Earthquake Resistance Test Specifications for Communications Equipment

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NTT DOCOMO, INC.

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1. INTRODUCTION

This document establishes the methods for a standard earthquake resistance test and determination of the earthquake resistance strength rank used to evaluate and rank the earthquake resistance strengths (physical damage and functional problems) of communications equipment in NTT DOCOMO, INC. node-related communications buildings.

2. EQUIPMENT TO BE TESTED

The equipment to be tested for earthquake resistance strength in this document is communications equipment housed in NTT DOCOMO node buildings (equipment built to NTT DOCOMO specifications, off-the-shelf equipment, cabinets, racks, etc.).

3. TEST PLAN

The earthquake resistance test for info-communication equipment and such other products are to be conducted by applying excitation with any anticipated earthquake vibrations at the building floor level, with the actual equipment/product placed on the vibration table. In this context, it is mandatory that the equipment under test be placed on the vibration table by exactly the same installation methods as the case of its actual commercial service, with all components and parts mounted on the cabinet or rack.

3.1 Equipment under Test

The followings require special attention when drawing a plan for the equipment under test.

(1) Except for cases where it is obvious that two or more cabinets are to be connected due to the functional characteristics of the system, the earthquake resistance test shall be conducted on a single unit of cabinet on which the equipment and/or such other product are all mounted.

(2) The configuration of the equipment to be mounted on the cabinet shall be based on conditions with the maximum mass and with the smallest rigidity (namely with the smallest natural frequency).

(3) In the case the actual equipment (hereinafter referred to as the actual equipment) cannot be mounted under constraint, a dummy device (or dummy weight) of the equivalent mass and the height of the center of gravity may be used. The same applies to any cables installed inside or on the top of the cabinet. In no event the dummy device shall exceed the actual equipment in terms of its rigidity.

(4) The mass of the equipment under test shall be measured prior to the conduct of the earthquake resistance test to verify that it satisfies the maximum mass requirements. Additionally, the height of the center of the gravity of the equipment under test in its entirety shall be measured to an extent possible to verify that it satisfies the equipment mounting requirements.

(5) The equipment to be subjected to the functional test (namely the actual equipment) needs to be tested under the most stringent conditions in terms of its vibration environment. That is, when mounting it on a self-standing cabinet, it shall be mounted at the highest position at which it is used for the actual commercial service.

3.2 Installation Methods

The followings require special attention when installing the equipment under test on the test table.

(1) The equipment under test shall be installed on the test table in the same manner as it is accommodated in the actual building. That is, when the equipment is installed on a raised floor, a stand of the same structure as the one used in the actual building shall be applied.

(2) When applying the stand above, the equipment under test shall be installed under the most disadvantageous conditions in terms of the rigidity and the strength of the entirety to be installed including the equipment itself.

(3) In the event the arrangements of bolts to secure the equipment and the stand on the building floor is anticipated to be diversified, the equipment under test shall be installed in an arrangement that will produce the maximum stress on the bolts.

4. MEASURING METHODS

Methods for measuring the vibration data in this earthquake resistance test shall be as follows.

(1) Data to be measured shall be the accelerations on the vibration table and each part of the equipment under test as well as the deformation on the top of the equipment under test.

(2) The acceleration measuring position shall be on the vibration table (if a highly rigid adapter such as a concrete plate or steel plate is used to install the equipment under test, then on that adapter) as well as on the top, the center and the bottom of the equipment under test. When the equipment under test

is installed on the aforementioned stand, the acceleration of the top face of the stand shall be measured.

(3) The acceleration measurement shall be taken in three different ways, namely two in the horizontal directions and one in the top-bottom direction.

(4) The frequency measuring range of the accelerometer and the amplifier shall be from 0.5Hz to 100Hz and higher, and the measuring accuracy shall be on the order of 1cm/s^2.

(5) Deformation on the top of the equipment under test shall be a horizontal relative displacement on the top of the equipment under test with reference to the vibration table, and shall be measured in two horizontal directions by use of an instrument such as a linear variable differential transformer (LVDT) and a contactless displacement sensor (optical or laser).

