



Electronic Communications Committee (ECC)  
within the European Conference of Postal and Telecommunications Administrations (CEPT)

**MONITORING METHODOLOGY TO ASSESS THE PERFORMANCE  
OF GSM NETWORKS**

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## **0 EXECUTIVE SUMMARY**

This report presents a procedure to assess the performance of GSM networks. It is based on the procedure used by the Belgian administration however the general concepts in this document apply to every GSM network.

The principle of the methodology is to check whether the operators' requirements, which are contained in their licence, are being met.

It must be noted that there may be particular requirements on the performance to be reached by national GSM networks.

The operators' requirements presented here concern the degree of coverage relating to the territory, the population and the highways as well as the blocking call rate and the dropping call rate.

As far as the coverage rates are concerned, the principle of the method consists in asking operators to provide their coverage files and checking the reliability of this data by means of measurements. This procedure makes it possible to limit the sample of measurements to verify the operator data..

As far as the blocking and dropping rates are concerned, specific tests are carried out. The principle of these tests is to carry out a sequence of calls and each call is scored depending on how it took place. A minimum number of calls has to be carried out and the blocking and dropping rates are deducted from the statistics on this score.

The general principle of the monitoring methodology is to assign an index to the different tests carried out and to combine these different indexes into a general index.

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## **1 INTRODUCTION**

This document presents first the significant parameters to assess the performance of a GSM network, the principle of the assessment procedure and the equipment necessary to carry out a measuring campaign. After these three items of a rather general nature, an example of a specific objective to be met by an operator is presented and the three following items tackle in detail the methodology of determining the coverage, blocking and dropping rates. Finally the last item concerns the calculation of the general index and enables us to decide whether or not the operator has honoured their commitments.

## **2 SIGNIFICANT PARAMETERS TO ASSESS THE PERFORMANCE OF GSM NETWORKS**

Three parameters are significant to assess the performance of GSM networks: the coverage, the blocking rate and the dropping rate.

### Coverage

The coverage of GSM-networks in a country can be expressed in percentage of coverage relating to the territory, the population or both. Moreover specific obligations such as coverage of some trunk roads can be set. The meaning of covered and uncovered areas has to be clearly defined with a common understanding by all parties involved. Unless otherwise stated in the license conditions, GSM networks should be considered as a whole and the coverage should be measured on all relevant frequency bands simultaneously.

### Blocking rate

The blocking rate is the percentage of blocked call attempts which are caused specifically by the operator's network against the sum of good and blocked calls.

### Dropping rate

The dropping rate is the percentage of calls that are dropped during the call period which are caused specifically by the operator's network against the sum of good and dropped calls.

### Other parameters

Other parameters such as audio quality can be assessed, however, they are not considered in this report.

## **3 PRINCIPLE OF THE NETWORK ASSESSMENT PROCEDURE**

To assess the performance of a GSM's network the operator's obligations have to first be defined. The assessment procedure will then aim at checking if the operator's obligations are met. This assessment is carried out by analysing the supplied data and the results of practical measurements.

If more than one network has to be assessed the measurements should be performed simultaneously.

All tests carried out are tagged with indexes which are combined into a general index. If the general index exceeds 1 the network can be considered as fulfilling its obligations.

## **4 EQUIPMENT TO MEASURE THE NETWORK AND ASSESS RESULTS**

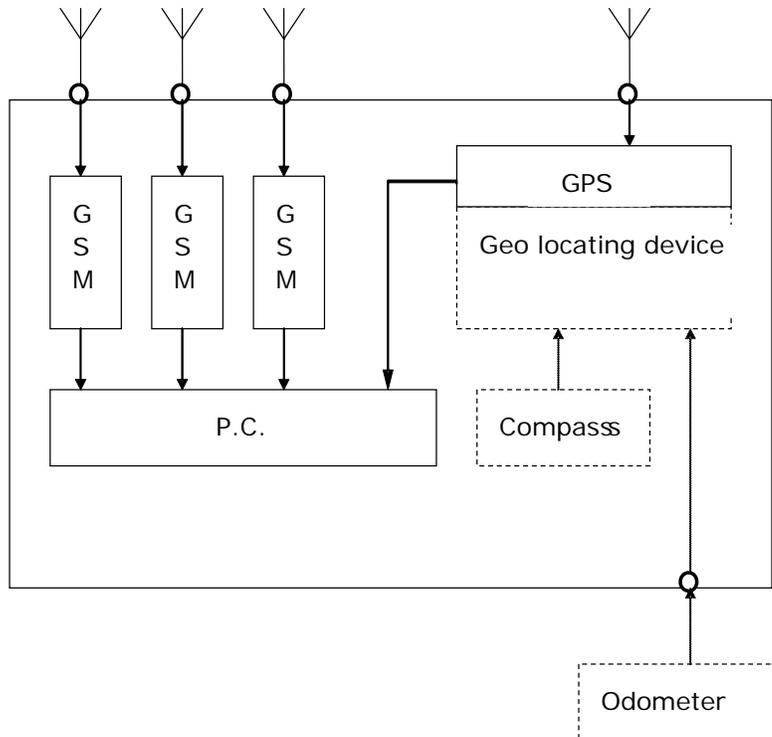
For the assessment, data processing software and appropriate measuring equipment are required.

