Application Note

Anritsu envision : ensure

Wireless LAN Product Evaluation Guide

~Competitor Investigation~

Wireless Connectivity Test Set MT8862A

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1. Introduction

In recent years, wireless communications functions have been added to domestic white goods, such as robotic cleaners, refrigerators, washing machines, etc., as well as to industrial products, including digital cameras and sensors. Moreover, future widespread deployment of IoT devices seems likely to expand use of wireless communications. In most cases, wireless communications functions are implemented using either Bluetooth or wireless LAN (WLAN) technologies, but this document describes products incorporating wireless LAN functions. To implement communications functions using WLAN, generally a WLAN module is built into the product/equipment, **but the performance described in the catalog for the built-in WLAN module is not guaranteed to be the same as the finished product containing the module**. Consequently, when either developing new products or implementing upgrades, performance comparisons with other companies products as well as with in-house products is a good way to understand market trends as well as an important step in assuring manufacturing of better products.

2. Competitor Investigation Procedure

This section describes competitor investigation, but it is important not only to compare performance with other companies' similar products, but also WLAN signal quality between a company's products. The performance investigation and comparison items are as follows:

- At product development, investigation of communications standards and modulation methods used by other companies and investigation of design concepts such as antenna directivity
- At product development, comparison of performance with other companies' products in same performance class
- Performance comparison before and after model changes and upgrades
- Presence/absence of faults due to firmware upgrades

The simplified competitor investigation flow is shown below.

1. Measure RF performance of several competing products
2. Compare and analyze home trends of competing products
3. Use competing product trends and usage environment to estimate market requirements

The next section explains the basic knowledge required for WLAN evaluation. And the section after next, explains how to compare WLAN signal quality and communications quality, and introduces actual comparison examples.

3. Basic Knowledge about Wireless LAN Evaluation

Wireless LAN technology is called by various names, such as Wi-Fi, WLAN, W-LAN, etc. It is deeply embedded in our current lives and is a key communications technology of the same importance as mobile cellular phone networks. There are many wireless LAN standards and many people do not know the differences between each standards or names.

This section explains basic knowledge about wireless LAN. If you already know this, skip forward to section 4.

3.1. Wireless LAN Standards

The wireless LAN standards are divided broadly into two: one prefixed by the term 11, such as 11a/b/g/n/ac/ax, and the other prefixed by the term Wi-Fi, such as Wi-Fi 4, 5, 6. What is the difference? The 11a/b/g/n/ac/ax description is an IEEE (Institute of Electrical and Electronics Engineers) 802.11 standard for wireless LAN. On the other hand, Wi-Fi 4, 5, 6 descriptions are more easily understood names assigned by the Wi-Fi Alliance based on the technology generation and matching the 11a/b/g/n/ac/ax standards; they are also used for certification programs as follows. As a result, basically Wi-Fi 6 and IEEE 802.11ax can be considered to be the same.

Table 1: W-LAN Standards and Certification Program

IEEE Standard	Wi-Fi Alliance Official Name	Wi-Fi Alliance Abbreviated Name
IEEE 802.11ax	Wi-Fi CERTIFIED 6	Wi-Fi 6
IEEE 802.11ac	Wi-Fi CERTIFIED 5	Wi-Fi 5
IEEE 802.11n	Wi-Fi CERTIFIED 4	Wi-Fi 4

Column: Actual differences between 11xx and Wi-Fi x

Based on the table 1, most people might think that Wi-Fi x is an easier term to understand 11xx. Although correct, the range of supported wireless LAN products is different. Wi-Fi x is a title used for wireless LAN products certified by Wi-Fi Alliance interconnectivity tests; a certified wireless LAN product can display the Wi-Fi Alliance Certified mark indicating guaranteed connectivity between certified products. When correctly managed, 11xx products are designed in accordance with the IEEE 802.11 standard and indicate wireless LAN products that can connect using the method specified on IEEE 802.11. Wi-Fi x means a product with assured connectivity according to the Wi-Fi Alliance in these product specified on IEEE 802.11.

3.2. Key Features of Each Standard

This document and Anritsu measuring instruments describe the wireless LAN standards as IEEE 802.11a/b/g/n/ac/ax from the viewpoint of technical standards since they deal widespread used wireless LAN products. The features of the standards are summarized in the following table.

