



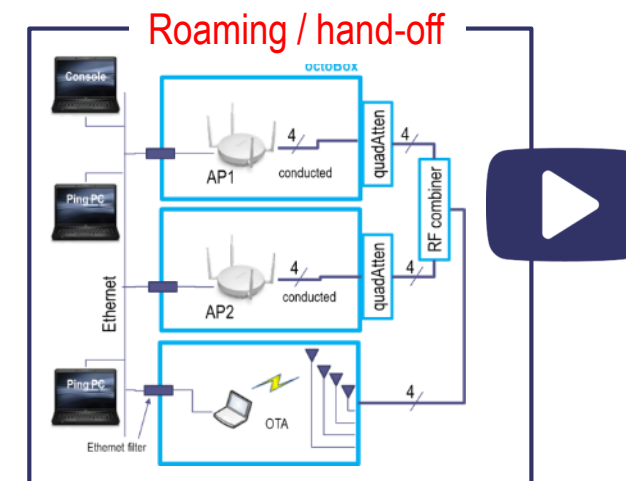
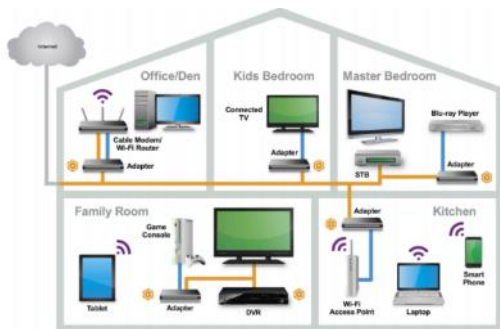
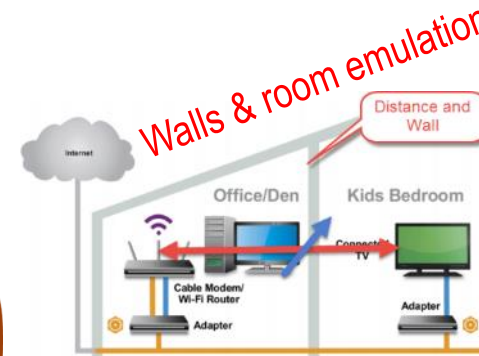
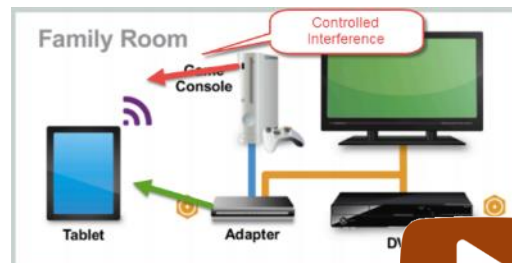
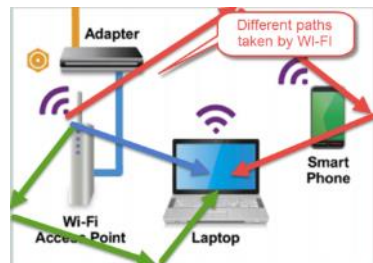
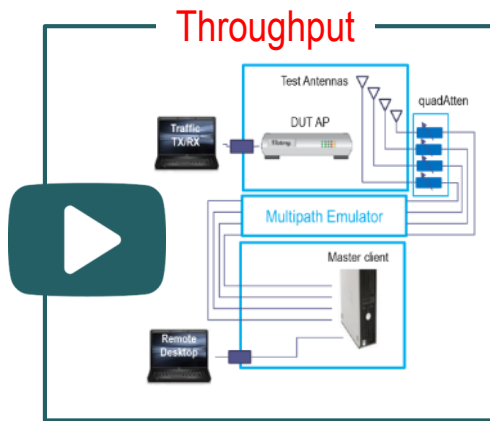
octoBox Wireless Testbed

December 2016

Fast, Automated, Repeatable



octoBox Testbed Summary



Video and multi-room emulation

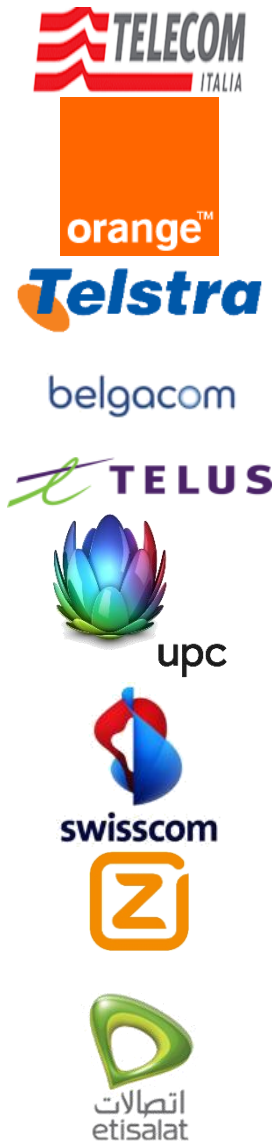
octoScope Customers

Operators

Labs

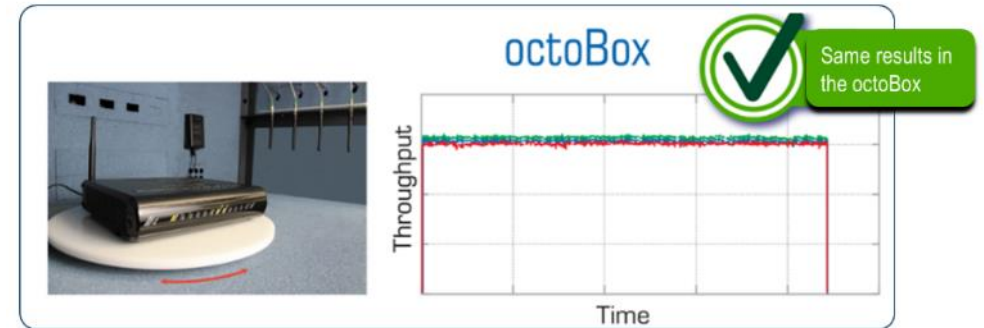
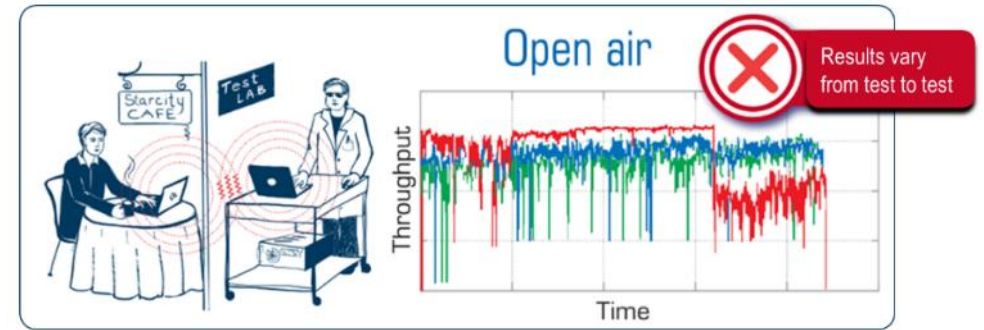
Chipset vendors

Equipment vendors



octoBox Benefits

- Reduce wireless test time from weeks to hours
 - Complete isolation and repeatable RF environment minimizes time-consuming open-air testing
 - Automation accelerates data collection, improves test coverage and product quality
- Demonstrate highest achievable performance
 - Ideal MIMO environment for highest possible throughput
 - Supports latest technologies, such as 160 MHz 802.11ac, 802.11ax, MU-MIMO, Beamforming, and beyond
- Demonstrate handling real-world challenges
 - Programmable range of condition from best MIMO environment to challenging real-life impairments



Wireless Test Applications

- Performance testing
 - MIMO OTA throughput
 - MU-MIMO gains
 - Load testing
 - Roaming
 - RX sensitivity
- Behavior testing
 - Adaptation to impairments, such as path loss, interference, multipath, load
 - Roaming behavior – find sticky clients
 - DFS (dynamic frequency selection)



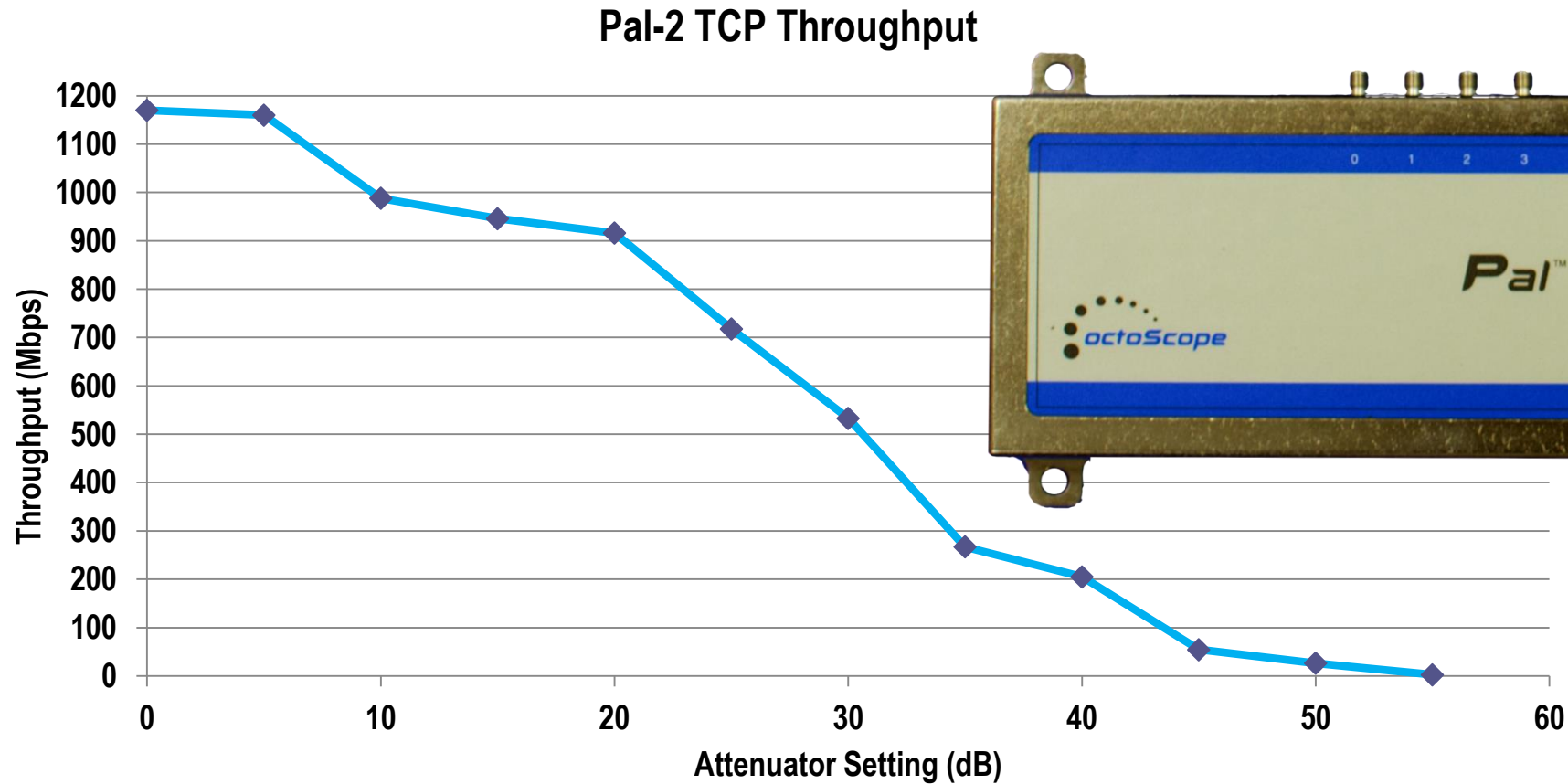
Pal-1 and Pal-2 Partner Devices

Throughput
Band steering
Roaming
Etc.



	Pal-1	Pal-2
MIMO OTA	X	X
MU-MIMO, beamforming		X
Channel width	20/40/80 MHz	20/40/80/80+80/160 MHz
AP	X	X
STA (client)	X	X
Virtual STA, vSTA	32	32
Traffic replay	X	X
Monitoring	X	X
2.4 GHz	X	
5 GHz	X	X

Pal-2 cabled to Pal-2 OTA Throughput > 1 Gbps



iGen live demo

<http://98.118.126.237:2227>

Pal live demo

<http://98.118.126.237:2228>

Key Wireless Test Capabilities

- ✓ Throughput performance
- ✓ Complete isolation
- ✓ Controlled interference
- ✓ Roaming behavior (sticky clients)
- ✓ Interoperability (vendor to vendor)
- ✓ Emulate a multi-room house



<https://www.youtube.com/watch?v=NYbUKICCNao>

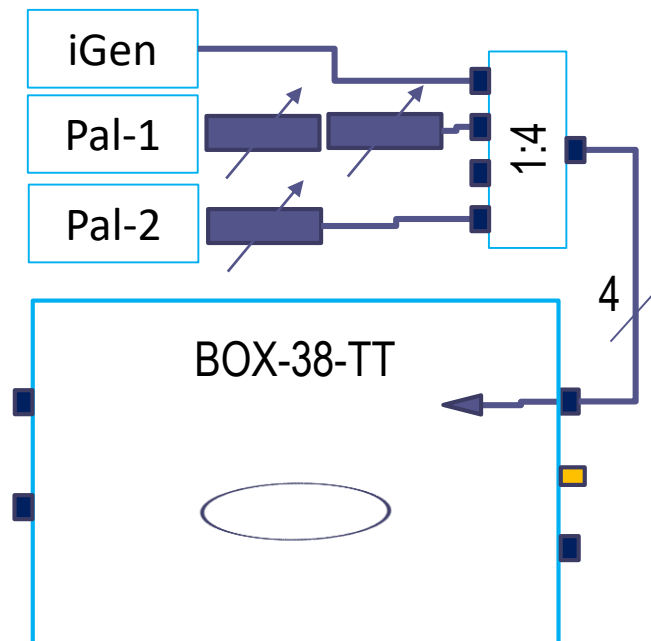
Throughput Test Video

- ✓ Throughput performance
- ✓ Complete isolation
- ✓ Controlled interference
- ✓ Roaming behavior (sticky clients)
- ✓ Interoperability (vendor to vendor)
- ✓ Emulate a multi-room house

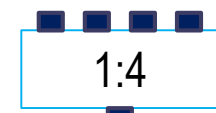







https://youtu.be/5_2spFW0laQ

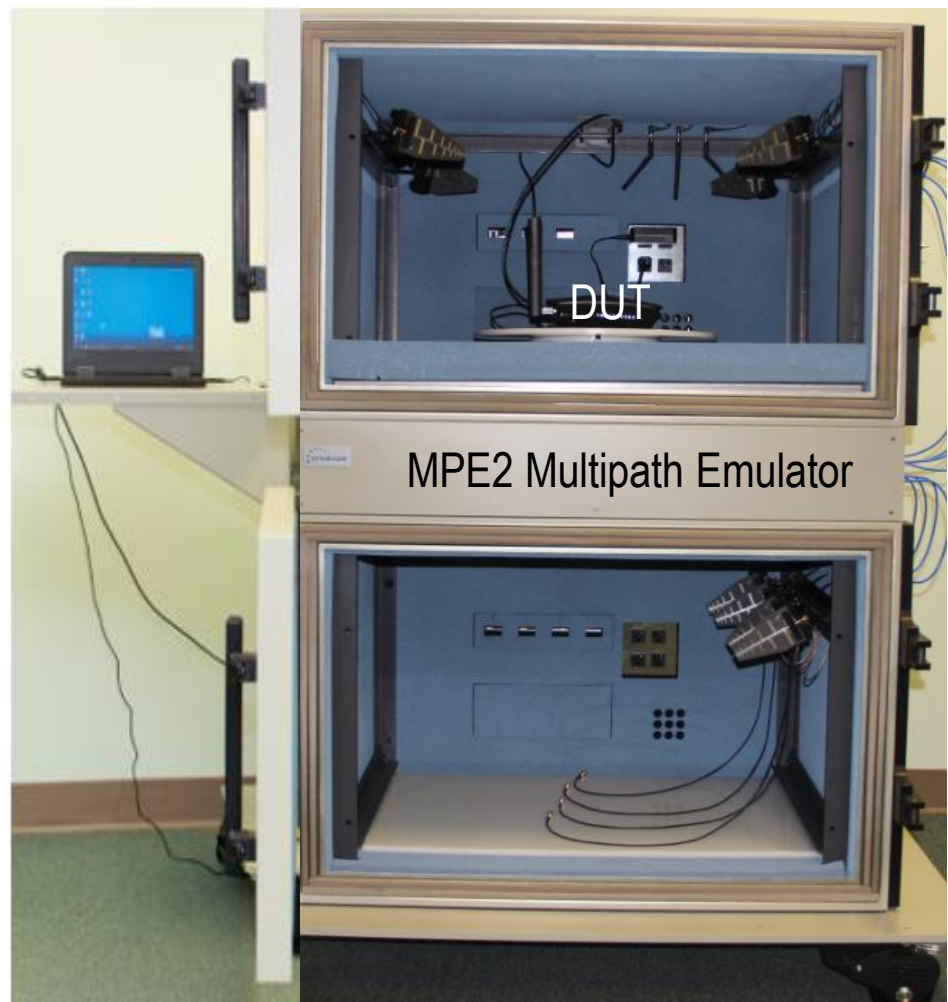
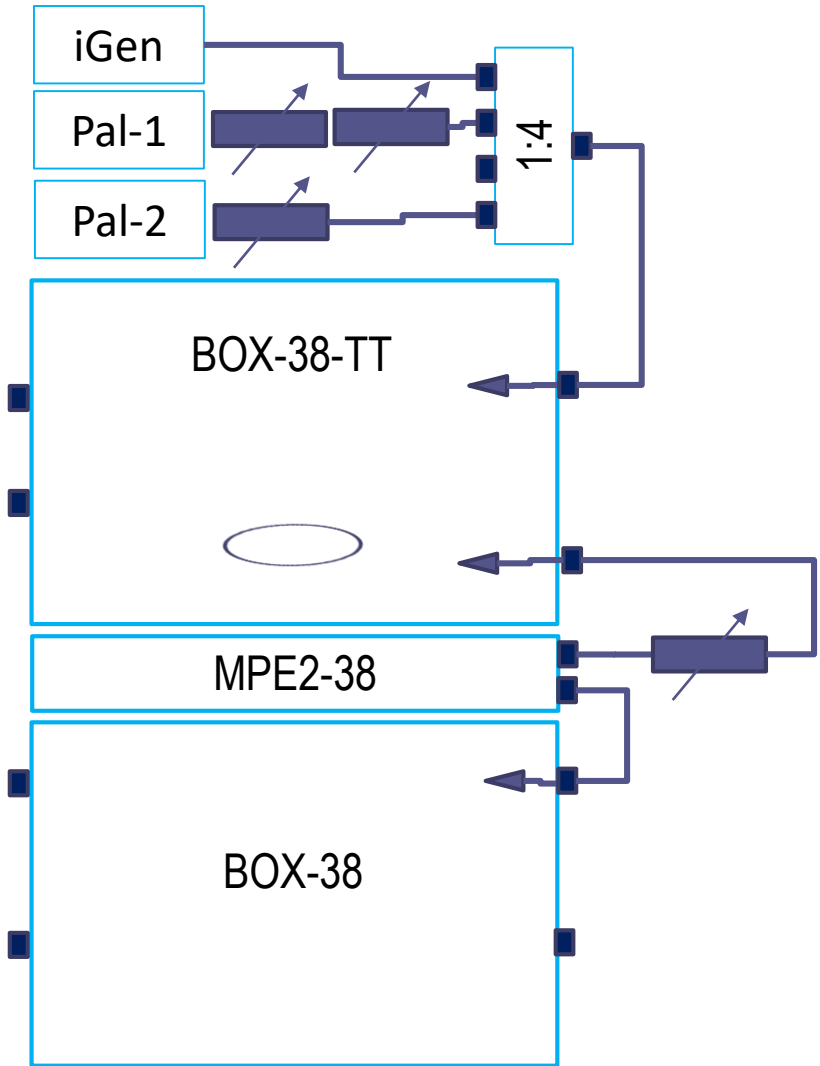
STACK-A Benchtop Testbed



Symbols

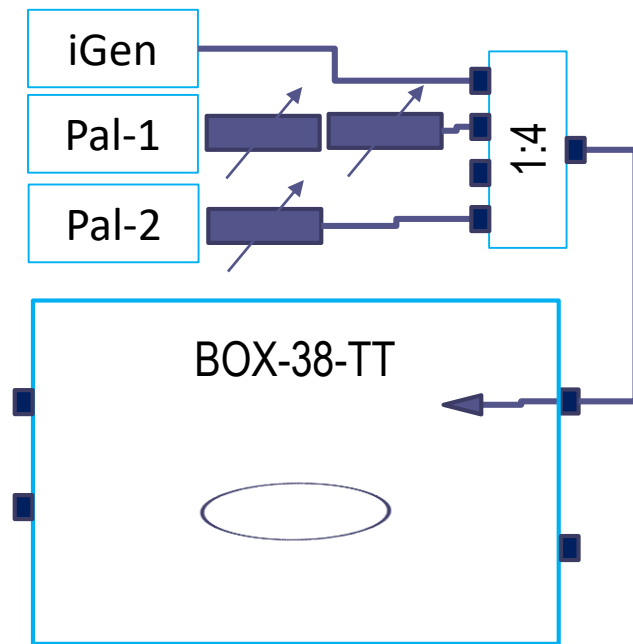
-  4x4 MIMO splitter
-  F connector
-  4 SMA connectors
-  4 high gain antennas
-  quadAtten
-  Turntable

