AUSTRALIA WIDE COMMUNICATIONS SYSTEM FOR RAILWAY OPERATORS

John Aitken

BE MIEEE AMIRSE

Aitken & Partners

SUMMARY

Australia has a sad history of incompatibility in railway radio communications. There is no standard for radio communications on the standard gauge track. Some states have incompatible radio systems on different track gauges; one has incompatible radio systems on the standard gauge track. The situation looks likely to continue for many years, imposing a substantial cost on each rail operator.

Incompatibility has a further cost to the community, as the McInerney inquiry into the Glenbrook rail accident[1] and the Hexham inquiry[2] show. The Hexham inquiry demonstrates that radio system design can affect the susceptibility of a rail network to human error. Ergonomics and equipment failure are regularly considered but there is rarely an analysis of the effects and consequences of human error in the radio communications system design. Some improvement could be gained from expanded Codes of Practice, identifying risks and hazards for consideration at the design and testing stages.

Over the last twenty years the mainland railways have moved towards a common frequency band for radio communications. Despite this, sufficient proprietary quirks have been implemented into the radio systems to ensure that no single radio can cover all systems. Locomotives are equipped with up to seven different radios to operate through the Defined Interstate Railway Network. Recent changes in the cellular telephone market have made the use of GSM-R feasible in Australia. GSM-R could replace incompatible train radio systems in higher traffic areas with internationally standardised equipment. GSM-R is not economical for low traffic areas but can be integrated with existing mobile radio and satellite telephone networks.

The paper concludes with a description of an integrated train radio system that was fitted to the CRT CargoSprinter. This is an example of a screen-based radio system that presents a consistent interface to the driver despite variations in radio communication technology along the track.

INTRODUCTION

A standard gauge locomotive can (within some weight restrictions) operate on any of the standard gauge track in Australia. The equipment and performance requirements for locomotives operating on the Defined Interstate Rail Network (DIRN)[3] have been defined in the Australian Code of Practice (the Code)[4]. While the braking systems, couplings and a host of other parameters have been defined in detail; the radio communications are poorly defined. The purchaser of a locomotive cannot use the Code to specify a locomotive radio system – the Code does not give sufficient information.

The disparate radio systems used in various areas demand the use of a number of radio transceivers and other devices. Some operators have sought to integrate these devices into a common user interface for the particular locomotive or fleet, others have simply bolted a number of radios and control heads into the locomotive cabs. The user interface is different for every operator, creating a dangerous source of error for drivers working on a variety of locomotives.

This paper reviews the requirements identified in the Code and discusses the susceptibility of some existing arrangements to human error. Extensions to the Code are suggested, together with a recommendation for a change in technology.

CODE OF PRACTICE

The relevant sections of the Australian Code of Practice for the defined interstate rail network state that:

a *Train crews and track workers operating trains, track vehicles or machines, shall be equipped with communications equipment that provides for reliable communication with train control. (Vol 3, 3.9.1)*

b *All communications between train control and train crews or track workers operating trains, track vehicles or machines, shall be subject to …voice logging in the case of voice communication. (Vol 3, 3.9.1)*

c *The worksite supervisor in charge of track workers present on or near the running lines shall have access to communications facilities that provide a reliable means of voice communication with train control. (Vol 3, 3.11.1)*

d *All communications between track workers and train control shall be subject to voice logging. (Vol 3, 3.11.1)*

e *The provision of locomotive based communication equipment required for the Defined Interstate Rail Network operations and safeworking shall be the responsibility of the operator. (Vol 3, 11.3)*

f *The operator shall ensure that locomotive communications equipment is maintained and functional for the intended purpose. (Vol 3, 11.3)*

g *Train Locomotives shall be fitted with voice communications equipment required for train driving and controlling on the Defined Interstate Rail Network. The requirements for voice communications equipment shall be as detailed in TABLE 6 [A list of lines and system names – summarised and updated in Table 1 of this paper]. (Vol 3, 11.3)*

While the Code of Practice gives extensive detail regarding the design of track and the performance requirements for rails, wheels, signs and braking systems, there is no real guidance regarding radio and telephone communications systems.

CURRENT REQUIREMENTS

1. Train Control Radio

The requirements (as we understand them) for the DIRN are summarised in Table 1.

Area	Control Radio
Perth – Kalgoorlie	UHF
Kalgoorlie – Esperance Kalgoorlie – Leonora	UHF (parts) Satellite phone
Kalgoorlie – Pt Augusta	UHF
Tarcoola – Alice Springs	UHF (parts) VHF, Satellite phone (future)
Alice Springs – Darwin	Satellite phone
Pt Augusta – Adelaide Adelaide – Broken Hill	UHF
Adelaide – Serviceton	UHF/GSM/None
Serviceton – Melbourne	UHF + ASW
Melbourne – Albury	UHF + MDC600
Albury – Goulburn Broken Hill – Parkes	Various (see below) – was Countrynet Satellite
Goulburn – Macarthur Newcastle – Greenbank Parkes – Lithgow Orange – Dubbo Newcastle – Tamworth	Various (see below) – was Countrynet terrestrial
Macarthur – Sydney Lithgow – Sydney Newcastle – Sydney	Various (see below) – was Metronet
Other NSW	Various (see below) – was Countrynet Satellite
Greenbank - Fisherman Islands (Qld)	UHF + Selcall

Table 1 – Train Control Radio

RIC Safeworking Rule NGE230 [5] prescribes the rules for use of communications equipment in the *Rail Infrastructure Corporation* (RIC) Network (effective from 1 December 2002). It states that:

"Communications equipment listed in the following table, or compatible with equipment listed in the table, may be used to establish effective communication[6] in the Network."

