Application of Realistic Propagation Prediction Models for HAP 3.5G Systems in Urban Environment

Jaroslav Holis, Pavel Pechac
Department of Electromagnetic Field, Czech Technical University in Prague,
Technicka 2,166 27 Praha 6, Czech Republic, holisj1@fel.cvut.cz
Phone: +420 224 352 250, Fax: +420 233 339 958

1. Introduction

The aim of this paper is to present the impact of application of realistic propagation prediction models on High Altitude Platform 3.5G systems. High Altitude Platform Stations (HAPS) should be situated in the stratosphere at an altitude ranging from 17 to 22 km [1]. HAPS can combine the benefits of both terrestrial and satellite communications. In particular, they have low Free Space Loss (FSL) when compared to satellites and limited shadowing at high elevation angles, i.e. they provide good coverage when compared to terrestrial networks in urban areas. In addition, the cell size in HAPS is far more limited by an antenna radiation pattern than by a terrain profile. A major advantage of using HAPS is the low cost of deployment and, especially in the event of a disaster, their rapid deployment.

This paper deals with system level simulations of 3.5G networks using realistic propagation prediction models in build-up areas instead of the simple FSL model, widely used for simulations of HAP 3G systems. The supposed impact of realistic models on an uplink quality of coverage of HAP 3.5G systems is presented. The 3G networks provided via HAPS can play an important role for providing voice and data services in urban areas during disasters or could be an alternative for providing wireless services in developing countries, especially in case of High Speed Data Access (HSPA) evolution of 3G networks.

2. Propagation Prediction Models for HAPS in Build-Up Areas

The FSL empirical model was utilized for propagation prediction in most studies on HAPS. The FSL model in dB can be expressed as follows

$$L_{FSL} = 20\log(d_{km}) + 20\log(f_{GHz}) + 92.4 \tag{1}$$

where d_{km} is the distance between a transmitter and a receiver in km and f_{GHz} the frequency in GHz. This model is probably too optimistic for HAPS, especially for low elevation angles.

In order to achieve realistic approach in real cities, it is very important to model shadowing effects of buildings for lower elevation angles and the penetration loss into the buildings. The propagation prediction model for HAPS in different types of build-up areas (suburban, urban, dense urban, and urban highrise) and in the frequency band from 2.0 to 6.0 GHz was shown in [2]. For the dense urban environment and the frequency of 2.0 GHz the path loss can be calculated based on

$$L = \begin{cases} 20\log(d_{km}) + 98.4 + normrnd(0,4) & \text{LOS} \\ 20\log(d_{km}) + 98.4 + normrnd(\dfrac{-94.2+\theta,}{-3.44+0.0318\theta}, \dfrac{-89.55+\theta}{-8.87+0.0927\theta}) + normrnd(0,10) & \text{NLOS} \end{cases} ,(2)$$

where d_{km} is the distance in km, θ is the elevation angle in degrees. The normrnd(μ,σ) function generates random numbers using the Normal distribution with the mean μ and the standard deviation σ in dB. Normrnd() is a standard Matlab function.

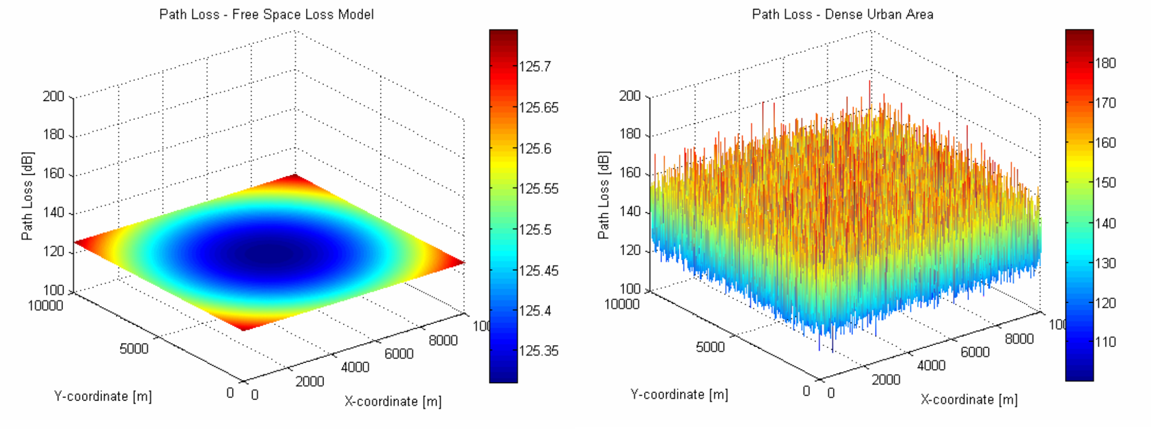
LOS probability in the streets as a function of an elevation angle for dense urban environment is defined as

$$P_{LOS}(\theta) = 120.0 + \frac{120.0}{1 + (\dfrac{\theta}{24.3})^{1.229}} , \qquad (3)$$

where θ is the elevation angle in degrees. Penetration loss into the building for HAPS was calculated using an universal empirical model for HAPS. The additional building penetration loss in dB at the frequency of 2.0 GHz above the FSL is defined as follows [3]

$$L_{PL}(\theta) = \sqrt{506 + 0.512(\theta - 70.4)^2} + normrnd(0,10) \qquad (4)$$

