Multipath Fading Effect on Terrestrial Microwave LOS Radio Links

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***Abstract*—In this paper, the calculation of both the total received power with the effect of the ground reflection and the fade margin to find out the link availability for terrestrial microwave LOS (line-of-sight) radio links is proposed. The expressions are derived from clear-air, rainfall propagation mechanisms and multipath fading due to multipath arising from surface reflection along the defined microwave LOS radio link. We verify the mathematical model by using the ATDI ICS telecom software over sample microwave LOS radio links located in Turkey.**

I. Introduction

The quality of point-to-point microwave LOS/NLOS radio link communication is expressed by the received power. In the literature, prediction models for deep-fading range of the multipath fading distribution have been in existence for several years. The best known techniques are Morita [1] for Japan, Barnett-Vigants [2], [3] for the United States and Rec. ITU-R P. 530 [4] in the worldwide. In accordance with Olsen-Tjelta [5] paper, the application of three methods for many regions around the world clearly shows that the ITU-R model [4] gives the best overall performance in modelling flat-fading statistics on overland links and also on links in rugged inland regions. In this study, the multipath fading outage prediction method proposed by Rec. ITU-R P. 530 model [4] is studied. Rec. ITU-R P. 530 multipath fading prediction model [4] is composed of four significant clear-air and rainfall propagation mechanisms on terrestrial microwave LOS/NLOS radio links: attenuation due to atmospheric gases and rain, fading due to the multipath effects like diffuse reflections among the defined path profile and diffraction losses over terrain obstructions.

This paper is divided into two parts. The first part figures out the calculation process of the total received power with the effect of the diffuse reflection points among the path profile and analyses link unavailability as a function of fade margin. The second part compares the overall performance in terms of the received power over some microwave LOS radio links with ATDI ICS telecom software platform [6]. Due to space limitation and to reduce the number of figures, we will present only one sample case study which illustrated results of both the proposed method and other model via ATDI ICS telecom software platform [6].

II. Theory of Ground Reflection Link Budget and Fade Margin Evaluation

Rec. ITU-R P. 530 model [4] provides a procedure of estimating the path losses for clear-air and precipitation conditions and outage probability on the terrestrial microwave radio links, but the available signal power formulation at the receiver with the effect of the diffuse reflection coefficient is not defined in the multipath fading prediction model. We also enhance the fade margin calculation according to the calculated received power in order to find the exact link availability value.

A free space loss, L_{FSL} (dB), is calculated using the Friis transmission loss formula expressed as [4]

$$L_{FSL} = 92.45 + 20log(d) + 20log(f) \tag{1}$$

where d is the distance between the Tx (transmitter) and Rx (receiver) antennas in km and f is the frequency in GHz.

The available signal power at the receiver site according to direct signal without ground reflection effect formulated as

$$P_r = P_{tx}+G_{tx}+G_{rx}-CL-(L_{FSL}+A_g+A_r+A_{diff}) \tag{2}$$

whereby, P_{tx} is the transmitted power in dBm, G_{tx} and G_{rx} are the gain of the Tx and Rx antennas in dB, *CL* is the cable loss in dB, A_g and A_r are attenuation due to atmospheric gases and rain in dB, and A_{diff} is the diffraction loss over the terrain profile in dB.

The total received power with the effect of the ground reflection in dBm is given by

$$P_{total} = 10\,log(10^{\frac{P_r}{10}} \times (1 - 10^{\frac{-min(L_S)}{20}})) \tag{3}$$

where L_s are the reflection losses of all reflection point candidates among the path profile in dB.

The fade margin calculation is also given by

$$A = P_{total} - P_N - SNR \tag{4}$$

where P_N is the noise power in dBm and *SNR* is target signal-to-noise ratio in dB.

For the unavailability due to multipath, the average worst month value, p_w, is calculated as a function of the calculated fade margin, terrain roughness, geoclimatic factor, path length and frequency parameters described in Rec. ITU-R P. 530 [4].

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Moreover, the worldwide terrain roughness data provided by ITU-R is too coarse so that we change the resolution of terrain roughness data and investigate its effect on the link availability [7].

