System Specification

enocean alliance
Building Smarter Connectivity

EnOcean Alliance Certification Specification, part 2
Radio Performance
V 2.3

San Ramon, CA, USA
Original Release 1.0, 2013

Executive Summary

A proper review of every device shipped is an important step to secure a correct functioning of every single device, especially to ensure a working interoperability. The EnOcean Alliance developed and agreed upon a specification, which describes the certification steps to be passed by every device before being introduced into the market(s). These steps are:

(1) Air Interface
(2) Radio Performance
(3) Communication Profiles
(4) Energy Harvesting of self-powered devices

This document specifies part (2) Radio Performance which is a mandatory part of the EnOcean Certification Program.

This document describes how to perform a qualitative radio range testing thus to evaluate the quality of the transmission, reception or both. Test method and description of the general test setup for the frequency bands 315 MHz, 868 MHz, 902MHz and 928 MHz are defined together with the relevant parameters of the test equipment to be used. Test cases for receiver and transmitter performance tests as well as the categorization of the test results are given. For simplifying the understanding of the test process, pictures showing the X-, Y- and Z-orientation of a device under test in the 3D space are included in the annex. Examples of directive diagrams for X-axis, Y-axis and Z-axis show test results that belong to different performance categories.

This document is owned by the Technical Working Group (TWG) of the EnOcean Alliance. It is maintained and will be progressed within the authority of the chairman of the TWG.

Changes to this document have to be proposed to the TWG for decision. The EnOcean Certification Task Group will then act up on request by the TWG.

REVISION HISTORY

Ver.	Editor	Change	Date
0.1	SC	Draft Document converted to EnOcean Template and reviewed by SC	May 05,2013
0.2	TR	Modification of 1.3.3 for a more generic description of the test equipment; Adding of chapter 3: DUT receiver sensitivity check	May 8, 2013
0.3	TR	Finalization of the modifications started in V0.2; receiver sensitivity check as part of chapter 2.2	May 13, 2013
0.4	OS	Review and minor changes	May 13, 2013
0.5	TR	Results from Berlin meeting (2013-05-18) added	May 20, 2013
0.6	TR	Clean version created, for ECTG call today	June 6, 2013
0.7	TR	Exec. Summary (SC) added, ANSI link extended, reference to Range Certification Worksheet added; minor editorial changes	June 18, 2013
0.8	TR	Clarification of standards referenced in chapter General Test Setup	June 19, 2013
0.9	SC	Document renamed to EnOcean Certification Specification, part 2 Radio Performance; Removed Link and Equation from Fresnel; Editorial changes and inputs from TWG added	July 23, 2013
0.A	SC	Editorial changes and inputs from TWG added	August 19, 2013
0.B	NM	Editorial changes, BoD feedback considered	Nov 08, 2013
1.0	NM	Approval by BoD, Release as PRELIMINARY	Dec 17, 2013
1.1	TR	TWG Meeting Munich	March 04, 2016
1.2	TR	Separation of the receiver performance test cases; introduced 10° steps of RTRX / DUT direction; For DUT categorization, percentage changed to a defined number of measurement results. TWG Input included; 15° measurement steps defined for DUT plus one measurement for RTRX; devices designed for limited radio coverage covered; check for consistency of wording and representation.	Aug 02, 2016
2.0	TR	Update after review with EnOcean GmbH: Chapter “Design Goals for Antenna and Electronic Circuit” deleted, will be shifted to an EnOcean Alliance application note; RX level detection capability of RTRX and TTRX clarified to be meant at coaxial input; MER	Aug 25, 2017

		requirements of RTRX and TTRX changed to RF level of -89dBm; MER test message clarified; MER test level for DUT increased to -89dBm; Minor editorial changes.	
2.1	NM	Feedback of TWG-review incorporated; Receiver MER Test: Step 6 and 12 re-worded	Oct 04, 2017
2.2	AP	Disclaimer added Link to documentation template added in annex	May 05, 2018
2.3	AP	Clarification added to use indoor only directional antenna for TTRX.	Nov 24, 2020

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1. Introduction

1.1. Objectives of Test

A sufficient and proper radio performance – mainly reflected in the range – is among the most important parameters of any wireless products, especially for EnOcean-based products. Even in scenarios with "reliable radio links" it is important to optimize the link budget to its best as a reserve for e.g. future layout or furniture changes inside buildings. Occupancy and un-occupancy – especially in high use scenarios – might also result in a strong impact to the link budget.

