

# W-LAN MIMO Rx Test using Vector Signal Generator

MG3710A

Vector Signal Generator

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## Introduction

Multi-Input Multi-Output (MIMO) is one technology for improving the speed and quality of data transmissions between wireless points; it is used by many wireless standards including LTE, W-LAN, WiMAX, etc., and it is already being used increasingly to increase data speeds. The MIMO standard used by W-LAN is evolving from IEEE802.11n to the IEEE802.11ac development version. W-LAN appliances with built-in MIMO technology are becoming commonplace and are expected to increase in number in the future.

Although MIMO uses multiple antennas, the MIMO processes handling assignment of data to each antenna, etc., are managed by the baseband chip. W-LAN appliance developers layout the baseband chip based on a reference design incorporating multiple power amplifiers and antennas as necessary. They assume that if each antenna routing operates normally, management of the MIMO processes should be problem-free depending on the guaranteed baseband chip operation. As a matter of fact, to reduce testing costs, most W-LAN appliance development sites test the operation of appliances by measuring each antenna route while in the SISO condition.

However, this test only guarantees the minimum operations and it is inadequate for obtaining test data to assure the throughput of W-LAN appliances in actual use and for inventing high-performance appliances. Even when assembling W-LAN chipsets and modules using tested packages, the final product vendors must still grope for hard-to-establish quantitative evaluation methods for the final products. If this can be achieved, not only will it play a key role in selection of even higher performance and lower-cost chipsets and modules as well as in troubleshooting, it will also be possible to improve the performance of W-LAN appliances through more efficient antenna arrangements as well as in achieving more appealing designs matching usage without drops in performance.

Since MIMO technology itself uses very high-level and hard-to-understand mathematics, gaining an understanding from first principles is a major stumbling block for already overworked W-LAN developers. Moreover, as previously mentioned, without a good understanding based on the theory of MIMO, it is impossible to develop W-LAN appliances supporting MIMO. The most important parts are quantifying and recording W-LAN appliance performance under different MIMO environments, assuring test reproducibility, and understanding the causal relationships.

This application note is targeted at engineers designing and evaluating W-LAN modules and final products; it explains how to perform evaluation tests of W-LAN appliance Rx characteristics in a MIMO environment using the Anritsu MG3710A Vector Signal Generator and IQproducer™ tool.

In this application note, the Packet Error Rate (PER) is used as an index for quantifying the performance of W-LAN appliances in a MIMO environment. The PER is one index expressing the performance characteristics of wireless receivers; it is the ratio of the number of correctly received packets to the number of packets sent from the transmitter. Irrespective of whether the PER is sufficiently low under SISO conditions, if the PER is high at MIMO, it indicates that the MIMO is performing inadequately under those conditions. By checking each parameter one-by-one, it becomes possible to approach the true cause of any performance problems.

The following abbreviations and technical terms are used in this application note.

BCC	Binary Convolutional Code
CCA	Clear Channel Assessment
GI	Guard Interval
HT	High Throughput
LAN	Local Area Network
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MIMO	Multi-Input Multi-Output
MPDU	MAC Protocol Data Unit
PER	Packet Error Rate
PLCP	Physical Layer Convergence Procedure
PMD	Physical Medium Dependent
PSDU	PLCP Service Data Unit
RSSI	Received Signal Strength Indication
SISO	Single-Input Single-Output
STA	Station
STBC	Space Time Block Coding

## Outline of MIMO

This chapter reviews the principles of MIMO as a prerequisite for understanding this application note.

In wireless communications, the phrase Multi-Input Multi-Output or MIMO is used as a single term meaning input first output second. It represents a system where multiple streams (signal series) are input to the wireless propagation path in (free) space from which the streams are then recovered. A feature of the system is its use of the same frequency. As a result, it is not necessary to acquire new frequency resources, or in other words widen the channel bandwidth, nor to add new channels.

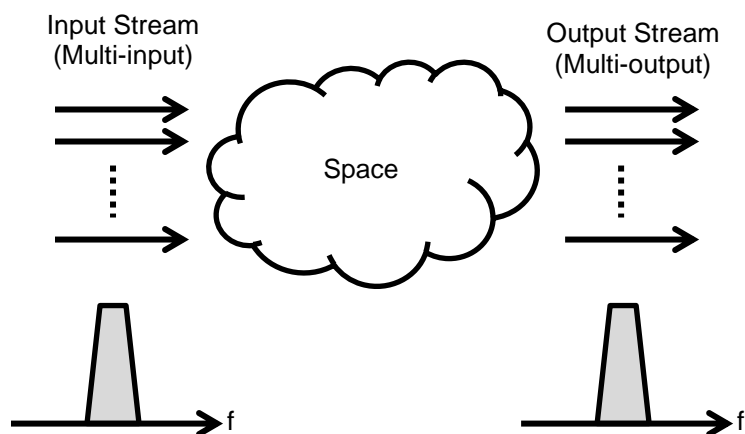


Fig. 1. Basic MIMO System Configuration

Using MIMO, the Tx stream is input to free space using multiple Tx antennas and the output stream is received from free space using multiple antennas too. If each stream carries the same information, even if the transmission quality of one or more streams drops, the original signal can still be recovered with high fidelity and the overall quality of the transmission is maintained. On the other hand, if each stream carries different information, the data transmission capacity is increased to increase the transmission speed.

Figure 2 shows the block diagram for a 2 x 2 MIMO system using two send (Tx) and two receive (Rx) antennas. The two data series A and B at the transmitter are formed into two streams by the MIMO signal generator processing and are sent at the same timing and frequency from Antenna 0 and Antenna 1. The receiver receives the data at the two Rx antennas and reproduces the data series A and B using the MIMO signal separator processing.

From Fig. 2, it is clear that the signal input to the receiver MIMO signal separator block is a mixture of multiple streams arriving from multiple signals paths. The path from one antenna at the Tx side to one antenna at the Rx side is called a channel, and there are 4 channels in a 2 x 2 MIMO system.

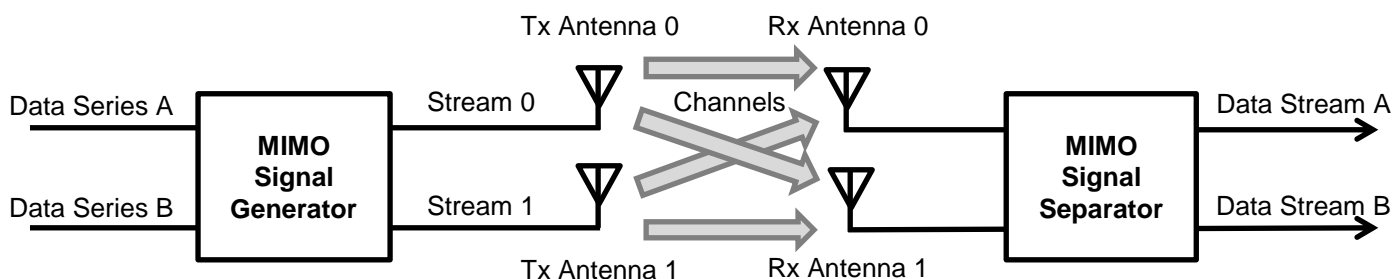
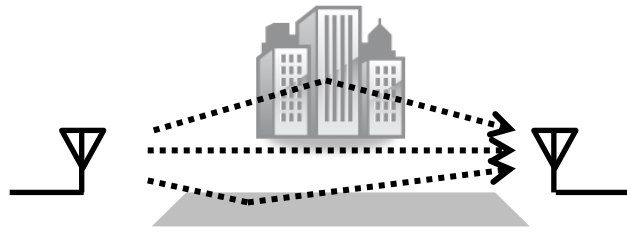


Fig. 2. 2 x 2 MIMO System Block Diagram

Normally, the electromagnetic (radio) waves output from the Tx antennas are reflected by walls and objects within buildings and by surfaces and buildings outside, so they arrive at the Rx antennas from slightly different paths due to the various incident angles. Consequently, each Rx antenna receives signals from different paths at different amplitudes, phases, and timings. The receiver separates these signals to recreate the original streams output by the transmitter.



