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TOSHIBA CORPORATION
NED

NRW-FPGA-Based I&C System Qualification Project

Electrical, Instrumentation & Control Test Report

Title: Nuclear Instrumentation & Control Systems Departmen

EMC Qualification Report for

Safety-Related Oscillation Power Range Monitor (OPRM)

Customer Name	None
Project Name	NRW-FPGA-Based I&C System Qualification Project
Item Name	OPRM Equipment
Item Number	C51
Job Number	9P04482
Applicable Plant	None

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0	See Cover Page	Initial Issue	See Cover Page	See Cover Page	See Cover Page

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1. EXECUTIVE SUMMARY

The Electromagnetic Compatibility (EMC) qualification test for safety-related Oscillation Power Range Monitor (OPRM) for NRW-FPGA-Based I&C System Qualification Project was performed from December 3 2012 through January 07 2013 at the test chamber No.1 in [ ]a,c (hereinafter referred to as [ ]a,c). The objective of the EMC qualification test is to demonstrate the suitability and compatibility of the OPRM in accordance with the requirements specified in the Master Test Plan (Reference (18)) and the EMC Qualification Test Plan (Reference (17)) based on the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.180, Revision 1 (Reference (3)) and the EPRI TR-107330 (Reference (13)).

The EMC qualification test was executed in accordance with EMI/RFI Test Procedure (References (22)), Power Surge Test Procedure (Reference (23)), ESD Test Procedure (Reference (24)), and [ ]a,c EMI Test Procedure (Reference (31)). The specific OPRM unit and its detailed configuration qualified through this EMC qualification program are identified in the Master Configuration List (MCL) (Reference (14)).

The following EMI/RFI test was successfully performed in accordance with Department of Defense Interface Standard MIL-STD-461E (Reference (8)):

- CE101 : Conducted Emissions, Low-frequency
- CE102 : Conducted Emissions, High-frequency
- RE101 : Radiated Emissions, Magnetic Field
- RE102 : Radiated Emissions, Electric Field
- CS101 : Conducted Susceptibility, Low-frequency
- CS114 : Conducted Susceptibility, High-frequency
- CS115 : Conducted Susceptibility, Bulk Cable Injection
- CS116 : Conducted Susceptibility, Damped Sinusoidal Transients
- RS101 : Radiated Susceptibility, Magnetic Field
- RS103 : Radiated Susceptibility, Electric Field

The following power surge test and ESD test were successfully performed in accordance with referenced International Electrotechnical Commission (IEC) Standards:

- IEC 61000-4-2, "Electromagnetic Compatibility (EMC)-Part 4: Testing and Measurement Techniques, Section 2: Electrostatic Discharge Immunity Test," International Electrotechnical Commission, 1995
- IEC 61000-4-4, "Electromagnetic Compatibility (EMC)-Part 4: Testing and Measurement Techniques, Section 4: Electrical Fast Transient/Burst Immunity Test," International Electrotechnical Commission, 1995
- IEC 61000-4-5, "Electromagnetic Compatibility (EMC)-Part 4: Testing and Measurement Techniques, Section 5: Surge Immunity Test," International Electrotechnical Commission, 1995
- IEC 61000-4-12, "Electromagnetic Compatibility (EMC)-Part 4: Testing and Measurement Techniques, Section 12: Oscillatory Waves Immunity Tests," International Electrotechnical Commission, 1996

The EMC qualification test results were documented in this report and the [ ]a,c EMI Test Report (Reference (32)).

It was concluded in this EMC qualification report that the OPRM was designed to accommodate the effects of and to be compatible with the environmental conditions required by the RG 1.180, Revision 1 (Reference (3)) and the EPRI TR-107330 (Reference (13)) and the OPRM was qualified for safety-related component for nuclear power plants.

2. PURPOSE

The purpose of this document is to report the result of EMC qualification test and qualification analysis performed on the safety-related OPRM for the NRW-FPGA-Based I&C System Qualification Project in accordance with the requirements of the EMC Qualification Test Plan (Reference (17)) which was established based on RG 1.180, Revision 1 (Reference (3)) and the EPRI TR-107330 (Reference (13)).

3. SCOPE

The Power Range Neutron Monitor (PRNM) subsystem consists of four equivalent divisions. One division of the PRNM subsystem consists of four Local Power Range Monitor (LPRM) units, one Average Power Range Monitor (APRM) unit, one OPRM unit, and one Relay unit. The LPRM units, APRM unit, OPRM unit, and Relay unit are included in the Neutron Monitor System (NMS) Panel per division and installed in the Main Control Room (MCR) back panel area.

The scope of the equipment to be qualified is one OPRM unit that is a part of functional subsystem of the PRNM per one division as enclosed by the bold and dotted line in Figure 3-1 which is a copy of Figure 4-1 of the Equipment Design Specification (EDS) (Reference (15)). The EMC qualification test is performed using test specimen as a type testing in accordance with Clause 5.1.1 of the IEEE Std. 323-2003 (Reference (9)).

According to the Advanced Boiling Water Reactor Design Control Document (ABWR DCD) (Reference (11)), the PRNM subsystem is classified as Category I for seismic category, Class 1E for electrical equipment, and Safety Class 3 (SC-3).

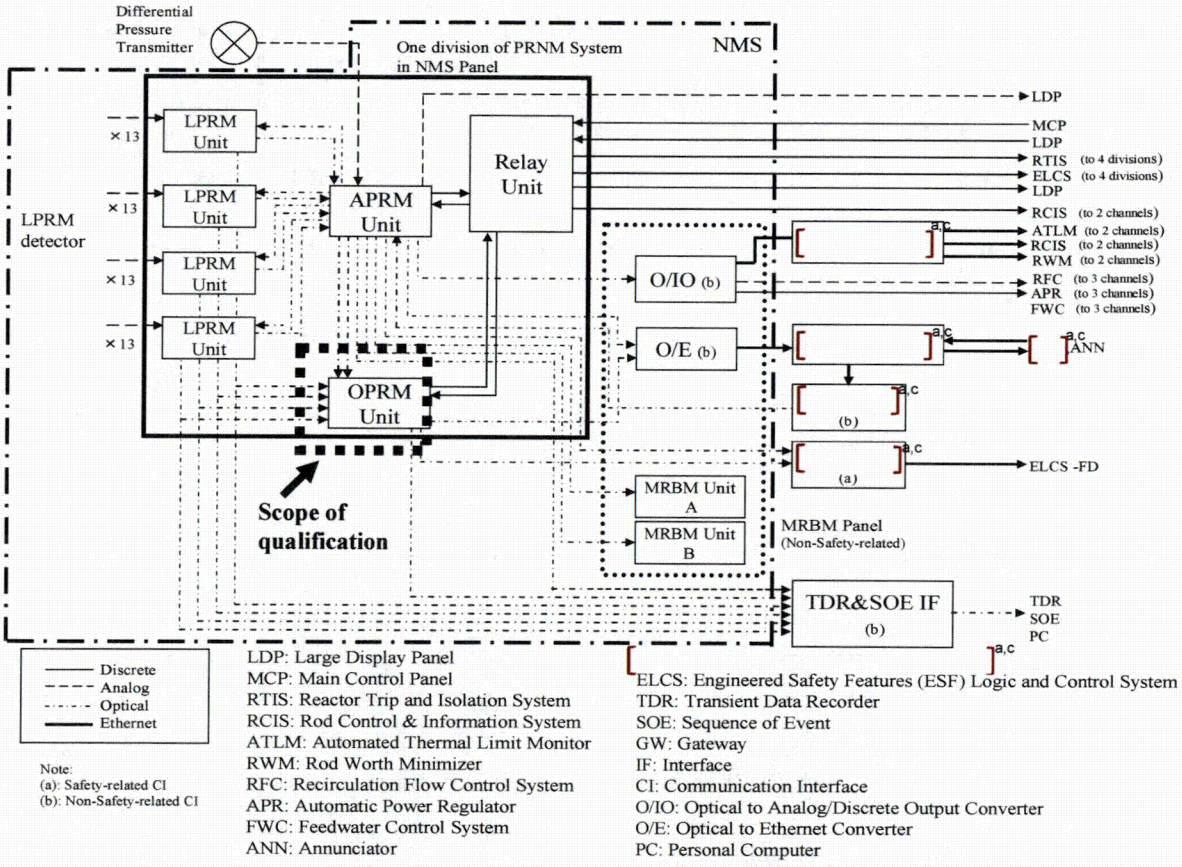


Figure 3-1 Scope of EMC Qualification

4. REFERENCES

4.1 Applicable Regulations, Codes and Standards

(1) 10 CFR 21, "Reporting of Defects and Noncompliances"

(2) 10 CFR 50 Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants"

(3) U.S. Nuclear Regulatory Commission, Regulatory Guide 1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems," Revision 1, October 2003

(4) IEC 61000-4-2, "Electromagnetic Compatibility (EMC)-Part 4: Testing and Measurement Techniques, Section 2: Electrostatic Discharge Immunity Test," International Electrotechnical Commission, 1995

(5) IEC 61000-4-4, "Electromagnetic Compatibility (EMC)-Part 4: Testing and Measurement Techniques, Section 4: Electrical Fast Transient/Burst Immunity Test," International Electrotechnical Commission, 1995

(6) IEC 61000-4-5, "Electromagnetic Compatibility (EMC)-Part 4: Testing and Measurement Techniques, Section 5: Surge Immunity Test," International Electrotechnical Commission, 1995

(7) IEC 61000-4-12, "Electromagnetic Compatibility (EMC)-Part 4: Testing and Measurement Techniques, Section 12: Oscillatory Waves Immunity Tests," International Electrotechnical Commission, 1996

(8) MIL-STD-461E, "Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment," 1999

(9) IEEE Std. 323-2003, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations"

(10) IEEE Std. 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations"

(11) ABWR Design Control Document (ABWR DCD)

(12) EPRI TR-102323 "Guidelines for Electromagnetic Interference Testing of Power Plants Equipment," November 2004, Revision 3

(13) EPRI TR-107330 "Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants," December 1996

4.2 Project Documents

(14) Toshiba, FC51-2504-1000 Rev.14 (5B8K0042), "Master Configuration List for NRW-FPGA-Based I&C System Qualification Project" (MCL)

(15) Toshiba, FC51-3002-1000 Rev.3 (5B8K0029), "Equipment Design Specification for Power Range Neutron Monitor" (EDS)

(16) Toshiba, FC51-3201-1000 Rev.10 (7K8K0002), "ECWD for OPRM Test System"

(17) Toshiba, FC51-7012-1001 Rev.4 (5B8K0055), "Nuclear Instrumentation & Control Systems Department EMC Qualification Test Plan for Safety-related Oscillation Power Range Monitor (OPRM)" (EMC Qualification Test Plan)

(18) Toshiba, FC51-7021-1000 Rev.1 (5B8K0040), "Master Test Plan for NRW-FPGA-Based I&C System Qualification Project"

(19) Toshiba, FC51-7021-1002 Rev.1 (AUY-10576), "Setup & Check-out Test Procedure for NRW-FPGA-Based I&C System Qualification Project" (Setup & Check-out Test Procedure)

(20) Toshiba, FC51-7021-1003 Rev.1 (AUY-10577), "Operability Test Procedure for NRW-FPGA-Based I&C System Qualification Project" (Operability Test Procedure)

(21) Toshiba, FC51-7021-1004 Rev.1 (AUY-10578), "Prudency Test Procedure for NRW-FPGA-Based I&C System Qualification Project" (Prudency Test Procedure)

(22) Toshiba, FC51-7021-1007 Rev.3 (AUY-10581), "EMI/RFI Test Procedure for NRW-FPGA-Based I&C System Qualification Project" (EMI/RFI Test Procedure)

(23) Toshiba, FC51-7012-1009 Rev.2 (AUY-10583), "Power Surge Test Procedure for NRW-FPGA-Based I&C System Qualification Project" (Power Surge Test Procedure)

(24) Toshiba, FC51-7012-1010 Rev.2 (AUY-10584), "ESD Test Procedure for NRW-FPGA-Based I&C System Qualification Project" (ESD Test Procedure)

(25) Toshiba, FC51-7021-1016 Rev.0 (ATC-103590), "EMI/RFI Test Record for NRW-FPGA-Based I&C System Qualification Project" (EMI/RFI Test Record)

(26) Toshiba, FC51-7021-1018 Rev.0 (ATC-103592), "Power Surge Test Record for NRW-FPGA-Based I&C System Qualification Project" (Power Surge Test Record)

(27) Toshiba, FC51-7021-1019 Rev.0 (ATC-103593), "ESD Test Record for NRW-FPGA-Based I&C System Qualification Project" (ESD Test Record)

(28) Toshiba, FC51-7021-1026 Rev.0 (ATC-103865), "Performance Proof (Pre-Qualification for EMC Test) Test Record for NRW-FPGA-Based I&C System Qualification Project" (Performance Proof (Pre-Qualification for EMC Test) Test Record)

(29) Toshiba, FC51-7021-1027 Rev.0 (ATC-103866), "Performance Proof (Post-Qualification for EMC Test) Test Record for NRW-FPGA-Based I&C System Qualification Project" (Performance Proof (Post-Qualification for EMC Test) Test Record)

(30) Toshiba, FC51-7501-1000 Rev.0 (ATC-103583), "Calibration Record of Toshiba's M&TEs for NRW-FPGA-Based I&C System Qualification Project" (Calibration Record of Toshiba's M&TEs)

(31) [ ]^{a,c}T70626-10 Rev. B, "ELECTROMAGNETIC INTERFERENCE (EMI) TEST PROCEDURE ON AN OSCILLATION POWER RANGE MONITOR (OPRM) SYSTEM" ([ ]^{a,c}EMI Test Procedure)

(32) [ ]^{a,c}T70626-01 Rev. C, "ELECTROMAGNETIC INTERFERENCE (EMI) TEST REPORT OSCILLATION POWER RANGE MONITOR (OPRM) SYSTEM" ([ ]^{a,c}EMI Test Report)

4.3 Toshiba Documents

(33) NQ-2003, "Procedure for Control of Software Tools"

(34) NQ-2024, "Procedure for Document Control"

(35) NQ-3005, "Procedure for Evaluation of Suppliers"

(36) NQ-3011, "Qualification Procedure of Test Personnel and QC Inspector"

(37) NQ-3017, "Measuring and Test Equipment Control Standard"

5. DEFINITIONS AND ABBREVIATIONS

5.1 Definitions

(1) **Burst**
[See Section 8 of EPRI TR-102323 (Reference (12)).]

(2) **Class 1E**
[See Clause 2 of IEEE Std. 603-1991 (Reference (10))]

(3) **Electrically-Fast Transient (EFT)**
[See Section 8 of EPRI TR-102323 (Reference (12)).]

(4) **Electromagnetic Compatibility (EMC)**
[See Section 8 of EPRI TR-102323 (Reference (12)).]

(5) **Electromagnetic Interference (EMI)**
[See Section 8 of EPRI TR-102323 (Reference (12)).]

(6) **Electrostatic Discharge (ESD)**
[See Section 8 of EPRI TR-102323 (Reference (12)).]

(7) **Immunity**
[See Section 8 of EPRI TR-102323 (Reference (12)).]

(8) **Interference**
[See Section 8 of EPRI TR-102323 (Reference (12)).]

(9) **Safety Function**
[See Clause 2 of IEEE Std. 603-1991 (Reference (10))]

(10) **Surge**
[See Section 8 of EPRI TR-102323 (Reference (12)).]

(11) **Susceptibility**
[See Section 8 of EPRI TR-102323 (Reference (12)).]

(12) **Test Specimen**
[See Section 2.1 of EPRI TR-107730 (Reference (13)). For the purpose of this project, this definition is interpreted as "FPGA-based OPRM unit, which is the set of unit chassis and modules including FPGA chip that embeds FPGA logic to perform its intended safety functions, used as the basis for generic Qualification Testing."]

(13) **Test Equipment**
[See Section 2.1 of EPRI TR-107730 (Reference (13)).]

(14) **Test Setup Boundary**
[See Section 3.11 of MIL-STD-461E (Reference (8)).]

(15) **Type Test**
[See Clause 5.1.1 of IEEE Std. 323-2003 (Reference (9)).]

5.2 Abbreviations

ABA	Amplitude Based detection Algorithm
ABWR	Advanced Boiling Water Reactor
AC	Alternating Current
APRM	Average Power Range Monitor
C	Celsius

CI	Communication Interface
CRC	Cyclic Redundancy Check
DC	Direct Current
DCD	Design Control Document
ECWD	Electrical Cable Wiring Diagram
EDS	Equipment Design Specification
ELCS	Engineered safety features Logic and Control System
EPRI	Electric Power Research Institute
EFT/B	Electrically Fast Transients and Burst
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EQ	Equipment Qualification
ESD	Electro Static Discharge
ESF	Engineered Safety Features
F	Fahrenheit
FD	Flat Display
FPGA	Field Programmable Gate Array
EUT	Equipment Under Test
GRA	Growth Rate-Based Detection Algorithm
Hz	Hertz
I&C	Instrumentation & Control
IEEE	Institute of Electrical and Electronics Engineers, Inc.
LDP	Large Display Panel
LISN	Line Impedance Stabilization Network
LPRM	Local Power Range Monitor
M&TE	Measuring and Test Equipment
MCL	Master Configuration List
MCR	Main Control Room
MRA	Mutual Recognition Arrangement
NMS	Neutron Monitoring System
NICSD	Nuclear Instrumentation & Control Systems Department
NIST	National Institute of Standard and Technology
NRC	Nuclear Regulatory Commission
NRW-FPGA	Non-Rewritable FPGA
OPRM	Oscillation Power Range Monitor
PBDA	Period Based Detection Algorithm
PFC	Power Factor Correction module
[ ]^{a,c}	[ ]^{a,c}
PLC	Programmable Logic Controller
PRNM	Power Range Neutron Monitor
QA	Quality Assurance
QC	Quality Control
RFI	Radio Frequency Interference
RG	Regulatory Guide
RPS	Reactor Protection System
SC	Safety Class
SNNR	Fuchu Site Nonconformance Notice Report
SOE	Sequence of Event
SRAM	Static Random Access Memory
TDR	Transient Data Recorder
V&V	Verification & Validation

6. DESCRIPTION OF TEST SPECIMEN

6.1 OPRM Function Overview

The OPRM unit monitors neutron flux oscillation. The OPRM unit receives 52 LPRM Levels from 4 LPRM units and forms 44 OPRM Cell configurations to monitor the neutron flux behavior of all regions of the core. For each Cell, the peak to average value of the OPRM signal is determined to evaluate the amplitude of oscillation and to be used in the setpoint algorithm. The OPRM trip protection algorithm consists of trip logic depending on signal oscillation amplitude, a signal oscillation period, and signal oscillation growth rate. If one of the Cells fulfills any one of three trip conditions, the OPRM unit generates a trip signal. The OPRM unit also receives APRM Level and Core Flow Level from the APRM unit and the trip algorithms are automatically bypassed if APRM Level is less than 30% (initial setpoint) or Core Flow Level is greater than 60% (initial setpoint). The OPRM provides optical transmission output signals to the Plant Information and Control System[ ]^{a,c}, Sequence of Event (SOE) and Transient Data Recorder (TDR) via Non-Safety-Related Communication Interface (CI) and Engineered Safety Features (ESF) Logic & Control System Flat Display (ELCS FD) via Safety-Related CI.

6.2 Test Specimen Structure

The test specimen is comprised of one OPRM unit with two Power Factor Correction modules (PFCs) as outside modules of the OPRM unit. The OPRM unit consists of a unit chassis and 11 modules comprising eight different functional modules: two RCV, one CELL, one AGRD, one PBD, one DAT/ST, two TRN, one DIO, and two LVPS modules. The PFC receives Alternating Current (AC) voltage from an external AC power supply. The AC voltage is converted into Direct Current (DC) voltage (about 220 VDC) by the PFC. The PFC supplies DC voltage to the LVPS modules.

The mechanical characteristics of test specimen are shown as follows:

- OPRM unit (Refer to Figure 6-1 for photograph. Detailed outline drawing is attached to Figure A- 1.)
  Dimensions: 482.6 (W) x 440.8 (D) x 177.0 (H) [mm]
  (19.00 (W) ×17.35 (D) ×6.97 (H) [inch])
  Mass: 14.742 kg

- PFC (Refer to Figure 6-2 for photograph. Detailed outline drawing is attached to Figure A- 2.)
  Dimensions: 170.0 (W) x 127.0 (D) x 35.0 (H) [mm]
  (6.69(W) ×5.00 (D) ×1.38(H) [inch])
  Mass: 0.540 kg

The test specimen used for test is identified in the Master Configuration List (MCL) (Reference (14)). The MCL also identifies the specific versions of the FPGA logic embedded in FPGA chips mounted on the test specimen. The identification, description, and quantity of the test specimen are shown below in Table 6-1.

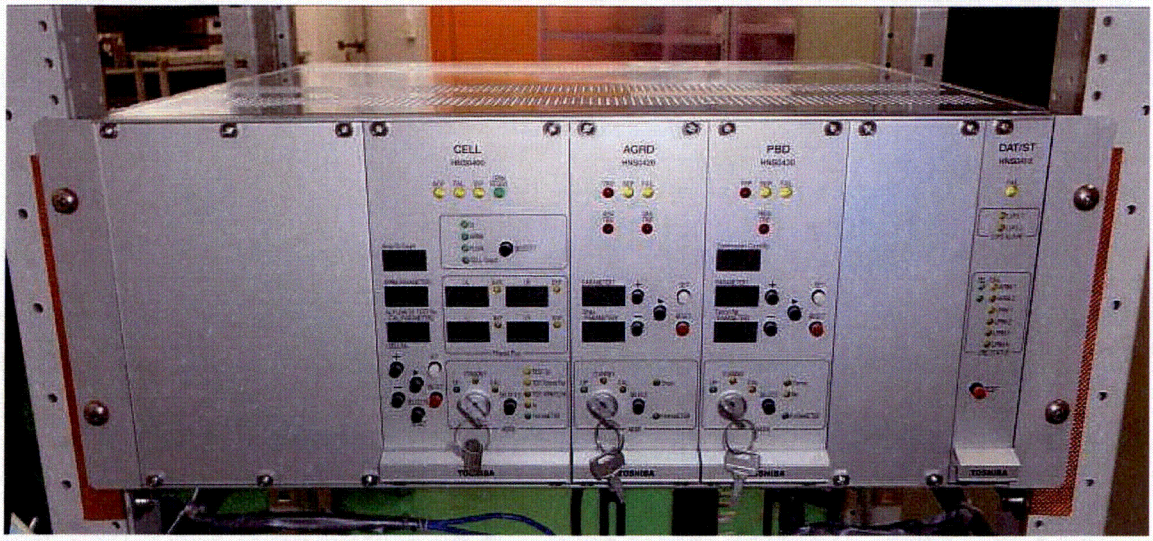


Figure 6-1 OPRM Unit Overview

[a,c]

Figure 6-2 PFC Overview

Table 6-1 Test Specimen List

Description		Model Number	Manufacturer	Qty	Slot ID	Serial Number	Note
OPRM Unit	Processor	HNU1200B00000	Toshiba	1	—	10920017	
OPRM Chassis	Chassis	[ ]a,c	[ ]a,c	1	—	[ ]a,c	
CELL Module	Processor	HNS0400B00000	Toshiba	1	FSL 5 to 7	1206818335	
AGRD Module	Processor	HNS0420B00000	Toshiba	1	FSL 8 to 9	1206818331	
PBD Module	Processor	HNS0430B00000	Toshiba	1	FSL 10 to 11	1206818312	
DAT/ST Module	Processor	HNS0410B00000	Toshiba	1	FSL 14	1206818322	
LVPS Module	Power supply	HNS0500B00000	Toshiba	2	PSSL 1	1282858	LVPS 1
					PSSL 2	1282859	LVPS 2
DIO Module	Interlock	HNS0520B00000	Toshiba	1	BSL 4	1202803706	
TRN Module	Optical Transmitter	HNS0531B00000	Toshiba	2	BSL 7	1206818325	
					BSL 8	1206818326	
RCV Module	Optical Receiver	HNS0541B00000	Toshiba	2	BSL 5	1206818316	
					BSL 6	1206818317	
PFC	Power Factor Correction module	[ ]a,c	[ ]a,c	2	—	[ ]a,c	PFC 1
					—	[ ]a,c	PFC 2

6.3 Safety-Related Functions to be Demonstrated

The safety-related functions to be demonstrated by the EMC qualification test are described below:

(1) Generate Normalized Oscillation Signal
The OPRM unit generates the Normalized Oscillation Signals using LPRM Levels for each OPRM Cell. The Normalized Oscillation Signals shall be checked by the optical transmission output signals from the TRN modules.

(2) Generate the following trip signals and provide to the Reactor Protection System (RPS)
The OPRM unit generates the following trip signals as discrete output signals.

(2-1) Growth Rate-Based Detection Algorithm Trip (GRA Trip)
The OPRM unit generates the GRA Trip signal when the amplitude growth rate of Normalized Oscillation Signal exceeds specified values. The GRA Trip shall be checked by monitoring a discrete output signal from the DIO module. Contact of discrete output interface opens if the GRA Trip signal is generated.

(2-2) Amplitude-Based Maximum Algorithm Trip (ABA Trip)
The OPRM unit generates the ABA Trip signal when the relative signal amplitude of Normalized Oscillation Signal exceeds specified values. The ABA Trip shall be checked by monitoring a discrete output signal from the DIO module. Contact of discrete output interface opens if the ABA Trip signal is generated.

(2-3) Period Based Detection Algorithm (PBDA Trip)
The OPRM unit generates the PBDA Trip signal when the number of successive oscillation cycles

within that frequency range and the oscillation amplitude of Normalized Oscillation Signal exceed specified values. The PBDA Trip shall be checked by a monitoring discrete output signal from the DIO module. Contact of discrete output interface opens if the PBDA Trip signal is generated.

(2-4) OPRM Inoperative

The OPRM unit generates the OPRM Inoperative signal when the instrument anomalies or error on the processes, or loss of all the power supplies occur, as described in "(6) Failure Detection and Diagnostic functions", which may cause significant negative impact on signal processing or trip determination. The OPRM Inoperative signal shall be checked by monitoring discrete output signals from the DIO module. Contact of discrete output interface opens if the OPRM Inoperative signal is generated.

(2-5) OPRM Trip

The OPRM unit generates the OPRM Trip signal if any of the following conditions is satisfied:

(a) The ABA Trip is detected in any of 44 OPRM Cells.
(b) The GRA Trip is detected in any of 44 OPRM Cells.
(c) The PBDA Trip is detected in any of 44 OPRM Cells.

The OPRM Trip signal shall be checked by monitoring discrete output signals from the DIO module. Contact of discrete output interface opens if the OPRM Trip signal is generated.

(3) Provide data signals, bypass state, trip state, annunciator, and operation state.

The OPRM unit provides one-way optical transmission output signal as safety-related signal to the ELCS - FD from one TRN module (hereinafter referred to as "ELCS[ ]^{a,c}data"). While, the OPRM unit also provides one-way optical transmission output signals as non-safety-related signals to TDR and SOE from the other TRN module (hereinafter referred to as "PC data").

Normally, the "ELCS[ ]^{a,c}data" as safety-related signal is only evaluated and the "PC data" is not evaluated. However, the "PC data" is generated based on the same information and equivalent processes as the "ELCS[ ]^{a,c}data" in the DAT/ST module, although the "PC data" is not safety-related signal. The "PC data" also contains more information for demonstrating the soundness of the OPRM units in addition to "ELCS[ ]^{a,c}data." Therefore, "PC data" should be monitored and recorded for failure analysis in case of failure under the environmental stress.

(4) Receive the bypass signal

The OPRM unit receives the APRM Bypass signal as discrete input signal at the DIO module from the Large Display Panel (LDP). According to Section 5.2.2.4.2.2 of the EDS, the OPRM Trip and OPRM Inoperative are bypassed by the APRM Bypass Signal in the Relay unit. In the OPRM unit, only when the APRM Bypass turns to disable from enable, the function of the OPRM unit is initialized. The APRM Bypass signal shall be checked by monitoring discrete input signals from the aux-relay plate to guarantee the soundness of the APRM Bypass signal. When APRM Bypass signal is provided to the OPRM unit, input voltage of the discrete input is 24VDC. Otherwise input voltage of the discrete input is 0VDC.

(5) Generate the OPRM Automatic Bypass signal

The OPRM Automatic Bypass signal is not classified as a safety-related function as described in Section 4.1.1.3 of the EDS. According to Section 5.2.2.3.7 of the EDS, however, the OPRM trip functions are automatically bypassed if the APRM reading or the same channel is 30% below the rated power or the core follow reading is 60% above the rated flow. Because the function of the OPRM trip is bypassed automatically under the condition stated above, the OPRM Automatic Bypass signal is regarded as a safety-related function in the EMC qualification test. The OPRM Automatic Bypass signal shall be checked by a monitoring discrete output signal from the DIO module.

(6) Failure Detection and Diagnostic functions

The OPRM generates an OPRM Inoperative signal when detecting any of the following failures:

(a)[ ]^{a,c}
(b)[ ]^{a,c}
(c)[ ]^{a,c}
(d)[ ]^{a,c}
(e)[ ]^{a,c}

(f) "STANDBY" mode or "CAL" mode is selected
(g) Number of Active OPRM Cell is lower than the setpoint
(h) [ ]a,c
(i) [ ]a,c
(j) APRM Inoperative occurs (APRM Inoperative flag is included in APRM Unit Data 1 and 2)

In the EMC qualification test, the functions (a), (b), (e), (h) and (i) of the OPRM Inoperative cannot be simulated unless the OPRM unit is decomposed. Since those functions are designed to be "fail-safe", it is ensured that the OPRM Inoperative signal is generated whenever there is an error in any of those functions. Even if the OPRM Inoperative signal cannot be generated due to spurious FPGA behavior under the conditions (a), (b), (e), (h) and (i), the error can be detected by monitoring optical transmission output data. Therefore, as long as the OPRM Inoperative signal and optical transmission output data are constantly monitored, the soundness of the OPRM unit is ensured without simulating the functions (a), (b), (e), (h) and (i).

The functional specifications of the OPRM unit are detailed in Section 5.1 of the EDS (Reference (15)).

6.4 Intentional Oscillators and Antenna

The intentional oscillator's (frequency generators) characteristics used in the OPRM unit are listed in Table 6-2. The OPRM unit has no antenna-connected receiver and antenna to emit electromagnetic field.

Table 6-2 Intentional Oscillator in OPRM Unit

Module	Number of modules	Frequency	Description
CELL	1	[	]a,c
AGRD	1		
PBD	1		
DAT/ST	1		
LVPS	2		
DIO	1		
TRN	2		
RCV	2		
PFC	2		

6.5 Modification

No design modifications were made to the test specimen throughout this EMC qualification program.

6.6 Failure and Repair

There was no failure and repair of the test specimen throughout this EMC qualification program.

6.7 Preventive Maintenance and Surveillance

No preventive maintenance and surveillance were required in this project.

7. DESCRIPTION OF TEST SYSTEM AND INSTRUMENTS

7.1 Test System Overview

The test system configuration is shown in Figure 7-2. The test specimen shown in Table 6-1 was mounted on a test specimen rack placed in an EMC chamber, which is the shielded enclosure of the [ ]a,c test chamber No.1 shown in Figure 7-1. Test equipment was mounted on a test equipment rack placed in the control room outside the EMC chamber. All the cables were connected to the test system according to the Electrical Cable Wiring Diagram (ECWD) for OPRM Test System (Reference (16)).

The test equipment mainly consists of

[ ]a,c

A [ ]a,c optical transmit output. A [ ]a,c optical receive input. The [ ]a,c simulates one APRM unit. A redundant optical transmission input signal from the APRM unit is simulated by [ ]a,c [ ].a,c Since optical transmission input signals from the APRM unit are only used for OPRM Region determination in the OPRM unit and need not undergo a transient change, those signals are output as constant data. The OPRM unit always monitors optical transmission input signals from the APRM unit, and the soundness of the constant data is ensured through a performance proof test before and after the EMC qualification test. Thus the simulated output of the APRM unit is not monitored at the [ ]a,c during the EMC qualification test. The [ ]a,c is used to simulate four LPRM units. One port of the [ ]a,c simulates optical transmission signals of one LPRM unit containing 13 LPRM Levels, which undergoes a transient change, and provides those signals to the OPRM unit. The [ ]a,c sends the same data as that sent by the [ ]a,c for loopback monitoring.