### **4.1 Data processing software**

A GIS (Geographic Information System) application is used which makes it possible to handle and to process the different information on network coverage.

## 4.2 Measuring section

The block diagram of the measuring equipment which is installed in a measurement vehicle can be seen below.



The measurement equipment comprises:

- several test mobile transceivers to test all operators simultaneously
- a laptop equipped with a measurement software
- a positioning system

The mobile transceivers used are specially developed for this type of tests and have an interface for communicating with the laptop.

The software of the measuring equipment

- controls the measurement mobiles
- records important signalling data exchanged between the mobile and the base station;
- receives the position information from the positioning system;
- stores raw data to hard disk
- processes and displays the desired data;
- exports the required data in the defined format.

The positioning system consists of a GPS-device. A dead reckoning system that enables continued recording of measuring point coordinates if GPS coverage is lost can also be added. This optional system is equipped with an electronic compass to define the direction and an odometer to determine the distance travelled. This allows extrapolation of the vehicle coordinates from the last received position should the GPS signal be lost.

The measuring antennas are mounted on the roof of the vehicle, at a height between 1.5 and 3 meters.

The measuring system including the positioning system has to be calibrated before use.

## 5 EXAMPLE OF LICENCE REQUIREMENTS

Three objectives have been defined for the coverage rate:

- Coverage of the territory:  $\text{obj}_{\text{cov, ter}}$  (e.g. 85%), weighting factor:  $P_{\text{ter}}$  (e.g. 35%)
- Coverage of the population:  $\text{obj}_{\text{cov, pop}}$  (e.g. 98%), weighting factor:  $P_{\text{pop}}$  (e.g. 35%)
- Coverage of the highways:  $\text{obj}_{\text{cov, hw}}$  (e.g. 100%), weighting factor:  $P_{\text{hw}}$  (e.g. 30%)

The weighting factor will be described in section 6.4.

Further objectives have also been defined for the blocking rate (e.g. 3 %) and the dropping rate (e.g. 2%).

## 6 MEASUREMENT OF THE COVERAGE RATE

The coverage assessment is based on the rules set for the GSM operator such as the coverage declaration by the operator. After analysis of this declaration, actual measurements will be made to ensure that it corresponds to reality. This method makes it possible to limit the number of measurement routes.

### 6.1 Decision criterion

First of all the criterion to decide if a location is covered or not has to be defined. For that purpose we base our judgment on two parameters - RxLev and RxQual - which are measured by the test GSM every 470 ms. These parameters are representative of the received level and the quality of the call.

#### Level

Every GSM mobile measures the parameter RxLev. During the call this parameter corresponds to the power level received by the mobile on the transmission channel. The measurement scale varies from - 110 dBm to - 47 dBm although the mobile actually reports another value (step) which varies from 0 to 63 with 0 corresponding to -110 dBm and 63 corresponding to - 47 dBm or greater.

Two parameters can be measured: RxLevFull and RxLevSub (although the generic term RxLev is used in this report). RxLevSub is more appropriate for this type of measurements. The report must clearly state which parameter was measured.

#### Quality

Every GSM in the process of a call measures the parameter RxQual. This parameter varies from 0 (best) to 7 (worst).

Two parameters can be measured: RxQualFull and RxQualSub (although the generic term RxQual is used in this report). RxQualSub is more appropriate for this type of measurements. The report must clearly state which parameter was measured.

