

# **Draft VTS – Voluntary Testing Standard 2102**

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Static Indoor Mobile Phone Repeaters

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# Foreword

## Background

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- 1.1 In our statement, dated 4 November 2021 and entitled “Mobile Phone Repeaters” (the “**2021 Statement**”)<sup>1</sup>, we explained that we have decided to extend the range of static indoor repeaters available for people to buy and install themselves without a wireless telegraphy licence. In particular, we decided that it would be appropriate to allow the use of provider-specific repeaters and multi-operator repeaters.
- 1.2 In each case the repeaters must meet appropriate technical requirements specified by Ofcom. These technical requirements are set out in the Wireless Telegraphy (Mobile Repeater) (Exemption) Regulations 2022 (the “**Exemption Regulations**”) as amended by the Wireless Telegraphy (Mobile Repeater) (Exemption) (Amendment) Regulations 2024. They are also summarised in UK Interface Requirement [IR 2102.1 and IR 2102.3](#) (the “**Interface requirements**”), a copy of which is provided below.<sup>2</sup>
- 1.3 We also explained in the 2021 Statement that, to help the public identify static indoor repeaters that can be used ‘legally’ without a licence – rather than ‘illegal’ devices that risk causing interference – we also intend to publish on our website a list of mobile phone repeaters that we understand comply with the technical requirements of our licence exemption regime (“**Ofcom’s List**”).
- 1.4 To be clear, Ofcom does not endorse or approve particular repeater products. Ofcom’s List simply identifies devices that have been subjected to testing by an accredited test house to show they meet our technical requirements, using this voluntary testing standard. For the avoidance of doubt, we only include static indoor mobile phone repeaters on Ofcom’s List; we do not include in-vehicle repeaters which meet the technical requirements set out in IR 2102.2 in that list.

## Purpose of this document

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- 1.5 This document sets out Ofcom’s voluntary testing standard (referred to as the “**VTS**”). It is intended to provide guidance on the testing of static indoor mobile phone repeaters for the technical requirements in the Exemption Regulations. It is therefore relevant for the testing of provider-specific (including single-operator) and multi-operator mobile phone repeaters which operate in all or parts of the frequency bands listed in Table 1. As noted above, it is not relevant for the testing of in-vehicle repeaters. Readers should be advised that (i) successful testing in accordance with this VTS does not guarantee that a repeater device satisfies the technical requirements in the Exemption Regulations, and (ii) where there is not a test standard within this VTS for some of the applicable technical requirements (e.g., the requirement that a repeater not cause undue interference), those technical requirements must still be satisfied in order for that device to benefit from licence exemption in the UK.

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<sup>1</sup> [Statement: Mobile Phone Repeaters \(ofcom.org.uk\)](#)

<sup>2</sup> The Exemption Regulations set out the detail of the technical requirements in full and, in the event of any inconsistency between the Exemption Regulations and IR 2102, the Exemption Regulations shall take precedence.

**Table 1: Service frequency bands**

Direction of transmission	Frequency Bands
Uplink	700 (703-733 MHz) 800 (832-862 MHz) 900 (880-915 MHz) 1800 (1710-1785 MHz) 2100 (1920-1980 MHz)
Downlink	700 (758-788 MHz) 800 (791-821 MHz) 900 (925-960 MHz) 1800 (1805-1880 MHz) 2100 (2110-2170 MHz)

- 1.6 This VTS does not provide guidance on meeting the requirements of the [Radio Equipment Directive 2014/53/EU](#) or the [Radio Equipment Regulations 2017](#), the requirements of which are separate from the technical requirements set out in the Exemption Regulations.
- 1.7 Manufacturers are not required to follow the VTS in order to satisfy themselves that their equipment is compliant with the Exemption Regulations. It is however necessary should a device manufacturer wish for its device to be included on Ofcom's List. In particular, where a manufacturer is able to provide sufficient evidence to demonstrate that a mobile repeater device has been tested by an accredited test house in accordance with this VTS, we would expect to include this on Ofcom's List.<sup>3</sup>
- 1.8 This VTS should not be relied upon as legal advice or understood as modifying any legal obligations which may otherwise apply.
- 1.9 Ofcom makes no representation or warranty, express or implied, with respect to the information contained in the VTS and any liability is therefore expressly disclaimed.
- 1.10 Ofcom reserves the right to modify the VTS from time to time. If we do so, we may require devices on Ofcom's List to be removed from that list until such time as it can be demonstrated that they have been tested in accordance with the modified VTS.

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<sup>3</sup> Whether or not a particular device will be included in Ofcom's List is at Ofcom's discretion. Whilst confirmation that a device has been tested in accordance with the VTS by an accredited test house is a pre-condition of inclusion on Ofcom's List, Ofcom may seek assurance on other matters before a device is included on its website. For example, Ofcom would also expect to be satisfied that a device is compliant with other national regulatory requirements (for example, that it was designed and manufactured in accordance with the essential requirements in the Radio Equipment Regulations 2017).

# Minimum Technical Requirements

- 2.1 The technical requirements with which static mobile phone repeaters for indoor use must comply in order to be exempt from the requirement for a wireless telegraphy licence in the United Kingdom are set out in the Wireless Telegraphy (Mobile Repeater) (Exemption) Regulations 2022 as amended. A copy of the Exemption Regulations is available at <https://www.legislation.gov.uk/uksi/2022/595/contents/made>
- 2.2 We appreciate that some stakeholders may be accustomed to the style and format of Interface Requirements. To aid readers, we have therefore also published the minimum technical requirements for mobile repeaters in the format of Interface Requirements alongside the Exemption Regulations. A copy of IR 2102.1 and 2102.3 (which apply to static indoor mobile phone repeaters) is below. Readers should be advised that, to the extent that there is any inconsistency between the Interface Requirements and/or this VTS and the requirements in the Exemption Regulations, the Exemption Regulations shall take precedence.