Communication Equipment	Protocol	Emergency Button
450.05 MHz	Open-channel	No
CountryNet	*Discrete-channel* if communicating with Train Control, otherwise open-channel	Yes
MetroNet	Discrete-channel	Yes
Government Radio Network	Open-channel and discrete-channel	No
UHF radios	Open-channel	No
Yard radios	Open-channel	No
Control phones	Discrete-channel	Some
Mobile phones	Discrete-channel	No
Satellite phones	Discrete-channel	No
Standard phones	Discrete-channel	No
Trackside phones	Treat as discrete-channel	No

Table 2 – RIC Communications Equipment

A conventional mobile radio can be used for the UHF train control areas outside NSW. In Victoria, this radio is useless unless connected to a Motorola ASW or MDC600 unit. (The Victorian train control radio system is commonly referred to as Train-to-Base radio.)

A special duplex radio is required for Metronet and Countrynet. There is only one source of duplex mobile radio to our knowledge, although one can contrive a full duplex radio from two simplex radios. One supplier has a base station that could be converted for use as a full duplex mobile. To further complicate the issue, the Metronet and Countrynet systems require the radio to be capable of continuous transmission (at 25 W in the case of Countrynet). No standard mobile radios (to our knowledge) are capable of operating continuously in full duplex mode at this power.

Access to the Metronet system is limited to a particular brand and model of mobile radio. (It is technically possible to implement the Metronet radio functions with other radio transceivers).

2. Local Radio

"Local Radio" is known by many names. In NSW it is commonly known as "WB" radio, the acronym referring to the radio equipment provided to train crews when "Without Brakevan" operation of trains was commenced.

The WB radio was a portable radio carried in the cab by the driver and second person. This radio was suitable for use as a "Local Radio", covering the local area around the train. It permitted the driver to communicate with the second person when inspecting the train and performing brake continuity checks.

In NSW the WB or Local Radio has also been used for communication between trains and signallers. There is now an extensive network of Local Radio base stations on NSW track. The base stations link signallers with the Local Radio used on trains.

In Victoria the Local Radio is known as an End-to-End radio, referring to its original use from end to end of the train. Local Radio is used in all states for roll-by inspections of trains by signal boxes and other trains. The roll-by inspection is a confirmation to the driver of the train that the train is complete (marker light is on the last wagon).

Hot Box Detectors in Queensland and NSW use the open channel Local Radio for their announcements. It is also used for other infrastructure alarm announcements such as Dragging Equipment Detection, points control and rock slide.

Local Radio is also used for shunting operations in various yards and other locations. In most cases a separate radio frequency channel is used for these operations but in many situations the shunting and other movements are performed on the Local Radio channel. There has been a move to stop this very dangerous practice and require a discrete communication channel for each shunting operation. However, the new RIC safeworking rules permit this practice in all locations other than those where it has been specifically prohibited.

As one might expect, a single Local Radio channel is not used across Australia. The radio frequency used in Victoria is different from that used in NSW, Qld and WA. The Victorian frequency is at least in the same frequency band as the NSW Local Radio channel. On the Trans Australian Railway the radio used for roll-by inspections is VHF simplex. This is a legacy of the original VHF radio system.

3. Train Location - GPS

GPS is an integral part of the NSW Countrynet train radio system and is employed in the Queensland Rail network.

GPS receivers have been fitted to the majority of locomotives operating on the DIRN. Unless these locomotives are operating on the CountryNet system this information is generally wasted. (The exception is the Pacific National Aware system, which provides GPS position information to the Pacific National operations centre. As described in the Glenbrook inquiry report, the Pacific National centre in Adelaide knew the precise location of the Indian Pacific. The signaller responsible for the area did not even know the position of the locomotive to the nearest track circuit (automatic signalling was in use with no circuit occupancy information being forwarded to the signaller).

A GPS "watchdog" system has been added to the train order computers used on the Parkes - Broken Hill line. This equipment verifies the location of the train when train orders are created and fulfilled.

There is potential for much better use to be made of the GPS data that locomotives are collecting.

COMMUNICATIONS & HUMAN ERROR

1. Confusion

If one is in any doubt about the confusion that is endemic in railway communications systems, it is only necessary to gather three or four drivers and make some very incorrect statement about radio communications in their area. At least one of the drivers will leap on the error and explain the fallacy. The other drivers will agree that the original statement was incorrect, but provide divergent views on the correct situation. Who is right? Usually they are all a little bit wrong.

Ask the Train Controllers about the situation and a different set of views may be expressed (or the Train Controllers may say they know nothing about the equipment on the trains). Ask the engineers responsible for the system and yet another view may be expressed. It has been the author's experience that all may be wrong. Unfortunately, it sometimes takes a rail accident to reveal the error[1].

Of course, Australia is not alone in this situation. Over ten years ago, C Kessel gave an interesting review of telecommunications in the aftermath of the King's Cross and Clapham incidents[7]. His paper discusses the telecommunications systems in use in the UK at that time, including the bespoke BR radio system. This system (BR1845) was an adaptation from the UIC753 system – good enough for Europe but not for the UK. Kessel notes that the resulting system could be "regarded as a design in its own right, capable of being exported to other countries where frequency shortage and cost are serious considerations". (The Sydney Metronet system was based on BR1845 but it is very different from the original system.)
A recent issue of IRSE news has an editorial entitled *One Clip or Three Phones*[8], which discusses the introduction in the UK of three different means of communication from the driving cab to the signaller. The editorial questions whether an interim GSM-R mobile is a radio or a mobile phone. If it is a mobile phone, the authors suggest that further thought may need to be given to how it complies with Railway Safety's protocol on the use of mobiles which is aimed at reducing the SPAD risk that their use may introduce. This protocol currently seeks that mobiles be switched off and only used when the train is at a stand.

