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Inventor(s)	Wu; Zhihui

Mobile terminal testing device and mobile terminal testing method

Abstract

A reception sensitivity test control unit **18** provided in a measurement device **1** and configured to execute a reception sensitivity test by repeatedly transmitting and receiving a test signal to a mobile terminal includes a test condition setting unit **18***a* that initially sets a test condition including an initial step level SL0 and a starting output level OL0 of the test signal at a start of the reception sensitivity test, and an AI prediction test condition change setting unit **18***b* that sets an AI prediction output level OL01, which is AI-predicted in advance by an AI prediction model based on the test condition set by the test condition setting unit **18***a*, as a first output level instead of the output level OL0.

Inventors:	**Wu; Zhihui (Kanagawa, JP)**
Applicant:	**ANRITSU CORPORATION** (Kanagawa, JP)
Family ID:	**1000008750729**
Assignee:	**ANRITSU CORPORATION (Kanagawa, JP)**
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References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
11251879	12/2021	Wu et al.	N/A	N/A
2014/0036715	12/2013	Chung	370/252	H04W 52/20
2020/0205018	12/2019	Chinbe	N/A	H04W 24/06
2021/0243621	12/2020	Kano	N/A	H04W 24/06
2022/0038197	12/2021	Endo	N/A	H04B 17/0085
2022/0236316	12/2021	Nakamura	N/A	H04B 17/21

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
2022-054744	12/2021	JP	N/A

OTHER PUBLICATIONS

7.3.2 of 3GPP (registered trademark) Technical Specification Chapter 38.521-2. cited by applicant

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Primary Examiner: Vo; Don N

Attorney, Agent or Firm: McDonald Hopkins LLC

Background/Summary

TECHNICAL FIELD
(1) The present invention relates to a mobile terminal testing device and a mobile terminal testing method for performing a reception sensitivity test of receiving a test signal by a device under test and measuring reception sensitivity a plurality of times, and testing a mobile terminal which is the device under test.
BACKGROUND ART
(2) For a wireless terminal that has been developed in recent years and transmits and receives a radio signal corresponding to IEEE802.11ad, 5G cellular, and the like, in which a signal in a wide band of a millimeter wave band is used, a performance test is performed of measuring an output level and reception sensitivity of a transmitted radio wave determined for each communication standard with respect to a wireless communication antenna included in the wireless terminal, and determining whether or not a predetermined reference is satisfied.

(3) For example, in a performance test in which a wireless terminal for a 5G New Radio (NR) system (hereinafter, a 5G wireless terminal) is used as a Device Under Test (DUT), an OTA test is performed using an anechoic box (OTA chamber) called a Compact Antenna Test Range (CATR) which is not affected by a surrounding radio wave environment.

(4) As an example of the OTA test, a DUT reception sensitivity test is provided in which an operation of receiving a test signal transmitted from a signal generator by a DUT (for example, 5G wireless terminal) to measure the reception sensitivity is performed a plurality of times, and aggregating measurement results. In the DUT reception sensitivity test, as disclosed in 7.3.2 of Chapter 38.521-2 of Non-Patent Document 1, there are regulations such as a minimum allowable output level [dB] of the test signal.

(5) As a method for realizing the reception sensitivity test in which an operation of measuring DUT reception sensitivity is executed a plurality of times while sequentially lowering the output level of the test signal up to the minimum allowable output level, for example, there are known a method for sequentially changing (linearly changing) the output level of the test signal by a constant level as the number of measurements increases from a value set in a first reception sensitivity test, a method for non-linearly changing the output level of the test signal, and the like.

(6) In addition, a method (in which a CP determination process is employed) is also known from the related art for setting a condition (CP condition) to be a check point (CP) and increasing the step level of the test signal in a case where a throughput measured during the test satisfies the CP condition, thereby shortening time until the measurement results are obtained (for example, refer to Patent Document 1).

RELATED ART DOCUMENT

Patent Document

(7) [Non-Patent Document 1] 7.3.2 of 3GPP (registered trademark) Technical Specification Chapter 38.521-2 [Patent Document 1] JP-A-2022-54744

DISCLOSURE OF THE INVENTION

Problem that the Invention is to Solve

(8) FIG. **15** shows examples of output level change patterns (EIS search path) until the end of the reception sensitivity test in the method for linearly changing the output level of the test signal and the method for non-linearly changing the output level of the test signal in the above-described mobile terminal testing device according to the related art. Here, EIS is an abbreviation for Equivalent Isotropic Sensitivity. As shown in FIG. **15**, the method for linearly changing the output level of the test signal (refer to curves L1 and L2) and the method for non-linearly changing the output level of the test signal (refer to curves NL1 and NL2) are common in a fact that the EIS search starts from a first measurement OL (output) level which is a fixed value. In both the methods, there is a large gap between the first measurement OL level and the output levels of reception sensitivity test end positions (EIS points 1 and 2).

(9) Therefore, in the mobile terminal measurement device according to the related art to which any of the above methods is applied, it is difficult to significantly shorten the EIS search time due to necessity to continue a significant number of EIS searches after setting the test signal to a first output level which is a fixed value and starting the EIS search.

(10) On the other hand, in the device according to the related art, which employs the CP determination process disclosed in Patent Document 1, a width of change in the output level is large with the CP as a boundary, so that it is possible to shorten the EIS search time rather than the method for linearly or non-linearly changing the output level. In Patent Document 1, a graph of FIG. **11** shows a relationship between the output level and the number of measurements until the end of the reception sensitivity test in the method for non-linearly changing the output level of the test signal and the method for changing the output level through the CP determination process. In FIG. **11**, a graph corresponding to a case of the non-linear change is denoted by reference numeral C3, and a graph corresponding to a case of the change through the CP determination process is

denoted by reference numeral C1. As shown in FIG. **11**, the method for changing the output level of the test signal through the CP determination process is employed, so that it is possible to reduce the number of measurements (up to four times in this example) compared to the method for non-linearly changing the output level, and, as a result, it is possible to shorten the EIS search time as many as the reduced number of measurements. However, even in the device according to the related art that employs the CP determination process, it is difficult to further reduce the number of measurements (the number of EIS searches) to a smaller number, so that there is a limit to shortening time of the EIS search time.

(11) The present invention has been made to solve the problems according to the related art, and an object of the present invention is to provide a mobile terminal testing device and a mobile terminal testing method that can set an output level of a test signal to a testable level in shorter time by reducing the number of measurements as much as possible and can efficiently perform a reception sensitivity test of a mobile terminal.

Means for Solving the Problem

(12) In order to solve the above problems, according to a first aspect of the present invention, there is provided a mobile terminal testing device (**1**), which includes a signal generator (**20**) that generates a test signal and a reception sensitivity test execution unit (**18**) that performs a reception sensitivity test of a mobile terminal (**100**) by transmitting and receiving the test signal a plurality of times between the signal generator and the mobile terminal, and tests the mobile terminal that is a device under test, the mobile terminal testing device (**1**) including setting means (**18***a*) for initially setting a test condition including a step level SL0 and an output level OL0 of the test signal at start of the reception sensitivity test, pass or fail determination means (**18***f*) for performing a throughput measurement by transmitting and receiving the test signal under the test condition and comparing a throughput measurement result with a determination threshold value to perform pass or fail determination, output level setting means (**18***e*) for setting the output level according to a result of the pass or fail determination of a previous throughput measurement in a case where the result of the pass or fail determination is fail, and AI prediction test condition change setting means (**18***b*) for holding an AI prediction model generated by performing machine learning on a relationship between parameter data and measurement result data from a measurement log file of the past reception sensitivity test using artificial intelligence, and setting an AI prediction output level OL01, which is AI-predicted in advance by the AI prediction model based on the test condition set by the setting means, as a first output level instead of the output level OL0.

(13) With this configuration, in the mobile terminal testing device according to the first aspect of the present invention, it is possible to quickly set the first output level of the test signal to a value close to the end of the measurement with existing non-linear control or the like by AI prediction, and, it is possible to set the output level of the test signal to a testable level in an extremely short time by significantly reducing the number of measurements compared to methods according to the related art, such as non-linear control and CP control, and thus it is possible to efficiently perform the reception sensitivity test of the mobile terminal.

(14) Further, in the mobile terminal testing device according to a second aspect of the present invention, the AI prediction test condition change setting means may set, instead of the step level SL0, an AI prediction step level SL01, which is AI-predicted in advance by the AI prediction model based on a measurement result of a first throughput measurement performed by transmitting and receiving the test signal at the AI prediction output level, as a step level for second and subsequent measurements.

(15) With this configuration, the mobile terminal testing device according to the second aspect of the present invention dynamically controls not only the first output level of the test signal but also the step level by AI prediction. Therefore, compared to a case of continuing the measurement by the method according to the related art, such as the non-linear control and the CP control, it is possible to set the test signal to a testable level in a shorter time and it is possible to further

improve the efficiency of the reception sensitivity test of the mobile terminal.

(16) Further, in the mobile terminal testing device according to a third aspect of the present invention, the AI prediction test condition change setting means, in a case where a result of the pass or fail determination for the measurement result of the first throughput measurement is fail, thereafter, may perform an update process of the output level for a next measurement using the AI prediction step level SL01 until a second throughput measurement.

(17) With this configuration, in the mobile terminal testing device according to the third aspect of the present invention, it is possible to avoid a situation in which the dynamic control described above is repeated uselessly even though the dynamic control of the first output level and the step level of the test signal by the AI prediction is limited to the second throughput measurement and the measurement starts from the value close to the end of the measurement in the non-linear control or the like.

(18) Further, in the mobile terminal testing device according to a fourth aspect of the present invention, the AI prediction test condition change setting means may designate loss of an external connection cable, an azimuth angle (θ, φ) of the mobile terminal, and a frequency to be measured as the parameter data, and may hold the AI prediction model generated by performing the machine learning on the relationship between the parameter data and the measurement result data.

(19) With this configuration, in the mobile terminal testing device according to the fourth aspect of the present invention, even in the environment in which each parameter data of the loss of the external connection cable, the azimuth angle (θ, φ) of the mobile terminal, and the frequency to be measured affects the measurement accuracy, it is possible to derive accurate AI prediction result to which each parameter data is added using the AI prediction model, and it is possible to set the test signal to a testable level in an extremely short time and reliably without dropping the measurement accuracy.

(20) Further, in the mobile terminal testing device according to a fifth aspect of the present invention, the reception sensitivity test execution unit, in a case where a result of the pass or fail determination for measurement result of a second throughput measurement is fail, may control the output level setting means to perform a level down process A, a level down process B, a level up process A, or a level up process B.

(21) With this configuration, in the mobile terminal testing device according to the fifth aspect of the present invention, in a case where the output level of the test signal does not reach the testable level through the dynamic control of the first output level and the step level of the test signal based on AI prediction, it is possible to immediately switch to a normal measurement routine and reliably set the output level of the test signal to the testable level.