Table 2: Key Features of Each IEEE 802.11 Standard

IEEE 802.11		11b	11a	11g	11n	11ac	11ax
Established		1999	1999	2003	2009	2014	Expected 2020
Freq. band	2.4 GHz	✔	n/a	✔	✔	n/a	✔
	5 GHz	n/a	✔	n/a	✔	✔	✔
	6 GHz	n/a	n/a	n/a	n/a	n/a	✔
Bandwidth [MHz]		22	20	20	20/40	20/40/80/ 160/80 + 80	20/40/80/ 160/80+ 80
Max. Com. Speed [bps]		11M	54M	54M	600M	6.9G	9.6G
Modulation		DBPSK DQPSK	BPSK QPSK 16QAM 64QAM	BPSK QPSK 16QAM 64QAM	BPSK QPSK 16QAM 64QAM	BPSK QPSK 16QAM 64QAM 256QAM	BPSK QPSK 16QAM 64QAM 256QAM 1024QAM
Multi-user Method		-	-	-	-	MU-MIMO (up to 4 users)	MU-MIMO (up to 8 users) OFDMA

Frequency Band: The frequency region (band) are decided by each wireless LAN standard; each band is divided into channels, and an access point sends and receives data on same channel as connected wireless LAN products. (Fig. Example of 2.4 GHz frequency band)

Bandwidth: Each channel has a width in the frequency domain, which is called the bandwidth.

Max. Communications Speed: In the IEEE standards, this is expressed as the data rate. It is the maximum data transfer speed which is determined by each modulation method, bandwidth and multi-user method. Since this numeric value is different from throughput, some care is required. As the concept image, the data rate expresses the speed of ship (or river) on which the cargo (data) is carried on ships across the water. The frequency (rate) at which this cargo reaches the collection point (dock) is the throughput. Read section 4 for more details.

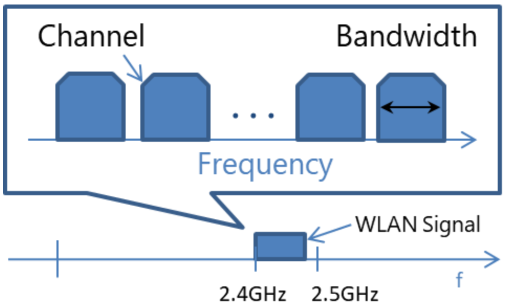


Figure 1 Example of 2.4 GHz frequency band

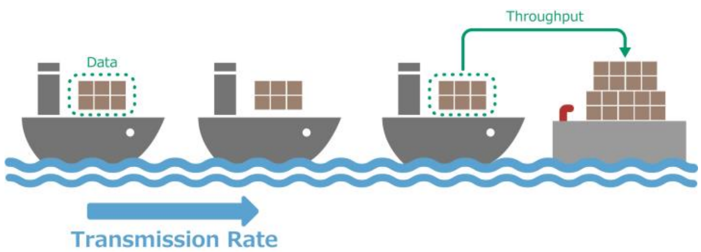


Figure 2 Difference Between Transmission Rate and Throughput

Modulation Method: Modulation is a method for converting data to be transmitted into a suitable signal (electrical or optical) for transmission. Typical transmission methods are amplitude modulation (AM) using the amplitude of the signal to discriminate data (1 and 0), and phase modulation (PM) using the signal phase to discriminate data (1 and 0).

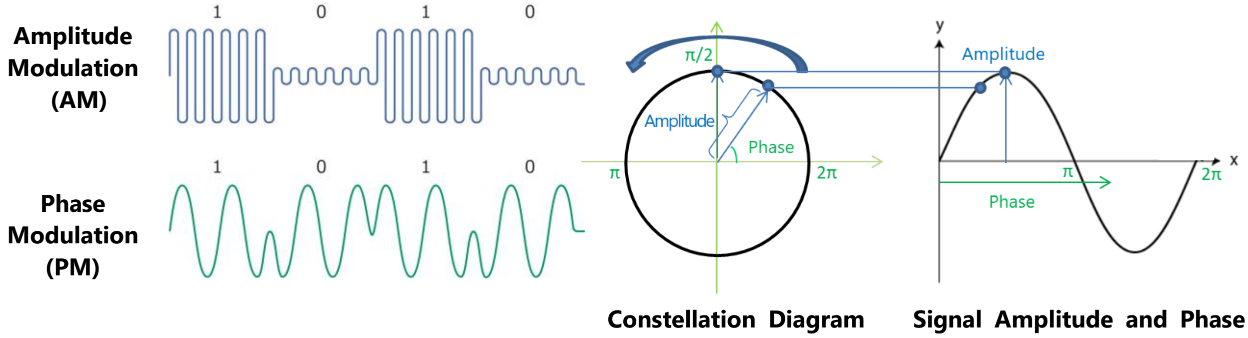


Figure 3 Amplitude Modulation (AM) and Phase Modulation (PM)

Wireless LAN uses combined modulation methods: Amplitude Modulation (AM), and Phase Modulation (PM). The phase and amplitude are represented as symbol points using a figure called a constellation (Refer Figure 3). For example, using the QPSK modulation method, the combination of amplitude and phase creates 4 points representing 2-bit data as four binary values (00, 01, 10, 11). In other words, this is equivalent to sending 2 bits of data per transmission. As shown in the following diagrams, the data rate increases because the number of bits sent each time increases as the number of symbol points increases.

