WHITEPAPER

A comparison of TETRA and GSM-R for railway communications

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Going further in critical communications

Many railways operators face a dilemma when choosing the wireless technology to support their networks' communications requirements: in 1993, a time when the TETRA standard was just being established, the Union Internationale des Chemins de Fer (UIC) chose the GSM standard as a basis for its future digital mobile system. This led to the specification of the GSM-R (GSM for railway) standard, and the introduction of Voice Broadcast Calls, Voice Group Calls and Priority features as new added services in GSM.

However, the rapid adoption of TETRA technology by the public safety sector has catalysed its use in a growing range of markets: TETRA is now the de facto radio technology for public transportation such as trams and metro systems. But why is TETRA so suited to railway operations? What are the factors that have driven its success and led to such exponential growth in its use?

This document looks at both TETRA and GSM-R, and compares the two technologies. It covers aspects relating to their performance and features, showing why TETRA has important advantages in comparison with GSM-R in the following areas:

- Spectrum efficiency
- Coverage
- Cost
- Public safety and mission-critical features
- Manufacturer support
- Future-proofing and future development of the technology

RF PERFORMANCE: COMPARISON

TETRA is a technology that was designed specifically for the private mobile radio market, with public safety features at the fore. GSM-R, however, was modified from GSM, a public radio network standard, for use in railway operations – a private mobile radio environment.

Private mobile radio systems are designed specifically for professionals who require fast communications, simultaneous communication within a work group and mission critical features.

Public radio networks, however, cater to a totally different audience, being designed for general public use and individual calls, with no requirement for fast call set-up times.

A comparison between TETRA and GSM-R RF performance is shown in the table below.

	GSM-R	TETRA
ETSI standard availability	Early 1997 (based on previous GSM)	Full ETSI status December 1995
Modulation	GMSK	Pi/4 DQPSK
Channel bandwidth	200 kHz providing 8 independent communication channels[1]	25 kHz providing 4 independent communication channels
Frequency Bands (MHz)	876-880/921-925[2]	380-400 410-430 450-470 806-821/851-866
TETRA/GSM-R CEPT SE7 Guard band in 800/900MHz for –60dBc (kHz)	300[3]	25
Receiver sensitivity (dBm)	-104	-103
Maximum terminal speed (km/h)	500[4]	500[4]
Maximum propagation distance (km)	40[5]	58[4]
Cell handover time (ms)	Seamless[6]	Seamless[5]

(1) In terms of frequency usage, TETRA is four times more efficient than GSM. TETRA offers four channels/25kHz, while GSM gives eight channels/200kHz, making TETRA systems more spectrum efficient: more channels are available, therefore there is more capacity to support significantly higher traffic levels. Having more capacity also allows for future mobile data applications to be implemented without the need for further RF equipment.

(2) TETRA operates in frequency bands 300 MHz and higher. GSM-R, by operating in the frequencies 876-915/921-960 MHz, requires many more base station repeaters than TETRA to obtain the same coverage. Using TETRA will lead to significant savings, not only in radio equipment, but also in civil engineering, such as buildings, shelters and towers.

(3) The 300kHz guard band required to prevent interference between GSM-R and/or analogue FM (GSM-R DMO Solution) is provided from the GSM-R frequency allocation of 2 x 4MHz (20 channels). These requirements could easily inhibit frequency planning in cities where railways terminate and traffic is greatest.

(4) Questions have been raised about the suitability of TETRA for terminals travelling at high speed – an important factor, since the average speed of trains is in excess of 200kph and speed has an effect on the TETRA radio data error rate. This is critical for high-speed rail applications where trains may run at speed of up to 350kph. The GSM-R standard specifies that the radio communication system should support speeds of up to 500kph. Simulations carried out by member companies of the TETRA community have proven that TETRA is effective at 500kph.

(5) The typical cell size of a GSM system in a rural area is around 5 to 10 km radius, whereas TETRA cell sites range between 10 to 25 km radius, depending on terrain. Therefore, fewer TETRA cell sites would be required to cover a given area, typically resulting in fewer RF sites along the track and lower infrastructure costs.

(6) Both TETRA and GSM-R will need special consideration for seamless handover when adjacent cells are busy (all traffic channels in use). However, TETRA is better provisioned to provide seamless handover continuity between cells, because ruthless pre-emption protocols already exist to disconnect lower priority users as part of the emergency call facility. This feature is very important from a safety perspective, as calls should not be dropped during data transmission and voice communication, even when trains are crossing between cells.

FEATURES AND TIME PERFORMANCE

This section provides a summary comparing the voice, data and rail specific-features supported by GSM-R and TETRA systems.

