The Pal Wi-Fi Test Instrument

The Pal® is a versatile Wi-Fi wave 2 test instrument that functions as an expert analyzer, traffic partner, virtual station emulator and a load generator for testing throughput, capacity and device functionality.

A highly controllable instrument, the Pal® functions as a station (STA), virtual stations (vSTAs), access point (AP), traffic generator, load generator, sniffer and an expert monitor for tests such as throughput, forwarding rate, roaming, mesh/IoT, band steering and more. The Pal can be used in the controlled RF environment of the octoBox wireless testbed or as a stand-alone instrument.

TEST APPLICATIONS

- MIMO OTA (over the air) throughput
- Multi-User (MU) MIMO and beamforming
- Band steering
- Data rate and channel adaptation
- Airtime fairness
- Quality of Experience
- Roaming
- Coexistence of Wi-Fi, LTE, Bluetooth, etc.
- Router association capacity, forwarding rate and multi station throughput

FEATURES & BENEFITS

- 802.11a/b/g/n/ac operation in the 2.4 and 5 GHz bands, licensed DSRC band
- Integrated endpoints for automated throughput testing: iperf2, iperf3, multiPerf, AT4-Agents and IxChariot
- Programmable channel frequency, channel width (20, 40, 80, 80+80, 160 MHz), MCS (modulation coding scheme) and WMM (Wi-Fi multi media) priority
- Convenient Ethernet/PoE power and control interface, filtered for isolation

The Pal is an embedded Linux Yocto device powered and controllable via its Ethernet port. The Pal's computing platform is based on a powerful quad-core 2 GHz Intel Atom in addition to a dedicated processor for the radio and protocol-specific functions.

There are 3 models of the Pal, determined by its radio card: Pal-245 dual band (2.4/5 GHz) wave 1, Pal-24 2.4 GHz wave 2 and Pal-5 5 GHz wave 2. Table 1 shows the capabilities the Pal vs. model.

Table 1: Summary of Pal capabilities

	Pal-245	*Pal-24*	*Pal-5*
	2.4/5 GHz 3x3 radio *QCA9880 3x3 80 MHz*	**2.4 GHz 4x4 radio (wave 2)** *QCA9984 4x4 40 MHz*	**5 GHz 4x4 radio (wave 2)** *QCA9984 4x4 160 MHz*
MIMO-OTA	√	√	√
MU-MIMO			√
Beamforming		√	√
Channel width	20/40/80 MHz	20/40 MHz	20/40/80/80+80/160 MHz
AP	√	√	√
STA (client)	√	√	√
Virtual STA, vSTA		32	32
Traffic replay	√		
Monitoring	√	√	√
Wireshark captures	√	√	√
2.4 GHz	√	√	
5 GHz	√		√

Based on the latest 802.11ac chipsets and with fine controls at the firmware and driver level, the Pal can function as a real device or as a precision test instrument. For example, to test band steering, the Pal can function at a set data rate, bandwidth and number of streams. You can set its WMM priority and configure it to function as any legacy device.

To test receiver sensitivity, the Pal can operate at a fixed modulation coding scheme (MCS).

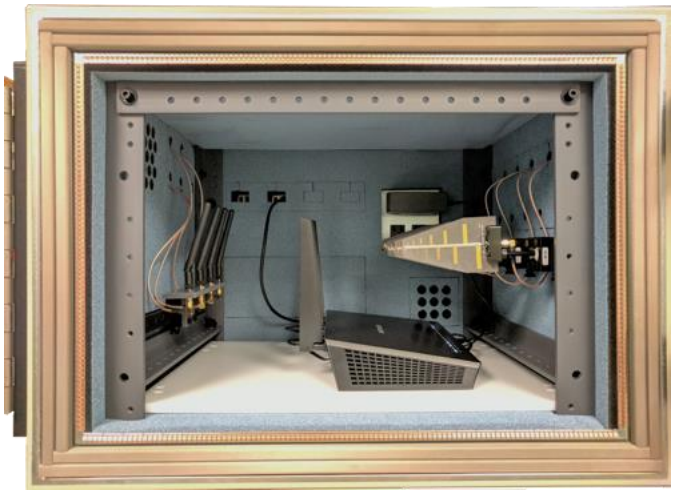
The Pal can also function as a real-time analyzer to show you adaptation behavior of modern Wi-Fi systems. The Pal can monitor and plot RSSI, data rate, # streams, channel width and other physical layer information. It can also capture packets and save them as PCAP files viewable in Wireshark and other sniffers.

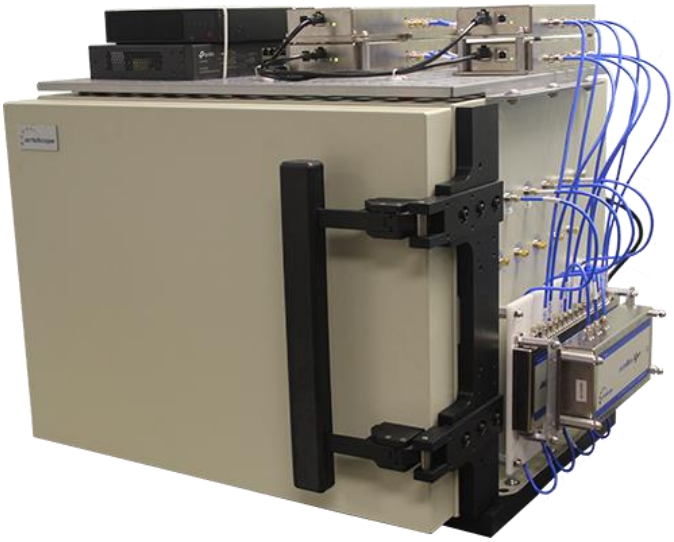
To test access point (AP) performance or to emulate a realistic network with multi-station traffic, the Pal can emulate up to 32 virtual stations (vSTAs) using the optional vSTA software.

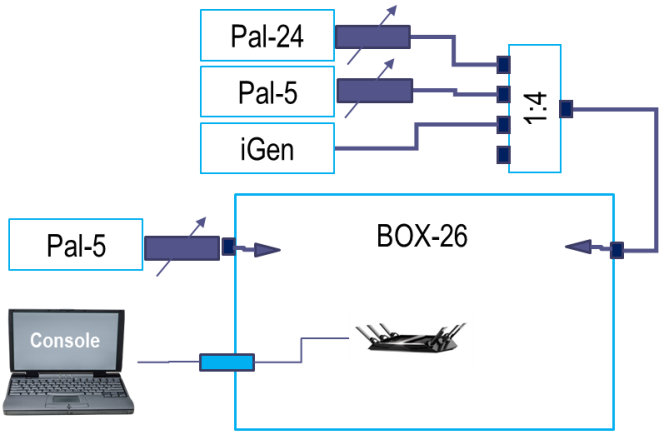
To emulate in-range networks that contribute to co-channel and adjacent channel interference (CCI and ACI), the Pal can replay saved PCAP files in a special replay mode without requiring association to transmit this traffic load.

