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(71) Applicant (*for all designated States except US*): **TELIA AB (publ)** [SE/SE]; Mårbackagatan 11, S-123 86 Farsta (SE).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **SOMMER, Magnus** [SE/SE]; Fallvindsgatan 2, S-128 32 Skarpnäck (SE). **NILSSON, Ulf** [SE/SE]; Algägen 30, S-137 32 Västerhaninge (SE).

(74) Agent: **SVENSSON, Peder**; Telia Research AB, Vitsandsgatan 9, S-123 86 Farsta (SE).

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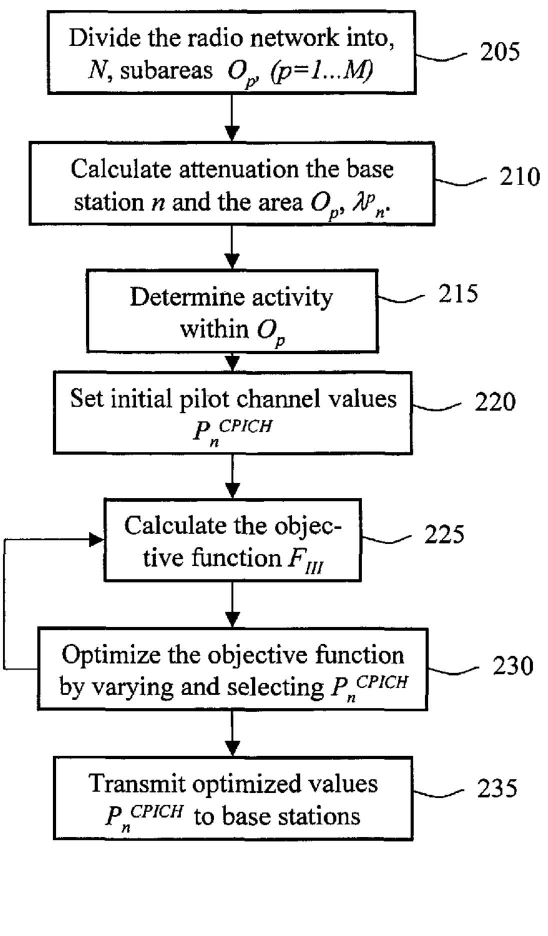
(54) Title: METHOD FOR CONFIGURING THE POWER OUTPUT OF THE PILOT CHANNELS IN A CELLULAR RADIO NETWORK



(57) Abstract: The present invention relates to a method and a software product at a mobile telecommunication and data communication system. More exactly the method intends to make possible an efficient pilot channel planning in a CDMA-based cellular radio network and includes the steps: Division of the radio network into subareas, estimation of the attenuation of the radio signal to subareas, calculation of an objective function to get a numerical value regarding the quality of the radio network, or part of the radio network, on basis of a configuration of pilot channel power output where the objective function includes a coverage related term and a capacity related term and optimization with the aim to configure the power output values of pilot channels so that the numerical value of the objective function is maximized.

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Method for configuring the power output of the pilot channels in a cellular radio network

Technical field

The present invention relates to a method, a system and software to plan and configure mobile telephone systems. More exactly is related to a method, a system and software to efficiently determine the power output of the pilot channel in different cells in a cellular mobile telephone system.

Prior art

In all mobile radio communication systems the supply of frequencies is a limiting factor. Each operator has one or more parts of the radio spectra allocated to him/her and must optimize the use of frequencies in order to offer high capacity, high quality and, with the new mobile telephone systems which at present are implemented, also flexibility regarding transmission speed and type of transmission. In TDMA-based (Time Division Multiple Access) networks, as for instance the globally distributed GSM-system, and the in North and South America common TIA/EIA-136 (TDMA), it is primarily the frequency planning which is, and has been, the object of optimization.

Communication systems based on CDMA-technology (Code Division Multiple Access), for instance UMTS (Universal Mobile Telecommunication System) and IS-95, are inherently interference limited. In such systems is of greatest importance that the radio network is planned to provide an optimal, or almost optimal, utilization of the allocated frequency range. Centrally for the planning of the radio network in CDMA-based systems is the so called pilot channel (CPICH). The pilot channel is used by the mobile terminal to search for best cell when the mobile terminal is switched on, and to with continuous measurements determine which cell that for the time being offers the best communication possibility, which constitutes the base for decision of change of cell. During communication, measurements on the pilot channel are used as base for decision of change to another cell (handover). By the mobile terminal received signal strength at a given point within a cell is determined by the power output of the pilot channel in combination with the radio environment, that is, among other things fading, shadowing and interference. The power output of the pilot channel by that constitutes a way to define the traffic coverage area of the cell, or in other words the coverage of the cell. Also the capacity of the system is influenced by the power output of the pilot channels, since the total emitted power output within an area controls available capacity. The pilot channels are described more in detail in the UMTS-document TS25.211.

In most existing systems the pilot channel planning, as well as frequency planning for TDMA-based systems, so far preferably has been made manually. Frequently a ”trial-error”-method is applied where the different power output of the pilot channels are determined manually either based on measurements or expected behavior of the radio network. After that, the pilot channel plan usually is tested with a simulation tool to check if wanted power is achieved. In most cases a great deal of re-location and a number of simulations are required to achieve a good result. The trial-error-methods are time-consuming and have to be executed by specialized and experienced staff to provide optimized systems. Due to this, many radio networks in operation are not optimized.

