Keysight Technologies
Eye on 802.11ax: What It Is and How to Overcome the Design and Test Challenges It Creates

White Paper

Abstract

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KEYSIGHT TECHNOLOGIES
Unlocking Measurement Insights

Wireless access to data has become an everyday necessity for both consumers and enterprises. In the last 30 years alone, unfettered access to information has transformed entire industries, fueling growth, productivity and profits. WiFi technology, governed by the IEEE 802.11 standards Association, has played a key role in this transformation, providing users with pervasive, low-cost access to high data rate wireless connectivity. The newest 802.11 standard, 802.11ax, is taking things one step further by promising to deliver that connectivity faster, over the 2.4 or 5 GHz band by utilizing OFDM, up to 1024 QAM, and multi-user MIMO.

While still in the early stages of development, the 802.11ax standard holds great promise, especially for dense deployments in both indoor and outdoor environments. Like any emerging standard; however, the new technologies it adopts present unique challenges when it comes to testing.

A Closer Look at 802.11ax

To better understand 802.11ax, it's crucial to first take a step back and look at 802.11ac. The 802.11ac standard allows up to 4 spatial streams of data. The 802.11ax draft specification, available since January 2016, builds on 802.11ac by doubling the number of spatial streams and significantly improving the efficiency (and in turn the throughput) of those streams. 802.11ax, like 802.11ac, also operates in the 5-GHz band where there is more space for its 80-MHz and 160-MHz channels.

What makes 802.11ax so appealing is its ability to dramatically increase throughput while improving power efficiency for mobile devices. And it's not just theoretical system-level throughput (e.g., the banner specification that each new technology touts) that's improved, but actual real-world throughput achieved by individual users in high-density scenarios, both indoors and outdoors, in the presence of interfering sources. Put simply, 802.11ax promises consumers a dramatically better user experience, in all possible scenarios. That's welcome news for emerging applications like interactive and high-definition video, which are often called on to work in challenging environments with a high density of WiFi users (e.g., stadiums and public transportation).

To deliver on these objectives, 802.11ax must utilize a number of different technologies. While it's anticipated that the standard will be based around OFDM, some of the other technologies currently have been adopted include: OFDMA, MU-MIMO and higher order modulation. OFDM is typically used for high data rate systems because of its resilience to channel irregularities (e.g., selective fading). In the case of 802.11ax, OFDM will need to be modified to have a reduced sub-carrier spacing (4x symbol length) and have more variable Cyclic Prefixes (CPs) to support different scenarios, especially long outdoor channels where the trade-off between efficiency and robustness becomes critical.

Another technology under consideration for its ability to improve performance is Overlapping Basic Service Sets (OBSS) interference handling. OBSS techniques, which can take many forms and may include some variant of beamforming reception, are important due to the increasing number of Access Points (APs) being deployed. These deployments make spectrum management and interference mitigation from adjacent APs increasingly important and that's where OBSS techniques come in. These techniques, like OFDM, OFDMA, MU-MIMO, and higher order modulation will improve 802.11ax's spatial reuse and spectrum efficiency, enabling it to achieve high system performance.

Beware: Challenges Ahead

Like all emerging standards, 802.11ax's use of technologies like OFDMA and interference handling techniques increase design complexity and create a number of new test challenges for the engineer. Some of those challenges arise when it comes to basic measurements, as shown in the Table 1, while others come from new test requirements. For example, while the transmitter tests and key receiver tests defined in the 802.11ax specification are carried over from 802.11ac, new tests for Multi-User (MU) transmission have been added. MU transmission is the one of most important new features in 802.11ax and relies on transmission accuracy and synchronization by STAs for effective operation. As a result, a number of new test requirements in support of MU transmission have been proposed.