2. Human Factors

This theme is continued in an excellent paper from the IRSE Technical Committee by PW Stanley on *The Influence of Human Factors on the Performance of Railway Systems.*[9] Stanley says:

"Engineers pay great attention to the requirements, specification and design of railway systems, but systems for only one part of the total railway operating environment. People, organisation and communication are equally important. … Only by understanding how all the processes and people interact can we predict the impact of technical progress, changed requirements and higher degrees of automation on people."

There was extensive discussion and review with the potential users of the NSW Countrynet system. Meetings were held with those who would use the system and sample equipment was shown. A complete demonstration system was built and tested before the contract was let and live traffic operated over the system in parallel with the existing system. Risks were identified and failure modes were analysed. The Contractor prepared a formal test plan. The system was put through factory tests and pilot trial working. Many tests were performed and user's comments and views were taken into account. However, the formal processes discussed by Stanley were not applied in this system, nor in any other radio communication system that the author can recall. Ten years later, problems have been identified that were not exposed by any of the formal tests. These problems were exposed by unexpected user interaction with the system.

By treating the voice communication system as independent from the "safety-critical" systems, we risk problems that arise from unintended operation and human error. A voice communication system that is not safety-critical under normal circumstances can impact on safety when the "safety-critical" signalling system fails. (The impact can be greatest when the safety-critical system reverts to "fail-safe" mode.)

Being wise after the event

Human error is certainly identified in accident investigation reports. Most reports now make reference to the fascinating work by Professor Reason on human error[10]. Reason proposes a conceptual framework of the origins of the basic human error types, distinguishing between:

- **Slip/Lapse** – an unsafe action where what was performed was not what it was intended (errors in execution)
- **Mistake** – an unsafe action purposefully executed, as intended, where the intention is erroneous (errors in planning)
- **Violation** – an additional type of unsafe intended action
- **Circumvention** – an unsafe action that is a deliberate but non-malicious violation of safety rules often done for, what is assumed, a "good" reason.

A number of the communications systems that are in use in Australian railways today provide ample scope for each of these types of errors. Examples of design and implementation deficiencies that have been found and fixed are identified in various incident and accident reports. Other problems have been identified but not resolved and no doubt, many have yet to be identified.

3. An Example - Hexham

The investigation into the Hexham incident[2] identifies a number of errors associated with that incident. The Countrynet and Local Radio systems were in use in the location of the incident. MO151, the derailed freight train and the Train

Controller had access to Countrynet and the Local Radio. The passenger train that collided with the derailed freight train and the signallers only had access to the Local Radio. Page 25 of the report states:

"*The "emergency call" mode [of the Countrynet system] was used by the driver of MO151 but inappropriately cancelled by Train Control evidently because of the lack of knowledge of the functionality of the system. The train controller cancelled the emergency call function and then re-established contact with the driver of MO151 using a normal call. While this was effective in communicating information between the train controller and the driver of MO151, it defeated the "broadcast feature" of the emergency call that would otherwise have alerted other trains fitted with the Countrynet system in the vicinity to the emergency situation."*

The driver of the passenger train, a 620 class DMU, had only a portable radio for the Local Radio (WB radio) operation. Again from Page 25 of the report:

"It is evident that the portable WB radio on 620 Class cars was unable to provide a reliable and effective means of communication with Network Control. Significant background conversations from the Port Waratah area reduced the effectiveness and clarity of transmissions on the WB radio. Although the driver of 714 heard Broadmeadow Train Control call different people, he was unable to understand much of the conversation due to the poor quality. Train Control tried to contact the driver of 714, however, the driver could hear but not understand the message and although his train was stopped at Tarro Station, he had to use his mobile phone. The guard of 715 tried unsuccessfully to contact Hanbury Junction signal box in an attempt to halt the progress of 714. Run 714 had been brought to a stand at Tarro railway station (due to the desired effect of the track-circuit shorting clips that were placed on the Up main line by the train crew of MO151)."

Problems continued in the signal boxes. A more subtle set of problems was revealed (page 25):

"In addition to the communication difficulties that confronted train crew, the signallers at Hanbury Junction signal box had to filter the few relevant messages from the large number of transmissions emanating from the Port Waratah area on the WB radio. …

"Recordings of in-coming calls to Hanbury Junction signal box verified that communications were received by the base station, but on some occasions, were not heard by the signallers. The equipment in the signal box required the signallers to select particular base stations for WB reception. The signallers made their selections to minimise interference from Port Waratah (above). They did not appreciate that their selections effectively isolated the signal box from the WB radio for much of their area."

The RIC requirements discussed earlier have been applied since the Hexham incident. The RIC safeworking rules do not state how one selects the appropriate communication device for any particular location. It appears from the documents that any device that can provide *effective communication*[6] is acceptable. Since it is not necessary for effective communication to be continuous, it would appear that the Hexham conditions could be repeated.

4. Engineering to Reduce Error

Single frequency radio systems

Railways have used single frequency radio systems for many years, as discussed earlier. The single frequency system is easily applied, cheap and has practical benefits for immediate communication between trains. The extension of this low-cost solution to the signal box or train control centre can create a hazard. While there is only one radio transceiver connected to the signal box or train control centre the situation is fairly simple. The signaller or train controller will be able to communicate with trains that are in a certain geographic area. The signaller and train drivers will identify the boundaries of that area and a cheap system will operate in a manner that may be adequate for the situation.

Problems arise when the coverage area is extended. A second and then a third base station will be added to the existing base, all operating on the same frequency. Since there is no difference between the base station transmitting and receiving frequency, each base can only transmit or receive and only one base station can transmit at a time[11]. The signaller or train controller must then select the base station that will be used for each conversation. Should the signaller forget to change the selection or make the wrong selection, the signaller may not be heard by the train driver.