The need for optimizing radio networks with methods which are possible to automatize consequently is great. In US patent 5,859,839 by M.T. Ahlenius et al, a method is described to automatically select power for pilot channels.

For the radio network which shall be optimized, a number of different values in a number of points are determined which intends to describe the system. Values can, for instance, be interference, hand-off-value, power, traffic load and weighting with regard to, for instance, type of communication. The values are collected in different meshes to make it possible to evaluate them and provide a picture of the performance of the radio network. Optimization is performed according to the principles for simulated annealing, but other optimization algorithms are mentioned, for instance genetic. At the optimization, certain power output of the pilot channels and the ″meshes″ are evaluated to find out if an improvement in performance has been achieved. The evaluation of the ″meshes″ and the weighing together of their importance for the performance of the radio network can be an extensive and time-consuming process. From the document is not evident how an unequivocal numerical value for the performance of the radio network shall be calculated, and for that reason it is desirable to find other methods to, from a time efficiency point of view, describe the performance of the radio network.

Patent application EP 1028543 by D. Di Huo describes a method for downlink power control which also can be used for pilot channel planning. Noise level and wave propagation are measured at a number of points in the radio network, and the power output in downlink is calibrated to satisfy a predefined objective value. The objective value here is a predefined value, a ″recommended″ value, and does not necessarily represent one for the system as a whole optimal condition.

Summary of the invention

The aim of the present invention is to reduce above mentioned problems to achieve an efficient pilot channel planning in one for CDMA-based cellular mobile telephone system.

This is achieved by a method and a software product described in the characterizing parts of the independent patent claims.

Owing to that the method according to the invention utilizes an objective function which describes the performance of the cellular radio network and includes a coverage related term and a capacity related term, the power output of the pilot channels can be configured so that the capacity is optimized at the same time as demands on coverage are satisfied.

One advantage with the present invention is that the objective function need not be simulated but can be calculated, which considerably reduces the need of processor power and time.

Another advantage of the present invention is that no particular verification step including simulation need to be performed to get a measure of the performance of the system.

Brief description of drawings

Figure 1a-b shows a cellular mobile telephone system in which the present invention can be utilized.

Figure 2 shows a flow chart for pilot channel planning according to the present invention.

Description of embodiments

Figure 1a is a schematic drawing over a cellular mobile telephone network of the type in which the present invention can be utilized. In the Figure a number of hexagonal cells 100, with a base station 110 located centrally in each are shown. The drawing shall be regarded as an idealized picture of a cellular network. In a real network the size and form of the cells vary considerably, for one thing because of topographical reasons, but also for making it possible to offer higher capacity and different degrees of service in different areas. In networks based on CDMA (Code Division Multiple Access) and W-CDMA (Wideband-CDMA), such as networks according to the standard UMTS (Universal Mobile Telecommunication System) the size of a cell is defined by the so called pilot channel, in the standard called CPICH. This is done by a mobile terminal, exemplified by mobile terminal 120 in Figure 1, continuously measuring which cell that provides the best communication possibility. The estimation is based on RSCP (received signal code power). The received signal strength, RSCP, depends on the transmitted signal strength of the pilot channel, the position of the mobile terminal in relation to the base station, and the propagation (attenuation) of the radio waves. The signal strength of the transmitted pilot channel consequently can be used to determine the traffic coverage area of the cells, that is, the size of the cells. The power output of the pilot channels from base station No. n is represented by P_n^{CPICH} (in Figure 1 exemplified by P_1^{CPICH}, P_2^{CPICH} och P_3^{CPICH}). Each base station further has a maximum available power output designated, $P_{n,max}$, ($P_{1,max}$, $P_{2,max}$, and $P_{3,max}$). Often there is also one by license providing authorities stipulated lower limit, which the RSCP of the pilot signal must not fall below. In for instance Sweden this limit has by the National Post and Telecom Agency, PTS, been set to 58 dBμV/m for at least 95% of the area. The designation P_{lvl} is used for the wanted signal level of the pilot channel and p_{target} for the wanted area probability. Limits as this in combination with the definition of the traffic coverage area in interaction with other cells and the satisfying of capacity and quality demands in different parts of the network are basic parameters for the pilot channel planning.

The power output P_n^{CPICH} of the different pilot channels, as well as a number of other parameters and all call control, are set via one (or more) Radio Network Controllers, RNC) 130, with which all base stations 110 communicate.

Pilot channel configuration is normally performed at start-up of a new network, or when parts of the network have been changed, for instance when new base stations (new cells) have been installed. Further it can be advisable to perform a reconfiguration of the pilot channels if the network does not show the performance which has been expected or in order to take into consideration changed conditions in the radio environment. It is also possible to dynamically pilot channel configure in order to better follow changes in traffic load during for instance a day.