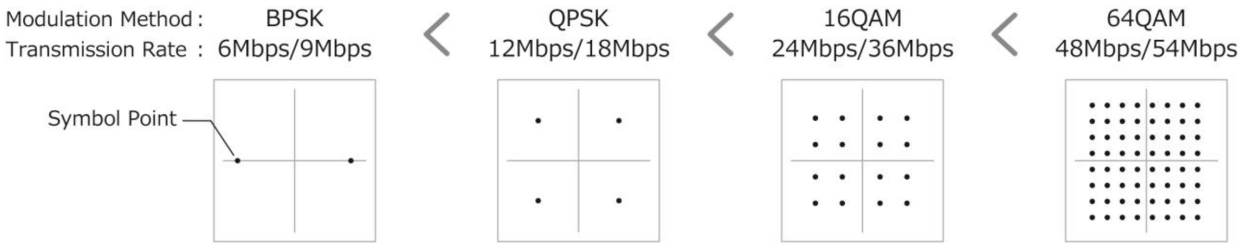


Figure 4 Constellation Diagram of Digital Modulation

Multi-user Method: One access point (AP) can support connections to multiple wireless LAN products (stations or STA), it is called a multi-user method that multiple lines or signal is transmitted simultaniusly. Until the 11n standard, because one AP could handle only one connection with one STA, multiple wireless LAN products were connected using time division. It is called a single user method. From the 11ac and after standard, a multi-user method divided broadly into two types has been used to connect multiple users simultaneously. In the first, a multi-user, multi-input, multi-output method (MU-MIMO) is implemented using multiple antennas. In the second, multiple wireless LAN products (STA) are connected simultaneously using the Orthogonal Frequency-Division Multiple Access (OFDMA) method with frequency division.

MU-MIMO: Multiple user equipment (UEs) can communicate simultaneously by adjusting the phase of the electrical waveforms at multiple antennas. Simultaneous communications by each UE connecting to the each AP antenna array is more efficient. In the 11ac standard, only the downlink connection (from AP to UEs) is multi-user, but from 11ax, the uplink connection (from UEs to AP) is also multi-user, increasing the communications efficiency.

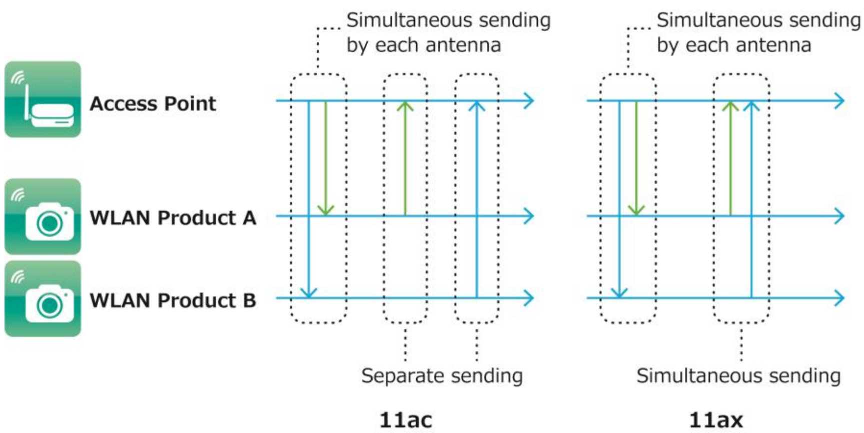


Figure 5 Difference of Multi User Communicate between 11ac and 11ax

OFDMA: This method is used to efficiently divide the occupied band between multiple users. It is adopted by the latest 11ax standard. As shown in the following diagram, until the 11n standard, wireless LAN products could only connect one-to-one for short time periods. As a result, when connecting multiple wireless LAN products to one AP, each terminal experiences longer wait times as the number of terminals increase because each terminal is communicating for some time period. In addition, the overall throughput drops because the wireless LAN products (users) occupy the communication band for fixed time periods even when sending only small amounts of data.