PAL BASED OCTOBOX TESTBEDS

The Pal enables compact yet powerful testbeds where it can run a range of automated tests. See below the block diagrams of two standard octoBox testbeds, STACK-BENCHTOP and STACK-SNB (SmallNetBuilder.com) and a table that summarizes tests supported by each of these testbeds.







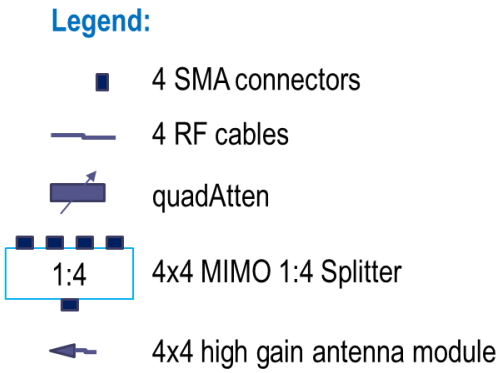


Figure 1: STACK-BENCHTOP testbed (photo above, block diagram below)

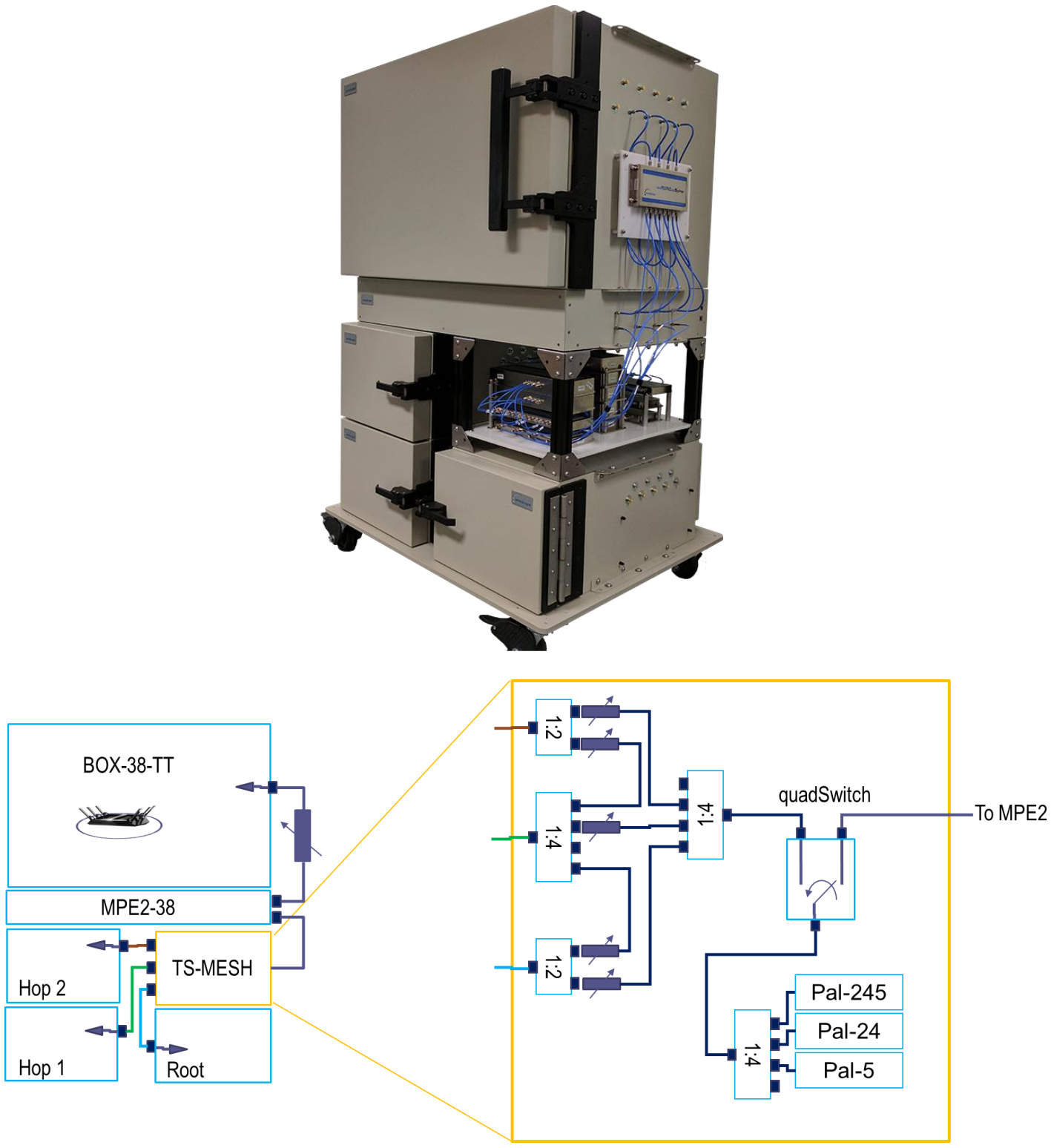


Figure 2: STACK-SNB testbed (photo above, block diagram below)

Table 2: Tests supported by STACK-BENCHTOP and STACK-SNB testbeds

	STACK-BENCHTOP	STACK-SNB
MIMO-OTA	√	√
MU-MIMO	√	√
Throughput vs. range	√	√
Throughput vs. range vs. orientation		√
Beamforming	√	√
Throughput vs. interference	√	√
Mesh		√
Interoperability with real devices		√
Roaming	√	√
Monitoring and analysis	√	√
Packet capture	√	√
Traffic replay for Co Channel and Adjacent Channel Interference (ACI, CCI)	√	√
Bluetooth, Radar and other interference	√	
DFS (dynamic frequency selection)	√	
Multi-channel aggregate throughput	√	√
Channel adaptation	√	√
Data rate adaptation	√	√
Roaming / band steering	√	√
Receiver performance	√	√
Association capacity	√	√

USER INTERFACE

The Pal is controllable via a browser-based user interface and an open API (applications programming interface). The API enables you to automate and easily sequence through important performance tests in the ideal conditions and in the presence of controllable impairments. You can use C/C++, Python or any other scripting language to create lengthy automated test sequences.

