What You Should Know About Regulatory Test for Wi-Fi 6E Devices

In today's increasingly connected world, wireless connectivity is growing in importance in everyday products. The Internet of Things (IoT) market is expected to grow to $1.6 trillion by 2025[1]. The estimated number of active IoT devices will surpass 25.4 billion in 2030[2]. Every IoT wireless device uses unlicensed frequency spectrum to enable connectivity; these devices are subject to comprehensive regulatory testing before entering the market. This white paper discusses the new Wi-Fi 6E standard (802.11ax, E for "Extended") and the existing Wi-Fi standards. The paper also covers the measurement challenges device makers need to overcome to meet the new regulatory requirements for wireless IoT devices.

The global regulatory landscape is very complex. Each region or country has its regulatory standards and requirements. Certification/authorization is necessary before marketing a product in a specific country, regardless of the manufacturing point of origin.

[1] 45 Fascinating IoT Statistics for 2021 | The State of the Industry (dataprot.net)
[2] ibid

KEYSIGHT TECHNOLOGIES

Most countries refer to two primary standards bodies for direction — the European Telecommunications Standards Institute (ETSI) in the European Union and the Federal Communications Commission (FCC) in the United States. Both organizations have multiple standards to cover the evolution of the IEEE 802.11 standard for wireless LAN (WLAN). Table 1 lists the evolution of the 802.11 standards, including data rates and frequency bands.

The introduction of Wi-Fi 6 (802.11ax) in 2019 allows more spectral efficiency and higher data rates than Wi-Fi 5 (802.11ac). This technology uses orthogonal frequency-division multiple access (OFDMA) to improve network performance and a higher-order quadrature amplitude modulation (QAM) of 1,024 to increase the data rates.

Table 1. Evolution of IEEE 802.11 WLAN standards

Generation / IEEE standard	Maximum link rate	Adoption year	Frequency band(s)
Wi-Fi 6E (802.11ax)	600 to 9608 Mbit/s	2020	6 GHz
Wi-Fi 6 (802.11ax)	600 to 9608 Mbit/s	2019	2.4 / 5 GHz
Wi-Fi 5 (802.11ac)	433 to 6933 Mbit/s	2014	5 GHz
Wi-Fi 4 (802.11n)	72 to 600 Mbit/s	2008	2.4 / 5 GHz
802.11g	6 to 54 Mbit/s	2003	2.4 GHz
802.11a	6 to 54 Mbit/s	1999	5 GHz
802.11b	1 to 11 Mbit/s	1999	2.4 GHz
802.11	1 to 2 Mbit/s	1997	2.4 GHz

Future Wi-Fi 6E devices operating in the unlicensed 6 GHz band will have an additional 1,200 MHz of bandwidth for new channels in the regions that follow FCC regulations. There will be 480 to 500 MHz in the regions that follow ETSI, as shown in Figure 1.

This additional bandwidth, however, comes with some restrictions. Manufacturers and telecommunication certification bodies must understand the new standards and their requirements to deliver IoT devices to the marketplace and take advantage of the new spectrum.

