

**Electromagnetic compatibility  
and Radio spectrum Matters (ERM);  
Road Transport and Traffic Telematics (RTTT);  
Dedicated Short Range Communication (DSRC)  
transmission equipment (500 kbit/s/250 kbit/s) operating in  
the 5,8 GHz Industrial, Scientific and Medical (ISM) band;  
Part 1: General characteristics and test methods  
for Road Side Units (RSU) and On-Board Units (OBU)**

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Reference

REN/ERM-TG29-0105

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**ETSI**

650 Route des Lucioles  
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C  
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## Foreword

This European Standard (Telecommunications series) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM), and is now submitted for the Vote phase of the ETSI standards Two-step Approval Procedure.

The present document is part 1 of a multi-part deliverable covering Electromagnetic compatibility and Radio spectrum Matters (ERM); Road Transport and Traffic Telematics (RTTT); Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band, as identified below:

**Part 1: "General characteristics and test methods for Road Side Units (RSU) and On-Board Units (OBU)";**

Part 2: "Harmonized EN under article 3.2 of the R&TTE Directive".

<b>Proposed national transposition dates</b>	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
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Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

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# 1 Scope

The present document applies to Road Transport and Traffic Telematics (RTTT) wireless systems:

- with or without antenna connectors;
- for digital data transmission;
- operating on radio frequencies in the 5,725 GHz to 5,875 GHz Industrial, Scientific and Medical (ISM) frequency band.

The applicability of the present document covers both the Road Side Units (RSUs) and the On-Board Units (OBUs) with transceivers and transponders.

The present document complies with ECC/DEC/(02)01 [1] and CEPT/ERC/REC 70-03 [3]. It is a specific standard covering various RTTT applications.

Additional standards or specifications may be required for equipment such as that intended for connection to the Public Switched Telephone Network (PSTN) or other systems.

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# 2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

Referenced documents which are not found to be publicly available in the expected location might be found at <http://docbox.etsi.org/Reference>.

- [1] ECC/DEC/(02)01: "ECC Decision of 15 March 2002 on the frequency bands to be designated for the co-ordinated introduction of Road Transport and Traffic Telematic Systems".
- [2] prEN 12253 (2003): "Road Transport and Traffic Telematics (RTTT); Dedicated Short Range Communication (DSRC); Physical Layer using Microwave at 5,8 GHz".

NOTE: prEN 12253 currently is in the approval process at CEN.

- [3] CEPT/ERC/REC 70-03: "Relating to the use of Short Range Devices (SRD)".
- [4] ETSI TR 100 028 V1.4.1 (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics".
- [5] IEC 60721-3-4 (1995) including Amendment 1 (1996): "Classification of environmental conditions; Part 3: Classification of groups of environmental parameters and their severities - Section 4: Stationary use at non-weather protected locations".
- [6] IEC 60721-3-5 (1997): "Classification of environmental conditions; Part 3: Classification of groups of environmental parameters and their severities - Section 5: Ground vehicle installations".
- [7] BS EN 12795 (2003): "Road transport and traffic telematics. Dedicated short range communication (DSRC). DSRC data link layer. Medium access and logical link control".
- [8] BS EN 12834 (2003): "Road transport and traffic telematics. Dedicated Short Range Communication (DSRC). DSRC application layer".



- [9] ISO/TR 14906 (1998): "Road Transport and Traffic Telematics (RTTT) - Electronic Fee Collection (EFC) - Application interface definition for dedicated short range communications".
- [10] CEPT/ERC/REC 74-01E (2002): "Spurious Emissions".
- [11] ETSI TR 102 273-2 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties; Part 2: Anechoic chamber".
- [12] ETSI TR 102 273-4 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties; Part 4: Open area test site".
- [13] ETSI TR 102 273-6 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties; Part 6: Test fixtures".
- [14] prEN 13372 (2003): "Road Transport and Traffic Telematics (RTTT); Dedicated Short Range Communication (DSRC); Profiles for RTTT applications".
- NOTE: prEN 13372 currently is in the approval process at CEN.
- [15] Commission Directive 95/54/EC of 31 October 1995 adapting to technical progress Council Directive 72/245/EEC on the approximation of the laws of the Member States relating to the suppression of radio interference produced by spark-ignition engines fitted to motor vehicles and amending Directive 70/156/EEC on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers.
- [16] CISPR 16-1 Edition 2.1 (2002): "Specification for radio disturbance and immunity measuring apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus".

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## 3 Definitions, symbols and abbreviations

### 3.1 Definitions

For the purposes of the present document, the following terms and definitions apply.

**adjacent channel:** A downlink adjacent channel refers to transmission in downlink direction using any one of the adjacent DSRC downlink channels at a distance of 5 MHz, i.e. in the channel at the next upper or lower centre frequency. An uplink adjacent channel refers to transmission in uplink direction using any one of the uplink communication channels related to a centre frequency at a distance of 5 MHz relative to the own downlink centre frequency.

**bit:** acronym for "binary digit" which can have one out of two possible values, e.g. 0/1 or +1/-1 or low/high

**bit rate:** in a bit stream, the number of bits occurring per unit time, usually expressed in bits per second

**bore sight:** direction of maximum radiation of a directional antenna

NOTE: If bore sight can not be determined unambiguously, then bore sight may be declared by the provider.

**carrier frequency:** frequency  $f_{TX}$  to which the RSU transmitter is tuned

NOTE: In DSRC, the carrier frequency is in the centre of a channel, see table 2 of the present document.

**carrier signal or carrier:** harmonic signal whose nominal single frequency  $f_{TX}$  can vary within a range specified by the carrier frequency tolerance and which is capable of being modulated by a second, symbol-carrying signal

**channel:** continuous part of the radio-frequency spectrum to be used for a specified emission or transmission

NOTE: A radio-frequency channel may be defined by two specified limits, or by its centre frequency and its bandwidth, or any equivalent indication. It is often designated by a sequential number. A radio-frequency channel may be time-shared in order to allow radiocommunication in both directions by simplex operation. The term "channel" is sometimes used to denote two associated radio-frequency channels, each of which is used for one of two directions of transmission, i.e. in fact a telecommunication circuit.

**co-channel:** A downlink co-channel refers to a transmission in downlink direction using the same frequency band of 5 MHz width. Up-link channels at the two sub-carrier frequencies related to the same downlink channel (downlink centre frequency) are referred to as co-channels.

**cross-polar discrimination, ellipticity of polarization:** Antenna designed to transmit left hand circular waves may transmit some right hand circular waves in addition. Cross-Polar Discrimination (XPD) is defined as the ratio  $P_{\text{LHCP}}/P_{\text{RHCP}}$  of power  $P_{\text{LHCP}}$  of the left hand circular polarized wave to the power  $P_{\text{RHCP}}$  of the right hand circular wave when the total power of the transmitted wave is  $P_{\text{LHCP}} + P_{\text{RHCP}}$ .

**environmental profile:** range of environmental conditions under which equipment within the scope of EN 300 674-1 is required to comply with the provisions of EN 300 674-1

**equivalent isotropically radiated power:** signal power fed into an ideal loss-less antenna radiating equally in all directions that generates the same power flux at a reference distance as the one generated by a signal fed into the antenna under consideration in a predefined direction within its far field region

**integral antenna:** antenna, with or without a connector, designed as an indispensable part of the equipment

**OBU sleep mode:** OBU may be either in sleep mode, the stand-by mode, or the transmit mode. The sleep mode is an optional mode for battery powered OBUs that allows to save battery power. In this mode, the OBU can only detect the presence of a DSRC down-link signal which under certain defined conditions, see prEN 12253 [2], will lead to wake-up, i.e. a transition to the stand-by mode.

**OBU stand-by mode:** OBU may be either in sleep mode, the stand-by mode, or the transmit mode. The stand-by mode is the mode, in which the OBU is capable of receiving DSRC down-link signals. In this mode the OBU is never transmitting.

**operating frequency:** nominal frequency at which equipment is operated; also referred to as the operating centre frequency

NOTE: Equipment may be able to operate at more than one operating frequency.

**out-of-band emissions:** emissions on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process and which cannot be reduced without affecting the corresponding transmission of information, but excluding spurious emissions (see also CEPT Recommendation 74-01 [10])

**polarization:** Locus of the tip of the electrical field vector in a plane perpendicular to the direction of transmission. Examples are horizontal and vertical linear polarization and left and right hand circular polarization.

**Portable Equipment (PE):** generally intended to be self-contained, free standing and portable

NOTE: A PE would normally consist of a single module, but may consist of several interconnected modules. It is powered by one or more internal batteries.

**provider:** manufacturer or person responsible for placing the apparatus on the market

**radiated measurements:** measurements which involve the measurement of a radiated electromagnetic field

**spurious emissions:** Emission on a frequency, or frequencies, which are outside an exclusion band of  $\pm 2,5$  times the channel spacing around the selected centre frequency  $f_{\text{Tx}}$ , and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products but exclude out-of-band emissions (see also CEPT Recommendation 74-01 [10]).

## 3.2 Symbols

For the purposes of the present document, the following symbols apply:

$A_{CW}$	Amplitude of CW signal
$A_{mod}$	Amplitude of modulated signal
$ATN_{AT2}$	Attenuation of attenuator AT2
$ATN_{BLN}$	Attenuation of balun BLN
$ATN_{CA1}$	Attenuation of calibrated coaxial cable 1
$BER$	Bit Error Ratio
$C_F$	Number of frames transmitted
$C_E$	Number of erroneous frames received
$d$	Distance between phase centres of transmitting and receiving antenna
$d_{displace}$	Horizontal displacement of TTA and RTA antenna phase centres
$d_{F1}$	Distance from transmitting antenna to first Fresnel ellipse
$d_{F2}$	Distance from first Fresnel ellipse to receiving antenna
$D_{fb}$	Distance between neighbouring ferrite beads
$D_i$	Directivity relative to an isotropic radiator
$D_{0,TA}$	Largest linear dimension of test antenna
$D_{0,EUT}$	Largest linear dimension of EUT antenna
$EIRP_{max}$	Maximum e.i.r.p. of RSU
$EIRP_{MaxObuTx}$	Maximum e.i.r.p. generated by the OBU in a single side band
$EIRP_{ObuTx}$	e.i.r.p. generated by the OBU within a single side band.
$EIRP_{OBU}$	e.i.r.p. generated by the OBU antenna
$EIRP_{TSM}$	e.i.r.p. referred to transmitter spectrum mask
$\Delta f_{RSU}$	Frequency error of RSU
$\Delta f_s$	Sub-carrier frequency error
$f$	Frequency
$f_c$	Centre frequency of receiving device
$FER$	Frame error ratio
$f_{ObuTx}$	Actual centre frequency of the lower and upper side band of the OBU up-link channel
$f_{MSS1}$	Frequency of MSS1
$f_{offset}$	Offset frequency
$f_s$	Nominal OBU sub-carrier frequency
$f_{Tx}$	Nominal RSU carrier frequency
$f_{Tx,actual}$	Actual centre frequency of the down-link carrier
$f_u$	Nominal centre frequency of unwanted signal
$f_{u1}, f_{u2}$	Centre frequencies of unwanted signal
$G_c$	Conversion gain
$G_{corr}$	Correction gain
$G_{OBU,Rx}$	Gain of OBU receiving antenna
$G_{OBU,Tx}$	Gain of OBU transmitting antenna
$G_{RSA}$	Gain of receiving substitution antenna
$G_{TA}$	Gain of test antenna
$G_{TSA}$	Gain of transmitting substitution antenna
$G_{RSU,Tx}$	Gain of RSU transmitting antenna
$k$	Expansion factor (coverage factor)
$\lg(.)$	Logarithm to the base ten
$m$	Modulation index
$N$	Total number of transmitted bits within a single frame
$P_{CW}$	Power of CW signal
$P_{D11a}$	Power limit for communication (upper)

$P_{D11b}$	Power limit for communication (lower)
$P_{inc}$	Incident signal power as received by an ideal isotropical receiving antenna
$P_{inc,scan}$	Incident signal power obtained from a scanning process
$P_{inc,dBm}$	$P_{inc}$ in dBm
$P_{LHCP}$	Signal power of left hand circular polarized wave
$P_{max}$	Maximum signal power
$P_{mod}$	Power of modulated signal
$P_{MMS1}$	Output signal power of MSS1
$P_{MMS2}$	Output signal power of MSS2
$P_{ObuRx}$	Incident signal power to OBU, referred to an ideal isotropical receiving antenna
$P_{pol}$	Signal power of wave with corresponding polarization
$P_v$	Signal power of wave featuring vertical polarization
$P_h$	Signal power of wave featuring horizontal polarization
$P_{PM1}$	Signal power measured by the power meter 1
$P_{ref}$	Reference signal power limit in Watt
$P_{ref,dBm}$	Reference signal power limit in dBm
$P_{reTx}$	Retransmitted signal power
$P_{RSA}$	Signal power obtained from receiving substitution antenna
$P_{RHCP}$	Signal power of right hand circular polarized wave
$P_{ssb}$	Signal power within single side band
$P_{sens}$	Declared sensitivity of receiver
$P_{spurious}$	Signal power of spurious signal
$P_{tot}$	Sum of signal power $P_1 + P_2$ , or $P_1 + P_2 + \dots + P_5$ , whichever applies
$P_{tot,dBm}$	$P_{tot}$ in dBm
$P_{TSM}$	Transmitter spectrum mask
$P_u$	Power of unwanted signal
$P_w$	Signal power of wanted signal
$P_0$	Reference signal power of 1 mW corresponding to 0 dBm
$RBW$	Resolution bandwidth
$T_{CW}$	Duration of CW signal
$T_{mod}$	Duration of modulated signal
$V_{max}, V_{min}$	Maximal amplitude of modulated output signal of RSU caused by data bit 1, or 0
$\alpha$	Tilt angle of test antenna
$\alpha_{displace}$	Displacement angle between TTA and RTA
$\theta$	Angle relative to OBU bore sight indicating worst case direction
$\lambda$	Wavelength
$\rho_{RSA}$	Reflection coefficient at antenna connector of the receiving substitution antenna
$\rho_{TSA}$	Reflection coefficient at antenna connector of the transmitting substitution antenna

### 3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

General abbreviations:

AT1	Attenuator 1
AT2	Attenuator 2
BER	Bit Error Ratio
BLN	Balun
BST	Beacon Service table
CA	Corresponding Antenna
CC	Coaxial Circulator
CRC	Cyclic Redundancy Checking

CW	Continuous Wave
DC	Direct Current
DEC	DECision
doa	date of announcement
dop	date of publication
dow	date of withdrawal
DSRC	Dedicated Short Range Communication
e.i.r.p.	Equivalent Isotropically Radiated Power also called EIRP, eirp, E.I.R.P.
EC	European Community
ECC	European Community Commission
EFC	Electronic Fee Collection
EUT	Equipment Under Test
FCCA	Ferrited Coaxial CAble
FCCA1	Ferrited Coaxial CAble 1
FER	Frame Error Ratio
ISM	Industrial, Scientific, Medical
LHCP	Left Hand Circular Polarized
LOS	Line-Of-Sight
LP	Linear Polarized
Mc	Location of the OBU antenna phase centre
$M_{\text{centre}}$	Centre point between phase centres of TTA and RTA
MSS1	Monochromatic Signal Source 1
MSS2	Monochromatic Signal Source 2
n.a.	not applicable
OBU	On Board Unit
PE	Portable Equipment
PM1	Power Meter 1
ppm	parts per million ( $10^{-6}$ )
PSTN	Public Switched Telephone Network
R&TTE	Radio and Telecommunications Terminal Equipment
RBW	Resolution BandWidth
RD	Receiving Device
REC	RECommendation
RF	Radio Frequency
RRxA	RSU Receiving Antenna
RSA	Receiving Substitution Antenna
RSU	Road Side Unit
RTA	Receiving Test Antenna
RTTT	Road Transport and Traffic Telematics
RTxA	RSU Transmitting Antenna
Rx	Receiver
SMS1	Signal or Message Source 1
SR	Special Report
SSB	Single Side Band
TA	Test Antenna
TD	Technical Document
TM1	Test Message 1
TS1	Test Signal 1
TS2	Test Signal 2
TSA	Transmitting Substitution Antenna
TSM	Transmitter Spectrum Mask
TTA	Transmitting Test Antenna
Tx	Transmitter
VBW	Video BandWidth
VST	Vehicle Service table
VSWR	Voltage Standing Wave Ratio
XP	Cross Polarized
XPD	Cross-Polar Discrimination

prEN 12253 [2] list of down-link parameter abbreviations:

D1	Carrier frequencies
D1a	Tolerance of carrier frequencies
D2	RSU Transmitter spectrum mask
D3	OBU minimum frequency range
D4	Maximum e.i.r.p.
D5	Polarization
D5a	Cross polarization
D6	Modulation
D6a	Modulation index
D6b	Eye pattern
D7	Data coding
D8	Bit rate
D8a	Tolerance of bit clock
D9a	BER for communication
D11a	Power limit for communication (upper)
D11b	Power limit for communication (lower)
D12	Cut-off power level of OBU

prEN 12253 [2] list of up-link parameter abbreviations:

U1	Sub-carrier frequencies
U1a	Tolerance of sub-carrier frequencies
U1b	Use of side bands
U2	OBU Transmitter spectrum mask
U4a	Maximum single side band e.i.r.p. (bore sight)
U4b	Maximum single side band e.i.r.p. (35°)
U5	Up-link polarization
U5a	Cross polarization
U6	Sub-carrier modulation
U6b	Eye pattern/duty cycle
U6c	Modulation on carrier
U7	Data coding
U8	Bit rate
U8a	Tolerance of symbol clock
U9a	BER for communication
U12a	Conversion gain (lower)
U12b	Conversion gain (upper)

---

## 4 General characteristics

### 4.1 Mechanical and electrical design

#### 4.1.1 Units

Units can be either Road Side Units or On Board Units.

Transmitters and receivers may be individual or combination units; some units may be transmitter only, some units may be receiver only and some units may combine transmitter and receiver functionalities.

#### 4.1.2 Controls

Those controls which if maladjusted might increase the interference possibilities to and from the equipment shall only be accessible by partial or complete disassembly of the device and requiring the use of tools.

## 4.2 Environmental profiles

### 4.2.1 Summary

The provider shall select one of the subsequent environmental profiles:

- environmental profile declared by the provider;
- voluntary ETSI environmental profile.

### 4.2.2 Environmental profile declared by provider

The requirements of the present document shall apply under the environmental profile for intended operation of the equipment, which shall be declared by the provider.

An environmental profile shall include at least minimum and maximum value of operational temperature range.

NOTE: For more details on environmental profile parameters see table 1.

The environmental conditions for tests shall be any convenient selection of environmental parameter values within the declared ranges.

### 4.2.3 Voluntary ETSI environmental profile

The requirements of the present document shall apply under the environmental profile for intended operation, either normal or extreme environmental conditions, which shall be selected by the provider in accordance with the following two clauses.

#### 4.2.3.1 Normal environmental conditions

The normal temperature and humidity conditions for tests shall be any convenient combination of temperature and relative humidity within the following ranges:

- temperature: +15 °C to +35 °C;
- relative humidity: 20% to 75%.

#### 4.2.3.2 Extreme environmental conditions

Extreme environmental conditions are classified in categories according to table 1.

**Table 1: Extreme environmental conditions**

Temperature category	RSU	OBU
Category I (General):	temperature: -20°C to +55°C	temperature: -20°C to +55°C
Category II:	IEC 60721-3-4 [5] / 4K2	IEC 60721-3-5 [6] / 5K2
Category III	IEC 60721-3-4 [5] / 4K3	IEC 60721-3-5 [6] / 5K3
Category IV:	IEC 60721-3-4 [5] / 4K4	IEC 60721-3-5 [6] / 5K4

The extreme environmental conditions for tests shall be any convenient selection of environmental parameter values, except temperature, of a single category. For tests at extreme temperature, measurements shall be made at both, the upper and lower temperature of the selected category.

## 5 General characteristics of Road Side Unit

### 5.1 RSU classes

There exist three classes of RSUs which are distinguished by the parameter D2 (4) "in band spurious emissions with modulated carrier wave" of prEN 12253 [2].

Those classes are called class A, class B and class C, see table 5. The provider shall declare to which class the equipment complies with.

NOTE: The use of class A for new equipment is not recommended.

### 5.2 Power supply

All the characteristics and requirements applying to RSUs shall be fulfilled within the range of the declared operational conditions of the power supply.

Power supply may be a built in battery, an external battery or a stabilized power supply, etc.

NOTE: If an RSU is supplied by the battery of a vehicle, e.g. car or truck, the automotive Directive 95/54/EC [15] applies.

### 5.3 Carrier frequencies

The present document applies to RSUs operating in some or all of the following channels detailed in table 2.

The centre frequencies  $f_{TX}$  indicated in table 2 are referred to as parameter D1 in prEN 12253 [2].

**Table 2: Frequency bands and centre frequencies  $f_{TX}$  allocated for DSRC**

	Pan European Service Frequencies	National Service Frequencies
Channel 1	5,795 GHz to 5,800 GHz, $f_{TX} = 5,7975$ GHz	
Channel 2	5,800 GHz to 5,805 GHz, $f_{TX} = 5,8025$ GHz	
Channel 3		5,805 GHz to 5,810 GHz, $f_{TX} = 5,8075$ GHz
Channel 4		5,810 GHz to 5,815 GHz, $f_{TX} = 5,8125$ GHz

Where equipment can be adjusted to operate at different operating frequencies other than channels 1 and 2, a minimum of two operating frequencies shall be chosen for the tests described in the present document such that the lower and higher limits of the provider's declared operating ranges of the equipment are covered.

### 5.4 Antenna characteristic

All RSU antennas shall be LHCP in accordance with parameters D5 and D5a in prEN 12253 [2].

### 5.5 Modulation

The carrier of frequency  $f_{TX}$ , see table 2, shall be modulated in accordance with parameters D6, D6a and D6b in prEN 12253 [2].



## 6 General characteristics of On Board Unit

### 6.1 OBU sets

There exist two sets of OBUs called Set A and Set B which differ by the following parameters either in terms of value or applicability, and which are defined in prEN 13372 [14].

**Table 3: Differences in OBU Sets**

prEN 12253 [2] parameter abbreviation	Set A	Set B
D11a	Power limit for communication (upper)	
D12	n.a.	Cut off power level of OBU
U4a	Maximum SSB e.i.r.p. (bore sight)	
U4b	n.a.	Maximum SSB e.i.r.p. (35°)
U12b	n.a.	Conversion gain (upper limit)

The provider shall declare which Set the unit complies with.

### 6.2 OBU assemblies

The OBU as identically supplied for testing and usage by the end-user is a physical assembly which is located and operated in or on the vehicle to either transmit or receive DSRC signals. The OBU e.g. may be assembled such that it is:

- mountable in or on any part of the vehicle structure by the end-user according to guidelines in the user-manual, and optionally removable after proper installation, or
- bonded to a part of the vehicle by a service station being authorized by the provider, or
- an integral part of a vehicle component, such as a windscreen, bumper or licence plate.

In case the OBU is removable from its mounting device by the end-user, tests shall be performed with the OBU properly attached to its mounting device.

The supplier shall declare the physical assembly of his OBU.

### 6.3 Power supply

All the characteristics and requirements applying to OBUs shall be fulfilled within the range of the declared operational conditions of the power supply.

Power supply may be a built in battery, an external battery or a stabilized power supply, etc.

NOTE: If an OBU is supplied by the battery of a vehicle, e.g. car or truck, the automotive Directive 95/54/EC [15] applies.

### 6.4 Up-link sub-carrier frequencies

The sub-carrier signal or sub-carrier is a signal whose nominal single frequency  $f_s$  can vary within a range specified by the sub-carrier frequency tolerance and which shall be capable of being modulated by a second, symbol-carrying signal, see clause 6.7.

The up-link sub-carrier frequency is referred to as parameter U1 of prEN 12253 [2].

Every DSRC OBU shall support the two sub-carrier frequencies  $f_s$  of 1,5 MHz and 2,0 MHz.

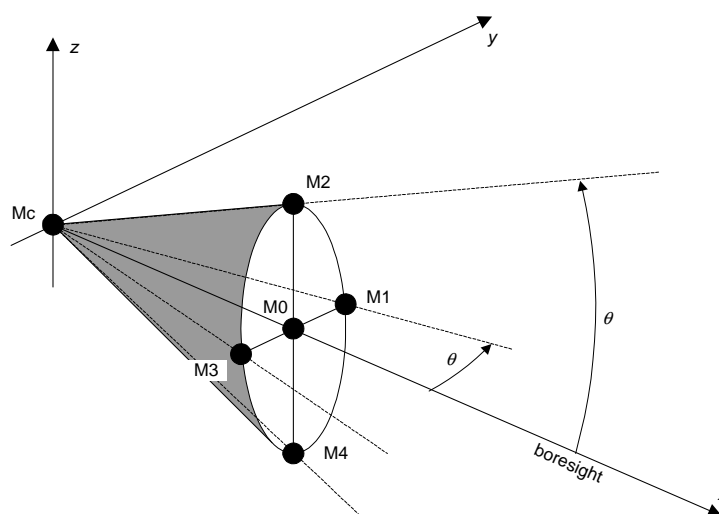
## 6.5 Antenna characteristic

All equipment antennas shall be LHCP according to parameters U5 and U5a in prEN 12253 [2].

