Mobile signal strength measurement systems

Measurement methodology and data description

Technical document

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Contents

Section

Annex

1. Overview

1.1 Ofcom has extensive in-house facilities and expertise to undertake mobile network coverage and quality measurements. We use network scanners for passive measurements to assess the availability of mobile services, whilst active measurements undertaken using commercial performance monitoring systems help us to understand the quality of mobile services delivered to consumers.

1.2 Our primary approach for data collection is vehicle-based drive tests however we can deploy our measurement systems on trains or undertake more focused outdoor and indoor measurement campaigns including walk testing.

1.3 We make our measurement data available for download on our website through Ofcom's open data initiatives. The data is released under the open government licence.

1.4 The focus of this document is on passive measurements i.e., our approach to mobile drive test measurements using network scanners installed in Ofcom's Spectrum Assurance vehicles and the processes we have developed to collect calibrated measurements. The scanners capture various signal transmissions of mobile networks suitable for understanding the availability and extent of coverage.

1.5 Reporting on mobile network quality and consumer experience require active measurements such as downloading videos, web browsing, etc. and are not covered in this document.

Our drive test approach – in brief

- We collect mobile signal data along the road network in United Kingdom. This data is collected from systems mounted in Ofcom vehicles that are used by our Spectrum Assurance engineers.

Our approach towards release of measurement data as open data

- The data we release as open data represents the strongest mobile signals (per mobile operator) for 4G and 5G as received by rooftop antennas mounted on our vehicles. It does not include signal loss into the vehicle and therefore does not represent what a mobile handset in the vehicle would receive.

2. Data collection methodology

2.1 This section provides information on the overall methodology we use for collecting 4G and 5G mobile network measurements.

The measurement equipment

2.2 We have developed an automated system that uses Rohde & Schwarz (R&S) network scanners (TSME6)[1], shown in Figure 1 and Figure 2. Each vehicle-based system uses two scanners that can be configured for different measurement campaigns. Typically, one is dedicated to measuring 5G signals and the second measures 4G.

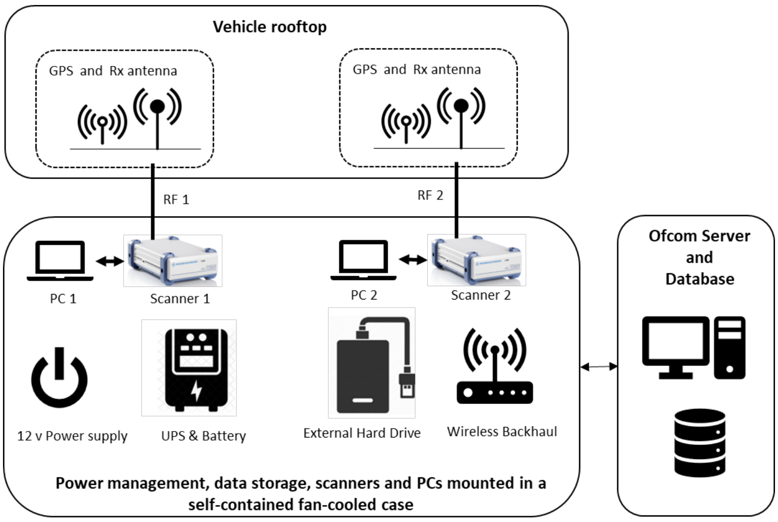
2.3 Each scanner is configured and controlled by R&S ROMES software installed on computers designed for vehicle use. These computers establish a secure connection to Ofcom's network using an in-built 5G modem for data backhaul and system administration purposes.

2.4 Two PCTEL 698-3800 MHz magnetic mount antennas (OP278H)[2] are installed on each of the survey vehicles; One antenna is connected to the first TSME6 RF network scanner for 5G specific data collection (RF1), and other antenna connected to the second TMSE6 RF network scanner for the collection of 4G data (RF2).

2.5 The rooftop antennas have integrated cables which are connected directly to the scanners. Positioning of the antennas on the roof is the same for all survey vehicles as shown in Figure 3. All vehicles used in collecting the data are of the same model make.

2.6 GPS antennas are mounted on each vehicle roof to provide timing and positioning information and are connected directly to the respective TSME6 scanners.

Figure 1: Block diagram of the drive test system



[1] https://www.rohde-schwarz.com/uk/products/test-and-measurement/network-data-collection/rs-tsmx-drive-and-walk-test-scanner_63493-526400.html
[2] PCTEL OP278H specifications- https://dev2.pctel.com/wp-content/uploads/2020/07/PCTEL-Outdoor-Scanning-Receiver-Antennas-Datasheet.pdf

Figure 2: Drive test system's power management, data storage, scanners and PCs mounted in a self-contained fan-cooled case