(6) The frequency measuring range of the displacement measuring instrument above shall be from 0.5Hz to 20Hz and higher, and the measuring accuracy shall be on the order of 1mm.

(7) When using a frame or the like on the vibration table as the immobile point of the displacement measurement, the natural frequency of the measurement frame shall be 20Hz or higher, with the displacement sensor fixed securely to the measurement frame so as not to vibrate.

(8) Sampling frequency for recording the data shall be 200Hz or higher.

5. EXCITATION METHODS

5.1 Vibration Characteristic Test

In order to examine the change in the natural frequency of the equipment under test during the earthquake wave excitation test, a vibration characteristic test is to be conducted before start of the test and after the excitation. The vibration characteristic test shall follow the procedures specified below.

(1) The vibration characteristic test shall be conducted by using either one of the following excitation methods to examine the natural frequency of the equipment under test.
a) Random wave excitation (white noise excitation)
b) Sinusoidal wave (sine wave) sweeping excitation

(2) The maximum acceleration for the vibration characteristic test shall be on the order of 1m/s^2, with the frequency range from 0.5Hz to 50Hz. In the case the excitation cannot reach the value of 50Hz due to restrictions including the

vibration table performance, the maximum frequency range shall not be smaller than 35Hz.

(3) The excitation duration of the random wave excitation test shall be a time period that shall allow five or more times of averaging in the FFT-based frequency response analysis. The excitation duration for conducting the analysis when the sampling frequency is 200Hz, the number of FFT points is 4096 with the averaging performed five times shall be approximately 100 seconds.

(4) The sweeping velocity during the sinusoidal wave sweeping excitation shall be not more than one octave per minute. The excitation duration when the sweep excitation from 0.5Hz to 50Hz at the velocity of one octave per minute shall be approximately 400 seconds.

(5) The measurement accuracy of the natural frequency shall be on the order of 0.1Hz.

5.2 Earthquake Wave Excitation Test

The earthquake wave excitation test shall follow the procedures specified below.

(1) A three-dimensional (3-D) vibration table shall be used, and the excitation shall be given simultaneously in the three direction, namely in the orthogonal horizontal two directions of the equipment under test (the width direction and the depth direction) and the top-bottom direction. (See Figure 1).

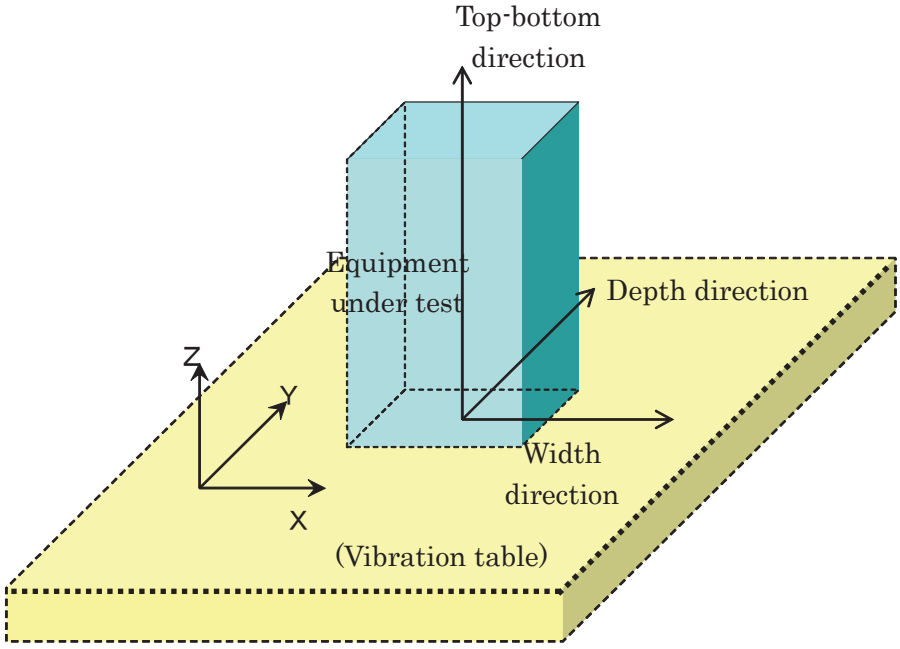

Figure 1 Simultaneous Excitation in 3 Directions (3-D Vibration Table)