The tests defined in this specification are designed to validate the RF-performance of EnOcean-based wireless products. Many such products contain antennas, which are located inside the enclosure of the product, and are therefore physically close to other components, which affect the antenna performance and in-circuit interference limitations might downgrade further the RF-performance.
Mounting conditions of the products can also have an impact. Proper placement of the antenna is critical to achieving a good performance in general. During the design phase of the product, improper attention to the placement of the e.g. product internal antenna will result in a reduced or even poor radio range. Among other factors, a reduced range can be caused by:

- a poorly positioned antenna on the transmitting end of a radio link
- a poorly positioned antenna on receiving end of a radio link
- in-band noise directly received through the antenna
- out-of-band noise coupling into the receiver or transceiver circuitry
- or by any combination of these four reasons

The RF-performance of an EnOcean-based wireless product is characterized by the following parameters:

- effective radiated transmitter power
- effective receiver sensitivity
- radiation pattern applicable to transmitter and receiver

The tests described in this specification ensure that the electronics design of an EnOcean-based product tested individually and the design and placement of its potentially integrated antenna provides a radio range performance, which is at least acceptably good from an EnOcean system point of view.

To pass the EnOcean Certification program a pass of the tests defined by this document is required.

The results of these tests are to be documented per device tested following the Radio Performance Documentation Template provided in Annex 3 of this document.

1.2. Definitions & References

1.2.1. Definitions

Antenna: A component, typically metallic, which either radiates (as used for a transmitter) or collects (as used for a receiver) electromagnetic waves.

Antenna Efficiency: The ability of an *antenna* to convert transmission line power to electromagnetic field intensity (transmitter) and vice-versa (receiver). It is used to account for losses at the terminals of an antenna. Losses are due to: 1) impedance mismatch between the antenna and the electronics connected to the terminals of the antenna and 2) conduction and dielectric losses. When an antenna is improperly positioned, such as when it is too close to metal objects, it can be “de-tuned”, which affects the impedance of the antenna, creating an impedance mismatch, which degrades the efficiency of the antenna.

Antenna Gain: Similar to *directive gain*, but accounts for *antenna efficiency*.

Directivity: The value of the *directive gain* in the direction of its maximum value.

Directive Gain: The ratio of the radiation intensity in a given direction to the radiation intensity of a reference antenna (usually an isotropic radiator). An antenna positioned improperly can affect the *radiation pattern* of the antenna, creating *radiation lobes* and *radiation nulls*.

DUT: Device under Test

EMI: Electromagnetic Interference

Fresnel Zone: An ellipsoid-shaped volume between two *antenna*s, which should be free of obstructions for best results.

Isotropic radiator: A hypothetical *antenna*, which has a radiation pattern, that is equal in all directions. That is, its radiation pattern forms a sphere in 3D space. The radiation pattern is omnidirectional - the same in all directions.

MER: Message Error Rate, a receiver related parameter that is calculated as the number of EnOcean Messages not decoded correctly by a receiver in relationship to the number of EnOcean Messages sent by a corresponding transmitter. The EnOcean Messages used to determine the MER shall be either the addressed Remote Management Ping message or any other standardized EnOcean Message of the same message length. Such messages shall be sent using three EnOcean sub-telegrams.

Radiation lobe: A portion of the *radiation pattern* of an *antenna*, which is surrounded by regions of less radiation intensity. A radiation lobe (both radiating and receiving) focuses in one direction. In some cases, radiation lobes are bounded by radiation nulls. In the case of point-to-point communication, radiation lobes are desirable. Radiation lobes are undesirable when a device must communicate with other devices that may be located anywhere (i.e. in any direction) around this device. In most applications using EnOcean devices, radiation lobes are not wanted.

Radiation null: A portion of the *radiation pattern* of an antenna where the radiation intensity is substantially weak and, under certain conditions, might be close to zero measurable signal strength.