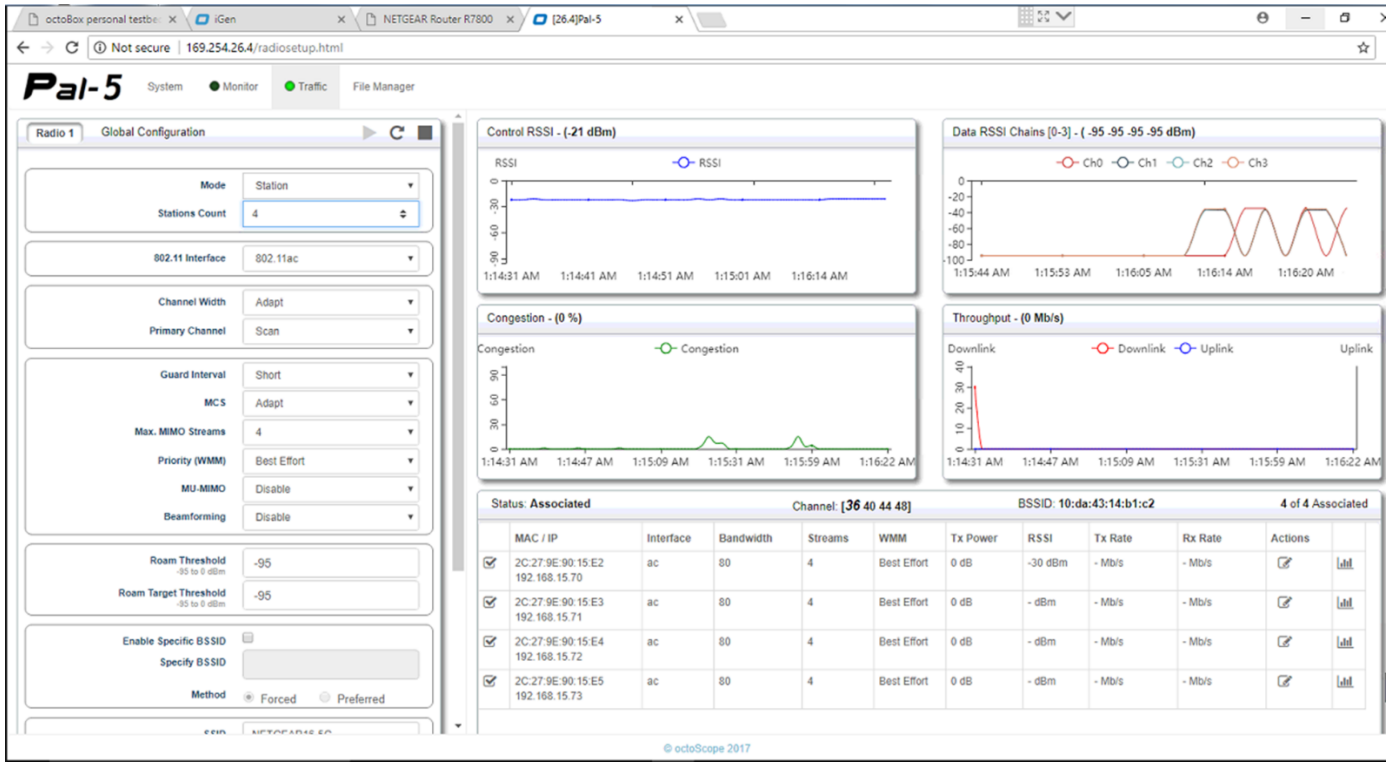


Figure 3: Pal browser UI screenshot showing settings on the left and a list of vSTAs and their settings and statistics on the right

VIRTUAL STATION EMULATION FOR LOAD TESTING

The Pal can emulate up to 32 virtual stations, vSTAs. Each vSTA can run its own IP traffic session via a traffic endpoint specifically instantiated for each vSTA.

For throughput measurements, the Pal supports octoScope's multiPerf, iperf2, iperf3, IxChariot and AT4 traffic endpoints. The octoBox software automates throughput vs. range and throughput vs. range vs. orientation tests with expert analysis around iperf3 based multiPerf™ developed by octoScope to send point-to-point, point-to-multipoint and multipoint-to-multipoint traffic.

To help diagnose performance issues, the Pal's expert analysis includes plots of throughput with the corresponding RSSI (per TX/RX chain), data rate, MCS, # MIMO streams, bandwidth and congestion. Analysis is available per vSTA.

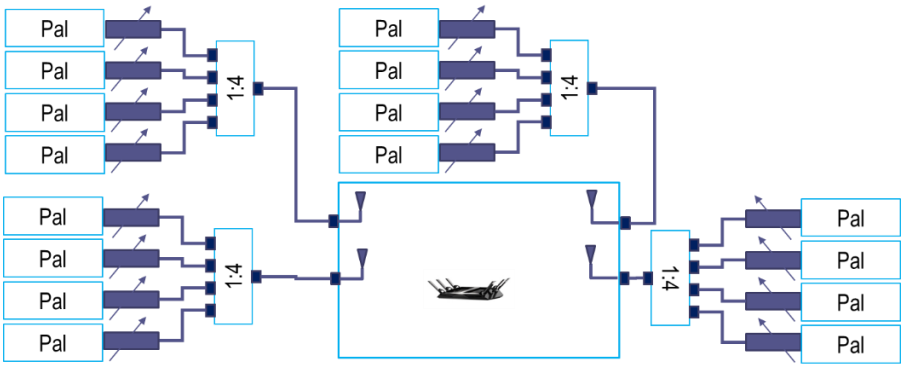
Each vSTA can be set to a specific 802.11a/b/g/n/ac standard with unique settings for # streams, MCS, WMM priority, TX power and channel bandwidth.

Status: **Associated** BSSID: **04:f0:21:2b:1c:85** Channel: **[36 40]** 5 of 5 Associated

MAC / IP	Interface	Bandwidth	Streams	WMM Q	Tx Power	RSSI	Tx Rate	Rx Rate	Actions
70:B3:D5:EF:34:C0 192.168.15.50	n	40	2	Best Effort	24 dBm	-20 dBm	300 Mb/s	300 Mb/s	
70:B3:D5:EF:34:C1 192.168.15.51	ac	20	1	Best Effort	24 dBm	-20 dBm	86 Mb/s	173 Mb/s	
70:B3:D5:EF:34:C2 192.168.15.52	ac	80	3	Best Effort	24 dBm	-15 dBm	1170 Mb/s	1170 Mb/s	
70:B3:D5:EF:34:C3 192.168.15.53	n	20	3	Best Effort	24 dBm	-19 dBm	216 Mb/s	216 Mb/s	
70:B3:D5:EF:34:C4 192.168.15.54	n	40	1	Best Effort	24 dBm	-19 dBm	150 Mb/s	150 Mb/s	