## IR2102.1: Minimum requirements for the use of provider-specific static mobile phone repeaters for indoor use

**Table 2 : Mandatory (1-10) for use of provider-specific static mobile phone repeaters**

Mandatory (1-10)			
1	Radiocommunication Service	Mobile	
2	Application	Provider-specific static mobile phone repeaters for indoor use	
3	Frequency bands	700	703-733 MHz (Uplink) 758-788 MHz (Downlink)
		800	791-821 MHz (Downlink) 832-862 MHz (Uplink)
		900	880-915 MHz (Uplink) 925-960 MHz (Downlink)
		1800	1710-1785 MHz (Uplink) 1805-1880 MHz (Downlink)
		2100	1920-1980 MHz (Uplink) 2110-2170 MHz (Downlink)
4	Channelling	Not specified	
5	Modulation / Occupied bandwidth	Not specified	
6	Direction / Separation	Repeater transmit/receive	
7	Transmit power/Power density	See Table A1	

8	Channel access and occupation rules	<p><b>Transmit Gain Control</b></p> <p>The uplink and downlink system gain in dB of a repeater, referenced to its input and output ports, shall not exceed <math>BSCL-30</math>, where BSCL (base station coupling loss) is the path loss between the base station and the repeater. Where BSCL cannot be determined, the repeater must not transmit.</p> <p>The uplink and downlink system gain of a repeater shall not exceed 100 dB.</p> <p>The apparatus shall determine the value of BSCL by calculating the difference between the carrier power received at the repeater and the carrier power transmitted from the base station. The carrier power transmitted by the base station may be determined from the system information messages sent by the base station on its control channels.</p> <hr/> <p><b>Automatic Standby</b></p> <p>When the repeater is no longer serving an active connection between a mobile device operating on the network of a particular mobile network operator and that mobile network, it must, after no more than 5 minutes, reduce any uplink noise power associated with the frequencies licensed to that mobile network operator to no more than <math>-70</math> dBm/MHz EIRP.</p> <hr/> <p><b>Anti-Oscillation</b></p> <p>Repeaters must detect and stop (i.e. by automatic gain reduction or shut down) any oscillations in uplink and downlink frequency bands. Oscillation detection must occur automatically within:</p> <ul style="list-style-type: none"> <li>• 0.3 seconds in the uplink band; and</li> <li>• 1 second in the downlink band.</li> </ul> <p>In cases where oscillation is detected, the repeater must continue any anti-oscillation technique for at least one minute. After anti-oscillation techniques have been used five times, the repeater must cease transmitting and cannot resume operation until manually reset.</p>
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		<p><b>Provider Specific configuration</b></p> <p>Where a repeater is only capable of amplifying frequencies licensed to one mobile network operator at a time, the Transmit Power/Power Density and Transmit Gain Control requirements shall be calculated and applied individually for each uplink and downlink frequency band (as defined in Mandatory 3) that is being amplified by that repeater.</p> <p>Where a repeater is capable of amplifying frequencies licensed to more than one mobile network operator at the same time, those requirements shall be calculated and applied individually for each of the uplink and downlink frequency bands licensed to each mobile network operator that is being amplified by that repeater.</p>
		<p><b>Noise Figure</b></p> <p>The repeater system noise figure shall not exceed 7 dB.</p>
9	Additional essential requirements	Nil
10	Frequency planning assumptions	Not specified
Informative (11-14)		
11	Planned changes	Nil
12	Reference	EN 303 609 EN 301 908-11 EN 301 908-15
13	Remarks	Nil
14	Notification Number (in respect of Northern Ireland)	2021/7013/XI

<b>Table A1</b>			
<b>Band</b>	<b>Technology</b>	<b>Maximum Uplink Power</b>	<b>Maximum Downlink Power (indoor use only)</b>
700 & 800	Technology Neutral	23 dBm EIRP	PSD 10 dBm / 5 MHz EIRP; and Total 17 dBm EIRP
900	GSM	33 dBm EIRP	10 dBm EIRP
1800	GSM	30 dBm EIRP	10 dBm EIRP
900, 1800 & 2100	3G	24 dBm EIRP	PSD 10 dBm / 5 MHz EIRP; and Total 17 dBm EIRP
900 & 1800	Technology Neutral (excluding GSM and 3G)	23 dBm EIRP	PSD 10 dBm / 5 MHz EIRP; and Total 17 dBm EIRP
2100	Technology Neutral (excluding 3G)	24 dBm EIRP	PSD 10 dBm / 5 MHz EIRP; and Total 17 dBm EIRP
Where PSD is power spectral density			

### IR2102.3 Minimum requirements for the use of multi-operator static mobile phone repeaters for indoor use

**Table 3 : Mandatory (1-10) for use of multi-operator static mobile phone repeaters**

<b>Mandatory (1-10)</b>			
1	Radiocommunication Service	Mobile	
2	Application	Multi-operator static mobile phone repeaters for indoor use	
3	Frequency band	700	703-733 MHz (Uplink) 758-788 MHz (Downlink)
		800	791-821 MHz (Downlink) 832-862 MHz (Uplink)
		900	880-915 MHz (Uplink) 925-960 MHz (Downlink)
		1800	1710-1785 MHz (Uplink) 1805-1880 MHz (Downlink)
		2100	1920-1980 MHz (Uplink) 2110-2170 MHz (Downlink)



4	Channelling	Not specified	
5	Modulation / Occupied bandwidth	Not specified	
6	Direction / Separation	Repeater transmit/receive	
7	Transmit power/Power density	<b>Maximum Uplink Power for each Frequency Band</b>	17dBm/ 5 MHz EIRP
		<b>Maximum Downlink Power for each Frequency Band</b>	10dBm / 5 MHz EIRP (indoor use only)
8	Channel access and occupation rules	<p><b>Transmit Gain Control</b></p> <p>The uplink and downlink system gain in dB of a repeater, referenced to its input and output ports, shall not exceed 10-RSSI, where RSSI is the downlink composite received signal power in dBm at the repeater donor port, for all base stations in the band of operation.</p> <p>A repeater shall provide the same uplink and downlink system gain.</p> <p>The uplink and downlink system gain of a repeater shall not exceed 100 dB.</p>	
		<p><b>Automatic Standby</b></p> <p>When the repeater does not serve an active connection between a mobile device and a mobile network it must, after no more than 5 minutes, reduce any uplink noise power to no more than -70 dBm/MHz EIRP.</p>	
		<p><b>Anti-Oscillation</b></p> <p>Repeaters must detect and stop (i.e. by automatic gain reduction or shut down) any oscillations in uplink and downlink frequency bands. Oscillation detection must occur automatically within:</p> <ul style="list-style-type: none"> <li>• 0.3 seconds in the uplink band; and</li> <li>• 1 second in the downlink band.</li> </ul> <p>In cases where oscillation is detected, the repeater must continue any anti-oscillation technique for at least one minute. After anti-oscillation techniques have been used five times,</p>	

		the repeater must cease transmitting and cannot resume operation until manually reset.
		<b>Noise Figure</b> The repeater system noise figure shall not exceed 7dB.
		<b>Intermodulation due to signals within the frequency band(s) of operation</b> For each frequency band that is being amplified by the repeater, transmitted intermodulation products due to input signals within that band shall not exceed -19dBm at the donor and coverage ports.
9	Additional essential requirements	Nil
10	Frequency planning assumptions	Not specified
<b>Informative (11-14)</b>		
11	Planned changes	Nil
12	Reference	EN 303 609 EN 301 908-11 EN 301 908-15
13	Remarks	Nil
14	Notification Number (in respect of Northern Ireland)	2021/7013/XI

# Testing for compliance with the minimum technical requirements

- 3.1 A mobile phone repeater supplied by a manufacturer for testing will be referred to as a unit under test (UUT) in this section.
- 3.2 This VTS is only applicable for conducted testing. If the UUT supplied for testing does not have a permanent antenna connector(s) then a temporary antenna connector(s) must be provided for test purposes.