(2) Each of the excitation waves in the horizontal two directions (X direction and Y direction) and the top-bottom direction (Z direction) shall have the acceleration response scale factor specified in Figure 2 and shall be artificial earthquake waves produced with the major excitation duration of 30 seconds or longer. In this case, the acceleration response scale factor shall be a value with reference to the attenuation constant h = 3%, with values below 0.5Hz and over 50Hz not specified. In addition, the duration of the major excitation means the time period from a moment at which the value exceeds 25% of the maximum acceleration for the first time to a moment at which it finally goes down below the 25% of the maximum acceleration.

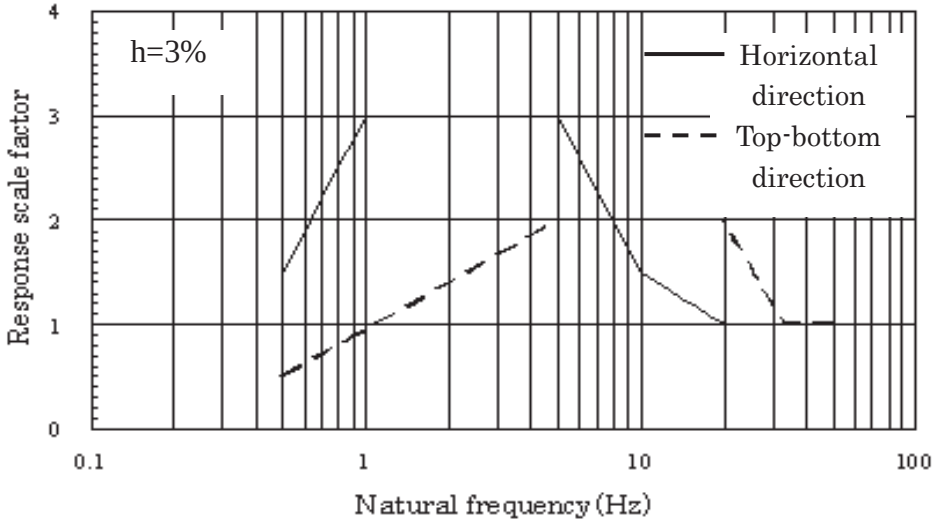

Figure 2 Acceleration Response Scale Factor of Excitation Waves (h = 3%)

(Horizontal direction)

Natural frequency	Response scale factor
0.5	1.5
1.0	3.0
5.0	3.0
10.0	1.5
20.0	1.0
50.0	1.0

(Top-bottom direction)

Natural frequency	Response scale factor
0.5	0.5
5.0	2.0
20.0	2.0
33.0	1.0
50.0	1.0