#### Decision threshold

The decision threshold is used to establish if a location is covered or not. Every administration is free to define its decision thresholds. For information these thresholds can be for an outdoor coverage:

$$\begin{aligned} \text{RxLev} &\geq -92 \text{ dBm} \quad [ \text{RxLev} \geq 18 \text{ (step)} ] \\ \text{RxQual} &\leq 5 \end{aligned}$$

#### Link between the power measured and the electric field strength

The measurement of RxLev indirectly enables us to assess the field radiated on the measurement frequency. The conversion factor between the power measured by the GSM and the external field strength is determined from the following theoretical formula:

$$\begin{aligned} E \text{ (dB}\mu\text{V/m)} &= P \text{ (dBm)} + C \\ E \text{ (dB}\mu\text{V/m)} &= P \text{ (dBm)} + 20 * \log f \text{ (MHz)} + 77,2 \text{ (dB)} - G_f \text{ (dB)} + P_{\text{con}} \text{ (dB)} \end{aligned}$$

where: E = electric field strength  
 P = power measured  
 C = conversion factor  
 f = frequency  
 G<sub>i</sub> = isotropic gain of the antenna  
 P<sub>con</sub> = loss at the level of connections

Therefore it is important to define for which kind of GSM the condition (RxLev<sub>≥</sub> - 92 dBm) has to be met. By applying the GSM standard, we have defined that the measures should theoretically be carried out by a reference GSM, which satisfies the equation:

$$- G_i(\text{dB}) + P_{\text{con}}(\text{dB}) = 0$$

The conversion factor in the case of a reference GSM, is therefore:

$$C_{\text{ref},900} = 20 * \log F(942,5) + 77,2 + 0 = 136,7$$

$$C_{\text{ref},1.800} = 20 * \log F(1842,5) + 77,2 + 0 = 142,5$$

$$(C_{\text{ref},900}; C_{\text{ref},1.800}) = (136,7 ; 142,5)$$

The threshold expressed in terms of field strength corresponds to:

$$E_{\text{ref},900} = -92 + 136,7 = 44,7 \text{ dB}\mu\text{V/m}$$

$$E_{\text{ref},1800} = -92 + 142,5 = 50,5 \text{ dB}\mu\text{V/m}$$

Hence the decision threshold, as far as the level received is concerned, can therefore be expressed as follows:

At the location of the measurement, there must be a minimum field strength of 44.7 dB $\mu$ V/m at 900 MHz and of 50.5 dB $\mu$ V/m at 1800 MHz on the transmission channel. At this location, the measurement should theoretically be carried out by a reference GSM that would measure, for these field values, a level of -92dBm.

In practice, the measuring chain is not composed of a reference GSM and it will be necessary to take its characteristics into account as part of the calibration of the receiving chain. This calibration results in a set of calibration factors that are stored in the measuring software and are taken into account during the measurements. This allows the receiving chain to be considered ideal.

## 6.2 Analysis of the operator's coverage area

### 6.2.1 Coverage prediction file

It is necessary that the operators deliver all the information needed to evaluate the coverage of their network.

For example, a file representing the combined coverage of their networks at 900 MHz and 1800 MHz in a format compatible with the GIS application used. This file is made up of a grid of squares, for example 50m x 50m, corresponding to the country. For every square the operator has to indicate if the cell is covered or not.

The following sections describe a way to evaluate the coverage of the operator based on this assumption. It must be considered as an example.

### 6.2.2 Treatment of the theoretical coverage files

The first step consists in analysing the operator's theoretical coverage files. The data processing software calculates the percentage of the territory surface covered according to the operator's declaration (D<sub>cov,ter</sub>). To calculate the percentage of the population covered, reference to the data of the National Institute of Statistics of the country should be used. By combining this data to the data delivered by the operator the software analysing the data can calculate the percentage of the population covered according to the declarations of the operator: D<sub>cov,pop</sub>.

For the calculation of the percentage of highways covered according to the operator's declaration (D<sub>cov,hw</sub>) the software uses the highways' geographical data and the coverage declaration of the operator.

Therefore this assessment of the operator's coverage files makes it possible to verify their declaration for the coverage of the surface, the population and highways.

### **6.2.3 Calculation of the theoretical coverage indexes**

The indexes in this document can be used to assess the difference between the operator's declaration and their obligations.

