Cell Planning

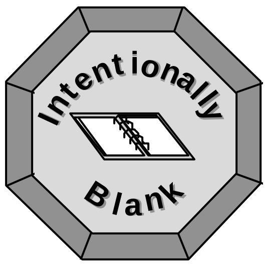
Chapter 10

This chapter is designed to provide the student with an overview of cell planning. It describes basic cell planning concepts and outlines the cell planning process.

OBJECTIVES:

Upon completion of this chapter the student will be able to:

- Describe 3 stages in the cell planning process
- Explain the terms ’Grade of Service’ (GOS) and ‘Erlang’
- Name 2 types of Interference
- Understand what is meant by the term ‘Hierarchical Cell Structure’
- Describe briefly the feature ‘BCCH in Overlaid Subcell’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10 Cell Planning

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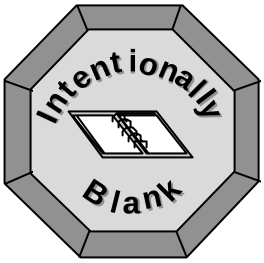
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INTRODUCTION

Cell planning can be described as all the activities involved in:

- Selecting the sites for the radio equipment
- Selecting the radio equipment
- Configuring the radio equipment

Every cellular network requires cell planning in order to provide adequate coverage and call quality.

CELLS

☞ Did you know?

Although the concept of mobile telephony originated in the 1920s, it was only in 1947 that the cellular network structure was devised. Up to then, no solution enabled an MS to roam far from the antenna system.

A cell may be defined as an area of radio coverage from one BTS antenna system[1]. It is the smallest building block in a mobile network and is the reason why mobile networks are often referred to as cellular networks. Typically, cells are represented graphically by hexagons.

There are two main types of cell:

- **Omni directional cell:** An omni-directional cell (or omnicell) is served by a BTS with an antenna which transmits equally in all directions (360 degrees).
- **Sector cell:** A sector cell is the area of coverage from an antenna, which transmits, in a given direction only. For example, this may be equal to 120 degrees or 180 degrees of an equivalent omni- directional cell. One BTS can serve one of these sector cells with a collection of BTS's at a site serving more than one, leading to terms such as two-sectored sites and more commonly, three-sectored sites.

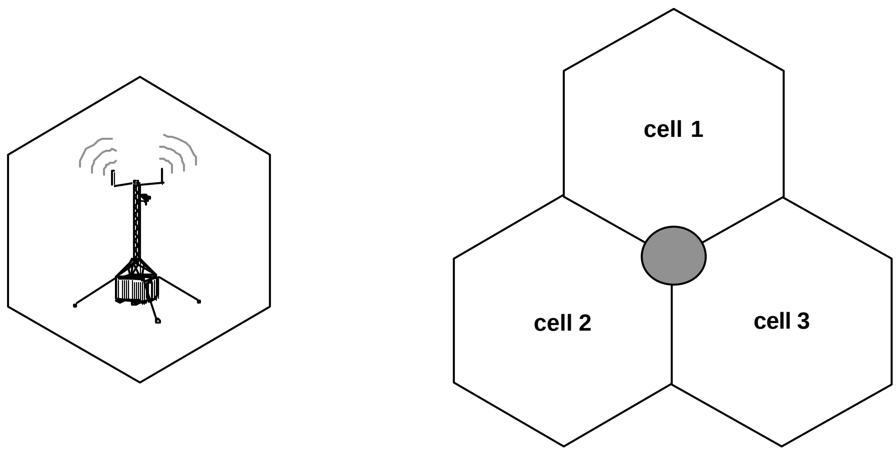


Figure 10-1 Omni directional and sector cells

Typically, omni-directional cells are used to gain coverage, whereas sector cells are used to gain capacity.

[1] Note: In some cases, such as pico cells, a single cell can be served by 2 antenna systems. Although there are two distinct areas of coverage, both areas can be associated with the same set of cell parameters.

The border between the coverage area of two cells is the set of points at which the signal strength from both antennas is the same. In reality, the environment will determine this line, but for simplicity, it is represented as a straight line.

If six BTS's are placed around an original BTS, the coverage area - that is, the cell - takes on a hexagonal shape.

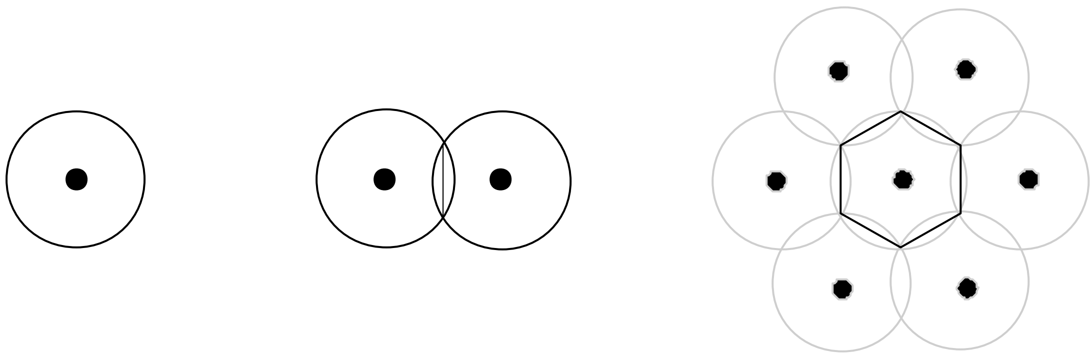


Figure 10-2 Border between omni directional cells

CELL PLANNING PROCESS

The major activities involved in the cell planning process are shown below.

