Coexistence between GSM-R and 3G / 4G-Systems in the 900 MHz Frequency Band - Swedish View.

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Executive summary

Two main interests in Europe, the evolution of mobile broadband services with new technology (3G/4G) in the GSM 900 MHz band, and the interoperable railway system with ERTMS, are not harmonized for coexistence.

For the railway sector it is extremely important that the coexistence issue has a quick solution that guarantees a high quality GSM-R service for railway operation and ERTMS, as well as working public mobile broadband services along the railway tracks for the train passengers.

For the mobile operators it is also extremely important that the coexistence issue has a quick solution so that they can roll out new broadband services, without any heavy restriction in the licensing conditions. This to be able to provide mobile telecom services along the railway tracks for both train passengers and those who live or work near the railways.

The issue contains of two separate problems that need to be solved for well functional coexistence:

- Unwanted emission from public mobile network systems leaking into the GSM-R frequency band.
- Strong wideband signals. Approved, ETSI compliant GSM-R equipment installed in railway vehicles cannot handle strong wideband signals from public mobile network systems (e.g. UMTS and LTE) in nearby frequency bands.

We have in Sweden a common understanding of how this issue may be solved, it includes regulations of emitted levels, filters at public base stations, improved GSM-R coverage and protective filters/improved radio module for the GSM-R terminal.

These actions together give a good base for coexistence with the overall lowest impact on the national economy. This ensures a well working railway system as well as a quick roll out of broadband services in the 900 MHz band.

What is needed from the European commission and ERA? (European Railway Agency)

- **Harmonized levels of wanted emissions**
  Harmonized levels of wanted emissions from public operators into the railway environment. Those levels should guarantee good coverage for train passengers as well as good GSM-R operations.

- **Permission to introduce switchable filters**
  Clear statement in TSI CCS (EIRENE) that switchable filters or other solution which meet the harmonized levels of wanted emissions is accepted.

- **Harmonized limits of unwanted emissions**
  Harmonized values of unwanted emission from public mobile operators into the GSM-R frequency band. (This can be handled on national level with technical conditions, but it will be an advantage if this also is included in the harmonization.)

- **Harmonized migration program**
  Handle the migration of improved GSM-R terminal on existing rolling stock - both in the short and long term.
Overview

This document is written by all the stakeholders in the issue of coexistence between GSM-R and the public mobile operators system in the 900 MHz band. The purpose of the document is to give a deeper understanding of the issue. The document describes economical, legal and technical issues. Mobile operators, train operators, railway infrastructure manager, agencies and authorities involved in the telecom- and railway sectors give their own view.

Today, no major interferences for the GSM-R system have occurred and this is because the railway infrastructure manager together with the frequency regulator and the public mobile operators have taken measures to make sure that the systems can coexist in the 900 MHz-band.

This is also the reason why we, at this time, do not have any reported cases were UMTS or LTE interfere with GSM-R in Sweden.

However, if we do not get any solution in place, allowing GSM-R terminal switchable protective filter or improved radio module, before last of June 2015, we will have a lot of interference cases as the limitation in emitted levels for the public mobile operators in the 900 MHz band are lifted.
Description of services and use of GSM-R in Sweden and Europe

Trafikverket’s GSM-R system MobiSIR

General information

In 1992, UIC decided to develop a joint radio communication system for the railway’s traffic control and operation in Europe. The system was built on the GSM standard (at the time world standard for mobile radio communication) and is internationally designated GSM-R. In Sweden, the system is referred to as MobiSIR.

As the first railway administration in the world, Banverket (the Swedish National Rail Administration) signed a contract for delivery of a GSM-R system in 1998 and in 1999, a contract for delivery of mobile terminals was signed. The GSM-R system was taken into operation on Öresundsförbindelsen (the bridge and tunnel between Sweden and Denmark) in the year 2000. After that, line by line was rolled out and in 2007 the system was commissioned on the entire railway network operated and managed by Banverket.

For the GSM-R terminal equipment in railway vehicles (e.g. CAB radio and EDOR), each vehicle owner respectively was responsible for the implementation.

Today, GSM-R is the Swedish railway’s operational communication system with 400 000 calls a month, of which 40 000 to trains and 90 000 to Trafikverket’s (former Banverket’s) railway traffic control centres, it is also used for 5000 ERTMS/ETCS call/month.

The Swedish GSM-R system MobiSIR has approximately 7 000 users, not including foreign trainborne GSM-R users.
As of today, the Swedish GSM-R system MobiSIR is implemented on all lines administered by Trafikverket (10 000 km) and at Inlandsbanan (700 km, last 300 km under construction), the railway network consists of approximately 1 200 base stations and 350 repeaters.

**Implementation of ERTMS in Sweden**

On three lines the GSM-R system are used for ERTMS in daily operations:

- Botniabanan 190 km, in service since August 2010 with ETCS L2
- Västerdalsbanan 140 km, in service since February 2012 with ETCS Regional (L3)
- Ådalsbanan 130 km, in service since August 2012 with ETCS L2

During 2013 one additional line of 160 km will be taken into service with ETCS L2 (Haparandabanan).
Implementation of GSM-R in Europe

GSM-R networks are rolled out over Europe and the largest implementations today are in Germany with 27000 km and in Italy with 10000 km. Roll out projects are ongoing in Denmark, Austria, Czech, France, Spain, Switzerland and Great Britain. Countries with completed GSM-R networks are Sweden, Belgium, Norway, Finland and the Netherlands.

Figure 2: Implementation of GSM-R networks in Europe
Description of the development of services in the 900 MHz band in Sweden and in Europe until now

Sweden has long been one of the leading countries when it comes to public mobile communications, with high subscriber penetrations figures and a strong mobile industry. GSM in the 900 MHz band has been an important part of this long running success story. Today the GSM networks in the 900 MHz band reaches near 100 % population coverage and a geographical coverage of over 90 % in Sweden. The 900 MHz band is also an important frequency band for mobile broadband coverage in Sweden, with two mobile broadband networks already reaching over 90 % population coverage.

In Sweden, commercial mobile service in the 900 MHz frequency band was started in 1987 with the introduction of the analogue NMT 900 system. NMT 900 was used as capacity expansion to NMT 450 that already operated in the 450 MHz frequency band.

