How CCC builds a GSM-R Network

Clear CinCom is a hands-on consultancy. We are familiar with every aspect of the network planning, validation and optimisation, so we can provide our clients with a complete roll-out of a GSM-R network.

In the following sections we shortly describe each aspect in the process of building a GSM-R network. Click on any of the elements for a description.

Nominal Cell Planning

Translation of Operator/Customer requirements

For the network planning, the coverage level is defined in terms of area and time where the minimum signal criteria are achieved. This we do in full compliance with the EIRENE specifications and with the customer's requirements. The level of coverage should be at least 95% of the time over 95% of the designated coverage area for a radio installed in a vehicle with an external antenna.

A GSM-R system must provide communications for mobiles travelling at speeds from 0 km/h to 140 km/h. However, each individual client specifies the maximum speed of their trains and this influences the cell overlap and nominal design.

For radio network planning, the minimum coverage level is defined as the power measured at the antenna port of an isotropic antenna (antenna gain: 0dBi) on roof of train; this is usually 4 meters above the track. This criterion will be met with a certain probability in the coverage area, as the target coverage power level is dependent on the statistical fluctuations caused by the actual propagation conditions. The minimum coverage level might be different, depending on special requirements from railway operators.

Although the network can be designed for minimal cost, a common recommendation is to use the following values:

- A minimum coverage level of 90dBm
- Probability 95%
- C/I greater than 12dB

In addition to the coverage and quality being specified for a train, other factors may be specified. This can include the required levels for handheld mobile equipment in shunting areas, or indoor for station staff and security operatives. Obviously, customers can specify other factors which can have great impact on the radio network design, such as the required redundancy in the network, either by utilising a full redundant coverage ETCS design or the Hot Standby TRX option.

Link Budgets

The link budget is created from the translation of the customer requirements into specific coverage/quality levels. It is a theoretical calculation using a number of assumptions, which provide the radio design engineers with a framework of radio losses and gains for both the downlink and uplink paths.

The information gleaned from the link budget provides a sound assumption for what the cell radius will be regarding the coverage, as well as an indication of the signal levels sent and received at antennas. This aids the radio engineers in the site count, handover overlaps and other aspects of the Nominal Cell Plan.

Nominal Cell Plan

The Nominal Cell Plan (NCP) is an official document with specifications of parameters and equipment used for the radio access. It also gives an estimate about the number of sites needed. The nominal cell plan is usually used as the starting point in the rollout of a GSM-R network.

The Nominal Cell Plan contains the following information:

- Explanation, description and specification of parameters and equipment used in the document
- Nominal site location, with specified search area per site (country specific coordinates, usage of railway kilometer to specify the site location
- Use of friendly sites: public GSM sites; analogue sites of the 450MHz train system, Railway Operator’s building. Use of these sites can contribute to a faster rollout and cost reduction
- Cell site configuration (Composite cell/sector), number of sectors, directions, power level and antenna type
- Propagation model description
- Number of carriers (estimation based on the traffic model or specified from customer)
- Initial frequency plan
- Nominal antenna height above ground, or above mean sea level
- Engineering tolerances (antenna heights, accuracy of the digital map, etc)
- Coverage prediction plots for the total area

Final Cell Planning

Train Line/Track Survey

The track and line survey is optional but can be a very useful exercise before the detailed planning commences.

In the survey, a train is utilised in which basic survey equipment is installed (GPS, mapping data). Records on a Tablet PC provide details such as the ground heights and the exact route the track takes.

This is coupled with notes taken at various kilometre markers along the track of features such as bridges, cuttings, tunnels and locations where the track runs through towns or thick forest areas. Together with the GPS reading, a camcorder records the line so that the radio engineers can minimize the number of surveys

Continuous Wave Measurements

Continuous Wave Measurements (CW-measurements) are used in preliminary radio path calculations, to derive initial qualitative and quantitative information, to design BTS site configurations and in particular to support antenna design. In addition to this, the data obtained here will also validate the computing algorithms of a radio planning tool used and adapt them to reality in order to comply with GSM-R requirements; this provides the engineers with accurate topology losses, which add further accuracy to the Final Cell Plan. This is known as model tuning.