Figure 2 shows a flow chart for the main steps of the method for pilot channel planning according to the present invention. A mathematical description of certain for the performance essential parts will be given below. In this embodiment is assumed that the following is known about the radio network: a) The locations of the base stations are fix and known, b) The wave propagation is known, or can be calculated with good accuracy by means of for the expert well known methods, c) The distribution of the traffic over the area is known or can be calculated or approximated. Centrally for the method is the defining and calculation of an objective function F_{III}, which shall express the performance of the radio network by a numerical value. The objective function must in a correct way describe influence from the power of the pilot channels on the network from all relevant aspects. In addition, the objective function must be possible to calculate in a time efficient way. The pilot planning method includes the steps:

205. The radio network, or that part of the radio network which shall be power output configured, is divided into smaller areas. The areas should be small enough that neither received signal strength nor distribution of traffic varies considerably within the area. In the following calculations and the optimization, constant received signal strength and constant distribution of traffic within the areas is assumed. The number of areas are designated M, and each area O_p. (p=1…M). In Figure 1b is schematically shown how a part of a radio network can be divided into smaller areas O_p. In Figure 1b a regular, uniform and with identically large sub areas, O_p, division of the radio network is shown. Such a type of division is easy to make, but in some applications it can be advantageous with an irregular and/or not uniform division. For instance can knowledge of the topology, the geography or expected traffic intensity indicate that it is better with a more detailed division in some part of the radio network than in others.

210. In a second step, the attenuation of the radio signal of the pilot channel between the base station n and the area O_p is calculated (where n can be any of the base stations within the area which shall be planned) according to for the expert known methods for wave propagation. The attenuation is represented by λ_p^n.

215. In a third step is assumed that the average number of active users within O_p of service number s (where s = 1 can stand for the speech service, s = 2 streaming etc) is known and equal to ρ_p^s.

220. In a following step, initial values are given to the pilot channel power, P_n^{CPICH}. These can, for instance, however not necessarily, be selected equal for all base stations and with sufficiently high level to meet the coverage demand.

225. In this step the objective function is calculated according to:

$$F_{III} = \frac{100}{\sum_n P_{\max,n}} \left(F_{\text{cov}} + \sum_n W_n^{III} \left(P_{\max,n} - P_n^{TOT} \right) \right) \qquad (1)$$

where $W_n^{III} = \begin{cases} 1, & \text{if } P_n^{TOT} \le P_{\max,n} \\ k_w & \text{otherwise} \end{cases}$ and

$$F_{\text{cov}} = \begin{cases} 0, & \text{if } p_{\text{cov}} \ge p_{target} \\ 100(p_{\text{cov}} - p_{target})k_{\text{cov}} \end{cases}$$

The objective function according to this embodiment has two principal terms which attend to that the objective function meets the demands which have previously been described. These terms are a coverage related term, F_{cov}, which attends to that the coverage demand is met with, and the remaining term, which is related to capacity and quality. The coverage term punishes networks which have too low coverage area by/with the weight k_{cov} for each per cent the coverage is below the objective. The capacity term consists in principle of the average value of the remaining power margin (in W) which are in the cells. This, however, only applies when no cell exceeds its maximum power output. If this occurs, this is punished by/with the weight k_W for each exceeding W. The weights are free parameters which normally are indicated at the utilization of the method. The including terms will be defined, and the necessary mathematical operations will be described below.

230. In an optimization step the objective function is optimized with regard to the power output of the pilot channels, P_n^{CPICH}. The optimization can for instance be based on that the power output of the pilot channels are modified and the objective function is calculated according to step 225. Preferably a genetical algorithm is used (described below) for the optimization, but also other methods, as for instance simulated annealing or evolution methods, can be used.

235. In a finishing step the new values, P_n^{CPICH}, for the pilot channel power output is transmitted/transferred to respective base station via RCN:130.

Mathematical description of the objective function

The objective function according to the present invention and which is calculated in step 225 is given by:

$$F_{III} = \frac{100}{\sum_n P_{\max,n}} \left(F_{\mathrm{cov}} + \sum_n W_n^{III} \left(P_{\max,n} - P_n^{TOT} \right) \right)$$
$$W_n^{III} = \begin{cases} 1, & \text{if } P_n^{TOT} \le P_{\max,n} \\ k_w & \text{otherwise} \end{cases} \qquad (1)$$

where

$$F_{\mathrm{cov}} = \begin{cases} 0, & \text{if } p_{\mathrm{cov}} \ge p_{target} \\ 100\left(p_{\mathrm{cov}} - p_{target}\right)k_{\mathrm{cov}} \end{cases}$$

p_{cov} is the obtained area probability and the total power output P_n^{TOT} are given by the matrix equation

$$\vec{P}^{TOT} = \left(1 - \vec{\Omega}\right)^{-1} \vec{\Lambda} \qquad (2)$$

where

$$\vec{P}^{TOT} = \begin{pmatrix} P_1^{TOT} \\ P_2^{TOT} \\ \vdots \\ P_N^{TOT} \end{pmatrix}, \quad \vec{\Lambda} = \begin{pmatrix} \Lambda_1 \\ \Lambda_2 \\ \vdots \\ \Lambda_N \end{pmatrix} \quad \text{and} \quad \Omega_{nm} = \sum_{p \in Q_n} x_p \omega_{pm}$$

Q_n represents the coverage area for cell number i, consequently the amount

$$Q_n = \left\{ p; \frac{P_n^{CPICH}}{\lambda_p^n} > \frac{P_m^{CPICH}}{\lambda_p^m} \quad \forall m \neq n \right\} \qquad (4)$$

and $b(p)$ represents the serving cell for the area p. If

$p \in Q_n$ then $n = b(p)$ applies.

