MOBILE TRAIN RADIO COMMUNICATION

INTRODUCTION

Mobile Communications Principles:

Each mobile uses a separate, temporary radio channel to talk to the cell site. The cell site talks to many mobiles at once, using one channel per mobile. Channels use a pair of frequencies for communication. One for transmitting from the cell site, the forward link, and one frequency for the cell site to receive calls from the users, the reverse link. Communication between mobile units can be either half-duplex or full-duplex. In case of half-duplex, transmit and receive communications between the mobile units are not at the same time, i.e. talking and listening can not be done at the same time. In case of full-duplex communication, transmit and receive communication is at the same time, i.e. one can talk and listen at the same time. When communications between mobile units are within a cell, and if the same is half-duplex, then it shall require only one pair of frequency. If the same is full-duplex, then requirement of frequency pair shall be two. When a mobile unit is communicating with a mobile unit outside the cell, then the requirement of frequency pair shall be one per cell for both half-duplex and full-duplex communication. Hence the system resources are utilized more if the mobile units communicate in full-duplex mode.

RADIO TELEPHONY SYSTEM
Figure 1: Basic Mobile Telephone Service Network

Early Mobile Telephone System Architecture
Traditional mobile service was structured similar to television broadcasting. One very powerful transmitter located at the highest spot in an area would broadcast in a radius of up to fifty kilometers. The “cellular concepts” structure the mobile telephone network in a different way. Instead of using one powerful transmitter, many low-power transmitters were placed throughout a coverage area. For example, by dividing a metropolitan region into one hundred different areas (cells) with low-power transmitters using twelve conversations (channels) each, the system capacity theoretically could be increased from twelve conversations - or voice channels using one powerful transmitter- to twelve hundred conversations (channels) using one hundred low-power transmitters.

Different Type Of Communication Systems:
The different types of communication systems available today can be broadly classified into the following categories.

- Land line System
- Cellular System
- Satellite System

The evolution of the above Systems had been broadly as a point to point system.

- Two-Way Radio System

The evolution of the Two-way Systems has been both as a point to point and a point to multi point system.

Mobile Communication Evolution :
Evolution of 2-Way Radio Platform:
The following diagram explains how the evolution of 2-Way radio platform has taken place.
MOBILE TRAIN RADIO SYSTEMS

Present Day Scenario
A choice of mobile system for a set up is governed mainly by the following facts.
- Coverage area
- Number of subscriber to be catered
- Frequency spectrum available
- Nature of the terrain
- Type of application i.e. voice of data or both
- Integration with other systems
- Future technological migration capability
- Cost of the system

Railways’ Present Day Requirements.
The Train Mobile System’s present day requirements are not just voice transmission, but also along with voice the system shall be capable of handling data also. Typical applications for the Modern Train Mobile System are as under.
- Text and status message transmission.
- Automatic Train operation’s critical alarms.
- Train status and alarm information
- Passenger information system control
- Train passenger emergency system
- Closed circuit TV system

**Comparison of Various Open Standard Technologies Available Today**

**MPT1327 System**

MPT1327 is an Open Standard for Analog trunked radio networks. The British Department of Trade and Industry (DTI) developed it in year 1988. In the course of the next twelve months of development continued and resulted in MPT1343 standards. A system based on MPT1327 generally comprises of several radio channels. At least one of these channels will have been defined as the CC (Control Channel) and all the other channels are TCs (Traffic Channel). Data messages between the mobiles and the networks are exchanged on the Control Channel at 1200 bits/sec using FSK (Frequency Shift Keying). Each subscriber in a trunked radio network has a unique call number. It consists of a prefix (3 digits), a fleet number (4 digits), and a subscriber number within the fleet (2 or 3 digits). After it has been entered the call number will be converted in the mobile to a 20-bit address. For the duration of the call a subscriber is exclusively allocated a traffic channel from the available trunk. Western Railway has already opted for a MPT1327 system for the Motorman and Controller communication in its Suburban Section in Mumbai Division. This system is as a part of the TMS project between Churchgate and Virar Sections. M/s Tait New Zealand has supplied the Mobile System.