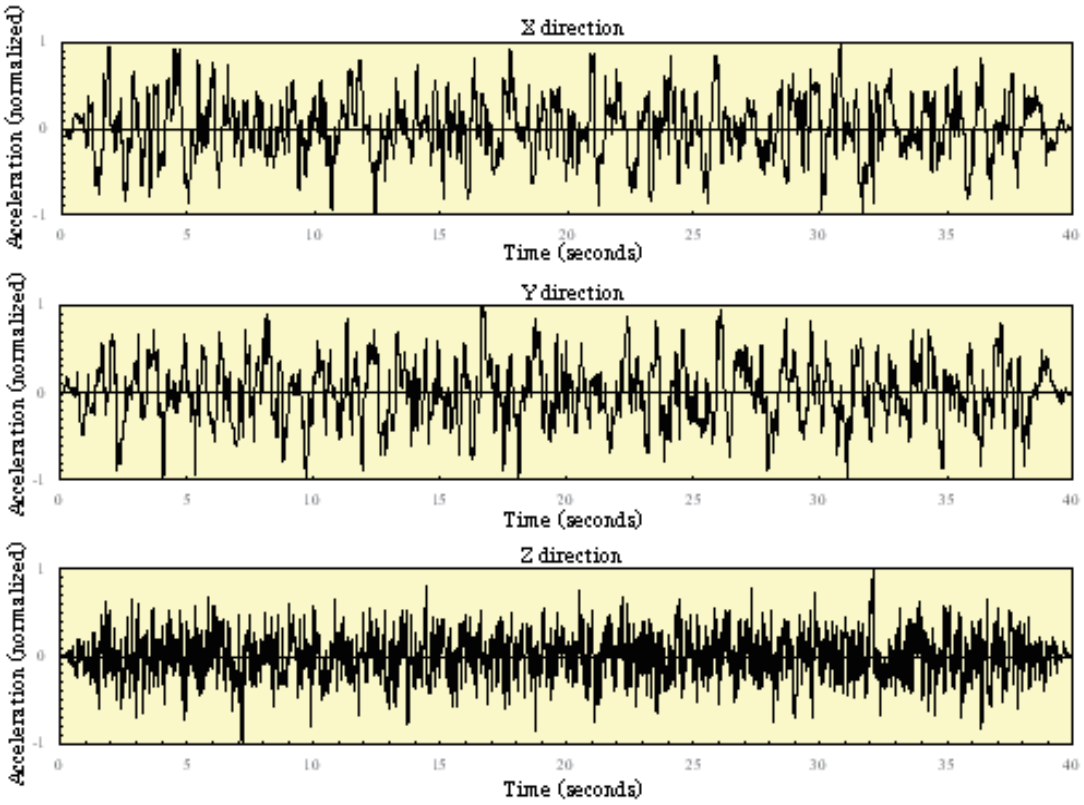

Figure 3 Time-based Excitation Waveforms (Maximum Acceleration normalized to 1)

(3) The excitation by earthquake waves shall be conducted by increasing the maximum acceleration stepwise from R04 to R12 as shown in Table 1. Each of the maximum accelerations in the table represents the target value for each acceleration level, whereas the maximum velocity represents the yardstick just for reference. In addition, unless otherwise specified, the number of excitations at each excitation level shall be one, namely once.

Table 1 Target Values of Excitation Wave Maximum Accelerations

Excitation level	R04	R06	R08	R10	R12
Maximum acceleration (m/s^2)	4	6	8	10	12
Maximum velocity (m/s)	0.5	0.75	1.0	1.25	1.5

Note 1) The maximum acceleration is in two horizontal and one top-bottom directions.
Note 2) The yardstick for the maximum velocity is in the horizontal directions. The maximum velocity in the top-bottom direction is approximately one half of that in each horizontal direction.
Note 3) Implement for R02 (maximum acceleration $2m/s^2$) as needed.

(4) The target value of the acceleration response spectrum (attenuation constant 3%) at each excitation level (RRS) is obtained by multiplying each maximum acceleration specified in Table 1 by the acceleration response scale factor specified in Figure 2.

(5) Each experimental value of the excitation wave maximum acceleration shall in no event be less than each target value specified in Table 1. In this case, the experimental value of the excitation wave means acceleration data actually reproduced on the vibration table (if the vibration table have a concrete plate or such other means simulating the building floor installed on it, then the acceleration data on that concrete plate or other means).

(6) The experimental value of the excitation wave acceleration response spectrum (attenuation constant 3%) (TRS) shall in no event be less than each target value (RRS) defined in item (4) above. In this case, TRS of the acceleration wave shall be calculated with reference to a frequency obtained by dividing the frequency range from 0.5Hz to 50Hz by a minimum of 1/6 octave interval (approximately 40 or larger in terms of the logarithm equal division).

(7) When the excitation performance of the vibration table comes up short in the low natural frequency region, TRS of the excitation wave may be smaller than RRS limitedly in a region where the performance is not more than one half of the primary natural frequency of the equipment under test and at the same time not more than 1.5Hz. Provided, however, that the some cases shall be excluded where the response in the low natural frequency region becomes longer, such as a case where the cover or mounted equipment is not securely fixed to the cabinet and where equipment that has any movable part is mounted.

(8) When verifying the presence/absence of any functional problems of the equipment, a functional diagnosis program shall be continuously run during the test to examine the presence/absence of an interruption or halt of any function, malfunction, damaged data as well as the presence/absence of the automatic recovery after completion of the excitation.