The [ ]a,c monitors the optical transmission output signals from the OPRM unit. Since the optical transmission signals output from the OPRM unit to ELCS and [ ]a,c are equivalent, one typical port of those four ports on the TRN module (TRN1) in the OPRM unit is monitored with one port of the [ ].a,c Since the optical signals output from the OPRM unit to SOE and TDR are equivalent, one typical port of those four ports on the TRN module (TRN2) in the OPRM unit is monitored with one port of the [ ].a,c The [ ]a,c monitors the optical transmission output signals from the PCTRN3. The signals recorded in the PC4 of the loop back monitor are not normally evaluated. However, if there is a problem in the qualification test result, these signals will be used to check the soundness of the [ ]a,c operation.

The Relay unit is simulated by the aux-relay plate which uses a general mechanical relay. Discrete output signals from the OPRM unit are monitored with the data recorder via the aux-relay plate. A discrete input signal (i.e., APRM bypass signal) is provided to the OPRM unit via the aux-relay plate.

The OPRM unit is powered from redundant Class 1E AC power supplies. Both of those AC power supplies provide nominal 120 VAC, 60 Hz power. Therefore, those two power supplies which satisfy the above-mentioned specifications are used as the test equipment in the EMC qualification test. Fuses, varistors, and noise filters equivalent to components used for actual installation are inserted to the power lines in the test specimen rack. These fuses, varistors, and noise filters are dealt as test equipment not as test specimen.

7.2 Electrical Interface

The test specimen was connected with the test system in accordance with the electrical interface requirements shown in Table 7-1, which will be applied to the actual installation.

Table 7-1 Electrical Interface

EUT	Module	Number of Conductors		Type	Connector Type	To/From	Voltage	Max. Current
OPRM Unit	DIO Module (BSL 4)	19	3	Discrete Input	[ ]a,c (38pin)	Relay Panel	0 to 24VDC	10 mA / line
			16	Discrete Output			0 to 24VDC	10 mA / line
	RCV module (BSL5)	4 Fiber		Optical Input	FC	PCTRN2	N/A	N/A
	RCV module (BSL6)	2 Fiber		Optical Input	FC	PCTRN1	N/A	N/A
	TRN module (BSL7)	1 Fiber		Optical Output	FC	PCRCV1	N/A	N/A
	TRN module (BSL8)	1 Fiber		Optical Output	FC	PCRCV1	N/A	N/A
	PFC 1 (External module)	3 (L, N, G)		Power	Wire	Power Supply	81 to 165VAC 51 to 70 Hz	10A
	PFC 2 (External module)	3 (L, N, G)		Power	Wire	Power Supply	81 to 165VAC 51 to 70 Hz	10A

7.3 Test Support Equipment

Table 7-2 shows the list of the test support equipment used for the EMC qualification test. The configuration of test equipment software has been controlled in accordance with NQ-2003 "Procedure for Control of Software Tools" (Reference (33)).

7.4 Measuring and Test Equipment (M&TE)

Table 7-3 shows the list of the Measuring and Test Equipment (M&TE) used by Toshiba for the EMC qualification test. The M&TEs were traceable to US National Institute of Standard and Technology (NIST), NIST through a Mutual Recognition Arrangement (MRA), or US nationally recognized standards in accordance with NQ-3017 "Measuring and Test Equipment Control Standard" (Reference (37)). All the Toshiba's M&TEs were demonstrated that the type, range, accuracy, resolution, and tolerance of the instrumentation were suitable for application, as shown in the Calibration Record of Toshiba's M&TEs (Reference (30)).

The M&TEs prepared by[ ]a,c were controlled in accordance with[ ]a,c applicable M&TE control procedure. The identification of the M&TEs prepared by[ ]a,c was documented in the[ ]a,c EMI Test Report (Reference (32)).

7.5 Test Laboratory

The EMC qualification test was conducted at[ ]a,c All the EMC qualification tests specified by EMC Qualification Test Plan (Reference (17)) were accredited as Certificate No. 0845.01 by the American Association for Laboratory Accreditation (A2LA).

Toshiba personnel were present when tests were conducted to ensure that EMC testing were performed according to supplier's test procedure, as well as to resolve any issues during the EMC qualification test.

7.6 Shielded Enclosures

The EMC chamber, which is the shielded enclosure of the[ ]a,c test chamber No.1 shown in Figure 7-1, provided a minimum of 100 dB attenuation to radio frequency (RF) electric fields. The magnetic field attenuation is a

minimum of 20 dB at 1 kHz, rising to 100 dB at 200 kHz and beyond. Low-pass filters on the 480 VAC / 60 Hz, 115 VAC / 60 Hz, 120 VAC / 400 Hz, and 250 VDC power lines provide a minimum of 100 dB of attenuation from 14 kHz to 10 GHz. The enclosure was kept free of all unnecessary personnel and equipment during the test.

Figure 7-1[ ]a,c Test Chamber No. 1

7.7 Quality Assurance

Toshiba performed the EMC qualification program under the Nuclear Instrumentation & Control Systems Department (NICSD) quality assurance program, which complies with the applicable requirements of 10 CFR 50, Appendix B (Reference (2)) and 10 CFR 21 (Reference (1)). Toshiba Test Personnel regarding this test activity was qualified in accordance with NQ-3011 "Qualification Procedure of Test Personnel and QC Inspector" (Reference (36)). All related documents were controlled in accordance with NQ-2024 "Procedure for Document Control" (Reference (34)).

[ ]a,c provided the EMC testing service for this EMC qualification program in accordance with the[ ]a,c quality assurance program, which complies with the applicable requirements of 10 CFR 50, Appendix B and 10 CFR 21. [ ]a,c was evaluated and registered in the Qualified Vendor List (QVL) of NICSD in accordance with NQ-3005 "Procedure for Evaluation of Suppliers" (Reference (35)).

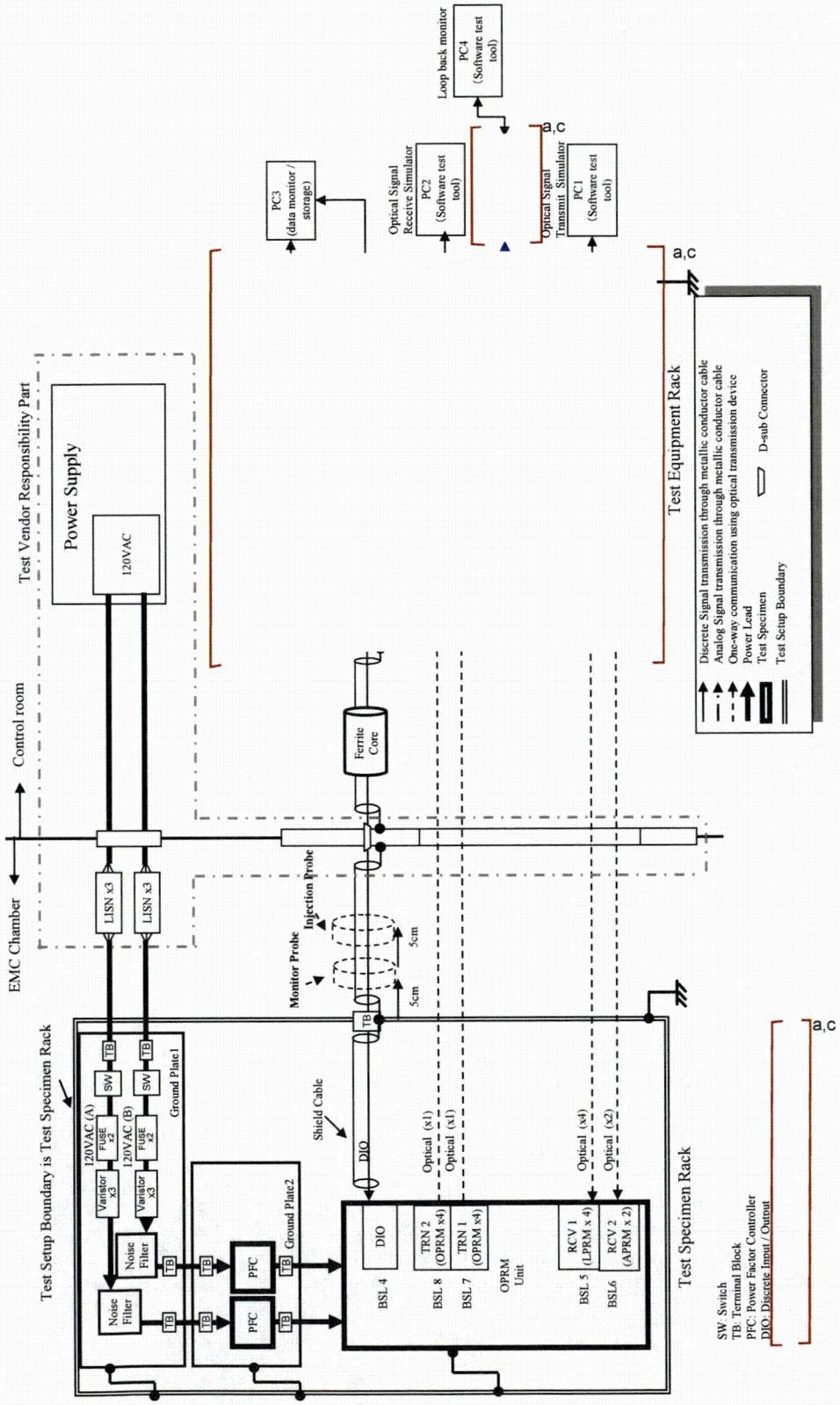


Figure 7-2 Test System

Table 7-2 Test Support Equipment List

No.	Description /Model#	Serial# / Control#	Manufacturer	Notes
1	AC Power Supply /PCR2000LA	[ ]a,c	[ ]a,c	For providing the test specimen with AC power.
2	Test Specimen Rack / None	None / None	Toshiba	For containing the EUT and power supply line components as test support equipment such as switches (SW), fuses, varistors, and noise filters. , (24" Width x 27" Depth x 63" Height)
3	Test Equipment Rack / None	None / None	Toshiba	For containing test support equipment such as aux-relay plate, DC power supply and noise cut transformer. (24" Width x 27" Depth x 63" Height)
4	Optical Signal Transmit Simulator (OSTS) /(Note 1)	(Note 1, Note 2)	Toshiba	Comprised of PC1, three PCTRNs in PCI Ex-Box1. For simulating optical transmission input signals to the OPRM unit.
5	Optical Signal Receive Simulator (OSRS) /(Note 1)	(Note 1)	Toshiba	Comprised of PC2 and one PCRCV in PCI Ex-Box2. For receiving optical transmission output signals from the OPRM unit.
6	Loopback Monitor (LBM) /(Note 1)	(Notes 1)	Toshiba	Comprised of PC4 and one PCRCV in PCI Ex-Box3. For receiving the optical transmission output from the OSTS and checking the soundness of the OSTS.
7	Data Logger [ ]a,c	[ ]a,c	[ ]a,c	For acquiring discrete input and output signals from the OPRM unit with PC3.

Note
1: The detailed hardware and software configuration of the OSTS, OSRS, and LBM is identified in the Software Tool Registration Application Form (FDTR-12-0003-KM Rev.0 (Software tool name: OPRM Test Tool)).
2: The test pattern files used for qualification tests and related documents are identified in the Software Tool Registration Application Form (FDTR-12-0004-KM Rev.0 (Software tool name: OPRM Test Pattern Files)).

Table 7-3 Measuring and Test Equipment List

No.	Description /Model#	Serial# / Control#	Manufacturer	Calibration Due Date	Notes
1	Digital Multimeter [ ]a,c	[ ]a,c	[ ]a,c	Jul. 31, 2013	For measurement of voltage of power supply
2	Clamp On AC/DC Hitester [ ]a,c	[ ]a,c	[ ]a,c	Jul. 31, 2013	For measurement of current and frequency of power supply
3	Scope Corder [ ]a,c	[ ]a,c	[ ]a,c	Jul. 31, 2013	For timing measurement of discrete output signals
	Extension Unit in Scope Corder [ ]a,c	[ ]a,c	[ ]a,c		

8. TEST PROCEDURE

The EMC qualification test has been completed meeting the requirements in the EMC Qualification Test Plan (Reference (17)).

8.1 Test Item and Test Sequence

The EMC qualification tests were performed in the following order.

1. Pre-Qualification Test (Performance Proof Test)
2. EMC Qualification Test
   2-1. EMI/RFI Emission Test, MIL-STD-461E
   2-2. EMI/RFI Susceptibility Test, MIL-STD-461E
   2-3. Power Surge Test, IEC 61000 series
   2-4. ESD Test, IEC 61000-4-2
3. Post-Qualification Test (Performance Proof Test)

8.2 Performance Proof Test

8.2.1 Description of Performance Proof Test

The purpose of the performance proof test is to determine the operational validation of the test system, and to demonstrate the soundness of the safety-related functions prior to, during, and after the EMC qualification test. The performance proof test is comprised of setup & check-out test, operability test, and prudency test. All the performance proof tests were performed in accordance with the following test specifications and test procedures as required by EMC Qualification Test Plan (Reference (17)) meeting the requirements in EPRI TR-107330 (Reference (13)). Performance degradation of the OPRM unit was evaluated in the performance proof test before and after exposing environmental stress. In the performance proof test, all kinds of trip operability in all Cells were checked and be analyzed.

Table 8-1 Test Specification & Test Procedure for Performance Proof Test

No.	Test Specification	Test Procedure
1	Setup & Check-out Test Specification FC51-7021-1023 Rev.0	Setup & Check-out Test Procedure FC51-7021-1002 Rev.1
2	Operability Test Specification FC51-7021-1024 Rev.1	Operability Test Procedure FC51-7021-1003 Rev.1
3	Prudency Test Specification FC51-7021-1025 Rev.0	Prudency Test Procedure FC51-7021-1004 Rev.1

8.2.2 Acceptance Criteria

The followings indicate the performance acceptance criteria for the test specimen.

(1) Performance of safety-related functions shall be satisfied with acceptance criteria prescribed in the Setup & Check-out Test Procedure (Reference (19)), Operability Test Procedure (Reference (20)), and Prudency Test Procedure (Reference (21)).

(2) There shall be no loss of output signal for safety-related functions (for example, open or short circuit).

(3) There shall be no spurious or unwanted output for safety-related functions (for example, relay contact bounce exceeding the specified limits).

(4) There shall be no loss of required performance characteristics for safety-related functions (for example, inability to change state).

8.3 EMC Qualification Test

The EMC qualification test was executed in accordance with EMI/RFI Test Procedure (References (22)), Power Surge Test Procedure (Reference (23)), ESD Test Procedure (Reference (24)), and [ ]^{a,c} EMI Test Procedure (Reference (31)).

8.3.1 Test Setup

8.3.1.1 General Test Setup

Test specimen was installed in the test specimen rack which has an open rack chassis structure. The general test setup in this EMC qualification test is shown in Figure 8-1 and Figure 8-2, which complies with FIGURE 4 "Test setup for free standing EUT in shielded enclosure" of MIL-STD-461E (Reference (8)). The general test setup was maintained during all testing.

Routings of cables except optic fiber cables in the test specimen rack were equivalent to those implemented in an actual installation. Since the optic fiber cables are made of non-metallic material, and do not emit or receive electrical noise as antenna, the routing of the optic fiber cables were freely implemented not considering the actual installation.

Two meters of input power leads for Line A and Line B comprised of line (L), neutral (N), and ground (G) were routed parallel to the front edge of the setup. The total length of power leads from the test setup boundary of the test specimen rack to LISNs was set [ ]^{a,c} meters. Since the length of the DIO cable used for the actual installation could be longer than [ ]^{a,c} meters, the length of the DIO cable in the EMC chamber was [ ]^{a,c} meters in accordance with Section 4.3.8.6.1 of MIL-STD-461E. The first [ ]^{a,c} meters of the DIO cable from the test boundary of the test specimen rack was run parallel to the front boundary of the setup in the same manner as the power leads. The remaining length of the DIO cable was routed to the back of the setup and was placed in a zig-zagged arrangement. Individual cables were separated by [ ]^{a,c} centimeters measured from their outer circumference.

The pass-through panel between the EMC chamber and the control room was used to avoid noise intrusion into the control room that may affect measuring of the EUT performance during the EMC qualification test. The shield of the EMC chamber side of the DIO cable was grounded to the surface of the pass-through panel in the EMC chamber as shown in Figure 8-3. The shield of the control room side of the DIO cable was grounded to the surface of the pass-through panel in the control room as shown in Figure 8-4.

The EUT was placed on the floor of the EMC chamber with a bonding strap connected between the chassis ground of the test specimen rack and the ground plane, as shown in Figure 8-5. All the measurements of bonding were acceptable as shown in Table 8-2. For MIL-STD-461E testing, the cables were isolated from the ground plane with the [ ]^{a,c} cm thickness of the Non-Conductive Standoff. For IEC 61000 series testing, the cables were isolated from the ground plane with the [ ]^{a,c} cm thickness of the Non-Conductive Standoff.

Test setup boundary was determined in accordance with the requirements in MIL-STD-461E (Reference (8)) and the IEC 61000-4 series (References (4) through (7)). The test setup boundary includes the boundary of the test specimen rack shown as the double line in Figure 7-2, and the [ ]^{a,c} meters of exposed DIO cable and power leads.

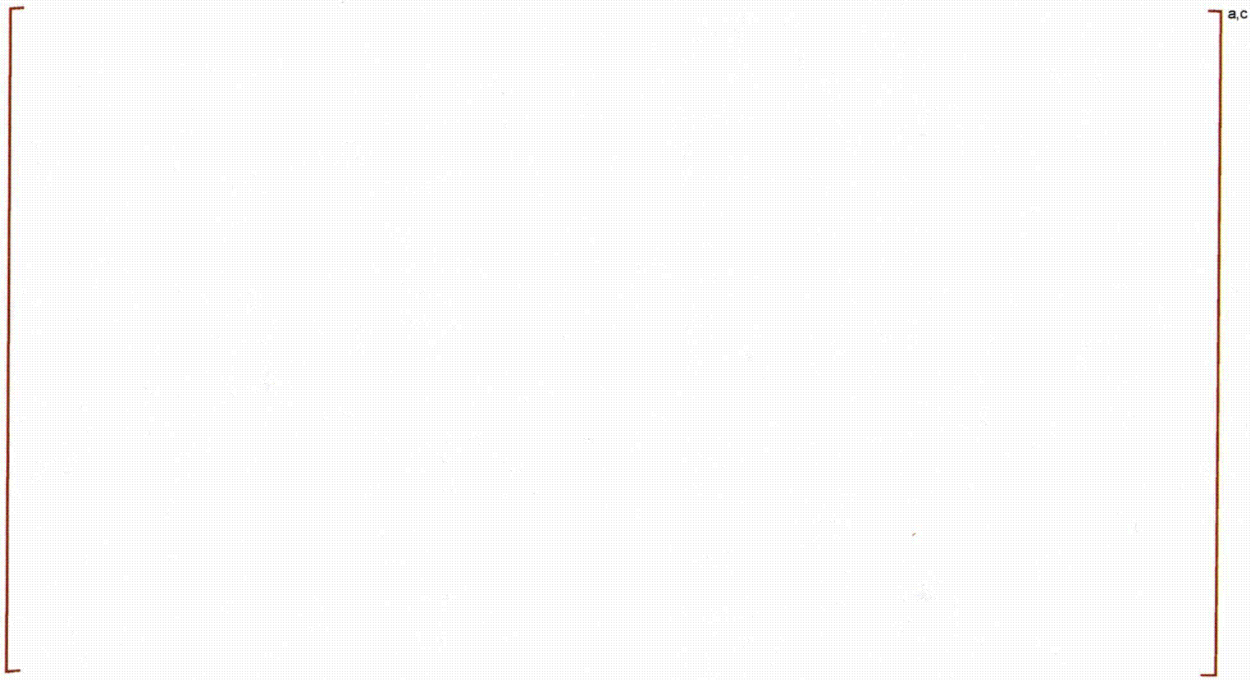
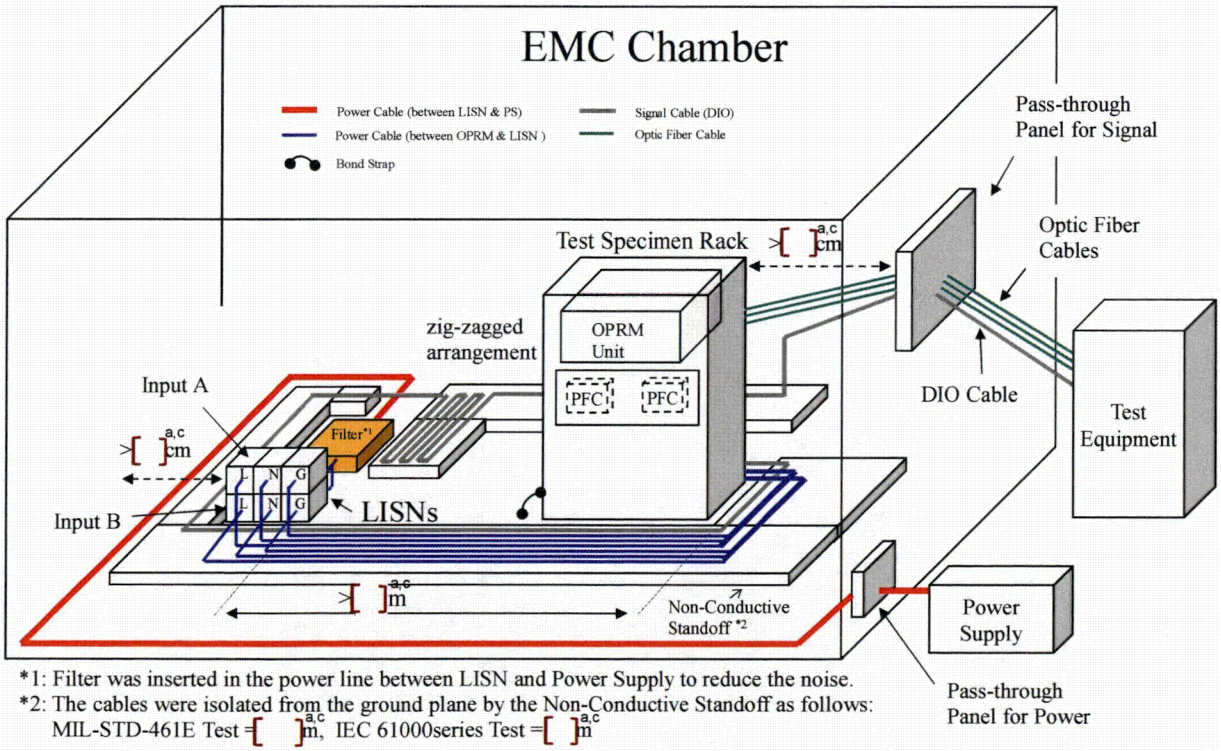


Figure 8-1 General Test Setup



*1: Filter was inserted in the power line between LISN and Power Supply to reduce the noise.
*2: The cables were isolated from the ground plane by the Non-Conductive Standoff as follows:
MIL-STD-461E Test = [ ]a,c m, IEC 61000series Test = [ ]a,c m

Figure 8-2 General Test Layout

Figure 8-3 Pass-through Panel Inside EMC Chamber

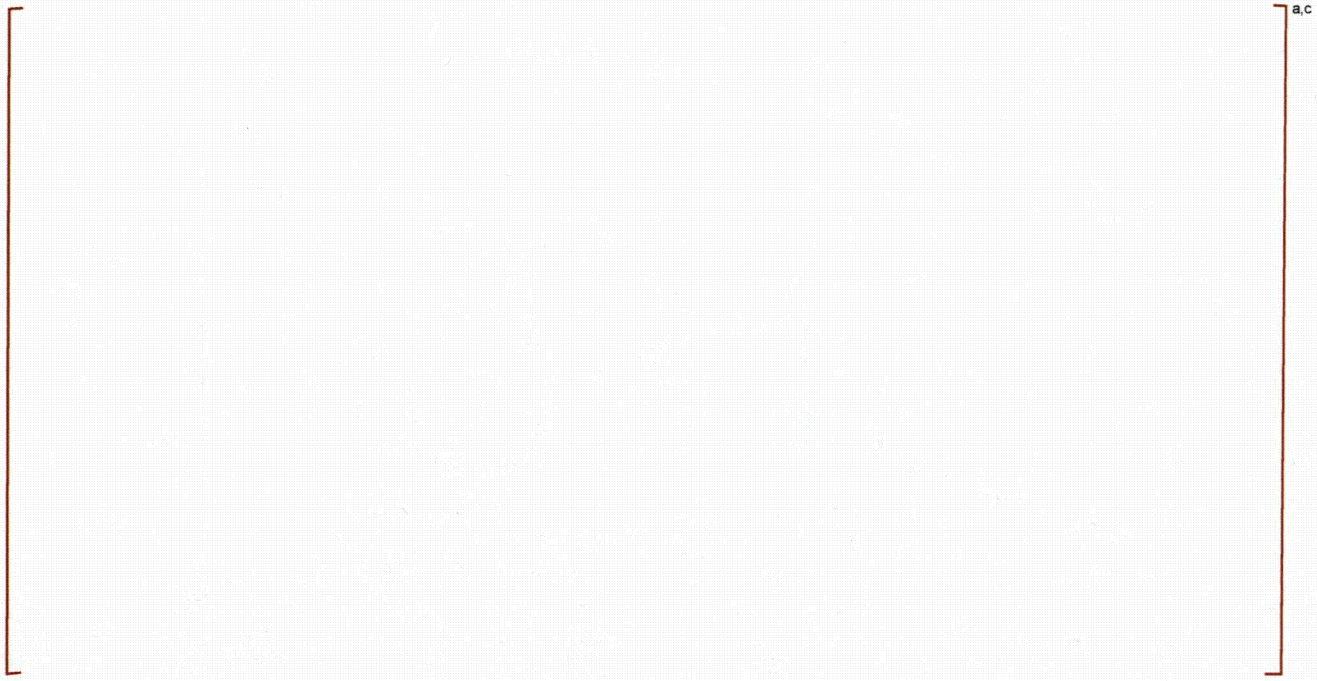


Figure 8-4 Pass-through Panel Outside EMC Chamber

Figure 8-5 Bonding Strap form Chassis Ground to Ground Plane

Table 8-2 MIL-STD-461E Bonding Summary

From	To	Bonding Reading	MIL-STD-461E Requirement	Result
Ground plane	LISN Input A –Ground	2.06 mΩ	2.5 mΩ	Acceptable
Ground plane	LISN Input A –Neutral	1.68 mΩ		Acceptable
Ground plane	LISN Input A –Line	1.33 mΩ		Acceptable
Ground plane	LISN Input B –Ground	1.57 mΩ		Acceptable
Ground plane	LISN Input B –Neutral	1.96 mΩ		Acceptable
Ground plane	LISN Input B –Line	1.62 mΩ		Acceptable
Ground plane	Chassis ground of test specimen rack	0.103 mΩ		Acceptable

8.3.1.2 Specific Test Setup

Specific test setups are as follows:

(1) RE102 and RS103
The OPRM unit of the EUT was placed such that the front panel of the OPRM unit was facing forward directly toward the front edge of the test setup boundary.

(2) RE101 and RS101
The loop sensor was located 7 cm from the OPRM unit, each of the PFCs, and the connector of the DIO cable connected to the OPRM unit. The plane of the loop sensor was oriented parallel to the OPRM unit, each of the PFCs. The plane of the loop sensor was oriented parallel to the axis of the connector of the DIO cable.

(3) CS114 (Power Cable)
Power cables subject to CS114 testing were defined as the cable bundle (i.e., line (L), neutral (N), and ground (G)) and the line (L) for Line A and Line B, respectively. The injection and monitor probes were placed around the power cable interfacing with the terminal block where the power cable was connected in the test specimen rack at the test setup boundary. The monitor probe was located 5 cm from the terminal block. The injection probe was positioned 5 cm from the monitor probe.

(4) CS114, CS115, and CS116 (Signal Cable)
Signal cable subject to CS114, CS115, and CS116 testing was defined as the cable bundle of the DIO cable. The injection and monitor probes were placed around the cable bundle interfacing with the terminal block where the DIO cable were connected in the test specimen rack at the test setup boundary. The monitor probe was located 5 cm from the terminal block. The injection probe was positioned 5 cm from the monitor probe. Optic fiber cables connecting the EUT and the test support equipment are not subject to CS114, CS115, and CS116 testing, since those optic fiber cables are made of non-metallic material cables.

8.3.2 EMC Qualification Test Requirements

The EMC qualification test items were determined as shown in Table 8-3. According to Regulatory Position 4.2 of RG 1.180, Revision 1 (Reference (3)), the CS114, CS115, and CS116 for the signal lines were selected for this EMC qualification program. The figures following Table 8-3 show emission and susceptibility envelopes applied for the EMC qualification test referenced in Table 8-3.

Table 8-3 EMC Qualification Test Items

Test Item	Test Method	Limit / Level	Range	Application
Conducted Emissions Low Frequency	MIL-STD-461E CE101	'AC POWER ≦ 1 kVA' Figure 8-6	60 Hz to 10 kHz	Power Leads
Conducted Emissions High Frequency	MIL-STD-461E CE102	'115V' Figure 8-7	10 kHz to 2 MHz	Power Leads
Radiated Emissions Magnetic Field	MIL-STD-461E RE101	Figure 8-8	30 Hz to 100 kHz	EUT
Radiated Emissions Electric Field	MIL-STD-461E RE102	Figure 8-9	2 MHz to 10 GHz	EUT
Conducted Susceptibility Low Frequency	MIL-STD-461E CS101	'SOURCE VOLTAGE > 28 V' Figure 8-10	120 Hz(1) to 150 kHz	Power Leads
Conducted Susceptibility High Frequency	MIL-STD-461E CS114	"Power Leads" Figure 8-11	10 kHz to 30 MHz	Power Leads
		91 dB μ A "Signal Leads" Figure 8-11	10 kHz to 30 MHz	Signal Leads
Conducted Susceptibility Bulk Cable Injection	MIL-STD-461E CS115	2 A	-	Signal Cable
Conducted Susceptibility Damped Sinusoidal Transients	MIL-STD-461E CS116	5 A max Figure 8-12	10 kHz to 100 MHz	Signal Cable
Radiated Susceptibility Magnetic Field	MIL-STD-461E RS101	Figure 8-13	30 Hz to 100 kHz	EUT
Radiated Susceptibility Electric Field	MIL-STD-461E RS103	10V/m	30 MHz to 10 GHz	EUT
Surge 100 kHz Ring Wave	IEC 61000-4-12 Ring Wave	Level 3 (2 kV)	-	Power Cable
Surge Combination Wave	IEC 61000-4-5 Combination Wave	Level 3 (2 kV)	-	Power Cable
Surge Electrical Fast Transient / Burst	IEC 61000-4-4 EFT/B	Level 3 (2 kV)	-	Power Cable
Electrical Discharge Susceptibility	IEC 61000-4-2 ESD	Level 4 (+/- 15 kV) Air discharge	-	EUT
		Level 4 (+/- 8 kV) Contact discharge	-	EUT

Note:

1. Since the EUT is ac operated, this test is applicable starting from 120 Hz, which is the second harmonic of the power line frequency of 60Hz, and extending to 150 kHz.

