RF GUIDELINES

1800 MHz

THE ERICSSON GSM SYSTEM R8

Contents

1 Revision history

Revision	Date	Description
A	2000-08-14	First revision, based on RF Guidelines, Ericsson GSM System R7.
		URL links updated.
		RBS 2206 figures added.
		New CDUs added.
		Log-normal fading margin (LNF_{marg}) changed.
		Coverage level in percent for a cell changed.
		Figure added for rural areas to the A parameter in the propagation model.
		General recommendations for antenna tilting.
		Maxite™ figures updated.
		References updated and added.

2 Introduction

This document contains information about site equipment and cell planning policy for GSM 1800.

The GSM 1800 system is required to operate in the following frequency band, with a carrier spacing of 200 kHz:

Table 1. Frequency band of GSM 1800.

MS transmit, BTS receive	1710-1785 MHz
Base transmit, MS receive	1805-1880 MHz

3 Equipment characteristics

In this chapter the equipment characteristics are presented. All values presented represent guaranteed values from base station, which are intended to be used in link budgets for cell planning.

Important note: Some of the equipment mentioned in this document is still being developed. Always check when the equipment you intend to use is available. Furthermore, the figures for sensitivity and output power may change. The most recent figures for sensitivity and output power can be found in ref. 1 and ref. 2, or at: *http://gsmrbs.ericsson.se/marketing/FAQ/faq.htm*, which is continuously updated.

In the GSM specification (ref. 3), reference sensitivity levels are mentioned. As well the BTSs as MSs must meet some predefined performance values in terms of FER, BER and RBER[1] defined in the GSM specification. The actual sensitivity level is defined as the input level for which the performance is met and should be less than a specified limit, called the reference sensitivity level. This section contains reference values for different types of BTS configurations and MS power classes. At temperatures exceeding 30°C and for hilly terrain the sensitivity figures can be changed, see ref. 1 and ref. 2.

3.1 RBS 2000

RBS 2000 (ref. 4) is the second generation of Ericsson base BTSs for GSM. six different types of RBSs are available: 2101 (2 TRU outdoor cabinet), 2102 (6 TRU outdoor cabinet), 2202 (6 TRU indoor cabinet), RBS 2302 (2 TRU micro BTS), RBS 2401 (2 TRX indoor base station) and RBS 2206 (12 TRU indoor cabinet).

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For RBS 2101, 2102 and 2202, functional units as for example combiners are included in a Combining and Distribution Unit (CDU). There are three different CDU types, A, C+ and D, all with different characteristics. When selecting CDU type, three different alternatives exist, the antennas referred to are cross-polarized:

- Maximum Range (CDU-A). It is designed to maximise the output power. With this alternative up to 2 TRUs can be connected to one antenna in a cell but it is configurable for up to 6 TRUs.
- Standard (CDU-C+). It contains a hybrid combiner, which allows 4 TRUs to be connected to one antenna in a cell but is configurable for up to 12 TRUs.
- High Capacity (CDU-D). It contains a filter combiner, which makes it possible to connect up to 12 TRUs to one antenna in a cell. Using CDU-D, it is not possible to perform synthesizer frequency hopping, only base band hopping.

There is another alternative, Smart Range, which allows a CDU-A and a CDU-C+ to be combined in the same cell. This solution combines high coverage with high capacity, up to 6 TRUs per cell can be connected.

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[1] FER = Frame Erasure Ratio; BER = Bit Error Ratio; RBER = Residual Bit Error Ratio

For RBS 2206 there exist two different types of CDUs, F and G, both with different characteristics and the possibility to be used together with TMA. The new CDUs makes it possible to support 3x4 configurations in one cabinet. The antennas referred to are cross-polarized:

- CDU-F. It contains a filter combiner, which makes it possible to connect up to 12 TRUs to one antenna in a cell. It is not possible to perform synthesizer frequency hopping, only base band hopping.
- CDU-G. With CDU-G the RBS 2206 can be configured in two modes: capacity mode or coverage mode. In capacity mode up to 12 TRUs can be connected to 2 antennas in a cell. It supports both synthesizer hopping and base band hopping.

Software Power Boost can be used to improve the downlink output power for RBS 2000 and thus achieve better coverage. A prerequisite is that CDU-A or CDU-G is used and that each cell is equipped with 2 TRUs per cell. TX-diversity is then used in order to obtain a downlink diversity gain of 3 dB, which should be added to the link budget.

Software Power Boost gain	3 dB

The RBS 2206 (ref. 8) is a macro base station supporting up to 12 TRUs per cabinet, which can be configured as one, two or three sector cell configuration.

For more information concerning RBS configurations for macrocells, see ref. 5.

The RBS 2302 (ref. 6) is a micro base station. 3 RBS 2302s can be connected in order to build up to 6 TRUs per cell (note: BTS 7.1 required). Software Power Boost can also be used together with RBS 2302.

The RBS 2401 (ref. 7) is the first dedicated pico radio base station, designed for indoor applications. It is equipped with 2 TRXs.

The output power, sensitivity and minimum carrier separation of the RBS 2000 series are listed in Table 2.

Table 2. Output power, sensitivity and minimum carrier separation of RBS 2000.

CDU/RBS	Output power [dBm]	Sensitivity [dBm]	Minimum carrier separation [kHz]
A	43.5	-110[1]	400[3]
C[2]	40	-110[1]	400[3]
C+	40	-110[1]	400[3]
D	41	-110[1]	1000
F	42.0	-110[1]	800
G	42.0/45.5[4]	-110[1]	400
RBS 2302	33	-106	400
RBS 2401	22	-100	400

[1] With TMA the sensitivity is –111.5 dBm. This sensitivity figure applies for antenna feeders with up to 4 dB loss. If the loss between the TMA and the BTS exceeds 4 dB the sensitivity is decreased, as described in section 3.4.3.

[2]CDU-C is today replaced by CDU-C+.

[3]The CDU can from a radio performance perspective handle 200 kHz carrier separation, but bursts may then be lost due to low C/A. From a system point of view the consequences of going below 400 kHz are not fully investigated. Problems with for example standing wave alarms may occur. Thus it is recommended to keep 400 kHz carrier separation.

[4] Output power is 42.0 dBm if hybrid combiner is used in the dTRU.

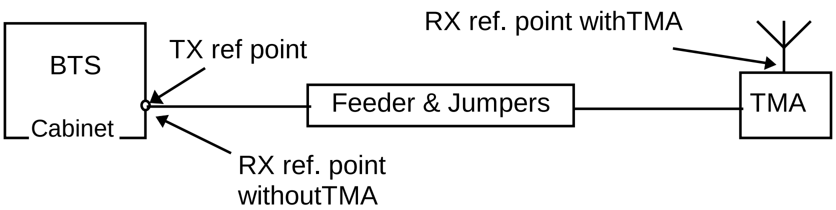

Figure 1. RBS 2000 TX and RX reference points referred to in Table 2.

3.2 RBS 205

RBS 205 (ref. 9) belongs to the first generation of Ericsson base stations for GSM. Each cabinet can take 4 Transceivers (TRX), and the cabinets must be placed indoors. The RBS 200 is designed for different types of combiners: filter combiners and hybrid combiners.

With filter combiners 1 to 8 transmitters can be connected to the same antenna. In order to use 9 to 16 transmitters in a cell, two filter combiners and two transmitting antennas must be used. Using filter combiners it is not possible to perform synthesizer frequency hopping, only base band hopping.

With one hybrid combiner 2 transmitters can be connected to one antenna and using three combiners 4 transmitters can be connected to the same antenna. Hybrid combiners allow both base band hopping and synthesizer hopping.

Table 3 shows the output power, sensitivity and minimum carrier separation for the different configurations.

Table 3. Output power, sensitivity and minimum carrier separation of RBS 205.

Combiner type	**Output power** [**dBm**]	**Sensitivity without TMA** [**dBm**]	**Minimum carrier separation** [**kHz**]
Filter (1-8 TX)	40	-106	1200
Hybrid (2 TX)	39.5	-106	400[1]
3 x Hybrid (3-4 TX)	36	-106	400[1]

[1]The combiner can from a radio performance perspective handle 200 kHz carrier separation, but bursts may then be lost due to low C/A. From a system point of view the consequences of going below 400 kHz are not fully investigated. Problems with for example standing wave alarms may occur. Thus it is recommended to keep 400 kHz carrier separation.

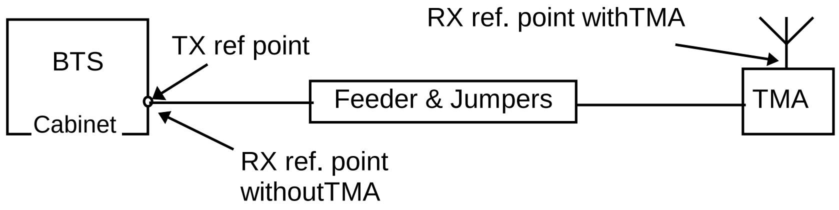

Figure 2 RBS 205 TX and RX reference points referred to in Table 3.

