DIURNAL VARIATIONS OF GROUND LAYER ATMOSPHERIC REFRACTIVITY

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1. Introduction

Distributions in space and time of atmospheric refractivity affect the radio wave propagation on terrestrial microwave paths. Long-term statistics of vertical gradient of refractivity are often used to assess the quality of a path. Usually, radiosonde data measured with a period of several hours are available only and the gradient of refractivity in the first 100 meters above the ground is extrapolated from measurements in higher altitudes. This paper describes the results of continuous tower measurement of atmospheric refractivity gradient at the receiver site of the experimental 19 GHz microwave path. Time series of the measured gradient are analyzed and the parabolic equation method (PEM) is used to calculate time series of received signal level at the receiver point of the path. Comparison of both simulated and measured signal levels is made and the drawbacks of real-time prediction of propagation conditions during no rain periods are described.

2. Measurement of vertical gradient of refractivity

Continuous measurements of the pressure, temperature and relative humidity have been run at the TV transmitter tower in Praha since August 2001. The sensors are located in the heights of 12 m, 126 m and 191 m above the ground level. The sampling rate is 15 seconds. The atmospheric refractivity index was calculated using ITU-R formulae:

$$N = \frac{77.6}{T}\left(p + \frac{4810 e_H}{T}\right) \qquad e_H = H\,\frac{6.1121 e^{\left(\frac{17.502t}{t+240.97}\right)}}{100}$$

where p (hPa) is the atmospheric pressure, T (K) and t (°C) is the temperature and e_H (hPa) is the water vapor pressure corresponding to the relative humidity H (%). The radio refractivity index is defined as $N = 10^6(n\text{-}1)$, where n denotes the refractivity index of the atmosphere.

Figure 1 shows cumulative distributions of the vertical gradient of radio refractivity index obtained from two years data.

Figure 2 shows time series of the refractivity index gradients during no rain period in August 2003.

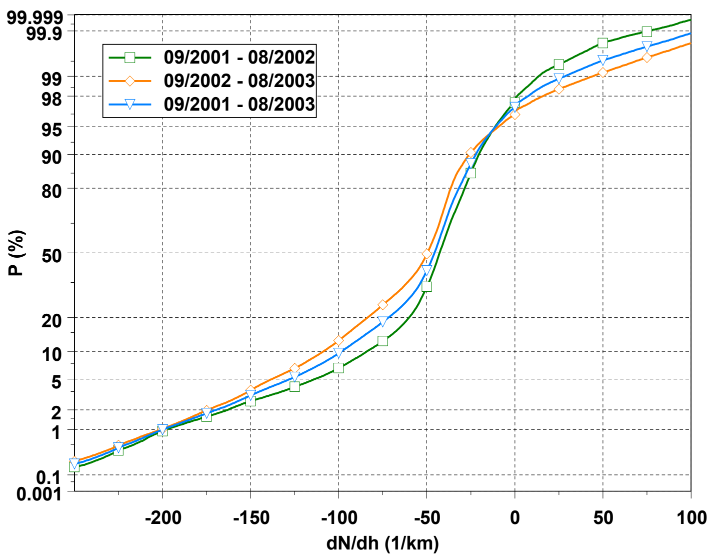


Fig. 1 Cumulative distributions of vertical gradient of radio refractivity index in the heights between 12 m and 126 m

ISBN: 4-88552-207-2 C3055©IEICE

Two gradients were calculated from measured data at three ground levels. Periodic diurnal structure is clearly visible in their evolution. It corresponds with diurnal variation of the temperature and relative humidity of the air. Periodical steep decrease and consequential increase of the gradient in the early morning was observed. Published results show that multipath-fading events occur just in that time most frequently.

