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Peculiarity of Availability Parameters for Microwave Systems

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Introduction

It is important to understand propagation conditions in the fixed broadband wireless networks (FBWN) and apply this knowledge to wireless system design or system maintenance. Telecommunication channels in wireless environment are different from wired channels due to radio wave attenuation in free space, multipath propagation, ducting and significant influence of atmosphere conditions.

In many cases for longer wireless distances microwave propagation multipath exist and it is irrelevant whether line-of-sight (LOS), near-LOS or non-LOS systems are used. Multipath activity period can be various duration and can occur in different time of a second, hour or day over transmission of signals. Multipath events, prediction methods and results of practical observations are analyzed and presented in [1].

The power that is transmitted from antenna in the free space decreases with distance due to path loss. Path losses inevitably occur due to physical properties and composition of atmosphere. In addition to the path loss microwaves reflects and refracts from physical tropospheric layers (particularly LOS at long distances) or multiform topographic obstructions (near-LOS or non-LOS in urban or complicated area). Reflected signals in this case arrive to the receiver with various phases and significant delays. The result of various phases and delays combine power fading effect in receiving antenna. When different phase shift signals are summing itself in the receiver the significant signal loss occur. In the same time in the data transmission systems depending on the fitted encoding methods of the signal the intersymbol interference can occur and bit error rate increases inevitable.

Microwaves greatly are influenced by tropospheric refraction when long distance LOS wireless antenna is raised from earth surface in corresponding altitude. Because tropospheric layers density and warm conditions are different peculiar effect called “ducting” can occur.

Some fading-related problems for long distances shortwave propagation in ionospheric conditions in Baltic region are analyzed in [2].

Our subject of interest is long distance LOS broadband wireless systems, link availability rate and radio wave propagation conditions in Baltic region.

Rain influence into the radio wave propagation

A matter of primary interest is the rain influence to the radio wave propagation. FBWN are realizable in frequencies from 2.4 GHz to 60 GHz and higher. Frequency ranges of 6, 7, 8, 10, 11, 13, 15, 18, 23, 26, 28, 32 and 38 GHz in Lithuania are appointed for microwave systems. It is interesting what rain drop attenuation level are in different frequency ranges and from what frequencies this attenuation necessarily must be estimated by radio link designers.

Wireless link performance due to rain influence can be calculated under:

- The ITU-R Rec. P.530-8/9/12/13;
- The Crane method;
- Other methods.

Radio path attenuation exceeded for 0.01% of the annual time is given by prediction formula [3]

$$A_{0.01\%} = \gamma_R d r, \text{ [dB]}, \tag{1}$$

where γ_R is the specific attenuation for the radio wave frequency, polarization and rain rate, dB/km; d is the actual path length, km; r is the path reduction factor.

Computing results of vertical polarization radio wave specific attenuation dependence from actual radio link frequencies, calculated for different rain rates are presented in Fig. 1. The results for higher frequencies were presented in [4, 5].

For comparison, relative results for horizontal polarization are presented in Fig. 2.

As we can see in Fig. 1 and Fig. 2, rain influence into the radio wave propagation sharply increases in frequencies above 10 GHz and influence is higher in horizontal polarization. That means that in frequencies higher 10 GHz rain influence is significant for both polarizations and should be estimated in the link design.

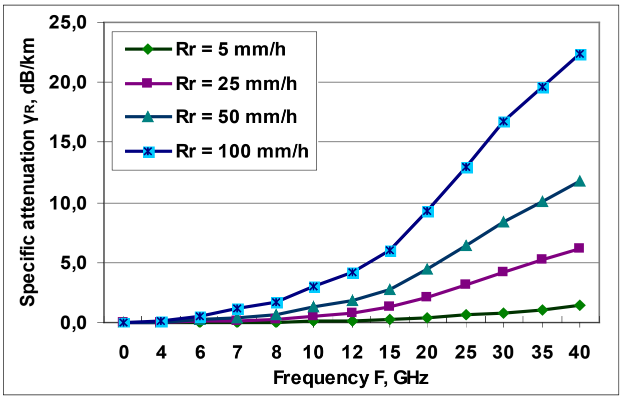


Fig. 1. The vertical polarization radio wave specific attenuation γ_R dependence from actual radio link frequencies *F*, calculated for different rain rates R_r