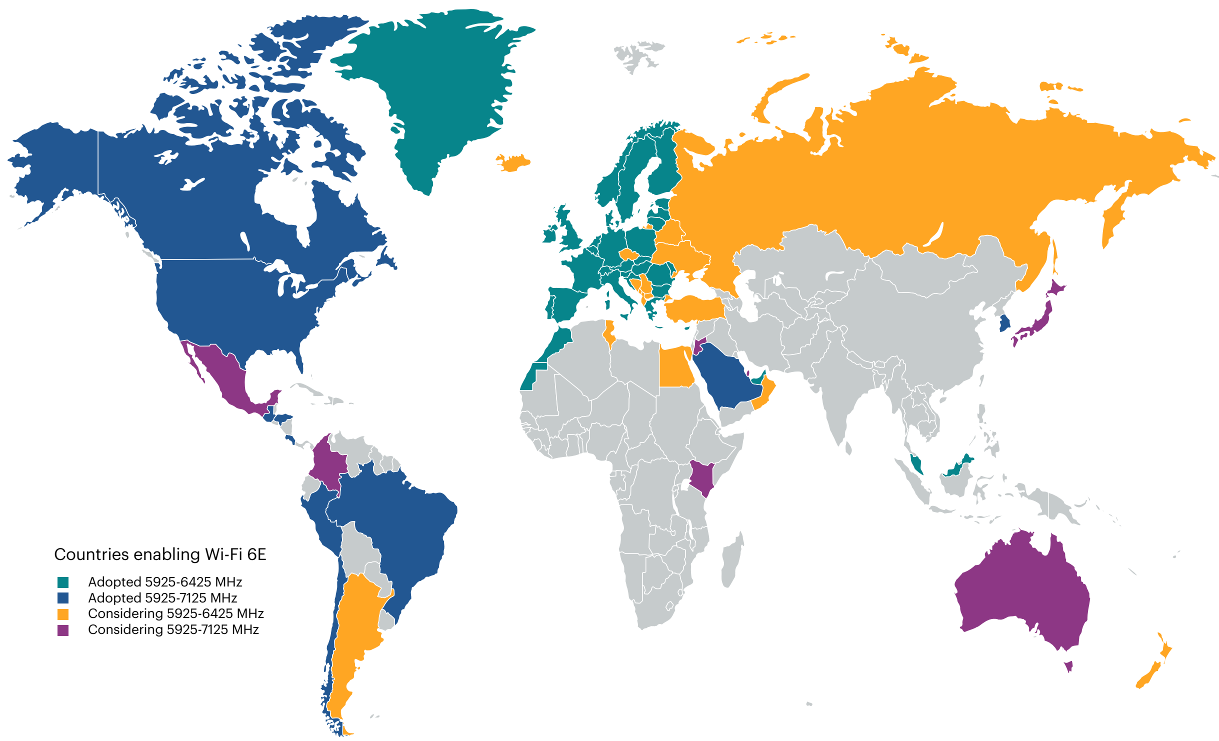

Figure 1. Wi-Fi 6E global map, December 2021, Source: Countries Enabling Wi-Fi 6E | Wi-Fi Alliance (© Australian Bureau of Statistics, GeoNames, Microsoft, Navinfo, OpenStreetMap, TomTom, Wikipedia)

The FCC and ETSI have different standards and test methods for the various frequency bands. Table 2 lists the different standards for the Industrial, Scientific, and Medical (ISM) and the Unlicensed National Information Infrastructure (U-NII) bands.

Table 2. Regulatory standards as of September 2021 for 2.4, 5, and 6 GHz unlicensed bands

Regulatory body	Regulation / test standard	Description
FCC	Part 15.247 / KDB 558074 D01 v05r02	• ISM devices operating within the 902 to 928 MHz and 2.4 to 2.4835 GHz bands • Frequency hopping and digitally modulated intentional radiators
	Part 15.407 / KDB 789033 D02 v02r01 KDB 905462 D02 v02 KDB 987594 D02 vo1r01	U-NII devices operating in these bands: • 5.15 to 5.35 GHz • 5.47 to 5.725 GHz • 5.725 to 5.85 GHz • 5.85 to 7.125 GHz • 15.407 (d)

Regulatory body	Regulation / test standard	Description
ETSI	EN 300 328 v2.2.2	• Wideband transmission systems using data transmission equipment operating in the 2.4 GHz ISM band • Systems using wideband modulation techniques
	EN 301 893 v2.1.1	• 5 GHz Wireless Access System (WAS) including Radio Local Area Networks (RLAN) equipment operating in the 5.15 to 5.35 GHz and 5.47 to 5.725 GHz U-NII bands
	EN 303 687 (draft 0.0.14) – updated in September 2021	• 6 GHz RLAN harmonized standard for access to radio spectrum for WAS / RLAN devices operating in the 5.925 GHz to 6.425 GHz U-NII bands

Regulatory agencies have reviewed and approved proposals to increase the spectrum allocation for wireless devices to operate in the 6 GHz unlicensed band. The Wi-Fi 6E spectrum, however, is not vacant. Incumbent users, including satellite and terrestrial microwave links, need protection from interference. The FCC and ETSI have developed new test requirements for devices that plan to use these new bands.

ETSI Harmonized Standard EN 303 687 version 0.0.14 is under draft as of September 2021 (expected release in March 2023). This standard covers Wi-Fi 6E devices operating in the 6 GHz band. The FCC has also published test standard KDB 987594 D02 under Part 15.407 that provides guidance on new requirements for Wi-Fi 6E devices. This white paper discusses the new test challenges for both standards.

