



National Association of Police Fleet Managers

A Design Guide for Vehicle Installations

Issue 5 – April 2014

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Contents	Page
1. Introduction-----	1
2. The Federation of Communication Services code of practice – FCS1362-----	2
3. Statutory Regulations -----	3
5 Condition of equipment prior to installation -----	5
6 General principles of installation design -----	5
7 Supplementary practices -----	6
8 Post installation testing and faults -----	7
APPENDIX A - Electromagnetic Compatibility-----	1
APPENDIX B – Abbreviations -----	3
APPENDIX C – Low Resistance Meter Requirements-----	4

1. Introduction

- 1.1 This guide replaces the previous NAPFM Code of Practice, Issue 4.

Airwave radio terminal and other ancillary equipment suppliers to the police now recommend the FCS 1362 code of practice to all police installers as the reference for installation practices for their equipment. Accordingly the NAPFM Code of Practice has been modified to become a supplement to FCS 1362 and is intended to provide additional information to assist police installers with designing more complex installations.

- 1.2 The Automotive and Equipment Section (AES) of the Home Office Centre for Applied Science & Technology (CAST), has prepared this guidance for the National Association of Police Fleet Managers. The document is the property of NAPFM. The information contained in this document is believed to be accurate and reliable, however no responsibility is assumed for inaccuracies

- 1.3 This document includes recommendations that are intended to minimise the possibility of Electromagnetic Interference (EMI) between the installed equipment and the vehicle electrical and electronic systems.

- 1.4 Definition of terms used throughout this document:

Installer - The installation technician, employed directly by a police force or by an equipment installation contractor.

Mobile equipment - Comprises any electrical or electronic equipment, including radio transceiver (transmitter/receiver), intended for installation and use in a vehicle and powered by the vehicle's battery.

Ancillary equipment - Any additional items required to ensure the installed mobile equipment is functional.

- 1.5 Precedence of instructions

The vehicle or equipment manufacturer's specific installation recommendations, instructions and procedures normally takes precedence.

- 1.6 Contact Details:-

AES@homeoffice.gsi.gov.uk

2. The Federation of Communication Services code of practice – FCS1362

- 2.1 In co-operation with industry and regulatory representatives the FCS1362 code of practice was extensively revised and republished by the FCS in 2010. The document undergoes regular revision, the current version is held on-line at fcs.org.uk. This document is primarily concerned with the installation of business (both PMR and trunked) radios, mobile telephone equipment, ancillary equipments and telematics. It has since been generally adopted by many Airwave terminal suppliers and is included within suppliers' installation instructions to police installers.

The code of practice can be obtained from:

FCS Ltd.
Provident House
Burrell Row
Beckenham
Kent
BR3 1AT

0207 186 5432

The document may be downloaded from the FCS web site – www.fcs.org.uk

3. Statutory Regulations

3.1 Health and Safety

The Health and Safety at Work Act is applicable for the installation of operational equipment in police vehicles. The legislation makes it mandatory on the installers of all aftermarket equipment, to take precautions to ensure that the addition of these items does not, under normal operating conditions, physically injure or hazard the lives of the occupants of the vehicle.

3.2 Competence and liability insurance

Installers should have product liability insurance that will cover the actual work carried out. In addition, the installer may have professional indemnity insurance that indicates some guarantee of his competence to do the work.

3.3 Vehicle type approval

Forces should be aware that current Department for Transport (DfT) advice is that the European Community Whole Vehicle Type Approval (ECWVTA) and UK National Approval requirements do not apply to cars used for policing. This is referenced to the provisions within Article 2 of the Directive 2007/46/EC.

However, all modifications that endanger safety may result in an offence being committed. Any modification carried out on the vehicle in order to install the equipment should not in itself make the vehicle less safe than it was prior to the equipment installation.

3.4 Alternative fuels

In general the information contained in the FCS1362 Code of Practice covers vehicles of any type. The installation in certain specialised vehicles, such as gas-propelled vehicles may be subject to additional safety regulations.

3.5 The EMC directives (2004/104/EC and 97/24/EC)

The Automotive EMC Directive is enacted into UK law through the Road Vehicles (Construction & Use) Regulations. It is essential that the installer understands the requirements of either the Automotive EMC Directive, or the Motorcycle Directive (depending on the whether the installation is being carried out on either a four wheeled or two and three wheeled vehicle) and ensures that the completed vehicle and its equipment are also compliant with the relevant Directive.