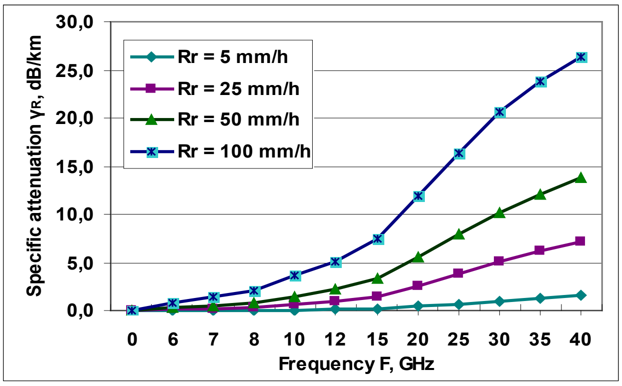


Fig. 2. The horizontal polarization radio wave specific attenuation γ_R dependence from actual radio link frequencies *F*, calculated for different rain rates R_r

It is very important, what must be radio wave attenuation margin from rain to the particular FBWN radio links in rain zone E and frequencies up to 10 GHz at different availability values.

Simple prediction technique can be used for estimating the long-term statistics of rain attenuation. The radio wave attenuation from rain at different availability values for frequencies up to 40 GHz and path lengths up to 60 km can be calculated by [3]

$$A_p = 0.12 A_{0.01} p^{-(0.546+0.043\log_{10} p)}, \qquad (2)$$

where *p* is the percentages of time in the range of 0.001% to 1%; A_p is the radio wave attenuation from rain at the desirable *p*, dB; $A_{0.01}$ is the rain attenuation at the 0.01% of time, dB.

Radio wave attenuation from rain calculated by (2) express attenuation margin *M* values that must be evaluated in the radio link design. Computing results of radio wave rain attenuation margin reliance from path distance, given for different radio link availability values and vertical polarization when radio link frequency 7 GHz in rainfall zone E are presented in Fig. 3.

For comparison, relative computing results for horizontal polarization are presented in Fig. 4.

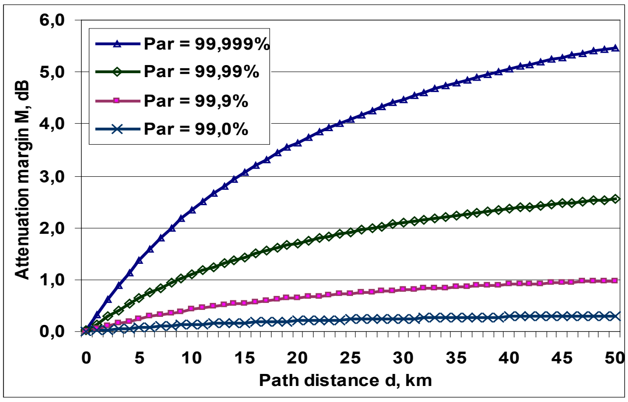


Fig. 3. Rain attenuation margin *M* dependence from path distance *d*, given for different radio link availability $P_{ar}(\%)$ values for radio wave vertical polarization

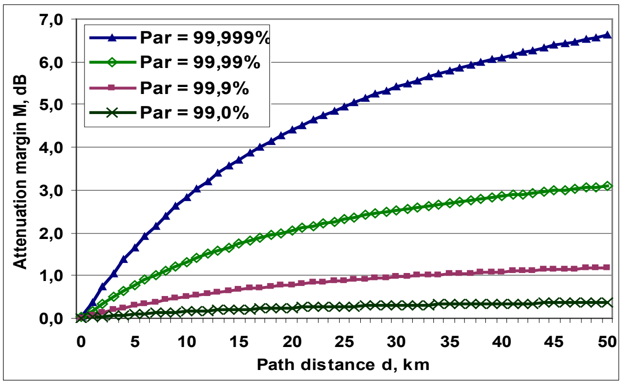


Fig. 4. Rain attenuation margin *M* dependence from path distance *d*, given for different radio link availability $P_{ar}(\%)$ values for radio wave horizontal polarization

As we can see in Fig.3 and 4, radio link designers must note down, that in rainfall zone E at distances 50 km and link radio frequency 7 GHz, radio wave rain attenuation margin in dependence with forecast link availability for vertical and horizontal polarization can disagree about 18-21 %. It can be easily shown that similar computing results are for radio link frequencies up to 10 GHz.