## Conditions for testing

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### Normal and extreme test conditions

- 3.3 It should usually be sufficient for all tests to be conducted under normal test conditions as declared by the manufacturer (e.g. operating temperature, humidity, voltage), except where otherwise stated.
- 3.4 Where technical performance varies under extreme environmental conditions, as declared by the manufacturer, the tests defined in the present document shall be carried out at representative points within the boundary limits of the declared operational environmental profile (i.e., at points between the minimum and maximum operating temperature and humidity).
- 3.5 Where required, tests shall be repeated under a sufficient variety of environmental conditions to give confidence of compliance for the affected technical requirements.
- 3.6 The UUT must be switched on for at least 20 minutes before any tests can be carried out.

### Antennas: Integral and external antennas

- 3.7 External antennas are antennas that are physically external to the equipment and are assessed in combination with the equipment against the requirements in the Exemption Regulations.
- 3.8 An antenna assembly referred to in the present document is understood as the combination of the antenna (integral or external), its coaxial cable and, if applicable, its antenna connector and associated switching components.
- 3.9 For a UUT with permanent antenna connector(s) and using external antenna(s), or for a UUT with integral antenna(s) but with a temporary antenna connector(s) provided for test purposes, conducted measurements shall be made and the results corrected to take into account the stated antenna assembly gain(s).
- 3.10 Where an external antenna is supplied, independent evidence shall be provided to the test house to validate the antenna specification declared by the manufacturer. Independent evidence may include data sheets or calibration certificates.

## Information to be provided by the manufacturer

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3.11 The following information relating to the UUT should be provided to the test house:<sup>4</sup>

- Type of mobile phone repeater described as: a provider-specific mobile repeater device or a multi-operator mobile repeater device.
- The intended technology (e.g., 4G, 5G).
- The operating frequency range(s) of the equipment.
- The nominal channel bandwidth(s) that the equipment can support.
- The Automatic Gain Control (AGC) range.
- The maximum power in the uplink and downlink directions.
- The maximum gain in the uplink and downlink directions.
- A declaration that the equipment meets the BSCL – 30 dB system gain requirement (for a provider-specific repeater) or the 10 dB – RSSI system gain requirement (for a multi-operator repeater).
- The external antenna gain (dBi) and power/power spectrum density (dBm or dBm/measured BW) of the antenna assembly intended to be used in combination with the equipment (if used).
- The integral antenna design used by the equipment, and measures to prevent the user from connecting a different antenna (if used).
- Rated output power of the repeater i.e., the mean power level per carrier available at the antenna connector port.
- The maximum EIRP level.
- Normal and extreme operating conditions (e.g., temperature and humidity range, operating voltage).
- The device type, model identifier, serial number, device emission class and firmware version of the repeater.

3.12 The following information shall be declared in the report provided by the test house to Ofcom:

- A declaration from the test house that the mobile repeater equipment has been tested in accordance with the VTS.
- A description of all components used during the testing including, but not limited to, transition connectors, cables and couplers.
- The normal and the extreme operating conditions (e.g., voltage and temperature) that were applied to the equipment during testing.
- A description of the test equipment used during testing including, where available, details of any relevant calibration.
- Results of test suites including comparison with limits set out in the Exemption Regulations (and summarised in the Interface Requirements).
- All results shall include the values obtained before and after system correction. For example, showing results before adjusting for cable/transmission loss and results after adjusting for cable/transmission loss.
- Any information that has been provided by the manufacturer as listed in paragraph 3.11.

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<sup>4</sup> Although we would expect this information to be shared with test houses to assist with testing, it is not a requirement for demonstrating conformity with the VTS.

## Test suite 1: Frequency band of operation

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- 3.13 This test suite applies to the frequency band rules defined in the Exemption Regulations. Specifically:
- Rules applicable to all mobile repeater devices: 5(2)
- 3.14 This test will identify the downlink and uplink frequencies over which the UUT may amplify signals, the frequency at which the maximum output power is realised within each UUT operational band and the AGC range of the UUT. The UUT shall reject amplification of other signals outside of its passband for it to be able to pass the test. The frequency at which maximum output power is realised and the AGC range are not required to demonstrate compliance with rule 5(2) of the Exemption Regulations, but are required in other test suites.
- 3.15 Results obtained shall be compared to limits set in the Exemption Regulations (and summarised in the Interface Requirements) to validate the UUTs compliance.

### Test method for both multi-operator and provider specific repeaters

#### 3.16 Step 1

- The UUT shall be connected as shown in Figure 1 found in Annex 1. For uplink direction, connect the spectrum analyser to the donor port of the UUT. For downlink direction, connect the spectrum analyser to the coverage port of the UUT.
- The spectrum analyser shall be configured with the following settings:

Setting	Value
Centre Frequency	Centre frequency of the band under test for multi operator repeater. For provider specific repeater, centre frequency of the MNO's operating band under test.
Frequency Span	1 MHz
Resolution Bandwidth	100 kHz
Video Bandwidth	$\geq 3 \times \text{RBW}$
Detector Type	Peak
Trace Mode	Trace1: Max Hold Trace 2: Clear write
Sweep Time	Auto

#### 3.17 Step 2: AGC Range and maximum output power.

- The signal generator should be used to generate a CW signal with centre frequency of the operating band being tested.
- The signal generator power,  $P_{\text{sig}}$ , shall be initially set to a level that is at least 6 dB below the power of AGC operational range specified by the manufacturer. If  $P_{\text{sig}}$  is not known, it can be calculated using the following equation:

$$P_{\text{sig}} = \text{Maximum Output power of UUT} - \text{Maximum Gain of UUT} - 6 \text{ dB}$$

- Slowly increase the signal generator power level until the output signal reaches maximum level (i.e. no further increase in output signal level is observed on the spectrum analyser). Record this output power level as  $P_{outmax}$ . The corresponding input power is the lower power limit of AGC operational level. Record this power level as  $AGC_{min}$ .
- Gradually keep increasing the signal generator power level until the output signal reaches the higher limit of AGC operational level.<sup>5</sup> The corresponding input power is the higher power limit of the AGC operational level. Record this power level as  $AGC_{max}$ .
- The automatic gain control (AGC) range is the difference between  $AGC_{max}$  and  $AGC_{min}$ .
- Reduce the signal generator power to a level that is 3 dB below  $AGC_{min}$ , (to ensure the AGC is not active) then manually reset<sup>6</sup> the UUT.