STACK-B Testbed with Real Partners + Pals and iGens

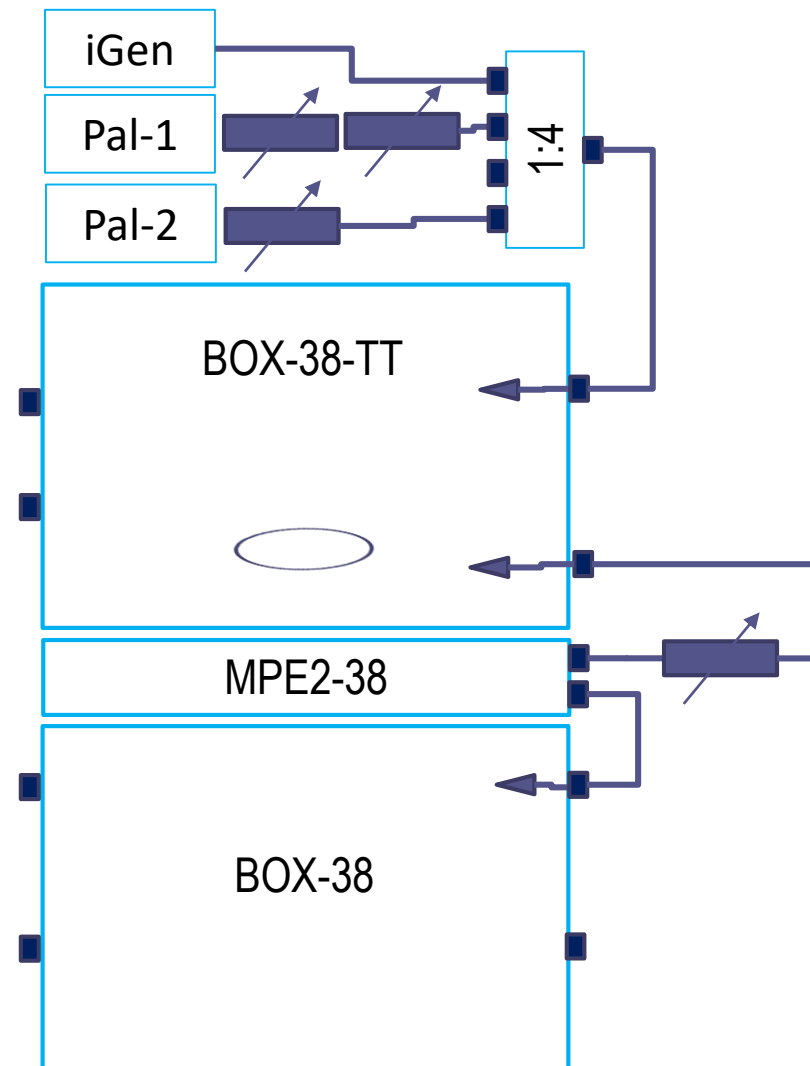


STACK Testbeds – Block Diagrams

STACK-A

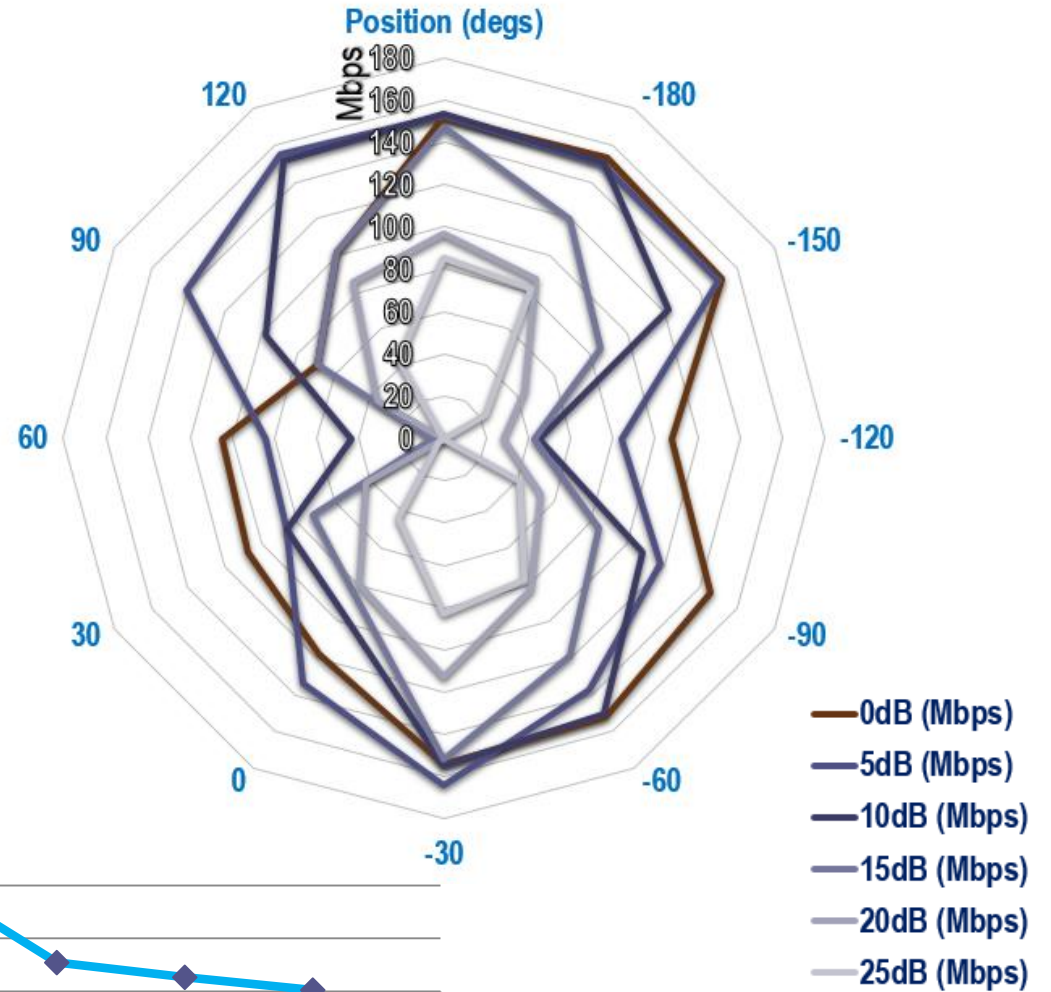
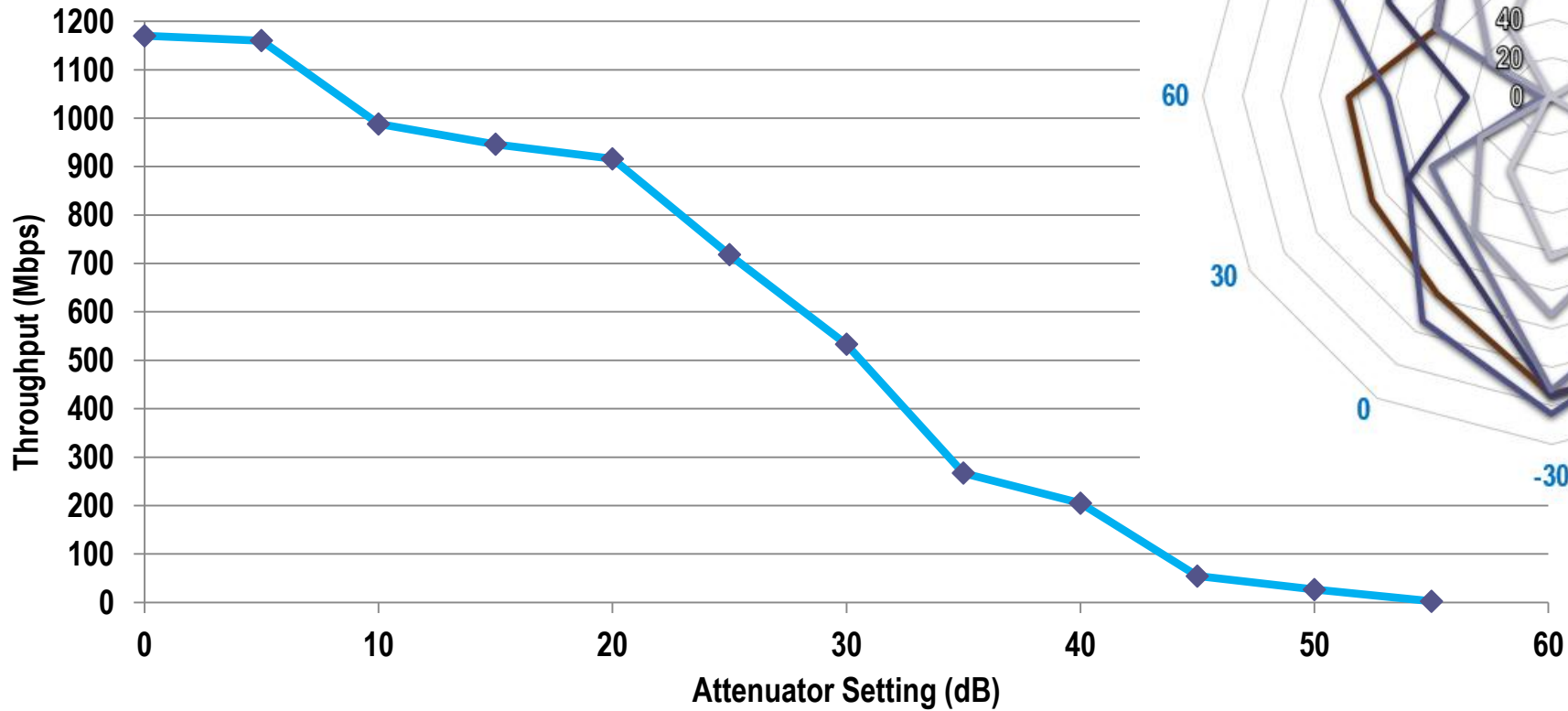


STACK-B



Throughput vs. Range vs. Orientation

Pal-2 TCP Throughput

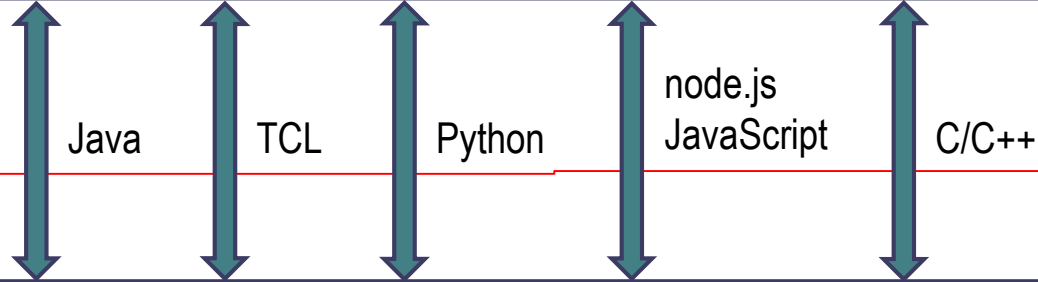


Software Stack

Applications



Testbed API



Device API

REST +
WebSockets



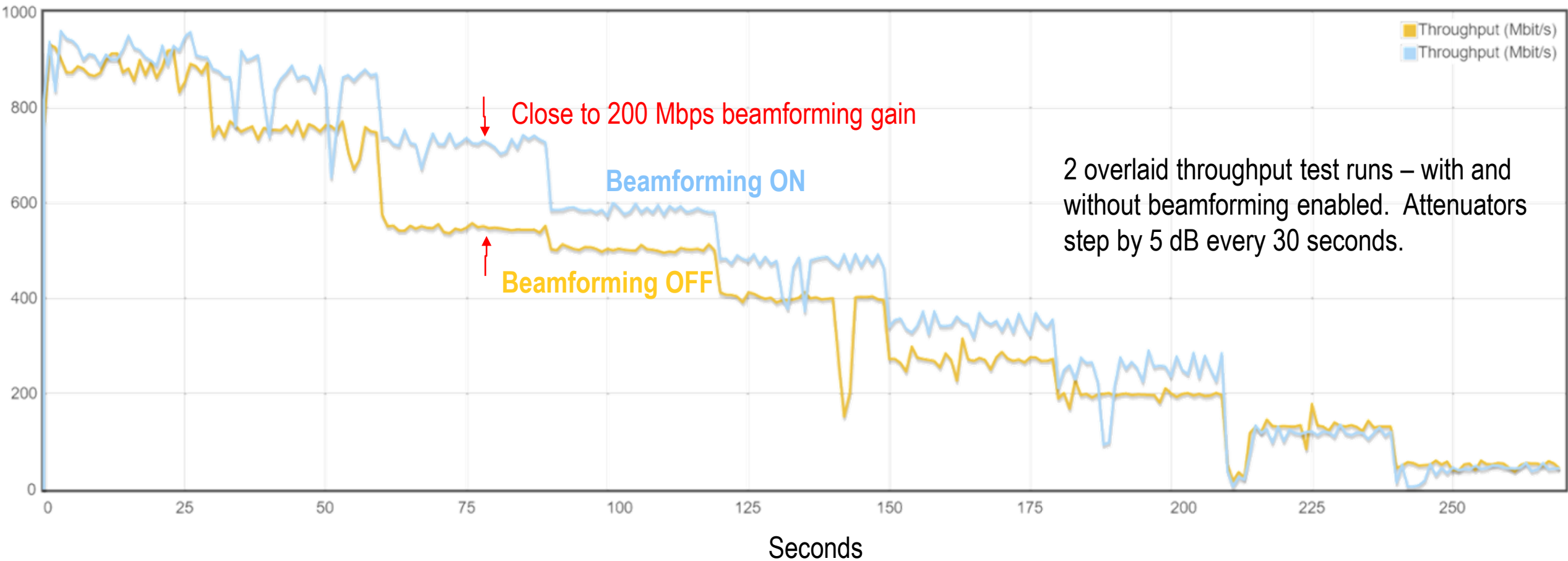
----- Under development

Throughput Script Browser Based User Interface

Configuration

Test Result

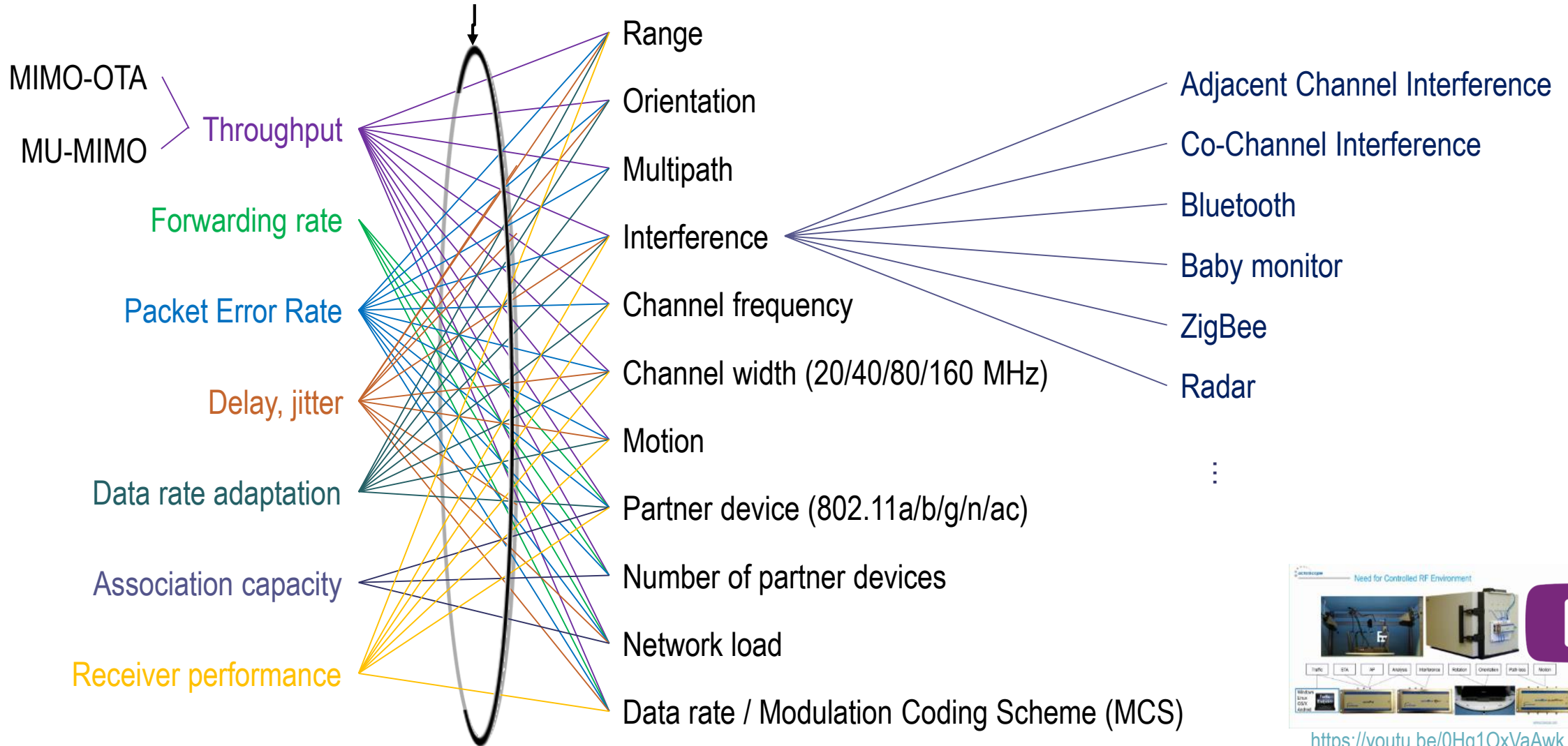
Mbps



2 overlaid throughput test runs – with and without beamforming enabled. Attenuators step by 5 dB every 30 seconds.

Tests Supported by the octoBox Testbed

Exponential number of tests vs. variables



MIMO = multiple input multiple output
 MU-MIMO = multi-user MIMO



<https://youtu.be/0Hq1OxVaAwk>

Tests Supported by the PAL Testbed

	Pal-1 (2.4 & 5 GHz)	Pal-2 (5 GHz only)	iGen
Throughput vs. range vs. orientation	Y	Y	
MU-MIMO and Beamforming		Y	
160 MHz channel width		Y	
Monitoring and analysis	Y	Y	
Fixed MCS vs. Range	Y	Y	
Traffic replay	Y	Y	
Channel adaptation (replay pcap traffic)	Y	Y	
Data rate adaptation*	Y	Y	
Roaming and band steering	Y	Y	
Receiver performance*	Y	Y	
Association capacity*	Y with vSTA	Y with vSTA	
Packet error rate*	Y	Y	
Forwarding rate*	Y with vSTA	Y with vSTA	
Delay and jitter*	Y	Y	

Add interference

* Software upgraded coming soon

The Pal Web Browser Menu

Linux Yocto OS

Mode	Access Point ▼
SSID	NETGEAR24-5G
Security	None ▼
Security Password	<input type="password"/>
IP Address	192.168.15.65
IP Subnet Mask	255.255.255.0
802.11 Interface	802.11ac ▼
Channel Width	80 MHz ▼
Guard Interval	Short ▼
MCS (Mbps/stream)	Adapt ▼
Primary Channel	36 (5180 MHz) ▼
Secondary Channel	<input type="text"/>



QCA9880 3x3 80 MHz

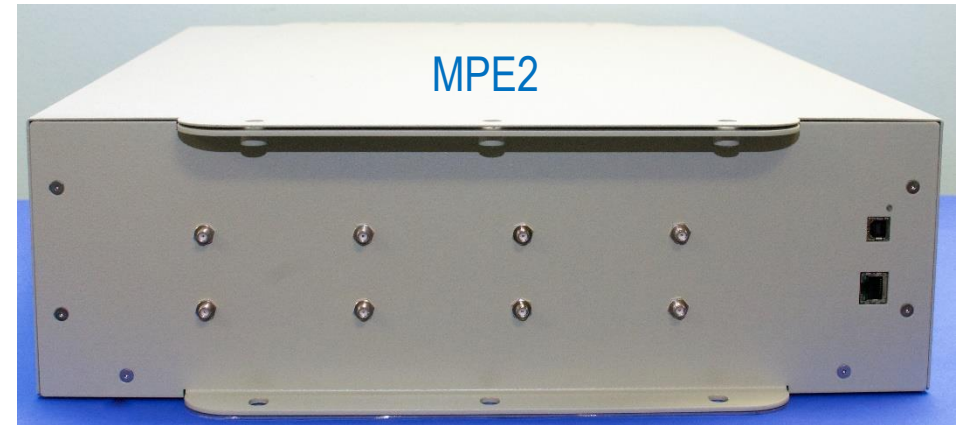


QCA9984 4x4 160 MHz

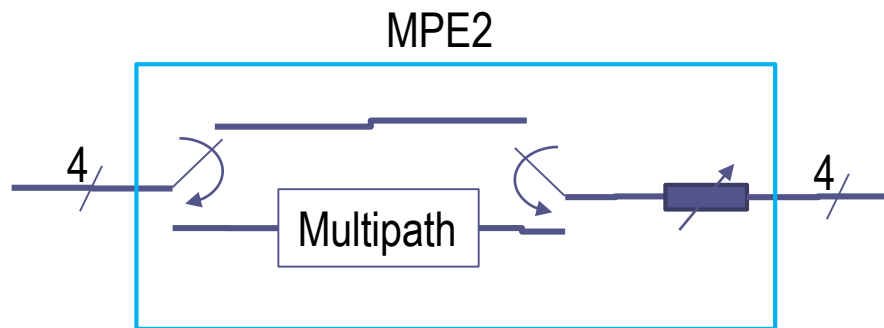
Priority (WMM)	Best Effort ▼
Maximum Number of Streams	3 ▼
Max aggregated frame size <small>1 to 1048575 bytes</small>	1048575
Beacon interval (ms) <small>40 to 2000 ms</small>	100
Fragmentation threshold <small>256 to 2346 bytes</small>	2346
RTS/CTS threshold <small>0 to 2347 bytes</small>	2347
Playback File	single_TCIPacket_3128B.pcap ▼
Inter-Packet Gap <small>0µsec minimum</small>	100 <input type="text"/> µsec ▼

Unique Patented Multipath Emulator (MPE) Technology

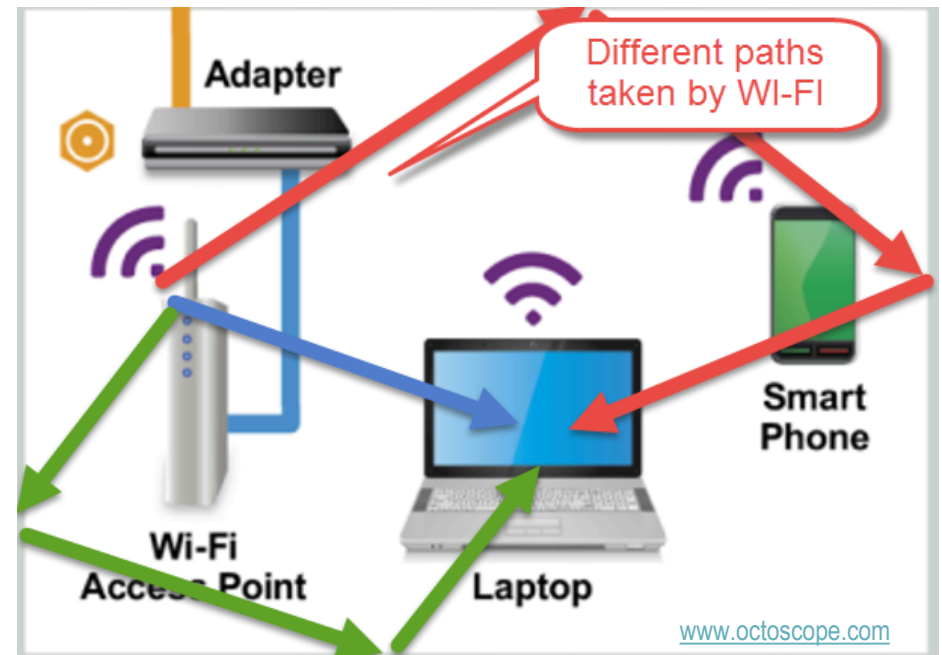
- Broadband (DC – 6 GHz) multipath emulator
- Accurately emulates a home channel model (IEEE 802.11 model B)
- Built-in bypass switch for LOS conditions
- Built-in programmable attenuators for range testing
- 4x4 MIMO link



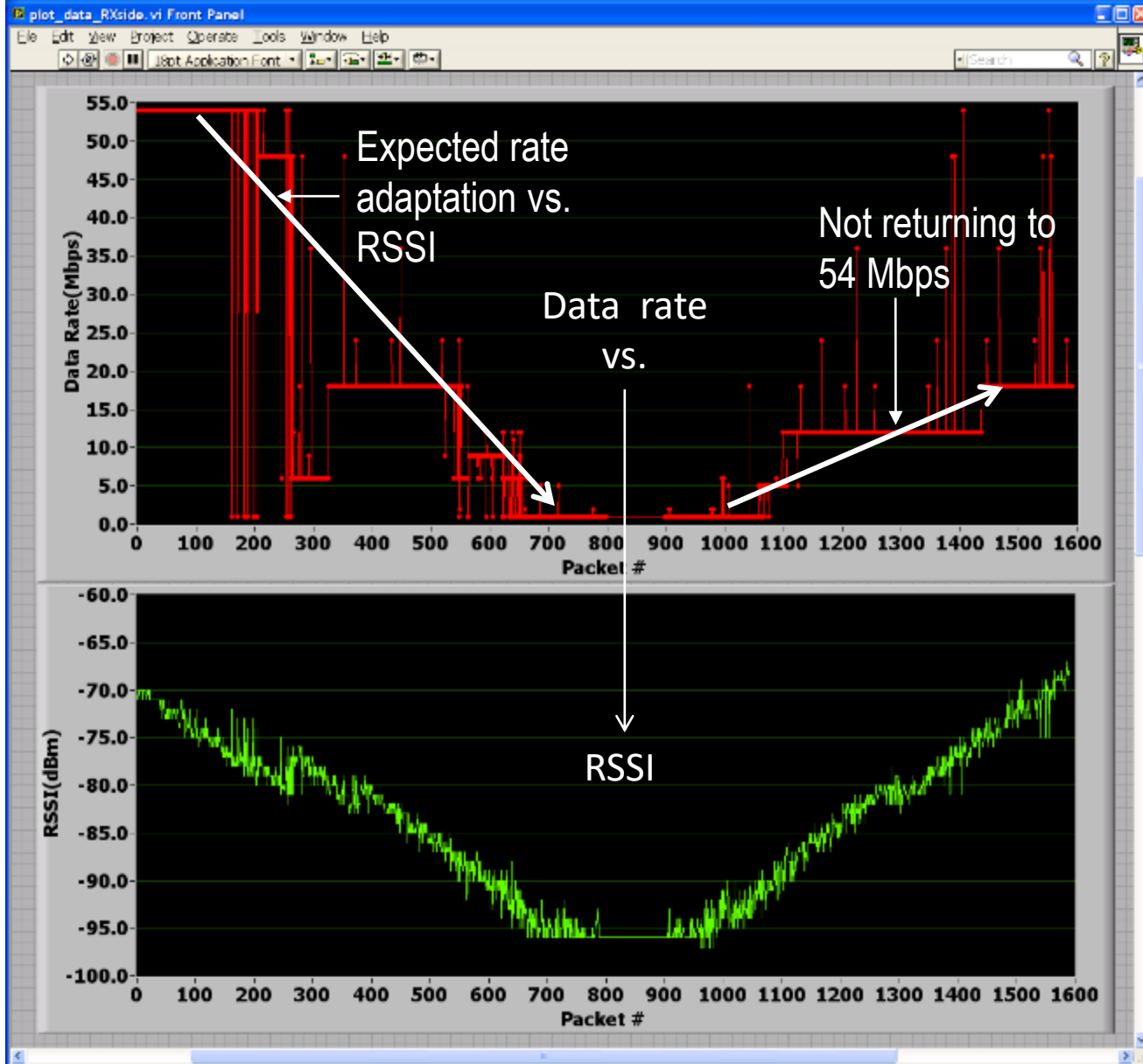
US Patent # 20140241408A1



LOS = line of sight



octoPal MCS / Data Rate Monitoring

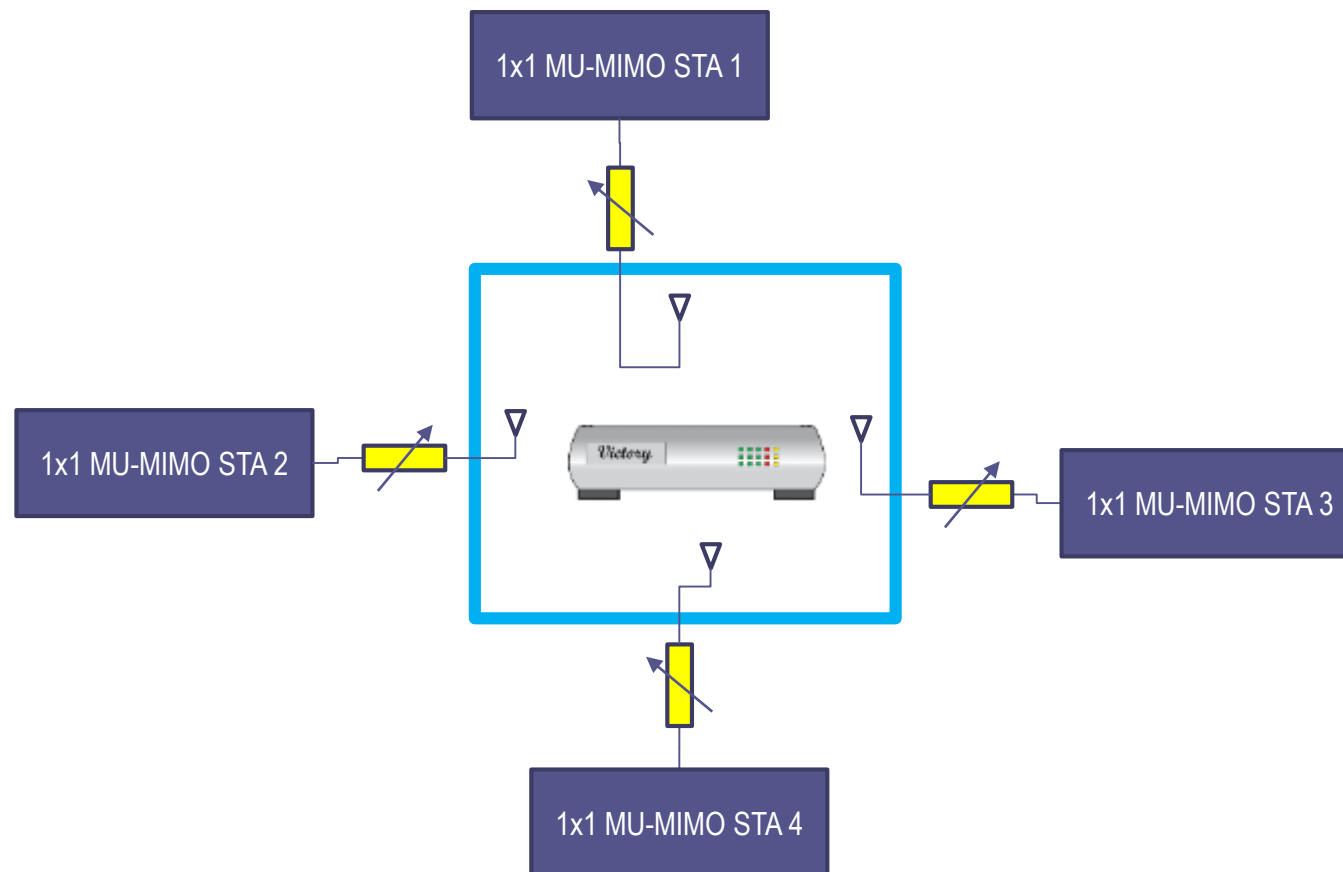


- Rate adaptation isn't optimum – DUT is not returning to the maximum data rate of 802.11g of 54 Mbps
- High isolation enables testing all the way down to the bottom of the RX dynamic range (-96 dBm in this example)
- Wi-Fi RX is sensitive enough to receive a small fraction of a microvolt and hence requires complete isolation from outside noise to enable observing the real performance or DUT behavior (e.g. rate or MCS adaptation)