Λ_n represents the load weighted average value of the wave propagation attenuations for cell number n,

$$\Lambda_n = \sum_{p \in Q_n} x_p N_p$$

$$N_p = N_0 \lambda_{b(p)}^p + \sum_{n=1}^{N} \left(P_n^{CPICH} + P_n^{common} \right) \omega_{pn} \qquad (5)$$

$$\omega_{pn} = \frac{\lambda_{b(p)}^p}{\lambda_n^p} \quad (n \neq b(p)); \quad \omega_{pb(p)} \equiv (1-\alpha).$$

where P_n^{common} is the power output for the "common control"-channels in cell number n. These are set with/by a constant offset, D (in dB), in relation to the power output of the pilot channel.

$$P_n^{common} = 10^{D/10} P_n^{CPICH}$$

Further, N_0 represents the noise power within the bandwidth, N the number of cells, and finally the load contribution from area p is represented by x_p:

$$x_p = \sum_s \rho_p^s \frac{(1-\alpha)R_s\gamma_s}{W+(1-\alpha)R_s\gamma_s} \qquad (6)$$

In this expression, R_s stands for the data rate for service number s, and γ_s for the Signal/Noise-requirement (E_b/N_o) (actually bit energy over noise power density) for service number s.

Free parameters which are set during the utilization of the method for pilot channel planning are k_{cov}, k_W and D. Suitable values of these parameters are given in the examples below. k_{cov} is selected preferably so that F_{cov} always is higher than the capacity term. k_W preferably should not be selected so small that the system selects to give an individual cell too high power output ("blocking") in order to in this way make it possible to provide higher capacity in other cells. At the same time k_W should be selected so that the proportion between F_{cov} and the capacity term is preserved.

It should be noted that the here suggested objective function can be calculated and need not be simulated, which is common in the known technology. That the objective function can be calculated results in great saving of time. Further saving of time is achieved by reformulation of the problem, as is given by equation (2). Equation (2) implies that there is needed a matrix inversion to determine the total power output. The matrix which shall be inverted, 1-Ω, is an N x N matrix (where N is the number of cells), which in all normal cases is a relatively rapidly executed operation. Without the reformulation, instead a matrix of the size M x M has to be inverted (M is the number of small areas, O_p). The saving of time thanks to this reformulation is extensive, since the time that is required for a matrix inversion is proportional to the cube of the number of columns (or lines) of the matrix. Typically N is of the magnitude 10^2, whereas M is about 10^4. The saving of time consequently is about one million, 10^6, times.

Alternative formulations of the objective function

The objective function can, which will be obvious to the expert, be formulated in many different ways and yet be within the frame of the present invention. A number of such alternatives are described below. In the below described embodiments it is primarily only the framing of the objective function that is varied, that is step 225. The preceding initiation steps, as well as the subsequent optimization steps, are essentially executed in the same way as previous.

In a first alternative embodiment, the objective function is intended to give full coverage and at the same time maximize the average value of the power margin (in dB) between the total available power output the CPICH power output for all cells. The distribution of the traffic load is not taken into consideration. The objective function, F_I, is given by:

$$F_I = \frac{1}{N_{cells}}\left(F_{\mathrm{cov}} + \sum_n W_n^I\left(10\log P_{\max,n}^{CPICH} - 10\log P_n^{CPICH}\right)\right)$$
$$W_n^I = \begin{cases} 1, & if\ P_n^{CPICH} \le P_{\max,n}^{CPICH} \\ k_W & otherwise \end{cases} \qquad (7)$$

Alternatively can instead the absolute power margin (in mW) be utilized, which gives the expression for the objective function F_{II}:

$$F_{II} = \frac{1}{N_{cells}}\left(F_{cov} + \sum_n W_n^I\left(P_{max,n}^{CPICH} - P_n^{CPICH}\right)\right) \quad (8)$$

In the following objective functions also the distribution of the traffic load is taken into consideration. F_{III} was described in detail above. The objective function F_{IV} offers an alternative way of regarding the traffic load. The total power output P_n^{TOT}, respective the maximum available power output $P_{n,max}$, can approximately be described according to:

$$10\log P_{max,n} = const. - 10\log(1 - X_{max,n})$$
$$10\log P_n^{TOT} = const. - 10\log(1 - X_n)$$

where the constant includes all load independent terms. Maximum load respective current load per cell is given by $X_{max,n}$ respective X_n. If the equations above are used to give a measure of the load margin, $X_M = X_{max,n} - X_n$ per cell, the following expression is obtained:

$$X_{M,n} = X_{max,n} - X_n \Rightarrow X_{M,n} = (1 - X_n)\left(1 - \frac{P_n^{TOT}}{P_{max,n}}\right)$$

and the objective function can be formulated as the average load margin for all cells:

$$F_{IV} = \frac{100}{N_{cells}}\left(F_{cov} + \sum_n (1 - X_n)\left(1 - \frac{P_n^{TOT}}{P_{max,n}}\right)\right) \quad (9)$$

The objective function F_{II} can be extended to also take into consideration the traffic load by each term in the sum being weighted by/with the load describing factor $1/(1-X_n)$. Cells with a traffic load exceeding 100% are discriminated by/with a weight factor k_x. The objective function then will have the form:

$$F_V = \frac{1}{N_{cells}}\left(F_{\text{cov}} + \sum_n W_n^I W_n^V \frac{P_{\max,n}^{CPICH} - P_n^{CPICH}}{1 - X_n}\right)$$
$$W_n^V = \begin{cases} 1, & if\ X_n < 1 \\ k_X & otherwise \end{cases} \quad (10)$$

<u>Description of the optimization step</u>

The optimization step, 230, consists of a number of stages. The here suggested method for optimization, genetic algorithm is known but has been modified for the current problem, and the modifications are described below. For a complete description is referred to "A Genetic Algorithm for Function Optimization: A Matlab Implementation", by C. Houck, J. Joines and M. Kay, ACM Transactions on Mathematical Software, 1996.