3.2.1 Maxite™

To provide a possibility of extending the limited coverage area of RBS 2302, Maxite™ (ref. 10) has been developed. Maxite™ consists of an RBS 2302 together with an Active Antenna Unit (AAU) and a Power Battery Cabinet (PBC). The AAU contains a set of distributed power amplifiers for the transmitted signals, a low noise amplifier for the received signals and an integrated patch antenna. Apart from extending the coverage of the RBS 2302 similar to a macrocell, it also provides the possibility to use thinner antenna feeders.

There is one type of AAU with power capabilities of 500W EIRP. It characteristics is described in Table 4. The values for output power and sensitivity are valid for a feeder loss of maximum 10 dB.

Table 4. Equipment characteristics of Maxite™.

Maxite™ Product	**Antenna**	**Diversity gain**	**Slant loss**	**Output power**	**Sensitivity**	**Minimum carrier separation**
Maxite 500 W	17.5 dBi	3.5 dB	1 dB	40 dBm	-111 dBm	400 kHz

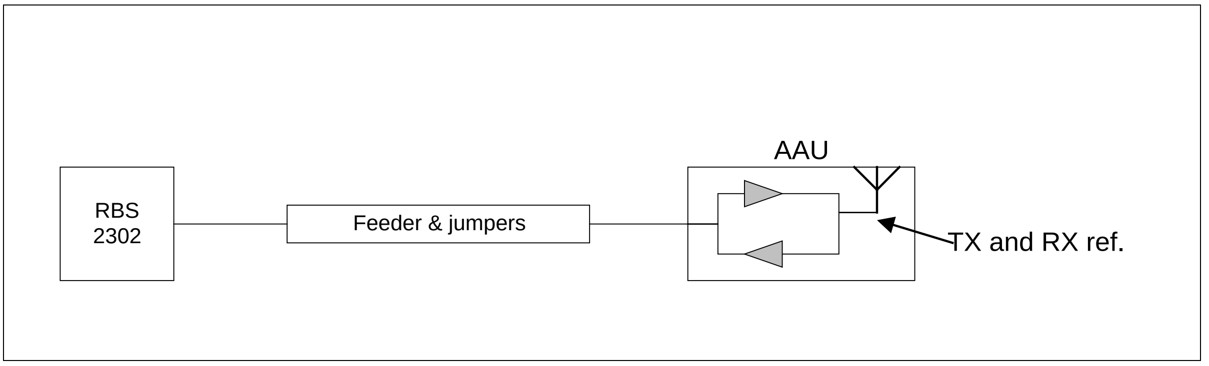

Figure 3. Maxite™ TX and RX reference *points. Both TX and RX reference points are defined at the antenna inside the AAU.*

3.3 Mobile station

There are three MS power classes described in the GSM 1800 Specification (ref. 3) however only MSs of class 1 and 2 are likely to be used. Typical figures for maximum output power and sensitivity are shown in Table 5. The figures are specified at the MS antenna connector.

Table 5. MS power classes.

MS power class	**Output power [dBm]**	**Sensitivity [dBm]**
1	30	-104
2	24	-104

According to the GSM Specification, the sensitivity is –102 dBm for GSM 1800 MSs. However experiences from leading mobile manufacturers show that the sensitivity is 2 – 4 dB better and therefore this value is set to -104 dBm dBm, see e.g. ref. 11.

No loss or antenna gain should be used for the MSs.

MS antenna gain: 0 dBi

3.4 Antenna near part

More information about the equipment mentioned in this section and the following can be found at the Ericsson intranet: *http://gsmrbs.ericsson.se/gsmsystems/solutions/rbs_site_solutions/antenna_systems/*

3.4.1 Base station feeders and jumpers

When calculating the power budget, the feeder loss must be taken into account. The most commonly used feeder type is 7/8”. In Table 6, the losses for the most common macrocell feeder types are listed (ref. 12).

Table 6. Attenuation in some feeder types at 1800 MHz.

Feeder type	Attenuation [dB/100m]
LCF 1/2”	10.5
LCF 7/8”	6.5
LCF 1-1/4”	5.3
LCF 1-5/8”	4.2

Apart from the feeder loss, additional loss will arise in jumpers and connectors. Typical values are 0.5 dB for every jumper and 0.1 dB for every connector.

3.4.2 External filters

Duplex filters make it possible to use the same antenna for transmission and reception. When an external duplex filter is used there will be an additional loss in both uplink and downlink.

Apart from external duplexers, some TMAs contain duplex filters, see section 3.4.3. Duplex filters can be used with RBS 205; RBS 2000 contains internal filters.

Table 7. Duplex attenuation values

Devise	Typical loss [dB]
External duplex filter	0.5

Diplex filters make it possible to use the same feeders for GSM 900 as GSM 1800 in a dual band site. They are needed in order to differentiate the two frequency bands.

Table 8. Diplex attenuation values

Devise	Typical loss [dB]
External diplex filter	0.3

Data sheets for filters can be found at: http://rsaweb.ericsson.se/market/filter-shop/brochures/

3.4.3 Tower Mounted Amplifiers

In order to improve the sensitivity on the uplink a Tower Mounted Amplifier (TMA) can be used. The purpose of the TMA is to amplify the received signal before it is further attenuated in the antenna feeder. There are two types of TMA with different number of duplex filters, see Table 9.

Table 9. TMA products for RBS 2000.

TMA products	# Duplexers	TMA downlink loss [dB]
RBS 2000 TMA 1800 Simplex	0	0
RBS 2000 TMA 1800 Duplex	1	0.3
RBS 2000 TMA 1800 Dual Duplex	2	0.3

With a TMA the receiver sensitivity will not be affected by the loss in the feeder as long as it does not exceed 4 dB. When the loss exceeds 4 dB the sensitivity decreases according to Table 10 (ref. 13). For example the sensitivity of CDU-A with a feeder loss of 8 dB between the RBS and the TMA would become –111.5 + 1.5 = -110 dBm at the TMA connector. For more information about how to use TMA, see ref. 14.

Table 10. Sensitivity deterioration when the loss between the TMA and the BTS exceeds 4 dB.

Loss [dB]	Sensitivity deterioration [dB]
≤ 4	0
6	0.5
8	1.5
10	2.5

3.4.4 TX Intermodulation products

Intermodulation products (IM) are created when two or more frequencies mix in for example antennas, combiners, connectors and duplex filters. IM products of order *n* have frequencies equal to the sums and differences in *n* terms of the original frequencies, see Figure 4.

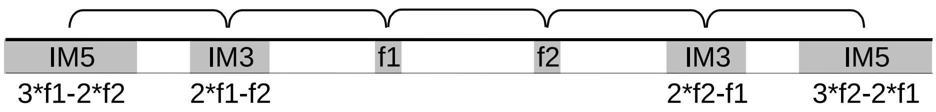

Figure 4. Examples of odd order IM products of two frequencies, f1 and f2.

The strength declines with higher order. Only IM products of 3rd and 5th orders need to be considered, therefore no products will fall into the RX band unless the separation of the TX frequencies is very large, see Table 11.

Table 11. Maximum band to avoid transmitter IM products of 3rd and 5th order in the RX band.

Duplex distance	**Maximum band – IM_3**	**Maximum band - IM_5**
95 MHz	47.3 MHz	31.37 MHz

For the Ericsson RBSs, IM3 products can only cause problems if two TRXs share combiner *and* duplex filter. In the combiner the two frequencies mix. The mixed frequencies can then create IM3 products in the duplex filter which then via the duplexer can leak into the receiver. These situations can occur in Ericsson RBS equipped with CDU-C, C+, D or F, RBS 2302 with the multicasting box and RBS 205 with duplex filters. For these configurations IM3 should be avoided by means of frequency planning.

For an Ericsson RBS equipped with CDU-A, RBS 205 without duplex filters and RBS 2302 without the multicasting box IM3 products will not cause any problems.

IM5 will not cause any problem unless external duplex or diplex filters not approved by Ericsson are used. Such filters may also create harmful IM3 products.

If the operator has such a large bandwidth and such equipment that IM products can be created, certain frequencies should not be mixed in the same cell.

Frequency planning rules to avoid harmful TX IM3, general case.