: Edit : Save : Cancel : Associated : Scanning : Disassociated

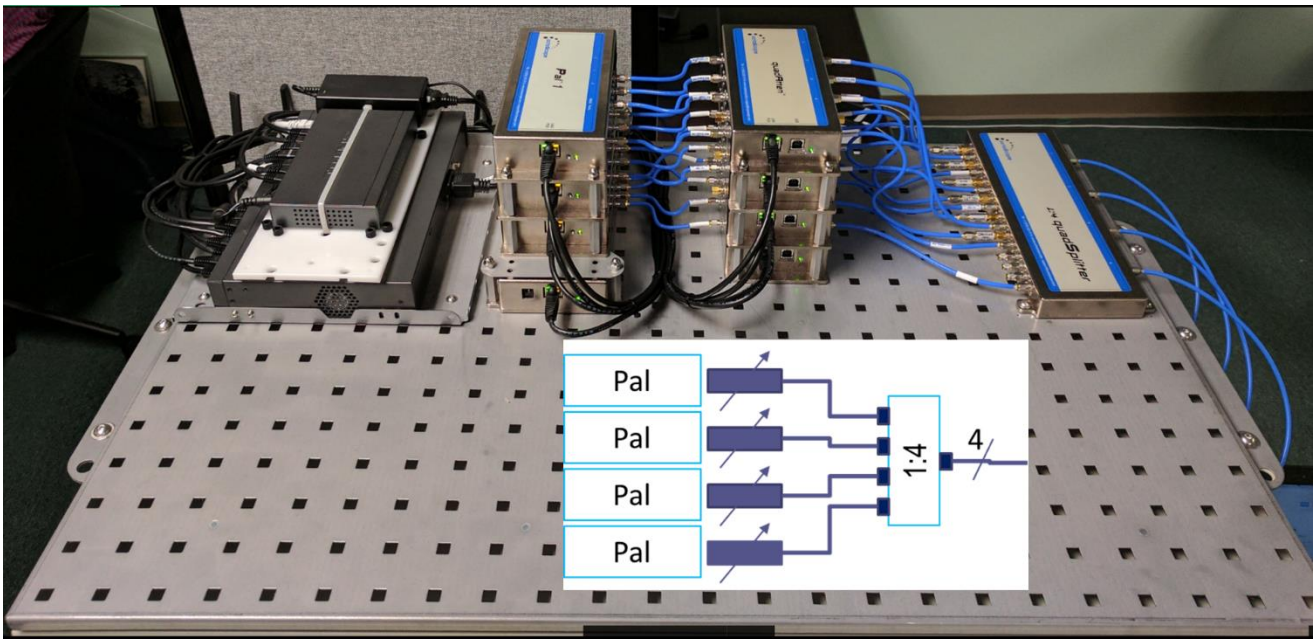
Multiple Pals can form a multiPal™ subsystem to create a scalable wireless MIMO-OTA testbed with traffic load from up to 16 physical radios each with 32 vSTA virtual stations. The testbed can easily scale to 16 Pals and beyond via, for example, octoScope's 1:4 MIMO splitters and 4 MIMO antenna arrays, as shown below.

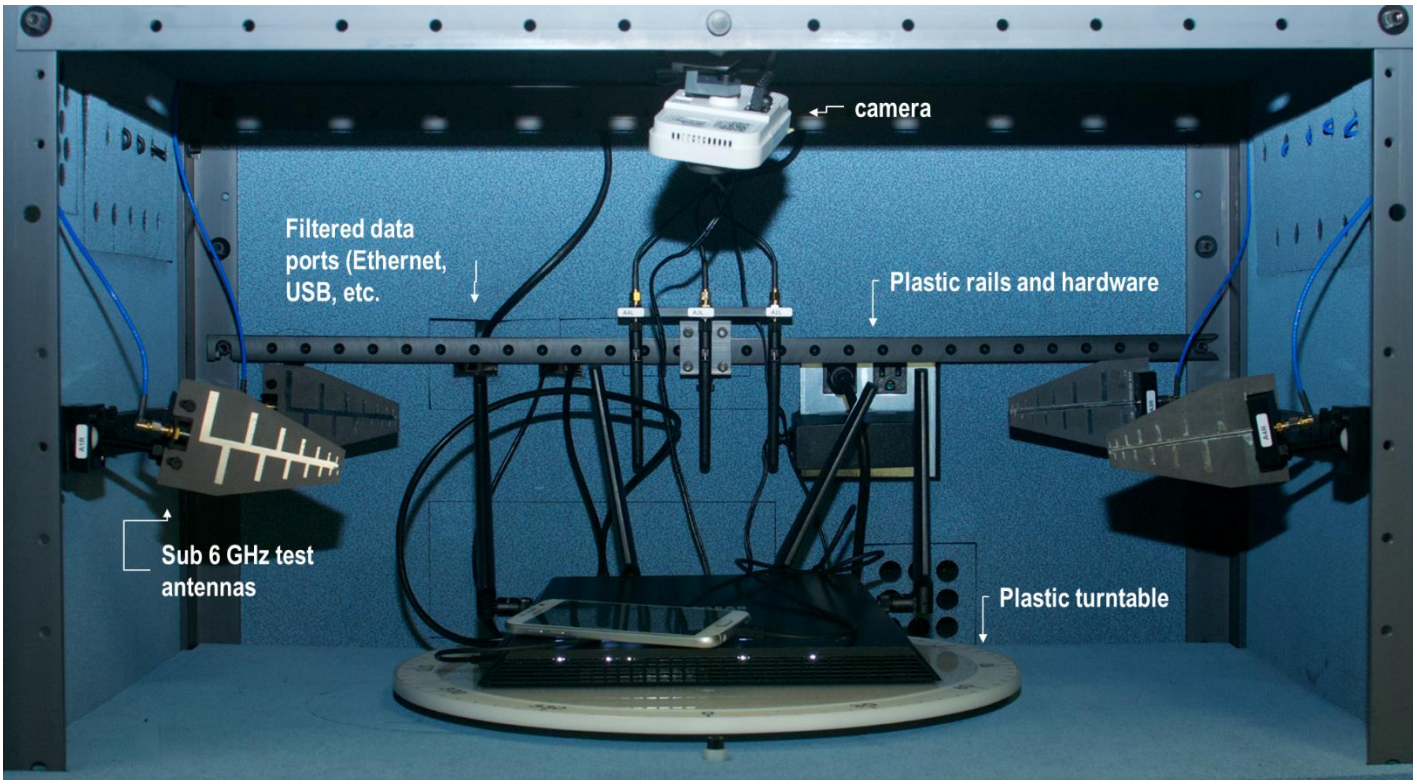


Each group of Pals can have its own angle of arrival with respect to the DUT inside the octoBox to create real-life test scenarios reflecting spatial diversity of stations in the testbed. The Pals can also be made to roam via programmable attenuators in an octoBox test topology such as the STACK-SNB that is set up for multi-AP or AP-extender systems.

A multiPal can generate or analyze multi-channel traffic to test router association capacity, throughput performance and ability to function in congested Wi-Fi environments.

The 1:4 MIMO RF splitter/combiner shown below feeds 4 antennas inside the octoBox:





MONITOR MODE – PAL AND IGEN

In Monitor mode, the Pal or iGen is set to a specific channel to monitor and list all the stations seen on that channel and a summary of their transmissions as shown (RSSI, MCS, streams, channel width, etc.).