**Tetra Systems :**

TETRA stands for Terrestrial Trunked Radio, covering PMR (Professional Mobile Radio) as well as PAMR (Private Access Mobile Radio) applications. As a trunked system, it is designed to be the true follower of MPT1327. TETRA applies digital speech transmission with TDMA (burst transmission), very fast call setup times, and may use powerful encryption. TETRA is an Open Standard defined by ETSI (European Telecommunication Standards Institute). TETRA applies a modulation format called pi/4 DQPSK, TDMA with 4 channels per carrier, and a carrier spacing of 25 KHz. TETRA does not have a fixed frequency allocation as GSM. But the systems currently planned or installed in Europe assumes frequencies in the range of 380-.400 MHz for public a safety communication, and 410-.430 MHz for commercial systems.

**GSM System:**

- The GSM (Global System for Mobile Communication) MoU Association, a Swiss registered Corporation, is the principle body responsible for promoting and evolving the GSM wireless platform worldwide. Today GSM is the most successful implementation of a global wireless standard using digital technology for point to point operations. There are over 293 members representing 120 countries/areas. The overall objective of the GSM MoU Association is “ The promotion and evolution of the GSM900, GSM1800, GSM1900 systems, and the GSM platform for international roaming, for the provision of standardized services.
Global System for Mobile Communications - Railway or GSM-Railway is an international wireless communications standard for railway communication and applications. A sub-system of European Rail Traffic Management System (ERTMS), it is used for communication between train and railway regulation control centers. The system is based on GSM and EIRENE-MORANE specifications which guarantee performance at speeds up to 500 km/h (310 mph), without any communication loss.

GSM-R is a secure platform for voice and data communication between railway operational staff, including drivers, dispatchers, shunting team members, train engineers, and station controllers. It delivers features such as group calls (VGCS), voice broadcast (VBS), location-based connections, and call pre-emption in case of an emergency. This will support applications such as cargo tracking, video surveillance in trains and at stations, and passenger information services.

GSM-R is typically implemented using dedicated base station towers close to the railway. The distance between the base stations are 7–15 km. This creates a high degree of redundancy and higher availability and reliability. The train maintains a circuit switched digital modem connection to the train control centre at all times. This modem operates with higher priority than normal users (eMLPP). If the modem connection is lost, the train will automatically stop. In Germany, Italy and France the GSM-R network has between 3000 and 4000 base stations.

In the UK, over 14,000 km of GSM-R enabled railway is planned, with 280 km currently in operation. GSM-R cab radio for use in UK trains is currently being developed by Network Rail and is undergoing trials in the Strathclyde and Glasgow areas of Scotland. It is currently in use on London Overground's East London Line, between Dalston Junction and New Cross Gate.

**Upper system**

GSM-R is one part of ERTMS (European Rail Traffic Management System) which is composed of:

- ETCS (European Train Control System).
- GSM-R.

**Frequency band**

In Europe, GSM-R uses a specific frequency band:

- 876 MHz — 880 MHz: used for data transmission (uplink)
- 921 MHz — 925 MHz: used for data reception (downlink)

However GSM-R can operate on a number of frequencies that are being used around the world.

In China GSM-R occupies a 4 MHz wide range of the E-GSM band (900 MHz-GSM). In Australia GSM-R is being implemented using frequencies in the 1800MHz band.

The used modulation is GMSK modulation (Gaussian Minimum Shift Keying). GSM-R is a TDMA (“Time Division Multiple Access”) system. Data transmission is made of periodical TDMA frames (with a period of 4.615 ms), for each carrier frequency (physical channel). Each TDMA frame is divided in 8 time-slots, named logical channels (577 µs long, each time-slot), carrying 148 bits of information.
There are worries that LTE mobile communication will disturb GSM-R, since it has been given a frequency band rather close to GSM-R. This could cause ETCS disturbances, random emergency braking because of lost communications etc.