An OBU may provide either none, one or two antenna connectors.

In case an OBU does not provide an antenna connector, then either one antenna for receiving and transmitting, or one antenna for receiving and one antenna for transmitting are implemented. In the first case, the phase centre of the OBU antenna is entitled  $M_c$ , see figure 1. In the latter case it is assumed that the two antennas are close to each other and point approximately to the same direction. The centre between these two antennas then is entitled  $M_c$ . For the purpose of easy reading of the present document, in what follows  $M_c$  is referred to as "phase centre of the OBU antenna".

The minimum operational direction of OBU receive and transmit antenna is characterized by a cone with opening angle  $\theta$  around bore sight as depicted in figure 1. The OBU shall provide specific properties inside the cone. The border of the cone itself is referred to as worst case direction. The directions  $M_0$  through  $M_4$  and the phase centre  $M_c$  of the OBU antenna are related to measurements described in the present document.



**Figure 1: OBU antenna characteristic**

The angle  $\theta$  is used in different tests of the present document.

A value of  $\theta = 35^\circ$  is required for OBU minimum conversion gain and for OBU maximum single side band e.i.r.p. according to prEN 12253 [2].

For other properties of the OBU, e.g. sensitivity, the provider may declare an opening angle  $\theta$  other than  $35^\circ$  of the cone.

## 6.6 Carrier frequencies

According to parameter D3 in prEN 12253 [2] every OBU shall be able to operate in all DSRC channels as indicated in table 2.

For tests of OBU parameters described in the present document, only the carrier frequencies  $f_{Tx}$  defined for channel 1 and channel 4 in table 2 shall be considered.

## 6.7 Modulation

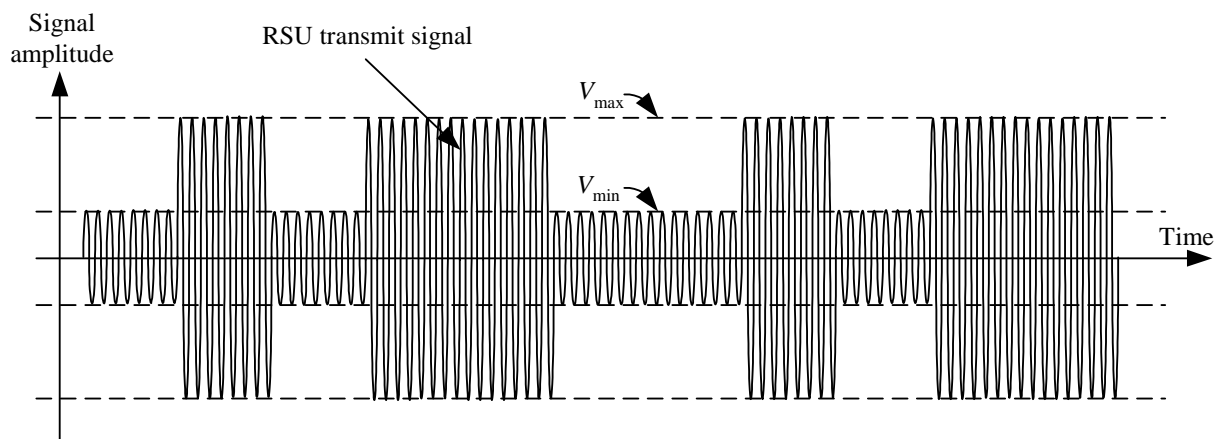
The up-link sub-carrier, see clause 6.4, shall be modulated according to parameters U1b, U6, U6b and U6c in prEN 12253 [2]. The modulated up-link sub-carrier then shall be used to modulate the carrier at frequency  $f_{Tx}$  received from a RSU, i.e. the modulated sub-carrier shall be multiplied with the received carrier.

## 7 Parameter description and required limits

### 7.1 RSU

#### 7.1.1 Modulation index

Figure 2 illustrates a two level amplitude modulated RSU carrier signal as required by parameter D6, D6a, and D6b in prEN 12253 [2].



**Figure 2: Modulated RSU transmit signal**

The modulation index  $m$  is defined as:

$$m = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$$

where  $V_{max}$ , and  $V_{min}$  are, respectively, maximum amplitudes of the modulated output signal of the RSU caused by bits 1 and 0.

The modulation index is referred to as parameter D6a in prEN 12253 [2].

The modulation index  $m$  shall be in the range  $0,5 \leq m \leq 0,9$ .

#### 7.1.2 Dynamic range

##### 7.1.2.1 Definition

The dynamic range of the RSU receiver is defined by the range of the received signal power referred to the antenna connector of the receiver produced by a properly modulated carrier at the carrier frequency  $f_{Tx}$  which will, without interference, produce after demodulation a data signal with a BER of  $10^{-6}$  or smaller.

The lower limit of the dynamic range is referred to as "RSU sensitivity".

The upper limit of the dynamic range is referred to as "RSU upper power limit for communication".

**NOTE:** The dynamic range to be implemented in a specific RSU depends on system requirements. These system requirements are outside the scope of the present document.

### 7.1.2.2 Sensitivity

The RSU sensitivity is the minimum received signal power  $P_{\text{sens}}$  at the antenna connector that allows the RSU to receive DSRC frames with a BER of  $10^{-6}$  or smaller.

The receiver sensitivity shall be  $P_{\text{sens}} \leq -104$  dBm if not declared otherwise by the provider.

### 7.1.2.3 Error behaviour at high wanted input signals

The upper limit of the dynamic range shall be equal to or greater than -50 dBm if not declared otherwise by the provider.

## 7.1.3 Intermodulation immunity

The intermodulation immunity is a measure of the capability of the receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of two or more unwanted signals with specific and different frequency relationships to the wanted signal frequency. This measure is in terms of signal power of the unwanted signals referred to a loss-less isotropic antenna.

For the purpose of the present document exactly two unwanted monochromatic signals shall be considered.

The frequencies  $f_{u1}$  and  $f_{u2}$  of the two unwanted monochromatic signals shall be either at  $f_{u1} = 5$  MHz and  $f_{u2} = 10$  MHz displaced from the centre frequency of the wanted signal, or  $f_{u1} = -5$  MHz and  $f_{u2} = -10$  MHz displaced from the centre frequency of the wanted signal.

The power level  $P_u$  of the two unwanted monochromatic signals shall be equal.

The power of the wanted signal shall be 6 dB above the declared sensitivity level of the RSU receiver.

The degradation limit is defined by the maximum allowed BER of  $2,0 \times 10^{-2}$ .

The intermodulation immunity shall be  $\geq -25$  dBm if not declared otherwise by the provider.

## 7.1.4 Co-channel rejection

The co-channel rejection is a measure of the capability of the receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of an unwanted signal, both using the same carrier and sub-carrier frequencies. This measure is in terms of signal power of the wanted and unwanted signals referred to a loss-less isotropic antenna.

For the purpose of the present document only an unmodulated monochromatic unwanted signal of power  $P_u$  shall be considered.

The power of the wanted signal  $P_w$  shall be 6 dB above the declared sensitivity level of the RSU receiver.

The degradation limit is defined by the maximum allowed BER of  $2,0 \times 10^{-2}$ .

The co-channel rejection is defined as the difference of the signal power  $P_w - P_u$  of the wanted and unwanted signals.

The co-channel rejection shall be  $\leq 6$  dB if not declared otherwise by the provider.

## 7.1.5 Blocking

The blocking capability is the receiver's capability to receive a wanted modulated signal at the receiver RF input without exceeding a given degradation due to the presence of an unwanted modulated or unmodulated signal at any other frequency outside an exclusion band of  $\pm 2,5$  MHz from the centre frequency  $f_{Tx}$  of the wanted signal, i.e. from the frequency  $f_{Tx}$  of the carrier transmitted by the RSU during receive mode, in terms of power of the unwanted signal referred to a loss-less isotropic antenna.

For the purpose of testing only an unmodulated monochromatic unwanted signal shall be considered.

The provider shall declare representative frequencies  $f_u$  of the unwanted signal to be tested. The frequencies  $f_u$  shall be within the frequency range 30 MHz to 26 GHz.

The degradation limit is defined by the maximum allowed BER of  $2,0 \times 10^{-2}$ .

The blocking capability shall be  $\geq -30$  dBm if not declared otherwise by the provider.

### 7.1.6 Selectivity

Selectivity is a measure of the capability of the receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of an unwanted unmodulated signal differing in frequency by an amount equal to the channel separation for which the equipment is designed.

The power of the wanted signal shall be 6 dB above the declared sensitivity level of the RSU receiver.

The degradation limit is defined by the maximum allowed BER of  $2,0 \times 10^{-2}$ .

The selectivity is the power level of the unwanted signal at which the degradation limit is achieved, referred to a loss-less isotropic antenna.

The selectivity shall be according to table 4 if not declared otherwise by the provider.

**Table 4: RSU selectivity limits**

	Frequency offsets from nominal carrier frequency $f_{Tx}$		
	$\pm 50$ kHz (see note 1)	$\pm f_s \pm 0,5$ MHz (see note 2)	$\pm 5$ MHz (see note 3)
Selectivity limit	$\geq -30$ dBm	$\geq -80$ dBm	$\geq -30$ dBm
NOTE 1: Considers SSB phase noise of the carrier oscillator.			
NOTE 2: $f_s$ is the sub-carrier frequency under test.			
NOTE 3: Considers the adjacent carriers.			

### 7.1.7 Maximum equivalent isotropically radiated power

The maximum e.i.r.p. is the e.i.r.p. in the direction of maximal radiation of the RSU antenna.

The maximum e.i.r.p. is referred to as parameter D4 in prEN 12253 [2].

The transmitter maximum e.i.r.p. shall not exceed the limit of 2 W independent of duty cycle.

### 7.1.8 Frequency error

The frequency error of the equipment is the difference between the frequency, at which the transmitter outputs its largest carrier signal level in its unmodulated mode of operation and the corresponding nominal carrier frequency  $f_{Tx}$  listed in table 2.

The maximum allowed frequency error is referred to as parameter D1a in prEN 12253 [2].

The frequency error shall not exceed  $\pm 5$  ppm.

### 7.1.9 Transmitter spectrum mask

The RSU TSM defines the maximum e.i.r.p. allowed to be transmitted by the RSU within specified frequency bands, where distinction is made between different classes providing different values of limits, see clause 5.1.

The RSU TSM is referred to as parameter D2 in prEN 12253 [2].

The limits for the TSM shall not exceed the values given in table 5. Those limits apply within an equivalent bandwidth as indicated in table 5.

Table 5: RSU TSM limits

Position	Frequencies	Unmodulated	Modulated			Equivalent Bandwidth
		All Classes	Class A	Class B	Class C	
Co-channel	$f_{TX} \pm 1,0$ MHz	-27 dBm	n.a.	n.a.	n.a.	62,5 kHz
Co-channel	$f_{TX} \pm 1,5$ MHz	-27 dBm	-7 dBm	-17 dBm	-27 dBm	500 kHz
Co-channel	$f_{TX} \pm 2,0$ MHz	-27 dBm	-27 dBm	-27 dBm	-27 dBm	500 kHz
Adjacent channels	$f_{TX} \pm 3,0$ MHz	-47 dBm	-30 dBm	-37 dBm	-47 dBm	500 kHz
	$f_{TX} \pm 3,5$ MHz					
	$f_{TX} \pm 6,5$ MHz					
	$f_{TX} \pm 7,0$ MHz					
Adjacent channels	$f_{TX} \pm 4,0$ MHz	-47 dBm	-30 dBm	-37 dBm	-47 dBm	62,5 kHz
	$f_{TX} \pm 6,0$ MHz					

### 7.1.10 Transmitter unwanted emissions

The e.i.r.p. of any unwanted emissions, i.e. spurious and out-of-band emission, shall not exceed the limits presented in table 6 for "operating" mode.

Measurements shall not be performed within an exclusion band of  $\pm 2,5$  times the DSRC channel spacing of 5 MHz, i.e.  $\pm 12,5$  MHz around the RSU carrier frequency  $f_{TX}$  under test.

Table 6: Limits of unwanted emissions as specified in CEPT/ERC/REC 74-01E [10]

Mode	Frequency bands	Limits (e.i.r.p.)	Reference bandwidth	Type of emission
<b>Operating</b> (see note 1)	47 MHz to 74 MHz 87,5 MHz to 118 MHz 174 MHz to 230 MHz 470 MHz to 862 MHz	-54 dBm	100 kHz	<b>Spurious and out-of-band emissions</b>
	Other frequencies > 30 MHz and $\leq 1$ GHz	-36 dBm	100 kHz	
	Frequencies > 1 GHz and < 26 GHz outside the exclusion band	-30 dBm	1 MHz	
<b>Stand-by</b> (see note 2)	Other frequencies > 30 MHz and $\leq 1$ GHz	-57 dBm	100 kHz	<b>Spurious emissions</b>
	Frequencies > 1 GHz and < 26 GHz outside the exclusion band	-47 dBm	1 MHz	
NOTE 1: Applicable only for operating transmitters, i.e. with modulation.				
NOTE 2: Applicable only for receivers. Stand-by mode is a mode, in which the device never transmits.				

### 7.1.11 Receiver Spurious emissions

The e.i.r.p. of any spurious emission shall not exceed the limits presented in table 6 for "stand-by" mode.

Measurements shall not be performed within an exclusion band of  $\pm 2,5$  times the DSRC channel spacing of 5 MHz, i.e.  $\pm 12,5$  MHz around the RSU carrier frequency  $f_{TX}$  under test.

## 7.2 OBU

### 7.2.1 Dynamic range

#### 7.2.1.1 Definition

The dynamic range of the OBU receiver is defined by the range of incident signal power referred to an isotropic loss-less antenna at the position of the OBU produced by a properly modulated carrier at the carrier frequency  $f_{Tx}$  which will, without interference, produce after demodulation a data signal with a BER of  $10^{-6}$  or smaller.

The lower limit of the dynamic range is referred to as "OBU sensitivity".

The upper limit of the dynamic range is referred to as "OBU upper power limit for communication".

#### 7.2.1.2 Sensitivity

The OBU sensitivity is the minimum incident power  $P_{sens}$  referred to a loss-less isotropic antenna at the location of the OBU receive antenna that allows the OBU to receive DSRC frames with a BER of  $10^{-6}$  or smaller. This applies for all orientations of the OBU receive antenna within a cone of opening angle  $\theta$  according to figure 1, denoted as worst case direction, around bore sight.

The OBU sensitivity  $P_{sens}$  and the worst case direction shall be declared by the provider. Additionally,  $P_{sens} \leq P_{D11b} = -43$  dBm shall apply.

If the supplier does not declare the worst case direction, then the sensitivity requirement shall apply for  $\theta = 35^\circ$ . In this case, measurements shall be performed at the directions indicated by M0, M1, M2, M3, and M4, see figure 1.

#### 7.2.1.3 Upper power limit for communication

**Table 7: OBU power limit for communication (upper) for Sets A and B**

Power limit for communication (upper) $P_{D11a}$ according to parameter D11a of prEN 12253 [2]	
Set A	Set B
-17 dBm	-24 dBm

The OBU shall provide a BER of  $10^{-6}$  or smaller at the upper power limit for communication  $P_{D11a}$ .

### 7.2.2 Cut-off power level

This parameter applies only to Set B OBUs.

The cut-off power level is the incident power level as received by a loss-less isotropic antenna below which an OBU shall not respond to a properly coded and modulated DSRC down-link signal.

NOTE: There are protocol related requirements that request an OBU not to respond. These requirements are outside the scope of the present document.

The cut-off power level is -60 dBm.

### 7.2.3 Conversion gain

The conversion gain  $G_c$  is defined by  $G_c = EIRP_{ObuTx} / P_{ObuRx}$ , where  $P_{ObuRx}$  is the incident received carrier power as referred to an isotropic loss-less antenna, and  $EIRP_{ObuTx}$  is the re-transmitted e.i.r.p. of the OBU in a single side-band.

The OBU conversion gain is referred to as parameter U12 in prEN 12253 [2].

NOTE: OBU conversion gain includes receive antenna gain, transmit antenna gain and OBU losses.

The OBU conversion gain  $G_c$  shall be at least 1 dB within a cone of  $\theta = 35^\circ$  relative to bore sight as depicted in figure 1.

For Set B OBUs the OBU conversion gain  $G_c$  shall not exceed 10 dB.

## 7.2.4 Maximum equivalent isotropically radiated power

The OBU maximum SSB equivalent isotropically radiated power  $EIRP_{MaxObuTx}$  is the e.i.r.p. of the OBU in a single side band measured within the valid range of incident signal power  $P_{D11a}$  according table 7 and  $P_{D11b} = -43$  dBm, according to parameter D11b of prEN 12253 [2]. The maximum e.i.r.p. shall not exceed the limits stated in table 8.

**Table 8: Limits for OBU maximum SSB e.i.r.p.**

CEN Parameter	Limits for OBU maximum SSB e.i.r.p.			
	Set A		Set B	
Direction	U4b (35°) (see note)	U4a bore sight	U4b (35°) (see note)	U4a bore sight
Value	n.a.	-21 dBm	-17 dBm	-14 dBm
NOTE: 35° denotes the opening angle $\theta$ of a cone symmetrically around bore sight, see figure 1.				

## 7.2.5 Frequency error

The sub-carrier frequency error  $\Delta f_s$  of the OBU is the ratio:

$$\Delta f_s = \frac{|f_{ObuTx} - f_{Tx,actual}|}{f_s} - 1,$$

where  $f_{ObuTx}$  is, respectively, the actual centre frequency of the lower and upper side band of the OBU up-link channel,  $f_{Tx,actual}$  is the actual centre frequency of the down-link carrier, and  $f_s$  is the nominal sub-carrier frequency.

The sub-carrier frequency error is referred to as parameter U1a in prEN 12253 [2].

The absolute value  $|\Delta f_s|$  of the OBU sub-carrier frequency tolerance  $\Delta f_s$  shall not exceed 0,1 %.

## 7.2.6 Transmitter spectrum mask

The OBU TSM is the maximum e.i.r.p. allowed to be transmitted by the OBU within specified frequency bands. The frequency bands are defined by their centre frequencies and bandwidths according to table 9 considering carrier frequencies  $f_{Tx}$  in accordance with clause 6.6.

The OBU TSM is referred to as parameter U2 in prEN 12253 [2].

**Table 9: OBU TSM limits**

<b>Centre frequency</b>	$f_{Tx} \pm 1$ MHz and $f_{Tx} \pm 4$ MHz	$f_{Tx} \pm 1,5$ MHz, $f_{Tx} \pm 2$ MHz, $f_{Tx} \pm 3$ MHz, $f_{Tx} \pm 3,5$ MHz, $f_{Tx} \pm 6,5$ MHz, and $f_{Tx} \pm 7$ MHz (see note)
<b>Bandwidth</b>	62,5 kHz	500 kHz
<b>Limit</b>	Set A: -39 dBm Set B: -35 dBm	
NOTE: Measurement shall not be performed at the used sub-carrier frequency, i.e. 1,5 MHz or 2 MHz.		

The maximum e.i.r.p. shall not exceed the limit as stated in table 9.



## 7.2.7 Transmitter unwanted emissions

The e.i.r.p. of any unwanted emissions, i.e. spurious or out-of-band emission, shall not exceed the limits presented in table 6 for "operating" mode.

Measurements shall not be performed within an exclusion band of  $\pm 2,5$  times the DSRC channel spacing of 5 MHz, i.e.  $\pm 12,5$  MHz around the RSU carrier frequency  $f_{TX}$  under test.

## 7.2.8 Receiver spurious emissions

The e.i.r.p. of any spurious emission shall not exceed the limits presented in table 6 for "stand-by" mode.

Measurements shall not be performed within an exclusion band of  $\pm 2,5$  times the DSRC channel spacing of 5 MHz, i.e.  $\pm 12,5$  MHz around the RSU carrier frequency  $f_{TX}$  under test.

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# 8 Basics on testing

## 8.1 General conditions

### 8.1.1 Environment

Tests defined in the present document shall be carried out at representative points within the boundary limits of the declared operational environmental profile.

Where technical performance varies subject to environmental conditions, tests shall be carried out under conditions as declared by the provider and being within the boundary limits of the declared operational environmental profile in order to give confidence of compliance for the affected technical requirements. If the provider does not declare conditions, then the normal conditions as defined in clause 4.2.3.1 shall apply.

A possible provider declaration can be based on the extreme categories I, II, III as defined in clause 4.2.3.2.

### 8.1.2 Power source

For testing the equipment shall be powered by a test power source, capable of producing test voltages as declared by the provider.

For battery operated equipment the battery shall be removed and an external test power source shall be suitably decoupled. For radiated measurements any external power leads shall be arranged so as not to affect the measurements. If necessary, the external test power source may be replaced with the supplied or recommended internal batteries at the required voltage, or a battery simulator. This shall be stated on the test report. For radiated measurements on portable equipment, fully charged internal batteries shall be used. The batteries used shall be as supplied or recommended by the applicant.

During tests the external test power source voltages shall be within a tolerance of  $\pm 1$  % relative to the voltage at the beginning of each test. The value of this tolerance can be critical for certain measurements. Using a smaller tolerance provides a better uncertainty value for these measurements. If internal batteries are used, at the end of each test the voltage shall be within a tolerance of  $\pm 5$  % relative to the voltage at the beginning of each test.

The internal impedance of the external test power source shall be low enough for its effect on the test results to be negligible. For the purpose of the tests, the voltage of the external test power source shall be measured at the input terminals of the equipment.

### 8.1.3 Thermal balance

Before measurements are made the equipment shall have reached thermal balance in the test chamber.

The equipment shall be switched off during the temperature stabilizing period.

In the case of equipment containing temperature stabilization circuits designed to operate continuously, the temperature stabilization circuits shall be switched on for a time period as declared by the provider such that thermal balance has been obtained, and the equipment shall then meet the specified requirements.

If the thermal balance is not checked by measurements, a temperature stabilizing period of at least one hour, or such period as may be decided by the test laboratory, shall be allowed. The sequence of measurements shall be chosen and the relative humidity content in the test chamber shall be controlled so that condensation does not occur.

## 8.2 Test signals

The following test signals and test messages are defined:

**Table 10: Test signals and messages**

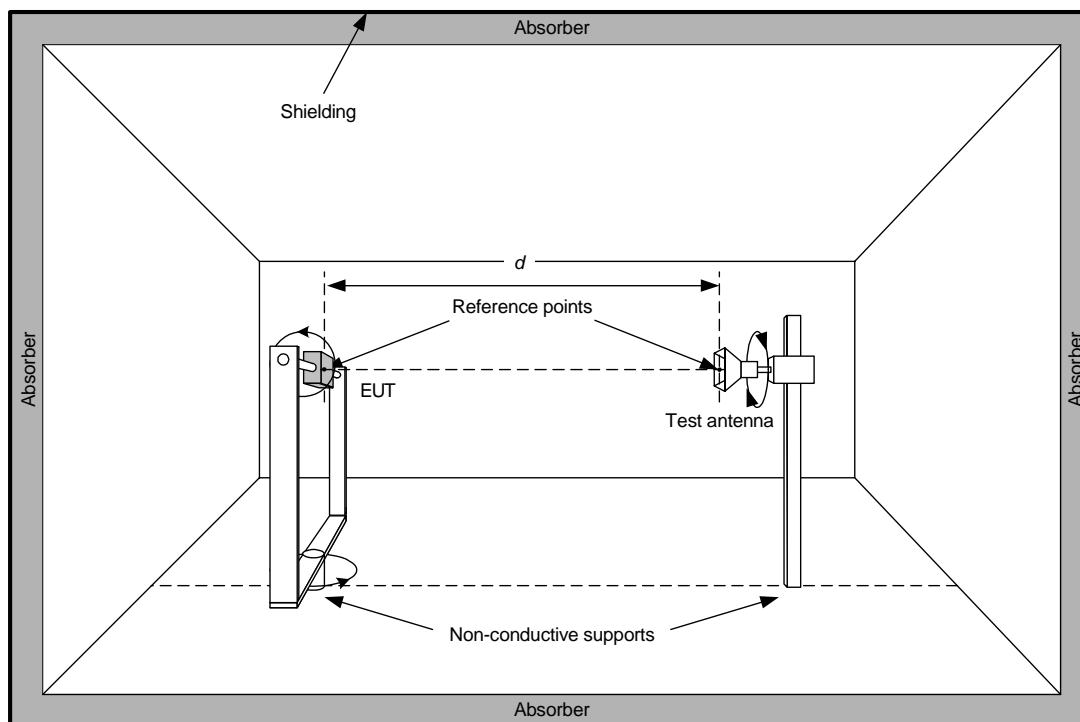
Test signal/message	Description
Test Messages (TM1)	Set of DSRC messages supporting initialization and ECHO command compliant to BS EN 12795 [7], BS EN 12834 [8], and ISO/TR 14906 [9].
Test Signal (TS1)	Properly modulated and coded DSRC signal where the data is a continuously repeated maximum length pseudo-random sequence generated by a linear feedback shift register. The period of the pseudo-random sequence shall be 511 bits.
Test Signal (TS2)	Continuous DSRC up-link signal with unmodulated sub-carrier. The sub-carrier frequency shall be settable to $f_s = 1,5$ MHz and $f_s = 2,0$ MHz, respectively.