The adaptation of the genetical algorithm to be used for the pilot planning problem is composed of the implementation of a *mutation* and a *crossover*, and the selection of *individual*. An individual is the amount of pilot power output for all cells, $\{P_n^{CPICH},\ \forall\ n \le N\}$. The mutation is a function which maps an individual on a new individual, that is, creates a new individual on basis of an old one. The following procedure is used:

1. Select randomly K different cells. (K is a free parameter).
2. For these K cells the pilot power output is randomly modified (each of them differently) according to

$$P_{n,new}^{CPICH} = P_{n,old}^{CPICH} + STEP \times (2 \times rand - 1) \quad [dBm]$$
$$rand \in Uniform(0,1)$$

STEP is set by the user and rand is a uniformly distributed random number.

The crossover function maps two (parent-) individuals on two new (child-) individuals. It functions according to the following:

1. Select a number randomly between 1 and N. Call this number z.
2. Change the pilot power for cell number z between the two parent individuals. In this way two child individuals are created.

The genetic algorithm modifies in each step the set of individuals (called population) by means of the functions mutation and crossover. After that, a selection process is applied on the population, which on basis of the objective function value, calculated according to equation (1), step 225, selects which individuals that shall be allowed to proceed to next step. The selection process is a ranking function based on the normalized geometrical distribution, which is a standard selection process for the genetical algorithm (see).

The optimization step here has been exemplified by a genetic algorithm, which is a preferred embodiment of the invention. Experts, however, will realize that a number of other optimization algorithms, as for instance simulated annealing or evolution algorithms, as well as simulation methods of Monte Carlo-type, can utilize the advantages of the suggested objective function F_{III}.

<u>Test and verification of objective function and optimization algorithm</u>

To verify the applicability of the here described embodiments of the present invention, here a test scenario consisting of 16 cells is described. The cells form a hexagonal square network with a distance between the base stations of about 346 m, which gives a longest distance from base station to cell border of 200 m. The network was divided into a rectangular square pattern, with 20x20 m large squares, which provided 5329 square points. The traffic was assumed to consist of only speech, with a bit rate R, of 12200 bits/s and a signal/noise-target (Eb/No) of 7,9 dB. The traffic load was assumed to be distributed to three hotspots with even load distribution between them. Two different traffic loads, one low and one high were tested. Further, values according to Table 1 were used to simulate an urban environment.

Table 1, parameters for test scenario

Parameter	**Value**
Losses in cables & connectors	3 dB
Cell radie	200 m
Antenna height of the terminal	1.7 m
Antenna height	25 m
Max power output (Node B)	43 dBm
Frequency	2,140 MHz
Shadow fading std.	7 dB
Shadow fading site correlation	0.5
Shadow fading correlation distance	110 m
Orthogonality factor (α)	0.5

The optimization for the different objective functions was performed in 2000 steps (generations). The weight factors had been selected according to Table 2. As reference a network where all CPICH-power output had been set equal was used. The result after 2000 generations is shown in Table 3.

Table 2. Weight factors

Objective function	k_{cov}	k_w	k_X	P_{target}	P_{lvl}
1	$1\cdot10^6$	1000		95%	-85.2 dBm
2	$1\cdot10^6$	1000		95%	-85.2 dBm
3	$1\cdot10^9$	1000	-	95%	-85.2 dBm
4	$1\cdot10^6$	-	-	95%	-85.2 dBm
5	$1\cdot10^6$	1000	$1\cdot10^6$	95%	-85.2 dBm

Table 3. Results

Objective function	Final objective function low/high load	CPICH cover-age low/high load	Average CPICH power output [dBm] low/high load	Average total power output [dBm] low/high load	CPU time [s] low/high load
Reference	-	95.01%	37 / 37	39.9 / 41.5	-
1	58.61 / 58.61	95.08%	37.7 / 37.7	41.8 / 48	393 / 350
2	16364 / 16364	95.01%	35.5 / 35.5	38.7 / 40.6	390 / 358
3	63.44 / 45.74	95.01%	35.5 / 35.9	38.6 / 40.3	3924 / 3802
4	60.21 / 39.66	95.01%	35.5 / 35.6	38.7 / 40.7	4205 / 4052
5	16035 / 15472	95.01%	35.6 / 35.5	38.7 / 40.5	666 / 646

At inspection of Table 3 can be seen that the here suggested objective functions in combination with the optimization steps, provide an improvement with regard to both the average power output of the pilot channels (CPICH) and the average total power output, with reasonable/ moderate process time (CPU-time).

