Paper

Fading Duration in Line-of-sight Radio Links at 6 GHz

Jan Bogucki and Ewa Wielowieyska

National Institute of Telecommunications, Warsaw, Poland

Abstract—Broadband fixed wireless access, local multipoint distribution service networks are promising wireless solutions to connect fixed users to the backbone network instead of wired copper or fiber optic networks, via point-to-multipoint cellular networks. Channel capacity is of primary importance in broadband fixed wireless access networks due to increasing demand for multimedia services and possibility of providing wireless internet. Modern radio transmission systems are specifically designed for meeting two main objectives: to provide a solution for long distance networks with high transmission capacity, and to guarantee the highest link quality. Availability of a radio-relay system is very important and dependent on many factors, particularly propagation conditions in the troposphere. The article describes wave propagation that determines the performance of a radio-relay path at 6 GHz. Attenuation of received signal level measured in this frequency range depends on propagation condition on terrestrial path. Examples of measured fading duration of are presented.

Keywords—fading, line-of-sight radio links, multipath, propagation.

1. Introduction

The fast expansion of the applications and services in the wireless networks and the competition between operators have increased the demands for improving the performance work of these systems. The performance of broadband fixed wireless access links operating under 10 GHz is predominantly controlled by multipath attenuation. Time operation of radio links is split into two periods, when it is in working order or out of order. Radio links are out of order when even one of its basic parameters is crossing permissible limit spread. This occurrence is called failure. It is not essential the failure to follow rapidly or gradually.

There are six transmission parameters, which may be used to characterize unsatisfactory quality performance. These are BER (Bit Error Ratio) or FER (Frame Error Rate), short interruption, delay, jitter, slip and quantizing noise. BER/FER and short interruption are the main indicators of unavailability. This is because jitter and slip will cause bit errors and short interruption in the network and that delay and quantizing noise are relatively fixed quantities in any connection.

Line-of-sight radio relay systems are defined unavailable when one or both of the following conditions occur for more than 10 consecutive seconds:

- the digital signal is interrupted,
- the BER in each second is higher than 10^{-3}.

It should be noted that the unavailability for system has to be considered for both “the go” and “the return” direction, that is twice the calculated value. Wave propagation in the atmosphere and its impact on the performance of digital radio relay systems is the main topic of this paper.

2. Propagation – Mechanism of Fadings

The propagation of radio signals is affected by several factors that contribute to the degradation of its quality. One of more important factors leading to link unreliability is the environment, which leads to multi-path propagation effects and contributes to background noise. The radio refractive index of the atmosphere n, is a number on order of 1.0003, varying between 1.0 for free space – above atmospheric influence and about 1.00045 at the maximum. For greater computational convenience, it is customary to utilize a term N, called “radio refractivity”, which is defined as:

$$N = (n-1)\cdot 10^6. \qquad (1)$$

The N term would be zero in free space, and a number on order at 300 at the earth surface. The radio refractivity of air is given as:

$$N = 77.6\frac{p}{T} - 5.6\frac{e}{T} + 3.75\cdot 10^5\frac{e}{T^2}, \qquad (2)$$

where:

p – total atmospheric pressure [hPa],
T – absolute temperature [K],
e – partial pressure of water vapour [hPa].

The $5.6\frac{e}{T}$ element is very small compare to the other two and Eq. (1) can be given as:

$$N = \frac{77.6}{T}\left(p + 4810\frac{e}{T}\right) = 77.6(N_s + 4810N_w), \qquad (3)$$

where:

N_s – term is frequently referred to as "dry term" and

N_w – term is called as "wet term".

By examination of Eq. (3), it can readily be seen that, while pressure and relative index, temperature as a function of N is the predominating factor. It is easily seen why the phenomenon of temperature inversion is of concern in connection with radio propagation.

