FM radio transmitter acceptance testing method

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Section

Overview

This document sets out a method for performing acceptance testing on VHF band II FM transmitters against certain technical requirements contained in (or referenced by) FM broadcasters' Broadcasting Act and Wireless Telegraphy Act licences (including the relevant requirements of the Ofcom Analogue Radio Technical Code).

The procedures outlined in this document describe one method for how licensees or transmission providers can conduct testing to verify that their transmitted signals meet these technical requirements and parameters. There is no regulatory requirement to use this specific method, and alternative test procedures may be used where desired or appropriate.

Licensees must however provide complete acceptance test (commissioning) data to Ofcom in the format set out in this document when installing a new transmitter or replacing an existing one.

The definitions used in this document adhere to those found in the Ofcom Analogue Radio Technical Code. The most recent version of this document can be found on our website.

Ofcom approval of installation

Licensed parameters (pre-installation)

Before installation takes place, licensees should email broadcastradiocompliance@ofcom.org.uk with details of the proposed model of transmitter equipment and the proposed antenna type. If using a directional antenna, licensees must include an antenna model (i.e. a NEC[1] model or results from similar antenna modelling software).

The details provided should also include a calculation of the transmitter power required to provide the licensed Effective Radiated Power (ERP) which takes account of system losses and gains introduced by the cables/feeders, filter, and antenna.

[1] Numerical Electromagnetics Code - Wikipedia

Test Equipment

Equipment required

The following equipment is required in order to carry out commissioning measurements:

- Spectrum analyser with a frequency range up to 1 GHz;
- Network analyser (only required if spectrum analyser does not include a tracking generator);
- Deviation meter;
- RDS monitor decoder;
- Directional coupler;
- Inline attenuators (these may be required to prevent overloading test equipment);
- Selection of RF test cables and adaptors; and
- A means of recording plots of the measurement results, e.g. a laptop or mobile phone camera.

Calibration

Spectrum Analyser

The spectrum analyser used for the measurements must be in calibration, and a copy of the calibration certificate should be submitted with the test report. If the analyser offers a self-calibration facility this should be used before starting measurements.

Cables and Connectors

The cables and connectors should be of good quality and in good condition with known characteristics. The losses of the cables will need to be taken into account when measuring the RF levels.

Be aware of signal levels – be cautious with equipment!

When connecting test equipment such as spectrum analysers or modulation analysers to directional couplers through which the transmitter’s power is being sampled, it is important to be aware of the levels that might be presented to the test equipment. Levels above 1 mW (0 dBm) may start to overload some test equipment and lead to erroneous measurements, and levels significantly above 100 mW (20 dBm) may damage equipment. It is prudent to calculate the levels likely to be encountered before connecting anything (see the transmitter power section below). It is always good practice to connect a 20 dB attenuator at the input of the spectrum analyser (at least initially until levels have been confirmed) to prevent costly damage.

Directional coupler

A directional coupler is a key part of the test arrangement, and it is important to know its characteristics across the range of frequencies that it is used. The method used to check the coupling factors at the in-use and harmonic frequencies is as follows:

- Using a tracking generator or a network analyser in two port mode, set the frequency range from 88 MHz to 600 MHz to capture the fundamental frequency and any lower order harmonics.
- Connect the RF output port of the tracking generator to the directional coupler input.
- Connect a 50Ω test (dummy) load to the output of the coupler.
- Connect the forward coupled port to the RF input port of the tracking generator and note the level of the fundamental frequency for later measurements (the coupling factor is typically in the region of 30 to 40 dB). Make a note of the measured levels at the transmitter's fundamental frequency, plus its second, third, and fourth harmonics.
- Note that coupler loss reduces as the frequency increases: this must be considered when taking harmonic measurements.
- An example plot of a typical coupler is shown in Figure 1, and the values obtained in this plot are tabulated in Table 1.