The CW measurements should be carried out in a variety of environments including cuttings, embankments, bridges, tunnels, routes in built up areas, as well as routes in both flat and hilly terrain. The measurements taken at varying base antenna heights ensure that the analysis takes into account the variation in base station antenna heights.

Site Surveys

It is vital that the engineers carrying out this survey have experience in radio survey and look at the situation through “radio eyes“. If possible, the survey team should be joined by trained radio network people who have already done the survey in other rollout projects.

The required details for a site survey are:

- Complete, up-to-date maps, showing the exact course of the railway line and the corresponding profile of same scale
- A unique number and unique name of the site location (tower or building)
- Photos of site location (tower, building etc.)
- Geographic coordinates in degrees, minutes and seconds (country specific)
- Exact address
- Complete height of tower above ground level
- Site location height above sea level
- Usable range of possible antenna mounting heights for all reasonable antenna directions marked in a sketch or plan giving the heights above ground level in meters
- Mark exact site location in map of appropriate scale (map has to contain course of railway). Direct distance to railway line should be seen or given in meters

- Take photos into both main directions, if possible from a roof top (in case of a building) or from possible antenna mounting height location (in case of towers if possible). The whole course of the railway to be covered from that site should be visible. All possible obstructions interfering the radiation in the directions of interest must be visible and marked.
- In case of a building a drawing indicating the possible exact antenna mounting locations for both directions must be given (location on the roof, if edge or pole) and the definite antenna mounting height above ground level.
- Exact description of all obstructions especially in the directions of the radiating antenna with giving of approximate distances of all obstructions.
- Rough classification of all areas along the railway track to be covered according to topological, morphological and vegetation aspects (e.g. urban, suburban, open, field, light forest, dense forest, hilly terrain, mountains, ascending/descending terrain in both directions of interest, ...) and marked in the corresponding maps.
- Maximum speed of the trains (e.g. 200km/h) at the track section
- Number of parallel tracks
- Type of track section (main station, station, goods/freight station, shunting areas, tracks for personal traffic, tracks for freight traffic)
- Distance in kilometers to the next site and the site before the current site
- Exact specification of Infrastructure parameters (Access availability, power and telecom supply)
- Specified Distance in meters from public houses (hospitals, schools, etc)
- Surrounding conditions that might prevent the site from being built (national park area, tourist area, etc)

All the details above should be included (if practicable) in a Site Survey Report. If a number of options are available, these should be ranked from best to worst. The relevant parties, including the engineer, acquisition manager and build manger, should then select the best option for inclusion in the Final Cell Plan.

Final Cell Plan

The Final Cell Plan is a detailed document which contains information about specific sites, site positions, antenna types, antenna heights, BTSE type etc, for the GSM-R network. The Final Cell Plan includes a detailed Traffic Plan and a Frequency Plan. Depending on the customers' requirements, it may have the possible inclusions of BCC and LAC codes, a neighbour list for the network and Voice Group Call Areas. The Final Cell Plan also contains a number of pictures taken at the site surveys

The release of the Final Cell Plan is the trigger to start the implementation and build of the sites required to provide the GSM-R network.

Radio Network Implementation

Technical Site Surveys for Selected Site Options

When the Final Cell Plan has been published and released, it contains the selected site options agreed upon for implementation in the radio network.

The survey team should be comprised of the radio design engineer who picked the site, a draughtsperson to compile the detailed drawings and perform physical measurements for feeder runs etc, the implementation manager to ensure compliance and legality of the design and the site landlord for any consultation issues.

The required details for a site survey are:

- Relevant details to complete an accurate scale drawing of the overall design
- Photo(s) of the site paying attention to access points, ladders, fiber connection points and power supplies
- Geographic coordinates in degrees, minutes and seconds (country specific)
- Exact address
- Exact height of tower above ground level
- Site location height above sea level
- Required Antenna type and tilts
- Required Feeder type attained from a detailed measurement of the feeder cable runs
- Any build specific details, such as brackets and flanges, need to be recorded for inclusion on the design drawings

When the Technical Site Survey is completed and the detailed design drawings are issued and signed off as accurate by all relevant parties, the site can be built and prepared for implementation.

Built Site Audits

After the site has been built, it needs to be inspected by the relevant implementation/build manager and the radio engineer, in order to ensure it has been built in accordance with the detailed design drawings compiled after the technical site survey.