(22) Further, the mobile terminal testing device according to a sixth aspect of the present invention may further include an anechoic box (**50**) including an internal space (**51**); and scanning means (**16**, **56**) for driving and scanning the mobile terminal to continuously vary an orientation of the mobile terminal in the internal space, in which the reception sensitivity test is performed in all orientations to be scanned by the scanning means in an over the air (OTA) measurement environment in the internal space.

(23) With this configuration, in the mobile terminal testing device according to the sixth aspect of the present invention, even in a situation in which the reception sensitivity measurement should be performed in all orientations under the OTA environment, the dynamic control of the first output level and the step level of the test signal by the AI prediction is applied, so that it is possible to set the output level of the test signal to the testable level in a short time.

(24) In order to solve the above problem, according to a seventh aspect of the present invention, there is provided a mobile terminal testing method for performing a reception sensitivity test of a mobile terminal by using a mobile terminal testing device (**1**), which includes a signal generator (**20**) that generates a test signal and a reception sensitivity test execution unit (**18**) that performs the reception sensitivity test of the mobile terminal by transmitting and receiving the test signal a

plurality of times between the signal generator and the mobile terminal (**100**), and tests the mobile terminal that is a device under test, and by transmitting and receiving the test signal between the signal generator and the mobile terminal a plurality of times, the method including a setting step (S**1**) of initially setting a test condition including a step level SL0 and an output level OL of the test signal at start of the reception sensitivity test, an AI prediction test condition change setting step (S**1***a*) of holding an AI prediction model generated by performing machine learning on a relationship between parameter data and measurement result data from a measurement log file of the past reception sensitivity test using artificial intelligence, and setting an AI prediction output level SL01, which is AI-predicted in advance by the AI prediction model based on the test condition set by the setting step, as a first output level instead of the output level OL0, a pass or fail determination step (S**4**, S**5**) of performing a first throughput measurement by transmitting and receiving the test signal at the AI prediction output level and comparing a first throughput measurement result with a determination threshold value to perform pass or fail determination, and a step level change setting step of setting, instead of the step level SL0, an AI prediction step level SL01, which is AI-predicted in advance by the AI prediction model based on a measurement result of the first throughput measurement, as a step level for second and subsequent measurements.

(25) With this configuration, in the mobile terminal testing method according to the seventh aspect of the present invention, the mobile terminal testing method is applied by using the mobile terminal testing device having the signal generator that generates the test signal and the reception sensitivity test execution unit that performs the reception sensitivity test of the mobile terminal by transmitting and receiving the test signal a plurality of times between the signal generator and the mobile terminal, and testing the mobile terminal that is a device under test. Therefore, it is possible to quickly set the first output level of the test signal to a value close to the end of the measurement with existing non-linear control or the like by AI prediction, and, it is possible to set the output level of the test signal to a testable level in an extremely short time by significantly reducing the number of measurements compared to methods according to the related art, such as non-linear control and CP control, and thus it is possible to efficiently perform the reception sensitivity test of the mobile terminal.

Advantage of the Invention

(26) The present invention can provide a mobile terminal testing device and a mobile terminal testing method that can set an output level of a test signal to a testable level in a shorter time by reducing the number of measurements as much as possible and can efficiently perform a reception sensitivity test of a mobile terminal.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a diagram showing a schematic configuration of an entire measurement device according to an embodiment of the present invention.

(2) FIG. **2** is a block diagram showing a functional configuration of the measurement device according to the embodiment of the present invention.

(3) FIG. **3** is a block diagram showing functional configurations of an integrated control device of the measurement device and a controlled element thereof according to the embodiment of the present invention.

(4) FIG. **4** is a block diagram showing a functional configuration of an NR system simulator in the measurement device according to the embodiment of the present invention.

(5) FIGS. **5**A and **5**B are diagrams showing total spherical scanning images of a device under test in an OTA chamber of the measurement device according to the embodiment of the present invention, in which FIG. **5**A shows a disposition mode of the device under test with respect to a

center of a spherical coordinate system, and FIG. **5B** shows a distribution mode of angular sample points PS in the spherical coordinate system.

(6) FIG. **6** is a diagram explaining a disposition mode of a test antenna **5** in the OTA chamber of the measurement device according to the embodiment of the present invention using the spherical coordinate system (r, θ, φ) shown in FIGS. **5A** and **5B**.

(7) FIG. **7** is a conceptual diagram showing a generation processing procedure of an AI prediction model used in the measurement device according to the embodiment of the present invention.

(8) FIG. **8** is a schematic diagram for explaining the difference in measurement start positions between a DUT reception sensitivity test to which AI prediction is applied in the measurement device according to the embodiment of the present invention and a DUT reception sensitivity test in the existing device.

(9) FIG. **9** is a flowchart showing a variable setting control operation of an output level of a test signal to which the AI prediction is applied in the reception sensitivity test of the DUT in the measurement device according to the embodiment of the present invention.

(10) FIGS. **10**A and **10**B are flowcharts showing details of a process in step S**8** of FIG. **9**, in which FIG. **10**A shows a level down process (A) and FIG. **10**B shows a level down process (B).

(11) FIG. **11** is a table showing the relationship between the number of measurements related to the reception sensitivity test of the DUT to which the AI prediction is applied in the measurement device according to the embodiment of the present invention and the reception sensitivity test of the DUT in the existing device, and the output level of the test signal and pass or fail determination result of the throughput measurement result.

(12) FIG. **12** is a graph showing the relationship between the number of measurements related to the reception sensitivity test of the DUT to which the AI prediction is applied in the measurement device according to the embodiment of the present invention and the reception sensitivity test of the DUT in the existing device, and the output level of the test signal and the pass or fail determination result of the throughput measurement result, the relationship being shown in the table of FIG. **11**.

(13) FIG. **13** is a graph for explaining the difference in EIS search paths between the DUT reception sensitivity test to which the AI prediction is applied in the measurement device according to the embodiment of the present invention and the DUT reception sensitivity test in the existing device.

(14) FIG. **14** is a graph showing the relationship between the measurement time of an EIS-CDF measurement to which the AI prediction is applied and the number of measurements for machine learning in the measurement device according to the embodiment of the present invention.

(15) FIG. **15** is a graph showing side by side various EIS search paths based on the linear and non-linear control of the test signal related to the DUT reception sensitivity test in the existing device.

BEST MODE FOR CARRYING OUT THE INVENTION

(16) Hereinafter, embodiments of a mobile terminal testing device and a mobile terminal testing method according to the present invention will be described with reference to the accompanying drawings.

(17) First, a configuration of a measurement device **1** according to the embodiment of the present invention will be described with reference to FIGS. **1** to **4**. The measurement device **1** constitutes the mobile terminal testing device of the present invention. The measurement device **1** according to the present embodiment has an external structure as shown in FIG. **1** as a whole, and includes functional blocks as shown in FIG. **2**. FIGS. **1** and **2** show a disposition mode of each component of an OTA chamber **50** in a state of being seen through from a side surface thereof.

(18) The measurement device **1** is operated, for example, in a mode in which each of the above-described components is mounted on each rack **90***a* of a rack structure **90** having the structure shown in FIG. **1**. FIG. **1** shows an example in which each of an integrated control device **10**, an NR system simulator **20**, and an OTA chamber **50** is mounted on each rack **90***a* of the rack structure **90**.

(19) As shown in FIG. **2**, the measurement device **1** according to the present embodiment includes the integrated control device **10**, the NR system simulator **20**, a signal processing unit **25**, and the OTA chamber **50**.

(20) For the configuration, here, the OTA chamber **50** will be described first for convenience. As shown in FIGS. **1** and **2**, the OTA chamber **50** includes, for example, a metal housing main body **52** having a rectangular internal space **51**, and accommodates a DUT **100** having an antenna **110**, a test antenna **5**, a reflector **7**, and a DUT scanning mechanism **56** in the internal space **51**.

(21) A radio wave absorber **55** is attached to a whole area of an inner surface of the OTA chamber **50**, that is, a bottom surface **52***a*, a side surface **52***b*, and a top surface **52***c* of the housing main body **52**. As a result, in the OTA chamber **50**, each element (the DUT **100**, the test antenna **5**, the reflector **7**, and the DUT scanning mechanism **56**) disposed in the internal space **51** has an enhanced function of regulating intrusion of radio waves from the outside and radiation of the radio waves to the outside. In this way, the OTA chamber **50** realizes an anechoic box having the internal space **51** that is not affected by a surrounding radio wave environment. The anechoic box used in the present embodiment is, for example, an Anechoic type.

(22) Among those accommodated in the internal space **51** of the OTA chamber **50**, the DUT **100** is, for example, a wireless terminal such as a smartphone. Communication standards for the DUT **100** include cellular (LTE, LTE-A, W-CDMA (registered trademark), GSM (registered trademark), CDMA 2000, 1×EV-DO, TD-SCDMA, or the like), wireless LAN (IEEE 802.11b/g/a/n/ac/ad, or the like), Bluetooth (registered trademark), GNSS (GPS, Galileo, GLONASS, BeiDou, or the like), FM, and digital broadcasting (DVB-H, ISDB-T, or the like). Further, the DUT **100** may be a wireless terminal that transmits and receives a radio signal in a millimeter wave band corresponding to IEEE 802.11ad, 5G cellular, or the like.

(23) In the present embodiment, the antenna **110** of the DUT **100** uses a radio signal in each regulated frequency band in conformity with, for example, 5G NR communication standard. The DUT **100** constitutes the device under test, that is, a mobile terminal in the present invention.

(24) In the internal space **51** of the OTA chamber **50**, the DUT **100** is held by a part of mechanism of the DUT scanning mechanism **56**. The DUT scanning mechanism **56** is provided to extend in a vertical direction on the bottom surface **52***a* of the housing main body **52** in the internal space **51** of the OTA chamber **50**. The DUT scanning mechanism **56** performs a total spherical scanning (refer to FIGS. **5**A and **5**B and FIG. **6**), which will be described later, on the DUT **100** while holding the DUT **100** on which a performance test is performed.

(25) As shown in FIG. **1**, the DUT scanning mechanism **56** includes a turntable **56***a*, a support column member **56***b*, a DUT mounting portion **56***c*, and a drive unit **56***e*. The turntable **56***a* includes a plate member having a disk shape, and has a configuration (refer to FIG. **3**) that rotates around an azimuth axis (a rotation axis in the vertical direction). The support column member **56***b* includes a columnar member disposed to extend in a direction perpendicular to a plate surface of the turntable **56***a*.

(26) The DUT mounting portion **56***c* is disposed near an upper end of the support column member **56***b* to be in parallel with the turntable **56***a*, and has a mounting tray **56***d* on which the DUT **100** is mounted. The DUT mounting portion **56***c* has a configuration (refer to FIG. **3**) capable of rotating around the roll axis (a rotation axis in a horizontal direction).