Key Differences Between ETSI Standards

Table 3 shows a comparison between EN 301 893 V2.1.1 for the 5 GHz band and EN 303 687 V0.0.14 for the 6 GHz band.

Table 3. ETSI standards differences for 5 and 6 GHz bands

Test Number	Description	EN 301 893 V2.1.1 (5 GHz)	EN 303 687 V0.0.14 (6 GHz)	Comments
1	Nominal center frequency	Yes	Yes	Similar test(s)
2	Nominal channel bandwidth / occupied channel bandwidth (OCB)	Yes	Yes	Similar test(s)
3	RF output power	Yes	Yes	Similar test(s)
4	Transmit power control (TPC)	Yes	No	Not required in EN 303 687
5	Power density / power spectral density	Yes	Yes	Similar test(s)

Test Number	Description	EN 301 893 V2.1.1 (5 GHz)	EN 303 687 V0.0.14 (6 GHz)	Comments
6	Transmitter unwanted emission in the out-of-band / spurious domain	Yes	Yes	Similar test(s)
7	Transmitter unwanted emission within the RLAN band (mask)	Yes	Yes	Significant changes in multichannel operation and mask
8	Rx spurious emission	Yes	Yes	Similar test(s)
9	Adaptivity / channel access mechanism (CAM)	Yes	Yes	Added with 5G NR interference signal
10	Receiver blocking	Yes	Yes	Similar test(s)
11	Dynamic frequency selection (DFS)	Yes	No	No radar signal in the 6 GHz band
12	Client-to-client operation	No	Yes	New test item for EN 303 687
13	Rx adjacent channel selectivity	No	Yes	New test item for EN 303 687

Transmit power control and dynamic frequency selection

In EN 303 687, no radar transmission in the 6 GHz band means that you do not need to perform TPC and DFS in this band.

Unwanted transmitter emission in 6 GHz RLAN bands

Wi-Fi 6E uses the new OFDMA modulation format. With OFDMA, multiple users can transmit on the same channel at various times using different bandwidths. This ability creates significant changes in multichannel operation and the transmit spectral power mask within the 6 GHz RLAN bands.

Multichannel operation is much more complex, and the mask looks unusual. You will need to construct the overall transmit spectral power mask based on the multichannel operations in adjacent or non-adjacent channels, as shown in Figure 2. The Wi-Fi 6E access point must be flexible in deciding which channel to turn on or off to ensure multichannel operation.

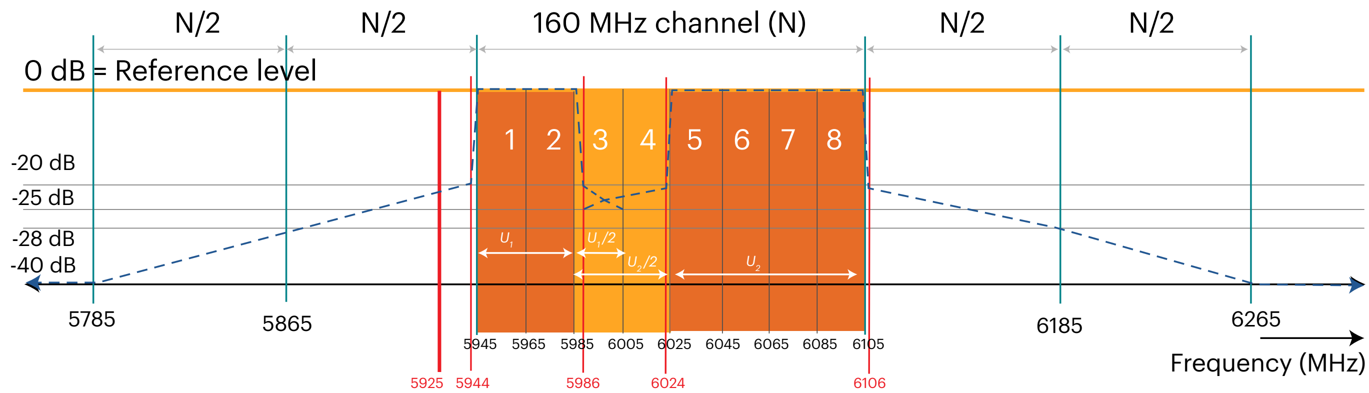

Figure 2. Example of overall transmit spectral power mask for multichannel operation in eight adjacent 20 MHz channels

Channel access mechanism

The CAM test is similar to the adaptivity test in EN 301 893. ETSI mandates the adaptivity test to ensure efficient and effective spectrum sharing among users. CAM is an automatic mechanism when a listen-before-talk (LBT) device performs a clear channel assessment check before using the channel for data transmission.

