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Guidance on Train Rooftop Antenna Positioning
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Guidance on Train Rooftop Antenna Positioning

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Guidance on Train Rooftop Antenna Positioning

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Guidance on Train Rooftop Antenna Positioning

Part 1 Introduction

1.1 Purpose of this document

This document gives guidance on train rooftop antenna positioning with the intention of assisting infrastructure managers, railway undertakings and other organisations required to fit antennas on train rooftops in relation to good practice for train rooftop antenna positioning.

This document does not constitute a recommended method of meeting any set of mandatory requirements or recommend any particular manufacturer's products.

1.2 Background

1.2.1 Scope

The correct positioning and installation of the antennas is key to the successful operation of radio systems and, importantly, by reducing the number of holes in the train roof by combining and fitting systems at the existing antenna positions.

The scope of this document is the trainborne arrangements for implementation and installation of rooftop radio antennas that support legacy, new digital radio communication systems and Global Navigation Satellite Systems (GNSS) on the GB railway. It includes guidance on the selection of the antennas, their mounting locations and arrangements, as well as information concerning the associated radio frequency components. It sets out good practice on the specification, implementation and installation of radio antennas on top of the roofs of trains. This good practice guidance applies equally to passenger trains, locomotives and on-track machines.

Research designated T739 and titled: Train Rooftop Antenna Positioning – Issues Study, was commissioned by RSSB on behalf of the GB railway industry to identify good practice for positioning of antennas on train rooftops. This guidance note is largely based on the output from this research.

1.3 Structure of this document

This document is structured to allow the reader to understand good practice for train rooftop antenna positioning in logical steps.

The earlier parts address the concept of antenna 'grouping' of the different radio systems on board the train, leading to the separation requirement of these groups. The latter parts set out guidance on antenna types and design requirements, antenna locations, and issues with antenna obstructions on the train, leading to installation and maintenance issues.

1.3.1 The main document comprises:

Part 2 sets out the way that radio systems are 'grouped' in terms of their importance for operational safety, operational importance or passenger use, relating to a simple method covering antenna separation.

Part 3 sets out an easy-to-follow positioning methodology which could be of use if the minimum separation distances in Part 2 are unable to be achieved.

Part 4 sets out guidance regarding the different parameters which are of importance for different radio systems and the different antenna types which are available. Part 4 also outlines some basic background information needed before tackling Part 5.

Part 5 sets out the guidance on the positioning of antennas on the train rooftop, design issues associated with train roofs and antenna obstruction issues.

Part 6 completes the main body of the document by setting out guidance on environmental, installation and maintenance considerations.

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1.3.2 The appendices comprises:

Appendix A sets out guidance on radio frequency (RF) system design considerations; this appendix is useful where a deeper knowledge of RF considerations is needed.

The remaining appendices set out useful reference material covering basic antenna design and specification information, as follows:

Appendix B Antenna Basics

Appendix C Antenna Terminology

Appendix D Losses Due to Diffraction Around Obstructions

Appendix E Suggested Outline Specification for the RF Frequency Multiplexer

Appendix F Antenna Datasheets

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1.5 Approval and authorisation of this document

The content of this document was approved by:

Control Command and Signalling Standards Committee on 8 April 2010.

This document was authorised by RSSB on 26 April 2010.

Part 2 Guidance on Antenna Grouping and Separations

2.1 Technical introduction – radio technologies for operational safety applications

- 2.1.1 The GB railway industry currently uses two legacy analogue radio systems on board trains for communication with the driver. Both systems are used throughout large parts of the GB railway industry and both are concerned with the operational safety of trains. Driver / signaller communications are made through a mobile radio unit mounted close to the driving cab (one for Cab Secure Radio (CSR) and another for the National Radio Network (NRN)) and an antenna (one for CSR and another for NRN) which is located on the roof of the train close to the driving cab.
- 2.1.2 These legacy systems are being replaced by a digital system: Global System for Mobile Communications – Railways (GSM-R). In the same manner as the legacy radio systems, communication to the driver is typically made through a mobile radio unit mounted close to the driving cab, and associated dedicated antenna located on the roof of the train close to the driving cab. GSM-R is planned to be used as a data bearer for train control applications such as the European Train Controls Systems (ETCS), an example application being General Packet Radio System (GPRS).
- 2.1.3 In addition, systems are currently being introduced on trains which make use of positioning data based upon the use of the satellite Global Positioning System (GPS).