To avoid IM3 problems make sure IM3 products do not fall in the uplink band of any used frequency in the cell. The frequencies f1 < f2 < f3 could create the following potentially harmful IM3 products:

2f1-f2, 2f1-f3, f1+f2-f3, 2f2-f3

Where all products are ±300 kHz around the centre frequency. For example f1=1806 MHz, f2= 1807 MHz and f3 = 1854 MHz will create IM products at:

1805±0.3 MHz, 1758±0.3 MHz, 1759±0.3 MHz, 1760±0.3 MHz

As can be seen three potentially harmful IM3 products are created in this example. Note that one of the IM3 products hits 1759 MHz which is the uplink frequency corresponding to downlink frequency 1854 MHz. This means that the frequencies in the example actually should not be used together. As can be imagined the complexity of avoiding IM3 products will be very big when many frequencies are combined together.

Frequency planning rules to avoid harmful TX IM3 when only two frequencies are combined.

In the special situation when only *two frequencies are combined*, for example in RBSs with CDU-C or CDUC+, RBS 205 with one hybrid combiner or RBS2302 with multicasting box the problem of avoiding IM3 decreases tremendously. In these situations the only requirement is that:

$\Delta ARFCN \neq 237,238$ (ARFCN:Absolute Radio Frequency Channel Number)

for the two frequencies in the cell.

Frequency planning rules to avoid TX IM5 products hitting the uplink band.

To avoid IM5 (usually not a problem unless poor external filters are used), make sure that IM5 products do not fall in the uplink band of any used frequency in the cell. The frequencies f1 < f2 < f3 < f4 < f5 could create the following potentially harmful IM5 products:

3f1-2f2, 3f1-2f3, 3f1-2f4, 3f1-2f5, 3f1-f2-f3….. and so forth

In the IM5 case the products will be ±500 kHz around the centre frequency.

As is the case with IM3 the complexity decreases when only two frequencies are combined together. In this case the only requirement to avoid harmful IM5 products is:

$\Delta ARFCN \neq 157,158,159$

for the two frequencies in the cell.

3.4.5 Diversity

One way of reducing the influence of multipath fading in the uplink is to use antenna diversity. In the Ericsson GSM system this means that the signals from two RX branches are decoded and the most probable bit values are chosen on a bit per bit basis. The result of the method is equivalent to maximum likelihood estimation. The antenna diversity gain will depend on the correlation between the fading of two antenna signals as well as the efficiency in power reception of the two separate antennas. There are two different types of antenna diversity: *space diversity and polarization diversity*.

Space diversity means that two RX antennas positioned at a certain minimum distance from each other are used. Typically, space diversity improves the uplink by 3.5 dB. The separation required to obtain sufficient space diversity gain for various configurations and antennas is described in ref. 15 (also available at the Ericsson intranet: *http://gsmrbs.ericsson.se/RBS_Site_Solutions_Antenna_Systems/RBS_Antennas/Intranet/ant_mounting_guides.htm*).

Polarization diversity offers relief by allowing two space diversity antennas separated by several meters to be replaced by one dual polarized antenna. This antenna has normal size but contains two differently polarized antenna arrays.

It has been shown (see ref. 16) that due to different propagation characteristics the propagation loss for the horizontally polarized component is larger than for the vertical component. This consequence is that an extra “slant loss” margin of 1 dB must be added to the normal path loss when ±45°polarized antennas are used. However, a dual polarized antenna offers very low correlation in critical environments such as indoor and in-car. In these situations the diversity gain of polarization is about 1 dB better than space diversity. This is just enough to compensate for the slant loss. For simplicity the uplink slant loss is in this document included in the diversity gain. This means that for space as well as polarization diversity the uplink gain is 3.5 dB, and that no slant loss should be added to the uplink.

Space and polarization diversity gain	3.5 dB

In order to compensate for the downlink slant loss, 1 dB must be added to the downlink propagation loss.

Slant (±45°) polarization downlink loss	1 dB

3.4.6 Antennas

There are a large number of antenna types available. Antennas for macrocell use can have various widths and shapes of the radiation pattern, giving a large spread in gain. The vertical lobe can be down tilted, the antennas can be dual polarized in some way and they can be more or less broad banded.

The standard antenna for a three-sector site has a horizontal beam width of 65°. This means that the gain at 32.5° is 3 dB less than the maximum gain. At 60° it is suppressed typically 10 dB. The gain of a macrocell antenna is typically 15-18 dBi. Broader antennas with 90° and 105° horizontal beam widths are alternatives. However, the difference in shape of the coverage area is small but the gain is slightly lower for a certain antenna length. Omni antennas for 1800 MHz have a typical gain of 8-11 dBi.

All antennas used shall comply with the basic specifications, which can be found on the Ericsson intranet at:
http://gsmrbs.ericsson.se/RBS_Site_Solutions_Antenna_Systems/RBS_Antennas/Intranet/ant_basicspecs.htm

3.4.7 Antenna isolation

The isolation between two antennas is defined as the attenuation from the connector of one antenna to the connector of the other antenna.

To avoid unwanted signals into the receiver, the isolation should be at least 30 dB between the transmitting and receiving antenna and between two transmitting antennas.

To obtain the required isolation values, the antennas must be positioned at a certain minimum distance from each other. The distance depends on the antenna types and on the configuration, see ref. 15 (also available on the Ericsson intranet:
http://gsmrbs.ericsson.se/RBS_Site_Solutions_Antenna_Systems/RBS_Antennas/Intranet/ant_mounting_guides.htm)

3.4.8 Antenna tilting

Antenna tilting means that the main vertical beam of the antenna is directed towards a point below the horizon, so called downtilt. Tilting is used in cellular systems basically for two reasons: to improve coverage at small cell sites with high antenna positions and to improve co-channel interference. There are two different kinds of tilt: electrical and mechanical tilt.

Electrical tilt means an in-built tilt that lowers the vertical beam in all horizontal directions. The tilting angle is normally fixed. When using mechanical tilt, the antenna is mounted with adjustable brackets in a way that the antenna can be adjusted on site. Mechanical tilt is only used on directional antennas. It is also possible to combine these two tilt methods.

There are two rules of thumb regarding antenna tilting, see ref. 17:

- If a *maximum reduction in co-channel interference* is desired, the first notch in the vertical antenna pattern should be aimed towards the area where a reduction of interference is desired. This may however result in an undesired decrease in signal strength at the cell border.
- If a *minimum coverage reduction* is desired, then the antenna may be tilted until the vertical beam points towards the cell border. About 1° additional tilt may be used without any significant decrease in signal strength at the cell border. Thus tilting the antenna towards the cell border is a safe way of increasing the carrier to interference ratio (C/I), without jeopardising the coverage.

In ref. 18 there are some general recommendations for antenna tilting:

- There is no point in tilting an antenna less than the angle which gives a 3dB loss at the horizon. This corresponds to around 7° tilt for a 15 dBi antenna, and around 3.5° tilt for an 18 dBi antenna. A smaller tilt gives a limited impact and is hardly worth the effort.
- Study the antenna diagram carefully before selecting the tilt-angle. Most of the tilting effect happens between the angle corresponds to the 3 dB point towards the horizon, and the angle that corresponds to tilting the first null towards the horizon. For example 8° tilt gives far more than twice the effect compared to 4°.
- Avoid down tilting more than the angle that corresponds to having the first null towards the horizon. Further down tilting can be done in extreme cases, but if there is a need for further reduction of interference or cell size, a reduction of output power, or possibly lowering of the antenna height, should also be considered. Very large down tilts (beyond the first null towards the horizon) should be carefully verified since the effect of such large tilts is difficult to predict.
- Verify all the effects after having performed a down tilt of more than 8° (15 dBi antennas) or 4° (18 dBi antennas). Remember that it is just as important to check the coverage and quality in the down tilted cell, as the area where the down tilt is expected to reduce interference. Even if one problem is solved, a new problem might have occurred.

3.5 Repeaters

A repeater can cover areas that otherwise would have been blocked by obstacles. Fields of application are roads in hilly terrain, tunnels or other obstructed low capacity areas. Repeaters can also be used for indoor applications. The signal is typically amplified by 50-80 dB. However, a systematic use of repeaters in order to save base stations have not shown out to be effective. For more information about how to cell plan with repeaters, see ref. 19 and ref. 20.

Some repeater types can not be used together with dynamic BTS power regulation. They produce a constant output power at incoming signals exceeding a threshold and no power at all for signals below that threshold. The connection is lost when the down regulation has brought the signal below the threshold. With constant gain in the repeater instead, the down regulation stops automatically when quality suffers.

4 Cell coverage

Section 3 presents the sensitivity level for both the MS and the BTS. However, when planning a system it is not sufficient to use this sensitivity level as a planning criterion. Various margins have to be added in order to obtain the desired coverage. In this chapter these margins are discussed and the planning criteria to use in different types of environments are presented. Furthermore the principles of how to perform coverage acceptance tests are described.

