Experimental Research of Signal Fading in Fixed Wireless Links

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***Abstract*—Two-year experimental research results of radio signal propagation and fading are presented in this paper. Microwave wireless links located in coastal and continental terrain and operated at 15 GHz were tested. The impacts of different atmosphere phenomena such as rain, brume, dew, weather, ground and dew point temperatures on the signal strength fading in these wireless links were assessed. Additionally, multipath effect origin and rain attenuation were analysed.**

***Index Terms*—Microwave propagation, radio link, signal fading, multipath effect.**

I. INTRODUCTION

The availability of fixed broadband wireless networks significantly depends on atmosphere conditions. The results presented in [1] give the received signal strength distribution and wireless link quality characteristics distribution in short diurnal time-periods. In [1] a twenty-four hours monitoring duration of the radio waves deep fading and attenuation variation was conducted. This calls for longer periods monitoring of the fading phenomena.

ITU-R recommendations of P.530-x series give prediction methods required for design of terrestrial radio links. It is indicated how very important is to evaluate real atmosphere characteristics of geographic terrains where the designed radio links should be installed.

It should be noted that many investigators certify the occurrence of multipath effect on link frequencies up to and higher than 10 GHz. But it is interesting to define what atmospheric conditions concerned with origin of multipath effect on these frequencies.

Unavailability investigation of 6 GHz line-of-sight (LOS) radio links in Poland due to multipath propagation was presented in [2]. There, a wide explanation of multipath propagation origin is given. Additionally, it is emphasized that multipath fading is a function not only of link path length and radio frequency but the function of climate and terrain conditions as well.

Results of practical observations of multipath propagation in different places of Latvia at link frequencies of 7 GHz–8 GHz were presented in [3]. One of the authors' conclusions was that "multipath activity is the highest during summer and the lowest during wintertime".

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Unavailability investigation of LOS radio links due to rain at link frequencies of 11.5 GHz and 18.6 GHz are presented in [4]. Research of seasonal rain attenuation and radio waves fading in LOS links at 19.5 GHz on South Africa terrain are presented in [5].

We attempt to define statistical annual data distributions of different atmosphere phenomena and its influence to radio wave propagation. It was very interesting to compare atmosphere phenomena distributions separately in the coastal and continental terrains because radio waves propagation is different in these locations.

This work is about signal strength fading in the medium distance broadband LOS wireless links operated at 15 GHz frequencies. Additionally, of interest, is to contrast radio wave propagation conditions in different seasons of the year in different Lithuanian terrains attributed to multipath propagation phenomena of radio waves higher than 10 GHz.

II. RESEARCH OBJECTIVES AND MEASUREMENT SYSTEM

We had a possibility to measure the received signal strength for two years in seven broadband LOS radio links located in different places of Lithuania (Fig. 1). Three of them were located in the coastal terrain (there is the highest level of rain precipitations and dominant wind direction is from the Sea) and four links were in the continental terrain. Frequency band of the radio links was 15 GHz, vertical polarisation of waves was used. Radio link path distance range was from 23 km to 35 km, the height of antennas above the earth surface was 50 m–60 m.

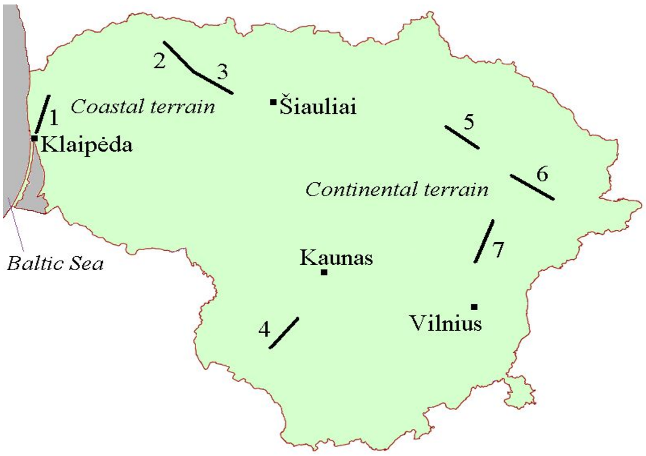

Fig. 1. The analysed wireless link locations in the coastal and continental terrains of Lithuania

Data of the atmospheric phenomena such as: water vapour pressure, weather pressure, weather temperature, relative humidity, existence of rain, snow, brume, dew, sleet, rainfall or thunderstorm in different places of terrain was obtained from Lithuanian hydro-meteorological Service (HMS).