*Fig. 3. Multiple Radio Wave Propagation Paths to Receive Antenna*

In this type of circumstance, there is a question about how the receiver is able to separate the original signals from the mixed received signals. One index indicating the ease of this signal separation is the degree of the correlation between these mixed signals. A correlation can be described as the degree of relatedness between two events. For example, if two signals have broadly similar characteristics, we can say they have a very high correlation. Conversely, if there are almost no similarities, the correlation can be said to be low. In the signal separation process, a specific signal pattern is extracted by mathematical processing from the mixed signal data. If the signal correlation is high at this time, when trying to remove signals other than the extracted target signals, in many cases the signal to be extracted is also removed. If the signal correlation is low, only signals other than the extraction target are removed and the required signal can be obtained. With MIMO, the transmitter creates signal streams so the receiver receives mixed signals with low correlation according to the usage form (propagation model) of each system and the correlation is changed due to changes in the signal amplitude and phase caused by various objects present in the propagation path through free space. This so-called fading phenomenon is closely related to MIMO system performance.

## W-LAN IEEE802.11n and MIMO

The first MIMO standard used by W-LAN was IEEE802.11n, supporting up to four channels. The IEEE802.11n standard uses a combination of the most efficient modulation method and encoding rate (64QAM and 5/6) to achieve theoretical transfer speeds of 600 Mbit/s using four channels with a guard interval (GI) of 400 ns.

The coding rate is the encoding rate of the error correction (convolutional code); the larger number indicates the better transfer capacity and efficiency. The GI is included in the signal units rather like a spacing overlap. Although the ability withstand signal delays is higher with a longer GI, it decreases the net amount of data included in the stream, in turn decreasing the transfer capacity.

The W-LAN IEEE802.11n PHY layer uses the so-called MCS (Modulation and Coding Scheme) value to express the modulation method, coding method, and number of channels. When the MCS is 0 ~ 32, the same modulation method is used for each channel (stream in free space). At MCS values of 33 and above, different modulation methods are used for each channel. The MCS is used when the IEEE802.11n Frame format is either HT-mixed or HT-Greenfield and not IEEE802.11a Transposition Mode (Non-HT).

Table 1. IEEE802.11n MCS List (using same modulation method for all streams)

MCS	Modulation Method	R	Space Stream No.	Data Transfer Speed (Mbit/s)			
				20-MHz Band		40-MHz Band	
				800 ns GI	400 ns GI	800 ns GI	400 ns GI
0	BPSK	1/2	1	6.5	7.2	13.5	15.0
1	QPSK	1/2	1	13.0	14.4	27.0	30.0
2	QPSK	3/4	1	19.5	21.7	40.5	45.0
3	16QAM	1/2	1	26.0	28.9	54.0	60.0
4	16QAM	3/4	1	39.0	43.3	81.0	90.0
5	64QAM	2/3	1	52.0	57.8	108.0	120.0
6	64QAM	3/4	1	58.5	65.0	121.5	135.0
7	64QAM	5/6	1	65.0	72.2	135.0	150.0
8	BPSK	1/2	2	13.0	14.4	27.0	30.0
9	QPSK	1/2	2	26.0	28.9	54.0	60.0
10	QPSK	3/4	2	39.0	43.3	81.0	90.0
11	16QAM	1/2	2	52.0	57.8	108.0	120.0
12	16QAM	3/4	2	78.0	86.7	162.0	180.0
13	64QAM	2/3	2	104.0	115.6	216.0	240.0
14	64QAM	3/4	2	117.0	130.0	243.0	270.0
15	64QAM	5/6	2	130.0	144.4	270.0	300.0
16	BPSK	1/2	3	19.5	21.7	40.5	45.0
17	QPSK	1/2	3	39.0	43.3	81.0	90.0
18	QPSK	3/4	3	58.5	65.0	121.5	135.0
19	16QAM	1/2	3	78.0	86.7	162.0	180.0
20	16QAM	3/4	3	117.0	130.0	243.0	270.0
21	64QAM	2/3	3	156.0	173.3	324.0	360.0
22	64QAM	3/4	3	175.5	195.0	364.5	405.0
23	64QAM	5/6	3	195.0	216.7	405.0	450.0
24	BPSK	1/2	4	26.0	28.9	54.0	60.0
25	QPSK	1/2	4	52.0	57.8	108.0	120.0
26	QPSK	3/4	4	78.0	86.7	162.0	180.0
27	16QAM	1/2	4	104.0	115.6	216.0	240.0
28	16QAM	3/4	4	156.0	173.3	324.0	360.0
29	64QAM	2/3	4	208.0	231.1	432.0	480.0
30	64QAM	3/4	4	234.0	260.0	486.0	540.0
31	64QAM	5/6	4	260.0	288.9	540.0	600.0
32	BPSK	1/2	1	n/a	n/a	6.0	6.7

R: Coding Rate

Table 2. IEEE802.11n MCS List (using different modulation method for each stream)