Data coding and bit rates in down-link and up-link shall be according to parameters D7, U7 and D8, D8a, U8, U8a of prEN 12253 [2], respectively.

## 8.3 Test sites

### 8.3.1 Shielded anechoic chamber

A typical anechoic chamber is shown in figure 3. This type of test chamber attempts to simulate free space conditions.

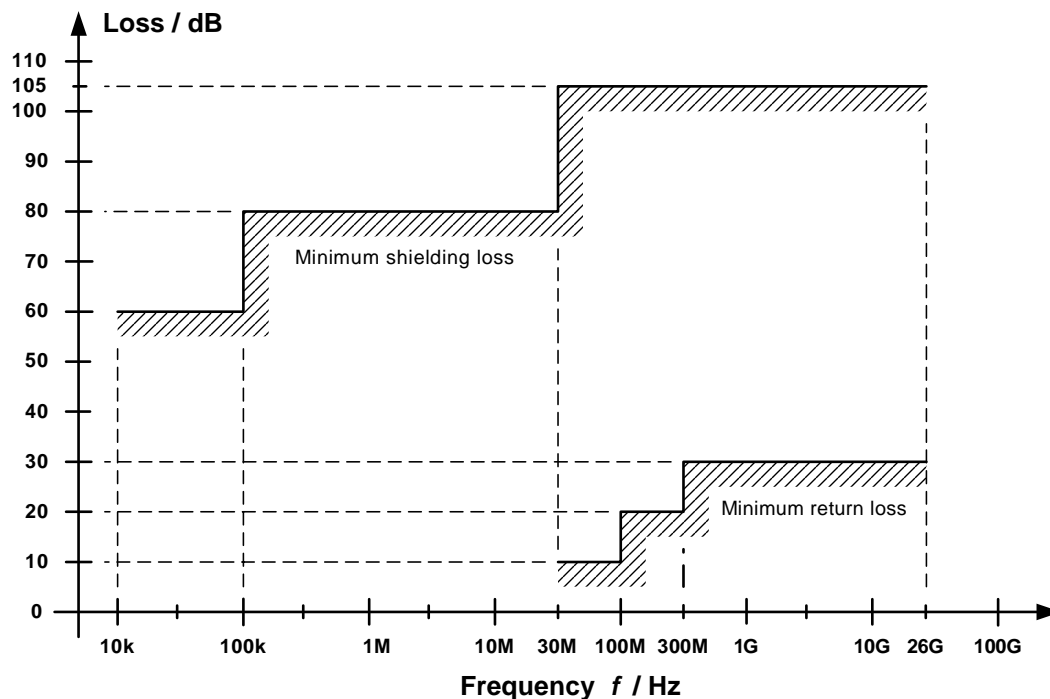


**Figure 3: Typical anechoic chamber**

The chamber contains suitable antenna supports on both ends.

The supports carrying the test antenna and EUT shall be made of a non-permeable material featuring a low value of its relative permittivity.

The anechoic chamber shall be shielded. Internal walls, floor and ceiling shall be covered with radio absorbing material. The shielding and return loss for perpendicular wave incidence versus frequency as detailed in figure 4 shall be met by anechoic chambers used to perform tests.



**Figure 4: Minimal shielding and return loss for shielded anechoic chambers**

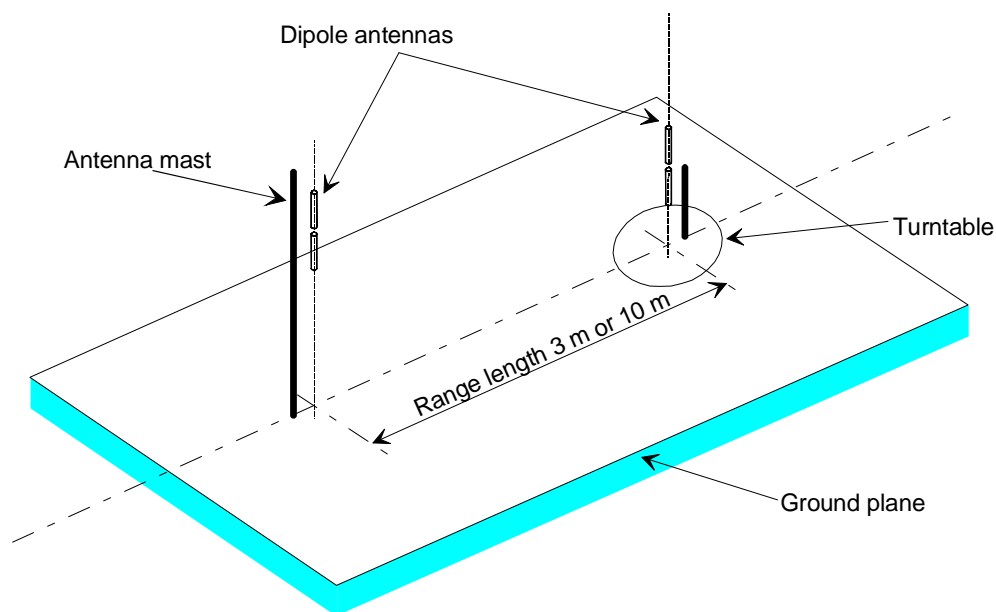
Both absolute and relative measurements can be performed in an anechoic chamber. Where absolute measurements are to be carried out the chamber shall be verified.

The shielded anechoic chamber test site shall be calibrated and validated for the frequency range being applicable.

NOTE: Information on uncertainty contributions, and verification procedures are detailed in clauses 5 and 6, respectively, of TR 102 273-2 [11].

### 8.3.2 Open area test site

A typical open area test site is shown in figure 5.



**Figure 5: Typical open area test site**

The ground plane shall provide adequate size, such as to approximate infinite size. Relevant parts of the ground plane shall be covered by absorbing material.

Test shall be limited to the frequency range between 30 MHz and 1 000 MHz.

Measurements performed in open area test sites follow the same procedures as detailed for radiated measurements performed in shielded anechoic chambers.

The open area test site shall be calibrated and validated for the frequency range being applicable.

NOTE: Information on uncertainty contributions, and verification procedures are detailed in clauses 5 and 6, respectively, of TR 102 273-4 [12].

### 8.3.3 Test fixture

A test fixture is a device that allows for conducted measurements of an EUT that does not provide antenna connectors itself. The EUT can be either an OBU or a RSU. A test fixture consists of at least one RF connector featuring a characteristic impedance of  $50 \Omega$ , subsequently called  $50 \Omega$  RF connector, and a device for electromagnetic coupling to the EUT. It incorporates a means for repeatable positioning of the EUT. The following figure 6 illustrates a typical test fixture.

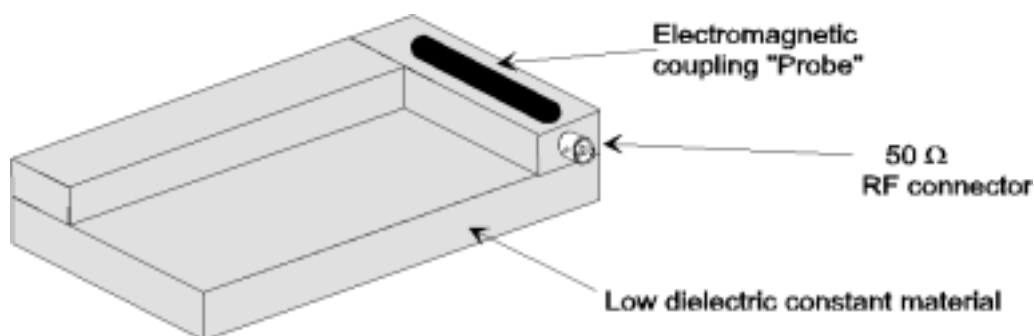


Figure 6: Typical test fixture

The coupling device usually comprises a small antenna that is placed, physically and electrically, close to the EUT. This coupling device is used for sampling or generating the test fields when the EUT is undergoing testing. Figure 7 illustrates an EUT mounted on a test fixture.

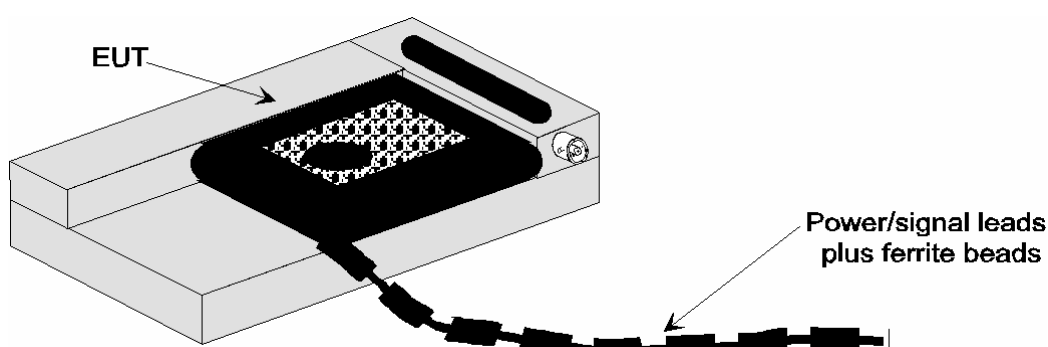


Figure 7: EUT mounted in a typical test fixture

The entire assembly of test fixture plus EUT is generally compact and it can be regarded as a EUT with antenna connector. Its compactness enables the whole assembly to be accommodated within a test chamber, usually a climatic facility. The circuitry associated with the RF coupling device should contain no active or non-linear components and should present a VSWR of better than 1,5 to a  $50 \Omega$  line.

Absolute measurements shall not be made in a test fixture as the antenna of the EUT and the one of the test fixture might be mutually in the near-field range of each other. Hence, only relative measurements shall be performed that have to be related to results taken on a verified free field test site.

The way to relate the results is by a process, referred to as field equalization, in which the relevant parameter, e.g. effective radiated power, receiver sensitivity, etc. is initially measured on a free field test site under normal environmental conditions and then subsequently re-measured using the test fixture under the very same environmental conditions. The difference, e.g. in dB, of the two results is termed the coupling factor of the test fixture and provides the link between all the results of EUT tests carried out in the test fixture and its performance on a verified free field test site. As a general rule, the coupling factor should not be greater than 20 dB.

Emission tests are generally limited to the nominal frequencies, for which the performance of the test fixture has been verified.

Only after it has been verified that the test fixture does not affect performance of the EUT, the EUT can be confidently tested.

The test fixtures shall be calibrated and validated for the frequency range they are used for.

NOTE: Information on uncertainty contributions, and verification procedures are detailed in clauses 5 and 6, respectively, of TR 102 273-6 [13].

## 8.4 General requirements for RF cables

All RF cables including their connectors at both ends used within the measurement arrangements and set ups shall be of coaxial type featuring within the frequency range they are used

- a nominal characteristic impedance of 50  $\Omega$ ;
- a VSWR of less than 1,2 at either of their ends, preferably better;
- a shielding loss in excess of 60 dB, preferably better.

All RF cables exposed to radiation shall be loaded with ferrite beads spaced with a gap of  $D_{fb}$  between each other along the entire length of the cable. Such cables are referred to as FCCA. The gap  $D_{fb}$  shall be smaller than half of the signal's wavelength under test.

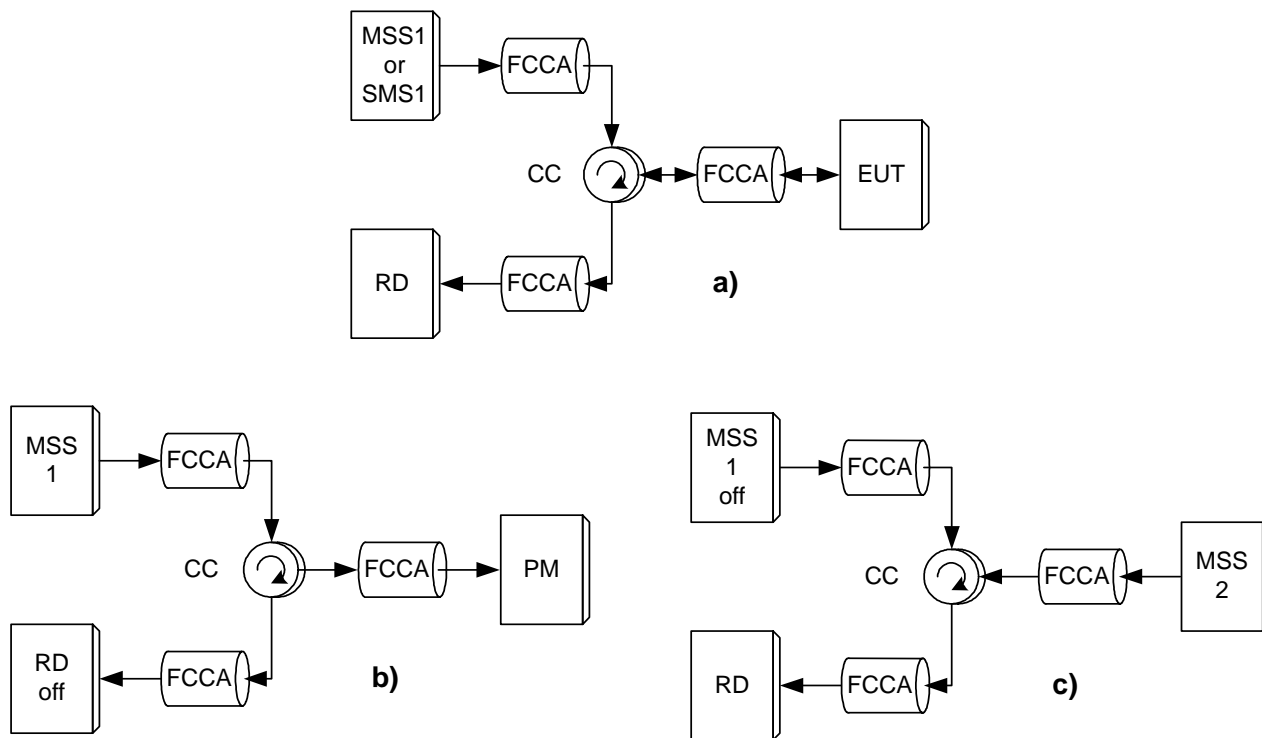
All RF cables shall be routed suitably in order to reduce impacts on antenna radiation pattern, antenna gain, antenna impedance.

NOTE: Further details are provided in TR 102 273-2 [11].

## 8.5 Conducted measurements

### 8.5.1 One antenna connector arrangement

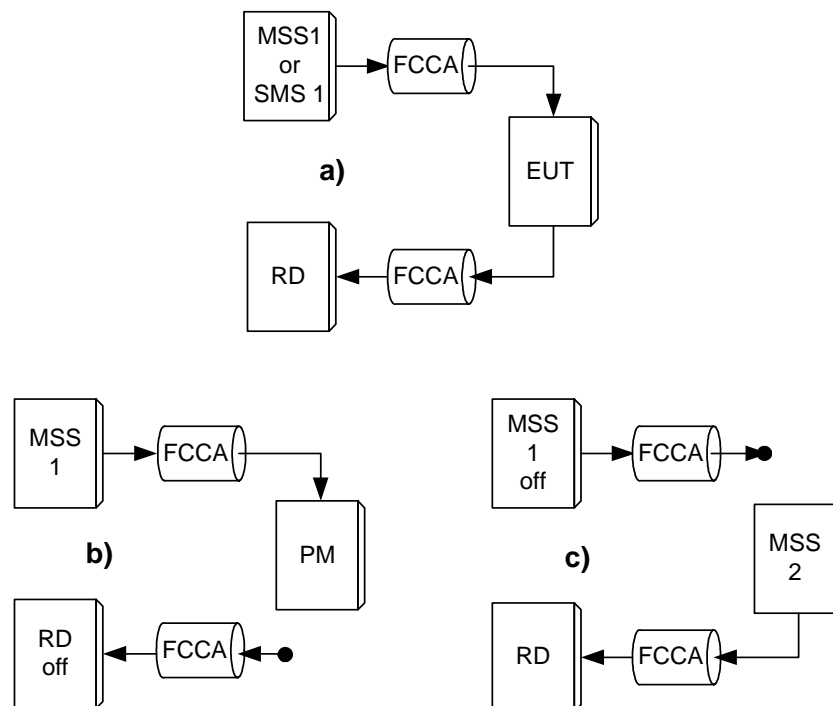
Figure 8 shows the measurement arrangements that shall be used in case of a single antenna connector at the EUT.



**Figure 8: Measurement arrangement with one antenna connector:**  
**a) for measurement of EUT parameters**  
**b) for adjusting input power to EUT**  
**c) for substitution measurements**

## 8.5.2 Two antenna connectors arrangement

Figure 9 shows the measurement arrangements that shall be used in case of a two antenna connectors at the EUT.



**Figure 9: Measurement arrangement with two antenna connectors:**  
**a) for measurement of EUT parameters**  
**b) for adjusting input power to EUT**  
**c) for substitution measurements**

## 8.5.3 Test site requirements

Conducted measurements shall be performed at the antenna connector(s) of the EUT.

## 8.5.4 Site preparation

### 8.5.4.1 Monochromatic signals

If the measurement arrangement with one antenna connector is used, the measurement set up depicted in figure 8 applies and the site preparation is as follows:

- 1) The calibrated MSS1 shall be connected to the antenna connector of the EUT via the calibrated CC providing three terminals.
- 2) The RD shall be connected to the antenna connector of the EUT via the remaining third terminal of the calibrated CC.

If the measurement arrangement with two antenna connectors is used, the measurement set up depicted in figure 9 applies and the site preparation is as follows:

- 1) The calibrated MSS1 shall be connected to the receive antenna connector of the EUT.
- 2) The RD shall be connected to the transmit antenna connector of the EUT.



### 8.5.4.2 Modulated signals

If the measurement arrangement with one antenna connector is used, the measurement set up depicted in figure 8 applies and the site preparation is as follows:

- 1) The calibrated SMS1 shall be connected to the antenna connector of the EUT via the calibrated CC providing three terminals.
- 2) The RD, i.e. either an RSU receiver or a measurement receiver, shall be connected to the antenna connector of the EUT via the remaining third terminal of the calibrated CC.

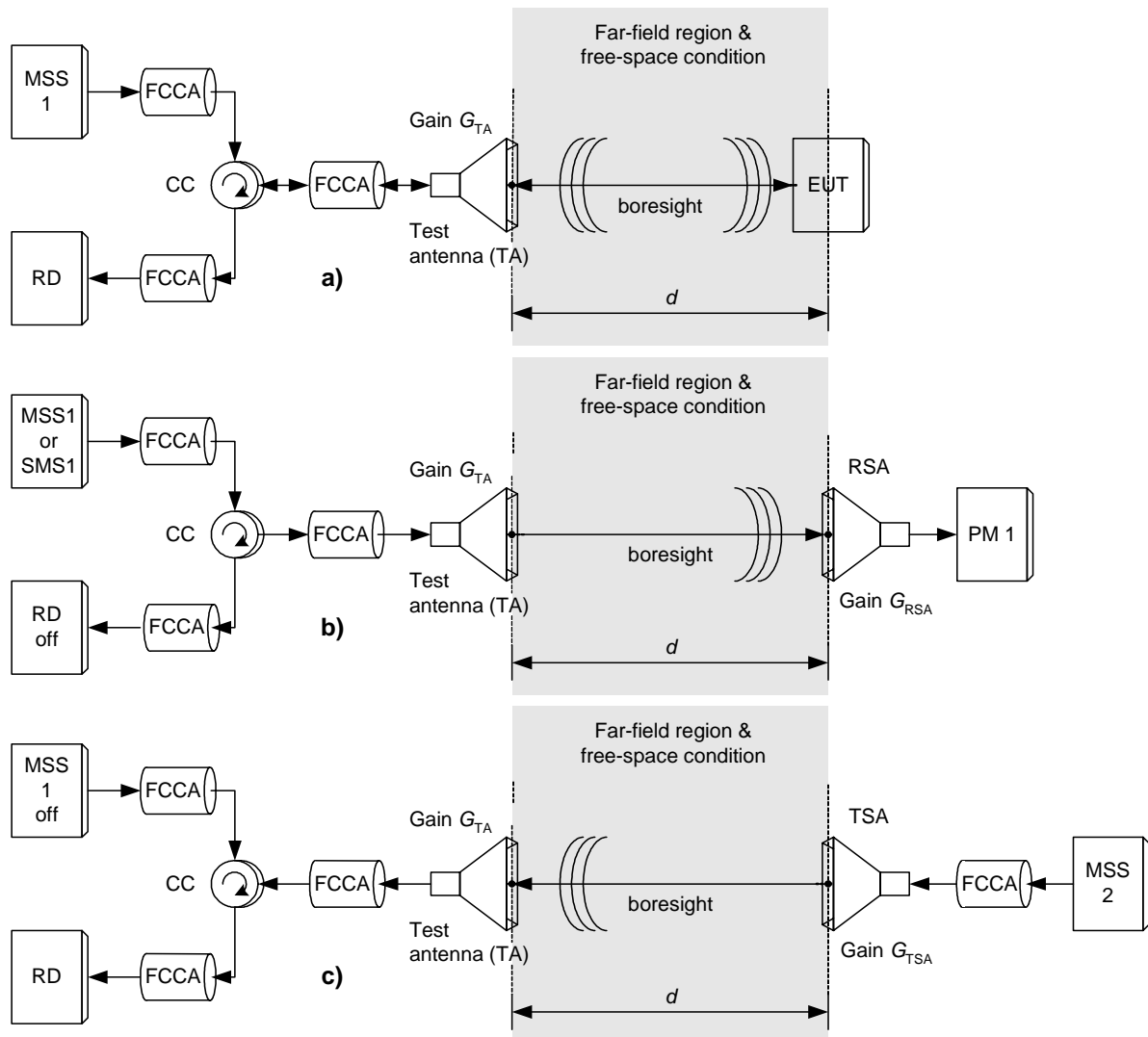
If the measurement arrangement with two antenna connectors is used, the measurement set up depicted in figure 9 applies and the site preparation is as follows:

- 1) The calibrated SMS1 shall be connected to the receive antenna connector of the EUT.
- 2) The RD, i.e. either an RSU receiver or a measurement receiver, shall be connected to the transmit antenna connector of the EUT.

## 8.6 Radiated measurements

### 8.6.1 One antenna arrangement

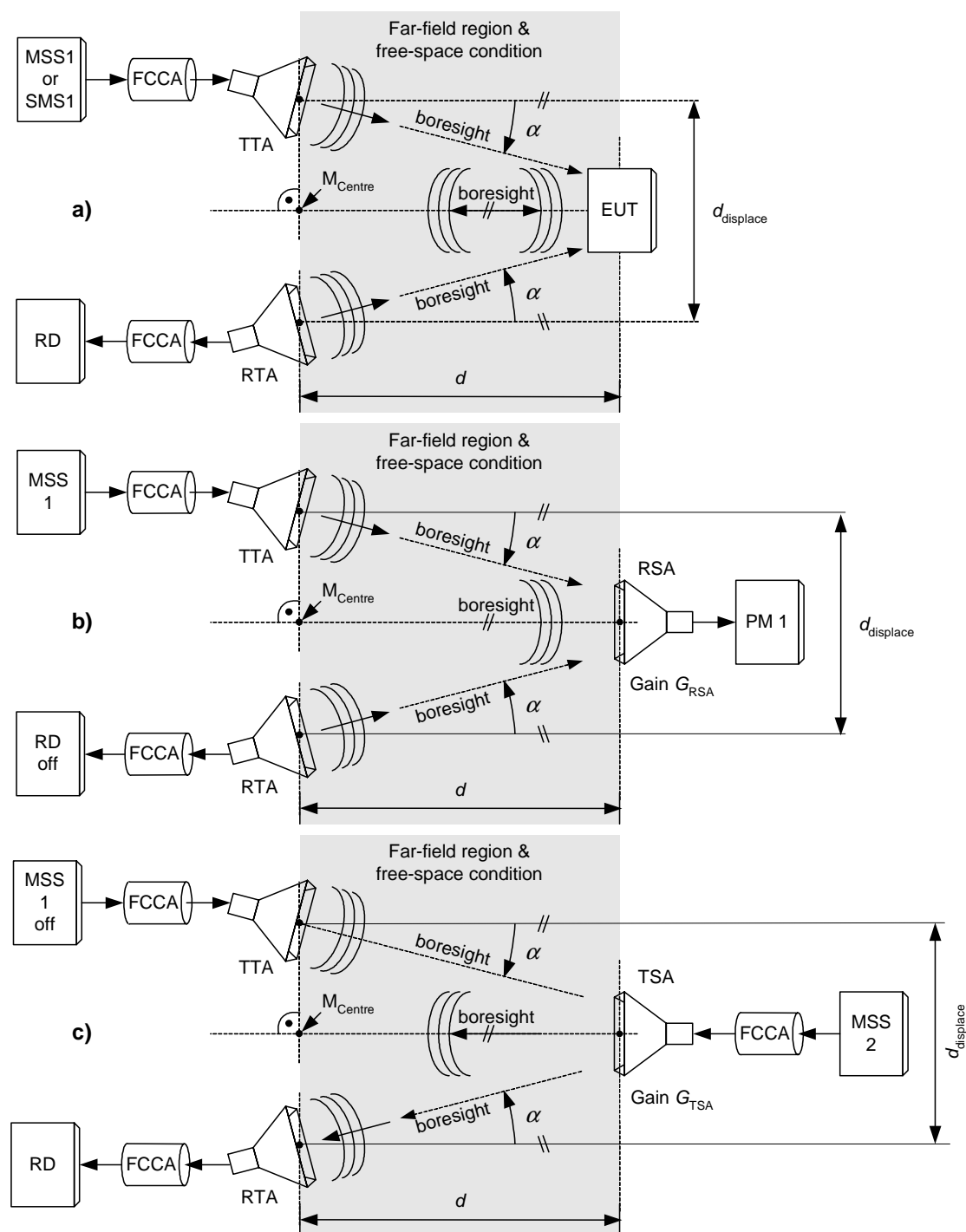
Figure 10 shows the measurement arrangements that shall be used in case one test antenna TA for transmitting and receiving signals are selected for testing the EUT.