III. ANALYSIS AND RESULTS

The phenomenon of signal fading can be described evaluating an impact of many atmospheric parameters. One of our interests was to determine atmospheric conditions that frequently originate signal fading and multipath propagation in upper indicated links.

For these purposes the received signal strength indicator in the links was used for measuring signal strength. After estimation of annual fading distributions in these links, different and mixed atmospheric parameters in corresponding terrains were analysed empirically.

In reality it is very difficult to distinguish when the signal fading originates because of the rain or multipath propagation or some other conditions. Only having the graph of signal strength level and statistical distributions of separate atmospheric parameters one can define what conditions have an ultimate impact on signal fading or multipath propagation.

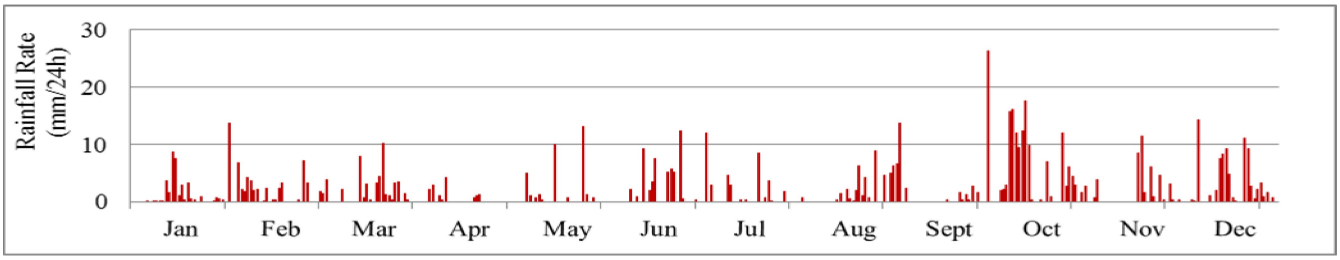

Fig. 2. Annual distribution of rainfall in coastal terrain.

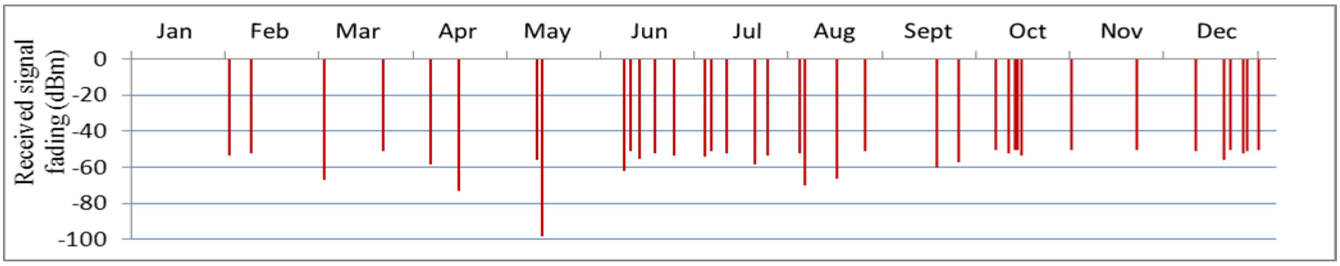

Fig. 3. Annual received signal strength fading distribution that was influenced by rainfall in coastal terrain.

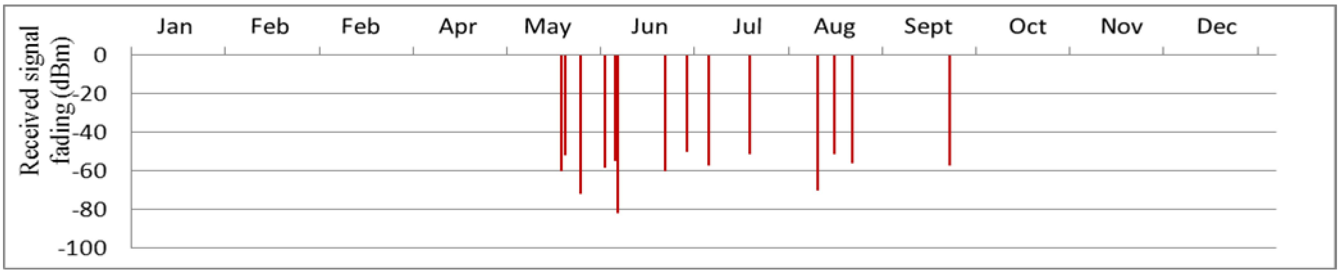

Fig. 4. Annual received signal strength fading distribution that was influenced by multipath effect in coastal terrain.