Radiation pattern: A graphical representation of the radiation properties of an *antenna* as a function of spatial coordinates. A radiation pattern graph shows how well an antenna radiates/receives in all directions. Radiation patterns are measured by rotating the antenna (or the whole device, including the antenna) around a full 360 degrees with respect to a separate antenna. Signals are transmitted between the reference antenna and the antenna under test and the signal strength is measured. The result is a graph that shows the radiation characteristics in the plane formed by the 360-degree rotation. Because we are interested in how well an antenna works in all directions, it is necessary to measure the radiation pattern in at least several planes.

RTRX: Reference Transceiver; an EnOcean capable transceiver device used as a reference for comparison testing. The technical specifications of a RTRX have to be in line with the relevant definitions contained in this specification.

TTRX: Test Transceiver; an EnOcean capable transceiver device used as a communication counterpart for RTRX and DUT during testing. The technical specification of a TTRX has to be in line with the relevant definitions contained in this document.

1.2.2. References

ANSI C63.4-2003
American National Standard for Methods of Measurement of Radio Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz
Chapter 5.4: Radiated Emission Tests (30MHz to 1GHz)
30 January 2004, Print SH95184 / PDF SS95184

ETSI TR 102 273-1 V1.2.1 (2001-12)
Electromagnetic compatibility and Radio spectrum Maters (EMR); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties
Chapter 8: Practical Test Sites
ETSI 2001, Reference RTR/ERM-RP02-057-1-1

Balanis, Constantine A., “Antenna Theory - Analysis and Design”, Copyright 1982, ISBN 0-471-60352-X

2. Test Method

2.1. Prerequisite

The test cases shall be performed such that the results delivered may also be achieved by a test repetition at any later time. Therefore, this specification includes definitions for the general test setup and the test equipment that shall be used.

2.2. General Test Setup

The general test setup shall ensure that the test results are representative for the RF-performance of the DUT under standard operating conditions. There are three relevant topics:

1) How does the standard DUT mounting affect the radiation pattern of the DUT antenna?
2) Does EMI from DUT internal circuitry operated regularly affect the DUT receiver sensitivity?
3) Does DUT external cabling affect the DUT radiation pattern or receiver sensitivity?

This specification defines a relative performance test, comparing the DUT with a RTRX that has well known and stable RF-parameters.

Tests shall be performed in an environment that avoids influence from reflected RF on the measurement results. Therefore, it is good practice to execute the specified tests outdoors on a wide-open space. **In case tests will have to be performed indoors, a directional antenna with low side lobes and a high front to back ratio shall be used with the TTRX**. Special care has to be taken about indoor specific (temporary) RF-effects, like man made noise, other frequency users or high power signals on nearby radio channels to avoid degradation of the test results.

The TTRX and the RTRX / DUT must be mounted at a defined distance and height, while such mounting shall ensure the first Fresnel Zone to be free from obstacles. The table below [Tab.1] provides rough information about the distance required between RTRX/DUT and TTRX as well as about the minimum height of both devices above ground.

	315MHz	868MHz	902MHz	928MHz
distance between antennas	≥5 meters	≥3 meters	≥3 meters	≥3 meters
height of antennas above ground	>1.2 meters	≥1.2 meters	≥1.2 meters	≥1.2 meters

Tab.1 Distance required between RTRX/DUT and TTRX and minimum height of both devices above ground

The following illustration [Fig. 1] shows a general test site arrangement for a TTRX with an omnidirectional antenna. In case a directional antenna with sufficient front-to-back ratio is used, the free space right-hand of the TTRX may be reduced to as low as 0.5m.

Fig.1 General test site arrangement for a TTRX with an omni¬directional antenna

Stands used to mount TTRX, RTRX and DUT must not be metallic; the best option are wooden tripods, wooden tables, wooden stakes, card boxes, etc. as these will have low influence on the antennas performance. The DUT stand will carry the RTRX, which is exchanged with the DUT during the test. The other stand carries the TTRX during the execution of all test cases.

The DUT’s RF-performance is influenced by its mounting conditions. Therefore, the DUT shall be mounted with the same conditions which will apply later for the final product mounting. If e.g. a device is supposed to be mounted on a metal surface, it needs to be tested under such conditions. If a device may be mounted on different surfaces (e.g.

plaster, dry-walls, concrete or tiles) it shall be tested with the typical mounting surface. However, it is good practice to run several test cases using all different mounting surfaces. In any case, the “mounting area” shall have dimensions exceeding the wavelength of the radio channel.