MCS	Modulation Method				R	Data Transfer Speed (Mbit/s)			
	Stream					20-MHz Band		40-MHz Band	
	1	2	3	4		800 ns GI	400 ns GI	800 ns GI	400 ns GI
33	16QAM	QPSK	-	-	1/2	39	43.3	81	90
34	64QAM	QPSK	-	-	1/2	52	57.8	108	120
35	64QAM	16QAM	-	-	1/2	65	72.2	135	150
36	16QAM	QPSK	-	-	3/4	58.5	65.0	121.5	135
37	64QAM	QPSK	-	-	3/4	78	86.7	162	180
38	64QAM	16QAM	-	-	3/4	97.5	108.3	202.5	225
39	16QAM	QPSK	QPSK	-	1/2	52	57.8	108	120
40	16QAM	16QAM	QPSK	-	1/2	65	72.2	135	150
41	64QAM	QPSK	QPSK	-	1/2	65	72.2	135	150
42	64QAM	16QAM	QPSK	-	1/2	78	86.7	162	180
43	64QAM	16QAM	16QAM	-	1/2	91	101.1	189	210
44	64QAM	64QAM	QPSK	-	1/2	91	101.1	189	210
45	64QAM	64QAM	16QAM	-	1/2	104	115.6	216	240
46	16QAM	QPSK	QPSK	-	3/4	78	86.7	162	180
47	16QAM	16QAM	QPSK	-	3/4	97.5	108.3	202.5	225
48	64QAM	QPSK	QPSK	-	3/4	97.5	108.3	202.5	225
49	64QAM	16QAM	QPSK	-	3/4	117	130.0	243	270
50	64QAM	16QAM	16QAM	-	3/4	136.5	151.7	283.5	315
51	64QAM	16QAM	QPSK	-	3/4	136.5	151.7	283.5	315
52	64QAM	64QAM	16QAM	-	3/4	156	173.3	324	360
53	16QAM	QPSK	QPSK	QPSK	1/2	65	72.2	135	150
54	16QAM	16QAM	QPSK	QPSK	1/2	78	86.7	162	180
55	16QAM	16QAM	16QAM	QPSK	1/2	91	101.1	189	210
56	64QAM	QPSK	QPSK	QPSK	1/2	78	86.7	162	180
57	64QAM	16QAM	QPSK	QPSK	1/2	91	101.1	189	210
58	64QAM	16QAM	16QAM	QPSK	1/2	104	115.6	216	240
59	64QAM	16QAM	16QAM	16QAM	1/2	117	130.0	243	270
60	64QAM	64QAM	QPSK	QPSK	1/2	104	115.6	216	240
61	64QAM	64QAM	16QAM	QPSK	1/2	117	130.0	243	270
62	64QAM	64QAM	16QAM	16QAM	1/2	130	144.4	270	300
63	64QAM	64QAM	64QAM	QPSK	1/2	130	144.4	270	300
64	64QAM	64QAM	64QAM	16QAM	1/2	143	158.9	297	330
65	16QAM	QPSK	QPSK	QPSK	3/4	97.5	108.3	202.5	225
66	16QAM	16QAM	QPSK	QPSK	3/4	117	130.0	243	270
67	16QAM	16QAM	16QAM	QPSK	3/4	136.5	151.7	283.5	315
68	64QAM	QPSK	QPSK	QPSK	3/4	117	130.0	243	270
69	64QAM	16QAM	QPSK	QPSK	3/4	175.5	195.0	283.5	315
70	64QAM	16QAM	16QAM	QPSK	3/4	156	173.3	324	360
71	64QAM	16QAM	16QAM	16QAM	3/4	175.5	195.0	364.5	405
72	64QAM	64QAM	QPSK	QPSK	3/4	156	173.3	324	360
73	64QAM	64QAM	16QAM	QPSK	3/4	175.5	195.0	364.5	405
74	64QAM	64QAM	16QAM	16QAM	3/4	195	216.7	405	450
75	64QAM	64QAM	64QAM	QPSK	3/4	195	216.7	405	450
76	64QAM	64QAM	64QAM	16QAM	3/4	214.5	238.3	445.5	495

R: Coding Rate

## W-LAN IEEE802.11n Rx Test

This section explains the contents of the main tests related to receiver performance. The IEEE802.11n standard (IEEE Std 802.11n-2009) describes the PHY layer Rx specifications in item 20.3.22 HT PMD Receiver Specifications. The measurement conditions for each described test are the basis of the MIMO tests.

Table 3. IEEE802.11n PHY Layer Rx Test Items

Item No.	Test Name
20.3.22.1	Receiver Minimum Input Sensitivity (Rx Sensitivity)
20.3.22.2	Adjacent Channel Rejection (Adjacent Channel Filtering)
20.3.22.3	Nonadjacent Channel Rejection (Non-adjacent Channel Filtering)
20.3.22.4	Receiver Maximum Input Level (Max. Input Level)
20.3.22.5	CCA Sensitivity
20.3.22.6	Received Channel Power Indicator (RCPI) Measurement
20.3.22.7	Reduced Inter-frame Space (RIFS)

### Minimum Input Sensitivity

This test is commonly called the Rx sensitivity test; it confirms that the minimum input level when PER is less than 10% is better than the specified values in Table 4. Input level here means the average power measured at the receiver antenna port. The number of channels must match the number of transmitter and receiver antennas. The antenna ports are connected by cable and this test uses packet lengths of 4096 octets, BCC error correction, an MCS value between 0 and 31, and a GI length of 800 ns.

STBC processing is disabled for this test; STBC is a Tx Diversity technology for improving the data transmission quality. After generation of the channel signal stream, it multiplexes the contents of the data sent by each antenna using a matrix.

Table 4. Minimum Input Sensitivity

Modulation Method	R	20-MHz Bandwidth [dBm]	40-MHz Bandwidth [dBm]
BPSK	1/2	-82	-79
QPSK	1/2	-79	-76
QPSK	3/4	-77	-74
16QAM	1/2	-74	-71
16QAM	3/4	-70	-67
64QAM	2/3	-66	-63
64QAM	3/4	-65	-62
64QAM	5/6	-64	-61

### Adjacent Channel Rejection

This test measures the PER while raising the power of the interference signal in the adjacent channel relative to the wanted signal to 3 dB higher than the minimum input level. Consequently, confirm that the level difference of the interference signal relative to the wanted signal when PER is at least 10% is more than the specified values in Table 5.

At the 20-MHz bandwidth test, the interference signal is positioned in the adjacent channel 25 MHz from the 5-GHz band and 25-MHz from the 2.4-GHz band. At the 40-MHz bandwidth test, the interference signal is positioned in the adjacent channel 40 MHz from any channel. The interference signal is an OFDM signal that must not be synchronized with the wanted wave, and the test-defined levels must be the same as in Table 4, and the signal On/Off ratio must be at least 50%.

This test is performed using a packet length of 4096 octets with BCC error correction, an MCS value from 0 to 31, a GI length of 800 ns, and STBC disabled.



Table 5. Adjacent/Non-adjacent Channel Rejection

Modulation Method	R	Adjacent Channel Rejection [dB]	Non-adjacent Channel Rejection [dB]
BPSK	1/2	16	32
QPSK	1/2	13	29
QPSK	3/4	11	27
16QAM	1/2	8	24
16QAM	3/4	4	20
64QAM	2/3	0	16
64QAM	3/4	-1	15
64QAM	5/6	-2	14

#### Non-Adjacent Channel Rejection

This test measures the PER while increasing the level of the interference signal in the non-adjacent channel relative to the wanted signal to 3 dB higher than the minimum input level. Consequently, confirm that the level difference of the interference wave relative to the wanted signal when PER reaches at least 10% is more than the specified values in Table 5.

This test is only performed for the 5-GHz band. At the 20-MHz bandwidth test, the interference wave is positioned at least 40 MHz away. At the 40-MHz bandwidth test, the interference wave is positioned at least 80 MHz away. The interference signal is an OFDM signal that must not be synchronized with the wanted signal, and the test-defined levels must be the same as in Table 4, and the signal On/Off ratio must be at least 50%.

This test is performed using a packet length of 4096 octets with BCC error correction, an MCS value from 0 to 31, a GI length of 800 ns, and STBC disabled.

#### Maximum Input Level

This test input signals of the following level to each antenna of the receiver and confirms that the PER does not exceed 10%. The test uses a packet length of 4096 octets and supports any modulation method.

Table 6. Maximum Input Level

Band	Max. Input Level [dBm]
2.4 GHz	-30
5 GHz	-20

## W-LAN MIMO Rx Test using Vector Signal Generator

The objectives/targets of MIMO system evaluation are as follows:

### Example MIMO System Evaluation Targets

- Spatial Propagation Path/Fading Environment
- Transmitter or Receiver Antenna Characteristics
- Transmitter or Receiver Antenna Baseband/Modem Circuits
- Receiver Characteristics Test (Rx Sensitivity, etc.).....Contents of this application note
- System Performance (Throughput, etc.)
- System Communications Protocol (Packet Analysis)

This application note explains the receiver characteristics tests performed using a vector signal generator. In addition, it also explains fading as a test condition.

Simply confirming the target W-LAN appliance operation just confirms that the appliance is operating under normal MIMO conditions as a basic access point and it can sometimes be possible to adjust the Rx level to the target level by changing the distance between appliances. Additionally, it can be possible to perform fading tests by positioning walls and obstructions between W-LAN appliances.