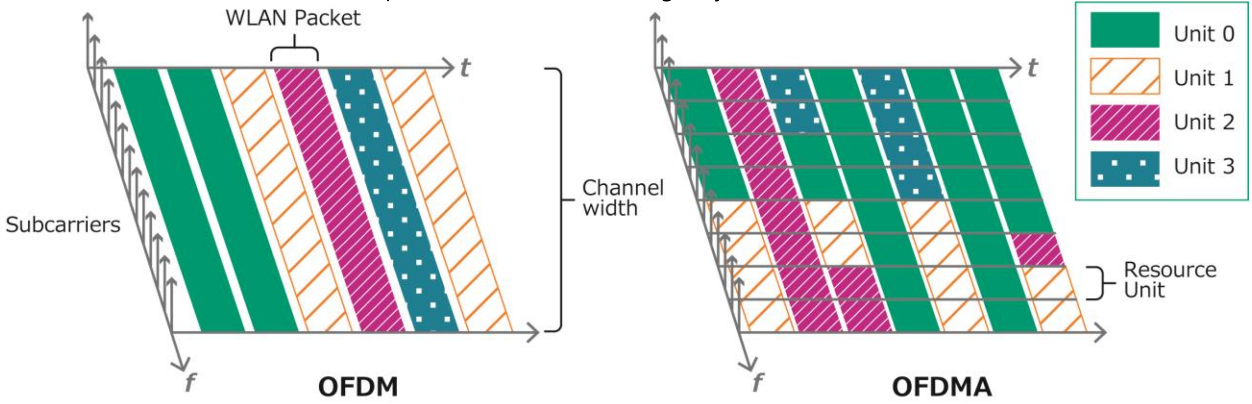


Figure 6 Resource Mapping Example of OFDM and OFDMA

The OFDMA method is adopted by the latest IEEE 802.11ax wireless LAN standard. As a result, multiple wireless LAN products can connect simultaneously to one AP at same time slot. Using OFDMA, the overall throughput is improved by dividing channels into more smaller units called resource units (RU) to make more efficient use of channels.

Column: What is the latest 11ax standard?

IEEE 802.11ax is being standardized for release in November 2020 as the new specification for high-efficiency, next-generation wireless LAN products. Whether or not your products meet the 11ax standard, you may be surprised by this talk. In fact, standardization has not yet been accomplished by IEEE and the latest Draft 6.0 describing interim specifications and test contents was submitted in February 2020. As a result, products are being designed assuming that these Draft specifications will become the Base specification.

With 802.11ax, wireless LAN products will be able to demonstrate their full communications performance even in environments with many competing wireless LAN products to offer simultaneous communications with one AP for hugely improved usability as a high-efficiency (HE) communications standard.

4. Throughput Evaluation Problems

We could examine the key features of each wireless LAN standard, so we retun to the competitor comparison viewpoint.

What should be the basis of comparison for wireless LAN performance of competing products in the same business field?

There are two criteria for good wireless products depending on the application. The first criterion is **achieveing high throughput**. The other one is **keeping stable communications even in a bad communications environment**.

Not Good ☐ Supported Standard
Not Good ☐ Throughput
Excellent! ☐ Signal Quality

To evaluate these criteria, comparison of three factors: supported standard, throughput, and signal quality might be considered, but the best comparison factor among these is evaluation of signal quality (RF performance). So why is it not better to compare supported standards and throughput?

4.1. Reliability of New Standard

Comparison of supported standards would seem to be the simplest method. However, it is too early to draw conclusions about the best products even if it supports latest standard, 11ax, and it has high-speed throughput specification.

The general trend in wireless LAN modules is to use a high-order modulation method achieving the best throughput in an ideal propagation environment (low noise, low loss).

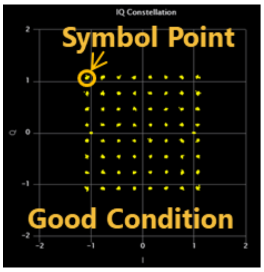
As shown in Table 2, the modulation method with the highest data rate is 1024QAM in the 11ax standard, so obviously 11ax wireless LAN modules supporting 1024QAM should be adopted to achieve the highest throughput in the same environments. However, high-order modulation methods such as 1024QAM will not be chosen when the signal quality and external environment are not good. **If the modulation accuracy is poor, there will be many data transmission errors and the communications between the AP and the wireless LAN product will switch to a modulation method with a lower data rate to secure stable communications.**

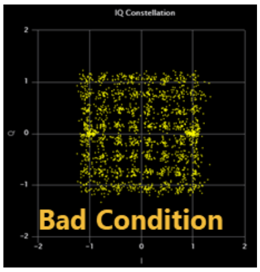
Since the modulation method may drop due to the terminal modulation accuracy and external environment even when the latest 11ax standard is supported, depending on conditions, there may be cases where a higher throughput is achieved using a wireless LAN module with good modulation accuracy supporting the earlier 11ac standard. Based on the above, it would be necessary to evaluate other conditions generally rather than making an unconditional decision about performance of a standard.