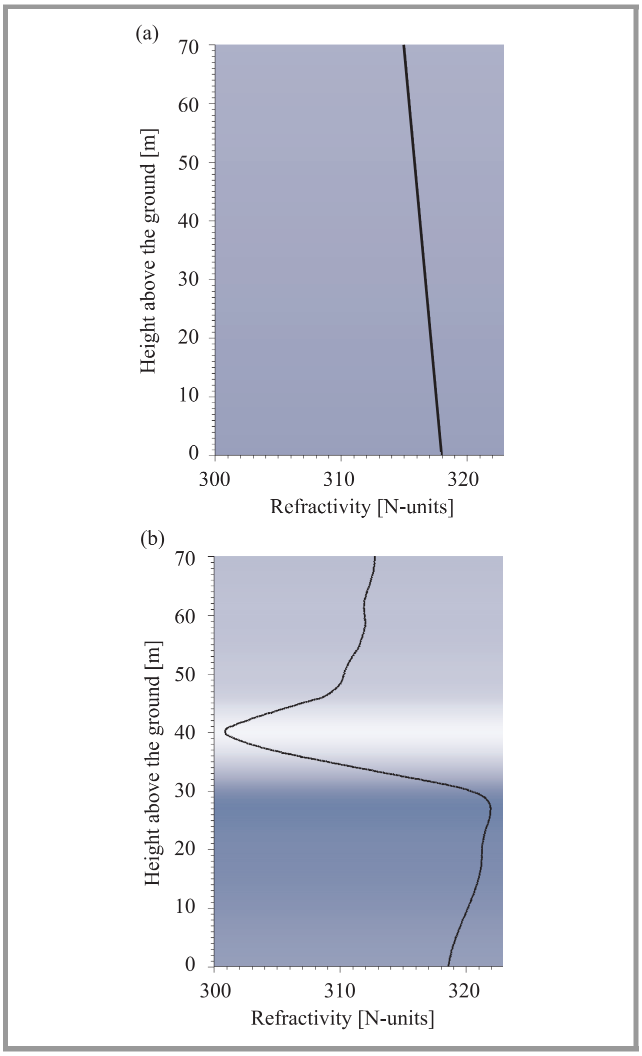

Fig. 1. The index of refraction for troposphere: (a) standard atmosphere, (b) atmosphere in elevated layers.

The beam of microwave energy is not a single line, but a wave front extending for considerable distance about center line. Since the index of refraction under normal atmosphere conditions is lower at the top of the wave front and higher at the bottom, and since velocity is inversely proportional to the index of refraction, the upper portion of the wave front under such conditions will travel slightly faster, with the result that the wave front as it moves along the path will tend to have the top tilted more and more forward. Since the direction of beam travel is always perpendicular to the wave front, the beam itself will be bent downward, thus increasing the apparent clearance. The amount of bending is actually very slight on a percentage basis, but is sufficient to cause significant variations.

Under certain atmospheric situations there can be even greater than normal negative N gradients (earth flattening type), or others in which the N gradients become less negative, or even positive. In the latter situation the lower part of the wave front will travel faster, and the beam will be bent upward, reducing the apparent clearance. This is earth-bulging type.

Most of the time gradients in the lower atmosphere are essentially linear (Fig. 1a). These linear variations affect clearance, and are also important when the path is reflective, but they do not produce atmosphere multipath situations.

When non-linear gradients occur such as shown in Fig. 1b, then there are suitable atmosphere conditions for multipath. These abnormal situations in the atmosphere can occur when conditions are such that stratified layers with different gradients may lie on top of one another. At night – before sunrise, radiation can cool the ground more rapidly then air, and the temperature may then increase with increasing altitude. Then it is possible to get the atmospheric multipath. Under these conditions the received signal is the vector sum of the various components, all of which are varying in phase in a random manner, and usually in amplitude as well. It is this phenomenon, which causes most of the fast, very deep fading.

3. Example of Empirical Data at Terrestrial Link 6 GHz

It is very important to estimate degradation of radio-relays. Meteorological conditions in the space separating the transmitter and receiver may sometimes cause detrimental effects to the received signal.

Six radio links of band 6 GHz were examined which paths were from 36.6 km to 69.8 km. Sites of 4 radio links were located near Warsaw and two of the longest paths were located at Mazurian Lakes District. Measurements were carried out during normal operation of radio links.