(27) As shown in FIG. **3**, the drive unit **56***e* includes, for example, a drive motor **56***f* that rotationally drives the azimuth axis, and a drive motor **56***g* that rotationally drives the roll axis. The drive unit **56***e* includes a biaxial positioner provided with a mechanism for rotating the azimuth axis and the roll axis in respective rotation direction thereof by the drive motor **56***f* and the drive motor **56***g*. In this way, the drive unit **56***e* can rotate the DUT **100** mounted on the mounting tray **56***d* in biaxial (the azimuth axis and the roll axis) directions for each mounting tray **56***d*. Hereinafter, there is a case where the entire DUT scanning mechanism **56** including the drive unit **56***e* is referred to as the biaxial positioner (refer to FIG. **3**). Each of the drive unit **56***e* and the drive

motors **56***f* and **56***g* constitutes drive means, first rotary drive means, and second rotary drive means in the present invention. The mounting tray **56***d* constitutes the device under test mounting portion in the present invention.

(28) The DUT scanning mechanism **56** performs total spherical scanning which sequentially changes a posture of the DUT **100** to a state where the antenna **110** faces all orientations of a surface of the sphere while assuming that the DUT **100** mounted (held) on the mounting tray **56***d* is disposed, for example, at a center O1 of the sphere (refer to a sphere B in FIGS. **5**A and **5**B). Control of the DUT scanning in the DUT scanning mechanism **56** is performed by a DUT scanning control unit **16** which will be described later. The DUT scanning mechanism **56** and the DUT scanning control unit **16** constitute scanning means in the present invention.

(29) The test antenna **5** is attached to a required position on the bottom surface **52***a* of the housing main body **52** of the OTA chamber **50** by using an appropriate holder (not shown). An attachment position of the test antenna **5** is a position at which visibility can be secured from the reflector **7** via an opening **67***a* provided on the bottom surface **52***a*. The test antenna **5** uses a radio signal in the frequency band of the same regulation (NR standard) as the antenna **110** of the DUT **100**.

(30) In a case where measurement related to the NR of the DUT **100** is performed in the OTA chamber **50**, the test antenna **5** transmits a test signal from the NR system simulator **20** to the DUT **100** and receives a signal under measurement transmitted from the DUT **100** that has received the test signal. The test antenna **5** is disposed so that a light reception surface thereof becomes a focal position F of the reflector **7**. The reflector **7** is not always required in a case where the test antenna **5** can be disposed so that the light reception surface thereof faces the DUT **100** and appropriate light reception can be performed.

(31) The reflector **7** is attached to a required position on the side surface **52***b* of the OTA chamber **50** by using a reflector holder **58**. The reflector **7** realizes a radio wave path that returns the radio signal (the test signal and the signal under measurement) transmitted and received by the antenna **110** of the DUT **100** to the light reception surface of the test antenna **5**.

(32) Subsequently, configurations of the integrated control device **10** and the NR system simulator **20** will be described.

(33) As shown in FIG. **2**, the integrated control device **10** is communicably connected to the NR system simulator **20** via a network **19** such as Ethernet (registered trademark). Further, the integrated control device **10** is also connected to a controlled system element in the OTA chamber **50**, for example, the DUT scanning control unit **16** via the network **19**.

(34) The integrated control device **10** comprehensively controls the NR system simulator **20** and the DUT scanning control unit **16** via the network **19**, and includes, for example, a Personal Computer (PC). The DUT scanning control unit **16** may be independently provided accompanying with the OTA chamber **50** (refer to FIG. **2**), or may be provided in the integrated control device **10** as shown in FIG. **3**. Hereinafter, description will be performed while assuming that the integrated control device **10** has the configuration shown in FIG. **3**.

(35) As shown in FIG. **3**, the integrated control device **10** includes a control unit **11**, an operation unit **12**, and a display unit **13**. The control unit **11** includes, for example, a computer device. The computer device includes a Central Processing Unit (CPU) **11***a* that performs predetermined information processing to realize the function of the measurement device **1**, and performs comprehensive control on the NR system simulator **20**, and the signal processing unit **25** as targets, a Read Only Memory (ROM) **11***b* that stores an Operating System (OS) for starting up the CPU **11***a*, the other programs, and control parameters, and the like, a Random Access Memory (RAM) **11***c* that stores execution code, data, and the like of the OS or an application which is used for an operation by the CPU **11***a*, an external I/F unit **11***d*, an input and output port (not shown), and the like.

(36) The external I/F unit **11***d* is communicably connected to each of the NR system simulator **20**, the signal processing unit **25**, and the drive unit **56***e* of the DUT scanning mechanism (biaxial

positioner) **56** via the network **19**. An operation unit **12** and a display unit **13** are connected to the input and output port. The operation unit **12** is a functional unit for inputting various information such as commands, and the display unit **13** is a functional unit for displaying various information such as an input screen, measurement results, and the like of the various information.

(37) The computer device described above functions as the control unit **11** in such a way that the CPU **11***a* executes a program stored in the ROM **11***b* while using the RAM **11***c* as a work area. As shown in FIG. **3**, the control unit **11** includes a call connection control unit **14**, a signal transmission and reception control unit **15**, a DUT scanning control unit **16**, a signal analysis control unit **17**, and a reception sensitivity test control unit **18**. The call connection control unit **14**, the signal transmission and reception control unit **15**, the DUT scanning control unit **16**, the signal analysis control unit **17**, and the reception sensitivity test control unit **18** are also realized by executing a predetermined program stored in the ROM **11***b* in the work area of the RAM **11***c* by the CPU **11***a*.

(38) The call connection control unit **14** drives the test antenna **5** via the NR system simulator **20** and the signal processing unit **25** to transmit and receive a control signal (radio signal) to and from the DUT **100**, thereby performing control to establish a call (a state where the radio signal can be transmitted and received) between the NR system simulator **20** and the DUT **100**.

(39) The signal transmission and reception control unit **15** performs a control of monitoring a user operation in the operation unit **12**, transmitting a signal transmission command to the NR system simulator **20** after the call is established through call connection control, by being triggered with a predetermined measurement start operation related to the measurement of transmission and reception characteristics of the DUT **100** by the user, and transmitting the test signal from the NR system simulator **20** via the test antenna **5**, and a control of transmitting a signal reception command and receiving the signal under measurement via the test antenna **5**.

(40) The DUT scanning control unit **16** drives and controls the drive motors **56***f* and **56***g* of the DUT scanning mechanism **56** to perform total spherical scanning of the DUT **100** mounted on the mounting tray **56***d* of the DUT mounting portion **56***c*. In order to realize the control, for example, a DUT scanning control table **16***a* is prepared in the ROM **11***b* in advance. The DUT scanning control table **16***a* stores, for example, coordinates of each angular sample point PS (refer to FIG. **5**B) in the spherical coordinate system (refer to FIG. **5**A) related to the total spherical scanning of the DUT **100**, drive data of the drive motors **56***f* and **56***g* associated with the coordinates of each angular sample point PS, and control data associated with a stop time (measurement time) at each angular sample point PS. In a case where the drive motors **56***f* and **56***g* are, for example, stepping motors, for example, the number of drive pulses is stored as the drive data.

(41) The DUT scanning control unit **16** expands the DUT scanning control table **16***a* into the work area of the RAM **11***c*, and drives and controls the drive motors **56***f* and **56***g* of the DUT scanning mechanism **56** based on the control data stored in the DUT scanning control table **16***a*. As a result, the total spherical scanning of the DUT **100** mounted on the DUT mounting portion **56***c* is performed. In the total spherical scanning, the antenna surface of the antenna **110** of the DUT **100** is stopped for a regulated time (the stop time) toward the angular sample point PS for each angular sample point PS in the spherical coordinate system, and, thereafter, an operation of moving to a next angular sample point PS (scanning of the DUT **100**) is sequentially performed while targeting all the angular sample points PS.

(42) The signal analysis control unit **17** captures a radio signal, which is related to the NR or the LTE received by the test antenna **5** in a case where the total spherical scanning of the DUT **100** is performed, via the NR system simulator **20** and the signal processing unit **25**, and performs an analysis process (measurement process) on the radio signal as a signal of a designated measurement item.

(43) The reception sensitivity test control unit **18** executes a reception sensitivity test of receiving the test signal, which is transmitted from the signal generation unit **21***a* of the NR system simulator

20, by the DUT **100** and measuring reception sensitivity a plurality of times, and performs control to aggregate measurement results of the reception sensitivity test, which is executed the plurality of times, as test results. The reception sensitivity test control unit **18** constitutes a reception sensitivity test execution unit and pass or fail determination means of the present invention.

(44) As shown in FIG. **3**, the reception sensitivity test control unit **18** includes a test condition setting unit **18***a*, an AI prediction test condition change setting unit **18***b*, a throughput measurement unit **18***c*, a drop state determination unit **18***d*, an output level variable setting unit **18***e*, and a measurement result output unit **18***f*. The test condition setting unit **18***a*, the AI prediction test condition change setting unit **18***b*, and the output level variable setting unit **18***e* respectively constitute setting means, test condition change setting means, and output level setting means of the present invention.

(45) The test condition setting unit **18***a* is a functional unit for setting a test condition of the reception sensitivity test. The test condition (setting parameter) set by the test condition setting unit **18***a* includes an initial step level SL0, a starting output level OL0, an error tolerance level (error tolerance of boundary level) EL, a connection drop determination threshold value (connection drop threshold) DT, and the like. The initial step level SL0 indicates an initial value of a step fluctuation range of an output level of the test signal which is changed stepwise in a case of the reception sensitivity test. The starting output level OL0 indicates an output level of the DUT **100** (an output level in a case of first transmission and reception) in a case of starting the reception sensitivity test. The error tolerance level EL indicates the fluctuation range (predetermined value) between previous and current output levels of a test signal for determining whether or not to continue the reception sensitivity test on a next output level. The connection drop determination threshold value DT is a set value of a bottom value which causes drop of call connection (call drop) in case where a value is lower than the connection drop determination threshold value. In an algorithm shown in FIG. **9**, the output level is lowered by a large step. Therefore, in a case where the process proceeds any further, call drop occurs, so that a threshold value which does not lower the output level is necessary. The value can be preset by the user.

(46) The AI prediction test condition change setting unit **18***b* is a functional unit that uses an AI prediction model Dai (see FIG. **7**) acquired by performing Machine Learning (ML) on relationship between parameter data and measurement result data from the measurement log files of the reception sensitivity test of the DUT **100** performed in the past in the measurement device **1** by the Artificial Intelligence (AI), and performs change setting on, instead of the initially set value, a specific setting parameter value which is AI-predicted in advance by the AI prediction model Dai based on the test condition (setting parameter) set (initially set) by the test condition setting unit **18***a* at the start of the test. The specific setting parameter subjected to change setting based on the AI prediction using the AI prediction model Dai by the AI prediction test condition change setting unit **18***b* includes, for example, an output level (starting output level OL0) and an initial step level SL0 of the initially set test signal. In the following (see FIG. **9**), an example is provided in which change setting is performed based on the output levels OL0 and OL1 and the initial step level SL0 of the test signal until the second measurement based on AI prediction.