Voice Services	GSM-R	TETRA
Call access time	5 - 8.5 sec	500 ms
Group call	Y (5 sec)	Y (0.5s)
Individual call	Y (5 sec)	Y (0.5s)
Broadcast call	Y (5 sec)	Y (0.5s)
Priority/emergency call	Y (2 sec)	Y (0.5s)
Full duplex voice	Y	Y
Telephone interconnect call	Y	Y
Call busy queuing	N	Y
Recent user priority	N	Y
Late entry	N	Y
Remote monitoring	N	Y

Voice call set-up time

GSM-R uses a public network type infrastructure that was inherited from GSM, making it extremely difficult to achieve very fast call set-up times. The set-up times currently achievable by GSM-R systems would not be acceptable in the event of an emergency.

TETRA, on the other hand, was specifically designed for use in mission-critical environments, where fast response times are essential. The typical response time achieved by TETRA systems is less than 500ms-300ms within a switch, and 500ms between switches – much faster than EIRENE specifies for GSM-R.

Data services	GSM-R	TETRA
Status messaging	Y	Y
Short data messaging	Y	Y
Circuit mode data	Y	Y
Data terminal interface	Y	Y
Simultaneous voice + data	Y	Y
Packet data	N	Y

Data call set-up time
The call setup time also affects the data call handover: due to set-up times currently achievable by GSM-R (around 5-8.5s), the onboard radio design would require the installation of at least two GSM-R radios. The process is as follows:

- A data call between the onboard radio 1 and the RBC 1 in the wayside (Radio Block Centre) is established → Train control from RBC 1
- When the train control has to be passed to a new RBC, a second data call between the onboard radio 2 and the RBC 2 in the wayside is established
- The train control is assumed by RBC 2
- The first call Radio 1 – RBC 1 can be disconnected

If there was just a single GSM-R radio, the handover between RBCs could take around 5-8.5s (the time to disconnect a call and connect a second one). During this time the train is not controlled, which is obviously not acceptable.

With TETRA, the handover between RBCs would take around 0.5s (TETRA call set-up time).

Other features	GSM-R	TETRA
Train run number	Y	Y
Customised console GUI	Y	Y
Direct Mode Operation (DMO)	Optional **(7)**	Y
Dynamic group number assignment	N	Y
Standalone operation (reliability)	N	Y **(8)**
Shunting mode	Y	Y
Integration with ETCS	Y	Y **(9)**

(7) The GSM-R standard does not offer integrated DMO mode. The GSM-R solution for DMO is to use analogue FM within the same radio terminal. Combining both GSM-R and FM requires good frequency separation due to the 300 kHz guard band requirement of GSM-R. To ensure that all GSM-R systems have equal access to DMO, a group of RF channels will need to be assigned from the 876-880/915-921 MHz frequency band, thus reducing GSM-R channel capacity. DMO is included within the TETRA, without the need to integrate any other FM analogue radio.

(8) In railway operations, it is important that emergency communications are maintained – even in times of drastic communication link failure between sites or between main and remote sites. When a remote site is isolated, a degraded mode of operation should allow emergency communications to continue, especially in catastrophic conditions. Within TETRA, radios within coverage of a site can communicate with each other even when site links go down. With GSM, the architecture requires centralised control – thus, when the link between the switch and base station is severed, the site is no longer operational and coverage in this area is completely lost.

(9) The GSM-R standard specifies data transmission at 2.4kbps for the exchange of signalling information. This is not a problem for TETRA, as it supports the European Train Control System (ETCS) or Automatic Train Control (ATC) applications – and in fact, even higher data rates.

It is expected that the data requirements for railway systems will, over time, increase significantly beyond the 2.4kbps specified. TETRA would therefore be fully capable of transporting the control application information as well as, or better than GSM-R.

In addition, although GSM-R is evolved from GSM, both systems cannot directly interoperate due to the allocated operating frequency and the fact that additional features incorporated within the GSM-R radio are not supported by the GSM infrastructure. GSM-R radios cannot roam into GSM networks and vice versa.

TETRA has been adopted as the digital radio trunking standard for public safety and private networks in Europe, and this trend has spread to the rest of the world. In the event of an emergency, when multiple agencies need to communicate and coordinate their activities, it is critical that the radio systems are able to interoperate with each other – typically by using the same standard. Without this functionality, railway personnel will not be able to communicate with other agencies in times of need.

In the case of derailment of a train, the emergency services, all using TETRA, can be easily and dynamically configured and placed into new talk groups with the railway operator to facilitate communications to coordinate rescue works, crowd control, etc. This kind of interoperability is especially critical during times of crises, where lives may be at stake.