Signal samples were received with frequency 5 Hz during high attenuation and 0.0033 Hz in the other times. The empirical characteristics of signal attenuation were obtained from the four year measurements. The monthly attenuation due to multipath distributions and its duration time are presented in this paper. Number of fadings and their duration time in January of each measured year is presented in Fig. 2 and the same graph for August in Fig. 3.

The percentage of general number of fadings at 10 dB, 20 dB and 30 dB, which duration times were not longer than indicated on ordinate axis, in the fourth year measurement in January are presented in Fig. 4 and in August in Fig. 5.

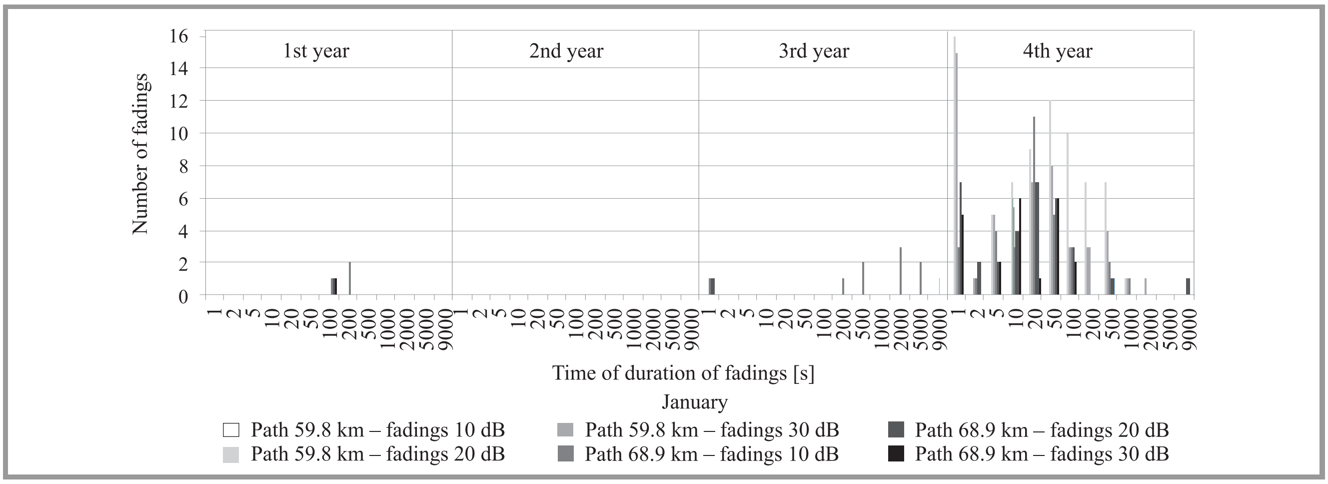

Fig. 2. Number of fadings and their duration time in January of each measured year.