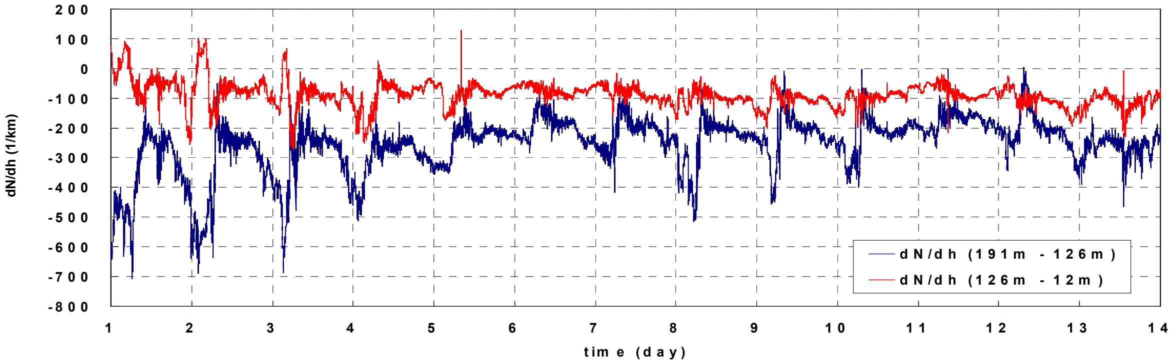


Fig. 2 The refractivity index gradient evolution in August 2003

3. Observed microwave path

Data of AGC voltage from the microwave path TV Tower Praha – Kladno operating at the frequency 19 480 MHz (antenna diameter 1.8 m) is primarily intended for studying absorption fading. However, terrain profile shown in Fig. 3 is relatively flat in the area of expected reflections. Thus multipath fading events are observed here quite often, mostly in summer and autumn early mornings. An example of such event is shown in Figure 4. Data were scanned via PC tablet from the drawn record of AGC and relative received signal level was calculated, using an AGC calibration curve.

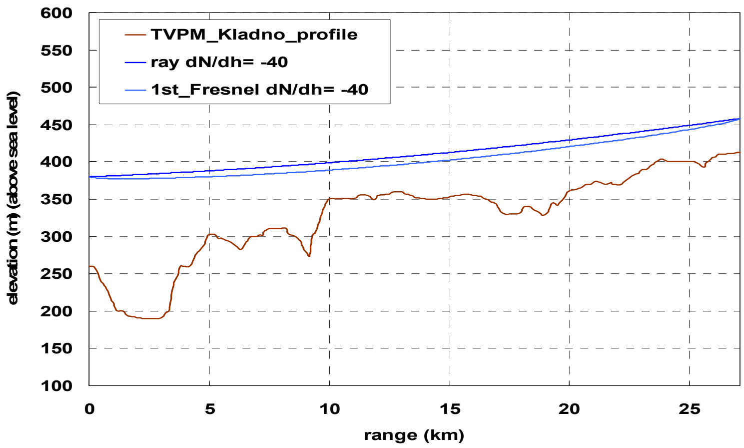


Fig. 3 Terrain profile of observed path

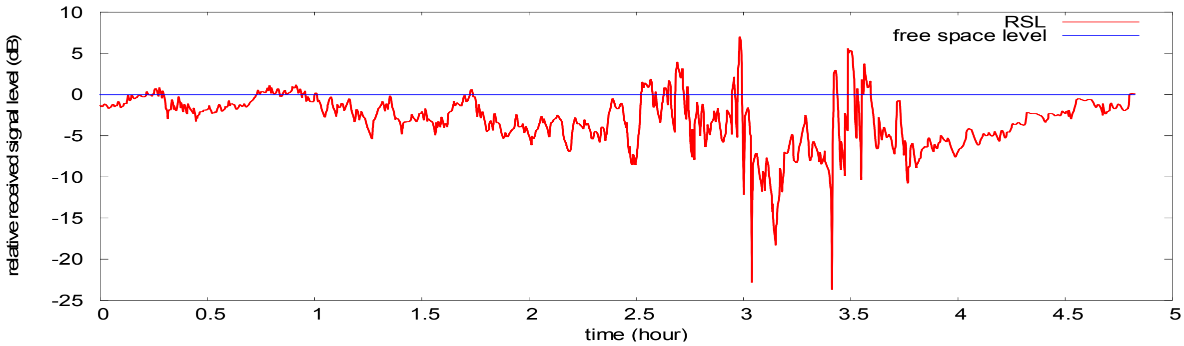


Fig. 4 Relative received signal level on the 4th of August 2003

4. Short-term correlation between refractivity and the vertical gradient of refractivity index

In many countries in temperate regions, certain correlation has been observed between monthly average of ground refractivity and the refractivity index gradient in the first kilometer. This long-term correlation was also partly observed in our experiment. However, from the point of view of real time prediction systems, short-term relation should be known. Evolution of refractivity measured in 3 altitudes is shown in Figure 5 for the same period of time as in Fig. 2.