### 3.18 Step 3: Downlink and uplink frequency band

- Adjust the spectrum analyser span to double the frequency bandwidth being tested.
- Adjust the tuned frequency of the signal generator to sweep over double the frequency bandwidth using the sweep function.
- Using three markers on the spectrum analyser, identify the signal band edges and the frequency where the maximum output power is realised.
- These values should be recorded as  $F_{min}$ ,  $F_{maxout}$ , and  $F_{max}$ , where  $F_{min}$  and  $F_{max}$  are the corresponding lower and upper frequency limits of signal band edges, and  $F_{maxout}$  is the corresponding frequency of maximum output power. The frequency band of operation of the UUT is the difference between  $F_{max}$  and  $F_{min}$  and should be within the respective operational band. Save the spectrum analyser plot showing these levels for inclusion in the test report.

### 3.19 Step 4

- Repeat Step 1 to Step 3 for all operational uplink and downlink bands for multi operator repeater. For provider specific repeater, repeat for all operational uplink and downlink MNO bands under test.
- Record  $AGC_{min}$ ,  $AGC_{max}$ , AGC range,  $F_{min}$ ,  $F_{maxout}$  and  $F_{max}$ , in a tabular format for inclusion in the test report, where AGC range is the difference between  $AGC_{max}$  and  $AGC_{min}$ .
- $AGC_{min}$ ,  $AGC_{max}$ , AGC range and  $F_{maxout}$  are parameters used in multiple test suites throughout this VTS, and as such are recorded to be used later.

## Test suite 2: Maximum transmit power / power density

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3.20 This test suite applies to the power limits and power spectral density requirements defined in the Exemption Regulations. Specifically:

- Rules applicable to provider-specific mobile repeater devices: 11(a), 11(b), 11(c), 11(d), 11(e), 11(f), 11(g), 11(h)
- Rules applicable to multi-operator mobile repeater devices: 15(1), 15(2)

<sup>5</sup> From observation of signal behaviour on the spectrum analyser; i.e., no further increase in output power as input power is increased or a significant drop in repeater gain. At this point some UUTs may shutdown automatically.

<sup>6</sup> Throughout this VTS the term “reset the UUT” refers to power cycling the unit and allowing it to complete its re-boot procedure.

3.21 Results obtained shall be compared to the power limits set in the Exemption Regulations (and summarised in the Interface Requirements) to validate the UUTs compliance.

### Test method to measure EIRP for provider specific repeaters

#### 3.22 Step 1

- To calculate downlink EIRP use  $P_{outmax}$  obtained in paragraph 3.17 for respective downlink frequency bands, and antenna gain and cable loss where provided by the manufacturer, in the following equation:  

$$EIRP_{downlink} = P_{outmax} + \text{External indoor antenna gain} - \text{Cable loss connecting UUT to indoor antenna (if any)}$$
- To calculate uplink EIRP use  $P_{outmax}$  obtained in paragraph 3.17 for respective uplink frequency bands, and antenna gain and cable loss where provided by the manufacturer, in the following equation:  

$$EIRP_{uplink} = P_{outmax} + \text{External outdoor antenna gain} - \text{Cable loss connecting UUT to outdoor antenna}$$
- Repeat Step 1 for all operational MNO uplink and downlink frequencies.
- Record the EIRP results in tabular format for inclusion in the test report.
- Proceed to paragraph 3.23.

### Test method to measure Power Spectral Density (PSD) for both multi-operator and provider specific repeaters

#### 3.23 Step 2

- The UUT shall be connected as shown in Figure 1 found in Annex 1. For uplink connection, connect the spectrum analyser to the donor port of the UUT. For downlink connection, connect the spectrum analyser to the coverage port of the UUT.
- The signal generator shall be configured to generate a modulated or AWGN signal with centre frequency of  $F_{maxout}$  and bandwidth equal or greater than 5MHz for the respective frequency band under test. Set the signal generator power level to  $AGC_{min}$  recorded in paragraph 3.17 to ensure maximum output power.
- The spectrum analyser shall be configured with the following settings:

Setting	Value
Centre Frequency	Set at $F_{maxout}$ captured in paragraph 3.18.
Frequency Span	$\geq 2x$ the bandwidth of the band under test
Resolution Bandwidth	100 kHz
Video Bandwidth	$\geq 3 \times RBW$
Detector Type	Power averaging (RMS)
Trace Mode	Clear Write
Sweep Time	1 second
Measurement Mode	Channel Power
Channel power bandwidth	5 MHz

Setting	Value
Measurement settings	Channel power measured in a 5 MHz bandwidth

### 3.24 Step 3

- Measure the channel power in dBm/5MHz using the spectrum analyser channel power mode.
- Record the PSD results in tabular format for inclusion in the test report.

### 3.25 Step 4

- Repeat Step 1 to Step 3 for all operational uplink and downlink frequency bands for multi operator repeater and all MNO downlink frequency bands for provider specific repeater.
- Record the results in tabular format for inclusion in the test report.

## Test suite 3: Transmit gain control

3.26 This test suite applies to the system gain limits defined in the Exemption Regulations. Specifically:

- Rules applicable to provider-specific mobile repeater devices: 12(1), 12(2), 12(3), 12(4), 12(5)
- Rules applicable to multi-operator mobile repeater devices: 16(1), 16(2)

3.27 For a provider specific mobile repeater the uplink and downlink system gain must not exceed whichever is the smaller of 100 dB and  $BCSL - 30$  dB, where BSCL (base station coupling loss) is the difference between the power transmitted by the base station (which may be determined from the system information messages sent by that base station on its control channels) and the power received by the UUT from the base station. The manufacturer must provide a declaration stating how the UUT meets the  $BCSL - 30$  dB requirement.

3.28 For a multi-operator repeater the uplink and downlink system gain must not exceed whichever is the smaller of 100 dB and  $10$  dB – RSSI, where RSSI (received signal strength indicator) is the total downlink signal power received at the donor port of the UUT, for all base stations in the frequency band being transmitted. The manufacturer must include a declaration stating how the UUT meets the  $10$  dB – RSSI requirement.

3.29 This section provides calculations for system gain, which in all cases must not exceed 100 dB in the uplink and downlink direction, and for a multi-operator repeater must be equal in the uplink and downlink direction.

3.30 Results obtained shall be compared to limits set in the Exemption Regulations (and summarised in the Interface Requirements) to validate the UUTs compliance.