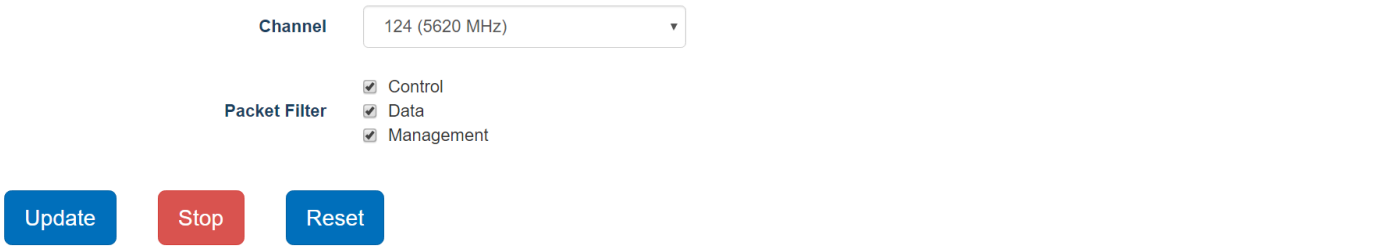


Figure 4: Pal or iGen browser UI showing the Monitor mode summary screen

Double-click on any MAC address in the summary screen shown above, and you will see a real-time plot of statistics vs. time for the selected device, plotted at 1 second intervals, as shown below.

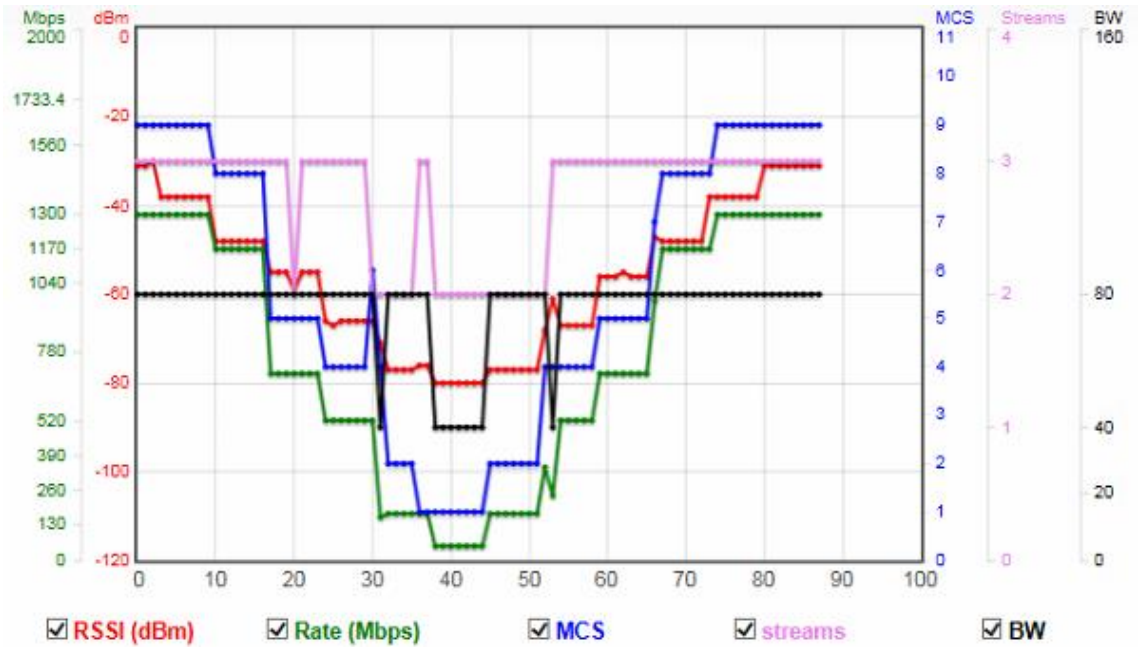


Figure 5: Monitor plots displaying RSSI, MCS, # of streams & bandwidth vs. time

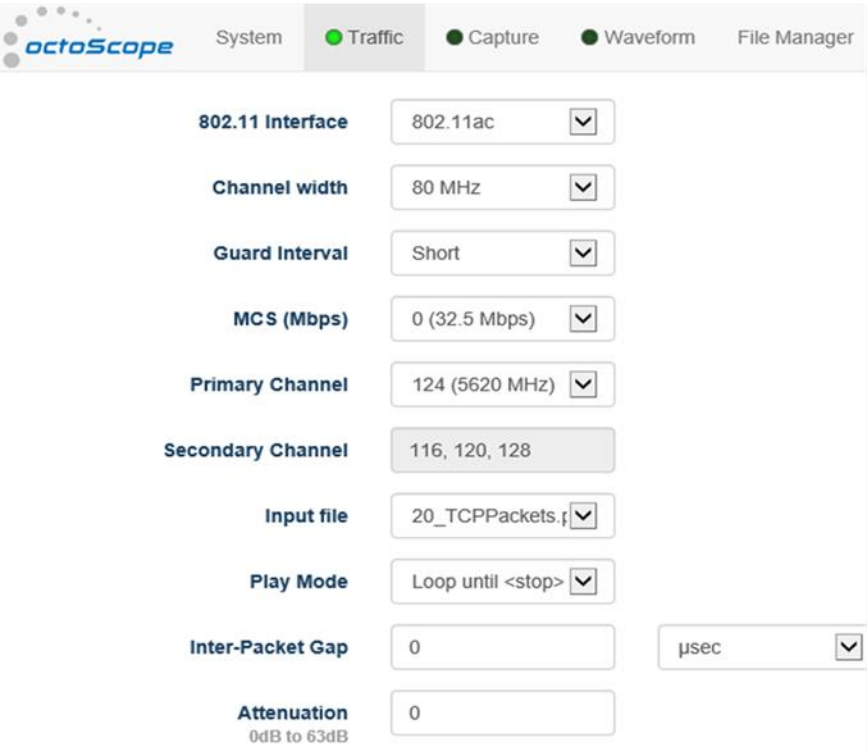
TRAFFIC REPLAY – PAL AND IGEN

Traffic replay mode is available in the Pal and iGen. You can load a standard PCAP file, used by sniffers such as the Wireshark and replay the captured traffic.

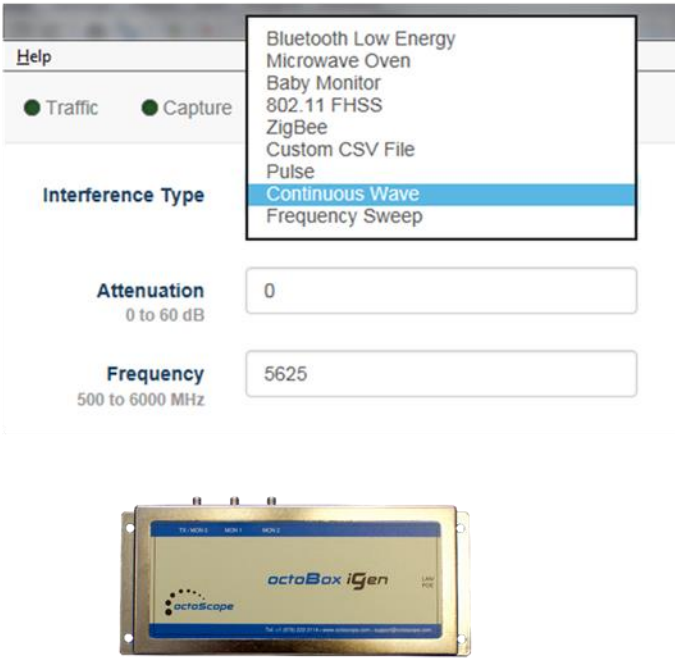
The PCAP files can contain one or more captured packets and these packets can be replayed with a controllable packet gap, priority, MCS and other parameters.