Feature	Description	Test challenges
Bands	2.4 and 5 GHz	Dual band.
Channel bandwidth	20 MHz, 40 MHz, 80 MHz, 160 MHz, 80+80 MHz	Need to generate and analyze wide BW signals.
FFT size	256, 512, 1024, 2048	Smaller sub-carrier space (78.125 KHz). More sensitive fo frequency and phase error and CFO impact.
Modulation types	Up to 1024QAM	Need better EVM and better power amplifier linearity.
Spatial streams	Max 8	More channels of signal generation and analysis, up to 8x8, and MIMO channel simulator needed.
Multi-user	OFDMA+ MU-MIMO	Test simultaneous transmission and receiving for multiple users and signal from each user would experience different impairments.

Table 1. Even for basic measurements, there are test challenges that arise because of the new technologies being adopted in 802.11ax.

In addition to these test requirements, there are also a number of design challenges that need to be dealt with. They include:

- Creating an indoor/outdoor channel model. IEEE 802.11ax aims to enhance the throughput per station in both indoor and outdoor operations. Compared to indoor channels, outdoor channels typically experience larger delay spreads and more time variations. To account for this, the 3GPP ITU-R Urban Micro (UMi) and Urban Macro (UMa) channel models have been selected for use as the baseline for 802.11ax outdoor spatial channel models. However, an appropriate level of modification is necessary to allow these models to address the new specification. The ITU-R channel models, for example, need to be expanded to support 802.11ax's 160 MHz bandwidth. Once all of these modifications are made, they need to be modeled, resampled and interpolated into the required system bandwidth.

- Additionally, since path loss is an issue for 802.11ax, path loss models for both indoor and outdoor scenarios become critical. The TGn channel B and D model has been adopted for the indoor case, simulating wall and floor penetration, while outdoor scenarios will be based on the UMi path loss model.

- Narrowband interference. One of the concerns for 802.11ax is narrowband interference, primarily caused by internal transmission signals or signals/harmonics generated from other devices falling into the same frequency band as the 802.11ax system. A number of new techniques are being employed on the receiver side to mitigate the harmful effects of this interference, for example, applying tone nulling after the Fast Fourier Transform (FFT) and notch filtering with CP/ZP-OFDM. Dual Sub-Carrier Modulation (DCM)—an optional modulation scheme applied to BPSK, QPSK and 16-QAM modulation—is another technique being considered. Ensuring all 802.11ax measurement solutions support these techniques will be essential.

- Dealing with higher order modulation. 802.11ax aims to quadruple wireless speed up to 10 Gbps to individual network clients using new Modulation and Coding Scheme (MCS) Index level 10 and 11 with a 1024QAM modulation scheme. With higher order modulation, the system becomes more sensitive to internal and external impairments, thus requiring a higher SNR to maintain an acceptable BER/FER level. Obtaining an SNR above 35 dB is difficult to achieve using economical hardware, since it exceeds the noise figure, impairments and losses of typical transceivers, particularly in RF circuits and ADCs/DACs. Consequently, being able to accurately model the effect that real imperfect hardware plays in the demodulation of the signal and resulting BER/FER becomes critical.

- MIMO detection techniques. At the receiver side, the main hindrance to employing 1024QAM in MIMO systems is the scalability of existing MIMO detection techniques. There are popular detectors that work in the range of current MIMO systems (e.g., Zero Forcing (ZF), Minimum Mean Square Error (MMSE), and the very complex Maximum Likelihood (ML) detector). There are also many suboptimal detectors that offer various complexity/performance tradeoffs. However, with 802.11ax, the need to build, model and test new custom detection algorithms in simulation first is going to be of the utmost importance.

Addressing The Challenges Head On

Addressing these challenges requires appropriate test and measurement solutions for simulation, signal generation and signal analysis, to address all stages of the product lifecycle, from design to validation and all the way through to manufacturing. However, because 802.11ax is an amendment to the 802.11 standard and currently still in development, many measurement solutions are also in development or in the process of being expanded to support the emerging standard. Now draft 1.0 has been released, which means the main frame structure of the standard has been stable.