MU-MIMO Testbed



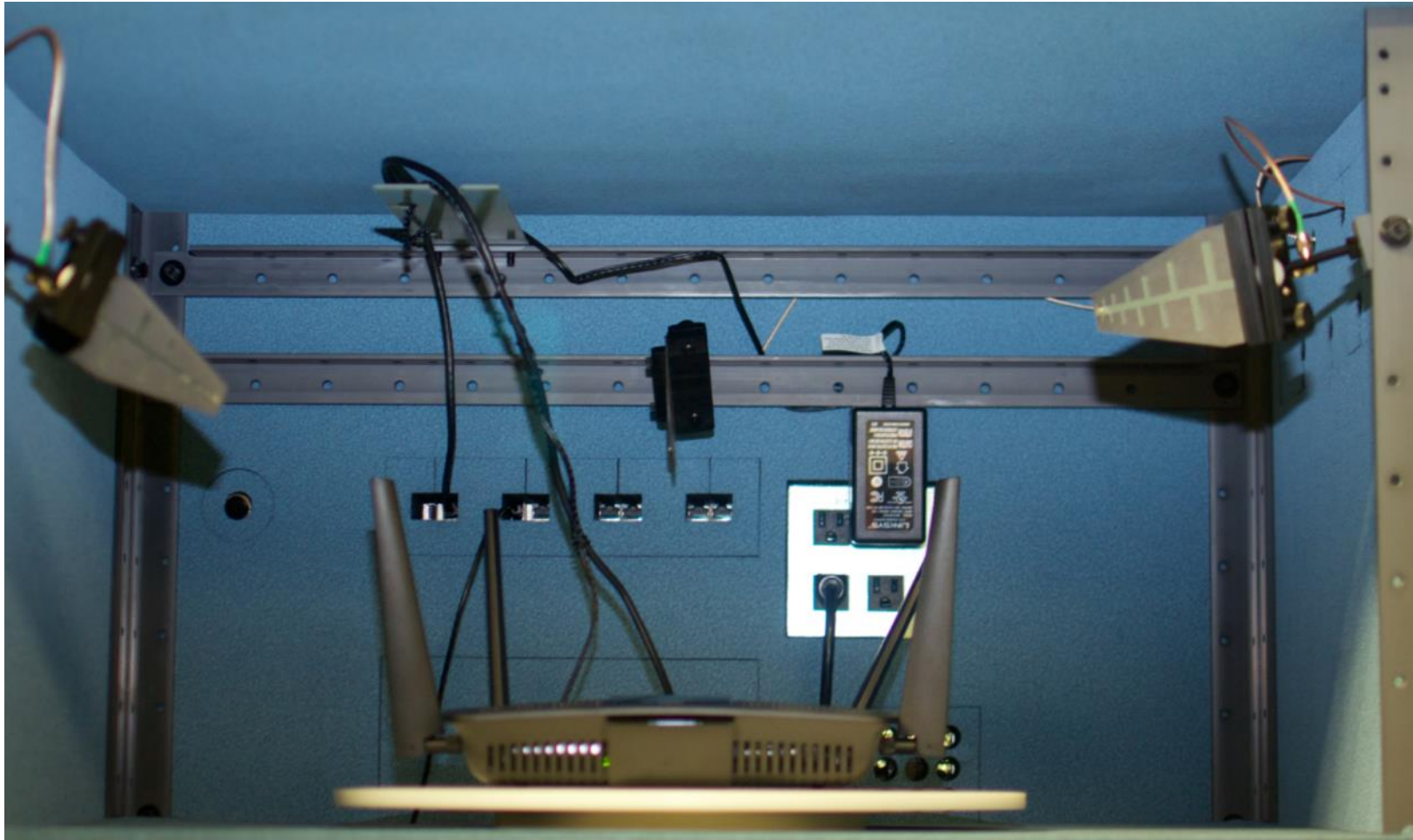
<https://youtu.be/6JhzmlmqGwc?t=232>



PATENT PENDING

MU-MIMO = multi user MIMO

MU-MIMO Gains – Measurement Example



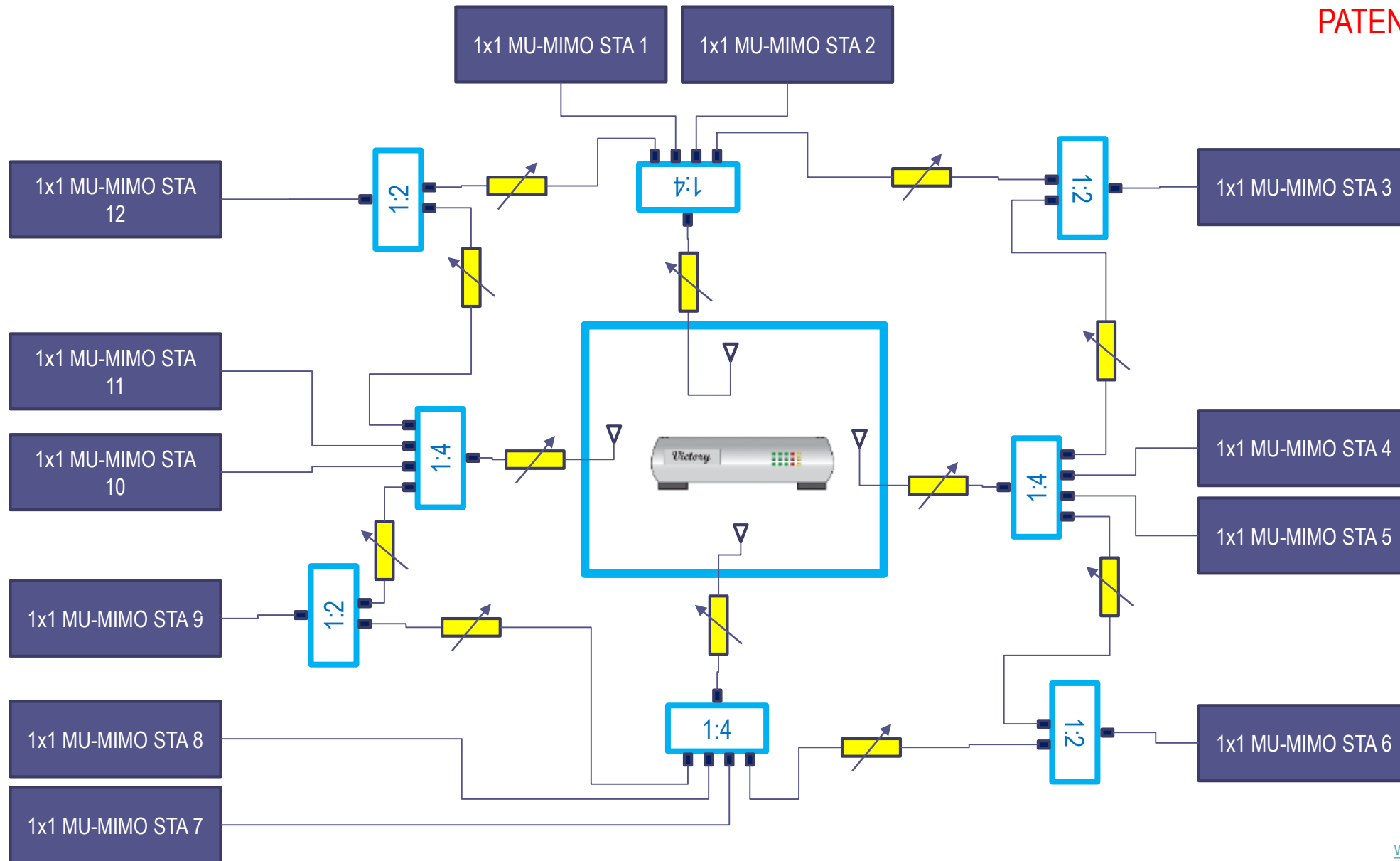
PATENT PENDING

Run #	MU-MIMO OFF (Mbps)	MU-MIMO ON (Mbps)
1	360	935
2	355	935
3	358	934
4	361	938
5	357	946
6	357	946

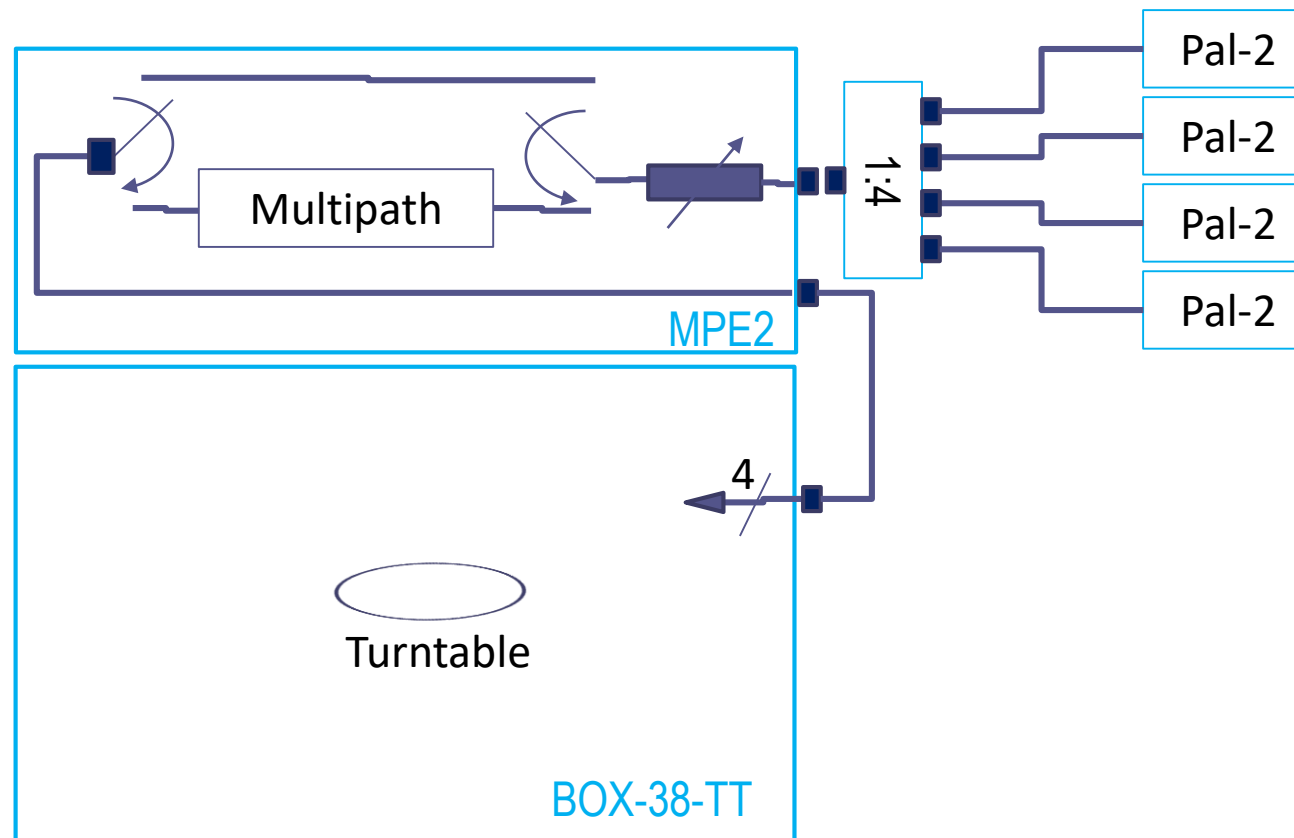
Over 2.6x gain

MU-MIMO with Controllable Correlation (Position of Station)

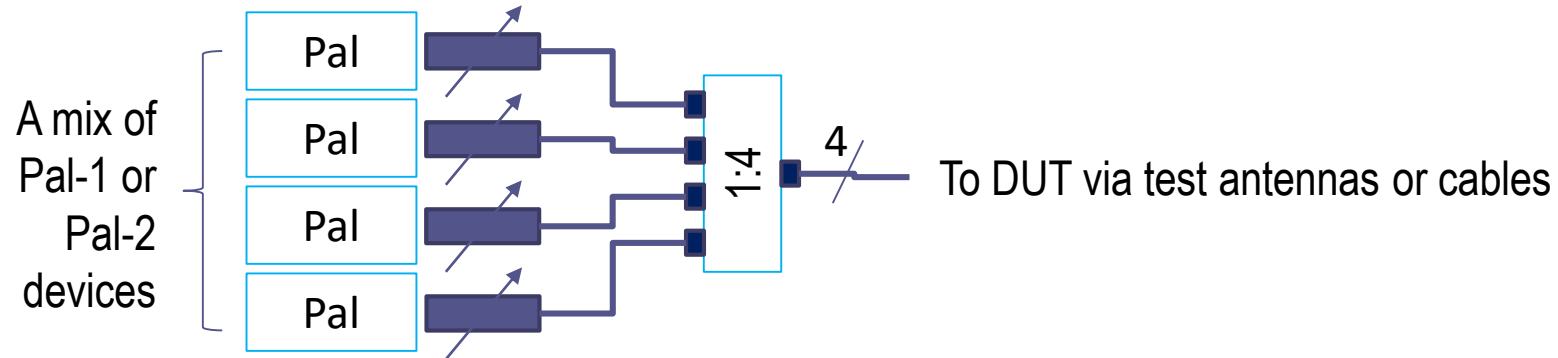
PATENT PENDING



Pal-2 Based MU-MIMO Testbed



multiPal™ Subsystem



Emulate up to 128 vSTAs or up to 4 APs
 Multi-channel operation
 Dynamic power control
 Motion emulation

Tests:

- Throughput
- Forwarding rate
- Capacity
- Roaming
- Monitoring
- Traffic generation
- Band steering

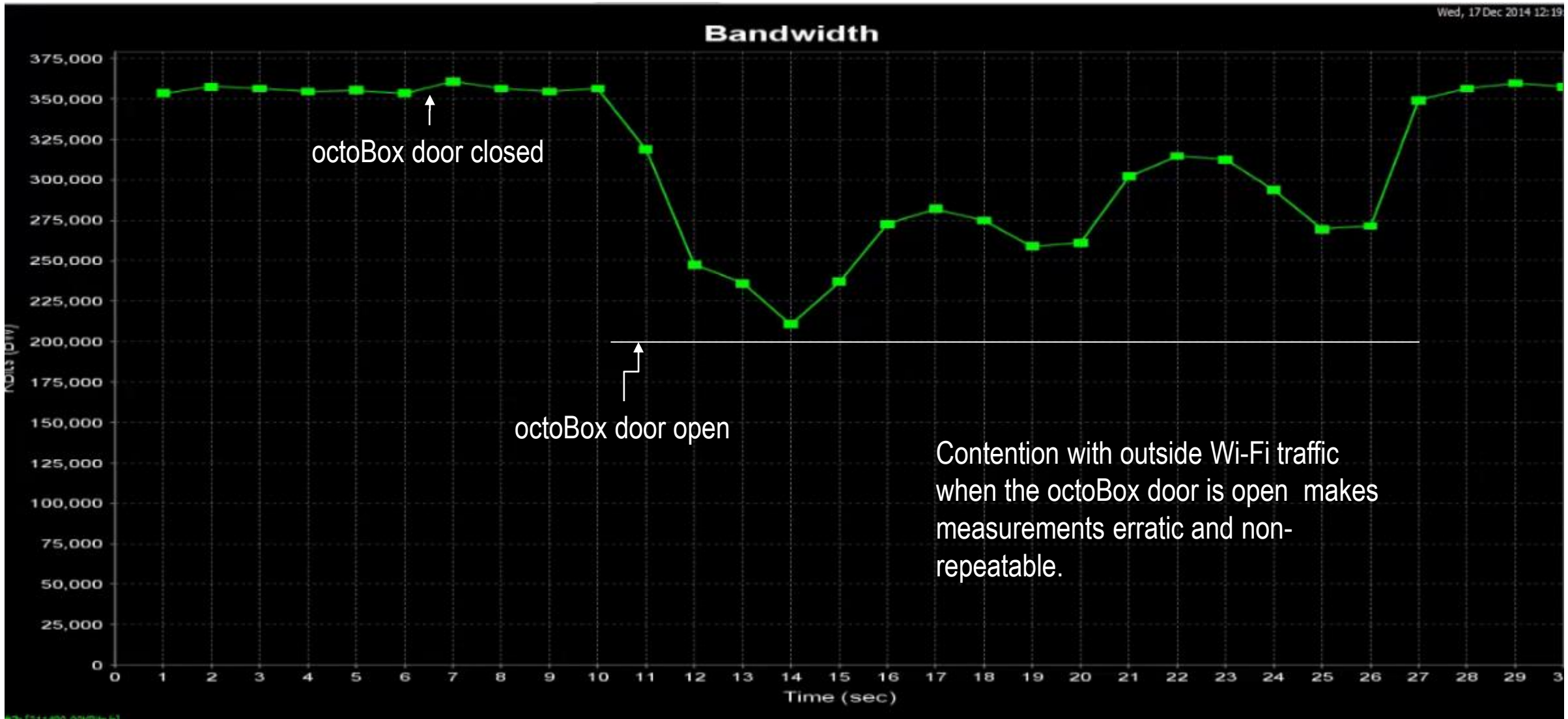
Key Wireless Test Capabilities

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- ✓ Emulate a multi-room house

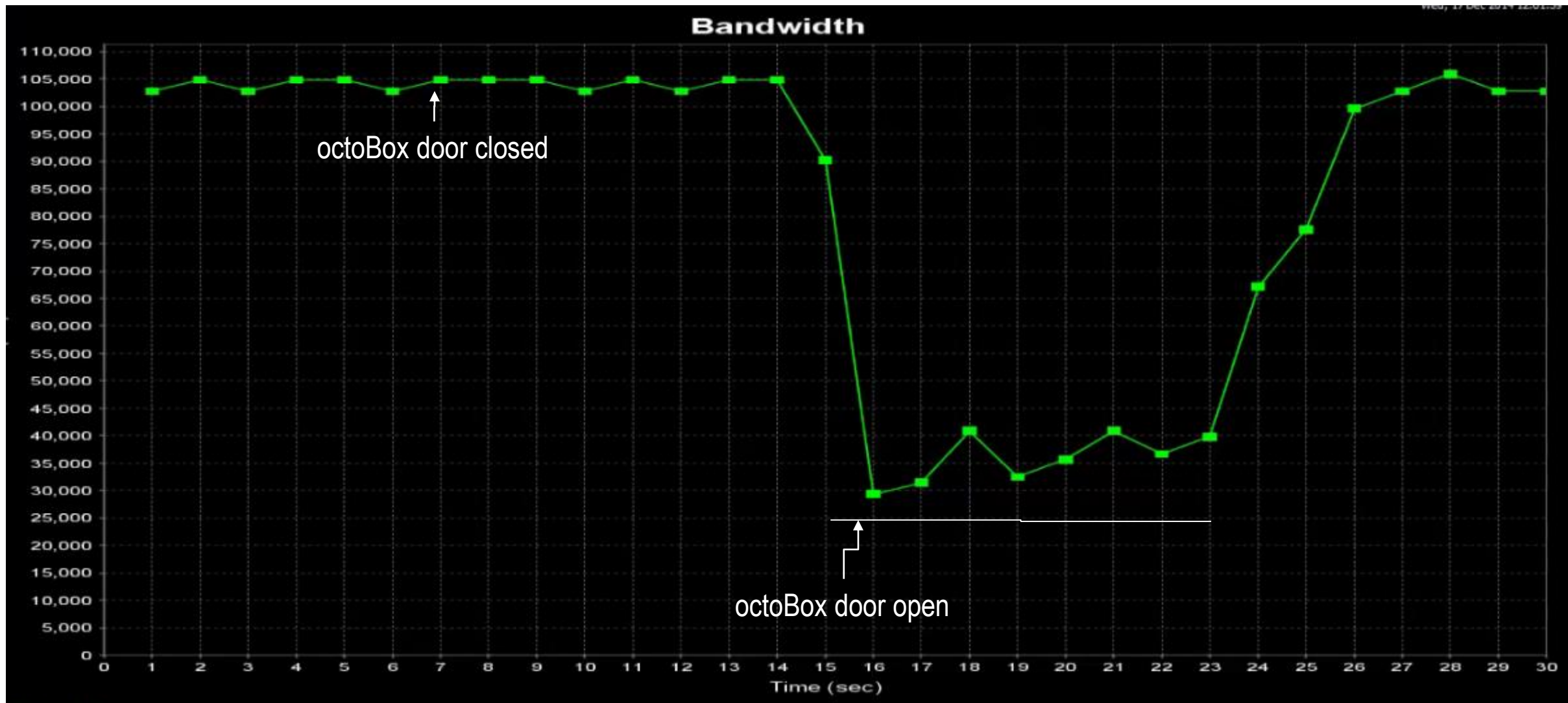


<https://www.youtube.com/watch?v=SK1857UkO04>

Jperf Run in the 5 GHz Band, 80 MHz Channel

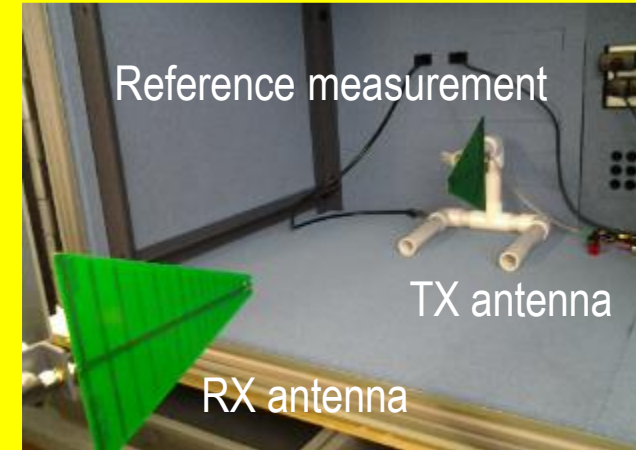
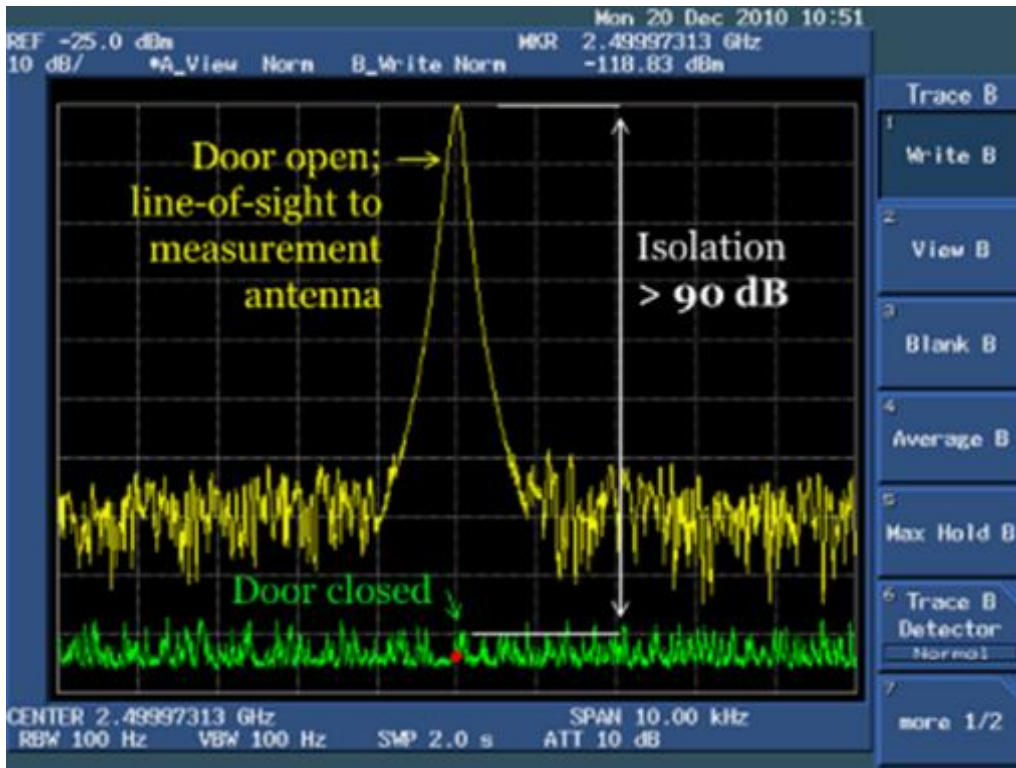