(47) The change setting process of the initially set starting output level OL0 by the AI prediction test condition change setting unit **18***b* is performed, for example, in step S**1***a* of the flowchart shown in FIG. **9**, in the flow of searching for the AI prediction output level OL01 which is AI-predicted in advance by the AI prediction model Dai (AI prediction model A1), based on the test condition (setting parameter) initially set in previous step S**1**, and setting, instead of the starting output level OL0 initially set in step S**1**, the AI prediction output level OL01 as the first output level. In addition, the change setting process of the initial step level SL0 is performed in step S**26** of the flowchart shown in FIG. **9** in the flow of setting, instead of the initial step level SL0 initially set in step S**1**, the AI prediction step level SL01 which is AI-predicted in advance by the AI prediction model Dai (AI prediction model A2) based on the processing results in previous steps

S**4**, S**5**, and S**25** (measurement results of the first throughput measurement when transmitting and receiving the test signal on which change setting is performed to the first output level in step S**1***a*). A generation processing procedure of the AI prediction model Dai (A1, A2) will be described later in detail with reference to FIG. **7**.

(48) The throughput measurement unit **18***c* is a functional unit that measures a throughput related to reception capacity of the DUT **100** for each reception sensitivity test. For example, the throughput measurement unit **18***c* may be configured to transmit a transmission rate of the test signal to the DUT **100** in accordance with the transmission of the test signal, and, thereafter, to measure the throughput from the received transmission rate in accordance that the DUT **100** notifies the NR system simulator **20** of a reception result (received transmission rate) of the test signal.

(49) The drop state determination unit **18***d* has a function of determining whether or not the throughput measurement result is in a dropped state to a preset proportion in the steep drop region related to the characteristic in which the throughput measurement result by the throughput measurement unit **18***c* drops steeply. In order to realize the function, for example, the test condition setting unit **18***a* presets a determination condition for determining whether or not the throughput measurement result drops to a certain proportion in the steep drop region. The drop state determination unit **18***d* determines whether or not the throughput measurement result is in the dropped state according to whether or not the measured throughput is in the steep drop region indicated by the determination condition. As the determination condition for determining whether or not the throughput measurement result is in the dropped state, for example, an example is provided in which a range which exceeds 95% and is equal to or less than 99% is set in a case where a value of the throughput, which is measured by the throughput measurement unit **18***c* through first test signal transmission and reception, is set to 100%. As a result, in a case where the measured throughput is in the set range, it is possible to determine the dropped state, and, in a case of a proportion higher than the range, it is possible to determine that the dropped state is not made (refer to steps S**7** and S**9***a* of FIG. **9**). Here, the determination condition is not limited to a case where the value of the throughput, which is measured with the first test signal transmitting and reception, is set to 100% (reference value) as described above and the range of the proportion, which exceeds 95% and is equal to or less than 99% with respect to the reference value, is set. Another range of a proportion with respect to the reference value may be set.

(50) The output level variable setting unit **18***e* is a functional unit that performs variable setting, according to a comparison result between a throughput measurement result by the throughput measurement unit **18***c* and a predetermined threshold value (throughput threshold value) set in advance, so that an output level of a test signal in a next reception sensitivity test is in an ascending (level up) or descending (level down) direction, that is, the output levels of the test signals between the reception sensitivity tests corresponding to before and after number of times become different.

(51) The measurement result output unit **18***f* is a functional unit that proceeds to the next reception sensitivity test (throughput measurement) in a case where a test result fluctuation range between a test result (throughput measurement result) of a current reception sensitivity test using the test signal, which has an output level after the variable setting, and a test result of a previous reception sensitivity test exceeds a range of a fluctuation range (EL) set by the test condition setting unit **18***a*, and outputs the test result in a case where the test result fluctuation range is in the fluctuation range (EL). The measurement result output unit **18***f* constitutes pass or fail determination means of the present invention, together with the reception sensitivity test control unit **18**.

(52) As shown in FIG. **4**, the NR system simulator **20** includes a signal generation unit **21***a*, a transmission and reception unit **21***f*, a signal measurement unit **21***b*, a control unit **21***c*, an operation unit **21***d*, and a display unit **21***e*. The NR system simulator **20** constitutes a signal generator of the present invention.

(53) The signal generation unit **21***a* generates a signal (baseband signal) that becomes a source of

the test signal. The transmission and reception unit **21***f* functions as an RF unit that generates the test signal corresponding to a frequency of each communication standard from the signal generated by the signal generation unit **21***a* and sends the generated test signal to the signal processing unit **25**, and restores the baseband signal from the signal under measurement which is sent from the signal processing unit **25**. The signal measurement unit **21***b* performs measurement process of the signal under measurement based on the baseband signal restored by the transmission and reception unit **21***f*.

(54) The control unit **21***c* comprehensively controls each of the functional units including the signal generation unit **21***a*, the signal measurement unit **21***b*, the transmission and reception unit **21***f*, the operation unit **21***d*, and the display unit **21***e*. The operation unit **21***d* is a functional unit for inputting various information such as commands, and the display unit **21***e* is a functional unit for displaying various information such as an input screen of the various information and measurement results.

(55) In the measurement device **1** having the configuration described above, the DUT **100** is mounted on the mounting tray **56***d* of the DUT scanning mechanism **56** (biaxial positioner) in the internal space **51** of the OTA chamber **50**, and it is possible to measure measurement items such as Equivalent Isotropic Radiated Power (EIRP)-Cumulative Distribution Function (CDF), Equivalent Isotropic Sensitivity (EIS)-CDF, Total Radiated Power (TRP) which are related to the radio signal of the DUT **100** while rotating the DUT **100** together with the mounting tray **56***d* in biaxial (azimuth axis and roll axis) directions (while changing the angle of the positioner).

(56) Here, control (total spherical scanning) of an angle of the DUT **100** by changing the angle of the biaxial positioner, which is required in a case of measuring each of the measurement items described above, will be described with reference to FIGS. **5**A and **5**B and FIG. **6**.

(57) Generally, related to measurement of radiated power targeting the DUT **100**, a method for measuring equivalent isotropic radiated power (EIRP) and a method for measuring total radiated power (TRP) are known. The EIRP is, for example, a power value measured at each measurement point (θ, φ) in a spherical coordinate system (r, θ, φ) shown in FIG. **5**A. On the other hand, the TRP is obtained by measuring the EIRP in all orientations of the spherical coordinate system (r, θ, φ), that is, at a plurality of angular sample points PS (refer to FIG. **5**B), which are regulated in advance, on a spherical surface equidistant from a center O1 (hereinafter, a reference point) of the total spherical scanning of the DUT **100**, and obtaining a total sum thereof.

(58) In the present embodiment, the number of divisions $N\theta$ and $N\varphi$) for calculating the total radiated power (TRP) is set to, for example, 12, respectively. As a result, in the present embodiment, the number of angular samples (N) is obtained as $N=132 (=(12-1)\times12)$. 132 angular sample points PS obtained as above are located as shown in FIG. **5**B when represented on a surface of the sphere B.

(59) In the measurement device **1** according to the present embodiment, as shown in FIG. **5**B, the EIRP is measured at positions of 132 points equidistant from the reference point of the spherical coordinate system (r, θ, φ), and, further, the EIRP is added at positions of all the point. Further, based on a result of addition of each EIRP, that is, a total sum of the EIRP at all the angular sample points PS of 132 points, the total radiated power (TRP) of the DUT **100** is obtained.

(60) In a case where TRP measurement is performed, the integrated control device **10** drives and controls the DUT scanning mechanism **56** to perform the total spherical scanning of the DUT **100**. In the total spherical scanning of the DUT **100**, the integrated control device **10** rotationally drives the turntable **56***a* around the azimuth axis while repeatedly driving/non-driving the drive motor **56***f*, and rotationally drives the mounting tray **56***d* around the roll axis while repeatedly driving/non-driving the drive motor **56***g*. Here, the integrated control device **10** performs control so that the drive motor **56***f* and the drive motor **56***g* are non-driven at each timing in which the antenna surface of the antenna **110** faces one angular sample point PS. By controlling the total spherical scanning of the DUT **100**, the DUT **100** mounted on the mounting tray **56***d* is rotationally driven around the

reference point so that the antenna surface of the antenna **110** sequentially faces (orients) all the angular sample points PS of the sphere B while the antenna **110** is held at a position of the reference point which is the center of the sphere B that regulates the spherical coordinate system (r, θ, φ).

(61) As shown in FIG. **6**, the test antenna **5** is disposed at a position of a specific angular sample point PS (one point) in the spherical coordinate system (r, θ, φ). In the above-described total spherical scanning, the DUT **100** is driven (scanned) so that the antenna surface of the antenna **110** sequentially faces the light reception surface of the test antenna **5**. As a result, the test antenna **5** can transmit and receive a signal for the TRP measurement to and from the antenna **110** of the DUT **100** on which the total spherical scanning is performed. Here, the transmitted and received signal is a test signal that is transmitted from the NR system simulator **20** via the test antenna **5**, and a signal that is transmitted by the DUT **100**, which has received the test signal, using the antenna **110**, that is, a signal under measurement that is received via the test antenna **5**.

(62) In the integrated control device **10**, in accordance that the DUT **100** is scanned to pass through each angular sample point PS in a φ direction while maintaining a certain angle of θ in the spherical coordinate system (r, θ, φ) shown in FIG. **5B**, the NR system simulator **20** is driven to generate the test signal by the signal generation unit **21***a* and the transmission and reception unit **21***f*, and the test signal is transmitted from the test antenna **5** via the signal processing unit **25**. Here, in a case where the DUT **100** receives the test signal at the antenna **110**, the DUT **100** sends out a response signal corresponding to the reception of the test signal.

(63) The integrated control device **10** further drives the NR system simulator **20** so that a signal, which is transmitted by the DUT **100** in response to the reception of the test signal and is received by the test antenna **5**, is received by the signal measurement unit **21***b* as the signal under measurement from the signal processing unit **25** via the transmission and reception unit **21***f*. Further, the integrated control device **10** drives and controls the signal measurement unit **21***b* to perform signal processing related to the measurement of the EIRP based on the received signal under measurement. In a case where the measurement control of the EIRP is performed in accordance with the total spherical scanning of the DUT **100** which passes through all the angular sample points PS by changing the angle of θ, it is possible to measure the EIRP for all the angular sample points PS of the spherical coordinate system (r, θ, φ) to correspond to NR in the NR system simulator **20**. Further, the integrated control device **10** can obtain the TRP which is the total sum of the EIRP measurement values for all the angular sample points PS.