In 1987 the GSM Directive reserved the use of a part of the 900 MHz frequency band for GSM. This first decision reserved the core GSM 900 band, 890-915 MHz and 935-960 MHz, for a public pan-European cellular digital mobile communication service to be provided in each Member State in accordance with a common specification, known as GSM.

In 1991 the first commercial GSM network was introduced.

In Sweden the commercial GSM 900 services was introduced in 1992, during this year three operators started offering GSM services in the core GSM 900 band, 890-915 MHz and 935-960 MHz. GSM was an imminent success in Sweden and 1995, only three years after the market introduction, the number of 2G/GSM subscribers surpassed those of the older 1G/NMT network.

The high subscriber growth in Sweden for GSM showed that more frequencies for GSM would be beneficial. So in 1996 frequencies for capacity enhancements was licensed for GSM in the 1800 MHz band, and services started in the following year 1997. The GSM 1800 networks were not built for coverage, it was instead built to increase the capacity in urban areas. As a whole, GSM still relied on the networks in the 900 MHz band for good coverage.

To meet the growing demand for GSM a new ECC-Decision for harmonization of the so-called GSM extension (E-GSM) band (880-890 MHz and 925-935 MHz) was developed in 1997. Until then these 2*10 MHz had separated the GSM-R band from the GSM 900 MHz band. With the introduction of the GSM extension band this guard band between GSM-R and public GSM

![Figure 3: Mobile subscriber growth in Sweden](image-url)
disappeared. The combination of the original GSM 900 MHz band and the E-GSM band is what we today normally mean when we talk about the 900 MHz band.

In 2002 a fourth GSM 900 license was issued Sweden. In an attempt to boost competition this fourth license was reserved for a new entrant in the 900 MHz band. The new license was issued to Swefour and included the top part of the E-GSM frequency range, leaving 5 MHz unused spectrum between the highest GSM-R channel and the lowest licensed public GSM channel.

In July 2006 CEPT was mandated by the Commission to develop appropriate technical conditions for frequency bands in the context of WAPECS (Wireless Access Policy for Electronic Communications Services). Key points to be considered were the need for harmonized conditions of use to facilitate pan-European services, and to allow consumers the freedom of choice both in terms of services and technologies provided. For the 900 MHz band this meant developing conditions that allowed other technologies than GSM.

Following technical investigation, CEPT concluded that UMTS 900 networks could be deployed in parallel with GSM 900 networks. The GSM directive was updated in September 2009 by the directive 2009/114/EC. The update allowed 3G (UMTS 900) to be used in the 900 MHz band. This decision was then again updated in 2011 in order ensure that also 4G (LTE) systems could be used in the 900 MHz band. These changes were introduced with the goal to help to achieve the broadband targets of the digital agenda for Europe.

The updated Commission decision allowing use of broadband systems in the 900 MHz band should have been implemented by Member States at the end of 2011.

The GSM 900 MHz licenses in Sweden were to expire at the end of 2010. In preparation for this PTS was working on investigating the future for the 900 MHz band. At this time it had become obvious for PTS that service and technology neutral regulation, in line with the WAPECS concept, was the preferred way forward for the renewed 900 MHz licenses. This would allow operators to introduce new broadband technology in the band and giving them a way to handle coverage issues for mobile broadband. As part of the preparatory work for the renewal of the licenses PTS had also come to the conclusion that there was a risk for interference from the public use in the 900 MHz band into GSM-R frequency band.

In 2008 PTS received an application for extension of the 900 MHz licenses from the public GSM operators. As a result a decision to extend the licenses in the 900 MHz band was taken in the beginning of 2009. These extended licenses were designed to allow the introduction of new technologies such as 3G and 4G in the 900 MHz band. The renewed licenses were also expanded in frequency so that the earlier unused parts of the 900 band were licensed. This expansion removed the earlier frequency separation between the public 900 licenses and GSM-R in Sweden. To manage the increased interference risk the extended licenses included temporary license conditions for the protection of GSM-R. PTS decision was however appealed by third party and the court process delayed the new license conditions until 24 May 2011.

The possibility to introduce new 3G and 4G systems in the 900 MHz band is already used in Sweden. In the beginning of 2013 there are one UMTS 900 network and one LTE 900 network operating in the 900 MHz band in, both with near national coverage. Support for UMTS 900 is included in many phones and mobile broadband modems, less devices support LTE 900. This means that the 900 MHz band is no longer a GSM only band in Sweden. Instead it has become an important mobile broadband frequency band shared with legacy GSM usage. So, in Sweden, unlike many other European countries, the 900 MHz band is already an important frequency band for mobile broadband.
How coexistence is regulated in Sweden

In 2008 PTS had started working on suitable licensing conditions to allow the future introduction of new broadband services in the GSM 900 band. These new “technology and service neutral licensing conditions” were to be included when the 900 MHz licenses were extended.

At this time CEPT already had performed compatibility studies between UMTS 900 and systems operating in adjacent frequency band. In ECC Report 96, which was the result of compatibility studies in CEPT, the following conclusions are listed for compatibility between UMTS 900 and GSM-R.

UMTS 900 can be deployed in the same geographical area in coexistence with GSM-R as follows:

1) There is a priori no need of an additional guard band between UMTS 900 and GSM-R, a carrier separation of 2.8 MHz or more between the UMTS 900 carrier and the nearest GSM-R carrier is sufficient without prejudice to provisions in point 2). This conclusion is based on Monte Carlo simulations assumed suitable for typical case.

2) However for some critical cases (e.g. with high located antenna, open and sparsely populated areas served by high power UMTS base stations close to the railway tracks, blocking etc, which would lead to assumption of possible direct line of sight coupling) the minimum coupling loss calculations demonstrate that coordination is needed for a certain range of distances (up to 4 km or more from railway track).

3) It is beneficial to activate GSM-R uplink power control, especially for the train mounted mobile station, otherwise the impact on UMTS uplink capacity could be important when the UMTS network is using the 5 MHz channel adjacent to the GSM-R band. However, it has to be recognized that this is only applicable in low speed areas as elsewhere the use of uplink control in GSM-R will cause significantly increased call drop rates.