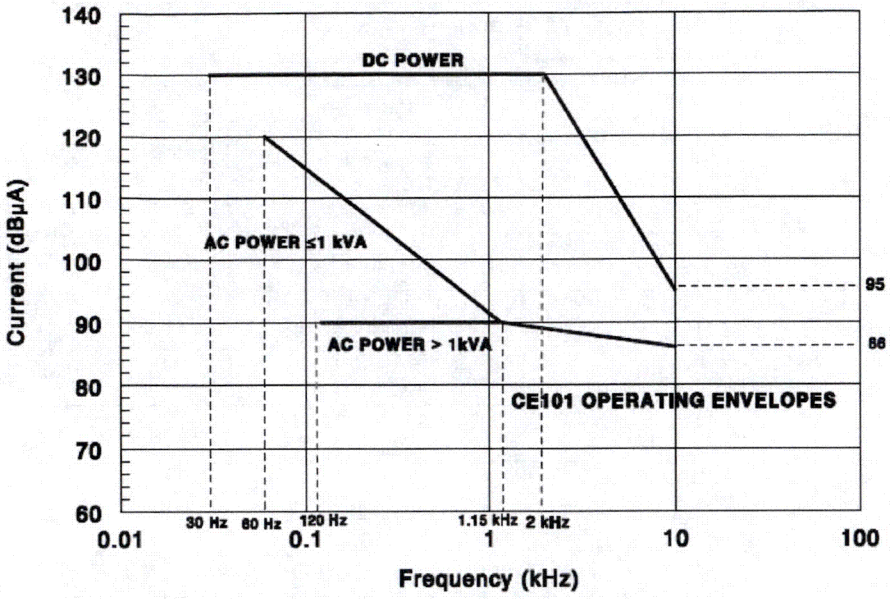


Figure 8-6 CE101 Limits (Figure 3.1 of RG 1.180, Revision 1)

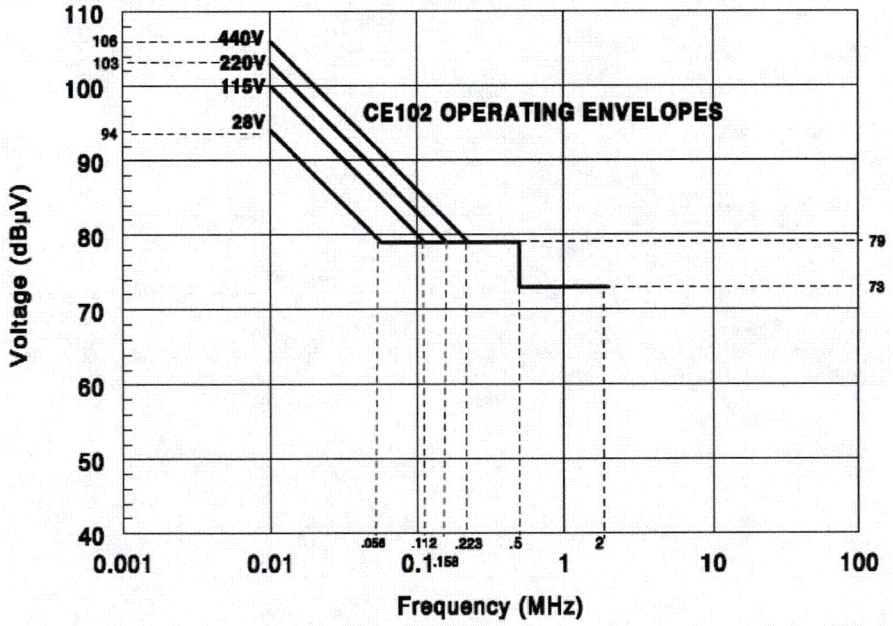


Figure 8-7 CE102 Limits (Figure 3.2 of RG 1.180, Revision 1)

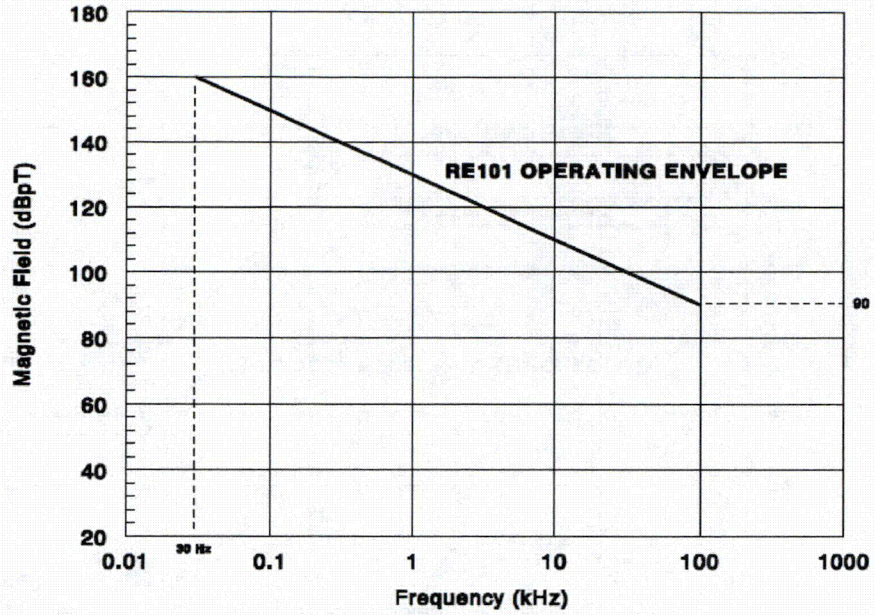


Figure 8-8 RE101 Limit (Figure 3.3 of RG 1.180, Revision 1)

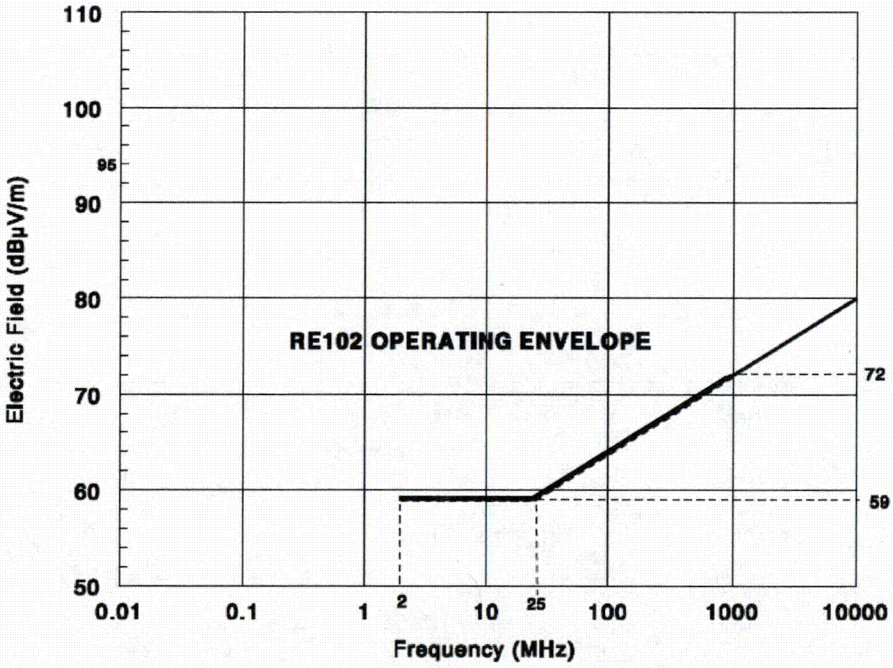


Figure 8-9 RE102 Limit (Figure 3.4 and Figure 6.1 of RG 1.180, Revision 1)

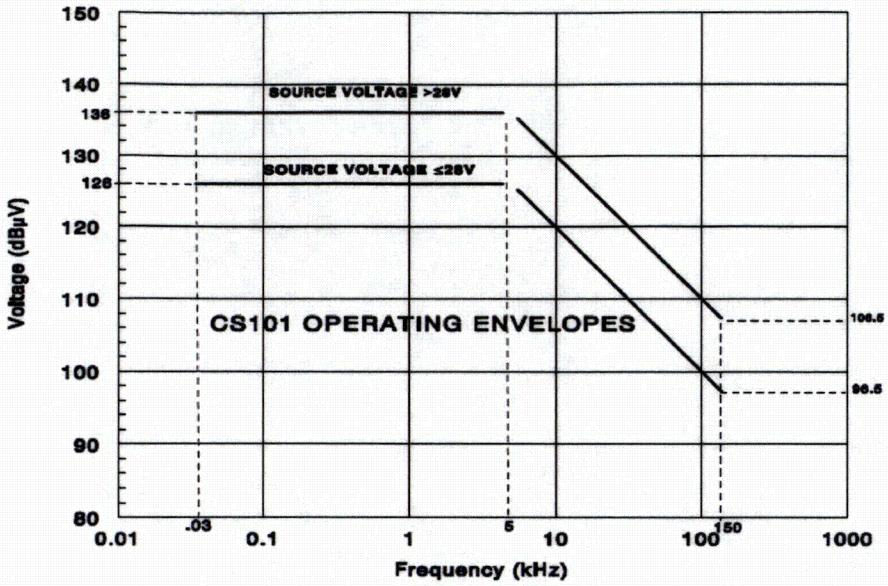


Figure 8-10 CS101 Levels (Figure 4.1 of RG 1.180, Revision 1)

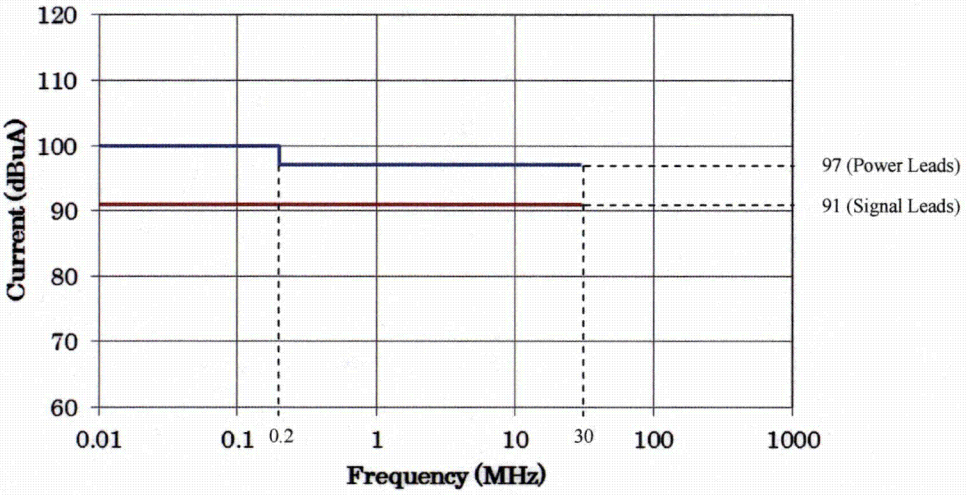


Figure 8-11 CS114 Levels

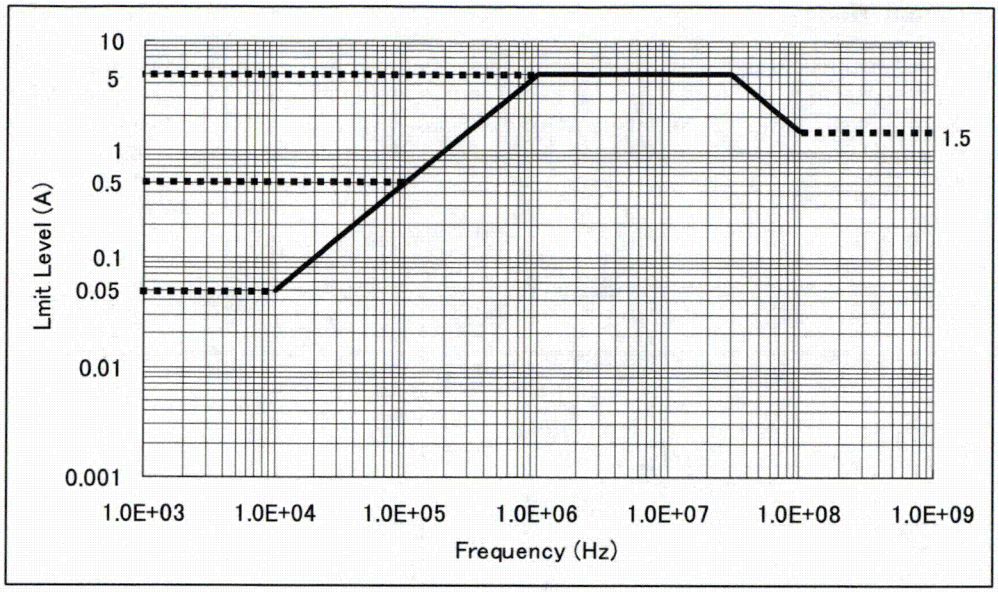


Figure 8-12 CS116 limit

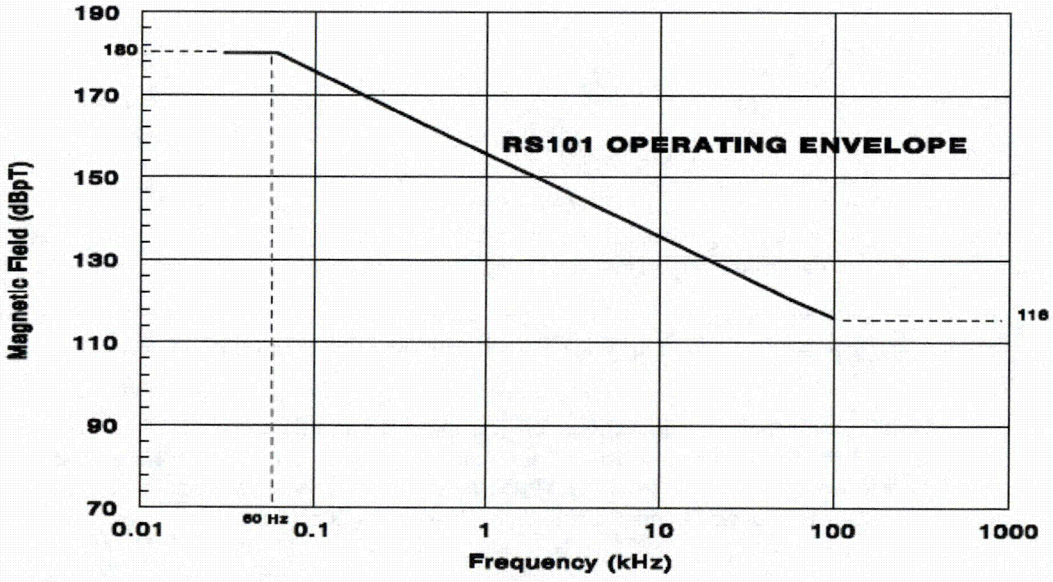


Figure 8-13 RS101 Level (Figure 4.3 of RG 1.180, Revision 1)

8.4 Operational Modes

Applicable operational modes during the EMC qualification test were determined as shown in Table 8-4. Since the OPRM unit is powered from redundant Class 1E AC power supplies in the actual installation, the "Normal" mode is defined as the mode that the EUT is powered form both AC power supplies, and the "Abnormal" mode is defined as the mode that the EUT is powered from single AC power supply simulating the event of a loss of single failure of the redundant power supplies.

Table 8-4 Operational Modes

Mode	Description	Test Item					
		CE	RE	CS	RS	Surge	ESD
R-equivalent	EUT is powered off and replaced with an equivalent resistor. Test support equipment is powered.	X	-	-	-	-	-
Ambient	EUT is powered off. Test support equipment is powered.	X	X	-	-	-	-
Normal	EUT is powered from both AC power supplies. Test support equipment is powered.	X	X	X	X	X	X
Abnormal	EUT is powered only from Line A of AC power supply, and is powered off from Line B of AC power supply. Test support equipment is powered. In this mode, the OPRM Minor Failure signal is generated.	X	-	X	-	X	-

X: Applicable
C = conducted, R = radiated, and S = susceptibility

8.4.1 OPRM Unit Operation Under Test

During the EMC qualification test, the OPRM unit was operated with a specific test pattern in the normal and abnormal modes for monitoring the OPRM performance in order to demonstrate the soundness of the test specimen throughout the test period. This section describes about the test pattern input to the OPRM unit.

An OPRM unit per division monitors the oscillation states of 44 Cells shared with 52 LPRM Levels in the reactor core, and generates the ABA Trip, GRA Trip, and PBDA Trip, as described in Sections 6.3 (2-1) through (2-3).

During the EMC qualification test, the OPRM unit was input the specific test pattern from the OSTS to check the performance of the EUT. The test pattern represented simulated 52 LPRM Levels from the LPRM units, APRM levels, and Core Flow levels from the APRM unit. In this section, the details of the test patterns are explained. An LPRM Level was simulated with the following equation.

[a,c]

The test pattern of LPRM levels was generated using above equations. This equation can simulate various

types of oscillation signals by changing the parameters.

If all the LPRM Levels in a Cell synchronize, the Normalized Oscillation Signal (St) can be simulated by the following theoretical formula which is simplified with four identical LPRM Levels filtered with the transfer function.

Normalized Oscillation Signal (St):

$$St = [\quad]^{a,c}$$

$$[\quad]^{a,c}$$

Based on the functionality of the OPRM unit, the expected output for the test pattern was determined as responses of the OPRM unit to the simulated Normalized Oscillation Signal (St).

The test pattern was developed so that the PBDA Trip, GRA Trip, and ABA Trip signals are separately generated in each of the target Cells of CELL 9, CELL 12, and CELL30. Additionally, the test pattern was developed so that the PBDA Trip signal is generated in the target Cell of CELL 33 by inputting the LPRM Levels with simulated random noise.

The test pattern has the following features.

Cell 9: PBDA Trip

Simulated LPRM Levels of channels 5, 16, 28, and 41 are input so that the PBDA Trip is generated only in Cell 9.

Cell 12: GRA Trip

Simulated LPRM Levels of channels 4, 17, 31, and 42 are input so that the GRA Trip is generated only in Cell 12.

Cell 30: ABA Trip

Simulated LPRM Levels of channels 8, 21, 36, and 49 are input so that the ABA Trip is generated only in Cell 30.

Cell 33: PBDA Trip

Simulated LPRM Levels of channels 9, 11, 48, and 50 are input so that the PBDA Trip overlapped with noise is generated only in Cell 33.

Figure 8-14 shows the simulated Normalized Oscillation Signals and the expected timing of the OPRM Trip generation in response to the test pattern. In Figure 8-15, the information on target Cells are shown as "CELL Number" and the corresponding LPRM channels are shown as "LPRM Signal Number."

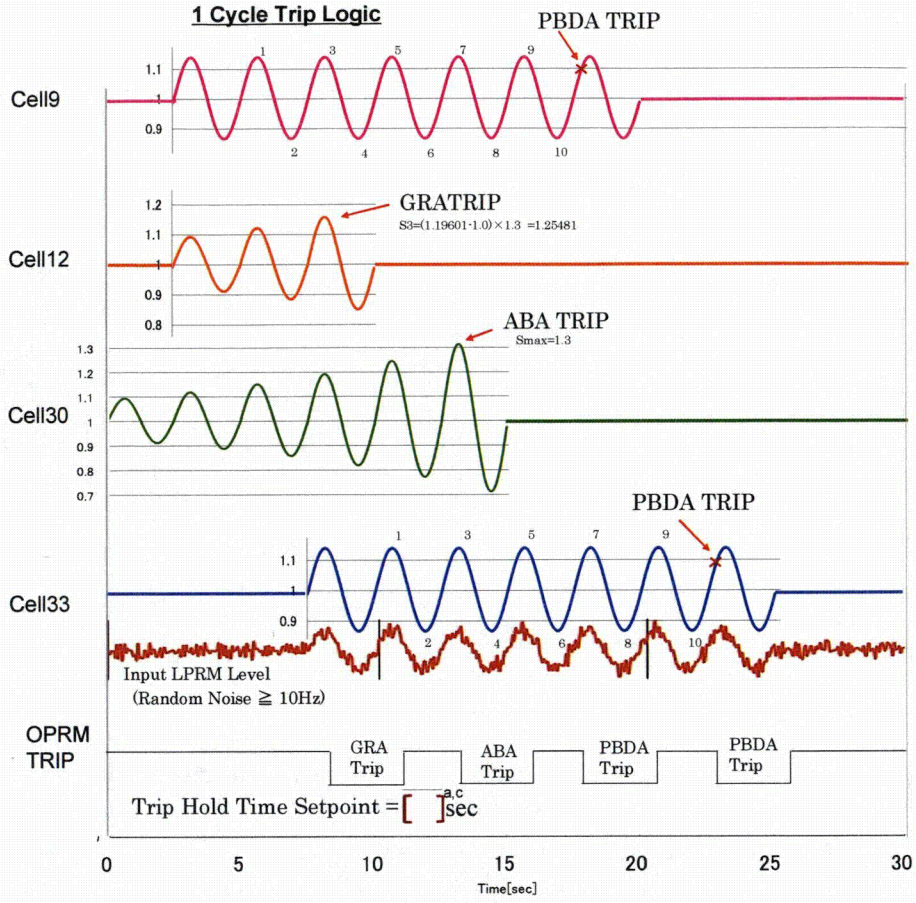


Figure 8-14 Test Pattern

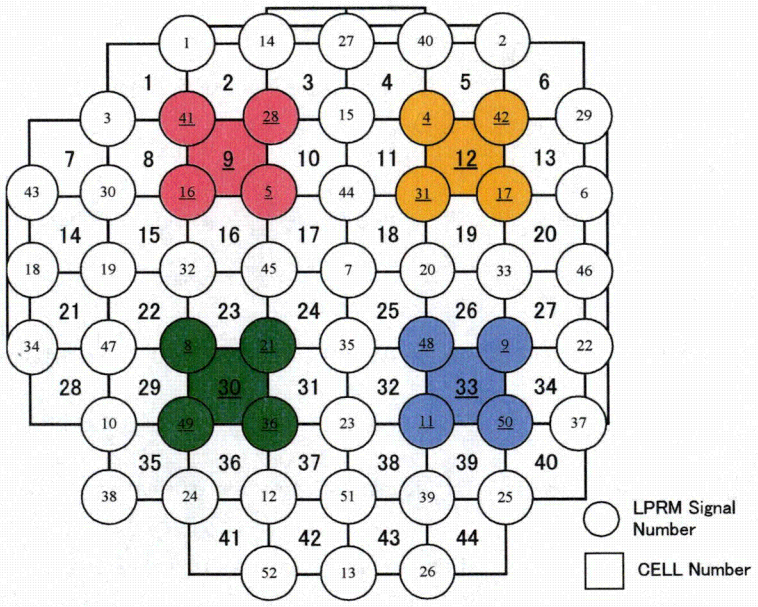


Figure 8-15 Allocation of Input LPRM Signal and Cell Number

In the test pattern, the LPRM Levels not involved in the Cell 9, Cell 12, Cell 30, and Cell 33 were provided as a constant signal, 50% power. Since those LPRM Levels which make up Cell 7, 14, 21, 28, 41, 42, 43, and 44 do not oscillate, the Normalized Oscillation Signal of those Cells converge to "1." The APRM Level of 50% power and the Core Flow Level of 25% of rated flow were provided during the running of the test pattern so as not to operate the OPRM Automatic Bypass function. The cycle of the test pattern was set to 30 seconds. This test pattern was repeatedly input to the OPRM unit from the OSTS during the EMC qualification test. The discrete output signals and optical transmission output signals are monitored during the testing.

8.4.2 Acceptance Criteria for EMC Qualification Test

(1) EMI/RFI Emission Test

The emissions from the test specimen shall not exceed specified limit values.

(2) EMI/RFI Susceptibility Test, Power Surge Test, and ESD Test

Susceptibility Criteria (Performance Criteria)

The following susceptibility criteria in Figure 8-5 were applied for the immunity testing.

Table 8-5 Susceptibility Criteria

Criteria Level	Performance Description
A	Normal performance within the specification limits
B	Temporary degradation or loss of function or performance which is self-recoverable
C	Temporary degradation or loss of function or performance which requires operator intervention or system reset
D	Degradation or loss of function which is not recoverable due to damage of equipment (components) or software, or loss of data

The test specimen shall not exhibit any malfunction, degradation of performance, or deviation from specified limits as follows, when subjected to an immunity test signal, as required in RG 1.180, Revision 1 (Reference (3)) and MIL-STD-461E (Reference (8)). Thus, Criteria Level A is only acceptable for this EMC qualification unless noted otherwise. Criteria Level A corresponds to the recommended classification 1) or a) "normal performance within the specification limits" described in the IEC 61000-4 series (References (4) through (7)).

EUT Acceptance Criteria

During the test, the discrete output signals and optical transmission output signals were monitored by Toshiba test personnel whether the EUT normally operated and error data such as protocol error or parity error did not occur inputting the test pattern explained in Section 8.4.1.

The trip generation data of discrete output signals and the optical transmission output signals acquired were checked in accordance with the following criteria.

- Trip interval time of the discrete output signal (i.e., the OPRM Trip signal) shall be within[ ]^{a,c}msec of the expected value (See Table 8-6).
- Trip interval time of the optical transmission output signal shall be within[ ]^{a,c}msec of the expected value (See Table 8-7).

When susceptibility indications are observed in the test specimen operation, the interference signal is reduced by 6 dB, and retest is performed. If the susceptible condition is no longer present at retest, the Toshiba engineer should determine whether further threshold measurement should be continued using the method specified in Section 4.3.10.4.3 of MIL-STD-461E (Reference (8)) and record the decision made on the threshold measurement on the anomaly information of test record based on engineering judgment.

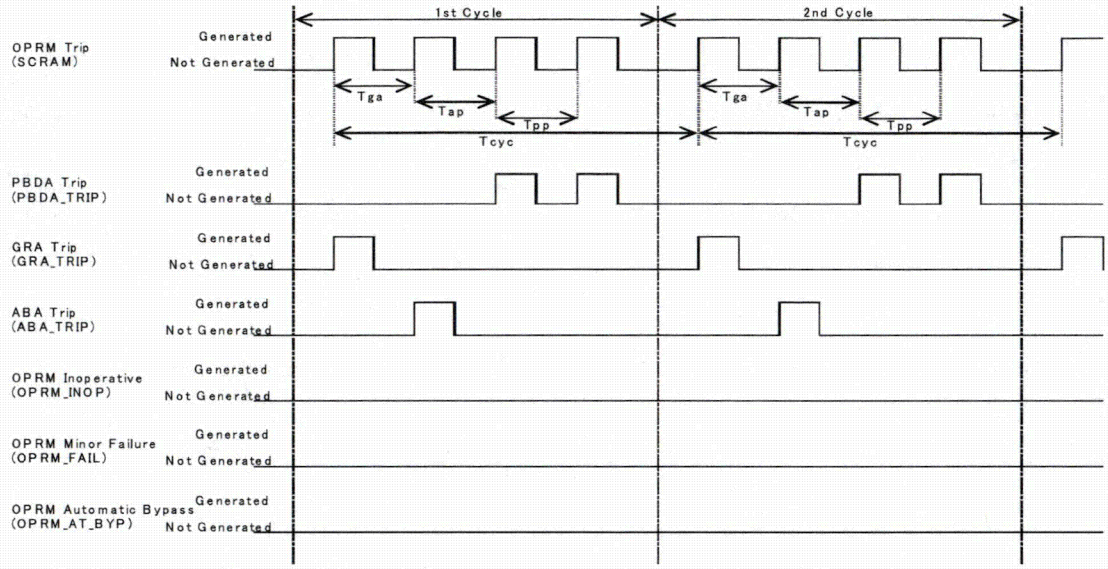


Figure 8-16 Check Method of Discrete Output Signal

Table 8-6 Acceptance Criteria for Discrete Outputs

	Acceptance Criteria
Tga	a,c
Tap	a,c
Tpp	a,c
Tcyc	a,c

Table 8-7 Acceptance Criteria for Optical Outputs

	Acceptance Criteria
Tga	a,c
Tap	a,c
Tpp	a,c
Tcyc	a,c

9. TEST RESULT

9.1 Pre-Qualification Test Result

The pre-qualification test was performed prior to the EMC qualification test to demonstrate the soundness of the OPRM safety-related functions on December 3, 2012 at the EMC chamber in[ ]^{a,c} The performance proof test as pre-qualification test was conducted, which was comprised of the setup & check-out test, operability test, and prudency test as described in Section 8.2. All the test results were documented in the Performance Proof (Pre-Qualification for EMC Test) Test Record (Reference (28)). All the test results satisfied the acceptance criteria specified in each test procedure and showed that the test specimen and test system correctly operated.

9.2 EMC Qualification Test Results

The EMC qualification test was performed in accordance with EMI/RFI Test Procedure (References (22)), Power Surge Test Procedure (Reference (23)), ESD Test Procedure (Reference (24)), and [ ]^{a,c} EMI Test Procedure (Reference (31)).

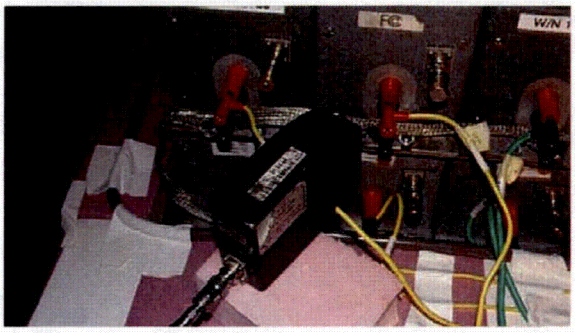
The test results obtained from December 13, 2012 through January 4, 2013 are reported in Sections 9.2.1 through 9.2.4 based on the test results in the [ ]^{a,c} EMC Test Report (Reference (32)) which includes detailed information on test setup, instrumentation, calibration data, test procedure, summary of test data, accuracy, and test anomalies.

9.2.1 EMI/RFI Emission Test Result

The EMI/RFI emission test was performed on December 13 and 14, 2012. All the test items of the EMI/RFI emission test were successfully completed. The test result for each test item was reported in the following subsections. During the EMI/RFI emission test, the performance of the OPRM unit was input the test pattern explained in Section 8.4.1, and checked whether the OPRM unit normally operated. The history of test progress and performance check result by Toshiba test personnel was documented in the EMI/RFI Test Record (Reference (25)) showing that the OPRM normally operated as expected performing its intended safety functions.

9.2.1.1 CE101: Conducted Emissions, Low-frequency Test Result

The test specimen was subjected to the CE101, Conducted Emissions Testing. The EUT equivalent resistive load was approximately 697 Ohms for Normal Mode ambient scans and 510 Ohms for Abnormal Mode ambient scans. The representative test setups (L1/L7:120 VAC Line A and L5 120 VAC Neutral B) are shown in Figure 9-1. The conducted emissions on all the measurement points did not exceed the specified limit values and no anomalies were observed throughout the CE101 test as shown in Table 9-1. Thus, the test specimen was found to be compliant with the emission level required in Figure 3.1 of RG 1.180, Revision 1 (Reference (3)). The test data of amplitude versus frequency profiles on X-Y axis outputs is shown in APPENDIX B.



L1/L7:120VAC Line A

L5: 120 VAC Neutral B

Figure 9-1 Representative CE101 Test Setup

Table 9-1 CE101 Test Results

Line Under Test I. D. No.	Line Under Test Description	Frequency		Operating Mode	Test Result
		Start (kHz)	Stop (kHz)		
L1	120 VAC Line A	0.06	10	Normal	Acceptable
L2	120 VAC Neutral A	0.06	10	Normal	Acceptable
L3	Ground A	0.06	10	Normal	Acceptable
L4	120 VAC Line B	0.06	10	Normal	Acceptable
L5	120 VAC Neutral B	0.06	10	Normal	Acceptable
L6	Ground B	0.06	10	Normal	Acceptable
L7	120 VAC Line A (without B)	0.06	10	Abnormal	Acceptable
L8	120 VAC Neutral A (without B)	0.06	10	Abnormal	Acceptable
L9	Ground A (without B)	0.06	10	Abnormal	Acceptable

9.2.1.2 CE102: Conducted Emissions, High-frequency

The test specimen was subjected to the CE102, Conducted Emissions Testing. The EUT equivalent resistive load was approximately 697 ohms for Normal Mode ambient scans and 510 ohms for Abnormal Mode ambient scans. The representative test setup (Line L1/L7: 120VAC Line A) is shown in Figure 9-2. The conducted emissions on all the measurement points did not exceed the specified limit values and no anomalies were observed throughout the CE102 test as shown in Table 9-2. Thus, the test specimen was found to be compliant with the emission level required in Figure 3.2 of RG 1.180, Revision 1 (Reference (3)). The test data of amplitude versus frequency profiles on X-Y axis outputs is shown in APPENDIX B.