In addition to traffic replay, octoScope's iGen interference generator also generates ON/OFF Keying (OOK) waveforms, such as frequency hopping Bluetooth waveforms, radar for testing DFS, etc. Refer to the iGen datasheet for further details.

Traffic interference



Waveform interference



THE PAL's BENEFITS

The Pal's key benefit is its ability to function as both a real device for real-life testing and as a test instrument for precision radio testing and expert analysis.

For example, to measure receiver sensitivity, the Pal can operate at a fixed MCS to measure throughput vs. path loss for each MCS.

To qualify MCS adaptation behavior of devices under test, the Pal can function as a real, adaptable device and monitor DUT (device under test) behavior.

Pal's key benefit is its ability to function as both a real device for real-life testing and as a test instrument for precision radio testing and expert analysis.

To test fairness of access, the Pal can be configured to operate at any WMM priority. When the airlink is oversubscribed and identical traffic is sent from the Pal and the DUT in the completely quiet and controlled octoBox environment, throughput will be equal when WMM priorities are equal.

THE BENEFITS OF THE OCTOBOX PERSONAL TESTBED

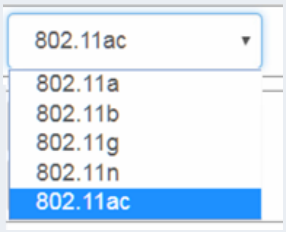
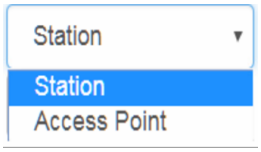
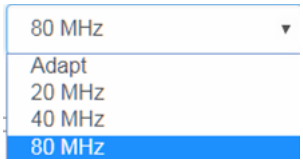
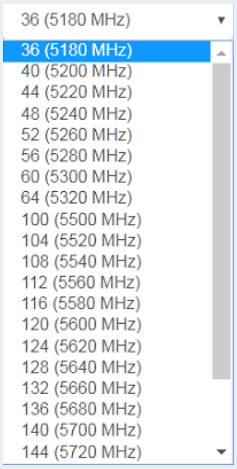
The octoBox® wireless personal testbed, incorporating the Pal and iGen instruments, offers three important benefits and enables you to:

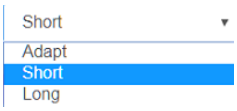
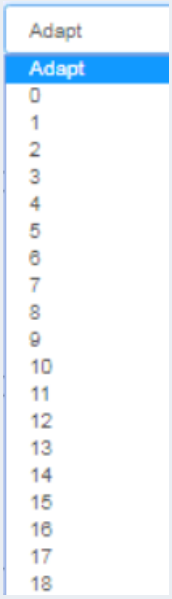
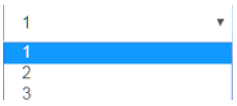
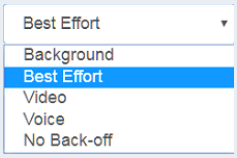
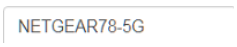
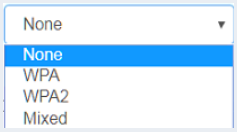
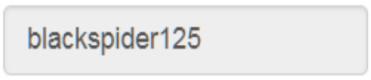
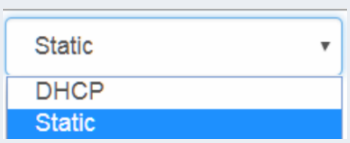
Reduce test time from weeks to hours	Complete isolation and repeatable RF environment minimizes time-consuming open-air testing. Test automation accelerates data collection and improves test coverage and product quality.
Demonstrate highest achievable performance	Ideal MIMO environment for highest possible 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

To learn more, view our instructional videos featuring the octoBox test configurations.

PAL BROWSER AND API SOFTWARE CONTROLS

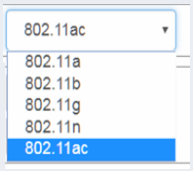
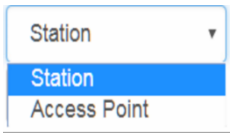
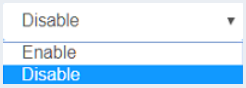
Table 3: PAL-245 station mode controls

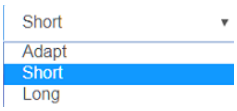
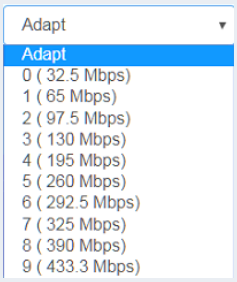
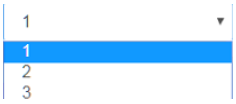
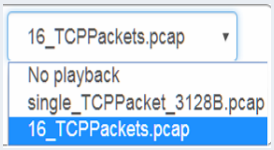
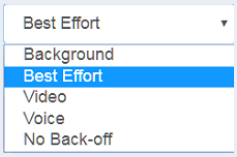
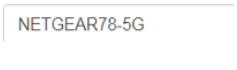
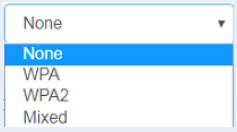
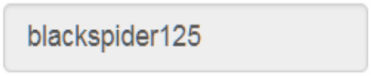
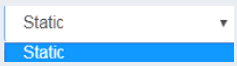
PAL-245 Station	GUI	Values	API
802.11 interface		11a/b/g/n/ac	
Mode		Station/Access Point	
Number of Stations			
Channel Width		Adapt, 20, 40, 80 MHz	
Primary Channel		<802.11 interface dependent list>	

Guard Interval		Adapt, Short, Long	
MCS		<802.11 interface and # streams dependent list>	
Max MIMO Streams		1, 2, 3	
Priority (WMM)		Background, Best Effort, Video, Voice, No Back-off	
SSID		User entry	
Security		None, WPA, WPA2, Mixed	
Security Password		User entry	
IP Mode		DHCP or Static	

IP Address	192.168.15.151	User entry IP address	
IP Subnet Mask	255.255.255.0	User entry subnet mask	

Table 4: PAL-245 Access Point mode controls

PAL-245 Access Point	GUI	Values	API
802.11 interface		11a/b/g/n/ac	
Mode		Station/Access Point	
AP Bridge Mode		Enable or Disable	
Channel Width		20, 40, 80 MHz	
Primary Channel		<802.11 interface dependent list>	

Guard Interval		Adapt, Short, Long	
MCS		<802.11 interface and # streams dependent list>	
Max MIMO Streams		1, 2, 3	
Playback File		User selection from drop down list of pcap files	
Inter-Packet Gap		User entry <1..> usec, msec	
Priority (WMM)		Background, Best Effort, Video, Voice, No Back-off	
SSID		User entry SSID	
Security		None, WPA, WPA2, Mixed	
Security Password		User entry password	
IP Mode		Static	
IP Address		User entry IP address	