Every aspect should be inspected and signed off on a check list. This includes the positioning and tilts of the antennas, inspection of the feeders and runs, weatherproofing of the joints between the feeders and tails and, physical configuration of the BTS equipment,etc.

When this is complete and the installation is compliant, then the BSS script files for the site can be implemented through the BSC to make the site active.

Individual Site Acceptance Testing

The last step for the implementation of the site is to conduct a SAT test (Site Acceptance Test). This comprises of the site being turned on and radiating, whilst a mobile test team drives a specified route and ensures the radio signal is propagating as it should. It will also indicate if the feeders are crossed or other issues which may degrade the effectiveness of the site in the completed network.

This test is recorded using various software applications connected to a receiver (such as Agilent or Kapsch radio) and the levels are recorded and processed for inclusion into a SAT report document. If this SAT Test is successful, the site can be integrated into the radio network.

Radio Network Delivery

Initial Drive Testing

When all the sites have been subjected to the various implementation tests and they are all compliant, the entire radio network can be tested in an end-to-end fashion.

The method commonly used for this important phase is the utilisation of a train, fitted with the relevant measurement equipment and driven the length of the network. This initial test will provide information and illustrate (in real time and real environment) the handover behaviour between cells and sites, any dropped calls (which can be caused through a number of issues such as low coverage, interference or poor handover behaviour) and a number of other issues which can affect the quality of the radio environment.

The minimum requirement for the test is ensuring the coverage passes at the required levels and the quality (C/I) is acceptable and within the specified values. To achieve this, the train must be fitted with the relevant measurement equipment.

An example setup could be:

- PC and relevant software for recording the RxLevels (in dedicated mode)
- Measurement Radio such as a Kapsch radio or Trio Rail
- GPS equipment to record location data (used in conjunction with the coverage measurements)
- PC and relevant software for recording the C/I ratio
- GSM-R test handset (used in conjunction with the C/I measurements)
- Roof mounted antennas

Further tests can be conducted at customer's request regarding the Bit Error Rate, Call Setup Success Rate and Idle Mode measurements to further measure the effectiveness of the radio environment. Ideally, the test train should be a dedicated unit allocated for testing. This will eradicate the variable results caused by the placement of antennas in different locations for other and subsequent tests. Consistency is the key to accuracy regarding train testing.

Optimisation

On completion of the initial train testing, the recorded results can be processed and analysed. This will provide the radio engineers with data on which they can base optimisation changes that will eradicate problems and improve performance.

This data, for example, may show areas where sites are overshooting and causing issues with other sites, therefore further tilts can be applied to improve overall network performance. Alternatively it may indicate poor hand over behaviour which can be improved by simple adjustments to the BSC parameters which will further improve the overall performance. These are just two examples of numerous issues which can affect a network and will only be identified by following a correct and comprehensive test procedure.

When the optimisation changes are implemented and completed, a final test drive can be conducted to gauge the effectiveness of the changes and illustrate any improvements.

Final Drive Test

The final drive test is a repeat of the initial drive test. However, this is to record the final state of the radio network (after the optimisation changes) and is used as proof that the radio design now complies with the required specifications and is ready to go live.

At this stage, all the results are documented and the radio network is now prepared for handover to the client.

Radio Network Continuation

Periodical Benchmark Testing

In many countries,operators which utilise a GSM-R network for their railways,will conduct periodical testing when necessary. This can take place at specified intervals.

It is important to conduct these periodical tests to ensure that sites are still performing as they should. Quality of Service can be affected for example by new buildings which are erected, or by wooded areas growing over time, causing issues near the tracks.

This periodical testing is dependent on the rail operators requirements, but it is recommended to test the radio network annually. There is however no fixed legislation which makes periodical benchmark testing a requirement.

Radio Network Upgrades

Over a period of time, the radio environment may require changes. These may be driven by the building and expansion of larger stations, new shunting areas and a higher volume of rolling stock on current lines,etc

Upgrades can range from carrier additions to accommodate additional capacity, or indeed a new site to cover new shunting areas,improve indoor solutions for newly built stations or expand existing stations as required.

When new elements are inserted into a mature network, these elements must be tested to ensure they do not degrade the current radio environment. Therefore, further testing along certain sections of the tracks which may be affected will usually be required.