Omnitele Whitepaper

Co-Existence of UMTS900 and GSM-R Systems

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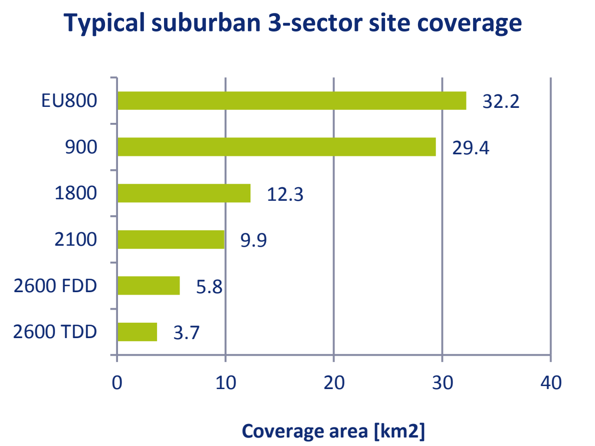
Co-Existence of UMTS900 and GSM-R Systems

Mobile operators are heavily deploying UMTS900 (and HSPA900) to boost the coverage and quality of the mobile broadband access in rural and suburban areas. GSM-Railway is a non-commercial system used in railway communications for voice and train control data. The systems are operating in adjacent frequency bands, which introduces certain challenges for practical network deployments. In this paper Omnitele analyses the co-existence of UMTS900 and GSM-Railway systems and presents practical guidelines for smooth co-existence of these two systems.

UMTS900 for Mobile Broadband Coverage

Mobile broadband access over 3G HSPA networks has turned out to be very attractive for the end users. The industry has witnessed sky-rocketing data volumes driven first by laptop access and more recently by smartphones. To supply mobile broadband demand in rural areas having lower population density, operators prefer to use lower frequency band at 900 MHz to extend indoor and wide area coverage. High site count kills operator business case in rural areas and the coverage benefit of sub-1GHz frequencies is notable as illustrated in figure below. UMTS900 coverage area is three times larger than UMTS2100.



UMTS900 deployment is also widely supported by the industry and it seems that UMTS900 will eventually be deployed to all GSM900 networks. EU regulation drives liberalisation of 900 MHz band for UMTS technology and network infrastructure vendors are providing multi-standard radio equipment capable of running GSM and UMTS (and LTE) simultaneously with latest HSPA+ features. New features enhancing GSM system spectral efficiency gives operators more freedom for refarming the 900 band for UMTS. UMTS900 is also supported by practically all new terminals.

GSM-Railway for in-Track Voice and Control Signalling

GSM-R (R for Railways) has been adopted by Europe as the standard data carrier for the European Train Control System (ETCS), which brings trackside signalling into the driver cabin to control train movements and to provide automatic train protection.

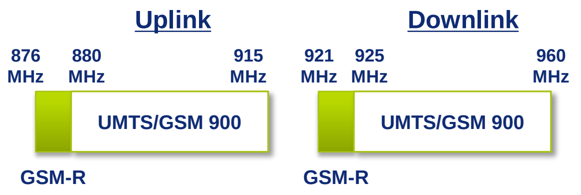
As the GSM-R signalling information is carried directly to the train itself, the system makes higher train speeds and greater traffic density possible while increasing the level of safety. GSM-R is especially beneficial for high speed trains as it supports mobility up to 500 km/h.

GSM-R specifications are largely based on traditional GSM standards and from technology point of view the two systems do not actually differ a lot. GSM-R operates on different frequency band (adjacent to GSM900 band) and has some railway specific services such as group calls and user priority handling. Needless to say, GSM-R availability and accessibility requirements are extremely high.

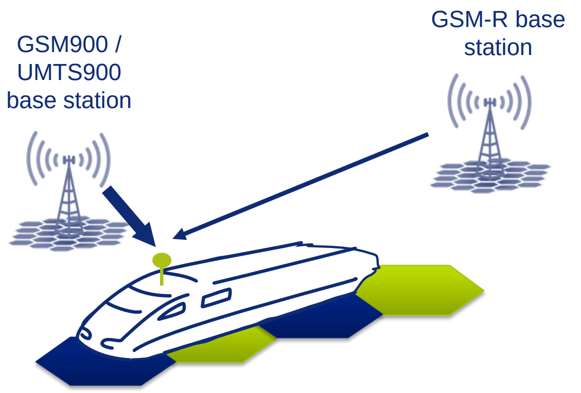
Spectrum Allocation and Co-Existence Analysis

GSM-R spectrum is located next to public mobile operators' GSM/UMTS900 band: uplink at 876-880 MHz and downlink at 921-925 MHz, see figure below. GSM-R and GSM/UMTS900 networks are frequently operated without any guard bands between them. The same applies also to public mobile operators' networks.. Thus, in principle the co-existence of

UMTS900 and GSM-R should not be more difficult than the co-existence of different mobile operators in general. However in practice issues do exist.