However, these simple methods have several disadvantages. First, these test spaces have no usage limitations and adjustment of the distances between devices to adjust the Rx level takes time (the distance between W-LAN appliances can range from 20 or 30 meters to hundreds of meters). Moreover, although most W-LAN appliances have an Rx level monitoring function called RSSI, it cannot be described as accurate for the most part. In addition, placing obstructions when configuring a fading environment requires a lot of time and manpower. Creating a physical expression of a propagation path with some specific characteristics and reproducing that environment is also very difficult.

Consequently, it is better to output the signals to be received by the W-LAN appliance to be evaluated using a vector signal generator, which also offers the following main advantages.

### Merits of using Vector Signal Generator for MIMO Rx Test

- Accurate level adjustment over wide range
- Repeated regeneration of predefined signal pattern
- Simple customized signal pattern generation using signal generation software
- Output of signal with synchronized phase and timing between RF ports (limited to some model types)

In other words, using a vector signal generator offers a simple MIMO Rx test evaluation environment without space limitations.

However, the local signal (LO) and baseband signal (BB) must be shared to synchronize the phase and timing between two vector signal generators. Additionally, for the W-LAN appliance to receive the signal from the vector signal generator, it is necessary to support a test mode not requiring protocols to establish communications.

Establishment of a fading environment can be achieved using a channel simulator, but such simulators are generally very expensive and require high-level technical knowledge for use. Consequently, if signal patterns can be generated with predefined fading by using signal generation software for output from a vector signal generator, it would be possible to obtain the same effect as using a channel simulator but at lower cost. Moreover, signal patterns could be saved to regenerate the signals again for the next evaluation, eliminating the time-wasting need to adjust parameters again.

Anritsu's MG3710A Vector Signal Generator has two RF ports with exactly the same performance and outputting the same frequency range making it possible to output signals with synchronized phase and timing between the RF ports without needing to connect extra cables.

The Anritsu MX370111A WLAN IQproducer™ software is ideal for creating W-LAN signals. Using this software makes it easy to generate W-LAN IEEE802.11a/b/g/n/ac/j/p signal patterns simply by setting the required parameters. Additionally, the Anritsu MX370107A Fading IQproducer™ software can generate signal patterns with added fading effects from previously generated W-LAN signals. The created signal patterns are transferred to the Anritsu MG3710A Vector Signal Generator for output. Using the IQproducer™ software in combination with the all-in-one, dual-RF port MG3710A makes it easy support configuration of a cost-effective test environment for 2 x 2 MIMO W-LAN signals with fading.

Figure 4 shows an example of the test system using a real environment. The materials cost is low and the test set-up is not difficult. Moreover, there is no need to switch the receiver to the test mode. However, configuration of a quantifiable test environment with high accuracy and assuring reproducible test results is extremely difficult and the test time is also long.



Fig. 4. Test Block Diagram for Actual Environment

Figure 5 shows an example of a test system using general vector signal generators and a channel simulator. A merit of this system is that the fading environment settings can be made in real time. However, the materials cost is high and a high degree of knowledge is required to use the system.

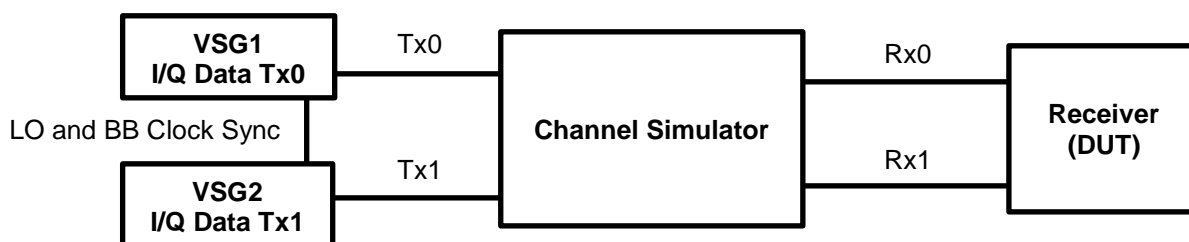


Fig. 5. Test Block Diagram for General Vector Signal Generators and Channel Simulator

Figure 6 shows an example of the test system using the Anritsu MG3710A Vector Signal Generator and IQproducer™ waveform generation software. Only a single vector signal generator with two RF ports is used as the measuring instrument. A faded signal is output directly from the MG3710A and the signal pattern is created using the IQproducer™ pattern generation software.

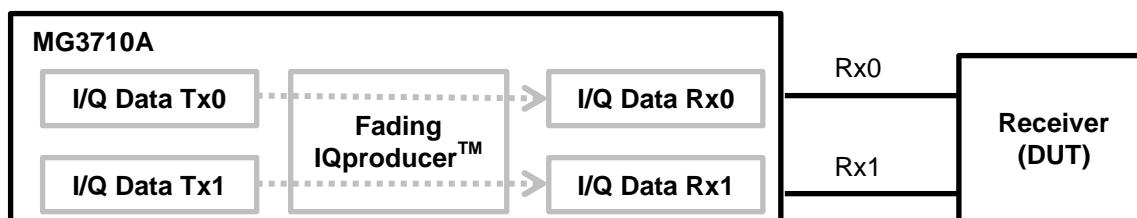


Fig. 6. Test Block Diagram using Anritsu MG3710A and IQproducer™

Table 7 summarizes the features of each 2 x 2 MIMO test system shown in Figs. 5, 6, and 7.

Table 7. Test System Comparison

Test System	Quantified Environment Structure and Reproducibility	Test System Difficulty	Materials Cost
Real Environment	Difficult	Low	Low
Using General Spectrum Analyzer and Channel Simulator	High	High	High
Using Anritsu MG3710A Vector Signal Generator and IQproducer Software	High	Low	Low

## W-LAN 2x2 MIMO Rx Sensitivity Test using Anritsu MG3710A Vector Signal Generator

The following sections introduce some examples of how to perform the W-LAN 2 x 2 MIMO Rx sensitivity test using the Anritsu MG3710A Vector Signal Generator and the IQproducer™ software.

This test creates the IEEE802.11n signals shown under the conditions in Table 8. The signal is output from the vector signal generator, received by the W-LAN appliance, and the PER is evaluated.

However, generally, to perform PER monitoring, a control application supporting the W-LAN appliance baseband modem chipset is required.

Table 8. Test Conditions

Condition	Input Level at Receiver Antenna Connector	Fading	Correlation Between Paths
1	Max. Input Level	No	—
2	Min. Input Sensitivity Level	No	—
3	Min. Input Sensitivity Level	Yes	Low
4	Min. Input Sensitivity Level	Yes	Medium
5	Min. Input Sensitivity Level	Yes	High

This test uses the W-LAN signals in Table 9 and the fading environment in Table 10.

Table 9. W-LAN Signal Parameters

Parameter	Value
Center Frequency	2412 MHz
Bandwidth	40 MHz
MCS	15 (64QAM R = 5/6 Channels = 2)
PSDU	4096 Octet
GI	800 ns
Tx Packet Count	1000

Table 10. Fading Environment

Parameter	Value
Profile	Model A (IEEE 802.11-03/940r) Typical Office/ non-line-of-sight (NLOS) conditions
Velocity	10.8 km/h
Doppler Frequency	24.137 Hz
Path	1
Type	Rayleigh

The following materials are used in this test. Unless specifically described, assume that the measuring instrument and software are in the initial condition (default settings).