4.1 Definitions

Required signal strength

To the sensitivity level of an MS, margins have to be added to compensate for Rayleigh fading, interference and body loss. The obtained signal strength is what is required to perform a phone call in a real-life situation and will be referred to as SS_{req}. SS_{req} is independent of the environment.

$$SS_{req} = MS_{sens} + RF_{marg} + IF_{marg} + BL \qquad (1)$$

where

MS_{sens} = MS sensitivity, Section 3.3.
RF_{marg} = Rayleigh fading margin, Section 4.2.1.
IF_{marg} = Interference margin, Section 4.2.3.
BL = Body loss, Section 4.2.4.

Design level

Extra margins have to be added to SS_{req} to handle the log-normal fading as well as different types of penetration losses. These margins depend on the environment and on the desired area coverage. The obtained signal strength is what should be used when planning the system and it will be referred to as the design level, SS_{design}. This signal strength is the value that should be obtained on the cell border when planning with prediction tools like EET/TCP.

The design level can be calculated from:

$SS_{design} = SS_{req} + LNF_{marg(o)}$	MS outdoor	(2)
$SS_{design} = SS_{req} + LNF_{marg(o)} + CPL$	MS in-car	(3)
$SS_{design} = SS_{req} + LNF_{marg(o+i)} + BPL_{mean}$	MS indoor	(4)

where

$LNF_{marg(o)}$ = Outdoor log-normal fading margin, Section 4.2.2
$LNF_{marg(o+i)}$ = Outdoor + indoor log-normal fading margin, Section 4.2.2
CPL = Car penetration loss, Section 4.2.5
BPL_{mean} = Mean building penetration loss, Section 4.3.2

4.2 Margins

4.2.1 Rayleigh fading

Rayleigh fading is due to multipath interference and occurs especially in urban environments where there is high probability of blocked sight between transmitter and receiver. The distance between two adjacent fading dips is approximately $\lambda/2$.

The required sensitivity performance of GSM in terms of FER, BER or RBER is specified for each type of channel and at different fading models (called channel models). The channel models reflect different types of propagation environment and different MS speeds. The sensitivity is measured under simulated Rayleigh fading conditions for all the different channel models and the sensitivity is defined as the level where the required quality performance is achieved. In a noise limited environment the sensitivity is the one listed in Chapter 1. This would mean that Rayleigh fading is already taken into consideration in the sensitivity definition.

However, the GSM specification allows worse quality for slow MSs (3 km/h) than for fast moving MSs. The sensitivity performance at fading conditions corresponding to an MS speed of 50 km/h in an urban environment (called TU50[2]), is in accordance with good speech quality, while the sensitivity performance for slow MSs at TU3[2] does not correspond to acceptable speech quality.

In order to obtain good speech quality even for slow mobiles, an extra margin, RF_{marg}, is recommended when planning. From experience, 3 dB margin seems adequate. In a frequency hopping system the Rayleigh fading dips are levelled out and there should be no need for a Rayleigh fading margin. But since a Broadcast Control Channel (BCCH) never hops, the Rayleigh fading margin is recommended in cell coverage estimations, regardless of using frequency

[2] TU50 = Typical Urban 50 km/h, TU3 = Typical Urban 3 km/h

hopping or not. Also antenna diversity reduces the effect of Rayleigh fading but in a different way than frequency hopping. Therefore, diversity gain is still relevant in frequency hopping systems. (For simplicity the diversity gain figure is considered independent of frequency hopping and MS speed distribution).

Rayleigh fading margin (RF_{marg}) = 3 dB

4.2.2 Log-normal fading

The signal strength value computed by wave propagation algorithms can be considered as a mean value of the signal strength in a small area with a size determined by the resolution and accuracy of the model. Assumed that the fast fading is removed, the local mean value of the signal strength fluctuates in a way not considered in the prediction algorithm. This deviation of the local mean in dB compared to the predicted mean has nearly a normal distribution. Therefore this variation is called log-normal fading.

The received signal strength is a random process and it is only possible to estimate the probability that the received signal strength exceeds a certain threshold. In the result from a prediction in for example EET or TCP, 50% of the locations (for example at the cell borders) can be considered to have a signal strength that exceeds the predicted value. In order to plan for more than 50% probability of signal strength above the threshold, a log-normal fading margin, LNF_{marg}, is added to the threshold during the design process.

Jakes' formulas

A common way to calculate LNF_{marg} is to use Jakes' formulas, ref. 21. In Jakes' formulas a simple radial path loss dependence ($1/r^n$) is assumed in order to calculate the **percentage of area** within an omni-cell with signal strength exceeding a certain threshold. The threshold is related to the **percentage of locations at the cell border** that have a signal that exceeds the same threshold. The border coverage corresponding to desired area coverage is given when the threshold referred to is the required signal strength in the MS. The margin in dB (LNF_{marg}) to go from the original 50% coverage at the cell border to the given border percentage is **x*Standard deviation**. x is the variable in the cumulative normal function F(x) when F(x) has the value of the border percentage given by Jakes formulas, see also ref. 22. Curves of Jakes formulas and F(x) are shown in Appendix 1.

Simulation of log-normal fading margin in a multi-cell environment

A disadvantage with Jakes' formulas is that it does not take the effect of many servers into account. The presence of many servers at the cell borders will reduce the required log-normal margin. This is because the fading patterns of different servers are fairly independent. If the signal from one server fades down below the sensitivity level a neighbour cell can fill out the gap and rescue the connection.

In order to find the log-normal fading margins in a multi-cell environment, simulations have been performed, see ref. 23 and Appendix 2.

The prerequisites for the simulations have been:

- 3 sectored sites
- correlation of log-normal fading between one MS and different BSs is 0.5
- lognormal fading correlation distance is 28.85 m
- the time to perform a handover is 0.5 s

The propagation environment is modeled with the Okumura-Hata formula as follows:

$L_{path} = A + 10\,\alpha\,\log d$ [dB] where A=15.3 and α =3.76,d[m].

Five different environments (σ_{LNF} = 6, 8, 10, 12, 14) have been studied. The used handover hysteres in the simulations is 3dB. In order to find the required value of LNF_{marg}:

1. Choose the curve corresponding to fading environment in question .
2. On the X-axis, find the log-normal fading margin for the desired area coverage (Y-axis).

Log-normal fading margins

Below the size of the log-normal fading margin is given for different types of fading environments and area coverage. The values originate from the simulations described above. A multi-cell environment with a handover hysteresis of 3 dB is assumed.

Table 12. Log-normal fading margins (LNF_{marg}) in dB for different environments.

	Coverage [%]				
σ_{LNF} [**dB**]	**75**	**85**	**90**	**95**	**98**
6	-3.7	-1.2	0.5	3.0	5.5
8	-3.4	-0.2	1.8	4.9	8.1
10	-3.1	0.7	3.2	6.8	10.7
12	-3.1	1.3	4.2	8.4	13.1
14	-3.2	1.8	5.1	9.9	15.3

These values are then used in Table 14 and Table 16, where design levels for various area types and coverage requirements are calculated.

4.2.3 Interference

The plain receiver sensitivity depends on the required carrier to noise ratio (C/N). When frequencies are reused, the received carrier power must be large enough to combat both noise and interference, that means C/(N+I) must exceed the receiver threshold. In order to get an accurate coverage prediction in a busy system, an interference margin (IF_{marg}) is defined.

The interference margin depends on the frequency reuse, the traffic load, the desired percentage of area coverage and whether the uplink or the downlink is considered. Frequency hopping, dynamic power control and DTX reduce the interference level. In a normal system an interference margin of 2 dB is recommended.

Interference margin (IF_{marg}) = 2 dB

4.2.4 Body loss

The human body has several effects on the MS performance compared to a free standing mobile phone.

1. The head absorbs energy.
2. The antenna efficiency of some MSs can be reduced.
3. Other effects may be a change of the lobe direction and the polarization. These effects can be neglected in the link budget since 1) no mobile antenna gain is used and 2) X-polarized antennas are standard equipment today. In this case the polarization loss is included in the downlink link budget and in the uplink, both polarizations can be received.

The body loss recommended by ETSI, ref. 20, is 3 dB for 1800 MHz.

Body loss (BL) = 3 dB

4.2.5 Car penetration loss

When the MS is situated in a car without external antenna, an extra margin has to be added in order to cope with the penetration loss of the car. This extra margin is approximately 6 dB, see ref. 24.

Car penetration loss (CPL) = 6 dB

4.3 Design levels

In this section the design levels, SS_{design}, are calculated for outdoor, in-car and indoor coverage. As described in Section 4.1, this signal strength is calculated as the sum of the required signal strength, SS_{req} and various margins, see Equations (2), (3) and (4). In this section, the value of SS_{req} has been taken to be:

$$SS_{req} = MS_{sens} + RF_{marg} + IF_{marg} + BL = -104 + 3 + 2 + 3 = \mathbf{-96\ dBm} \qquad (5)$$

4.3.1 Outdoor and in-car coverage

The design levels for outdoor and in-car coverage are calculated according to:

$SS_{design} = SS_{req} + LNF_{marg(o)}$ MS outdoor

$SS_{design} = SS_{req} + LNF_{marg(o)} + CPL$ MS in-car

where $LNF_{marg(o)}$ is the log-normal fading margin that is needed to handle the outdoor log-normal fading. This fading will be represented by its standard deviation $\sigma_{LNF(o)}$ and depends on the area type. Typical values of $\sigma_{LNF(o)}$ are presented in Table 13.