The declaration of the coverage of the territory ( $D_{cov,ter}$ ) is compared to the objective defined in the operator's licence ( $obj_{cov,ter}$ ) in order to define the index of the territory theoretical coverage:

$$i_{th,ter} = \frac{D_{cov,ter}}{Obj_{cov,ter}}$$

The index of the theoretical coverage of the population is similarly defined by comparing the coverage declaration of the population ( $D_{cov,pop}$ ) to the objective defined in the operator's licence ( $obj_{cov,pop}$ ).

$$i_{th,pop} = \frac{D_{cov,pop}}{Obj_{cov,pop}}$$

Similarly the coverage index of the highways is calculated by comparing the coverage declaration of the operator for highways ( $D_{cov,hw}$ ) with their obligations ( $obj_{cov,hw}$ ).

$$i_{th,hw} = \frac{D_{cov,hw}}{Obj_{cov,hw}}$$

## **6.3 Measurements on site**

On site measurements are conducted to verify the data of the operator.

### **6.3.1 Choice of the test routes**

We present below an example of a test route program:

Ten test routes have been chosen to check the coverage of the territory. The following criteria are applied for their choice:

- The country's municipalities are divided up into 5 categories of population density.
- Only the municipalities covered at least at 10% are retained.
- Two municipalities are chosen randomly in each of the categories.
- The selected municipalities must be separated by at least 30km.
- The route of around 100km is defined through and round this municipality.

Five test routes have been chosen for highways, of a length of about hundred kilometers. They are also randomly chosen..

### **6.3.2 Carrying out of the measurements on site**

#### Territory measurement route

The test route first defined is transferred to the measuring team either on paper maps or electronically. So for example the use of the software makes it possible to define the route on a computer and to download it electronically to the vehicle's GPS.

All operators are simultaneously tested.

Every measuring equipment GSM is set to make a continuous call to a dedicated answering machine placed on the network of the operator under test. The call enables the monitoring of the operator's network. This answering machine must pick up when the call is made and maintain the call as long as it is not dropped by the measuring equipment.

During the test all the parameters of the call are registered (signalling data exchanged between the GSM and the network) by the measuring equipment and can be visualised by the technician who checks that the test is progressing well.

Having completed the test drive the recorded data can be processed. The two useful parameters are RxLev and RxQual. The data must be exported in a format compatible with the GIS application.

For example, a 30m x 30m grid is superimposed on the measurement route. The average of the RxLev and RxQual values measured inside a square are calculated and the averages are associated with the center of the square. This results in a file in ASCII format, in which each line is composed of the coordinates in latitude/longitude of the centre of the square and of the parameters RxLev and RxQual associated with that square.

#### Measurement routes of the highways

These routes are carried out in the same way as the territory measurement routes. The exportation of data is however made by superimposing a grid of 60m x 60m instead of 30m x 30m on the route. This takes account of the higher speed of the measurement vehicle.

### **6.3.3 Assessment of the measurements along the route**

The files from the measuring equipment are imported to the data processing software.

It is necessary to assess the measuring data. For that purpose the measurements made on site are compared to the declaration of the operator. This comparison results in the definition of the measured coverage indexes of which an example is given below.

#### Calculation of the measured index for the territory measurement routes

The 30m x 30m grid is superimposed on the 50m x 50m grid on which the calculations are carried out. The average of all the values in a square of 50m x 50m is worked out and associated with the centre of this square.

It should be noted that the grid spacing used for the measurements should preferably be the same as used for the coverage predictions however sufficient care has to be taken in order to avoid a systematic 'offset' gap between the measured data and the theoretical data.

The following operations are carried out on the file containing the route referred to on the 50m x 50m grid:

- For every square the value '1' is assigned if the decision thresholds are exceeded (in our example, RxLev  $\geq$  18 (step) and RxQual  $\leq$  5), otherwise the value '0' is assigned.
- The percentage of the territory covered along the route according to the measurements is calculated: %<sub>mes,ter,dt</sub>.
- The percentage of the territory covered along the route according to the declaration of the operator is calculated: %<sub>th,ter,dt</sub>.
- The index for the route is calculated as follows:

$$i_{mes,ter,dt} = \frac{\%_{mes,ter,dt}}{0,95 \times \%_{th,ter,dt}}$$

The factor 0.95 is introduced in order to take all measuring uncertainties into account: if a measured coverage index is 95% of the declarations of the operator, the index is worth 1.