With the proprogess of standard, there are options for helping engineers working on 802.11ax system. One option is to use pre-existing IP to quickly model new 802.11ax systems. This is possible today using Electronic System Level (ESL) design software. The ESL software provides engineers the flexibility to modify current 802.11ac libraries and OFDM reference transmitter/receiver models, connected with flexible 3GPP channel models, to accommodate the changes in the emerging standard. The necessary digital signal processing algorithms (e.g., for optimal MIMO detection) can also be developed, and engineers can simulate baseband processing, model the RF transceiver and even create their wireless channel—all from within the software.

Assuming the ESL software links to a range of hardware, engineers can then take their simulated waveforms and play them through actual test and measurement instruments. Doing so provides the ideal way to test early 802.11ax devices (see Figure 1).

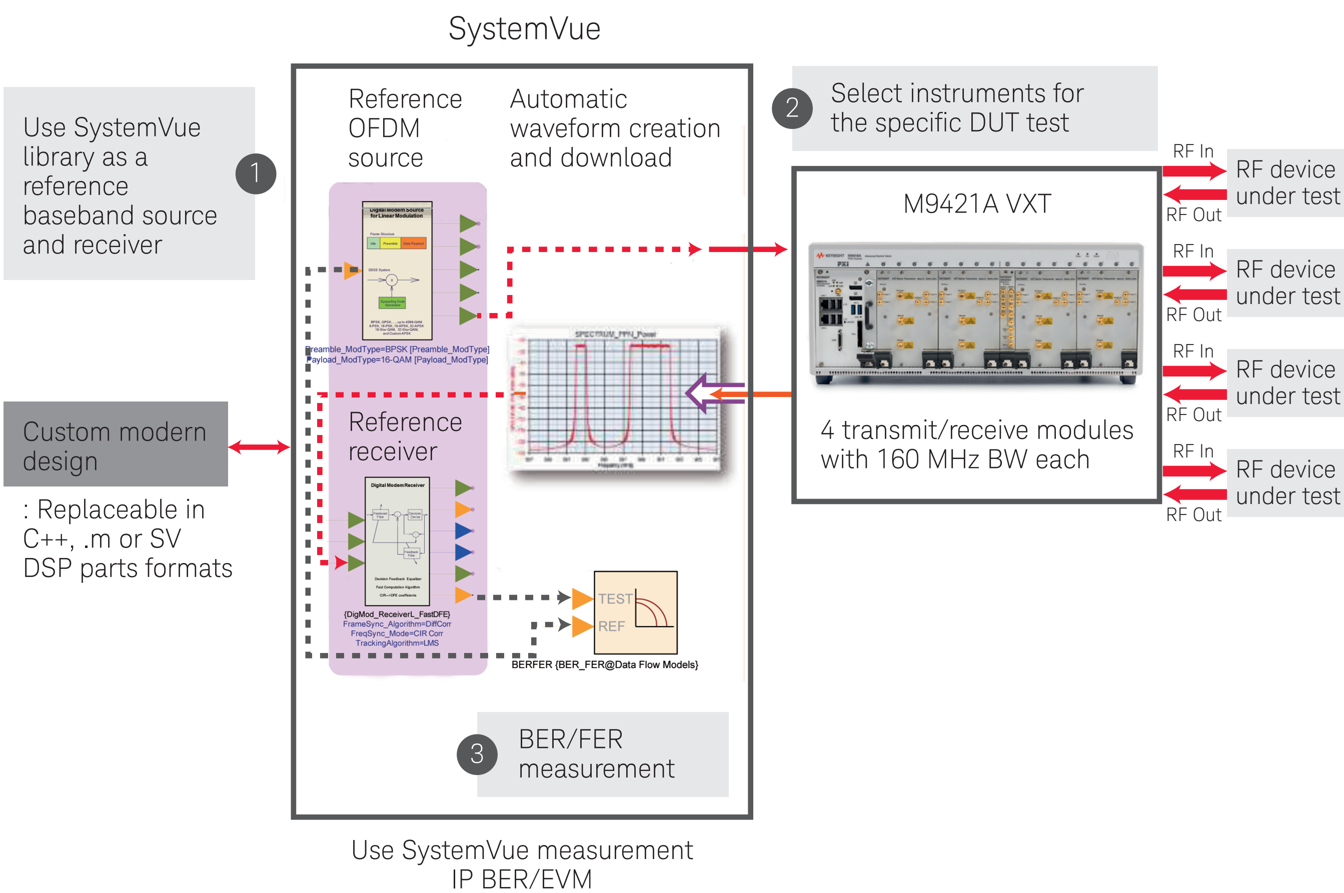

Figure 1. Shown here is a proposed, early 802.11ax device evaluation flow diagram. At the core of the flow is Keysight's SystemVue ESL software. With its powerful capabilities and flexibility, it can be used to address the challenges associated with the design and test of 802.11ax devices. Using SystemVue, the IP developed in the pre-standard proposal phase can be quickly connected to various Keysight instruments for the design verification test.

In addition to flexible ESL software, there are a number of other solutions tied more closely to the 802.11ax specification that can be used during test. A prime example would be Signal Studio for Wireless LAN that's been enhanced to support 802.11ax. Using such software, engineers can quickly and easily generate 802.11ax compliant test signals, with or without impairments, and then download the waveforms to a signal generator.

The ideal 802.11ax signal creation software will support all new 802.11ax capabilities, including such things as: 1024QAM, Long Symbol/Guard, OFDMA, MU-MIMO, and DCM. And, it will be able to generate waveforms for multi-user signals. The availability of flexible and hierarchical parameters to support all the new High Efficiency (HE) PLCP Protocol Data Unit (PPDU) formats in 802.11ax will also be critical.

The 89600 VSA software and WLAN Measurement Applications on Keysight Signal Analyzer platforms are signal analysis tools that engineers can use today for demodulation and signal quality analysis of 802.11ax signals (see Figure 2). Generally speaking, hardware platforms for signal generation and signal analysis can be chosen based on the performance requirements and test cases, which are optimized for R&D and manufacturing, respectively.