Under CAM operation, the client and primary devices pair together and transmit and occupy a specific channel. Once occupied, other users cannot use the channel. The Wi-Fi 6E standard requires the current user to check the probability that other users can use the same channel to ensure fair usage of available channels. You can calculate the probability using the minimum measured idle time divided by the maximum channel occupancy time (COT). It should be less than the identified percentage in the standard.

The maximum COT determines whether the device is Class 1, 2, 3, or 4 — with Class 4 having the highest priority. The CAM test is complex and time-consuming because it requires extensive post-processing to calculate the results. Manual operation is nearly impossible.

For example, load-based equipment (LBE) can require over 10,000 samples for the COT measurement with a resolution of less than or equal to one microsecond. This process translates into the measurement and collection of many data points. The basis for the CAM measurement calculation comes from the probability bins of the device priority class. Figures 3 and 4 show examples of these measurements using Keysight's IOT0047A regulatory test solution.

Figure 3. COT measurements

Figure 4. CAM measurements

Adaptivity interference

As part of the adaptivity test, you can perform interference analysis with several types of signals injected into the device to see when it detects and responds to interference signals. You need to add a 5G New Radio (NR) waveform to simulate the interference from other 5G users, as shown in Figure 5. This is because, for Wi-Fi 6E, the 5G signal coexists in the 6 GHz band.

CAM | Transmission | **Interference**

Waveforms | Testing

Waveform File	Sample Clock (MHz)	Channel (MHz)	Inital Level (dBm)	Modulation Loss (dB)
AWGN20MHZ.BIN	45	5955	0	-13.585
OFDM20MHZ.BIN	45	5955	0	-14.759
5GNR(OFDM2.BIN)	30.72	5955	0	-14.759

Figure 5. 5G NR interference signal

Interference testing also requires a known signal level and bandwidth — it is important to calibrate the level and bandwidth of the interference signals. The requirement calls for calibration of the interference level to -75 dBm. The bandwidth should cover 100% of the device under test (DUT) transmission bandwidth. You will need to measure and apply the results of the DUT OCB test. Once the software, as part of the test process, programs the signal generator to inject the interference signal, the device should limit the transmission to below a minimum of 5%.

Figure 6 shows a failed sample of an interference test. Some transmissions failed the limit of 5% after injecting the interference signal. The measurement time is approximately 80 seconds, which requires up to 100 million data points to meet the test requirements.