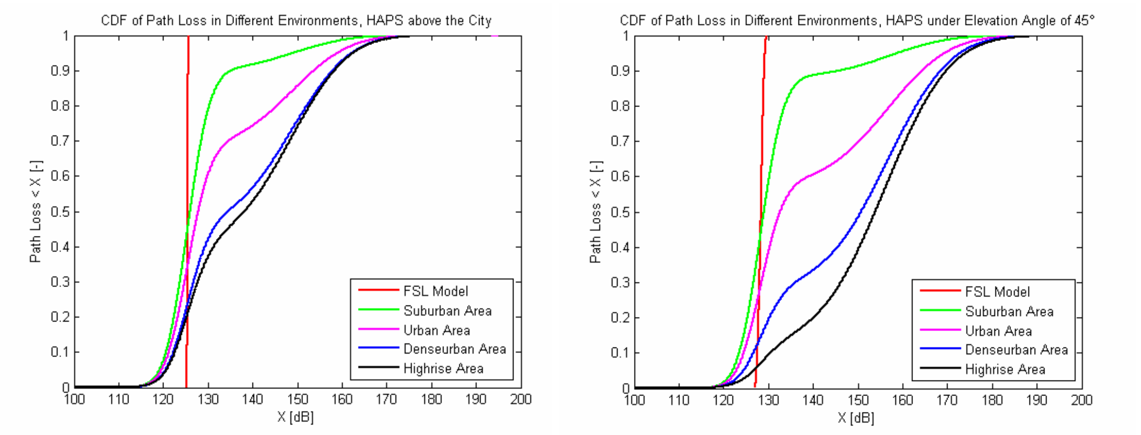
where θ is the elevation angle in degrees and the normrnd(μ,σ) generates random numbers using the Normal distribution with the mean μ and the standard deviation σ in dB.
Fig. 1 illustrates a comparison of path loss modeling based on FSL (a) and realistic models (2) –(4) for the build-up area with dimensions of 10 by 10 km in case of a HAP station situated directly above the city at the altitude of 22 km.



(a) (b)

Figure 1: The comparison of path loss for 3G systems at 2.0 GHz provided via HAPS in the dense urban area: (a) The FSL model; (b) The realistic propagation model.

Fig. 2 illustrates then the comparison of CDF for the path loss modeling for a HAP situated directly above the city (a) and for a HAP situated under the elevation angle of 45 degrees (b). From Fig. 2 it is evident that for high elevation angles is the path loss in dense urban area on average higher about 10 dB and for HAPstations situated under the elevation angle of 45 degrees (to the centre of target area) is the path loss higher about 20 dB.



(a) (b)

Figure 2: Comparison of FSL model and the realistic model for HAPS in different types of build-up areas: (a) HAPS situated directly above the city; (b) HAPS situated under the elevation angle of 45°

3. System Level Simulations Results

3.1 Simulation Approach

The simulations were based on a static simulation approach using iteration loops described in [4]. The HSDPA evolution of 3G network was modeled using an approach introduced in [5]. The main difference in the system level simulations of 3G and 3.5G systems is that the basic parameters for radio network planning of 3G systems is E_b/N_0 (Energy per Bit to the Spectral Noise Density) while in the case of 3.5G systems it is the CIR (Carrier to Interference) ratio [4], [5]. 37 cells with cell radius of 900m were situated in the target area of dimension 10 by 10 km.

3.2 Example of Simulation Results

The first parameter under investigation is the probability of quality of coverage in the uplink. The HSDPA requires an additional power margin in the uplink, of about 2 dB, to compensate for the additional control information sent over the uplink to support HSDPA on the downlink [4]. Fig. 3 illustrates the quality of coverage in the uplink as a function of the data bit rate (speech service – 12.2 kbps, and three different data services – 64, 144, and 384 kbps. The unsuitability of the FSL model application for the study of the quality of coverage for 3.5G systems is obvious from this figure.