Figure 9-2 Representative CE102 Test Setup (Line L1/L7: 120VAC Line A)

Table 9-2 CE102 Test Results

Line Under Test I. D. No.	Line Under Test Description	Frequency		Operating Mode	Test Result
		Start (MHz)	Stop (MHz)		
L1	120 VAC Line A	0.01	2	Normal	Acceptable
L2	120 VAC Neutral A	0.01	2	Normal	Acceptable
L3	Ground A	0.01	2	Normal	Acceptable
L4	120 VAC Line B	0.01	2	Normal	Acceptable
L5	120 VAC Neutral B	0.01	2	Normal	Acceptable
L6	Ground B	0.01	2	Normal	Acceptable
L7	120 VAC Line A (without B)	0.01	2	Abnormal	Acceptable
L8	120 VAC Neutral A (without B)	0.01	2	Abnormal	Acceptable
L9	Ground A (without B)	0.01	2	Abnormal	Acceptable

9.2.1.3 RE101: Radiated Emissions, Magnetic Field

The test specimen was subjected to the RE101, Radiated Emissions Testing. The representative test setup (Position 1: Front of OPRM unit) is shown in Figure 9-3. The radiated emissions on all the measurement points did not exceed the specified limit values and no anomalies were observed throughout the RE101 test as shown in Table 9-3. Thus, the test specimen was found to be compliant with the emission level required in Figure 3.3 of RG 1.180, Revision 1 (Reference (3)). The test data of amplitude versus frequency profiles on X-Y axis outputs is shown in APPENDIX B.

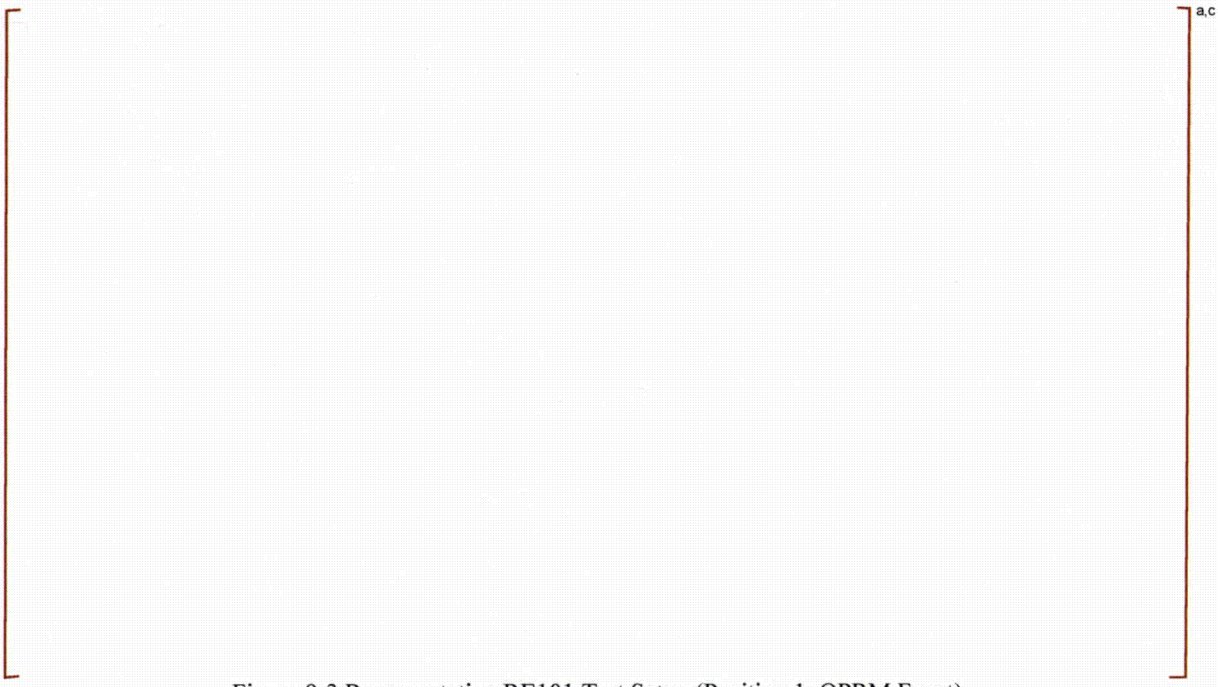

a,c

Figure 9-3 Representative RE101 Test Setup (Position 1: OPRM Front)

Table 9-3 RE101 Test Results

Test I.D.	Position Number	Location Type	Frequency		Operating Mode	Description	Test Result
			Start (kHz)	Stop (kHz)			
EUT Location	1	Front	0.03	100	Normal	Chassis – Highest Emanation Location Of Each Side	Acceptable
	2	Back	0.03	100	Normal		Acceptable
	3	Left	0.03	100	Normal		Acceptable
	4	Right	0.03	100	Normal		Acceptable
	5	Top	0.03	100	Normal		Acceptable
	6	Bottom	0.03	100	Normal		Acceptable
PFC's	7	PFC1, Top	0.03	100	Normal	Top, Highest Emanation Location	Acceptable
	8	PFC2, Top	0.03	100	Normal		Acceptable
Connectors	9	DIO Cable	0.03	100	Normal	Connector Location at Each Cable End	Acceptable
	11	LVPS1 Cable	0.03	100	Normal		Acceptable
	10	LVPS2 Cable	0.03	100	Normal		Acceptable

9.2.1.4 RE102: Radiated Emissions, Electric Field

The test specimen was subjected to the RE102, Radiated Emissions Testing. The RE102 testing was performed from 2 MHz to 10 GHz with two antenna orientations (vertical and horizontal), except for the rod antenna. The active rod antenna bonding measurement was approximately 0.13 milliohms. The representative test setups are shown in Figure 9-4. The radiated emissions on all the measurement points did not exceed the specified limit values and no anomalies were observed throughout the RE102 test as shown in Table 9-4. Thus, the test specimen was found to be compliant with the emission level required in Figure 3.4 and Regulatory Position 6 of RG 1.180, Revision 1 (Reference (3)). The test data of amplitude versus frequency profiles on X-Y axis outputs is shown in APPENDIX B.

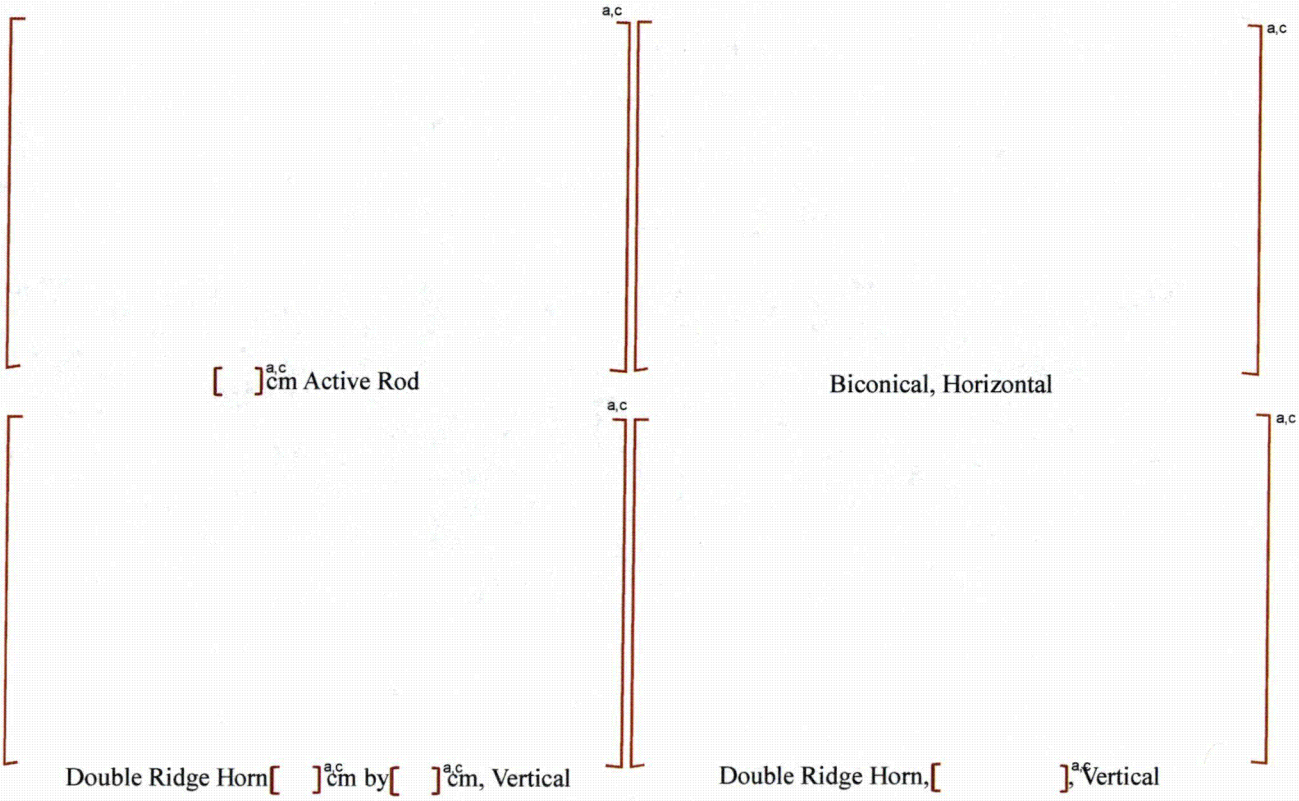


Figure 9-4 Representative RE102 Test Setup

Table 9-4 RE102 Test Results

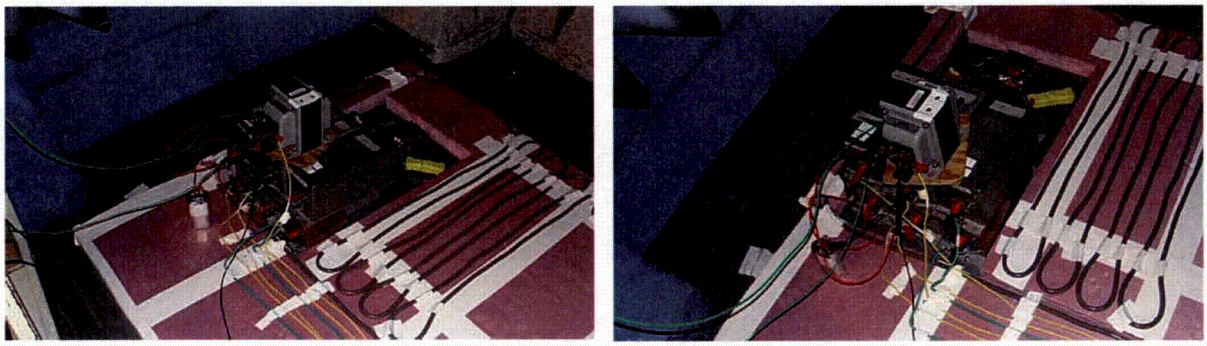
Polarization	Antenna Description	Frequency		Operating	Test Result
		Start (MHz)	Stop (MHz)	Mode	
Vertical	[ ]a,c cm Active Rod	2	30	Normal	Acceptable
	Biconical	30	200	Normal	Acceptable
	Double Ridge Horn[ ]a,c cm by[ ]a,c cm	200	1000	Normal	Acceptable
	Double Ridge Horn,[ ]a,c	1000	10000	Normal	Acceptable
Horiszontal	Biconical	30	200	Normal	Acceptable
	Double Ridge Horn[ ]a,c cm by[ ]a,c cm	200	1000	Normal	Acceptable
	Double Ridge Horn,[ ]a,c	1000	10000	Normal	Acceptable

9.2.2 EMI/RFI Susceptibility Test Result

The EMI/RFI susceptibility test was performed from December 15 through 29, 2012. All the test items of the EMI/RFI susceptibility test were successfully completed. The test result for each test item was reported in the following subsections. During the EMI/RFI susceptibility test, the performance of the OPRM unit was continuously monitored inputting the test pattern explained in Section 8.4.1. The performance of the test specimen was checked by Toshiba test personnel whether the test specimen met Criteria Level A explained in Section 8.4.2 (2) without showing any susceptibility to applied test level. The history of test progress and performance check result by Toshiba test personnel was documented in the EMI/RFI Test Record (Reference (25)) showing that the OPRM normally operated as expected performing its intended safety functions.

9.2.2.1 CS101: Conducted Susceptibility, Low-frequency

The test specimen was subjected to the levels indicated in Figure 4.1 of RG 1.180, Revision 1 (Reference (3)) in the frequency range of 120 Hz to 150 kHz. The test setup is shown in Figure 9-5. The test specimen did not exhibit susceptibility to the required interference conditions on any lines listed in Table 9-5. No anomalies were observed, and the test specimen met Criteria Level A. Thus, the test specimen complies with the susceptibility requirements in Regulatory Position 4.1.1 of RG 1.180, Revision 1.



L1/L3:120VAC Line A　　L2: 120 VAC Line B

Figure 9-5 CS101 Test Setup

Table 9-5 CS101 Test Results

LUT I.D. No.	Application Point	Frequency Start (kHz)	Stop (kHz)	Operating Mode	EUT Response	Test Result
L1	120 VAC Line A	0.12	150	Normal	No deviations observed	Acceptable
L2	120 VAC Line B	0.12	150	Normal	No deviations observed	Acceptable
L3	120 VAC Line A (without B)	0.12	150	Abnormal	No deviations observed	Acceptable

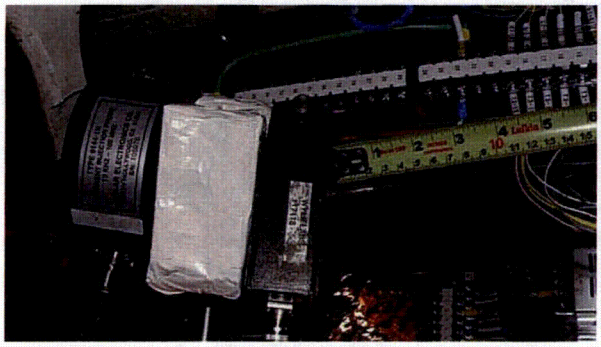
9.2.2.2 CS114: Conducted Susceptibility, High-frequency

The test specimen was subjected to the levels indicated in Figure 4.2 and the CS114 part of Table 14 of RG 1.180, Revision 1 (Reference (3)). The representative test setups are shown in Figure 9-6.

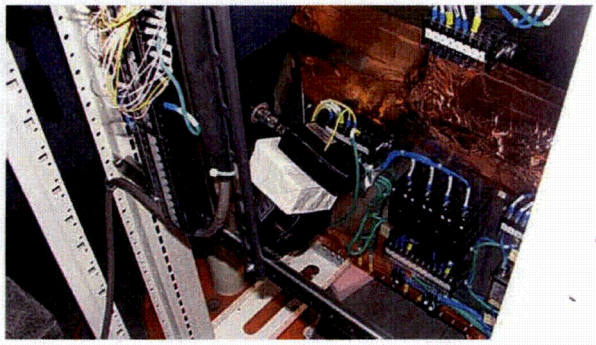
An anomaly that [ ]a,c test technician applied incorrect level to the DIO cable was observed. The evaluation of the anomaly is described in Section 9.2.5.2. As reported in Section 9.2.5.2, the re-testing of the CS114 on the DIO cable was successfully performed as the disposition of the anomaly with the proper test level.

Eventually, the test specimen did not exhibit susceptibility to the required interference conditions on any lines listed in Table 9-6 meeting Criteria Level A. Thus, the test specimen complies with the susceptibility requirements in Regulatory Position 4.1.2 and the CS114 part of Regulatory Position 4.2 of RG 1.180, Revision 1.

During reviewing [ ]a,c EMI Test Report Revision A, Toshiba Engineer found out an issue about injection probe. It was evaluated the issue did not affect the CS114 test result as described in Section 9.2.5.3.



L1: DIO Cable



L3/L7: 120 VAC Line A

Figure 9-6 Representative CS114 Test Setup

Table 9-6 CS114 Test Results

Test I.D. No.	Cable Type	Application Point	Frequency Start (MHz)	Frequency Stop (MHz)	Operating Mode	EUT Response	Test Result
L1	Signal	DIO Cable	0.01	30	Normal	No deviations observed	Acceptable
L2	120 VAC Line A	L, N, G Simultaneous	0.01	30	Normal	No deviations observed	Acceptable
L3		L	0.01	30	Normal	No deviations observed	Acceptable
L4	120 VAC Line B	L, N, G Simultaneous	0.01	30	Normal	No deviations observed	Acceptable
L5		L	0.01	30	Normal	No deviations observed	Acceptable
L6	120 VAC Line A (without B)	L, N, G Simultaneous	0.01	30	Abnormal	No deviations observed	Acceptable
L7		L	0.01	30	Abnormal	No deviations observed	Acceptable

9.2.2.3 CS115: Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation

The test specimen was subjected to the levels indicated in the CS115 part of Table 14 of RG 1.180, Revision 1 (Reference (3)). The test setup is shown in Figure 9-7. The test specimen did not exhibit susceptibility to the required interference conditions on a line listed in Table 9-7. No anomalies were observed, and the test specimen met Criteria Level A. Thus, the test specimen complies with the susceptibility requirements in the CS115 part of Regulatory Position 4.2 of RG 1.180, Revision 1.

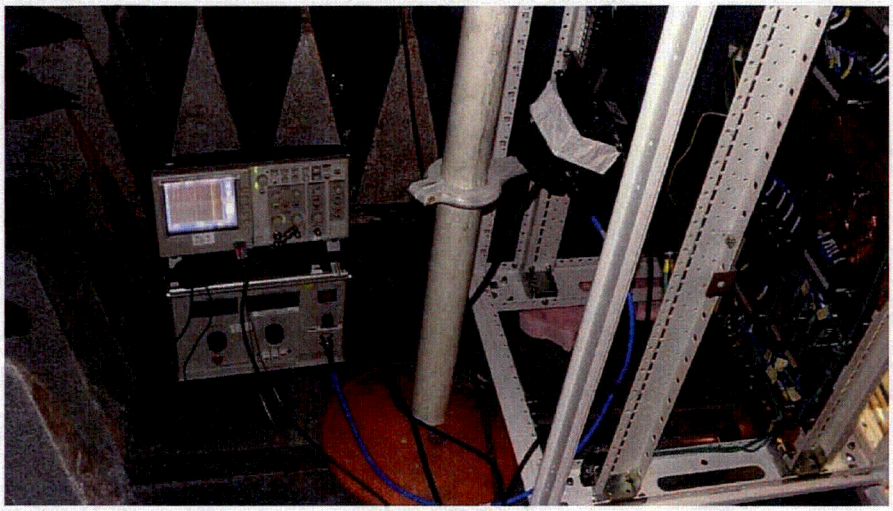


Figure 9-7 CS115 Test Setup

Table 9-7 CS115 Test Results

Cable Under Test I.D.	Cable Type	Application Point	Test Duration	Operating Mode	EUT Response	Test Result
L1	Signal	DIO Signal Cable	1 minute	Normal	No deviations observed	Acceptable

9.2.2.4 CS116: Conducted Susceptibility, Damped Sinusoidal Transients

The test specimen was subjected to the levels indicated in the CS116 part of Table 14 of RG 1.180, Revision 1 (Reference (3)) at the following frequencies: 0.01, 0.1, 1, 10, 30, and 100 MHz. The test setup is shown in Figure 9-8. The test specimen did not exhibit susceptibility to the required interference conditions on any positions tested listed in Table 9-8. No anomalies were observed, and the test specimen met Criteria Level A. Thus, the test specimen complies with the susceptibility requirements in the CS116 part of Regulatory Position 4.2 of RG 1.180, Revision 1.

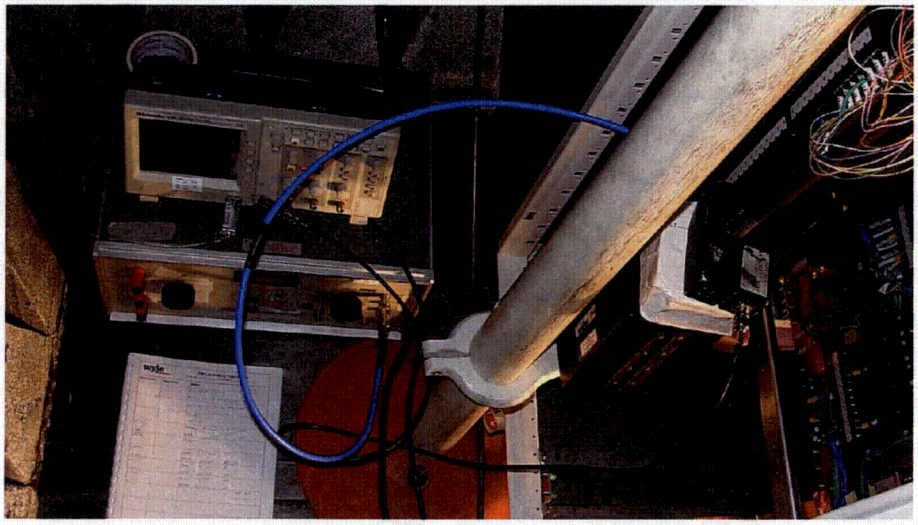


Figure 9-8 CS116 Test Setup

Table 9-8 CS116 Test Results

Cable Under Test I.D.	Cable Type	Application Point	Test Frequency	Test Level	Test Duration	Operating Mode	EUT Response	Test Result
L1	Signal	DIO Signal Cable	10 kHz	0.05 A	5 minutes	Normal	No deviations observed	Acceptable
			100 kHz	0.5 A	5 minutes	Normal	No deviations observed	Acceptable
			1 MHz	5A	5 minutes	Normal	No deviations observed	Acceptable
			10 MHz	5A	5 minutes	Normal	No deviations observed	Acceptable
			30 MHz	5A	5 minutes	Normal	No deviations observed	Acceptable
			100 MHz	1.5A	5 minutes	Normal	No deviations observed	Acceptable

9.2.2.5 RS101: Radiated Susceptibility, Magnetic Field

The test specimen was subjected to the radiated magnetic fields level indicated in Figure 4.3 of RG 1.180, Revision 1 (Reference (3)) in the frequency range of 30 Hz to 100 kHz. The representative test setup is shown in Figure 9-9. During the RS101 testing at the position 18 (111 mm from the front edge and 89 mm from the bottom edge on the left side panel of the OPRM unit), a PBDA Trip was failed to occur was observed once. Toshiba engineer confirmed that this event was the same event as that reported in SNNR-I-12-003, and the evaluation of the anomaly is described in Section 9.2.5. The test specimen did not exhibit susceptibility to the required interference conditions on any line tested listed in Table 9-9 meeting Criteria Level A.. Thus, the test specimen complies with the susceptibility requirements in Regulatory Position 4.3.1 of RG 1.180, Revision 1.

Figure 9-9 Representative RS101 Test Setup (Position 18 – OPRM Left Front)

Table 9-9 RS101 Test Results

Position Number	Location Type	Application Point	Operating Mode [a,c]	EUT Response	Test Result
Position 1	Connectors		Normal	No deviations observed	Acceptable
Position 2			Normal	No deviations observed	Acceptable
Position 3			Normal	No deviations observed	Acceptable
Position 4	PFC's		Normal	No deviations observed	Acceptable
Position 5			Normal	No deviations observed	Acceptable
Position 6	Front Panel		Normal	No deviations observed	Acceptable
Position 7			Normal	No deviations observed	Acceptable
Position 8	Back Panel		Normal	No deviations observed	Acceptable
Position 9			Normal	No deviations observed	Acceptable
Position 10	Top Panel		Normal	No deviations observed	Acceptable
Position 11			Normal	No deviations observed	Acceptable
Position 12			Normal	No deviations observed	Acceptable
Position 13			Normal	No deviations observed	Acceptable
Position 14	Bottom Panel		Normal	No deviations observed	Acceptable
Position 15			Normal	No deviations observed	Acceptable
Position 16			Normal	No deviations observed	Acceptable
Position 17			Normal	No deviations observed	Acceptable
Position 18	Left Panel		Normal	One anomaly was observed. As a result of the data checking, it was concluded that this event was not an indication of susceptibility by the OPRM unit.	Acceptable
Position 19			Normal	No deviations observed	Acceptable
Position 20	Right Panel		Normal	No deviations observed	Acceptable
Position 21			Normal	No deviations observed	Acceptable

9.2.2.6 RS103: Radiated Susceptibility, Electric Field

The EUT was subjected to the radiated electric fields level indicated in the Regulatory Position 4.3.2 of RG 1.180, Revision 1 (Reference (3)) in the frequency range of 30 MHz to 10 GHz. The test specimen did not exhibit susceptibility to the required interference conditions on any positions tested listed in Table 9-10. No anomalies were observed, and the test specimen met Criteria Level A. Thus, the test specimen complies with the susceptibility requirements in Regulatory Position 4.3.2 of RG 1.180, Revision 1.

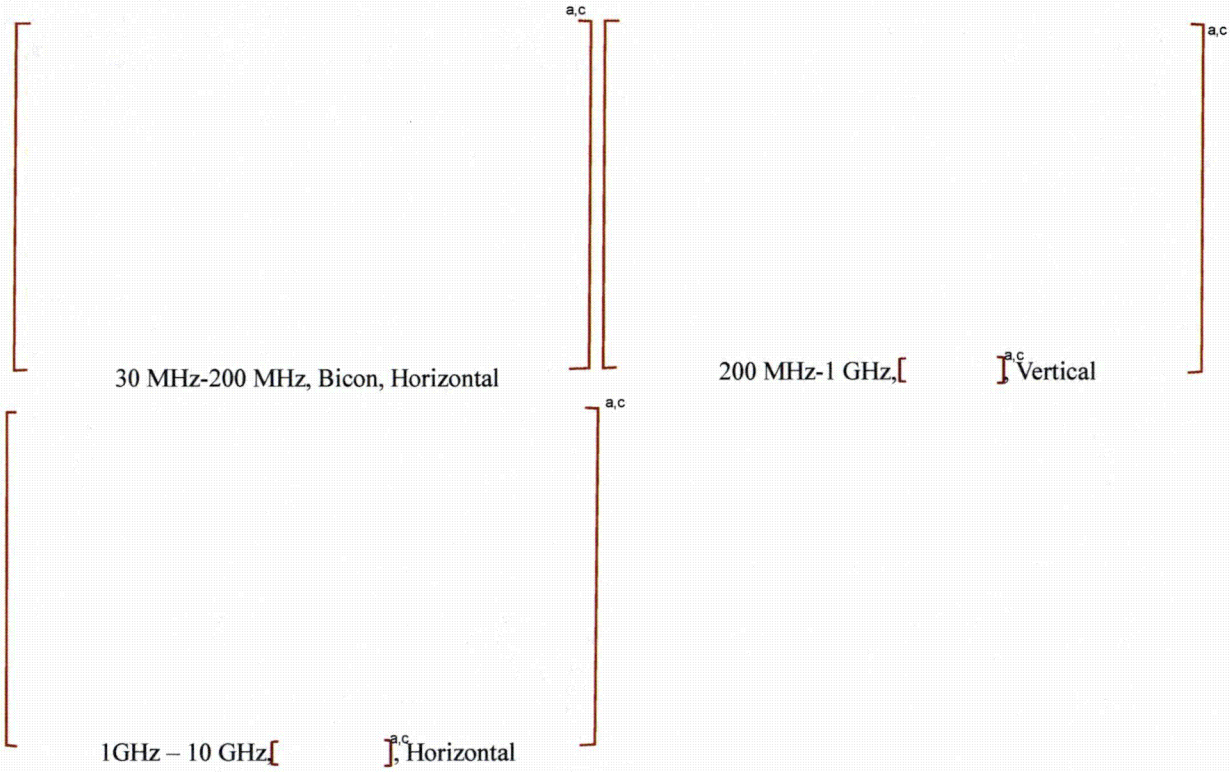


Figure 9-10 Representative RS103 Test Setup

Table 9-10 RS103 Test Results

Polarization	Antenna Description	Frequency		Operating Mode	EUT Response	Test Result
		Start (MHz)	Stop (MHz)			
Vertical	30 MHz–200 MHz,	30	200	Normal	No deviations observed	Acceptable
	200 MHz–1 GHz,	200	1000	Normal	No deviations observed	Acceptable
	1 GHz – 10 GHz,	1000	10000	Normal	No deviations observed	Acceptable
Horiszontal	30 MHz–200 MHz,	30	200	Normal	No deviations observed	Acceptable
	200 MHz–1 GHz,	200	1000	Normal	No deviations observed	Acceptable
	1 GHz – 10 GHz,	1000	10000	Normal	No deviations observed	Acceptable

9.2.3 Power Surge Test Result

The power surge test was performed from December 30, 2012 through January 3, 2013. All the test items of the power surge test were successfully completed. The test result for each test item was reported in the following subsections. During the power surge test, the performance of the OPRM unit was continuously monitored inputting the test pattern explained in Section 8.4.1. The performance of the test specimen was checked by Toshiba test personnel whether the test specimen met Criteria Level A explained in Section 8.4.2 (2) without showing any susceptibility to applied test level. The history of test progress and performance check result by Toshiba test personnel was documented in the Power Surge Test Record (Reference (26)) showing that the OPRM normally operated as expected performing its intended safety functions.

9.2.3.1 IEC 61000-4-12: Ring Wave Immunity Test Result

IEC 61000-4-12 testing was performed by applying the disturbances of ±2 kV categorized as "Category B locations" and "Low Exposure levels" in Regulatory Position 5 and Table 22 of RG 1.180, Revision 1 (Reference (3)). The distance between the EUT and the Coupling Network was 1 meter with excess power lead length gathered into a coil of 20 cm in diameter and spaced 10 cm (4 in) above the ground plane as shown in Figure 9-11. All signal/control test cables were also positioned approximately 10 cm (4 in.) above the ground plane as shown in Figure 9-11. The test specimen did not exhibit susceptibility to the required interference conditions for all levels and applications, as listed in Table 9-11. No anomalies were observed, and the test specimen met Criteria Level A. Thus, the test specimen was demonstrated the surge withstand capability required in Regulatory Position 5.1 of RG 1.180, Revision 1.

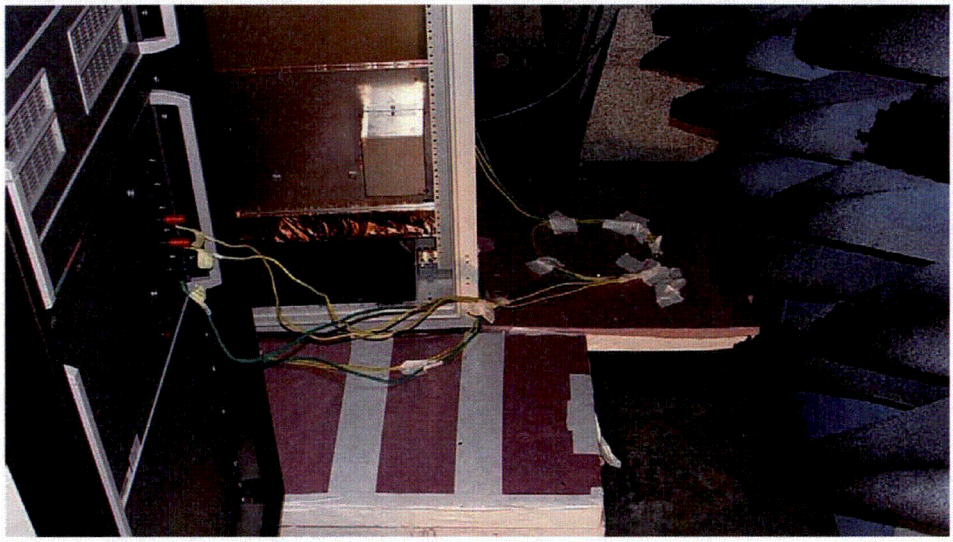


Figure 9-11 Ring Wave Test Setup (120 VAC (B))

Table 9-11 Ring Wave Test Results

Cable Type	Application Point	Operating Mode	Phase Synchronization Angle			EUTResponse Severity Level (kV) ±2.0	Test Result
120 VAC (A)	Line (L)- Neutral (N)	Normal	0	90	270	A	Acceptable
	Line (L)- Ground (G)	Normal	0	90	270	A	Acceptable
	Neutral (N) - Ground (G)	Normal	0	90	270	A	Acceptable
	Line (L) & Neutral (N) - Ground (G)	Normal	0	90	270	A	Acceptable
120 VAC (B)	Line (L)- Neutral (N)	Normal	0	90	270	A	Acceptable
	Line (L)- Ground (G)	Normal	0	90	270	A	Acceptable
	Neutral (N) - Ground (G)	Normal	0	90	270	A	Acceptable
	Line (L) & Neutral (N) - Ground (G)	Normal	0	90	270	A	Acceptable
120 VAC (A) without 120 VAC (B)	Line (L)- Neutral (N)	Abnormal	0	90	270	A	Acceptable
	Line (L)- Ground (G)	Abnormal	0	90	270	A	Acceptable
	Neutral (N) - Ground (G)	Abnormal	0	90	270	A	Acceptable
	Line (L) & Neutral (N) - Ground (G)	Abnormal	0	90	270	A	Acceptable

9.2.3.2 IEC 61000-4-5: Combination Wave Immunity Test Result

IEC 61000-4-5 testing was performed by applying the disturbances of ±2 kV categorized as "Category B locations" and "Low Exposure levels" in Regulatory Position 5 and Table 22 of RG 1.180, Revision 1 (Reference (3)). All signal/control test cables were positioned approximately 10 cm (4 in.) above the ground plane as shown in Figure 9-12. The test specimen did not exhibit susceptibility to the required interference conditions for all levels and applications, as listed in Table 9-12. No anomalies were observed, and the test specimen met Criteria Level A. Thus, the test specimen was demonstrated the surge withstand capability required in Regulatory Position 5.2 of RG 1.180, Revision 1.