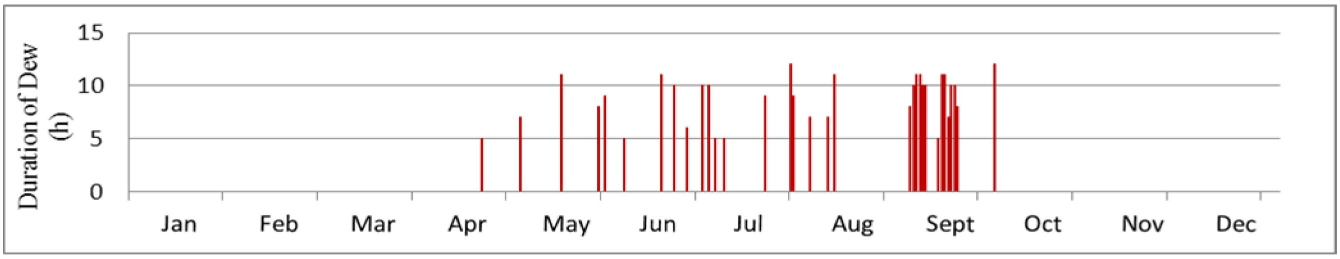

Fig. 5. Annual distribution of dew existence in coastal terrain.

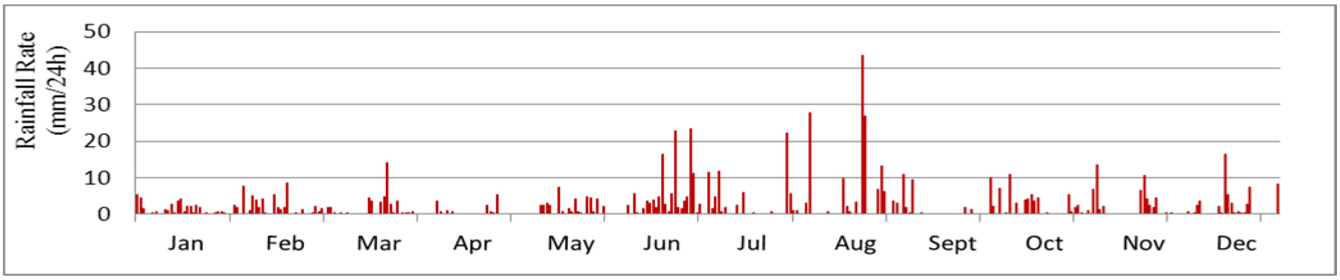

Fig. 6. Annual distribution of rainfall in continental terrain.

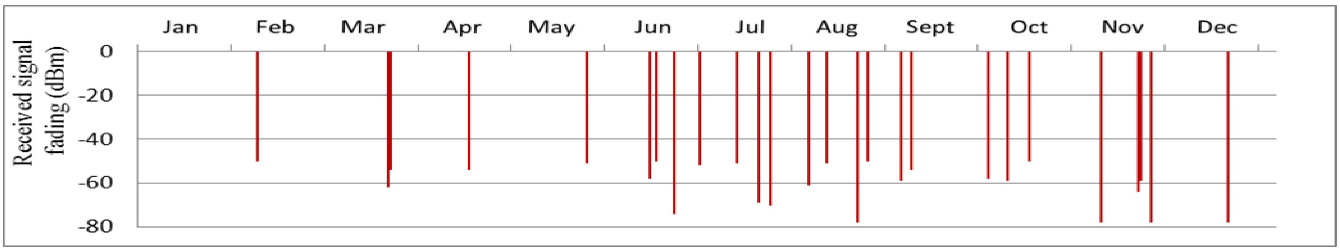

Fig. 7. Annual received signal strength fading distribution that was influenced by rainfall in continental terrain.

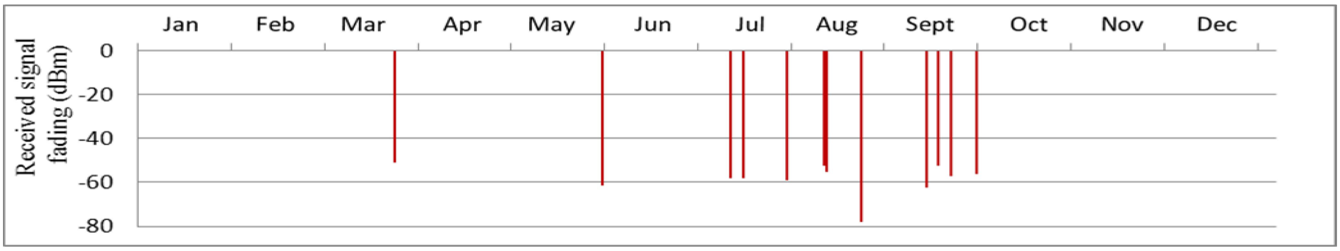

Fig. 8. Annual received signal strength fading distribution that was influenced by multipath effect in continental terrain.