The author has heard of numerous cases where signallers are said to ignore radio calls – often the signaller answered the radio calls but the train driver did not receive the transmission. The problem may be in the engineering; not in the user.

There are alternatives to single channel radio systems being used in this manner. Conventional mobile radio technology offers several solutions, including simulcast operation of the base stations and receiver voting. Two-frequency operation and disciplined channel allocation would vastly improve the situation. Other technologies such as GSM-R provide comprehensive approaches to the entire railway communication environment.

Screen-based manual systems

Both Victoria and NSW have examples of manually operated radio systems being transferred to screen-based devices. However, in both cases, the screen-based device simply mimics the operation of the manual system. This has not solved the problem – a radio system user with no knowledge of radio propagation, interference ratios and channel selection is still required to make decisions about these parameters. Whether the selection is made with a rotary switch, push button, mouse or touch screen; the potential for human error remains. A better engineering solution is to redesign the underlying system to remove the hazard. This may be achieved, for example, by automating the selection algorithm for a single frequency open channel system or by removing the single frequency operation. The re-engineering may appear to be costly but the consequences of human error can be more costly.

Locomotives

Screen based communication systems are being adopted enthusiastically as locomotives are redesigned. The locomotive purchasers can see the benefits of equipment that can be reprogrammed and updated without being removed from the locomotive. The locomotive crews are finding the advantages of having radio and channel selection automated and simplified.

There are at present three screen-based communications systems on the DIRN and a variety of systems using individual items of radio equipment. The screen-based system on the Pacific National NR class locomotives uses character graphics and text information. The Westnet Rail system is more graphically orientated. The CRT system has a strong graphical user interface with web style operation. Each performs much the same functions: each is different.

The challenge in designing a screen-based user interface for a locomotive is to create an arrangement that will

- minimise distraction to the driver
- unambiguously display information
- simplify call handling
- be intuitive to operate.

The basic handicap in such work is that the design is performed by an engineer who understands how the system is intended to operate. The train driver does not know how this particular system was intended to operate but brings knowledge of many other systems and practices. Great care must be taken in the layout of the screen display and in the operation of the selection menus. Feedback from train crews is essential and often reveals modes of operation or hazards that had not been discovered in factory tests.

There is at present no guidance in Australia regarding the design and implementation of screen-based radio communication systems.

Cross-connection at Train Control

The communication situation in NSW is particularly concerning as it relies upon the train controller or signaller to advise each train in the area of any hazard. The Glenbrook and Hexham investigations have both identified the problems inherent in this approach.

One solution is to implement cross-connection of the radio systems at train control and signal box locations. Whenever an emergency is signalled from a train or identified by the train controller, the various radio systems could be put into a broadcast mode so that all parties are aware of the situation and hear the reports first-hand.

This approach can be applied to cellular telephones and other switched circuit devices. The Pacific National Limited network has a Communication Control Centre (CCC), which provides for automatic dialling and connection of cellular and satellite telephone calls. The CCC includes a voice buffer so that the full message is replayed to each train as it connects to the system.

European approaches

The European approach has been one of strict standardisation, based on research into human errors. Albert Bidinger presented a paper at the IRSE in London in January 2001[12]. The paper reviewed the technical details of the implementation of GSM-R in Germany. A further paper by Christian Frerichs[13] reviewed the technological aspects of the cab. The System Requirements Specification for EIRENE[14] (which encompasses GSM-R) gives details of requirements to be satisfied but does not refer to the reasoning that underlies those requirements.

A project funded by the European Commission has investigated human factors for multicultural and multilingual rail environments[15]. A checklist for human factors in Appendix 2 of the project report identifies considerations in the design of user interfaces (inter alia). This type of information is absent from the technical specifications for the Driver Machine Interface of the European Rail Traffic Management System (ERTMS)[16].

A recent review of Train Control Research in Europe[17] describes many performance and safety related projects but none that relate to human error.

IS IT TIME FOR A CHANGE IN TECHNOLOGY?

With such a diversity of systems and approaches, surely it is time to move towards standards in communications. Not just in the equipment but in the practices and thought processes that are applied to radio system design.

1. Impediments to Change

Railways have made large step changes in radio communications systems. For example, the Victorian Train-to-Base radio was introduced in a short time period as a standalone system in response to a serious accident. This system was later expanded to incorporate electronic safeworking but remains a standalone system. Similarly, the Metronet and Countrynet systems in NSW are standalone systems. Each uses protocols and technologies that are embedded into their hardware. The hardware is now obsolete or reaching obsolescence, limiting expansion and change of the systems.

The train control equipment for both the Victorian and NSW systems is integrated into the radio communication system in a manner that impedes any change or enhancement.

Multi-million dollar changes to entire communication systems could be managed in the vertically integrated railways of the past. Decisions were made, funding was obtained and the taxpayer funded the entire system. It is no longer so simple as the infrastructure owner; network operator and rail users are now separate bodies. While changes can be mandated by the regulator, such mandates will be met with considerable resistance from each party.

In the author's view, it would be very difficult for any regulator to mandate that all rail users should use a particular technology for radio communications, particularly if that technology had a single source of supply. Legal impediments, practical factors such as vehicle availability, cutover details and simple obstruction will mitigate against forced change. Any process of change will require parallel operation of new and old systems for an extended period. In any case, no single technology could usefully be applied to the whole of the DIRN. The vast differences in traffic levels, population and infrastructure demand different radio technologies. A system that is cost-effective in Melbourne or Sydney is unlikely to be cost-effective at Tarcoola or Cook.