4) In order to protect GSM-R operations, UMTS operators should take care when deploying UMTS in the 900 MHz band, where site engineering measures and/or better filtering capabilities (providing additional coupling loss in order to match the requirements defined for the critical/specific cases) may be needed in order to install UMTS sites close to the railway track when the UMTS network is using the 5 MHz channel adjacent to the GSM-R band.

From a regulatory point of view, point 2 and 4 was of special interest. A coordination distance of up to 4 km from the GSM-R enabled railway tracks might be needed and special protection measures should be taken when broadband 900 MHz systems are deployed close to railway tracks in the first 5 MHz block of the 900 MHz band.

After a more thorough analysis of the report PTS came to the conclusion that there would be a risk of harmful interference into GSM-R if no provisions were made to give GSM-R additional protection.

Based on this analysis and after some discussions with the GSM-R operator, PTS started working on additional technical license conditions for the protection of GSM-R. As a result a set of temporary conditions to protect GSM-R was included in the license conditions when the 900 MHz licenses were extended in 2009.

The plan was to replace these temporary conditions with a permanent solution based on voluntary coordination at a later stage. The idea was that the public 900 MHz operators and
the GSM-R operator would coordinate their roll out in a corridor around the GSM-R enabled railway tracks and thereby avoid interference.

In 2009, after the decision to extend the licenses had been taken, all affected parties, the public 900 MHz operators and the GSM-R operator, were invited to PTS for informal meetings about implementation of the voluntary coordination solution. These meetings went on for a year without the involved parties reaching an agreement. The concept of coordination could be accepted by all parties, but the big “stumbling block” was the definition of rights and obligations in a coordination situation. These rights and obligations decides, in principle, the partitioning of costs for implementing the extra protection measures that would be a result of the coordination and this became a contentious issue.

When it became evident that an agreement about a voluntary coordination solution could not be reached, PTS instead had to implement a fallback solution of updating the GSM-R protection conditions in the 900 MHz licenses. The goal for PTS was to find a solution that was proportionate and achieved a fair distribution of burdens and costs between all the involved parties.

The principle that governed the design of the new license conditions was that of “equal pain”, where all involved parties had to take measures to achieve a common goal. The solution chosen, in practice, distributes the burden to achieve a good coexistence situation between the affected parties.

1) The public operators
2) The GSM-R operator
3) The train operators

With the implemented regulation the different parties will all take costs to ensure a good coexistence situation. The two coexistence issues addressed are unwanted emission from public mobile network systems into the GSM-R band and that the GSM-R receiver can be blocked by the public operator signals. The distribution of the burden between the parties can conceptually be described as follows:

1) The public operators will in areas with GSM-R enabled railway tracks take measures to limit the out of band noise (unwanted emission) that is generated into the GSM-R band. To achieve this there are several options to chose from, for example install improved out of band filters on 3G and 4G base stations and thereby limit the noise that is generated into the GSM-R band or reduce the signal strength so that the noise that falls into the GSM-R band is limited. The later solution would results in a loss of coverage near the railway tracks. As a public operator you can thereby choose to take your burden either as extra cost or loss of coverage.

2) The GSM-R operator will on request locally strengthen the signal levels in the GSM-R network. This will allow secure GSM-R operation even if the noise that is generated from the public operator in the adjacent 900 MHz bands in the GSM-R band is increased. This way the public operators and the GSM-R operator are sharing the burden for mitigating the out of band noise problem.

3) Until 30 June 2015 the public operators must limit the signal strength (wanted emission) inside its own licensed spectrum in areas with GSM-R enabled railway tracks. This will protect legacy GSM-R terminals from blocking. This limitation of the use the public operators own licensed spectrum is a result of the performance of the GSM-R terminal and will lead to a degradation of coverage.
4) After 30 June 2015 the public operators will be allowed to increase the signal strength inside its own licensed spectrum in areas with GSM-R enabled railway tracks. So at that time legacy GSM-R will no longer have full protection from blocking. To handle this new situation it is envisioned that the train operators implement either extra filtering of the 900 MHz band or better GSM-R radio modules in their trains. In this way the GSM-R receivers will be able to handle the increased signal levels in the adjacent 900 MHz band.

It is envisioned that after 30 June 2015 all parties will have implemented and taken their part of the total burden. With the chosen solution PTS feels that a balance have been achieved between the need for protection of GSM-R and the ability to roll out mobile broadband in the 900 MHz band. It should also be noted that currently the mobile operators in the 900 MHz band is taking a dual burden both for reducing the out of band noise and to protect the GSM-R terminals from blocking.

The decision to implement the new GSM-R protection conditions in the 900 MHz licenses was taken in July 2011. Trafikverket was dissatisfied with some parts of the decision and appealed the decision. After some negotiations between the involved parties an agreement was reached on an acceptable change that could satisfy both Trafikverket and the public 900 operators. The agreed change was implemented by a court decision in December 2012. These new GSM-R protection conditions will be in effect until the 900 MHz licenses expire at the end of 2025.

The unofficial translation of the final license conditions are given below.

**Licence conditions for protection of GSM-R when using technology other than GSM**

This is a nonbinding translation for information only.

**Conditions for the licence holder operating in the frequency band 925-930 MHz**


A) The maximum permitted radiated power from transmitters operating in the assigned spectrum within the frequency band 925-960 MHz is -64 dBm/100 kHz e.i.r.p. in the frequency band 876-880 MHz.

The values provided below refer to a 0 dBi antenna 4 metres above a railway in the GSM-R network that existed on 1 January 2011, as well as along Inlandsbanan between Mora and Gällivare.

B) Radio transmitters operating in assigned spectrum in the frequency band 925-960 MHz must not generate an aggregated signal strength exceeding -107 dBm/200 kHz in the frequency band 921-925 MHz.

C) The above-mentioned signal level may, by radio transmitters operating in assigned spectrum within the frequency band 925-930 MHz, be increased locally to -95 dBm/200 kHz provided that the GSM-R operator concerned in the frequency band 921-925 MHz has been informed. The higher signal level may be executed at a date specified by the GSM-R licence holder, but not later than six (6) months after the date of notification.

