A Study of the Effect of Land Relief on the Design of Wireless GSM Coverage

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Abstract – **The paper summarizes the basic steps in the design of a GSM network. We consider a hypothetical design using EDX-SignalPro software. We select an area from the digital map generated by the software. We conduct a study of traffic patterns, demography and the land surface suitability in a given area in order to select the number and location of base stations. The network parameters are entered into the software package, generating a visual results exhibit. We demonstrate the advantages of computer-aided design using software such as EDX-SignalPro, which include greatly reduced cost and time spent on the design process.**

Keywords – **Design, Wireless, GSM network, EDX-SignalPro software**

I. Introduction

Proper planning of network is essential for obtaining largest possible coverage, appropriate level of service and lowest possible cost. Assume that there is a permission for the make-up of a certain cellular system in a corresponding consumer field. To begin with, it is necessary to determine two elements: the standards and norms in the selected country/area and the current situation on the target market [1, 2].

The aim is to cover the largest cities first, then the busiest highways and border checkpoints. Due to economic considerations it is not expedient to ensure a *100%* of quality coverage.

It is a widespread practice to determine the coverage zones on the basis of *90%* (*10%* are allotted for poor quality communications).

II. Steps of Effecting Network Make - Up

1. Selection of areas to be covered and stages of network construction.
2. Selection of location of components. Selection of points for BTS. A good knowledge of the area map and the available TV towers is of vital importance.
3. Prognostication of field *E* intensity, i.e. what is the distance that will ensure quality connection (the size of the cell)
4. Evaluation of prospective communications traffic in the area which is covered by one BTS
5. From item 4. we get the number of radio channels required for the proper service within the zone covered by a single cell.
6. Estimation of mutual interferences (what is the extent to which other transmitters interfere with this or other particular frequencies). These also depend on the intensity of the communications traffic. When estimating interferences it should be taken into account that the range of two adjacent cells will overlap to a certain extent – (interference prognostication)
7. Structure of radio channels is made up on the basis of item 6. (what is the distance that will allow for an identical frequency to be repeated). After that *D* is determined (the distance between cells which share channels) and the number of cells in a group.
8. Then comes the channels distribution for all cells and investigation of probable lockings of each cell within the BTS as well as its recovery.

Applicable check up of the lay-out (blueprint) requires a good knowledge of both techniques and conditions for distribution within a certain network. In reality there are always some unserviced zones (recovery measures include: addition of cells, splitting a cell into sectors, use of directed antennae) [1, 2, 3].

2.1. Prognostication of the mean value of field E_{mean}

When prediction is made of *E* field of a certain cell, it should be divided into small enough sectors, which will allow predicting the average square value of signal for each sector.

Now the average square value of E_{mean} at a certain point (sector being determined by averaged values) will depend on the following:

1. Frequency f
2. Distance d.
3. Height of the antenna over the ground (*H base*)
4. Height of receiver's antenna over the ground
5. Average altitude of the terrain
6. Landscape features and peculiarities of the terrain (sea, land, forest, barriers)

Prediction database for E_{mean}

1.Topographic (average altitudes)

2.Database for specific terrain (through satellite mapping-field, forest, etc.)

a) densely populated city

b) suburban or country area

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d) forests and fields- pure forest terrain; mixed terrain – fields and forests(parks), green patches, agricultural areas

e) others: rock, sands, roads, tarmacs, water surface

Since prediction by utilizing theoretic formulae is very difficult to achieve, some other practical models are used instead [1, 4].

2.2. Estimation of probable communications traffic in a certain area covered by one BTS

Network planning basis involves traffic requirements such as the number of subscribers in the network and the amount of traffic they could possibly generate. The unit of traffic intensity is Erlang (*E*). Generated traffic is calculated by the following formula:

$$A=n.T/3600Erlangs,$$

Where *A* is the traffic generated by one or more subscribers in the system, *n* is the number of calls per hour and *T* is the average duration of a call in seconds.

Geographical distribution of traffic can be calculated by employing specific data such as:

- distribution of population
- distribution of the use of vehicles
- distribution of incomes among the population
- agricultural and other kinds of use of the land
- statistic surveys of the use of telephones
- other factors such as subscription fees and cost of mobile phones [1, 4].