Most new radio systems require additional space for the new equipment to be fitted into the cabs and equipment areas while the old equipment is still operational. The transition as locomotives operate through new and old areas brings scope for human error in radio selection, operating techniques and interaction with track maintenance staff. The earlier discussion in this paper has emphasised the importance of these factors.

2. Facilitating Change - Codes of Practice

A set of Codes of Practice should be developed to deal with the detailed requirements of radio communication. The codes could consist of the following.

***Code of Practice -
Train Crew Communications Facilities***

This Code of Practice will define the minimum facilities that are to be provided to the crew of any train operating on the network. The Code of Practice may differentiate between the requirements for operation in electrified areas, high-density areas and other areas. There are essential differences in the railway operations that have been recognised in the existing radio communications systems. These differences may still apply. The Code of Practice will include consideration of Driver Only Operation and off-train communications. The code will include requirements for the "look and feel" of the crew interfaces.

***Code of Practice –
Track Work Communications Facilities***

This Code of Practice will define the minimum facilities that are to be provided to track workers operating on the network. The Code of Practice may differentiate between the requirements for operation in the electrified area, high-density areas and other areas. The Code of Practice will include consideration of train movement information, communication with train control and communication with trains.

***Code of Practice –
Controller/Signaller Communications Facilities***

This Code of Practice will define the minimum communication facilities that are to be provided to a signaller or train controller. The facilities description will encompass fixed line as well as wireless communications. Consideration will be given to the inevitable introduction of Internet facilities in these locations.

The Code of Practice will discuss the user interface and the conflicting communications requirements that must be resolved in any application.

***Code of Practice –
Maintenance of Communications Systems***

Maintenance is essential if communications systems are to perform to specification. The Code of Practice will define minimum standards of maintenance and maintenance strategies that must be in place. Recognising that there are at least two ends to any communication, each controlled by different parties and that there may be intermediate links supplied by other parties, the Code of Practice will emphasise the need for overall system testing as well as equipment item testing. Protocols and responsibilities will be assigned.

Code of Practice – Access to Signallers/Train Controllers

The fundamental requirement for diversity in communication technology can only be met if there is a standardised but versatile means of access to the signallers and train controllers.

At present the radio communications systems are tightly integrated and are bound to the existing technologies. The code should examine the interfaces that are necessary to connect diverse technologies to the signallers and train controllers. It should define and document a minimum set of requirements for access. The use of TCP/IP connections for both voice and data should be considered in the development of this code.

3. Facilitating Change on the Locomotive

Over two hundred of the locomotives operating on the standard gauge track have screen based communication systems. Screen based systems facilitate changes in radio systems as there is generally no need to make any physical change in the locomotive cab. A new software version can integrate the new functionality and should be able to deal with switching between sets of equipment. In most cases, the GPS equipment on the locomotive can be used to automatically switch between new and old networks.

Despite their overall size, locomotives rarely have sufficient space for communications equipment and the available space is quickly filled. New systems either should use existing hardware or directly replace an existing hardware item. (The continued reduction in physical size of radio devices is making this more achievable). One of the advantages of the screen-based system is the electrical and logical separation of the user interface and the radio equipment. This simplifies location of equipment for the transition.

4. Facilitating Change at the Control Centre

Control centre equipment (signallers and train controllers) is largely computer and screen based. The underlying technologies vary from rather primitive, low speed terminal emulations to LAN connected systems with redundant configuration and dynamic change of operation area.

Changes in radio communication technologies would be facilitated if the train controller and signaller interface were changed to be independent of the technology. For example, the Rail Infrastructure Corporation in NSW is introducing a screen-based interface for all communication systems. The interface connects to the networks by LAN data and PABX voice switches. New communication technologies can be linked into such systems relatively easily as a new LAN connection does not require hardware modification. The software modifications would generally consist of adding device drivers that should not be apparent to the user.

If this approach were applied throughout the DIRN, the existing technology-limited systems could readily be expanded. New radio communication technologies could then be added and operated in parallel with the existing systems.

5. Introduction of GSM-R

Readers of IRSE papers will be familiar with the concept of GSM-R. Built on the GSM telephony platform, GSM-R adds functions such as rapid emergency call connection, broadcast calls and call pre-emption that are essential for rail operation[18]. The functions and facilities are discussed by Bidinger[12] and the System Requirements Specification[14]. A recent paper by Harmer et al[19] expands on the application of GSM-R for Level 2 of ETCS. This paper discusses some timing issues and looks at some benefits of an enhancement of the GSM-R system. (The enhancement takes advantage of the standard GSM network data transmission system GPRS mode). Comprehensive information about the application of GSM-R for rail traffic management is available from the ERTMS web site[20].

In previous studies, it has been thought that GSM-R would be impractical to implement in Australia. The UIC started planning for GSM-R in the mid 1980s and had frequency spectrum reserved for their purposes when the GSM bands were being planned. No such provision was made in Australia and until recently spectrum was not available. The failure of some carriers, changes in technology and reduced demand has resulted in radio frequency spectrum being available for a GSM-R implementation in Australia. It is now feasible to implement GSM-R technology, even in the major cities.

GSM-R is a mature technology, with multiple suppliers and international standardisation. It has been designed expressly for the purpose of railway radio communications and does not need to be customised or “improved” for use in this country. It offers an ideal solution for the Sydney and Melbourne metropolitan areas, with high communications traffic requirements. GSM-R could extend through the areas that have higher levels of rail traffic. In lower traffic areas, the existing UHF and satellite systems could continue to operate.

The screen-based systems in use today could readily accommodate the addition of GSM-R. The small size of the GSM-R equipment and antennas would simplify the addition of this technology to other locomotives.