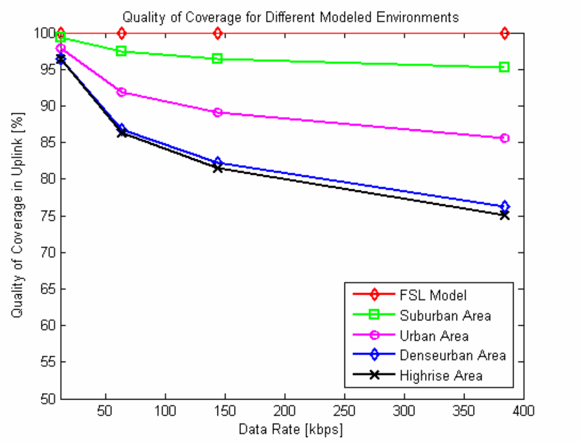
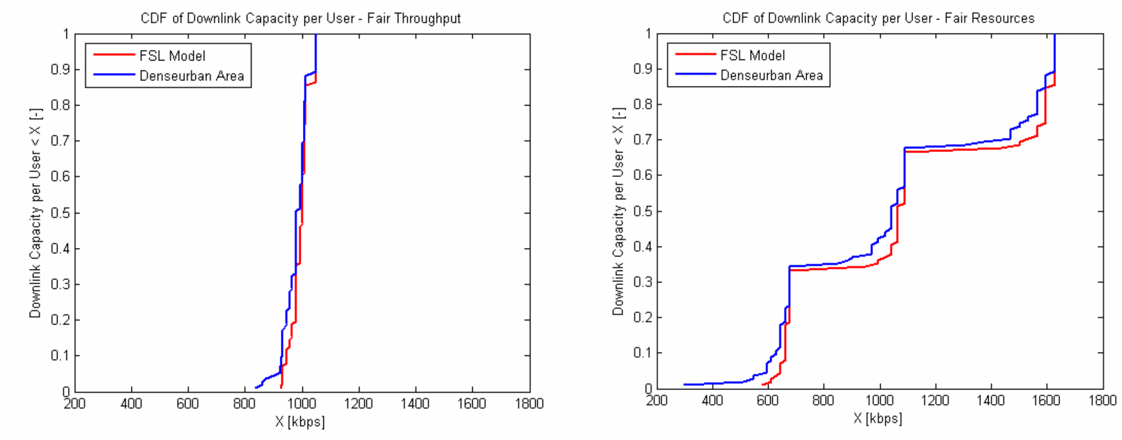


Figure 3: Quality of coverage in the uplink.

Finally, Fig. 4 illustrates the CDF comparison of the HSPA capacity per user in downlink for the FSL and more realistic models for two simulation approaches: (a) “Fair Throughput” – each user should have allocated the same capacity regardless of its position in the cell and path loss, respectively; (b) “Fair Resources” – each user has got the same number of allocated codes. Fig. 4 proves the expected conclusion – the realistic propagation model affected especially the quality of coverage in the uplink. For the more realistic model the cell is smaller, but there is a better isolation of the neighbour cell and the downlink capacity is almost the same then. Three HSDPA users were allowed to be served per cell.



(a) (b)

Figure 4: CDF of data rate in the downlink for HDSPA: (a) Fair Throughput; (b) Fair Resources.

4. Conclusion

The impact of realistic propagation prediction models for the radio network planning of 3.5G mobile systems provided via High Altitude Platform Stations including the penetration loss modeling in comparison with generally used Free Space Loss model was presented in this paper. It was shown that the realistic propagation prediction for HAP 3.5G systems affected especially the uplink quality of coverage. The application of the FSL model for dimensioning of HAP 3.5G systems seems to be absolutely unsuitable.

Acknowledgments

This work was supported by the Czech Ministry of Education, Youth and Sports under project no. OC092 - COST 297.

References

[1] T. C. Tozer, D. Grace, “High-altitude platforms for wireless communications,” *IEE Electron. Commun. Eng. J.*, vol. 13, no. 3, pp.127-137, June 2001.

[2] J. Holis, P. Pechac, “Elevation dependent shadowing model for mobile communications via High Altitude Platforms in built-up areas,” *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 4, pp. 1078-1084, April, 2008.

[3] J. Holis, P. Pechac, “Penetration loss measurement and modeling for HAP mobile systems in urban environment,” *EURASIP Journal in Wireless Communications and Networking*, vol. 2008, no. 2, pp,. 1-7, April, 2008.

[4] J. Laiho, A. Wacker, T. Novosad, *Radio network planning and optimization for UMTS*, 2nd edition, John Wiley & Sons, 2005.

[5] Ch. Chevallier, Ch. Brunner, A. Garavaglia, K.P Murray, K. R. Baker, *WCDMA (UMTS) Deployment Handbook: Planning and Optimization Aspects*, John Wiley & Sons, 2006.