**GSM-R uses**

GSM-R permit new services and applications for mobile communications in several domains:

- transmission of Long Line Public Address (LLPA) announcements to remote stations down the line
- control and protection (Automatic Train Control/ETCS) and ERTMS
- communication between train driver and regulation center,
- communication of on-board working people
- information sending for ETCS
- communication between train stations, classification yard and rail tracks

**Main use**

It is used to transmit data between trains and railway regulation centres with level 2 and 3 of ETCS. When the train passes over a Eurobalise, it transmits its new position and its speed, then it receives back agreement (or disagreement) to enter the next track and its new maximum speed. In addition, trackside signals become redundant.

A GSM-R mobile phone used by the National Railway Company of Belgium

A modern GSM-R cab radio

Like other GSM devices, GSM-R equipment can transmit data and voice. New GSM-R features for mobile communication are based on GSM, and are specified by EIRENE project. Call features are:

**PtP Call**: Point-to-Point Call, the same type of call as a normal GSM call

- **VGCS**: Voice Group Call System, quite similar to walkie-talkie communication
- **VBS**: Voice Broadcast System, like a VGCS but only the call initiator can speak (the other are only listeners)
- **REC**: Railways Emergency Call, it is a special VGCS with high priority dedicated to emergencies.
- Priority control of all the different calls (PtP, VGCS, VBS and REC calls)

There are other additional features:
- *Functional Addressing*, alias system to call someone registered on the GSM-R network, only by knowing the temporary function user (engine driver of train such-and-such, …)
- *Shunting* mode, when users work on the tracks.

**ASCI (Advanced Speech Call Items) features:**

**VGCS (Voice Group Call Service)**

VGCS allows a great number of users to participate in the same call. This feature imitates the analogue PMR (Private Mobile Radio) group call with the PTT key (Push-to-Talk). Three kinds of users are defined: the Talker, the Listener and the Dispatcher. The talker can become a listener by releasing the PTT key and a listener becomes a talker by pressing the PTT key. Portable GSM-R Cab Radio system

One advantage of VGCS compared to multi-party calls (the GSM conference call feature) is the spectrum efficiency. Indeed, when many users are in the same cell they will use only one frequency for all listeners and two frequencies for the talker (as in point-to-point call). In a multi-party call, one timeslot is dedicated to each user. The second advantage compared to multi-party calls is that it is not necessary to know which mobiles are to take part in the call. A VGCS call is established on a purely geographic basis, subject to a mobile having previously enabled reception of the group concerned.

Compact GSM-R Cab Radio

**VBS (Voice Broadcast Service)**

VBS is a broadcast group call: this means that compared to VGCS, only the initiator of the call can speak. The others who join the call can only be listeners. This kind of call is mainly used to broadcast recorded messages or to make announcements.

**REC (Railway Emergency Call)**
*REC* is a group call, or VGCS, dedicated to urgency. It is a higher priority call (*REC* priority is level 0 — see below : eMLPP)

**Multi-Level Precedence and Pre-emption Service (eMLPP)**

This defines the user’s priority. The different priority levels are:
- A and B: Highest priority levels (not used by GSM-R networks)
- 0: Highest priority levels for ASCI and normal calls (mainly used for REC calls)
- 1: Lower priority than level 0
- 2: Lower priority than level 1
- 3: Lower priority than level 2
- 4: Lowest priority level (default priority, assigned to Point-to-Point calls)

An *Auto-Answering* feature with a timer is also available for calls with priority 0, 1 and 2.

![Dual Mode Cab Radio (GSM-R and UIC 751-3) as 19" rack](image)

**Eirene features**

**Functional number management**

- Functional numbering
  - Allows to call an MS by its function: driver of the train xxx, ...
  - It uses:
    - USSD and Follow Me
    - UUS1 (for number display)
- Location dependent addressing
  - Establishes a call from an MS to (usually) a fixed subscriber/dispatcher performing a function in the area where the MS is located

**End Call Confirmation**

End Call Confirmation feature is only available for highest priority (Priority level 0) group calls (VGCS) and broadcast calls (VBS) (see eMLPP).

It consists of an end call report which sent by all MSs (mobile stations) which joined the high priority call (initiator included). This report informs about:
- Call type
- Call duration
- MS Identity
- End call cause Normal, ended by user, MS power off by user, power off due to
low battery, …)

…

If the report can't be sent (MS power off by user or power off due to low battery), the MS will try again (several times if needed) to send the report at the next power on.