The 2004/104/EC directive requires vehicle manufacturers to provide specific declarations in respect of mobile radio and radiotelephone equipment together with fitting instructions. These are intended to ensure the safe operation of the vehicle when the radio equipment is used. These declarations include radio frequency operating band, transmitter power and installed vehicle antenna position.

Installers should fit equipment in accordance with these instructions. Vehicle and terminal suppliers may adopt or refer to FCS1362 in this regard.

Police Fleet Managers should ensure that:

- all operational electrical, electronic and communications equipment presented to the installer for fitting carry an appropriate 'e' or 'CE' mark and also address the requirements of Automotive EMC Conformance Specification 5. (See section 4)
- all vehicles and motorcycles presented to the installer have been declared suitable for use with relevant frequency bands and transmitter powers and have met the requirements of Automotive EMC Conformance Specification 6. (See section 4)

3.6 Radio licence

Unless the equipment is specifically operating under deregulated conditions all users of radio equipment should hold a licence in that behalf granted by Ofcom. A separate licence is not required for subscribers to the Airwave system or public radio telephone networks as these are held by the service provider.

3.7 Interior fitting directive

The installation of equipment into the interior of four wheeled vehicles should comply with the essential requirements of the Interior Fittings Directive, 74/60/EEC, as amended. Whereas the installation of equipment in two and three wheeled vehicles should comply with the essential requirements of Chapter 3, of the Motorcycle Directive 97/24/EC.

4 AES Automotive EMC Conformance Specifications

- 4.1 The purchase of vehicles or operational equipment that does not meet a suitable EMC standard can be a contributory factors to failures caused by interference. As previously mentioned in Section 3, all new type four wheel and two wheeled vehicles are required to comply with the EMC requirements of 2004/104/EC and 97/24/EC respectively. It is the responsibility of the Police Fleet Manager to supply the installer with compliant electrical, electronic and communications equipment for installation in the vehicle.
- 4.2 However, an examination of EC EMC directives shows that the limits set cannot guarantee to deliver the EMC standard that is required for the successful use of operational equipment in Police vehicles.
- 4.3 AES has developed and published Automotive EMC Conformance Specification 6. This specification relates to the EMC performance of vehicles required for use by the Police Forces. The limits set by this specification ensure that a vehicle meeting those EMC requirements should be suitable for police operational use.
- 4.4 AES has also developed and published the Automotive EMC Conformance Specification 5. This specification relates to the EMC performance of vehicle mounted, electrically powered equipment, intended for installation

in vehicles by the Police Forces. The testing method and the limits set by this specification ensure that that any equipment meeting the requirements should be suitable for operational use.

5 Condition of equipment prior to installation

- 5.1 New operational electrical and electronic equipment will have been quality assured. The equipment should have been inspected carefully before being issued to the installer. All new equipment intended for fitment into 4-wheeled vehicles should carry the "e" mark or "CE" mark conforming to EN50498 confirming it meets the requirements of the Automotive EMC Directive. In addition all mobile radio equipment should carry the "CE" mark to illustrate its compliance with the RTTE Directive. Class M2 vehicles fitted to carry 8 persons or over (not including the drivers seat), currently need not comply with these requirements. However, police forces and installers may choose to insist on "e" mark or "CE" marking in the interests of safety and good practice.
- 5.2 Used equipment should be presented to the installer having first been checked to ensure that it meets the original manufacturers' specification. No recovered equipment should be damaged or have sharp edges or loose mechanical parts. The installer should either carry out local remedial action or return it to the customer for replacement, as appropriate.
- 5.3 All ancillary equipment used with the main electrical, electronic and radio equipment should have been physically checked and electrically tested before being issued to the installer for fitting to the equipment in the vehicle.
- 5.4 The installer should obtain from the Police Fleet Manager any information that is available regarding the installation of the mobile radio equipment.

6 General principles of installation design

- 6.1 For safety of the vehicle occupants in the event of an impact from interior fitted equipment, including after-market, in four wheeled vehicles, there is a requirement for the vehicle manufacturer to comply with European Directive 74/60/EEC (as amended).
- 6.2 A risk assessment process should be conducted before installing equipment on motorcycles which will consider the possibility of degradation of the motorcycle's handling characteristics. Where there is concern, the motorcycle manufacturers' advice should be sought.
- 6.3 Due care should be taken when installing equipment to the front of a motorcycle to ensure that cables are not strained when the handlebars are rotated to their maximum left or right positions. Any equipment installed should not be capable of fouling/snagging the handlebars throughout their rotational movement
- 6.4 The final installation design should be the result of a consensus between the parties involved. These may include the police vehicle Fleet Manager, Airwave Project Manager and, where applicable, the IT Manager, or their representatives. The customer's representatives together with the installer should ensure that the installation complies with any regulations pertaining to that class of vehicle. The layout should provide for maximum