If the Metronet, Countrynet terrestrial, Victorian Met (Storno) and Victorian Train-to-Base systems were replaced with GSM-R, there would be a degree of standardisation not previously seen in Australia. Locomotives operating on the DIRN would have direct compatibility with the metropolitan passenger trains and with trackside staff.

Australia does not need to design two or three new radio systems – the solution is already available.

IMPLEMENTATION EXAMPLE – CargoSprinter

1. Overview

The CargoSprinter has an integrated train radio system that was designed for flexibility and ease of operation. A touch sensitive computer screen was selected as the primary interface to the driver. A single telephone handset is used for all voice communications. The handset has a keypad and small display, which are used in addition to the touch screen.

The CargoSprinter cab has limited space for radio equipment. The radio transceivers have been fitted into the space below the windscreen, immediately in front of the observer's seat. There is a small space here, sufficient for a satellite telephone, a power supply and equipment boxes with a total volume of approximately 500 mm x 200 mm x 320 mm. Seven radio antennas are installed on the roof of the cab.

2. Equipment Complement

The equipment complement for the CargoSprinter is shown in Figure 1. The equipment is suitable for all the radio systems identified in Table 1. (The Metronet and terrestrial Countrynet functions are not implemented at this stage). A future GSM-R radio has been included to show how such a transceiver would be added.

The CargoSprinter equipment is in its second implementation. The original USB based configuration was described at a recent CORE conference[21]. This configuration was economical but proved to be inflexible and prone to faults. There was considerable difficulty in getting the USB connected boxes to work correctly. USB devices have been retained in the new design but are only used within each equipment box.

LAN connections are now used between equipment modules. This has improved reliability and simplifies fault-finding as monitoring devices can be connected to the LAN. The processing load is spread over several processors, albeit with increased communications overhead.

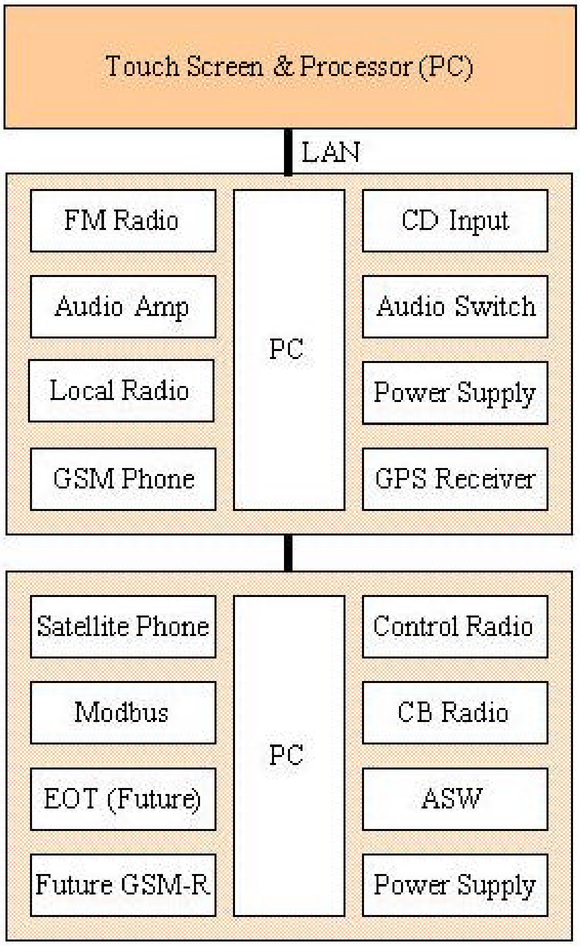

Figure 1 –CargoSprinter Configuration

3. Entertainment System

An entertainment system has become a standard fitting in most modern locomotive cabs. The CargoSprinter is no exception. The train has been high quality MB Quart speaker systems, an FM radio receiver, a CD player input and an MP3 file player. This entertainment system is automatically muted during train radio traffic.

Since the FM radio receiver is built into the system and is controlled from the driver's console, there is minimal additional hardware cost. The FM radio has scanning and station memory buttons.

4. Operating System

Linux is the operating system of choice for the CargoSprinter system. Linux is very cost-effective, it is extremely adaptable and it is very reliable. Linux drivers were available for most of the devices used in the system and additional drivers were readily created for the remaining devices.

5. Application Software

The application software has been developed in assembler, C, Phoenix and Kylix. Kylix is a Linux version of Pascal that permits rapid development of graphical applications. The Kylix code is object oriented, very readable and has rigorous type and bounds checking. Linux signals and TCP/IP protocols are used between modules of the application software.

6. User Interface

The CargoSprinter driver's desk has a very clean, uncluttered appearance. The display screen for the communications system follows this approach. The overall view can be seen in Figure 2. The driver's desk has a screen-printed overlay on steel panels. The edges of the panels are softened by a polished wood trim. The whole of the driver's desk is hinged for access to the PLC control system.

The normal train radio screen display has only the most essential information. The unused areas of the screen are blue, toned to match the rest of the driver's desk. On the left of the screen there are "buttons" to switch the handset between radio systems. The options are Control, Local, Phone and CB radio.

At the top of the selection panel there is a button for the entertainment system and at the bottom of the panel there is a button for backlight control. The button colour has been chosen to tone with the wooden trim on the driver's desk.
The train location is determined from the GPS data and is displayed as a line of text on the bottom of the screen. A warning message is displayed on this line if the GPS receiver is unable to provide accurate data.

Figure 2 – CargoSprinter Driver's Desk

7. Audio and Volume Control

The speaker volume is controlled with the lower knob on the left of the screen. This is a master speaker volume control. There is independent control of the relative volume of each part of the entertainment system. The handset earpiece volume is controlled from the handset (up/down buttons).