**Figure 10: Measurement arrangement with one test antennas:**  
**a) for measurements of EUT parameters**  
**b) for adjustment of the incident power to the EUT**  
**c) for measurement steps using the substitution antenna**

## 8.6.2 Two antennas arrangement

Figure 11 shows the measurement arrangements that shall be used in case two test antennas, i.e. TTA and RTA, are selected for testing the EUT.



**Figure 11: Measurement arrangement with two test antennas:**  
**a) for measurements of EUT parameters**  
**b) for adjustment of the incident power to the EUT**  
**c) for measurement steps using the substitution antenna**

## 8.6.3 Test site requirements

### 8.6.3.1 Measurement distances

Within an open area test site or a shielded anechoic chamber the measurement distance or range length  $d$  depicted in figures 10 and 11 shall be such, that the antennas on both sides of the radio link are mutually in the far field of each other, i.e.  $d$  shall be according to the most stringent of the following three equations:

$$d > \frac{2 \times (D_{0,TA} + D_{0,EUT})^2}{\lambda}, \quad d > 5 \times (D_{0,TA} + D_{0,EUT}) \quad \text{and} \quad d > 2 \times \lambda,$$

where  $D_{0,TA}$ ,  $D_{0,EUT}$  and  $\lambda$  denote the largest dimension of the test antenna, the EUT antenna, and the wavelength, respectively.

This distance  $d$  shall be measured between:

- the centre of aperture of the test antenna TA, in case of a horn antenna, or the feeding point in case the TA is of an other type; and
- the feeding point of the EUT antenna if the location of the EUT antenna is known, or the volume centre of the EUT if the location of its antennas is unknown.

### 8.6.3.2 Free-space wave propagation

Within an open area test site or a shielded anechoic chamber a radio path between a transmitting and receiving antenna requires a certain amount of clearance around the central or direct ray if the signal expected from free-space propagation is to be received.

The clearance is usually quoted in terms of Fresnel zones. As depicted in figure 12 the first Fresnel zone encloses all radio paths from the transmitting to the receiving antenna for which the detour path length  $d_{F1} + d_{F2}$  relative to the length  $d$  of the direct radio path does not exceed half of the wavelength  $\lambda$ , i.e. a phase change of  $180^\circ$ , of the radiated signal in air.

$$d_{F1} + d_{F2} - d \leq \lambda/2.$$

Disregarding the non-conductive, dielectric supports of the EUT and the test antenna(s) the clearance around the LOS path between the transmitting and receiving antenna shall be such that at least the first Fresnel zone is free of any obstacles.

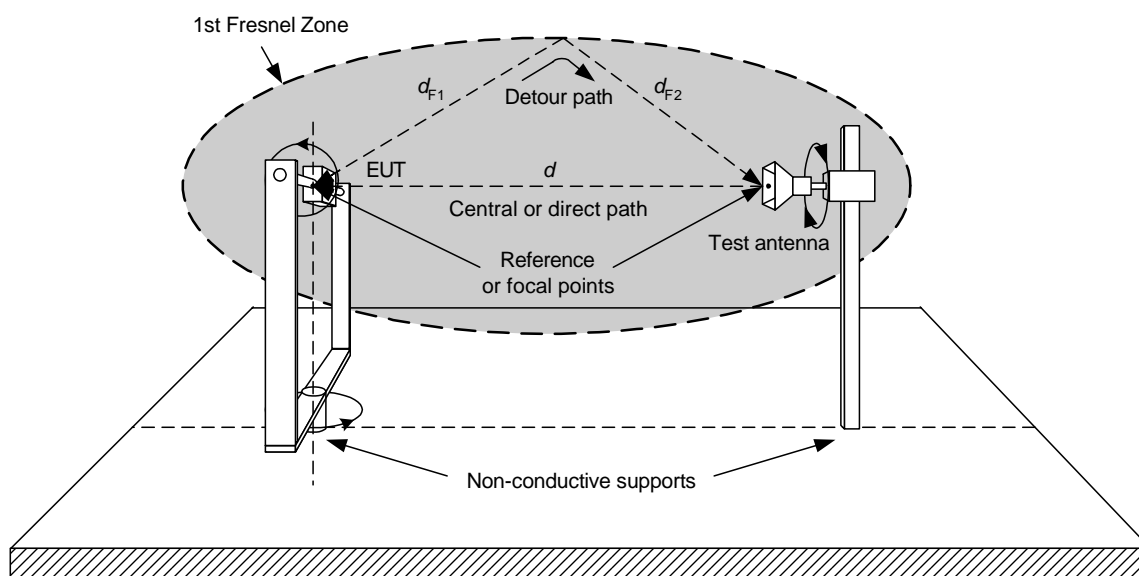


Figure 12: First Fresnel zone with direct and detour radio path

## 8.6.4 Test and substitution antennas

Test antennas are used to detect the radiation from the EUT or to transmit a signal towards the EUT while substitution antennas together with signal generators are used to replace the EUT and its antenna in substitution measurements.

The test or substitution antenna shall be either LHCP, LP, or XP, whichever is required in the test procedure of the respective EUT parameter. Cross-polarized test or substitution antennas require a XPD > 25 dB within their specified frequency range.

Preferably test or substitution antennas with pronounced directivities shall be used. However, their directivities  $D_1$  relative to an isotropic radiator shall be such that the antennas on both sides of the radio link are mutually in the far field region of each other.

If the symmetry of the test or substitution antenna does not match the one of its feeding cable, a symmetry matching circuit (balun) shall be inserted between the antenna output and the input of its feeding RF cable.

The return loss at the terminal of the test or substitution antenna shall exceed 15 dB within its specified frequency range.

When measuring signals in the frequency range up to 1 GHz the test or substitution antenna shall be either:

- a half wavelength dipole, resonant at the operating frequency, or
- a shortened dipole, calibrated to the half wavelength dipole, or
- a biconical antenna.

For measurements between 1 GHz and 4 GHz either:

- a half wavelength dipole, or
- a biconical antenna, or
- a horn radiator may be used.

When measuring signals in the frequency range above 4 GHz a horn antenna shall be used.

The type of test or substitution antenna actually used in the tests shall be stated in the test report.

## 8.6.5 Site preparation for OBU measurements

### 8.6.5.1 Monochromatic signals

If the measurement arrangement with one test antenna is used, the measurement set up depicted in figure 10 applies and the site preparation is as follows:

- 1) The LHCP calibrated Test Antenna (TA, TTA: transmit path, RTA: receive path) shall be suited for the range of carrier frequencies  $f_{Tx}$  in accordance with clause 6.6. It shall be mounted in a shielded anechoic chamber on a vertical pole. The distance between any part of this TA and the ceiling, floor or walls shall be at least 0,5 m. The height of the phase centres above floor of the TA and the CA shall be equal. The CA is either the OBU antenna (EUT) or the RSA. The bore sight of the TTA shall point towards the phase centre of the CA.
- 2) The TA shall be connected via a CC featuring three terminals to a calibrated MSS1 using calibrated FCCAs. The remaining third terminal of the circulator shall be connected via a calibrated FCCA to the input of a calibrated RD, i.e. spectrum analyser or measuring receiver, calibrated at the frequencies of the monochromatic signals under consideration. Appropriate precautions shall be taken to prevent overloading the input of the RD.

- 3) The LHCP calibrated RSA of gain  $G_{\text{RSA}}$  shall be suited for the range of carrier frequencies  $f_{\text{Tx}}$  in accordance with clause 6.6. It shall be mounted on a vertical pole within the "quiet zone" at the other end of the shielded anechoic chamber. This pole shall be mounted on a turntable allowing rotating the RSA's phase centre around a vertical axis. The distance between any part of the RSA and the ceiling, floor or walls shall be at least 0,5 m. Further, the distance  $d$  between the TTA and the RSA shall be such that the two antennas are mutually in the far field of each other, see clause 8.6.3.1. The bore sight of the RSA shall point towards the phase centre of the TA. The output of the RSA shall be connected directly to the power sensor of power meter PM1 that shall be calibrated to the frequency of the monochromatic signal under consideration.

If the measurement arrangement with two test antennas is used, the measurement set up depicted in figure 11 applies and the site preparation is as follows:

- 1) The LHCP calibrated TTA and the LHCP calibrated RTA shall each be suited for the range of carrier frequencies  $f_{\text{Tx}}$  in accordance with clause 6.6. They shall be mounted in a shielded anechoic chamber on a vertical pole. These two antennas shall be displaced either horizontally or vertically such as to minimize the coupling between them. Vertically polarized TTA and RTA shall be displaced vertically whilst horizontally polarized TTA and RTA shall be displaced horizontally. Additionally, the phase centre of the TTA shall be displaced from the phase centre of the RTA by a distance  $d_{\text{displace}}$  such that the coupling loss between the two antennas becomes larger than 30 dB and the overall uncertainty of the measurement set-up shall comply with the requirements stated in table 13. The actual coupling loss and the distance  $d_{\text{displace}}$  between the TTA and RTA shall be stated in the test report together with a unique identification of the TTA and RTA used. The position between both phase centres is denoted  $M_{\text{centre}}$ . The distance between any part of the TTA and RTA with respect to the ceiling, floor or walls shall be at least 0,5 m. The height of  $M_{\text{centre}}$  and the phase centre of the CA above floor shall be equal. The CA is either the OBU antenna or the RSA. The bore sight of the TTA and RTA shall point towards the phase centre of the CA.
- 2) The TTA shall be connected to a calibrated MSS1 using calibrated FCCAs.
- 3) The RTA shall be connected to the input of a calibrated RD, i.e. spectrum analyser or measuring receiver, using calibrated FCCA. The RD shall be calibrated at the frequencies of the monochromatic signals under consideration. Appropriate precautions shall be taken to prevent overloading the input of the RD.
- 4) The LHCP RSA of gain  $G_{\text{RSA}}$  shall be suited for the range of carrier frequencies  $f_{\text{Tx}}$  in accordance with clause 6.6. It shall be mounted on a vertical pole within the "quiet zone" at the other end of the shielded anechoic chamber. This pole shall be mounted on a turntable allowing to rotate the RSA's phase centre around a vertical axis. The RSA shall be positioned close to the middle between the ceiling and the floor. Its bore sight shall point to the centre between the phase centres of the TTA and RTA. The distance between any part of the RSA and the ceiling, floor or walls shall be at least 0,5 m. Further, the distance  $d$  between the TTA and the RSA as well as between the RTA and the RSA shall be such that the two antennas on both sides of the radio link are mutually in the far field region of each other, see clause 8.5.3.1. Additionally, the distance  $d$  between CA and the position  $M_{\text{centre}}$  shall be such that the displacement angle  $\alpha_{\text{displace}}$  between TTA and RTA as observed from the CA complies with:

$$\alpha_{\text{displace}} = 2 \cdot \arctan\left(\frac{d_{\text{displace}}}{2 \times d}\right),$$

$$\alpha_{\text{displace}} \leq 2^{\circ} \text{ for horizontally displaced antennas,}$$

$$\alpha_{\text{displace}} \leq 6^{\circ} \text{ for vertically displaced antennas.}$$

The output of the RSA shall be connected directly to the power sensor of power meter PM1 that shall be calibrated at the frequencies of the monochromatic signals under consideration.

### 8.6.5.2 Modulated signals

If the measurement arrangement with one test antenna is used, the measurement set up depicted in figure 10 applies and the site preparation is as follows:

- 1) The LHCP calibrated test antenna (TA, TTA: transmit path, RTA: receive path) shall be suited for the range of carrier frequencies  $f_{Tx}$  in accordance with clause 6.6. It shall be mounted in a shielded anechoic chamber on a vertical pole. The distance between any part of this TA and the ceiling, floor or walls shall be at least 0,5 m. The height of the phase centres above floor of the TA and the CA shall be equal. The CA is either the OBU antenna (EUT) or the RSA. The bore sight of the TTA shall point towards the phase centre of the CA.
- 2) The TA shall be connected via a CC featuring three terminals to a calibrated SMS1 using calibrated FCCAs. The remaining third terminal of the circulator shall be connected via a calibrated FCCA to the input of a calibrated RD, i.e. RSU receiver or measuring receiver, calibrated at the frequencies of the modulated signals or messages under consideration. Appropriate precautions shall be taken to prevent overloading the input of the RD.
- 3) The LHCP calibrated RSA of gain  $G_{RSA}$  shall be suited for the range of carrier frequencies  $f_{Tx}$  in accordance with clause 6.6. It shall be mounted on a vertical pole within the "quiet zone" at the other end of the shielded anechoic chamber. This pole shall be mounted on a turntable allowing to rotate the RSA's phase centre around a vertical axis. The distance between any part of the RSA and the ceiling, floor or walls shall be at least 0,5 m. Further, the distance  $d$  between the TTA and the RSA shall be such that the two antennas are mutually in the far field of each other, see clause 8.6.3.1. The bore sight of the RSA shall point towards the phase centre of the TA. The output of the RSA shall be connected directly to the power sensor of power meter PM1 that shall be calibrated at the frequencies of the monochromatic signals under consideration.

If the measurement arrangement with two test antennas is used, the measurement set up depicted in figure 11 applies and the site preparation is as follows:

- 1) The LHCP calibrated TTA and the LHCP calibrated RTA shall each be suited for the range of carrier frequencies  $f_{Tx}$  in accordance with clause 6.6. They shall be mounted in a shielded anechoic chamber on a vertical pole. These two antennas shall be displaced either horizontally or vertically such as to minimize the coupling between them. Vertically polarized TTA and RTA shall be displaced vertically whilst horizontally polarized TTA and RTA shall be displaced horizontally. Additionally, the phase centre of the TTA shall be displaced from the phase centre of the RTA by a distance  $d_{displace}$  such that the coupling loss between the two antennas becomes larger than 30 dB and the overall uncertainty of the measurement set-up shall comply with the requirements stated in table 13. The actual coupling loss and the distance  $d_{displace}$  between the TTA and RTA shall be stated in the test report together with a unique identification of the TTA and RTA used. The position between both phase centres is denoted  $M_{centre}$ . The distance between any part of the TTA and RTA with respect to the ceiling, floor or walls shall be at least 0,5 m. The height of  $M_{centre}$  and the phase centre of the CA above floor shall be equal. The CA is either the OBU antenna or the RSA. The bore sight of the TTA and RTA shall point towards the phase centre of the CA.
- 2) The TTA shall be connected to a calibrated SMS1 using calibrated FCCAs.
- 3) The RTA shall be connected to the input of a calibrated RD, i.e. RSU receiver or measuring receiver, using calibrated FCCA. The RD shall be calibrated to the frequency of the modulated signal or message under consideration. Appropriate precautions shall be taken to prevent overloading the input of the RD.

- 4) The LHCP RSA of gain  $G_{\text{RSA}}$  shall be suited for the range of carrier frequencies  $f_{\text{Tx}}$  in accordance with clause 6.6. It shall be mounted on a vertical pole within the "quiet zone" at the other end of the shielded anechoic chamber. This pole shall be mounted on a turntable allowing to rotate the RSA's phase centre around a vertical axis. The RSA shall be positioned close to the middle between the ceiling and the floor. Its bore sight shall point to the centre between the phase centres of the TTA and RTA. The distance between any part of the RSA and the ceiling, floor or walls shall be at least 0,5 m. Further, the distance  $d$  between the TTA and the RSA as well as between the RTA and the RSA shall be such that the two antennas on both sides of the radio link are mutually in the far field region of each other, see clause 8.5.3.1. Additionally, the distance  $d$  between CA and the position  $M_{\text{centre}}$  shall be such that the displacement angle  $\alpha_{\text{displace}}$  between TTA and RTA as observed from the CA complies with:

$$\alpha_{\text{displace}} = 2 \cdot \arctan\left(\frac{d_{\text{displace}}}{2 \times d}\right),$$

$$\alpha_{\text{displace}} \leq 2^\circ \text{ for horizontally displaced antennas,}$$

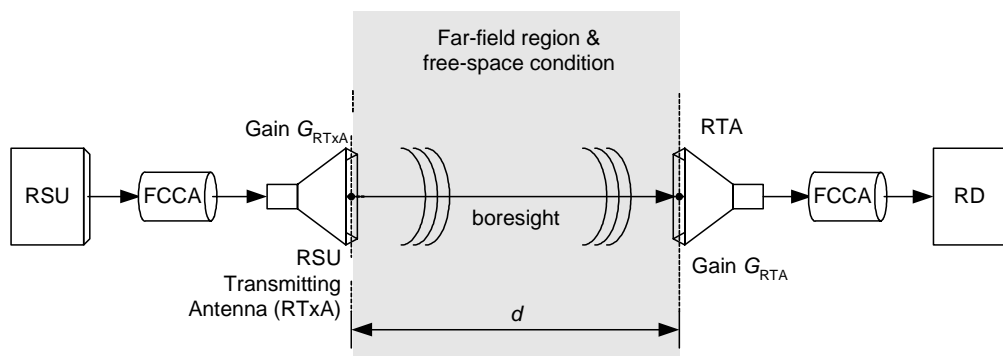
$$\alpha_{\text{displace}} \leq 6^\circ \text{ for vertically displaced antennas.}$$

The output of the RSA shall be connected directly to the power sensor of power meter PM1 that shall be calibrated at the frequencies of the monochromatic signals under consideration.

## 8.6.6 Site preparation for RSU measurements

### 8.6.6.1 Arrangement for transmit parameters

Figure 13 details the arrangement used for measurement of the transmitter parameters maximum e.i.r.p., frequency error, TSM, spurious and out-of-band emissions and receiver spurious emissions.



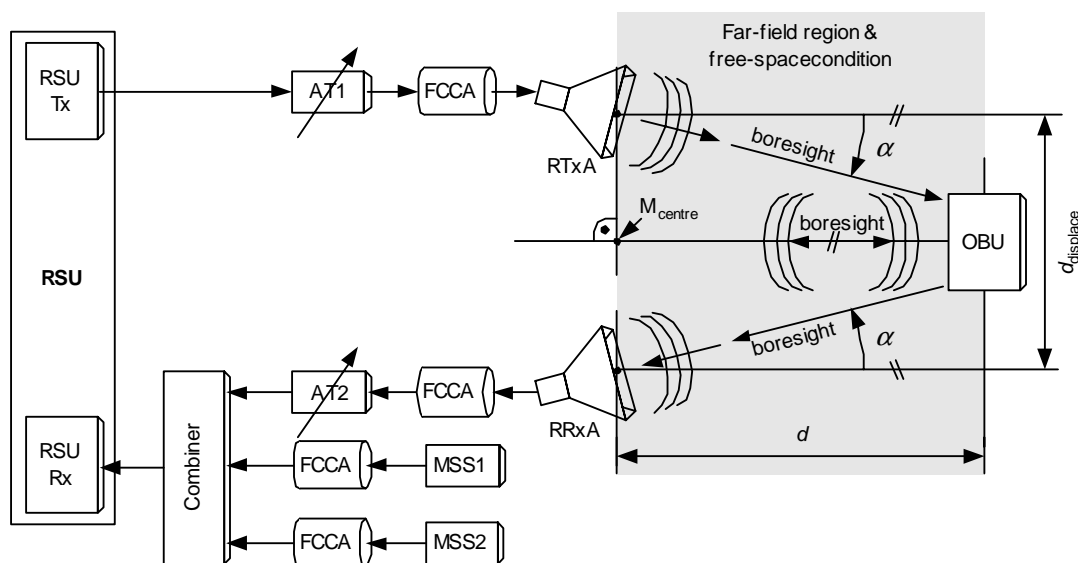
**Figure 13: RSU transmit parameter measurement arrangement**

- 1) The LHCP RTxA shall be mounted on a vertical pole within the "quiet zone" of the shielded anechoic chamber. The distance between any part of the RTxA and the ceiling, floor or walls shall be at least 0,5 m.
- 2) The RTA shall be suited for the range of carrier frequencies  $f_{\text{Tx}}$  in accordance with clause 5.3. It shall be mounted on a pole at the other end of the shielded anechoic chamber. The distance between any part of the RTA and the ceiling, floor or walls shall be at least 0,5 m. The RTA shall be LHCP if not stated otherwise in the test procedures.
- 3) The distance  $d$  between the RTxA and the RTA shall be such that the two antennas are mutually in the far field of each other, see clause 8.6.3.1.
- 4) The phase centres of the RTxA and the RTA shall be at the same height above floor.
- 5) The bore sight of the RTA shall point towards the phase centre of the RTxA. The bore sight of the RTxA shall point towards the phase centre of the RTA.
- 6) Connect the RSU transmitter to the RTxA via an FCCA.
- 7) Connect the RTA to the RD via an FCCA.



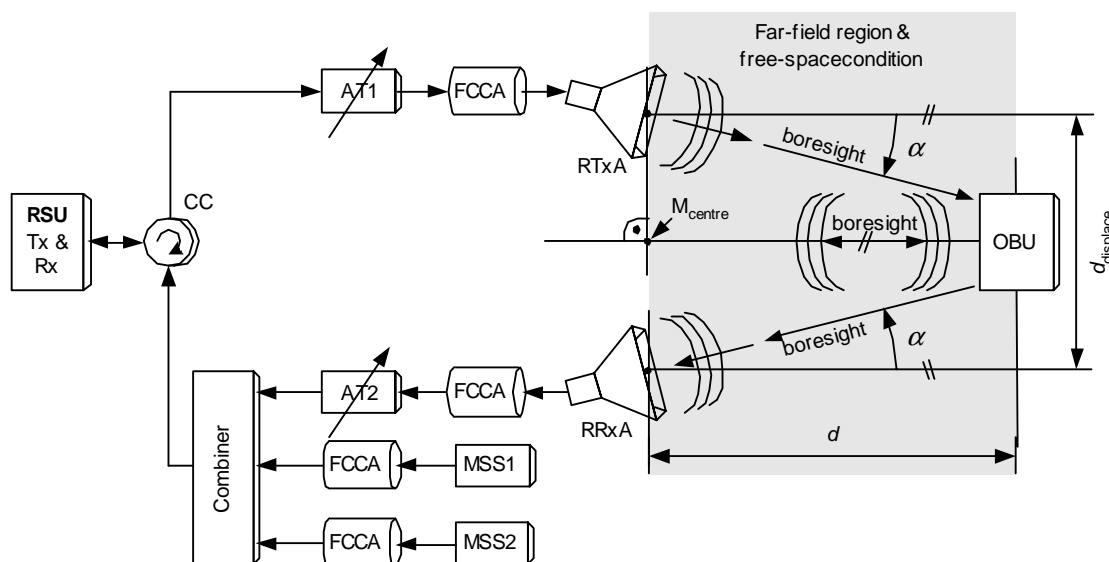
### 8.6.6.2 Arrangement for receive parameters

Figures 14 and 15 detail the arrangements used for measurement of the receiver parameters dynamic range, intermodulation immunity, co-channel rejection, blocking and selectivity. Figure 14 applies for a RSU with separate antenna connectors for the receive and transmit path.



**Figure 14: RSU receive parameter measurement arrangement for horizontally separated antennas**

In case the RSU under test provides only a single antenna connector for both, the transmit and receive path, a CC shall be used in order to split up the single antenna connector into two antenna connectors, one for the receive path and one for the transmit path; see figure 15.



**Figure 15: RSU receive parameter measurement arrangement with CC for horizontally separated antennas**

- 1) The RTxA shall be mounted on a vertical pole within the "quiet zone" of the shielded anechoic chamber. The distance between any part of the RTxA and the ceiling, floor or walls shall be at least 0,5 m.
- 2) The RRxA shall be mounted on a vertical pole within the "quiet zone" of the shielded anechoic chamber. The distance between any part of the RRxA and the ceiling, floor or walls shall be at least 0,5 m.
- 3) The phase centre of the RTxA shall be displaced from the phase centre of the RRxA by  $d_{displace}$ . The position between both phase centres is denoted  $M_{centre}$ .