![A graphical GSM-R cab radio interface - capable of displaying different languages](image1)

**Shunting mode**

Shunting mode is the term used to describe the application that will regulate and control user access to shunting communications. A Link Assurance Signal (LAS) is provided in order to give reassurance to the driver that the radio link is working.

![GSM-R user interface with colour display](image2)

**Direct mode**

Direct mode is the walkie-talkie mode (mobiles station talking to each other without the network) and has been proposed in Eirene, however it has never been in application since being based on analogue radio. Sagem claims to have developed a GSM direct mode, not currently recognised in the GSM-R specification, and has no frequency allocation.
GSM-R operating device for SBB

**GSM-R market:**

**GSM-R market groups**

Different groups make up the GSM-R market:

The network operators and the railway operators

<table>
<thead>
<tr>
<th>Country</th>
<th>Network operator</th>
<th>Railway operator(s)</th>
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<tbody>
<tr>
<td>Australia</td>
<td>Department of Transport Victoria</td>
<td>Metro Trains Melbourne</td>
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<td>Australia</td>
<td>RailCorp</td>
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<td>DB Netz</td>
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<td>Nokia Siemens Networks</td>
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<td>Siemens together with SBB Telecom</td>
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<td>Slovakia (Pilot site)</td>
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<th>Feasibility phase:</th>
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<td>Slovenia</td>
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<td>USA</td>
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Source: UIC (23 May 2006)[4]

The network operators

The companies Nokia Siemens Networks, Huawei, and Kapsch (formerly Nortel) are the main suppliers of the GSM-R infrastructure.

Dispatch and control centre solutions

Siemens Mobility, NEC Portugal, Frequentis, Wenzel Elektronik, Hörmann Funkwerk Kölleda GmbH and Ascom (Switzerland) Ltd.

The terminal manufacturers

Handset manufacturer

Sagem (Safran group) is the main GSM-R handset supplier, followed by AJA Solutions Selex Communications, Triorail, and Huawei.

Cab radio manufacture

Selex Communications, Siemens Mobility, NEC Portugal, Alstom, Center Systems and Hörmann Funkwerk Kölleda GmbH are the main suppliers. Hoermann Funkwerk Kölleda (formerly Kapsch) and Sagem mainly provide the GSM-R core of these cab radios.

Railways using GSM-R
**TGV POS**, linking **Paris** to **Germany** and **Switzerland**

A fully-functional GSM-R system is being trialed on the **North Clyde Line** in Scotland from 2007. For some years before these trials commenced however, GSM-R has been in use for voice-only purposes (known as the 'Interim Voice Radio System' (IVRS)) in some locations where **axle counters** are used for train detection, for example parts of the **West Coast Main Line (WCML)** between Crewe and Wembley. Britain’s GSM-R network should be fully operational by 2013 at a cost of £1.2 billion. This cost though does not include the WCML.

- The first train (390 034 on the 09.15 Manchester Piccadilly service to London Euston) to use GSM-R on the south end of the West Coast Main Line ran on 27 May 2009. This is the first vehicle to run in passenger service with GSM-R outside of the Strathclyde trial.[citation needed]
- On 2nd Sept 09 the Rugby to Stoke section went live.
- Network Rail has fitted out a test train at Derby it purchased for RSV testing of the GSM-R network. The train is formed from ex Gatwick Express stock. At a cost of £5.9 million, this custom-built machine known as the RSV (Radio Signal Verification) train, has already started monitoring the Newport Synergy scheme and the **Cambrian Line**.
- The **Cambrian Line ERTMS** – **Pwllheli** to **Harlech** Rehearsal commenced on 13 February 2010 and successfully finished on 18 February 2010. The driver familiarisation and practical handling stage of the Rehearsal has provided an excellent opportunity to monitor the use of GSM-R voice in operation on this route.
- The first train departed Pwllheli at 0853hrs in **ERTMS** Level 2 Operation with GSM-R voice being used as the only means of communication between the driver and the signaller.