D) The licence holder’s radio transmitters operating in the frequency band 925-930 MHz must not generate an aggregated signal strength exceeding -33 dBm/5 MHz in that
band. The specified limit applies until and including 30 June 2015 or such earlier date as may occur as follows:

- Filters have been installed on all train-mounted GSM-R-terminals in the traffic concerned, or
- Two years after publishing in Official Journal of the European Union standardized requirements that allow GSM-R terminals to limit the reception to 921-925 MHz.

Thereafter, the signal must not exceed -5 dBm/5 MHz.

The conditions contained in B, C and D above may be exceeded following special agreement with the operator responsible for the running of the GSM-R network in the area.

Conditions for the each of the licence holders operating in the frequency band 930-960 MHz

For conditions A, B and C below please see


For condition D below, please see

http://www.pts.se/upload/FR%20dom%20i%20mål%20nr%2015176-11.pdf

In case of discrepancies between the Swedish and English version the Swedish version is valid.

A) The maximum permitted radiated power from transmitters operating in the assigned spectrum within the frequency band 925-960 MHz is -64 dBm/100 kHz e.i.r.p. in the frequency band 876-880 MHz.

The values provided below refer to a 0 dBi antenna 4 metres above a railway in the GSM-R network that existed on 1 January 2011, as well as along Inlandsbanan between Mora and Gällivare.

B) Radio transmitters operating in assigned spectrum in the frequency band 925-960 MHz must not generate an aggregated signal strength exceeding -107 dBm/200 kHz in the frequency band 921-925 MHz.

C) The abovementioned signal level may, by radio transmitters operating in assigned spectrum within the frequency band 930-960 MHz, be increased locally to -98 dBm/200 kHz provided that the GSM-R operator concerned in the frequency band 921-925 MHz has been informed. The higher signal level may be executed at a date specified by the GSM-R licence holder, but not later than six (6) months after the date of notification.

D) The licence holder’s radio transmitters operating in the frequency band 930-960 MHz must not generate an aggregated signal strength exceeding -23 dBm/5 MHz in that band. On certain railway lines, as specified in Appendix 1, the licence holder’s radio
transmitters operating in the frequency band 930-960 MHz must not generate an aggregated signal strength exceeding -33 dBm/5 MHz in that band. The specified limits applies up to an including 30 June 2015 or such earlier date as may occur as follows:

- Filters have been installed on all train-mounted GSM-R-terminals in the traffic concerned, or
- Two years after publishing in Official Journal of the European Union standardized requirements that allow GSM-R terminals to limit the reception to 921-925 MHz.

Thereafter, the signal must not exceed 0 dBm/5 MHz.

The conditions contained in B, C and D above may be exceeded following special agreement with the operator responsible for the running the GSM-R network in the area.
What problems have occurred or are likely to occur between GSM-R and other services in the 900 MHz band

Description of the Swedish GSM-R system MobiSIR

In this section it is described how the Swedish GSM-R system MobiSIR is designed and how it is affected by the implementation of technology neutral licensing (that makes it possible to use any technology, e.g. UMTS and LTE) in the 900 MHz frequency band (frequency range 880 - 915/925 - 960 MHz according to directive 2009/114/EU and decision 2009/766/EU) with the protective licensing conditions for GSM-R decided by the Swedish frequency regulator PTS.

Figure 4 shows the Swedish GSM-R system MobiSIR schematically. The radio network along the railway line is built with a great amount of redundancy symbolized by the red and blue circles.

Demands for full redundancy from a radio aspect have only been made for the ETCS L2 lines, where any base station may fail without the service being affected. When the system was designed for main lines in 1997, the lowest planned level was set to -82 dBm/200 kHz.

During design of the Swedish ETCS L2 lines (Botniaban, Ådalsbanan and Haparanda–banan) an additional demand was made: in case of a failed base station, the signal level from the neighbour base stations must not be lower than -95 dBm/200 kHz.
The demands for coverage (minimum signal level) according to the EIRENE SRS, version 15, are:

- > -98 dBm/200 kHz for voice communication
- > -95 dBm/200 kHz for ETCS L2 and L3 for speeds up to 220 km/h
- > -92 to -95 dBm/200 kHz for ETCS L2 and L3 for speeds between 220 and 280 km/h
- > -92 dBm/200 kHz for ETCS L2 and L3 for speeds over 280 km/h

Main issues affecting GSM-R terminals

The following two main issues affect the GSM-R terminals CAB radio and EDOR:

- Unwanted emission from public mobile network systems
- Strong wideband signals

Approved, ETSI compliant GSM-R equipment installed in railway vehicles cannot handle strong wideband signals from new mobile network systems (e.g. UMTS and LTE) in nearby frequency bands.

Unwanted emission from public mobile network systems

![Figure 5: Signal level in the Swedish GSM-R system MobiSIR – situation before 2009](image)

- -82 dBm/200 kHz is MobiSIR's lowest planning signal level on main lines.
- -95 dBm/200 kHz is the lowest planning signal level at a base station failure on ETCS L2 lines.

For sufficient service in a GSM-R system, a signal to-noise ratio better than 12 dB is required. Between 1999 and 2010, the noise level in the GSM-R frequency band was generally lower than -110 dBm/200 kHz, which made it easier to keep a high quality in the GSM-R system. The reason for this is that the public part of the 900 MHz frequency band has been using GSM technology in the P-GSM frequency band. The E-GSM frequency band, adjacent to the GSM-R frequency band, has not been used in Sweden. With these conditions it has been possible to obtain a signal to-noise ratio better than 20 dB in the GSM-R frequency band. The major cause for noise was our own nearby placed transmitters.
Figure 6: Unwanted emission less than -107 dBm/200 kHz from wideband systems (e.g. UMTS and LTE) in the GSM-R frequency band

For acceptable circuit-switched data service, a signal to-noise ratio better than 12 dB is required. For this requirement to be fulfilled when a base station in the Swedish GSM-R system MobiSIR fails, the interference from the public mobile network systems must not exceed -107 dBm/200 kHz. The unwanted emission from the public mobile network systems appear as noise for the GSM-R terminals.

The implementation of technology neutral licensing making it possible to use technologies as UMTS and LTE in the 900 MHz frequency band with the protective licensing conditions for GSM-R as decided by the Swedish frequency regulator PTS. This implies unwanted emission from public mobile network systems (e.g. UMTS and LTE) in to the GSM-R frequency band.