The coverage index measured for all the routes is calculated from these different indexes by taking into account a weighting factor proportional to the length of the routes:

$$i_{mes,ter} = \sum_{drive\ tests} \frac{l_{dt}}{\sum_{drive\ tests} l_{dt}} \times i_{mes,ter,dt}$$

Calculation of the index measured for the motorway measurement routes

The calculation is done in a similar way. The 60m x 60m grid is imported and we deduct the index for the route of the percentage of the territory covered along the route according to the measure ( $\%_{mes,hw,dt}$ ) and according to the declaration of the operator ( $\%_{th,hw,dt}$ ).

$$i_{mes,hw,dt} = \frac{\%_{mes,hw,dt}}{0,95 \times \%_{th,hw,dt}}$$

The coverage index measured for all the routes is deducted in the same way too:

$$i_{mes,hw} = \sum_{drive\ tests} \frac{l_{dt}}{\sum_{drive\ tests} l_{dt}} \times i_{mes,hw,dt}$$

#### 6.4 Calculation of the coverage indexes of the territory, the population and the highways and of the coverage index of the network

It is necessary to assign a coverage index to the network. This index will indicate to what extent the network meets its coverage obligations.

For this purpose the various indexes previously calculated are combined. This relates to the theoretical coverage indexes (comparison between the declaration of the operator and the objectives of their licence) and the measured coverage indexes (comparison between the measurements and the declaration of the operator).

Coverage index of the territory

The coverage index of the territory is calculated from the theoretical coverage index of the territory multiplied by the measured coverage index of the territory.

$$i_{ter} = i_{th,ter} \times i_{mes,ter}$$

Coverage index of the population

It is important to note here that we do not define any measured index of the population. This is due to the difficulty to calculate the population percentages along the measurement routes and the sources of uncertainty it can bring about. The coverage index of the population is thus calculated from the theoretical coverage index of the population by multiplying it by the measured coverage index of the territory.

$$i_{pop} = i_{th,pop} \times i_{mes,ter}$$

Coverage index of the highways

The coverage index of the highways is calculated from the theoretical coverage index of the highways and multiplied by measured coverage index of the highways.

$$i_{hw} = i_{th,hw} \times i_{mes,hw}$$

Coverage index of the network

In order to combine the three sub-indexes, it is necessary to assign relative weights to them. To that end we use the weight factors that have been defined in the licence of the operators.

$$i_{cov} = P_{ter} \times i_{ter} + P_{pop} \times i_{pop} + P_{hw} \times i_{hw}$$

## 7 MEASUREMENT OF THE BLOCKING RATE

### 7.1 Principle of the test

The measuring equipment is set to initiate a series of successive calls. Every call or call attempt is categorised depending on the signalling messages exchanged with the network which can be:

- Good : The call was successful.
- Blocked : Signalling messages between the network and the test GSM indicate, during the phase of putting the call through, that the call is impossible.
- Dropped : Signalling messages between the network and the test GSM indicate, during the call, that this call is dropped.
- No service : There is no coverage.

The number of calls in each category is registered by the measuring equipment and the results of the blocking test are calculated on the basis of this data.

Tests are carried out at fixed points. There could be other types of tests, for example along the route.

### 7.2 Number and location of the tests

We present below an example of chosen tests.

In total six tests are carried out. Two municipalities are chosen at random in each of the three groups of highest population density (according to the classification of the country's municipalities into five groups of population density). Other tests sites can be chosen, such as business areas with low population density. The tests measurements are carried out at locations where  $RxLev \geq -70$  dBm in order to avoid blocking calls because of the bad quality of the radio link.

### 7.3 Test time

Tests should preferably be carried out at peak hours. These peak hours should be defined in co-operation with the operators. If the peak hours considerably differ from one operator to another it might be impossible to test the different operators simultaneously.

If it is too difficult to clearly define peak hours the administration may decide to carry out the tests at the hours of its choice during working days.

### 7.4 Test procedure

The test consists of the repetition of the following sequence:

1. Putting the call through
2. Maintenance of the call for 15 s
3. Termination of the call
4. Waiting time of 15 s

If the call has been blocked, a 15 s waiting time is observed before any new attempt is made.

The call is made to a dedicated answering machine placed on the operator's network to ensure that any blocking recorded is caused by the operator's network.

The software registers the different outcomes concerning the calls during the test and the procedure is stopped when between 200 and 220 calls that are qualified of 'Good' have been made.

The blocking rate for the test is calculated as follows:

$$t_{bloc,test} = \frac{\text{number 'blocked' calls}}{\text{number 'good' calls} + \text{number 'blocked' calls}}$$

It should be pointed out that in this calculation we do not take into account the calls that could have categories other than 'Good' or 'Blocked' so that the test only concerns the blocking performances.