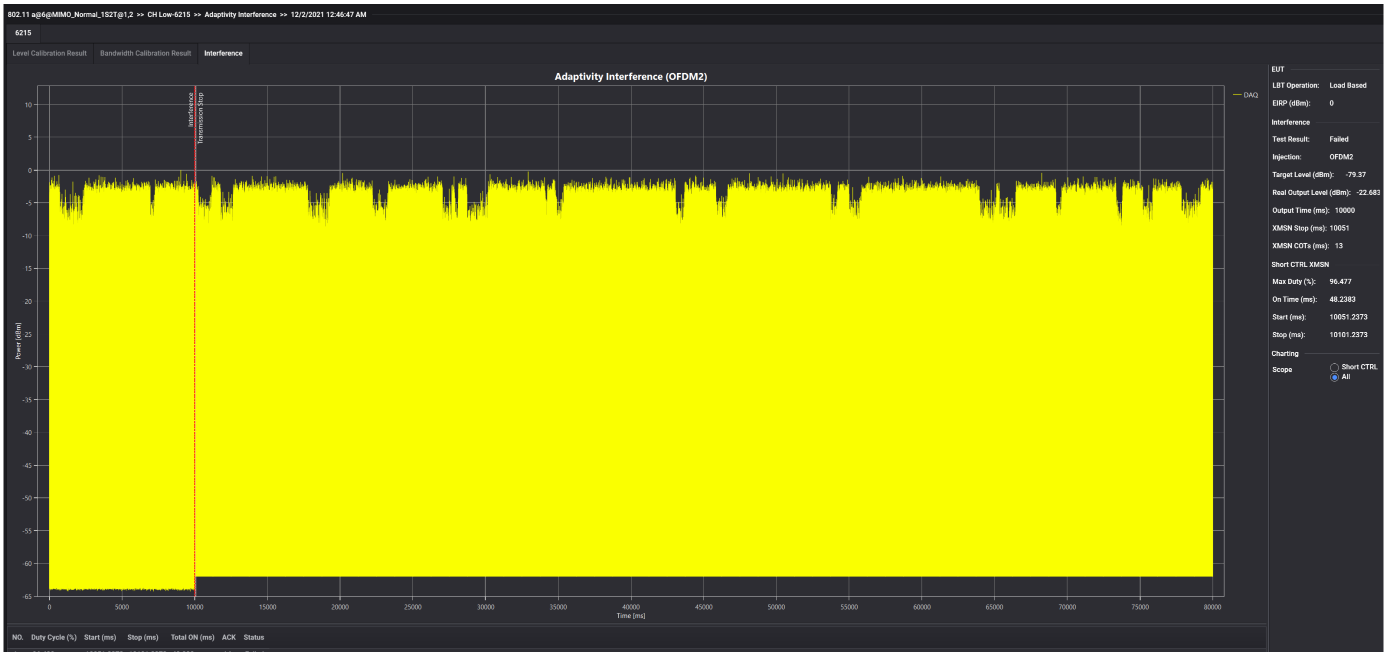

Figure 6. Example of failed adaptivity interference test

Receiver adjacent channel selectivity

Receiver adjacent channel selectivity is a new test case in EN 303 687. It measures the capability of the device to receive a wanted signal on its channel without exceeding a given degradation due to the presence of an interfering signal in an adjacent channel. The minimum performance criteria is a packet error rate (PER) of less than or equal to 10% for equipment supporting this testing.

Client-to-client operation

Client-to-client operation is a new test in Version 0.0.14 of EN 303 687. This test is similar to the adaptivity interference test, except that the interference signal is an enabling signal from another client device. The test also requires monitoring for up to 60 seconds once the device under test detects the enabling signal requiring millions of measurements and post-processing.

Key Differences Between FCC Standards

Table 4 compares the KDB 789033 D02 v02r01 (5 GHz band) and KDB 987594 D02 v01r01 standards for the Wi-Fi 6E bands (5,925 to 7,125 MHz).

Table 4. Comparison of FCC standards for 5 GHz and Wi-Fi 6E bands

Test Number	Test description	5 GHz	Wi-Fi 6E	Comments
1	Frequency stability	Yes	Yes	Similar tests
2	Duty cycle, transmission duration, maximum power control level	Yes	Yes	Similar tests
3	Emission bandwidth	Yes	Yes	Similar tests
4	Occupied bandwidth (OCB) at 99%	Yes	Yes	Similar tests
5	Maximum conducted output power	Yes	Yes	Similar tests
6	Maximum power spectral density (PSD)	Yes	Yes	Similar tests
7	Unwanted emissions	Yes	Yes	Similar tests
8	Emission at an elevation higher than 30 degrees from the horizon	If the access point is an outdoor device	If the access point is an outdoor standard power device	Similar tests
9	Contention-based protocol (CBP)	No	Yes	New test item for 6E bands
10	In-band emissions	Yes	Yes	Similar tests
11	Dynamic frequency selection (DFS)	Yes	No	No radar signal in 6 GHz band
12	Dual client test	No	Yes	New test item for 6E bands

Dynamic frequency selection

No radar transmission in the 6E band for KDB 987594 eliminates the need to perform DFS testing in this band.

Contention-based protocol

CBP is a new requirement for the 6E band and is very similar to the adaptivity interference test of ETSI EN 301 893. The test aims to avoid co-channel interference with incumbent devices sharing the same frequency band.

Low-power indoor devices must detect a co-channel radio frequency power of -62 dBm or lower. The device must detect the interference signal throughout the channel. Although the standard does not specify the type of interfering signal to use, it should be noise-like. Using a 10 MHz-wide Additive White Gaussian Noise (AWGN) signal is best to simulate incumbent transmissions.

The CBP test requires testing the interference signal across the device bandwidth, at the channel's center frequency, and elsewhere across the channel. You need to repeat the test at least ten times to verify that the device can detect an AWGN signal with at least a 90% level of certainty. Like the ETSI adaptivity interference test, this test requires multiple measurements, large amounts of measurement data, and post-processing to determine accurate results.