operational efficiency while not compromising the safety of the vehicle crew

- 6.5 The vehicle and RF transmitting equipment manufacturers' instruction manuals and installation notes must be followed where they take precedence over FCS1362. The vehicle manufacturer's instructions will always take priority in case of conflict.
- 6.6 However, for safety considerations there will be occasions when, despite every endeavour by all the parties involved, an agreement cannot be reached. Under no circumstances should equipment be mounted into a vehicle in any position that is considered to be a safety hazard to the occupants. If this situation cannot be reconciled amicably with the customer's representatives then it is in the interest of the installer to review his position in respect of the Health and Safety issues and the relevant acts.
- 6.7 The installer cannot transfer his health and safety responsibilities to the vehicle operator.

7 Supplementary practices

7.1 The mobile antenna

Under the requirements for Directive 2004/104/EC new vehicles should now be type approved with manufacturer EMC declarations and installation instructions in respect of any radio transmitting equipment considered suitable for the vehicles application. For example, it is likely that all new vehicles will be automatically supplied with declarations and installation instructions in respect of GSM mobile telephones.

The 2004/104/EC EMC declarations:

- a) Frequency band -Ensure vehicles are suitable for use in the Airwave UHF bands.
- b) Power output -Ensure vehicles are suitable for use with Airwave mobile transmitters at the Airwave recommended RF output power.
- c) Antenna position - Check that a viable antenna position has been declared for the Airwave service by the vehicle manufacturer.

7.1.1 Operating a vehicle with any transmitting equipment working outside of the vehicle manufacturers EMC declarations might render the operator and/or installer vulnerable to allegations and be liable for any consequential damages arising in the event of an accident. It may also render the vehicle's warranty void.

7.1.2 Where operating the vehicle outside of manufacturers declarations is unavoidable, or where no such declarations have been made, the installer should thoroughly test the vehicle to ensure there are no adverse effects

during use. It is important that a report providing evidence of satisfactory operation and performance should be raised and filed for future reference. In case of an accident and consequent litigation, it may be prudent to keep these records for a time after the vehicle has been sold unless it has been re-instated to its original condition prior to sale.

7.1.3 The antenna should be positioned such that the RF field-strength in the areas of the vehicle containing the electronic modules is minimised, while maintaining an acceptable radio performance. This is normally towards the rear of the roof.

- In particular the antenna should not be mounted close to the windscreen or other apertures as antennas mounted in these positions can enhance non-ionising radiation levels within the occupied areas.
- Unless specifically designed for the purpose, antennas should not be mounted on light-bar assemblies as mounting in this way may cause the light-bar to act as a conduit for electromagnetic disturbances and interference.
- Care must be taken when installing more than one antenna. A physical separation should be provided of at least $\frac{1}{4}$ wavelength (λ) for transmit frequencies below 600 MHz and one wavelength for transmit frequencies above 600MHz.

Ensure the earthing of the antenna base is satisfactorily achieved as poor connections can develop with time reducing antenna efficiency, increasing the risk of interference and degraded Airwave coverage. It is important to ensure that suitable antenna feeder cable is used, and the cable is securely laid and that terminations are well found. Loosely fitted connectors have been responsible for many faults. The feeder should be checked in accordance with FCS 1362.

8 Post installation testing and faults

The following information should always be recorded on the test sheets: Sponsor/customer; Job Number; Vehicle Make and model; Vehicle Fleet number and Registration No.

8.1 Earth bonding and power supply return checks

Minimising the unwanted voltage drop developed across the (-ve) power supply return to the battery will improve the performance of the installed equipment. Hence a low resistance DC return path to the battery and bonding of the radio to the vehicle chassis will reduce the risk of EMI.

NOTE: These measurements can only be made using a suitable low resistance milliohm meter. (See appendix C)

- Power supply return test

Measure and record between the battery negative terminal and the negative connection, with the antenna disconnected. A reading of 10m Ω or less for motorcycles and 20m Ω for typical motorcars is considered satisfactory. Canbus

systems that remain active after ignition is switched off will frequently degrade measurements of return path resistance.

- Earth bond resistance

Measure and record the Earth Bond Resistance between the battery negative terminal and a secure and good earth point on the radio case or frame with the antenna disconnected. For readings in excess of 50mΩ the bonding should be re-examined with the aim of reducing the reading. Note that if the vehicle battery remains connected then anomalous readings might be obtained with some equipment.