Multipath radio link availability

Another point of interest is multipath radio wave propagation in long distance LOS systems. When multipath fade occur, signal power at a particular time can drop below receiver threshold level and signal transmission probability can be very small in this case. As will be shown late probability of radio links generally depends from multipath effect because it assert in rainless time when no another radio wave propagation limiting factors. When fades are more than 15 dB, radio link fade outage probability $P_F(\%)$ for the average worst month without any additional techniques can be calculated by prediction formula [6]

$$P_F(\%) = K d^{3.6} F^{0.89} (1+|\varepsilon_p|)^{-1.4} \times 10^{-A/10}, \qquad (3)$$

where K is geoclimatic factor for worst fading month; d is path length, km; F is frequency, GHz; ε_ρ is path inclination, mrad; A is the fade depth, dB.

It is interesting how radio link worst month availability depends from link path distance when different radio frequencies are used. Computing results of radio link worst month availability P_{am} – total link probability in dependence from the path distance, given for different radio wave frequencies are presented in Fig. 5. Calculations were executed with antenna gain 43 dBi, transmitter power 29 dBm and magnitude of the path inclination 0 mrad.

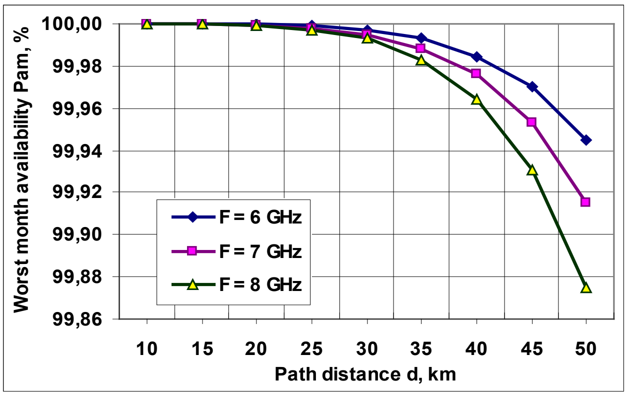


Fig. 5. Radio link worst month availability $P_{am}(\%)$ in dependence from the path distance d, given for different radio wave frequencies F

As we can see in Fig. 5, for indicated link conditions worst month availability calculated according formula (3) in short distances is stationary and decreases with longer path distances and higher radio frequencies. It can be explained because in (3) path distance exponent is accepted 3,6 and in longer path distances the margin of signal level decreases and radio system become sensitive to any interference, i. e. link availability decreases also.

It is interesting what was fading margin level in calculations of curves in Fig. 5. Computing results of radio link fading margin M (after making assumption in (3) that $M=A$) in dependence from the path distance, given for different radio wave frequencies are presented in Fig. 6.

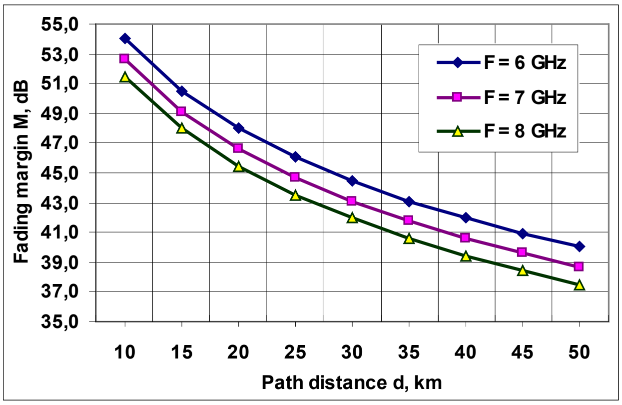


Fig. 6. Radio link fading margin M in dependence from the path distance d, given for different radio wave frequencies F

As we can see in Fig. 6, the margin of signal level decreases when longer path distances are used.

Measurement results

It is very interesting, what is the radio link availability in particular links in different working conditions, for example, in coastal and continental regions. Also interesting multipath effect assert in rainless time when no another radio wave propagation limiting factors. Other authors [7, 8] declare also that “fading due to layering of the atmosphere is the dominating degradation factor of radio-relays...”. Results of practical observation of multipath effect in radio links in Baltic region are presented in [1].