- DUT W-LAN appliance
- PC for controlling W-LAN appliance and monitoring PER
- Signal analyzer or power meter (if required) for measuring W-LAN appliance power
- Anritsu MG3710A Vector Signal Generator with Opt-17, -36, and -66 (hereafter MG3710A)  
The following IQproducer™ waveform licenses must also be installed.
- Anritsu MX370111A WLAN IQproducer™ (hereafter WLAN IQproducer)
- Anritsu MX370107A Fading IQproducer™ (hereafter Fading IQproducer)
- Other necessary cables and connectors

The MG3710A firmware version must be 2.01.00 or newer with IQproducer version 14.01 or newer.

## Creating W-LAN IEEE802.11n Signal with WLAN IQproducer

This section explains the basic test and how to create the W-LAN signal pattern.

### [Procedure: Creating W-LAN Signal]

1. Start IQproducer on the MG3710A.

The IQproducer procedure is described below.

2. Select [WLAN] at the System (Non-Cellular) tab.

The WLAN IQproducer procedure is described below.

3. Press the [Normal Setup] button.
4. Set the Common → System value to [11n].
5. Set the Common → Bandwidth value to [40] MHz.
6. Set the Common → Number of Packets value to [1000].
7. Set the Common → Repeat Count value to [1].
8. Select [MPDU] at the tree on the left side of the screen to display the [MPDU] setting window at the right side.
9. Set the MPDU → MCS value to [15].

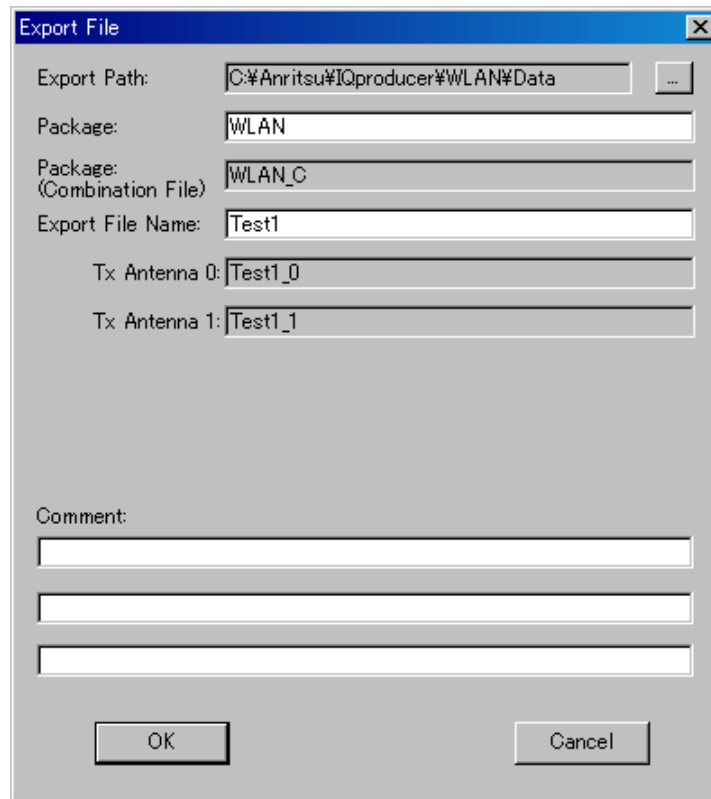
The screenshot shows the 'WLAN IQproducer for MG3710' software window. The left sidebar has a tree view with 'Common' selected. The main area is divided into two panels: 'Common' and 'MPDU'.

Common		MPDU	
System	11n	PHY	
Number of Packets	1000	PPDU Format	HT Mixed
Number of Antennas	2	MCS	15
Convolutional Encode	On	Number of Spatial Streams	2
Interleave	On	Stream 1	64QAM
Scramble	On	Stream 2	64QAM
Scramble Initial Value	5D hex	Code Rate	5/6
PBCC Encode	On	Spatial Mapping	Direct Mapping
Oversampling Ratio	2	GI	Long
Sampling Rate	80 MHz	Smoothing	Off
Bandwidth	40 MHz	Not Sounding	On
Duty Cycle	50.0000 %	Number of Transmit Chains	2
Burst On Length	164.000 us	Number of Space Time Streams	2
Burst Off Length	164.000 us	Number of Extension Spatial Streams	0
Burst Period	328.000 us	Half Bandwidth	N/A
Repeat Count	1	MAC	
A-MPDU	Off	Data Length	4096 octet(s)
Filter		MPDU Length	4096
Filter Type	None	MAC Frame Type	General
Roll Off BT	0.50	Frame Control	0800 hex
Spectrum Shaping		Duration / ID	0000 hex
Windowing Length	8 Sample	Address 1	FFFFFFFFFFFF hex
Ramp Length	8 Sample	Address 2	202222222202 hex
		Address 3	505555555505 hex
		Sequence Control	0000 hex
		Address 4	644D20030000 hex
		QoS Control	0000 hex
		HT Control	00000000 hex
		MAC FCS	On
		MAC Data Type	PN9fix
		Increment Sequence Number	Off
		Sequence Number Increment Period	1
		Increment Fragment Number	Off

Fig. 7. W-LAN IEEE802.11n Parameter Settings

The above procedure completes setting of the W-LAN parameters defined in Table 9.

10. Press the [Calculation] button to create the waveform pattern file.
11. In this example, the file name is [Test1]. This name is the name for the Tx0 and Tx1 signal set. Two files are created and the extension [\_0] and [\_1] is appended to each file name.



The image shows a Windows-style dialog box titled "Export File". It contains several input fields and buttons. The "Export Path:" field is set to "C:\Anritsu\IQproducer\WLAN\Data" with a browse button "...". The "Package:" field is set to "WLAN". The "Package: (Combination File)" field is set to "WLAN\_C". The "Export File Name:" field is set to "Test1". Below this, there are two fields for "Tx Antenna 0:" and "Tx Antenna 1:", both set to "Test1\_0" and "Test1\_1" respectively. At the bottom, there is a "Comment:" label followed by three empty text boxes. The "OK" and "Cancel" buttons are at the bottom right.

*Fig. 8. Pattern File Generation Screen*

12. Press [OK] to create the files.  
The files are output to the file paths [C:\Anritsu\MG3710A\User Data\Waveform\WLAN] and [C:\Anritsu\MG3710A\User Data\Waveform\WLAN\_C] on the MG3710A hard disk.

## Outputting Signal from Vector Signal Generator

This section explains how to select the waveform patterns for loading to SG1 and SG2, as well as how to adjust the power at the antenna terminals.

### [Procedure: Selecting Waveform Pattern to Load]

1. Press the [SG1] key at the MG3710A to start the SG1 operation. (Press the [SG2] key for SG2.)
2. Press the [Load] key.
3. Move the scrollbar to show the bottom of [Packages] at the left side of the screen and select the [WLAN] package name. Package is the name of the folder with the waveform pattern files and indicates the waveform pattern group name.
4. Select [Test1\_0] ([Test1\_1 for SG2) from [Patterns in Package: WLAN] at the right side of the screen.
5. Press the [Select] key.
6. Move the scrollbar to show the bottom of [Packages] at the left side of the screen and select the [WLAN] package name.
7. Select [Test1\_0] ([Test1\_1 for SG2) from [Patterns in Package: WLAN] at the right side of the screen.
8. Select [F6] Select and select the waveform pattern.

This procedure is the same for selecting/loading waveform patterns with other names.

Next, the W-LAN signal is output and the power at the receiver antenna terminal is adjusted to the required level. The purpose of this work is to confirm the power attenuation caused by the connection cable between the vector signal generator and receiver.