Trafikverket has – in co-operation with PTS – estimated that interference from public mobile network systems in the GSM-R part of the 900 MHz frequency band lower than -107 dBm/200 kHz does not have any major impact on the Swedish GSM-R system MobiSIR.

-107 dBm/200 kHz is the level that the public mobile network operators have to conform to according to the PTS decision regarding protection of GSM-R. The public mobile network operators have the right to increase this level to -95\(^1\) (-98\(^2\)) dBm/200 kHz after announcement to Trafikverket. Trafikverket have to give permission for the level increase no later than six months after the announcement.

The unwanted emission, with a level up to -95 dBm/200 kHz in the GSM-R frequency band, hampers all redundant coverage between base stations in the Swedish GSM-R system MobiSIR. Trafikverket has accepted to increase the signal level with at least 12 dB in the Swedish GSM-R system MobiSIR in order to maintain today’s redundancy coverage.

The public mobile network operators on the other hand must install ”unwanted emission limiting filters” at the base stations, lower the power output from the base stations or not establish base stations close to the railway so that the unwanted emission never exceeds -95\(^1\) (-98\(^2\)) dBm/200 kHz (see figure 7).
For mobile network operators using the frequencies 925 - 930 MHz, the interference power level can be raised to -95 dBm/200 kHz, provided that the GSM-R operator using the frequencies 876 - 880/921 - 925 MHz is notified.

For mobile network operators using the frequencies 930 - 960 MHz, the interference power level can be raised to -98 dBm/200 kHz, provided that the GSM-R operator using the frequencies 876 - 880/921 - 925 MHz is notified.

An increase of the signal level with 12 dB generally in the entire Swedish GSM-R network MobiSIR is estimated at a cost of approximately 15 - 20 million Euro for Trafikverket.

Trafikverket’s commitment is to increase the coverage in the Swedish GSM-R system MobiSIR in order to maintain service, function and accessibility. This work started during autumn 2011 and is expected to be finalized in 2014.

**Strong wideband signals**

Approved, ETSI compliant GSM-R equipment installed in railway vehicles cannot handle strong wideband signals from public mobile network systems (e.g. UMTS and LTE) in nearby frequency bands. The GSM-R terminal receiver is blocked by the strong wideband signals.

When the specifications for GSM and GSM-R were developed (in the 1980’s for GSM and in the early 1990’s for GSM-R), wideband 3G and 4G signals were not considered. The condition at the time was that a GSM-R terminal’s receiving range should cover the entire 900 MHz frequency band 876 - 915/921 - 960 MHz (see figure 8). This made use of public GSM network systems during the roll out of national GSM-R networks possible (roaming) as well as use of public networks on lines not planned for expansion of GSM-R.

The reports (e.g. CEPT EC 96) forming the basis of the decision to introduce wideband technologies in the 900 MHz frequency band were not thorough enough to give a correct picture of the impact on the GSM-R systems.
In order to protect the GSM-R terminals from blocking, PTS has in its decision (see chapter “Licence conditions for protection of GSM-R when using technology other than GSM”) initiated restrictions regarding maximum emitted power from public mobile network systems.

**Improved GSM-R Terminal (protective filter or improved radio module)**

An improved GSM-R terminal will improve the situation as it prevents the GSM-R terminal from blocking if there are strong wideband signals in the frequency band 925 to 960 MHz, the public 900 MHz band.

The improved GSM-R terminal may be either a conventional GSM-R terminal with an external switchable protective filter or a significantly improved and modified radio module in the GSM-R terminal, or even a combination of both.

**Improved/modified radio module**

Significantly improved/modified radio modules for the GSM-R terminal have recently been tested. The results shows that it will improve the situation if the interfering signals are coming from the 930 – 960 MHz, but have very limited effect on interfering signals coming from the 925 – 930 MHz band.

The blocking performance of the improved radio modules are better when using the GSM-R band, but when roaming to the public GSM band the receivers are as prone to blocking as before. So the usage of public GSM will be limited if there is strong UMTS/LTE signals in the public band.

These improved radio modules have worse receiving sensitivity than standard GSM-R terminals. The sensitivity has decreased with about 4 dB, which is just within the limit in specifications.

An improved radio module does only improve the GSM-R system down link, no protection for the uplink of public UMTS/LTE base stations will be achieved. (In the case that the GSM-R terminal’s unwanted emissions are strong and interfere with the uplink of the public base stations.)
Switchable protective filter

The function of the switchable protective filter is to filter out signals in the public 900 MHz band (925 – 960 MHz as well as 880 – 915 MHz). When the filter is in circuit, roaming to public GSM networks is disabled.

Measurement tests with switchable protection filters show that interfering signals coming from the 925-960 MHz can be handled within the signal levels agreed upon in Sweden, even after the 30 June 2015. The switchable protection filter is hence a long term solution.

The blocking performance with the protective filter is better when using GSM-R band, but when roaming to public GSM networks as the filter is switched out, the receiver is as sensitive to blocking as before. So the usage of public GSM will be limited if there is strong UMTS/LTE signals in the public band.

The insertion loss of the switchable filter is less than 2 dB.

A switchable protective filter does two things:

1. Protects the GSM-R receiver from strong signals coming from the 925-960 MHz band.
2. Protects the public UMTS/LTE base stations from 8 W CAB-radios and EDORS possible unwanted emissions to interfere in the uplink.

Conclusion

When the 925 – 930 MHz is going to be used for UMTS or LTE, with the levels stated valid after 30 June 2015 by the Swedish frequency regulator, the switchable protective filter is, so far, the only solution.
Consequences of these problems for the railway operators, telecom operators, administrations and regulators

Railway Operators

Rail customers’ expectations

Mobile telecommunications are fully integrated in today’s economic and social society. The public is expecting good coverage in all densely populated areas and also on public transport. For passenger rail operators it is a key selling point that passengers have the ability to use the travel time for work and recreation (in its marketing SJ calls this “A useful moment”).

As car and bus travel becomes more environmental friendly, the usefulness of the travel time on trains will become even more important as a unique selling point for SJ and other passenger operators. Good mobile communication is a key to both work and recreation today, and will be even more important in the future. Against this background, it is a severe constraint that interference between GSM-R and commercial LTE results in worse LTE coverage along the tracks, compared to other parts of the society.

