Prediction of Signal Fadings in Air Radio Communications

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Abstract— In the article the analysis of the fading deepness of the signal at the receiving antenna input of the aircraft flying in the air space between the repeater station and a power line were presented as well as it was determined if the level of fadings generated by signal reflections from power columns has destructive effects to the quality of radio link used. To this purpose, the analysis of the terrain between the repeater station and individual power columns was carried out. Basing on the analysis results it could be accepted that the propagation of the radio link at the sector of the ray reflected, i.e., the repeater station antenna, reflecting surface of particular power columns and receiving antenna installed on the plane, can be modeled using the free space propagation model.

1. INTRODUCTION

The algorithm of procedures during analysis of power high voltage links effects to the quality of radio communications between land repeater station and an aircraft was presented in this article. Power high voltage lines and their overhead transmission line supports — the height of which can sometime be up to 60 m, can be the factors able to change the direction of propagation. This case will take place within a radio link between a land relay station installed on a mast at h_1 height over the terrain level and aircraft being at the height of h_2. The communications of the aircraft with the flight control tower is done, among others, on the frequency from 118 MHz to 136 MHz. The rays of the electromagnetic wave reflected from metal construction elements of particular overhead transmission line supports can interfere with the direct ray generated by the relay station, and in the result of these fadings of the signal level can be formed at the aircraft's receiving antenna input. The above fadings can be the reason for periodic changes of the signal to noise ratio (S/N) at the input of the receiver, what can result in worsening the audio monitoring quality of the information transmitted. On the signal to noise ratio (S/N) has influence the used antenna type [2, 3, 5, 6].

2. POWER OF SIGNAL AT THE RECEIVER INPUT

The signal level P at the input of the receiving antenna installed on the aircraft board is dependent on the level and phase of the direct ray signal P_{ray1} as well as of the level and phase of the component being the sum of the rays P_{ray2} reflected from particular power overhead transmission line supports taken into account in a radio communication link. The signal level P can be calculated from the dependence:

$$P = P_{ray1} + P_{ray2} \tag{1}$$

In order to evaluate influences of particular power overhead transmission line supports to the quality of radio communications, the signal level P coming to the receiving antenna installed on the aircraft board was calculated taking into account the level and phase of the direct ray signal P_{ray1} as well as the level and phase of the ray signal P_{ray2} reflected from a given power overhead transmission line support.

In order to take into account influences of particular power overhead transmission line supports to the radio communication quality it should be assumed that the depth of fadings for the signal being the sum of the direct ray and reflected one at the input of the radio receiver installed on the aircraft board depends on:

1. The signal level coming to the antenna of the radio receiver installed on the aircraft board as the direct ray P_{ray1}. The signal level of the as the direct ray depends on the propagation path length between the repeater station and the receiving antenna on the aircraft as well as of electrical parameters of the repeater station.
2. The signal level coming to the antenna of the radio receiver installed on the aircraft board as the ray P_{ray2} reflected from the metal structures of particular power overhead transmission line supports. The signal level of the reflected ray depends on the:

- propagation path length that is consisted of two segments running through the points of: the repeater station, reflecting surface of particular power overhead transmission line supports as well as receiving antenna on the aircraft board,
- section of the terrain in a segment between the repeater station as well as particular power overhead transmission line supports,
- electromagnetic wave reflection coefficient from metal structures of particular power overhead transmission line supports,
- electrical parameters of the repeater station.

The diagram of affecting the signal transmitted by the repeater station to the receiving aircraft by the metal structure of the power overhead transmission line support is shown in the Fig. 1.

The depth value of the fadings at the input of receiving antenna installed on the aircraft generated by influencing the amplitude and phase of the direct ray P_{ray1} as well as reflected one P_{ray2} was determined by the simulation program written in the Matlab environment.

Arrangement parameters of the repeater station in relation to positions of particular power overhead transmission line supports located within the considered radio communication link were used as the input data for the simulation procedure. Basing on the arrangement parameters of the repeater station and power overhead transmission line supports the terrain profiles should be defined between the repeater station as well as particular power overhead transmission line supports.

