM
  - Strength of signal is higher closest to CM
  - Plant is likely most suspect where signal is strongest



Solution Approach - OUDP Test Bursts

- Configure OFDMA channel for optimal data transmission
- Select test region frequency band close to (NOT within) aeronautical band
  - Minimize spectrum in test region – 1.6 MHz/four minislots target
- Configure burst descriptors for test region with known, dense Pilot Pattern
- Configure leakage detection meters with test region frequencies, Pilot Pattern, …
- Schedule OUDP Test Bursts for DOCSIS 3.1 CMs in test region using these descriptors
- Go looking for leaks using field detectors designed with matched filters



Configuring for Leakage Detection

- OFDMA channel configuration supports test region definition

Parameter	2K FFT	4K FFT	Comments
Channel Start Frequency	108.50	108.50	Frequency of first active subcarrier in OFDMA channel (subcarrier# 74 | 148)
Channel Width	95	95	Range of active subcarriers within OFDMA channel (max 95 MHz)
Subcarrier Spacing (kHz)	50	25	
Symbols per Frame (K)	6	6	Range: 6-18 (2K FFT), 6-9 (4K FFT)
Cyclic Prefix	512	512	Value: 96, 128, 160, 192, 224, 256, 288, 320, 384, 512, 640
Pilot Pattern in Test Region	4	11	Configure in the Burst Descriptor for Test Region minislots (use IUC 13)
Test Region Start Frequency	138.10	138.10	Preferred frequency of first subcarrier of Test Region
Test Region Stop Frequency	139.70	139.70	Stop - Start should = multiple of 400 kHz (recommend 1.6 MHz, or 4 minislots)

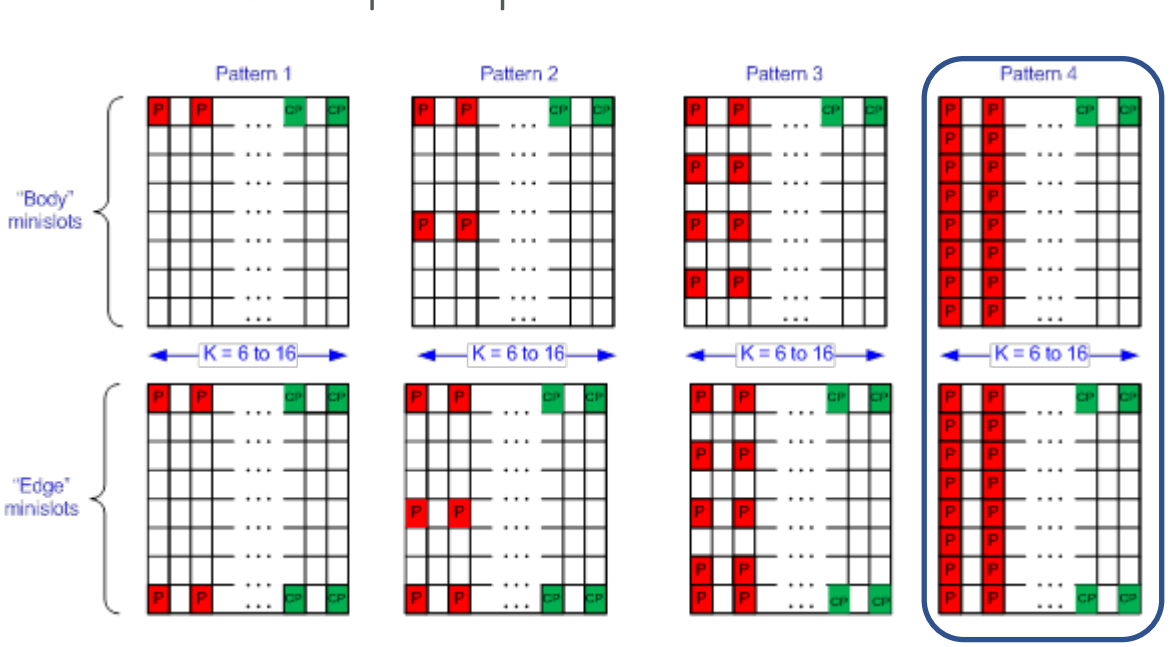
- Test session configurations support round-robin scheduling through lists of CMs