The normal configuration of radios directs the train control radio to the left speaker and the local radio to the right speaker. The relative levels of these radios are preset and both are adjusted simultaneously with the main volume control.

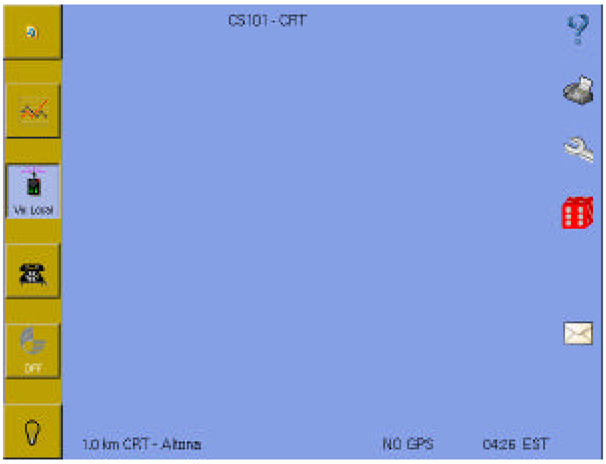

Figure 3 – Normal Screen Display

8. Emergency Calls

Emergency radio calls are initiated by pressing the button on the top right of the console. In those radio systems where there is no emergency call function (eg South Australia and Western Australia) a warning message to this effect is displayed to the driver if the emergency button is pressed.

9. Telephone Calls

GSM and satellite telephone calls may be made by the driver at any time. The handset dialling buttons can be used to make the call or the driver can use a touch screen telephone directory. The touch screen directory operates in a similar manner to an ordinary cellular telephone phonebook.

To access the touch screen directory the driver simply touches the phone button on the left of the display. When the button is first touched, the handset is switched to the telephone. If the button is touched again, the phone directory display will be visible. (The phone directory will be hidden if the button is touched again). The phone directory information is stored in a text file that can readily be updated.

The screen display includes a signal strength display for each of the GSM and satellite telephones. The default telephone device can be set in the track database, as can any desired limitation on use of either phone. The driver can switch between phone devices by touching the signal strength display. The system software continuously monitors the satellite and GSM phone network availability and automatically switches systems if coverage is lost.

10. Local Radio

Under normal conditions, the local radio is switched to the channel defined in the track database for the current train location (based on GPS data). However, the driver can change the local radio channel at any time by touching the Local Radio button twice (as for the phone directory) and displaying a channel selection panel. The driver can select any yard or local radio channel from this panel. The panel shows the channel number and a channel description. The channel number displayed can be used to easily set the portable radio channel.

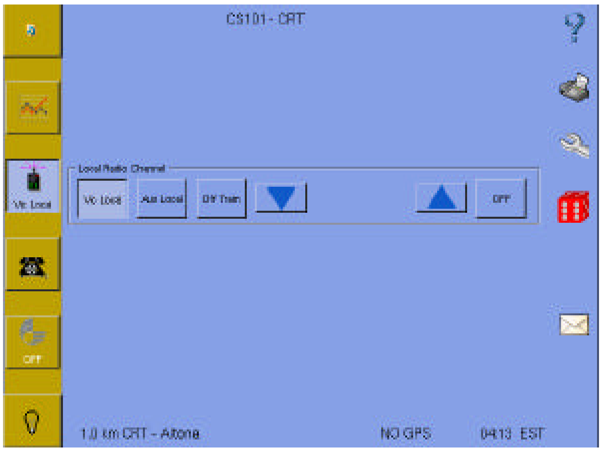

Figure 4 – Local Radio Selection

11. CB Radio

The CB radio has a similar panel operation to the local radio and phone. The panel is smaller and provides channel selection for the CB channels as well as three preset channel buttons.

CRT use the CB radio transceiver on standard mobile radio channels for shunting operations within their yards. The additional radio transceiver considerably increases the flexibility of these operations.

12. Control Radio

The Train Control radio is dynamically allocated as the train travels along the track. It can be switched between the UHF radio and the VHF radios (if fitted) or the satellite telephone. In NSW the satellite telephone is used for Countrynet access.

The Control button operation is similar to that for the Local radio, CB and Phone. The Control panel contents will vary from area to area, depending on the interface required for the particular system. In most areas there is only a display of the selected radio channel.

A special screen panel has been developed for ASW operation in Victoria. This panel reproduces the two display screens used in the hardware Locomotive Display Units (including the fixed pitch text). The various buttons that are used to accept and return authorities are included in the display panel.

DICE is used in Victoria for Driver Initiated Control of Equipment. A number of crossing loops can be switched with through DICE codes. The DICE code is entered on the display touch screen. The DICE functions are included in the ASW panel.

13. Context Sensitive Help

There is context-sensitive help information for each feature of the CargoSprinter system. If the user touches any area of the screen and then touches the "?" button, a hypertext help screen will be displayed.

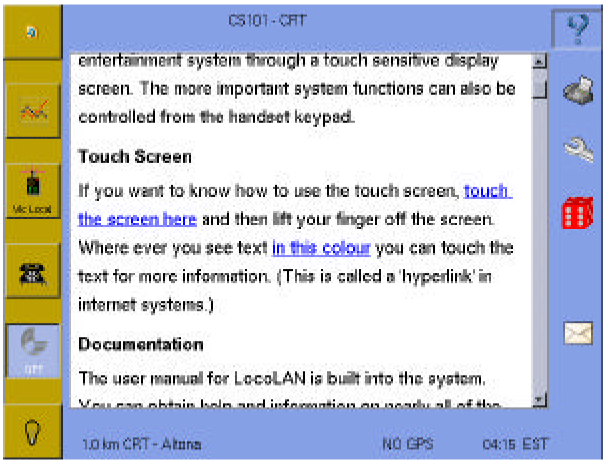

Figure 5 – Touch Screen Help

The help screen will generally have a reduced image of the area that has been touched, along with a description of that area. Any related topics are indicated in the text by hypertext links. The user can touch these links to gain further detail.