	Earth Bond Resistance mΩ	Notes
Airwave Radio		
Antenna Feeder Outer		
Antenna Feeder Inner		

8.2 Antenna testing

Prior to conducting functional testing the installed antenna(s) should be tested using a proprietary antenna analyser to show the Voltage Standing Wave Ratio (VSWR) or equivalent. A typical installation should exhibit a worst case centre transmit band frequency VSWR of about 1.5:1 worsening to about 2.1:1 at the band edges. Due to the compromises inherent in covert installations a centre transmit frequency VSWR of 2.5:1 is acceptable.

The antenna to groundplane connection should be tested by means of a milliohm meter between the antenna connector outer and the vehicle body at a suitable un-insulated point. The test should be repeated between the antenna connector inner and the antenna rod if un-insulated. The two readings should be of similar values, typically between 100 and 200 milliohms. This reading will be dependant upon the antenna feeder length.

Antennas exhibiting a worse performance than indicated above should be examined for installation faults, being of an incorrect type, or being fitted in too close proximity to another antenna or metalwork / wiring.

8.3 A guide to the functional testing of the Airwave radio

The main aim of these checks is to ensure that the Airwave radio system is operational and, as far as is possible, free from interference. The sources of interference degradation may arise from the vehicle and its systems, other radio equipment, or other on-board equipment such as mobile devices and navigation systems. Degradation of incoming (received) signals due to noise or other spurious emissions emanating from any of the above can lead to a lack of Airwave coverage, intermittent coverage, or impaired speech quality.

Unfortunately it is not always possible to determine the presence of harmful interference on a digital radio system by simply listening to background noise. Occasionally noise can be transferred to the transmitter microphone circuits and this can cause degradation to the audio speech reproduction at the receiving station, or control room.

Precise testing of the TETRA radio in the presence of noise and interference requires knowledge and test equipment working within a controlled test environment, which is unlikely to be available to many installers. For these reasons post installation testing will normally be limited to carrying out routine functional tests whilst operating the vehicle, its automotive systems and other on board equipment.

Two types of test call should be undertaken:

- Airwave group or private call via the network using an approved force talkgroup.
- Direct Mode Call using an approved Direct Mode frequency.

The test procedure adopted and the result should be recorded by the installer. The procedure will normally involve activating various combinations of on-board equipment together with running the vehicle engine whilst evaluating the quality of signals received by the mobile terminal and by the receiving station during transmissions. The table below may be used as a guide.

Activated Item	Speech test via network		Speech test using DMO		NOTES
	Pass/Fail	criteria	Pass/Fail	criteria	
Main and side lights					
Indicators/hazard lights					
Warning lights					
Speedometer					
Rev. counter #					
Engine speed #					
Receiver audio #					
Police role equipment					
Data equipment					
ANPR equipment					
Speed metering equipment *					

* These tests do not confirm accuracy of the measuring device.

8.4 Vehicle immunity testing

The main aim of this assessment is to identify whether the vehicle or its systems are affected by the Airwave radio transmitter when connected to its antenna.

Operate and observe the following items while transmitting. In order to subject the vehicle to the strongest radio frequency fields the test must be conducted under constant transmitter power conditions. Since the Airwave transmitter may reduce its power when using an Airwave trunked mode call this test should be always be conducted using Direct Mode on an approved channel or talkgroup.

Run the engine at 1500~2000 rpm, but vary the engine speed for the tests marked "#".

Item	TETRA	Analogue	Notes and observations
Main and side lights	Pass/Fail	Pass/Fail	
Indicators/hazard lights	Pass/Fail	Pass/Fail	
Dash board warning lights	Pass/Fail	Pass/Fail	
Speedometer	Pass/Fail	Pass/Fail	
Rev. counter #	Pass/Fail	Pass/Fail	
Engine speed #	Pass/Fail	Pass/Fail	
Cruise control (if fitted)	Pass/Fail	Pass/Fail	
Wipers	Pass/Fail	Pass/Fail	
Brakes * see footnote			
Police role equipment			
Wailers/sirens	Pass/Fail	Pass/Fail	
Light bars	Pass/Fail	Pass/Fail	
Mobile data equipment	Pass/Fail	Pass/Fail	
ANPR equipment	Pass/Fail	Pass/Fail	
Speed meter equipment	Pass/Fail	Pass/Fail	
Public address	Pass/Fail	Pass/Fail	

Testing for vehicle immunity should always be a part of any post installation road tests conducted at the discretion of the installer, see recommendation in FCS1362 section 5.3.6