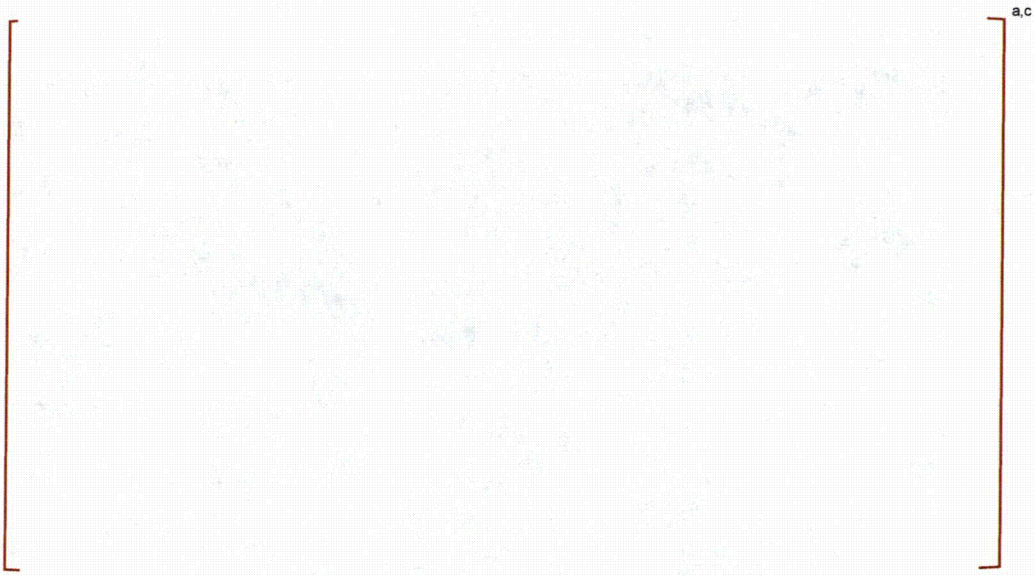


Figure 9-12 Combination Wave Test Setup (120 VAC (A))

Table 9-12 Combination Wave Test Results

Cable Type	Application Point	Operating Mode	Phase Synchronization Angle			EUTResponse Severity Level (kV)			Test Result
						±0.5	±1.0	±2.0	
120 VAC (A)	Line (L)– Neutral (N)	Normal	0	90	270	A	A	A	Acceptable
	Line (L)– Ground (G)	Normal	0	90	270	A	A	A	Acceptable
	Neutral (N) – Ground (G)	Normal	0	90	270	A	A	A	Acceptable
	Line (L) & Neutral (N) – Ground (G)	Normal	0	90	270	A	A	A	Acceptable
120 VAC (B)	Line (L)– Neutral (N)	Normal	0	90	270	A	A	A	Acceptable
	Line (L)– Ground (G)	Normal	0	90	270	A	A	A	Acceptable
	Neutral (N) – Ground (G)	Normal	0	90	270	A	A	A	Acceptable
	Line (L) & Neutral (N) – Ground (G)	Normal	0	90	270	A	A	A	Acceptable
120 VAC (A) without 120 VAC (B)	Line (L)– Neutral (N)	Abnormal	0	90	270	A	A	A	Acceptable
	Line (L)– Ground (G)	Abnormal	0	90	270	A	A	A	Acceptable
	Neutral (N) – Ground (G)	Abnormal	0	90	270	A	A	A	Acceptable
	Line (L) & Neutral (N) – Ground (G)	Abnormal	0	90	270	A	A	A	Acceptable

9.2.3.3 IEC 61000-4-4: Electrical Fast Transient/Burst Immunity Test Result

IEC 61000-4-4 testing was performed by applying the disturbances of ±2 kV categorized as "Category B locations" and "Low Exposure levels" in Regulatory Position 5 and Table 22 of RG 1.180, Revision 1 (Reference (3)). The distance between the EUT and the Coupling Network was 1 meter, with excess power lead length gathered into a coil of 40 cm in diameter and spaced 10 cm (4 in) above the ground plane as shown in Figure 9-13. All signal/control test cables were also positioned approximately 10 cm (4 in.) above the ground plane as shown in Figure 9-13. The test specimen did not exhibit susceptibility to the required interference conditions for all levels and applications, as listed in Table 9-13. No anomalies were observed, and the test specimen met Criteria Level A. Thus, the test specimen was demonstrated the surge withstand capability required in Regulatory Position 5.3 of RG 1.180, Revision 1.

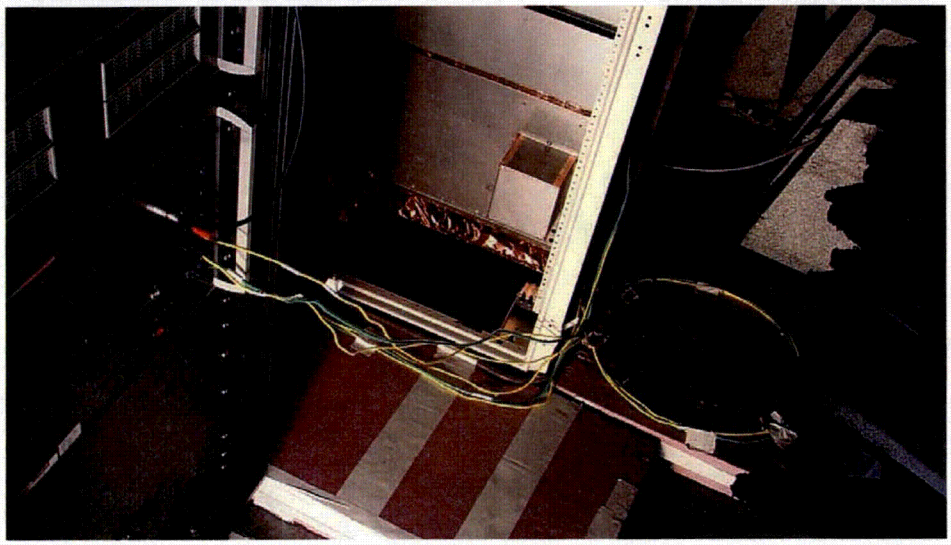


Figure 9-13 EFT/B Test Setup (120 VAC (A))

Table 9-13 EFT/B Test Results

Cable Type	Application Point	Duration	Operating Mode	EUT Response	Test Result
120 VAC (A)	Line (L)	60	Normal	A	Pass
	Neutral (N)	60	Normal	A	Pass
	Ground (G)	60	Normal	A	Pass
	L, N, G simultaneous	60	Normal	A	Pass
120 VAC (B)	Line (L)	60	Normal	A	Pass
	Neutral (N)	60	Normal	A	Pass
	Ground (G)	60	Normal	A	Pass
	L, N, G simultaneous	60	Normal	A	Pass
120 VAC (A) without 120 VAC (B)	Line (L)	60	Normal	A	Pass
	Neutral (N)	60	Normal	A	Pass
	Ground (G)	60	Normal	A	Pass
	L, N, G simultaneous	60	Normal	A	Pass

9.2.4 Electrostatic Discharge (ESD) Test Result

ESD test was performed on January 3 and 4, 2013. During the ESD test, the performance of the OPRM unit was continuously monitored inputting the test pattern explained in Section 8.4.1. The performance of the test specimen was checked by Toshiba test personnel whether the test specimen met Criteria Level A explained in Section 8.4.2 (2) without showing any susceptibility to applied test level. The history of test progress and performance check result by Toshiba test personnel was documented in the ESD Test Record (Reference (27)) showing that the OPRM normally operated as expected performing its intended safety functions.

The ESD test in accordance with IEC 61000-4-2 (Reference (4)) was performed by applying the Level 4 shown in Table 1 of IEC 61000-4-2. The representative ESD test setup is shown in Figure 9-14. The test specimen did not exhibit susceptibility to the required interference conditions for all levels and applications, as listed in Table 9-14 and Table 9-15. No anomalies were observed, and the test specimen met Criteria Level A. Thus, the test specimen was demonstrated the ESD withstand capability required in Section 4.3.8 of EPRI TR-107730 (Reference (13)).

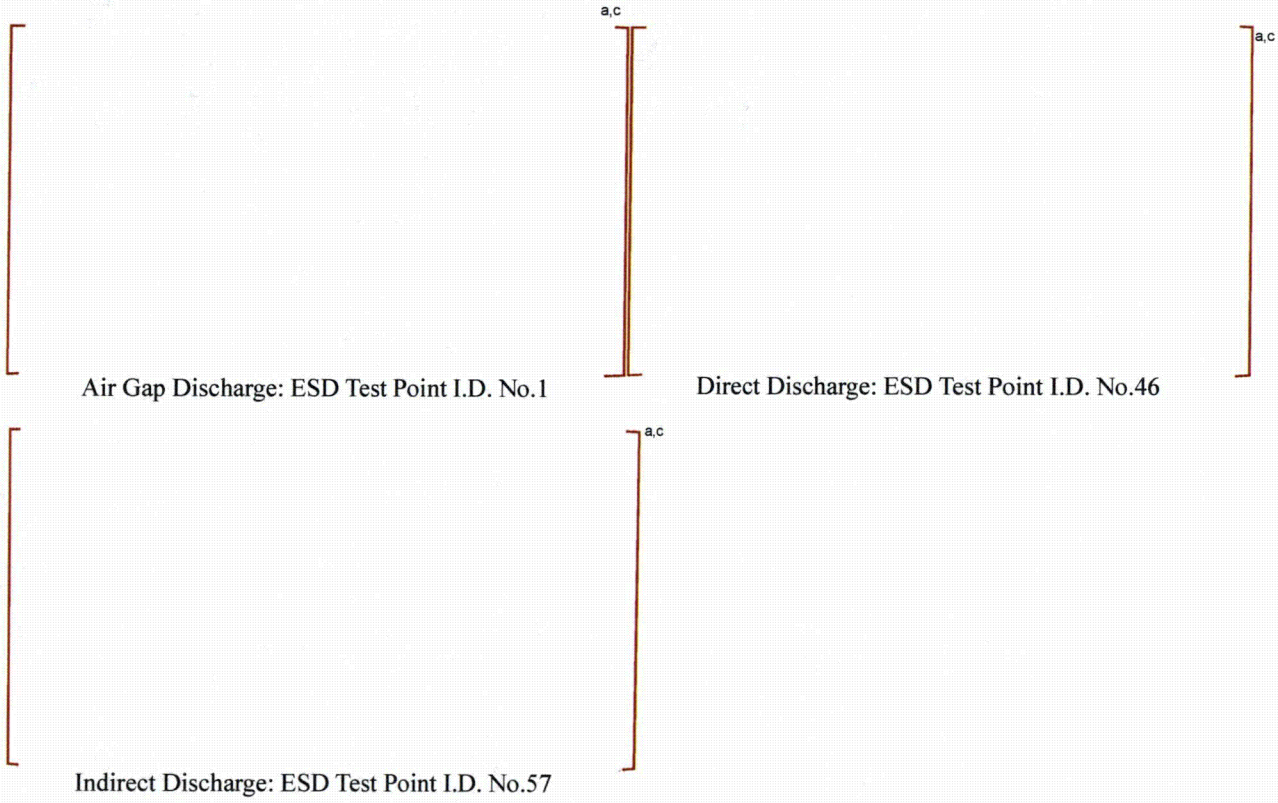


Figure 9-14 ESD Test Setup

Table 9-14 ESD Test Results (Air Gap Discharge)

Test Type	ID	Position	Total Pulses		EUT Response Severity Level (kV)				Test Result
		a,c	+	-	±2.0	±4.0	±8.0	±15.0	
Air Gap Discharge	1		10	10	A	A	A	A	Acceptable
	2		10	10	A	A	A	A	Acceptable
	3		10	10	A	A	A	A	Acceptable
	4		10	10	A	A	A	A	Acceptable
	5		10	10	A	A	A	A	Acceptable
	6		10	10	A	A	A	A	Acceptable
	7		10	10	A	A	A	A	Acceptable
	8		10	10	A	A	A	A	Acceptable
	9		10	10	A	A	A	A	Acceptable
	10		10	10	A	A	A	A	Acceptable
	11		10	10	A	A	A	A	Acceptable
	12		10	10	A	A	A	A	Acceptable
	13		10	10	A	A	A	A	Acceptable
	14		10	10	A	A	A	A	Acceptable
	15		10	10	A	A	A	A	Acceptable
	16		10	10	A	A	A	A	Acceptable
	17		10	10	A	A	A	A	Acceptable
	18		10	10	A	A	A	A	Acceptable
	19		10	10	A	A	A	A	Acceptable
	20		10	10	A	A	A	A	Acceptable
	21		10	10	A	A	A	A	Acceptable
	22		10	10	A	A	A	A	Acceptable
	23		10	10	A	A	A	A	Acceptable
	24		10	10	A	A	A	A	Acceptable
	25		10	10	A	A	A	A	Acceptable
	26		10	10	A	A	A	A	Acceptable
	27		10	10	A	A	A	A	Acceptable
	28		10	10	A	A	A	A	Acceptable
	29		10	10	A	A	A	A	Acceptable
	30		10	10	A	A	A	A	Acceptable
	31		10	10	A	A	A	A	Acceptable
	32		10	10	A	A	A	A	Acceptable
	33		10	10	A	A	A	A	Acceptable
	34		10	10	A	A	A	A	Acceptable
	35		10	10	A	A	A	A	Acceptable
	36		10	10	A	A	A	A	Acceptable
	37		10	10	A	A	A	A	Acceptable
	38		10	10	A	A	A	A	Acceptable
	39		10	10	A	A	A	A	Acceptable
	40		10	10	A	A	A	A	Acceptable
	41		10	10	A	A	A	A	Acceptable
	42		10	10	A	A	A	A	Acceptable
	43		10	10	A	A	A	A	Acceptable

Table 9-15 ESD Test Results (Contact Discharge)

Test Type	ID	Position	Total Pulses		EUT Response Severity Level (kV)				Test Result
		a,c	+	-	±2.0	±4.0	±6.0	±8.0	
Direct Contact Discharge	44		10	10	A	A	A	A	Acceptable
	45		10	10	A	A	A	A	Acceptable
	46		10	10	A	A	A	A	Acceptable
	47		10	10	A	A	A	A	Acceptable
	48		10	10	A	A	A	A	Acceptable
	49		10	10	A	A	A	A	Acceptable
	50		10	10	A	A	A	A	Acceptable
	51		10	10	A	A	A	A	Acceptable
	52		10	10	A	A	A	A	Acceptable
	53		10	10	A	A	A	A	Acceptable
Contact Discharge	54		10	10	A	A	A	A	Acceptable
	55		10	10	A	A	A	A	Acceptable
	56		10	10	A	A	A	A	Acceptable
	57		10	10	A	A	A	A	Acceptable
	58		10	10	A	A	A	A	Acceptable
	59		10	10	A	A	A	A	Acceptable

9.2.5 Evaluation of Test Anomaly

Four anomalies were observed in the EMC qualification test as follows.

[a,c]

[a,c]

[a,c]

[ ]a,c

[ ]a,c

9.3 Post-Qualification Test Result

After the completion of the EMC qualification test, the post-qualification test was performed on January 7, 2013 at the EMC chamber in[ ]a,c. In the post-qualification test, the performance proof test which was comprised of the setup & check-out test, operability test, and prudency test were conducted as described in Section 8.2. All the test results were documented in the Performance Proof (Post-Qualification for EMC Test) Test Record (Reference (29)). All the test results satisfied the acceptance criteria specified in each test procedure and showed that the test specimen and test system correctly operated.

10. EMC QUALIFICATION ANALYSIS

10.1 Similarity Evaluation for New Module Design

The test specimen listed in Table 6-1 was qualified through the EMC qualification test. The design changes of the TRN module, the RCV module, and related FPGAs used in those modules were made to add Cyclic Redundancy Check (CRC) functions. Supplemental software safety analysis activities and Verification & Validation (V&V) activities were performed on the changes of module and FPGA designs in a same manner applied to the test specimen listed in Table 6-1.

Table 10-1 shows the relationship between the module types of the TRN modules and the FPGA code names applied to each module type before and after the design change. The design change is implemented on the FPGA logic change made on TRNOPT3 to enhance the integrity of data transmission between the RCV module and the TRN module used within the PRNM system, and data transmission between the PRNM system and external system. No change is made to the printed circuit board wiring, parts, hardware structure, and manufacturing process of the modules. Thus hardware design change is not included in this design change. The HNS0531B00001 has the same hardware configuration as that of the HNS0531B00000.

Table 10-1 Applicable Module Type and FPGA Code Name for TRN Modules

Before design change		After design change		
Module Type	FPGA Code Name	Module Type	FPGA Code Name	Modified in this deign change?
HNS0531 B00000	TRNOPT2	HNS0531 B00001	TRNOPT3	**Modified**
	TRNAD		TRNAD	Use as is
	TRNUNIT		TRNUNIT	Use as is

Table 10-2 shows the relationship between the module types of the RCV modules and the FPGA code names applied to each module type before and after the design change. The design change is implemented on the FPGA logic change made on RCVUNIT3 and RCVOPT3 to enhance the integrity of data transmission between the RCV module and the TRN module used within the PRNM system, and data transmission between the PRNM system and external system. No change is made to the printed circuit board wiring, parts, hardware structure, and manufacturing process of the module. Thus hardware design change is not included in this design change. The HNS0541B00001 has the same hardware configuration as that of the HNS0541B00000.

Table 10-2 Applicable Module Type and FPGA Code Name for RCV Modules

Before design change		After design change		
Module Type	FPGA Code Name	Module Type	FPGA Code Name	Modified in this deign change?
HNS0541 B00000	RCVUNIT2	HNS0541 B00001	RCVUNIT3	**Modified**
	RCVOPT		RCVOPT3	**Modified**

As discussed above, it was evaluated those new module designs had no effect on the EMC qualification test results of the OPRM unit reported in Section 9, and the qualification test results obtained for the test specimen listed in Table 6-1 were extended to the new module designs.

11. INSTALLATION PRACTICE AND ADMINISTRATIVE CONTROL

The purpose of this section is to prescribe the installation practice and administrative control when the OPRM unit is installed in the actual plant.

11.1 Mounting and Orientation

1. The OPRM unit shall be mounted on a cabinet which is an enclosure made with steel.
2. The OPRM unit shall be mounted on the cabinet so that the front panel of the OPRM unit faces forward.
3. The PFCs shall be placed inside the cabinet so that the PFCs can not be seen from outside the cabinet.
4. The interconnecting power leads connecting the OPRM unit and the PFCs shall be wired inside the cabinet so that the cables can not be seen from outside the cabinet.
5. The OPRM unit and PFCs shall be fixed to the cabinet using the specified mounting bolts.
6. The cabinet shall be designed so that no painting or coating is applied to the area of contact between the cabinet and the OPRM unit as well as between the cabinet and PFC.

11.2 Power Line Configuration

1. The varistors and noise filters shall be inserted into the power lines in the cabinet as shown in Figure 11-1. Noise filters to be inserted into power lines should be appropriately selected taking into account the quality of power source of the actual installation under the in-service conditions. As described in Section 1.1.1.1 , it is recommended to use a noise filter (Model name:[ ]a,c manufactured by Tyco Electronics Connectivity Corp., or of equivalent performance to reduce emission noise if the power source is of poor quality.

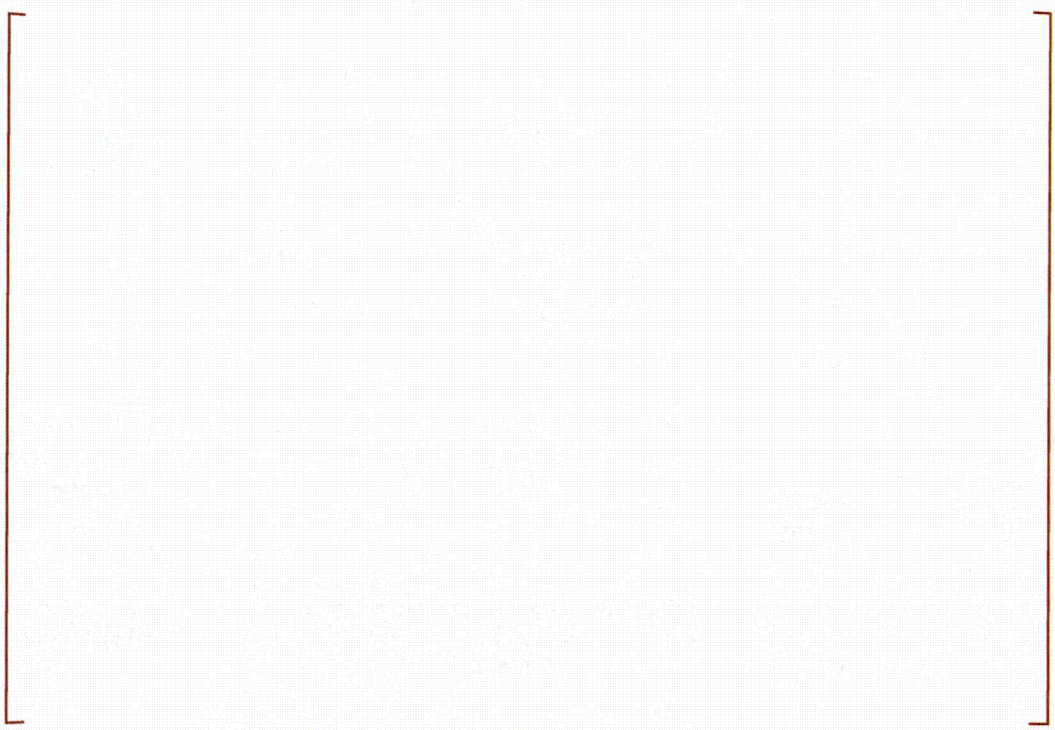


Figure 11-1 Power Line Configuration

11.3 Electrical Interface

1. There is no limitation for power leads from power source outside the cabinet. The power leads from power source shall be connected at the interfacing terminal block within the cabinet.

2. The shielded DIO signal cable shall be used. For DIO signal interface, the following 2 methods are assumed to be used:

   - DIO signals are directly connected to system outside the cabinet, or

   - DIO signals are connected via a Relay unit inside the cabinet to system outside the cabinet.

   The former case shall involve termination of the DIO signal cable shield at the cabinet end. The latter case shall also involve termination of the shield of the cable connected to the Relay unit at the cabinet end. At the same time, the shield of the cable between the Relay unit and the OPRM unit shall be terminated at the Relay unit in the latter case.

3. Non-metallic optic fiber cable specified by Toshiba shall be used.

11.4 Administrative Control (Maintenance, Surveillance, and Replacement Program)

There are no maintenance, surveillance or replacement requirements defined as a result of the EMC qualification program.

12. CONCLUSIONS

The EMC qualification test was performed in accordance with the requirements of EMC Qualification Test Plan (Reference (17)) based on RG 1.180, Revision 1 (Reference (3)) and the EPRI TR-107330 (Reference (13)). The qualification program included type testing and similarity analysis.

The OPRM unit installed meeting installation practices required in Section 11 was qualified by the results of this EMC qualification test as follows:

1. The EMI/RFI emission test results in Section 9.2.1 show that the conducted and electromagnetic emissions from the test specimen satisfied the limit level specified in Regulatory Position 3 of RG 1.180, Revision 1.

2. The EMI/RFI susceptibility test results in Section 9.2.2 show that the test specimen was not exhibit any malfunction, degradation of performance, or deviation from specified limits specified in Section 8.4.2, when subjected to an immunity test signal specified in Regulatory Position 4 of RG 1.180, Revision 1.

3. The power surge test results in Section 9.2.3 show that the test specimen was not exhibit any malfunction, degradation of performance, or deviation from specified limits specified in Section 8.4.2, when subjected to an immunity test signal in Regulatory Position 5 of RG 1.180, Revision 1.

4. The ESD test results in Section 9.2.4 show that the test specimen response met the performance criterion "1)" classified in the Section 9 of the IEC 61000-4-2 (Reference (4)) for all levels and applications.

As a result of the similarity evaluation, it was determined that this EMC qualification test result could be applicable to the new TRN module and RCV module which were made to add Cyclic Redundancy Check (CRC) functions.

It was concluded in this EMC qualification report that the OPRM was designed to accommodate the effects of and to be compatible with the environmental conditions required by the RG 1.180, Revision 1 (Reference (3)) and the EPRI TR-107330 (Reference (13)) and the OPRM was qualified for safety-related component for nuclear power plants.

APPENDIX A
TEST SPECIMEN OUTLINE DRAWINGS

Page

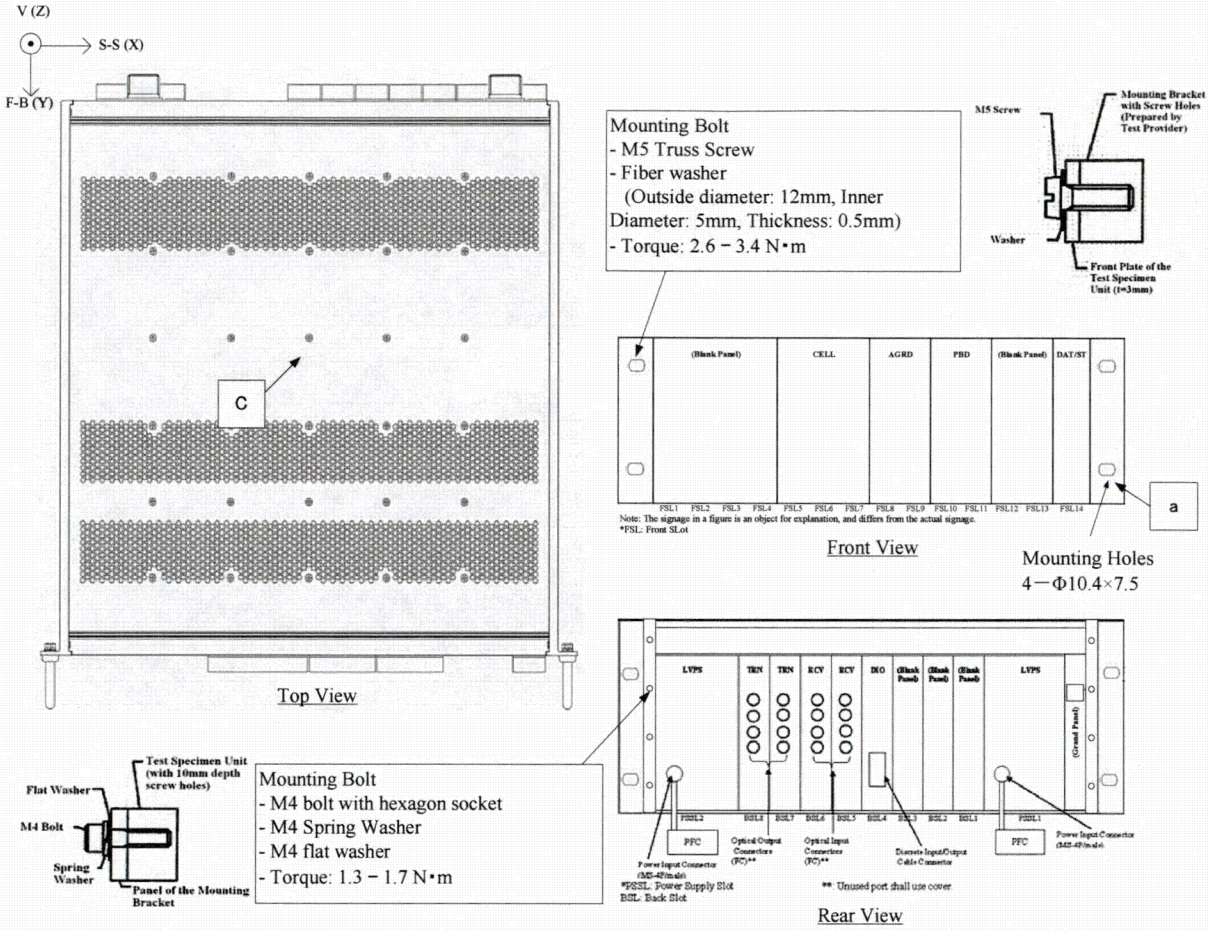


Figure A- 1 Outline Drawing of OPRM Unit

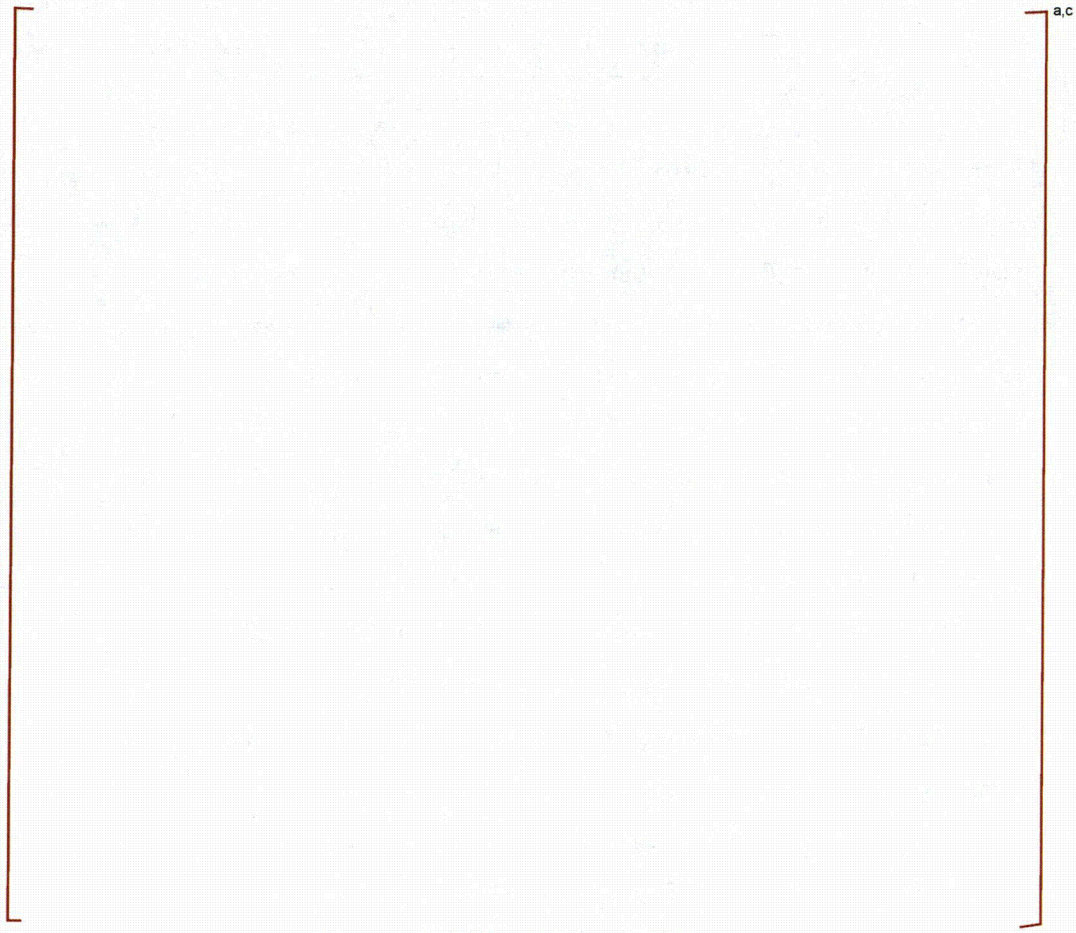


Figure A- 2 Outline Drawing of PFC

APPENDIX B
EMC TEST DATA

CE101 Test Result (1/2)