(9) Installed conditions of the equipment under test, installed conditions of each measuring instrument and sensor, and the presence/absence of damage at each part of the equipment under test after the excitation shall be recorded in photographs and the vibration conditions during the excitation shall be recorded in the video format.

6. DATA ARRANGEMENT AND ANALYSIS

With respect to each of the following items, its relevant data shall be arranged and subjected to analysis.

(1) Vibration characteristic test

- Frequency response of each part of the equipment under test with reference to the vibration table (acceleration amplitude ratio and phase difference)
- Change in the natural frequency at each excitation level before and after the excitation

(2) Earthquake resistance test

- Presence/absence of functional problems and/or functional degradation of the equipment under test before, after and during the excitation
- Presence/absence of permanent deformation at any of the major structures, cracks in welded connections and loosened bolts, among other changes
- Presence/absence of positional movement or projection of mounted objects, removal or dropout of covers, and opened doors, among other changes
- Acceleration time-based waveforms of the vibration table and each part of the equipment under test

- Acceleration response spectrum (TRS) of the excitation wave (acceleration records on the vibration table)
- Maximum acceleration (absolute value maximum) of the vibration table and each part of the equipment under test
- Acceleration response scale factor (absolute value maximum) of each part of the equipment under test with reference to the vibration table
- Maximum horizontal deformation (in the two horizontal directions) on the top of the equipment under test

7. DETERMINATION OF EARTHQUAKE RESISTANCE STRENGTH RANK

Each earthquake resistance strength rank of equipment and such other products shall be determined through the procedures specified below.

(1) The earthquake resistance strength rank of equipment and such other products shall be determined in accordance with one of the five criteria specified in Table 2 as selected by the user.

Table 2 Criteria for Ranking the Earthquake Resistance Strength of Equipment, etc. and Determination Requirements

<table>
<tr><th colspan="4">Determination requirements</th></tr>
<tr><td rowspan="2">Functional problem</td><td>F1</td><td colspan="2">Normal functions are maintained both during and after the excitation.</td></tr>
<tr><td>F2</td><td colspan="2">Even if functionality stops during excitation, normal return after the excitation *1</td></tr>
<tr><td rowspan="3">Physical damage</td><td>P1</td><td>No damage is caused in any of the main structures.</td><td rowspan="3">No projection of mounted object or no door left open is found.</td></tr>
<tr><td>P2</td><td>No crack or no noticeable plastic deformation is caused in any of the main structures. (Maximum response deformation on the top: not more than 50mm) *2</td></tr>
<tr><td>P3</td><td>No collapse or disintegration, or fractures caused in any of the main structures.</td></tr>
</table>

*1: Automatic recovery or manual recovery (not requiring repair) are as per user specifications.

*2: This requirement applies when it is necessary to specify the rigidity of the equipment in such cases where heterogeneous devices adjoin.

*3:If earth quake resistance tests are difficult to be conducted in the specified way stated above, earth quake strength rank of the single equipment which is based on NEBS(Zone4(level3))could be regarded as R06.

(2) The earthquake strength rank shall be evaluated based on the maximum excitation level satisfying the criteria specified in Table 2, with each excitation level in Table 1 used as the parameter. For example, if the equipment under test satisfies the predetermined criteria with respect to an R06 acceleration and does not satisfy the predetermined criteria with respect to an R08 acceleration, then the earthquake resistance strength of this equipment as determined shall be R06.

8. REPORTING OF MEASUREMENT RESULTS

With respect to the earthquake resistance ranks determined from the earthquake resistance test, the test results shall be put together on each of the items specified below and a test report shall be prepared accordingly.

(Items to be reported)

- Summary of testing (testing date, testing authority & location, testing official)
- Summary of test (equipment configuration diagram, measurements, mass, installation methods, installation diagram)
- Vibration characteristic test methods
- Earthquake wave excitation method
- Earthquake resistance rank criteria (F__, P__)
- Earthquake resistance strength rank (R____)

9. OTHERS

All descriptions and details specified herein are subject to change without prior notice as a result of any revision or alteration of applicable laws and/or other standards, etc., development of any new technologies and/or introduction of any new research results.

10. INQUIRIES ABOUT THIS DOCUMENT

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