Dual client test

This requirement is new for the 6E band. A client device may connect to a standard power access point with a maximum power level of 30 dBm effective isotropic radiated power (EIRP). A client may also connect to a low-power indoor access point, but the power level has a maximum limit of 24 dBm EIRP. Suppose a client has the flexibility to connect to both access points. In that case, you will need to verify that it connects to both types of access points to show that it can distinguish between the two configurations and control the different power levels.

This test is similar to the client-to-client test for ETSI 303 687 because it requires adjusting the power level of the low power access point to simulate the device moving from outdoors to indoors. However, the test is unnecessary if the client RF power is certified to never operate above 24 dBm EIRP.

Considerations for Wi-Fi 6E Regulatory Tester Setup

Knowing the differences between the standards enables you to select a test system or upgrades to meet the new requirements. Performing an equipment assessment will determine if you need to upgrade your current regulatory tester to support new test cases or purchase a new system. You may only need new hardware, like a higher frequency signal analyzer and signal generator, to extend the operation of your test system to 7.2 GHz.

Complexity of new test cases

It is essential to understand the complexity of new test cases. Consider if you can perform the tests manually, how difficult it is to develop an automation software to support the new test cases, and the time it would take to develop, test, deploy, and support the software.

Some test cases are highly complex and require careful timing control and synchronization between multiple pieces of equipment. These test cases require measuring the response of the DUT and the companion device, performing calculations, and then comparing the results with complex test limits. You also need to repeat the tests for many settings, such as different channels, modulations, bandwidths, and data rates. It is almost impossible to run these tests manually.

It is also extremely complex to develop software that automates the tests without knowing the standards' requirements. Using the wrong algorithm generates incorrect results and can significantly impact the reputation of your test lab or delay the shipping of the device to a telecommunication certification body. It could be quicker and less expensive to purchase a new system with automation software from an industry-leading test and measurement company.

Total test time

Setting up the test system and conducting the tests for regulatory testing is a tedious task. You need to set up many different test conditions and parameters and repeat this process to obtain the full signaling and non-signaling test results. For example, the total test time for a 2x2 Wi-Fi dual-band device supporting 802.11a/b/g/n performed manually can take up to a week (including test-setup changes and configurations, setting up test equipment, capturing and analyzing data), as shown in Tables 5 and 6.

Table 5. Estimated test time for 2 x 2 Wi-Fi dual-band device signaling tests using Keysight's IOT0047A IoT regulatory test solution

<table>
<tr><th colspan="7">Signaling Test Requirements</th></tr>
<tr><th>Test parameters</th><th>Seconds</th><th>Radio formats</th><th>Channels</th><th>Extreme conditions</th><th>Number of repeat tests</th><th>Seconds</th></tr>
<tr><td>Traffic load check</td><td>30</td><td rowspan="5">802.11a (1)
802.11n20 (1)
802.11n40 (2)
802.11ac20 (1)
802.11ac40 (2)
802.11ac80 (4)
() is multichannel testing</td><td>Low, high</td><td>C9 Normal</td><td>6 radios x 2 channels</td><td>360</td></tr>
<tr><td>Adaptivity CAM</td><td>80</td><td>Low, high</td><td>C9 Normal</td><td>6 radios x 2 channels</td><td>960</td></tr>
<tr><td>Adaptivity interference</td><td>80</td><td>Low, high</td><td>C9 Normal</td><td>11 multichannel bandwidth x 3 waveforms (AWGN / OFDM / LTE) x 2 channels</td><td>5,280</td></tr>
<tr><td>Receiver blocking</td><td>80</td><td>Low, high</td><td>C7 Normal</td><td>1 radio (11a) x 2 channels</td><td>160</td></tr>
<tr><td>DFS channel shutdown</td><td>180</td><td>High (5250 to 5350 MHz)</td><td>C5 Normal</td><td>2 radios (20 / 40) x 1 channel</td><td>360</td></tr>
<tr><td colspan="7">Total test time: 7,120 seconds or 2 hours</td></tr>
</table>

Table 6. Estimated test time for 2 x 2 Wi-Fi dual-band device non-signaling tests using Keysight's IOT0047A IoT regulatory test solution