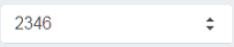
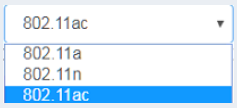
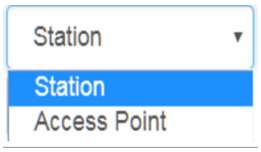
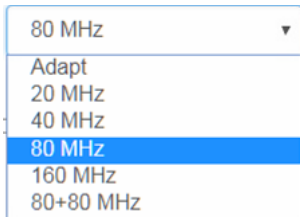
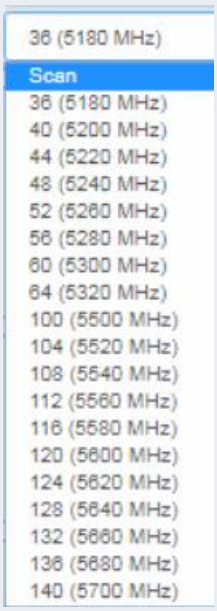
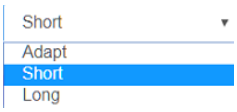
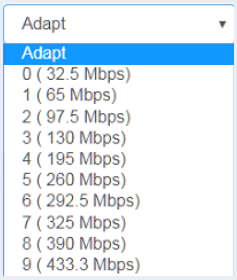
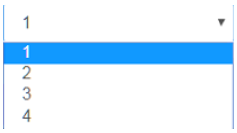
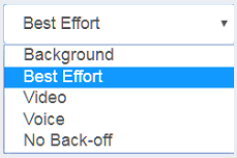
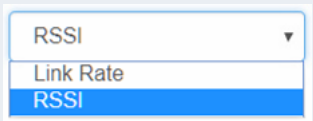
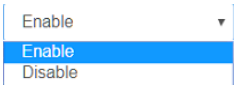
Max aggregate frame size		User entry <1…1048575>	
Beacon Interval (ms)		User entry <40…2000>	
Fragmentation threshold		User entry <256…2346>	
RTS/CTS threshold		User entry <0…2347>	

Table 5: Pal-5 station mode controls

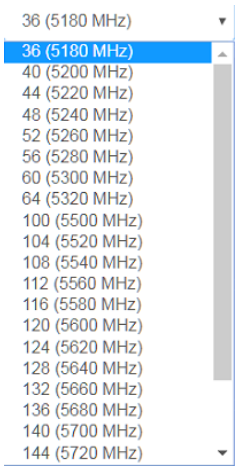
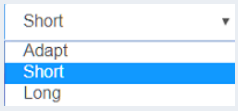
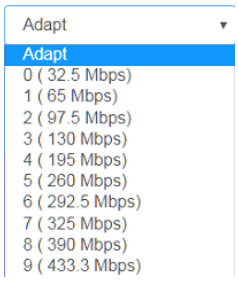
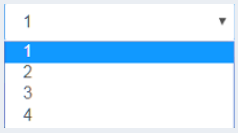
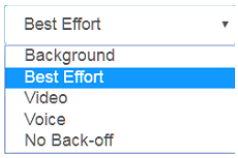
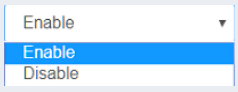
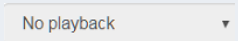
Pal-5 Station	**GUI**	**Value**	**API**
802.11 Interface		11a, n, ac	
Mode		Station	
Number of Stations		User entry <1…32>	
Channel Width		Adapt, 20, 40, 80, 160, 80+80 MHz	

Primary Channel		Scan, channel # in the 5 GHz band	
Guard Interval		Adapt, Short, Long	
MCS(Mbps)		Adapt, 0…9, data rate is # streams dependent	
Max MIMO Streams		1, 2, 3, 4	
Priority(WMM)		Background, Best Effort, Video, Voice, No Back-off	
Roam Threshold		User entry in dBm <-95…0>	
Roam using		Link Rate, RSSI	
MU_MIMO		Enable, Disable	

SSID	NETGEAR78-5G	User entry SSID of the AP	
Security	None None WPA WPA2 Mixed	None, WPA, WPA2, Mixed	
Security Password	blackspider125	User entry password	
IP Mode	Static DHCP Static	Static,DHCP	
IP Address	192.168.15.151	User entry IP address	
Subnet	255.255.255.0	User entry subnet mask	

Table 6: Pal-5 Access Point mode controls

Pal-5 Access Point	**GUI**	**Value**	**API**
802.11 Interface	802.11ac 802.11a 802.11n 802.11ac	11a, n, ac	
AP Bridge Mode	Disable Enable Disable	Enable, Disable	
Channel Width		20, 40, 80, 160, 80+80 MHz	

Primary Channel		Channel # in the 5 GHz band	
Guard Interval		Adapt, Short, Long	
MCS(Mbps)		Adapt, 0…9; data rate is a function of # streams	
Max MIMO Streams		1, 2, 3, 4	
Priority(WMM)		Background, Best Effort, Video, Voice, No Back-off	
MU_MIMO		Enable, Disable	
Playback File		User to select a preloaded PCAP file for replaying traffic to emulate ACI, CCI	
Inter packet gap		User entry <1..> usec, msec	

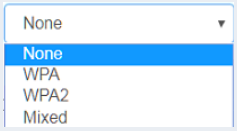
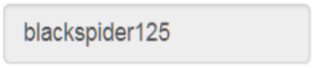
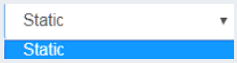
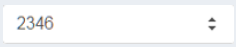
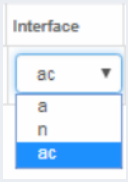
SSID		<user input SSID of the AP>	
Security		WPA,WPA2,Mixed	
Security Password		Characters and numerical values	
IP Mode		Static	
IP Address		<user input IP address>	
Max aggregated frame size(1 to 1048575 bytes)		<user input 1…1048575>	
Beacon Interval (40 to 2000 ms)		<user input 40…2000>	
Fragmentation threshold(256 to 2346 bytes)		<user input 256…2346>	
RTS/CTS threshold (0 to 2347 bytes)		User entry <0…2347>	

Table 7: vSTA settings

vSTA	GUI	Value	API
802.11 interface		11a, b, g, n, ac; Pal dependent	

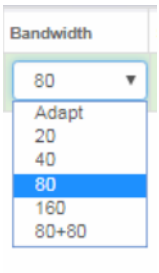
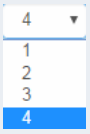
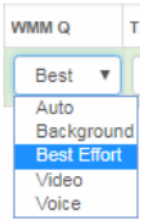
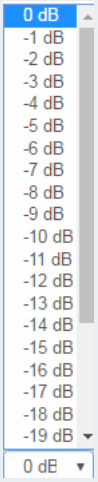
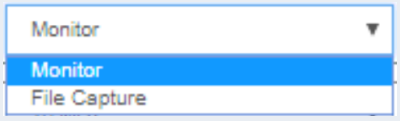
Bandwidth		Adapt, 20, 40, 80, 160, 80+80 MHz; Pal dependent	
Streams		1, 2, 3, 4; Pal dependent	
WMM		Auto, Background, Best Effort, Video, Voice	
TX power		-26dB to 0dB	