Column: Relationship between modulation accuracy (EVM) and modulation method (MCS)

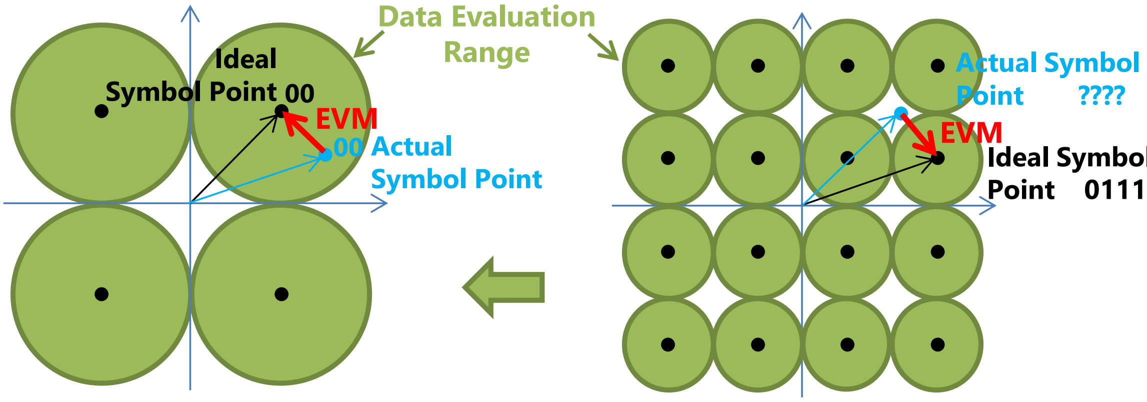
The figure on the right is an example of the 64QAM constellation screen. With 64QAM, the 8 x 8 vertical/horizontal matrix has 64 symbol points. Expressing errors vs ideal symbols as a percentage indicates the Error Vector Magnitude (EVM).

When the modulation accuracy is good, symbols are focused at one point; when the modulation accuracy is bad, the points appear fuzzy. As shown in the right figure, data cannot be evaluated correctly when the EVM is poor with higher-order modulation methods (MCS).





If the wireless LAN product 's EVM and environment are not good, it is impossible to achieve high throughput even with products supporting the latest 11ax standard.



With QPSK, even data with large EVM can be evaluated, so bad signal quality and even data with large noise can be received.

Data with the same EVM cannot be recognized with 16QAM, and QPSK modulation is used instead since 16QAM is weak against aggravated signal quality and noise. But it will be higher throughput than QPSK if good.

4.2. Throughput Not Reaching Theorogical value

How do you think about comparing the throughput with competing products in the same environment using the latest APs? Comparisons can be made for products if which can be installed throughput measurement software, such as iPerf. When comparing IoT products, since it is difficult to install measurement tools in the product, only a rough comparison may be possible such as transfer large files.

In addition, **when calculating throughput using some method, all wireless LAN products will have dispartion and lower value than the standard.** This is probably due to the connection environment or to the AP being used, which may sometimes have insufficient power, or perhaps the wireless LAN product quality is poor; determining the exact cause can be extremely difficult.

Consequently, throughput evaluation has many pitfalls and **the wireless LAN product throughput still does not meet the standards** even when none of the above problems are relevant. Why?

For example, in Table 2, the maximum throughput for the 11ac standard is listed as 6.9 Gbps. This is the maximum data rate in the IEEE 802.11ax standard. And the bandwidth is assumed 80+80 MHz in 8x8 MIMO as maximum MIMO. Currently evaluated wireless LAN products have just oneantenna (SISO) with a bandwidth of 80 MHz, supporting a theoretical best-effort data rate of 433 Mbps according to the IEEE standards.

6930Mbps	x 1/8	x 1/2	= 433Mbps
8x8MIMO 80+80MHz BW	SISO	80MHz BW	Theoretical Data Rate

The data rate in the IEEE 802.11 standards is theorogical value, not throughput. The data rate is the basic unit of transmission performance, and is expressed as the number of bits that can be transferred in 1 second; It is a speed when data transmitted continuously. In reality, various header data and intervals or breaks between data packets (composed of headers and data) are appended to sent data. **<u>Consequently, the actual maximum throughput is not the same as the theoretical data rate because there is no consideration of intervals between headers.</u>**

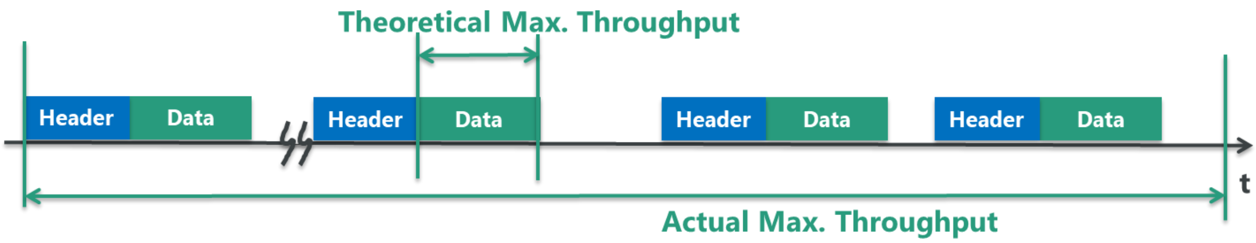


Figure 7 Theoretical Throughput and Actual Throughput

Furthermore, since the wireless LAN standard uses a random interval length, throughput changes at each measurement. Considering this, the actual throughput under 11ac 80 MHz SISO conditions is about 60% to 70% of the theoretical maximum data rate with a variation of about 10%.