We have possibility to present some measured characteristics of radio links located in Lithuania region coastal and continental terrain and working in frequencies below 10 GHz. We can present received signal level and links quality characteristics measured for radio link path distance 50 km in frequency range 8 GHz with antenna gain 43 dBi, transmitter power 29 dBm and receiver threshold level -69 dBm. In these systems antenna space diversity is used and we have possibility to present results of signal level from each antenna.

Received signal level measured in rainless weather conditions in summer time for digital LOS radio link in continental terrain in two diurnal time-periods in time intervals of 30 min for upper and lower antennas and respectively combined signals on the input of receiver is presented in Fig. 7.

As we can see in Fig. 7, in two diurnal time-periods in upper antenna received signal level is significantly below receiver threshold level at 2 and 4 o’clock on one day and at 5, 6, and 8 o’clock on the next day in the morning time. Respectively in lower antenna received signal level is significantly below receiver threshold level at 1-3 and 4, 6 o’clock on one day and 6-9 o’clock on the next day. After respective combining of signals from both antennas received signal level is significantly below receiver threshold level at 2 and 4 o’clock on one day and 8 o’clock on the next day. We can see that availability of link after applying antenna space diversity technique increases significantly.

For comparison, relative results for digital LOS radio link in coastal terrain at the same conditions are presented in Fig. 8.

As we can see in Fig. 8, in upper antenna received signal level is significantly below receiver threshold level at 1 and at 3-6 and at 8 o’clock on one day and at 0-2 and at 3, 4, 6 o’clock on the next day in the morning time. Respectively in lower antenna received signal level is significantly below receiver threshold level at 0-8 and 23-24 o’clock on one day and 0-2 and at 3-6 o’clock on the next day. After respective combining of signals from both antennas received signal level is significantly below receiver threshold level at 1 and 4-6 and at 8 o’clock on one day and 0-1 o’clock on the next day.

