Service area estimation for mobile radio by the aid of a topographical data base

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1. Introduction

The mobile radio channel is affected by diffraction and scattering in the terrain. In /1/ an attempt has been made to compute the scattered waves by use of a topographical data base of the University campus of Kyoto. In this data base detailed information about the buildings is stored. Even then a considerable difference between measured and computed field-strength levels occurs because the wavelength is much smaller than the excess delay path length and the fading depends on the phase relations between the scattered waves.

Topographical data bases described by other authors in 1983 from Italy /2/, from the United Kingdom /3/, from Japan /4/, from Canada /5/ and from Germany /6/ cover much less data about the terrain. The approach in all these papers is modest compared to the expectation what could be computable if the locations of all the scatterers were known exactly.

2. The topographical data base used in the Federal Republic of Germany

The topographical data base used in Germany is organized in a meshed grid according to geographical coordinates. The size of one area element is five seconds of arc in square, i.e. 150 m in the north-south direction and 100 m in the east-west direction. Besides of the height the German topographical data base contains environmental data indicating the major part of land usage within the area element considered: Built-up area, forest, rural area and water.

3. The propagation prediction algorithm used with the German data base

A packet of FORTRAN programmes has been written to predict the area coverage for mobile radio. For the computation of the field-strength level at one point first of all the path profile is determined by stringing the height values and the figures for land usage which are found in the topographical data base along a polygonial approximation of a great circle. In the next step of the programme the base station effective antenna height h_1 is determined. The definition of the CCIR recommendation 370-4 /7/ and Okumura /8/ was altered /9/in

$$h_1 = \begin{cases} h_b + h_{ob} - h_{om} & \text{for } h_{ob} > h_{om} \\ h_b & \text{for } h_{ob} \leq h_{om}, \end{cases} \qquad (1)$$

with h_b being the height of the base station antenna above ground and h_{ob} and h_{om} the terrain heights at the base and the mobile station, respectively. This definition yields smaller mean prediction errors on the average.

If there is no free line-of-sight the method proposed by DEYGOUT /10/ for multiple-edge diffraction is applied. The following correction functions proposed by OKUMURA are used:

- the basic median attenuation in urban areas,
- the base station effective antenna height gain with the altered definition for h_1 according to Equ.(1),
- the open area correction factor and
- the slope correction factor.

Due to the lack of data in the German data base some correction functions defined by OKUMURA /8/ cannot be applied:

- the "along and across path correction factor", by which the different attenuation caused by the orientation of the road is considered,
- the suburban correction factor and
- the mobile antenna height correction factor which could take into account the level of the road compared to the level of the terrain.

On the other hand we have defined some new correction functions based on our measurements which take into account the attenuation due to the obstacles in the vicinity of the mobile. The size of the area elements in the German data base is relatively small. Rivers, sport yards, parks, small stripes of forest or open areas can be identified by analysing the path profile. The mixed land usage combined with terrain undulations near the mobile affect the wave propagation strongly. We have pondered on the determination of parameters to be extracted from the rather poor information stored in the data base. By statistical comparison with a large number of measurements we have examined whether the application of these parameters in new correction functions would reduce the prediction errors. More details are descibed in /9/.

4. Definition of the prediction error

We have performed a large number of CW-measurements at 450 MHz and a smaller amount at 900 MHz in different parts of the Federal Republic of Germany. The measured field-strength values were recorded every 20 cm. For runs of 200m up to 1,500m in length measured in an area not changing in land usage we have computed the median field-strength level. For the middle of each section we have computed the predicted level. The prediction error ΔF is the difference of both.

5. Aspired accuracy of a prediction programme

In mobile radio the variation of the field strength is caused by

a. the length of the radio path,
b. the influence of the orography,
c. the influence of buildings and vegetation and
d. the short-term fading due to the superimposition of scattered waves.

The rapidity of the variation increases from a to d. For topic a no data base is necessary and topic d cannot be computed even if a very detailed data base would be available. In the CCIR documents /7/, the topics b and c are taken into account statistically by a local distribution with a standard deviation σ_L = 13.5 dB at 900 MHz according to Report 567-2 assuming Δh = 50 m. By the use of a topographical data base the main part of this variation should be predictable. The smaller variations

within a certain type of land usage cannot be considered by a planner. Otherwise the frequency economy would be unacceptable. We have found from measurements that the standard deviation of this residual variation is in the order of s = 3...7 dB. Additionally, a seasonal variation of the attenuation caused by vegetation with a standard deviation of σ_{vds} = 3 dB is to be taken into account.
The total standard deviation to cope with is

$$\sigma_T = \sqrt{\sigma_R^2 + s^2 + \sigma_{vds}^2} \qquad (2)$$

with the standard deviation σ_R = 5.6 dB for Rayleigh fading. In planning procedures this statistical variation is to be taken into account. In relation to these natural probability distributions the planner has to consider the prediction error. According to our measurements ΔF is Gaussian distributed. The standard deviation of the prediction error is $\sigma_{\Delta F}$. The standard deviation of the probability function for the planned value becomes

$$\sigma_P = \sqrt{\sigma_T^2 + \sigma_{\Delta F}^2} \quad . \qquad (3)$$

Considering the values of the terms s, σ_R and σ_{vds} a standard deviation for the prediction error $\sigma_{\Delta F}$= 4 dB to 5 dB is tolerable as it does not increase σ_P considerably compared to σ_T.

6. Discussion of the prediction errors

The mean value $<\Delta F>$ of the prediction errors was less than 2dB. The standard deviations of the prediction errors based on measurements at 450 MHz along sections a total of 1,000km was 5 dB for quasi-flat terrain and 7...8 dB for paths obstructed by mountains. The estimation of the attenuation due to the orography cannot be improved by a more sophisticated diffraction analysis of the direct path. A three-dimensional scan of the terrain is necessary to find out the main scatterers and to estimate their contribution to the received power. This analysis would allow also the estimation of the delay spread respectively the coherence bandwidth in order to associate maximum bit-rates with the type of terrain.

7. Graphical display of the area coverage

Scaled overlays on topographical maps indicating the area coverage gained by repeated computation are produced by the aid of an electrostatic plotter. On this overlay the estimated field-strength levels are identified by different shades of gray. Examples have been published in previous papers /6,12/.

8. Conclusions

With regard to the topographical data base it can be concluded:
- The area element size seems to be a good choice, a reasonable reduction of prediction errors using smaller area elements cannot be expected.
- The environmental data used, although coarse, are very valuable. A considerable reduction of prediction errors, however, could be achieved by the countrywide inclusion of main traffic lines and the orientation

of the road grids in cities.
Prediction errors up to 5 dB seem to be tolerable. With regard to environmental data

- the consideration of the road orientation and
- the improvement of correction functions at the borders of different land usage

will reduce the errors considerably. With regard to errors due to orographical obstructions a three-dimensional scan for the estimation of the scatterers in the terrain is inevitable. Although this approach will be difficult and will involve a large increase of computer time the result will be a considerable reduction of the prediction errors. The development of an algorithm for this procedure does not require any changes of the existing data base and also will allow an estimation of the delay spread which is important for the maximum bit rate in digital mobile radio communication.

9. References

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