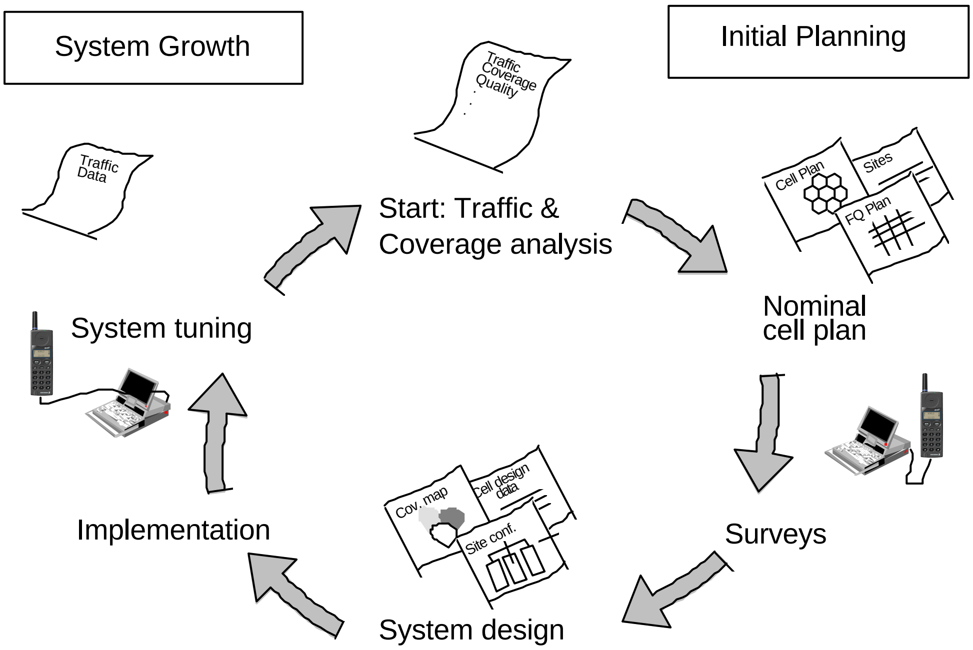


Figure 10-3 Cell planning process

STEP 1: TRAFFIC AND COVERAGE ANALYSIS

Cell planning begins with traffic and coverage analysis. The analysis should produce information about the geographical area and the expected capacity (traffic load). The types of data collected are:

- Cost
- Capacity
- Coverage
- Grade Of Service (GOS)
- Available frequencies
- Speech quality
- System growth capability

The basis for all cell planning is the traffic demand, i.e. how many subscribers use the network and how much traffic they generate. The Erlang (E) is a unit of measurement of traffic intensity. It can be calculated with the following formula:

$$A = n \times T / 3600 \text{ Erlang}$$

Where,

A = offered traffic from one or more users in the system

n = number of calls per hour

T = average call time in seconds

The geographical distribution of traffic demand can be calculated by the use of demographic data such as:

- Population distribution
- Car usage distribution
- Income level distribution
- Land usage data
- Telephone usage statistics
- Other factors, like subscription/call charge and price of MSs

Calculation of required number of BTS's

> ☞ Did you know?
>
> *Based on experience, Ericsson recommends between 25mE and 33mE when planning GSM networks.*

To determine the number and layout of BTSs the number of subscribers and the Grade Of Service (GOS) have to be known. The GOS is the percentage of allowed congested calls and defines the quality of the service.

If n=1 and T=90 seconds then the traffic per subscriber is:

A = 1 x 90 / 3600 = 25mE

If the following data exists for a network:

- Number of subscribers: 10,000
- Available frequencies: 24
- Cell pattern: 4/12
- GOS: 2%
- Traffic per subscriber: 25mE

this leads to the following calculations:

- Frequencies per cell = 24 / 12 = 2
- Traffic channels per cell = 2 x 8 - 2 (control channels) = 14 TCH
- Traffic per cell = 14 TCH with a 2% GOS implies 8.2 Erlangs per cell (see Table 10-1)
- The number of subscribers per cell = 8.2E / 25mE = 328 subscribers per cell
- If there are 10,000 subscribers then the number of cells needed is 10,000 / 328 = 30 cells.
- Therefore, the number of three sector sites needed is 30 / 3 = 10