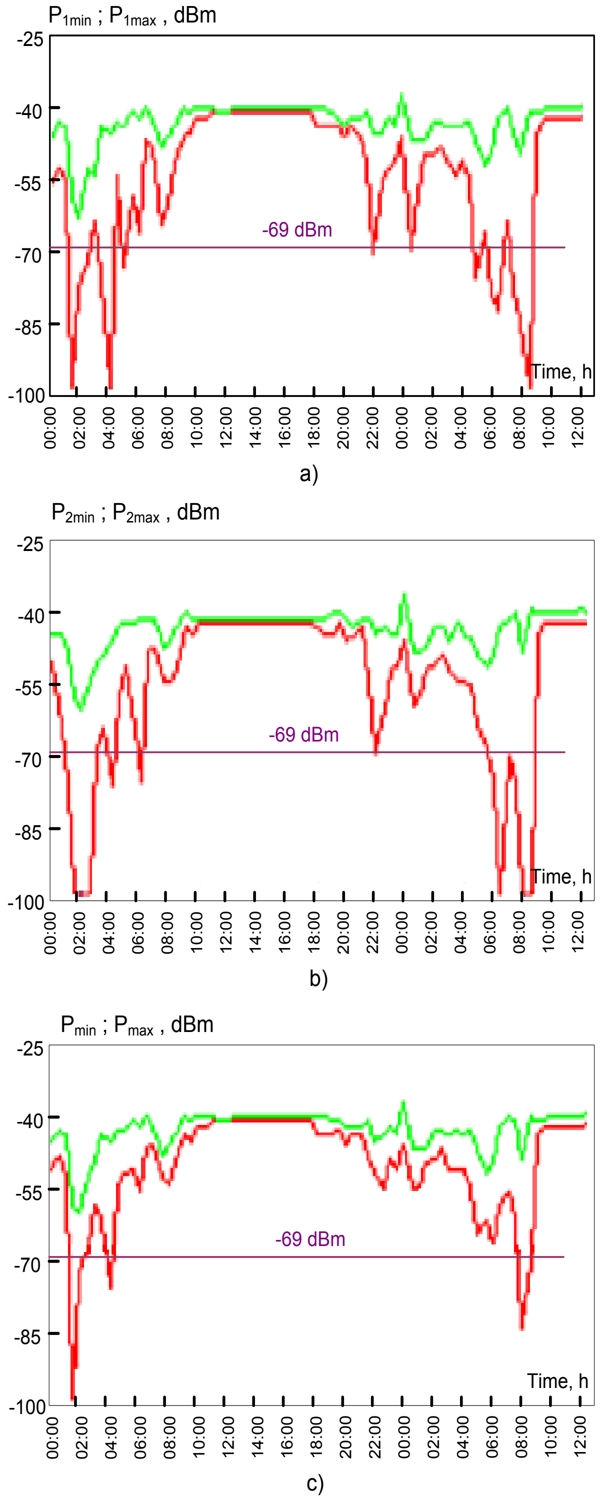


Fig. 7. Received signal level measured in continental terrain in two diurnal time-periods in discrete time intervals of 30 min: a) - for upper antenna; b) – for lower antenna; c) – for respectively combined signals from both antennas on the input of receiver. P_{min} and P_{max} are minimum and maximum power levels.

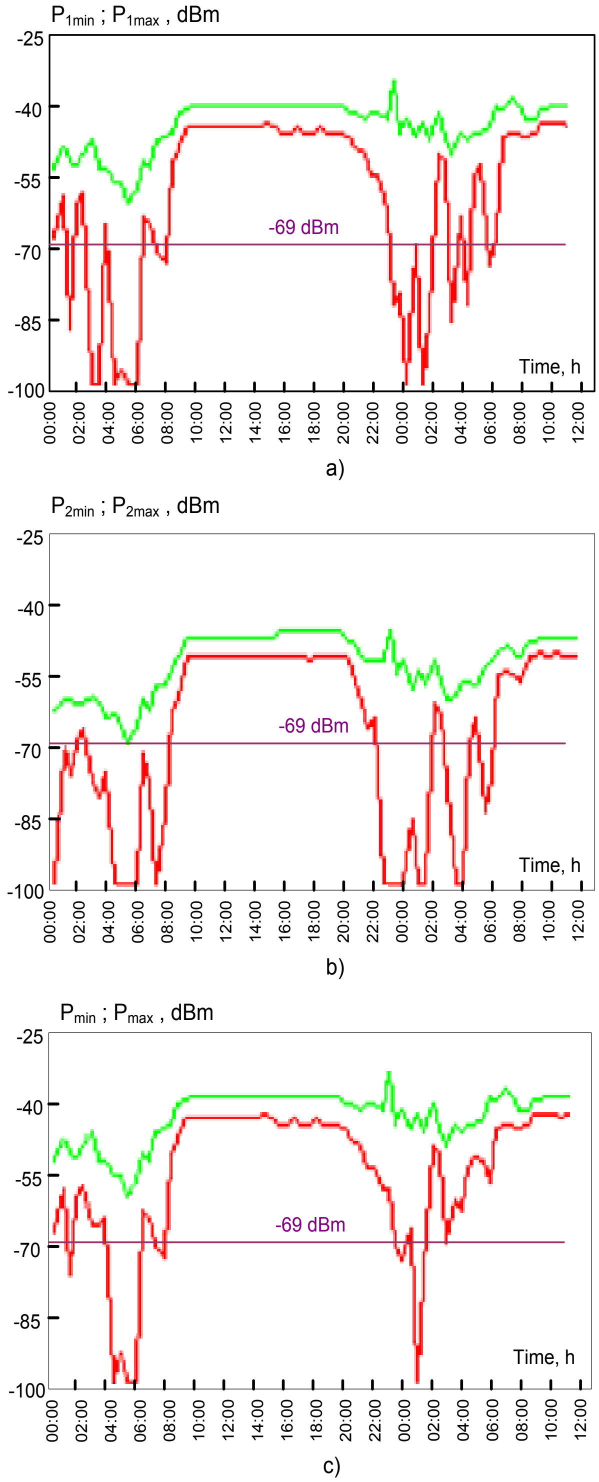


Fig. 8. Received signal level measured in coastal terrain in two diurnal time-periods in discrete time intervals of 30 min: a) - for upper antenna; b) – for lower antenna; c) – for respectively combined signals from both antennas on the input of receiver. P_{min} and P_{max} are minimum and maximum power levels.

So much signal fading in these links in rainless time was due to the action of multipath propagation. Multipath effect much more assert in night and early morning time. And as we can see, the time when signal power is below receiver threshold level is significant.