Table 8: Monitor mode controls

Monitor	**GUI**	**Value**	**API**
Mode		Monitor	

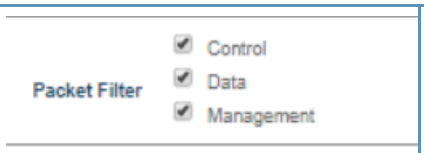
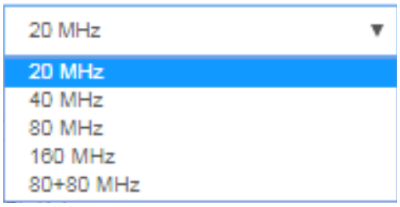
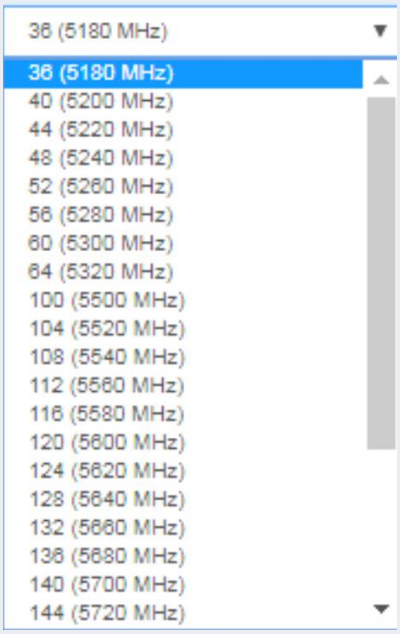
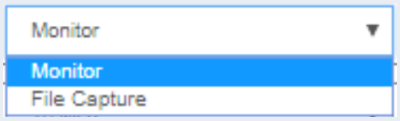
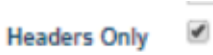
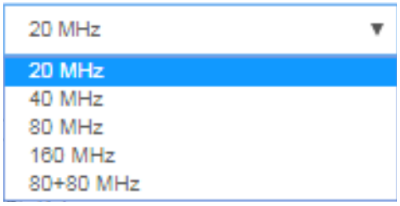
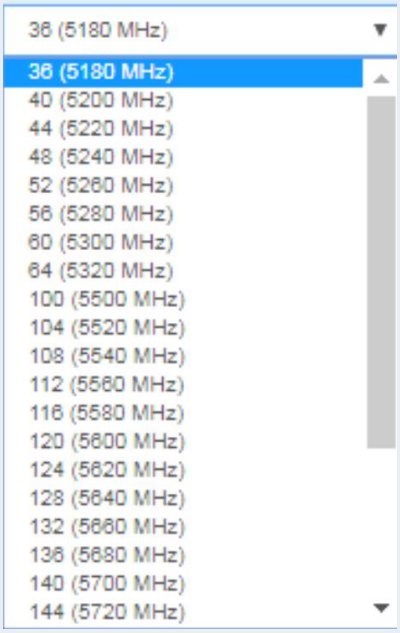
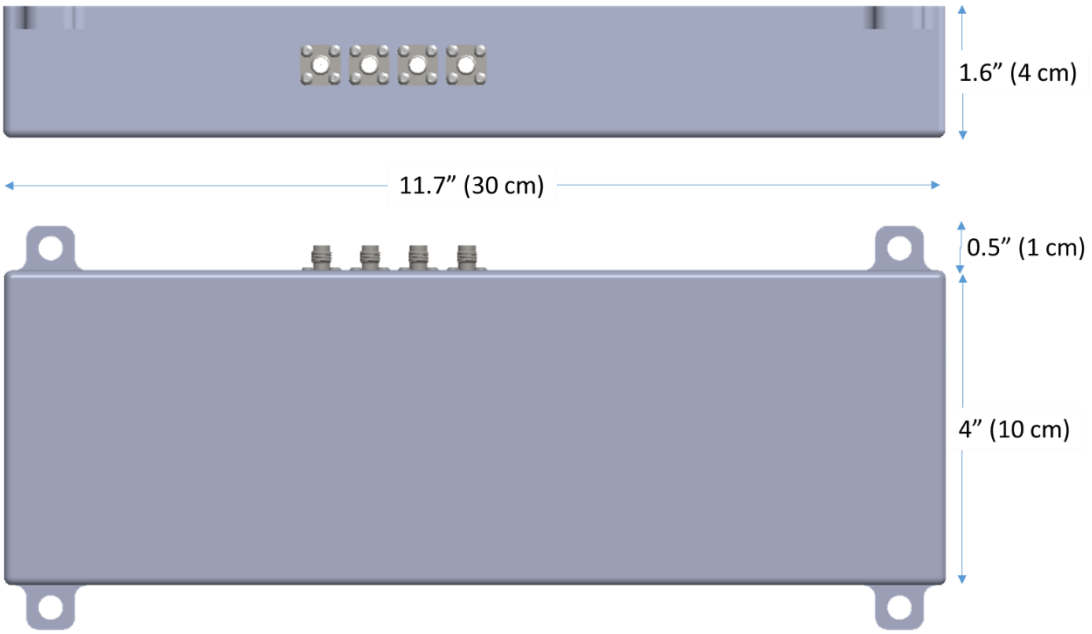
Packet filter		Check the types of packets to process	
Channel Width		20, 40, 80, 160, 80+80 MHz; Pal dependent	
Primary Channel		Channel # in 2.4 or 5GHz band; Pal dependent	

Table 9: File Capture mode controls

File Capture	**GUI**	**Value**	**API**
Mode		File Capture	
Headers Only		Check for saving headers only with no packet payload	

Channel Width		20, 40, 80, 160, 80+80 MHz	
Primary Channel		Channel # in the 2.4 or 5 GHz bands; Pal dependent	

PAL SPECIFICATIONS

Parameter	Specification
Frequency channels	All 5 GHz international 802.11 channels 20/40/80/80+80/160 MHz wide; Wi-Fi operation on 20 MHz wide DSRC channels 173, 177, 181 and 40 MHz wide DSRC 173/177 channel combo
Traffic endpoints	multiPerf, iperf2, iperf3, AT4-Agent and IxChariot
RF connectors	4 SMA connectors for up to 4x4 MIMO operation
Programming	Ethernet
Power	Power over Ethernet (same cable as programming and control); optional power adapter; 15W max
Dimensions	
TX power	MCS, # stream, frequency and channel width dependent
Processor subsystem	Intel Atom quad core, 2 GHz clock, L2 cache 2 MB, DRAM: dual channel 8GB onboard DDR3L with 1333 MT/s

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