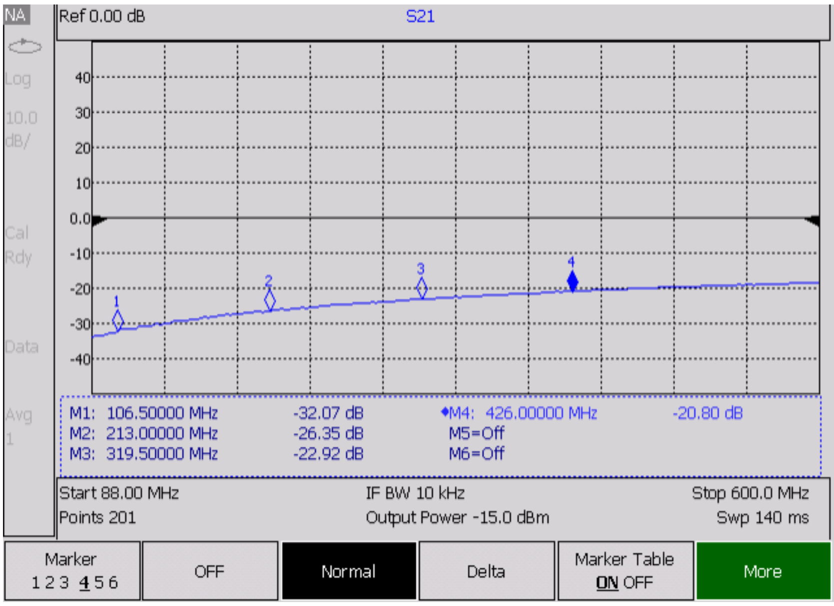

Figure 1 - Plot of coupler loss

	Marker	Frequency	Level
Fundamental	Marker 1	106.5 MHz	-32.07 dB
2nd Harmonic	Marker 2	213.0 MHz	-26.35 dB
3rd Harmonic	Marker 3	319.0 MHz	-22.92 dB
4th Harmonic	Marker 4	426.0 MHz	-20.80 dB

Table 1 - Coupler loss at fundamental and harmonic frequencies

Commissioning Process

Measurements & Checks Required

The following data and measurement results should be recorded in (or submitted with the FM commissioning checklist form):

- Confirmation of site location (NGR or Latitude and Longitude)
- Antenna:
    - Installed height above ground level
    - Type and bearing if directional
    - Return loss
    - Gain (dBd)
    - Feeder and interconnecting cables losses
    - In-line filter losses
- Calibration of directional coupler
- Transmission:
    - Power
    - Frequency
- Maximum deviation
- Stereo pilot deviation level
- RDS:
    - Deviation level
    - Data (PI code and radio text data)
- Spectral occupancy
- Harmonic and spurious emissions:
    - Aeronautical frequency band check (108 MHz – 136 MHz)
- Results:
    - Screen shots of spectrum analyser plots
    - Photographs of the installed equipment and antenna
    - Complete results spreadsheet (example is shown in Annex)
- Studio feed type e.g., Band I link, broadband, satellite

Measurement Methods

Antenna return loss check

The antenna return loss is measured by powering the transmitter with the directional coupler in line with the antenna. The power is measured on both the forward and return ports of the coupler with a spectrum analyser on the in-use frequency. Figures 2 and 3 below show example spectrum analyser plots for these measurements.

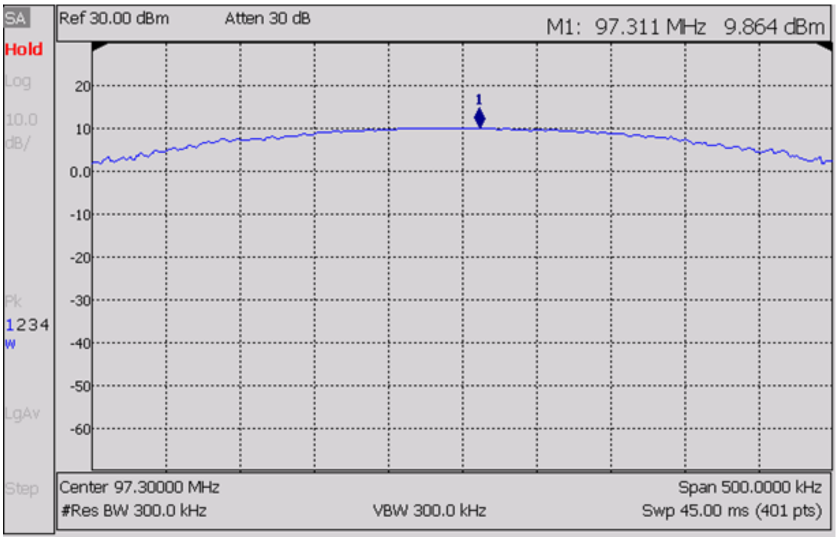

Figure 2 - Forward power (9.864 dBm).

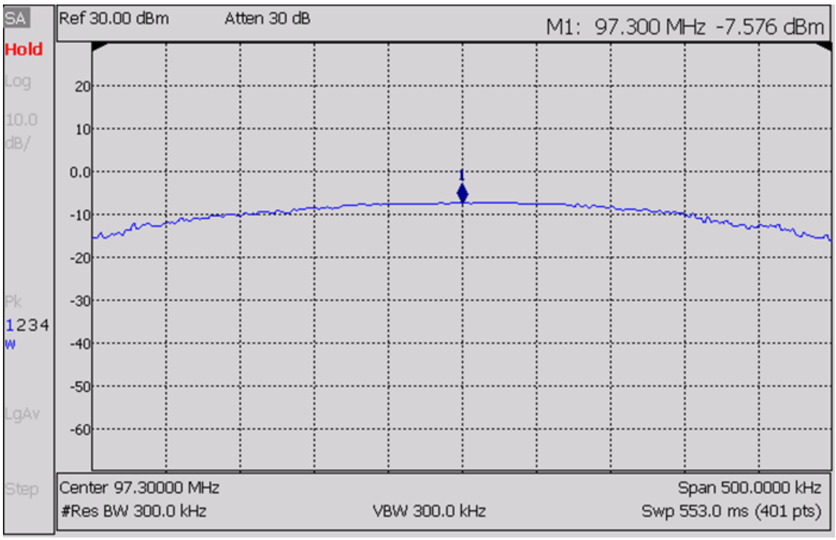

Figure 3 - Reverse power (-7.576 dBm)

In the example in Figure 1 and Figure 2 the return loss is the difference in levels measured between forward and return coupler ports, i.e. 9.864 dBm and -7.576 dBm = **17.4 dB** (rounded): the minimum required return loss is 14 dB.