Also we can see that antenna space diversity technique significantly decreases activity of multipath effect but don't remove completely. Negative action of multipath activity in the night and early morning time should be more investigated by researchers.

For link described in Fig. 7, the error performance events at receiver threshold level -69 dBm are presented in Fig. 9 and respectively for link described in Fig. 8, the error performance events are presented in Fig. 10.

Error performance characteristics are presented as worst events in time intervals of 30 min for link systems with antennas space diversity. The abbreviations in these figures correspond to the abbreviations in [9]: *es* – errored second occurs if there are one or more errored blocks or at least one defect; *ses* – a severely errored second occurs if there are 30% or more errored blocks or defect; *bbe* – background block error – is en errored block not occurring as part of an *ses*; *uas* – unavailable second.

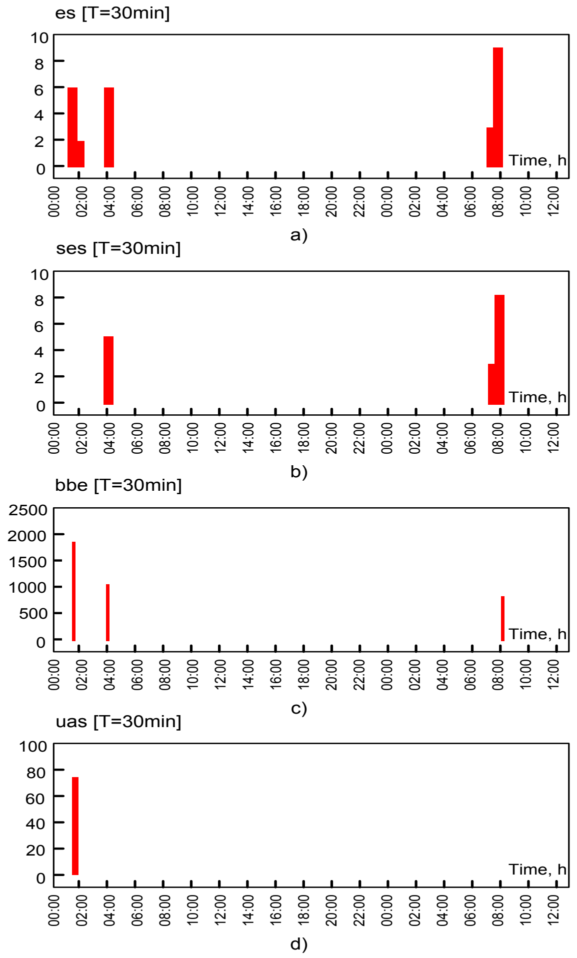
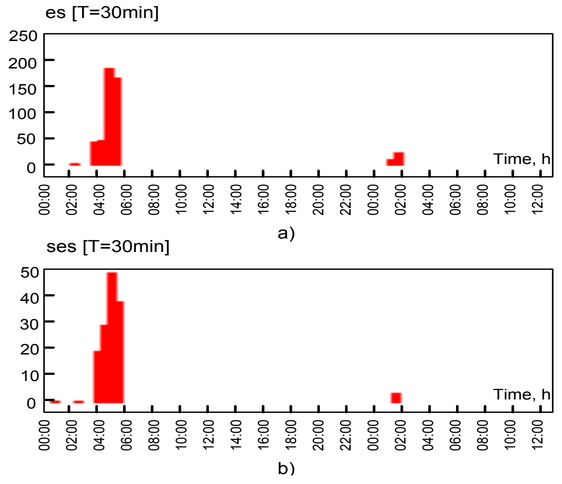


Fig. 9. Error performance events at receiver threshold level -69 dBm for radio link described in Fig. 7: a) – *es*; b) – *ses*; c) – *bbe*; d) – *uas*