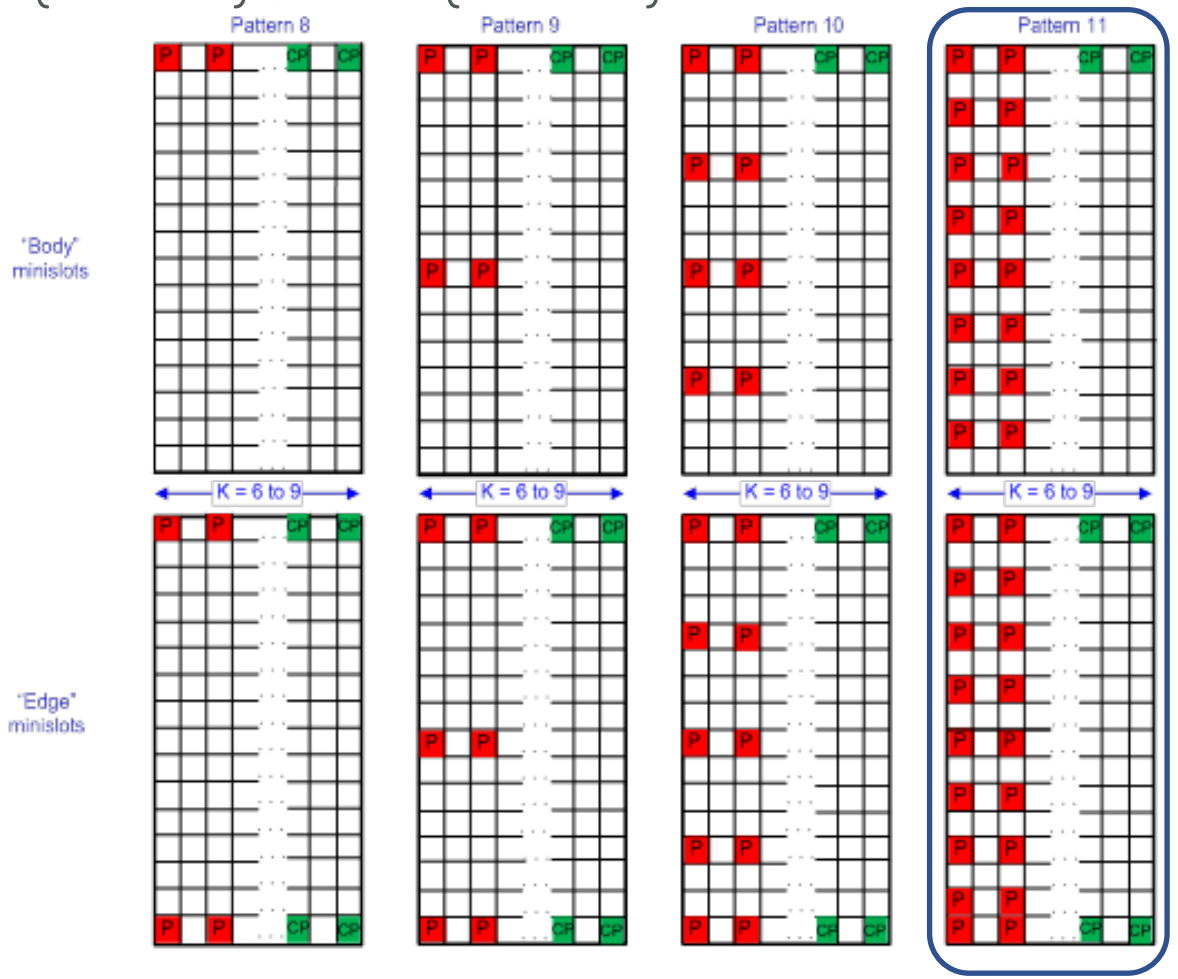
Parameter	2K FFT	4K FFT	Comments
Burst Duration per CM (Frames)	8	4	
Gap Between Cable Modems (Frames)	0	0	
Gap Between Cycles Through List (Frames)	8	8	Leave for Probe processing; each CM gets a full symbol in Probe frames

- Field detector configuration must align with OFDMA channel and test session configs

Pilot Patterns

- Densest pilot patterns are Pilot Pattern 4 (2K FFT) and 11 (4K FFT)