Transmitter Frequency Measurement

The following test should be carried out with the transmitter operating at its normal power.

It is important that there is no modulation of the carrier frequency.

- Adjust the spectrum analyser settings as follows (guideline values):
    - **Centre Frequency:** Set to the transmission frequency (97.3 MHz in the example below)
    - **Span**: 20 kHz
    - **Resolution Bandwidth (RBW):** Auto
    - **Video bandwidth (VBW):** Auto

- Connect the analyser input to the forward port of the coupler and place a marker on the peak of the centre frequency.
- Stabilise the trace by implementing 'Trace Averaging' if available.
- The marker will indicate the frequency of the transmitter. Ensure that it is within ±2 kHz of licensed frequency.
- Record this value.
- Save a plot of the trace to include in report.

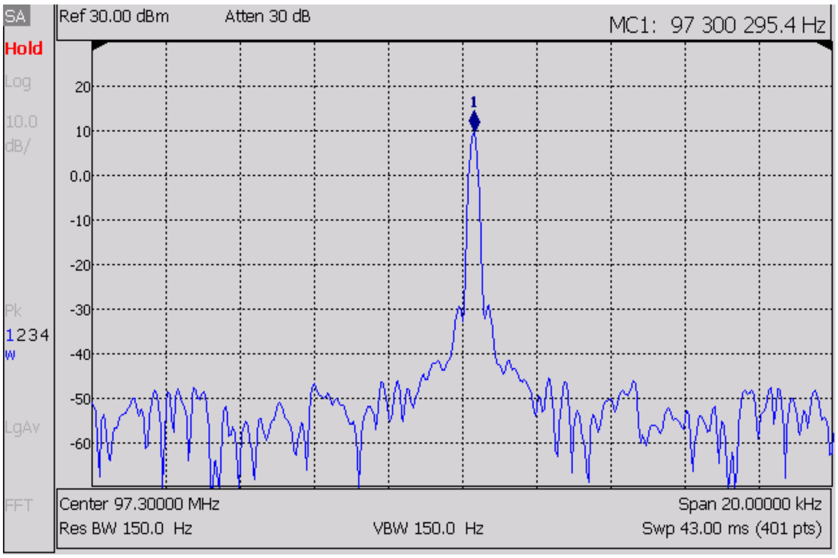

Figure 4 – plot of transmitter frequency measurement.

The example plot in Figure 4 shows that the measured frequency of 97,300,295.4 Hz has a frequency offset of 295.4 Hz, which is within the required tolerance of ±2 kHz.

Transmitter power

Calculation of transmitter normal output power

1) Convert to watts to dBm

The transmitter's licensed ERP in watts is stated in the Wireless Telegraphy Act licence in Box K (*'Maximum power').* This value needs to be converted to dBm (decibels relative to one milliwatt) for use in the formulas below. To convert watts to dBm use the following formula:

Licensed ERP (in dBm) = 30 + 10 x $\log_{10}$(Licensed ERP in watts)

2) Allow for system losses

The transmitter's normal output power is the power needed to deliver the licensed ERP from the antenna, taking into account the antenna's gain and the losses in the feeder cables and any filter. The normal power can be calculated using the following formula:

Normal transmitter power (dBm) = Licensed ERP in dBm + feeder loss + filter loss – antenna gain

Values for antenna gain, feeder loss and loss of the filter (if fitted) are all in dB.

3) Convert dBm back to watts

To covert dBm into watts use the following formula:

Normal transmitter power (watts) = $10^{(\text{Normal transmitter power (in dBm)} - 30)/10}$

4) Measurement of normal transmitter power

The transmitter power is measured with the directional coupler connected in-line with the antenna cable between the transmitter and antenna, and the analyser connected to the forward port of the directional coupler. The power required to be measured at the coupler forward port can be calculated using the following formula :

Measured forward power (dBm) = Normal transmitter power (dBm) - coupling factor (dB)

Example power calculation for a 20W ERP service

- Licensed ERP: 20 watts
- Feeder loss: 1.8 dB
- Filter loss: 0 dB
- Antenna gain: 3 dB
- Measured coupling factor: 32 dB

Using the formula in section 1) above, the licensed ERP of 20W converts to:

$$30 + 10 \times \log_{10}(20) = \mathbf{43dBm}$$

Using the formula in section 2) above, the normal transmitter power in dBm is calculated:

Normal transmitter power (dBm) = 43 +1.8 + 0 - 3 = **41.8 dBm**

Using the formula in section 3) above, the normal transmitter power calculated in watts is:

$$10^{(41.8 - 30)/10} = \mathbf{15.1\ W}$$

Using the formula in section 4) above, the power to be measured on the directional coupler is calculated:

Measured forward power = 41.8 – 32 = **9.8 dBm**

Therefore the transmitter’s power is correctly set when the power measured by the analyser on the coupler’s forward port is +9.8 dBm.