- 4) The displacement shall either be horizontally or vertically such as to minimize the coupling between these antennas. The distance  $d_{\text{displace}}$  shall be such that the coupling loss between the two antennas exceeds 30 dB. The actual coupling loss and the distance  $d_{\text{displace}}$  shall be stated in the test report together with the unique identification of the RTxA and RRxA used.
- 5) The OBU shall be mounted on a vertical pole at the other end of the shielded anechoic chamber, such that its bore sight points towards  $M_{\text{centre}}$ .
- 6) The height of the phase centres above floor of the RTxA, RRxA and the OBU antenna shall be equal.
- 7) Bore sight of the RTxA shall point towards the phase centre of the OBU antenna.
- 8) Bore sight of the RRxA shall point towards the phase centre of the OBU antenna.
- 9) The OBU antenna(s) shall be mutually in the far field of RTxA and RRxA, see clause 8.6.3.1.
- 10) Connect the RSU transmitter to the RTxA via an adjustable attenuator AT1 and an FCCA.
- 11) Connect the RRxA to the RSU receiver via a combiner with four terminals, an isolator, an adjustable attenuator AT2 with attenuation  $ATN_{\text{AT2}}$  and an FCCA.
- 12) Connect a MSS1 via a FCCA to one of the remaining terminals of the combiner.
- 13) Connect a MSS2 via a FCCA to the remaining terminal of the combiner.

## 8.7 Instruments

### 8.7.1 Receiving device

The RD shall be either a spectrum analyser or a measurement receiver. The subsequent requirements shall apply for a spectrum analyser:

- 1) The level of the superposition of all RF signals simultaneously fed to the input of the spectrum analyser shall be within its range of specification applying for its calibrated operational mode of operation.
- 2) The RD shall be operated only within modes for which the instrument has been calibrated.
- 3) For any frequency to be measured, the noise floor of the RD shall be at least 10 dB below any power value intended to be measured, e.g. limits for spurious emissions, referred to the location where the limit applies.
- 4) The DC voltage fed to the input of the spectrum analyser shall be within its range of specification applying for its calibrated operational mode of operation.
- 5) The frequency error of the spectrum analyser shall be compliant with table 13.
- 6) The nominal characteristic impedance of the spectrum analyser's input connector shall match the nominal characteristic impedance of the device connected to this input connector. The VSWR shall be smaller than 2,0. If this cannot be met, an attenuator or an isolator featuring a VSWR smaller or equal to 2,0 within the frequency range of the measurement shall be attached to the input of the spectrum analyser and the EUT shall be connected to the input of this attenuator or isolator.
- 7) The Video BandWidth (VBW) shall always be equal to or larger than the Resolution BandWidth (RBW) selected. The RBW will also be referred to as the reference or equivalent bandwidth. See as well clause 4.5 of CISPR 16-1 [16].
- 8) For spurious and out-of-band emission measurements the RBW of the spectrum analyser shall be set to the required RBW specified in the test procedure:
  - The measurements may be performed using an RBW that is smaller than the required one and multiple measurements shall be carried out across the required RBW within non-overlapping frequency bins whose width equal to the selected RBW. The signal power measured within each of these frequency bins shall be added up to obtain the wanted signal power within the required RBW.

- If the required RBW is smaller than the smallest one offered by the spectrum analyser and does not match any of the available ones of the spectrum analyser, the measured signal powers shall be performed with a RBW that is closest to the required RBW. The signal power measured shall be scaled according to the ratio of the required RBW to the RBW used while performing the measurements.
- 9) Signal power measurements performed using the spectrum analyser's CW mode shall equal to the arithmetic average of the largest and smallest signal level measured during the observation time.
- 10) The spectrum analyser shall be used only after the instrument has warmed up. The minimum warm up duration is usually specified in the manual of the spectrum analyser. If this is not the case, a warm up time of at least half an hour shall be considered.
- 11) The spectrum analyser shall be calibrated before usage.
- 12) If the dynamic range of the spectrum analyser in conjunction with the required setting of the RBW is not sufficient to measure relevant weak signals in the presence of irrelevant strong signal components appropriate measures to suppress the irrelevant strong signal components shall be applied in agreement between provider and test laboratory and shall be described in the test report.
- 13) The peak detector shall be used.

For the usage of a measurement receiver the above requirements shall apply as well with the exception, where requirements are not applicable, e.g. VBW.

### 8.7.2 RF power sensor

The subsequent requirements shall apply for RF signal power measurements.

- 1) RF signal power measurements shall not be performed before warm-up of the RF power sensor and the RF power meter. The warm-up duration is usually specified in the manual of the instrument. If this is not the case the instrument shall be allowed for a warm-up time of at least half an hour.
- 2) The RF power sensor and RF power meter shall be calibrated and zeroed before usage according to the requirements and the procedure specified in the manual of the instrument.
- 3) The RF power sensor shall be kept within a small enough temperature range such as to keep the measurement uncertainty of the measurement set up within the range specified in clause 11.2.
- 4) The VSWR at the input of the RF power sensor shall be smaller than 1,5 within the frequency range of the measurement under investigation.
- 5) The level of the superposition of all signals simultaneously fed to the input of the RF power sensor shall be within the dynamic range of the RF power sensor as stated by its manufacturer for its operational mode.
- 6) The power sensor shall be dedicated for the signal waveform under consideration.

### 8.7.3 Combiner

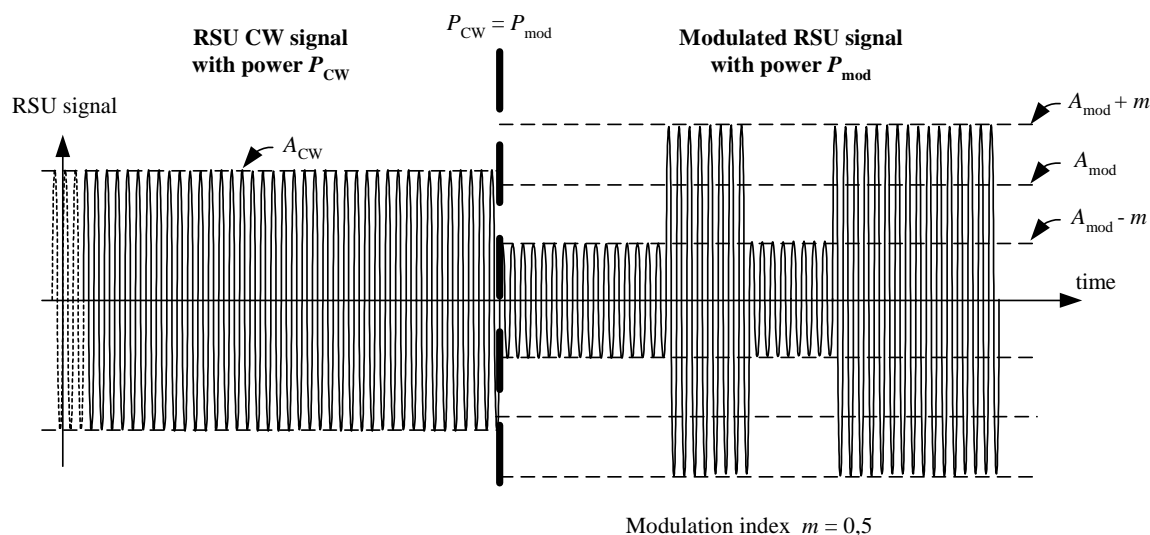
All RF combiners used within the measurement arrangements and set ups shall provide coaxial connectors at all ports and feature within the frequency range they are used:

- a nominal characteristic impedance of 50  $\Omega$  at each port;
- a VSWR of less than 1,5 at each port;
- an isolation between the input ports of at least 10 dB; and
- an amplitude balance between each of the input ports and the output port of less than 1 dB.

## 8.8 Power of modulated RSU carrier

Figure 16 illustrates as an example the basic time-dependent sequence of unmodulated and modulated RSU transmit signals for a case of a modulation index  $m = 0,5$ , where the transmit signal power  $P_{\text{mod}}$ , and  $P_{\text{CW}}$ , respectively, of the modulated, and unmodulated signal parts are equal. The condition of equal power  $P_{\text{mod}} = P_{\text{CW}}$  is not required by the present document.

NOTE: Figure 16 does not allow extracting valid timing relations between carrier frequency and bit rate.



**Figure 16: RSU transmit signal**

An RSU normally allows for a transmit mode "send unmodulated carrier", i.e. continuous transmission of the unmodulated carrier. Thus it is possible to measure the power of the unmodulated signal in figure 16,  $P_{\text{CW}} = \frac{1}{2} A_{\text{CW}}^2$ , by means of a thermal power sensor or a spectrum analyser.

An RSU does normally not allow for continuous transmission of the modulated carrier. In what follows a procedure is described, that allows to estimate the power  $P_{\text{mod}} = \frac{1}{2} A_{\text{mod}}^2 (1 + m^2)$  of the modulated carrier:

- 1) Set the RSU in a mode that it transmits an unmodulated carrier. Measure  $P_{\text{CW}}$ .
- 2) Set the RSU in a mode that it transmits BSTs of maximum possible duration  $T_{\text{mod}}$  with a repetition period as close as possible to twice of the duration of a BST transmission. The gap between subsequent BST transmissions has duration  $T_{\text{CW}}$ . The duration  $T_{\text{mod}}$  and  $T_{\text{CW}}$  shall be constant within the following test.
- 3) Measure the average signal power  $P_{\text{avg}}$  of the signal transmitted according to step 2 with measurement time of at least ten times the repetition period  $T_{\text{CW}} + T_{\text{mod}}$ .
- 4) Measure the duration  $T_{\text{mod}}$  and  $T_{\text{CW}}$ .
- 5) Calculate  $P_{\text{mod}} = P_{\text{avg}} + \frac{T_{\text{CW}}}{T_{\text{mod}}} (P_{\text{avg}} - P_{\text{CW}})$ .

## 8.9 Bit error ratio measurements

### 8.9.1 Basics

The required BER for communication is referred to as parameters D9a and U9a in prEN 12253 [2].

BER measurements shall be conducted either in a direct or indirect way.

The direct way requires the possibility to generate and receive a continuous bit stream of significant length. The fraction of erroneous bits out of the total number of received bits is the BER. This approach uses standard laboratory equipment for BER measurement and requires a modification of the EUT.

The indirect way is based on generating and receiving frames of limited length where any bit errors in the frame can be detected by means of a CRC. The fraction of erroneous frames out of the total number of frames, which is called the FER, allows to estimate the BER assuming that bit errors are equally distributed. Precautions shall be taken to prevent drops of error-free received frames caused by specific implementation of upper layers.

### 8.9.2 BER measurement

BER may be measured indirectly, see the following clause.

### 8.9.3 FER measurement

#### 8.9.3.1 Mathematical expressions

Assuming equally distributed and statistically independent occurrence of erroneous bits the following relations between *FER*, *BER*, and total number *N* of transmitted bit within a single frame apply:

$$FER = 1 - (1 - BER)^N,$$

$$BER = 1 - 10^{\frac{\lg(1-FER)}{N}} = 1 - \sqrt[N]{1 - FER}.$$

The minimum number  $C_F$  of frames together with the frame size shall be reported.

**EXAMPLE 1:** With  $BER = 10^{-6}$  and frame length  $N = 1000$  the equivalent *FER* amounts to approximately  $1,0 \times 10^{-3}$ . A reasonable number  $C_F$  of frames to be transmitted is 10 000, i.e. 10 frames may be lost on average.

**EXAMPLE 2:** For a large value of *FER*, e.g. 0,9999 which may result from a  $BER = 2,0 \times 10^{-2}$  as used for test, a reasonable number  $C_F$  of frames to be transmitted is 100 000, i.e. 10 frames may be error-free on average. The very large number of frames to be transmitted is to be able at all to estimate the *BER*, as a small variation in erroneous frames may change significantly the corresponding estimated *BER*.

#### 8.9.3.2 Equipment

*FER* measurements can be easily conducted using the set of test messages TM1. Thus standard DSRC equipment might be used, if the following software configuration has been implemented:

- initialization with BST and VST is implemented; see BS EN 12795 [7] and BS EN 12834 [8];
- the EFC command ECHO is implemented; see ISO/TR 14906 [9].

In case of a bit error performance measurement of the RSU receiver, the following additional configuration requirements apply:

- An ECHO.request transmitted by the RSU and not responded by the OBU shall be treated as "never transmitted", as in this case the ECHO.request was received erroneous.

- An erroneous ECHO.response received shall not result in a retransmission of the related ECHO.request as normally required by the DSRC protocol, but shall just lead to an increment of the frame error counter.

In case of a bit error performance measurement of the OBU receiver, the following additional configuration requirements apply:

- An ECHO.request transmitted by the RSU and not responded by the OBU shall not result in a retransmission of the related ECHO.request as normally required by the DSRC protocol, but shall just lead to an increment of the frame error counter.
- An erroneous ECHO.response received shall not result in a retransmission of the related ECHO.request as normally required by the DSRC protocol, but shall just be ignored, as in this case the ECHO.request was received error free at the OBU.

### 8.9.3.3 Procedure

- 1) The RSU shall perform initialization with the OBU by exchanging BST and VST. The signal level at the receiver input relevant for BER measurement shall be set to the level required for the test. The signal level at the other receiver input shall be set at a reasonable high value as declared by the provider such that error free reception is very likely. In the unexpected case of transmission errors, the initialization attempt shall be repeated. During initialization any additional interfering signals as requested by a specific test procedure shall be switched off.
- 2) The RSU shall transmit a single ECHO command of maximum length. Reception of the corresponding response from the OBU is expected to be error free. In case of errors, repetitions of the ECHO command according to the DSRC protocol shall happen. This finalizes initialization.

In case of a bit error performance measurement of the RSU receiver, the following additional procedural steps shall be processed:

- 3) Repeat step 2  $C_F$  times,  $C_F$  see clause 8.9.3.1, and report the total number  $C_E$  of erroneous ECHO.response frames received by the RSU. Calculate the actual Frame Error Ratio  $FER = C_E / C_F$ . Continue with step 5.

In case of a bit error performance measurement of the OBU receiver, the following additional procedural steps shall be processed:

- 4) Repeat step 2 for  $C_F$  times,  $C_F$  see clause 8.9.3.1, and report the total number  $C_E$  of ECHO.response frames not received by the RSU. Calculate the actual Frame Error Ratio  $FER = C_E / C_F$ .
- 5) Calculate  $BER$  out of  $FER$  according to clause 8.9.3.1.

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## 9 Testing of Road Side Unit

### 9.1 Modulation index

#### 9.1.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.1.

#### 9.1.2 Radiated measurements

- 1) Set up the measurement arrangement as detailed in clause 8.6.6.1.
- 2) Set the transmit power of the RSU to its maximum possible operational value.

- 3) Set the modulation index of the RSU to its minimum adjustable value within the allowed range.
- 4) Set the RSU to the mode, where it transmits continuously test signal TS1.
- 5) Set the RSU transmit carrier frequency  $f_{TX}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 6) Set the RD into the CW mode, also called zero span mode of operation, where the instrument is not sweeping across a frequency band.
- 7) Set the RBW to 2 MHz.
- 8) Measure  $V_{max}$  and  $V_{min}$  from envelope of RF signal, see figure 2.
- 9) Calculate modulation index  $m$  according to formula in clause 7.1.1.
- 10) Repeat steps 8 and 9 for the remaining value of the carrier frequency  $f_{TX}$  in accordance with clause 5.3.
- 11) Set the modulation index of the RSU to its maximum adjustable value within the allowed range and repeat steps 8 through 10.
- 12) For all measurements the modulation index  $m$  shall be within the limits as stated in clause 7.1.1.

### 9.1.3 Conducted measurements

- 1) The output of the RSU transmitter shall be connected to the RD.
- 2) Set the transmit power of the RSU to its maximum possible operational value.
- 3) Set the modulation index of the RSU to its minimum adjustable value within the allowed range.
- 4) Set the RSU to the mode, where it transmits continuously test signal TS1.
- 5) Set the RSU transmit carrier frequency  $f_{TX}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 6) Set the RD into the CW mode, also called zero span mode of operation, where the instrument is not sweeping across a frequency band.
- 7) Set the RBW to 2 MHz.
- 8) Measure  $V_{max}$  and  $V_{min}$  from envelope of RF signal, see figure 2.
- 9) Calculate modulation index  $m$  according to formula in clause 7.1.1.
- 10) Repeat steps 8 and 9 for the remaining value of the carrier frequency  $f_{TX}$  in accordance with clause 5.3.
- 11) Set the modulation index of the RSU to its maximum adjustable value within the allowed range and repeat steps 8 through 10.
- 12) For all measurements the modulation index  $m$  shall be within the limits as stated in clause 7.1.1.

## 9.2 Dynamic range

### 9.2.1 Sensitivity

#### 9.2.1.1 General

This test shall be performed with radiated measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.2.2.

The description below assumes that an OBU is used to receive down-link signals and to generate up-link signals, both of type TM1.

NOTE: The provider may extend the test in order to determine the actual value of the receiver sensitivity.

### 9.2.1.2 Radiated measurements

- 1) Set up the measurement arrangement as detailed in clause 8.6.6.2.
- 2) Switch off MSS1 and MSS2 as these sources are never used in this test. Alternatively, these sources shall be replaced by 50  $\Omega$  terminators.
- 3) Set the RSU carrier frequency  $f_{Tx}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 4) Set the RSU to the mode that it transmits an unmodulated carrier.
- 5) Set the RSU output power to its maximum allowed value.
- 6) Set the modulation index to any convenient value, if it is adjustable.
- 7) Switch on the RSU transmitter and adjust AT1 such, that the incident signal power received by an loss-less isotropic antenna at the location of the OBU antenna equals -25 dBm in order to ensure reliable reception of messages by the OBU.
- 8) Set the OBU into a test mode that it transmits test signal TS2.
- 9) Replace the RSU receiver by a power meter PM1.
- 10) Adjust AT2 such, that the power measured by PM1 equals a value  $P_{sens}$  equal to the sensitivity of the RSU declared by the provider.
- 11) Replace the PM1 by the RSU receiver.
- 12) Set RSU and OBU to a mode that they are able to process test messages TM1.
- 13) Set the RSU to a mode such that the OBU shall use the lower sub-carrier frequency.
- 14) Measure BER of the RSU receiver according to clause 8.9. If the BER is larger than  $10^{-6}$  the test failed.
- 15) Repeat step 14 for the upper sub-carrier frequency.
- 16) Repeat steps 4 through 15 for the remaining value of the carrier frequency  $f_{Tx}$  in accordance with clause 5.3.

## 9.2.2 Error behaviour at high wanted input signals

### 9.2.2.1 General

This test shall be performed with radiated measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.2.3.

The description below assumes that an OBU is used to receive down-link signals and to generate up-link signals, both of type TM1.

### 9.2.2.2 Radiated measurements

The procedure as detailed in clause 9.2.1.2 applies with the following modification:

- 1) In step 10, the power shall be set to in accordance with clause 7.1.2.3.



## 9.3 Intermodulation immunity

### 9.3.1 General

Independent of the environmental profile declared by the provider, this test shall be performed only under normal test conditions defined in clause 4.2.3.1.

This test shall be performed with radiated measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.3.

NOTE: The provider may extend the test in order to determine the actual value of the intermodulation immunity.

### 9.3.2 Radiated measurements

- 1) Set up the measurement arrangement as detailed in clause 8.6.6.2.
- 2) Set the RSU to the mode that it transmits an unmodulated carrier.
- 3) Set the RSU output power to its maximum allowed value.
- 4) Set the modulation index to any convenient value, if it is adjustable.
- 5) Set the RSU carrier frequency  $f_{TX}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 6) Set the RSU to a mode such that the OBU shall use the lower sub-carrier frequency  $f_s$ .
- 7) Set the frequency of the MSS1 to  $f_{TX} + f_s + 5$  MHz and the frequency of the MSS2 to  $f_{TX} + f_s + 10$  MHz.
- 8) Ensure that MSS1, MSS2 and the RSU are switched off.
- 9) Replace the RSU receiver by a power meter PM1.
- 10) Switch on MSS1 and adjust the power of its output signal such that PM1 measures a value of -25 dBm.
- 11) Switch off MSS1.
- 12) Switch on MSS2 and adjust the power of its output signal such that PM1 measures a value of -25 dBm.
- 13) Switch off MSS2.
- 14) Switch on the RSU transmitter and adjust AT1 such, that the incident signal power received by an loss-less isotropic antenna at the location of the OBU antenna equals -25 dBm in order to ensure reliable reception of messages by the OBU.
- 15) Set the OBU into a test mode that it transmits test signal TS2.
- 16) Adjust AT2 such, that the power measured by PM1 equals the sum of the sensitivity of the RSU declared by the provider plus 6 dB.
- 17) Replace the PM1 by the RSU receiver.
- 18) Set RSU and OBU to a mode that they are able to process test messages TM1.
- 19) Switch on MSS1 and MSS2.
- 20) Measure BER of the RSU receiver according to clause 8.9. If the BER is larger than  $2,0 \times 10^{-2}$  the test failed.
- 21) Set the RSU to a mode such that the OBU shall use the upper sub-carrier frequency  $f_s$ .
- 22) Repeat step 20.

- 23) Set the RSU to a mode such that the OBU shall use the lower sub-carrier frequency  $f_s$ .
- 24) Set the frequency of the MSS1 to  $f_{TX} + f_s - 5$  MHz and the frequency of the MSS2 to  $f_{TX} + f_s - 10$  MHz.
- 25) Repeat steps 8 through 22.
- 26) Repeat steps 6 through 25 for the remaining value of the carrier frequency  $f_{TX}$  in accordance with clause 5.3.

## 9.4 Co-channel rejection

### 9.4.1 General

Independent of the environmental profile declared by the provider, this test shall be performed only under normal test conditions defined in clause 4.2.3.1.

This test shall be performed with radiated measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.4.

NOTE: The provider may extend the test in order to determine the actual value of the co-channel rejection.

### 9.4.2 Radiated measurements

- 1) Set up the measurement arrangement as detailed in clause 8.6.6.2.
- 2) Switch off the MSS2 as it is never used in this test. Alternatively, this source shall be replaced by a 50  $\Omega$  terminator.
- 3) Set the RSU to the mode that it transmits an unmodulated carrier.
- 4) Set the RSU output power to its maximum allowed value.
- 5) Set the modulation index to any convenient value, if it is adjustable.
- 6) Set the RSU carrier frequency  $f_{TX}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 7) Set the RSU to a mode such that the OBU shall use the lower sub-carrier frequency  $f_s$ .
- 8) Set the frequency of the MSS1 to  $f_{TX} + f_s$ .
- 9) Ensure that MSS1 and the RSU are switched off.
- 10) Replace the RSU receiver by a power meter PM1.
- 11) Switch on MSS1 and adjust the power of its output signal such that PM1 measures a value equal to the sensitivity  $P_{sens}$  of the RSU declared by the provider.
- 12) Switch off MSS1.
- 13) Switch on the RSU transmitter and adjust AT1 such, that the incident signal power received by a loss-less isotropic antenna at the location of the OBU antenna equals -25 dBm in order to ensure reliable reception of messages by the OBU.
- 14) Set the OBU into a test mode that it transmits test signal TS2.
- 15) Adjust AT2 such, that the power measured by PM1 equals the sum of the sensitivity  $P_{sens}$  of the RSU declared by the provider plus 6 dB.
- 16) Replace the PM1 by the RSU receiver.
- 17) Set RSU and OBU to a mode that they are able to process test messages TM1.

- 18) Switch on MSS1.
- 19) Measure BER of the RSU receiver according to clause 8.9. If the BER is larger than  $2,0 \times 10^{-2}$  the test failed.
- 20) Set the RSU to a mode such that the OBU shall use the upper sub-carrier frequency  $f_s$ .
- 21) Repeat step 19.
- 22) Set the RSU to a mode such that the OBU shall use the lower sub-carrier frequency  $f_s$ .
- 23) Repeat steps 8 through 21 for the remaining value of the carrier frequency  $f_{Tx}$  in accordance with clause 5.3.

## 9.5 Blocking

### 9.5.1 General

This test shall be performed with radiated measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.5.

The representative frequencies  $f_u$  of the unwanted signal as selected by the provider for testing shall be stated in the test report.

NOTE: The provider may extend the test in order to determine the actual value of the immunity against other services.

### 9.5.2 Radiated measurements

- 1) Set up the measurement arrangement as detailed in clause 8.6.6.2.
- 2) Switch off the MSS2 as it is never used in this test. Alternatively, this source shall be replaced by a 50  $\Omega$  terminator.
- 3) Set the RSU to the mode that it transmits an unmodulated carrier.
- 4) Set the RSU output power to its maximum allowed value.
- 5) Set the modulation index to any convenient value, if it is adjustable.
- 6) Set the RSU carrier frequency  $f_{Tx}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 7) Set the RSU to a mode such that the OBU shall use the lower sub-carrier frequency  $f_s$ .
- 8) Set the frequency of the MSS1 to the initial value of  $f_u$ .
- 9) Ensure that MSS1 and the RSU are switched off.
- 10) Replace the RSU receiver by a power meter PM1.
- 11) Switch on MSS1 and adjust the power of its output signal such that PM1 measures either  $P_{PM1} = -30$  dBm or the value declared by the provider.
- 12) Switch off MSS1.
- 13) Switch on the RSU transmitter and adjust AT1 such, that the incident signal power received by a loss-less isotropic antenna at the location of the OBU antenna equals -25 dBm in order to ensure reliable reception of messages by the OBU.
- 14) Set the OBU into a test mode that it transmits test signal TS2.