*321 Mbps is an example measured by the Anritsu MT8862A

Moreover, even these value cannot be unconditionally quantified due to differences in standards and parameters. At connection with an AP, since it is impossible to know parameter settings for competing wireless LAN products it is impossible to evaluate whether the throughput is adequate or whether the wireless LAN product signal performance is bad. In shielded environments with minimum impact from external noise, it may be possible to perform comparative evaluations taking throughput randomness into consideration at identical AP settings (parameters). However, from the competitive investigation viewpoint, it is inadequate to use throughput as the deciding factor in assessing the performance superiority or inferiority of a single competing wireless LAN product because it is impossible to evaluate whether the best maximum throughput is being output for the settings and environment. In the current situation, it is extremely difficult to evaluate throughput in this way.

5. RF Performance Comparison Examples

As explained in previous sections, wireless LAN products cannot be investigated performance simply by using applicable standards and throughput measurements. Competitive inspection requires looking at the competing product signal quality, or in other words the RF performance.

So exactly to what degree does signal quality differ? How much will the signal quality change when integrating a purchased wireless LAN module? There is a lot to consider here.

Performance differences due to the following design requirements as well as lack of considerations after assembly can cause trouble.

<u>Design Factors</u>

- ☐ Antenna arrangement
- ☐ Noise effects of parts near WLAN module,wiring on PC board, and cable wiring
- ☐ RF Performance of module itself

Ignored Factors

- ☐ Device runaway due to internal temperature increase
- ☐ Disrupted communications due to unexpected increase of data packets
- ☐ Discarded data due to short packet interval

This section explains both the RF performance evaluation environment and also shows some actual results for domestic electrical products measured by measuring instruments.

5.1. Evaluation Environment

A measuring instrument is required to evaluate signal quality because Signal quality is unknown by AP connections. Available WLAN testers supporting the Network mode to **evaluate the TRx performance of commercial WLAN products by connecting using the same procedure as a regular wireless LAN**. Check whether the tester supports WLAN security because many commercial WLAN product are under security.

In addition, provision of a stable radio-wave evaluation environment with little impact from external electrical noise requires use of a chamber, shield box, etc. The diagram on the right shows a example of test environment to evaluate a WLAN module with Anritsu Wireless Connectivity Test Set MT8862A.

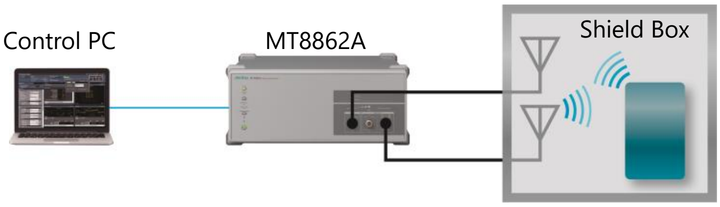


Figure 8 Test Configuration Example

Efficient evaluation can be achieved by determining the following communications conditions.

- ✓ Communications Method (11a/b/g/n/ac/ax)
- ✓ Channel (Frequency)
- ✓ Data Rate

The minimum evaluation items to be confirmed by the competitor/product comparison are as follows:

- ☐ Evaluation of Tx characteristics: Power, Modulation Accuracy (EVM*1)
- ☐ Evaluation of Rx characteristics: Rx Sensitivity (PER*2)

*1: EVM: Error Vector Magnitude
*2: PER: Packet Error Rate

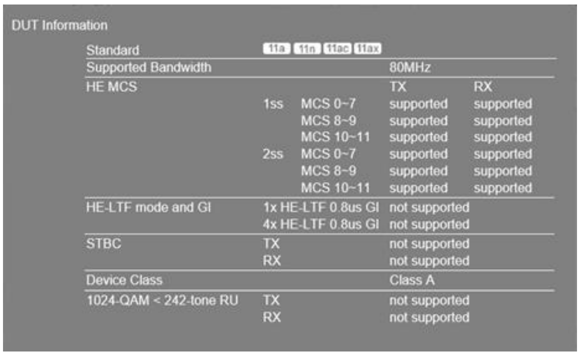


Figure 9 DUT Information

In addition, the MT8862A supports at-a-glance confirmation of the capabilities of the connected wireless LAN product and the current connection conditions like the Figure 10.