Table 13. Typical values of the standard deviation of the outdoor log-normal fading for different area types.

Area type	$\sigma_{LNF(o)}$ **[dB]**
Dense urban	10
Urban	8
Suburban	6
Rural	6

In Table 14 the design levels SS_{design}, for different area types and coverage requirements are calculated. The value of $LNF_{marg(o)}$ is calculated according to the simulations in Appendix 2 which includes the multi-server gain, see also Section 4.2.2. A hysteresis value of 3 dB between the cells has been used.

Table 14. Design levels for various area types and coverage requirements. A car penetration loss (CPL) of 6 dB has been used.

Area type	Coverage [%]	SS_{req} [dBm]	$LNF_{marg(o)}$ [dB]	SS_{design} outdoor [dBm]	SS_{design} in-car [dBm]
Dense urban $\sigma_{LNF(o)}$ = 10 dB	75	-96	-3.1	**-99.1**	**-93.1**
	85	-96	0.7	**-95.3**	**-89.3**
	90	-96	3.2	**-92.8**	**-86.8**
	95	-96	6.8	**-89.2**	**-83.2**
	98	-96	10.7	**-85.3**	**-79.3**
Urban $\sigma_{LNF(o)}$ = 8 dB	75	-96	-3.4	**-99.4**	**-93.4**
	85	-96	-0.2	**-96.2**	**-90.2**
	90	-96	1.8	**-94.2**	**-88.2**
	95	-96	4.9	**-91.1**	**-85.1**
	98	-96	8.1	**-87.9**	**-81.9**
Suburban + rural $\sigma_{LNF(o)}$ = 6 dB	75	-96	-3.7	**-99.7**	**-93.7**
	85	-96	-1.2	**-97.2**	**-91.2**
	90	-96	0.5	**-95.5**	**-89.5**
	95	-96	3.0	**-93**	**-87**
	98	-96	5.5	**-90.5**	**-84.5**

4.3.2 Indoor coverage

Definitions

Indoor coverage
By indoor coverage is understood the percentage of the ground floors of all the buildings in the area where the signal strength is above the required signal level of the mobiles, SS_{req}.

Building penetration loss
Building penetration loss is defined as the difference between the average signal strength immediately outside the building and the average signal strength over the ground floor of the building, see for instance ref. 25 and ref. 26. The building penetration loss for different buildings is log-normally distributed with a standard deviation; σ_{BPL}.

Variations of the loss over the ground floor could be described by a stochastic variable, which is log-normally distributed with a zero mean value and a standard deviation of σ_{floor}.

In this document σ_{BPL} and σ_{floor} is lumped together by adding the two as were they standard deviations in two independent log-normally distributed processes. The resulting standard deviation, σ_{indoor} or $\sigma_{LNF(i)}$, could be calculated as the square root of the sum of the squares.

General

Indoor coverage in this document is about calculation of a required margin to achieve a certain indoor coverage in a fairly large area; large compared to the average macrocell size. It is assumed that it is the macrocells in the area that provides the major part of the indoor coverage. Hotspot microcells in the area will of course improve on the indoor coverage but that effect is not covered in this document.

The guidelines in this document regarding indoor coverage are not applicable to the case where the area of interest basically is covered by contiguous microcells and where macrocells only are used as umbrella cells.

It is common knowledge that the building penetration loss to floors higher up in the building in general decreases. This effect is known as height gain. This is actually an effect of the building penetration loss definition and not of the building structure.

Indoor design level

The indoor design level is calculated according to (see Section 4.1):

$SS_{design} = SS_{req} + LNF_{marg(o+i)} + BPL_{mean}$ MS indoor

where the sum of BPL_{mean} and $LNF_{marg(o+i)}$ can be seen as the indoor margin. BPL_{mean} is the mean value of the building penetration loss and $LNF_{marg(o+i)}$ is the margin that is required to handle the total log-normal fading which are composed of both the outdoor log-normal fading ($\sigma_{LNF(o)}$) and the indoor log-normal fading $\sigma_{LNF(i)}$.The total standard deviation of the log-normal fading is given by:

$$\sigma_{LNF(o+i)} = (\sigma_{LNF(o)}^2 + \sigma_{LNF(i)}^2)^{1/2} \qquad (6)$$

In Table 15 some values of $BPL_{mean,}$ $\sigma_{LNF(o)}$ and $\sigma_{LNF(i)}$ are presented. These figures are based on values presented in ref. 26 to ref. 30 and on experience. Note that the characteristics of different urban, suburban etc. environments can differ quite a lot over the world. Thus the values in Table 15 must be treated with restraint. They should be considered as a reasonable approximation when no other information is obtainable. Rural areas are not considered in Table 15, since they are usually not designed for indoor coverage.

Table 15. Some typical values of building penetration loss, and log-normal fading for different area types. These figures are based on values presented in ref. 26 to ref. 30 and on experience.

	BPL_{mean} [dB]	**$\sigma_{LNF(o)}$ [dB]**	**$\sigma_{LNF(i)}$ [dB]**	**$\sigma_{LNF(o+i)}$ [dB]**
Dense urban	18	10	9	14
Urban	18	8	9	12
Suburban	12	6	8	10

In Table 16 the design levels required to obtain 75%, 85%, 90%, 95% and 98% indoor coverage are given.

The parameters for the building penetration and the log-normal fading are taken to be those presented in Table 15.

The log-normal fading margins are given by the simulations in Appendix 2, see also Section 4.2.2. A multi cell environment has been assumed with a hysteresis value of 3 dB.

Table 16. Indoor design level for various area types and coverage requirements.

Area type	Coverage [%]	SS_{req} [dBm]	$LNF_{marg(o+i)}$ [dB]	BPL_{mean} [dB]	SS_{design} in door [dBm]
Dense urban $\sigma_{LNF(o+i)}$ = 14 dB	75	-96	-3.2	18	**-81.2**
	85	-96	1.8	18	**-76.2**
	90	-96	5.1	18	**-72.9**
	95	-96	9.9	18	**-68.1**
	98	-96	15.3	18	**-62.7**
Urban $\sigma_{LNF(o+i)}$ = 12 dB	75	-96	-3.1	18	**-81.1**
	85	-96	1.3	18	**-76.7**
	90	-96	4.2	18	**-73.8**
	95	-96	8.4	18	**-69.6**
	98	-96	13.1	18	**-64.9**
Suburban $\sigma_{LNF(o+i)}$ = 10 dB	75	-96	-3.1	12	**-87.1**
	85	-96	0.7	12	**-83.3**
	90	-96	3.2	12	**-80.8**
	95	-96	6.8	12	**-77.2**
	98	-96	10.7	12	**-73.3**

4.4 Coverage acceptance test

4.4.1 General

The verification of a cell plan is done by performing measurements in the system. The aim is to measure the signal strengths and to estimate if the received level corresponds to the required signal strength $SS_{req.}$ The recommended equipment to use in acceptance tests is a TEMS mobile phone with rooftop antenna. This equipment shall be used in all acceptance cases below.

In order to be connected to the best server as much as possible during the acceptance test a pure signal strength ranking, K-ranking, shall be used in the locating algorithm. In addition a small handover hysteresis, for example 3 dB shall be used. Power Control downlink shall also be switched off.

Compensation should be made for different objects affecting the measured values, e.g. feeder loss and antenna gain in the external antenna.

4.4.2 Outdoor

The acceptance level to verify is the required signal strength SS_{req} for outdoor coverage. This level should be measured at least in A % of the samples, where A represents the required area coverage.

Example 1. 95% outdoor coverage.

Criteria for downlink signal strength	Rural, 95% outdoor coverage
Acceptance level, (SS_{req}) dBm or better in 95 % of the samples	**-96**

4.4.3 In-car

The acceptance level to verify is the required signal strength SS_{req} for in-car coverage. This level should be measured at least in A % of the samples, where A represents the required area coverage.

Example 2. 95% in-car coverage

Criteria for downlink signal strength	Rural, 95% in-car coverage
Acceptance level, (SS_{req}) dBm or better in 95 % of the samples	**-90**

4.4.4 Indoor

To verify indoor coverage, subtract the *outdoor* log-normal fading margin $LNF_{marg(o)}$ corresponding to the desired coverage (A%) from the SS_{design} value. This level should be measured at least in A % of the samples.