GoS

n	.007	.008	.009	.01	.02	.03	.05	.1	.2	.4	n
1	.00705	.00806	.00908	.01010	.02041	.03093	.05263	.11111	.25000	.66667	1
2	.12600	.13532	.14416	.15259	.22347	.28155	.38132	.59543	1.0000	2.0000	2
3	.39664	.41757	.43711	.45549	.60221	.71513	.89940	1.2708	1.9299	3.4798	3
4	.77729	.81029	.84085	.86942	1.0923	1.2589	1.5246	2.0454	2.9452	5.0210	4
5	1.2362	1.2810	1.3223	1.3608	1.6571	1.8752	2.2185	2.8811	4.0104	6.5955	5
6	1.7531	1.8093	1.8610	1.9090	2.2759	2.5431	2.9603	3.7584	5.1086	8.1907	6
7	2.3149	2.3820	2.4437	2.5009	2.9354	3.2497	3.7378	4.6662	6.2302	9.7998	7
8	2.9125	2.9902	3.0615	3.1276	3.6271	3.9865	4.5430	5.5971	7.3692	11.419	8
9	3.5395	3.6274	3.7080	3.7825	4.3447	4.7479	5.3702	6.5464	8.5217	13.045	9
10	4.1911	4.2889	4.3784	4.4612	5.0840	5.5294	6.2157	7.5106	9.6850	14.677	10
11	4.8637	4.9709	5.0691	5.1599	5.8415	6.3280	7.0764	8.4871	10.857	16.314	11
12	5.5543	5.6708	5.7774	5.8760	6.6147	7.1410	7.9501	9.4740	12.036	17.954	12
13	6.2607	6.3863	6.5011	6.6072	7.4015	7.9667	8.8349	10.470	13.222	19.598	13
14	6.9811	7.1154	7.2382	7.3517	8.2003	8.8035	9.7295	11.473	14.413	21.243	14
15	7.7139	7.8568	7.9874	8.1080	9.0096	9.6500	10.633	12.484	15.608	22.891	15
16	8.4579	8.6092	8.7474	8.8750	9.8284	10.505	11.544	13.500	16.807	24.541	16
17	9.2119	9.3714	9.6171	9.6516	10.656	11.368	12.461	14.522	18.010	26.192	17
18	9.9751	10.143	10.296	10.437	11.491	12.238	13.385	15.548	19.216	27.844	18
19	10.747	10.922	11.082	11.230	12.333	13.115	14.315	16.579	20.424	29.498	19
20	11.526	11.709	11.876	12.031	13.182	13.997	15.249	17.613	21.635	31.152	20
21	12.312	12.503	12.677	12.838	14.036	14.885	16.189	18.651	22.848	32.808	21
22	13.105	13.303	13.484	13.651	14.896	15.778	17.132	19.692	24.064	34.464	22
23	13.904	14.110	14.297	14.470	15.761	16.675	18.080	20.737	25.281	36.121	23
24	14.709	14.922	15.116	15.295	16.631	17.577	19.031	21.784	26.499	37.779	24
25	15.519	15.739	15.939	16.125	17.505	18.483	19.985	22.833	27.720	39.437	25
26	16.334	16.561	16.768	16.959	18.383	19.392	20.943	23.885	28.941	41.096	26
27	17.153	17.387	17.601	17.797	19.265	20.305	21.904	24.939	30.164	42.755	27
28	17.977	18.218	18.438	18.640	20.150	21.221	22.867	25.995	31.388	44.414	28
29	18.805	19.053	19.279	19.487	21.039	22.140	23.833	27.053	32.614	46.074	29
30	19.637	19.891	20.123	20.337	21.932	23.062	24.802	28.113	33.840	47.735	30
31	20.473	20.734	20.972	21.191	22.827	23.987	25.773	29.174	35.067	49.395	31
32	21.312	21.580	21.823	22.048	23.725	24.914	26.746	30.237	36.295	51.056	32

Table 10-1 Erlang table

STEP 2: NOMINAL CELL PLAN

A nominal cell plan can be produced from the data compiled from traffic and coverage analysis. The nominal cell plan is a graphical representation of the network and looks like a cell pattern on a map. Nominal cell plans are the first cell plans and form the basis for further planning.