### [Procedure: Adjusting Power at Antenna Terminal]

Set-up as shown in Fig. 9.

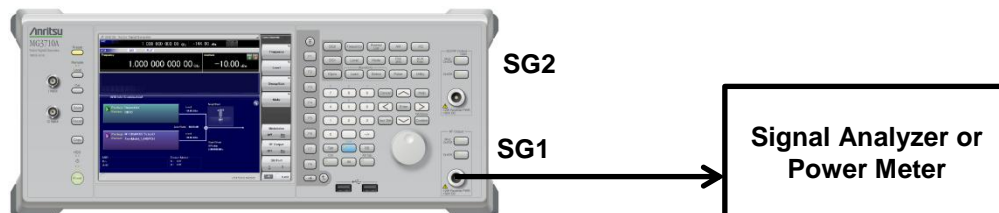


Fig. 9. Power Adjustment at Antenna Connector (SG1)

1. Press the [SG1] key at the MG3710A for SG1 operation. (Press the [SG2] key for SG2.)
2. Press the [Frequency] key and set the center frequency to 2412 MHz.
3. Press the [Level] key and set the output level to  $-30$  dBm.
4. Set both the [Mod On/Off] key and RF Output [On/Off] to [On] to output the W-LAN signal.
5. Measure the average power in the burst on segments using either the signal analyzer or the power meter and adjust the MG3710A output level so this value is  $-30$  dBm.
6. Calculate the difference offset of  $-30$  dBm from the value found at step 5 and set this attenuation value using [Level] → [F3] Offset Value. Set [F2] Offset to [On]. For example if the value at step 5 is  $-25$  dBm, set  $-5$  dB at [Offset Value].

After that, displayed Level value is the same value at the antenna connector of the terminal.

## Synchronizing Signals between Ports

When outputting signals from 2 or more RF ports, the signal synchronization and its effect must be considered. The synchronization between signals can be broadly divided into the level shown in Table 11. Level 1 is completely no synchronization and the synchronization accuracy increases as the level value becomes larger.

Table 11. Synchronization Levels between Signals

Level	Baseband Signal (waveform pattern regeneration start timing)	Local Signal	Phase Error	Timing Error
0	Asynchronous	Asynchronous	Random	Random
1	Synchronous	Asynchronous	Random	Random
2	Synchronous	Synchronous	Constant and small	Constant and small
3	Synchronous	Synchronous	Constant and minimum	Constant and small
4	Synchronous	Synchronous	Constant and minimum	Constant and minimum

Even when using a multiple-antenna W-LAN appliance, there is no need to consider the synchronization status at each antenna when measuring under the SISO condition. However, when measuring under the MIMO condition, it is necessary to consider the Level 1 condition at a minimum. With MIMO, since the same timing data is distributed between multiple antennas, when this timing data is sent by Antenna 0 and Antenna 1, demultiplexing at the receiver side may be impossible if there is a large difference in this output timing. This means that the path delay differences may exceed the system delay tolerances. However, since these phase and timing differences may change slightly even at Level 1, Level 2 and higher offers a more quantitative test. For example, very rarely, with fading at the Rx antenna side, the signal may be negated with a sum power of 0 if the phase difference between path is as much as 180°.

In the examples in this section, tests are performed under the Level 2 conditions. Generally, the phase and timing are synchronized between the vector signal generator RF ports; in other words, the delay difference between signals is constant. Moreover, if the GI length is sufficiently short, deliberate delay processing has limited impact on the signal pattern and almost no effect on the W-LAN appliance Rx performance. This is probably why most W-LAN appliances have sufficient performance margins to meet the specifications. This is not a problem when monitoring the performance of a W-LAN appliance relative to the test parameter differences.

However, when observing the fading performance with propagation in free space using antennas without cabling between the vector signal generator and W-LAN appliance, or when evaluating the ultimate performance of a W-LAN appliance by imposing delay characteristics in a fading profile, it is better if the phase and timing between the RF ports of the vector signal generator are as small as possible because the measuring instrument components play a major role in factors affecting the test results.

For the method to minimize the phase and timing differences between the RF ports of the MG3710A, refer to the application note entitled "Adjusting MIMO Phase Coherence using Vector Signal Generator" (Doc. No.: MG3710A-E-F-3).

The following section explains the procedure for outputting synchronized baseband and local signals from the two ports of the MG3710A.

### [Procedure: Synchronizing Signal between RF Ports]

1. Select and output the waveform patterns for each of the MG3710A SG1 and SG2 ports. At this stage, the synchronization is "Level 0" in Table 8.
2. At the MG3710A, press [Mode] → [→] (Function Menu page 2) → [F8] Sync Multi SG to display the Sync Multi SG function menu.
3. Select [F1] Sync Type → [F4] SG1&2.  
If the signal is output at this stage, the synchronization is "Level 1" in Table 8.
4. Return to the preceding Sync Multi SG function menu and set [F4] LO Sync to [On].  
If the signal is output at this stage, the synchronization is "Level 2" in Table 8.  
This operation fixes [Mode] → [→] (Function Menu page 2) → [F2] Start/Frame Trigger → [F1] Start/Frame Trigger to [On].



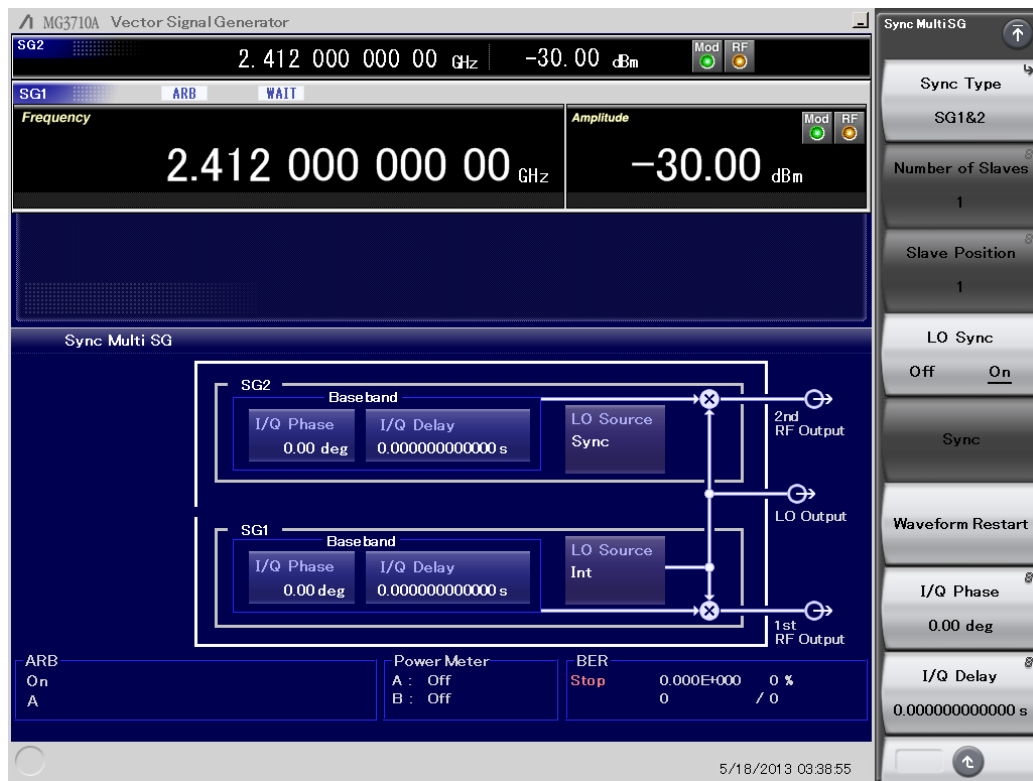


Fig. 10. Synchronizing Local Signal of SG1 and SG2

5. Set [Mode] → [→] (Function Menu page 2) → [F2] Start/Frame Trigger → [F2] Mode to set [Frame].
6. Press [Mode] → [→] (Function Menu page 2) → [F2] Start/Frame Trigger → [F3] Source to set [Trigger Key].
7. Press [Mode] → (Function Menu page 2) → [F2] Start/Frame Trigger → [F7] Frame Count to set the number of packets to be sent.
8. Return to the preceding Start/Frame Trigger Key function menu and press [F8] Trigger to start synchronization.