- 15) Adjust AT2 such, that the power measured by PM1 equals the sum of the sensitivity  $P_{\text{sens}}$  of the RSU declared by the provider plus 6 dB.
- 16) Replace the PM1 by the RSU receiver.
- 17) Set RSU and OBU to a mode that they are able to process test messages TM1.
- 18) Switch on MSS1.
- 19) Measure BER of the RSU receiver according to clause 8.9. If the BER is larger than  $2,0 \times 10^{-2}$  the test failed.
- 20) Set the RSU to a mode such that the OBU shall use the upper sub-carrier frequency  $f_s$ .
- 21) Repeat step 19.
- 22) Repeat steps 9 through 21 for all remaining values  $f_u$  of the frequency of the unwanted signal.
- 23) Set the RSU to a mode such that the OBU shall use the lower sub-carrier frequency  $f_s$ .
- 24) Repeat steps 8 through 22 for the remaining value of the carrier frequency  $f_{\text{Tx}}$  in accordance with clause 5.3.

## 9.6 Selectivity

### 9.6.1 General

This test shall be performed with radiated measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.6.

NOTE: The provider may extend the test in order to determine the actual value of the selectivity.

### 9.6.2 Radiated measurements

The procedure as detailed in clause 9.5.2 applies with the following modifications:

- 1) The test shall be performed for all frequencies  $f_u$  of the unwanted signal as detailed in table 4 and with the corresponding limit  $P_{\text{PM1}}$  as detailed in the same table.

## 9.7 Maximum equivalent isotropically radiated power

### 9.7.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.7.

The provider has to declare all RSU transmit centre frequencies  $f_{\text{Tx}}$  supported by this RSU in accordance with clause 5.3. In case of conducted measurements the provider shall declare the gain  $G_{\text{RSU,Tx}}$  of the RSU transmit antenna to be used with this RSU device.

### 9.7.2 Radiated measurements

- 1) Set up the measurement arrangement as detailed in clause 8.6.6.1.
- 2) Replace the RD by a power meter PM1.

- 3) Set the transmit power of the RSU to its maximum possible operational value.
- 4) Set the RSU to the mode, where it transmits only an unmodulated carrier.
- 5) Set the RSU transmit centre frequency  $f_{Tx}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 6) Measure the power  $P_{CW}$  with PM1 and report the value together with the actual carrier frequency  $f_{Tx}$ .
- 7) Repeat step 6 for the remaining value of the carrier frequency  $f_{Tx}$  in accordance with clause 5.3.
- 8) Replace the RTxA by the LHCP TSA with maximum gain  $G_{TSA}$  and reflection coefficient  $\rho_{TSA}$  at the antenna connector such that their phase centres and bore sights coincide.
- 9) Connect the output of the TSA via the optional balun BLN, if required, of feed through attenuation  $ATN_{BLN}$ , and a calibrated FCCA of feed through attenuation  $ATN_{CA1}$  to a MSS1.
- 10) Set the frequency  $f_{MSS1}$  of the MSS1 output signal equal to the initial value of the carrier frequency  $f_{Tx}$  supported by this RSU in accordance with clause 5.3.
- 11) Adjust the power  $P_{MSS1}$  such that PM1 shows the same value  $P_{CW}$  as report for this frequency  $f_{MSS1} = f_{Tx}$  in step 6 and report  $P_{MSS1}$  together with  $f_{MSS1}$ .
- 12) Repeat steps 10 and 11 for the remaining value of the carrier frequency  $f_{Tx}$  in accordance with clause 5.3.
- 13) Calculate the maximum equivalent isotropically radiated power for all tested carrier frequencies  $f_{Tx}$ :

$$EIRP_{\max} = P_{MSS1} \times G_{TSA} \times \left( 1 - |\rho_{TSA}|^2 \right).$$

- 14) The maximum of  $EIRP_{\max}$  from all measurements performed in this test is the maximum e.i.r.p. of the RSU. This value shall not exceed the limit reported in clause 7.1.7.

### 9.7.3 Conducted measurements

- 1) Connect a power meter PM1 to the connector for the RSU transmit antenna.
- 2) Set the transmit power of the RSU to its maximum possible operational value.
- 3) Set the RSU to the mode, where it transmits only an unmodulated carrier.
- 4) Set the RSU transmit centre frequency  $f_{Tx}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 5) Measure the power  $P_{CW}$  with PM1. Calculate the corresponding maximum equivalent isotropically radiated power  $EIRP_{\max} = P_{CW} \cdot G_{RSU,Tx}$ .
- 6) Repeat step 5 for the remaining RSU transmit centre frequency  $f_{Tx}$  in accordance with clause 5.3.
- 7) The maximum of  $EIRP_{\max}$  from all measurements performed in this test is the maximum e.i.r.p. of the RSU. This value shall not exceed the limit reported in clause 7.1.7.

## 9.8 Frequency error

### 9.8.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.8.

The provider has to declare all RSU transmit centre frequencies  $f_{Tx}$  supported by this RSU and in accordance with table 2.

## 9.8.2 Radiated measurements

- 1) Set up the measurement arrangement as detailed in clause 8.6.6.1.
- 2) Set the transmit power of the RSU to its maximum possible operational value.
- 3) Set the RSU to the mode, where it transmits only an unmodulated carrier.
- 4) Set the RSU transmit centre frequency  $f_{Tx}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 5) Measure the actual carrier frequency  $f_{Tx,actual}$ .
- 6) Calculate the frequency error:

$$\Delta f_{RSU} / \text{ppm} = \frac{|f_{Tx} - f_{Tx,actual}|}{f_{Tx}} \times 10^6.$$

- 7) The test failed if the frequency error exceeds the maximum allowed limit as stated in clause 7.1.8.
- 8) Repeat steps 5 through 7 for the remaining carrier frequency  $f_{Tx}$  in accordance with clause 5.3.

## 9.8.3 Conducted measurements

- 1) Connect output of the RSU transmitter to the RD.
- 2) Set the transmit power of the RSU to its maximum possible operational value.
- 3) Set the RSU to the mode, where it transmits only an unmodulated carrier.
- 4) Set the RSU transmit centre frequency  $f_{Tx}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 5) Measure the actual carrier frequency  $f_{Tx,actual}$ .
- 6) Calculate the frequency error:

$$\Delta f_{RSU} / \text{ppm} = \frac{|f_{Tx} - f_{Tx,actual}|}{f_{Tx}} \times 10^6.$$

- 7) The test failed if the frequency error exceeds the maximum allowed limit as stated in clause 7.1.8.
- 8) Repeat steps 5 through 7 for the remaining carrier frequency  $f_{Tx}$  in accordance with clause 5.3.

## 9.9 Transmitter spectrum mask

### 9.9.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.9.

The provider has to declare all RSU transmit centre frequencies  $f_{Tx}$  supported by this RSU and in accordance with table 2 and the class, e.g. A, B or C, of the RSU. In case of conducted measurements the provider shall declare the maximum gain  $G_{RSU,Tx}$  of the RSU transmit antenna to be used with this RSU device.

The centre frequencies  $f_c = f_{Tx} + f_{offset}$  and the resolution bandwidth  $RBW$  of the RD shall be set for measurements in the sequence as indicated for the offset frequencies  $f_{offset}$  in the following table, both valid for unmodulated and modulated emissions of the RSU.

**Table 11: Offset frequencies and RBW for testing RSU Tx spectrum mask**

#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
$f_{offset}$ / MHz	-1	+1	-1,5	+1,5	-2	+2	-3	+3	-3,5	+3,5	-4	+4	-6	+6	-6,5	+6,5	-7	+7
$RBW$	30 kHz		100 kHz								30 kHz				100 kHz			

## 9.9.2 Radiated measurements

- 1) Set up the measurement arrangement as detailed in clause 8.6.6.1.
- 2) Set the transmit power of the RSU and its modulation index  $m$  to the maximum possible operational value.
- 3) Set the RSU to the mode, where it transmits only an unmodulated carrier.
- 4) Set the RSU transmit centre frequency  $f_{Tx}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 5) Set the RD to the CW mode, also called zero span mode of operation, where the instrument is not sweeping across a frequency band.
- 6) Select one of the offset frequencies  $f_{offset}$  from table 11. If  $f_{offset}$  amounts to either  $\pm 1$  MHz,  $\pm 4$  MHz or  $\pm 6$  MHz, proceed with step 7, otherwise proceed with step 12.
- 7) Set the centre frequency  $f_c = f_{Tx} + f_{offset} - RBW/2$  and  $RBW$  of the RD according to table 11.
- 8) Measure the power  $P_1$  and report this value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ .
- 9) Set the centre frequency  $f_c = f_{Tx} + f_{offset} + RBW/2$  and  $RBW$  of the RD according to table 11.
- 10) Measure the power  $P_2$  and report this value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ .
- 11) Determine the total signal power  $P_{tot}$  by summing up the two signal power values as  $P_{tot} = P_1 + P_2$ , and compute the power  $P_{tot,dBm}$  in dBm as  $P_{tot,dBm} = 10 \times \lg(P_{tot}/P_0)$ . Report this value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ . Proceed with step 18.
- 12) Set the centre frequency  $f_c$  of the RD to its initial value  $f_c = f_{Tx} + f_{offset} - 2 \cdot RBW$  and  $RBW$  according to table 11. Set the counter  $i = 1$ .
- 13) Measure the power  $P_1$  and report this value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ .
- 14) Increase the value of the counter by 1. When the counter equals 6, proceed with step 17, otherwise proceed with step 15.
- 15) Increase the centre frequency  $f_c$  of the RD by  $RBW$  and measure the signal power  $P_1$  from the RD and record its value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$  in the test report.
- 16) Repeat steps 14 and 15.

- 17) Determine the total signal power  $P_{\text{tot}}$  by summing up five signal power values as  $P_{\text{tot}} = P_1 + P_2 + P_3 + P_4 + P_5$  and compute the total power  $P_{\text{tot,dBm}}$  in dBm as  $P_{\text{tot,dBm}} = 10 \times \lg(P_{\text{tot}}/P_0)$ . Report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ .
- 18) Repeat steps 6 through 17 until the whole sequence of offset frequencies listed in table 11 has been processed.
- 19) Repeat steps 6 through 18 for the other carrier frequency  $f_{\text{Tx}}$  in accordance with clause 5.3.
- 20) For a specific combination of carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$  the value of  $P_{\text{tot}}$  reported shall apply for the subsequent evaluation.
- 21) Replace the RTxA by a LHCP calibrated TSA of gain  $G_{\text{TSA}}$  and reflection coefficient  $\rho_{\text{TSA}}$  at its connector suited for the range of carrier frequencies  $f_{\text{Tx}}$  in accordance with clause 5.3 in such a way that its phase centre coincides with the one of the RTxA. The bore sight of the TSA shall point towards the phase centre of the RTA.
- 22) Connect the output of the TSA via the optional balun BLN, if required, of feed through attenuation  $ATN_{\text{BLN}}$ , and the calibrated FCCA1 of feed through attenuation  $ATN_{\text{CA1}}$  to a MSS1.
- 23) Tune the frequency of the MSS1's output signal to the frequency  $f_c = f_{\text{Tx}} + f_{\text{offset}}$ , where  $f_{\text{Tx}}$  is one of the values supported by this RSU in accordance with clause 5.3 and  $f_{\text{offset}}$  shall be according to table 11.
- 24) Adjust the output signal level  $P_{\text{MSS1}}$  of the MSS1 until the level, measured on the RD, becomes identical to  $P_{\text{tot}}$  as reported in step 20 at the same combination of carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ . This output signal level  $P_{\text{MSS1}}$  from the MSS1 shall be reported together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ .
- 25) Repeat steps 23 and 24 for all remaining combinations of carrier frequencies  $f_{\text{Tx}}$  and offset frequencies  $f_{\text{offset}}$ .
- 26) The TSM at this combination of carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ , expressed as an e.i.r.p. of the RSU shall be calculated by:

$$EIRP_{\text{TSM}} = \frac{P_{\text{MSS1}} \times G_{\text{TSA}} \times \left(1 - |\rho_{\text{TSA}}|^2\right)}{ATN_{\text{CA1}} \times ATN_{\text{BLN}}},$$

where all the parameters in the above formula are related to the corresponding measurement frequencies. The result shall be reported together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ . It shall not exceed the limit stated in clause 7.1.9.

- 27) Repeat steps 4 through 26 for a mode, where the RSU transmits a modulated carrier using test signal TS1.

### 9.9.3 Conducted measurements

- 1) Connect the RSU transmitter output via a calibrated FCCA to the input of the RD.
- 2) Set the transmit power of the RSU and its modulation index  $m$  to the maximum possible operational value.
- 3) Set the RSU to the mode, where it transmits only an unmodulated carrier.
- 4) Set the RSU transmit centre frequency  $f_{\text{Tx}}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 5) Set the RD to its CW mode, also called zero span mode of operation, where the instrument is not sweeping across a frequency band.
- 6) Select one of the offset frequencies  $f_{\text{offset}}$  from table 11. If  $f_{\text{offset}}$  amounts to either  $\pm 1$  MHz,  $\pm 4$  MHz or  $\pm 6$  MHz, proceed with step 7, otherwise proceed with step 12.
- 7) Set the centre frequency  $f_c$  of the RD to  $f_c = f_{\text{Tx}} + f_{\text{offset}} - RBW/2$  and select  $RBW$  according to table 11.



- 8) Measure the signal power  $P_1$  from the RD taking into account all losses the signal suffers between the output connector of the OBU and the input connector of the RD and report this value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ .
- 9) Set the centre frequency  $f_c$  of the RD to  $f_c = f_{Tx} + f_{offset} + RBW/2$  and select  $RBW$  according to table 11.
- 10) Measure the signal power  $P_2$  from the RD taking into account all losses the signal suffers between the output connector of the OBU and the input connector of the RD and report this value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ .
- 11) Determine the total signal power  $P_{tot}$  by summing up the two signal power values as  $P_{tot} = P_1 + P_2$ , and compute the power  $P_{tot,dBm}$  in dBm as  $P_{tot,dBm} = 10 \times \lg(P_{tot}/P_0)$ . Report this value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ . Proceed with step 18.
- 12) Set the centre frequency  $f_c$  of the RD to its initial value  $f_c = f_{Tx} + f_{offset} - 2 \cdot RBW$ , select  $RBW$  according to table 11 and set the counter  $i = 1$ .
- 13) Measure the signal power  $P_i$  from the RD taking into account all losses the signal suffers between the output connector of the OBU and the input connector of the RD and report this value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ .
- 14) Increase the value of the counter by 1. When the counter equals 6, proceed with step 18, otherwise proceed with step 15.
- 15) Increase the centre frequency  $f_c$  of the RD by  $RBW$  and measure the signal power  $P_i$  from the RD and record its value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$  in the test report.
- 16) Repeat steps 14 and 15.
- 17) Determine the total signal power  $P_{tot}$  by summing up five signal power values as  $P_{tot} = P_1 + P_2 + P_3 + P_4 + P_5$  and compute the total power  $P_{tot,dBm}$  in dBm as  $P_{tot,dBm} = 10 \times \lg(P_{tot}/P_0)$ . Report this value together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ .
- 18) Repeat steps 6 through 17 until the whole sequence of offset frequencies listed in table 11 has been processed.
- 19) Repeat steps 6 through 18 for the other carrier frequency  $f_{Tx}$  in accordance with clause 5.3.
- 20) For a specific combination of carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$  the value of  $P_{tot}$  reported for different sub-carrier frequencies  $f_s$  shall apply for the subsequent evaluation.
- 21) Compute the signal power  $P_{TSM}$  associated with each carrier frequency  $f_{Tx}$  and each offset frequency  $f_{offset}$  from the corresponding signal power values  $P_{tot}$  considering all losses within the signal path between the RD and the connector of the RSU's transmitting antenna. Record all values of  $P_{TSM}$  together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ .
- 22) The TSM for each combination of carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ , expressed as an e.i.r.p. of the OBU shall be calculated by:

$$EIRP_{TSM} = P_{TSM} \times G_{RSU,Tx}.$$

It shall be understood that all parameter values are taken at the corresponding frequency  $f = f_{Tx} + f_{offset}$ . The result shall be reported together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$  in the test report. None of these values shall exceed the limit stated in clause 7.1.9.

- 23) Repeat steps 6 through 22 for a mode, where the RSU transmits a modulated carrier using test signal TS1.

## 9.10 Transmitter unwanted emissions

### 9.10.1 General

Independent of the environmental profile declared by the provider, this test shall be performed only under normal test conditions defined in clause 4.2.3.1.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.10.

The test shall be performed with radiated measurements within all frequency bands as referred to as "operating state" in table 6.

The provider has to declare all RSU transmit centre frequencies  $f_{Tx}$  supported by this RSU in accordance with clause 5.3.

The test shall be performed either in an anechoic chamber or in an open area test site. The set up is illustrated in figures 3 and 17.

Figure 17 shows the turntable in its initial position MT0. MT1, MT2, MT3, MT4, MT5, MT6 and MT7 indicate the other angular positions used.

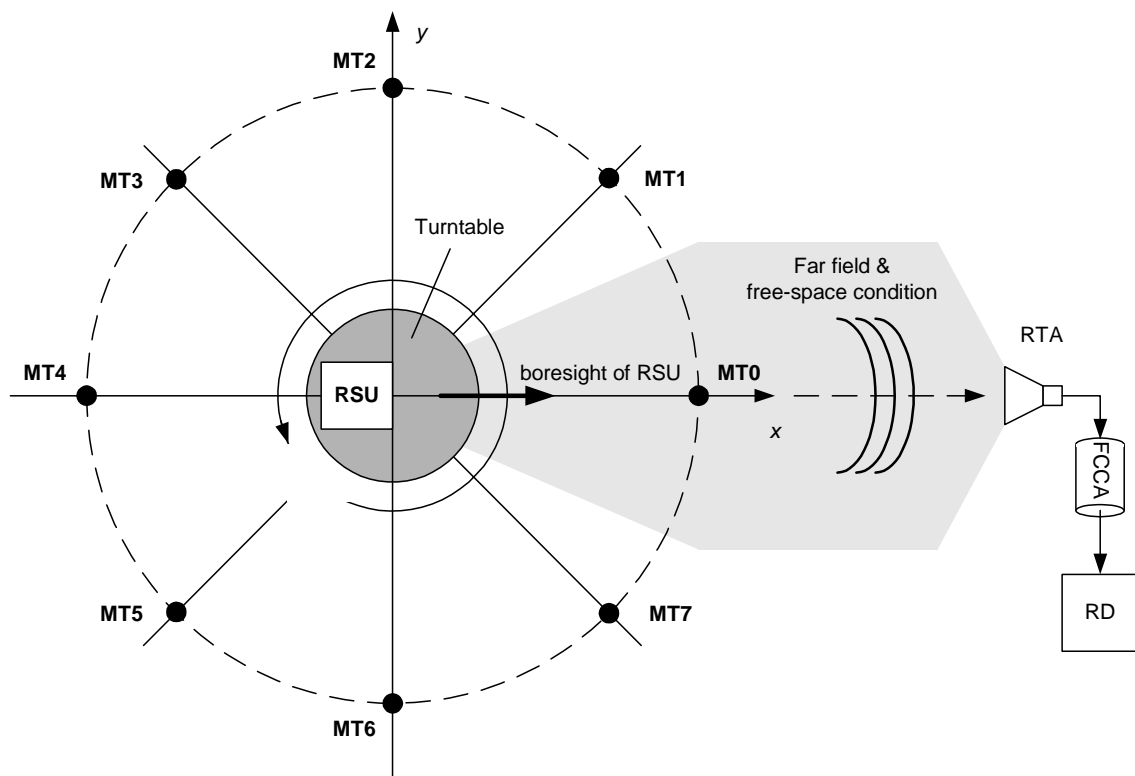


Figure 17: Test set up for RSU unwanted emission measurements (top view)

### 9.10.2 Radiated measurements

The following procedure applies for simultaneous spurious and out-of-band emissions radiated by the RSU transmit antenna.

- 1) Set up the measurement arrangement as detailed in clause 8.6.6.1.
- 2) Replace the RTxA by a vertical polarized TSA such that their bore sights and phase centres coincide.

- 3) The vertical polarized TSA shall be suited for the range of carrier frequencies  $f_{Tx}$  in accordance with clause 5.3. It shall be connected to a calibrated MSS1 using calibrated FCCA.
- 4) The vertical polarized RTA shall be suited for the range of carrier frequencies  $f_{Tx}$  in accordance with clause 5.3.
- 5) Move the turntable to its initial angular position MT0 as shown in figure 17.
- 6) For all frequencies within the bands indicated in clause 7.1.10, see there table 6 for the "operating state" and the exclusion band, adjust the output power of the MSS1 such that the e.i.r.p. of the TSA is equal to the limit for spurious and out-of-band emissions as indicated in table 6 for the operating state and measure the power at the RD with a RBW equal to the reference bandwidth as indicated in table 6. Report the power as a function of frequency in Watt measured at the RD for further usage as a limit line.
- 7) Replace the TSA by the RTxA such that the volume centre of the RSU transmitter matches the phase centre of the TSA. The RSU transmitter output shall be connected to a terminator matched to its nominal characteristic impedance featuring a VSWR of less than 1,5 in order to avoid radiation. The distance between any part of the RSU transmitter and the ceiling, floor or walls shall be at least 0,5 m.
- 8) Set the RSU to the mode, where it transmits test signal TS1.
- 9) Set the transmit power of the RSU and its modulation index  $m$  to the maximum possible operational value and switch on the RSU transmitter.
- 10) Select the first frequency band to be tested according to table 6.
- 11) Set the RSU transmit centre frequency  $f_{Tx}$  to the initial value supported by this RSU in accordance with clause 5.3.
- 12) Move the turntable to its initial angular position MT0 as shown in figure 17.
- 13) The resolution bandwidth of the RD used to measure signal power shall be set equal to the reference bandwidth as indicated in table 6. Measure the power spectrum  $P_{pol}$ , i.e.  $P_{pol} = P_v$  in case of vertical polarized RTA and  $P_{pol} = P_h$  in case of horizontal polarized RTA, received by the RD and report the result for further processing in step 18. Repeat this step for all other angular positions MT1 ...MT7 of the turntable according to figure 17.
- 14) Repeat steps 12 to 13 for the other carrier frequency  $f_{Tx}$  in accordance with clause 5.3.
- 15) Repeat steps 11 through 14 for all frequency bands indicated in clause 7.1.10, see there table 6 for the operating state of the RSU and the exclusion band.
- 16) Rotate the RTA such that it is horizontally polarized, without changing position of its phase centre and bore sight orientation.
- 17) Repeat steps 10 through 15.
- 18) Compute the resulting power  $P_{spurious} = P_v + P_h$  and compare it with the limit line. If the power  $P_{spurious}$  exceeds the limit evaluated in step 6 for any frequency, the test failed.
- 19) Replace the RSU by the RTxA such that the volume centre of the RSU matches the phase centre of the RTxA, and such that the RTxA points towards the phase centre of the RTA and connect the RSU transmitter output to the RTxA.
- 20) Repeat steps 8 through 18 without step 12 and with the restriction that in step 13 there is no repetition.

## 9.11 Receiver spurious emissions

### 9.11.1 General

Independent of the environmental profile declared by the provider, this test shall be performed only under normal test conditions defined in clause 4.2.2.1.

The test shall be performed with radiated measurements within all frequency bands as referred to as "stand-by state" in table 6.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.1.11.

The provider has to declare all RSU transmit centre frequencies  $f_{Tx}$  supported by this RSU and in accordance with table 2.

The test shall be performed either in an anechoic chamber or in an open area test site. The set up is illustrated in the following figures 3 and 17.

### 9.11.2 Radiated measurements

With reference to figures 3 and 17, the test procedure for spurious and out-of-band emissions according to clause 9.10.2 shall apply with the following modifications:

- 1) The RSU shall be operated in the receive mode.
- 2) If the RSU supports a receive only mode, the applicable limits and resolution band widths are indicated in table 6 for the "stand-by" mode.
- 3) If the RSU does not support a receive only mode, but is transmitting a carrier whilst receiving, the applicable limits and resolution band widths are indicated in table 6 for the "operating" mode.

## 10 Testing of On Board Unit

### 10.1 Dynamic range

#### 10.1.1 Sensitivity

##### 10.1.1.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.2.1.2.

The description below assumes that an OBU is used to receive down-link signals and to generate up-link signals, both of type TM1. The test can be performed accordingly based on laboratory instruments, i.e. an RSU simulator, to generate down-link signals of type TS1 and messages of type TM1 and to receive and evaluate up-link signals of type TM1.

NOTE: The provider may extend the test in order to determine the actual value of the upper power limit for communication.

##### 10.1.1.2 Radiated measurements

The following procedural step shall apply:

- 1) Prepare the test site according to clause 8.6.5.2.
- 2) If the provider declared a worst case direction, position the OBU such that this worst case direction points towards the phase centre of the RTA.
- 3) Set the SMS1 such that it continuously transmits test signal TS1.
- 4) Set the carrier frequency  $f_{Tx}$  of SMS1 defined for channel 1 according to table 2 and clause 6.6.

- 5) Set the modulation index of the signal transmitted by the SMS1 to 0,5 or to the smallest possible value within the allowed range of 0,5 to 0,9 supported by the SMS1.
- 6) Replace the OBU receiver by a RSA of gain  $G_{\text{RSA}}$  such that their phase centres and bore sights coincide. Connect the RSA to a power meter PM1.
- 7) Adjust the output signal power of the SMS1 such that the signal power indicated by the power meter PM1 amounts to:

$$P_{\text{RSA}} = P_{\text{ref}} \times G_{\text{RSA}} \times \left(1 - |\rho_{\text{RSA}}|^2\right),$$

where  $\rho_{\text{RSA}}$  denotes the reflection coefficient at the connector of the RSA.