Example 3. 95 % indoor coverage

Criteria for downlink signal strength	Urban, 95% indoor coverage
SS_{design} [dBm]	-70
Acceptance level, (SS_{design}- $LNF_{marg(o)}$ dBm) or better in 95 % of the samples	**-75**

5 Cell planning

5.1 Wave propagation models for estimation

When roughly estimating the cell coverage, without respect to specific terrain features in the area, a fairly simple propagation algorithm can be used. That means the diffraction loss due to “knife edge” and “spherical earth” can be ignored.

The signal is attenuating more rapidly in a 1800 MHz system than for a 900 MHz system. A simple empirical model, based on the original Okumura-Hata algorithm, has been derived (ref. 31). The equation below describes the propagation loss L_{path}:

$$L_{path} = A - 13.82\log HB + (44.9 - 6.55\log HB)\log R - a(HM) \quad [dB] \qquad (7)$$

where

A	= 153.8	urban areas
A	= 146.2	suburban and semi open areas
A	= 134.1	rural areas
A	= 124.3	open areas
HB	= base station antenna height [m]	
R	= distance from transmitter [km]	
HM	= mobile station antenna height [m]	
a(HM)	= $3.2(\log 11.75HM)^2 - 4.97$	
a (1.5)	= 0	

The cell range is the distance R corresponding to maximum allowed path loss $L_{pathmax}$. According to Okumura-Hata the range is:

$$R = 10^{\alpha}, \text{ where } \alpha = [L_{pathmax} - A + 13.82\log HB + a(HM)]/[44.9 - 6.55\log HB] \qquad (8)$$

For small cells in an urban environment the cell range is typically less than 1 km and in that case the Okumura-Hata algorithm is not valid. The COST 231-Walfish-Ikegami model, (ref. 32, ref. 33) gives a better approximation for the cell radius in urban environments. The path loss according to Walfish-Ikegami is:

$L_{path} = 153.2 + 38\log R - 18\log(HB - 17)$ [dB]	(9)

According to Walfish-Ikegami, the cell range is:

$R = 10^{\alpha}$, where $\alpha = [L_{pathmax} - 153.2 + 18\log(HB - 17)]/38$	(10)

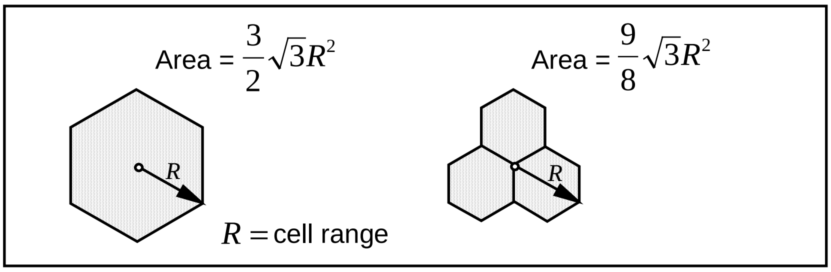

Figure 5. Relation between coverage area and cell range.

5.2 Power budget

Path balance implies that the coverage of the downlink is equal to the coverage of the uplink. The power budget shows whether the uplink or the downlink is the weak link. When the downlink is stronger, the EIRP used in the prediction should be based on the balanced BTS output power. When the uplink is stronger, the maximum BTS output power is used instead. Practice indicates that in cases where the downlink is the stronger it is advantageous to have a somewhat (2-3 dB) higher base EIRP than the one strictly calculated from power balance considerations. This is because the diversity gain sometimes exceeds 3.5 dB.

In the calculations below the antenna gain in the MS and the MS feeder loss are both zero and therefore omitted. It is also assumed that the antenna gain and the feeder loss are the same for the transmitter and receiver side of the BTS.

Following abbreviations are used:

Pin_{MS}	= Received power in MS	[dBm]
MS_{sens}	= Sensitivity MS	[dBm]
Pin_{BTS}	= Received power in BTS	[dBm]
BTS_{sens}	= Sensitivity BTS	[dBm]
$Pout_{MS}$	= MS maximum transmitted power	[dBm]
$Pout_{BTS}$	= BTS transmitted power	[dBm]
$Pout_{bal}$	= BTS balanced transmitted power	[dBm]
L_{f+j}	= Feeder and jumper loss at BTS	[dB]
L_{dupl}	= External duplex loss at BTS	[dB]
L_{slant}	= Slant polarisation (±45°) downlink loss	[dB]
L_{TMA}	= Duplex loss at TMA	[dB]

L_{path}	= Path loss between MS and BTS	[dB]
G_{ant}	= Antenna gain in BTS	[dBi]
G_{div}	= Diversity gain in BTS	[dB]
Δ_{sens}	= $MS_{sens} - BTS_{sens}$	[dB]

Downlink budget:

Downlink (DL) is the direction from the BTS to the MS. The downlink budget gives the power level received in the MS.

Uplink budget:

Uplink (UL) is the direction from the MS to the BTS. The uplink budget gives the power level received in the base station.

5.3 Power balance

5.3.1 Power balance with TMA at the antenna

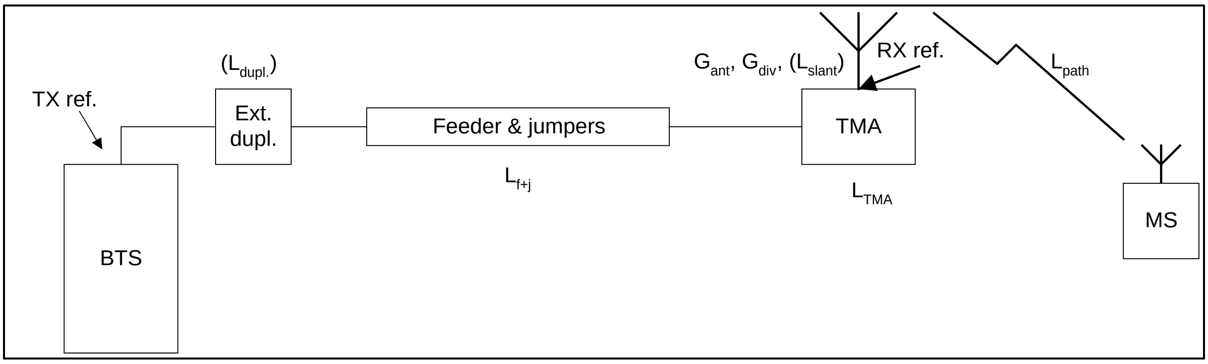

Figure 6. System with TMA at the antenna. L_{dupl} should only be taken into account if an external duplexer is used. L_{slant} should only betaken into account if ±45° polarized TX antennas are used.

DL:	$Pin_{MS} = Pout_{BTS} - L_{f+j} - (L_{dupl}) - L_{TMA} + G_{ant} - (L_{slant}) - L_{path}$	(11)
UL:	$Pin_{BTS} = Pout_{MS} - L_{path} + G_{ant} + G_{div}$	(12)

Pin_{BTS} is referenced to RX ref. point and $Pout_{BTS}$ is referenced to TX ref. point.

Assuming that the path loss is reciprocal, i.e. $L_{pathUL} = L_{pathDL}$. Then (11) and (12) give:

$$Pout_{BTS} = Pout_{MS} + G_{div} + L_{f+j} + L_{TMA} + L_{dupl} + (L_{slant}) + Pin_{MS} - Pin_{BTS}$$

A balanced system is obtained when $Pin_{MS} = Pin_{BTS} + \Delta_{sens}$, where $\Delta_{sens} = MS_{sens} - BTS_{sens}$.

$$Pout_{bal} = Pout_{MS} + G_{div} + L_{f+j} + L_{TMA} + (L_{dupl}) + (L_{slant}) + \Delta_{sens} \qquad (13)$$

The corresponding EIRP is given by:

$$EIRP = Pout_{bal} - L_{f+j} - (L_{dupl}) - L_{TMA} + G_{ant} - (L_{slant}) \qquad (14)$$

Example with TMA:

In Table 17 the balanced BTS output power for RBS 2000 equipped with CDU-A, TMA, and ±45° polarized antenna is calculated. No software power boost is used. The calculation is done according equation (13).

Table 17. Balanced BTS output power at TX reference point.

	MS class 1	**MS class 2**
$Pout_{MS}$ [dBm]	30	24
G_{div} [dB]	3.5	3.5
L_{f+j} [dB]	3	3
L_{dupl} [dB]	-	-
L_{TMA} [dB]	0.3	0.3
L_{slant} [dB]	1	1
Δ_{sens} [dB]	-104-(-111.5) = 7.5	-104-(-111.5) = 7.5
$Pout_{bal}$ [dB]	**45.3**[1]	**39.3**

[*] The maximum output power for RBS 2000 equipped with CDU-A is 43.5 dBm, thus in this example the uplink will be stronger than the downlink.