Power measurement method

Important – ensure all modulation is removed from the transmitter

The transmitter should be operating into the antenna or a test load with all modulation removed.

- Adjust the spectrum analyser settings as follows (guideline values):
    - **Centre Frequency:** set to the transmission frequency (97.3 MHz in the example below)
    - **Span**: 500 kHz
    - **Resolution Bandwidth (RBW):** 300 kHz
    - **Video bandwidth (VBW):** 300 kHz

- Connect the analyser to the forward port of the directional coupler.
- Set a marker at the centre frequency and read the value.
- Record this value.
- Save a plot of the trace to include in report.

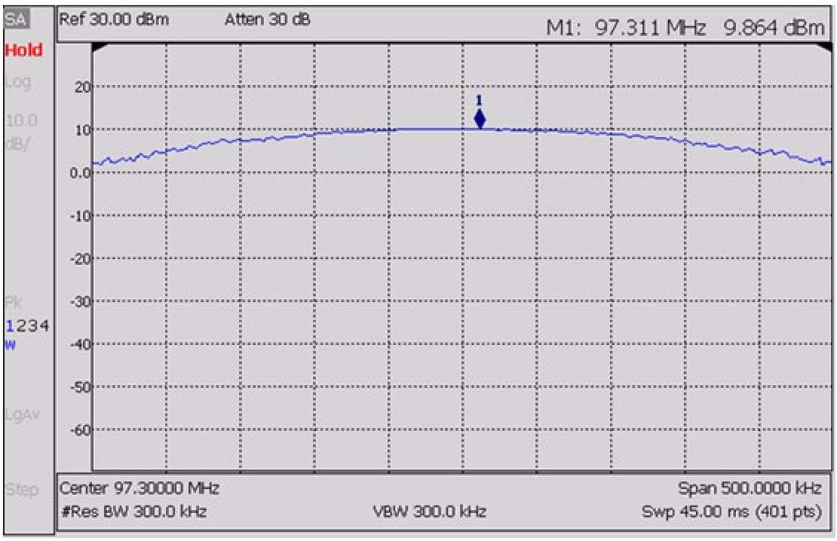

Figure 5 - Forward power (9.8 dBm)

Deviation

The transmitter should be operating with its normal audio source applied, with stereo pilot (if the service is in stereo) and RDS operating (if the service is to carry RDS).

- Connect the modulation meter to the forward port of the directional coupler.
- Measure the peak deviation, which must be no more than ±75 kHz.
- Momentary overshoots greater than ±75 kHz are permissible if there are fewer than five overshoots in any five minute period.
- Save a plot of the trace to include in report.