Jperf Run in the 2.4 GHz Band, 20 MHz Channel

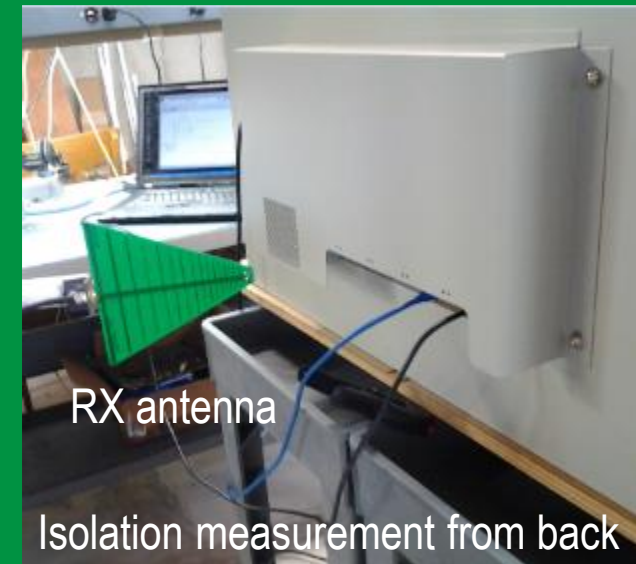


Achieving Repeatability

- Complete isolation
 - octoBox testbed design with filtered data and power connections provides complete isolation

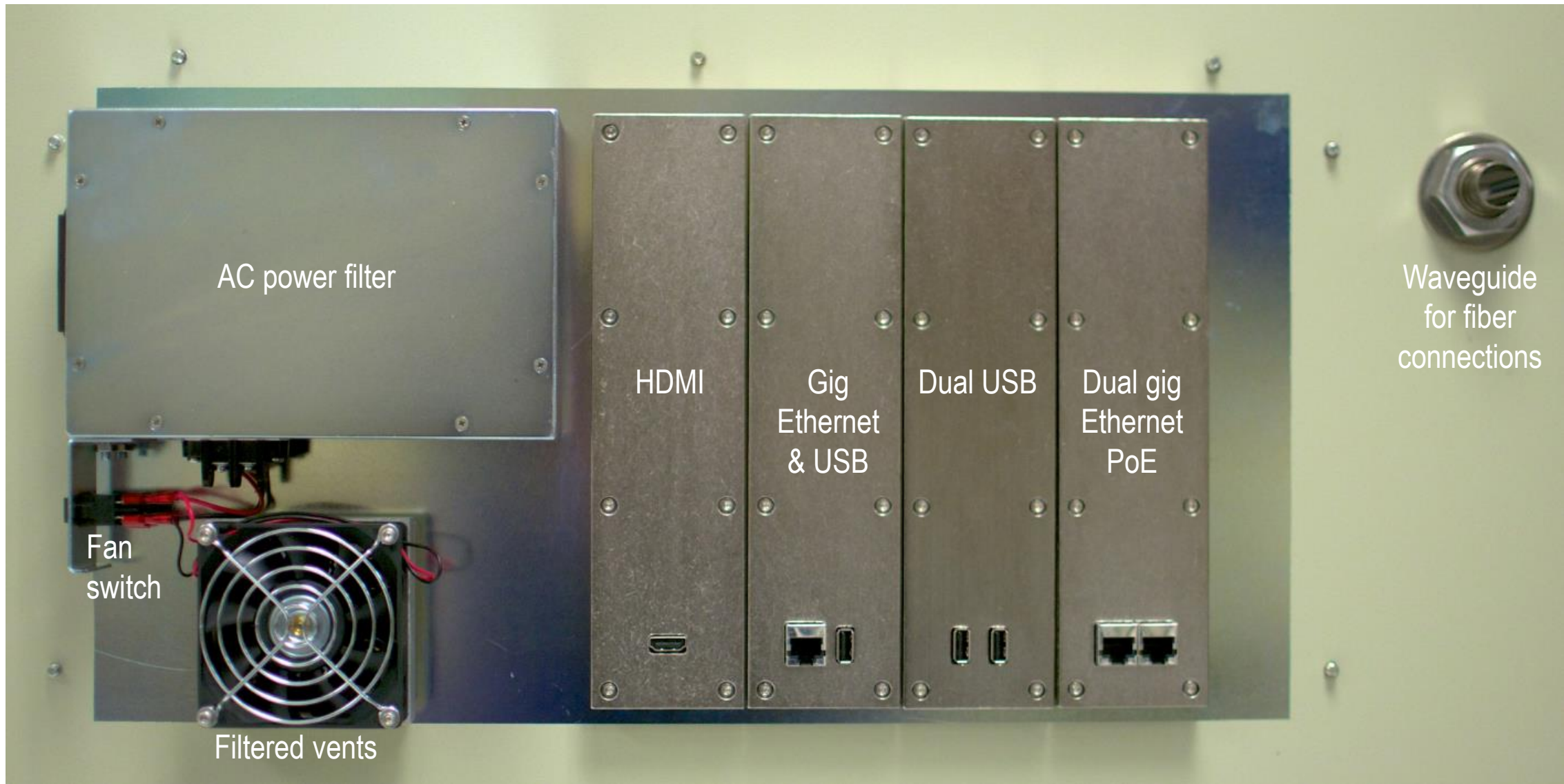


Door open



Door closed

Under the Shroud - Filters



Internal side



OBS-05-X2
Ethernet filter



OBS-06-X2
USB filter



OBS-09
Eth+USB filter



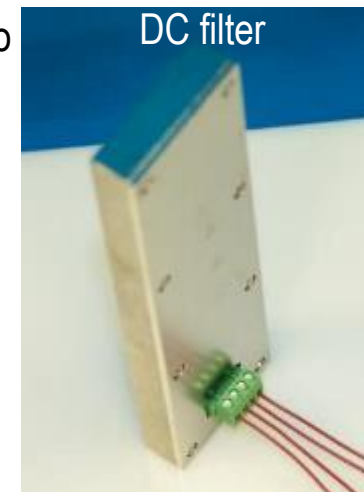
OBS-08
HDMI filter



OBS-10
3.5 mm phono
jack filter



OBS-07
DC filter



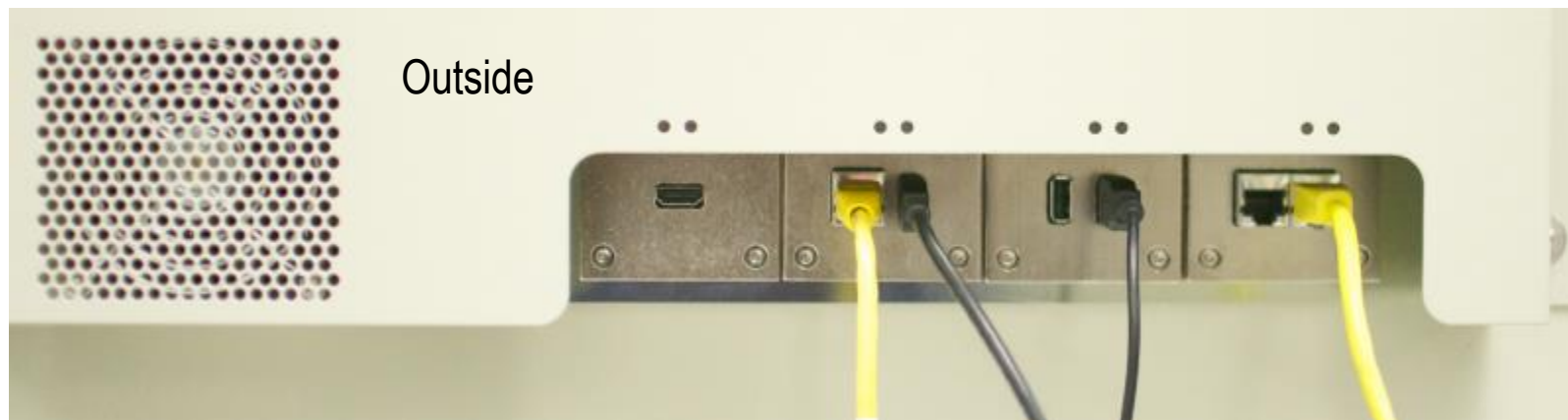
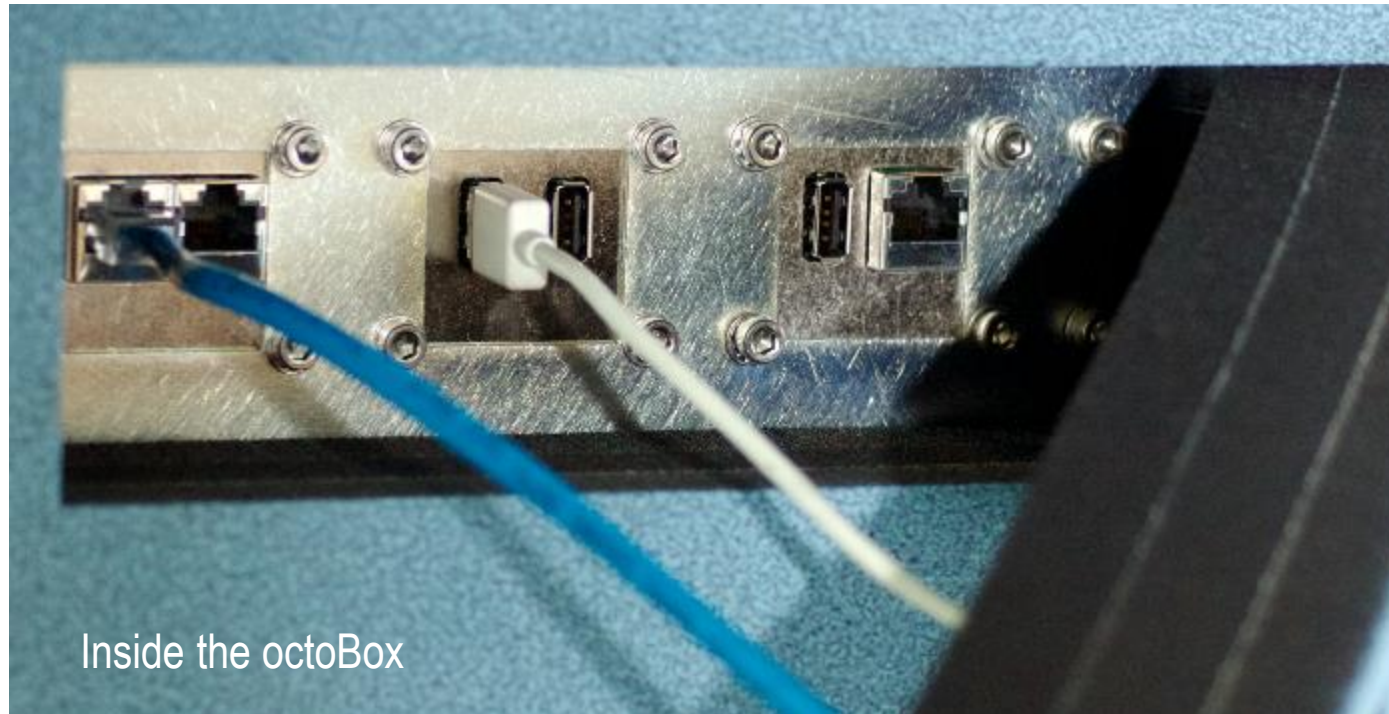
DC current
handling:

10A 50V on any
of the DC filter
(OBS-07) lines

6A 50V on any
of the Ethernet
filter (OBS-05)
lines

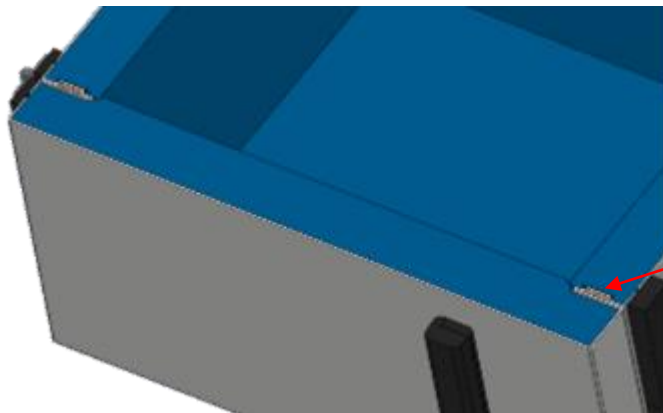
1.5A 5V over
the USB filter
(OBS-06) power
pair

Data Filters – Internal and External Views



Achieving Repeatability

- Semi-anechoic (non-echoing)
 - 20dB of absorption allows for OTA (over the air) testing which is essential when working with devices with embedded antennas (laptops, cellphones etc.)
 - Makes a small box behave like a large room in terms of reflection magnitude and creates excellent surround-sound MIMO-OTA environment (delay profile of a room is emulated by the MPE module)

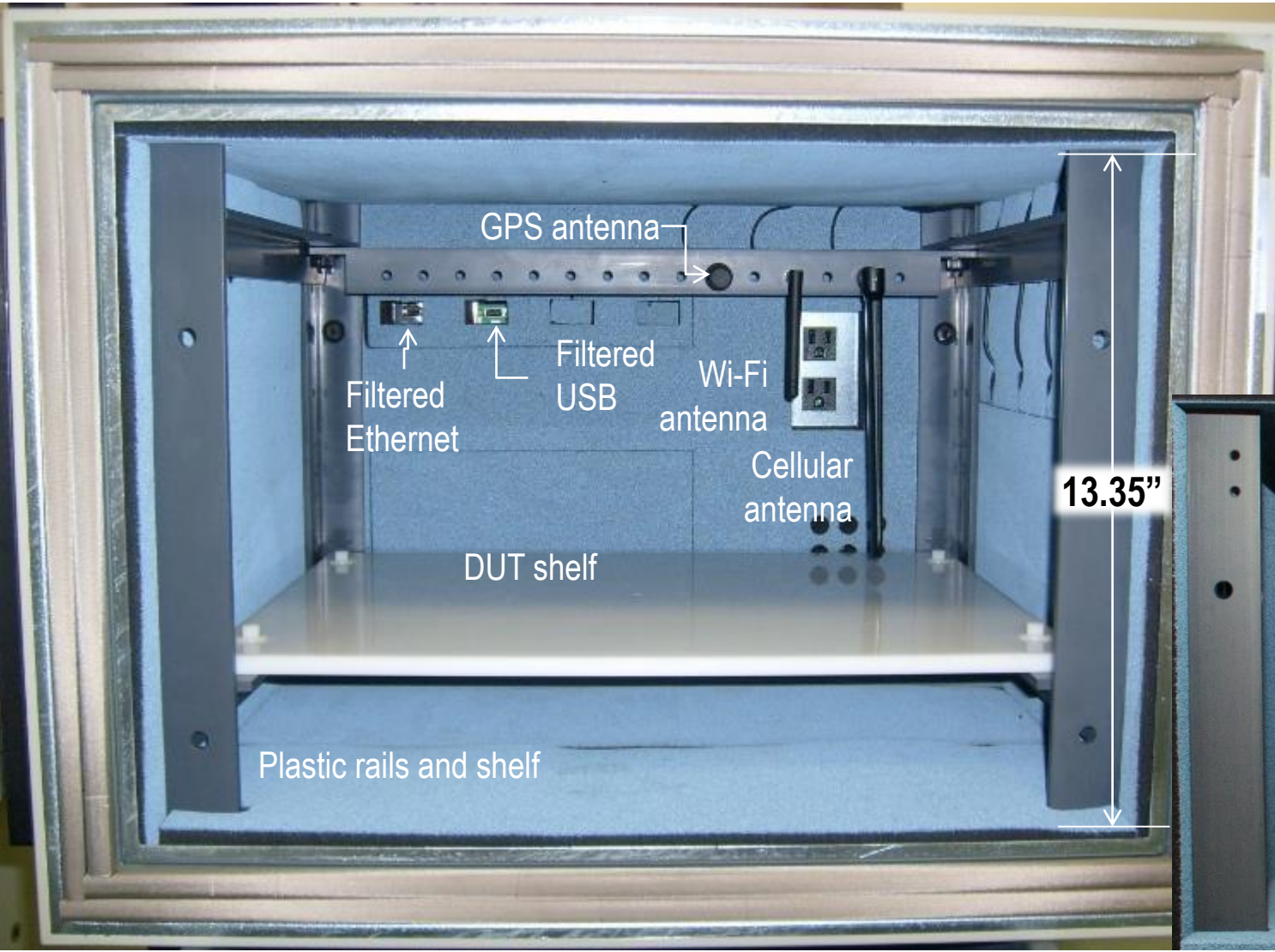


Dual gasketing and right angle door seals



octoBox-26 Internal View

Small octoBox



Example of Multiband Cellular/LTE Antenna Mounting



Multiband cellular antenna such as Pulse-Larsen SPDA24700/2700* (shown) enables cellular or LTE testing including Wi-Fi to LTE offloading.

Multiband cellular/LTE antennas

2-6 GHz (Wi-Fi) high gain antennas

LTE to Wi-Fi handover testbed

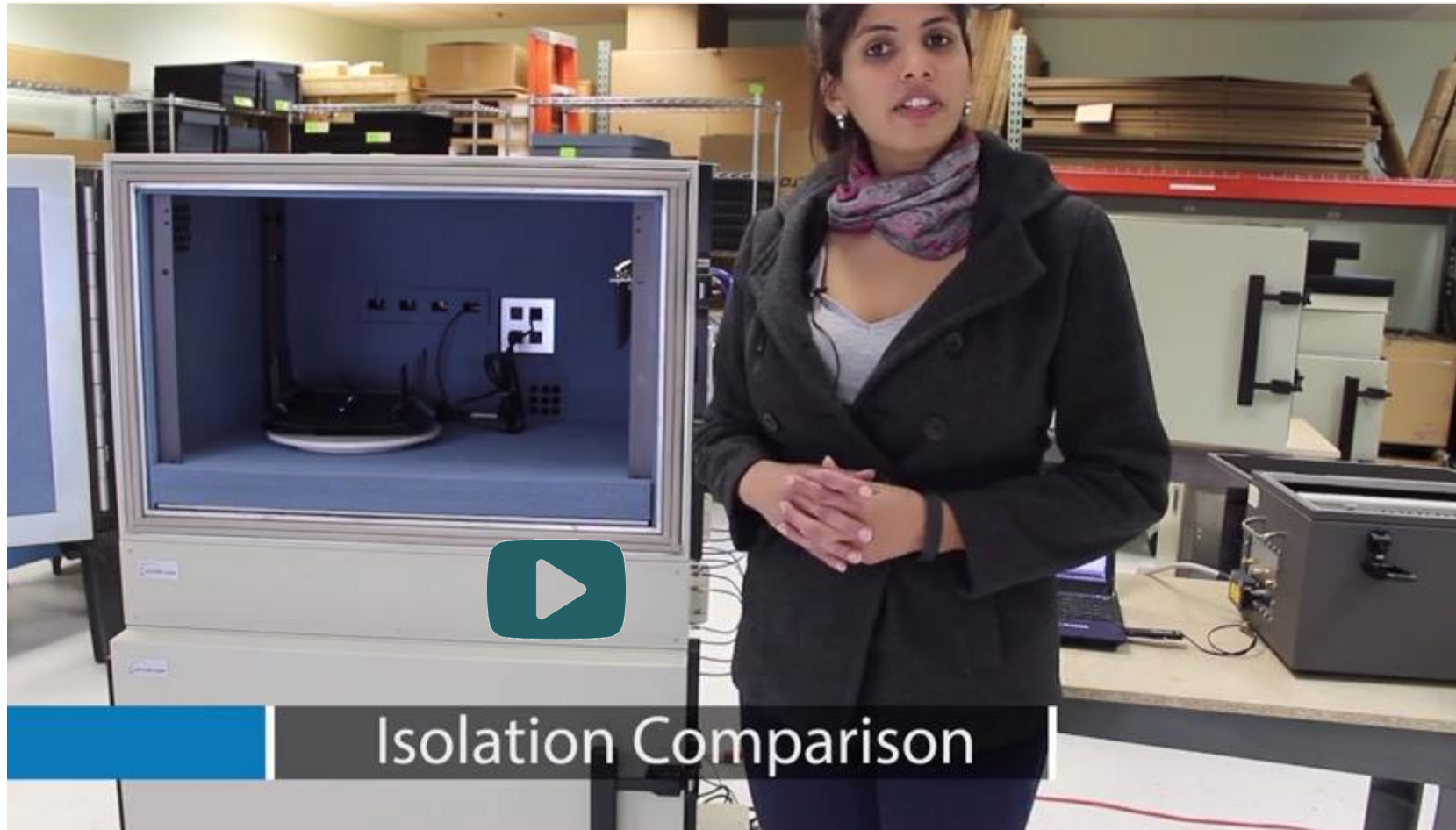
* Frequency bands: 698-960 MHz, 1710-2170 MHz, 2500-2700 MHz; 2 dBi

Mountable shelves to keep the entire testbed, including the console and endpoint PCs, neatly connected and mobile

octoShelves



octoBox vs. Common Shield Box



<https://www.youtube.com/watch?v=Q6xlcTSVKeo>

Key Wireless Test Capabilities

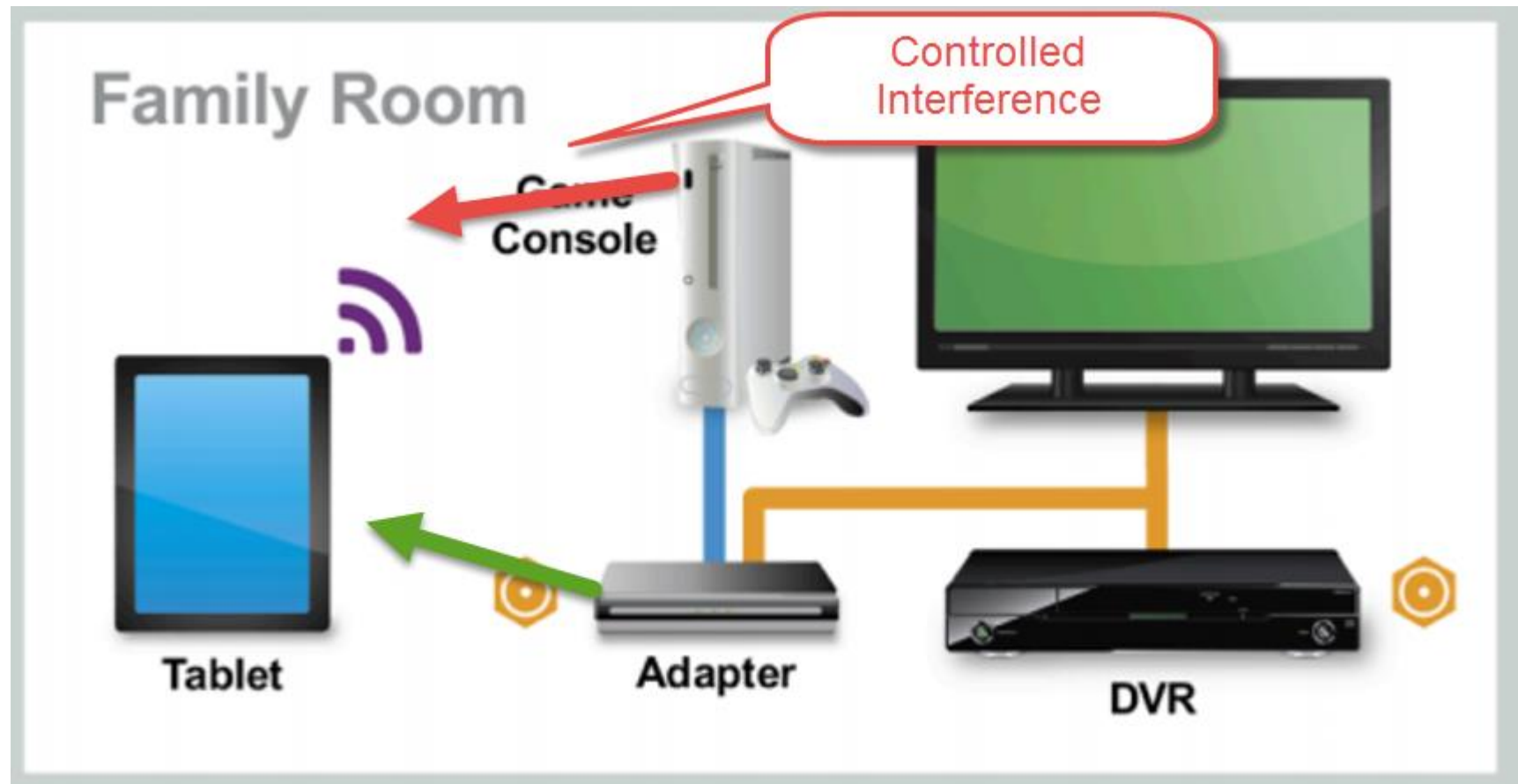
- ✓ Throughput performance
- ✓ Complete isolation
- ✓ Controlled interference
- ✓ Roaming behavior (sticky clients)
- ✓ Interoperability (vendor to vendor)
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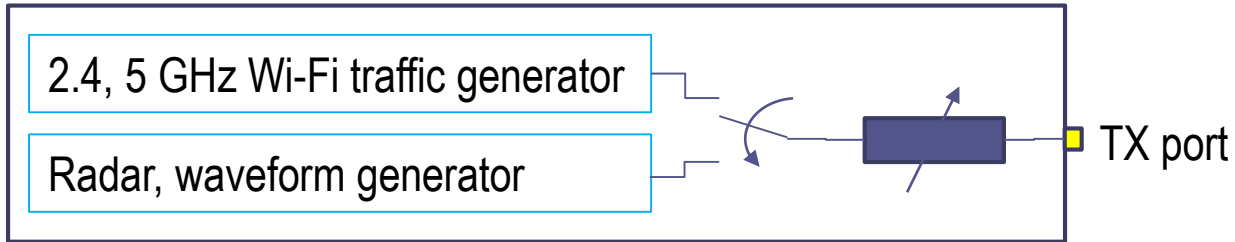
<https://youtu.be/pZ9bsQAPvII>