The above measurements enable general evaluation of the product.

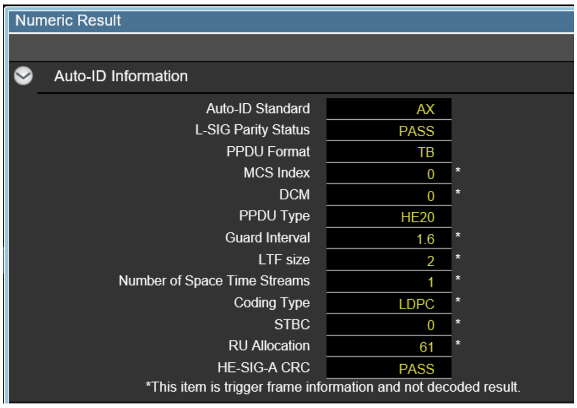


Figure 10 Connection Status

Section Conclusions:

- ■ Main indices for assessing whether product achieved high throughput
  → WLAN capability/current connection conditions, modulation accuracy (EVM)
- ■ Main indices for assessing whether product maintains communications in degraded radio environment
  → Rx Sensitivity (PER), Tx Modulation Accuracy (EVM), Power

5.2. Tx Performance Comparison

The quality of the signals sent from wireless LAN products changes according to the data rate, frequency, etc. The following sections describe the results of signal quality comparisons related to data rate and channel for eight types of domestic WLAN products.

5.2.1. Performance Differences due to Tx Rate (Modulation Method)

Since the data rate changes when the modulation method is changed, it is important to confirm the modulation accuracy (EVM) at each data rate. In the following example, there are products with a stable date rate, and other products in which the EVM changes as the data rate changes.

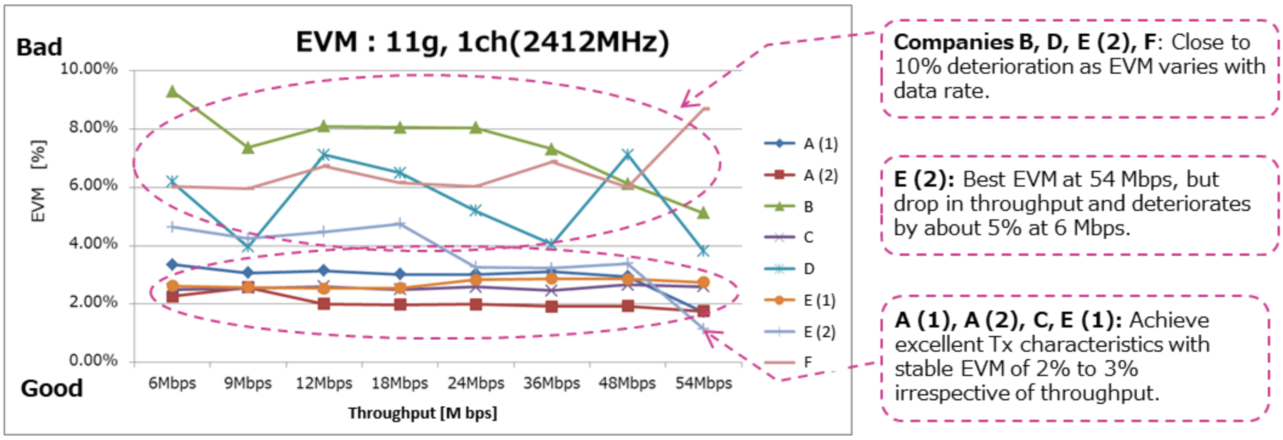


Figure 11 EVM vs Tx Rate

Based on the measured performance of each product, as the graph shows, there are clear performance differences between products designed for, checked, and calibrated at each data rate, and other products.

5.2.2. Performance Differences due to Channel (Frequency)

Changing the product channel changes the frequency. As shown in the Figure 12, some products have stable EVM when the channel changes, while the EVM of other products changes with channel changes.