5.3.2 Power balance without TMA

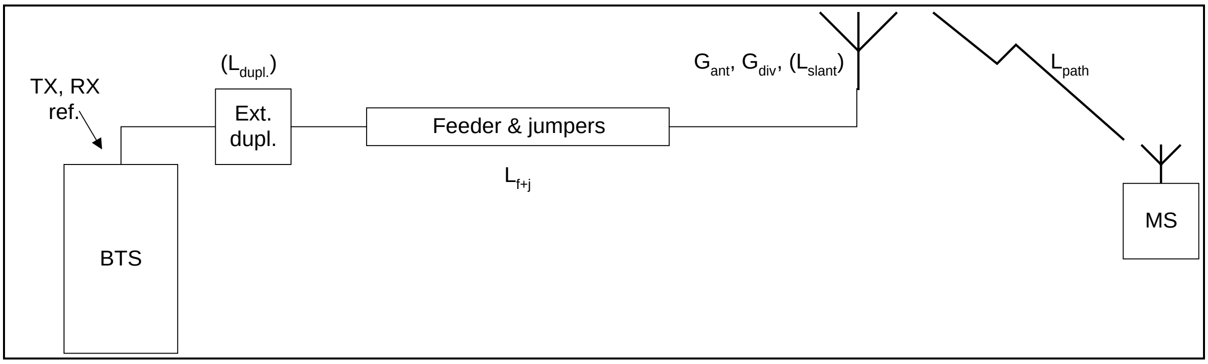

Figure 7. System without TMA at the antenna. L_{dupl} should only be taken into account if an external duplexer is used. L_{slant} should only be taken into account if ±45° polarized TX antennas are used.

DL:	$Pin_{MS} = Pout_{BTS} - (L_{dupl}) - L_{f+j} + G_{ant} - (L_{slant}) - L_{path}$	(15)
UL:	$Pin_{BTS} = Pout_{MS} - L_{path} + G_{ant} + G_{div} - L_{f+j} - (L_{dupl})$	(16)

Pin_{BTS} and $Pout_{BTS}$ is the power in the TX and RX ref. point.

Assuming that the path loss is reciprocal, i.e. $L_{pathUL} = L_{pathDL.}$ Then 15 and (16) give:

$$Pout_{BTS} = Pout_{MS} + G_{div} + (L_{slant}) + Pin_{MS} - Pin_{BTS}$$

A balanced system is obtained when $Pin_{MS} = Pin_{BTS} + \Delta_{sens}$, where $\Delta_{sens} = MS_{sens} - BTS_{sens}$.

$$Pout_{bal} = Pout_{MS} + G_{div} + (L_{slant}) + \Delta_{sens} \qquad (17)$$

The corresponding EIRP is given by:

$$EIRP = Pout_{bal} - (L_{dupl}) - L_{f+j} + G_{ant} - (L_{slant}) \qquad (18)$$

Example without TMA:

In Table 18 the balanced BTS output power for RBS 2000 equipped with CDU-A, and ±45° polarized antenna is calculated. The calculation is done according to equation (17). As can be seen the uplink is much weaker compared to the example with TMA.

Table 18. Balanced BTS output power at TX reference point.

	MS class 1	MS class 2
$Pout_{MS}$ [dBm]	30	24
G_{div} [dB]	3.5	3.5
L_{slant} [dB]	1	1
Δ_{sens} [dB]	-104-(-110) = 6	-104-(-110) = 6
$Pout_{bal}$ [dB]	**40.5**	**34.5**

5.4 Cell size

The maximum allowed path loss ($L_{pathmax}$) can be calculated from the downlink power budget:

$$L_{pathmax} = EIRP - SS_{design} \quad (19)$$

Once the maximum allowed path loss has been calculated, the approximate cell size can be found by using one of the wave propagation models in Section 5.1.

Table 20 and Table 21 show the calculated cell range, R, for 95% area coverage and for the macrocell case. The allowed path loss, $L_{pathmax}$, corresponds to outdoor path loss, for power balance according to the class 1 MS in the Example with TMA, Section 5.3.1. R is calculated with equation (8).

Table 19. Assumptions for the cell sizes calculated in the tables below.

EIRP	55.7 dBm sector (17 dBi antenna, X polarized) 51,2 dBi omni (11 dBi antenna, Ver. polarized)
Design level (SS_{design})	See Table 14 in Section 4.3.1 and Table 16 in Section 4.3.2.
Height of MS (HM)	1.5 m
Height of BTS antenna (HB)	30 m

Table 20. Cell sizes for sector cell, 95% area coverage.

MS class	Area	Outdoor		In-car		Indoor	
		$L_{pathmax}$	**R** [km]	$L_{pathmax}$	**R** [km]	$L_{pathmax}$	**R** [km]
class 1 30 dBm (1 W)	urban	146.7	**2.4**	140.7	**1.6**	125.7	**0.6**
	suburban	148.7	**4.5**	142.7	**3.0**	133.7	**1.7**
	rural	148.7	**9.9**	142.7	**6.7**	133.7	**3.7**
	open area	148.7	**18.7**	142.7	**12.6**	133.7	**7.0**

Table 21. Cell sizes for omni cell, 95% area coverage.

MS class	Area	Outdoor		In-car		Indoor	
		$L_{pathmax}$	**R** [km]	$L_{pathmax}$	**R** [km]	$L_{pathmax}$	**R** [km]
class 1 30 dBm (1 W)	urban	142.2	**1.8**	136.2	**1.2**	121.2	**0.5**
	suburban	144.2	**3.3**	138.2	**2.3**	129.2	**1.3**
	rural	144.2	**7.3**	138.2	**5.0**	129.2	**2.8**
	open area	144.2	**13.9**	138.2	**9.4**	129.2	**5.2**

When determining the cell range for small cells in urban environments, the Walfish-Ikegami model is recommended. 95 % coverage area is considered and the allowed path loss, $L_{pathmax}$, corresponds to outdoor path loss, for power balance according to the class 1 MS in the Example with TMA, Section 5.3.1. The following assumptions are made:

Table 22. Assumptions for the cell size for a small cell in an urban environment, 95% indoor coverage

EIRP	55.7 dBm sector (17 dBi antenna, X polarized)
Design level (SS_{design})	-70 dBm, see Table 16.
Height of MS (HM)	1.5 m
Height of BTS antenna (HB)	22 m

Cell size (R) = 400 m

6 References

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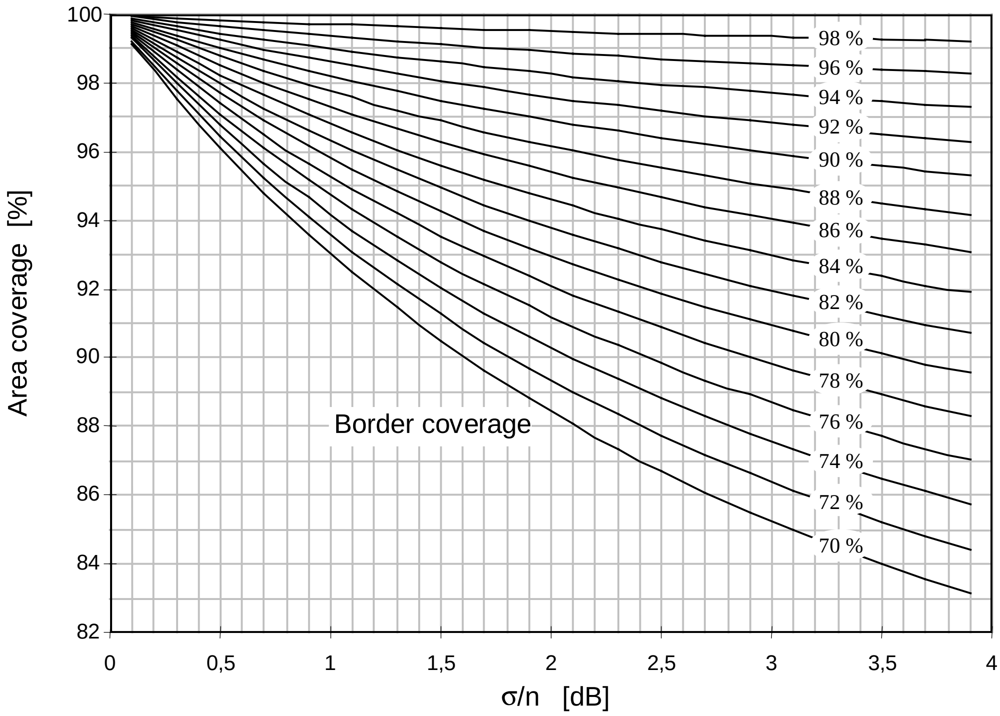
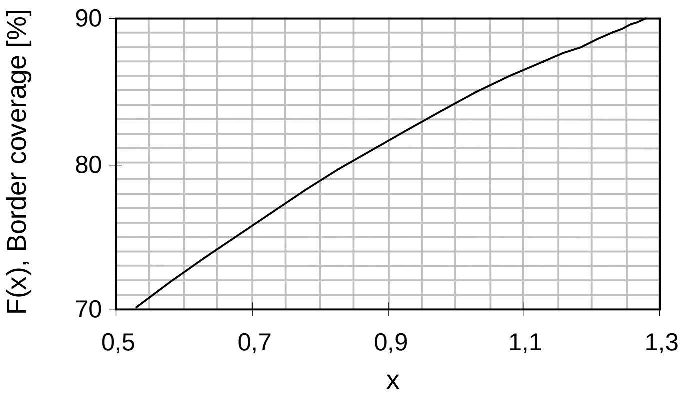
Curves of Jakes formula