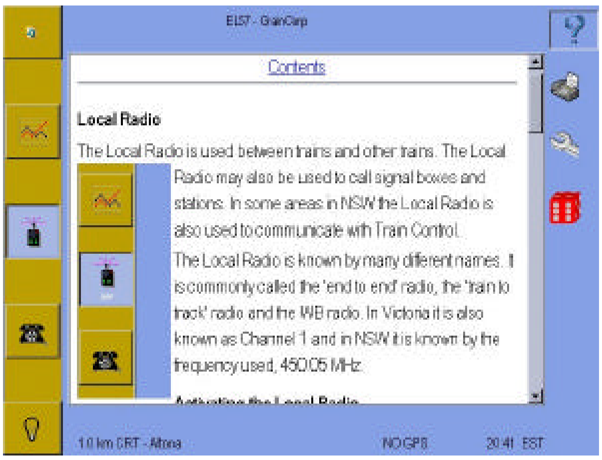

Figure 6 – Context Sensitive Help – Local

The help contents are accessible at the top and bottom of each help screen. The contents table is itself a hypertext list.

14. Summary

The CargoSprinter communications system uses commercially available off-the-shelf components to form a comprehensive communications system. The hardware elements are drawn from the industrial computer market and are designed for very similar applications in industry.

The cost and size of the equipment has been controlled by modular design. Rather than permanently fit all radio transceivers that may be required, the design permits quick exchange of modules to suit particular areas.

The software design is equally modular and accommodates changes in application. The modular software design has already proven to be readily expanded or reconfigured.

A great deal of engineering effort has been dedicated to the user interface. The goal is to have a user interface that is self explanatory and intuitive in operation.

While systematic planning is important, prototyping and field-testing have proved to be very valuable. Software prototyping has been employed with good effect, taking advantage of the rapid development environment that Kylix offers.

CONCLUSION

Rail operators in Australia have insufficient documentation of the disjointed radio communication systems that are in use on the Defined Interstate Rail Network. Extensions to the Code of Practice are proposed to deal with radio communications at a level of detail comparable to that applied to other engineering disciplines.

Communications systems have been identified as sources for human error in recent incident investigations. The findings of the Hexham inquiry have been highlighted to draw attention to hazards that are still present in a number of locations in Australia.

Technological change is essential and inevitable. Rather than the big, step changes that could be applied in a vertically integrated railway, future changes should be gradual and co-ordinated. The proposed Codes of Practice would facilitate expansion and improvements to the radio systems and would reduce the risk of error in the use and application of the systems.

A technological change is urgently required in the Sydney and Melbourne metropolitan areas. GSM-R provides a tailor-made solution for railway communications. The time is right and the radio frequency spectrum is available for a standard system to be applied in both cities.

REFERENCES

[1] The Honourable Peter Aloysius McInerney, Special Commission of Inquiry Into the Glenbrook Rail Accident, Final Report,April 2001 (http://www.transport.nsw.gov.au/safety_reg/rail_investigations/index.html).

[2] Transport NSW, Incident Investigation, Passenger Train Collision with a Derailed Coal Train at Hexham NSW, 12 July 2002 – Final Report, December 2002. (http://www.transport.nsw.gov.au/safety_reg/rail_investigations/index.html)

[3] Defined Interstate Rail Network - http://www.dotars.gov.au/arou/network.htm

[4] Australian Rail Operations Unit, *Code of Practice for the Defined Interstate Rail Network,* http://www.arou.gov.au/obtain_code.htm

[5] http://external.ric.nsw.gov.au:8080/railsafe/

[6] The RIC Glossary defines *effective communication* as "*The ability to successfully send, receive and understand information. The communication does not need to be continuous*."

[7] Clive Kessel, Telecommunications on the Operating Railway, IRSE Paper read in London on 9th January 1992.

[8] News View – One Clip or Three Phones – IRSE News, Issue 82, page 2, January 2003

[9] PW Stanley, The Influence of Human Factors on the Performance of Railway Systems, IRSE Paper read in London on 15th February 1996.

[10] James Reason, Human Error, Cambridge University Press, 1990.

[11] "Simulcast" systems can be used – in this case the base station frequencies are closely controlled to minimise interference. This technique is widely used for paging systems but has not been used to any extent for railway communications in Australia.

[12] Albert Bidinger, GSM-R, the platform for mobile communication of the railways, ie status of the project, IRSE paper read in London on 17th January 2001.

[13] Christian Frerichs, Eurocab and the Driver MMI – an introduction to the technology, IRSE Paper read in London on 10th December 2002.

[14] EIRENE Project Team, European Integrated Railway Radio Enhanced Network (EIRENE), System Requirements Specification, 15th December 2000.

[15] Human Safe Rail in Europe, Managing the Human Factor in Multicultural and Multilingual Rail Environments – Human Factor Analysis Techniques for Cross-Border Rail Operation, RA-97-RS-2094, 28th February 2000.

[16] CENELEC European Standard prEN50XX6-6, European Rail Traffic Management System, Driver Machine Interface, March 2000.

[17] Felix Schmidt, Train Control Research in Europe, IRSE paper read in London on 13th February 2002

[18] http://gsm-r.uic.asso.fr/

[19] John Harmer, Kevin Turner and Charles Riley, EuroRadio and the RBC, IRSE Paper read in London on 6th November 2002.

[20] http://www.ertms.com/.

[21] John Aitken, Australia Wide Communications for the CargoSprinter. Proceedings Core 2002, Wollongong November 2002.