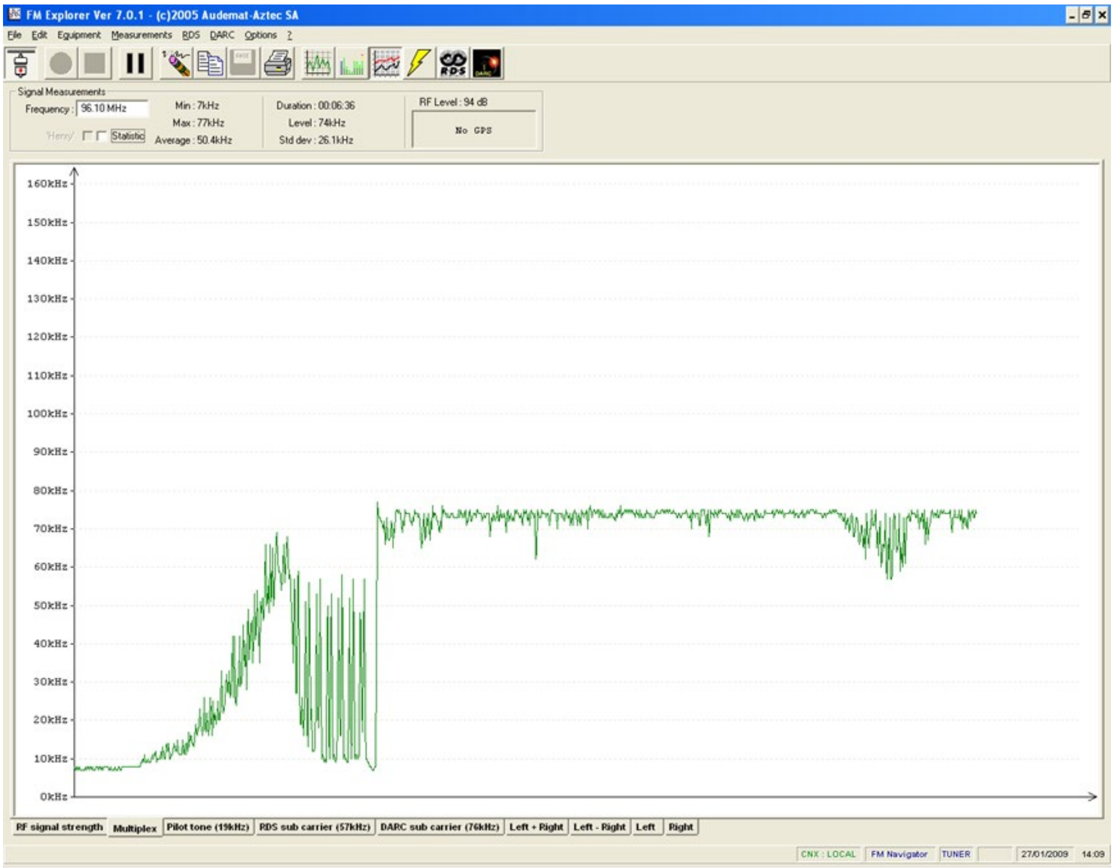

Figure 6 - Deviation over time

Spectral occupancy

The transmitter should be operating with its normal audio source applied, with stereo pilot (if the service is in stereo) and RDS operating (if the service is to carry RDS).

- Adjust the spectrum analyser settings as follows:
  - **Centre frequency:** transmission frequency in use
  - **Span:** 500 kHz
  - **Resolution bandwidth (RBW):** 300 kHz
  - **Video bandwidth (VBW):** 300 kHz
- Connect the spectrum analyser to the forward port of the directional coupler.
- Put a marker on the centre frequency and markers at ±150 kHz of the centre frequency.
- Make a note of the level on the centre frequency, this is your reference.
- Now set the **Resolution** and **Video** bandwidths to 3 kHz.
- Read the values for the markers set to ±150 kHz.
- Record these values, they should be at least 60 dB less than the reference.