### Test method for both multi-operator and provider specific repeaters

#### 3.31 Step 1

- The UUT shall be connected as shown in Figure 1 found in Annex 1 with the centre frequency as  $F_{\text{maxout}}$  in the frequency band under test.
- The spectrum analyser shall be configured with the following settings:



Setting	Value
Centre Frequency	Set at $F_{\text{maxout}}$ captured in paragraph 3.18.
Frequency Span	1 MHz
Resolution Bandwidth	100 kHz
Video Bandwidth	$\geq 3 \times \text{RBW}$
Detector Type	Peak
Trace Mode	Max Hold
Sweep Time	Auto

- Using a CW signal, vary the input signal power ( $P_{\text{in}}$ ) of the signal generator from -100dBm to -30dBm in 5dB steps and record the corresponding output signal power ( $P_{\text{out}}$ ) on the spectrum analyser.
- Use respective  $P_{\text{out}}$  and  $P_{\text{in}}$  values in the following equation to obtain the gain, G:

$$G \text{ (dB)} = P_{\text{out}} \text{ (dBm)} - P_{\text{in}} \text{ (dBm)}$$

- Use the above formula to calculate the gain for each combination of  $P_{\text{out}}$  and  $P_{\text{in}}$  and record the gain values in tabular format for inclusion in the test report.

### 3.32 Step 2

- Verify that the uplink and downlink system gain does not exceed 100 dB, and for a multi-operator repeater the uplink and downlink system gain is equal, when measured separately for each of the frequency bands being transmitted.

### 3.33 Step 3

- Repeat Step 1 and Step 2 for all operational uplink and downlink bands.
- Record the results in tabular format for inclusion in the test report. Include the manufacturer's declaration stating how the UUT meets the BSCL – 30 dB requirement (for a provider specific repeater) or the 10 dB – RSSI requirement (for a multi-operator repeater).

## Test suite 4: Automatic standby

3.34 This test suite applies to the automatic standby requirement defined in the Exemption Regulations. Specifically:

- Rules applicable to provider-specific mobile repeater devices: 10(1), 10(2)
- Rules applicable to multi-operator mobile repeater devices: 14(1), 14(2)

3.35 Results obtained shall be compared with limits specified in the Exemption Regulations (as summarised in the Interface Requirements).

## Test method for both multi-operator and provider specific repeaters

### 3.36 Step 1

- Connect the UUT to the test equipment as shown in Figure 2 found in Annex 1.
- The spectrum analyser(s) shall be configured with the following settings:

Setting	Value
Centre Frequency	Centre frequency of the operating band under test.
Frequency Span	$\geq 2x$ the bandwidth of the band under test
Resolution Bandwidth	100 kHz
Video Bandwidth	$\geq 3 \times$ RBW
Detector Type	Power averaging (RMS)
Trace Mode	Clear Write
Sweep Time	1 second
Measurement Mode	Channel Power
Channel power bandwidth	Equal to the bandwidth of the band under test
Measurement settings	Channel power measured in a 1 MHz bandwidth

- To simulate an active signal the signal generator should be used to generate a CW signal with centre frequency of the operating band under test.
- Set the signal generator power level to  $AGC_{min}$  recorded in paragraph 3.17 to ensure maximum output power.

### 3.37 Step 2

- After approximately 15 seconds switch off the signal generator to simulate a loss of active connection.
- After a period  $\geq 300$  seconds measure the channel noise power in dBm/MHz using the spectrum analyser channel power mode.
- Calculate EIRP of the uplink noise power in dBm/MHz, including antenna gain and loss of cable connecting UUT to the outdoor antenna, where provided, using the following equation:

$$EIRP \text{ (dBm/MHz)} = \text{Channel noise power (dBm/MHz)} - \text{Cable loss (dB)} + \text{Antenna Gain (dB)}$$

- Verify that after a period of 300 seconds any transmissions using the uplink frequencies do not exceed the noise power limit of  $-70$  dBm/MHz, as specified in the Exemption Regulations (and Interface Requirement).

### 3.38 Step 3

- Repeat Step 1 and Step 2 for all supported uplink bands.

- Record the uplink noise power and the time taken for the UUT to reduce its emissions to this level in tabular format for inclusion in the test report.

## Test suite 5: Anti-oscillation

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3.39 This test suite applies to the anti-oscillation requirements defined in the Exemption Regulations. Specifically:

- Rules applicable to all mobile repeater devices: 7(1), 7(2), 7(3), 7(4), 7(5), 7(6), 7(7).

3.40 Results obtained shall be compared to the limits set in the Exemption Regulations and Interface Requirements to validate the repeater's compliance to the set limits.

### Test method for anti-oscillation detection for multi-operator and provider-specific repeaters

3.41 Step 1

- Connect the UUT to the test equipment as shown in Figure 3 found in Annex 1.
- The optional signal generator shall be used if the UUT requires an input signal to prevent it from entering automatic standby. The signal generator should be configured to generate a CW signal with centre frequency just above the lower band edge of the operating band under test.<sup>7</sup> Adjust the RF output level to prevent the UUT entering automatic standby.
- The spectrum analyser shall be configured with the following settings:

Setting	Value
Centre Frequency	Centre frequency of the band under test.
Frequency Span	1.1x the BW of the frequency band under test
Resolution Bandwidth	≥1 MHz
Video Bandwidth	≥ 3 x RBW
Detector Type	Power averaging (RMS)
Trace Mode	Clear Write (Trace 1) Max Hold (Trace 2)
Sweep Time	Auto

3.42 Step 2

- Set the variable attenuator to its maximum attenuation setting (at least 100dB attenuation).
- Decrease the attenuation of the variable attenuator until the spectrum analyser displays a signal within the band under test. Using a marker on the Max Hold trace, identify the approximate centre frequency of the oscillation,  $F_{osc}$  and the attenuator setting,  $Att_{osc}$ .

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<sup>7</sup> The frequency should be chosen so that it does not obstruct the measurement of the strongest oscillation peak (likely to be near the centre of the operating band).

- Reset the attenuation back to 100 dB and reset the UUT.

#### 3.43 Step 3

- Repeat Step 2 twice to ensure that the centre of the signal created by the UUT remains within the frequency span displayed by the spectrum analyser.
- If the frequency of the signal is unstable, confirm that the spectrum analyser display is centred between the extremes of the frequency response observed.
- Set the spectrum analyser to zero span mode, with centre frequency of  $F_{osc}$  and a sweep time of 5 seconds.

#### 3.44 Step 4

- Reset the UUT.
- Force the UUT into oscillation by changing the attenuation of the variable attenuator to  $Att_{osc}$  measured in Step 2.

#### 3.45 Step 5

- Use the marker function of the spectrum analyser on the Max Hold trace to measure the time from the onset of oscillation until the UUT activates any anti-oscillation mitigation technique.
- The spectrum analyser sweep time may be adjusted to improve the time resolution of these cursors.

#### 3.46 Step 6

- Capture the spectrum analyser zero-span trace for inclusion in the test report.
- Verify that any oscillations in the uplink frequencies are detected within 0.3 seconds, and any oscillations in the downlink frequencies are detected within 1 second, as specified in the Exemption Regulations.
- Repeat Step 4 to Step 6 for all supported uplink and downlink bands.
- Record the results in the test report.