The root cause of co-existence issues is the differing network design principles of the systems. The public mobile networks are typically designed to provide good indoor coverage with 15-20 dB building penetration loss for terminals with small antennas. On the other hand GSM-R networks are designed for train roof-top antennas resulting in significantly lower site density compared to public 900 MHz mobile networks. Due to the higher commercial network base station density it is possible that the signal levels of commercial 900 MHz mobile networks are notably higher than GSM-R levels as illustrated in figure below.



GSM-R was originally designed to be capable of operating in commercial 900 MHz band as well, thus the RX filter of GSM-R radio passes through the unwanted signals from commercial GSM/UMTS900 networks (along the desired GSM-R signal). To achieve high availability for GSM-R reception, train mounted antennas with gains at least of 0 dBi are used. The received signal levels are consequently high not only from the GSM-R network, but also from the public mobile operators' transmitters potentially causing reception issues in the GSM-R receiver. Most common problems are RX blocking caused by high GSM/UMTS900 power and interference caused by unwanted out-of-band emissions from GSM/UMTS900 system.

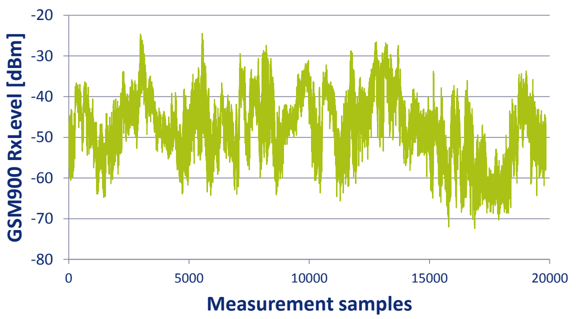
It is also commonly speculated that GSM-R train radio transmit signal is causing reception problems for GSM/UMTS900 system uplink. According to Omnitele analysis this is however not the case as the RF filters of typical GSM/UMTS900 equipment tend to be sufficiently selective. And moreover, the train radio uplink transmission is not continuous but usually limited to one or two timeslots (out of eight) limiting the total emitted interference energy. Thus Omnitele sees that GSM-R is the suffering system in practically all cases with co-existence issues because of lower GSM-R site density and very high GSM-R availability requirements

As an afterthought it is easy to point out that the mentioned problems should have been anticipated. GSM-R is targeted for almost 100% coverage and availability without any guard bands or interference margins to GSM/UMTS900 system. Typical availability targets for commercial networks are around 95%-99% with interference margins applied in network planning.

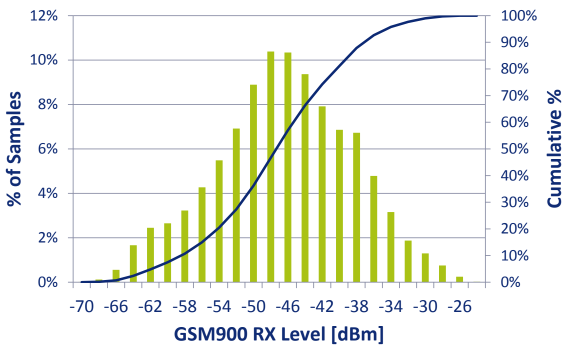
Overcoming RX Blocking Issues in GSM-R System

The GSM-R cab radio's blocking performance requirements are based on the same GSM specification as commercial GSM900 terminals. These RF requirements are not designed for cases with very large signal level differences which may occur as explained earlier. The blocking requirements of GSM specifications are also limited as the interfering test signal in the definitions is narrowband continuous wave, not modulated GSM or UMTS signal.

Practical GSM-R field measurements in several European countries has shown that GSM-R cab radio's blocking performance seems to be typically for GSM900 and UMTS900 signal around -40 dBm. On the other hand Omnitele field measurements show that the signal levels of GSM900 and UMTS900 networks can be higher than -30 dBm, which can evidently cause problems in GSM-R reception. See example measurement results below.



The measurements were performed with antenna located on top of the train cabin. The GSM900 levels vary mainly between -25 and -70 dBm. The probability of signal level exceeding -40 dBm was approximately 20% and exceeding -30 dBm was 1%. See detailed statistical analysis below.



Measurements in Germany, Holland and Sweden show even higher percentage of signal exceeding the -30 dBm level. Single GSM900 signals may approach -10 dBm in urban areas in the proximity of railway stations. Field measurements thus suggest that RX blocking is an issue that should be solved already for GSM900 deployment and not considered only when deploying UMTS900. Due to practical GSM-R cab radio blocking performance, the best way to overcome RX blocking issues is to improve the RX filtering of GSM-R cab radio. Improved filtering means that the public network frequencies 925-960 MHz are attenuated by 30…40 dB.