2.2 Technical introduction – radio technologies for other applications

- 2.2.1 Radio systems for other non-safety related applications are planned for introduction in the near future. These include applications related to railway administrative purposes, inter-coach communication, passenger voice, entertainment and internet access.
- 2.2.2 A wide variety of possible radio based technologies is likely to be involved in the provision of these services, including Wireless Local Area Network (for example, Wi-Fi), Third Generation Partnership Project (3GPP), Universal Mobile Telecommunications System (UMTS), Broadband Wireless Networks (based on IEEE802.16; WiMax), Global System for Mobile Communications – Public 900MHz (GSM-P 900) and Global System for Mobile Communications – Public 1800MHz (GSM-P 1800).
- 2.2.3 Each of these radio systems is likely to require its own radio unit and require the use of a dedicated antenna or a shared antenna.
- 2.2.4 GPS receivers connected to a rooftop-mounted GPS antenna on the train also support non-safety related applications.

2.3 Antenna grouping

- 2.3.1 The space on top of the roof of the train is limited and in such cases there may be competition for the most advantageous locations on the train. Antennas integral with radio systems on the train, that provide operational safety, should be given priority over other facilities in their placement on the train rooftop.
- 2.3.2 To achieve priority of antenna positioning on train rooftops, the antenna systems are recommended to be grouped in order of the priority of each application. A set of groups for GB applications is set out in Table 1.
- 2.3.3 Voice applications are allocated to Group A and signalling data applications are allocated to Group B, with both groups being classed as operational safety. Both these groups have the same importance and, when considering positioning, this can be undertaken in any order. What is important is that the recommended separation distances are maintained.

Guidance on Train Rooftop Antenna Positioning

- 2.3.4 Groups A and B antennas should be considered to take precedence over the positioning of Group C applications, which are classed as operationally important, operationally useful and for passenger use.
- 2.3.5 GPS as a location application may be included within all groups of antennas, with trains having one or more GPS antennas.

Application classification	Systems included	Assigned antenna group	Notes
Operational safety (voice and satellite location)	NRN, CSR, GSM-R voice, GPS	A	Operational trains currently use individual antennas for each of these services
Operational safety (signalling data)	GSM-R for ETCS, GPS	B	ETCS is expected to use two separate antennas dedicated to one of two data radios giving equipment diversity
Operationally important	GPS, GPRS	C	GPS is potentially useful in combination with all equipment ranks. It is included here as it could easily be incorporated within a multi-band antenna
Operationally useful	WiFi, 3GPP/UMTS, GPS, GPRS	C	As above
Passenger use – system is likely to be implemented by TOCs	WiMax, WiFi, GSM-P 900, GSM-P 1800, UMTS 900, UMTS1800, GPS	C	As above

Table 1 Application classifications and antenna groupings

2.4 Antenna separation

2.4.1 Antenna Group A

- 2.4.1.1 The antennas in Group A serve the following systems: NRN, CSR, GSM-R voice and possibly GPS (if the GPS receiver is located close by). Each of these systems should use its own independent, approved antenna that has been used historically, in order to avoid new approvals for these systems.
- 2.4.1.2 If there is only one driver's cab on the leading vehicle of the train, the Group A antennas should normally be located close to that cab. Otherwise, where there are two cabs on the leading vehicle and each cab is fitted with a driver's HMI which shares a single radio unit, the antenna should be located close to that radio unit.
- 2.4.1.3 The recommended spacing between antennas of different radio systems within Group A are set out in Table 2.

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Antenna 1 Wanted signal	Antenna 2 Interfering signal	Recommended minimum separation for systems in simultaneous operation		Recommended minimum separation for systems in non-simultaneous operation
		Blocking	Spurious emissions	
NRN	CSR	2.1 m	2.0 m	0.5 m
NRN	GSM-R voice	0.3 m	1.3 m	0.5 m
NRN	GPS	0.5 m	0.5 m	0.5 m
CSR	GSM-R voice	4.9 m	9.3 m	1 m
CSR	GPS	0.5 m	0.5 m	0.5 m
GSM-R voice	GPS	0.5 m	0.5 m	0.5 m

Table 2 Recommended spacing between antennas within Group A

2.4.1.4 Theoretical calculations and some limited static testing have indicated that there may be degradation in the performance of CSR under certain circumstances when both the GSM-R and CSR systems are being operated simultaneously. Simultaneous operation of these systems is not permitted within a vehicle cab; therefore, any risk is likely to occur where the onboard antenna separation is less than 9.3 m and the following conditions exist:

- When two trains are on adjacent tracks, one with CSR and the other with GSM-R radios simultaneously
- Where there is both GSM-R and CSR operational infrastructure, and a GSM-R transmitter antenna, base station or repeater is located close to the track and the CSR signal strength available to the train is at a low level.

2.4.1.5 Because it is considered that the likelihood of this occurring with the GSM-R and CSR voice systems is very low, and the risk is time limited, as CSR will eventually be replaced by GSM-R, industry believes that this risk is acceptable. However, the system interference risk is likely to be greater following the introduction of ERTMS, and in particular the GSM-R data channel where there is likely to be significantly more GSM-R system usage.

2.4.1.6 Where multiple train radio systems are installed on a single train, the preferred option is for designs to implement the recommended minimum separation distances, for systems in non-simultaneous operation, as set out in Table 2. GE/RT8080, section 5.2.9, sets out the requirement to prevent simultaneous operation of voice radio systems.

2.4.1.7 If a derogation is sought because of a non-compliance with GE/RT8080, section 5.2.9, and it is intended that these systems are operated simultaneously, then the minimum separation distances, set out under simultaneous operation in Table 2, are recommended. The definitions of 'Blocking', 'Spurious emissions' and 'Simultaneous operation' are set out in the definitions section of this guidance note.

2.4.1.8 CSR and GSM-R voice frequencies, in particular, have been shown in RSSB research project (T739) to be sufficiently close to each other to create a problem of mutual interference over many metres, where both radio systems are intended to operate simultaneously. It is recommended that the installed distance between CSR and GSM-R voice antennas, determined under test conditions, is 4.9 m to avoid blocking interference, and 9.3 m to avoid noise through spurious emissions interference.

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- 2.4.1.9 The addition of a suitable inline filter allows the separation distance between GSM-R and CSR to be relaxed. The recommended inline filter specification can have the same characteristics as the RF frequency multiplexer, as set out in Appendix E.
- 2.4.1.10 Where train radio systems, as set out in Table 2, are installed on a single train and it is intended that these systems are operated simultaneously, but installed at the non-simultaneous separation distances, then it is recommended that a type test of that installation is carried out to subjectively assess the voice clarity and potential noise.
- 2.4.1.11 When planning the separation of antenna, consideration should also be given to the effect of degradation in performance introduced by longer antenna feeder cables balanced against the potential degradation from antenna proximity.

2.4.2 Antenna Group B

- 2.4.2.1 Group B is intended for ETCS data provided by the GSM-R data radio system, an example application being General Packet Radio System (GPRS). This antenna group usually comprises two antennas, each one connected to a dedicated train data radio.
- 2.4.2.2 Only one of the ETCS antennas is normally transmitting at any one time, so it is possible to group these two antennas together. Group B also includes the GPS antenna (if this is convenient for the GPS receiver).
- 2.4.2.3 The recommended spacing between antennas within Group B is set out in Table 3.

Antenna 1	Antenna 2	Recommended minimum separation
GSM-R data radio	GSM-R data radio	2.0 m
GSM-R data radio	GPS	0.5 m

Table 3 Recommended spacing between antennas in Group B

2.4.3 Radio systems sharing the multi-band antenna (Group C)

- 2.4.3.1 The following radio systems are classified as Group C systems in Table 1, as follows: WiFi, 3GPP, UMTS, WiMax, WiFi, GSM-P900, GSM-P1800, UMTS900, GPS.
- 2.4.3.2 These radio systems normally use a shared multi-band antenna fitted with a frequency multiplexer to provide isolation between the different radio systems that share the antenna, as well as protecting those radio systems in the antenna Groups A and B from radio emissions.
- 2.4.3.3 The frequency multiplexer (as set out in 4.6) is recommended for Group C radio systems and, if the remaining antennas within Groups A and B have at least the recommended spacings, then the possibility of any of the radio systems interacting to cause interference is minimised.
- 2.4.3.4 Additional restrictions apply to the radio systems within Group C multi-band antenna, as set out below:
- Only one radio system in the 900MHz band should be included (that is one of either GSM-P 900 or UMTS 900), and
 - Only one radio system in the 1800MHz band should be included (that is one of GSM-P 1800 or 3GPP 1800).
- 2.4.3.5 Each of the Group C multi-band antennas should be connected to the mobile via a multiplexer, with only one multiplexer per antenna. Therefore, if more than one 900MHz or 1800MHz system is required on a train in either of these bands, then a separate multi-band antenna should be used, spaced at least 4 m away from the other antennas.

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- 2.4.3.6 It is assumed that the data links to the systems using multi-band radio antenna(s) are transferred along the train on a communications backbone, and therefore possible to position these multi-band radio antenna(s) anywhere on any part of the train, physically remote from Groups A and B systems.
- 2.4.3.7 Where the multi-band antenna includes an integrated GPS antenna, consideration should be given to the fitting of a filter in line with the GPS antenna coaxial feeder connected to the GPS port on the antenna. This is to protect the GPS receiver from high signal levels, which could be coupled in from the other radio systems sharing this common antenna.

2.4.4 Separations between Group C antenna groups and other specific radio systems

- 2.4.4.1 Tests have shown that closer antenna separation is possible between Group C antennas and other specific radio systems from Group A, as set out in Table 4.

Antenna in first group	Antenna in second group	Recommended minimum separation
Multi-band (Group C)	GPS	1 m
Multi-band (Group C)	NRN	2.5 m
Multi-band (Group C)	CSR	1.7 m

Table 4 Separations between specific radio systems

2.5 Separations between antennas of radio systems sharing frequency bands

- 2.5.1 The antenna separations recommended for Groups A, B and C systems assume only one radio system of each type is fitted within each group, or that these systems are interlocked for non-simultaneous operation.
- 2.5.2 Where radio systems that share the same frequency band are to be fitted, these antennas should be spaced further apart than antennas within radio systems that do not share frequency bands, in order to achieve the required radio frequency (RF) isolation. The increase in antenna separation avoids problems arising from electrical interaction at similar radio frequencies.
- 2.5.3 The following radio systems share the 876 MHz to 960MHz radio band:
- a) GSM-R voice (Group A) and the GSM-R data mobiles (Group B), and
 - b) GSM-P 900 (Group C) and UMTS 900 (Group C).
- 2.5.4 The following radio systems share the 1800 MHz to 2100MHz radio band:
- a) GSM-P1800 (Group C), and
 - b) UMTS 1800 (Group C).
- 2.5.5 The groups of antennas should be spaced apart, so that the antenna separations are met, as set out in Table 5.

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Antenna in first group	Antenna in second group	Recommended minimum separation
GSM-R voice (Group A)	GSM-R data (Group B)	4 m
Any GSM-R (Group A or B)	Multi-band antenna (Group C)	4 m
Multi-band antenna (Group C)	Multi-band antenna (Group C)	4 m

Table 5 Separations between antennas of radio systems sharing frequency bands

2.6 Absolute limits on antenna separations

- 2.6.1 The recommended spacings should be used wherever practicable. These are regarded as 100% spacings.
- 2.6.2 Where it is unavoidable, due to physical constraints on the train rooftop, then closer spacings than the recommended 100% figures between the antennas' positions should be used. Consideration should then be given to reduce the risk of interference between individual antennas.
- 2.6.3 Bringing antennas closer than the 100% figure also increases the risk of interference between the larger groups of antennas.
- 2.6.4 The manner in which this risk increases is shown in Figure 1. (See Tables 2 to 5 for the recommended spacings of 100%.)

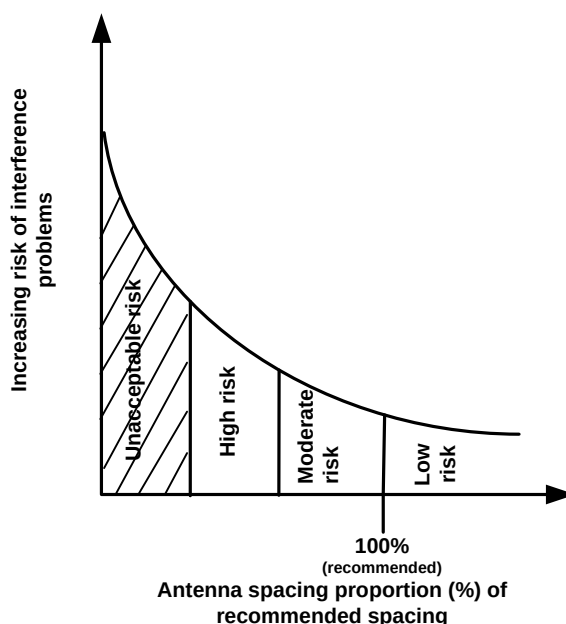


Figure 1 Illustration of the risk of reducing antenna separations

- 2.6.5 The concept of grouping antenna systems and applying separation distances is shown in Figure 2.

Not to scale (typical example where simultaneous operation of voice radio is not expected)

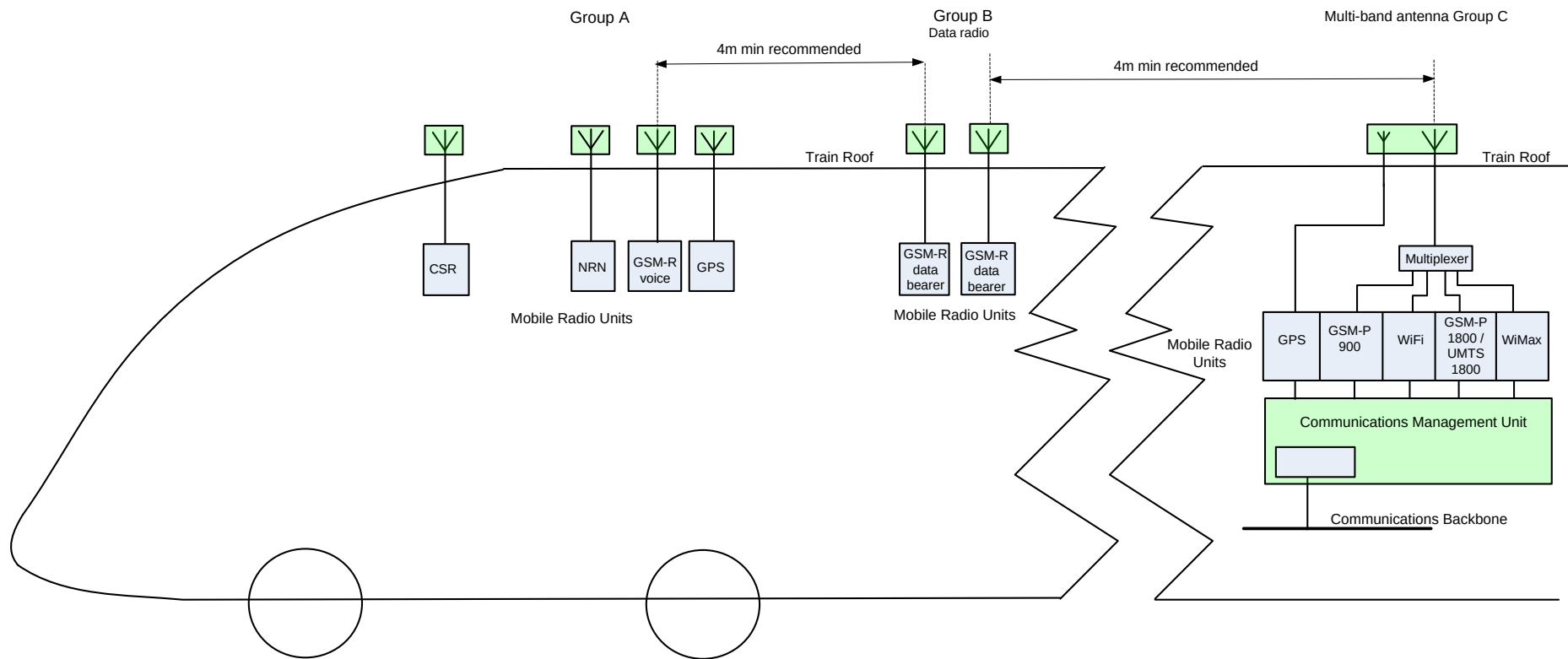


Figure 2 Train radio systems and antenna grouping

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Part 3 Guidance on Positioning Methodology

3.1 Positioning methodology

- 3.1.1 The problem of identifying the best combination of antenna positions on a particular train is unique to each class of train. The difficulty of the task varies from being fairly straightforward, if there is plenty of room on a train roof having few obstructions, to being one where there could be a complex set of compromises and trade-offs between existing antenna systems.
- 3.1.2 This Part 3 proposes a methodology which should be used as guidance when developing the best combination of antenna positions. The methodology addresses the problem in the order of the 'groups' (as set out in Part 2) of the radio systems, so that safety related systems achieve the best positions on the train roof. This conveniently corresponds to the antenna groupings set out in Table 1.
- 3.1.3 Consideration of the fitting of other antennas and radio units for known future radio systems should be undertaken when designing the location for any other antenna. The space above the driver's cab is often one of the more accessible areas of the train, and equipment cupboards at the inner end of the cab may tend to have space available.
- 3.1.4 For trains which are already in service, the existing placement of antennas on the train should be considered when positioning the remaining antennas. There is little point in changing the position of already installed antennas on in-service trains unless there is a valid technical reason. For GB, these antennas are likely to include NRN and/or CSR. Generally, the methodology set out in 3.1.2 should be followed for all new installations, taking cognisance of the fact that the existing antenna locations are already fixed.

3.1.2 Group A and Group B radio systems

- 3.1.2.1 Groups A and B radio systems should be considered first, as they take precedence.
- 3.1.2.2 For Groups A and B radio systems (not including GPS) the antenna requirements are all very similar, because the systems are all served by ground base stations, which are typically mounted close to the railway. Although the required line of sight and position for these groups of antennas is normally towards the front and rear of the railway vehicle, consideration should be given to positioning each individual antenna so that a good view is achieved in all directions.
- 3.1.2.3 In some cases there are two sets of Groups A and B antennas on the train, corresponding to the two drivers' cabs' locations. A variety of recommended locations for the antenna groups on different train configurations is shown in Figures 3 and 4.

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(Typical examples where simultaneous operation of voice radio is not expected)

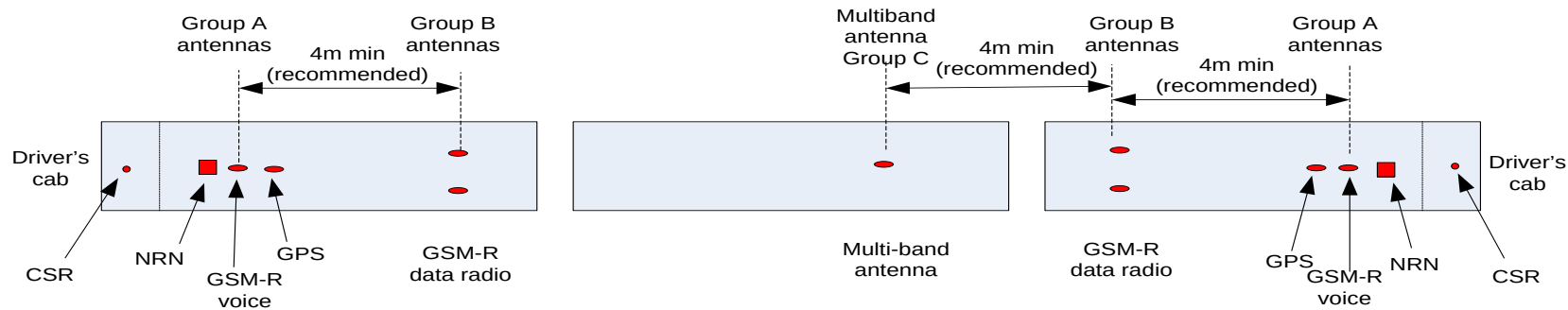


Figure 3 Potential antenna locations on an EMU or DMU

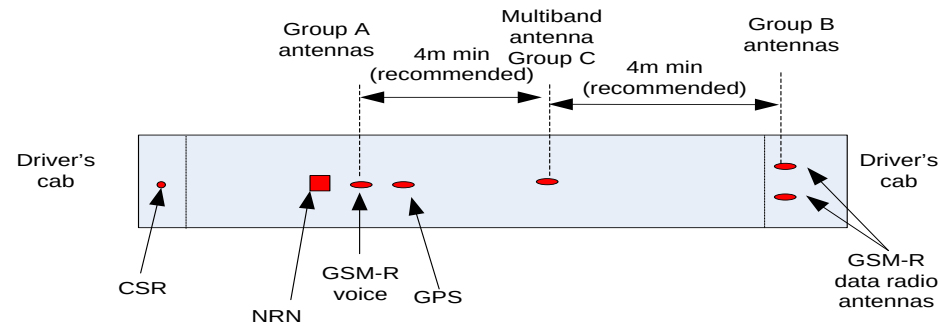


Figure 4 Potential antenna locations on a locomotive

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- 3.1.2.4 The following sequence of steps should be carried out in selecting the Groups A and B antenna locations on a train:
- a) List all the radio systems being positioned on the train by group, as set out in Table 1
 - b) Identify the location of each of the radio units for the different radio systems and determine the feeder routes from the radio units to the vicinity of the antenna locations
 - c) Identify mounting locations for each of this group of radio antennas, bearing in mind the following issues:
 - i) Select antenna locations close to the mounting position for the radio unit, which are at the highest practical locations on the train and which are within the vehicle gauge limitations
 - ii) Select antenna locations where there is access to the underside of the train roof for fitting the antennas and for a feeder cable route
 - iii) Select locations which have a good 360 degrees azimuth view around the antenna
 - iv) Select antenna locations which result in an overall cable feeder loss (between each antenna and radio unit) that is less than the requirement laid down in Appendix A Table A.1. This typically limits each Groups A and B antenna positions to within approximately 5 m of the radio unit that the antenna serves, dependent upon the performance of the feeder cables at the frequency of operation
 - v) Calculate the total loss between each antenna and radio unit, by using the figures for loss per metre of feeder cable at the operating frequency of each radio system, using the manufacturer's data for each potential cable. Select the cable which provides the lowest loss and which is flexible enough to pull through the cable route for each radio system individually. Information on feeder cables is set out in 6.3.2. If there are any additional components in line with the feeder (filters, splitters, etc) then the loss in these components should be added to the cable loss when arriving at total loss
 - vi) Select locations which meet the antenna spacing separations set out in the tables in Part 2. For the GSM-R ETCS data radio units (usually there are two of these), the antennas are in Group B antenna group
 - vii) Select locations on the roof with an adequately sized ground plane (as set out in 4.8). Refer to the antenna manufacturer's data sheet for the minimum ground plane area required
 - viii) Select locations on the roof which are typically more than 5 m from a pantograph for GPS and 4 m for all other antenna types
 - ix) For the GPS antenna, select a location that is close to the train centre-line, with the best possible view of the sky, and at least 2 m away from metallic objects which are higher than the antenna.
- 3.1.2.5 Allocate the antennas to the positions having the best view, preferentially to Group A systems, in the order set out below:
- a) GPS antennas (highest priority)
 - b) GSM-R antennas

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- c) CSR antennas
- d) NRN antennas.

3.1.3 Group C radio systems

- 3.1.3.1 These radio systems, generally, also require their antennas to have a good all-round view from the train. Some of the radio services use public networks with base stations that are not always located alongside the railway.
- 3.1.3.2 The recommended implementation is for a number of radio units to share a single multi-band antenna in combination with a frequency multiplexer, to split the combined signal to the different radio units (as set out in 4.6). This eases the competition for the best antenna locations for each system. All the radio units sharing this single antenna would normally be expected to be located in close proximity to each other, in order to minimise the coaxial feeder lengths, and should be placed on the same rail vehicle.
- 3.1.3.3 The procedure for locating the best position for the shared antenna is set out below:
 - a) List all the radio systems to be positioned on the train within this group and seek advice with the radio system integrator that it is permissible for the different radio systems to share the antenna. If some of the systems cannot share the antenna, then an additional antenna(s) should provide these separate services. This additional (shared) antenna should be mounted at least 2 m away from the first shared antenna and in line with the antenna separations set out in Table 5 for shared groups of antennas, and
 - b) Follow the same series of steps as for positioning Groups A and B radio system antennas, bearing in mind that the shared antenna could have an associated GPS antenna.

3.2 Positioning of GPS antennas

- 3.2.1 As GPS is a receiving-only antenna it is unlikely to pose any threat to the other radio systems and could be positioned in any of the antenna groups, anywhere on the train, as long as the antenna separation requirements are met. It should ideally be located on the vehicle as close to the longitudinal centre-line as practicable, in order to optimise the line of sight to the satellites. The roof at the mounting position should be as close to the horizontal as practicable.
- 3.2.2 In order to achieve high accuracy from GPS, the GPS antenna should be placed above the highest reflecting element, to minimise reflected waves. Certain GPS antennas require a ground plane to increase gain at low elevation angles.

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Part 4 **Guidance on Antenna Types and Design Requirements**

4.1 Antenna directionality and gain

4.1.1 General considerations

- 4.1.1.1 Radio systems perform optimally when particular technical parameters are met by the antenna; these parameters are the antenna gain and the direction in which the antenna's main lobe is orientated. The sections below set out the general attributes of the different kinds of antennas used on trains.

4.1.2 Antennas used for land mobile applications – general information

- 4.1.2.1 The majority of present train communications' applications (for example, NRN, CSR, GSM-R, WiMax, depot communications) use radio networks where the base stations are located on the ground. The gain from these radio networks is directed equally in all directions around the horizontal plane, at approximately zero degrees elevation. Practical antennas, once installed, typically have a gain in the region of 0dBi (isotropical) at approximately zero degrees elevation, while their peak gain is typically several dB higher, but at an elevated (and therefore not usually particularly useful) angle.
- 4.1.2.2 When comparing the gain of antennas from different manufacturers, some manufacturers quote the peak gain of an antenna as their figure, whereas others quote the average gain at zero degrees elevation.
- 4.1.2.3 The gain performance of an installed antenna which is intended to communicate with terrestrial base stations is influenced by the details of the installation, including the shape of the train roof and the obstructions on it. On a typically curved train roof, even where an antenna is installed with minimal obstructions, the gain of this antenna type at zero degrees elevation is likely to fluctuate around the nominal 0dBi figure. This aspect is set out in more detail in Appendix A.
- 4.1.2.4 When comparing the gains of different manufacturers' antennas, then consistent gain values should be used. For example, some manufacturers measure gain in decibels compared with the gain of a dipole antenna (measured in units of dBd), while others measure gain in decibels compared with an isotropically radiating antenna (measured in units of dBi). Both units of measurement are valid, although the isotropically radiating antenna is only a theoretical concept (as set out in Appendix B.8). Due to the difference in the two standards, a gain measured in dBi always give a numerical value 2.15dB higher than the same gain measured in dBd for the same antenna.
- 4.1.2.5 The polarization of these mobile antennas is typically vertical.

4.1.3 GPS antennas – general information

- 4.1.3.1 For train antennas serving GPS or other similar satellite positioning systems (GLONASS, Galileo), the antenna provides near hemispherical coverage. If the antenna is passive, it typically has a gain in the region of 0dBi in this coverage area, indicating that the feeder cables should be kept very short to maintain the loss below 1dB to 2dB.
- 4.1.3.2 Most GPS antennas for railway use are not passive and either include the GPS receiver or a low noise amplifier within the antenna radome. Either of these approaches overcomes the problem of excessive losses in the feeder cable and minimises the effect of any interference generated within the GPS feeder cable, by other on-train systems. If an amplifier is used, then it should have a gain that is at least sufficient to offset the losses in the feeder cable.
- 4.1.3.3 The GPS satellite signals are Right-Hand Circularly Polarised (RHCP) and therefore a conical helix antenna or a similar variation is suitable. Antenna designs vary from helical coils to thin patch antennas.

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- 4.1.3.4 If train location accuracy is of concern, then by installing a special type of antenna known as a 'choke ring antenna', this technique helps to reduce the multipath effect. This antenna consists of a number of vertically aligned concentric ring cylinders around a central antenna. It is particularly effective at attenuating multipath signals arriving from directions close to the horizon, thereby improving the accuracy of the position reading from the receiver. The benefits offered by this relatively complex type of antenna are not generally required by railway applications, because train location accuracy is not especially of concern.

4.1.4 Antennas for satellite communications

- 4.1.4.1 Antennas intended for broadband satellite services have the following parameters: a relatively narrow beamwidth and a high gain output. The following two different types of antenna technologies have these parameters:
- a) Steered dish antennas – these antennas are mechanically complex and are typically too large to fit within the GB train gauge on a standard train vehicle, and
 - b) Phased array antenna – these antennas are horizontally mounted, of low profile and meet the gain parameters for satellite services. In common with all antennas, the gain provided is dependent upon the antenna's operating frequency and its overall size. Phased arrays have the advantage of being electronically steered, so do not have mechanically moving parts. The complexity of this device lies in the control electronics, and it is relatively expensive compared with conventional passive antennas, especially if the radio system both transmits and receives radio signals. The fitment of this type of antenna to a train vehicle, due to its physical size, impacts on the vehicle's mechanical integrity and an assessment of this mechanical integrity should be considered.

4.2 Multi-band antennas

- 4.2.1 The term multi-band antenna implies that an antenna works over more than one frequency band and facilitates optional use by more than one radio system. This is distinct from the antennas used by Group A CSR, GSM-R, NRN and Group B radio systems, which are dedicated to a single radio system and have a relatively narrow bandwidth.
- 4.2.2 The main advantages of a multi-band antenna is that it is shared between a number of radio systems. The advantages are that:
- a) It reduces the competition for locations for antennas on the rooftop
 - b) It standardises the installation of the radio systems, both within a single train class and, to some extent, between train classes, potentially reducing the scale of the design approval process
 - c) It reduces the extent for structural modification of the train, reducing the number of holes in the train and limits the potential for degradation of its structural integrity
 - d) It reduces rooftop clutter, which generally enhances the aesthetics of a train design.
- 4.2.3 Multi-band antennas tend to be of two basic types:
- a) Multiple radiating elements installed in a single radome with separate radiating elements and connectors for each radio band, and
 - b) Multi-band antenna with a single radiating element and one connector carrying all bands of interest.

Each of these types of antennas has its own separate advantages and disadvantages, as set out in 4.3 and 4.4 respectively.