Table B-1 Summary of CE101 Test Result

Scan Description	Line Under Test	Highest Recorded Emanations		Limit (dBμA) @ Frequency	Compliant w/ Specification Yes /No
		Frequency (kHz)	Amplitude (dBμA)		
Signal Verification	Current Probe	≈ 1	85.4922	91.156	Yes
		≈ 3	83.217	86.164	Yes
		≈ 10.0	80.650	83.00	Yes
Ambient – Normal Mode	L1	0.060	105.648	114.0	Yes
	L2	0.060	105.083	114.0	Yes
	L3	0.060	69.699	114.0	Yes
Active – Normal Mode – Input A	L1	0.060	106.863	120.0	Yes
	L2	0.060	105.782	120.0	Yes
	L3	0.060	71.54	120.0	Yes
Ambient - Normal Mode – Input B	L4	0.060	104.95	114.0	Yes
	L5	0.060	105.36	114.0	Yes
	L6	0.060	74.73	114.0	Yes
Active – Normal Mode – Input B	L4	0.060	105.16	120.0	Yes
	L5	0.060	105.01	120.0	Yes
	L6	0.060	72.27	120.0	Yes
Ambient – Abnormal Mode – Input A Without B	L7	0.060	108.06	114.0	Yes
	L8	0.060	108.02	114.0	Yes
	L9	0.060	70.23	114.0	Yes
Active – Abnormal Mode – Input A Without B	L7	0.060	110.36	120.0	Yes
	L8	0.060	108.03	120.0	Yes
	L9	0.060	69.32	120.0	Yes

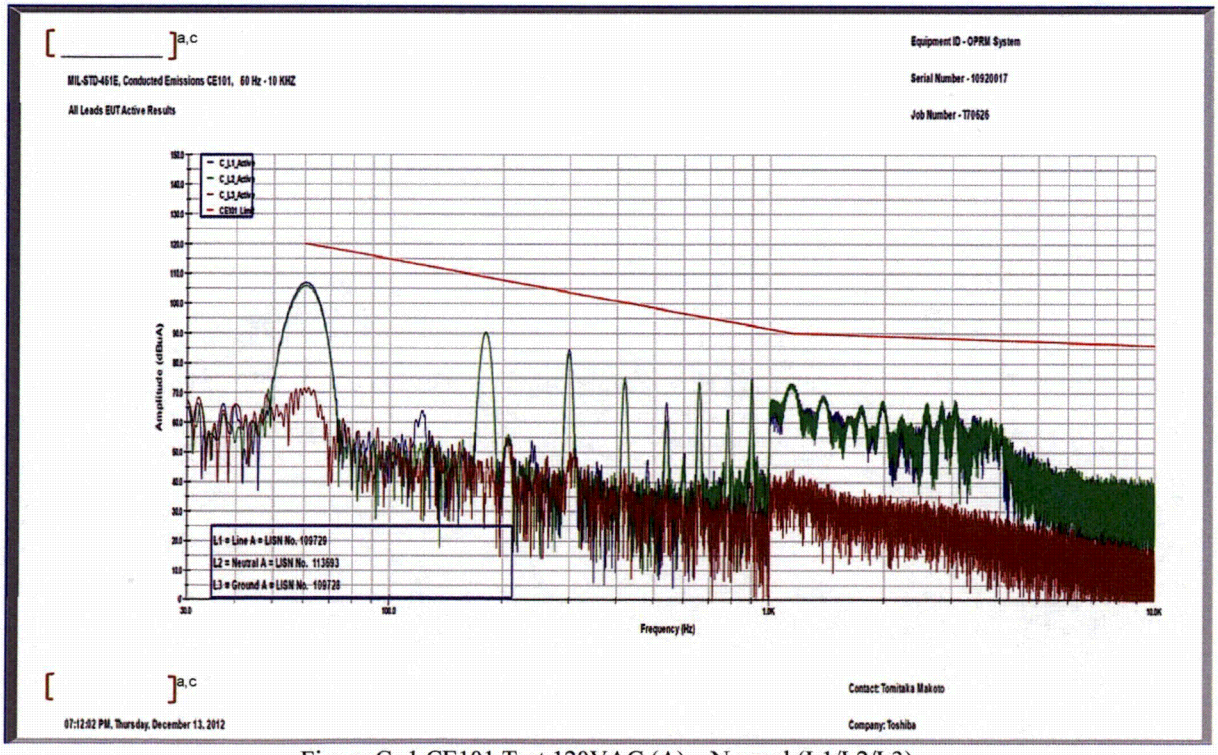


Figure C- 1 CE101 Test 120VAC (A) – Normal (L1/L2/L3)

CE101 Test Result (2/2)

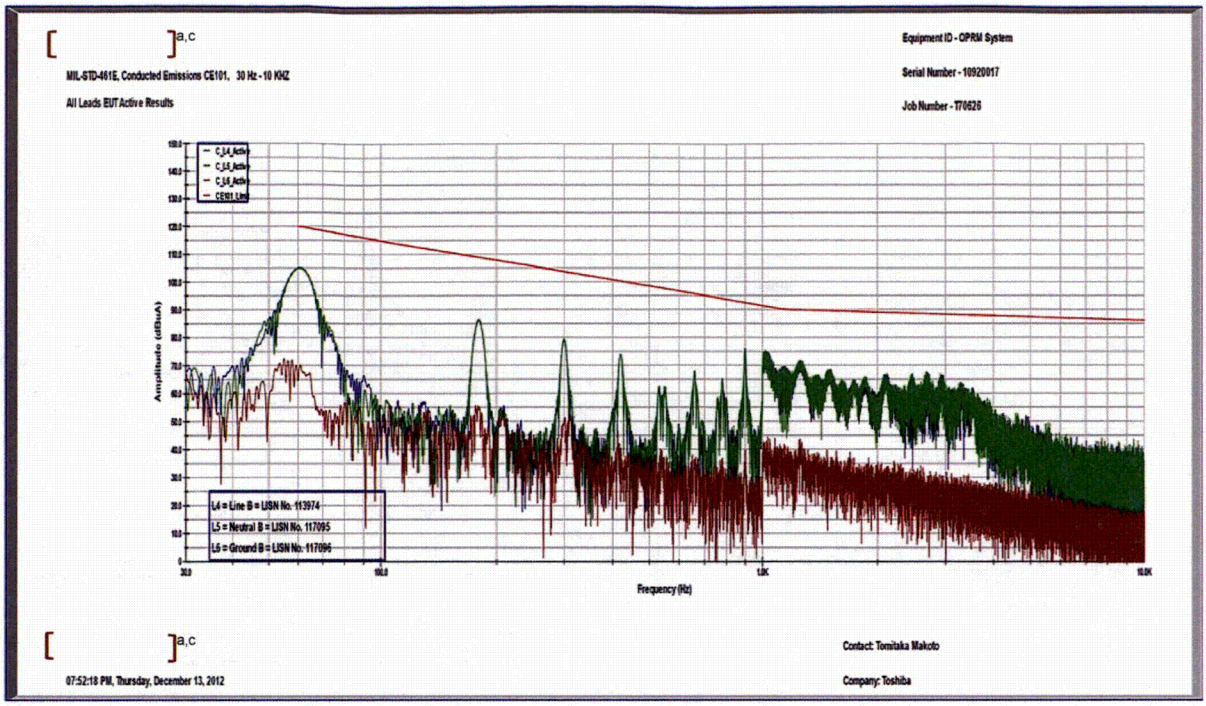


Figure C- 2 CE101 Test 120VAC (B) – Normal (L4/L5/L6)

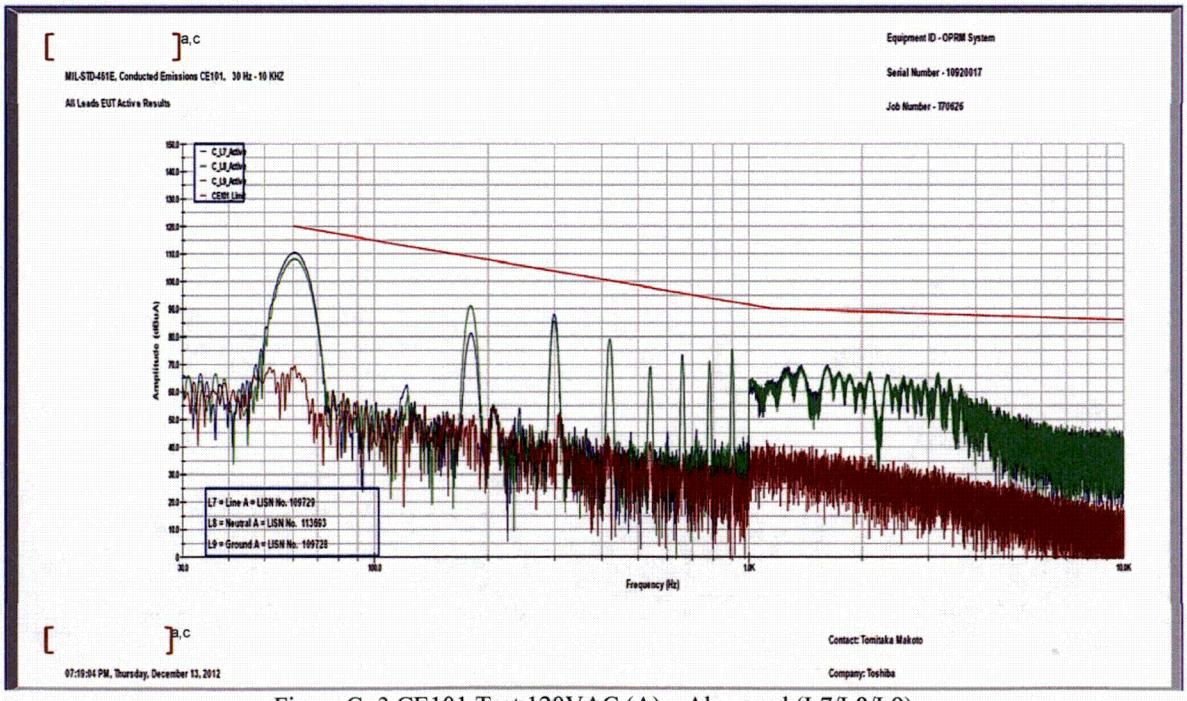


Figure C- 3 CE101 Test 120VAC (A) – Abnormal (L7/L8/L9)

CE102 Test Result (1/6)

Table B-2 Summary of CE102 Test Result

Scan Description	Line Under Test	Highest Recorded Emanations		Limit (dBμA) @ Frequency	Compliant w/ Specification Yes /No
		Frequency (kHz)	Amplitude (dBμA)		
Signal Verification	Input A Line L1/L7	≈ 10	94.535	94 +/- 3	Yes
	L1/L7	≈ 100	74.72	73.87 +/- 3	Yes
	L1/L7	≈ 2000	67.44	67 +/- 3	Yes
	Input A Neutral L2/L8	≈ 10	94.71	94 +/- 3	Yes
	L2/L8	≈ 100	74.55	73.87 +/- 3	Yes
	L2/L8	≈ 2000	67.47	67 +/- 3	Yes
	Input A Ground L3/L9	≈ 10	94.76	94 +/- 3	Yes
	L3/L9	≈ 100	74.35	73.87 +/- 3	Yes
	L3/L9	≈ 2000	67.26	67 +/- 3	Yes
	Input B Line L4	≈ 10	94.45	94 +/- 3	Yes
	L4	≈ 100	74.62	73.87 +/- 3	Yes
	L4	≈ 2000	67.49	67 +/- 3	Yes
	Input B Neutral L5	≈ 10	94.58	94 +/- 3	Yes
	L5	≈ 100	74.56	73.87 +/- 3	Yes
	L5	≈ 2000	67.51	67 +/- 3	Yes
	Input B Ground L6	≈ 10	94.49	94 +/- 3	Yes
	L6	≈ 100	74.56	73.87 +/- 3	Yes
	L6	≈ 2000	67.25	67 +/- 3	Yes
Ambient – Normal Mode	L1	34.71	71.6	88.56609155	Yes
	L2	33.34	63.89	88.91476702	Yes
	L3	33.59	34.49	88.84998028	Yes
Active – Normal Mode – Input A	L1	34.74	67.48	88.55862625	Yes
	L2	34.76	79.58	88.55365331	Yes
	L3	33.625	37.47	88.84095238	Yes
Ambient - Normal Mode – Input B	L4	33.41	63.35	88.89657312	Yes
	L5	33.41	64.35	88.89657312	Yes
	L6	33.275	36.9	88.93169893	Yes
Active – Normal Mode – Input B	L4	34.76	67.3	88.55365331	Yes
	L5	34.85	77.15	88.53131388	Yes
	L6	33.39	38.5	88.9017671	Yes
Ambient – Abnormal Mode – Input A Without B	L7	34.71	71.42	88.56609155	Yes
	L8	33.36	65.85	88.90956448	Yes
	L9	33.53	36.8	88.86548071	Yes
Active – Abnormal Mode – Input A Without B	L7	33.41	71.05	88.89657312	Yes
	L8	34.79	66.03	88.54619979	Yes
	L9	33.27	36.99	88.93300289	Yes

CE102 Test Result (2/6)

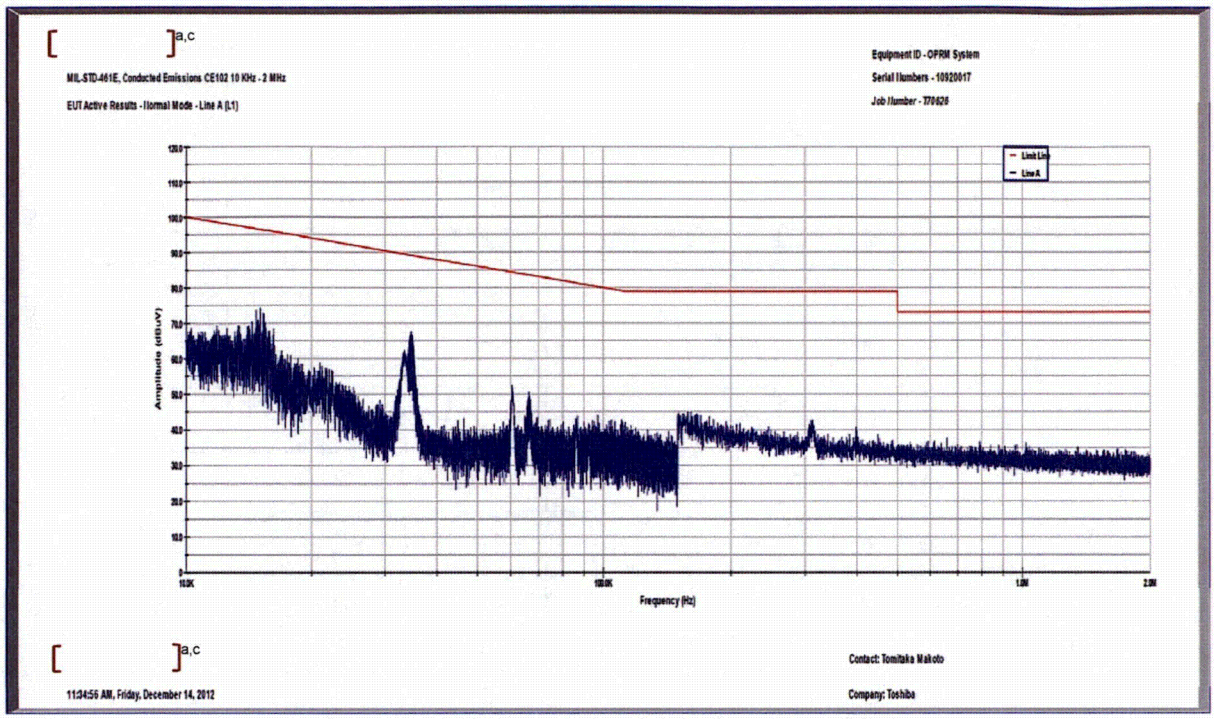


Figure C- 4 CE102 Test 120VAC (A) Line – Normal (L1)

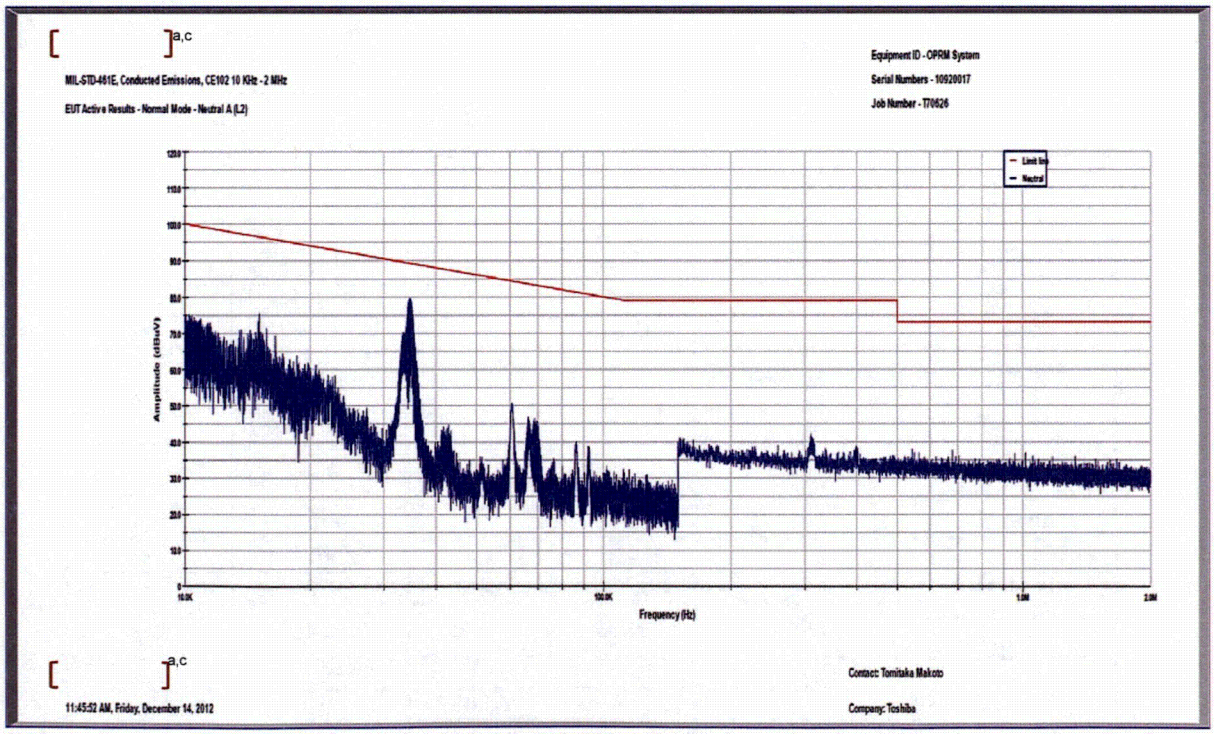


Figure C- 5 CE102 Test 120VAC (A) Neutral – Normal (L2)

CE102 Test Result (3/6)

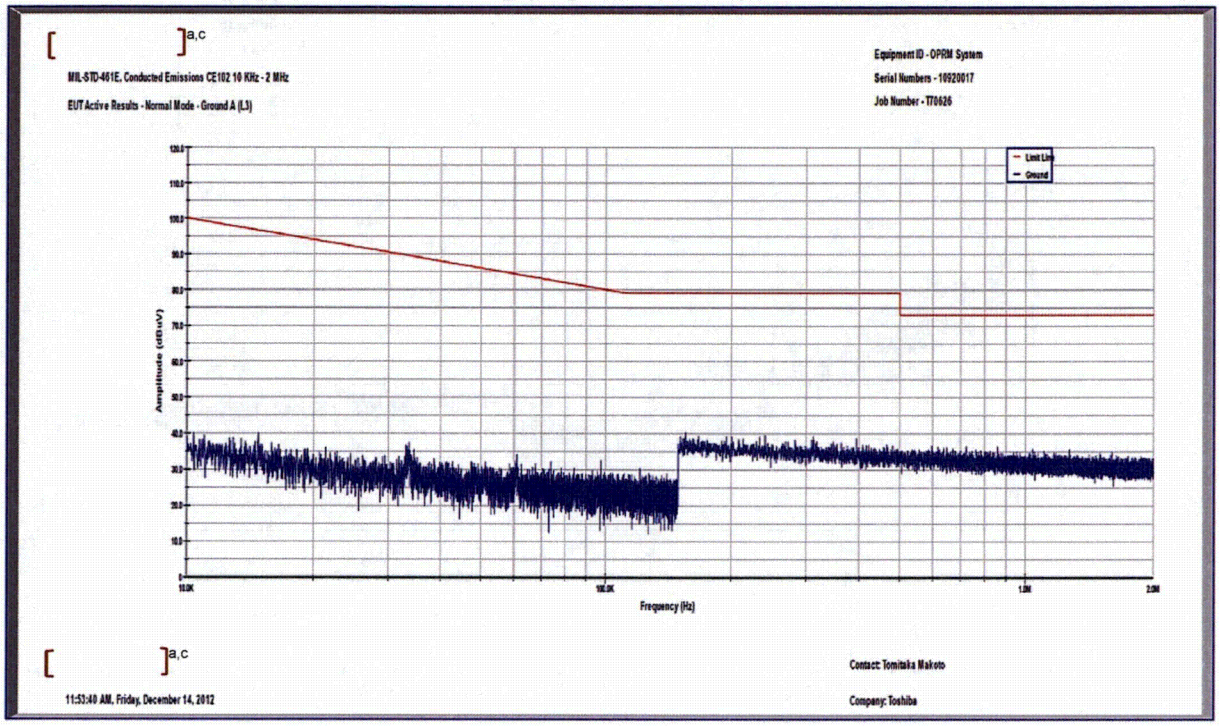


Figure C- 6 CE102 Test 120VAC (A) Ground – Normal (L3)

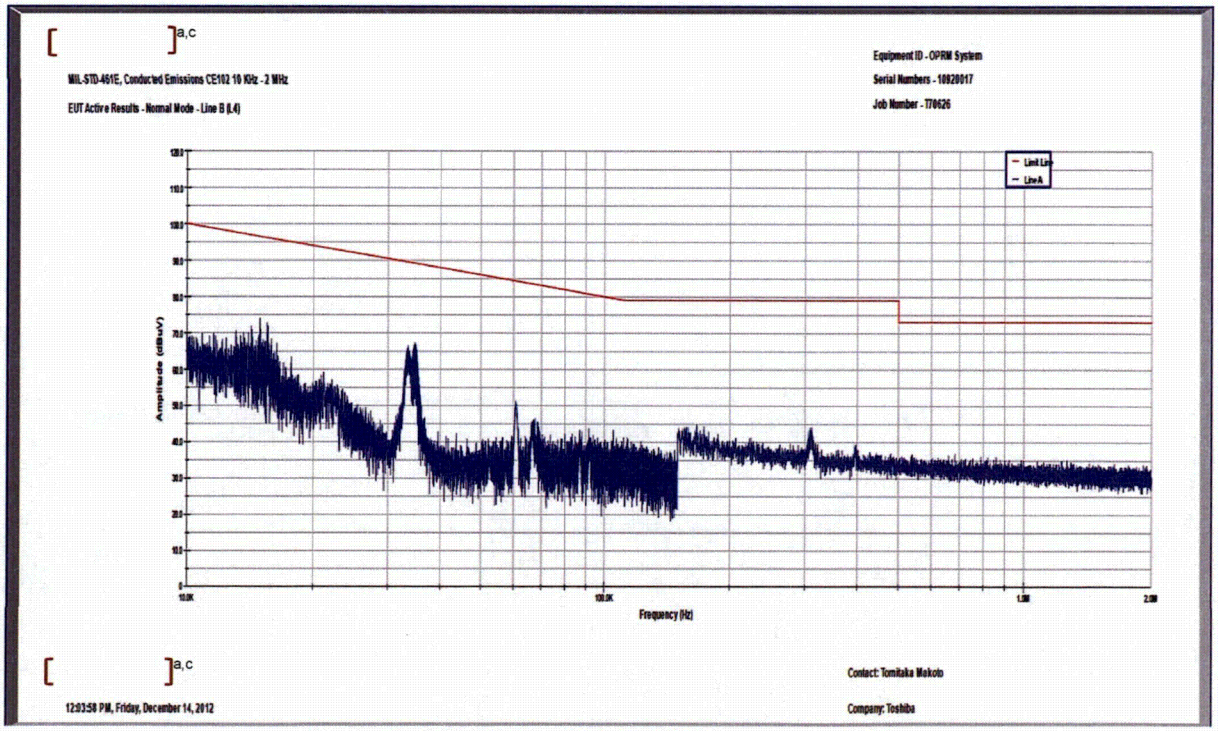


Figure C- 7 CE102 Test 120VAC (B) Line – Normal (L4)

CE102 Test Result (4/6)

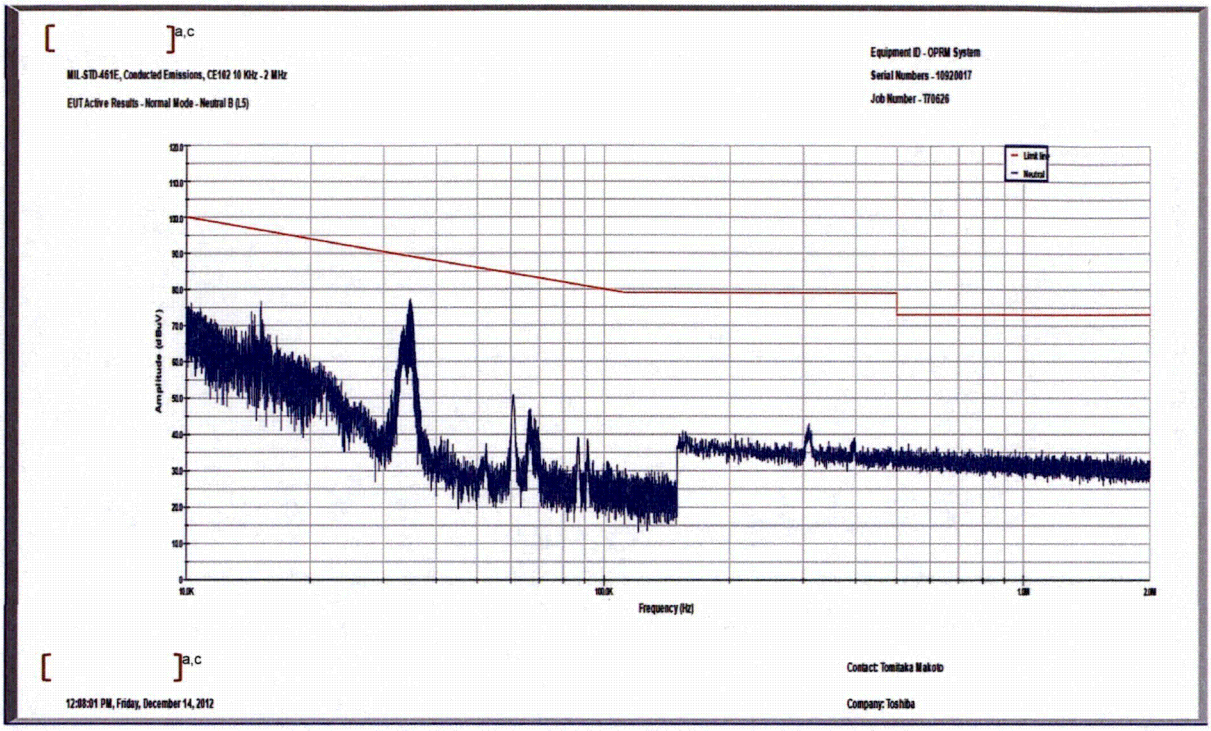


Figure C- 8 CE102 Test 120VAC (B) Neutral – Normal (L5)

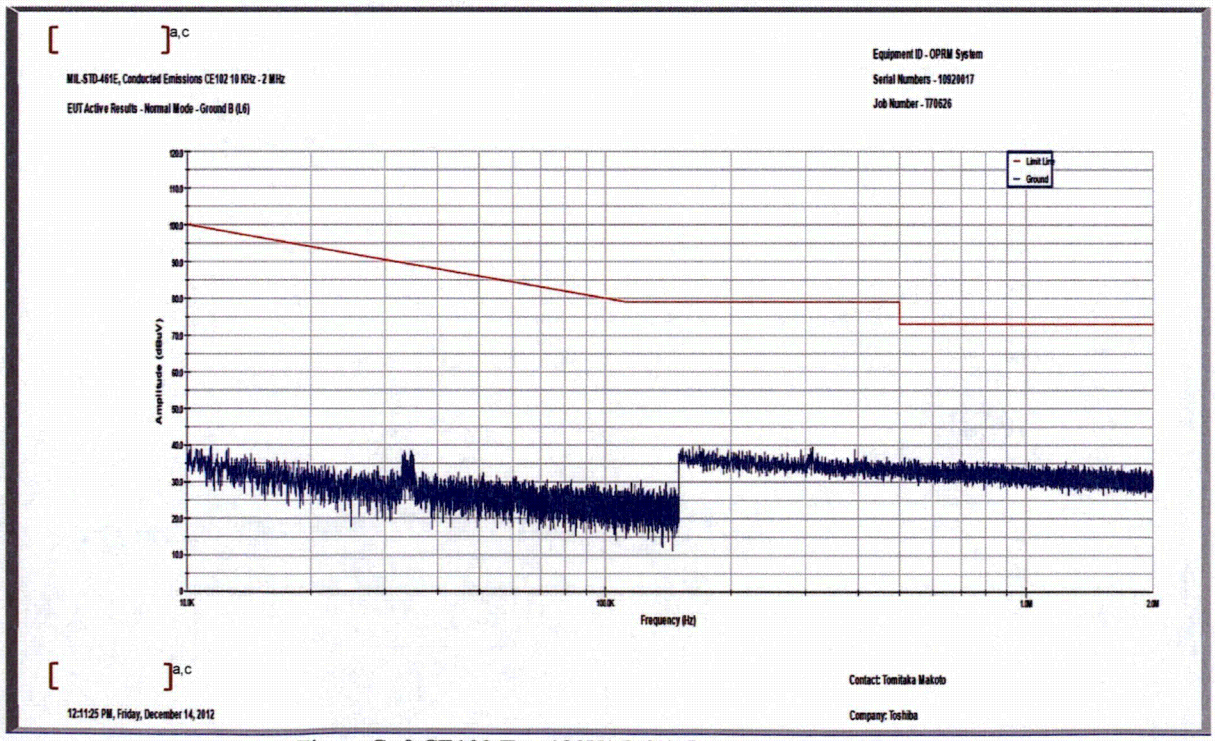


Figure C- 9 CE102 Test 120VAC (B) Ground – Normal (L6)

CE102 Test Result (5/6)