Generate Interference

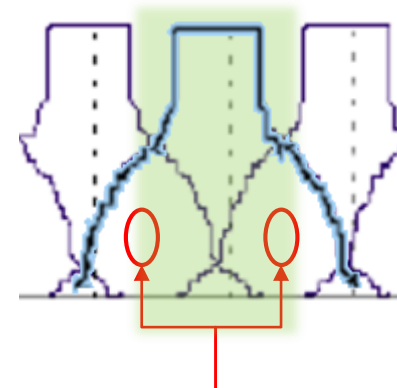
octoBox iGen interference generator generates realistic traffic and waveform interference.



octoBox iGen Interference Generator



- Generates Wi-Fi traffic or an interference waveform
- Test cases
 - Automated channel selection algorithm
 - DFS (Dynamic Frequency Selection)
 - Fairness of access (CSMA/CA and WMM)
 - CCI with WMM priorities; no other generator can set priorities
 - ACI
 - Performance in the presence of IoT, BT, microwave, baby monitor
 - Rate adaptation



802.11 ACI significantly impacts performance

ACI = adjacent channel interference
 CCI = co channel interference
 WMM = wireless multi media
 CSMA/CA = carrier sense multiple access / collision avoidance
 OOK = on off keying
 BT = Bluetooth
 IoT = internet of things

iGen Browser Based GUI

Traffic interference

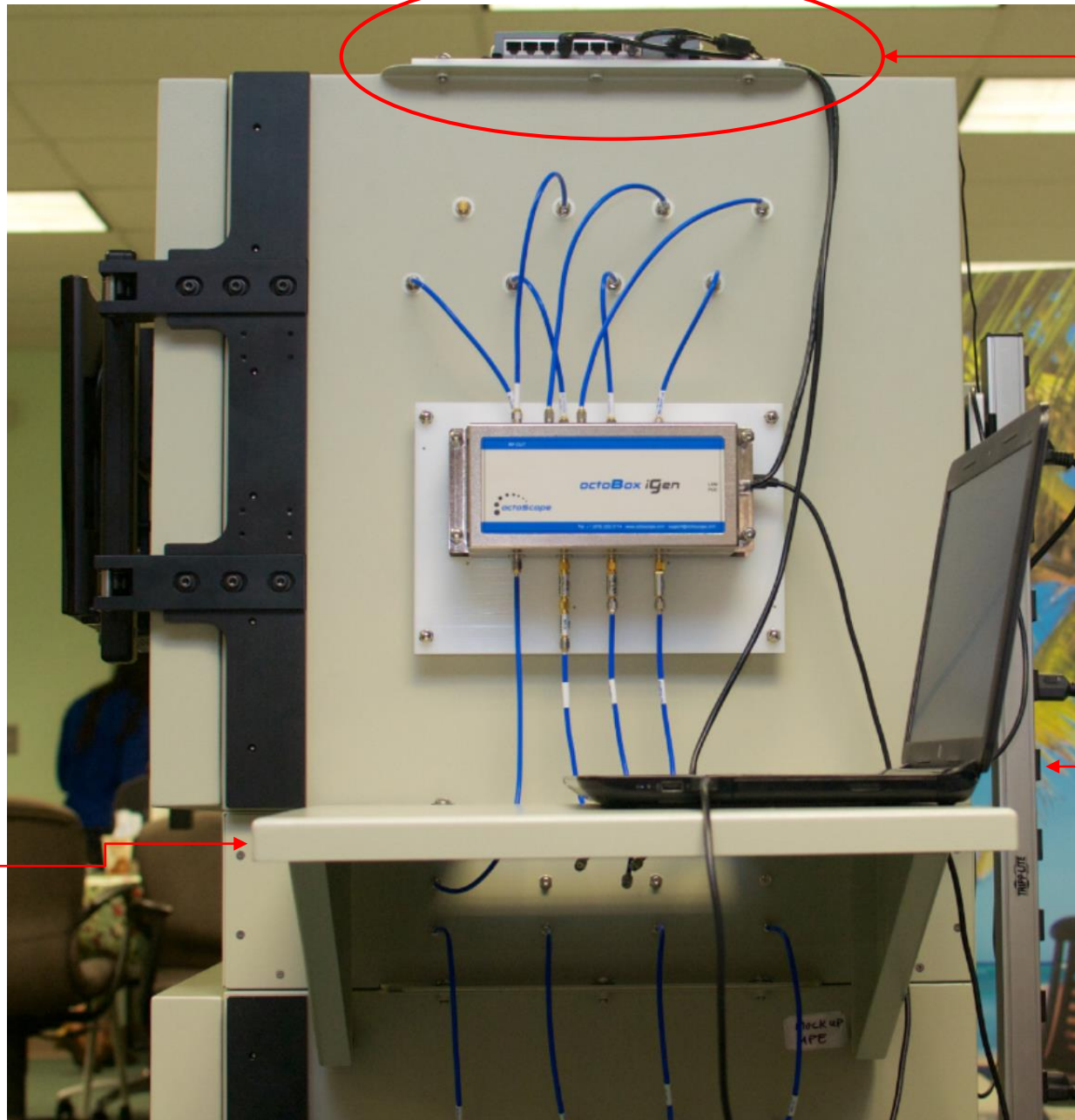
System	<input checked="" type="radio"/> Traffic	<input type="radio"/> Monitor	<input type="radio"/> Waveform	File Manager
802.11 Interface	802.11ac ▼			
Channel width	40 MHz ▼			
Guard Interval	Short ▼			
MCS (Mbps)	0 (15 Mbps) ▼			
Primary Channel	124 (5620 MHz) ▼			
Secondary Channel	128			
Input file	single_TCIPPacket_3128B.pcap ▼			
Play Mode	Loop until <stop> ▼			
Priority (WMM)	Best Effort ▼			
Inter-Packet Gap 300µsec minimum	300	µsec		
Attenuation 0dB to 60dB	0			

Waveform interference

Help	
<input checked="" type="radio"/> Traffic	<input checked="" type="radio"/> Capture
Interference Type	<ul style="list-style-type: none"> Bluetooth Low Energy Microwave Oven Baby Monitor 802.11 FHSS ZigBee Custom CSV File Pulse Continuous Wave Frequency Sweep
Attenuation 0 to 60 dB	0
Frequency 500 to 6000 MHz	5625



Powering and controlling the testbed building blocks

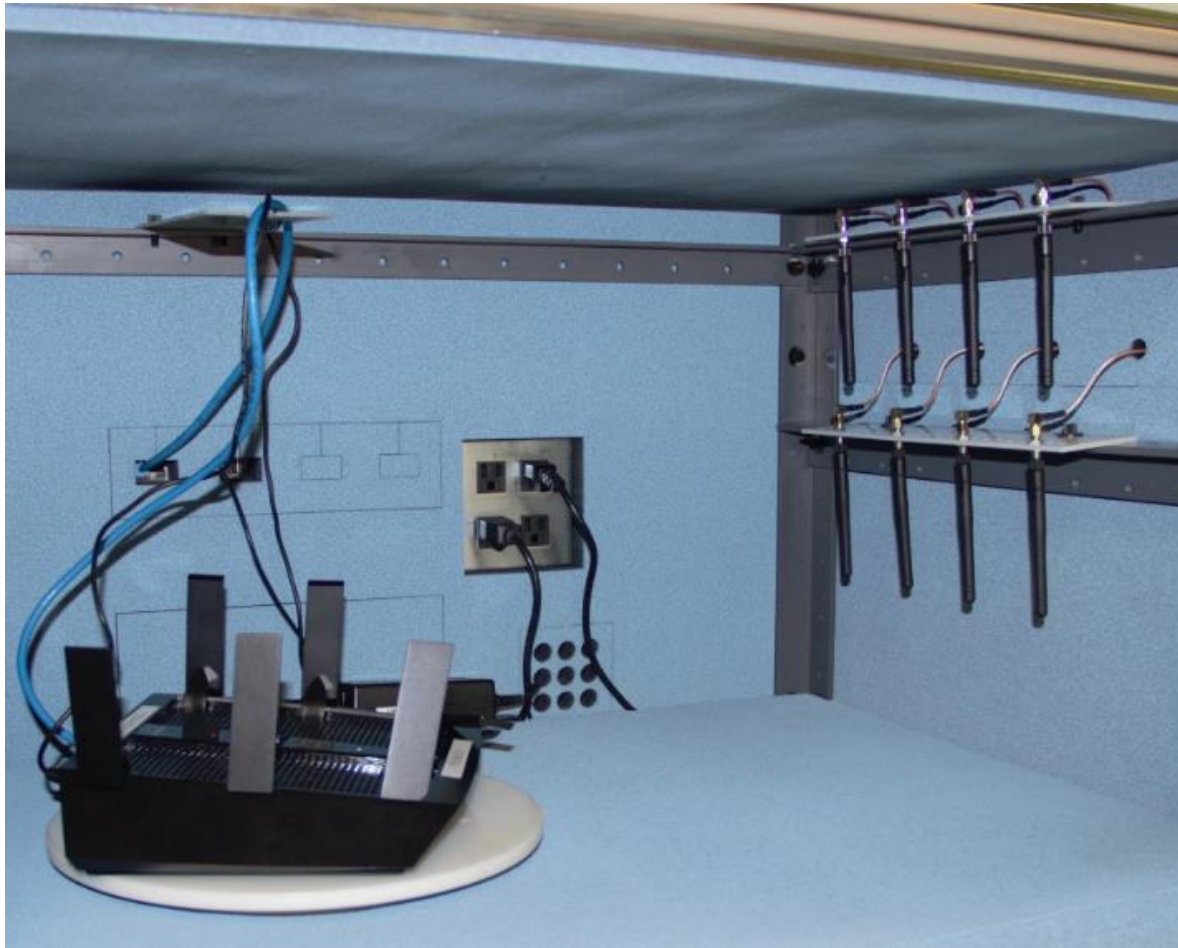


Side shelves can hold the console and endpoint PCs

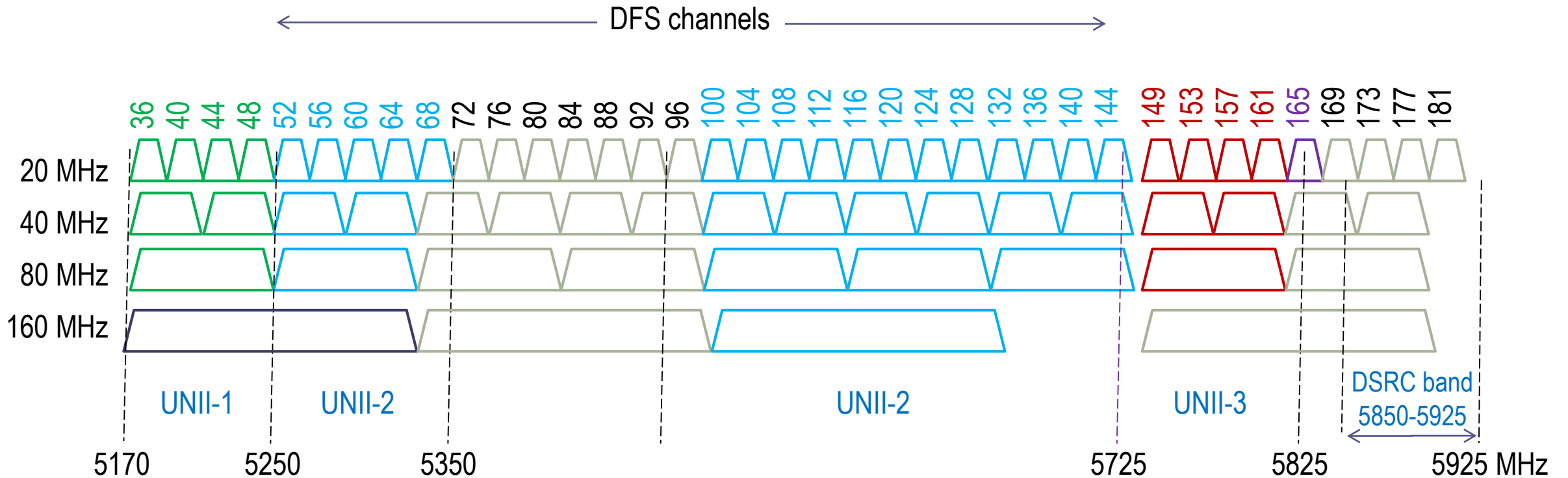
octoPal, iGen and quadAtten can be powered via the provided PoE Ethernet switch.

Equipment can plug into the magnetically attached power strip

Antenna Mounting Options



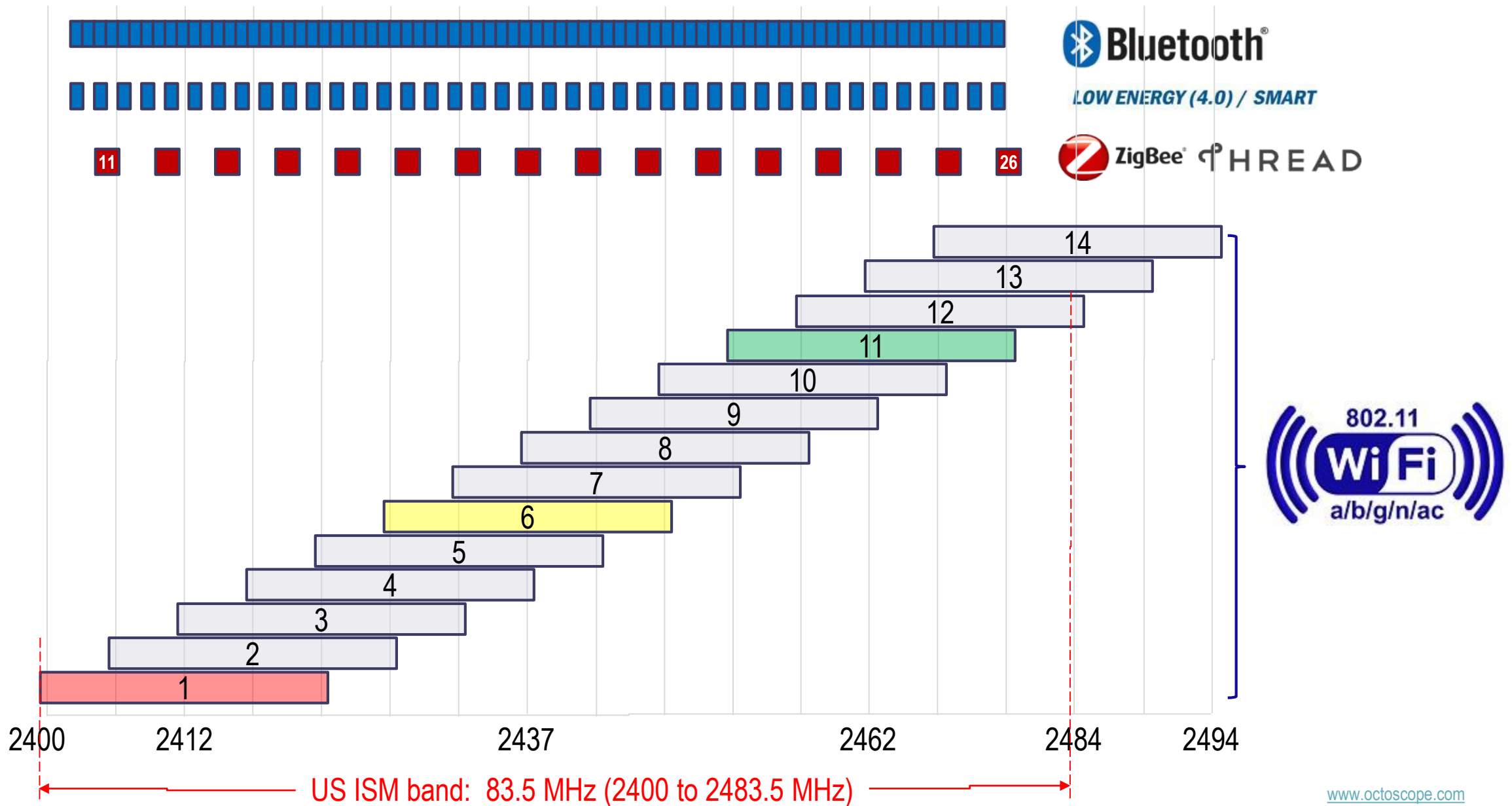
5 GHz Band Channel Allocation



UNII = unlicensed national information infrastructure
 DSRC = direct short range communications

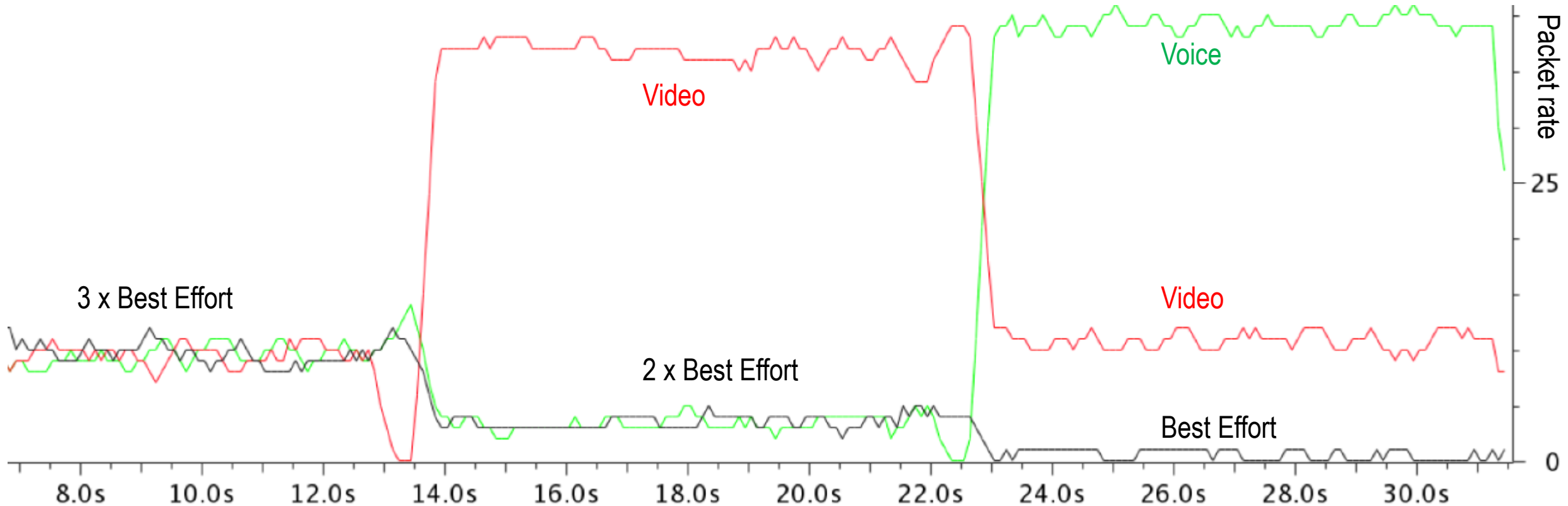
▭ 40 mW
 ▭ 200 mW
 ▭ 800 mW
 ▭ 1000 mW
 ▭ Licensed Targeted for sharing by the FCC

2.4 GHz Band Channel Allocation



WMM (wireless multi media) – Streams of Different Priorities

3 iGen modules transmitting inside an octoBox and sharing the airlink at different priorities



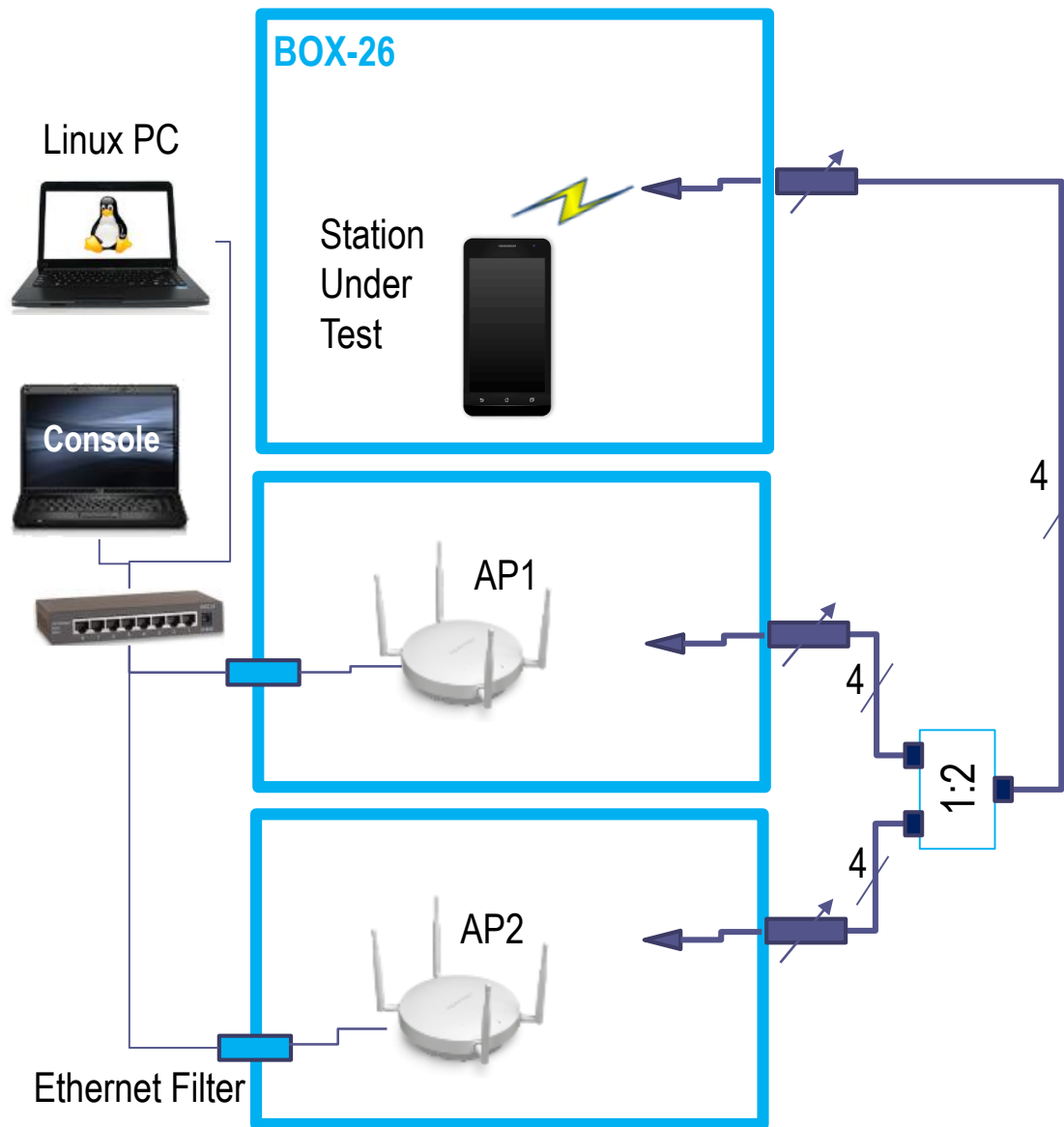
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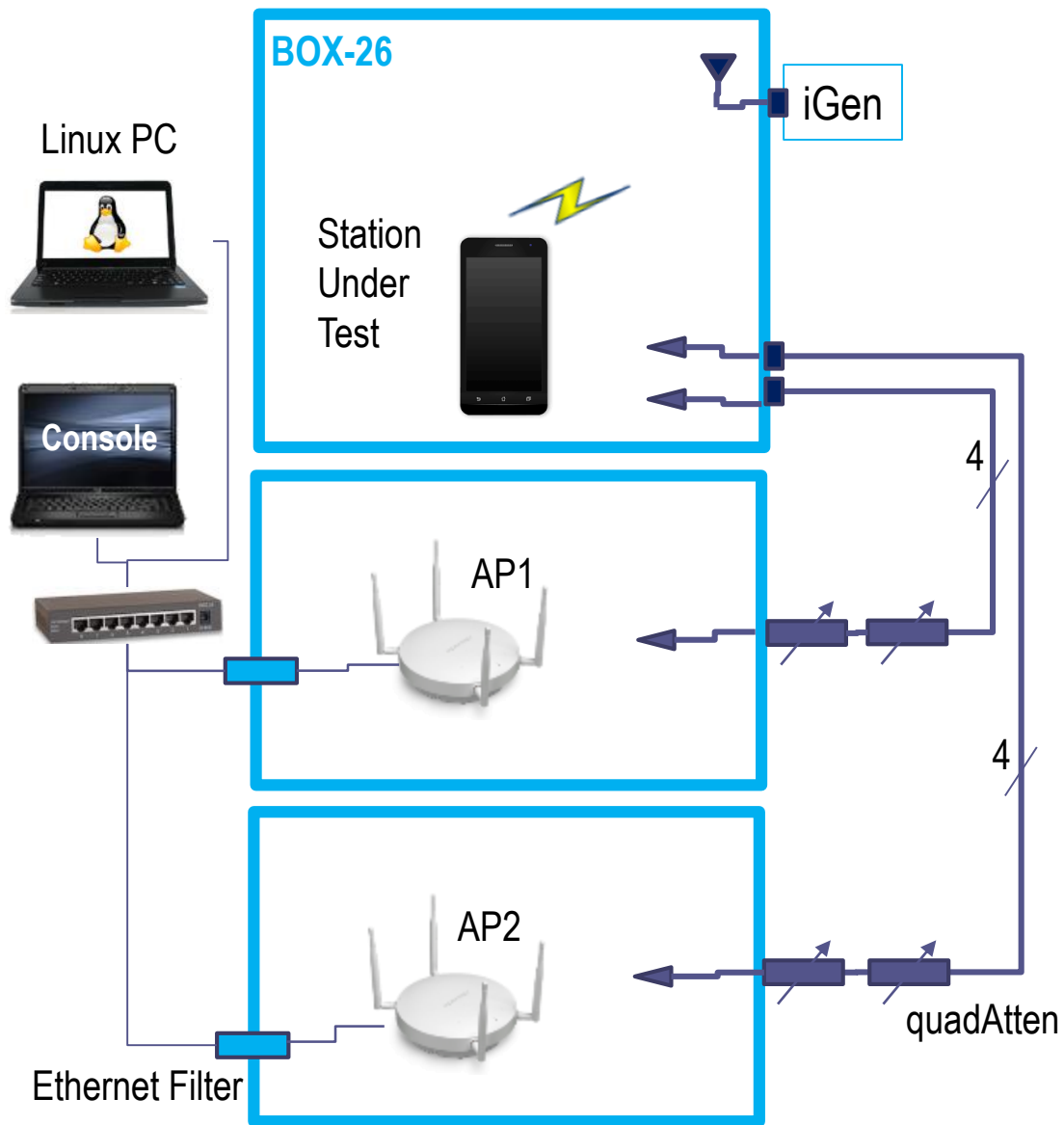