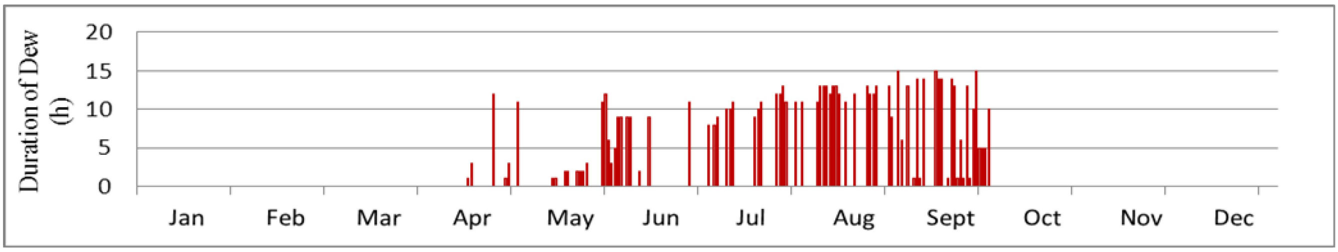

Fig. 9. Annual distribution of dew existence in continental terrain.

Figure 2 presents the annual distribution of rainfall. Figure 3 shows the distribution of annual received signal strength fading that was influenced by rainfall. Figure 4 demonstrates the distribution of annual received signal strength fading that was influenced by multipath propagation. And finally, Fig. 5 displays the annual distribution of dew existence. This group of figures presents the results that were obtained for one of the links operated in coastal terrain. In reality measuring discretization in time was every 30 s in twenty-four hours duration but because of the great quantity of data the time discretization on the figures is in days.

For comparison the same annual distributions for one of the links operated in continental terrain are presented in Fig. 6 –Fig. 9.

Presented received signal fading on figures is shown only for events when the signal level drops off less than –50 dBm though the receiver threshold level was –69 dBm.

After processing the great quantity of the data obtained from links and HMS we took the view that fading because of the multipath propagation in rainless days was unrelated with HMS observational weather parameters such as: weather temperature, dew point temperature, water vapour pressure, relative humidity, weather pressure et al., that are measured in weather stations on the ground and at one point at 10 m above the earth surface. Figure 10 presents the distribution of weather, ground and dew point temperatures in the days when multipath effect occurs in the coastal terrain. It can be seen that the significantly complicated inter-distribution of weather, ground and dew point temperatures does not indicate the direct correlation with radio wave multipath propagation. Some inter-distribution of temperatures in continental terrain is less complicated but it also does not indicate the direct correlation with radio wave multipath propagation.

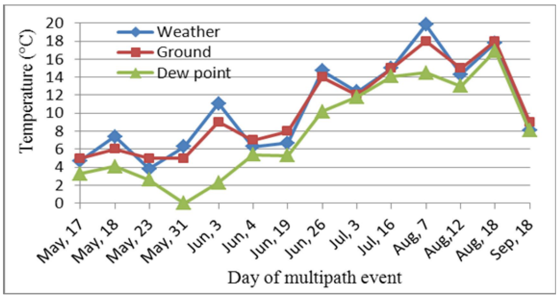

Fig. 10. Distribution of temperatures in coastal terrain in the days when multipath propagation occurs.

It is noticed that the multipath propagation of radio waves in atmosphere is related with the rising dew frequently in the early morning time of the day during warm seasons of the year. It is presumed that the multipath propagation during this time is related with radio wave propagation ducting effect.

For the links located in the coastal terrain the presence of dew when multipath propagation occurs was 22 %–30 %. Whereas, for the links located in the continental terrain the presence of dew was 40 %–70 %. The typical distribution of the received signal fading is presented in Fig. 11 where one can see multipath propagation in the morning time of the day in absence of dew or other precipitations and in Fig. 12 – when there is the presence of dew and rainfall. However, by comparison distributions particularly in Fig. 8 and Fig. 9, one can see that not only rising dew is related with the multipath effect origin because multipath propagation occurs not in every presence of dew. For more precise deduction a deeper investigation is required.