III. Planning and Development of Model Project by Means of "EDX-SignalPro" Software

"EDX-SignalPro" offers computer modeling of radio networks, pertaining to all known systems, by preassigned digitalized map or by a map generated through the software. In the particular case of study the total area amounts to *36370 km²*. Out of this area is picked a region of *7000 km²* of specific relief which allows simultaneous investigations of the signal in a plain, urban, semimountainous, mountainous and rural regions For the sake of getting a better impression of the relief it would be a good idea to make a 3D image. Colours are selected to correspond to the relief and altitude printed on standard maps. Each image is supplied with a legend, which indicates the boundaries of individual colours and the perimeters they correspond to. In this way we get detailed information for the investigated area. In our particular case forests and mountainous areas occupy *5900,25 km²* (*82,27%*) Areas of arable land are *675,50 km²* (*10,29%*), *292,2 km²* or *4,46%* pertain to residential areas whereas industrial areas are equal to *48,5 km²* (*0,74%*), open spaces amount to *9,25 km²* (*0,14%*); and water bodies are *124 km²* or (*1,87%*)

3.1. Selecting the location of BTSs

Initial cellular plan indicates the locations of BTSs, each antenna coverage, and the distribution of frequencies among the cells. Factors such as these are based on traffic prediction so that after having tuned the layer according to the relief another layer, that of traffic intensity, is generated as well as a layer of the population distribution (number of persons per *km²*). Both investigations make it evident that high traffic intensity corresponds to high population concentrations in the separate areas.

Basic parameters that are taken into account in selecting the sites and the number of BTSs include traffic intensity, utilization of land, demographic distribution and the relief of the landscape. Five stations have been selected (BTS1, BTS2, BTS3, BTS4 and BTS5) and located at vantage sites of suitable altitude, as close as possible to densely populated settlements with high traffic intensity. Fig. 1 shows the locations of BTSs as a proof of above statement.

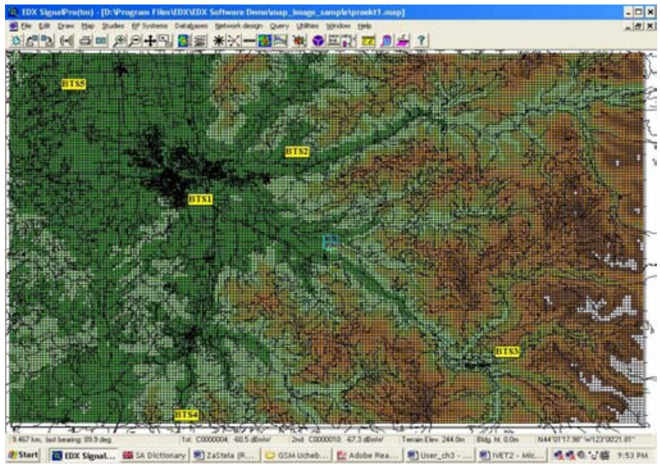

Fig.1. Locations of BTSs

The next parameter to be taken into account is the height of the equipment, which is in direct dependence on location (Table 1). In this case the recommended location from Table 1 is not kept for all BTSs because selected locations in real settings are properly made and that could bring to considerable cost cuts.

Table 1
GSM900

Parameters of BTS	Rural zone (plain terrain)	Rural zone (quasi plain terrain)	Urban area
Height of BTS, *m*	100	100	50
Height of MS, *m*	1,5	1,5	1,5
Hata's formula of losses (*d* is in *km*)	90,7+31,8*lg*(*d*)	95,7+31,8*lg*(*d*)	123,3+33,7*lg*(*d*)
Losses within the building (internal), *dB*	10	10	15

3.2 Assigning the parameters of the mobile unit

The parameters of the mobile station are assigned by standard values (Fig .2) [4] such as type of antenna (cross/ guided) average antenna (height above ground)

$$h.a.g = 1,5m,$$

gain = 3dB, maximum transmission power *ERP = 2W*, minimum permissible signal to noise ratio, intermodulation distortions:

$$C/(I+N) = 16\ dB.$$

Maximum permissible receiver noise level - *R.n.l. = -122 dBmW*.