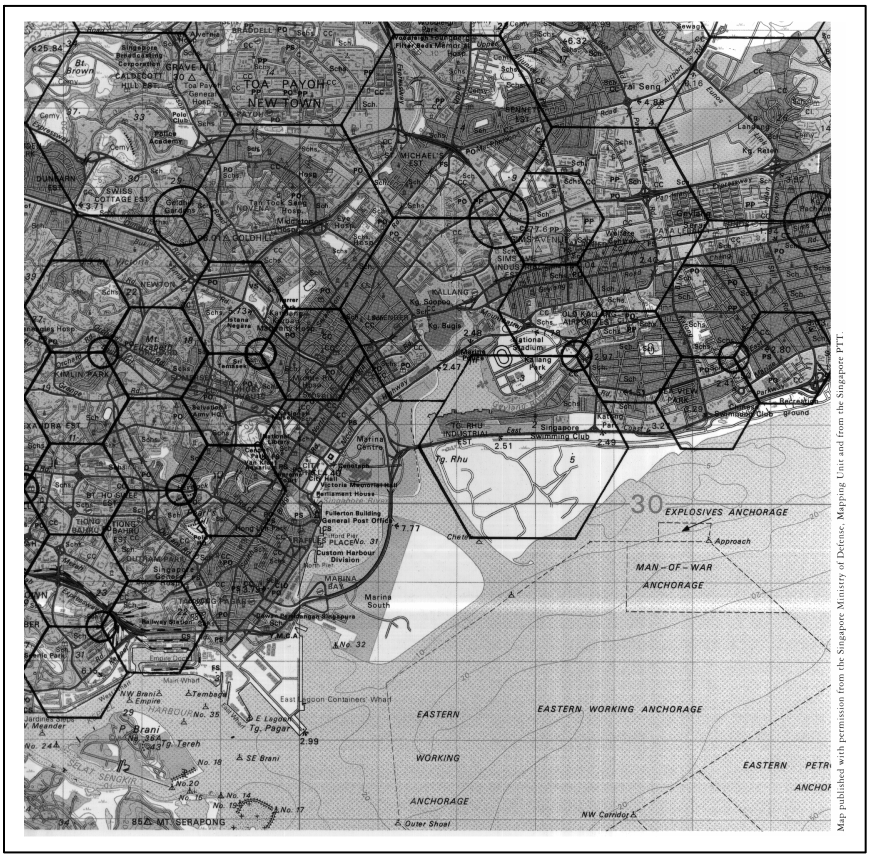


Figure 10-4 Nominal cell plan

Successive planning must take into account the radio propagation properties of the actual environment. Such planning needs measurement techniques and computer-aided analysis tools for radio propagation studies. Ericsson's planning tool, TEst Mobile System (TEMS) CellPlanner, includes a prediction package which provides:

- Coverage predictions
- Composite coverage synthesis
- Co-channel interference predictions
- Adjacent channel interference predictions

TEMS cell planner is a software package designed to simplify the process of planning and optimizing a cellular network. It is based on ASSET by Airtouch.

With TEMS CellPlanner, traffic can be spread around on a map to determine capacity planning. The traffic can be displayed using different colors for different amounts of Erlangs/km^2 or the user can highlight the cells that do not meet the specified GOS.

It is possible to import data from a test MS and display it on the map. TEMS CellPlanner can also import radio survey files, which can be used to tune the prediction model for the area where the network is to be planned. Data can also be imported from and exported to OSS.

For example, if there are doubts about the risks of time dispersion at a particular site the following steps could be taken:

- The site location could be changed
- The site could be measured with respect to time dispersion
- The site could be analyzed with a carrier–to–reflection ratio (C/R) prediction tool

Radio Propagation

☞ Did you know?

The antennae of some base stations in Hong Kong are positioned on top of tall buildings, with the antenna at a 45° angle to the building to ensure street coverage.

In reality, hexagons are extremely simplified models of radio coverage patterns because radio propagation is highly dependent on terrain and other factors. The problems of path loss, shadowing and multipath fading all affect the coverage of an area. For example, time dispersion is a problem caused by the reception of radiosignals, which are reflected off far away objects. The carrier-to-reflection (C/R) ratio is defined as the ratio between the direct signal (C) and the reflected signal (R).

Also, due to the problem of time alignment the maximum distance an MS can be from a BTS is 35 km. This is the maximum radius of a GSM cell. In areas where large coverage with small capacity is required, it is possible to allocate two consecutive TDMA time slots to one subscriber on a call. This enables a maximum distance from the BTS of 70km.

Frequency Re–use

Modern cellular networks are planned using the technique of frequency re-use. Within a cellular network, the number of calls that the network can support is limited by the amount of radio frequencies allocated to that network. However, a cellular network can overcome this constraint and maximize the number of subscribers that it can service by using frequency re-use.

Frequency re-use means that two radio channels within the same network can use exactly the same pair of frequencies, provided that there is a sufficient geographical distance (the frequency re-use distance) between them so they will not interfere with each other. The tighter frequency re-use plan, the greater the capacity potential of the network.

Based on the traffic calculations, the cell pattern and frequency re-use plan are worked out not only for the initial network, but so that future demands can be met.

Interference

Co-channel Interference (C/I)

Cellular networks are more often limited by problems caused by interference rather than by signal strength problems. Co-channel interference is caused by the use of a frequency close to the exact same frequency. The former will interfere with the latter, leading to the terms interfering frequency (I) and carrier frequency (C).

The GSM specification recommends that the carrier-to-interference (C/I) ratio is greater than 9 decibels (dB). However, Ericsson recommends that 12 dB be used as planning criterion.

This C/I ratio is influenced by the following factors:

- The location of the MS
- Local geography and type of local scatters
- BTS antenna type, site elevation and position

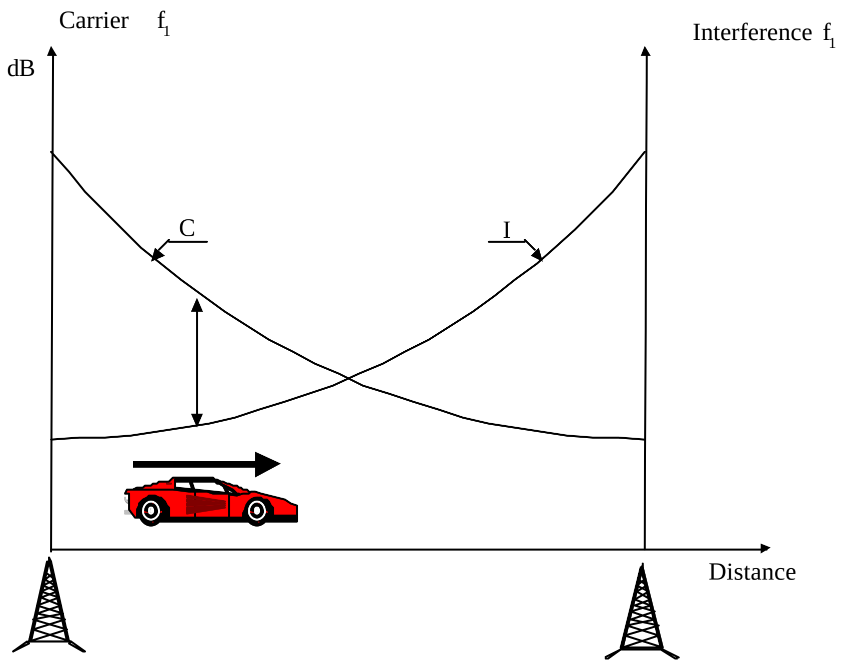


Figure 10-5 Co-channel interference

Adjacent channel interference (C/A)