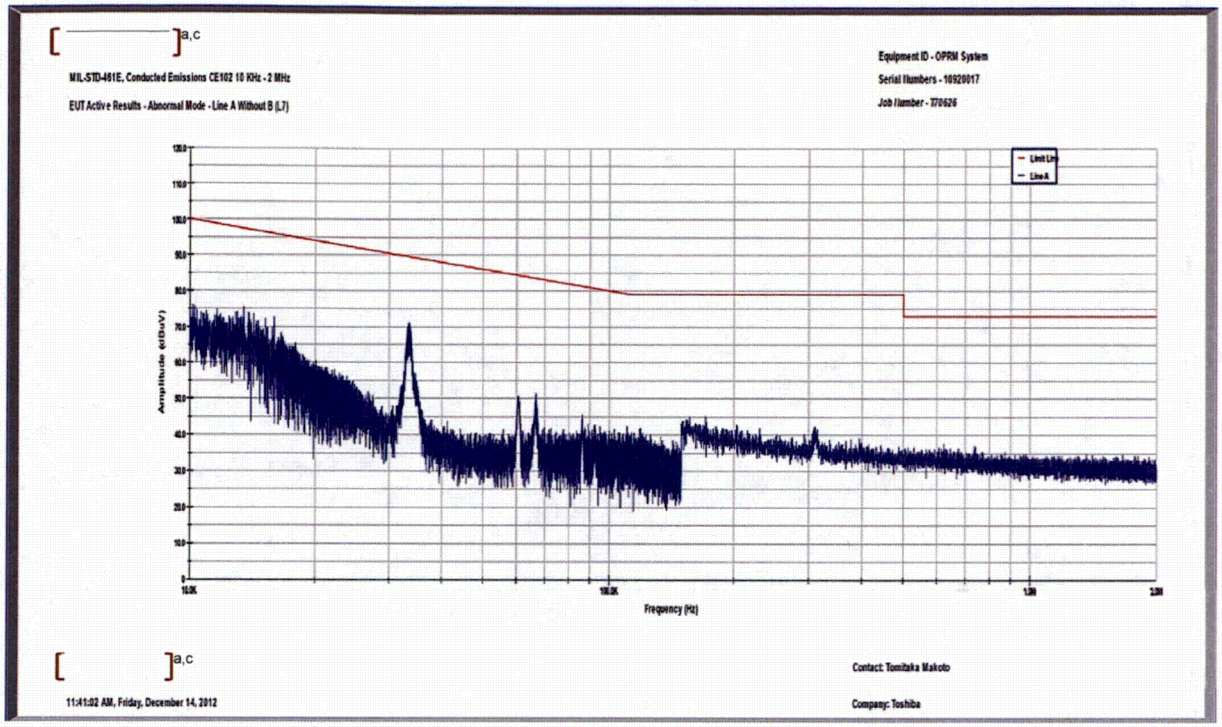


Figure C- 10 CE102 Test 120VAC (A) Line – Abnormal (L7)

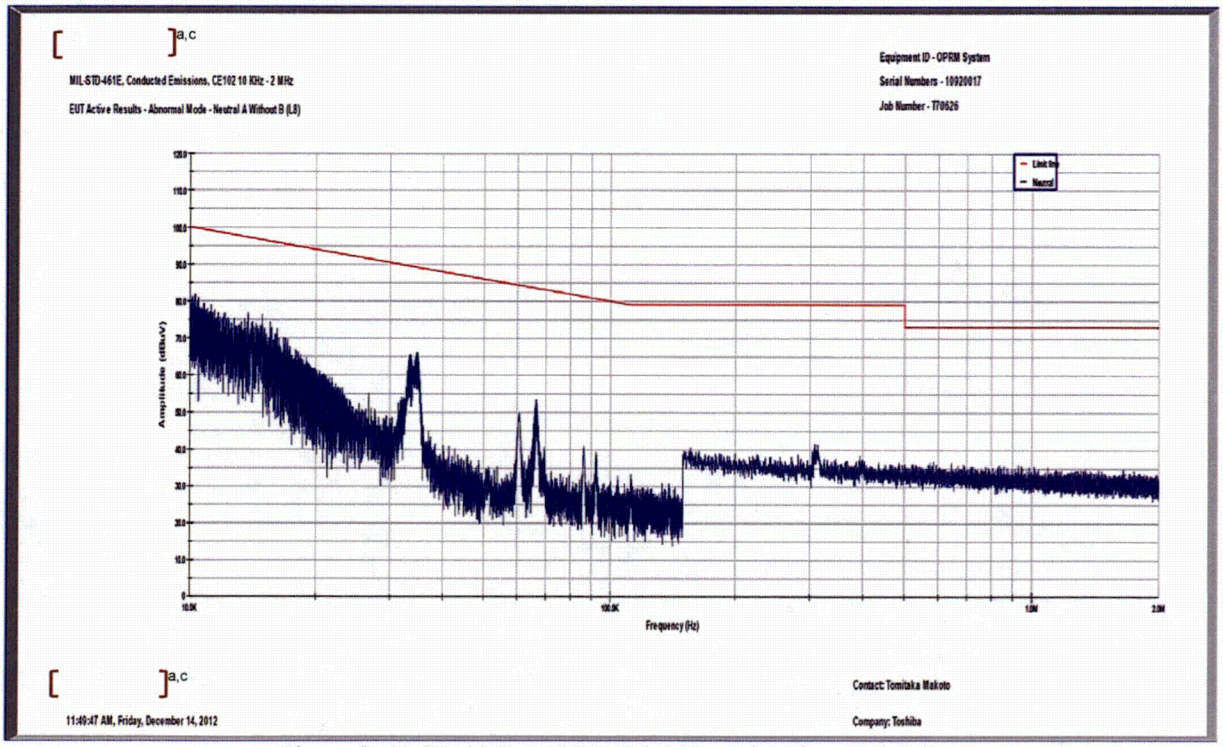


Figure C- 11 CE102 Test 120VAC (A) Neutral – Abnormal (L8)

CE102 Test Result (6/6)

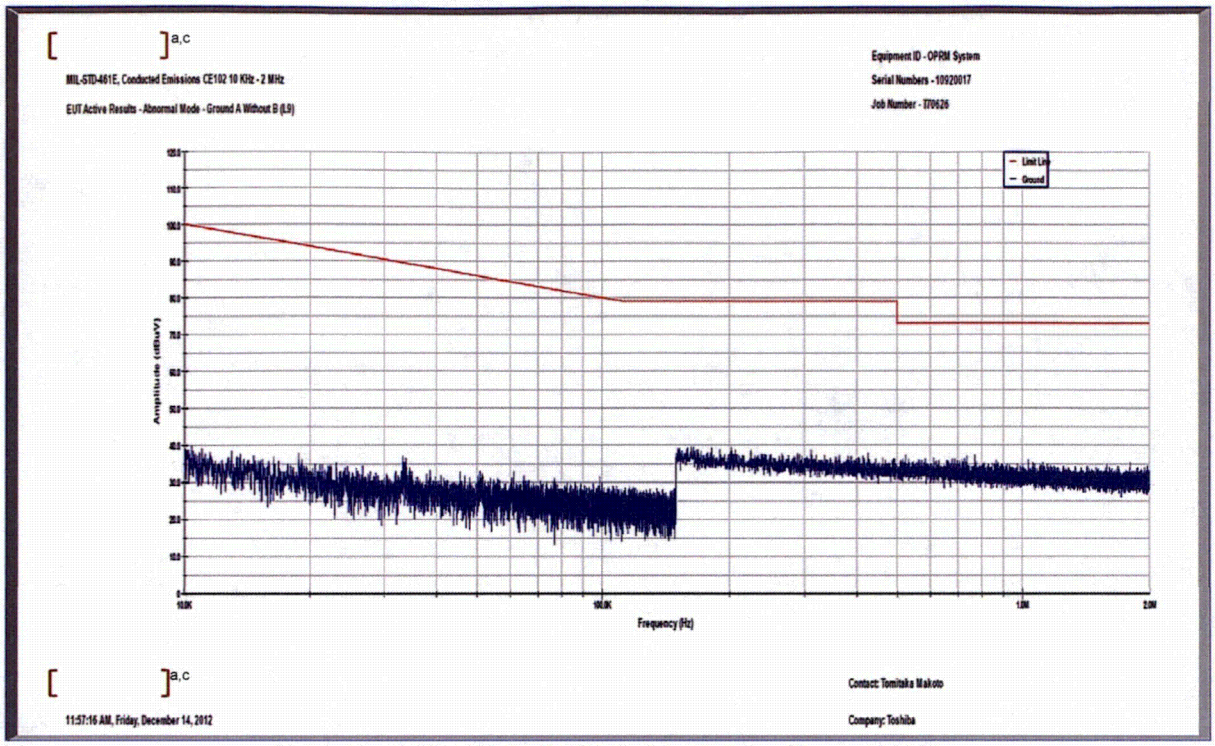


Figure C- 12 CE102 Test 120VAC (A) Ground – Abnormal (L9)

RE101 Test Result (1/12)

Table B-3 RE101 Test Matrix (Loop Positions)

Test I.D.	Position Number	Location Type	Operating Mode	Number of Locations	Description
Connectors	9	DIO Cable	Normal	1	Connector Location at Each Cable End
	11	LVPS1 Cable	Normal	1	
	10	LVPS2 Cable	Normal	1	
PFC's	7	PFC1, Top	Normal	1	Top, Highest Emanation Location
	8	PFC2, Top	Normal	1	
EUT Location	1	Front	Normal	1	Chassis - Highest Emanation Location Of Each Side
	2	Back	Normal	1	
	5	Top	Normal	1	
	6	Bottom	Normal	1	
	3	Left	Normal	1	
	4	Right	Normal	1	

Table B-4 Summary of RE101 Test Result

Measurement / Scan Description	Highest Recorded Emissions		Limit (dBpT) @ Frequency	Compliant w/ Specification Yes / No
	Frequency (Hz)	Field Strength (dBpT)		
Position 1	52	95.007	155.253	Yes
Position 2	39	87.962	157.736	Yes
Position 3	52	90.829	155.253	Yes
Position 4	53	93.023	155.089	Yes
Position 5	57	87.91	154.461	Yes
Position 6	58	93.337	154.311	Yes
Position 7	54	94.551	154.928	Yes
Position 8	57	95.2	154.461	Yes
Position 9	60	91.804	158.67	Yes
Position 10	58	95.456	154.311	Yes
Position 11	56	95.45	154.614	Yes

RE101 Test Result (2/12)

[a,c]

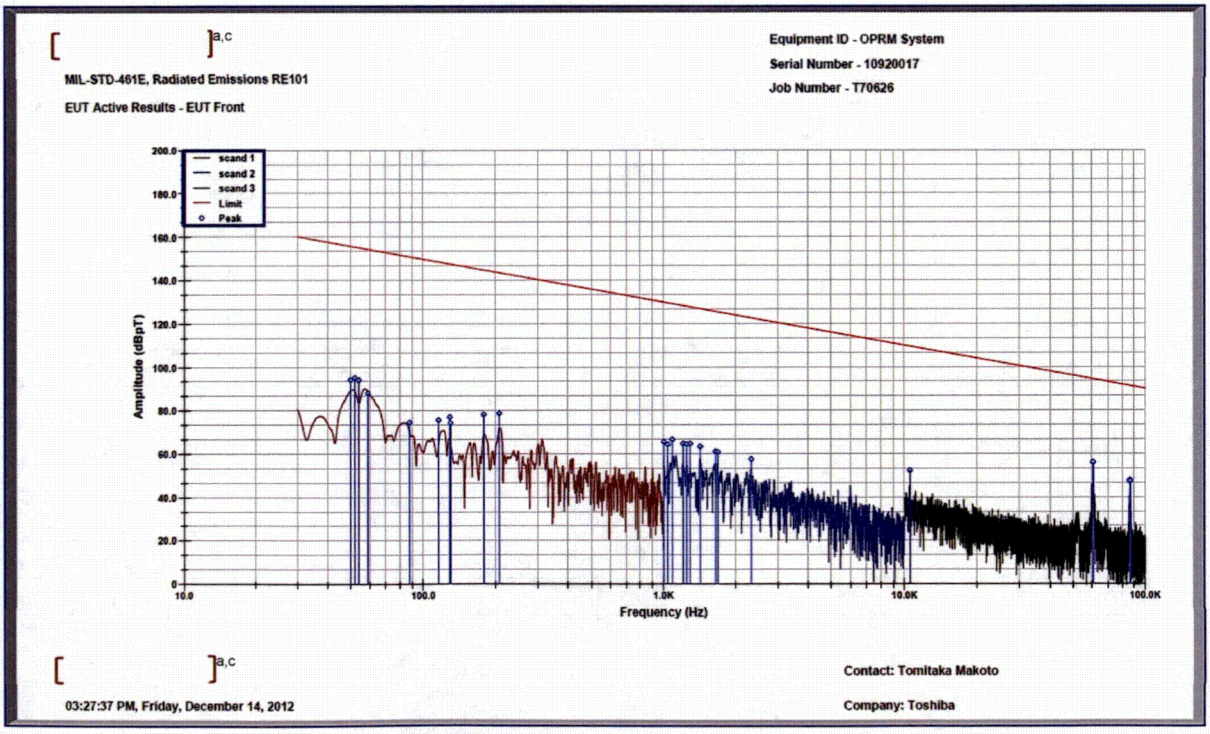


Figure C- 13 RE101 Test – OPRM Front (Position 1)

RE101 Test Result (3/12)

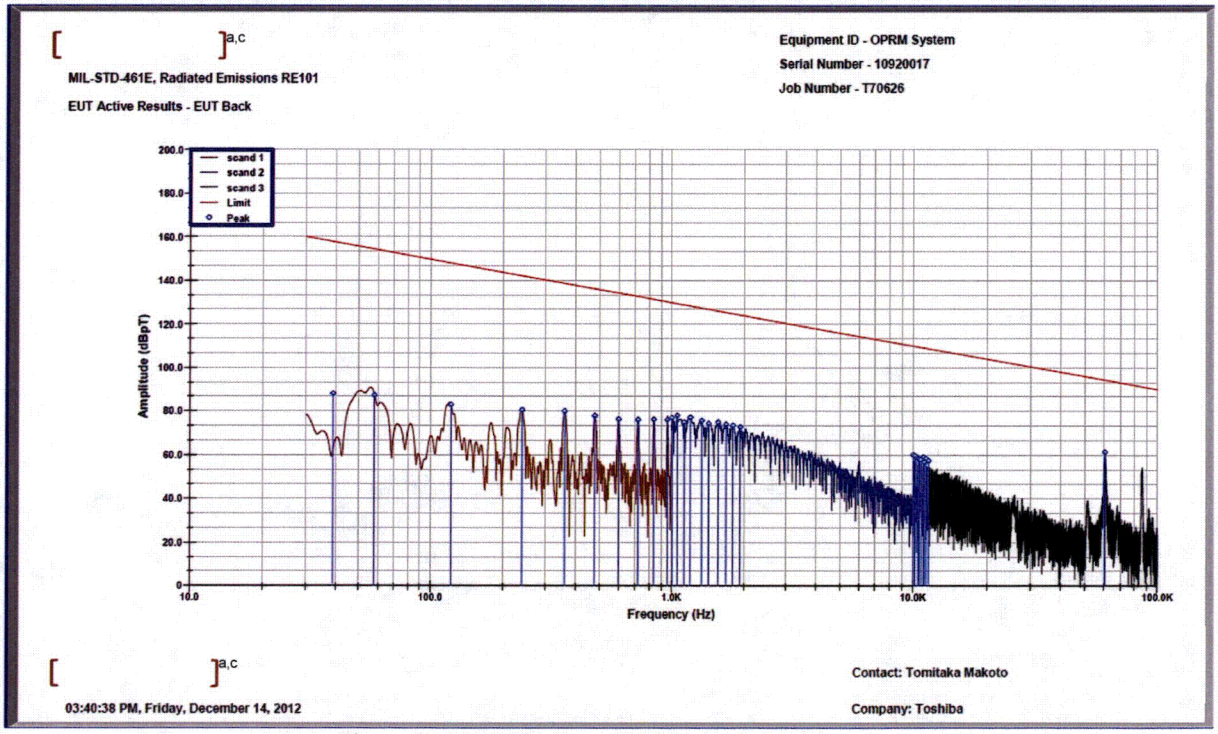


Figure C- 14 RE101 Test – OPRM Back (Position 2)

RE101 Test Result (4/12)

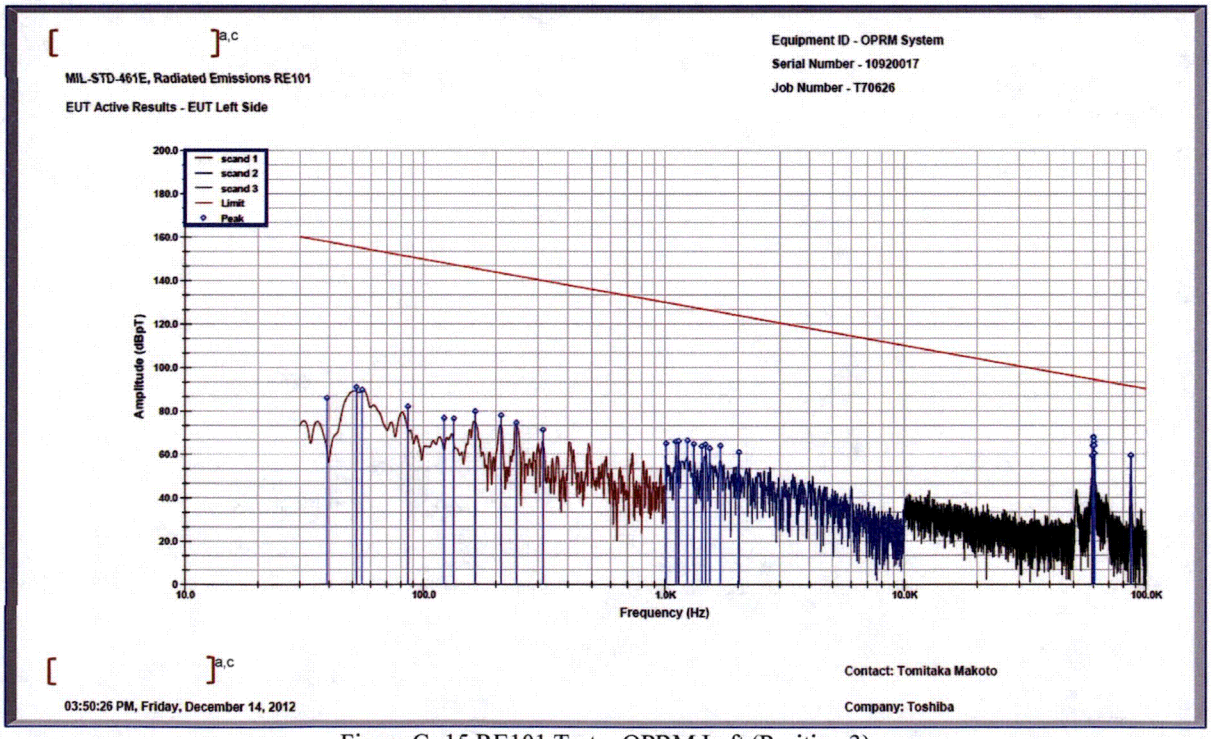


Figure C- 15 RE101 Test – OPRM Left (Position 3)

RE101 Test Result (5/12)

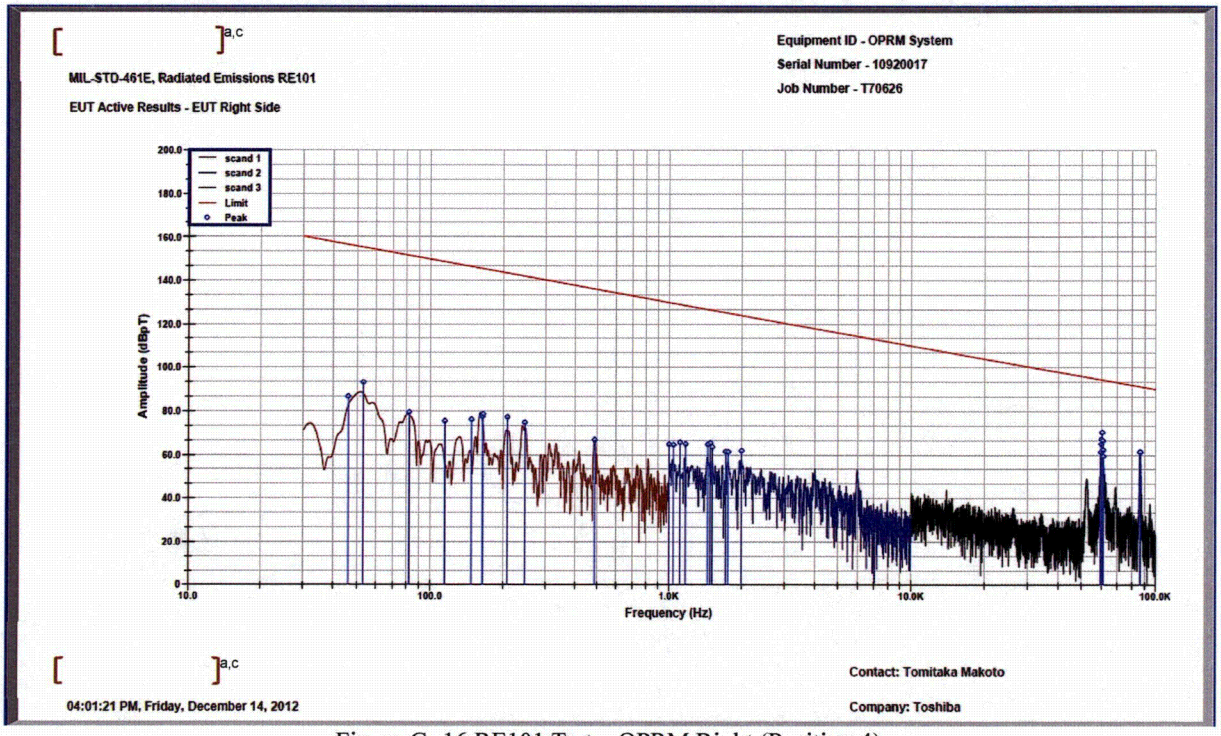
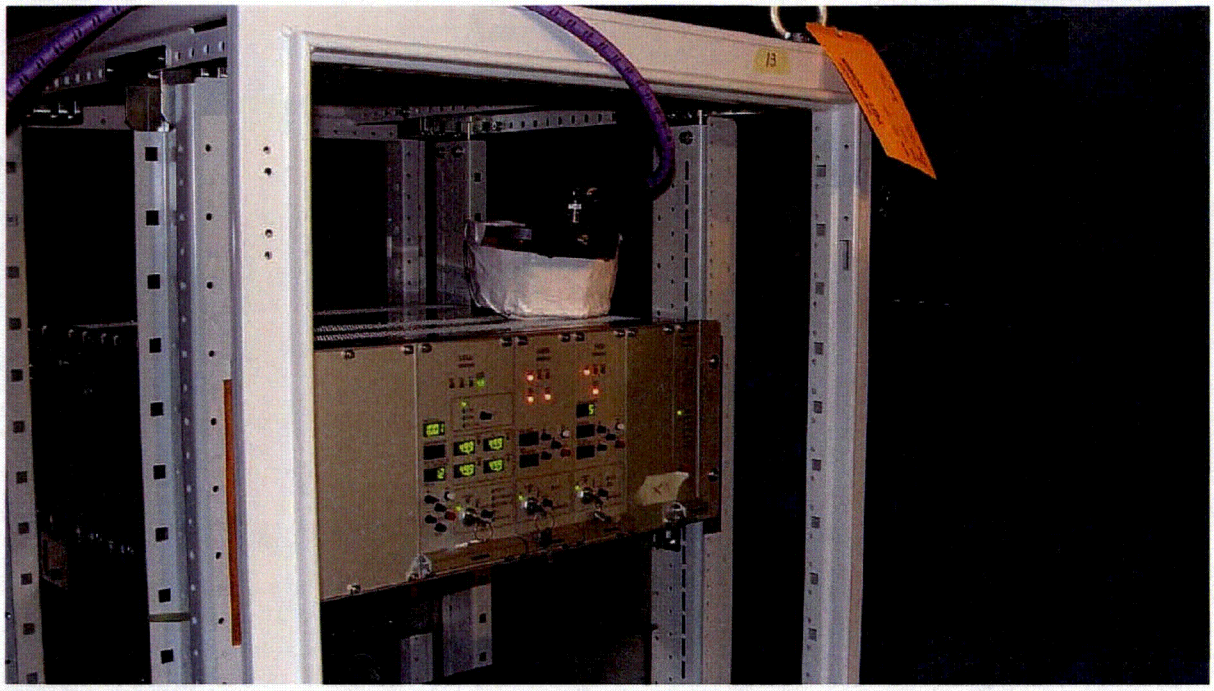


Figure C- 16 RE101 Test – OPRM Right (Position 4)

RE101 Test Result (6/12)



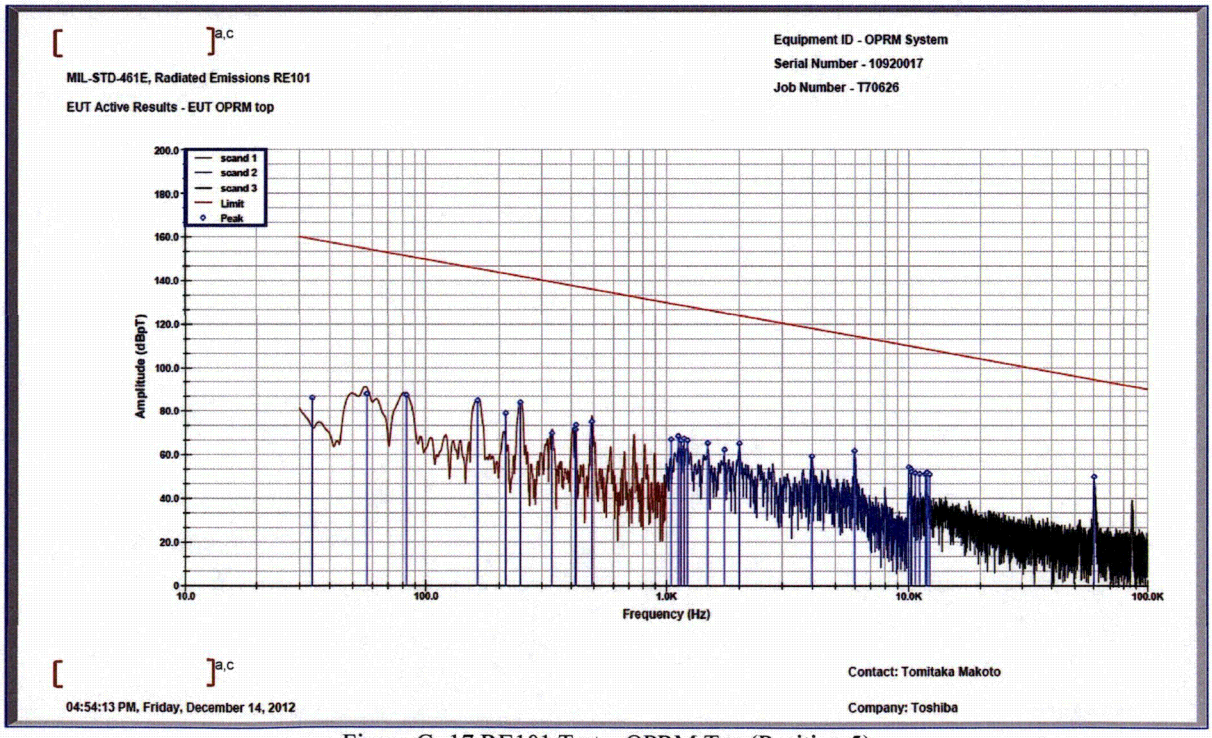
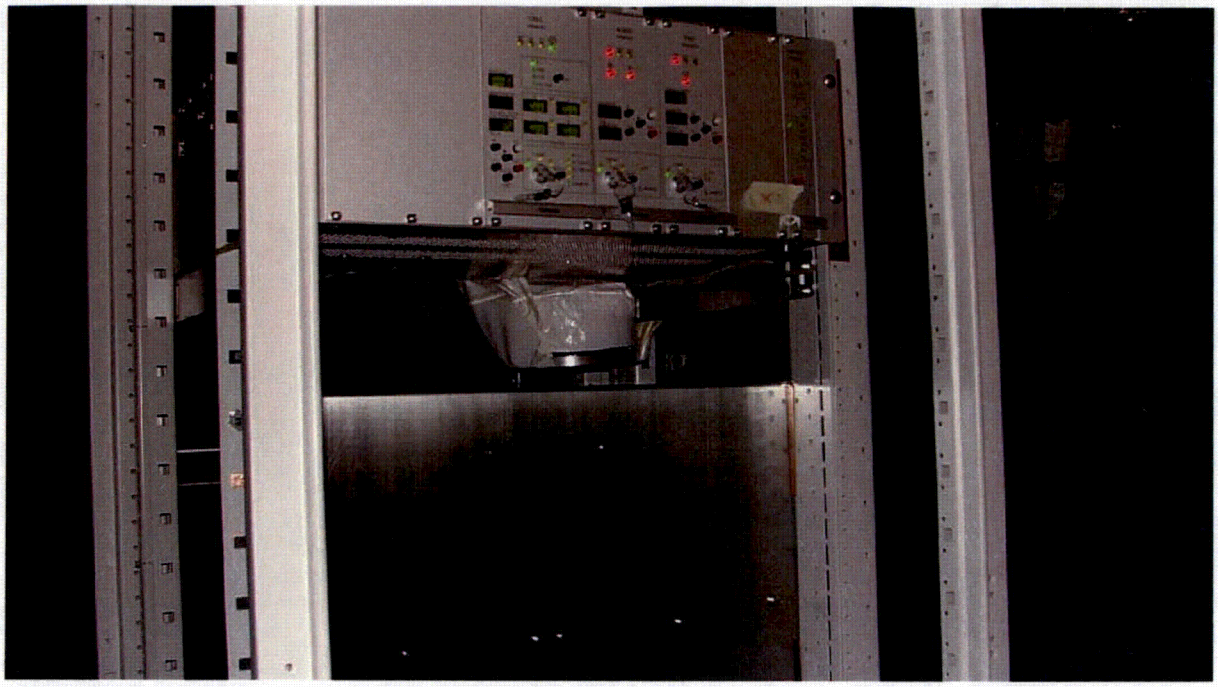


Figure C- 17 RE101 Test – OPRM Top (Position 5)

RE101 Test Result (7/12)