Power supply and other connection wires running to the DUT influence the antenna’s radiation behavior. Therefore, the DUT shall be powered, connected and operated the same way it will be under standard operating conditions.

RTRX, TTRX and DUT – if applicable – are controlled by a computer that allows for sending and receiving of radio signals and reading of receiver signal strength values. Further, it is good practice that also this computer documents all individual test results for each direction, in each plane under test.

Detailed background on properly setting up the test site is given in ANSI C63.4 whereas ETSI TR 102 273 provides some insights on the evaluation of measurement uncertainties of different test sites (refer to chapter 1.2.2. , please).

2.3. Test equipment

- RTRX specification and setup
    - TX output power of +1dBm (±1.0dB) at a 50Ω coaxial connector
    - RX Detection capability for maximum length EnOcean messages of <0.025%MER at -89dBm RF input level at a 50Ω coaxial connector
    - RX signal strength detection ranging from -50dBm to -85dBm (±1.5dB accuracy) at a 50Ω coaxial connector
    - Omnidirectional antenna, either vertically or horizontally polarized, with 50Ω impedance, ≥15dB return loss and 0dBd (±1.5dB) antenna gain at the EnOcean radio channel
    - Reference Transceiver software that allows for cyclic or continuous transmission and for continuous detection and logging of received signal strength

  The RTRX setup shall ensure that transmission and reception of RF-signals is predominantly through the antenna. Thus, the electromagnetic shielding of the RTRX setup – including RF and signal cabling, RF connector or cable properly terminated with 50 Ω – shall exceed 80dB.
  In case the RTRX output power is known and stable, but different from the power level defined above, it shall be ensured that such delta is taken into account when comparing the DUT to the RTRX. A delta of ±6.0dB shall be allowed at maximum.

- TTRX specification and setup
  - TX output power of +1dBm (±1.0dB) at a 50Ω coaxial connector
  - RX Detection capability for maximum length EnOcean messages of <0.025%MER at -89dBm RF input level at a 50Ω coaxial connector
  - RX signal strength detection ranging from -50dBm to -85dBm (±1.5dB accuracy) at a 50Ω coaxial connector
  - Directional (indoor or outdoor) or omnidirectional (**only outdoor**) antenna, polarization same as RTRX antenna, with 50Ω impedance and ≥15dB return loss at the EnOcean radio channel.
  - RF attenuation to be added into the 50Ω antenna path allowing for a step size of ≤1.0dB and an overall attenuation of ≥50dB (either integrated into the TTRX or connected externally, or a combination of both). At least an attenuation range of 20dB shall be achieved by a controllable step attenuator and thus without modification of the physical RF path (no exchange of fixed attenuators, to avoid e.g. changing of TTRX antenna positioning).
  - Test Transceiver software that allows for cyclic or continuous transmission and for continuous detection and logging of received signal strength

  The TTRX setup shall ensure that transmission and reception of RF-signals is predominantly through the antenna. Thus, the electromagnetic shielding of the TTRX setup – including RF and signal cabling, RF connector or cable properly terminated with 50 Ω – shall exceed 80dB.
  In case the TTRX output power is known and stable but different from the power level defined above it shall be ensured that such delta is within ±6.0dB at maximum.

- Software to control testing and to allow for logging of results; especially to control transmission and reception of both, TTRX and RTRX
- Stands for the TTRX and the RTRX / DUT.
- AC or DC power to supply the DUT in a way comparable to its regular operating conditions
- Any other equipment that is required to operate the DUT under standard operating conditions.

3. Test Cases

In general, the Transmitter Performance Test – see 3.1. – and the Receiver Antenna Pattern Test – see 3.2.1. – shall be performed in three orthogonal planes, each with a full 360 degree sweep. However, as there may be EnOcean devices that are designed not to work in all directions, the device manufacturer may decide to exclude:

a) One of the tree orthogonal planes, and / or

b) From not excluded planes either two non-adjacent 70-degree segments or one segment ranging up to 180 degrees.

