REDUCTION OF ELECTROMAGNETIC POLLUTION IN MOBILE COMMUNICATION SYSTEMS BY AN OPTIMIZED LOCATION OF RADIO BASE STATIONS

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ABSTRACT

This research has the purpose of creating a tool for the planning of new radio base stations (RBS), considering both the health protection and the communication requirements. The optimization procedure is based on the genetic algorithm, and is applied to an ideal town, with selected characteristics. The mathematical formulation of the problem consists in the development of five functionals, one for each problem to be solved (environmental impact of the electromagnetic fields, and system requirements as coverage, C/I ratio, traffic, and profit); an overall functional is a linear weighted combination of the previous ones.

INTRODUCTION.

The increasing demand for personal communication systems leads to an increasing number of radio base stations (RBS) in order to assure the complete radio coverage of the territory for a greater number of users. At the same time people have become more sensitive to the problem of possible hazards due to the electromagnetic pollution, and consider RBSs dangerous for human health. Even though no scientific evidence of any relationship between electromagnetic fields and human diseases has been shown, all precautionary measures against an uncontrolled increase of the electromagnetic field level must be taken. On the other hand, also the quality of service (QoS) has to be assured, and this seems to many people to be in contrast with the precautionary principle.

Cooperation between local government, with their technical staff, and the providers of the communication service, seems to be the best solution of many unnecessary alarms.

This research has the purpose of creating a tool for the planning of new RBSs , considering both the health protection and the communication requirements. In particular the tool is based on an optimization algorithm that explores possible solutions of the problem. The optimization procedure is based on the genetic algorithm, and is applied to an ideal town, with selected characteristics. The mathematical formulation of the problem consists in the development of five functionals, one for each problem to be solved (environmental impact of the electromagnetic fields, and system requirements as coverage, C/I ratio, traffic, and profit); an overall functional is a linear weighted combination of the previous ones. The characteristics of each functional are presented in this paper.

FORMULATION OF THE PROBLEM.

In this paper the genetic algorithm [1] is used to optimize a functional that represents mathematically the behavior of a system. The optimization procedure is required because in the problem of the wireless network design, the solution is represented by the best compromise by contrasting aspects, as the minimization of the em. field [2] and the QoS.

In the proposed model, after choosing the number of RBSs to cover the interested area, station positions, antenna tilt, and radiated power are the parameters that must be optimized considering that the principal requirements are: minimization of the em. field, maximization of the carrier/interference (C/I) ratio, traffic to be served, coverage percentage and the economical efficiency of the base station system.

The first requirement is not only due to a general precautionary principle, but also to a specific law: in fact the Italian standards, regarding the e.m. emissions, impose a limit of 6 V/m for long term exposed people, and state that, however the e.m. field emissions have to be minimized compatibly with the QoS.

The maximization of the served traffic and the costs are requirements important for the network providers, in order to increase the economic efficiency of the system.

The C/I ratio, and the coverage are important for users, because these parameters assure a good QoS and the utilization of the cellular phone in wide areas.
For each of the above, a functional has been developed, so that an optimal solution for each requirement can be found. The overall optimal solution is represented by a linear combination of the functionals:

$$F = w_1 f_1/f_{1max} + w_2 f_2/f_{2max} + w_3 f_3/f_{3max} + w_4 f_4/f_{4max} + w_5 f_5/f_{5max} \quad (1)$$

where f_i is the functional for the i-th requirement, normalized to its maximum value f_{imax} ; normalization is necessary because they are very different in value and represent non homogeneous quantity. The w_i are weighting parameters, and according to specific situations, their values can be properly chosen to emphasize a particular aspect: for example, if the constrain concerning the environmental impact, represented by functional f_1, is dominant, the value of w_1 will be greater than all the other weights.
From a graphical point of view, the optimization of the overall functional F can be seen as the maximization of the area of the pentagon in Fig. 1.

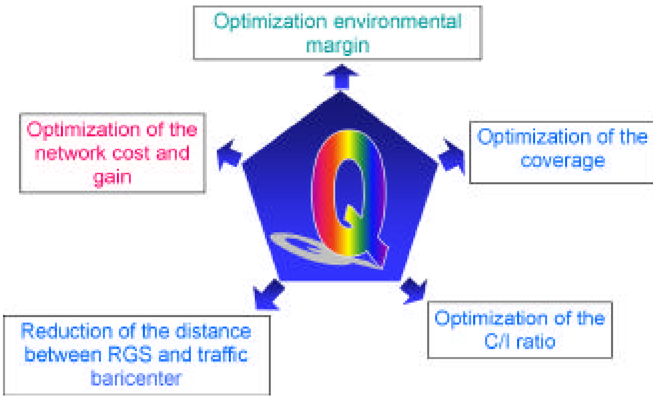

Fig.1 Scheme of the optimization of a radio base station network.