Reduced telecommunications decrease competitiveness for rail services

The present situation reduces the possibility for good communications on trains via 3G and 4G technologies, especially for passengers connected to operators focusing on the 900 MHz-band for LTE-coverage in rural Sweden. Passengers using these telecommunication operators will have a much worse experience on board the train compared to other means of transportation and public areas. This will result in fewer passengers choosing the train. The loss of bandwidth from LTE on 900 MHz will also indirectly have a negative impact for passengers that use mobile operators who do not focus on 900 MHz for LTE, since the load on the 3G networks will increase.

Several operators (among them SJ) have a Wi-Fi service onboard their trains. This solution has a much higher customer demand for bandwidth than can be supplied today. The Wi-Fi system combines and aggregates bandwidth from all surrounding mobile networks, and the loss of bandwidth from LTE on 900 MHz could mean less total capacity and less satisfied passengers. Again this will result in an advantage for other means of transportation and fewer train passengers.

Affected service functions onboard the trains

The passenger rail operators have several applications onboard which require good mobile communications. These are primarily:

- Cash registers at restaurants and bistros (including card payment terminals)
- Ticketing terminals for regional traffic
- Handheld terminals for electronic ticketing verification on long-distance trains
- Driver applications in handheld computers

Less 3G and 4G will have negative effects on these applications. In summary, the rail customers expect telecommunication possibilities to be of the same quality as along the main highways for road traffic.
Technical consequences

Communication with railway vehicles using GSM-R network serves two purposes:

- Data communication with ETCS onboard equipment EDOR (ETCS Data Only Radio)
- Driver’s voice communication

Good quality is necessary for both these communication channels in order to ensure safe and reliable operation.

EDOR needs continuous access to the ETCS-infrastructure through the GSM-R network. EDOR transceives data streams to and from the vehicle to ensure safe train movement. If this connection is interrupted the train will automatically stop after a specified time. It is thus not primarily a safety issue, but lower availability will be a major issue for train operators. EDOR is currently only used on the Botnia, Ådal and Västerdal lines in the northern part of Sweden. Within the next few years EDOR communication will take place in main railway corridors, such as the Southern Main Line, with significantly more traffic in the GSM-R network.

Driver’s voice communication is used for important calls to the dispatcher. One example may be emergency calls activated to inform train drivers in a specific location about a dangerous situation. It is also equally important that a driver can call the dispatcher and other trains. If information about a dangerous traffic situation cannot be transmitted from the dispatcher to the trains or from one train to another, accidents with personal injuries may follow.

Other functions, such as registration of “Function number” in the GSM-R network, are essential for the reliability of train operation. Failure due to GSM-R disturbances will delay departure and thus affect schedule, making travelling by train less attractive and less safe for passengers.

Present situation

The present situation with restrictions from PTS will thus result in reduced communications services to passengers. When the restrictions are to be changed in June 2015 increased train traffic disturbances will occur if no measures are taken.

Technical solutions with filters

Using an external filter designed to separate GSM-R from the public GSM network may be a solution. However, such a solution must be fully compliant with TSI and other relevant specifications. Furthermore, the solution must be accepted by ERA and by all affected National Safety Authorities.

Improved radio modules

An alternative solution might be to modify and improve the radio module itself. This means that frequency separation will be better than the specification calls for, but might not be enough for coexistence with mobile networks operating in the 925-930 MHz band. However, such a solution must be fully compliant with TSI and other relevant specifications. Furthermore, the solution must be accepted by ERA and by all affected National Safety Authorities.
Legal consequences

A strict requirement for any solution is that it fulfils the standard for rail operations in EU (including Norway), that is TSI Control command and signalling (2012/88/EU), index 32 (Eirene FRS version 7.3.0) and index 33 (Eirene SRS version 15.3.0).

At present there is important and growing rail traffic between Norway – Sweden – Denmark – Germany. If the above requirement is not met, it could ultimately put an end to the existing cross-border traffic.

Financial consequences

The total cost for the solution where an external filter is used will be significantly higher than the cost of the component itself. The filter must be purchased and stored, drawings and installation instructions must be produced for different types of vehicles. Existing vehicle documentation must be updated and re-distributed. Vehicles must also be scheduled for installation in a work shop with a corresponding loss of production. It is also most likely that a new safety approval is needed.
Mobile Telecom Operators

Technical consequences

The roll out of 3G/4G services is delayed in large areas along the railways, due to the signal strength restrictions for the 900 MHz band. This is of course negative for the train passengers, but it is also negative for people who live or work near the railways. Since railway stations often are situated in city centres, it is obvious that the railway passes through many dense populated areas. The “restriction corridor” along the railway is approximately 800 meters (400 meters on each side of the railway) for use of 930-960 MHz and about the double for use of 925-930 MHz. Approximately 1.7 million people live in the smallest “restriction corridor”, which is almost 20 % of the population.

The restrictions have caused coverage gaps in rural areas, and to some extent also in suburban areas, where roll out of 3G/4G in the higher frequency bands (2100 and 2600 MHz) is inefficient, i.e. no 3G/4G service at all available. Train coverage in rural areas is dependent on collocation with masts/towers deployed for GSM-R, which not is possible with the restrictions. In urban areas with roll out in the higher bands is the degradation in most cases limited to poor indoor coverage and reduced capacity.

Figure 9: Example of “restriction corridor”

Financial consequences

The report “Konsekvensanalys av införande av skyddskriterier för GSM-R”, ordered by PTS, indicates substantial investments for the mobile operators when it comes to possible actions for limiting the negative effects of the restrictions. The total cost for deployment of additional sites and base station filters would be in the range 500 to 1000 million SEK (about 50 to 100 million Euro). It is important to conclude that these investments will not fully compensate the lost coverage and capacity due to the restrictions, there will still be degraded areas, especially coverage inside the trains.

Legal consequences

*Editorial note: No legal consequences reported.*
Administrations (Trafikverket)

Technical consequences

The installation of GSM-R protective filter functions or filters does not affect Swedish railway vehicles operating outside Sweden, since there is no roaming to foreign public mobile network operators for Swedish vehicles. The situation for these railway vehicles will, if anything, become better since the interference risk becomes lower. However, foreign trains entering into Sweden without GSM-R protective filter functions or filters will be exposed to a great interference risk and interoperability may not be guaranteed. Still, the overall situation will be better, since the majority of the trains operating Swedish lines will be protected. Without GSM-R protective filter functions or filters on trains, the situation will become impossible with train stops and delays as a consequence.