In such case, the device manufacturer shall communicate the resulting restrictions in radio coverage in the installation or user manual of the device, e.g. by showing the radiation pattern(s) in an easy to understand illustration.
Consequently, no measurements need to be performed for such excluded areas.

3.1. Transmitter Performance Test

1 Set up the RTRX and the TTRX as described above.

2 Set the RTRX antenna to direction 0 degree, pointing to the TTRX antenna.

3 Set the RTRX to an output power of +1dBm, alternatively within the range specified above, and note this power for calculation purposes when comparing RTRX to DUT.

4 Enable the RTRX to transmit radio signals.

5 Enable the TTRX to receive radio signals and add as much attenuation into the receiver path as required to ensure the received RTRX signal is within the signal detection range of the TTRX. Note “RTRX-ATT” for calculation purposes.

6 Measure and document the effective radiated power of the RTRX:
   a Note the signal strength received by the TTRX as “RTRX-TX-Result”.
   b In case the RTRX output power is different from +1dBm correct RTRX-TX-Result accordingly and save it for comparison with DUT.

7 Replace the RTRX with the DUT and run it to transmit radio signals.

8 Enable the TTRX to receive radio signals and add as many attenuation into the receiver path as required to ensure for all DUT directions the received DUT signal is within the signal detection range of the TTRX. Note “DUT-ATT” for calculation purposes.

9 Set the DUT to direction 0 degree, pointing to the TTRX antenna.

10 Measure and document the effective radiated power and the radiation pattern of the DUT:
   a Note the signal strength received by the TTRX.
   b Rotate the DUT clockwise in steps of 15 degrees.
   c Repeat measurements for each of the 24 DUT directions, creating 24 individual “DUT-TX-Results” when the entire 360-degree sweep has been completed.
   d In case RTRX-ATT is different from DUT-ATT correct the “DUT-TX-Results” accordingly and save them for comparison with RTRX.

11 Repeat DUT measurements in two additional orthogonal planes, for a total of three orthogonal planes (see ANNEX, 4.1.). For each plane, perform step 8 thru step 10 accordingly.

12 Compare DUT to RTRX
   a On the same set of axes, plot all 24 DUT-TX-Results (see ANNEX, 4.2.).
   b Analyze and categorize DUT
      i Good-

         At ≥18 directions for a full 360 degree sweep,
         or at all directions if one or two excluded areas apply,
         DUT-TX-Result ≥ (RTRX-TX-Result – 10dB).
         Test PASSED

      ii Marginal-

         At ≥18 directions for a full 360 degree sweep,
         or at all directions if one or two excluded areas apply,
         DUT-TX-Result ≥ (RTRX-TX-Result – 18dB).
         Test PASSED

      iii Bad-

         At ≥7 directions and < 18 directions for a full 360 degree sweep,
         or at ≥1 direction(s) if one or two excluded areas apply,
         DUT-TX-Result < (RTRX-TX-Result – 18dB).
         Test FAILED

   c Analyze and categorize DUT for the two additional orthogonal planes, for a total of three orthogonal planes

3.2. Receiver Performance Test

3.2.1. Receiver Antenna Pattern Test

1 Set up the RTRX and the TTRX as described above.

2 Set the RTRX antenna to direction 0 degree, pointing to the TTRX antenna.

3 Enable the RTRX to receive radio signals and read the received signal strength.

4 Enable the TTRX to transmit radio signals and adjust transmitter signal attenuation such that the signal strength received by the RTRX is within the signal detection range of the RTRX. Note "RTRX-ATT" for calculation purposes.

5 Note the signal strength received by the RTRX as "RTRX-RX-Result" and save it for comparison with DUT.

5 Replace the RTRX with the DUT and cause it to read the received signal strength.

6 Enable the TTRX to transmit radio signals and adjust transmitter attenuation such that the signal strength received by the DUT for all DUT directions is within the signal detection range of the DUT. Note "DUT-ATT" for calculation purposes.

7 Set the DUT to direction 0 degree, pointing to the TTRX antenna.

8 Measure and document the radiation pattern of the DUT antenna:
  - a Note the signal strength received by the DUT.
  - b Rotate the DUT clockwise by steps of 15 degrees.
  - c Repeat measurements for each of the 24 RTRX directions, creating 24 individual "DUT-RX-Results" when the entire 360-degree sweep has been completed.
  - d In case RTRX-ATT is different from DUT-ATT correct DUT-RX-Results accordingly and save them for comparison with the RTRX.