In France, the first commercial railway route opened with full GSM-R coverage is the **LGV Est Européenne** linking Paris **Gare de l'Est** to **Strasbourg**. It was opened on the 10th of June 2007.

- On Sunday, June 10, 2007 at 0643, the first high speed train run on it was the **ICE**, the **high speed train** from the German passenger operator : **DB**. It linked the **Gare de l'Est** in **Paris** to **Saarbrücken** (Germany).
- On the same day, 0715, it was the opportunity of the **TGV POS**, the last generation high speed train from the French operator, **SNCF**. It linked **Strasbourg** to Paris (Gare de l'Est). ([Réf. SNCF - Paris AFP, 10 June 2007][5])

In Norway, the GSM-R network was opened on all lines on 1 January 2007.

In The Netherlands, there is coverage on all the lines and the old system called **Telerail** was abandoned in favour of GSM-R in 2006.
As of 2008, in Italy more than 9000 km of railway lines are served by the GSM-R infrastructure: this number includes both ordinary and high speed lines, as well as more than 1000 km of tunnels. Roaming agreements with other Italian mobile operators allow coverage of lines not directly served by GSM-R. Roaming agreements have also been set up with French and Swiss railway companies and it is planned to extend them to other countries.

ICE 3M at Gare de l'Est in Paris

**WESTERN RAILWAY SUBURBAN SYSTEM (CHURCHGATE TO VIRAR):**
Western Railway has gone for a mobile communication system in its suburban section in Mumbai. This project is a part of the Train Management System, which is commissioned in the suburban section of Mumbai Division. Basic purpose of this communication system is to provide a continuous communication between the Motorman and the controller. The system consists of two base stations. One is installed at Mahalakshmi, and the other at Borivili each transmitting 50 watts of power. The Regional Node is installed at Mumbai Central. Mobile units are 25 watts full-duplex sets installed in the Motorman and Guard compartment of the 75 EMU rakes of the Suburban section of the Mumbai division. Together they cover the whole suburban section between Churchgate and Virar, a distance of 60 Kms. The system works on the principle of trunking, and is based on the MPT1327, MPT1343 protocols. M/s Tait New Zealand has supplied the System.
Figure 4: Western Railway Churchgate to Virar Mobile
5: Western Railway Churchgate to Virar Mobile:

The System (T1540) Overview
The system consists of a number of radio sites, which are linked in groups to “Regional Nodes” (in the Western Railway System there are two radio sites, one at MX, and the other at BVI). Regional Nodes may be linked together to form a wide area network. Radio sites (base stations) are connected by fixed audio and data links (V.24 interface at 1200 bauds) in “Star Configuration around the Regional Node”.

In case of wide area network the interconnection between the Regional Nodes shall be with X.25/TCP IP (9600-baud link) for data, and by an audio network consisting of fixed link bearers for audio signals.

PSTN & PABX interconnection is provided at the Regional Node now.

The expansion capability of the T1540 system is as under.
- Each Regional Node can support upto 16 base stations connected in a star configuration.
- Each base station can support upto 24 channels including the control channel (both the base stations of W.R are configured for only 5 channels each).
- Overall System can be configured for a maximum of 32 Regional Nodes.

The overall access for management of the system is provided by the Network Provider Interface (NPI). The NPI provides an interface for external systems running applications (a Network Provider Package (NPP)) using the following facility.
- Statistic
- System Configuration
- Validation
- Monitoring
- Fault Management and Alarms
- Call Records
- NPI management

Frequency of operation of the Western Railway System is between 338 to 350 MHz.

**Conclusion:**

Mobile Communication today is a fast growing field. No one can deny its role in Modern Railway Operations. However there is a need of proper choice of technology looking into Railways' Operational needs. It is beyond doubt that incorporation of Mobile Communication into Railways will open new operational avenues, there by reducing operational costs and increasing customer satisfaction by providing better services. This shall not only help in increasing productivity, but also help in increasing safety of operations. This is an age of communication. Indian Railways, which is a lifeline of the nation, is also geared up to take the requirements of the new millennium, which is knocking the door of this century.