Environmental Impact of the Electromagnetic Field

The first functional represents the level of the em field and has to be minimized (maximum reduction of the emission in the figure). For simplicity it is called the environment functional.
The area to be covered is divided into regions, each of them served by one RBS antenna. Moreover the area is discretized into a number of pixel PxQ, approximately of 10m side. The dimension of the pixel gives a reasonable spatial resolution, for the orographic description of the area. Different field safety levels can be assigned to the areas, so it is important to define for each pixel which kind of protection is due. In residential area, for example, the accepted e.m. field level is lower than the analogous level for an industrial area. The functional also accounts for the possibility to exclude some highly protected areas (hospitals, historical centers of towns, etc…) from the RBS positioning.
The functional of the environmental impact is:

$$f_E \equiv \sum_{i=1}^{pxq} \left(\sqrt{\left(\sum_{k=1}^{m} C_k \times \left[E_{i,k}\right]^2 + \left(E_{0i}\right)^2 \right)} \right) / Q_i \quad (2)$$

where, Q_i is the level (3,6,20 V/m) of protection for the i-th pixel, $E_{i,k}$ is the electric field radiated by the k-th RBS in the i-th pixel, C_k is the number of carriers for each RBS, $E0_i$ is an electric field already present in the area to be covered, m is the total number of RBS, pxq is the number of pixel in which the area is divided.
Minimizing electric field radiated in the area, leads to a minimun value of the functional f_E. In particular, if an area is highly protected its quality factor Q_i is low so the corresponding terms in the summation are characterized by a high weight. In this way the algorithm tries to limit the value of the field in those pixels, decreasing the corresponding terms by changing the position of the RBSs, their radiated power and their tilt.

C/I ratio

The third functional is related to the QoS in terms of C/I ratio. The optimization consists in maximizing the ratio in each cells. In this case the input data necessary for the code, is the minimum C/I ratio allowed for each pixel. The algorithm tries to reach the fixed minimum value if the C/I ratio is lower than the limit, but it ignores the pixel if the C/I ratio is better.

$$f_{C/I} \equiv -\sum_{k=1}^{m}\sum_{i=1}^{nk}\left(\sum_{\substack{j=1\\ j\neq k}}^{m}\left(P_{kik}-P_{kij}\right)/(m-1)-Q_{k,i}\right) \tag{4}$$

where $Q_{k,i}$ is the limit for the C/I ratio in each pixel, it can assume the values 9 or 18 dB, $P_{k,i,j}$ is the power radiated by the j-RSB, in the pixel i in the region k, m is the number of RBS, n_k is the number of pixel in region k. The power levels in this function are taken in dBm.

With this function, the algorithm tries to position the RBS far from each other, but near the zone where the C/I desired is greater. It also increases the tilt of the antennas.

Traffic

The second functional takes into account the requirement that the RBSs have to be as close to the traffic baricenter as possible. This objective can be obtained weighting the distances of each pixels from the RBS, the traffic being defined in each cells (input data). In this way the algorithm tries to reduce the distance from the RBS to the pixels with high traffic. The functional for the traffic is

$$f_{dist} \equiv \sum_{k=1}^{m}\left(\sum_{i=1}^{nk} T_{i,k} \times \left(\mathrm{dist}\left(SRB_k - Pixel_{i,k}\right)\right)\right) \tag{3}$$

where $T_{i,k}$ is the traffic in the i-th pixel belonging to region k, and its value can be 10 or 25 or 45 erlang, m is the number of regions and nk the number of pixel in the k-th region.

Coverage

The fourth functional evaluates the coverage level. In this case, the input data represent the desired signal power in each pixel. These values are used to weight the actual power received in each pixel. The functional is simply the sum of the power received in each pixel, so that the algorithm tries to maximize the entire sum.

$$f_{COV} \equiv -\sum_{i=1}^{pxq}\left(Q_i \times P_{RX_i}\right) \tag{5}$$

where, Q_i is the desired power level in the i-th pixel, and P_{Rxi} is the power actually received, i is the indice for the pixel. All the power levels in this functional are considered in W. Using this functional the algorithm tries to locate the RBSs close to the region where the desired coverage level is maximum, but without missing the areas where a minimum coverage is requested by a proper increasing of the radiated power.