Figure 11 shows the waveform at the signal analyzer when the Frame Count value, or the number of sent packets, is set to [10]. Ten bursts are observed.

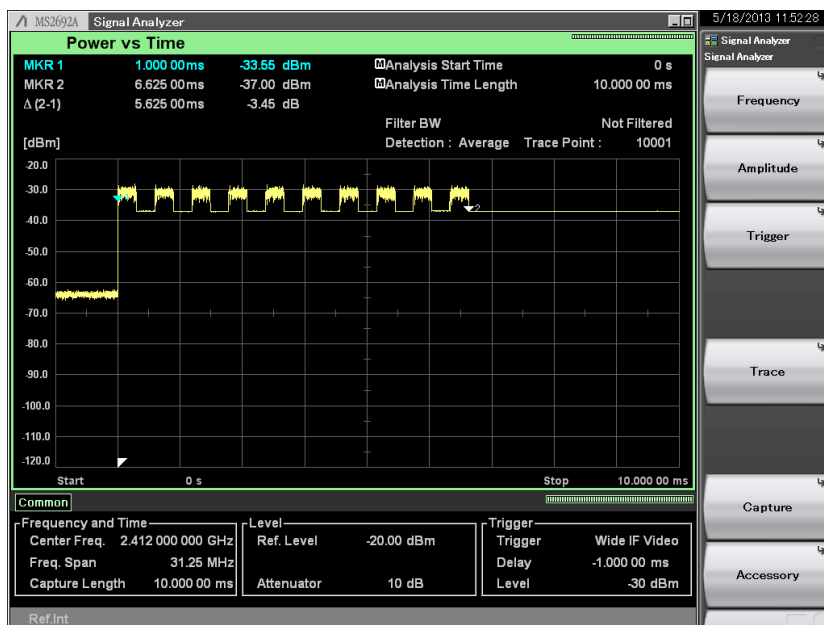


Fig. 11. Time Domain Measurement when 10 Packets Sent

## *Adding Fading Effect to W-LAN IEEE802.11n Signal*

This section explains how to add fading effects to the W-LAN signal pattern.

### **[Procedure]**

1. Start IQproducer at the MG3710A.

The IQproducer procedure is described below.

2. Select [Fading] at the General Purpose tab.

The Fading IQproducer is described below.

3. Set the Channel Configuration value at the Common tab at the left side of the screen to [2x2 MIMO].
4. Press the [Reference] button at the Tx Antenna1 tab at the right side of the screen to open the folder with the waveform pattern file created using WLAN IQproducer.
5. Select the waveform pattern file with [\_0] appended to the name and open it.
6. Set [RF Frequency] at the Tx Antenna1 tab to [2412] MHz.
7. Press the [Reference] button at the Tx Antenna2 tab at the right side of the screen to open the folder with the waveform pattern file created using WLAN IQproducer.
8. Select the waveform pattern file with [\_1] appended to the name and open it.
9. Set [RF Frequency] at the Tx Antenna2 tab to [2412] MHz.
10. Press the [Select Profile] button at the Channel 1 tab at the bottom left of the screen and select WLAN → Model A.
11. Press the [Select Profile] button at the Channel 1 tab at the top left of the screen to display the channel Path setting display.
12. Put a check mark in [Path1] only.
13. Set [Correlation Setting] at the rightmost column of the Path1 row to [Edit] to open the Correlation Matrix window.
14. Input the low correlation matrix according to Table 12. Press the [Save File] button after input to save the settings. Saved settings can be recalled subsequently by pressing the [Recall File] button.
15. Press the [OK] button to open the Correlation Matrix window.  
  
Execute [Edit] → [Copy Channel 1 to All] at the Fading IQproducer menu bar. This operation sets the same fading profile at all channels.
16. Press the [Calculation] button.
17. Input the package name and file name after the Export File dialog is displayed.
18. Select Output Gain at the Scaling group and set the value. The peak power after fading processing is adjusted to the reference output level when Output Gain is set. On the other hand, since the average power after fading processing is set as the reference level at the RMS Value setting, there is a risk that a signal exceeding the generator baseband output level may be clipped. Moreover, when Output Gain is set, for safety, set a level of -5 dB or lower because the correlation between paths is not considered.

**Export File**

Export Path: C:\Anritsu\IQproducer\Fading\Data

Package: WLAN

Full Path: C:\Anritsu\IQproducer\Fading\Data

Export File Name: Test3\_LowCorr

Rx Antenna 1: Test3\_LowCorr\_1

Rx Antenna 2: Test3\_LowCorr\_2

Scaling

☐ RMS Value ☒ Output Gain

☐ Auto Setting  [dB]

Comment:

RF Frequency=2412.00000000 MHz

AWGN: OFF = Rx1, Rx2

OK Cancel

Fig. 12. Pattern File Generation Screen (with Added Fading)

19. Press the [OK] button to create the waveform pattern.

The above procedure completes setting of a waveform pattern meeting the fading profile for condition 3. Refer to the section Outputting Signal from Vector Signal Generator for how to output the created waveform pattern from the MG3710A.

The above procedure is the same for conditions 4 and 5. Use Table 14 and Table 15 for the correlation matrix in step 15.

Table 12. Example of Low-Correlation Matrix Elements

	Channel 1	Channel 2	Channel 3	Channel 4
Channel 1	1	0	0	0
Channel 2	0	1	0	0
Channel 3	0	0	1	0
Channel 4	0	0	0	1

Table 13. Example of Medium-Correlation Matrix Elements

	Channel 1	Channel 2	Channel 3	Channel 4
Channel 1	1	0.9	0.3	0.27
Channel 2	0.9	1	0.27	0.3
Channel 3	0.3	0.27	1	0.9
Channel 4	0.27	0.3	0.9	1

Table 14. Example of High-Correlation Matrix Elements

	Channel 1	Channel 2	Channel 3	Channel 4
Channel 1	1	0.9	0.9	0.81
Channel 2	0.9	1	0.81	0.9
Channel 3	0.9	0.81	1	0.9
Channel 4	0.81	0.9	0.9	1

## Receiving at W-LAN Appliance

Set-up the system configuration as shown in Fig. 13; output the signal created for each condition from the MG3710A and monitor PER at the W-LAN appliance.