Omnitele recognises the conflicting interests between the two camps (GSM-R and commercial operators) and it's easy to sympathise both of them. Why should the GSM-R operators implement external filtering while they have been promised to have a spectrum which was thought to be practically free from interference? On the other hand commercial GSM/UMTS900 operators follow the regulation and they have paid a lot for their spectrum assets and for the equipment that fulfils specifications, so why should they be responsible for the problems and pay for solutions?

Omnitele still sees that external RX filtering for GSM-R receivers is the most efficient solution to solve almost all the co-existence problems. Furthermore, such filtering is inevitably required already due to GSM900 system regardless of whether UMTS900 is deployed or not. From philosophical perspective GSM-R is the "victim" of the initial receiver design specifications and "too good" receiver antennas – not the interference from commercial operators who are following regulations.

Unwanted Out-of-Band Emissions from UMTS900

Additional filtering helps to overcome the GSM-R cab radio's RX blocking issues but GSM900 and UMTS900 systems also leak some power towards GSM-R band causing direct in-band interference. Compared to the GSM900 base stations, typically these unwanted emissions from UMTS900 base stations are somewhat higher. Next we analyse how severe the problem is and how to overcome the related challenges.

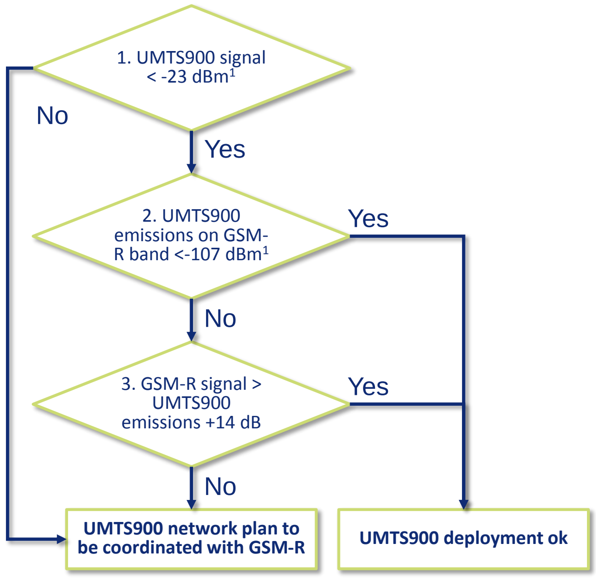
The UMTS900 base station measurements show that the maximum emissions to GSM-R band are typically -30 dBm/200 kHz or lower, which is 76 dB below the base station transmission power of 46 dBm. One reason for the low emission levels is that UMTS900 signal is wideband (5 MHz) while GSM-R channel filter picks only 200 kHz bandwidth. To calculate the GSM-R sensitivity level we can assume that the minimum Carrier-to-Interference (C/I) ratio requirement for GSM-R is 14 dB. Thus focusing now only in the unwanted emissions and assuming that additional RX filtering is used, the minimum required GSM-R signal level in the presence of UMTS900 emissions can now be calculated as

$$Min\_GSMR\_RxLevel = GSM900\_RxLevel - 76dB + 14dB$$

Example: If we have GSM900/UMTS900 signal level of -20 dBm, good quality GSM-R reception can be provided with GSM-R signal level of -82 dBm. If GSM900/UMTS900 signal level is around -30...-40 dBm, good quality GSM-R reception requires -92…-102 dBm. From the measurements we can conclude that the probability of UMTS900 base station out of band emissions causing problems towards GSM-R is relatively low. The problems can only happen with low GSM-R signal level combined with high UMTS900 signal level and both systems being deployed on the edge of their spectrum allocations.

Example Coordination Rules Currently in Use

Current guidelines used for UMTS900 deployment coordination were first introduced in Finnish UMTS900 license in year 2007 as follows:



[1]4 meters on top of railtracks

- In Phase 1 it is verified that UMTS900 signal does not cause GSM-R receiver blocking.
- In Phase 2 UMTS900 emissions to GSM-R band are verified to be low enough compared to GSM-R thermal noise level.
- In Phase 3 High enough GSM-R C/I is verified in presence of UMTS900 emissions. The 14 dB C/I condition needs to be achieved even with a single GSM-R BTS out of order. (Redundant coverage)

The presented coordination rules however do not fully work. As our analysis showed, -23dBm UMTS900 signal is already causing severe RX blocking for GSM-R receiver. But when defining this -23dBm signal level threshold in 2007, the regulator did not have experience from GSM-R train radios' practical blocking performance.

Practical Deployment Guidelines

The practical deployment rules should be able to identify the problem cases while not bringing unnecessary limitations for the network deployments.