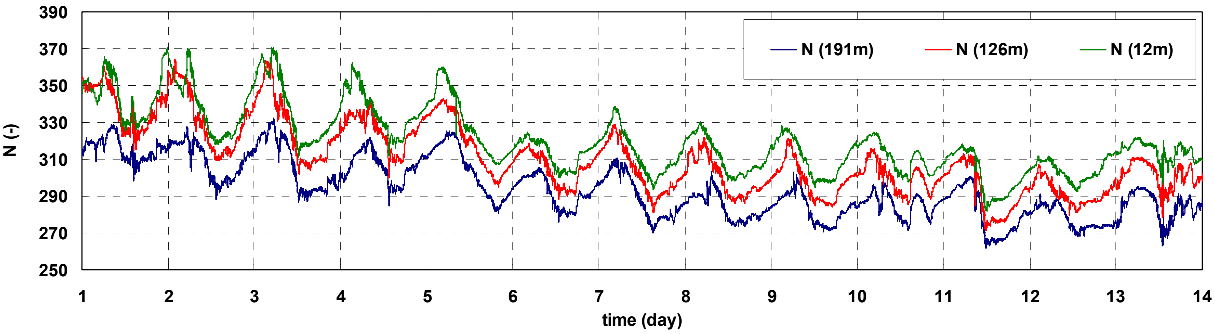


Fig. 5 Evolution of refractivity in August 2003 at TV Tower Praha

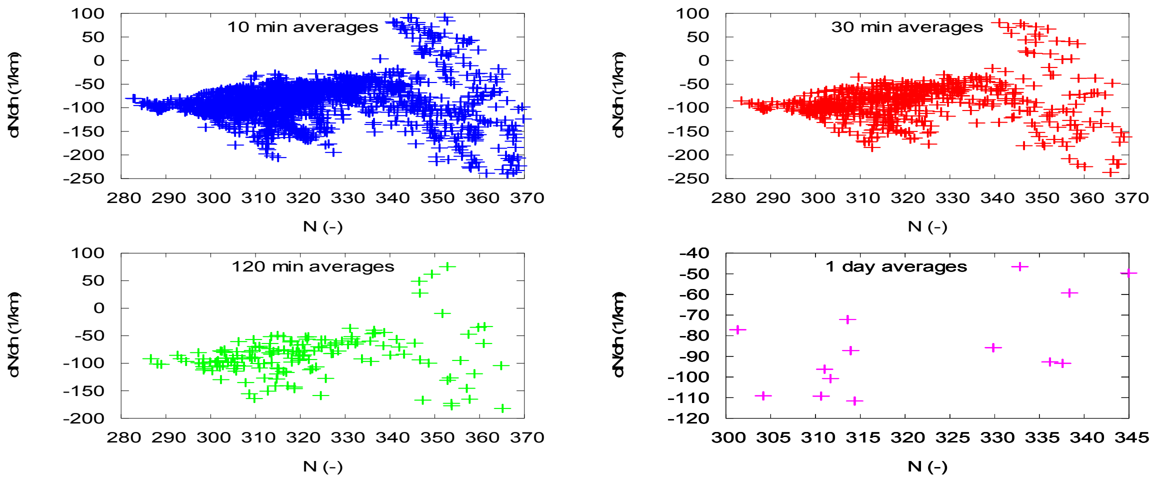
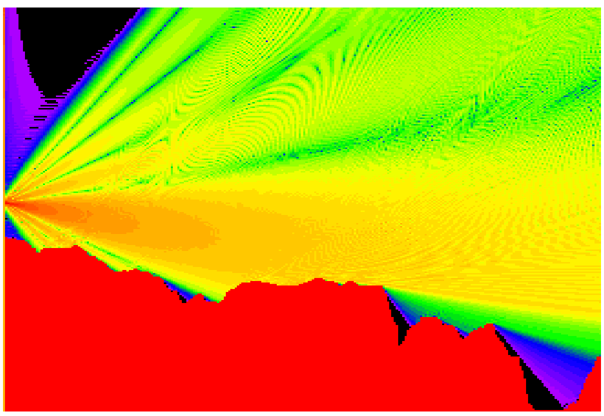


Fig. 6 Dependence of vertical gradient of refractivity in heights between 126 m and 12 m on ground refractivity in 12 m

In the scatter plots (Figure 6) no short-term correlation is observed. Useful information is that the probability of occurrence of extreme gradients is higher with higher values of ground refractivity. This is what confirms the results of long-term measurements.