III. Simulation Results

To verify the proposed method in the microwave performance analysis, we applied simulations on terrestrial microwave LOS radio links located in Ankara, Turkey. A path profile between transmitter and receiver sites generated using a Digital Terrain Elevation Data (DTED 1) that has a post spacing with 3-arc seconds (approximately 100 meters). Some main parameters used for simulation are summarized in Table I. The terrain path profile of the terrestrial microwave LOS radio link is presented in Fig. 1. The obtained results are also summarized in Table II and III.

The analysis of overall performance in terms of the total received power over sample microwave LOS radio link shows that the proposed method is compatible with the other model via ATDI ICS telecom software platform [6].

TABLE I
Terrestrial link parameters for Kazan - Elmadag microwave LOS radio link

Parameter	**Kazan - Elmadag Microwave R/L**
Transmitter station, Kazan	40^{o} N $18'$ $37.60''$ 32^{o} E $36'$ $43.00''$
Receiver station, Elmadag	39^{o} N $48'$ $3.30''$ 32^{o} E $59'$ $2.00''$
Altitude of transmitter station (a.s.l)	1665 m
Altitude of receiver station (a.s.l)	1825 m
Antenna height (a.g.l)	15 m
Radio frequency	2 GHz
Transmitted power	25 dBm
Transmitter/Receiver antenna gain	22 dBi
HPBW	8^{o}
Cablo losses	2×1 dB
Target SNR	6.95 dB
Bandwith	40 MHz
Diffraction method	Delta-Bullington
Time percentage for rain attenuation	0.01%
Polarization type	Vertical
Ground type	Medium Dry Ground
Season type	Winter

TABLE II
Link study simulation results on Kazan - Elmadag terrestrial microwave LOS radio link

Parameter	**Kazan - Elmadag Microwave R/L**
Azimuth	150.69^{o}
Path inclination	2.475 mrad
Minimum LOS clearance	61m, 1.00 km from Kazan
Free space loss	134.77 dB
Attenuation due to atmospheric gases	0.40 dB
Attenuation due to rain	0.13 dB
Diffraction loss	0 dB
Attenuation due to reflection loss	3.667 dB
Total received power	-71.97 dBm
Noise power	-97.95 dBm
Fade margin	19.04 dB
Link availability	99.9931%

TABLE III
Results of ATDI ICS telecom software on Kazan - Elmadag terrestrial microwave LOS radio link

Parameter	**Kazan - Elmadag Microwave R/L**
Free space loss	135 dB
Attenuation due to atmospheric gases	0.40 dB
Attenuation due to rain (27.66 mm/h)	0.20 dB
Diffraction loss	0 dB
Attenuation due to reflection loss	3.0 dB
Total received power	-71.24 dBm

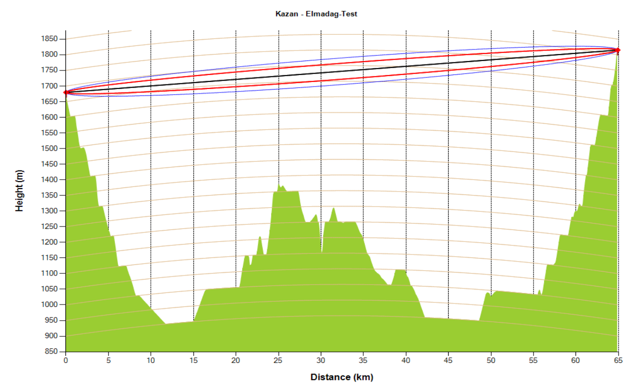

Fig. 1. Kazan - Elmadag microwave LOS radio link profile over terrain with the terrain elevations in above sea level adjusted for 4/3 effective Earth radius curvature. (The blue and the red curve indicate the First Fresnel zone and the 0.6 First Fresnel zone, respectively.)

IV. Conclusions

In this paper, the performance analysis in terms of both total received power and link availability of terrestrial microwave LOS radio link have been simulated and evaluated. The effect of the ground reflection is investigated on the worst month link availability of the microwave LOS radio link. The link analysis for the proposed method is approved by using the ATDI ICS telecom software platform [6]. The ongoing work will be focused on field measurements which will be used for better comparison of the results of the proposed method.

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