Adjacent frequencies (A), that is frequencies shifted 200kHz from the carrier frequency (C), must be avoided in the same cell and preferably in neighboring cells also. Although adjacent frequencies are at different frequencies to the carrier frequency they can still cause interference and quality problems.

The GSM specification states that the carrier-to-adjacent ratio (C/A) must be larger than -9dB. Ericsson recommends that higher than 3 dB be used as planning criterion.

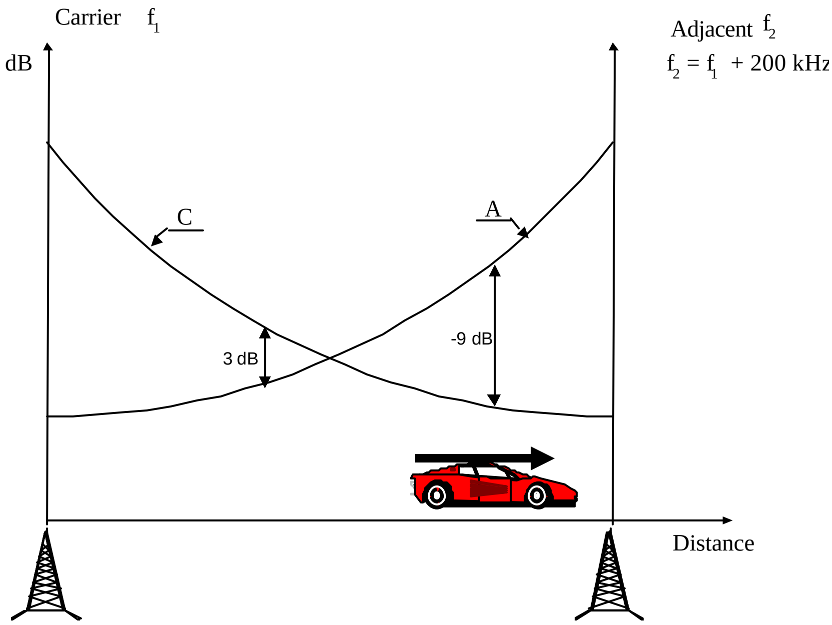


Figure 10-6 Adjacent channel interference

By planning frequency re-use in accordance with well established cell patterns, neither co-channel interference nor adjacent channel interference will cause problems, provided the cells have homogenous propagation properties for the radio waves. However, in reality cells vary in size depending on the amount of traffic they are expected to carry. Therefore, real cell plans must be verified by means of predictions or radio measurements to ensure that interference does not become a problem. Nevertheless, the first cell plan based on hexagons, the nominal cell plan, provides a good picture of system planning.

Clusters

Groups of frequencies can be placed together into patterns of cells called clusters. A cluster is a group of cells in which all available frequencies have been used once and only once.

Since the same frequencies can be used in neighboring clusters, interference may become a problem. Therefore, the frequency re-use distance must be kept as large as possible. However, to maximize capacity the frequency re-use distance should be kept as low as possible.

The re-use patterns recommended for GSM are the 4/12 and the 3/9 pattern. 4/12 means that there are four three-sector sites supporting twelve cells using twelve frequency groups.

> ☞ Did you know?
>
> *Other frequency re-use patterns such as 7/21, with a long frequency re-uses distance, are recommended for networks, which are sensitive to interference, for example analogue networks.*

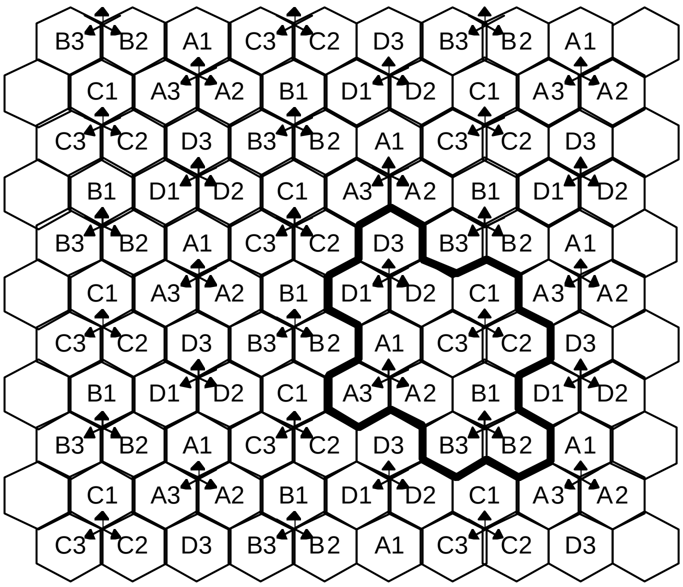


Figure 10-7 4/12 cell pattern

The 4/12 cell pattern is in common use by GSM network operators.