5. Propagation modeling using PEM

Multipath fading occurrence depends on the geometry of the path as well as on spatial distribution of atmospheric refractivity. The PEM model is capable to take into account both aspects mentioned. Figure 7 shows the coverage diagram of the path described in section 2 considering standard atmosphere ($dN/dh = -40 km^{-1}$). An antenna diagram is approximated with the sin x/x function scaled for 1.8 meter antenna. The elevation angle is -0.29 degree (best direction for standard atmosphere). Perfectly conducting ground is considered as an unfavorable case.



Loss: 80 dB 200 dB

Fig. 7 Coverage diagram of terrestrial microwave path Kladno-TV Tower Praha in 19 GHz band

Horizontal distribution of refractivity along the 27 km path is assumed to be nearly constant at the first approximation. Then Figure 8 shows relative received signal calculated according to PEM.

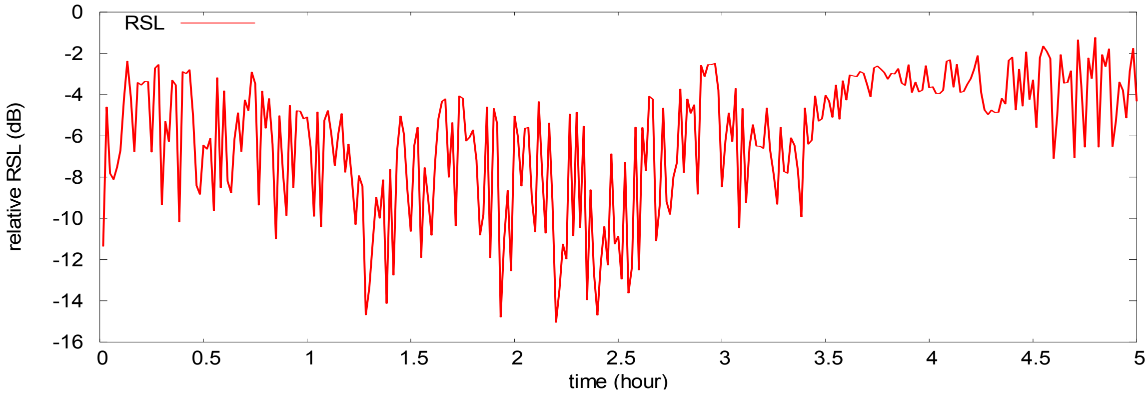


Fig. 8 Evolution of received signal level on 4th August 2003 as calculated from PEM model

Comparing Figures 8 and 4, considerable differences can be seen. Experiments show that simulated received level is affected mainly by the gradient between 126 and 191 meters. On the other hand, the value of the gradient between 12 and 126 meters has no significant influence on the received signal on the analyzed path profile. Large negative gradients in the height of the transmitting antenna cause the drop of mean signal level due to apparent deviation of the elevation angle.

From the example above, several drawbacks of the approach are seen. Calculation of the real gradient from a two-height measurement may be insufficient on inclined paths. Horizontal distribution of refractivity cannot be derived from one-point measurement. Therefore spatial correlation of refractivity should be studied. Finally, radiation pattern envelope of receiving antenna is not included.

Despite of the previous criticism, the knowledge of diurnal variations of atmospheric refractivity helps to improve predictions of propagation conditions during no rain periods of time.

6. Conclusion

Vertical distribution of atmospheric refractivity has been measured at TV Tower Praha in order to obtain basic statistics for planning terrestrial microwave paths in the Czech Republic, and to study the influence of anomaly refractive conditions on radio wave propagation. In this paper, two-year statistics, the examples of measured time series of refractivity and of the gradient were presented. An attempt was made to use the PEM method for calculating received signal level through applying time series of measured gradients.

7. Acknowledgement

We gratefully acknowledge that the Czech Science Foundation supports this project under the grant No. 102/01/0029 (experimental measurement) and under the grant No. 102/04/2153 (data processing and simulations).

8. References

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