### 7.5 Calculation of the blocking rate index

In order to assess the result of the test it is necessary to combine the results of the different tests and to define an index for the blocking rate. The blocking rate for all the tests is calculated by weighting the blocking rates of the different tests depending on the population density of the municipalities where the tests have been carried out:

$$t_{bloc} = \frac{\sum_{tests} \rho_{pop,test} t_{bloc,test}}{\sum_{tests} \rho_{pop,test}}$$

The blocking index aims at comparing the result of the blocking tests ( $t_{bloc}$ ) to the objectives set in the licence ( $obj_{bloc}$ ). The following formula can be used by limiting the blocking index to 1 (see comment in section 9):

$$i_{bloc} = 1 - \frac{t_{bloc} - obj_{bloc}}{2 \times obj_{bloc}}$$

## 8 MEASUREMENT OF THE DROPPING RATE

### 8.1 Principle of the test

The principle of the test is identical to the principle used for the measurement of the blocking rate, i.e. making successive calls and categorising them as 'Good', 'Dropped', 'Blocked' or 'No Service' (see item 7.1). The tests are carried out along a route.

### 8.2 Number and location of the tests

Below is an example of a chosen test.

Five tests are carried out. The country is divided into five regions. In each region a route is defined, that must be situated in an area declared covered by the operator. This enables us to avoid the dropped calls because of the edge of the coverage area of the operator.

If several operators are being tested simultaneously the route has to be defined in an area covered by all of these operators.

### 8.3 Test time

The comments made in section 7.3 also apply.

### 8.4 Test procedure

The following sequence is carried out:

1. Putting the call through
2. Maintenance of the call for 2 minutes
3. Termination of the call
4. Waiting time of 15 s

If the call has been dropped, a 15 s waiting time is observed before any new attempt is made. Again the call is made to a dedicated answering machine placed on the operator's network to ensure that any dropping recorded is caused by the operator's network. The procedure is stopped when we have made between 100 and 110 calls that are categorised as 'Good'. The dropping rate for the test is calculated as follows:

$$t_{drop, test} = \frac{\text{number 'dropped' calls}}{\text{number 'good' calls} + \text{number 'dropped' calls}}$$

It should be pointed out that in this calculation we do not take into account the calls that could have categories other than 'Good' or 'Dropped' so that the test only concerns the dropping performances.

### 8.5 Calculation of the dropping rate index

In order to assess the result of the dropping tests it is necessary to combine the results of the different tests and to define a dropping index. Below an example for these calculations:

The dropping rate for all the tests is calculated by working out the average of the dropping rates of the different tests.

$$t_{drop} = \frac{\sum_{tests} t_{drop, test}}{\text{Number of tests}}$$

The dropping index, aimed at comparing the results of the measurements ( $t_{drop}$ ) with the objectives of the operator ( $obj_{drop}$ ), can be calculated as follows, by limiting the dropping index to 1 (see item 9 – Comment):

$$i_{drop} = 1 - \frac{t_{drop} - obj_{drop}}{2 \times obj_{drop}}$$

## 9 GENERAL QUALITY INDEX

The procedure aims at checking if the operator's objectives are met. For that purpose all the tests carried out make it possible to define three indexes, corresponding to the monitoring with respect of the three objectives of the operator:

- The coverage index of the network (see section 6):  $i_{cov}$
- The blocking index (see section 7) :  $i_{bloc}$
- The dropping index (see section 8) :  $i_{drop}$

These three indexes should be combined in a general index.

For example the following formula can be used (the formula may be modified depending on the importance the administration puts on the different objectives):

$$i_{gen} = 0,8 \times (10 \times i_{cov} - 9) + 0,1 \times i_{bloc} + 0,1 \times i_{drop}$$

If the general index is greater 1 the operator is considered to comply with their licence.

### Comment on the indexes presented in this document

The indexes presented for information in this document have the following limits:

$$\begin{array}{ll} i_{cov} & [ 0 ; > 1 ] \\ i_{bloc} & [ < 0 ; 1 ] \\ i_{coup} & [ < 0 ; 1 ] \\ i_{gen} & [ < 0 ; > 1 ] \end{array}$$

With the indexes defined in this way and the calculation formula of the general index indicated above the operator can make up for a bad result for the dropping or blocking rate (blocking or dropping indexes lower than 1) thanks to a good result concerning coverage (coverage index higher than 1), but the contrary is not true. If the coverage index is lower than 1, the general index will be lower as well because the blocking and dropping rates are limited to 1.

## **10 REFERENCES**

GSM standards as published by the European Telecommunications Standards Institute.