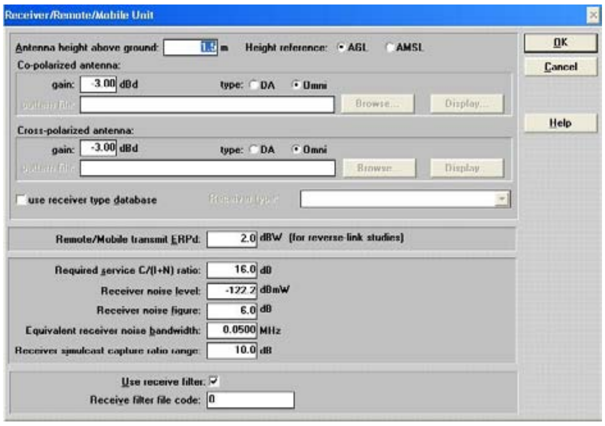

Fig.2. Window for tuning of mobile unit parameters

It is recommendable to make a preliminary estimation of field intensity for each BTS in order to find out whether the tunings are appropriate and, if not, to make necessary corrections [4].

3.3. Investigation results

Fig.3 shows the window for defining of investigation parameters whereby most measurements that underlie coverage quality are made. These are received power at remote (the level of signal i.e., power gain at the mobile unit antenna), field strength at remote (levels of field intensity), Shadow map (direct visibility zones and the zones of signal reflected by the environment). All have been selected from Area study type menu.

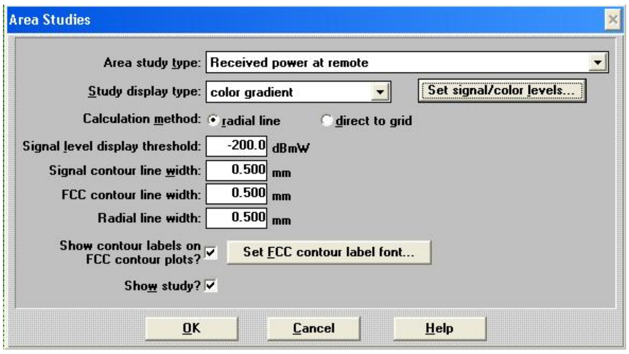

Fig.3. Defining investigation parameters

Signal power, which comes to the mobile unit in *dBmW* is shown in Fig.4. Graded colours are used for the purpose of better visualization. Minimum usable level which allows standard quality connection is [3, 4]: *m.u.l.= -104 dBmW.*

The figure makes clear that a very good coverage is achieved in densely populated areas (red and yellow), the power values being far above the minimum required for quality connection. Lower power areas are marked with green. However, it is sufficient because the traffic there is low. Lowest power is indicated by blue colour (it is almost close to the permissible lows), however, the relief there is mountainous and there are no inhabited settlements, so such signal level is permissible.

When predicting field *E* intensity we use basic dependences for distribution of EMB – attenuation with direct visibility and behind a barrier. The purpose of predicting is to determine the average value of *E* which is due to the slow variations of the field (slow fading). Accordingly, it is necessary to know which areas are with direct visibility and which are not.

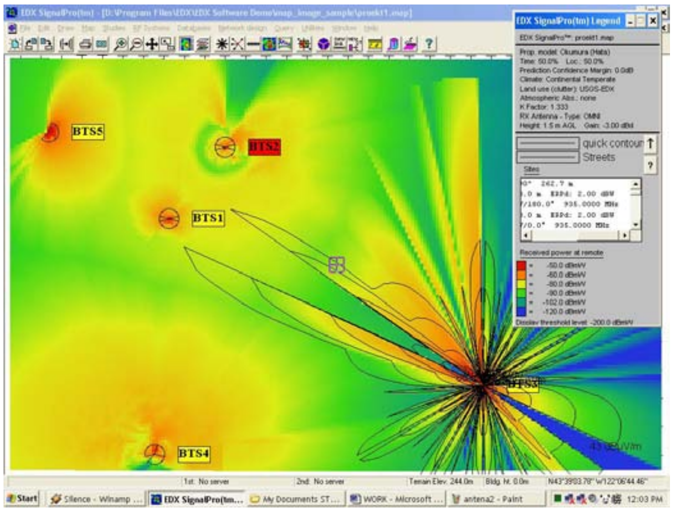

Fig.4. Level of signals in dBmW(Power gain at the antena of the mobile unit)