The objective functions and the optimization algorithm have here been used to optimize the pilot channel power. The location of the base stations have in this analysis been assumed to be fixed. The here described method can also be used to optimize the location of the base stations. Then objective function 1, F_I, or the like is preferably used.

The aim of the present invention is to optimize the pilot planning in a CDMA-based cellular network for mobile telephony, here exemplified by W-CDMA cellular network according to the UMTS-specifications. The invention should be possible to utilize, with minor modifications in CDMA-networks according to IS-95, and the further development of CDMA according to IS-95 which are under development. As the expert realizes, similar methods can be usable also for other optimization of cellular radio networks, but requires that the objective functions are re-defined to describe the current need of optimization. Optimizations where the method according to the present invention can be utilized can for instance be frequency planning in GSM-networks, base station power output in GSM- or TDMA-networks etc.

The method is easiest applied in form of a software product, where the definition of objective function and input of necessary parameters to describe current radio network can constitute one module, and the optimization algorithms another. By a module construction can, for instance, change of optimization algorithm easily be made.

The software can be stored in, and be executed on, a computer, preferably a PC, work station, or if high calculation capacity is needed, a specifically dedicated computer. The computer is suitably in connection with the mobile telephone system for easy transmission of received/obtained CPICH-values to the base stations, preferably put through/transmitted via the RNC. If the power output of the pilot channels shall be managed dynamically, the software product should be implemented so that information rapidly can be transmitted between the computer which performs the optimization and the control functions of the radio network. The software product can be provided and/or marketed for instance stored on computer storing media such as diskette, CD, DVD, or be transmitted for instance via Internet.

The above described embodiments can be modified in many ways and be varied within the frame of the basic idea of the invention. Such variations and modifications are regarded to be within the frame of the invention as it is defined in the enclosed patent claims.

Patent claims

1. Method to, in a cellular radio network, configure power output of pilot channels, radio network including a plurality of cells and to each cell an associated base station and a pilot channel, including the steps:

division of the radio network, or part of the radio network, into subareas/parts of area,

estimation of the attenuation ($\lambda_p{}^n$) of the radio signal for all, or defined combinations of, subareas/parts of area and cells,

estimation of type of traffic and traffic load within each subarea/part of area,

calculation of an objective function to get a numerical value regarding the quality of the radio network, or part of the radio network, on basis of a configuration of power output of pilot channels,

optimization with the aim to configure the power output values of pilot channels so that the numerical value of the objective function is maximized,

c h a r a c t e r i z e d in
that the division of the radio network, or part of the radio network, is so made that in each subarea the signal strength from the pilot channels of the cells are expected to be essentially constant and within each subarea the traffic load is expected to be essentially constant, and

that the objective function includes a coverage related term and a capacity related term.

2. Method as claimed in patent claim 1, c h a r a c t e r i z e d in that the coverage term punishes, by/with one to the coverage related weight factor (k_{cov}), suggested configurations which do not meet with the coverage demand.

3. Method as claimed in patent claim 2, c h a r a c t e r i z e d in that the capacity term essentially describes an average value of remaining power margin in the cells, and if any cell exceeds its maximum power output, suggested configuration is punished with/by one to the capacity related weight factor (k_W).

4. Method as claimed in patent claim 1, c h a r a c t e r i z e d in that the optimization step includes an optimization algorithm including random variation of power output of selected pilot channels and a selection process to select the power output values of those pilot channels which maximize the numerical value of the objective function.

5. Method as claimed in patent claim 1, c h a r a c t e r i z e d in that the optimization step is composed of a genetic algorithm.

6. Method as claimed in patent claim 3, c h a r a c t e r i z e d in that the objective function (F_{III}) essentially can be described according to

$$F_{III} = \frac{100}{\sum_n P_{\max,n}} \left(F_{\text{cov}} + \sum_n W_n^{III} \left(P_{\max,n} - P_n^{TOT} \right) \right)$$

where F_{cov}, is the coverage related term, the sum $\sum_n W_n^{III} \left(P_{\max,n} - P_n^{TOT} \right)$ is the capacity related term,

$$W_n^{III} = \begin{cases} 1, & if\ P_n^{TOT} \le P_{\max,n} \\ k_w & otherwise \end{cases} \quad \text{and} \quad F_{\text{cov}} = \begin{cases} 0, & if\ p_{\text{cov}} \ge p_{target} \\ 100\left(p_{\text{cov}} - p_{target}\right)k_{\text{cov}} \end{cases},$$

where P_n^{TOT} is the total power output, $P_{n,max}$ is the maximum available power of each base station, p_{cov} is an assumed area probability, and p_{target} is the wanted area probability.

7. Method as claimed in patent claim 2, c h a r a c t e r i z e d in that the capacity term essentially is calculated on basis of the load margin per cell and that the capacity term of the objective function essentially describes the average load margin.

8. Method as claimed in patent claim 7, c h a r a c t e r i z e d in that the objective function (F_{IV}) essentially can be described according to

$$F_{IV} = \frac{100}{N_{cells}}\left(F_{\text{cov}} + \sum_{n}(1 - X_n)\left(1 - \frac{P_n^{TOT}}{P_{\max,n}}\right)\right)$$

where F_{cov}, is the coverage related term, the sum $\sum_{n}(1 - X_n)\left(1 - \frac{P_n^{TOT}}{P_{\max,n}}\right)$ is the capacity related term,

$$F_{\text{cov}} = \begin{cases} 0, & if\ p_{\text{cov}} \geq p_{target} \\ 100(p_{\text{cov}} - p_{target})k_{\text{cov}} \end{cases},$$

where X_n is current load per cell, P_n^{TOT} is the total power output, $P_{n,max}$ is the maximum available power of each base station, p_{cov} is an assumed area probability, and p_{target} is the wanted area probability.