(64) Further, the integrated control device **10** has an output level control function of adjusting the output level (power level) of the test signal in the NR system simulator **20** to an appropriate level regulated by, for example, the 3GPP standard before performing a performance test of the DUT **100**, which is performed while changing an angle of the biaxial positioner (DUT scanning mechanism **56**) in the OTA chamber **50**, specifically, for example, measurement of measurement items such as EIRP-CDF, EIS-CDF, and TRP. With the output level control function, the output level of the test signal, at which the DUT **100** can exhibit maximum ability in a case of the measurement of each of the items, is searched (EIS search). Therefore, the above-described output level control function by the NR system simulator **20** can be regarded as a control function related to the reception sensitivity test for searching for the reception sensitivity for the DUT **100**. The control function related to the reception sensitivity test is realized by the reception sensitivity test control unit **18** provided in the control unit **11** of the integrated control device **10**.

(65) (Convergence Control of Output Level of Test Signal in Reception Sensitivity Test)

(66) In the integrated control device **10**, the reception sensitivity test control unit **18** controls the reception sensitivity test of the DUT **100** by transmitting and receiving the test signal a plurality of times between the NR system simulator **20**, which is the signal generator, and the DUT **100**. In the control, a throughput is measured according to the transmission and reception of the test signal at each time during the reception sensitivity test to be converged to an output level, at which an

appropriate value of the throughput (measurement result) is obtained, while performing level down or level up on the output level of the test signal according to the comparison result between the throughput measurement value and the throughput threshold value.

(67) As an example of the convergence control of the output level of the test signal in the reception sensitivity test described above, in the measurement device **1** according to the present embodiment, the reception sensitivity test control unit **18** of the integrated control device **10** is provided with a first measurement parameter change setting function of performing change setting on specific setting parameters (for example, starting output level OL0 and initial step level SL0) of the test conditions set at the start of measurement of the DUT **100** from the initial setting value based on the AI prediction technology, to dynamically control the output level of the test signal so that the EIS search starting point is as close as possible to the end point of the original EIS search. By providing the first measurement parameter change setting function, in the measurement device **1** according to the present embodiment, the output level of the test signal is quickly converged to the target level so that the EIS search time can be significantly reduced, as compared to a method for sequentially changing (linearly changing) the output level by a constant level each time the number of measurements increases from the initially set output level (see curves L1 and L2 of FIG. **13**), a method for controlling the output level to vary non-linearly while repeatedly decreasing or increasing the output level of the test signal (see curves NL1 and NL2 in FIG. **13**), and further various existing methods for reducing the number of measurements by applying a CP determination process.

(68) The AI prediction test condition change setting unit **18**b provided in the reception sensitivity test control unit **18** as the first measurement parameter change setting function holds the AI prediction model Dai acquired by performing machine learning on the relationship between the parameter data and the measurement result data from the measurement log files of the reception sensitivity test of the DUT **100** in the past of the measurement device **1**, and performs change setting on the above-described starting output level (OL0) and the initial step level (SL0) using the AI prediction model Dai to a value used for the first measurement or the second measurement based on the AI prediction.

(69) The generation processing procedure of the AI prediction model Dai will be described in detail with reference to FIG. **7**. As shown in FIG. **7**, in order to generate the AI prediction model Dai, measurement log files are prepared which are collected from reception sensitivity measurements of the DUT **100** performed a plurality of times in the past in the measurement device **1** according to the present embodiment (step S**31**). The prepared measurement log files include, for example, an EIS measurement log file, an EIS-CDF measurement log file, or the like. The measurement log files preferably collect a number corresponding to the number of measurements (for example, 10 or more) that can maintain sufficient accuracy as the AI prediction model Dai to be generated.

(70) Next, in the generation processing procedure, the EIS measurement result data (EIS-CDF log file) from the EIS measurement log file (or EIS-CDF log file) collected through n measurements prepared in step S**31** and the parameter data used (set) for each measurement are extracted (step S**32**). The parameter data extracted here include, for example, at least the loss of an external connection cable (external path loss), the angle of the DUT scanning mechanism **56**, that is, the azimuth angle (θ, φ) of the DUT **100**, and the frequency to be measured.

(71) Furthermore, in the generation processing procedure, the relationship between the parameter data and the measurement result data extracted in step S**32** is machine-learned using AI (step S**33**), and the machine-learning result is collected as the AI prediction model Dai and is stored in the predetermined storage area (step S**34**). Here, multiple types of AI prediction models Dai are generated to which the types of parameter data extracted from the past measurement log files are reflected. In the present embodiment, the AI prediction model Dai is stored in, for example, the AI prediction model storage unit **18**b1 provided in the RAM **11**c in the control unit **11** of the integrated control device **10**.

(72) As can be understood from the generation processing procedure shown in FIG. **7**, the AI prediction model Dai generated by the generation processing procedure consists of statistical data of the relationship between the parameter data and the measurement result data in reception sensitivity tests of the DUT **100** performed a plurality of times in the past. In short, the AI prediction model Dai is the statistical data that indicates what measurement result is obtained with what value of the parameter data.

(73) As a result, in the measurement device **1** according to the present embodiment, it is possible to search the setting parameters initially set in the reception sensitivity test of the DUT **100** for the output level, the step level, or the like of the test signal at an EIS search point within the range of the predetermined number of searches from the final EIS search point on an EIS search path in the existing measurement method by the AI prediction based on the AI prediction model Dai. In other words, in the measurement device **1** according to the present embodiment, it is possible to skip the EIS search up to the final EIS search point using the initially set setting parameters, start the EIS search from the final EIS search point, and significantly reduce the number of EIS searches.

(74) Further, in the present embodiment, the external path loss, the azimuth angle (θ, φ) of the DUT **100**, and the frequency to be measured are used as the parameter data for generating the AI prediction model Dai. Therefore, it is possible to derive an accurate AI prediction results obtained by considering each parameter data using the AI prediction model, and it is possible to set the test signal to a testable level in an extremely short time and reliably without dropping the measurement accuracy.

(75) FIG. **8** shows a comparison example of measurement start positions of a DUT reception sensitivity test to which the AI prediction is applied in the measurement device **1** according to the present embodiment and a DUT reception sensitivity test in an existing device (device according to the related art). As shown in FIG. **8**, in the existing device, regardless of whether the output level of the test signal is controlled linearly or non-linearly, the measurement starts from a fixed value (for example, OL0=−80 dBm) initially set at the start of measurement of the EIS ("measurement according to the related art" in FIG. **8**). Therefore, in a case where the measurement of "EIS1", which satisfies an end condition at −90 dBm, is performed by a procedure of the "measurement according to the related art", the number of measurements is, for example, n. On the other hand, in a case where the "EIS2" measurement, which satisfies the end condition at −96 dBm, is performed by the procedure of the "measurement according to the related art", the number of measurements is, for example, N (N>n) which is even greater.

(76) On the other hand, in the measurement using the AI prediction in the measurement device **1** according to the present embodiment ("AI measurement" in FIG. **8**), the EIS search starts from an AI-predicted value (for example, OL01: (prediction value)) using the AI prediction model Dai from the initially set setting parameters. Here, in a case where EIS1 is measured, the AI-predicted value OL01 is a value corresponding to, for example, the EIS search point within a predetermined range (in this example, once time before) from the final EIS search point (point corresponding to "n-th measurement) in the "measurement according to the related art". As a result, in the measurement of EIS1 based on AI prediction, the first measurement is performed in such a way that the output level of the test signal is set to, for example, −89.8 dBm, the second measurement is sequentially performed in such a way that the output level is set to, for example, −90 dBm, and, in a case where it is determined that the end condition is satisfied here, the EIS search ends at the second measurement.

(77) Further, in a case where EIS2 is measured, the AI predicted value OL01 is, for example, a value corresponding to the EIS search point within a predetermined range (in this example, one time before) from the final EIS search point (point corresponding to "N-th measurement) in the "measurement according to the related art". As a result, in the measurement of EIS2 based on AI prediction, the first measurement is performed in such a way that the output level of the test signal is set to, for example, −95.8 dBm, the second measurement is sequentially performed in such a way

that the output level is set to, for example, −96 dBm, and, in a case where it is determined that the end condition is satisfied here, the EIS search ends at the second measurement.

(78) As shown in FIG. **8**, in the measurement device **1** according to the present embodiment, the output level of the test signal that starts the measurement according to the set parameters is dynamically and adaptively controlled, so that it is possible to significantly shorten the EIS search path, as compared to the "measurement according to the related art" in which measurement always starts from the fixed value, and it is possible to set the output level of the test signal to a testable level in a shorter time by significantly reducing the number of EIS searches.

(79) Based on a time shortening method of the reception sensitivity test of the DUT **100** based on the AI prediction using the AI prediction model described above, a variable setting control operation of the output level of the test signal for the reception sensitivity test of the DUT **100** by the integrated control device **10** of the measurement device **1** according to the present embodiment will be described below with reference to FIGS. **9** and **10**.

(80) FIG. **9** is a flowchart showing the variable setting control operation of the output level of the test signal to which the AI prediction is applied in the reception sensitivity test of the DUT **100** in the measurement device **1** according to the present embodiment. In FIG. **9**, steps S**20**, S**1**a, S**25**, S**26**, and S**27** are a part of the output level change setting process to which the above-described AI prediction is applied. As a storage form of the control data for realizing the output level change setting process to which the AI prediction is applied, a method for storing data of the result which is AI-predicted in advance (prediction result data) based on the AI prediction model Dai from setting parameters and a method for storing the AI prediction model Dai and executing the AI prediction each time based on the AI prediction model Dai from the setting parameters initially set at the start of the reception sensitivity test of the DUT **100** are conceivable. The following description assumes that the former method is applied. All the storage destination of the control data is, for example, the AI prediction model storage unit **18***b***1**.

(81) In the measurement device **1** according to the present embodiment, in order to start the reception sensitivity test of the DUT **100** along the flowchart shown in FIG. **9**, first, the reception sensitivity test control unit **18** in the control unit **11** of the integrated control device **10** performs setting (initial setting) of the test conditions (setting parameter) (step S**1**). Specifically, the test condition setting unit **18***a* receives an operation input in the operation unit **12**, and sets, for example, respective values of the initial step level SL0, the starting output level OL0, the error tolerance level EL, the connection drop determination threshold value DT, and the determination condition of the steep drop region of the throughput (refer to steps S**7** and S**9***a*), which are described above.

(82) As the starting output level OL0 and the initial step level SL0, which are set in step S**1**, for example, −75 dBm and 10 dB are assumed, respectively. The error tolerance level EL is assumed to be, for example, 0.2 dB. The connection drop determination threshold value DT is assumed to be, for example, −90 dBm. Further, as the determination condition of the steep drop region of the throughput, for example, a condition is assumed that the throughput measurement value is set to a range of a proportion which exceeds 95% and is equal to or less than 99% with respect to the reference value.