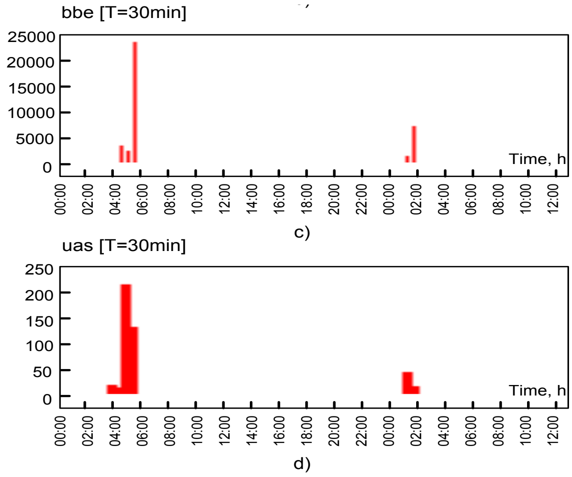


Fig. 10. Error performance events at receiver threshold level -69 dBm for radio link described in Fig. 8: a) – *es*; b) – *ses*; c) – *bbe*; d) – *uas*

Error performance events presented in Fig. 9 and 10, display quality of corresponding digital links and signal transmission errors in the corresponding time. As we can see, errors in transmitted signal occur in time when signal level is in deep fading.

Conclusions

1. Rain influence into the radio wave propagation in rainfall zone E is insignificant for the LOS radio systems in frequencies until 10 GHz.
2. Radio wave attenuation margin in rainfall zone E for the frequencies until 10 GHz and along path distances until 50 km for the link availabilities 99,0-99,999% for vertical and horizontal polarization can disagree about 18-21 %.
3. The multipath fade prediction method according formula (3) enable more clearly to estimate radio link availability in the longer LOS path distances.
4. The main reason of radio signal fading in wireless networks in rainless time on link frequencies up to 10 GHz is multipath effect.
5. Multipath effect assert at night and early morning time in rainless weather in the summer time independently where are placed radio systems in the continental or in the coastal region.
6. The antenna space diversity technique significantly decreases activity of multipath effect but don't remove completely.

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V. Grimaila, S. Kašėta. Peculiarity of Availability Parameters for Microwave Systems // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 8(104). – P. 97–102.

It is very important to estimate radio wave propagation conditions in fixed broadband microwave systems when different radio frequencies are used. Influence of rain attenuation and multipath conditions for line-of-sight radio link availability parameters are presented. Calculation and measurement results also are presented. It is indicated that rain influence into the radio wave propagation in rainfall zone E is insignificant for the LOS radio systems in frequencies until 10 GHz. It is shown that the graph calculated under multipath fade prediction method in short distances is stationary and decreases with longer path distances and more expressed at higher radio wave frequencies. Ill. 10, bibl. 9 (in English; abstracts in English, Russian and Lithuanian).

В. Гримайла, С. Кашета. Особенности параметров работоспособности микроволновых систем связи // Электроника и электротехника. – Каунас: Технология, 2010. – № 8(104). – С. 97–102.

При проектировании широкополосных беспроводных микроволновых радиосистем необходимо оценить условия распространения радиоволн разных частот. Представлены результаты расчетов и измерений влияния дождя и условий многолучевого распространения на работоспособность микроволновой радиосистемы прямой видимости. Показано, что в зоне осадков E небходимо учитывать подавление сигнала на частотах выше 10 ГГц. Также показано, что метод прогноза ослабления сигнала при многолучевом распространении позволяет оценить ослабление сигнала только на больших расстояниях передачи и более выражен при высоких частотах сигнала. Ил. 10, библ. 9 (на английском языке; рефераты на английском, русском и литовском яз.).

V. Grimaila, S. Kašėta. Mikrobanginių sistemų ryšio patikimumo parametrų ypatumai // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 8(104). – P. 97–102.

Projektuojant fiksuotas plačiajuostes bevieles mikrobangines perdavimo sistemas labai svarbu įvertinti įvairių dažnių radijo bangų sklidimo sąlygas. Pateikta tiesioginio matomumo mikrobangines perdavimo linijos patikimumo parametrų priklausomybės nuo lietaus slopinimo ir daugiakrypčio signalo sklidimo skaičiavimo ir matavimo rezultatai. Parodyta, kad E signalo slopinimą lietaus kritulių zonoje tiesioginio matomumo sistemose tikslinga vertinti tik nuo 10 GHz. Daugiakrypčio signalo prognozavimo metodu galima nustatyti signalo slopinimą tik esant didesniems perdavimo atstumams, ir jis yra ypač ryškus esant didesniems radijo bangų dažniams. Il. 10, bibl. 9 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).