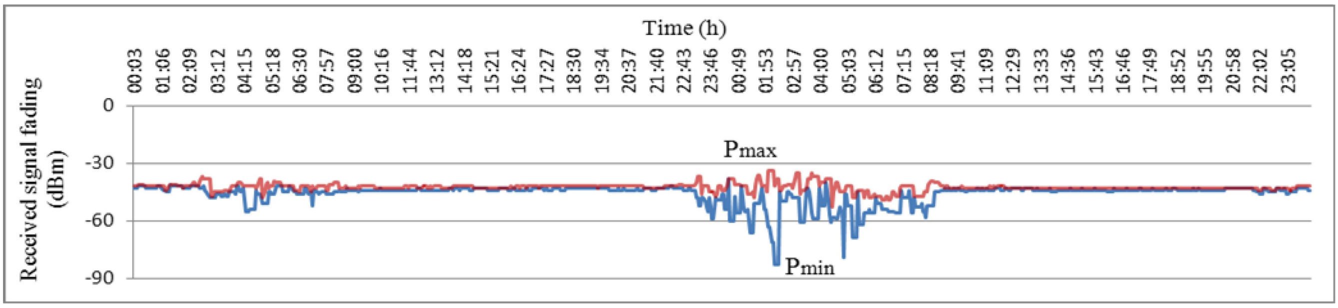

Fig. 11. Typical distribution of received signal fading and multipath propagation events in two diurnal time period in summer season in coastal terrain.

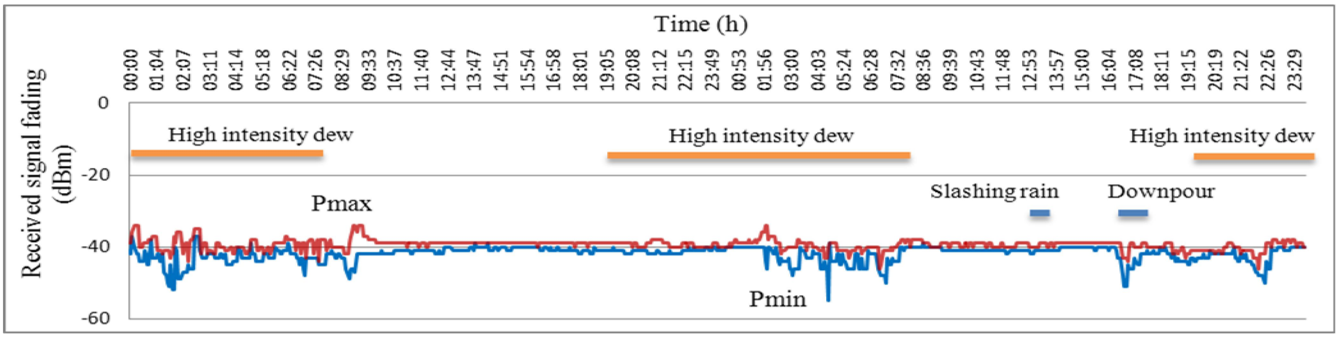

Fig. 12. Typical distribution of received signal fading and multipath propagation events in two diurnal time periods in summer season in continental terrain.

Multipath propagation in the middle of the day or in the middle of the night was determined very rarely in warm seasons. We never have defined multipath propagation effects in cold seasons.

By comparison appearance time of events on Fig. 2 and Fig. 3 and on Fig. 6 and Fig. 7, respectively, we can see that the received signal fading on 15 GHz frequencies is highly concerned with presence of rainfalls but it also can be seen that the signal fading is not the obligatory outcome of every rainfall event.

IV. CONCLUSIONS

1. The received signal fading on LOS microwave links at 15 GHz frequencies is highly concerned with the presence of rain precipitations and their intensity but every signal fading event is not the obligatory outcome of every rainfall event.

2. The multipath propagation in fixed microwave links at 15 GHz still appears in warm seasons of the year in coastal and continental terrains of Lithuania.

3. Majority of atmospheric parameters measured on weather stations do not indicate the direct relation with radio waves multipath propagation.

4. Investigations in coastal and continental terrains indicate that the multipath propagation of radio waves in atmosphere is related with the rising dew frequently in the early morning time of the day in warm seasons of the year. We presume that multipath effect at this time is related with radio wave propagation ducting effect.

5. For more precise estimations of multipath propagation and rising dew relations the deeper investigation is required.

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