<https://www.youtube.com/watch?v=GAIfugKSQ1A>

Roaming Testbed Diagram

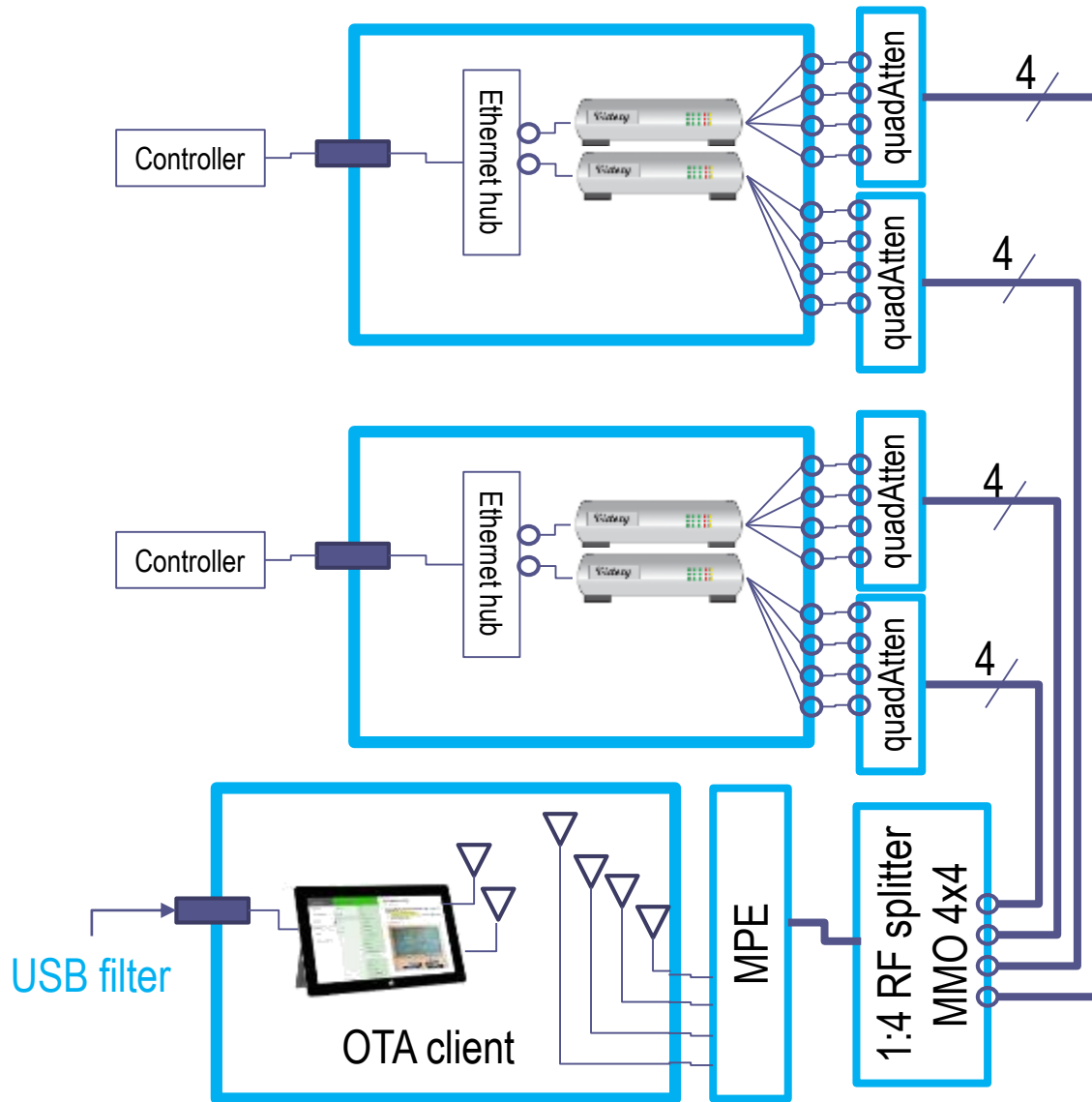


Roaming Testbed Diagram Alternative

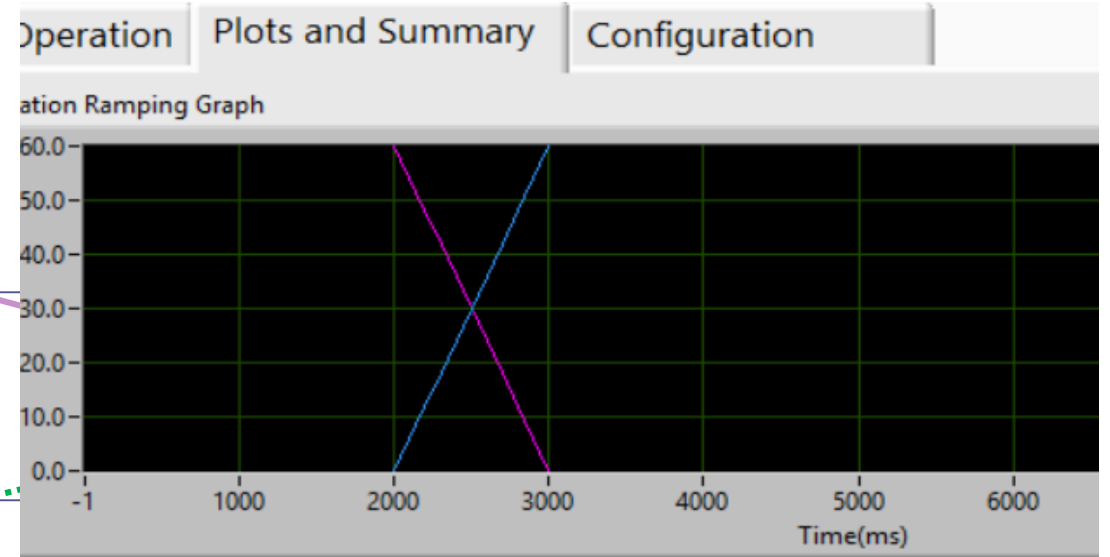
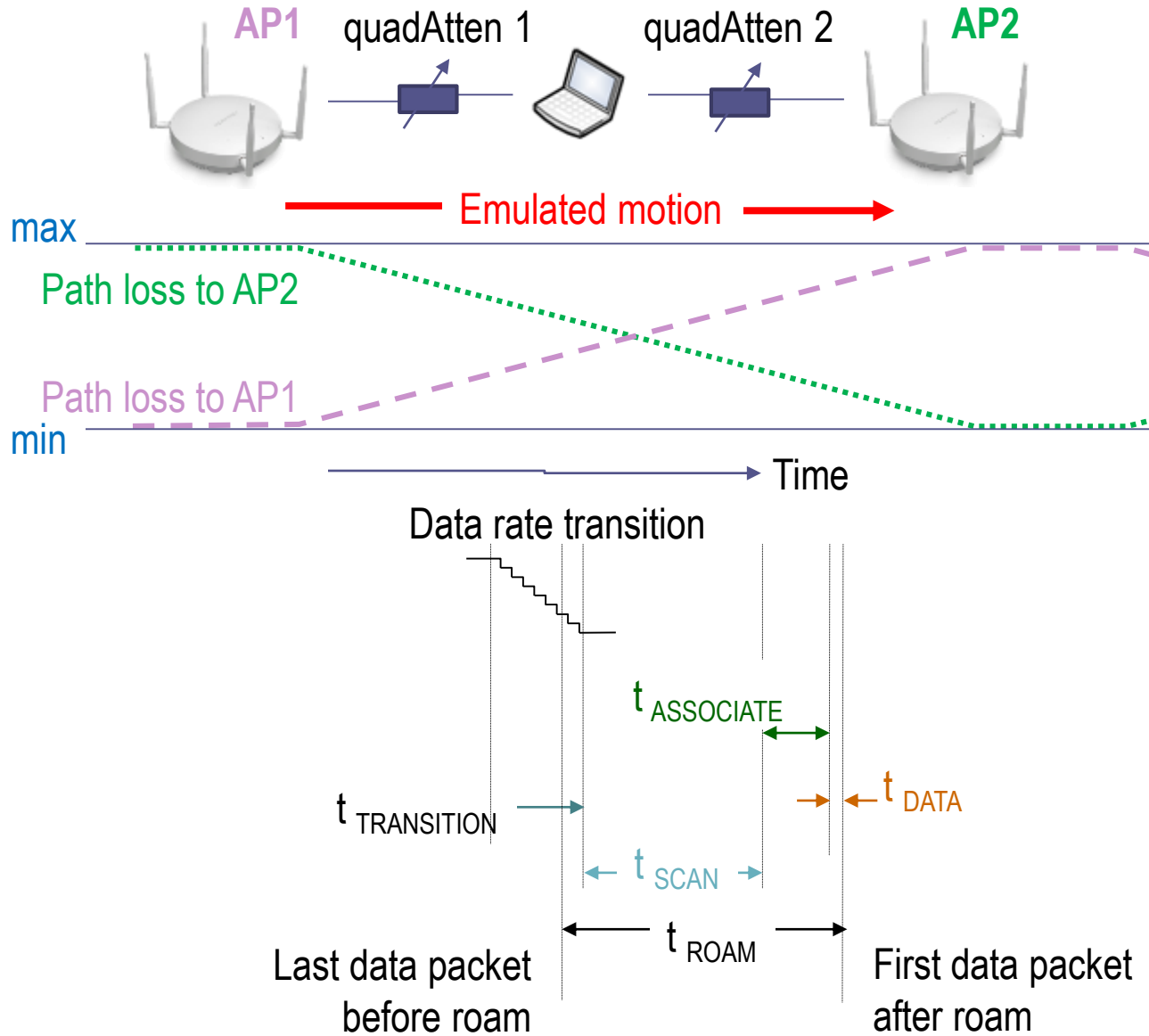


Alternative cabling with no splitter and with the iGen interference generator/monitor

Multi-AP Roaming



Roaming Test Conceptual Diagram



Outage due to roaming

Roaming Test Application, OB-ROAMING

roaming-gui-11.vi

octoScope **Roaming Test** Version 2.0

Roaming Operation | Plots and Summary | Configuration

Exit

Attenuation

Atten 1 (dB) 0 20 40 60

Atten 2 (dB) 0 20 40 60

AP 1 AP 2

Roam

Total Ping Duration (sec) 10

Ramp Delay (sec) 2

Expected Ping Progress (sec)


0 2 4 6 8 10

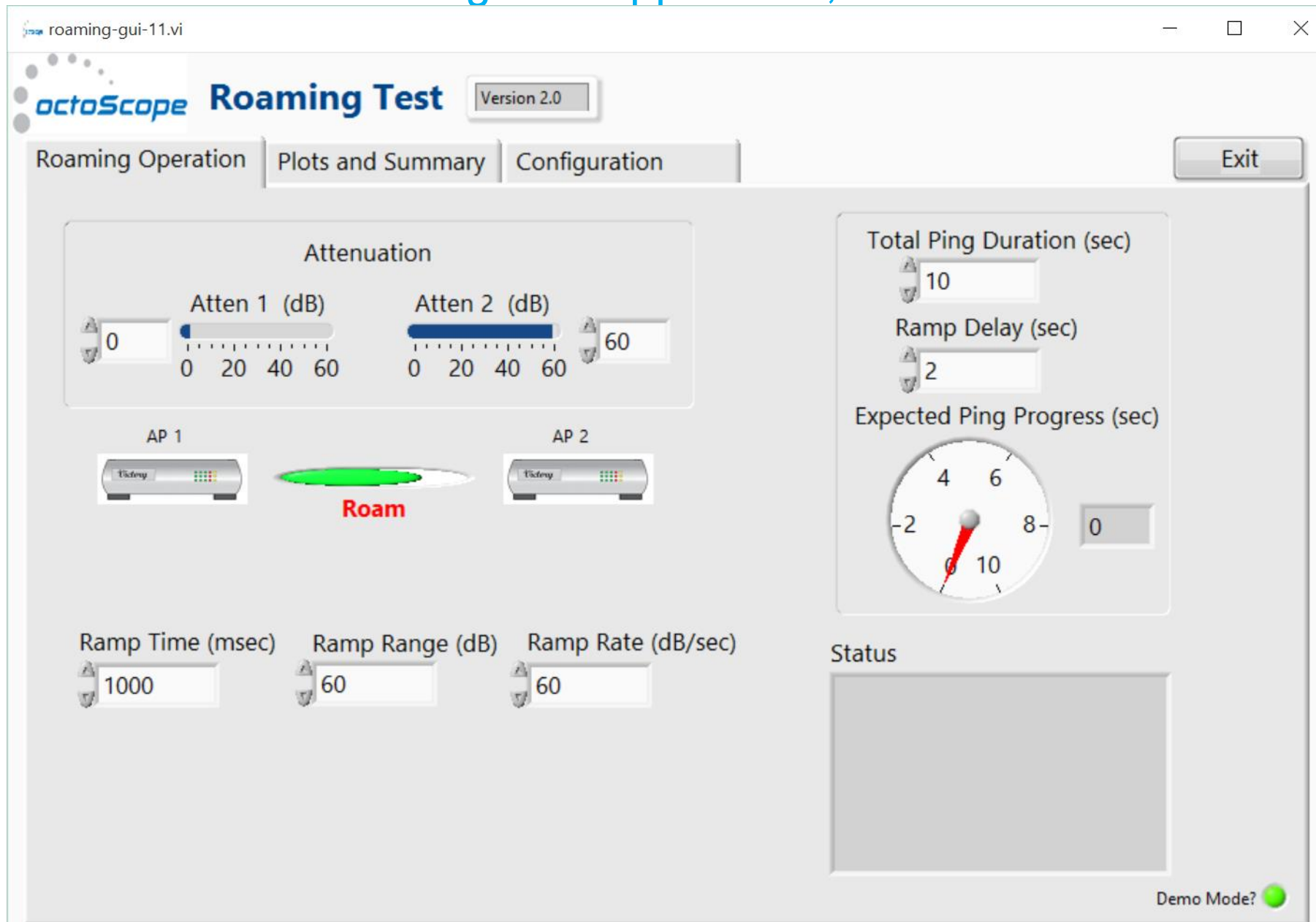
Ramp Time (msec) 1000

Ramp Range (dB) 60

Ramp Rate (dB/sec) 60

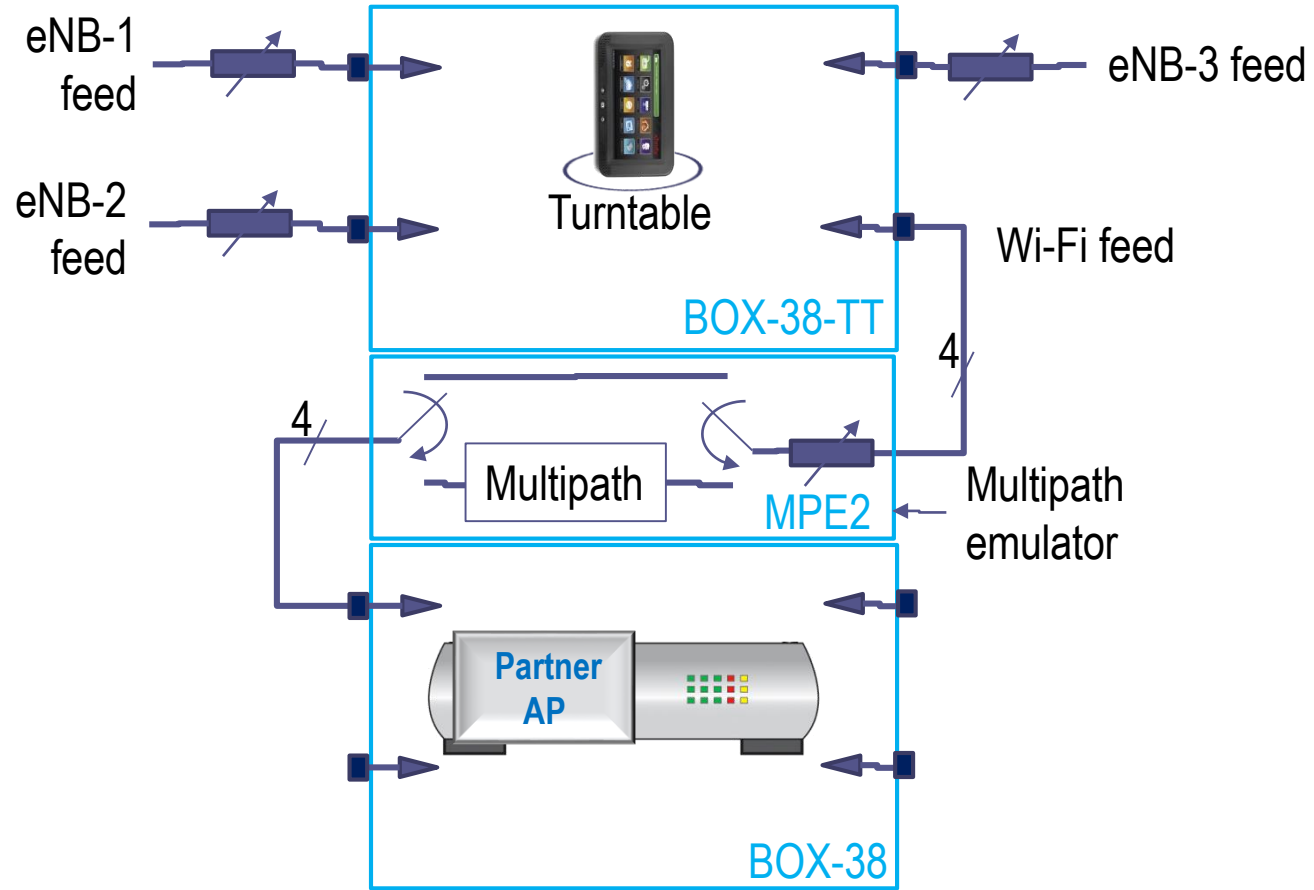
Status

Demo Mode? 

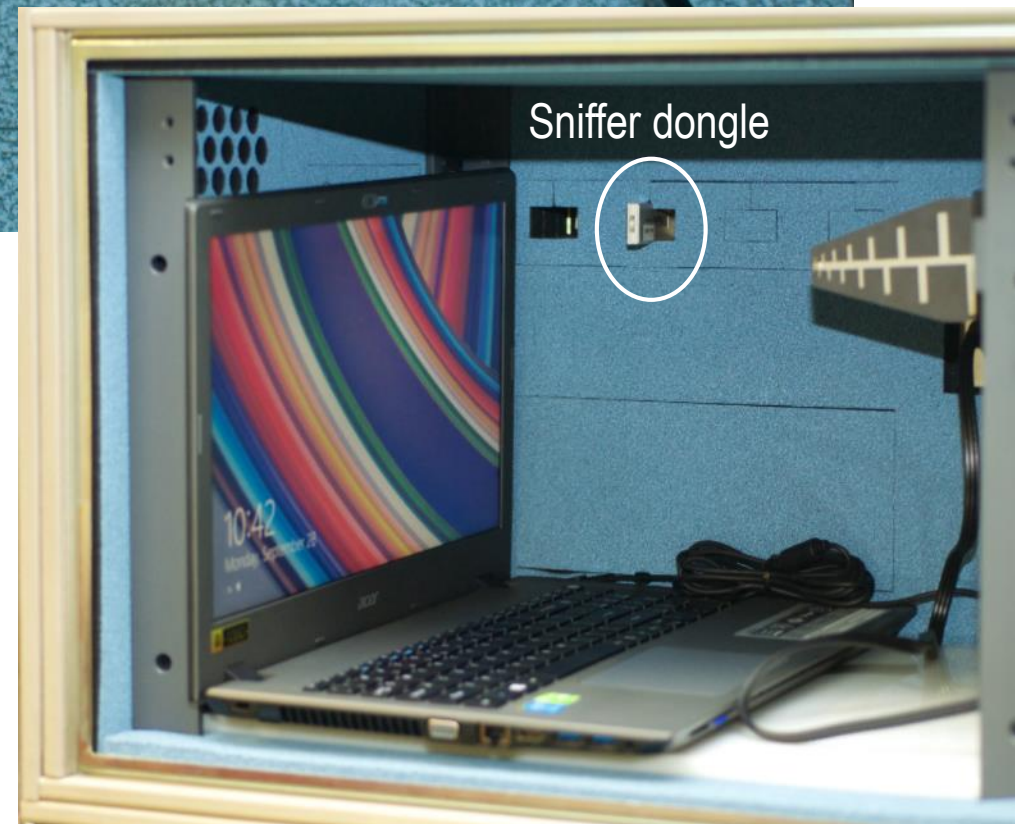


Controls motion,
velocity, pinging,
graphical reporting

Wi-Fi Offload Test Configuration Example



Connecting a Sniffer for In-depth Analysis



Connect the sniffer USB dongle to the inside port of the octoBox USB filter (shown) and sniffer PC to the outside port of the USB filter.