(83) After completing the initial setting of the test conditions in step S**1**, the reception sensitivity test control unit **18** performs a process of changing and setting the initially set starting output level OL0 based on the AI prediction (step S**1***a*). Specifically, in the reception sensitivity test control unit **18**, the AI prediction test condition change setting unit **18***b* searches for the AI prediction result data based on the AI prediction model Dai stored in the AI prediction model storage unit **18***b***1** based on, for example, the starting output level OL0 set in step S**1** (step S**20**), and performs change setting on the value of the starting output level OL0 which is being set to the AI prediction output level (OL01) which is AI-predicted in advance corresponding to the starting output level OL0 (step S**1***a*). That is, the change setting is performed on the initially set starting output level OL0 to the

first output level OL01.

(84) Next, the reception sensitivity test control unit **18** increments the number of measurements n by +1 (step S**2**), and performs a process of setting a parameter related to the N-th measurement, and reading a value of the output level OL set in step S**8** (including steps S**8***a* and S**8***b*) of performing, for example, the OL level down process or step S**9** of performing the OL level up process before the setting (step S**3**). Subsequently, the reception sensitivity test control unit **18** performs control to perform the n-th measurement related to the throughput of the DUT **100** while transmitting the test signal based on the parameter, which is set (or read) in step S**3**, related to the measurement (step S**4**).

(85) As a specific example of the control in steps S**3** and S**4** (throughput measurement control), the reception sensitivity test control unit **18** reads, as the parameter related to a first measurement, a first output level OL01 set through the change setting based on the setting of the test conditions in step S**1** and the AI prediction in step S**20**, and performs the throughput measurement while driving and controlling the DUT **100** at the first output level OL01.

(86) Next, the reception sensitivity test control unit **18** checks whether or not a step level interval with respect to the previous throughput measurement related to the current throughput measurement, that is, the step level SL(n) is larger than the error tolerance level EL which is set in step S**1** (step S**5**). When it is determined that the step level SL(n) is larger than the error tolerance level EL (YES in step S**5**), the reception sensitivity test control unit **18** proceeds to step S**25** and continues the throughput measurement and step level search control. As described above, a first throughput measurement starts from the transmission of the test signal at the first output level OL01, and there is no width of change of SL with respect to the previous measurement, so that the process of step S**5** is skipped and the process proceeds to step S**25**.

(87) In step S**25**, the reception sensitivity test control unit **18** checks whether or not the number of measurements N is 1. Here, in a case where it is determined that the number of measurements N is not 1 (that is, 2 or more) (NO in step S**25**), the reception sensitivity test control unit **18** proceeds to a process after step S**6**, that is, a measurement process based on the existing measurement method.

(88) On the other hand, in a case where it is determined that the number of measurements N is 1 (YES in step S**25**), the reception sensitivity test control unit **18** performs a process of acquiring the AI prediction step level SL01 which is AI-predicted in advance from the initial step level SL0 set in step S**1**, and a process of setting an output level OL1 used for the second measurement based on the acquired AI prediction step level SL01 (step S**26** and step S**27**). Specifically, in the reception sensitivity test control unit **18**, the AI prediction test condition change setting unit **18***b* searches for the AI prediction result data stored in the AI prediction model storage unit **18***b***1**, and acquires the AI prediction step level SL01 which is AI-predicted in advance from the initial step level SL0 set in step S**1** (step S**26**). Next, the AI prediction test condition change setting unit **18***b* performs a process of setting the output level OL1 (=OL01+SL01) of the test signal used for the second measurement based on the acquired AI prediction step level SL01 and the first output level OL01 changed and set in step S**1***a* (step S**27**).

(89) Thereafter, the reception sensitivity test control unit **18** continues the processes in steps S**2**, S**3**, and S**4**. That is, the reception sensitivity test control unit **18** increments the number of measurements n by +1 (step S**2**), sets the parameters for the second measurement, reads the value of the output level OL1 set before, for example, in step S**27** based on the AI prediction (step S**3**), and, thereafter, controls to perform the second measurement related to the throughput of the DUT **100** while transmitting the test signal based on the set (or read) parameters related to the measurement (step S**4**).

(90) Specifically, in the control (throughput measurement control) in steps S**3** and S**4**, the reception sensitivity test control unit **18** reads the output level OL1 (=OL01+SL01) set in step S**27**, and performs second throughput measurement while driving and controlling the DUT **100** at the output level OL1.

(91) Further, the reception sensitivity test control unit **18** checks whether or not a step level interval with respect to the previous throughput measurement related to the current throughput measurement, that is, the step level SL(n) is larger than the error tolerance level EL which is set in step S**1** (step S**5**).

(92) Here, in a case where it is determined that the step level SL(n) is equal to or less than the error tolerance level EL (NO in step S**5**), the reception sensitivity test control unit **18** stops the throughput measurement and the step level search, and ends a series of measurement operations by outputting the measurement result at this time (step S**10**). In accordance with this, the reception sensitivity test control unit **18** performs a process of feeding back the throughput measurement result output in step S**10** and the parameter data set by the AI prediction test condition change setting unit **18***b* and updating the AI prediction model Dai (AI prediction model A1) used in step S**20** (step S**11**).

(93) On the other hand, in a case where it is determined that the step level SL(n) is greater than the error tolerance level EL (YES in step S**5**), the reception sensitivity test control unit **18** checks whether or not the number of measurements N is 1 (step S**25**). Here, in a case where it is determined that the number of measurements N is not 1 (that is, 2 or more) (NO in step S**25**), the reception sensitivity test control unit **18** executes the process after step S**6**, that is, the measurement process based on the existing measurement method.

(94) As described above, in the variable setting control operation of the output level of the test signal related to the reception sensitivity test of the DUT **100** in the measurement device **1** according to the present embodiment shown in FIG. **9**, an example is provided in which the setting change based on AI prediction from the starting output level OL0 initially set in step S**1** is limited to two times (step S**1***a* and step S**26**), and, in a case where the determination result of "YES" is not obtained in step S**5** during that time, the measurement process based on the existing measurement method after step S**6** is executed. Here, the number of change settings based on the AI prediction is not limited to two times, and other numbers of times are also possible.

(95) The measurement process based on the existing measurement method after step S**6** is the same as a process after step **6** in the flowchart of FIG. 7 of Patent Document 1, and the outline us as below.

(96) First, in step S**6**, the reception sensitivity test control unit **18** compares the throughput measurement value in step S**4** with a preset throughput threshold value, and, in a case where it is determined that the throughput measurement value is equal to or greater than the throughput threshold value (state of "PASS" in step S**6**), proceeds to step S**7** and determines whether or not the determination condition is satisfied that the throughput measurement value is set to the range of the proportion which exceeds 95% and is equal to or less than 99% with respect to the reference value.

(97) In a case where it is determined that the throughput measurement value exceeds 99% with respect to the reference value and the determination condition is not satisfied (NO in step S**7**), the reception sensitivity test control unit **18** executes an OL level (output level) down process (A) of lowering the output level of the test signal (step S**8***a*). On the other hand, in a case where the drop state determination unit **18***d* determines that the throughput measurement value is within the range of proportion which exceeds 95% and is equal to or less than 99% with respect to the reference value and the determination condition is satisfied (YES in step S**7**), the reception sensitivity test control unit **18** executes the OL level down process (B) (step S**8***b*). The OL level down process (A) is shown in FIG. **10**A, and the OL level down process (B) is shown in FIG. **10**B.

(98) On the other hand, in a case where it is determined that the throughput (measurement value) is equal to or less than the throughput threshold value (in a state of "FAIL" in step S**6**) in step S**6**, the reception sensitivity test control unit **18** sequentially executes a determination process in step S**9***a*. Here, in a case where the throughput measurement value exceeds 80% with respect to the reference value and it is determined that the determination condition is satisfied (YES in step S**9***a*), the OL level up process (A) of raising the output level of the test signal is executed. On the other hand, in a

case where it is determined that the throughput measurement value is equal to or less than 80% with respect to the reference value and the determination condition is not satisfied (NO in step S9*a*), the OL level up process (B) or (C) is executed according to the determination result in step S9*c*.

(99) After processing of the OL level down processes (A) and (B) or the OL level up processes (A), (B), and (C), the reception sensitivity test control unit **18** continues the processes in steps S**2** to S**4**. In a case where it is determined in subsequent step S**5** that the step level SL(n) is equal to or lower than the error tolerance level EL (NO in step S**5**), the reception sensitivity test control unit **18** stops the throughput measurement and the step level search (step S**10**), and thereafter, ends the series of measurement operation. Here, the reception sensitivity test control unit **18** performs a process of feeding back the throughput measurement result and updating the AI prediction model Dai (AI prediction model A1) used in step S**20** (step S**11**).

(100) According to the series of measurement control shown in FIG. **9**, the change setting process (see steps S**20**, S**1***a*, S**25**, S**26**, and S**27**) performed on the starting output level OL0 and the initial step level SL0 initially set in step S**1** based on the AI prediction is targeted to be performed, for example, up to the second measurement.

(101) According to the change setting process for the starting output level OL0 based on the AI prediction, for example, it is possible to complete the measurement with only two EIS path searches, and it is possible to further reduce the number of EIS searches as compared to the measurement based on the existing measurement methods that employ the non-linear and the CP determination condition executed after step S**6** in FIG. **9**. This point will be described below with specific examples.

(102) FIG. **11** is a table showing the relationship between the number of measurements related to the reception sensitivity test of the DUT **100** to which the AI prediction is applied in the measurement device **1** according to the present embodiment and the reception sensitivity test of the DUT **100** in the existing device, and the output level of a test signal and the pass or fail determination result of the throughput measurement result. FIG. **12** is a graph showing the relationship between the number of measurements related to the reception sensitivity test of the DUT **100** to which the AI prediction is applied in the measurement device **1**, which is shown in the table of FIG. **11**, according to the present embodiment and the reception sensitivity test of the DUT **100** in the existing device, and the output level of the test signal and the pass or fail determination result of the throughput measurement result.

(103) In the table shown in FIG. **11**, the second and third columns from the left show a data example related to the reception sensitivity test of the DUT **100** by non-linear output level control in the existing device, the fourth and fifth columns from the left show the relationship between the number of measurements related to the reception sensitivity test of the DUT **100** to which the output level control by the AI prediction of the measurement device **1** according to the present embodiment is applied, and the pass or fail determination result of the output level and the throughput measurement result of the test signal. Similarly, in the graph shown in FIG. **12**, a graph corresponding to the data example of the output level control of the test signal according to the AI prediction related to the present embodiment in FIG. **11** is shown using reference numeral C1 (a graph showing a relationship between the number of measurements and the output level), and a graph corresponding to the data example of the output level control of the non-linear test signal in the existing device in FIG. **11** is shown using reference numeral C2 (a graph showing a relationship between the number of measurements and the output level).

(104) As shown in FIG. **11** (see first to third columns from the left) and characteristic C2 in FIG. **12**, in the reception sensitivity test of the DUT **100** by the non-linear output level control in the existing device, a first test starts while the DUT **100** is set to the output level OL(0)=−80 dBm at a measurement point P21 of the characteristic C2, and the OL level down process is performed after the throughput measured at this time is determined to be within the allowable range (PASS).