The maximum allowed UMTS900 power above railway to preserve adequate GSM-R reception is a function of received GSM-R signal power. In the lower end of the GSM-R signal level dynamics the limiting factor is the unwanted UMTS900 emissions leaking into GSM-R band. When the signal level of GSM-R becomes higher, unwanted emissions no longer limit the reception but instead it is the RX blocking issue that is deteriorating connection quality.

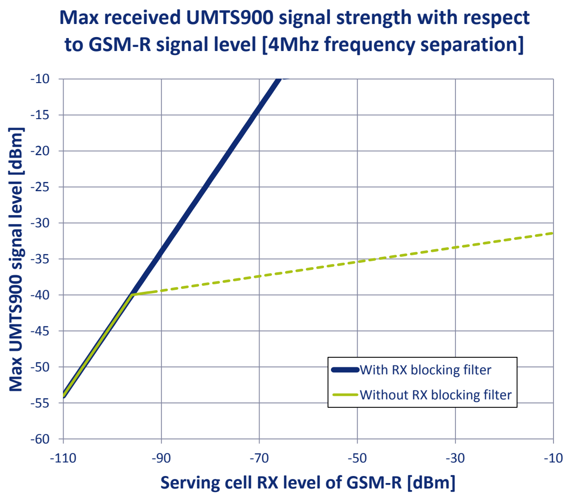
BTS measurements have shown that typical unwanted emission levels of UMTS900 to GSM-R band are 76dB lower than the BTS transmit power. The specifications however allow higher emission levels, thus to be on the safe side Omnitele suggests using 70dB offset for calculations. Thus we estimate that from emissions perspective the minimum GSM-R RX level is

$$Min\_GSMR\_RxLevel = GSM900\_RxLevel - 70dB + 14dB$$

For RX blocking, based on our field measurement experiences, we suggest using -40 dBm threshold value for UMTS900 signal level instead of -23 dBm as is the case with current deployment rule in place. We furthermore predict that when GSM-R signal becomes stronger, slightly higher UMTS900 signal values can be tolerated in GSM-R receiver. This is yet to be verified with performance measurements.

Omnitele sees that RX blocking filtering for GSM-R is indeed essential for smooth co-existence. But if the systems have frequency separation of 2.8 MHz (UMTS900 on the lowest possible and GSM-R on the highest possible frequency), RX filtering benefits are less radical. The reason is the practical limitations for filter design. With 4 MHz frequency separation between the systems, RX filtering already provides great benefits.

Compiling above figures and analysis Omnitele sees that the maximum received UMTS900 signal power on top of rail tracks follows the curves presented in figure below.



The dashed line shows our estimation for blocking performance with higher GSM-R signal levels (not verified with measurements). The blue line for filtering is applicable for frequency separation over 4 MHz. If we assume lowest possible (2.8 MHz) frequency separation for the systems, only the green line applies.

Our analysis suggests that If UMTS900 level is below -30 dBm and additional RX filtering is used, GSM-R reception works well with signal levels above -86 dBm. The benefits of RX filtering are evident.

We also wanted to showcase a fresh concept for practical deployment guidelines by defining the coordination rules as functions instead of constant threshold values.

Summary and Conclusions

UMTS900 has turned out to be an attractive solution for public operators wishing to improve coverage of their mobile broadband network for laptop access and for smartphones. GSM-Railway (GSM-R) is an important system for bringing the trackside signalling into train driver cabin to control train movements and provide automatic train protection.

The two systems are currently having co-existence issues as GSM-R can in some cases suffer from interference caused by GSM/UMTS900 networks. A series of actions (and in some cases also clear mistakes) made by various industry players have caused this:

- Differing design principles of GSM/UMTS900 and GSM-R networks
- Over-relaxed standardisation for GSM-R receiver performance
- Impaired regulation for the deployment guidelines

Due to this, it is debatable which entity should be responsible for the causes and be the one paying for a solution.

In this paper we have illustrated our views on the best practices how these two systems can be deployed in the same area without guard bands. It seems that the situation is actually not as bad as it could be. The UMTS900 equipment provided by infrastructure vendors typically performs better than the specifications require.

Most of the interference cases in GSM-R networks in practice today are caused by the GSM-R receiver blocking and intermodulation from GSM900 base station transmissions. Those issues can be solved by additional RF filtering in GSM-R cab radios. The solution also helps to prevent RX blocking in the presence of UMTS900 signal. The interference probability caused by UMTS900 base station emissions is low in practice and can be solved by network planning rules and by coordination between UMTS900 and GSM-R operators. The suggested deployment guidelines do not cause excessive limitations for the rollouts of these two networks.

The results of this paper can also be applied for the co-existence of LTE900 and GSM-R. The 3GPP emission requirements of LTE900 base station are equal to UMTS900 requirements and thus the co-existence analysis would be similar for LTE900 as well.

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