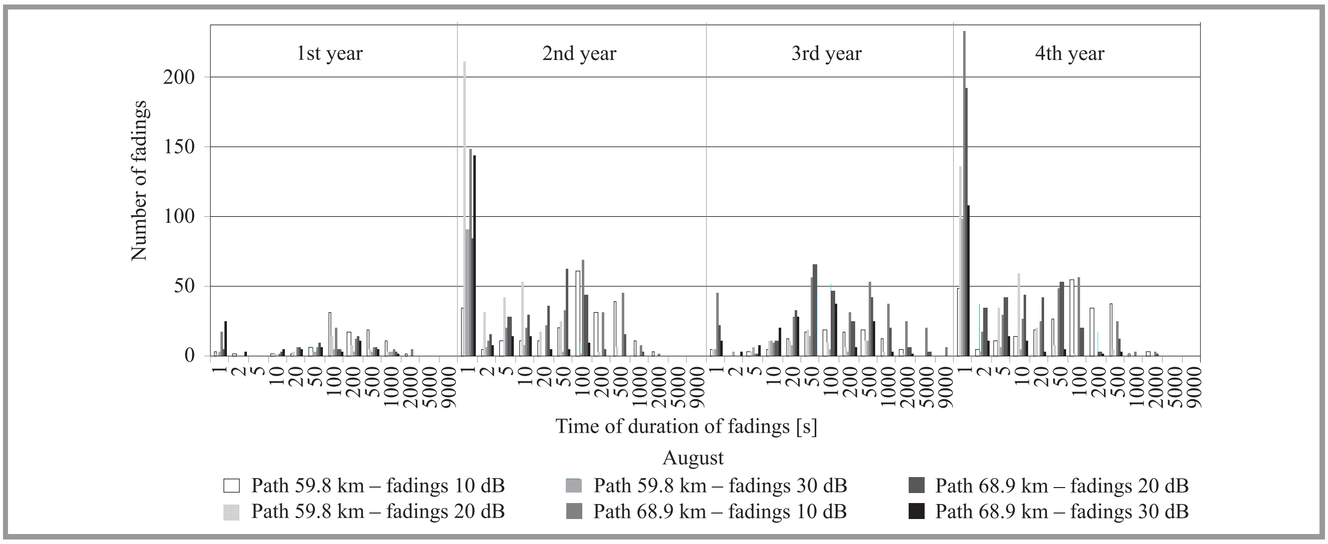

Fig. 3. Number of fadings and their duration time in August of each measured year.

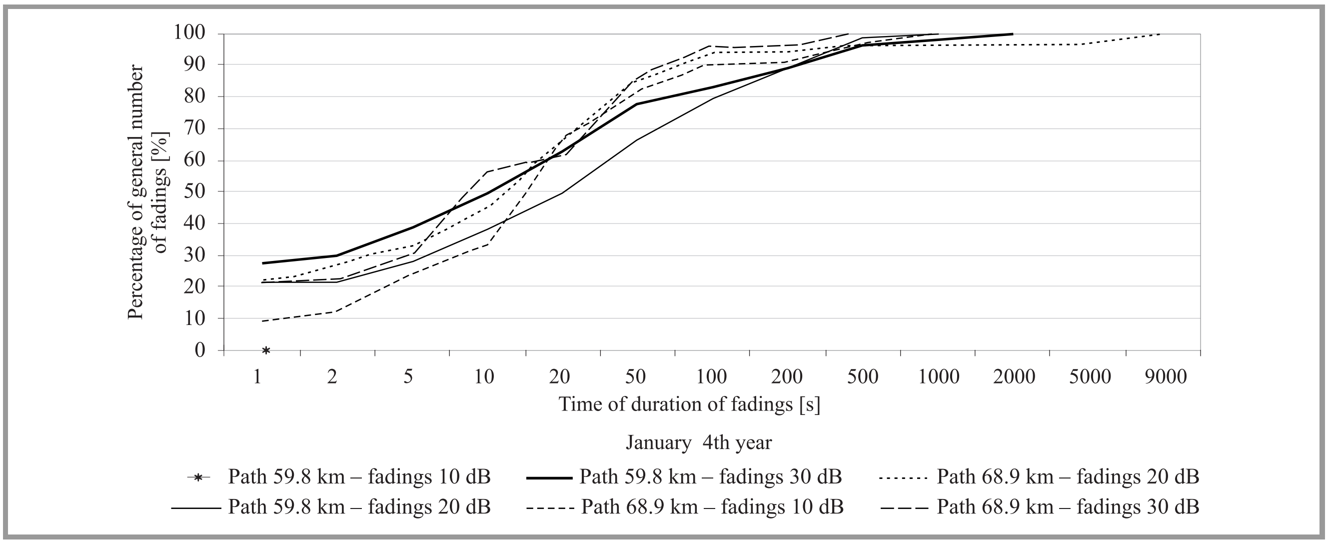

Fig. 4. Percentage of general number of fadings at 10 dB, 20 dB and 30 dB in January of the fourth year measurement, which duration times were not longer than indicated on ordinate axis.