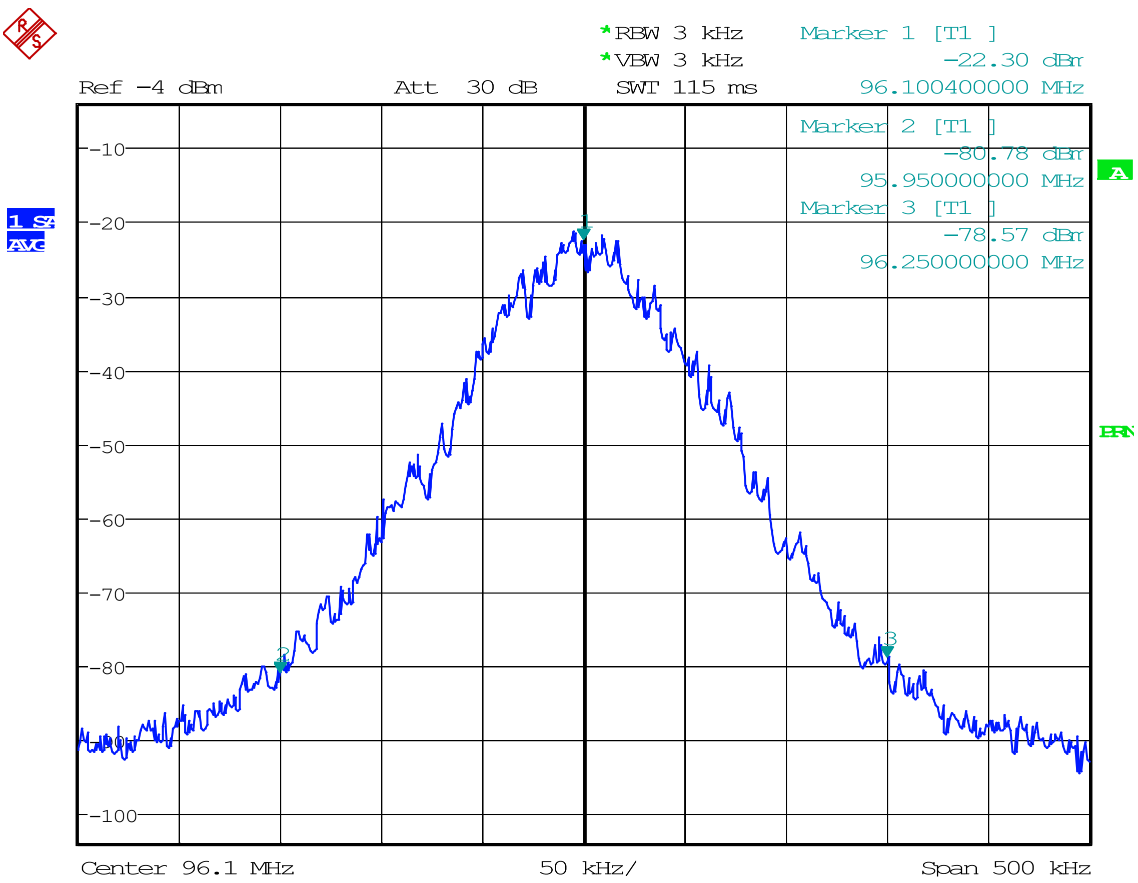

Figure 7 - Spectral Occupancy

Harmonics and Spurious measurements

The transmitter should be operating with its normal audio source applied, with stereo pilot (if the service is in stereo) and RDS operating (if the service is to carry RDS)

- Adjust the spectrum analyser settings as follows:
  - **Start frequency:** 88 MHz
  - **Stop frequency:** 500 MHz
  - **Resolution bandwidth (RBW):** 50 kHz
  - **Video bandwidth (VBW):** 50 Hz
- Connect the spectrum analyser to the forward port of the directional coupler
- Put a marker on the transmitter's carrier frequency – this is the reference level (106.5 MHz in the example below)

Harmonics

- Put markers on the harmonic frequencies of 2x carrier frequency, 3x carrier frequency etc. (e.g. 213.0 MHz, 319.5 MHz and 426 MHz in the example below, although only the second harmonic is of interest in this example).
- Read the values at the harmonic frequencies.
- Record these values.
- Save a plot of the trace to include in report.

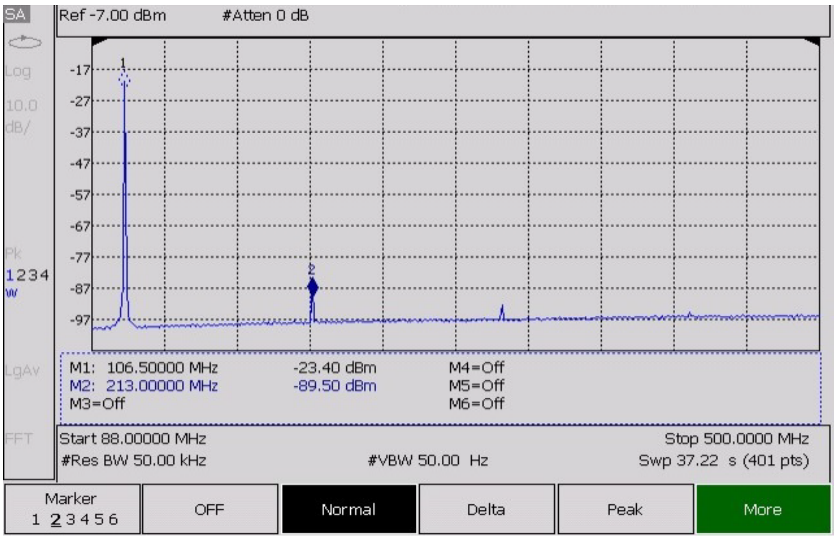

Figure 8 – Plot of harmonics

Spurious emissions

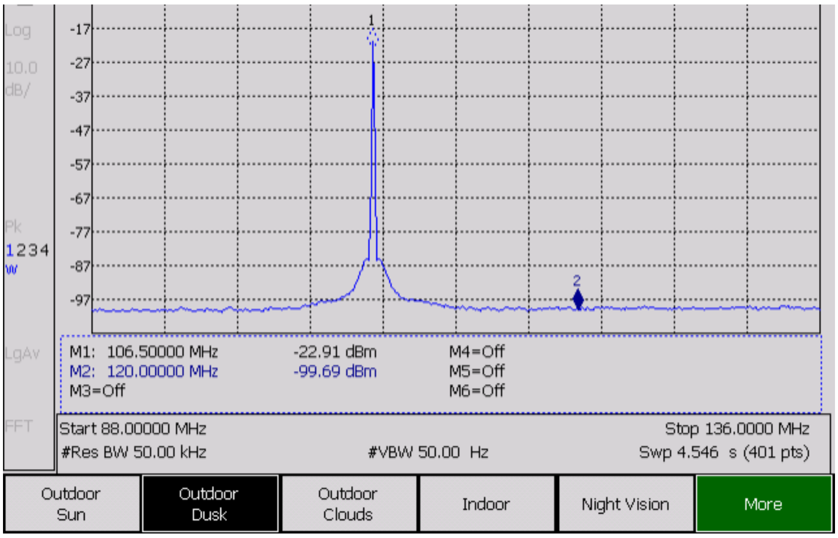

Figure 9 -Plot of spurious emissions

- Examine the analyser trace for evidence of spurious emissions on any frequency.
- Pay particular attention to frequencies between 108 MHz to 137 MHz which are used by aeronautical services and have specific limits in the Analogue Technical Code.
- Record the values of any notable spurious emissions.
- Save a plot of the trace to include in report.