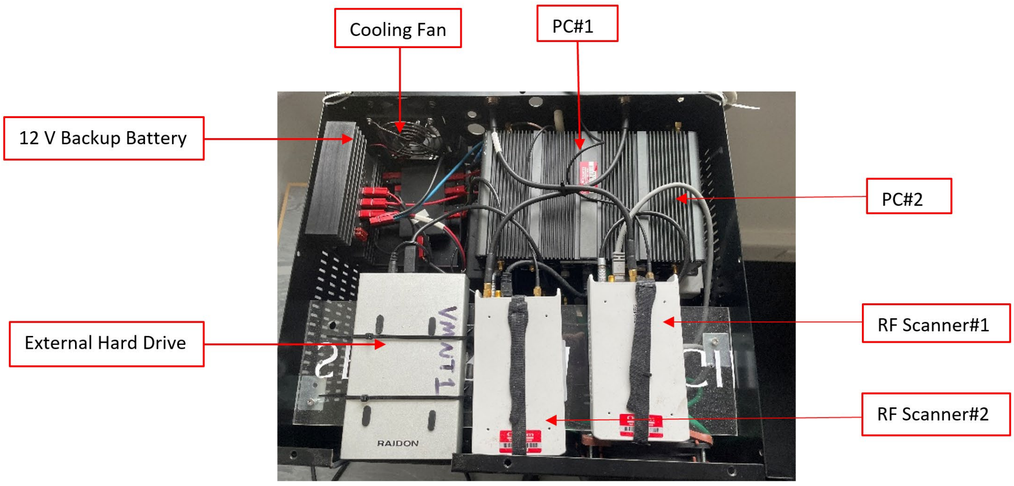


Figure 3: Side view of antennas mounted on survey vehicle

Data collection

2.7 Measurement data is collected continuously when the vehicles are running and after the system has booted up.

2.8 All the processes are automated from the point when the vehicle is powered up, to when it comes to a stop after its journey. This includes starting the measurement software with the desired settings, system stability checks, data collection, and export of the data. All of this is achieved by pre-installed scripts and configuration files.

Remote monitoring

2.9 Measurement systems can be accessed remotely to troubleshoot issues, or any configuration changes required. The system status is continuously monitored, with system health, measurement data errors, and the ability to track vehicle location.

3. System calibration methodology

3.1 This section describes the overall measurement systems calibration approach including the characterisation work undertaken in-house to establish the receive antennas average gains and losses associated with other components.

3.2 The main component of our drive test systems i.e., the network scanners are calibrated at regular intervals by the manufacturer ensuring the reported measured signals are within the acceptable tolerance (< 1.5 dB).

3.3 We also undertake end-to-end system characterisation to establish the receive antennas average gain and cable/connector losses of various components of our system. This characterisation of our measurement systems is undertaken in situ at Ofcom's antenna test range which is equipped with a vehicle turntable as shown in Figure 4.

Figure *4*: Baldock antenna test range.

3.4 Figure 5 depicts the system characterisation methodology. A signal generator is set with a continuous waveform (CW) signal and connected to a calibrated transmit antenna via an RF cable.

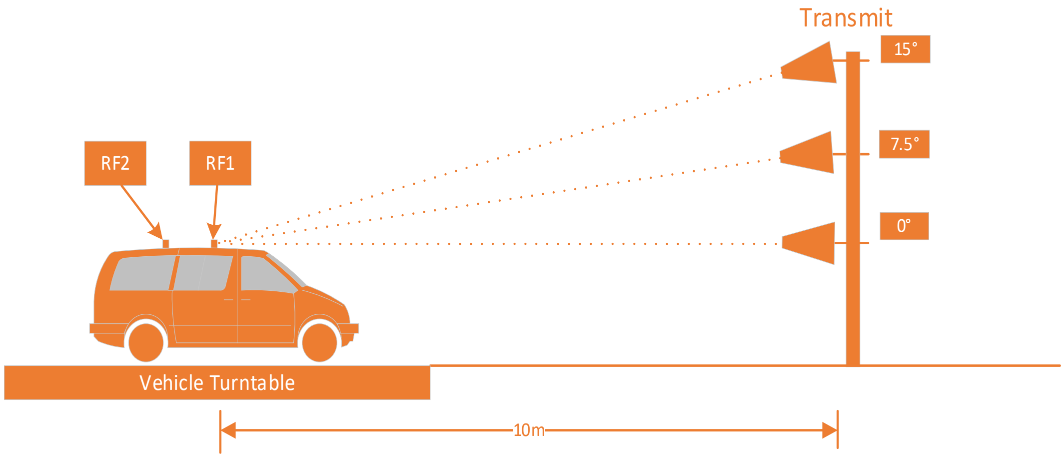
3.5 The test antenna is mounted on a height variable mast in vertical polarisation and positioned 10 m away from the vehicle's rooftop receive antennas (which are at 2m height). The vehicle is positioned so the antenna under test is on the central axis of the turntable.

3.6 A spectrum analyser is placed inside the vehicle under test, connected to a PC. The vehicle is positioned facing the transmit antenna (0° rotation) and initial boresight receive levels are measured to ensure consistency between the vehicle antennas.