The propagation of the radio link at the distance of the reflected ray: antenna of the repeater

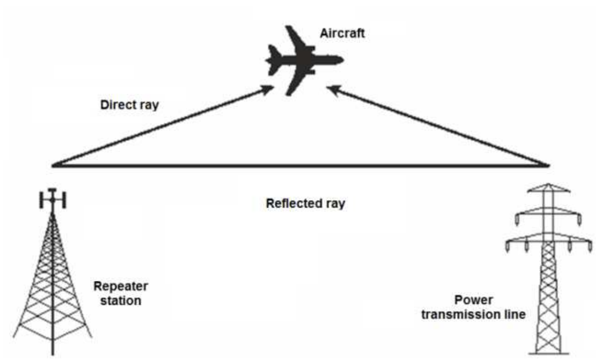


Figure 1: Radio communication link analysed.

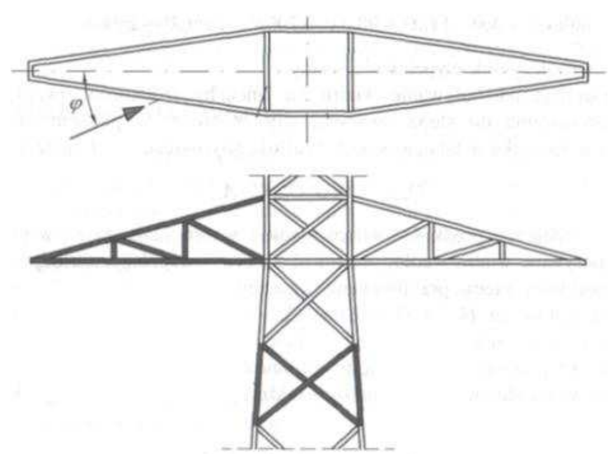
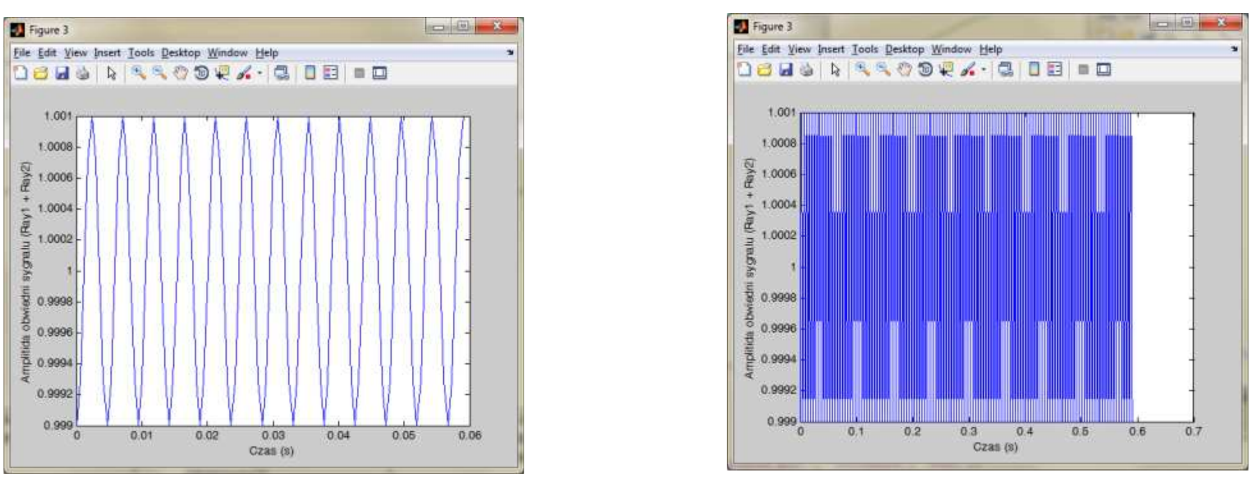


Figure 2: Example structure of power overhead transmission line support.



(a) (b)

Figure 3: Amplitude of signal envelope $P_{ray1} + P_{ray2}$. (a) For a short time of observation (0.06 sek). (b) For a long time of observation (0.7 sek).

station, reflecting surface of particular power overhead transmission line supports as well as receiving antenna installed on the aircraft can be modelled using the free space (with no terrain obstacles) propagation model.