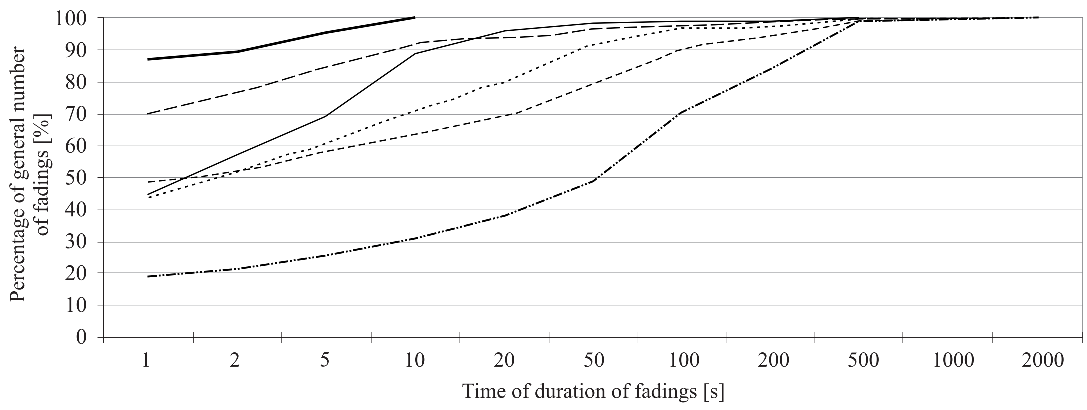

Fig. 5. Percentage of general number of fadings at 10 dB, 20 dB and 30 dB in August of the fourth year measurement, which duration times were not longer than indicated on ordinate axis.

4. Conclusion

This paper describes propagation effects in radiolinks applications. It has been experimentally validated in typical radiolinks of 6 GHz that when fadings approach near line-of-sight links are considered to free space value for typical atmosphere conditions.

Microwave radio links can be properly and precisely engineered to overcome potentially detrimental propagation effects. Knowledge of the fading statistics is extremely important for the design of wireless systems. During some stagnant, horizontally layered atmospheric conditions, the vertical gradient in atmospheric index of refraction produces multiple propagation paths between the transmitter and the receiver of line-of-sight microwave radio links. Microwave radio links can be properly and precisely engineered to overcome potentially detrimental propagations effects. The received signal varies with time, and the system performance is determined by the probability for the signal to drop below the radio threshold level or the receiver spectrum to be severely distorted. In order to estimate the performance of radio link system, it is very important to notice – what was found from measurements – that:

– attenuation of all events exceeding 30 dB resulted in situations when there were numerous short fadings,

– in case of lower levels, 10 dB, the exceedances lasted up to 5000 s,

– sometimes in winter months fadings did not occur.

Multipath fading in the atmosphere is not a permanent phenomenon. It occurs when there is no wind and the atmosphere is well stratified. It is more frequent at night and in the early morning hours and it is seldom felt at mid-day but never during periods of intense rain. In Poland it is frequent in July and August.

The effects of these materials have been investigated by means of real terms working radiolinks. This has permitted to integrate the influence of different materials on the tag performance into the models.

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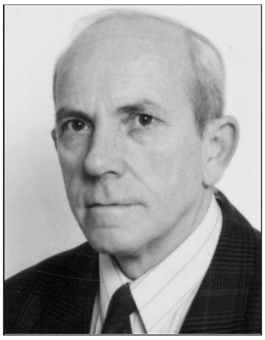

Jan Bogucki graduated from Technical University of Warsaw (1972). Since 1973 he has been employed at National Institute of Telecommunications, Warsaw, where he has been engaged in problems connected with digital radio links, digital television, microwave propagation in the troposphere and electromagnetic compatibility. He is the author or co-author of over 150 publications in scientific journals and conference proceedings.

E-mail: J.Bogucki@itl.waw.pl
Equipment and Systems Testing Department
National Institute of Telecommunications
Szachowa st 1
04-894 Warsaw, Poland

Ewa Wielowieyska graduated from Faculty of Mathematics, Informatics and Mechanics of Warsaw University. Since 1981 she has been employed at National Institute of Telecommunications, Warsaw, where she has been engaged in tasks connected with software of measurement systems and problems of microwaves propagation in the troposphere, propagation of digital radio signals on short and medium waves.

E-mail: E.Wielowieyska@itl.waw.pl
Equipment and Systems Testing Department
National Institute of Telecommunications
Szachowa st 1
04-894 Warsaw, Poland