9 Repeat DUT measurements in two additional orthogonal planes, for a total of three orthogonal planes (see ANNEX, 4.1.). For each plane, perform step 6 thru step 8 accordingly.

10 Compare DUT to RTRX:
  - a On the same set of axes, plot all 24 DUT-RX-Results (see ANNEX, 4.2.).
  - b Analyze and categorize DUT
    - i. Good-

      At ≥18 directions for a full 360 degree sweep,
      or at all directions if one or two excluded areas apply,
      DUT-RX-Result ≥ (RTRX-RX-Result – 10dB).
      Test PASSED

ii. Marginal-

At ≥18 directions for a full 360degree sweep,
or at all directions if one or two excluded areas apply,
DUT-RX-Result ≥ (RTRX-RX-Result – 18dB).
Test PASSED

iii. Bad-

At ≥7 directions and < 18 directions for a full 360degree sweep,
or at ≥1 direction(s) if one or two excluded areas apply,
DUT-RX-Result < (RTRX-RX-Result – 18dB).
Test FAILED

c Analyze and categorize DUT for the two additional orthogonal planes, for a total of three orthogonal planes

3.2.2. Receiver MER Test

1. Set up the RTRX and the TTRX as described above.
2. Enable the RTRX to receive radio signals and read the received signal strength.
3. Set the RTRX antenna in direction 0°, pointing to the TTRX antenna.
4. Enable the TTRX to transmit maximum length EnOcean messages (consisting of three sub-telegrams) and adjust transmitter attenuation such that the signal strength reading of the RTRX reports -83dBm. Note “RTRX-ATT” for calculation purposes.
5. Increase transmitter attenuation by 6db.
6. Under this radio link condition (-89 dBm) the RTRX shall provide a MER ≤ 0.05% when receiving at least 2,000 maximum length EnOcean messages (consisting of three sub-telegrams).
   If this applies, proceed with step 8. Otherwise, verify carefully the test set-up and the RF situation of the test location.
7. Replace the RTRX with the DUT and run it to read the received from the TTRX signal strength.
8. Set the DUT in direction 0°, pointing to the TTRX antenna.
9. Enable the TTRX to transmit maximum length EnOcean messages (consisting of three sub-telegrams) and adjust transmitter attenuation such that the signal strength reading of the DUT reports -83dBm. Note “DUT-ATT” for calculation purposes.

10. Check difference between RTRX-ATT and DUT-ATT against difference between RTRX-RX-Result and DUT-RX-Result, both at the direction of 0°.
    If the differences are within a range of 3dB, proceed with step 11. Otherwise, verify carefully the test set-up and the RF situation of the test location.
11. Increase transmitter attenuation by 6db.
12. Under this radio link condition (-89dBm) the MER of the DUT shall be measured when receiving at least 1,000 maximum length EnOcean messages (consisting of three sub-telegrams). Record the result.

11 Categorize DUT:

iv. Good-

Message Error Rate ≤ 0.1%.
Test PASSED

v. Bad-

Message Error Rate > 0.1%.
Test FAILED

4. Annex

4.1. Annex 1: Orientation of a DUT in Three Orthogonal Planes (Example)

All three views from TTRX antenna; a 360-degree sweep is performed clockwise:

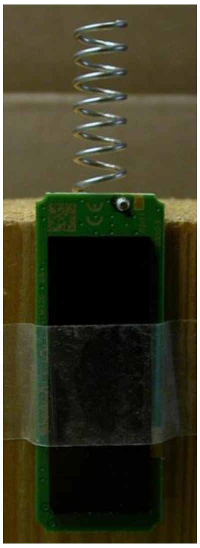

Fig.2 XZ-Plane sweep → DUT is mounted vertically and turned around its Y-Axis.

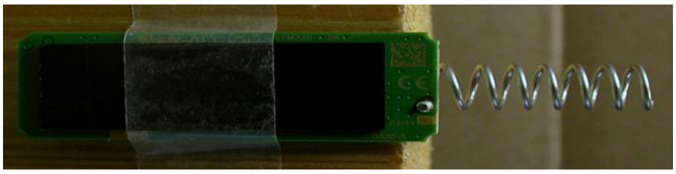

Fig.3 YZ-Plane sweep → DUT is mounted horizontally (rectangular to earth plane) and turned around its X-Axis.