- Set for test region in burst descriptors

Scheduling Test Bursts

Time

Test Region Frequencies

MAP #1						MAP #2						P-MAP #1		MAP #3					
Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6	Frame 1	Frame 2	Frame 1	Frame 2	Frame 3	Frame 4	Frame 5	Frame 6
15	31	47	63	79	95	15	31	47	63	79	95			15	31	47	63	79	95
14	30	46	62	78	94	14	30	46	62	78	94			14	30	46	62	78	94
13	29	45	61	77	93	13	29	45	61	77	93			13	29	45	61	77	93
12	28	44	60	76	92	12	28	44	60	76	92			12	28	44	60	76	92
11	27	43	59	75	91	11	27	43	59	75	91			11	27	43	59	75	91
10	26	42	58	74	90	10	26	42	58	74	90			10	26	42	58	74	90
9	25	41	57	73	89	9	25	41	57	73	89			9	25	41	57	73	89
8	24	40	56	72	88	8	24	40	56	72	88			8	24	40	56	72	88
7	23	39	55	71	87	7	23	39	55	71	87			7	23	39	55	71	87
6	22	38	54	70	86	6	22	38	54	70	86			6	22	38	54	70	86
5	21	37	53	69	85	5	21	37	53	69	85			5	21	37	53	69	85
4	20	36	52	68	84	4	20	36	52	68	84			4	20	36	52	68	84
3	19	35	51	67	83	3	19	35	51	67	83			3	19	35	51	67	83
2	18	34	50	66	82	2	18	34	50	66	82			2	18	34	50	66	82
1	17	33	49	65	81	1	17	33	49	65	81			1	17	33	49	65	81
0	16	32	48	64	80	0	16	32	48	64	80			0	16	32	48	64	80

K Symbols per Frame

Configuration for this example:

- Test region start frequency = at start of Frame 1, “minislot” 6
- Test region end frequency = at end of Frame 1, “minislot” 9
- Ordered list of CM MAC addresses = CM 1, CM 2, CM 3
- Burst duration = 4 frames
- Inter-CM gap duration = default (none)
- Inter-cycle gap duration = 4 frames (example includes 2 Probe frames in first gap)

	CM 1, SID X OUDP Burst
	CM 2, SID Y OUDP Burst
	CM 3, SID Z OUDP Burst
	Probe Grants
	IM, SM, Req, Data Grants

Leakage Detection Verification

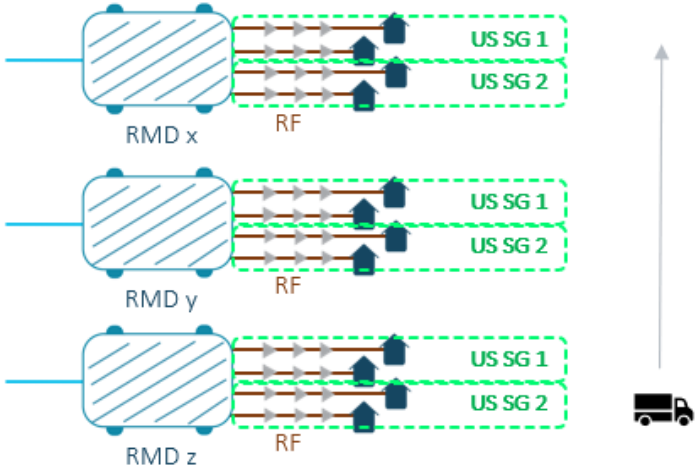
- In a perfect world there is no leakage detected
- Then what? How do you know and prove the testing was done and is working?

- We added metrics to do this…

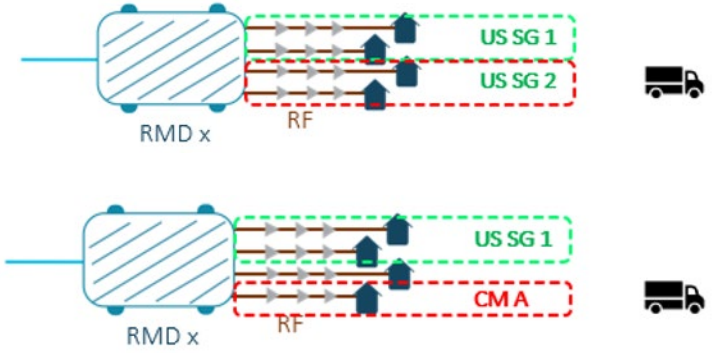
Attribute Name	Units	Description
NumBurstsGranted	Grants	Count of grants made to a Cable Modem's OUDP Test SID during a leakage detection test session
NumBurstsNotReceived	Bursts	Count of bursts not received for bursts that were granted during a leakage detection test session
NumTestBytesReceived	Bytes	Count of bytes received for grants made to Cable Modem's OUDP Test SID during a leakage detection test session

Leakage Detection Use Cases

- Sweep level test sessions
  - CMTS, CCAP, MAC Manager, RPD/RMD scope
  - OFDMA channel, test region configs must be common within session scope
  - Constituent test sessions independently controllable
    - Suspend/resume per US SG, MAC Domain, node