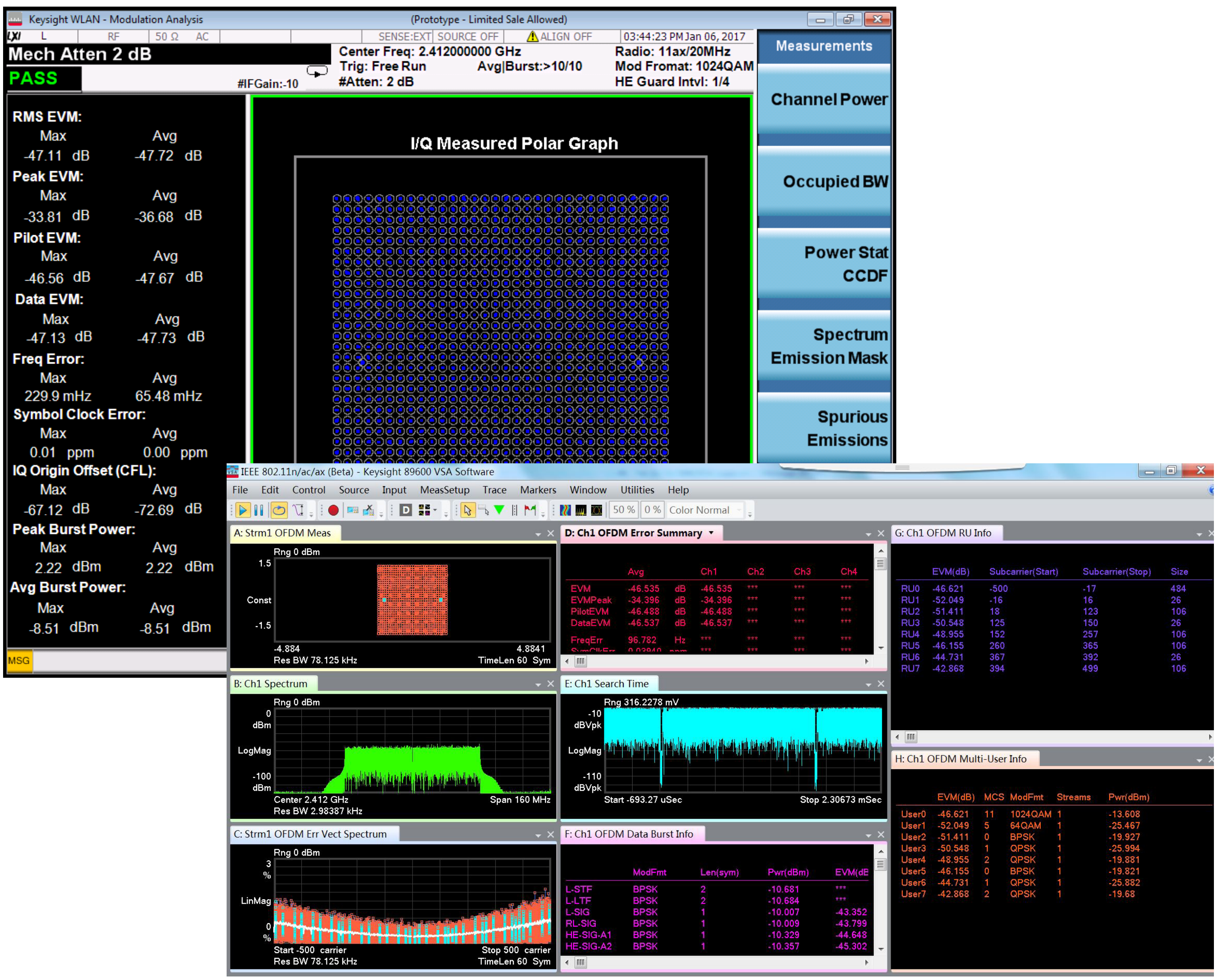

Figure 2. Shown here is 802.11ax analysis performed using Keysight's 89600 VSA software and X-Series measurement applications running on a Keysight signal analyzer. Each solution offers options for 802.11ax modulation analysis, covering all of the bandwidths and modulation types, up to 8x8 MIMO. Both support a variety of hardware configurations for the performance, bandwidth, and number of channels engineers need.

Conclusion

The 802.11ax specification is the next in a long line of 802.11 standards promising not only to deliver higher throughput but really improve the end-user experience, especially in dense deployments. While the specification has not yet been finalized, it's clear that the new technologies and techniques it plans to utilize will present some unique challenges for the engineers designing and testing 802.11ax devices. The good news is that there are measurement solutions for simulation, signal generation and signal analysis that engineers can use today to test their 802.11ax devices and that can address these challenges head on—at all stages of the product lifecycle. Moreover, their capabilities will track the evolution of the 802.11ax specification as it winds its way toward formalization. In doing so, these solutions will not only ensure engineers have the tools they need to design and test their 802.11ax devices, but also help enable the rapid deployment and industry-wide acceptance of these 802.11ax-based devices.

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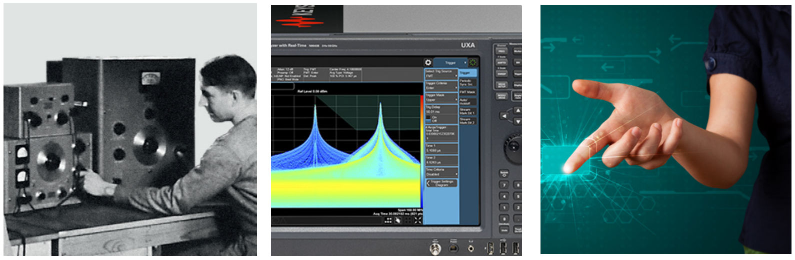

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