9. Method as claimed in patent claim 2, c h a r a c t e r i z e d in that the capacity term of the objective function is weighted by/with a load describing factor and that the cells which have a traffic load exceeding a predefined value are punished by/with one to the traffic load of the cell related weight factor (k_x).

10. Method as claimed in patent claim 7, characterized in that the objective function (F_V) essentially can be described according to

$$F_V = \frac{1}{N_{cells}}\left(F_{\text{cov}} + \sum_n W_n^I W_n^V \frac{P_{\max,n}^{CPICH} - P_n^{CPICH}}{1 - X_n}\right)$$

where F_{cov}, is the coverage related term, the sum $\sum_n W_n^I W_n^V \frac{P_{\max,n}^{CPICH} - P_n^{CPICH}}{1 - X_n}$ is the capacity related term,

$$F_{\text{cov}} = \begin{cases} 0, & \text{if } p_{\text{cov}} \ge p_{target} \\ 100(p_{\text{cov}} - p_{target})k_{\text{cov}} \end{cases},$$

$$W_n^{III} = \begin{cases} 1, & \text{if } P_n^{TOT} \le P_{\max,n} \\ k_w & \text{otherwise} \end{cases},$$

$$W_n^V = \begin{cases} 1, & \text{if } X_n < 1 \\ k_X & \text{otherwise} \end{cases},$$

where P_n^{CPICH} is the power output of the pilot channels per cell n, $P_{max,n}^{CPICH}$ is the maximum allowed power output of the pilot channels per cell, X_n is current load per cell, P_n^{TOT} is the total power output, $P_{n,max}$ is the maximum available power of each base station, p_{cov} is an assumed area probability, and p_{target} is the wanted area probability.

11. Software product which directly can be loaded to an internal memory in a processor in a computer intended to be used for pilot channel configuration, the software product including software code for execution of the steps in just any of the patent claims 1-10.

12. Software product stored in one for computers usable storing medium, including one or more programs to effect/achieve a process in a computer intended to be used for pilot channel configuration, to check the

execution of the steps in just any of the patent claims 1-10.

13. Radio network for mobile communication in which the method according to any of the patent claims 1-10 is implemented.