(105) As a result of the OL level down process, the second test starts while the DUT **100** is set to the output level OL(1)=−90 dBm at a measurement point P22 of the characteristic C2, and the OL level down process is performed after the throughput measured at this time is determined to be within the allowable range (PASS).

(106) As a result of the OL level down process, the third test starts while the DUT **100** is set to the output level OL(2)=−95 dBm at a measurement point P23 of the characteristic C2, and the OL level down process is performed after the throughput measured at this time is determined to be within the allowable range (PASS).

(107) As a result of the OL level down process, the fourth test starts while the DUT **100** is set to the output level OL(3)=−97.5 dBm at a measurement point P24 of the characteristic C2, and the OL level up process is performed after the throughput measured at this time is determined to be out of the allowable range (FAIL).

(108) As a result of the OL level up process, the fifth test starts while the DUT **100** is set to the output level OL(4)=−96.2 dBm at a measurement point P25 of the characteristic C2, and the OL level up process is performed after the throughput measured at this time is determined to be out of the allowable range (FAIL).

(109) As a result of the OL level up process, the sixth test starts while the DUT **100** is set to the output level OL(5)=−95.6 dBm at a measurement point P26 of the characteristic C2, and the OL level down process is performed after the throughput measured at this time is determined to be within the allowable range (PASS).

(110) As a result of the OL level down process, the seventh test starts while the DUT **100** is set to the output level OL(6)=−95.9 dBm at a measurement point P27 of the characteristic C2, and the OL level up process is performed after the throughput measured at this time is determined to be out of the allowable range (FAIL).

(111) As a result of the OL level up process, the eighth test starts while the DUT **100** is set to the output level OL(7)=−95.8 dBm at a measurement point P28 of the characteristic C2, and the throughput measured at this time is determined to be out of the allowable range (FAIL). However, the step level SLn between the throughput and the previous (seventh) measured throughput becomes equal to or lower than the error tolerance level EL, and the series of measurements ends.

(112) On the other hand, as shown in FIG. **11** (see the first, fourth, and fifth columns from the left) and the characteristic C1 in FIG. **12**, according to the reception sensitivity test of the DUT **100** to which the output level control by the AI prediction is applied in the measurement device **1** related to the present embodiment, a first test starts while the DUT **100** is set to the first output level OL(01)=−95.9 dBm which is changed and set by the AI prediction (see steps S**20** and S**1***a* of FIG. **9**) at a measurement point P11 of the characteristic C1, and the OL level up process is performed after the throughput measured at this time is determined to be out of the allowable range (FAIL).

(113) As a result of the OL level up process, the second test starts while the DUT **100** is set to the output level OL(1)=−95.8 dBm, which is set and changed by the AI prediction (see steps S**26** and S**27** in FIG. **9**) at a measurement point P12 of the characteristic C1, and the throughput measured at this time is determined to be within the allowable range (PASS). However, the step level SLn between the throughput and the previous (first) measured throughput is equal to or lower than the error tolerance level EL, and the measurement ends.

(114) Even though non-linear output level control is performed in the reception sensitivity test of the DUT **100** in the existing device, as shown by the characteristic C2 in FIG. **12**, it is necessary to perform eight measurements at P21, P22, P23, P24, P25, P26, P27, and P28.

(115) On the other hand, in the reception sensitivity test of the DUT **100** in the measurement device **1** according to the present embodiment, dynamic control of the first output level of the test signal is applied based on AI prediction, so that it is possible to end the reception sensitivity test with the two measurements at P11 and P12.

(116) A reason that it is possible to end the reception sensitivity test of the DUT **100** in the

measurement device **1** according to the present embodiment with a small number of measurements is that the AI prediction technology is used based on the AI prediction model Dai generated from the past measurement log files and the first measurement starts from a value close to the setting parameter (for example, output level) just before the end of the past measurement. In order to realize this, in the measurement device **1** according to the present embodiment, by the AI prediction, the change setting is performed on the initially set starting output level OL0 (for example, −75 dBm) to an AI prediction output level OL01 (for example, −95.9 dBm: see FIG. **11**) corresponding to the value obtained, for example, two times before from the end of measurement in the past measurement. Here, the closer the value of the changed and set setting parameter (AI prediction output level (first output level) OL01) to the value near the end of measurement of the same setting parameter in the past measurement, it is possible to shorten the convergence time to the output level at which the target throughput value (measurement result) is obtained.

(117) The time shortening effect of the reception sensitivity test of the DUT **100** to which the AI prediction is applied in the measurement device **1** according to present embodiment will be described with reference to FIG. **13**. In a graph shown in FIG. **13**, curves L1 and L2 show search paths of the EIS search based on the linear output level control in the reception sensitivity test of the DUT **100** in the existing device, and curves NL1 and NL2 show search paths of the EIS search based on the non-linear output level control in the DUT reception sensitivity test in the existing device. As shown by the curve L2 and the curve NL2, both the EIS searches based on the linear and non-linear output level control in the reception sensitivity test of the DUT **100** in the existing device end at an EIS point 1.

(118) Under such measurement conditions, in a case where the measurement is performed using the AI prediction in the measurement device **1** according to the present embodiment, for example, from the first measurement OL level (starting output level) set at the start of the measurement based on the non-linear output level control, by the AI prediction in which the AI prediction model Dai is used, it is possible to set, for example, a value (AI prediction result) corresponding to an AI prediction point Pai0 within an AI prediction range Rai in the predetermined range from the EIS point 1 as the above-described first output level OL01 (see step S**1***a* in FIG. **9**). As a result, as shown by curve Lai on the graph of FIG. **13**, the EIS search path in a case where the AI prediction is applied in the measurement device **1** includes two measurements which start from the AI prediction point Pai0 within the AI prediction range Rai and end at the EIS point 1 through a subsequent AI prediction point Pai1 (measurement result).

(119) In a case where description is performed while assuming the reception sensitivity test of the DUT **100** when the measurement result data shown in FIGS. **11** and **12** is obtained, in step S**1***a* of FIG. **9**, the measurement device **1** according to the present embodiment changes and sets the value (first output level OL01) corresponding to the AI prediction point Pai0 within the AI prediction range Rai shown in FIG. **13** from the starting output level OL0 set in step S**1** based on the AI prediction. Thereafter, in a case where the second measurement is performed, the value OL1= (OL01+SL01) corresponding to the AI prediction point Pai2 within the AI prediction range Rai shown in FIG. **13** is changed and set based on the AI prediction in step S**27** of FIG. **9**. After the second throughput measurement, the determination of "YES" is obtained in step S**5**, and the measurement ends.

(120) FIG. **13** discloses the AI prediction result of the output level in a case where the EIS measurement is performed for each angular sample point PS shown in FIG. **5**B. However, more time is required in a case where the EIS-CDF measurement is performed. Here, with reference to FIG. **14**, the relationship is verified between the measurement time achievable in the EIS-CDF measurement to which the AI prediction is applied in the measurement device **1** according to the present embodiment and the number of measurements for machine learning. For the measurement conditions in the measurement device **1** for the verification, for example, Meas. Metric (measurement target) is set to EIS-CDF, Grid Type is set to Constant Step, Pont (the number of

angular sample points PS) is set to 168, Range (measurement range) is set to a hemisphere, Step (angle to move to the next angular sample point PS) is set to 15 deg, Error Control (the same as the above-described "error tolerance level EL") is set to 0.2 dB.

(121) In a case where the EIS-CDF measurement is performed in the measurement device **1** prepared for the verification under the above-described measurement conditions, the verification results shown in a graph of FIG. **14** are obtained according to the number of measurements. In the graph of FIG. **14**, the measurement corresponding to "0-th measurement" corresponds to a measurement result obtained without applying the AI prediction, that is, in a case where the measurement is performed in a device according to the related art. Also, the measurement corresponding to the "first measurement" corresponds to a measurement result obtained by using the AI prediction model prepared by default. In addition, the measurements corresponding to the "second measurement" and later (in this example, the measurement corresponding to the "second measurement" and the measurement corresponding to the "third measurement") correspond to measurement results using the AI prediction model obtained by the machine learning based on the immediately before measurements, that is, the measurement corresponding to the "first measurement" and the measurement corresponding to the "second measurement". As shown in the graph of FIG. **14**, it takes 173 minutes to end the measurement in the measurement corresponding to the "0-th measurement". On the other hand, in the measurement corresponding to the "first measurement", machine learning is applied, and as a result of starting the measurement from the AI-predicted output level OL01, the measurement ends in 126 minutes which is shorter than the measurement corresponding to the "0-th measurement". Furthermore, the measurement corresponding to the "second measurement" and the measurement corresponding to the "third measurement" show a tendency that the time to end the measurement is 72 minutes and 67 minutes, respectively, and the measurement time is shortened as the number of times of machine learning increases. From the graph shown in FIG. **14**, it can be understood that the machine learning effect related to shortening of the measurement time begins to appear from the second to third machine learning times. From this, it can be inferred that further improvement in measurement speed can be expected by using the measurement device **1** to store measurement information in the future.

(122) It is possible to execute a work of storing the measurement information using the measurement device **1**, for example, according to the procedure shown in FIG. **7**, as described above. Here, for the measurement conditions and the number of measurements that can be expected to improve the measurement speed, the inventors of the present invention can confirm that, in a case where the measurement conditions are set to be "automatic update just by performing EIS/EIS-CDF measurement", the effect of improving the measurement speed began to appear from about 10 machine learning times.

(123) In the above embodiment, the reception sensitivity test operation control specialized for the measurement on a single surface (EIS measurement) is illustrated. However, the present embodiment can be applied to a reception sensitivity test related to the measurement on the entire spherical surface (TRP measurement: refer to FIGS. **5**A and **5**B).

(124) Further, the above embodiment discloses a system configuration example in which the integrated control device **10** is provided outside the measurement device **1**. However, the present invention may have a configuration in which the measurement device **1** is provided with a control function of the integrated control device **10**.

(125) As described above, according to the present embodiment, there is provided a measurement device **1**, which includes a signal generator **20** that generates a test signal and a reception sensitivity test execution unit **18** that performs a reception sensitivity test of a mobile terminal (DUT **100**) by transmitting and receiving the test signal a plurality of times between the signal generator and the DUT, and tests the mobile terminal that is a device under test, the measurement device **1** includes a test condition setting unit **18***a* that initially sets a test condition including a step level SL0 and an output level OL0 of the test signal at start of the reception sensitivity test, a

measurement result output unit **18***f* that performs a throughput measurement by transmitting and receiving the test signal under the test condition and comparing a throughput measurement result with a determination threshold value to perform pass or fail determination, an output level variable setting unit **18***e* that sets the output level according to a result of the pass or fail determination of a previous throughput measurement in a case where the result of the pass or fail determination is fail, and an AI prediction test condition change setting unit **18***b* that holds an AI prediction model generated by performing machine learning on a relationship between parameter data and measurement result data from a measurement log file of the past reception sensitivity test using artificial intelligence, and sets an AI prediction output level OL01, which is AI-predicted in advance by the AI prediction model based on the test condition set by the test condition setting unit, as a first output level instead of the output level OL0.