With installation of external GSM-R protective filters, the GSM-R terminals CAB radio and EDOR in railway vehicles do not need to be modified.

Legal consequences

Trafikverket can not enforce any railway operator to install external protective filter or improved GSM-R terminal. This may lead to disturbance in the railway operations with great consequences if the GSM-R terminal is interfered, not only the train in question but a lot of train in the surroundings will be affected.

Financial consequences

Trafikverket have agreed to increase the signal levels in the Swedish GSM-R system MobiSIR with at least 12 dB, to handle increased levels of unwanted emissions from public networks, at an estimated cost of approximately 15 - 20 million Euro.

The cost for implementation of protective filter functions or filters is estimated to 8-10 million Euro. A fast implementation of protective filter functions or filters for the GSM-R terminals may give the public mobile network operators earlier access to higher output power from their base stations, since their restrictions are lifted. This might give financial support from several sources for the GSM-R protective filter functions or filters for CAB radio and EDOR. Without financial support the railway undertakings have to take the cost themselves.

Without an exception allowing protective filter functions or filters for GSM-R terminals, the railway operation with GSM-R and ERTMS is jeopardized in Sweden, and the cost is not possible to estimate. This will give us problems with the railway operation, delayed and cancelled trains, increased risk for accidents and in the end an unmanageable railway system.
Telecom Authority (PTS)

Technical consequences

Today the coexistence between 3G/4G networks in the 900 MHz band and GSM-R in the frequency band below the 900 MHz band is not explicitly regulated at the EU level.

In EU countries there are two major instruments when it comes to managing coexistence between different users of radio spectrum.

1. License conditions for the use of radio equipment
2. Harmonized standards for radio equipment

Harmonized standards should normally be designed so that the equipment can function in their expected radio environment. This normally means that they should specify requirements on egress into neighbouring frequency bands so that the equipment in normal operation does not cause harmful interference into the radio use in these neighbouring frequency bands. Requirements are in many cases also included in the standards so that receivers can work in the expected radio environment seen in its own frequency band and neighbouring frequency bands.

In the case of coexistence between GSM-R and wideband systems in the 900 MHz it can be noted that the standards alone do not guarantee a good coexistence. In geographical areas where both GSM-R and wideband 900 MHz systems are operating there will be a need for complementary measures to assure good coexistence.

In situations like these where there is deemed to be a need for local additional measures a spectrum regulator can choose between a number of different implementation options.

At least the following three options have been used in different countries when it comes to handling the GSM-R issue.

1. Do nothing and wait for complaints about harmful interference. With this course of action the regulator will over time, when complaints are resolved, define the different parties' rights and obligations through administrative practice. It is probable that some of the complaints will be handled through dispute resolution where the regulators will have to decide on the partitioning of the burden between the different parties. With this approach there is an initial risk for uncertainty for all involved parties while their rights and obligations are somewhat undefined from the beginning. A drawback of this solution is that it is that the involved parties will be forced to implement change to their installation after that they have been taken into operations.

2. Implement a requirement that coordination between the involved parties should be performed before new sites are commissioned. In this case it will be clear what rights and obligations you have before you take new transmitters into service. There is however still an uncertainty about the rights and obligations of different parties in the coordination process. In those cases where the involved parties cannot agree, the regulator will need to perform dispute resolution. In the same way as for option 1, this will over time define the rights and obligations of the different involved parties through administrative practice.
3. Implement well defined rights and obligations in license conditions that assure the coexistence. Such a solution can be implemented in a way that combines elements of coordination but with predefined rights and obligations for the involved parties. This would take away the need for dispute resolution and all involved parties would already from the start know the limitations for their network planning.

While PTS was in the fortunate situation that the license condition in the 900 MHz band was to expire the third solution was chosen. A set of technical license conditions that was deemed to guarantee coexistence was therefore developed. These license conditions were also weighted in such a way that they were deemed to partition the burden for guaranteeing the coexistence in a proportionate way between the involved parties.

**Legal consequences**

**EU-legislation regarding mobile broadband**

As an instrument for the fulfilment of the Digital Agenda a new Directive and a Decision modernising the 1987 GSM Directive was approved in 2009. These new EU measures, Directive 2009/114/EC and Decision 2009/766/EC, facilitates the introduction of 3G and 4G high-speed broadband technologies in the 900 MHz band. The implementation deadline for member states to introduce the necessary measures to allow introduction of broadband systems in the 900 MHz band was May 9 2010 for UMTS and December 31 2011 for LTE and WiMAX.

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2. **2009/766/EC COMMISSION DECISION of 16 October 2009 on the harmonisation of the 900 MHz and 1 800 MHz frequency bands for terrestrial systems capable of providing pan-European electronic communications services in the Community**

3. **2011/251/EU COMMISSION IMPLEMENTING DECISION of 18 April 2011 amending Decision 2009/766/EC on the harmonization of the 900 MHz and 1 800 MHz frequency bands for terrestrial systems capable of providing pan-European electronic communications services in the Community**
**Swedish implementation**

Sweden implemented the directive and decision when the 900 MHz licenses were extended in 2009. The new license conditions for the 900 MHz operators allowed for the introduction of broadband systems in the 900 MHz band, but they also included temporary license conditions for GSM-R protection.

After an appeals process in court the new license conditions came into force in May 2011, allowing the introduction of 3G and 4G technology in the 900 MHz band in Sweden.

The temporary licence conditions for GSM-R protection was then replaced by permanent conditions which came into force in December 2011.

The licenses in the 900 MHz band are valid until 31 of December 2025 as are the licence conditions. As noted in the chapter describing the license conditions there will be an already decided change in the licence conditions for GSM-R protection which enters into force in June 2015.

PTS is legally bound to maintain the given license conditions until they expire in 2025, any changes to the existing license conditions in a more restrictive direction could thereby not be initiated by PTS.

Changes to the existing license conditions could only be implemented if all concerned parties, that are the mobile operators and the GSM-R operator, agrees on the change and send in an application for change of license conditions to PTS, or as a result of a binding international treaty, for example an EC-decision outlining technical implementation measures.