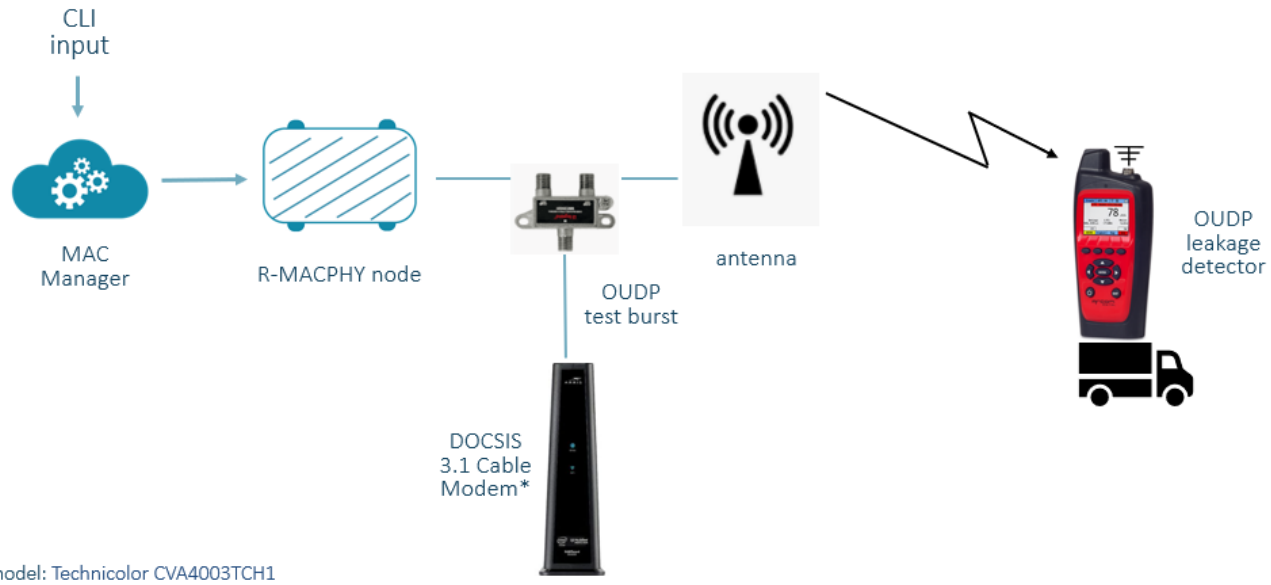


- Targeted test sessions
  - Single US SG, MAC Domain scope
    - Can specify CM MAC list for auto isolation
  - CM scope
    - Specific CM MAC address