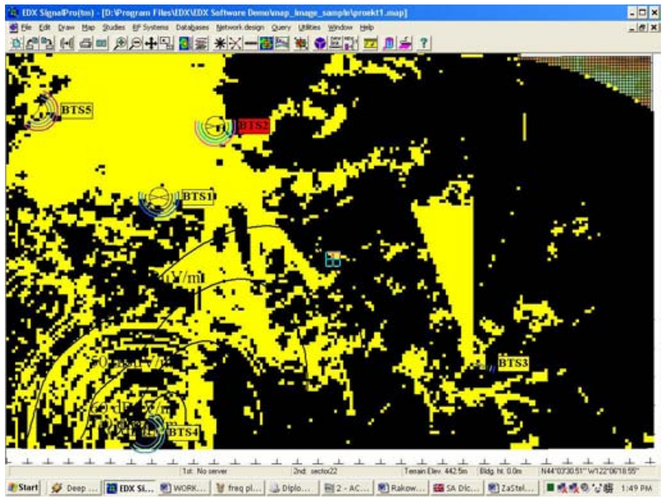

Fig.5. Line of sight zones and zones with signals reflected by the environment (yellow indicates line of sight; black – reflected signal)

Field intensity created by the transmitters is shown in Fig.6. Colour gradation is also used in there. The standard minimum value of intensity, which allows for quality connection, is *43 dBμV/m*.

Here the conclusions are similar with those in Fig. 4.Consequently, we draw the conclusion that the quality of connection across the investigated area is good and it is better for the densely populated areas and not so good for the sparsely populated and uninhabited areas (yet within the permissible limits). This is indicative of a correctly designed network whose parameters are selected comparatively well. The model development does not claim to be the perfect solution nevertheless it is helpful for the make-up of a network of adequate coverage.

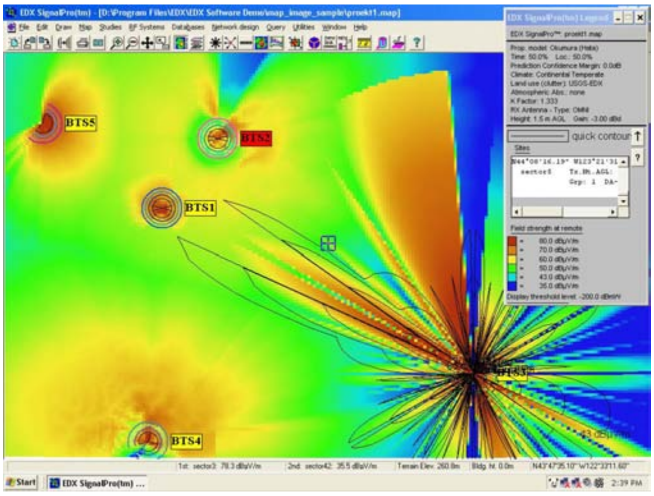

Fig. 6. Levels of field intensity in *dBμV* (minimum permissible level ***– 43dBmV/m***)

IV. Conclusion

The aim of the paper is to build up a system of the steps needed to design a GSM network. Next comes the design of a model network by means of EDX-SignalPro" software. Further steps include the selection of appropriate digitalized map, investigation of traffic intensity, demographic distribution, utilization of land in the selected area etc. Based on these it is possible to select the number of BTSs and their location. After that all required network parameters are entered and results are visualized.

A GSM network design is a long and complex process, which involves a number of procedures, investigations and a sound knowledge of network standards. Soft products such "EDX-SignalPro" could be used effectively in various applications, which would considerably reduce the amount of time and funds that have been so far demanded by similar projects.

References

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