#### 3.47 Step 7

- Set the spectrum analyser zero-span sweep time for a minimum of 120 seconds, with a Resolution Bandwidth of 3MHz and a single sweep.
- Manually trigger the spectrum analyser zero-span sweep, and after a few seconds force the UUT into oscillation as described in Step 4.

#### 3.48 Step 8

- When the sweep is complete, place cursors between the first two oscillation detections and measure the time between them. Save the plot for inclusion in the test report.
- Verify that, if the UUT uses an anti-oscillation technique, it continues to apply that technique for at least 60 seconds, as specified in the Exemption Regulations.
- Repeat Step 7 and Step 8 for all supported uplink and downlink bands.
- Record the results in the test report.

#### 3.49 Step 9

- Set the attenuation of the variable attenuator back to 100 dB and reset the UUT.

- Set the spectrum analyser zero-span sweep time for a minimum of 480 seconds, with a Resolution Bandwidth of 3MHz and a single sweep.
- Manually trigger the spectrum analyser zero-span sweep, and after a few seconds force the UUT into oscillation as described in Step 4.

### 3.50 Step 10

- When the sweep is complete verify that if an anti-oscillation technique has been used on a maximum of five occasions and the UUT subsequently detects further oscillations, it ceases transmitting until manually reset, in accordance with the Exemption Regulations.
- Repeat Step 9 and Step 10 for all uplink and downlink frequency bands.
- Record the results in the test report.

## Test suite 6: Noise figure

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3.51 This test suite applies to the system noise figure limit defined in the Exemption Regulations. Specifically:

- Rules applicable to all mobile repeater devices: 8(1), 8(2)

3.52 Results obtained shall be compared to limits set in the Exemption Regulations (as summarised in the Interface requirements) to validate the repeater's compliance to the set limits.

### Test method for both multi-operator and provider specific repeaters

#### 3.53 Step 1

- Connect the UUT to the test equipment as shown in Figure 4 found in Annex 1.
- For uplink measurements, the signal generator shall be configured for AWGN operation with a 99% BW of the corresponding downlink frequency band under test; for downlink measurements, the signal generator shall be configured for AWGN operation with a 99% BW of the corresponding uplink frequency band under test.
- For uplink measurements, the signal generator should be connected to the downlink port; for downlink measurements, the signal generator should be connected to the uplink port.
- The spectrum analyser shall be configured with the following settings:

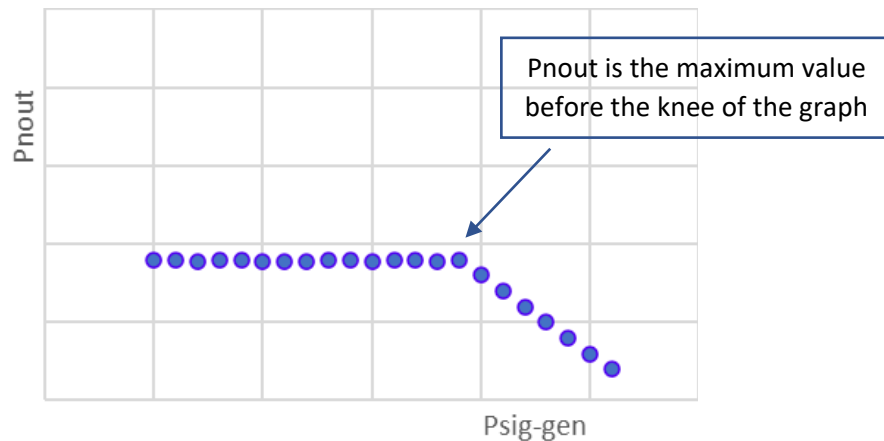
Setting	Value
Centre Frequency	Centre frequency of the operating band under test.
Frequency Span	≥ 2x the bandwidth of the band under test
Resolution Bandwidth	1 MHz
Video Bandwidth	≥ 3 x RBW
Detector Type	Power averaging (RMS)
Trace Mode	Clear Write
Sweep Time	Auto

Setting	Value
Measurement Mode	Channel Power
Channel power bandwidth	Equal to the bandwidth of the band under test
Measurement settings	Channel power measured in the bandwidth of interest, or Channel power spectral density measured in dBm/Hz

- If the optional filter is used, ensure that no additional noise is added within or outside the passband.
- Through observation on the spectrum analyser, ensure that the signal generator does not contribute to the noise level in band or out of band.

### 3.54 Step 2

- Measure the uplink noise power ( $P_{nout}$ ) while varying the downlink signal generator (or measure the downlink noise power ( $P_{nout}$ ) while varying the uplink signal generator) output level from  $-80$  dBm to  $-30$  dBm with 2dB steps.
- Plot  $P_{nout}$  (y-axis) against the signal generator level (x-axis) and include this figure in the test report.
- Use this figure to find the maximum value of  $P_{nout}$  without the influence of AGC (i.e. before the “knee” of the graph), as shown in the example below.



- Calculate the Noise Figure from the following equation:

$$Noise\ Figure(dB) = P_{nout} - (-174dBm/Hz + Gain + 10\log_{10}(BW))$$

- Where:
  - $P_{nout}$  is either the maximum uplink or downlink noise power, before AGC activation, for either a multi operator or provider specific repeater.
  - $-174dBm/Hz$  is the noise power density at room temperature ( $290^{\circ}K$ ).
  - $BW$  is the bandwidth in Hz over which the noise power measurement,  $P_{nout}$ , is made (i.e. equal to the channel power measurement bandwidth).
  - Gain is the maximum gain of the UUT measured in Test Suite 3: Transmit Gain Control.

- If the output noise power density in dBm/Hz has been measured ( $P_{\text{outD}}$ ) the Noise Figure equation can be simplified as:

$$\text{Noise Figure(dB)} = P_{\text{outD}} + 174\text{dBm/Hz} - \text{Gain}$$

### 3.55 Step 3

- Repeat Step 2 for all supported uplink and downlink bands.
- Record the system Noise Figure results in tabular form for inclusion in the test report.

## Test suite 7: Intermodulation products

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3.56 This test suite applies to transmitted intermodulation products defined in the Exemption Regulations. Specifically:

- Rules applicable to multi-operator mobile repeater devices: 17(1), 17(2)

3.57 Results obtained shall be compared to limits set in the Exemption Regulations (as summarised in the Interface Requirements) to validate the repeater's compliance to the set limits.

### Test method for multi-operator repeaters

3.58 Testing procedures for intermodulation are specified in section 5.3.4 and section 5.3.7 of ETSI standard: EN 301 908-15.

3.59 To ensure compliance with the Exemption Regulations, an additional measurement using the test procedures mentioned in paragraph 3.56 shall be made using two tone CW 300 kHz below and above the frequency under test with the highest power as recorded in paragraph 3.17. The test should be repeated for each supported frequency band of operation.