Below is an example of how a network operator could divide 24 available frequencies (1-24) into a 3/9 cell pattern:

Frequency group	A1	B1	C1	A2	B2	C2	A3	B3	C3
Channels	1	2	3	4	5	6	7	8	9
	10	11	12	13	14	15	16	17	18
	19	20	21	22	23	24			

Table 10-2 24 frequencies in a 3/9 cell pattern

In the 3/9 cell pattern there are always 9 channels separating each frequency in a cell. However, when compared with the 4/12 pattern, cells A1 and C3 are neighbors and use adjacent frequencies (10 and 9 respectively). Therefore, the C/A interference will increase. In this case, an operator may use frequency hopping which, if planned correctly, could reduce the possibility of such adjacent channel interference .

☞ Did you know?

Mobile networks based on non-GSM standards may find it difficult to use the 3/9 pattern due to its tight frequency re-use. The modulation technique in GSM enables greater tolerance of such interference.

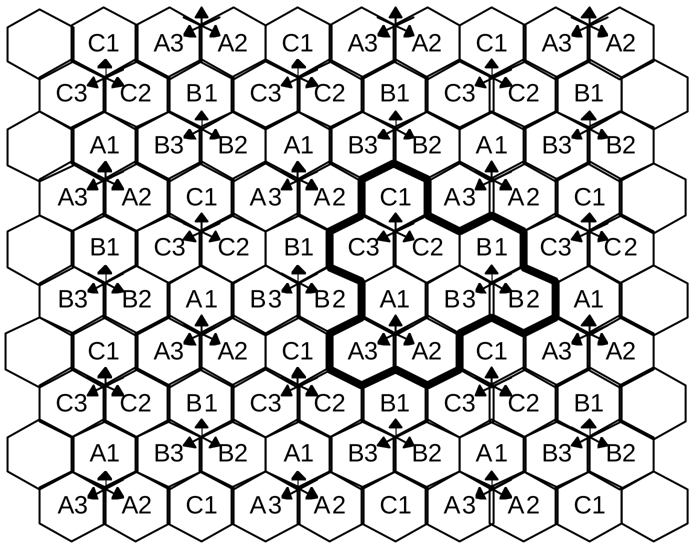


Figure 10-8 3/9 cell pattern

In a real network the allocation of channels to cells will not be as uniform as in table 10-2 above, as some cells will require more channels and some will require less. In this case, a channel may be taken from a cell with low traffic load and moved to one with a higher traffic load. However, in doing so, it is important to ensure that interference is still minimized.

STEP 3: SURVEYS

Once a nominal cell plan has been completed and basic coverage and interference predictions are available, site surveys and radio measurements can be performed.

Site Surveys

☞ Did you know?

One of the most expensive aspects of cellular network operation is payment of rent for sites, e.g. hotel rooms. Great care is often taken to ensure public support for sites. (E.g. in California some BTSs are hidden within fiber glass palm trees.)

Site surveys are performed for all proposed site locations. The following must be checked for each site:

- Exact location
- Space for equipment, including antennas
- Cable runs
- Power facilities
- Contract with site owner

In addition, the radio environment must be checked to ensure that there is no other radio equipment on site that causes problems.

Radio Measurements

Radio measurements are performed to adjust the parameters used in the planning tool to reality. That is, adjustments are made to meet the specific site climate and terrain requirements. For example, parameters used in a cold climate will differ from those used in a tropical climate.

A test transmitter is mounted on a vehicle, and signal strength is measured while driving around the site area. Afterwards, the results from these measurements can be compared to the values the planning tool produces when simulating the same type of transmitter. The planning parameters can then be adjusted to match the actual measurements.

STEP 4: SYSTEM DESIGN

Once the planning parameters have been adjusted to match the actual measurements, dimensioning of the BSC, TRC and MSC/VLR can be adjusted and the final cell plan produced. As the name implies, this plan can then be used for system installation.

New coverage and interference predictions are run at this stage, resulting in Cell Design Data (CDD) documents containing cell parameters for each cell.

STEPS 5 AND 6: SYSTEM IMPLEMENTATION AND TUNING

Once the system has been installed, it is continuously monitored to determine how well it meets demand. This is called system tuning. It involves:

- Checking that the final cell plan was implemented successfully
- Evaluating customer complaints
- Checking that the network performance is acceptable
- Changing parameters and taking other measurements, if necessary

TEst Mobile Systems (TEMS)

TEst Mobile Systems (TEMS) is a testing tool used to read and control the information sent over the air interface between the BTS and the MS. It can be used for radio coverage measurements. In addition, TEMS can be used both for field measurements and post processing.

TEMS consists of an MS with special software, a portable Personal Computer (PC) and optionally a Global Positioning System (GPS) receiver.