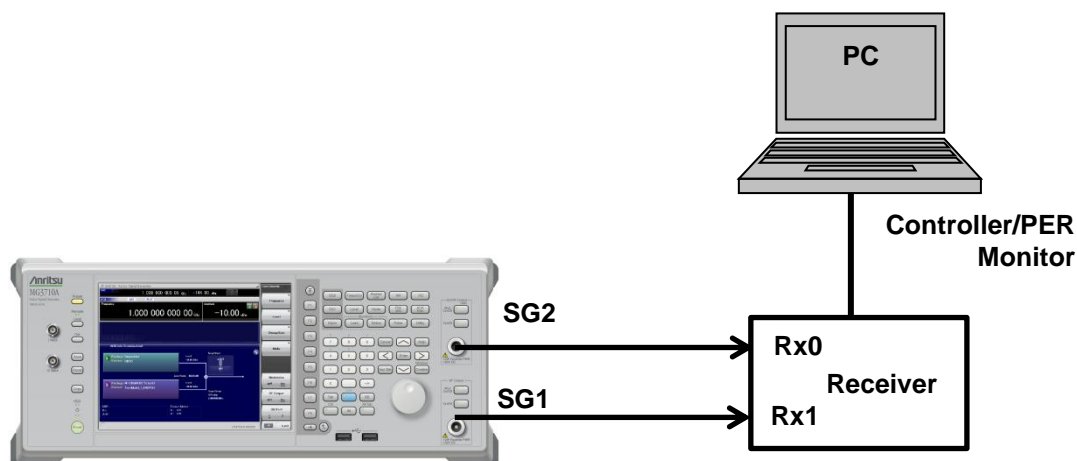


Fig. 13. Test Setup

Table 15 shows the type of captured measurement results. These results indicate that the W-LAN DUT satisfies the maximum PER 10% requirement at the maximum and minimum input levels. In addition, when fading effects are added, the results show that when the inter-channel correlation is high, the receiver cannot receive many packets because it cannot separate the signals correctly.

Table 15. Test Results

Condition	Receiver Antenna Input Level [dBm]	Fading	Inter-channel Correlation	PER
1	-30	No	—	1000/1000
2	-61	No	—	992/1000
3	-61	Yes	Low	985/1000
4	-61	Yes	Medium	543/1000
5	-61	Yes	High	308/1000

## Conclusions

This application note has introduced a quantitative method for evaluating the MIMO Rx performance of a W-LAN appliance using the Anritsu MG3710A Vector Signal Generator. Using the test examples introduced in this note, users should be able to determine the detailed characteristics of W-LAN appliances by changing and adding test conditions. We hope these tests will help effective troubleshooting of factors affecting the performance of W-LAN appliances as well as in clarifying individual differences between W-LAN appliances for the same waveforms.

## Note

## ● United States

### **Anritsu Company**

1155 East Collins Blvd., Suite 100, Richardson,  
TX 75081, U.S.A.  
Toll Free: 1-800-267-4878  
Phone: +1-972-644-1777  
Fax: +1-972-671-1877

## ● Canada

### **Anritsu Electronics Ltd.**

700 Silver Seven Road, Suite 120, Kanata,  
Ontario K2V 1C3, Canada  
Phone: +1-613-591-2003  
Fax: +1-613-591-1006

## ● Brazil

### **Anritsu Eletrônica Ltda.**

Praça Amadeu Amaral, 27 - 1 Andar  
01327-010 - Bela Vista - São Paulo - SP - Brazil  
Phone: +55-11-3283-2511  
Fax: +55-11-3288-6940

## ● Mexico

### **Anritsu Company, S.A. de C.V.**

Av. Ejército Nacional No. 579 Piso 9, Col. Granada  
11520 México, D.F., México  
Phone: +52-55-1101-2370  
Fax: +52-55-5254-3147

## ● United Kingdom

### **Anritsu EMEA Ltd.**

200 Capability Green, Luton, Bedfordshire, LU1 3LU, U.K.  
Phone: +44-1582-433200  
Fax: +44-1582-731303

## ● France

### **Anritsu S.A.**

12 avenue du Québec, Bâtiment Iris 1- Silic 612,  
91140 VILLEBON SUR YVETTE, France  
Phone: +33-1-60-92-15-50  
Fax: +33-1-64-46-10-65

## ● Germany

### **Anritsu GmbH**

Nemetschek Haus, Konrad-Zuse-Platz 1  
81829 München, Germany  
Phone: +49-89-442308-0  
Fax: +49-89-442308-55

## ● Italy

### **Anritsu S.r.l.**

Via Elio Vittorini 129, 00144 Roma, Italy  
Phone: +39-6-509-9711  
Fax: +39-6-502-2425

## ● Sweden

### **Anritsu AB**

Borgarfjordsgatan 13A, 164 40 KISTA, Sweden  
Phone: +46-8-534-707-00  
Fax: +46-8-534-707-30

## ● Finland

### **Anritsu AB**

Teknobulevardi 3-5, FI-01530 VANTAA, Finland  
Phone: +358-20-741-8100  
Fax: +358-20-741-8111

## ● Denmark

### **Anritsu A/S (Service Assurance)**

**Anritsu AB (Test & Measurement)**  
Kay Fiskers Plads 9, 2300 Copenhagen S, Denmark  
Phone: +45-7211-2200  
Fax: +45-7211-2210

## ● Russia

### **Anritsu EMEA Ltd.**

#### **Representation Office in Russia**

Tverskaya str. 16/2, bld. 1, 7th floor.  
Russia, 125009, Moscow  
Phone: +7-495-363-1694  
Fax: +7-495-935-8962

## ● United Arab Emirates

### **Anritsu EMEA Ltd.**

#### **Dubai Liaison Office**

P O Box 500413 - Dubai Internet City  
Al Thuraya Building, Tower 1, Suit 701, 7th Floor  
Dubai, United Arab Emirates  
Phone: +971-4-3670352  
Fax: +971-4-3688460

## ● India

### **Anritsu India Private Limited**

2nd & 3rd Floor, #837/1, Binnamangla 1st Stage,  
Indiranagar, 100ft Road, Bangalore - 560038, India  
Phone: +91-80-4058-1300  
Fax: +91-80-4058-1301

## ● Singapore

### **Anritsu Pte. Ltd.**

60 Alexandra Terrace, #02-08, The Comtech (Lobby A)  
Singapore 118502  
Phone: +65-6282-2400  
Fax: +65-6282-2533

## ● P.R. China (Shanghai)

### **Anritsu (China) Co., Ltd.**

Room 2701-2705, Tower A,  
New Caohejing International Business Center  
No. 391 Gui Ping Road Shanghai, 200233, P.R. China  
Phone: +86-21-6237-0898  
Fax: +86-21-6237-0899

## ● P.R. China (Hong Kong)

### **Anritsu Company Ltd.**

Unit 1006-7, 10/F., Greenfield Tower, Concordia Plaza,  
No. 1 Science Museum Road, Tsim Sha Tsui East,  
Kowloon, Hong Kong, P.R. China  
Phone: +852-2301-4980  
Fax: +852-2301-3545

## ● Japan

### **Anritsu Corporation**

8-5, Tamura-cho, Atsugi-shi, Kanagawa, 243-0016 Japan  
Phone: +81-46-296-1221  
Fax: +81-46-296-1238

## ● Korea

### **Anritsu Corporation, Ltd.**

502, 5FL H-Square N B/D, 681  
Sampyeong-dong, Bundang-gu, Seongnam-si,  
Gyeonggi-do, 463-400 Korea  
Phone: +82-31-696-7750  
Fax: +82-31-696-7751

## ● Australia

### **Anritsu Pty. Ltd.**

Unit 21/270 Ferntree Gully Road, Notting Hill,  
Victoria 3168, Australia  
Phone: +61-3-9558-8177  
Fax: +61-3-9558-8255

## ● Taiwan

### **Anritsu Company Inc.**

7F, No. 316, Sec. 1, NeiHu Rd., Taipei 114, Taiwan  
Phone: +886-2-8751-1816  
Fax: +886-2-8751-1817

Please Contact: