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## **GSM-R – ADVANCED, AVAILABLE, APPROVED AND APPLICABLE**

### **PART 3 – APPLICABLE**

JOHN AITKEN, AITKEN & PARTNERS  
MARTIN LEHRBAUM, NORTEL NETWORKS  
GLYN OWEN, SIEMENS

#### **SUMMARY**

GSM-R, the railway extension of GSM telephony, has been designed specifically to satisfy railway radio communication requirements.

In this three-part paper we describe the advanced features of GSM-R that set it apart as a railway system and demonstrate that it is available technology, ready for use today. We explain how GSM-R has been approved by international standards organisations and has a Notified Body process for type and system approval. Finally, we show that GSM-R is applicable to Australia, providing an effective solution to many of the communication problems of Australian railways.

Part 3 discusses the applicability of GSM-R for Australian railways. The general requirements of Australian railways are reviewed and compared with the facilities and functions offered by GSM-R. We demonstrate the applicability of GSM-R through two case studies.

#### **INTRODUCTION**

Each railway in Australia has a different train radio communication system. There are also many other railway radio systems, specifically for train guards, security officers, maintenance staff and other operational personnel.

The requirements for these radio systems are generally no different from those for equivalent radio systems in Europe.

However, there is the obvious difference between metropolitan railways and railways in country areas. In the metropolitan areas there is a very close correspondence between the Australian railways and those of Europe. While the Defined Interstate Rail Network has lower levels of traffic, it could potentially support a system such as GSM-R.

It would obviously be difficult to make a case for investment of any sort on many of the Australian branch lines. Most of these lines have only seasonal traffic and cannot support any communications infrastructure. A public telecommunications service is generally all that is affordable for these lines.

In this paper we explore the feasibility of implementing GSM-R as the railway communication system for Australia. We

review the features of GSM-R, comparing it with the requirements defined in Part 1, then review its application with a case study. The case study examines GSM-R for the Perth Metropolitan area.

### **1 AUSTRALIAN REQUIREMENTS**

#### **1.1 Key Requirements**

Some of the key requirements for a communication system for the Australian railways were identified in Part 1 as:

- a** A nationally interoperable and compatible system.
- b** Based on open, non-proprietary systems and a publicly available architecture.
- c** Capable of supporting electronic and communications based safeworking systems.
- d** Designed for data transmission
- e** Able to support the safety and business needs of track managers and train operators
- f** Suitable for local train operations as well as main lines (including shunting).

## **1.2 Nationally Interoperable & Compatible**

We have seen in Part 1 that GSM-R is designed and defined for international compatibility. Within Australia there is a single set of standards for telecommunications that is based largely on the European specifications. There is no difficulty applying ETSI (European Telecommunications Standards Institute) compliant systems in Australia, as the existing infrastructure is compatible. The significant difference between Australia and Europe relates to frequency allocation. In Europe there is a dedicated part of the electromagnetic spectrum for GSM-R. In Australia, no such allocation has been made.

### ***Radio Frequency Compatibility***

The GSM-R hardware currently on the market is flexible in operating frequency. The more modern base stations and mobile radio equipment can operate through the standard GSM band, the European GSM-R band and the 1800 MHz band. This flexibility will be the key to GSM-R implementation in Australia. Within the cities, 900 MHz spectrum is now fully occupied and there is little immediate prospect of further spectrum being made available. However, in each of the cities there is 1800 MHz spectrum available, either through the carriers or by purchase of unused spectrum. (At the time of writing the One-Tel spectrum is still for sale).

There is no inherent need for a specific band of frequencies for GSM-R. One frequency band can be used in one city and another in another city. It is sufficient to have mobile equipment that is capable of operating in each band. This greatly simplifies the application of GSM-R and means that spectrum is available throughout the country. Outside the cities 900 MHz spectrum is available and would be used for preference. Within the cities the 1800 MHz band can be employed.

### ***Network Interoperability***

The GSM-R specifications ensure international compatibility. Within Australia, separate GSM-R networks can be implemented for each state or infrastructure owner. The different networks can then be treated as though they were different national networks within the GSM-R structure. Roaming between networks

is achieved by a data connection between the GSM-R networks, in the same manner as international roaming in the GSM system.

If each network is constructed within the GSM-R specifications, there are no other interoperability considerations within the GSM-R portion. Should a mobile move outside the GSM-R networks, that mobile can roam (automatically) to a public GSM network. While no longer able to access the GSM-R specific features, the mobile is still accessible to others in the GSM-R network. (This presumes that there is a roaming agreement between the GSM-R network operators and the public network operators.)

## **1.3 Open, Non-Proprietary Standards**

Parts 1 and 2 of this paper have demonstrated that GSM-R complies with the requirement that an Australian system be based on open non-proprietary standards and have a publicly available architecture. The GSM-R standards and architecture are readily available, with internet access. No special design or standards are required for application of GSM-R in Australia, except for the detail of the numbering plan.

## **1.4 Supports Electronic Safeworking**

There is a clear requirement that the communication system be capable of supporting electronic and communications based safeworking systems. Within Australia there are two main systems of electronic safeworking, ASW and DTC.

### ***ASW***

The Alternative Safe Working (ASW) system developed by VicTrack would work very well with a GSM-R system. The inadequate radio communication system currently available to ASW impairs its operation. With the secure and reliable data communication provided by GSM-R, the ASW data transmissions would be faster and much more reliable. (Previous work by Aitken & Partners has demonstrated that ASW can operate through GSM.)

### ***DTC***

Direct Train Control (DTC) is a Queensland Rail system that uses voice communication to transfer train movement authorities. The movement authorities are encoded in short

character strings that are read over the radio, typed into a computer on the train and decoded on the computer. The transactions that occur at present would be replicated with GSM-R (although GSM-R could offer more functionality).

### **CBSS**

ARTC is currently negotiating the design and development of a communication based signalling system. The details of this system have not been made public so it is not practical to verify that GSM-R would be suitable for this system.

### **ETCS**

The European Train Control System (ETCS) is a communication based signalling system that has been specified for application throughout Europe. This system is based on GSM-R and has been demonstrated to work through GSM-R networks. (There are other papers at this conference dealing with ETCS).

## **1.5 Designed for Data Transmission**

GSM-R is a digital radio transmission system. It carries voice and data in the same format and is capable of simultaneous voice and data transmission within a call. All the data transmission facilities of GSM are available in GSM-R.

GPRS (General Packet Radio Service) is a GSM enhancement that provides for high-speed data packet transmission. At present GPRS is not a part of the GSM-R specifications but the standards groups are working on its adoption. GPRS can be used by GSM-R mobiles and equipment but the GSM-R features are not available to equipment operating in GPRS mode.

## **1.6 Supports Safety and Business needs of Track Owners and Train Operators**

GSM-R is able to support the safety and business needs of both track managers and train operators. The voice and data functions and facilities of GSM provide for most of the business requirements of track owners and train operators.

With the enhancements of GSM-R, the safety requirements can readily be satisfied. The special features of GSM-R:

- a** Emergency Call with rapid connection,
- b** Voice Group Calls,
- c** Voice Broadcast Calls,
- d** Access Matrix,
- e** Priority and Pre-emption,
- f** Functional Addressing and
- g** Location Dependent Addressing,

accommodate the requirements that have been expressed for track owners and train operators. Access to the GSM-R network is a matter for both commercial negotiation as the priority and pre-emption features deal with access for important traffic.

## **1.7 Suitable for Local Train Operations**

Local train communication is built into GSM-R. A local call can be established to all trains within a specific area by entering a group call code on the mobile or train radio.

There are programmed short codes for the most frequently used calls so the user will normally only have to key in three or four digits to set up the call. A call between specific parties can of course be set up as a normal telephone call. However, urgent or group local communications are best handled with an emergency, group or broadcast call.

# **2 GSM-R ISSUES FOR AUSTRALIA**

## **2.1 Open Channel vs Closed Channel**

Australian railways and railway operators have differing views on the desirability of “open channel” operation. In an open channel system, the conversations on any line or group of lines are heard by all radio users.

Some railways broadcast both the train controller and the driver’s speech; others simply broadcast the train controller’s conversation to all parties at all times. There are variations to this, for example, the NSW Countrynet radio has a *Priority Call* feature in which the train controller is heard by all trains within a specific area. Normally Countrynet calls are “closed channel” or private: only the parties directly involved in the call hear any part of the conversation.

There are strong views regarding the desirability of open channel communication.

Some railways maintain that open channel calls are essential for verbally issued train movement authorities. Other railways are adamant that train movement authorities should never be given over an open channel. Each approach can be supported by cases where the particular approach has been of advantage.

The various train radio systems in use in Australia at present have been designed to accommodate the requirements of the operators for closed or open channel operation. (Although it could be argued that in many cases, the style of operation of the radio system was imposed on the operators by the technology.)

“Open channel” versus “closed channel” operation is not a design decision in GSM-R. The radio channel can be made open or closed for each call.

## 2.2 Group Calls and Broadcast Calls

The GSM-R Group Calls and Broadcast Calls fit in neatly with current call definitions in the Australian railways. Some effort will be required to set up the group call area definitions and to ensure that the databases are adequate.

## 2.3 Alphanumeric Train Numbers

The Functional Addressing scheme is designed to accommodate train run numbers that are numeric and are of fixed length. Most Australian train run numbers are alphanumeric and are of variable length, generally up to six characters.

The Functional Addressing encoding scheme does not have sufficient capacity for the full alphanumeric codes so a translation or more efficient coding scheme will be required in Australia.

The UK also uses alphanumeric train numbers. There are UK and European studies investigating a suitable method of encoding alphanumeric run numbers for GSM-R. The issue should have been resolved before it requires detailed consideration in Australia. It should be noted that the solution must be applied to both the mobile equipment and the portable equipment. The portable equipment will be very expensive (or impossible) to

change unless there is international standardisation of the approach to alphanumeric entry.

## 2.4 Location Dependent Addressing

Some areas, particularly the Sydney Metropolitan Area have signaller areas that are small and do not fit neatly into base station coverage areas. The NSW Metronet system uses track-mounted transponders to identify the signaller boundaries and switch the radio mode for that system. These transponders could continue to be used in the GSM-R implementation, supplemented by a GPS version for locomotives. (Locomotives are not fitted with the transponder interrogators at present and the adequacy of GPS for the task has been demonstrated.)

## 2.5 Dispatchers

If GSM-R is used, as it should be, for all railway communications there will be many more dispatchers. The railway organisations responsible for track maintenance, signal maintenance, electric power supply to track in electrified areas, security and cleaning will all have dispatcher requirements.

The design of GSM-R permits each of these people to be connected to the GSM-R network through ISDN or the PABX systems. Careful thought must be given to the allocation of the mobile users to the various call groups so that the dispatcher functions operate successfully.

## 2.6 RF Spectrum

The issue of radio frequency spectrum now appears to be less significant than it was originally thought to be. There is spectrum available in cities in the 1800 MHz band under various arrangements. In addition, there may be some spectrum available in cities in the 900 MHz band. There is certainly spectrum available at 900 MHz outside the city areas.

There are some trade-offs in moving to 1800 MHz. There are higher transmission losses and reduced maximum speeds. However, the designs that have been employed in the existing systems suggest that it is obstruction loss rather than free space attenuation that is controlling the separation of the base stations.

The higher frequency band is considered unsuitable for high-speed trains. There does

not appear to be any problem at speeds of less than 200 km/h so this is not a serious issue in Australia. If trains were operating in any area where higher speeds were required, it is probable that there would be 900 MHz spectrum available as the population density in these areas would be low.

## 2.7 Roaming To/From GSM-R

GSM-R has specific features and advantages that are essential for railway communication. However, a GSM-R network may not cover all areas in which a train or a railway person may operate. In the same manner as international roaming is possible, GSM-R terminals can roam from GSM-R to GSM and back. To achieve this, there must be a roaming agreement between the GSM-R operator and the GSM operator.

With a roaming agreement in place, the terminal SIM cards and Home Location Registers are programmed with the permitted roaming conditions. The terminal can be set to roam to a GSM network upon loss of GSM-R coverage. Although the terminal will not automatically revert to GSM-R operation when in a GSM-R area, it can be switched to GSM-R operation by the user.

Roaming provides a useful backup for a GSM-R network. The functionality is certainly degraded if the mobile roams to another network but the numbering scheme and HLR should ensure that basic telephony functions are maintained. This facility is not available in private mobile radio (PMR) or trunked radio systems.

The Italian railways have taken advantage of the roaming facilities by initially using public networks for all their GSM operations. As the GSM-R network is implemented on each line, the mobile equipment switches to GSM-R and a smooth transition is made between systems.

## 3 IMPLEMENTATION

### 3.1 Options for Implementation

The railway networks in Australia generally are no longer vertically integrated. In the process of separation of the infrastructure and the train operations elements, there has been a change in approach to investment. The track

owners are less enthusiastic about investing in anything other than track and look for outsourced services for most of their requirements.

Outsourcing is not new in the communications area. Carriers have been established for over a century and for much of that time some part of the railway communications task has been handled by the carriers.

A rail operator or infrastructure owner could, of course, build and operate a GSM-R network. However, this would require substantial investment in sites, equipment and technological skills. The more cost effective approach is for a telecommunications carrier with an existing GSM network to operate and maintain the GSM-R network. This approach provides the lowest cost of access to existing GSM sites, minimises construction costs and impact and utilises existing skill sets.

### 3.2 Broad Scale GSM-R Implementation

The core of a GSM-R network represents a fixed cost that is, largely, independent of the number of GSM-R users. This cost should be spread across as many users as possible, rather than being incurred in each state.

We suggest that the core of the network should be installed in two or more geographic centres, to provide site redundancy and optimise transmission costs under normal operations. The existing railway communication networks and most other networks have star configurations with these locations as hubs.

It would seem logical for a set of core equipment to be installed in Perth, with a further set of core equipment in one or two other cities operating as the redundant system. This distributes the cost of the core equipment and maximises the geographical independence of the redundant equipment.

One possibility would be for the core and the overall network to be managed by an existing GSM service provider. The service provider has the necessary skills and infrastructure to house and maintain the GSM-R core at a low incremental cost. If the service provider has GSM core equipment in several cities then the GSM-R equipment could be co-located with the GSM equipment in those cities. Site redundancy is achieved and the link cost is

minimised. The mated pair operation of the intelligent networks and Home Location Register equipment can be configured to operate with one device in each centre.

### 3.3 Radio Networks

The radio networks could be constructed under a number of different models. Different countries in Europe have chosen different models. Some have chosen to build own and operate their own systems, some contract out the entire operation and various intermediate combinations have been implemented.

There are competent organisations in Australia for each of the models.

### 3.4 Connections to the Mobile Switching Centre from Railway Sites

Most railway sites in Australia do not have G.703 2 Mbps access. Many have 64 kbps access but most only have railway owned (or leased) analogue lines. (This is not a problem at carrier operated cellular telephone sites, all of which connect with multiples of 2 Mbps G.703 services).

There will initially be only a very low level of traffic on the Australian GSM-R network, partly because few trains will be equipped but largely because the rail traffic levels in Australia are generally low. A base station site with low traffic levels could be connected to the MSC with 3 x 64 kbps streams. One of these streams is required full time for signalling, the others are required during voice calls on the base station.

### 3.5 Locomotive Fit-out

A considerable variety of locomotives operates on the Australian railways. The locomotive fleet is concentrated in ownership, with a few large operations having the majority of the locomotives. One of these organisations is Pacific National; another is WestNet Rail.

In recent years, Pacific National has installed the AWARE system on its NR class locomotives. AWARE is an integrated train radio system that provides a common interface to the train crew for the multiplicity of train radio systems that are active in Australia. One of the communication devices in the AWARE system is a GSM telephone. Should Pacific

National wish to install GSM-R on their locomotives, it would be a very simple matter to replace the existing GSM telephone with a GSM-R telephone module. The GSM-R telephone has the same GSM standard interface protocol as the existing telephone.

Westnet Rail has an Advanced Train Communication System (ATCS). This system is similar in capability to the Pacific National system but uses LAN based data communication. The ATCS incorporates a GSM telephone module. The Westnet Rail GSM module could be changed to a GSM-R module with minimal difficulty.

In the Sydney Metropolitan area, the electric trains are currently equipped with a Siemens Metronet system. This system is similar to the British Cab Secure radio system. Siemens are developing a dual mode control head for the Cab Secure system that could be suitable for use with Metronet. The dual mode of operation would simplify the transition from Metronet to GSM-R in Sydney.

The other locomotives are equipped with individual radio transceivers and control heads. The small size of GSM-R equipment and the simple user interface to this equipment should mean that it is relatively easy to fit to the trains.

## 4 CASE STUDY – PERTH METRO AREA

### 4.1 Case Study Assumptions

As a case study, we have explored the feasibility of establishing a GSM-R network in the city of Perth. The network design has been based on the base station sites of one of the existing carriers. We have assumed that additional sites can be established on railway land where necessary. This design provides only for coverage of the railway lines.

Many assumptions have been made in this analysis. The first assumption is that there is a carrier willing to implement the network and that there is a valid business case.

Discussions with the carriers suggest that there would be interest from a carrier in establishing a GSM-R network as an overlay on their existing network.

## 4.2 Perth Metropolitan Area GSM-R

The design for the case study is based on the Perth electric suburban service lines. There are standard gauge and dual gauge tracks in this area that will be partially covered but our study has been limited to the narrow gauge electrified track.

The design study has been based on limited information and is not the basis for a network implementation. Our intention in developing this design was to explore the feasibility of implementing GSM-R on existing sites in Australia.

The information about the existing sites consisted only of the publicly available details of their location and a nominal antenna height so the information predicted will not be accurate. However, it provides a useful basis for comparison of the alternative frequency bands and coverage requirements for different specifications.

## 4.3 Performance Requirements

The GSM-R SRS<sup>1</sup> states that for network planning the coverage level is defined as the field strength at the antenna on the roof of a train (nominally 4 m above the track). The minimum coverage to be achieved with is coverage probability of 95%, based on a field strength of 38.5 dB $\mu$ V/m for voice and non-safety critical data. (This is equivalent to a received signal of -98 dBm with an isotropic antenna.)

The SRS design is based on trains travelling at up to 500 km/h and assumes that the radio system is operating in the 900 MHz band. The Perth system is highly unlikely to ever reach 200 km/h so there is considerable margin in this specification.

The coverage definition is further expanded in the SRS. The coverage probability is stated to mean that with a probability value of at least 95% in each location interval (length 100 m) the measured coverage level is at least that specified. The coverage levels allow for a maximum loss of 3 dB between the mobile antenna and receiver and allow an additional margin of 3 dB for other factors.

In this study we have assumed a received signal level of -95 dBm for on train equipment (a 3 dB margin over the SRS requirements).

## Portable Radio Operation

The GSM-R specification does not discuss portable radio operation. The design has been concentrated on fixed equipment in the locomotive cab, with any portable equipment being used in open trackside areas.

In Australia there is an established practice of having security guards on board passenger trains at certain times of the day or night. It would be desirable for the security guards to be able to use GSM-R portables inside the trains.

Our design study has allowed for this and has allocated a minimum received signal (isotropic antenna) of -85 dBm for radios used inside the train.

## 1800 MHz Operation

The GSM carriers consider the 900 MHz band to be fully occupied so we have performed the study at both 900 MHz and 1800 MHz.

The same received signal specifications have been used for 900 MHz and 1800 MHz. In a more realistic design there would be a greater margin for 1800 MHz operation of portables.

There are two reasons for this: firstly, the portable radios have lower output power at 1800 MHz and secondly, the clutter loss and attenuation into the trains may be higher at 1800 MHz. Field tests on the particular trains would be desirable to determine the loss experienced in normal operations.

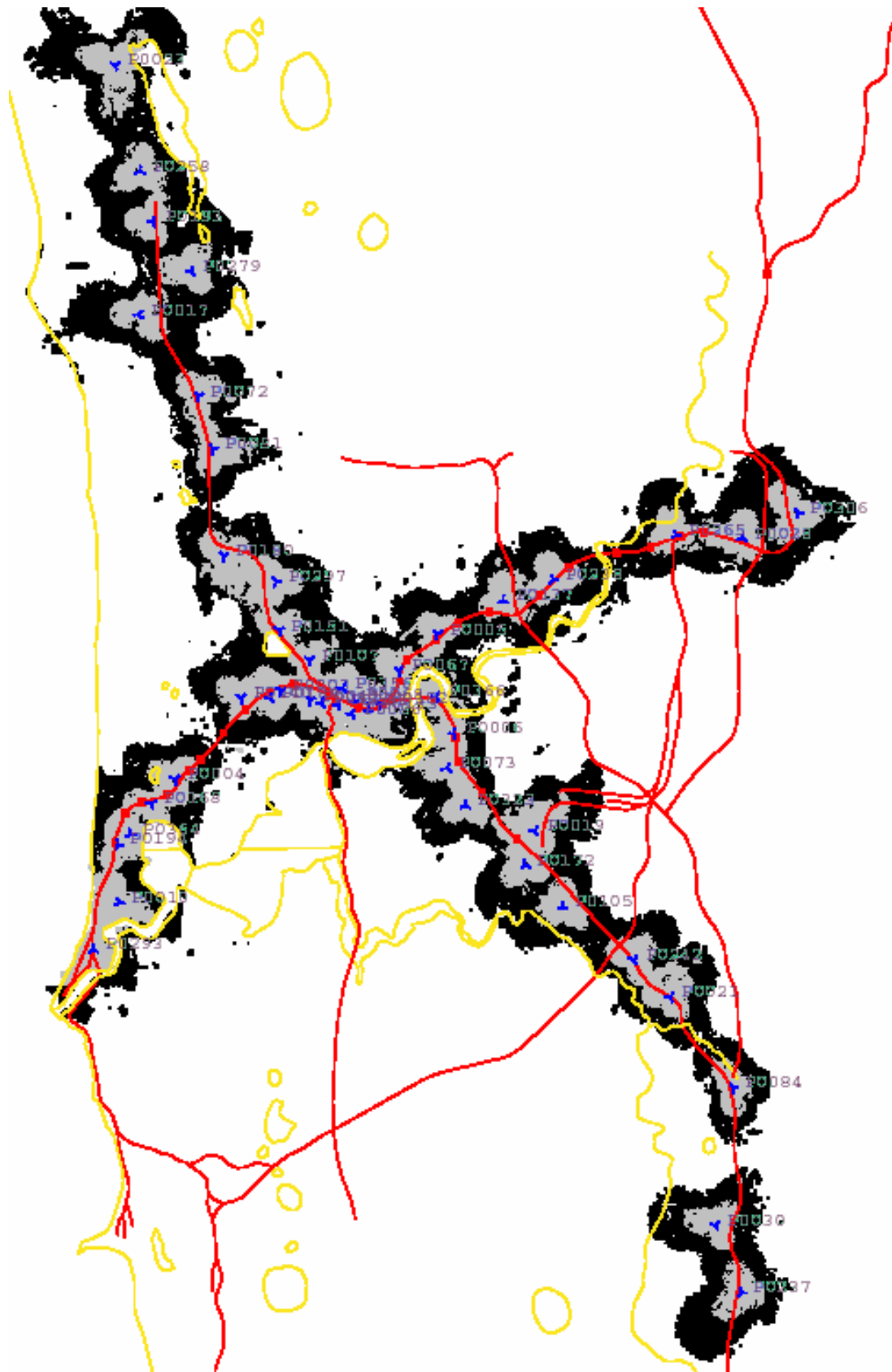
## 4.4 Coverage Plots

The coverage plots for 900 MHz and 1800 MHz are reproduced on the following pages. The reproduction quality is limited by the size of the page and the restriction to black and white printing. (Further detail will be available during the conference presentation.)

It can be seen that coverage of the railway line can be achieved, with only a few gaps, if the existing sites of one of the carriers are used.

These sites provide the least expensive way of introducing GSM-R as there is minimal cost in adding base station transceivers and, if necessary, antennas to an existing building and tower. The transmission links to the switching centre may have spare capacity that could be used for the GSM-R network.





Coverage at 1800 MHz using existing sites. The lighter coloured coverage area is the in-train coverage area and the darker coloured area is the coverage for an externally mounted antenna.

The gaps in coverage can be filled with a few additional base stations. The additional base stations would be installed on railway land and optimised in coverage for the railway line.

## 5 CONCLUSIONS

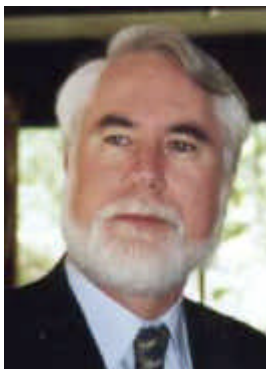
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John Aitken BE  
Director, Aitken & Partners  
Consulting Engineers



John Aitken has been associated with train radio in Australia over the last twenty years. His largest project was the development of Countrynet in (NSW), pioneering the use of GPS and satellite telephone systems for railways. This was followed by the Pacific National AWARE locomotive system and the Communications

Control Centre (CCC) project. Experience with railway radio and passenger security systems in NSW, Queensland, Victoria and Western Australia has reinforced his enthusiasm for systems that are based on international standards. John has a particular interest in human factors and systemic issues in railway communications.

Martin Lehrbaum, MSc.  
GSM-R Sales and  
Marketing  
Nortel Networks



Martin Lehrbaum has a Senior Management role within Nortel Networks, focused on GSM-R. His primary interests are in developing new markets for GSM-R throughout the world and enhancing the existing Nortel market relationships. Through his extensive customer interaction and knowledge of customer requirements Martin has become involved with the GSM-R product development strategy and architecture.



Over the last year Martin has been leading the customer marketing team for Germany, the biggest GSM-R project awarded worldwide so far. This project has revealed many of the issues (both technical and operational) that are faced by early implementers of a new technology.

Glyn Owen  
Marketing Manager  
GSM-R  
Siemens Transportation Systems



Glyn Owen has spent 25 years working on railway projects for Plessey and Siemens Transportation Systems. Projects have included Transponder Systems for the Advanced Passenger Train, Signal Post Telephone systems and Track to Train Radio systems in the UK and overseas. Glyn was the systems design manager for the Metronet train radio system in Sydney. Glyn was involved in the initial work on GSM-R by Siemens Transportation.



Glyn represents STS within the GSM-R INDUSTRY GROUP, is deputy speaker of the Technical Group, and is involved from the industry side in the task of updating and controlling the GSM-R specifications.

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<sup>1</sup> EIRENE SRS, Section 3.2