σ = standard deviation

$\frac{1}{R^n}$ = distance dependence



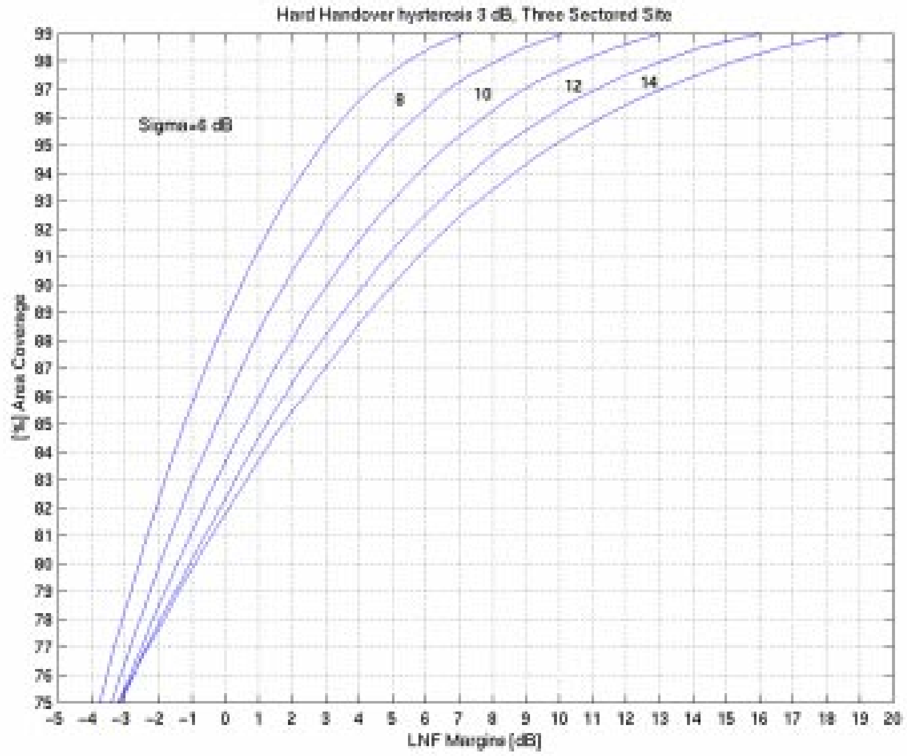
Cumulative normal function



Log-normal fading margin $= x \times \sigma -$ HO gain

Simulated log-normal fading margins

Hysteresis = 3 dB
Log-normal fading correlation, one MS to different BSs = 0.5
Propagation = 15.3 + 37.6log(d)
Handover delay 0.5s



Quick Reference - Cell planning, GSM 1800

RBS Equipment

Output power, sensitivity and minimum carrier separation of RBS 2000.

CDU/RBS	Output power [dBm]	Sensitivity [dBm]	Minimum carrier separation [kHz]
A	43.5	-110	400
C	40	-110	400
C+	40	-110	400
D	41	-110	1000
RBS 2302	33	-106	400

Output power, sensitivity and minimum carrier separation of RBS 205.

Combiner type	Output power [dBm]	Sensitivity without TMA [dBm]	Minimum carrier separation [kHz]
Filter (1-8 TX)	40	-106	1200
Hybrid (2 TX)	39.5	-106	400
3 x Hybrid (3-4 TX)	36	-106	400

Equipment characteristics of Maxite™.

Maxite™ Product	Antenna	Diversity gain	Slant loss	Output power	Sensitivity	Minimum carrier separation
Maxite 500 W	17.5 dBi	3.5 dB	1 dB	40 dBm	-111 dBm	400 kHz

Mobile Station

MS power classes.

MS power class	Output power [dBm]	Sensitivity [dBm]
1	30	-104
2	24	-104

Miscellaneous

Feederloss

Feeder type	Attenuation [dB/100m]
LCF 1/2”	10.5
LCF 7/8”	6.5
LCF 1-1/4”	5.3
LCF 1-5/8”	4.2

Other losses.

Type of loss	Typical loss
Jumper loss	0.5 dB per jumper
connector	0.1 dB per connector
External duplex loss	0.5 dB
External diplex loss	0.3 dB
±45° polarization downlink loss	1 dB

Diversity gain

Space and polarization diversity gain	3.5 dB

Margins

Rayleigh fading margin .

Rayleigh fading margin (RF_{marg}) = 3 dB

Log-normal fading margins (LNF_{marg}) in dB in different environments.

	Coverage [**%**]				
σ_{LNF} [**dB**]	**75**	**85**	**90**	**95**	**98**
6	-3.7	-1.2	0.5	3.0	5.5
8	-3.4	-0.2	1.8	4.9	8.1
10	-3.1	0.7	3.2	6.8	10.7
12	-3.1	1.3	4.2	8.4	13.1
14	-3.2	1.8	5.1	9.9	15.3

Interference margin.

Interference margin (IF_{marg}) = 2 dB

Body loss

Body loss (BL) = 3 dB

Car penetration loss

Car penetration loss (CPL) = 6 dB

Design levels

Design levels for various area types and coverage requirements.

Area type	**Coverage** [%]	SS_{req} [dBm]	$LNF_{marg(o)}$ [dB]	SS_{design} outdoor [dBm]	SS_{design} in-car [dBm]
Dense urban $\sigma_{LNF(o)}$ = 10 dB	75	-96	-3.1	**-99.1**	**-93.1**
	85	-96	0.7	**-95.3**	**-89.3**
	90	-96	3.2	**-92.8**	**-86.8**
	95	-96	6.8	**-89.2**	**-83.2**
	98	-96	10.7	**-85.3**	**-79.3**
Urban $\sigma_{LNF(o)}$ = 8 dB	75	-96	-3.4	**-99.4**	**-93.4**
	85	-96	-0.2	**-96.2**	**-90.2**
	90	-96	1.8	**-94.2**	**-88.2**
	95	-96	4.9	**-91.1**	**-85.1**
	98	-96	8.1	**-87.9**	**-81.9**
Suburban + rural $\sigma_{LNF(o)}$ = 6 dB	75	-96	-3.7	**-99.7**	**-93.7**
	85	-96	-1.2	**-97.2**	**-91.2**
	90	-96	0.5	**-95.5**	**-89.5**
	95	-96	3.0	**-93**	**-87**
	98	-96	5.5	**-90.5**	**-84.5**

Indoor design level for various area types and coverage requirements.

Area type	**Coverage** [%]	**SS_{req}** [dBm]	**$LNF_{marg(o+i)}$** [dB]	**BPL_{mean}** [dB]	**SS_{design} in door** [dBm]
Dense urban $\sigma_{LNF(o+i)}$ = 14 dB	75	-96	-3.2	18	**-81.2**
	85	-96	1.8	18	**-76.2**
	90	-96	5.1	18	**-72.9**
	95	-96	9.9	18	**-68.1**
	98	-96	15.3	18	**-62.7**
Urban $\sigma_{LNF(o+i)}$ = 12 dB	75	-96	-3.1	18	**-81.1**
	85	-96	1.3	18	**-76.7**
	90	-96	4.2	18	**-73.8**
	95	-96	8.4	18	**-69.6**
	98	-96	13.1	18	**-64.9**
Suburban $\sigma_{LNF(o+i)}$ = 10 dB	75	-96	-3.1	12	**-87.1**
	85	-96	0.7	12	**-83.3**
	90	-96	3.2	12	**-80.8**
	95	-96	6.8	12	**-77.2**
	98	-96	10.7	12	**-73.3**

BTS output power for system balance with TMA at the antenna.

$Pout_{bal} = Pout_{MS} + G_{div} + L_{f+j} + L_{TMA} + (L_{dupl}) + (L_{slant}) + \Delta_{sens}$

$EIRP = Pout_{bal} - L_{f+j} - (L_{dupl}) - L_{TMA} + G_{ant} - (L_{slant})$

BTS output power for system balance without TMA.

$Pout_{bal} = Pout_{MS} + G_{div} + (L_{slant}) + \Delta_{sens}$

$EIRP = Pout_{bal} - (L_{dupl}) - L_{f+j} + G_{ant} - (L_{slant})$