- 8) Replace RSA by the OBU receiver.
- 9) Measure BER of the OBU receiver according to clause 8.9. If the BER is larger than  $10^{-6}$  the test failed.
- 10) Repeat steps 6 through 9 for the carrier frequency  $f_{\text{Tx}}$  defined for channel 4 according to table 2 and clause 6.6.
- 11) If the provider declared a worst case direction, the test is finished. Otherwise repeat steps 4 through 10 for the four remaining orientations M1, M2, M3 and M4 of the OBU according to figure 1.

### 10.1.1.3 Conducted measurements

The following procedural step shall apply:

- 1) Prepare the test site according to clause 8.5.4.2.
- 2) If the provider declared a worst case direction, set a correction gain  $G_{\text{corr}}$  equal to the gain of the OBU receive antenna in the worst case direction as declared by the provider. Otherwise set  $G_{\text{corr}}$  equal to the maximum gain of the OBU receive antenna as declared by the provider.
- 3) Set the SMS1 such that it continuously transmits test signal TS1.
- 4) Set the carrier frequency  $f_{\text{Tx}}$  of SMS1 defined for channel 1 according to table 2 and clause 6.6.
- 5) Set the modulation index of the signal transmitted by the SMS1 to 0,5 or to the smallest possible value within the allowed range of 0,5 to 0,9 supported by the SMS1.
- 6) Replace the OBU receiver by a power meter PM1.
- 7) Adjust the output signal power of the SMS1 such that the signal power indicated by the power meter PM1 equals the  $P_{\text{ref}}$  in dBm plus the gain  $G_{\text{corr}}$  in dB.
- 8) Replace PM1 by the OBU receiver.
- 9) Measure BER of the OBU receiver according to clause 8.9. If the BER is larger than  $10^{-6}$  the test failed.
- 10) Repeat steps 6 through 9 for the carrier frequency  $f_{\text{Tx}}$  defined for channel 4 according to table 2 and clause 6.6.
- 11) If the provider declared a worst case direction, the test is finished. Otherwise repeat steps 4 through 10 for the four remaining orientations M1, M2, M3 and M4 of the OBU according to figure 1, where for each orientation  $G_{\text{corr}}$  takes on the corresponding value as declared by the provider.

## 10.1.2 Upper power limit for communication

### 10.1.2.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.2.1.3.

The description below assumes that a RSU is used to transmit down-link signals and to receive up-link signals, both of type TM1. The test can be performed accordingly based on laboratory instruments.

NOTE: The provider may extend the test in order to determine the actual value of the upper power limit for communication.

### 10.1.2.2 Radiated measurements

The following procedural step shall apply:

- 1) Prepare the test site according to clause 8.6.5.2.
- 2) Set the SMS1 such that it continuously transmits test signal TS1.
- 3) Set the carrier frequency  $f_{Tx}$  of SMS1 defined for channel 1 according to table 2 and clause 6.6.
- 4) Set the modulation index of the signal transmitted by the SMS1 to 0,9 or to the greatest possible value within the allowed range of 0,5 to 0,9 supported by the SMS1.
- 5) Replace the OBU receiver by a RSA such that their phase centres and bore sights coincide. Connect the RSA to a power meter PM1.
- 6) Adjust the output signal power of the SMS1 such that the signal power  $P_{RSA}$  measured by the power meter PM1 amounts to:

$$P_{RSA} = P_{inc} \times G_{RSA} \times \left( 1 - |\rho_{RSA}|^2 \right),$$

where  $P_{inc}$ , and  $\rho_{RSA}$  denote, respectively, the maximum allowed value according to table 7 converted to Watt, and the reflection coefficient at the connector of the RSA.

- 7) Replace RSA by the OBU receiver.
- 8) Measure BER of the OBU receiver according to clause 8.9. If the BER is larger than  $10^{-6}$  the test failed.
- 9) Repeat steps 5 through 8 for the carrier frequency  $f_{Tx}$  defined for channel 4 according to table 2 and clause 6.6.

### 10.1.2.3 Conducted measurements

The following procedural step shall apply:

- 1) Prepare the test site according to clause 8.5.4.2.
- 2) Set the SMS1 such that it continuously transmits test signal TS1.
- 3) Set the carrier frequency  $f_{Tx}$  of SMS1 defined for channel 1 according to table 2 and clause 6.6.
- 4) Set the modulation index  $m$  of the signal transmitted by the SMS1 to 0,9 or to the greatest possible value within the allowed range of 0,5 to 0,9 supported by the SMS1.
- 5) Replace the OBU receiver by a power meter PM1.
- 6) Adjust the output signal power of the SMS1 such that the signal power indicated by the power meter PM1 equals the sum of the maximum allowed value according to table 7 in dBm and the gain in dB of the OBU receive antenna as declared by the provider.
- 7) Replace PM1 by the OBU receiver.
- 8) Measure BER of the OBU receiver according to clause 8.9. If the BER is larger than  $10^{-6}$  the test failed.
- 9) Repeat steps 5 through 8 for the carrier frequency  $f_{Tx}$  defined for channel 4 according to table 2 and clause 6.6.

## 10.2 Cut-off power level

### 10.2.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.2.2.

The description below assumes that an RSU is used to receive up-link signals and to generate down-link signals, both of type TM1. The test can be performed accordingly based on laboratory instruments, i.e. an RSU simulator, to generate down-link messages of type TM1 and to receive and evaluate up-link signals of type TM1.

### 10.2.2 Radiated measurements

The following procedural step shall apply:

- 1) Prepare the test site according to clause 8.6.5.2.
- 2) Set the SMS1 such that it continuously transmits test message TM1, i.e. invites the OBU for initialization by sending BSTs.
- 3) Set the carrier frequency  $f_{Tx}$  of SMS1 defined for channel 1 according to table 2 and clause 6.6.
- 4) Set the modulation index  $m$  of the signal transmitted by the SMS1 to 0,9.
- 5) Replace the OBU receiver by an RSA of gain  $G_{RSA}$  such that their phase centres and bore sights coincide. Connect the RSA to a power meter PM1.
- 6) Adjust the output signal power of the SMS1 such that the signal power indicated by the power meter PM1 amounts to:

$$P_{RSA} = P_{inc} \times G_{RSA} \times \left( 1 - |\rho_{RSA}|^2 \right),$$

where  $P_{inc}$  equals -61 dBm converted to Watt, and  $\rho_{RSA}$  denotes the reflection coefficient at the connector of the RSA.

- 7) Switch off the SMS1.
- 8) Replace RSA by the OBU receiver and wait until the OBU is in sleep mode.
- 9) Switch on the SMS1.
- 10) Observe for the time needed for transmission of 100 subsequent BST messages whether the OBU responds with a VST. If a VST is received, the test failed.
- 11) Repeat steps 5 through 10 for the carrier frequency  $f_{Tx}$  defined for channel 4 according to table 2 and clause 6.6.

### 10.2.3 Conducted measurements

The following procedural step shall apply:

- 1) Prepare the test site according to clause 8.5.4.2.
- 2) Set the SMS1 such that it continuously transmits test message TM1, i.e. invites the OBU for initialization by sending BSTs.
- 3) Set the carrier frequency  $f_{Tx}$  of SMS1 defined for channel 1 according to table 2 and clause 6.6.
- 4) Set the modulation index  $m$  of the signal transmitted by the SMS1 to 0,9.

- 5) Replace the OBU receiver by a power meter PM1.
- 6) Adjust the output signal power of the SMS1 such that the signal power indicated by the power meter PM1 equals the sum of -61 dBm plus the maximum gain in dB of the OBU receive antenna as declared by the provider.
- 7) Switch off the SMS1.
- 8) Replace PM1 by the OBU receiver and wait until the OBU is in sleep mode.
- 9) Switch on the SMS1.
- 10) Observe for the time needed for transmission of 100 subsequent BST messages whether the OBU responds with a VST. If a VST is received, the test failed.
- 11) Repeat steps 5 through 10 for the carrier frequency  $f_{Tx}$  defined for channel 4 according to table 2 and clause 6.6.

## 10.3 Conversion gain

### 10.3.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.2.3.

### 10.3.2 Radiated measurement

The test procedure is as follows:

- 1) Prepare the test site according to clause 8.6.5.1. The initial alignment of the OBU as needed in step 4 shall be according to M0 in figure 1, i.e. the bore sight of the OBU antenna shall point towards the phase centre of the TA.
- 2) Switch on the MSS1, tune its frequency to the carrier frequencies  $f_{Tx}$  defined for channel 1 according to table 2 and clause 6.6.
- 3) Adjust the output power of the MSS1 such that the power  $P_{RSA}$  measured by the power meter PM1 amounts to:

$$P_{RSA} = P_{inc} \times G_{RSA} \times \left( 1 - |\rho_{RSA}|^2 \right),$$

where  $P_{inc}$ , and  $\rho_{RSA}$  denote, respectively, the minimum allowed incident signal power  $P_{D11b} = -43$  dBm as requested in clause 7.2.1.2, and the reflection coefficient at the connector of the RSA.

- 4) Replace the RSA by the OBU such that its phase centre  $M_c$  is as coincident with the axis of rotation of the turntable as possible. If the phase centre  $M_c$  of the OBU is unknown and no antenna is visible, the volume centre of the OBU shall be used instead. Align the OBU's bore sight as required.
- 5) Set the OBU to a test mode such that it re-transmits test signal TS2 with sub-carrier frequency  $f_s$ .
- 6) Measure the smaller of the power levels  $P_{ssb}$  within the two side bands by the RD with a RBW of 100 kHz and report this value together with the value of  $f_s$  and  $f_{Tx}$  and the orientation  $M_i$ ,  $i = 0 \dots 4$ , see figure 1.
- 7) Repeat step 6 for the other value of the sub-carrier frequency  $f_s$ .
- 8) Repeat steps 3 through 7 for the carrier frequency  $f_{Tx}$  defined for channel 4 according to table 2 and clause 6.6.



- 9) Repeat steps 2 through 8 for all remaining OBU orientations  $M_i$  as indicated in figure 1.
- 10) Replace the OBU by a LHCP calibrated TSA of gain  $G_{TSA}$  and reflection coefficient  $\rho_{TSA}$  at its connector suited for the range of carrier frequencies  $f_{Tx}$  listed in table 2 in such a way that its phase centre coincides with the one of the OBU transmitting antenna. If the measurement arrangement with one test antenna is used, the bore sight of the TSA shall point towards the phase centre of the TTA. If the measurement arrangement with two test antennas is used, bore sight of the TSA shall point towards position  $M_{centre}$ .
- 11) Connect the output of the TSA via the optional balun BLN, if required, of feed through attenuation  $ATN_{BLN}$ , and the calibrated FCCA1 of feed through attenuation  $ATN_{CA1}$  to a calibrated MSS2 that shall be tuned to the frequency which is the sum of the carrier frequency  $f_{Tx}$  as set in step 2 and the sub-carrier frequency  $\pm f_s$  as set in step 5. The sign of the sub-carrier frequency is defined by the side band, which provided the smaller of the two power levels  $P_{ssb}$  in step 6.
- 12) Adjust the output signal level  $P_{MSS2}$  of the MSS2 until the level, measured on the RD, becomes identical to the corresponding value of  $P_{ssb}$  recorded in step 6. Calculate the retransmitted power:

$$P_{reTx} = \frac{P_{MSS2} \times G_{TSA} \times \left(1 - |\rho_{TSA}|^2\right)}{ATN_{CA1} \times ATN_{BLN}},$$

where all the parameters in the above formula are related to the corresponding measurement frequencies, and report it together with the value of  $f_s$  and  $f_{Tx}$ .

- 13) Repeat step 12 for all remaining combinations of  $f_s$  and  $f_{Tx}$  for which a result is available from step 6.
- 14) The conversion gain  $G_c$  of the OBU shall be calculated by:

$$G_c = \frac{P_{reTx}}{P_{inc}}$$

None of the calculated conversion gains shall be outside the limits stated in clause 7.2.3.

### 10.3.3 Conducted measurement

The test procedure is as follows:

- 1) Prepare the test site according to clause 8.5.4.1. With regard to the gain of the OBU's receive and transmit antenna, the initial alignment of the OBU as needed in step 4 is assumed to be according to direction M0 in figure 1.
- 2) Tune the frequency of the MSS1's output signal to the carrier frequencies  $f_{Tx}$  defined for channel 1 according to table 2 and clause 6.6.
- 3) Replace the OBU receiver by a power meter PM1.
- 4) Adjust the output power of the MSS1 such that the power measured by the power meter PM1 matches the minimum allowed incident signal power  $P_{inc,dBm} = P_{D11b} = -43$  dBm as requested in clause 7.2.1.2 increased by the maximum gain  $G_{OBU,Rx}(M_i)$  of the OBU receive antenna, i.e. in direction  $M_i$ ,  $i = 0 \dots 4$ , according to figure 1, as declared by the provider.
- 5) Replace the power meter PM1 by the OBU receiver.
- 6) Set the OBU to a test mode such that it re-transmits test signal TS2 with sub-carrier frequency  $f_s$ .
- 7) Measure the smaller of the power levels  $P_{ssb}$  within the two side bands by the RD with a RBW of 100 kHz taking into account all losses the signal suffers between the output connector of the OBU and the input connector of the RD and report this value together with the value of  $f_s$  and  $f_{Tx}$ .

- 8) The retransmitted power  $P_{\text{reTx}}$  of the OBU shall be calculated by:

$$P_{\text{reTx}}(\text{Mi}) = P_{\text{ssb}} \times G_{\text{OBU,Tx}}(\text{Mi}),$$

where  $G_{\text{OBU,Tx}}(\text{Mi})$  is the OBU's transmit antenna gain in the direction Mi.

- 9) Repeat steps 7 and 8 for the other value of the sub-carrier frequency  $f_s$ .
- 10) Repeat steps 3 through 9 for the carrier frequency  $f_{\text{Tx}}$  defined for channel 4 according to table 2 and clause 6.6.
- 11) Repeat steps 2 through 10 for all remaining OBU orientations Mi as indicated in figure 1.
- 12) The conversion gain  $G_c(\text{Mi})$  of the OBU shall be calculated by:

$$G_c(\text{Mi}) = \frac{P_{\text{reTx}}(\text{Mi})}{P_{\text{inc}}}$$

None of the calculated conversion gains  $G_c(\text{Mi})$  shall be outside the limits stated in clause 7.2.3.

## 10.4 Maximum equivalent isotropically radiated power

### 10.4.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.2.4.

Measurement shall be conducted with the reference incident power  $P_{\text{inc}}$  set equal to the maximum incident signal power  $P_{\text{D11a}}$  according to parameter D11a of prEN 12253 [2], see table 7.

In order to identify the incident signal power  $P_{\text{inc}}$  at which maximum e.i.r.p. occurs, a scanning procedure shall be performed. The measurement shall be repeated at this value  $P_{\text{inc}} = P_{\text{inc,scan}}$  of the incident signal power and the result shall be reported together with this incident signal power.

The conversion gain shall be adjusted to the maximum possible value, if applicable.

NOTE: This test implicitly tests the CEN parameter U12b, i.e. the upper limit of the OBU conversion gain.

### 10.4.2 Radiated measurement

The test procedure is as follows:

- 1) Prepare the test site according to clause 8.6.5.1. The initial alignment of the OBU as needed in step 4 shall be according to M0 in figure 1, i.e. the bore sight of the OBU antenna shall point towards the phase centre of the TA.
- 2) Switch on the monochromatic output signal of the MSS1, tune it to the carrier frequency  $f_{\text{Tx}}$  defined for channel 1 according to table 2 and clause 6.6.
- 3) Adjust the output power of the MSS1 such that the power  $P_{\text{RSA}}$  measured by the power meter PM1 amounts to:

$$P_{\text{RSA}} = P_{\text{inc}} \times G_{\text{RSA}} \times \left(1 - |\rho_{\text{RSA}}|^2\right),$$

where  $P_{\text{inc}}$ , and  $\rho_{\text{RSA}}$  denote, respectively, the reference incident signal power as requested in table 7, and the reflection coefficient at the connector of the RSA.

- 4) Replace the RSA by the OBU such that its phase centre  $M_c$  is as coincident with the axis of rotation of the turntable as possible. If the phase centre  $M_c$  of the OBU is unknown and no antenna is visible, the volume centre of the OBU shall be used instead. Align the OBU's bore sight as required.
- 5) Set the OBU to a test mode such that it re-transmits test signal TS2 with sub-carrier frequency  $f_s$ .
- 6) Measure the larger of the power levels  $P_{\max}$  within the two side bands by the RD using a RBW of 100 kHz and report this value of  $P_{\max}$  together with the orientation of the OBU  $M_i$ ,  $i = 0 \dots 4$ , and the values of  $f_s$  and  $f_{Tx}$ .
- 7) Repeat step 6 for the other value of the sub-carrier frequency  $f_s$ .
- 8) Repeat steps 3 through 7 for the carrier frequency  $f_{Tx}$  defined for channel 4 according to table 2 and clause 6.6.
- 9) In case of a Set B OBU proceed with step 10, otherwise continue with step 11.
- 10) Repeat steps 1 through 8 for all remaining OBU orientations as indicated by M1, M2, M3, and M4 in figure 1 in order to measure the CEN parameter U4a.
- 11) Replace the OBU by a LHCP calibrated TSA of gain  $G_{TSA}$  and reflection coefficient  $\rho_{TSA}$  at its connector suited for the range of carrier frequencies  $f_{Tx}$  listed in table 2 in such a way that its phase centre coincides with the one of the OBU transmitting antenna. If the measurement arrangement with one test antenna is used, the bore sight of the TSA shall point towards the phase centre of the TTA. If the measurement arrangement with two test antennas is used, bore sight of the TSA shall point towards position  $M_{\text{centre}}$ .
- 12) Connect the output of the TSA via the optional balun BLN, if required, of feed through attenuation  $ATN_{BLN}$ , and the calibrated, FCCA1 of feed through attenuation  $ATN_{CA1}$  to a calibrated MSS2 that shall be tuned to the frequency which is the sum of the carrier frequency  $f_{Tx}$  and the (signed) sub-carrier frequency  $f_s$  reported as a set together with the OBU orientation in step 6.
- 13) Adjust the output signal level of the MSS2 until the level, measured on the RD, becomes identical to  $P_{\max}$  recorded in step 6 for this set of values of  $f_{Tx}$ ,  $f_s$  and  $M_i$ . This output signal level  $P_{MSS2}$  from the MSS2 shall be reported.
- 14) The e.i.r.p. of the OBU shall be calculated by:

$$EIRP_{\text{OBU}} = \frac{P_{\text{MSS2}} \times G_{\text{TSA}} \times \left(1 - |\rho_{\text{TSA}}|^2\right)}{ATN_{\text{CA1}} \times ATN_{\text{BLN}}},$$

where all the parameters in the above formula are related to the corresponding measurement frequencies. The result shall not exceed the limit stated in table 8.

- 15) Repeat steps 12 through 14 for all remaining sets of values of  $f_{Tx}$ ,  $f_s$  and  $M_i$ .

### 10.4.3 Conducted measurement

The test procedure is as follows:

- 1) Prepare the test site according to clause 8.5.4.1.
- 2) Tune the frequency of the MSS1's output signal to the carrier frequencies  $f_{Tx}$  defined for channel 1 according to table 2 and clause 6.6.
- 3) Replace the OBU receiver by a power meter PM1.
- 4) Adjust the output power of the MSS1 such that the power measured by PM1 matches the reference incident power as indicated in table 7 increased by the gain of the OBU receive antenna as declared by the provider.
- 5) Replace PM1 by the OBU receiver.

- 6) Set the OBU to a test mode such that it re-transmits test signal TS2 with sub-carrier frequency  $f_s$ .
- 7) Measure the signal power within each of the two side bands by the RD using a RBW of 100 kHz and compute the corresponding signal power at the connector of the OBU's transmitting antenna taking into account all losses the signal suffers between the output connector of the OBU and the input connector of the RD. Report the larger of these two values, the power  $P_{\max}$ .
- 8) Repeat step 7 for the other sub-carrier frequency.
- 9) Repeat steps 3 through 8 for the carrier frequency  $f_{Tx}$  defined for channel 4 according to table 2 and clause 6.6.
- 10) Compute the corresponding e.i.r.p. for all the power levels  $P_{\max}$  recorded within step 7 into the test report using the equation:

$$EIRP_{OBU} = P_{\max} \times G_{OBU,Tx}(Mi)$$

where  $G_{OBU,Tx}(Mi)$  denotes the gain of the OBU transmitting antenna in the directions M0 through M5 as indicated in figure 1. None of the results shall exceed the limit stated in table 8. In case of a Set A OBU only direction M0 is applicable.

## 10.5 Frequency error

### 10.5.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.2.5.

### 10.5.2 Radiated measurements

The test procedure is as follows:

- 1) Prepare the test site according to clause 8.6.5.1.
- 2) Switch on the monochromatic output signal of the MSS1, tune it to the carrier frequencies  $f_{Tx}$  defined for channel 1 according to table 2 and clause 6.6 and adjust its output power to a level that produces an incident power at the location of the CA within the dynamic range of the OBU according to clause 7.2.1.
- 3) Replace the RSA by the OBU such that its phase centre  $Mc$  is as coincident with the axis of rotation of the turntable as possible. If the phase centre  $Mc$  of the OBU is unknown and no antenna is visible, the volume centre of the OBU shall be used instead. The bore sight of the OBU antenna shall point towards the phase centre of the TA.
- 4) Set the RBW of the RD used for frequency measurements to  $\leq 1$  kHz.
- 5) Set the OBU to a test mode with test signal TS2 and with sub-carrier frequency  $f_s$ .
- 6) Connect temporarily the output of the MSS1 to the RD and measure and report the actual carrier frequency  $f_{Tx,actual}$  of the down-link radio signal. Reconnect the output of the MSS1.
- 7) Measure with the RD the actual centre frequency  $f_{ObuTx}$  of the up-link radio signal in one of the two side bands as convenient.

- 8) Calculate the actual sub-carrier frequency error  $\Delta f_s = \frac{|f_{ObuTx} - f_{Tx,actual}|}{f_s} - 1$  and convert the value to percent.

The actual value shall not exceed the limit stated in clause 7.2.5.

- 9) Repeat steps 6 through 8 for the other sub-carrier frequency  $f_s$ .

## 10.5.3 Conducted measurements

The test procedure is as follows:

- 1) Prepare the test site according to clause 8.5.4.1.
- 2) Tune the frequency of the MSS1's output signal to the carrier frequencies  $f_{Tx}$  defined for channel 1 according to table 2 and clause 6.6.
- 3) Replace the OBU receiver by a power meter PM1.
- 4) Adjust the output power of the MSS1 such that the power measured by PM1 is within the dynamic range of the OBU according to clause 7.2.1 reduced by the gain of the OBU receive antenna as declared by the provider.
- 5) Replace PM1 by the OBU receiver.
- 6) Set the RBW of the RD used for frequency measurements to  $\leq 1$  kHz.
- 7) Set the OBU to a test mode with test signal TS2 and with sub-carrier frequency  $f_s$ .
- 8) Connect temporarily the output of the MSS1 to the RD and measure and report the actual carrier frequency  $f_{Tx,actual}$  of the down-link radio signal. Reconnect the output of the MSS1.
- 9) Measure with the RD the actual centre frequency  $f_{ObuTx}$  of the up-link radio signal in one of the two side bands as convenient.
- 10) Calculate the actual sub-carrier frequency error  $\Delta f_s = \frac{|f_{ObuTx} - f_{Tx,actual}|}{f_s} - 1$  and convert the value to percent.  
The actual value shall not exceed the limit stated in clause 7.2.5.
- 11) Repeat steps 8 through 11 for the other sub-carrier frequency  $f_s$ .

## 10.6 Transmitter spectrum mask

### 10.6.1 General

This test shall be performed either with radiated or conducted measurements.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.2.6.

For this test, the incident signal power  $P_{inc}$  shall be adjusted such that the power measured in the test is maximum. A suitable value for  $P_{inc}$  is the value  $P_{inc,scan}$  as evaluated in clause 10.4.

**Table 12: Offset frequencies and RBW for testing OBU Tx spectrum mask**

$f_{offset}$ / MHz	-1	+1	-1,5	+1,5	-2	+2	-3	+3	-3,5	+3,5	-4	+4	-6,5	+6,5	-7	+7
<b>RBW</b>	30 kHz		100 kHz						30 kHz		100 kHz					

### 10.6.2 Radiated measurements

The test procedure is as follows:

- 1) Prepare the test site according to clause 8.6.5.1.
- 2) Switch on the monochromatic output signal of the MSS1, tune it to the carrier frequency  $f_{Tx}$  defined for channel 1 according to table 2 and clause 6.6.

- 3) Adjust the output power of the MSS1 such that the power  $P_{\text{RSA}}$  measured by the power meter PM1 amounts to:

$$P_{\text{RSA}} = P_{\text{inc}} \times G_{\text{RSA}} \times \left(1 - |\rho_{\text{RSA}}|^2\right),$$

where  $P_{\text{inc}}$ , and  $\rho_{\text{RSA}}$  denote, respectively, the incident signal power as requested in clause 10.6.1, and the reflection coefficient at the connector of the RSA.