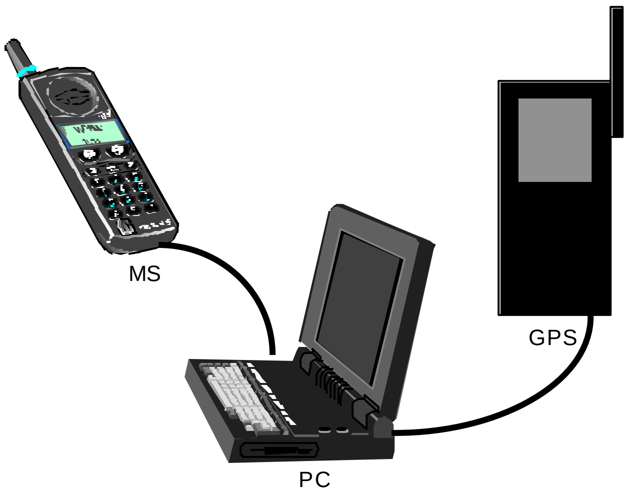


Figure 10-9 TEMS Hardware

The MS can be used in active and idle mode. The PC is used for presentation, control and measurements storage.

The GPS receiver provides the exact position of the measurements by utilizing satellites. When satellite signals are shadowed by obstacles, the GPS system switches to dead reckoning. Dead reckoning consists of a speed sensor and a gyro. This provides the position if the satellite signals are lost temporarily.

TEMS measurements can be imported to TEMS CellPlanner. This means that measurements can be displayed on a map. For example, this enables measured handovers to be compared with the predicted cell boundaries. Measurements can also be downloaded to spreadsheet and word processing packages.

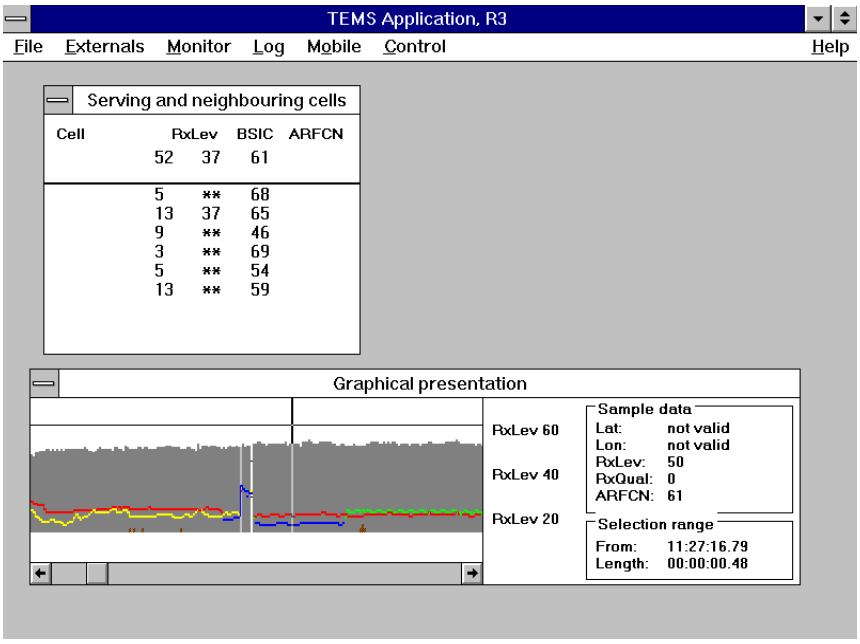


Figure 10-10 TEMS graphical user interface

STEP 7: SYSTEM GROWTH/CHANGE

Cell planning is an ongoing process. If the network needs to be expanded because of an increase in traffic or because of a change in the environment (e.g. a new building), then the operator must perform the cell planning process again, starting with a new traffic and coverage analysis.

HIERARCHICAL CELL STRUCTURES (HCS)

> ☞ Did you know?
>
> *It may not be feasible for fast moving MSs to use the lowest layer, as many handovers will occur. In this case, Ericsson's GSM systems will handover the call to a higher layer, resulting in less handovers.*

The feature Hierarchical Cell Structures (HCS) divides the cell network into up to 8 layers. The higher layers are used for large cells and the lower layers for small cells. For example, large cells are added to a cellular network to provide coverage at coverage gaps. The large cells then act as umbrella cells for medium sized cells. Additionally, micro cells can be added to a cellular network in order to provide hot spot capacity. The medium sized cells then act as umbrella cells for the micro cells.

The different cell layers can be seen as a priority designation with the lower layer as the highest priority. Thus, when selecting a BCCH carrier, an MS will choose an acceptable signal in as low a layer as possible. HCS makes it possible to pass between cell layers in a controlled way, facilitating dimensioning and cell planning in cell structures where large and small cells are mixed.