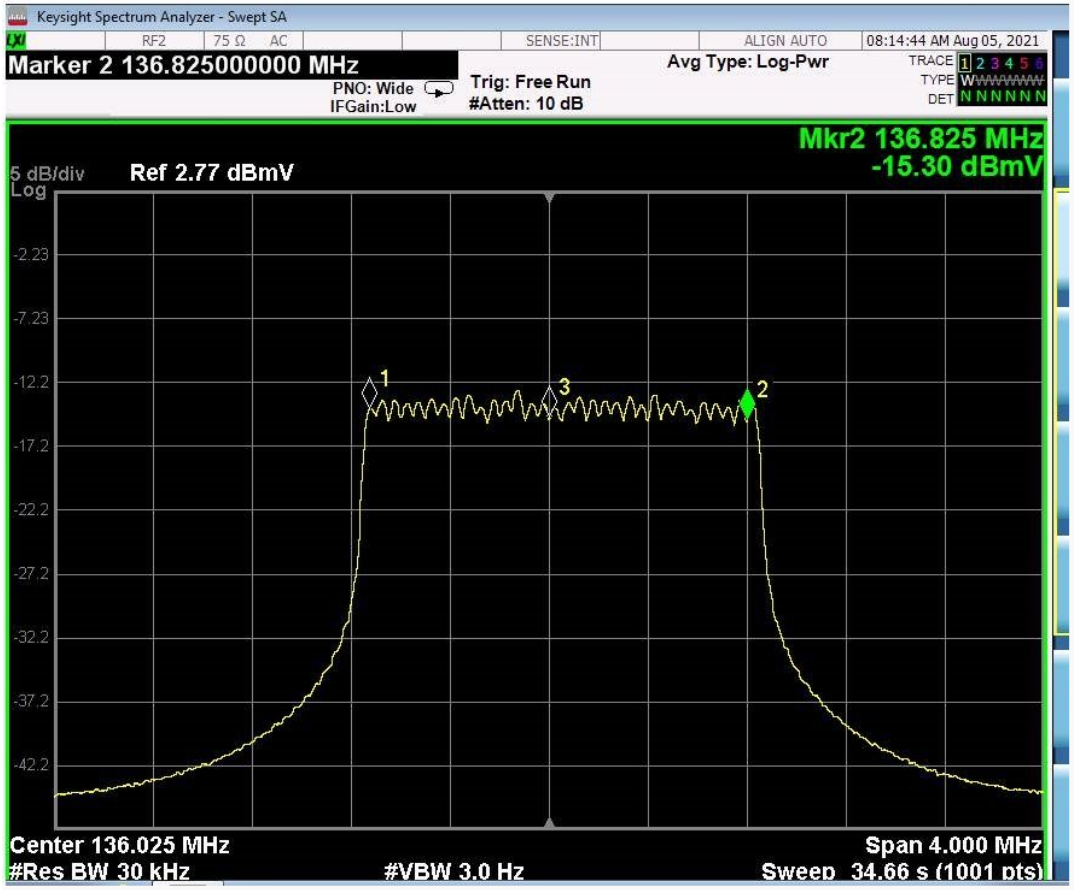


Leakage Detection Test Results

Test environment with leakage generation



* model: Technicolor CVA4003TCH1

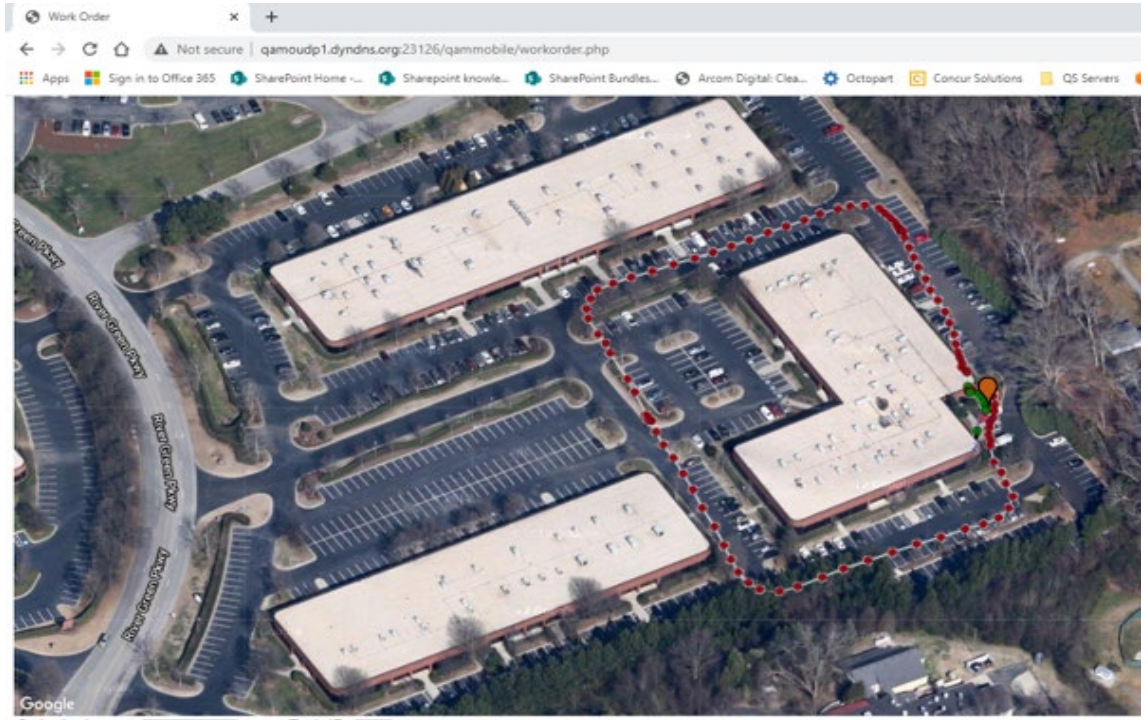


Spectrum analyzer view of test bursts

Leakage Detection Test Results

Leakage signal on in-vehicle field detector

Vehicular route used in drive-out testing



Conclusions

Standardized Leakage Detection Solution Unblocks High-Split and Ultra-High Split

- We picked a viable leakage detection solution – OUDP test bursts from CMs
- We published the solution in the CableLabs DOCSIS® 3.1 standard
- We tested the solution with a Vecima R-MACPHY node and an Arcom field detector
- We verified the solution works
  - Nodes schedule OUDP test bursts
  - Cable Modems transmit OUDP test bursts
  - Field detectors detect leaks based on known Pilot Pattern
- We are evolving the solution to provide a tool chest of capabilities for operators
  - These tools enable solutions with as much or as little automation as needed

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Thank You!

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