Fig.4 XY-Plane sweep → DUT is mounted horizontally (parallel to earth plane) and turned around its Z-Axis.

4.2. Annex 2: Plots of Transmitter Performance Test Results (Example)

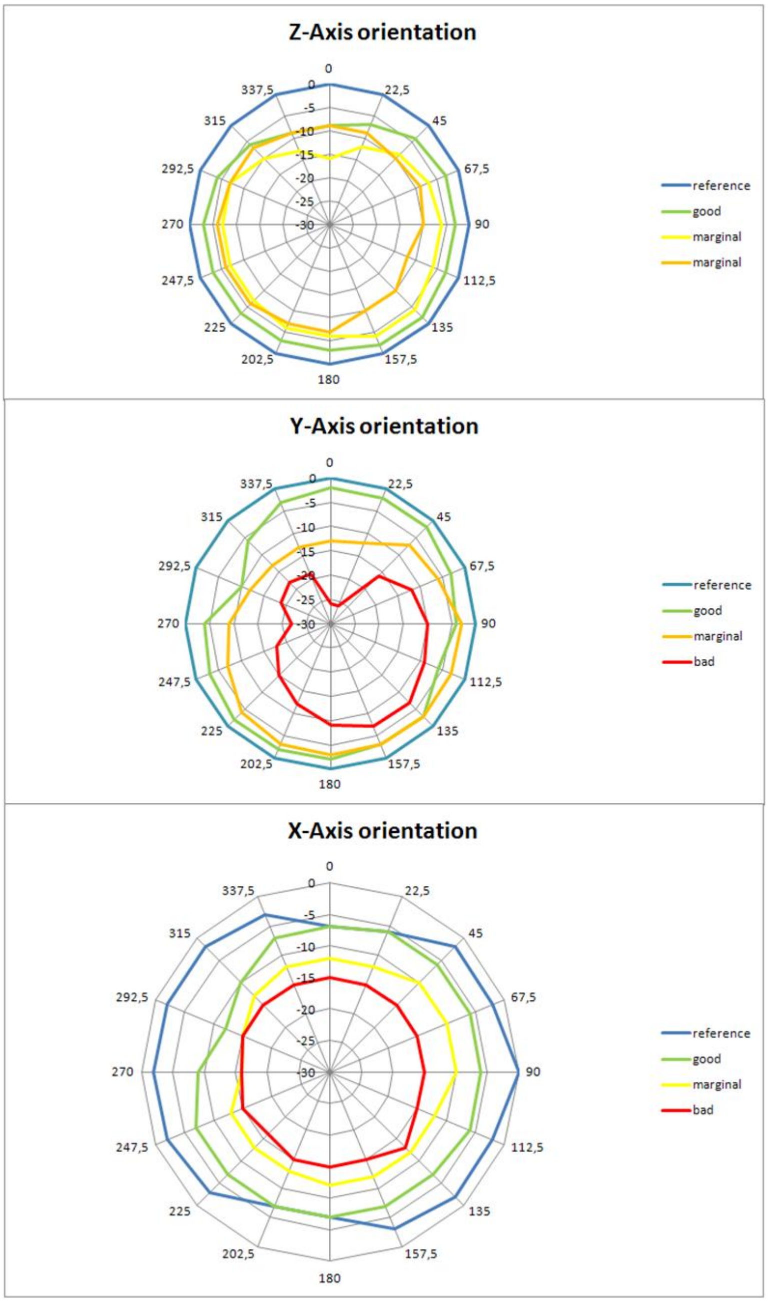

Fig.5 Plots of transmitter performance test results (example)

IMPORTANT REMARKS:

- These plots do NOT belong to the device shown in ANNEX 1 above.
- Step size shown in the plots is 22.5 degrees instead of 15 degrees specified in this document.

4.3. Annex 3: Radio Performance Documentation Template

A template for the radio performance test documentation is available on the web site of the EnOcean Alliance
https://www.enocean-alliance.org/specifications/ .