Limits for both harmonic and spurious emissions are contained in Section 3 (Tables 1 to 3) of the Analogue Radio Technical Code.

Stereo Pilot tone and RDS data

If the radio station is in stereo, or is providing RDS data, then the deviation of those components must be checked. To carry out these tests, the transmitter should be operating with its normal audio source applied, with stereo pilot and/or RDS operating as appropriate.

- Connect the modulation analyser to the directional coupler's forward port
- Read the deviation values for pilot tone at 19 kHz (if the station is in stereo) and for RDS (if this data is being provided):
    - 19 kHz pilot tone should be at 6.7 kHz (6 to 7 kHz);
    - RDS should be no greater than 4 kHz, and is typically set to 2.4 kHz.

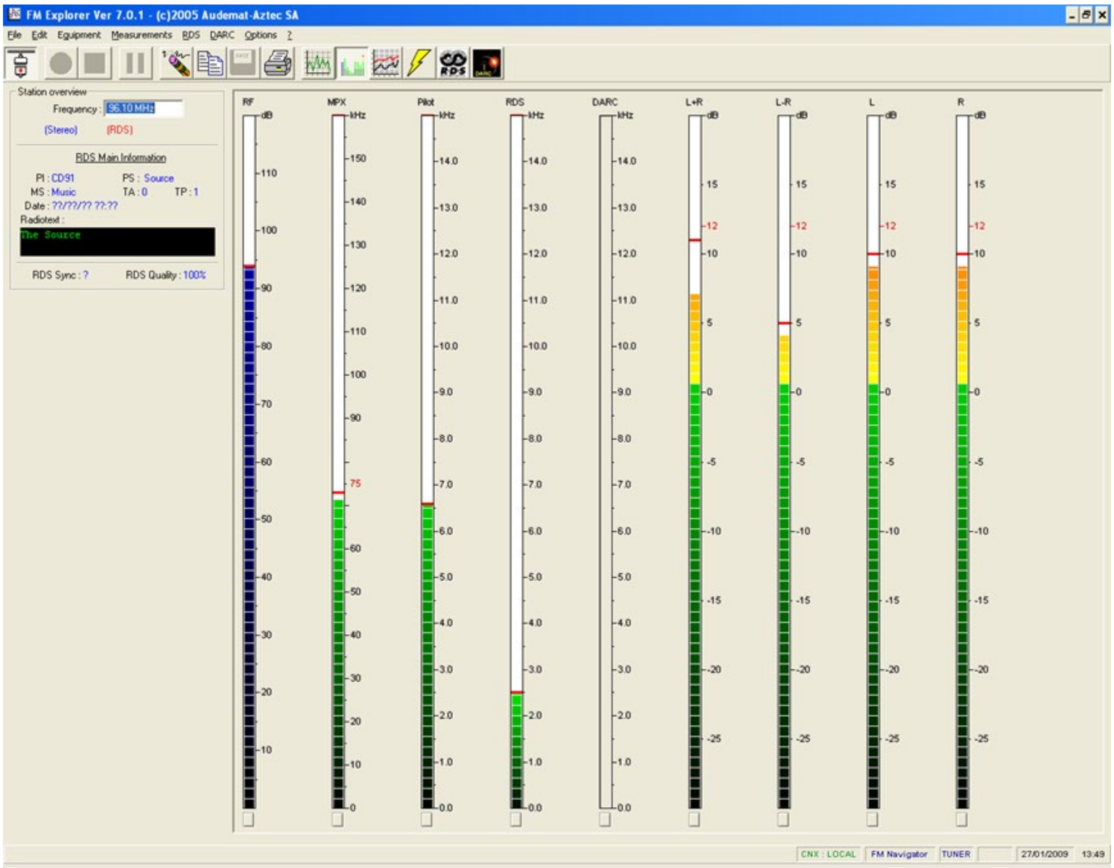

Figure 10 - Stereo pilot and RDS deviation measurements.

RDS data

It is optional for broadcast stations to transmit RDS. If the station is planning on transmitting RDS data, then checks should be made of the accuracy of some of the key data that is used to identify the service to ensure that radios receiving the service operate correctly and consistently.

- Connect the modulation analyser to the directional coupler's forward port
- Navigate to the screen that displays the following data, and take a screen shot of the following:
    - RDS PS (programme service name);
    - RDS PI code: this is a unique code allocated by Ofcom. In some cases there may be two PI codes if the station has regional opt outs;
    - AF list: alternative frequencies used, if there are relay sites; and
    - TA/TP: if using traffic flags note whether this option is in use.