Profits

The last functional is developed to quantify the economic return for the provider. In this case the considered parameter concerns the overall system efficiency in the sense that each RBS have to serve the maximum traffic as possible. Moreover, the functional works to give approximately the same amount of traffic to each RBS, considering that a configuration where RBSs share fairly the same traffic give a better profit than a configuration where some RBSs serve more traffic than the other. In this case the functional is

$$f_{return} \equiv \prod_{k=1}^{m}\left(\frac{1}{\sum_{i=1}^{nk} traffic_{i,k}}\right) \tag{6}$$

where, $traffic_{i,k}$ is an input data on the traffic forecasted in each i-th pixel, belonging to the k-th region, m being the number of regions, nk the number of pixel in region k. This functional changes only the position of the antennas and doesn’t change either power or tilt; in the optimized solution a uniform traffic amount pertains to each RBS.

RESULTS.

The algorithm has been applied to the ideal, level, square area (side of 5 km) shown in fig. 2. The area was divided in three parts, each of them characterized by different traffic, C/I, coverage, and environmental impact levels; moreover into an inner zone the location of RBS is forbidden. At this stage of the research, this situation was chosen to test at first the five functionals separately, and then working all together.

When functionals were tested separately, an optimal solution for each one was found, and therefore also the value f_{imax} to be used in eq.1. When the algorithm evolves to optimize one particular functionals, also the other functionals change their values, even if they do not affect directly the optimization procedure. In this way it is possible to see what happens to the other requirements when the network planning takes into account one parameter only. In particular this procedure highlights the contrasting nature of the requirements, so that the contemporaneous maximum optimization of all requirements is impossible, and the solution provided by the algorithm is the best compromise. Fig. 3 shows the electric field in the proposed area, for the optimization of the 5 functionals together. The electric field is plotted in $dB_{\mu V/m}$.

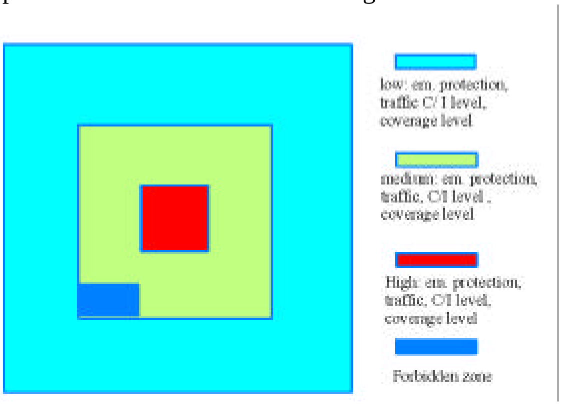

Fig.2 Plane area, used for the validation of the functionals

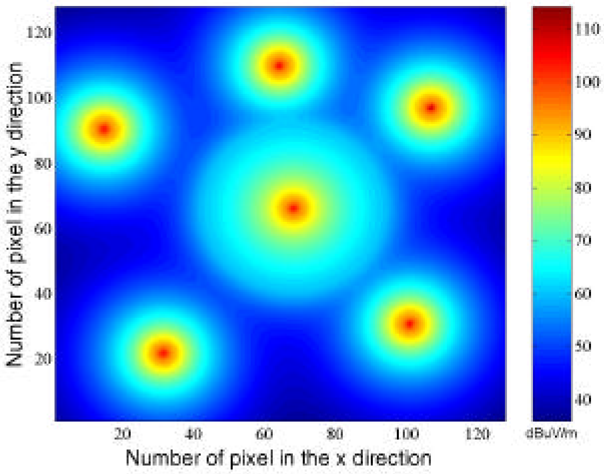

Fig.3. Electric field pattern in the chosen area.

CONCLUSIONS.

An optimization procedure for planning the location of RBSs in a cellular phone network is developed by using the genetic algorithm. The quality of service as well as the environment protection against electromagnetic pollution are the parameters on which it is based the code. In particular the C/I ratio, traffic, coverage, and economic efficiency are considered as constrains of the communication system. Five functionals are defined and the algorithm is applied separately to each one, and to their combination. Many results has been found, from which one can infer that an optimized solution represents the best compromise among contrasting requirements.
Future development of the research concerns the use of different prediction models for the evaluation of the electromagnetic field, as, for example, a ray tracing model for areas in the RBS proximity, and a simple statistic model for areas far from it. In order to accomplish this, the 3D cartography of the analyzed region, showing position and geometry of buildings, has to be inserted in the code.

REFERENCES

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