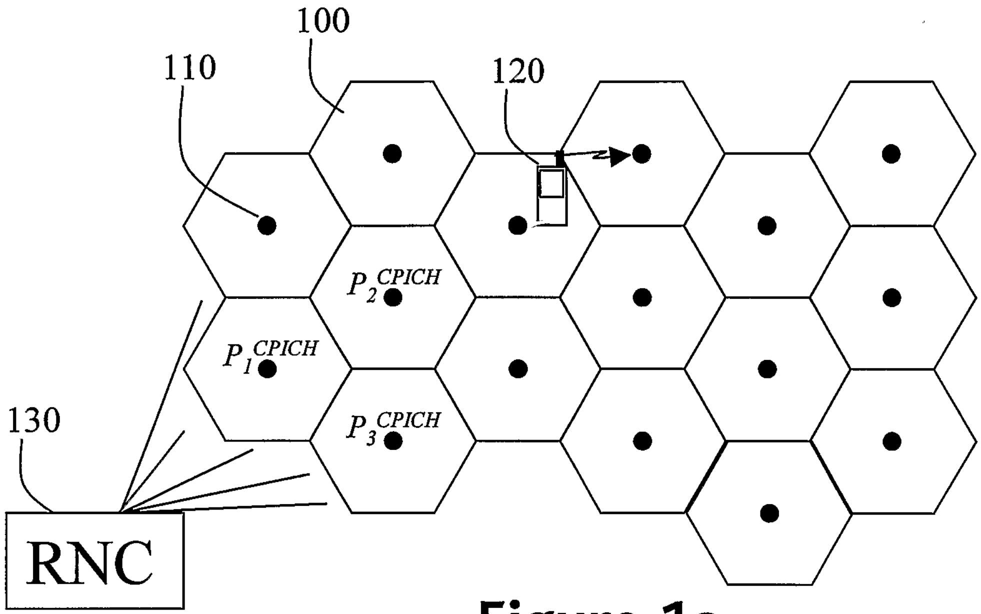


Figure 1a

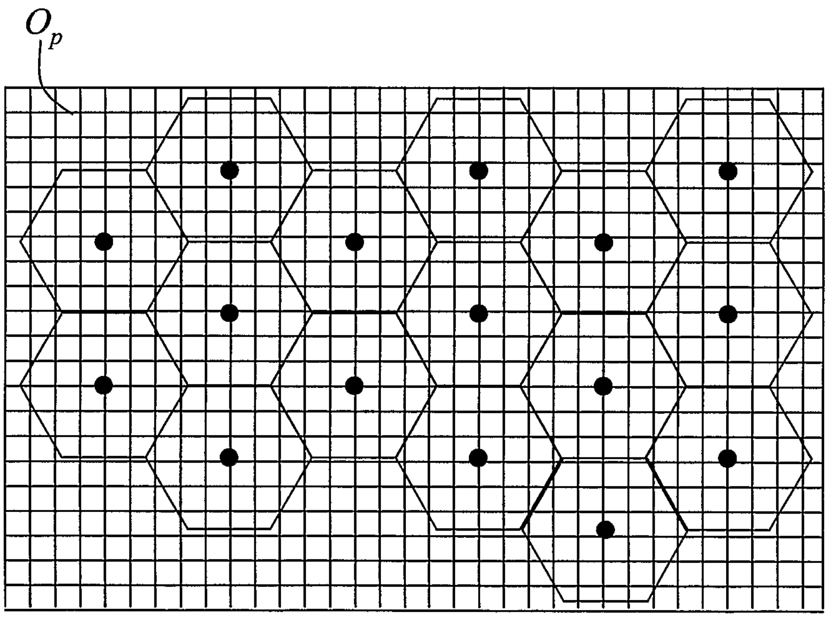
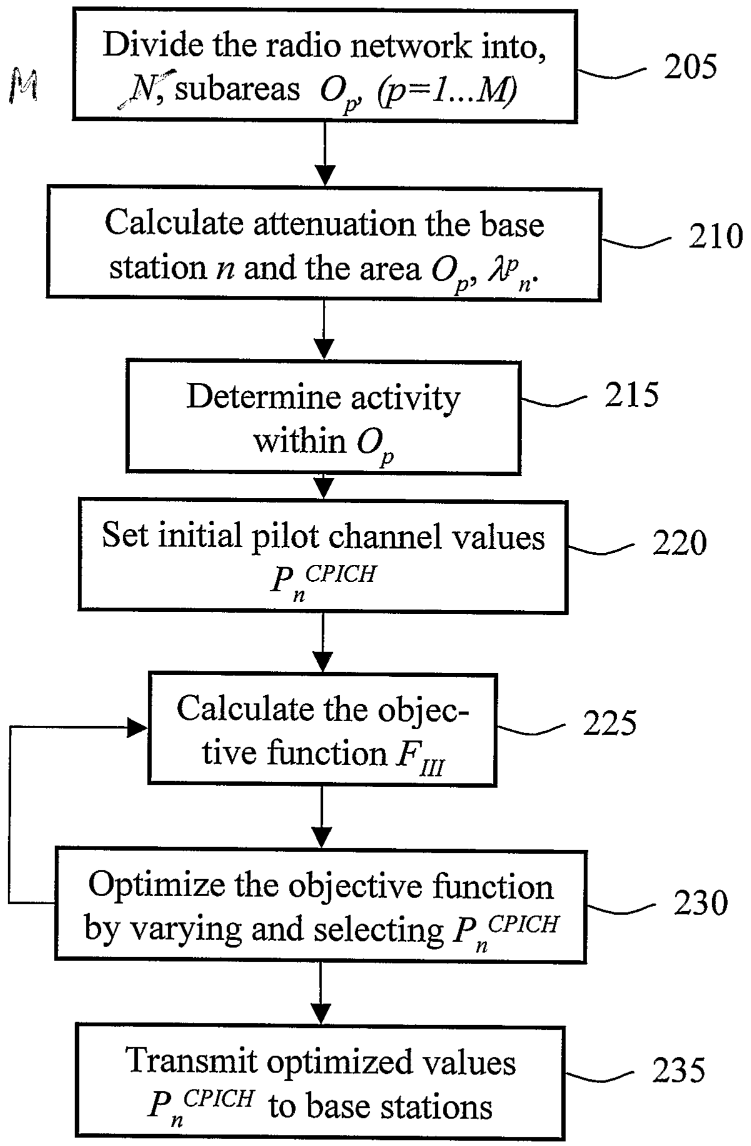


Figure 1b

2/2



M
Divide the radio network into, N, subareas O_p, $(p=1...M)$
205
Calculate attenuation the base station n and the area O_p, $\lambda^p{}_n$.
210
Determine activity within O_p
215
Set initial pilot channel values P_n^{CPICH}
220
Calculate the objective function F_{III}
225
Optimize the objective function by varying and selecting P_n^{CPICH}
230
Transmit optimized values P_n^{CPICH} to base stations
235

Figure 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 03/00392

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: H04B 7/005, H04Q 7/36
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: H04B, H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Akl, R.G. "Multicell CDMA network design" Vehicular Technology, IEEE Transactions on Page(s): 711-722, vol 50 ISSN: 0018-9545 see page 712, column 1, line 39 - 54 abstract --	1-13
A	US 6314294 B1 (MATHILDE BENVENISTE), 6 November 2001 (06.11.01), column 15, line 4 - column 16, line 47, abstract -- --------	1-13

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 June 2003	16-06-2003
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Catharina Karlsson/mj Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

29/04/03

International application No.
PCT/SE 03/00392

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6314294 B1	06/11/01	CA 2350875 A	25/04/98
		CA 2350939 A	25/04/98
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		JP 2002101468 A	05/04/02
		US 6442397 B	27/08/02
		US 6473623 B	29/10/02
		US 6496699 B	17/12/02
		US 2002098847 A	25/07/02
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		JP 10013926 A	16/01/98
		US 6112092 A	29/08/00