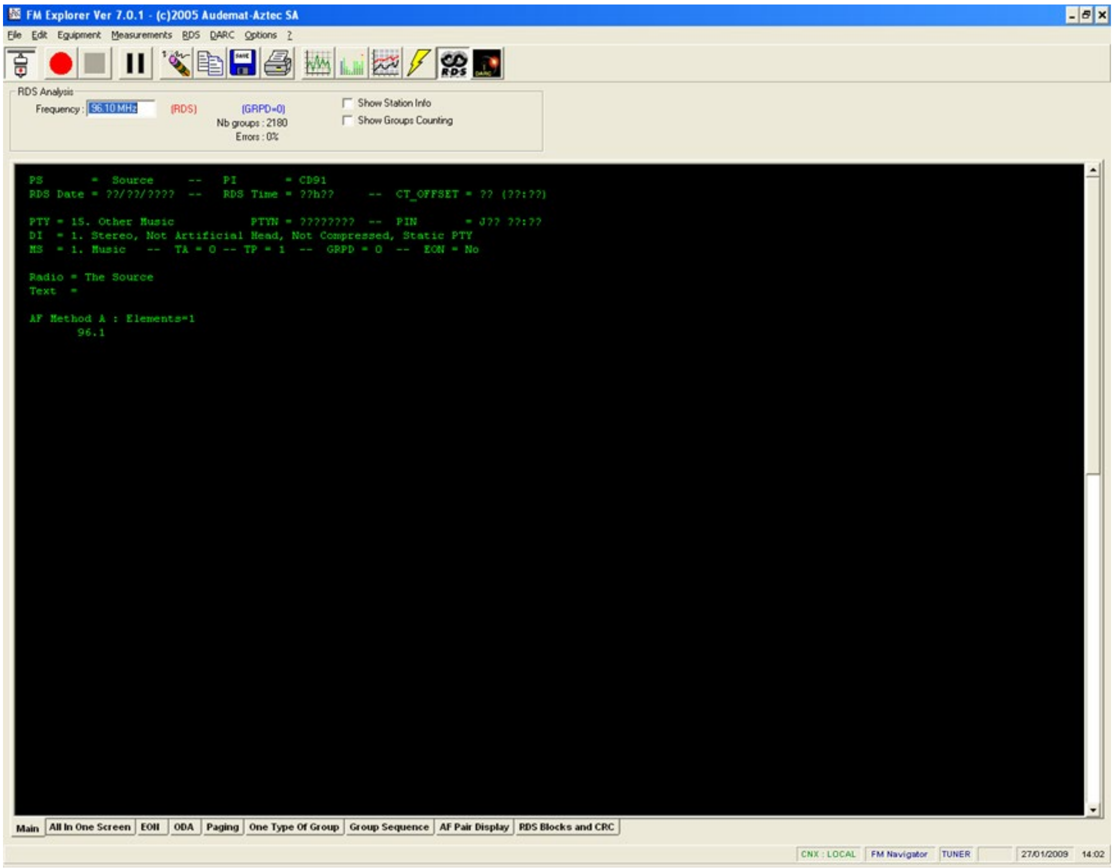

Figure 11 - RDS information.

Results – record sheet

When acceptance testing is completed fill out Table 2. An Excel template version of this table is available on Ofcom's website.

FM radio acceptance test items	Result	Screen shot or photo required
Date of commissioning		
Engineer name, organisation and email		
Site name and postal address		
Site NGR confirmation to 8 figures		
Antenna type		
Vertical or mixed polarisation		
In use height (metres above ground level)		
Antenna gain (dBd)		
Feeder type and calculated loss/Filter loss if used (dB)		
Calculated tx power (dBm)		
Calculated transmitter power (W)		
Directional coupler type		
Directional coupling factor at in use frequency (dB)		
Transmitter type		
Processor type if in use		
RDS type if in use		
RDS PI code in use		
RDS PS name in use		
Studio to Tx link type (ie 4G/5.8Ghz)		
STL frequency if used		
Measured return loss of antenna (minimum 14dB)		
Measured tx frequency (limit ±2kHz from nominal)		Yes
Measured harmonics (minimum 60dBc)		Yes
Aero band measurements 108 to 118MHz (see Tech Code for limit)		Yes
Aero band measurements 118 to 136MHz (see Tech Code for limit)		Yes
Any noteable IP if so list:		
Spectral occupancy (60dB)		Yes
Overall Deviation (maximum 75kHz)		Yes
19kHz pilot tone level (if stereo service)		Yes
RDS level (if used)		Yes
Test equipment used (attach current calibration certificate)		Yes
Site photos of the antenna installation, and tx rack.		Yes
EMF calculation for compliance distance [2] (metres from antenna)		
Note Harmonic levels vary depending on in use power		
See notes in the Analogue Radio Technical Code for guidance.		

Table 2 – Acceptance tests results sheet

[2] The distance a licensee should maintain between their antenna and members of the general public. Guidance is available in this document: Guidance on EMF Compliance and Enforcement (ofcom.org.uk) and an Ofcom online EMF calculator is available at EMF Calculator (ofcom.org.uk)