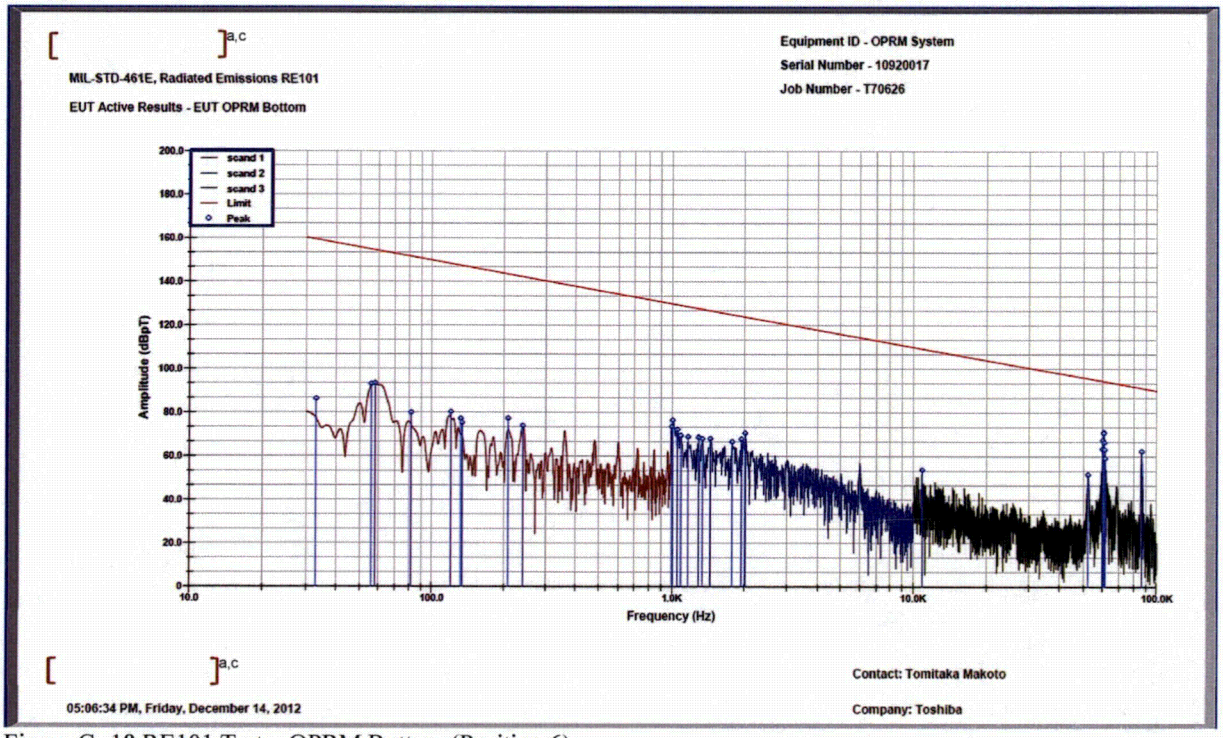
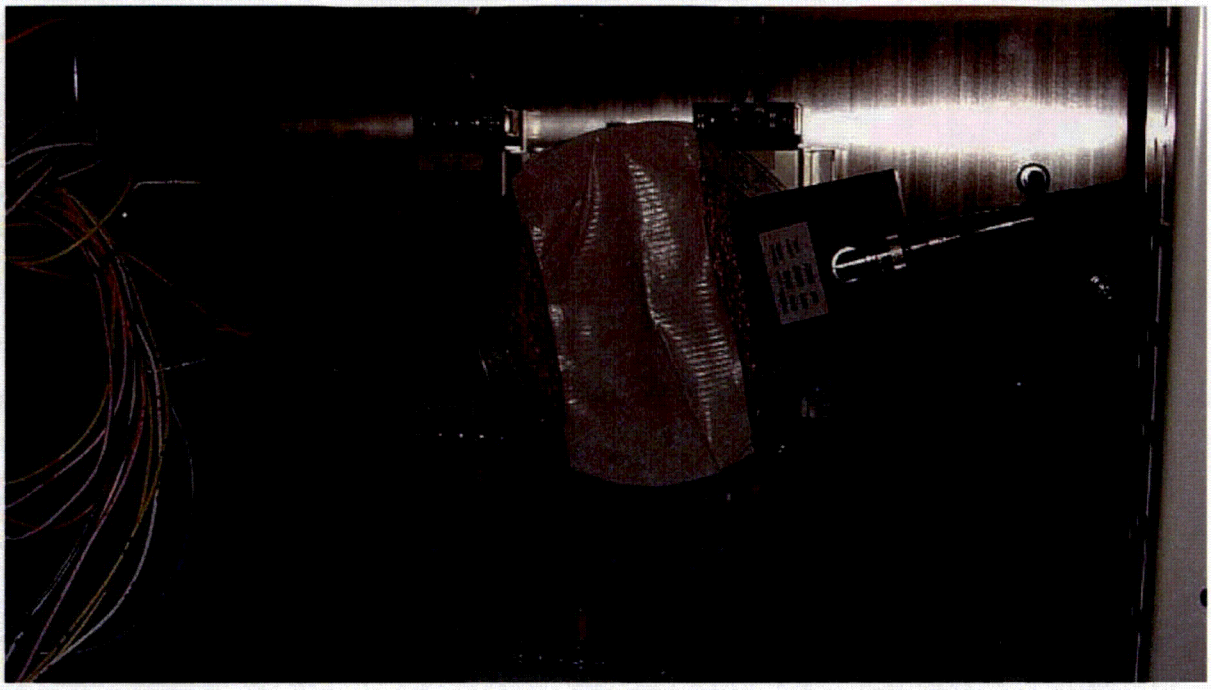


Figure C- 18 RE101 Test – OPRM Bottom (Position 6)

RE101 Test Result (8/12)



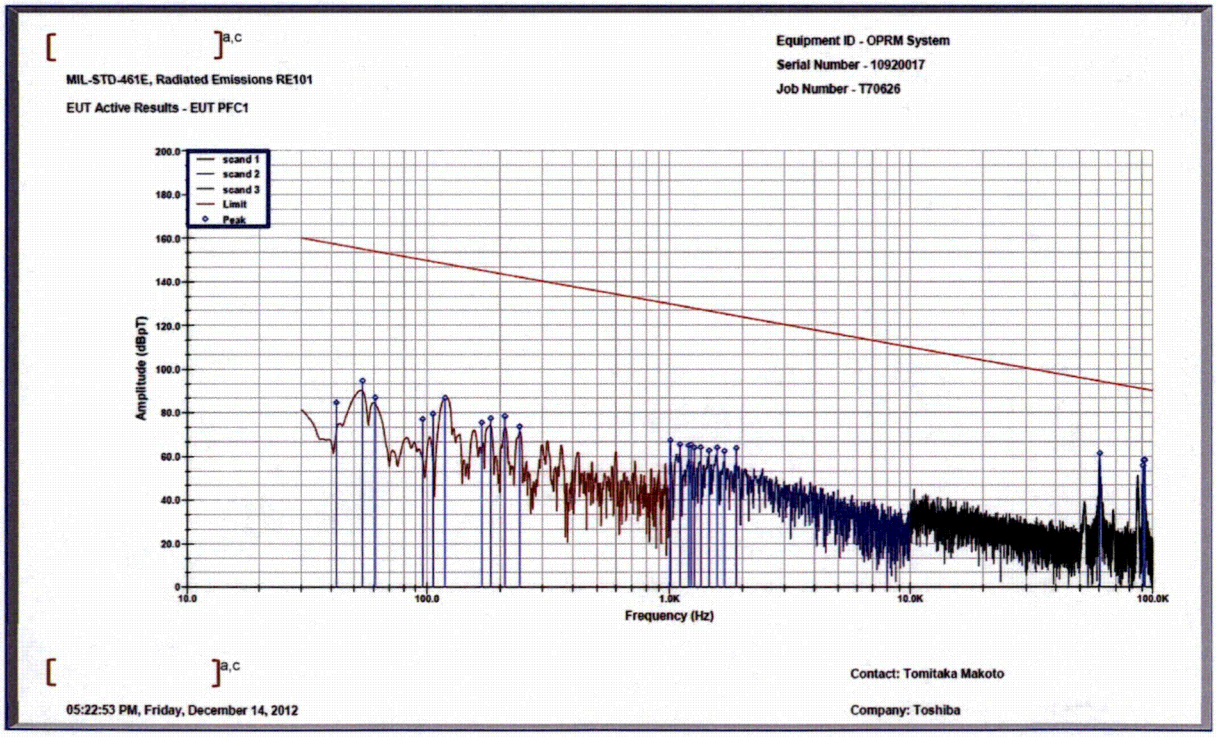
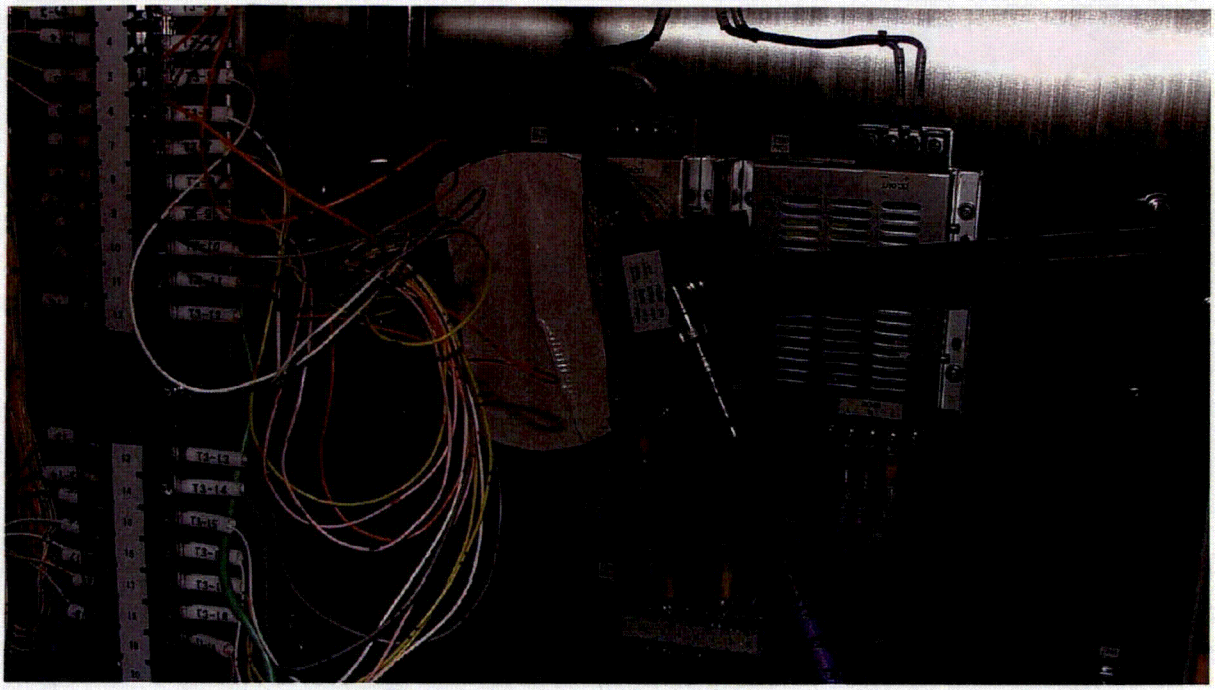


Figure C- 19 RE101 Test – PFC1 (Position 7)

RE101 Test Result (9/12)



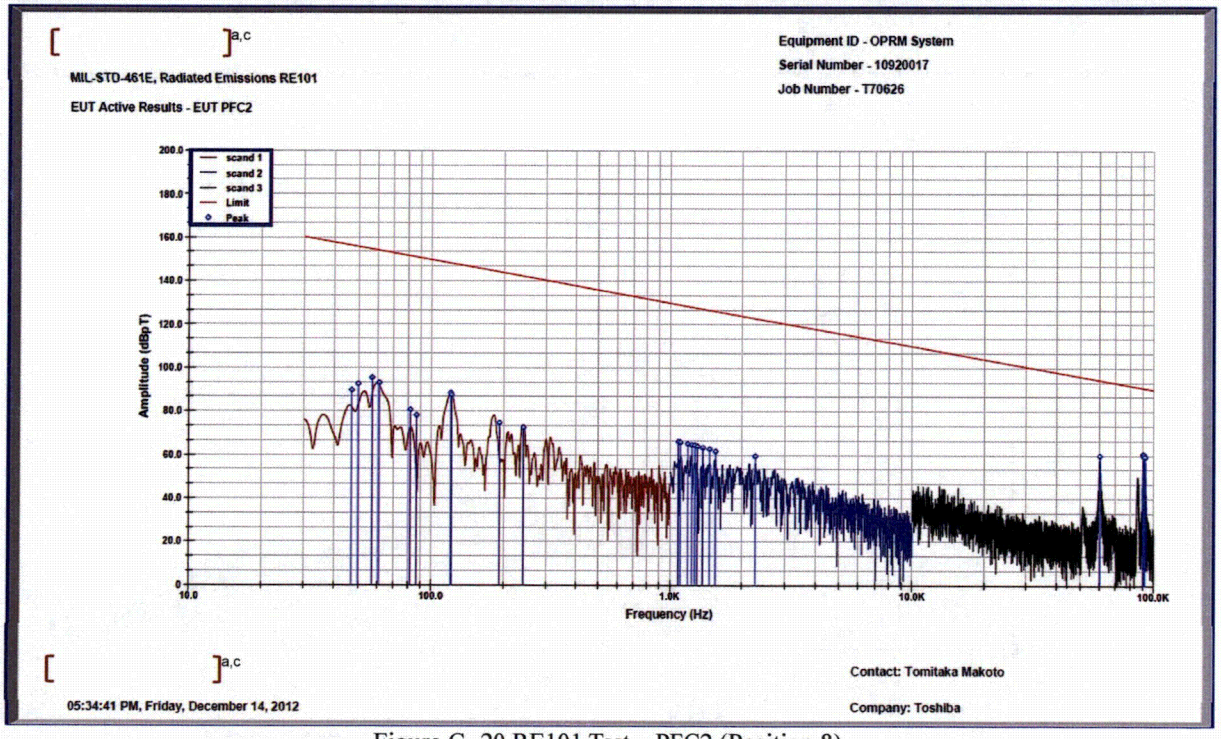


Figure C- 20 RE101 Test – PFC2 (Position 8)

RE101 Test Result (10/12)

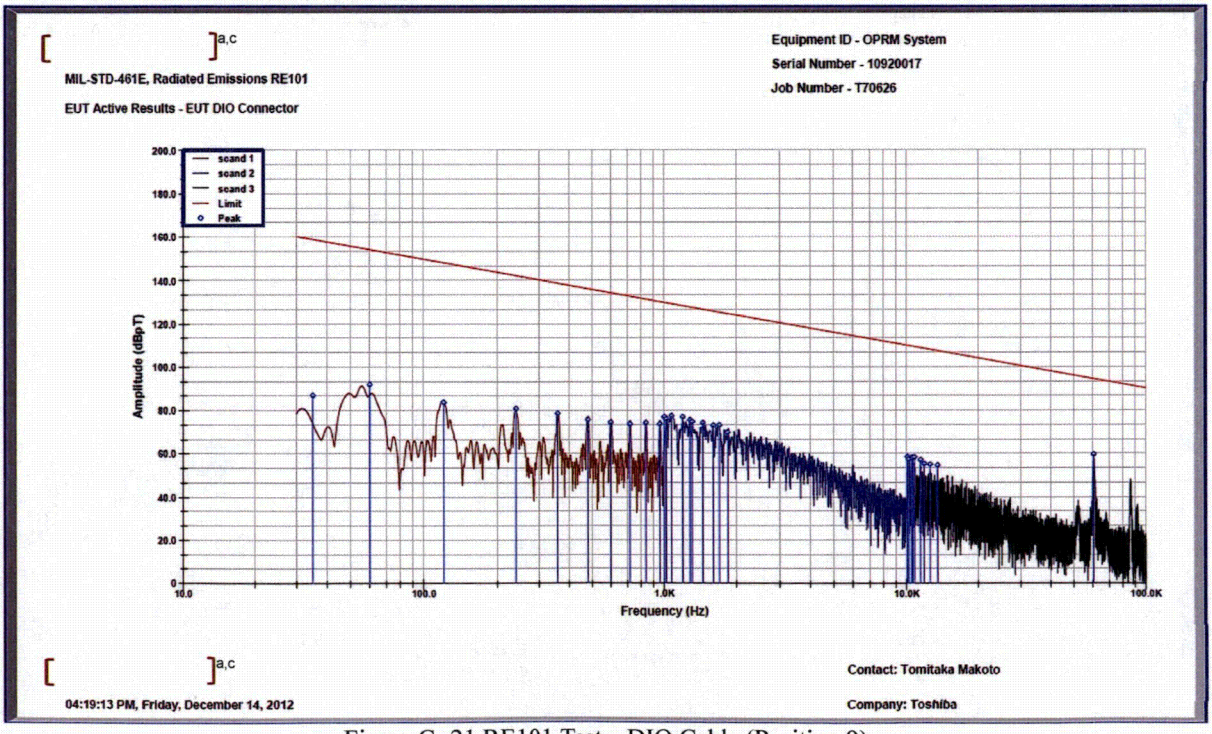
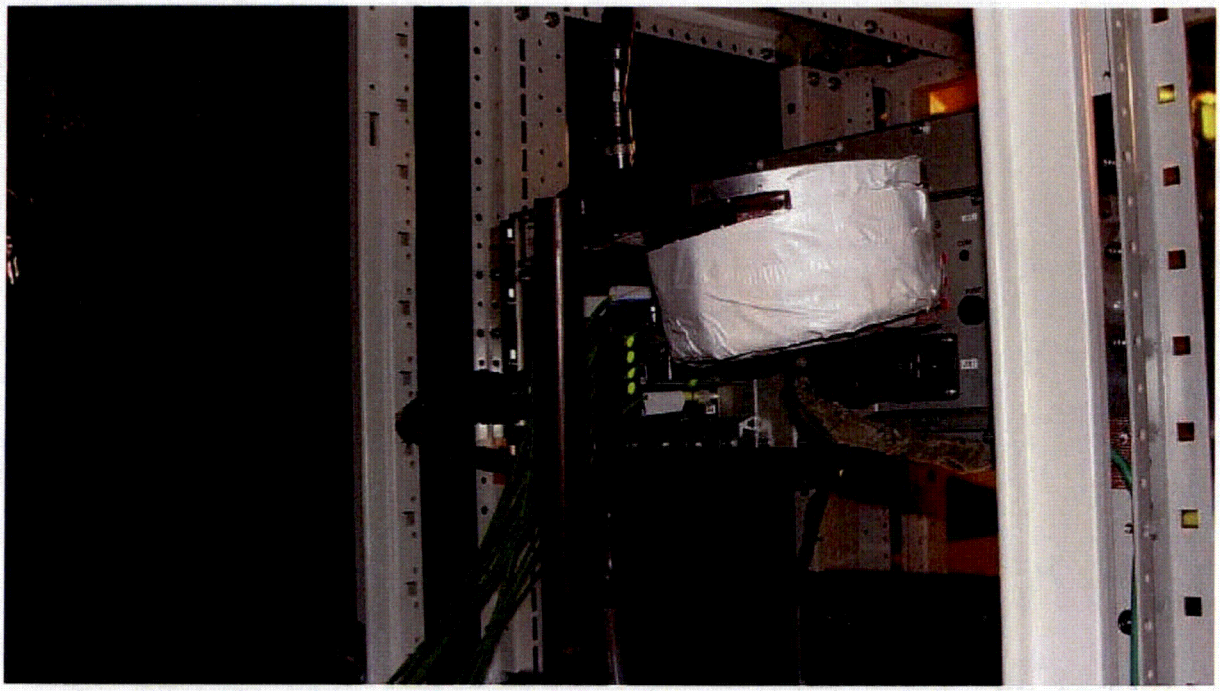


Figure C- 21 RE101 Test – DIO Cable (Position 9)

RE101 Test Result (11/12)



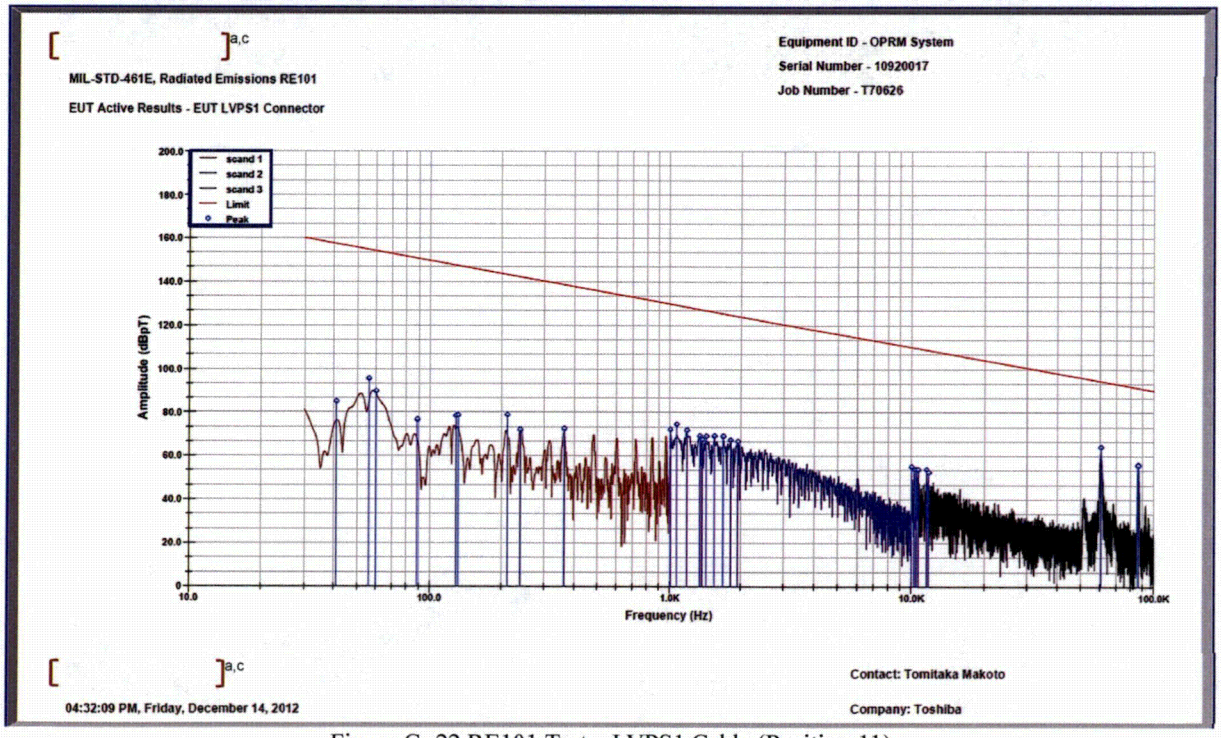


Figure C- 22 RE101 Test – LVPS1 Cable (Position 11)

RE101 Test Result (12/12)

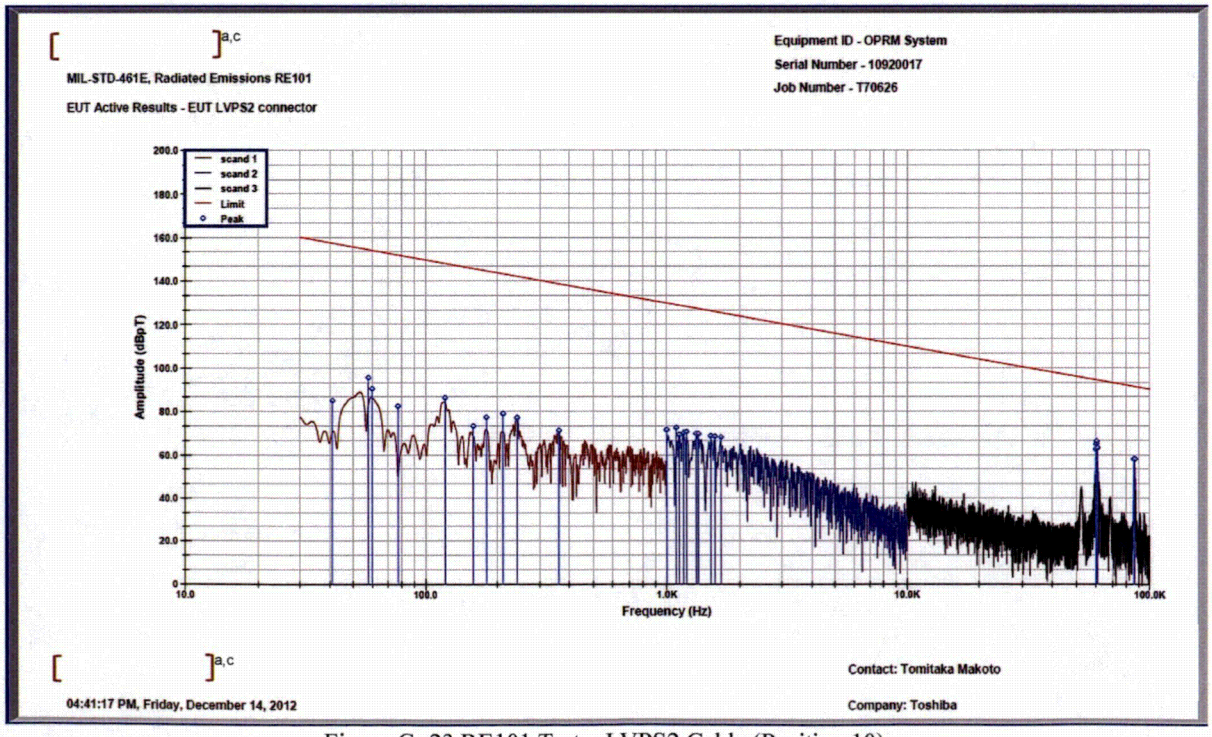


Figure C- 23 RE101 Test – LVPS2 Cable (Position 10)

RE102 Test Result (1/2)

Table B-5 Summary of RE102 Test

Scan Description	Antenna & Polarization	Highest Recorded Emissions		Limit (dBuV/m) @ Frequency	Compliant w/ Specification Yes / No
		Frequency (MHz)	Amplitude (dBuV/m)		
Signal Verification	Active Rod	≈ 2.0	52.996	53 +/- 3	Yes
		≈ 15.0	53.279	53 +/- 3	Yes
		≈ 29.9	52.69	53 +/- 3	Yes
	Biconical	≈ 30.1	53.59	53 +/- 3	Yes
		≈ 100.0	53.38	53 +/- 3	Yes
		≈ 199.5	56.5	55.76 +/- 3	Yes
	Large Horn	≈ 200.0	56.7	55.76 +/- 3	Yes
		≈ 625.0	61.9	60.6 +/- 3	Yes
		≈ 999.0	64.095	62.69 +/- 3	Yes
	Small Horn	≈ 1300.0	65.64	63.9 +/- 3	Yes
		≈ 10000.0	74.86	74 +/- 3	Yes
Ambient	Active Rod – Vertical	≈ 22.45	24.88	53	Yes
	Biconical – Vertical	≈ 99.01	15.95	53	Yes
	Large Horn – Vertical	≈ 989.1	24.74	62.6	Yes
	Small Horn - Vertical	≈ 4158.4	45.11	69.4	Yes
	Biconical – Horizontal	≈ 189.5	18.44	55.5	Yes
	Large Horn – Horizontal	≈ 997.5	25.6	62.6	Yes
	Small Horn - Horizontal	≈ 2695.8	42.28	67.3	Yes
EUT Active	Active Rod – Vertical	≈ 27.0	33.72	59	Yes
	Biconical – Vertical	≈ 57.46	57.81	59	Yes
	Large Horn – Vertical	≈ 368	40.26	64.3	Yes
	Small Horn - Vertical	≈ 1013.7	41.67	68.7	Yes
	Biconical – Horizontal	≈ 164.78	56.87	60.98	Yes
	Large Horn – Horizontal	≈ 391.9	34.01	64.57	Yes
	Small Horn - Horizontal	≈ 1110	47.32	69.17	Yes

RE102 Test Result (2/2)

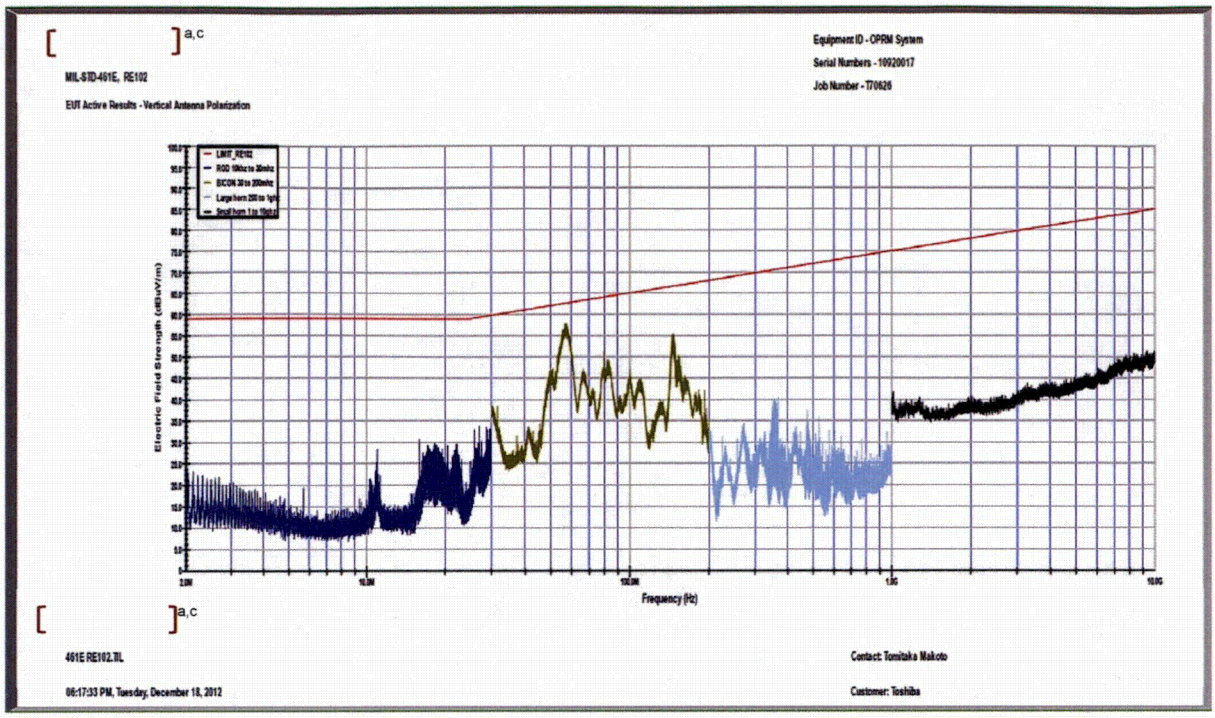


Figure C- 24 RE102 Test – Vertical Antenna Polarization

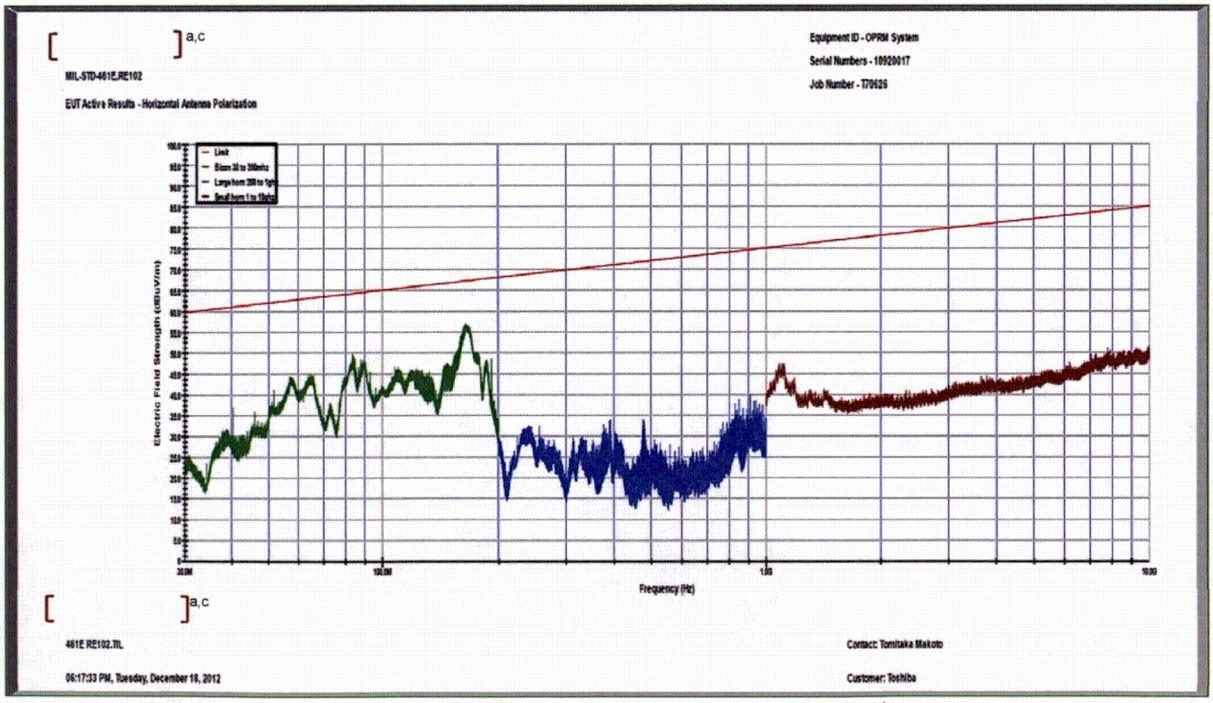


Figure C- 25 RE102 Test – Horizontal Antenna Polarization