3.7 To capture the azimuth and elevation specific measurements, the vehicle is rotated on the turntable over 360° with a measurement taken every 1°. The transmit antenna height is varied to obtain measurements at three elevation angles (0°, 7.5°, 15°), corresponding to transmit antenna heights of approximately 2 m, 3 m, and 4.5 m respectively, with the vehicles' rooftop receive antennas positioned 10 m from the transmit antenna. This setup is repeated for each azimuth angle and elevation height combination and measurements are recorded using an automated process.

3.8 The elevation angle range of 0° to 15° helps to characterise the average performance of receive antennas in real-world drive testing as the signals from the base stations are in general, confined to low elevation angles considering the average base station heights (18 m) and their proximity to the road network in the UK.

Figure 5: System characterisation methodology



3.9 System characterisation results are averaged across all vehicles to establish the overall system gain values for each frequency band and antenna. Table A1 in the Annex A1 provide system gain values for data collected in 2023.

4. Data processing and reported parameters

4.1 This section explains the parameters that we collect and how data is processed before we publish it.

4.2 An exhaustive list of measurement parameters is collected by RF scanner and reported by Rohde & Schwarz ROMES system. We create a subset of these parameters defined by our 4G and 5G parameters schema as listed in Table 2 and Table 3 and is published as open data.

4.3 The measurement data is sorted into discrete pools based on the mobile operator via mobile network code (MNC) on 4G and new radio-absolute radio frequency channel number (NR-ARFCN) on 5G. The ranking of the strongest cell is decided on a rolling two second window and chosen using the following power parameters:

- For 4G, the reference symbol received power (RSRP) of the strongest and next three best cells are included in the data set.
- For 5G, the synchronisation signal reference symbol received power (SS-RSRP) of the strongest cell is included in the data set.

4.4 These settings have been in use since 2021. The data released in 2020 only includes the strongest cell measured for both 4G and 5G. It should be noted that parameters reported may be subject to change in the future.

4.5 No correction for receive system gain (as explained in section 3) has been applied to the measurement results in the dataset.

4.6 Table 1 provides the schema used for location[3] and time information included in the data we release where:

- Each hour in the month has been replaced with a randomised unique identifier; and
- Each measurement point within the hour has been replaced with an incrementing sequence.

Table 1: Location and time information schema

Field	Description
Longitude	Longitude reported by GPS in decimal degrees
Latitude	Latitude reported by GPS in decimal degrees
Date	Month/year only
Time	Changed to an hourly randomised unique identifier
rnum	Sequential incrementing number per measurement, in the hour

[3] The location parameters reported are directly from the scanner and have not been corrected for any inaccuracies. Due to this, a small fraction of measurements may appear not aligned to the road network.

4G parameters

Table 2: 4G data schema

Field	Description
PCI	Physical Cell Identifier
RSSI	Received power on secondary synchronisation signal
SINR	Signal-to-Interference-plus-Noise Ratio
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
EARFCN	E-UTRA Absolute Radio Frequency Channel Number
ADD_PLMN	Top N Add PLMNs. Additional PLMNs that share this 4G base station
MCC	Mobile Country Code
MNC	Mobile Network Code
5G_NR	5G NR is supported by this cell

5G parameters

Table 3: 5G data schema

Field	Description
PCI	Physical Cell Identifier
RSSI	Average power of all resource elements carrying OFDM signals, interference, and noise within all SS/PBCH Blocks (SSBs) used for carrying out the measurement
SSB_IDX	SSB Index. Serving NR cell beam SS/PBCH Block index
SS_RSRP	Reference signal received power of resource elements of secondary synchronisation signal in SS-PBCH block
SS_RSRQ	Reference signal received quality of resource elements of secondary sync signal in SS-PBCH block
SS_SINR	Signal to Interference & Noise Ratio of resource elements of secondary synchronisation signal in SS-PBCH block
NR_ARFCN	New Radio Absolute Radio Frequency Channel Number
ADD_PLMN	Top N Add PLMNs. Additional PLMNs that share this 5G base station
MCC	Mobile Country Code (may not be available as Mobile Operator dependant)
MNC	Mobile Network Code (may not be available as Mobile Operator dependant)
NR_MODE	Top N 5G NR Mode 5G NR operation mode reported by scanner

Drive test routes

The routes covered are shown on a map which is available on our website[4] highlighting the data collected since 2020. The coverage data is not exhaustive for the entire UK. We plan to update this map yearly as new measurement data and locations become available.

[4] https://www.ofcom.org.uk/phones-telecoms-and-internet/coverage/mobile-signal-strength-measurement-data/drive-route-map

A1. System characterisation results

Table A1: System gain results for data collected in 2023

System gain for both receiver chains		
Frequency (MHz)	**RF1 5G (dB)**	**RF2 4G (dB)**
760	-0.6	-0.6
940	-0.6	-0.6
1470	-0.3	-0.1
1910	0.9	0.9
2140	1.1	1.2
2370	0.8	0.9
2630	0.4	0.0
2655	0.1	-0.4
3500	-2.7	-3.1
3600	-2.9	-3.3
3700	-2.7	-3.3
3800	-2.8	-3.7