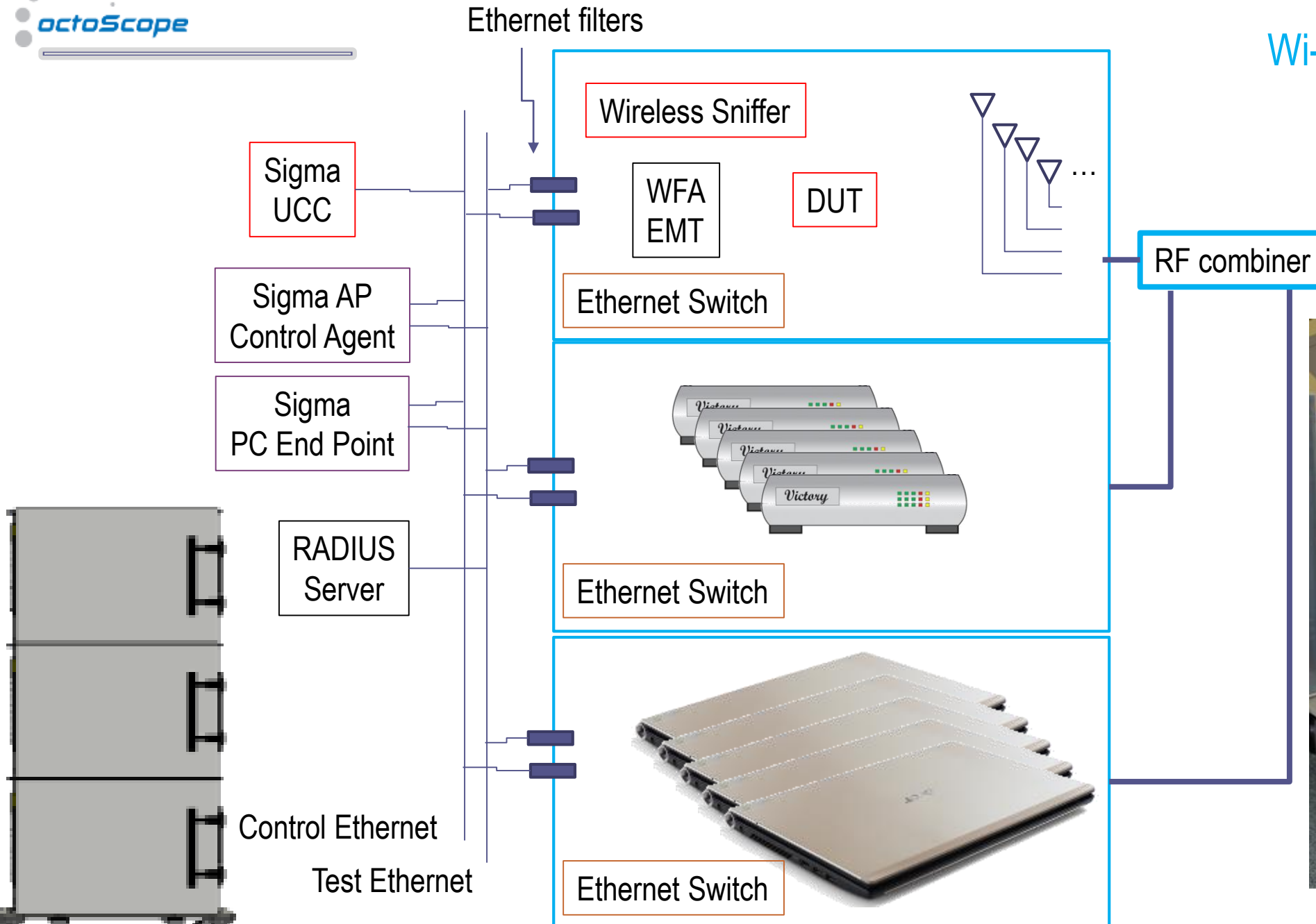
Key Wireless Test Capabilities

- ✓ Throughput performance
- ✓ Complete isolation
- ✓ Controlled interference
- ✓ Roaming behavior (sticky clients)
- ✓ Interoperability (vendor to vendor)
- ✓ Emulate a multi-room house

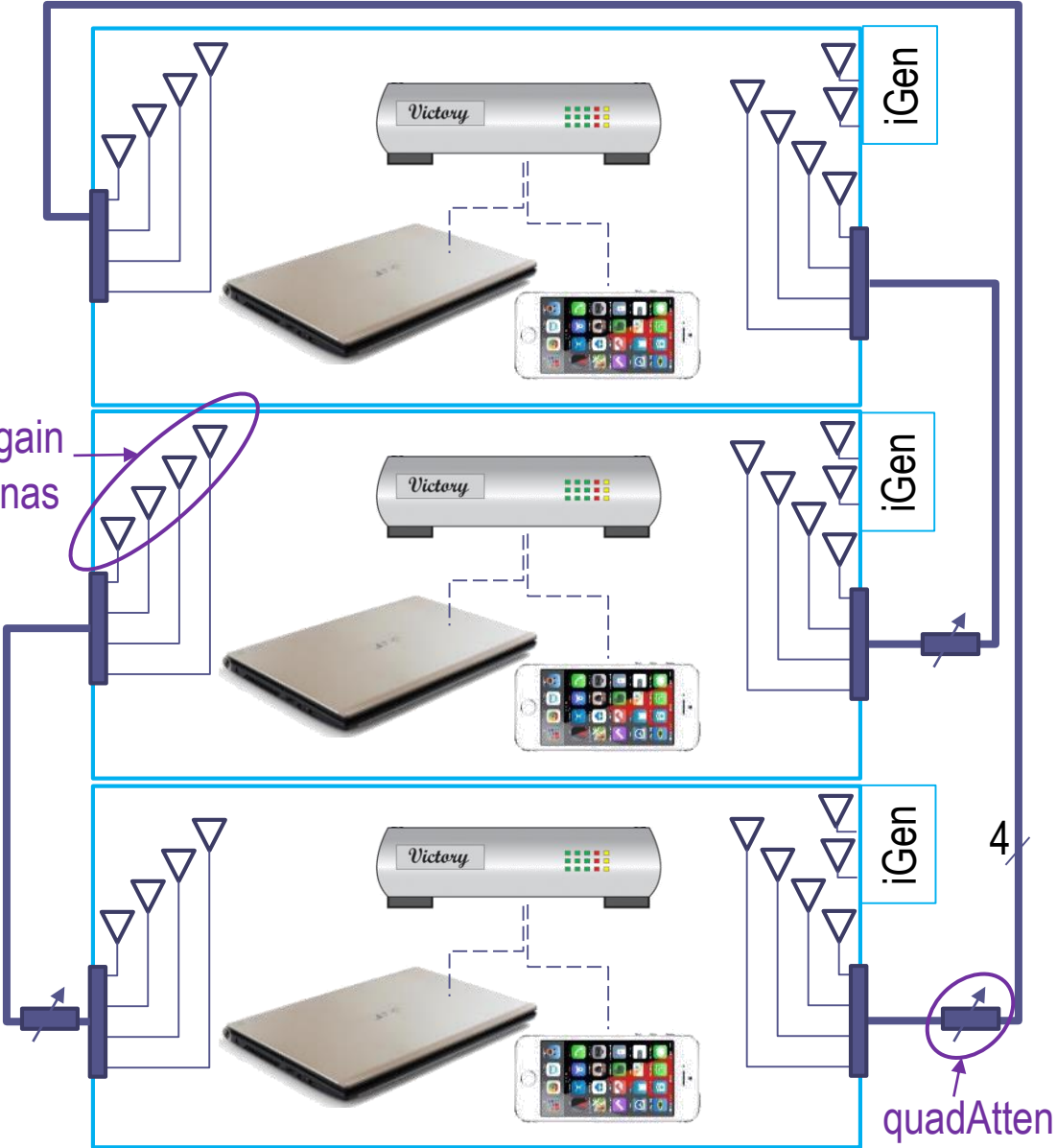
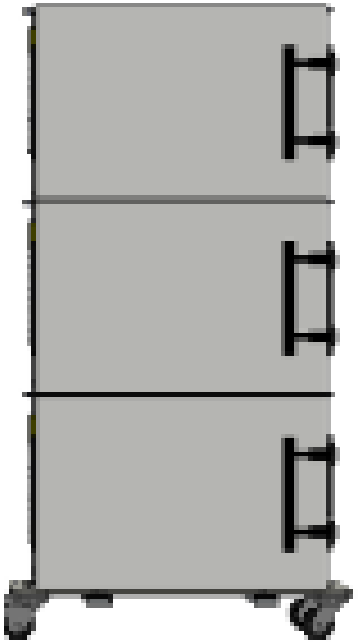


<https://www.youtube.com/watch?v=CaNxaTxCWWc>

Wi-Fi Alliance Testbed in an OB-38 triStack



Coexistence and Auto Channel Adaptation Testbed



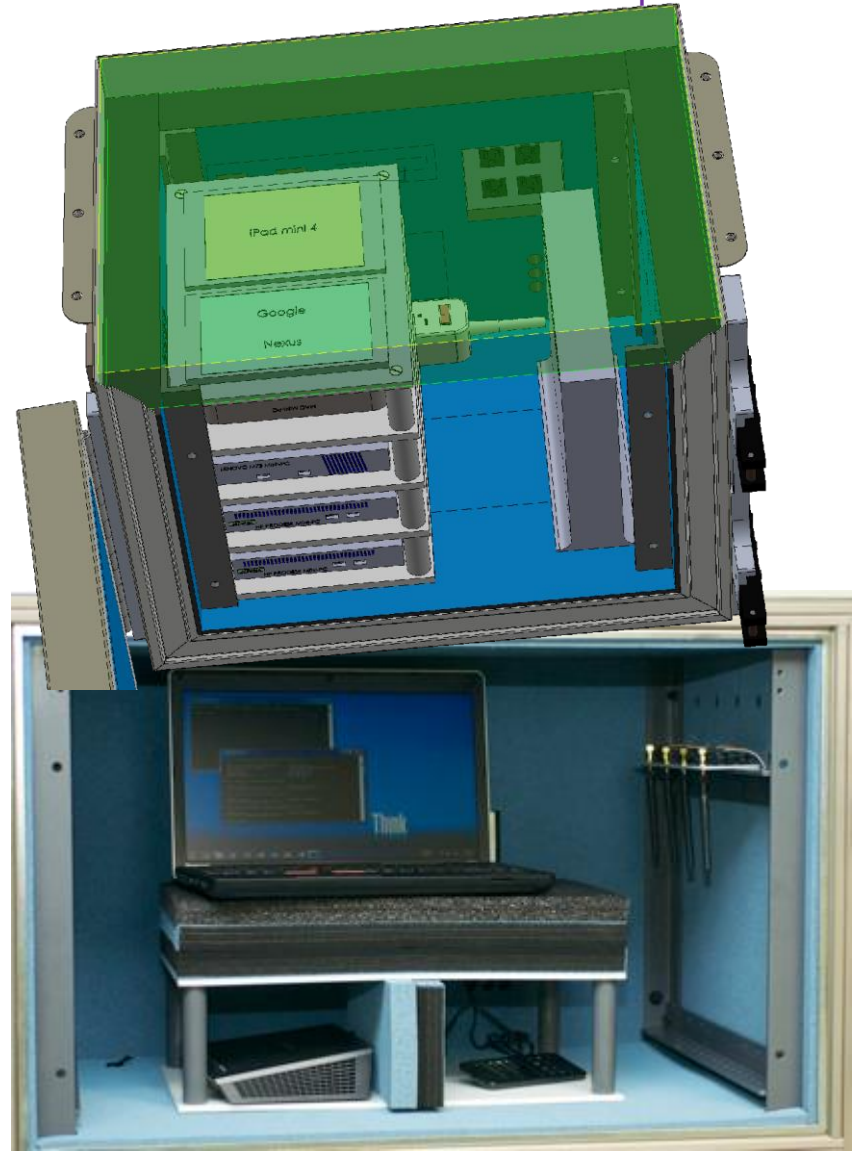
High gain antennas

AP and 2-client 'cell' in each octoBox

quadAttens control amount of cell-to-cell signal coupling

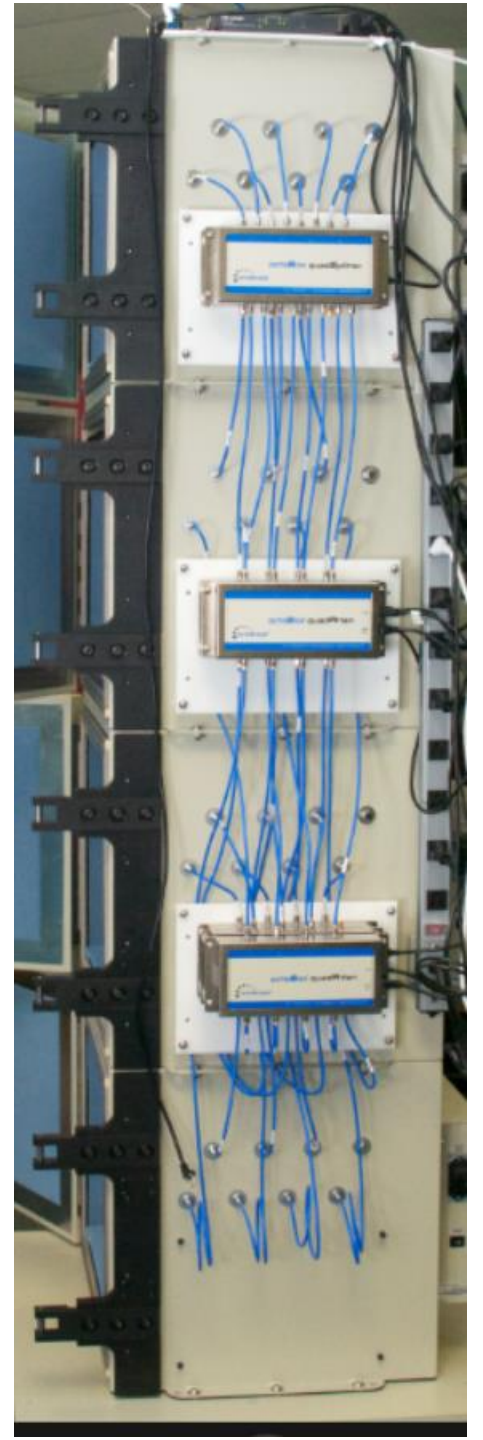
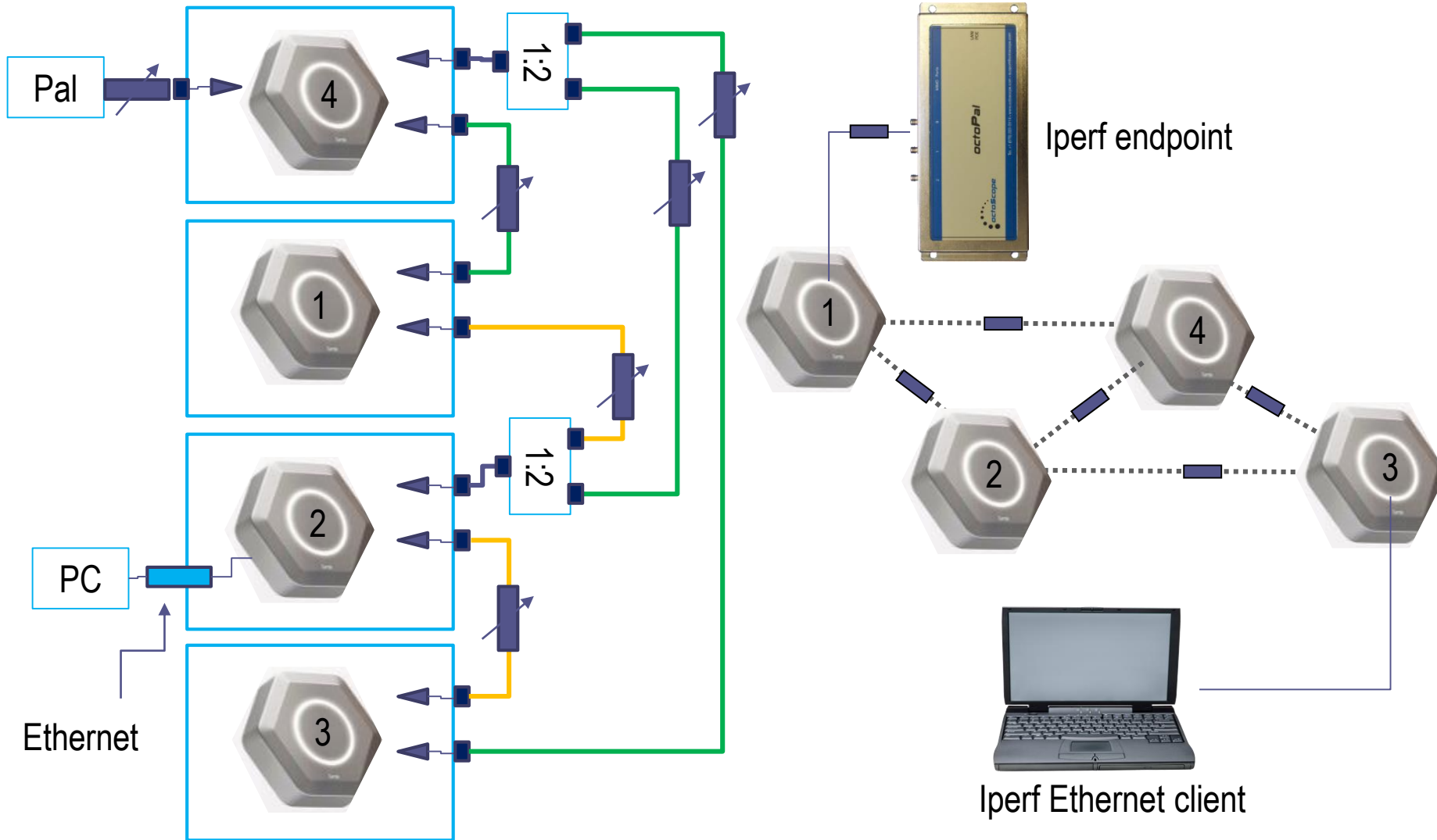
quadAtten

Multi-DUT shelf – use examples



Mesh Testbed Example

Throughput, roaming and mesh test cases

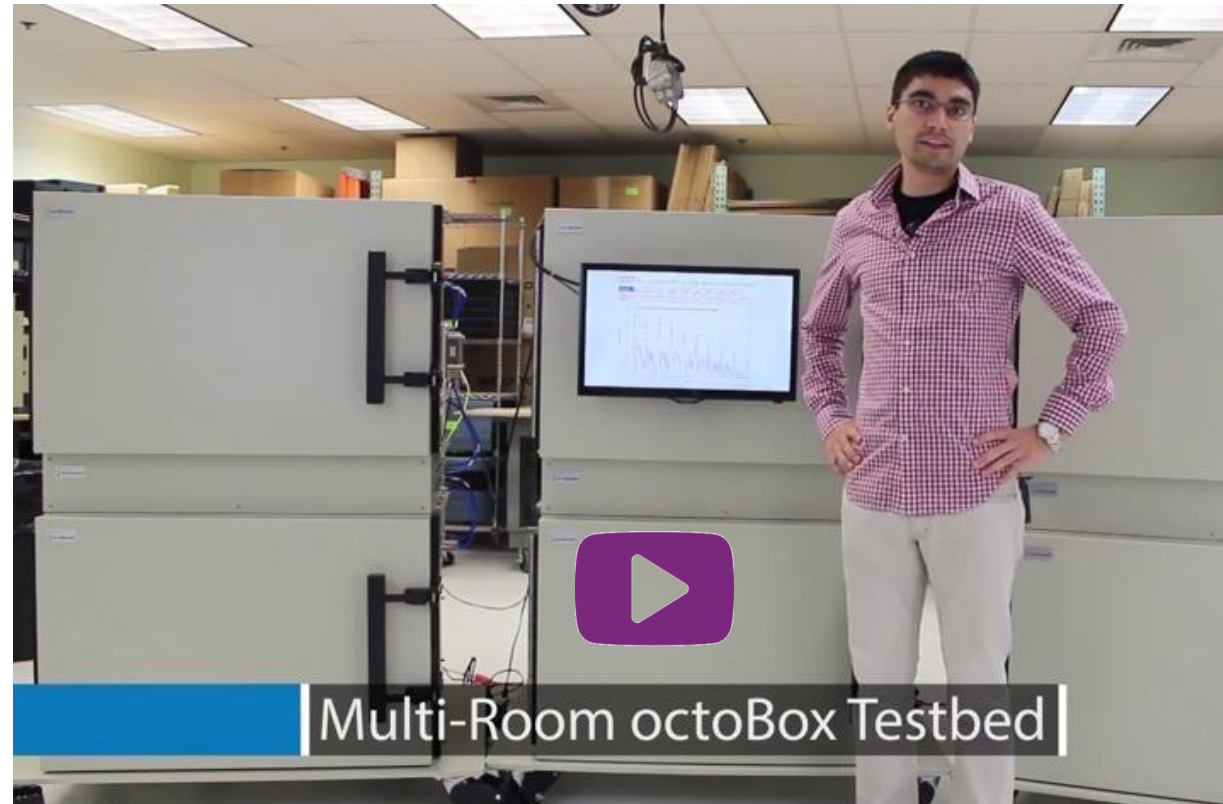


Highly Scalable Wireless Testbeds for Data Centers



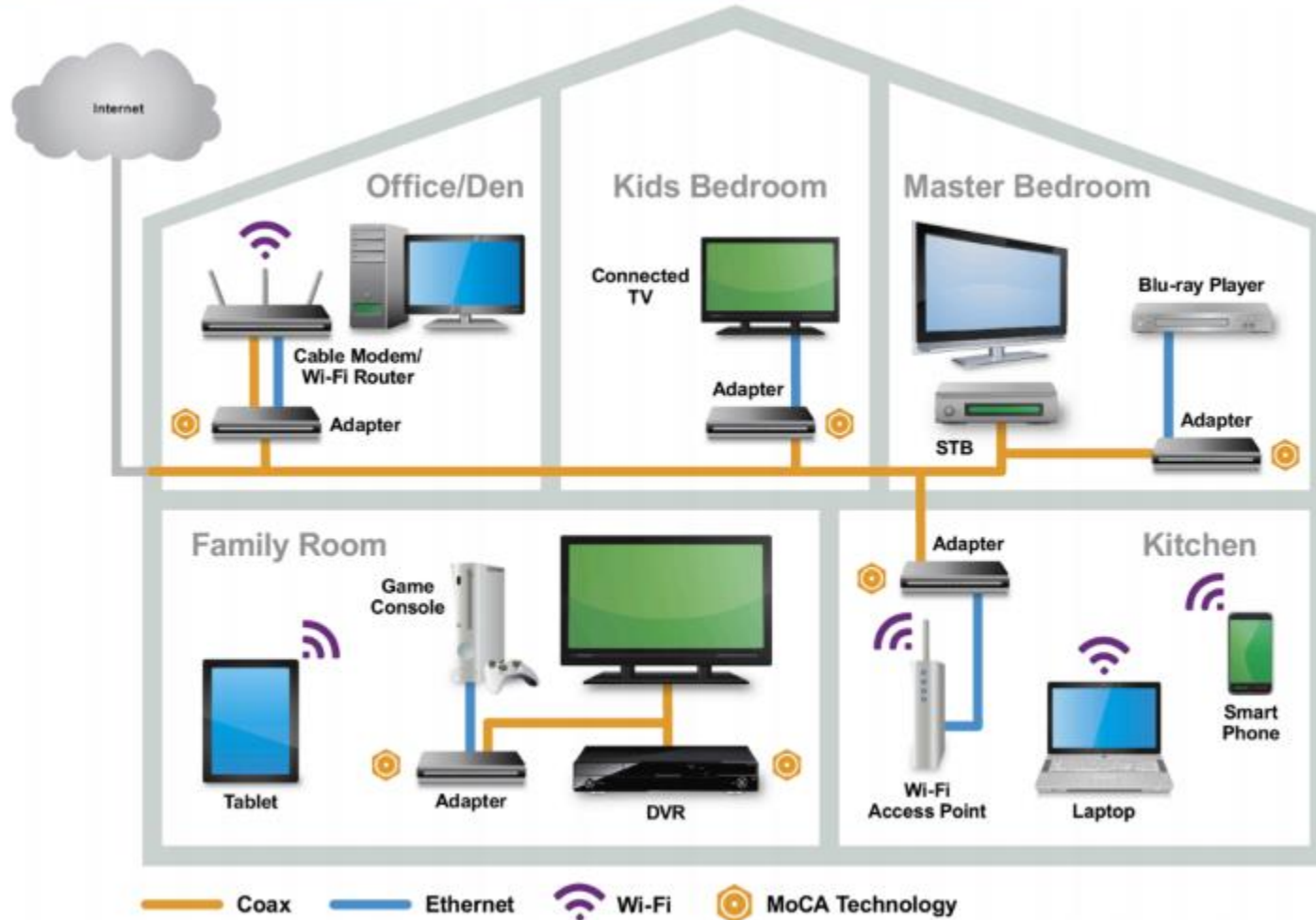
Key Wireless Test Capabilities

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- ✓ Emulate a multi-room house



<https://www.youtube.com/watch?v=UTXtebyORQA>

Multiple Boxes to Emulate Multi-room Connected House



Controlled environment octoBox testbed emulating a multi-room house



Three OB-38 triStacks



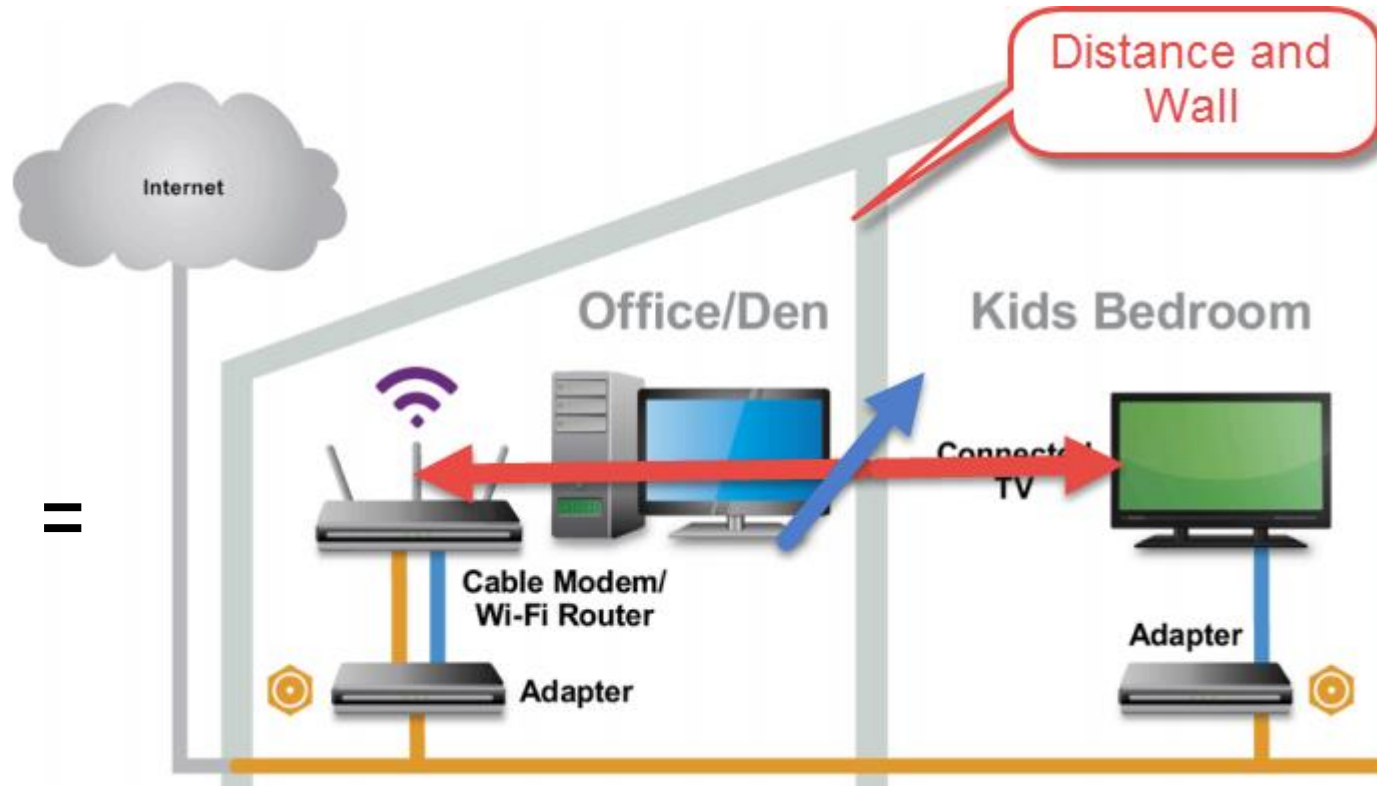
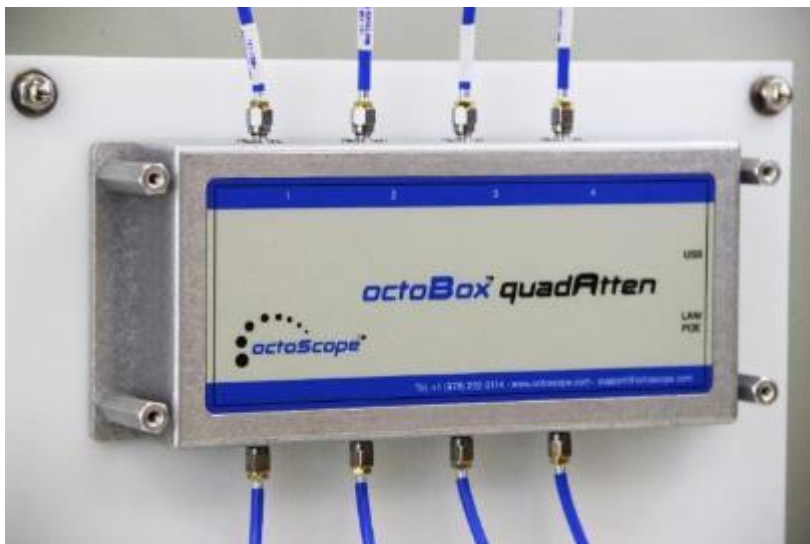
Testbed Emulating an 8-room House + Basement Video Gateway