Non-Signaling Test Requirements							
Test parameters	Seconds	Antennas	Radio formats	Channels	Extreme conditions	Number of repeat tests	Seconds
Output power (with TPC)	40	1 to 4	802.11a 802.11n20 802.11n40 802.11ac20 802.11ac40 802.11ac80	Low, high	C1 / C2 temp^{HL}/ voltage^{HL}	6 radios x 2 channels x 4 conditions x 2 TCP (P_H+P_L)	3,840
Carrier frequency	20	2		Low, high	C7 temp^{HL}/ voltage^{HL}	6 radios x 2 channels x 4 conditions x 2 antennas	1,920
PSD	60	2		Low, high	C1 / C2 normal	2 radios (a/n 20) x 2 channels x 2 antennas	480
OCB	60	2		Low, high	C7 normal	6 radios x 2 channels x 2 antennas	1,440
Emission mask	80	2		Low, high	C1 / C2 normal	2 radios (a/n 20) x 2 channels x 2 antennas	640
Tx spurious	80	2		Low, high	C7 normal	2 radios (a/n 20) x 2 channels x 2 antennas	640
Rx spurious	80	2		Low, high	C7 normal	2 radios (a/n 20) x 2 channels x 2 antennas	640
Total test time: 9,600 seconds or 2.7 hours							

Signaling control of DUT

For signaling tests — DFS, adaptivity, receiver blocking, adjacent channel selectivity, CBP — you need a companion device to test the DUT. In the United States, it is not difficult to obtain 6E companion devices, but it is not the case in other parts of the world. Currently, companion device simulators are not available to support the 6E bands. You will have to prepare your companion device and ensure that your regulatory test system works well with the device.

Support for various regulatory standards

ETSI provides different standards based on frequency bands, including EN 300 328 (2.4 GHz), EN 301 893 (5 GHz), and EN 303 687 (6 GHz). Soon, the EN 302 502 standard for the 5.8 GHz band will merge with EN 301 893.

Most Wi-Fi devices will require testing across different standards. For example, an 802.11a/ac/ax device requires testing using the EN 301 893 and EN 303 687 standards. The FCC requires testing the device using the KDB 789033 and 987594 standards. Ensuring your regulatory test solution is backward compatible to support existing regulations is critical for complete device certification.

Data processing and reporting

Regulatory testing involves many test parameters, conditions, and settings. You need to manage and include vast amounts of data, plots, and test conditions in the final report. When test cases fail, you need to debug and sometimes retest only certain cases.

Processing and exporting the data offline for further analysis is essential for troubleshooting and debugging. Automation software needs to be flexible enough to run only certain test cases and capture the latest results into the final report in different document formats, including Microsoft Excel, Word, Adobe PDF, and more.

Resource management flexibility

You can divide the regulatory test setup into smaller test systems to perform signaling or non-signaling test cases. This option makes it more flexible for test labs, chipset, or device makers to manage equipment utilization and plan for resources. For example, the signaling tester may have higher utilization due to the complexity of the tests and increased setup time. Signaling tests may also have a higher failure rate requiring more time for debugging and retesting. Dividing the regulatory test setup also enables more flexibility when selecting test systems to meet test capacity or utilization targets.

Commercial Software

Commercially available software eliminates the need to dedicate engineering resources to monitor updates and changes to regulatory standards and develop, update, test, deploy, and support automation software.

Accelerating Wi-Fi 6E Regulatory Testing

Wi-Fi 6E offers many improvements in speed and transmission quality. Those improvements, however, come with complex testing requirements. Device manufacturers will want to be the first to gain market share, and test labs will need to be ready for the new testing requirements.

Whether you are a manufacturer or a test lab, you will need a regulatory test solution that supports 2.4 GHz and 5 GHz ISM and U-NII bands and draft versions for 6E bands. You will need metrology-grade instruments to deliver accurate results. Signal generators must accurately simulate the interference or radar signals needed for adaptivity testing, DFS, receiver blocking, CBP, and adjacent channel selectivity tests.

Finally, the new tests will require many measurements and data processing to meet the testing requirements of the regulatory standards. An automated solution is the best way to accelerate Wi-Fi 6E testing and should allow for regular software updates based on the evolving standards.

Learn More

- IOT0047A Regulatory Compliance Solutions
- IoT Regulatory Compliance eBook