ECONOMIC CONSIDERATIONS

GSM-R infrastructure tends to be expensive, as it is based on GSM architecture, which was developed for mobile telephony (public networks), where the infrastructure cost is supported by millions of subscribers. By contrast, TETRA was created for low-density private systems, with a usage profile closer to the requirements of railway systems. This technology profile – GSM for public networks (infrastructure heavy) and TETRA for private networks (infrastructure light) – makes TETRA much more cost-effective than GSM-R.

In addition, GSM-R terminals are very different – in terms of both features and function – from typical GSM terminals, and do not benefit from the economies of scale achieved by their production. Furthermore, the relatively small market for GSM-R hand-portable terminals does little to drive competition between suppliers, potentially resulting in higher prices and reduced choice for users.

Economic factors	GSM-R	TETRA
Application	Designed for railways	PMR applications, including rail **(10)**
Network scalability	No small network capability	Scalable from single site to nationwide network
Infrastructure cost	Slightly higher than GSM (standard GSM elements + rail-specific elements)	Cheaper than GSM-R. TETRA was specifically defined for professional usage, and requires no commercial architectural elements.
Mobile terminal cost	Higher (due to DMO integration, ruggedisation, low volume market, etc.)	Competitive (terminals already supporting DMO and PMR features in ruggedised housing)
Customised terminal cost (cab radio)	Same as TETRA (radio control panel, train control interface, DC converter, etc.)	Same as GSM-R (radio control panel, train control interface, DC converter, etc.)
Maintenance cost	Higher (more sites to maintain)	Cheaper than GSM-R
Rural area coverage	High infrastructure cost and low user density in rural areas	Scalable design allows large coverage area for rural users
Bearer circuits	Use at least E1 circuit (30 channels) per base station site	A single TETRA base station requires just one 64kbps channel. Any backhaul between node and base stations is suitable. Re-use of customer-owned elements is possible
Second source security	Limited suppliers	Greater choice of suppliers

Value added services	GSM style services + limited PMR services	GSM style services + advanced PMR services **(11)**

(10) TETRA has received greater widespread market acceptance than GSM-R with thousands of projects awarded worldwide, in market sectors including public safety, transportation and utilities. GSM-R projects have so far been limited to European railways only.

Almost all new or upgraded metro and mass rapid transit lines – whose needs are very similar to those of railway operators – are selecting TETRA as their technology of choice when deploying digital trunked radio systems.

(11) Although GSM has many manufacturers supporting it, the same cannot be said of GSM-R. Due to its limited market size, most GSM manufacturers have elected not to support GSM-R. TETRA has significantly greater manufacturer support for both infrastructure and terminals, leading to greater competition and a greater choice of terminals that match users' needs.

TETRA AND GSM-R ARCHITECTURE

One of the main differences between TETRA and GSM-R is the architecture. While GSM-R is based on a circuit switching architecture, TETRA, particularly Sepura's infrastructure, is based on Ethernet (packet switching architecture).

This provides a wide range of advantages:

SEPURA TETRA: 100% Ethernet / IP	Advantages
All modules can be duplicated to achieve complete redundancy	Completely failure-tolerant system; maximum reliability
All elements in the system can be freely distributed	The transport network can use any kind of technology
The control nodes don't need to be geographically centralised	Failure points are avoided
Optimised method for packet data transmission throughout the transport network	Bandwidth requirements between SCNs and SBSs are reduced
Standard network equipment	Reduced obsolescence risk and reduced costs
Standard maintenance IP services	Standard tools: FTP, SNMP, TELNET, HTTP

FUTURE DEVELOPMENT

Obsolescence is a key factor in the selection of the most appropriate technology to support railway communication requirements. A long lifecycle is mandatory, and the chosen technology should have a migration or evolution upgrade path to meet foreseeable future trends.

TETRA has consistently evolved to meet the needs of the professional market; the life of the technology is guaranteed for many years to come.

However, GSM-R's path into the future is less certain. It is not clear how GSM-R will be updated following the evolution of the public networks. The plans for new 3G and 4G public networks do not include the special railway functions of GSM-R, leaving the technology locked in to the initial, 1997 specification. For this reason, GSM-R is considered to be a technology that is near to the end of its life.

CONCLUSIONS

The TETRA standard betters GSM-R in terms of performance, features and price – as well as having a more clearly defined future. Flexible and open, the standard allows software application interfaces to be written to address the highly specific requirements of the railway sector.

Although the GSM-R standard was designed to meet the requirements of the railway industry, TETRA is arguably a better standard for railway operators to adopt, offering:

- Better spectrum efficiency
- Better coverage
- Lower cost
- Public safety and mission-critical features
- More manufacturer support
- Clearer future plans and evolution of the standard

To learn more about how Sepura can help with your critical communications, contact your local Sepura representative or visit www.sepura.com