- 4) Replace the RSA by the OBU such that its phase centre  $M_c$  is as coincident with the axis of rotation of the turntable as possible. If the phase centre  $M_c$  of the OBU is unknown and no antenna is visible, the volume centre of the OBU shall be used instead. The bore sight of the OBU antenna shall point towards the phase centre of the TA.
- 5) Set the RD to its CW mode, also called zero span mode of operation, where the instrument is not sweeping across a frequency band.
- 6) The OBU shall be operated with sub-carrier frequency  $f_s$  in a test mode such that it transmits the test signal TS1.
- 7) Select one of the offset frequencies  $f_{\text{offset}}$  from table 12. An absolute value of the offset frequency equal to the value of the actually used sub-carrier frequency  $f_s$ , e.g.  $f_{\text{offset}} = \pm 1,5$  MHz or  $f_{\text{offset}} = \pm 2,0$  MHz, is invalid for this test. If  $f_{\text{offset}}$  amounts to either  $\pm 1$  MHz or  $\pm 4$  MHz, proceed with step 8, otherwise proceed with step 13.
- 8) Set the centre frequency  $f_c$  of the RD to  $f_c = f_{\text{Tx}} + f_{\text{offset}} - RBW/2$  and select  $RBW$  according to table 12.
- 9) Measure the signal power  $P_1$  from the RD and report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ .
- 10) Set the centre frequency  $f_c$  of the RD to  $f_c = f_{\text{Tx}} + f_{\text{offset}} + RBW/2$  and select  $RBW$  according to table 12.
- 11) Measure the signal power  $P_2$  from the RD and report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ .
- 12) Determine the total signal power  $P_{\text{tot}}$  by summing up the two signal power values as  $P_{\text{tot}} = P_1 + P_2$ , and compute the power  $P_{\text{tot,dBm}}$  in dBm as  $P_{\text{tot,dBm}} = 10 \times \lg(P_{\text{tot}}/P_0)$ . Report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ . Proceed with step 19.
- 13) Set the centre frequency  $f_c$  of the RD to its initial value  $f_c = f_{\text{Tx}} + f_{\text{offset}} - 2 \cdot RBW$ , select  $RBW$  according to table 12 and set the counter  $i = 1$ .
- 14) Measure the signal power  $P_i$  from the RD and report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ .
- 15) Increase the value of the counter by 1. When the counter equals 6, proceed with step 18, otherwise proceed with step 16.
- 16) Increase the centre frequency  $f_c$  of the RD by  $RBW$  and measure the signal power  $P_i$  from the RD and record its value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$  in the test report.
- 17) Repeat steps 15 and 16.
- 18) Determine the total signal power  $P_{\text{tot}}$  by summing up five signal power values as  $P_{\text{tot}} = P_1 + P_2 + P_3 + P_4 + P_5$  and compute the total power  $P_{\text{tot,dBm}}$  in dBm as  $P_{\text{tot,dBm}} = 10 \times \lg(P_{\text{tot}}/P_0)$ . Report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ .
- 19) Repeat steps 7 through 19 until the whole sequence of offset frequencies listed in table 12 have been processed.
- 20) Repeat steps 7 through 19 once for the other sub-carrier frequency  $f_s$ .

- 21) Repeat steps 1 through 20 for the carrier frequency  $f_{Tx}$  defined for channel 4 according to table 2 and clause 6.6.
- 22) For a specific combination of carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$  the maximum value of all  $P_{tot}$  reported for different sub-carrier frequencies  $f_s$  shall apply for the subsequent evaluation.
- 23) Replace the OBU by a LHCP calibrated TSA of gain  $G_{TSA}$  and reflection coefficient  $\rho_{TSA}$  at its connector suited for the range of carrier frequencies  $f_{Tx}$  listed in table 2 in such a way that its phase centre coincides with the one of the OBU transmitting antenna. If the measurement arrangement with one test antenna is used, the bore sight of the TSA shall point towards the phase centre of the TTA. If the measurement arrangement with two test antennas is used, bore sight of the TSA shall point towards position  $M_{centre}$ .
- 24) Connect the output of the TSA via the optional balun BLN, if required, of feed through attenuation  $ATN_{BLN}$ , and the calibrated FCCA1 of feed through attenuation  $ATN_{CA1}$  to a calibrated MSS2.
- 25) Tune the frequency of the MSS2's output signal to the frequency  $f_c = f_{Tx} + f_{offset}$ , where  $f_{Tx}$  is according to clause 6.6 and  $f_{offset}$  shall be according to table 12.
- 26) Rotate the TSA through  $360^\circ$  until the maximum level is detected by the RD.
- 27) Adjust the output signal level  $P_{MSS2}$  of the MSS2 until the level, measured on the RD, becomes identical to  $P_{tot}$  as reported in step 22 at the same combination of carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ . This output signal level  $P_{MSS2}$  from the MSS2 shall be reported together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ .
- 28) Repeat steps 25 through 27 for all remaining combinations of carrier frequencies  $f_{Tx}$  and offset frequencies  $f_{offset}$ .
- 29) The TSM at this combination of carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ , expressed as an e.i.r.p. of the OBU shall be calculated by:

$$EIRP_{TSM} = \frac{P_{MSS2} \times G_{TSA} \times \left(1 - |\rho_{TSA}|^2\right)}{ATN_{CA1} \times ATN_{BLN}},$$

where all the parameters in the above formula are related to the corresponding measurement frequencies. The result shall be reported together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ . It shall not exceed the limit stated in clause 7.2.6.

### 10.6.3 Conducted measurements

The test procedure is as follows:

- 1) Prepare the test site according to clause 8.5.4.1.
- 2) Tune the frequency of the MSS1's output signal to the carrier frequency  $f_{Tx}$  defined for channel 1 according to table 2 and clause 6.6.
- 3) Replace the OBU receiver by a power meter PM1.
- 4) Adjust the output power of the MSS1 such that the power measured by PM1 matches the incident power as indicated in clause 10.6.1 increased by the gain of the OBU receive antenna as declared by the provider.
- 5) Replace PM1 by the OBU receiver.
- 6) Set the RD to its CW mode, also called zero span mode of operation, where the instrument is not sweeping across a frequency band.
- 7) The OBU shall be operated with sub-carrier frequency  $f_s$  in a test mode such that it transmits the test signal TS1.

- 8) Select one of the offset frequencies  $f_{\text{offset}}$  from table 12. An absolute value of the offset frequency equal to the value of the actually used sub-carrier frequency  $f_s$ , e.g.  $f_{\text{offset}} = \pm 1,5$  MHz or  $f_{\text{offset}} = \pm 2,0$  MHz, is invalid for this test. If  $f_{\text{offset}}$  amounts to either  $\pm 1$  MHz or  $\pm 4$  MHz, proceed with step 9, otherwise proceed with step 14.
- 9) Set the centre frequency  $f_c$  of the RD to  $f_c = f_{\text{Tx}} + f_{\text{offset}} - RBW/2$  and select  $RBW$  according to table 12.
- 10) Measure the signal power  $P_1$  from the RD taking into account all losses the signal suffers between the output connector of the OBU and the input connector of the RD and report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ .
- 11) Set the centre frequency  $f_c$  of the RD to  $f_c = f_{\text{Tx}} + f_{\text{offset}} + RBW/2$  and select  $RBW$  according to table 12.
- 12) Measure the signal power  $P_2$  from the RD taking into account all losses the signal suffers between the output connector of the OBU and the input connector of the RD and report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ .
- 13) Determine the total signal power  $P_{\text{tot}}$  by summing up the two signal power values as  $P_{\text{tot}} = P_1 + P_2$ , and compute the power  $P_{\text{tot,dBm}}$  in dBm as  $P_{\text{tot,dBm}} = 10 \times \lg(P_{\text{tot}}/P_0)$ . Report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ . Proceed with step 20.
- 14) Set the centre frequency  $f_c$  of the RD to its initial value  $f_c = f_{\text{Tx}} + f_{\text{offset}} - 2 \cdot RBW$ , select  $RBW$  according to table 12 and set the counter  $i = 1$ .
- 15) Rotate the OBU through  $360^\circ$  in the horizontal plane until signal power detected by the RD reaches its maximum value  $P_i$ . Record this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$  in the test report.
- 16) Increase the value of the counter by 1. When the counter equals 6, proceed with step 19, otherwise proceed with step 17.
- 17) Increase the centre frequency  $f_c$  of the RD by  $RBW$  and measure the signal power  $P_i$  from the RD and record its value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$  in the test report.
- 18) Repeat steps 16 and 17.
- 19) Determine the total signal power  $P_{\text{tot}}$  by summing up five signal power values as  $P_{\text{tot}} = P_1 + P_2 + P_3 + P_4 + P_5$  and compute the total power  $P_{\text{tot,dBm}}$  in dBm as  $P_{\text{tot,dBm}} = 10 \times \lg(P_{\text{tot}}/P_0)$ . Report this value together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$ .
- 20) Repeat steps 8 through 19 until the whole sequence of offset frequencies listed in table 12 have been processed.
- 21) Repeat steps 8 through 20 once for the other sub-carrier frequency  $f_s$ .
- 22) Repeat steps 1 through 21 for the carrier frequency  $f_{\text{Tx}}$  defined for channel 4 according to table 2 and clause 6.6.
- 23) For a specific combination of carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$  the maximum value of all  $P_{\text{tot}}$  reported for different sub-carrier frequencies  $f_s$  shall apply for the subsequent evaluation.
- 24) Compute the signal power  $P_{\text{TSM}}$  associated with each carrier frequency  $f_{\text{Tx}}$  and each offset frequency  $f_{\text{offset}}$  from the corresponding signal power values  $P_{\text{tot}}$  considering all losses within the signal path between the RD and the connector of the OBU's transmitting antenna. Record all values of  $P_{\text{TSM}}$  together with the associated carrier frequency  $f_{\text{Tx}}$  and offset frequency  $f_{\text{offset}}$  in the test report.



- 25) The TSM for each combination of carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ , expressed as an e.i.r.p. of the OBU shall be calculated by:

$$EIRP_{TSM} = P_{TSM} \times G_{OBU,Tx}$$

where  $G_{OBU,Tx}$  denotes the maximum gain of the OBU transmitting antenna. It shall be understood that all parameter values are taken at the corresponding frequency  $f = f_{Tx} + f_{offset}$ . The result shall be reported together with the associated carrier frequency  $f_{Tx}$  and offset frequency  $f_{offset}$ . None of these values shall exceed the limit stated in clause 7.2.6.

## 10.7 Transmitter unwanted emissions

### 10.7.1 General

Independent of the environmental profile declared by the provider, this test shall be performed only under normal test conditions.

The test shall be performed either in an anechoic chamber or in an open area test site. The set up is illustrated in the following figures 18 and 19.

The test shall be performed with radiated measurements within all frequency bands as referred to as "operating state" in table 6 outside the exclusion band stated in clause 7.1.10.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.2.7.

For this test, the incident signal power  $P_{inc}$  shall be adjusted such that the power measured in the test is maximum. A suitable value for  $P_{inc}$  is the value  $P_{inc,scan}$  as evaluated in clause 10.4.

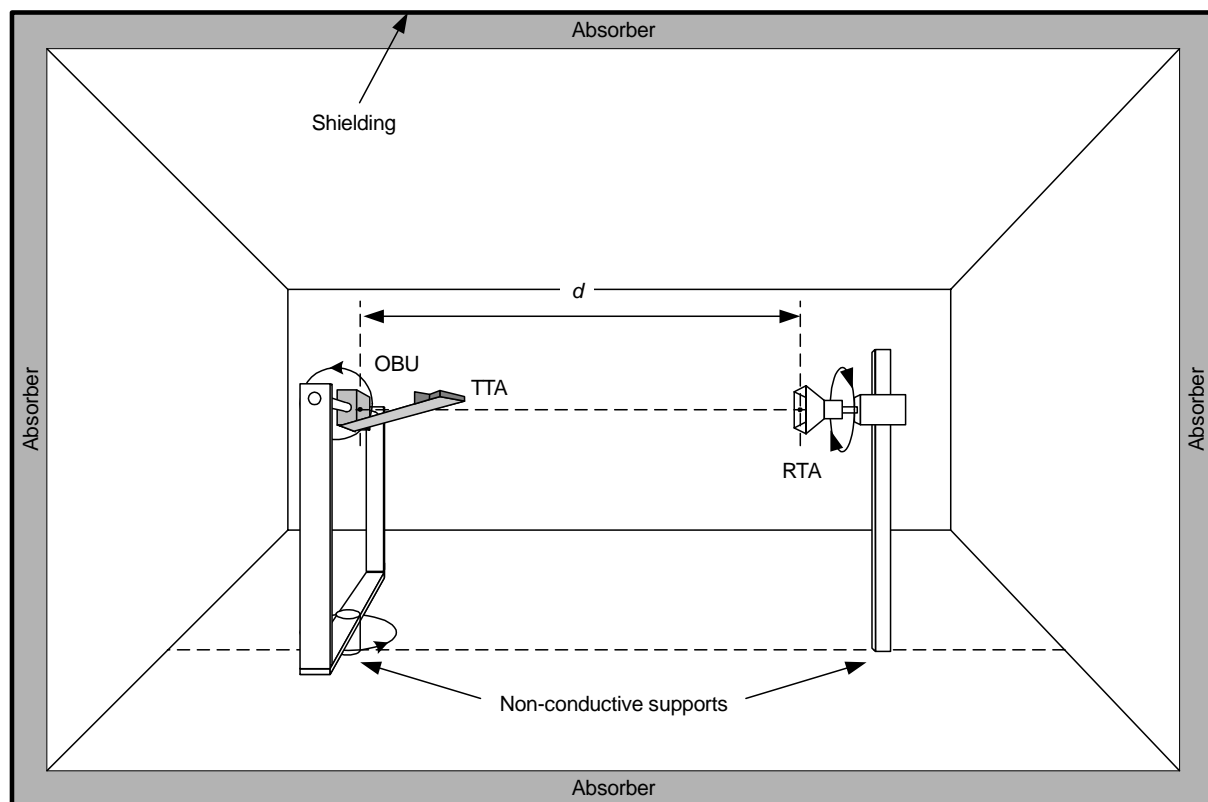


Figure 18: Test set up for OBU unwanted emission measurements (side view)

Figure 19 shows the turntable in its initial position MT0. MT1, MT2 and MT3 indicate the other angular positions used.

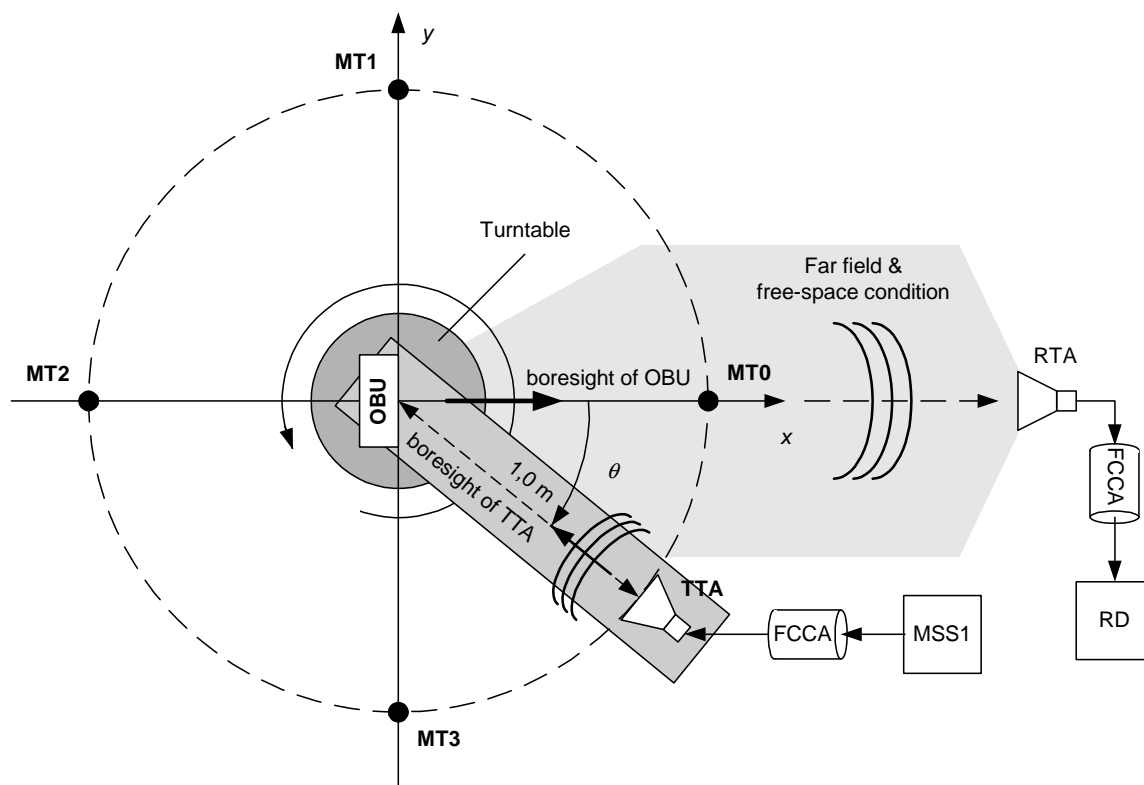


Figure 19: Test set up for OBU unwanted emission measurements (top view)

## 10.7.2 Radiated measurement

With reference to figures 18 and 19, the following test procedure shall apply for simultaneous spurious and out-of-band emissions radiated by the OBU transmit antenna.

- 1) The LHCP calibrated TTA and the OBU antenna shall be installed at fixed distance of 1,0 m with fixed orientation relative to each other on a support, which itself is mounted on a turntable. The bore sight of the TTA shall point towards the phase centre of the OBU antenna. The phase centre  $M_c$  of the OBU antenna shall be in the axis of the turntable. If the phase centre  $M_c$  of the OBU is unknown and no antenna is visible, the volume centre of the OBU shall be used instead. Bore sight of the OBU shall point to the phase centre of the RTA in case the turntable is in its initial angular position MT0 as shown in figure 19. The TTA shall be suited for the range of carrier frequencies  $f_{Tx}$  listed in table 2.
- 2) The vertical polarized calibrated RTA shall be dedicated to the frequency band actually under test. Different frequency bands shall be tested according to table 6. The RTA shall be mounted on a vertical pole. The distance from the RTA to the axis of the turntable shall be such as to allow for full  $360^\circ$  rotation of the turntable. The height of the phase centres above ground of the RTA and the OBU antenna shall be equal.
- 3) The distance between any part of the TTA, and OBU antenna, respectively, and the ceiling, floor or walls shall be at least 0,5 m.
- 4) Every antenna of this set up shall always be mutually in the far field of any other antenna of this set up.
- 5) The distance between any part of the RTA and the ceiling, floor or walls shall be at least half of the wavelength actually under test.
- 6) The RTA shall be connected to the input of a calibrated RD, i.e. spectrum analyser or measuring receiver, using a calibrated, ferrited coaxial cable. The RD shall be calibrated to the frequency to the actual frequency under test.

- 7) Replace the OBU by the TSA such that their phase centres, and bore sights coincide, respectively. Bore sight of the TSA shall point towards the phase centre of the RTA. The TSA shall be connected to a calibrated MSS2 using calibrated, ferrited coaxial cables. Polarization of the TSA shall match the one of the RTA.
- 8) Move the turntable to its initial angular position MT0 according to figure 19.
- 9) For all frequencies within the bands indicated in clause 7.1.10, see there table 6 for the operating state of the OBU and the exclusion band, adjust the output power of the MSS2 such that the e.i.r.p. of the TSA is equal to the limit for spurious and out-of-band emissions as indicated in table 6 for the operating state and measure the power at the RD with a RBW equal to the reference bandwidth as indicated in table 6. Report the power as a function of frequency in Watt measured at the RD for further usage as a limit line.
- 10) The TTA shall be connected to a calibrated MSS1 using calibrated, FCCA.
- 11) Switch on the monochromatic output signal of the MSS1, tune it to the carrier frequency  $f_{Tx}$  defined for channel 1 according to table 2 and clause 6.6.
- 12) The LHCP RSA of gain  $G_{RSA}$  shall be suited for the range of carrier frequencies  $f_{Tx}$  listed in table 2. Replace the TSA by the LHCP RSA such that their phase centres, and bore sights coincide, respectively. The output of the RSA shall be connected directly to the power sensor of power meter PM1 that shall be calibrated to the frequency of the monochromatic signal under consideration. Adjust the output power of the MSS1 such that the power  $P_{RSA}$  measured by the power meter PM1 amounts to:

$$P_{RSA} = P_{inc} \times G_{RSA} \times \left(1 - |\rho_{RSA}|^2\right),$$

where  $P_{inc}$ , and  $\rho_{RSA}$  denote, respectively, the incident signal power as requested in clause 10.7.1, and the reflection coefficient at the connector of the RSA.

- 13) Repeat step 1, which actually replaces the RSA by the OBU.
- 14) Select the first frequency band to be tested according to table 6.
- 15) Set the OBU to a test mode with test signal TS1 and with sub-carrier frequency  $f_s$ .
- 16) Move the turntable to its initial angular position MT0 according to figure 19.
- 17) The resolution bandwidth of the RD used to measure signal power shall be set equal to the reference bandwidth as indicated in table 6. Measure the power spectrum  $P_{pol}$ , i.e.  $P_{pol} = P_v$  in case of vertical polarized RTA and  $P_{pol} = P_h$  in case of horizontal polarized RTA, received by the RD and report the result for further processing in step 23. Repeat this step for all other angular positions MT1, MT2, MT3 of the turntable according to figure 19.
- 18) Repeat steps 16 and 17 once for the other sub-carrier frequency  $f_s$ .
- 19) Repeat steps 15 to 18 for the carrier frequency  $f_{Tx}$  defined for channel 4 according to table 2 and clause 6.6.
- 20) Repeat steps 14 through 19 for all frequency bands indicated in clause 7.1.10, see there table 6 for the operating state of the OBU and the exclusion band.
- 21) Rotate the RTA such that it is horizontally polarized, without changing position of its phase centre and bore sight orientation.
- 22) Repeat steps 14 through 20.
- 23) Compute the resulting power  $P_{spurious} = P_v + P_h$  and compare it with the limit line. If the power  $P_{spurious}$  exceeds the limit evaluated in step 9 for any frequency, the test failed.

## 10.8 Receiver spurious emissions

### 10.8.1 General

Independent of the environmental profile declared by the provider, this test shall be performed only under normal test conditions. Conducted measurements are not possible.

The test shall be performed with radiated measurements within all frequency bands as referred to as "stand-by state" in table 6 outside the exclusion band stated in clause 7.1.10.

The test shall be performed either in an anechoic chamber or in an open area test site. The set up is illustrated in figures 18 and 19.

Basic requirements and guidelines for measurements are provided in clause 8.

Parameter descriptions and limits are provided in clause 7.2.8.

### 10.8.2 Radiated measurement

With reference to figures 18 and 19, the test procedure for spurious and out-of-band emissions according to clause 10.7 shall apply with the following modifications:

- 1) There shall be no TTA and no MSS1. Thus statements on the carrier frequency  $f_{TX}$  shall not apply.
- 2) There shall be no RSA.
- 3) The OBU shall never transmit. Thus statements on sub-carrier frequency  $f_s$  shall not apply.
- 4) The OBU shall never be in the sleep mode.
- 5) The applicable limits and resolution band widths are indicated in table 6 for the "stand-by state" rather than for the "operating state".

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## 11 Interpretation of results and measurement uncertainty

### 11.1 Interpretation of results

The interpretation of the results recorded in the test report for the measurements described in the present document is the "shared risk" approach, and is defined in TR 100 028-2 [4] in its annexes B and C as follows:

- the measured value related to the corresponding limit shall be used to decide whether an equipment meets the requirements of the present document;
- the measurement uncertainty value for the measurement of each parameter shall be included in the test report;
- the recorded value of the measurement uncertainty shall be, for each measurement, equal to or lower than the figures of measurement uncertainty given in table 13.

### 11.2 Measurement uncertainty

The measurement uncertainty figures shall be calculated in accordance with TR 100 028 [4] and shall correspond to an expansion factor (coverage factor)  $k = 1,96$  which provides a confidence levels of 95 % in the case where the distributions characterizing the actual measurement uncertainties are normal (Gaussian).

The expansion factor used for the evaluation of the measurement uncertainty shall be stated in the test report.

The accumulated measurement uncertainties of the test system in use, for the parameters to be measured, shall not exceed those given in table 13, to ensure that the measurements remain within an acceptable standard.

**Table 13: Absolute measurement uncertainty**

<b>Parameter</b>	<b>Uncertainty</b>
RF power (conducted)	±4 dB
RF frequency, relative	±1 x 10 <sup>-7</sup>
Radiated emission of transmitter, valid to 40 GHz	±6 dB
Adjacent channel power	±5 dB
Sensitivity	±5 dB
Two and three signal measurements	±4 dB
Two and three signal measurements using radiated fields	±6 dB
Radiated emission of receiver, valid to 40 GHz	±6 dB
Temperature	±1 K
Relative humidity	±5%

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## History

<b>Document history</b>		
V1.1.1	February 1999	Publication as ES 200 674-1
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