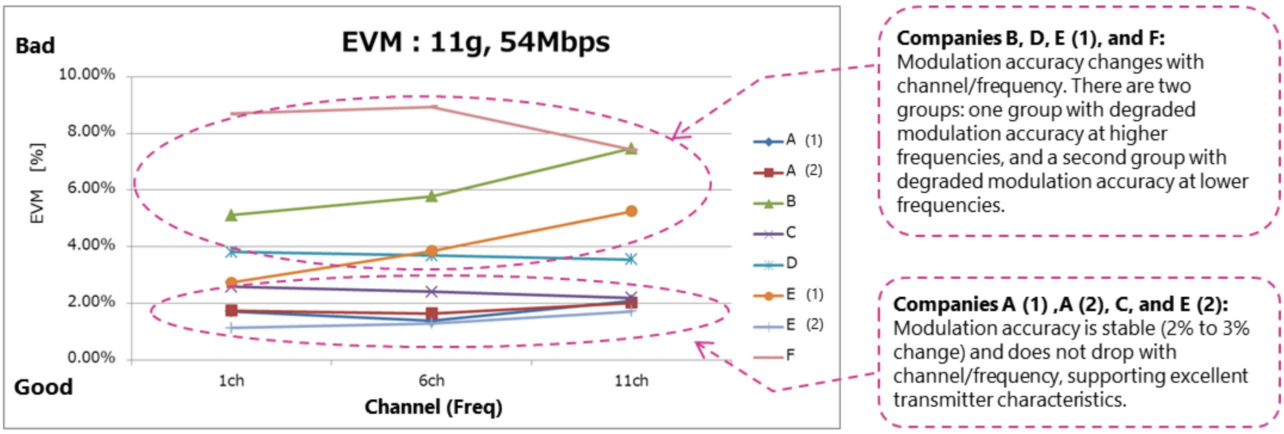


Figure 12 EVM vs Frequency

We assume that some of these products use analog components with frequency characteristics or when there is noise or interference at some specific frequency, the frequency-characteristics performance has an impact on EVM.

<u>Conclusions on Tx Characteristics:</u> In some cases, EVM changes with modulation method and frequency. In these examples, it is clear that products from Companies A (1) (2), and C have excellent transmission characteristics under all conditions.

5.3. Rx Performance Comparison

Since noise from nearby parts, wiring, etc., has an impact, it is important to confirm the Rx characteristics of the final assembled product and not just the wireless LAN module itself. In the example, there are clear differences in the Rx sensitivity level between products.

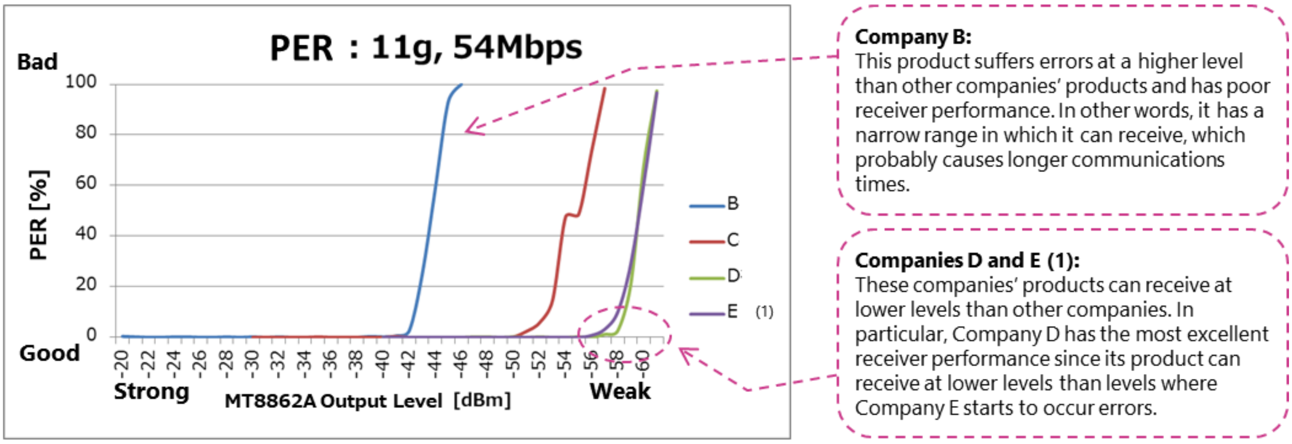


Figure 13 PER vs Output Level

Conclusions on Rx Characteristics: As well as differences in levels for Rx sensitivity between products, differences in increased error rates (gradients) are also confirmed.
In this example, it is clear that products from Companies D and E (1) have excellent Rx characteristics.

6. Conclusions

Investigation of competing products clarifies performance trends. Considering this information and the company's assumed usage environment can help determine wireless LAN performance required by the market. Moreover, if you find extremely high-performance products, teardown analysis can help with consideration of design features, such as which wireless LAN module to use, and how to layout antennas.

In addition to comparing competing product start Iot Product, comparison at the design stage, between a company's old and new models, and between production lots, etc., **using quantitative and high-reproducibility evaluations of finished-product TRx performance can help prevent degraded performance.**
Such evaluations reduce the risk of WLAN performance-related claims, such as 'I cannot get a connection', or 'I am easily cutoff', or 'The connection speed is slow', to improve sales, service and brand image.

Note:

envision : ensure

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1911

Printed in Japan 公知 2020-4 MJM No. MT8862A-E-F-2-(1.00)