(126) With this configuration, in the measurement device **1** according to the present embodiment, it is possible to quickly set the first output level of the test signal to a value close to the end of the measurement with existing non-linear control or the like by AI prediction, and, it is possible to set the output level of the test signal to a testable level in an extremely short time by significantly reducing the number of measurements compared to methods according to the related art, such as non-linear control and CP control, and thus it is possible to efficiently perform the reception sensitivity test of the mobile terminal.

(127) In addition, in the measurement device **1** according to the present embodiment, the AI prediction test condition change setting unit **18***b* may set, instead of the step level SL0, an AI prediction step level SL01, which is AI-predicted in advance by the AI prediction model based on a measurement result of a first throughput measurement performed by transmitting and receiving the test signal at the AI prediction output level, as a step level for second and subsequent measurements.

(128) With this configuration, the measurement device **1** according to the present embodiment dynamically controls not only the initial step level of the test signal but also the first step level by the AI prediction. Therefore, compared to a case of continuing the measurement by the method according to the related art, such as the non-linear control and the CP control, it is possible to set the test signal to a testable level in a shorter time and it is possible to further improve the efficiency of the reception sensitivity test of the mobile terminal.

(129) Further, in the measurement device **1** according to the present embodiment, the AI prediction test condition change setting unit **18***b*, in a case where a result of the pass or fail determination for the measurement result of the first throughput measurement is fail, thereafter, may perform an update process of the output level for a next measurement using the AI prediction step level SL01 until a second throughput measurement.

(130) With this configuration, in the measurement device **1** according to the present embodiment, it is possible to avoid a situation in which the dynamic control described above is repeated uselessly even though the dynamic control of the first output level of the test signal by the AI prediction and the step level is limited to the second throughput measurement and the measurement starts from a value close to the end of the measurement in the non-linear control or the like.

(131) Further, in the measurement device **1** according to the present embodiment, the AI prediction test condition change setting unit **18***b* may designate loss of an external connection cable, an azimuth angle (θ, φ) of the DUT **100**, and a frequency to be measured as the parameter data, and may hold the AI prediction model generated by performing the machine learning on the relationship between the parameter data and the measurement result data.

(132) With this configuration, the measurement device **1** according to the present embodiment, even in the environment in which each parameter data of the loss of the external connection cable, the azimuth angle (θ, φ) of the DUT **100**, and the frequency to be measured affects the measurement accuracy, it is possible to derive accurate AI prediction result to which each parameter data is added using the AI prediction model, and it is possible to set the test signal to an

testable level in an extremely short time and reliably without dropping the measurement accuracy.

(133) In addition, in the measurement device **1** according to the present embodiment, the reception sensitivity test execution unit, in a case where a result of the pass or fail determination for measurement result of a second throughput measurement is fail, may control the output level variable setting unit to perform a level down process A, a level down process B, a level up process A, or a level up process B.

(134) With this configuration, in the measurement device **1** according to the present embodiment, in a case where the output level of the initial step level does not reach the testable level through the dynamic control of the first output level and the step level of the test signal based on AI prediction, it is possible to immediately switch to a normal measurement routine and reliably set the output level of the test signal to the testable level.

(135) Further, the measurement device **1** according to the present embodiment may further include an anechoic box **50** including an internal space **51**, and a DUT scanning control unit **16** and a DUT scanning mechanism **56** for driving and scanning the mobile terminal to continuously vary an orientation of the mobile terminal in the internal space, in which the reception sensitivity test is performed in all orientations to be scanned by the DUT scanning control unit **16** and the DUT scanning mechanism **56** in an over the air (OTA) measurement environment in the internal space.

(136) With this configuration, in the measurement device **1** according to the present embodiment, even in a situation in which the reception sensitivity measurement should be performed in all orientations under the OTA environment, the dynamic control of the first output level and the step level of the test signal by the AI prediction is applied, so that it is possible to set the output level of the test signal to the testable level in a short time.

(137) Further, in order to solve the above problems, there is provided a mobile terminal testing method for performing a reception sensitivity test of a mobile terminal by using a measurement device **1**, which includes a signal generator **20** that generates a test signal and a reception sensitivity test execution unit **18** that performs the reception sensitivity test of the mobile terminal by transmitting and receiving the test signal a plurality of times between the signal generator and the mobile terminal **100**, and tests the mobile terminal that is a device under test, and by transmitting and receiving the test signal between the signal generator and the mobile terminal a plurality of times, the mobile terminal testing method including a setting step S**1** of initially setting a test condition including a step level SL0 and an output level OL of the test signal at start of the reception sensitivity test, an AI prediction test condition change setting step S**1***a* of holding an AI prediction model generated by performing machine learning on a relationship between parameter data and measurement result data from a measurement log file of the past reception sensitivity test using artificial intelligence, and setting an AI prediction output level SL01, which is AI-predicted in advance by the AI prediction model based on the test condition set by the setting step, as a first output level instead of the output level OL0, a pass or fail determination step S**4** and S**5** of performing a first throughput measurement by transmitting and receiving the test signal at the AI prediction output level and comparing a first throughput measurement result with a determination threshold value to perform pass or fail determination, and a step level change setting step of setting, instead of the step level SL0, an AI prediction step level SL01, which is AI-predicted in advance by the AI prediction model based on a measurement result of the first throughput measurement, as a step level for second and subsequent measurements.

(138) With this configuration, in the mobile terminal testing method according to the present embodiment, the mobile terminal testing method is applied by using the measurement device **1** having the above configuration. Therefore, it is possible to quickly set the first output level of the test signal to the value close to the end of the measurement with existing non-linear control or the like by the AI prediction, and, it is possible to set the output level of the test signal to a testable level in an extremely short time by significantly reducing the number of measurements compared to methods according to the related art, such as non-linear control and CP control, and thus it is

possible to efficiently perform the reception sensitivity test of the mobile terminal.

INDUSTRIAL APPLICABILITY

(139) As described above, the mobile terminal testing device and the mobile terminal testing method according to the present invention have advantages in that it is possible to set an output level of a test signal to a testable level in a short time by reducing the number of measurements as much as possible and it is possible to efficiently perform the reception sensitivity test of the mobile terminal, and are useful for all the mobile terminal testing device and the measuring method for performing the reception sensitivity test of the mobile terminal, such as a 5G wireless terminal, having high-speed communication capability.

DESCRIPTION OF REFERENCE NUMERALS AND SIGNS

(140) **1**: Measurement device (Mobile terminal testing device) **16**: DUT scanning control unit (Scanning means) **18**: Reception sensitivity test control unit (Reception sensitivity test execution unit, pass or fail determination means) **18***a*: Test condition setting unit (Setting means) **18***b*: AI prediction test condition change setting unit (AI prediction test condition change setting means) **18***e*: Output level variable setting unit (Output level setting means) **18***f*: Measurement result output unit (Pass or fail determination means) **20**: NR system simulator (Signal generator) **50**: OTA chamber (anechoic box) **51**: Internal space **56**: DUT scanning mechanism (scanning means) **100**: DUT (Device under test, Mobile terminal)

Claims

1. A mobile terminal testing device, which includes a signal generator that generates a test signal and a reception sensitivity test execution unit that performs a reception sensitivity test of a mobile terminal by transmitting and receiving the test signal a plurality of times between the signal generator and the mobile terminal, and tests the mobile terminal that is a device under test, the mobile terminal testing device comprising: setting means for initially setting a test condition including a step level and an output level of the test signal at start of the reception sensitivity test; pass or fail determination means for performing a throughput measurement by transmitting and receiving the test signal under the test condition and comparing a throughput measurement result with a determination threshold value to perform pass or fail determination; output level setting means for setting the output level according to a result of the pass or fail determination of a previous throughput measurement in a case where the result of the pass or fail determination is fail; and AI prediction test condition change setting means for holding an AI prediction model generated by performing machine learning on a relationship between parameter data and measurement result data from a measurement log file of the past reception sensitivity test using artificial intelligence, and setting an AI prediction output level, which is AI-predicted in advance by the AI prediction model based on the test condition set by the setting means, as a first output level instead of the output level.

2. The mobile terminal testing device according to claim 1, wherein the AI prediction test condition change setting means sets, instead of the step level, an AI prediction step level, which is AI-predicted in advance by the AI prediction model based on a measurement result of a first throughput measurement performed by transmitting and receiving the test signal at the AI prediction output level, as a step level for second and subsequent measurements.

3. The mobile terminal testing device according to claim 2, wherein the AI prediction test condition change setting means, in a case where a result of the pass or fail determination for the measurement result of the first throughput measurement is fail, thereafter, performs an update process of the output level for a next measurement using the AI prediction step level until a second throughput measurement.

4. The mobile terminal testing device according to claim 1, wherein the AI prediction test condition change setting means designates loss of an external connection cable, an azimuth angle (θ, φ) of the

mobile terminal, and a frequency to be measured as the parameter data, and holds the AI prediction model generated by performing the machine learning on the relationship between the parameter data and the measurement result data.

5. The mobile terminal testing device according to claim 2, wherein the reception sensitivity test execution unit, in a case where a result of the pass or fail determination for a measurement result of a second throughput measurement is fail, controls the output level setting means to perform a level down process A, a level down process B, a level up process A, or a level up process B.

6. The mobile terminal testing device according to claim 1, further comprising: an anechoic box including an internal space; and scanning means for driving and scanning the mobile terminal so as to continuously vary an orientation of the mobile terminal in the internal space, wherein the reception sensitivity test is performed in all orientations to be scanned by the scanning means in an over the air (OTA) measurement environment in the internal space.

7. A mobile terminal testing method for performing a reception sensitivity test of a mobile terminal by using a mobile terminal testing device, which includes a signal generator that generates a test signal and a reception sensitivity test execution unit that performs the reception sensitivity test of the mobile terminal by transmitting and receiving the test signal a plurality of times between the signal generator and the mobile terminal, and tests the mobile terminal that is a device under test, and by transmitting and receiving the test signal between the signal generator and the mobile terminal a plurality of times, the mobile terminal testing method comprising: a setting step of initially setting a test condition including a step level and an output level of the test signal at start of the reception sensitivity test; an AI prediction test condition change setting step of holding an AI prediction model generated by performing machine learning on a relationship between parameter data and measurement result data from a measurement log file of the past reception sensitivity test using artificial intelligence, and setting an AI prediction output level, which is AI-predicted in advance by the AI prediction model based on the test condition set by the setting step, as a first output level instead of the output level; a pass or fail determination step of performing a first throughput measurement by transmitting and receiving the test signal at the AI prediction output level and comparing a first throughput measurement result with a determination threshold value to perform pass or fail determination; and a step level change setting step of setting, instead of the step level, an AI prediction step level, which is AI-predicted in advance by the AI prediction model based on a measurement result of the first throughput measurement, as a step level for second and subsequent measurements.