**Financial consequences**

While PTS has already taken all the necessary decisions there are no financial consequences going forward for PTS.
National Safety Authority (Transportstyrelsen)

Technical consequences

New mobile communication services in the 900 MHz frequency band (primarily UMTS, “3G”, and LTE, “4G”) will cause interference to GSM-R equipment on board railway vehicles. This interference may affect voice communication between train drivers and train traffic control, causing conversations to shut down or making it impossible to place calls. This might hamper the ability to conduct effective railway traffic, and also have a negative impact on safety as emergency calls and other necessary communication will be affected. Any threat to safety is naturally a cause of great concern for the NSA.

Legal consequences

The Interoperability Directive and the TSI system in general

The EU is aiming at harmonizing the railway system in Europe. Among other acts with this aim the so called Interoperability Directive (2008/57/EC) was adopted. Based on the Interoperability Directive a series of legislative acts, Technical Specifications for Interoperability (TSIs), have been published. The TSIs contains requirements for railway equipment in Europe.

EU-legislation regarding GSM-R

Annex II of the Interoperability Directive lists all the subsystems which are affected by the TSIs. The requirements for GSM-R are included in the TSI Control-Command and Signalling (2012/88/EU, “TSI CCS”). This TSI concerns the Control-Command and Signalling onboard subsystem and the Control-Command and Signalling track-side subsystem. The TSI CCS’ Annex A (updated by decision 2012/696/EU) includes certain mandatory standards and technical requirement specifications, among them EIRENE FRS (index no 32) and EIRENE SRS (index no 33).

Examples of relevant paragraphs in the EIRENE specifications are 1.4.3.2 and 4.2.1 of EIRENE SRS and 4.1.3 of EIRENE FRS. These paragraphs stipulates that GSM-R equipment shall be “capable of operation” in the 921-960 MHz spectrum.

The authorisation process – a brief description

According to the Interoperability Directive a subsystem, or railway vehicle, shall need an Authorisation for Placing in Service (APIS) whenever

1) A new subsystem, or railway vehicle, is placed into service for the first time.

2) A new APIS is deemed, by the MS, to be required because of a renewal or upgrading. Such a new APIS shall, according to article 20, be required “whenever the overall safety level of the subsystem concerned may be adversely affected by the works envisaged”.

In order to get an APIS the applicant has to deliver an EC declaration of verification to the NSA. Such a declaration shall include an assessment from a notified body (NoBo) that the relevant TSI requirements are fulfilled.

Financial consequences

If a (new) APIS is deemed to be required due to, for example, installation of new equipment this would require resources from the NSA.
Measures need to be taken

EU level

The interference issue is at a basic level a result of conflicting EU legislation in the telecom and railway areas. As such it is a European problem, and should be handled accordingly, rather than on a national level.

The situation is urgent and the MS and actors must be given the relevant tools to handle it. Measures to avoid disturbances must be taken. Switchable protective filters are a potential technical solution to the problem. Such filters should be placed between the antenna and the GSM-R terminal (radio) in the railway vehicles. The use of switchable protective filters would not threaten interoperability for vehicles equipped with such. To allow railway undertakings to install switchable filters would be one way of addressing the problem. New GSM-R terminal modules is another potential solution, however, such modules might not work for all of the existing GSM-R terminals. Furthermore, their effectiveness has yet to be proven.

It would be very beneficial if it could be more explicitly stated in TSI CCS/EIRENE that switchable filters are allowed. By changing the TSI CCS/EIRENE specifications as follows, this would be more clearly stated.

<table>
<thead>
<tr>
<th></th>
<th>Mandatory</th>
<th>Optional</th>
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<tbody>
<tr>
<td>Downlink</td>
<td>921 – 925 MHz</td>
<td>925 – 960 MHz</td>
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</table>

Time aspect

It is very important that a way to solve the interference problem is found rapidly. From June 2015 onwards the public operators in Sweden will be able to use UMTS/LTE in the 900 MHz band, without restrictions in regard to the railway. A solution must therefore be found within short. Any adjustment or technical solutions to the problem will be time consuming and time is scarce.
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>APIS</td>
<td>Authorisation for Placing in Service</td>
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<tr>
<td>BSC</td>
<td>Base Station Controller</td>
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<tr>
<td>BTS</td>
<td>Base Transceiver Station</td>
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<tr>
<td>CEPT</td>
<td>Conférence européenne des administrations des postes et télécommunications</td>
</tr>
<tr>
<td>EDOR</td>
<td>ETCS Data Only Radio</td>
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<tr>
<td>E-GSM</td>
<td>Extended - Global System for Mobile communications</td>
</tr>
<tr>
<td>EIRENE</td>
<td>European Integrated railways Radio Enhanced NEtwork</td>
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<tr>
<td>ERA</td>
<td>European Railway Agency</td>
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<tr>
<td>ETCS</td>
<td>European Train Control System</td>
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<tr>
<td>ETSI</td>
<td>European Telecommunications Standards Institute</td>
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<tr>
<td>FRS</td>
<td>Functional Requirements Specification</td>
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<td>GSM</td>
<td>Global System for Mobile communications</td>
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<td>GSM-R</td>
<td>Global System for Mobile communications – Railway</td>
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<tr>
<td>GSM-RE</td>
<td>Global System for Mobile communications – Railway Extended</td>
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<tr>
<td>LTE</td>
<td>Long Term Evolution</td>
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<tr>
<td>MobiSIR</td>
<td>Mobile Swedish International Railway radio</td>
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<td>MS</td>
<td>Member State</td>
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</tbody>
</table>
MSC
Mobile Switching Centre

P-GSM
Public - Global System for Mobile communications

PTS
Post- och telestyrelsen (the Swedish frequency regulator)

R-GSM
Railway - Global System for Mobile communications

RE-GSM
Railway Extended - Global System for Mobile communications

SRS
System Requirements Specification

TRAU
Transmission Rate Adaption Unit

TSD (TSI)
Technical Specification for Interoperability

UIC
Union Internationale des Chemins de Fer

UMTS
Universal Mobile Telecommunications System

WAPECS
Wireless Access Policy for Electronic Communications Services