3.60 The test should be performed twice, once using the maximum output power without activating the AGC and another 10dB above the  $\text{AGC}_{\text{min}}$ .

3.61 Verify that the power level of transmitted intermodulation products due to input signals within that frequency band does not exceed -19dBm at the donor port and coverage port of the UUT. Record the results in tabular form for inclusion in the test report.

# Document History

Version	Date	Changes
1.0	27/05/2022	First release
2.0	08/02/2024	Removal of requirement to repeat a 2G and/or 3G mobile signal. Clarification and updates to test suites.



# A1. Measurement system setup examples

A1.1 This annex gives examples of measurement system setups that can be used when verifying compliance with the Exemption Regulations. Alternative setups may be used provided they are fully documented in the test report provided to Ofcom.

**Figure 1: Test setup to measure frequency band of operation and gain, common to both multi-operator and provider specific repeater**

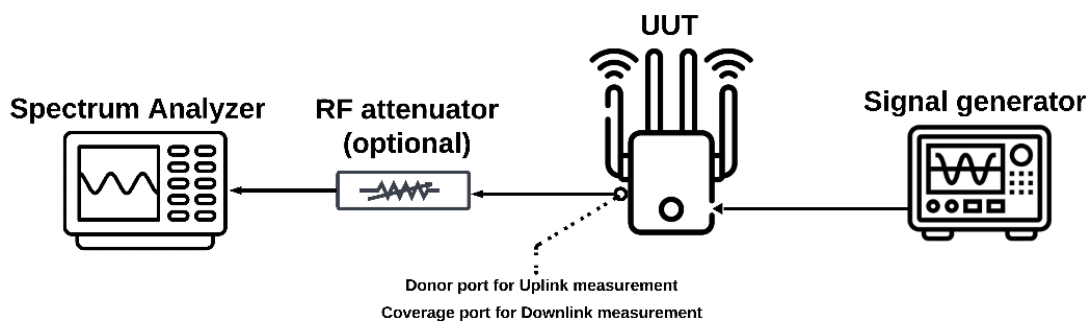


Figure 2: Test setup for automatic standby, common to both multi-operator and provider specific repeater

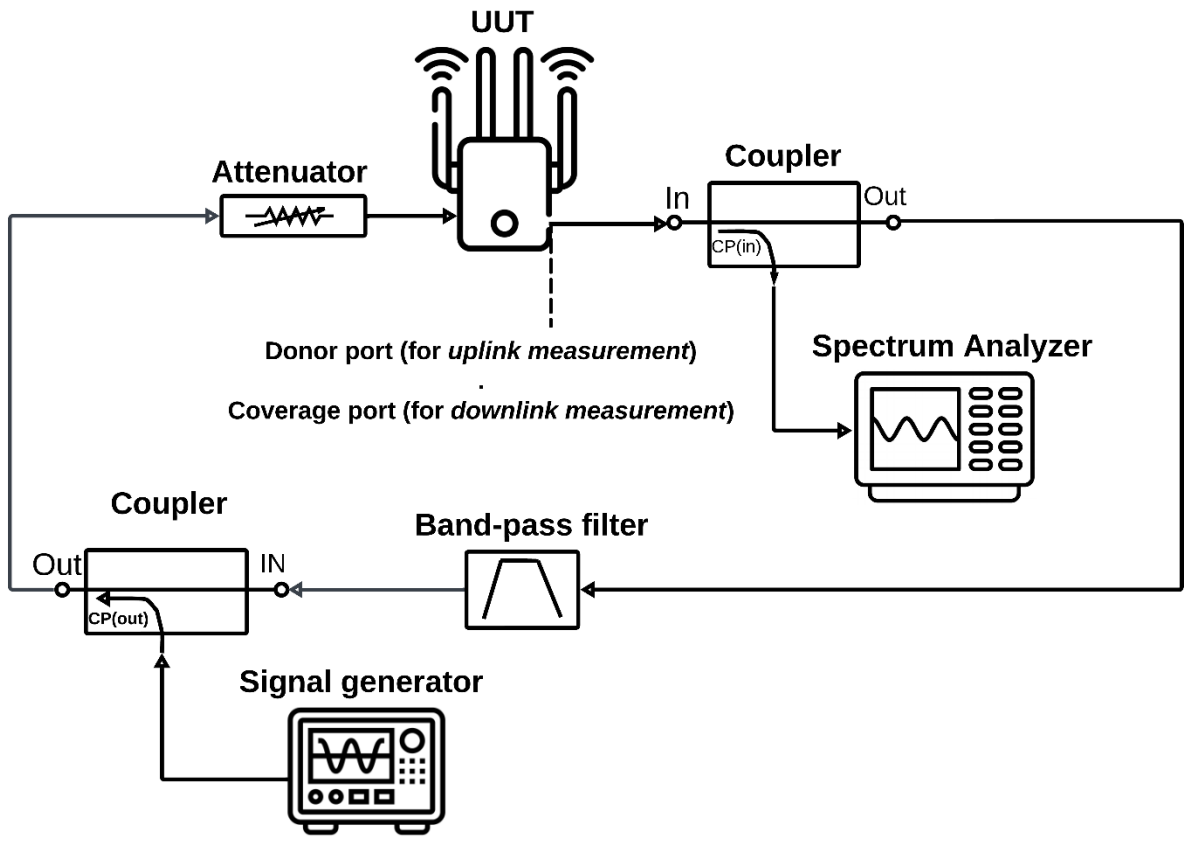
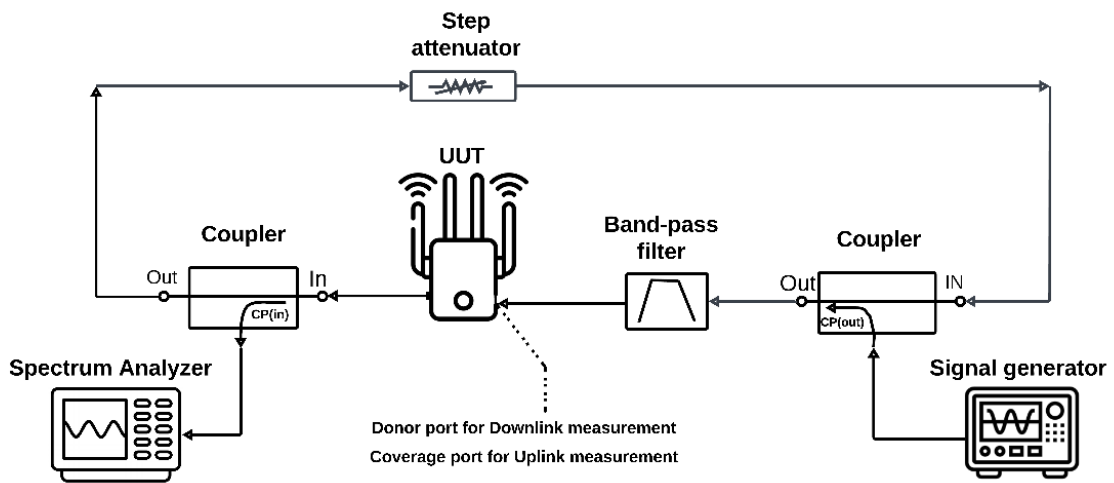
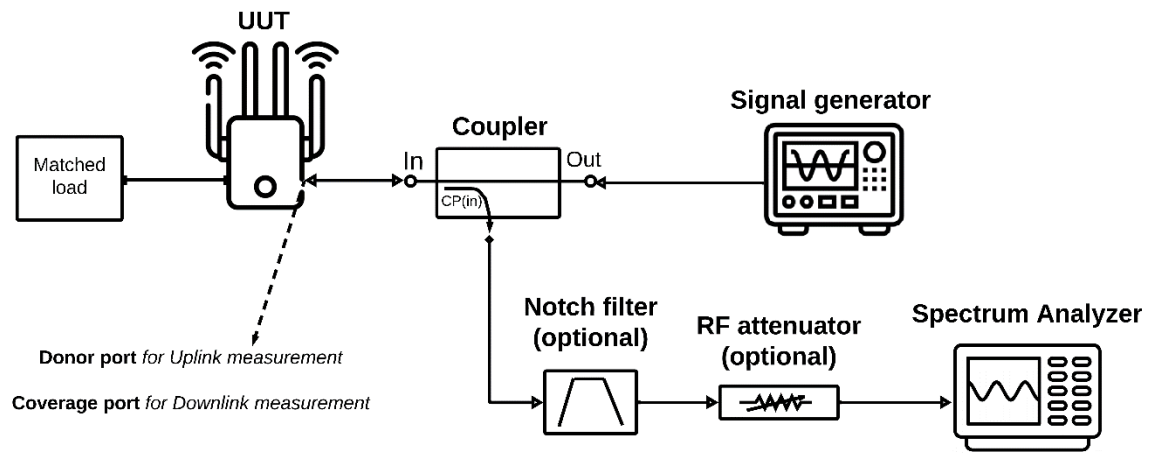