For the purpose of analysis the scenario was assumed that aircraft is moving along the straight line on a constant ceiling between the repeater station and a selected power overhead transmission line support.

The fading depth value of the signal at the input of receiving antenna is affected by the reflection coefficient of the signal from metal structures of particular power overhead transmission line supports.

Basing on the data related to metal surfaces of particular power overhead transmission line

Table 1: Values of reflection coefficients for particular segments of power lines maintained by consecutive power overhead transmission line supports.

Item	Area of metal structures of consecutive power overhead transmission line supports [m^2]	Height of the power overhead transmission line support [m]	Average value of the spacing between particular power overhead transmission line supports [m]	Reflection coefficient of a power segment line maintained by a given power overhead transmission line support
1	33.740	36.8	396	0.0019
2	34.200	39.1		0.0019
3	26.748	46.2		0.0015
4	33.985	55.2		0.0019
5	33.985	55.2		0.0019
6	34.453	36.8		0.0019
7	26.748	46.2		0.0015
8	32.214	52.2		0.0018
9	32.214	52.2		0.0018
10	34.563	39.1		0.0019
11	21.156	40.2		0.0012
12	23.097	43.2		0.0011
13	28.191	49.2		0.0016
14	33.738	36.8		0.0019

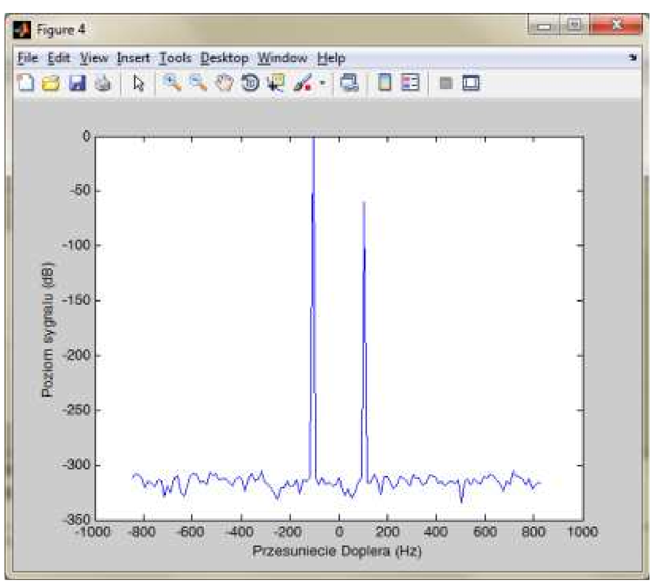


Figure 4: Signal spectrum with the component corresponding to the direct ray as well as reflected one.

supports Fig. 2, the values of reflection coefficients were evaluated for particular segments of power lines maintained by consecutive power line supports. The results of the reflection coefficients calculations are presented in the Tab. 1. Their levels oscillate around the value of 0.002. The references describing the electromagnetic factors of materials are [1, 4, 6, 7].

The results of the computer simulations for the sectors of power lines maintained by particular power overhead transmission line supports are presented in the consecutive figures. Fig. 3 presents amplitude of the signal envelope $P_{ray1} + P_{ray2}$. Fig. 4 presents the signal spectrum together with the component corresponding to the direct ray as well as reflected one (the difference -70 dB). The frequency difference of both components results from the Doppler shifting created by the motion of the aircraft.

3. CONCLUSIONS

Basing on the data presented it can be stated that the antenna of the repeater station illuminates almost as the whole of particular power supports. There is no essential terrain obstacles between the supports and transmitting antenna of the repeater station. In connection to the above it can be stated that the signal level of the reflected ray coming to the receiving antenna installed on the aircraft will be affected only by the reflection coefficient of the electromagnetic wave reflected from the metal structures of particular power overhead transmission line supports as well as by the attenuation of the path: repeater station, reflecting surface of particular power overhead transmission line supports as well as receiving antenna installed on the aircraft.

The depths of fadings corresponding to particular sectors do not exceed 2% of the carrier wave amplitude value at the input of the aircraft receiver. The depths of fadings of this order do not affect destructively onto the quality for simplex communications between the repeater station and the radio on the aircraft board.

The references connected with the topic of this article are [9–14].

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