Video, data over Wi-Fi testbed

Emulate Walls and Distance

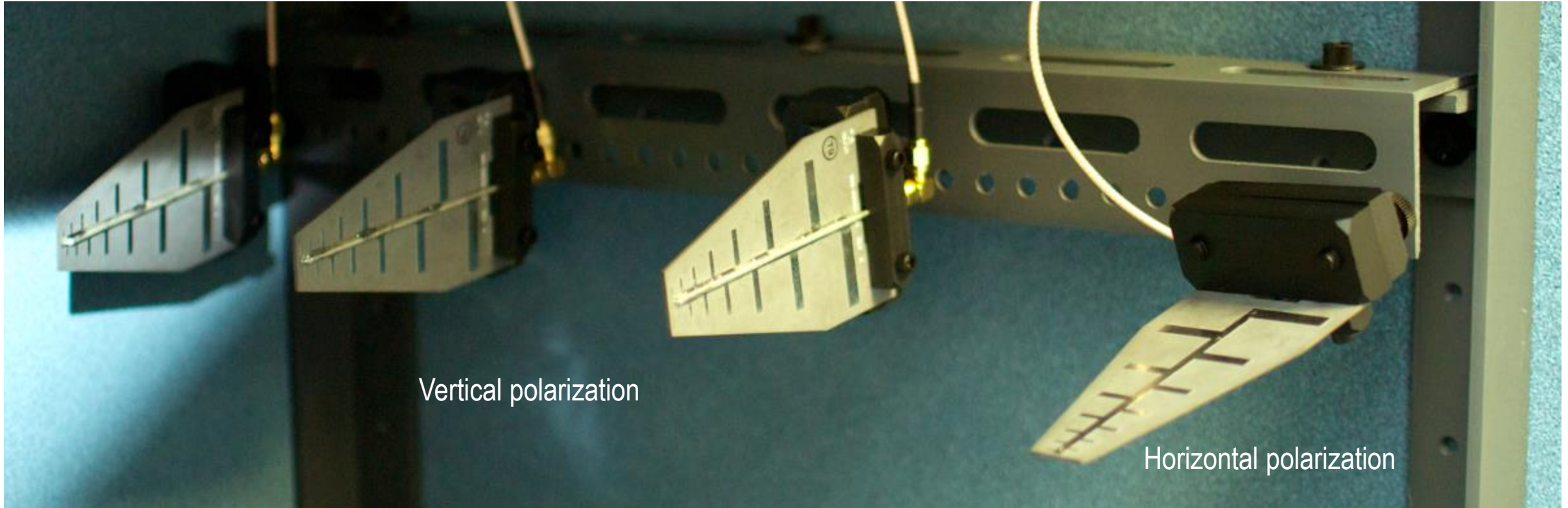
octoBox quadAtten emulates walls, floors/ceilings, space and motion of devices.



Two sizes of the octoBox
and STACK: -38 and -26

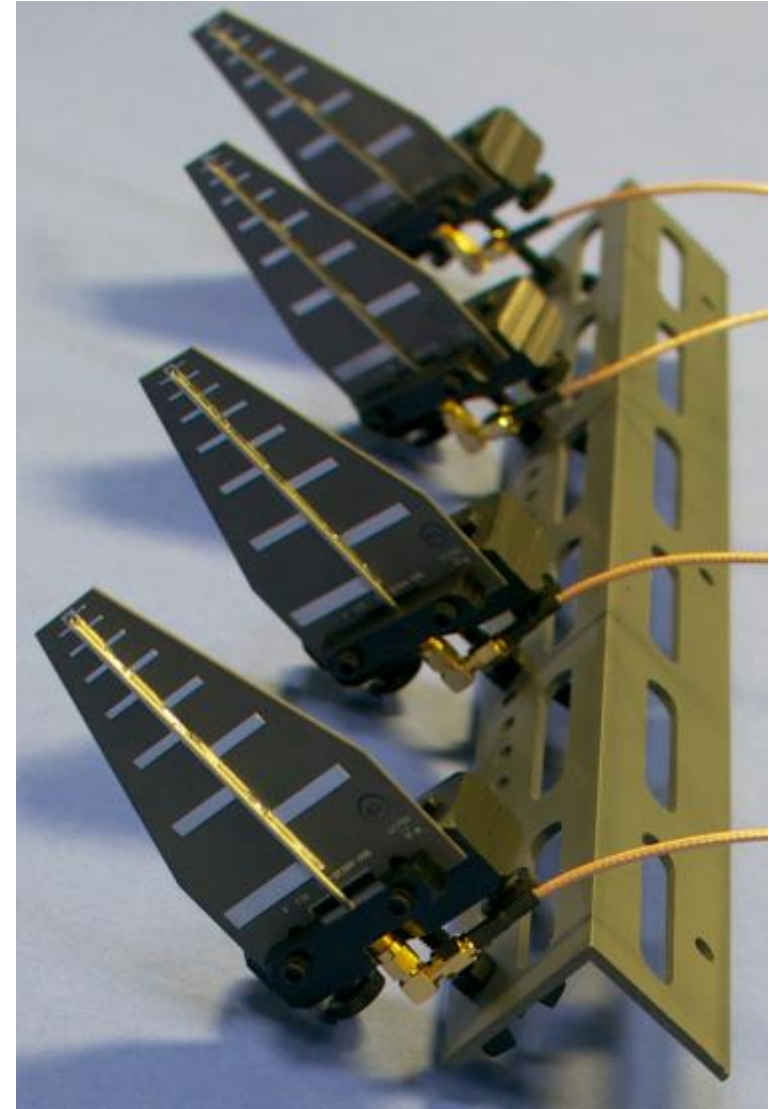
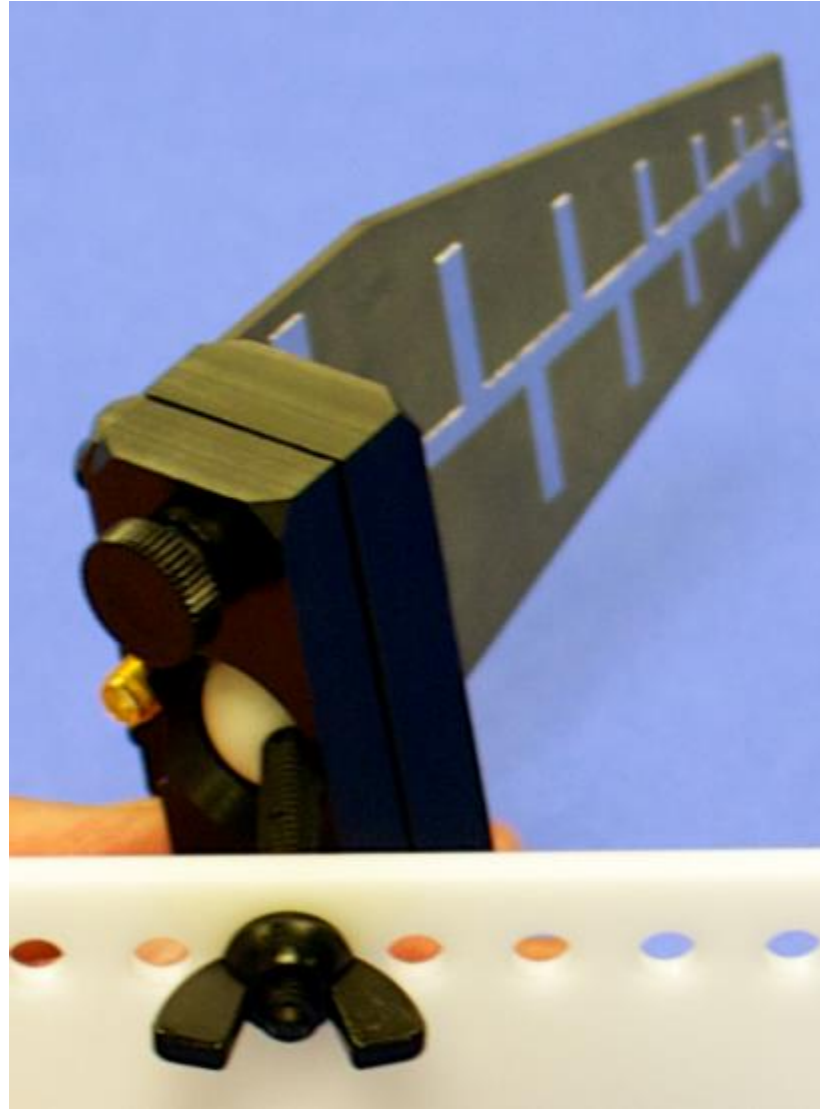
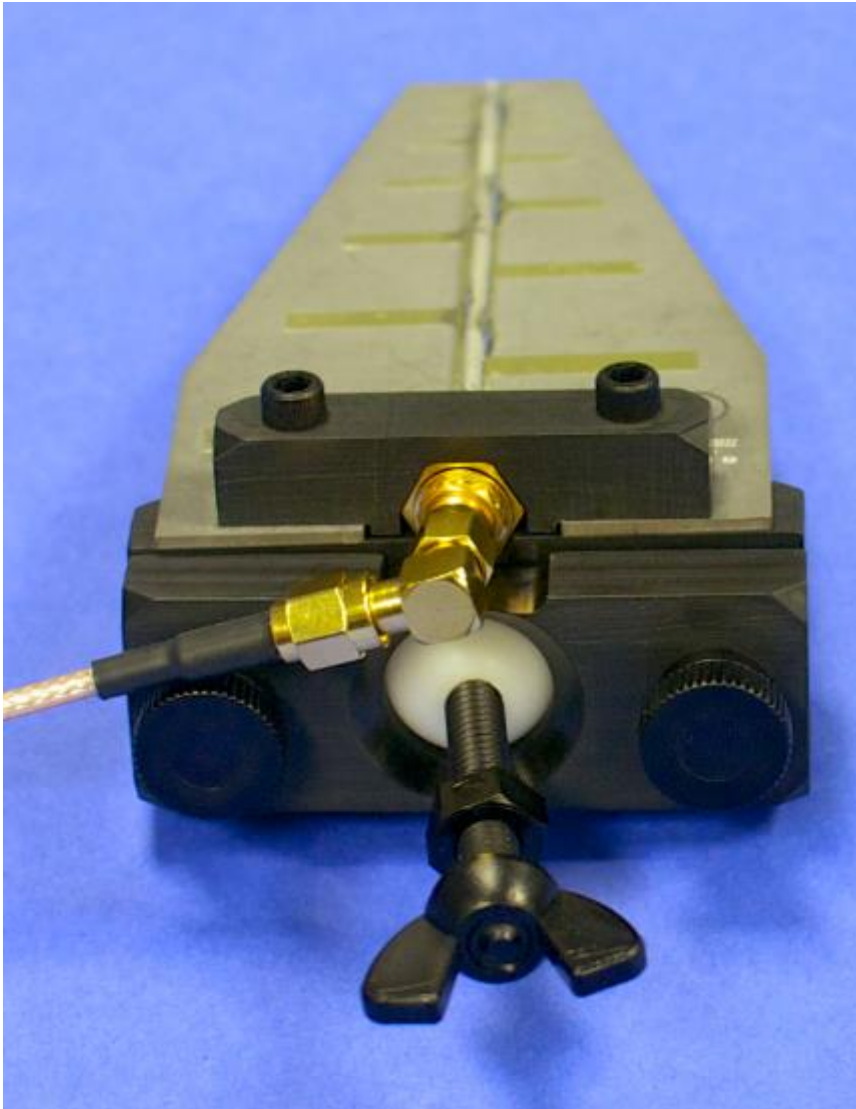


High Gain MIMO Antenna Array

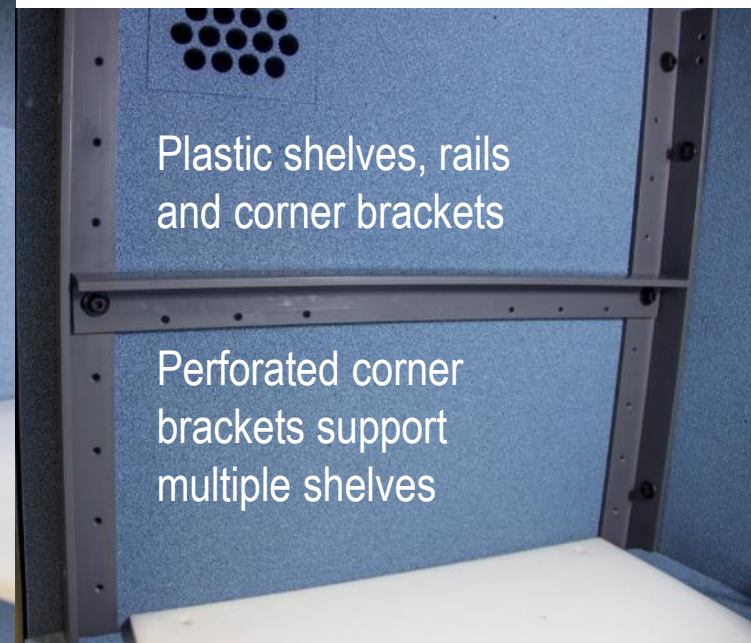


Easily rotate to set precise polarization

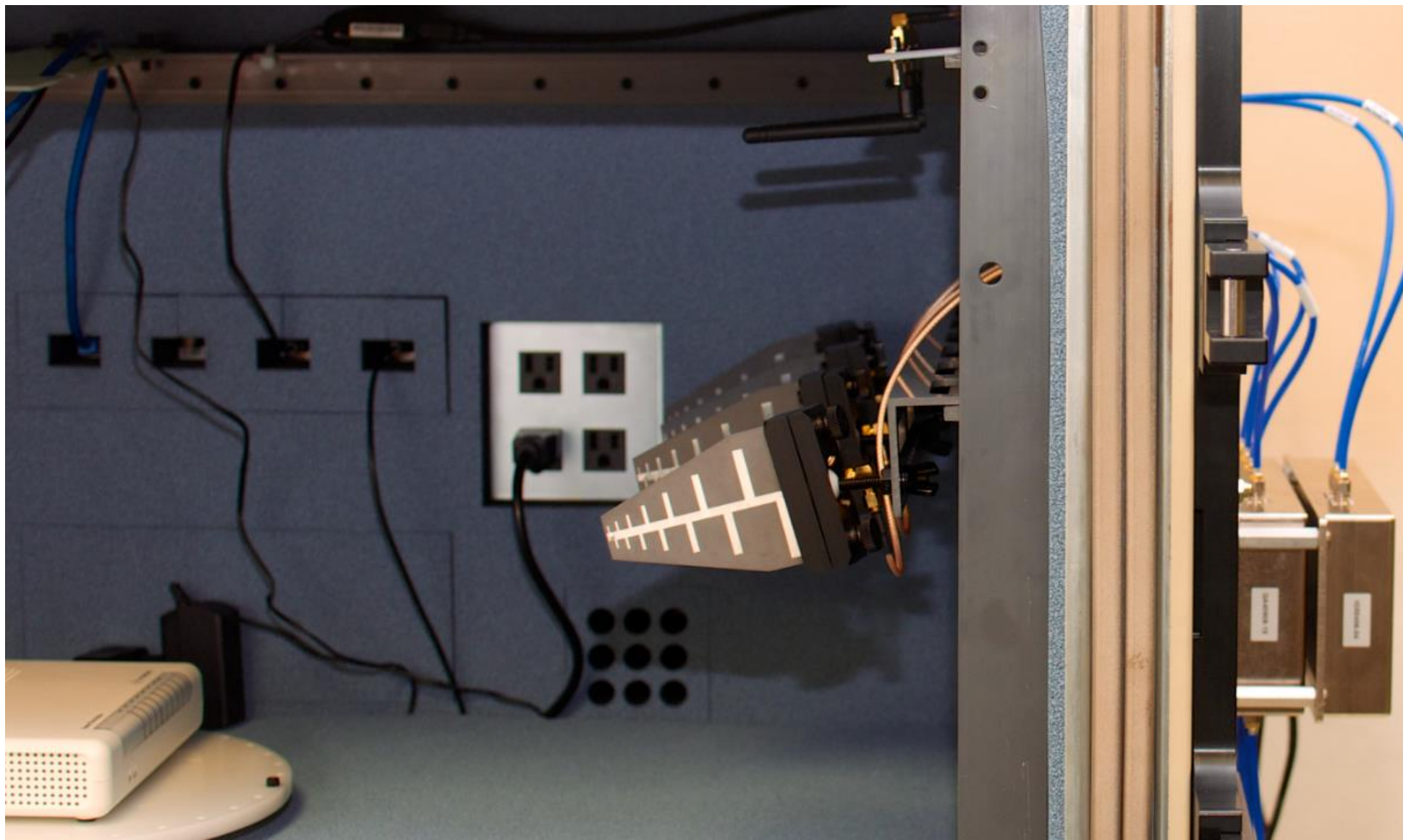
Ball Joint For Ultimate Pointing Control; Thumb Screw Tighten



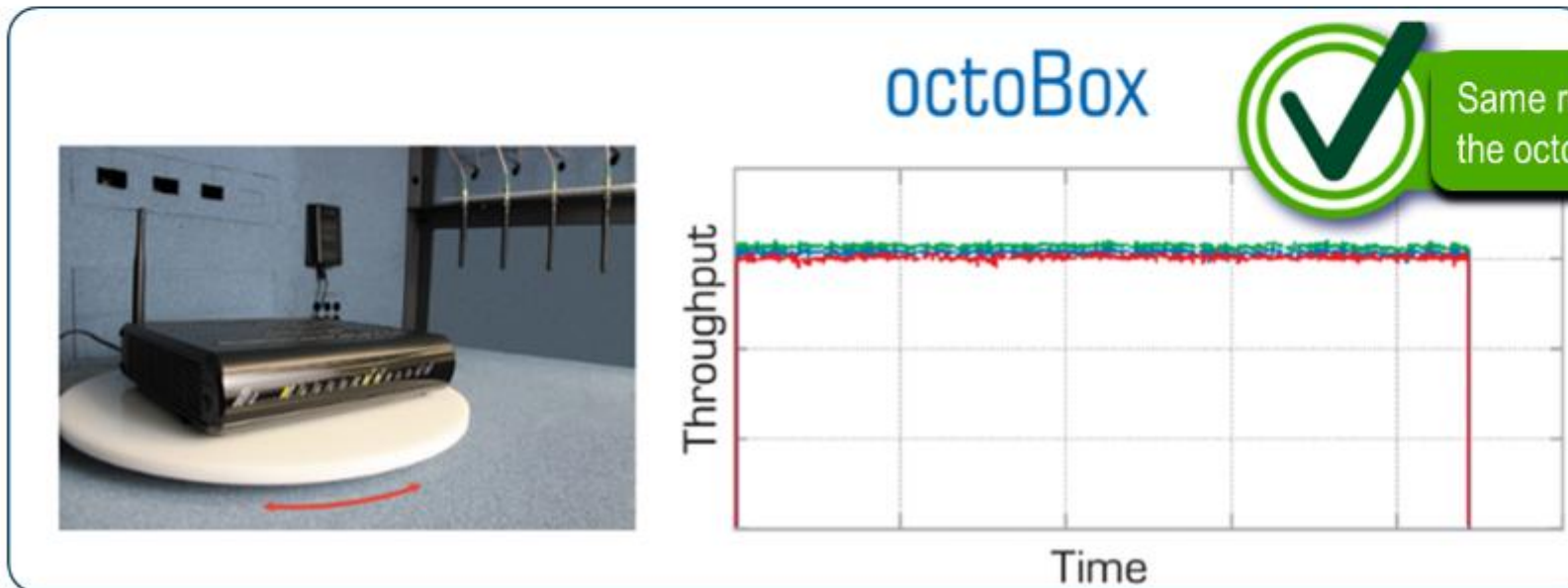
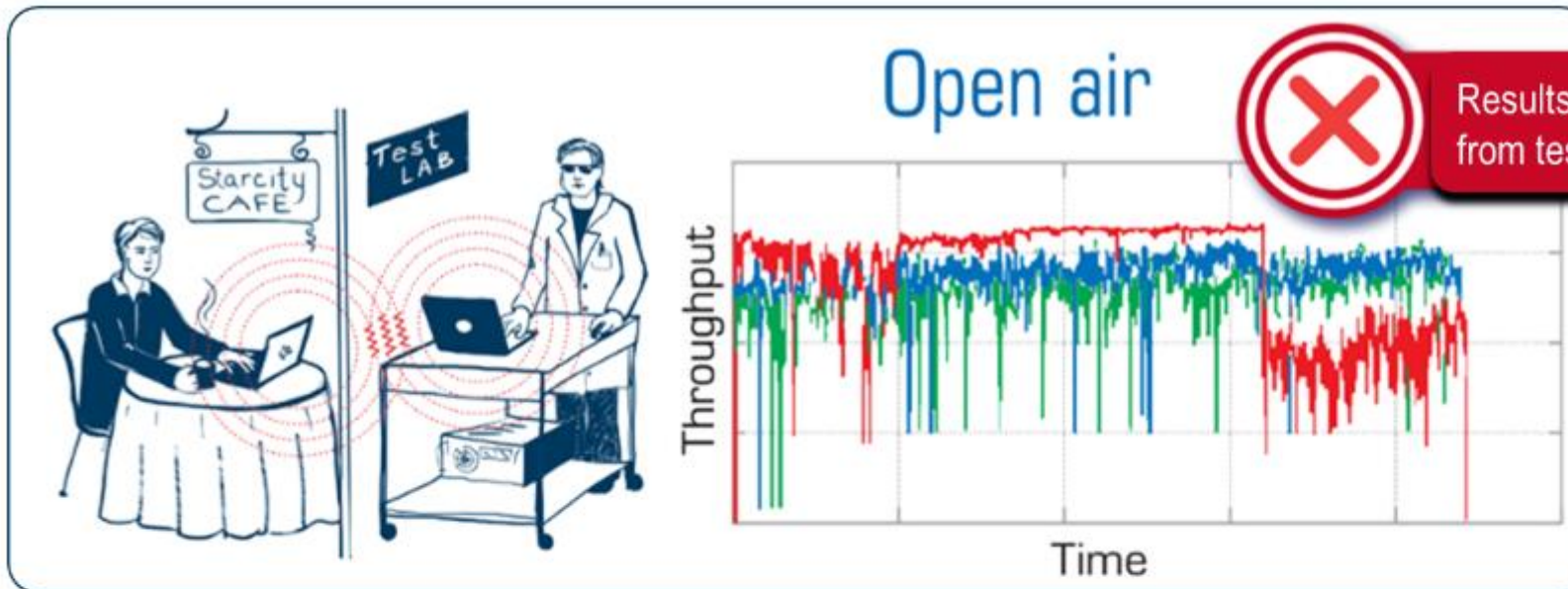
Multi-DUT Arrangement Examples



Test Antennas



octoBox Controlled Test Environment



Technologies Applications

Wi-Fi	Throughput
LTE	Roaming
2G/3G	Wi-Fi Alliance
Bluetooth	Wireless video
ZigBee	Coexistence
Proprietary	Multi-node/mesh

Capabilities

- MIMO (up to 8x8)
- Multipath + path loss
- Multi-channel interference
- Turn table for realistic results
- Completely isolated
- Stackable, configurable, compact
- Powerful test automation

Customer Value Proposition

- Repeatable RF environment makes wireless measurements easy to manage
- Automation accelerates data collection and time to market; improves quality
- Graphical reporting helps visualize device performance or behavior issues

Compact wireless test platform delivers cost-effective high performance repeatable MIMO OTA environment

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Littleton, MA

USA