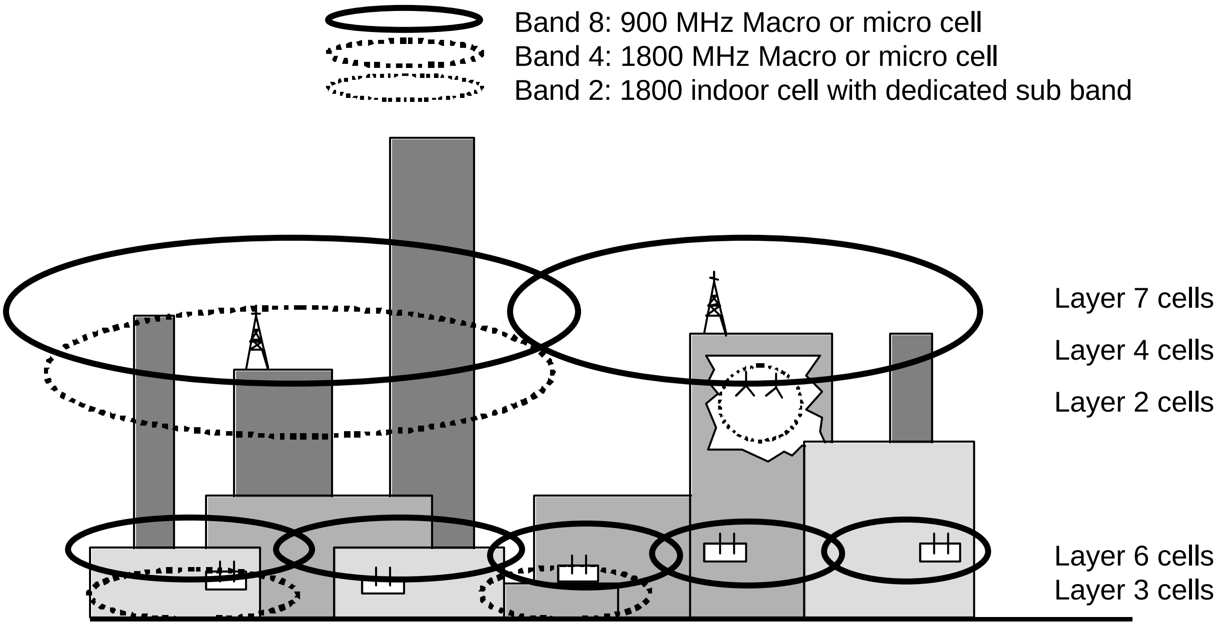


Figure 10-11 Hierarchical Cell Structures (HCS) divides the cell network into up to 8 layers

OVERLAID/UNDERLAID SUBCELLS

The overlaid/underlaid subcells feature provides a way to increase the traffic capacity in a cellular network without building new sites.

A set of channels in a BTS is assigned to transmit at a certain power level. These are the underlaid subcell channels. Another set of channels in the same BTS is assigned to transmit at a lower power level. These are the overlaid subcell channels.

The feature makes it possible to use two different frequency re-use patterns: one pattern for overlaid subcells and another pattern for underlaid subcells. Each overlaid subcell serves a smaller area than the corresponding underlaid subcell and the frequency re-use distance for the overlaid subcells can therefore be made shorter. Consequently, the number of frequencies per cell can be increased providing an increased traffic capacity in the cellular network.

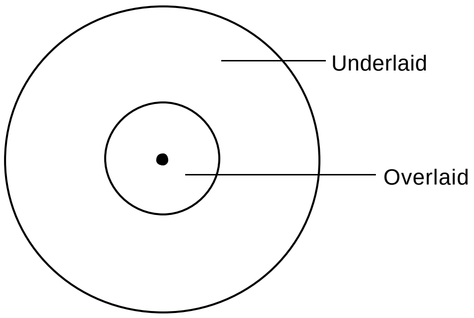


Figure 10-12 Overlaid/underlaid subcells

BCCH IN OVERLAID SUBCELL

The main goal of the feature ‘BCCH in Overlaid Subcell’ is to allow tighter reuse of BCCH carrier frequencies. This is achieved by configuring a BCCH carrier in the Overlaid subcell and distributing the TCH traffic between Overlaid and Underlaid subcells.

To ensure that the BCCH can be received in the whole cell, the output power of the BCCH carrier in the overlaid subcell shall be the same as if it had been in the underlaid subcell.

Traffic is geographically distributed so that Mobile Stations located far from the cell are served only by TCH channels in the underlaid subcell.

Introducing BCCH in Overlaid Subcell, in a network where the BCCH is not frequency hopping, gives the following benefits:

- Possibility to substantially tighten the frequency reuse for the non-hopping BCCH carrier. The frequencies not required for BCCH anymore could, for example, be used to increase the macro-cell capacity, or to implement a micro-cell layer.

- Reduced need for investment in new sites/cells, due to increased capacity in existing cells.

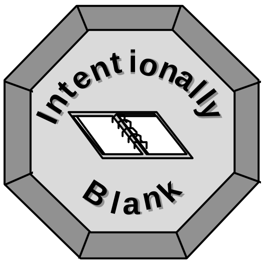
- Better speech quality since frequency hopping traffic channels will be used at the cell borders.

- BCCH-frequency used for traffic in a smaller cell area , that is the OverLaid area (OL)

If an MS is assigned a TCH on a BCCH carrier in an overlaid subcell, the radio channel quality is improved on the downlink because the MSs are close to the serving BTS and thus receive a very strong signal from it. The stronger signal strength enables the MSs to withstand the increased interference that the tighter BCCH reuse will cause. Downlink power control also provides a general improvement in interference levels.

On the uplink, since the MSs are close to the BTS, the BTS will receive a strong signal, which helps it to withstand interference. The situation in the uplink can be improved further by using Dynamic MS Power Control. This will ensure that the MSs are transmitting with minimum output power and generate very little interference in the network. The reduced interference level on the uplink will also result in improved accessibility and fewer random access failures despite the tighter frequency reuse.

BCCH in Overlaid Subcell cannot be used together with Extended Range, which can only be configured in the Underlaid Subcell. Trying to configure the BCCH in Overlaid and Extended Range in Underlaid will cause a fault code.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