- * Note *Assessment of braking efficiency whilst transmitting may be considered outside of the installer's ability. An informal assessment of the vehicles braking ability during radio transmissions might be attempted during drive testing if safe to do so. However these tests should normally be undertaken while using a suitable and safe automotive test facility where any degradation of the vehicle's ABS system can be measured using suitable instrumentation.*

End of Installation Guide

APPENDIX A - Electromagnetic Compatibility

1. The majority of police vehicles employ ECUs in safety critical areas, for example ABS or engine management. The operation of each ECU relies on electrical signals passing from one point to another, therefore creating electromagnetic fields that are continually growing and decaying. Hence each system becomes a miniature transmitter. Likewise each system can receive signals transmitted from other units that will cause the ECU to malfunction, due to its connecting cables acting as an antenna.
2. It is necessary to define some of the terms used in describing this phenomenon.
3. An electromagnetic disturbance is electromagnetic noise that, if it affects other equipment, is termed interference.
4. Electromagnetic interference (EMI) is defined as an electromagnetic disturbance that causes the degradation of the performance of a device or system. Thus an electromagnetic disturbance is the cause and EMI the affect.
5. Vehicle ignition systems generate disturbances that may affect radio reception in the general environment and within the vehicle. This is referred to radio frequency interference (RFI.)
6. If any device generates and propagates electromagnetic disturbances it is said to create emissions. Emissions are classified as either being conducted or radiated.
7. Conducted emissions are disturbances transferred along wiring harnesses into the power supply terminals of other electronic components or modules. They are usually generated by the interruption of the current flowing in an inductive component and are almost always transient in nature. For example, electrical motors produce a continuous train of pulses when they are in operation. Solenoids and relays produce a transient every time they are operated. These emissions can cause a temporary fault or, in severe cases, permanent damage to other electronic systems. They can also cause interference to the mobile radio system installed in the vehicle.
8. Radiated emissions are disturbances radiated through space. Electrical components generate conducted emissions and these are radiated, in the form of broadband interference from the wiring harness, which acts as an antenna. These emissions, which may extend over much of the RF spectrum, can interfere with radio reception in the vehicle or affect the performance of other electrical components.
9. Radio transmitters are designed to radiate energy through space. The strength of the radio frequency emission from any transmitter may be capable of interfering with a vehicle ECU.
10. Every vehicle or operational ECU usually contains an electronic clock oscillator. Emissions from these clock oscillators can be radiated directly from the ECU itself or from the connecting harness. These emissions may affect the mobile

radio's reception on individual channels in the form of narrow band interference.

11. When various types of electronic equipment are required to operate in close proximity to each other, the ability of all the devices to function without mutual interference is important. Electromagnetic Compatibility (EMC) is defined as the ability of an equipment or system to function satisfactorily in its electromagnetic environment, without causing EMI to affect any other equipment, or being affected itself by EMI from other electrical devices.
12. Radiated immunity is a measure of an equipment or system's ability to withstand interference radiated through space.
13. Conducted immunity is a measure of an equipment or systems ability to withstand interference entering through its electrical connections via the interconnecting cables.

APPENDIX B – Abbreviations

Abbreviations used throughout this document are listed below:

ABS	Antilock Braking System
AES	Automotive & Equipment Section
CBS	Combined Braking System
ECE	Economic Commission for Europe (United Nations)
ECU	Electronic Control Unit
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMS	Engine Management System
HT	High Tension
ICE	In Car Entertainment
ISO	International Standards Organisation
IT	Information Technology
PATS	Passive Anti-Theft System
PCM	Powertrain Control Module
RF	Radio Frequency
RFI	Radio Frequency Interference
RTTE	Radio & Telecommunications Terminal Equipment (Directive)
SI	Statutory Instrument
STU	Separate Technical Unit
TCS	Traction Control System
TLED	Traffic Law Enforcement Device
UHF	Ultra High Frequency
VHF	Very High Frequency
VSWR	Voltage Standing Wave Ratio

APPENDIX C – Low Resistance Meter Requirements

Specification for a Low Resistance Measuring Meter for Vehicle Installation

Description

The instrument should be of lightweight design, suitable for use by semi-skilled personnel for the measurement of low resistance bonds on vehicle communication and electronic installations.

The instrument should be battery powered and completely portable.

The measuring voltage should be of such a level as to prevent the penetration of any resistive film that is present.

Test leads should be of such a length as to allow an overall check of a vehicle's earth bond resistance to be carried out. i.e. 5 metre lengths.

Specification

Bond measurement: Meter display - 1 to 200 milliohms

Accuracy: Plus or minus 10%

Measuring voltage: 100 micro volts (peak)

Built-in calibration standards should be available