Figure 3: Test setup for anti-oscillation detection, mitigation and shut-down, common to both multi-operator and provider specific repeater



**Figure 4: Test setup for thermal noise measurement, common to both multi-operator and provider specific repeater**



# A2. Definitions, symbols and abbreviations

## Definitions

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For the purposes of the current document, the following definition apply:

AGC	Automatic gain control used to increase and decrease the gain of the receiving amplifier according to the signal level received.
BSCL	The base station coupling loss, which is the difference between (i) the power transmitted by the base station (which may be determined from the system information messages sent by that base station on its control channels) and (ii) the power received by the mobile repeater device from the base station.
Coverage Port	The interface between a mobile repeater device and its coverage antenna. Typically, this port is equivalent to the repeater's indoor antenna port.
Donor port	The interface between a mobile repeater device and its donor antenna. Typically, this port is equivalent to the repeater's outdoor antenna port.
GSM	An electronic communication networks network that complies with standards EN 301 502 and EN 301 511 published by ETSI for the Global System for Mobile Communications (also known as GSM).
Multi-operator mobile repeater	A repeater that amplifies signals carried by more than one MNO, with amplification by the same level and not calculated individually for each MNO. To be licence-exempt, such repeaters must comply with Regulations 5 to 12 and 14 to 17 of the Exemption Regulations (as summarised in IR 2102.3).
Provider specific mobile repeater	A repeater that amplifies signals carried by one or more MNOs, whilst individually setting the level of amplification for each MNO's signals. To be licence-exempt, such repeaters must comply with Regulations 5 to 12 of the Exemption Regulations (as summarised in IR 2102.1).
RSSI	The received signal strength indicator, which is the total downlink signal power received at the donor port of the mobile repeater device, for all base stations in the frequency band being transmitted.

## Symbols

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

dB	Decibel
dBi	Antenna gain in decibels referenced to an isotropic antenna
dBm	Decibel referenced to 1 mW.
MHz	$10^6$ Hz

## Abbreviations

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

AWGN	Additive White Gaussian Noise
BW	Bandwidth
CW	Continuous Wave carrier
EIRP	Equivalent Isotropically Radiated Power
IR	Interface Requirement
MNO	Mobile Network Operator
PSD	Power Spectral Density
RBW	Resolution Bandwidth
RF	Radio Frequency
RMS	Root Mean Square
Span	Frequency Span (frequency domain display)
UUT	Unit Under Test
VBW	Video Bandwidth
VTS	Voluntary Testing Standard

## A3. References

- [1] EN 303 609 Global System for Mobile communications (GSM); GSM Repeaters; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU
- [2] EN 301 908-11 IMT cellular networks; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 11: CDMA Direct Spread (UTRA FDD) Repeaters
- [3] EN 301 908-15 IMT cellular networks; Harmonised Standard for access to radio spectrum; Part 15: Evolved Universal Terrestrial Radio Access (E-UTRA FDD) Repeaters
- [4] EN 301 908-1 Introduction and Common Requirements
- [5] EN 301 908-11 IMT cellular networks; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 3: CDMA Direct Spread (UTRA FDD) Base Stations (BS)
- [6] EN 301 908-15 IMT cellular networks; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 15: Evolved Universal Terrestrial Radio Access (E-UTRA FDD) Repeaters
- [7] ETSI TR 102 273 Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties
- [8] FCC 935210 D02 Federal Communication Commission, Office of Engineering and Technology: Signal Boosters Basic Certification Requirements v04r04
- [9] FCC 935210 D04 Federal Communication Commission, Office of Engineering and Technology: Provider Specific Consumer Signal Boosters Compliance Measurements Guidance v02r04
- [10] The Wireless Telegraphy (Mobile Repeater) (Exemption) Regulations 2022: <https://www.legislation.gov.uk/uksi/2022/595/contents/made>
- [11] Proposed changes to the Wireless Telegraphy (Mobile Repeater) Exemption Regulations 2022: [https://www.ofcom.org.uk/\\_data/assets/pdf\\_file/0019/270136/Consultation-Mobile-phone-repeaters.pdf](https://www.ofcom.org.uk/_data/assets/pdf_file/0019/270136/Consultation-Mobile-phone-repeaters.pdf)
- [12] UK Interface Requirement 2102: [https://www.ofcom.org.uk/\\_data/assets/pdf\\_file/0024/238218/ir2102-may-22.pdf](https://www.ofcom.org.uk/_data/assets/pdf_file/0024/238218/ir2102-may-22.pdf)